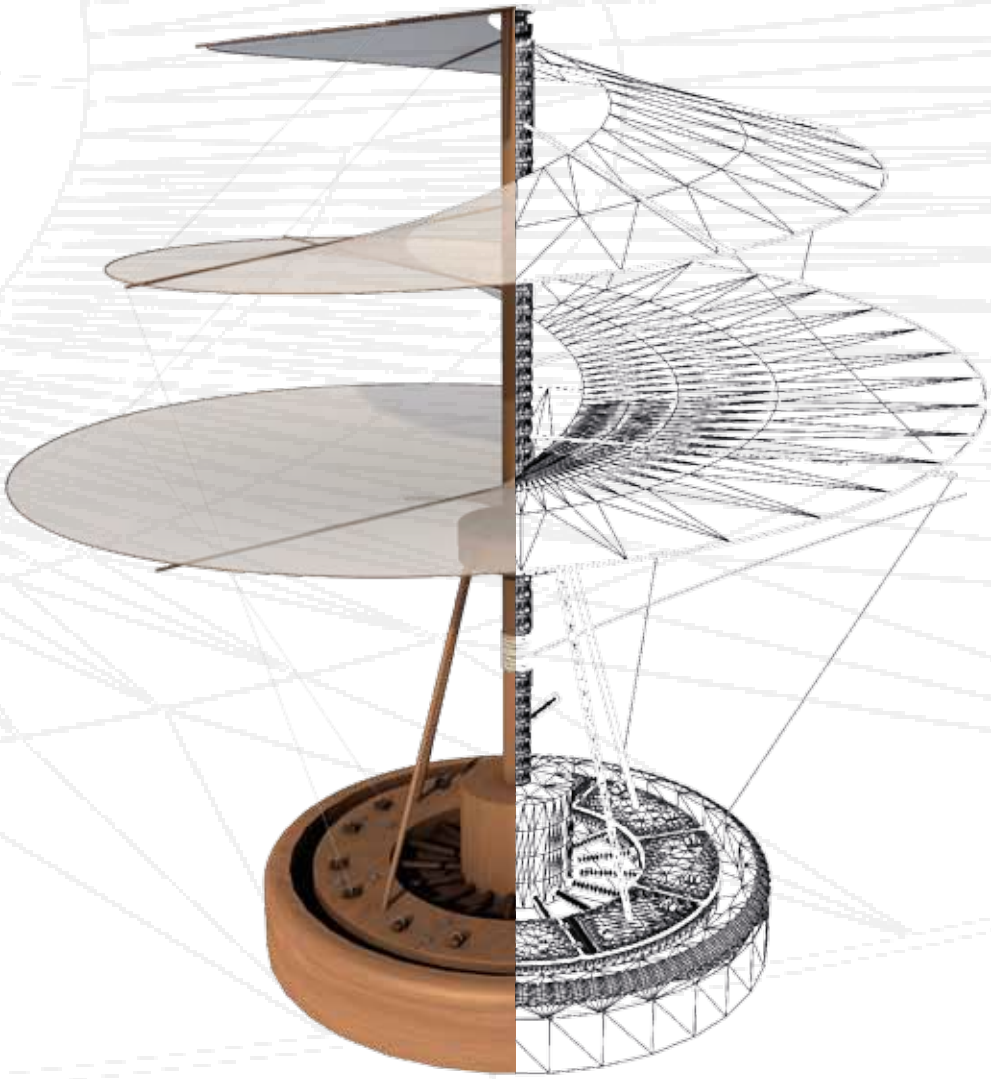
European Commission

Leonardo Da Vinci

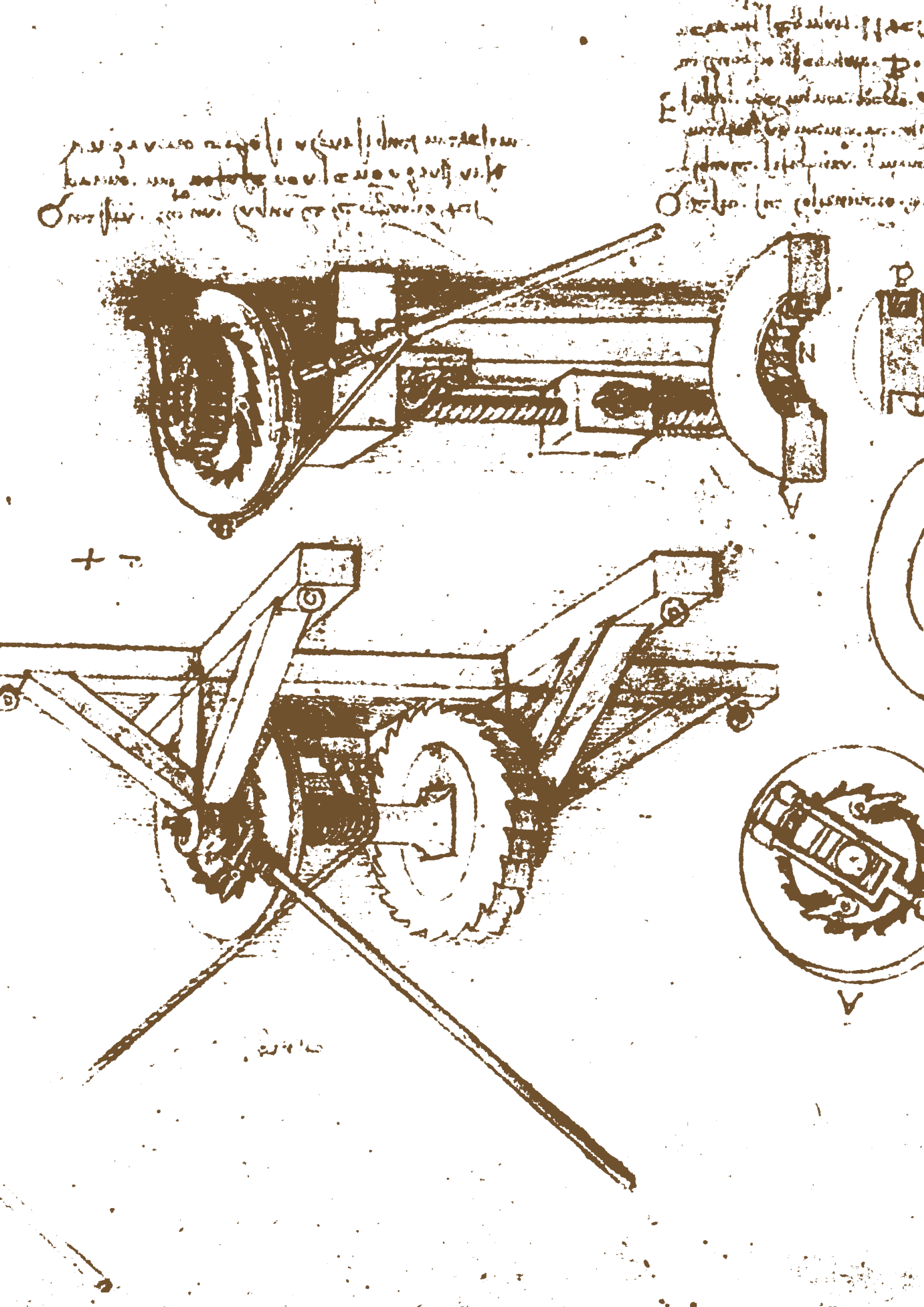
a Genius and his Secrets

Studies and reconstructions by

Gabriele Niccolai



NICCOLAI SNC
TEKNOART
FIRENZE



European Commission

2 April – 24 April 2014

European Commission, Piazza – Berlaymont
rue de la Loi/Wetstraat 200, 1040 Brussels

The exhibition of Leonardo da Vinci's devices organised in 2010 in the Berlaymont building by Renouveau & Démocratie was an overwhelming success. Speakers, participants and viewers had expressed their wish to have a second edition to learn even more about this man of genius. Therefore, we are pleased to present this new exhibition about Leonardo da Vinci's inventions.

Further research on his famous «Codex» showed that some of his drawings were very much inspired by principles of older technologies. Leonardo's knowledge derives, in fact, from the science of «engineers» who had been his forerunners, such as Brunelleschi, Heron of Alexandria, Vitruvius, Archimedes of Syracuse. From these characters who have built our History, by laying the foundations for the mechanics through the study of physics, mathematics, etc., Leonardo succeeded in reinterpreting the knowledge and adapting it to the needs of his time.

This exhibition brings together to the Berlaymont fifteen new models, illustrated with photos and explanatory information, including eight models which will be presented to the public for the first time.

Sponsored by Maroš Šefčovič, Vice-President of the European Commission, this exhibition has been possible thanks to the skilled craftsmanship of a Tuscan family-owned company (Niccolai Teknoart SNC), who are passionate about Leonardo da Vinci's achievements, and have produced the world's largest private collection of machines designed by this great Renaissance genius.

It is our pleasure to invite you to visit and enjoy this exhibition, which will be on display in the Piazza of the Berlaymont, from 2 to 24 April.

R&D Renouveau Démocratie
www.renouveau-democratie.eu

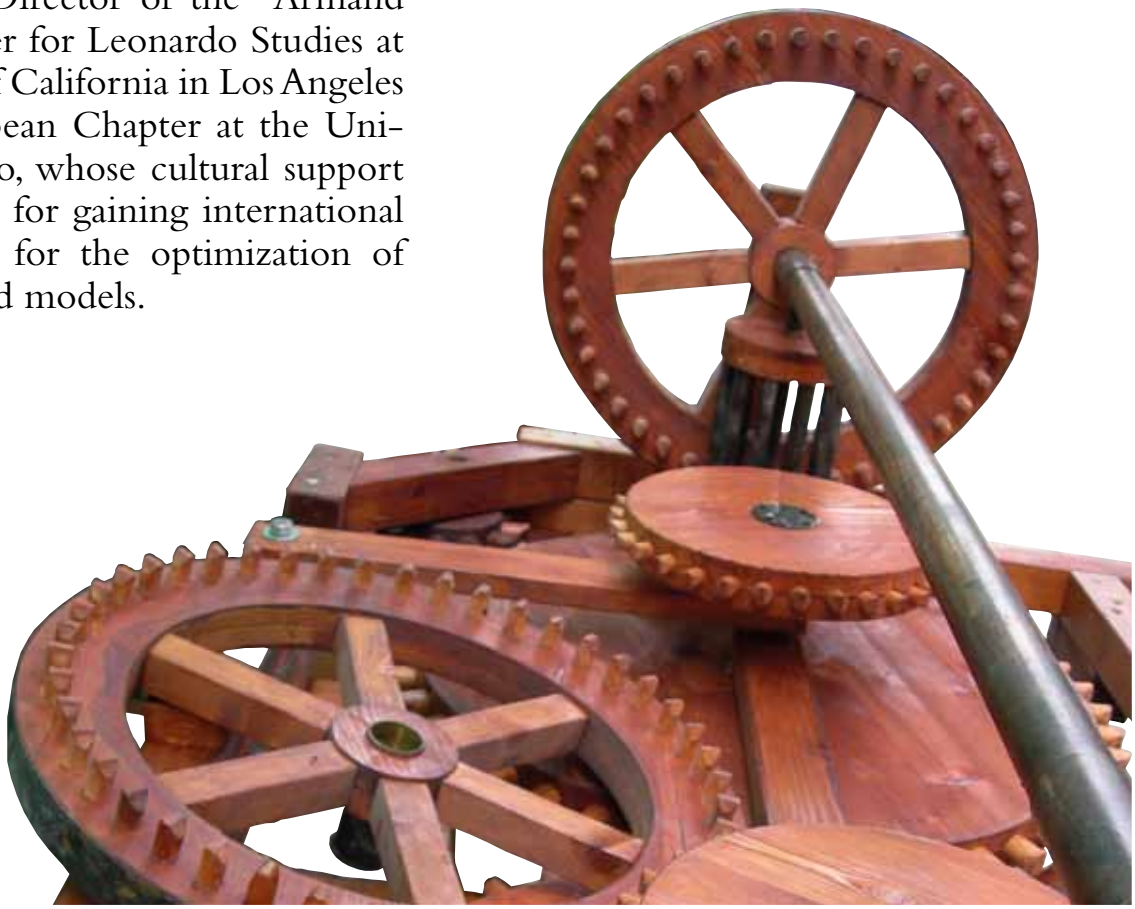
The Niccolai Collection

From the gestures of a student to the precious copies of Leonardo da Vinci's machines. For over 60 years the Niccolais have been taking pride in their ability to surprise even the most famous International museums with their Da Vinci's machines.
Carlo Niccolai was only a youngster when he first came across a few copies of Leonardo's inventions. He was attending the Leonardo da Vinci Technical Institute of Florence when he had the chance to carry out some restoration works on the entire collection owned by the Institute under the superintendence of his teachers. His love for Leonardo stemmed right from the aforesaid experience and, in 1995, led him to devote the whole of his time and energies to the study and reconstruction of some of the amazing inventions of the Maestro himself.
Today the Niccolai Collection, with its 250 models rebuilt with materials dating back

CARLO NICCOLAI, *l'automa tamburellatore di Leonardo*, Firenze

as far as the 15th and 16th centuries (wood, metal, ropes and fabrics), is the most relevant and impressive private collection of Leonardo da Vinci's machines.
In addition to a permanent exhibition at the Leonardo da Vinci's Museum in Florence, the collection has so far successfully travelled the world, gathering enthusiastic reviews both from critics and the general public comparable to those awarded to the most important displays.
The machines faithfully reproduce the original inventions and the preliminary research conducted by the creators has led to the discovery of several previously unknown or obscure theorems hidden by Leonardo into his fascinating masterpieces. It was only thanks to the several practical and mechanical tests carried out during the manufacturing of such models and to the Niccolais' professional approach to such work, that the sheer genius of the inventor of the original machines was officially reconfirmed and many researchers and experts have started reconsidering Leonardo's priceless work, including Professor Carlo Pedretti, Director of the "Armand Hammer" Center for Leonardo Studies at the University of California in Los Angeles and of its European Chapter at the University of Urbino, whose cultural support was crucial both for gaining international recognition and for the optimization of the manufactured models.

Over the past few years, finally, the Niccolai Collection has been expanded and successfully promoted by Gabriele, Carlo's son, who has enriched it thanks to the cooperation of a team of historians, engineers, architects and craftsmen who contributed to refine his historical-scientific research, unveiling to the world how Leonardo da Vinci's robot worked and providing new, interesting theories concerning his mechanical lion.



Method of Work
from the codex to the exposition

Manuscript

Gabriele Niccolai, following a detailed and lengthy study of drawings in the Da Vinci Codices, has concluded that Leonardo's designs are cryptic because the mechanical components of each machine are distributed over different pages. Many of the drawings left to us by Leonardo are not complete images, but rather deliberately vague sketches, sufficient for the artisan engaged to make the component, but not the whole machine.
Carlo and Gabriele Niccolai, as well as their detailed research, enthusiastic reading and a laboratory full of precision equipment, have also made use of collaboration with specialist historians, who have helped them to validate or perfect the results of their investigations, and of technical experts for the animation of the 3D models. Through this close collaboration, they have acquired a more profound understanding of Leonardo's mechanisms and technology.
This passion of theirs has led them to create many working models over the past fifteen years, which have been displayed

and admired in over a hundred exhibitions across the world, from Australia to Brazil, from China to the Arab Emirates and from New Zealand to the United States of America. Their company's philosophy has evolved from that of the small Nineties workshop to today, when more weight is now given to scientific and historical research into the links between the machines described in the Codices and the designs of great engineers and architects who preceded and succeeded Leonardo. They have also ensured that their reproduction machines are working models, with good mechanical descriptions, so that the public might understand the principles of physics underlying their movement or use. The results of this great endeavour have been much appreciated by the public, which is keen to acquire new knowledge regarding the secrets of Leonardo's mechanics and, above all, is keen to try them in action.
And as the thirst for knowledge about Leonardo da Vinci's work, on the part of father and son Niccolai, is infinite, in future they will produce many more models as a result of their interpretation of these most wonderful Codices.

Exhibition hall of the Galleria Michelangiolo, Florence

The *Atlantic Codex* folio 140 r/v contains numerous drawings by Leonardo of catapults. Firstly, we might note the system used to assemble the wooden elements that made up these objects. The parts of the catapult were assembled using a series of wooden joints, without any metal elements such as nails or bolts. This system of assembly enabled the object to resist the great stresses that it must undoubtedly have had to undergo when in use.
Secondly, the war machines shown in these drawings have no device to enable them to adjust their force according to the weight used. The lack of a locking mechanism and ballistic adjustment makes these machines totally inefficient. Catapults need different weights for different ranges, so they need a device to keep the machine locked, enabling the operator to increase the level of weight. This can be done by using a self-locking mechanism.
Leonardo illustrates the ballistic adjustment mechanism in another part of the *Atlantic Codex*, on sheet 148 r/v to be precise, where he gives a series of self-locking mechanisms. Given that this was a war machine, one might imagine that Leonardo drew the components of the same object on separate folios in order to safeguard his inventions and guard against the military espionage common at the time.

GABRIELE NICCOLAI, *Catapult*, exhibition in Vienna, 2005

Aerial Screw and Drill

Aerial Screw

With reference to experiments with flight, the aerial screw is without doubt one of the best known drawings of Leonardo da Vinci. The structure of the aerial screw had to be both rigid, to support its own weight, and light enough to fly. Observation of the sails of ships may have inspired Leonardo to insert turnbuckles to support the helical structure.
In his drawing of the aerial screw in *Manuscript B f.83v*, Leonardo shows a circular base that acts as a flywheel to enable storing kinetic energy and to help keep the axis vertical during flight.
Driving force is given to the screw by a rope wound around the central shaft, which unwinds rapidly to give the object a rotary movement, enabling it to rise upwards. This principle is used today by modern helicopters.

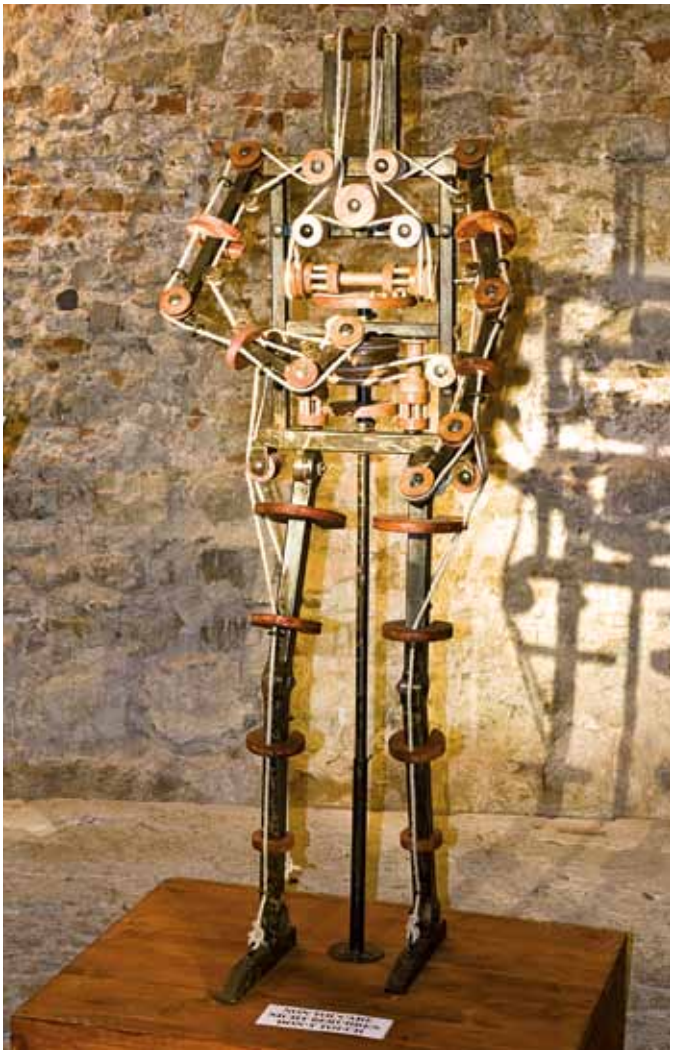
Gabriele Niccolai, *Aerial screw*

Marble Drill

Manuscript B f.83v does not contain a detailed explanation of the mechanism and working principle of the aerial screw. However, if we leaf back through the manuscript – to f.51r to be precise – we find a drill for boring through stone, comprising a metal drill bit fixed to a central shaft around which a rope is wound to start rotation. In the upper part of the structure there is a circular flywheel. It is not hard to see the analogy between the drill for marble in f.51r and the aerial screw. The missing mechanism of the aerial screw in folio 83v is shown in f.51r, with the difference that this time the flywheel is placed on top and drives the drill downwards, while in the case of the aerial screw, the flywheel is on the bottom.

Gabriele Niccolai, *Drill*

If we study folio 579r of the *Atlantic Codex*, we find a series of mechanisms and a suit of armour with helmet. This drawing has been taken to be an early reference for the study of an automaton in armour and the relative pulley mechanisms for its arm movements. On first sight, the sequence of the objects seems to be very chaotic, so we might imagine that this folio was one of those pages given to artisans commissioned to do the work, while avoiding illustrating the definitive design.
Looking at the drawing, we are immediately struck by a drum, which seems to have no possible connection with the rest of the drawings. For this reason, the first prototypes created did not take into consideration the hypothesis of a drummer-robot.
Studies by Sara Taglialagamba, however, confirm that drummer boys were employed in many festivities and events during the Renaissance, sometimes wearing light armour (Sara Taglialagamba, *Leonardo da Vinci automazione e robotica*). We therefore turned our attention to building a drumming robot that actually worked. The main mechanism of functioning of the automaton was identified as a reciprocating mechanism, also found on folio 1077r.
This design, originally intended for a mechanism for clocks, was modified and adapted for the proposed use and the construction of the model confirmed our theory. The mechanism did not have sufficient strength to bend the mechanical arms at the elbow, because of excessive friction, but it had enough to propel movement of the wrists to play the drum.



Gabriele Niccolai, *Programmable automaton*

The mechanical movement of the wrists is aided by two return springs, which alleviate mechanical friction of the various pulleys and resemble those found in the *Madrid I Codex* f.85r.
Folio 579r also shows a reciprocating lantern gear that, if connected to the transmission of the cylinder with the sinusoidal cam, was used to separate the beats.
When the cylinder engages with the teeth it produces the movement of the wrist and beating of the drum. Vice versa, when it

meets the part in between the teeth, there is a pause in the drumming.
The automaton created is fully functioning and has kept its mechanical characteristics even after numerous stress cycles. So we have been able to include it in the Galleria Niccolai and in travelling exhibitions, as one of the interactive machines.

Gabriele Niccolai, *The automatic drummer*

The Herodotus Machine

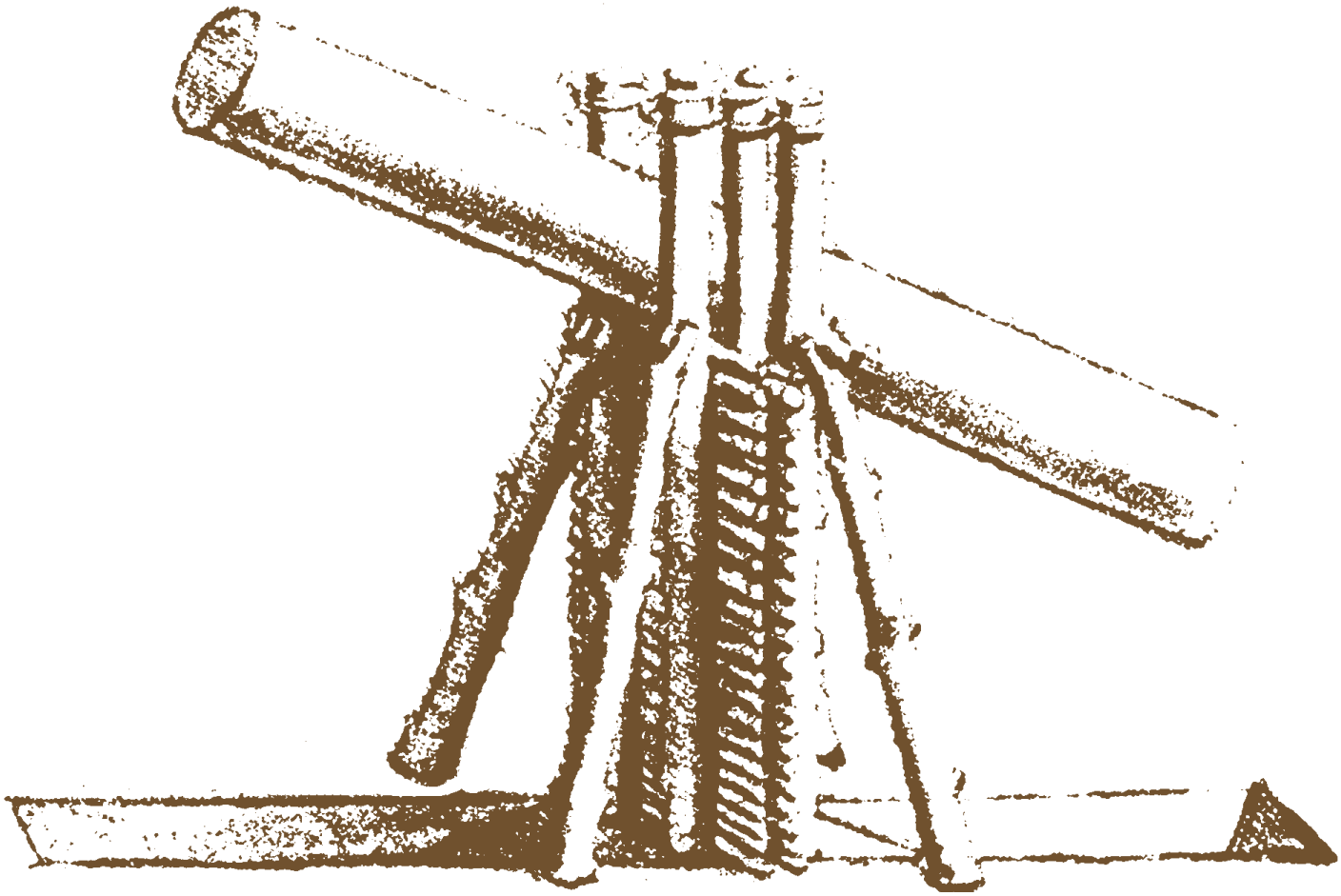
Herodotus writes in his *Histories*: "…This pyramid was built like this, tier after tier … they raised the stones … with machines made of short wooden lengths, lifting the stones from the ground up to the first tier of steps."

The short plank machine described by Herodotus had been used to raise the stones used in building the Egyptian pyramids. As the machine was very light, it could easily be moved by the workers from one stone tier to the next.

The Egyptians did not have complex machines such as those of ancient Greece or Rome. They did however know about machines like the balance or the *shaduf* (used in agriculture), which employed a system of counterweights to transfer the weight on the central fulcrum.

In the Leonardo da Vinci codices, and precisely in f.818v of the *Atlantic Codex* and f.29r of the *Madrid I Codex*, there are two drawings illustrating a machine that could correspond to the description given by Herodotus.

The drawings give different versions of a machine that can lift a very large stone column, exploiting the balancing of the actual column with respect to the central fulcrum where all the weight is concentrated.

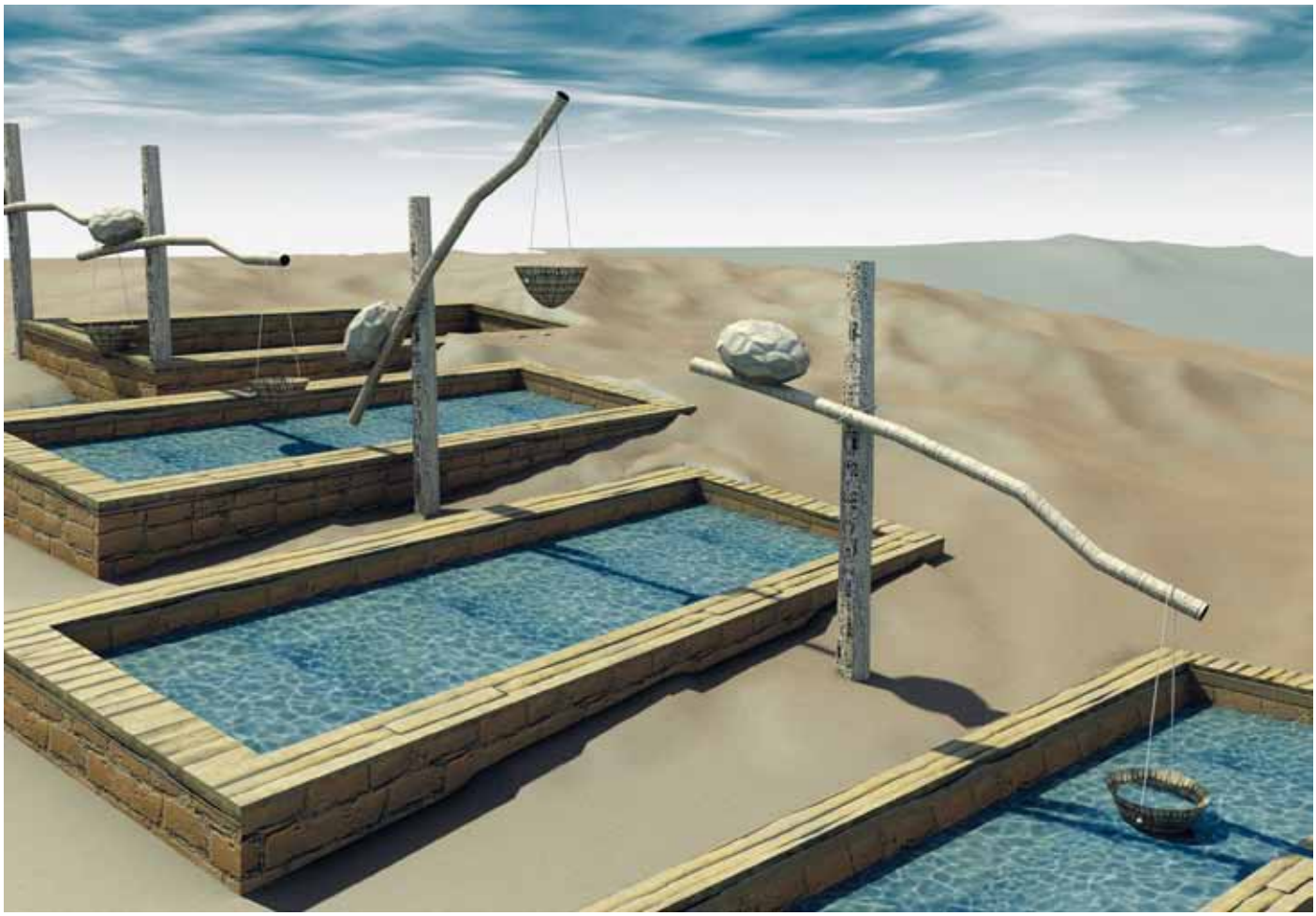


Gabriele Niccolai, *Short plank machine*

The column swings to the other side of the central fulcrum, creating enough space to insert a short plank underneath it. It is then swung back again to the opposite side, creating enough space to insert another wooden plank. The operation is repeated several times until the column is lifted to the desired height.
If, in place of the column drawn by Leonardo, we substitute blocks of stone comparable with those used in building the pyramids, we can perceive a mechanism very similar to that described by Herodotus. A 1:5 scale model of a machine similar to that designed by Leonardo was made and tested in February 2011, with a reinforced concrete block weighing about 300 kg.
Contrary to all expectations, not only did the scale model manage to lift the block of concrete, but it reduced its weight so much that a child of just 6 years old was able to make it rise up.

Shaduf

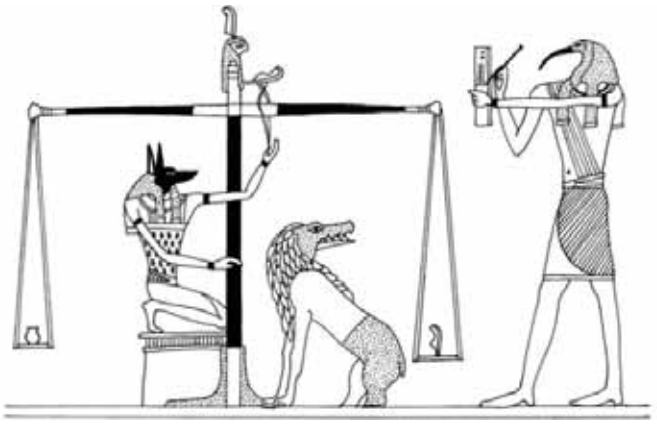
The *shaduf*, used in Egypt from the 2nd millennium B.C., is a means of raising water up to a higher level or fetching water from a river.
At one end of the longest arm there is a bowl and, on the opposite end, a counterweight – often a stone – to balance the load. In this way just one man can lift to a height extremely heavy containers.
When the difference in height is considerable, several *shadufs* are placed in a line along the natural slope.
The *shaduf* has two pillars about 2 metres high, joined at the top by a short wooden beam. A slender pole is balanced on the beam, with on one end a container for water and on the other a heavy clod of turf that acts as a counterweight. A man on the riverbank dips the container into the river or canal and then uses the counterweight to lift it up to the desired height or to the next *shaduf*.



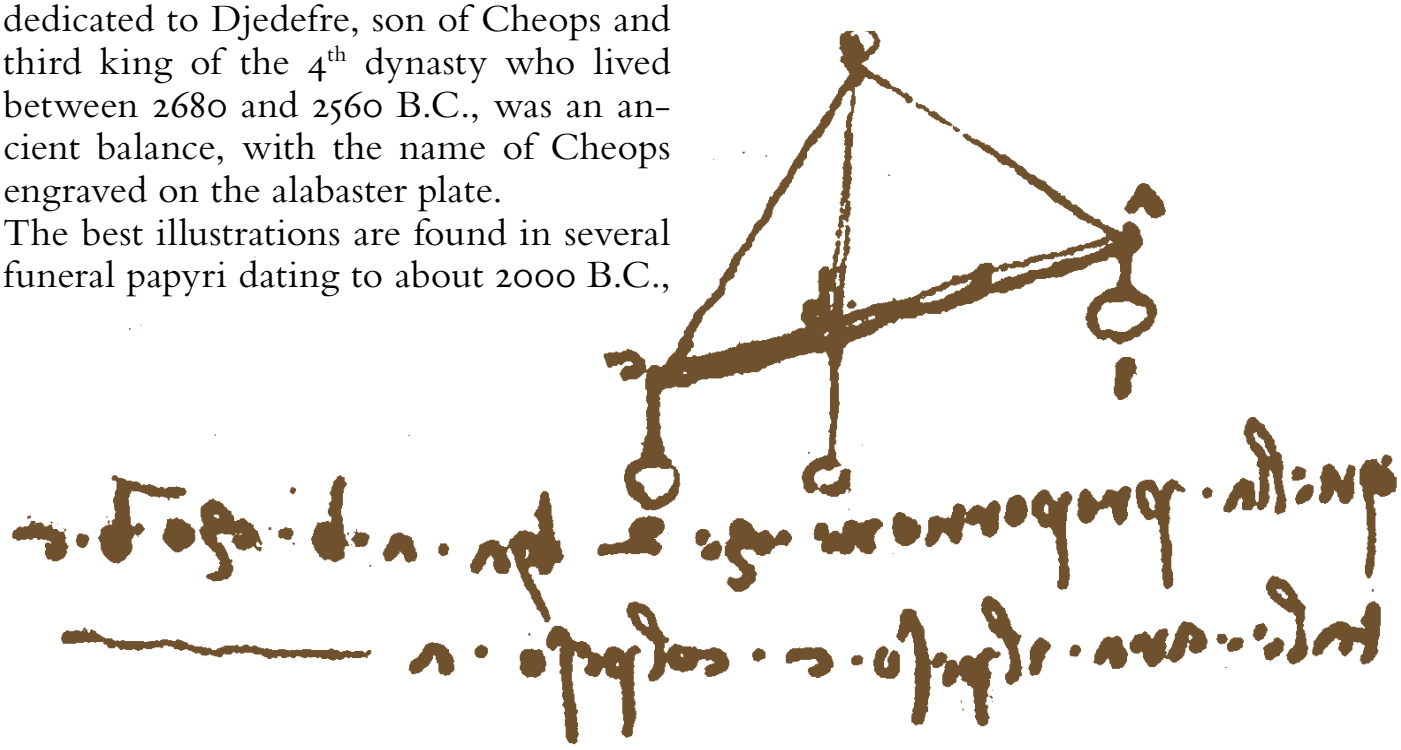
Virtual reproduction of the shaduf

Egyptian scales

There are numerous drawings showing the construction and use of balance scales in Egypt.
Derived from the Latin *bilanx*, which means "with two plates", the balance, in its simplest form with equal-length arms and central suspension, is one of the oldest instruments invented by mankind. Examples have survived from the civilisations of Mesopotamia and Egypt dating from the 5th millennium B.C.
It is believed that the first balance was invented in Egypt about 7000 years ago.
This balance has equal arms, two plates, a central pointer and was used for small weights. The base weight was the copper *deben* (about 90 grams) on whose value the price of the product was calculated. When both plates are level this means that the product weighs the same as the weights.
Among the latest finds at the pyramid dedicated to Djedefre, son of Cheops and third king of the 4th dynasty who lived between 2680 and 2560 B.C., was an ancient balance, with the name of Cheops engraved on the alabaster plate.
The best illustrations are found in several funeral papyri dating to about 2000 B.C., in particular in the papyrus of 1350 B.C. known as the *Book of the Dead*, conserved in the British Museum. This is because, according to the religious beliefs of ancient Egypt, especially the doctrine of Osiris, at the moment of death the value of the human soul was established by weighing it. So this judgement is frequently shown on funeral papyri found in the mummies' bands.

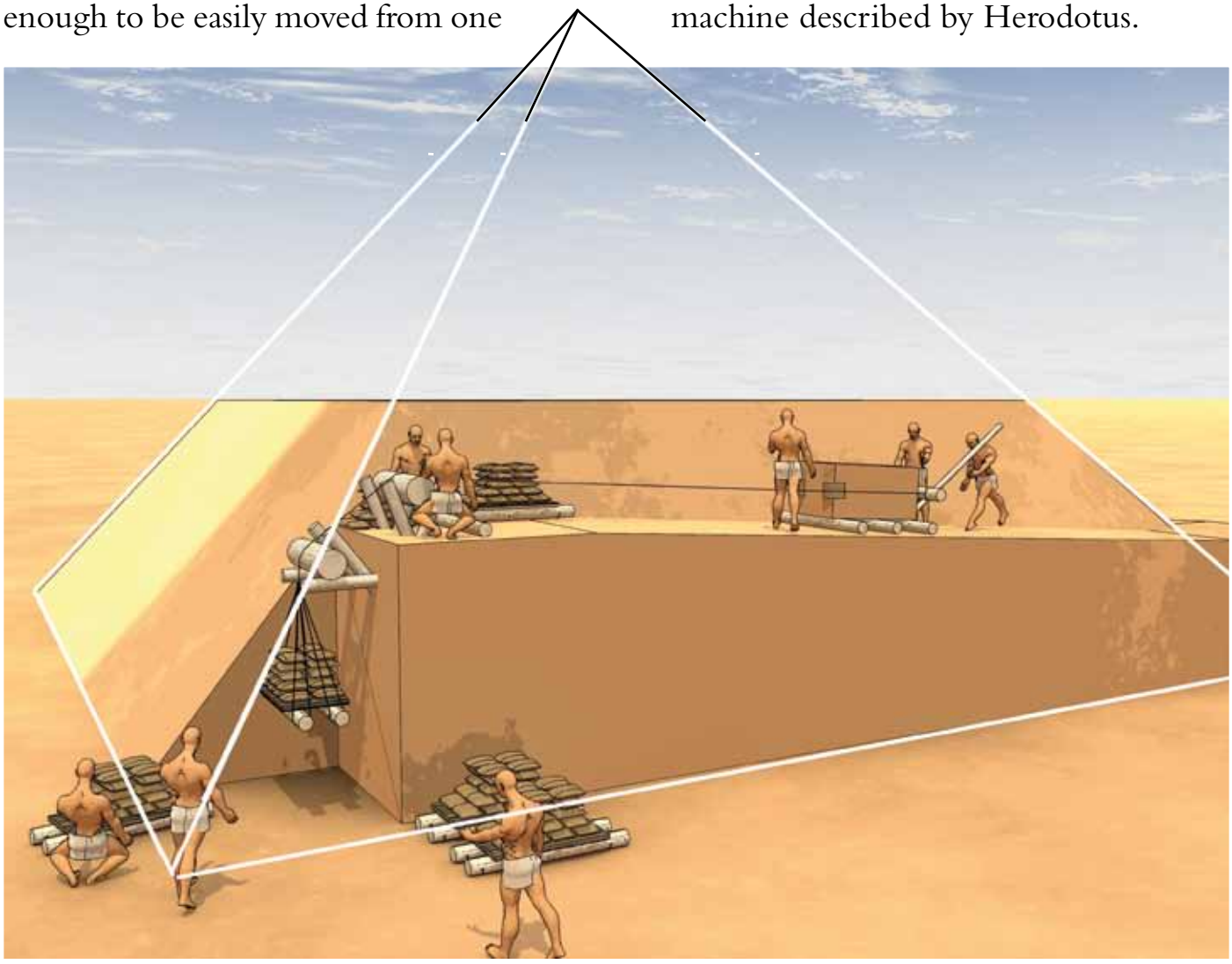


Weighing the heart, papyrus scroll, 1285 B.C.



Construction of the Pyramids

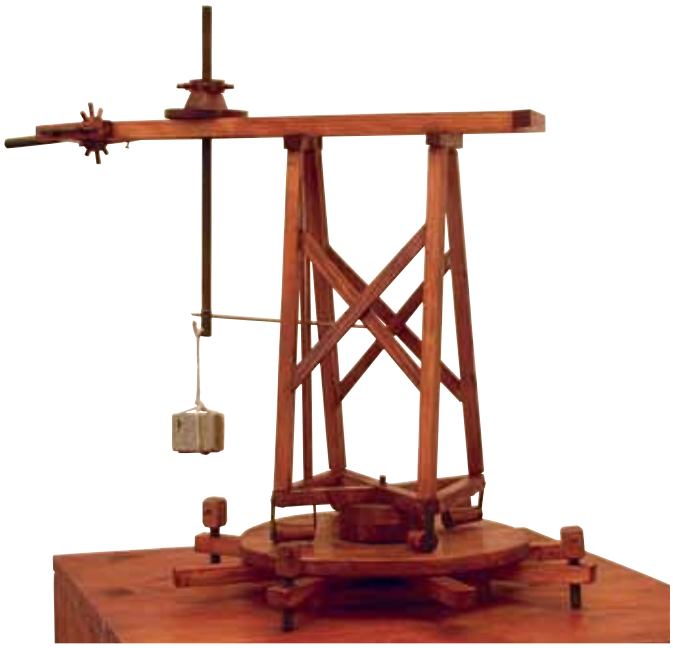
Based on information gathered regarding Egyptian technology and following reflection on ideas thrown up by earlier theories, we make so bold as to offer our modest contribution on the technology used in the construction of the pyramids.
Starting from the only reliable source, that is, from the description by Herodotus of his "short plank machine", we can certainly exclude the use of the *shaduf* in raising the blocks.
It has neither short planks nor is it light enough to be easily moved from one tier of steps to another. We cannot, however, exclude the use of weights and counterweights, of pulleys and slopes to raise the loads using specially placed ramps.
Human effort united with mechanical engineering enabled the building of the pyramids.
The stone blocks were brought in by canal as far as the building site deposit, then a system of slopes and ropes aided their transport up to the height needed, including assistance from the with short plank machine described by Herodotus.



Virtual reproduction of the methods of lifting blocks

Leonardo's Crane

It might be easily imagined that Leonardo obtained his inspiration from the countless building machines developed by Filippo Brunelleschi to build the Cupola of Santa Maria del Fiore.
The *Atlantic Codex* f.808v shows a crane with elements similar to that probably developed by Filippo Brunelleschi for building the "lantern" of the Cathedral of Florence.
It is highly likely that already by the Middle Ages machines were employed in the construction sector to hoist building materials, using technology inherited from the ancient Greeks and Romans.
In the Middle Ages, a model of a crane, forerunner of that developed by Filippo Brunelleschi and perfected by Leonardo da Vinci would without doubt have facilitated the construction of very tall buildings.
So we have come to the conclusion that, although the majority of mediaeval towers have putlog holes on their facades, a crane must have been used in building them, helping them rise upwards.
This proposed suggestion would include cranes partly similar in appearance to the one shown in the *Atlantic Codex*, which could sit on the upper part of the tower during its construction. Underneath the platform there are adjustable feet located at the ends of the radial spokes, to enable the crane to be lifted during all phases of construction.
This system is still used today to build skyscrapers, although the materials and the technology are different, as the photo of the building site of the Shanghai Tower shows. This skyscraper is being built in the Pudong district of Shanghai, China.

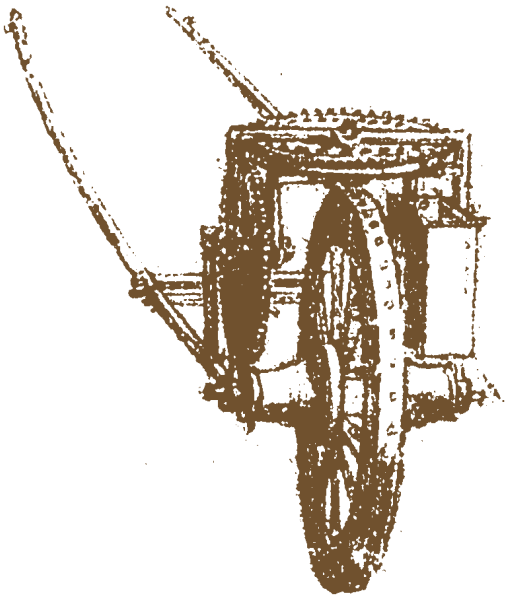


Gabriele Niccolai, *Revolving Crane with lantern framework*

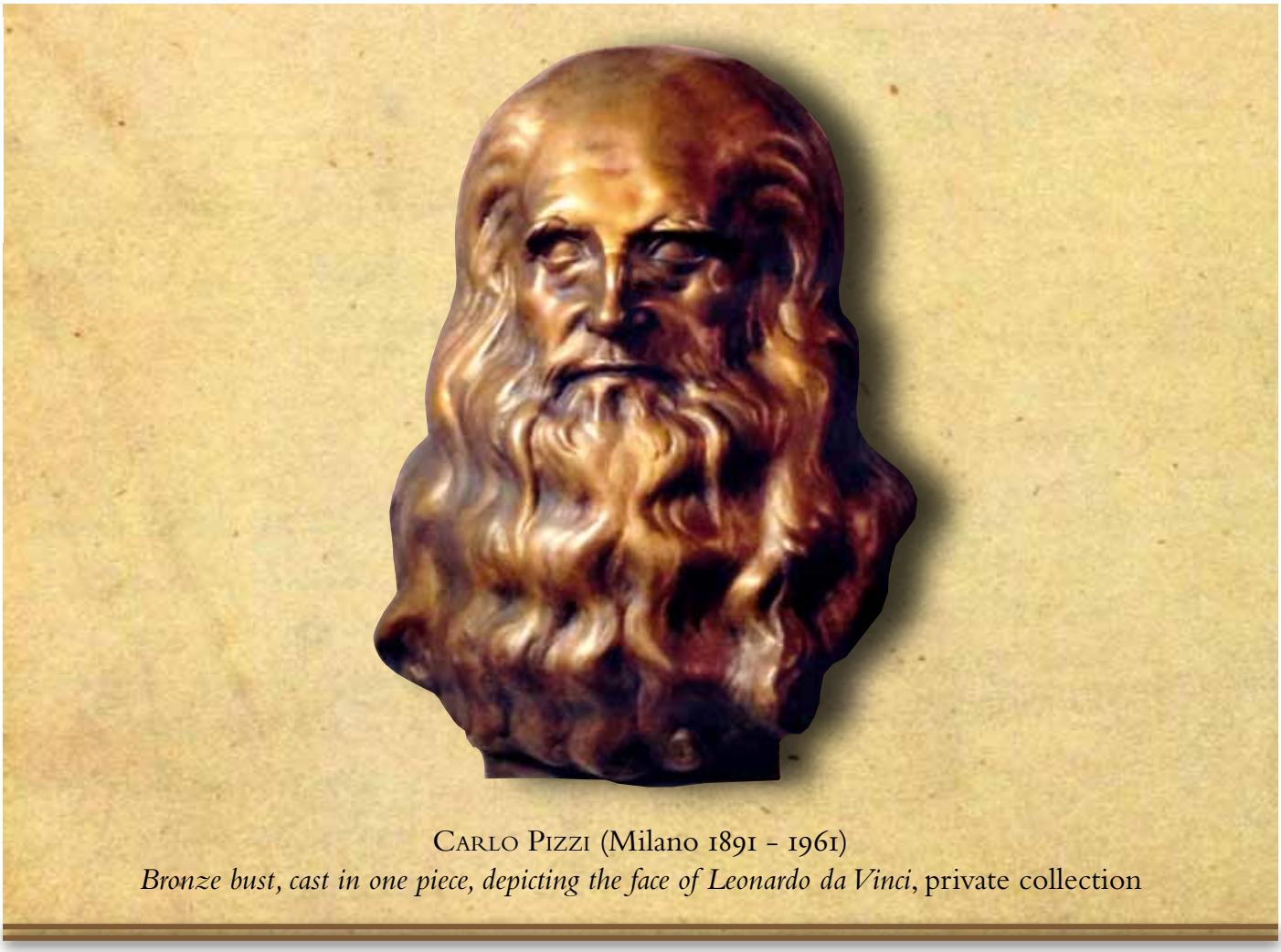
When completed, this building will be over 600 metres high and the second-highest building in the world after Burj Khalifa in Dubai.

Roman Ground Odometer

The odometer was fixed to one of the cart's axles and regulated based on the wheel circumference. This instrument comprised an arrangement of toothed gears. With every turn of the wheel, the teeth operated a device that let a pebble drop into a container for every mile covered. At the end of the journey, by counting the pebbles one could know how many miles had been covered. Leonardo da Vinci drew two models of odometer in the *Atlantic Codex* f.1r, from indications by Vitruvius, streamlining their mechanics and improving the machine's running.



Gabriele Niccolai, *Revolving Crane with lantern framework*



Carlo Pizzi (Milano 1891 - 1961)
Bronze bust, cast in one piece, depicting the face of Leonardo da Vinci, private collection

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