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Brett D. Steele and Tamera Dorland, Eds. *The Heirs of Archimedes: Science and the Art of War through the Age of Enlightenment*. Cambridge, Mass.: The MIT Press, 2005. 397 pp. Notes and index. $55.00 U.S. (hb). ISBN 0-262-19516-X.

Review by Michael Wolfe, Pennsylvania State University, Altoona.

After the nuclear annihilations of Hiroshima and Nagasaki brought the carnage of World War II to an end, historians naturally began to investigate the roots of what seemed the obvious relationship between modern science and modern war. The notion of "revolution" no doubt seemed irresistible when seeking to characterize developments that bore such awesome results, as seen beginning with Herbert Butterfield's Cambridge lectures in 1948 on the origins of modern science and Michael Roberts' lecture seven years later at the Queen's University of Belfast on the "military revolution."[1] While the concepts of the Scientific Revolution and Military Revolution continue to be refined and revised, dissenting voices, most persuasively that of A. Rupert Hall, have long contested the assertion that the art of war prior to 1800 owed much, if anything, to the changes wrought by the paradigm shift to the Newtonian universe.[2] Although most of the contributors argue in favor of a vital relationship between these two "revolutions", they do little in the end to seriously contest Professor Hall's original thesis. Indeed, the new warfare perhaps owed less to Archimedean mechanics and more (much more) to the strong-willed architects of the bureaucratic state and gifted craft innovators in brickworks, forges, foundries, and shipyards across Western Europe.

The introduction by Brett Steele and Tamera Dorland laments the general ambivalence, if not downright negligence, that most historians display toward the impact of the new science on the art of war prior to 1800. Yet their discussion of the complexities of military organization point in a distinctly Weberian direction, for the greater levels of operational planning and execution achieved by the early modern state sprang more from administrative rationalism than scientific reason--a point that a number of the essays also later confirm. The essays in part one examine the impact of gunpowder technology in Christian and Islamic lands from the late 1300s to the 1700s, and unwittingly affirm Hall's thesis that "formal scientific knowledge played a nominal role in the transformation of gunpowder weapons into essential military instruments" (p. 12).

Kelly DeVries opens with an essay that continues his ongoing investigation into the early impact of gunpowder weaponry on fortification design in northern Europe in the late fourteenth and fifteenth centuries. He further confirms his initial findings that design innovations, such as gunports, boulevards, and artillery towers, constituted an integrated system of defense that predated the celebrated *trace italienne*, so emblematic for Geoffrey Parker and other likeminded historians of the Military Revolution's synergy with Euclidean geometry. Drawing on his earlier synthetic study on the history of war, Frederic J. Baumgartner attributes the abiding reluctance of the French to embrace firearms technology prior to the seventeenth century to the cultural prejudices of French aristocrats rather than the technical deficiencies of French artisans.[3] The key change, first seen among the Spanish whose nobility adhered no less fiercely to a code of martial honor, lay in adopting more bureaucratic soldierly norms that made possible the creative deployment of arquebuses in the famed *tercio* infantry formations--a move it took the French more than a century to emulate.

The tension between hidebound warrior caste traditions and more rational, technologically-based behaviors also affected the military policies of the Ottoman Turks, argues Barton Hacker in his essay on

Islamic gunpowder empires between 1450 and 1650. The term "gunpowder empires" achieved currency in the 1970s in the work of Marshall Hodgson and has since found a central place in world history studies.[4] It refers to the huge military-patrimonial-bureaucratic states built by Ottoman, Safavid, and Mughal rulers that stretched from the Balkans across upper Mesopotamia and Persia to the vast Indo-Gangetic plains of northern India. Hacker synthesizes recent scholarship on these regimes, which (much like their Christian counterparts in Europe) employed gunpowder technology mainly to secure central control over regional warlords. Gunpowder weaponry (again, much as it did in Christian Europe) altered the complex political and social calculus on which stability rested, though resistance to such innovations, together with serious fiscal constraints, eventually brought these changes to a halt in the eighteenth century, after which the Islamic gunpowder empires found it increasingly difficult to compete with better-equipped and better-trained European armies and navies. Prior to this historic divergence, Christian Europe and the Ottoman Empire exhibited remarkably similar patterns in terms of acquiring and domestically developing new firearms and gunpowder manufacturing capabilities, according to Gábor Ágoston in his essay on what he calls "the Turkish war machine" (p. 101). In this well-researched and tightly argued piece, Ágoston rejects as a historical fallacy the Ottomans' reputed technological backwardness prior to 1700. They fell short rather because of their cultural reluctance to embrace the new mathematical and mechanistic sciences in the eighteenth century. This limited the Turks' technical proficiency to compete with Christian enemies, particularly the Hapsburgs and Romanovs, who began after 1700 to coordinate their military actions against the overextended Ottoman Empire.

The essays in part two address the interactions between mathematical science and naval power. Alexandra Hildred's essay on the monster Tudor warship, the *Mary Rose*, analyzes recent archeological discoveries at the wreck site at Spithead where the ship sank in 1545. Based on this evidence, she argues that "the major developments that revolutionized early modern naval warfare were borne neither in the forge nor in the foundry but in the shipyards" (p. 137). Structural innovations in the ship's design enabled it to be outfitted with a myriad of different guns, many already quite antiquated; these advances nevertheless pointed to the future importance of firepower, rather than the ability to board another ship, in naval tactics. Here again the ability of the Henrician state to mobilize the resources necessary for constructing such a vessel proved critical, not any new developments in science. Hildred's essay, while interesting, will be of limited scholarly use because it lacks footnotes. Nor is it altogether clear where mathematical sciences fit into the picture here.

Such is not the case in the next essay by Lesley B. Cormack on the close connection between theoretical mathematicians and practical navigators. Drawing on her recent study of geography education in England, Cormack identifies the crucial role played by a group of men, such as Edward Wright (1561-1615) and Thomas Harriot (1560-1621), whom she calls "the mathematical practitioners" (p. 182).[5] They sought ways to apply new mathematical concepts to the arts of navigation and cartography, tackling among other problems the knotty challenge of determining longitude. State patronage of these inveterate adventurers and tinkers "proved extremely attractive in this time of military and imperial expansion," Cormack argues (p. 187). She attributes these transformations to the evolving socio-economic and political structure of early modern Europe rather than some deep shift in metaphysics and epistemology, however. Echoing the views of Steven Shapin, she considers the Scientific Revolution (and also the Military Revolution?) largely as a sociological, not an intellectual phenomenon.[6]

In another gloss of a recently published monograph, Amir Alexander examines the relationship of rhetoric and imagery to scientific practice in the work of John Dee (1527-1609) and Thomas Harriot.[7] Like Cormack, he sees a close link between exploration and empire and advances in mathematics, though he argues for growing metaphysical differences as well. Dee envisioned empire in more universalistic, Neo-Platonic terms, where mathematics served to unlock the analogical mysteries of the cosmos, while Harriot evinced a much more pragmatic, Baconian approach to discovery that valued utility and progress. Part two concludes with a very brief essay by Michael S. Mahoney on the centuries-long quest to determine longitude, a problem finally solved in 1743 by the marine chronometer invented by John Harrison (1693-1776). While Mahoney suggests that this story was one of the "possible links between the Scientific and Military Revolutions" (p. 221), his essay never really goes in that direction but instead stresses how the new science "became part of the infrastructure of the modern state" (p. 228). Beyond the creation of more accurate maps and navigational techniques, it is still not altogether clear what any of these developments had to do with the Military Revolution beyond temporal coincidence.

The essays in part three explore different aspects of gunpowder manufacturing. Brenda J. Buchanan's excellent essay on English gunpowder production argues that this state-managed industry relied on skilled craftsmen and time-honored methods to make gunpowder. From the outset, England imported significant quantities of saltpeter and sulfur, as well as sought to appropriate the skills of foreign craftsmen. Rising demand for powder in the seventeenth century, she argues, encouraged both technological adaptations and improved methods of procurement. The application of scientific thinking and experimental methods only began to occur after 1740, however, with the appointment of Charles Frederick to the Board of Ordnance. In the process, gunpowder manufacture came to rely less on the "art and mystery" (p. 265) of skilled craftsmen and more on ensuring quality through controlled conditions based on scientific methodology.

Thomas Kaiserfeld's essay on gunpowder production in eighteenth-century Sweden tells a slightly different story of institutional continuity, if not regression, alongside scientific innovation. Sweden's rise as a paramount military power in the sixteenth century owed much to the state-run system of processing saltpeter from animal and human waste in special state-run saltpeter barns. In the 1700s, a debate arose in cameralist circles over how to use manure more efficiently both for gunpowder manufacture and fertilizing crops. Swedish officials turned to the brain trust assembled in the Royal Swedish Academy of Science, an institution modeled after the one established under Louis XIV. Like Charles Frederick in Britain, Swedish scientists and civil servants sought to improve the system of gunpowder manufacture using scientific methods arising from alchemy's transformation into modern chemistry. Yet it was the Swedish peasantry, long opposed to the state-run system of saltpeter barns, who eventually forced the Swedish Rikstag in 1805 to abolish the centralized allocation of manure and instead return it directly to the tillers of the land, much has been the practice prior to 1600.

Political factors also shaped the evolution of gunpowder works in eighteenth-century France and England, argues Seymour H. Mauskopf. His comparative study highlights institutional similarities and disparities between these two great adversaries as each sought to remedy deficiencies in the quality and quantity of powder available for realizing their competing military ambitions. In the search for better powder, both countries turned after the Seven Years' War to systematic and experimental investigations led by Antoine-Laurent Lavoisier (1743-1794) in France and William Congreve (1772-1828) in England. One measure of Enlightenment, they discovered, was that military power derived from the effective deployment by governments of science-based "useful knowledge" to reform and improve industry (p. 313). While that was the stated goal, a true understanding of the chemical properties of gunpowder only came, Maukopf concedes, in the second half of the nineteenth century. The synergy of modern science and modern war thus appear to be a very recent phenomenon indeed.

The two essays in part four close the volume with a look at military engineering and artillery during the eighteenth century. Janis Langins presents a synopsis of her recent book on French fortification theory after Sébastien le Prestre de Vauban (1633-1707), examining in particular the controversial ideas of Marc-René, the Marquis of Montalembert (1714-1800) on *la fortification perpendiculaire.*[8] Vauban had insisted that his methods of siege warfare could not be reduced into a science of hard and fast rules. Yet the generation of French military engineers he inspired, such as Bernard Forest de Bélidor (1697?-1761) and Louis de Cormontaigne (1695-1752), later converted his ideas into a prescriptive applied science that became taught at the legendary École de Mézières. The pioneering work with the calculus by Charles-Augustin Coulomb (1736-1806) introduced advanced mathematics into the military engineering curriculum, influencing both fortification design and the use of artillery. For all that, however, it was the social discipline instilled at the École de Mézières rather than scientific theory that made French military engineering the envy (and most copied) of the rest of Europe. As Langins demonstrates, both sides in the Montalembert controversy invoked science mainly as a rhetorical device to bolster their claims to legitimacy, rendering the status of the "science of fortification" in the late Enlightenment "ambiguous" at best (p. 349).

Brett D. Steele's concluding essay on so-called military "progress" and Newtonian science in the age of Enlightenment is essentially an extended critique of Ken Alder's 1997 book on the alleged technological shortcomings of the reform ideas of the French artillery theorist, Jean-Baptiste Gribeauval (1715-1789).[9] While conceding Alder's point on French advances in creating a technical bureaucracy, Steele argues that historians must judge technical applications at the time in terms of eighteenth-century rational mechanics, experimental physics, and military practice, not the latest modern sophisticated standards. Seen in this light, Gribeauval's ideas about ballistics made eminent sense theoretically (though less so on the battlefield). Steele provides an overview of the impact of Newtonian physics on the high-level mathematics of ballistics theory (principally differential and non-linear differential equations) and the ensuing incorporation of these new ideas into the curriculum of military schools, especially on the subject of artillery. Central to this process was the work of Benjamin Robins (1707-1751), a mathematical disciple of Newton, and the Swiss mathematician Leonhard Euler (1707-1783). Gribeauval's ideas thus proved very derivative, though nonetheless significant in advancing the place of Newtonian science and the calculus in formal military education. Steele may overstate his case, however, when he claims that this "intellectualization" of artillery technology in terms of the "mechanical philosophy of the Scientific Revolution was not unique to the eighteenth century," for if so, why did this embrace of the new science not yield much by way of military fruits until the late 1700s (p. 381)? His concluding remarks on Western military domination in the modern era ironically resurrect old chestnuts about Oriental backwardness that the earlier essays on Islamic empires had supposedly put to rest.

In conclusion, this collection of essays presents something of a mixed bag. Overall, it does not really make the case that a strong relationship existed between Archimedean mechanics (or is it Newtonian physics or Lavoisierian chemistry?) and the art (or should it be science?) of warfare prior to the mid-eighteenth century. Some of the essays are decidedly weak or derivative, though there are some real gems in the collection. Standouts include the pieces by DeVries, Ágoston, Buchanan, Kaiserfeld, Mauskopf, and Steele.

LIST OF ESSAYS

- Brett D. Steele and Tamera Dorland, "Introduction"

Part One: The Global Development of Gunpowder Weaponry

- Kelly DeVries, "Facing the New Technology: Gunpowder Defenses in Military Architecture before the Trace Italienne, 1350-1500"
- Frederic J. Baumgartner, "The French Reluctance to Adopt Firearms Technology in the Early Modern Period"
- Barton C. Hacker, "Gunpowder and the Changing Military Order: The Islamic Gunpowder Empires, ca. 1450-ca. 1650"

- Gábor Ágoston, "Behind the Turkish War Machine: Gunpowder Technology and War Industry in the Ottoman Empire, 1450-1700"

Part Two: Naval Innovations: Hardware and Software

- Alexandra Hildred, "The Mary Rose: A Tale of Two Centuries"
- Lesley B. Cormack, "Mathematics and Empire: The Military Impulse and the Scientific Revolution"
- Amir Alexander, "Harriot and Dee on Exploration and Mathematics: Did Scientific Imagery Make for New Scientific Practice?"
- Michael S. Mahoney, "Charting the Globe and Tracking the Heavens: Navigation and the Sciences in the Early Modern Era?

Part Three: Gunpowder Production: The Refinement of Waste

- Brenda J. Buchanan, "'The Art and Mystery of Making Gunpowder': The English Experience in the Seventeenth and Eighteenth Centuries"
- Thomas Kaiserfeld, "Chemistry in the War Machine: Saltpeter Production in Eighteenth-Century Sweden"
- Seymour H. Mauskopf, "Chemistry in the Arsenal: State Regulation and Scientific Methodology of Gunpowder in Eighteenth-Century England and France"

Part Four: Military Engineering and Artillery

- Janis Langins, "Eighteenth-Century French Fortification Theory after Vauban: The Case of Montalembert"
- Brett D. Steele, "Miltiary 'Progress' and Newtonian Science in the Age of Enlightenment"

NOTES

[1] Herbert Butterfield, *The Origins of Modern Science, 1300-1800* (New York: The Free Press, 1957), subsequently reprinted many times, and Michael Roberts, *The Military Revolution, 1560-1660: An Inaugural Lecture Delivered before the Queen's University of Belfast* (Belfast: Boyd, 1956), also reprinted many times, most recently in C. J. Rogers, ed., *The Military Revolution Debate: Readings on the Military Transformation of Early Modern Europe* (Boulder, Colo.: Westview Press, 1995), pp. 13-35.

[2] See in particular, Floris H. Cohen, *The Scientific Revolution: An Historiographic Inquiry* (Chicago: University of Chicago Press, 1994) and Geoffrey Parker, *The Military Revolution: Military Innovation and the Rise of the West 1500-1800* (Cambridge: Cambridge University Press, 1996). For Hall, see his essay "Science, Technology, and Warfare," in A. R. Hall, *Science and Society: Historical Essays on the Relations of Science, Technology, and Medicine* (Aldershot, Hampshire: Variorum, 1994), pp. 210-234. Hall first began to articulate his position in his seminal study on early modern ballistics, *Ballistics in the Seventeenth Century: A Study in the Relation of Science and War with Reference principally to England* (Cambridge: Cambridge University Press, 1952).

[3] Frederic J. Baumgartner, *From Flintlock to Spear: A History of War in Europe and the Middle East to the French Revolution* (New York: Praeger, 1991).

[4] Marshall G. S. Hodgson, *The Gunpowder Empires and Modern Times,* volume 3 of *The Venture of Islam: Conscience and History in a World Civilization* (Chicago: University of Chicago Press, 1974).

[5] Lesley B. Cormack, *Charting an Empire: Geography at the English Universities, 1580-1620* (Chicago: University of Chicago Press, 1997).

[6] A leading exponent of viewing the Scientific Revolution primarily as a sociological phenomenon has been Steven Shapin. See, for example, his *The Scientific Revolution* (Chicago: University of Chicago Press, 1996).

[7] Amir Alexander, *Geometrical Landscapes: The Voyages of Discovery and the Transformation of Mathematical Practice* (Stanford: Stanford University Press, 2002).

[8] Janis Langins, *Conserving the Enlightenment: French Military Engineering from Vauban to the Revolution* (Cambridge, Mass. The MIT Press, 2004).

[9] Ken Alder, *Engineering the Revolution: Arms and Enlightenment in France, 1763-1815* (Princeton: Princeton University Press, 1997).

Michael Wolfe
Pennsylvania State University, Altoona
mww4@psu.edu

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