

Leonardo Da Vinci Land Surveyor and Cartographer

Let no man who is not a Mathematician read the elements of my work.⁽¹⁾

Brian S. BLEVINS, PLS

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SUMMARY

Leonardo da Vinci (1452 – 1519 CE) is the archetypal Renaissance man and one of the most prolific geniuses in history. His creative, analytic, and visionary inventiveness might be unmatched in all of history. Leonardo... is best known as an artist, the creator of such masterpieces as the *Mona Lisa*, *Madonna of the Rocks* and *The Last Supper*. Yet Leonardo was far more than a great artist: he had one of the best scientific minds of his time.⁽²⁾

In the words of his biographer Giorgio Vasari:

The most heavenly gifts seem to be showered on certain human beings. Sometimes supernaturally, marvelously, they all congregate in one individual. . . . This was seen and acknowledged by all men in the case of Leonardo da Vinci, who had. . . an indescribable grace in every effortless act and deed. His talent was so rare that he mastered any subject to which he turned his attention. . . .⁽³⁾

Leonardo's scientific work was virtually unknown during his lifetime.⁽⁴⁾ While portions of Leonardo's technical treatises on painting were published as early as 1651, the scope and caliber of much of his scientific work remained unknown until the 19th century.⁽⁵⁾

Only through the painstaking translations of his massive manuscripts are we learning the full extent of his genius. His discoveries in anatomy, flight, civil and mechanical engineering, robotics, biology and geology are much celebrated. His concept and invention of building canals with beveled lock gates played a part in the evolution of canal design and can still be seen today in the Panama Canal.

Leonardo also made great contributions to physical geography including land surveying and mapping. He was a great cartographer who made his own surveys of the land for a variety of purposes. Throughout his life, Leonardo observed...and... drew beautiful and accurate maps of entire watersheds....⁽⁶⁾ Leonardo was both painter and cartographer. For him the painter, the naturalist and the geographic surveyor were aspects of the single enquiring mind.⁽⁷⁾

This paper will explore Leonardo's life, in a mostly chronological order, highlighting his surveying and cartographic contributions. We will examine his extensive and accurate land measurements and the many elaborate cartographic masterpieces that he created. We will see how he invented and improved surveying tools and introduced cartographic techniques that are still used today.

We will witness how Leonardo, like so many great people before and after him, earned his livelihood through the art of measuring and mapping the Earth. Leonardo da Vinci, land surveyor and cartographer, a master of measuring and mapping the earth.

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LEONARDO'S TIME

In order to have a more complete understanding of Leonardo's surveying and cartographic contributions it is important to understand the time in which he lived – the Renaissance.

In Western intellectual history, the Renaissance... marks the period of transition from the Middle Ages to the modern world.⁽⁸⁾ The sweeping intellectual changes that took place in the Renaissance and prepared the way for the Scientific Revolution could not have happened without a technological breakthrough that changed the face of the world - the invention of printing [Johannes Gutenberg, 1450].⁽⁹⁾ Printing introduced two fundamental changes to the distribution of texts: rapid diffusion and standardization.⁽¹⁰⁾

Like every good scientist, Leonardo consulted the traditional texts and used their conceptual framework as his starting point. The ideas of Greek philosophy and science, on which the Renaissance worldview was based, were ancient knowledge. Yet for Leonardo and his contemporaries, they were fresh and inspiring, because most of them had been lost for centuries. They had been rediscovered only recently in the original Greek texts and in the Arabic translations.⁽¹¹⁾

While explorations of the rediscovered classical texts greatly extended the intellectual frontiers of the Italian humanists, their physical frontiers were also being extended by the geographical discoveries of the famous Portuguese explorers and those who followed them. The Renaissance was the golden age of geographical exploration... the great ocean voyages led to numerous improvements in... cartography, astronomy, and other sciences and technologies associated with navigation.⁽¹²⁾

Also important during this time is remembering that Renaissance Italy was constantly at war. Leonardo shrewdly recognized that employment as a consulting military engineer and architect was one of the best ways to secure his financial independence.⁽¹³⁾ Realizing that the power of the Sforza's came from their military might... he wrote a carefully composed letter to the Moor, in which he offered his services as a military and civil engineer....⁽¹⁴⁾ Possibly

the most brilliantly creative man in European history, he advertised himself, first of all, as a military engineer⁽¹⁵⁾ and was able to support his claims and design through his land surveying and cartographic art.

Any successful civil, structural and military engineer needs an accurately surveyed base map. For Leonardo, artist and scientist, it seems only obvious that he would also thrust himself into land surveying and cartography. Since a complete assimilation of the ancient surveying and mapping knowledge had not yet been completed, Leonardo had to invent and design most of his measuring instruments. These included... various types of odometers to record distances traveled. In the course of surveying land, Leonardo would sometimes attach a pendulum to his thigh, which moved the teeth in a cogwheel to count the number of his steps. At other times he would use a cart with a cogwheel, and the cogwheel was designed to advance one cog with every ten *braccia* (about twenty feet) traveled, until a pebble audibly dropped into a metal basin at a distance of one mile. In addition, he made many attempts to improve clock mechanisms for time measurement, which was still in its infancy in his day.⁽¹⁶⁾ Leonardo left behind a vast amount of evidence that shows that he was indeed an excellent surveyor and a cartographer ahead of his time.

LEONARDO'S GIFTS

Leonardo was able to become a land surveyor and cartographer because of his great gifts, because of his mind and spirit. [He] was one of the greatest inventor-scientists of recorded history. His genius was unbounded by time and technology, and was driven by his insatiable curiosity, and his intuitive sense of the laws of nature.^(17&18) [He]... was a great lover of geometry.⁽¹⁷⁾

Evidence of his genius can be seen in his notebook entry under 'Astronomy' regarding a heliocentric universe, which pre-dates the Copernican Revolution by decades.

The earth is not in the centre of the Sun's orbit nor at the centre of the universe, but in the centre of its companion elements, and united with them. And any one standing on the moon, when it and the sun are both beneath us, would see this our earth and the element of water upon it just as we see the moon, and the earth would light it as it lights us.⁽¹⁹⁾

He worked on lenses for a telescope and provided a treatise on Perspective, both significant in the development of surveying. It is known that Leonardo... was preparing lenses for a telescope before 1520, and [that] may have been the foundation for his belief that "all the universe would be made visible to the human eye." In 1508, [Leonardo] explored visual angles in surveying under the heading of perspective. An interplay between surveying and perspective thus helps to account for the origins of an instrument called the proportional compass (cf. Galileo). There were close links between surveying and linear perspective. In

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Germany, it was assumed that the term "perspective" was synonymous with the "art of measurement."⁽²⁰⁾

As a scientist Leonardo towered above all his contemporaries. His scientific theories, like his artistic innovations, were based on careful observation and precise documentation. He understood, better than anyone of his century or the next, the importance of precise scientific observation.⁽²¹⁾ Like all true scientists, Leonardo based his science on systematic observation.⁽²²⁾ One hundred years before Galileo and Bacon, he single-handedly developed a new empirical approach to science....⁽²³⁾

[Leonardo]... experimented with several methods of approximately mapping a sphere onto a plane... the cartographer's problem of finding accurate plane maps of the surface of the Earth.⁽²⁴⁾ Topological thinking---thinking in terms of connectivity, spatial relationships, and continuous transformations---was almost second nature to Leonardo. Leonardo's topological techniques can also be found in his geographical maps. In the famous map of the Chiana valley, now in the Windsor Collection, he uses a topological approach to distort the scale while providing an accurate picture of the connectivity of the terrain and its intricate waterways.⁽²⁵⁾

... Leonardo identifies three basic properties of light rays: They are rays of energy generated at the center of luminous bodies; they are infinitely thin and without material substance; and they always travel in straight lines. Before the discovery of the electromagnetic nature of light in the nineteenth century, nobody could have improved on Leonardo's description, and even then contradictions concerning the nature of light waves persisted until they were resolved by Albert Einstein in the twentieth century.⁽²⁶⁾

Leonardo... drew analogies between a segment of a line and a duration of time: "The line is similar to a length of time, and as the points are the beginning and end of the line, so the instants are the endpoints of any given extension of time." Two centuries later this analogy became the foundation of the concept of time as a coordinate in Descartes' analytic geometry and in Newton's calculus.⁽²⁷⁾

LEONARDO'S LIFE AND WORKS

1452, Leonardo was born on April 15, 1452 "at the third hour of the night" in the Tuscan hill town of Vinci, in the lower valley of the Arno River in the territory of Florence. His full birth name was "Leonardo di ser Piero da Vinci", meaning "Leonardo, (son) of (Mes)ser Piero from Vinci".⁽²⁸⁾

1466 – 1469, (age 14 – 17), Sometime in his mid teens, Leonardo goes to Florence as an apprentice in the studio of Verrocchio where he learns a wide variety of artistic, creative and craftsman skills.

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1473, (age 21) Leonardo's earliest known dated work is a drawing in pen and ink, "La valle dell'Arno" ("The Arno Valley"), drawn on August 5, 1473. This drawing demonstrates Leonardo's ability to capture the geographic perspective that would provide the foundation for the development of his land surveying and cartographic achievements.

This early study would also form the basis of maybe his most grandiose project, (**1473 to 1513**) The Florence and Pistoia Canal. The deviating [of] the Arno through Prato and the Val di Nievole... on which he worked for over forty years serves to define numerous itineraries through the places of his Tuscany. The attempt to confer a regular course on the Arno River must be counted among the most ambitious projects ever conceived by man for redesigning the territory and its environment.⁽²⁹⁾

Based on his [own] reconnaissance of the territory and study of the historical-geographic sources, Leonardo formulated the project for channeling the Arno from Florence to the Padule di Fucecchio through Prato, Pistoia and the Val di Nievole. Harmoniously converging in his project were the experiences of the ancients, deduced from observations of Etruscan "cuts", Roman aqueducts and "cicognole" ("swan-like" hydraulic machines, that is, with elbow or horn, used to bring water over hills and valleys) up to the artistic-technological innovations developed in the [enthusiastic] intellectual environment of Renaissance Tuscany.⁽³⁰⁾

Testifying to this Renaissance "dream" are remarkable studies, unique in their beauty and originality. The most famous are those found in the Windsor Royal Library, but other autograph pages as well, whose importance has not yet been fully evaluated, must not be overlooked. They range from cartographic surveys to technical calculations, from structural details to the concept of urban planning and territorial management on a grand scale.⁽³¹⁾

1480's, Leonardo leaves Florence for Milan and enters the service of the duke of Milan, Ludovico Sforza. Leonardo's life was driven by his tremendous scientific curiosity. He always sought to find stable situations with regular incomes that allowed him to engage in his intellectual pursuits relatively undisturbed...⁽³²⁾ Realizing that the power of the Sforza's came from their military might... he wrote a carefully composed letter to the Moor, in which he offered his services as a military and civil engineer...⁽³³⁾ Leonardo shrewdly recognized that employment as a consulting military engineer and architect was one of the best ways to secure his financial independence.⁽³⁴⁾

1483 – 1486, Leonardo paints the "Virgin of the Rocks".

1486, (age 34), Leonardo begins to explore human flight.

1487, (age 35) Leonardo draws "The Vitruvian Man" a world-renowned drawing and maybe the most referenced and reproduced artistic image in history. The drawing is based on the

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correlations of ideal human proportions with geometry described by the ancient Roman architect Vitruvius in Book III of his treatise *De Architectura*. This image exemplifies Leonardo's keen interest in proportion and embodies the blending of art and science during the Renaissance. In addition, this picture represents a cornerstone of Leonardo's attempts to relate man to nature. What is not generally known about this piece of work, what I like to call 'The secret of The Vitruvian man,' is that it is a scale and unit converter!

1488, (age 36), Leonardo begins making anatomical drawings in the manuscripts.

1492, (age 40), Leonardo designs a flying machine.

1495, (age 43), Leonardo paints "The Last Supper."

1496, (age 44) Leonardo meets mathematician Luca Pacioli, with whom he studies Euclid and systematically works through all thirteen volumes of Euclid's foundational exposition [*Elements*] and filled two notebooks with mathematical notes.⁽³⁵⁾ He also studied several works of Archimedes.⁽³⁶⁾

1499, (age 47), Leonardo paints "Madonna and Child with St. Anne."

1499, (age 47), October, Louis XII [new French King] entered Milan in triumph. ..., he offered Leonardo a position as military engineer.⁽³⁷⁾

1500 – c.1516, (age 48-64), Known as Leonardo's second Florentine period was perhaps the most productive period of his life. Leonardo's maps from that period show geographical details with a degree of accuracy far beyond anything attempted by the cartographers of his time. He used washes of different intensities to follow the contours of mountain chains, different shades representing different elevations, and he pictured the rivers, valleys, and settlements in such a realistic manner that one has the eerie feeling of looking at the landscape from an airplane. [See Map of the Chiana Valley, 1504, Windsor Collection, Drawings and Miscellaneous Papers, vol. IV, folio 439v]⁽³⁸⁾

Leonardo's drawings of maps and plans number amongst the most magnificent of the period around 1500. They were executed in some cases for military purposes and in others to satisfy the need for reliable topographical maps for peacetime projects.⁽³⁹⁾

During the years between **1502 to 1507**, Leonardo pushed the art and science of cartography to the point of which for many years after will not be reproduced again. It was during Leonardo's time in Florence... that the magnificent maps — reckoned to be amongst the first achievements of modern cartography - were created.⁽⁴⁰⁾

1500, (age 48), From Mantua, Leonardo journeyed to Venice, where the Senate was in urgent need of a military engineer with his talents. The Venetians had just suffered a defeat in a naval battle against the Turks. And the Ottoman army was encamped in the Friuli region on the banks of the river Isonzo, threatening an invasion from the republic's northeastern borders. Leonardo went to Friuli, studied the topography of the land and came back to the Senate with a plan to build a movable lock on the Isonzo.⁽⁴¹⁾

Leonardo was also asked to examine the Venetian canal system for possible improvements. In the course of his work, he invented a beveled lock gate that played a part in the evolution of canal design.⁽⁴²⁾

1500, April, Leonardo was back in his native Tuscany.

1502, (age 50), Leonardo enters into the service of the Borgia family. Pope Alexander VI had enlisted his son, the young military commander Cesare Borgia, to help him build a papal empire in central Italy.⁽⁴³⁾ Cesar turned to the military engineer with the greatest reputation, Leonardo da Vinci. In 1502, Leonardo was hired by Cesar to travel throughout central Italy, inspect the ramparts, canals, and other fortifications of the newly conquered cities, and make suggestions for their improvements.⁽⁴⁴⁾

During the next six to eight months, Leonardo traveled extensively in Tuscany and the adjacent [areas]...--- making exquisite maps of various regions, working out schemes to build canals and drain marshes....⁽⁴⁵⁾

1502, (age 50), Leonardo creates The Town Plan of Imola. In October [he] joined Cesar Borgia in Imola, where the troops had taken up winter quarters. He spent the rest of the year designing new fortifications for the citadel and drawing a highly original and very beautiful circular map of the town.⁽⁴⁶⁾

Leonardo's magnificent plan of Imola is believed to be one of the earliest Renaissance geometric town views to have been made. There is some disagreement as to whether he drew the plan from scratch, or altered a map dating from 1473, but the consensus is that he did survey his plan himself, perhaps using the older plan to check his measurements.⁽⁴⁷⁾

Nevertheless, the famous map of Imola is the work of the illustrious artist. It is the first zenith map and the oldest example of a town map still preserved. Leonardo was called upon by Cesare Borgia in 1502 as a military engineer to inspect the defense system of the Rocca Sforzesca (Fortress). After inspecting the town, he elaborated the famous urban map, with modern intuition and a picturesque touch, and he also traced some sketches of the antique areas of the town. These documents belong to the Royal Collection of Windsor Castle.⁽⁴⁸⁾

1502, (age 50), Leonardo creates The Map of the Chiana Valley in Tuscany. With his map of central Italy, Leonardo da Vinci introduced the cartographic convention of using color to indicate changes in elevation.⁽⁴⁹⁾

1503, (age 51), A scheme for a canal to bypass the Arno. The Florentine Republic had been besieging Pisa since the 1490s. The Pisans could resist the attacks as long as they maintained their link to the sea via the river Arno. In 1503-4 Leonardo was consulted on a plan to divert the Arno, thus cutting off Pisa's access to the sea. This vigorous drawing shows the proposed route for the canal. There were three main difficulties with the scheme: 100-metre-high hills, the flooding of the river Arno in summer, and the huge expense of digging the canal. Work began in August 1504, but the power of the Arno's waters proved too great. Amid growing unrest about unpaid wages, the project was abandoned after two months.⁽⁵⁰⁾

It was his hope that the multiple benefits of such an "industrial" canal would bring peace and prosperity to the warring cities. Leonardo's dream of peace through technology was never realized, but he would probably have been pleased to know that five hundred years later the *autostrada* linking Florence with Lucca and Pisa would follow exactly the route he proposed for his waterway.⁽⁵¹⁾

1504, (age 52), In the summer of 1504 Leonardo surveyed the Arno near Florence and produced a number of maps of the river. The notes are in conventional script (unlike Leonardo's usual mirror writing), and the maps are carefully finished with colored washes. This, and the emphasis here on the damage to the embankment where the water passes through a weir, suggest that the maps were commissioned by the Florentine government as surveys of territory that required civic maintenance.

1504, (age 52), Leonardo begins painting the "Mona Lisa."

1506 – 1513, (age 54-61), Leonardo again went to Milan, at the summons of its French governor, Charles d'Amboise. In Milan he continued his engineering projects. For the next six years Leonardo divided his time between Milan and Florence

1508, (age 56), Leonardo explored visual angles in surveying under the heading of perspective. An interplay between surveying and perspective thus helps to account for the origins of an instrument called the proportional compass (cf. Galileo). There were close links between surveying and linear perspective. In Germany, it was assumed that the term "perspective" was synonymous with the "art of measurement."⁽⁵²⁾

1509, Louis XII, in alliance with the Vatican, had achieved a brilliant victory over the Venetians.

1510, Pope Julius II made peace with Venice and persuaded several European rulers to form a Holy League in order to drive the French “barbarians” from Italy. The French troops resisted for a while, but in December **1511** the League, using Swiss mercenaries to do the fighting, stormed Milan, expelled the French, and nominally installed Maximiliano Sforza, the young son of Ludovico, on the ducal throne his father had occupied. Leonardo, finding himself once again unwelcome in the city that had treated him so well, retired to the Melzi estate in Vaprio on the river Adda, some twenty miles distant.⁽⁵³⁾

1510, (age 58), Leonardo undertakes detailed anatomical studies.

1513, February, Pope Julius II died in Rome, and Giovanni de’ Medici, the younger son of Lorenzo il Magnifico, was elected to the papacy under the name of Leo X. His brother Giuliano became commander in chief of the papal troops. With their support, the Medici, after an absence of almost twenty years, were able to reestablish themselves as the rulers of Florence.⁽⁵⁴⁾

... Giuliano was well aware of Leonardo’s reputation as a military engineer...⁽⁵⁵⁾ [and] invited Leonardo to the papal court in Rome. Leonardo could not have hoped for a more powerful and sympathetic patron, and when invited was only too glad to join the papal court. In September **1513**, [Leonardo] embarked on the journey to Rome....⁽⁵⁶⁾

During his years in Rome, Leonardo was consulted by his patron Giuliano de’ Medici and by other members of the Medici family about various architectural and engineering projects....⁽⁵⁷⁾

1515, January, the French king Louis XII died. He was succeeded by his cousin Francois I. The young king - not yet twenty when he ascended the throne - aspired to be noble warrior in the mold of the French chivalric knights....⁽⁵⁸⁾ Francois I would become Leonardo’s greatest patron.

1515, (age 63), Leonardo paints the famous “Self Portrait.”

1515, (age 63), Leonardo produces an idealized plan of Florence showing the straightening of the river Arno. He suggested dividing the population into ten townships along the river.

1515, (age 63), Leonardo creates a Map of the Roman Southern Coast, The Pontine marshes.

1515, (age 63), Leonardo creates a mechanical lion for the coronation of Francis I, King of France.

1519, (age 67), Leonardo dies at Ambrose. Legend has it that King Francis I was at his side when he died, cradling Leonardo's head in his arms.

LEONARDO'S LEGACY

The development of the measuring and surveying techniques promoted by the Renaissance "engineers" and the fortunes of the work by Piero del Massaio were at the basis of the cartographic experiments of Leonardo da Vinci and Girolamo Bellarmato. Already in his paintings and drawings, Leonardo depicted the landscape with a surprising scientific spirit. The meticulous cartographical sketches represented the prelude of veritable maps, where art and science, drawing and measurements came together to attain extraordinary results. The *Chorographia Tusciae* by military engineer from Siena Girolamo Ballarmato was also founded on the direct observation of the territory. Printed in Rome in 1536, the map was taken up in the course of the century by many famous cartographers.⁽⁵⁹⁾

[Leonardo] invented a water gate that utilized the pressure of water to create a tight seal. Unforeseen by [Leonardo] at the time – his experiments and detailed technical drawings of this water gate would survive through time and eventually be used in designing the lock gate system of the Panama Canal.⁽⁶⁰⁾

TAPESTRY OF TIME AND TERRAIN NOT JUST ANOTHER MAP

By combining techniques developed by Leonardo da Vinci with today's computer applications, an artist and two scientists at the U.S. Geological Survey in Menlo Park, Calif., have produced one of the most dramatic and beautiful maps of the United States, ever published.

Fittingly titled, "A Tapestry of Time and Terrain," the map weaves together, in vivid colors and shadings, the topographical and geological components of the lower 48 states, as well as the geologic age of those components. This union of topographic texture with the patterns defined by units of geologic time creates a visual synthesis that has escaped most prior attempts to combine shaded relief with a second characteristic shown by color.⁽⁶¹⁾

CONCLUSION

Leonardo da Vinci was the archetypal Renaissance man and one of the most prolific geniuses ever recorded. His creative, analytic, and visionary inventiveness might be unmatched in all of history. His talent was so rare that he mastered any subject to which he turned his attention....⁽⁶²⁾

Renaissance Italy was constantly at war. To secure his financial independence during this time Leonardo astutely advertised himself as a military engineer. Possibly the most brilliantly creative man in European history, Leonardo was able to support his engineering claims and designs through his land surveying and cartographic art. For Leonardo, artist and

scientist, it seems only obvious that he would also thrust himself into the art of measuring and mapping the Earth.

He invented and improved surveying tools and introduced cartographic techniques that are still being used today. He performed extensive and accurate land measurements created many elaborate cartographic masterpieces. For him the painter, the naturalist and the geographic surveyor were aspects of the single enquiring mind.⁽⁶³⁾

Striving to increase the prestige of the art and science of surveying, mapping and geographic information, the surveyors and mapmakers of today can take great pride in knowing that it was our art to which Leonardo turned his indescribable grace. Leonardo da Vinci was an extraordinary land surveyor and cartographer. He was one of us. He was a Master of Earth.

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CONTACT