The Heirs of Archimedes: Science and the Art of War through the Age of Enlightenment edited by Brett D. Steele and Tamera Dorland

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Brett Steele and Tamera Dorland's edited volume grew from presentations made at two conferences, 'Science and Warfare in the Old Regime' in 1998 and 'Colonels and Quartermasters' in 1999. The editors, by collecting these works, are trying to correct what they see as a lack of attention paid to the historical relationship between military technology and science; what attention it has received places it in the 20th, possibly the 19th century, whereas Steele and Dorland see this relationship emerging much earlier, with a significant flowering after the Renaissance. They introduce the collection by claiming, as did Voltaire, that this relationship extends as far back as the time of Archimedes, and then they shed light on that classical beginning. Through the succeeding essays, they hope to answer the question 'In short, when did Archimedes have real intellectual heirs who re-created for themselves his personal union of science and the art of war?' [3]. That brings up a key point of this book, particularly in regard to its title: despite the introduction, the focus of the book is firmly on the 'Heirs' and *not* on 'Archimedes'.

The introduction gives an excellent, concise, historical, and historiographical account of the science-military connection. I found that some parts of this introduction, though, lead the reader down the wrong path by creating some expectations of discussions that never occur in the collected essays (nor should they, I have also come to believe). In describing Archimedes' intermingling of science and war, the editors provide a framework, accompanied by a diagram, that maps connections, decisions, and/or movements made by Archimedes. Steele and Dorland draw on modern terminology to write sentences such as 'For Archimedes, the science of mechanics may have

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also facilitated the optimum coordination of the tactical, operational, acquisitional, and political domains' [6]; and in their brief overviews of each essay, they sometimes employ these terms and framework. But this does not seem necessary or fruitful for full appreciation of the links that they are trying to describe, nor does any of the essays use this language.

A major strength of the book lies in its organization, for which the editors should be commended. The essays have been well-grouped into four sections. Each section either explicitly or implicitly uses a technology or technological process as its focal point (gunpowder weaponry, naval innovations, gunpowder production, and military engineering/artillery). Within each section, the articles, although informative and thought-provoking on their own, are often so compatible that they create a much richer narrative when coupled and grouped together as done by Steele and Dorland.

The four essays in the book's first section, 'The Global Development of Gunpowder Weaponry', describe historical developments and events that occurred whereby formal science was *not* 'a necessary condition for the invention, innovation, and diffusion of the fundamental weapons systems that dominated the late Medieval and Renaissance eras' [13]. One might ask why they are thus included in this work. The answer is that they are crucial in describing the cultural, and especially technical, landscapes that existed prior to the inclusion of formal science: the choice to include science and its impact on certain cultures is made clearer by comparison with an earlier time that lacked this relationship.

In 'Facing the New Technology: Gunpowder Defenses in Military Architecture Before the *Trace Italienne*, 1350–1500', Kelly DeVries extends an earlier study in which he focused on changes made in fortification design and construction prompted by the use of gunpowder weapons used against them, to show how gunpowder weapons changed the nature of siege warfare during this period. His previous study tried to show that the *trace italienne* (a type of defense work design) was an evolution from medieval work, rather than the revolution in design claimed by Geoffrey Parker [Parker 1988]. DeVries obligingly gives enough explanation of his earlier study so that readers will have no trouble understanding how and why this present article offers an even better example in support of his claim. While

both DeVries and Parker had used England and Italy for their earlier studies, DeVries now switches to France and the southern Low Countries as more indicative of this evolutionary change; he believes it is perhaps more fruitful a time and place for this type of study, as this area was more of a hotbed of continuous war. He describes the construction of four basic gunpowder fortification defenses: gunports, boulevards, artillery towers, and pre-*trace italienne* and non-*trace italienne* artillery fortifications. Within the essay, DeVries uses a rich combination of extant structures, historical accounts, and plans as evidence; he includes copies of some of these, and relevant photos that greatly enhance our understanding of the changes made in construction and design.

Frederic J. Baumgartner's article is in many respects a good companion piece to DeVries' study, and a wise choice in organization by the editors. Where DeVries focused on French choices regarding military architecture in the late Middle Ages, Baumgartner concentrates on French choices regarding firearms in the early modern period. In 'The French Reluctance to Adopt Firearms Technology in the Early Modern Period', Baumgartner cites 15th-century losses to Swiss pikemen and the influence of several groups, such as French artisans and the French military forces, as barriers to the adoption of firearms. There are some similarities in Baumgartner's case to the Japanese cultural resistance described by Noel Perrin in *Giving Up the Gun* [Perrin, 1979]. Baumgartner claims that France, as a major participant in 16th-century European wars, would have played a different role if it had not been reluctant to adopt firearms; and that this reluctance impacted the way in which treasury funds were disbursed and allowed Spain (which had adopted a firearms culture) to obtain and maintain an edge. An interesting question emerges from the DeVries and Baumgartner studies as to just where states were placing their attention and funds and why. The articles taken together give a more complete picture.

In an essay showcasing the mastery of sources and care for bibliography that colleagues have come to expect from him and eagerly anticipate, Barton C. Hacker expands our understanding of the introduction and use of gunpowder technologies beyond the European boundaries. In 'Gunpowder and the Changing Military Order: The Islamic Gunpowder Empires, *ca.* 1450–*ca.* 1650', his research focuses on three 'gunpowder empires', as designated by Marshall Hodgson

[Hodgson, 1974], that were large military-patrimonial-bureaucratic states: the Ottoman empire in the Near East, the Safavid in Iran, and the Mughal in India [88]. After first reviewing the Mongol successes of the 13th century and the impact that gunpowder firearms had on their decline in the 15th and 16th centuries, Hacker describes the Ottoman janissary corps and its acquisition and use of European gunpowder technology. In the case of the Safavids in Iran, it seems to have been more a problem of wanting firearms but not being able to get them. The Shah, encountering resistance to firearms among his supporters, established a standing army drawn from a slave class. European expansion influenced the rise of the Mughal gunpowder empire in India, in addition to contact with, and acquisition of technology and tactics from, the Ottoman empire. Key in all three empires covered by Hacker seems to be the personal interest taken by the ruler himself in the actual technology. Hacker concludes that, as is clearly shown in these cases, gunpowder use favored well-organized central authority [95].

Citing old fallacies that have been slow to die, Gábor Ágoston has two agendas in 'Behind the Turkish War Machine: Gunpowder Technology and War Industry in the Ottoman Empire, 1450–1700', as he tries 'to demonstrate the need for a more balanced and cautious approach in studying [Ottoman] military technology by broadening the scope of examination' [102]. He does this by first commenting on the questionable biases that exist and have existed in other studies and, second, by looking more closely at the Ottoman war industry and its supply of weaponry and ammunition. For example, Ágoston points out that the employment of foreign technicians and artisans by the Ottomans does not mean they were technologically inferior, as all of Europe was doing the same thing [106]. While the impressive flood of facts can be overwhelming, and at times it seems as if there are two essays here instead of one, Ágoston's contribution is both an enlightening piece of research and a good cautionary tale to historians that no subject has seen its final word. And, as before with the DeVries and Baumgartner essays, reading the Hacker piece followed by the Ágoston piece gives readers a much more comprehensive view of this region and time period.

The second section of the book, 'Naval Innovations: Hardware and Software', contains essays in which the authors explore a subject by focusing on the life and work of a central figure or figures. In

the first essay, Alexzandra Hildred's 'The *Mary Rose*: A Tale of Two Centuries', the central figure happens to be a ship. Although the editors claim that the essays in this section 'address the relationships between early modern science and naval power' [17], and despite revolutionary innovations seen on the *Mary Rose*, Hildred's study demonstrates a 'limited relationship between scientific theory and naval practice' [18]. She argues that major developments in naval warfare during the late-15th and early-16th centuries were prompted by developments in the shipyards, where new armaments and designs were being integrated with the old rather than replacing them, and that the resulting changes in design and construction are indicative of a new stage in the tactics of naval warfare. In many ways, Hildred's study can be viewed as the biography of a famous artifact, which is often much harder to write than that of a person—what 'tale' is the ship able to tell about the changes in its 'life'? Hildred's detective work is impressive, as she draws on the artifact, historical documents such as ship inventories, and visual works in an attempt to tell this tale. Why is this one ship so significant? As Hildred states, 'neither shipwright's plans nor models exist in Britain for vessels of this period' [142]; so the discovery and analysis of the *Mary Rose* provides exciting new avenues for historical research in many areas.

In Lesley B. Cormack's 'Mathematics and Empire: The Military Impulse and the Scientific Revolution', we finally see much clearer connections between science and the military, and 'heirs' (as promised by the editors), emerging in 16th and 17th century Europe. Cormack claims that mathematical practitioners 'signify a connection between the Military and Scientific Revolutions' [182]: 'these men combined mathematical insights with commercial concerns and laid basic foundations for the Scientific Revolution in England' [181]. Mathematical practitioners connected theory and practice in their approaches and investigations. To illuminate these abilities and connections, Cormack focuses on the works of the geographers Edward Wright and Thomas Harriot, who both used their voyages of discovery in their theoretical attempts to explain the world, and who both represent the reliance of research on continuing forms of patronage. The military fits into their stories in a broader way: European rulers, with an eye toward imperial expansion, sought the help of the mathematical practitioners who, in seeking patronage, were more than

willing to look for research areas and to choose issues important to military expansion and practice [195].

Amir Alexander follows Cormack in looking at mathematical practitioners; but where she uses Edward Wright and Thomas Harriot, Alexander focuses on Thomas Harriot and John Dee. As described by Steele and Dorland in their introduction, where Cormack 'revealed many similarities' in her study, Alexander's work highlights 'vast differences' between his subjects [20]. In the title of his article, Alexander asks: 'Harriot and Dee on Exploration and Mathematics: Did Scientific Imagery Make for New Scientific Practice?' He restates and expands upon this question early in his study, asking 'Do different scientific approaches draw on different inspiring tales, and do conflicting metaphors tend to generate opposing scientific practices?' [206]. Again like Cormack, Alexander uses biography as background for exploring such differences as exhibited by Harriot and Dee. For instance, although both men were 'leading advocates and practitioners of maritime exploration and imperial expansion' [208], Dee's arguments for British supremacy sprang from legal and historical foundations, while Harriot's sprang from a spirit of adventure and the hope of financial gain. Alexander proceeds with his investigations by analyzing maps and drawings made by these men that further serve to demonstrate how they perceived the relationship between mathematics and exploration.

As with the other essays in section 2, Michael S. Mahoney's 'Charting the Globe and Tracking the Heavens: Navigation and the Sciences in the Early Modern Era' focuses primarily on a central figure (or figures), his work and its greater impact In this case, the subject is Christiaan Huygens, his work on clocks, its impact on the longitude problem, and its broader implications for the new mechanics. Mahoney depicts Huygens as working within the context of the relationship between war and science: Huygens investigated clocks to find practical benefits to navigation for war (and commerce and exploration), but this had benefits to the science of mechanics as well. This work on clocks furthered a relationship between science and the state: Mahoney explains how Huygens and his work on clocks played a pivotal role in the relationship between the Academy of Sciences and the government of Louis XIV.

Brenda J. Buchanan's essay, 'The Art and Mystery of Making Gunpowder: The English Experience in the Seventeenth and Eighteenth Centuries', opens the third section, 'Gunpowder Production: The Refinement of Waste'. In it, Buchanan cites the lack of attention paid by historians to the development of, and experimentation with, gunpowder manufacturing in England during the early modern centuries, as the inspiration for her research [234]. She successfully presents in four phases 'a thorough analytical history of early English gunpowder acquisition' [234] that demonstrates its evolution from a 'craft-based practice to a process based more securely on scientific methodology' [265]. Her story stretches from English attempts to adopt the skills of foreign craftsman through the shift to home manufacture of gunpowder that culminates with the contributions made by Charles (later Sir Charles) Frederick (1709–1785) during his tenure at the Board of Ordnance and the Royal Laboratory in the latter half of the 18th century. Frederick advocated powder manufacture that incorporated both the art and the science of the time; it was good practice coupled with an experimental approach [262]. By the end of the essay, gunpowder has acquired almost human qualities—a life of its own—in Buchanan's narrative.

In 'Chemistry in the War Machine: Saltpeter Production in Eighteenth-Century Sweden', Thomas Kaiserfeld 'addresses how science participated in organizing production' of saltpeter in Sweden during this time period, under the competing influences of agrarian, military, and mining interests [275]. Kaiserfeld presents the reader with an enigma, and effectively demonstrates how it occurred: technical changes in saltpeter production based on scientific findings prompted a reversion to an older institutional condition (control by the peasantry), rather than the rise of a new condition as one might assume. While explaining how a new understanding of saltpeter evolved, he also treats the reader to an array of characters who participated in the debates over who would control its production.

Seymour H. Mauskopf makes a good case for why historians of science should be interested in the development of munitions in the 18th and 19th centuries, rather than being 'usually puzzled and put off' because they think that nothing really happened in that area after the ascendancy of firearms [292]. In 'Chemistry in the Arsenal: State Regulation and Scientific Methodology of Gunpowder in Eighteenth-Century England and France', Mauskopf focuses on 'the

developing role of the state in the regulation of munitions' production and the role of science in the hoped-for amelioration of munitions' [294]. Mauskopf elucidates the role of science in the reform of the gunpowder industry and the improvement of gunpowder by highlighting the organizational reforms of Antoine-Laurent Lavoisier, as a director in the Régie des Poudres, and of William Congreve, as Comptroller of the Royal Laboratory at Woolwich, and their systematic and experimental investigations of gunpowder [314]. As clearly evident in this essay, the reader may notice the emerging theme of 'better war through science'. Mauskopf says that 'given the historical conundrum of gunpowder, science, and the Military Revolution, I want to be cautious with my claims' [315]. But in this brief, well-structured and clear piece, it seems as if his claims are justified, and that historians should start taking note of this, in addition to other topics that might have been getting the same cold-shoulder.

The final section, 'Military Engineering and Artillery', with its two essays, has the clearest connection to the ideas presented in the book's introduction regarding the heirs of Archimedes, although the essays themselves do not bring Archimedes or that connection into their discussion. In 'Eighteenth-Century French Fortification Theory after Vauban: The Case of Montalembert', Janis Langins focuses 'on France and the relation between science and military engineering, a central issue for warfare in both the Baroque and the Enlightenment Ages' [335]. He does this by first looking at the object or artifact, and then moving to the actors. He sets the stage by giving examples of the interaction as it played out in practical military needs, such as the influence of topographical studies on siege warfare and fortification design. Then, using the verbal battle between Marc-René, the Marquis de Montalembert (1714–1800), and the French military engineering establishment over fortification design, Langins explores 'to what extent formal science was used by fortifiers in their material as well as rhetorical designs' [335]. An underlying and recurring question, as pointed out by Langins here and elsewhere [Langins 2003], is what exactly was 'science' in the 18th and 19th centuries? One can appreciate this essay even more by returning to several of the earlier essays, particularly the DeVries piece: the significant developments in fortification design and siege warfare become clearer upon comparison of the essays.

Co-editor Brett D. Steele contributes the final essay in the book. In 'Military "Progress" and Newtonian Science in the Age of Enlightenment', he 'explicitly addresses the convergence of Enlightenment ideals of progress and military practice in the eighteenth century' [26]. His insightful introduction to the essay points out that modern-day notions of technological progress and success may not apply to 18th-century Europe. 'More illuminating is to historicize eighteenth-century artillery by asking how close its organizers conformed to the notion of "progress" according to the standards of their own era' [362–363]. For example, Steele describes how several European schools of artillery, such as the Turin Academy, attempted to unify Newtonian science and artillery practice in a setting of formal education. Weaving together historical data and events, and intellectual developments, Steele paints a very comprehensive picture of ballistics researchers and artillery institutions working within the context of Enlightenment thought.

There are a few disorienting features to this collection. As I pointed out previously, the editors introduce a modern framework that, despite comments in the introduction, is often difficult (and unnecessary?) to reconcile with material presented in the essays. Also, in their introductory comments for each essay, the editors seem to be reading much more into some of the articles than is actually there, sometimes bringing in material that is not covered by the authors (for example, in their discussion of the *tercio* in relation to the Hacker piece). While this is admirable in some ways, it can also be misleading. Finally, though usually in reviews I do not comment on the 'look' of the book, there is, I must say, a typesetting or formatting problem throughout the book that is so prevalent as to be distracting. There is often no spacing between the period at the end of a sentence and the beginning of the next sentence, making paragraphs read like huge run-on sentences. Not something I would have expected from this particular press.

When invited to write a book review, one is often asked to comment on the work's place in the current scholarship of a field. For this collection of essays, it is an easy task: this collection is much of the most current and interesting scholarship addressing the historical evolution of the relationship of science and military technology. And, as I mentioned earlier, the organization of the essays strengthens the readers' understanding of that evolution. Was (and is) there 'better

war through science'? Although that may not be answered here, this book demonstrates the ways in which the inclusion of science and the relationship to scientific figures and institutions changed the technology and nature of warfare. Admittedly, if someone does a keyword search on 'Archimedes' and gets the citation for this collection, he might be disappointed. But for those interested in the history of the relation of science and military technology, this is an excellent, long-awaited contribution to the subject.

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