The
Art of Gunnery
in
Renaissance England

by

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Abstract

Previous histories of artillery have concentrated on the guns themselves and their use in military actions, whereas this dissertation attempts to understand those guns as the core of a technological system in late Tudor England and the meaning of that system to its contemporaries. Theoreticians, authors, and gunners all looked to "gunnery" as a field of inquiry, and this thesis proceeds from theoretical gunnery, through its practical operation, to its bureaucratic and intellectual organization in Renaissance England.

First I investigate the ballistic work of Thomas Harriot (*c*1560-1621), to provide insight into the theoretical analysis of gunnery in the 1590s. Re-dating Harriot's work to *c*1598-1600 and surveying Harriot's career, personal influences, and scientific sources suggests that Harriot's interest in gunnery was not generated by his first patron, the professional soldier Sir Walter Raleigh (as is usually assumed), but rather from his second patron, the military dilettante Henry Percy, ninth Earl of Northumberland. Next, printed English works on gunnery up to 1600 populate two species: practical manuals by Peter Whitehorne, William Bourne and Cyprian Lucar; and arithmetical/analytical works by Leonard and Thomas Digges and Thomas Smith. Then an analysis of two manuscript gunners' manuals, written by practicing gunners, shows what the users themselves recorded.

Next, a survey of artillery use by the Tudor monarchs establishes the extent and role of cannon in sixteenth-century England, noting that Tudor warfare predisposed them not to develop their artillery skills. Analysis of two Ordnance Office surveys of 1580 and 1592 show what they did develop and records of ancillary

gunnery equipment and gunner employment records more fully represent the practice of gunnery. And, as both confirmation and augmentation of this picture, the field notebook of a practicing gunner in the Irish wars rounds out the picture of gunnery as a personal occupation.

Finally, the bureaucratic and intellectual position of gunnery is told in the story of the Artillery Garden outside Bishopsgate and of William Thomas' petitions to the Council for a formally chartered corporation for the licensing of gunners . Gunnery as a "mathematical" art and the gunners as "mathematical practitioners" concludes the thesis and indicates where gunnery "fit" into the late Elizabethan epistemology of practices.

Vita

Steven A. Walton

Steven Ashton Walton was born November 6, 1968 in Milwaukee, Wisconsin, where he remained until he matriculated at Cornell University in Ithaca, New York, in 1987. Majoring in mechanical engineering, he graduated in 1991 with distinction and then proceeded to the California Institute of Technology in Pasadena, California, where he obtained a M.S. in mechanical engineering the next year. Avoiding the managerial fate that befalls many engineers and following his avocation, in 1992 he moved to Toronto, Ontario, to enroll in the M.A. programme at the Institute for the History and Philosophy of Science and Technology (IHPST) at the University of Toronto. Completing the M.A. in 1994 with a thesis on early-modern automata, he began research in pre-modern military history and the history of technology, culminating in his Ph.D., awarded in 1999. While at IHPST, he received a Dibner Library Visiting Fellowship at the Smithsonian Institution, Washington, DC and undertook his doctoral research in London, Oxford, and Delaware on University of Toronto Associates Graduate Travel Fellowships.

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List of Abbreviations

APC	*Acts of the Privy Council of England*, new series, 46 vols. (1890-64)
B.L.	British Library, London
B.L., Add.	British Library, Additional Manuscripts
Bod. Lib.	Bodleian Library, Oxford
Bod. Lib., Rawl.	Bodleian Library, Rawlinson Manuscripts
CCML	*Calendar of Carew Manuscripts Preserved in the Archiepiscopal Library at Lambeth*, 6 vols. (1867-73)
CPR	*Calendar of Patent Rolls, Edward VI*, 6 vols. (1924-29); Philip and Mary, 4 vols. (1937-39); and Elizabeth I, 7 vols. (1939-82),
CSPD	*Calendar of SPD, Edward VI, Mary, Elizabeth I, and James I*, 12 vols. (1856-72)
CSPF	*Calendar of SPF, Edward VI*, 1 vol. (1861); *Mary*, 1 vol. (1861); and *Elizabeth I*, 12 vols. (1863-1950)
CSPI	*Calendar of SPI, Henry VIII, Edward VI, Mary and Elizabeth I*, 11 vols. (1860-1912)
DNB	L. Stephen and S. Lee (eds.), *Dictionary of National Biography*, 22 vols. (1898-1909).
DSB	Charles C. Gilispie (ed.), *Dictionary of Scientific Biography*, 18 vols. (New York: Scribners, 1970-90)
L&A	*List and Analysis of State Papers, Foreign, Elizabeth I*, 6 vols. to date (1964-)
L&P	*Letters and Papers, Foreign and Domestic, Henry VIII*, 21 vols. (1864-1932)
MS / MSS	Manuscript / Manuscripts
OED	*Oxford English Dictionary*, 2nd edition
PRO	Public Record Office, Chancery Lane, London (now at Kew)
RV	David Beers Quinn, *The Roanoke Voyages 1584-1590*, Haklyut Society, vol. 104-5 (London: Haklyut Society, 1955).
SPD	State Papers, Domestic (MS not covered in the *Calendars*)
SPF	State Papers, Foreign ´´
SPI	State Papers, Ireland ´´
STC	A.W. Pollard and G.R. Redgrave, *A Short-Title Catalogue of Books Printed in England, Scotland, and Ireland and of English Books Printed Abroad, 1475-1640*, 2nd ed., 2 vols. (1972-92)

THB John W. Shirley, *Thomas Harriot: a Biography* (Oxford: Clarendon Press, 1983).

TRP Paul L. Hughes and James F. Larkin, C.S.V. (eds.), *Tudor Royal Proclamations*, 3 vols. (New Haven: Yale University Press, 1964-69).

A Note on Transcription

When quoting material from original manuscript sources, I have adhered to a dual convention: other scholars' transcriptions have had the editorial apparatus omitted and u/v and i/j usage normalized, while for transcriptions of my own hand, editorial apparatus is maintained in italics and spelling is unchanged. That is to say, if the manuscript contained 'psõ' with a stroked staff on the 'p', from a printed source it would appear herein as "person". If, however, I am responsible for this transcription, I would write "p*er*so*n*". Similarly crossed-out text in published sources is silently omitted unless relevant, whereas my transcriptions replicate it thus: "the quick ~~blue~~ brown fox". Inferred transcriptions will be placed in brackets, thus: "the qu[ick] brown fox". The only exceptions to this rule are texts which are here included as appendices: in each appendix the editorial apparatus is reproduced in full as above, but when that material is then quoted in the chapters, it is treated as if it were from a printed source and the apparatus accordingly suppressed for the sake of readability.

Chapter 1

Introduction

> *The most notable attribute of any technology has come to be the way in which it is organized and owned, rather than exactly what it does.*
> — Karl Hess*

The art of gunnery – as a subset of the history of technology and of military history – looks like progressive history in microcosm. From the first vase-shaped, arrow-firing cannon of the fourteenth century and the wrought-iron bombards throwing meter-wide stone balls in the fifteenth, artillery has steadily become more and more technically accurate until modern rifled battleship guns can drop a 2,000 pound shell on a target 25 miles away while rolling and pitching in a storm. In the process, warfare was redefined from a man-to-man conflict to an impersonal contest of technical expertise. Typical of this attitude is Carlo Cippola:

> The "art of gunnery" produced a new type of warrior, the cold-blooded, technically inclined man who in the middle of the fight had to carry out a series of measurements and calculations, no matter how rough and imprecise. This new type of fighter vividly contrasted with the hot-blooded warrior of the old days who daringly threw himself into the mêlée with feathers, flag and sword, screaming and shouting and perspiring as much as humanly possible.[1]

Embedded in this fantastic story is the assumption that not just the men, but gunnery itself was "cold-blooded", technical, and analytical. Even more sober accounts, despite "qualifications and nuances", make the assumption that "at first sight [war] presents the classic case of a 'medieval' to 'modern' transition," and that transition is from chivalry to science.[2] And if the historical record is whittled from both ends to discover when it was that gunnery became "scientific", the sixteenth century seems to stand at the crossroads between the medieval and the

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* K. Hess, *Community Technology* (New York, 1969), p. 67.

1 C.M. Cipolla, *Guns, Sails, and Empires* (Manhattan, Kansas, 1965), p. 152.

2 C.S.L. Davies, "Henry VIII and Henry V: the Wars in France," in J.L. Watts (ed.), *The End of the Middle Ages?* (Thrupp, 1998), p. 236.

modern. This dissertation seeks to unpack the meanings around the artillery subset of the "military revolution" of the sixteenth century with reference to England and to penetrate the "modern" veil of science and technique that cloaks gunnery of the period. Ultimately, I hope to answer the ontological question, what gunnery 'meant' to a sixteenth-century Englishman.

We take many things for granted in modern life. Few know, understand, or care to understand, how most of the technologies around us function. We only sit up and take notice when things do not work as we expect them to. And therein lies the crux: how we *expect* them to. In coming to know the properties of technologies, Donald MacKenzie argues that we can come to know them through authority, induction, or deduction: *authority* if people we trust tell us what their properties are; *induction* if we discover the properties through use or testing; and *deduction* if we infer those properties from theories or models.[3] In the case of sixteenth-century artillery, I will argue below that the deductive route was not one open to the practitioners, as the theory was at that time unable to cope effectively with the artillery (the chapters on Harriot and printed books, below, shall indicate this). The inductive route would be that taken by those who actually used cannon, both gunners and possibly commanders (here the chapter on gunnery manuals will be particularly instructive). But ultimately, I shall argue that the authoritative route largely conditioned what "gunnery" was in sixteenth century England.

The "authority" of cannon came from different places, depending upon the recipient of the information. For common gunners authority was vested in the master gunners who taught them the art. But it might also be vested in printed authorities (as the case of Edmund Parker, a gunner in Elizabeth's Irish

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[3] D. MacKenzie, "How do we Know the Properties of Artifacts? Applying the Sociology of Knowledge to Technology," in R. Fox (ed.), *Technological Change* (Amsterdam, 1996), pp. 249-51*ff*.

Wars, will show). For commanders we might assume that printed books would predominate, but in fact, master gunners often held authority seemingly incommensurate with their rank and commanders looked to them for knowledge. For those outside the military establishment, where inductive learning was not an option (other than through observation, for which the Artillery Garden provided a venue), deduction from (inaccurate) theories was a possibility, but more often than not when confronted with technologies outside our immediate experience, authority tells us what they "are." What I am arguing, then, is at this time gunnery was still in the process of developing meaning and it was the practitioners of gunnery who had the opportunity to define the authority that it came to have by the opening of the seventeenth century.

This then raises the question of the scope of a technology, or what I shall call, mathematically, its "technological radius".[4] At the basic level (r=0), it is the artifact, cannon in this case. But cannon cannot function alone, and therefore this "technology" must include the objects in its immediate radius (r1): gunpowder (which includes saltpeter refining, charcoal-making, and sulphur purification), metal (iron for the shot, but also brass and iron for the cannon themselves), and wood (carriages and wheels).[5] Then, of course, there are the operators, supply and support systems, as well as all the values and beliefs associated with

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[4] I have developed the idea of a technological radius from Arnold Pacey's discussion of the problems of definition associated with technology; see A. Pacey, *The Culture of Technology* (Boston, 1983), pp. 4-7. His "restricted sense" of technology in figure 1 (p. 6) corresponds to my unit radius (r=1).

[5] I define r=1 as the technological radius at which the artifact is a complete, self-contained system, exclusive of motive forces (human or animal). In many cases, there may only be the single artifact at (r1), as for example, a sword or a hammer. There are also many ancillary components for artillery (r1): cord for the match; cloth or paper for cartridges; wood for rammers, ladles (often using copper also), sponges (whose mirkins used other materials), and lintstocks; and a myriad of chemicals for the fireworks which so commonly engaged gunners of the day. Obviously here I have taken a definitional stance based upon materials; other stances could be imagined.

technologies ($r>1$).[6] And, of course, there is a radius beyond which particular technologies have virtually no effect.[7] My own radius in this dissertation is larger than traditional history of technology, which only very rarely went beyond a unit radius ($r=1$).[8] My overall interest is in fact very wide ranging (rÈ1) in that I want to understand the values and ideas associated with gunnery in Renaissance England. Nevertheless, in the chapters that follow, I shall contain myself to radii not very much more than a unit value, since, as suggested above, it is the practitioners of gunnery who largely defined the meaning of gunnery.

Obviously, my approach is centered on the artifact, in this case, cannon. Such an approach runs the danger of what the economist Nathan Rosenberg has termed "black-boxing": assuming that the technology is a closed and fixed entity that directs (or even determines) the historical developments with which it is associated.[9] Admittedly, some have complained that the black-boxing of technology is a dangerous methodology, as did Hall and DeVries in their wider critique of Geoffrey Parker's sweeping book, *The Military Revolution: Military Innovation and the Rise of the West, 1500-1800*:

> Like a whole generation of economic historians, Parker uses technology as a "black box," a primary *explanans* whose nature is itself inexplicable.

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[6] Following the idea of technological radius, the operators would obviously be closer to the artifact than the suppliers, who in turn would be much closer than values associated with that technology ($1<r_{operator}<r_{supplier}$Ç values).

[7] So, for example, the technological radius of an atomic bomb is much larger than that of a can opener, for the former has profound ramifications well beyond the laboratory or missile silo

[8] Carol Pursell makes the point that "the history of technology, as currently studied, privileges design over use, production over consumption, and periods of 'change' over those which seem static and traditional" ("Seeing the Invisible: New Perceptions in the History of Technology," *ICON* 1 [1995]: 9). Although his concern is rediscovering the "lost voices" of African-Americans and women in 19th and 20th-century America, his message is equally (and perhaps even more) applicable to pre-modern history of technology, where much of the work is more purely artifactual.

[9] N. Rosenberg, *Inside the Black Box: Technology and Economics* (Cambridge, 1982), sought to "break open and examine the contents of the black box into which technological *change* has been consigned by economists" (p. vii, emphasis added). He did not look at the technologies themselves and therefore also left the technology proper black-boxed, although he has slightly rectified this lacuna in his more recent *Exploring the Black Box: Technology, Economics, and History* (Cambridge, 1994).

> Just as economic historians have begun to probe the innards of that box, so too anyone interested in military history must look at the real makeup of the technologies he finds so compelling as agents of historical change.[10]

In a more recent extension of that position, Hall specifically berates military historians for black-boxing and he himself does an admirable job in disclosing the inner workings of gunpowder and its ramifications for European society.[11] If, however, the intention to do so is consciously acknowledged and explicitly stated, then such a study serves a useful purpose. And indeed, most users of technologies – cannon included – treat them as closed black boxes. Here I will leave the inner box of cannon and gunpowder ($r \rightarrow 0$, in my terminology) closed and instead open only the box enclosing the system surrounding the cannon and investigate the materials used to operate a cannon (shot, fireworks, recipes, theories – r1) and the people and institutions that interacted with that system closely (authors, gunners, the Board of Ordnance, and theoreticians – $r \rightarrow 1^{+}$). Since not all users pry at their black boxes, studying those technologies as reifyied elements of a system is an entirely valid methodology and one which seems closest to understanding how *they* made sense of *their* technology in *their* time. We cannot, of course, ever fully understand other peoples' ideas and concepts and values, especially when separated from them by four hundred years in this case, but it is the goal of the historian to try.

Gunpowder first drew Europeans' attention in the thirteenth century, and the first cannon appeared at the end of the first quarter of the fourteenth. Most cannon of the fourteenth and fifteenth centuries were made out of wrought iron staves forged together and hooped by more wrought iron, in the same manner

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[10] B.S. Hall and K.R. DeVries, "Essay Review — the 'Military Revolution' Revisited," *Technology & Culture* 31 (1990): 506-7. G. Parker, *The Military Revolution* (Cambridge, 1988), drew his ideas from the comments of the historian Michael Roberts, who in 1955 gave an inaugural lecture to the University of Belfast entitled "The Military Revolution, 1560-1660."

[11] B.S. Hall, *Weapons and Warfare in Renaissance Europe* (Baltimore, 1997). His comments against black-boxing are on pp. 2-5. I also engage in some tentative disclosure in ch. 4, where the workings of recipes for fireworks are investigated.

as coopers made barrels.[12] Although cast bronze guns apparently existed alongside wrought iron ones from the earliest days of artillery, it was not until the mid-fifteenth century that bronze began to clearly displace iron as the gunmetal of choice. Part of the hindrance was cost, the copper in bronze being sometimes up to ten times as expensive as iron; the other hindrance was the difficulty with casting bronze guns as large as the smiths could forge iron guns. Given the inefficiencies of early artillery, bigger was better, and wrought iron remained dominant. By the middle of the fifteenth century, bronze cannon of relatively large calibre were adopted as more useful than their wrought-iron counterparts, despite their higher cost. These guns were stronger for their weight and thus allowed larger powder charges to be used. In addition, the development of cast iron cannonballs by the early fifteenth century provided a denser shot which more closely fit the barrel to be delivered against the target, both of which increased its effectiveness, that is, its ability to destroy walls.[13] Therefore, by the end of the fifteenth century, gunpowder artillery had "arrived" and Charles VIII inaugurated this arrival by using his artillery to great effect in his remarkably quick subjugation of the Italian peninsula in 1494-5.[14]

Although over two hundred years old by the time of Elizabeth, it was only in the time of her grandfather (and more dramatically in the time of her father and sister) that gunpowder weaponry became at all common in the English arsenal. In that sense, Englishmen felt it novel and potentially dangerous

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[12] For a convenient brief history and modern analysis of these earliest cannon, see J.J. Simmons, "Early Modern Wrought-Iron Artillery: Macroanalyses of Instruments of Enforcement," *Materials Characterization* 29 (1992): 129-38 and C.M. Cipolla, *Guns, Sails, and Empires*, pp. 30-54. See also J.F. Guilmartin, *Gunpowder and Galleys* (Cambridge, 1974), App. 3, pp. 284-91, which although flawed in its presentation of *why* cannon were cast the way they were, nevertheless provides a very useful brief survey of the history of cast bronze cannon.

[13] Cast iron cannonballs were also much more economical, eliminating the time-consuming shaping of stone into spheres.

[14] The classic case-study is his taking of Monte San Giovanni – which had withstood a traditional siege for 7 years – by battering down its walls in only eight hours; see in general, F.L. Taylor, *The Art of War in Italy, 1494-1529* (Cambridge, 1921), ch. 5.

(in more than the simply corporeal way) and throughout the sixteenth century, commentators repeatedly called for a return to the traditional bow, or at least lamented its passing. But only a few ever seriously considered completely abandoning gunpowder weapons, and large gunpowder weapons in particular. Cannon were clearly there to stay. One wonders what was it about them that apparently convinced virtually everyone that they were a "good" thing. They were very expensive – although the military has always had notoriously deep pockets. They were cumbersome – yet again, the military cares less about transport costs than do merchants. They were largely inaccurate – most battles in which they figured had few casualties from artillery and the sieges in which they were used more often than not ended through endurance, not breaching.

Cannon, however, had one thing that previous military hardware did not: sublimity. David Nye, in another context entirely, noted that technologies can, and have been, seen as sublime: the "repeated experiences of awe and wonder, often tinged with an element of terror, which people have had when confronted with particular natural sites, architectural forms, and technological achievements."[15] Although cannon cannot be said to have the same impact as the Grand Canyon, the Empire State Building, or the Hoover Dam, his criteria for those sublime experiences are still valid for artillery. One cannot help but be in awe and wonderment when a loaded cannon is fired – the intense sound felt deep in one's stomach alone signals there is something impressive happening. And cannon, after all, were designed to instill terror. In fact most historians suggest that that was usually their only purpose on the battlefield for the first 175 years or so of their existence. And although Nye concentrates on the

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[15] D.E. Nye, *American Technological Sublime* (Boston, 1994), p. xvi. Here he also notes (n. 10) the sublimity of military experience in general (he singles out "the rockets' red glare and bombs bursting in air" – gunpowder weaponry) which has yet to receive a comprehensive analysis.

uniqueness of the technological sublime to the American experience of monumental technologies, I believe that the European story, at least with cannon, followed the same broad outline. Further, gunnery garnered or even demanded respect in its own time for it was largely unnatural. Gunpowder was a mysterious substance, often linked with the devil, whose effects were anything but expected of a gray, lumpy powder. It was the alchemists' success story, creating dramatic effects with the lightest touch of a smoldering match. In essence, cannon demanded attention – and got it.

The dawn of the sixteenth century therefore understood gunpowder artillery as an integral unit of the military arsenal of European states. The sixteenth century is also notable for two other developments: printing and the beginnings of the Scientific Revolution.[16] Printing appeared in Germany in the mid-fifteenth century and spread rapidly throughout Europe. By the mid-sixteenth century, printed books had appeared that collated and standardized editions of canonical works and new material appeared to extend the range of reading material. At the same time, scientists used the new medium to present and debate both old and new ideas. Thus, 1543 serves as a convenient inaugural date for the Scientific Revolution, for it saw the publication of Vesalius' anatomy, *De humani corporis fabrica*, and Copernicus' astronomy, *De revolutionibus*.[17] By the end of the century, changes in reading, science, and warfare would have been obvious to even the most casual observer.

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[16] While the term "Scientific Revolution" (and indeed any term using "revolution") has been roundly criticized as being not all that revolutionary (nor sometimes all that scientific; *vide* the mention of alchemy, above), it nevertheless remains a useful guidepost to the intellectual developments of the 16th and 17th centuries. The other 16th-century development of no little importance was of course the Reformation, but for the purpose of this study, there seems little direct relation between military and theological matters, unless the latter precipitated greater use of the former.

[17] 1543 also saw Tartaglia's vernacular editions of both Euclid and Archimedes. The first printed book on artillery, his *Nova Scientia*, appeared 6 years earlier.

Structure

This thesis, then, considers the art of gunnery in Renaissance England, from Henry VIII to James I, but with a concentration on the Elizabethan era. It moves from theory (or more properly, theoretician) to practice (or practitioners), playing off both the contemporary book of Robert Barret, *The Theorike and Practike of Modern Warres* (1598), and the modern book of Henry Webb, *Elizabethan Military Science: the Books and the Practice* (1965). In beginning with a theoretician, Thomas Harriot, I pay a certain homage to the "grand old men of science" school of historiography, but then in immediately moving permanently away from theoreticians emphasize the point that Renaissance gunnery is *not* only about great theoreticians like Tartaglia and Galileo; it is about them and the popularizers and actors (ch. 3 and 4), bureaucrats and employees (ch. 5, 6, and 7). In short, gunnery was *of* the age and penetrated many different areas; it *became* a science, even without marked development in its actual practice.

Chapter two, therefore, begins with "Thomas Harriot and Ballistics." A contemporary of Drake, Raleigh, and Bacon, Harriot probably possessed the keenest mathematical and scientific mind in England at the time and one of his many activities was to consider the ballistics of great ordnance. Ballistics, the science said to have originated with Niccolò Tartaglia in the 1530s, defines gunnery to the modern mind, and to a certain extent to Harriot as well. But Harriot's (and historians') concentration on the theory of ballistics and trajectories has hitherto hidden the motive behind his studies. While Appendix I surveys and critiques Harriot's mathematical ballistics, this chapter investigates the context in which he performed those investigations, suggesting that they were not done for Sir Walter Raleigh, Harriot's first patron, but for Sir Henry Percy, Ninth Earl of Northumberland, his second. Raleigh was a military man

who acknowledged artillery, but saw no particular need for its analysis; Percy was a patron of the sciences and a military dilettante who sought to fuse these two areas of interest. In this suggested revision of the accepted influences, I set the stage for reconsidering what gunnery meant to the late sixteenth-century mind.

Chapter three, "Printed Books on Gunnery in England to 1600," investigates what the wider community could have known of the art of gunnery through printed books. I survey the works of the five English-language authors on artillery before the 1620s, with a particular eye towards the intended audiences for those books. Since the English cultivated the military literature genre rather late, their output is not particularly copious, this has led previous studies to emphasize the paltry output of the island nation. But here I argue that their per capita output rapidly rose and that by the end of the century they should not be considered backwards or insular, at least textually. Nevertheless, in considering the authors' definition of the operational space for the gunnery in these books, two streams of thought begin to diverge at this time. I coin the two streams the "practical" versus the "analytical", the former corresponding to how-to manuals which instruct readers how to use artillery and the latter to "scientific" textbooks which analyze and attempt to systematize the study of artillery.

While the latter stream was evident in Harriot's approach, the first stream appears in chapter four, "Manuscript of Gunnery Practice," through an analysis of two surviving manuals of gunnery. Written by practicing gunners, these two manuscripts (reproduced in full in App. II and III) indicate – in distinction to the printed books – what those directly engaged with great ordnance felt worth recording, but the two approach the material from slightly different perspectives. Situating these manuals in the craft tradition of *Rezeptliteratur*, we

find that they emphasize fireworks and firework recipes, a topic largely ignored in print, and also demonstrates the level of understanding of practicing gunners. This, then, suggests two sorts of audiences: didactic for the books, and mnemonic for the manuals.

Of course, such information on gunnery is purely academic if it is not put to use, which is the subject of chapter five, "Artillery and Tudor Military Tactics." Largely insulated from the large-scale Continental warfare of the sixteenth-century, the English had the opportunity to build up their gunnery stores without the immediacy that drove their Continental contemporaries. Henry VIII and his children created an Ordnance Office for the acquisition, supply, and maintenance of the artillery, and the English put it to good use in the few conflicts in which they participated. But the character of those conflicts also shaped the usage patterns of their artillery. This chapter chronologically surveys the integration of great ordnance into the Tudor military from the accession of Henry VIII to the death of Elizabeth, suggesting that the particular conditions England encountered in her military actions predisposed the country not to develop her artillery skills.

Chapter six, "Providing Materials for Artillery Warfare," then surveys what the English did have in their stores with which to wage their campaigns. Here, I diverge from the classical school of ordnance stores analysis in that I am not only curious about the guns (which I do analyze through a comparison of 1580 and 1592 Ordnance Office inventories), but also in terms of the other elements an army needs to wage artillery warfare: projectiles and the gunners themselves. Largely ignored until now, projectile analysis sheds a new light on artillery warfare, for it is in this variable that the commanders and gunners had their freedom of choice. The differing types of shot suggest the differing types of conflict they expected to see, and their reporting of those shot suggest how

they understood the operation of their machines. Additionally, noting gunners as one more piece of *materiel* reminds us that all the cannon in the world are useless without cannoneers, but the analysis of some Elizabethan employment records indicates that "gunner" was hardly a full-time occupation. Finally, the chapter concludes with the story of one particular gunner in Elizabeth's Irish wars, Edmund Parker. Parker's interests as recorded in his field notebook, though perhaps atypical, suggest how a practicing gunner pictured himself and the art of gunnery at the time.

Chapter seven, "The Artillery Garden and the Corporation of Gunners," brings the study of gunnery from theory to the final element of its practice, namely institutionalization. Institutionalization requires a locus and an impetus and these elements appear to have been the Artillery Garden outside Bishopsgate and the gunner William Thomas, respectively. I contend that throughout at least the second half of Elizabeth's reign, the Artillery Garden served as the primary gunnery school in England, but that it had both private and governmental aspects at the same time. Thomas, as the primary agitator for a formal, chartered, corporation of gunners, left a number of letters to Governmental officials in the 1580s (fully transcribed in App. IV) that indicate where he thought gunnery should stand from a bureaucratic and legal point of view.

Finally, the concluding chapter then returns to the topic of theory, but rather than from within gunnery, from without. It shows how Elizabethan commentators claimed gunnery as a "mathematical art" – and by extension, gunners as mathematical practitioners – and tried to incorporate it into a number of educational reforms at the end of the century. This, then, situates gunnery and all its trappings within the understanding of Elizabethans. It also suggests how sixteenth-century attitudes were formative for the modern

conceptualization of technology as autonomous, authoritative, and mathematical.

If we think of gunnery as a box into which we cannot peer, then this study takes a look at the four facets of that box (theory, public presence, bureaucracy, and education) as well as its base (the artifactual system within a unit technological radius) to try to understand the methods of knowing and controlling the technology of great ordnance. It is about the intersection of the details of the technology and the constrictions of society and to some extent the environment – heterogeneous engineering as John Law calls it[18] – yet with the sights set on gunnery as a system – *à la* Thomas Hughes[19] – rather than the usual analysis of the development of an artifactual technology. So, too, does it go beyond a simple bureaucratic history which would likely black-box the technology in order to explain wider societal changes. And throughout these chapters runs an undercurrent of attempting to divine the "scientific" nature of gunnery – whether it was scientific; whether it could be scientific; whether, when it was scientific, just what it was that was scientific about it. Above all, the following chapters seek to understand what it meant to refer to the "art of gunnery" in Renaissance England.

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[18] J. Law, "Technology and Heterogeneous Engineering: The Case of Portuguese Expansion," in W.E. Bijker, T.P. Hughes, and T.J. Pinch (eds.), *The Social Construction of Technological Systems* (Cambridge, Mass., 1992), pp. 111-134.

[19] T.P. Hughes, *Networks of Power*(Baltimore, 1983).

Chapter 2

Thomas Harriot on Ballistics

> *When a gunner or a soldier employs gunpowder, it is not necessary, that he should consider, or so much as know, of what, and of how many ingredients (much less what kind of atoms) it is made.*
>
> — Robert Boyle*

Introduction and Reputation

Although far from a household name in the history of science, Thomas Harriot's reputation as a Renaissance scientist has undergone a remarkable transformation in the second half of this century. He has hitherto been primarily known as the shadowy figure who first described America in English and who may have "invented" algebra. Famous to his contemporaries and raised to high fame by John Wallis in the seventeenth century (primarily for his posthumous work on algebra), he is today recognized as having performed rigorous scientific experiments and explicated various mathematical relationships before – and sometimes well before – contemporaries who later had their names attached to those same discoveries. In some respects, some of this scholarship has gone too far in looking for more "firsts" in his work than are rightfully there and in producing a sadly nationalist historiography. Nevertheless, modern commentators lament his failure to publish his work and therefore all we can do today is recognize a lone genius isolated in his own little world.

In fact, Harriot's world was far from little and even if he did end his life in relative solitude – which is not to say isolation – his contributions to the physical sciences should not be dismissed as just isolated discoveries. Harriot personally knew and collaborated with such Renaissance "celebrities" as John Dee, Sir Walter Raleigh, Henry Percy (the Ninth Earl of Northumberland known to his

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* Robert Boyle, "A Proëmial Essay, wherein, with some Considerations touching Experimental Essays in General," *The Works of the Honourable Robert Boyle*, 6 vols. (London: F. Rivington, 1772), I: 310.

contemporaries as the "Wizard Earl"), Johannes Kepler, Walter Warner, and Christopher Marlowe. And although he did not apparently know or correspond with them personally, he became familiar with the works of Galileo, Giovanni Battista della Porta, Agricola, Simon Stevin, and Guido Ubaldo del Monte. We are only now coming to understand the complexity of Harriot's life, in no small part due to the labors of the late John W. Shirley of the University of Delaware, who produced the first truly scholarly biography of Harriot in 1983.[1] To be fair to the historians, Harriot's fame has been hindered by his remarkable reticence to publish his own findings and his order that some of his papers be destroyed after his death. In his lifetime, he only published one item, *A Briefe and True Report of the New Found Land of Virginia* (1588, although composed as early as 1586), and that probably because Sir Walter Raleigh, for whom he worked at the time, asked him to publish it as propagandistic support for further colonization efforts. Only one other work by Harriot, his *Artes Analyticæ Praxis* which was one of the earliest works of algebra, was posthumously published in 1631 through the collaboration of Walter Warner and Nathaniel Torporley, Harriot's friends and students. Nevertheless, he was quite aware of his growing reputation at the turn of the century and played an active role in London's mathematical life, if not the continent's.[2]

Thomas Harriot's work ranged far beyond voyages of exploration and algebra; he worked on optics, physics, linguistics, astronomy, hydraulics, geometry, mineralogy and alchemy, fortification, navigation, naval architecture,

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[1] J.W. Shirley, *Thomas Harriot: a Biography* (Oxford, 1983) . Most of the biographical information in this sketch of Harriot is from Shirley (hereafter abbreviated as *THB*). Non-footnoted biographical information on Harriot and his associates may easily be found in Shirley's index. M. Rukeyser, *The Traces of Thomas Harriot* (New York, 1971) provides a fascinating and largely correct pseudo-biography, but she provides no references and little support for many of her tantalizing observations.

[2] See D.B. Quinn and J.W. Shirley, "A Contemporary List of Hariot References," *Renaissance Quarterly* 22 (1969): 9-26 and Shirley, *THB*, pp. 201-2*ff*.

and of relevance here, ballistics. Today, it is generally accepted that he turned the telescope towards the heavens perhaps a year or so before Galileo,[3] engaged in correspondence with Johannes Kepler (who initiated the exchange) on optics, and that he experimentally discovered the mathematical law of refraction at least 30 years before Willebrord Snell.[4] He could have been remembered as one of the greatest Renaissance scientists had he only published, but instead his name perished in the shadow of Galileo, Pascal, Toricellli, Kepler, and other luminaries of the scientific revolution.

Students of North American colonization history will know Harriot from his *Briefe and True Report* which described Virginia and the Algonquin Indians as he found them in 1585-6, while he was employed as one of the scientific members on Sir Walter Raleigh's Roanoke expedition. Students of the New Historicism may also know Harriot's book in an infamous way because of Stephen Greenblatt's widely-disseminated use of Harriot as a whipping-boy for colonial imperialism and emblem of subversive religion.[5] Harriot, born in about 1560, attended Oxford and upon graduation, was employed by Raleigh in his

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[3] For the most recent assessment of his lunar cartography, see A. Alexander, "Lunar Maps and Coastal Outlines: Thomas Hariot's Mapping of the Moon," *Studies in the History and Philosophy of Science* 29 (1998): 345-368, who compares Harriot's selenography to drawing coastlines.

[4] Snell is credited with the discovery in 1631. Snell's Law states that $n_1 \sin\theta_1 = n_2 \sin\theta_2$, where n_1 and n_2 are the indices of refraction of the two media in contact (*e.g.*, air and water), and θ_1 and θ_2 are the angles of incidence of the transmitted light ray, measured from the normal to the interface of the two media. See J.W. Shirley, "An Early Experimental Determination of Snell's Law," *American Journal of Physics* 19 (1951): 507-8, and Shirley, *THB*, p. 380-87.

[5] Greenblatt originally addressed Harriot in an article entitled "Invisible Bullets: Renaissance Authority and its Subversion, Henry IV and Henry V," in *Glyph: Textual Studies* 8 (1981): 40-60, but it has been reprinted numerous times, most recently in his S. Greenblatt, *Shakespearean Negotiations: the Circulation of Social Energy in Renaissance England* (Berkeley, 1988) . Harriot's reputation, though, has been more recently rehabilitated by B.J. Sokol, "The Problem of Assessing Thomas Harriot's *A Briefe and true Report* of his Discoveries in North America," *Annals of Science* 51 (1994): 1-16. T. McAlindon, "Testing the New Historicism: 'Invisible Bullets' Reconsidered," *Studies in Philology* 92 (1995), esp. 415-20 on Harriot, and C. Parker, "Are We being Historical Yet?" *South Atlantic Quarterly* 87 (1988): 743-86 tease apart Greenblatt's inconsistencies.

household as a scientific advisor, principally for matters of navigation and cartography which were to culminate in his voyage to Virginia. From about 1580 to the early 1590s, Harriot served Raleigh in various capacities, but then began shifting his employment to Henry Percy, Ninth Earl of Northumberland. Harriot served both these patrons for the rest of his life – until his death in 1623 from a facial cancer, probably from his tobacco addiction – although from about 1595 on he was retained directly by Percy and lodged in his household.

Harriot's writings on the ballistics of large ordnance are not polished, nor at all complete. Only a few examples of full paragraphs of thought remain. Shirley has explicitly claimed that Harriot did in fact develop a formal ballistics treatise which would have been presented to Raleigh for use on his 1595 piratical and colonial expedition to Guiana, based on the fact that he did present a complete navigational treatise called *Articon* to Raleigh in the mid-1580s.[6] As far as can be determined, and despite Shirley's contention, he never codified his thoughts in any systematic treatise: no such work survives, and what does survive does not suggest that such a treatise was ever composed. The first set of ballistics research should certainly be dated to the second half of the 1590s, and more than likely, to 1598 or 1599. That the second set of investigations dates from about 1606 corroborates the contention that the impetus behind their composition came not entirely from a man of the sea, Sir Walter Raleigh, but from a man of leisure, Henry Percy, as will be shown below.

The remaining notes in his manuscripts comprise about 100 folios, some double-sided, with a large proportion covered with working diagrams and calculations. Further, there is no guarantee that Harriot's papers exist in

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[6] Shirley, *THB*, pp. 242-3: "The next assignment that Ralegh gave his young friend was much more challenging – to bring his science and mathematics to bear on improving the accuracy of fire of his heavy ordnance, particularly of the cannon on his ships at sea." Harriot himself tells us that he had written the *Articon* in about 1584 at Raleigh's request. See *Ibid*., p. 86-9.

anything like their original order, due to probable rearrangement by later investigators,[7] as well as the fact that Harriot died relatively unexpectedly while in London, with his papers disorganized in his residence at Syon House, upstream near Kew, and that he ordered many of them destroyed in his will.[8] Therefore, determining Harriot's underlying assumptions and theories must necessarily remain an incomplete task. Still, some observations and conclusions can be teased out of his scattered *Nachlasse*.

The ballistic papers are isolated in two main bundles at the British Library, London, and at Petworth House, Sussex.[9] In these he has scattered statements of principle, followed by tables of calculated numbers and references to various sources, namely William Bourne, Luis Collado, and Allesandro Capobianco.[10]

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[7] Franz Xavier, Baron von Zach, in the later 17th century and John Rigaud in the early 19th are largely to blame for reorganizations; Rigaud, we know, tried to collect disparate topics unto discrete bundles, and it is his ordering now reflected in the bound British Library volumes. For a summary of the history of Harriot's papers, see J.V. Pepper, "The Study of Thomas Harriot's Manuscripts: Harriot's Unpublished Papers," *History of Science* 6 (1967): 17-40. Harriot's papers apparently lay largely undisturbed from his death until the end of the 18th century, when Zach was given permission to extract relevant papers for a posthumous *Opera* of Harriot for Oxford University Press in 1786. These extracted papers form the Petworth collection. Some evidence exists that even if Zach or Rigaud tried to reorder the papers, they did not do so systematically. For example, in Petworth MS 241, fols. 2-5 begin with the headings "a.b.c. 1.)", "11).", "12).", and "a.b.c. 2.)", respectively. Had either investigator tried to organize the papers, they certainly would have at least put the "a.b.c." pages one after the other.

[8] In his will he informed his executor, Nathaniel Torporley, that "there is a Canvas bagge of papers concerning Irishe Accomptes (the persons whom they Concerne are dead many yeares since in the raigne of queene Elizabeth wch I desire alsoe may be burnte as likewise many Idle papers and Cancelled Deeds wch are good for noe use." H. Stevens, *Thomas Hariot, the Mathematician, the Philosopher, and the Scholar* (London, 1900) , p. 202. The single open parenthesis does not have a closing mate in Stevens' transcription. Oddly, there is little mention of this clause in R.C.H. Tanner, "The Study of Thomas Harriot's Manuscripts: Harriot's Will," *History of Science* 6 (1967): 1-16.

[9] These groups are B.L. Add. MS 6789, fol. 2-86 and Petworth House Archives, HMC 241/VIa, fol. 1-13 (hereafter referred to simply as Add. MS 6789 and Petworth MS 241).

[10] William Bourne, *The Arte of Shooting in Great Ordnaunce* (London, 1578; see ch. 3); Luis Collado, *Pratica Manuale di Arteglieria* (Venice, 1586) or *Platica Manuale de Artilleria* (Milan 1592), the latter being a revised edition of the 1586 edition "sufficiently different to be considered a distinct work" (M.J.D. Cockle, *A Bibliography of Military Books up to 1642* [London, 1957] , pp. 171-2); and Alessandro Capobianco, *Corona e Palma Militare di Artiglieria* (Venice, 1598 or 1602). Shirley, *THB* (p. 259, n. 33 and 34), following Cockle, noted these same authors and books, yet despite the dating of Capobianco to *c*1598, still dated Harriot's ballistic work as "characteristic of… the period 1590-95" (*Ibid.*, p. 250).

We would expect that his approach is anti-Aristotelian, for elsewhere Harriot described Aristotle as "the devell that was bound for a thousand years and after let loose to deceave the people in the four quarters of the earth."[11] Yet by and large, in the two previous analyses of Harriot's ballistics contributions the tenor and scope of his work has been somewhat distorted. In accordance with the belief that Harriot was a pre-Galileian Galileo, historians have looked for anti-Aristotelian theory behind Harriot's graphs and numbers. What they have failed to fully acknowledge is first, how firmly within the Aristotelian tradition Harriot worked, and second, how fully empirical his approach is.

A more thorough technical description and analysis of the ballistic papers may be found in Appendix I, but here some general remarks on their character is in order. At first glance, Harriot's papers present a jumbled mess of tables, calculations, equations, and graphs. Both Shirley and Lohne[12] have concentrated on Harriot's statements of doctrine scattered throughout the papers, yet a rough count of the number of folios devoted to the various types of work shows that this was not in fact Harriot's primary concern. For example, in the larger block of work, 22% of the folios are graphs, in both rough and finished formats, 16% contain tabulated data (most of these being the range tables examined below), and 26% are full of scratch calculations.[13] Only the remaining 36% of the folios contain a roughly equal amount of prose statements or clear geometrical equations. When presented abstracted from the manuscripts, Lohne tried to

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[11] B.L. Add. MS 6782, fol. 374^{v}, as quoted in H. Gatti, *The Renaissance Drama of Knowledge: Giordano Bruno in England* (London, 1989) , p. 58. Here Harriot is paraphrasing Revelation 20: 1-3, quite explicitly condemning Aristotelian precepts by equating him with Satan.

[12] These two works are Shirley, *THB*, pp. 241-68 and J. Lohne, "Essays on Thomas Harriot. II. Ballistic Parabolas," *Archive for the History of Exact Sciences* 20 (1979): 230-64. While groundbreaking, Lohne's article can be criticized on numerous levels, not the least of which is poor referencing and the fact that he spends more time on other scientists' writings than he does on Harriot's. But more seriously damning is his clearly teleological search for precursors of Galileian and Newtonian ballistic theories in Harriot's work. In this search, he often glosses over many salient points in the papers and assumes others.

[13] B.L., Add. MS 6789, fol. 2-86.

show that Harriot was essentially on the right track – the "right" track being Galileo's and Newton's – while Shirley was content to give a sampling of the larger blocks of text and a summary of the other comments and the more polished diagrams. In a sense, Shirley was the more honest of the two, for in Harriot's writings we are presented a picture of a scientist taking notes, sketching, calculating, and noting small conclusions, but not really "proving" anything like a geometrical law or an axiom of free-fall. The most complete section of his work is a table of numbers for angles from 0° to 90° in painstaking increments of 10´, but these turn out to be simply the calculated sines of the angles (admittedly, accurate to four decimal places). We do not, however, find an equation for the motion of a cannonball once it leaves the muzzle; what we do find are graphs that *look* like trajectories, but which were designed to calculate ranges. The most polished drawings in the manuscripts depict a trajectory as a tilted parabola, arcing up and right, enclosed in a right triangle which bounds the motion (see fig. A1.1 and A1.5 in Appendix I). Harriot ultimately came to the "wrong" final conclusion in that he analytically predicted the maximum range of the cannonball would be attained at an elevation angle of 27°55´, rather than the "correct" value of 45° (or slightly less if air resistance is considered). In addition, Harriot spent a fair amount of time performing numerical calculations on published (and perhaps unpublished) sources, attempting to determine the range of a cannonball given its elevation angle.[14]

Ultimately, however, Harriot left no firm statements of his findings, although the more polished of his graphs indicate that he did develop a relatively sophisticated solution to the problems he considered. Shirley (and to a lesser degree Lohne) assumed that the surviving manuscripts are but rough drafts of a

[14] Interestingly, he never considered differing powder charges imparting differing initial velocities. Apparently, Harriot assumed a level of uniformity in artillery operation that was simply non-existent at the time.

polished work on ballistics. Leaving aside the question of for whom Harriot wrote that (hypothetical) work, I believe that the remaining manuscripts indicate a scientist who attempted to understand ballistics, came to comprehend a few details of actual gunnery practice, abstracted them into a geometrical realm where he was comfortable, and came to conclusions which held in that realm, but would not hold in the "real" world (see Appendix I for details). Thus, it seems unlikely to me that a practical treatise on ballistics could have been generated from the work we can say for certain that Harriot performed.

Influences

The question of the analytical background of Harriot's ballistics has been cautiously avoided precisely because Harriot himself rarely if ever directly named or even alluded to his theoretical sources. We know he was an atomist. We know he was an avowed anti-Aristotelian. His contemporaries believed that he rejected almost all scholastic thought.[15] He would certainly have been trained in Aristotelian physics in Oxford, and we know he made long-lasting friendships with a number of his teachers, especially Thomas Allen. But, by and large, Oxford could not provide a very conducive incubation space for Harriot's nascent mathematical talent. Mathematics was by the sixteenth century no longer purely a phenomenon of the universities, as it had been during the middle ages; it had largely moved outside to grapple with practical problems of surveying, navigation, and astronomy – and, occasionally, ballistics.[16] While it is

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[15] See J. Jacquot, "Thomas Harriot's Reputation for Impiety," *Notes and Records of the Royal Society* 9 (1952): 164-87.

[16] M. Boas, *The Scientific Renaissance, 1450-1630* (London, 1962), pp. 239-40: "The science of the early modern period begins in the university; but, however much it remained true that most scientists were university-trained,… the science of the later sixteenth-century was not indigenous to the university." Boas points out that this due to the conservatism of universities, but even more so to the changing nature of science of the day. J. Gascoigne, "A Reappraisal of the Role of the Universities in Scientific Revolution," in D.C. Lindberg and R.S. Westman (eds.), *Reappraisals of the Scientific Revolution* (Cambridge, 1990), pp. 207-60 (esp. 220-29 on

true that the sciences were not so under-represented in universities as had once been believed (and as some leading seventeenth-century mathematicians like John Wallis would claim), at Oxford the picture is one of a prescribed curriculum of elementary classical mathematics, with small groups of interested men who might investigate further, grouped around singular individuals (like Allen).[17] Few students, however, remained in the University for more than three or four years of their undergraduate education, gravitating instead to other venues, usually London.[18] Clearly a gifted mathematician in his own right, Harriot created his ballistics within the intellectual context of the physics of his time, which at once stimulated and limited him, and then sought to apply them outside the university. And it is not too much to say that it was Harriot's other work on algebra and analysis which needed to be done before any of his ballistic work could have been proven. But again, this is getting ahead of the story.

In his Oxford curriculum, it would have been unlikely for Harriot to come across references to artillery, although he certainly read general works touching motion as part of the standard curriculum.[19] And he most certainly would have

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mathematics), has clarified this view somewhat. New scientific discoveries and information were to be found in the universities, but the best he can offer is that the universities helped "in providing the social and intellectual milieu that made the Scientific Revolution possible" (p. 208). Further, the majority of his analysis is 17th-century and continental; he notes that in France and Britain (as compared to Italy and Germany) "the university system proved considerably less hospitable to original scientific inquiry, though important in its dissemination" (p. 248; see also Simon [next note], p. 358).

[17] M.H. Curtis, *Oxford and Cambridge in Transition 1558-1642* (Oxford 1959), pp. 235-50. Cambridge tended to foster the mathematics more effectively than did Oxford. Other than Harriot, the most renowned English mathematicians of the second half of the 16th century were John Dee, Thomas Digges, Richard Mulcaster, and Robert Recorde; they all attended Cambridge, but interestingly, none became faculty there. Although Cambridge had instituted a first year concentrating on mathematics (arithmetic, geometry, cosmography, and astronomy) in 1549, they eliminated it in 1558 in favor of rhetoric. See *ibid.*, pp. 243-47 and J. Simon, *Education and Society in Tudor England* (Cambridge, 1966), pp. 252-3 and 358, n. 1.

[18] London is the origin of both Gresham College and, later, the Royal Society. While both of these scientific institutions had personal "links" to Oxbridge, it should not be surprising that the leading intellectuals (of any field) in the 17th century should have been educated there.

[19] E.D. Sylla, "Science for Undergraduates in Medieval Universities," in P.O. Long (ed.), *Science and Technology in Medieval Society* (New York, 1985) , pp. 172-3, suggests that an undergraduate would certainly have seen Aristotle's *Physics*, Euclid's *Elements*, Boethius'

learned the works of William Heytsbury and Richard Swineshead on proportions and infinite series which were used in disputations, not often for their technical content, but for their rigorous Scholastic method.[20] But in his personal contacts with his teachers, he would have investigated the nature of motion more thoroughly and may have even considered the flight of a cannonball as an archetype. Harriot's methodology is rigorously geometric, as one would expect coming from the tradition of late medieval mechanics. Lohne suggested that Heytsbury's fourteenth-century text on motion formed the core of Harriot's analysis,[21] although it is clear that other sources which interpreted Heytsbury were foremost in Harriot's mind. There is no reason to believe, however, that Harriot departed very far from this seminal source of numerical geometry.

The closest teachers and mentors Harriot had at Oxford were Thomas Allen and Richard Hakluyt, and they remained friends for the rest of Harriot's life. A member of Christ Church, Richard Hakluyt (1552?-1616) is of course best known for his work on navigation, and Shirley speculated that it is likely his instruction led Harriot to his employment in Raleigh's colonial ventures.[22] Thomas Allen (1542-1632), on the other hand, was connected with Trinity

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Arithmetic, the *De sphæra*, and works on *computus*, *algorismus*, and possibly perspective (Alhazen or Witello's commentary thereupon) and Ptolemy's *Almagest*. While she here refers to the 15th century, there is little indication that Oxford would have changed much by Harriot's day with respect to mathematics. M. Feingold, *The Mathematicians' Apprenticeship* (Cambridge, 1984), provides an extensive overview of mathematics – or, rather, mathematicians – at the Oxbridge colleges but detailed curricular information is scarce and scattered throughout the work.

[20] E.D. Sylla, "Science for Undergraduates in Medieval Universities," p. 182-3.

[21] J. Lohne, "Essays on Thomas Harriot. II. Ballistic Parabolas," p. 235.

[22] J.W. Shirley, "Sir Walter Raleigh and Thomas Harriot," in J.W. Shirley (ed.), *Thomas Harriot: Renaissance Scientist* (Oxford, 1974), p. 17. Interestingly, in this early work on their connection, Shirley makes no mention of the ballistic work. Hakluyt repeatedly attempted to get a lectureship for (practical) mathematics established at Oxford throughout the 1580s (*i.e.*, after Harriot had graduated), but met with little success until the foundation of Gresham College in London in 1596 (K. Charlton, *Education in Renaissance England* [London, 1965], pp. 281-86).

College (admitted 1561, B.A. 1563, fellow 1565, M.A. 1567) and taught in lay residence at Gloucester Hall there from about 1570. Known to posterity as a great antiquary and book collector, to his contemporaries it was for his mathematical interests and ability that he was particularly renowned.[23] Allen, though, is not known to have published at all – he is only known to have written two manuscript commentaries on Ptolemy's *Almagest* – but his interest in motion was widely known. Allen seems to have been the sole Oxford mentor who would have nurtured Harriot's interests in mathematics and motion during his stay there, so when Harriot took up his work on ballistics in the late 1590s, it would follow that he might turn to Allen for advice and guidance.

When Harriot attempted to define a cannonball's flight,[24] he made passing reference to the "doctrine of Bagdedimus, Comandinus, or Stevinus," that is, Abu Mansur Al-Baghdadi,[25] Federico Commandino,[26] and Simon Stevin.[27] He seems, however, to have simply accepted these authorities as background knowledge on motion, as nowhere else does he mention them or quote specific passages from their works. But on a number of pages in the section where

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[23] He was also a practicing astrologer and accused of using these "black arts" to entice Queen Elizabeth to marry the Earl of Leicester, with whom Allen was very close. See DNB and *British Biographical Archive* (Munich, 1984), fiche 20, frames 141-68. See also A.G. Watson, "Thomas Allen of Oxford and his Manuscripts," in M.B. Parkes and A.G. Watson (eds.), *Medieval Scribes, Manuscripts & Libraries: Essays Presented to N.R. Ker* (London, 1978), pp. 279-314, which surveys the fate of Thomas' vast manuscript collection, but which does not, unfortunately, detail their contents. M. Feingold, *The Mathematicians' Apprenticeship*, pp. 157-9, surveys what is known of Allen, but unfortunately adds little new information.

[24] B.L., Add. MS 6789, fol. 30.

[25] Abu Mansur Al-Bagdadi (†1037), known as Machometus Bagdedinus in the Latin West, wrote a commentary on Euclid's book on the division of geometric figures which was translated into Latin by Gerard of Cremona (DSB). See following note.

[26] Federico Commandino (1504-75) published Gerard's commentary on Euclid's *On Divisions*, in 1570, based on the Latin translation of Al-Baghdadi's manuscript given to him by John Dee. See P.L. Rose, "Commandino, John Dee, and the 'De superficierum divisionibus' of Machometus Bagdedinus," *Isis* 63 (1972): 88-93. See also E.I. Rambaldi, "John Dee and Federico Commandino: an English and an Italian Interpretation of Euclid during the Renaissance," in S. Rossi and D. Savoia (eds.), *Italy and the English Renaissance* (Milan, 1989), pp. 123-53.

[27] Simon Stevin (1548-1620). The work here referred to must be either his *L'Arithmétique* (1585) or his *De Beghinselen der Weeghconst* (1586) on statics (see DSB for a list of his works).

Harriot was attempting to grasp asymptotic series, he did make notes on the sources he consulted. In one section "Ad propositiones elementarus de motu," Harriot made a note "Aluarus 73b"; in another he refers to "2 corrol qui loc. Al. Thomæ pag 80"; and in yet another place he mentions "Aluarus Thomas 2 conclusio pars 66b" as well as "Bernardus Tornius Florentinus in doctrinu*m* H[ey]tis[b]eri de motu locali pag 77".[28] The *Liber de triplici motu* of the Portuguese Alvarus Thomaz (fl. *c*1510) was published in 1509 and discussed the Richard Swineshead's work on numerical ratios and local motion.[29] "Bernardus Tornius Florentinus" refers to the work of the Florentine professor of medicine at Pisa, Bernardo Torni (1452-97) and his 1494 work, *Caputulum de motu locali Heytisberi*.[30] Harriot clearly followed the *calculatores* school of thought, growing out of the fourteenth-century work of the Oxford Merton School.[31] In particular, Thomaz's work gave him the logical structure for the analysis of motion. According to Thomaz – typically for the early sixteenth century – all motion

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[28] B.L., Add. MS 6789, fol. 51-2, 42, and 44, respectively. These notes are in his "private hand" with frequently indistinct letters.

[29] Alvarus Thomaz, *Liber de Triplici Motu Proportionibus Annexis… Philosophicas Suiseth Calculationes ex Parte Declarans* (Paris, 1509). See W.A. Wallace, *Prelude to Galileo: Essays on Medieval and Sixteenth-Century Sources of Galileo's Thought* (Dordrecht, 1981) , pp. 80-90, 100-1 and the DSB: "At Paris… there can be little doubt that Thomaz was the calculator par excellence at the beginning of the 16th century, and the principle stimulus for the revival of interest there in the Mertonian approach to mathematical physics" (13: 349-50). E.D. Sylla, "Alvarus Thomas and the Role of Logic and Calculations in Sixteenth Century Natural Philosophy," in S. Caroti (ed.), *Studies in Medieval Natural Philosophy* (Firenze, 1989), pp. 257-98 provides a general overview of Thomaz's approach and extracts from the *Liber de triplici motu*.

[30] Bernardo Torni, *Bernard Tornij Florentini Medici ac Philosophi in Capitulum de Motu Locali Hentisberi quedam annotata incipiunt* (Pisa, 1494); W.A. Wallace, *Prelude to Galileo*, p. 99 notes that fol. 73^{v}a-77^{v}a deal with categories of motion, and it is indeed these range of pages to which Harriot refers. Torni is an obscure figure with no entry in the DSB and even the works in the *Archiva Biografico Italiano* (Munich, 1987-92), fiche I.957, frames 173-5, ignore his contributions to physics in favor of his work in medicine.

[31] The best survey is W.A. Wallace, *Prelude to Galileo*, "The *Calculatores* in the Sixteenth Century," pp. 78-90. Although Galileo had by 1589-90 turned his attention to motion and understood uniformly accelerated motion by the end of the decade, he did not publish any of his work in other than manuscript form until the 17th century. Since Harriot had no contacts with the Italian schools, he could not have known of Galileo's (or Guidobaldo's) work, and in this sense stands as a last icon of scholastic physics.

could be divided into equal and unequal motion, which could be further subdivided depending on whether the temporal or spatial component were equal or unequal.[32] In struggling to find a numerical sequence that would reflect relative ranges given in a contemporary published work, this framework of motion illuminated his investigation, but he also looked elsewhere for inspiration.

"The Laundry List"

One other small note in his manuscripts provides a clue as to where Harriot's thought was roaming while working on ballistics. In a hand which Shirley calls "characteristic of Harriot during the period of 1590-95," Harriot wrote himself a "laundry list" of items in the corner of a page. It reads:

Memorandum
The properties of the four elements
Master Allens Book
Varro
My notes of ordinance
Proclus de moto.

Clearly Harriot has jotted down a number of things that he needed to remember to do, or look into, in the near future. Shirley has italicized the fourth item and concluded that "what this undoubtedly means is that Sir Walter Raleigh… has asked Harriot for the conclusions of his study on the improvement of gunnery, possibly about the time he was preparing for his voyage to Guiana where he

[32] B.L. Add. MS 6789, fol. 52, has a Ramist-style table headed "Alurus 73.b" with "motu*m* velocitates seu gradus", subdivided into "æqualies (insentise) qui extenditur vel continutat*es*" and "Inæqulaes qui extenditur", which in turn are further subdivided according to "æqualis", "inæqualis", or "proportio" units of time. See W.A. Wallace, *Prelude to Galileo*, pp. 91-109. The calculators used compounds of the terms 'uniform' and 'diform', as in 'uniformly diform' (equal to a modern 'smoothly [or linearly] accelerated') or 'diformly diform' ('non-linear acceleration').

expected to meet the Spanish," that is, in 1594 or 1595.[33] He further concluded that Harriot would have drafted a final report in a fair hand with accompanying tables and diagrams and presented it to Raleigh. It would then have been lost with the rest of Raleigh's papers after his imprisonment by James I in 1603.

Unfortunately, Shirley's scenario is pure speculation. There is no evidence that Raleigh requested these investigations. There is no evidence that Harriot provided him with notes on ballistics. It is a conclusion arrived at by the parallel case of Harriot's work for Raleigh on navigation for which he was hired, and for which clear evidence exists in Harriot's own note that he had written such a work.[34] There is, however, another interpretation of this list with distinct implications for Harriot's work on ballistics – one which is internally consistent and considerably more likely. This list, as one of the only surviving records of items with which Harriot was dealing at the same time as his work on ballistics, provides the framework for this scenario.

The first item on the list, "the properties of the four elements" suggests that at the time Harriot was interested in Aristotelian matter theory, although no correlation with Raleigh's venture would be in order here. Shirley himself noted that Harriot's work on the four elements peaked in May and June, 1599, so it is likely that the list is from later than Shirley suggested.[35] The second item, "Master Allens Book," is clearly a reference to a book belonging to Thomas Allen of Oxford. Harriot had either borrowed a book from his old teacher and was

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[33] Shirley, *THB*, p. 250. The list is in B.L. Add. MS 6786, fol. 364^{v}.

[34] This was his *Articon*, which he mentions in notes on navigation dating from c1595: "How [the error of reading a cross-staff] may be knowne & reformed I haue demonstrated & taught 11 yeares past in my booke called Articon" (B.L. Add. MS 6788, fol. 486 [=Shirley, *THB*, p. 86]). This would date *Articon* to *c*1584, the period when Harriot was preparing for the Virginia voyage and is known to have been actively teaching Raleigh's mariners the navigational arts. Harriot was in no way so closely connected with teaching Raleigh or his men in 1595.

[35] Shirley, *THB*, p. 238 and on the experiments, pp. 268-73. Of course, Harriot was likely interested in Aristotelian matter theory throughout the 1590s. I must thank Peter Nockolds from the Durham Thomas Harriot Seminar for this reminder.

reminding himself to return it or perhaps was reminding himself to borrow a book from Allen, but given the discussion above, it may well have been Thomaz's or Torni's books. Indeed, Harriot borrowed many books and manuscripts from Thomas that he could not find, even in the Wizard Earl's large library. Upon his death, Harriot had "some written Coppies to the number of twelve of fowerteen (more or lesse) lent unto [him] by Thomas Allen of Gloster Hall in Oxford Mr of Artes." He asked his executors to "restore them safely according to the noate that hee shall deliver of them," Harriot admitting that he doubted "whether I have anie true noate of them my selfe."[36]

"Varro" is unlikely to be a reference to the Roman historian and agronomist – and incidentally, military commander – Marcus Trentino Varro (116-27 B.C.) who wrote *De re rustica* on farming and husbandry and *De lingua latina* on Latin etymology and syntax. It is more likely that Harriot has simply misspelled the name of a different author, Sebastian Verro. In 1581 Verro published *Physicorum Libri X* – the *Ten Books of Physics* – in Basle and London.[37] A copy of the 1590 edition of this relatively rare book still remains in the library of the Wizard Earl at Alnwick Castle, Northumberland, although there are no annotations by Harriot in this copy (although there are a few in the earl's hand).[38] Verro summarizes Aristotelian natural philosophy and unites all realms from heave and earth to inanimate, animate, and spiritual matter within one

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[36] Harriot's will, quoted in Shirley, *THB*, p. 463.

[37] *Sebastian Verronis Friburgensis Helvetii Physicorum libri X. Nunc Primum in lucem editi* (London: Henrie Bynneman, 1581; STC 24688). There was also a 1590 reprint by John Harison (STC 24689) and George Bishop (STC 24689.5). Sebastian Verro (1555-1614), or Werro, as he is known in Switzerland, came from a distinguished family in the canton of Freiburg. A Jesuit priest, prévôt, and administrator in and around Lausanne, Werro assisted in calendrical reform sponsored by Pope Gregory XIII and spent the last 2 decades of his life vigorously pursuing counter-Reformation ideals. His work on physics was his first work and he did not apparently return to the subject. See *Dictionnaire Historique & Biographique de la Suisse* (Neuchatel, 1933), 7: 288.

[38] I should like to thank Prof. Gordon R. Batho, University of Durham, for securing me research time in the Percy archives at Alnwick and the archivist there, Dr. Colin Shrimpton, for his kind attention.

Ramist analysis (see fig. 2.1). There is nothing in the *Physicorum* that could be directly applied to the surviving ballistic papers, yet Harriot's "notes of ordnance" follow directly after its entry in the laundry list. There is a section on local motion (*de motu locali*), but Verro treats it as a subsection of book nine, on souls (*Animae*). The notable feature of the book is its rigorous Ramist hierarchy, but its inclusion also emphasizes the Aristotelian nature of the entries in the list. This is especially clear when it is considered in conjunction with the last entry.

"Proclus de moto" unambiguously refers to a work by the Byzantine philosopher and theologian, Proclus (*c*410-85), entitled the *Elements of Physics*. In the Middle Ages and Renaissance, however, this work was frequently known as *de motu* – "On Motion." Proclus's *Elementatio Physica* (Στοιχειωσις Φυσιχε) summarizes and mathematizes Books VI and VII of Aristotle's *Physics* and Book I of *De Cælo*. It boils down the thought of Aristotle into something "whereby one may in a few days know what otherwise would take many months to learn from Aristotle."[39] Considered one of Proclus' earliest works relying on a deductive method,[40] it is not surprising that it might appeal to Harriot, for his approach to ballistics relies heavily on deduction.[41] The *Elements of Physics* is not among the works for which Proclus is notably remembered today,[42] but in the

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[39] Justus Velsis' introduction to the 1545 Latin edition (see below), quoted by L.J. Rosán, *The Philosophy of Proclus: the Final Phase of Ancient Thought* (New York, 1949) , p. 50. The *Element of Physics* was considered as a seminal source for ideas on motion in the preface to a 12th century Sicilian translation of Ptolemy's *Almagest*: "Phisicaque Procli Elementatione prelusi" (*De motu* also was translated into Latin at the same time under Frederick II of Sicily). This also suggests yet another connection with Allen, who wrote commentaries on books 2 and 3 of the *Almagest*. See also C.H. Haskins, *Studies in the History of Mediaeval Science* (Cambridge, MA, 1924) , p. 191, 243-4. This may also be the work Aristippus (also 12th century Sicilian) referred to as Proclus' book on mechanics, whose "proofs" on motion presumably made more sense with the now-missing diagrams.

[40] Proclus, *The Elements of Theology* (Oxford, 1963) , pp. xiv-xv.

[41] The classical induction / deduction debate, usually tied to Francis Bacon's works from the early 17th century can often be seen in later 16th-century works. It all depends upon whether one sees Bacon as inaugurating or summarizing an age.

[42] Proclus' most important connection in the history of science is his work known as the *Sphæra*. It was first printed in Latin by the Englishman Thomas Linacre in Venice in 1499, went through 72 editions by 1670 (65 of them in the 16th century), and was "Englished" in 1550

mid-sixteenth century, it was something of a best-seller. A number of editions of the work were published which Harriot might have used.[43] Simon Grynaeus published an edition in 1531 in Basel which was later republished in Paris in 1542, but they both were in Greek, a language Harriot seems never to have learned or used in any great way. The first Latin edition coincided with the reprint of Grynaeus' work (Paris, 1542), this time translated by Spiritus Martinus Cuneas. J. Velsiusin (Basle, 1545) and F. Patrizzi (Ferarra, 1583) also produced Latin translations, while P. Forcdel (Paris, 1565) published a French translation.[44] Both the Cuneas and Velsius editions were entitled *De motu*, making it entirely likely that it was one of these two volumes to which Harriot refers in his list.[45]

De motu is organized into two books, one on terrestrial and one on celestial motion. Each book is then organized in wonderfully Euclidean form

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by William Salysburye as *The Description of the Sphere or Frame of the Worlde*. See L.J. Rosán, *The Philosophy of Proclus*, pp. 252-54 for the list of editions (although he dates the first English ed. to 1553) and 46-7 for contents. Also notable in the context of this study is Proclus' *Commentary on Euclid's Elements*, bk. I, ch. XIII, which suggests a division of mathematics into the entirely knowable (arithmetic and geometry) and the partly knowable, partly sensible, this latter category containing nearly an exhaustive list of what would become known as the "mixt mathematics" in the 16th and 17th century (mechanics, astronomy, optics, surveying, harmony, practical arithmetic, and military strategy). See *ibid.*, pp. 44-5 and 247. This work only saw two editions in the 16th century, but John Dee's indebtedness to it is clear; see N.H. Clulee, *John Dee's Natural Philosophy: Between Science and Religion* (London, 1988), pp. 157-59. Debus' introduction in the modern edition of Dee's *Mathematicall Praeface* does not mention this connection.

[43] See L.J. Rosán, *The Philosophy of Proclus*, p. 249 for a full list of editions.

[44] The only further editions were a French edition in H. Meynier's, *Paradoxes contre les Mathematiiens qui abusent la jeunesse* (Paris, 1652) and a partial English edition (an uncritical and incomplete translation of the postulates on celestial mechanics in book II) included in Thomas Taylor's, *Ocellus Lucanus on the Nature of the Universe* (London: Bohn, Bohn and Rodd, 1831), pp. 85-96. Two modern editions exist, a Greek-German edition: Proclus, *Institutio Physica* (Leipzig, 1911-12) ; and a Greek-Latin edition based on the extant medieval manuscripts: H. Boese, *Die Mittelalterliche Übersetzung der ΣΤΟΙΧΕΙΩΣΙΣ ΦΥΣΙΚΗ des Proclus* (Berlin, 1958) . Boese's edition – consistently missed in bibliographies of Proclus studies – reconstructs the stemma of the seven surviving MS copies (none of which exist in England): two each from the 13th, 14th, and 15th centuries, and one from the 16th century spread from Toledo to Dresden (see pp. 7-15).

[45] The British Library holds 2 copies of the Cuneas edition with slightly different title-pages, either of which may have been the edition Harriot used. I have not examined either for marginal notes, but Dr. Stephen Clucas, Birkbeck College, London, who has examined these volumes in connection with Harriot and Percy informs me that they have no manifest connection to Harriot.

(not surprising, since Proclus also wrote a commentary on Euclid's *Elements*), made up of axioms (6 and 14, respectively) and propositions (31 and 4). In the propositions, Proclus attempts to prove his assertions with geometrical diagrams, which do not survive, although this poses little problem on most of the propositions, as most refer only to dividing lines into parts. Propositions in book I range from "Every divisible continuum is always divisible" (I.5), to "All times are infinitely divisible, as are all magnitudes and all motions" (I.11) and discuss the (im)possibilities of infinite motions in finite times and other similar matters.[46] The "geometrical" nature of the proofs is superficial, referring to lines AB and motions from B to G to D.

Ultimately, *De motu* would have provided little new or stunning information to Harriot, merely confirming Aristotelian ideas of motion with no "modern" concepts of impetus or air resistance. But its treatment of motion as relative lengths of different line segments would have been exactly what Harriot was looking for in his section "on oblique motions" (see fig. A1.4a in Appendix I) and entirely complementary to the analyses of Thomaz and Torni. While he does not acknowledge Proclus on those folios in the way he acknowledged the other authors in the section on asymptotic series, it seems fairly certain that this is why "Proclus de motu" would have been added to the "laundry list" immediately after his "notes of ordinance." That Proclus is a primer on Aristotelian motion also ties in nicely with Verro's primer on Aristotelian nature and whatever Harriot meant by the first entry of the list on Aristotle's four elements.

Modern commentators dismiss Proclus' *On Motion* as a "slim volume…. [which] is nothing more than an excellent and faithful primer on Aristotle's theory of motion.… It is Neo-Platonic in only a limited sense: it is written and

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[46] "Omne continuum divisible est in semper divisibilia" and "Omne tempus in infinitum dividitur et omnis magnitudio et omnis motus." Boese (ed.), pp. 32 and 36.

arranged by a Neo-Platonist with the educational 'scope' to show how Aristotle's theory of motion leads to an immaterial prime mover."[47] Verro, too, is limited in scope, but nonetheless is organized to demonstrate the hierarchies of the universe (including humans). And despite the fact that Proclus was one of the first Greek treatises on science to be translated into Latin, as far as modern commentators are concerned, it played little to no role in the thinking on matter and motion in the Renaissance. Moreover, it served as the primer on Aristotle but not the modifications and rejections of his theories. The works would have been appealing to Harriot, however, although ultimately not of terribly much help in his immediate attempt to understand projectile motion numerically.

It is, however, important to note that Proclus partially dismantled Aristotle's theory of natural motion, believing that the natural motions applied only when the matter was in its natural place. When it was trying to get to the natural place, it was actually moving perpendicular to its natural motion: "When Fire is carried upward it is because it is in a foreign place and… likewise a lump of Earth is moved downwards and in general the tendencies of the Elements to move in a straight line are those whose conditions are contrary to nature."[48] Thus, the motions of fire rising or bodies falling was not constrained in Proclus' view to the standard Aristotelian idea of rectilinear motion in the terrestrial realm and circular motion beyond it, and hence the two realms are unified with respect to one coherent law of physics. Realistically, however, this "law" was

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[47] L. Sirovanes, *Proclus: Neo-Platonic Philosophy and Science* (Edinburgh, 1996) , pp. 246-7. It was more John Philoponus, following Proclus, who was responsible for the reformation of Aristotelian ideas of motion, specifically the introduction of impetus theory; Galileo was quite familiar with Philoponus although Harriot was apparently not. See Michael Wolff, "Philoponus and the Rise of Preclassical Dynamics," in Richard Sorabji (ed.), *Philoponus and the Rejection of Aristotelian Science* (London, 1987), pp. 84-120.

[48] Proclus, *Commentary on Plato's Timeaus*, 2.12.3-6, quoted in L. Sirovanes, *Proclus*, p. 245. Sirovanes goes so far as to claim that Proclus contains a nascent theory of the trade-off between potential and kinetic energy (*i.e.* conservation of energy, although he carefully avoids using this term) in that he posits that things move when they are not in their natural place.

something more like an anti-law, as Proclus does not speculate in what the functional relationship might be in the *Elements of Physics*. Harriot's reading of the sixteenth-century editions, however, provided him the essence of this idea and may have contributed to his disassociation of the horizontal and vertical components of motion which is characteristic of his analysis.

Thus, the notation on ordnance which so interested Shirley presents two possibilities. First is his suggestion that it was indeed a work by Harriot for Raleigh which is now lost. But more plausible is to take the adjective "my" as referring to his own work, rather than work for others. By the mid-1590s, Shirley has shown that Harriot had begun to act more like a free-agent than an employee of any one patron. Placing a contemporary work on motion immediately after one on ordnance, and that entry immediately after a survey of all of Aristotelian physics and possibly a work on motion from his teacher, suggests that there is indeed a link between the items on the list. Harriot obviously thought about the topic within an Aristotelian framework, in his characteristically inductive manner. In the surviving ballistics papers, the work is on balance not theoretical, but it is clear that Harriot would have wished to have give his empirical studies theoretical foundations, if they were available.

Personal Contacts

Beyond his intellectual analyses, Thomas Harriot interacted with the fringes of the Elizabethan court and while in London mingled with his contemporaries, Shakespeare, Marlowe, and Johnson. His contacts at court also kept him in contact with a full range of society, from Lord Burghley and the Privy Council to shipbuilders and instrument makers. There is no evidence he ever met Queen Elizabeth, although he certainly met King James shortly after his accession, when James visited Syon House, the Earl of Northumberland's

residence, where Harriot then lived. But in working on ballistics – as distinct from navigation – there were few people in England who might have been of help. As far as is known, Harriot never interacted with any of authors of works on artillery.[49] But Harriot did have relations with a man more important in Elizabethan London, a man whose fame precedes him, and a man who may not have ever fired a cannon, but one who thought analyzing them by mathematics was an entirely possible and productive endeavor: John Dee.

John Dee and Thomas Harriot moved in the same circles[50] and in fact Dee and Harriot, as well as Harriot's patrons, Raleigh and Percy, interacted quite closely on a number of occasions. Raleigh occasionally did favors at court for Dee, and Dee aided Raleigh's half-brothers, Adrian and Humphrey Gilbert (no relation to William Gilbert of *De Magnete* fame) in preparation for their voyages of exploration. Similarly, the circle of mathematicians around Dee and those in the Northumberland circle often overlapped and interacted. We have only a few references to Harriot and Dee meeting, but on at least half a dozen occasions, he was a guest at dinner in Dee's household and both he and Dee dined at the table of Northumberland.[51] Most telling, however, is an inscription from 1590/1 in Dee's hand in a Spanish book on the exploration of New Mexico, noting that it was a gift from Harriot, "my friend."[52]

The book is interesting, and besides confirming their friendship and demonstrating that they both had command of Spanish, it casts some light on Harriot's activities and allegiances in 1590/1. The book, published in Spanish and

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[49] There is a chance that he may have met Thomas Digges, and Digges may have been the author of a military preparation memorandum for the Roanoke Voyage (see below). See ch. 3, below, for a discussion of those contemporary authors.

[50] P. French, *John Dee: the World of an Elizabethan Magus* (London, 1972) , pp. 171-2.

[51] G.R. Batho, *Thomas Harriot and the Northumberland Household* (Durham, 1983), p. 20.

[52] P. French, *John Dee*, p. 172, n.4. The title-page reads *El viaje que hizo Antonio de Espejo en el anno de ochenta y tres* (Madrid, 1586) and includes a note in Dee's handwriting: "Joannes Dee: A^{o} 1590. Januarii. 24 Ex dono Thomas Hariot, Amici mei."

French in 1586, appeared in English translation in 1587.[53] Had Harriot not wanted the book so keenly, he would not have had to wait long for an English version, but through some unknown channel, he obtained a copy of the Spanish edition. This also argues that he received it (or ordered it through some bookseller or dealer) in 1586 or early 1587, while still in Ireland. In many respects, we should not be surprised that he would want a book on the New World at this time. It had only been just over a year since he himself returned, and it was at this time that he was finishing his own *Briefe and True Report*. But also, the fact that he gave it to John Dee within 4 years suggests that by 1590/1 he considered his days as an explorer over.[54] This, in turn also makes sense, in that Harriot seems to have begun shifting patronage from Raleigh to Northumberland at about this time. Percy had little interest in exploration and discovery, and so Harriot, too, probably steered away from that topic. It is also possible that this gift indicates one of the connections between Dee's circle of mathematicians and the Northumberland household, with Harriot as a new pensioner.

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[53] The English translation was, Antonio de Espejo , *New Mexico. Otherwise, The voiage of Anthony of Espeio, who in the yeare 1583. with his company, discouered a lande of 15. prouinces, replenished with townes and villages, with houses of 4. or 5. stories height, it lieth northward, and some suppose that the same way men may by places inhabited go to the lande tearmed De Labrador*. (London, [1587]; STC 18487). It was actually an extract of "Historia de las cosas mas notables de la China" by Juan Gonzales de Mendoza, based on accounts by Martin Ignacio de Loyola rather than Espejo himself.

[54] Harriot never gave up on navigation and exploration entirely, but after 1590 seems to have acted in an advisory capacity more than playing any active role in any adventures. In 1594 the preface to Robert Hues' *De globis et eorum usu* (STC 13906) announced that Harriot was about to publish a work entitled *De rumborum ortu, natura et usu*, but it never appeared. This may have been an updated *Articon*, a supposition strengthened by the fact that Hues was also in the pay of Raleigh and *De globis* carried Raleigh's arms on the title page. Hues also later migrated to the Northumberland camp, becoming tutor to Henry's son, Algernon Percy (later the 10th Earl). Harriot did draft a report "Three Reasons to Prove a N.W. Passage" which is still extant in MS form from 1611, but this probably never went beyond Harriot's immediate circle of patronage; see L.B. Cormack, "Twisting the Lion's Tail: Practice and Theory at the Court of Henry Prince of Wales," in B.T. Moran (ed.), *Patronage and Institutions: Science, Technology, and Medicine at the European Court, 1500-1750* (Rochester, NY, 1991) , pp. 80-81, esp. n. 69.

But Harriot's friendship with Dee is important on another level as well. Though Dee worked on geometry and alchemy, his connection with Harriot undoubtedly stems, at least initially, from his work on navigation. It would be surprising if Harriot had not sought Dee's input or comments when employed by Raleigh to improve the trans-Atlantic navigational skill for his expeditions. Unlike many historians who see Dee's "spooky influences"[55] and focus on his association with the medium and charlatan Edward Kelly, in the history of technology Dee is primarily known for one work, the *Mathematicall Praeface* to Henry Billingsley's translation of Euclid's *Elements* of 1570. While not a work of much practical value, it sets out a philosophical organizational scheme for all the mathematical arts, with divisions quite beyond the classical geometrical subjects one might expect in a preface to Euclid.

The *Mathematical Praeface* is a work in its own right: fifty-four pages of closely-set type and a large Ramist-style "Groundplat of [the] Mathematicall Præface" accompanying which allowed his readers to "see" the vast range of arts which "the mathematicks" covered (see fig. 2.2). Besides the "principall" mathematics, arithmetic and geometry, and their practical applications, Dee enumerated the twenty "derivative" mathematical arts: the modern fields of perspective, astronomy, music, cosmography, astrology, statics, pneumatics, horology, architecture, and navigation, as well as fields for which he coined terms, including "anthropographie" (mathematics of the human body), "trochilike" (the study of circular motions), "helicosophie" (the study of spiral motions, including conic sections), "menadrie" (multiplication of forces), "hypogeiodie" (subterranean geometry), "hydragogie" (hydraulics and irrigation), "zographie" (perspective drawing), "thaumaturgike" (mechanical

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[55] See Stillman Drake's review of J. Dee, *The Mathematicall Praeface to the Elements of Geometrie of Euclid of Megara (1570)* (New York, 1975) in *Technology & Culture* 17.1 (1976): 128-9.

magic), and "archemastrie" (a broad term for the "*scientia experimentalis*"). Artillery appears in his prescriptive taxonomy of mathematics concluding the section on "menadrie", the science of weights and forces:

> nothing inferior to the invention of [catapults], was the invention of Gunnes. Which, from an English man, had the occasion and order of first inventing: though in an other land, and by other men, it was first executed. And they that should see the record, where the occasion and order generall, of Gunning, is first discoursed of, would thinke: that, small things, slight, and comon: coming to wise mens consideration, and industrious mens handling, may grow to be of force incredible.[56]

Dee's failure to develop *how* guns were mathematical is typical of his *Praeface*, but their inclusion legitimized the study of ballistics as a mathematical science. In the publication history of English-language gunnery books, Peter Whitehorne in 1560 included little mathematical context or content in his book, but by the end of the 1570s William Bourne and Leonard and Thomas Digges would very definitely speak of gunnery as a mathematical art (see ch. 3). In 1588, when Thomas Hood accepted the position of "Mathematicall Lecturer to the Cittie of London", he would specifically add "the Gunner witnesse in planting his shot" among the beneficiaries of the lectureship (see ch. 8).[57] Clearly influenced by Dee's conception of the extent of mathematics, Hood very specifically addressed his address to the education of men in "Martiall affaires," including gunners. Dee's far-reaching conception of the mathematics' utility in the military arts likely influenced the young Harriot which, combined with Harriot's natural mathematical penchant, inspired him to find numerical and geometrical explanation for the behavior of artillery.

Practice interested Harriot more than theory throughout his life and his investigations indicate that he used many avenues of inquiry to further his work.

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[56] J. Dee, *The Mathematicall Praeface* (London, 1570), sig. d.i.^{v}. Dee's reference to an Englishman's invention of guns must refer to Roger Bacon's mention of gunpowder in *c*1260.

[57] F.R. Johnson, "Thomas Hood's Inaugural Address as Mathematical Lecturer of the City of London (1588)," *Journal of the History of Ideas* 3 (1942): 105. See also ch. 9, below.

He began his career in Raleigh's service creating the *Articon*, a practical book on navigation. He was sent to Virginia to observe, map, catalogue, and record – not to theorize. He spent time on board ships and discussed shipbuilding with men in the yards, later developing his own theories about the optimal shape of ships' hulls.[58] So although he would eventually attempt to mathematize what he found in the yard or field, he often worked in an inductive manner. One note in his manuscripts raises interesting questions about who he might have consulted about his work on ballistics. At the bottom of one page there is the following table:[59]

By Bourne

15°	78	794
20°	87	885

Apparently some sort of note of ranges (or velocities) at two elevations, Harriot clearly ascribes this data to William Bourne, the author of *The Arte of Shooting in Great Ordnance*. It is tempting to see the second column as denoting the two editions of Bourne's work, which appeared in 15*78* and 15*87*, but since the numbers do not appear in any of Bourne's surviving writings, the answer is not forthcoming.[60]

John Shirley made a note to this effect and concluded that "they [the numbers] must have been obtained from Bourne himself, who was a gunner,"[61] although modified this thought in the printed biography: "As a matter of fact,

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[58] See Shirley, *THB*, pp. 96-104*f* and below.

[59] Petworth MS 241, fol. 11.

[60] Only one copy of the 1578 edition survives (at the Royal Artillery Institution, Woolwich), but it and the 1587 edition are apparently identical. There are also two manuscript versions of the text, one to Lord Burghley from 1573 (B.L., MS Sloane 3651) and one apparently from c1578 (Bod. Lib., MS Rawlinson D 704). In cursory examinations of both of these, the content does not deviate greatly from the printed version, nor have I found "794" or "885" in them. For further information on Bourne, see ch. 3, below. Harriot may have been in possession of a manuscript by Bourne which no longer survives.

[61] Note on photocopy of Petworth House Archives, MS HMC 241/VI[a], fol. 3, in the Archives at the University of Delaware, whom I must thank for access to the John W. Shirley Papers which include photocopies of all of Harriot's manuscripts.

[Harriot's] notes contain data from Bourne… not covered in his published works, showing that he did not confine himself to the data in books."[62] Shirley must have modified his personal annotation for publication because he realized that Bourne died in 1582. There would therefore only have been a brief period in which he and Harriot could have met, and this was at least a decade before Harriot turned his attention to ballistics. But their meeting would have been entirely likely, given that Bourne was the leading author on navigation of his day and Harriot had just been hired to teach navigation to Raleigh's mariners. Bourne's *Regiment for the Sea* had already gone through three editions (1574, 1577, 1580) and Bourne would have been a natural contact for Harriot to have made. If Bourne and Harriot did ever meet, Bourne might well have turned the discussion to his recent *Arte of Shooting in Greate Ordinance*.[63] Bourne knew Dee and on at least one occasion late in Bourne's life they met to discuss "the mathematics,"[64] although he did not interact with the rest of the Northumberland circle directly, due to his removed location at Gravesend and the unavoidable social distinctions. Dee, like Harriot was pleased to discuss practical problems with practical people, so it should not be surprising that Harriot did become good friends with Dee, nor that he might have sought out Bourne last years of Bourne's life. While Harriot's reputation in the history of science has tended to make him out as a great scientist, much of his practical, hand-on – that is to say, technological – work has been obscured. It remains to

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[62] Shirley, *THB*, p. 251.

[63] Shirley, *THB*, p. 243, incorrectly claimed that Bourne was self-conscious about issuing his book and therefore delayed publication until 1587. This posthumous 2nd edition was a response to the Armada scare – see ch. 3, below.

[64] In his second edition of *A Regiment for the Sea* (1580), Bourne added a passage at the end which mentions that "upon a time I being with Master *Dee* at his house at *Murclacke*," that they fell "in talke about the discoverie to *Cattay* & so talked as touching the shipping whereupon he opened a Booke and shewed [Bourne] a note what number of ships the great *Cane* [*i.e.* Khan] had readie at one time to goe unto sea." See E.G.R. Taylor, *A Regiment for the Sea and Other Writings on Navigation by William Bourne of Gravesend, a gunner (c.1535-1582)* (Cambridge, 1963) , pp. xxxi-xxxii and 313.

be seen, however, whether the ballistics are indeed work of utility or work of curiosity.

Patronage

The study of Renaissance science and technology asks not only what was done, who did it, and why, but also who caused or allowed it to be done. The matter of patronage is wide and varied, but since Harriot enjoyed the favour of two influential patrons in his lifetime, their influences upon him require investigation. Harriot worked on ballistics in the 1590s and into the 1600s. At this time, Harriot was in the process of switching patronage from Sir Walter Raleigh to Henry Percy, the ninth Earl of Northumberland. But to say that he was switching patronage is not to say that he was switching allegiances. Although Harriot derived the bulk of his income from Percy beginning in about 1594, it might be more correctly said that Percy kept Harriot "on staff" while Harriot still occasionally did contract work for Raleigh throughout the 1590s.[65] Raleigh and Percy were quite close friends, especially during their long imprisonment in the Tower following the Gunpowder Plot of 1605, but it is the pre-Plot days which are of interest here.

Sir Walter Raleigh

Of Sir Walter Raleigh, little needs to be said here as his fame precedes him.[66] Soldier, explorer, poet, author, courtier, and eventually prisoner, Raleigh flitted about the Elizabethan court as a favored minion, and procured for himself a living quite above his station, being the second son of a country gentleman's

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[65] On the whole changeover in patronage from 1590-1600, see Shirley, *THB*, ch. V.

[66] Biographies abound of Raleigh. For a recent, readable one, see S. Coote, *A Play of Passion: the Life of Sir Walter Ralegh* (London, 1993) . The classic academic title is still W. Stebbing, *Sir Walter Raleigh, a Biography* (Oxford, 1899) . For his oeuvre, see Sir W. Ralegh, *The Works of Sir Walter Ralegh, Kt. Now First Collected* (Oxford, 1829) [hereafter, Raleigh, *Works*].

third marriage. But fame can be fleeting and Raleigh's fortunes in the last decade of Elizabeth's reign were as mercurial as was her temper.[67] In the years he knew and employed Harriot, Raleigh was in his "colonial" phase, repeatedly petitioning Elizabeth to back his explorations of the new world or his plantations in Ireland. He did spend a few years as a direct employee of the Crown – in the Irish wars from 1585-87, as a soldier and commander on the Cadiz expedition in 1596 and the "Islands Voyage" to the Azores in 1597 – but most of his time was spent as a private citizen and entrepreneur. As far as his employment of Harriot is concerned, Raleigh hired Harriot fresh from Oxford to tutor him in mathematics and to undertake practical investigations that might profit Raleigh's various endeavors. Raleigh had Harriot work out tables of longitude and quick-reference works on navigation for the training of his crews. He may have asked for Harriot's thoughts on shipbuilding,[68] and the standard interpretation is that Raleigh asked Harriot to compile a useful handbook on ballistics for his use in his exploration and piracy expeditions.

There are a number of telling remarks in Raleigh's work, however, that suggest he would not have turned to Harriot for help on ballistics. Before his

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[67] In 1592 Raleigh secretly married Elizabeth Throckmorton, one of Elizabeth's maids of honor, and had a son by her. Elizabeth was furious with him for this union, and when he tried to leave the country on his Guiana voyage, Elizabeth manifested her displeasure by confining the new family to the Tower. Her need of his services caused his release from prison, although not from custody. Combined with these political troubles, it was in the mid-1590s that Raleigh (and Harriot with him) was under attack for atheism and "conjouring".

[68] Muriel Seltman has suggested that Harriot worked on 4th order polynomial equations as solutions to optimal ship hull profiles (IHPST Colloquium, University of Toronto, 26 April 1996, and personal communication, Dec. 1998). David McGee (IHPST/Dibner Institute, MIT) has suggested to me that he does not believe Harriot's hull designs were as mathematically rigorous as Seltman believes. I have not fully investigated this possibility, and although he did clearly take an interest in hull design and naval architecture in general, I am tempted to argue that this, too, may turn out to be an example of a personal interest (in polynomial arithmetic and graphing) becoming intertwined with employment duties (provisioning and outfitting ships for Raleigh's voyages, both Virginia in the 1580s and Guiana in the 1590s, although his notes date from after both Raleigh and Percy were in the Tower; see J.V. Pepper, "Harriot's Manuscript on Shipbuilding and Rigging (ca. 1608-1610)," in D. Howse (ed.), *Five Hundred Years of Nautical Science, 1400-1900* [Greenwich, 1981], pp. 204-16).

imprisonment in 1603, Raleigh's scientific leanings tended to be more practical than theoretical. When he went to Harriot he asked for specific advice on specific questions to help him further his goals. Ballistics was not practical and did not serve any of his needs in the 1590s. In his *Notes on the Royal Navy* Raleigh is at great pains to complain of the over-gunning of ships. This work has been recently redated to 1598 rather than the end of the next decade, by the similarity of its contents to a manuscript now in the Folger Shakespeare Library in Washington, D.C.[69] During the "Islands Voyage" of 1597, Raleigh noted that there was a "huge & excessive proportion of Artillery, wherof if many had not bene stroken down into holt [*i.e.*, stored in the hold]…, diverse of the Shipps with the host & charge therof, would have foundered in the Sea," a complaint he would repeat in other works.[70] In particular, Raleigh was complaining of his flagship, the *Warspite*, which although new, was not built to take the large number of guns assigned her. If, however, Raleigh had been a strong supporter of artillery, he might have complained about the ship rather than the ordnance.

Although he does note that the "Perfection of our ordeinance & Gunners" was a goal to be sought (along with all the other dreams of a naval captain such as "aboundance & reddines of our victuallinge" and "goodness of our havens & harboroughes"), he nevertheless complained that there was an over-reliance on shipboard artillery.[71] He did, however, recognize the general importance of artillery, for, as he said, "what are all the ships in the world to be valued at, other than a company of floating tubs, were they not furnished with ordnance, either

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[69] S. Gossett, "A New History for Ralegh's *Notes on the Navy*," *Modern Philology* 85 (1987): 12-26. She shows quite convincingly, that the 1608-10 version, dedicated to Henry, Prince of Wales, was a rewriting and augmentation of a tract originally composed for Queen Elizabeth.

[70] Folger Library MS J.a.1, fol. 163^{v} [Gossett, "A New History…," p. 18]. On Raleigh's other comments about the instability of contemporary ships, see his "A Discourse of the Invention of Ships, &c.", in his *Works* VIII.324*ff*.

[71] Folger Library MS. J.a.1, fol. 165^{v} [Gossett, "A New History…," p. 20].

to offend others, or defend themselves?"[72] But while he knew it would be foolishness to abandon great ordnance, he argued strenuously that less is more. Citing the famous 1545 sinking of Henry VIII's flagship, the *Mary Rose*, by a modest breeze that heeled her over, dipping the lower gunports below water, Raleigh argued that ordnance should never be mounted lower than four feet above the waterline and that small, nimble and lightly-armed ships were more useful than a heavily-gunned ones.[73] Ultimately, he begins his section "Of great ordnance" in his "Observations concerning the Royal Navy" by saying that "It were also very behoveful that his majesty's ships were not so over-pestered and clogged with great ordnance as they are."[74] The forty pieces that common wisdom places on board are even more than the "twenty or thirty good brass pieces [that are] a royal battery for a prince to bring before any town or strong fortress." Not only did he claim that a reduction in the number would save powder, shot, and stress on the ships, it would also make them more nimble for the broadsides encounters which were the only sort of encounter fought to any effect.

Raleigh, then, discounted the need for over-reliance on offensive artillery at sea in his writings, but so too did he seem to discount its effectiveness against him in his personal experience. During the "Islands Voyage" of 1597, Raleigh, in a rash move (against Essex's orders) landed on the island of Fayal, intending to take the town. Quite to the amazement of his men, he advanced in the face of "thick" defensive fire, urging them on repeatedly. As reported by Sir Arthur

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[72] Raleigh, "A Discourse of the Invention of Ships, &c." [Raleigh, *Works* VIII.331].

[73] See "A Discourse of the Invention of Ships, &c." [Raleigh, *Works* VIII.337-9] and "Observations concerning the Royal Navy and Sea-Service" [Raleigh, *Works* VIII.347-8], where he argues that the "superflous great pieces in every ship" might more profitably be withheld to provide instead "swords, targets of proof, morions, and curats [curiasses]" to embolden the sailors when they close with the enemy. Recall that larger guns mean longer ranges, where range tables would be of some use.

[74] Raleigh, *Works* VIII.342-3, where he also notes the chronic under-supply of gunners in the Navy, of which, see ch. 7, below.

Gorges, Raleigh's brother-in-law and captain of the *Warspite*, "whilst with their great ordnance and musketry [they] were very shrewdly pelted," Raleigh continued the assault on Fayal town.[75] Despite various wounds from small arms fire and even as "two of [their] train had their heads stricken clean from their shoulders" by "the great artillery which did beat upon the old walls amongst the which [they] were to pass," Raleigh succeeded in taking the fort. While allowing for a certain amount of bravado in the actions as well as the reporting, it is clear that Raleigh was not overly-concerned about the effectiveness of the Spaniards' ordnance. He echoed as much in his relation of the Cadiz expedition the year before: he noted that as he sailed into Cadiz harbor in 1596, the forts of St. Philip and Puntal "terrified us not,… though it played upon us with four demi-cannons within point blank, from 6 in the morning till 12 at noon."[76] And indeed, other naval commanders echoed Raleigh's attitude: Monson opined, "he that shooteth far off at a ship has as good not shot at all."[77]

Raleigh had never apparently been an energetic promoter of artillery, for in the Second Virginia Voyage to Roanoke Island, he, or the men under his command, made little provision for ordnance, despite the fact that in the sixteenth century, and indeed well into the eighteenth, colonial voyages were by definition also military voyages. In a planning note for the voyage,[78] provision was made for a force of 800 soldiers, 400 harqubusiers, 100 sword and buckler

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[75] S. Coote, *A Play of Passion*, pp. 266-69.

[76] Raleigh, *History of the World*, V.i, quoted in C.R. Markham, *The Fighting Veres: Lives of Sir Francis… and Sir Horace Vere* (London, 1888) , p. 228, n. 1. A demi-cannon's point-blank range was from 350 up to 500 paces (533-760m).

[77] M. Oppenheim (ed.) *The Naval Tracts of Sir William Monson* (London, 1913) , IV.43.

[78] The short 4-page manuscript, entitled "For Master Rauleys Viage", is preserved in the Essex County Record Office, County Hall, Chelmsford, MS D/DRh, M 1, and is transcribed in D.B. Quinn, *The Roanoke Voyages 1584-1590* (London, 1955) , I.130-39 (hereafter Quinn, *RV*). The work is not signed nor is the author identified in any way; it is only endorsed to Master Cavendish, that is Thomas Cavendish, the commander of the 50-ton *Elizabeth*. D.B. Quinn has suggested the author was either Sir John Smythe, Sir Roger Williams, or Thomas Digges.

men, 150 longbows, 150 "Armed men"[79] and the sort of fortifications that should be used.[80] Notably, here the author makes no provision whatsoever for large ordnance. In the list of important men to recruit (or impress) for the expedition the author included unspecified officers, a physician, geographer painter, apothecary, surgeon, an "alcamist" (metallurgist), a "lapidary" (mineralogist), and an "Ingenyr and Cunynge treuese Master."[81] Nowhere in his entire recommendation does he mention artillery or specially trained gunners. Spanish informants in London reported to Madrid that Grenville's fleet had at least 30 pieces of ordnance, and we know that the flagship, the 140 ton *Tiger* carried five guns on each side and 2 at the bow,[82] but little of this ordnance seems to have been a concern for the settlement.

Realistically, the lack of large ordnance can be seen as a trade-off between benefit of defensibility and the cost of leaving expensive ordnance "behind" in the colonies. Additionally, there was no doubt a realization that having such

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[79] Quinn, *RV*, I.130-31. 100 of these men were to be in light "millan corsseletes" and 50 with "lyght Corsseletes with short weapons" (*i.e.*, pikes and half-pikes).

[80] Quinn, *RV*, I.132-33: "What maner of forte I woulde have I would haue It a pentangell in this manner. with .v. large bulwarkes the Casemates of the Boulwarkes large and open, with a way out of the bulwarke and Into the Streat." This sort of pentagonal fort was commonplace at the end of the sixteenth century. Harriot also composed a work on fortification (B.L., Add. MS 6788, fol. 55-65) which Quinn here noted (Quinn, *RV*, I.132, n.3) and dated to *c*1595. Shirley sees this work as worth only a footnote in his biography (Shirley, *THB*, p. 127, n. 59). In fact, Harriot's pages on fortification are one of the few "polished" bits to be found in his manuscripts, with numbered pages, carefully-written textual passages, and lettered, ruler-drawn figures keyed to the text. Like his ballistics, I would date this work to *c*1598-1600.

[81] Quinn, *RV*, I.134-6. The "Ingenyr" (engineer) could be gunner, but "treuese (traverse) Master" suggests the planner had a surveyor in mind. "Ingenyr", then, probably means a fortification expert, the position that was filled by Ralph Lane. Lane was second in command of the expedition, after Sir Richard Grenville, but they did not get along, and Lane was put in charge of the entire colony after only 2 months when Grenville returned to England "for supplies." Lane had extensive maritime, military, and fortification experience; see the DNB and Quinn, *RV*, I.202 and I.262-3, nn. 4, 6.

[82] P.E. Hoffman, *Spain and the Roanoke Voyages*(Raleigh-Durham, NC, 1987), pp. 27 and 22. In 1576 she had been fitted out with 6 demi-culverins, 6 sakers, and 1 minion – hardly a formidable fighting platform as ships of the day went – and carried a complement of about 80 mariners, 12 gunners and either 8 or 20 soldiers, depending on the source one uses (Quinn, *RV*, I.178-9, n. 6). It is interesting to note that while the number of sailors and soldiers are either approximate or confused, the number of gunners is definitely established in all sources.

large ordnance in the colony was of little use, since any colonial force had no realistic chance of defending itself against any concerted naval attack, even from a relatively lightly-armed vessel. Against other Europeans arriving by sea, the land ordnance would be ridiculously under-matched to the sea-borne ordnance and therefore functioned more as a security blanket for the colonists, reminding them of their European-ness and "invincibility" (it also served the utilitarian function of signaling). Against the Indians such ordnance was note very useful, but not because the colonists were out-gunned. Rather, the Indian canoes would have presented minuscule targets for inaccurate great ordnance. It could however provide defense by firing in the general direction of the Indians and acting as a psychological deterrent, but as an effective point-to-point weapon its efficacy was again next to nil.

In considering Raleigh's career, then, the argument that his interest in ballistics was a parallel case to that in navigation cannot be maintained. He depreciated the value of artillery against him. He depreciated its value to him. His military service on land was in a theatre where artillery played little role (see ch. 5, below). In the 1580s, Raleigh did not know how to navigate, so he hired Harriot to teach him and his men. In the 1590s, Raleigh certainly did know how to wage war, and when he did, artillery was not his chosen method. In short, then, there would have been no compelling need for Raleigh to have sought Harriot's advice on degree-by-degree shooting. And Raleigh always came to Harriot out of need, not out of interest.

Henry Percy, Ninth Earl of Northumberland

Turning to Harriot's other patron, Henry Percy was born in 1564, being 4 years Harriot's junior. At the age of 21 he became head of the powerful Percy family when the eighth Earl of Northumberland, his father and namesake, was

found dead in the Tower, a victim of a suspicious suicide. As Shirley described the new ninth Earl,

> Henry had followed the pattern expected of the heir in a wealthy and noble family. He had been broadly educated at home under private tutors…, and had mastered not only the sports and skills demanded of Elizabethan gentlemen, but also the extremely sophisticated education in languages and humanistic studies that had come into vogue with the Renaissance. In the traditional manner, too, he had traveled abroad at the age of eighteen to polish his education, and had learned to sow his wild oats as the young cosmopolite was expected to do – to gamble heavily, to drink the spirits of wine and usquebaugh which were coming into fashion, and to 'drink' the new weed tobacco when it became available in England.[83]

For much of his life, Percy was an avid inquirer into new and potentially dangerous ideas, including questions of religion.[84] It was into this household of a patron of the arts and friend of Spenser, Shakespeare, and Johnson as well as a scientific dilettante with deep pockets that Harriot would gravitate in the 1590s.

Shirley places all of Harriot's ballistic work after 1590, based on characteristic phases of Harriot's handwriting. One might expect his greatest burst of military research just after his return from Virginia, as the war with Spain flared up, culminating in the Armada of 1588. But Harriot seems to have contented himself with affairs in Ireland at this time. Shirley suspects he was "continuing his regular duties in Raleigh's household – collecting information, assembling maps and charts, maintaining liaison between Raleigh and Elizabeth's officers, and keeping a close eye on Raleigh's estates and business dealings while

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[83] Shirley, *THB*, p. 168.

[84] See H. Gatti, *The Renaissance Drama of Knowledge*, ch. 2, "The Northumberland Texts", pp. 35-48 for a consideration of Percy's interest in Giordano Bruno's atomistic writings. Bruno, it should be recalled, was burned at the stake in 1600 for heresy. Harriot, too, seems to have been an apprentice Brunophile, but his interest in the infinitesimal does not bear on ballistics as far as can be ascertained; see *ibid.*, Ch. 3, "The Northumberland Circle: Harriot's Papers," pp. 49-73. On the matter of religion, Percy had been a strong supporter of toleration, even though he remained Protestant. It was this open-mindedness, along with the unfortunate association with his cousin, Thomas Percy, and a grudge borne against him by the Earl of Salisbury which landed him in the Tower as an (innocent) accomplice in the Gunpowder Plot in 1605 (see n. 87 , below).

Raleigh was otherwise engaged."[85] In the first few years of the 1590s, Harriot began to distance himself from Raleigh, remaining in London while Raleigh attempted to settle in Dorset. Undoubtedly, around 1592 Harriot sought to insulate himself from the allegations of impiety and atheism which began buffeting Raleigh, despite his apparent disdain for dogma. Quinn places the departure of Harriot to Northumberland's service in about 1594, and Shirley suggests that as early as 1591 Harriot might have been looking for a more stable patron than Raleigh.[86] This period of Percy's life is worth examining for clues on Harriot's interests.

In the early 1580s, Henry Percy went on his "grand" tour of Europe, although it really only took him to Paris, where he preferred to stay for the duration of his time abroad.[87] It was at this time that he developed his life-long interest in alchemy and astronomy, incubated while recuperating from a spell of poor health (possibly induced by his youthful overindulgences). Upon his return to England to take up his rightful place in the landed aristocracy, Percy discovered he was an abject failure at estate management and retreated into bookish seclusion. His studies ranged from architecture, gardening, and political

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[85] Shirley, *THB*, p. 173.

[86] Quinn, *RV*, I.387, n. 3. and Shirley, *THB*, pp. 202ff.

[87] Despite his fame as the "Wizard Earl", no full biography has ever been written on Henry Percy (Dr. Stephen Clucas, Birkbeck College, London is currently working on one). Even the DNB article is terse in the extreme. Snippets of his life appear in connection with the Gunpowder Plot, but the only comprehensive sources of his life are in G. Brenan, *A History of the House of Percy* (London, 1902) and E.B. de Fonblanque, *Annals of the House of Percy* (London 1887). These works, however, cover the entire history of the Percy family. The 9th Earl occupies considerable parts of de Fonblanque (vol. 2, ch. 12, pp. 177-365) and Brenan (vol. 2, ch. 2, pp. 31-98 concentrates on his pre-Gunpowder Plot days, and ch. 3, pp. 99-209, chronicles his and his cousin's [Thomas Percy] ill fortunes during the Plot investigations and [briefly] his life in the Tower thereafter). In at least one case, Brenan reordered material without acknowledgment, so he should be used only as an overview. For a more detailed investigation of the trial of the Earl with a transcript of the proceedings (Bod. Lib., MS Perrott 7, fol. 200-8), see Mark Nichols, "The 'Wizard Earl' in Star Chamber: the Trial of the Earl of Northumberland, June 1606," *The Historical Journal* 30.1 (1987): 173-89. Unless otherwise noted, quotations and information on Percy's life comes from Brenan, and most of the relevant information is from ch. 2.

science to geography and military science, and much of his time was spent in alchemical, astrological, and astronomical pursuits. It is the military connections which most interest us here, for I wish to suggest a revision in the standard interpretation of Harriot's ballistic (and other military) work. I believe that the impetus for Harriot's work on these topics came, not from Sir Walter Raleigh, the seasoned military veteran and explorer, but from Henry Percy, Ninth Earl of Northumberland, gentleman, dilettante, and would-be soldier.

By the end of his life, Henry Percy's library contained nearly two thousand volumes, on all manner of topics, including a sizable collection of works on military matters. G.R. Batho has noted that outside his well known literary attempts such as *Advices to his Son* and a few other minor period-pieces, his only attempt at composition was an unfinished work on the art of war.[88] The larger volume, is an elaborate Ramist analysis of warfare that attempts to include absolutely everything. Percy covers morale, discipline, munitions, marching, watching, camping, and battle, but significantly, has absolutely no analysis of artillery. The only mention of gunnery at all is in an exposition of the "Marshalls instruments in the field" and explains why it is omitted:

> Note that the Gen: of the Artillery is here left out as one of the Marshalls intruments [*sic*] in the field, bycause by him he is not commanded, butt by the Gen: only; in many places being estemed as an officer of equal rank with the Marshall, yett for diuers rea-[sons] I cannot allow him other then a subordinate officer in the army.[89]

And nowhere else does he detail how artillery is used or managed in the remarkably detailed manner in which he details the other practices of contemporary warfare. Although comfortable with every other branch of

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[88] See G.R. Batho, "The Library of the 'Wizard' Earl: Henry Percy Ninth Earl of Northumberland (1564-1632)," *The Library* 5th ser., 15 (1960): 249-50 and 250, n.1. Alnwick Castle MSS 511 and 512 are impressive Ramist-style analyses of all military matters, *except* artillery (see below).

[89] Alnwick Castle, Northumberland, MS 512, p. 10. Percy does note great ordnance as one of the elements in his taxonomy of weaponry, but only notes that the motion of the cannonball is either of its "Levell range" or "Random vpon any elevation" (p. 586).

military science, Percy would not touch gunnery, and his admission that artillerists are immediately subordinated to the General of the army only indicates the esteem with which it was held at the time.

In terms of printed works, the Earl read widely in French, Italian, and English. He annotated a number of books, including general works as well as works on specific topics such as cavalry, leadership, fortification, and military classics.[90] Nor did he confine himself to printed editions, as he commissioned a manuscript translation of Simon Stevin's work on fortification, *De Sterctenbouwing*, originally printed in Leiden in 1594.[91] It is instructive to note, however, that of the annotated military works in his library, all were printed in 1602 or earlier.[92] The importance of this date is highly relevant with respect to Percy's military career.

Percy never served the crown in any official military capacity, but he was never far from his country's defense. In 1587, as a sort of cooling-off period over

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[90] *Ibid.*, pp. 254-55. On fortification he made notes in Perret's *Architectura et Perspectiva des Fortifications et Artifices* (1602) and Lorini's *Delle Fortificationi* (1597); on cavalry Corte's *Il Cavallerizzo* (1573) and Broue's *Le Cavalerice François* (1602); general annotated works include Barret's *Theorike and Practice of Modern Warres* (1598), Durrant's *Traicté del la Guerre de Malte* (1553), and Patrizzi's *Paralleli Militari* (1594); on leadership he read Cataneo's *Le Captaine* (1593) and his classical reading included a four-volume Italian edition of Caesar's *Commentaries* (1598) and Patrizzi's *La Militia Romana* (1583). He also annotated Sir John Smythe's *Certain Discourses Military* (1590), a polemical defense of archery over firearms, and one which landed Smythe in jail. It is instructive to note that one of his "works" on military matters (Alnwick castle MS 511) consists largely of noted taken from Cataneo.

[91] Leconfield MS 138, now held at Petworth House, West Sussex. It is unclear whether Percy had retained Paul Ive, the author of the first printed English-language work devoted to fortification, *The Practice of Fortification* (1589), to translate the work for him, or whether Ive dedicated it to Percy after its completion in hopes of remuneration. If the latter, it would demonstrate that Percy was known not only as a general patron of the mathematics and sciences, but also specifically of the military-mathematical sciences. The DSB article on Stevin notes that "although cost prohibited the implementation of the ideas [on fortification]…, these notions were put to practical effect a century later by Vauban and Coehoorn" (XIII.50). Stevin's work on motion was known to Harriot, as he noted Stevin's doctrine of geometrical division, B.L., Add. MS 6789, fol. 30^{r}.

[92] G.R. Batho (Durham) and Stephen Clucas (Birkbeck College) who are in the process of compiling a complete list of the Wizard Earl's library (not just the annotated volumes, as Batho did in 1960) have confirmed that this is not a sampling error; Percy did for all intents and purposes stop reading military literature about 1602 or 1603.

his marriage intrigues brought about in all likelihood by the machinations of Cecil, Percy was sent as a volunteer with Leicester to the Low Countries. He must not have remained there long, however, for during the Armada scare, he outfitted a number of ships, levied troops, and reinforced coastal fortifications at his own expense. Nevertheless, although he was one of the "young nobility and gentry [who]… from a zeal to serve their country joined in the grand fleet [against the Armada]," he appeared somewhat uninterested in actual military service, preferring to donate large sums of money for others to go and fight in his stead.[93] On April 26, 1593, he and four other men became Knights of the Garter, joining a select group of only 18 other people.[94] The list is quite exclusive, including the monarchs of England, Scotland, France, Spain, and Germany, as well as Lord Burghley and the Earls of Cumberland, Shrewsbury, Ormond, Essex, Pembroke, and Huntingdon. The occasion was marked with much pomp and circumstance, and Percy punctuated the day by commissioning a commemorative poem for £3 from George Peele. His poem, "The Honour of the Garter," records the deeds of Percy the man, as well as the history and characteristics of Knights of the Garter in rather blunt, yet nevertheless flowing verse.[95] Nevertheless, the deeds it does record for him are peculiarly non-

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[93] Nichols, *The Progress of Queen Elizabeth*, vol. ii, quoted in G. Brenan, *A History of the House of Percy*, p. 46.

[94] R.C. Strong, "Queen Elizabeth I and the Order of the Garter," *The Archaeological Journal* 19 (1962): 245-69 emphasizes the pageantry surrounding the institution. See also R. Strong, *The Cult of Elizabeth: Elizabethan Portraiture and Pageantry* (London, 1977) , ch. 6, pp. 164-85.

[95] For Peele, see D.H. Horne, *The Life and Minor Works of George Peele* (New Haven, CT, 1952) . For this poem in particular, see commentary on pp. 95 and 173-77 and the text with notes on pp. 245-59 and 279-81. The text of the poem quoted here is from A. Dyce, *The Dramatic and Poetical Works of Robert Greene & George Peele* (London, 1874) , pp. 582-90. Interestingly, it is at the same time that the first substantial payment from the Earl to Harriot is to be found. In a list of payments surrounding the festivities of the Earl's knighthood, Harriot received £80 for no apparent reason. This is most likely the beginning of his yearly pension at that rate, although the first clear record of a payment to him for that purpose is in 1598. See Shirley, *THB*, pp. 210-12. This may be another indication that Harriot was more closely connected with the Earl's *military* career than has previously been believed.

military in nature. Percy, the "Thrice-noble earl…/ That artisans and scholars dost embrace," is extolled for

> That admirable mathematical skill,
> Familiar with the star and zodiac,
> To whom the heaven lies open as her book;
> By whose directions undeceivable,
> Leaving our schoolmen's vulgar trodden paths,
> And following the ancient reverend steps
> Of Trismegistus and Pythagoras,
> Through uncouth ways and unaccessible,
> Dost pass into the spacious pleasant fields
> Of divine science and philosophy. (ll. 2, 6, 8-17)

Military prowess on his part was apparently not one of his more important qualities. Not that a Knight of the Garter needed any military ability whatsoever – witness Elizabeth's membership – but other inductees were noted for these traits. For example, Lord Borough, who later held the decidedly military post of Lord Deputy of Ireland, was noted for his military and political abilities: "Borough, brought up in learning and in arms,/ Patron of music and chivalry, Brandish thy sword in right, and spend thy wit/ In commonwealth affairs" (ll. 385-88). Percy, on the other hand, would later receive an honorary M.A. from Oxford as "a great encourager of learning and learned men, especially mathematicians."[96]

Nevertheless, Henry Percy, now Sir Henry, made yet another attempt at something of a military career. In August, 1599, he recruited and equipped a regiment of horse and 2 ships for the Dutch wars, for which he was created a general of the cavalry, although he apparently never served. In 1600/01, he and six other English nobles outfitted themselves lavishly and embarked for the Low Countries to lend their support for Elizabeth's efforts against the Duke of Parma, the Earl himself serving as an official envoy for Elizabeth to the States General. He joined together with the Earl of Rutland, Lord Monteagle, Lord Grey, Lord

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[96] Brenan, p. 98. The degree was conferred August 30, 1605, a few months before the Earl was to loose his freedom under suspicion in the Gunpowder Plot.

Cobham, and Sir Walter Raleigh and set out to join in the fighting at Ostend in June.[97] They outfitted themselves magnificently, dressing more for a court pageant than the reality of a siege in the Low Countries. In preparation for his visit, his household records include various purchases of fineries:

> some necesary payments as for mending your Lordship's Armoure and for powther & shot vij^{s}… for mending your lordship's .2. pistols & for iiij moulds to them iij^{s} vij^{d}… Crymsen velvett & taffatie to face your lordship's Armor… for making cleane of vij pistolls & for a new head for your lordship's pike… for a new sword & dager guilt with gold… for a golden hatched rapier.[98]

Their party must have made quite a sight when they arrived in August, 1600. At the same time, it is clear that Percy was not only outfitting himself materially for his foray to the Netherlands, but intellectually as well. Walter Warner, another of Percy's mathematical tutors and Harriot's friend, accompanied the Earl to the Netherlands and kept the accounts of his progress. In them, there are countless disbursements for maps of the various Dutch towns – ostensibly his task for the Queen – but there are also payments for "ij discourses of warre" as well as "a discourse of the Armye of Cales."[99] Percy clearly took his military role seriously.

Upon their arrival at Ostend, which was shortly to see the worst and most prolonged siege of the wars in which English participated, the commander of Ostend, Sir Francis Vere, made it quite clear how little he appreciated the assistance of these "popinjays."[100] Since they were not royal envoys, but rather

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[97] John Chamberlain give a slightly different list, with Lords "Harbert" and "Windsore" (*i.e.*, William Herbert and Henry, 5th Lord Windsor) instead of Lords Grey and Cobham; John Chamberlain to Dudley Carleton, London 24 June 1600, [=SPD Eliz. 275,15] (N.E. McClure, *The Letters of John Chamberlain* [Philadelphia, 1939] , I.100-1). He added that they "pretend to go over to service," confirming their lukewarm commitment to service.

[98] Alnwick Castle account books, extracted in Shirley, *THB*, p. 295.

[99] *Ibid.*, p. 296.

[100] The information on this episode is well-known, but less than well-documented. Primarily, I have used G. Brenan, *A History of the House of Percy* , pp. 68-77, and the DNB article on Sir Francis Vere as guides. The first two biographies of Vere ignore the Percy-Vere conflict entirely; see A. Collins, *Historical Collections of the Noble Families of Cavendishe, Holles, Vere, Harley, and Ogle* (London, 1752) , pp. 286-330 and G.R. Gleig, *Lives of the Most Eminent British Military Commanders* (London, 1831) , pp. 124-198. C.R. Markham, *The*

"spoilt children of fortune" volunteering for active service the reality of which they were completely ignorant, Vere suggested that "the gold so lavishly expended upon their backs might have been used to greater advantage in furnishing sorely needed recruits for the service"[101] and that "their room was preferred to their company."[102] The two Earls, three Lords and perhaps the most decorated English sea-captain did not enjoy being commanded by their social inferior, even if he did hail from a noble family with direct lineage to William the Conqueror's expedition. Vere was known for being a hard but not unreasonable commander, and the year before had refused a number of captains he felt unfit for service that the Earl of Essex had sent over to his command, and he had also dismissed one of Percy's "inefficient… creatures," a Captain Lower.[103] Camden relates that even James I took off his hat in deference to the

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Fighting Veres, pp. 306-7, 313, and 334-37 does relate the "unpleasant" story, although biases his account strongly against the "consequential, pompous"(305) Percy (a "foolish brawler" [335]), in favour of Vere, "who kept his temper and acted with dignity and sound judgment" (357). Vere left an unfinished autobiography (B.L. King's MS 265, pp. 407-504), but it breaks off with the siege and defense of Ostend, 1601-4 , thereby omitting the Percy episode. See also J.P. Collier, "Sir Walter Raleigh and Sir Francis Vere," *Archaeologia* 35 (1853): 373-8 for a contemporary, albeit one-sided relation of the events.

[101] G. Brenan, *A History of the House of Percy* , p. 68-69. Vere had just returned to duty after recovering from wounds received at Brill and then a severe head wound on 4 August in the opening phase of the Siege of Ostend. He clearly overstated the inexperience of some of the members of this group. Vere and Raleigh had served together in various piratical raids in 1597, although then only after calling a truce over a previous conflict between them. Lord Grey held various commands in the Low Countries in the 1590s, and of course, Percy had in theory served at least some time in the Low Countries in 1587, but their opulent arrival made it quite clear their true interests in being in Ostend. Gentleman volunteers for service in the Low Countries were not uncommon right from the start when Leicester landed magnificently in 1585, "not overburdened with military experience or brains" (see C. Wilson, *Queen Elizabeth and the Revolt of the Netherlands* [London, 1970] , p. 90 and G.R. Gleig, *Lives of the Most Eminent British Military Commanders*, p. 129), but in most cases, they came prepared for war, not pageant.

[102] C.R. Markham, *The Fighting Veres*, p. 317.

[103] On Essex: Chamberlain to Carleton, London, 15 Feb. 1599 [=SPD Eliz. 270,39], (N.E. McClure, *Letters of John Chamberlain*, I.68). In fact, one of Carleton's friends, Sir Callisthenes Brooke was also discharged early in 1601 after taking in the sights in Amsterdam with Carleton. Although Vere did not much like Essex, it would uncharacteristic of Vere to dismiss Essex's recruits purely out of spite. On Capt. Lower: C.R. Markham, *The Fighting Veres*, p. 307.

military skill of Vere.[104] For his part, Vere apparently overcompensated in the situation and treated these volunteers perhaps more sternly than he needed to, but the volunteers were also less than interested in the gritty details of Renaissance warfare. With the exception of Raleigh, they were only students of military science, interested in learning all the new and important theories of war developing on the Continent. They were not, however, soldiers.

Shortly after the group's less than cordial welcome, Northumberland posed a "certain question of strategy" to Vere.[105] Vere, uninterested in the higher, and from his point of view irrelevant, points of military theory returned a "surly and even contemptuous answer." Percy did not appreciate the brusque treatment, and made his displeasure known. In September, 1601, the "popinjay" party finally got the message that their presence was not appreciated, and they departed from Ostend.[106] Rumors of the incident apparently made it back to London, for in July, John Chamberlain wrote to his employer, Dudley Carleton, that he did not "easilie beleve… a flieng report… that at a banquet in the Low Countries the erle of Northumberland had stroken [Vere]."[107] While none of the members ever publicly slandered Vere for his actions – after all, he was within his rights as the commander of the expeditionary forces and he never publicly disgraced any of them – neither did they forget his slight.[108]

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[104] J.P. Collier, "Sir Walter Raleigh and Sir Francis Vere," p. 372. Although note that this would have been after the successful defense of Ostend. Still, even in 1600 Vere's military ability easily surpassed the popinjays'.

[105] I have been unable to determine what the question concerned. The phrase is Brenan's; de Fonblanque merely reported that the Earl "put a question to the great commander on a military question [*sic*]" and that Vere "answered him home" (p. 218).

[106] Vere wrote to Cecil, "The Earl of Northumberland went hence yesterday, weary enough of the discommodities of this place, and of the little observance done him." C.R. Markham, *The Fighting Veres*, p. 317, n. 1.

[107] Chamberlain to Carleton, London, 8 July 1601 (N.E. McClure, *Letters of John Chamberlain*, I.127). Chamberlain justified his belief by noting that "yt is most certain that they have not met there since theyre [*i.e.*, Percy and company's] last going over."

[108] Lord Grey, for example, when given "the command of a troupe of three or foure hundreth horse" in the Low Countries in May of 1602, "stoode first upon some pun[c]tillos not to be commanded by Sir Fra: Vere, but since they be agreed and become good frends." Chamberlain to

Upon Vere's return to London in 1602 after his until-then successful defense of Ostend, Percy challenged Vere to "give satisfaction" for his rude behavior to a superior. As Chamberlain reported the event:

> The erle of Northumberland sent Cap: [Edmund] Whitelock with a letter to Sir Fra: Vere, [saying] he had wrongde him in such and such points, and therefore desired to be satisfied: wishing him to take his horse and bring one with him, as he of his honor wold do the like, and meet him where he shold apoint, willing him to send his determination yea or no by word of mouth and not by writing. Sir Fra: Vere wrote an aunswer and sent yt by Captain Ogle, which the erle refued to receve. The contents was that though he assured himself he could satisfie him, yet he would not go about to satisfie any man that has his sword in his hand, but yf they might meet in peacable manner before any persons of the state whom his Lordship wold choose, he wold geve him reasonable satisfaction, otherwise let him take what course he thought best.[109]

Both actors in this drama initially wished to keep the Queen out of the picture, as she was notoriously opposed to duels and preferred to avoid dissent between her officers. The Dutch ambassador, Noel Charon, however, took it upon himself to notify the Queen of these developments, leading her to prohibit Northumberland from taking any action against Vere. Vere, however, correctly felt that he was under her protection, as he had been (and was) an acting agent of the Crown. Nevertheless, a large volume of correspondence ensued, as did public pamphlets from both parties. Northumberland published a declaration against Vere calling him "a knave, a coward, and a buffon" in English, French, and Italian. Not to be outdone, Vere responded in form, citing the Queen's protection and calling Percy "a liar and a base minded man", although he one-upped the Earl by adding Spanish to the languages of his reply.[110] There the

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Carleton, London 8 May 1602, [=SPD Eliz. 284,7] (N.E. McClure, *Letters of John Chamberlain*, I.142).

[109] *Ibid.* [= Chamberlain to Carleton, London 8 May 1602.] Chamberlain first heard the rumor on the 25th of April.

[110] *Ibid.* [= Chamberlain to Carleton, London 8 May 1602.] Chamberlain later noted that the case stood "doubtful as yt did at first," and that he was "very indifferent and respect neither of them greatly…, but let them brabble and fight yt out yf they will." Chamberlain to Carleton, London 17 June 1602, [=SPD Eliz. 284,37] (N.E. McClure, *Letters of John Chamberlain*, I.150-1).

affair rested when Vere went back to defend Ostend in the famous siege, but the whole matter festered for over two years. After James ascended the throne, Percy struck Vere in front of the King and was confined to Lambeth Palace for a time.

The Percy–Vere confrontation is instructive in indicating what a nobleman sought to gain from military involvement at the end of Elizabeth's reign and it sheds light on Harriot's interest and work in ballistics. From about 1587 to 1600, Percy tried occasionally to find a place for himself in Elizabeth's military establishment. He had no real experience or training, but the proper function of a wealthy nobleman was to defend his country, and as Percy interpreted it, this meant outfitting ships, hiring recruits, and leading musters. The unmonied elite found their place in the thick of battle – witness Sir Francis Vere or Lord Mountjoy – while the likes of Northumberland contented themselves with a passing knowledge of the newest and best military theories. Percy also seems to have seen his role as more chivalrous than the warfare of the day would allow. Raleigh, on the other hand was a sea captain and explorer. He was quite familiar with how to run a military engagement and did so successfully on a number of occasions.

Raleigh hired Harriot to teach him what he did not know – navigation in this case – not what would be of little use to him. Similarly, it seems that Percy would use Harriot to instruct him on unknowns, and I suggest here that these unknowns for Percy would have been questions of artillery and ballistics. This seems much more in accordance with his scientific and mathematical leanings. Therefore, I must take exception to Shirley's dating of the ballistic papers to 1590-95, which rests solely on Harriot's handwriting – the chronology of which Shirley never clearly developed – and the assumed connection with Raleigh's 1594 Guiana Voyage – a voyage (like all naval endeavors) unlikely to have generated

ballistic research. I propose instead 1595-1600 for their composition, and more likely at the very end of this period, and within Henry Percy's sphere of influence. This would place the timing of Harriot's ballistic work with the peak of Percy's military pretensions. As Shirley noted, there are some later additions from the first decade of the seventeenth century, but they seem less complete, suggesting that perhaps Harriot once again became interested in his old pursuit (perhaps if he used the 1602 edition of Capobianco which is now in the British Museum rather than the 1598 *editio princeps*) but rapidly rediscovered his inability to come to any satisfactory conclusions. And by this time, he would not have had Percy's direct encouragement – or requests – for information. Harriot's interests then turned to pursuits more "scientific", such as matter theory, astronomy, and optics.

Conclusion

After a brief but exciting voyage of exploration in 1584-5, Harriot spent his life in the bucolic splendor of England, undisturbed by the open warfare, plague, and counter-Reformation terror with which the Continent was continually disturbed. Unlike his contemporary, the astronomer Johannes Kepler, who was forced from Graz to Prague by Catholic authorities evicting Lutherans, from Prague to Linz by war and Rudolph II's abdication, and finally from Linz to Ulm by counter-Reformation forces occupying the city, Harriot was given an estate in Ireland by Raleigh, deeded land in Northumberland which gave him an independent income, and finally a house and laboratory at Syon House by Percy. He was allowed to read and experiment as he saw fit, with only occasional pressing requests from his patrons. With regard to ballistics, that request probably came from Percy in 1598 or 1599, when the Earl prepared for his expedition to the Netherlands as a proud, if completely inexperienced, soldier

of fortune. The payment of six shillings from Percy's paymaster to Harriot in early 1598 for "a boke of Warre" may well be the one piece of hard independent evidence of his work on artillery at the time.[111] In any event, by 1602, Percy had largely lost interest in military matters, the next year Raleigh went to the Tower, and Harriot moved on to his optical and alchemical research.

Perhaps it was the absence of a need to produce that kept Harriot from publishing his discoveries. Perhaps he was genuinely uninterested in sharing his knowledge until he realized it was too late. Perhaps he abandoned the line of inquiry upon realizing his inability to reach any clear doctrinal conclusions or analytical solutions, since even though his geometrical proofs seem fully developed, they did not agree with experience. Had he been willing to disseminate his geometrical construction of trajectories, one can only speculate how it might have benefited the field. To be sure, the method would have been above the heads (quite literally) of the majority of practicing gunners. But some, given a rudimentary geometrical education (such as Edmund Parker – see below, ch. 6) would have been likely able to appreciate and use the method. Since it relied on very little theory, but instead on rote geometrical construction, its popularity could easily have approached that of geometrical fortification studies in the next century. Even beyond that, it could have generated qualitative range tables, even if they were flawed. And despite his error in "proving" the maximum range was to be found at an elevation of 27°55´, the mere existence of these sorts of "proofs" would undoubtedly have spurred other investigators to attempt to correct and refine Harriot's methods.

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[111] Alnwick Castle, MS U.I.2, "Accompte of Robert Stapleton gentleman… fforeyne Paimaster… 18 Feb. 1597[/8] – 6 May 1598." Transcription by John W. Shirley in the Shirley Papers, University of Delaware Archives. Harriot was also paid £27 for tobacco and $46^{s}6^{d}$ for tobacco pipes at this time. See also G.R. Batho, *Thomas Harriot and the Northumberland Household*, p. 21, no. 11.

Renaissance England, however, had no Galileos who would publish new theories that would fundamentally alter mechanics forever. Interest in gunnery, however, extended from the workers in the Ordnance Office who handled the guns to most advanced mathematician and scientist of the age. The intellectual stature of gunnery was only paralleled in this manner by navigation and the allied science of astronomy, although other “mathematical” arts such as surveying, mensuration, and mining generated some interest to theoretician and practitioner alike. This wide interest is reflected in the published books of the day, and it is to those books on the art of gunnery to which we must now turn.

Figure 2.1

Table of Content Structure from
Sebastian Verro, *Physicorum Libri X* (London, 1590)
compiled from sig. [A6]^{r} – [B8]^{r}

Topic					*Lib..*
Nature	Corporeal	Generalia			*Mundo et Natura* 1
		Specialis	Simplices	Constans	*Coelum* 2
				Inconstans	*Elementa* 3
			Mistæ	Affectiones	*Generatio* 4
				Corpus Imperfectum	*Meteora* 5
				Corpus Perfectum	Stupidum — *Fossila* 6
					Vivum
		Vivum	corpus organicum	Vegetum	*Stirpes* 7
				Animatum	*Animalium* 8
			corpus inorgranicum		*Animæ* 9
	Incorporeal				*Mens* 10

Figure 2.2

The "Groundplatt" of John Dee's
Mathematicall Præface to the Elements *of Euclid* (London, 1570)

- Artes Mathematicall
  - Principall
    - Arithmetike
      - Simple
      - Mixt
    - Geometrie
      - Simple
      - Mixt
  - Derivative
    - Principalls
      - Arithmetike
        - different types
      - Geometrie
        - At Hand
          - Length
          - Area
          - Volume
        - Distance
          - Geodesie
          - Geographie
          - Chorographie
          - Hydrographie
    - Propre names
      - Perspective
      - Astronomie
      - Musike
      - Cosmographie
      - Astrologie
      - Statike
      - Anthropographie
      - Trochilike
      - Helicosophie
      - Pneumatithmie
      - Menadrie
      - Hypogeiodie
      - Hydragogie
      - Horometrie
      - Zographie
      - Architecture
      - Navigation
      - Thaumaturgike
      - Archemastrie

Chapter 3

Printed Books on Gunnery in England to 1600

Heere, may you fight by Booke, and never Bleede:
Behold a wall blown up, and yet no Breach:
And here the neighing of a still-born steede:
And Startle at an engrav'n canon's speeche.
— Edm. Plumme*

Introduction

Studying the Tudor Army is like studying the Swiss Navy, so the saying goes.[1] While it is true that the English never engaged in warfare like continental powers in the sixteenth century, the corollary that the English were not interested in military matters cannot be maintained. Recent studies have established that the English were quite martial in their outlook and metaphors,[2] although we might expect as much from a country not engaged in foreign actions: one can afford to speak boldly when unlikely to be called to act. Still, faced with the numerous risings throughout the country, barely subjugated Irish subjects, a northern neighbor allied closely with France, and the break with Rome, Elizabethan Englishmen believed that they would be called upon to act at any moment. While the country may not have seen large-scale military conflict on its soil, it was anything but conflict-free. At the same time, however, the

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* Edm[und] Plumme, "To our Countrymen imployed in Forraine Service," in Robert Ward, *Animadversion of Warre, or A Militarie Magazine of the Truest Rules…* (London: John Dawson, 1639; STC 25025a), sig. [(*8)]^{v}, quoted in J.H. Hanford, "Milton and the Art of War," *Studies in Philology* 18 (1921): 240. This poem is not included in the other edition of Ward's book.

1 J.S. Nolan, "The Militarization of the Elizabethan State," *Journal of Military History* 58 (1994): 391.

2 *Ibid*. See also P.A. Jorgensen, "Theoretical Views of War in Elizabethan England," *Journal of the History of Ideas* 13 (1952): 469-81, for the "complexity" and "reasonableness" of martial thought in the period, and B. Donagan, "Halcyon Days and the Literature of War: England's Military Education before 1642," *Past & Present*, no. 147 (1995): 65-100, for the early 17th-century situation. C.C. Breight, *Surveillance, Militarism and Elizabethan Drama* (London, 1996) has recently argued that the English under the *Regnum Cecilianum* (Burghley and his son, Robert) were anything but pacifists, and although his rhetoric is perhaps stronger than his evidence, his point is worth considering.

English have been accused of being armchair soldiers,[3] but that penchant manifested itself in the production of numerous works with military themes, from plays about wars and warriors[4] to Greek and Roman military history[5] to instruction manuals for soldiers. It is this last class of books which concern us here.

In focusing on Tudor artillery, this thesis limits itself to a very small subset of all military activity in England at the time and one whose details are difficult to access. The books under consideration here addressed contemporary (potential) practitioners of gunnery, that is, the gunners. As such, they address artillery munitions and operation, not the tactical or strategic use of artillery. For that, one needs to turn to one of the most common sources of information on the military establishment: "memorials". These texts, rarely reaching print, listed all the offices of the army and their qualities and responsibilities. Most simply, they informed their contemporary as well as the modern reader that with respect to artillery, a master-gunner needed to "be skilfull & ready in chargeing, dischargeing, cooling, leuelling, & mounting" of ordnance and be knowledgeable of "balle[s], powder, ladells, sponges… cariages & wheeles."[6] Memorials do, however, point out that master-gunners were not just technical experts, but managers as well: "the m^{r} gonner must be expert in that Science at all pointe[s] placing and apoingting such men to be Canoners as haue like experience [and] be able to governe the same as to that conyng science appertayneth."[7] they

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[3] F.W. Beckett, "The Amateur Military Tradition in Britain," *War & Society* 4 (1986): 1-16. This claim could be levelled at many countries at many times. Interest in military topics seems to be largely independant of actual military activity.

[4] As recently investigated by N. De Somogyi, *Shakespeare's Theatre of War* (Aldershot, 1998).

[5] H.J. Webb, *Elizabethan Military Science: the Books and the Practice* (Madison, 1965) , ch. 1, "Elizabethan Military Literature: Its Classical Background," pp. 3-16.

[6] B.L., MS Harley 1893, fol. 84.

[7] Robert Hare, "Treatise on Military Discipline [1556]" (B.L., Cotton MS Julius F.v, fol. 26). Interestingly, Hare only uses the term "science" with regard to gunners. By 1670, authors would

occasionally provide commentary on the gunner's character of soldiers, including gunners: every soldier from humble carter to the Master General should be upright, God-fearing, and of course free from all vices, drinking, swearing, or whoring. And of course, "expert in his arte." It is in this expertise that the memorials provide a glimpse, not of what the cannoneers knew and did, but of how the other officers saw them and what they did. In this sense, these descriptions provide a useful foil to the gunners' manuscript books presented in chapter 4 below, as well as the printed books on artillery discussed in this chapter.

Thomas Audley wrote a number of these memorials, although none were ever published, and beyond them nothing is known for certain of his life.[8] That they never were printed and yet numerous copies survive suggests that they had an appeal to a specific audience but one that the Elizabethan publishing industry did not consider relevant to the population at large. That said, the information authors like Audley presented to generals and other military leaders about gunnery is as follows.[9] The master of the ordnance needed to be "expert and skilful in all points [of] cannonry," which is to say exactly nothing to the reader, since they are not expected to know what "all points of cannonry" included. While the master gunner trained all the under-cannoneers, he was to make sure that "every cannoneer apointed to any piece of ordnance is able to

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be more specific, ascribing "all parts of the Mathematicks and Gunnery" to the Master of the Ordnance (B.L., MS Sloane 1052, fol. 13).

[8] Audley does not have a DNB entry, nor does he appear in the various indices of State Papers. Dr. Robert Tittler, Concordia University, has suggested to me that he may the the Sir Thomas Audley (1488-1544), Lord Chancellor of England from 1532-44, who so successfully presided over the Dissolution of the Monasteries and the execution of More and Cromwell. Unfortunately, nothing about this Audley's life suggests that he would have taken any particular interest in military affairs; see J.L. Campbell, *Lives of the Lord Chancellors… of England* (London, 1868), II.34 (pp. 78-113). Audley's memorials include B.L., MS Stowe 146, and Bod. Lib., MS Rawlinson D 363 and MS Tanner 103, and the one discussed below.

[9] This particular Audley manual (PRO E 101/62/31) is abstracted in C.G. Cruickshank, *Henry VIII and the Invasion of France* (Stroud, Glouc., 1990) , pp. 71-2.

govern the same as to that cunning science appertaineth," which again absolves the reader of knowing anything about that cunning science. Audley does specify in some detail what each gunner needed to know: he should be "skillful in the weight of his powder and shot, and the height of the mouth" of the cannon and know the "receipt" and "authority" (*i.e.*, recipes and strength) of his powder. Oddly, Audley also adds that the common gunner should be able to check that his cannon is truly bored and free of honeycombing, that is, internal voids in the casting. This sort of detailed information stands in contrast to the more vague description of the higher officer's duties. Nevertheless, the information provided in memorials generally does not include the details of the art of gunnery, from the simple topics like the names of cannon (the most common being falcons, minions, sakers, culverins, demi-culverins, cannon, and demi-cannon),[10] the composition of gunpowder (a mixture of saltpeter, charcoal, and sulphur), methods of disparting cannon (*i.e.*, creating a front sight on the muzzle of the cannon), and the composition of various incendiary devices (known as wildfire or fire-works, the later term including the modern sense of fireworks). The impression one is left with from reading English non-artillery military books is that the artillery constituted some sort of "other", standing apart from the mainstay of warfare of the day, which still largely concerned itself with the larger

[10] Throughout this work, I shall use the term "cannon" loosely in the modern sense to refer to any piece of Tudor artillery, although this sloppiness would never have been tolerated in their day. To them, the various classes were definitionally distinct categories of great ordnance, even though the physical characteristics of the various classes overlap to some extent. All large artillery is today called cannon due to a historical process of the widening gap between smaller ordnance (falcons, sakers, and minions) and larger pieces (cannon and culverins, including the demi- versions of both) and the confluence of the physical proportions of culverin and cannon class pieces. This generally lead to the disappearance of the smaller class entirely, and a rationalization of the larger class along a cannon-style caliber ratio (*i.e.*, a length to bore ratio around 20:1). See App. V, below, for a glossary of Elizabethan artillery terms.

picture of land battles and sieges, as well as the classical sources for military science, which obviously could not include topics on gunpowder artillery.[11]

That authors composed numerous books on military topics, and that printers published them, suggests that a reading public existed and was willing to buy the books. The sixteenth century stands at a crossroads in cultural and intellectual history. Compared to the previous century, the populace was becoming more and more literate.[12] At the same time, presses were churning out more and more books, pamphlets, and broadsides to both meet and create the demand. Although estimates only begin to become available for literacy rates in the last three decades of the sixteenth century, they suggest rates of 60-80% for craftsmen in London (although only 20-50% outside London),[13] but the cost of books would have limited their purchase to the wealthier, and therefore, more educated members of society. Military books are but a small subset of all printed books, and books pertaining to artillery a smaller subset still. Yet we can make some statements about this genre.

First, the contention that the English were slow off the blocks must be examined. When Johann Gutenberg opened shop in Mainz in about 1454, no

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[11] For the best overall survey of the field, see H.J. Webb, *Elizabethan Military Science: the Books and the Practice*, although his analysis is rather limited. Despite its subtitle, Webb largely took the books to be the practice. J.S. Nolan, "Militarization of the Elizabethan State," largely rectifies that problem.

[12] While the rise of literacy and the advent of printing are something of a chicken-and-egg question, Bennett has suggested that by the end of the reign of Mary I, quite a large proportion of the population of England, at least in urban centers were literate, in no small part due to the availability of vernacular Bibles, and then to Reformation questions of what commoners were allowed to or supposed to believe. See H.S. Bennett, *English Books & Readers 1475 to 1557* (Cambridge, 1970) , ch. 2, pp. 19-29. His estimate of 6,000 different titles produced in England by the time indicates a substantial reading populace, and the 1543 prohibition of "women, artificers, apprentices, journeymen, serving-men of the rank of yeomen and under, husbandmen and labourers" from reading the Bible in the vernacular suggests that wide segments of all classes were literate (p. 27). See also K. Thomas, "The Meaning of Literacy in Early Modern England," in G. Baumann (ed.), *The Written Word: Literacy in Transition* (Oxford, 1986), pp. 97-132.

[13] D. Cressy, *Literacy and the Social Order: Reading and Writing in Tudor and Stuart England* (Cambridge, 1980) , ch. 7, but esp. graph 7.3, p. 147.

one could have predicted how rapidly the printing press would spread throughout Europe. Wiliam Caxton opened the first Press in England in 1476 in London and within four years presses were in operation in London, Westminster, Oxford and St. Albans. By 1600 at least three hundred printers had produced volumes in London (with probably one hundred active near the end of the century) and presses existed in 28 other towns in the British Isles.[14] By the middle of the sixteenth century, England was comfortably holding its own relative to its population vis-à-vis Continental book production. As far as military books are concerned, it is usual to claim that the English were uninterested and therefore produced few titles and those that did get printed rarely went through multiple editions.[15] However, the data that gives rise to this theory can also provide another interpretation when viewed differently.

The publication of military books in England follows an intermittent pattern. Nearly a century ago, Maurice J.D. Cockle compiled his magisterial *Bibliography of Military Books up to 1642* which, with a revision in 1957, has remained the primary reference work on the topic.[16] Given the ready availability of this source, it is surprising that historians have not spent a few moments analyzing English production patterns, rather than lamenting the English tardiness and paucity of publication.[17] Examining English book

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[14] These numbers are based on R.B. McKerrow (ed.) *A Dictionary of Printers and Booksellers in England, Scotland, and Ireland… 1557-1640* (Oxford, 1968); I have only estimated the number of London printers for this period, but those for the entire period covered by the dictionary fill 335 pages at an average of approximately 1-2 biographies per page. Printers outside London are listed on pp. 339-43.

[15] The paradigmatic statement to this effect comes from T.M. Spaulding, "Elizabethan Military Books," in J.G. McManaway, G.E. Dawson, and E.E. Willoughby (eds.), *Joseph Quincy Adams Memorial Studies* (Washington, 1948), pp. 495-505.

[16] M.J.D. Cockle, *A Bibliography of Military Books up to 1642* (London, 1957) . This work has only been supplemented by two brief addenda to his entries. For a comparative study for Italian books along the lines of what follows, see J.R. Hale, "Printing and Military Culture of Renaissance Venice," *Medievalia et Humanistica*, n.s. 8 (1977): 21-62.

[17] Generally, this position follows Oman's magisterial work (C.W.C. Oman, *A History of the Art of War in the Sixteenth Century* [Eltree, Hertfordshire, 1937]), conflating English inaction on the battlefield with disinterest in print. Some have argued otherwise, such as H.J.

production dispels many of these complaints (see figure 3.1). While the indictment of English authors as plagiarists of Continental authors remains entirely valid – although note that not all Continental authors were original either – original English output is not insignificant.[18] The first military book from an English press was Christine de Pisan's *Boke of the Fayt of Armes and Chivalrye* in 1489 (C**1**).[19] A translation of an early fifteenth-century French work which was in turn a free translation of the classical *Epitome rei militaris* by Vegetius, Christine's work was not wholly characteristic of Caxton's production, being translated from a manuscript of Henry VII.[20] It indicates that in the later fifteenth century, the impetus for military matters, not surprisingly, came from the highest levels of society, that is, at a time when the traditional chivalric elite was still the driving force for military matters. By the end of the next century, this pattern was to change dramatically.

After this work, the English presses fall nearly silent until the end of Henry VIII's reign, producing only two more military volumes in the next four decades. At the end of Henry's reign, however, and likely related to his final burst of militarism against France in the 1540s, seven books appeared, ranging from works on battle orders taken from Vegetius to an account of the Protector Somerset's 1544 Scottish expedition. The year 1545 marks the true beginning of

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Webb, *Elizabethan Military Science*, p. 170 and J.S. Nolan, "The Militarization of the Elizabethan State," *passim*, but the prejudice still lingers.

[18] It is nevertheless true that the English works were almost never noticed on the Continent until well into the 17th century, and even then only occasionally.

[19] In order to avoid unnecessary repetition, all information in the following discussions may be assumed to be from either Cockle or the source described. Also, since Cockle provides easy access, titles and STC numbers will be omitted in what follows in favor of a notation in the form (C**n**), for the entry number **n** in Cockle.

[20] See A.T.P. Byles (ed.) *The Book of Fayttes of Armes and of Chivalrye Translated and Printed by William Caxton from the French Original by Christine de Pisan* (London, 1937) for the modern critical edition and B.S. Hall, "'So Notable Ordynaunce': Christine de Pizan, Firearms and Siegecraft in a Time of Transition," in C. DeBacker (ed.), *Culturhistorisch Kaleidoskoop: Een Huldealbum aangeboden aan Prof. Dr. Willy L. Braekman* (Brussels, 1992), pp. 219-40 for a recent analysis.

English military publishing as far as this study is concerned, for in that year, Roger Ascham published his *Toxophilus, The Schole of Shooting* (C**9**). Considered a classic of English literature, *Toxophilus* is also the first English military textbook addressed to a general readership. Ascham, tutor to the young princess Elizabeth and advisor to the Tudor court for over fifty years, clearly realized that an audience existed in the lay people of England for a general account of archery, both historical or practical. His use of the vernacular is not surprising – all military books were in fact in the vernacular, a significant quality in itself – nor is his subject matter. Archery provided the quintessential English pastime, or rather it had done so. The national mythos enshrined archery as the key to their victories at Crecy, Poitiers, Agincourt, and even as recently as Flodden Field in 1513. But by the end of Henry VIII's reign, interest in archery was waning, so if Ascham was filling the desire to read about archery, at the same time he was promoting the archery as the paragon of English virtue in the face of threatening foreign influences, notably the popular Italian fashions.[21] And one of those Italian influences would easily have been seen as guns, the Italians being considered the best artillerists of the day. Ascham, though, does not directly disparage guns, suggesting that they should be used in harmony with archery, to better protect England from all sides, although for its effect upon the user, archery was clearly to be favored. In the end, though, *Toxophilus* initiated a line of treatises on the mechanical arts which set out in plain prose, step by step, the equipment and procedures needed for a reader to become expert at those arts.

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[21] On Ascham and *Toxophilus*, see L.V. Ryan, *Roger Ascham* (Stanford, 1963), ch. 4, pp. 49-81. Although Ascham's own visit to Italy was still 6 years in the future when he wrote *Toxophilus*, it would appear that his teacher, Sir John Cheke, had thoroughly instilled in him a dislike for the Italian vogue. For the anti-Italianism of the age, see E.J. Baskerville, "The English Traveller to Italy, 1547-1560" (Ph.D., Columbia University, 1967) , ch. 2 and K.R. Bartlett, "The Strangeness of Strangers: English Impressions of Italy in the Sixteenth Century," *Quaderni d'italianistica* 1 (1980): 46-63. Indeed, *Toxophilus* may be read as a very direct attack on the liberality of Italian education (and Italian universities), as compared to the English belief in specificity of knowledge in this case the art of archery.

It is in this sense, and not with respect to the overt moralistic or nationalistic messages he included, that Ascham made an important contribution to English technical writing of the Renaissance and initiated the "military textbook" tradition.

After a brief dry spell after *Toxophilus*, English presses regularly issued military titles from 1560 onwards. Production peaked in 1587-91 in reaction to heightened tensions with Spain and the Armada scare (see fig. 3.1, detail), and despite a brief dip in production in the first decade of James I's reign, continued vigorously in the 1620s, 30s, and 40s. While no one has compiled a comparable guide to Cockle for post-1642 edition, a brief survey of the Wing Catalogue suggests that military books continued to be popular throughout the seventeenth century, not in small part due to the Civil War. Still, only 166 military titles appeared between 1489 and 1642 (not counting later editions), an average of just over one per year, the English do indeed appear not to have been prolific martial authors.[22]

This view changes upon considering English output with regard to Continental output for the same period. Figure 3.2 depicts the English and Continental military book production for 1470-1640, as well as the ratio between their total outputs. The bottom graph indicates that Continental output grew slowly but steadily from 1470-1540 and then increased uniformly thereafter with a slight slowdown in the early seventeenth century. English books (middle graph), on the other hand, got off to a slow start, but surged about 1540 and then about 1590, increasing more non-uniformly, but proportionally more rapidly. In absolute numbers they fall short, but comparing the total number of titles produced in England to that for the Continent, the English begin to appear respectable (top graph). Of course, it should be remembered that most

[22] Admittedly, military books formed a small percentage of total English book production.

members of the English officer class would have read French and Latin, and quite possibly Italian, and would therefore have had access to the foreign works. Still, by the end of the century, English-language output clearly indicates a growing demand for vernacular titles. Initially only a small percentage in the fifteenth century (and one whose sample size renders it somewhat meaningless), by the last third of the sixteenth century, English production grew to 20% of Continental totals, and surpassed ⅓ of the totals in the second decade of the seventeenth century. Given that the population of the British Isles in 1600 was just over 6 million, compared to a conservative estimate of 75 million for all of Europe, to have produced one-quarter of the military books is no mean feat (*i.e.*, roughly 1 in 12 people produced 1 in 4 books).[23] And of course the military books Cockle included in his survey do not include all the fiction and drama works with military themes. Military topics enter into virtually all of Shakespeare's output, although artillery topics are rare.[24] Nor does it count the newsbooks and pamphlets about wars on the Continent, especially during the Dutch Wars of Independance. Ultimately, it would appear that, as Nolan rightly pointed out, "by 1603, the groundwork of an English national military structure was laid upon institutions which became major bones of contention in the political struggles of the seventeenth century."[25] His institutions are social, bureaucratic, and political, but to them we should rightly add the publication of works which fed a need within England for information on military topics.

English Books on Gunnery

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[23] C. McEvedy and R. Jones, *Atlas of World Population History* (New York, 1978), fig. 1.10 and p. 49. The total given for Europe does not include Eastern Europe (fig. 1.10), and England and Wales alone had about 4.25 million people (pp. 41-48). While demography before about 1700 is an inexact science at best, the general proportions should still follow these lines.

[24] See, generally, P.A. Jorgensen, *Shakespeare's Military World* (Berkeley and Los Angeles, 1956) and A.F. Falconer, *A Glossary of Shakespeare's Sea and Naval Terms including Gunnery* (London, 1965) for specific instances.

[25] J.S. Nolan, "The Militarization of the Elizabethan State," p. 419.

Leaving aside the revivified English military publishing industry, let us concentrate specifically on gunnery books in Europe before the mid-1620s. That decade was both the end and beginning of an era in artillery, for it saw the publication of Robert Norton's books, *The Art of Great Artillery* (1624; C**100**) and *The Gunner, Shewing the Whole Practice of Artilerie* (1628; C**114**). *The Gunner*, largely a translation of Diego Ufano's *Tratado del Artilléria* (Brussels, 1613; C**684**),[26] provided the most complete handbook of artillery in England, summarizing Continental practice – which by this time might be properly termed European practice, the English having come up to speed in the Dutch Wars of Independence (aiding the States General) and the later French Wars of Religion (aiding Henry of Navarre, later Henry IV, of France). The mid-1620s is also convenient with regard to English Political history. In 1625 Charles I ascended the throne, and reinstated a period of English expansionism with the raids on Cadiz (1626) and the Isle of Rhé (1627). Although both expeditions were failures, they marked a turning point in English policy after the relatively pacific reign of James I. The English learned a great deal about artillery during the Civil Wars and at that time finally incorporated Continental developments in infantry warfare, producing the New Model Army of 1645. Since evidence in the following chapters is largely confined to the period up to the 1620s, Norton again provides a convenient *terminus ante quem*. As such, *The Gunner* stands outside this study as a benchmark against which future works can be compared and to which, in some sense, earlier works led. A.R. Hall bluntly claimed that after Tartaglia in the 1540s, "there were few further contributions to the theory of

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[26] Norton also wrote *The Gunners Dialogue* in 1628 (C**165**, although Cockle wrongly noted the 1643 ed. as the first and only edition) as a companion piece to his *Gunner*. It is a slim 36-page volume of 50 questions and answers to "frequently-asked questions" (*e.g.* "Q33. How would you order things, to shoot at a Squadron of the Enemies Souldiers, and what Peeces would you choose?" [22]). It was clearly intended for gunners themselves.

gunnery before the middle of the seventeenth century."[27] However, Webb more correctly observed that, with the addition of "a few useful footnotes" by Digges, Bourne, Alaba y Viamont, Collado, Birunguccio, Cardano, and Santbech, "they were all compiled and made available in one volume" by Norton's *Gunner* in 1628.[28] It is therefore an epitome of gunnery works towards which these earlier books made fumbling progress.

In what follows, technical analysis will be left to a minimum in order to concentrate on the perceived audience and style of presentations for those works. This study is, in effect, a study of the consumers of the technology, not the producers or developers, and as such, these early books on gunnery may be critically viewed as a form of operator manual, and the question may be asked who those readers *cum* operators were.

Peter Whitehorne

The honor of first English-language author on artillery does not go to a gunner, William Bourne, as most writers assume, but instead to a gentleman, Peter Whitehorne. In 1562, Whitehorne, who called himself a student at Grays Inn,[29] published a translation of Niccolò Machiavelli's *Arte della Guerra*, as *The Art of Warre* (C**13**). To this and the later editions of 1573 and 1588 was annexed a work by Whitehorne himself, entitled *Certain Waies for the orderyng of Souldiers in Battelray* (C**14**).[30] Since it only appeared as an addendum to Machiavelli, as Cockle put it, "it has almost been lost sight of as a separate work," and indeed it

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[27] A.R. Hall, *Ballistics in the Seventeenth Century* (Oxford, 1965), p. 42.

[28] H.J. Webb, *Elizabethan Military Science*, pp. 146-7.

[29] The DNB notes that he does not appear to have been admitted there unless he be "p. Whytame," admitted in 1543, based on Joseph Foster, *The Register of Admissions to Gray's Inn, 1521-1889* (London: privately printed by Hansard Publishing Union, 1889) which I have been unable to consult. At any rate, he never seems to have practiced law.

[30] The first edition of C**14** is dated 1562, two years after his translation of Machiavelli; as far as is known, the two always appear together, so the discrepancy is puzzling.

has never received its own STC number.[31] It does, however, treat the topics Machiavelli ignored or glossed over and treats them in a very different manner. Machiavelli addresses artillery and besieging in book seven, but addresses the theoretician or fortifier.[32] Whitehorne, by contrast, addresses the besieger or practitioner throughout. That is, Machiavelli is *strategic*, Whitehorne is *tactical*.

Of Whitehorne himself, we know very little, but he appears to have been a gentleman adventurer, and probably a mercenary. In the dedication to Queen Elizabeth in the *Arte of Warre*, we learn that he first encountered Machiavelli's book around 1550 ("about .x. yeres paste") when he was present at the "siege & winnyng of Calabbia, Monestrerio and Africa", presumably accompanying Emperor Charles V in his wars against the Turks (a.iii).[33] Apparently on the same sojourn, Whitehorne spent 1549 and 1550 travelling in Italy, taking in the sights as a gentleman traveller, and was frequently in the company of Sir Thomas Hoby.[34] In September 1549 Hoby arrived in Sienna, where he found Whitehorne already in residence among a number of other English gentlemen. In November, Hoby, Whitehorne, Henry Parkar, and William Barkar left for Rome together to witness the election of Pope Paul III's successor (Cardinal Reginald Pole, Archbishop of Canterbury being a leading contender). In January

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[31] The 2nd edition of the *Short-Title Catalogue of Books Printed in England, Scotland, and Ireland and of English Books Printed Abroad, 1475-1640*, edited by A.W. Pollard and G.R. Redgrave (1972-92), or STC for short, lists all printed books and pamphlets and assigns each edition of each work a unique number; the STC number is used as the standard bibliographical reference for pre-Civil War books.

[32] The convenient modern edition is N. Machiavelli, *The Art of War* (Indianapolis, 1965).

[33] The DNB entry incorrectly says "'Calibbia,' a monastery in Africa," but all three editions are quite clear in the reading quoted above. I have been unable to determine where this place or places were, other than in "Barbary" a generic term for the Mediterranean coast of Africa. Charles V was at war with the Turks from the early 1530s onward. His major assaults in North Africa were against Tunis in 1535 (which was successful) and Algiers in 1541 (which was a disaster due to fall storms), but Whitehorne was probably active in the 1550s; see C.W.C. Oman, *A History of the Art of War in the Sixteenth Century*, pp. 688-98. Also note that signature notation shall be used for referencing Whitehorne's book.

[34] The following is pieced together from T. Hoby, "The Travels and Life of Sir Thomas Hoby, Kt. of Bisham Abbey, Written by Himself, 1547-1564," ed. by E. Powell in *Camden Miscellaney 10* (London, 1902) , pp. 19, 21, 25, 52-7, 61.

1550, the group seems to have continued together to Naples and Capua, although there Hoby left the other Englishmen, "for the tung's sake", and sailed to Messina.[35] Upon Hoby's return to Naples at the end of March, he found that Parkar and Barkar had left to return to Sienna, although at this time he rejoined Whitehorne (whose company he had perhaps never left) and with two other Englishmen they journeyed to Amalfi. At a nearby Spanish garrison they were "gentlie receave[d] with loving entertainment" by the Marquis of Capistrano, an acquaintance of Hoby's from Sienna.[36] At the Marquis' urging, on the way back to Naples they visited the fortress on the island of Ischia, "one of the strongest places and worthiest to bee seene of all christendom," and were present in Naples when some "iij hundrethe brass peeces great and small" arrived for the Emperor from a victory over the Germans. Whitehorne apparently then went to Florence, where Hoby caught up with him in July, although at some time in 1550 he returned to Sienna, as he was there bilked for a loan by the ex-man-at-arms and notorious con-artist, William Horsemandon.[37] At some time during the summer of 1550 he was also cruising the north African coast in the company of Charles V's famous commander, Andrea Doria,[38] and in 1557 he was back in Sienna, promoted by Spanish captains to bear arms in the city during the famous siege of that city.[39] These last two important pieces of information suggest that he served as a soldier attached to the Charles V's Spanish forces.

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[35] Their passage to Naples together is inferred from Hoby's comment that "Upon this we determined in the meane time to make a journye to Naples. And as we cam to Roome together, so not to depart companie untill we cam thither" (p. 26).

[36] Hoby and Whitehorne shared a bedchamber "hanged with clothe of gold and vellet, wherein there were two beddes, th'on of silver worke and the other of vellett, with pillowes bolsters and the shetes curiouslie wrought with neelde [*sic*] worke" (p. 54).

[37] E.J. Baskerville, "The English Traveller to Italy, 1547-1560," p. 14.

[38] I must thank A.J. Carlson, professor emeritus from Austin College, for this information.

[39] Kenneth Bartlett from the University of Toronto kindly provided me with this unpublished information from the Sienna archives.

Whitehorne's only other known production was a 1563 translation, again from the Italian, of Onasander's *Office of the General Captain* (C**14**). In it we learn that he had also been to Constantinople and Turkey (A.iii). In both of his published prefaces, he styles himself a law student; from his other activities it seems likely that he participated in these various campaigns a combatant rather than a gentleman observer. His goal in *Certaine Waies* was to "profite the desirous man of warre, [rather] then to delight the eares of the fine Rethorician, or daintie curious scholemanne" ([a.iv]). He also struck the ever-present chord of English mistrust of foreigners, noting "how daungerous and pernitius it is for a Prince & his Realme, to be driven to truste to the servis of straungers, for lacke of sufficient skilfull men of their owne" and therefore claiming his sole intent was to have his "naturall countriemen not to be inferior to any in warlyke knowledge" (N.i^{v}). It is ironic, of course, that virtually all of the information in *Certaine Waies* is gleaned from his "servis *to* strangers" he advises the realm not to trust, but in the mid-sixteenth century, if a man wished to learn the military arts, the Continent was the only place to do so. He argues, then, like Ascham, for an English knowledge base to be built up, and offers his *Certaine Waies* as a beginning.

Certaine Waies covers an eclectic mix of topics, including the marshaling proclaimed in the title, as well as the "new" fortification, the making of saltpeter, gunpowder, and fireworks, as well as "other thynges apertaining to the warres." In 96 pages, Whitehorne covers topics of at least three distinct subject areas, which means that none receives in-depth treatment. Instead, the book is designed to provide an educated reader, but not one necessarily employed militarily, with a basic understanding of the "modern" form of warfare. And such an audience would be entirely expected, given that Whitehorne's work was

appended to Machiavelli.[40] Although the great Italian writer was often treated as a military authority, he was in fact foremost a diplomat and politician. Whitehorne's additional military matters that Machiavelli had omitted might be expected to be more practical than Machiavelli's more theoretical treatments.[41] In some cases they are. With regard to arranging soldiers on the battlefield (Aii-Diii^{v}, 26pp.), the instructions are very straightforward, with accompanying diagrams composed of typeset letters in the desired formations. Fortification ([Div]-[Fiii], 13pp.), however, is heavily decorated with woodcuts of circular bastioned cities and lacks any real practical value to either a besieger or defender, or even a prospective fortifier.[42] In effect, it instructs the reader to follow the picture to attack a city.[43] Whitehorne repeatedly refers to the "fation" of fortification, rather than the practice, again suggesting a superficial treatment. If the audience is assumed to be gentlemen soldiers, such men might be called upon to arrange soldiers in "battelray", but would be unlikely to be called upon to attack a town, or even less likely, refortify one. Nevertheless, any well-read soldier would have been expected to know a bit about these matters.

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[40] One such reader of whom we know was Gabriel Harvey who owned two copies of Whitehorne's translation of Machiavelli. The 1573 edition, now at Princeton, has been separated from Whitehorne's *Certaine Waies*, which now resides in the War Office in Whitehall. I have seen a microfilm of the former, but Harvey in it unfortunately makes no reference to the latter, which I have as yet been unable to see. Harvey's other copy was dated in his hand "1572" so must be the 1560 edition, although Stern strangely ignored that option, suggesting instead it was the 1537 Italian ed.; see V.F. Stern, *Gabriel Harvey: His Life, Marginalia, and Library* (Oxford, 1979) , p. 161-4, 226, and 238. On Harvey' reception of military literature, see the end of this chapter.

[41] There is in fact a certain school of thought that Machiavelli's *Art of War* is all about what *not* to do in warfare and that Machiavelli was being consciously and outrageously ironic in the topics he treats, and especially in omitting the "modern" topics of fortification and artillery.

[42] Whitehorne copied this section and its illustrations almost verbatim from G.B. Zanchi, *De modo di fortificar le città* (Venice, 1554) and his unacknowledged French translation, François de la Treille, *La manière de fortifier villes, chasteaux, et faire autres lieux fortz* (Lyon, 1556). See Martin Biddle's introduction to Robert Corneweyle, *The Maner of Fortification of Citties, Towns, Castelles and Other Places, 1559* (Richmond, 1972), p. v.

[43] *E.g.*, "[T]he bullwarke C, battered of the artillerie D, is seen [in figure 7]. Whereby also may be perceived how the ordnaunce may be planted to make a breach" (sig. Fii).

Alternately, a non-military reader would certainly have wanted to hear about the latest fashion in fortification.

This then raises the question of intent with regard to the larger section of Whitehorne's book, that on ordnance *materiel* ([Fiv]-Miii^{v}, 53pp.). Therein, he does not first treat cannon types and sizes as other later authors do as a matter of course. Instead he launches directly into the more fundamental discussion of how to make and refine saltpeter and make gunpowder from it. The material presented has the amount of detail that saltpeterers would need, rather than what a soldier might reasonably use. This change of tone seems to indicate a change of audience – from the spectator to the practitioner – although one would assume that the book was written with only a single audience in mind. The audience, then, must be assumed to have had an interest in those practical details of fireworks and incendiaries, but not fortification. Or, in other words, they would have wanted to know about saltpeter and fireballs but not about bastions and ravelins. And it is in these details that we can begin to locate the status of gunnery matters, or at least a subset of gunnery matters in mid-sixteenth century England.

In the discussion of the production of saltpeter, he devotes seven pages to the construction of a saltpeter house, the tubs, kettles, strainers and other equipment needed for its purification, its qualities with regard to strength testing, and even how to double-refine it for saltpeter "which shalbe good saltpeter to make powlder withall, but not verie commendable to enie other use" (G.iii). In short, claiming that "that [which] I have declared in this chapter, is as muche as I can saie of saltpeter," (G.iii^{v}), he provides a fuller description than any other general English book on gunnery for the next century. In the same way, he devotes the following seven pages to gunpowder production, and then provides 23 separate recipes for gunpowder, giving the number of parts of

saltpeter (sodium or potassium nitrate), brimstone (sulphur), and "coles" (charcoal) to each ([H.iii]-[H.iv]^{v}). The recipes range from "newer sortes" to "older sortes" and from "The first invention and oldest maner in making of sarpentine poulder, or poulder of ordinaunce" with a ratio of 1:1:1 (#1) to "Grose poulder of a newer sorte" at 10:20:37 (#9) and "finer and stronger handegun poulder" at 8:1:1 (#19; the approximate modern formula) which specified "Coles of yong hasell twigghes having their ryndes pilled of" (*i.e.*, debarked). His recipes range quite widely in composition, to the point where one wonders whether some would indeed work as gunpowder, particularly those data points away from the bottom right corner of the graph in figure 3.3 where the saltpeter percentage falls below 50%.[44] Despite his ability to go on at great length about saltpeter and gunpowder, these recipes make the modern reader wonder if he truly understood of what he wrote. Regardless, Whitehorne clearly felt the range of recipes warranted repeating, and repeating in a textually very forceful manner by setting each off in a tabular manner, rather than simply describing the different sorts in usual paragraph format.

Two-thirds of the way through *Certaine Waies*, Whitehorne finally admits to the reader his purpose for writing:

> For as muche as if Gunners shulde chaunce to be slaine or otherwyse lackinge, to the intente that every souldier in time of nede maye know how to serve in one of their stedes, I have thought it good and necessarie, to shewe and declare the maner of charging and shooting of peces of ordinaunce. (I.i)

This does not explain the preceding 32 folios, however, for no soldier would be expected to refine saltpeter if a gunner were slain. Nor, for that matter, would the gunner have been expected to do so. That information can only exist for intrinsic interest in the topic. But here Whitehorne seems to be repositioning his

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[44] See B.S. Hall, *Weapons and Warfare in Renaissance Europe: Gunpowder, Technology, and Tactics* (Baltimore, 1997) , pp. 67*ff*.

book for the practical soldier, and admits that this information would already be known by the gunners they might have to replace. And indeed, his instructions for shooting a cannon are as simple as his description for attacking a fortified town; in effect, he says to point the cannon at the target by looking down the barrel. Admittedly, this method would be sufficient at point-blank range, but he omits the mainstay of later gunnery manuals, namely disparting and elevations (for which, see below under Bourne).

Whitehorne then turns to a rather esoteric matter, but one that does again seem to be targeted for the practicing soldier, rather than the armchair theorist: de-spiking cannon. If a defending army was overrun by their attackers and was forced to abandon their artillery, they drove iron spikes into the touch-holes to render them inoperable, lest the attackers turn them against the fleeing defenders. He offers simple, yet practical advice in this instance, suggesting oil to loosen the nail and then igniting them from the mouth to blow the nail from the touch-hole.[45]

At this point in his work, Whitehorne seems to have shifted to a practical treatise, and this impression is confirmed by the concluding section on fireworks, but before he reaches that, he interrupts his manual with an eight-page dissertation on "How much the artillerie ought to be esteemed of the armies now adayes, and whether the same opinion of them which is had universally be trew" (L.ii^{v}-K.ii). With numerous examples drawn from Continental warfare from the first half of the century and allusions to Roman warfare (but not classical authors, as we might expect from the translator of Onasander) he concludes that "artillerie is proffittable in an armie, when the auncient vertue is mingled therewith, but without the same, against a pussante armie, it is moste

[45] This same method was one of two given by Niccolo Tartaglia in his *Quesiti et Inventioni Diverse* (bk. I, colloq. 17), which was to later be "Englished" by Cyprian Lucar (see below).

unproffittabell." That "auncient virtue" is training and the willingness of a field army to close upon its enemy; in all other cases artillery inevitably wins (cap. xxvij). Interestingly, he makes no mention of naval gunnery at all. But once again, he has shifted his apparent audience, here philosophizing not on recipes or tactics or offices, but rather on inevitability and discipline.

The final section of *Certaine Waies* treats a very practical matter relating to gunnery, but one which is often glossed over in survey histories of artillery: fireworks. In this sense Whitehorne as the first English author on gunnery rebuts earlier Whiggish historiographical blinders that earlier scholars wore. They were not concerned with what Tudor gunners did so much as what they did with regard to what they knew to be important later. In fact, fireworks and wildfire appear to have been the mainstay of the Tudor gunner, not the skilled battery or field fire in which seventeenth- and eighteenth-century armies excelled. And Whitehorne provides a very detailed primer of types of fireworks as well as their uses (K.iii^{v}-M.iii^{v}, 17pp.). In this section we learn specific recipes and instructions for building the devices, in some cases including amounts in absolute units (pounds, ounces) as compared to the relative units given for gunpowder recipes and measurements (*e.g.*, "as bigge as a mans thighe"). More interestingly, however, at the end of most of the recipes, Whitehorne provides suggestions for their use, something which cannot always be said for other later authors on fireworks. Flare-like devices called trunks which were mounted on staffs, we learn, are "an excellente thinge for the faighte on the sea, or for to disorder a bande of horsemen"; with ceramic fire-pots, napalm-like grenades, "good hede must be taken that it be firste well kendeled before it bee throwen," suggesting it was not as tenacious a flame as we might expect; and cast-metal

grenades are suggested as wonderful anti-personnel devices,[46] especially when thrown over town walls, but Whitehorne warns that the timing of the fuses is very variable and tests should be made beforehand to determine the time between lighting and explosion. In other recipes, he provides some answers to the still-difficult explanation of the recipes' ingredients and appearances: "hogges grease" or pig fat "maye make the fire to [en]dure the lengher"; in order to see a firework spouting from brass tubes affixed round the perimeter of a shield, the shield must be covered with "blacke buckeram" fabric, suggesting that it did not burn very brightly; fire-lances (which seem to be distinct from "trunks", despite many similarities to the reader) typically spewed a two-yard long flame; and a long discourse on the raw ingredients and manufacture of *lutum sapientia*,[47] which was a sort of clay used to tightly seal vessels while in furnaces.

In this section the question of Whitehorne's perceived audience again surfaces. On one hand, some of his recipes seem tailored for use in battle and might profit a campaigning soldier. On the other hand, other recipes include steps like burying the fixture under a dung heap for one to three months, which suggests that the dilettante reader should not be discarded even if some other recipes are couched in terms of immediate military application. And indeed the last two topics in *Certaine Waies* reinforce this image: an inner-tube flotation device for armored soldiers crossing a river[48] and a cipher-signaling system using one or two lanterns flashed a number of times. In initiating the English-

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[46] This is, to my knowledge, the first description of a cast shrapnel grenade. Other authors use copper sheets to make the casings, which would tear, not fragment. Whitehorne suggests a brass and tin melt in a 3:1 ratio, although he notes that the brass must be "molte" before the tin is added (L.i).

[47] Interestingly, Whitehorne (or his printer) italicizes his Latinate words as well (the primary text is in blackletter).

[48] Whitehorne collected his works out of Continental authors and the source of this popular device was originally Guido di Vigevano, although Whitehorne most likely knew it from printed editions of Robert Valturio, *De Re Militari*.

language military publication tradition, Peter Whitehorne impresses the modern reader with the heterogeneity of his subject matter. He did not produce a textbook in the modern sense, with logical progression from first principles to finished product. Instead, he offers snapshots of the practice of his day. And far from considering him primitive or eclectic, it is more profitable to assume that he was in fact characteristic of his day. Rather than dismiss Whitehorne because he did not produce the sort of book we would expect or desire to find, let us instead proceed holding his methodology as a model, rather than an anomaly.

William Bourne

The next English writer on gunnery has at the same time received more credit than he is due and less than he deserves. William Bourne published *The Arte of Shooting in Great Ordnaunce* in 1587 and is rightly hailed as the father of English artillery; as Cockle, put it, he "deserves great credit…. Until it appeared, there was nothing printed in our language, in a connected form, whereto a gunner could go for instruction" (C**35**; p.30). But as the preceding section on Whitehorne began to show, the question remains open whether the "gunner" would go to these printed books for said instruction. It has commonly been assumed that Bourne wrote the *Arte* as a direct response to the Spanish War of 1585-7 and published it in 1587, just in time for the Armada crisis, an idea which fits well with the English belief that they defeated the Spaniards with their gunnery. All but one of the copies of Bourne's *Arte* are dated 1587, and the single existing copy dated "1578" has been assumed to be a printer's error for 1587.[49] The evidence for the earlier date, however, is clear and convincing. First, Bourne died in 1582 and his wife the following year, and although posthumous works are commonplace, it is clear that the book was in print during his lifetime. In about 1573, Bourne presented a manuscript to Lord Burghley known as Bourne's "Book of Ordnance", indicating he already had, as E.G.R. Taylor put it, "the substance" of the *Arte* composed.[50] More concretely, however, after the preface to the reader in his 1581 book, *An Almanacke and Prognostication for x. yeeres*, Bourne included "a note of such books as have been written by the Authour William Bourne, that are extant in Print," which included a "booke

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[49] The Royal Artillery Institution, Woolwich, holds this unique copy (STC 3419.7).

[50] B.L. Sloane MS 3651. E.G.R. Taylor (ed.) *A Regiment for the Sea and other Writings on Navigation by William Bourne* (London, 1963) , p. 441-2. The 1587 edition (and presumably therefore the 1578 edition as well, since the 2nd edition does not announce that it was an expansion or even a 2nd edition for that matter) was an expanded work from the MS, which also provided some of the substance for his *Inventions and Devices* and *Treasure for Travellers*, both also printed for the first time in 1578.

called the Art of Shooting in great Ordenaunce."[51] Also noted in that same place is his other book *Inventions and Devices* (C**24**), which included various "devises of ordenaunce" and also appears to have appeared in about 1578, although again, no copy survives; it was reprinted c.1590.[52] The Stationer's Company transcript records the Arte as licensed to Henry Bynneman on 22 July, 1578, the year which also saw the appearance of his third book, *Treasure of Travellers*.[53] And finally, the famous John Dee notes a copy of the 1578 edition in his library, possibly a gift from Bourne himself, whom Dee knew.[54] Thus, 16 years after Whitehorne and not 25 as most assume, the second book covering gunnery was printed in English.[55]

Bourne's book does rightly deserve the credit as the first work solely on gunnery, codifying all the branches of the practice, although to say that the "foundations for English *scientific* gunnery were laid" somewhat overstates the case.[56] Of his life, we know a surprising amount, given his humble origins.[57] Born about 1535, Bourne styled himself a "poor gunner", although he made his living as an inn-keeper in Gravesend, thirty miles down river from London. Gravesend, and Tilbury blockhouse on the north side of the Thames, served as the last line of defense for London against an invading fleet, so it is natural that there would always be gunners stationed there. But since there were only blockhouses at both at Gravesend and Tilbury, the gunners therein were more

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[51] E.G.R. Taylor (ed.) *A Regiment for the Sea*, p. 328.

[52] The dating of this book is only approximate as the date 1578 comes from the title page of the undated (but c1590) edition: "Written by W. Bourne An. 1578."

[53] E.G.R. Taylor (ed.) *A Regiment for the Sea*, p. 444. Numerous copies survive of the 1578 edition of *Treasure for Traveilers* (STC 3432), which was printed by Thomas Woodcocke, not Henrie Bynneman.

[54] J. Roberts and A.G. Watson (eds.), *John Dee's Library Catalogue* (London, 1990), p. 37. For Dee and Bourne, see above, ch. 2.

[55] Dating Bourne securely to c1578 also allows us to take his plea for "study in the time of peace" (sig. [Av])seriously, whereas it would be out of place in a book of 1587.

[56] T.M. Spaulding, "Elizabethan Military Books," p. 499. Italics added.

[57] The following section derives from E.G.R. Taylor (ed.) *A Regiment for the Sea*, p. xiii-xxxv, which generally supplants the DNB entry.

akin to military reserve than regular army, as a gunner's post at the Tower or Berwick (the two major forts of the realm at this time) might have been. Thus we would expect gunners at Gravesend to support themselves in other pursuits, as Bourne did in inn-keeping and Jasper May (another Gravesend gunner whose name survives) did as a shipwright.

Bourne and his wife, Dorothy Beare Bourne, lived in relative comfort, being the union of two principal families of Gravesend, and he served one term as port-reeve of the town, a position equivalent to mayor. Still, where and how he became educated in the mathematical arts is entirely unknown. Although Gabriel Harvey would refer to him as "Unlectured in Schooles or Unlettereed in Bookes", Bourne must have had command of Italian and French, for his *Arte* and *Inventions* derive largely from Niccolò Tartaglia's *Quesiti et Inventioni* and Jacques Besson's *Théâtre des Instruments*, respectively. An acquaintance of John Dee, one of Tudor England's most respected mathematicians, but not apparently of Leonard or Thomas Digges, two of the others, Bourne would undoubtedly have been in contact with soldiers and seamen coming or going through Gravesend, but as far as we know, he never left there, except for a brief period near the end of his life when he wrote from Upnor Castle. He may have been training gunners and seamen there by the patronage of Edward Clinton, Lord High Admiral. There is no evidence that he had a library of his own, nor do his or his wife's wills contain any instructions for the disposal of books;[58] Lord Clinton may have been his source for continental and recent English books, but this must remain conjectural. What we can say for certain is that William Bourne enjoyed a prolific career as an author in the mathematical sciences: navigation, mensuration, hydrostatics, hydrography, astronomy, surveying, and last but not least, gunnery.

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[58] For the Bournes' wills, see E.G.R. Taylor (ed.), pp. 434-8.

Bourne, then, wrote two books whose audience is clear: students of the mathematical sciences. In the localized context of a book on gunnery Bourne explicitly makes this connection, although he likely extrapolated it from John Dee's famous *Mathematicall Preface* to Billingsley's 1570 edition of Euclid's *Elements*.[59] Dee himself only passingly links gunpowder weaponry to the mathematical arts, although by extension from his categories, its inclusion is logical.[60] Bourne clearly states in his preface to the reader his intention to rectify the faults of England's gunners, given their inability to determine relative ground heights, elevations of their pieces, and distances to their target (Aiii-[Avi]^{v}). And, despite enmity from

> a number of them that be Gunners, waying and considering with my selfe what a number there bee, that will take upon them to be Gunners, yea and that maister Gunners, that are not sufficient nor capable in those causes, but are in respect altogether ignorant, standing upon no other thing but their antiquitie, that they have served as Gunners so long time,

Bourne nonetheless believed it necessary for the realm to give them "some good instruction" ([Aiv]^{v}). Yet as suggested in the preceding section, it is not a necessary or sufficient assumption that gunners would have bought or read Bourne's works. While a gunner would indeed be the logical candidate as an audience for Bourne's *Arte*, as he himself recognized, most of that contained within it would have been much too simplistic for their needs, if not wholly

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[59] The influence of Dee's *Preface* has been stated again and again, although to my mind, without a great deal of hard evidence to demonstrate that it was influential. I fully concede that it was groundbreaking and encyclopedic in its scope, but have not seen any contemporary authors refer to it as formative in their minds, although Thomas Hood probably followed its precepts. And Dee was probably following the lead of Sir Humphrey Gilbert's proposal for an Academy to Elizabeth (See ch. 8, below, for a discussion of the mathematical arts in Elizabethan England). The emphasis should perhaps be shifted from Dee's influence upon others to his encapsulation of the *zeitgeist* of Elizabethan England. For the Mathematical Preface, see J. Dee, *The Mathematicall Praeface to the Elements of Geometrie of Euclid of Megara (1570)* (New York, 1975).

[60] See the section on Dee in ch. 2, above. Dee's attempted clarification of the relationship between the mathematical arts was a large step in the organization of technical knowledge; see E. Tebeaux, *The Emergence of a Tradition: Technical Writing in the English Renaissance, 1475-1640* (Amityville, N.Y., 1997) , ch. 3.

irrelevant: "I [have] written this little treatise, not to the intent to teach them that be cunning, but to give instructions unto them that be of the simplest sorte", he wrote ([Av]). This then raises the question of who were these men who "will take upon them to be Gunners" and what were the skills they would be expected to acquire.

It would be unprofitable to rehearse all the topics of which Bourne treats in this overview.[61] Instead, following only a brief summary, I here want to discuss the types of knowledge the assumed audience of the book would have needed. In 26 chapters Bourne covers topics which fall into four categories: physical characteristics of great ordnance (including gunpowder), numerical calculations of these properties, instrumentation, and the process of laying a shot (including range- and elevation-finding). He does not cover these in what appears to a modern eye as a logical order, but rather flits back and forth, as he sees fit. Sections on physical characteristics are spread throughout the book, rather than concentrated at the beginning, as a modern arrangement would have. Instead, Bourne provides ten "Considerations" regarding great ordnance to open his book, and while important, they are at the same time vague and unspecified (B-B2^{v}). They are simple maxims, providing qualitative explanations for missing the mark or else notes to the gunner of things to remember. For example, he notes that if the powder is bad or the ball too small or the tail depressed, you will shoot short; he also reminds the gunner to note how truly the piece is bored or disparted (*i.e.*, provided with an appropriate front sight). But the ten maxims do not correspond directly to the following chapters, and

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[61] For a more complete understanding of the details of sixteenth-century artillery, readers are directed to the concise introduction to A.B. Caruana, *Tudor Artillery: 1485-1603* (Bloomfield, Ont., 1992) who treats the *materiel*; H.J. Webb, "Elizabethan Field Artillery," *Military Affairs* 19 (1955): 197-202; and H.J. Webb, *Elizabethan Military Science*, pp. 124-47, who topically surveys the practice. Appendix V, below, provides a glossary of Elizabethan artillery terms.

although he does in one case mention the chapter to which the maxim refers (#10 to ch. 2), there is no sense of the developed logic of technical manuals that had by this time been in print in England for a decade or more.[62]

By comparison, the manuscript book Bourne presented William Cecil, newly Lord Burghley, in 1573 covers much the same ground, but the printed version has been padded with nine extra chapters, most of which add little to the utility of the book as an instruction manual. While the book could provide reference for some of the details a gunner might need to look up, as the weight of an iron shot given its diameter or the sizes and charges of the various class of cannon, it is organized more as a "ramble through gunnery" all the while claiming to be a textbook on the subject. Compared to Bourne's other major work, *A Regiment for the Sea* (11 editions between 1574 and 1631, as well as 3 in Dutch), which begins with 28 definitions and then treats each subject in a tightly encapsulated format, the *Arte* is divided into chapters, but often chapters relating to one another are spread throughout the book. So while chapter 3 is on the weights of shot and powder in relation to the weight of the cannon, chapter 20 also covers the same ground from a different angle. Not surprisingly, chapter 20 is an addition not present in the 1573 Burghley manuscript. Here the question is not as much a question of content as presentation. Bourne's *Arte* is unfortunately poorly organized in terms of training the novice gunner he claims to be addressing.

Part of the difficulty is in the technology of printing at the time. Tables were difficult to typeset compared to blocked text, so while the manuscript version has numerous tables to allow easy access to numerical data, the printed version fails miserably in this regard. In the discussion of the weight of different diameter shot, the manuscript uses no text other than a title announcing the

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[62] On this, see E. Tebeaux, *The Emergence of a Tradition*, ch. 3.

subject matter, instead relying on a ruler-like diagram with the weights entered next to the appropriate tick mark.[63] The reader then uses the culturally-defined but therefore widely understood image of a ruler to understand that the "5" refers to a five-inch shot (weighing 16 lbs., 9 oz., in this case) and the next three ticks to refer to $5\frac{1}{4}''$, $5\frac{1}{2}''$, and $5\frac{3}{4}''$ diameter shots, respectively. And, naturally, the $5\frac{1}{2}''$ tick mark is twice as long as those for $5\frac{1}{4}''$ and $5\frac{3}{4}''$. In the printed version, there are instead 32 repetitive lines of text of the form, "A shot.5.ynches a quar. high, doth wey.17.*lb*.5.ounces" (14), which allows more difficult access to the information contained within its pages than does the manuscript. This rather modifies Tebeaux's contention that logical page design arose in the seventeenth century;[64] it had existed earlier in MS form, but the moveable type was actually a "reverse salient" to its dissemination in print.[65] Similarly, the illustrations in the MS are much more detailed and more copious than in the book, where the cost of cutting woodblocks was prohibitive.

Unlike Whitehorne, Bourne produced a book specifically on gunnery, and one which does cover all the topics a gunner would need to know. For that he is justly famous. That he did not do so in the most efficient manner should be of little concern, despite what earlier historians have had to say about it, because that such a book exists immediately informs us that by 1578, gunnery was

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[63] B.L. MS Sloane 3651, fol. 14^{v}.

[64] E. Tebeaux, *The Emergence of a Tradition*, ch. 6. In fact, Tebeaux unwittingly uses Bourne's book as an example of this phenomenon: "Tables… are poorly drawn with broken columnar lines and lack of clear column headings…. This table also illustrates the lack of early tabular design expertise by Renaissance *writers and printers*. This work, when we compare it with seventeenth-century military works, becomes a useful text for tracking the development of tabular display of data" (p.216, emphasis added.) For more on tabular data, see ch. 4, below.

[65] The concept of a "reverse salient" comes from T. Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore, 1983), who fittingly enough took it from military historians who use it to describe "any part of an advancing line which has fallen back" (p. 14). Hughes defines reverse salients as "obvious weak points, or weak components, in a technology that are in need of further development. A reverse salient is obvious and creative imagination is not needed to define it, [but] that, when solved, would remove the impediment" (p. 22, 371).

considered a separate and bounded art by military writers, and therefore, presumably by the populace at large. And even if the general readership might previously have made gunnery just one subsection of the "art military", the publication of Bourne's *Arte* immediately defined gunnery as a separate and independent branch. One of the striking features of general military books is their almost complete disregard of artillery in their exposition of warfare, despite the fact that by the end of the sixteenth century, anyone involved in virtually any military action should have realized that artillery was a large component (intellectually, if not physically) of any army or navy.[66] That they pass over it without much guilt indicates that to them it was a separate and autonomous field in a way that transport, recruitment, victualling, and of course infantry tactics were not. Bourne may not have been the "foundation for English scientific gunnery", but he was the foundation of English autonomous gunnery.

Cyprian Lucar

If Bourne can be criticized for being too disorganized, then Cyprian Lucar, the next English author, should be disparaged for his prolixity. Lucar's 1588 work, *Three Bookes of Colloquies concerning the Arte of Shooting* (C**38**) combined a translation of books I-III of Niccolò Tartaglia's *Quesiti et Inventioni Diverse*, originally published in Venice in 1546 (C**660**), with a compilation of military matters from "divers good authors in diverse languages" entitled *A Treatise named Lucar Appendix*. The *Appendix* is considerably longer than the translation

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[66] For example, Thomas Proctor's, *Of the Knowledge and Conduct of Warres* (1578; C**23**), which Cockle describes as the "first technical military book written by an Englishman" is extracted entirely from classical sources (as was an edition of Vegetius in 1572; C**17**). Geoffrey Gates, *The Defence of Militarie Profession* (1579; C**26**), Thomas Styward, *The Pathwaieto Martiall Discipline* (1581; C**28**), Barnaby Rich, *A Pathway to Military Practise* (1587; C**36**), and Albert Meier, *Certain Briefe and Speciall Instructions for Gentlemen* (1589; C**44**) all completely ignore artillery. Other foreign works translated into English cover everything from riding to military medicine and infantry practice, but they too ignore artillery (and fortification).

itself. Born in 1544 to a member of the Merchant Taylors' Company, Lucar was schooled at Winchester College from the age of eleven and became a fellow of New College, Oxford by 1564. In 1568 he entered Lincoln's Inn, one of the Inns of Court in London. Other than this work, he published one other, *A Treatise named Lucarsolace* [sic], in 1590, which is another compendium of information covering building, timber, surveying, measurement, and a host of other practical mathematical arts. *Three Colloquies* is dedicated to Robert Dudley, Earl of Leicester, by Lucar's publisher who urged him to use it to good effect in his lieutenancy in the Netherlands, suggesting that his publisher, at least, saw a practical use as its market. Tartaglia had attained a reputation by the 1580s as the primary author on ballistics, for in 1537 he published *Nuova Scientia*, an exposition of ballistic theory which was not to be superseded until Galileo. Nine years later, his *Quesiti* served as an extension and modification to the *New Science*, for while the latter was geometrically rigorous and defined the motion of a bullet at any elevation of the gun barrel, the former extended those ideas to real-world situations, modifying (and largely correcting) them in order to more convincingly explain how artillery (as compared to projectiles) worked.[67]

Lucar produced a verbatim translation of books I to III of the *Quesiti*, which, like many books of its day, was written as a series of dialogues. These dialogues imitated a student-teacher relationship, having various characters pose questions of the learned Tartaglia, who would promptly answer and gently

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[67] While Tartaglia is justly famous as the first ballistician, the non-Italian literature on his output is surprisingly meager. The foremost technical analysis of his work is S. Drake and I.E. Drabkin, *Mechanics in Sixteenth Century Italy: Selections from Tartaglia, Benedetti, Guido Ubaldo, & Galileo* (Madison, 1969) , although more recently, Sarafina Cuomo has provided more social context: S. Cuomo, "Niccolo Tartaglia, Mathematics, Ballistics and the Power of Possession of Knowledge," *Endevour* 22 (1998): 31-35 and S. Cuomo, "Shooting by the Book: Notes on Niccolò Tartaglia's *Nova Scientia*," *History of Science* 35 (1997): 155-88. The prominent French historian of science Alexander Koyré has also engaged Tartaglia's output; see *P. Guidera*, "Koyré e Tartaglia," in C. Vinti (ed.), *Alexandre Koyré: l'avventura intellettuale* (Napoli, 1994), pp. 487-502.

correct when the student made further naive observations on his "truths". Strangely, Tartaglia proudly claimed never to have touched or fired either cannon or gun in his life, being provoked to the topic by a "skilled gunner" from Verona in 1531 (sig. ∴3v).[68] Taken at face value, this claim provides a lay testimonial that practitioners looked to mathematicians – Tartaglia being one of the most highly esteemed in Italy at the time – for answers about mundane problems, such as the flight of a cannonball. But if we suspend our belief in Tartaglia's honesty for a moment and consider what this statement implies if there was no "skilled gunner", then a different story may be constructed. If a practitioner did not ask Tartaglia for his opinion, then Tartaglia must have become interested for some other reason, but then sought to attribute his interest to a humble user. The reason for his interest is fairly self-evident, in that a flying projectile epitomizes the Aristotelian problem of natural versus violent motions. And since the widespread introduction of artillery in the French conquest of Italy in the 1490s, there was now a new, large, and particularly "violent" (in both senses of the word) projectile to consider. Tartaglia's compulsion to ascribe his interest to a practitioner serves a dual purpose. First, it suggests to the reader that Tartaglia's information was actually relevant, since the material presented in the *New Science* was really of little practical value. But more importantly, the second purpose in informing the reader that a practitioner asked for the information was to suggest to the reader (whether practitioner or dilettante) that they *should* be asking the mathematicians for this sort of information. In this sense, published books created the field that they were trying to reach more than the field demanded a specific type of book for their use.

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[68] Although this appears in the introduction to the *Quesiti*, it was referring to the incident which caused Tartaglia to write the *Nova Scientia*.

For current purposes, however, Cyprian Lucar's impetus in offering his books for publication is of more relevance than Tartaglia's. The timing of this book, like Bourne's second edition and a number of other books, related to the heightened tensions with Spain, against whom war was declared in 1585. This spurred authors to address military topics, but many of the books did not appear until a year or two after the Armada (see fig. 3.2, detail). That Lucar chose to present Tartaglia's book largely hinges on the latter's dedication to Henry VIII as well as the fame apparently ascribed him, even in England, by those concerned with gunnery.[69] The *Appendix*, however, makes no offer of a reason for its compilation. There is no dedicatory chapter here, and even the dedication to Leicester in the *Colloquies* was penned by John Harrison, Lucar's publisher, not Lucar himself. Chapter one of the *Appendix* immediately lists the qualities of a gunner, from being "lustie, hardie, patient, and prudent" to ascertaining the goodness of his carriages' axles, to keeping a log of all gunnery-related needs, supplies, and expenditures. After this, Lucar presents chapter after chapter of close-set pages of information on all sorts of topics. Given no prologue by Lucar or a clearly-stated indication of the purpose of this book, we must therefore judge it on its contents. And those contents, unlike Bourne's *Arte* and quite beyond Whitehorne's brief treatment, but very much like Bourne's *Inventions*, are eclectic and simply presented one after the other. There is no attempt at serial instruction as would be understood today. The two textual aids introduced by Lucar, however, are marginal annotations of the topics within each chapter, and when discussing instruments rather than processes, clear naturalistic

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[69] While not allowing Tartaglia a large place of honor in the way the Digges' would, Bourne nevertheless knew of his work: "I have heard that Tartalia the Italian hath made proofe [of range-tables]… wherupon, he hath made Tables (by reporte) very exact, yet I could never come to the sight of them, neyther are they in his Booke that he hath made for these causes" (38). Since this was written in 1578, 10 years before Lucar, this suggests that Bourne read Italian, although nowhere else does he suggest this ability.

woodblock illustrations tightly specific to the topic at hand.[70] As such, Lucar's *Appendix* is still not the first gunnery textbook, but can truly be considered the first English-language gunnery reference manual.

The *Colloquies* are divided into three books, which treat the "art of shooting", or sighting and mounting of cannon; range-finding and weights and measures of bullets; and gunpowder and corning methods,[71] respectively. *Lucar Appendix*, on the other hand, includes 123 chapters covering everything form further details on gunpowder to firework recipes, sizes and construction methods for all the material associated with artillery, gunners' offices, as well as specifics on aiming and range-finding.[72] Lucar admits that he has gathered this material from many other authors, naming nine Italian authors and eleven Latin authors. He also names four English authors, including Peter Whitehorne and Thomas and Leonard Digges, who he counts as one.[73] He interestingly omits William Bourne, but includes Robert Recorde, a widely-popular author of basic mathematical books which included sections on surveying,[74] and William

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[70] Illustration clarity is a large consideration in the estimation of instructional value. Whitehorne's illustrations, while well-cut and printed, tend to be of pastoral scenes of the topic at hand. Bourne's are, although well-rendered when included, relatively sparse and frequently generic (his *Inventions* has none).

[71] Corning is a second stage of gunpowder manufacture where the mixed powder is wetted and forced through sieves to produce small pellets of gunpowder. See B.S. Hall, *Weapons and Warfare in Renaissance Europe*, ch. 3, pp. 67-104.

[72] The two books are comparable in size, despite the disparity indicated here. The *Colloquies* has 3 books (of 30, 12, and 9 chapters) totaling 80 pages; the *Appendix*'s 123 chapters fill 120 pages, although with many more illustrations. The difference lies in the delivery: for the same amount of text, *Colloquies* dialogue fashion "wastes" much more room than the *Appendix*'s straightforward "plain style" descriptive manner (see Tebeaux, *Emergence of a Tradition passim*.).

[73] The bulk of Leonard and Thomas Digges' output on artillery comes in 1590 and 1591. The first edition of their works were however in print by the time Lucar wrote, although as will become clear below, it is unclear what Lucar might have been able to take away from it for inclusion in his *Appendix*.

[74] Recorde wrote 6 books which went through a combined total of at least 42 editions by 1640 (his *Grounde of Arts* on arithmetic appearing 29 times alone, and does not count early editions of his *Gate of Knowledge* on mensuration, which only survives in a later edition). In addition to his 5 works on mathematics (arithmetic, geometry, algebra & equations, Ptolemaic astronomy, and mensuration), he also wrote one on medicine called the *Urinall of Physick*. See F.R. Johnson

Cunningham, who did not write on military matters at all.[75] So although he has been censured for not being original, Lucar provided a very valuable service in collecting all these matters in one place. He followed a similar method in his *Lucarsolace*, although there he claimed more original material than in the *Appendix*. Ultimately, Lucar's testimony to gunnery at the end of the 1580s suggests where the field was headed. Whitehorne advertised himself as a law student, but he travelled and fought in Emperor Charles V's Mediterranean wars and his additions were appended to the most famous military author of the Renaissance, Machiavelli. Bourne was an active gunner, so it should not be surprising that he would write on gunnery. Lucar, however, saw a niche and filled it. He was not a practicing gunner, and as far as we can tell, not a soldier or surveyor. His skill lay in his realization that there was an audience for these topics, and his education allowed him to collect information from many Continental sources for the better instruction of Englishmen.

Leonard and Thomas Digges

The next books relating to gunnery come as a pair and were first printed in the 1570s and then, greatly expanded and issued in second editions in the 1590s. They come from the pens of the father and son team of Leonard and Thomas Digges; but, as will become clear below, it is primarily Thomas, the son, to whom credit for the artillery sections should go. The two books in question are *A Geometrical Practice, named Pantometria* (1571; 2nd ed. 1591; C**16**) and *An Arithmeticall Militarie Treatise, named Stratioticos* (1579; 2nd ed. 1590; C**25**). These two deviated from the established tradition and initiated a second branch of

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and S.V. Larkey, "Robert Recorde's Mathematical Teaching and the Anti-Aristotelian Movement," *Huntington Library Bulletin* 7 (1935): 59-87.

[75] This reference must be to Cunningham's *Cosmographical Glasse* (London, 1559; STC 6119), although what he extracted from it is unclear.

gunnery works which fully embraced the idea that great ordnance was a mathematical science and could therefore be dealt with using the tools of that discipline. Earlier books called gunnery "mathematicall" but used the term advisedly, in a broader sense. Lucar noted that a gunner ought to be "skillful in Arithmeticke and Geometry"[76] and mathematized as large a proportion of his topics as he could. To the Diggeses, gunnery was mathematical in that it used numbers and graduated instruments, but also because it could be made *analytical*, that is, analyzed in a rigorous, logical fashion. While the Diggeses were not alone in this belief (witness Thomas Harriot), they were the first to set this belief in print.

The Diggeses' history is interesting and well-documented, although no scholar has codified it into a monograph study.[77] Leonard, born into an ancient but non-noble family of Kent was Oxford educated (leaving University College, however, without his degree) and was admitted to Lincoln's Inn in 1537. He later became renowned in Kent for his mathematical and architectural skill,[78] but after joining Wyatt's rebels against Queen Mary in 1554, he was deprived of his property and exiled from England. Pardoned early in Elizabeth's reign, he did not apparently return to England until about 1571, dying either during or very shortly after his return.[79] His son Thomas, took up the newly restored family

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[76] Cyprian Lucar, *Lucar Appendix*, p. 1.

[77] This has been lamented by A.R. Hall as well (p. 34, n. 3). The sources for the following brief biography are: the DSB and DNB articles, the former supplanting the latter; E.G.R. Taylor (ed.) *A Regiment for the Sea*, pp. xv-xvi, xxii-xxxiii; and for the more technical analysis A.R. Hall, *Ballistics in the Seventeenth Century*, pp. 43-49.

[78] This facet of his life bore fruit in his *Book named Tectonicon* (London, 1556; STC 6849.5) on mensuration, practical carpentry, and construction. He published one other book on astrological meteorology in his lifetime (*A Prognostication Everlasting* [1553 *et seq.*; STC 435.39]) and left manuscript drafts of *Stratioticos* and *Pantometria* to his son.

[79] Joy B. Easton's article on Leonard Digges in the DSB claims he died in *c*1559 and calls the DNB article "wholly unreliable." Nevertheless, since Digges was restored to his property in 1563, unless this was a posthumous act for the benefit of Thomas, he must have lived into Elizabeth's reign. And although clearly a Marian exile, Digges is not calendared in Garrett's book of the same name. That Leonard's life is less than well known is indicated by his birth date being listed as *c*1520 and that of his son as *c*1530.

estates and his father's mathematical and publishing interests with vigor. He also reëstablished the family as one of importance in Elizabeth's, James', and Charles I's governments, he himself serving her in the Low Countries and his sons, Leonard and Sir Dudley, the Stuarts in various capacities. For our purposes, however, it is Thomas who is of interest.

Thomas Digges was born to Leonard and Bridget Digges in the early 1530s and took his BA and MA at Queen's College, Cambridge in 1551 and 1557, respectively. Under Elizabeth he became a respected authority on fortification and construction, being appointed chief overseer of the reconstruction of Dover harbour in the 1580s. Under Leicester, and perhaps through his direct patronage, Thomas served as a muster-master general in the war in the Low Countries, and survived Leicester's ignominious recall in 1591. Digges was discharged in the spring of 1594, possibly for an Antarctic voyage of discovery that never came to fruition, and died in August of the following year. His works range from mathematics to astrology to an anonymous 1590 apology for Leicester's loss of Sluys three year before. Most of his work is mathematical in nature and most in the vernacular, although he did write three treatises in Latin, on astronomy, the war in the Netherlands, and a health regimen.[80]

It is clear that Thomas Digges was more interested in artillery than was his father. In many places he promises a book on "Martiall Pyrotechnie and great

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[80] Both first editions of Digges' works touching artillery (*S1* [1571] and *P1* [1579]; see next note) and the first edition of Bourne's *Arte* (1578) were printed and sold by Henrie Bynneman (as wsa Sebastian Verro, *Physicorum Libri X* [1581], see ch. 2, above), one of the more prolific and varied London printers; see H.R. Plomer, "Henry Bynneman, Printer, 1566-83," *The Library* n.s 9 (1908): 225-44, who unfortunately takes no notice of Bourne's or Digges' works from Bynneman's press. There is no direct indication that Bourne and the Diggeses' knew each other, although this common printer suggests that they might have, and noting that Lord Clinton was a kinsman of Digges and the possible patron of Bourne strengthens that possibility. Nevertheless, Bynneman clearly recognized the profit to be had from including scientific/technical works in his output.

Artillerie, hereafter to be published",[81] although no such work ever appeared, possibly due to his untimely death. As far as is known, no draft of such a book was left in his papers, although he claims that it was largely written. Digges first mentions artillery in the 1571 edition of *Pantometria*, but not as a topic in and of itself. Instead, it is one of the arts to which the art of *Longimetra*, or length-measuring, may be put.[82] Eight years, later, however, Digges included a long section on "Certeine Questions in the Arte of Artillerie, by Mathematical Science joyned with Experience, to be debated and discussed" in the first edition of *Stratioticos* (Z.iij-[&.iv]). The treatment, however, leaves much to be desired from the point of view of the practical use of artillery. Instead of the textbook approach of earlier authors, Digges takes an Aristotelian tack, immediately introducing the "causes" of artillery's actions:

> The diversity of the force & violence of great Artillerie, & of the farre or nigh shooting & variable randge of their Bullets, doth chiefly arise & grow of these 4 principall causes: Powder, Peece, Bullet, & Randon. In Powder is considered Quantitie & Qualitie. In the Peece the length & proportion of the Cylinder. In the Bullet his waight & Quantitie. In Randon the degrees of Altitude from the Horizon or plain wher the Peece must play. These may be called the Prime, substantial or effectuall causes.
> (Z.iij)

So while other books busied themselves in considering the types of cannon and how many pounds of powder a demi-culverin takes for its "due charge", Digges instead asks *why* cannon behave the way they do. And it is quite significant that his causes are four in number, just as Aristotle would have four causes. Digges even goes further, for he immediately then introduces an additional number "secondary or accidental causes": "rarity or Density" of the air and cross-, head-, or tail-winds; wadding and ramming of the charge; unevenness of ground or

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[81] *Pantometria* (1591 ed.), title page. References to the two editions of the two books will hereafter be abbreviated as follows: *S1= Stratioticos* (1579), *S2=Stratioticos* (1590); *P1=Pantometria* (1571), *P2=Pantometria* (1591).

[82] *P1*, I.25 ([G.iv]^{v}-H.ii). Even here, artillery is only directly indicated by its prominent inclusion in the woodcut illustrations, keyed by letters to the accompanying chapter on right-triangle triangulation.

platform or the carriage wheels; irregularities in the boring of the cannon, "the diste*m*pering of the Peece hot or cold", and the fit of the ball to the bore. But in good Scholastic form, these causes, he assures us, "by Practize and use [may] be learned, and their errours by discretion reformed". That is to say, gunnery may be reduced to exactly four variables: powder, piece, bullet, and random.[83]

While Digges promises that reduction, he does not fully accomplish that goal in *S1*. The remainder of the chapter deals with the four principal causes in due course, and proposes between seven and 20 questions regarding each one. As advertised in the chapter heading, these questions are to be debated and discussed, not answered. Table 3.1 provides some paraphrased examples of the sorts of questions Digges asks. He does not, however, answer any of these questions. Instead he concludes the chapter with a short essay that begins on the topic of artillery, wanders to his father's skills[84] and his tribulations, and concludes with a promise that "there are yet many Mysteries that by farther profes and trials Experimental, I must resolve, before I can reduce that Art [artillery] to suche perfection as can content me.… [M]y first endeavours shal be entierly to finishe the Treatise of that newe Science of manedging this newe fourious Engine & rare Invention of great Artillerie" ([&.iv]).

Digges berates practicing cannoneers, noting "how far off… [they] are from the first Elements of that Science" and that, being able to make a shot at all, "thinke themselves therefore perfit Masters", although he offers little in the way of direct help to instruct them in those "first elements" (&.ij^{v}). By suggesting

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[83] "Random" or "randon", which refers to the angle of elevation of the piece, derives from a medieval meaning of random, to move with great motion of violence (see OED). It is sometime used to refer specifically to the maximum elevation (either 45° or sometimes ~42° – frequently called "utmost random") but can also refer to any elevation above point-blank (*i.e.*, 0°).

[84] Including his work with optics and mention of what many have taken to be the first description of the telescope. Others, however, dismiss the assertion. See J. Rienitz, "'Make glasses to see the moon large': An Attempt to Outline the Early History of the Telescope," *Bulletin of the Scientific Instrument Society* 37 (1993): 7-9 and C. Ronan, "The Invention of the Reflecting Telescope," *Yearbook of Astronomy* (1993): 129-40.

Table 3.1: Sample Questions from Thomas and Leonard Digges, *Stratioticos*

Powder (7)	2. Does a piece shoot the same distance repeatedly, using the same charge, ball, wadding, and elevation? 4. What is the relation between distance and charge weights – linear, quadratic, or cubic (or no relation)? 7. Are ranges proportional to some "commixtion" (*i.e.*, ratio) of the variables?
(Z.iij^{r-v})	
Piece (10)	2. Do longer cannon shoot farther, all other things being equal? [5]. Do equal weights of corned and serpentine powder give the same ranges?[85] [7]. Is the range proportional to the total length of the cannon or the vacant length in front of the charge, ball, and wad?
(Z.iij^{v}-[Z.iv])	
Bullet (16)	1. Does a lighter (*i.e.*, less dense) bullet fly further than a heavier one? 7. Is the ratio of ranges for a lead and an iron bullet constant for different charge weights? 9. Will a saker shoot the same distance as a falcon of equal length?[86] 15. What quantities of powder will cause two known (but different) guns to shoot the same range?
([Z.iv]-&.[i]^{v})	
Random (20)	1. Are the "right lines" equal or proportional for elevations of 0° and 45°?[87] 3. Is the right line at 45° the average of the right line at 0° and 90°? 7. Is the maximum range attained at one (numerical) elevation, regardless of the inclination or declination of the ground under the piece?[88] 9-10. Does a ball fired at *x*° also land at *x*°? 11-20. What conical sections occur in trajectories?
(&.[i]^{v}-&.ij^{v})	

• Numbers in parentheses by section headings indicate the number of questions in each section.

that even Archimedes would need "Expereince, long practise, & sundrie trials" to discover those first elements, including the "mixt Helical Arcke or circuity of the Bullet, componed of violent, & natural motions, receyving infinite diversitie, according to the several proportion of their Temperature" truly takes artillery into another realm than that of Whitehorne, Bourne, or even Lucar who while propounding Tartaglia's theories, brought it closer to the practical level of the gunner. And, typically, Digges does not allow Tartaglia to escape his scorn:

[85] While this question would logically belong in the powder section, Digges places it here. We can either ask whether this is a printer or author error – and it could conceivably be a switch with #4 in the powder section, which might make sense in the piece section – or whether the behavior of the different powders in Digges' mind were affected by the piece's length. One explanation may be that in the first three sections, Digges progressively "builds" the variable list, considering first the powder alone, then the length and the powder together, and finally the bullet and the length and the powder all together. The fourth section, on Randons, is again a self-contained section.

> albeit he were an excellent Geometer, taking upon him to deliver sundrie Demonstrations in this new Science, yet for want of Practise, and Experience, [he] hath erred even in the first Principles, and so consequentlye in the whole substance of his discourse.[89]

One mathematician (Digges) berating another mathematician (Tartaglia) for lacking practical experience (even though he admits as much) must not have seemed as hypocritical to an audience which apparently wanted to believe that gunnery could indeed be reduced to a science.[90]

If Digges teased the reader with over fifty questions that were to make artillery a science in 1579, he failed to satisfactorily provide the answers to those questions when he reissued the book some eleven years later. In the 1590 edition of *Stratioticos*, the same questions and commentary are printed verbatim – "to give parcticioñers [*sic*] some Encouragement to try Conclusions" (361) – but by way of answering those questions, Digges added marginal notes to about half of the questions (32 of 53 on pp. 349-60). Unfortunately, those answers are all of the briefest form, usually just "yes" or "no." In some cases the simple affirmative or negative does sufficiently answer the questions, as for example, that ranges are not universal, but rather specific to each individual cannon. In

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[86] This is one of the few places where real-world examples invade Digges' discourse. All other discussions are of simple dualisms: greater / lesser, longer / shorter, &c.

[87] Digges problematically defines the "right line" in a preamble to this section as the distance "the bullet first violently issueth out a good distance directly without making any sensible declination."

[88] Throughout, I have used 45° as a convenient equivalent to Digges' "utmost random", or elevation for maximum range. He clearly knows that they are not the same, but does not state what the utmost angle is: in the very last question he asks "Whether the Parabolical Section be not made at 45 Grades of Randon, rather than at the Grade of utmost Randon, and so the Hyperbole at al Randons above, and the Elepseis at al inferiour Randons" while on the next page he berates Tartaglia for taking 45° as the angle of the "utmost randons", "an Errour knowen even to the first practitioners."

[89] It seems to me that Digges must here be speaking of Tartaglia's *Nuova Scientia* rather than his *Quesiti* (*i.e.*, Lucar's *Three Colloquies*), since the former is more couched in terms of principles along Digges' line of reasoning.

[90] Digges' section on artillery ends, in both *S1* and *S2*, with the Latin motto, *Virescet Vulnere Virtus*, or power injures a man, suggesting a negative side to his work. This may be yet another reason Digges chose never to publish his complete book on artillery, although inability to finish it seems more likely.

other cases, he waffles, as in whether longer pieces shoot farther: "not alwayes" he says. Whether equal charges of serpentine and corned powder have equal effects, he says no, but he does not even provide the obvious "answer" as to which type is stronger or by how much.[91] His explanation to this paucity of development is that "albeit there are divers Reasons that move me not to Imprint my Treatise of great Artillerie… [I have here] resolved the greater part and briefly opened divers great Secrets of that Science" and would indeed publish his book. But, as mentioned before, he never did.

Digges did, however, provide an additional section, independent from the original questions where he discusses some errors of "many Treatises of great Ordinance both in Latin, Dutch, Italian and English" that he had read (361). Unfortunately, in discussing the five "foul and gross" errors he has found in foreign works, he fails to provide the corrections to those errors. He merely negates the other authors' propositions. So, we are "corrected" from believing that the trajectory of a cannonball is a straight line to its zenith and then a straight line perpendicular to the ground.[92] We learn that the range of a projectile is not simply proportional to the length of the piece, and that the correct answer is a "proportion mixt," but that "it were now too long to enter [into that discussion], for this matter alone would require a large Treatise" (363). We learn the same regarding the range and different weights of powder, but not what the correct answer might be; on the matter of the angle of maximum range, we learn that it is definitely *not* 45°, but only that it is "more then one, 2 . 3

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[91] The answers he gives to the sample questions in the previous table are as follows (Ø=no answer given): **Powder** 2) No, 4) No, 7) "Referred to my treatise of Great Artillerie"; **Piece** 2) "Not Alwayes", 5) No, 7) Ø; **Bullet** 1) "Note alwayes there is meane convenient" (?), 7) No, 9) Ø, 15) Ø; **Random** 1) "Not equal but proportional", 3) No, 7) No, 9-10) No, 11-20) Ø, but suggests "helical" rather than "conical" and not circular.

[92] In effect, the hypotenuse and altitude of a right triangle whose base is the ground. This theory was advanced by Daniel Santbech in his *De Artificio Eiaculandi Sphæras tormentarias* of 1561. See A. Kleinert, "Zur Ballistik des Daniel Santbech," *Janus* 63 (1976): 47-59.

. or 4 . degrees lesse then 45" (366). Finally, Digges attacks the notion that range increases linearly with increasing elevation using the analogy of the changing length of days between the summer and winter solstices. This astronomical argument, which he used in the question of maximum range as well, once again suggests the audience to which he was reaching. University educated gentlemen would have had the training to grasp Digges' discussion of the "Æquinoctiall line"; practitioners who would become gunners probably would not. And indeed, his conclusion that

> the Theorike of these circuits of Bullets mixt of violent and naturall motions being farre more intricate and diffuse, and such as require many mo [*sic*] and more strange varietie of cocnentrike Epicicles and Excentrike Circles or rather Arkes Helicall, then either that of the Sunne, or any other Planet (367-8)

belies his indebtedness to relatively complex mathematical astronomy.[93]

Digges' final foray into gunnery appeared in the next year, in his second edition of *Pantometria*, although it, too, leaves much to be desired as a handbook of artillery. And if in *Stratioticos* his organization appeared Aristotelian, in the second edition of *Pantometria*, Euclid served as his model. Instead of his repeatedly promised separate work on the artillery, he provides 40 definitions and 51 theorems "as Pathes to leade my ingenious Countrimen to the understanding also of this new Science" (Aa[1]).[94] The section headings he claims are abstracted from his "booke of Pyrotechnie Militarie, and great Artillerie" – the first 20 definitions from the third book [Aa1^{v}] and second 20 from the fifth

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[93] Incidentally, this also suggests that he was not entirely Copernican, for if he were, the sun would not need epicycles. Considered one of the first Copernicans in England, he had promised a commentary on the Copernican theory, but like his treatise of artillery, it was never finished in his lifetime (DSB). At the request of Lord Burghley, Digges wrote a book in 1573 (2nd ed. 1581) on mathematical astrology and one on the 1572 nova entitled *Alæ seu Scalæ Mathematicæ*, "Wings or Mathematical Ladders" (STC 6871). In 1592 he published a small book on the description of the celestial orbs "according to the most ancient doctrine of the Pythagoreans" (STC 435.47), suggesting he may have been influenced by Giordano Bruno during his stay in England in the 1580s. This, then would put him in contact with the Northumberland circle and Thomas Harriot; see ch. 2, above.

[94] The pagination of *P2* is also inconsistent, so signature notation has been used.

book [Aa2^{v}], in that order – but their incompleteness and degeneration near the end of the theorems suggests that despite his best intentions, he found it impossible to produce that work.

Nevertheless, while the content of *P2* is lacking, the format is highly instructive. In devoting almost half of his space to definitions, Digges sets his sights high in terms of what he is clearly trying to accomplish. The first set of definitions range from mundane descriptions of the head, tail, neck, and bore of the cannon to the axis of the cannon (the "axis of the body") and the axis of the bore (the "axis of the soul") as well as measures between them if the piece had been improperly bored (both a distance measure if the axes were parallel and the two angles, "altitude" and "latitude", defining the relation between non-parallel axes). The second set of definitions relate to his attempt to codify trajectories. Clearly Digges is setting out all conceivable terms he might need in further analyses of cannon. The intent of Digges' work is clear: to put gunnery, both the before and after firing, on not only arithmetical footings, but geometrical footings as well. The distinction is critical, for while others both before and after Digges were content to make gunnery mathematical by introducing rigorous numeration into the art, he began an altogether more difficult task, mathematization by geometrization. Put another way, Digges was the first Englishman to try to discuss *ballistics*, as compared with *gunnery*. The attempt can be traced back to Tartaglia, clearly, but Lucar had largely attempted to minimize the geometrical content of Tartaglia – translating parts of his *Quesiti* rather than the *Nuova Scientia*, to begin with – leaving Digges the task of defining the parameters under which ballistics could be studied in the English vernacular. That he did not get very far need not concern us here, for that topic is the concern of A.R. Hall's *Ballistics in the Seventeenth Century*, but that he tried to do so at all signifies a second strand of gunnery in Tudor England. This strand was

that taken up by Thomas Harriot a few years after Digges' books appeared, although outside the arena of print.

On Digges' contribution one further postscript needs to be added. Robert Norton's books of the 1620s provide a convenient closing curtain on the Tudor art of artillery, and one of them, *Of the Art of Great Artillery*, does so especially well with regard to Digges' work. Norton advertised it (in the subtitle) as "The Explanation of the most excellent and necessary Definitions, and Questions, pronounced and propounded, by that rare Souldier and Mathematician, Thomas Digges,… in his Stratioticos, and Pantometria." Norton, a gunner, engineer, author, and translator epitomizes the fusion of the two strains of gunnery books by the reign of Charles I into men equally at home considering theorems of trajectories at one moment and powder compositions and ladle sizes the next. Norton was later to become Master Gunner of England, which cannot alone testify to his practical experience, but while Digges served as a mustermaster in the Low countries and would have been in contact with guns and gunners, it would have been Norton's job to purchase, test, and use guns and gunpowder. In his *Art* he brings Digges' work down to the level of common gunners, providing equivalent terminology for his "dificill Definitions" from *P2* and elaborating on the "darkly resolved" yes/no answers for some of the "obscure Theorems" and "subtil Quetions" from *S1* and *S2*.[95] Although he does expand on the definitions in *P2*, he merely reprints the 51 theorems, making no further comment upon them. The largest part of the *Art*, however, attacks the questions from *S1* and gives reasons for a large proportion of Digges' yes or no answers in *S2*.[96] Norton does not (or could not) answer all Digges' propositions, notably

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[95] R. Norton, *Of the Art of Great Artillery* (London, 1624), sig. A2^{r-v}.

[96] *E.g.*, Digges answered "no" to the question of whether two consecutive shots from the same cannon with the same charge will have the same ranges (*S2*, Mm.i^{v}). Norton explains that the second shot will fly further because 1) the air has become "broken" along the shot's path and 2)

omitting those on the geometrical shape of a bullet's trajectory. He does add a number of other questions he attributes to Digges that Digges never asked, but nonetheless, *Of the Art of Great Artillery* characterizes the early seventeenth-century approach to gunnery which would eventually bear fruit not only in more practical, complete manuals for users, but also in more rigorous investigations of "scientists" like Benjamin Robbins.[97]

Thomas Smith

The final Elizabethan author on gunnery needs only brief mention here, as his output, while substantial, is very easy to define. Thomas Smith wrote two books, the first in 1600 entitled *The Arte of Gunnerie* (C**73**) and one the next year called *Certaine Additions to the Booke of Gunnery* (C**74**). While Cockle lists these books, he make no comment about them whatsoever, except to note that Smith's *Arte* went through three editions (1600, 1627, and 1643). That it did, unlike other books, suggests that its particular approach to gunnery appealed to the reading public. And that approach, in contra-distinction to all that had come before, was arithmetical. Smith styles himself "but one of the meanest soldiers" in the garrison of Berwick upon Tweed (Aij^{v}), and nothing more is known of him beyond his output of these books, although the DNB suggests that he had never seen any active service based on the character of his work.

While all previous authors on artillery, with the possible exception of Whitehorne, consciously positioned their works within the mathematical realm, they did so very much less explicitly with respect to arithmetic than did Smith. The opening of his book announces as much in that it covers length, area, and

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the cylinder will be drier and warmer which causes the powder to "fire quicker, and better together, which will adde more force thereunto" (27).

[97] See B.D. Steele, "Muskets and Pendulums: Benjamin Robins, Leonhard Euler, and the Ballistics Revolution," *Technology & Culture* 35 (1994): 348-82.

weight measures, one-, two-, and three-dimensional measures, which then leads to a discussion of extracting cube roots (pp. 1-7). These skills are then put to immediate use in "story problems" – familiar to every modern grade school student – on finding the weight of a bullet given its diameter, or its circumference or volume, or similar quantities.[98] And the emphasis is on *quantities* rather than qualities or tendencies. Digges may have wanted to reduce gunnery to a mathematical science, but his answers, such as they were, only were in terms of "more" or "less", "farther" or "shorter." Smith, on the other hand, instructs the gunnery how to arrive at exact numerical answers to his questions.

The scope of Smith's *Arte* is less ambitious than that of Digges. It treats simple plane and solid geometry, along with weight ratios and proportionalities for size, range, and powder charges. It does not go on to more difficult questions like the geometrical shape of a bullet's trajectory. In fact Smith's entire book is a compilation of story problems designed to provide all the conceivable manners in which a gunner *could* use arithmetic to arrive at an answer. As such, it suggests that there was a desire among the soldiers to be able to calculate, or more importantly, to be able to *claim* they could calculate solutions to problems involving their art. Indeed, a manuscript copy made of Smith's *Arte* eight years after its publication confirms that this is how at least one copyist took the book.[99] Among copies of Smith's fairly sparse illustrations, the copyist has added a few of his own. A few are of cannon but the majority are careful explications of the book's calculations, each of which has its answer enclosed in a scroll illustration, signifying the numerical resolution of each problem (see figure 3.4).

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[98] See W. Van Egmond, "Types and Traditions of Mathematical Problems: a Challenge for Historians of Mathematics," in M. Folkerts (ed.), *Mathematische Probleme in Mittelalter* (Wiesbaden, 1996), pp. 379-428, for an attempt to classify these "boring" types of question problems (with a suggested taxonomy).

[99] B.L., MS Cotton Julius F.iv.

In many cases, his solutions are facile, presumably in order to serve his numerical needs. For example, in a discussion of predicting the range of a cannon mounted at any degree of elevation, Smith claims that the piece will shoot $^{1}/_{45}$ of the distance between the point-blank range and the maximum range for every degree mounted, that is a linear function of elevation.[100] Such an assertion may be mathematically convenient, but is hardly correct, and, as Digges would say, "an errour known even to the first practitioners."[101] In a few places such simplistic approximations served Smith well, however, so the assumption of linear functions should not be surprising.[102] His book is not all mathematics, though. Sprinkled in among the story problems are asides which give practical advice on the current powder charges for selected classes of artillery (67), battering walls (69), and the duties of various officers of the ordnance (74-6 and 94-7, which admits that "they ought to have some sight in the Mathematicalles, the better to teach and instruct such as would shoote at all randons"[74]). In other places, he adds parenthetical comments that allow us a glimpse of the practice of the day, as when he mentions that most gunners quadrants of the day used a 12-point gradation, rather than a 360° gradation (45).

In the very last section of the *Arte* (pp. 97-103), Smith diverges from his purely mathematical methodology in order to address many of the concerns that Digges raised, although with no acknowledgment of their source. These

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[100] That is, $R_n = n \cdot \frac{R_{45} - R_0}{45}$, where R_n is the range at n degrees elevation, taking 45° as the maximum range. See p. 44*f*.

[101] Leonard Digges, *Stratioticos* (1579 ed.), sig. &.iij.; (1590 ed.), sig Nn i^{V}.

[102] For example, on pp. 55-58, Smith provides the rule to find the height of elevation (h), given the length of the piece (l) and the angle of elevation (α): $h = \frac{2l \cdot \pi \cdot \alpha}{360}$ which provides a height within 0.55% of the correct answer from 0° to 10°. His method is incorrect in that the physical cannon would be pivoted at the trunions, not at the breach as his geometric method assumes (that is, using a right triangle of hypotenuse l and height h, inclined at α – *i.e.*, $\sin \alpha = h/l$). His answers are uniformly high by a factor of the relative position of the trunions along the barrel (a factor of 2 if the trunions were at the midpoint).

comments are statements of "fact" with little or no explanation, which departs from the format of the book as an arithmetical primer for gunners. They also appear in a format which would not lend itself to instruction, *per se*. In his *Certaine Additions* from the next year, Smith continued that which he began at the end of the *Arte*, for it is basically a collection of recipes (broadly construed). The first section covers "certaine principall pointes belonging to the arte of gunnerie", but does so without any organizational apparatus or textual clue for the reader to easily find the "principall" he sought.[103] The second section, on "devices of certain serviceable fire-works" follows the same format, although here Smith added numerous engravings of the devices, making identification easier. The final section on range-finding and triangulation finally included some "titles" for the various subsections, although a large proportions of the titles are "Another Way." In effect, the entire book reads as a list of points upon which Smith mused and collected.

In fact, the information in the first two sections are more suggestions or maxims than rules. Many are straightforward recapitulations of topics mentioned by Bourne, and would indeed have served to train a gunner, but only a gunner who already knew the material. Smith gives suggestions of how to hit the mark, not degree by degree, but rather in terms of general sighting rules. He provides narratives on how to load, sight, and service cannons, and mentions various performance characteristics.[104] He provides recipes for fireworks as well, but again, without any organization, textual or logical; he merely presents one after another in individual, untitled paragraphs. The illustrations greatly

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[103] In this sense, it is much like William Bourne's *Inventions and Devices* of *c*1578 and *c*1590.

[104] Including, to my knowledge, the earliest description of a sonic boom: "The violent motion of a bullet… passeth with such a strong motion… that flying over houses three or foure hundred yardes above the same, doth often shake them insuch sort, that the glasse on the windowes wil breake in peeces, and the platters on the benches or such like things standing loose will fall downe" (*Certain Additions*, p. 8).

augment (or even enable) his textual descriptions in this section, but often serve more to entertain than to instruct. We are left with an impression of a soldier who had served as a gunner or at least among gunners,[105] who set pen to paper to encapsulate the "points" of the art, but not necessarily the "art" itself in any systematic treatise written specifically for instruction of novice gunners.

On the "Art" of Textual Gunnery (or the "textual art" of gunnery)

On the other hand, we might well reconsider what that "art" of gunnery consisted of. Whitehorne added some interesting "nuggets" as a postscript to his translation of Machiavelli's *Art of War*, but these additions covered topics not omitted by Machiavelli. Bourne provided a relatively concise book, divided into short chapters covering the information surrounding great ordnance. But he also provided a book on the "Inventions and Devices" one could use for, among other things, the management and "perfection" of great ordnance, this one divided simply into "chapters" of the nth invention." Lucar, beyond his straight translation of Tartaglia, provided rule after rule for a rather disparate collection of gunnery topics. Digges did little better than to rattle off various (inter)relationships that came to his mind once he had divided the topic into a fairly clean Aristotelian taxonomy. And even after more than a decade, he either chose to do or could do little to extend those ideas into any form of coherent narrative of the "art." And Smith, while an excellent arithmetician, could do little more than juggle numbers for very basic proportions.[106] This is not to

[105] It is interesting that Smith only styles himself a soldier at Berwick. If, as I have suggested, gunnery constituted an independent, autonomous discipline by this time, then if he did not claim himself a gunner, can we assume that he was not? And if so, then is the subject-matter dealt with in his works indicative of that which gunners would know or care about? In fact, as I will suggest below, the subject-matter of gunners was distinct and not entirely congruent with the topics covered in the printed manuals.

[106] I use the term "juggle" purposely; see K. Hill, "'Juglers or Schollers?': Negotiating the Role of a Mathematical Practitioner," *British Journal for the History of Science* 31 (1998): 253-74.

suggest that gunnery was backward or primitive in a derogatory sense, but rather to point out that this "primitiveness" was the "state of the art" in the last quarter of the sixteenth century. And only Digges seemed to notice or care that this was a concern. Smith, at the end of our period, published two works (which, not incidentally, went through multiple later editions) which suggest that his audience was content to see gunnery as a set of points rather than a coherent narrative.

It is my contention, then, that we cannot consider a pointwise exposition of an art necessarily primitive. In a technological milieu where theoretical frameworks are absent, impossible, or irrelevant, we should not impose a modern viewpoint which suggests that without that framework, the art was useless. Time after time, gunners proved that their art was far from useless. They destroyed walls, disabled ships, slaughtered enemies, and entertained spectators (with fireworks, not slaughter, of course). Complaints against gunners tend to be that they are too few, not that they are too useless (see William Thomas' comments to Lord Burghley in ch. 7). And if gunnery was inaccurate, then, as Norton put it "unless some of these over-ruling causes or accidents cause the contrary,… then the fault is not in the Gunner, but in the Gunne, which hee must with judgement and good disccretion rectifie."[107] Gunnery was a science in the modern sense of the word to those sixteenth- and seventeenth-century practitioners. That is, it was predictable and controllable. And that control was attainable through pointwise exposition of the "art", not the full logico-theoretical development we have come to expect in a post-Newtonian worldview. And these books provided an outlet for those inclined to understand the art as it was then practiced.

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[107] R. Norton, *The Gunner Shewing the Whole Practise of Artillery* (London, 1628), p. 109.

Those people who did take up the book – and only the book – to learn what soldering was all about naturally received scorn from the veterans. For example, Iago complained about Cassio, the "great arithmetician":

> [He] never set a squadron in the field,
> Nor the division of battle knows
> More than the Spinster; unless the bookish theoric
> Wherein the toged consuls can propose
> As masterly as he. Mere prattle, without practice,
> Is all his soldiership.[108]

And such complaints filled prologue after prologue of the gunnery works as well. Thomas Smith would complain that many believed, "more wayward than wise, that the Art of Soldiery may be perfectly attained in two or three moneths practise," despite the fact that a mariner "may saile seven yeares, and yet be far from a Navigator," or "Mechanical Artificers may labour diverse yeares, and yet be far from perfection."[109] And although Smith himself fed that need for soldiers to learn the art without serving in the field, his successor, Robert Norton, allayed that irony in providing the details "in this Art" of gunnery where "many silly Gunners that never sounded the deepe Channell of this Art, will not sticke to say, they know enough, and scorne to learn more, when they God knowes understande not the first principles of good Art or practice."[110] Caught in an uncomfortable position between a desire to publish their skills and yet feeding the populace who were not soldiers but clearly desired soldierly knowledge, these mathematical practitioners who wrote on gunnery produced books at once complex and yet too simple. Their output served to define a field, and in fact two branches of a field. But they defined quite differently from the way in which it

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[108] William Shakespeare, *Othello*, I.i.19, quoted in P.A. Jorgensen, *Shakespeare's Military World*, p. 112. Of course Iago (and Shakespeare) was not a real veteran, but this sort of complaint is a common one levelled against "armchair soldiers"; see F.W. Beckett, "The Amateur Military Tradition in Britain," *War & Society* 4 (1986): 1-16.

[109] T. Smith, *The Arte of Gunnerie* (London, 1600), sig. A ij.

[110] R. Norton, *Of the Art of Great Artillery*, sig. A 3^{v}.

would be defined later, that is, mathematically with regard to projectiles trajectories.

The Diggeses codified one branch of gunnery as mathematical. If Whitehorne, Bourne, and Lucar are the intellectual ancestors of Norton and later practical gunnery manuals, then the Diggeses (and Smith at a very basic level) are the intellectual ancestors of the analytical gunnery of Benjamin Robins and Isaac Newton. While I do not claim that the Diggeses made any specific contribution to the study of exterior ballistics *per se*, they did define that such a field could exist. Such analysis had to wait for not only more elaborate mathematical tools, but also for a more general percolation of the intellectual thought processes manifested in Digges' books to experimenters and practitioners. Instead of considering an experimental science as simply numerically tabulable, they had to consider it as axiomatically analytical, using those numerical data as evidence for their theory. Printing itself had the effect of standardizing and codifying, not only language, but meaning and ideas.[111] Thomas Digges said as much when, in the prologue to his discussion of artillery, he wrote that in treating "so newe and rare a Science as this of great Artillerie" he must necessarily "bee also enforced to use sundrie strange termes, not understande perhaps to the verye Artificers themselves that most Manedge that kinde of Engine."[112] The cannoneers, he notes, "have wordes good inough to expresse their owne meanings," but once that meaning began to be disseminated to the rest of society (regardless of audience), those "wordes" needed to be regularized and agreed-upon. And with Smith's fusion of Digges' theory and the gunners' parlance, such an endeavor could take place. But that is

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[111] M. McLuhan, *The Gutenberg Galaxy: the Making of Typographic Man* (Toronto, 1962) , pp. 228-38.

[112] T. Digges, *A Geometrical-Practical Treatise Named Pantometria* (London, 1591), sig. Aa.

a story of the seventeenth, not the sixteenth, century. Our story, however, now continues with the “wordes” of the gunners themselves.

Figure 3.1

English Military Books, 1480-1660
(compiled from M.J.D. Cockle [1957])

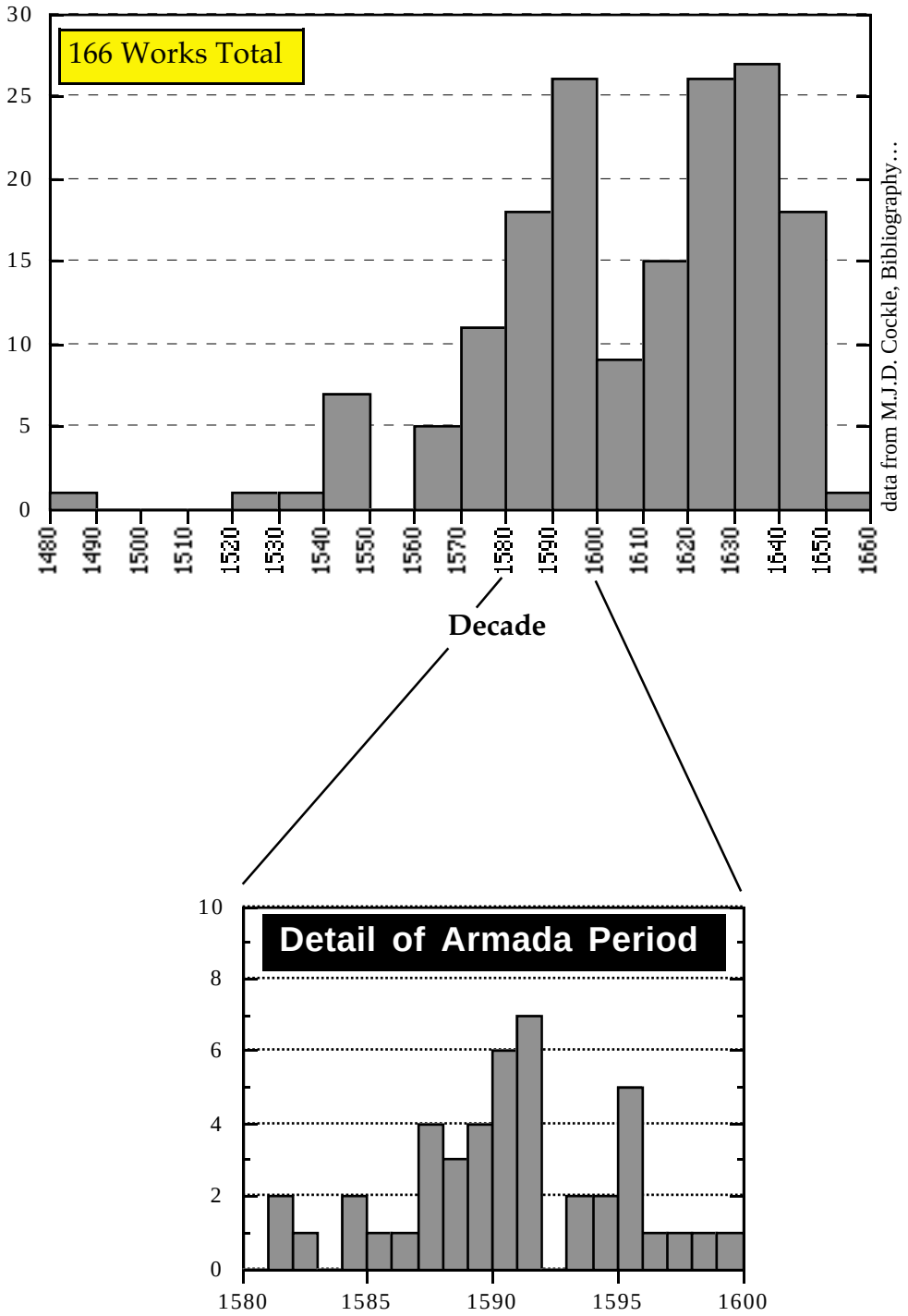


Figure 3.2

Comparison of English and Continental
Military Book Output, 1470-1640+
(compiled from M.J.D. Cockle [1957])

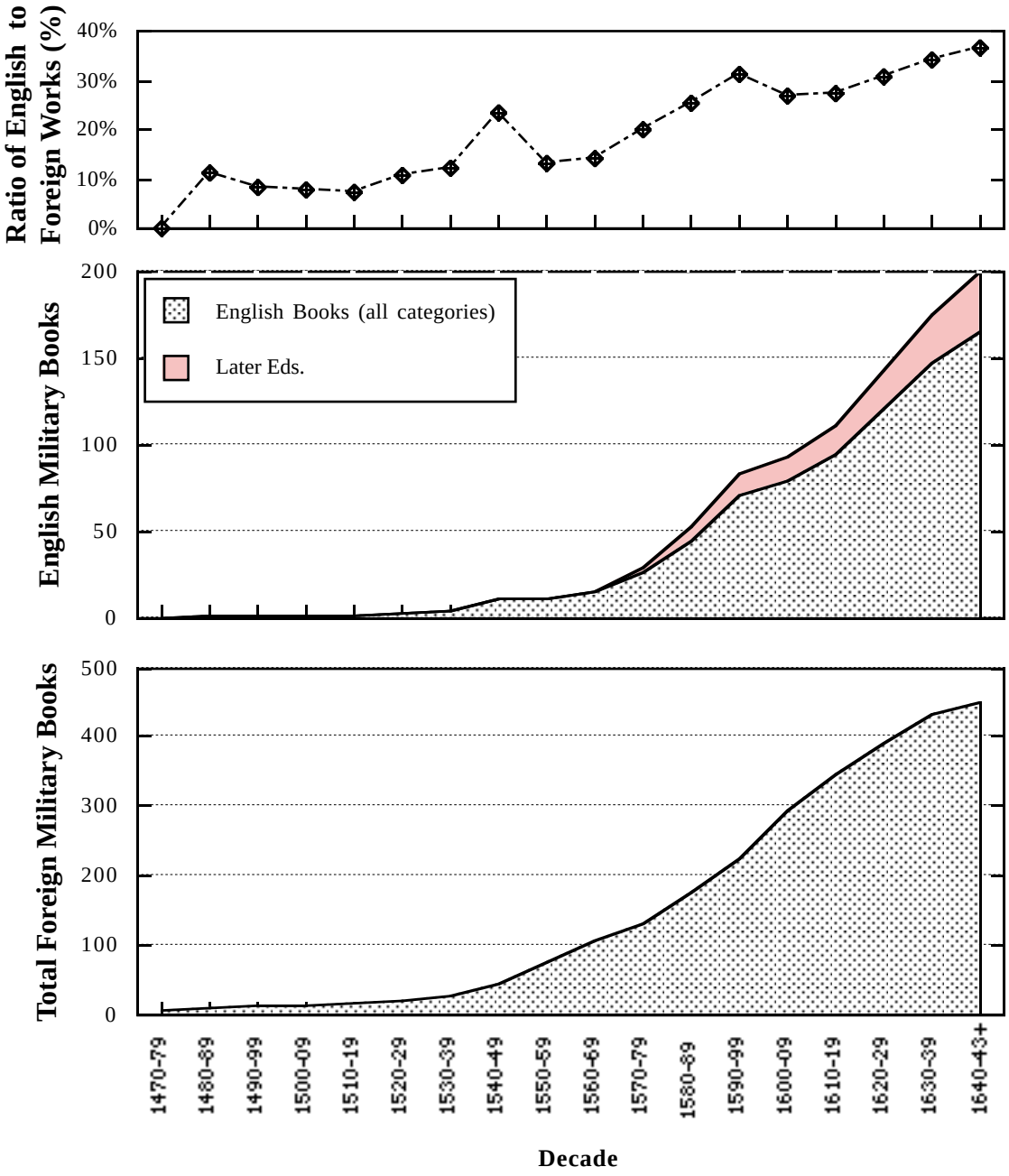


Figure 3.3

Peter Whitehorne's Gunpowder Composition Recipes
(from Peter Whitehorne, *Certain Waies of Ordering Soldiers in Battleray*[1560], sig. [H.iij] - [H,iv]^{v})

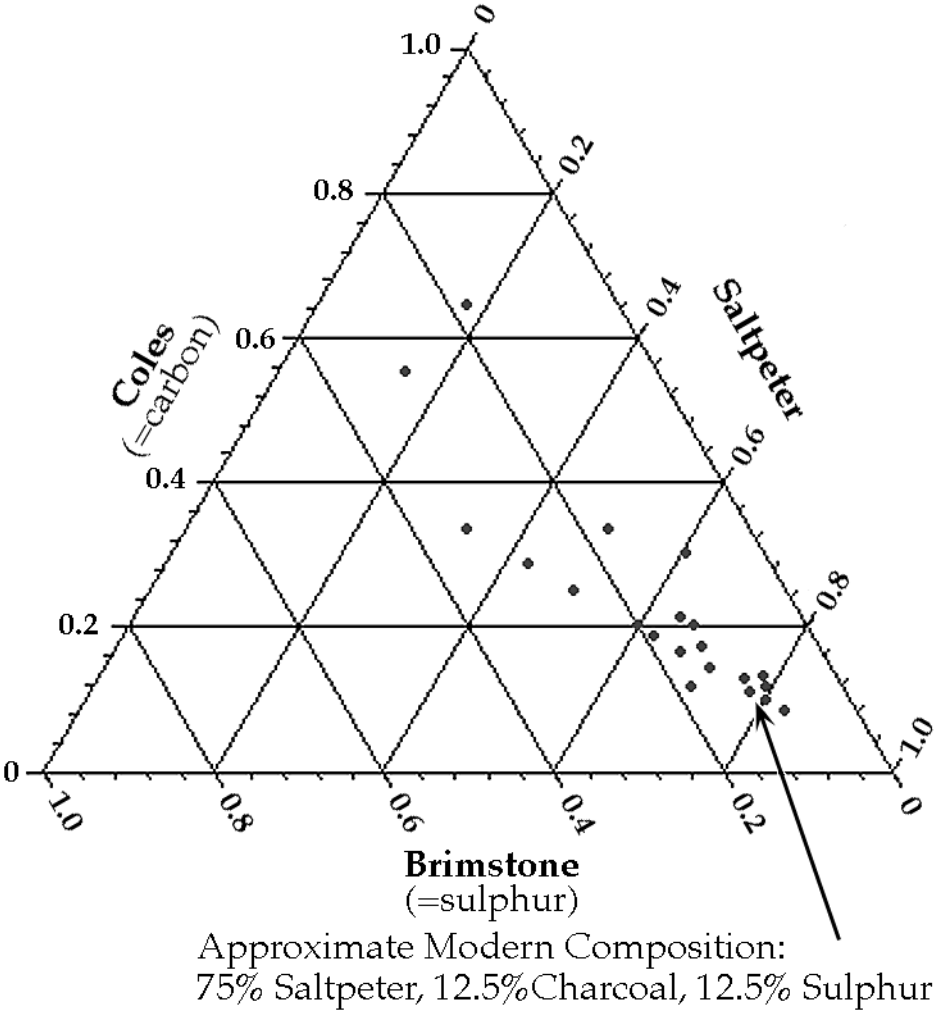


Figure 3.4

Comparison of Print vs. Manuscript Presentation

a) Thomas Smith, *The Art of Gunnerie*, 1600, p. 18

b) British Library, MS Cotton Julius F.iv, fol. 7v

a)

How you may find out the solid content or crassitude of any round bullet or globe, &c. diuerse wayes.

Question.

In the question before propounded of the bullet, whose diameter was 21 inches, I would know how many inches is in all the solid or massiue content thereof?

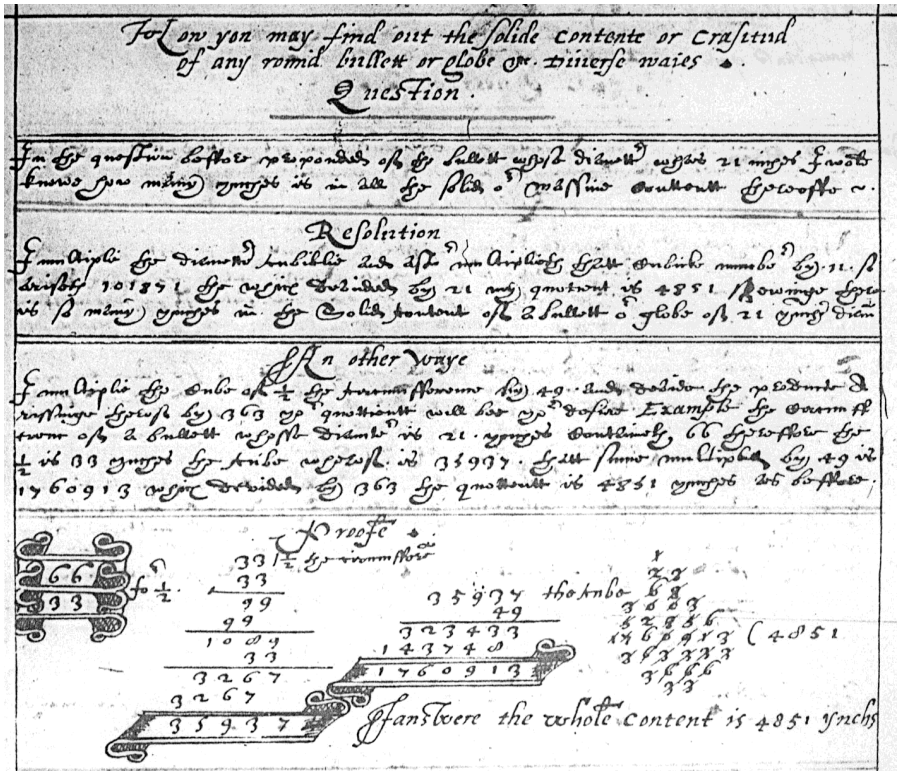
Resolution.

I multiply the diameter cubickly, and after multiplieth that cubicke number by 11, so ariseth 101871, the which deuided by 21, my quotient is 4851, shewing there is so many inches iu the solid content of a bullet or globe of 21 inches diameter.

Another vway.

Multiply the cube of $\frac{1}{2}$ the circumference by 49, and deuide the product arising thereof, by 363, your quotient will shew your desire. *Example*: The circumference of a bullet whose diameter is 21 inches, containeth 66 inches, the $\frac{1}{2}$ thereof is 33 inches, the cube whereof is 35937, that summe multiplied by 49 is 1760913, which deuided by 363, the quotient is 4851 inches as before.

b)



Chapter 4

Manuscripts of Gunnery Practice

Primary documents can be so maddening, can't they? So seldom do they tell you the big things, the things you're after. The great questions of the age are usually commonplaces, which no one bothers to remark

— Ronald Wright*

Introduction

Printed books from the period of the 1570s up to the Civil War record, in varying detail, the state of martial science in England. Or so common knowledge would suggest. But to ignore manuscript sources in the early seventeenth century, and especially in the sixteenth, is to commit a grave error. This was a time of transition. Books were becoming more and more common but they were not yet articles of mass-consumption as they are today, nor even as they were in the eighteenth century. Nor, I think, did books immediately create the "separate audience" McLuhan sees with the advent of typography.[1] Manuscripts circulated freely and largely without the "archaic" connotation that Eisenstein seems to imply printing gave them in the Early modern period.[2] Not only did printed books have relatively modest print runs, but many foreign works, though potentially available through London booksellers, were frequently beyond the linguistic grasp of Englishmen and therefore spawned translations in manuscript form. The cost of books also presented a barrier; where scribal

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* Ronald Wright, *A Scientific Romance* (Toronto, 1997), p. 243.

[1] M. McLuhan, *The Gutenberg Galaxy: the Making of Typographic Man* (Toronto, 1962) , pp. 130-3. It should also be noted that his idea that "applied knowledge in the Renaissance had to take the form of translation of the auditory into visual terms, of the plastic into retinal form" (p. 159-61) is also misleading; his dichotomy is between written and oral culture, not the written and printed cultures he claims to be describing.

[2] See, generally, E.L. Eisenstein, *The Printing Revolution in Early Modern Europe* (Cambridge, 1983) or her *The Printing Press as an Agent of Change: Communications and Cultural Transformations in Early-Modern Europe* (Cambridge, 1979), II: 520-74, "Technical Literature goes to Press."

labour was plentiful, manuscript copies were still economical.[3] Indeed as we have seen in chapter 2, much of the printed military knowledge in English was a blatant or not-so-blatant theft of contemporary Continental authors: Machiavelli, Tartaglia, and later Ufano among the most popular.

However, the opaque veil which these printed works place over to the *actual* English military practice lifts when vernacular manuscripts are considered. The English were not prodigious producers of these manuscripts, but a number of remarkable manuscripts do survive. In a sense, even this is surprising, for I believe we might be surprised if instruction manuals of our day outlive us by four hundred years, and they have the benefit of being produced in the hundreds of thousands if not tens of millions. Perhaps a half dozen substantially complete Elizabethan gunnery manuals of varying size survive, and fragments of at least another half dozen lie scattered throughout the manuscript repositories of Britain.[4] Adrian Caruana has published a manuscript of 1586-7 by John and Christopher Lad (hereafter the "Lad MS"),[5] although in a more popular than critical edition. I have reproduced two others as Appendices II and III, below: Richard Wright's "Notes on Gunnery" from 1563 and "The Secret of Gunmen" an early seventeenth-century copy of a mid- to late-sixteenth-century work (hereafter the "Wright" and "Gunmen" MSS, respectively).[6] These three

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[3] Indeed, that scribal labour was often one's own self. High-status individuals (like peers) would have a book copied for them, but lower-status people (like students) would copy it, or parts of it, themselves. In addition, the manuscript was still the vehicle for initial presentation copies, which might or might not later get printed.

[4] In my research I have combed the Folger Shakespeare Library (Washington, DC), British Library, Bodleian Library, Society of Antiquaries, Lambeth Palace Library, and College of Arms. Further work should be undertaken at Cambridge, Edinburgh, Trinity College (Dublin), and perhaps the Guildhall Library and other large private libraries in the United Kingdom.

[5] A.B. Caruana, *Tudor Artillery: 1485-1603* (Bloomfield, Ont., 1992) reproduces Bod. Lib., MS Rawlinson A 192, although he took a number of liberties on silently reordering sections and did not transcribe every section of the MS. Notably absent are some of the recipes which figure so prominently in this genre of text.

[6] The text of the manuscripts are reproduced in full in the appendices and appear by the kindness of the Society of Antiquaries, London, (MS 94 for Wright's MS) and the Bodleian Library, Oxford (MS Ashmole 343 for the Gunmen MS).

represent the most complete extant manuals, in terms of form, style, and content, and all date from Elizabeth's reign. In the analysis below, these works will serve as the basis of comparison for other fragmentary manuscripts. From them, a fairly reliable measure of the interests and duties of Elizabethan artillery servicemen appears from beneath the veil of the Jacobean and largely sanitized printed material.

Material the gunners themselves knew to be important – as compared to what contemporary authors interested in selling their books felt was important about operating cannon – resides in the contents of these notebook manuals. Manuscripts are not *prima facie* closer to the actual practice of gunnery than printed books on the subject. But even though both of these manuscripts are polished copies, not quite of "presentation" quality, but well above jottings or memoranda, their lack of explicitly enunciated connections between ideas or procedures or of preambles indicates a closeness to practicing gunners. By comparison, printed manuals do not share this feeling: they instead claim a pedagogical mandate. In the manuscript manuals, the learning process (as compared to the education process) remains paramount.

Printed manuals like those of Bourne and Norton contain textual apparatus (headings, chapters, and logical progressions) to lead a novice reader through the concepts of guns and gunnery. These manuscripts, on the other hand, take that knowledge for granted. If the motivation for the authors of these manuscripts may be guessed, it would likely be a desire to channel their knowledge into a handsome volume, but not one designed for publication. The illustrations in these manuscripts are little more than mnemonic, and in most cases would not even be useful as exact representations of the rule or proportion supposedly recorded in them. Other manuscripts do exist that have explicit illustrations which, although not necessarily drawn to scale, would allow a novice

to reproduce the matter at hand, such as the gradations of a quadrant or the form of a powder ladle. The concept of replicability from the written or printed description also enters into the determination of these manuscripts' closeness to practice in that they make the assumption that the reader already knows what he is doing. They therefore often omit the details that would allow a complete novice to perform those tasks they describe.[7]

I have chosen to reproduce these two manuscripts for their completeness, but also for their uniqueness. The Wright manuscript (App. II) is interesting in that not only is it an index of early Elizabethan practice, but also because it was clearly a labour of love for its author. The opening words are "I will give thanks to the Lord with my whole heart; I will speak of all the marvelous works; I will be glad and rejoice…; yea, my song will I make of Thy name" (fol. 2).[8] Invocations such as this are simply not found in printed technical treatises, but here lends this work a devotional character. Wright clearly took great pains in illustrating it with beautiful full-page illustrations of heraldic devices and, presumably, of himself as the proud gunner (fig. 4.1), as well as numerous small illustrations of cannon, ladles, and fireworks. However, it lacks the apparatus one would expect if the work were destined for someone else's eyes and contains numerous marginalia and scribbles along the lines of pen-tests or what we might today consider as "in-class doodles." Given the lavish illustrations, both full-page and interlinear, it is clearly not a book of notes taken in a class on gunnery, but it might be considered a second generation copy, produced in

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[7] This sort of tension in technical literature has been remarked upon frequently. Most recently, see J.R. Pannabecker, "Representing Mechanical Arts in Diderot's *Encyclopédie*," *Technology and Culture* 39 (1998): 33-73.

[8] The first folio is taken up by pen jottings, and notes to himself (or a later owner to himself) and the treatise begins on fol. 2 (Appendix II). That this is indeed part of the gunnery treatise is indicated by the large calligraphic "I" that begins the quotation and contains Richard Wright's name; it is in the same style and hand as the illuminated 'H' on fol. 3^{v}.

Wright's spare time after class, but likely while he was still engaged in learning the material.

The order of topics as well as the orthography in the manuscript provide the evidence for this interpretation. Each fact, point, or idea is set off in its own paragraph and the first line or phrase of each is done in a bold blackletter script, while the remaining portion is in a standard secretary hand. He follows this pattern quite consistently, with only an occasional slip into secretary hand for the last word or two in the first line. But he also will occasionally break off in mid-sentence, skip a line, and continue the sentence in blackletter, as if it were the start of a new idea. This strange organization suggests that Wright may not have been overly familiar with printed works and the conventions of normal paragraph usage. Instead, he seems to have tried to present equal "paragraphs", regardless of the length of one particular idea. It would be in keeping with the presumed social position of gunners to consider him a literate person (perhaps we might use the term "paraliterate") who was for the first time entering a world of scholarship, a world emphasizing book-learning alien to him.[9] As a personal display of his learning in this new, arguably higher social sphere, Wright appears to have produced a treatise imitating those he might have seen around him, although with mixed success. His convoluted spelling – even for an age without standardized spelling – and the calligraphic quality of the writing tends to reinforce this impression of someone not perfectly familiar or comfortable with written language, but trying to become so.

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[9] Gunners' social status is a thorny issue. Few ever appear as more than names in Ordnance Office records. We know that some, like John Phillippes, could not sign their names: he acknowledged the surrender of his gunner's fee by making his mark (CPR, Eliz. I, vol. 1 [1558-60], no. 1559). Further gleanings of Crown gunners' status will appear in ch. 6 and 7, but that questions should be the subject of a separate monograph. On technical vs. standard literacy, see B.S. Hall, "'Der meister sol auch kennen schreiben und lesen': Writings about Technology, ca.1400-ca.1600, and their Cultural Implications," in D. Schmand-Besserat (ed.), *Early Technologies: Invited Lectures on the Middle East at the University of Texas, Austin* (Los Angeles, 1979), pp. 47-58.

Finally, had Wright had more time to consider the material and digest it, it would be more likely that he would have organized it better. Instead, the order is seems somewhat haphazard, but in an order that would not be incongruous with the order of instruction if we were to imagine a course on gunnery. He opens with the 10 precepts of gunnery, a sort of table of contents for the work. After this, however, he runs through a rather loose assemblage of topics: questions of range versus other variables, powder proofs, a summary of the classes of cannon, back to ranges for various pieces, accuracy and its detractors, disparting, saltpeter testing, ladles, a large section on all manner of fireworks, one on powder types and testing, tables of shot weight and diameters, and finally a section on charges in terms of shot weight and caliber.[10] Although his "sections" do largely correspond to the table of contents, they do not appear in the same order, and within each section Wright is inconsistent with the information he provides. Under some pieces he mentions how to make a ladle for that piece even though he has a section on ladles later, and under others he mentions shot weight or charge or powder testing. We are left, then, with the impression of a young gunner-in-training who is attending some sort of class, taking notes, and returning home in the evening to recopy those notes into "his bokeh" in a clear script, formatting them in imitation of a published book, and adding illustrations to dress it up a bit.

The Gunmen MS (App. III), by comparison, lacks illustration, and is written in a fine but informal italic hand with occasional secretary letter-forms. The information is again not digested as in a book, but rather in point form, with recipes, maxims, and procedures to take heights, disport pieces, and determine charges. Overall, the material covered is quite similar to Wright, but also adds a

[10] For Elizabethan artillery terminology, see Appendix V, below.

few more "academic" topics, as the construction of a quadrant.[11] As preserved, the manuscript is catalogued as "put into writing by some experienced person, about the time of James I,"[12] but is clearly a copy of an earlier manuscript. The copyist had the original notes out of order, as on fol. 134^{v} he breaks from one sentence discussing elevations taken on quadrants to another discussing ladle construction. On fol. 138^{v}, we find the continuity again broken, where he is discussing ladles and shifts suddenly to quadrant measures, and these discontinuities mate perfectly when reordered. We could assume that this copy was a fair copy made from rough notes which also date to the early seventeenth century, but since the book is a seventeenth-century copy book containing material as diverse as fifteenth-century medical astrology, sixteenth-century bible passages, and an extract from a printed book of 1619,[13] there is no explicit reason to adopt this hypothesis. Rather, the internal information in the Gunmen MS suggest a middle or late Elizabethan composition date, as will be demonstrated below.

Finally, it should be reiterated that these manuscripts are not unique survivals of the genre. If anything, the survival of so many other fragmentary bits about cannons and gunnery drives home the impression that gunnery was not a subject limited to a few skilled professionals, but rather that many people took at least a superficial interest in this new technology. A copiously illustrated manual resides in the British Library, but the author clearly privileged pictorial over textual information and the manuscript only really gives the textual equivalent of a shot/charge table and a few recipes.[14] Numerous other

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[11] Quadrant construction and use are more rare in MS gunners' manuals, although some do include them. B.L., MS Add. 4473.8, fol. 17^{v} has a table of ordnance and a detailed scale drawing of one.

[12] W.H. Black, *A Descriptive, Analytical, and Critical Catalogue of the MSS… of Elias Ashmole* (Oxford, 1895), col. 247-8.

[13] J. Selden on Tilleslies' *History of Tithes* (1619), *ibid.*, col. 246.

[14] B.L., MS Sloane 2497, fol. 38-44.

fragments exists in various libraries of tables of cannon bores, charges, shot, and ranges.[15] Some others contain information on quadrant construction. A few others even contain the recipes for fireworks and gunpowder testing. Nor is this literature in any way unique to England. The Germans especially, in the *Feuerwerkbuch* tradition, produced numerous gunners manuals, as did, not surprisingly all European countries.[16] The literature has, however, been sorely neglected, partly due to its cookbook-like nature, and partly due to the difficulty of collecting and collating the information contained in the manuscripts alongside the much easier task of printed books, where the information has already been distilled, arranged, and clearly presented.

Of the authors of these notebooks, very little is known. While the authors of published books often discuss themselves in their prefaces, or at least left clues to their identities scattered throughout their works, these manuscript writers never included the odd anecdote or put that final polish on their prose which allow historians insight into their lives. Printed book authors write for posterity, while most manuscript authors write for the here and now (or the there and then, as it were). Only two authors of these gunnery treatises are even known by name, one of those names being Richard Wright whom we will deal with in the next section, and the other Edmund Parker, whose notebook informs the last section of chapter 6, below. Nothing at all is known of Richard Wright, other than that he wrote his illustrated manual about 1563. We can probably surmise that he was either connected with the navy or at least composing his book in a

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[15] B.L., MS Cotton Otho E.IX, fol. 363^{v}-76^{r} contains "Various necessary memorials on warfare" (*temp* Eliz. I) which contains a hodge-podge of these matters.

[16] One of the most handsome German manuals resides in the Dibner Library at the Smithsonian Institution in Washington, DC, as MS 835B, "Künstbüech der Püchsenmeistery, 1589." Although beyond the immediate scope of this thesis, it is interesting to note that German MS editions are always better, that is, more accurately, illustrated. The Dibner book is no exception. The only other printed gunners' manual I have found, other than Caruana's edition, is of an early 16th-century Greek version of Italian practice; see G. Morgan, "A Greek Gunner's Manual," *Annual of the British School at Athens* 49 (1954): 57-71.

larger port town since on fol. 29 he drew a well-executed picture of a large ship which could have taken 42 guns in all. We can only assume he may have been stationed or lived in London, since many of the gunners who went into service in both civilian merchant ships and royal warships were trained and embarked from there. He was not, however apparently employed by the Crown as far as can be determined from published state records. Although he included a very detailed heraldic blazon on fol. 6, it tells us nothing beyond his devotion to the English crown, being a form of the royal arms of England with a Tudor rose above and to the right. For now, Wright's life remains a mystery, another anonymous member of Elizabethan society.

The Contents of Gunners' Manuals

Gunners' manual subject matter is quite uniform, even if the details vary widely from one source to the next. Gunners noted powder charges for various classes of cannon, the sizes of these cannon and their shot, recipes for mixing various types of gunpowder, and construction methods for different sorts of fireworks, a term which included incendiary weapons as well as aerial and ground-effect crowd-pleasers like those still used at public spectacles. Less surprisingly, they are also very interested in the sizes and construction methods of ladles for loading the cannon, and for good reason. Compared to the printed gunnery books, the manuscript tradition emphasizes the practical over the big picture. Much of the information is the same (charge weights, and ranges), but much that is minimized in books is emphasized in manuscript (ladles and, curiously, fireworks).

The primary goal of printed book and manuscript gunner's notebook alike is the identification of cannon. The broad appeal of such a goal is shown by the addition of these identifications with a table in William Harrison's *Description*

of England (1574), whereas other of Her Majesty's munitions are only passingly described.[17] In the later sixteenth century, cannon types had begun to stabilize, but there were still a wide range of pieces, shooting shot from under 2 inches in diameter, to eight inches or more. It would appear that the first thing students of artillery learned was the name of the eight or nine major types of cannon, their bore diameters, shot diameters, shot weights, and standard powder charges in pounds. Their names and the "standard" bores of these pieces are shown in Table 4.1.[18] These diameters should not be taken as the canon for cannon, as it were, since a certain amount of variation exists over time and from table to table. Although the number of books is limited, manuscripts present a more complete picture of cannon in later Elizabethan England, but one that emphasizes their variability. Figure 4.2 shows the shot diameters recorded in 15 manuscripts and books ranging from about 1540 up to the Civil War.[19,20] Over

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[17] W. Harrison, *The Description of England: the Classic Contemporary Account of Tudor Social Life* (Ithaca, 1968) , II.xvi (p. 236).

[18] There is great difficulty in assigning these values absolutely as Michael Lewis points out (M. Lewis, *Armada Guns: a Comparative Study of English and Spanish Armaments* [London, 1961], ch. I "Classification"), but in presenting a statistical analysis of artillery classes in ch. 6, below, I find that if we ignore his difficulties with the "perrier" classes so ubiquitous on the Armada ships, much of the nomenclature falls into relatively neat order. *Cf.* table 1 in E.B. Teesdale, *Gunfounding in the Weald in the Sixteenth Century* (London, 1991) , p. 21. See also App. V, below.

[19] In some tables, the shot diameter is not given but the bore diameter is. In this case, the shot diameter has been taken as ¼ inch less than the bore diameter, as will be explained below. The sources are: B.L., MS Harley 304, fol. 80; B.L., MS Harley 2048, fol. 257; B.L., MS Add. 4473, #8, fol. 17; B.L., MS Cotton Otho E IX, fol. 36^{v}-70^{r}; B.L., MS Cotton Otho E IX, fol. 366-7; B.L., MS Cotton Otho E IX, fol. 368^{r-v}; B.L., MS Sloane 2497, fol. 38-40^{v}; Folger Library (Washington DC), MS V.b.182; a brass gunners rule (see E.O. Hopkins, "An Old Table of Ordnance," *Minutes of the Proceedings of the Royal Artillery Institution* 28 [1901-2]: 365-6); O.F.G. Hogg, *English Artillery, 1326-1716* (London, 1963) , p. 21; Norton and Eldred (O.F.G. Hogg, *English Artillery*,p. 29); Robert Norton, *The Gunner Shewing the Whole Practise of Artillery* (1626); Thomas Smith, *The Arte of Gunnery* (1600; MS version, 1608); Thomas Smith, "The Complete Souldier" (1628); William Eldred, *The Gunners Glasse* (1646). A number of these sources predate the 1580 cutoff Teasdale, *Gunfounding in the Weald*, cites for the earliest list (p. 124).

[20] The analysis of cannon types has provided a pastime for a number of historians, although each to their own purpose. Rather than list all their work here, see H.L. Blackmore, *The Armouries of the Tower of London. I. Ordnance* (London, 1976) , app. II, pp. 391-406 for numerous lists spanning 1455-1866 although with little analysis; and E.B. Teesdale, *Gunfounding in the Weald*, app. I, pp. 124-5 (esp. n. 5), for a summary of such lists.

Table 4.1: "Standard" Bore of Common Artillery Classes

Gun Name	**Bore Diameter** (ø)
falconet	2 in.
falcon	2½ in.
minion	3 in.
saker	3½ in.
demi-culverin	4½ in.
culverin	5½ in.
demi-cannon	6½ in.
cannon	7 or 8 in.

the course of about a century, there is no discernible overall change in the diameters of each class of ordnance, except perhaps a slight shrinkage of a full cannon from about an 8" bore to a 7" bore. But within each series there is considerable variation, usually on the order of 1", although less for smaller shot. While this may not seem like a great deal of difference, it does affect the performance of cannon in two related ways.

First, there is the simple problem that a cannonball might not fit the cannon, which could render the cannon inoperable, ineffective, or unsafe. If the ball were too large for the bore – either because the cast iron ball was cast too large, or because of "scale", or powder residues, built up inside the cannon – the cannon could not be fired. If the ball were too cast too small, it would fire inaccurately as it bounced around in the barrel. Finally, if the ball were cast out of round or the cannon imperfectly bored, the ball could get stuck in the barrel upon firing, bursting the cannon and likely killing or at least maiming its entire crew.[21] On the other hand, the ball could just as easily get stuck in the bore upon loading in this situation, which, while not harming the crew, would take the cannon out of service. Even if the ball did not get stuck, the scale of build-up

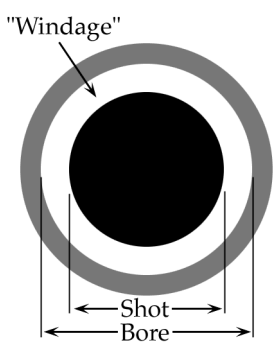
[21] Despite the frequent warnings by gunners about this danger, in actual practice it seems to have been rather rare. But, who can blame the gunners for erring on the side of caution? Gunners were more frequently killed by exploding powder-kegs.

might also put a cannon out of action by clogging the touch-hole, as Sir George Carew discovered in Ireland while besieging Glin Castle, Co. Limerick in 1600:

> the next day, when we looked that the cannon should begin to play, the Cannoniere found the Peece to be cloyed, all the art and skill which either the Smith, or [Carew] himself could or did use, prevailed nothing. The President (who is a man that knowes well to manage great Artillery) commanded that the peece upon her carryage (as she was) should be abased at the tayle, and elevated at the musle, as high as it might bee: then hee willed the Gunner to give her a full charge of powder, roule a shott after it and to give fire at the mouth, whereby the touch-hole was presently cleared, to the great rejoycing of the Armie, which of necessitie in attempting the Castle, (without the favour of the Cannon) must have endured great losse.[22]

Between irregular cannonballs, inexact boring, and scale build-up, a cannon's performance was anything but constant.

The second effect of variation of shot diameter directly affects the performance of the cannon. Cannonball diameters were nominally assumed to be 1/4" smaller than the bore to allow for "windage", that is, just the extra gap which would prevent a misshapen or oversized ball from getting lodged in the barrel. Contemporaries always expressed windage in terms of the differing diameters, but for modern analysis, the differences in area provide a more meaningful measure of the effect of windage on cannon performance:



$$A_{Windage} = A_{Bore} - A_{Shot}$$

$$A_W = \frac{\pi D_{Bore}^2}{4} - \frac{\pi D_{Shot}^2}{4}$$

$$A_W = \frac{\pi}{4}\left[D_B^2 - \left(D_B - C\right)^2\right]$$

$$A_W = \frac{\pi}{4}\left[D_B^2 - \left(D_B^2 - 2D_B C + C^2\right)\right]$$

$$A_W = \frac{\pi}{4}\left[2D_B C - C^2\right]$$

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[22] Thomas Stafford, *Pacata Hibernia, Ireland Appeased and Reduced*, (London, 1633), pp. 63-64 (I.115-6 in 1821 ed.) quoted in S.d. hÓir, "Guns in Medieval and Tudor Ireland," *The Irish Sword* 15 (1982) : 77-8 and incorrectly in W.A. McComish, "The Survival of the Irish Castle in an Age of Cannon," *The Irish Sword* 9 (1969) : 18-19.

That is to say, since the windage is considered a constant (usually ¼´´ – note that in the diagram above, C is the windage, which means there is a ½C (*i.e.*, ⅛´´) gap on either side of the shot) in sixteenth-century gunnery, the area of that windage is simply a linear function of the bore diameter (D_B). This is critical, since the windage is also the pressure release valve from the powder charge. Since the windage area increases linearly but the cannonball's mass (and, correspondingly, the resistive force to the charge, since the charge increased roughly proportional to the shot weight) increases as the cube of its diameter, the pressure lost per unit mass therefore is inversely proportional to the diameter squared ($P_{lost} \propto 1/D^2$). Thus, a larger gun had a smaller pressure release valve, but as the pressure lost is a rough measure of the inefficiency of the cannon, the larger cannon also transmitted the charge's force to the shot more efficiently. This is the fuller explanation of Michael Wood's comment that "the heavier the gun, the less powder it took to fire a pound of shot, an efficiency curve whose upper bounds were set more by the practical immobility of guns much heavier than the [demi-] cannon rather than any technical limitation in gun design or metallurgy."[23] Correspon-dingly, the inevitable variation in shot diameter will more strongly affect a smaller-bore weapon than a larger-bore weapon. Since a larger ball would have been, in theory, more accurate, it would appear that these effects should have biased sixteenth century users towards larger ordnance.[24] In practice, however, smaller ordnance tended to be more common, due to both financial and logistical measures of economy. Larger guns were more expensive to produce and required more powder, heavier shot, more men to operate, and more draft animals to move. (This may also be the cause of the drop in full

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[23] J.B. Wood, *The King's Army: Warfare, Soldiers, and Society during the Wars of Religion in France, 1562-1576* (Cambridge, 1996) , p. 159.

[24] See B.S. Hall, *Weapons and Warfare in Renaissance Europe: Gunpowder, Technology, and Tactics* (Baltimore, 1997) , ch. 5, pp. 134-56.

cannon size in the reign of Charles II – see fig. 4.2). Despite contemporaries' apparent understanding that larger guns were thought to be "better" on various axes, often the mundane difficulties surrounding them outweighed their perceived advantage.

The foregoing analysis should in no way be taken as an indication of clean standardization in sixteenth- and seventeenth-century cannon. In fact, when analyzing numerous tables, the variation in all measures becomes immediately apparent. In the case of shot and bore diameters, some of the confusion may arise from the author entering shot diameter in the bore diameter column, or vice versa. But were cannon truly standardized, we might expect to see an occasional error of this sort, but not the obvious continued confusion. The question, then, arises of how cannoneers transmitted cannon data.

Pedigrees of the various shot tables rarely become apparent, but in a few cases, rather interesting connections may be made between them. One, which appears on a brass gunner's rule from the end of the sixteenth century lists the weight of a culverin at 3021 or 4000 pounds.[25] The same two possibilities for culverin weight also appear in a manuscript table in the British Library.[26] Further, both sources record a demi-culverin at 2544 lbs. It is rare for a table to give more than one weight for a piece (which has furthered the impression that cannon were standardized), but in this unique case where two are given, and agree, proves a common provenance for them. That the demi-culverin weights also agree seals the case, for it is exceedingly rare for the weight of a piece to be given in anything other than multiples of one hundred, and in the rare cases where this rule is not followed, weights are rounded to the nearest 10 lbs. (and

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[25] E.O. Hopkins, "An Old Table of Ordnance." The whereabouts of the rule, which at that time was "at the British Museum for inspection and possible retention," are unknown to me. I have not discovered whether the British Museum retained the piece.

[26] B.L., MS Cotton Otho E.IX, fol. 366-7. The MS was damaged in the 1731 fire of the Cottonian library, with some data loss.

usually 50 lbs.). While finding two sources from the same tradition might not be surprising, further comparison of the two suggests that the idea of a standardized ordnance under Elizabeth cannot be maintained. Most striking is the different information the two tables contain. The brass rule's table is much more complete, including not only the 8 common cannon, but also data for four other types: Robinet ($1\frac{1}{2}$″ø),[27] Basilisk (9″ø), Cannon Royal ($8\frac{3}{4}$″ø), and "E.Cannon" or Elizabeth Cannon (8″ø). It also contains point-blank ranges for the pieces. Table 4.2 compares the shared information on the brass rule and the manuscript. Taken as comparisons, the two sources disagree on nearly 60% of the data.[28] Although this disagreement is small in all cases, in some it presents more of a problem than others. The matter of shot and bore diameters will be dealt with separately below, but consider the case of charge weights. A difference of 10 lbs. powder vs. 9 lbs. is not of great significance in the case of a demi-culverin, but in the case of a falconet, using 25% more powder for discharge would obviously influence performance. Similarly, the slight difference between a 60 lb. shot and a 61 lb. shot for a cannon may be safely ascribed to a rounding choice or small weighing error (it is only 1.7%, after all), but the 100%, 25%, or even 12% differences in weights for the shot of falconets, falcons, and minions, respectively, indicate how variable these "standardized" pieces of ordnance really were.

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[27] Following engineering practice, I shall use "ø" as a short hand for "diameter"

[28] That is, in 14 of the 24 represented categories. Bore and shot diameters are directly linked through an allowance for windage, which is constant at $\frac{1}{4}$ inch in both tables, so each pair counts only as one category for this statistic.

Table 4.2: Comparison of Data from a MS and a Gunner's Rule

	Bore Diam. (in.)		**Shot Diam.** (in.)		**Shot Wt.** (lb.)		**Charge** (lb.)	
	Rule	MS	Rule	MS	Rule	MS	Rule	MS
Falconet	2	$2\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{1}{4}$	2	1	$1\frac{1}{4}$	1
Falcon	$2\frac{3}{4}$	$2\frac{3}{4}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$	2	$2\frac{1}{4}$	2
Minion	3	$3\frac{1}{4}$	$2\frac{3}{4}$	3	$4\frac{1}{2}$	4	$4\frac{1}{2}$	4
Saker	$3\frac{1}{2}$	—	$3\frac{1}{4}$	3	5	5	5	5
D.Culv.	$4\frac{1}{4}$	$4\frac{1}{4}$	4	4	10	9	10	9
Culverin	$5\frac{1}{4}$	$5\frac{1}{4}$	5	5	18	18	18	18
D.Can.	$6\frac{1}{4}$	—	6	—	30	30	28	25
Cannon	$7\frac{3}{4}$	$8\frac{1}{4}$	$7\frac{1}{2}$	8	60	61	40	30

Crucial to the understanding of the shot weight tables is an understanding of cast iron production in the later sixteenth century, but not as it has been studied in the past. Previous studies on cast-iron artillery have focused on the production of the cannon as the most interesting element in the system.[29] And they are interesting, but those studies have never considered the material properties of the shot. Beyond noting that stone, cast iron, or lead (for smaller shot diameters) could be used, modern commentaries assume that iron shot is iron shot. This neglect and its associated anachronistic assumption of uniformity has obscured an important degree of variability in the materials employed, as well as the cognitive understanding of these materials by Early Modern soldiers.

Consider, for example, the list of shot diameters and shot weights given by Thomas Smith in his *Arte of Gunerye* of 1600. As noted in chapter 3, this work is highly arithmetical and emphasizes the arithmetical processes used to arrive at the values.[30] In fact, at first glance, Smith appears to be doing something very different than the other authors in that his work is filled with numbers galore,

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[29] The standard works are H.R. Schubert, *History of the British Iron and Steel Industry from c.450 B.C. to AD 1775* (London, 1957) and E.B. Teesdale, *Gunfounding in the Weald*.

[30] A 1608 manuscript abridgment of Smith (B.L., MS Cotton Julius F.IV.43) is even more mathematical in nature, appearing more as an arithmetical calculation manual than the prose guidebook of the 1600 printed original.

but they are nothing more than multiplication, long division, and the occasional root extraction. Admittedly, root-finding, or one of the "cossicke" arts as Robert Recorde called it,[31] was considered a rather esoteric art in the sixteenth century, but the ostentatious mathematics involved in *The Art of Gunerye* really had nothing to do with artillery as much as pure mathematics. It served as a form of mathematical recreation, rather like a story problem serves to teach grade-school children proportions, but here with the subject matter of the new "science" of artillery. The shot table, like many other contemporary tables, contains columns for the diameter and weight of cast iron shot then in use in eleven different cannon types (Table 4.3). This sort of table appears unproblematic at first glance, but further analysis reveals an interesting flaw. The formula for the weight (W) of any object is $W = \rho V$, where ρ is the density and V the volume. For a sphere, the volume is given by $V = \frac{4}{3}\pi r^3 = \frac{\pi}{6}D^3$, with r and D being the radius and diameter, respectively. Since here we have the diameter and the weight given, the only unknown, in the modern sense, is the density, which is given by $\rho = \frac{6W}{\pi D^3}$. Calculating this value for the eleven data points given by Smith, we find that his "value" for the density averages out to be 0.271 lb./cu.in. (7.49 g/cc), which is reasonable for the modern value of cast iron. More interestingly, however, is the fact that the value varied between 6.8 and 8.8 g/cc (see figure 4.3) and seems to be higher and more variable for smaller diameters, settling down to an average of 7.19 g/cc for diameters greater than 4

[31] The "cossicke" art first appeared in English in Recorde's, *The Whetstone of Wit* (1557). The term "cossike" refers to finding the unknown variable in the equation, but the pun works on another level in that the Latin word for "whetstone" is *cos*, which adds an interesting twist on the standard interpretation of Recorde as the great vernacular instructor. Clearly he was appealing not only to English-only speakers.

Table 4.3: Thomas Smith's Shot-Weight Table

Diam (in.)	$2\frac{1}{4}$	$2\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{3}{4}$	$4\frac{1}{2}$	$5\frac{1}{4}$	$5\frac{1}{2}$	6	$7\frac{1}{4}$	$7\frac{1}{2}$	8
Weight (lbs.)	$1\frac{1}{8}$	$2\frac{1}{3}$	$4\frac{3}{4}$	6	$11\frac{3}{4}$	$16\frac{1}{4}$	19	$24\frac{1}{2}$	$46\frac{3}{4}$	52	64

inches.[32] Clearly, then, Smith, despite his claim to mathematical rigor and aptitude, did not use a constant value for ρ, and could not have used a modern method to calculate the weight from the diameter. Smith's other option would have been physical measurement, but this, then, raises the question of why actual small shot would be more dense than large shot.[33]

Graphing the cannonball weights from the same 15 sources used for shot diameter analysis above provides another striking example.[34] Figure 4.4 indicates the spread these recorded weights have with respect to their diameter. While we would obviously expect a cubic relation between shot weight and shot diameter, the best fit is considerably shallower, buoyed down by the concentration of data points for small shot. The best fit cubic line, which translates into a mean density of about 7.9 g/cc, indicates the variability the authors recorded. Perhaps most striking are the larger shot, where, for example, a $7\frac{1}{4}$" shot is recorded as weighing 44, 52 (x4), 53⅓, and 64 pounds. A 52 pound shot this size would have a density of 7.21 g/cc, an entirely reasonable value for cast iron, but the 44 and 64 pound shots would have densities of 6.10 and 8.88 g/cc, respectively. Pure wrought iron weighs in at 7.8 g/cc, so something is clearly askew in the 64 pound case. The 44 pound shot may also seem

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[32] Graphing weight vs. diameter produces a fairly close cubic fit, although the best fit is $W=D^{2.868}$ ($r^2=0.999$), and density vs. weight gives the same result as density to diameter, obviously.

[33] Possibly smaller shot were not weighed singly, but in multiples (much as eggs vs. pumpkins today). Still, even the smallest shot could not have been weighted in very large quantities.

[34] The only modern author I have encountered who considers the variation in shot weights and diameters is M. Lewis, *Armada Guns*, pp. 208-9, but his analysis is exceedingly brief.

anomalous, but there is a tantalizing suggestion that it may in fact be more realistic than even the 52 pound shots.

In a 1949 metallurgical study of a cast iron cannonball from the siege of Leith in the opening stages of the English Civil War, Hurst and Riley discovered that it exhibited properties expected with a spherical casting of its type.[35] Their ball weighed 14¼ pounds and measures 4.92 inches in diameter, giving an average density of 6.13 g/cc. This relatively light density arose not from impurities (although copper and tin were noted to be anomalously high), but instead to a relatively large shrinkage cavity in the center of the ball. As they reported, "the general nature of this cavity is not uncommon [and] similar cavities would be expected in any spherical casting of this type unless special means were taken to feed the casting completely" (p. 263). Since the "casting compared favorably with cast-iron balls made at the present time" this raises the question of how typical this sort of feature would have been in sixteenth-century casting. Hurst and Riley suggest it was quite natural, which indicates the need for more examinations of historical cannonballs. Contemporary authors frequently cautioned gunners to beware "honeycoming" in the cannon, indicating that they knew about casting voids, but only rarely was this warning extended to the shot.[36] On one hand, there is no reason it would need to, since a void in a solid shot would not pose a threat to the gunners, but on the other hand, their silence does not tell us whether or not they understood that all castings are subject to shrinkage cavities. Although cannon metallurgy is routinely examined, this cannonball study seems to be unique. At this time, no

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[35] J.E. Hurst and R.V. Riley, "A Metallurgical Examination of a Cast-Iron Cannon Ball," *Foundry Trade Journal* (1949): 261-66.

[36] For example, Richard Wright noted in 1563 that he was recording "the Iuste waygth of all Iornne shote… yf [they] be full caste and Rounde and without bloing or honne comynge." He immediately afterwards mistakenly wrote that "yf he be not full caste he shall waye more then this for said Rull shoithe." London, Society of Antiquaries, MS 94, fol. 11^{v} (App. II, below).

more specific conclusions about shot weight and density can be made, but some general ones can.

In the middle of the sixteenth century, tables of ordnance began to appear in gunnery manuals and printed books. Tables, of course are nothing new, as tabular data exists from astronomical, calendrical, and liturgical sources (and of course, they are all related). But tables for *technical* data are a new phenomenon at this time. In the middle of the century, as for example in the Wright and Lad MSS, the data for the cannon are provided in paragraph form, but by the 1580s and 90s, columnated data predominate. This indicates a shift in mentality about how technology can and should be understood. Separating one technology – artillery – into eight or more classes suggests that technologies are comparable. Before this time, each example of a technology, be it a crossbow, a winch, a mill, a boat, or a cannon, was unique and purpose-built. Cannon had individual names, such as Henry VIII's "Twelve Apostles" and therefore were dealt with on an case by case basis. By this time, however, cannon became not only grouped into classes but this in turn reinforced the idea that cannon *should* be grouped into classes. That the various properties listed in artillery are clearly related yet mathematically disconnected, indicates that Early Modern users had not yet fully embraced the idea, but had only begun organizing their thoughts along these lines. And it is only once this mental threshold has been reached that the concept of standardization can even begin to be understood in any meaningful way. Once could argue that the Swiss standardized warfare in the fifteenth century, but they standardized the behavior, not the technology. Any 15' pike would do, in essence, because there were no outside factors with which it had to interact. Similarly the Spanish *tercio* worked fine as long as each soldier carried a roughly similar sword and shield. A cannon is a different story, since it had many parts: shot, powder, ladle, carriage, and draught team. Standardization can only make

sense in a machine system as would eventually appear in the so-called "American System," which of course has roots at least as far back as early eighteenth-century France.[37] No such standardization occurred in the time period under consideration here, but artillerists took the first step, that of the simple device of the cross-comparisons made possible by tables.

To provide more analyses along these lines would be to belabor the point and would only serve to highlight the inconsistencies in gunnery texts from the sixteenth and early seventeenth centuries. But we are left with the question, then, of how the gunners understood their pieces. From these analyses the answer must be "on an individual basis." While this is true and any given gunner would need to measure his piece and compensate for its idiosyncrasies, the fact that they categorized their pieces and wrote general manuals for their use implies that they believed they could control their cannon. That opinion may also be inferred from what the authorities say: "all guns - both ancient and modern ones, except the mortar - shoot in a straight line at the desired thing if they are made accurately.... I also do not wish to omit telling you as a warning that, as long as the gun is straight, *every error made in its operation is yours and not that of the gun*."[38] Today we would allow for such factors as wind, air resistance, and other uncontrollable variables. Such was the Renaissance mind, however, in believing that all technology should be controllable by man.

Rezeptliteratur and Fireworks

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[37] See K. Adler, *Engineering the Revolution: Arms and the Enlightenment in France, 1763-1815* (Princeton, 1997) , esp. ch. 6, although the seminal reference on this system is still M.R. Smith, *Harpers Ferry Armory and the New Technology: the Challenge of Change* (Ithaca, NY, 1977) .

[38] V. Biringuccio, *The Pyrotechnia of Vannoccio Biringuccio* (Venice, 1540), Book X, Chapter 3, pp. 419-20. The italics are mine.

Gunners' manuals fall into the genre of *Rezeptliteratur*, or recipe literature. These collections of individual descriptions of any variety of substances, processes, or mixtures provided *aides memoire* for their users from the Middle Ages, through the Renaissance, and form the pedigree of modern cookbooks and how-to manuals (referred to hereafter as do-it-yourself, or DIY, manuals). Another difference between Renaissance gunnery manuals and their modern descendants exists, however: examples of *Rezeptliteratur* assume some previous knowledge of the field about which they record information. Many of today's DIY manuals are designed for the complete novice. For example, a basic cookbook such as *Fanny Farmer* or *The Joy of Cooking* may ask for a hard-boiled egg in a recipe, and the index will direct you to a page that will tell you how to make that hard-boiled egg. Renaissance recipe literature will not include that step. And Renaissance recipe literature will rarely include an index. These works are comprised of item after item, often set off with bold headings, which may be confined to a relatively narrow topic, as are our gunners' manuals, or may range freely over domestic science, medicine, prognostication, agriculture, or the search for the Philosopher's Stone.

Michael McVaugh once remarked that "recipe collections… spread out tediously over several folios… in monotonous… detail [and] encourage the modern reader to dismiss them as neither tractable or interesting."[39] Seen in that light, they can appear rather opaque and boring. Further, the recipes in this particular subset of gunnery manuals are intractable in the sense that it would be exceedingly hazardous to attempt to replicate these explosives and incendiaries, even if local fire marshals would permit the experiments. It is not the goal of this research project to understand how these various recipes behaved, but rather to

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[39] M. McVaugh, "Two Montpellier Recipe Collections," *Manuscripta* 20 (1976): 175-180, p. 175.

note how the users of the recipes recorded them. The detailed chemistry of the recipes presented below and Appendices II and III will have to wait for another investigator and another investigation.

The recipes in Tudor gunnery manuals tend to focus on one class of product: fireworks with generic names like “trunkes”, “ringes”, and “balls”. This focus is interesting in that historians of artillery have largely ignored them for more ‘scientific’ pursuits, namely ballistics.[40] And indeed, we have seen that the scientists of the time (*i.e.*, Harriot) also looked to ballistics as the proper *ens* of artillery. But the gunner did not do so. Not only were they incapable mathematically, but such considerations would have been largely meaningless to their understanding and operation of great ordnance. Instead, they focused on a product they could control and understand, at least qualitatively.

Printed manuals devote less space to fireworks than do the manuscripts, which seems puzzling, for one would expect the print manuals to embody contemporary practice. Although Whitehorne had a section on them in his addendum to Machiavelli’s *Arte of Warre*, Bourne makes little mention of this sort of thing, and Norton devotes only 12 of his 158 pages to the matter.[41] But clearly the gunners thought them important or at least interesting, since there they are. It is more plausible that they are there not because they are simply interesting or particularly odd, but rather because they were a common element of the gunners repertoire, one that was difficult to remember, and one which was not used or tested nearly as often as other things in the printed manuals.

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[40] The classic study of course being A.R. Hall, *Ballistics in the Seventeenth Century* (Oxford, 1965) .

[41] W. Bourne, *The Arte of Shooting in Great Ordnaunce* (London, 1587), R. Norton, *The Gunner* (London, 1628), and P. Whitehorne, *Certaine Waies for the Orderyng of Souldiers in Battelray* (London, 1562) . A number of secondary sources say that fireworks were only fired from perrier-class guns, a distinction that cannot be sustained by the English historical record; the distinction may derive from Joseph Furttenbach’s influential *Halinitro-pyrobolia. Beschreibung einer newen Büchsenmeistery* (1627 – see P. Kirsch, *The Galleon: the Great Ships of the Armada Era* (London, 1990) , p. 59, M. Lewis, *Armada Guns*, p. 52).

Conversely, printed manuals' topics are the ones that would be first introduced to tyros (their assumed readership); active gunners would either not need to know that information after basic training, or learned and readily retained that sort of information, therefore making it unworthy of incorporation in the manuscript manuals.

Fireworks in the broad sense can be traced back to late Antiquity, with the infamous, inflammable Greek fire. Although just what this substance was remains a mystery, its purpose was clear, to set the enemy's ships, defenses, and troops afire.[42] The same sort of incendiary weapons were commonplace in Renaissance warfare and went under the generic name of "wildfire."[43] Examples can be found even before gunpowder weaponry could make any claim to battlefield dominance, as incendiary devices delivered by means of "fire arrows". Some late medieval manuscripts illustrate the use of fire arrows quite clearly, as in the Royal Armouries copy of the *Feuerwerk-buch* from *c*1450 where they are fired at the shingled, and therefore flammable, town roofs (fig. 4.5).[44] The arrows take the form of a common arrow, fletched with a barbed head, but with an egg or barrel shaped collar just behind the head. They appear bound both transversely and lengthwise (like the lines of latitude and longitude on a globe) with two small tubes projecting towards the head of the arrow. The crossbowman's arrow emits smoke from these tubes, indicating that the fire

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[42] See H.R.E. Davidson, "The Secret Weapon of Byzantium," *Byzantinische Zeitschrift* 66 (1973): 62-74; A. Roland, "Secrecy, Technology, and War: Greek Fire and the Defense of Byzantium, 678-1204," *Technology & Culture* 33 (1992): 655-79; and Bert S. Hall, "Introduction" to J.R. Partington, *A History of Greek Fire and Gunpowder* (rpt. Baltimore: Johns Hopkins University Press, 1998).

[43] Some authors have assumed that wildfire and Greek fire were synonymous, others that they were unique (*e.g.* P. Kirsch, *The Galleon*, p. 59). We simply do not know.

[44] S.B. Bailey, "The Royal Armouries 'Firework Book'," in B.J. Buchanan (ed.), *Gunpowder: the History of an International Technology* (Bath, 1996) , fig. 3, p. 64. This book also shows "assembly-line" manufacture of fire arrows; see fig. 24-5, pp. 84-5. The earliest English example of incendiary weapons I have come across is an Irish Ordnance Office record for 1537-9 which lists "wyldefire" as one of the purchased commodities; see B. Trainor, "Extracts from Irish Ordnance Accounts, 1537-1539," *The Irish Sword* 1 (1952-53) : 325.

would be directed onto whatever surface the arrow head penetrated, ideally a flammable wall or roof. In the early seventeenth century, Robert Norton included a full-page plate of fire arrows in his treatise on fireworks, next to a bow and crossbow indicated as launching devices.[45] Nevertheless, some historians have suggested that these weapons were archaic by the middle of the fifteenth century.[46]

This *Feuerwerkbuch* illustration also conveniently also shows the transitional stages of this weapon, as some soldiers use crossbows while one soldier fires his arrow from the mouth of a musket. Some military historians have expressed their opinion that the artists knew not of what they drew in these cases, doubting that arrows of any sort could be fired from a musket. They argue that there would be no way to seal the gasses behind the arrow upon ignition, and it would lazily plop out of the barrel, rather than be forcefully ejected towards the target. And Norton's later image without a musket has been taken to imply that "primitive" strung weapons either remained in use to deliver fire arrows, or that they represented an antiquated practice by the end of the sixteenth century.

But the evidence clearly shows that fire arrows were commonly discharged from muskets. Some authors refer to them in passing as Thomas Digges did in his discussion of the bow vs. musket debate: "Muskets being charged with arrows and mounted to convenient Randoms… beate at all distances within a myle compasse on every side with greater violence then the

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[45] R. Norton, *The Gunner* (1628), following sig. Y[1]^{v}. His plates were reused from Theodore deBry's French and German editions of Diego Ufano's *Tratado de Artilléria* (Frankfurt, 1614) [M.J.D. Cockle, *A Bibliography of Military Books up to 1542* (London, 1957) , p. 90].

[46] G.W. Kramer, "Das Feuerwerkbuch: its Importance in the Early History of Black Powder," in B.J. Buchanan (ed.), *Gunpowder: the History of an International Technology* (Bath, 1996) , p. 53: "the account of the manufacture of powder for fire arrows is also unexpected, for it shows the old firelances were still of importance." Even into the 1620s and 1630s the English kept pondering this weapon: M.C. Fissel, "Tradition and Invention in the Early Stuart Art of War," *Journal of the Society for Army Historical Research* 65 (1987): 133-47.

best archer in England is able to do at five score."[47] Although it should be emphasized that they are not common stores, at least after the Armada, the English Ordnance Office considered them useful items to have on hand. Tampions, the same word which comes down in modern English as "tampon", are the wadding rammed down the barrel after the powder, to create a tight seal needed for the system to work effectively. In an inventory taken at the Tower in July 1589, 570 dozen "Tampions for Muskett arrows" were listed as remaining among the stores at the Tower on 19 July.[48] Another 780 dozen tampions were listed as "Bought 1589," suggesting that in the first six months of the year, some 1,620 tampions had been used, possibly for training. The inventory also dutifully lists 281 sheaves of "Musquet Arrow" remaining at the Tower in 1589, and 362 sheaves bought in 1590, along with another 2000 sheaves of arrows "for fireworks" (*i.e.*, fire arrows). Sheaves were nominally 24 arrows, indicating that the Ordnance department kept over 15,000 musket arrows and 48,000 fire arrows on hand the year after the defeat of the Armada. Indeed, Richard Hawkins suggested that they were a particular favorite among English troops and even a secret of their service.[49]

In 1601 Fynes Moryson provides a rare glimpse of incendiary arrow use in Ireland: "Captaine Bodley made readie thirtie arrowes with wildfier, and so

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[47] Quoted in J.X. Evans (ed.), *The Works of Roger Williams* (Oxford, 1972) , p. xcvi, although this passage is not on the signature in *Straticos* which Evans provides in n. 4 (in fact, the signature does not even exist in the 1590 edition, which he appears to be quoting); I have not checked the 1579 edition.

[48] Bod.Lib., MS Rawlinson A 207, fol. 7^{v}-8^{v}.

[49] J.S. Corbett, *Drake and the Tudor Navy* (New York, 1899) , I: 379. Richard Hawkins related that upon surrendering his ship to the Spanish, "General Michaell Angell demanded, for what purpose served the little short Arrowes, which wee had in our shippe, and those in so great quantitie" (*i.e.*, musket arrows). Hawkins explained Angell's surprise by noting that "they are not as yet in use among the Spaniards, yet of singular effect and execution as our enemies confessed.... [O]f all the shot used now a daye, for the annoying of an Enemie in fight, by Sea, few are of greater moment for many respects: which I holde not conveneient to treate of in Publique." R. Hawkins, *The Observations of Sir Richard Hawkins Knight, in his Voyage into the South Sea, Anno Domini 1593.* (London, 1622) , p. 164.

they both [Bodley's two units] fell downe with one hundred shot close to the water, where shot [was] playing incessantly upon the Yland, while the other delivered their arrowes. Suddenly the houses fired, and burnt so vehemently, as the rebels lodging there forsooke the Iland and swumme to the further shoare."[50] This passage, however, indicates the confusion between fire arrows and musket arrows in use sources: it is unclear whether Bodley's second unit that fired the "wildfier arrowes" was armed with guns or bows. At any rate, this hardly amounts to an unused and obsolete weapon. It was in fact a weapon with a long and successful history, one which can be traced back to at least the twelfth century.

In the recipe-book known as the *Mappae Clavicula*, there are a number of incendiary recipes, including one for "the arrow which emits fire."[51] It begins by describing the "arrow for emitting fire" as "triple-spiked and perforated." The ingredients are given with their various amounts: naphtha, tow, seasoned pitch, "native sulphur", *climatis*, sea salt, olive oil, "raw bird lime", jet stone, some soap made from olive oil, and a woman's milk. After mixing these together you are left with a "fatty" milk in which you dip some flaxen rope which is then fastened to the arrows. When all is ready, "you stretch your bow [and] set the arrow on fire and immediately shoot it where you want a fire to be started." Although the delivery system is old-fashioned by the time of the gunners' manuals, and ingredients are apparently more magic-laden than ours,[52] the style of the recipe is similar. Compare it to one from the Gunmen manuscript:

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[50] F. Moryson, "Use of Fire Arrows, 1601," *Irish Sword* 4 (1960): 251, quoted from his *Itinerary* (1617), pt. 2, p. 97. Mountjoy, Lord Deputy of Ireland, 1601-3, was known for his scorched-earth policies.

[51] C.S. Smith and J.G. Hawthorne, *Mappae Clavicula: a Little Key to the World of Medieval Techniques* (Philadelphia, 1974) , no. 266. The section on incendiary mixtures continues to no. 278-A.

[52] For example, why would woman's milk be suggested rather than cow's milk, goat's milk, or the perennial magical favorite, mare's milk? In *Mappae Clavicula* it appears only in these incendiary recipes, although goat's milk is used elsewhere to cut glass (no. 289).

> To make ffire arrowes.
> Take heter oyle, quicke brimstone, harpoyes, and gunpowder that is good. Put the same in a bason, & set it in a kettle of hott water to drye, & ketle it, when it is keiled [cooled] molten among them then shall you take a little vpon an arrowe head at the end, then put it about a linnen cloth with smale ends of Launces, when you wille shoote fire the launces, & when they fire it cannot be quenched.[53]

In essence they amount to the same weapon, although in the details, they are worlds apart. Both use a linen wicking material, possibly because it provides a better mantle than wool or other cloth, or perhaps because it was cheap and readily accessible. Other than that, though, they have no ingredients in common, that is, unless the unknown "harpoys" is identical with the similarly unknown "climatis".[54] The *Mappae Clavicula* specifies specific amounts of all the ingredients, in *solidi* or ounces, and describes each step of the process. The Gunmen recipe says to simply melt the four ingredients together, and wipe them on the head of the arrow with linen strips like gonfalons (my interpretation of "put it about a linen cloth with smale ends of Launces"). Perhaps the sixteenth century recipe is more forgiving than that of the twelfth, but this is unlikely. Rather, the two recipes were written from two very different didactic standpoints: *Mappae Clavicula* is a recipe book more akin to a modern cookbook, intended for someone unfamiliar with the various recipes and processes and it therefore presents all the amounts and steps to achieve the desired result; the Gunmen MS, on the other hand, is written as if from one confidant to another, both skilled in the various techniques pertaining to incendiary creation, but who might not know (or might forget) which ingredients to mix to make the appropriate fire for linen-wrapped arrows.

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[53] Bod. Lib., MS Ashmole 343, fol. 131^{v} (App. III).

[54] This is another difficulty with *Rezeptliteratur*, namely nomenclature. Readers, it was assumed, would know what harpoys or climatis was, so no further explanation was warranted. B.S. Hall rightly critiqued Hawthorne and Smith's for not providing more information or suggestions on obscure terms in the *Mappae Clavicula* in *Isis* 67.236 (1976):123-124.

This then points to an important facet of the entire realm of *Rezeptliteratur*: the intended audience. Recipes for various tasks have very different readers in mind when they are written. In the modern world, the historical distance can be difficult to achieve when there is a software manual on every desk, a cookbook in every kitchen, and a VCR manual stuffed in a drawer even if it is of no real use anyway. But all these manuals have one thing in common; they are rarely used for systematic learning. Textbooks, on the other hand, lead you through each logical step towards the desired result. Recipe books, however, list individual tasks in a boiled-down format (pardon the culinary pun) for someone who already knows how to perform the task and just needs the ingredients and perhaps instructions on some particular step or condition in the process that might be difficult. So, when you look up the recipe for a lemon meringue pie, you are told to beat the egg whites until stiff and glossy; it is assumed that you know that you need a mixer, bowl, how to separate eggs, and what condition "stiff and glossy" refers to. Thus, the *Mappae Clavicula* is more a textbook than the Gunmen or Wright's MSS ever pretend to be. Still, it is not a pure textbook, as we are never told why a woman's milk is better. In gunnery, Bourne provided the first attempt at a textbook treatment in 1578, but it was not until 1628, with Norton's *The Gunner* that a full textbook treatment of great artillery became available.

Gunners' Manual Recipes

Since these manuals were not written for outside eyes, the information contained in them presents the modern reader with some difficulty in terms of the nuances of the art omitted by the authors. First, there is the matter of the literacy of the author and format of the manuals alluded to above with respect to Richard Wright's "paragraphs". If we accept the paraliterate status of the

authors, then we may ask where this sort of knowledge fit into society and, conversely, what cultural constructs the authors would have brought to the study of gunnery. The Wright MS provides one answer in its formulaic and somewhat enigmatic entry after a number of its entries: "*probatum est*". This Latin phrase, meaning simply "it is proven" or "it is tested" is added at the end of the various recipes or hypotheses. At first glance this suggests that the various items had been proposed and then later tested for validity. We might therefore assume that the elements which do not have *probatum est* added were either untested, had failed the test, or even were not considered to have required testing. They were not, as Jerry Stannard put it, "what we understand as experimentally conducted laboratory tests [or] clinical trials."[55] But the *probatum est* notations are in all cases added in the same hand with no clear indication of having been added later, even if it was by Wright himself. In a few cases, they are in the blackletter he reserves for headings, but again, they appear similar to the heading which follows.[56] In medical recipes, Claire Jones has suggested that *probatum est* may simply refer to the recipe having been witnessed, but not necessarily tried by the compiler of the recipe text.[57] From the evidence, then, we cannot reach any clear conclusion about whether Wright himself tested any of these recipes. It would not be incongruous to assume, however, that if the Wright MS is indeed a second-generation copy, produced, say, in the "evenings" after class, then the items which are marked "probatum est" might well have

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[55] J. Stannard, "Rezeptliteratur as Fachliteratur," in W. Eamon (ed.), *Studies on Medieval Fachliteratur* (Brussels, 1982), p. 72 and C. Jones, "Formula and Formulation: 'Efficacy Phrases' in Medieval English Medical Manuscripts," *Neuphilologische Mitteilungen* 99.2 (1998): 203. Her suggestion that *probatum est* might "show that the distant origins of the recipe were from a theoretical text where the principles underlying a therapy were proven by scholastic, rather than empirical means" (p. 206) seems irrelevant in a gunnery context.

[56] There are some cases where an annotation has been made noting the falsity of an idea in the text, as for example, on fol. 11^{v}, where "It is not true" has been noted next to the text claiming that a 6" shot will weigh 8¼ lbs.

[57] C. Jones, "Formula and Formulation," pp. 202-4.

been demonstrated to him in that day's class and the others merely taught as givens.

The items which garner the notation fall into two categories: generalized rules of operation and specific recipes, in this case for fireworks. The generalized rule so annotated relates the strength of powder to its temperature: "A question whether it is the piece that shall make the shot to mont after twice or thrice shooting or that it is the powder by reason of the heat of the pes" (fol. 5). The solution to this query, noted with the *probatum est* epithet suggests a positive correlation: "Reason: If that when the powder is in the hot peice and the powder growing hot also makes the powder stronger by reason of the heat that dries it, for powder being hot burneth stronger then [when it] is coulde." Wright then also noted the proof of this observation in the following lines: "the proof: take… powder out of a barrel and… warme [it] in a pan over the fire and when it is hot, then burn the cold and the warm both together asunder and you shall find the warm powder [is] the stronger." Clearly, though, this "proof" really proves nothing, or at least he notes nothing in his text which will necessarily convince a modern reader. The suggestion, then, is that Wright learned this concept from his instructor, likely by demonstration, and recorded the results in his manual – but not the proof in the modern sense – and therefore noted that it had indeed been "proven".

On the other hand, a later general statement regarding charges for various cannon also received the notation *probatum est*: "Item from a saker upward, take the height of the mouth of the piece then give him iij times his height to his charge of the piece" (fol. 7). This seems straightforward enough, but then his example immediately confuses its meaning: "if it is iij inches, they give him xviij inches long for his chase," which is a factor of 6, not 3 as initially stated. This rule appears immediately after a rule for the weights of charges

based on the material of the shot. For a lead shot, Wright suggests a charge of equal weight, while for iron he prescribes one-third the weight ("the iij parte", fol. 6^{v}). He also adds "if it be single then the one half [weight,] and so shall he go to his marke," which may refer to the distinction between solid iron shot and bar, chain, or dice shot, the former receiving 50% more powder than the latter; in the later part of the MS he specifically mentions differences between dice and solid shot. But Wright's example giving an 18 inch charge for a 3 inch ball (with the wrong factor of proportionality) suggests that Wright is telescoping two or more ideas into one.

In order to understand those ideas, consider the light this passage sheds on the handling of powder in the Early-Modern military. Wright does not say that for a certain diameter bore, use a certain weight of powder, the relation a modern user might expect. And although the tables in later works will list powder charges in pounds and parts thereof, Wright's usage, also echoed in other manuals, indicates how the gunners themselves would have dealt with these charges. Citing a weight of powder for a cannon charge would be next to useless for a gunner in the field or in a garrison for the simple fact that scales were few and far between. Even if gunners might have had access to one, it would have been slower and clumsier than the methods they developed. Wright indicates the general methodology. For certain bore, use a certain *length* of powder.

This cavalier use of incongruous units strikes modern eyes as odd, but do not confuse a *functional* unit with a *tangible* unit. Tangible units may be considered the unit which measures a fundamental property of a substance and which captures its being without ambiguity. Thus, for a powder of any sort, either weight or volume might do. Temperature or time would not. Functional units, on the other hand are units we use to describe the materials in particular,

defined situations. The most common example would be using graduated cylinders in a chemistry lab. Although the glass cylinders are marked in milliliters, the scale is actually a linear one and in effect, one is measuring the length of the column of liquid, but since the cross-sectional area is constant, the length is in effect a measure of the volume. Renaissance cannoneers went one step further. Since the cannon barrel was more-or-less constant, they too were measuring volume by specifying length, but volume only provides an intermediate (unarticulated) value between the functionally measured length and the tangibly prescribed weight.

These powder weights, then, were defined in so many cannonball lengths, or calibres. Wright sends mixed messages about the number of calibres in the general rule, and within his enumeration of the properties of each type of artillery, he continues the inconsistency (Table 4.4). Wright only provides values for four classes of cannon. These four types formed the core of most gun installations, be they on land or at sea, and therefore suggest that the training gunners received was on a need-to-know basis, at least to begin with. Next, notice that both ladle sizes and cartridge sizes are provided. Since the width of both are uniformly wider than the shot, Wright clearly used circumferential measures. We also know he used a value of $\pi = 3$: a "facon shote of ij enches is vi enches in Compaes" (fol. 7^{v}). In providing the length and the width (or breadth) of the ladles and cartridges for four pieces, he then indicates the two ways in which cannon were charged. Cartridges are quite straight forward, and are first reported in the mid-sixteenth century. Biringuccio suggests in 1540 that cartridge loading was at that time quite new and notes the other great benefit of cartridges, that is, to be able to make up a number ahead of time.[58] Wright

[58] V. Biringuccio, *Pyrotechnia*, Bk. X, cap. 3, p. 418. What may be cartridges are illustrated in a woodcut of cannon loading on p. 421. See S. Bull, "Evidence for the Use of Cartridges in Artillery, 1560-1660," in R.D. Smith (ed.), *British Naval Armaments* (London, 1989), pp. 3-8.

Table 4.4: Richard Wright's Powder "Rules"[60]

TYPE	shot (in.)	ladle (in.)	cartridge (in.)	powder (lbs.)
falcon	2	$3\frac{1}{2}$w x 12l	6b x 10l	2
saker	*3*	7w x 16l	9b x 16l	5
culverin	$5\frac{1}{4}$	10w x 22l	14b x18l	12
demi-culverin	$4\frac{1}{4}$	$8\frac{1}{4}$w x 18l	12b x 18l	$9\frac{1}{2}$

note: 'w' and 'b' for the ladle and cartridge refer not to diameters, but measurements along their circumferences. Thus, the ladles have **U**-shaped scoops with arcs ranging from 200° to 267° and diameters matching their shot. The cartridges' circumferences ('b') are less than the inner diameter of the piece's bore to allow them to slide in.

echoes this benefit in his discussion of the culverin cartridges, whose "forme for the cartwhich is xiiij enches brode and xviij enches longe." here again, we find a great deal of variability in his prescriptions or mathematical abilities. His culverin cartridge holds 12 pounds of powder, implying a powder density of nearly 1.2 g/cc, much lower than the modern value of about 1.8 g./cc.[59] His values for the demi-culverin and saker agree quite closely with this, but the values for the falcon yield a powder density of over 1.9 g/cc. Therefore, although he gives the impression of mathematical precision, the data he provides varies widely. It seems that on more than one occasion, Wright's zeal for recording technical data may have lead him astray in the accuracy of that data.

Although cartridges existed and would become the standard loading method from the late seventeenth century onwards, ladles were the mainstay for charging cannon in the sixteenth. The widths Wright provides indicate that they were cylinders, open at the top to varying degree (from just over a 90° gap for the saker to a wide 160° opening for the falcon). This impression is confirmed by illustrations at the end of the section specifically on the construction of ladles (fol. 15-16), although there he specifies that they should be

[59] A. Marshall, *Explosives* (Philadelphia, 1917) , II. 414-5.
[60] Fol. 7^{v}-8^{v}. The saker's shot diameter is inferred.

⅖ open on top (*i.e.*, 144°).[61] In this section, he clears up the confusion he created on fol. 6^{v} by explaining the ladle loading process more clearly: "understand that in a ladell makynge ix balls of lenthe shall holde of powder waight for waight with the shote whether the ladell be made of iij Balles as moste commonly be used or of more" (fol. 15). That is, a nine calibre long ladle holds an amount of powder equal in weight to that of the cannonball, regardless of the bore. This is effectively a density argument although, like the earlier example of shot diameter and weight, it is not explained in terms of a modern understanding of density.[62]

Wright then explains how these various ladles are used to load a certain amount of powder into a cannon. A common 3-calibre-long ladle "iij tyms fylld shall holde the waight of your shote" which is equivalent to "juste ix balles," that is, calibres. But his further examples again indicate he did not have as clear a grasp of the mathematics as we might expect. On one hand he claims that "yf your ladill be made of iij balls in lenth that same ladill ij fylled Holdith waight for waight lakynge the ix parte", that is while the weight of 9 calibres of powder equals the weight of 1 calibre of shot, 6 calibres of powder equals 8/9 calibres of shot.[63] He continues, "also a ladill mad of iij Balls and halfe and that ladill ij timms fyllid equally holdeth juste waight for waight and is the full ix balles"; so here 7 calibres of powder from a 3½-calibre ladle appear to weigh the same as 9 calibres with a 3-calibre ladle. His last example, however, does work mathematically: "there be ladills made of v balles of length and that ladill t[w]o tymes fyllyd berith waight for waight and the ix parte more", that is, 10 calibres

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[61] A.B. Caruana, "The Gunners' Powder Ladle," *Arms Collecting* 29 (1991): 55-57, discusses the powder ladle for the 18th and 19th centuries. He mentions the Wright MS in passing, but demonstrates a very poor knowledge of 16th century artillery and should therefore be used with extreme caution.

[62] In modern terms, assuming he is consistent with his ⅖ gap rule for the ladles, this effectively means that cast iron was 8.1 times as dense as black powder.

[63] In other words, he claims that 9:1::6:0.89, which is clearly false.

of powder is 1/9 more than 9 calibres. It would appear then, that his confusing earlier statement confounds the size of ladles and the number of calibres of powder required for each ball.

Ultimately, however, the image of a paraliterate and here para-numerate gunner is made strikingly clear. This also explains why many printed gunners manuals such as those by John Smith and John Babbington go to such great length to teach the seemingly elementary rules of proportionality.[64] If Wright, although writing some 35 year before Smith, is characteristic of the skill-level of gunners-in-training, those later authors can not be seen as teaching a rudimentary mathematical knowledge in order to simply fill pages. They were instead clearly responding to a need. Ladles, while forming the mainstay of gunners equipment were clearly a means to unburden the gunners from this type of calculation. Cartridges went a step further, although at the cost of the materials – either canvas or paper – and time to make them. In essence, this is an early form of gauging and can be seen as yet another example in the long line of military necessities surrounding gunpowder weaponry which led to standardization and, ultimately, to interchangeable parts.

Returning to the matter of the other type of entry which received the *probatum est* notation, firework recipes frequently appear to have been "proven" to Wright in his gunnery instruction. Firework recipes occupy nearly half the volume (fol. 18-32), and within those pages, *probatum est* appears no less than 22 times, although in only 3 of these cases are the words written out in full. In all the other cases, Wright made the notation of a 'p' with a stroked staff (ꝑ) after the recipe in question. Since he categorically does not use this common abbreviation in its usual meaning of "per", "par", or "pre" and since it appears

[64] For Smith, see ch. 3, above. J. Babbington, *Pyrotechnia, or, a Discourse of Artificiall Fireworks* (London: Ralph Mab, 1635).

only at the end of individual recipes, it seems clear from the context that this is his shorthand for the longer Latin phrase.[65] Further, the recipes that the notation follows appear to be the sorts of recipes that could be demonstrated to novice gunners in a lecture or even hands-on learning situation, and they also appear to be the sorts that would be demonstrated to interest the students. So, for example, Wright records recipes for canvas-wrapped "trunkes" (a sort of flare on a staff), a general purpose flammable mixture which cannot be extinguished with water, "Balls of manye Sundry Collers" presumably more for spectacle than warfare, coatings for fire balls fired from cannon in the place of solid or dice shot, incendiary arrows, incendiary pots which may have been what today might be called a ground-display firework, and finally a number of examples which would demonstrate the relative quality of various powder lots. The items which are not marked in this series include a few recipes, although these tend to be "another recipe" for some particular effect, or else less "spectacular" effects, particularly with respect to powder testing. It seems clear, then, that Wright likely recorded these recipes as he was taught them, and for a good number of them, he was likely shown a demonstration just as we might see today in a high school chemistry lab.

Unfortunately, as mentioned before, the exact or even gross effects of these various recipes can only be guessed within wide margins without dangerous replications. On the other hand, examining the different ingredients

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[65] It is possible that, being paraliterate, Wright may have seen the common stroked 'p' and wished to imitate it, although again, not fully grasping its meaning or limitations. In two cases, he wrote both *probatum est* and the contraction. C. Jones, "Formula and Formulation," notes that the 'macaronic' mix of Latin and English illustrates "the authoritative effect of Latin… lend[ing] more gravitas to the text" (p. 202) and that "the use of Latin may have been a stylistic choice given that Latin was still very much the language of scholarship, authority, and 'secrets'" (p. 205). L.E. Voigts, "The Character of *Carecter*: Ambiguous Sigils in Scientific and Medical Texts," in A.J. Minnis (ed.), *Latin and Vernacular: Studies in Late-Medieval Texts and Manuscripts* (Woodbridge, Suffolk, 1987), pp. 91-109 is informative, although not directly relevant here.

which appear indicates a great deal about the sophistication of the military chemistry of the time. The main ingredients are the ones we would expect to find in the context of gunpowder warfare: saltpeter, charcoal, and sulphur. Of course pre-mixed powder appears in both its serpentine and corned incarnations as well as "fine" and "gross" which may or may not be the same, but its individual ingredients appear more often than not as individual additives to the mixtures. In a few cases, the charcoal's source is specified either as birch wood or willow wood.[66] Presumably the less dense willow or harder birch would create a charcoal particularly suited for that recipe or it is even possible that trace elements found in either might have made a qualifiable difference in performance that the gunners could have detected and encouraged. The Gunmen MS in one place also specifies willow charcoal. Other principal ingredients include linseed oil made from flax; rosin, a generic term for various plasticized saps, usually from coniferous trees; turpentine, a distillate of pine wood, although since it is measured in pounds probably the more viscous form with high resin content, rather than the refined modern paint thinner; pitch, which was generally used to seal the canvas housings from the weather and readily available in the shipbuilding industry; and various oils, including "sweet" oil (unidentified), rape oil (from the rape seed), camphor (a more gummy oil which would have had to have been imported from the Mediterranean, if not the East), and the oils "debaye" and benedict.

Beyond these core ingredients (usually measured in pounds), various other substances appear in the recipes (in smaller quantities), although their particular effects remain mysterious. "Smyths dust", or iron filings, made a more "sparkling" firework as the filings vaporized. Verdigris, a generalized term for the tarnish on copper (either simple oxides or the acetates formed by reacting

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[66] *E.g.*, Bod. Lib., MS Ashmole 343, fol. 131, 132 (App. III).

acetic acid with copper) commonly appears. Various chemicals and pigments turn up, including aqua vitae (alcohol), liquid mercury and mercury "subley" or sublimate (HgCl), arsenic, red lead (Pb_3O_4), and "unwrought" (*i.e.*, unslaked) lime. Some common "household items" also show up, including red and white vinegar, powdered glass which may or may not be the same as "deme glase" (fol. 26), sawdust, and tallow. Some recipes also use "ocame" (fol. 22) or "okame" (fol. 27) (modern: "oakum"), a tar-impregnated jute or hemp rope used to caulk ships seams. Finally, more esoteric substance are listed, like "asafetidston", that is, a medicinal gum resin, *asafetida*, also imported from the East. In addition, a number of as yet unidentified substances appear: "detratiuan" (fol. 19, although the word is unclear in MS) or "deteatary"; "mysket" (fol. 19); "Callemare" (fol. 22) which might possibly be calomel (L. *calomelas* – mercurous chloride, Hg_2Cl_2),[67] a medicine used as a purgative and fungicide; "Combuste" (fol. 22), presumably some combustible material not given another name; and the enigmatic "Exodus" (fol. 27).

The question immediately arises what sort of comprehension the various gunners could have had of most of these substances. Most ingredients presented little difficulty, as in the case of sawdust, iron filings, or vinegar. The various types of gunpowder would have become familiar to them quite quickly, one would imagine. Still, some of the others might have not come so easily. One glaring example of Wright's novice stature occurs in a recipe where he calls for one ounce of mercury and half an ounce of quicksilver (fol. 20), clearly misunderstanding that they are one and the same. In another (fol. 22), he noted that both "verdegrace" and "greene Corpers" "pertayne vnto wyllde fyer", although it is likely that these two are also identical. In that sense, these recipes

[67] If correct, this would be the only Latinate term in the Wright MS, but it is safe to assume that he came to know the term without knowing Latin.

must have appeared quite magical and mysterious. Nevertheless, even though many of the substances also had currency in contemporary alchemical investigations, Wright does not ascribe any magical affects of causes to these mixtures. Instead, he treats them as very straightforward processes to produce (slightly) specific results. In this sense, A.R. Hall's belief that these ingredients "show the impact of chemical… science upon the traditional art of war"[68] cannot be sustained, unless "chemical science" also be allowed an impact on alchemy and folk medicine. Far from being a science, the gunners in the sixteenth and into the seventeenth century and later cared not so much for the science of their ingredients but for the art of their mixture.

Of course, it is possible that the fireworks recipes were taught to the gunners and were never used in the field. Such potentially superfluous instruction is not uncommon in virtually any technical field, and serves as a means to engage and maintain the interest of the student above and beyond the more mundane information. This is not to say that this information is entirely useless, but merely to make the rather obvious point that in any occupation, 95% of an employee's time is occupied by the mundane tasks. But fireworks were nonetheless a large part of Elizabethan pageantry.[69] Fireworks accompanied the English entry into the Netherlands' conflict. Feasts and processions abounded. "Cannon roared, tar barrels blazed, bells pealed, dragons soared on fiery wings, wreaths of flowers descended and the visitors were deluged in cascades of

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[68] A.R. Hall, *Ballistics in the Seventeenth Century* (Oxford, 1965) , p. 23.

[69] There is a beautiful presentation MS in the Bodleian Library, Oxford, with plates of fireworks by J. Callot (†1635), the famed French fireworker (MS Douce d.8). Fireworks were first given in honor of the Queen at Warwick in 1572 and figured prominently at Kenilworth in 1575: "when [the Queen entered to courtyard] after did follo so great a peal of gunz and such lighting by fyr work a long space toogither…: for indeed the noiz and flame weat heard and séene a twenty mile of" (F.J. Furnivel [ed.], *Robert Lancham's Letter: Describing a part of the Entertainment unto Queen Elizabeth at the Castle of Kenilworth in 1575* [London, 1907] , pp. 11-12, 18). The standard work on the pageantry of the period is R. Strong, *The Cult of Elizabeth: Elizabethan Portraiture and Pageantry* (London, 1977) .

endless Latin Orations.'[70] This, then explains the predominance of fireworks in the gunners manuals. The gunners might not have had to make them often, but were fireworks ordered, the gunners would have been the men who provided the entertainment. In many cases, gunners procured and created the pyrotechnics for theatrical productions.[71]

Inventories occasionally indicate that supplies for fireworks were kept on hand. For example, Sir Peter Osborne and Capt. John Bingham took a survey of munitions at Castle Cornett on the Isle of Guernsey in June 1621.[72] The castle was apparently not yet fully complete or supplied, so they included the current stores as well as those yet required. Beyond the expected lists of brass and iron ordnance, powder, and shot for the great ordnance, the survey includes a long section on carriages and equipment for the ordnance, "engineering" tools such as pick axes, hammers, tongs, "gynnes" (probably winches) and sewing needles and thimbles, as well as various small arms and armour. They also include a section on "Receipts for fireworks," listing the various ingredients the castle kept on hand (Table 4.5). They also included the materials to make the casings which Wright mentions: "marlin" corde, packthread, canvas, and twine. The Guernsey inventory may be atypically complete in the variety of supplies, but ordnance lists for regular deliveries also included not insubstantial amounts of firework supplies. For example, a "typical" Ordnance Office supply list for Ireland at the turn of the century included 6 gallons of linseed oil, 100 weight each of rosin and

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[70] C. Wilson, *Queen Elizabeth and the Revolt of the Netherlands* (London, 1970) , pp. 90-91.

[71] P. Butterworth, *Theatre of Fire: Special Effects in Early English and Scottish Theatre* (London: Society for Theatre Research, 1997): for example, William Harris, gunner, provided the London Skinners Guild with "squibs for the wild men" in 1551 (p. 24); the master-gunner of England and his ordinary fee'd gunners of the Tower oversaw all royal fireworks (pp. 123-7); and in 1613 a team of gunners under John Noades provided fireworks for the King and Frederick and Elizabeth (pp. xxi-xxii and App. 1E). The examples could be easily multiplied.

[72] APC, vol. 37 (1619-1621), pp. 413-18. The list is interesting in its mixture of "old" and new types of ordnance and munitions at this late date. For example, brass pieces make up nearly half the great ordnance (12 of 40) and "obsolete" items such as stone-shot port pieces and fowlers seem still to be in service.

Table 4.5: Ingredients for Fireworks at Castle Cornet, Guernsey, 1621

	on hand	to be supplied
mealed powder	—	1 cwt.
saltpeter	1 demi-barrel	20 lbs.
sulphur	1 barrel	20 lbs.
mercury	6 lbs.	—
turpentine	1 barrel	50 lbs.
rosin	—	100 lbs.
linseed oil	—	4 gal.
verdigris	—	6 lbs.
"bolearmonicke"[74]	—	6 lbs.
"Coliphonia"[75]	—	6 lbs.
arsenic	—	3 lbs.
"stonepitch"	—	100 lbs.
"baysalt"[76]	—	4 bushells
tar	—	50 lbs.
and tallow	—	30 lbs.

pitch, as well as 50 pounds each of marlin cord and twine.[73] Even earlier, an 1580 inventory of the Tower ordnance listed

> stuffe for ffier worke, vizt: camphire, salarmonacke, vitrioll, Arsenick, Verdigrese, Coperas, masticke, mercury sublimat, Arsa fetida, Rossen, Turpentyne, Aqua vite, Trayne oyle, Lynced Oyle, Lyme Pott*es*, Marlyne and Tyne, Packthreed, Trunck*es*, Staues for Trunck*es*, Canes, Roddes for Rockett*es* and diurse other receipt*es* and ymplement*es* acordinge to the nature and service of the fire work.[77]

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[73] R.W. Stewart, *The English Ordnance Office 1585-1625: A Case Study in Bureaucracy* (Woodbridge, Suffolk, 1996) , App. 3, p. 163. Stewart also mentions in a naval supply list from 1594 which included camphor, turpentine, rosin, pitch, tallow, and various oils to the value of £6 13s 7d, indicating that fireworks were not solely a landlocked pursuit (p. 165).

[74] Bole armoniac was "a fine clay originally from Armenia used medicinally" (R. Huggett, J. Hugget, and S. Peachy, *Early 17th Century Prices and Wages* (Bristol, 1992) , pp. 30-1) but here probably as packing material in explosive shells. P. Whitehorne, *Certaine Waies* mentions that some apothecaries sold a reddish clay found in "greate quantety" in Apulia as "Boale Armenick" (sig. [L.iv]^{v}). Less likely, it could also be a mistake for *sal armoniac* – ammonium chloride (NH_4Cl) – which was not infrequently called for in these recipes.

[75] Unknown substance.

[76] That is, sea-salt; not the igneous rock. Probably the same as the "grey salt" called for in the Gunmen manuscript.

[77] B.L., MS Sloane 3194, fol. 22-23v. "masticke" is yet another resinous substance used in varnishes and glues. The reference to "Rockettes" is interesting for being so early, some 30 years prior to the first mention in the OED.

Clearly, then, fireworks were not an insubstantial matter in Ordnance supplies, so there is no reason to believe that the firework recipes in the gunners' manuals were not included for practical purposes.

The larger proportion of this section has been spent on the Wright manuscript as it is the more polished and earlier of the two under consideration here. The Gunmen manuscript, on the other hand, being a copy, presents the historian with a list of items, but not as much contextual information. Gunmen, like Wright, opens with a list of things the gunner must know, although its list varies considerably from Wright. Gunners must know good saltpeter from bad, and know all different types of ordnance 'measurably", that is, quantitatively. His third maxim sheds a great deal of light on the consideration of fireworks: "you must know how to make 3 or 4 sortes of fireworkes at least, whether it be by water or land, *if you will get lords wages*."[78] Thus, the inclusion of the firework recipes are a form of value-added insurance to the student gunners: everyone knows how to load and shoot a piece, but only the well-paid gunners can devise fireworks. At this point, though, he leaves the maxims to discuss the testing, rehabilitating, and creation of powder.

The Gunmen manuscript is also not as well organized as Wright's, even though Wright's is not a polished book either. The copyist's page mis-ordering aside, the original document jumps from topic from topic with little concern for continuity. So in one place, the author notes a remedy for shooting iron balls out of brass pieces, triangulating a tower in the dark, and a firework recipe (fol. 129^{r-v}) and in another how to prove chambers and guns, how to use chambers, and how to build a quadrant (fol. 133^{r-v}). But those topics that are covered are often extended to a higher level than Wright. Wright considers guns and recipes. Gunmen considers these and triangulation and range-finding, proof of great

[78] Bod. Lib., MS Ashmole 343, fol. 128 (App. III). Italics added.

ordnance, quadrant construction and use, analytic description of ranges, and even construction of machines, like fire pumps.[79] While his sections on fireworks are as elaborate as Wright's, the sections on cannon data are very rudimentary, suggesting that he no longer found this basic information of interest. Metrically, the Gunmen MS suggests a different approach to recipes in that the most common measure of ingredients is a "lead". Clearly a unit of weight, it is not a *specific* unit of weight.[80] Nor in many cases are Gunmen recipes specific in their amounts. Instead they prescribe relative amounts for the various ingredients. So the recipe for "fire balls" that burn in water, uses "vndressed lime, Sulphire and olye benedick, of each like quantity" (fol. 130^{v}) and for a "speciall ffire" prescribes "vnwrought lime & soe much Swanell as chalke
& oyle of Linseede" (fol. 131^{v}). In a few cases, he does provide measures in pounds or ounces, and in others he mixes ill-defined units (*e.g.*, a "scope", scoop) with proper ones (ounces; fol. 132^{v}). By and large, however, the recipes are clearly designed to allow the user to create batches of whatever size he wishes. This, too, reinforces the impression that it is a more advanced manual than Wright's, designed for a more advanced gunner.

One might assume, then, that this is a later manuscript and perhaps the Bodleian Library catalogue's dating to *temp. Jas. I* should stand, but the prominent and repeated mention of chambers suggests an earlier, rather than a later, date. While it is true that chambered pieces continued in use until well into the seventeenth century,[81] gunnery textbooks ceased dealing with them by the time of Robert Norton (1628), and even Thomas Smith (1600) only mentions

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[79] That is, a flame-thrower, not a pump for water to put *out* fires.

[80] R.E. Zupko, *British Weights and Measures: a History from Antiquity to the Seventeenth Century* (Madison, 1977) , p. 85, notes that the plumbers were given jurisdiction over all lead weight measures in London in 1611, suggesting a wide range of sizes was in use.

[81] Robert D. Smith, "Bombards, Serpentines and Murderers: Medieval Artillery?" 32nd International Congress on Medieval Studies, Kalamazoo, Mich., 10 May 1997.

them in passing. One could argue that the Gunmen manuscript might reflect a niche use of chambered pieces in the time of James I, but that niche would most likely have been on board a ship and the author of the Gunmen manuscript tends to privilege land warfare examples over naval ones. In all likelihood, then, the Gunmen manuscript composition date should be placed somewhere in the reign of Elizabeth, although an earlier date is not impossible.

Again, the Gunmen manuscript demonstrates a fixation on firework recipes. By and large, they differ little from the Wright recipes. This author, too, uses a wide range of ingredients, some of which also elude identification. "Swanells" figure prominently in the recipes. In some cases it seems to provide the sulphurous ingredient but he also frequently uses brimstone, suggesting otherwise. In one case he instructs the reader to melt "swanels hares & other hares" (fol. 130^{v}) and in another place we learn that candles can be made of swanels (fol. 131). "Hares" cannot mean "hairs", as hair does not melt, but it may be a corruption of "herl", feathers, then swanells may be subcutaneous swan fat. This would be in keeping with at least some of the recipes that call for the ingredient, those for fireworks that burn under water or that cannot be extinguished by water. The use of sympathetic magic, in this case fat from a waterfowl preventing aqueous dousing,[82] should not be ruled out as these recipes are not so far removed from their magical past as we might wish to believe. The ingredient "harpoys" is called for in a number of places, although this ingredient is entirely mysterious. Numerous trace ingredients adjust the mixtures: linseed and hemp oil; oil benedict and "oil of Notts"; both "peter oyle" and "heter oil" (not apparently a scribal error); "Spanish greene Camphire" which suggests import and presumably higher expense; "grey salt", probably a

[82] Conrad Keysar also suggests the use of waterfowl's fat in some recipe in the *Bellifortis*; thanks to Bert Hall for this reference.

form of unrefined sea-salt; and other oddities like "gueese pitch" of goose fat, "Sweete powder" perhaps analogous to the herb distilation known as "sweet oil," and the ambiguous "burne stone that is called Amery". In some cases, the author appears as a Paracelsian in his terminology, where salts and fats provide determining qualities for the various tests. His learning also seems more advanced than Wright in that he occasionally uses the Latinate names for his ingredients, as in "olin lini" for linseed oil, "olen bartari" for another type of oil (fol. 130^{v}) and "gerili sublimat" for some sublimated (oxidized) substance (fol. 131).[83]

Beyond the firework recipes and a brief section on cannon proving, the latter half of the manuscript concentrates on the mathematical subject of range finding using a quadrant or other means. In the description of the quadrant construction, the Gunmen author clearly enters new territory, for he leaves behind the simple descriptions found in the recipe section, turning instead to more verbose step-by-step directions. He also begins introducing new terminology, signaled by phrases such as "which is called" or "which shalbe callid." And these new terms are the Latin names of quadrants' various parts: "Lymbus" for the quarter-circle plate with the gradations marked upon it, "umbra" (both "errant" and "versa") for the shadow lines marked on the limbus, and "scala altimetra" for the vertical marking scale. A long passage then follows on how to read the scale in various situations; if, for example, sighting to the top of a tower the plumb line hangs on 6 (of the 12-point scale; *i.e.*, 45°), then you are as far from the tower as the tower is high. The other readings do not lend themselves nearly as easily to simple calculation rules, nor does the author

[83] We cannot entirely discount that these terms may have crept in through the agency of the copyist, who would have been more likely to have known Latin. Nevertheless, the overall feeling of the Gunmen author is of more advanced learning and possibly a more advanced gunnery student.

provide the correct ones. For most readings, his method takes the reciprocal ratio plus or minus some unrelated proportion. So, if the plumb lies on 11, "y^{n} you haue ye eleuenth part of the height of the Tower adding the strength of your eyes from vpon the grounde" (fol. 134). That is, if the quadrant reads $7\frac{1}{2}°$ (11 on a 12-point scale), he claims that the tower is 0.091 as high as your distance from it, plus the height to your eyes. The correct ratio is approximately 0.132 times as high (tan $7\frac{1}{2}°$), plus your height. He provides similar rules for the other points on the quadrant, with varying degrees of accuracy, but in the absence of an understanding of decimals or trigonometry, his rules end up hopelessly complicated.[84]

The quadrant, however, does provide another fundamental rule for the author: "The rule of the quadrante sheweth as masters teach how farr soe much powder may cast such a shot at poynte blanke & soe from degree to degree to the best of the random," (fol. 143^{v}) or in other words, relative ranges. Here, the author is very clear on the rule: the utmost random range is five and a half times as far as the point blank range. And while in the preceding discussion of height-finding he never mentioned degrees at all, here he implies that a gunner could calculate the ranges degree by degree using the quadrant.[85] In this area the Gunmen only just begins to approach the concern shown for ranges by the printed books, and nowhere comes close to Harriot's analysis, flawed as it may be. In the discussions of ranges, however, the Gunmen writer adds some detail not found in other manuscript sources, but sometimes that is echoed in the

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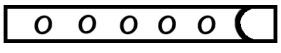
[84] There is also the additional difficulty of the author's understanding of the *umbra* and *versa* scales. In general, quadrants were marked with 12-point scales, but in some cases both the *scala umbra* and *scala versa* (*i.e.*, 45° rather than the full 90°) were marked with their own 12-point scales (*i.e.*, a "point could be either $3\frac{3}{4}°$ or $7\frac{1}{2}°$). See A. Simi and L.T. Rigatelli, "Some 14th and 15th Century Texts on Practical Geometry," in M. Folkerts and J.P. Hogendijk (eds.), *Vestigia Mathematica* (Amsterdam, 1993), pp. 459-60.

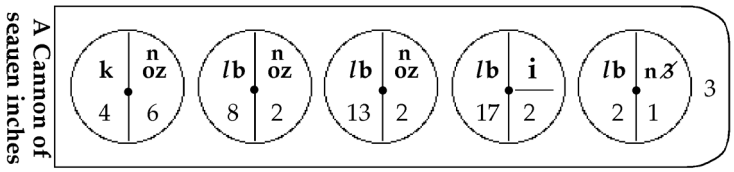
[85] Depending upon the quadrant's scales, this method could provide a sinusoidal rage function, rather than the linear one usually assumed (see ch. 3, n. 99, above); the range function should be parabolic. Unfortunately, the Gunmen MS does not specify the exact relationship.

printed works, namely a discussion of *why* different pieces shoot different distances. For example, the "bastard Caliuer" (*i.e.*, a bastard culverin) will cast "at poynte blanke xxi score & a quarter, ye reason is because the shot is more of weight and more of length which euer causeth the shot to voyde wth more violence" (fol. 136), a sort of Aristotelian impetus-like theory. There is no reason to assume higher learning, however, since the term "violent" need not automatically imply Aristotelian motion theory. Bourne, for example, speaks of the "vyolence of the blast of the pouder."[86] But the notion that a larger shot would fly farther does suggest a certain internalization of impetus theory over purely Aristotelian understanding of motion. On the other hand, the author also picked up on the "longer-is-better" maxim current in sixteenth century gunners, as he noted that a "Demy Culveryn… shall cast at poynte blanke 18 scores because the peice is of alonge length," specifically above "26 balls of length." This 26-calibre maxim appears in Diego Uffano's treatise of 1614, but there is no reason to believe that it was not common knowledge before that time.

One last facet of the Gunmen manuscript deserves mention. The author frequently makes use of interlineal illustrations to describe the concept at hand. The illustrations are very crude, and if we can assume that the copyist drew them very close to the originals, they provide another example of the non-textbook nature of this class of document. It would be impossible to construct the object described in the manuscript from the illustrations given, but clearly the author felt it necessary to illustrate a salient feature of the object that he found difficult to convey in words. So, in his description of a fire pump, he writes "you must haue a pompe of wood in this forme  hollowed out" (fol. 132), which is clearly insufficient to construct a pump unless you already knew how to make pumps and this was but one type. Similarly, in the instructions for

[86] W. Bourne, *Arte of Shooting in Great Ordnaunce*, p. 38.

a type of flare, all he says is that "you shall haue apipe or forme oppen in this figure  " (fol. 131^{v}). Although these are insufficient for an outside reader to use, they do suggest the author was more of a visual thinker than a textual thinker, an impression reinforced by other diagrammatic elements in the manuscript. Included are tables for charges of cannon which resemble the cannon themselves, although what data they actually represent is not clear:



(fol. 134^{v}[left] and 137 [below])

And in another place, the author includes a table of powder capacities for different ladles which is a direct visual transcription of the marking scale from a carpenter's ruler (fol. 136^{v}).[87]

We are once again left, then, with a culture which is entering the written form, but still very much grounded in the visual and tactile realm. The manuscripts provided a transitional format as the craft tradition evolved into a more academic, scholastic tradition as would be embodied in later seventeenth- and eighteenth-century instruction textbooks. In Elizabethan times, however, the equipment and discipline itself were insufficiently regularized – which is not necessarily to say standardized – for that development to have taken place. Nonetheless, the practitioners could see that such developments were possible

[87] See S. Johnston, "The Carpenter's Rule: Instruments, Practitioners, and Artisans in 16th Century England," in G. Dragoni, A. McConnell, and G.L.E. Turner (eds.), *Proceedings of the Eleventh International Scientific Instrument Symposium, Bologna University, 9-14 September 1991* (Bologna, 1994), pp. 39-45.

and desirable, and thus worked towards that goal. Manuscript manuals provide insight into the practice of gunnery which are unavailable to reader of printed sixteenth-century treatises on the subject. Manuscripts include material not covered by printed books, and printed books cover material not found in the manuscript manuals. Although they could both be created by practitioners (manuscripts more likely than books, however), their audiences were one and the same yet worlds apart. The books often loose sight of the minutiae in order to impart an overall, and therefore imperfect, understanding. Manuscripts revel in the minutia, taking the overall for granted. "Gunnery", as an unknown art or science has windows both from above (the books) and below (the manuscripts), both of which reflect the practice but transmit its essence in two very different directions. From here, then, the question is how all this knowledge was used by the Elizabethan military.

Figure 4.1

Richard Wright, Novice Gunner, 1563
(from London, Society of Antiquaries MS 94, fol. 5v)

Figure 4.2

Variation in Artillery Shot Diameter
(from English ordnance tables, c.1540-c.1650)

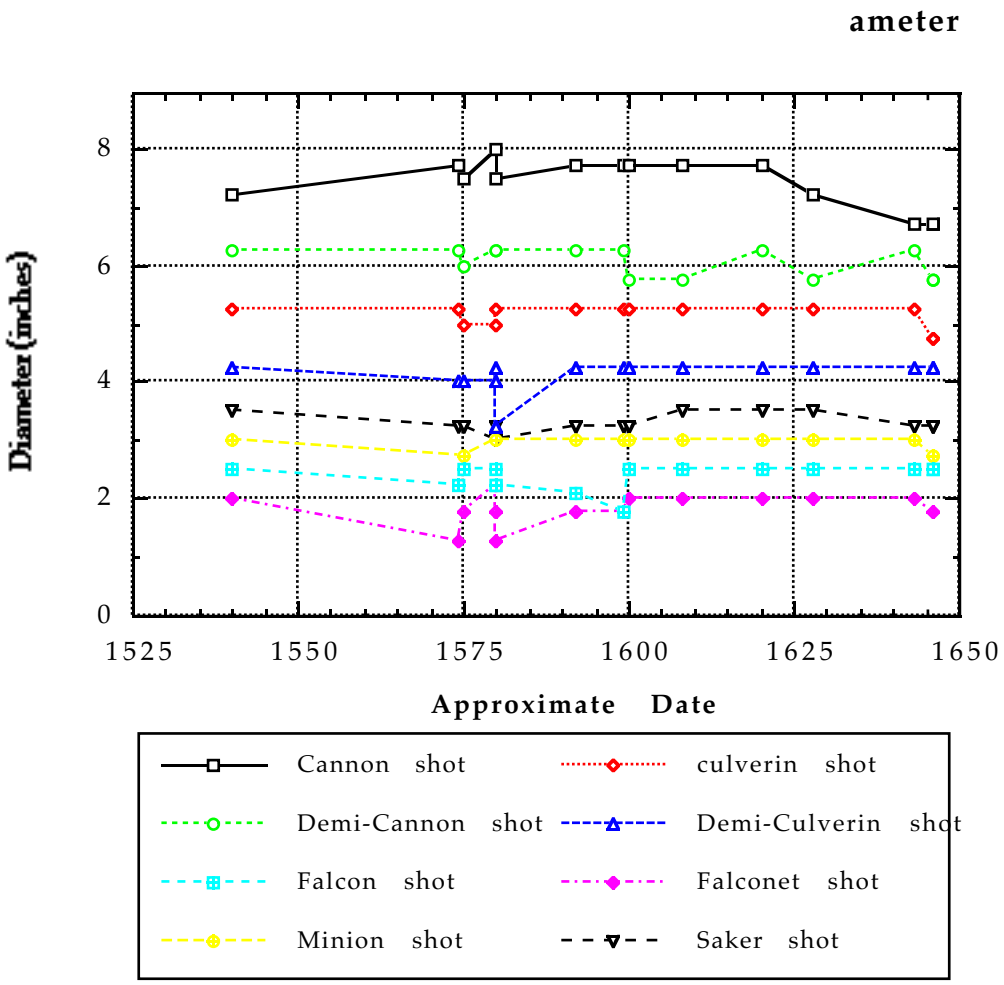


Figure 4.3

Variation in Density from Shot Weight Calculations
(from Thomas Smith, *The Arte of Gunnerye* [MS version,, 1608], fol. 9v)

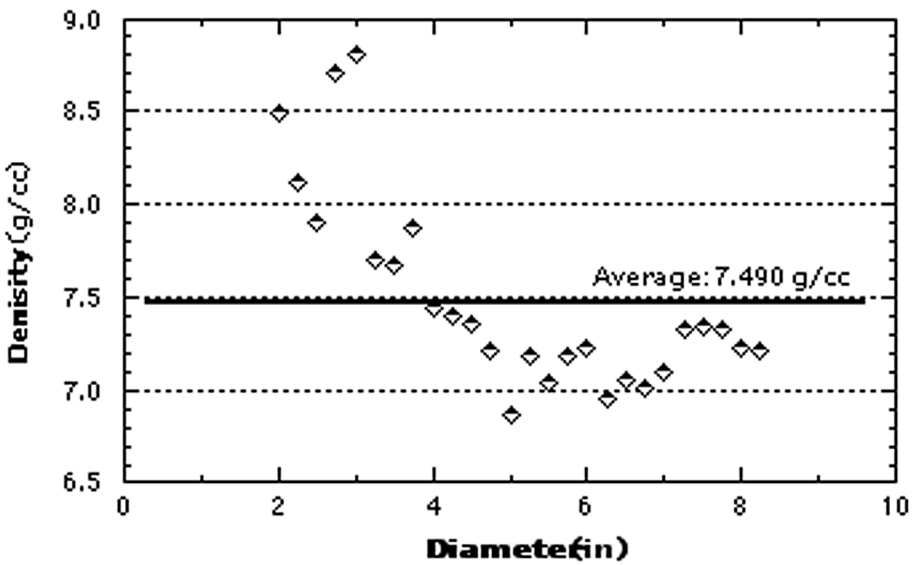


Figure 4.4

Comparison of Shot Diameters and Weights
(from English ordnance tables, c.1560-1620)

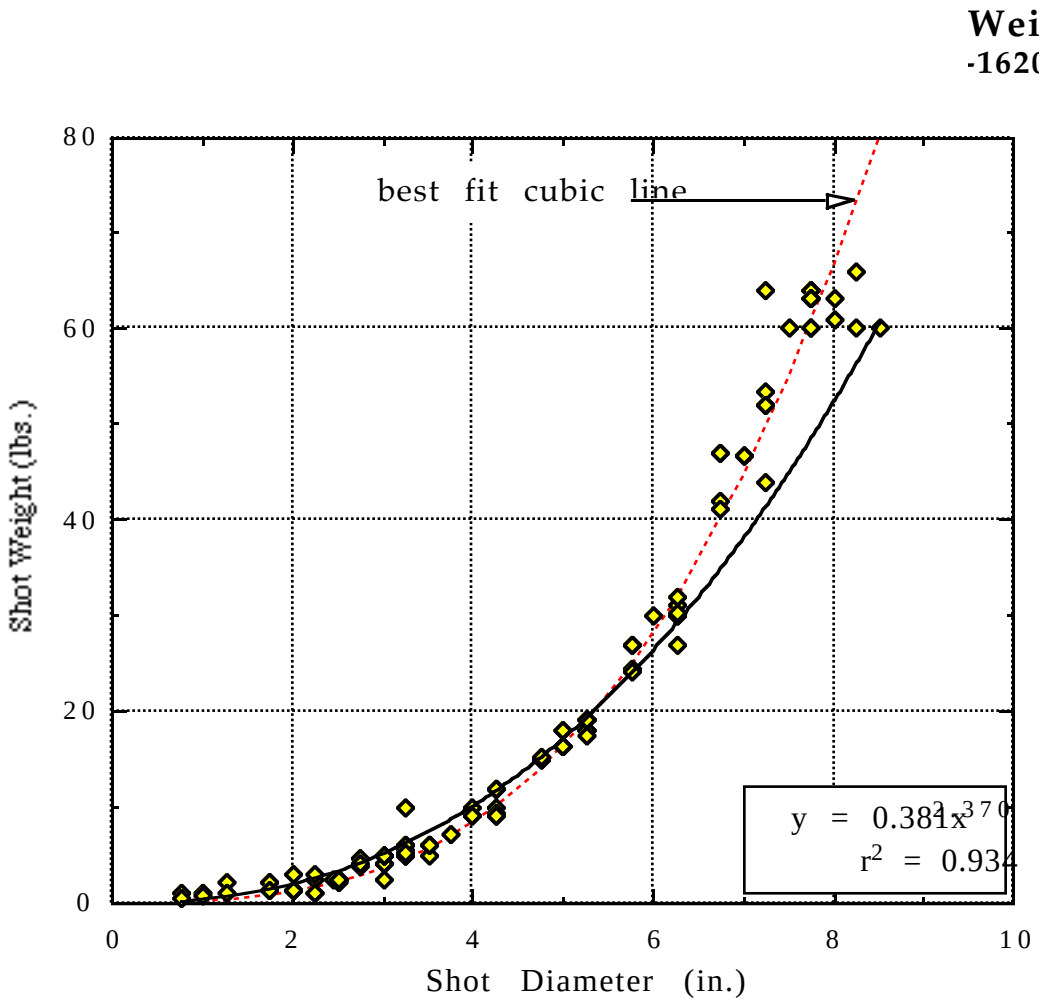
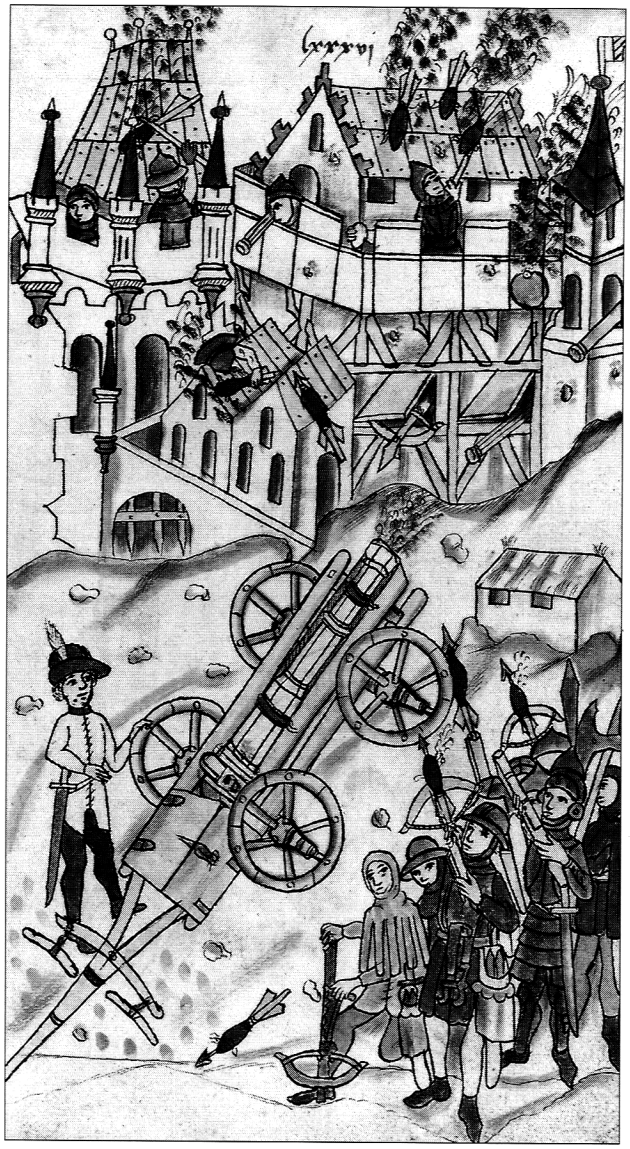


Figure 4.5

Soldiers Attack a Town with Fire Arrows (*c*1450)
(from the Tower *Feuerwerkbuch* [Bailey (1996), fig. 3, p. 64])



Chapter 5

Artillery and Tudor Military Tactics

As a breaker of ramparts and walls /Am I known
O'er mountain and valley fly balls / By me thrown
— cannon inscription*

Introduction

The English army arose out of the Civil War, or so you will read in many surveys of this institution. The fourth edition of Sheppard's *A Short History of the British Army*, for example, devotes all of twelve pages to "The Beginnings of the British Army, 55 B.C. - A.D. 1660" and eight of those to the Civil War Era developments. In his opinion, "apart from certain isolated military episodes such as Flodden, the period of close on 200 years, from 1485 to 1642, must from the point of view of military history be regarded as a fallow one."[1] Even Charles Oman's great survey of sixteenth century warfare suggests that the entire century is "singularly dull from the point of view of the historian of the [English] art of war."[2] But no fallow field may bear crops without sowing some seeds or for that matter, plowing the soil. And it was in the sixteenth century that artillery had developed to a degree that it began to sprout in the military establishment of England, even if its growing season started a bit later than those of the Continental powers.

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* Inscription (original in Dutch) on the bronze cannon known as "Queen Elizabeth's Pocket Pistol" (now at Dover) given to Henry VIII by Maximilian, Count of Buren in 1544. Quoted and translated in H.L. Blackmore, *The Armouries of the Tower of London. I. Ordnance* (London, 1976), p. 48.

[1] E.W. Sheppard, *A Short History of the British Army* (London, 1950) , p. 7.

[2] C.W.C. Oman, *A History of the Art of War in the Sixteenth Century* (Eltree, Hertfordshire, 1937) , p. 368. His further suggestion that "its interest is political, diplomatic, commercial, religious, literary, exploratory, but not naval," I believe misses the point, in that the "military" was largely intermingled with at least 4 of these other 6 societal factors. Still he concludes this same chapter opining that "the reign of Elizabeth makes a very depressing chapter in the history of the English Art of War" (p. 388). This negative view is also found throughout the writings of R.B. Wernham, especially *After the Armada*, whose popularizing works have spread the "David that was England – Goliath that was Spain" concept. See also the recent D. Eltis, *The Military Revolution in Sixteenth-Century Europe* (London, 1995), ch.5.

Thankfully, not all generalized histories are as dismissive of the Tudor era, although to be sure, no one has come out in strong support for its importance.[3] Sheppard is right in noting that the sixteenth-century English army looked nothing like the modern standing, professional army responsible to a military bureaucratic arm of the government. In some ways her sixteenth-century armies were more centralized than this and in other ways more decentralized. So, for example, the army was run directly by the Privy Council, yet individual captains recruited, clothed, armed, and victualled their men, which of course encouraged corruption from both ends. The one area which did not fit this centralized decentralization, however, and which mirrors the modern understanding of military organization was the artillery. In order to examine the use of artillery by the gunners, however, we must seek an understanding of the bureaucratic position of artillery in the British military.

Sixteenth-Century English Artillery

The Board of Ordnance had existed since the early fifteenth century as part of the Privy Wardrobe, but Henry VIII expanded and made it independent specifically to oversee the King's troops in all their facets. By the middle of the sixteenth century, however, it had evolved (or, more properly, devolved) into a government body theoretically responsible for the supply of equipment to the troops, but in reality primarily responsible for the purchasing and control of large gunpowder artillery and ancillary supplies. While they did keep track of the traditional munitions of bows, armor, and pole arms, these supplies

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[3] See, for example, C. Barnett, *Britain and Her Army, 1509-1970* (London, 1970), ch. 1, "The Rise of the Nation State, 1509-1603," pp. 3-58, for a brief positive assessment. Sir Geoffrey Elton noted that "It very much looks as though by the early 16th century the English were not a martial people, or at least not a military one; a call to war found no ready response among them"; G. Elton, "War and the English in the Reign of Henry VIII," in L. Freedman, P. Hayes, and R. O'Neill (eds.), *War, Strategy, and International Politics: Essays in Honour of Sir Michael Howard* (Oxford, 1992), p. 10.

gradually shrank throughout the century as warfare moved towards gunpowder weaponry. Headquartered in the Tower of London along with the mint, Royal Armoury, and prison, the Ordnance Office became home to a large proportion of England's professional artillerymen who were known as "fee'd gunners of the Tower."[4] These grants are often assumed to have been pure sinecures, places where old faithful servants were put away to age gracefully on pension. While this may have been true in some cases, and it was more likely the case at fortifications outside London,[5] a survey of the records indicates that the men given rooms at the Tower were active members of the Ordnance establishment.[6]

Long neglected, the common soldier has undergone something of a renaissance since the 1970s. Perhaps in the face of the debacle of the Vietnam conflict, and certainly as a consequence of the societal revolutions of the 1960s (both of which were of course intimately related), historians like John Kegan have called for a reappraisal of the experience of the soldier on the battlefield, rather than the story of the officer in the staff-room.[7] In the case of the artillery,

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[4] The term "fee'd gunner" refers to a gunner who had received a royal patent, usually for life, of a "gunner's room in the Tower of London." These patents came with a yearly stipend, or "fee", usually specified as a *per diem* wage (between 6*s* and 12*s*) to be paid annually. Although the records for these fee'd grants pepper the CPR volumes and appear to be full-time salaried positions, as will be shown below, surviving records suggest that very few of the fee'd gunners worked anything even approaching full time. Similarly, there is no evidence one way or the other how many of these gunners actually lodged in the "gunner's rooms" they had been granted; the Tower did, however, have at least some gunners in full-time residence. Shakespeare has Viola respond haughtily to Olivia, "I am no fee'd post, lady; keep your purse" (*Twelfth Night*, I.v.268).

[5] As for example at Berwick, where in 1580, an Ordnance Office document recorded the "old Garrison" as having 28 gunners paid a total of £284, while the same number of gunners were paid £580 in the "new Crewe". This probably reflects a sort of pension plan. B.L., Sloane MS 3194, fol. 20.

[6] This generalization is based upon a survey of the grants to gunners recorded in the CPR. I have surveyed the period from Edward VI into the mid-1570s and while a few gunners fees are quickly re-granted upon the death of the holder, most continue for decades. In addition, a fair number turn over in reversion, suggesting that the holders voluntarily gave up their post for some other pursuit, again not indicative of an entirely aged and decrepit staff of gunners. See also below for a discussion of the day-to-day activities of the gunners.

[7] J. Kegan, *The Face of Battle: Agincourt, Waterloo and the Somme* (London, 1976).

the common men were the gunners and master-gunners serving the Crown, merchant ships, and in come cases, chartered towns. In most cases, however, these gunners did not leave records of themselves (if they even could have).[8] Rather, we know of them only as names on lists and pawn for higher-ranking military officers to assign or request as necessary. Despite this apparent unimportance in the military hierarchy, gunners actually enjoyed a position comparable to "skilled" professions like surgeons and preachers.

Since the Ordnance Office developed outside the normal military hierarchies of the Tudor army and navy, its structure reflected a rather strange set of priorities. Common laborers were used to move the cannon and their *materiel*, and gunners operated them, usually in two to four man crews, depending on the calibre of the gun. For every administrative unit, be it a ship, a squadron of ships, a garrison, or a field expedition, a master gunner was appointed to oversee the gunners in his command, but he was still very much a line soldier in terms of handling his equipment. In this sense, he is one of the first classes of soldier to be acknowledged for his expertise rather than simply for his corporeality. At this level, the command structure reflected that of the captains and their infantry bands, although unlike those captains, master gunners were not responsible for raising an allotment of gunners; they were, however, responsible for trying to get the government to pay, feed, and clothe their gunners.[9] Above the master gunners in each unit – and note that a master gunner did not necessarily exist for *each* unit; they were created or shifted as need arose – the next ranking officer was the Master of the Ordnance. There were no intermediate grades as were found in the footbands, the cavalry, or the

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[8] Recall that John Phillippes could not sign his name (ch.4, n. 9, above).

[9] On the clothing, see the request from William Thomas, master-gunner of Flushing (*q.v.*, ch. 7, below) in L&A, vol. 2 (July 1590 - May 1591), no. 62, p. 112 and Burghley's comment to Thomas Shirley in L&A, vol. 1 (Aug. 1589 - June 1590), no. 158, p. 144.

navy. The various units would obviously be attached as necessary to a expedition and for that time might be directed by the expedition leader, as for example, in the battle of Nieuwpoort in 1600 where Maurice of Nassau used Sir Francis Vere's cannoneers to good effect,[10] but in towns or fortifications, the gunners' natural habitat, as it were, they were largely their own masters. As for the education of the gunner, there is no evidence whatsoever from the reigns of Henry VII or Henry VIII. What little can be inferred about Edward VI and Mary's periods all comes from the reign of Elizabeth. Training was of course necessary in all periods, but as far as we can tell, it was not regularized or codified in any way. Gunnery logistics will be handled in the next chapter and gunners' training in chapter seven. An understanding of Tudor gunnery, however, requires an understanding of its bureaucratic and strategic position in the Tudor military.

Henrician and Edwardian Artillery

The position of "master gunner" or "gonner" goes back at least to The Wars of the Roses, when Patrick de la Meyte became "chief gunner" in 1484 . A succession of "chief gunners", "master gunners of the ordnance", and "master gunners in / of the Tower" continued until 1571, when Anthony Fenrutter became the "master gunner of England", suggesting that it was not until well into Elizabeth's reign that regal power extended far enough to create a truly national Ordnance Office.[11] This is the only permanent gunnery post in the government, all others existing only for the duration of the assignment, such as the Master Gunners of Flushing or Brill during the Dutch expedition. This failure to develop a bureaucracy deserves a moment of attention if the contention that

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[10] J.P. Puype, "Victory at Nieuwpoort, 2 July 1600," in M. Van Der Hoeven (ed.), *Exercise of Arms: Warfare in the Netherlands, 1568-1648* (Leiden, 1998), pp. 69-112.

[11] See O.F.G. Hogg, *English Artillery, 1326-1716* (London, 1963) , pp. 101-2 and 276.

artillery use developed during the Tudor period is to be maintained. Henry VIII had inherited a substantial store of guns from his father (despite Oman's contention that artillery was largely "despised" during the Wars of the Roses),[12] but unlike Elizabeth, he was more than interested in producing and using artillery. The story of Henry VIII's military aptitude and zeal need not be repeated here, for any student of Renaissance English history will likely hold in mind the image of an older, portly, bearded Henry in sumptuous finery with the huge codpiece: the very model of an Early Modern major general.[13] In the area of gunnery, however, Henry was for a time, especially zealous. Henry nearly bankrupted England in his desire for military hardware, but in the process he imported foreign craftsmen to build up England's native armament industry. From the German armourers in the early years of Henry VIII's reign working in Southwark and eventually Royal workshops in Greenwich (founded 1515),[14] to German and Italian engineers designing his elaborate coastal fortifications in the 1540s,[15] Henry spared no expense to promote his image as a proper Renaissance warrior and England's rightful place among Renaissance states.

Although never a great fan of small gunpowder weapons in his campaigns, Henry for a time lavished much of his attention on great ordnance.[16]

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[12] C.W.C. Oman, *Art of War in the Sixteenth Century*, pp. 284-5. On Henry VII's Ordnance Office, see J.R. Hooker, "Notes on the Organization and Supply of the Tudor Military under Henry VII," *Huntington Library Quarterly* 23 (1959-60): 19-31. Henry VII was indeed aware of the utility of guns and gunners, increasing the latter's number in the Tower from 30 to 47 in the 1490s; E.B. Teesdale, *Gunfounding in the Weald in the Sixteenth Century* (London, 1991), p.10-11.

[13] See R. Strong, *Holbein and Henry VIII* (London, 1967).

[14] A. Williams and A. de Reuck, *The Royal Armoury at Greenwich 1515-1649* (London, 1995) , pp. 26-30.

[15] On this, see L. White, Jr., "Jacopo Aconcio as an Engineer," in his, *Medieval Religion and Technology* (Berkeley, 1978), pp. 149-74 and M. Merriman, "Italian Military Engineers in Britain in the 1540s," in S. Tyacke (ed.), *English Map-Making 1500-1650: Historical Essays* (London, 1983), pp. 57-67.

[16] In this he seems to have been following the lead of his brother-in-law, James IV of Scotland, and also Emperor Maximilian I; H.L. Blackmore, *The Armouries of the Tower of London*, p. 4-5*f*. See also C.S.L. Davies, "Henry VIII and Henry V: the Wars in France," in J.L. Watts (ed.), *The End of the Middle Ages?* (Thrupp, 1998), pp. 247-8.

The well-studied story of his elaborate fortification reforms along the coast of England need not be repeated here, but only mentioned to remind us that fortification is of course the other side of artillery. In the first decade of his reign Henry purchased over 140 cannon from Hans Poppenruyter in the Netherlands and by about 1514, he had brought Peter Baude from France to begin a domestic cannon foundry.[17] In one case he had a triple-barreled and a seven-barreled brass saker cast to his specifications by Baude; although strikingly novel for his or anyone's day, their utility was never as great as their promise.[18] During his reign, Henry made three expeditions to France in 1513-16, 1522-23 and 1543-45. In 1513 he made a great show of his artillery train, and visual representations of the campaigns bristle with many cannon barrels protruding from his ships and fortresses. In battle scenes, however, the artists reverted to more traditional medieval imagery, leaving the artillery marginalized.[19] In his third expedition, illustrations again bristle with artillery; the reality was less grand, despite the drawn out siege of Boulogne in 1544.[20]

While prominent in the visual rhetoric of Henry's reign, in terms of the *use* of artillery, his reign was relatively sterile (although the same cannot be said

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[17] Teesdale, *Gunfounding in the Weald in the Sixteenth Century*, pp. 12-13*f*. Baude was also made a gunner in the Tower in 1528. Occasions where gunners were active Ordnance Office suppliers grew more and more rare as the century progressed.

[18] H.L. Blackmore, *The Armouries of the Tower of London*, no. 28, pp. 58-9 and pl. 6-7. The 3-barreled piece is now on display at the Tower, the 7-barreled one having been lost in the 1841 Tower fire.

[19] For example, the Battle of the Spurs is always depicted as a mass of infantry and cavalry battle. When cannon are illustrated, they appear as marginalia, as in the illustration reproduced in C.G. Cruickshank, *Henry VIII and the Invasion of France* (Stroud, Glouc., 1990), p. 99.

[20] See especially the now-lost contemporary mural from Cowdray House, in S.J. Ayolffe, "An Account of Some Ancient English Historical Paintings at Cowdry in Sussex," *Archaeologia* 3 (1775): 239-72 and C.G. Cruickshank, *Henry VIII and the Invasion of France*, fig. 15 and 16, p. 42. On the siege of Boulogne, see J.H. Leslie, "The Siege and Capture of Boulogne – 1544," *JSAHR* 1 (1922): 188-99, L. Macmahon, "The English Invasion of France, 1544," MA thesis (Warwick, 1992), and D.L. Potter, "Diplomacy in the Mid-Sixteenth Century: England and France 1536-1540" (Ph.D., University of Cambridge, 1973). Many thanks to Laura Hunt, CRRS, University of Toronto for these last two references.

for that of his son). At Flodden (9 September 1513), both James IV of Scotland and Henry's forces under Thomas Howard (the Duke of Norfolk and Earl of Surrey) brought artillery trains to the engagement, and in fact, James' was considered by most to be remarkably large and modern for the time. Nevertheless, the battle itself was decided by hand-to-hand combat (and James lost his life to it). James' artillery did allow him to quite quickly take the castles of Norham, Etal, Ford, and Chillingham on his way to Flodden, but despite being dug in on the height of Branxton Hill during the battle, it only served to frighten off a small contingent of Lord Dacre's Borderer contingent.[21] Interestingly, the chronicles of the battle did in one case try to privilege the use of artillery in claiming that it killed Robert Borthwick, the master-gunner of Scotland.[22] And while the supply train exerted great effort in getting Henry's cannon to the various sieges in the first French campaign, by and large they remained a small element in the execution of the campaign.[23] Although he made quite a show of taking the city of Tournai in 1516 with his artillery, the actual battery seems to have had much less effect than the politics of the siege.[24] In the 1522-23 French campaign on the Continent Henry's forces either failed to use artillery to great effect (despite early successes, the season turned against them) or had to retreat for lack of artillery (as at Hesdin), and ultimately accomplished nothing.[25] Henry hired Italian and Dutch gunners who had been solicited for him by Margaret of

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[21] For Flodden, see C.W.C. Oman, *Art of War in the Sixteenth Century*, IV.2, pp. 297-321.

[22] They in fact did not kill him; Oman, p. 314. Such a claim, though, is analogous to claiming to have beaten the enemy's "best" weapon.

[23] See C.G. Cruickshank, *Henry VIII and the Invasion of France*, pp. 63-8.

[24] See *Ibid.* and on Tournai in particular, C.G. Cruickshank, *The English Occupation of Tournai, 1513-1519* (Oxford, 1971). For the political side of Henrician warfare, see G. Elton, "War and the English in the Reign of Henry VIII," (n. 3, above). G. Phillips, "The Army of Henry VIII: a Reassessment," *JSAHR* 75 (1997): 8-22, suggests that to claim that Henry VIII's army was "backward" is to read too much into the (technological) development of weaponry in the first half of the 16th century; he does not, however, discuss artillery, except to note that Henry recognized "the importance of this new arm" of the military (pp. 15-6).

[25] Oman, IV.3, pp. 322-9.

Austria, by which we can infer that few skilled Englishmen could be found to provide the expertise Henry required, and most of his ordnance came from Emperor Charles V's stores.[26] By the 1543-45 campaign the English had provided for a large contingent of artillery for sieges, but failed to use it at Montreuil; Boulogne provided the one high-point of artillery action in the "Enterprise" of France, although the English managed to lose a large proportion of their store within days of the surrender to a late French counter-attack.[27] So while Henry clearly understood the necessity of arming his fleet and coastal defenses with great artillery,[28] during his reign no particular actions ever served to justify his expenditures.

On the other hand, at the battle of Pinkie, one year after Henry's death, the English had clearly learned how to use artillery to good effect. The Duke of Somerset's overall strategy was to establish a 'pale' in Scotland (as in Ireland), but here anchored with great *trace italienne* artillery fortifications that would force the Scots to negotiate and eventually submit. Somerset approached the Scottish line – again apparently firmly entrenched on a ridge as at Flodden – and with a coördinated assault by cavalry and both field and naval artillery, managed a complete victory.[29] By the time of Edward VI, the Ordnance Office had a

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[26] S.J. Gunn, "The Duke of Suffolk's March on Paris in 1523," *English Historical Review* 106 (1986): 599-603.

[27] Oman, IV.4, pp. 330-49, esp. 342-5. Part of the neglect of artillery came from its limited range. For example, when the French built a fort across the river at Outreau to command Boulogne's harbor, their guns were unable to reach the quays and the English ships went to and fro unhindered (p. 349).

[28] Henry's coastal defenses are an entire topic in themselves; see A. Saunders, *Fortress Britain: Artillery Fortifications in the British Isles and Ireland* (Liphook, Hantshire, 1989), ch. 1-3, and the brief but comprehensive B.M. Morley, *Henry VIII and the Development of Coastal Defence* (London, 1976) .

[29] See C.W.C. Oman, *Art of War in the Sixteenth Century*, IV.6, pp. 358-67. The best recent assessment, with tactical maps, is D.H. Caldwell, "The Battle of Pinkie," in N. MacDougall (ed.), *Scotland and War A.D. 79-1918* (Edinburgh, 1991), pp. 61-94. The English field artillery consisted of 15 pieces of ordnance, while the Scots had 25-30 (various sources report 14 bases, 1 culverin, and 3 sakers, plus assorted smaller guns). Caldwell concludes that the Scots were defeated through the use of offshore bombardment which drove the Scottish host towards the English, followed by a judicious use of light artillery among Somerset's forces and heavier guns

network of 109 paid gunners, stationed in castles and defensive works throughout the realm.[30]

Queen Mary, King Philip, and Artillery

Although Somerset had shown the ability of the English artillery early in Edward VI's reign, the ensuing succession difficulties and religious squabbles between his death in 1552 and the death of Mary in 1558 effectively quelled all interest in military matters. Philip II of Spain's marriage to Mary in 1554 could have seen an injection of Continental gunnery knowledge into England at this time, but no such transference took place. Tom Glasgow, Jr., long ago claimed that Philip had an effect on the English military establishment. When planning to escort his father, Charles V, from the Netherlands to Spain in 1555, Philip requested a dozen English ships to serve in the escort. Upon hearing that the English could not provide the ships in time, Philip berated the Council for their unpreparedness, especially as an island nation. This, then – Glasgow claimed – triggered a small flurry of shipbuilding (or at least ship-planning), but as David Loades more recently put it, "the evidence for Philip's role in initiating a fresh phase of naval development boils down to a report of one irritated letter to the English council some two months after he had left England" (in fact, dockyard activity did not substantially increase until Elizabeth's reign).[31] Others have

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planted atop a hill beside Falside castle (in 1558 the English again successfully used offshore bombardment against Henry II's troops in France). By using offshore bombardment, in only 6 hours Somerset recapitulated the French success in reducing St. Andrews' castle the previous May, whereas the Scots under the earl of Arran had failed to take it from land for months. For related analysis of the Scottish case, see I. MacIvor, "Artillery and Major Places of Strength in the Lothians and the East Border, 1513-1542," in D.H. Caldwell (ed.), *Scottish Weapons and Fortifications, 1100-1800* (Edinburgh, 1981), pp. 94-152 and D.H. Caldwell, "The Use and Effect of Weapons: the Scottish Experience," *ROSC* 4 (1988): 53-62.

[30] B.L. MS Harley 240, fol. 9^{v}.

[31] D.M. Loades, *The Tudor Navy: an Administrative, Political and Military History* (Aldershot, 1992), p. 7 and 169-70 (esp. p. 170, n. 1). Loades had initially followed Glasgow (*Mary Tudor: a Life* (Oxford, 1989), p. 280), but his detailed research on the Navy has apparently changed his mind. Philip may have in fact desired a strong English fleet (to augment his own decrepit Atlantic one) to counter the French naval presence, but since his

claimed the Tudor army was affected by the marriage,[32] but at least in the area of artillery, there is no evidence of a transfer of knowledge.

As with proving any negative, it is not clear why the English failed to benefit from their new king and his Continental military. Philip had always been a strong supporter of science and technology and was later to establish an Academy of mathematics, which included a gunnery school, at Burgos in 1582.[33] The armies built up by his father employed all the Continental knowledge then available and had seen practical experience in the Italian Wars and his ongoing was against Henry II in France. Given that there were undoubtedly those in the English military establishment who would have been interested in Italo-Iberian instruction, one wonders why no Spaniards or Italians appear in the Ordnance lists from 1554-8. Throughout the second half of the sixteenth century, in military and other technological areas the English consistently preferred to use their own men rather than import foreigners.[34] It is true that Philip's favour was instrumental in the fortunes of a number of English gentry, such as Walter

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marriage treaty to Mary prohibited him from involving England in that war against Henry II, his hands were tied (p. 163). Glasgow's work on Philip is in his, "The Navy in Philip and Mary's War, 1557-1558," *Mariner's Mirror* 53 (1967): 322, and the theme is continued in his "The Maturing of Naval Administration, 1556-1564," *Mariner's Mirror* 56 (1970): 3-26.

[32] C.S.L. Davies, "Henry VIII and Henry V: the Wars in France," in J.L. Watts (ed.), *The End of the Middle Ages?*, p. 247: "It was not until the militia reforms of Mary's reign (prompted in part at least by King Philip) and of Elizabeth's that a serious attempt was made to modernize English infantry methods and training." Davies here cites D. Eltis, *The Military Revolution in Sixteenth-Century Europe*, ch. 5, "English Military Development," despite the fact that this chapter says nothing about Philip's influence on Mary's army.

[33] D. Goodman, "Philip II's Patronage of Science and Engineering," *British Journal for the History of Science* 16 (1983): 58-8. Goodman notes that ultimately, mathematical instruction for gunners and engineers was less successful than expected. On Philip's father's interests in this area, see W. Eisler, "The «Wunderkammer» of Charles V: the Emperor, Science, Technology and the Expanding World," *Annali dell'Istituto Storico Italo-Germanico in Trento* 19 (1993): 11-52. A.R. Hall, *Ballistics in the Seventeenth Century* (Oxford, 1965), p. 31, also notes that Spain had an artillery school in the 16th century.

[34] Even Glasgow admits this in noting that all the English shipwrights from Mary's time on were English. The only foreigner was on Italian whom Henry VIII had imported. Glasgow, "The Maturing of Naval Administration", p. 10. For the general picture, see L.H. Yungblut, *"Strangers Settled here Amongst us" : Policies, Perceptions, and the Presence of Aliens in Renaissance England* (London, 1996).

Raleigh (Sr.), the Dudley brothers, and Lords Arundel and Pembroke, and it is also true that a number of Englishmen volunteered to serve for Philip in his war in France in 1557-8.[35] But they do not seem to have brought any tangible gunnery knowledge back with them. Since he was forbidden by the marriage treaty to place any Spanish troops in English garrisons, his direct effect upon military affairs was negligible.[36]

While Philip did take some interest in the English military *condition* (particularly the navy), since he could not rule upon Mary's death he had no particular reason to take an interest in the military *affairs* in the country. More likely, since their marriage proved so unpopular so quickly, even if Philip had wanted to reform the English military it would have undoubtedly been seen as a foreign power seizing the home defenses. This in fact became a common element of anti-Spanish propaganda, and a rumor that the Spanish planned to seize the Tower caused panic in the city.[37] Friction between the Spaniards and English was inevitable, and while the nobles did their best to get along (largely by the Spanish nobles departing as soon as tactfully possible), the retainers did not behave as well.[38] As Stone noted, "Philip's suite and the servants of his servants were far less careful than the King was himself not to offend the nation's susceptibilities, and on the slightest provocation, Spaniards produced their knives," a situation which led Philip to prohibit his entire entourage from

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[35] D.M. Loades, *Mary Tudor: a Life*, p. 279.

[36] D.M. Loades, *The Tudor Navy*, p.173; *ibid.*, *The Reign of Mary Tudor: Politics, Government and Religion in England, 1553-1558* (London, 1979), p. 254-5; and *ibid.*, *Mary Tudor*, p. 231. Davies (next note) also claims that Philip personally disliked the military life (p. 186), although he did participate in a number of jousts in late 1554 and early 1555 (Loades, *Mary Tudor*, pp. 332-4).

[37] C.S.L. Davies, "England and the French War, 1557-9," in J. Loach and R. Tittler (eds.), *The Mid-Tudor Polity c.1540-1560* (London, 1980), p. 177. Loades (*Tudor Navy*, p. 173) disagrees with Davies (p. 180) that Philip was directly responsible for Lord Howard being replaced as Admiral by Lord Clinton. For the Tower rumor, See D.M. Loades, *Mary Tudor*, p. 256.

[38] *Ibid.*, p. 229 likened them to modern football fans, "attracting violence even when they were not responsible for inciting it." See also, pp. 256-7 for further incidents of tension between the nationals.

carrying weapons in London.[39] Wyatt's Kentish Rebellion in January and February 1554 might well have become a regional or national uprising if the King of Spain had showed a keen interest in reforming – which is to say controlling – what was seen as England's most powerful technology.[40] Philip wanted England on-side for his designs against France and in the Netherlands; he did not, however, try to make their military an extension of his own.[41]

Elizabethan Artillery

With this sort of negative pressure exerted on any potential influences, it is not surprising that England remained isolated from Continental military influence at the time of Elizabeth's succession. Nor was her ascension any great help to the furtherance of military science. Her own disinterest in martial pursuits combined with her remarkably penurious attitude towards all expenditures frequently stifled any attempt to increase ordnance stores. Further, she avoided embroiling England in the Continental squabbles until quite late in her reign, even if she often gave tacit approval for her subjects to join the fighting (as she did in 1572 when the Sea Beggars revolted against the Spaniards in the Low Countries). While her reign was anything but trouble-free, the numerous conflicts at home never broke out into open fighting – even the Scottish expedition of 1560 she entered begrudgingly. All the difficulties

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[39] J.M. Stone, *The History of Mary I. Queen of England* (London, 1901) , pp. 343-4. He continued: "Affrays were of constant occurrence between Englishmen and Spaniards, and Philip issued to the effect that the first Spaniard who should dare use a weapon was to have his hand cut off… [or] should be hanged."

[40] On Wyatt's Rebellion in general, see D.M. Loades, *Two Tudor Conspiracies* (Cambridge, 1965).

[41] Ironically, Philip was directly responsible for the advances in English navigation *after* he ceased to rule the country. In 1558, just as Mary lay dying, Philip invited the English explorer, Stephen Borough, to visit the *Casa de Contrataction* in Seville where the Spanish concentrated all their maritime and navigational expertise. Borough used the opportunity to observe the workings of the *Casa*, make copies of charts and notes, and obtain a copy of Martin Cortes' *Arte de Navegar*, which was published in English translation in 1561 (Loades, *Tudor Navy*, pp. 176-7).

surrounding factions loyal to her or to Mary Queen of Scots did precipitate a rather unstable beginning to her reign, they were usually not the sort of conflicts that would (or did) precipitate the use of artillery[42] – the siege of Leith in 1560 may be seen as the singular exception.[43] So in that respect, Elizabeth's reign was relatively quiet until the 1580s when she threw in her support for the Dutch rebels, actively began dealing with Irish insurrections, and later, aided Henry of Navarre in France. Although Richard Wright composed his gunnery manual in 1564 (ch. 4, above), gunnery and all things military were not pushed to the forefront of the English consciousness until the end of her reign.[44] What role, then, did artillery play in the main Elizabethan campaigns of the 1580s and 90s?

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[42] The siege of Barnard Castle during the Northern Rising is indicative: when Thomas Percy, Earl of Northumberland, and Charles Neville, Earl of Westmorland, besieged Sir George Bowes, neither the besiegers not the castle had any artillery with which to effect the siege (the castle did surrender as the garrison deserted to the rebels); N. Jones, *The Birth of the Elizabethan Age* (Oxford, 1993), p. 82. Even the small expeditionary force at Newhaven (Le Havre) in 1562 made little use of artillery, since plague and starvation bettered them; *ibid.*, pp. 192-5.

[43] At Leith, the English had about 2 dozen cannon and did acquit themselves respectively, despite failing at the siege. See G. Dickinson (ed.) *Two Missions of Jacques de la Brose* (Edinburgh, 1942), pp. 111-45*ff*. The French had 42 cannon in total. Overall, while both sides clearly privileged artillery, its small effect on the outcome of the siege demonstrates how frequently inefficient cannon was at this time. On the first day of the siege, the English fired all day, "without killing a single person" (p. 117). Repeatedly de la Brose's journal records artillery firing all day to accomplish perhaps a dozen or two dead.

[44] Excluding chivalric themes, of course, which remained popular throughout the period.

Ireland

Ireland has long served as the thorn in the paw of England, and no mouse has yet appeared to remove it, despite some recent hopeful developments. Since the twelfth century incursions of Norman Lords hoping for a quick victory like Hastings, the English have dreamed of subduing the Irish to their rule, and have never quite succeeded. The second half of the sixteenth century saw a particularly troublesome period in Ireland, with local rebellions and feared or realized invasions by Spaniards, French, and sundry other Papists. With regard to the Tudor military, Oman suggested that the "obscure strife… against an irregular enemy [left] behind it certain lessons as to guerrilla warfare, but no record of military importance."[45] While a staff officer might quite rightly dismiss Elizabeth's Irish experience as uninteresting, when considered from the other side of the coin, Ireland largely forms the core of military experience for an entire generation of English military commanders. The rebellions of James Maurice Fitzgerald (1568-73), the Earl of Desmond (1579-83), and Hugh O'Neill, the Earl of Tyrone (1594-1603 – also known as the Nine Year War) drained men and *materiel* from Elizabeth's coffers and employed virtually every well-known Elizabethan hero in a military capacity at one time or another: Sir Walter Raleigh, Sir Robert Cecil, Robert Deveraux the Earl of Essex, Sir George Carew, Sir William FitzWilliam, Sir Charles Blount (Lord Mountjoy), Sir Francis Knolleys, Sir Henry Sidney (Phillip's father), Sir Henry Norreys and his brother Sir John, and even Edmund Spenser (as a non-combatant).[46]

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[45] Oman, p. 368. On the general tenor of the century's conflict in Ireland, see S. O'Domhniall, "Warfare in Sixteenth-Century Ireland," *Irish Historical Studies* 5 (1946): 29-54.

[46] The best works covering Tudor-Irish military relations are S.G. Ellis, "The Tudors and the Origins of the Modern Irish States: a Standing Army," in T. Bartlett and K. Jeffery (eds.), *A Military History of Ireland* (Cambridge, 1996), pp. 116-135 and two related works: N.P. Canny, *The Elizabethan Conquest of Ireland: a Pattern Established, 1565-76* (Hassocks, 1976) and J. McGurk, *The Elizabethan Conquest of Ireland: the 1590s Crisis* (Manchester and New York, 1997).

In one sense, however, Oman's comment rings true, in that the Irish wars were almost all guerrilla actions, which goes far to explain the unimportance of artillery to the English there. This is not to say that the English did not value artillery – in fact, they tended to drag it along on numerous occasions not so much out of actual as out of perceived necessity – but that the siege mentality fostered on the Continent which drove artillery use and development rarely became relevant in Ireland. At one point during the height of the O'Neill Rebellion, even the Queen realized its irrelevance. In a memorandum "conceived by the Queen's Majesty to be imparted to her Deputy and Council in Ireland," and endorsed by Lord Buckhurst, "It appeareth by the books of certificate sent from thence [*i.e.*, Ireland] that there are certain weekly allowances made to preachers, cannoneers, surgeons, and engineers, to the sum of 68*l.* sterling, and above, the week." Elizabeth, always conscious of every penny, proposed to stop payment for these positions: "Touching the cannoneers, for that there is seldom any use of such officers within that realm, Her Majesty's pleasure is to dissolve those allowances, except it be in some times of necessity, to continue no longer than the occasion."[47] The engineers' pay was also discontinued, except on a case-by-case basis, and the pay for preachers and surgeons was entirely discontinued; men already held letters patent for those positions which therefore made these extraordinary payments superfluous. But yet, as the correspondence regarding Edmund Parker in chapter six will show, the commanders in Ireland still greatly valued their cannoneers. So far from being unimportant and dismissed because it was not the Continent, Ireland should be recharacterized as a "practice-ground" for her soldiers and especially

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[47] CSPI, vol. 9 (Mar.-Oct. 1600), pp. 275-6. The entire memorandum fills pp. 272-8. J. McGurk, *Elizabethan Conquest of Ireland* incorrectly ascribes this memo to a muster master (and references the wrong CSPI volume number).

for English artillery and gunners.[48] Despite Elizabeth's reluctance to actually provide her Irish forces with gunpowder and munitions,[49] serving officers there saw the Irish theatre as a chance to learn and practice with these relatively new instruments and hone their skills, should they ever be fortunate enough to serve in Continental conflicts.

Throughout the Irish conflict, though, England was hindered by lack of able gunners and engineers when they were needed. Even as late as the closing year of Elizabeth's reign, Lord Deputy Mountjoy would need to urgently request skilled gunners from other commanders.[50] After Sir George Carew assumed Mastership of the Ordnance for Ireland, he petitioned Lord Burghley for certain reforms in the structure of the Ordnance establishment. He specifically asked that "the clerks, gunners, and artificers attending the Office of the Ordnance [in Dublin], *being very few*, should be efficient men."[51] Complaining that previous Lord Deputies had appointed their own servants to positions for which they were unsuited and that in some cases they did not even attend those offices, he asked to appoint these positions himself so that Elizabeth (and he) might be

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[48] Here I disagree with Michael West's general tenet regarding Ireland vs. the Continent: "The guerrilla warfare of the Irish marches made possible military anachronism that would have been grotesquely out of place in the increasingly mathematical siege warfare of the Lowlands. Spenser's nostalgia for the mounted knight obliquely reflects the essential backwardness of Elizabethan armies" (p. 658-9). Spenser's love on knights may say something about English love of chivalry, but little about the Irish armies. See M. West, "Spenser's Art of War: Chivalric Allegory, Military Technology, and the Elizabethan Mock-Heroic Sensibility," *Renaissance Quarterly* 41 (1988): 654-704.

[49] See, for example, CSPI, vol. 6 (1596-97), 21, 29, 45, 374;*ibid*., vol. 9 (1600), 108, 253, 258, 275; *ibid.*, vol. 10 (1600-1), 223, 381, 389, 443. In general on the supply problems in Ireland, see R.W. Stewart, "The 'Irish Road': Military Supply and Arms for Elizabeth's Army during the O'Niell Rebellion in Ireland, 1598-1601," in M.C. Fissel (ed.), *War and Government in Britain, 1598-1650* (Manchester and New York, 1991), pp. 16-37.

[50] See the section on Edmund Parker in ch. 6, below. Mountjoy requested him because he had "very great use for an engineer for my present journey Northward, having here [Dublin] only one Dutchman, whom [he] suffered to [send] to Connaught, for the necessity of service in those parts"; CCML, vol. 4 (1601-1603), no. 234, p. 233.

[51] Carew to Burghley, 24 May 1591; CCML, vol. 3 (1589-1600), no. 113, pp. 51-53, italics added. Interestingly, he also asked Burghley to replace "needless artificers" such as bowyers, fletchers, joiners, jack-makers, and collar-makers with more up-to-date tradesmen like armourers, "stockers of pieces" (*i.e.*, carriage-makers), pick-makers, and refiners of powder.

better served. His petition bears some resemblance to William Thomas' reasoning from a decade before (see ch. 7, below), suggesting that even though some sort of training existed in London, it had failed to graduate a sufficient number of gunners. Or, more likely, most gunners trained there would either have been assigned to Elizabeth's ships, to forts at home, or have been sent to the Low Countries before being posted to Ireland, in keeping with at least a strategic rationale that Ireland did not need gunners as urgently as other theatres of action.

Part of the problem in Ireland was transportation. In a country with poor roads, and roads actively sabotaged by the local insurgents, transporting great ordnance as well as its supplies was next to impossible.[52] Before the introduction of light, mobile carriages in the mid-seventeenth century, virtually every campaign was hindered at one point or another by the cannon becoming bogged down in wet ground or by their marches being diverted for want of finding a way to get the artillery across rivers or over hills.[53] Even in the Low Countries with its well-developed network of roads and canals, keeping men and artillery functioning was a challenge for lack of proper cartage. As Sir Roger Williams had to explain to the Privy Council at one time, "for want of Carriages in both Armies, as well the enemies as ours, was such that I sawe… bothe the king's & the Duke's [soldiers] faine to leave their Cannon Bulletts… in great

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[52] J. McGurk, *Elizabethan Conquest of Ireland*, pp. 227-8 and see CSPI, vol. 7 (1598-99), p. 242 for the great trouble the English took to get cannon to the Battle of the Yellow Ford.

[53] For example, Henry VIII lost and then regained his prized cannon, "St. John", in a marsh on the way to Guinegate ("The Battle of the Spurs"). The Earl of Surrey had to split his detachment in order to get that artillery across the River Till on the way to Flodden Field. See C.W.C. Oman, *Art of War in the Sixteenth Century*, pp. 292, 307, 310. In other cases, we find a reluctance to commit artillery for fear of loss because pieces were so hard to remove once committed: Henry IV (of Navarre) besieged Paris in Oct./Nov. 1589 but refused to bring the guns into the city, and was consequently driven back (J.X. Evans (ed.) *The Works of Roger Williams* [Oxford, 1972] , p. xxxviii); Maximilian I failed to take Padua in 1509, being unwilling to commit guns so late in the season with the approaching autumn rains (F.L. Taylor, *The Art of War in Italy, 1494-1529* [Cambridge, 1921] , p. 84, n. 5); and the point could easily be belabored.

quantitie behinde them in theire quarters."[54] In Ireland, artillery was "a thing impossible to be conveyed in these countries by land" and in one case a saker, one of the lighter types of cannon, became "bogged [and] staied the battayle so longe that it could not be recovered, and the oxen killed that drew it."[55] No army abandons equipment if it can be helped, and given the higher than average chance that Irish campaigns might force them to do so, the Ordnance Office was less likely to commit heavy ordnance to the country.

The other part of the problem was of course the sort of enemy the English faced. Artillery was as yet not a terribly effective field weapon, being too cumbersome and slow.[56] The only place that the English had a chance to use field artillery against the Irish seems to have been the battle of Blackwater Fort (July 1601), where they used musket shot in falcons and robinets to great effect.[57] Against an enemy who steadfastly refused to meet on the open battlefield, artillery was irrelevant. But the other Irish tactic, that of holing up in a castle, should have precipitated much more activity with great ordnance than it did. Yet even in this, the high-walled Irish castle survived as an effective means of defense until well into the seventeenth century.[58] Often, even if the castle were accessible to artillery, the artillery was of such inferior quality – Ireland having never developed any indigenous cannon-founding industry[59] – that they were

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[54] J.X. Evans, *Works of Roger Williams*, pp. lxiii-lxiv; S.P.F. vol. xxviii, fol. 133.

[55] Quoted from State papers in S. de hÓir, "Guns in Medieval and Tudor Ireland," *The Irish Sword* 15 (1982): 87.

[56] de hÓir reminds us as well that the soggy Irish climate mitigated against using gunpowder weaponry there (p.86). Corning the powder largely alleviated this trouble, but the English were slower to adopt this method than Continental powers; see B.S. Hall, *Weapons and Warfare in Renaissance Europe: Gunpowder, Technology, and Tactics* (Baltimore, 1997).

[57] G.A. Hayes-McCoy, "Strategy and Tactics in Irish Warfare, 1593-1601," *Irish Historical Studies* 2 (1941): 273-4. See also "The Blackwater Forts," *The Irish Sword* 2 (1955): 212-14.

[58] See W.A. McComish, "The Survival of the Irish Castle in an Age of Cannon," *The Irish Sword* 9 (1969): 16-21 and C. Cairns, "Guns & Castles in Tipperary," *Irish Sword* 16 (1985): 110-17.

[59] Although an international arms market existed in Amsterdam, the Irish rebels could not have afforded to import guns, even if they could have eluded the English on the open seas.

often more dangerous to the crew than the besieged. And of course, a gunner who had some inkling of what to do in a siege was necessary although not always forthcoming. This is not to say that cannon were never used at all. Balrath Castle, Co. Westmeath was demolished by the Earl of Kildare (a great exponent of cannon) in 1488, in the first siege employing gunpowder artillery in Ireland.[60] Henry VII, Henry VIII and Elizabeth all sent cannon and gunners to Ireland, but sieges never became the focus of Irish warfare in the way that they did on the Continent.

Of course, for the purposes of this study, the impression of artillery upon the populace at large is of more interest than the actual use of that artillery in the field. For it is the attitudes of those people entering into training that matter with regard to the production of gunners' manuals and of course, those former gunners who wrote books for publication are concerned with the interests of their audience. In this regard, many of the critiques of past military historians have been quite correct in assuming an audience of interested dilettantes for these books. People wanted to know about artillery. It was the "new" thing, even thought it had been around for over 200 years, and many authors fed this need. A case in point is a minor siege in the Irish Wars at the town of Smerwick.

In September, 1580, a foreign fleet appeared off Ireland, intending to land at the harbor of Smerwick, on the north side of a promontory on Ireland's southwest coast, near Dingle.[61] They landed without incident through the stroke of luck that Sir William Winter, the English naval commander, had just left for England (against orders) to reprovision his ships. Given contemporary anxieties,

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Spain, their occasional ally, offered men but never artillery directly to the rebels. In this, they were like most countries, who rarely let valuable cannon out of their control.

[60] S. de hÓir, "Guns in Medieval and Tudor Ireland," p. 81*f*.

[61] For general recapitulations of the event, see C. Falls, *Elizabeth's Irish Wars* (London, 1950) , pp. 138-45. See also F.M. Jones, "The Plan of the Golden Fort at Smerwick, 1580," *Irish Sword* 2 (1954): 41-2.

all assumed that this was a Spanish fleet sent by Philip II to bolster Catholic insurrection in Ireland under the Earl of Desmond. In fact, it seems to have been almost entirely an Italian force raised by the Pope, although with some financial aid and port facilities for the venture provided by Philip (and a few volunteer Spanish captains). The Italians, about 700 strong but apparently preparing for reinforcements, took command of the town. They immediately augmented the earthen defensive works which had built by the rebel James Fitzmaurice in 1569, and mounted their ships' guns on the walls to defend themselves. The Earl of Ormonde marched on the town for the Queen, but he decided not to attack immediately for lack of artillery, eight pieces of which finally arrived with William Winter's revictualled return in early November. In the meantime Ormonde had contented himself with observation, refusing to be taunted by the Italian skirmish parties, while Lord Grey had arrived from Dublin with another 800 men. With Winter's culverins, Grey began to batter Smerwick and within three days the garrison surrendered. This small and relatively insignificant battle would in all likelihood have been relegated to a footnote if Lord Grey had then not promptly executed all 600 of the Papal force.[62]

The relevance of the Siege of Smerwick lies in its atypical use of artillery on both sides. That this was a force of Continental soldiers is indicative in that it was usually only in cases like this that any of the Irish actions revolved around artillery. In that sense, the English passed this test of artillery competency with flying colors. The incident was speedily reported at home in London. A modern eye might expect the execution of the Italian soldiers to provide the drama, but it was in fact a minor consideration. Very shortly after the siege, a certain "A.M."

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[62] Modern reprobation aside, it would appear that Lord Grey's contemporary reputation was far from hindered by this action; see C.G. Canino, "Reconstructing Lord Grey's Reputation: a New View of the *View*," *Sixteenth Century Journal* 29 (1998): 3-18.

published a small pamphlet of 8 pages about the Smerwick landing.[63] Its size indicates the popular appeal such news would have had, playing on fears of Popish plots and Spanish spies. Penetrating beyond that tabloid mentality, the manner of relation of the siege bears examination. A.M. begins by noting that the invaders were "very surely entrenched in the Forte… and sufficiently manned with soldiers, to withstand a far greater force than our Englishe men," and that the ratio of 500 invaders inside a fort and only 800 attackers without is a verie vnequall match… considering the ods of the place."[64] Toying with the events as they happened, he compares the invaders, "having they Ordinaunce, placed at all advauntage," to the English, "naked, utterly without Municion, or opportunity of placing any Ordinance… continually subject to their [*i.e.*, the enemy's cannon] annoyaunce." Upon Winter's arrival with the cannon, which A.M. attributes to fortune (ignoring Winter's insubordination), Grey planted his ordnance "about fowre hundreth paces from the enimies Forte, to batter it." The outcome on that "ninth of November" was that the "Ordinaunce was so well plyed all that day… that they galled the enimie greevously, and beat them away from plying theyr Ordinaunce." The climatic part of the siege for A.M.'s readers came on November 10, when

> they cast an other Trench for small shotte, within an hundreth, and three score paces of the Forte,[65] and began a freshe batterie, and espying certayne Pieces within the Forte, that were lyke to annoy the Campe, planted theyr Ordinance against them, and dismounting two of theyr Demicanons, brake and defeated the rest, to the number of foureteene or fifteene great pieces.

The tract then goes on to describe a third trench at 120 paces from the wall and the "house of boordes" from which musket fire issued, and how the English

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[63] A. M., *The true report of the prosperous succes which God gave vnto our English Souldiours against the forraine bands of our Romaine enemies, lately ariued… in Ireland, in the yeare 1580* (London, 1581).

[64] *Ibid.*, sig. Aiii.

[65] Lord Grey reported that it was within 5 score paces of the fort. See Lord Grey de Wilton to the Queen, 12 November 1580, CSPI, vol. 2 (1574-1585), no 29, extracted on pp. lxix-lxxvi.

"beat that downe with the Ordinance," precipitating the surrender.[66] A rather self-righteous description of the slaughter follows, and the tract concludes with the expected moralizing about the righteousness of the English cause and other rumors of the rebels in Ireland, other Spanish plots, and invasion fleets. A.M. tells his readers that "certayn great Peeces" from the English ships destroyed two Italian demi-cannon and 14 or 15 other great pieces. No heroic individuals are mentioned. The victory is presented as victory of great ordnance over Italian muskets and ordnance, and of course of the righteous English over the Papal enemies.

Even the official reports make reference to the interplay of artillery in this action. Richard Bingham was pleased to report that he had first entered the harbor "within falcon-shot" of their cannon (*i.e.*, the shortest-range type of artillery), but the Italians had harassed him to little effect. He, however, "returned them an exchange better than theirs twenty in the hundred."[67] The Lord Deputy reported that in the opening of the siege the English came within "six score of the rampier" and while over 600 shot, "great and small" were fired on them, "no man touched our side."[68] The English on the other hand, slew three of their soldiers in the night and then next day slew "nine of their chiefest soldiers and one captain… with two shot of our ordnance." Nor is the emphasis on the artillery unique to the news reports; Lord Grey wrote to the Queen that in destroying the little timber house, "Sir William Wynter himself made the shot,"

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[66] The English had clearly learned siege warfare tactics well. The use of three trenches, or parallels, at 400, 160, and 120 "paces" is a very sound method for moving in on and reducing an enemy stronghold (A "geometrical pace" was defined to be 5 feet by T. Smith, *The Arte of Gunnerie* [London, 1600], p. 1). 400 paces (2,000 feet or just over ⅓ of a mile) is quite distant for the first trench, but it may either be a mistake or exaggeration (for 300 paces?) on A.M.'s part, or simply referring to a base camp, which at that distance would have been largely immune to fire from Golden Fort.

[67] Richard Bingham to the Earl of Leicester, 18 October 1580; CCML, vol. 2 (1575-1588), no. 482.

[68] Lord Grey de Wilton to Walsingham, 11 November 1580; CSPI, vol. 2 (1574-1585), no 27, extracted on p. lxviii.

thus acknowledging the importance and interest in the use of artillery by the commanders.[69]

While Smerwick was atypical of Irish military actions during the Tudor reign, and indeed until the Civil War, it nevertheless demonstrates the relish with which contemporary military men regarded artillery. Given the chance, they were happy to use it. Given guns and gunners, they were able to put them to good use. But in the Irish campaigns, where most men served at least some of their tour of duty, without *materiel*, manpower, or clear uses, they rarely got the chance they so desired. That chance, however, appeared in the mid-1580s in the Low Countries.

The Netherlands

The only other major conflict in which England participated in the sixteenth century, and the most important one for the evolution of the military, was the Dutch Revolt in the Netherlands. The Low Countries had become part of the Habsburg dominions, passing to Philip II upon the death of Charles V in 1555. The Dutch, however, were never pleased with this turn of events, seeing Philip as an absentee landlord, and a Catholic one at that. At first, their rebellion consisted of withholding taxes, but by the early 1570s, faced with a Spanish army of occupation, the Netherlanders rose in armed rebellion.[70] The English first became involved at this time, when Sir Humphrey Gilbert led a volunteer force to Flushing in 1572 in an attempt to keep its governance out of the hands of the French, whom they considered puppet bureaucrats for Philip II.[71] Although

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[69] Lord Grey de Wilton to the Queen; *op cit*. (n. 54, above), p. lxxi. This is also reminiscent of Sir George Carew's interest and ability in ordnance (ch. 4, n. 22, above).

[70] The standard work on the Dutch Wars of Independence still remains P. Geyl, *The Revolt of the Netherlands, 1555-1609* (London, 1962) .

[71] C. Wilson, *Queen Elizabeth and the Revolt of the Netherlands* (London, 1970) , pp. 90. Although the Zeelanders wished the English to stay, the French governor rejected their help and without Elizabeth's formal support, English participation in the revolt remained voluntary.

Elizabeth did not formally declare war on Spain or advocate the volunteers' actions, it is clear that Lord Burghley was inclined to do so and since the musters took place quite publicly, it is clear that Elizabeth at least gave her tacit approval. The English volunteer forces continued to reinforce the Dutch throughout the 1570s, but it was the assassination of William of Orange at Delft in 1584 that galvanized Elizabeth into action. In the Treaty of Nonsuch (named after Henry VIII's now-destroyed Nonsuch Palace in Surrey, south of London), England agreed to send troops and supplies to the aid of the Dutch with the return assurance of Flushing and Brill as collateral, the so-called "cautionary towns." Both towns were then to be garrisoned and paid for by England. By December 1585 Englishmen – from veterans of the 1570s conflicts, to nobles eager for glory, to rabble impressed for service – filled the garrisons under the command of Robert Dudley, the Earl of Leicester.[72] Their participation would continue through Elizabeth's reign, although throughout the 1590s the Dutch with their English Allies continually lost ground to Philip's forces. The English involvement ended in 1604 when, after the loss of Ostend the year before and following his conciliatory nature, James I sued for and won peace with Spain.

The Dutch conflict, though, gave a large number of Englishmen their first taste of the "new" European form of land warfare denied them in Ireland or the occasional expedition into France or Scotland earlier in the century.[73] Primarily a defensive force, the English learned first-hand about the new *trace italienne* fortification system and watched as William of Orange and his son, Maurice of Nassau, reformed the infantry in what has come to be known as the "Military

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[72] On Leicester's abortive and mildly disastrous Governorship of the Netherlands, see R.C. Strong and J.A. Van Dorsten, *Leicester's Triumph* (London, 1962) . For an overall reassessment of the English (political) involvement in the Low Countries in the dozen years following the Treaty of Nonsuch, see T. Borman, "Untying the Knot? The Survival of the Anglo-Dutch Alliance, 1587-97," *European History Quarterly* 27 (1997): 307-337.

[73] The best brief introduction is G. Parker, *The Army of Flanders and the Spanish Road, 1567-1659* (Cambridge, 1972) , pp. 3-25, "The Character of the Low Countries' Wars."

Revolution."[74] In addition, some of the ancillary operations, such as the expedition to Portugal in 1589 and the aid to Henry of Navarre in Brittany in the early 1590s allowed the English to experience some limited offensive warfare.[75] Some of the same negative factors operating in Ireland were to be seen in the Low Countries as well: transport difficulties, supply problems, and lack of able men.[76] Nevertheless, even in the Netherlands, artillery still ran a distant third to cavalry and infantry.[77]

Perhaps the best known soldier of Elizabeth's day to put pen to paper recording his activities in the Low Countries was Sir Roger Williams.[78] The child

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[74] This is not the place to go into the entire military revolution debate, but despite all the revision and rejection of the Roberts/Parker thesis, William and Maurice have kept their central place in the debates. Whether one accepts the gradualist thesis of Hall and DeVries, the neo-biological "puncutated equilibrium" of Rogers, or the full-blown Parkerian revolution, the Maurician reforms of the first decade of the 1600s maintain their watershed characteristic; what remains questionable is whether that watershed is a cliff, a beach, or repeatedly inundated salt flats. For a concise recent critique, see K. DeVries, "Catapults are not Atomic Bombs: Redefinition of "Effectiveness" in Premodern Military Technology," *War in History* 4 (1997): 454-70 and for a general survey, D. Eltis, *The Military Revolution in Sixteenth-Century Europe* (London, 1995), esp. ch. 2, "The Military Revolution and the Historians."

[75] For an excellent survey of these, the Dutch, and even some Irish service, see J.S. Nolan, *Sir John Norreys and the Elizabethan Military World* (Exeter, 1997). Throughout, however, the paucity of artillery becomes painfully clear; a *good* siege might have half a dozen cannon (Nolan calls one attempt with only 4 cannon an "almost comic" [p. 143]; they nonetheless succeeded).

[76] See, for example, L&A, vol. 3 (June 1591 - April 1592), no. 266, pp. 200-1, where the "only" deficiencies in the fighting force were cannoneers, miners, and pioneers, and despite having 15 pieces of ordnance, "neither the 'necessaries to draw the ordnance' nor the cannoneers" were to be found. And of course the English felt "the French gunners were not to be trusted to handle this good ordnance." This national prejudice seems to have been common: in 1592 the English sent their own gunners with guns let to de Chatte, "not wanting French cannoneers to handle them" (L&A, vol. 3 [July 1591 - April 1592], no. 326, p. 226). The Ostend captains also complained about the master-gunner, who often left his post "unfurnished"; L&A, vol. 1 (Aug. 1589 - June 1590), no. 200, p. 161-2.

[77] From 1586-90, Elizabeth spent a total of just under £513,000 in the Netherlands. Officer's wages amounted to £45,400, horse £93,000, and foot £350,000. Ordnance only cost £2,000, exclusive of transport, or only 0.4% of total expenditures (all figures rounded); L&A, vol. 2 (July 1590-May 1591), no. 171, pp. 159-60.

[78] J.X. Evans, *Works of Roger Williams* provides the only modern biography of Williams as well as edited editions of Williams' two works. His *Actions of the Low Countries* has also been edited by D.W. Davies (Ithaca: Cornell University Press, 1964). Also well worth reading for explication of these wars is J.S. Nolan, *Sir John Norreys and the Elizabethan Military World*. It is not autobiographical like Williams' work, but Norreys and Williams were often in (conflicting) command of parts of the English expeditionary forces.

of an ancient but not particularly wealthy family from Monmouthshire, Williams was Oxford educated but went immediately into military service after his matriculation in 1554, serving in one continental army after another. For Huguenots and Spaniards he fought wherever he was welcome, although all his life he spurned Ireland as a backwater and considered it only a final alternative to unemployment. He developed quite a reputation for himself as an able, honest, and courageous soldier. When the Dutch revolted against their Spanish masters, Williams was one of the first Englishmen to join in their cause, fighting for 13 years before Elizabeth formally declared her support for the rebels. From 1574-78, while captured by the Spaniards, he fought for and learned from some of the best Continental soldiers, including Julian Romero and Don Juan of Austria. In his youth and after the Armada he fought for Henry of Navarre. His career spanned nearly 40 years and he served in every major conflict of the second half of the sixteenth century. In the final analysis, his words speak louder than any political historian of the conditions and attitudes in warfare of the time.

Williams' biographer, John Evans, laments his lack of attention to artillery, noting that "his neglect of the subject is troubling because European soldiers had long been familiar with heavy artillery."[79] Williams does, however, devote a number of pages to the matter of fortification[80] – much to Evans' pleasure. While Evans is quite right in noting that Williams had little interest in artillery, he errs in suggesting that artillery was not interesting and that Williams ignored it because it was completely ineffectual. Williams frequently mentions artillery and accords it proper respect. What he doesn't assume, however, is that the artillery *should* be decisive. Evans falls into the trap of many modern military historians in assuming that as soon as artillery could be made a science, it would tend to

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[79] J.X. Evans, *Works of Roger Williams*, p. cxxxii (hereafter simply *Works* when referring to Williams' works therein).

[80] Williams, *Briefe Discourse of Warre*, sig. G4^{v}-H3^{v} (*Works*, p. 41-6).

dominate the field; instead he concludes that "gunnery was barely a science, and the genuine master gunner relied less on current theory than on his own singular talent… [which] was a gift of nature, not something to be acquired readily from another soldier or a textbook."[81]

Williams passes over artillery for two reasons. First, as Evans correctly notes, "in William's time [cannon] remained expensive, unpredictable, and often disappointing." In addition, they were used at such short ranges that the skill and erudition Evans wants to see was never a factor. Put simply they were bludgeons, not scalpels.[82] But Williams, as a trained soldier, also considered artillery the domain of specialists in a way that the other branches of the service were not. His names for the various officers in the Spanish army for which he serves belie his distinction between grade officers and artillery specialists not completely bound up in the military hierarchy. Williams notes the principal Spanish officers one would expect – Marshal, General of the Horse, Muster-Master, Treasurer and so on – but the men in charge of the great ordnance, he calls "Gentlemen of the Artillerie."[83] While this is a small peg upon which to hang a large cloak, it is worth noticing that this is the only office in the entire army for which he uses the term "gentleman", not a word to be ascribed lightly in Elizabethan society. This distinction is something that previous military historians have not made, but one worth pursuing. In considering the education of a military leader, various subjects repeatedly appear in the list of things he ought to know: horsemanship, infantry drill, fortification, and artillery. But what

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[81] Evans, p. cxxxiv.

[82] This is not the place to dwell on the skills involved in gunnery (rather, see H.J. Webb, "Elizabethan Field Artillery," *Military Affairs* 19 [1955]: 197-202), but note that in the cases where Williams provides us with a range for the cannon, it is always within "pont-blank" distance. For example, in the second siege of Tergoose, Williams notes that "wee landed sixe Pieces of battery within sixe score of the walls," that is, 120 yards, where as point-blank for cannons and culverins were well over 200 yards; see Williams, *Actions in the Lowe Countries*, sig. M1^{v} (*Works*, p. 118).

[83] Williams, *Briefe Discourse of Warre*, sig. C4^{v} (*Works*, p. 18).

training did they receive in these matters? Of course any knight would need to know how to ride, and had likely been brought up in the saddle. Williams demonstrates that the mainstay of their experience was as infantry and he notes that fortification provided the surest form of success in battle, although this was no doubt conditioned by the fact that the Dutch were fighting an essentially defensive war. Education in artillery, was, however, still something of a rarity. An occasional commander might make use of his allotment of powder and shot for training his gunners, but it was rare.[84] And when gunners (or engineers) were referred to in official dispatches, they were often grouped with preachers and surgeons.[85] No one would hesitate to describe preachers or surgeons as skilled practitioners of their art. It would seem the gunners and engineers also garnered this same sort of respect, albeit on a lower scale. And, indeed, when the Queen finally decided to do something about the chronic shortfalls in pay for her troops, she ordered that "all principal officers of the army and the Council of state *and the cannoneers* (as well as those at Flushing and Brielle) were to receive full pay weekly."[86] Even the muster-masters were only to receive half-pay weekly. Clearly, the gunners commanded a great deal of respect, despite their relatively low rank.

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[84] Francis Drake did so in Plymouth, but Lord Charles Howard warned him that he had better curtail his powder expenditures in doing so (J.S. Corbett, *Drake and the Tudor Navy* [New York, 1899] , II:288).

[85] For example, CSPI, vol. 9 (Mar.-Oct. 1600), p. 64 (this entry only gives the topic of S.P. vol. ccvii, pt. 2, no. 69, but unfortunately not its contents) and L&A, vol. 1 (Aug. 1589 - June 1590), no. 94, p. 123 where Captain N. Errington notes he had to provide pay for his minister and master-gunner out of his own pocket. Sir John Norreys balked when Burghley wanted to reduce dead-pays from 1 in 15 to 1 in 20, since the cannoneers and medical staff were paid from these and the reduction would make it impossible to retain them; J.S. Nolan, *Sir John Norreys and the Elizabethan Military World*, p. 200. J. McGurk, *Elizabethan Conquest of Ireland*, claims without attribution that "preachers and cannoneers, positions *normally filled by the gentlemen volunteers*, were paid in Ireland out of the captain's allowances of 'dead-pays'" (p. 37, emphasis added).

[86] L&A, vol. 1 (Aug. 1589 - June 1590), no. 217, p. 169. Emphasis added. Two years later, Sir John Norreys requested 20 cannoneers and reassured the Council that they "would be bestowed among the companies and so would only cost their sending," thereby implying that cannoneers were considered otherwise "expensive"; L&A, vol. 2 (1590-91), no. 581, p. 346.

Williams does not, as Evans suggests, completely ignore artillery. In fact, his reports are full of references to it but references which apparently do not demonstrate the excitement Evans seems to think ought to appear. In one letter to Burghley, Williams demonstrates full well that in order to hold a port town, 600 men, and 4 demi-cannons and 4 demi-culverins with 3,000 shot and associated powder and match would be necessary.[87] In describing the various sieges he never omits mentioning where the besiegers planted their ordnance, nor the number and size of the pieces. In some cases, he notes what a large undertaking a siege was, as in the case of the siege of Mons in 1572, where Alva's 22 cannons discharged 24,000 shot by his account.[88] But nonetheless, in a section on the differences between "rawe men and expert Souldiers", Williams notes that "it is an errour to thinke that experimented Souldires are sodeinlie made like glasses, in blowing them with a puffe out of an iron instrument."[89]

In July 1587, when Parma invested Sluys with something approaching 10,000 troops, Williams sailed to its defense, coming into the harbor safely despite substantial shore batteries on either side which attempted to stop their entry, although he noted the "danger was not so little".[90] Again we see the same sort of bravado that Raleigh showed in his taking of Fayal (see ch. 2, above), suggesting that there is more to these actions than simple foolhardiness.[91] These

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[87] J.X. Evans, *Works of Roger Williams*, p. lxiii, n. 2.

[88] Williams, *Actions in the Lowe Countries*, sig. G2 (*Works*, p. 91).

[89] Williams, *Briefe Discourse of Warre*, sig. B3^{v} (*Works*, p. 11).

[90] On the siege of Sluys, see G. Mattingly, *The Armada* (Boston, 1959), ch. XII, pp. 129-45; W.E. Griffis, *Motley's Dutch Nation, being the Rise of the Dutch Republic (1555-1584)* (New York and London, 1908) , pp. 711-2.; J.X. Evans, *Works of Roger Williams*, p. xxviii*f*; and Williams, *Briefe Discourse of Warre*, sig. H3^{v}-I3^{v} (*Works*, p. 46-51). This quote is from sig. H4^{v} (p. 47). Williams does note that town defenses can be a danger to passing ships, but never suggests that ships could not relatively safely enter harbors because of it; see his description of the Flushing defenses in *Actions in the Lowe Countries*, sig. Q4^{v} (*Works*, p. 144).

[91] Historians have occasionally censured 16th-century sea captains for fearing to enter a harbor protected by guns, as when Drake failed to enter Lisbon during the counter-Armada. In all likelihood, however, he was trying not to alienate the Portuguese to England's cause (J.S. Corbett, *Drake and the Tudor Navy*, II:92-4, 286-333). By comparison, one author noted that at

seasoned soldiers understood that while artillery was to be respected, it was not to be feared outright. Sluys was eventually lost after a spectacular battery, but most of its casualties came from repelling attacks made in the breached defenses. From Williams' point of view, artillery opened the walls, but was not a serious threat to the soldiers themselves; that very real threat came from the assaults, not the battery. Williams noted the protective value of artillery in that "experimented Captains wil confesse, the furie of all breaches are tried in few hours, and the furie of artillerie prevented without sodaine attempts" (sig. H4^{v}).

In one day (July 14), Sluys was

> battered with thirtie Cannons and eight Culverings on S. Jacobs eve: from three of the clock in the morning untill five in the after noone, they shot above 4000 Cannon shot.[92] By the Dukes [*i.e.*, Parma] owne confession he never saw so furious a batterie in one day: we were made saultable [*i.e.*, breached] above 200. and 50. paces…: we were above five times at the push of the pike for our breach, where wee spoyled the enemies in great numbers… afterwards we kept the Towne 18. daies."
>
> (sig. I1)

As Evans noted, the town held out in all for 60 days and eventually capitulated from lack of men and supplies, not from the battery.[93]

Williams' response is one we should expect from a sixteenth century soldier serving in the Netherlands. To him, although artillery was nothing to laugh at – "where the cannon plaies no defendant dare shew himself"[94] – its main purpose was against fortification which would eventually pave the way for an armed assault, which was the decisive factor. As a commander of foot and as a cavalry officer (as he considered himself), his disparagement of the burden of artillery seems entirely apropos: "[the] Duke d'Alvaes vantguard… marched

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Smerwick in Ireland "the enemy shot 30 shot a day [for 17 days] and neither could hit Ship nor man"; A. M., *The true report*…, sig. Aiii.

[92] Williams counts over 17,400 cannon shot fired on the town during the entire siege (sig. I2) and that they lost 16 of their 20 field pieces to enemy fire.

[93] J.X. Evans, *Works of Roger Williams*, p. cxxxiii. Note, however, that Evans does follow mainstream historical analysis in claiming that when Henry IV besieged Rouen in 1591, he was unable to take the city for want of artillery (pp. lvi-lvii).

[94] Williams, *Briefe Discourse of Warre*, sig. H3 (*Works*, p. 45).

very slowly: and not without reason. For they haled with them two and twentie pieces of batterie, besides some other field pieces, with all the munition belonging to them."[95] It should not be surprising that he does not discuss artillery in the manner Evans would apparently like him to do, that is, from a theoretical point of view. It simply was not a mainstay of a Renaissance soldier's bailiwick. And while artillery might be mentioned in literary accounts of warfare, be they training manuals or news reports, the vast majority of soldiers or pseudo-soldiers would not have trained in artillery, and therefore the authors' concentration on infantry or cavalry warfare should come as no surprise.

Conclusion

Artillery in the English Renaissance, then, starts off with a bang under the two Henrys, declines into a sort of incubationary stupor through the middle of the sixteenth century, and then rises in importance again as the century drew to a close. The English did not spurn cannon – far from it, they seem to have noticed it whenever possible and only a few commentators ever disparaged it entirely (and even there it was small arms they disliked) – but neither did they wholeheartedly embrace it. In 1515 Francis I deployed over 70 pieces at the battle of Marignano; in Brittany in 1591 Sir John Norreys begged for more than four.[96] The age of Nelson and Napolean was to see the true predominance of great ordnance, but that of Henry and Elizabeth saw its first integration into the military organization of the English nation. Yet the integration was far from complete when the Tudor throne passed to the Stuarts (who let it go dormant for a generation), and it would take a Civil War, with very clear need for siege trains on home soil, to fully thrust artillery into the military. We cannot

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[95] Williams, *Actions of the Lowe Countries*, sig. G1^{v} (*Works*, p. 90).

[96] Marignano: D. Eltis, *The Military Revolution in Sixteenth-Century Europe*, p. 24 and B.S. Hall, *Weapons and Warfare in Renaissance Europe*, pp. 174-5. Brittany: L&A, vol. 2 (1590-91), no. 581, p. 346.

reprimand earlier investigators who passed over English Renaissance warfare in a rush to the eighteenth century, but the Tudors' contributions cannot be entirely omitted from the story. It is in fact the other elements of the story – materials (both *materiel* and personnel) for gunnery and the training of gunners – that serve to complete the picture and suggest why the Elizabethan period was not so fallow for gunnery as we have been led to believe.

Chapter 6

Providing Materials for Artillery Warfare

… this day will pour down,
If I conjecture aught, no drizzling shower
But rattleing storm of arrows barbed with fire.
— John Milton*

Introduction

Elizabethans bandied about the terms "Theory" and "Practice" with such great abandon in military affairs, one would think that we would know quite a lot about both. But as the shortcomings of Henry Webb's book, *Elizabethan Military Science: the Books and the Practice*,[1] amply demonstrate, Renaissance Englishmen left to posterity much more information on what they thought about warfare than information on how they actually practiced it. Perhaps this should not be surprising. Warfare was intermittent, foreign, and hardly a preoccupation of the masses. Memoirs were few and far between – in fact, only Leicester and Sir Roger Williams set pen to paper in their lifetimes; Sir Francis Vere started, but his *Commentaries* were not published until after the Civil War. So of the matters that concerned the gunners for Elizabeth's and James' armies as they fought on the seas, in the Netherlands, in Ireland, and more unlikely, in foreign mercenary armies, only scant material is preserved.

Conversely, information about what they fought with is amply preserved. If the Elizabethans provided one development to Western government, it is a love for bureaucracy and bureaucratic record-keeping and preservation (they of course left much more than just this). Frequently, the modern historian may discover list upon list of cannon, men, and supplies assigned to individual ships or garrisons. But the very anonymous and non-analytical nature of these lists can stymie all but the most dedicated statistical

* J. Milton, *Paradise Lost* (New York, 1975), VI.544-6 (p. 140).
[1] H.J. Webb, *Elizabethan Military Science: the Books and the Practice* (Madison, 1965).

historian. Nevertheless, they, too provide important information on the period and supplement our understanding where narrative or contemporary analytical sources stop or simply do not exist. In the analysis of great ordnance, two sorts of useful records exist: Ordnance Office inventories and monthly personnel pay records. Following the analysis of examples of these two record classes, a notebook of an active gunner in the Irish campaign will suggest how one remarkable man made use of the *materiel* during his employment.

Ordnance Inventories

While the English never built up their store of artillery to continental levels, they nonetheless maintained a respectable store for a country not at war. While Henry VIII bought elaborate arms to create the very image of a Renaissance warrior, his son and daughters were never eager to follow in his footsteps, not least of all because he spent so lavishly that he left them relatively little capital. The mid-1580s saw the turning point for ordnance stores, after England became officially involved in the Netherlands and the Armada scare. Consequently, from about 1580 Ordnance Office inventories became more regular and copies survive which provide a glimpse into the military furniture held by the Crown. Comparing surveys from 1580 and 1592 (Table 6.1) indicates how priorities shifted from the first half of Elizabeth's reign, where isolationism and international placation were the rule, to near the end, where necessity and interest combined to build up England's stores of military hardware.[2] The surveys show that in the 12 years England's total

[2] The two surveys are contained in B.L., Sloane MS 3194, fol. 21^{r-v} (1580) and Lambeth Palace Library MS 293 (1592). For an explanation of terms, see Appendix V, below. A few odd pieces of ordnance listed in the 1592 survey have been omitted from the following table and analysis: 2 mortar pieces, 3 robinettes, 2 wagon bases, "one piece made to shoote iij Bullett*es* of ffawconet shott at once wth vj chambres" and "one other pece made to shote vij bullet*e* at once" (fol. 18^{v} – probably the ones cast for Henry VIII by Hans Poppenruyter mentioned in ch. 5, above), as well as a "small quantitie" of cast-iron "ffloukmouthed pieces… never yet founde rated by weight in any former Remaine [*i.e.*, inventory]" (fol. 24). In addition 177 forged iron pieces of ordnance were inventoried at Upnor castle (fol. 25), but seem to have been considered out of service.

Table 6.1: English Artillery on Land or at Sea in 1580 and 1592

Type of Ordnance	**1580**			**1592**		
	Land	Ships	**Total**	Land	Ships	**Total**
Cannon	18	–	**18**	17	27	**44**
Cannon Perrier	14	24	**38**	–	–	–
Demi-Cannon	11	36	**47**	6	68	**74**
Demi-Cannon Perrier	–	5	**5**	–	–	–
Culverins	8	76	**84**	10	193	**203**
Demi-Culverins	20	118	**138**	42	252	**294**
Sakers	11	173	**184**	23	187	**210**
Minions	7 [3]	30	**37**	8	51	**59**
Falcons	–	39	**39**	17	69	**86**
Falconets	20	30	**50**	15	4	**19**
Port Pieces	–	30	**30**	3	29	**32**
Fowlers	–	47	**47**	26	71	**97**
Totals	*109*	*608*	***717***	*167*	*951*	***1,118***

stock of ordnance increased 56%, a large increase to be sure, but not as large as the shift from isolationism to open warfare might have predicted. In this regard, Parker's recent critique of Elizabeth's naval spending is corroborated: "despite her celebrated reputation for parsimony, Elizabeth spent heavily on naval construction [and] maintenance… throughout her reign."[4] In this sense, England's overall military disinterest before the Armada might reasonably be questioned, as John Nolan has recently suggested in terms of troop levels for the second half of the century.[5]

More interestingly, however, the surveys indicate a shift in armament patterns.[6] Table 6.1 provides a synopsis of the two surveys by type of ordnance and storage location, either on land or on the Queen's ships at sea. The category

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[3] This number represents minions *and* falcons in the Tower of London, as the surveyor lumped them together, but in either case they were clearly never a major item kept in the Tower.

[4] G. Parker, "The *Dreadnought* Revolution of Tudor England," *Mariners Mirror* 82 (1996): 284.

[5] J.S. Nolan, "The Militarization of the Elizabethan State," *Journal of Military History* 58 (1994): 391-420. See also C.C. Breight, *Surveillance, Militarism and Elizabethan Drama* (London, 1996) for a post-modern critique of Elizabethan militarism. Breight does not deal in numerical analyses but rather polemic innuendo, but his re-reading of Elizabethan "peace" is nonetheless worth consideration.

[6] Here this study differs from previous analyses of Elizabethan armament, as they concentrate solely on naval issues, to the exclusion of land stores.

"land" for the 1580 survey meant almost exclusively guns at the Tower of London, whereas in 1592, pieces are listed there as well as at Woolwich, the Minories just north of the Tower, the Artillery Garden outside Bishopsgate (see ch. 7, below), and even a few at Rochester, corroborating the expansion of the Ordnance department's "supply radius."

Not represented in table 6.1 is the breakdown of artillery in the 1592 census by material, either brass or cast iron. Although cast iron cannon had been available and in use since the end of Henry VIII's reign, either it did not make up a substantial proportion in the 1580 inventory or more likely, the census-takers found no reason to note these "new" weapons; artillery was artillery. In 1592, however, the census-takers used material as their major category, enumerating the weight and place of each cannon in the Queen's control. Nevertheless – and counter to received wisdom that less expensive cast iron rapidly overtook costly brass after 1550 – cast iron ordnance comprised only 21% (240 pieces) of her store. This discrepancy likely arises from two interrelated causes. First, the newer cast iron cannon continually flowed out of England to other countries. Elizabethan commentators continually complained that new ordnance was sold freely into the Low Countries, France, Germany, and even to Spain, and proposals to stop these abuses litter the archives.[7] From the producers' point of view, however, given that Elizabeth spent her money on ships foremost and then on ordnance, the flourishing export business made economic sense and

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[7] The formal prohibition did not come until 11 Sept. 1592 (TRP, III.107-8, no. 747 [but see also *ibid.*, III.83-6, no 737). See for example, Lambeth Palace Library, MS 553 (=Anthony Bacon Papers VII), fol. 14-23^{v} for a number of resolutions relating to the illegal export of cast iron ordnance in 1596; APC vol. 20 (1590-91), p. 61 for Bristol merchants shipping 50 tonnes to Spain via Dublin; and APC, vol. 21 (1591), pp. 430-32 on Sussex gunfounders trading with the enemy. In general, see also P. Croft, "Trading with the Enemy 1585-1604," *Historical Journal* 32 (1989): 281-302, esp. 293-4 for ordnance. See also A.I. van Wakeren, "English Cast-Iron Guns: a Dutch Trade 1609-1640," in J.P. Puype and M. van der Hoeven (eds.), *The Arsenal of the World* (Amsterdam, 1996), pp. 28-35, which notes that Englad became a net importer by the mid-17th century.

allowed the foundries to continue operating.[8] Second, the number of cast iron cannon listed in the stores likely appeared so low because much of the government-owned iron ordnance might have been sent to the Low Countries before brass ordnance in the stores. Table 6.2 subdivides the 1592 totals along lines of type of metal and place of service. There appears to be little differentiation between the type of gun that went to either location, for each area of service had 3 to 4 times as many brass guns as they did cast iron. Similarly, either metal was between 5 and 6 times more likely to be at sea than on land. That is, likelihood of placement for either type of metal was the same, and so too was the likelihood of finding each type of metal in either arena, although guns are more likely to be at sea, regardless of their metal. Again, this runs counter to common wisdom which suggests that cast iron ordnance was unsuitable for maritime use since it corroded, whereas brass better resisted the salt spray. It also deflates the belief that cast iron represented technological progress and was pressed into service immediately. Rather, this suggests that cast iron was "just another material" to the Elizabethans – cheaper to be sure, but no better, no worse for any particular service – as the Ordnance Office apparently made no such distinction at this time. If nothing else, the idea that one material replaced the other ignores the fact that even if iron were "better" (it certainly was cheaper), that did not somehow make brass cannon immediately obsolete as a consequence.

[8] The Elizabethan government may have realized this necessary evil, which would account for their "inability" to stop the illegal trade.

Table 6.2: Land / Sea vs. Brass / Iron Artillery (1592)

	on land	at sea	total
brass guns	124 *(14% by location)* *(74% by metal)*	754 *(86% by location)* *(79% by metal)*	878 *(79%)*
cast iron guns	43 *(18% by location)* *(26% by metal)*	197 *(82% by location)* *(21% by metal)*	240 *(21%)*
total	167 *(15%)*	951 *(85%)*	1,118

Returning to the comparison between the 1580 and 1592 inventories, the most significant change over the twelve years other than the overall increase in the total number of pieces is that there was virtually no change in the percentage of her Majesty's guns on board her ships. In both cases, 85% of the stores were in service on Royal warships. This again seems surprising, since we have been taught to believe that the Elizabethan navy burgeoned in response to the Armada, and indeed it did grow sizably during the 1580s.[9] These inventories, however, suggest that Elizabeth and her Council, which is to say largely William Cecil (Lord Burghley) and from 1585 Charles Howard (Lord High Admiral), did not unnecessarily privilege the new warships, instead keeping a stable proportion of guns in the Tower stores. Of course, the English were always wary of impending Spanish invasion, and not without reason, and this may go far to explain the Ordnance Office's sensible precautions. The small proportion of guns on land should not be taken as indicative that Elizabeth armed *only* her ships, because of course the numbers in both surveys for land stores included "All wch peices… doe remayne as before over and aboue all those that haue ysued out of the store from tyme to tyme for the supplie of the Fort*es* and

[9] See G. Parker, "The *Dreadnought* Revolution," esp. fig. 5, p. 285, which suggests that the Elizabethan navy went through three phases, 1574-84, where expenditures were low and constant (a baseline for upkeep), 1585-93, where expenditures peaked in response to the Armada and then fell again, and then 1594-1605 where the Navy did indeed grow in more permanent terms.

Castles alongste the coste and other her ma*tes* places of strength and service by sundrie warrant*es* from her hignes and the councell &c."[10] Since London was not a site of major defense, the 85/15 ratio of sea to land stores should not be surprising. Thus far, there does not seem to have been a great deal of change during the crisis years in the composition of English ordnance, but analysis along another axis suggests otherwise.

Figures 6.1 and 6.2 graphically represent the percentages of different types of cannon in Ordnance stores for 1580 and 1592, respectively. The larger pie charts show the percentage of each type of gun listed in the inventories while the two smaller charts below separate the total number into those stored on land and those aboard ships. For the sake of the analysis, I have divided the types of guns into "light" artillery and "battery" artillery. Culverin- and cannon-class guns were used primarily in sieges against towns, while smaller great ordnance was reserved for anti-personnel fire or naval use against rigging and sails, although it, too, was often used against fortified site if larger artillery was unavailable or in short supply.[11] In each chart, the battery guns are represented by the fourth quadrant of each circle, continuing clockwise into the third, and sometimes the second quadrants. The limits of these divisions are indicated by short radial lines. Here, where absolute numbers of cannon are suppressed in favor of percentages of the whole, patterns appear in Elizabethan ordnance procurement.

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[10] B.L., Sloane MS 3194, fol. 21.

[11] This is not to imply anachronistically that the smaller cannon were *in*effective, simply that the larger ones, should they be able to be leveled against a town, were *more* effective. This classic division, which effectively divides the artillery by absolute weight is supported, for example by contemporaries Francis Markham (cf. *Five Decades of Epistles of Warre* [London, 1622], p. 186) and William Winter, as well as modern authors J.S. Corbett, *Drake and the Tudor Navy*: I.373 and G. Parker, "The *Dreadnought* Revolution": 272 ("ship-smashing" vs. "anti-personnel"). Another division, based on caliber length has also been used for analysis of performance (*cf.* M. Lewis, *Armada Guns: a Comparative Study of English and Spanish Armaments* [London, 1961]).

Between 1580 and 1592, battery guns grew in proportion of all the stores from 37% to 55%, even while the older, stone-shot battery ordnance (cannon perrier and demi-cannon perrier) were retired from service. Superficially, this suggests that in the crisis years the Ordnance department favored bigger guns, understandably given her new involvement in the Netherlands and in a form of siege warfare she had never known, as well as the conscious attempt to continue augmenting the navy. More specifically, this shift in gun procurement seems to have come primarily in the demi-culverin class. The proportion of cannon, demi-cannon, and whole culverins remained nearly steady over the two inventories (28% to 29%), but the percentage of demi-culverins grew from 19% to 26% of the total stores. And interestingly, this growth in the percentage of demi-cannon is exactly mirrored in the decrease in proportion of sakers, the next lightest guns. Also, together these two types of gun made up 45% of Elizabeth's stores in both periods. This commitment to mid-sized guns seems entirely apropos of Elizabethan attitudes on military matters – neither hot nor cold, neither lavish nor entirely spend-thrift – but also indicates a certain rationality in procurement.

Guns are heavy objects and require men, animals, and machines to move them around. On this account, smaller guns should be favored, but of course, smaller guns have smaller shot and therefore do less damage. As in most facets of life, gun choice is a trade-off. James Wood's concept of "throw-weight" allows us access to this decision-making process.[12] He suggests useful measures of cannon would be "the number of pounds of iron shot each type of gun could throw per thousand rounds for each man or horse in its equipage and for each pound of powder it expended" (p. 158). Table 6.3 expresses his numbers in

[12] J.B. Wood, *The King's Army: Warfare, Soldiers, and Society during the Wars of Religion in France, 1562-1576* (Cambridge, 1996), pp. 157-60, esp. Table 6.1B.

Table 6.3: Relative "Effectiveness" of Ordnance Types

	per man	per draft animal	per pound of charge
demi-cannon	198	135	178
culverin	100	100	100
saker	102	71	67
falconet	61	51	44

English terms, with the culverin taken as a baseline of 100.[13] In his analysis, he finds the demi-cannon more efficient than the culverin on all three counts, that is, nearly twice as efficient on manpower, one third as efficient on animal use, and able to deliver three-quarters as much shot to the target per pound of powder. He also rightly emphasizes the huge advantage that demi-canon had over the small saker and falconet, especially in terms of shot/charge where it was over 4 times as efficient. So although he uses his numbers to justify the French preference for larger guns, his analysis lends itself nicely to a partial explanation of Elizabethan procurement policy.

The culverin and saker are almost identical in terms of manpower needed for their operation, exclusive of transportation. While a demi-cannon is nearly twice as efficient as the culverin in that category, it was only one-third more efficient with respect to animal power for cartage. In an English context, the animal column and the manpower column may in many ways be collapsed, since the English did not engage in much mobile warfare and most artillery movement would have been largely ships-to-shore. Here gunners enter into the equation, "cartage" being their single largest duty. When cannon needed to be moved, the English (in London at quayside) were more likely to use the men

[13] The conversion of Wood's different classes is difficult. The 4 French classes given by Wood were "cannon", "Great culverine", "Bastarde", and "Moyenne" with shot weights of 32, 15, 7, and 2 *livres*, respectively. The closest English types given above were chosen based on those shot weights from R. Norton, *The Gunner Shewing the Whole Practise of Artillery* (London, 1628) , p. 53, "A Table of Ordinary proportions allowed for English Ordnance" and other contemporary ordnance tables.

themselves than the French were (on campaign in the field), suggesting that ideas about human efficiency might have spoken more loudly for them. In some cases, the men were even used to move artillery on expedition, as in the Protector Somerset's expedition to Scotland for Edward VI in 1544,[14] although this was exceptional. In that respect, the near identical efficiency of crew operations for culverin and saker allows us to infer that they may have been considered equivalent in some way to the Elizabethan Ordnance Office.

Referring again to figures 6.1 and 6.2, the breakdown of artillery types by location provides at least a partial answer as to why the demi-culverins were preferred. In particular, consider the change in location of types of artillery between the two figures. In 1580, battery-class ordnance accounted for some 65% of Tower stores and only 32% of shipboard stores. By 1592, the proportions had reversed, with only 45% battery-class ordnance in the Tower and now 56% of shipboard artillery in this class. Not surprisingly, the English had more heavily-gunned ships in action after the Armada than before. But even more revealing is how they gunned those ships. They shifted their preference to shipboard demi-culverins and culverins, largely at the expense of sakers. Correspondingly, their land-based stores show a loss of battery-class ordnance in favor of the lighter pieces. What appears to have happened is that culverins and demi-culverins became more favored weapons at sea, while in land stores, sakers, falconets, and fowlers took more prominent positions.[15] In all likelihood this represents a greater number of larger ships in the Royal Navy which might

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[14] M.J.D. Cockle, *A Bibliography of Military Books up to 1642* (London, 1957), p. 6.

[15] There is a possibility that the high proportion of fowlers (very long, chambered, small bore guns – usually about 1´´ in diameter – which were in this case all brass) seen in the Tower stores represents the recall of these older, "obsolete" weapons from active service. But, unlike the wrought iron ordnance which was indeed old, outdated technology and stored entirely at Upnor castle, the lists of fowlers makes no hints that these were obsolete, and indeed, their proportion on ships shrank only 1% between the two surveys.

take these larger guns.[16] It also reflects a rather different side to the standard story that in the last third of the sixteenth century, navies abandoned cannon-class guns in favor of culverin-class guns, despite the culverins' longer length.[17] In that scenario, Elizabethan naval officers realized that cannon were much too heavy for the ships' superstructures and provided relatively little advantage for their bulk. Culverins were lighter, but longer (their aspect ratio usually over 32:1, as compared to cannon at about 26:1) and therefore were of little use as lateral armament, confined instead to the bow or stern as chasing pieces.[18] There was certainly support for this idea, not only in some ship records, but also in contemporary naval commentaries of Sir Richard Hawkins and Sir William Monson.[19] Here we see not so much an abandonment of cannon-class guns, for overall their proportion only shrank 1% at sea (although 5% overall, and this largely due to the removal of perriers), but largely a redistribution of the culverin class. And given that the English liked to believe they had beaten the Armada in a running sea-fight, they would be expected to outfit ships after 1588 with more and more ordnance. It does not, however, necessarily reflect an Elizabethan "admission" that larger guns were "progress" in armament, since they had been in service all along; they had simply shifted their distribution. On the landward side, though, the increase in light guns – from 34% to 56% of Tower stores or 38 to 92 in absolute terms – reflects experience gained in Ireland and especially in the Netherlands. Elizabethans learned that if you wanted to

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[16] See G. Parker, "The *Dreadnought* Revolution" and P. Kirsch, *The Galleon: the Great Ships of the Armada Era* (London, 1990) , pp. 17-26. Still, Kirsch records that in 1603, the new King inherited a fleet of 37 royal ships, only 14 of which exceeded 400 tons in burden.

[17] This common assertion can be found throughout the works of Corbett and most recently in P. Kirsch, *The Galleon*, pp. 52-8.

[18] P. Kirsch, *The Galleon*, ch. 3, "Ordnance".

[19] *Ibid.* Hawkins, considered by many (especially Corbett) as the architect of the Elizabethan Navy, argued for smaller guns based on the inaccuracy of long-range guns (long guns and long shots being synonymous in his mind), and Monson concurred, based on a fear of longer guns being more likely to overpressure and burst. Recall also Sir Walter Raleigh's comments on "over-pestered" ships (ch. 2, above).

fight on land smaller, lighter, and more mobile guns were the answer.[20] As England matured and veterans returned from foreign engagements, they began to incorporate that experience into the operations of the nation.

And more field artillery destined for land warfare, whether used or not, required a different type of gunner. While naval gunnery remained the fundamental mainstay of the Elizabethan military, learning about land warfare opened up exciting new opportunities for the gunners themselves. While naval gunner's duties tended to be circumscribed by the operational characteristic of their "machines", that is, point-blank shooting from confined, pre-defined positions, field gunners had to cope with varying terrain, distances, and targets. They also had the luxury naval gunners never had, namely stable platforms. Despite Bourne's complaints about difficulties arising from softer ground under one wheel or the other,[21] as a gunner in a haven town, he must have realized he was splitting hairs compared to the confined conditions of a naval gunner. This, then, allowed gunners to explore new areas such as triangulation range-finding and elevations, profoundly more mathematical subjects than basic cannonry.

Projectiles in Ordnance Lists

The Ordnance Office inventories also provide evidence of various ancillary munitions, which in turn throw more light on the activity of gunnery. Table 6.4 summarizes the amount of shot for ordnance of all sizes in the stores in 1592.[22]Surprisingly, only slightly better than half of the projectiles are common cast iron cannonballs. Hailshot makes up over a quarter of the stores, suggesting that anti-personnel fire was more important to the Elizabethan

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[20] The objection may be raised that these light guns were simply removed from the ships to make room for the larger ordnance, but if ship numbers and sizes were increasing and anti-personnel fire was still important, then this is not a zero-sum scenario.

[21] W. Bourne, *The Arte of Shooting in Great Ordnaunce* (London, 1587) , p. 2-3.

[22] Lambeth Palace Library MS 293, fol. 25^{v}-27^{v}.

Table 6.4: Shot in Ordnance Office Stores, 1592

spherical shot	73,944
"Burre shot alias Haileshott" . .	38,166
Stone shot	16,784
cross-barred shot	5,714
dice shot	2,886
jointed shot	82
chain shot	51
"hollowe shott armed wth fierwork*es*".	38
lead-covered falcon shot . . .	34
total	137,699

artillery than has previously been emphasized.[23] It also suggests that gunners would have needed to spend a great deal of time manufacturing case shot for use in the field. This, too, would explain the prevalence of rules for cartridge-making found in the manuscript notebooks discussed in chapter four. In order to make case in a timely and efficient manner, gunners needed to know the charges and sizes of the various classes of artillery and their associated cartridge template sizes. Whether or not they worked on an assembly-line basis or with each worker making his own cartridges is unknown, but that they would have been needed in vast quantities is clear from these inventories.[24]

There is also the remarkable amount of stone shot still in the stores. According to the survey, about half of the store was already "polished", that is, formed into proper spheres, while the other half remained in its rough state.

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[23] General histories tend to avoid this topic, although whether out of squeamishness or rarity is unclear. Cruickshank, for example, only mentions in passing that Lord Willoughby considered using hailshot against his own men during an insurrection as a last resort (*Elizabeth's Army*, p. 171). Lewis analyzes round shot in excruciating detail, but entirely ignores other types of ammunition (*Armada Guns* ch. pp. 177-87). Bourne, however, felt it necessary to inform his readers that "smal base shot,… all manner of of spoyling shot, as chayne shotte, or cliue shot, and dise shot, and such other like" was preferable against horse or foot (*Arte of Shooting in Great Ordnance*, p. 61). Early in Elizabeth's reign, chain shot from a pistol was disparaged as that which only "reiters" (*i.e.*, foreign mercenaries) use; CSPF, vol. 6 (1563), no. 806.8, p. 371. Such anti-personnel fire is usually considered a mainstay of Napoleonic, not Renaissance, warfare ("a whiff of grapeshot").

[24] See S.B. Bailey, "The Royal Armouries 'Firework Book'," in B.J. Buchanan (ed.), *Gunpowder: the History of an International Technology* (Bath, 1996) , fig. 5, p. 66 for an example of a 15th-century production line for fire arrows.

Whether this represents stone shot still in use, even though the cannon perriers and demi-cannon perriers had been largely retired from service, or whether it is shot still left in the stores from earlier in the century when stone-shooting ordnance was more common, is unclear. All kinds of cannon could of course shoot properly-sized stone shot, but the negative economics of stoneworking and iron's greater density argued for cast iron shot. Since the inventories are usually quite clear about obsolete stores, it would seem that, true to form, Elizabeth did not want to waste this shot, keeping it ready should the need arise.

The other types of shot in the stores are interesting as well. Cross-barred shot are to be expected in any maritime power, as they are the easiest method for taking down an enemy ships rigging. However, jointed and chain shot combined, later used for the same purpose as well as very effective anti-personnel uses, make up less than one tenth of one percent of the stores. The strong selection pressure against these shot was likely economic, since cross-barred shot could be cast in one piece, whereas the others required hand assembly and would therefore cost more.

Most interesting, however, are the 38 hollow shot armed with "fierworkes." They suggest a form of cannon-fired grenade, or "granadoe" as they were called in the sixteenth century. Usually filled with gunpowder mixtures, rather than incendiary material that the name "firework" now denotes, such assemblages were made for export in the Low Countries in the first half of the seventeenth century.[25] At this time, however, local manufacture would be more probable. While these hollow shot make up no more than a token part of the store, they indicate a connection with the other part of

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[25] H. Vogel, "Arms Production and Exports in the Dutch Republic, 1600-1650," in M. Van Der Hoeven (ed.), *Exercise of Arms: Warfare in the Netherlands, 1568-1648* (Leiden, 1998), p. 202, n. 11, cites the case of the English purchasing 500 grenades in the Netherlands for use in Ireland in 1638.

Ordnance Office responsibilities. Often glossed over by military and artillery historians, these inventories and the gunners' manuals presented in chapter four drive home the fact that knowledge of incendiaries and explosives constituted a large part of the Renaissance gunner's trade.

One item this inventory describes, however, has, to my knowledge, never been mentioned before in the literature surrounding the period. In a section relating to miscellaneous munitions, the document lists over 1800 "musket arrows", 1200 "arrows for fireworks", 169 "bows for fireworkes", and 25 "crosbowes for fireballes", of which 21 were in use on ships at the time.[26] Non-gunpowder missile weapons firing incendiary arrows had existed for a long time, but it is these weapons combined with the following entry which turns our ideas about incendiaries on its ear: "Balles of copper wth fierwork*es* inclosed in them, for crosbowes als[o] Engynes conteined in xxiiij barrels after 90 in everi barrell" (fol. 42). In all, the document lists 2,531 of these balls, about 10% of which were on ships at sea. Nor are they unique to the 1592 ordnance list; they also appear as stores delivered to Elizabeth's ships in 1589-91.[27] Clearly these balls were not an insubstantial production of the English military output, yet they have until now apparently escaped the attention of military or technical

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[26] The documents actually record mixed units of "v^{C} 55 shef xiij" (=1866) of the former and "52 shef xiij" (=1261) of the later; Lambeth Palace Library MS 293, fol. 30^{v}-31. 24 arrows comprise a sheaf.

[27] Bod. Lib., MS Rawlinson A 474 records 60 "Balls of copp*er* wth rec'" [*i.e.*, "reciepts" – incendiary recipes] delivered to the *Revenge* along with 4 "crosbowes for firewo^{r}k*es*" in March 1590/1 (fol. 11), the same number to the *Garlande* (fol. 11^{v}), and 2 crossbows with 30 balls to the *Nonparyele* in April (fol. 28^{v}). There is a high proportion of "Waste" (*i.e.*, spoiled munitions) for many entries in this list, with proportions ranging from no loss to 100% for any individual munition. For example, figures for the *Revenge* show the waste for every munition as equal to that "remaining" plus that "supplied", suggesting she encountered a storm or some other form of disaster. The *Garlande*, on the other hand, last 89% of her saltpeter and sulphur to waste (she was supplied with "C^{wt}" and had "100 wt." waste; I take the different notations to indicate a long hundredweight [112 lbs.] and a true hundredweight, respectively), only 25% of her firework arrows (6 of 24), but none of her musket arrows, copper balls, or crossbows. This demonstrates the fragility of contemporary incendiary weapons, especially at sea. See also "Stores Rec'd by Thomas Bedwell" (1589), PRO, WO 55/1659, fol. 7^{r-v} and 20^{r-v}.

historians, who have long preferred to concentrate on set-piece battles and high-ranking officers, rather than the day-to-day operations of the common soldier. Around 1622, a writer could allude to the distinction between "the fier-master [who] is one y^{t} hath ye art to compound all manner of fierworkes" and "ye masiter gunner [who] onely medleth wth ye ordinance," but also noted that "in these latter times they haue for ye sauing of double wages, brought these 2 officers into one, who is called by ye name of ye master-gunner."[28] In fact, it is likely that in earlier – Elizabethan – times, the two officers were also one and the same, and coalesced under the term "gunner."

Gunners' Employment Records

Most of the information about gunners is contained in records of the activities of the Ordnance Office, and largely in pay records or expenditure records where each project is briefly described (but only in some years). Gunners, by and large, rarely created documents themselves, perhaps from illiteracy, but more likely than not, simply because their low position in the Tudor administrative hierarchy mitigates against the survival of records they might have created. A few letters of gunners to their superiors lie scattered in the State Papers, and a few Privy Council actions concern gunners. By and large, however, gunners fly under the radar of governmental notice. In order to fully understand the role of gunners in Tudor operations, detailed garrison and army records would need to be sifted, collated and considered. What follows, then, is an introductory sketch of what can be gleaned from the records these gunners have left or those that relate to them.

One brief example should suffice to suggest the place of the gunners in the military establishment in mid-century. In 1545 Symon Sage, a gunner at

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[28] Bod. Lib., MS Eng. misc. e.82, p. 4 (fol. 19^{v}). This MS contains notes taken by Abraham Wright on Francis Markham's *Five Decades of Epistles of Warre* (London, 1622; STC 17332), p. 87. Most of Wright's notes are on officers of the army and their duties, although he was apparently an Oxford-educated clergyman.

Berwick, wrote to the Secretary, Sir W. Petre, regarding the "keeping" of Berwick castle.[29] The letter sets out the current state of the fortress and how it is garrisoned and equipped. Interestingly, however, he opens with a complaint: "ffirst there is in the side castell x gounners in wag*es* and ther is butt foure that can shoite whoas names followith Richard Cellinggson lyell haggerston Symond Sage me Iham's Cest" He never defines exactly what he means by "shoite", but clearly he is referring to the level of knowledge of these men drawing wages as gunners. In his opinion, and assumedly it is one of authority if he is the one writing to the Secretary, six of the men do not know enough about great ordnance to hold those positions. He does not specifically suggest a remedy, although reading between the lines, it is safe to say he would like to see Celingson, Haggerston, Cest, and himself remain while the others were replaced with able men. The next four items in his letter detail the manpower of the fortress and how it is sorely lacking. The Captain was often away at home, leaving his "nott all of the wyssyst" son in charge with only "xviij p*er*sons w^{t} hym" and not more than 30 men altogether remained in the town. Sage then lists the ordnance in the garrison: one "portingell basse" on the wall and two that "lyeth besid*es* the dungion", one brass falconet, two falcons on the wall and two that "lyeth in the white wall", three sakers, one demi-culverin, and seven "hagebuthes that standeth in a hause." He notes that there is "good store" of shott for the ordnance and above 3 lasts of powder (360 lbs.), as well as the number of bows, bills, arrows, and "old morresse pik*es*." Thus, his letter provides Secretary Petre with a snapshot of the state of Berwick in March, 1545.

Such a document indicates the sorts of duties a master gunner of a garrison or castle might be expected to carry out. He would be responsible for inventorying the ordnance of all types and noting the strength of the garrison.

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[29] B.L., Add. MS 32,656, fol. 230^{r-v}.

But more importantly, it is clear that either it was their duty (or they felt it was their duty) to inform their superiors in London of the deficiencies or needs of their garrison as well. To a modern eye, this should seem strange, since the master gunner was not the highest position in a fort. He should be reporting to the captain or the constable. But this is not necessarily a case of a gunner jumping rank. While the constable or captain could have taken a report from the gunner and relayed it to the Tower, gunners apparently often wrote to the Ordnance Office directly, not to go over the heads of their direct supervisors, but rather because their local supervisors were in fact not part of the chain of command when it came to gunpowder weaponry. As the Earl of Northumberland noted around the turn of the century, the Master of the Ordnance fell under the direct control of the General, with no intermediary officers. As in all technological systems, specialized knowledge creates power within specialized areas.

In the sixteenth century, and even into the seventeenth, it seems that the English Ordnance Office could not decide how to fit artillery into their hierarchy. It did not belong with the infantry.[30] It did not belong to the cavalry. In some ways it did not even belong to the navy. Yet it was not its own branch of each service, as the artillery is today in modern armed forces.[31] It was both subordinate to each service in the field and yet superordinate to each in administration and in peacetime. Even in wartime, the artillery formed a

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[30] So, for example, we find the Ostend cannoneers listed by name, but not enrolled under any company; L&A, vol. 1 (Aug. 1589 - June 1590), H516.

[31] A similar story can be told about the early use of military aircraft. In the British case, the Royal Flying Corps emerged as its own branch from the Royal Engineers only after a prolonged struggle (largely by Capt. John D.B. Fulton). See H. Driver, *The Birth of Military Aviation: Britain 1903-1914* (Woodbridge, 1997) , esp. pp. 268-9, who also notes that, "[i]t was not a case of having to create a new establishment to accommodate the emergence of an unprecedented technology. Rather it was a matter of assimilating experimental advances within an already established framework. In other words the military… were cautiously adapting to a dynamic technological environment [and] not… seeking to build a new arm from scratch" (p. 147). I must thank Ken Bartlett for suggesting I make this comparison here.

separate and distinct jurisdiction from the army on campaign: the Provost of the Artillery could overrule the Provost Marshall in matters of ordnance and the artillery camp traditionally formed a separate city within a city in the army's camp.[32] This new technology was part of all branches and yet part of none. Although the modern interpretation of proper hierarchies and chains of command would not be entirely foreign to a Tudor soldier, the linkages between artillery and the armed forces cannot be thought of with reference to modern bureaucracies. The command structure reflected this by being unable to place master gunners fully under any other garrison commander and chose instead to place them more or less directly under the Master of the Ordnance and the Master Gunner of England in the Tower. And on board ship, the master-gunner was considered both enlisted and officer-class at the same time.[33]

The other example of gunners' duties suggests one reason why this organizational system seems familiar yet foreign. Put simply, many gunners were part-time soldiers, although more regular than most other sixteenth century positions. In any number of surviving pay summaries, all Ordnance Office workers are listed month by month, and broken down into categories. Thus, all the carpenters, wheelwrights, plumbers, and other trades are listed, with the number of days worked, pay rate, and total pay. Frequently, next to each trade's heading, annotations regarding the sort of work performed by that

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[32] The subject of the responsibilities and privileges of the various officers and soldiers in the Tudor army (often referred to by contemporaries as "martial discipline") is one far too vast to undertake here. The forgoing comments follow from College of Arms, London, MS Vincent 430, pp. 31-4, but see in general, C.G. Cruickshank, *Elizabeth's Army*, pp. 47-50, although it only scratches the surface. Beyond the printed books, a number of manuscripts survive on this topic: see Robert Hare, "Treatise on Military Discipline [1557]" (B.L. Cotton MS Julius F.v); Sir Robert Constable(?), "Treatise on the Art of War" [c.1577] (B.L. Add. MS 34,553); Sir Thomas Audley, "A treatise of Martiall Discipline" (Bod. Lib., MS Rawlinson D 363) and *ibid.*, "Introduction of A.B.C. of Warre" (Bod. Lib. MS Tanner 103); Sir Francis Vere, "notes of… everey Mans office in the Army [c.1600]" (B.L. MS Harley 6844).

[33] W. Ralegh, *The Works of Sir Walter Ralegh, Kt. Now First Collected* (Oxford, 1829) , 8:346.

crew appear. In some cases, the tasks are specified only very generally, but in others (for workers other than general labourers) the tasks are specified quite closely. Gunners are no exception: they form one of the smaller groups of workers (carpenters and labourers being typically the largest) and generally have their duties specified in a detailed manner.

While a full picture of gunners' duties in this period is beyond the scope of this chapter and would require locating more annual records, one list from 1570/1 provides a particularly complete glimpse of the sort of records which do survive.[34] Table 6.5 records the gunners' names and days worked each month. The only constant member of the lists is Anthony Fenrutter, the Master Gunner of England,[35] who worked every month of the year. He is also the only one who could even remotely be considered as employed full-time. He worked of average of 24¼ days per month, which allowed for only 22 days off for the year, beyond the expected Sunday of each week. His pay for the year, at 12*d* per day, amounted to a total of £14 11*s*, a comfortable living wage for the later sixteenth century when you consider that this was above and beyond room and board.[36] Everyone else, however, at only 10*d* per day and working between two and 63 days out of the entire year, earned under £1 for an average of 21 days' work for the year. Only six men appear frequently in the list (marked with asterisks in the table), suggesting that they formed the core of the gunnery crew for the Ordnance Office. We might expect that they were the fee'd gunners of the tower, and indeed Eaton, Foster, Heynes, Phillippes, and Spencer were or were

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[34] A fair copy of this list is preserved in Bod. Lib., MS Rawlinson A 235. Folio notations will be given in the text.

[35] Fenrutter became Master Gunner of England in January 1571, although curiously, he was believed "deceased" in March of the previous year, when his regular gunner's fee was reassigned to John Lambert; CPR, Eliz. I, vol. 5 (1569-72), no. 25 and 2063.

[36] R. Huggett, J. Hugget, and S. Peachy, *Early 17th Century Prices and Wages* (Bristol, 1992), p. 5 notes annual rent about 50 years later as only 8-12*s p.a.* While they note a wealthy yeoman might earn £200-300 *p.a.*, skilled workers earned £10-15 *without* room and board. See also below for further discussion on wages.

soon to be.[37] On the other hand, John Harris appears never to have been granted a gunner's room and William Thomas, who was a fee'd gunner, worked for only 15 days of the year, and those only in four of the first five months of the year (for more on Thomas,

[37] Some of these men had been gunners for some time: Phillippes since 14 Nov. 1559 (CPR, Eliz. I, vol. 1 [1558-60], no. 1559), Heynes since 3 Feb. 1565 (CPR, Eliz. I, vol. 3 [1563-66], no. 1226), and Eaton just since 23 Dec. 1570 (CPR, Eliz. I, vol. 5 [1569-72], no. 2038). On the other hand, Thomas Foster did not receive his fee until 13 June 1572 (CPR, Eliz. I, vol. 5 [1569-72], no. 3295). James Spence(r) is an interesting case, for he was a gunner at Carlisle Castle in Wales, and was granted the master-gunnership of that castle shortly after his work at the Tower noted above and "for his service" to the Queen: CPR, Eliz. I, vol. 5 (1569-72), no. 3112 (13 Dec. 1571).

Table 6.5: Ordnance Office Gunners' Work Records for 1570/1

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total annum
Anthony Fenrutter	25	22	27	22	25	24	25	26	24	26	23	22	291
Thomas Foster*	4	7	3		4		2		24	6	3	10	63
Richarde Heynes*	4	5	5	3			7	2			12	13	51
John Pewet								24	24				48
Anthony Eaton*	2	9	1				10				12	13	47
Edwarde Thompson				22	4					20			46
James Spence[r]*	4	5	5	3			8				12	7	44
John Harris[se]*	4	3	11	14				2			3	6	43
John Commyn			4	17			7	2				10	40
Richard Barton	4	8	5	4			10	4					35
John Phillippes*	4	5	8		4						3	6	30
John Williams						24				6			30
Robert Thompson							6	3				14	23
James Humfride	1	5	5	3			7						21
John Hunte			5	15									20
Edmund Martin	4	5	5	3									17
William Thomas	2	4	5		4								15
Robert Butler	4	5	5										14
Roger Grene	4	6	3										13
Roger Bouthe		5	5										10
Edmund Kelinge		5	5										10
Thomas Marshall	3	2	3	2									10
Thomas Butler	2		4								3		9
Edwarde Hemminge			5	3									8
William Lombarde		3	5										8
Hugh Blande		3	4										7
Jacob Myller												6	6
George Fawconer			4	1									5
Markes Braie			4										4
Lawrence Cowper	4												4
Thomas Hawknie	4												4
James Howper	4												4
John Martin	2												2
Cristofer Reynolds	2												2
Total per mensis	62	85	109	90	16	24	57	37	48	32	48	85	

* primary Ordnance Office gunners (*i.e.*, listed first in MS, regardless of days worked).
Note: Totals at the bottom do not include Anthony Fenrutter. Shaded cells indicate men employed in other Ordnance Office jobs for those months.

see chapter 7, below). Whether these duties listed in the Ordnance Office lists were their fee'd position or over-and-above the guaranteed income they received for those positions is impossible to tell. The pay rates are the same (10*d*

per diem), so they could be either, but one would expect a fee'd position to be worth more than £1 a year.

Extensive wage lists and records remain for the sixteenth century, but annual incomes are a different matter. While we can say with a great deal of certainty that the average skilled laborer, such as a carpenter or plumber, earned 8*d* a day in the middle of the sixteenth century, rising to 12*d* a day by the early seventeenth, the number of days of the year they worked is another question entirely. Economic historians tend to speak in terms of price indices and relative real wages rather than absolute incomes, and there the historical record is quite clear.[38] We know that the cost of living in London more than tripled between 1500 and 1600, and from the patents issued to gunners we know that their fees did not keep pace, rising from a range of 6*d*-10*d* per day in mid-century to only 8*d* to 12*d* near the end.[39] But neither did they need to, since the Ordnance Office absorbed their room and board, the very thing "cost of living" measures. Some annual incomes are known, but these are on the upper end of the scale: typical peers of the realm enjoy rents and favors totaling £30,000 *p.a.*, while an average knight might have revenues of £650 and a wealthy yeoman farmer £200-300.[40] By way of comparison, wages of common laborers fell far, far below that level: a servant in a large house might make £40 year, while a live-in cook only £3, the same as a master gardener, although he would also have to pay his two

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[38] H.P. Brown and S.V. Hopkins, *A Perspective of Wages and Prices* (London, 1981) is the classic study, although it has been recently to some degree challenged by D. Woodward, *Men at Work: Labourers and Building Craftsmen in the Towns of Northern England, 1450-1750* (Cambridge, 1995).

[39] For gunners fees, see CPR, *passim*, *s.v.* "London, places in and around—Tower of London—gunners" and for the London cost of living, see S. Rappaport, *Worlds within Worlds: Structures of Life in Sixteenth-Century London* (Cambridge, 1989), pp. 403-7. As with any large city, London's cost of living tended to be 35-40% higher than the rest of southern England (p. 85). The real wage index bottomed out around 1600, even though it had been fairly stable in mid-century (H.P. Brown and S.V. Hopkins, *Perspective of Wages and Prices*, p. 19).

[40] R. Huggett, J. Hugget, and S. Peachy, *Early 17th Century Prices and Wages*, p. 5.

assistants out of that wage;[41] journeymen might make £2 10*s*–£5 a year in the later part of the century, while householders made £10-15, a skilled construction worker £12-19, and a clerk £15, an amount considered "sufficient for the maintenance of any single man of modest carriage."[42] Fenrutter's £14 11*s*, then places him in this category, although with room and board provided as part of the office, his social standing, at least measured on his income, would certainly have put him above the clerk. While a gunner who had a fee'd position at the Tower might only earn £1 per year, he might still be able to make ends meet by doing other jobs on an irregular basis. And of course, given how little they seem to have worked *as* gunners, they might easily have made a good deal more income elsewhere. Those who did not have a gunner's room at the Tower would most certainly have plied another trade in or around London. A number of occupations immediately suggest themselves – gunpowder-maker, founder or foundry assistant, mariner – all positions immediately connected with the Ordnance Office and ones which would accommodate the intermittent work schedule offered or required as a gunner. Other jobs which demanded more full-time attendance or investment – merchant, tailor, butcher, or any agricultural job – seem less likely. Their time as gunners, however, never occupied more than a token part of their lives.

The other facet of these gunners' duties that the Ordnance Office lists provide are their activities for the month. Given as one short sentence next to the heading, they do not always have the detail we could hope for, but are

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[41] *Ibid.* , p. 6. These figures are for Hatfield house in the 1620s.

[42] S. Rappaport, *Worlds within Worlds*, p. 221, n. 16. Whether the clerk's pay would support a family or not is another question. Different sources suggest different amounts of work needed to sustain a worker. H.P. Brown and S.V. Hopkins, *A Perspective of Wages and Prices* suggests carpenter needed steady work for between 30 and 52(!) weeks a year to obtain a "composite unit of consumables" (*i.e.*, to subsist, p. 101), while in the famine year of 1597, J.E. Thorold Rogers, *Six Centuries of Work and Wages* (London, 1909) estimates annual incomes of "artisans" at about £5, with only 43 weeks needed to meet the subsistence level.

nonetheless revealing. Most months, their primary duty was simply moving the ordnance around the Tower and Tower Wharf. In July, November, and December the men were busy at "propping the Ordinaunce within Ordinaunce house at the Tower" (fol. 36^{v}). The May, August, September, and October entries provide more detail about the men in that in those months they were employed, "attendant for the making of cariages for mounting of Ordinaunce aborde the seuerall shippes wherein they serve" (fol. 47^{v}). This then explains that Thomas Foster, John Pewet, and Edward Thompson clearly served most of their time aboard ships, upon which they were presumably the master-gunners. It is likely, however, that the other gunners employed in those months were merely helping them for two to six days, as needed. Thompson must have also been outfitting his ship in April as well, since the list says the men were "attendant for the seuerall proporcions of diuers her Ma^{tes} shippes" (fol. 19). This month, though, there was clearly more to do on a number of ships, since a dozen men worked up to three weeks each.

The late spring and early summer was obviously a slow time in the Ordnance Office, since beyond the ships' master-gunners, very few men worked at any tasks. In June Fenrutter only used one other man for the full month for the "dryenge of powder" (fol. 30^{v}). The time leading up to the New Year (*i.e.*, March 25) was clearly the busiest time. Gunners were occupied in "placing brasse Ordinaunce vpon the Tower wharfte aswell for proof as otherwise against her maieste passinge by to Grenewiche" (fol. 1^{v}) in January, and continued moving it about until after her passing in March. Unfortunately the records fail to specify whether the 19-23 men working in those months worked all together on four or six days of the month or came in smaller groups spread out over the month. Given that the year's activity seems to happen in a handful of days here and there (omitting for now the ships' master-gunners' attendance), it seems

more likely that in January through March, the Ordnance Office called in up to two dozen men for a few days to move the ordnance about as required and then let them go back to whatever else it was that they were doing for the rest of the month.

This, then, raises the question of what gunners did do when they were not gunning. Unfortunately, the question cannot be answered with any certainty. The ordnance lists give an occasional hint. In addition to paying John Phillippes for five days as a gunner in February, a John Phillippes was also hired as a bricklayer for 10 days that month. But he does not appear as a bricklayer again for the year, although he does as a gunner, so this may be another man. Edwarde Heminge, however, seems quite clearly to have been a wheeler, as he was paid for a full month's work as one in August, September, and October. In November and December he drew pay as just a "Labourer", as Edward Kelinge did part-time (6 days) in March and full-time in May and from August to December. Gunners must therefore have had other trades around London to support themselves, yet they were for the not important or rich enough to make clear impressions in state records. As such, what they did when they were not gunners must for now remain a mystery.[43] This brief examination demonstrates that we might more profitably think of Elizabethan gunners as reserve officers, so far were they from being a standing force.

Edmund Parker, Irish Gunner

Although the bureaucratic remains of gunners are scarce and the absolute number of gunners was never that high, we can still come to know a few of these men, or at least their art. Richard Wright appears to us from his manuscript instruction manual, setting out what a novice gunner learned while

[43] Searches of local and parish records would augment our understanding of gunners' non-gunnery activities.

training for duty (ch. 4). Edmund Parker, on the other hand, gives us a glimpse of what the gunner did once he was trained and went out into the world. Parker serves as another anchor for knowing gunners at the end of the sixteenth century, and as such, he provides an impressive sense of gunners' competency.

Of Edmund Parker, little is known. While Wright's gunnery notebook is a fine treatise potentially ready for presentation, Parker's is a notebook in the Leonardian sense: a book of jottings and calculations never meant for publication or for others' eyes.[44] It contains memoranda, calculations, tables, marginal notes, and an occasional diagram. Most of the pages are textual notes to himself on how to perform certain operations or recordings of his opinions on various matters. Perhaps the most striking example of its true notebook nature is that the book has been used from both ends to the middle, so that leafing through the material in the first pages of the manuscript, at fol. 49^{v} one encounters upside-down writing which is in fact the last page of the writing which began on the penultimate folio (fol. 100) of the manuscript (fol. 101 is right-side up). Indeed, on various pages he will write right-side up, up-side down, or sideways, apparently in whatever orientation he found convenient at the time, but by and large the impression is of two books, one starting from each end, although the subject-matter does not divide neatly into "front" and "back" topics.

The association of this notebook with Parker comes from a single leaf containing a diagram on taking elevations which is captioned "To take a distance by goinge forwarde or Backwarde At too staciones Edmund Parker, 1598."[45]

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[44] The manuscript resides in Lambeth Palace Library, MS 280, and has until now been completely overlooked by historians of artillery. The manuscript was described only as "Rules touching Great Ordnance" in the printed catalogue of 1812 and omitted in the 1930-32 revision. Only in the 1991 typescript revision of the 1812 Todd catalogue did E.W.G. Bill give a more complete description and contextual information.

[45] Fol. 28. While it is not impossible that this indicates that the author of the MS was learning the material *from* Parker, rather than Parker himself autographing the work, that would imply not only that Parker was a very advanced gunner, but another gunner interested in wider learning. While this would be a boon to a study such as this, for now it is more

We know that there was a gunner named Parker who fought in Ireland under Sir George Carew and whose skill Carew praised highly, but whose given name Carew never mentioned. The implication is that the manuscript came into the possession of Carew when this Parker died of an illness on 28 May 1602 near the Abbey of Bantry. Carew presumably requested Parker's notebook specifically, noting that "it hath pleased God to lay his Cross upon us, as I have lost the best cannonier in my opinion that England these many years hath bread."[46] Parker's death figured prominently in the correspondence between Mountjoy and Carew because in early May the former had specifically requested "one parker, an engineer" for his imminent Ulster campaign in 1602.[47] Carew was clearly fond of Parker, quite beyond his immediate dependence upon him for siegework, for in notifying Mountjoy of Parker's death, he said that "his loss is no small grief unto me, being an ancient servant of my own, and the want of him will be a great impediment to the service, being (if my judgment fail not) the best cannionier that served her majesty."[48] Mountjoy, too, regretted Parker's loss.[49] If indeed Parker had been one of Carew' personal retinue, this would go far to

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conservative to follow the textual evidence and the cataloguer and ascribe the MS to Parker himself.

[46] Carew to Mountjoy, 28 May 1602; CCML, vol. 4 (1601-1603), no. 241, p. 239.

[47] H.J. Todd, *A Catalogue of the Archepiscopal Manuscripts in the Library at Lambeth Palace* (London, 1812) , p. 123, referring to Lambeth Palace Library, MS 615, fol. 594; Mountjoy to Carew, 3 May 1602 (CCML, vol. 4 [1601-1603], no. 234, pp. 233-4): "remembering that there is one Parker with your Lordship, who I know to be very sufficient and industrious, and fit to do anything wherein we shall have occasion to use him, I.. pray your Lordship to send him hither so soon as possibly you can spare him from Berehaven, where I think he is now employed." I have been unable to discover where Berehaven was, much less what work might have been ongoing there. At this time, Mountjoy was in ill health, still recovering in Dublin from the victory over the Spanish at Kinsale, but he did not engage Tyrone's rebels in Ulster until June; see C. Falls, *Elizabeth's Irish Wars* (London, 1950) , pp. 324-28.

[48] Carew to Mountjoy, 1 June 1602 (CCML, vol. 4 [1601-1603], no. 242, p. 242).

[49] See Mountjoy to Carew, 9 June 1602 (CCML, vol. 4 [1601-1603], no. 248, p. 245) and *ibid.* to *ibid.*, 29 July, 1602 (CCML, vol. 4 [1601-1603], no. 274, p. 285). When he learned of Parker's death, Mountjoy then requested Jollye, Carew's other master gunner for his Ulster campaign, but Carew steadfastly refused to give him up, suggesting the value placed on a competent gunner in the Irish wars. Oman considered Mountjoy's talents "wasted in the distressful wars of Ireland" (p. 389).

explain how his notebook might have been preserved among Carew's papers, not to mention Carew's personal interest in gunnery.[50]

Beyond this, very little is known for certain of Parker. E.W.G. Bill has taken the two references in Parker's notebook to "observing" at Rainham to mean that Parker resided in Kent.[51] The Rainham Parker refers to, however, is more likely the Rainham on the north bank of the Thames, just downriver from Woolwich. Parker recorded his measurement of Rainham's latitude as 51° 35', only 4' greater than the latitude of the town near London, but 14' greater than the Kentish town.[52] Whether Parker resided there is another question. The placement of the two notes at fol. 27 and 60^{v} – which is effectively fol. 40 counting from the back – does not necessarily allow that generalization, since they might reflect two relatively contemporaneous entries, one from each end of the book. At any rate, the most that can be said is that Parker was either in London or Kent in the spring of 1596/7. In only one other places does Parker mention a specific place: "Crockehauen in Ireland" (fol. 18).[53] This note occurs three folios after a note dated 2 July 1597, so since one of the Rainham

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[50] It is even possible that Carew retained Parker to teach him about great ordnance. Thomas Stafford suggested that Carew became expert in gunnery more from need than inclination: "for Canonier or other Atificer (skilfull in the mountures of Ordnance) he had none" (*Pacata Hibernia, Ireland Appeased and Reduced* [London, 1633], p. 45 quoted in W.A. McComish, "The Survival of the Irish Castle in an Age of Cannon," *The Irish Sword* 9 (1969): 18). Recall that Carew unstopped a cloyed cannon (ch. 4, n. 22, above).

[51] E.W.G. Bill, "Revisions of H.J. Todd's A Catalogue of the Archiepiscopal Manuscripts in the Library at Lambeth Palace (1812) (MSS 113-283)," [typescript in reading room at Lambeth Palace], no. 280.

[52] Rainham (London) lies at 51° 31.2'N 0° 11.8'E (O.S. TQ 5282); Rainham (Kent) is today an eastern suburb of Chatham/Gillinham and lies at 51° 21.6'N 0° 35.5'E (TQ 8065); There is also a Rainham in Norfolk (now Raynham, 52° 47.5'N 0° 47.5'E [O.S. TF 9230]). See J.H.F. Brabner (ed.), *The Comprehensive Gazetteer of England and Wales* (London, 1894-5), V.236 and Ordnance Survey (O.S.) Maps of Great Britain. There is no Rainham in Ireland.

[53] Crookhaven is a long, narrow harbor on the very southwestern-most peninsula of Ireland. In the spring of 1602, the harbors in this entire area was surveyed for depth at low tide, timber stores, and potable water supplies, in an attempt to predict where Spaniards might try to land. This mission did survey the places Parker mentions – Crookhaven, Cape Cleare, and Great Island – so it is possible (although unlikely) that his entry may date from 1602, just before Parker' death; see CCML, vol. 4 (1601-1603), no. 226, p. 222.

observations is dated 16-17 March 1596/7, it is probably fair to say that Parker arrived for Irish service in the early summer of 1597 and that his measurement(s) at Rainham were made upon his embarkation.[54] Sir George Carew sailed on both the Cadiz voyage of 1596 and the Islands Voyage of 1597 and was only appointed Master of the Ordnance in Ireland in 1597,[55] so if Parker was indeed an "ancient servant" of Carew, he must have shipped to Ireland ahead of his master. It is also possible, however, that Parker was only assigned to Carew when he assumed the office of Lord President of Munster in February 1600.[56] All the dated entries from the notebook fall into the period 1596-98, but since so few of the entries are dated at all there is no reason to assume that its use did not extend a year for two before and after that date. It appears, then, that this is the notebook of a man who learned his gunnery and related mathematical sciences in England, but then continued to make entries while on active service in Ireland.

Parker's notebook bears out Carew's eulogy, and its contents show us a well educated man, conversant with recent books in various fields, and one who dabbled in a wide range of independent fields, all related through "the mathematics." Most historians have assumed that gunners were in effect craft workers, who learned by doing and who passed that information on orally. Indeed, the Wright and Gunmen MSS largely tend to support that interpretation, as they make no mention of printed material or individual authorities. Parker,

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[54] If this reconstruction is accurate, then the Rainham near London is again the more likely, since The Elizabethan navy largely mustered out of the Depford terminal, just across the river from Woolwich. While the possibility exists that Parker had been serving in Ireland for a longer time and was only on a temporary leave at Rainham, I consider it less likely.

[55] See ch. 2, above, for information on the Islands Voyage, and Carew's log of the Cadiz Voyage in S. and E. Usherwood, *The Counter-Armada, 1596: the Journal of the 'Mary Rose'* (London, 1983). The latter also includes a short biography of Carew, which I have supplemented with that of the DNB. Carew was also in charge of the recovery of sunken ordnance lost by Armada ships that foundered on Irish shores; see CCML, vol. 3 (1589-1600), nos. 18 and 28.

[56] C. Falls, *Elizabeth's Irish Wars*, p. 252.

by contrast, not only knows of the authorities in his field, but actively evaluated their teachings.

The best example of this appears on fol. 11, where Parker describes "How to know if the Concauitie of anye pece of ordinanc be trulye bored or placed in the mides of her mettell." This common problem for sixteenth-century gunners arose from the poor casting and boring methods of the day. Cannon were cast as individual units from unique molds which were broken apart to remove the cast piece. A core was placed inside the mould to provide a concavity which would later be reamed out to the finished dimension. If this core shifted after insertion before the pouring of the molten metal, or if the flowing metal dislodged it slightly, the concavity might not be coaxial with the axis of the gun. In addition, if the reamer did not travel truly, the bore might also end up askew.[57]

This was of concern since the gunners sighted along the axis of the barrel, if axes of the barrel and bore were not collinear, their shot might land well off the mark. Parker realized this, and proposed the following method to test his gun (fig. 6.3a). Take, he says, a 6-7 foot ladle staff, "verye drye and as straight as maye be" and put two rammer heads for the particular cannon you wish to test on it, one at the end, and one three or four feet up the shaft. The rammer heads (**a** in the diagram) were to be made "a littell to lowe and sumthinge tapringe towardes the for end." Wool or clothe stripes were then nailed or glued to the heads to allow them to snugly fit the bore. Two or three feet outside the mouth, the gunner placed a three inch thick block of wood (**b**), turned "verye true and rounde" and "all wayes… verye ner as brodde as the mettell at the mouth."

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[57] Another possibility is that the core might not be a true cylinder, which might also cause the reamer to wander. A particularly stunning example of a "wandering bore" may be seen in a sectioned Chinese bronze cannon on display at the Museum of Artillery at the Rotunda in Woolwich. Its chase wanders back and forth on the order of an inch in a 3' long, 5"ø bore.

Then, with a string (**cdef**) attached to nails driven into it, the block is moved in or out on the rammer until the string just grazes the cannon at the tail and the mouth (**d** and **e**). Then, if the string also grazes fore and aft all the way around the piece, it is truly bored; if not, then "marke the differenc ther of whiche showethe how muche it is."

In concluding these instructions, Parker writes,

> This I hould far better than tartaglies or bornes deuice for that ther instrument beinge so longe and so weacke will swaige to and frowe wher by no gret sertentye may be geuen to it ther resen is good if the instrument wer as good but this other waye is withe out all dout if the guner worke Cuningelye or eles blame the workeman and not the deuice ·1596·

Without a doubt, then, Parker knew of William Bourne's *Arte of Shooting in Great Ordnaunce* and of Tartaglia, presumably through Cyprian Lucar's *Three Books of Colloquites*. In Book I, Colloquy 23, Tartaglia presents a dialogue between himself and a gunfounder who wished to know how to tell if the bore be in the "midst of the Mettall."[58] He self-agrandizingly describes an instrument of his invention to accomplish the task, while the gunfounder asks him to "Thinke a while of it, for I have asked this doubt of many… Engenars, and have not found any of them able to resolve mee therein." Tartaglia proposes an assembly of two parallel pieces of wood about a "brace" (*i.e.*, the length of your forearm) longer than the length of the bore, connected by two shorter pieces, "somewhat more than half the thicknes of the Peece at the tail." His illustrations indicate that the shorter pieces fasten the longer ones parallel to one another after the fashion of a tic-tac-toe grid (figure 6.3b). Then, by inserting one of the longer pieces into the bore and pressing it tight to one side or the other and measuring the gap between the outside of the gun and the other piece of wood at various places

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[58] N. Tartaglia, *Three Bookes of Colloqvies Concerning the Arte of Shooting in Great and Small Peeces of Artillerie* (London, 1588) , pp. 43-5.

around the cannon, the gunner may ken if the bore is indeed coaxial with the outside of the piece.

Bourne, in his chapter 2, describes Tartaglia's instrument as well as another one, effectively an oversized, double-ended caliper (fig 6.3c).[59] Two pieces of wood, "double the length of the hollow or concavity of the piece," are fixed on a hinge in their center and allow the gunner to insert one leg into the bore and close that end on the cannon wall, the thickness of which will register as the gap at the other end of the instrument. Parker rightly notes that these instruments would be prone to "swaige" since the shortest ones to test falcons would need to be at least six or seven feet long, and one of Bourne's second type to measure a whole cannon would be at least 18 feet long. Further, with no mention of cross-bracing, the common type mentioned by both Lucar and Bourne would be prone to racking which would cause the distance between the staffs to vary, even if preserving them in parallel.

In other places throughout his notebook, Parker indicates that he is reading quite widely. Early in the manuscript, he recorded a story problem on how, given the weight and diameter of one shot, to calculate the weight of another shot of a given diameter. He incorrectly uses a simple proportion (*i.e.*, $\frac{D_1}{W_1} \propto \frac{D_2}{W_2}$), but notes that his method "not as Recward borne nor luker do teche - but another way" (fol. 3). Here he indicates knowledge of Bourne again and may be referring to his *Arte*, although Bourne's development of this sort of proportion correctly provides the cubic relation (*i.e.*, $W \propto D^3$) in a scanty fashion.[60] Parker may actually be referring to Bourne's earlier book, *Treasure for Travelers* of 1578, where he deals with proportions with more mathematical rigor (pt. 3, referred to in his *Arte*). This is made more likely given that he here also

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[59] W. Bourne, *The Arte of Shooting in Great Ordnaunce*, pp. 8-9.
[60] *Ibid.* , ch. 18, p. 63.

mentions "Recward", that is, Robert Recorde, whose mid-century books, *The Pathwaie to Knowledg* (1551), *The Grounde of Artes* (1552), *The Castle of Knowledge* (1556), and *The Whetstone of Witte* (1557), provided basic arithmetical, geometrical, and algebraical instruction throughout Elizabeth's reign and beyond. Parker's mention of "luker" here likely refers to Parker's differentiation between Cyprian Lucar's *Colloquies*, which Parker rightly notes as being a straight translation of Tartaglia, and the appended work, *A Treatise Named Lucar Appendix*, which, while no more original in information, was at least Lucar's compilation of various authors. In Ch. 23 of *Lucar Appendix*, he presents his method for finding W_2 given D_1, W_1, and D_2. While Parker does record an incorrect method, we might forgive him for not accepting Lucar's method, which while correct, is not presented in the most understandable fashion. Instead of relating the two weights to the cubes of the diameters, he instead relates the two diameters to the cube roots of the weights (*i.e.*, the more difficult calculation, $\frac{D_1}{\sqrt[3]{W_1}} \propto \frac{D_2}{\sqrt[3]{W_2}}$, rather than the easier, $\frac{D_1^3}{W_1} \propto \frac{D_2^3}{W_2}$). Then, in a show of pure mathematical bravado, he works through one example using a given diameter of $5\frac{299}{413}$ so that his cubic roots remain rational, which, although producing the correct result, must have left reality-bound Parker quite cold. Lucar, to his credit, foresaw this difficulty, "fearing that the unlearned Gunners (who commonly esteeme all that for naught woorth which they cannot understand) will judge it a combrous, paynefull, and needlesse labor to seeke for the diameters" as he had shown, and appended two tables of bullet diameters (for 1 to 10 in.) and weights (one for iron, one for stone).[61] But, true to form, he gives the weight of each bullet in

[61] C. Lucar, *A Tretise named Lvcar Appendix* (London, 1588), p. 23. The tables are on sig. [I6]^{v}-[I7].

pounds, ounces, drams, scruples, grains, and parts of grains with an "accuracy" in one case of $\frac{1}{4244852}$ of a grain, approximately 15 nanograms (15×10^{-9} g)!

Parker also actively evaluated the information he received. On one folio (fol. 100^{v}), he clearly made notes to himself on the value of various ideas, although the source is unclear:

11	This is A verye good waye and soe is targli[nes] and bornes if the instrument be made of Iron and exactlye donne
12	This is Artificiall and good
13	This is true in Arte but wee shall find it difer in experience: And in the morter peece I know it Cannot houlld
14	A verye good and serviciable invention if the Gunner bee surcumspecte: and Artificiall
15	Verue excelente good rules: for fortification & well explaned

He seems to be referring to chapters or pages, but I have as yet been unable to discover the book to which he referred. Since this is the very last folio of the manuscript and it is written right-side-up, unlike fol. 100 and before which use the book upside-down, Parker must have had some source of information before him while he was working on the front part of the book (which probably dates the entry to 1596 or 1597) and jotted notes to himself. Clearly it must be something other than the works of Tartaglia or Bourne, since in "11" he favorably compares this instrument to their version. Nor can the subject matter even be determined in these cases. Number eleven clearly refers to an instrument, but it cannot be the collinearity gauge discussed above, since such a large instrument would not have been made of iron. Numbers twelve and fourteen give no clue of their topic, other than that they are clearly about man-made processes. Number thirteen probably critiques shooting at different elevations, the logical topic to which one could compare mortars. The order of subjects given here may suggest that this was not a book at all, however. This organization scheme would be unlikely in a printed book, with a chapter on fortification following immediately after ones on gunnery instruments and the

operation of cannon, as Parker's phrasing suggests. It is possible that the notes may even refer to some sort of lecture or demonstration. Regardless, Parker clearly demonstrates his willingness to learn and consider, compare, and critique information concerning his profession of gunnery and military engineering.

Parker also read books outside his field in the similarly mathematical disciplines of navigation and astronomy. In an entry dated 2 July 1597, he mentions "How by the Mathimticall Iuell to geue the longitut in all places at seae by hellp of the effemeride*s* or m^{r} blackegraues vranium" (fol. 15^{r-v}). John Blagrave published the *Mathematicall Jewell* in 1585, so while he may not have been reading it hot off the press, he was nevertheless familiar with the English offerings. The "uranium" Parker refers to is a special type of astrolabe described in Blagrave's 1596 book, *Astrolabium Uranicum Generale*, which also incidentally followed the Copernican system. "Effermerides," or ephemerides, are tables of astronomical events and Parker is likely referring to one of the many printed "prognostications" for that year.[62] In another note, made on 16 March 1596/7, he noted that he "obserued the suns' meridian altitude at Rainham and found it to be 41gr – 15min. The declinacon then by davys booke being 2gr – 6." (fol. 27). The booke by "davys" to which he refers is undoubtedly John Davis' *Seamans Secret*, which included tables of declination of the sun for every day on various years.[63] In both these cases, Parker was clearly quite current in his reading, since both Davis' book and Blagrave's *Astrolabium* had only been published the year

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[62] I am grateful to Gary McIntyre of IHPST, University of Toronto for suggesting the common Elizabethan ephemerides tables. The most common authors of these prognostications were Gabriel Frende, Thomas Buckminster, Robert Westhawe and Robert Watson. Continental Copernican tables were also available.

[63] J. Davis, *The Seamans Secrets* (London, 1593) , sig. E2. Parker uses an OS date, and Davis' tables do not show any discontinuity on March 25, even though each table (giving each month's days' declinations at a glance) are designed to be used for 12 years, repeating in a four year cycle. This book and its useful tables went through numerous updated editions. Bourne's 1581 *Almanacke* also gives 2°6′ (E.G.R. Taylor [ed.], *A Regiment for the Sea and other Writings on Navigation by William Bourne* [London, 1963] , p. 334).

before Parker made his notes, and we can perhaps envision an inquisitive Parker "trying out" his new books, as it were. Two measured drawings in his notebook also attest that Parker understood the new *trace italienne* fortification, although he mentions any specific authorities (fol. 32^{v}-36).

At a more basic level, Parker demonstrates a fairly in-depth knowledge of classical learning, for in a number of places he explicitly mentions the authority of Euclid and Archimedes. In noting how to calculate the circumference of a circle, that is, the value for π, he compares their opinions: "The Curcumferenc of Euerye Cercille to his diameter beres as $21\frac{3}{5}$ to 7 nerrer then 22 to 7 as Archimedes afferm," but "Euclid sayes it is lesse then thre tymes the diameter and ⅐ and more then thre tymes the diameter and $\frac{10}{71}$" (fol. 86)[64] Given that he never graduated from either Oxford or Cambridge, this level of sophistication speaks quite highly of the mathematical instruction available outside the universities, and a far cry from Richard Wright's $\pi = 3$. Taken as a whole, the range of mathematical ability Parker displays in his notebook is rather limited, but with a broad competence within that range. Parker largely restricted himself to the "rule of three", that is a simple proportion rule, given three values, find the fourth (a:b::c:d).[65] He demonstrates an impressive understanding of their use and the way in which numbers ought to relate, as in some cases where the proportions should involve single power relations, and others where either higher-power or extracted root relations are called for. The other topic Parker attempted in a few places was algebra, although he seems to have been in the

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[64] There is an unintelligible word before Euclid in the MS, which may be a reference to the particular edition Parker knew, possibly the Billingsley / Dee edition of 1570, although the letters do not appear to be Roman, suggesting the tantalizing although incredible possibility that Parker was referring to a Greek version. The Euclidean approximation is closer ($3.1408<\pi<3.1429$) than the Archimedean ($3.0857<\pi<3.1429$).

[65] Much of what he records Parker could have easily learned from published books of the time, but his notes do not seem to be straight regurgitation, indicating that even if he did learn these ideas from books, he internalized the properties and rules and could extend them at will.

process of learning it when he composed the notebook. He was quite fond of story problems involving a number of unknowns which are solvable with a system of linear equations in x, y, and z.[66]

Far and away the most interesting aspect of Parker's notebook is his singular devotion to another military practice, firing non-spherical projectiles from great ordnance. While the earliest representation of a gunpowder weapon, from the Walter de Milamete manuscript of 1326, shows a vase-shaped gun firing an arrow from its mouth, very soon afterwards projectiles became uniformly spherical (except, of course, for the occasional bar- or chain-shot). To suggest that at the end of the sixteenth century armies might return to the use of such antiquated weaponry strikes most historians as preposterous. Yet this is exactly the sort of weaponry Parker advocates in his manuscript. More interesting is that he is not arguing for the reintroduction of archery at the expense of gunpowder weaponry,[67] but rather more abstractly, suggesting a combined use. Further, he implies that it was in use at the time in Ireland and was very effective. Parker provides a glimpse into a world unknown to the printed literature of artillery, but nevertheless a pragmatic, ongoing concern of the Irish wars.

Peppered throughout the notebook, Parker repeatedly makes notes and calculations on the practice of firing arrows and bolts from gunpowder weapons, from $1\frac{1}{4}$"ø muskets up to $12\frac{1}{4}$"ø bombards. "Many and straynge thinges maye be

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[66] For example, on fol. 94^{v}, he related the rather amusing story of how a gunner bribed by the enemy to reveal how much powder the garrison has in store, might confuse his captors by speaking of lasts, barrels, and loose powder being in certain proportions to one another, which Parker then solves with a simple cubic equation. That such knowledge could be used to conceal information from one's captors speaks to its esoteric status at the time.

[67] For the 16th-century debate between archery and musketry, primarily between Sir John Smythe and Humphrey Barwick, see E.G. Heath, *Bow versus Gun* (East Ardsley, Yorkshire, 1973) and T. Esper, "The Replacement of the Longbow by Firearms in the English Army," *Technology & Culture* 6 (1965): 382-93 . In one place, Parker does seem to be justifying its continued use, but the passage strikes me as one responding to other's suggestions that the use should be discontinued rather than that it had been discontinued and ought to be reintroduced.

wrought by this art," he relates, "If you Consider of it well, for It maye be Called the new art of Archerye" (fol. 83). While "musket arrows" appear frequently in ordnance lists, Parker kindly clears up the distinctions between various kinds of arrows in noting that a "shefe" arrow[68] had a diameter of "uerye nere ½ of an inche" while the musket arrow measured "nere ¾" (fol. 9). He also, however, mentions that another type of sheaf arrow "of massyeue wood" measuring ⅝´´ or 1´´ in diameter.[69] The thicker shafts would have conveniently served to increase penetration power, but may also have been necessary to endure the compressive forces from launch by gunpowder rather than by bowstring, especially since these largest arrows were "merueloes good for great ordinaunce" such as the demi-culverin. In all cases, the arrows are 16 or 18 inches long and made of wood, the heavier the better,[70] have leather or pasteboard fletching, and serve offensively or defensively on land and at sea, those for the latter being "great arroes… withe forked heades of t[w]o foote Broode or better as the peces ar of bignes for whiche thaye shaull serue to cute the shroudes mastes yardes or sayelles or anye other thinge thaye take a mongeste the shroudes" (fol. 44). And in one case, rather than filling the

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[68] Parker is inconsistent on the spelling for this type of arrow: in some places he gives "shefe", *i.e.*, a sheaf or common arrow, and in others he writes "shefte", *i.e.*, shaft. I shall use the former.

[69] "A ordinarye sheffe arrowe wayes commenlye about ·2· ounces… and so the other sorte of sheffe arrooes of ⅝ of aninche maye waye be tyene ·2· and ·3· ounces waight or happelye more." A musket arrow weighed 3-4 ounces. He never specifies the weight of 1´´Ø arrows.

[70] In two places, he recommends that they be made of "brasell or some other heuye wood to Increce ther wayght" (fol. 83; *q.v.* fol. 25^{v}). "Brassel" does not refer to brass, but rather to brassel (Brazil) wood, a generic term for dense dye-wood from Asia, and by this time for new species from South America for which the country was later named; see OED, s.v. "brazil" 1. Roger Ascham mentions this wood as a poor choice for bowstaves (sig. Oiii), but a common choice for arrow shafts (sig. [Qii]), despite the fact that it made them "dead, heavy lu*m*pish, [and] hobblyng" (sig. [Qiii]). Its density also made it a good wood for knocks or splices to modify the balance of the arrow (sig. [Qiv]^{v}); R. Ascham, *Toxophilvs: the Schole of Shootinge* (London, 1545) .

chamber of a large field piece with a few dozen or more arrows,[71] Parker claims that "a pece of $4\frac{1}{8}$ inches in heit of his diameter… withe one pound of good powder [will] deliuer a shafte of 4 foot longe and fit for the pece of 40 or 50 pound wayghte" against "any houce or anye Castell gate or platforme… withe muche lese charge and labore" (fol. 18^{v}). In effect, he advocates launching a four foot log, with a "head of Irone and tipet withe stelle" rather than use a mortar piece and suggests that it would use less powder for its weight and is more likely to pierce the target than to shatter upon impact. Characteristically, many of his notes on the new art of archery are numerical arguments, either for the effectiveness of one shot in terms of missiles launched or powder used, or else apparently arguments for the economy of purchasing and using these munitions over normal round shot.[72]

The most astounding facet of Edmund Parker as preserved in his gunnery notebook, however, is his apparent devotion to experimental science. It is in no way surprising to find a gunner suggesting a novice make a few ranging shots with his piece so that he might understand its peculiarities. Nor is it odd to find a gunner aware of the variability in his piece, the powder, and the setting. This is experimentation after a fashion, but Parker goes further. In his singular devotion to the efficacy of musket arrow over round shot, Parker performed what a modern eye is tempted to call a controlled experiment to determine which projectile was "better". Parker gives no title to the relatively dense text and marginal comment on fol. 88, beginning succinctly: "the diameter of a musket bullet is $\frac{22}{30}$ of aninche and wayes of lead $1\frac{1}{2}$ ounce verye nere" and "the musket arrowe of that height wayes $3\frac{1}{4}$ ounces." This sort of quantification is not

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[71] His "rule of 3" calculation suggest that a falconet (2" ø) would take 5 sheaf arrows and a culverin (5" ø) 75 (fol. 19), while a demi-culverin (4" ø) would take one dozen 1" arrows, and a $8\frac{1}{8}$" ø mortar holds 200 small arrows, 80 musket arrows, or 50 1" arrows (fol. 25^{v}).

[72] See fol. 48^{v} and 65^{v} for his numerical analyses of the cost and effect of the arrows, and fol. 83 for a powder-efficiency argument.

out of place in his notebook, but the adjacent marginal note is: "My profes wer withe a thembell that ·6· wer an ounce and the pouder ordinarye Cannon pouder suche as is for the great ordenance in the shippes of her magestiy." Parker alludes to tests with a relatively fine instrument, a thimble of $\frac{1}{6}$ ounce capacity and standardized powder, such as could be expected in the last decade of the sixteenth century. What he does with it is quite astounding, not in terms of results, but in terms of methodology. In the case of the powder, he weighed out an ounce of it, "beinge somewhat moyste or danckes" and then dried it. In the process he found that "when it was drye… it wanted of his wayght… about the $\frac{1}{12}$ of an ounce." Other sixteenth century gunners might mention that powder *can* get wet but their suggesting how much water it might absorb under normal condition is unheard of. Admittedly, Parker's methods are far from a modern controlled and calibrated test, but his commitment to understanding his art rigorously and quantitatively is apparent.

Taking his "experiment" further, Parker discharged "a musket withe her bullet… wayinge $1\frac{1}{2}$ ounce and Charged… with one ounce of powder… agaynest a tre." It penetrated "about ·5· inches depe." When he discharged his musket with an arrow weighing $3\frac{1}{4}$ ounces with only $\frac{1}{3}$ ounce of powder, it "perced ·10· or ·11· inches depe into that tre." Parker only analyzes these results simply, noting that the musket bullet had three times as much powder but only penetrated half as far as the arrow. He does not go further and suggest the obvious "conclusion" that the arrow is some six times more efficient. While he does note that "the arrowe [was] more then twice as heuye as the bullet wase," suggesting a rudimentary understanding of an efficiency, he only concludes, "Not[e] well this great difference bothe in wayght and pouder." Clearly he is interested in powder-savings, and the greater penetration power of the arrow. He indicates no concern over the shape of the two bodies, nor does he continue the

investigation to understand why the musket arrow penetrates further.[73] For him the gross effects are sufficient to justify the experiment, but the experiment's importance arises because it was conceived of and reported as a quantitative experiment, not just anecdotal evidence.

Edmund Parker is probably as atypical a gunner as Thomas Harriot was a scientist. But these men provide virtually the only glimpses into the world of early modern artillery in the Tudor military. In some ways, what they have to show is rather mundane and incomparable to the later seventeenth-century achievements in mechanics, military organization, and firepower. In that sense it is understandable why people like A.R. Hall would dismiss the Tudor period as uninteresting in comparison. But at the same time much of what a later seventeenth-century gunner would learn would be exactly the same as a late- or even mid-sixteenth-century gunner. While the seventeenth century would see the development of a more purely mathematical tradition of gunnery, the robust craft tradition that had flourished from the late fourteenth century on the Continent and at least the earlier sixteenth century in England continued unabated. And people like Parker demonstrate that the printed books which flooded the English market after about 1580 did not entirely fall upon deaf ears. And indeed, at least one copy of a number of books made it into the hands of a practitioner.

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[73] A complete modern analysis is not possible because of the number of unknowns involved. It would include the drag factors for the two shapes (likely on the order of 4:1 for a sphere to an arrowhead; the shaft drag factor is irrelevant since the arrowhead would be doing the work upon penetration), as well as the changing force exerted on them as they penetrated the wood. Nevertheless, a simple analysis of a sort may be proposed. A modified kinetic-potential energy balance ($\frac{1}{2}mV^2=Fd$, that is, the kinetic energy upon impact [mass times the square of velocity] is equal to the work done to bring the projectiles to rest [force times distance]) suggests that $V \propto \sqrt{d/m}$ (assuming here that the force (F) is a constant). In this case, the relative velocities are almost equal, suggesting that differing penetration is entirely due to the shapes and masses. On the other hand, if we do assume equal velocities, and hence kinetic energies only proportional to the relative weights (~2.17:1), since the arrow required only $\frac{1}{3}$ as much powder, it was in effect 6.5 times more efficiently launched.

Certainly Parker was exceptional, as the majority of gunners throughout Queen Elizabeth's reign probably followed an employment pattern like those recorded in the 1570/1 Ordnance Office pay records. Only after England went to war with Spain and began garrisoning Dutch towns and actively aiding the States General and, later, Henry of Navarre, would a large number of gunners find full-time employment from the Crown. But this ignores the many gunners – drawn from the same stock as garrison gunners, to be sure – on merchant ships (as well as the few dozen royal warships) who would have been employed full time, or at least seasonally. Here the Elizabethan artillery procurement and disbursement policies would have put the types of artillery into the hands of the men who needed them. The final question to consider, however, is how these men came to be interested in gunnery and came to be instructed in its finer points.

Figure 6.1

Analysis of Ordnance stores, 1580
(compiled from B.L. Sloane MS 3194, fol. 21r-v)

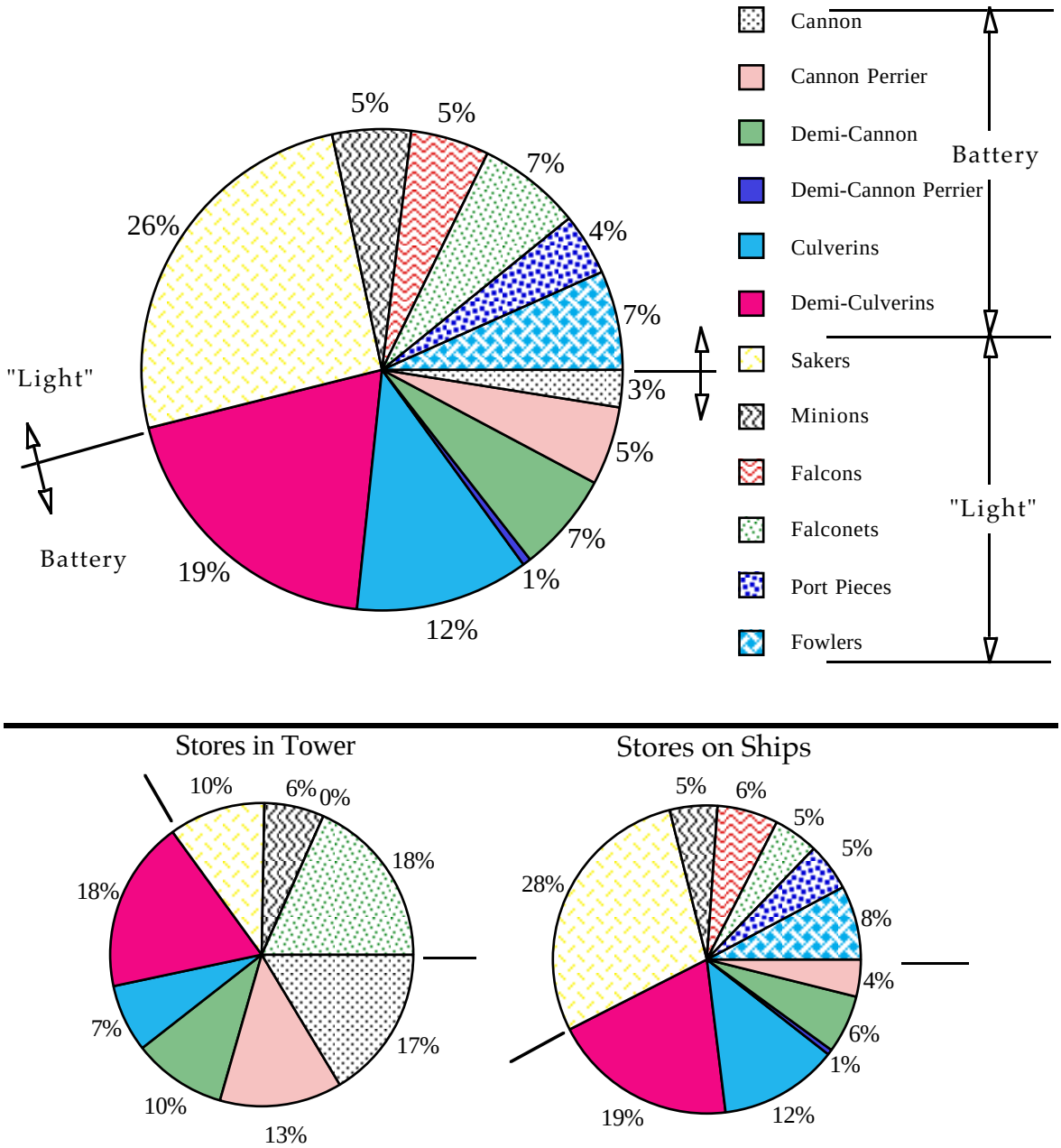


Figure 6.2

Analysis of Ordnance stores, 1592
(compiled from Lambeth Palace Library MS 293)

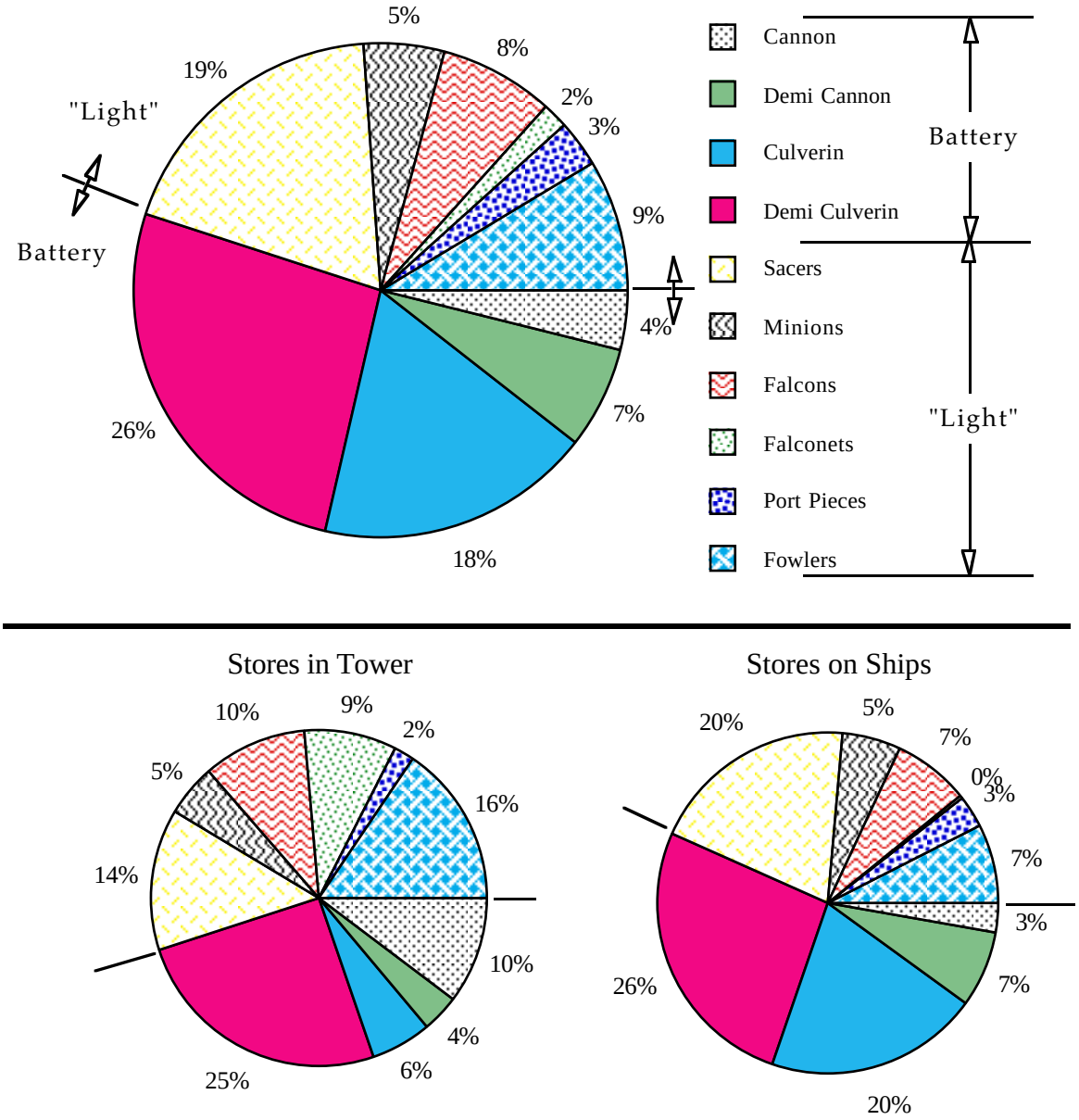
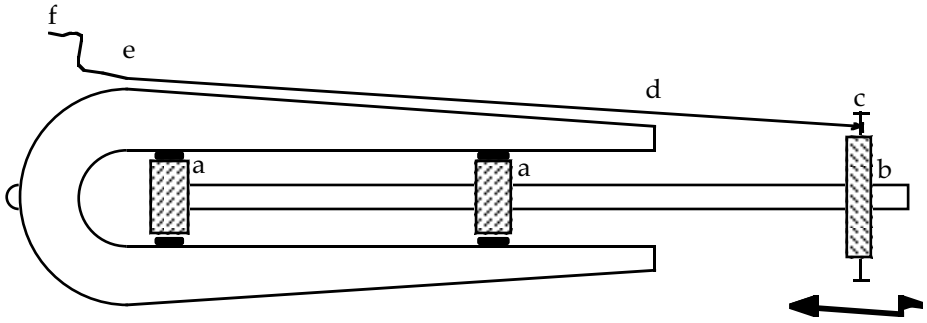


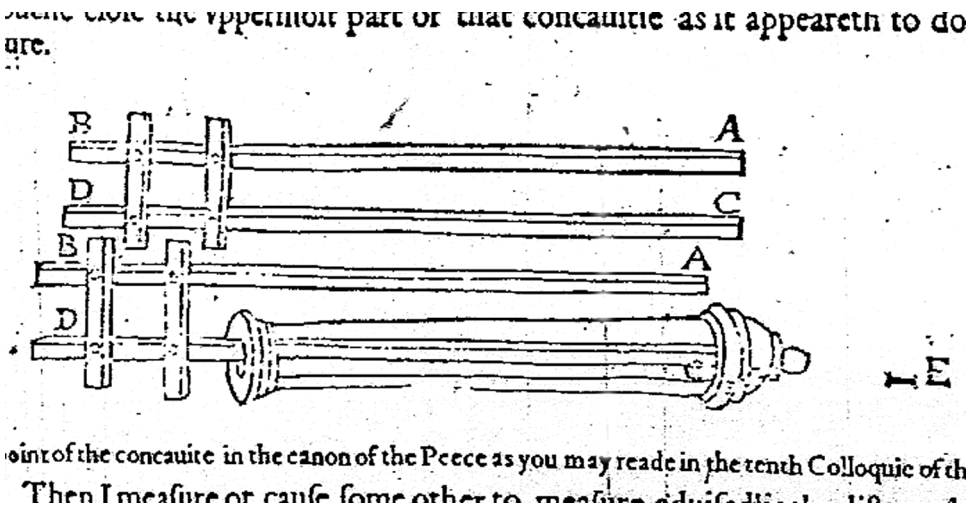
Figure 6.3

Cannon Concavity Testing Methods
a) William Parker (from Lambeth Palace Library MS 280, fol. 11)
b) Niccolo Tartaglia (from Tartaglia [1588], p. 45)
c) William Bourne (from Bourne [1587], p. 9)

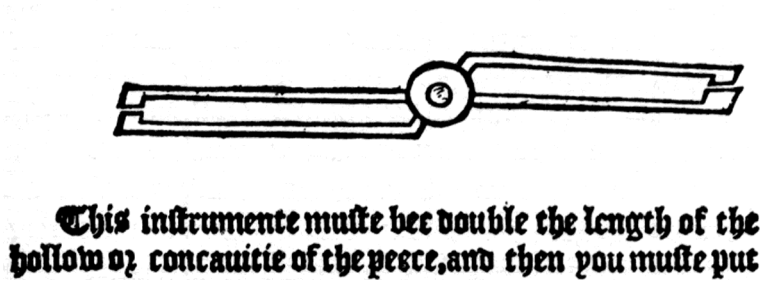
a)



b)



c)



Chapter 7

The Artillery Garden and the Corporation of Gunners

the soldiour and scholler cannot sit both on the same stoole,
the Souldier must give place to the scholler.
— Count Haniball Romei of Ferrara*

Introduction

The Royal Artillery Institution at Woolwich did not open its doors until 1751, yet England had gunners for hundreds of years before that time. It would be surprising to find that there was no formalized gunnery training in England before that time, and the survival of manuscripts like Wright's or the Gunman MS argue against such an assumption. So where did that training happen? In fact, it occurred exactly where one might guess, but yet in a place subsequent historians have known but dismissed. They have been misled by later uses of the same space and others like it around London as well as ambiguous terminology, and it would appear that formal instruction in the care and use of great ordnance in Elizabethan London fell somewhere between governmentally-sponsored training and citizen-inspired militia clubs. Not until after the Civil War did artillery became institutionalized in the government and not fully until the establishment of the Royal Artillery Institution at Woolwich in 1751. But in the latter half of the sixteenth century the Artillery Garden outside Bishopsgate did serve as the first, but perhaps not only, gunnery school in England.

"She is growne so Great, I am almost afraid to meddle with Her," said Daniel Lupton of London in 1632. "She's certainly a great World, there are so many little worlds in Her… [that] I am sure I may call her a gally-morphrey of al[l] Sciences, Arts, & Trades."[1] Among these little worlds were sundry areas of

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* Count Hanniball Romei, *The Courtiers Academie*, trans. by I.K. ([London]: Valentine Sims, [1598]; STC 21311), p. 267 (sig. Nn2).

[1] D. Lupton, *London and the Covntrey Carbonadoed and Quartered into seuerall Characters* (London, 1632) , p. 1-2. "Gally-morphrey" = gallimawfrey (F. *gallimafrée*); a hodge-podge,

London such as the Tower, Cheapside, the new and old Royal Exchanges, and Paris Garden, as well as various places or groups of people like playhouses, fencing-schools, enclosures and tenants (both by lease and "at will"), and even "Currantoes or weekely Newes." For each category, Lupton characterizes the place or the people with various attributes, all for the most part surprisingly positive, even for the lower sorts like fisherwomen and sanitation workers (the "gold-finders"). Chapter 18, however, describes the "Artillery Garden" where, in "the Cities Campe, and Mars his Schoole," the four brave flowers of society – manhood, acuity, courage, and arms – practice the "expert skill of Warre."[2] Poetic and impressionistic, Lupton describes "the fiue qualifications gracing Military Discipline" – decency, nimbleness, skill, uniform order, and experience – "vsually… to be view'd" at the Artillery Garden, moving like jack-wheels, wheeling(!) this way and that in perfect sync. He allows himself liberal word-play, noting that "'tis no marvell why Souldiers desire to fight, for they are alwayes in Divisions," and that "they seeme to bee suddenly angry, for one word moves them all." Other early seventeenth-century descriptions, albeit without the light-hearted approach of Lupton, echo that the Artillery Garden was a place wherein the new military art of pike and musket marching drill is practiced. And indeed, this was its – or their – primary use.

Consulting the earliest printed maps of London, various features strike the modern eye as rather incongruous. The prominence of the city walls, the concentration of the city between the bend in the Thames and the White Tower, and the remarkably rapid change from urban density to rural pasture

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mixture, or stew (Samuel Johnson, *Dictionary* [1755]: "any inconsistent or ridiculous medley"; J.O. Halliwell, *Dictionary of Archaic and Provincial Words* [1847]: "it is applied metaphorically to any confused jumble of things"). Although "carbonadoed" means to be grilled or burned, Lupton's book does not seem to have the viciously satiric intent that this word implies, but only light-hearted punning.

[2] The entire section on the Artillery Garden is on pp. 70-74.

immediately beyond the wall remind us that however much the London of Elizabeth may have been that of Henry VIII or even Henry V, it was little like that of Charles I, or more strikingly, that of James II and Charles II. The Great Fire of 1666 changed the face of London more than any single event, leveling nearly 85% of the old medieval city within the walls, but even more important was the restoration of the monarchy six years before. With this "return to normalcy" the landed gentry returned to London *en masse*, but rather than again taking up residences in the old city, they built grand new houses and created a new London – the London of today in many senses – upstream in Westminster.

Artillery Gardens in London

On the various pre-Civil War maps of London, beyond the Tower, the city wall, and the proliferation of churches, the next most prominent feature on the maps is the lack of open space within the wall. On the other hand, the open spaces just beyond the wall are well defined and conspicuously labeled: Moorfields, St. Giles fields, the Spital fields, and Finsbury field. As Alessandro Magno noted in 1562, the city dwellers could escape the town to these spaces for open spaces or sport and other entertainments – hence the term extramural for leisurely pursuits, literally "outside the walls."[3] The maps,[4] however, also label one type of field which served a special purpose, called variously the artillery

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[3] C. Barron, Coleman, Christopher and Gobbi, Claire, "The London Journal of Allesandro Magno 1562," *The London Journal* 9 (1983): 136-52, p. 141, 147.

[4] Various maps survive of London and environs starting in the 1550s, although with an unfortunate gap of accurate representations from the 1560s to 1650s. See J. Fisher, *A Collection of Early Maps of London, 1553-1667* (Lympne Castle, Kent, 1981) for facsimiles of the "Copperplate" map of c. 1553-59, the Braun and Hogenberg map of 1572/4 (a reduced version of the Copperplate map), the "Ralph Agas" map of c.1562, , Faithorne and Newcourt's map and Hollar's "Great Map" both of c.1658, and Leake's post-Fire survey of 1667. Other post-Fire maps include *Gründtriss der Statt London* of c.1670, Ogilby, John, *A Large and Accurate Map of the City of London* of 1677, and W. Morgan, *London & c. accually survey'd* of 1682. Useful 18th-century maps are J. Rocque, *A Plan of the Cities of London and Westminster, and Borough of Southwark* (1746) and J. Pine, *Plan of the Cities of London and Westminster and Borough of Southwark (*1749).

yard, ground, or garden. There were five of these yards around London at various times in the sixteenth and seventeenth centuries (see fig. 7.1): 1. one just outside Bishopsgate on the northeast corner of the city; 2. one in old Finsbury Fields outside of Moorgate on the northwest side of Moorfields; 3. one just west of St. Giles in the Fields, today just southwest of the intersection of Oxford Street and Charing Cross Road; 4. one west of Westminster Abbey on the eastern fringe of Tothill ('Tutle') fields south of St. James' Park; and finally, 5. one in Southwark, just across the river from the Tower. All were about 200 by 300 feet in size, with Moorfield perhaps a bit larger and St. Giles a bit smaller. Most were frequently walled and abutted by roads rather than buildings, at least in their beginning, and all were only at most about a quarter mile beyond dense urban habitation.

The one with the longest history and of most interest here, however, it the "Old Artillery Garden" outside Bishopsgate in the Spital (of "Spitel") fields. Although only two of an original fifteen plates survive from the earliest known printed map of London, the so-called "Copperplate" map of c. 1553-9, one of them fortunately includes this area (fig. 7.2), although the Artillery Garden is not labeled. In a long, low-walled field running parallel to Bishopsgate Street, two men standing next to a butt at the south end of the field fire muskets at a similar butt at the north end. A moderately large, double-gabled house stands inside the wall at the north end of the field, immediately adjacent to "S. Ma Spittel", while in a very large field just outside the wall to the east labeled "The Spitel", men practice archery and other men who appear to be armed with swords converse, or possibly practice fencing. The map shows women and children (as spectators rather than participants in any of the activities), while formal gardens and orchards appear to the north of the Artillery Garden. Founded in c.1200, the Augustinian Priory of St. Mary Spitel outside Bishopsgate served London's ill and

orphaned until the Dissolution of the Monasteries when it appears to have already been partially dilapidated.[5] The hospital lands passed into the hands of the City of London, while the adjacent fields, gardens, and orchards were retained for use by the Crown, although primarily by the Ordnance Office from about 1537.

The field appears very similar on the "Agas Map" of the early 1560s and on the Braun and Hogenberg version issued in the 1572 edition of their *Civitates Orbis Terrarum*, although it, too shows the city as it was before 1561. All three maps' histories appear to converge, so this similarity should come as no surprise.[6] It is unfortunate, however, that no further maps of any great accuracy seem to have been produced until the Civil War. The "Artillerie garden" with a large three-spired building along its south end is labeled on Cornelius Dankerts map of 1604, although this map privileges streets over structures and should only be taken as schematic.[7] It does, however, indicate that the area had attained recognized status by the opening years of the seventeenth century.

On the 1658 Faithorn and Newcourt map the "Artillery Yard" is also clearly labeled, although this map most likely represents the state of the city during the Civil War about 1642/3 (see. fig. 7.3). It shows what is presumably the same large structure on the south side of the Artillery Garden, the field now irregularly shaped but fully walled, and with open fields to the east and north. This map is not as reliable for the outlying areas of London, but its details – primarily the irregular shape – are echoed in a German map of c.1670 and more

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[5] The best source for the history of the fabric of the hospital and Artillery Garden is London City Council, *Survey of London*, vol. 27 (London, 1957) , ch. 2-3, pp. 21-30.

[6] See J. Fisher, *A Collection of Early Maps of London, 1553-1667* (Lympne Castle, Kent, 1981) , pp. 1-2.

[7] Dankerts' map was engraved by Augustus Ryther and is reproduced as a silent frontispiece to C.L. Kingsford, *Chronicles of London* (Oxford, 1905) . The large structure should not be the New Armoury, since this sole recorded major construction project in that area was not begun until 1622, but for one possible identification, see below.

importantly in a 1681/2 plan of the "Old Artillery Garden" next to “Spittle Field” (see. fig. 7.5).[8] This plan, however, makes no indication of what bordered the grounds. In Leake’s *Survey of London* after the Great Fire in 1667, however, the Garden is shown nicely rectangular and walled with the house on the south end, but with dense urban development on the south, west and north (fig. 7.4). It is not until the late 1670s that accurate, house-by-house surveys of London were completed, and surveys of the time show the Artillery garden encroached on all sides, although without any indication of what the large building shown on Dankerts’ and Faithorn & Newcourt’s maps could have been (fig. 7.3).

The other four artillery yards were open pasture according to the sixteenth-century maps, first appearing on Faithorn & Newcourts’ map of London in the 1640s. They are not, however, direct responses to Civil War exigencies. In the 1620s, a wave of interest in military matters swept the country, and volunteer bands grew up all over the country to practice “armes.” The Privy Council ratified the creation of artillery yards around the country – Colchester in 1621, Bury St. Edmund (Suffolk) in 1622, Norwich in 1625, Gloucester, North Yarmouth (Norfolk) and Chester in 1626, and Nottingham and Ipswich in 1629[9] – and as early as the very end of 1615 had allowed “diverse citizens in Westminster, St. Martins in the fields, St. Clement Danes, the Savoy, Hoolborne, and St. Giles in the fields” to be trained at their own charge under

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[8] See *Gründtriss der Statt London* for the German map and *Survey of London*, p. 29 for the plan.

[9] Although Chester’s yard had to be rechartered in 1629 to Captain Edward Holmwood, when the original patentee, Captain William Dutton, apparently failed to produce a company of trained men. Some of the foundations were for a specified maximum number of men: 200 in Bury St. Edmunds, Norwich, and Ipswich, and 240 in Nottingham. For these charters, see the relevant dates in the APC: Bury St. Edmund, 25 Oct. 1622; Norwich, 23 Feb. 1624/5; Gloucester, 15 May 1626; North Yarmouth, 10 Jan. 1625/6, Chester, 5 May 1626 and 20 Apr. 1629; Nottingham, 31 Dec. 1629; and Ipswitch 29 Sep. 1629. See also G.A. Raikes, *The History of the Hounourable Artillery Company* (London, 1878), I.58. Elizabeth had acknowledged the importance of handgun practice, but cautioned against it near inhabited places (TRP, III.442-5, no. 641).

Capt. Thomas Holcrofte, although at that time they did not specify a particular training ground for them.[10]

What connection, then, do the artillery yards have to great artillery if Lupton has already established their use as infantry drill yards? Ambiguity arises immediately from their very name. We use "artillery" today as a synonym for ordnance, that is, large, crew-serviced military engines, yet "any projectile-throwing weapon" remains a broader and valid, if less common, definition. It is in fact this earlier definition which Elizabethans preferred; witness the King James Version of 1 Samuel 20:40, "And Jonathan gave his artillery unto his lad, and said to him, go carry them to the city." Robert Barret wrote in 1598 that "artillaria" was "a forraine word, and is that which we call the great ordnance."[11] To Elizabethans, artillery and ordnance were (usually) separate and distinct. Ordnance Office inventories made a distinction between the heavy ordnance – cannons, culverins, mortars, and the like – and the artillery – bows, crossbows, pistols, and handguns, although generically a "list of ordnance" might include all these weapons and provisions along with swords, shields, and

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[10] APC, vol. 34 (1615-16), pp. 360-1 [31 Dec. 1615]. For our purposes, however, the "Artillery Garden" referred to in sources through James I's reign seems clearly to be that outside Bishopsgate. The fate of these fields, other than those outside Bishopsgate and Mooregate which will be described below, should be mentioned. The St. Giles military field appears to have been relatively short-lived. Tradition assigns its founding to Prince Henry, son of James I, as either a complement or competitor to the Artillery Garden (Walker suggests a founding in 1635, 23 years after Prince Henry's death). Most 17th century maps are frustratingly incomplete in the area where it appears for the first time on the 1658 map of Faithorn and Newcourt. A German map of London after the Great Fire (c. 1670) also shows it, but by 1682 the military yard and adjacent St. Giles Fields have been infilled with residential development; See C.L. Kingsford, *The Early History of Piccadilly, Leicester Square, Soho, and their Neighbourhood* (Cambridge, 1925) , pp. 57-63. The Westminster artillery ground does not appear until the mid-17th century and continues in use until the mid-18th; by the 1790s it was only just beginning to be filled in. Still, citizens of St. Martins in the Fields had been practicing somewhere for a number of years by 1617; see APC, vol. 35 (Aug. 1616 - Dec. 1617), p. 415. The artillery yard in Southwark appears on maps from 1658 to 1682, and was probably founded in the mid-1630s. Mid-18th century maps show it unlabeled although still vacant until the 1790s when development has encroached on all sides. See G.G. Walker, *The Honourable Artillery Company, 1537-1926* (London, 1926) , ch. 3, pp. 23-49, although his evidence is frustratingly unreferenced.

[11] R. Barret, *The Theorike and Practike of Moderne Warres* (London, 1598), sig Y4.

body armour. "Artillery," then, were clearly personal weapons. And most of the reference of activities at the Artillery Garden are to soldiers practicing archery or marksmanship with personal firearms, as on the Copperplate map, or to rank and file military drills as on Ogilby's 1677 survey of the "New Artillery Garden outside Moorgate." (fig. 7.6) And indeed, Lupton's description at the beginning of this section reinforces the image of the Artillery Garden as a parade and drilling ground for the infantry, not for artillerymen in the modern sense. But note that these are both descriptions from the middle or end of the seventeenth century.

The Artillery Garden outside Bishopsgate does not fit this pattern. Its relation to great ordnance is considerably stronger and much more ancient. Some suppose the connection arises from the incorporation of the Fraternity of St. George in 1537 for "the Science of Artillary that is to witt for Longe Bowes Crossbowes and Handgonnes &c," since it is from this charter that the Honourable Artillery Company of England traces its descent.[12] Today the H.A.C. is connected primarily with large ordnance, but as their own biographer admits, it was not until 1781 that the company began to train in gunnery of this sort.[13] In the phrase above, the "&c" is never specified and the rest quite clearly relates to personal missile weapons only. Another Henrician charter to a member of the fraternity makes the structure of the guild quite obvious. Upon the induction of a certain "W.A." into the fraternity, a certificate was drawn up which provided him with various rights and freedoms, all in the name of the principal directors of the company, who had been given independent charge of

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[12] The charter is dated August 25, 1537 and is printed in full in G.G. Walker, *Honourable Artillery Company*, pp. 2-7. In fact, the guild may date from as early as 1515, but the evidence is ambiguous; see *ibid.* p. 2, 7-11, and G.A. Raikes, *History of the Hounourable Artillery Company*, I.17-21.

[13] G.A. Raikes, *History of the Hounourable Artillery Company*, ch.1-2 is at great pains to demonstrate the continuity of the HAC and archery statutes from as far back as the reign of Henry II.

the company in the original charter. Among these men was Sir Christopher Mores, then Master of the Ordnance, and five other men all closely connected with the King's household and army.[14] "W.A.", by becoming a "brother and fellowe of the same" was allowed not only to keep bows, crossbows, and handguns in his house, but "for his dysporte and pastyme from tyme toe tyme duryng his lyff shall [n]owe at his libertie vse and shote in the same ingiens / at all man*er* markes, buttes and other game or games as at the game of alman*er* ffowles whatsoever they be / aswell within the citie of London the Suburbes of the same, as in every other place or places in any parte of this the King*es* Realme."[15] This included not only any game within Royal forests and parks, but also heron and pheasant "w*ith*in two myles of any of the King*es* Castell*es* manners or other places wher his magiestie shall lye and demoure." The guild, then, was not about great artillery or the education of gunners. It was a gun club for the higher echelons of English society.

William Thomas' Corporation of Gunners

Documents begin to survive from the reign of Elizabeth which show more clearly the connection between the government and an organized group of military men conducting the formal instruction of gunners for great ordnance and the Artillery Garden. Sadly, the evidence for that connection is incomplete, but surviving documents suggest that what one group hoped would come to pass did in fact happen. The earliest documents in this web of connections date from the middle of Elizabeth's reign, when the Queen's "moste faithfull Subiect*es* and Servaunt*es* the Gonners aswell belonginge to your tower of London as to

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[14] The other members were Anthony Knyvett and Peter Meanties ushers of the King's Privy chamber, Cornelius Johnson, Henry Johnson, Anthony Anthony, who would become better known as an important member of Elizabeth's Ordnance Office.

[15] Bod. Lib., MS Ashmole 1134, fol. 63^{r-v}. A later 17th-century copy of /W/A/'s induction is preserved in MS Ashmole 1111, fol. 18^{v}, and bears the partially damaged note, "Ex autor… Bibb… Cottoniana."

the Navye" petitioned her to begin licensing the master gunners of England. The document is undated itself, but is catalogued in the State Papers, Domestic for February, 1581.[16] It calls for the testing and licensing of all men of the realm wishing to call themselves master gunners on land or, primarily, at sea. The petition clearly states its motivation as a lack of competent gunners in England at the time:

> Experience hathe shewed and is daylye to be seine and founde true at everye presse made for the setting forth of your graces Navye. For whearas your graces Navye requireth to be furnyshed in tyme of service with a supplye of eight hondred gonners There is not founde when they come to service (besides your graces owne servauntes) fourskore hable men to supplye the places of gonners. (fol. 189)

In another place, the authors suggest that not one man in six pressed into duty as a gunner is knowledgeable in the "Science." Nor is it a case of the skilled men being lured away by the free market, for merchant ships could also not find skilled gunners to man their artillery.

The remedy, they suggest, is for the master gunner of England and four designated associates, located in the Tower of London, to deputize a master gunner for each of 14 out-ports around England, from Berwick on the Scottish border to Falmouth near Land's End to serve as local licensing bureaus. Each haven town would then "prove and trye thexperience & skill of eny persone that shall serve or take charge as chief or Mr. Gonner in any shippe or shippes or vesselles of [the] Realme" (fol. 191). Those passing their trial would be entered in a book, along with their place of residence, to be kept for time of need. Further, the petition proposes that after the following Christmas, any master gunner on any English ship leaving or entering the Realm (that is, coastal traffic excepted) who is not duly licensed by these outposts or at the Tower be fined and imprisoned for one month. The petition, however, is not in final form, as

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[16] PRO S.P. 12/147/94, fol. 189-195, abstracted in CSPD, vol. 2 (1581-90), p. 9. The document is reproduced in full in Appendix IV.1.

evidenced by blank spaces where the amount of fines should be. Clearly the author or authors worked out the structure but not the mechanics of this proposal, and it never gained Elizabeth's or the Privy Council's assent, as no such record books or fines appear in later State Papers. But such a suggestion making no reference to the Fraternity of St. George and proposing that a new corporate body be set up must suggest that even then the Fraternity was not in the business of large artillery.

The Tower gunners also specified the number of gunners that any given ship ought to have. Ships under 60 tonnes (which is to say most of them) were exempt from this scheme, but a ship from 60 to 100 tonnes was required to carry at least two certified gunners, those of 100-140 tonnes four gunners and so on in increments of 40 tonnes.[17] The penalty for an insufficient number of licensed master gunners fell upon the owners of the ships and is an again unspecified amount of money per missing gunner. These fines are to be collected, with half going to the Queen, and half to the Master Gunner at the Tower (along with his aforesaid four associates) for the use of the company in any court cases arising against them.

This document is but one of five preserved in the State Papers, Domestic which all relate to the establishment of a legal body, or corporation, for the better regulation and training of England's gunners.[18] In a number of places,

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[17] Interestingly, this is inconsistent with article 2 in PRO S.P. 12/157/40, fol. 75 (App. IV.3), where a 400 ton ship is given a complement of 36 gunners. By the scheme set out here, it should only require 28. We should probably ascribe the higher number to hyperbole since in App. IV.3, the author argues that of the required 36, "there are not Syxe expert men at all tymes to be had."

[18] The critical transcriptions of these documents in Appendix IV.1-5 were previously printed as Appendix D in G.A. Raikes, *History of the Hounourable Artillery Company*, I: 437-50. He provides an accurate transcription with only minor emendations, but full modernization. This source was obtained after the originals had been transcribed, but in places of disagreement, I have relied on my own reading. A.R. Hall, *Ballistics in the Seventeenth Century* (Oxford, 1965) , p. 31 and J.S. Corbett, *Drake and the Tudor Navy*, II:288, make only passing mention of the following episode.

they mention the meeting of the corporate "board" and the testing of the gunners at the Artillery Garden. In 1580, as far as is known, none of the other gardens around the city yet existed, which makes it clear that the Artillery Garden outside Bishopsgate is meant. The terms "gunner" and "master gunner" applied only to men in charge of the great ordnance, not small arms, so here we finally have ordnance and the Artillery Garden firmly linked, in some capacity. Two of these documents are catalogued in the State Papers for February of 1581, although tentatively. The others are all dated with the same reservation to 1582. Nor do the compilers of the *Catalogue of State Papers* make any indication of how they assigned months to the first two documents, although the years were clearly derived from the original cataloging which consigned the first two to bundle 147 and the other three to bundle 157. None is dated absolutely, only relatively, as in the note to "any time or tymes after the Feast of the Birthe of our Lorde god now next ensuynge and comyng."[19] Since England did not adopt a January New Year's day until 1752, "Feb.(?) 1581" dates should be taken as February, 1581/2. Given the remarkable consistency between the documents – in their proposals, wording, and even spelling, although it is marginally better in the more polished ones – it is likely that they all arose from a single person at a single point in time, but since they were but proposals, they never became rigorously dated. If in fact the first two documents are from February, an assumption we need not necessarily make, and they got filed in bundle 147, the other three could be from any time later in the year, and since they were never acted upon, they might well have been filed into bundle 157 at the end of the year during the Council's "spring cleaning." In all likelihood, then, all five documents derive from the same calendar year, that is, 1582.

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[19] PRO S.P. 12/147/94, fol. 192 (App. IV.1).

While the dating must be inferred, the same is not true for the author of these proposals. He was kind enough to autograph one of the proposals as "your humble Oratoure, William Thomas."[20] William Thomas first began his career for the Ordnance Office in 1557, when he was granted a gunner's fee in the Tower upon the death of Edward Thompson.[21] We might, then conservatively estimate that he was born towards the end of Henry VIII's reign, probably within the five years on either side of 1540. Granted one of the lower positions in the Office, he earned only 6*d* per day, whereas other gunners were frequently appointed at 8*d*, 10*d*, or even 12*d* a day. This may have been a form of inverse nepotism, for it would appear that he came from a family of Thomases serving as gunners for their Majesties. Although the family relations are not explicitly set forth in the Patent Rolls, a few years before William a Richard Thomas served as a 12*d* per day gunner and as "master of the gunners in the Tower of London" (with his co-master, Christopher Gold) from 1559 until his death late in 1566. In 1561 Robert Thomas the Younger (assumedly his son) was granted the late Robert Chancell's gunner's fee for life, although his life ended a short 3 years later.[22] Samuel and John Thomas also served as gunners in the Ordnance Office about 1580.[23] In 1571 Thomas worked a total of 15 days at

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[20] PRO S.P. 12/157/42, fol. 79 (App. IV.5). PRO S.P. 12/157/40, fol. 76^{v} (App. IV.3), is also endorsed "Certyne articles set downe by the Mr Gonner of England for the service of her Ma^{tye}." Thomas never held this office as Raikes (pp. 32-3) asserts. At this time it was held by Stephen Bull, Sr., and Thomas was presumably acting as a sort of spokesperson for the Tower gunners, as in App. IV.1. Nevertheless, his other letters suggest that he was the principle agitator for the corporation.

[21] CPR, Philip & Mary, vol. 4 (1557-8), p. 127 [7 Feb. 1557]. His grant for life was renewed on 11 July 1565; CPR Elizabeth I, vol. 3 (1563-1565), no. 1772.

[22] Robert Thomas: CPR, Edward VI, vol. 3 (1549-51), p. 165 [initially granted fee, 28 Sep. 1549], CPR Elizabeth I, vol. 1 (1558-60), p. 41 [fee renewed, 14 Nov. 1559], *ibid.*, vol. 2 (1560-63), p. 530 [co-mastership, 18 Dec. 1562], and *ibid.*, vol. 3 (1563-65), no. 2061 [replaced in fee, 1 Nov. 1566]. Robert Thomas the Elder had first entered service to the Crown under Edward VI (28 Sep. 1549; CPR, Edward VI, vol. 3 [1549-51], p. 165). Robert Thomas the Younger: CPR Elizabeth I, vol. 2 (1560-63), p. 4 [granted fee, 8 Feb. 1561] and *ibid.*, vol. 3 (1563-65), no. 953 [replaced in fee, 18 Jan. 1564].

[23] See Bod. Lib., MS Rawlinson A 204, and B.L., MS Harley 1640, "Ordnance Books," *passim*.

10*d per diem* for the Ordnance Office (ch. 6, above), but by 1580, he was earning a more sizable income. In April of that year, he and four other gunners were paid 12*d* per day for a full month's work (24 days) "for the Furnishing of the greatt ordenance for her ma^{tis} Shippes vizt the Elizabeth, Jonas the Triumph And the Bear and Antelope."[24] The work, however seems to have been again intermittent, for he is not listed in any of the other monthly lists of gunners engaging in various tasks at the Tower at this time. Given the clues in the earlier ordnance payroll, we can probably infer that at this time he was the master-gunner aboard one of these ships, in addition to holding his fee'd position at the Tower. In the spring of 1583/4 he again sent to Burghely and the rest of the Queen's Council "certaine articles… wherein was conteyned the greate wante of skilfull gonners to serve her ma^{tie}, in her highenes navie, and other fortificacõns, the cause thereof, and in [his] simple judgem^{t} the remedie for the same."[25] This petition seems to be the same as those delivered in 1582, but his 1585 letter to Burghley suggests that his earlier "humble sute" got him "greate displeasure, by the practize of some privie enymyes," but that he was now ready and willing to defend it point by point if Burghley would only give him the chance.

The William Thomas who penned the idea for a corporation of gunners may also have been the same William who was granted the office of "keeper of the Queen's mews at Charing Cross" along with the associated lodgings and ground in 1579, the income of which amounted to some £12 3*s* 4*d* per annum. He surrendered the same to Edward Thomas, possibly his son, in 1597.[26] There

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[24] B.L., MS Harley 1640, fol. 15^{r}.

[25] B.L., MS Lansdowne 43, art 31, fol. 70 (App. IV.6 – Jan. 1585) apparently referring to B.L., MS Lansdowne 39, art. 62 (App. IV.5 – 1584 version). This raises the question of whether S.P. 12/157/42 (App. IV.5) should be dated later or the version that is dated 1584 is indeed a copy circulating a year or two after Thomas made the initial proposal. State Papers might be filed in a later bundle, but it is unlikely for them to be filed in an earlier one, so I prefer to see Thomas' as a campaign spanning nearly a decade.

[26] CPR, Elizabeth I, vol. 8 (1578-80), no. 723 [28 Aug. 1579]. The grant was originally for life. For the surrender, see CSPD, vol. 4 (1595-97), p. 475, which notes that it was "in reversion",

are a number of other William Thomases peppered throughout sixteenth century English history, but the surviving evidence does not let us decide whether our William was related, for example, to the William Thomas, clerk of the Council under Edward VI and Mary, the same William Thomas who was executed in connection with Wyatt's rebellion in 1553.[27] At any rate, if he was indeed the holder of the mews and from a long and distinguished (in one way or another) line of Thomases serving the crown, this might have made him bold enough to try to propose the plan directly to the Council. It seems fairly certain that he did so more or less by himself, since copies of his petitions are not known to survive in the papers of any of the higher officers of the Ordnance Office of the time. Most are addressed to Burghley alone, although one mentions the earl of Warwick as one of the requested masters of the proposed corporation, and one other notes that the proposals had been shown to the Earl of Leicester, but of their responses, we know nothing.[28] One would expect petitions with the backing of a group like the Ordnance Office or a concerted effort of the gunners of the Tower of London to have had more impact, or at least to have triggered a response, something Thomas' petitions cannot be said to have done. He had, however, made use of one of Thomas' suggestions, for on Christmas Day, 1585

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suggesting that this William Thomas was not yet dead, although perhaps too aged to continue in his post.

[27] For this William Thomas, see L&P, *passim*; CSPD, vol. 1 (1547-80), pp. 43, 59, and 61 and E.R. Adair, "William Thomas: a Forgotten Clerk of the Privy Council," in R.W. Seton-Watson (ed.), *Tudor Studies presented... to Albert Frederick Pollard* (London, 1924), pp. 133-60, who notes that this Thomas may have been distantly related by marriage to William Cecil, Lord Burghley (p. 133). If he and our Thomas were related, this may explain some of our Thomas' familiarity. There is also another William Thomas of Cænarvonshire, Wales who took bribes, possibly illegally or possibly as a sting operation; see B.L., MS Lansdowne 111, art. 2, fol. 6-7^{v} and P.W. Hasler, *The House of Commons, 1558-1603* (London, 1981) , III.484-5. Adair's comment on his William Thomas is equally applicable to ours: "Thomas is so common a name, and Welsh geneology so mystical a science, that William Thomas's ancestry must remain a highly speculative problem" (p. 134).

[28] Ambrose Dudley, the earl of Warwick, was the younger brother of Sir Robert Dudley, earl of Leicester. Whether Thomas strategically proposed Ambrose in order to influence Sir Robert is unclear.

the indefatigable Burghley jotted a memorandum to himself that "the officers also of the Ordnance have delivered their demands in a writing apart." He continued that "order shall also be taken, to have a register of all the gunners, both serving by her majesty in the ships and in forts and of others serving merchants, to as yearly they shall be viewed, that none depart the realm."[29] So although Burghley was not swayed by the requests of the officers of the Ordnance, he at least realized the value in one small part of their suggestions.

Boldness, however, was not in short supply in the case of William Thomas. Thirty years after becoming a gunner in the Tower, in 1587 we find him in the Netherlands as part of Elizabeth's aid to the States General, ensconced as master-gunner of Flushing, then under the governorship of Sir Philip Sidney. Flushing, the easternmost port in the Scheldt estuary was of prime importance throughout the Dutch Wars of Independence, as it (and Middleburgh on the north side of the same island) controlled the main shipping channel to and from Antwerp, and therefore, most of the Baltic/Atlantic trade. We know that he was the master-gunner of the *Victory* in 1584,[30] so it would be reasonable to assume that Thomas was probably granted the post of master-gunner at Flushing as soon as Elizabeth formally committed to the defense of the Dutch Revolt in November, 1585. The Treaty of Nonsuch, signed August 20, 1585, gave both Flushing and Brill to England as collateral for Elizabeth's help for the Dutch rebels, although to be garrisoned and paid for by England. In December "the flower and chief gallants of England" had been posted or had volunteered

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[29] J.S. Corbett (ed.), *Papers Relating to the Navy During the Spanish War 1585-1587* (London, 1898) , p. 55. The original is S.P. Domestic 185/32, which I have not seen. Queen Mary had actually specified as much in her proclamation "Prohibiting unlicensed departure of mariners; 3 May 1558 (TRP, II.89, no. 442).

[30] D. Loades, *The Tudor Navy: an Administrative, Political and Military History* (Aldershot, 1992) , p. 197; although he gives no reference for this assertion, it must be based on B.L., MS Lansdowne 43, art 31 (App. IV.6). Also note that the *Victory* was not one of the ships mentioned in the 1580 payroll.

themselves to these garrisons.[31] Therefore, at the end of 1585 the Privy Council would have appointed a master-gunner: William Thomas.[32]

On 13 January, 1587 Thomas sent a half-page letter to the Council entitled "Requirements touching the ordnance at Flushing" covering the state of the guns there as well as the pay needed for the garrison.[33] Such a letter would be entirely fitting for a year-end review, had he been posted 12 months previously, or, given the remarkable efficiency of the Elizabethan bureaucracy, the letter would also not be unusual for a newly-appointed master-gunner. Still, Thomas took every opportunity to write to the Council – or Lord Burghley, or the Lord Admiral – to explain the deficiencies in the Flushing garrison and his personal views on how things should be run. He wrote that September to notify the Lord Treasurer that the magistrates of Flushing were careless "in not repairing their ordnance and platforms," that their walls were decayed and useless, and that the dikes were so easily breachable that "if the enemy do come [they] shall not need to bring the cannon." Burghley apparently ignored this letter, for Thomas wrote again in April 1588 with the same complaints as well as to complain of the inaccurate, overblown accounts of provisions provided by the States'

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[31] C. Wilson, *Queen Elizabeth and the Revolt of the Netherlands*, pp. 90, although he notes the governor of Flushing was not "overburdened with [recruits with] military experience or brains." After the French assumed governance of Flushing shortly after its capture by the Sea Beggars in 1572, a small, unofficial, fighting force under the leadership of Sir Humphrey Gilbert (the explorer and Sir Walter Raleigh's brother-in-law) attempted to garrison the town to keep it falling entirely under French control. Although the Zeelanders wanted them there, the French governor rejected their help and English participation in the revolt continued to be on a volunteer basis. There is no evidence of an English bureaucracy in Flushing that would include the post of master-gunner until after 1585, and besides, in Thomas' missives of 1581/2, he makes no mention of foreign service. See *ibid*., pp. 28-30 and 86-95f for the details on Flushing.

[32] A William Thomas is listed among a January 1586 list of Leicester's train, which arrived in Flushing on 20 December 1585, although his profession is unlisted; R.C. Strong and J.A. Van Dorsten, *Leicester's Triumph* (London, 1962) , App. III, p. 131.

[33] CSPF, vol. 21, pt. 2 (June 1586 - March 1587), p. 316 (extract only). He shared the master-gunners post with James Spencer, who had previously been a provost marshal for the English expeditionary force in the Low Countries.

representatives.[34] In June, with tensions running higher with Spain, he tried again, pleading that Burghley heed his warnings of a terribly decayed and weak Flushing. He also begged to be relieved of his post, at least temporarily, to fight the Spaniards in England, "hoping that the talent which the Lord hath given me shall not be without some good success against the enemy, wheresoever… I shall be appointed to serve."[35]

Thomas spent the time during the Armada crisis at Flushing, and on September 30 he yet again wrote to Burghley, although not this time to ask for leave or for more supplies, support, or manpower at Flushing, but simply to say "told you so." He reminded Burghley in a formal but slightly condescending tone that he had written before, proposing the re-chartering of the Henrician corporation of gunners, but that he and the Privy Council had ignored the petition.[36] Therefore, he continues,

> our sins and unworthiness caused that suit so little to be regarded, as it may plainly appear this day; for if it had pleased God that her Majesty's ships had been manned with a full supply of good gunners, according to the forces they carry, when the Spanish fleet came through the Narrow Seas and her Highness's navy so long in fight, it could not otherwise have come to pass, the Lord not being against them, but that it would have been the woefullest time or enterprise that ever the Spaniard took in hand.

So, although "our gracious God hath dealt mercifully with us," he concluded, "it were greatly to be wished that your Honours were more truely certified of that blind exercise and unskilful teaching by the name of scholars in the artillery, whereby her Highness may no longer be deceived, neither your Honours therein any further abused." Although he did then "cease, craving [Burghley's]

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[34] CSPF, vol. 21, pt. 4 (Jan.-June 1588), pp. 255-6.

[35] *Ibid.*, pp. 533-4.

[36] SP Holland, 57, printed in J.K. Laughton (ed.), *State Papers Relating to the Defeat of the Spanish Armada, Anno 1588* (London, 1894) , II: 258-60. Thomas makes note to a petition to the Council "three years past." This would seem, then, to be referring to the 1585 "reminder" letter to Burghley (App. IV.6) about a 1584 petition (App. IV.5).

favour in this [his] boldness," we can but wonder at Burghley's response to Thomas' impetuousness.[37] As far as is known, he never responded to Thomas, and again, the petition was officially ignored. Thomas' 1588 letter does, however, shed some light on contemporarly gunnery training. That the corporation would remedy the "blind exercise and unskilful teaching" of certain people calling themselves "scholars in the artillery" demonstrates that at this time there was some sort of formal instruction taking place, but that Thomas at least, considered its efficacy to be substandard, presumably based on the sample of gunners he was receiving at Flushing. This contrasts with modern analysts, who tend to believe that Elizabeth's gunners were probably more skilled than Parma's when the two fleets met off Gravelines.[38]

After the Armada, Thomas' letters to the Council shift in tone for the next two years or so. He becomes more of the servant he actually was, writing on more mundane topics, although still with a boldness surprising for his position. In a letter to Walsingham, he tries to make the Council aware of the terrible state of soldiers in the Low Countries, of the drunkenness, gambling, cheating, stealing, and starvation then rampant; he describes the pitiful condition of discharged soldiers who cannot afford to eat while their ships back to England are delayed by contrary winds; he suggests that assigning a preacher to each garrison could go far to alleviate the vices in the men and that the one in Flushing had never been paid; he asks Burghley to try to remove the prostitutes from the camps; he tries to extract the long overdue pay for his men.[39] Perhaps

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[37] Thomas also spoke to Burghley and the Council more harshly than we might expect in the 1585 petition: "there is noe other successe to be loked for, but that greate dishonnor will fall to her ma^{tie}, and to your honnors, wth greate greife to all faithfull subject*es*,… and all because your honnors did not use the meanes to prevente the same when tyme served" (B.L., MS Lansdowne 43, art. 31, fol. 70 [App. IV.6]).

[38] M. Lewis, *Armada Guns*, p. 171. On the other hand, the Spanish soldiers did not think much of the English gunners.

[39] Preacher: L&A, vol. 1 (Aug. 1589-June 1590), no. 108, p. 127 [4 Dec. 1589]; preacher and prostitutes L&A, vol. 2 (July 1590-May 1591), no. 67, p. 113-4 [25 July 1690]; pay in arrears: *ibid.*,

he simply fell into routine work at Flushing and gave up lobbying for a gunnery corporation, but more likely, with the worsening of conditions in the Netherlands, he became too busy simply trying to keep the garrison together to worry about much else.[40]

The last we hear of William Thomas for certain is in 1592, when he was still thumping the drum of the necessity – nay, imperiveness – for a fraternity of gunners a decade after he began his crusade.[41] While in London on leave at the end of 1591, he had a chance to meet with gunners from the *Revenge*, Queen Elizabeth's flagship, and to read her proclamation about the renewed threat from Spain. He wrote to Lord Burghley after returning to his master-gunner's post at Flushing to reiterate his suggestion for a fraternity of gunners, based upon the lost charter from Henry VIII.[42] His argument this time included the ideas that such a corporation would be beneficial "to keep men in honest and

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no. 62, p. 112; starving soldiers: CSPF, vol. 22 (July-Dec. 1588), p. 345 [26 Nov. 1588]. He also takes note in this last dispatch of the soldiers' practice of bringing serving boys with them to the Wars and then dismissing them when their resources fail (not infrequently due to the lack of pay forthcoming from England), thereby creating packs of adolescent thieves roaming the Low Countries.

[40] There is a strange entry in the APC dated 27 Jan. 1588/9 from the Council to the Governor of Flushing. In it they report that a certain Robert Day informed them "that one William Thomas, Master Gonner of [Flushing], is content to resigne and yelde up unto him [*i.e.*, Day] that place and chardge" and that Day has asked to be recommended to the Governor as a suitable new master-gunner. It does not, however, note what Thomas was being relieved for or where he was to be posted next. It is possible that Thomas' letter about the Armada angered the Council and that he was being forced out, but he appears to have continued in the post for at least another four years. See APC, vol. 17 (1588-89), p. 52. Day had been in charge of East County ordnance from 1579-86 and was "a man of good skill and experience in such matters" (see APC, vol. 11 (1578-80), p. 379 and APC, vol. 14 (1586-87), p. 114-5), but he disappears from the records after this Jan. 1588/9 appearance. He may have been the Day listed in Leicester's train in 1586 (R.C. Strong and J.A. Van Dorsten, *Leicester's Triumph*, App. III, p. 114) and he and Thomas may well have been the "two engineers" mentioned by Strong (*ibid.*, p. 32).

[41] If in fact he was indeed the William Thomas, keeper of the Queen's Mews, we know that he lived at least until 1597, when he would have been nearing at least 60; see n. 26, above. The published CPR series ceases at 1580, so it is not possible to determine when Thomas' gunners fee in the tower was reassigned.

[42] L&A, vol. 3 (June 1591 - Apr. 1592), no. 77, p. 118 [3 Jan. 1592] – the editors note here that "the letter to Queen Elizabeth about re-establishing the charter was granted. He [Thomas] now writes to Burghley" which is clearly a mistake, given the content of the letter. Thomas noted in the close of this letter that he had also written to the Lord Admiral (Charles Howard) and offered to defend his idea point-by-point if need be.

civil government" was necessary for the country's defense, and that it would not cost Her Majesty any more than any other corporation. His tone is interesting, however, for he now writes as a complete subordinate, asking the great Lord's permission to suggest something that had occurred to him. He almost seems cordial, as if they were friends. He notes that he understood Burghley had not had a chance to read the Queen's proclamation "because it was said to be too tedious," and that while he had to return to Flushing because his passport had expired, "he felt it his duty to write, in view of the great want of gunners for the Queen's forces by sea." Since there is never any return correspondence to Thomas,[43] Burghley apparently never took Thomas up on his idea, for the very last ever heard of Thomas was a signed receipt for powder at Flushing in May 1592.[44] By then he had served the crown for 35 years, conservatively putting him in his mid-50s. Without more sources to document his passing, we cannot know what happened to Thomas. He may have died in the intensified fighting in the latter part of the decade or perhaps even at the monumental siege of Ostend in 1601-04. By 1593 he may have moved to East Smithfield and become a turner, supplying the Ordnance office with pullies, rammers, and tampions.[45] Or he may have retired to obscurity in London, surrendering the Queen's Charing Cross mews in 1597.

Thomas' proposals, then, taken as a whole, provide a clear indication of the sort of gunnery system which was lacking in England in the early 1580s, and

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[43] At least not in the calendared State Papers or the Lansdowne collection.

[44] L&A, vol. 4 (May 1592 - June 1593), no. 72, p. 103. I should note, however, that the L&A series has only been completed through 1595, so further references to Thomas may appear as that series progresses.

[45] The Ordnance Office recorded payments to "Willm Thomas of Estsmithfield turner" throughout 1595. See for 1593: PRO WO 49/17, fol. 70 and for 1595: PRO WO 54/1(2), fol. 3; WO 54/1(6), fol. 4; WO 54/1(7), fol. 4; WO 54/3(1), fol. 3^{v}; WO 54/3(2), fol. 3^{v}; and 54/3(5), fol. 4^{v}. The recorded deliveries range from a few tampions for two royal ships costing the Ordnance Office 21*s* to an obviously much larger order of pulleys, both "doble and single", and tampions for £52 5 6*d*.

indeed well into the next decade, but they also indicate that some sort of system did exist. Gunners were primarily connected to the Navy, not because they were necessarily any more important there, but because this was the only part of the Elizabethan military which could even remotely be considered standing at the time. Further, since Thomas' life was centered in the Tower, it is not surprising that he would have been in frequent contact with the gunners from Her Majesty's ships as well as merchants ships, since all ordnance in the Realm had to go through Tower Wharf. The trained bands did exist, but had little use for great ordnance. As noted above, the Irish troubles did not call for ordnance on land service, and Elizabeth had committed few field troops to the defense of the Netherlands. Thomas noted that since the Queen's fleet "gave her a force by sea far exceeding other nations'," it should be manned with trained gunners in proportion to its ordnance so that "no prince's force could encounter them."[46] A second connection with the navy existed, however, in Thomas's suggestion that a gunner be appointed to test and register all able gunners in 15 outposts around the south and east coasts of England.[47] Not only were these places of embarcation for naval and armed merchant ships manned by licensed master gunners of the proposed corporation (Thomas' scheme called for the regulation of both[48]), but so, too were the main coastal defense works outside the Thames estuary. As we might expect, Thomas realized that " the strength of… all the Fortes and places of service within the Realme… depende inholye upon the use of greate ordenaunce," and that this sort of licensing should also therefore apply

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[46] L&A, vol. 3 (June 1591 - Apr. 1592), no. 77, p. 118.

[47] PRO S.P. 12/147/94, fol. 191 (App. IV.1, n. 4).

[48] That "the merchauntes shippes of this yor Realme maye be the better furnyshed in tyme of service and otherwise with skilfull men in the saide Science, (a thing verye requisite)," PRO S.P. 12/147/94, fol. 190 (App. IV.1).

to land service.[49] The shore defenses would need trained and skilled gunners on call and ready for action at any time, should danger such as foreign invasion threaten, a constant Elizabethan fear.

In speaking for the other gunners in the various petitions, Thomas indicates some of the corruption already creeping into the Elizabethan military. Commanders pocketing the pay of deceased soldiers once in their charge, or "dead-pays" as they were called, were quite common at the time,[50] but Thomas fingers a different sort of skimming. Apparently men would present themselves to the military forces, but then "those Gonners to whom hir majestie graunteth fee and wages so sone as they be assured of living doe disperce themselfes in severall plases utterly ignorant to the said officers and Mr Gonner."[51] For this reason, Thomas recommends that a master list be kept of all fee'd gunners with their civilian locations.[52] More troublesome, however is their failure to appear when needed. Instead "unskilfull men suche as never knewe what Gonne ment be of necessitie interteigned, for want of those that be bounde at suche time to make there present repaire." Thus, he concludes, "the Quenes majestie [is] deceved of an expert Gonner and yet charged with fee and wages, and also the service by unskilfull men hyndred and the comendable science in tracte of time decaied and forgotten."

Overall, Thomas' argument appeals to the defense of the Realm above all, rather than arguing from a purely self-interested standpoint. He does not

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[49] PRO S.P. 12/157/40, article 5, fol. 75 (App. IV.3). "inholye" = "entirely" I have here reordered the sentence, but not changed the meaning.

[50] On the pay system in general, see C.G. Cruickshank, *Elizabeth's Army*, pp. 143-58. See also C. Barnett, *Britain and Her Army, 1509-1970* (London, 1970) , pp. 45-7 and H.J. Webb, *Elizabethan Military Science: the Books and the Practice* (Madison, 1965) , pp. 66-7. For dead-pays specifically, see *ibid.*, p. 192, n. 50 and C.G. Cruickshank, "Dead-Pays in the Elizabethan Army," *English Historical Review* 53 (1938): 93-7. Sir Walter Ralegh noted that muster masters tended to discharge able men "for considerations to themselves best known", and were said to "carry the best and ablest in their pockets" (Ralegh, *Works*, 8:346).

[51] PRO S.P. 12/147/95, fol. 196 (App. IV.2). The next two quotations are from the same folio.

[52] PRO S.P. 12/157/40, article 6, fol. 75 (App. IV.3).

suggest that there is any element of competition in the same way that the Masters of Defense were responding to foreign fencing masters setting up shop in England.[53] In fact, there is no reason to suspect that there was any competition from foreigners at all and that Thomas' strategy was to divert attention from it. The English were never hesitant to blame their woes on foreigners and often went to great lengths to subordinate foreign to domestic abilities, even if domestic abilities were inferior.[54] And, indeed, in a study of the names of gunners recorded in the patent records, there are virtually no foreign surnames to be found after about 1550.[55] Instead, Thomas simply argues that there are not enough gunners, and few competent ones among those that can be found.[56] His letters were not entirely altruistic, of course, since he admits one of the benefits of incorporating the gunners would be to give them legal standing as a guild, to litigate, and to hold property independent of the Ordnance Office. But nonetheless, in the petition in which he sets forth the causes and effects of that incorporation, he appeals only to internal order among the fraternity members and the minimization of danger and inability in the use of ordnance in

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[53] C. Turner and T. Soper, *Methods and Practice of Elizabethan Swordplay* (Carbondale and Edwardsville, Ill., 1990), p. xxx. On the Masters of Defence, see below.

[54] This phenomenon was discussed by Laura Hunt Yungblut, "Immigrants, government policy and the dissemination of technology in Elizabethan England", Society for the History of Technology (SHOT) Meeting, London, England, 4 August 1996. More generally, see L.H. Yungblut, *"Strangers Settled here Amongst Us": Policies, Perceptions, and the Presence of Aliens in Reniassance England* (London, 1996) , *passim*, but esp. 67-8, 98, and 103. See also George Buc's comments at the end of this chapter.

[55] E.B. Teesdale, *Gunfounding in the Weald in the Sixteenth Century* notes that "many aliens were appointed gunners at the Tower between 1494 and 1509" (p. 11). An occasional Italian name appears during Henry VIII's reign. Of course, there is no way to penetrate fully Anglicized foreign names. No prosopographical study of the gunners has ever been undertaken, but O.F.G. Hogg, *English Artillery, 1326-1716*, pp. 279-80 presents an [incomplete] unordered list of gunners' names from the reigns of Henry VII through 1566. R.W. Stewart, *The English Ordnance Office 1585-1625: A Case Study in Bureaucracy* (Woodbridge, Suffolk, 1996) includes lists of salaried Ordnance Office personnel (App. 1 and 2), but curiously omits fee'd gunners. I have compiled a list of the gunners listed in the CPR for Mary and the first 20 years of Elizabeth which, along with Hogg, forms the basis of the assertion above.

[56] He does in one place allude to the notion that some gunners have been tenured in their "rooms" through personal favors, rather than ability, and that the corporation should be allowed to replace such "unskilfull" persons; see PRO S.P. 12/157/41, fol. 77^{v} (App. IV.4).

the Queen's service, besides the generic effect, of course, "To increase knowledge."

As for the Artillery Garden, William Thomas considers it a meeting place for the proposed corporation, and he clearly does so with the assumptions of someone who already uses it for a similar purpose. He does not propose that they begin using the Artillery Garden, nor that it would simply make a convenient place for their meetings. Rather, in one document he says that they should assemble and be allowed to shoot "within thartillerye yarde or in anye other convenient place."[57] It is mentioned in the sense of already being in use for other Ordnance Office business – that is, some training already going on – and that they therefore might as well continue using it for the gunnery corporation. Another of his proposals opens with the requirement

> that once [a] yere… all the Gunners and other servitares apperteyning to that offise doe appere within the Tower of London there to give there names to the Clarke of the saide office of there apparons and then to be comaunded to assemble in the Artillarie garden vpon an appointed daie in the presence of thaforsaid officers, and by the Instrucion of the Mr Gonner to shewe proof of their knowlege and cunyng in the use and practize of the great and small ordinance.[58]

Further, he suggests that at least four times a year, these gunners meet in the Artillery Garden to practice their skills so that they may past these tests.

While to this point, the *instruction* of the gunners has been curiously passed over, Thomas does in one place touch upon the subject. In a petition addressed repeatedly to "your honnor," and therefore probably again intended for Lord Burghley, he proposes the following:

> That there maie be… chosen, fower of the cheifest of her maiesties gonners to be vndermasters whoe, with the M^{r} gonner of Englande, maie have the *teachinge of all the Schollers*… as shall take vppon them the cherge of a Maister gonner in any of her Maties shippes fortes or castelles, or shall have of her Maiestie any gonners fee

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[57] PRO S.P. 12/157/41, fol. 77^{v} (App. IV.4).
[58] PRO S.P. 12/147/95, fol. 196 (App. IV.2).

and that

> That there maie be… given to the fower vnder Maisters and the Mr Gonner, that pouder, and other… allowance, for the *teaching and instructing of Schollers* in the Scyence or misterie of shooting in greate and small ordenance.[59]

Thomas, then, is asking for the right to train anyone in annual paid service of the Realm who is in charge of cannon as well as the *materiel* with which to train them. This would then amount to a sort of officers' training school for the artillery at the Artillery Garden. Unfortunately, since this proposal was never acted upon, we cannot necessarily date official training of gunners to 1582.

Interlude: Alternate Uses

The Artillery Garden was not used solely for Tower business. It had been traditionally also used for infantry drill and the Copperplate map suggests recreational archery was a favorite pastime there (fig. 7.2). Although references are scanty, it would appear that it was used on at least a few occasions for other public spectacles where a large open space was required. One such example comes from an initiation into the Masters of Defense of London in 1579. The Masters of Defense was the guild which officially oversaw and regulated fencing instruction in and around the city of London. They organized public exhibitions of fencing skill for the trials, or "prizes", which raised members of the company to "free scholar", "provost" or "master" of the company.[60] These were very much public spectacles, organized and conducted as dramas with a number of

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[59] PRO S.P. 12/157/42, no. 3, fol. 79^{v} and no. 7, fol. 80 (App. IV.5), emphasis added.

[60] H. Berry, *The Noble Science* (Newark, Del., 1991) , p. 25-37. Virtually all information on the masters of defense in this section comes from this source, especially ch. 1, pp. 1-14, but see also J.P. Anglin, "The Schools of Defense in Elizabethan London," *Renaissance Quarterly* 37 (1984): 393-410.

acts organized around various combinations of weapons, and played in many of the same venues that would have held other forms of public entertainment.[61]

One of the names recorded frequently in the Papers of the Masters of Defense was John Blinkinsop. Of interest to us is his elevation to master in 1579. The entry recording the feat reads as follows:

> John Blinkinsop playd his maisters prize the first daye of June at the Artillerye garden at four kynde of weapons That is to saye the two hand sword the backe sworde, the sword and buckeler and the staff Ther playd with him six maisters vide*licet* Richard Peters / Anthony ffenruther / Gregory Grene Richard Smyth Richard Donne & Henrye Naylor An[d] so the said Blinkinsop was admitted maister vnder Willyam Thompson maister / 1579 / [62]

On the face of it, this entry is as common as all the others, with the types of weapons and opponents listed as well as the candidate's master. Blinkinsop seems to have advanced more or less normally through the process of free scholar (10 June 1572?) and provost (9 June 1577?) to his mastership in 1579. He did stumble upon his first entry into the company, being at first denied admission as a free scholar "by cause of misdemenor by him committed and for want of his games wch weare not in place."[63] He seems to have been an active member of the guild, opposing numerous other would-be scholars, provosts, and masters throughout the reign of Elizabeth. He also seems to have been one of the more popular fencers of the day, for the playwright Ben Jonson could refer to "Blinkinsopps the Bold" in his play, "The New Inn."[64]

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[61] Berry notes that 45 of the 108 prizes recorded in Sloane MS 2539 were played in proper public playhouses, including 37 of the 39 prizes played in London from 1575-90, and that professional actors were among the members of the company (p. 5).

[62] B.L., Sloane MS 2530, fol. 3 (H. Berry, *The Noble Science*, p. 47). It should be noted that the publication of this manuscript corrects some of the chronology in previous works. A case in point is Turner's note that in 1583 "Blinkinsopps the Bold and Anthony Ffenreuther were 'allowed' Master" (Turner and Soper, *Methods and Practice of Elizabethan Swordplay*, p. 16).

[63] B.L., Sloane MS 2530, fol. 41 (H. Berry, *The Noble Science*, p. 123).

[64] C. Turner and T. Soper, *Methods and Practice of Elizabethan Swordplay*, p. 14.

In other respects, however, the entry is odd, and therefore interesting. It is the only prize played at the Artillery Garden and one of only a few played in a non-enclosed place.[65] Almost all of the other entries were performed on raised stages in enclosed venues, not entirely surprising, since these events drew paying crowds, and open air halls with a number of tiers of seating would obviously be advantageous to the day's ticket sales. In fact, from the 1570s on, the company preferred to use proper playhouses and inns, despite the fact they had to rent these venues, unlike the free public spaces they had previously favored. London city records record that on occasion the crowds were so great at a prize match, most businesses closed for the day.[66] Possibly Blinkinsop or one of his opponents had some connection to the Artillery Garden, but since this is his only appearance here, it would appear that this was not the case. Similarly, Grene, Smyth, Donne, and Naylor fought in many prizes listed in the manuscript. The connection, then, appears to lie with Anthony Fenruther, or Fenrutter, for this is the only reference to him in the manuscript, although he must have also played at unrecorded prizes, since he is, of course, also a master.[67] We have met Fenrutter before as Master Gunner of England from 1571-78. He remained a gunner in the Tower at the time of Blinkinsop's prize so it is safe to assume that it was his connection in the Ordnance Office which allowed the Masters of Defense to use the Artillery Garden in this instance. The record is incomplete between the 1550s and the 1590s, and this single reference to a prize played at the Artillery Garden begs the question of whether it was used for a number of events, or that Blinkinsop's mastership was something of a *hapox legomenon* – a one-off. Other sources suggest that it was one of numerous

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[65] The Artillery Garden was enclosed by a brick wall, but was not enclosed in the sense that an inn or playhouse would have been.

[66] *Ibid.*, p. 9.

[67] J.P. Anglin, "The Schools of Defense…," p. 405, claims that he was "one of the most prominent members of the copporation."

venues, but leaves open the question of how often it was used in comparison to other places.[68]

In some ways, the parallels between the gunnery corporation and the Masters of Defense should not surprise us. Both styled themselves a 'science' – the gunners corporation, "the science and knowlledge of shotinge in greate ordenance" and the Masters of Defense "the noble science"[69] – and considered their members "scholars" of their particular arts. While the word "science" did not have the connotation it has today, it still referred to a specialized knowledge and was not used except as an indication of status.[70] But beyond that the parallels may seem more remote, although it should not be surprising given the contemporary structures of society. The structures of the rules of the Defense society bear a striking similarity to the structure of the duties of a Master of Ordnance in the mid-sixteenth century. The society appears to have been incorporated (or perhaps re-chartered) on All Hallows Eve, 1549 ("the last daye of October In the Therd yeare of the raigne of our soveraign Lorde Kinge Edward the sixte") by the self-styled "four anciant maisters of the noble science of Defense Within the Citye of London"[71] Repeatedly, in the laws touching free scholarship, provostship, and mastership, the existing masters are referred to as the "ancient" masters. This is not to imply any institutional connection between the two societies, despite the plausible idea that those interested in gunnery might also be interested in swordsmanship. Rather, both societies cloaked their

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[68] Turner and Soper, p. xix list the favorite fencing spots in London: "A fencer might be found playing at Ely Place in Holborn, the Belle Savage on Ludgate Hill, the Curtain in Holywell, Grey Friars within Newgate, the Bull in Bishopsgate Street, Bridewell, the Artillery Gardens, Leaden Hall, and… Smithfield."

[69] G. Silver, *Paradoxes of Defence* (London, 1599) placed this science but one notch below divinity: "I speake not against… the Science, it is noble, and in mine opinion to be preferred next to Diuinitie; for as Diuinitie preserueth the soule from hell and the diuell, so doth this noble Science defend the bodie from wounds & slaughter" (p. 2 [sig. B[1^{V}]]).

[70] I know of no study of the shifting meaning of the word "science". Oddly, such a study should have been done it would seem, given the importance attached to the modern word.

[71] B.L., Sloane MS 2530, fol. 21 (H. Berry, *The Noble Science*, p. 83).

practice in a semi-formal language typical for the day, and, both being concerned with martial exploits, were probably conceived under the same rubric.

On an institutional basis, both societies traced their roots back to Henry VIII. The Masters of Defense were initially granted letters of patent in 1540, after a number of years of lobbying for protection. The King, though, likely saw them as just another element in the military buildup of the English state.[72] Generally, the corporation was chartered to provide fencing instruction to "all manner of estates gentilmen or yeomen of what estate so ever he or they be wch are Willinge to learne the noble sciense of Defense," and indeed, those men of various estates had to willingly defer to their masters, regardless of the master's estate in society.[73] The Masters of Defense included highly-connected members of society, such as Richard Tarlton, one of the Queen's jesters and one of the most famous comic actors of the day, who became a master on 23 October 1587, although he seems to have been one of four masters who received their masterhood by "agreement" rather than the actual playing of the prize. Other members included William Hearne, a yeomen of the Queen's guard and the lord chief justice, Sir James Dyer, and three other judges of the Court of Common Pleas refereed a number of the prize matches. Overall, the society attracted common men, not the nobility, who would have had their own fencing coaches and would not need the validation that comes with a formal society. Originally, however, there was a connection to the artillerists, if not the gunnery corporation itself. Richard Beste was one of the 9 original masters (along with 11 provosts) when the Masters of Defense were granted letters patent in 1540. Beste was a gunner in the tower of London at the time.[74] In another sense,

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[72] Turner and Soper, pp. 9, 12-13.

[73] B.L., Sloane MS 2530, fol. 35 (H. Berry, *The Noble Science*, p. 111).

[74] J.D. Alward, *The English Master of Arms, from the Twelfth to the Twentieth Century* (London, 1956) , p. 19 and Turner and Soper, p. 13

however, the Masters of Defense were also not unlike the gunners corporation in their eventual ineffectiveness. Silver points to this idea when he criticizes the schools of fence for not teaching useful fighting tactics: "surely, I thinke a downe right fellow, that never came in schoole, using such skill as nature yeeldeth out of his courage, strength, and agilitie, with good downe right blows and thrusts… shold put one of these imperfect schollers greatly to his shifts."[75]

They also had the trappings of a guild or secret society: the provost is "bound in his sayd obligacion not to teach anny scholler this Noble scyence of Defense excepte he doth sweare him vnto his owne Maister."[76] Compare this to William Thomas's assertion that "no manner of person from hensforthe shalbe placed in any Gunners Rowm or take charge of any peece of greate ordenaunce…, but onelye by the consent of the Master of the Ordenaunce and upon proofe made of eche persons abilitye by the undermasters and wardeyns of the saide Fraternitye."[77] The Masters of Defense routinely publicly tested the contestants for proficiency, leading to the various levels within the society itself. Thomas also suggests that "once in the yere viz at Mighelmas all the Gunners and other servitares apperteyning to that offise doe appere within the Tower of London" to register, and then "to be comaunded to assemble in the Artillarie garden vpon an appointed daie in the presence of thaforsaid officers, and by the Instrucion of the Master Gonner to shewe proof of their knowlege and cunyng in the use and practize of the great and small ordinance."[78] And Thomas explicitly made the analogy to a guild structure in one of his letters to Burghley:

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[75] G. Silver, *Paradoxes of Defence* (London, 1599), p. 24 (sig. [D4]). He actually advocates teaching "dirty" fighting in the schools: "there is no manner of teaching comparable to the old ancient teaching, that is, first their quarters, then their wardes, blowes, thrusts, and breaking of thrusts, then their Closes and Gripes, striking with the hilts, Daggers, Bucklers, Wrastlings, striking with the foote or knee in the Coddes,… [which is] the perfectest & most best teaching" (p. 25).

[76] B.L., Sloane MS 2530, fol. 19 (H. Berry, *The Noble Science*, p. 79).

[77] PRO SP 12/157/41, fol. 77^{v} (App. IV.4).

[78] PRO SP 12/147/95, fol. 196 (App. IV.2).

"the saide Master and Ruler and cominaltye maye at all tymes at their pleasure… assemble together as other corporacons of the Citye use to doe in their halles."[79]

All this is in no way surprising for a chartered society in the latter part of the sixteenth century. What is surprising is that these are not mercantile societies. This sort of organization would be entirely expected from one of the numerous guilds in London at the time, but to modern eyes, military fraternities that license, regulate and care for their members seem anomalous. Such functions are usually tied to a profession from which most members dervive their livelihoods, which cannot be said for the Masters of Defense, where the senior members would have, but not so the junior ones. But in an era without a formalized standing army, such societies were necessary from the standpoint of creating a trained populace, but also desirable from the point of view of the potential membership. Admittedly, the Masters of Defense catered to a more popular than militarily useful art, but they did serve a similar function for the members. Members gained knowledge in a relatively arcane technique, one ostensibly for their own prowess and the other ostensibly for the national defense. But I would argue that in some ways those learning to fence properly convinced themselves that in addition they were learning a skill which, should, say, Spain ever force their hand, could become indispensable to the national defense as well. Conversely, the gunners who would have been part of the stillborn gunnery corporation undoubtedly believed that they were useful citizens for the State, but also they were learning esoteric knowledge which they might never need to put to use, but which had its own intrinsic appeal.

Further, both societies "performing" at the Artillery Garden fulfilled a need from both sides of the table, as it were. Not only would the masters, those with the power, derive pleasure and recognition by having their tests at the

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[79] PRO SP 12/157/41, fol. 77^{v} (App. IV.4).

Garden, but so too, would the Garden provide a convenient venue for the spectacle for onlookers not interested, willing, or able to participate themselves. The role of pageantry and spectacle cannot be ignored in discussions of any Tudor or Stuart public event, and by holding the yearly gunners' trials at the Garden would provide a popular distraction for some of the populace. This last suggestion must remain speculative, for there is no evidence that large crowds did form, but neither is there any evidence that no one went or that the populace thought the gunners a nuisance. The sources are simply mute. But much as any military spectacle certainly did draw thousands of spectators then as now,[80] men firing large guns must have drawn at least a modest gallery of curious onlookers. And of course, when the Ordnance Office was not practicing with the great artillery, the Artillery company might well be found practicing drill with personal firearms.

The Artillery Garden as the first English gunnery school

But then what of formal instruction of gunners in Elizabethan England? In reference to the site for this training, Thomas claims that the Artillery Garden was given to the office of the ordnance specifically for the training of gunners by Henry VIII, although the original charter was by that time lost. One record, although dating from James I's reign and during a dispute between the Tower gunners and the Artillery Company, claims that in 1537 William Major, the last Prior of the convent at St. Mary Spitel leased the old Teasel Ground for 297 years for the practice of great and small artillery.[81] In asking for the Queen to reissue this charter, Thomas notes that the charter had apparently been "left in the

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[80] Generally, see R. Strong, *The Cult of Elizabeth: Elizabethan Portraiture and Pageantry* (London, 1977) , esp. ch. 5-6 for military tournaments.

[81] G.A. Raikes, *History of the Hounourable Artillery Company*, p. 31.

hands of Sir William Pelham" before it disappeared.[82] Pelham was the Lieutenant of the Ordnance 1576-87, which suggests that there may well have been an actual charter and this was not a manufactured claim, unlike later conflicting claims for the use of the Garden.[83] The other evidence for such a charter comes from the acrimonious disputes over the grounds between the Honourable Artillery Company and William Hammond and John Reynolds, Master Gunners of England in the 1610s and 20s, which were exactly the sort of disputes prone to spawn spurious charters. Since, in the 1580s, Thomas simply argues that it would not cost the Queen anything to formally charter the corporation and is not arguing for its incorporation against another claim; we may take his tacit acknowledgment that the gunners already use the Garden at face value.

Independently of Thomas, by 1580 we find clear proof of the Artillery Garden in use for great artillery and as a training centre for the gunners of the Tower, and presumably other gunners as well. Since there was no formal War Office until after the Civil War, the various reports drawn up at years' end for the officers of the Ordnance, once acknowledged, were no longer required and therefore do not survive as a continuous sequence in the sixteenth century. Thus, the records of yearly Ordnance Office activities lie scattered about various repositories in England and in them one can catch guarded glimpses of the day-to-day workings of the Ordnance Office. The earliest tantalizing suggestion comes from an Ordnance Office pay list for 1571. There we read that in February John Gibson, carter, was paid 2*s* for the drawing of "one fawcon from the Artillarie garden to the ffounders and another from the Tower to the Artillarie Garden."[84] In July he was paid "for cariage of vj lodes of powder and shotte

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[82] PRO S.P. 12/157/42, fol. 79^{v} (App. IV.5) and PRO S.P. 12/147/95, fol. 196^{v} (App. IV.2).
[83] See, in general, G.A. Raikes, *History of the Hounourable Artillery Company*, ch. 3 and 4.
[84] Bod. Lib., MS Rawlinson A 235, fol. 8. The following quote is from fol. 38^{v}.

tither for thexercise of the goners and skollers." While the location referred to as "thither" is unspecified, it seems reasonable to assume, given the use of the terms "scholar" and "gunner" together, that it was the Artillery Garden. And it would appear that in February they had received a replacement falcon for their training, suggesting that they had already worn one out.

At the end of the decade, Anthony Fenrutter, the Master Gunner and a Master of Defense, was paid £4 6*s* 8*d* for various work at the Artillery Garden. These tasks included "soeing of the Canvas for the Coueringe of the standing," "the heyre of laborers & for carriage of Clay and doung for the reparing of the great butt there at ye artillary garden," as well as for "wheels for a brass fawconet in the garden & for tallow for the same," among other things.[85] Whether the canvas awning was for practice in the rain or for spectators is unclear, but what is unmistakable is that this work clearly relates to great, not small, ordnance. Also, the fact that the work was not carried out directly by the Ordnance Office, but was instead only reimbursed by them emphasizes that the Artillery Garden, while sponsored by the Crown, remained a quasi-private institution at this point. Another work order informs us that Richarde Beaumonte, a plasterer, received 40*s* for materials "for reparacions by him doune vppon a shedde and howse Standing at the Artillary Garden where thordenaunce is placed right against the Greate butt."[86] While this reference to "ordenaunce" is ambiguous with respect to great or small, eight months earlier, when a pair of smiths were paid 2*s* a day for 24 days work, they are listed as having made "yron worke for the Great ordenaunce… for the Artillary

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[85] Bod. Lib., MS Rawlinson A 204, fol 43^{v}; 28 Dec. 1579. Interestingly, another 17th-century document labeled Fenrutter "a souldier", while the other master gunners from the 1540s to until 1638, received no further descriptions. In that later year, James Wemyss (John in the MS) is described as "an experienc'd souldier & good artist, and a scotch man by birth" (B.L., Sloane 871, fol. 150). Whether Fenrutter's soldiery has any connection to his membership in the Masters of Defense remains an open question.

[86] Bod. Lib., MS Rawlinson A 204, fol. 76^{r}; 29 Dec. 1581.

Garden."[87] Clearly, four weeks work by two men would have produced a large amount of iron work, indicating that the great ordnance at the Garden must have been more than the single falcon mentioned a decade before.

More revealing, however are a series of entries in 1581 regarding the construction of a house at the Artillery Garden.[88] The trail begins in February, when two sawyers were detailed to saw timber to repair the "buthowsses" in the Garden. In March these two men were employed to saw timber into gunstocks and sawing timber, while seven carpenters working under master carpenter Thomas Townson began "taking down of certain old roofs of the 'Buthowsse' within the Artillary Garden which were decayed and ready to fall down." Four "brickelers" were also employed 24 days for taking down "sundry gable ends of brick and uncovering certain old decayed 'buthowses'," and for "making one howsse with the old brick." At the same time, however, the carpenters began "Erecting a howsse for the assembly of the officers of the ordenance the m^{r} Gonner the rest of the Queen's maiesties gonners & scollers for ye Apoyntinge of gonners and scollers to serue at all times as well in her ma^{tis} shippes as also by land as occasion of service shalbe for her ma^{tie}." Here we have Thomas' dream come true, although it is nowhere acknowledged in official paperwork beyond payroll, as far as I have been able to determine. The house construction lasted the entire year, and by the fall the house was probably usable.[89] In all, the Ordnance Office records record a total of at least £95 spent,

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[87] *Ibid.*, fol. 94^{v}.

[88] All these entries are found in *ibid.*, fol. 58 and 90^{r}-103^{v}. B.L., MS Harley 1640, fol. 45^{v}, notes that in December 1580, 2 bricklayers and tilers were at work at "the Tower the minoris & the Artillary garden &c.", but this should probably be taken as general retainer work and not related to the house construction.

[89] The carpenters and bricklayers worked on through the spring months, building the foundation in April, reframing the old roof timbers into a new roof in April and May, and setting up that new frame in June. Four tilers began work in June as well, presumably beginning to do finish work on the inside of the new house or perhaps work on the chimney. In July the plasterers arrived to continue work with the carpenters and bricklayers still at work there. The carpenters seem to have finished in that month, since they are not listed as working in

employing a team of about 14 men (10 carpenters and 4 bricklayers, on average) to build a new two-story meeting house for the "thoficers of her ma^{tis} ordenaunce the m^{r} Gonner wth the rest of her ma^{ties} gunners & skollers for her ma^{tis} better s^{r}vice." This, then would have served as a place for the Tower gunners to meet, but also as a place for their own trial and instruction and may well be the large structure shown at the south end of the field on Dankert 1604 map and the Faithorn and Newcourt Map of 1658 (fig. 7.3). But more importantly, given the historic use of the Artillery Garden as a quasi-public space, it is probable that this new house became home to a school for instructing novice gunners.

Gunner training would have made eminent sense throughout the 1580s, with the Dutch Revolt in full swing and of course the Armada scare of 1588. The 1590s, too, were times of unrest in that constant fear of another Spanish armada circulated, prompting the raising of the militia in 1591, 1595, the Cadiz expedition in 1596, and the counter-Armada or "Islands Voyage" in 1597, not to mention the increasing English commitment to the Low Countries' struggle and Tyrone's Rebellion in Ireland from 1598-1603. But the surviving evidence suggests that the new building of 1581 did not serve its purpose for very long. As the seventeenth century dawned, various discrepancies in the Ordnance Office had become noticeable enough that inquiries were ordered. In due course various abuses were uncovered: falsifying receipts and deliveries, inaccurate records of stores in and out of the Tower, false pricing, false returns, and the like. Buried among the details of over-extended contracts and improper record-keeping is one of those rare descriptions that would never have survived otherwise. It is

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August, although in September, nine of them are back, "making… a paire of starres in thartillary garden at the erectid howsse there." October seems to have been a slack month, although bricklayers were back in November working on a cellar and a few carpenters continued to do unspecified work in December, although finish carpentry might be a reasonable guess.

found in "A Coppie of Mr Lynewrayes Booke for reformation of abuses in the Office of the Ordnance," compiled for inquiries beginning 1601. As first a clerk of deliveries, John Lynewray became Surveyor of the Ordnance from 1602-6, probably as a reward for bringing down the previous Surveyor, Sir John Davies during the 1601 inquiry.[90] While nominally in charge of keeping inventories of *materiel* in the Tower as well as recording deliveries and disbursements, he was particularly good (or motivated) at sniffing out corruption within the department and compiled a long list of out-and-out graft as well as various places where money could be saved. Among this list is a description of the Artillery Garden's history:[91]

> [Whereas] in the Artillery Garden against the waule next vnto the Preaching place in the Spitle where a Scaffold yeerely at Easter was want to be erected & sett vp for the fitting at Officers Artificers & Clerkes p*er*tining to thoffice to heare ye sermon is since erected a faire howse And in the daies of her late Matie of famous memory vnder Colour of that purpose to be continued wch after Stephen Bull Wm. Bull Wm. Hamond & now John Reinolds vseth as a dwelling house, w^{t} benefitt of all the fruit, grasse, and great garden lett to his great benefitt & his man dwelling in the gatehouse and selleth drinke yet all the houses there rep*ar*d by his ma'tie. All the fruite Trees digged vp & made aplace for Trayning of Souldiers & a faire storehouse built for keeping of their furniture.

Thus, it appears that since 1581, the Master Gunner of England lived in that same house which was built for the assembly of the officers of the Ordnance.[92] But, Lynewray complained, although it was his principal dwelling-place, he continued

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[90] For Linewray and the corruption in the ordnance office, see R.W. Stewart, *The English Ordnance Office 1585-1625* (Woodbridge, Suffolk, 1996), p. 15, 23n, and 44-51. Stewart repeatedly dates Linewray's "Booke" to 1601, but mentions that it covers 1601-27. It actually continues until at least 1638, as James Wemyss is included in the list of Master Gunners of England, and he did not attain the office until then.

[91] B.L., Sloane MS 871, fol. 129-151^{v}. The extracts are all from fol. 150^{v}. Although the extracts are not dated, they most likely date from the later 1630s. He notes that John Reynolds then was the Master Gunner and living in the Garden.

[92] The sermon seems to have been an annual event throughout the last quarter of the 16th century and continued through the 17th, although as time went on it became a sermon before the Artillery Company, not the Gunners of the Tower. A number of these sermons were printed just before and during the Civil War.

to allow the Crown to pay for its upkeep, all the while taking the fruit and produce from the gardens (presumably remnants of those seen to the north of the Spitel Fields on the Copperplate map [fig. 7.2]) and selling beverages out of the gatehouse. While Lynewray did not entirely censure this practice, he did suggest that it was not financially beneficial to the Office or to King James. He continued, writing that whereas, "in the dayes of Mr Webb & Mr Anthony Fenrutter according to ye plentid of fruit that God sent yeerely, Thoffic^{e} of Thordn*an*ce haue bin yeerely remembred & my M^{r} harma*n* Harrison had a nagge at grass there, but by Hamond hold as inheritance with out any respect but all for himself." Here he refers to yearly bounty from the orchards during the earlier part of Elizabeth's reign, as Richard Webb and Anthony Fenrutter served as Master Gunners of the Tower and England from 1566-71 and 1571-78, respectively, but by then William Hammond, who served from 1610-23, kept it all for himself and considered it his permanent home.

Continuing, Lynewray noted that,

> Als in time past it was a vse wth the Mr Gunner ou*er* & besids Trayning his Schollars at the Butt, sometimes to haue apeece out of the garden into the Feild for exercise of Schollars at Randon & vnknowne marks wch now is out of vse. And againe where powder, shott, plancke, &c. was wont to be r*ecieve*d out of her Ma^{ts} Store for that purpose to the encouragem^{t} of Schollars. but since his quarterly allowance for that seruice Doth not only pinch & spare of the wonted expence, that they shall make but 3 shott one day in a weeke wch they accompted well, but yet he would be paid of the Schollars for the same: and being paid for so much as is expended, whie should he haue allowance of lxx^{li}. a yeere of his ma^{tie}. therefore out of Thordinary of Thoffice to the prejudice of his highnes Store of soe much prouision as wth the saide some might yeerely be prouided for supply thereof.

Most interesting here is the suggestion besides the routine training of the gunners at the butt within the Artillery Garden, the Master Gunner had kept a piece of large ordnance available for long-range shooting ("at Randon") out into the field to the East. Shooting at "unknowns" likely refers to shooting at targets

at unknown distances, which would give the gunners practice in range-finding and triangulation, skills emphasized in the printed books of the time.[93] No other source suggests that this practice could have taken place so close to the densely inhabited Bishopsgate street, but it does suggest that the lack of urban sprawl to the east on the 1658 Faithorn and Newcourt Map was real, and not due to a disinterest in representing areas beyond the city. Rather, it would appear that between the 1570s and the 1650s when maps provide coverage for the area, the area east of the Artillery Garden had remained largely pasture, possibly through the influence of the Ordnance Office in keeping it clear for just such long-range artillery practice. Nevertheless, Lynewray does confirm the suspicion that there was a formal, quarterly Ordnance grant of powder, shot, and plank (for targets, presumably) "to the encouragement of Schollars" under Elizabeth. And although he clearly believes that Hammond was abusing this grant, he also confirms that they at least kept up the pretense of training into the 1620s.

On the previous page of his "Booke" (fol. 150^{r}), Mr. Lynewray noted the names of the Master Gunner of England since "Christopher Goulde" in the time of Edward VI (*i.e.*, Christopher Gold, who served from 1536-66) as well as the salaries and allowances for their office. Included in these charges is the £70 per year mentioned above for the "200 schollars sworne to the practice of shooting in great ordnance" for "powder, shott, match, plancks, and wadding spent in Trayening" them in the Artillery Garden.[94] It therefore appears that this practice may indeed have been a tradition for all of Elizabeth's reign, and given Thomas' petitions of the 1580s, it would seem that there had been activity in the Artillery Garden for nearly a hundred years before Lynewray wrote. The £70 allowance

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[93] See ch. 3, above.

[94] A 1589 list records one hundredweight of powder delivered to Stephen Bull, the then Master Gunner of England, specifically for "Thartilery garden", but interestingly it is inculded under the category of "Delivery to other private parsens"; Bod. Lib., MS Rawlinson A 474, fol. 31^{v}.

was also not a drop in the bucket, as the yearly salary of the Master Gunner was only £36 10s and the entire budget, including salaries and the training money was £133 per year. It appears, then, that over half the budget was indeed being pocketed by Hammond, and probably John Reynolds before him, and that this abuse had been occurring since James came to power.

Part of the problem arose from the continued competition between the Guild of St. George and the Ordnance Office for the use of the Artillery Garden. The space had apparently never been reserved exclusively for one group or the other, and evidence that the Masters of Defense occasionally played there suggests that throughout Elizabeth's reign, it provided a general-purpose facility for education, training, entertainment, and recreation. By 1610, the infantry practice in the Garden had fallen off, for in that year, around the end of June, the practice was grandly and ostentatiously revived. One chronicler claimed that "the ancient use of the Artillery Garden [had] fallen into disuse since 1588."[95] But this disuse had had its price. In 1615/6 the Artillery Company complained to the Privy Council that William Hammond had barred them from the use of the Artillery Garden, "pretending the sole property of the estate and right in the sayd ground to be in himself and to his own behoof."[96] And although the Privy Council reaffirmed their right to practice there, Hammond's successor, John Reynolds, barred them from practice again in 1631 and they filed suit again. While in the 1615/6 case there was no indication that Hammond had used the space for anything but the abuses for which Lynewray censured him, in the later

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[95] G.B. Harrison, *A Second Jacobean Journal* (Ann Arbor, Michigan, 1958), p. 211. The practice seems to have repeatedly deteriorated, as it was grandly revived in 1622 as well; see the celebratory poem by "Mariscallus" [*i.e.*, Henry] Petowe, the Marshal of the Artillery Company, in J. Stow, *A Survay of London* (London, 1633) , p. 764-5.

[96] 17 March 1615/6; APC, vol. 34 (1615-1616), pp. 445-7. For the Artillery Company's practice at the time, see J. Stow, *Annales* (London, 1615) , pp. 906-7 [sig. Gggg3^{r-v}]. At about the same time, a leadership crisis arose within the Artillery Company; for the source documents, see *Analytical Index to the Series of Records known as the Remembrancia Preserved among the Archives of the City of London, A.D. 1579-1664* (London, 1878) , pp. 19-24.

petition, the members of the Artillery Company specifically promised that their exercise "would be no prejudice to the Butt, or if it were they would repaire it at their charge."[97] Further, they promised not to hinder "the Schollers that learned the use of the great Artilleie in the Ordnance way." This was in response to Reynold's petition which claimed they interfered with "his Majesties Canoniers… exercise and proofs."[98] The outcome was again in favour of the Artillery Company, although at Reynolds request it was referred to the Council of War "to sett downe such dayes and tymes for exercise of Armes as might best stand with his Majesties service," that is, the gunner's practice. This, then, corroborates the comment in the 1633 edition of Stow's *Survey*:

> There is also a large close, called Tazell Close, sometime, for that there were Tazels planted for the use of Cloth-workers: Since letten to the Crosse-bow makers, wherein they used to shoote for games at Popingey. Now the same being inclosed with a Bricke wall, serveth to bee an Artillery yard, or Garden, whereunto the Gunners of the Tower weekly doe repaire, namely, every Thursday, and there levelling certaine Brasse Pieces of great Artillery against a But of earth, made for that purpose, they discharged them for their exercise. Present use is made thereof, by divers worthy Citizens, Gentlemen, and Captaines, using Martiall Discipline, and where they meet (well-neere) weekely, to their great commendation in so many worthy an exercise[99]

This information about the Garden and the gunners appears in Stow's 1603 edition,[100] although without mention of the infantry drill. Similarly, George Buc confirmed the active instruction at the Artillery Garden in 1615 when he listed instruction in "Arstelorum, or Artillerie, and… Pyrotechnic" as arts available to London's citizens.[101] He related that "the arte of Shootinge in great ordinance is

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[97] 18 May 1631; APC, vol. 46 (June 1630-June 1631), pp. 331-2.

[98] 22 April 1631; *ibid.*, pp. 302-3.

[99] J. Stow, *A Survay of London (*1633), p. 175.

[100] J. Stow, *A Survey of London by John Stow Reprinted from the Text of 1603* (Oxford, 1908), I.166.

[101] G. Buc(k), Kt., *The Third University of England* (London, 1615) , cap. 43: "Arstelorum, or Artillerie, and of Polemica or art Military, and of Pyrotechnie, and the art of Swimming," which is printed as part of J. Stow, *Annales* (London, 1615), pp. 985-6 [sig. Oooo2^{r-v}]). "Arstelorum," or *ars telorum*, is the art of missiles. The tract had been composed in 1612 for private circulation.

taught in a field enclosed by a brick wall, without Bishopsgate, called the Artillery Garden… [A]ll the men which come thither to learn this Art are first solemnly sworne not to teach any forayner, or Alien this art, nor to serve any forain prince therewith without the leaue or commaundement of the king of England their soueraigne Lorde." All this confirms the impression that despite some of the interruptions noted by Lynewray, training of Tower gunners had at least been occurring since the end of Elizabeth's reign. The other evidence seems to push that date back to the early 1570s, and perhaps even before. Thus, when in 1593 we read that in a contingent of reinforcements for the Netherlands than among them should be "20 cannoneers from London,"[102] it is safe to assume that these then would have been graduates of the artillery school in the Artillery Garden.

Conclusion

The art of gunnery in England was not the complete backwater such respected authors as Charles Oman and A.R. Hall imply. Englishmen recognized the need for such training and attempted to see that it was provided one way or the other. In addition, gunners took their art seriously, even if the government sometimes failed to agree. Ultimately, the standard impression of English artillery in late Tudor and early Stuart times is due for a revision. Rather than accepting Corbett's belief that William Thomas' proposals were sparked by gunnery instruction "so scientific… that a supply of gunners was one of the chief difficulties of the Admirality,"[103] we should instead see his proposals as an

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[102] L&A, vol. 4 (May 1592 - June 1593), no. 373, pp. 248-9. The same request asks for "miners from those counties where they could be had", reinforcing the idea that London produced gunners in the same way Cornwall produced miners. Similarly, the year before, a number of English companies arrived in Brittany, expecting 50 men from Dorset to join them, but "they had heard nothing of the artillery from Jersey and cannoneers from London" (L&A, vol. 3 [June 1591 - April 1592], no. 428, p. 273).

[103] J.S. Corbett, *Drake and the Tudor Navy*, I: 380.

attempt to *make* gunnery scientific to appeal to more novices. England enjoyed the relative peace and prosperity which allowed it to avoid conflict, and when it did arise, it either did not depend on artillery, as in Ireland, or else on very straight-forward uses in defense, as in the Netherlands, or on board ships, as in the singular case of the Armada.

As technological and economic historians have pointed out, there is no shame in not being first, and a country can often avoid many of the pitfalls of those first out of the starting blocks. English authors were plagiarists it is true, but her gunners seem to have learned their art without aid (or interference) from the outside. As noted in chapter three, almost all of their printed information came from abroad, but they supplemented this relatively scanty material with their own manuscript compilations, indicating a commitment to the new technology not born of governmental command. In fact, the story of the Artillery Garden emphasizes that gunnery was at once funded by the State, yet regulated as an independent corporation. This dichotomy characterizes gunnery throughout the English Renaissance: it was studied by dilettantes, but used by professional soldiers; it sought a wide technical audience yet with information those who practiced it considered relatively trivial; it was both subordinate and superordinate to the army at different times. This ambiguity characterizes new technical fields, seeking their position among the established fields. How gunnery sought to do so forms the concluding chapter of this dissertation.

Chapter 8

Conclusion

Ut ignis arum, ita Mathemateca ingenium
The Mathematics are unto the wit, as fire is to the golde
— Thomas Hood*

The beauty of history is its access to the unknown, for the unknown is at once intriguing and mystifying. The art and science of gunnery was both intriguing and mystifying in the sixteenth century. Those who practiced it came to know its workings to a point, but the rest of society could only look on and wonder. Regardless, gunnery – along with printing and navigation – could be cited by Francis Bacon as indicative of the progress in his day. In Renaissance England gunnery came of age. But what was it that came of age? Despite the assumptions of general military historians, it was clearly not mathematical ballistics, as Harriot's late-medieval number theory investigations demonstrate. It was not rationalized textbook instruction, as the English printed books on artillery indicate. Nor was it a formal, professional gunnery corps serving Queen Elizabeth, as William Thomas' repeatedly ignored petitions suggest. What came of age were people like Edmund Parker: men with a keen interest in the new "mathematical sciences" who read various books of diverse topics and attempted to apply that knowledge to their chosen profession, gunnery. That their success was not equal to Newton or Robins is immaterial – few first attempts ever are. Instead, what all these men and their interests point to is a new conception of technology arising in the sixteenth century as a mathematical, analytical, and even a democratic force in society.

* F.R. Johnson, "Thomas Hood's Inaugural Address as Mathematical Lecturer of the City of London (1588)," *Journal of the History of Ideas* 3 (1942): 105.

Technology became mathematical in the obvious sense; it became numerical, that is, quantified. Gunnery was particularly suited to this development in that its elements – diameters, lengths, distances, weights, angles – were numerical by their very nature. But other disciplines also had quantifiable elements – speeds of ships, flows of pumps, volumes of canals[1] – and yet did not become as numerical as gunnery at this time. Part of its mathematical nature lies in the fact that the values associated with gunnery were easily measured. But other arts could have availed themselves of measurement techniques to a similar degree – masonry, for example, had always embodied a wide knowledge of geometrical constructions and its lengths and distances were easily measured and grasped, yet it remained a craft rather than being elevated to a science. Gunnery stood apart in the vanguard of the new science, or, rather, contemporaries *believed* that gunnery stood apart. And, indeed, historians have shared (or inherited) that belief and repeatedly claimed that gunnery was one of the first mathematical sciences, despite the fact that it never showed even remotely similar development as the other arts which also came of age, particularly navigation.

Technology became analytical in that late sixteenth-century Englishmen began to believe that they could make progress in analyzing cannon and their performance, once again, whether or not that progress actually ever happened. People like Leonard and Thomas Digges took the notion that reducing complex technical systems to a series of independent (or mostly independent) variables would allow the performance to be characterized, and most importantly,

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[1] These particular quantities were suggested by Paolo Rossi's contention that "there had been an expected insistence on the importance that many practical problems (such as those of the speed of ships, the construction of canals, ballistics, the manufacture of pumps, the ventilation of mines) assumed with the birth and progress of a series of investigations of a theoretical character (hydrostatics, hydrodynamics, chronometry, and dynamics)"; P. Rossi, *Philosophy, Technology, and the Arts in the Early Modern Era* (New York, 1970) , p. 37.

predicted. Harriot found those variables and developed a predictive method (albeit a wrong one). Again like navigation, they felt that by enumerating the properties of cannon and powder in the same way they measured heights of stars and triangulated terrestrial distances, artillery successes analogous to the circumnavigation of the world would be theirs. They are an example of Bijker and Law's observation that the "working or failing [of a technology] is always shaped by a wide range of disparate factors. Technologies… are shaped. They are shaped by a range of heterogeneous factors. And, it follows, *they might have been otherwise*."[2]

Finally, technology became democratized in the sense that in certain areas, the mechanical arts were not only no longer to be despised, but actively embraced by members of all classes of society. Greco-Roman Antiquity bequeathed to the Middle Ages a concept of technology which embodied a sharp class distinction: technologists were not found among the social elites and vice versa. The Middle Ages began to erode this barrier, but gunnery in the Renaissance was one of the technical arts (again like navigation) which a noble could safely learn without being considered a "rude mechanical." And, indeed, it became one of the arts a gentleman had to learn, along with fortification, astronomy, and traditional "science" like music and dancing if he expected to be a well rounded (*i.e.*, "Renaissance") man. Gunnery benefited by being an element of warfare, a traditionally noble occupation. In effect, the nobility appropriated gunnery and chose not to appropriate hand firearms, a lowly

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[2] W.E. Bijker and J. Law (eds.), *Shaping Technology/Building Society* (Boston, 1992), p. 3. The italics are original.

weapon of the masses.[3] In this way, gunnery "became" part of the elite segment of the military arts.

This, then, raises the question of why gunnery was so important to so many people, whether or not they considered it mathematical or not. The obvious answer would be that it was so "powerful" and that power engenders awe and respect, as well as interest.[4] But guns are powerful in particular ways. First, they are violent. Violence fascinates and repulses at the same time, and while the merits of humanity's attitudes on violence are debated ceaselessly, peril is to those who ignore ubiquitous violence.[5] And cannon are violent both in their effect and in their execution – killing and maiming men as well as destroying walls and ships and doing so "as quicke as the twinklinge of an eye," as one of the gunners' training manuals put it.[6] In effect, they command even a casual observer to stand up and take notice – they are the sublime. Finally, guns are movables and can therefore be "owned" in a way that other large, powerful objects (ships, fortresses, and industrial sites such as mills and foundries) cannot.[7] They are in that sense more "personal", and people took this characteristic to heart, investing a large part of their interest into this one technology.

Gunnery and the Mathematical Arts

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[3] They did, however, appropriate pistols on horseback as an extension of their traditional role as cavalry. It would seem to be a distinction of individual action vs. group participation. For more on the education of gentlemen, see below.

[4] It also engenders fear and vituperation, and cannon certainly received their share of scorn as a devilish weapon.

[5] This also touches on the anthropological question of violence and warfare, a topic too large to engage here, but see Doyne Dawson, "The Origins of War: Biological and Anthropological Theories," *History & Theory* 35.1 (1996): 1-28 and R. Paul Shaw, "Humanity's Propensity for Warfare: a Sociobiological Perspective," *Canadian Review of Sociology & Anthropology* 22.2 (1985): 158-83.

[6] Bod.Lib., MS Ashmole 343, fol. 138 (App. III).

[7] Here I use the term "own" not in its usual fiscal sense, but rather in an intellectual way. One can own an object if he or she can move it about and control it according to their desires, whether or not they hold the bill of sale for that object.

Mathematics is a conceptual technology, rather than a mechanical one. That is, rather than having any physical elements, it is a process which orders and manufactures information which can then be applied to itself or other technologies, mechanical or conceptual.[8] The connection between mathematics and gunnery, however, is rarely made immediately clear. Often such connections are merely stated: "Amongst the [Ordnance] Office's employees, mathematical skills were essential for the engineers, the Firemaster (who dealt with gunpowder and explosive devices) and the Master Gunner, and were recognized as useful, if not absolutely necessary, for the ordinary gunners and 'fireworkers'."[9] In works not specifically on military matters, the use of arithmetic is taken as a given.[10] Because the new *trace italienne* fortification was so clearly geometrical, artillery was taken as such by association.[11] As mentioned above, gunnery can be numerical, and certainly later seventeenth- and eighteenth-century analysts with their mathematical tools did mathematize

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[8] I take this concept from M.J. Voss, "Between the Cannon and the Book: Mathematicians and Military Culture in 16th-Century Italy" (Ph.D., Johns Hopkins University, 1995) , p. 43, who claims to be appropriating the idea from Andrew Warwick, although without a reference. See also A.G. Molland, "Semiotic Aspects of Medieval Mathematics," in M. Folkerts (ed.), *Mathematische Probleme in Mittelalter* (Wiesbaden, 1996), pp. 1-16.

[9] F. Willmoth, "Mathematical Sciences and Military Technology: the Ordnance Office in the Reign of Charles II," in J.V. Field and A.J.L. James (eds.), *Renaissance and Revolution* (Cambridge, 1993), p. 120. This article deals with the later 17th-century Ordnance Office, but her assertion seems to percolate back to the late 16th-century as well.

[10] K. Thomas, "Numeracy in Early Modern England," *Transactions of the Royal Historical Society* 5th ser. 37 (1987) : 108: "It [arithmetic] was necessary for the military arts, particularly gunnery and fortification."

[11] A. Keller, "Mathematics, Mechanics and the Origins of the Culture of Mechanical Invention," *Minerva* 23 (1985): 355-6. His other example of Peter Ramus' concept of mining and metallurgy as mathematical is illustrative of this sort of transference (p. 351-2): mining happens underground and the compass can be used to orient oneself and the compass is mathematical (another transferred conception); mathematics could *in theory* be used to improve machines if they broke down; all machines rely indirectly on the lever (and the other 4 simple machines: screw, wedge, pulley, and windlass) and could therefore *in theory* be reduced to circle and line in rotational motion and gear ratios relate numbers of teeth to those circles and arcs. Ultimately, it would seem that mining and metallurgy are mathematical because Ramus *wants* them to be. In the present case, it would not be too much to say that gunnery was mathematical because its users decided to make it so.

the flight of a projectile: Galileo was of course the progenitor of closed analytical ballistic theory.[12] And trajectories were thought of as being geometrical in that they were extended lines in a plane, but the users would rarely have contemplated trajectories as geometrical objects, so again, the "mathematicality" of gunnery remains elusive.

The solution lies not in mathematics as understood today, but in the medieval conception of mathematics as the quadrivium of the liberal arts. Boethius enunciated seven liberal arts, grouped into the trivium (grammar, rhetoric, and logic) and the quadrivium (arithmetic, geometry, music, and astronomy). The quadrivium formed the core of the mathematical arts, as compared to the "trivial" or verbal arts, but the four disciplines within the quadrivium were not limited to the equivalent modern subjects. Arithmetic embodied not just operations like addition and subtraction, but contemplated quantities and numbers as wholes; geometry extended magnitudes to figures and enumeration to lines and areas; music was not simply notes and singing, but regarded concepts of ratio, proportion, and harmony; and astronomy expanded geometry's study of magnitudes to those magnitudes in motion.[13] As such, any magnitude, figure, ratio, or motion was mathematical in this frame of reference. Gunnery, then, with its diameters, weights, distances, shot/powder ratios, and violent motion very easily fit into this conception of a mathematical art.

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[12] Here I am arguing against the standard ascription of this honor to Tartaglia on the grounds that Tartaglia's trajectories are "wrong" (a conscious modernist judgment), but more importantly, that they were internally inconsistent and not extendible without major modification (as Harriot tried to do; see ch. 3, above). And Tartaglia himself abandoned his geometrical approach in his *New Science* (1537) for a more qualitative approach in his *Quesiti et Inventioni* (1543). I would argue that while Tartaglia might be regarded as writing the first book on ballistics, ballistics as a "science" did not in fact exist until Galileo.

[13] T.J. Reiss, *Knowledge, Discovery, and Imagination in Early Modern Europe* (Cambridge, 1997) , pp. 136-7.

Where, then, do the mathematical arts fit into society in Renaissance England? Everywhere it would seem, if all number and measure is to be included. All mercantile activity would clearly follow, but so too would "refined" arts like architecture and navigation. Abstract mathematics, which is to say algebra, also came into its own in the sixteenth century and was applied to everything it could be, with varying degrees of success.[14] Architecture is important, for one of the distinctive branches of architecture for the period was the new *trace italienne* military architecture, which was predicated on geometrical relationships. In military science the new form of pike warfare with ordered squares of men certainly qualified as arithmetic, if not geometric.[15] Gunnery clearly belonged to the quadrivium, but it was up to society to determine whether it fit grudgingly like lowly bookkeeping, neutrally like surveying, or eminently like learned astronomical measurement. Ultimately, gunnery emerged with a relatively high status among the mathematical arts, partially due to its position within the wider military frameworks of the time, but also due to its internal elements.

As chapter five suggested, the English did not really know where to place artillery within their military hierarchy. While it was used at sea, it was not part of the navy. When used on land, it was part of the army, but since the army disbanded after each campaign and the artillery remained, it could not be exclusively part of the army either. The Board of Ordnance became its

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[14] G.J. Withrow, "Why did Mathematics begin to Take off in the Sixteenth Century?," in C. Hay (ed.), *Mathematics from Manuscript to Print, 1300-1600* (Oxford, 1988), pp. 264-69. Mathematics was even applied to some things it "couldn't" be applied, such as the numerical "force" of love or "values" of theology.

[15] Indeed, a number of military textbooks of the age included handy tables for extracting square roots specifically so that a captain, provided with, say 540, men, could discover he could make a square of 23×23 men, with 11 men left over, or use them all to form a rectangle 20×27. See, for example, *Most Brief Tables* (London, 1588), which was issued with that year's edition of Machiavelli/Whitehorne's *Arte of Warre*.

institutional home, because since the Board was responsible for the *materiel*, so too would it become responsible for the men. But as the confusion surrounding the Artillery Garden indicated, training those men was sometimes part of the government's duty, and sometimes not. This ambiguity of military position for artillery meant that it was not therefore automatically burdened with the preconceptions that come with predefined positions. It was free to become an art of laborers or an art of kings. While it largely used laborers for its day to day operations, at the same time kings were keenly aware of it and interested in it. They even practiced it, although it is unlikely they personally touched the cannon themselves.[16] That a number of the nobility in England were willing to become adept at cannonry suggests that it was not relegated to the bottom of the contemporary arts hierarchy.[17]

For the seventeenth century, a great deal of literature exists about the "construction" of the profession of mathematician and the places where those men might seek or create employment.[18] Nearly half a century ago, E.G.R.

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[16] Henry VIII's interest in owning cannon has been touched upon in ch. 5, above, but other British monarchs are known to have been personally interested in artillery. James IV of Scotland promoted a native gun industry in Edinburgh and personally placed great importance on his artillery train on the way to Flodden, where he was killed. There was an amusing incident when Henry VII sent Thomas Wolsey on a diplomatic mission to James IV in 1508: Wolsey "was kept waiting in Edinburgh… because James as too busy experimenting with gunpowder to see him" (D. Dunlop, "The Politics of Peace-Keeping: Anglo-Scottish Relations from 1503 to 1511," *Renaissance Studies* 8 [1994]: 147). Although James I of England was renown for his pacific tastes, he nevertheless encouraged his eldest son Henry, Prince of Wales, in gunnery, having butts built for his instruction and amusement at both Richmond Palace and St. James Park. At St. James Henry also received "'a little Artillarye house' was made against an orchard wall…containing a cannon directed towards a butt where there was a 'stronge large boarde of Elme for a marke for the Prince to shoot at'" (H.M. Colvin, *et al.*, *The History of the King's Works* [London, 1982], IV.244, 231, 35). Beyond England, there are frequent references to the Princes, Kings, and other nobles being present for trials and practices of artillery, suggesting that all took more than simply a passing interest in this new technology.

[17] Sir George Carew and Sir William Winter are known examples; see ch. 6, n. 49 and ch. 5, n. 69, above.

[18] See K. Hill, "Mathematics as a Tool for Social Change: Educational Reform in Seventeenth-Century England," *The Seventeenth Century* 12 (1997): 23-36 and her "'Juglers or Schollers?': Negotiating the Role of a Mathematical Practitioner," *British Journal for the History of Science* 31 (1998): 253-74 (which is largely about the 1632 Delamain-Oughtred

Taylor defined a class of people known as "mathematical practitioners" which included all people employed in mathematical trades; the myriad of occupations attests to the breadth of mathematics at the time. Thus, Taylor included mathematicians (teachers and writers), navigators, mariners, instrument makers (of all kinds of instruments), surveyors, cartographers, "mechanics", assayers, astronomers, almanac-makers, not to mention gunners.[19] Thus, it would appear that many professions sought mathematics and the universal certainty that comes with it, to bolster and enhance the position of their works. As Stephen Johnston recently put it, "The mathematicalls were not, however, merely a collection of interlinked arts. The ideas included a particular evaluation of their character: they were portrayed as plain and profitable, pleasurable and certain, fit for both the private individual and the commonwealth."[20] This same shift (or perhaps "progression") may be seen in the intellectual shift from "trivial" to "quadrivial" argument; from rhetoric to logic as the proper means of knowledge production.[21] Thus, I am arguing that the gunners and others interested in

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dispute) and the literature cited therein. The earlier and considerably more advanced Italian case is studied in Mario Biagioli's seminal article M. Biagioli, "The Social Status of Italian Mathematicians, 1450-1600," *History of Science* 27 (1989): 41-95. One of his touchstone criteria for social status is the professionalization of military engineering.

[19] E.G.R. Taylor, *The Mathematical Practitioners of Tudor and Stuart England* (Cambridge, 1954) . This is not an exhaustive list, although the majority of entries in her biographical section are for teachers of mathematics and instrument makers.

[20] S. Johnston, "Mathematical Practitioners and Instruments in Elizabethan London," *Annals of Science* 48 (1991) : 319.

[21] T.J. Reiss, *Knowledge, Discovery, and Imagination*. His programme is to document a shift from a belief that "the foundation of the highest human culture was writing and the transmission of the written texts and the arts dealing with them" (in the 1520s and before) to a point where "people were increasingly distinguishing between language as a means of rational communication (grammar and rhetoric) and language as a means of discovery (logic), [and a] source, precisely, of 'productive knowledge'," which used mathematics rather than grammar as its tool (p. 1-2). His assumption is that "such rational 'systems' (whether in 'art', 'science', 'philosophy', or whatever) correspond not simply to real human practices, but also to structures of feeling and felt suppositions about the human organism and its relation to a natural and social environment that change over time" (p. 192). Reiss' book, while stimulating, is momentarily frustrating in that it refers most of its "real world" claims to its "companion volume" (entitled *Descartes, Philosophy, and the Public Sphere*), which is not yet published.

gunnery picked up on the *Zeitgeist* of late Tudor England and attempted to appropriate the "mathematical way" to their own ends.[22]

Amir Alexander's recent work on Thomas Harriot's coastal cartography and atomism also suggests another direction in which to take Tudor mathematics: "Elizabethan mathematics was not a self-evident, naturally enclosed category, operating solely in accordance with its own internal principles. It was, rather, a cultural field which interacted fruitfully with other cultural domains."[23] His analysis concentrates on the area of Elizabethan exploration – using Thomas Harriot's work on rhumb lines as his touchstone – where mathematics had obvious utility in navigation, cartography, and shipbuilding. But his idea can be extended to the practices surrounding gunnery as well. Alexander's concept that Harriot's maps of Virginia served as signs which encoded myths,[24] may be transferred to cannon, which also encoded myths for early modern society and this "imperialist rhetoric" is certainly therefore applicable to military technology,[25] which repulsed its observers with its fury, but also enticed them with its power. Cannon therefore can "encode" ideas of domination of other countries, if only their workings could be controlled. And it was in this search for control that mathematics became a tool as well as an over-arching organizational concept into which to place artillery.

Mathematics, the Military Arts, and Education

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[22] The "mathematical way" is Peter Dear's phrase: P. Dear, *Discipline & Experience: the Mathematical Way in the Scientific Revolution* (Chicago, 1995).

[23] A. Alexander, "The Imperialist Space of Elizabethan Mathematics," *Studies in the History and Philosophy of Science* 26 (1995) : 561.

[24] The exposition of this idea, phrased as "Barthian myths", is on *ibid.*, p. 567.

[25] Note that this is another place that Stephen Greenblatt's analyses have been taken as canon for the analysis of exploration. I do not agree with all the tenets of this idea – especially that Harriot was an active cultural hegemonist – but Alexander's linking Harriot's atomistic continua with a conception of a New World coastline divided by rivers at regular intervals does have a certain validity. For the Greenblatt-Harriot controversy, see ch. 2, n. 5, above.

On the matter of mathematical education, a number of pieces of evidence remain from this period which demonstrate quite strongly that gunnery had become one of the higher, analytical, mathematical arts. John Dee's *Mathematicall Praeface* has been noticed already (chapter 2, above), but to his suggestions for all-encompassing mathematical knowledge should be added a fuller discussion of Thomas Hood's position as mathematical lecturer to the City of London as well as mention of a plan by Sir Humphrey Gilbert, sent to Queen Elizabeth about 1570, for a mathematical academy for the city of London.

As we have seen in chapter two, Hood accepted a position as the publicly-financed "Mathematicall Lecturer to the Cittie of London" in 1588, and in his acceptance speech, specifically mentioned "the Gunner witnesse in planting his shot" among the beneficiaries of the lectureship.[26] A precursor to Gresham College, founded a decade later, these public lectureships were designed to educate the city's tradesmen in the finer points of their art, to the benefit of their and the country's prosperity.[27] It is also worth noting that after a decade or so of attempts to create such a lectureship, this foundation finally came in 1588, a time when England was feverishly searching for ways in which to protect herself from Continental threats. In this case, they apparently believed that advancements in mathematical education would be as efficacious as musters at Tilbury.[28] The Armada clearly on his mind, Hood noted that "we have all seene

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[26] F.R. Johnson, "Thomas Hood's Inaugural Address," p. 105. There is also an oblique double meaning *vis-à-vis* artillery in his opening statement: "this day there is a *platforme* laied for the better increace of the Mathematicall science" (p. 99, my italics). For Hood's career, see also S. Johnston, "Mathematical Practitioners," pp. 330-341.

[27] The topic of Gresham College falls outside the scope of the present study, being founded in 1597 but not fully operational until the first years of the next century. For a convenient overview, see M. Feingold, *The Mathematicians' Apprenticeship: Science, Universities and Society in England, 1560-1640* (Cambridge, 1984) , ch. 5, "Gresham College and its role in the genesis of 'London science'," pp. 166-89. Interestingly, Gresham College was just inside Bishopsgate, while the Artillery Garden was just outside; a connection between the two should not be ruled out.

[28] F.R. Johnson, "Thomas Hood's Inaugural Address," pp. 96-7.

them on our coaste, and heard the thunder of their shot, in how cruell manner the… Spaniard of late daies hath threatened [us] with fire and sword." Clearly, what are needed are "Captains, for what is the bodie without an heade, or the Schollers without a Master [*i.e.*, Hood], or souldiers wanting such as might instruct them in feates of warre?" He claimed, therefore, that it "pleased… divers grave, wise and pollitick men, giving encouragement therunto… to erecte a lecture for the mathematicall science, *a knowledge most convenient for militarie men*.[29] Thus, did his instruction in astronomy, agriculture, geography, topography, hydrography, and the mechanical arts (equivalent to Dee's "thaumaturgie," on the making of mechanical marvels like automata), have at its root a military cause and a military *raison d'être*.

We might take this as a bit of hyperbole on Hood's part, inspired by Philip II's aggression in 1588, except that if we look back nearly twenty years, we find another plan for educational instruction, inspired by nothing as much as the need for educated men at the helm of England's ship of state. It, too, contains a striking amount of military content. In about 1570, Sir Humphrey Gilbert, explorer of Newfoundland and Sir Walter Raleigh's elder half-brother, sent a proposal to Queen Elizabeth for the foundation of an Academy in London, much like the 1588 lectureship Hood accepted and Gresham College in 1597. It was designed "for Education of Her Majesties Wardes, and others in Youth of Nobility and Gentlemen," for, so Gilbert claimed, so many of them "though the defaltes of their guardians for the most part [are] brought up, to no small grief of their friendes, in idleness and lascivious pastimes, estranged from all serviceable vertues to their Prince and Country, obscurely drowned in education for sparing

[29] *Ibid.*, pp. 99, 100 (emphasis added).

charges of purpose to abuse their mindes."[30] His remedy is to endow an academy in London with a broad range of faculty: a Schoolmaster teaching grammar, Latin, and Greek, along with four tutors ("ushers") in those subjects; a Hebrew instructor; the "Orator", a professor of logic and rhetoric teaching specifically in the vernacular; one reader of moral philosophy and one of natural philosophy;[31] two mathematicians each of which has a number of under-teachers for sub-disciplines of their art; a "Doctor of Physick" for instruction in medicine and surgery; readers of civil law, common law, and of divinity; language instructors for French, Spanish, Italian, and High Dutch, as well as a soldier, fencing-master, dancing coach, and musician; and finally, an expert in heraldry and a librarian[32] as well as all the support staff to keep this large institution running.

Of interest here are the mathematicians. The second-named position was to "reade one day Cosmographie and Astronomy, and the other day tend the practizes therof onely to the arte of Navigacion," which included instrument-making and nautical terminology. He also had an assistant who taught

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[30] H. Ellis, "Copy of a Plan proposed to Queen Elizabeth by Sir Humphrey Gilbert, for instituting a London Academy," *Archaeologia* 21 (1827) : 508. Gilbert pulls no punches on his estimation of the current state of affairs: "by erecting this Academie, there shall be hereafter, in effecte, no Gentleman within this Realme, but good for somewhat; whereas now the moste parte of them are good for nothinge" (p. 520). His proposal has also been edited with original spelling and all textual apparatus by F.J. Furnivall in the *Early English Text Society*, Extra Series, vol. 8 (London, 1869), pp. 1-12, although the editor strangely takes no notice of the long passages on mathematicians cited below in his introduction (pp. x-xi). I here quote from Ellis' edition as the more readable one, but follow Furnival's punctuation.

[31] Unfortunately for the history of science, this is one of the positions that incudes no description of their subject matter. He was to be paid £40 *per annum*, the same as the schoolmaster and the orator, whereas the Hebrew teacher received £50, the language instructors, fencing-master, dance coach, and the librarian received £26 each, and ushers were paid £20-40. Gilbert clearly realized the relative value of qualified teachers.

[32] Gilbert proposes that all English printers be required to deposit a copy of everything they print with the Academy and that all "Bringers of Bookes" from foreign book fairs give the Academy the right of first refusal on any books they import.

cartography, perspective, and mensuration.[33] The first-named mathematician's position, however, is worth repeating in full:

> Also there shall be placed two Mathematicians; and the one of them shall one daye reade Arithmetick, and the other day Geometry, which shall be onely employed to Imbattelinges, fortificac*i*ons, and matters of warre, with the practiz of Artillery, and use of all manner of Instruments belonging to the same. And shall once every moneth practize Canonrie (shewing the manner of undermininges), and trayne his Awditorie [*i.e.*, listeners – students] to draw in paper, make in modell, and stake owt all kindes of fortificac*i*ons, as well to prevent the mine and sappe, as the Canon, with all sortes of encampinges and Imbattelinges and shall be yearely allowed for the same 100*li*.
>
> Also this Engineer shall be yearely allowed for the powder and shotte which shall be employed for the practize of Canonry and the use of mines 100*li*.[34]
>
> Also there shall be under him one Usher, who shall teach his schollers the principles of Arithmetick and shall be yearely allowed for the same 40*li*.
>
> Also there shall be one other Usher, who shall teach his schollers the principles of Geometrie and shall be yearely allowed for the same 40*li*.[35]

Not only fortification with its clearly geometrical base, but artillery too was mathematical; in fact it *was* mathematics.[36] He provided for a soldier to teach the youths "to handle the Harquebuz" and to practice "skirmishings, imbattelinges, and sondrey kindes of marchinges," and this position (along with an equitation-master, was listed between the two mathematicians on the list.[37] To Gilbert at least, the proper use of the quadrivium was clearly military. Overall, his proposal is largely geared for martial training: even the reader of moral philosophy was to divide his readings into civil and martial policy, the Academy

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[33] Ellis, "Copy of a Plan," p. 512. These two men received £66 13*s* 4*d* and £40 *per annum*, respectively.

[34] Interestingly, this is the arrangement that was eventually used by the Ordnance Office at the Artillery Garden (see ch. 7, above).

[35] *Ibid.*, p. 511.

[36] This same conflation / confusion continued into the 18th century. See, for example the recent confusion over whether artillerists were engineers (*ingénieurs*) during the French Revolution in C.C. Gillispie and K. Adler, "Exchange: Engineering the Revolution," *Technology & Culture* 39.4 (1998): 733-54, at pp. 739-40 (Gillispie) and 749 (Adler).

[37] Ellis, "Copy of a Plan," p. 512.

being designed for the young men to "study matters of action meet for present practize both of peace and warre."[38] Further, if they "will not dispose themselves to letters, yet they may learne languages or martial activities for the service of their Cowntry; yf neyther the one nor the other, then may they exercize themselves in qualities meet for a Gentleman." Nothing ever came of this petition, although William Cecil did see and endorse it. It, along with John Dee's taxonomy of the mathematical arts from the same year and Thomas Hood's inaugural address some 18 years later, all point to a common conception of gunnery (and its allied art of fortification) as both mathematical and "meet for a Gentleman."[39]

By the early seventeenth century, mathematical education of gentlemen had become commonplace, and a flourishing trade in mathematical instruments – globes, drawing instruments, astrolabes, navigational instruments, &c. – arose to supply the expanding market.[40] Elites like Thomas Elyot, Henry Percy, and Henry Peacham counseled their own children and others to study mathematics and military arts.[41] Interest in military matters, too, was very common, despite the truly pacific reign of James I.[42] At the same time, and perhaps extending

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[38] *Ibid.*, pp. 510, 518.

[39] There are echoes of this attitude on the Continent as well. Agostino Ramelli, a military engineer in the service of Henry III of France styled "the true knowledge of honoured mathematics" as "the only foundation of all the other liberal and mechanical arts… about which are found ranged the perfection of all instruments and machines, new and old – which bring great convenience and benefit in times of both war and peace." See his preface, "On the Excellence of Mathematics" in A. Ramelli, *The Various and Ingenious Machines of Agostino Ramelli* (1588; rpt. Aldershot, 1976), pp. 46-53 (quote on p. 52).

[40] A.J. Turner, "Mathematical Instruments and the Education of Gentlemen," *Annals of Science* 30 (1973): 51-88.

[41] K. Hill, "'Juglers or Schollers?'," pp. 260-61, referring to Thomas Elyot, *Boke Named the Gouvernor* (1531), Henry Percy, 9th Earl of Northumberland, *Advice to his Son* (1609), and Henry Peacham, *The Complete Gentleman* (1622).

[42] B. Donagan, "Halcyon Days and the Literature of War: England's Military Education before 1642," *Past & Present*, no. 147 (1995): 65-100. Unfortunately, she concentrates on more general military books, making no notice one way or the other of the increasing number of published artillery works in the 17th century.

back into the later sixteenth century, military careers began to promise a form of upward social mobility that many found attractive.[43] This, combined with the prestige of mathematics as an esoteric science may have come together in gunnery and offered artillerists the hope of advancement. This was not to come to fruition in any real sense (despite William Thomas' best efforts), although certainly I have suggested that people like Edmund Parker were valuable commodities to their commanding officers. And a few pure mathematicians also took an interest in military matters. Harriot and Digges have been mentioned above, and to this list the inventor of logarithms, John Napier, could be added, for he made a proposal for an "invention of war" which was a new type of artillery.[44] In addition, gunners (and fencers) appropriated the term "scholar" in an attempt to legitimize their study in imitation of Oxbridge "scholars". The term would generally not have been applied to the lowest-level practitioners in a university setting, but here, even the tyros appear to have immediately become "scholars" of their art.

At the same time though, and not unlike today, the connotation of mathematical learning was one of anti-social behavior: Edward Worsop said that "they that have no understanding in mathematicall arts, when they see a fellow with a running head, or light brain, especially if he be studious, and given to

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[43] The analogous situation in Italy has been analyzed in G. Benadusi, "Career Strategies in Early Modern Tuscany: the Emergence of a Regional Elite," *Sixteenth Century Journal* 25 (1994): 85-99. Although a provocative article, it must be emphasized that the 16th-century Italian situation was distinct from the English, in that the regional elite of Tuscany had the Florentine grand ducal militia to aspire towards. The English had no equivalent standing force for advancement until the later 17th century, although certainly advancement through technical military careers in 18th-century England and France replay this same story. These class-based analyses did have some analogies in the later 16th century: the Spanish navy had a rigid class distinction aboard ship, with soldiers foremost, gunners second yet autonomous and still powerful, and mariners that had to serve them both (J.S. Corbett, *Drake and the Tudor Navy* (London, 1898), I:388 citing Hawkin's *Observations*).

[44] Lambeth Palace Library, Cod. Tennison 658, fol. 58.

solitarines, say in way of scorning, he hath a mathematicall head."[45] Actual social ineptitude aside, this sort of negative response by the unlearned is a response to the unknown: scholars have an esoteric knowledge which may or may not mean anything to unlearned people (but thereby gives the scholars some level of power over them), but lampooning or belittling that knowledge effectively give the unlearned an upper hand. But quite beyond social posturing, the fear of mathematics seems to have been a real phenomenon. That is, the unlearned did believe that mathematics held power over them and their lives. We cannot forget that numerology, judicial astrology, and sacred geometry were often taken as seriously as what we consider rigorous science. Cornelius Agrippa wrote that

> the mathematical disciples [*sic* – disciplines] are so necessary and cognate to magic that, if anyone should profess the latter without the former, he would wander totally from the path and attain the least desired result. For whatever things are or are effected in the inferior natural virtues are all effected and governed by number, weight, measure, harmony, motion, and light, and have their root and foundation in theses.[46]

Mathematicians were considered "conjourers" or "jugglers"; surveyors, who made measurements at a distance, were accused of trickery; simple machines which moved "as if possessed" were used to startle and amaze onlookers; men lifting tons with compound pulleys were thought to have been supernaturally aided; and the list could continue.[47] By allying themselves with the mathematics,

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[45] E. Worsop, *A Discoverie of Sundrie Errours… [of] Land-Meaters* (London, 1582), sig. F2^{v}, quoted in K. Thomas, "Numeracy in Early Modern England," *Transactions of the Royal Historical Society* 5th ser. 37 (1987): p. 109, n. 29. Roger Ascham, too, thought mathematically-inclined people "unapte to serve in the world" and "less fit for active life, and common conversation" (*ibid.* and see E.G.R. Taylor, *Mathematical Practitioners*, pp. 3-6).

[46] A.G. Molland, "Cornelius Agrippa's Mathematical Magic," in C. Hay (ed.), *Mathematics from Manuscript to Print*, p. 210. This is the opening to Book II of Agrippa's widely-popular *De occulta philosophia*, whose three books treat natural, mathematical, and ceremonial magic.

[47] J.P. Zetterberg, "The Mistaking of 'the Mathematics' for Magic in Tudor and Stuart England," *Sixteenth Century Journal* 11 (1980): 83-97, *passim*. Similar material for Europe over a wider time period may be found in W. Eamon, "Technology as Magic in the Late Middle Ages and Renaissance," *Janus* 70 (1983): 171-212.

gunners at once became initiates of this esoteric art and at the same time removed themselves from the unlearned masses, for anything, once mastered, cannot frighten. And even when they did not mathematize gunnery as much as later commentators have assumed they did, they explored other arcane subject areas such as the "Wonderfull ffire[s]" or "marvaylous workes" of fireworks, subjects fraught with "occult properties".[48]

Concluding Remarks

One of the stronger forces in history (and culture) today is essentialism – seeking to understand what made things, whether people, disciplines, or artifacts, the way they were (and are). In the case of gunnery, the question of it essence is complex and yet simple. The simple answer is that mathematics made it what it was, but that simple answer is complex because as I have argued above, "the mathematics" is not as nicely bounded then as it is now. Mathematics was both a science and an art. And in being an art, it was both a good art and a black art. To characterize mathematical and technological development of artillery as a case of essentialism is also rather ironic, since the whole point of the Scientific Revolution was supposed to have been the replacement of Aristotelian essentialism with mathematical materialism and rationalism.[49] But it seems to me that the gunners and theoreticians did consider

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[48] Gunmen MS, fol. 131^{v} (App. III) and Wright MS, fol. 2 (App. II). The mention of occult properties serves to remind us of another strong movement in the recent historiography of the Scientific Revolution: the importance of magic and Hermetic ideas. As Agrippa wrote, "they are called occult properties because their causes are hidden, so that human intellect cannot fully investigate them, wherefore philosophers arrived at the greatest part of them by long experience more than by the search of reason" (A.G. Molland, "Cornelius Agrippa's Mathematical Magic," p. 219).

[49] See the perceptive comments on the historiography of the Scientific Revolution in A.M. Smith, "Knowing Things Inside Out: The Scientific Revolution from a Medieval Perspective,"

that there was something "essential" about artillery and projectile motion, whether or not they could understand it – or even chose to try to understand it. Gunnery was the "hot" topic of the sixteenth century: it was new; it was powerful; it was "sexy", to use the modern term.[50]

Ever since Charles VIII invaded Italy in 1494, historians have assumed that the gun had come of age.[51] But in the study of Tudor gunnery, a number of things have become apparent. Published works on the topic largely served two audiences: interested dilettantes and students of "the mathematicalls". While a practicing gunner might pick one of these books up, the profession clearly had more to do with craft knowledge than even the best "textbook" (Bourne) could offer. Mathematicians who engaged the subject, despite the best insight and training available, found dead-ends. And, if the case-study of Thomas Harriot can speak for the general situation of the day, the military men using artillery were less interested in analyzing its performance than those on the periphery who thought that analysis might be their entry ticket into that profession. Humble practitioners who sought advancement and esoteric knowledge created a craft-based body of knowledge to produce effective results, but adopted the rhetoric of scholarly knowledge useful for the commonwealth.

The combination of theory and practice is attractive precisely because we believe that such a union can only produce better and better things. Artillery provided one tangible artifact in which the sixteenth century attempted to fuse

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American Historical Review 95 (1990): 726-44, although he admits he ignores the empiricism and experimentalism with which the study of gunnery must be concerned.

[50] J.R. Hale, "Gunpowder and the Renaissance: an Essay in the History of Ideas," in C.H. Carter (ed.), *From Renaissance to Counter-Reformation* (New York, 1966), p. 126: "Fundamentally, guns came to stay because they worked, they won battles, they demolished walls. But they were accepted, too, because of their appeal at a less rational level. They appealed because of their noise and violence, because they were modern and ingenious, because they enlisted both national and professional pride."

[51] In addition to the discussion in chapter 5, see F.L. Taylor, *The Art of War in Italy, 1494-1529* (Cambridge, 1921) , esp. pp. 88-92*ff*.

theory and practice, and despite a remarkable lack of success it remained a touchstone for scientific investigation from that point onward. After all, it was the motion of a projectile which embodies the entire Galilean and Newtonian revolution in dynamics. Artillery also serves as a concrete example of technophilia in a society where need was largely a secondary consideration. Ultimately, it is an example of how unconscious assumptions are made about new technologies and how these assumptions affect their adoption or rejection within society.

The study of the art of gunnery in Renaissance England provides a field of inquiry where the study of history, science, and technology meet in a clearly-defined point. Radiating out from that point – the cannon – are a whole range of ancillary objects, people, and institutions, all of which comprise what gunnery "was" at the time. To suggest – or worse, to state – that "it was like that then" runs the dire risk of applying anachronistic values to other times. But by investigating all these facets together, a more nuanced conception develops. Gunnery was mathematical to the Tudor Englishman, but not in the sense we assume it to be today. Yet many of today's assumptions seem to have had their foundation in the period, and if not solely in this one artifact, cannon are surely indicative of the contemporary attitude. By examining the lives and output of people whose lives were intimately bound up with artillery like Harriot, Thomas, and Parker, along with the guns themselves, we have come to an understanding of where artillery stood – and what it stood for – in the contemporary consciousness.

Appendix I

Technical Analysis of Thomas Harriot's Ballistic Papers

Thomas Harriot's ballistic papers are confined to two bundles, one in the British Museum, the other in Petworth House, Sussex, plus an occasional page elsewhere in his oeuvre that relates to some element of the work. The only previous investigators to take any notice of this work were John Shirley and Johannes Lohne.[1] These authors provide analyses of Harriot's work which is on one hand too topical (Shirley), and on the other, too teleological (Lohne). What follows here is an attempt to reconstruct how Harriot approached the theoretical and practical investigation of his ballistics, based upon the pages of his manuscripts that remain. While the fate of these investigations beyond these manuscript pages may only be hypothesized, I doubt that they ever made their way into a polished treatise on ballistics as previous historians have assumed.

Theoretical Investigations

Johannes Lohne has been the only historian to analyze Harriot's ballistics mathematically. He has found, through a confusing mixture of Harriot's notation and diagrams with modern laws of gravitational free-fall, that Harriot effectively derived a relationship for the range of a shot (R) in terms of its angle of elevation (α), all other things being equal:

$$R = K \frac{\sin\alpha \cdot \cos\alpha}{\left(1+\sin^2\alpha\right)^2}$$

[1] J.W. Shirley, *Thomas Harriot: a Biography* (Oxford, 1983), pp. 241-68 (hereafter "Shirley, *THB*") and J. Lohne, "Essays on Thomas Harriot. II. Ballistic Parabolas," *Archive for the History of Exact Sciences* 20 (1979): 230-64 (hereafter "Lohne").

The constant of proportionality (*K*) in this case is 400,000.[2] Although Harriot nowhere enunciated this formula in so concise a form, comparison with one of his range tables show that his calculation was indeed equivalent.[3]

What Harriot does provide are a number of diagrams showing retarded parabolic paths, the feature which more than any other has caused modern analysis to see startlingly modern ideas in his work. Harriot's trajectories, however, were not designed to provide graphical *representations* of cannonballs' flight. Rather, they were designed to provide graphical *solutions* to the overall range of the cannonballs' flight. The two are intrinsically intertwined, of course, and the methodology Harriot used to generate these tables does follow a logic which can be readily understood in a post-Galilean physics, but that does not mean that Harriot's physics itself was Galilean. Shirley pointed out Harriot's methodology succinctly in saying that he "examined the data carefully, and sought out those mathematical relationships which might be manipulated to derive simple and effective formulae for use in solving other unknowns."[4]

Harriot enumerated two fundamental principles for which he does deserve credit: gravitational attraction and air resistance. In using the term "gravitational attraction," this is not to say that Harriot understood a concept of Newtonian gravity. Instead, his was a simple notion of *gravitas*, or weight, which

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[2] In an example of Lohne's single-minded modernity, he gives the constant of proportionality, *K*, as $2v_0^2/g$, and states that Harriot then used the value 100,000 "for the height $v_0^2/2g$." Harriot had no concept of the value of *g*, nor does he appear to have worked through the units analysis to comprehend that a velocity squared over an acceleration is a height. He does, however, seem to have used 100,000 as his "base" unit here and elsewhere. Lohne sees this as an inverse way of working to five decimal places, which is true, but again this in effect anachronizes Harriot's work, hardly having "been true to Harriot's ideas and intentions insofar as they can be deduced from the surviving papers" (Lohne, p. 233).

[3] Lohne mis-transcribed one of the values from Petworth MS 241, fol. 4: in his article (p. 239), for an elevation of 7° 30´, reported a range of 43,208 for Harriot's value of 34,186. Harriot's value for this datum is 14% low for the formula's predicted value (50,044), although the values for 15°-45° agree to within 1%.

[4] Shirley, *THB*, p. 251.

could be explained in Aristotelian, Galilean, or Newtonian frameworks. Harriot does not explain his framework, but it is clear that *gravitas*, to him is a purely vertical action. His explication of these ideas appear in a statement of purpose accompanied by a small diagram (see figure A1.1):

> I propose ac to be the line of levell: the angle dac the angle of greatest random which is about 45 degree so that the line abc would be continually crooked till it came to c; after if the motion did continue it wold be right as ce & perpendicular to ac the horizon. Now I say because of the bulletes gravity the crooked line is made. If the gravity be abstracted the motion wold be only in the right line ad; & if the resistance of the ayre or medium be abstracted, his motion would be infinitely onward.[5]

In the closing sentence, Harriot correctly notes that it is the bullet's gravity which pulls its line of flight way from a simple straight line, *ad*. He also notes that if indeed, there was no air resistance, it would continue forever. There are, however, two things to notice about this seemingly modern view. The first is that he believes that the bullet, when fired at an angle of 45°, struck the ground perpendicularly; that is, the curved line, *abc*, is tangent to the right line, *dce*, at point *c*. A Galilean explanation would say that in the absence of air resistance, the angle of impact ($\angle bca$) is equal to the angle of elevation ($\angle dac$); that is, if shot at 45°, the bullet would land at 45°. And even if air resistance were factored in, the angle of impact would still not be 90°. In making this claim, Harriot betrays one of his primary assumptions: the forward momentum of the bullet is entirely exhausted in a finite distance. In this case, that distance is the same as the range *ac*, or, put in his terms, at the same time its "gravity" returns the bullet to the ground. In other cases, however, we will see that this finite distance (hereafter called the "momentum distance") is apparently chosen arbitrarily.

In asserting that the angle of impact was 90°, Harriot appears to have been following the lead of Niccolo Tartaglia, although without acknowledgment.

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[5] B.L., Add. MS 6789, fol. 30^{r} (Shirley, *THB*, p. 255). This passage has also been copied verbatim by a contemporary and labeled "Mr Hariot:"; B.L., MS Harley 6002, fol. 25^{v}.

Tartaglia's *Nova Scientia* of 1537 presented the path of a bullet as an initial straight line, followed by the arc of a circle (*abc* in fig. A1.2). Although he merely states but nowhere justifies the assumption, the circle was centered on the horizon with its size defined such that it is tangent to the line of elevation (*ad*). Therefore, it must be perpendicular to the horizon at the point of impact (*i.e.*, tangent to *dc* at *c*).[6] By *geometrical definition*, then, Tartaglia's angle of impact must be 90°. Although Harriot nowhere defines his theoretical assumptions and his trajectory is clearly not as rigorous as Tartaglia's at the outset, he eventually developed a more elaborate one than Tartaglia ever proposed. And Tartaglia himself abandoned his rigorous geometrical trajectory in his later work, *Quesiti et Inventioni* (1546), translated into English by Cyprian Lucar in 1588 as *Three Bookes of Colloquies* (see ch. 3). Harriot clearly had read William Bourne's *Arte of Shooting in Great Ordnance* (London, 1578 and 1587), but Bourne's definition of trajectories (chapter 9, pp. 38-41) is qualitative and lacks the line of elevation (*ad*) as an important element of the construction. Harriot, however, maintained a rigorous geometrical approach based on the line of elevation, although his later developments clearly abandoned the notion of a 90° impact angle in favor of the preservation of other geometric relations.

What we find in the more polished of Harriot's drawings is the construction of a retarded parabolic path which combined his two axioms of

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[6] Tartaglia, *Nova Scientia*, bk. II, prop. ix (S. Drake and I.E. Drabkin, *Mechanics in Sixteenth Century Italy* [Madison, 1969] , pp. 94-7). This culmination of his book on trajectories circuitously proves that the point-blank distance (*ae*: the distance the bullet travels before it is affected by gravity if shot at 0° elevation) is "about four times" the straight segment of a shot at 45° (*ab*). This is based on the assumption that the utmost range (*ac*) is 10 times the point-blank range (*ae*), with *ae* set equal to 1, and the radius of the circle unknown. His result that $ab/ac=$ 200-10 4.14 is what he set out to prove, but is geometrically incorrect. If you assume a unit circle (R=1) tangent to *ad* at *b* and tangent to *dc* at *c*, then $ae = \sqrt{2} - 1 \approx 0.414$ and therefore $\frac{ab}{ae} = \frac{1}{\sqrt{2}-1} \approx 2.41$ and $\frac{ac}{ae} = \frac{\sqrt{2}+1}{\sqrt{2}-1} \approx 5.83$. The contradiction lies in assuming that a circle can lie inside a 45° triangle such that ac/ae=10 with the tangents as noted (this can only be done with an elevation angle of 54.9°, and in that case $ab / ae = \sqrt{10} \approx 3.16$).

gravitas and air resistance (fig. A1.3). Harriot's solution was to allow the cannon bullet to fall from the line of elevation by a certain amount in each time interval, and move horizontally (or, more correctly, "obliquely" as he called it, along the initial line of elevation) a certain amount in each time interval. His "air resistance" is embodied in the concept that the horizontal motion is less in each succeeding interval up to the momentum distance (the bottom right corner marked O in fig. A1.3); that is, the intervals shrink from left to right on the graph. Ultimately, Harriot embraced a square-law of fall from the line of elevation, although he clearly experimented with different linear series, as he noted in the top left corner of fig. A1.3.[7]

While Harriot did not fully explain how he arrived at this construction, he did provide one page which formulates his reasoning, if not the solution.[8] The page is entitled "For oblique motions", a title which appears on numerous pages where he attempted to work out the proof for his contention (see fig. A1.4a).[9] "To finde where a motion at random will cut the horizon", he opens, "Suppose it cut in the poynt ι & let ιδ be a perpendiculer. The time of δι is æquall to the time of δα; for γθ is æquall to γα & βη to βα, &c." Having established that the motion along the line of elevation is independent of the vertical motion, he then defines the question: "Now the space of αε is geuen & the time: the time of δα or δι is required." In order to prove this, he set out another figure (fig. A1.4b) which defined relative velocities. The problem is to draw the line *bc* such that the ratio of areas of *bfnm* to *bac* is equal to the proportion αδ to δι. While he states at the bottom of the page that "this probleme is answered in the page following" and

[7] Lohne makes much of the square-law of fall, and it is shown on fol. 67 (Shirley, *THB*, fig. 11, p. 260), but Harriot does not seem to have been wedded to it. I suspect that he may have "played" with various series until he found one that fit his prediction.

[8] B.L., Add. MS 6789, fol. 26.

[9] The folios in this group appear to be fols. 23-26, 28, 31-2, 38, and 72, but they are out of order.

"that which in deed answereth the question is in page .5.", due to the reordering of his manuscripts, the "page following" is no longer following, and there is no page numbered ".5.".

He does, however, appear to have proven this to his own satisfaction, as a number of carefully drawn diagrams like that in fig. A1.5 remain in his notes where he defined a momentum distance (*ah*), extended the line of elevation up to it (*ag*), divided it into a diminishing series (*ab*>*bc*>*cd*>…>*fg*), and then dropped the trajectory from those points. Ultimately, however, he seems to have realized that his construction was equivalent to a tilted parabola, as the auxiliary construction (*aijk*) perpendicular to the line of elevation and defined by the points where the trajectory crosses the vertical divisions shows. With this construction, the trajectory can be seen as a parabola tilted by half the complement to the elevation angle (*i.e.*, $90-\alpha/2$), as the dotted lines in fig. A1.5 indicate. Harriot, then, decided that the flight of a cannonball was a parabola, but not a Galilean parabola. Rather, Harriot's parabolic trajectories were a logical outgrowth of his geometrical reasoning, but not a product of theoretical reasoning about motion.[10] Not incidentally, Harriot spent a great deal of time in explicating the geometry of conic sections, including parabolas, independent of his work on ballistics. These conic-section investigations have curiously been almost entirely ignored by his biographers. Ultimately, however, his geometrical method led him astray, as another diagram labeled "manimu[m]" he calculated 27°55′ as the

[10] For Harriot on parabolas, see B.L., Add. MS 6788, fol. 131^{v}-136^{v}, 257^{v} ("Archimedes de parabolæ"), and 280-293; Add. MS 6789, fol. 448-450^{v}; Petworth MS 241, fol. 20-22; and Shirley, *THB*, pp. 259-61. Shirley also makes a slight mistake in reading punctuation in two page titles: he correctly reproduces the second as "To proue the perabola a speciall way. good." (fol. 70), but misses the first period in the first title, which should read "To proue the parabola vniversally. best." (fol. 69). Harriot is presenting two proofs on the parabola, one which is "good", the other "best", or in other words, it is not that the parabola is "universally best," but that it is best to prove something "universally."

maximum range attainable, whereas Galileo proved that the maximum occurs at 45° (and about 42° if air resistance is considered).[11]

Thus, *contra* Lohne, Harriot did not think of a "retarding force depending on the initial velocity" (although he is correct in noting that it was independent of the speed), but rather as a geometrical construct which facilitated his analysis.[12] Shirley came closer to the truth in noting that Harriot apparently developed an idea of how a cannonball should move, and then "sought out those mathematical relationships which might be manipulated to derive simple and effective formulae." But like all his researches, his ballistic considerations did not exist in a purely theoretical space. Rather, I believe that his impetus and data were entirely practical in their origin.

Practical and Numerical Investigations

Harriot's ballistic work is not primarily concerned with constructing the geometrical trajectories of cannonballs, but instead, he used geometry as a means to an end to predict ranges, an entirely different programme. In the absence of photographic technologies, trajectories are only qualitatively predictable, whereas ranges are experimentally verifiable. And there is some evidence that Harriot may have actually performed some real-world experiments to verify his theoretical calculations.

As a corollary to his question of ballistics, Harriot did ask questions of motion in general, but was led to these considerations through an attempt to define a law of ranges. On one page, Harriot wrote out a table:[13]

The ranges of Capo Bianco pag. 34

[11] B.L., Add. MS 6789, fol. 63.

[12] J. Lohne, "Essays on Thomas Harriot. II. Ballistic Parabolas," p. 233.

[13] B.L., Add. MS 6789, fol. 36. The MS is tightly bound, with a few characters lost in the gutter. Harriot does not use the modern degree symbol (°), but rather overlines the number's last digit.

Experemented by a Sacre

[deg]rees	0°	7°30´	15°	22°30´	30°	37°30´	45°
[p]ases	250	1250	2125	2650	2850	2975	3000
rate	1	5	$8\frac{1}{2}$	$10\frac{3}{5}$	$11\frac{2}{5}$	$11\frac{4\frac{1}{2}}{5}$	12
rate	10	50	85	106	114	119	120

Harriot is drawing from Allesandro Capobianco's *Corona e Palma Militare di Artiglieria*, which gives on folio 34^{v} a table of ranges for 29 different classes of cannon, from a 1-*póto* "Mochetto da giuoco" to a 200-*póto* "Cannon petriero Camerato."[14] Harriot chose the saker, whose ranges are neat multiples of one another and in the third row he has divided through by the point-blank distance to obtain relative ranges. On the previous page Capobianco had enumerated these same rates in the text, but in the last row, Harriot multiplied by ten and rounded to produce an integer series which he could use to develop a convenient rule for ranges. Realizing that the series was diminishing, and in conjunction with his assumption that there was a finite momentum distance, he assumed that the series was an asymptotic series. Thus, on a number of folios he tried various fractional series that approach a unit value in a unit time (*i.e.*, they proceed from 0 to 1 in the time of 1 unit), although he never clearly chooses one (see fig A1.6).[15] He does appear to have found one that worked closely for the case of the saker, but then abandoned it as too imprecise, for on that same page he added a smaller table of the elevations, the rate series (*i.e.*, row four from the table above), and then began calculating values in a third column. He only

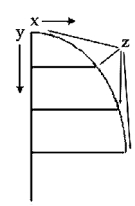
[14] Alessandro Capobianco, *Corona e Palma Militare di Artiglieria* (Venice, 1598 or 1602). The 1598 and 1602 editions are identical, this table appearing on sig. [F4]^{v}. Therefore, we cannot determine which version Harriot might have used, so this work can only be dated to *after* 1598. There is no value for 0° in the table, but these point-blank values are on the preceding page (fol. 34^{r}). I must thank Dr. Tim Johnson, Special Collections Department, University of Minnesota for checking the 1598 edition for me; I have consulted the 1602 edition. Dr. Johnson also suggested that the insecure dating to "1598?" for the first edition may be due to a sloppiness in composition that raised the '8' in the date slightly above the line of '159'. If anything, this may mean that the publication had been planned for 1597, but slipped into the new year, with a reset title-page date. The colophon date, however, is secure at 1598.

[15] His work on these series fill B.L., Add. MS 6789, fol. 41-2 and 44.

entered values for $7\frac{1}{2}°$, 15°, and $22\frac{1}{2}°$, but they correspond quite closely to the Capobianco numbers: against 50, 85, and 106, he wrote 50,754, $\frac{2}{10}$, 86,282, $\frac{1}{10}$, and 107,599.[16]

As far as we know, Harriot never had access to a cannon to test his theories. But there are some tempting hints that he may have done some experiments. One of these fills the first folio of the Petworth ballistic papers, although it is not entirely clear that it should be part of the ballistic group. The page is entitled "Second experimente" in the top right-hand corner and appears similar to one of Galileo's free-fall diagrams, with a parabola arcing down and to the right from a horizontal tangent at the top (*i.e.* $y=x^2$, in mathematical notation with the origin at the top left and ordinates increasing down and right – see diagram accompanying table, below). At each horizontal line, he has one number next to the vertical axis (*y*), one number which relates to the line (*x*), and one number at the intersection of the line and the parabola (*z*). But more interestingly, next to this last number on the three lower lines, he has a second number, preceded by the word "calculo" or "assumptu*m*". Tabulated, his results are as follows:[17]

y	*x*	*z*	Calculo
0	15	1	-
2.25	428	28.53	29.60
4.50	628	41.87	41.96
7.44	748	49.20	53.90



Harriot's calculated numbers are consistently high, by 3.7%, 2.1%, and 9.6%, respectively, just as his series for Capobianco's ranges was. What is confusing is that although he has drawn a fairly accurate parabola, the *x*,*y* coordinates do not

[16] His series was diverging slightly faster than his data, but the fit is nonetheless impressive.

[17] Harriot uses fractions throughout his work. I have reduced them to 2 decimal places for simplicity in this table. The *x* column is in whole numbers, and the fractional units are 16^{ths} for *y*, 15^{ths} for *z*, and 10^{ths} or 100^{ths} for the calculations.

correspond to a quadratic law, for while any three pairs will define a parabola, in this case the fourth pair (0,15) does not agree. While the word "experiement" generally implies a physical test, here Harriot may be using it to refer to a trial of an equation he was then considering. Since a record of the "Firste Experiemente" no longer exists it is unclear whether Harriot had some sort of inclined plane set up to experiment with gravitationally accelerated motion, as did Galileo, or whether he was merely experimenting with numbers.[18]

Beyond utilizing other authors' works for data, Harriot also clearly tried to reconcile his work with the published works of other authors. The Petworth papers contain a number of pages clearly from a larger and now dispersed work.[19] The extracts on fol. 3 and 4 are headed "11.)" and "12.)", respectively, and there is a note in the middle of page 11 to "vide pg. 12.". Clearly the work had at one time 10 pages that had come before and which are now missing and may well have had more following. The style is very similar to his work on fortification, where the material is presented in semi-polished, ordered format: not quite set out for publication, yet far above simple calculations and personal musings:[20]

> 11.) The rate of randons supposing:
> The velocity is at the mouth, equal. & 1000,000.
> The vpright rando . 50,000.
> The double vpright . 100,000

This is then followed by two tables, giving the ranges for 5°, 10°, 15°, 20°, 42°, and 45°. The value for 20° is starred in both and is the maximum in each series,

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[18] One possible connection is with Henry Percy's interest in a form of wargaming (the "art militaire" or *Kriegspiel*) which was played with lead soldiers and somehow involved "conic sections"; G.R. Batho, *Thomas Harriot and the Northumberland Household* (Durham, 1983) , p. 16.

[19] The Petworth bundle was "gathered" in the late 17th century by Baron von Zach (see ch. 2, n. 7, above). Petworth MS 241 seems to be one of the sections which he extracted, which were retained by the earl of Northumberland when the bulk of the papers were donated to the British Museum by Lord Egremont in 1810.

[20] Petworth MS 241, fol. 3.

suggesting that these tables predate his geometrical constructions where he noted that the maximum range occurred at 27°55´.[21] In the first table Harriot then took the differences between the adjacent values, which, like reducing Capobianco's ranges to "rates" is a practical numerical analysis method, know as taking "first differences." Since the rest of the page is incomplete, it would appear that he gave up on this line of attack when the first three differences ([30,280], [27,342], and [15,201]) failed to suggest any pattern to him. But he clearly is thinking in a parallel manner as he was with Capobianoco's ranges.

The following page reads:[22]

12.) For finding ye velocityes of Bornes rates.
In the sa*m*e rando, as ~~dia~~ the diagoniall shorter, hath to his longer so hath the square of the just velocity to ye square ye seco*n*d: And so the sayd diago*n*ialls so are ye rates if the horizontall ranges. Therefore I worke as followeth

	ranges	Bourne ranges	Squares of Velocityes	Squares of Velocityes	rootes
5°	34,186	47,374	100,000,00000	138,577,19,534	117,718
10°	64,466	71,061	100,000,00000	110,230,19,886	104,995
15°	87,888	92,379	100,000,00000	105,169,74,430	102,552
20°	103,039	103,039	100,000,00000	100,000,00,000	100,000
42°	94,900	117,251	100,000,00000	123,532,10,000	111,153

Harriot appears to have already developed some formula to predict ranges given elevation.[23] There is then another identical table below for the same

[21] And, indeed, a numerical formula would be required to determine that the maximum of his geometrical construction occurred at 27°55´, since ascertaining differences within 5´ from a diagram would have been impossible. This may suggest why he had a table of sines for 0-45° by 10´ with his ballistic papers. The diagram of "27.55´ maximu", then, would be a formal geometrical demonstration of the maximum range, not a proof.

[22] Petworth MS 241, fol. 4.

[23] Harriot's method of work is as follows: he tabulates "his" ranges (R_1) for various elevations alongside Bourne's ranges (R_2); taking "his" velocities that produced "his" ranges as all equal and assumed equal to 100,000 (hence the square of $V_1^2=10^{10}$), then by the ratio $R_1 : R_2 :: V_1^2 : V_2^2$, he can calculate the square of Bourne's velocities in column 5 (V_1^2), and thus Bourne's velocities in column 6 ($V_2 = \sqrt{V_2^2}$). These are only the relative velocities of Bourne's shots, since Harriot's initial velocity of 100,000 is arbitrary. This suggests that Harriot believed that the range of a cannon shot is proportional to the square of its (initial) velocity, not the retarding force as Lohne believed. Apparently, then, he assumes ranges are a function of

purpose, but here comparing his "æqual velocity" ranges (column 2, above) to the ranges of Capobianco, although these, too, are clearly calculated. In both cases the values recorded for Bourne and Capobianco do not appear in their printed works, suggesting that at least here the data Harriot extracted from those works has been manipulated before being entered in these tables. Combining his tabulated values shows that his theory predicted range as a function of the square of the elevation to a very high degree of correlation (fig. A1.7a).[24] It is also clear that his tabulated ranges do correspond to his geometrical constructions with their 27°55´ maximum. Figure A1.7b shows the differences between Harriot's "parabolic" theory, who tried to account for air resistance by defining a momentum distance, and the "modern parabolic" theory of Galileo, who ignored air resistance and instead decomposed orthogonal forces entirely.

In another section Harriot specifically analyzed other people's experiments. In one place he noted "The experim*entes* of Luys Collado spaniard con vn Falconete de 3 libros. p[…] 79.6" and tabulated the following data:[25]

Degrees :	poynt	[shyte pases]		
0	0	368.	368.	286.
		326.	226.	326.
7.5	1	694.	594.	594.
			200.	200.
15	2		794.	
			160.	
22.5	3		954.	
			56.	
30	4		1010.	
			30.	

that velocity, but without any method to measure the real velocities, must rely on arbitrary, and hence relative, numbers.

[24] An r^2 value of 0.987 on the graph indicates that there is only a 1.3% variation from a true parabola. This is the same function Lohne derived in terms of the angle of elevation, above.

[25] Petworth MS 241, fol. 11. Luis Collado, *Pratica Manuale di Arteglieria* (Venice, 1586) or *Platica Manuale de Artilleria* (Milan 1592), the latter being a revised edition of the 1586 edition "sufficiently different to be considered a distinct work" (M.J.D. Cockle, *A Bibliography of Military Books up to 1642* [London, 1957] , pp. 171-2).

37.5	5	1040.
		13.
45	6	1053
52.5	7	muy muo corto el tiro de to que fus el de el sexto.[26]
60	8	betwixt 2 & 3 py[n]tes
67.5	9	betwixt 1 & 2.
75	10	nere to pece.

It is clear what he has done is to read Collado's experiments and extract the distances in paces as functions of points of elevation. Since the point division of a circle is based on 48 points to the circle (1 point = 7.5°), he has converted them to degrees in the first column and then in the third again used the first differences method (that is, taken differences between Collado's figures in each row).[27] The first row, therefore reads: 0° is equivalent to 0 points and Collado found that 3 shots flew 368, 368 and 268 paces. The second line indicates that there was a difference of 326, 226, and 326 paces between those three shots and the ranges of the next three shots (ranging 694, 594, and 594 paces at 7.5° or 1 point elevation). Again Harriot is taking differences, not explicitly demonstrating any functional relationship. He continues at the bottom of the page, saying "He shot in a falconet whose bullet was 4li and fo*un*d the leuel range poynte blanke — 250 pases. The leuell range of the mettall of the piece — 440 pases." These references to the "mettal" of the piece apparently relate to a distinction that Tartaglia makes: shooting at level means that the piece has been properly disparted and the bore of the piece is truly level; shooting at the level of the metal of the piece means that the top of the breech and the top of the muzzle are level with one another, which means that the bore is slightly elevated, since the

[26] Translated, this reads, "The shot of that gun was just short [*muy muo corto*] of the sixth [point]", *i.e.*, only a slightly shorter range than at 45°.

[27] Note that this concurs with Thomas Smith's comment that most gunners' quadrants of the day used a 12-point gradation, rather than a 360° gradation (T. Smith, *The Arte of Gunnerie* [London, 1600], p. 45), but see also ch. 4, n. XXX[vestiga math]76, below.

muzzle diameter is smaller than the breech diameter.[28] Harriot then continues, "with the same piece he shot at a mavse 400 pases of. The axis [of the] pece li*n*e poynt blanke, the shot vnder .2 palmes. The mettall liy*n*e level, [t]he shot ouer .2 palmes." That is, at 400 paces, a shot drops 2 palms (about 6-8´´) from the intended target, while when elevated slightly ("to the metal") shot 6-8´´ high of the mark. It would seem, then, that Harriot would have eventually liked to predict not only ultimate ranges degree by degree, but also the small deviations of a shot at given distances, depending upon the mounting of the cannon.

Although Harriot's practical investigation of ballistics is less clear than his theoretical work, it is clear that he was interested in discovering mathematical relationships to predict the range of a cannon fired at different angles of elevation. He was not interested in trajectories or laws of motion, as Galileo, Torricelli, and Newton would later be. His aims were practical, even if he usually abstracted this practice to a theoretical level for solutions that appear "wrong" to modern analysis (as well as being physically incorrect). But at the end of the sixteenth century his methodology would have been approved by most mathematicians. That his conclusions are "wrong" indicate that this work was not destined for a practical treatise on gunnery (say, for Raleigh), for such errors would have obvious to even the most novice practitioner.

[28] That is, if the muzzle and the breech were 6´´ and 8´´ in diameter, respectively, if they were level with one another, the cannon would be inclined 1´´ over its length (*i.e.*, half the difference in diameters). See N. Tartaglia, *Three Bookes of Colloquies Concerning the Arte of Shooting in Great and Small Peeces of Artillery* (London, 1588) , first colloquie.

Appendix II

Richard Wright's Notes on Gunnery, 1563
MS 94, Society of Antiquaries, London

•*transcribed and here printed with permission from the Society of Antiquaries, Burlington House, Picadilly, London W1V 0HS*

items are expanded scribal contrations
~~items~~ are crossed out in the text
[items] are inferred from missing of damaged text
{items} are faint in the MS itself
<items> are editorial notes (pictures, blank pages, &c.)
items are notes inserted in the margins

Sãuell Thomas **fol. 1**
Tves [the]
T[v]ese[d]aye xij of february {vij xij of …}

Itm payde too my [n]orese iiij s.
for amonethe wages

B B the xx of february Sãuell Thomas

Itm payd to ~~the nor~~ Robart
B Shaye in payrte of payment xx^{s}
B of xxx^{s}

[t…o] m[ake] enyke

pout to a quarte of water
the beste [&] 5 ownses of gavlle
blakeeynke and gren koppers ———— 3 ounses
and of gonne pout to it ——— 2 ounses
and boyl it then pout a pynt of water
more and sooe boyle hin to a quart

Leik wys to maike a nye coulered eynke

94. [1]

Note. this M.S. I found in a Cheesemongers Shop near St. Clements
in June 1804 [I Iany Iunl]
<blank> **fol. 1^{v}**

Presented to the Society of Antiquaries of London **fol. 2**

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[1] In a modern hand from here to end of folio and the top 2 lines of fol. 2.

by the Right Hon Sir Joseph Banks, 14th Dec. 1809

[Richard Wright Bokeh] I will geue [t]hankes [2]
to the olorde wth my whole harte
I will speke of all the ~~wa~~ maruaylous
workes I wil be glade and reioice in
the yea my songe will I make of thie
name oh thou most higheste Be causte

<blank> **fol. 2v**

<Picture: 3 rough sketches of heads (3 female, 1 male) and 1 male figure study. > **fol. 3**

<Picture: Illuminated initial 'h' using a dragon, a rose and Celtic knotwork on the shorter (right) stem of the 'h'. The Rose is presumably a reference to the House of Tudor. The date '1563' appears in the middle band of the 'h'. > **fol. 3v**

The ferste Is t[o] knowe his pese **fol. 4**
i be treu of no in the kore and to
knowe the wayte of the metell
so euery pes of wat hayte sooe euer it be

2 The secoms Is to kno the Desparte
of his e metell be for an be heind

3 The therd Is to kno to sheit his
shot to euere oes wat sooe euerr it is

4 The forth Is to Larne to maike
Ladelles for euere pes ~~yeh~~
that shoutes yerne or stone

5 The fifthe is to knowe his pouder
of & wat He sete it Is maid of

6 The seixst Is to knowe to Layide
his pes and gone to shout it at
ane marke of bout or tones or abord
the sheippe at seie

7 The *f*[eventh] Is to knowe hou to
sheut in Reull or quaderent
at anne tones or anne banketh
or at anne hell or doune the hell

[2] The initial 'I' is a large calligraphic letter with 'Richard Wright Bokeh' placed vertically in the staff of the 'I'

or doun the tones or stepell

8 The ayte Is to make his pouder 8 **fol. 4v**
of to Re setes korne of sarpentine

9 The Is to Larn to maik his sallt [3]
peter and his Kolles for pouder

10 The tein Is to Lau…note maike
his feiere workes of all sortes.

ii Itm for stonne shout the on haulf in pouder [4]
that the shout wayes Is [half] a leneares

A questen wether the pes that Is long shall shout
farther by the quaderine then the porte pes or not
by quaderent the the lonng pes and by ~~shoot~~ Ryeulle [5]
the shourt pes shouttethe farther he then the long

And up*es* the heill apeithe mor haith in Reull or
Compas in quadereintt then Doun the heille

Robinedoe Borne **fol. 5**
And if thov wyste nnnndaaaa… [6]

A questen whether It Is the peis that shall maike the
X ~~the peis~~ the shoot to mont after tyse or threis shouting
or that It ~~e~~ is the pouder by Resoun of the het of the
pes she Reson If that wen the pouder Is in the hot
pes and the pouder groeing hot all sooe maikethe the
pouder the strounger by Reson of of the het that dreisit [7]
for pouder beieng hout bourn*n*eth strounger then that Is
coulde probatom est

X to prouf taike to prouf of pouder out of a bareill and of the
beste warme the on in a pan ouer the feier and wen it Is
hout then born then the could and the warme bouth together
asonder and you shall fynd the wa^r^me pouder the stronger.

<Picture: a gunner: man in puffed and slashed dress with bear- **fol. 5v**

[3] There is no '9' added in this point.

[4] The rest of this folio and all of fol. 5 is writen in the same hand but a differnt ink. This, and the fact that the content is more probing, suggest that it was added at a later time.

[5] "the the" [sic]

[6] These two lines seem to be pen tests.

[7] "of of" [sic]

foot sabatons and with a curved sword holding up a one foot rule (with wrist strap) with gradations above his hand and a 5/4 writen below. See ch. 5, fig. 5.1. >

<Picture: heraldic device: arms quartered with 3 supine lions in the NE & SW corners and 3 fleur d'lis (2 above, 1 below) in the NW & SE quadrants. A grifon bearing on left and a lion on right, both with clearly-drawn male genitalia. A hot-water bottle with a leaf above left and a rose above right. > **fol. 6**

To know the wayte of **fol. 6v**
Shoutes & **of peces yf yt** [8]
Be lede gyue him whayt for
whayte and yf it Be Iorne then give him
the iij parte of it and yf it be syngull then
the one hallfe and ~~sh~~ so shall he go to his marke

To know all maner **fol. 7**
of Brasse pyeces as ffoloethe
Item frome a Sake^r vpwarde take the eighe of the
mothe of the peace then geve him iij tymes his eight to his charg [9]
of the pece and yf it be iij enches they geve hym xviij
enches longe for his chase **probatum est**

The names of Braspeces
And for the Cartewhiche take canvays

Item A base A Robenet A fawconet
A fawcone A Sake^r A morter pece A Basterd Cullueryng
A demye Cullueryng A demye Cannon A dowbble
Cannone A Bassallisco as herafte^r you shall seye

Base peces [10]
<Picture: top view of long thin cannon (160mmx13mm). >
<Picture: similar. >
<Picture: similar, but mounted on a field carridge. >
A robenete

A facon shote of ij enches **fol. 7v**
the is vi enches in Compaes and wayeth
in dyce and lede ij pounde v ounces and
of Iorne a pounde iii *quarter* the ladyell must

[8] Beginning here, the first 1-3 lines of each 'chapter' are written in larger blackletter text while the body of each 'chapter' is in a standard secretary hand. Boldface here represents the blackletter 'headings'.

[9] Throughout the MS, Wright omits the initial 'h' in 'height'.

[10] Note, "Base" here does not seem to refer to mortar-class cannon; see App. V.

be of breadth iij enches and *half* xij enches
longe for the cartwhich vi enches brod x enches
longe A holdes in powder ij pounde

A saker shote wayes v pund
and *half* the lenghe of the ladell is xvi enches
vij enches brod v pounde of poude^r^ and
half descharges the same shote for the cartwhiche
is ix enches brode xvj enches longe and holdeth
in powder v pounde

This ys the trewe knowleydge
of all peces howe far he shall caste at poynte
Blanke fyrste a favcon shall cast at pynte blanke
xiiij skore havying the ix part of poude^r^ more
then the wayte of the shote and loke that the shot
be rounde and close and yf you^r^ shot be to loke
lowe for your pece you shall rate alwayes
the eight lenghe that you shoulde cast at
pynte blanke and yf you^r^ shot be trowe
and cast at poynt xiiij skore he shall cast
at the Ranger v tymes so fare and halfe
so fare and so shall ye doo with you^r^ othe^r^
peces.

A ffacon and a faconet **fol. 8**

<Picture: falcon on a field carriage with cannonballs filling open space. >

<Picture: falconet on a field carriage. This cannon is slightly longer than the above (130mm vs. 125mm). >

A Sake^r^

<Picture: A saker, drawn the same lenght as, but slightly larger in diameter than the above 2 cannon. >

<Picture: a morter > **Thys ys A morterus pece**

A holle Collueryng shote **fol. 8^v^**
of v enches *quarter* hie xv enches compas and wayes
of Iornne xviij pound the ladell must be x
enches brode and xxij enches longe the forme
for the cartwhich is xiiij enches brode and xviij
enches longe xij pounde of powde^r^ descharges
that shote

A deme Colleuerynge
shote of iiij enches and *quarter* hie xij enches and
half compas and wayes of dyce and leade

xij pounde and the Iornne ix ponde *half* the
ladell viij enches and *quarter* brode and xviij enches
longe the cartwhich is xij enches brode
xviij longe and ix pounde of powde^r and *half*
dyscharges the same shote

Also there be other peces
mayde that doo sustayne ij hunderith
wayte of metall for one hunderith
whate of shote as there be sakers and
other shotes that wayes but v pounde
and the pece wayeth in mettell xij hunderth
or a boue all suche peces maconvenyently
bere more then wayte be cavse … the
shott is but smalle and the pece is dubble
ffortefyed which mettell all suche peces
maye convenyently bere more then
wayght for waight by the ix parte ~~of~~ in ponde

This ys A bastard culluer **fol. 9**
ryng: and a deme cullverynge
<Picture: a bastard culverin on a field carriage with cannon balls. >
<Picture: a demi-culverin treated similarly and with helical ornament on the barrel. >
<Picture: top views of 2 ladles.  >

As a pece that his shote **fol 9^v**
wayse lx pounde of Iornne whiche is called A
Cannon ~~Thy reson wherof~~ the reson wherfore
ys be cavse that a pece that shouteth suche
a shote of xl ~~li~~ and the pece wayethe [11]
in mettell a boute iiij thousande wayte
or a lytell abowe whiche maye be one hundereth
whate of mettell for one pounde of shott

As by th example Also
I take saker and I fynde that he is of eighte iij
enches and a halfe and I fynde the forsaid rull
that a shot for the pece should waye v pound
then I take a ladell after this manner of v
balles of lengke and the ladell shall holde at
a tyme ij pounde and *quarter* of pouder and ij tymes
that ladell fyllyd equally as the full dwtye [12]

[11] Note that in some of his abbreviations for pound, 'li' is written stroked, a convention I shall retain, as in this example. It does not refer to crossed-out text. This one is uncharacteristically not supercripted.

[12] *I.e.*, 'duty'.

of syche a pece and in lyke wyse by thes
ladell you may make ladells for thes sortes of pesces

Also to make a ladell for a cvrtall or for a
cannon or suche lyke peces you shall doo
as is aforsaid in takyng the eight of the shote
that sarveth for suche peces and as you fynd
in your Revll then ad to iij tymes as moche
and you shall fynde that suche a ladell ij tymes
fyllide holdeth waight for waight lakyng
the ix parte all syche ladills serveth for suche
peces yf the be fortefyed with metell / but
some peces ther be that is chambered for the
whiche you mvste make your ~~m~~ ladell after
anether sorte

A dubble Cannone **fol. 10**
<Picture: a double cannon with cannon balls. "E•R" and a rose on the barrel. >
A deme Cannone
<Picture: a demi-cannon with cannon balls. "E•R" on the breech and a spiral decoration on the muzzle. >
<Picture: top view of a ladle.  >

That ys aforesayde as a fawcon **fol. 10v**
and for a fawconet and A basterd cvllvering and as
you haue done By the Saker shote aforsaid so shall
you do By the other said peces in takyng the eight
of the shote and then loke one theforsaid Rewll for your
ladells and than you shall fynde what one ball of lengthe

In the makynge of your Ladell
will do and whate he holdeth in poud then loke how
many balles you will make your ladill one as to
so manye tymes the waight that you fynde in the
forsaid Reull and so shall every v balles of lenght in
the ladell holde halfe the ix parte more than halfe the
waight

Also to make a ladelle for a demy
Cvllveryng or suche a lyke pece you shall do as is
aforesaide in the taking of the eight of a ball you shall
ad to iij tymes as moche and a halfe and you shall
fynde that suche a ladell shall holde at a tyme Iuste
halfe the waight of the shote and ij tymes that
ladell fyllyd is the dutye of suche a pece

Also whoso wyll vnderstande
the eight and waight of Iornne shote shall fyrste take
the shote and compas yt aboute a whan you haue
so done devyde the said compase in to iij partes of the
which iij partes you mvste take the therd parte of the
compas for the eight of you^r shotte and so many enches
as the therd parde of you^r shot is in length mesured
By ench Reull loke so many enches and *quarters* as the
Reull is marked in nvmbe^r and so manye pounde
~~waight~~ waieth you^r shotte.

A Basylysco **fol. 11**
<Picture: a baselysk and shot which is too large for this particular cannon. The image flows off the page. >

A bumbarde
<Picture: a bombard, the composition of which is also overflowing the page. A ball next to the bombard appears to have a lifting loop. >

Allso another waye ther ys **fol. 11^v**
to take the eight of your shotes wher by not
you shall evydently knowe the eight and the true
waight of you^r shot in the forsaid Reull
you shall take a payre of Callapares compas
ces and take the eight of your shote of you^r [13]
shote and then take the eight by a Reull and
somannye enches as you do fynde by you^r Rull
that you^r shot is of waight and then loke [14]
and then loke so many enches ~~sa~~ as the forsaid
Reull is marked and so many pounde Iustly
wayeth your shote as by this profe I take a shot
and measure it the eight and I do fynde the
eight vj enches and then I fynde by this
for said Reull that my shot shvlld ~~well~~

Waye viij pounde and It is not
A *quar^ter* which is the Iuste waygth of all Iornne true [15]
shote of that eight yf so be full caste and
Rounde and without bloing or honne comynge
and yf he be not full caste he shall waye
more then this for said Rull shoithe and [16]

---

[13] The initial "ces" in this line is the unhyphenated pluralization of "compas" in the line above. Wright also repeats "of your shot" twice.

[14] He repeats "and then look" twice.

[15] This contration is actually in the semi-contracted form "q^tr". I will attempt to replicate Wright's various abbreviations for "quarter" as follows: q = *quarter* and q^tr=*quar^ter*.

yf he be Rounde caste he shall Iustly way
as the foresaid Rull shoith

<Picture: A cannon on a field carriage. >

The flouare of Suche a ladel **fol. 12**
that ~~shoith~~ for ~~ech~~ suche a pece what that he
holdeth this is the rull that the quadrant serueth
doth showe as maisters doth teache howe
fare so mvche powder maye caste such a shote
at poynte Blanke and frome degre to degre
to the laste of the Rannde^{r} and becavse that

One pece Shutithe not so fare
as a nothe^{r} therfore you mvste vnderstande
that anny pece that you have yf he caste at
pynt Blanke one hvnderth and iiij skore
he shall shevte at the Rande^{r} a myll and fortte
fowte good and so lyke wyse all othe^{r} peces
when you do knowe howe fare your pece

Shall caste at pynte Blanke
you shall caste at the Rande^{r} v tymes so fare and
A halfe Also you shall knowe By thes fygures
of the Qvayde^{r}n that is showed howe you shoulde
Reken from degre to degre howe fare that you^{r}
pece casteth for the movntynge of one degre
and soforthe of all othe^{r} ~~deg~~ But you mvste

[M]arke and knowe that you^{r} [17]
pece that you will shout with all be perfetly dis partid
and devidid so that you maye knowe the goodnes
of you^{r} pece or whethe^{r} you^{r} pece be caste so as
Sume tyme it so chancith that some peces the
curry dependeth more to the one syde then to
the other wherfore that no man can shoute

Syche a pece excepe he haue **fol. 12^{v}**
the pece devyded by his right lynne and knowe
perfetly what waye the pece castethe moste
and all suche peces be dangerus for fere of
brekynge with a full charge of them that
beyng n orante but yf that you fynde that you^{r}

[16] Wright incorrectly claims that a hollow-cast shot will weight *more* than a full cast shot.
[17] The initial 'M' appears as 'ay' in the text, but it must be a scribal error.

Peace be made Be a trewe corye
and haueynge a Beame made be a trewe corrye then whan
you haue Iustly desportide you^r^ pece take you^r^ quadrante
and Loke that eight of you^r^ dyspartinge and the eight of you^r^
peces Be all equall and then se that you^r^ shote Be rounde and [18]
full caste and close to the pece and you shall fynde that
in so Doynge that you shall

Shewte as Nygh the marke
Beynge with in pynnte Blanke as thowthe it where w^t^
A hond govne and then marke the wyndynge of you^r^
plommete in you^r^ quadrante and you shall fynde by yor
Quadrante howe moche more or farthe^r^ that your pece
shall caste in the mvntynge of ~~y~~ on~~^r^~~ degre and soforth [19]
to the laste of the Rannde^r^
Also amaner to showe you fyrste
to desport you^r^ pece you mvst take the compase abowe
the tayll of you^r^ pece and then dysporte you^r^ pece equaly X
in the iij parte and then take on of the iij parte which
is Iuste the eight of tayll of you^r^ pece And then
take the eight and goo to the mõthe of the pece

And measure the eight of the mouthe **fol. 13**
of the said pece this done take the saide eight of the
said mouthe and cvt it of and that which remanyth
of the eight taken Be hinde at the tayll of you^r^ pece
depart yt in to parts and take one parte and
set yt upon the mouth of you^r^ pece so that the yende^r^
parte may touch the mouth selfe and the other
to stonde

Apone the pece the whiche
makes A parffete shot you^r^ pece is hei Before as be
[h]inde then take a ponne the eight of the mettell of you^r^ [20]
pece then goe to the tope of you^r^ disportinge stande a
pone the mouthe of you^r^ pece and brynge this to toge
the^r^ with you^r^ marke and all beyng of one eight you
shall not fayll of you^r^ marke

Another waye ther ys to desporte

---

[18] The initial word in this line, "peces", is added in the left-hand margin. Obviously the author was thinking faster than he was writing.

[19] A rather interesting use of deletion, turning "your" into "on[e]", 'u's and 'n's being orthographically similar.

[20] The initial letter of this line reas as an 'f', but only makes sense as an 'h'.

you^{r} pece more lyghtte^{r} But not at all tymes
So trewely you shall take a prymynge Iorne and
put it in to the toche hole of you^{r} pece and take the
eight of you^{r} pece from the depthe to the eight of
the mettell Be hind and that takynge goo to the
mouthe of you^{r} pece and take the eight of the
mouthe Considerynge

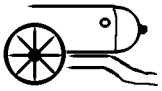
That the pece ys more strayghte **fol. 13^{v}**
Be hinde in the collet then she is in the mouthe before
and then the saide eight takenne in the mouthe and
cut that of and caste it awaye and that whiche
Remanyneth as is beforesaid that sele apon the mouth
of the pece with the Iuste eight of the mettell

Be hynde And the toppe of the
dysporttynge and the marke beinge all one shall make
a perfet shote exsepte that you^{r} pece wher not trwly
Borred in the toch holl the which maye dysceave you
in you^{r} desporttynge Servith not But shall
Deceve you

Also ther ys another despor
tynge that provith to be trewe and servethe for all
peces take one ench Rull that is marked ench
and hallfe enche and *quarter* then take this Rull and
laye it laste vppon the pece tayll and than
take you^{r} plomet and you^{r} lyne and laye oue^{r}
the Rull that it may tvche the sydes of the pece

voyt voyt [21]

<Picture: largish cannon on a field carriage with spiral design ahead of the trunions and a touchole drawn approximately 60˚ off to the side. >



Fyrste one the one syde and then **fol. 14**
one the othe^{r} syde and so shall you haue the Iuste eight
and then take the fyrste eight and laye it apon the mouth
of you^{r} pece and devyes the thekenes of you^{r} pece
be his lyne as you did Before at the tayle and
somany enches and *quarters* of enches that you^{r} pece is
thiker by hinde then she is Be fore

And then take Iuste halfe
so moch and set it Apon the pece Be fore then
than take the eight of you^{r} pece Be hinde and the
tope of you^{r} disportinge Be fore and you^{r} marke

[21] Here and above, the mysterious "voyt" has been added, rotated 90˚, in the left margin.

shalbe all one and you shall not chuse But to
hit the marke afte^{r} this disportinge and by
this disportinge you shall perfetly knowe yf you^{r}
pece Be not eQually

Cast or note as ys Aforsaide
of Some peces that ar not trewlye caste havinge
more mettell one that one side then the othe^{r} side
or that some place more than that some othe^{r}
place the which you shall prefetly knowe by
this Rull of desporting this is the trewe
Knolyge of all peces howe far he shall
caste at
X / alserues in one [22]

The end of pece and shote
ffor to deuyde Sallte pete^{r} **fol. 14^{v}**
coll and soullfer the one from the other yf
you will devyde you^{r} sallte peter sullfe^{r}
and coll A sunder you muste take faye^{r} lye
and let it stande xxiiij oures and take the
fayreste therof and put it panne and set
it over the fye^{r} and let it be luke warme
and that donne put in you^{r} powde^{r} and let
it stan one or towe ou^{res} then put it oue^{r} the
fye^{r} and let it ball a lyttell or elles be
skoldynge hote and in the mene sesone se that
you haue a faye^{r} bowll or an nerthen pot
with a lyme cloth laid ove^{r} it and then laye
a hie a pone the cloth and put a fueoo fyne wode
ashes that be very sharpe in the mouth

Or in the tastyng in te tounge
and then laye them a Bravde A pon te heie and
then A nothe^{r} lynen cloth uppon that ashes
and so put the lycu^{r} apon the same halfe a
nower or more and whan all is gonne throwoe
and with in a whill as the space of halfe a no[-]
we^{r} or more then take a waye the clothe &
loke a pon the lycu^{r} that is warme Rovne
throwe let it stande and colle xxiiij oweres [23]
and you shall seye the sallt petter ⊥ cleve vnto
the sydes lyke vnto yes and persue that lyecu^{r}
in to a glasse for it is a principall goode

[22] This line is inserted in another hand.
[23] Rovne throwe = "run through", *i.e.*, through the cloth filter.

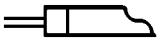
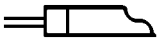
medson for a tette^{r} or for a keanke^{r} with in
a man or horse that hath the ffarches & [24]

To make all manner of ladells **fol. 15**
as herafte^{r} foloyth for to vnde^{r}stande howe to make the
Breathe of you^{r} Ladeles for all sortes of peces beyng great
or smalle that is to saye you mvste take the Compas
of you^{r} shote Iustlye and devyde the compas in to v
partes of the which v partes you shall take iij parts for
the Breathe of your ladelle
<Picture: top view of a ladle. >

And the other to partes to be as
voyde for the vppe^{r} parte of the ladell and By this devy[-]
syon you shall make ladells for all sortes of peces ex[-]
cepte a peces that is chambred and yf it be achambrd
pece you mvste take of the chamber and that eight
iij tymes takenge and that iij tymes to be devydded
in to v partes as it is aforsaid and so you mvste take
<Picture: top view of a ladle. >
Thre partes for the Breathe
of your ladill and the other to parts to stande voyde &
of none effecke, This Rull shoith the lenthe of all
ladills and what powde^{r} the doo cary at a tyme in
a Ball of lenthe ~~of all ladells~~ or halfe a Ball or iij
quar^{ters} of a Ball fyrste you saye that a Ball of lenth
in the makynge of a ladell shall holde so mvche powd^{r}
as this forsaid shote and that a ball is to Be vnder[-]
stande the eight of you^{r} shote whethe^{r} it be of to eight
or more contaynynge to ix enches all wayes to
Bevnderstande that in aladell makynge ix balls
of lenthe shall holde of powde^{r} waight for waight
with the shote whethe^{r} the ladell be made of iij
<Picture: top view of a ladle. >

Balles as moste commonly be **fol. 15^{v}**
yonsyd or of more that ys to saye that a ladell
shall holde so mvche powder at a tyme as this
forsaid Rull Shoith and that a ladell iij tyms
fyllyd shall holde the waight of your shote and
this is in all Iuste ix balles so lyke wyes yf
you^{r} ladill be made of iiij balls in lenth that

[24] The concluding ampersand is added in a later pen.

sa[m]e ladill ij fylled
<Picture: side view of a ladle.  >
Holdith wayght for whaght
lakynge the ix parte and this ladill ij tymes
fyllid is Iuste ix Balles Also a ladill mad
of iiij Balls and hallfe and that ladill ij tim*e*s [25]
fyllid equally holdith Iuste waight for
waight and is the full ix balles allso the^{r}
be ladills made of v balles of lenght and
that ladill to tymes fyllyd Berith waight
for waight and the ix parte more then waight
for waight as A pece that his shote wayes
ix pounde of Iornne whoch maye be compard
to A Canonne
<Picture: side view of 2 ladles.  >

To make alade for a pece that ys **fol. 16**
chamber As some Cannones Be And it is
fortefyed with mettell and maye compaye^{r} to hevy
whaight for what lakyng the ix parte and
other the^{r} be that maye skante compaye^{r} to
haue ij ix partes lese for the whiche parte
you muste make you^{r} ladell in the wyse that
is to saye you mvste take the eight of the

Chamber with iñ and take
the forsaid Rull and be hohlde howe moche
a Ball of lenthe sholld hollde with a ladill
of suche a lenght then mvltiplye you^{r} ladell
in lengthe tell that you fynde that you^{r}
ladell doo holde at a tyme halfe the waight
of the shote lakynge the ix parte and A
halfe and that ladill to tymes fyllid
is the ~~C~~ dutie of suche a pece
p [26]
<Picture: top view of a ladle:  >
The ende
<Picture: top view of a ladle:  >
Of all Ladells

<Picture: full page illustration of staffs fireworks crossed in the center of the page with two flankinng ring fireworks > **fol. 16^{v}**

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[25] Here Wright wrote an m-tilde in "tims". He frequently uses a tilde or overlining to stand for *any* omitted letter, not just the usual 'n' or 'm'.

[26] This stroked-p (= *per*?, *pro*?, *probatum est*?) has been added in a later hand.

Here Begynnethe the
Knõlege to make fyere
workes as here afte^{r}
followythe

fol. 17

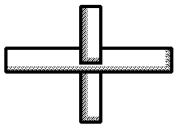
Item fyrste for atrunke take
sarpyntie powder iiij pounde and Sallt pette^{r}
one pounde and of Soullfe^{r} one pounde and of lynt
syede oyll one pynte and of Rossyne iiij pounde
And a Lyttell Smyths duste and Beate all
thes togethe^{r} small and then store them all Rowne
togethe^{r} And then take one pound of turpentyne
and melt it one the fyere and then stir it with
you^{r} Handes A gayne and so let it stande tell
it Be drye And so laye them at lenthe Agay[-]
nste that you^{r} trunke Be surely Bounde for
Brekynge

A ryceate for fyere workes
And the temperannces for Speres Harroes
hvpes Balls Quarrelles and pottes as here
After followthe
<Picture: 3 balls with horizontal fire jets: O- -O- -O >

<Picture: full page illustration of 3 staff fireworks. > **fol. 17^{v}**

fol. 18

Take corne powder xxxj
pounde and viij pounde of Sallfer and
myngle the to gethe^{r} then take iiij pounde
of swet oyll And iij pounde of turpentyn
and iij pounde of Campher and pute them
in a pote ove^{r} the fyere mylke warme
or more then strayne it over the receates
and myngell them to gether and Rube them
Betwen you^{r} handes half a nower then take
mercury subley and iiij pounde of fynde powde^{r}
and ij pounde of verdegrace and ij pounde of arse[-]
n{n}yke And Bet all thes to gether in powde^{r} and
then take Sallt peter iiij pounde so that it be
A Bowe them take Canvas and cut it afte^{r}
this sorte the lenthe of xiiij enches and vij enches
in Breadethe then take marlyn corde or whipe
corde to bynde them with all And iiij pounde
of pyche to Borde^{r} this Receath But remembe^{r}
the toche holl and to make stronge worke in you^{r}
workyng this if for spires tunkes arroves p

<Picture: crossed trunkes(?):  >

A fyer worke that dõthe Born take X [27,28]
vnwrocht lyme iiij pounde and sulfe^r as mvche
and halfe as moch oyll Benedycke and make
a dowe of it then make Balles of canvas
and arme them with whip corde and let
it be drye when you do occopye them and then

<Picture: full page illustration with 4 rows: 1) 2 kettles, one square-bottomed with a lid through which protrudes a pestle handle and one pot-bellied type with 3 legs; 2) 2 balls with jets; 3) 1 ball with 2 jets; 4) a large cauldron, roughly bathtub-shaped. > **fol. 18^v**

Caste waytter on yt and yt **fol. 19**
shall Bourne that no watter shall
Quenche it and yf you will Quench it
poure oyll the^r of or elles nothing [29]
will quenche it probatom este p

Another stronge fyer wor[-]
ke As foloith take xij ounces of groce
powder and ij ounces of lynced oyll
and viij ounces of Sallte pette^r
and ij ounces of sullfer and ij ounces
of oyle debaye and ij ounces of deme
glase And Bruse all the same to ge[-]
the^r in a morte^r and seye that it be
well dryed in the sonne ande then
make you^r Balles very stronge p

Another ffyere worke for
the watte^r take ij pounde of Cores powde^r and
halfe a ponde of Sallt pette^r ij ounces of
lynsed oyll and ij ounces of detrat{iu}an and
iij ounces of Comfer and ij onces of mysket
and one ounce of Camfere And Brouse
the same and worke it iij owers And then
quenche it with a Quanytie and Red wynge^r

[27] "Born take" added in left margin at beginning of next line.
[28] Here and in a few places below, an X has been added in the margin.
[29] There is a blank space left in the MS, obvioulsy to specify what kind of oil is needed.

And So make you^r Balles and drye them in the
sonne and arme them very stronge
for it is very Dangerous probatum est p

<Picture: 3 staff fireworks: spears with flaming balls just below their heads. > **fol. 19^v**

Another fyere worke to make **fol. 20**

A Balls of m^a^yne sundry Collers take on pounde

of vardegrace and halfe a quarte^r of Camfere
and one ounce of marcury and hallfe a ounce of
quycke Sellve^r and a ounce of fyne poude^r And
browes all them togethe^r in a morte^r And quenche
it with oyll Benedicke And then arme you^r Balls
with fynne marlyn corde p

<Picture: Three flaming balls. >

A instemente for pykes the which
is a very strange Receate that goith to it as her
afte^r foloyth take xx pounde of powde^r and viij
pounde of sulfe^r and iiij pounde of Rossen and
iij pounde of sallt pette^r and halfe a pounde
of marcury and ij pounde of sublen and ij ponde
of verdygrace and ij pound of Red leade and put
all thes to gethe^r one afte^r anothe^r and ster them
in a morte^r almoste to the necke with the
stronge Receates and the Rest of the receate to
put a Boute you^r pykes as hard as you canne
and Arme them strongly for brekynge

<Picture: Two large flaming balls. >

<Picture: Full-page illustration of three pike trunkes: | | | > **fol. 20^v**

A instremente to gyne knowlege **fol. 21**
howe to youes Balles of wylld fyer fyrstle take
a yerththen pote And one pounde of Sulfe^r and
one pound of Rossen and [f]ome them to gethe^r in
a morte^r and then seythe them in the same pote
then take you^r Balles and depe them in tywse
or thryse so take them out of the pote and then
make you^r tovche holl and then hange them vp in
the Sonne in the Byndynge and trimyng of
them Besue^r to make them stronge for it is very
Daungerus Probatum est p

<Picture: Three balls with Jets: –O –O– O– >

The order of trownkes As

hereafte^{r} you shall seye and perseyve fyrste
you muste seye that you^{r} trounke be xx enches
longe x enches in compas one enche and
halfe hie in the mouthe then to laye fyrste
cornne pouder then fyll him iij enches
hie and next take Rossen iij pounde and
hallfe and halfe a pounde of cornne poud^{r}
and a lyttell sullfe^{r} as small as a bene
and then wrope canvas a bute it and
so lett it settell And thus you mvste orde^{r}
you^{r} trounkes p

<Picture: Full page illustration of 2 pikes flanking a center staff device and then two flaming pots and 2 flaming balls between. > **fol. 21^{v}**

Here ys to make pykes arowes **fol. 22**

Balles pottes eche of them in the^{r} degre take canvas
and cut yt after this sorte the length of vj enches and the
Arowes afte^{r} the same sovrte the lenthe of vj enches
and then sowe Bothe the sydes of the canvas to gethe^{r}
and pute pyche in it and fyll it vp of receates of the
wilde fyer and then take a Roll of canvas and put
Rounde a boute it then take a longe lynde And bynd
it hard as you can a fynger broude in Sund^{r}
Betwen lynne and lynne and make sue^{r} worke ther
& of strong ^ Also then feth^{r} you^{r} Arrowes Arme you^{r} pykes
make Reddy you^{r} Balles Arme you^{r} potes that
every thing be in his degre then take ~~any~~ an
Iornne ladel and put it a pan the pyche and holde
them close that shall be for the pykes and lyke wyse
the arrowes and the potes and so let it settell and
then couue^{r} it with halfe a pounde of salt pette^{r}
and a pounde of marcury and sublen and So bynnde
it and cove^{r} it close tell you have nede to ocu[-]
pye them p

Thes thynges duthe pertayne

vnto wyllde fyer as herafte^{r} foloith Rossen Rape
oyll povde^{r} glase sallt pette^{r} sullfe^{r} lynnsed
oyll marcury sublen camfer verdegrace tu^{r}[-]
pentyne grenne Corpers Arssnyke Assafetid

ston pyche Callemare Combuste aQuavite
wynege^{r} warge vnslaked lyme ocame saudust
p

fol. 22^{v}

<Picture: a most curious firework,
elaborately made to spin in flight. >

A fyer worke that no wayter fol. 23
shall quenche as hereafte^{r} folowith take v p
ounces of vnslaked lyme and as mvche sulfe^{r}
and halfe a ounce of oyll Benedycke and temp
them to gethe^{r} and make a Ball of canvas
and put the monycions in yt and wall them
well before you do occupye it and let it
be dryed then caste the Ball in to the
watter and the more it shall Bornne
you shall not quenche it But with mylke p

A receate for arroues pykes +
Balles hvpes and speres As here afte^{r} foloithe
take Sarpentyne powde^{r} one pounde And
viij pounde of Soullfer fyrste mex them to
gethe^{r} And then take swyt oyll iiij ounces and
iij pounde of turpentyne And iij ounces of camfer then
set thes aponne the fyer tell the be mylke warme
And stranne the receates and myng them well
to gethe^{r} And rube them well Betwen you^{r}
handes the space of hallfe A nowe^{r} and more
thene take of marcury iiij pounde And make it
in to fynne poude^{r} and ij pounde of verdegrace
and ij pounde of arssinecke and ij pounde of salte
pette^{r} And then seye that it be as Byge in
peces as Bennes And then pote all these to
gethe^{r} then cut canves after this sorte and
fassyon which you shall here perseve youre

<Picture: full page illustration of a fire arrow in the centre of fol. 23^{v}
the page flanked by 2 rings and 2 fire pots which are in turn
flanked by 2 pikes. >

Canvas muste be cute Crose **fol. 24**
of the lenthe of xvj enches And pute you^{r} monycions
in to it And then take marlyne corde or whipe
corde to wall them And then take pyche
[t]alloo And Rossen for the Tappyng of them [30]
Thus muste you^{r} harrowes pyckes Balles
And Speres be yoused so that you do
Loke suerly to the Armyng of them And
Bynde them shouerlye so shall you be sue^{r}
the shall not breake p̲

ffor to make astronge fyer take +
vi ounces of sarpentyne poude^{r} iiij ounces and half
A ounce of salt pette^{r} and halfe a nounces of Sullfe^{r} and
halfe anounce of lynsed oyll and bet all thes to gethe^{r}
And make a Ball of Canvis ~~of~~ or fustyan and put
the monycians in to the Ball And let it be Suerly
and well wallid as ys Aforesaide And for a pro*o*fe
make one Ball to try it p̲

Another fyer worke for Balles
take iiij ounces of cornepoude^{r} And ij ounces of turpentyne
And ij ounces of sallt pette^{r} And halfe a nounce of sulfe^{r}
And one ounce of oyll debaye And worke it well
and make Bales of Canvas A put in the receates and
Besue^{r} you doo wall them shuerly for fere of brekyng
p̲

<Picture: A fire arrow with a ring and 4 balls, the top pair of which are spiked, but all flaming. > **fol. 24^{v}**

Another fyer worke as folloeythe + **fol. 25**
tak xxx pounds of rossyen and xxx poundes of sallt pette^{r}
and x pounde of Byrche coll And then myngell thes to
gether with a qua ~~vhhe~~ But let it be well sterred [31]
xxiiij oweres longe And then make as manye Balls
as you will of them And the will last and indue^{r}
A holl yere yf you will you^{r} sellfe p̲

A reyceate for all kynde of wylde +
fyer as arrowes Croste barde forked Balles rounde

[30] The initial 't' could be an 'l', but I take the word to be 'tallow'.
[31] The characters are covered over with a darker ink, now illegible.

Balles of fyer with all others starte as you have synne thake iiij punde [32]
of turpentyne one pounde of cornne powde^r And a pounde
of sullfer one pounde of rossene And halfe a pounde
of pette^r and worke all thes to gethe^r with some
oyll Benedycke and a lyttell venege^r then drye
all thes receates to gethe^r in the Sonne
And make thereof whit fustian or whit canvas
Balles And than put in you^r monycions and make
vp you^r Balles and be sue^r you wall them strong[-]
ly And than yf you will you maye proue them
with a lyttell stofe and yf it Burne to faste you^r
stofe is to strong and yf it Burne hastely
and the Smoke doo goo frome it thene is
you^r stofe good And yf it be to stonge myxe
it with Rossynne And Sullfe^r and
oyll Debaye p

<Picture: 2 staff items, the left of which is a simple flaming 'mace' with a spherical head (the "balles upon staves", below), and the right one a cross-trunk on a pole. > **fol. 25^v**

Another fyer worke as folloythe **fol. 26**
for Crosse trunkes And for balles Apon staves
fyrste take xij poundes of groces powde^r and
vij ounces of sallt pete^r and ij ounces of rossen
and ij ounces of lencede oyll and ij ounces of
oyle debaye and one ounce of deme glase
and stomp all thes to gethe^r in a morte^r and
Drye them in the Sonne And soo make you^r
trunkes and balles vp and bynd them
shuerly you maye make as moche as you will
p

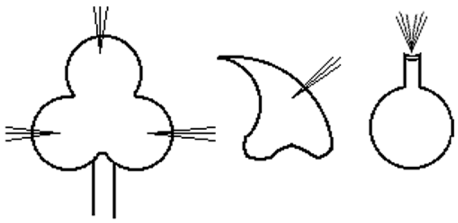
Another fyer worke as foloyth
take one pounde of corse powde^r And halfe a
poune of salt pette^r and ij ounces of lynsed oyll
and ij ounces of detratary and iiij ounces of
turpentyne to ounces coll and one ounce
of mastycke and halfe a ounce of camfere
and stompe them in a morte^r and quench it
with aquavytie and thane make you^r
Balles shouer and Drye them in the sonne

[32] The initial word in this line was added in the left margin; clearly Wright or a copyist missed a word in writing the sentence.

X

<Picture: 2 balls with 2 jets each -O- -O- >

<Picture: full page with 2 'club' headed staffs flanking 3 'bagges' and 2 pots. Examples: >



fol. 26v

To make Clobes as foloythe **fol. 27**

take halfe a pounde of cornne powde^r and a pynte
of oyll and A *quar^ter* of a pounde of Rossen And blende [33]
them to gethe^r And so worke them And then make
vp you^r Cloubes this stofe is but for one clube
you maye make as many as you will puttyng in more
stovfe p

A fyer worke for potes as

foloithe take one pounde of Sullfe^r in mell and
A nounce of Saweduste and vij ounces of
groce powde^r and A ball of okame Rowled in and
v ounces of turpentyne then worke all thes to
gethe^r And then put this in to the pottes and fyll
them full And wropte the mought with canvas
and decke them with pyche and make a vent
in the myddeste of the mouthe and put the^r in
a mach p

Another fyer worke for +

Bagges as foloeth take a quantitie of Exodus
and A quantitie of pyche and as moche soullfe^r
and as moche salt pette^r and a quantitie of oyll
Benedycke and a quantitie of groce poude^r
Soo myngle you^r stovfe as you have harde before
then make vp you^r bagges and wall them
shuerly for no waytte^r shall quense them

To make all maner of ffynne powder **fol. 27v**

[33] See n. 15.

Item take of Salte petter +
ix poundes of Sullfer one pounde and
of willoo coll ij pounde and also of mydell
powder xiij pounde this thinges servethe
for fyne powder p

the knowelege of
geve **Here ye ~~to make~~ ^ gunpowder** [34]
As here after ffoloeth it maye be knowne by iij
propertes the fyrst in te tastyng of the tou*n*ge
to knowe the sharpnes therof the cecones
by the farnes of his coller the therde by
burnyng of it shoith yf the powder be of a hie {koller}
the which receates douth make the powder

Douth make the powder
good and for lacke of Receates it maketh the
pouder symple Also the fayrnes of the powder
shoith it to be goode and yf that hie haue
A Roundances of of the maister and will [35]
wrought he shall have a more fayrrore coller
and for lacke of the maister he hath

A conterary coller very darke **fol. 28**
and for lacke of workynge it dothe make the
powder loke very Darke the which be ffyer
you shall knowe with[r] that your maister
wher well Reassyned or not whether

That the maister wher
full of greace or sault as here after more
planly douthe declare also yf you have
powder and the maister be not well wroght
but left full of sallte and grece you shall
knowe it by this properttie that is to saye
after the burnynge ther will remyne [36]
knottes and that place will be dankewes
for the maister and the sallt will geue

Agayne after the Burnynge

---

[34] The term 'geve' is added in the left margin, although it does not make sense as the beginning of this sentence. "the knowledge of" is added above, in the secretary hand.

[35] "of of" [sic].

[36] The penultimate letter in "remyne" appears to be a 'v' in the MS, but "reamin" makes more sense here than "remove."

and will be com waytte^{r} whiche syngnyfyeth
that the powde^{r} was grecie also the knotts
Remaynynge afte^{r} the powde^{r} is Burnt
that is not well wraght thies knotes
will not consume to wayte^{r} but will
remayne styll hard and syngnyfyeth
that the powde^{r} was not well wroght
also and yf that you haue of that sortte
of pouder afte^{r} the burnyng what it is

<Picture: men defending a town. > **fol. 28^{v}**

<Picture: ship with 17 guns and 3 empty gunports and 2 mines in the water. > **fol. 29**

That yf you haue aboundañce **fol. 29^{v}**
of the m^{r} and do lacke workynge the poude^{r} ys ve[-]
ry dañgerus for his propertie is yf he do ly longe
ladene in a pece and be kepte drye and with
out moystenes he will in a longe tyme
Soffer that yf you Burne it not owte
at ~~of~~ the shewtynge it will put the pece in [37]
Dange^{r} of Breakynge and this is
the prõffe ꝑ

ꝑ **Another sourte of poude^{r}**

the^{r} is that you shall knowe By the
Burnynge the whiche will Be lyke
white perrelles as the othe^{r} is but his
Burnynge shall be So quicke But
of a Darke Coller which dõthe
Signyfye for lacke of maister and
thi powde^{r} you maye Be boulde to

To geue a pece more then
his dutie by the ix parte more then
of the othe^{r} Also this is a nothe^{r} sourte
of poude^{r} whiche is with oute sawlte
which of his colle^{r} he will blowe

As the moure whiche couller synge[-] **fol. 30**
nyfyeth the a Boundance of m^{r} and well workeng he
in the burnyng and he is so quicke as the twyn[-]
klynge of anye And nothinge remaynneth

[37] See n. 32.

but with smoke colle^r

There as the powder was
Burnt and this powde^r is a starke powde^r
wherfore you muste measure you^r hande and
not you^r charge for dange^r that will beffall
in that ou^r ladynge || and Also this Rull p [38]
foloynge declarith the eight and waight
of Iornne Shotte beynge at ij enches and iij
quarters perswaydyng to ix enches of eight
a mounge the which eightes all wayes
contynvally al peces be made of Iornne
this is the Rull ffoloinge

< Fol. 30^v-31 comprise a table with a ruled grid of 20+ rows by 28 columns, but with more irregular rows on fol. 31. Values are only spottily filled in, and actually comprise only 3 rows (but all the columns). The heading runs across both pages. Rows 6, 12 and 18 of the table (the only cells with entries) are reproduced below. >

Thes be the rules of all Iorne shote Beinge at ij enches **fol. 30^v**
And Soo from quarte^r to halfe enches and iij quarters perswaydynge **-31**
to ix enches [39]
of eight

[40]

2				3				4				5				6			7				8				9
1 4	1 2		1 2	1 4				1 4	3 4	2 4		4	1 4	1 2	1 4	1 4	1 2	1 4	1 2	1 2	1 4	2	2				
1	0 1	2	2	3	4	5	6	7	8	10	12	14	16	18	21	24	27	31	35	34	44	49	55	62	77	84	92

To make clene A pece that **fol. 31^v**
is ~~cl[k]yed~~ cloyede take a gallannd of raphe oyll and boyll it [41]
as hotte as you can And then stope the towche holl X
and the mouthe of the pece as close as you canne
for a season and So it will consvme the canke^r

[38] These two vertical slashes look similar to long 's's, but lack the superior terminal, which the scribe is otherwise quite diligent about forming. They seem to be equivalent to a ¶ symbol.

[39] This and the preceeding line are all on one in the MS. The next line, "of eight", is its own right-justified line, however.

[40] The entries for "4 3/4" and "4 2/4" in the second row are out of order and are written with irregular characters: the "3" and "2" in these entries are not proper numerals, but rather rune-like, although resembling the proper forms.

[41] See n. 32.

of the shotte And make it cvme out

ffor †† to make Salte pette^{r} +
you Shall take vnslaked lyme and put it
in to Lyee And let it stande tell it Be Cleare
and then take the clearistе therof And therwith
trye you^{r} salt pette^{r} and melt it And it is
Bette^{r} then the fyrste that was maide
And yf you wyll melte your pette^{r} you moste
take of the lyce^{r} of the lye so moche as shall coue^{r}
the pette^{r} in the poñe And Breake your pette^{r}
in poude^{r} and Set it oue^{r} the fye^{r} and
stere them well to gethe^{r} and as you^{r} moystnes
douth drye So will you^{r} pette^{r} Melte
And yf that you se that you^{r} pette^{r} be fautie
then take Sulfe^{r} and bette it to powde^{r}
And then set the ponne oue^{r} the fye^{r} tell the
ponnes Bottome be as hote as you maye
suffe^{r} you^{r} fynge^{r} oue^{r} it then put you^{r} pette^{r}
A Broude and strawe you^{r} Soulfe^{r}
the^{r} in and it will take awaye all the
fattnes the^{r}of p

And yf you wyll make powde^{r} **fol. 32**
of the beste Sorte take viij pounde of pette^{r}
beinge in mealle and iiij ounces of Sulfe^{r} in melle
& iiij ounces of coll in melle And so syfte it throught
a fyne Syve and put them to gethe^{r} and A
quantitie of varges & a quantitie of aquavytie
for to slake the duste of the coll And So
put the Receates in to a morte^{r} And Bett them to
gether as you shall thinke mete and than take therof &
laye it one a stone and drye it well and fo[r] a
proufe therof put fye^{r} ther to And yf it
burne clenne waye it is goode or elles
you shall Se the faute therof / / p

<Fol. 32^{v}-33 is another table as on fol. 30^{v}-31, although this time more exactingly ruled. Each page has a separte table with three narrow colums on each edge with one wide column in the centre (although this center column is entirely blank on both pages and has been omitted in the transcription). The title runs across both pages. >

Thes Be the r*u*ll_es from the Cannon ryoll to the faucõnet **fol. 32^{v}-33**

<fol. 32v>

	ye eigh of ye of ye pece	ye eigh of ye &	ye wat ye shot	ye wait ye ye	ye lenth ladell	bredth of
A cannon Ryoll	8	7∴	63	40	23	15
A demi cannon	6	6	33	20li 22	22 :	| 12 11 :
A coulverynge	5	5	18	1	22 ·	9x

<fol. 33>

	ye eight ~~wat~~ of pece	ye eight ~~len~~ ye shot	ye ~~eight~~ wat ~~breth~~ ye ~~ladell~~ shot	ye wat of poider	ye len ye	eight bredth ladell
A Deme collvering	4 :	4	9	8 9	20 1	9 •
A saker	3 :	3 •	5	5	15 :	5 :
A favconne	23	2 :	2 :	2 2 •	12	8
A favconet	2 ·	2	11	1 :	12	43 ~~4~~

Item in enches of eight the **fol. 33v**

shote waythe one ~~li~~ ij enches *quarter* waythe jli *quarter* [42]
ij enches iij *quarter* waythe ijli a *quarter* iij enches waithe
iijli a *quarter* iij enches A *quarter* waithe iiijli iij enches
halfe waithe vli iij enches iij *quarters* waithe vjli
iiij enches waithe viili one *quarter* iiij enches a *quarter* waithe
viijli iij *quarters* iiij enches halfe wayes xli one *quarter*
iiij enches iij *quarters* waithe xijli v enches waithe xiiijli
v enches a *quarter* waithe xvjli a *quarter* v enches *half*
waithe xviijli one quarter

v enches iij *quarters* waithe xxjli

one *quarter* vj enches waithe xxijli one *quarter* vj enches

[42] See n. 15.

A *quarter* waithe xxvij^{li} vj enches halfe waithe
xxxj^{li} one *quar*^{ter} vj enches iij *quarters* waithe xxxv^{li}
one *quar*^{ter} vij enches waithe xxxix^{li} one *quar*^{ter}
vij enches a *quarter* [w]aithe xliiij^{li} one *quar*^{ter} vij enches
half waithe xlix^{li} a *quarter* vij enches iij *quar*^{ters} waithe
lv^{li} one *quarter* viij enches waithe iij^{xx} ij^{li} viij enches
a *quarter* waithe lxix^{li} viij enches *half* waithe
lxxvij^{li} viij enches iij *quarters* waithe iiij^{xx} iiij^{li}
ix enches waithe iiij^{xx} xij^{li}

This Rulle Delarethe **fol. 34**
wat A ball of lenthe holdeth in the makynge
of you^{r} ladell in powde^{r} and then loke howe many
Balles olenthe you will make you^{r} ladelles of &
ad to iiij tymes So moche as this forsaid rull
shoithe and then you shall fynde ij ladeles of that
lenthe shall holde waight for waight with
your shott lakynge the ix parte / / / A ball of ij
enches caries in poude^{r} ij ounces one *quarter* A ball
of ij enches one *quarter* caries in poude^{r} ij ounces halfe
A ball of ij enches & halfe caries in poude^{r} iij
ounces A *quarter* ij enches iij *quarters* caries in poude^{r} iiij
ounces one *quarter* iij enches caries in poude^{r} v ounces
iij *quarters* iiij enches one *quarter* caries in poude^{r} vij ounces

~~v~~ iij enches and a halfe caries X
in poude^{r} ix ounces iij enches iij *quarters* caries in Lefte
poude^{r} xi ounces an *quarter* iiij enches caries in poude^{r} probatõ
xiiij ounces iiij enches *quarter* caries in pouder xv ounces
one *quarter* iiij enches halfe caries in poude^{r} one pounde
ij ounces iiij enches iij *quarters* caries in poude^{r} one
pounde v ounces v enches caries in poude^{r}
one pounde ix ounces v enches one *quarter* caries
in poude^{r} one pounde xiij ounces v enches &
halfe caries in poude^{r} ij pounde one ounce v
enches iij *quarters* caries in poude^{r} ij ponde vj ounces
vj enches caries in poude^{r} ij^{li} xi ounces vj
quarter caries in poude^{r} iij^{li} vj enches and half
caries in poude^{r} iij^{li} halfe vj enches iij *quarters* caris
in poude^{r} iij^{li} xv ounces / / /

<Scribbled in the bottom right margin: iii
x ~~xxxx~~ *iii* iiii
44 ~~4~~ ~~4~~ ~~4~~ ~~4~~ 8 >

vij enches Caries in pouder **fol. 34v**

iiij^{li} vj ounces vij enches one *quarter* caries in poude^{r}
iiij^{li} xv ounces vij enches halfe caries in
pouder v^{li} halfe vij enches iij *quarters* caries in
poude^{r} vj^{li} iij ounces viij enches caries in
poude^{r} vj^{li} and half viij enches one *quarter* caries
in poude^{r} vij^{li} xj ounces viij enches halfe
caries in pouder viij^{li} ix ounces viij enches
iij *quarters* caries in poude^{r} ix^{li} v ounces ix enches
caries in poude^{r} x^{li} iiij ounces

Her is the ende of this Boke

<Picture: full page initial of an A or and I with flowers sprouting from the ends and a Celtic-style knotwork design about the middle. > **fol. 35**

<Blank> **fol. 35v**

A Reulle to knowe wiche of the xij Sigens **fol. 36**

ar beste to taike anne gournne or wege to prosper in ^

Item ferste medle not vppone the change or quarter Dayse
for it is wery troublesome, and yt Be farr all to god bout
yf ye can Refrayne this time

Aris

The second is if you fynd the moune in arres begen thene
thy Iorñye or the thing that thou willte dooe and to thestwarde
hei is beste

Taries

And if you feind the moune in taries I counsell the to take
no Iorny for if you Dooe you may Repent it but if you dooe
it hei is beste to the southe part fo^{r} it is his koursse

Gemeny

And if you feind the moune in gemeny then begen thy Iornye
for thoue shallt sped best to the west ward fo^{r} it Is his corsse

Cancer

And if you feind the moune in cancerse then dowte no Iarnd
and hei Is beste to the n^{o} wardes for it Is his koursse

Leowe

And if the moune be in leow thoue shallt not be glad nore
sore bout it is best to the ~~Southe~~ Est ward for it is his
koursse

Virgo

yf the moune be in wirgo begen no Iourny bout if you dooe

It is best to the Sowthe ward for it is his koursse

Libro

if in ly bro then shallt fynd frendshipe and hei is best
to the weste warde

Scorpio

yf the moune be in scorpeo then tacke no Iorne and
hie is beste to the northe partes

Saigetares **fol. 36v**

yf the moune be in saigetares then shallt sped of
thye Iourne or Demand Resonabell and hei Is
best to the este partes

Capirecon

yf the moune be in caprecoynes than begyne
nothing for it Is evelle thou shallt not speid and
his coursse is to the os wardes

Aquares

yf the moune be in aquares be glad for it is
good and prosperouse ether by watter or by land
and his koursse is best to the west wardes

Pissis

if in pissis [t]hou shallt sped bout pourly out and
pourly home nether men nor par

... hend of the -12- seines to be fooleid
bout pout youer troust in god a lone

<Picture: a crudely drawn fire arrow and a 4-pointed flaming star firework. > **fol. 37**

fol. 37v

a
all
men
in
Reme

T
The

Thous that fereith god
and wallkith in his waye
hape and bleste Is hei Glary

In all thye begeinng Seie then He speke the
Cending

In all thye begeinnge seie then He speket the
Cinding / and seie then medell with the

Appendix III

"The Secret of Gunmen"

temp Jas. I

MS Ashmole 343, fol. 128^{r}-139^{r}, Bodleian Library, Oxford

items are expanded scribal contrations
~~items~~ are crossed out in the text
[items] are inferred from missing of damaged text
{items} are faint in the MS itself
<items> are editorial notes (pictures, blank pages, &c.)
items are notes inserted in the margins

note: Paragraph breaks have been added to increase readablity.
The MS lines are all equally spaced, regardless of content.

The secrets of Gunmen	**fol. 128**
ffirst you must know good salt-peter from bad i [1]	
whether it be fatt or salte or allu*m* therein, & y^{n} after	
what manner it ought to be put out p*ro*fitably: & then	
the salt peter being good & fayre, how y^{n} you ought	
to make good powder thereof for all manner of	
good shot	
you must know all peeces measurably to charge	2
or lade them, & to parte y^{m} over feild, land, or roades,	
to shoote as hereafter declareth.	
you must know how to make 3 or 4 [s]ortes of fireworkes	3
at least, whether it be by water or land, if you will	
get lords wages.	
Whensoever there cometh to your hands salt pet^{r}	i
not p[re]pared to make y^{m}, y^{n} you shall see whether it	
be salt or fatt, & y^{t} thus; lay it on the fire, & if it	
let after athinge like a scom[m]e, y^{n} it is fatt, if it	
leape it is salt, but if it be white or cleare	
burned still, y^{n} it is good.	
To amend this, is to put out salt or Allum,	2
take vntemp*er*ed lime & make thereof good lime	
or good ashes, & seeth it therein 3 or 4 times, y^{t}	
the salt or fatt may goe out, & take heed y^{t} you	
seeth it not in a fatt kettle.	
If you will haue this saltpeter very good, y^{n}	
take ye saltpeter when it is sodden in the lye	

[1] These marginal numbers are actually in the left margin in the MS

very drye, and put it in a fayre yron pott, & set
it on ye fire, & when it hath stood longe therevpon
y^{n} it will melt for hotnes, & when it is melted
cast therein a little handfull of sulphire, y^{n} it will
burne, & if there be yet any filthe therein, it
will burne it out. Ashes of the barke of abay tree
are very good to make lye to sithe salt peter, & it
maketh sylver or gold very fayre.

Good powder to shote hand-gunns
withall **fol. 128^{v}**

Receiue of good salt peter *oz* vj of Sulphire *oz* i
scant waight of coles *oz* i as much as you take from y^{e}
brimstone ad to the coles, seeth your coles with white
wine then drye them before you weigh or breake y^{m}

To make good powder take water of nettles & sprinkle
your powder, & y^{t} you may keepe it longe good But
if you must spend your powder p^{r}[e]sently y^{n} take aqua
vitæ, & y^{n} ye same powder y^{t} is soe made must be well
laboured, y^{n} it shalbe drye in the sun wth water y^{t} is
pressed out of the shells of orenges which makes it
very sweete.

To make powder that giueth noe Sound.

℞ p*ar*^{t} i of camphire, of coles p*ar*ts 2 & of saltpet^{r} [2]
p*ar*ts 3, but this powder cannot last longe, & it ought
not to be vsed, because much harme hath bin don
therewith.

To make powder for great shot

℞ Of Saltpeter p*ar*ts 4. of brimstone & coles of
every p*ar*te j. breake y^{m} & sifte them by them selues,
& when you bringe them to gather, mixt y^{m} with
vinegar, & it will last longe.

To make white powder

℞ of this next powder vnder & laye it 2 or 3
dayes in stonge lye, & y^{n} it will waxe very white,
them put saltpeter & brimstone to the same as [3]
thereto belongeth, & this is ye white powder.

To make good powder

℞ The stalks of hemp & drye them in an Oven,
& stampe them. To whome a gun is given to shoote,

---

[2] Here and throughout the MS, the author uses an abbreviation which stand for *Recipe*, 'take', or Rx in modern pharmaceutical notation. The MS form is ℞

[3] "them" (*sic*) for "then".

& must seeke his stone amongst very many greater
or smaler, let him take ye measure of the mouthe 3
double, & y^{n} vnder 3 doublenes in ameasure, y^{n} seeke **fol. 129**
astone that the measure may goe about.

All Guns of Iron that shoote stone haue theire
chambers comonly made, & set forth, & if they be
not, y^{n} take of stone lb 3 of powder lb 2 but he y^{t}
will shote an Iron peice with Iron shot, must take
as much powder as Iron.

To a brasse peice that shoeteth Iron, take of
Iron parts 3 and of powder parts 2, & for y^{t} it
may not shoote soe much as an Iron peice, for
she waxeth by & by hott & y^{n} there is dainger and
the must be often times wyped & made wett
with vinegar.

To shoote a good shott vpon a Tower by daye,
& ye same againe at night, thus doe, marke by day
with a compasse after what manner the Tower
lyeth, East, West, North, or South, & when you shoote
this shott first take a thred & lay it on ye gunn, and
let the thred hand ouer at the mouth of the [P]eece [4]
downe to the ground, & keepe ye sight, & set a marke
there with a pricke or pinne, & behind at ye tayle
of the pece set amarke in ye ground, y^{n} by a squadron
looke whether your peece stand too lowe or too
high at ye one side or ye other or right & iust, if it
be iust take alether Table of finger broad & a
palme & halfe long hollowed out, & againe sticke
it with wax on ye one side & poynte at the other
side, before you shoote doe this to be in ye mouth
of your gun, & let alead with apoynte thinge ~~fall~~
downe from aboue ye gun, this table, ye waxe & y^{e}
poynte keepe well, y^{t} hee goe not out, y^{n} shoote y^{e}
peice of If you suppose that it is a good shot re-
member the sayde poynte & the poynte in the
waxe table, & ye height & lownes vpon ye squadron
& with the poynte you shal shoote by night againe

If theine come to your hand apeice of brasse
or Iron y^{t} is laden to be shot with aladle & knowe
not whether it be laden too much or not, take
your stone firste out, & y^{n} take alonge sticke and **fol. 129^{v}**
beate of the Iron & make the sticke square sharpe
and bore therewith through ye powder vntill the

[4] "hand" (*sic*) for "hang".

hinder parte thereof y^{n} put ye stone in againe, y^{n}
discharge the Gun, & soe it will not burst

To make all manner of com*m*on fireworke

℞ of Turpintine ^{lb} 4 of gunpowder ^{lb} j or Sulphure
^{lb} j of Saltpeter & Rosin equally ij *oz* & mix them
together with pure oyle wherein is noe salt, & with
a little vinegar make your balls, & bind euery ball
fast in alittle cloth, & for a say set it on fire, if
the Rosin burne fatly y^{n} ye matter is too stonge,
but if it burne longe shineinge, y^{n} it is good, but
if it be stronge breake it with Rosin, brimstone
and oyle, The nature of oyle is to cause the matter
to burne steadfastly, vinegar keepeth it longe good,
ye saltpeter bloweth, & ye Gunpowder and brimstone
make fire, & ye Rosin giueth strength to ye matter
& burneth deepe in whatsoeuer it toucheth. after
this sorte you shall know how to helpe it whether it
be too stonge or too weake. This shall you order
a Sake[r] to afire lance and then laden with the
same matter, & when it is laden wrappe the same
well in a kable yarne and power vpon Harpoys
mingled with Brimstone & fatt, with the same
matter allsoe you shall lade all little balls to
cast out of the hand, to shoote out of stone guns,
or fire arrowe to shoote with guns with, the
same matter, but when you shall shoot y^{s} ball out
of a Gun, bore there in foure holes throughout &
fill them with good powder, & strew halfe aspoone
full of powder in your gun, & giue to one of those
holes fire y^{n} set it in the gun, & y^{n} fire ye gun before.

To make balls to shoote out of great peices

Lay two manner of substances, ye first manner
thus, If you will haue your ball to be round, cut it
of 8 peices vpon the Compasse, that he must waxe
well round, then take the same matter to the **fol. 130**
number of 5 or 6 balls, y^{n} take of Candid a *oz* j
of Saltpeter *oz* j, of oyle *oz´* 2 of oyle of hemp *oz* 2 [5]
of Turpintine *oz* j, [~~singel *oz* 2~~] of Quicksiluer cam-
phire 1.3, these things with other matter lay in
your balls, & lay likewise in the midst therof 3
or 4 sarpentine leades, after that your ball wilbe
great, your sacke you must make of new canvase
& wrap it well with good stonge kable yarne, &

[5] For the amount of oil, I have used the unit "oz´" to indicate that the copyist seems to have made a distinct symbol via-à-vis the other oz. symbols in the text, but it may be a meaningless flourish.

vpon y^{t} make anew canvase coate, & swadle it vp,
after sprinkle it, y^{n} vpon that againe make another
coate & swadle it, & sprinkle it againe, & when you
will shoote this ball of out of a gun bore therein
4 holes through, & fill them with good pouder,
& strew halfe asponefull of pouder in the Gun,
and set him there in the gun, then fire the Gun
before. /

To make fire Launces.

To burne for pleasure lade them, thus, make
the balles of tarre, & wrapp them with yarne y^{t} is
good, & when you will lade the Launce lay first
vpon the bothome of the launce Towe, & vpon the
Towe matter, & vpon the matter an handfull of
powder, & vpon the powder little ball 2 or 3, after
that the launce is bigge, then againe put powder
vpon the balles, & thus forth vntill it be laden, &
when you will burne her, then give fire before.

To make fire potts or balls to cast out at ship topps,
make in every pott 20 or 30 balls, accordeing to the
quantity of the pott, & lay vnder y^{m} in the pott towe
& theerevpon matter powder, & vpon the powder balls,
& againe towe & matter, & y^{n} againe powder, as thereto
belongeth, & y^{n} wrapp ye pott that it burst not in the
casteing, then bind a lownt with 8 or 10 ends about [6]
the pott as about a lowntsticke, & y^{n} cast the pott &
when hee falleth and bursteth then ye powder &
the matter kindleth of the Launces, the which be
bound thereabouts In the same pott you may lay
allsoe nimicke Irons if you haue them for
they burne much the enemye.

To make a lyeing fire that beginneth **fol. 130^{v}**
to burne as it is layde

Make a lownte of Cotten and seeth it in Cam-
phire with aqua vitæ, y^{n} noe man smelleth the
same nor the fire, & laye the same in ahollowe
reede or wood cou*er*ed & vpon y^{m} of the reed lay
on water, y^{e} stronger y^{e} better, & make it wett with
Camphire water, y^{n} noe man shall smell it, & make
your launce as longe as you will, y^{t} it may be long
or short before it begin to burne, & then kindle
it vpon the grounde.

[6] "Lownt" seems to be equivalent to "lint" (hence "lowntstick"="linstock") and refers to match.

To make fire balls to burne in
water

℞ vndressed lime, Sulphire and olye benedick,
of each like quantity, & make of it aball, & when
it cometh to the water it burneth of it selfe.

To make fire of diuerse colours

℞ Spanish greene Camphire, Sulphire,
Turpintine, oyle of Linseede, oyle benedict, these giue
in the night many colours, & fearefull to see.

To make balls that cannot be quenched

℞ 2 Leads Camphire, j lead aquâ of oyle benedict, & seeth
them togather & when it is cold, take goe and make
balls therof, & when that burneth it cannot be put
out with any manner of water.

To make flight powder for handiguns

℞ 5 leads of Saltpeter, j leade of coales, & j leade
of Brimstone

To make fire balls to burne as longe vnder
the water as aboue.

℞ lb j of powder, halfe apounde of Saltpeter put
thereto olin lini, or olen bartari, or olen benedict, &
make thereof adough, put allsoe therto halfe a *quart* of [7]
Turpintine, after the dough is moulde, take 2 round
peeces of ffustian old & new & sowe them togather vpon
afinger neare y^t you may get the sayde matter through, when
the sayde matter is therein, sowe the balls & bagge togather,
and wind him with mariners yarne that he burst not,
then melt swanells hares & other hares – and turne the
ball therein, then take him out & let him coole a **fol. 131**
while, & then in againe vntill it be aboue a finger
thicke about, make a little hole to the midst &
put powder therein, y^n kindle it and cast it forth
& it will burne as well vnder the water as aboue.

He that will make fireworkes he shall take
those matters & make thereof strange fireworks,
or otherwise, as men will haue it, & then by this
good meane, powders, brimstone, Saltpeter,
Rosin, Turpintine, ffrankinsence, Camphire,
Quicksiluer, Salarmoniacke, gray salt, for to
make the same, wet aqua vitæ, ~~of~~ quickwater,
oyle of linseede, oyle of Notts, oyle benedict, Heter
oyle, & all manner of oyle that hath noe salt in its

[7] The abbreviation here is like a modern script 'qr', which I have rendered as ounce, rather than the more obvious "quart" or even "quarter [pound]". In other places, (c*f* table, fol. 136^v) he use 'qr' rather indiscriminately with the symbol for ounce, a script 'z'.

these sayde matters & Substances haue each of them sundrye strengths and vertues, & make sundrye labours in ffireworkes, ~~f~~ he that knoweth not their strength, to him is not counsell to be giuen y^t^ hee bringe them in ffireworke but make ffireworke flight & right.

To make a pounde of fine powder

℞ of Saltpeter, that is, good & make it smale, y^n^ take 3 or 5 Ounces of coles of Willows, & stamp them togather vntill you find not one coale of Brimstone or Saltpeter. ℞ lb ij of quicke waters, lb 3 of Swenell, lb 9 of Saltpeter lb j of ~~f~~ salar-monicke, lb 2 of gerili sublimat, & this matter in the Sun & make thereof ffireballs or arrowes y^t^ you [&] proue them with swanell candels, this is the[8] best matter & Substance that you can make for balls, arrowes & pelts

ffor a Wilde fire mischevous to shoot in a Citty or Towne

℞ A light gunstone [&] annointe it or dippe it in molten Swanell & hares & sprinkle it with good Gunpowder & y^n^ put it againe in the swanell & hars, then take acleane cloathe & rowle it in the swanell [&] hares, & y^n^ sprinkle that with good gun-powder, & shoote where you will haue it.

A Wonderfull ffire **fol. 131^v^**

℞ aside gesoden with guees pitch, & with quicke brimstone, & peter oyle, when you lighten the same, then whatsoeuer the fire toucheth it burneth & cannot be quenched with water, for it burneth stone, Iron and steele.

A speciall ffire

℞ vnwrought lime & soe much Swanell as chalke & oyle of Linseede & binde the same in acleane cloth

ffor to make ffire potts

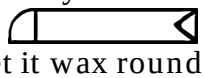
℞ potts with eares & put therein brimstone quicke mell scraped & make in powder & shaueing of woode & gunpowder of each alike, worke this to gather, y^n^ put it in the pott, & bind on eu*er*y eare of the pott a dowble lownce, & when you will throw this pott into aship then fire the lownce. /

[8] The interpreted ampersand here is actually a counterclockwise spiral of sorts, the same as 5 lines below, *et seq.*, rather than the standard MS ampersands which he uses in most places. "And" does makes sense, however, so I will use an ampersand in brackets for this symbol.

To make ffire arrowes.

℞ Heter oyle quicke brimstone, harpoyes and gunpowder that is good, put the same in a bason, & set it in a kettle of hott water to drye, & ketle it, when it is keiled ℞ molten among them y^{n} shall you take alittle vpon an arrowe head at the end, then put it about alinnen cloth with smale ends of Launces, when you wille shoote fire the launces, & when they fire it cannot be quenched.

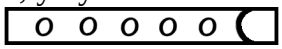
To make fire that kindleth when water cometh by it.

℞ Quicke chalke alittle, quick brimstone, linseed oyle, & mix them togather, [&] when there cometh water by or about it, y^{n} it will burne, & let it seeth then shall you haue apipe or forme oppen in this figure  y^{n} put the same & power it therein and let it wax rounde & although there were put in j *oz* of peter oyle y^{n} were it better, & could not be quenched with water, when you fire the same, laye some fire on it or launce, & let it lye and burne, & what falleth thereof or melteth for hottnes of the fire that may be powred in steeples or walls of Citty burning, & y^{t} cannot be quenched aquâ [9]

aquâ. To make fire pomps in ships or other places **fol. 132**
to assay & it is made with many little balls, y^{t} is good to make shipes without sayles & to burne y^{m}

℞ Canvas or grosse sayle cloth & make thereof smale baggs lesse then a ~~ball~~ balle and fill them with gunpowder that is good, y^{n} choose well molten hares or Harpoyes, make fast the little balls togather when the gunpowder is therein y^{n} seeth the balls deepe in the hares, & let them drye or wax cold, bring as shalbe sayde.

A ffire [P]ompe [10]

Boare a hole therein with a bodkin soe that you may throw the same fire [~~att~~] by lettinge powder, y^{n} you must haue a pompe of wood in this forme  hollowed out & the same you shall

[9] Here, as in all of the pages of the MS, the scribe has keyed the first word of the next page at the bottom, as in printed books. Here he includes “aquâ”, which technically is first word on fol. 132, although it make little sense. Additionally, here he has written it more like a scribal insertion, rather than a keyed word. And indeed, it appear to intrude on a “chapter “ heading on the next page. In fact, the first line on fol. 132 seems out of place entirely.

[10] Here and 6 lines below, the scribe has written “Hompe”, although it is clear a pump is meant.

put in awide stone gun that shalbe meete for it
ffirst put these little balls in the Pompe & to y^{e}
chamber of the gun, & then to fire them, take a
corde behinde at the chamber that the pompe may
remaine therein then you neede not to make a
new and every time, then fill the chamber with
gunpowder that belongeth to the gun, y^{n} shoote
therewith as with other guns, y^{n} whtsoeuer it
toucheth it burneth, eyther wall or gate

Another manner of Gunpowder

Serpentine powder in grosse ℞ ^{lb} 3 saltpeter $^{[l]b}$ j
swenells as much l · li [~~...~~] iij of Coles, Sweete powder
℞ ~~lb~~ 2 Saltpeter, 12 lead coales, 12 lead swanells
℞ ^{li} 5 Saltpeter, 24 ^{lb} coales, 24 ~~lb~~ swe'nells.

To make ffire powder of gray powder if
the gray powder be not like a stammy

℞ : viij lead Saltpeter *oz* lead Swanells then it
is good powder to witt grosse powder ^{lb} j yet better
if you will make grosse powder there. ℞ viij
[gr] ^{res} — Saltpeter viij lead coles 5 lead swanells [11]
Then — that is good powder

To make for Peices [12]

℞ burned Camphire & burned salt Armoniacke
that lyeth as burned stone that is called Amery and **fol. 132^{v}**
put them in a morter and stamp them smale to powder,
keepe it well till you will occupy it for you may doe
noe more powder in apounde of gunpowder then a
quarter lead & thereto awaight of coales, & one waight of [13]
Brimstone, this is the best powder y^{t} can be made.

Another manner of makeing powder.

℞ viij lead saltpeter, 3 lead coales, 2 lead swanells,
grosse powder. / ℞ i *quarter* saltpeter, 2 lead swanells
scant i lead coales.

To make stronge powder

℞ take i $^{[l]b}$ coales, 3 $^{[l]b}$ brimsone, ij $^{[l]}$~~b~~ saltpeter, 3 lead
Camphire, i lead Quicksilu*er*, y^{n} it is good for to shoote

To reducte all powder to his owne
Substance

℞ 3 scope Vinegar, 3 onses aqua vitæ, & 13

[11] The 'res' and the preceding spaces are superlineated (*i.e.*, a line is drawn above them).
[12] Here again the copyist uses a capital 'H' when a capital 'P' is clearly called for.
[13] This "quarter" and the one four lines below are a non-standard contractions: here, a superlineated script 'qr', and below, the same without the superlineation.

times soe much water, after make the lye stronge,
& let them stand & worke in themselves halfe a
day longe, y^{n} put in the Gunpowder wch you will seeth,
and put it halfe a hands breadth vnder the lye, &
scom*m*e it wel the coales, & keep it well in store for
the cuñing sake & the saltpeter shall lye in the
midst & the swenells in the bottome, & thus you
shall powre out the lye 4 or 5 times til you haue
diuided these 3 substances asunder, & keepe euery
one in store cun*n*ing sake. /

To make saltpeter ^{out} of the grounde.

℞ a Tonne or pipe with a toppe and lay vpon
the bottome of the tonne 5 or 6 great stones, &
therevpon lay aloose bottome that is bored full of
holes then lay vpon the holes alittle hay or some
other thinge that the hollow be not stopped, then
put in the earth when you will make your salt-
peter and then put your water therevpon & let it stand
and sinke & then take it in alittle kettle & laye
therein stickes y^{t} burne of themselues if it be soe
they touch not the bottome of the kettle then take
the third part of wood ashes therevpon & then powre
the lye first vpon it, but the lye must first be
assundred vpon the third part as is sayde, & y^{n} **fol. 133**
when this lye is well drye scommed then keepe y^{e}
fowlenes well in store & seeth the lye againe till
the third part: and when you will know $^{when}_{\wedge}$ it is enough
sodden, y^{n} let it dropp adrop vpon a knife, if it be such
as it waxed little starres then it is enough, but if it
be as it were red y^{n} it is sodden too much then powre
it in a kettle of raine water & let it melt & when
it is melted it wilbe good againe

How you ought to purify true
saltpeter out of the earth

℞ Wine vinegar or lye & cast the saltpeter [14]
therein & stirre it to gather, & let it seeth a little
and when it is sodd put it on the fire againe, &
scom*m*e it well, & when it is well, take soe much
salarmoniacke as you will, & put it in akettle
& powre vpon it a quart of wine in 3 parts y^{n} let
it keele, & y^{n} powre the wine & drye ye salarmoniacke
then it is good

ffor filling of Guns

[14] Interesting, as it is suggested to take *either* a strong acid or a strong base to the same end.

How you ought to fill peices of mettle or Iron in
ye Chambers before, you shall take a shime of wood
after ye chambers be reayde within, & make the
shime of one foot or almost, after y^{t} ye peice is
bigge & shod the shimes with blacke tile in the
midds or more, y^{n} put the gunpowder therein vn-
till the chamber be full or after y^{t} ye powder is
good then take allsoe ashime of Lyndon wood or
of willowes & put it at the end of apike y^{t} it be
meete for the mouth of the chamber, & beate y^{m}
fast in & shoote therewith with astone or without
as you will.

To proue Chambers

℞ a prop as long as he is broade in the thinnest
of the gun haue a chamber of her y^{n} you shall
put ye prop vpon apike, & y^{n} put the prop with y^{e}
pike in the chamber, y^{n} you shall take astampe
with astocke by the which you shall driue in the
prop, & the stamp must haue arounde shime vpon **fol. 133^{v}**
which the stampe must ride when you driue in
the prop & driue it from ye chamber for to order
guns.

It is necessary to haue amettle vnder ye wch ye gun
shall lye for to preserue him y^{t} letteth ye gun goe
of: ffor great peices you shall make apit in y^{e}
gounde 7 or 8 foote deepe 5 foote broade or
else y^{f} ye grounde is good there you shall make y^{e}
pitt great after the peice is bigge, y^{n} you shall
make the pitt behind against your order many
square peices of woode the one by the other as far
as the pitt is longe that shee may stand fast
at your foote aboue ye grounde, & y^{n} you shall
let square in the grounde asquare logge y^{t} he bet
from beneath till about in ye ground like ye other
grounde, and y^{n} you shall take a square logge, & lay
before the thickest peice of wood ~~3~~ standeth before
ye other & before the logge you shall lay the gunne
vpon the one side afoote higher

How you shall shoote — in agreat
peice or in other small guns

The Chamber s[ha]ll not be laden fuller y^{n} ye lead
or prop might touch ye powder. knowe allsoe that a
gun may be laden with 2 manner of powders
now when they be dymen with the one & now wth

the other & the best powder layde next to the let
hole

To make a Quadrante

℞ any Table smoth or streight & therevpon
you shall diuide & rediuide and therevpon make
a quadrante. In the same quadrante you shall
take one halfe rounde from wch is called Lymbus
& the same Lymbus you shall diuide in x like
partes wherevpon you shall ma~~b~~ke ye number
y^t^ standeth writen vnder in Lymbus. after you
shall make asquare called a quadrante, that is
the same quadrante, & diuide ye one side into
12 poyntes which shalbe called vmbra vsu*er* and **fol. 134**
vnder in the right 4 square shalle alwayes 12
to be vnderstoode & shalbe vmbra errant of
man In the other side in the same likenes called
v^r^sa — & under the right square shalbe allways
12 to be men shall in the side vmbra errant
from aboue downe · 1 · 2 · 3 · 4 · 5 · 6 · 7 · 8 · 9 ·
10 · 11 · 12 · & vnder that where lymbus is
there shalbe a scala altimetra or vmbra as
before is writen & vpon the quadrante shall
you 2 little holes for to see in all quadrante
gelenteliken is to make & aboue in the qua-
drante shall hange aprop or thing with a
silke thred the which at euery corner
shalbe very like

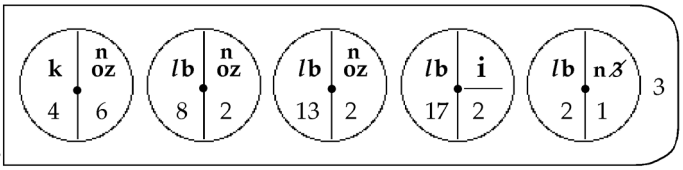
To take the height of any thinge

When you see the head of any tower, church
or Castle or the like, with this sayde quadrante
you shall know, hold ye side scala altimetra shede [15]
or vmbra errant shede againe your eyes & looke after y^e^
height of any highnes you will measure allwayes looke-
ing through the little holes after the heighest of the height
and when you have the height through ye little holes
y^n^ marke you therevpon y^t^ it p*er*fectly fall, & it falleth
vpon in the middest of the quadrante then you bee
euen soe ward from the height that you haue mesured
as the height contineth, & allwayes you may ad there
vnto ye length of your eyes from the grounde nigh as
though you had layne vpon your backe and seene
ye vppermost allsoe of the perpendicular falleth
vpon the ij vpon ye same side if the vmbra errant y^n^ you

[15] The pen and ink change after "know,", but the hand remains the same. The garbling in the chapter immediately above might suggest that this represents a different sitting when the copyist grew weary.

haue ye eleuenth part of the height of the Tower
adding the strength of your eyes from vpon the
grounde. if it falleth vpon 10 y^{n} it is the 10th part
and ye 5 parte adding thereto the height of your
eyes. If ye perpendicular fall vpon the 9 then you
have the 9th part of the height of the Tower adding
a quarter of your eye sight vpon the grounde, if
it fall vpon 8 y^{n} the third part of 8 & the midst **fol. 134^{v}**
of the third part of your eyes then it ye height
& 8th part of the highnes. yf it fall on 7 then add
thereto the 5 quarter part of your sight & that is
the height. yf on 6 then take the distance 8 [gte] [16]
that waxed to the Tower double alsoe the length
of your eyes to the foote is the height. if it fall
on 5 y^{n} the distance is double with ye first part
of your sight and that is the height. if on 4 y^{n} take
ye distance 3 fould with the length of your eyes
3 times in the height. ffor to make aladel for [17]
a Curtall or cannon or for such like peices, you
shall take as is aforesayde the height of the shoote
of the peice and as you find in your sayd rule then
ad thereto 3 times as much & you shall finde such a
ladle twice filled holdeth weight for weight takeing
a 9th parte and such aladle serueth for such like peices
if there be forsayd of mettle, but some peices there
be that be chambered for the which you must make
your ladle otherwise. To make a ladle for a peice
that is chambered as some cannon bee and y^{t} by
forsayth of mettle and may compert to haue weight for

A Cannon of seauen inches



waigh lacke
a 19 part [18,19]
or over
therebe
y^{t} may
scant
compert

[16] This last word, 'gte', is faint and in a different hand.

[17] Here there is a break in continuity that connects to a similar break on fol. 138^{v}.

[18] This graphic seems to be a charge chart in pounds and ounces for a 7" cannon. The labeling, however, is far from clear. The 'k' in the leftmost circle is probably a mistake for 'b', as in the other 4 circles, the symbol for pound being the stroked 'b'. What I have taken to be 'oz' for ounces is written more like a single character 'o' and then a script version of 'qr', especially in circles 2 and 3; it cannot be 'quarters', however, because in the first circle, the amount is listed as 6 units. In comparison with fol. 137, it is possible that this stands for 'grains'. The 'i' in the fourth circles is a mystery, as are the superscript 'n's in circles 1-3 and the 'n' in place of the 'o' in the fifth. There is also no indication of what the lone '3' is doing to the right of the fifth circle.

to haue 2 19th parts lesse for the which peices you
shall make your ladle on this wise. Take the height of
your chamber within & looke how many ynches it is
heigh so in your sayde rule how much about the length
shall you hold in aladle of such length then m u l t your [20]
ladle in length till yt you find that your ladle shall hold
at atime halfe waight for waight with the shot lackeing
a 19th part, & 2 times that ladle is the dutie of ye peice
the figure of such aladle that serueth for such apeice
with the powder that holdeth. [21]

The rule of the quadrante sheweth as masters teach how
farr soe much powder may cast such a shot at poynte
blanke & soe from degree to degree to the best of the
random, & because one peice shooteth not soe farre
as an other, go if eu*er*y peice cast at poynte blanke 12 [22]
score he shall cast at random amile 940 foote and **fol. 135**
soe likewise all other peices, when you knowe howe
farr your peice casteth at poynt blanke he shall cast
at random v times & a halfe soe farre againe.

Understand that the quadrante shooteth from poynte
to poynte & from degree to degree; how far that your
peice cast further at the mounteing of one degree &
soe of other degrees. But first marke that your peice
be perfectly disp*ar*ted and allsoe diuided soe that you
may know the goodnes of your peice, & whether the
peice be truely cast. for sometime the core of the
peice bendeth more to one side yn to another, whereby
the peice is thicker on the one side yn the other.
wherefore noe man can shoote with such apeice
truely except he haue ye peice first diuided by his
right line & knowe which way perfectly the peice
casteth most & such peices be dangerous for feare
of breakeing with a full charge of them yt be ignorant.
but if your peice be made with atrue core, when
you have iustly disperted the same take the quadrant
and set it vpon your peice & looke by your quadrant
that the height of your disperted and the sight
of your marke be equall, yn soe yt your shot be round
and fill close the peice & soe you shoote as neare your
marke being within poynte blanke as though it were
with a handgun. then marke ye winding of your plum*m*ets

[19] Here and below when the scribe writes '19', it seems clear, based upon comparison with Richard Wright's manuscript, he meant '⅙'.

[20] Here the letters 'm u l t' are quite clearly written and separated by distinct spaces.

[21] The text indicates that a figure should be here, but the copyist apparently omitted it.

[22] There is a dot over each of the letters in 'go'.

in your quadrante and you shall finde how much further your peice shall cast mounteing in one degree, & soe vnto the best randon.

A rule how to dispert apeice

Take the compasse about the thickest of the tayle & dispart y^{t} compasse into 3 equall parts, take one of the 3 parts that is iust the height of the tayle of your peice then with the height goe to the mouth of the peice & measure the height thereof, y^{n} take the sayde height of the mouth and cut it of then y^{t} which remaineth of the height of the tayle disp*ar*te into 2 p*ar*ts, take one of y^{m} & set it vpon ye mouth of your peice soe that the end may touch the mouth itself, & the other end to stand vp aboue ye peice the which maketh the peice as high behind before, y^{n} looke ye mettle **fol.. 135^{v}** of your peice & the toppe of the disparted standeinge on the mouth of your peice, bring those 2 & the marke all in one sight, & this truely donne you shall not fayle of your marke.

Another way to disperte apeice lighter donne but not at all times soe true

Take a priming Iron and put it in the touch hole of the peice & take the depth from the bottom to the highest of the mettall behinde, that taken goe to the mouth of the peice and take the height thereof somewhat considering that the peice is straighter behind then in the mouth and in the sayde taken in ye mouth cut of and cast away y^{n} y^{t} which remaineth set on the mouth of the peice with the iust height of ye mettle behind y^{n} bring these 2 & the marke in one sight, soe shall you haue a good shoote [&] perfect except ye peice [23] was not truely bored in the touch hole which may deceiue you disperting. allsoe if the peice be chambered that disp*ar*teing will not serue but will deceiue you.

Another disperteing wch is p*er*fect true, and serueth for all peices

Take an ynke rule that is marked by quarters and take the midst of the rule and lay it aloft on ye tayle of your peice then take your plum*m*etts & your line & hange it vpon your rule y^{t} it touch the side of ye peice first on one side y^{n} on the other side of your peice and soe shall you haue the iust height of thickenes take ye sayd height and lay it vpon the mouth of your peice & likewise take the thickenes of the mouth by

[23] See n. 8, above.

your line as you did before at the tayle and see
how many ynches halfe ynches, quarters d[em]i quarters [24]
that your peice is thicker behind then before & take
iust halfe soe much & set aloft vpon the mouth of
your peice then take the height behind and the top
of the disparted before & your marke togather, & you
shall not fayle but hit your marke. Likewise by this
disparteing shall you p*er*fectly knowe if y^{t} your peice be
equally cast, or not haueing more mettle behinde y^{n} before **fol. 136**

To know how far all peices shall cast at poynte blanke.

A ffawkenet shall cast xiiij score haueing a ixth part
more powder then the weight of his shot, if his shot be
close & rounde, but if his shot become lowe, you shall
abate of the strength that he should cast soe much
as you see the shot low, v , if the shot lacke a quarter [25]
of an ynch of ye height y^{t} should serue for the peice you
must abate a xvjth parte of the way it should cast be
cause soe much winde scapeth out of the peice, as
should carry the shot further, but the best remedy is
when you haue such a lucke shot to make your firste
foxe as hard and as full as you can soe that ye faste- [26]
nes of the foxe shall close in the winde vntill the
shot be disclosed, & soe likewise of all other peices.

Take your ffawcon likewise as you did your ffawknet
and hauing the like powder he shall cast poynte 14 score
and a halfe. Also a sacar to vse her according to y^{e}
sayde peices with shot and powder shall cast at poynte
blanke 16 score and a halfe. Likewise a bastard
Caliuer soe vsed with shot and powder shall cast
at poynte blanke xxi score & a quarter, ye reason
is because the shot is more of weight and more of
length which euer causeth the shot to voyde wth more
violence & soe shall all like peices y^{t} may comporte
to haue a 9th part more powder then they weigh
being peices of length as these peices be that is to
say that the peices be made of 26 balls of length
as most com*m*only the sayde peices be here following.
A Demy Culveryn that may shoote waight for
waight of powder with the shott & shall cast at poynte
blanke 18 scores because the peice is of alonge
length. Allsoe a Culluerin shall cast at [~~L...dles~~] [27]

[24] That is inches, halves, quarters, and eighths.

[25] A space is left here in the MS for a later insertion.

[26] The word "foxe" seems to refer to the tampion, suggesting it was perhaps made of fur.

[27] Here the copyist obviously unwittingly copied from misordered pages once again. The proper textual stream picks up on fol. 139^{v}.

for all sortes of peices except chamber [28]
peices, and for the sayde Chamber peices you
must take the height of the chamber 3 times &
that 3 times must be diuided in 5 partes as is, & **fol. 136v**
take 3 parts of the breadth of the ladle & then 2
to stand voyde & soe of all other.

This rule followeing showeth the length of all
ladles & what powder they may cary at atime in
a ball of length & soe of halfe a ball or of the 3d part
of the ball

9	8	7	6	5	4	3	2
4℔ 6 oz	6℔ 34 z	3℔ 15 oz	2℔ 11 z	1℔ 13 z	i℔ 5 qr	9 oz	2 oz i qr
4℔ 15 z	5℔ 9 oz	3℔ 8 oz	2℔ 6 z	i℔ 9 z	15 oz i/2	7 O	2 z 3 qr
6℔ 14 z	6℔ 2 z	3℔	2℔ i oz	1℔	11 z qr	5 z 3 qr	3 oz 2
7℔	7℔						4 z 3 qr
8℔ 2 z	8℔						
9℔ 5 z	9℔						

[29]

A ball of length in your ladles makeing shall hold
so much as this afore sayd rule sheweth aball is to be
vnderstood the height of a shot whether your shott 2
ynches or more more mounteing to 9 ynches. In a [30]
ladle makeing 9 balls of length shall hold of powder
waight for waight with the shot whether your ladle
be of 3 balls as com*m*only hath bin vsed or of more yt
is to say a ladle of 3 balls shall hold at a time soe
much powder as the aforesayd rule sheweth & yn 3
times ye ladle equally filled shall hold the waight
of your shott & is in all ivst 9 balls; so in like cause
if your ball be of 4 balls of length that ladle 2 times [31]
filled shall hold waight for waight [l]akeing 9th parte
of these 2 ladles be the full of 8 balls allsoe aladle
made of 4 balls & ahalfe of length 2 times filled
holdeth iustly waight for waight & is the full of 9
balls. allsoe another ladle made of 5 balls of length
that ladle 2 times filled holdeth waight for waight
and a 9th part more as some peices may comport

---

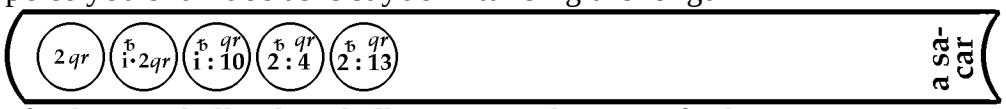
28 There is a blank space at the beginning of this line, but not as the copyist did for “chapter” headings. Perhaps he was confused by lack of continuity in the narrative, but nonetheless continued copying.

29 This table is quite clearly constructed in the MS, although there are some scribal errors. The stroked ‘b’ throughout is for ‘lb.’ Presumably, the 6 lbs. 34 oz. should be read as 6 lbs. 3 oz., with the extra ‘4’ being a copyist mistake for the line below. He was also frequently lax in writing the ‘o’ in ‘oz.’ It is unclear whether “1 lb 5 qr” is a mistake for ¾ or he means 5 oz.

30 “more more” (*sic*).

31 “your ball” (*sic*) for “your ladle”.

more y^n^ waight for waight of powder. and likewise
some other peices may not comport to haue waight for waight
as apeice his shott weith x^*lb*^ pounde of yron
which may be called a Cannon, the reason is because
the peice that shooteth in shot of xl^*lb*^. the peice hath
of mettle 4 in waight more which may be a 6 waight
of mettle for a pound of shot as a Sacar whose shot **fol. 137**
waigheth v^*lb*^, & the peice hath of mettle xij^*lb*^ or more,
all such peices may comport to haue waight for
waight of the shot because the shot is smale & of
small waight & the peice is double fortifyed with
mettle all such peices may haue 9 partes more y^n^
waight for waight as by example. | Take asacar
whose shot is of 3 ynches & *demi*, and I find by the rule [32]
that such a height shall weigh 2^*lb*^ y^n^ take aladle with
balls of length & the ladle shall hold at a time 2 ^*lb*^
& 3 *gr* & it 2 times filled that ladle is the full duety
of the peice, & in like manner by the selfe same
ladle may you make ladles for these sortes of peices [33]
viz: for a ffawkenet, affawcon, a Bastard cul-
u*er*in, and as you haue done here by the sacar shot
aforesayde soe shall you doe by these other peices
takeing the height of the shot and like in ye same
rule for your ladles, & there shall you finde what
one ball of length in your ladle holdeth then take
how many balls that your ladle is of length &
to soe many times ye sayde waight y^t^ you find
written in the sayde rule & so shall v [34]
balls of length in aladle holdeth *demi* a 9 parte more
than *demi* the waight of the shot. Allsoe to make a
ladle for a demi-culu*er*in or a Culu*er*in or such like
peice you shall doe as is sayde in takeing the length



[35]

of rule you shall... doe aball & soe much as you find
a ball to hold of powder by the 3 times & *demi* soe

---

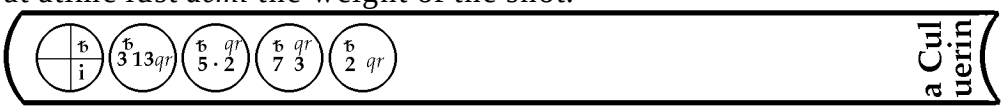
[32] "Demi" = "half".

[33] "self same ladle" (*sic*) for "self same rule".

[34] Blank space left in MS.

[35] In this diagram and the next, the 5 balls drawn inside the barrels of the saker and culverin seem to represent the weight of that number of balls of powder. Hence, in the first, one ball of length weighs 2 oz., 2 balls, 1 lb. and 2 oz., 3 balls 1 lb. and 10 oz., etc. and similarly for the culverin. The additive weights, however, do not tally and the culverin's fifth ball has a value less than all but its first ball. Clearly, however, the author felt a visual mnemonic would be of use for this information.

much and you shall find y^t such aladle shall hold
at atime iust *demi* the weight of the shot.



A rule to knowe the goodnes of all sortes of
Gunpowder

Gunpowder may be knowne by 3 mann*er* of p*ar*ts **fol. 137v**
i By tasteing of the tounge to knowe his sharpnes
2 By fayrenes of color, 3:^ly by the burneing. the
tasteing of the tounge sheweth if the powder bee
of a high receipt or low, y^t maketh ye powder good
and for lacke of receipt, simple. the fayrenes
of colour sheweth the powder to be good for if it
haue abundance of moysture and is well wrought
it will haue afayre colour, & for want of moysture
the contrary, to wit very darke, & lacke of workeing
will make it shew darke ye which by fire you shall
knowe, for if it lacke working there will re-
maine after the burneing as it were white p*ar*ts
of the Master wch signifyeth euill workeing allsoe
by the fyre you shall knowe whether ye maister
was well refined or y^t it be greazy or salt after
the burneing there will remaine smale knotts
when it was burned & ye place wilbe dankish, for
the moysture and the salt after the burning will
giue againe to moysture & water ye which sig- [36]
nifyeth y^t the powder is greasy. allsoe like knotts
will remaine after the burneing of the powder y^t
is not well wrought, & these knotts will not giue a-
gaine to water but will remaine hard. Allsoe yf
you haue of that sort of powder which after the
burneing sheweth what the powder signifyeth
that he hath abundance of moysture, & lacketh
workeing and this powder is daingerous, for his
property is if it be long laden in a peice, & be kept
dry without any moyste ayre, it shalbe soe fine
that if you shoote of the peice it shalbe in dainger
of breakeing. Alsoe there is another sorte of powder
that by burneing will lye like pearles white & red as
the other did but this burneing shalbe notheinge
soe quicke, & of a darke colour y^t signifyeth lacke
of moysture, & of this powder you may boldly giue **fol. 138**
apeice more by the ix^th p*ar*te y^n of the other. there is

[36] The space left before "water" suggests that a certain *type* of water was meant, but never entered.

another sorte of powder that is without fault w^{ch}
is blew of colour & fayre wch signifyeth abundance
of moysture and well wrought & ye burneing
as quicke as the twinklinge of an eye & nothing
remaineth but white smoaky colour there as
the powder was burned, & this powder is stronge
wherefore you must fauour your hand & not ou*er*
charge for feare of dainger in euer[y] ladeinge

This rule declareth the height & waight of all
Iron shotte begining at 2 ynches and soe from
a *quarter* to a *demi* ynch & 3 *quarters* untill the height of 9
ynches amongst the which height most comonly
all peices be made *quarter* that a yron shot is, that [37]
a peice shooteth Iron and not lead or stone, as
Iron peices shot Iron shot.

To know the height and waight of Iron shot
measure the compas round about & diuide [38]
the same compas into 3 parts, or of the 3
parts take for the waight of the & soe
many ynches as the third part is of length
measured by an ynch rule, looke how
many ynches and quarters that the sayd
rule is marked in number soe many *lbs*
waigheth your shot. alsoe take a payre
of cala*pers* compas and measure the thicke- [39]
nes of your shott & that is the height,
measure the height of an ynch rule &
soe many ynches as the rule sheweth
soe many pounds iustly waigheth your
shot, as may be proued by ashot 6 ynches
high, looke out 6 ynches vpon the rule
which sheweth that the shot should waigh
xxiiij:^{lb} *quarter* which is the iust waight of
all yron shott of that heigh if it be full
cast [40]

i	0	2
i	8	
2		
2	8	
3	0	3
4		
5		
6		
7	0	4
8	8	
10		
12		
14	0	5
16		
18		

[37] This scribal contraction for "quarter" is odd. It has the usual 'qr' but with a superscripted 'a' over its centre.

[38] Despite inconsistant ruling, this table and the one following give shot weights for different diameter iron shot in $\frac{1}{4}$´´ increments. Thus, a 2´´ shot weighs 1 lb.; a $2\frac{1}{4}$´´ shot weighs 1 lb. 8 oz.; a $2\frac{1}{2}$´´ shot weighs 2 lb.; and a $2\frac{3}{4}$´´ shot weighs 2 lb. 8 oz.

[39] The contraction of "calipers" is clearly confused: the scribe has written "cala*qr*".

[40] The small tables here and on the next folios fill out the space allotted them. Here typographic necessity fails to make the table and neighboring text the same height.

18		
2i		
24	0	6
27		
3i		
35		
39		[7]
40		
49	8	
55		
62		8
69		
72		
89		
92		9

fol. 138v

To make the breadth of
Ladles for all manner
of peices

Take the shot that serueth for your
peice great or smale and take ye compas
of your shot iustly, diuide the sayd compas
into 5 partes where of take 3 parts to make
the breadth of your ladle & the other 2
parts to stand voyde for the vppermost [41]
part of the ladle. if it fall vpon 3 then
is the distance 3 times soe far or soe
high with 3 times your sight addeing, if
it fall vpon 2 then take the distance 6
fould with the length of your eyes, if it
fall vp[on] i take the distance 12 tymes
with the length of your eyes allways addinge.

Againe for the contrary, if the p*er*pen-
dicle fall upon 12 vmbra versa from
distance parte or church therevnto the
12 parte of your sight done awaye, if
it fall on a 11 then the 6 parte of your
sight from your foote where you stande
vp. if it fall on 10 take from the distance
quarter doeing away a quarter of the length
of your eyes. if on a 9 take from the distance
athirde parte takeing a 3° parte of ye eyes,
if on 8 take from the distance the 12th parte
likewise of your sight. if on 7 take from the
distance the iust *demi* allsoe your sight. if on 6 y^n^
pull from the distance ye 3^d^ p*ar*te of the sight of y^e^
eyes. if on 5 then take from the distance 2 parts
and the 3^d^ p*ar*te of ye sight. if on 4 take from the
distance the 3 quarter likewise of the sight of
your eyes. if on 3 take from the distance the 5th p*ar*te.
likewise of the sight. yf on 2 take ye distance be-
tweene you and the Tower 11 tymes standeinge
there with the sight of the eyes vnder from ye foote **fol. 139**

ffor to make the Compas

[41] Here again we have a discontinuity in the flow of the text, probably from where the scribe had pages out of order and did not notice it. We segue abruptly from ladles to measuring distances with the quadrant. This break picks up from fol. 134v.

yf you make your compas of lesse diuision y^{n}
you shall allwayes ad or diuide if it fortune
you cannot come to the towne or like for water
demi, or any other let. yf you will know the height
than you shall see thorough ye compas like as you
haue hertofore done and soe goe backeward along
as long as you may see the pin of the sayde tower
like through the 2 little holes and hangeing the
perpendicle straight in the migdst of the qua- [42]
drante or on 12 y^{n} marke the place where you
stande with asticke, & y^{n} goe backeward wth
the sayde quadrante alwayes looking through
the little holes at the highest of the tower, or like
when the p*er*pendicule hangeth on 8 y^{n} marke y^{e}
place whereas your foote be afterward mea-
sure ye length or distance & add thereto the height
your eyes and that is the very height of the
Tower which you haue measured, & thus you
may with the same quadrante or compas
quickly measure or take the height.

To measure all manner of
straightnes by ye quadrante

If you will stand on any height & see a high tower
or any other height & will know how much
higher the top of the Tower is then the height
wheare you stand then set the quadrante or
Compas against your eyes & look through y^{e}
sights thereof. if the p*er*pendicle fall in the
midst y^{n} is ye place where you stand and the
other height all one, Example, see the apple
of any Tower & that the perpendicule hange in
the midst y^{n} is amountaine where you stand
as high as the vppermost of the Tower which
you saw with the Compas. How to measure **fol. 139^{v}**
The sun shineing all manner of heights, take a
sticke of 3 foote longe, the same sticke must
haue apin of yron to see in the grounde so y^{t} y^{e}
same sticke [43] poynte blanke xx score being
alike vsed as the demiculu*er*in which wayeth of
powder. A demiculu*er*in cast at poynte xv score
and a *quarter* haueuing a 9th parte lesse of powder y^{n}
the waight of the shot, & allsoe a Cannon shall
shote at poynte blanke xvj score hauing
like powder as the demy curtall that may

[42] "miqdst" (*sic*) for "midst".

[43] Continuity picks up here from fol. 136.

comport to have the waight for waight of
powder to carry her shott, & this you shall
seeke vnto the rule of the quadrante, and
whereas you find in the quadrante marked
at poynte blanke xij score & haue another
peice which is xx score take soe as xx score
is about xij and soe much shall you add to
the number of xij score in your quadrante,
and you shall find from degree to degree
how much euery peice may cast, for as you doe
perceiue that xx scote is 8 score aboue xij
score at poynte blanke, ~~sh~~ soe shall ye sayde
peice y^t^ casteth xx score be 8 score more
in number at the best of the random, & y^n^
shall you finde marked in your quadrante
at the best of the randon, & this shall finde
from degree to degree adding to euery number
soe much more as afore is rehearsed, that
your peice cast at poynte blanke xij score
and aboue. / ffinis. / [44]

[44] There is a page number (25) placed on fol. 140, but the rest of the signature (ff. 140-146^v^) is blank.

Appendix IV

Articles by William Thomas largely relating to the Establishment or Continuance of Instruction and Regulation of Gunners[1]

App. IV.1:	Licensing of Regional Gunnery Testing Stations	Feb.(?) 1581
App. IV.2:	Proposal for Gunners' Competence Testing	Feb.(?) 1581
App. IV.3	Proposal for a Corporation of Gunners	1582(?)
App. IV.4	Benefits of a Gunnery Corporation	1582(?)
App. IV.5	Notes on the Number of Gunners Required	1582(?)
App. IV.6	Complaints against the Gunners to Lord Burghley	Jan. 1584/5

items	are expanded scribal contrations
~~items~~	are crossed out in the text
[items]	are inferred from missing of damaged text
<items>	are editorial insertions (as foliation, &c.)

Appendix IV.1: **Licensing of Regional Gunnery Testing Stations**

P.R.O. S.P. 12/147/94, fol. 189-95

(CSPD 1581-90, p. 9. Feb.(?) 1581)

<f. 189>To the quenys moste excellent Maiestie. In moste humble wise shewen vnto yor moste excellent Maiestie your moste faithfull Subiect*es* and Servaunt*es* the Gonners aswell belonginge to your tower of London as to the Navye of this your Realme. That whereas at this present there are verye fewe (other then yor Maiesties Servaunt*es*[)] to be had in this your graces Realme wch are skilfull in the science and knowlledge of shotinge in greate orden*a*nce as when nede requireth for the provision and defence of your maiesties Navye and other affayres in this yor Realme Experience hathe shewed and is daylye to be se[in]e and founde true at euerye presse made for the setting forth of your graces Navye. For whearas your graces Navye requireth to be furnyshed in tyme of service w^{t} a supplye of eight hondred gonners There is not founde when they come to service (besides your graces owne[2] serv[aun]t*es*) fourskore hable men to supplye the places of gonners So that when any of your graces shippes of yor Navye of the burthen of CCCC Tonnes beinge appoynted to serve dothe [require to] be furnysshed w^{t} xxxvj gonners, there is not sounde amonge the

[1] To my knowledge, these first five documents have only ever appeared before as Appendix D to G.A. Raikes, *The History of the Hounourable Artillery Company* (London, 1878), I.437-50. They are reproduced here as critical transcriptions from the original manuscripts, replacing Raikes inaccessible and sanitized versions. The other two documents (III.6 and the alternate copies of III.5) have, so far as I have been able to determine, never been transcribed before.

[2] "owne" superlineated with caret.

saide nomber <f. 190> Sixe hable men expert in the saide Science. And not w^{t}standing that those men who are pressed for gonners be found altogither vnskilfull in the saide Science yet doo they take yppon theym to supplye the place of gonners aswell in yor graces Navye as in m^{r}chant*es* saide Shippes if oportunytye of Se^{r}uice shoulde so require, yet mecessytye requireth to presse them.

For Reformacon wherof, and to thintnet that aswell your ~~Merchaunt*es*~~ Maiesties Navye, as the m^{r}chaunt*es* shippes of this yor Realme maye be the better furnyshed in tyme of service and otherwise w^{t} skilfull men in the saide Science, (a thing verye requisite) and also that it maye the better be knowen at the tyme of any presse wheare to have sufficient and hable men to furnysshe your grac*es* Navye

May it please yor lord*es* Spiritual temp*or*all and yor Comons in this highe Co^{r}te of Parlyam^{t} assembled and by the aucthorytye of the same tht yt maye be enacted that the m^{r} Gonner of this yor Realme or his depute w^{t} iiij other of yor moste exp*er*te gonners in {s…e}[3] <f. 191> in yor Tower of London, where the same Mr Gonner or his depute shall assigne and thincke mete to associate w^{t} them and also suche other p*er*sone and persones whom the saide Mr Gonner and the saide Fower other associate w^{t} hym shall depute in those haven townes ensuyinge that is to saye in falmowthe in plymowthe in dartmowthe in lynne in Bristowe in Chichester in Pole in Portismowthe in Barwicke in Newcastell vppon tyne in hull in Boston in Lymne and yarmowthe[4] shall and maye have full power and aucthorytye to prove and trye thexperience & skill of eny p*er*sone that shall serve or take charge as chief or Mr Gonner in any shippe or shippes or vessell*es* of yor Realme and vppon the p*ro*fe and fyndeng of eny or any such p*er*sone or p*er*sones skilfull in the saide Science or facultie, first to take his name and dwelling place and the same to Register in a boke for the saide purpose to be kepte by the saide Mr Gonner or his sufficient depute, and the like boke to be Kepte by other his deputes in the haven Townes before expressed. and the names of suche <f. 192> p*er*sones whome the saide deputes shall allowe for gonners also to be Registered in the smae and thereuppon to graunte to eny

[3] The corner of the page is missing; the word is likely "service".

[4] The first ⅔ of the list lists ports along the southern coast of England: Falmouth is on the south coast at the western end of Cornwall almost to Penzance; Plymouth is to the east on the southern border of Devon and Cornwall; Dartmouth is just east again, as the coast turns north to Torquay; "lynne" here or "Lyme" on f. 195 probably refers to Lyme Regis, east of Torquay on the border of Devon and Dorset; Bristol is the lone port mentioned at the mouth of the Severn, between England and Wales; Chichester returns the list to the south coast, just east of Portsmouth; listing Po[o]le next takes the list back west of Portsmouth, in fact just west of Bournemouth at the root of St. Alban's head; then back to Portsmouth. The northeast coast is covered by the ports of Berwick-upon-Tweed at the Scottish border; then Newcastle-upon-Tyne some 65 miles south; Hull on the north shore of the Humber; Boston controlling the western shore of the Wash between Lincolnshire and Norfolk; "Lymne" here or "Lynne" on f. 195 referring to Kings Lynn on its southern shore; and finally Great Yarmouth lying on the eastern extremity of Norfolk.

suche p*er*sone so founde skilfull a Lycense to contynue and exercise the saide Science and facultie of a chief of m^{r} gonner in any shippe or shippes or vessell*es* of this your Realme.

And that no man*er* of p*er*sone or p*er*sones whatsoeu*er* shall at any time or tymes after the Feast of the Birthe of our Lorde god now next ensuynge and comyng[5] take charge of enterprize to serve as a Chief of m^{r} gonner in any englishe shippe or shippes or vessell*es* of what burthen or burthens soeu*er* the same be passinge oute of this yor Realme to any parte or place or p*ar*ties of beyond the Seas oute of yor Maiesties domynyons other then onely such p*er*sone and p*er*sones as the m^{r} gonner of this Realme for the time beinge or his depute w^{t} iiij other of the most expert gonners in yor Tower in Fee appoynted by and associate w^{t} the saide m^{r} gonner or his depute as is aforesaide or the depute or deputes of the same M^{r} gonner and iiij other gonners associate w^{t} him (to be appoynted in the saide haven Townes[)] shall have had proufe and experience of his and their skill and knowlledge <f. 193> and thereuppon shall lycense and assigne to and for that purpose accordinge as is abouemencioned vppon payne of eny p*er*sone offendinge herein to forfett for eny offence at eny voiage that he or they shall make contrarye to the true meanyinge hereof < blank > of laufull money of England and one monethes ymprisonm^{t}

And that it maye also be enacted by thaucthorytye aforesaide that no englishe shippe or shippes or vessell*es* whatsoeu*er* of the burthen of lx Tonne of vpward shall at any tyme or tymes after the saide Feaste of the birth of o^{r} lorde god nowe next ensuynge pass or sayle oute or frome this yor noble Realme or any p*ar*te or place therof tp any parte or place of beyond the Seas oute of yor maiesties domynyons w^{t}oute that eny suche shippe and vessell at eny voiage to be made w^{t} her havinge ordenaunce have and shall have suche convenyent nomber of Gonners as shall [be] mete for a shippe of that or like burthen accordinge to the order hereafter ensuynge that is to saye that eny shippe or vessell of the burthen of lx Tonn*es* shall haue ij gonners at leaste wch shall exercise that facultie whereof the chief or m^{r} gonner to be suche one wch hathe bene allowed and lycensed to exercise the Ronne of <f. 194> a gonner by suche p*er*sones as are for that purpose aboue appoynted to have aucthorytye as is abouemencioned and eny shippe and vessell of the burthen of C Tonne shall haue iiij gonners at the leaste wch shall exercise that facultie wherof the chief or m^{r} gonner to be suche one as hathe bene allowed for a gonn*er* as is aforesaide And so to and for eny en[cr]eace of[6] xl Tonne vpward of the hole burthen of eny suche shippe and shippes and vessell*es* one gonner more in nomber to exercuse that facultie vppon payne that the owener or owen*er*s of eny such shippe and shippes or vessell*es* that shall so passe the Seas havinge Ordenaunce for defence and not havinge the saide nomber of gunners as is aforemencioned (after the

[5] Christmas, 1582?.

[6] "encrease of" superlineated with caret.

burthen of eny suche shippe and shippes and vessell*es* according to the true meanynge hereof) shall forfett and paye for eny gonner lackeinge of the due nomber at eny voiafe vppon one prouse thereof made < blank > of laufull mony of England.

The one moytye[7] of all wch losses and forfeytures to be to the vse of your maiesti yor heue and Successomes and thother moytye to be to vse of the m^{r} gonner of England and [the] rest of the Companye of gonners in your Tower of London in Fee for the <f. 195> beinge or of suche other p*er*sone or p*er*sones as they or the greater p*ar*te of them shall lycense and appoynte to sue for the same in any of yor Courte or Court*es* of record by accou*nt* of debtte bill playnte Informacon or otherwise In wch sute no essoyue p*ar*teccon[8] or wager of lawe for the defendante shalbe admytted.

Provided alwayes And be it farther enacted That the saide m^{r} gonner w^{t} the iiij other gonners appoynted and associated w^{t} hym for the lycenseing of m^{r} gonners of shippes as is abouemencioned shall have aucthorytye to make and appoynte vnder hym and theym sufficient depute for theym to examyne prove and hye the experience and skill of eny p*er*sone tht shall take charge as m^{r} gonner in any shippe or shippes or vessell*es* at the saide havens and Townes of Falmowthe Plymowthe dartmowthe Lyme Bristowe Chichester Pole Portismowthe Barwicke newcastele vppon Tyne hull Boston Lynne and yarmowthe as is abouemencioned

[7] *I.e.*, "moiety"= half.

[8] That is, issue a petition.

Appendix IV.2: **Proposal for Gunners' Competence Testing**
P.R.O. S.P. 12/147/95, fol. 196r-v
(CSPD 1581-90, p. 9. Feb.(?) 1581)

Itm that once in the yere viz at Mighelmas all the fol. 196
Gunners and other servitares apperteyning to that offise
doe appere wtin the Tower of London there to give there
names to the Clarke of the saide office of there apparons
and then to be comaunded to assemble in the Artillarie
garden vpon an appointed daie in the presence of thaforsaid
officers, and by the Instrucion of the Mr Gonner to
shewe proof of their knowlege and cunyng in the vse and
practize of the great and small ordinance. Wch shalbe
very necessarie aswell to cause them to acknowlege there
dueties to there soveraine Ladie and mrs, as also to force
them to be redy and servicable in that exercize: For
want of wch meting and assemble in most part of those
Gonners to whom hir matie graunteth fee and wages so sone
as they be assured of living doe disperce themselfes in
severall plases vtterly ignorant to the said officers and
Mr Gonner, that when the time of service, ~~requireth~~
vnskilfull men suche as nevr knewe what Gonne ment
be of necessitie intrteigned, for want of those that be
bounde at suche time to make there present repaire. And
so the Quenes matie deceved of an expert Gonner and yet
charged wt fee and wages, and also the service by
vnskilfull men hyndred and the comendable science in
tracte of time decaied and forgotten.

Itm that where the said place commonly called the Artillerie
garden was of purpose given by the prince of fa[mous]e
memorie kinge henry the eighte to thoffice of Thordinance fol. 196v
for the trayning vse and practize of Gonners: a thing
very requisite in time of peace and warre for the defence
of the Realme and service of her matie, yt maie be laufull
to the saide officers iiijor times of the yere a[t] the least to
assemble suche and so many gonners that be in her mates
ordinarie fee and wages wtin the said garden, as they shall
thinke mete: there to be putt in practize the vse ~~and~~ of the
great and small ordinance, to thintent that the knowledge wch
they have alredie maie be mainteined and increased for her
mates better service when they shalbe ymploied in the same

and at suche time to allowe shotte and powder w^{t} other necessaries
as to there discreciou[n] shalbe thought mete and requisite
whereof the m^{r} of thordinance in any wise to be made
privie – and therin to allowe his onely ordre and appointment

Appendix IV.3: **Proposal for a Corporation of Gunners**
P.R.O. S.P. 12/157/40, fol. 75-76v
(CSPD 1581-90, p. 84. 1582(?))

<fol. 75>

Carteyne Articles wherein are set downe the necessitie of a coporacon for the compnye of Gonners and the benifyt ensuing there vppon.

1. First the number of skilfull Gonners at the present to be hadd, is soe smale as in tyme of nede there haue not ben founde aboue A hundrethe and Fiftye able men beside her maiesties owne servunt*es*.

2. Euerye shippe of Fower hundrethe Tonnes will require the number of Sixe and Thirtye gonners, againste the whiche there are not Syxe expert men at all tymes to be had.

3. The Navye and Service of this Realme by Sea and Lande, yf occacon shoulde happen cannot require soe Fewe as Seven hundrethe gonners, and then to commit the chardge of great ordenaunce to ignorant persons is a thinge most Dangerous, beinge for want of gouernement, more readie to Destroye the subiecte then to anoye thennemye

4. It'm whereas for wante of the saide corporacon everye man that will maie pretende the Science thoughe he be never ~~skilfull~~ soe unskelfull to the greate Daunger aswell of her maiesties shippes, as also of the merchaunte as some of them haue proved to Late, to the vtter Discouraginge of those that for theire skill and knowledge as worthye to be cherished. It is provided by a clause of the saide corporacon that the Mr gonner of everye merchauntes shippe of the burden of [ ][9] Tonnes be placed by the heade maisters of the saide corporcon of gonners for the better preferment of suche as deserue and the incurragement of others in that Facultie.

5. The like also to be done in all the Fort*es* and places of seruice within the Realme, and Triall to be had of the sufficiencie of those alreadie placed, a thinge moste needful to be looked vnto consideringe the strength of those plac*es* to depende inholye vpon the vse of greate ordenaunce.

6. By all which premisses as the number no Double shalbe Dailye increased and augmented for the better Service of hir matie and the Strengths of the

[9] The space for the tonnage is left blank in the MS.

Realme. Soe by keapinge also of a Register of their names and Dwellinge plac*es*, in the saide corporacon Likewise remembred, thei maye be at anie tyme founde readye for service vpon all expedicons

Certyne articles set downe by the Mr Gonner of England for the service of her Ma^tye^. <fol. 76^v^>

Appendix IV.4: **Benefits of a Gunnery Corporation**
P.R.O. S.P. 12/157/41, fol. 77-8
(CSPD 1581-90, p. 84. 1582(?))

<fol. 77> **Causes** and Effect*es* of Acorporcon For Gunnarye of greate and smale ordenance to be graunted From the Queenes Matie.

The Effects:	The Causes
To Increase good Gonners to geue credit to the facultie and to holde it in good gouerment.	**That** there be one Bodye and pe^{r}petuall Fellowshipp Incorporate of her Ma^{tes} erection &c. that shalbe called the Fraternitye companye and Fellowship of artillerye of great and small ordenaunce for ever by succession to endure in that name. And that there be chiefe Governers appoynted for the Rule thereof Of which principall Governers, the M^{r} of her highnes ordenaunce the Livetennannt of the same ordenaunce [ ][10] and the Mr Gonner of England for the tyme being shalbe the Chiefe nd the same chiefe governers nowe to be nominated and constituted by her Ma^{tes} L*ette*res Patente
To be readie to redresse eche suddeyn euent and yet to endure no longer then they shall deale well	**That** the saide heade Governers maye freelye at all tymes heareafter choose and appoyncte Foure of the moste expert sage and skilfull Persons of the saide Fraternitye to be vnder Maste^{r}s which shalbe assistant*es* to the saide heade M^{rs} and shall continewe in their Rownes and Aucthoritys duringe the pleasure of the heade maste^{rs}.
To Receave and paye and to haue the gouerment and custodye of the Land*es* good*es* &c. of the saide Fraternitie and to yealde accompt*es* thereof &c ~~of~~ at the yeares ende:	**That** the saide heade masters and vnder masters with assent of ten others of the most auncient persons of the saide Fraternitye may yearleye vppon the feaste Daye of the purification of the blessed virgin marye[11] elect Two other Persons of the saide Cominaltys to be Guerdians wch Wardens are also firste to be nominated in theise L*ette*res Patent*es* and shall onelye continewe for one whole yeare followinge and gove^{r}n by the consent and advisement of the saide heade masters and Governours

[10] Half a line is here left blank apparently for the insertion of another governor.
[11] Most likely, February 2nd. See Clemens Jöckle, *Encylopedia of Saints* (London: Alpine Fine Arts Collection, 1995), *s.v.* "Mary."

To houlde the n[u]mber of officers [in] continuallye good order:

That when anye Parson beinge vndermaster or wardeyn of the saide Fraternitye shall die or be displaced that then and soe often the heade masters &c (for the tyme beinge) maye Lawfullye electe and appoyncte one or mo[r] other p*er*son or p*er*sons of the saide Fraternitye into the rometh of hym or them so put oute, or deceased to execute the same duringe the residue of the tyme then to come, of the Officer deceased or put oute.

To animate the fraternitye throughe hope of eredite Safelye and preferment to be Industrious and yet to be them within lymit*es*
<fol. 77v>

That the saide Fraternitye be forever made a bodie corporate by that name hable and capable by lawe to purchase take and possesse in fee p*er*petuity Tearme of Lyves or yeares or othe^r^weis manno^r^ messuagies, Land*es* &c. And them to sell Aleyn &c. So as (it be not in Mortmayne without speciall License of her Matie &c nor the land*es* &c purchased excede not the client yearly value of [ ][12] anye Statute &c to the contrarye.
And that the same Fraternitye (by that name) ympleade and be ympleaded &c in all Court*es* and before all Iudges for all matters concerninge the saide Fraternitye &c and the affayres and busines of the same onelye as Largelye anye other Corporacon of this Realme maye doe and, and[13] haue a com*m*on seale thearefore.

To treate and counsell for the State and wise gouernment of the saide fraternitie and to make and ordeine Lawes for that purpose and to increase the numbre of skilfull gonners wheareof theare is great want.

That the saide Master and Ruler and cominaltye maye at all tymes at their pleasure (within thartillerye yarde or in anye other convenient place) assemble together as other corporacons of the Citye vse to doe in their halles. And that the saide masters with their assistent*es* together wth the wardeyn[s] and Ten of the most auncyent of the saide cominaltye &c and their successors may make lawes &c for the good condicon and lawdable rule of the said Fraternitye from tyme to tyme, And maye admit to be free of the saide corporacon suche and soe manye as shalbe by them thoughte meete good convenient and necessarye.

12 Blank left for missing value.
13 *Sic*.

To avoide the placinge of vnskillfull men which frendship hath heretofore placed to the great daunger of her Maiesties hold*es* hasarde of the losse of her ordenaunce and great trouble to the Realme &c: if the enemie should attempt*es*

That no man*n*er of p*er*son from hensforthe shalbe placed in any Gunners Rowme, or take chardge of any peece of greate ordenaunce or be admitted into her Ma^{tes} holdes &c or for the service of the seas, But onelye by the consent of the M^{r} of the ordenaunce and vpon proofe made of eche p*er*sons habilitye by the vnderm^{rs} and wardeyns of the saide Fraternitye. And also that he be Free of the saide com*m*inaltye and haue his Placard for the same vnder the com*m*on Seale of the saide Fraternitye. And that the saide Masters Rulers and wardeyns for the tyme beinge shall at their pleasures at all tymes convenient viewe searche and trie all the gunners which do or shall serve in her ma^{tes} Fort*es* &c. And to signifye to [ ][14] the names of the vnskilfull that they maye be removed, and others of more skill placed.

To avoyde the rash audacitie of vnskilfull Novises and the daunger dependinge thearon and to furnishe all shippes wth perfectte good Gonners.

That no p*er*son or p*er*sons shall at anye tyme hereafter frequent to shoote in anye ordenaunce greate or smale in anye ship of this Realme beinge aboue the burthen of Fiftie Tonnes except he be free of the saide Fraternitye and assigned theareto by the masters of the same, vpon suche payne as the saide m^{rs} or their assistant*es* shall assess:

To kepe all gonners in obedience

And within gournment

That the saide M^{rs} and Rulers maye make lawes and also lymit mulctes[15] and penalties vpon the offende^{rs} in the contrarye: And also forfeytures and ymprisonment or either of them vpon anye offende^{r} of the said Fraternitye for anye offence tuching the fellowshippe: Againste which lawes yf anye of the saide Fraternitye be founde contrarious, the m^{r} Rulers and assistant*es* shall and maye punishe them accordinge to their discrecons as the qualitye of the offence requireth:

[14] Blank left for officer in charge of replacements.

[15] From the Latin *mulcta*, fine or payment.

<fol. 78> To limit the power of the Masters &c

And the offendo^{r} not to declyne from the saide M^{rs} &c. So as the saide Lawes onelye concerne the saide M^{rs}, wardeyns, Rulers, cominaltye men and matterrs of the saide Fraternitye. And be not against the lawes &c of the Realme, ne contrarye to the severall dueties of her Ma^{tes} Subiect*es* toward*es* her highnes her heirs and Successo^{rs} and that the saide M^{rs} &c. maye take the fyne &c to the vse and toward*es* the maynetenaunce of the saide Cominaltye

To encorrage the towarde and obedient

To increase knowledge

That every p*er*son of this Fraternitye shall and maye vse and exercose[16] to shoote in great and smale ordenaunce in thartillerye Garden or i[n…][17] other plac*es* meete or convenient for that purpose without Incurringe any penaltye &c for the same.

To avoyde disodre of vnrulye people and perill from the Gonner

That if anye p*er*son throughe his owne negligence or rashe audacitye be slayne or hurte in runninge standinge going or beinge betwixt anye knowen marke or matche in open place shot at, by the Mrs Rulers and cominaltye of the saide Fraternitye, after he that shootethe shall openlye and lowdelye pronounce this vsuall worde (Faste) that then suche Mr Ruler or brother whatsoever shall not by that occacõn be attacked &c molested &c or suffer deathe, nor loase anye number, nor forfeicte anye Land*es* &c

That theise L*ette*res be made Patent*es* withoute fyne or fee greate or smale in the Chauncerye to her Maiesties vse, or the the vse of her highnes heirs in the Hanaper of the saide Chauncerye &c. So that expresse mencõn &c In witnes &c.

[16] *Sic*. Raikes (I:446) has ammended this to the obvious "exercyse".

[17] Page torn here, but Raikes has "in anie".

Appendix IV.5: **Notes on the Number of Gunners Required**

P.R.O. S.P. 12/157/42, fol. 79-80
(CSPD 1581-90, p. 84. 1582(?))

Another copy is preserved in B.L., MS Lansdowne 113, art. 58, fol. 165-6, undated, which follows the S.P. version very closely with only slight spelling differences (referred to as the "L113.58" version). A third copy in a fair hand with more standardized orthography, however, is found in B.L., MS Lansdowne 39, art. 62, fol. 216-7, and is dated 4 March 1584 (referred to as the "L39.62" version). This last copy has some larger differences, with the more salient differneces entered in the text below in square brackets. Where the S.P. includes extra text, it will only be noted if provides a different sense than L39.62.

<fol. 79> A briefe content of suche doubtfull informacions as yor humble Oratoure, William Thomas, hathe of longe time soughte opportunitie to shewe vnto yor honnor by worde of mouthe[18]

1. Where it hath pleaseid the Almightie of his greate love, towarde this Realme of England, to blesse the same, not onelie[19] wth a puissannt Navye of shippes for defence, but also hath stirred vp, the myndes of Princes and Nobilitie, to Furnishe [them to there great charge, with plentye of great and terrible] Ordena*n*ce, to be the onelie terrour to the Enemies, as is better Knowen vnto yor honor, then yor Orato^{r} can sett forth.

2. This realme thus beinge indewed with twoo so notable blesing*es*, all faithfull subiect*es* are to lament the wante of skilfull men,[20] to supplye the roome of skilfull gonners p*er*tinent to the same. Whiche wante hath ofte[21] beene founde at generall prest*es* and if occasion were, would be nowe proved, for it is moste certaine, that there woulde not be founde so many skilfull gonners, as fower of her highenes shippes should have occsion to occupie.

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[18] This opening paragraph is absent in the L39.62; it merely says "William Thomas his informacõns".

[19] "not onlie" omitted in L39.62.

[20] "gonners" in L39.62.

[21] "alwayes" in L39.62.

3. Under yor honners Correction yor Oratoure hartelie wisheth that by yor honners meanes there maie be founde and in time established some good order that there maie be a full supplie of skilfull gonners to serve in her Maiesties Navie at every prest, if occasion shall serve Otherwise [it is greatlie to be feared] in respecte of the same wante, there is no other successe to be looked for, but the same navye to be made prizes, to the Enemies, or to be destroyed by the vnskilfullnes of the gonners thereof, Orell*es* be forced to runne awaie, to the greate encouragement of the Enemies abroade and at home, Which [thinges] yor Orato^{r} hartelie praieth to almightie god, maie be, by your honnors good discrecion speedilie prevented.

<fol 79^{v}> [The introduction] For the remedie of the causes [touchinge her maiesties Navye] aforeside in yor Oratoures simple iudgemente, (vnder yor honno^{rs} correction) bee, as followeth [and so hath bene alreadie shewen vnto the right honnorable the Erle of Leicester][22]

1. Wheare there was a Charter graunted to the fraternitie of Artillary in greate and smale ordena*n*ce, by the famouse Prince H·8· and the peice of grounde, nowe called thartillary gardein, by his graces meanes appoincted, for the exercize of the same fraternitie as by the leasse thereof graunted, to the same fraternitie, beinge left in the hands of Sir William Pelham maie appear and the same Charter since by him delyvered to the handes of the right honorable, the Lorde Treasorer, and as it is saide cannot be founde, That it would please your honnor to be the meanes, if it soe maie stande wth yor honno^{rs} pleasure, that the same Charter maie be confyrmed and nowe established with other nedeful addicions thereunto, as hereafter shalbe shewed.

2. That yor honno$^{r[s]}$ with some others[23] as yor honno^{r} shalbe thereunto best advised, would be the speciall cheife maisters or governoures of the same fraternitie, for the more effectuall and speedie reformacion of the foresaide wante, and reducinge the same to good order,

[22] That is, Robert Dudley, who was shortly to become commander in the Netherlands.

[23] L113.58 has "the right honorable thearle of warwick" in place of "some others", while L39.62 has neither.

3. That there maie be, by the cheife Maisters or governo^{r}s chosen, fower of the cheifest of her maiesties gonners to be vnder M^{rs}, whoe, with the M^{r} gonner of englande, maie have the teachinge of all the Schollers, and the proving of all such men as shall take vppon them the cherge of a Maister gonner in any of her Maties shippes fort*es* or castell*es*, or shall have of her Maiestie any gonners fee, and to make reporte, to the cheife masters of their knowledge, before they shalbe admytted to any service.

4.[24] That it woulde pleaze yor hono^{r} to take suche order, as that, noe shippe or vessell having Orden*a*nce in her, shall crosse the Seas withoute that the same have in her, suche nomber of gonners, as hereafter is lymyted, Videlt, euery shippe of the burthen of lx tonnes, to have three gonners, wherof the cheife or M^{r} gonner, to be suche a one, as shalbe tryed allowed and lysenced by suche, as shalbe for that purpose appoincted, and euerye shippe of iiij score tonnes, to have fower gonners to be tried as aforesaide, and so for euery xx tonne[s more], one gonner more to nomber

<fol. 80>

5. That the cheife Officer in euery the havens townes port*es* and places, where shippinge is vsed, shall take the names of all p*er*sons in that same towns port*es* and places, which doe take charge, or serve as a gonner in any shippe or vessell and the same register in aboke for that purpose, and in euery Easter terme, sende vp the same names, and their dwelling places to the Mr Gonner and his fower associat*es*, for the time beinge, by whiche it maie be knowen, where to have skilfull gonners [and sufficient nomber], to serve her Matie when oportunitie requireth. [The accomplishement of all wch p*re*misses wilbe noe further charge neither to her ma^{tie} nor anie of her subiect*es* then is alreadie allowed for the same intents.]

6. That all suche shippes as shalbe freighted wthin the ryver of thamis, with merchaundize or [merchaunt*es*][25] gooddes, shall, for the safegarde therof, have for euerie two pieces one suche sefaring man as shalbe a scholler, to be taught and instructed in the science of shootinge in grete and small orden*a*nce accordinge to thintent of her Maisties allowance, for the same purpose

[24] From this point on, the numbering of L39.62 differs: §4 -7 of S.P. correspond to §5, 7, 6, and 4 of L39.62, respectively. L39.62 does not have §8 and 9 of S.P.

[25] "merchaundize or" omitted in L39.62.

7. That there maie be, by the cheife M^{rs} suche streight comaundem^{t} given to the fower vnder Maisters and the Mr Gonner, that, that[26] pouder, and other her Maiesties allowance, for the teaching and instructing of Schollers in the Scyence or misterie of shooting in greate and small orden*a*nce, be by them iustlie and truelie expendyd, aboute the same purpose that it is allowed for, and not otherwise, vppon some paine and perrill to fall thereon

8. Also that the fower associat*es*, or vndermaisters, wth the M^{r} gonner, for the better service of her Maiestie, maie have the proofe of all suche salt peter, cole, sulphure, powder matche orden*a*nce carriages wheeles, stock*es* and iron worke, as shalbe for her Maiesties service and store, and that none shalbe received but that, that they shall finde to be good and fitt for her highenes service, vppon some penaltie to fall thereon by yor honno^{r}s

9. Then that there maie be sett downe suche a perfect government in euery one of her Maiesties shippes by yor honno^{r}s, bothe for their owne safegardes, and a terror to the Enemye, as heretofore was never put in practize by any.

[26] *Sic* (in all versions), although Thomas does the same thing in no. 8, below.

Appendix IV.6: **Complaints against the Gunners to Lord Burghley**

B.L., MS Lansdowne 43, art. 31, fol. 70
(dated Jan. 1584 [*i.e.*, 1585])

Right honnorable, and my verie good Lorde, my humble dutie remembred cravinge your honnors pardon for my attempte herein, for that, that I intend to certifie your honnor of, is in discharge of my conscience, and my dutie, towardes her ma^{tie} Whereas aboute Shrovetyde last I did deliuer vnto your honnor, and other of her ma^{ties} honnorable councell, certaine articles in writinge, wherein was conteyned the greate wante of skilfull gonners to serue her ma^{tie}, in her highenes navie, and other fortificacõns, the cause thereof, and in my simple iudgem^{t} the remedie for the same, wch rememdie wilbe noe more charges, to her ma^{tie} then is allowed euerie yeire, out of her ma^{ties} store, for the same exercise, if it were well ymployed. For the wch my humble sute therein, I haue gotten greate displeasure, by the practize of some privie enymyes, whiche neither regarde her highenes estate, neither consider the losse of her ma^{ties} shippes orden^{a}nc*es*, ffortes, munition, and people, and the greate mischeife, that thereof maie ensue, Doe reporte that there is noe suche nede of increase of gonners, neither will there be, suche lacke of skilfull men, when nede shalbe, but to make the sute p*ro*cede noe further, give oute in speche, that if the same sute, might be obteyned, then shoulde the m^{r} of the Orden^{a}nce doe nothinge wthout our consent, and thereby (as it should seme) make his honnor con[ceive] some dowbtfulnes of let thereof. Wherefore I moste humblie beseche your honnor, for the love your honnor hath of the p*re*seruacon of her highnes estate, that your honnor woulde, yet once againe, p*er*vse the saide articles, And if there be anie, that shall make anie obiection, against anie one of them that with your honnors favour, I maie be p*er*mitted, to answere the same, before your honnor, or the rest of her highnes honnorable councell, And that there maie be, some spedie remedie for the same wante. Orell*es* there is noe other successe to be loked for, but that greate dishonnor will fall to her ma^{tie}, and to your honnors, wth greate greife to all faithfull subject*es*, but great victorie is like to ensue to the enymyes, whensoeuer her ma^{tie} shall haue occasion to encounter them, and all because your honnors did not vse the meanes to prevente the same when tyme served, And thus once againe my good lorde I crave your honnors favourable p*ar*done, for my over boldnes herein, And so I comit your honnor to the tuytion of the almightie, for whome (as my dutie buideth) I will contynuallie praie/.

your honnors moste humble to comaunde/.
Wm Thomas.

Jan. 1584 m^{r} gonner of the Victory

Appendix V

Elizabethan Artillery Terms

(including other munitions commonly listed with the ordnance)

The following definitions provide a basic summary of the various objects used in gunnery in the sixteenth century. Absolute identification of all of them is difficult, especially with regard to ordnance types, which occasionally overlap or are used with different meanings by different writers. See above, pp. 275*f* for further discussion.

References:
[1] R. Norton, *The Gunner* (London, 1628), p. 53.
[2] D. Loades, *The Tudor Navy* (Aldershot, 1992), p. 286-7.
[3] A.R. Hall, *Ballistics in the 17th Century* (Oxford, 1965), p. 166-8.
[4] T. Smith, *The Arte of Gunnerie* (London, 1600), p. 1.

Base the small and uncommon pieces of artillery, the base had a bore of 1¼´´ and a length of about 3½´, and weighed about 200 lbs. (33-caliber length) [1]; the term "wagon-base" refers to these guns mounted on carts for mobility.

Bastard a prefix used with cannon and culverin class guns to indicate that they deviate from accepted proportions, usually slightly smaller (either bore diameter or length).

Bastion a protruding section of a fortress' wall, often shaped like an arrowhead allowing the artillery mounted inside to fire out from the walls as well as rake their length.

Battery direct fire intended to breach a town or fortress wall (or, buy extension, direct fire against a ship); also a line of guns set up for such purpose. (*cf.* bombardment)

Bill a common type of pole arm, usually with a straight, parallel-sided blade with a small hook at the top, derived from agricultural reaping implements; "blackbills" were fire-blackened or blued bills which were less prone to rust.

Bombardment high-angle, lobbing fire intended to destroy or set afire structures behind an enemy wall; frequently used with incendiaries and considered less honorable than battery (*q.v.*).

Breech the back, or tail end of the cannon, where the touch-hole (*q.v.*) is located.

Caliber the non-dimensional measure of a gun's size equal to the inside diameter of the barrel. Thus, a 12´ long demi-cannon of 6´´ bore was 24 calibers long (12´=144´´/6´´=24).

Caliver 1. a large hand firearm, usually supported on a rest.

2. a metonym used as a synonym for culverin (*q.v.*).

Cannon (*q.v.* Perrier, below) the largest of the common pieces of battery, the cannon proper had a bore of 7´´ and a length of about 10´, and weighed about 5000-7000 lbs. (17-caliber length). [3]

There were other types of cannon with names such "Cannon Royal" or "Elizabeth Cannon" which tended to have bores of 8´´, lengths from 8-10´, and weights up to 8000 lbs. (12-15-caliber lengths); sources occasionally list cannon with bores up to 14´´ (*e.g.*, [3], p. 46), but these were rarely if ever made in this period.

Cavalier a raised platform inside the bastion of a fortress upon which the cannon would be mounted to allow them a commanding view of the perimeter.

Culverin (*q.v.* Perrier, below) the most common pieces of battery both by land and sea, the culverin had a bore of 5½´´ and a length of about 11´, and weighed about 4500 lbs. (24-caliber length) [3]

Curtal also "curtow"; an early short (as in "curt") gun, firing shot of undefined size. [OED, *s.v.* "curtal" A.4.a.]

Demi-Cannon (*q.v.* Perrier, below) the demi-cannon had a bore of 6½´´ and a length of about 12´, and weighed about 4000 lbs. (22-caliber length). [3]

Demi-Culverin (*q.v.* Perrier, below) the smallest of the pieces of battery, the demi-culverin had a bore of 4½´´ and a length of about 10´, and weighed about 3500 lbs. (27-caliber length). [3]

Dispart also "dispert"; the small front sight on a piece of artillery that gunners manufactured and attached to the muzzle; also the verb for the procedure of making a dispart.

Drake an early small gun, firing small-diameter shot of undefined size, but usually under 2´´.

Falcon the second smallest of the common pieces of great ordnance, the falcon had a bore of 2½´´ and a length of about 6´, and weighed about 800 lbs. (29-caliber length) [3]

Falconet the smallest of the common pieces of great ordnance, the falconet had a bore of 2´´ and a length of about 4´, and weighed about 500 lbs. (24-caliber length). [3]

Firework(s) a generic term used for any inflammable composition using gunpowder, saltpeter, flammable oils, and resins. In Elizabeth's time, this referred not only to ground and aerial displays as we know them today, but also incendiaries for use against, troops, horse, ships, or towns.

Fowler another form of small ordnance, largely obsolete by Elizabeth's reign; it had a bore of less than 2´´, and a length ranging from 3-5´ (18-30-caliber length).

Hackbutt also “hagebut” and other similar variants; a corruption of the German *Hackenbüchse*, or “hook-gun”, which was a small-bore canon (1´´ or less) used primarily on wall defenses. The hook, cast as part of the barrel, protruded below the muzzle to be hooked over a parapet or wall, absorbing the recoil of the shot.

Halberd also “halbert’; a pole arm with a triangular, axe-like blade and a spike on the top. Often gilt for ceremonial guard duties.

Lintstock a rod or pole with a clip at one end to hold a slow-burning match (a cotton or linen rope impregnated with gun-powder or saltpeter) with which gunners would touch off their cannon; its length allowed them to stand to once side of the cannon and remain clear of its recoil.

Minion a medium-small piece of great ordnance, the minion had a bore of 3´´ and a length of about 8´, and weighed about 1000 lbs. (32-caliber length). [3]

Morris Pikes a generic term for a pole arm with both blade and spike; a corruption of “Moorish” pike [2]

Musket Arrow an arrow specifically made to be fired from a personal firearm in place of the bullet; the shafts tended to be stouter and the fletching stiffer than common arrows.

Muzzle the open end of the cannon pointing towards the target.

Pace a unit of distance equal to 5 feet commonly used to describe ranges. [4]

Perrier used as a modifier for other cannon names or sometimes by itself to specify a type of cannon that fired stone shot.

Port Piece an early heavy gun, firing stone shot of undefined size [2]

Random also “randon”; a term used for both the elevation of a gun (in degrees or points [7.5°]) and the range attained at that elevation; “Utmost Random” referred to the maximum range and usually to 45° elevation.

Robinet an form of small ordnance, somewhat obsolete by Elizabeth’s reign with a bore of $1\frac{1}{2}$´´ and a length of 4´ (32-caliber length). [1]

Saltpeter The principle ingredient of gunpowder (~75-80% by volume); a nitrate of either potassium of sodium (KNO_3 or $NaNO_3$) refined from animal and human waste.

Saker the largest of the field pieces, the saker had a bore of $3\frac{1}{2}$´´ and a length of about 9-10´, and weighed about 1400 lbs. (30-34-caliber length). [3]

Shot any non-incendiary projectile shot from a cannon. The different types of shot are:

Chain Shot: two spherical cast iron pieces connected by a length of chain, usually 1-2 feet long, and used either against troops or ships' rigging.

Cross-Barred Shot: Two hemispheres joined by a solid iron bar like a baton, and cast in one piece 1-2 feet long. Generally used against ships' rigging.

Dice Shot: shot in the form of small metal or stone cubes used as anti-personnel fire. Loaded in their own paper bag or as part of a cartridge.

Hail Shot: any shot consisting of small fragments (musket balls, dice, nails, broken pottery, etc.) used as anti-personnel fire. Also usually pre-bagged.

Jointed Shot: two cast iron balls connected by two hinged iron bars. Like chain shot, the balls would separate upon firing, but the solid bars acted as scissors on the target.

Tampion also "tampon"; a block of wood or cloth placed between the charge and the shot in a cannon to more fully contain the force of the charge's explosion; called "wadding" by the 19th century.

Touch-hole The small hole on top of the breech to which the gunner touches the lit match to fire the cannon.

Trunk also "trunke"; a cylindrical firework device, usually mounted on a staff, that spewed flame from one end. Possibly similar to modern Roman candles.

Wildfire a type of firework, but one specifically for incendiary use. Wildfire can either be an ingredient in other fireworks or a type of firework itself.

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MS 512	Henry Percy's "booke of Memoriall of things belonging to the warrs," n.d. (*c*1600?)

Folger Shakespeare Library, Washington, DC
MS V.b.182 table of ordnance

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