The Apollo Project of the Golden Renaissance

Brunelleschi's Dome

The magnificent dome of the Florence Cathedral embodies the achievement of Renaissance science—man's increasing dominion over nature—and of the individuals whose political battles made that Renaissance possible.

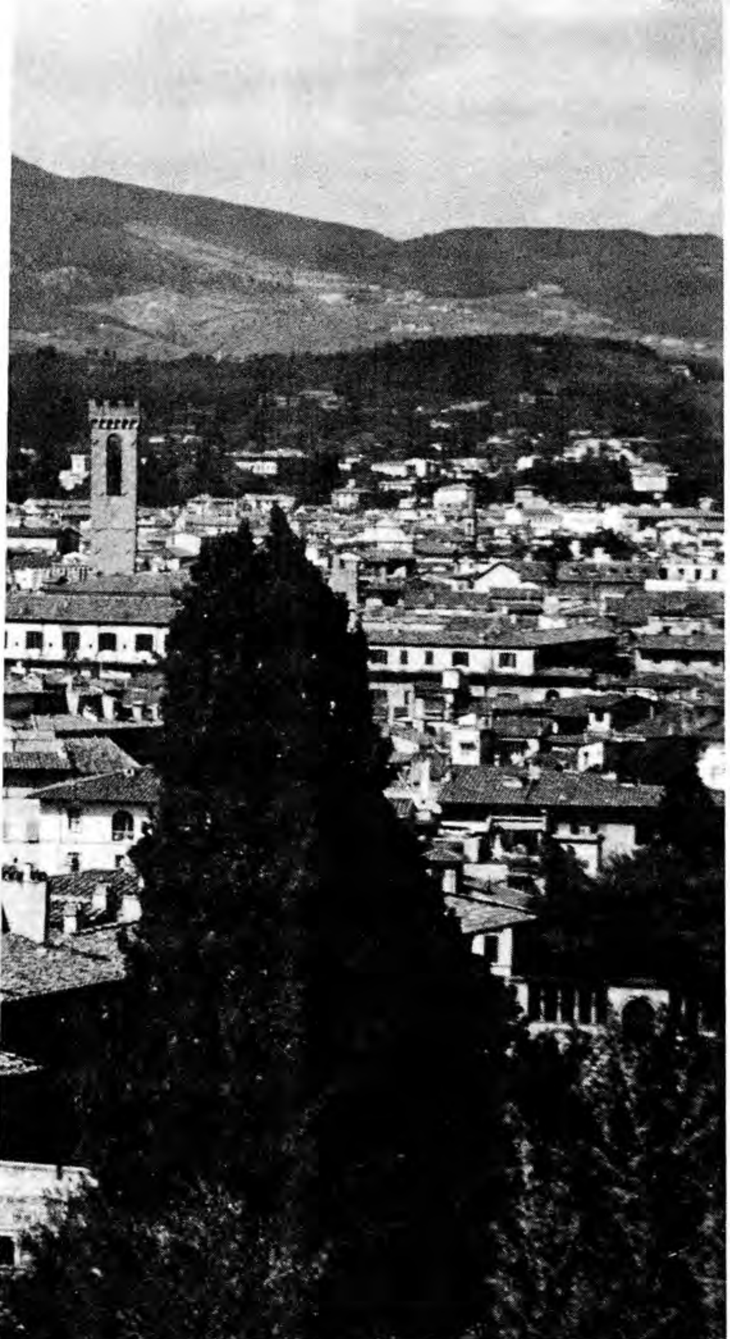
by Nora Hamerman and Claudio Rossi

The soaring dome of Florence Cathedral, built more than 550 years ago by Filippo Brunelleschi and intended to last for 1,000 years, is now on a course toward self-destruction. The dome, which stands as the greatest symbol of the Renaissance rediscovery of science, is endangered by the irrational blundering of a generation that no longer grasps or sympathizes with the principles by which it was built.

The major cracks in the dome are widening, increasing the dome's outward thrust at the base to potentially disastrous levels. According to the Florentine architect Lando Bartoli, author of two books on Brunelleschi, this is the result of an arbitrary step taken in 1979, when the 48 staging holes that Brunelleschi left at the base of his Cupola were filled with reinforced cement, in order to support a system of trusses for the restoration of the 16th-century frescos decorating the inside of the dome. These large holes (60-cm square) had been left open by Brunelleschi on the inside of the dome and covered on the outer shell. Since they were stopped up a decade ago, the normal seasonal process of expansion and contraction of the masonry has been blocked, because the masses no longer have room to expand into these fissures. Despite this fact, Bartoli's public campaign, begun in 1985, to remove the cement from the holes has been greeted with evasions even more shockingly irrational than the original action.

Panorama of Florence with the cathedral dome and Giotto's Belltower at the center.

Brunelleschi's dome, known in Italy as the Cupola, or "Cupolone" (giant cupola), came into being as a national mission by the city-state Republic of Florence, which was



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Brunelleschi and the Florence Cathedral: A Chronology

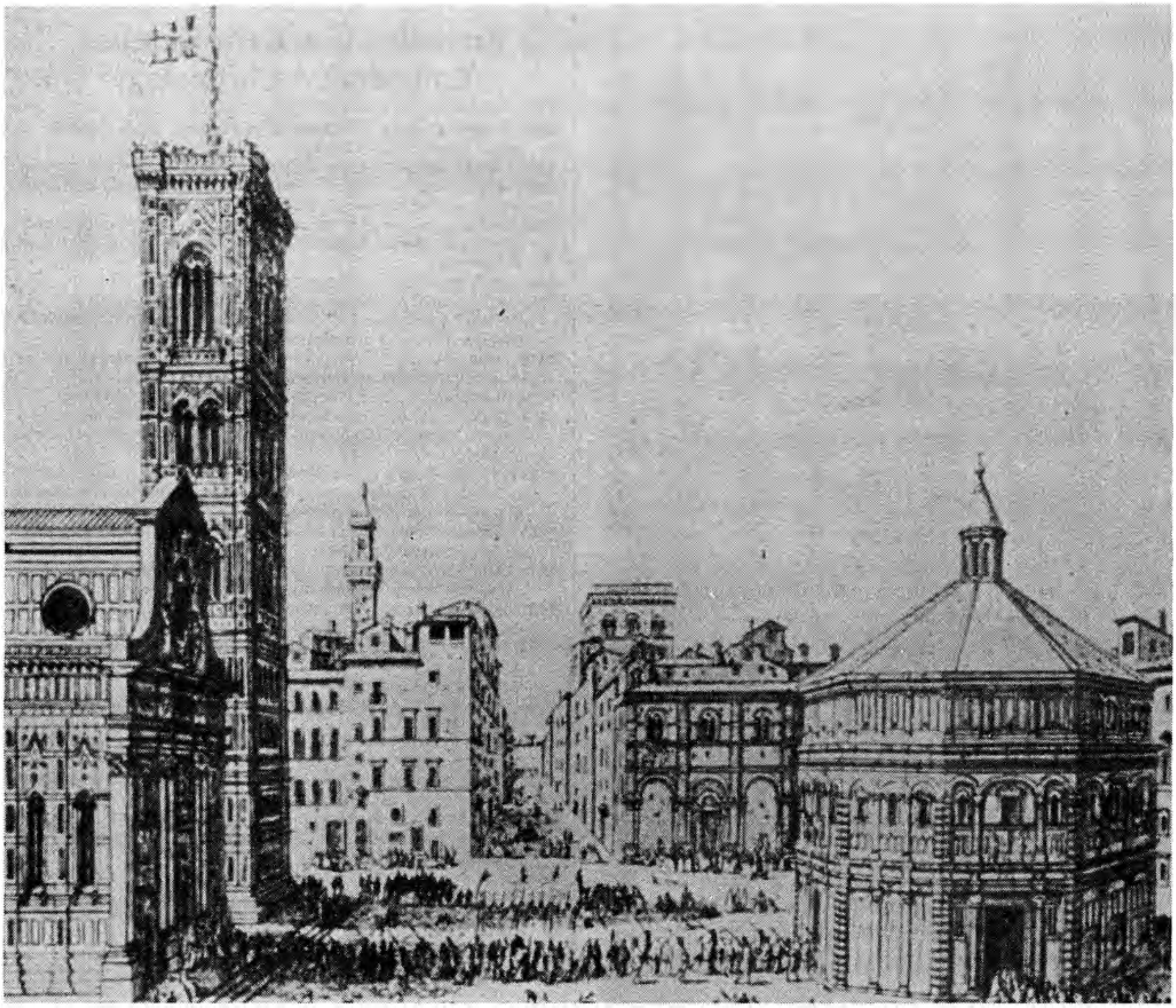
1294: Project to rebuild the Cathedral of Florence, Santa Reparata, is begun, under Arnolfo di Cambio
1357: First documented mention of plans for a dome, 37 meters in diameter.
1367-1368: Committee of Artists wins factional battle for design of octagon with a 42-meter internal diameter.
1402: Brunelleschi comes in second in contest for design of Baptistery doors, after fellow goldsmith Ghiberti; begins serious studies of architecture.
1410 (ca.): High octagonal drum of dome is constructed.
1414-1418: Council of Constance unifies papacy, elects Martin V (Oddo Colonna), establishes Councils as ongoing institution. Medici family of Florence become chief papal bankers.
1418: Florence Cathedral Works (Opera del Duomo) declares contest for vaulting the octagon without centering.
1420: Brunelleschi's project is declared contest winner and work begins.
1421: Brunelleschi wins first recorded monopoly patent (for design of a barge to transport marble) granted by maritime affairs minister Cosimo de' Medici.
1425 (ca.): Masaccio, a young collaborator of Brunelleschi, paints "Trinity" in S. Maria Novella, Florence, displaying Brunelleschi's architectural design and scientific perspective.
1425: Brunelleschi elected to be one of the priors, the highest Florentine public office (two-month term).
1425-1426: Giovanni di Gherardo da Prato attacks Brunelleschi publicly, says dome violates the original plan and will collapse.
1431: Brunelleschi wins a second contest, for the design of the lantern of the dome.
1433: Brunelleschi is briefly imprisoned by enemies but then freed. Cosimo de' Medici is jailed by political rivals, the Albizzi family; escapes to Venice to avoid being killed.
1434: Medici return to Florence and assume substantial, although unofficial, political power.
1435: Alberti's *On Painting,* the first scientific book on the subject, explains perspective; dedicated to Brunelleschi.
1436: Dome completed up to the lantern; Cathedral is dedicated by Pope Eugene IV, then residing in Florence.
1437: Nicholas of Cusa, at Council of Basel, rallies to cause of Pope Eugene and undertakes mission to Constantinople to bring Patriarch and Emperor to Italy for Council.
1438: Ecumenical Council of Eastern and Western Churches convenes in Ferrara in northern Italy; Nicholas of Cusa soon departs for Germany; Council is forced to move to Florence after a few months, to avoid the plague. Costs are borne by the Medici family.
1439 (June): Council of Basel excommunicates Pope Eugene.
1439 (July): Council of Florence ends the Schism with proclamation of "Laetentur Coeli" under the dome of Florence Cathedral. Council continues until 1443, as other Eastern churches sign the same document.
1446: Brunelleschi dies, is honored by burial in Cathedral.
1461: Lantern of Florence Cathedral is completed and surmounted by gilded ball and cross.
1474: Sundial of Paolo Toscanelli installed in lantern of dome.
1492: Fifty years after the closing of the Council of Florence, Columbus lands in America.

committed to building this monument for more than a century, even before Brunelleschi himself was born. Although a series of plans to execute this work was debated in painstaking detail, never for a single moment did the Florentines doubt the wisdom of the project of a lofty dome spanning an octagon 42 meters in diameter, or doubt their ability to resolve the huge technical problems the project involved.

It was under Brunelleschi's newly completed dome, exactly 550 years ago in 1439, that a proclamation was made unifying the Eastern and Western Christian churches and ending the 400-year-old great Schism (see box). From then on, the principle of the necessity of scientific progress as the basis of government, so dramatically embodied in the dome, became an international organizing principle. This very principle, fostered by a unique combination of social, political, and technical conditions in the Florentine Republic of Brunelleschi's era, is today under concerted assault by the insurgent Malthusian movement, which might be glad to see such a proud monument to man's dominion over nature crumble to dust.

A project like the Cupola could not be built today without a reversal of the policy of politically backing the enemies of science who oppose progress in the name of "environmentalism." The recorded objections of Brunelleschi's opponents strike the same "sour notes" (the metaphor is Brunelleschi's own) as those of the irrational foes of nuclear power and the Strategic Defense Initiative today.

Filippo's irascible personality and "authoritarian" behavior during the project became legendary. By standardizing decorative details, and even taking charge of bringing food



The Florence Cathedral Group, a masterpiece of urban design created in the 1300s and 1400s. The construction projects shown in this 18th century engraving were exhaustively debated, but no one ever doubted the wisdom of the grandiose plan. The somewhat exaggerated perspective portrays the Baptistery facing the facade of the cathedral and Giotto's Belltower and looks toward the other pole of civic life, the square around the Priors' Palace (the tower in the background).

to the work site, Brunelleschi anticipated certain methods of modern industrial capitalism. He sought, and obtained, monopoly patents for his inventions. He invented special hoists to save labor and horsepower. He played extravagant practical jokes on those who refused to understand—forcing them either to make a conceptual breakthrough, or as in the case of the famous carpenter "Grasso," to flee and join the army. His opponents even tried jailing him at the height of the project, on the pretext of nonpayment of gild dues, but this tactic was foiled. As a result of his development of projective geometry, it became theoretically possible to conceive a building in one hemisphere of the world and construct it in another, a discovery with implications for the reproduction of knowledge and potential population growth as vast as the invention of printing in the same century—a comparison made even by Filippo's early biographers.

Doing the Impossible

The most famous of Filippo's achievements in raising the Cupola over this enormous space was that he did it without the traditional *centering*, a pre-formed board structure reinforced by a wooden framework. This framework supported the masonry and remained in place until the mortar had set and mostly shrunk, and was then carefully removed. The amount of wood that would have been required to build such a centering not only far exceeded the Florentine exchequer, but may have required trees larger than those that grew in the forests of Tuscany!

The diameter of the Florentine Cupola was much larger than that of Hagia Sophia in Constantinople, a sixth-century building celebrated as one of the wonders of the world (approximately 27 meters); and was equal to the dome of the Pantheon in Rome of the early second century. The Greco-Roman building technology that had achieved those two earlier, hemispheric domes was long since lost. Moreover, Brunelleschi was faced with an esthetic requirement far more demanding than the Greco-Roman models, because the dome of Florence was to be imposing both on the outside and on the inside, just as the individual interacting with a free, republican society mirrors the internal beauty of his soul in the external beauty he creates in that society. The ancient domes, products of the first and second Roman Empires, had been designed to be magnificent within, but externally they lacked the concept of perspective by which the Brunelleschi dome, lifted on a high drum well over the shoulders of the cathedral nave vaults, dominates the entire city and surrounding hills as far as the eye can see.

The Cupola was the fitting manifestation of a culture that was fighting for the doctrine of the immortality of the *individual* soul and struggling to frame a constitution that would wed individual liberty to the highest common good.

In 1446, after Brunelleschi had died, the Consuls of the Wool Gild, the republic's strongest economic body, hinted at their recognition that the architect had begun a revolution in political economy in their decision to accord him the exceptional honor of burial in the Cathedral. They singled out for praise Brunelleschi's success in cheapening the cost of the enormous project such "that by his careful economy the greatest expenses that it would have been fitting for his genius and intelligence to make were removed. . . ."

Brunelleschi himself conceived of his achievement on a much higher level, however. In a famous exchange of sonnets, he replied to an invidious attack on the project (ca. 1425), by asserting: "When hope is given us by Heaven, . . . we rise above corruptible matter/ and gain the strength of clearest sight. . . . Only the artist, not the fool/ discovers that which nature hides./" In the final tercet of his sonnet, Filippo confidently concluded that his enemy's "sour notes" would be exposed, "when your 'impossible' comes to pass" (Hyman 1974).

The Dome He Inherited

Brunelleschi, born in Florence in 1377, grew up under the shadow of the unsolved technical problem of covering the east end of the cathedral, or Duomo. The previous generation of Florentine leading citizens, including his own father, a well-known notary, had decided upon a project that was esthetically bold but structurally weak, when in 1367, they mandated the dimensions of the Cupola's octagonal base with an internal diameter that comes out to about 42 meters when one converts the Florentine *braccia,* a unit about the length of a man's arm (*braccio* in Italian), into modern terms.

The dome was the crowning touch (but for the aborted project of the cathedral facade) in the centuries-long project of building the Cathedral Square in Florence, the group of buildings that included the beloved octagonal Baptistery from the 11th century, the Bishop's Palace, the cathedral (originally named Santa Reparata), Giotto's Belltower (Campanile), and the carefully designed surrounding square with the adjoining buildings mandated by law to follow certain design guidelines.

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Brunelleschi, as portrayed in a sculpture inside the Florence Cathedral by Buggiano, ca. 1447.

With the emergence of the free Communes in the 12th and 13th century, the late-blooming towns of central-north Italy developed a bipolar city plan, as the bishops were supplanted as the primary political authority by secular communal governments with their own palaces. In the case of Florence, this urban development reached a high point in the 1290s, around the time that Florence's greatest son, the poet Dante Alighieri, was entering the political career that led to his persecution and exile. During that decade both the new Priors' Palace, where the city's highest officials resided during their two-month term in office, and the new cathedral, rechristened Santa Maria del Fiore, were begun.

The cathedral was always the seat of the bishop; and while the bishop had lost his temporal power, the cathedral complex remained the center of expression of Florentine civic identity, irrespective of party politics.

Commissioned in 1294 from the prominent sculptor and architect Arnolfo di Cambio, Santa Maria del Fiore had a ground plan many times larger than the old Santa Reparata. Whether Arnolfo's building was designed to include a dome, no document proves with certainty; an oral tradition about his project, still alive in the 15th century, suggests that the distinguished Arnolfo indeed planned an enormous church with a vaulted nave and side aisles and a huge cupola (dome), which would not be situated above the structure of the nave as in Pisa's cathedral, but would have its own basement that would stand out from the ground up, built for that purpose. This was what had been done by Florence's leading rival in Tuscany, the city-state of Siena, although the Sienese cathedral would seem almost diminuitive next to Florence's Santa Maria del Fiore.

From 1357—less than a decade after the Black Death that had swept away perhaps 50 percent of the Florentine popu-

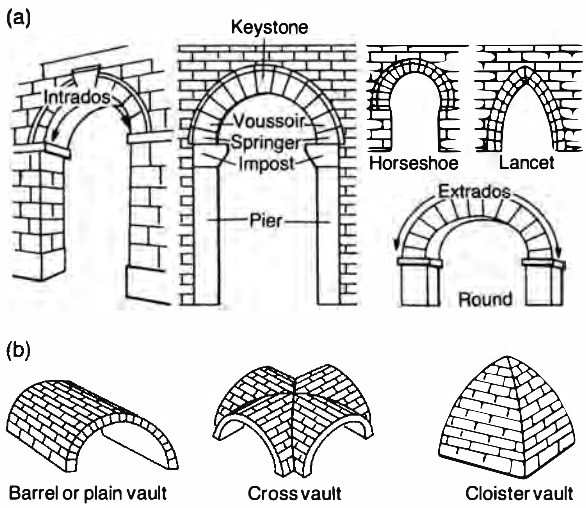


Figure 1
SOME OF THE MAIN TYPES OF ARCHES AND VAULTS
An arch (a) is a typically curved structural member spanning an opening and serving as a support. A pointed arch is called an ogee or ogive. A vault (b) is an arched structure of masonry usually forming a ceiling or roof. Major types are shown here.

lation—we have the first definite reports of a cupola, about 37 meters across, occurring in the plans for Florence Cathedral. The measurements are taken from a scale model made by one Francesco Talenti, then chief architect, in whose time the decision was also made to build the church "completely of stone." Talenti's is one of the first recorded of a whole series of large-scale models that remained on public display within the cathedral as the project proceeded.

The second project is known as that of the "masters and painters" of 1367. They established the present groundplan dimensions of 42 meters diameter for the cupola, and also, many believe, set the form of a high octagonal tambour or drum with large round windows, which would lift the Cupola above the vaults of the nave and cause it to soar freely over the city against the backdrop of the surrounding hills (Sanpaolesi 1965).

The professional architects of the cathedral in the second half of the 14th century wanted to use the Gothic structural form of flying buttresses—outside supports to bolster the walls so that they could thereby be made taller and penetrated by more windows. But the artists insisted that a more "Italian" form required heavier walls, and they rejected flying buttresses. According to one account: "In October 1367, the city organized a large, new committee to make a final decision in the dispute between Gothic and Romanesque factions. . . . One member was [Filippo's father] Ser Brunellesco di Lapo Lapi, who had just returned from a trip abroad as a lawyer in the service of Florence. . . . The committee expressed itself in favor of the artists." The decision was then confirmed by a referendum of some 500 citizens (Prager and Scaglia 1961, p.9).

Work on the dome proceeded apace in the first decade of the 15th century, under the Gothic-trained master Giovanni d'Ambrogio, who once again tried to introduce buttresses, which he was ordered to lower. The tambour, begun around 1410, raised and strengthened the support of the cupola and also showed an interest in perspective not likely in the 14th century. This is one reason that scholars Prager and Scaglia have strongly argued that this tambour, in the form it exists today, was not decided upon until around 1410—a point at which the 33-year-old Filippo Brunelleschi, well established as a sculptor and beginning to be known in architecture, might well have intervened. Their argument is encouraged by the fact that the main pictorial image of the Florentine Cupola, from after 1367 but before Brunelleschi, shows the dome without a high tambour. It was not until the next stage, the competition of 1418, that there is firm documentation of Filippo's role.

Brunelleschi's Model

On August 19, 1418, the Opera del Duomo (Cathedral Works) announced a public competition. Likely, the terms of the context were suggested by Brunelleschi himself, who knew that he could win. Their announcement reads in part (Prager and Scaglia 1961, p. 27):

> Whoever desires to make any model or design for the vaulting of the main Cupola of the Dome under construction by said Opera—for an armature, scaffold or other thing or any lifting device pertaining to the construction and pefection of said Cupola or vault—shall do this before the end of the month of September. . . . If. . . the model . . . be used . . . he shall be entitled to a payment of 200 gold Florins, and if any one does work in connection with this matter the Opera will . . . compensate him. . . .

Of some 20 models submitted, Filippo's was unique in proposing to omit the wooden structure that supported the masonry of a dome or vault while under construction. He also had novel ideas for the masonry design. He proved these ideas by his model, which the Opera built for him on a scale of approximately 1:12 so they could inspect and test it while in progress. When the model was completed at the end of October, Giovanni d'Ambrogio was fired as chief architect. By July 1420, Brunelleschi's final plans for the dome were approved, and work began.

The construction, as can be seen from the first detailed analysis, made by G.B. Nelli in the 18th century, relied upon the use of 24 upright ribs (8 major and 16 intermediary) interconnected by several kinds of horizontal supports, which included tie rings or "chains" of stone and wood. The "crown" of the cupola consisted of an inner and outer shell, separated by a space.

The Construction of Arches and Vaults

Since very ancient times the arch has been the only structure to cover a space longer than the longest beams available (Figure 1). The bricks or stones of the arch are disposed in such a way that their joints are all pointing to the center of curvature. In case of a pointed arch (ogive), the bricks point to the center of symmetry (the middle) rather than to the two centers of curvature. The construction of any arch requires a scaffolding able to sustain the weight of the bricks, at least until the arch has been completed and the last brick posed. Also, the construction of simple vaults (comparable to a succession of arches with a round, elliptical, or ogival section) requires a framework.

Brunelleschi's younger contemporary and admirer, the architect and theorist Leon Battista Alberti, knew very well, as the ancients knew, that the key to the stability of the arch was in its geometrical closure, and that the issue was quite different for domes with a circular base.

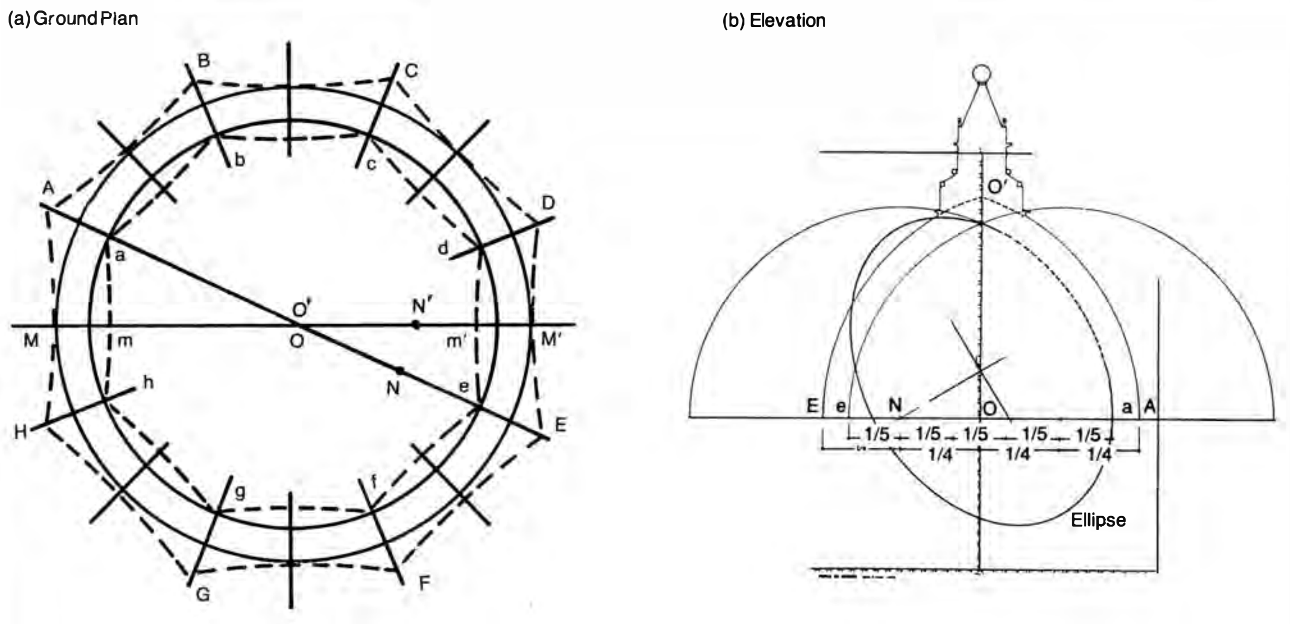
The fact that the Romans built the Pantheon with a very obvious opening just in the place where the keystone of the arch is usually placed, seems to underline that the understanding of the principles behind the stability of spherical domes was quite deep. Alberti, in his *Ten Books on Architecture* in 1452, is very explicit: Spherical domes (the "perfect cupola") can be built without a framework, or with a very light scaffolding (Alberti 1755, p. 59):

> Yet there is one sort of vault which stands in no need of these machines, and that is the *perfect cupola*; because it is composed not only of arches, but also, in a manner, of cornices. and who can conceive the innumerable ligatures that there are in these, which all wedge together, and intersect one another both with equal and unequal angles? So that in whatsoever part of the whole cupola you lay a stone, or a brick, you have been said at the same time to have laid a keystone to an infinite number, both of arches, and cornices. And when these cornices, or arches are thus built one upon the other, if the work were inclined to ruinate, where should it begin. . .? You may likewise turn the angular cupolas without a center [framework], if you make a perfect one [cupola] in the middle of the thickness of the work.[1]

Brunelleschi's dome is of the type called angular cupola (sphaericam angularum) by Alberti, consisting of "a number of barrel vaults meeting in a point at the top," the number in this case being eight cylindrical vaults that meet at the corners of the octagon and form the ribs.

The Shape of the Dome

Filippo left no written documents that can be used to derive definitively his method of construction. There are no drawings from his hand, and the brickwork of the two shells, although visible in part in the space between them, is mainly covered up on the inside by the frescos and on the outside by the red tiles that form the roofing. What little can be seen of it confirms the extraordinary quality of the bricks themselves and the precision with which they were laid, operations that were personally supervised by the architect from start to finish.



Source: Ground plan by Claudio Rossi, after Lando Bartoli.

Figure 2

HOW BRUNELLESCHI CONSTRUCTED THE CURVATURES OF THE INNER AND OUTER DOMES

The ground plan of the dome (a) shows the projection of curvature of the vault segments ("cells" or "sails"). According to Bartoli's hypothesis, the center for the differing curvature of the internal ("pointed fifth") and external ("pointed fourth") shells is the same (O), as can be seen in (b), a diagram of an elevation of the dome, based on the Giannini photogrammetric survey in 1967-1968. The arc of the circle constructed from that center and the arc of the ellipse whose center lies on the vertical axis of the dome are virtually identical.

We know from archival documents of the period of the dome's construction that he was asked to build the dome with a curvature of a *quinto acuto*, or pointed fifth; that is, the radius of curvature of the rib of the intrados (the inner shell) had to be 4/5 of the diameter of the circle circumscribing the octagon of the intrados at the base. But in the 16th-century biography of Filippo by Vasari, the curvature is repeatedly described as a *quarto acuto,* which means pointed fourth.

Very precise photogrammetric measurements were made of the dome in the 1960s. Because of unavoidable imperfections in construction and the deformations caused by settling over centuries, the data are not uniform, nor are the sides of the octagon perfectly equal. But taking this into account and looking only for a level of precision that was meaningful on the scale of observation of the dome's builders, Bartoli has given a highly convincing hypothesis about the shape of the dome, showing that the inner and outer shells have two different curvatures that correspond to arcs of two circles constructed from a common center (Bartoli 1977).[2] (Others suggest that the curvature of the ribs may actually correspond to a different curve, the tractrix.)

The photogrammatic measurements average out to show that the giant ribs on the extrados (outer shell) of the dome are best described as arcs of an ellipse. But, as Bartoli notes, the maximum difference between this very precise ellipse and an arc of "pointed fourth," which is the kind of curvature used to describe the dome by several architects of the time of Brunelleschi, is only 3 or 4 centimeters, which is absolutely insignificant if compared to the giant ribs of 40 meters in length.

On the basis of these facts, Bartoli concludes that Brunelleschi gave a curvature of a pointed fourth to the external edge of the dome (the arc that is drawn from *A* to the top of the dome *O'* has as its center the point *N* and the radius *AN* is 3/4 of the diameter *AE*) and of a pointed fifth to the internal edge of the dome (the arc from *a* has as its center the same point *N* and the distance *aN* is 4/5 of the internal diameter *ae*). As noted, the circles of the pointed fourth and pointed fifth for the external and the internal surface of the dome have the same center and are therefore the generating curves of the two parallel surfaces of the dome (Figure 2).

In Bartoli's analysis, the ribs are arcs of circles whose radius is 3/4 of the diameter of the octagon of the external surface of the dome (pointed fourth). Similarly, the parallel curve of the inner dome (intrados), at the edge between two vaulting cells, would be an arc of circle whose radius is 4/5 of the diameter of the octagon of the internal surface of the dome (pointed fifth), and whose center is the same point *N*.

On this basis, the vaulting cells have a cylindrical curvature, but the cylinder is not of circular cross section. It is, rather, generated by an ellipse that results from the projection of the circle of the ribs (for example *AO'* or *O'H*) on the axis (*MM'*) of the side of the octagon. In other words, to obtain the ellipse of the vaulting cell one must project a circle on a plane that forms an angle of 22.5 degrees (1/2 of 45 degrees, the angle at the center formed by the radii *AO* and *OH*).

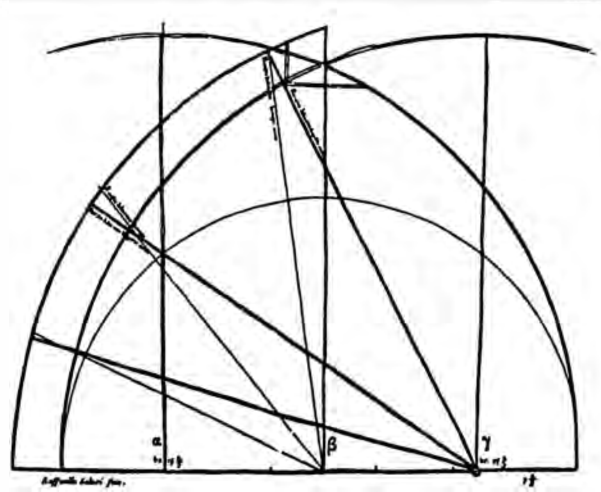
The pointed-fifth curve happens to be an arc of a circle whose radius is in the ratio of 8:5 to the radius of the circumscribing circle of the internal octagon base—a ratio in the Fibonacci series that closely approximates the famous Golden Section, the self-similar growth ratio. Throughout the 15th century, this 8:5 ratio was used as the equivalent of the Golden Section, which at the end of the century was named the Divine Proportion by Leonardo da Vinci's collaborator Luca Pacioli. Similarly, the pointed-fourth curvature yields a ratio of 3/2 of the radius of the external base octagon to the radius of the vault curvature, another proportion in the Fibonacci growth series.

Bartoli provides the following dimensions for the dome (Bartoli 1977):

diameter external octagon (*AE*) = 54.50 meters
curvature of the rib (*AN*) = 40.90 meters

diameter of internal octagon (*ae*) = 45.50 meters
curvature of the intrados = 36.40 meters

It is easily calculated that the point *N*, from which the two curves are projected, will be the same point. It was precisely because of this device of using two different curves, with a common center, that Brunelleschi's rabid enemy, Giovanni di Gherardo di Prato, attacked him around 1426, in a detailed critique of the construction of the dome, for having allegedly deviated from the original design of the dome, which called for a "pointed-fifth" curvature (Figure 3).



Source: L. Bartoli, *Requiem per una Cupola,* Florence, 1988.

Figure 3
HOW BRUNELLESCHI BROKE THE 'RULES'
Brunelleschi's critic Giovanni di Gherardo da Prato accompanied his complaints about Brunelleschi with this drawing, ca. 1426, as reproduced by Nardini Despotti Mospignotti. Giovanni complained bitterly that Brunelleschi was breaking the rules and not giving the same "pointed fifth" curvature to the inner and outer shells of the dome, but rather projecting both curves from a common point.

The cylindrical surface that connects the side *AH* to the top of the dome *O'* is generated by an ellipse that has as its major axis the distance *AN* (starting from *N'*, of course perpendicular to the surface of the paper), and as a minor axis the distance *MN'* (which is a projection of *AN* on the plane *MM'*).

The Model of the Dome

Brunelleschi's contemporaries could not believe that he would have been able to build a dome like that without a framework. He demonstrated the appropriateness of his ideas on the constructive techniques of the dome, not by explaining with words but by building a sort of real-scale model of the method of construction. In the church of San Jacopo sopr'Arno he was commissioned to build a hemispherical dome (*cupoletta*) 4.5 meters in diameter over the Schiatta Ridolfi chapel. According to Brunelleschi's biographer Manetti, it was built "in that way that is still called *a cresta e vele* [by 'crest and sails']" and furthermore ". . . with a cane or stick fixed in the lower part, turning on every side, and while going up it was getting narrower, touching the bricks that were laid, until the dome was closed" (Bartoli 1988, p. 46).

Contemporaries understood. Today this seems more a mystery. The description deals with two features of the construction: on one hand the masonry technique or the building method, and on the other, the shape, which is hemispheric. Because it is clear that the dome of Santa Maria del Fiore had to be octagonal, not hemispheric, the aspect of the shape of the cupoletta of Schiatta Ridolfi must be understood as a description of the *structural* shape of the dome—but this aspect will be dealt with later on.

A well-known drawing attributed to a Florentine architect from the later 15th century, Antonio da Sangallo the Elder, is associated with the "herringbone" brickwork used for vaulting in Florence without the benefit of centering, as the inscription on the drawing stipulates (Figure 4). This drawing, however, differs from the Cupola of the cathedral in that it describes a hemispheric dome of circular ground plan, as in the Schiatta Ridolfi model.

So, what are the "crests and sails" and the "herringbone"?

It is possible to build a small circular dome by setting the bricks on horizontal courses, with the upper side of the bricks leaning toward the center of the dome. The rings of bricks will be ever more inclined toward the center of the dome, as one layer of bricks is added on top of another. When the slope of the upper side of the wall in construction becomes steep enough, every brick laid tends to slide on the previous layer and it will be necessary to sustain it with a light scaffolding, at least until the ring of the bricks is completed. The completed ring has its own stability and cannot slide any longer, as Alberti explains, so that at that

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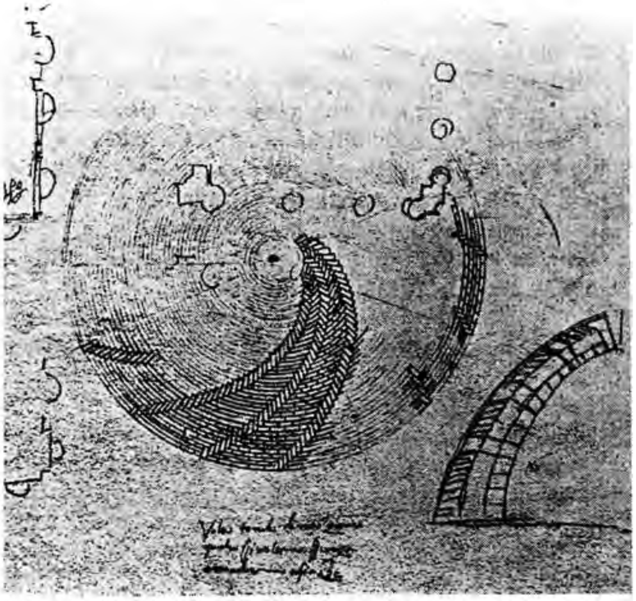
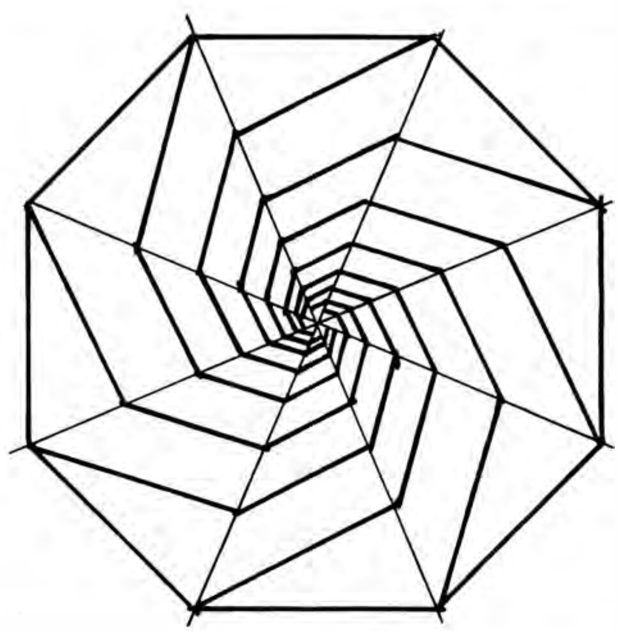


Source: Uffizi Museum, Florence; L. Bartoli, *La Rete Magica del Brunelleschi* 1977, p. 80.

(a)



(b)

Figure 4
THE HERRINGBONE CONSTRUCTION

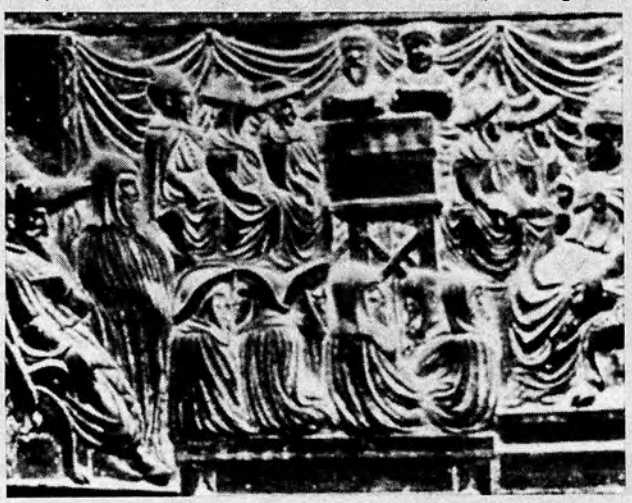
The drawing and inscription (a), attributed to Antonio da Sangallo the Elder (late 15th century), shows how cupolas could be vaulted without centering, using the famous "herringbone" system of construction where vertical bricks lock each string course into place as the dome increases in slope toward the center. This was also termed construction "by crests and sails." Shown in (b) is Bartoli's diagram of the "spiral" path of herringbone brickwork projected on a pyramidal form.

The 1439 Council of Florence Affirms the Idea of Progress

On July 6, 1439, in the city of Florence on the Arno river in north-central Italy, the assembled Church hierarchy and imperial authority of the Eastern Orthodox Church and the leaders of the Roman Catholic Church jointly proclaimed a document of Union entitled *Laetentur coeli,* "Let the Heavens Rejoice." After the great Schism, dating from the mutual excommunications of the Pope and Patriarch of Constantinople in 1054, the Council of Florence had finally reunified the Eastern and Western branches of Christianity. The Union occurred at a moment of mortal strategic peril to European civilization, when the Ottoman Turk threatened to overrun the entire continent.

The Union was proclaimed jointly by the Greek Bessarion and the Italian Cesarini from the pulpit of the Florentine cathedral of S. Maria del Fiore, under the great Cupola that had just been completed in 1436. As the two major branches of Christianity convened to rediscover their common roots in the period of the Early Christians' struggle against the Roman empire, they witnessed the literal, physical rebirth of civilization before their very eyes, in a building that harkened back to antiquity's achievements but surpassed them.

At the Council, the Byzantines finally agreed to the doctrine that had long distinguished the Western, Augustinian form of the faith: the "Filioque" clause added in the West to the Nicene Creed, which clause was understood to define the necessity of technological progress as a central premise of the doctrine of the Trinity, by stating that the Holy Spirit proceeds both from the Father *and the Son* (in Latin, *Filioque*), who is both God and man.



The proclamation of unity is celebrated on July 6, 1439 from the pulpit under Brunelleschi's Cupola, by Cesarini for the Latins and Bessarion for the Greeks. This is a detail of the bronze door of St. Peter's Basilica in Rome, 1444, by the sculptor Filarete.

Scientific and Technological Progress

Because it pivoted upon the concept of scientific and technological progress, the Council of Florence was to lead to a reaction from the Russian hinterland of Orthodoxy, where a violent rejection of the lessons of Florence soon led to the imperial doctrine of "Moscow the Third and Final Rome." It also led directly to the voyages of discovery and the subsequent founding of the American republic as an outgrowth of the Italian Renaissance ideals. This sowed the seeds for the great strategic conflict of the 20th century, already in the 15th century.

At the outset of the 15th century, as the strategic threat of the Turkish conquest grew, Western Europe was a shambles. Neither France nor England really existed—they were torn apart by the Hundred Years' War into feudal entities, and the centralized nation-state was a shriveled shadow of its former self. Recovery from the massive depopulation of the 14th century, which had begun at least 50 years before the outbreak of the Black Death in 1348, was slow throughout the continent. Cynicism over corruption had wrecked the institutional credibility of Church amid the demoralization that followed the Plague. The Schism of the West had led since 1373 to two, and after 1409, three competing popes. The grand historical design of the Conciliar Movement was to bring a new Christian unity into being, based on higher principles.

The first major step was accomplished at the Council of Constance 1414-1418, where a single Pope was elected, Oddo Colonna, as Martin V, and the rivals all renounced their claims. Under Martin V, the process of resolving the Hundred Years' War began to move forward, under a diplomatic effort led by Cardinal Niccolo Albergati of Bologna. Albergati persuaded the powerful Duke of Burgundy to shift his allegiance from England to France, and by 1435, the basis for peace had been established. In Albergati's service were key Florentine-trained figures such as the future Pope Nicholas V, Tommaso Parentucelli, and L.B. Alberti, the first "universal man" of the Italian Renaissance. While in northern Europe, Albergati's portrait was painted by Jan Van Eyck, the greatest Flemish artist of the era, hailed by contemporaries as a profound master of geometry. Further investigation would undoubtedly reveal Albergati as a pivotal figure in the cultural and political birth of the Renaissance.

The conciliarists believed that the reforms of the papacy were still totally inadequate, and convened the

Council of Basel in 1431. It was for this Council that Cusa wrote his first great work, *De Concordantia Catholica,* envisioning a community of sovereign nation-states within a universal church. The lack of unity at Basel ultimately convinced him that the higher principle of concordance he sought would not be found there. He found that higher principle in the strategic task of East-West unity on the basis of the Filioque.

Cusa: A 15th Century Benjamin Franklin

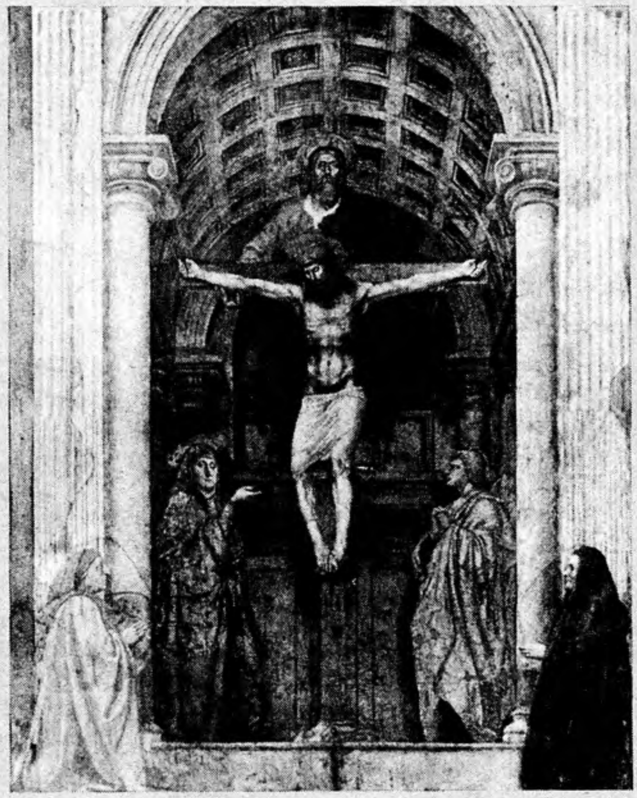
Cusa was to the Council of Florence what Benjamin Franklin was to the American Revolution, for which he organized crucial support in Paris. Cusa was the envoy who traveled to Constantinople in late 1437 to fetch the potentates of Byzantium to Italy for an Ecumenical Council, bringing with him also hundreds of Greek patristic manuscripts to bolster the arguments of the Florentines; he then spent a decade—often at the risk of his life—preaching, organizing, and negotiating in northern Europe for the papal cause. Cusa was preventing the break between Germany and Rome, which later erupted with Luther in the early 16th century. One month before the Union was signed, at their ongoing Council of Basel, the German princes' representatives had excommunicated Pope Eugene IV and elected an antipope, Felix V. Cusa's mission was completed only in 1449 when Felix finally renounced his claims; by then, all the German princes and Emperor had recognized the Pope in Rome.

Thus, Cusa was not on hand in Florence to witness the signing of the union proclamation under Brunelleschi's dome on July 6, 1439. The news caught up with him in Germany, whence he wrote jubilantly on Aug. 4, 1439, to his good friend Tommaso Parentucelli, "The Holy Spirit has made itself heard not in Basel, but in Florence." (Parentucelli, a Florentine-trained humanist, became Pope as Nicholas V in 1447, and made Cusa a cardinal of the Church.)

No sooner did the Greek prelates and imperial rulers return to Byzantium in 1443 then the backlash against acceptance of the Filioque broke out throughout the remaining Byzantine territories, whipped up by reactionary monks of the Mount Athos school. The Metropolitan of Moscow, Isidore of Kiev, who led the Muscovite delegation to the Council, had signed the union proclamation and forced the other Russian delegates to also sign. But when he returned to Russia, the other delegates sabotaged the commitment made in Florence and Isidore was expelled from Moscow. The Russian Orthodox Church declared itself autocephalous in 1448, on the basis of explicit rejection of the Filioque, and the doctrine of "Moscow as the Third and Final Rome" was born. Isidore fled to Kiev, where he built up a Western-tied school of thought.

Meanwhile, the Venetian and Genoese oligarchies made sure that no effectual or timely military support was provided to Constantinople as the Turk drew the noose tighter, and in a terrible bloodbath, overran the city in 1453. Only in the last months of the siege did the Emperor finally have the Filioque proclaimed in Hagia Sophia, and by then it was too late. After they conquered Constantinople, the Turks imposed a new Patriarch, Gennadios, on the Greek Orthodox Church, who promptly renounced the Filioque, even though he had been among the signers in Florence.

Constantinople fell, the Muscovites then argued, because it had compromised with the decadent West. This rejection of the Idea of Progress embodied in the Council of Florence is the *cultural* root of subsequent Russian imperial designs on the West.

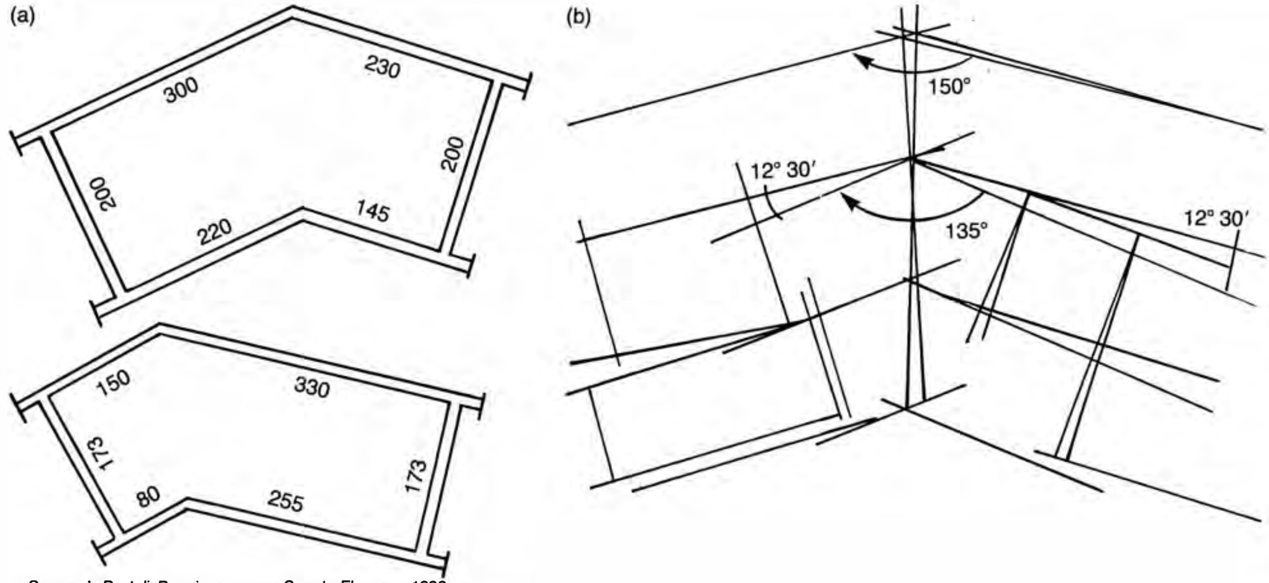


1425 Trinity by Masaccio/Brunelleschi

When the Council delegates convened at the church of S. Maria Novella in Florence in 1439, they were greeted by a life-size fresco by Brunelleschi's painter protégé Masaccio, painted in 1425. A single, heroic Christ is presented simultaneously as a member of the Trinity with God the Father and the dove symbolizing the Holy Spirit (above him), and as Man, in the historical crucifixion scene flanked by Mary and John below.

The necessity of progress is expressed by the magnificent architecture in the new Renaissance style of Brunelleschi, and in the perspective (projective geometry) method of constructing the painting, an invention ascribed to Brunelleschi. The challenge to the living citizens of the Republic to become what Cusa called the "living image of God" (imago viva Dei) is imparted by the inclusion of full-size portraits of the donor—a high public official—and his wife, as well as by the direct gaze of the Virgin Mary.

Complementing the Cupola, this painting seems to proclaim, "Vote Filioque!"



Source: L. Bartoli, *Requiem per una Cupola*, Florence, 1988.

Figure 5
THE CORNER BRICKS

The molds for bricks used in the construction of the Cupola are shown in (a), with the dimensions given in millimeters. The molds are on display in the Florence Museum of the Operá del Duomo. Bartoli's hypothesis (b) is that the bricks were adjusted for a slope of the brick stringcourse of 45 degrees (the angle formed by the tangents to the corde brande is about 150 degrees).

Continued from page 31
point the light scaffolding can be moved, to sustain the next layer of bricks.

For a larger construction, but also to make the structure more resistant it is better to link together several rings, as Alberti says (Alberti 1755, pp. 58–59):

> But I have observed that some have not always thought themselves obliged to make continued solid ribs, but in their stead have, at certain distances, set bricks sideways, with their head joining into each other, like the teeth of a comb, as a man locks his right hand fingers into his left. . . .
>
> I think, those acted much more prudently, who in raising this sort of cupola [hemispherical] used the same methods as in walling to cramp and fasten the under ring to the next above, and the arches too in several places.

So, after having set some horizontal bricks, one vertical brick is laid. The first course completed, the second is set down, and near each vertical brick of the first course another vertical brick is posed. While the new layers of bricks are being added to the previous layers, the diameter of the ring gets smaller and smaller and the number of horizontal bricks included between two vertical bricks is smaller, until at the top of the cupola it becomes just a herringbone structure, an ordered alternation of vertical and horizontal bricks.

The succession of vertical bricks has the configuration of a spiral with a slope of 45 degrees (these are the "crests," compared by Bartoli to the crest of a rooster). The horizontal bricks included between two successive "crests" are the "sails." This method allows one to build hemispherical domes (or at least, domes with a circular base) without a framework. The "sails" are locked between two "crests" which, converging toward the center of curvature, close the bricks of the "sails" as the keystone closes an arch.

Noncircular Domes

This does not make obvious, yet, how Brunelleschi proceeded for Santa Maria del Fiore, where the dome is octagonal. In a barrel vault (cylindrical), such as the one that connects any two edges of the octagon, even the structure of the "crests" could not be enough to sustain the "sails," and a centering frame would be absolutely necessary until the dome were finished.

In the dome of Santa Maria del Fiore the bricks are laid by "crests and sails" as if Brunelleschi had built a circular dome. But the dome is indeed octagonal.

In order to build a cylindrical vault, like the eight vaults that constitute both the inner and the outer shells of the dome of S. Maria del Fiore, the bricks would be placed on horizontal courses and the plane corresponding to the depth of the wall of the cupola would be inclined toward the center of symmetry of the dome (in the same way that in the arch, the joints of the bricks all point toward the center of the arch).

The eight planes of the masonry surface of the eight vaults, if connected to the center O of the base octagon, would form an upside-down pyramid. In the edges (in the ground-plan, in the area uniting *Hh, Aa, Bb,* and so on), the bricks belonging to two adjacent vaults would have to form an angle (like two adjacent faces of the pyramid) and should be special bricks built in the form of an "open book."

In the Museum of the Opera del Duomo in Florence, there still exist the frames to build irregular hexagonal bricks that form an angle of 135 degrees, exactly the internal angle of the octagon (Figure 5). Such a brick is flat and could be used only in the layers near the base. The fact that it is not shaped like an "open book" prevents its use as the slope increases further up the dome.

This would be the situation *if* Brunelleschi had reasoned as his contemporaries (or as today's engineers and the architects). The corner bricks would have been a mistake. We will see that Brunelleschi did not make a "mistake" and in doing so we will understand the procedure he used.

The courses of the bricks in Santa Maria del Fiore are not set straight on a line parallel to the octagonal base but follow a curved path. Why? Let's go back for one moment to the hemispheric *cupoletta* of Schiatta Ridolfi. In a hemispheric dome, the seams of the horizontal bricks would draw a set of circles reminiscent of the network of parallels on a globe map. The vertical bricks (of the "crests") would be placed along imaginary meridians passing through the north pole (the center of the lantern in the case of the Cupola) and perpendicular to the network of parallels.

As stated above, the courses of the bricks in the octagonal dome are not horizontal but are disposed like a *corda branda* (literally, a hanging rope, hence a catenary) that goes from one rib to the adjacent one.

Now we can begin to learn the lesson of the *cupoletta* of Schiatta Ridolfi. Using a "simple" method of projective geometry, Brunelleschi transformed an octagonally *shaped* dome into a cupola with *hemispherical* structure.

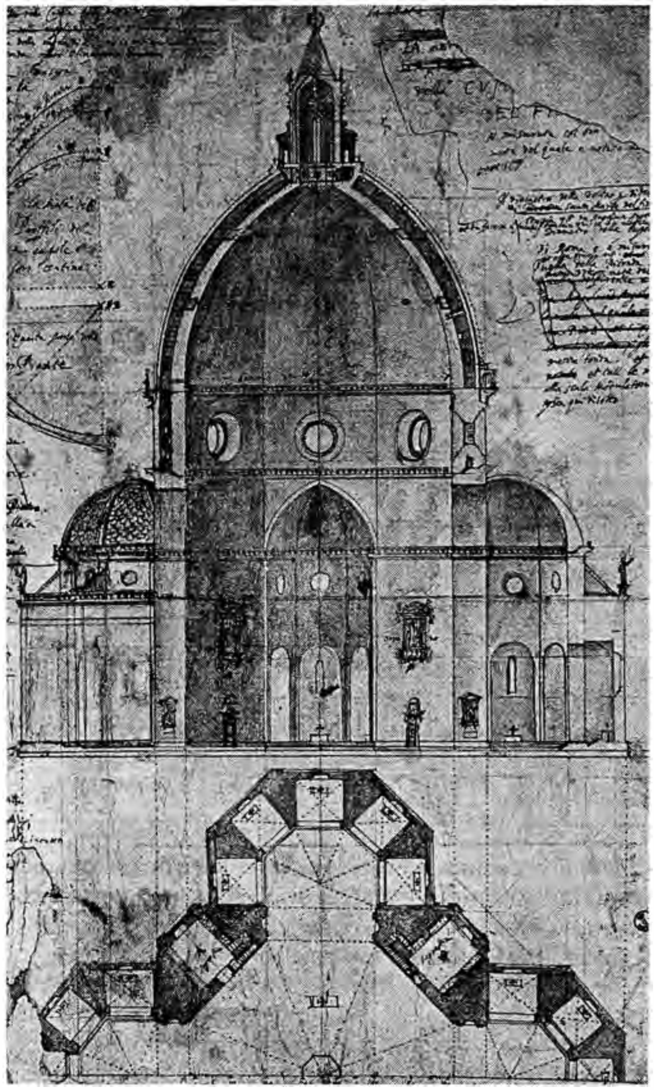
Let's follow the hypothesis of Professor Bartoli.

First, we draw a circle that circumscribes the octagon at the base. From point N, we raise a circle of pointed fourth and draw one rib (for example, the one that goes from A to O', the base of the lantern). Now we rotate this rib around the vertical axis OO', which will create a rotational dome that has features similar to the *cupoletta* of Schiatta Ridolfi, except that it is ogival (of pointed curvature) and not hemispherical. The self-sustaining quality is maintained in the ogival dome.

Now, if we draw on the ogival dome a net of meridians and parallels (as on a globe), we obtain a map for the disposition of the bricks in a self-sustaining cupola, like the one of Schiatta Ridolfi.

The ribs of the octagonal (the *real*) dome coincide with eight of the infinitely many meridians of the ogival dome. We must now project the network of parallels (which will become the shape of the "horizontal" courses of bricks) of the ogival dome on the octagonal dome, using the center of the octagon O as center of projection. This amounts to using each parallel on the ogival dome as the circular base of an upside-down cone with the apex on the center of the octagon of the base (Figure 6).

The intersection of this cone with the real octagonal dome will give the profile of the courses of the bricks. This layer, which was horizontal in the hemispheric *cupoletta* of Schiatta Ridolfi, will no longer be horizontal in the octagonal dome, but will have varying height. The maximum height will be on the ribs, while the minimum will be in the midpoint of the octagon: It will be like a *corda branda* (catenary) going from one rib to the other. The surface of the layer of the bricks will correspond to the surface of the interior of a cone and therefore will be a surface without discontinuities, even vis-à-vis the ribs—that is, no shift in direction of curvature at ribs (Figure 7). It should now be clear that it is no longer necessary to postulate strange bricks built like an "open book." The irregular hexagonal bricks conserved at the Museum of Santa Maria del Fiore could have been used very well, and the laying of these bricks would not have been more difficult than covering a flat surface.



This 18th century drawing shows the Cupola in cross section (above) rising above the octagonal ground plan; half the ground plan is shown separately below. An interesting comparison is made on the upper left between quarters of the ground plans and dome cross sections respectively of the Pantheon, St. Peter's (built in the 16th century on a circular ground plan but with a pointed curvature), and Florence Cathedral. Note the similarity in dimensions.

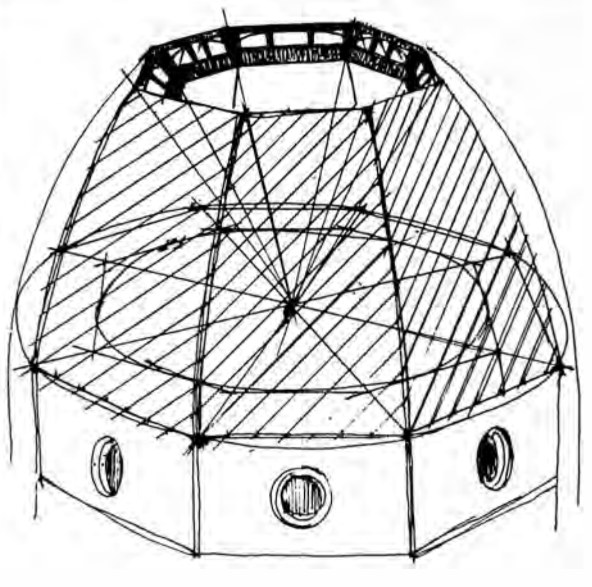
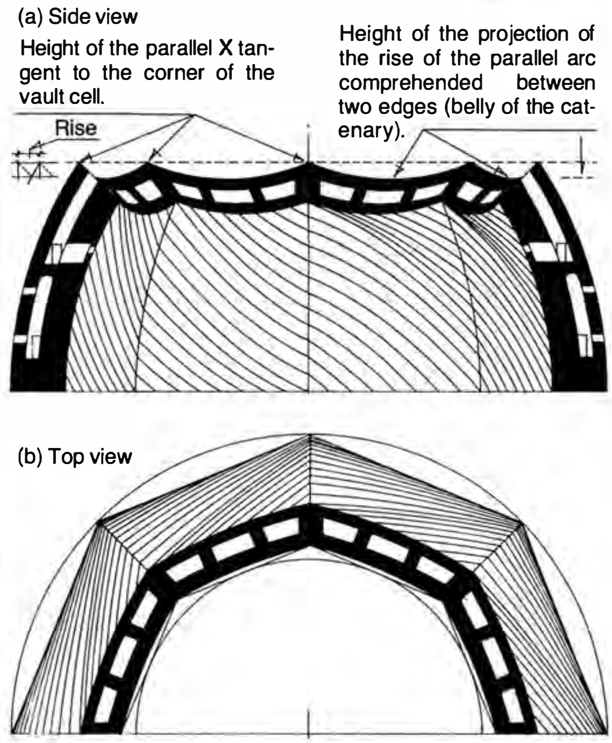


Figure 6
THE BRICKLAYING APPARATUS
Bartoli's perspective sketch of the brick-laying apparatus, set up like an inverted pyramid with a single center of convergence. The diagonal lines across each rib show the spiral path of the herringbone brick work



Source: L. Bartoli, *Requiem per una Cupola*, Florence, 1988, p. 63.

Figure 7
A ROTATIONAL VAULT EMBEDDED IN AN OCTAGONAL CLOISTER VAULT
The bricks are laid with a single center of convergence of the rings as they progress toward the top. Alberti, in his Ten Books on Architecture, *says that only perfect cupolas (hemispheres) can be erected without a framework—except for what he calls "angular spheres" with a sphere "in the thickness of the work."*

The side view (a) and top view (b) of the cells of the dome wall, show the catenaries that guide the courses of bricks. In architectural terms, the "rise" is the maximum altitude of an arch, while the "span" is the rectilinear distance between the two corners of the arch.

Of course, on every horizontal layer we would continue to see the structure of the "crests and sails"; therefore, once in a while one vertical brick belonging to the 45-degree spirals would have to be placed.

The projection of the meridians (the vertical lines of the ogival dome) on the octagonal dome would not be difficult. The meridians are drawn as vertical cross sections of the ogival dome and therefore, in a sense, represent the direction of the field of gravity. They can be drawn (and give the direction in which to lay the vertical bricks) by using an isosceles plumb rule (*archipenzolo*) of the type that was "standard equipment" in the 15th century. The direction of the spiral of the crest could be found by combining the plumb line of the *archipenzolo* and a bevel (*calandrino*) set at 45 degrees (Figure 8).

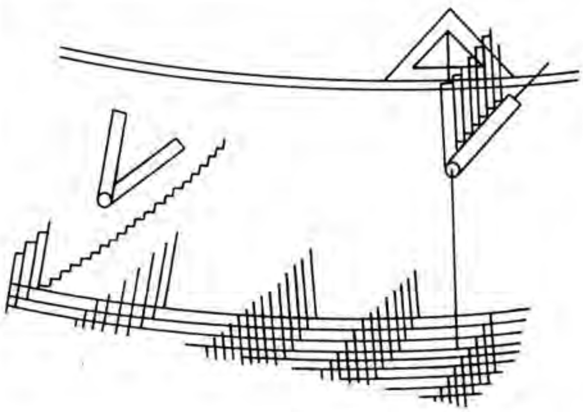
The Florentine Conspiracy

Where did Brunelleschi derive the extraordinary leap in conception that allowed him to solve the problem of vaulting the great dome of Florence without a centering framework, by embedding in its construction the form of a sphere and following the "least action" principle later developed by Leibniz and by the masters of the 19th century mathematical physics, from Gauss to Beltrami?

The answer to that question may never be known in detail, but in broad outline it lies in a political-scientific conspiracy of the late 14th and early 15th century, whose headquarters was Florence. While many partial histories of this period exist, no one has as yet made the obvious connections between the political, artistic, diplomatic, scientific, theological, and *military* aspects of the conspiracy, nor has any historian come to grips with the *international* scope of the republican grand design that inspired the Florentine Renaissance. Yet these connections are threads of a network, which becomes clear in outline merely by looking at the personnel involved.

The crucial example is Nicholas of Cusa, the towering leader of advances in physical science of the 15th century. Cusa's writing, dedicated to Paolo Toscanelli, developed the crucial isoperimetric theorem in the process of tackling the Archimedean problem of "squaring the circle." Cusa showed in that book that a circle is the minimum perimeter that can enclose a given area. Kepler and Leibniz later stood on the shoulders of Cusa as they developed the conception of the "least action" principle in the physical universe.

Born in 1401 in Germany, Cusa studied at the famed University of Padua in northern Italy in the early 1420s, together



Source: L. Bartoli, *Requiem per una Cupola*, Florence, 1988, p. 66.

Figure 8
METHOD OF PROJECTION OF A CATENARY
Bartoli's hypothesis on the use of the "gualandrino with three cords," which was cited in the records of the dome construction as the method of determining the curvature. The isosceles plumb-rule resting with its base on the corda branda *(loose rope) and with the altitude of the triangle aligned with the "meridian" would guide one arm of the bevel* (calandrino) *while the other, set at a 45-degree angle, guided the alignment of the "herringbone" bricks.*

with Giuliano Cesarini, who later presided over the Council of Florence, and the Florentine physician and astronomer, Paolo dal Pozzo Toscanelli. Their mutual teacher of mathematical perspective, and probably of music theory, was the famous Prosdocimo de' Beldemandi.

Toscanelli's real importance is hard to judge because most of his own works are lost, but there can be no doubt of his role as a link among the greatest scientific minds of the day. He is reported by early sources to have instructed Brunelleschi in formal mathematics. When Leon Battista Alberti, who was a younger student in Padua at a famous private school during the early 1420s, wrote his treatise *On Painting* in 1435, which launched the theory of scientific perspective, he dedicated it to Brunelleschi, whom he credited as perspective's inventor. Shortly afterward, Alberti dedicated his book *Intercoenales,* a series of remarkable dialogues touching on political economy and other issues, to *Toscanelli.* Some decades later, Toscanelli designed a gnomon, or sundial, which was installed in the lantern of Brunelleschi's dome and marks the summer solstice at a fixed point on the floor.

All of these circumstances tie Brunelleschi closely to both Alberti and Toscanelli, but do not confirm the connection to Cusa, who was occupied with German affairs throughout the late 1420s and who played a leading role, beginning in 1432, in the Church Council of Basel, for which he wrote his first major book *De Concordantia Catholica.* Cusa traveled to Rome in 1425, and on that occasion he could well have visited Florence, where the dome project was in its early phases of construction and the violent attacks on Brunelleschi by Giovanni di Gherardo di Prato were breaking out. Cusa was well known and respected by the Florentine humanist circle of Traversari and Cosimo de' Medici, who in 1429 sought to obtain from him precious manuscripts of Roman comedies, which the brilliant young German canon had unearthed in a Swiss monastery.

Ambrogio Traversari, the man looking directly out in this detail from the bronze doors of the Florentine Baptistery (known as the "Gates of Paradise"), is one of the major personalities linking the scientific, strategic, and religious threads of the "grand design" of the Renaissance—Brunelleschi and his Florentine contemporaries—to Nicholas of Cusa.

Later, after Brunelleschi's death in 1446, there is absolutely no doubt of the intellectual and personal ties between Cusa and the Florentine group. In 1464, when Cusa died, he made his close friend Toscanelli the executor of his will.

Cusa was probably recruited to the Council of Florence plot by Ambrogio Traversari, a figure who brings together the scientific and strategic sides of the story. It was Traversari, then the general of the Camaldulensian Order, who was sent by Pope Eugene IV in 1435 to the Council at Basel to organize leaders to work for the pope for an Ecumenical Council of East and West, to be held in Italy (Stinger 1977). In 1437, Cusa did indeed leave Basel with a minority group and went on a diplomatic mission to Constantinople (Krämer 1971; Meuthen 1971). Later that year they returned and debarked at Venice with the Byzantine Emperor and Patriarch and their retinues and proceeded to Ferrara, where the Council opened in April 1438. Traversari, later referred to by Cusa as "my good friend," met him again in Ferrara.

Traversari had inherited from the circles of the poet Petrarch the task of leading a group of Florentine thinkers who, since the early 1400s, had been preparing the intellectual ammunition to win the battle for the Western notion of the Trinity over their Greek counterparts. At the prompting of Petrarch, these circles also yearned to liberate Latin learning in the West from the heavy weight of Aristotelian reductionist thinking, and they looked to Greek science, especially as represented by Plato and his school, as the source for a revival of true scientific hypothesis. Under Traversari's encouragement, among others, classical Greek was mastered and the early Greek Church Fathers' writings were scrutinized to develop the arguments that would

Nora Hamerman

Dr. Lando Bartoli (right) with author Claudio Rossi at a May 1989 Conference on the Council of Florence in Rome.

prove there was no contradiction between East and West in the early centuries when Christendom had still been unified. The Byzantines who traveled to Italy for the Ecumenical Council in 1438 were astounded by this Western mastery of their own heritage, including the classical Greek texts that were available in the West.

Traversari was an ardent collector of such texts and a proponent of the thesis that Christianity must not ignore the fruits of classical Greek civilization, but "baptize" these cultural riches to the greater good of Christendom. In 1423, one of his Greek associates brought back to Italy from Constantinople a treasure trove of Plato, some 238 manuscripts. In 1424, Traversari is reported engaged in an assiduous search for a work by Archimedes on military machines and hydraulics, a search that is particularly interesting in regard to the genesis of the isoperimetric theorem by Cusa at a later date.

During the 1420s, Traversari's monastic cell at Santa Maria degli Angeli near Florence was the meeting place for a grouping of humanists linked to the Medici banking family. The following account is based on an essay by Thomas Goldstein (Goldstein 1965). Traversari was personally instrumental in 1433 in saving the life of Cosimo de' Medici when Cosimo was imprisoned by the oligarchic Albizzi family, and he helped to bring the Medici to power in Florence in 1434. Later, perhaps in gratitude for this, Cosimo de' Medici financed the huge costs of bringing the Ecumenical Council, which had initially convened in Ferrara in 1438, down to Florence to escape the plague. Other members of Traversari's entourage included Niccolo Niccoli, whose fabulous collection of antique books formed the basis of the Platonic Academy of Florence; Gianozzo Manetti, author of the first "Oration on the Dignity of Man"; Enea Piccolomini, the future Pope Pius II; and, of course, Toscanelli.

It seems, according to the 19th century historian Uzielli, that there was a long series of symposia on various topics including especially geography, a topic of great interest to the Florentine merchants who wished to break the Venetian grip in the Oriental trade.

Poggio Bracciolini, another humanist in this group, gives us a glimpse of himself, Cosimo, and Niccoli poring over a manuscript of Ptolemy's *Geography,* which had been translated into Latin in 1410 in Florence. Despite its serious flaws, the Ptolemy manuscript employed a spherical projection method of mapping and inspired cartographic reforms. In mid-1428, Prince Pedro of Portugal, brother of the famous Henry the Navigator, arrived in Florence to collect maps and pointers for his brother's enterprise. Florence was the theoretical storehouse for expeditions into Africa from the Iberian peninsula.

It is not difficult to see how the mathematical and geographical studies of this group, occupied precisely with the least-action path of navigation on the globe, would be relevant to Brunelleschi's work on the dome.

Such symposia came to a high point at the Council. In 1439, Gemistos Plethon arrived as part of the Greek entourage brought to Italy by Cusa and gave the Florentines a lecture series on Strabo, the Hellenistic geographer. The Council provided Toscanelli (and Brunelleschi?) with the opportunity to talk with foreign delegates from every corner of the globe and fill in details missing from their mental map. Toscanelli took copious notes. Isidore, the Metropolitan of Moscow, who briefed him about the geography of Russia, was destined to play a key role in the losing battle to bring the Renaissance to Moscow. In 1474, the very elderly Toscanelli reportedly wrote a letter to Christopher Columbus that revised the basic concept of the Earth with the revolutionary premise that the ocean could be used as an intercontinental waterway, and that the navigable Ocean Sea included the Southern Hemisphere.

Toscanelli tells Columbus that he had written on the same subject to Fernão Martins, the canon of Lisbon Cathedral. Toscanelli and Martins may have discussed this question at length at the house of Cusa at S. Pietro in Vincoli in Rome, where the three men met frequently in Cusa's last years (Goldstein 1965).

The Strategic Dimension

As a "national mission" for Florence, the city with a great civilizing mission, Brunelleschi's dome can be compared best to the prospective United States project to place a colony on Mars by the year 2027. It is also comparable to the crash effort of the U.S. "Manhattan Project" that created the atomic bomb or the original proposal for the Strategic Defense Initiative. Some may object because of the "military" nature of the latter two projects compared to the religious-civilian nature of the dome. However, there was also a pressing military-strategic issue in the Brunelleschi-Toscanelli-Cusa circle. The fact that we know relatively little about this is simply a reflection of the secrecy that was involved—a secrecy to which Brunelleschi himself referred, in his famous "interview" at the end of his life with the Sienese engineer Taccola (Hyman 1974).

At the time of the Council, the Byzantine Empire, the center of Eastern Christendom, had been reduced to a tiny enclave around Constantinople by the military might of the barbaric Turkish hordes. Everyone knew that if the Latin West failed to intervene, the Turks would soon be overrunning continental Europe, spreading in their wake the massa-

Nicholas of Cusa, a leading Renaissance conspirator, in a detail from an anonymous painting in the Cusa Library in Bernkastel-Kues, West Germany.

cre of many Christians, enslavement of the survivors, and destruction of civilization. It is unlikely that the Council fathers could have succeeded in their Florentine conspiracy had this threat not been so clear.

If a successful military campaign had been carried out coming out of the Council of Florence, the cultural superiority of Brunelleschian science and republican political forms of government would have been universally vindicated, just as the Cupola demonstrated to all but the most close-minded Mt. Athos monk present at the Council that Florence had absorbed, and improved upon, the greatest achievements of ancient *Greek* science. The industrial revolution would have arrived much earlier in the West, and there would never have been a Russian imperial problem of the sort we know today.

Instead, the new crusade was consistently sabotaged, particularly by the Venetians, who, like today's Western advocates of a new Yalta-type condominium with the Soviets, envisioned continuing fat profits from their trade with the East, under the victorious Turk. Later, in 1458, Pius II brought Cusa to Rome and put him in charge of the Church's governance, so that he could travel to the East at the head of such a crusade. However, both men died, without bringing this plan to fruition, in 1464—the same year Cosimo de' Medici died.

Finally in 1571, the major Western military powers united to deliver a crushing defeat to the Turk at the Battle of Lepanto, which the Spanish genius Cervantes described as the most glorious moment in all of history. This did save Europe from descent into a full-scale dark age, but was too late and too short-lived to prevent the emergence of a new "Turk," the Russian empire.

Yet, for decades, even after Brunelleschi died in 1446, the dome project made Florence's art studios into the "national laboratories" for public works, science, and the military defense of the Florentine republic. In 1431, Filippo won a new competition for the design of the lantern that surmounts the dome, whose form had been partly determined by the architect's decision to make the oculus octagonal rather than round. The lantern was not completed during his lifetime. Leonardo da Vinci, born in 1452, was a young assistant in the studio of the sculptor Verrocchio and helped with the cast of the great ball globe of gilded copper that surmounts the lantern, one of the largest casting projects ever undertaken in Florence. Half a century later, Leonardo reflects in his notebooks on his memory of that youthful experience, as he opened another scientific frontier with a rudimentary design for a telescope.

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Notes

1. Lando Bartoli points out when quoting this, that "through any point belonging to a sphere there pass infinite vertical planes, each of which corresponds to an arc of intersection with the sphere."
2. The monograph by Howard Saalman, *Filippo Brunelleschi: The Cupola of Santa Maria del Fiore*, (London: A. Zwemmer, 1981, 317 pp. plus 167 plates) which provides the most detailed available review of all the documentation surrounding the dome, came to our attention too late to be used for this article, but should certainly be consulted by anyone who wishes to study this topic in depth. Saalman is also the editor of a modern critical edition of the early biography of Brunelleschi by Manetti.