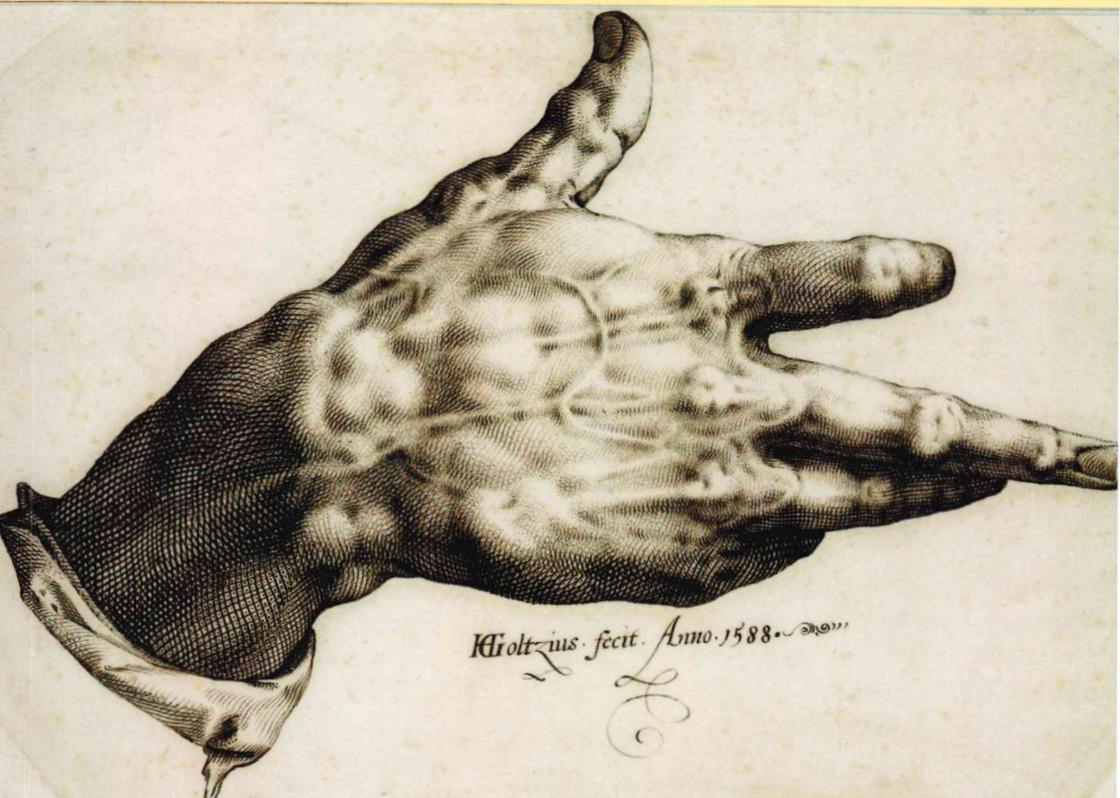


New Studies on Old Masters:
Essays in Renaissance Art
in Honour of Colin Eisler

Edited by John Garton and Diane Wolfthal



THE SCALING LADDERS OF LEONARDO DA VINCI: ART AND ENGINEERING

JOHN GARTON¹

In an increasingly war-torn Europe, Renaissance artists of the highest rank occasionally devoted themselves to military design. Francesco di Giorgio devised various assault weapons, Andrea Verrocchio and Hans Burgkmair each designed armour, Michelangelo created ramparts, and Albrecht Dürer wrote a treatise on fortifications — to name a few. Even artists averse to violence could hardly ignore the constant threat of war and its impact on the cityscape. Leonardo's notebooks, particularly the drawings assembled by Pompeo Leoni in the 1560s to create the *Codex Atlanticus*, chronicle Leonardo's involvement with weaponry design while serving Duke Ludovico Sforza of Milan. These drawings may never have been intended to form an organized military treatise; indeed, they range in style from quick, conceptual sketches to carefully shaded, perspectival showpieces probably meant to impress the duke or his advisors. The little-known sheet of drawings at the center of this essay dates to around 1487–90, a period of intense absorption for Leonardo in the arts of warfare. While the drawing's provenance has received some scholarly attention regarding possible origins in the *Codex Atlanticus*, its innovative technology remains poorly understood (fig. 7.1).² The sheet, now in the Pierpont Morgan Library, reveals much about Leonardo's thinking as a military

¹ My introduction to Leonardo studies began in 1998 in a seminar at the Metropolitan Museum of Art with Carmen Bambach, Associate Curator of Drawings and Prints. I choose to revisit Leonardo here, in honour of Colin Eisler, with the hopes that further scrutiny of the works of that polymath from Vinci might reflect warmly on Colin's eclectic interests and ceaseless work ethic. Certainly Colin's insatiable curiosity, compassion for animals and fondness for a crammed study are in keeping with Leonardo's character as recorded in sixteenth-century sources. I wish to thank the Higgins School of the Humanities, Clark University, for funding my research.

² Carlo Pedretti has suggested the sheet may have formed part of the *Codex Atlanticus*, but Gustina Scaglia has persuasively argued that the sheet probably arrived in Jacques Garnier's early nineteenth-century estate in La Rochelle, south of Brittany, by other means. Pedretti, "Leonardo at the Morgan Library," 142–144; Scaglia, "Leonardo da Vinci's Drawing," 27–36.

designer. Knowledge of Leonardo's drawing style can be used to illuminate his engineering goals in the Morgan sheet, particularly with regard to the topmost drawing of an enigmatic and highly original assault mechanism.

In Leonardo's now-famous letter, penned around 1481–82 to Ludovico Sforza of Milan, the artist enumerates his skills in designing siege craft and defences. Whether "Il Moro" ever received the letter, which now survives in a copy, the numbered list of qualifications is a telling synopsis of how Leonardo planned to serve the duke.³ Following his first nine talents in military engineering, the artist mentions also that in times of peace he can provide excellence in architecture and in "guiding water from one place to another."⁴ Leonardo's skills in painting and sculpture are mentioned only in passing at the letter's end, as though addenda to the more pressing matters of battlefield engineering. Modern scholarship has reordered these priorities in the study of the artist; Leonardo's few paintings are usually privileged over the numerous technical drawings. The few notable exceptions in the critical literature only underscore the need for more interdisciplinary study if the chasm separating the artist and engineer is to be bridged.⁵ Part of the struggle with building such a bridge is that it sometimes requires highly technical, experiential knowledge in order to arrive at the full span of Leonardo's conceptual development. This article balances a close and technical interpretation of one sheet of Leonardo's drawings with a broader view of his contributions to siege ladder design — a field that includes all types of scaling ladders used to surmount an enemy's fortifications from land or sea, generally called *sanbuche* or *scale di assalto*.

The Pierpont Morgan Library acquired Leonardo's sheet of drawings (fig. 7.1) in 1986, and the work has not yet been analyzed alongside scaling ladder drawings in the Codex Atlanticus or the Codex Trivulzio, nor have Leonardo's designs been fully compared with those of Mariano Taccola (1382–c.1453) and Francesco di Giorgio (1439–1502), two talented Siene

³ On the letter's complicated status, see Calvi, *I manoscritti*, 65–70; Pedretti, *Commentary*, 2:295.

⁴ Richter, *The Literary Works*, 398.

⁵ Some landmarks in the study of Leonardo as engineer include: *Leonardo da Vinci: Engineer and Architect*; *Renaissance Engineers From Brunelleschi*; Kemp, *Experience, Experiment and Design*; and the *Universal Leonardo Project* (2006).

engineers whose works were likely known to Leonardo (fig. 7.1).⁶ Such a focused study provides a concrete example of how the artist approached a design challenge while exploring the various solutions offered by peers and predecessors. The latter part of this article addresses broader issues of originality and conceptual approaches to design, while arguing for the technological and functional importance of the Morgan drawing.

The upper design on the Morgan sheet represents a device to be mounted on a boat (fig. 7.1). Near the top of the mechanism, Leonardo has written, “full of wet hay,” (“piē[no] dj fieno bagniato”) and to the side, “A day-time instrument used by sea to climb to the top of a tower. If there are two towers, place yourself on such a line as to make one tower shield the other. But see to it that the sea is perfectly calm,” (“Strumē[n]to djurno | e da mare per i[s]calare | vna tore dj sopra esselle | fussino due torri va per | tale linia chelluna facci scudo · allaltra ma | fa chel mare · sia chōtu | tj · i segnj dj tranqujlita”). The lower drawing is of a device for bending beams. Leonardo’s tight rendering and confident hatching in the beam-bending device differs from the loose and uncertain pen lines that mark the drawing at top, though both are clearly from his hand. The discrepancy suggests that the siege ladder is a design still in its formative stages. The improvisational quality of the drawing has led Gustina Scaglia to interpret the scaling ladder as a “fanciful” device seemingly incapable of working.⁷

Recent investigations of Leonardo’s designs for gliders and for the giant crossbow have shown those drawings to contain a greater knowledge of functional design and relevant detail than had been previously assumed, and similarly, our appreciation of the Morgan drawing might profit from a more careful look at its details. Figure Two reproduces Leonardo’s sketch with its component parts labelled in an effort to clarify discussion of the “inner workings” of the machine. The rungs of the ladder are not visible in the sketch. In the seven drawings of scaling ladders in Leonardo’s notebooks, the artist sometimes carefully delineates its rungs and at other times hides the ladder beneath a pitched, triangular shield made of heavy wooden planks. The Morgan sketch conforms to this second type; the seven marks on the fixed

⁶ Gustina Scaglia’s 1995 important provenance study mentioned in note two above makes passing references to some of this comparative material, but without close technological comparisons. Bambach offers the most complete catalogue entry: *Leonardo da Vinci: Master Draftsman*, 405–406.

⁷ Scaglia, “Leonardo da Vinci’s Drawing,” 28.

arm (A) provide shorthand for the plank lumber of the shield, rather than the rungs of a ladder. This is confirmed by the end of the arm at point B which is triangular, suggesting a triangular shield similar to those used to protect the under-ladders in three other drawings by Leonardo (Codex Atlanticus f. 50, f. 1084, and f. 1087). Component (E) is not likely to be the ladder since it bears no demarcation of rungs, even though exposed, and appears positioned to secure the ladder once it is raised, as we shall discuss in a moment.

The beams of the base are brought up in pyramidal fashion to the point of axial rod (G), and this provides the fulcrum over which the arm (A) is balanced like a teeter totter. When one end of arm (A) is heavier, the other end will raise up. That this lever mechanism was intended to function on the principle of weights and counterweights has never been questioned, and is affirmed by Leonardo's own inscription "full of wet hay," ("pieno di fieno bagnato") with the wet hay functioning as a weight. Leonardo's inscription is positioned close to the criss-crossed rib (H) that runs along the left side of the shell (F). The placement of the text leads Scaglia to conclude that, "the criss-crossed pattern on the shell's curvature is where the wet hay seems to have been stored."⁸ However, this interpretation is problematic: the volume of the criss-crossed rib is so small as to be a rather ineffectual counterweight, and it would be difficult to force wet hay through the interior of the narrow rib and around the curve of the shell. It seems more plausible that the wet hay was to be placed in the interior of shell (F), an area of darkened hatching in Leonardo's drawing.

We now come to the crucial point of how the scaling tower was to be raised, and what role the shell (F) played in this process. There are two possible theories: either (1) the shell's position remained fixed and the weight of the hay loaded on top of the end of arm (A) caused it to move independently *within* the stationary shell (fig. 7.3), as Scaglia has proposed, or (2) the shell was rigidly affixed to arm (A) and the weight of the hay caused the entire shell to move in a downward arc, simultaneously lifting the narrow scaling tower on the other end (fig. 7.4). In either theory, parts (A) and (E) move together, so that the projection of one long element does not prohibit the other from reaching out to the enemy's fortification. The launching tower must have been raised, and kept at a slight angle to allow the men to cross over to the enemy's fortifications. Leonardo's other drawings of scaling ladders record this necessary incline (Codex Trivulzio f. 2r, and Codex

⁸ Scaglia, "Leonardo da Vinci's Drawing," 28.

Atlanticus 353v-a / 977v). Martin Kemp has noted that the lower of the two sides of the scaling ladder (E) seems to pass under a roller (D) to permit it to remain at the same level as the fixed central arm (A).⁹ This issue of flexibility and adjustment must have struck Leonardo as critically important, since the incline and rigidity of a siege ladder had consequences in battle. As early as 1203–1204 in the Siege of Constantinople, the accounts of Venetians sailing under Doge Dandolo's command note instances in which some of the ships had to disengage from the towers to which they were connected by scaling ladders, for fear they might dislodge or pull down the structures containing their own men fighting in hand-to-hand combat with the enemy.¹⁰ Leonardo's own annotation reminds the viewer of the delicacies of the deployment: "see to it that the sea is perfectly calm."

Each of the two theories concerning how the ladder could be raised deserve greater attention since they bear on whether we interpret this drawing as a mere *fantasia* or something more deliberate. In advancing the first theory, Scaglia claims that the support (I) is hinged at the point where it joins the apex of the shell and is lifted to allow arm (A) to rise *within* the shell (fig. 7.3). Categorizing this mechanism with other "equally fanciful" devices, she concedes that, "Even when the path attained its full tilt, its angle would not be high enough to reach the top of a tower."¹¹ A hinge, however, is not clearly indicated at the point of support (I); it appears more likely to be a brace. In Scaglia's interpretation the crescent shape of the shell (F) makes little sense, because the end of arm (A), hidden in the interior of shell (F), must necessarily taper to conform to the shell's shape (fig. 7.4). This results in a diminished surface area (and less weight) on the end of arm (A) at the point of greatest leverage. To follow the simple analogy offered earlier: there is less weight at the end of the teeter-totter, where it would be most needed. It becomes hard to imagine why an engineer would choose such an odd and disadvantageous form.

On the other hand, if we accept that arm (A) and shell (F) swing together as one unit, the scaling ladder can soar to a new and functional height (fig. 7.4). This interpretation also explains why Leonardo chose the enigmatic crescent form, an efficient shape for a counterweight that might be made to move through the curved form of a ship's hull.

⁹ Kemp, *Leonardo da Vinci*, 200.

¹⁰ Bradbury, *The Medieval Siege*, 195.

¹¹ Scaglia, "Leonardo da Vinci's Drawing," 28.

This second theory, that arm (A) and shell (F) are one unit swinging almost like a pendulum (fig. 7.3), seems more logical, but is marred by the graphic inconsistencies in what might be called the “undercarriage” of the mechanism. In particular, there is an ambiguous component in the space below axial rod (G), between the triangular supports on each side of the base. The pen lines here are darker, more agitated, and magnification reveals loose underdrawing that is not followed closely by the pen in many areas. Confounding matters is the fact that some intersecting pen lines overlap in transparent fashion, making it difficult to distinguish which component is in front of the other. This part of the drawing seems to be in a tentative stage of development, subject to spontaneous revision. The most problematic of these components (J) seems to span the base of the structure in such a way that it would obstruct the motion of the shell, or if the shell could pass beneath it, the ropes (C) would seem to catch upon it. The arc of the shell might also eventually hit rod (D), but this is not of great concern, since by that time the scaling ladder would be raised to a functional height. So, how does one account for this small, singular component (J) that seems to inhibit an otherwise largely functional design?

If (J) is a beam or rod, it does not seem to be drawn as an intentional stop for the swinging mechanism, at least not in the same way as, for example, the plank inserted into the spinning wheel of the famous cross-bow weapon in Codex Atlanticus 387 r-a / f. 1070 r. In the case of the cross-bow weapon, the plank which stops the wheel’s motion is prominent, clearly rendered, and its purpose self-evident. Component (J) is haphazardly defined, difficult to see, and its purpose unclear. Looking at other studies by Leonardo suggests a means of interpreting the marks of (J) as perhaps an early, misplaced attempt at penning the mechanism’s base. In the beam-bending device at the bottom of the Morgan sheet, for example, the buried braces at the lower right are overlapped in such a way that the intersecting pen lines make the components oddly transparent in a manner similar to the ambiguities of components (J) and (C) (fig. 7.1). It is difficult to tell which brace is on top of the other. One wonders why such braces are shown on the right and not on the component on the left. There are also many instances where Leonardo puts down a pen line in an illustration and then designs over it or around it as if it were never there. Leonardo’s compositional studies, such as *The Virgin, Child and Cat* in the British Museum, present instances of revised contours and ignored pen lines, but there are also mechanical drawings that illustrate

similar revisions. For example, a drawing of a gig-mill for raising nap on cloth shows a substantial reworking of a gear, as if the first and larger version in pen had not been drawn (Codex Atlanticus f. 38r-a /106r). In fact, if the viewer does not overlook the first failed attempt, and instead accepts it as an integral part of the machine, then the device can no longer function properly. In designs for a cambered bridge (Codex Atlanticus 312r-a / 855r), Leonardo reworked the arc of the bridge, paying no heed to the elements of his earlier misplaced lines in ink. In Codex Atlanticus f. 1108, Leonardo redrew the ink lines of a conical rapid-fire gun. As a result, the rod that forms part of the gun's base in his first attempt, an element similar to (J) in the Morgan sheet, must be overlooked so that the larger cone of his second attempt can rotate unencumbered. In the end, this process of revision in ink should not strike the viewer as extraordinary, given the dexterity of Leonardo's thought and his often quick and light handling of the pen.

To conclude this study of the machine's structure, there are two choices for accepting the functionality of the Morgan maritime assault mechanism: either the arm moves within an immobile shell, in which case the odd shape of the shell reduces the efficiency of the counterbalance, and the range of motion for the scaling ladder is greatly restricted, or the arm and shell are firmly fixed and the shell serves as counterweight, in which case the tiny component (J) should be overlooked as a misplaced first-attempt at penning in the base, or some similar error in execution. The first theory suggests two fundamental mistakes in the conception of the mechanism; the second theory requires reckless penmanship or a change of mind. In the absence of a tidy solution, the second theory pays greater credit to Leonardo's powers as an engineer. But is the design and the structure innovative?

Judging from the numerous drawings in Conrad Kyeser's *Bellifortis*, circa 1405, Giovanni Fontana's *Bellicorum instrumentorum liber*, c. 1420, and Mariano Taccola's *De ingeneis*, c. 1419–1441, scaling ladders were becoming an increasingly important component of European warfare by the 1400s.¹² All three authors are vanguards in a nascent pictorial genre that would come to hold great interest for Leonardo: the illustrated treatise of mechanical and

¹² Göttingen, Cod. ms. philos. 63; Munich, Cod. icon 242; Munich, Cod. Lat. Monacensis 197. On the importance of Kyeser, Fontana, and Taccola, see Long, *Openness*, 104–118.

military arts—a visual tradition particular to Italian and German-speaking lands, as Bert Hall has noted.¹³

Of these illustrated manuscripts, Taccola's *De ingeneis* (1419–1441) circulated among both Tuscan and Siennese artists, and contains drawings that seem to prefigure some of Leonardo's devices for mechanical, hydraulic, and military engineering.¹⁴ Pages of Taccola's manuscript resemble several of Leonardo's drawings for such diverse subjects as the giant crossbow, a perpetual motion machine, an underwater breathing device, and a system for raising a bell into a tower. Taccola's *De ingeneis* survives with annotations by Leonardo's colleague, the Siennese artist and engineer Francesco di Giorgio Martini.¹⁵ Much of Books I and II of *De ingeneis* was also copied by the anonymous author of Add. 34113, a manuscript now in the British Library. This treatise and its copies circulated among several leading Florentine architects, including Antonio da San Gallo the Younger (1484–1546).¹⁶ It remains unclear whether Leonardo studied Taccola's designs in one of the copies of Florentine provenance, from Add. 34113, or from the original manuscript in Francesco di Giorgio's possession (CLM 197). Leonardo's earliest documented encounter with Francesco is in 1490, when Francesco was called to Milan to advise on several projects, including the *tiburio* for the Cathedral.¹⁷ In that same year, both he and Leonardo traveled to Pavia to offer their engineering expertise on the construction of that city's cathedral. A copy of Francesco's treatise on architecture bears annotations in Leonardo's hand, confirming that some exchange took place between the two.¹⁸ Leonardo's seven drawings of siege ladders are generally dated on stylistic grounds to 1487–90, roughly contemporaneous with his prolonged encounter with Siena's greatest engineer, translator of Vitruvius, and collector of Taccola's notebooks.

¹³ No similar manuscripts survive from England, Scandinavia, the Low Countries or the Slavic area, despite those countries' high technological development. France's only example is authored by Guido da Vigevano. Hall, *The Technological Illustrations*, 16; see also Keller, *review*, 109–111.

¹⁴ Taccola, *De machinis*, 21.

¹⁵ Taccola, *De ingeneis*, 1–30.

¹⁶ Taccola, *De ingeneis*, 28–31.

¹⁷ Mussini, *Il trattato*, 163.

¹⁸ Florence, Cod. Ashburnham 361.

The pages of Taccola's Sienese *De ingeneis* are graced with more than thirty drawings of siege ladder designs that seem to prefigure much of the technology explored and refined in several of Leonardo's drawings. In folio 76v (fig. 7.5), Taccola has drawn various scaling ladders on the bottom half of the page, scattered around a larger drawing of a siege tower mounted on wheels. The faint image at far left depicts a scaling ladder secured to an upright pole mounted on a wheeled platform. The apparatus actually consists of two ladders: a lower one leans against the pole, and an upper ladder, the one that would incline toward the enemy's fortifications, is held more precariously in position by the tension of ropes connected to a pulley on the pole's summit and secured to a hoist at the rear of the platform. Given the prevalence of this design in other treatises and in the later works of Francesco di Giorgio, it may have actually served on the battlefield.

A different type of scaling ladder appears in dark ink at the center of the same folio. Here, Taccola has sketched both sides of the ladder before deciding to add the triangular-shaped protective covering to the upper half. Soldiers presumably could pass through this upper wooden space without fear of enemy fire, though the structure looks oddly transparent since Taccola's earlier, misplaced lines in ink on the ladder's far side are still visible (a rapid and changing execution similar to Leonardo's example mentioned above). In Codex Atlanticus f. 391v/1084 (fig. 7.6), Leonardo's drawing departs from Taccola's structural design, transcending its prototype by increasing the scale of the mechanism and adding a visible hoist. Leonardo has inserted an axis at the point where the triangular-shaped protective covering begins, and oxen shown near the wheels of the base are yoked to turn a hoist that raises the "bridge" into position. In fairness to Taccola's knowledge of technology, he also drew oxen-powered hoists and mills in other contexts, as did Francesco di Giorgio. Leonardo, in this case, appears to be combining existing technology, while creating a more skilled, perspectival drawing that shows the mechanism as though already functioning in battle.

Other drawings by Leonardo appear more derivative. A scaling ladder in Leonardo's Codex Trivulzio (f. 28v) is too small and schematic to reveal much of its technology, but seems to utilize a hoist to extend and retract the ladder in the same fashion as an earlier drawing by Taccola.¹⁹ Two drawings in the Codex Atlanticus also record Leonardo's attempts to define specific components of a siege ladder: one includes a view of the hoist lever

¹⁹ Munich, CLM 197, f. 92^{br}.

and rung lock (f. 1087), the other a study of interlocking ladders and bridging devices *à la* Taccola and Francesco di Giorgio (f. 50r – fig. 7.7). In both, the scaling apparatus is a tall, sloping structure encased in timber, the actual ladder hidden from view under the pitched roof. Leonardo carefully defines the triangulated wooden shell and the convincing angle of perspective, suggesting the device could be pushed or pulled into position beside the enemy's walls.

For fortifications overlooking water, Taccola's *De ingeneis* contains several concepts useful for creating a maritime scaling ladder intended to be mounted on a boat. On folio 91v (fig. 7.8) beside a drawing of a large crossbow, the artist has rapidly penned four possible designs, ranging from a fixed stair extending off the ship's prow, to three versions utilizing a ship's central mast to support a ladder. Of the three versions, the sketch at bottom left shows Taccola's familiarity with using a lever affixed to the mast; one end of the beam is pulled down towards the ship's deck as the other side raises the ladder into position. Venetians used just such contraptions with ladders fixed high on the masts to climb onto the city towers of Constantinople as early as the Fourth Crusade. Technologically and conceptually, Leonardo's earliest attempts at maritime siege ladders in the Codex Trivulzio (f. 2r, 353v) offer only minor variations on Taccola's themes. Both are quick and schematic representations using a lever mechanism which was already a standard component in earlier designs by Francesco di Giorgio and others. In these, and indeed in most of the surviving drawings of siege ladders from Central Italy, whether by Taccola, Francesco di Giorgio, Leonardo, or others, the ladder is raised and secured by a system of ropes, pulleys, and hoists.

The Morgan Library's sheet is quite important because it departs from these design conventions (fig. 7.1). Though Leonardo may have begun with the notion of a hoist, and maintained it as a securing device in the undercarriage of the apparatus, his notations make clear that he conceived of a scaling ladder that swings more freely with the use of a powerful counterweight.

The Morgan sketch reveals Leonardo's *lateral thinking* in the field of military design. Leonardo's apparatus relies on a strongly pivoting, counterweight technology that previously had been applied more commonly to weapons, notably the trebuchet—a catapult used for hurling heavy stones and missiles. The short end of a trebuchet bears the tonnage of the counterweight, that once released, sends the long arm upward with its sling

and projectile. Leonardo adapts the working forces to a gentler application in his siege ladder. His predecessors and contemporaries remained bound by the conventions of hoists and ropes, even though they, like Leonardo, had also sketched various types of trebuchet. Leonardo modifies counterweight technology that was common to one branch of military design so that it might improve a different genre. Such lateral thinking is in keeping with Leonardo's approach, especially where nature's mechanisms of force are involved. In Manuscript H, Bibliothèque de l'Institut de France, Paris (101v), for example, he connects the pressure of a mountain spring to the pressure that sends blood surging from a severed vessel in the temple of a man's head, though ultimately he comes to realize the limits of the mechanical analogy. As Martin Kemp has noted, Leonardo's thinking could extend liberally across the study of bubbles, rivers, storms, and even human hair when examining the forces of the vortex.²⁰ On a more modest scale, this siege ladder design reflects a similar willingness to cross subject boundaries when forces of motion are under consideration.

Leonardo's sketch also represents an efficient adaptation to site and circumstance. The crescent shape allows for easy movement within the angled confines of a ship's hull, assuming the apparatus to be mounted on deck and the counterweight to descend below through a special opening. Alternatively, the relatively narrow shell could also be made to fit between two ships held side-by-side in pontoon-fashion, a form of mounting sometimes utilized with other weapons. Water, the most plentiful natural resource surrounding the boat, offers counterweight in the form of wet hay, mitigating potential fire damage in the process. Rather than manpower and hoists having to bear the continued tension of a ladder's suspension, once the counterweight is moved into position, the system is secured by gravity. An effective engineer works with natural forces rather than against them. One is reminded of how Leonardo in the Codex Leicester (32r) inserted a weir upstream from a house suffering erosion, so that nature, rather than teams of men, would do the work of depositing silt and protecting the home's foundations. The Morgan sketch is in keeping with a conceptual approach that exploits natural efficiency.

Leonardo made first-hand studies of canonry and other types of weapons, but it is difficult to know if by the time he penned the Morgan drawing (c. 1487–90) he would have actually witnessed a scaling ladder or trebuchet in action. Records of his first Milanese period are unfortunately

²⁰ Kemp, *Leonardo da Vinci*, 6–11, 33–48.

too few to be of assistance. However, his later activities suggest he would have relished the opportunity; he is documented, for example, from July to September of 1502 in the service of the captain general of papal armies, Cesare Borgia “Il Valentino” (1475–1507) conducting military inspections in Urbino, Cesena, Porto Cesenatico, Pesaro, and Rimini.²¹

More broadly, Leonardo’s drawings for siege ladders reflect an emerging military reality in Italy: warfare was becoming increasingly dependent on infantry, sieges, and artillery-resistant defences.²² The sieges of Sarzanello (1487) and Novara (1500 and 1513) are bloody examples on different scales of the growing role of gunpowder and fortifications. When the artist entered Milan in 1482, he would have encountered the towering defences of Castello Sforzesco. From behind Milan’s new walls, Ludovico Sforza must have realized that just as important as the bastion is the technology to scale over it. As it happens, Leonardo was soliciting the duke’s patronage with similar thoughts in mind. Items number two and nine in the famous letter referenced at the start of this article are particularly instructive:

2) I know how, in the course of the siege of a terrain, to remove water from the moats and how to make an infinite number of bridges, mantlets and scaling ladders and other instruments necessary to such an enterprise...

9) And should a sea battle be occasioned, I have examples of many instruments which are highly suitable either in attack or defence...²³

Our close study of Leonardo’s drawings of scaling ladders suggests the artist attempted to fulfill these promises on paper if not in practice. In the case of the Morgan sketch, he did so with an enterprising look to other forms of engineering and an innovative grasp of nature and technology.

CLARK UNIVERSITY

²¹ Bambach, *Leonardo da Vinci*, 234.

²² Hale has noted that alongside this strategic development a new focus of artistic representation emerges: the siege-piece as a genre in Germanic images. Hale, *Artists and Warfare*, 13.

²³ Kemp and Walker, *Leonardo on Painting*, 251–252.

CITED WORKS

Manuscript Sources

- Florence. Biblioteca Medicea Laurenziana (BML)
Codex Ashburnham 361, Francesco di Giorgio, *Trattato di architettura*.
- Göttingen. Universitätsbibliothek (UB)
Cod. ms. philos. 63, Conrad Kyeser, *Bellifortis*.
- Munich. Bayerische Staatsbibliothek (BSb)
Cod. icon 242, Giovanni Fontana, *Bellicorum instrumentorum liber*.
Cod. Lat. Monacensis 197, Mariano Taccola, *De ingeneis*.

Printed Sources

- Bradbury, Jim. *The Medieval Siege*. Woodbridge: Boydell Press, 1992.
- Calvi, Gerolamo. *I manoscritti di Leonardo da Vinci dal punto di vista cronologico, storico, e biografico*. Bologna: Zanichelli, 1925.
- Denison, Cara D. "A Drawing by Leonardo da Vinci." *Twenty-First Report to the Fellows of the Pierpont Morgan Library 1984–1986*. New York: Pierpont Morgan Library, 1989, 304–307, 357–358.
- Galluzzi, Paolo. *Prima di Leonardo: Cultura delle macchine a Siena nel Rinascimento*. Milan: Electa, 1991.
- Hall, Bert S. *The Technological Illustrations of the So-called "Anonymous of the Hussite Wars"*. Wiesbaden: Ludwig Reichert Verlag, 1979.
- Hale, J.R. *Artists and Warfare in the Renaissance*. New Haven: Yale University Press, 1990.
- Keller, Alex. Review of Bert Hall, *The Technological Illustrations of the So-called "Anonymous of the Hussite Wars."* *Technology and Culture* 25:1 (1984): 109–111.
- Kemp, Martin. *Leonardo da Vinci*. London: Yale University Press, 1989.
- _____. *Leonardo da Vinci: Experience, Experiment and Design*. Princeton: Princeton University Press, 2006.
- _____ and Margaret Walker. *Leonardo on Painting*. New Haven: Yale University Press, 1989.

- Leonardo da Vinci: Engineer and Architect*, ed. Paolo Galluzzi. Montreal: The Montreal Museum of Fine Arts, 1987.
- Leonardo da Vinci: Master Draftsman*, ed. Carmen Bambach. New York: Metropolitan Museum of Art, 2003.
- Long, Pamela. *Openness, Secrecy, Authorship: Technical Arts and the Culture of Knowledge from Antiquity to the Renaissance*. Baltimore: Johns Hopkins University Press, 2001.
- Mussini, Massimo. *Il trattato di Francesco di Giorgio Martini e Leonardo: il Codice Estense restituito*. Parma: Electa, 1991.
- Pedretti, Carlo. *The Literary Works of Leonardo da Vinci*, 2 vols. Berkeley and Los Angeles: University of California Press, 1977.
- Pedretti, Carlo. "Leonardo at the Morgan Library." *Achademia Leonardi Vinci: Journal of Leonardo Studies and Bibliography of Vinciana* 1 (1988): 142–144.
- Renaissance Engineers From Brunelleschi to Leonardo da Vinci*, ed. Paolo Galluzzi. Florence: Giunti Editore, 1996.
- Richter, Jean P. *The Literary Works of Leonardo da Vinci*, 2 vols. Reprint. New York: Dover, 1970.
- Scaglia, Gustina. "Leonardo da Vinci's Drawing in the Pierpont Morgan Library: Its Travels from Milan to La Rochelle (1519–1572)." *Arte lombarda* 113–115 (1995): 27–36.
- Taccola, Mariano. *De ingeneis: liber primus leonis, liber secundus draconis, addenda*, translated and with commentaries by Gustina Scaglia, Frank Prager, et. al.. Wiesbaden: Reichert Verlag, 1984.
- Taccola, Mariano. *De machinis: The Engineering Treatise of 1444*, translated and with commentaries by Gustina Scaglia. Wiesbaden: Reichert Verlag, 1971.

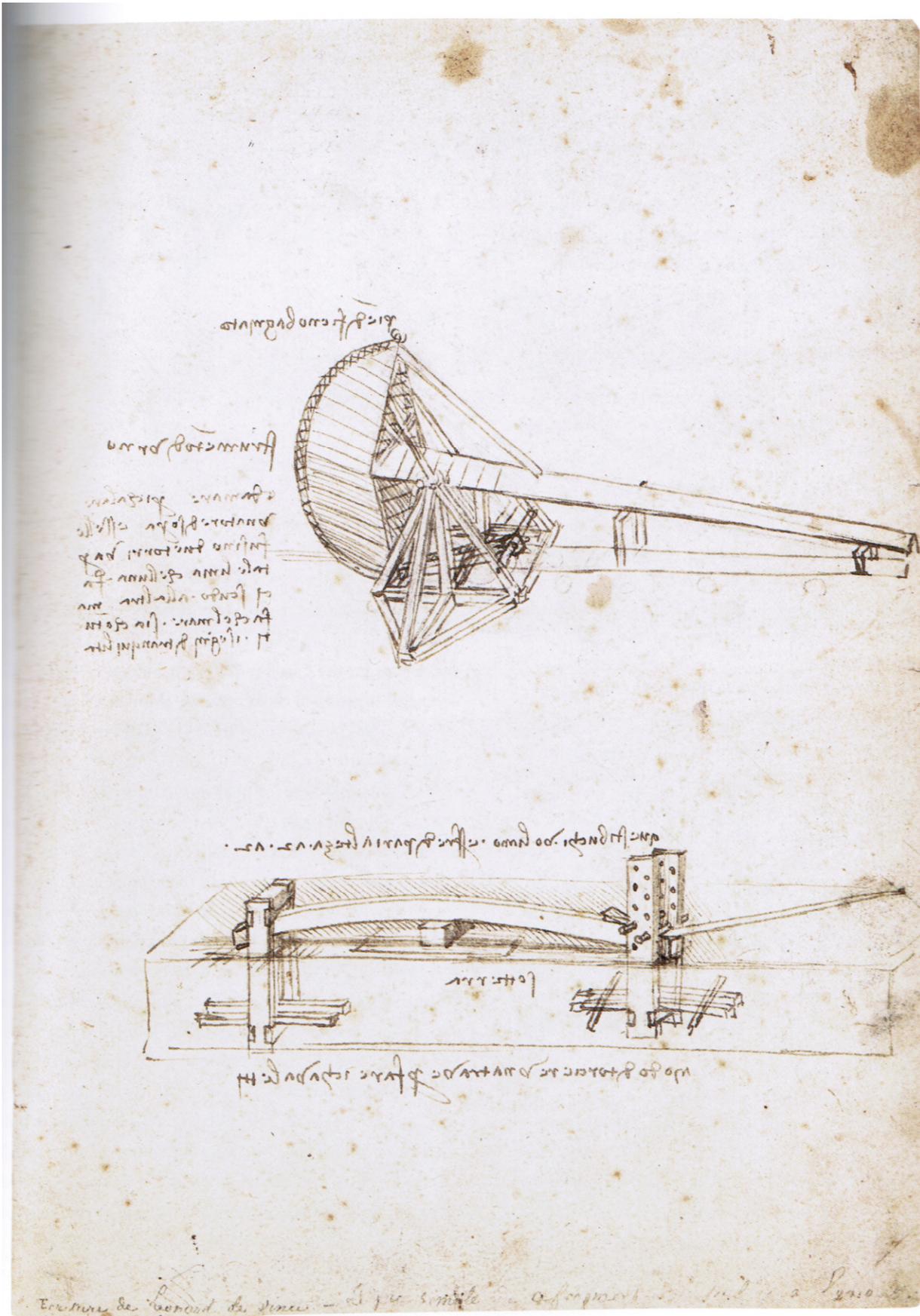


Fig. 1 Leonardo da Vinci, *Designs for a Maritime Assault Mechanism and a Device for Bending Beams* (c. 1489). Photographic credit: The Pierpont Morgan Library, New York, Inv. 1986.50

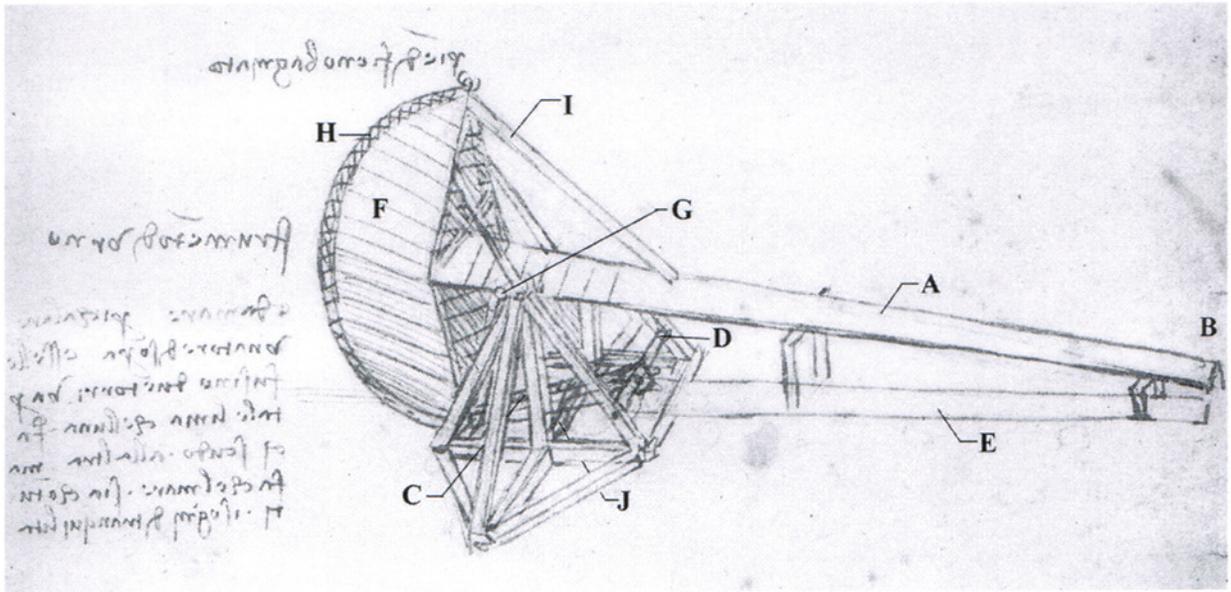


Fig. 2 Detail of Figure 1 with component parts labeled

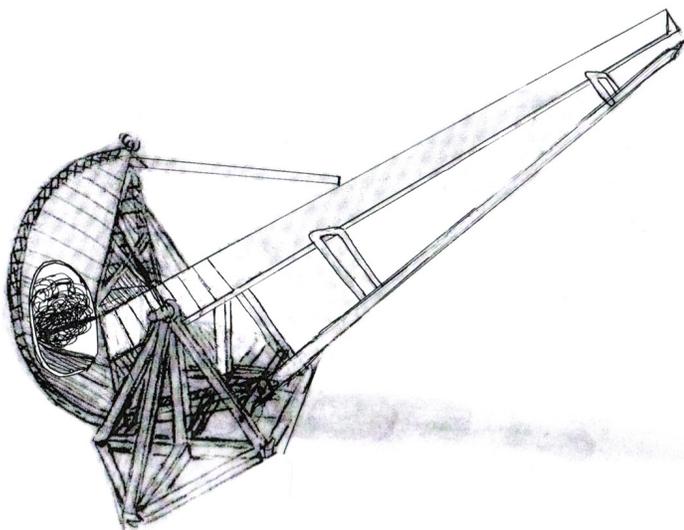


Fig. 3 Reconstruction of the mechanism of Figure 1 according to the first theory, J. Garton.

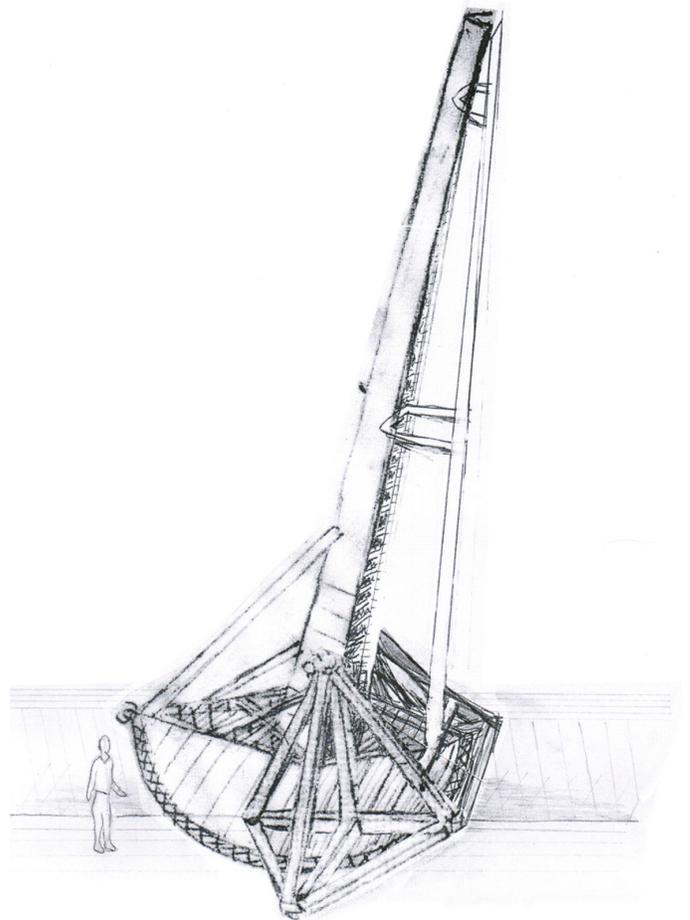


Fig. 4 Reconstruction of the mechanism of Figure 1 according to the second theory, J. Garton.

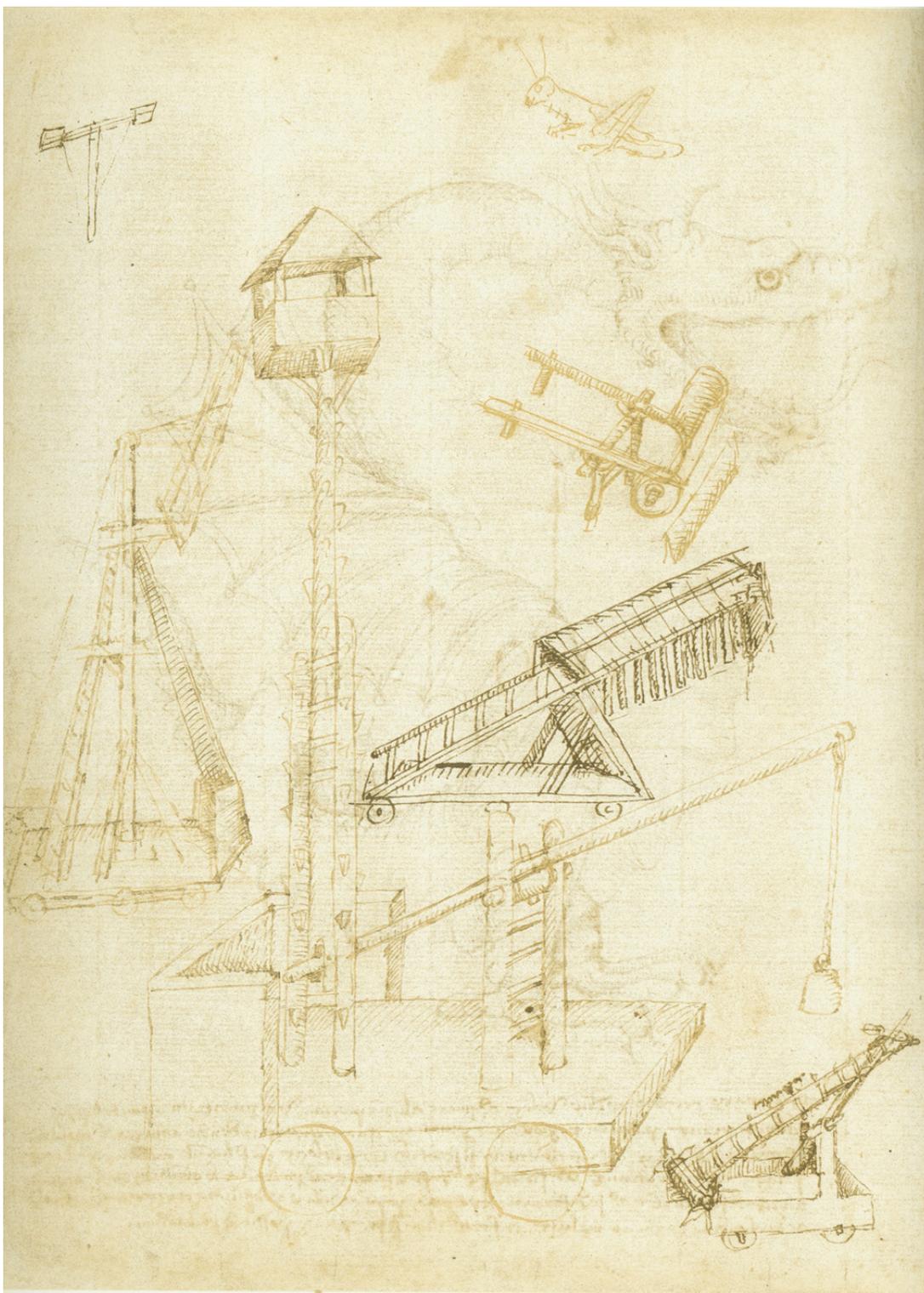


Fig. 5 Mariano Taccola, *De ingeneis*, Bayerische Staatsbibliothek, Munich, CLM 197, f. 76v.

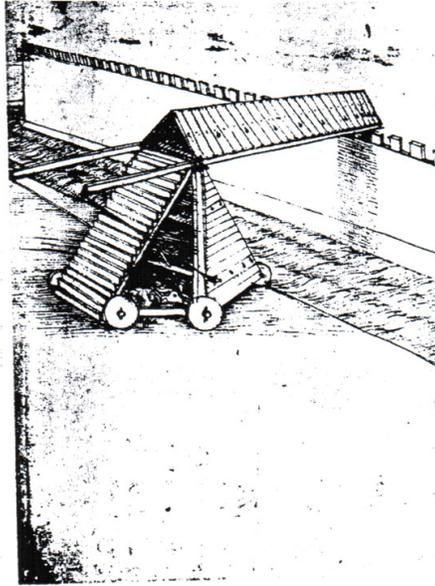


Fig. 6 Leonardo da Vinci, *Design for a Scaling Ladder*, Codex Atlanticus, f. 391v

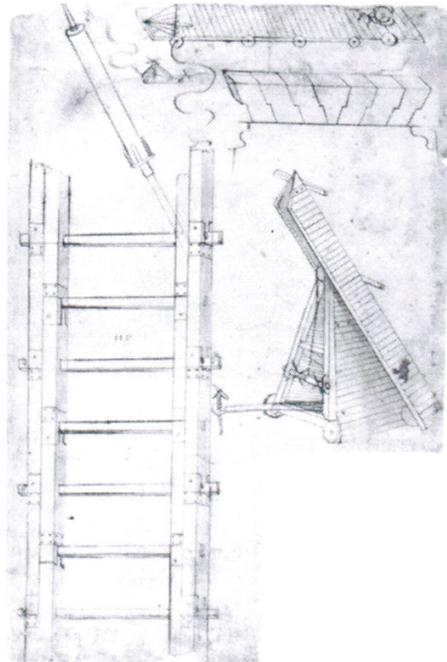


Fig. 7 Copy after Leonardo, *Design for a Scaling Ladder*, Codex Atlanticus, f. 50.

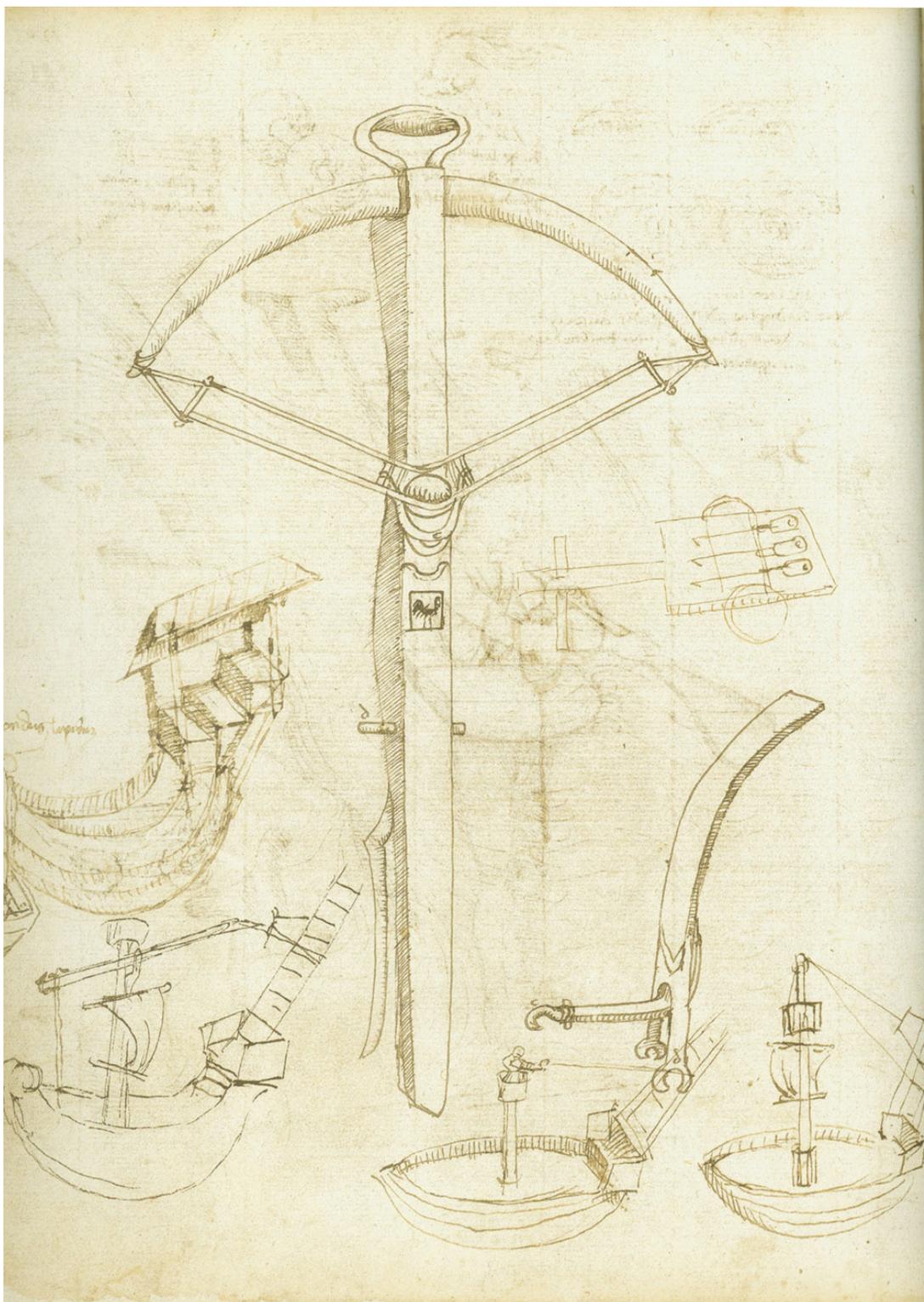


Fig. 8 Mariano Taccola, *De ingenis*, Bayerische Staatsbibliothek, Munich, CLM 197, f. 91v