Santa Margherita at Montefiascone and Carlo Fontana's Knowledge on Dome Construction

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ABSTRACT: This paper presents a study of the dome of Santa Margherita in Montefiascone, built in 1670-1672/73 by the architect Carlo Fontana (1638-1714), and an analysis of the technical construction knowledge upon which it was based. The paper questions Fontana's 1673 manuscript justification of the dome's design, and compares the architect's manuscript presentation of the built dome with the evidence that emerges from a new architectural survey of the church and dome executed by the present author. The paper aims at investigating the way in which Carlo Fontana gathered, handled and interpreted information about dome construction, and how he went about synthesising past and current technical knowledge. The paper studies Fontana's Montefiascone experience as the starting point for his development of a set of influential rules for the construction of single shell domes that he published in 1694.

INTRODUCTION

Carlo Fontana's dome (1670-1672/73) of the cathedral of Santa Margherita in Montefiascone and the manuscript (Bibl. Estense a) in which he defended its design, have been extensively studied with respect to history, aesthetics, and construction (see references for major publications). The information collected by Fontana in the manuscript has been considered significant in construction histories as a exposition of traditional design practices and treatise rules for dome structures (cfr. D'Amelio/Marconi 1997; Marconi 1997; López Manzanares 2003; Huerta 2004). The present paper attempts to reconsider the building on the basis of a new survey, and to re-investigate the effective vericity of the manuscripts statements about domes.

SANTA MARGHERITA IN MONTEFIASCONE: THE BUILDING HISTORY

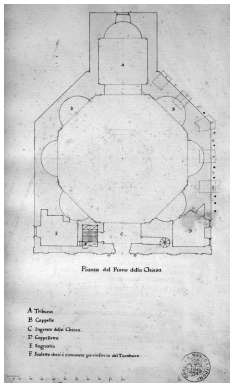
The cathedral of Santa Margherita was begun in 1483 on the outer edge of the medieval hilltown of Montefiascone. The octagonal lower church, with outer walls measuring about 4.5 m in thickness, was built in the local tufa and consists of a central octagonal space surrounded by an ambulatory, with entrances on the north and south sides. On the valley (east) side, a rectangular structure extends from the main body of the octagon; in the upper church this extension hosts the presbytery. The large octagon of the upper church (fig. 2) is enclosed by walls containing monumental niches and measures no less than 25 m in diameter. The choir and main entrance from the town square are positioned on opposite sides of the octagon. The upper church was built up to the level of the drum and was covered in 1601-1602 with a low pyramidal roof (Ost 1970, Hager 1975).
After a fire destroyed the roof on 4 April 1670, cardinal Paluzio Albertoni Altieri, the bishop of Montefiascone, obtained a commitment from his uncle, the newly elected pope Clemente X for the expenses of repairing the church as well as for the realisation of a dome and lantern, which were designed by Carlo Fontana, who had already worked for the Altieri family. Work began on 10 September 1670 and the cathedral reopened on 16 December 1674 (Hager 1975, p.146; De Angelis 1841, p.45). To support his dome, which was built in tufa, Fontana reinforced the outer angles of the existing octagonal drum, creating concave swing-backs in the middle of each side. This surface modulation continues above on the exterior of the dome shell. Doubts expressed by local experts concerning the stability of the dome led the architect to write a justification for his design, dated 1 January 1673 (Bibl. Estense a; figs. 2, 3, 4, 9 middle and right). When Carlo Fontana obtained the

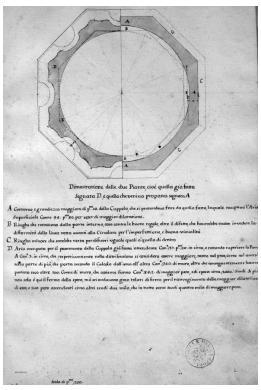
commission for the Montefiascone dome he was already a well-established architect, though not exactly a dome specialist. From 1659 he had collaborated with the studio of Gianlorenzo Bernini, and was therefore certainly familiar with the latter's domed church projects such as Sant'Andrea al Quirinale in Rome (begun 1658) and Santa Maria Assunta in Ariccia (begun 1662). He also collaborated with Carlo Rainaldi during the 1660s, and became second architect of St. Peter's in 1663, as well an Accademico di San Luca per merito in1667. In 1671 he obtained the commission for the dome of Santa Maria in Montesanto, though Bernini intervened in the project.
In 1840-1843 the entrance façade of the cathedral of Montefiascone with flanking towers designed by Paolo Gazola was added. In 1890-1893, Luigi Fontana executed the fresco and sculptural decoration of the interior (Ballarotto et.al. 1992, p. 65-69), and probably on this occasion the height of the drum was visually increased by introducing a new entablature at a higher level. The resulting ambiguity of the dome impost and the much richer architectural articulation of the drum radically altered the space Fontana and his predecessors had created.

THE MANUSCRIPT ON THE MONTEFIASCONE DOME (BIBL. ESTENSE A)

Description of the manuscript and its content and the research on it so far

The manuscript, published by Hager (1975), is dated 1 January 1673 and dedicated to cardinal Altieri. It measures 415 x 270 mm, and consists of 28 sheets, 10 of which contain illustrations (Abbreviations in the text like f.12, f.24 or f.28 always refer to the single sheets in the Manuscript Bibl. Estense a). The illustrations include plans, sections, and elevations of the cathedral of Montefiascone (figs. 2, 3, 9 middle and right), which Fontana states to be documentation drawings of the executed church and dome. Furthermore we find plans of other churches, and rules of dome construction extrapolated chiefly from the treatise literature (fig. 4). The drawings, often with extensive captions, are all drawn to the same scale (1:200) and executed in pen-and-ink over a pencil preparatory drawing, with gray, yellow and brown wash. One of the images, the first cross-section on f.24 (fig. 9 middle), is probably from the immediate dome design context, something that is also suggested by the fact that the paper support has a different watermark.





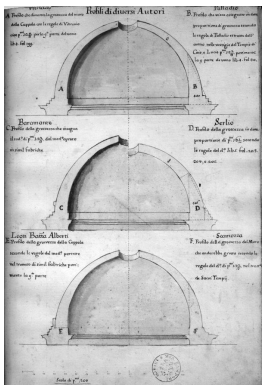


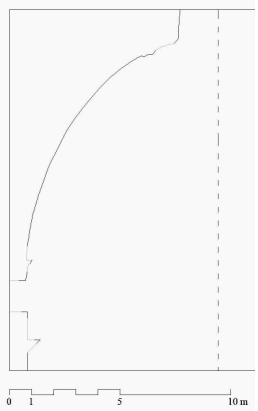
Figure 1: Montefiascone, S. Margherita, dome; (photo Schlimme),
Figure 2: Carlo Fontana, plan of the upper church, Bibl. Estense a, f.16; (Hager 1975, p. 152),
Figure 3: Carlo Fontana, plan of the executed dome shell at the bottom (left half), Bibl. Estense a, f.28; (Hager 1975, p. 154),
Figure 4: Carlo Fontana, dome profiles following the rules of other architects, Bibl. Estense a, f.22, left half: Vitruvius, Bramante, Alberti, right half: Palladio, Serlio, Scamozzi; (Hager 1975, p. 158)

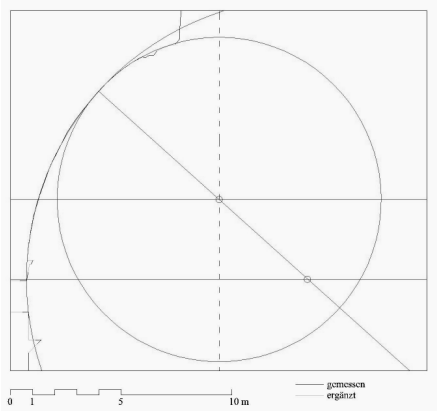
The pressure that Fontana must have felt is evident from his report. In a far-reaching bid to vindicate himself, he compiled every piece of information related to dome construction that he could lay hands on. In the first part of his manuscript, he defends his design, recounting that before its execution, in consultation with the architect Angelo Torroni and the capomastro Simon Brogi, he carefully evaluated the extant parts of the structure and the site of the church, and found them adequate. During the phases of the design process he continued to consult the two experts and the authorities in order to have their approval. Before designing the Montefiascone dome Fontana says that as a precaution he measured the thicknesses of several domes in Rome with different heights between the impost and crown. He says that from these examples he was able to obtain a valid model for the new dome in Montefiascone, because the described domes in Rome, being made of brick and therefore much stronger and more durable, would have suggested even greater thickness for the dome shell of Montefiascone, which is built of weaker tufa stone. But Fontana, in order to keep the dome shell light preferred to design it with the same thickness as those in brick. (Bibl. Estense a, f. 3v).
In the second part of his manuscript, Fontana responds to three objections. To rebut the criticism that the dome is too thick and thus too heavy, he says that he made a survey (fig. 4) of all statements on vault construction in the relevant treatises, with the result that his dome is a third, or even as little as half the width cited in the treatises. (This survey is dealt with later in the text.) Furthermore, although his critics said that a crack

which had appeared in the dome was the result of the latter's horizontal thrust, Fontana declares that it was caused by a hole in the foundation that he had filled before initiating the dome construction. Finally, his critics had observed that the circular dome of Montefiascone rests on the octagonal drum in such a way that it overhangs the corners of the drum towards the inside (fig. 3). In this case, the counter-examples Fontana invokes to prove that this was common praxis do not in reality corroborate his argument. An examination of the domes of the church of Il Gesù and the Sistine and Paoline chapels in Santa Maria Maggiore in Rome, show that at these sites both the drums and domes are circular, while in Santa Maria in Loreto, the overhanging is masked by the entablature.

Fontana's survey of the domes in Rome

In his manuscript Fontana also furnishes a table of surveys of late 16th and 17th century domes constructed in Rome. This table has been considered by construction historians as an exposition of traditional design practices for dome structures, and in fact it would seem so at first glance. But a closer examination of the quality of the information will reveal a different picture.





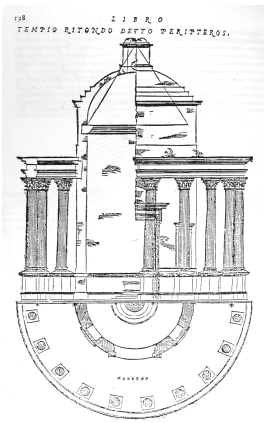


Figure 5: Rome, Sant'Agnese in Agone; (photo Schlimme),
Figure 6: Rome, Sant'Agnese in Agone, survey of the inside dome profile; (survey and drawing Schlimme),
Figure 7: idem, analysis of the geometry; (Schlimme),
Figure 8: Vitruvius/Barbaro (1567), p. 198

Diameters of domes are easily measured as they can be taken from the church floors. In fact, Fontana's measurement for Il Gesù is correct [80 palmi; 1 palmo (Roman palm) = 0,2234 m]. (A survey by the Technische Universität München gives the measurements as 79,7 palmi.) For Sant'Agnese in Agone, however, Fontana's manuscript gives the diameter as 58 palmi (a writing error?) when in reality it measures almost 78 palmi. Much more difficult is measuring a dome's thickness at bottom and at the crown. And from the values Fontana provides for the Chiesa Nuova it becomes clear that he did not take the measurements of all the domes he mentions: the seven palmi thickness he cites for the bottom of the Chiesa Nuova dome is much larger than the two palmi that Fontana himself reports two years later in his assessment to the same dome (Bibl. Estense b). Measurements for Sant'Agnese in Agone are provided in the respective chapter on the misura e stima of the dome in *Ms 168*, [Biblioteca Corsini, Rome (published in Montalto 1985, pp.181-182)]. The real thickness of the dome shell at the bottom is seven palmi and at the top, five. Fontana instead provides the values of seven and four palmi. Thus he did not have this source at hand. So where might he have taken his measurements from? Those of Sant'Andrea della Valle, San Carlo ai Catinari and the Chiesa Nuova he could have taken from Regnart (1650), though this does not seem to be the case, since Fontana consistently provides greater thicknesses (increased by around 20%) than drawn by Regnart. Might Fontana have done this purposely to make his cupola appear slimmer? The upper widths of these dome shells are all around two thirds of the bottom widths (66%, 71%, 60%). Did Fontana simply assume that this decrease was a rule of thumb?
To summarize, it may be said that Fontana did not consistently measure the churches he cites and that he compiled information from heterogeneous and undeclared sources. Marconi in 1997 (pp. 231-232) had observed that the measurements were manipulated to some extent, since the *Tempio Vaticano* (Fontana 1694) contains a similar list of domes with different values.
It is moreover interesting to discover how much Fontana did not know about the geometry of the domes he documents. A case in point is Francesco Borromini's dome of Sant'Agnese in Agone (1654), which the present author surveyed in November 2008 (fig. 5). The profile of the dome follows the geometry of an oval (figs. 6-7). The design accords with the drawing *Az.Rom 59* (Vienna, Albertina), as Bellini correctly assumed (Bellini, 2004, pp. 222-233). Survey and drawing, when superimposed, do not coincide perfectly, but the oval geometry is common to both of them, and that is the important thing. Fontana was evidently unaware of the oval geometry of S. Agnese, and moreover he was probably unfamiliar with any other dome geometries except those based on simple circular arcs. Indeed, in his treatise survey (fig. 4) he assumes all profiles as circular. In the *Tempio Vaticano* (Fontana 1694, p. 329, cfr. Bellini 2004, p. 117), Fontana states that measuring the profiles of

domes was extremely time-consuming and difficult. Indeed, the only easily available dome profile was that of St. Peter's, a simple circular arc, which had been incised in scale into the pavement of San Paolo fuori le Mura (today lost).

The "dome-proportions" from the treatises and "Vitruvius' rule"

As already mentioned, Fontana compiled all statements (fig. 4) on dome construction found in other architects' writings (especially in the treatise literature). During the Renaissance, architects imagined the covering of all ancient circular temples as domed. Indeed, in Palladio's treatise the roofs of all temples except the Pantheon and the Temple of Minerva Medica (which were and still are visible) are reconstructed as domes. According to Palladio's reconstructions, the width of all dome shells at the impost matches that of the wall below. The width of the dome shell of the Temple of Vesta in Tivoli is 1/10 of its diameter, and another he shows is 1/11. The widths of the Temple of the Minerva Medica (also known as Tempio di Caio e Lucio) are respectively 1/9 and 1/6,25, and that of the Pantheon 1/6,5. When Fontana extracts 1/9 as a Palladian rule, he is deliberately taking the most convenient proportion for his purposes. Alberti does not refer to ancient Roman buildings when discussing domes. In the third book, chapter 14, he treats vault types und describes their realisation, but offers no rules on their proportions. Nonetheless, Fontana cites him (fig. 4). Serlio indicates the thickness at the impost as 1/7 of the diameter, as Fontana correctly reports. Serlio is the only author who indicates the form of the dome profile, represented correctly by Fontana as a precise quarter-circle with its centre point in the vertical axis. Fontana assumes that the other authors propose a sesto acuto, although they say nothing of the kind. Fontana manipulates his sources and selects rules to his advantage to create an integrated exposition. The present author is not the first to question the accuracy of Fontana's survey. Yet up to now, only Huerta 2004, p. 274, shed doubt on Fontana's compilation (fig. 4), observing that only the affirmation that the width of the dome shell at the bottom should be 1/9 of the dome diameter can be derived from Vitruvius's treatise, while the profile of the dome cannot (nor from Alberti's treatise). But even the 1/9 proportion is tricky to obtain.
Fontana cites the fourth book of Vitruvius, page 199 in the Italian translation by Daniele Barbaro. Vitruvius says that the inner diameter of the cella of a circular temple must be as large as the height of the columns in the ambulatory of the temple. From here, in fact, it can be deduced that the width of the bottom of the dome shell should be 1/9 the diameter of the cella. But only when we take a series of other explicit and implicit statements by Vitruvius into account do we obtain the 1/9 rule. One of these statements is that the wall and column should be equal in width. Further, according to the ancient architect, the height of a Corinthian order column is 10 times its diameter. Barbaro shows a Corinthian order temple on p.198 of his Vitruvius translation (fig. 8). This would mean that the wall of the cella would be one tenth of the cella diameter. Barbaro draws it in the section as 1/10 but in the plan as 1/9. Fontana evidently relies on the plan. In this way the „9" comes into play. (Later in the *Tempio Vaticano*, 1694, Fontana introduces besides the 1/9 also the 1/10 rule; see below). Vitruvius himself, on the contrary, did not define the architectural order for his rule. This means that the width of a wall is 1/9 of the diameter of the cella, but only in the application of the Corinthian order (and of Barbaro's plan). In the case of the Doric order the wall would be 1/7 of the diameter of the cella. But a further step is necessary. Because the upper elements of a building should have the same width as those below, we can say that the bottom of a dome shell (like the wall below) should measure 1/9 of the diameter of the dome. But this affirmation is only true for the Corinthian order. This allows us to deduce that Fontana is confusing a formal with a constructive criterion. It is furthermore necessary to follow a complex train of thought to arrive at such an affirmation, which makes it doubtful that Vitruvius intended in the first place to affirm anything about dome shell dimensions.
To summarize, Fontana sought to substantiate his arguments further through the authority of Vitruvius, even though the dome on a drum was by no means a classical building type. Thus, the rule of 1/9 (for weaker natural stone domes) and 1/10 (for stronger brick domes), disseminated by Fontana in his *Tempio Vaticano* (1694) as a rule for the dimension of the drum and thereafter considered a rule of thumb in traditional dome construction, was more or less an invention of Carlo Fontana.
Another affirmation taken by Fontana from Vitruvius, underlines his approach. In the context of the circular temple type, Vitruvius talks about a pyramid. In his Vitruvius commentary, Daniele Barbaro explains this as the pyramid which was in several cases put on the top of antique temples. In order to give the reader an idea, Barbaro draws an equilateral triangle on top of the temple (fig. 8). Only the upper part of the triangle is intended as the pyramid, the rest of the triangle just shows the pyramid's geometric collocation. Vitruvius just mentions the pyramid without giving any geometric information about its shape or collocation. Thus the use of a triangle in order to collocate and define the pyramid is Barbaro's hypothesis. Barbaro then talks about the dome, which is not mentioned in Vitruvius' text. In the end Barbaro shows all this in the illustration (fig. 8), where we have the casual graphic superposition of the triangle and the dome. It is precisely this casual graphic superposition that Fontana took as a "Vitruvian rule". Bellini (2004, p. 231-232) mentions that Fontana named it "Vitruvian rule", and Marconi (1997, p. 231) says that Fontana used the "accredited" triangle rule of Vitruvius, but neiter of them discusses the background of the "rule". Huerta (2004, pp. 199-200) cites with Baldassare Zamboni and Jean Rondelet two authors of the later 18th century who took up the rule with the triangle. Huerta does not discuss the rule in the context of Montefiascone.
Whether Fontana worked hastily or whether he helped himself with a non-existing rule, cannot be determined. In any case he "found" the triangle in the cross-section f.12 (fig. 9 right) of the dome in Montefiascone. But is the effectively realised dome in Montefiascone really based on the "Vitruvian rule"? A survey of the realised building will explicate this question.

CHURCH AND DOME IN MONTEFIASCONE: SURVEY BY THE AUTHOR OF THE INTERIOR AND THE EXTERIOR

The width and centre point of the dome shell geometry

In July 2008 the present author carried out an architectural survey of the church and dome in Montefiascone (figs. 9 left, 10 left) using a Laser-Tachymeter. The survey enables a comparison between the manuscript presentation of the built dome with the effectively realised dome.
In his manuscript Fontana invariably measures the width of domes with octagonal exteriors in the middle of one side, and without counting the outer ridge. In the case of Montefiascone this position does not really exist because of the concave spaces on the exterior surface. Fontana projects the outer profile into the cross section and measures the dome shell at its bottom as 8,5 palmi in f.12 (fig. 9 right) and f.28 (fig. 3) in the manuscript. The width of the shell at its thinnest is given by Fontana as 2,5 palmi though it is drawn in f.12 (fig. 9 right) as if much thicker. The present author measured two vertical profiles on the outside of the octagonal dome, one at the thinnest point of the dome shell, the other at an outer edge. The measurements reveal a thickness that varies between 1,73 and 1,80 m (minus lead roofing and minus the outer ridge of 20 cm). The outer profile follows an irregular line probably due to irregularities in the lead roofing. At the thinnest point of the domeshell, the measurements vary between 81 and 66 cm (minus lead roof and the irregular upstanding joint of the lead sheeting, where the measurements were taken). The profile follows an irregular line, which is a little thicker around the upper third point and a little thinner around the lower third point of the dome. Thus a thickness of around 2,5 palmi is probable, just as Fontana says. One thing is certain: the dome shell does not diminish in thickness from bottom to top, although in his cross-section drawing f.12 (fig. 9 right) Fontana shows a reduction of about 50% of the width.
Geometrically, the Montefiascone dome is not very precise. The present author measured the interior vertical profile six times. All profiles show a circular geometry with a medium diameter of ca. 35,60 m (fluctuation: 32,10 – 37,85, cfr. fig. 9 left). The centre points of the circles are on average ca. 3,30 below the impost of the dome (fluctuation: 2,04 – 4,43). This shows that geometrical precision was not the most important feature of the dome – it was rather the material and the quality of execution that made the difference. On the other hand, it is evident that the circular shaped dome shell was built with the center point below its impost (and thus with a lower profile!). The explanation for this is found in the comparison between the realised dome and the two cross sections, f.12 (fig. 9 right) and f.24 (figs. 9 middle, 10 middle), which are part of the manuscript.

Comparison between f.12, f.24 (both from Bibl. Estense a) and the results of the building survey

In the manuscript, Fontana says that he started his work in Montefiascone with a survey of the existing building and its site, and with a survey of Roman church domes. On this basis he developed the profile f.24 (figs. 9 middle, 10 middle), consulting with the aforementioned experts and authorities. F.24 was shown and explained to the workmen. Subsequently, he created a second profile, which was later documented in f.12 (fig. 9 right) leaving the quantity of dome masonry unchanged but altering its distribution, creating concavities in the centres of each side, and slightly thickening the edges of the dome shell and the drum on the outer side. These changes were made to increase the amount of light through the drum windows and to lighten the weight of the drum in the middle of each side. In doing so less mass weighed on the walls with monumental niches in the main order below (f.3v). In f.24 and f.12 Fontana draws the dome slightly too large: 115 palmi vs. the measured 112 ½.
In fig. 9 the surveyed cross section and the cross sections f.24 and f.12 are juxtaposed and levelled so that the line of union between the preextant octagonal drum and the new circular dome shell is at the same height in all three sections (shown by a horizontal line in fig. 9, which is also indicated on the edges of Fontana's drawings). In the realised church the point of union between the octagonal drum and circular dome is masked by the new entablature added to the drum in the 1890s. However, the original position is visible in the access tunnel that leads from the spiral staircase inside the drum to the walkway on the inside entablature of the drum. As we have seen from Fontana's manuscript and his drawing, f. 28 (fig. 3) the circular dome shell hangs to the inside over the octagonal drum; portions of this bottom view are clearly visible in the gap behind the new entablature. These portions show refined plaster work indicating that it was a surface that was visible from the inside of the church. In comparing the realised building with Fontana's cross sections f.12 and f.24, it is striking that there are so many significant differences: the dome as realised stands about 1 m lower than drawn in f.24 and 2 m lower than drawn in f.12. The total height in f.12 appears 4 m higher than it effectively is.
In fig. 10, a comparison between the building survey and f.24 is shown; here f.24 is shifted downwards about 1 m. The dome shell in f.24 is about 1 m higher than in reality while the drum is 1 m lower, so that the two balance each other. And in fact the entablature of the main order, the drum window and the inside profile of the dome match (fig. 10 right). With the exception of (1) the outside form of dome and drum (2) the diminishing dome shell width, and (3) the level of the line of union between the octagonal drum and circular dome, f.24 is the dome which was effectively built. That Fontana shifted the impost line of the dome to a meter higher without changing the overall section, may be explained by a need to respect the existing octagonal drum while "force-fitting" it to the circular dome he proposed to build. Instead of having a 1,70 m overlap (as drawn in f.24), one of about 65 cm was realised, probably because of the presence of beam slots as well as damage from the recent fire. In the contract between bishop Altieri, Fontana and the master builders, we read that the impost of the dome is at the level of the crown of the preextant drum (ANM, paragraph 4; published in Serra

1974, p. 225). To sum up, Fontana omitted the lowest part of the dome planned in f.24. All this was probably the result of economic considerations.
Equally interesting is the comparison of f.24 with the second profile f.12 (fig. 9 middle and right). The caption of the elevation in the manuscript (f.10) reads "Prospetto giometrale della Chiesa e Cupola esterna, che ha fatto fare l'Em.mo e Rev.mo S.r Cardinale Altieri nella Città di Montefiascone" and that of the cross section f.12 reads "Profilo della detta chiesa…", meaning that the drawings claim to precisely document the church that had been built. The fact is that there is a much greater difference between f.24 (respectively the realised church) and f.12, than Fontana claims. He says only that he changed the quality (i.e., the form) of the dome by introducing the concave elements. But in fact there is also a difference in his representation of the pre-extant drum. With respect to the impost of the circular dome, the crown of the preextant drum (which Fontana always indicates in yellow wash, seen in a slightly lighter tone in f.24 and a slightly darker tone in f.12) is in fact represented very differently: in f.24 the extant drum is about 1,75 m higher than the impost of the dome; in f.12 intead, it is about 1,50 m lower! Thus there is a difference of no less than 3,25 m, which allows Fontana to draw a completely different dome in f.12, and one which is not preconditioned by the preextant drum. Here alone the "Vitruvian rule" with the triangle really fits, while in the lower domes (realised and f.24) it does not fit at all. It is interesting to see that the height from the church floor to the top of the pre-extant drum in the two cross sections f.12 and f.24 differs not by 3,25 m, but by only 1,20 m. Did Fontana deliberately minimizing this difference in order to make the representation of the extant drum in f.12 seem more truthful? If so this would explain the increase of four meters height in f.12. What this shows is that in f.12, Fontana presents a false, deliberately idealised image of the realised dome.

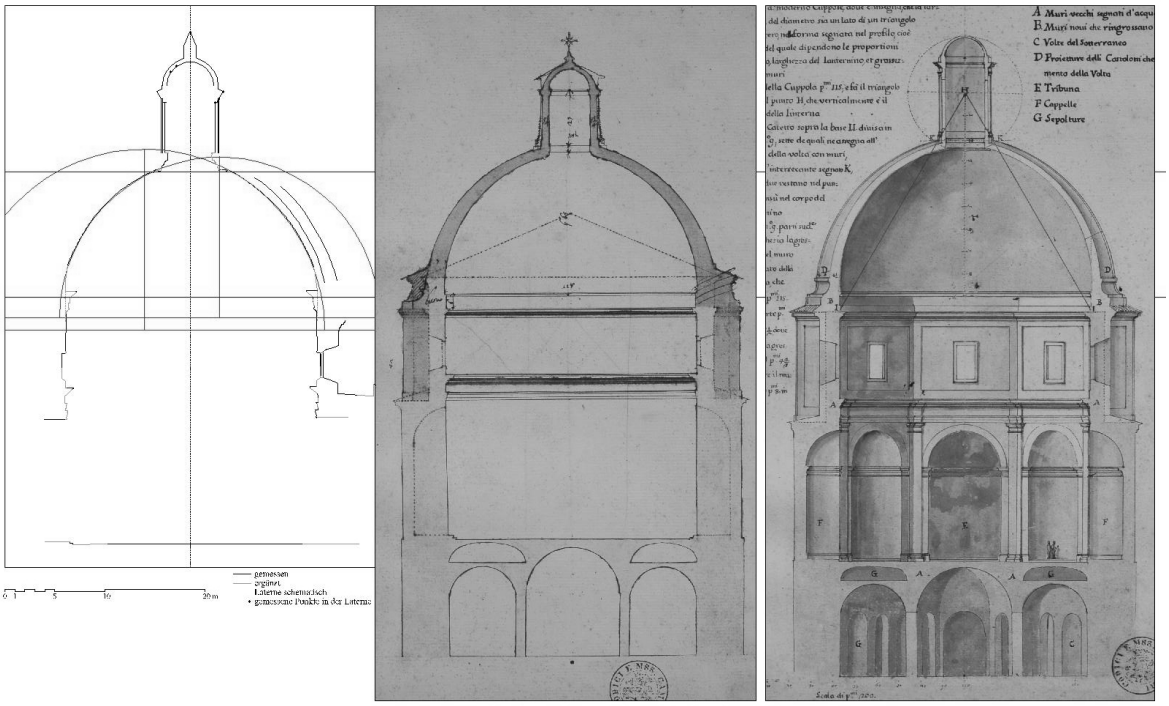


Figure 9: Comparison in scale of the building survey (left, with circular geometry of dome shell; see Figure 10 for the survey drawing without geometrical analysis), the cross section by Carlo Fontana, Bibl. Estense a, f.24 (middle, Hager 1975, p. 155) and the cross section by Carlo Fontana, Bibl. Estense a, F.12 (right, Hager 1975, p. 156); the two horizontal lines in the survey, which are also indicated on the edges of Fontana's drawings, show the level of the dome's crown in the survey and the level where in all drawings the octagonal drum ends and the circular dome begins; (graphics/survey Schlimme)

But might the difference between f.12 and the executed dome instead be explained as on-site decisions made by the master builders who realised the dome? As Fontana was not often present on the construction site, as sources show (Miscell. Arch. Catt. di Montefiascone; cfr. Serra 1974, p. 223), this seems possible. However, this cannot be so, since by contract Fontana was obliged to design the profile and width of the dome shell and to see and approve the scaffolding before construction of the dome itself could begin (ANM, paragraphs 12-13; published in Serra 1974, pp. 226-227). In section f.24 Fontana had effectively designed the later-executed plan. The modified design for the building site, in which Fontana, as he himself declares in the manuscript, changed only the outside surface of the dome by introducing the concave elements, was available by contract to the master builders through plan and profile drawings, which seem to not have survived (see ANM; published in Serra 1974, pp. 224-230). F.12 does not represent these drawings as Fontana explicitly declares it to document the church and dome as it was executed. Finally, as explained above, f.12 shows many more differences with respect to f.24 than Fontana himself claims that there are. F.12 thus has to be seen as a later idealisation.

Fontana countered his critics concerning the Montefiascone dome, not only by defending it, but also by turning it into a paradigmatic show case of correct dome construction. The extent of graphic idealisation needed for the already built dome reveals that Fontana must have built his dome without much reflexion on the construction principles of domes. Probably he had relied in part on his earlier experience in Bernini's studio: the dome in Ariccia for instance also has a truncated profile. Ariccia and Montefiascone followed an efficient, unwritten construction praxis, and both are still standing. When defending Montefiascone after construction was complete, Fontana post-rationalised his dome: in f12, instead of the realised truncated profile, the dome appears stilted, and corresponds to his interpretation of the authoritative architecture treatises where he believed stilted profiles were found. As in the "treatise rules" derived by Fontana, in f.12 the dome shell diminishes in thickness towards the crown, whereas the realised dome shell, as has been shown here, has a constant thickness from bottom to top. As well, the "Vitruvian rule" with the triangle also only fits into the idealised cross section f.12. The tracing back of the dome to Vitruvian authority and to the later treatises was imperative for Fontana. That these rules were misunderstandings and inventions on Fontana's part - and Fontana was aware of this at least in some cases – seems not to have been problematic. Nevertheless Fontana's ability to synthesise knowledge from disparate material is striking, and the cross section f.12 a fully convincing drawing. It is thus not surprising that cross section f.24 was never copied, while f.12 was widely disseminated in copies: Fontana's pupil Nicodemus Tessin the younger (Stockholm, Nationalmuseum T.H.C. 1957) and Giacomo Amato (Galleria Regionale della Sicilia, disegni di Giacomo Amato, tomo II, n.40; cfr. Nobile 1999) copied it, Bernardo Vittone (Paris, Musée des Arts Decoratifs) copied all the Montefiascone drawings from the manuscript except f.24. And the anonymous copy in Vicenza (Bibl. Bertoliana) includes all drawings except f.24, which in fact is the only drawing that is not extensively pricked in the manuscript original.

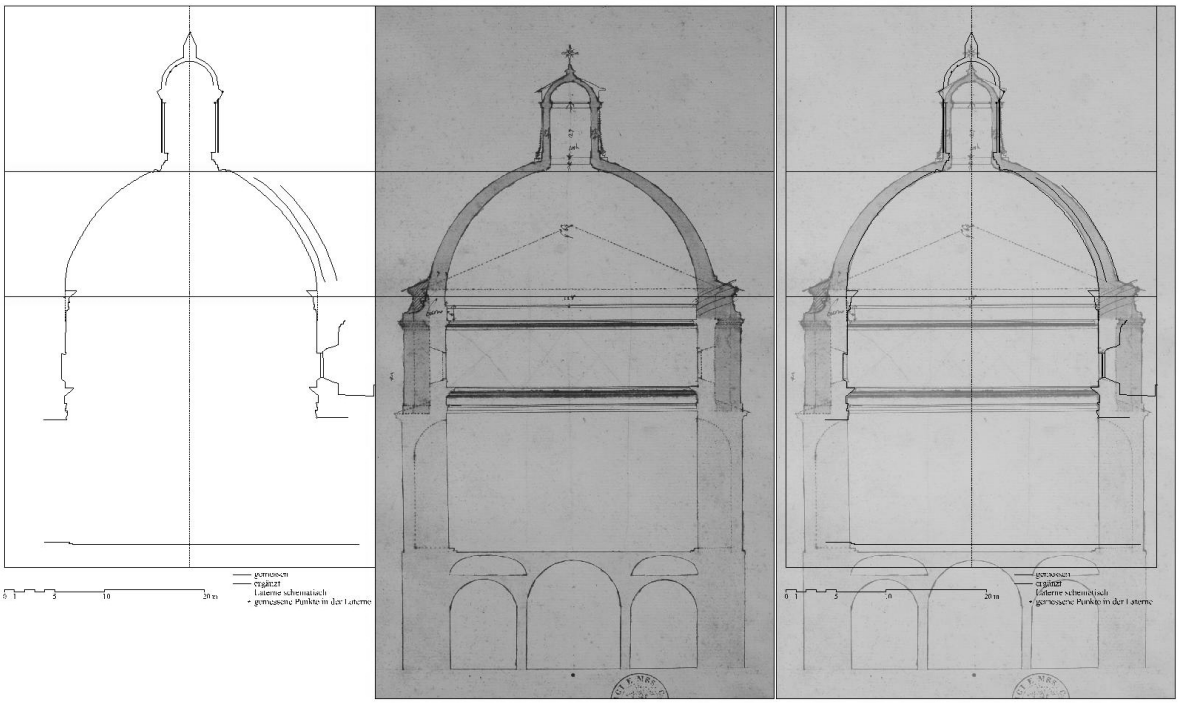


Figure 10: Comparison in scale of the building survey (left) and the cross section by Carlo Fontana, Bibl. Estense a, f.24 (middle, Hager 1975, p. 155) and the two superposed (right); (graphics/survey Schlimme)

Carlo Fontana's Montefiascone experience was the first, and probably most important step towards the rules for the construction of single shell domes he published in the *Tempio Vaticano* (1694, pp. 361-364). A series of further, post-Montefiascone experiences (i.e., assessments, built and projected domes) flowed into these rules. The 1694 set of dome construction rules enjoyed great success, and through the Accademia di San Luca, where Fontana played a preeminent role, and his numerous pupils, they were disseminated and used throughout Europe. Ironically, however, this success was largely based on fragmentary and invented information.

CONCLUSIONS

The present paper has analysed Carlo Fontana's dome construction in Montefiascone on the basis of a new building survey. Furthermore, it re-evaluated the manuscript in which Fontana defended his construction. It has been shown that the manuscript is based on fragmentary and in part false and misinterpreted information from treatises and from extant drum domes in Rome. The rule according to which the width of the drum should be 1/9 resp. 1/10 the dome diameter, later disseminated by Carlo Fontana in his *Tempio Vaticano* (1694) and commonly understood as a rule of thumb for traditional dome construction, is not from Vitruvius, but an over-interpretation of Vitriuvius by Fontana.

Fontana's dome in Montefiascone was built following an efficient, unwritten construction praxis. Instead, in his manuscript he post-rationalises the realised dome and traces it back to "Vitruvian rule". In the cross section f.12 he presents a false, deliberately idealised image of the realised dome, which appears as a paradigm for the implementation of Vitruvian and later architectural "rules". Carlo Fontana's Montefiascone experience was the first, and probably most important step towards the rules for the construction of single shell domes he published in the *Tempio Vaticano* (1694). Through his numerous pupils, Fontana's 1694 rules were diffused throughout Europe. Fontana's synthesis of construction knowledge is remarkable given that so many of his sources were fragmentary, obliging him to fill the gaps with his own imagination. Fontana seems to have been unaware of more complex (e.g. oval) dome profiles, proposing only simple, circular arcs as profiles. Thus through the success of his 1694 rules, there was probably on the other hand even a loss of knowledge in dome construction at least among his immediate followers.
With the analysis and re-evaluation of the Montefiascone manuscript, the present paper attempts to contribute to the wider history of knowledge in architecture and shows how complex, discontinuous and at times unsatisfactory knowledge in architecture was interpreted, applied, and transmitted.

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