CORRECTED 19 MARCH 2004; SEE LAST PAGE

BEYOND THE IVORY TOWER

The Sinews of War: Ancient Catapults

Serafina Cuomo

In antiquity, catapults not only changed the art of war, but also inaugurated a new era in the relations between political power and technical experts.

It is widely believed that in antiquity, theory and practice were on opposite sides of an unbridgeable divide and that science and technology were marginal to ancient society. Yet, a close look at the development of the catapult shows that such a divide did not exist in reality. Catapult engineers combined mathematical and engineering skills to create the most powerful weapons of their time. Both the engineers and their achievements were an important part of ancient society.

Image not available for online use.

Relief of a catapult facing the viewer on the grave of C. Vedennius Moderatus, late 1st century A.D.

Until the discovery of gunpowder, the catapult was the most powerful weapon. The Roman army had stone-throwers capable of hurling projectiles weighing 27 kg across a distance of 150 meters. Archimedes' legendary engines are said to have used stones three times as heavy. The construction of catapults or "belopoietics" (*poietike* = making of; *belos* = projectile, projectile-throwing device) was a key part of ancient mechanics, a branch of mathematics that also included fortification building, statics, and pneumatics.

Belopoietics attracted the interest and financial support of governments. It combined geometry, physics, and technology. Ancient engineers saw their knowledge as cumulative and progressive and believed that they were making an important contribution to the welfare of cities and the power of kings and emperors. The study of catapults thus challenges familiar historical stereotypes, including the idea that science and technology did not play an important role in ancient society.

Let us go back to Sicily, 399 B.C., Dionysius, tyrant of Syracuse,

> gathered skilled craftsmen, commandeering them from the cities under his control and attracting them by high wages … his purpose was to make weapons in great numbers and every kind of projectile … the catapult was invented at this time…, since the best craftsmen had been collected from everywhere into one place. The high wages as well as the numerous prizes offered to the craftsmen who were judged to be the best stimulated their zeal. Moreover, Dionysius circulated daily among the workers … and rewarded the most zealous with gifts and invited them to his table (*1*), §14.41.3–14.42.2.

That is an inspiring example of policy-driven research, if not of historical accuracy. In fact, catapults seem to figure in a 9th-century B.C. relief from Nimrud (Iraq). In the 4th century B.C., they spread rapidly around the Mediterranean.

The earliest Greek catapult was the "belly-bow," a large bow mounted on a case, one end of which rested on the belly of the person using it. When the demands of war required a faster, stronger weapon, the device was enlarged, and a winch pull-back system and base were added.

"The study of catapults [shows] that science and technology … play[ed] an important role in ancient society."

The next step was perhaps achieved by engineers working for Philip II of Macedonia. Instead of arms, the bow structure now had "springs," that is, tight bundles of sinews or ropes wrapped around two frames, which in turn were fixed on the case and connected with the release mechanism. A wooden arm was then inserted through each bundle or "spring" and a bowstring tied to the ends of the arms. The sinews in the springs were tightly twisted, imparting huge power when the arms were released. The torsion catapult could be used either as an arrow-shooter or, with a modified spring to allow for heavier projectiles, as a stone-thrower (*2*–*4*).

Further changes were introduced over time, and the theory of belopoietics was established. Philo of Byzantium (ca. 200 B.C.) remarked (*5*), §50.

> The ancients … did not reach a conclusion…, because their experience did not arise from many facts; but they did reach the heart of the matter they were looking for. Those after them examined the question on the basis of former mistakes, [used] subsequent experiments as a guide, and introduced the basic principle of construction.

This principle was that all parts of a catapult, including the weight or length of the projectile, were proportional to the size of the torsion springs.

Whereas in the old days of trial-and-error, results could never be guaranteed, the introduction of proportionality and thus mathematics allowed catapult construction to be almost standardized. Tables of specifications were compiled for quick and easy reference. From a geometric point of view, the problem of proportionally modifying the size of a catapult could be reduced to the problem of doubling the cube. Philo is our earliest direct source for a solution to this problem (*6*). Hero of Alexandria (1st century A.D.) provides an alternative proof (*7*). Both present an interesting combination of deductive style and mechanical procedure that relies on the use of a moving ruler.

In the belopoietics treatises, we find a combination of science and technology with experience and reflection. Philo underpins his account with theoretical explanations based on mathematics and physics,

The author is at the Centre for the History of Science, Imperial College London, London SW7 2AZ, UK. E-mail: s.cuomo@imperial.ac.uk

but also punctuates it with references to cost, expediency, durability, and structural strain. He identifies market demands and suggests improvements to old designs. He proposes an engine that provides long-range shots, because shooting far is something "which they display the greatest enthusiasm over and would exchange anything for," but does not recommend a repeat arrow-shooter, because he sees "no advance" in it (*8*).

The persons whose enthusiasm Philo courts may have been powerful political figures. He tells us that the technicians in Alexandria were "heavily subsidized because they had ambitious kings who fostered craftsmanship" (*5*). Biton addressed his artillery treatise to king Attalus I of Pergamum (241 to 197 B.C.), and Vitruvius his books on architecture to the Roman emperor Octavian. Demetrius Poliorketes, king of Macedonia (336 to 282 B.C.), built such war ships and siege towers that even his enemies admired the beauty of his creations. Plutarch tells us that it was Hiero, another king of Syracuse, who spurred Archimedes into military engineering. His splendid catapults kept the Roman troops at bay until the besieged city fell in 212 B.C. as a result of treachery. By the 1st century A.D., Roman technical expertise was such that Sextus Julius Frontinus proudly and somewhat prematurely wrote: "The invention of [machines of war] has long ago been completed and I don't see anything surpassing the state of the art" (*9*).

The remains of two 1st-century A.D. catapults in Cremona suggest that they could be in service to a legion for more than 20 years and that their production and allocation were controlled by the upper levels of command. Catapults appear as a normal part of military life on Trajan's victory column. More humbly, a catapult has also been found to mark the grave of a soldier (see the first figure). The epitaph tells us that Vedennius was an "architectus" with the army; was honorably discharged after 18 years; and was then retained, probably because of his technical expertise, for 23 more years. Tombs of soldiers were often decorated with a portrait of the deceased with weapons and body armor. Vedennius, or those who commissioned his tombstone, must have seen the catapult as the emblem of his life.

Other artifacts also point to the central importance of catapults in Roman society. The washer in the second figure (left) was found at a Roman temple in Bath, England, where pilgrims would cast votive objects into a sacred pool. When archaeologists drained the pool in 1979, along with coins, statuettes, and curse tablets they found a piece of a catapult. Its size suggests a small arrow-shooter. The washer must have been a prized possession for the person who offered it to the goddess of the temple. Perhaps an engineer had come to thank the divinity for having survived many campaigns.

Copper alloy washer, probably 1st century A.D. Placed on top of the twisted bundle in the spring carrier, it would have been pinned into place through the small holes on its rim.

Much has been made of the alleged ancient bias against technical knowledge and of the social marginality of its practitioners. But the treatises and objects discussed above tell a different story. By the end of the 4th century B.C., any state with political aspirations needed a semiprofessional army, any army required machines, and any city had to have a fortified wall. The change in ancient warfare is captured by a saying attributed to king Archidamus of Sparta (338 to 331 B.C.): Plutarch wrote that "On seeing the missile shot by a catapult which had been brought then for the first time from Sicily, he cried out, 'By Heracles, this is the end of man's valour!'"(*10*).

The military ideals epitomized by Homeric heroes and Spartan kings became threatened by different notions of leadership: more technical, knowledge- rather than virtue-based, acquired rather than innate. A leader needed new expertise, as evidenced by the treatises addressed to kings and other documents. For example, a 3rd-century B.C. inscription from the island of Ceos in the Cyclades regulates catapult shooting competitions for the young. They were to take place in the gymnasium, along with the other traditional Greek sports that were originally also meant as military training, and were rewarded with prizes (*3*).

The rise of advanced catapults, better fortifications, and manuals on artillery and tactics was accompanied by a rise in the visibility and status of engineers, who also worked as architects and surveyors. They were proud of their achievements: "Though very many years have passed since the design [of the catapult] was discovered and established, and there have naturally been many machine- and artillery-makers, no one has dared to depart from the established method. We were the first to do so and we have passed on many excellent ideas" (*11*).

The engineers saw themselves as an international community: Philo mentions his exchanges with colleagues in Alexandria and Rhodes, Biton his colleagues from Magnesia, Abydos, Macedonia, and Colophon. They also traveled: for instance, Zopyrus, a specialist in belly-bow design from Tarentum in Southern Italy, created one design in Miletus (Asia Minor) and another in Cumae (central Italy) (5, *12*).

With the ascent of Rome, technicians became more vocal and bolder in their statements. Vitruvius affirmed that the architect-engineer, as well as being a military expert, should know about history, law, and medicine, embodying an aristocratic ideal of a broad education. Hero claimed in his *Belopoietics* that catapults are necessary to the well-being and security of a city—the philosophy of machines compares favorably to the philosophy of mere speeches.

Catapults marked not the end of valor, but the beginning of a quest for more powerful and accurate ways of hurling projectiles against enemies and their cities—from oversized arrows to Patriot missiles. Ancient engineers had a role in society and often an ambivalent relationship with political power. The technology they boasted of may now be obsolete, but their anxieties, their curiosity, and their pride in their knowledge are not—perhaps the people behind the machine have not changed that much.

References and Notes

1. Diodorus of Sicily, *Library of History*, C. H. Oldfather, transl. (Harvard Univ. Press, Cambridge, MA, 1954), §14.41.3–14.42.2, with modifications. See also §14.50.4.
2. E. W. Marsden, *Greek and Roman Artillery: Historical Development* (Clarendon Press, Oxford, 1969).
3. Y. Garlan, *Recherches de poliorcétique grecque* (École Française d'Athènes, Paris, 1974).
4. D. Baatz, *Bauten und Katapulte des römischen Heeres* (F. Steiner, Verlag, Stuttgart 1994).
5. Philo, *Belopoietics*, (*13*), §50. Unless otherwise indicated, translations are taken from (*13*) and modified.
6. Philo, *Belopoietics*, (*13*), §52.
7. Hero of Alexandria, *Belopoietics*, (*13*), §117–119.
8. Philo, *Belopoietics*, (*13*), §56, 76–77.
9. Frontinus, *Stratagems*, C. E. Bennett, transl. (Harvard Univ. Press, Cambridge, MA, 1925), 3rd preface, with modifications.
10. Plutarch, *Sayings of Kings and Commanders …*, vol. 3 of *Moralia*, F. C. Babbitt, transl. (Harvard Univ. Press, Cambridge, MA, 1927), §191e with modifications. The same story can also be found in this volume in *Sayings of Spartans*, §219a.
11. Philo, *Belopoietics*, (*13*), §58–59.
12. Biton, *Belopoietics*, (*13*), §62, 65.
13. E. W. Marsden, *Greek and Roman Artillery: Technical Treatises* (Clarendon Press, Oxford, 1971).

14. The author thanks G. Al-Madfai, R. Ashcroft, D. Edgerton, E. Mayhew, and the librarians of the Institute of Classical Studies, London, for their kind help.

ERRATUM

post date 19 March 2004

ESSAY: "The sinews of war: Ancient catapults" by S. Cuomo (6 Feb. 2004, p. 771). Proper credit for the first figure, on page 771, goes to the German Archaeological Institute, Berlin, and for the second figure, on page 772, to the Institute of Archaeology, Oxford, UK.

Science

The Sinews of War: Ancient Catapults

Serafina Cuomo

Science **303** (5659), 771-772.
DOI: 10.1126/science.1091066