The engineer Leonardo and the Leonardo engineer: designing rotorcraft under his name five centuries later

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INTRODUCTION

The fact that, five hundred years after his death, Leonardo da Vinci's work is still producing admiration, debates, subjects for movies and, closer to us, inspiration for the industry, shows how important and persisting the Italian inventor's legacy is.

Born in a small village in Tuscany in 1452 as love child of Ser (Sir) Pietro da Vinci, Leonardo arrived in Florence as a self-educated boy and started there his polyhedral activity as painter apprentice. In this period he became proficient not only in painting but also in the drawing techniques, and familiarizing himself with classical subjects as well as with architecture, mechanics and sculpture, developing his characteristic approach to the reality.

After starting his career as a painter, Leonardo widened his activities to engineering and architecture, mostly working as a consultant –as we would say today- for the most important Lords of the period. In 1482 he introduced himself to the Duke of Milan preparing a presentation [Cod. Atl.] of his skills, ranging from engineering to architecture, from military construction to hydraulics, as well as painting and sculpture. Leonardo da Vinci died in 1519 in Amboise, were he spent his last years working for the king of France as a researcher, architect and painter.

Attracted by the theoretical aspects of mathematics and physics, he always paid attention to the applications of his inventions, representing one of the first examples of modern innovators and showing at the same time attitudes typical of today's hi-tech entrepreneurs. Most of this inventor's work was collected in a series of notebooks, in which a huge number of drawings, sketches, renderings and annotations keep revealing not just the products of his mind but also a surprisingly modern technical mentality.

Thousands of books and articles have been written about Leonardo Da Vinci, touching on his complex personality, his unique skills and his modern attitude. Hundreds of books have been dedicated to the inventor Leonardo Da Vinci, conceiving wings, parachutes, tanks and of course helicopters. But today a new smalltile can be added to this rich mosaic; a perspective which is on one hand personal but at the same time is also more or less shared amongst thousands of people in Europe and in the World. The choice of the Leonardo name by a company provokes its employees to face the values and the ideas connected to the great man. And the fact that in some cases the Leonardo name has substituted very old and famous brands makes this perspective also difficult.

So today, in the Leonardo helicopter design group, there are engineers conceiving new air vehicles as the great inventor did five centuries before them. This article is an attempt to discover and to discuss the attitudes, principles and even the techniques followed by these engineers daily, which reflect more or less immediately the Da Vinci vision, perhaps even without their knowledge.

THE FIRST CONNECTION: THE USE OF GRAPHICS IN THE DESIGN

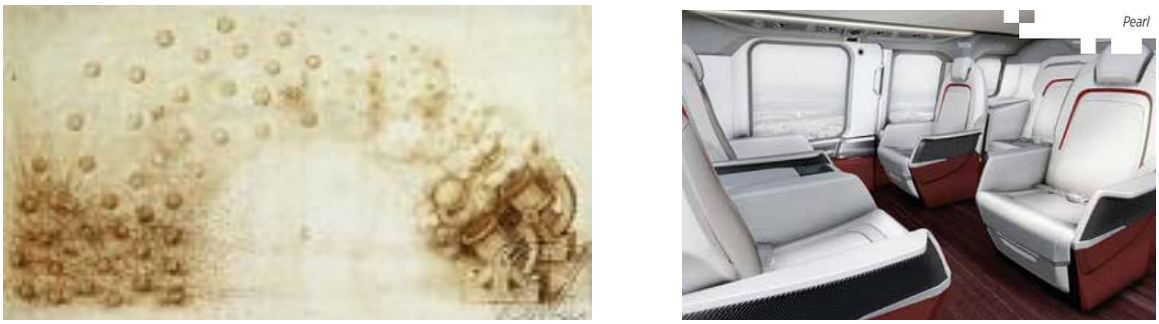
The most evident point of contact between the engineer Leonardo and a Leonardo engineer are the images. Drawings, sketches and paintings are what really made the inventor from the small village of Vinci famous, and

those are still today the most powerful tool used to communicate ideas in the design groups. Not surprisingly, all the advances in the computer graphics bring us closer to Leonardo's visual approach: charts are used in place of numbers, colourful slides in place of verbose reports, and 3D renderings in place of descriptions.

Examples are all around. On the workstations used every day at work, black screens with green or white text have been replaced by graphical user interfaces, in a revolution that has seen companies change their destiny and generations of engineers change their way of working: so today the young engineers almost ignore the meaning of a "c:\dir" command line or the joy of reading text results on a continuous paper output. Also during the short history of mobile phones, text entries for people's phone numbers have been superseded by icons of their face.

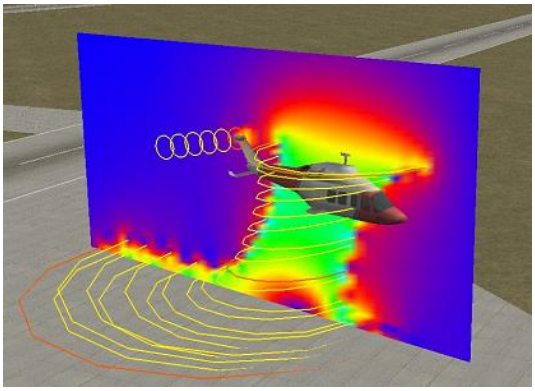
This evolution seems in a way an involution towards trivial communication channels and in fact, in some conservative technical contexts, the introduction of the first GUIs was perceived as somewhat entertaining, closer to a toy than to a working tool. However, apart from normal human resistance to changes, the adoption of graphics generally results in quicker and more effective communication and perhaps the fact that this is what kids use is not a coincidence.

So if today on the computer screen of a Leonardo engineer there are icons, charts and drawings, the engineer Leonardo was using similar tools. Of course computer and screens were not there already, but the essence of the graphics communication was well mastered by Da Vinci. One of the most interesting examples is the self-introduction material that Leonardo presented to Ludovico il Moro in 1562: today it would be defined as a curriculum vitae or even as a PowerPoint presentation, with numbered bullets of the abilities of the inventor, complemented by detailed images of concepts and ideas described in the text. This material, today dispersed in the pages of the Codice Atlantico, included several famous drawings such as the howitzer or the tank.



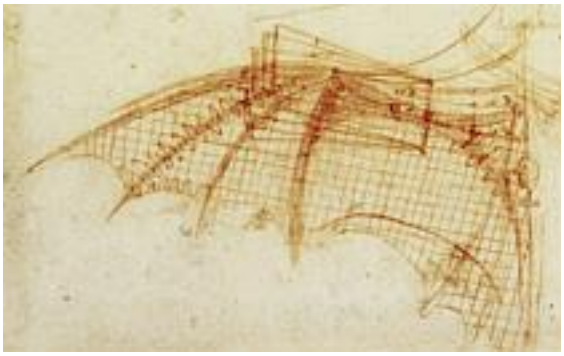
A picturesque rendering of a gunfire by Leonardo (left, source wikimedia) and a rendering of a Leonardo Helicopters product interior

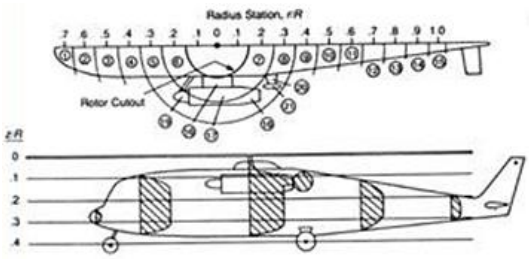
Leonardo's drawings are not always intended as communication means, but they represent for the author also working tools, in the same way the drawings are used today on the screens of the workstations by the Leonardo engineers. The best examples are found in the Codice Atlantico, an exploded view of a differential gear or simplified schematics accompanying the more realistic renderings, help the engineer to understand the behaviour of the systems he is designing.



A sketch of a water flow by Leonardo (left, source wikimedia) and a real-time visualization of the helicopter wake in Leonardo Helicopters simulation

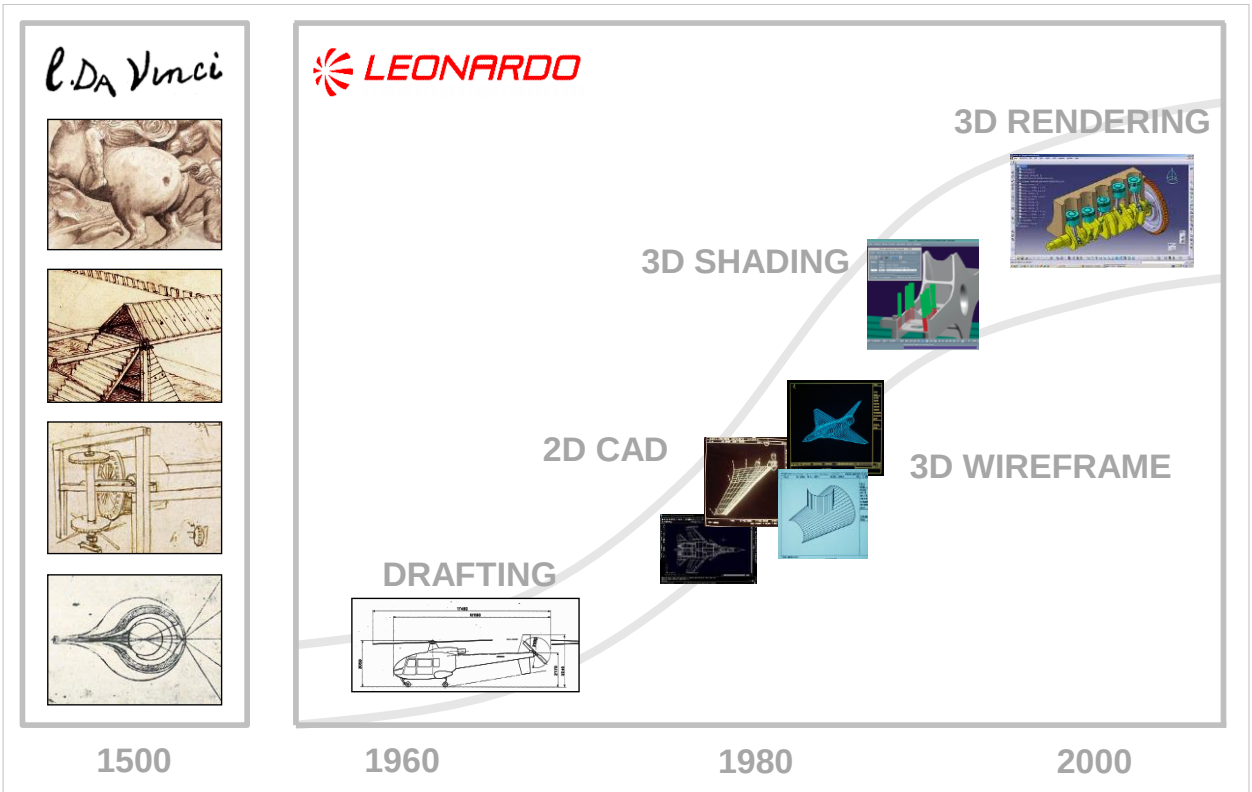
In some cases the drawing is directly used as a mathematical aid: a sort of square meshing of the wing visible on a page of Codice Atlantico seems to show a method for calculating the wing surface, while a series of circular sectors are used in several pages of the same notebook in order to calculate the area of various circular figures.





A graphical calculation of the surface of a wing by Leonardo (left, source wikimedia) and the schematic of a graphical method for the calculation of the download of a helicopter

Finally, to properly frame this analogy between the Leonardo engineer and the engineer Leonardo, it is interesting to consider how the use of image has developed in the design world and where, in this evolution, the inventor would fall in terms of quality, innovation, effectiveness. So for example, in the experience of Leonardo Helicopters, looking back at the AGUSTA times, the use of the image in technical activities was evolving from the paper drawings to simple computer aided imaging, moving in the last twenty years to 3D modelling, becoming more and more realistic through shading and rendering techniques.



A parallel between the representation possibilities by Leonardo (left, source wikimedia) and the evolution of design graphics capabilities

More or less, Leonardo Da Vinci's work can be compared with all levels of this evolution: he was of course able to sketch simple schematics to highlight basic concepts, as done in a 2D technical draft; he was also able to produce simple but effective 3D representations similar to the first 3D results produced by computers in the Eighties with the hidden line technique; some works by the inventor present a simplified shading, used to better represent the volumes in space rather than to actually render materials, with a technique much similar to the 3D shading used most of the time in the 3D solid modelling computer programs. Finally, also being a painter, Leonardo is of course mastering the most realistic representations, up to a level produced today with rendering software.

Obviously if on one hand a good parallel can be established in the level of quality of the images, the huge difference is in the effort and in the cost necessary to produce the images allowed in the last thirty years by the computers, with a ratio that seems almost ridiculous. If we assume for simplicity that 500 years ago Leonardo took an hour to produce a good shading of a machine, today an average computer can manage real-time shading, i.e. produce an image in 0.02 seconds, about two hundred thousand times faster than Leonardo Da Vinci.

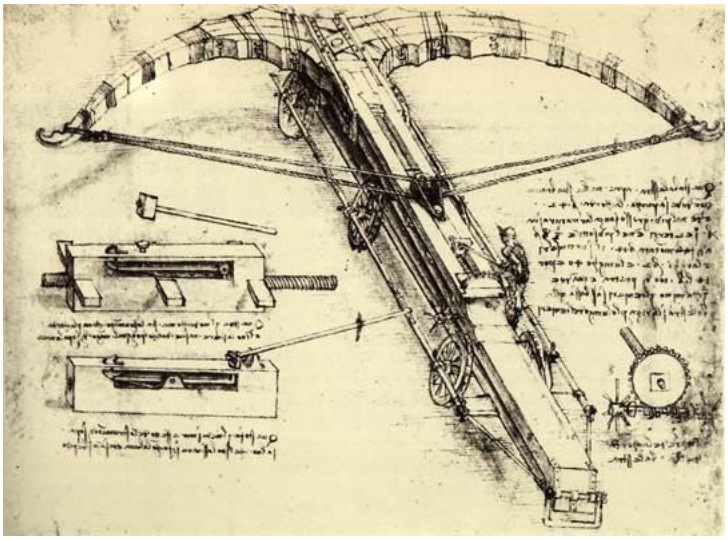
THE SECOND CONNECTION: THE DETAILS.

The second point of contact is the attention to the details: Leonardo's drawings are full of plenty of small characteristics, parts, components that build the concepts and reinforce the ideas behind them, avoiding in the first place the need of real prototypes. The same can be seen on the drawings -or better on 3D models on computer screens- in the design departments, where rotors, airframes, transmissions are illustrated with thousands of parts, to compose the so called digital mock-up. Here design solutions can be evaluated and stressed before the physical manufacturing.

A good example of the use of details in the works of Leonardo da Vinci is the famous giant crossbow: the drawing, set up as a 3D representation of the weapon, is in fact plenty of small elements that are not essential to the concept but definitely communicate a message of accuracy and of confidence in all the aspects of the invention.

The device is actually the well-known crossbow, just scaled up in dimensions, so a simple sketch could have been sufficient. Instead Leonardo is drafting the strings linking the flexible elements, the twin ropes attached to the shooting mechanism, the wheels installed to provide some mobility on the field and the loading mechanism. The latter is also detailed with an auxiliary image, showing how people would load the weapon; other pictures on the same page show how the trigger would be realized. The silhouette of a man is also used to show operational aspects increases the sense of concreteness of the device.

The result is not just the description of a big crossbow but rather an image of confidence in the possibility to realize and operate such weapon. And perhaps Leonardo's goal, who often used these drawings as a portfolio for self-introduction to his customers, was actually to promote himself as the man knowing exactly how to introduce extraordinary solutions in his world.



The giant crossbow (source wikimedia) by Leonardo: an example of the use of details in the illustrations

The same is done today by designers and engineers: in the era of computers and 3D models, it is of course easier to add as much detail as desired, from structural parts to equipment: the geometry of all elements of a product are stored in a database and are retrieved once a graphical representation is requested. And if the product is complex, as in the case of the aircraft created by the Leonardo engineers, this process may involve thousands of components and millions of surfaces. This is the case of the so-called digital mock-up, a 3D model intended to substitute to all means the mock-up of an aircraft, allowing the designer to evaluate volumes, interference, accessibility and visual aspect of the product.

A digital mock-up of a Leonardo helicopter with 3D modelling of thousands of parts and components

As with the drawings of Leonardo, the goal of the digital mock up is to verify the soundness and the feasibility of a product. The digital mock-up takes shape during the preliminary design and is one of the key tools during the design reviews in order to freeze the configuration and move to the production phase, anticipating risks before committing to the realization of hardware. In this field the challenge is to provide designers and managers with the best insight, bringing the non-physical representation as close as possible to the real solution, not just from a pure geometry perspective but also considering ergonomics, tactile characteristics, surface finishing. In the last 20 years technology has made great steps here, producing high quality renderings, virtual reality glasses, wearable sensors and tactile gloves. Today it is possible to virtually sit in the cockpit of an aircraft before one single piece of hardware has been built or to fly in the intake of a jet engine following the trajectory of an air particle. Nevertheless, in some cases the physical object is still a must: luxury interiors for VIP aircrafts, product displays at airshows and of course prototypes for testing are typical examples. The challenge is to understand how and also if the virtual representation can be used in these cases, following that same approach envisaged by Leonardo da Vinci 500 years ago.

THE THIRD CONNECTION: THE CONCEPTUAL DESIGN APPROACH

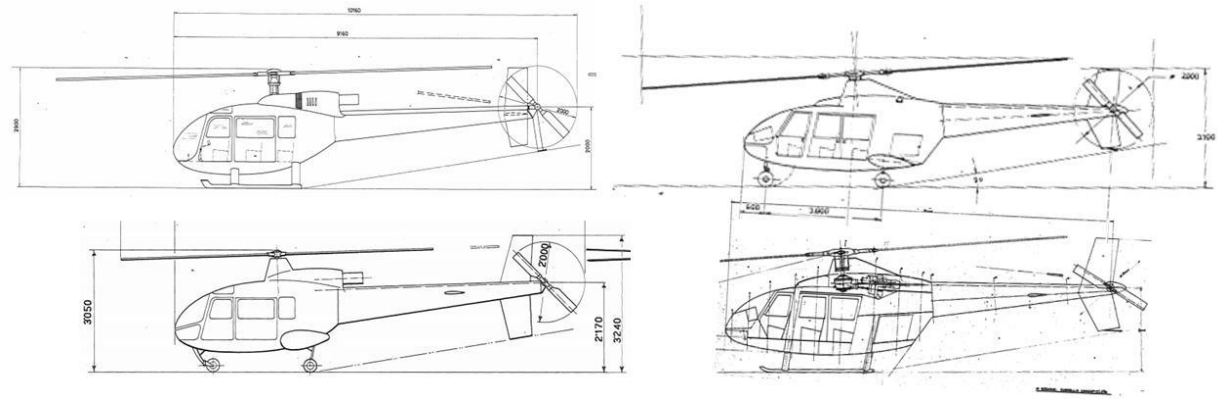
The third commonality is somehow more evident in the preliminary phases of a product design rather than in the detailed development: Leonardo's engineering notes and documents can, in a way, be compared to simulation results, most of the time reflecting approximations, iterations, refinements, design evolutions or trade-offs.

In this phase of the life of a product, in fact, there is a strong need for visualizing phenomena or figuring out solutions in order to evaluate design options, highlight the values of the possible alternatives and of course support relevant decisions. Also when or if a solution is pursued, the iterative design is a pretty common approach: with complex products or behaviours, it is often difficult to have explicit formulas or procedures to achieve an optimal solution; in these situations it is instead easier to progress with refinements or small variations reaching the optimum by means of a sequence of steps.

Another characteristic of the conceptual design, both by the engineer Leonardo and the Leonardo engineers, is to have a frequent and effective communication with the customer, to interact on the product and to show progress; ultimately to reduce risk from both sides, as the designer gets confirmations from the customer as the concept takes shape and on the other side the customer being assured regarding the progress. This communication needs to be effective, showing for example sufficient detail as discussed above; frequent and cheap, excluding the use of physical models or artistic impressions; possibly interactive, allowing display and feedback, for example taking notes or quickly drafting on a large drawing laid on a table. In the 16th century all these needs were addressed by Leonardo, with his exceptional skills, just by using pen and paper; in the industry nowadays the conceptual design mostly makes use of computers and in particular of simulations, in the widest interpretation, ranging from the typical

graphical virtual representation of the reality (cad or renderings) to the most complex multi-domain simulations (FEM, CFD, multi-body).

And typically, during the design, these simulations regard a large number of solutions that are discarded, since only the final concept, the one selected to become the product, is built as a real prototype and eventually is put into production. Bringing this point to an extreme, one could say that most of Leonardo's work was only a simulation of conceptual design, since no helicopter, tank or even equestrian monument has been realized out of it. Well, this shows another commonality, since also the destiny of many studies done in preliminary design, where against a successful solution many options are explored and discarded, so also the archives of Leonardo Helicopters are plenty of unborn models like the ones visible on the pages of Leonardo's codes.



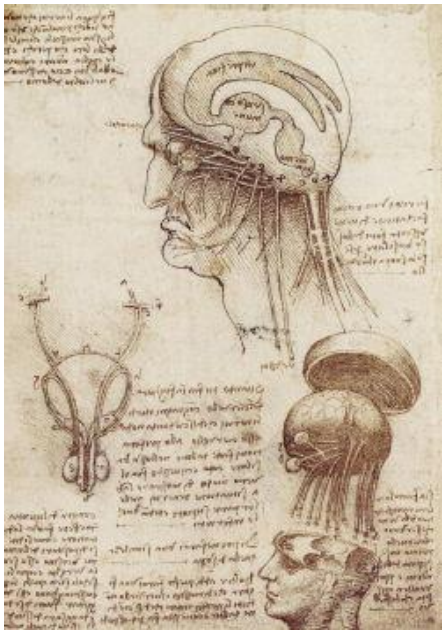
Drawings of some first conceptual design iterations of the A109 helicopter (above), together with a picture of the last version (below) giving an idea of the evolution taking place during the initial design phases

ONE MORE CONNECTION: THE CAPABILITY TO INTEGRATE THE KNOWLEDGE

Finally and perhaps most important point of contact between the engineer Leonardo and a Leonardo engineer is the integration capability. Notebooks, drawings, paintings of the man from Vinci combine knowledge and information coming from various directions, from hydraulics to math, from illustration to mechanics. The wings of the angels in the paintings look convincing to an aircraft designer and vice-versa Leonardo's technical drawings are also completed with painting touches.

This is not surprising, as Leonardo Da Vinci is not just an inventor or a scientist; he is a versatile person, proficient in engineering, in painting, in music, in sculpture, in architecture and in science. And he is also making the best synergy using his wide knowledge, with several useful contaminations, so engineering drawings include artistic touches and vice versa paintings or sculptures show technical details.

A good example of integration, concerning in a way the flight aspects, is the painting of the "Annunciazione", where the wings of the angel look realistic, inspired by observation of birds and perhaps also by the design of mechanical flying machines: the feathers are reproduced accurately, the root of the wing is structurally solid and the leading edge is properly rounded.



The "Annunciazione" and a human head drawing by Leonardo (source wikimedia)

So in other paintings or images, the eye of the scientist is evident: clouds, streams, vortices shown in artworks look similar to the ones that Leonardo was sketching in his engineering notebooks. In the same way, anatomy studies include cutaways or exploded views that one would expect to see on a technical manual of a machine: the illustrations of the human head present in the Leicester Code is in this case a good example.

And if the artwork is benefitted by the engineer hand, the technical drawing definitely includes artistic techniques. The iconic sketch of the aerial screw, although just conceptual and simple, has a hatched background in order to highlight the white fabric of the blade; the siege machine has nice shading to highlight covered spaces and empty volumes; the drawing of the assault chariot shows detailed shades of the parts of the device, perhaps to better illustrate the distance from the ground level.

The importance of the integration of different skills and techniques is not so different today: in the VIP helicopter sector for example, style needs to conjugate with functionality, while transformative products tend to combine performance and capabilities taken from different machines. This is the case of the AW609 tiltrotor, an aircraft that is capable to take off, land and hover like a helicopter, and capable of flying in cruise like an aeroplane, well above the weather and with twice the speed of a conventional rotary wing machine. This unique possibility is achieved by rotating the rotors installed at the tips of the wing: in helicopter mode they produce lift pointing upwards while in aeroplane mode they provide the thrust, pointing forwards.

As is easily understandable, projects like the AW609 require the integration of knowledge and expertise coming from two worlds, the rotary world and the fixed wing world, realizing somehow the polyhedral and integrated vision of the design that Leonardo was using in his world.

And integration goes also to a greater scale, in particular since Leonardo has become a single entity unifying a number of different companies: in this vision, product and solutions are now created by integrating knowledge and

capabilities of the various parts of the one company, for example with Leonardo aeroplanes equipped with Leonardo avionics or with Leonardo helicopters carrying Leonardo radars and so on.

The Leonardo poster for the new brand

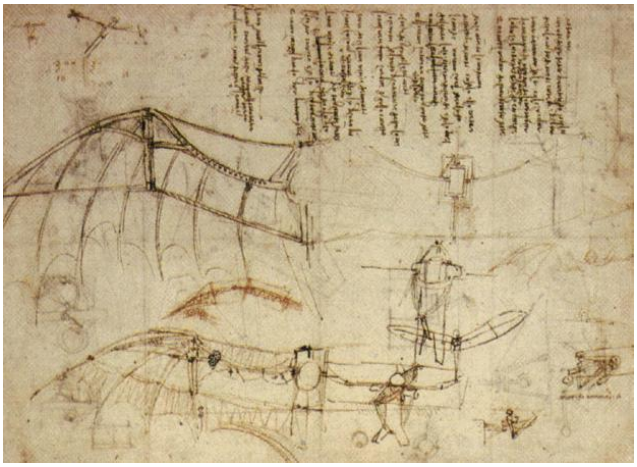
This vision of integration of different knowledge and capabilities, pursued by the ingenuity of one man in the Renaissance, is today inspiring an entire company, as strongly expressed by the new company name and by the communication campaign following the rebranding. So we can say that products and services are created more and more from the various souls of Leonardo Company, including the special one coming from a small village named Vinci.

ANNEX: THE LEONARDO ENGINEER AND THE ENGINEER LEONARDO: PARALLEL CONCEPTS

The connections between the engineer Leonardo Da Vinci and the Leonardo engineers, summarized above under three main aspects, can be also seen in the ideas and in the products of the inventor and of the Company. The following pages represent a small selection of some significant parallels, highlighting the commonality of the approach, the connections of the basic ideas, the developments often surprising of these ideas and in some cases also the limits of inventions that never saw a realization.

FLYING MACHINE WING

L. Da Vinci



Leonardo's flying machine consists mainly in its wing and in particular in the internal structure, while little description is given on the wing surface and apparently no detail at all is provided about the aerofoil of the wing.

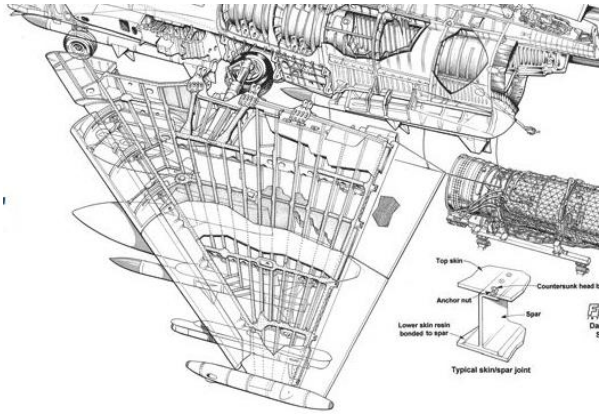
This might reflect Leonardo's approach which starts from the observation of the nature as the first laboratory available before the inventor. So while the feathers of the birds were probably a given for Leonardo, the internal structure with all the light bones and joints was more interesting and was considered perhaps the key of the flight capability, pointing in the wrong direction or at least neglecting the aerodynamics of the lifting surfaces.

However, the structural aspects are pretty well studied and Leonardo's wing shows already many of the elements that characterize today's wings, including the spars, the ribs and an elaborated plan-form.

The machine is completed by a mechanism suggesting a flapping movement, an approach suggested of course by nature but bringing Leonardo and many subsequent inventors to a misleading direction until, in the XIX century, the gliders were adopted as the starting point for the powered flight. Nevertheless, although unsuccessful, this detail shows the attention of Leonardo to the product rather than to the single aspect, considering at the same time lifting function, structural function and propulsive function.

EUROFIGHTER WING

LEONARDO



The wing of a modern fighter is an optimized compromise among several needs, ranging from pure aerodynamic performance to fuel capacity, from structural dynamics to geometric constraints.

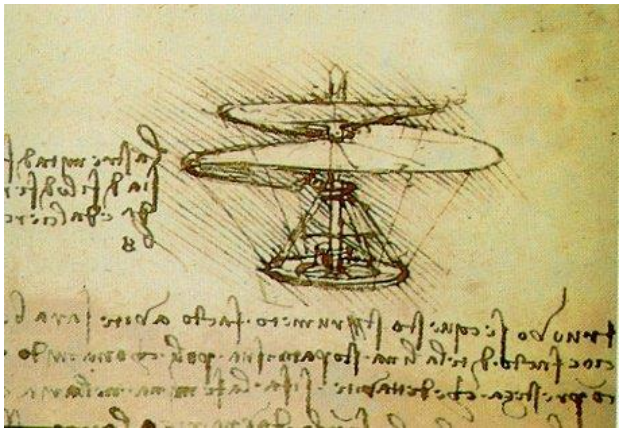
The Eurofighter is a perfect example: the wing of this fighter is designed to provide the necessary positive or negative lift to balance respectively up to nine to three times the aircraft weight, working in normal attitudes or at high angle of attack, at low speed or in supersonic conditions; the wing also accommodates the fuel tanks, the retracted landing gear and a number of pylons for external stores.

To satisfy all these needs, the wing has a number of aerodynamic features, including advanced aerofoils, high-sweep delta plan-form, leading edge flaps and trailing edge flaperons. From the structural standpoint the Eurofighter wing is also an outstanding example, with multiple-spar structure and composite skins ensuring high stiffness and at the same time low weight.

The attachments of the stores are also a challenge, with pylons that must be small in order to limit the drag, must include complex release mechanisms and interfaces, ensuring at the same time adequate structural characteristics to withstand heavy concentrated loads and proper stiffness to avoid vibrations and flutter phenomena.

AERIAL SCREW

L. Da Vinci



wikipedia

The famous Leonardo's helicopter, actually named "aerial screw" by the inventor, is an icon of innovation and vision. But differently from other concepts developed by the Italian inventor like guns, gears or wings, the aerial screw appears only once in the Codice Atlantico, on a relatively small spot of a page which also reports a nice description of the working principle, reporting the famous sentence "una vite che si fa femmina nell'aria".

But in reality the aerial screw, although being a brilliant vision, is actually based on an ancient invention, born almost 2000 years before Leonardo: the Archimedes' screw. That device, basically consisting in a screw rotating inside a tube, had been used over the centuries for example as a pump for boats. Nevertheless, the idea to use in the air what was used for water reflects Leonardo's intuition that air and water are physically the same.

However, the concept inspiring Leonardo is also the killer of it, because as we today know, the effective way to achieve vertical lift is a rotating wing with small chord and big radius rather than a blunt surface with small radius and big chord like the aerial screw. And, as typically pointed out, the aerial screw designed by Leonardo does not consider the necessary propulsion, apparently to be provided by humans, and the anti-torque effect which today in most helicopters is managed with tail rotor.

So, notwithstanding the value of the idea, it is therefore not surprising that the aerial screw did only exist on paper and that the technology took other way for the vertical flight.

HELICOPTER

LEONARDO

The AW169 is the latest-generation 4.5 tonne class twin-turbine helicopter, featuring class-leading performance for versatile capability in the most demanding operating conditions.

The aircraft exceeds the most demanding market and regulatory requirements, including the most recent FAA and EASA Part 29 standards for performance and safety. Pilots benefit from an advanced open-architecture avionics suite with fully digital glass cockpit and excellent external visibility for optimised situational awareness and minimised workload. Operators benefit from a large, rapidly reconfigurable cabin, with constant-height cross section and easy access for adaptability to a variety of missions. APPLICATIONS: Executive and Private Transport, Medical and Rescue Services, Security Services, Energy Services, Utility

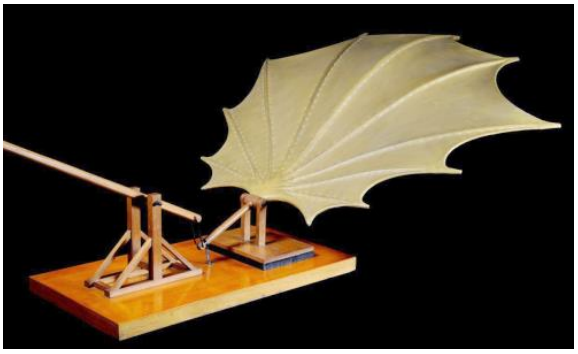
MAIN FEATURES

MTOW: 4.6/4.8 tonnes

Powerplant: 2 x PW210A (1,000 shp class each)

Crew/Passengers: 1 or 2 pilots with 8 or 10 passengers

FLAPPING WING



source Wikimedia

Many of the invention of Leonardo were related to the flight and the flapping wing is conceptually the first one of this stream of ideas. IN fact Leonardo, inspired in many cases by the creatures and phenomena seen in nature, for the flight Leonardo is obviously looking at the wings of the birds and of the insects.

As a matter of facts, many scientists and inventors have approached the problem of flight of vehicles heavier than air by means of flapping rather than gliding. In nature this concept is actually providing vertical take-off capability at the cost of the complication of a fully instrumented and actuated structure, as de facto is the wing of a bird.

One aspect that however is key in a flapping wing is the structural advantage of the flapping hinge, taking forces but not bending moment, requiring therefore lighter structures. This principle, probably not really considered by Leonardo, is used in the helicopters, where an articulated connection between blade and mast is the most used type of rotor.

FLAPPING HINGE

Early inventors like Leonardo da Vinci did consider important for the flight, if not essential, the flapping movement of the wing, as shown by birds and insects in nature. But this flight mechanism, which combines lift and thrust, was not effective for flying machines, as proven by some failing experiments.

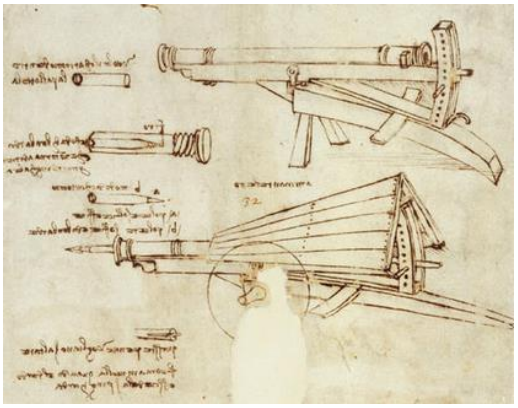
But the flapping wing concept was going to be resurrected by another application, a few decades later, the helicopter. In fact when studying the autogyro, La Cierva soon faced the problem of the unbalance of the rotor in forward flight, where during the rotation the advancing blade was introducing more force than the retreating blade. He solved the problem by using a hinge rather than a cantilever to connect the blade to the mast, leaving to the blade the possibility to flap freely.

This configuration of the rotor, called articulated, has become the most common in helicopters and is still used today. Some improvements have been introduced in the arrangement of the articulation or using elastomeric elements in place of a physical hinge.

Most of the models produced by Leonardo Helicopters use articulated rotors, optimized to reduce loads and vibrations on the cabin and designed in order to minimize maintenance, weight and cost of the rotor system. This rotor design, properly scaled, is applied to light helicopters like the SW-4 or the 109 family as well as mid-size products like the AW Family (169, 139, 189) or the heavy products, like the AW-101 or the CH-47.

GUN

L. Da Vinci



source Wikipedia

As stated by Leonardo in his famous self-introduction letter to Francesco Sforza, a great part of his inventions are intended for military use, following of course the interest of most of his customers at the time: guns are no exceptions and appear on many drawings.

And if guns are not an invention of Leonardo, the way he is arranging them is definitely innovative. So in particular on the pages of the Codice Atlantico there are single guns, multiple guns, armoured installations and so on.

The ideas are completed with notes, details of the mountings and description of the ammunitions.

As with other ideas by Leonardo da Vinci, the design of the various guns have essentially not been realized, although many concepts have been applied centuries later, for example in the machine guns or in the tank.

OTO 76/62 "SUPER RAPIDO" NAVAL GUN

LEONARDO

The 76/62 Super Rapid (SR) Gun Mount is a light weight, rapid-fire naval gun providing unrivalled performance and flexibility in any air defence, particularly in anti-missile role. Capability for very effective engagement of shore based targets and surface vessels are also provided for unique multi-role performance. The 76/62 SR is suitable for installation on ships of any type and class, including small naval units. Interface to a large variety of ship's Combat Management System and/or FCS/EOS is possible according to digital and analogical standard including open architecture. The Firing rate can be selected from single shot to firing 120 rds/min. In operational conditions the tactical time is less than 3 seconds and the standard deviation at firing is less than 0.3 mrad thus providing excellent accuracy. The 76/62 SR (together with the 76/62 COMPACT) is the only medium calibre naval gun on the market capable of sustained fire, which is a fundamental requirement in any scenario involving the simultaneous engagement of multiple manoeuvring targets as in asymmetric warfare scenarios. Automatic loading is provided through a revolving magazine and rapid reloading is easily undertaken even during firing actions by two ammunition handlers.

“El Paradiso a similitudine de uno mezzo uovo”

L. Da Vinci

source author’s reconstruction

In 1493, when working in Milano, Leonardo was preparing the solemn celebrations of the marriage of Gian Galeazzo Maria Sforza with Isabella d'Aragona, as documented by himself and by authors of that period.

Along with the typical exhibitions and decorations, the greatest attraction of the event was the representation of the paradise, rendered by a spherical screen in which a number of lights were representing the stars and the planets were impersonated by actors appearing through holes in the screen. All these elements were moving and the scene was completed by music and songs.

Although this representation reflects scenic machines used in theatres, the concept of the spherical screen to represent the sky, the use of moving elements, light sources and sound, is a significant effort for an immersive representation, in a way that later is used for flight simulation .

Leonardo Helicopters “AWARE” Simulator

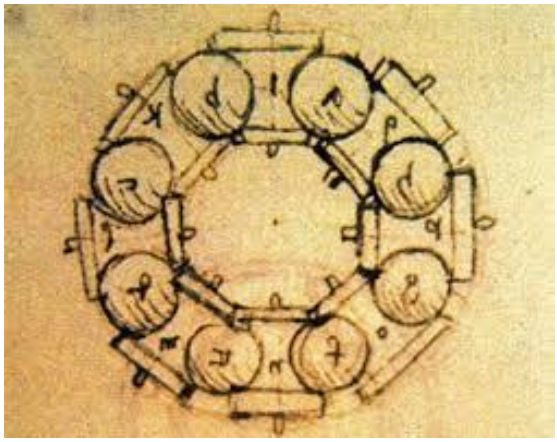
LEONARDO

AWARE is the Leonardo Helicopter Division flight mechanics simulation environment, designed for virtual prototyping of rotorcraft for the design and testing of handling qualities behaviour, control systems, inceptors and flight procedures.

Physically, the simulator is made up of: a rotorcraft cockpit mock-up representative of the AgustaWestland product “Family” (AW169, AW139, AW189), equipped with re-configurable touch-screen displays and actively-controlled pilot sticks; a set of fourteen PCs, to perform the required computational tasks, including the flight mechanics real-time calculation, the stick force feedback control, the display image generation as well as the visual image generation; four operator stations, to control the virtual experiments, display data in real-time and record all the relevant information; a 3-meter wide cylindrical screen, allowing the rendering of the simulated “out-of-the-window” scene by three projectors, plus an additional fourth channel dedicated to the pilot lower field of view.

BALL BEARING

L. Da Vinci



source wikimedia

The most simple example of roll bearings is perhaps existing in nature: round stones placed between flat surfaces clearly show a reduction in the friction.

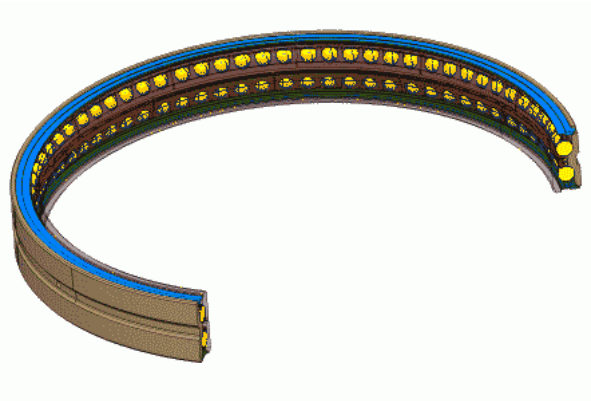
Maybe Leonardo was starting by simple observation of natural phenomena when he conceived the idea of a rolling bearing, documented in a picture of the Codice Atlantico.

The idea was possibly known to the ancient romans, but also in this case, Leonardo's drawings represent the first clear representation of the device.

The concept is similar to the rolling bearings used today, although in the drawing is not clear the presence of the inner and outer rings with the traces.

BALL BEARING

LEONARDO



The rolling bearings are of course a key element for a rotorcraft, since a number of parts need to rotate at high speed, with the minimum possible friction.

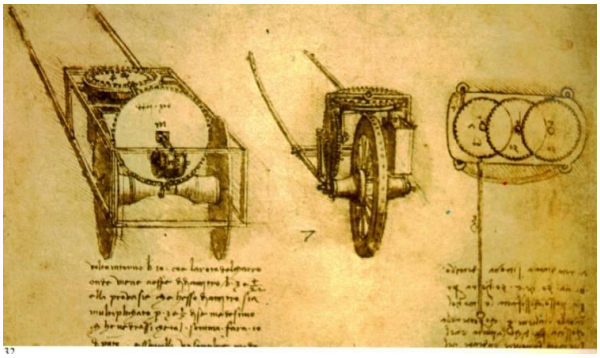
Rotating bearings are used in fact in the helicopter transmissions, on the controls, in the landing gear, in the engines as well as in some equipment.

The rotating bearings have the primary function to minimize the friction of rotating components, reducing at the same time the waring of the interfaces. In some cases the bearings have also the function to withstand significant axial forces, like the thrust of a rotor or of a turbine stage.

One important challenge case for the bearings in the helicopter transmissions is the so called no-oil test, in which a failure of the lubrication system is simulated, with critical operating conditions for the gears and for the bearings. Leonardo Helicopters have demonstrated the best results, with no-oil capabilities exceeding in most cases by far the strict safety requirements imposed by the Certification Authorities.

ODOMETER

l.DA Vinci



source Wikimedia

The odometer is not an invention of Leonardo Da Vinci, since several descriptions of such devices can be found in classical tests and also precise measurements of roads have been produced in the past by Greek and Romans. However, the illustration in the Codice Atlantico is one of the first technical representations of the device although it is not clear if Leonardo himself did realize the device. The odometer illustrated by the inventor consisted in a series of gears attached to the wheels that cause a hole to open every given number of turns, letting a stone fall in a box: so the distance was obtained by counting the number of stones.

This simple object represents in fact a mechanical integrator and embodies the basic concept of distance measurement, with most of the related aspects, including need for calibration, integration error depending on distance, overflow phenomena when all stones are used.

A distance measurement method not based on integration of speed and/or acceleration has been introduced later in the maritime world with the determination of the coordinates and, more recently, with the availability of the GPS system.

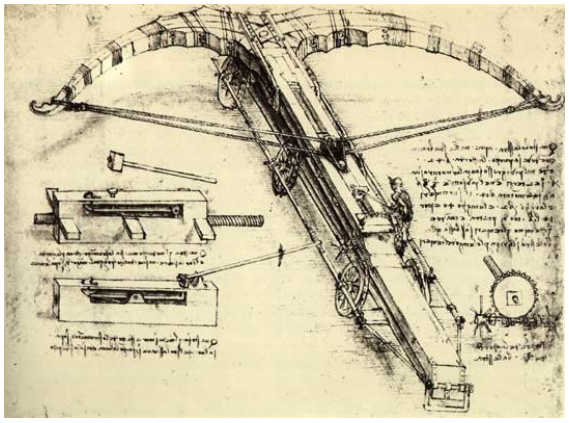
SMD-55 MULTI FUNCTION DISPLAY

LEONARDO

The SMD-55 is a 5 inches by 5 inches high performance Active Matrix Liquid Crystal Display with full colour capability under all conditions, from full sunlight to NVG operations. The SMD unit includes twenty soft keys. The Smart MFD is designed to:-

Manage dual redundant 1553B bus used to receive controls and real time symbology parameter update and to transmit internal status and soft key inputs, Accept two selectable RGB video input according to STANAG 3350 Class B or C and generate synthetic imageries by using the state-of the art digital technology. The on-the-board symbol generator is based on high performance “SHARK 21060 DSP” and on the last generation of Graphic Co-processor ASICs. The active thermal management allows the unit to operate in the full environmental range without external cooling. The SMD-55 is especially optimized for avionics application using the best AMLCD technology today available and ultra-bright LEDs for backlight. Optical filters are used to redirect light into the specified viewing angle.

GIANT CROSSBOW



source wikimedia

In the attempt to increase the range of the well know crossbow, Leonardo was thinking to a giant version of the weapon.

The device depicted in the Codice Atlantico includes also the silhouette of a soldier operating it as several details of the loading and firing mechanism.

The giant crossbow was approximately 25 meters wide, the elastic element was made of laminated arms and the loading was realized by a series of gears and teeth pulling and locking the launching element The device was mounted on six wheels, allowing the movement on the field.

The giant crossbow was never realized by Leonardo; recently a 1:1 model was realized and tested for a television documentary.

MBDA "MARTE" MK2 MISSILE

Medium Range, Lightweight Anti-Ship Missile System Ship Launched. Marte Mk2/N is a derivative of the proven and in service Marte Mk2/S helicopter-launched anti-ship weapon system.

Both variants deploy the same Marte Mk2 missile. With the availability of various launcher configurations, Marte Mk2/N is suitable for installation and integration, either as a new build or retro-fit on a wide range of naval vessels from 25 to 50 m.

Options range from two single or double launchers for a small patrol craft up to quadruple launchers for larger vessels. Marte MK2/N provides small warships with an attack capability against targets of similar or greater size standing within the horizon of the ship-borne sensors.

PARACHUTE

L. DA Vinci

The parachute designed by Leonardo is one of the best examples of his approach, combining ideas, calculations and graphic representation.

The idea, perhaps inspired by various examples in nature, is translated in a very rationale design with the typical pyramid shape, the rigid elements keeping the device open and the configuration of the ropes holding the human load.

Leonardo is also providing here some precise numbers for this invention, estimating a side and an height of seven meters for his pyramidal parachute and specifying that the device would work for any height, showing to understand the concept of drag and limit speed for a falling and drag

The graphic rendering of the concept is brilliant,

EUROFIGHTER DROGUE PARACHUTE

LEONARDO

The drogue parachute is essentially a parachute used to reduce the aircraft speed by increasing its drag, with the same physical principle used for the conventional parachute.

The drogue parachute was invented by Giovani Agusta, the founder of Leonardo Helicopters, in 1911: the original use was the reduction of the speed of falling aeroplanes, while later it has been used essentially to reduce the landing distance of the airplanes. An example of this application is the Eurofighter, which includes a drogue parachute at the root of the fin.

Another application of the parachute is on the ejection seats, installed on several Leonardo products like the Eurofighter, on the M346 and on the M345. In this case, following an emergency ejection of the pilot, the parachute is deployed once the seat has separated from the aircraft and is used to reduce the falling speed to an acceptable value.

Armoured Car

One of the most famous inventions by Leonardo, the tank or armoured car concept is represented in several papers of the genius. As other military concepts, the tank idea is perhaps intended to show practical advantages to a potential sponsor.

In fact, among various ideas, this is one of the closest to a practical realization, while it combines known elements like guns, wheels and some simple armour, with a concept not far from ancient roman war machines. It must be noted that Leonardo was considering multiple guns in order to shoot to all directions.

The original characteristics are in fact the combination of all those elements in a vehicle that could have really made a difference in the battlefield, as it actually did during the first World War.

As for other inventions by Leonardo, his armoured car is lacking a real solution for power, although horses or humans in this case could have provided some basic capability.

One aspect that is interesting of this invention is the graphical rendering of the concept, which shows -by means of few effective signs- details of the armour, the presence of multiple guns, the idea of a moving vehicle.

Centauro armoured Car

The new Centauro armoured vehicle represents a new stage in the evolution of the storied Centauro 105 and 120mm armoured vehicle, the first 8x8 wheeled antitank vehicle in the world with a high-pressure gun. As regards mobility in particular, the power-to-weight ratio, increased to 24 HP/tonne, provides unequalled performance in terms of speed and acceleration thanks to the new-generation IVECO engine, offering more than 720 HP, and to the associated modernisation of the transmission, braking system and control electronics.

The third generation 120/45 mm gun (optional 105/52mm interchangeable to 120 mm), with integrated and stabilised low-recoil muzzle brake, provides the same fire power as most modern main battle tanks, with the capability of firing all latest generation 120 mm NATO APFSDS and multi-role MP munitions.

The turret, equipped with new anti-mine seats, has a crew of three men - commander, gunner and loader – with the latter able to use the new automatic loading system, while being able also to undertake manual loading operations, as back-up, or other emergency operations. Optronic equipment includes a panoramic commander's sight and a gunner's sight, both latest-generation, and a back-up sight for use in degraded mode. The vehicle is fully network-integrated (for NCW). In the turret, as an alternative to the external turntable-mounted anti-aircraft machine gun, a remote-operated HITROLE Light turret can be installed, with the possibility of using 7.62 or 12.7 calibre machine guns as well as 40 mm AGLs, integrated with the firing system, allowing the loader to undertake battlefield surveillance from a protected position.