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Analysis, interpretation and digital reconstruction of the centrally planned churches of Leonardo da Vinci's Manuscript B

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Abstract

This thesis addresses the issue of the analysis and three-dimensional reconstruction of the centrally planned churches depicted in Leonardo da Vinci's Manuscript B. Among the sacred buildings contained in the latter, only the ones that were drawn by using a plan view paired with a bird's-eye view were considered. This constitutes an innovative depiction technique, which allows to combine the immediacy of the perspective view in understanding the disposition of volumes with the measurability of the drawings. However, the lack of interior or section views does not allow to know the interior arrangement of the edifices and the small dimension of the drawings makes it difficult to have certainties about their architectural details. For this reason, our study starts from an analysis of the historical context of Manuscript B, with the aim to identify coeval architectural examples that can be used as references for the process of three-dimensional reconstruction. Then, the aggregative rules that characterize the churches were taken into account in order to define a method for their classification. There are, in fact, several common elements in the churches' layouts, made with an aggregation of volumes around a central octagonal space, and the study of the state of the art on this theme was the starting point for making a new proposal. The latter is based on the definition of a classification code, able to describe the aggregative layout of each edifice, that was then used as a base for the definition of a Grasshopper script that is able to resemble a three-dimensional base for the churches. Then, the geometric process for the construction of the plan and its relation with the measures in height was studiedfor each church. These information were then used for the realization of three-dimensional models, distinguishing more output variants, each time there was an inconsistency between plan and perspective view, a variability of one architectural element or an uncertainty.

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Se io non ho potuto fare

Se io

Leonardo da Vinci, *Epitaffio*, Codex Madrid II f.141 r

Introduction

This thesis aims to analyse the centrally-planned churches depicted in Leonardo da Vinci's Manuscript B in order to create their digital three-dimensional model as means of understanding their features and representation technique. To achieve this goal, it is necessary to consider the peculiarities of this manuscript and define a clear methodology.

Manuscript B, which is preserved in the library of the Institut de France and was written in Milan approximately between 1487 and 1490, is part of the Paris Manuscripts and contains drawings of several subjects, from flying and war machines to centrally-planned churches. The latter, which are the topic of this work, are characterized by some elements that we shall now consider.

First of all, among the several churches depicted in the manuscript, only the ones that are represented through a pairing of a plan and a perspective view and that are centrally-planned were considered[1]. The perspective view of the latter, however, is a bird's-eye view that almost resembles a cavalier perspective, so that, if we take a cube as a reference, we have two faces that are parallel to the picture frame and that are consequently in true form. In this way, Leonardo takes advantage of the capacity of axonometric representation to give immediate information about the volumetric layout and it combines it with the plan view to specify the interior distribution of space.

However, this representational approach does not define all the elements that constitute the edifice, since there is a lack of information regarding the interior development of the elements in height. This uncertainties imply the need of making multiple assumptions about the interior spaces of the churches, thus, in order to maintain a rigorous approach, it is necessary to use coeval or related architectural references as examples. This necessity derives also from another important characteristic of the drawings: they are extremely limited in their dimensions, since they are contained in *folios* that measure approximately 16 cm x 23 cm, so they do not contain any architectural detail. Moreover, the churches' drawings are not accompanied by any information regarding their dimension and scale.

These features are fundamental to try and understand the purpose of those drawings, but we must always keep in mind that they are, in fact, personal annotations, regardless of the reason why Leonardo did them in the first place[2], and thus must necessarily be schematic and not very precise.

Given all these elements, the goal of this work is to study the aggregative rules behind these designs and produce three-dimensional models of the churches, distinguishing more hypotheses of restitution for each one on the basis of all the possible variables found in the drawings' analysis, with a focus on the inconsistencies between plan and perspective views. Then, the results of this study will be put together in order to attempt a better comprehension of the purpose of these designs and the reason why Leonardo used this particular representation tool.

1 Sixteen churches in total were digitalised, as will be thoroughly explained in Chapter 4.

2 This work will also try to suggest an opinion on the subject, in light of the results obtained during the digitalization process.

In fact, the combined use of a plan and a bird's-eye view for the representation of an edifice is a peculiarity that should be considered and investigated. The use of these tools for the architectural representation, in fact, apparently is in contrast with what was claimed by Leon Battista Alberti in his *De Re Aedificatoria* about the difference between the drawings of the painter and that of the architect, who should draw using a plan and an elevation and thus avoid the use of perspective views[3]. Then again, Raffaello, in his letter to pope Leo X, wrote that the architectural representation of an edifice should be done using three instruments: plan, elevation and section views[4]. He discarded, in fact, the use of the perspective view since he claimed that to be the instrument of the painter, rather than that of the architect, for its inability to give dimensional information. However, after our analysis, we will argue that the representation used by Leonardo can be seen in accordance with Vitruvio's statements on the subject[5] and also shows affinities with the importance given by L. B. Alberti to the realisation of models[6] as a means of control of the project.

The methodology used to create the three-dimensional models starts from a thorough analysis of the historical context of the manuscript for the identification of architectural examples, that can be used as a reference for the assumptions that have to be made for the architectural details, for the interiors and for the building's dimension. Regarding the analysis of the drawings, the plan views will be deconstructed in their components in order to define a possibility for the geometric process behind their creation. Then, a relation between the geometric elements in plan and their height will be searched in the related bird's-eye views. The aggregative study, other than a goal, is also useful in order to take advantage of all the recurrences between the churches in the process of digitalisation.

Chapter 1 contains an historical analysis of the manuscript's context and identifies relevant architectural examples in Italy and in coeval treatises, that Leonardo is likely to have seen. In particular,

3 "The difference between the drawings of the painter and those of the architect is this: the former takes pains to emphasize the relief of objects in paintings with shading and diminishing lines and angles; the architect rejects shading, but takes his projections from the ground plan and, without altering the lines and by maintaining the true angles, reveals the extent and shape of each elevation and side - he is one who desires his work to be judged not by deceptive appearances but according to certain calculated standards". See Alberti, Leon Battista, Cosimo Bartoli, and Giacomo Leoni. *The Ten Books of Architecture*: The 1755 Leoni Edition. New York: Dover Publications, 1986. p. 22.

4 "Il disegno adunque degli edifici si divide in tre parti, delle quali la prima è la pianta, o vogliamo dire disegno piano, la seconda è la parte di fuori con li suoi ornamenti, la terza è la parete di dentro pur con li suoi ornamenti. [...] Né si diminuisca nella estremità dell'edificio, ancorché fosse tondo, né ancor se fosse quadro, per fargli mostrar due faccie, come fanno alcuni, diminuendo quella che si allontana più dall'occhio, che è ragione di prospettiva e appartiene al pittore, non all'architetto, il quale dalla linea diminuita non può pigliare alcuna giusta misura: il che è necessario a questo artificio, che ricerca tutte le misure perfette in fatto, non quelle che appaiono e non sono. Però al disegno dell'architetto s'appartengono le misure tirate sempre con linee parallele per ogni verso.". See Raffaello Sanzio, and Pietro Ercole Visconti. *Lettera di Raffaello d'Urbino a papa Leone X*. Roma: Tip. delle Scienze, 1840.

5 In the Einaudi Italian translation of Vitruvio's famous passage on architectural representation it is claimed that there are three instruments that should be used for the architectural representation: , which have been translated with some differences in the various edition but should probably indicate the plan, the elevation and the perspective. "Gli aspetti della disposizione, quelli che in greco si definiscono idéai, sono i seguenti: icnografia, ortografia, scenografia. L'icnografia si ottiene con l'uso successivo del compasso e della squadra secondo una misura ridotta ed è a partire da essa che vengono tracciate le piante sul suolo delle aree di costruzione. L'ortografia consiste nella rappresentazione in elevazione della facciata e nella sua raffigurazione in scala ridota secondo le proporzioni dell'opera da realizzare. Per scenografia poi si intende lo schizzo della facciata e dei lati che si allontanano sullo sfondo, con la convergenza di tutte le linee verso il centro della circonferenza". See Vitruvius Pollio, Marcus, Pierre Gros, Antonio Corso, and Elisa Romano. *De architectura*. Torino: Einaudi, 2007, I, p.27

6 Alberti writes "I have often conceived projects in the mind that seem quite commendable at the time; but when I translated them into drawings I found several errors[...]. Finally, when I pass from the drawings to the model, I sometimes notice further mistakes in the individual parts, even in the numbers etc.". See Alberti, Leon Battista, Cosimo Bartoli, and Giacomo Leoni, 1986. p. 22.

these references will be divided on the basis of their location. The areas that will be considered are Florence and the surrounding area, Lombardy (with a particular attention to Milan), and Rome. As regards the treatises, we will consider Francesco di Giorgio Martini and Filarete's production, as well as other drawings made by Leonardo and contained in other manuscripts. Each reference will be described, with attention to the reasons behind its connection with the churches of Manuscript B.

In Chapter 2 the information collected with this analysis will be used in order to study the recurring elements in the interiors and in the details, with attention to their proportions. This study on the references will be carried out in parallel, in order to define a casuistry for the elements of the churches, in particular that ones that will be used to make hypothesis on the dimension of the edifice, that are the interior and exterior openings.

In Chapter 3 the analyses that were carried out in the past on the composition of the designs are critically studied and a personal proposal is suggested. In particular, we will consider the works of J. P. Richter and that of J. Guillaume, who both proposed a classification of the churches based on their layout. Then, starting from these, we will define a personal system for the classification of the churches, based on the combination of volumetric elements around a central, octagonal space. The churches, in fact, are united by a common taste for the combination of elements, almost like a geometric play. This makes it possible to use the results of the aggregative study as the theoretical basis for the definition of a Grasshopper script for the first stage in the three-dimensional modelling. The nature of the layouts is ideal for a parametric study, that could potentially resemble all the churches starting from the same rules, as will be pointed out in the chapter.

Finally, Chapter 4 describes thoroughly the process of analysis and digitalisation carried out for each church. First, the state of the art in the study of the drawings will be presented, with attention to the works made by P. H. Scholfield, C. Pedretti, J. Guillaume and F. P. di Teodoro. Then, the methodology used for the process of digitalisation will be explained, along with the list of the churches that will be digitalised. The latter will be then analysed one by one, applying the method of classification defined in chapter 2, pointing out in each case all the variables that should be considered in the production of variants, and explaining all the assumptions made on the basis of the references presented in Chapter 1.

The overall result will be then considered and presented, in order to make motivated assumptions on the purpose of the drawings and the reason that lies behind their representation method.

1. Architectural references

1. Introduction

Manuscript B was written by Leonardo da Vinci between 1487 and 1490, during his Milanese period. Among the several subjects depicted in its pages we will here consider the ones that depict centrally planned churches using a plan view paired with a bird's-eye view.

One of the main characteristics of the drawings in Ms. B is their small size[1] and their nature of simplicity, being probably Leonardo's personal annotations and instruments to reason on the theme of centrally planned churches,. For this reason, they lack of a high level of detail, showing only the most important elements of the construction and the geometrical guidelines that lead the composition. Moreover, the presence of a plan paired with an exterior view makes it impossible to have many certainties when modelling the development of the interior spaces.

These problems makes it necessary to rely also on the churches and the influences that might have affected Leonardo's work during the years when he worked on Ms. B[2]. In this chapter those references are presented and will be later used to elaborate different possibilities for each church in the manuscript.

Some of the churches analysed in this chapter are previous than Leonardo's Manuscript B, and are considered as possible influences on his work; others, on the other hand, are coeval or immediately subsequent. In this case, I am considering them because of their undeniable connection with the historical period of the late fifteenth century and also because they may have been influenced by Leonardo's studies on sacred buildings.

2. Churches in Florence and Tuscany

We know little about Leonardo's apprenticeship with Andrea Verrocchio in Florence in his youth, except from the description made by Vasari. It is likely that Leonardo moved to Florence after his grandfather death in 1468, when his father Ser Piero had been appointed notary to the *Signoria*[3]. Leonardo probably joined the workshop of Verrocchio around 1469 and in 1472 his name was inscribed on the roll of the Florentine "*Compagnia di San Luca*", i.e. the painter's Confraternity.

1 Every folio, in fact, measures about 16 cm x 23 cm.

2 According to the observations made by Gerolamo Calvi the manuscript can be dated between 1487 and 1490, a period of time that corresponds to Leonardo's first anatomical studies collected in the Windsor Collection. See Calvi, Gerolamo, *I manoscritti di Leonardo da Vinci: dal punto di vista cronologico, storico e biografico*. Bologna: Zanichelli, 1925; reprinted, Busto Arsizio: Bramante Editrice, 1982, p.77-82.

3 Roberts, Jane. *"The Life of Leonardo". Leonardo Da Vinci, Hayward Gallery, London, 26 January to 16 April 1989*. 1989, p. 23

The Florentine period lasted until Leonardo moved to Milan probably around the end of 1481 or the start of 1482. So, this period is prior to the one when Leonardo wrote Ms. B, but has been fundamental for his architectural education and, in particular, here we considered Brunelleschi's churches as a likely influence over Leonardo.

2.1. Brunelleschi's Rotonda degli Angeli

The Rotonda (also known as Tempio degli Angioli) was designed by Filippo Brunelleschi in 1434 (fig. 1). Its position is directly related to the lantern of Santa Maria del Fiore, as it is positioned in a cone of vision between two of the ribs of the lantern. Pedretti suggested that this particular relationship between the Rotonda and the lantern of Santa Maria del Fiore was intentionally created by Brunelleschi, and, moreover, that maybe the Rotonda was intended to be seen from that specific point of view to resemble the visual effect created by a model placed on a table.[4]

We know from Vasari that Leonardo was the apprentice of Verrocchio and that copper sphere used to complete the lantern was commissioned to him in 1469 and placed in 1471. The fact that Leonardo directly collaborated with Verrocchio for the creation of the sphere is proved by Leonardo himself when, writing about methods for soldering in f. 84v of Ms. G, states *"Ricordati delle saldature con che si saldò la palla di Santa Maria del Fiore"* i.e. *"Remember the soldering used to solder the ball of Santa Maria del Fiore"*[5].

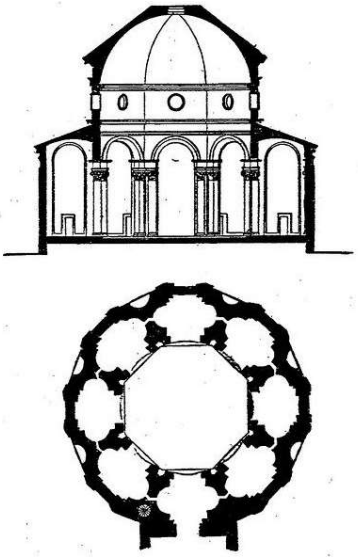

Fig. 1 - Brunelleschi's Rotonda, plan and section

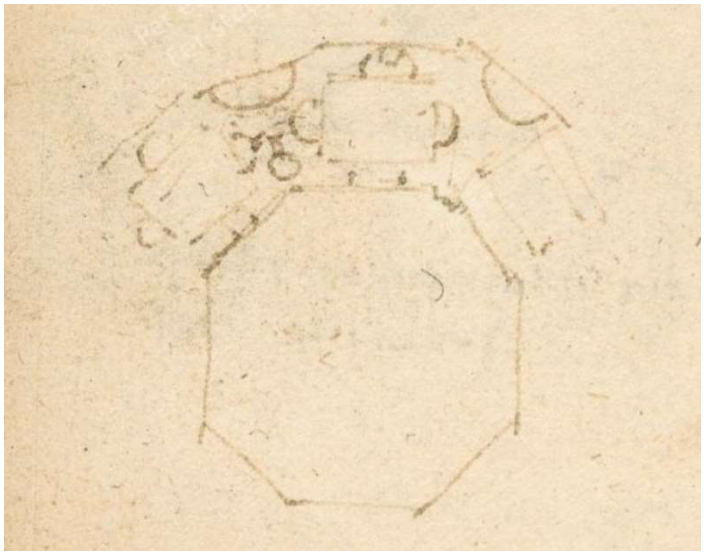

Fig. 2 - Leonardo's drawing of Brunelleschi's Rotonda in f. 11v. Ms.B

Considering these elements, it is logical to assume that Leonardo might have been several times in the lantern upon the dome. The hypothesis made by Pedretti is that the particular point of

4 See Pedretti, Carlo. *Leonardo architetto.* Milano: Mondadori Electa, 1996. p. 12-14 for the considerations about the relationship between the Lanterna of Santa Maria del Fiore and Brunelleschi's Rotonda.

5 Venerella, John. *The manuscripts of Leonardo da Vinci in the Institut de France: manuscript G.* Milano: Ente raccolta vinciana, 2002, p.149.

view under which the Rotonda is seen - a three-quarter view from high above - might be related to the perspective views used by Leonardo in his drawings.

This church represents the first example of centrally planned church based on the models of antiquity[6], and contains elements that are deeply related to the ones we find in Leonardo's manuscript. Its octagonal structure, with square-based chapels carved with curvilinear niches has a connection with the aggregative rules used by Leonardo in Ms. B.

The interest of Leonardo in Brunelleschi's Rotonda is also proved by the drawing he made of its plan in f. 11v of Ms. B (fig. 2). It is also interesting to notice how the plan made by Leonardo differs for several elements from the real one.

In particular there are noticeable differences in the niches of the chapels, that are on three sides - instead of two - and appear simplified, being depicted as semicircles. Another difference is in the connections between the chapels that, in turn, become more complex and contain an additional narrow circle-based space, maybe confirming that this drawing wasn't made in Florence, but later, with Leonardo having to recall the features by heart, or that maybe he drawn it based on the information he gained from Luca Fancelli around 1487, when he was working on the model for the *tiburio*[7]. This assumption is strengthened also by the already recalled dating of the manuscript in correspondence of Leonardo's Milanese period. This, however could not be the only reason: while Giuliano da Sangallo reproduced the church's plan accurately, Leonardo may have modified it intentionally with additions and variations[8].

2.2. San Lorenzo, Sagrestia Vecchia

The sacristy of the church of San Lorenzo (fig. 3), commissioned to Brunelleschi by Giovanni di Averardo de' Medici in 1419 and completed in 1429, is characterised by a square-based space with spherical pendentives and an umbrella vault with twelve sides.

The architectural choices in its design are deeply related to the fact that it was intended to be the Medici's funerary chapel[9], as the centralized plan in Renaissance architecture, in contrast with the longitudinal one, is related to the religious significance of the memorial[10]. The design of the church is characterised by clarity and simplicity of form, being composed by a main cubic space in which the walls are divided in half by an entablature on pilaster strips. The centrality of the plan however is interrupted by the presence of the *scarsella* in one of its sides.

6 See Bruschi, Arnaldo. *Filippo Brunelleschi*. Milano: Electa, 2006.p.144-146 for an extended description of the Rotonda and its characteristics.

7 It is unlikely that Leonardo took this information from Giuliano da Sangallo, as his drawing he made in his Codex Barberinus are dated 1492 and Ms. B cannot follow this dating. (Pedretti, Carlo, 1996. p.55)

8 Frommel, Sabine. 2016. "Giuliano da Sangallo and Leonardo da Vinci: cross-pollination or parallels?" in *Illuminating Leonardo* / Edited by Constance Moffatt, Sara Taglialagamba. pp.92-93

9 Bruschi, Arnaldo, 2006, pp. 85-102

10 See Lotz, Wolfgang. *Studies in Italian Renaissance Architecture*. Cambridge, Mass: MIT Press, 1990. pp. 66-67 for further notes on the symbolic meaning of centralized buildings during the Renaissance.

The construction shows an interest towards the union of the two geometrical forms of the circle and the square, focusing on the study of proportions between the elements and the use of symmetry, thus involving multiple symbolic elements[11].

The umbrella vault constitutes the main element of innovation and "modernity" of this construction. In fact, it presents innovative constructive features: it's constructed with a system of ribs that end with ring holding the lantern, the ribs are then connected with each other through a sailing vault that also leans on the drum. The advantage of using this system instead of the semi-spherical dome is that doing so it is possible to place openings in the base of each part of the dome[12].

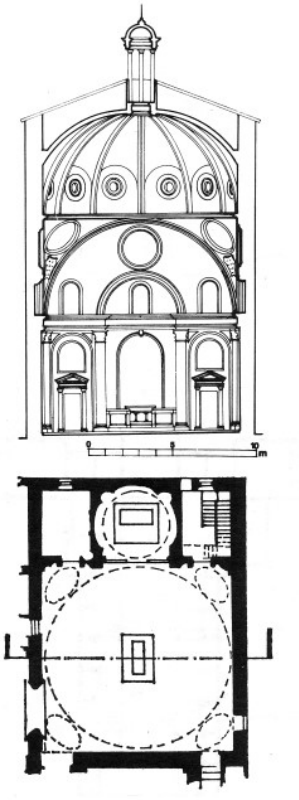

Fig. 3 - San Lorenzo, Sagrestia Vecchia, plan and section

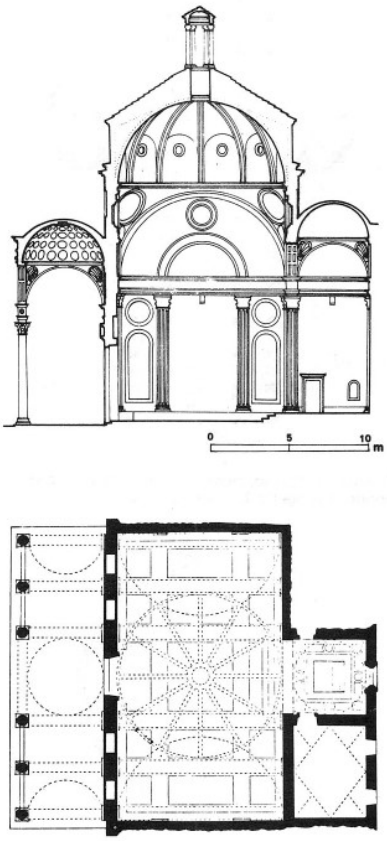

Fig. 4 - Cappella de' Pazzi, plan and section

2.3. Santa Croce, Cappella Pazzi

The design of this chapel (fig. 4) was probably commissioned to Filippo Brunelleschi around the second half of the 1420s, but it was constructed only later, after Brunelleschi's death. For

11 Arnaldo Bruschi suggested that this unprecedented architectural composition could have been suggested by that of the Baptistery of Parma's Cathedral, in addition to the symbolic spiritual meaning of the geometrical shapes that it contains. (Bruschi, Arnaldo, *"L'architettura religiosa del Rinascimento in Italia da Brunelleschi a Michelangelo"* in Millon, Henry A., and Vittorio Magnago Lampugnani. "*Rinascimento da Brunelleschi a Michelangelo la rappresentazione dell'architettura.*" Milano: Bompiani, 1994. p. 123

12 Battisti, Eugenio. *Filippo Brunelleschi.* Milano: Electa, 1989.pp. 79-97

this reason some elements, especially the ones of the decorations, were probably rearranged following a different design from Brunelleschi's one, but it is likely that the main elements constituting it are his creation and there might have been a drawing and/or a model that described his intents.[13]

The center of the construction, with its square nucleus surmounted by four spherical pendentives and a domical umbrella vault is similar to Sacrestia Vecchia, that was probably yet to be finished in the years when Cappella de' Pazzi was designed. However it is not sure to what extent Brunelleschi had the intention to repeat, after decades, exactly the same structure used in the dome for Sacrestia Vecchia[14].

What, with more probability, can be addressed to Filippo Brunelleschi is the masonry structure of the lower part that had to respect the constraints given by the presence of pre-existent walls and solve the problem of proportionality between elements in a construction that had to combine two spaces with different width.

2.4. Santo Spirito

Santo Spirito has been designed by Filippo Brunelleschi around the first half of 1430 decade, and therefore constitutes one of the works of his artistic maturity, as these are the years of the construction of the dome of Santa Maria del Fiore.

It is characterised by a latin cross plan (fig. 5) and, above the crossing, it presents the same spherical pendentives and dodecagonal umbrella vault already seen in Sacrestia Vecchia and in Cappella de' Pazzi[15]. The church of Santo Spirito manages to keep together a longitudinal system with a centrally-planned nucleus covered by a great dome and represents a fundamental expression of Brunelleschi's program[16]. The construction is characterized by the presence of semicircular chapels that surround its perimeter, thus recalling the multiplication of chapels in Leonardo's studies[17]. Those chapels, moreover, were originally emerging from the exterior perimeter[18], recalling the multiplication of semicircular chapels we can see in Leonardo's and Giuliano da Sangallo's drawings, but they were later covered with a straight exterior wall. In particular we are able to know the original plan for the church thanks to the reproduction made by Giuliano da Sangallo[19]. Even though the church wasn't completed following precisely Brunelleschi's project, its innovation surely had an important influence on the artists of its time: Giuliano da Sangallo,

13 Bruschi, Arnaldo, 2006, pp. 123-124

14 Battisti, Eugenio, 1989.pp. 222-226

15 Bruschi, Arnaldo, 2006, p. 127

16 Bruschi, Arnaldo, Millon, Henry A., and Vittorio Magnago Lampugnani., 1994, p. 125

17 Di Teodoro, Francesco P., Matthew A. Cohen, and Maarten Delbeke. 'Leonardo Da Vinci: The Proportions of the Drawings of Sacred Building in Ms. B, Institut De France". *Proportional Systems in the History of Architecture* / Edited by Matthew A. Cohen and Maarten Delbeke. 2018. p. 384

18 Battisti, Eugenio, 1989.pp. 196-197

19 F.. 14r Barberini Codex, Vatican Library, Latin 4424

Leonardo, Francesco di Giorgio and Bramante.

Leonardo draws its plan in f. 11v Ms B, that is the same folio where he depicted the plan of Brunelleschi's Rotonda of Santa Maria degli Angeli (fig. 6). In this case there isn't any evident difference from the real plan (apart from the entrances) and the errors are only related to the nature of the drawing, that merely represents a quick hand-drawn sketch, probably made by heart.

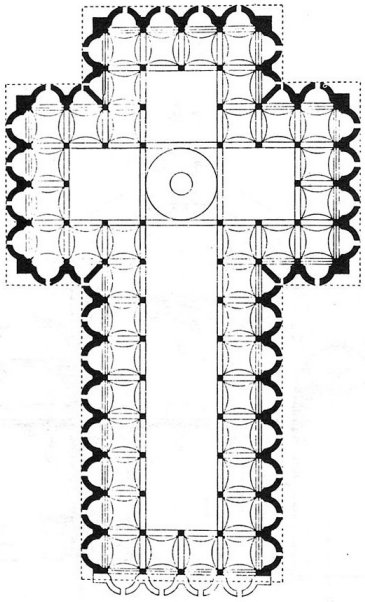

Fig. 5 - Santo Spirito, plan

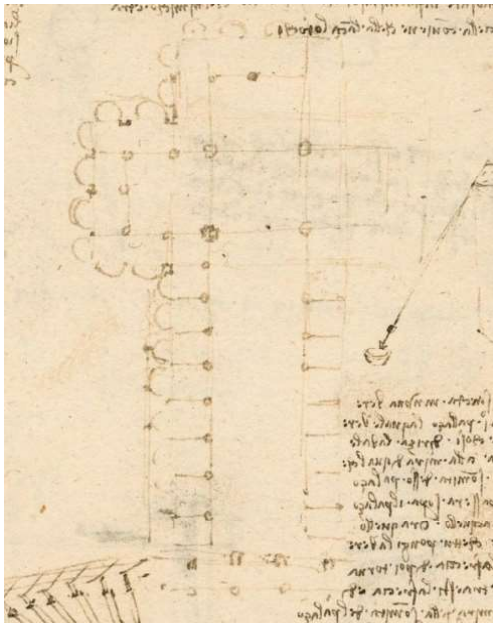

Fig. 6 - Leonardo's drawing of the plan of Santo Spirito in Ms.B f. 11v.

2.5. Santa Maria del Fiore's dome

The construction of the dome began in 1420 and it was finished in 1436. It was already pointed out the fact that certainly Leonardo must have been in the lantern of Santa Maria del Fiore's dome during the insertion of the copper sphere on top of it, and certainly Brunelleschi's masterpiece must have influenced his reasoning on domed buildings.

In fact, most of the churches of Ms. B the dome that imposts on the octagonal drum recalls the pointed cloister-vaulted shape of the one of Santa Maria del Fiore.

2.6. Battistero of San Giovanni, Florence

The construction of the Baptistery of San Giovanni in Florence (fig. 7) began around the IV century AD, it was consecrated in 1059 by Pope Niccolò II and then went under several modifications in the following centuries. During the fourteenth century some believed that the edifice had been in origin a temple dedicated to the god Mars.

We know from Vasari that Leonardo designed a system to lift the Baptistery of Florence with

the intent to introduce the stairs (*scalee*) that would have changed the visual relationship with the cathedral, especially for the scenic effect that it would have produced during religious ceremonies[20]. Currently however, only the description of the design remains, for example with the words used by Vasari:

> *"E fra questi modeli e disegni ve n'era uno col quale più volte a molti cittadini ingegnosi che allora governavano Fiorenza mostrava voler alzare il tempio di San Giovanni in Fiorenza et sottomettervi le scalee, senza ruinarlo[...]"* [21]

Pedretti suggested how maybe the contents of the lost drawings of Leonardo may be contained in the prints that were published in Borghini's *Discorsi*, that interestingly depict a version of the Baptistery as it was an ancient temple and that shows it separated from the paving of the square through stairs that raise it.

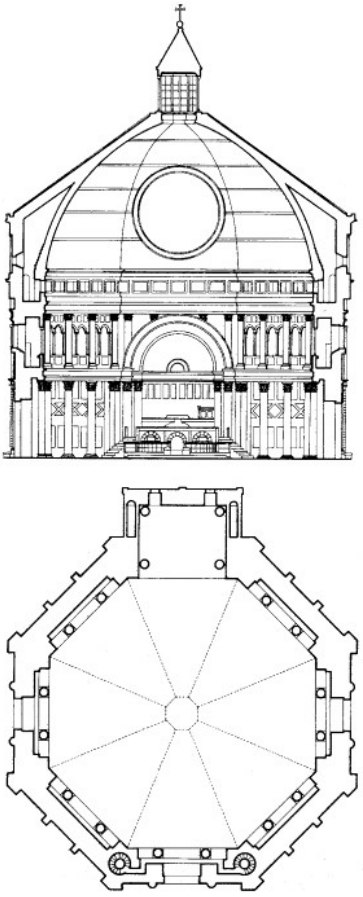

Fig. 7 - Plan and section of the Battistero of Florence

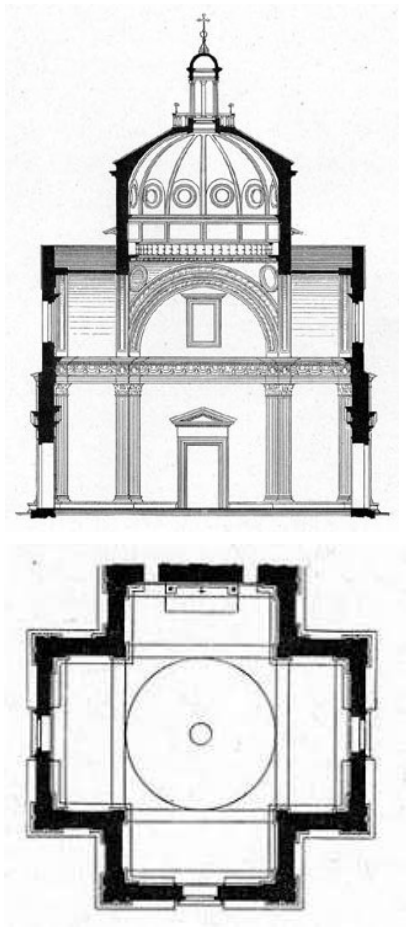

Fig. 8 - Plan and section of Santa Maria delle Carceri in Prato

20 This was a juvenile design but Leonardo came out with this ideas more than once, so it may suggest an interest that goes on over the years (PEDRETTI, CARLO, 1996. p.16).

21 i.e. "And among those models and drawings there was one through which he used to show to many of the ingenious citizens that were running Florence at that time that he wanted to raise the ground level of the temple of San Giovanni in Florence and place underneath it the stairs without damaging it.". VASARI, GIORGIO. *Vite de' più eccellenti architetti, pittori et scultori.* In Fiorenza: Appresso i Giunti, 1568. IV, p.18.

2.7. Santa Maria delle Carceri, Prato

The church of Santa Maria delle Carceri in Prato (fig. 8) was designed by Giuliano da Sangallo under the guidance of Lorenzo il Magnifico in 1485 and it was completed in 1499. Giuliano da Sangallo also supervised directly the construction works.

The connections between Leonardo da Vinci and Giuliano da Sangallo are several: they share a similar education, being born around the same years and working as apprentices at well-known workshops in Florence and they were both later influenced by the works of Filippo Brunelleschi. We also know from Vasari that Giuliano and Leonardo met in October 1492[22], in occasion of Giuliano's presentation of the wooden model of the Villa Medici in Poggio a Caiano to Ludovico il Moro. Their production in architecture was very different, with Giuliano showing a more pragmatic approach to design and construction, but their interests showed common elements. For instance, they were both interested in the sacralization of private buildings and in centralized buildings, following Alberti's ideal of central-plan churches[23].

Giuliano da Sangallo, in contrast with Leonardo's tendency to the design of complex and hierarchical layouts rich of *ludo geometrico,* followed Alberti's recommendations on the simplicity of structures and this can be well seen in Santa Maria delle Carceri in Prato.

In Florence, in the cultural environment of Lorenzo il Magnifico, the interest in centrally planned buildings culminated around 1485 with the project for Santa Maria delle Carceri in Prato, by Giuliano da Sangallo, who also personally oversaw its construction between 1485 and 1499.

The church's layout is entirely defined by harmonious proportions, following the ideas contained in the treatise of Leon Battista Alberti. The plan is a greek cross and the central space is covered by an umbrella vault on four spherical pendentives.

3. Churches in Lombardy

The Milanese period of Leonardo corresponds to the one when he wrote Ms. B, so it appears fundamental for the influences he might have had. In this section the churches that probably influenced Leonardo's works are presented, as they could be a hint of the characteristics of some architectural elements and details, when not further specified in the drawings of the manuscript.

3.1. Santa Maria delle Grazie, Milan

In 1493 Ludovico Sforza decided to demolish the pre-existing chancel built by Guiniforte Solari about twenty years before, in order to realize the memorial chapel of the Sforza. At this time

22 *"Nella medesima città furono insieme Giuliano e Lionardo da Vinci, che lavorava col Duca".* Vasari, Giorgio. 1568. IV, pp.138-139

23 Frommel, Sabine. 2016. pp. 85-96

Leonardo was painting his Last Supper in the nearby refectory and, after the completion of the works on the chancel, the nave and the façade of the church were to be rebuilt[24].

A well known letter from Ludovico Sforza to his secretary Marchesino Stanga, dated 29 June 1497, lets us know that Leonardo finished his Last Supper and that Ludovico Sforza wanted to call the best architectural experts in order to proceed with the transformation of the entire church of Santa Maria delle Grazie. Pedretti suggested a likely inclusion of Leonardo among those[25], other than Amadeo, Dolcebuono and Bramante, finding evidence for his collaboration with the latter[26] and found an element of connection between the studies of Leonardo on the theme of centralized churches and his possible contribution in the reconstruction of the church of Santa Maria delle Grazie[27]. In fact, in f. 123r of Ms. H^3, dated 1493 - one year after the beginning of the works on the church - he draws a centralized plan that recalls his previous works, and again in 1497 he draws a plan which depicts exactly Santa Maria delle Grazie and a section of its dome[28].

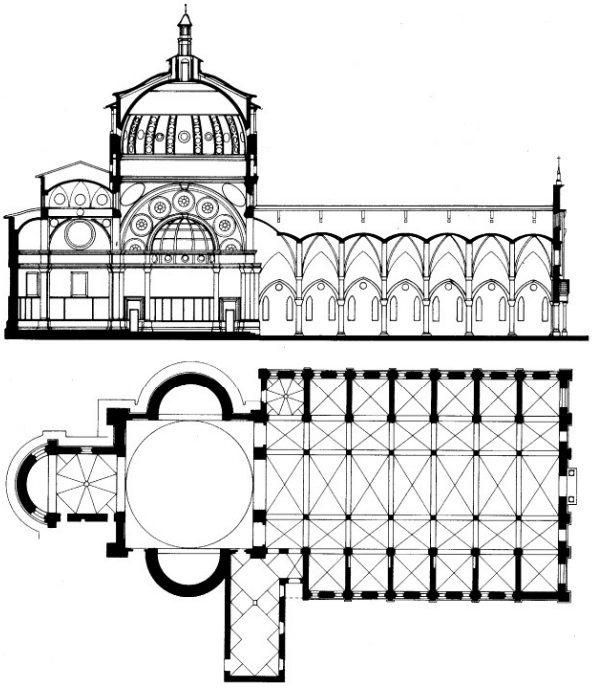

Fig. 9 - Plan and section of the church of Santa Maria delle Grazie at Milan

It is not clear, as we well know, what was the aim of Leonardo in his study of centrally planned

24 The projects beginning in 1497 however were not realized due to the political situation of the time, which led to Ludovico's fall in 1499 (Heydenreich, Ludwig H., and Wolfgang Lotz. *Architecture in Italy 1400 to 1600*. Harmondsworth: Penguin, 1974.p.108)

25 Pedretti, Carlo, 1996. p.85

26 First, Bernardino Arluno places the name of Leonardo da Vinci - defined as *"pictorem mollissimum, cuius in hunc diem picturae vivunt"* - with Bramante, Caradosso and Iacopo Antiquario among the ones that contributed to realise Ludovico Sforza's program. Then, the fact that Leonardo himself draws in f. 53v of Ms. M, dated 1499, a drawbridge with the annotation *"modo del ponte levatoio che mi mostrò Donnino",* thus proving that Donato Bramante showed it to him.

27 Pedretti, Carlo, 1996. p.86-89

28 Ms. I, f. 70r and Madrid Ms. I, f.113 v

churches and one of the hypotheses made in the past include the possibility for them to be a study for a Sforza mausoleum[29]. Although the answer remains unknown, it may be useful to notice that Santa Maria delle Grazie had in fact the purpose of family sepulchre and it is likely that the drawings of Leonardo deeply influenced the work of Bramante for this church[30].

Santa Maria delle Grazie shows common elements with the example of Brunelleschi's Sacristy of San Lorenzo, thanks to the presence in plan of two squares, with the smaller one placed right after the other, a solution that Bramante enriches adding three semicircular niches to the layout[31] and recalls local architectural models both on a small scale and on a large scale, for the presence of corner pilasters in the main square space, similar to the ones in Santa Maria presso San Satiro and in Cappella Portinari[32].

3.2. Santa Maria presso San Satiro, Milan

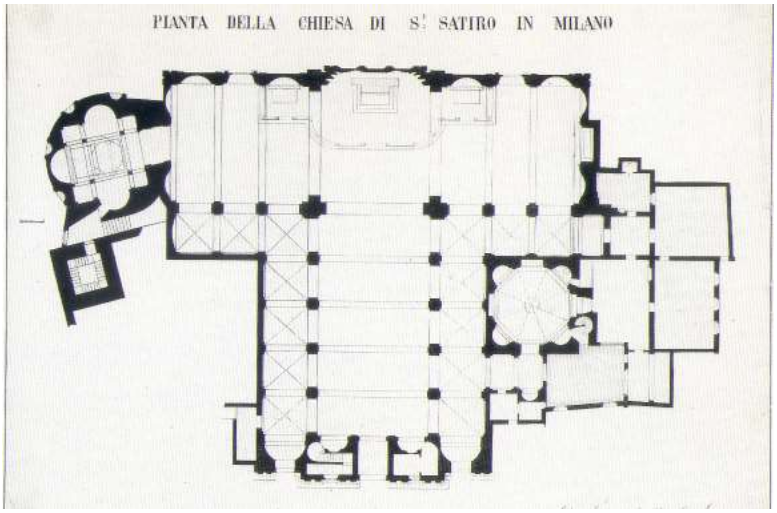

Fig. 10 - Plan of Santa Maria presso San Satiro

Between 1479 and 1483 Donato Bramante designed an oratory that was to be added to the small pre-Romanesque centrally-planned church of Santa Maria presso San Satiro[33]. Then, with the purchase of the site that stands between the present Via Falcone and Via Torino in 1482 by the confraternity in charge of the building, it was decided to enlarge the oratory that was under construction into a basilica[34]. In 1486 Giovanni Antonio Amadeo was appointed to build its facade

29 S. Lang claimed that the drawings constitute a progressive series for the creation of a Sforza Sepulchre (Lang, S. "Leonardo's Architectural Designs and the Sforza Mausoleum". *Journal of the Warburg and Courtauld Institutes* / Ed. E.H. Gombrich [U.a.], 1968. pp. 218-235.).

30 Kemp, Martin, Ernst H. Gombrich, Jane Roberts, and Philip Steadman. *Leonardo Da Vinci: [Catalogue of an Exhibition Held at Hayward Gallery, London, 1989!* New York: Yale University Press, 1989. p.206

31 Benevolo, Leonardo. *Storia dell'architettura del Rinascimento*. Roma [u.a.]: Laterza, 1988. p.273

32 Schofield, Richard. "Bramante e un rinascimento locale all'antica". *Donato Bramante* / Accademia Raffaello, Urbino. A Cura Di Francesco Paolo Di Teodoro. Scritti Di Enzo Bentivoglio. 2001. p. 64.

33 The decision dates back to about 1476, but it was only in 1478 that the site could be acquired (Heydenreich, Ludwig H., and Wolfgang Lotz. 1974.p.103

34 In this way the space that constituted the sacristy became the transept of the church that was to be built.

along with Bramante, who, on the other hand, was appointed to study the juxtaposition of the stone colors[35].

Santa Maria presso San Satiro has a virtual latin cross layout, thanks to the space created by the visual illusion painted in the apse. The crossing between the nave and the transept is covered by a tiburius with a dome on spherical pendentives. The interior recalls the coffered barrel vault of the church of Sant'Andrea at Mantova, link that could be justified by the fact that Bramante certainly had seen its model and the vestibule of its facade[36].

There are however two other elements of interest in the church: the sacristy and the *sacello carolingio* of San Satiro. The sacristy, which was built in the same years of the church, shows a different layout from the latter. The *sacello* (i.e the pre-Romanesque church of San Satiro) was altered by Bramante too, with a restoration that incorporated the exterior niches in a thick circular based exterior wall. It is interesting to notice the similarities between this layout and many of Leonardo's churches design in Ms. B.

3.3. Holy Sepulchre, Milan

The Holy Sepulchre is one of the few existing churches that Leonardo drawn in his manuscripts. However he did more than that: apart from drawing the church and its crypt in Ms. B f. 57 r, Leonardo quotes it as an example for the articulation of spaces in one of the churches of the manuscript[37].

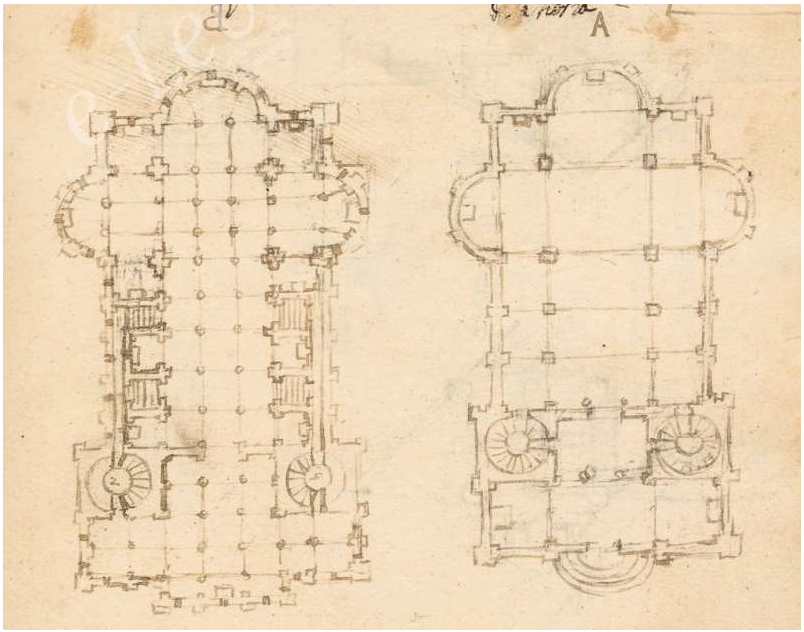

Fig. 11 - Leonardo's drawiong of Santo Sepolcro's plan in Ms. B f. 57r.

35 Schofield, Richard V. *Giovanni Antonio Amadeo: documents*. Como: Ed. New Press, 1989.

36 Heydenreich, Ludwig H., and Wolfgang Lotz. 1974. p.104.

37 Ms. B, f. 94 r: "questo edifitio è abitato di sotto e di sopra come è San Sepulcro [...]" (i.e. "this building is accessible below and above, like San Sepolcro [...]"

3.4. San Lorenzo Maggiore, Milan

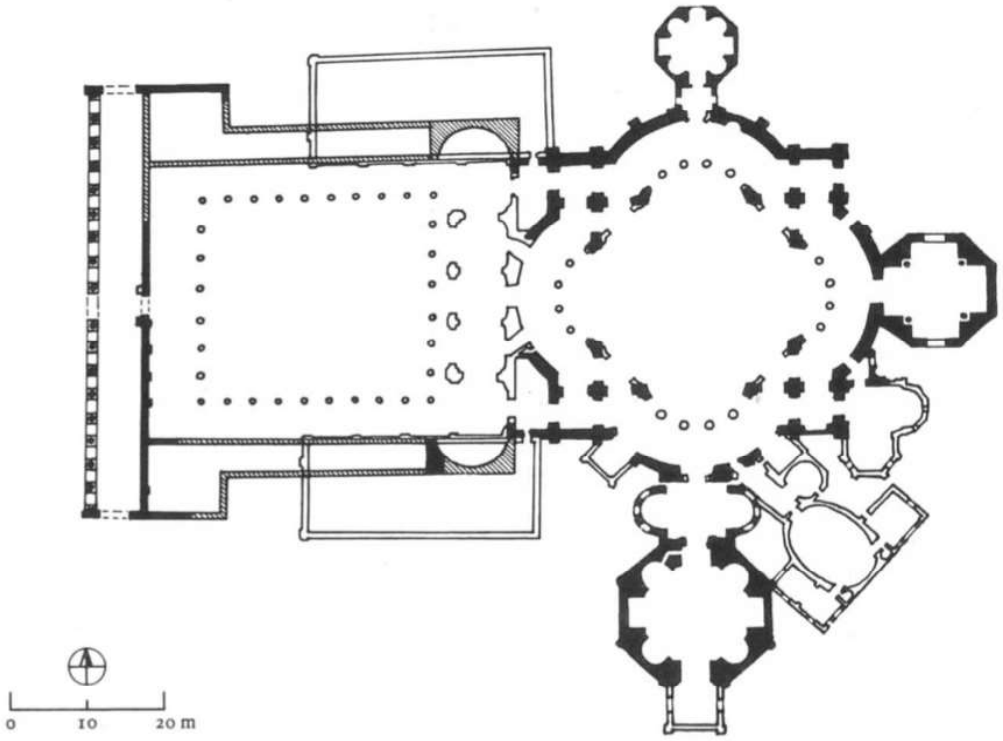

Fig. 12 - Plan of San Lorenzo Maggiore at Milan

The Basilica of San Lorenzo Maggiore in Milan is a paleochristian church, probably erected about 370, that was later modified in the twelfth and in the sixteenth century[38]. It is a great quatrefoil structure characterized by a double shell: an outer one, made by the two-storey galleries, and an inner one, made by the main central space. This one was originally surmounted by a square drum, instead of the current sixth-century[39] octagonal drum, and its position is still recognizable by the four L-shaped piers in the corners of the room. Outside, the quatrefoil structure is surrounded by four towers at the corners.

In his drawings Leonardo proposes more than once layouts that are without any doubt deeply connected with San Lorenzo. One should only bear in mind that Jean Paul Richter, in the process of creating a classification of Ms. B churches into groups, decided to dedicate a whole class of the sketches to the ones *"suggested by San Lorenzo at Milan"* [40] as he pointed out that they show a direct influence from this church[41] and that Leonardo drawn its interior spaces in CA F. 7v b. dated 1495-7[42].

38 Krautheimer, Richard. *Early Christian and Byzantine Architecture.* (Pelican History of Art). 1965.

39 This clearly implies that the church was still intact at the time when Leonardo wrote Ms. B.

40 Richter, Jean Paul. *The Notebooks of Leonardo Da Vinci. Vol. 2. / Compiled and Edited from the Original Manuscripts by Jean Paul Richter.* New York: Dover, 1970. pp. 50-51. The classification made by J.P. Richter will be discussed in detail in Chapter 3.

41 The church of San Lorenzo Maggiore, according to Richter could likely have influenced also Bramante's design for the dome of St. Peter in Rome. (Richter, Jean Paul.1970. p. 40)

42 Firpo, Luigi. *Leonardo architetto e urbanista.* [Torino]: Unione tipografico-editrice torinese, 1971. p.31

The nearby smaller structure of Sant'Aquilino, which seems to be coeval to the Basilica, could as well be important for the analysis of Leonardo's designs, as its layout - an octagon with alternate rectangular and semicircular niches - recalls many of them.

3.5. Santa Maria della Passione, Milan

Between 1482 and 1485 Giovanni Battagio da Lodi built the centrally planned church of Santa Maria della Passione (fig. 13), that was then transformed into a longitudinal church between 1573 and 1591, when a nave was set in front of it, upon request of Carlo Borromeo.[43]

Thus, Leonardo may have seen the church in its original form during his Milanese period and, more interestingly, before he started writing Ms. B in 1487. With this in mind, the articulation of the church becomes an important reference to consider in the study of Leonardo's work:. The church is characterized by a massive central octagon articulated with piers, with four chapels on the main axes, which are composed by a rectangular space combined with a semicircular one and four semicircular niches on the diagonal axes.

This layout clearly recalls many plans drawn by Leonardo, but the similarities are also present in the elevation of the building, both in its centre - an octagonal cloister vault and an octagonal drum completed with a layered octagonal roof - and in the volumetric articulation of the chapels and niches on the outside.

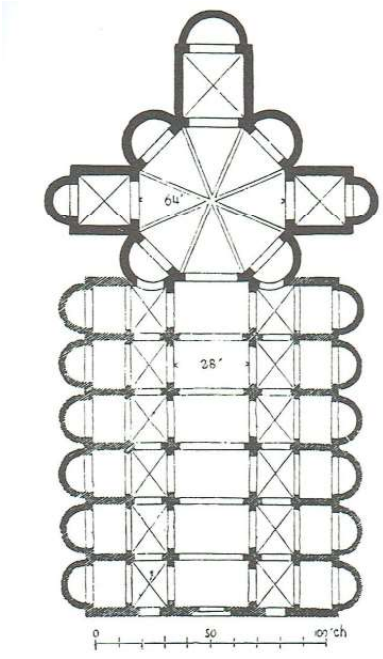

Fig. 13 - Plan of Santa Maria della Passione at Milan as it is in the present

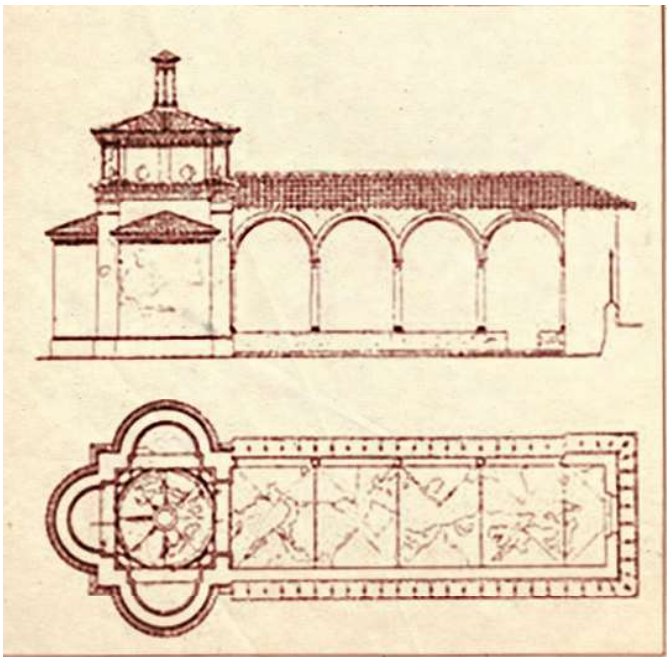

Fig. 14 - Plan and elevation of Cascina Pozzobonelli

43 Heydenreich, Ludwig H., and Wolfgang Lotz. 1974.p. 110

3.6. Cascina Pozzobonelli, Milan

A the four-arched portico and a small chapel are all that remains nowadays of what is known ad Cascina Pozzobonelli (fig. 14), for which the date of construction and the architect are still unknown and debated. Even though the uncertainties, the most accredited theories date it to the last quarter of the fifteenth century and some claim it was built by Bramante, even though the latest study on the building couldn't answer this question[44]. On the other hand the dating is also a much debated subject: Beltrami dated it as 1498, Malaguzzi Valeri claimed it was made after the construction of Santa Maria presso San Satiro, Bruschi and Terzaghi dated it back to the period of Bramante's activity in Milan, while Baroni thought it was built before Bramante even arrived in Milan[45].

3.7. Santa Maria dei Miracoli presso San Celso, Milan

The church was begun in 1493 by of Giovanni Giacomo Dolcebuono and in 1494 it continued with the collaboration with Cristoforo Solari and Amadeo for the construction of its *tiburio*, when the latter became the engineer of the *fabbrica* of Santa Maria presso San Celso.[46]

The church had initially a centralized plan with a centre on four pillars and, even though it is hard to reconstruct its original plan, it corresponded closely to Leonardo's plan characterized by four apses and four pillars.

3.8. Pavia Cathedral

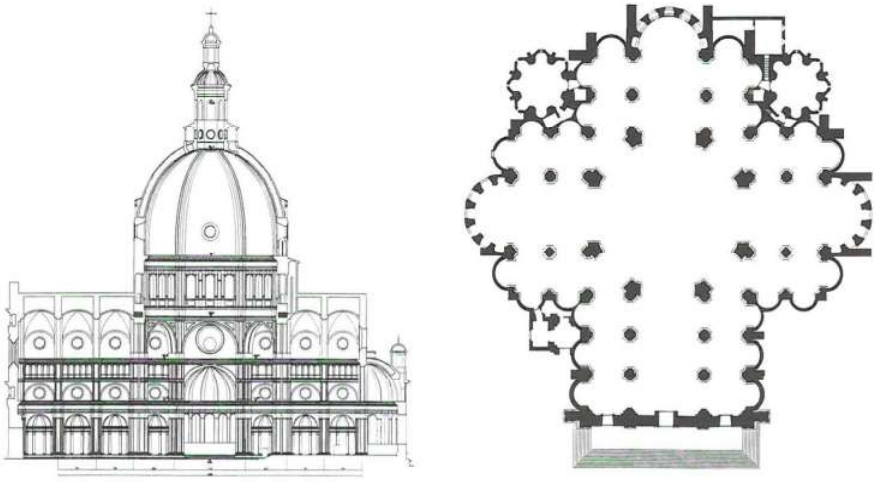

Fig. 15 - Plan and section of Pavia's Cathedral

44 Righini Ponticelli, Sylvia. "Nuove indagini sulla cascina Pozzobonelli a Milano". *Arte Lombarda* / ISAL, Istituto Per La Storia Dell'Arte Lombarda. 1988. p. 114.

45 Alessandrini, Giovanna. 1989. "Bramante in Milan: The Cascina Pozzobonelli ; Technical Examination and Restoration". *Studies in Conservation*. 1989. pp. 53-66.

46 Heydenreich, Ludwig H., and Wolfgang Lotz. 1974.p. 110

In 1486 the clergymen of Pavia Cathedral expressed their will to construct a new cathedral based on the style of the antique Roman monuments and on Saint Sophia of Costantinopoli. Bramante was summoned to Pavia in August 1488 to provide his knowledge on Roman antiquities[47] but we know that when he arrived he found the plan already advanced and thus it is difficult to know to what extent Bramante influenced the church's plan[48].

The 20th of June 1490 Leonardo is in Pavia with Francesco di Giorgio Martini to give consultation about the cathedral[49] (at the time, Cristoforo Rocchi had already made a model). The church then underwent many alterations and maybe Bramante's influence, as Heydenreich and Lotz pointed out[50], can be seen in the idea of a plan that aimed to combine a centralized and basilical scheme, idea that is certainly deeply connected to Leonardo's reasoning on centralized buildings. So, even though we don't know the extent of Leonardo's share in the modification of the initial plan, the importance of this church appears to be undeniable, especially considering the similarities between the central octagonal space in the churches of Ms. B and that of Pavia's Cathedral.

3.9. Santa Maria in Pertica, Pavia

ff. 34 v and 35r contains two geometrical exercises that refer to the church of Santa Maria in Pertica, as proven by the plan contained in f. 55 r where Leonardo himself writes the caption *"Santa Maria in P(er)ticha da Pavia"*. This could suggest that Leonardo may have visited Pavia before the already recalled consultation for the cathedral in 1490[51].

The church of Santa Maria in Pertica (or also Santa Maria alle Pertiche) was founded around the VII century, but was later destroyed. Nowadays the only historical records of it are the drawings that were made and we through these testimonies we know that it was centrally planned with aisles.

3.10. Tempio dell'Incoronata, Lodi

The Tempio dell'incoronata was designed by Giovanni Battagio da Lodi and its foundation stone was laid on 5 May 1488.[52] The layout recalls the type of the sacristy of Santa Maria presso San Satiro. It is particularly interesting for its octagonal interior layout and the drum and dome system.

47 Schofield, Richard 2001. pp. 62-64

48 Heydenreich, Ludwig H., and Wolfgang Lotz. 1974.pp.106-107

49 Pedretti, Carlo, 1996. p.52

50 Heydenreich, Ludwig H., and Wolfgang Lotz. 1974.p.108

51 Pedretti suggests that some anatomical studies made by Leonardo, dated 1487-8 (Windsor Collection, ff. 12632 and 12634), may in fact be the reproduction of the statues of the so-called Boezio Tower in Pavia, as seen from its windows. The tower no longer exists, but we know its features thanks to a reproduction made by Giuliano da Sangallo in his Codex Barberinus, among other reproductions. (Pedretti, Carlo, 1996. pp.53-55)

52 Heydenreich, Ludwig H., and Wolfgang Lotz. 1974.p.110

3.11. Santa Maria della Croce, Crema

The church was designed by Giovanni Battagio da Lodi, as well as the already quoted churches of Santa Maria della Passione at Milan and Tempio dell'Incoronata at Lodi, and its construction begun in 1493.[53] It is characterized by an interior octagonal shape embraced by an exterior circular wall, surrounded by four octagonal chapels on the main axes. This particular layout is akin to that of the church in f. 21r of Ms. B

3.12. Cappella Colleoni, Bergamo

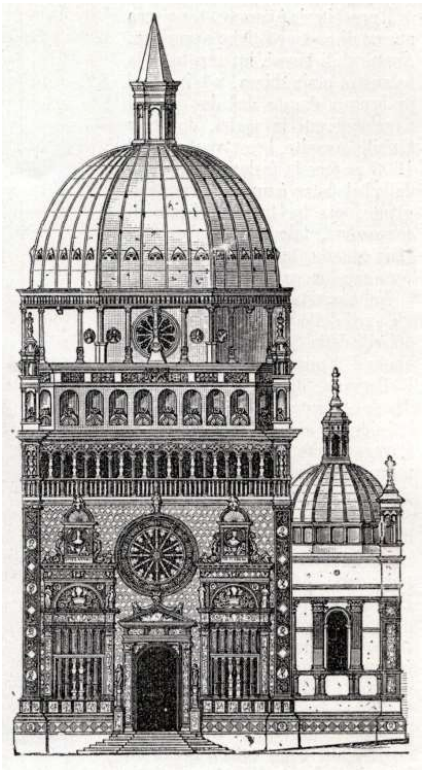

Fig. 16 - Elevation of Cappella Colleoni at Bergamo

Cappella Colleoni was designed by Giovanni Antonio Amadeo with the purpose of becoming Bartolomeo Colleoni's personal mausoleum and it was built between 1470 and 1476.

The church's design is characterized by an octagonal drum, that well combines with the nearby basilica of Santa Maria Maggiore, and an octagonal umbrella vault, in which four of its eight parts are opened with circular openings at their base. The combination of simple and closed volumes with decorations that are made with compact elements of great sculptural quality had a great success at the end of the fifteenth century in Lombardy and can be found in several other churches in the territory - some of which are considered in this chapter as references for Leonardo's work - such as the Tempio dell'Incoronata in Lodi, Santa Maria dei Miracoli in

53 Heydenreich, Ludwig H., and Wolfgang Lotz. 1974.p. 110

Brescia, the Sanctuary of Saronno, Santa Maria presso San Celso, Santa Maria delle Grazie and Santa Maria presso San Satiro in Milan[54].

Moreover, this church represents an example of how a local architect as Giovanni Antonio Amadeo, who probably never had the chance to see large-scale ancient architecture, could evoke antiquity just relying on the information gained by drawings and books, in accordance with R. Schofield's theory about a renaissance style based on local ancient models[55].

The reason why we propose to take into account Amadeo's work in Bergamo relies in its connection with Donato Bramante, who went from Urbino to Bergamo in 1477, before arriving in Milan. Cappella Colleoni was one of the first buildings he saw when he arrived in Lombardia[56] and the common elements between his architecture and Amadeo's are several, some deriving directly from this chapel and some from Lombardy's tradition in architectural details.

3.13. Santuario di Santa Maria di Piazza, Busto Arsizio

Even though this church was built at the beginning of the sixteenth century, this church is characterized by a scheme that is closely related to the fifteenth century layouts collected in this chapter. It is interesting for our study since it has an octagonal layout with niches on the sides and angular pilasters.

3.14. Other churches

We will list here some other interesting churches that could be useful as references, but for which was not considered necessary a thorough discussion:

1. Santa Maria di Canepanova, Pavia
2. Chiesa dell'Incoronata, Sabbioneta
3. San Sebastiano, Mantova

4. Churches in Rome

4.1. Cappella Chigi, Santa Maria del Popolo, Roma

The construction of Cappella Chigi started between 1512 and 1514 under the direction of Raffaello and it was completed by Gian Lorenzo Bernini around 1556. In this chapel Raffaello

54 Benevolo, Leonardo. 1988. p.158

55 R. Schofield focused on the tendency during the Renaissance to use local ancient examples in architecture, instead of a broader approach to the models, calling it "stile rinascimentale locale all'antica". It is interesting to notice that the lack of great-scale models for Amadeo in Bergamo made him design Cappella Colleoni with a style that was aimed to allude to antiquity, taking its elements from small local examples or even just drawings and books. (Schofield, Richard 2001, pp.48-50)

56 Schofield, Richard 2001, p. 51

manages to combine an octagonal plan with a circular drum, following the model of St. Peter[57], thanks to double curved pendentives that manage to connect a straight segment with a quarter of circumference.

Even though this example distances itself from the previous ones both chronologically and geographically, it was used as possible solution in the cases where Leonardo draws an octagonal space in plan along with a circular drum in the exterior perspective view.

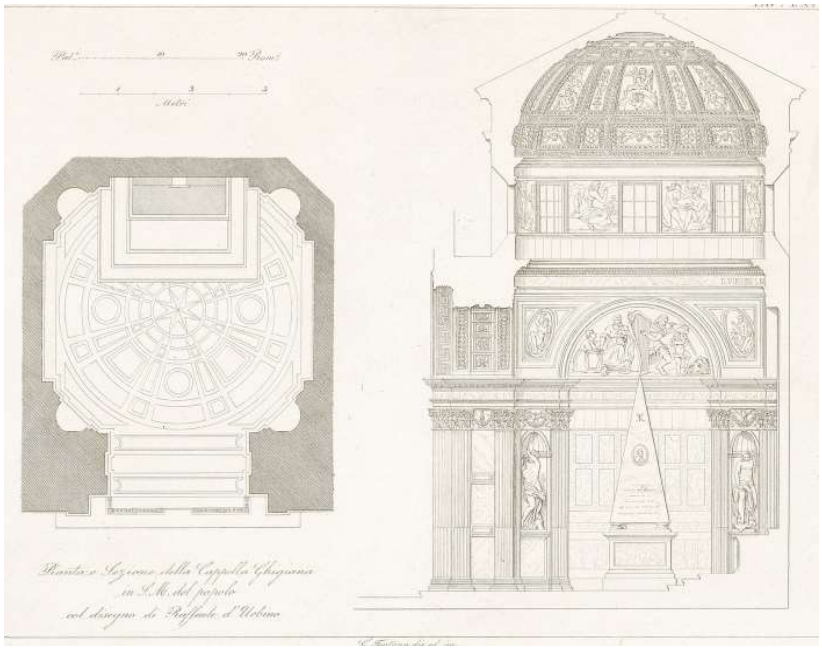

Fig. 17 - Cappella Chigi, plan and section

5. References from other manuscripts' drawings

Some hypothesis about the characterisation of the interiors can be made analysing the drawings of Leonardo Da Vinci contained in other collections. These references were used in order to enrich the three-dimensional models of the churches, since the drawings contained in Manuscript B don't contain any information about the interiors of the buildings.

5.1. Codex Atlanticus, f. 104 r

The first reference that has been used is the perspective view contained in f.104 r, Codex Atlanticus. It depicts a centrally planned church with four semicircular apses. This building perfectly

57 Benevolo, Leonardo. 1988. p.330

resembles the elements that appear repeatedly inside Manuscript B, and that are particularly described in f. 93 v.

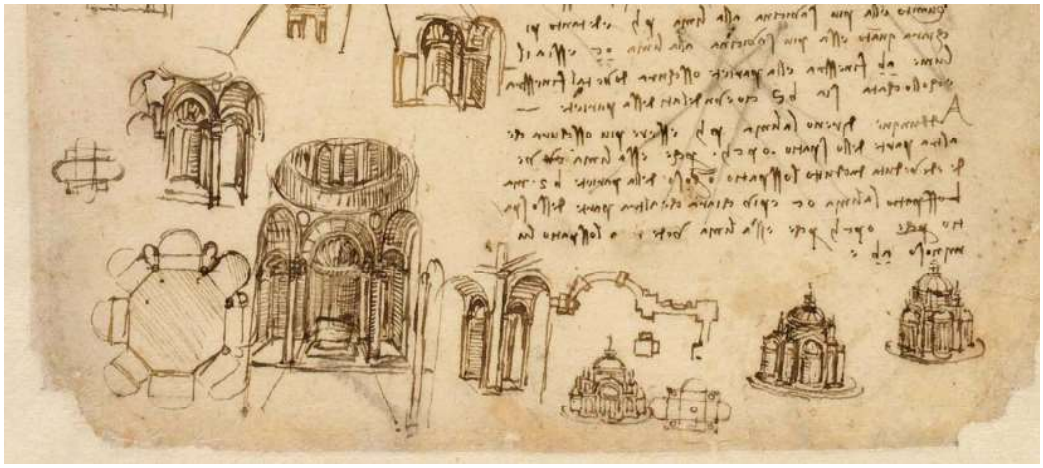

Fig. 18 - Codex Atlanticus, f. 104 r

A similar drawing, however appears in one of the drawings of the Windsor Royal Collection and it can be used for the interior characterization of the buildings that have a four-lobed layout with four pilasters in the centre (fig. 19).

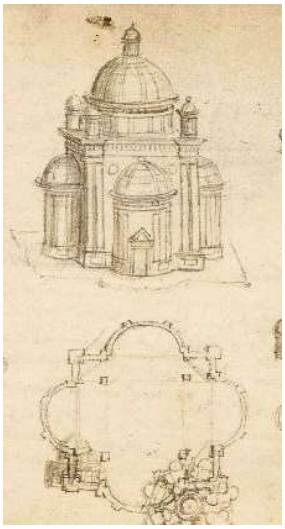

Fig. 19 - Ms. B, f 93 v

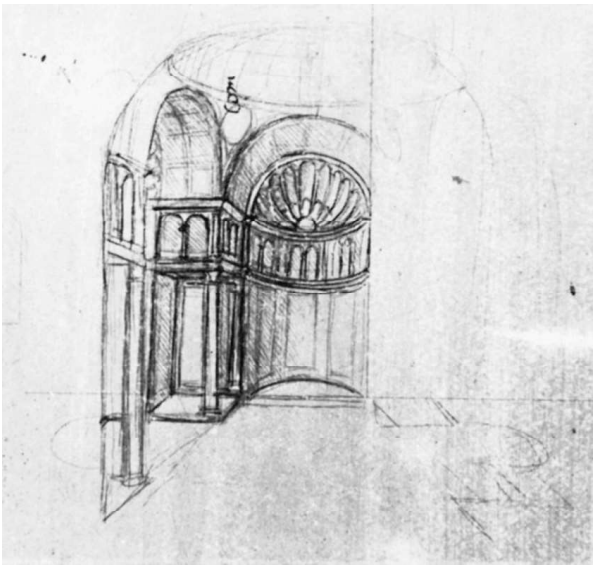

Fig. 20 - Royal library, Windsor Castle, f. 12609 v

5.2. Royal library, Windsor Castle, f. 12609 v

The drawing here represented was hardly visible before its examination under UV rays[58].

The drawing appears to be extremely similar to the previous one. Moreover C. Pedretti in his article suggests additional correspondences with the pen and ink drawings of interior elevations in Codex Atlanticus, f. 42 v-c, which corresponds with the plan in Ms. B f.57 r, that Leonardo him-

58 Roberts, Jane and Carlo Pedretti, "Drawings by Leonardo da Vinci at Windsor newly revealed by ultra-violet light", *Burlington Magazine*, CXIX. 1977. pp. 396-408

self describes as the records of the crypt and ground plan of the church of S. Sepolcro in Milan.

C. Pedretti also reports the hypothesis about the dating of this folio made by Ludwig H. Heydenreich.[59] Heydenreich showed that in the Codex Atlanticus sheet there is a note, handwritten by Leonardo, which points to the date 1485 and this may be a bearing on the date of the Windsor f. 12609 v.

According to C. Pedretti, this drawing could represent Leonardo's suggestion for a restoration programme for the existing structures of Santo Sepolcro, inspired by Bramante, or maybe it could be related to Leonardo's first attempts to design Pavia's Cathedral.

There is, in fact a deep similarity between Pavia's Cathedral and some of the churches depicted in Ms. B (e.g. ff. 18v and 19r for the dome and f. 93 v for the elements in the corners).

As Pedretti points out, Ms. B was dated between 1487 and 1490[60], which could give suggestions also for the dating of the folios of Codex Atlanticus and of the Royal Library previously described.

6. Filarete and Francesco di Giorgio Martini's treatises

In his book, L. Firpo notices how the churches' layouts truly express the interest, typical of the Renaissance, for star-shaped symmetrical polygons, that were already theorized by Filarete[61] (Antonio di Pietro Averlino). In fact, the star-shaped town was first formulated by Filarete and then, twenty years later, this subject was further investigated by the architect, painter and sculptor Francesco di Giorgio Martini.

Filarete wrote his "*Libro architettonico*"[62] between 1451 and 1464, while he was in Milan at the service of Francesco Sforza. The books are written in the form of an allegorical dialogue, set in the narrative frame of a banquet in the presence of the Prince, where the author is asked to plan a new city, Sforzinda, for which he takes inspiration from a fictional "Golden Book"[63]. In the treatise Filarete describes the city and its buildings. These are particularly interesting if compared with Leonardo's production, since they stress the theme of star-shaped and centrally planned building. In fact, not only the plan of the city has the shape of an eight-pointed star inscribed in a circle, but its cathedral recalls directly - as we will see in Chapter 4 - the shape of two churches of Ms. B.

Francesco di Giorgio Martini and Leonardo knew each other personally, in fact, we know that the

59 Heydenreich, Ludwig H. *Die Sakralbau-Studien Leonardo da Vinci's: Untersuchungen zum Thema: Leonardo da Vinci als Architekt.* Engelsdorf-Leipzig: C.u.M. Vogel, 1929. pp.18-19, 24, 73-76.

60 Pedretti, Carlo, 1978, p. 19

61 Firpo, Luigi. 1971. p.32

62 Filarete uses the words "*architettonico libro*" to call his oeuvre (i.e. Architectural Book) instead of *"Trattato di Architettura"* (i.e. Architectural Treatise) as it is also known nowadays. [Filarete, *Trattato di Architettura,* a cura di A.M. Finoli e L. Grassi, Milano, 1972, I, 7, *Magl.*, f. 1v]

63 Pfisterer, Ulrich. "I libri di Filarete". *Arte Lombarda* / ISAL, Istituto Per La Storia Dell'Arte Lombarda. 2009. pp. 97-110.

first was requested in Milan on the 31st of May 1490 to create the model for the *tiburio* of Milan's Cathedral and that later he visited with Leonardo the Cathedral of Pavia on the 21st of June of the same year[64]. Moreover Leonardo had a copy of Francesco di Giorgio's "Trattato di Architettura Civile e Militare" where he wrote notes, known as Codex Ashburnham 361, which is likely to have been given to Leonardo the year they met. The importance of this connection is mainly represented by the mutual influences they had on each other, for example on the use of symmetry and of star-shaped polygons.

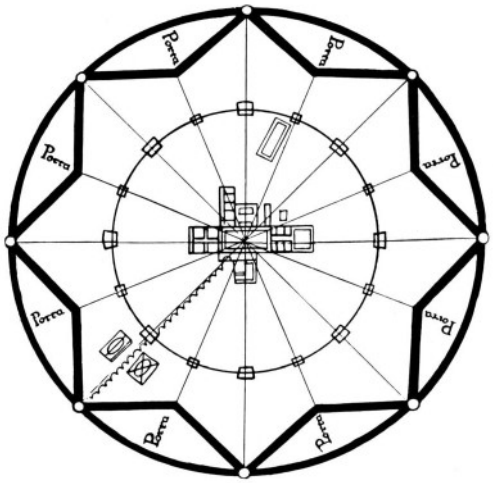

Fig. 21 - Plan of the city of Sforzinda, designed by Filarete

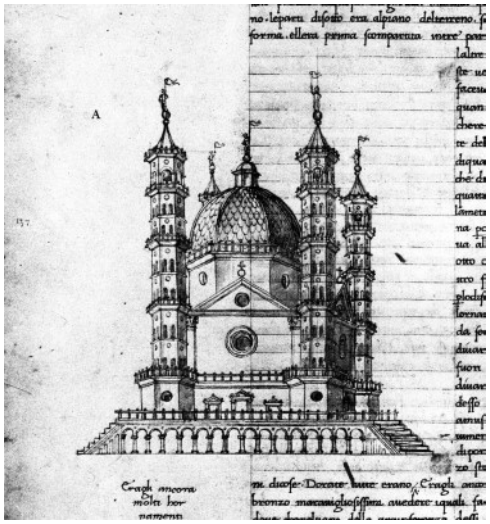

Fig. 22 - Drawing of Filarete's cathedral of Sforzinda

64 Marani, Pietro C. "Leonardo, Francesco di Giorgio e il tiburio del Duomo di Milano". *Arte Lombarda* / ISAL, Istituto Per La Storia Dell'Arte Lombarda. 1982. p. 81.

2. Hypotheses for the architectural details

1. Introduction

The churches studied and digitalized in this work come from small sketches that lack of architectural details and orders, and that therefore require to proceed through hypotheses, always starting from the information obtainable directly from Leonardo's drawings.

In the churches of Ms. B there are several recurring elements that connect the different designs: in this chapter those have been grouped in order to work horizontally, while making assumptions on the details of their features. Evidently, in this stage, the information contained in the more accurately drawn churches is taken into account with more attention than that of the quickly sketched ones.

After the analysis of the drawings, each architectural element has been related to the equivalent in one of the reference churches identified in the previous chapter in order to make an hypotheses for the process of three-dimensional reconstruction.

This process, however, is not possible for the interior elements, since we do not have any indications from Leonardo's drawings. In this case I started from the few interiors drawn by Leonardo and made some assumption for the use of external references (that are the ones defined in Chapter 1).

2. Octagonal drum

Fig. 1 - Comparison between the octagonal drums and domes in Ms. B

For the study of the features of this element, among the drawings presenting the higher level of detail, only the churches with a central octagonal drum were considered (see fig. 1 for the complete list of churches taken into account).

First of all a set of common elements and related measures has been identified (fig. 2) and a series of proportions to analyse was decided[1]. In particular all the drums present an entablature subdivided in three parts (apart from f. 95v and f. 24r, that seem to have an additional upper element

1 In order to compare the features of the drum of the churches it would be pointless to use absolute measurements since Leonardo's drawing lack of any reference to a scale. For this reason I instead proceeded through the proportions between elements.

- maybe a balustrade), in which the central one shows vertical decorative elements, one circular opening per side (or three, in f. 25v(A) case), edge ribs, that in the most detailed drawings seem to feature a capital, and a base.

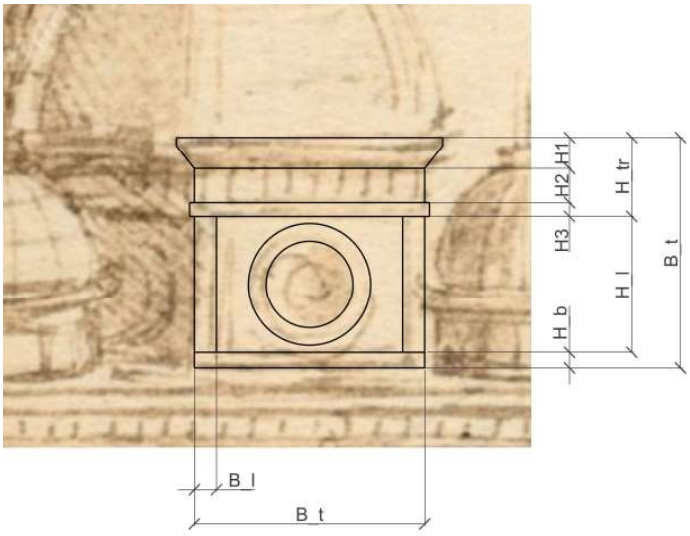

Fig. 2 - Graphical representation of the values that were considered.

Then, for each of the churches previously listed, the proportions have been calculated and compared. In order to do so the mean of the value, its variance and its coefficient of variation (i.e. the ratio of variance to the mean) were calculated, but unfortunately the obtained value of coefficient of variation - that gives us an indication of the variability of the value was far too high (in some cases above 50%) to make some statistical assumption on the proportions in the drawings[2].

Because of that, a different approach has been tried, working instead through similarities with the churches listed in the previous chapter. In the following images the most significant ones have been selected.

The tiburio of **San Lorenzo at Milan** - even though it was erected after Leonardo's Milanese Period - could be considered for the use of *lesene* or ribs in the corners that show a capital, like some of the churches in Ms. B (for instance ff. 17v - 18r A, 24r, 25v B, 39 v, 95 v).

Cappella Colleoni on the other hand could be a source for the outline of the entablature on top of the drum, because of its similarity in terms of form (the entablature appears to be divided in three parts and the central one is decorated with vertical elements) even though Amadeo's decorative richness will be discarded. The vertical elements drawn by Leonardo, on the other hand, could also represent the series of small openings that we can see in **Pavia's Cathedral**, or just protruding decorative elements like the ones in **Santa Maria della Passione** or in **Cascina Pozzobonelli**.

The connection with **Santa Maria del Fiore**, on the other hand, appears undeniable, especially for the shape of its dome, for its monumentality and for the circular openings placed between the ribs of the drum.

2 This is clearly related to the small number of drawings we have and the error connected to their limited dimension.

Fig. 3 - San Lorenzo at Milan

Fig. 4 - Cappella Colleoni at Bergamo

Fig. 5 - Pavia's Cathedral

Fig. 6 - Santa Maria della Passione at Milan

Fig. 7 - Santa Maria del Fiore at Florence

Fig. 8 - Cascina Pozzobonelli at Milan

3. Rectangular façades

Some of the churches of Ms. B, as will be pointed out with more detail in the chapter about the aggregative study, present a square volume that envelops the chapels in the corners. This volume has some recurring elements: a main entablature with *lesenes* on the corners and on the façade, sometimes a secondary one that divides the central *lesenes* in a minor order, single or double arched windows, circular windows and a base.

Three churches have been selected as examples (ff. 22r, 24 r, 93 v) both for their higher definition among the others and because they show three variations of the elements just listed.

Both the church in f. 22r and f.93v show an entablature which is divided in three parts and that recalls many examples in contemporary architecture, like that of Santa Maria della Passione, Cappella Pazzi and Santa Maria delle Carceri with regard to the intermediate level, while in f. 24r the parts of the entablature seem to be four.

In f. 22r the dimensions on the lesenes is undifferentiated between the central ones and the corners, while in f. 24r there is a bigger and a minor order and in f. 93v (F) Leonardo places double lesenes on the corner. References for the first two may be found in the corners or Cascina Pozzobonelli and Santa Maria della Passione, while the double lesenes can be found in Santa Maria delle Carceri and the upper level of Cappella Pazzi.

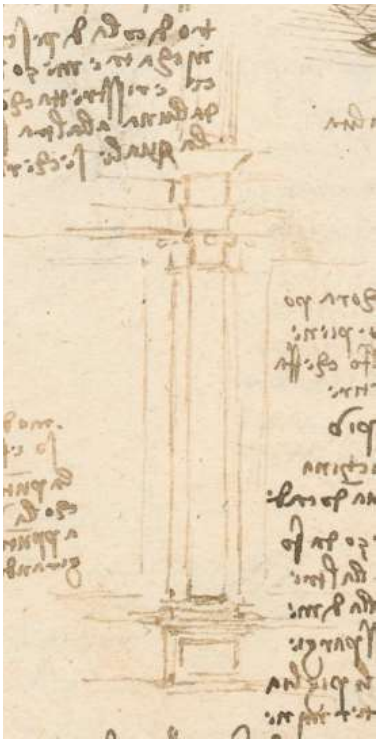

Fig. 9 - Ms. B, f. 59r

Unfortunately it seems difficult to make assumptions on the orders of columns and entablatures, but it may be useful to remind that in f. 59r of Ms. B (fig. 9) Leonardo draws a column on a *lesene* and an entablature. On top of it another order of *lesene* and column can be seen. Even though in the drawings that were previously analized, the *lesene* do not seem to have any column, the base and the entablature really seem to correspond to that of the churches, so we could use those elements in order to know more about the molding of the upper and lower parts of the entablature.

One of the most fitting reference, also because of the similarities in the semicircular apses, seems to be Santa Maria della Passione at Milan, a church that, as it was already pointed out, Leonardo probably saw before writing Ms. B and which at that time was still centrally planned.

This church, moreover could give us a path to follow in the definition of the dimensions of the internal openings. This constitutes in fact a problem, since we only have the extension in plan and those are often out of scale if compared with the total height of the church.

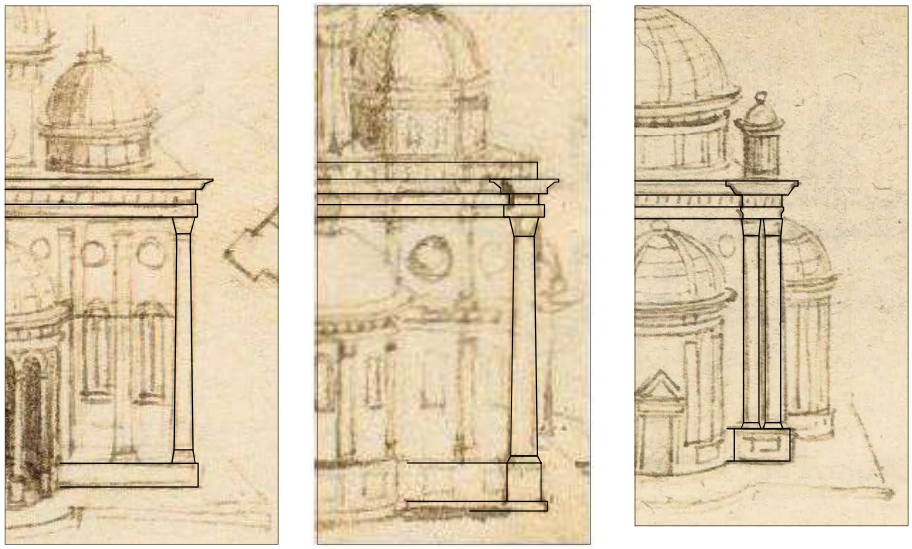

Fig. 10 - Examples for the elements in the façade.

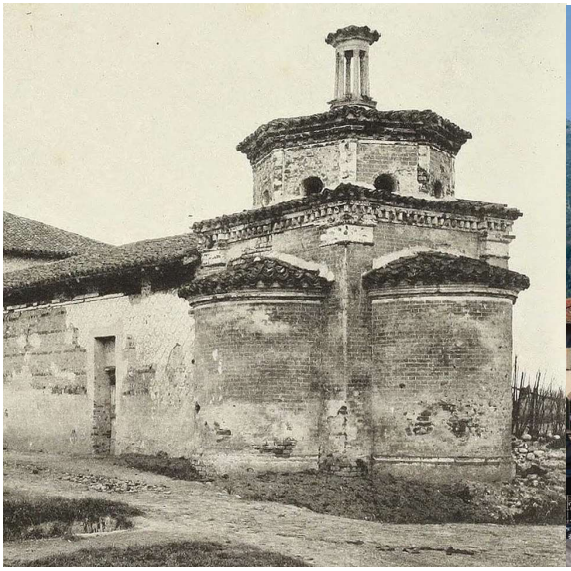

Fig. 11 - Cascina Pozzobonelli at Milan

Fig. 12 - Santa Maria delle Carceri at Prato

Fig. 13 - Santa Maria della Passione at Milan

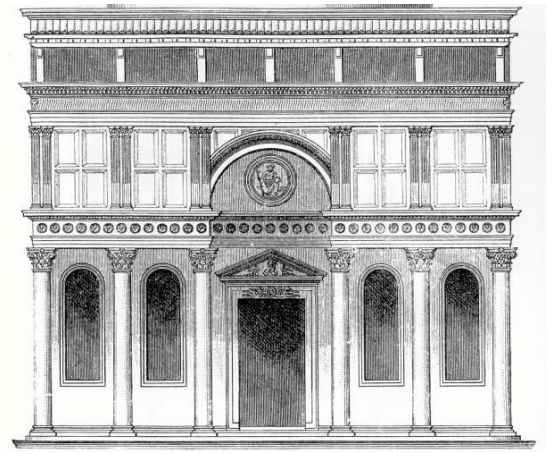

Fig. 14 - Elevation of Cappella Pazzi at Florence

4. Interiors

In order to make assumptions for the interiors of the buildings I started from the few perspective sections drawn by Leonardo. In particular the two that were considered the most relevant are CA, f.104 r and RL, f. 12609 v.

Then, I decided to proceed with a double procedure: first carrying out a general analysis of the proportions in order to find similarities with other references, then a visual process, based more on the research of similarities with other church's architectural elements. Then the few architectural details drawn by Leonardo are presented (but it is important to consider that they were made only later).

The first observation that must be done is that these perspective sections are referred to the square-based with four lobes and columns type of church (the one that corresponds to the layout of the Sacello Carolingio of San Satiro), there isn't any drawing that gives us information about the interior of the central octagonal space, even though that is the one that Leonardo draws mostly in the exterior views. For this reason, the assumptions made for that one will be the less sure.

The proportions between the elements in the folio from Codex Atlanticus and the one from the Royal Collections are, much interestingly, the same, and they only differ for the presence of an upper *matroneo* (i.e. the women's gallery) with double arched openings. The same proportions can be found in other examples of architecture (the already quoted church of Santa Maria della Passione) and architectura ficta (in the painting of Pala di Brera by Piero della Francesca).

It is interesting to notice as there is a compatibility between the height of capitals and entablature in Leonardo's drawing and Santa Maria della Passione, so this example could be used for the shape and height of the moldings.

Besides the proportions, an analysis of the recurring architectural elements can be done. First the use of shell-headed niches resembles that of the Sacristy of San Satiro and Cascina Pozzobonelli at Milan. Then, the *matroneo* can be related to San Lorenzo Maggiore, Pavia's Cathedral, Chiesa dell'Incoronata at Sabbioneta and again the Sacristy of San Satiro. The last one, then, appears to be an important reference for the interiors in Leonardo.

Regarding the hypothesis we can make for the octagonal space, the examples that could be considered are the ones that show a semi-pilaster in their corners between two columns or semi-columns that give access to the chapels, since this is a feature that Leonardo draws in the most accurate drawings of Ms. B like f. 95v and others. The references that show similar features are Santa Maria della Passione, San Lorenzo Maggiore, Chiesa dell'Incoronata at Sabbioneta and the Sacristy of San Satiro. Considering the feature of these churches it seems likely to assume that the corner pilasters continue in the inside of the dome until the lantern.

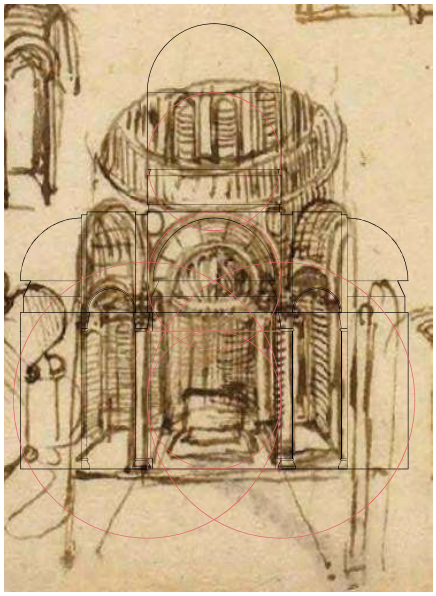

Fig. 15 - Codex Atlanticus, f. 104 r

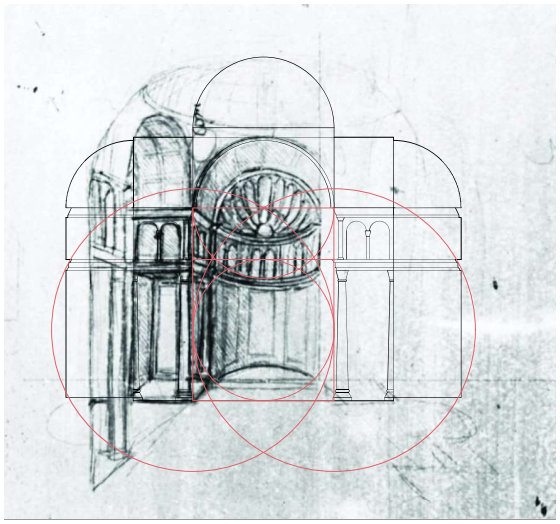

Fig. 16 - Royal library, Windsor Castle, f. 12609 v

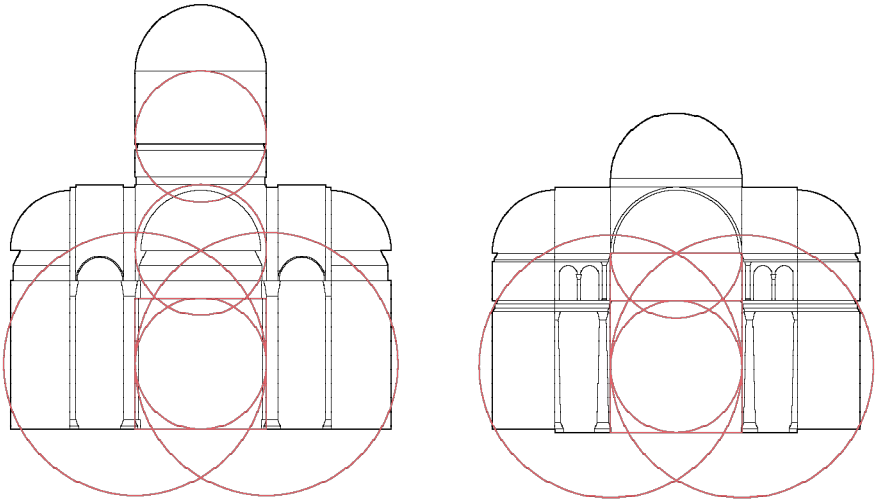

Fig. 17 - Comparison between the interiors obtained from the two drawings.

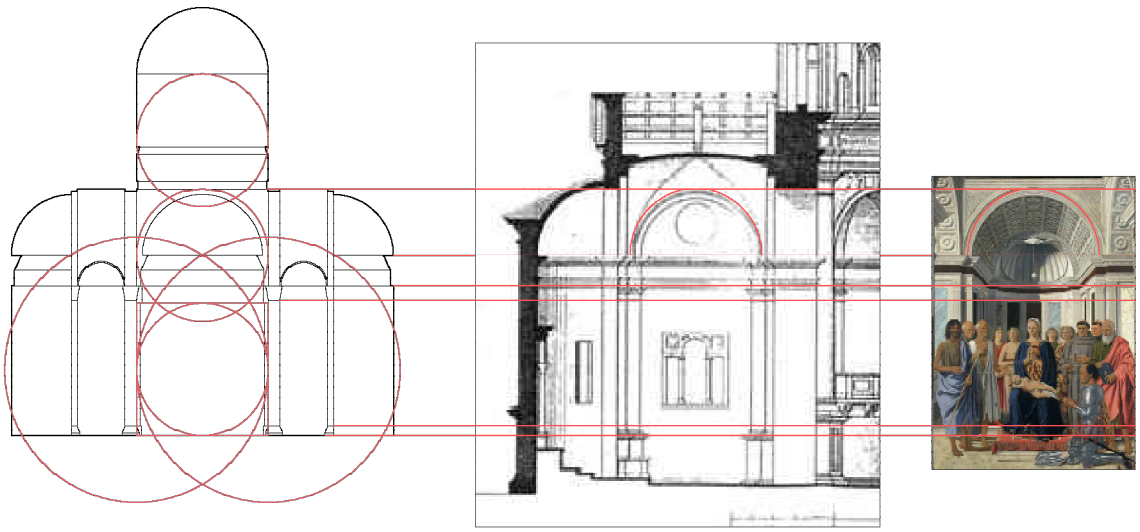

Fig. 18 - Comparison between the proportions in height in S.M. della Passione and in Piero della Francesca's Pala di Brera.

Fig. 19 - San Lorenzo Maggiore at Milan

Fig. 20 - Pavia's Cathedral

Fig. 22 - Chiesa dell'Incoronata at Sabbioneta

Fig. 26 - Santa Maria della Passione at Milan

Fig. 25 - Santa Maria delle Grazie at Milan

Fig. 24 - Sacello Carolingio of San Satiro, Milan

Fig. 23 - The sacristy of San Satiro at Milan

Fig. 21 - Cascina Pozzobonelli at Milan

5. Openings

The churches of Ms. B lack of any reference to dimensions or scale[3], for this reason, it was necessary to find some elements that could give hints about the extension of the building. Doors and windows are useful in order to achieve this goal, since it is possible to refer to their usual dimension in coeval edifices and infer an approximate minimum value.

In particular there are five elements that have been measured in the reference churches:

1. single-arched and rectangular windows;
2. double-arched windows;
3. circular windows;
4. internal doors;
5. entrance portal.

Among the churches previously listed, only the ones having one or more of those elements have been considered. Moreover, regarding the analysis of double-arched windows, one should keep in mind that it is indeed more common to find these in palaces, rather than in churches of this period, and in fact they are not present in any of the churches considered as example. Because of that it was necessary to evaluate also civil buildings[4].

The single-arched windows were measured in Cappella Colleoni, in Cappella Pazzi and in Santa Maria della Passione[5].The minimum measured value, regarding the width, is of about 0,9 meter in Cappella Colleoni, with a ratio equal to 1:3. Cappella Pazzi's windows, on the other hand, measure about 1,2 per 4,2 metres and therefore have a ratio of 2:7, while Santa Maria della Passione's ones show a 1:2 ratio with a 1,5 metres width. Thus, the minimum width - equal to 0,9 metres - will be considered as a guide for this kind of element.

The double-arched windows of Palazzo Rucellai, Palazzo Medici Riccardi and Palazzo Strozzi are marked by the same proportions and dimensions, with the shorter side equal to about 2 metres and a height of 3,5 meters, with a proportion of 4:7. Therefore it is logical to assume that a double-arched window in Leonardo's designs should not differ too much from this size (especially from a minimum value).

The circular windows measured - the ones of Brunelleschi Rotonda's and Cappella Colleoni - had both a diameter of two metres, measure that could be useful to have an order of magnitude.

The doors, on the other hand represent a peculiarity, since the internal ones are never depicted by Leonardo, apart from their width in plan which is however often quickly sketched. Two churches that have rectangular openings connecting the chapels are Cappella Pazzi - which has a 1 per 2 metres door - and Brunelleschi's Rotonda - with 1,2 per 3 metres door and thus a 2:5 ratio. The latter is especially important because the narrow connection running along all the church and connecting the radial chapels is an element that Leonardo places in several churches of Ms. B.

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3 Apart from the peculiar case of the one depicted in f. 94v, that will be described in detail in the chapter about the process of three-dimensional reconstruction.

4 In particular, three palaces of Florence have been analysed - Palazzo Rucellai, Palazzo Medici Riccardi and Palazzo Strozzi - since Leonardo must certainly have seen them during his Florentine period.

5 In this last church, however the windows are rectangular but they were considered relevant because their position in the semicircular chapel resembles many cases that Leonardo drawn.

The main entrances were measured in Cappella Colleoni, Cappella Pazzi and Santa Maria delle Carceri. Even though they present different width (respectively 2 m, 2,5 m and 2,75 m) the interest here could perhaps lay in their ratio with the entrance height, which is in all the above quoted cases equal to 1:2.

6. Conclusion

In order to summarize the references that will be used in Chapter 4 two tables were created, one organized by date and one on the basis of what the reference was used for.

Reference	Author	Location	Date	
Battistero di San Giovanni	-	Florence	IV century	Before the X century
San Lorenzo Maggiore	-	Milan	appr. 370	
Santa Maria in Pertica	-	Pavia	VII century	
Santa Maria presso San Satiro, Sacello Carolingio	-	Milan	IX century	
San Lorenzo, Sacrestia Vecchia	F. Brunelleschi	Florence	1419-1429	1400-1449
Santa Maria del Fiore's dome	F. Brunelleschi	Florence	1420-1436	
Rotonda degli Angeli	F. Brunelleschi	Florence	1434	
Santa Croce, Cappella Pazzi	F. Brunelleschi	Florence	1441-1478	
Santo Spirito	F. Brunelleschi	Florence	1444-1487	
Palazzo Medici Riccardi	Michelozzo	Florence	1444	
Palazzo Rucellai	L. B. Alberti and B. Rossellino	Florence	1446	
San Sebastiano	L. B. Alberti	Mantova	1460-1529	1450-1499
Cappella Colleoni	Amadeo	Bergamo	1470-1476	
Santa Maria della Passione	Giovanni Battagio da Lodi	Milan	1482-1485	
Santa Maria presso San Satiro, Sacrestia	D. Bramante	Milan	1483	
Santa Maria delle Carceri	Giuliano da Sangallo	Prato	1485-1499	
Pavia Cathedral	Amadeo, Bramante	Pavia	1488 -	
Tempio dell'Incoronata	Giovanni Battagio da Lodi, Dolcebuono	Lodi	1488-1493	
Palazzo Strozzi	Benedetto da Maiano	Florence	1489	
Santa Maria delle Grazie	D. Bramante (and Amadeo?)	Milan	1493-1497	
Santa Maria dei Miracoli presso San Celso	Dolcebuono, Solari and Amadeo	Milan	1493-1494	
Santa Maria della Croce	Giovanni Battagio da Lodi	Crema	1493 -	
Cascina Pozzobonelli	(Bramante?)	Milan	1498?	
Santa Maria di Canepanova	Amedeo	Pavia	1500-1507	1500-1600
Santa Maria del Popolo, Cappella Chigi	Raffaello and Bernini	Rome	1512-1556	
Santuario di Santa Maria di Piazza	Antonio da Lonate	Busto Arsizio	1517	
Chiesa dell'Incoronata	-	Sabbioneta	1586-1588	

Fig. 27 - List of the references ordered by date.

Reference	Author	Location	Date	Used as a reference for:
Santa Maria della Passione	Giovanni Battagio da Lodi	Milan	1482-1485	Decorative system
Santa Maria presso San Satiro, Sacrestia	D. Bramante	Milan	1483	
Santa Maria delle Carceri	Giuliano da Sangallo	Prato	1485-1499	
Santa Croce, Cappella Pazzi	F. Brunelleschi	Florence	1441-1478	
Tempio dell'Incoronata	Giovanni Battagio da Lodi, Dolcebuono	Lodi	1488-1493	
Santo Spirito	F. Brunelleschi	Florence	1444-1487	
Battistero di San Giovanni	-	Florence	IV century	Drum and dome system
Santa Maria del Fiore's dome	F. Brunelleschi	Florence	1420-1436	
Pavia Cathedral	Amadeo, Bramante	Pavia	1488 -	
Cascina Pozzobonelli	(Bramante?)	Milan	1498?	
Santa Maria di Canepanova	Amedeo	Pavia	1500-1507	
San Lorenzo Maggiore	-	Milan	appr. 370	Interior layout
Santa Maria in Pertica	-	Pavia	VII century	
Santa Maria presso San Satiro, Sacello Caradinario	-	Milan	IX century	
San Lorenzo, Sacrestia Vecchia	F. Brunelleschi	Florence	1419-1429	
Rotonda degli Angeli	F. Brunelleschi	Florence	1434	
San Sebastiano	L. B. Alberti	Mantova	1460-1529	
Cappella Colleoni	Amadeo	Bergamo	1470-1476	
Santa Maria delle Carceri	Giuliano da Sangallo	Prato	1485-1499	
Santa Maria delle Grazie	D. Bramante (and Amadeo?)	Milan	1493-1497	
Santa Maria dei Miracoli presso San Celso	Dolcebuono, Solari and Amadeo	Milan	1493-1494	
Santa Maria della Croce	Giovanni Battagio da Lodi	Crema	1493 -	
Cascina Pozzobonelli	(Bramante?)	Milan	1498?	
Santa Maria del Popolo, Cappella Chigi	Raffaello and Bernini	Rome	1512-1556	
Santuario di Santa Maria di Piazza	Antonio da Lonate	Busto Arsizio	1517	
Chiesa dell'Incoronata	-	Sabbioneta	1586-1588	
Santa Croce, Cappella Pazzi	F. Brunelleschi	Florence	1441-1478	Windows
Palazzo Medici Riccardi	Michelozzo	Florence	1444	
Palazzo Rucellai	L. B. Alberti and B. Rossellino	Florence	1446	
Cappella Colleoni	Amadeo	Bergamo	1470-1476	
Santa Maria della Passione	Giovanni Battagio da Lodi	Milan	1482-1485	
Palazzo Strozzi	Benedetto da Maiano	Florence	1489	
Rotonda degli Angeli	F. Brunelleschi	Florence	1434	Doors
Santa Croce, Cappella Pazzi	F. Brunelleschi	Florence	1441-1478	
Cappella Colleoni	Amadeo	Bergamo	1470-1476	
Santa Maria delle Carceri	Giuliano da Sangallo	Prato	1485-1499	

Fig. 28 - List of the references catalogued on the basis of the elements that they were used for.

3. Aggregative study

1. Introduction

The churches of Ms. B show to have an underlying set of aggregative and dimensional rules that enables us to carry out a general investigation on them. It's not easy though, to define those rules, as the classification of the elements of the buildings can be done regarding different points of view. These, moreover, are about both what the authors of the classification think are the final purposes of Leonardo's drawings in Ms. B and the kind of approach - planimetric or volumetric - they carry on in the analysis of drawings.

For this reason, in the following section two important contributions on this theme are explored, in order to use them as guides for a later personal proposal.

The first one was made by Jean Paul Richter in 1883 in his book about the notebooks of Leonardo Da Vinci[1], re-edited in 1970. As we will later point out, his study is based on the theory that the drawings of churches are aimed at the realisation of a treatise on domes, and are not referred to the construction of any particular building. For this reason the study is focused on the planimetric study of how domes are connected with the construction.

The second contribution we will analyse is the one carried out by Jean Guillaume in 1987 in the occasion of the exhibition that took place in the *Musée des beaux-arts* of Montreal about Leonardo architect and engineer[2]. In this case, the point of view of the author is different and focuses more about the elements and their aggregations around the central space. Moreover J. Guillaume also tries, after a analysis in plans, to carry out a volumetric approach that could consider the informations contained in the perspective views drawn by Leonardo.

2. Jean Paul Richter's work

The study carried out by J.P. Richter focuses on the domes drawn by Leonardo for the churches in Ms. B, rather than the aggregative rules behind the composition of the churches. This decision comes from his theory regarding the purpose of these drawings: according to J. P. Richter , in fact, these are Leonardo's personal reasoning and annotations for writing a *"Trattato delle Cupole"* (i.e. a Treatise on Domes) that would have contained a theoretical study of the laws behind the construction of a great central dome, surrounded by smaller ones around it.

1 Richter, Jean Paul. *The Notebooks of Leonardo Da Vinci. Vol. 2. / Compiled and Edited from the Original Manuscripts by Jean Paul Richter*. New York: Dover, 1970.

2 Guillaume, Jean. "Léonard et l'architecture". *Montreal Museum of Fine Arts. Léonard de Vinci, ingénieur et architecte:* [Catalogue]. Montréal: Musée des beaux-arts de Montréal, 1987. pp. 207-286

Doing so, J. P. Richter goes against the theories that would want the churches of Ms. B to be explorations for the construction of a specific building (the Sforza Mausoleum, for example), but he does take into account the influences Leonardo might have had from the building that were being constructed in those years[3], The ones that he must have seen and studied[4] and his connection and collaboration with Donato Bramante.

In the following sections we will describe J. P. Richter's classification of the churches in order to find useful elements for the construction of one of our own.

First of all, Richter makes a first distinction between the churches formed on the plan of a Greek cross and on a Latin cross, considering examples from the complete Leonardo's production, we will here present only the classification of the Greek cross planned ones with attention to the examples related to Manuscript B.

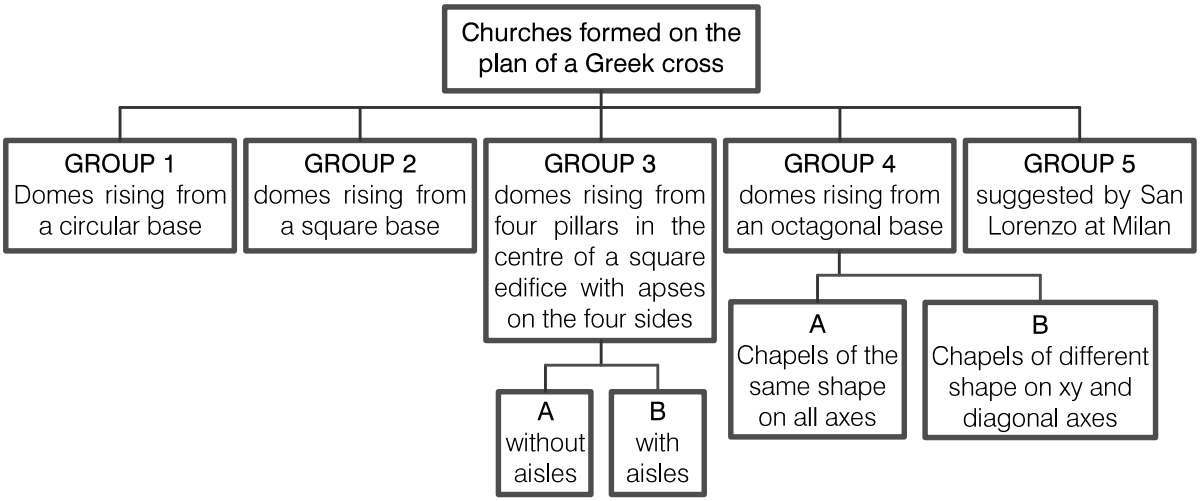


Fig. 1 - Diagram of the classification proposed by Richter.

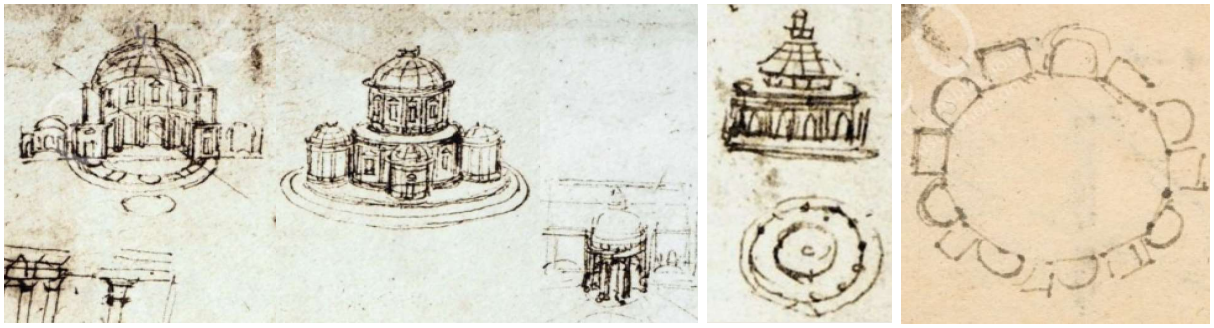
2.1. Group 1: domes rising from a circular base

Richter classifies this first possibility ad the simplest one for a centrally-planned building. The examples he lists for this group are the following:

1. C.A., f. 362 v b (plan and elevation)
2. C.A. f. 205 v a (elevation)
3. Ms. B, f. 25 v (dodecagonal plan)

3 i. e. the Cathedral of Pavia, the Cathedral of Como, Santa Maria delle Grazie in Milan and the Tiburio for the Cathedral of Milan.

4 i. e. Santa Maria del Fiore and the Baptistery in Florence, the church of San Lorenzo in Milan. See the chapter dedicated to the architectural references that might have influenced Leonardo's work for further information about these churches.



C.A. 362v - b C.A. 205v - a Ms.B 25v

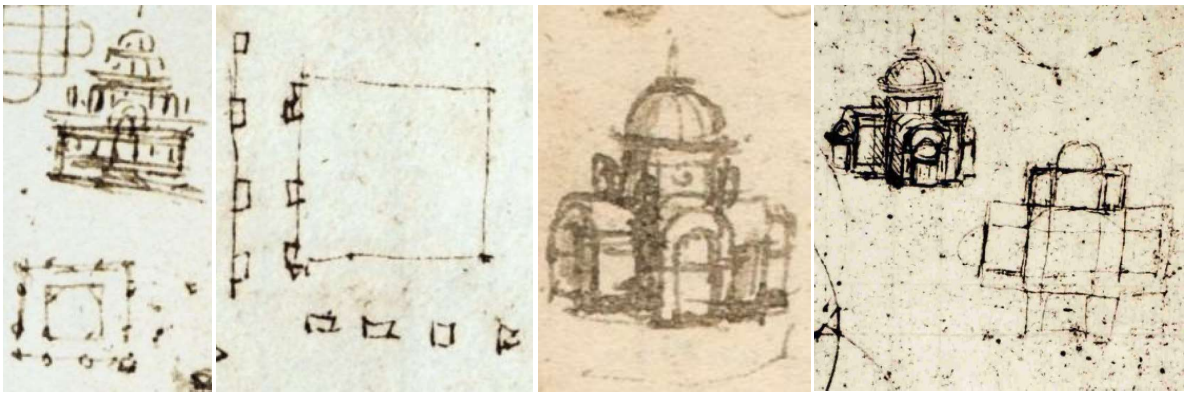
Fig. 2 - Group 1: domes rising from a circular base

Therefore, the only example found in Ms. B is in f.25 v and its inclusion is in fact an approximation, since the dome does not rise from a circular base, but from a dodecagonal one. Moreover this plan view is not accompanied by any bird's-eye view, so we shall conclude that, in order to define a classification for the churches we are analysing, this group can easily be discarded.

2.2. Group 2: domes rising from a square base

The second groups is made of those churches whose dome rises from a square base. However in this group Richter includes also the ones that are square-based in the exterior, but are octagonal interiorly:

1. C.A., f. 362 v b (plan and elevation)
2. C.A., f. 205 v a (plan)
3. Ms. B, f. 93 v (B) (elevation)
4. C.A., f. 362 r b (plan and elevation)[5]



C.A. 362v - b C.A. 205v - a Ms.B 93v (B) C.A. 362r - b

Fig. 3 - Group 2:domes rising from a square base

This classification concerns the four-lobed type of churches, then it is useful to consider it, even though we will propose a way to classify them in a joined way with the next group.

5 Richter listed f. 3[a] of Codex Atlanticus, instead of this one, but it was impossible to find any building of this type in the Hoepli edition, so it was substituted with it.

2.3. Group 3. domes rising from a square base and four pillars

This group, which Richter relates to the example of the Sacello Carolingio in the church of San Sariro at Milan, is further divided into two types:

a. First type: a dome resting on four pillars in the centre of a square, four-lobed edifice

Richter found eleven examples of this type:

a.1. Ms. B, f. 21 v (plan)
a.2. C.A., f. 362 v b (plan and elevation)
a.3. Ms. B, f. 25 r (elevation)
a.4. Ms. B, f. 93 (B) (plan)
a.5. Ms. B, f. 93 (D) (plan and elevation)
a.6. Ms. B, f. 93 (E) (plan and elevation)
a.7. Ms. B, f. 93 (F) (plan and elevation)

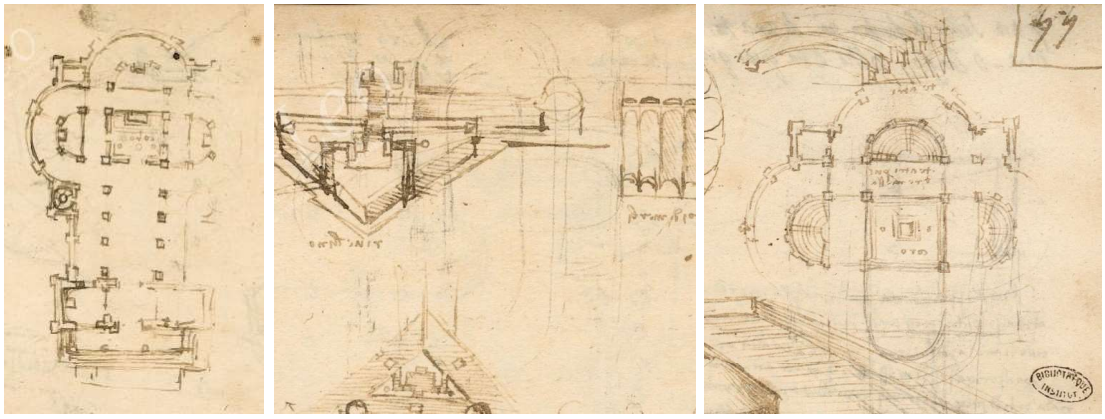
Fig. 4 - Group 3, first type: a dome resting on four pillars in the centre of a square four-lobed edifice

b. Second type: obtained by adding aisles all around the first type

These churches' plan is very similar to that of San Lorenzo at Milan. Here Richter lists three plans, one of which is in fact longitudinal since it shows a nave:

b.1. Ms. B, f. 35 v (plan)

b.2. Ms. B, f. 57 v (plan - scarcely visible)
b.3. Ms. B, f. 55r (plan)



Ms.B 35v Ms.B 57 v Ms.B 55 r

Fig. 5 - Group 3, second type: the plan is obtained by adding aisles all around the previous layout

However, all the churches that belong to type b are not part of our analysis, in fact the first one (f. 35v) is longitudinal and the others (ff. 57v and 55r) lack of a perspective view. Moreover the last one is the church that Leonardo calls "teatro da predicare" and thus constitutes a particular case that should be analysed along with the others that investigate the form of a church most proper for preaching.

2.4. Group 4: domes rising from an octagonal base

This group, like the previous one, is divided in two classes:

a. First type: chapels of the same shape on all axes

Richter further distinguishes six sub-cases of this class depending on the shape of the chapel:

a.1. Square chapels: Ms. B, f.34 ;
a.2. Circular chapels: Ms. B, ff. 17 v, 18 r, 25 v (A) and C.A., f. 362 v b;
a.3. Octagonal chapels: Ms. B, ff. 21 v, 30 r, 34 v;
a.4. Square with three niches: Ms. B, f. 11 v;
a.5. Square with four niches: Ms. B, f. 93 v
a.6. Chapels of richer combination: Ms. B, f. 95 v.

The distinction based on the shape of the chapels will be used also in our system of classification, even if with some adjustments.

b. Second type: chapels of different shape in diagonal and principal axes

b.1. Ms. B, f. 17 v - 18 r (B) (plan and elevation);
b.2. Ms. B, f. 18 v -19 r (plan and elevation);
b.3. Ms. B, f. 21 r (A and B) (plan and elevation);
b.4. Ms. B, f. 22 r (plan and elevation);
b.5. Ms. B, f. 25 v (B) (plan and elevation);

b.6. Ms. B, f. 30 r (plan);
b.7. Ms. B, f. 39 v (plan);
b.8. C.A., f. 362 v b (two plans);

Another element that will be kept in our study is the attention on what is the shape of the chapels on the various axes. However, when cataloguing class b of this group, we can notice that Richter does not maintain the same division based on the form of the chapels, so, we tried to find a general method of classification that could focus on this element in both cases.

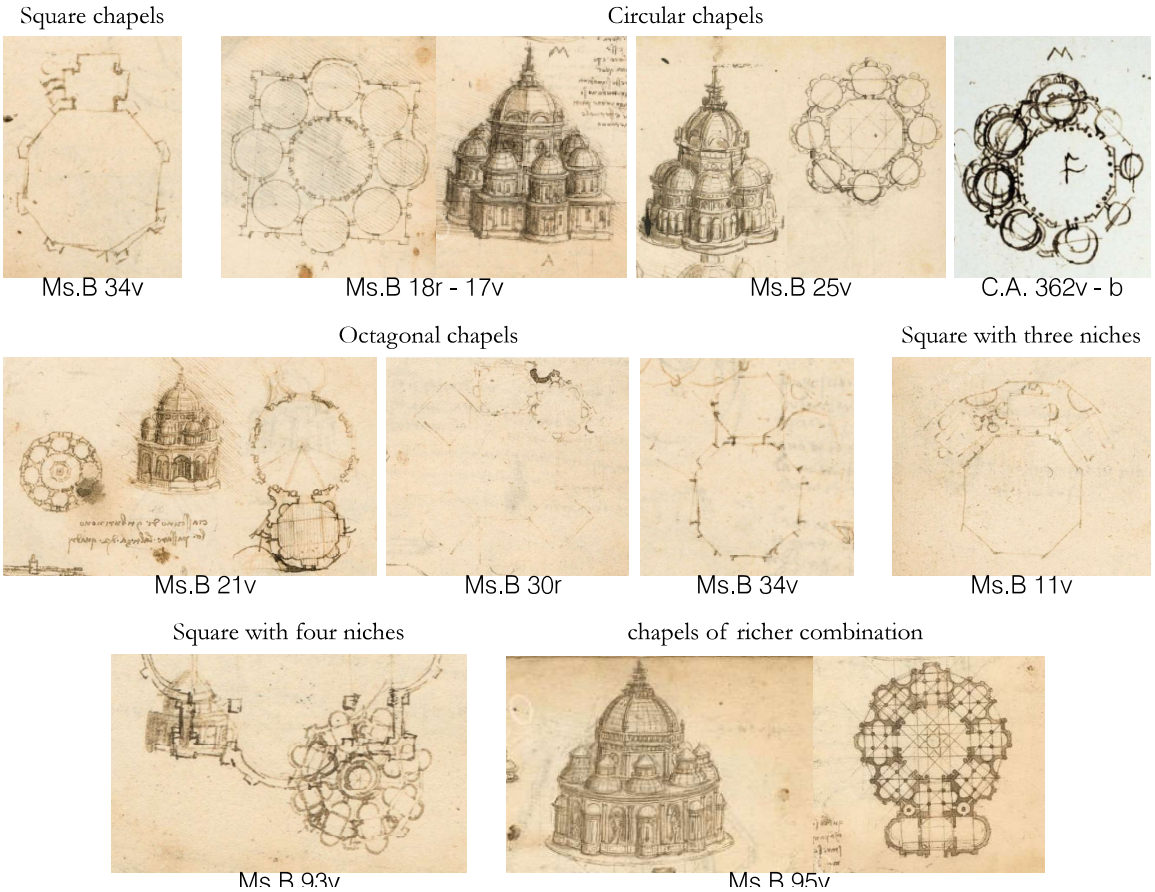


Fig. 6 - Group 4, first type: domes rising from an octagonal base with chapels of the same shape on all axes

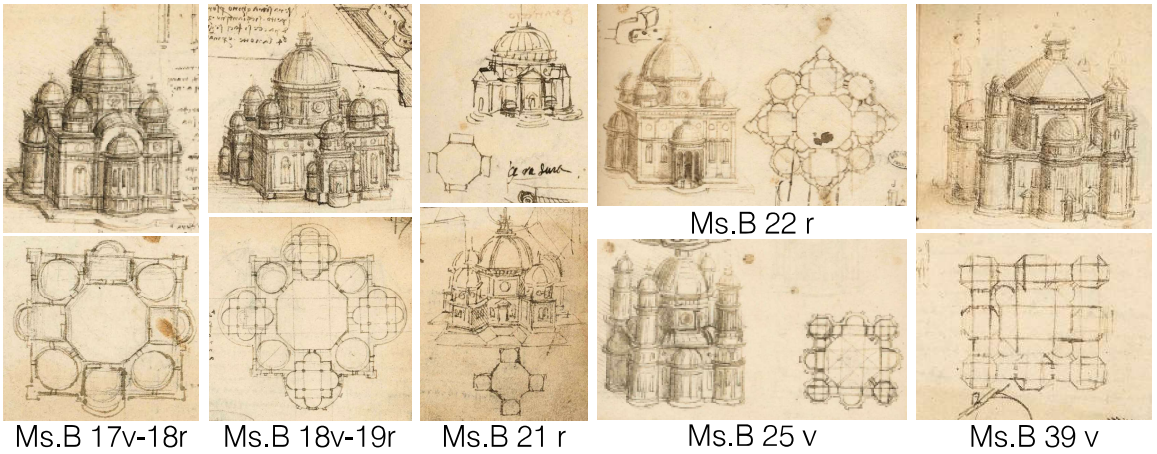
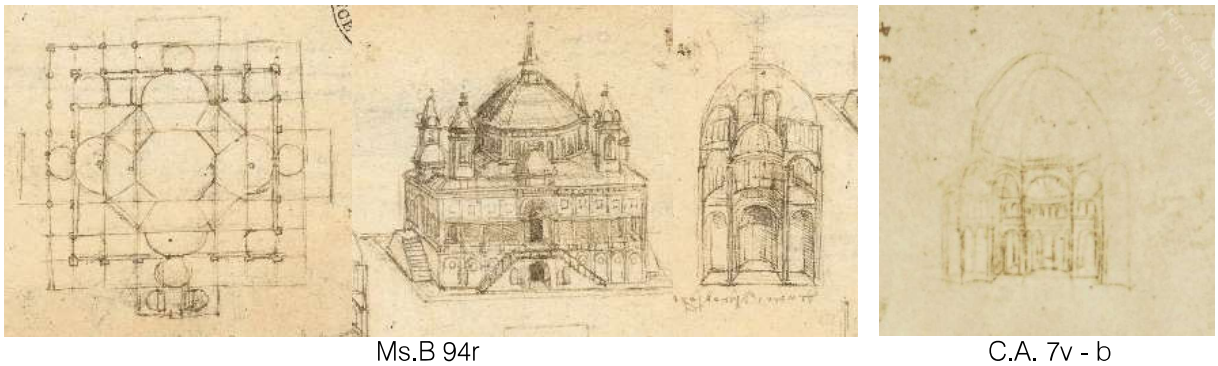


Fig. 7 - Group 4, second type: domes rising from an octagonal base with chapels of different shape on the axes

2.5. Group 5: suggested by San Lorenzo at Milan

1. Ms. B, f.94 r;
2. C.A., f. 7 v b.

The importance of this reference for Richter is proved by the fact that he catalogues a group of churches on the basis of its influence on their designs. However, this group is in fact constituted just of the church depicted in Ms. B f.94 r since the other one (CA. f. 7 v b) is probably just a representation of the interior of San Lorenzo itself. For these reason we will consider this distinction less relevant for the definition of classification of the churches.



Ms.B 94r C.A. 7v - b

Fig. 8 - Group 5: churches suggested by San Lorenzo at Milan

3. Jean Guillaume's contribution

J. Guillaume develops a study that considers both plans and volumes, in opposition to the one carried out by Richter, and divides them in two separate categorisations.

The first one considers the aggregative rules that lie behind all Leonardo's plans of ecclesiastical architecture. In fact, the analysis doesn't even exclude the churches that do present a nave, and thus a longitudinal development, in contrast with what was previously done by J. P. Richter, who even dedicates two different chapters to centrally and longitudinally planned churches. Moreover, Guillaume's study considers all the drawing of churches that can be found in Leonardo's production, and isn't limited to a specific manuscript like in our case.

The second analysis carried out by J. Guillaume considers the volumes that surround the central space (often octagonal) using the nomenclature he previously defines in the study of plans.

These considerations will be here explored and presented considering only the churches of Ms. B, in order to later develop our personal aggregative rules that will take into account the uniqueness of this group of buildings. As we know, in fact, the churches designed in Ms. B belong to a coherent production that takes place in a relatively short period of time (1487-1490) and thus deserve, in our opinion, a specific study.

3.1. The types of plan

J. Guillaume considers here "complex plans", i.e. the ones that present a central space and peripheral ones. Those plans are then divided into five groups and some of those further divided, as can be seen in the diagram below.

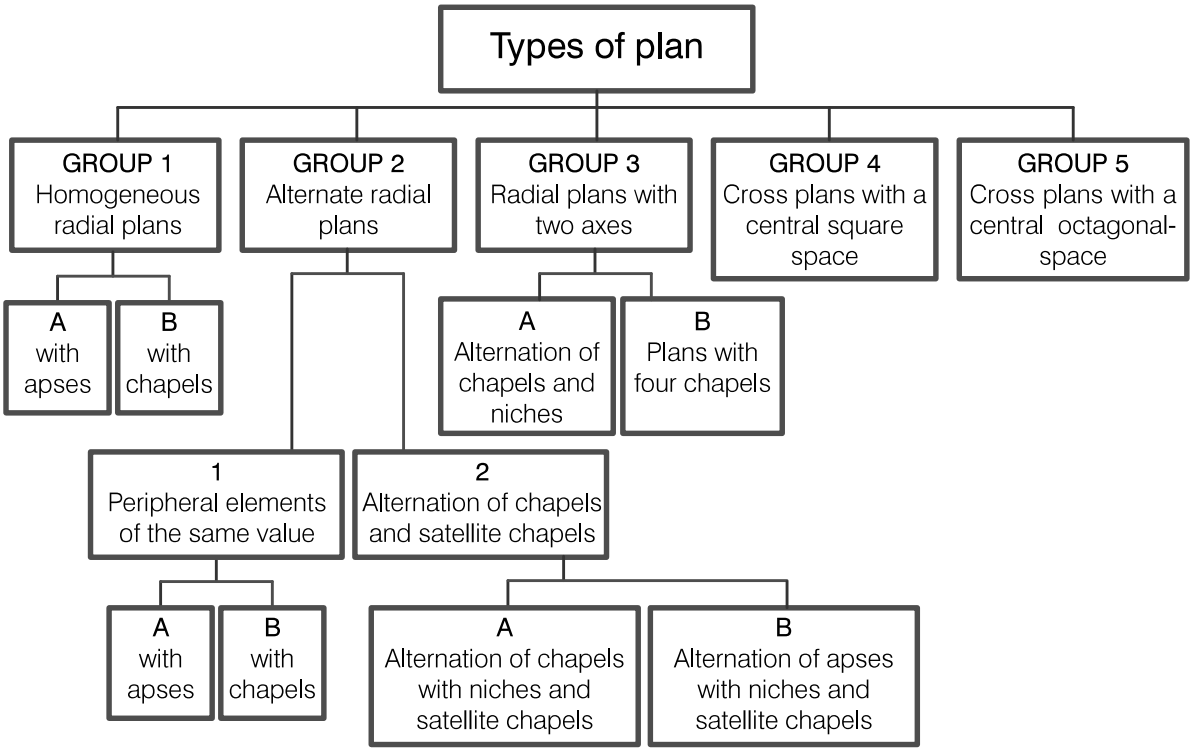


Fig. 9 - Types of plan according to J. Guillaume

3.1.1. Homogeneous radial plans

In this case all the elements that are placed around the central space are equal. A further division is made, based on the element that surrounds the central space, making a distinction between apses and chapels.

a. With apses

a.1. f.56 v

b. With chapels.

b.1. f. 17 v - 18 r (A)

b.2. f. 25 v

b.3. f. 21 v

The chapels are connected with the central space through a narrow passage. The reference is mostly Brunelleschi's Rotonda that Leonardo draws in f. 11 v of Ms. B, with some variations.

3.1.2. Alternate radiant plans

These plans present two types of peripheral elements that alternates around the central space. The importance of this disposition is that it enables to conciliate a central plan to a cross one, with a most evident effect when the difference between the two elements is enhanced, as it will privilege two directions. Also in this case, J. Guillaume further defines the group with sub-cases:

1. Peripheral elements with the same value
   a. With apses
      a.1. f. 24 r is the only example of this group Guillaume finds in Ms. B. This is however a longitudinal plan, that he decides to consider because the nave is probably the result of a later work the artist did to the plan.
   b. With chapels
      b.1. f. 17 v - 18 r (B)
      b.2. f. 18 v - 19 r
      In these cases the octagons are irregular and thus enhance the perception of two main axes, getting closer a cross plan.

2. Alternation of chapels and "satellite" chapels

J. Guillaume here defines the satellite chapels as the ones that are laying on the diagonal axis of the church, that are placed in a major distance from the central octagon and that communicate with it through a narrow passage that gives access to a niche in the side of the octagon itself, which is almost always irregular. This group is further defined by sub-cases:

   a. Alternation of chapels with niches and satellite chapels
      a.1. f. 22 r
      a.2. f. 39 v
   b. Alternation of apses with niches and satellite chapels
      b.1. f. 25 v

3.1.3. Radial plans with two axes

Even though these plans only present two axes, they cannot be considered cross plans, as the chapels on the axes are elements with their own autonomy, that generally even result to be centrally planned themselves, and don't have the characteristics usually owned by churches' aisles. This group is further divided into two other categories:

   a. Alternation of chapels and niches
      a.1. f.30 r
   b. Plans with four chapels
      b.1. f.21 r
      These plans, that contain four square or rectangular chapels, represent the simplest examples in the variety of churches of Ms. B, and this can be an explanation of Leonardo's

choice of leaving the drawings to a very low level of detail. J. Guillaume suggests, as a possible reference for the design of these churches, the Baptistery of San Giovanni in Laterano.

3.1.4. Cross plans with a central square space

1. f. 93 v
2. f. 57 r
3. f. 55 r

These plans differ from the previous ones because the central space is created by the encounter of the aisles on two perpendicular axes.

In Ms. B, one of the churches that belong to this group is in fact the representation of an existing church, that is San Sepolcro in Milan (f. 57 v).

Then another church with these characteristics is depicted in f. 55r[6], but it won't be further discussed by us, because it doesn't have any external perspective view associated .

Other examples of cross plans in Ms. B can be found in four of the churches drawn in f. 93 v, that Guillaume relates to the reference of San Sepolcro in Milan. However, it can be noticed how these plans seem to resemble the cross planned chapels that we have already seen surrounding the central octagonal space in some of the churches of the manuscript. For this reason we do here suggest that f. 93 v might represent a deeper study of those chapel, rather than another group of churches in the *corpus* that Leonardo was composing.

3.1.5. Cross plans with a central octagonal space.

1. f. 52 r

In this case the central space is octagonal, as in Santa Maria del Fiore Cathedral. The only example of this group that J. Guillaume managed to find in Ms. B is represented by f. 52 r which, however, shows a longitudinal development with a nave and isn't accompanied by an exterior perspective view, and thus won't be further analysed in our digitalisation process.

3.2. Classification of the churches based on the volumes

In this analysis, Guillaume mostly focuses on the presence or absence of a unifying exterior element (circular or square), and this distinction will be kept in our classification method. In order to do an analysis of the elevation, the author starts from the distinction made in the plans' study between homogeneous and alternate plans and plans with four surrounding elements.

According to J. Guillaume the use of a volume that incorporates the chapels and/or the apses, is

6 According to J. Guillaume this church comes from the influence of the church of San Lorenzo in Milan, church that was in fact drawn by Leonardo himself more than once in Codex Atlanticus (CA f. 286 / 7 v-b, that shows an interior view with some variations and CA f. 733 v/ 271 v-d).

the expression of Leonardo's attempt to bring together a unitary conception and a hierarchical one, like he learnt from Brunelleschi.

This classification is made of just three groups:

1. Buildings with eight equal peripheral elements
   a. with the peripheral volumes absorbed by a circular volume
   b. without it (the walls are enveloping the volumes and following their shape)
2. Buildings with eight alternated chapels
   a. with the chapels incorporated by a square based volume
   b. without it
3. Buildings with four peripheral elements

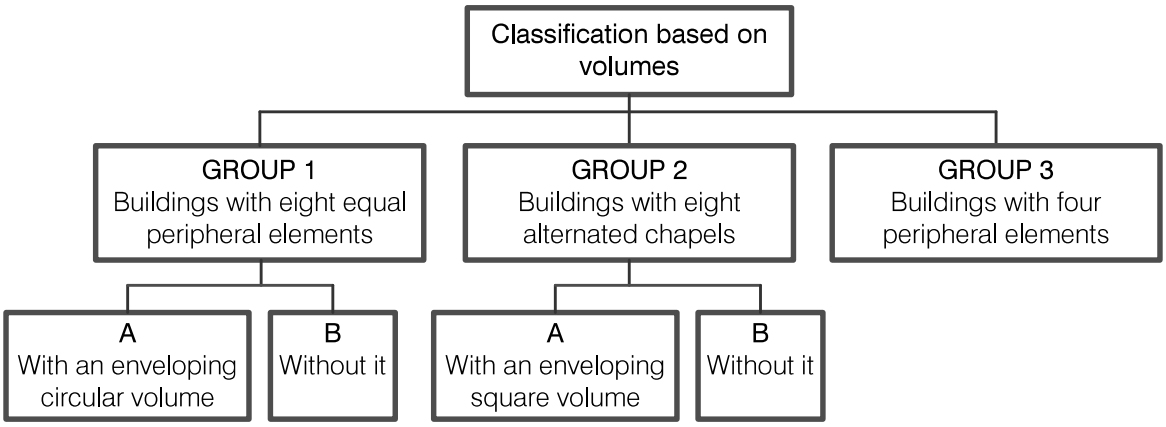


Fig. 10 - Classification of the churches based on the volumes, according to J. Guillaume

This division will be used also in out classification, but in a slightly different way, since we will consider the buildings with four peripheral elements as buildings with alternated chapels (thus considering the absence of a chapel as a variation). Moreover, the volumetric approach used here is particularly useful when considering the plans paired with their elevation.

Perhaps, a problem that may be noticed in this classification is that the majority of the classes just contains one element (but, of course, this is also related to the fact that the examples contained in Ms. B are limited in number, even considering also the churches that are only depicted in plan).

4. A proposal for a new classification method

The works we just analysed, starting from the same churches, defined two different methods for their classification into groups, that both show several elements of interest for the definition of a new one. First of all, given the similarities between the churches of Ms. B it was decided to focus on them and study a unitary set of rules that could define all of the churches that we will digitalise in the next chapter[7].

7 See Chapter 3 for the exact list of the considered churches.

Our proposal is to make a first distinction between two macro-groups of edifices:

1. Churches that have a central octagonal space
2. Four-lobed churches

An interesting element here is that the second group is also part of a category of chapels that Leonardo uses for the churches of the first group, so, the analysis of the layout of the second group is in fact part of the first one. The difference is that in one case the four-lobed layout is used as an independent system that stands alone as edifice, while in the other it becomes the shape of a chapel of a bigger system.

Given this, we propose, rather than a system of groupings, a system of *variables* with the definition of their possible values. The decision to operate in this way comes from the observation of a characteristic of these layouts: they are, in fact the recombination of a group of elements around a central space, like in a geometric play, and they can thus be studied through a script (at least in a simple way, as we will see). Moreover, dealing with groupings has the problem that it is necessary to pick one first feature/variable to divide the cases and, doing so, we are giving more importance to one variable rather than another.

Therefore, the idea is to start from the first group of churches and define a set of variables (in our case both topological and geometrical) that can define uniquely their layout. Then for each variable, all the possibilities that Leonardo explores are listed: these are the *values* of our *variable*. If we decide to establish an order for the variables and define a conventional symbol/initial for each value, then our classification system will be created through an *identification code*[8].

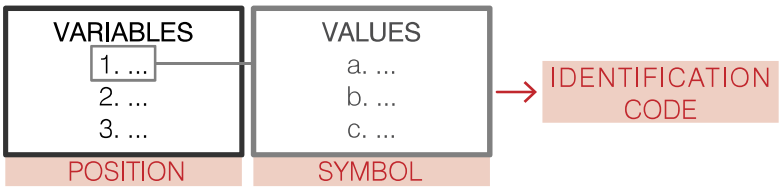


Fig. 11 - Scheme of a proposal to create an identification code for the churches

4.1. Churches with a central octagonal space

We will now list, in order, the variables and their possibilities:

1. Shape of the central octagonal space[9]:
   a. Regular (R)
   b. Irregular (I)
2. Disposition of the chapels around the central space:
   a. Along a circle (C)
   b. Along a square (Q)

8 There could be of course several methods to achieve this goal and different possibilities for the choice of the variables. However, the choices we made for the variables are based on their utility for the realisation of a grasshopper script that could help us with the modelling of the churches.

9 This clearly constitutes a geometrical difference and not a topological one.

3. Morphology of the chapels on the xy axes (A-) and on the diagonal axes (D-):
   a. Octagonal chapels (-O)
   b. Circular chapels (-C)
   c. Semicircular chapels (-SC)
   d. Square chapels (-Q)
   e. Rectangular chapels (-R)
   f. Chapels that are made by the combination of more circles (-CC)
   g. Chapels that are made by the combination of a square and circles (four lobed chapel) (-QC)
   h. Chapels made by a rectangular shape combined with a semicircular one (-RSC)
4. Presence of an exterior square-based volume (B-) that envelops some of the chapels:
   a. Yes (-Y)
   b. No (-N)

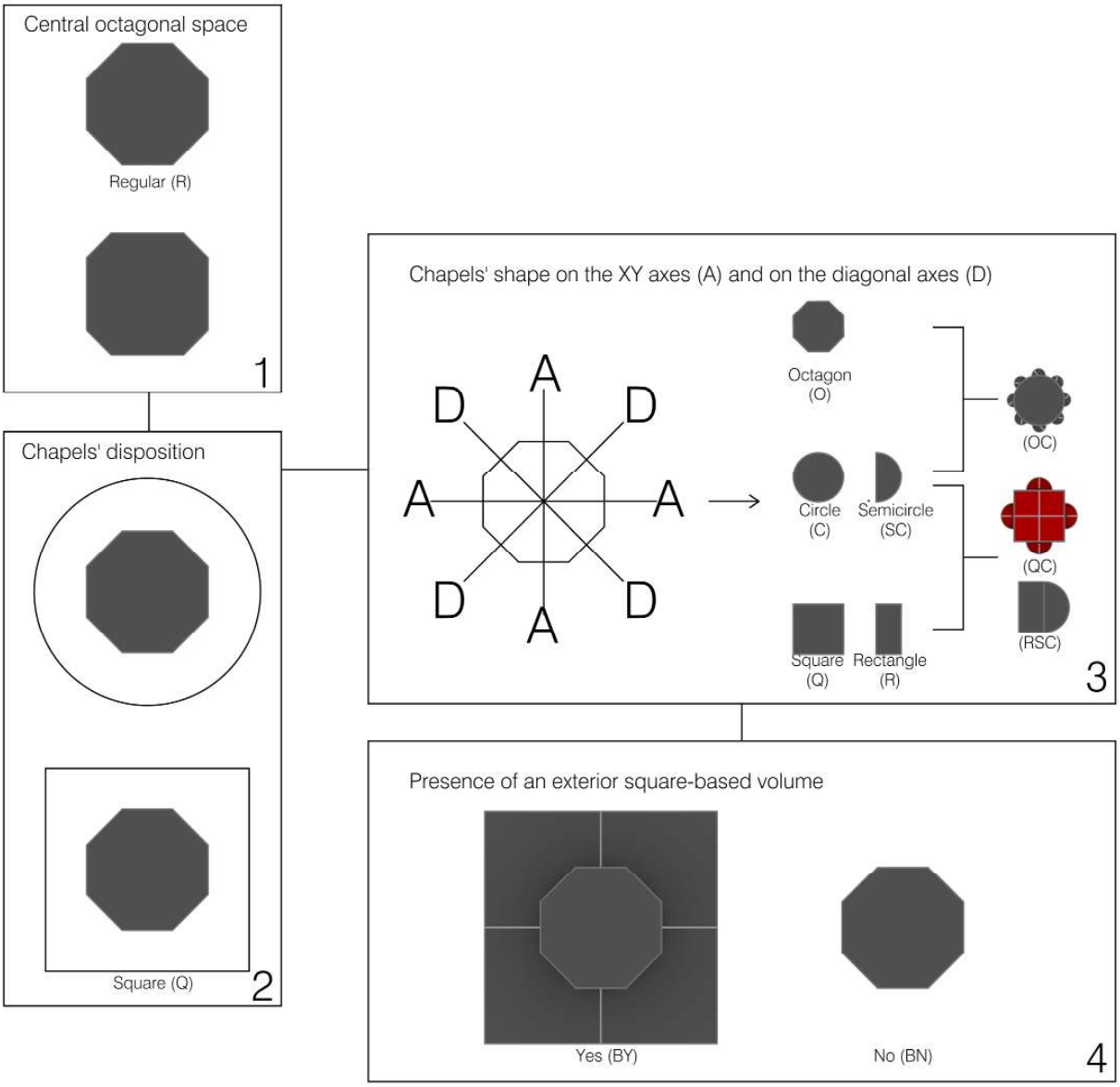
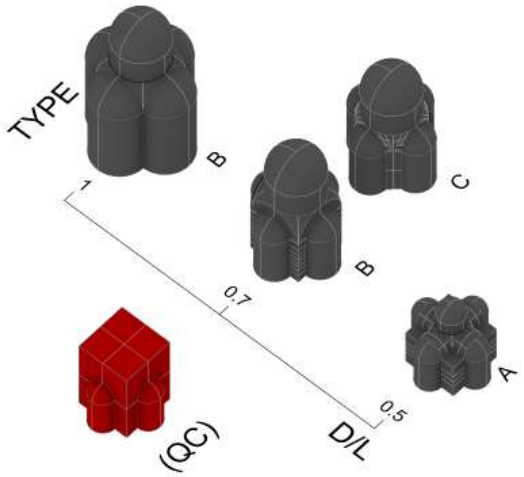


Fig. 12 - Graphical elaboration of the classification code

4.2. Four-lobed churches (QC chapel)

As we have seen, one of the possible shapes for the chapels is the one that comes from the combination of a square with four semicircular niches, named QC in the diagram seen before. Unlike what was done before by Richter and Guillaume, we will try to define a unitary discussion for all the chapels that are four-lobed, including the ones that have a dome rising from four pillars, from a square base or from an octagonal one. The idea is to try and include all these three possibilities in the same reasoning and use it in order to develop a unitary parametric model with Grasshopper, as we will see in the next section. The elements to consider in our classification are two: the first one is the type (A, B, or C) and the second one is the ratio D/L.



Three dimensional representation of the modifications in the QC chapels due to the type (A, B, C) and the D/L value

Type A is the one where there are four pillars inside the main square space. There are different possibilities for its realisation in detail, since the ceiling in the corners can assume different shapes (groin vault, sailing vault or flat), but this will not be considered in this aggregative analysis (while it will be fundamental in the later stage of three dimensional reconstruction). The reference here is the Sacello Carolingio in the Church of Santa Maria presso San Satiro, at Milan. Type B instead has the four spherical pendentives leaning on the sides of the square central space and can be referred, for example, to Cappella Pazzi, Santa Maria delle Grazie and the Sacrestia Vecchia in the church of San Lorenzo at Florence. In Type C, the endpoints of the semicircular niches are joined to form an octagon and its oblique sides become the basis for the pendentives, as it is done in Cappella Chigi at Rome.

The ratio D/L gives us information about the diameter of the niches in comparison with the sides of the central square space. In this case we decided to consider for it a range of values from 0.5 (since we cannot find any example below it in both the references and Ms. B drawings) to 1. A value of D/L equal to 1 is in fact the borderline case, where Type B and Type C coincide (even though we will consider it as a Type B case, since topologically the central space is a square and not an octagon) and Type A cannot be done (the pilasters would end in the corners of the square space, bringing us back to Type B).

5. A parametric approach

Given all the previous observation we tried to build a parametric model with Grasshopper (and a little bit of Python code to create some tools) that could potentially resemble all the churches (at least in their basic form) of the manuscript. The idea is to turn our classification system into a system of toggles and sliders that can construct the basic shape of the church just choosing between them

This goal was fully obtained for the QC chapels, whose level of relatevely low complexity makes it possible to create a script able to model all their possibilities. On a theoretical level this could be done also for the churches with a central octagonal space, but the computational complexity here is higher and would require a more deep research and accuracy in the development of the script. An attempt was made and, for now it can resemble all the churches that have square, circular, rectangular chapels or chapels made up by a rectangle and a semicircle (-RS chapels). The script also allows to regulate the distance of the chapels, the features of the central drum and the type of dome: pavillion (pointed or round, umbrella or spherical). The highest difficulty found in this process is the computational time: it would be necessary to rethink it with a higher efficiency before adding the other chapels' shapes, but we think this could be an interesting element to develop in the future.

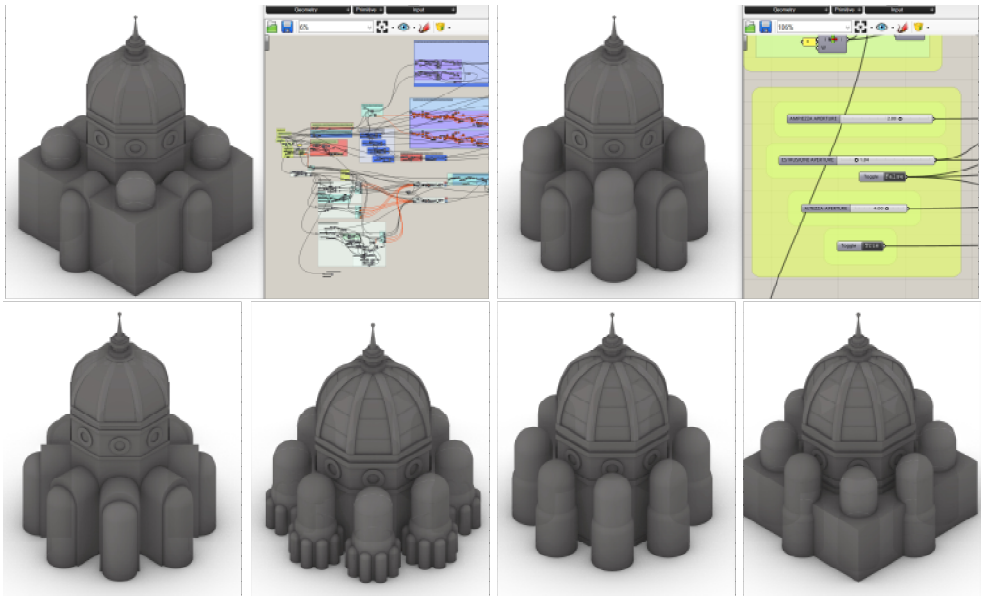


Fig. 13 - Examples of the results that can be obtained using the Grasshopper script for the churches with a central octagonal space

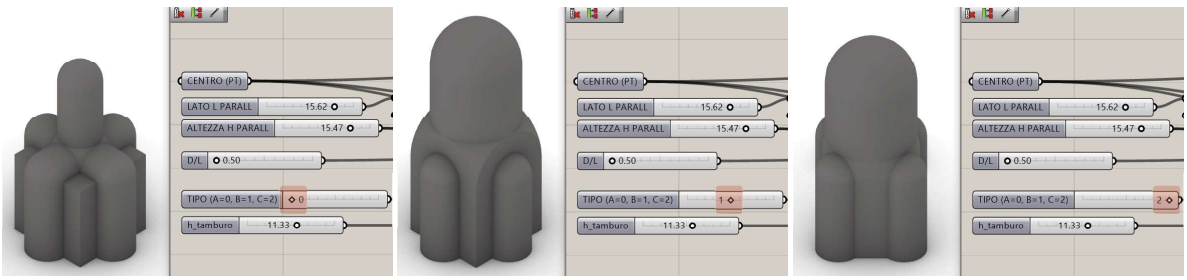


Fig. 14 - The three types of chapel -QC can be obtained from the same script by changing a toggle.

4. Three-dimensional reconstruction

1. Introduction

This chapter describes the process used for the three-dimensional reconstruction of the sacred buildings in Ms. B. In particular, at this stage, all the churches were digitalized using a manual approach through the software Autocad and Rhinoceros 3D, starting from a proportional study and using the results of the parametric approach, explored in the previous chapter.

Carlo Pedretti was the first to study the proportions of one of Leonardo da Vinci's buildings with the study he conduced on the drawing no. 238 v of the Academy of Venice, deducing the floor plan from an external perspective view[1]. However, previously Scholfield[2] studied the relation between the octagonal star scheme related to Pell series and Silver Ratio[3] and the church depicted in f. 95v of Ms. B. These considerations are especially useful because this relationship is not only present in f. 95 v but is widely used in many of the buildings of the manuscript.

Then, a systematic study of the drawings in Ms. B was made by Jean Guillaume for the exhibition "Leonardo Da Vinci Engineer and Architect" for the Montreal Museum of Fine Arts[4]. Guillaume's study, in addition to reconstructing in three-dimensions some of the churches of Ms. B, developed a complex categorisation of the buildings, focused on the chapels and on the apses that surround the central octagonal space.

Francesco P. Di Teodoro then made his contribution[5] in the study of the proportions both of plans and elevations. One of the elements noticed in his article is that many of the churches in Ms. B are impossible to model with consistency between the plan and the perspective view. This problem is probably related to the fact that the drawing Leonardo makes in Ms. B are - in Di Teodoro's opinion - intended as personal notes and don't present yet the characteristics of real-life projects. This contribution will be widely used in our work, since we will evaluate the consistency between perspective and plan views for each church and try to understand the reasons behind these differences in the drawings.

1 Pedretti, Carlo. *A Chronology of Leonardo Da Vinci's Architectural Studies After 1500: In Appendix: a Letter to Pope Leo X on the Architecture of Ancient Rome*. Genève: Droz, 1962. pp. 130-136

2 Scholfield, Peter Hugh. *The Theory of Proportion in Architecture*. Cambridge: University Press, 1958. 139-141

3 The geometrical figure of the octagon is strictly related to Pell numbers and Silver Ratio. In fact, given a regular octagon with a unitary side, the inradius of the octagon equals $1+\sqrt{2}$, which is the Silver Ratio. The Silver Ratio can be obtained also dividing two consecutive numbers of the Pell Series and those numbers can also be retrieved drawing an eight-pointed star from the first octagon and then joining the points. It's interesting to notice that Leonardo seems to reason more than once on eight-pointed stars in Ms. B, as he draws this geometric construction both by itself, both inside the plan of a church (f. 95 v, Ms. B).

4 Galluzzi, Paolo, and Jean Guillaume. *Leonardo Da Vinci Engineer and Architect [Exhibition, Montreal Museum of Fine Arts from May 22 to November 8, 1987]*. Montreal: The Montreal museum of fine arts, 1987.

5 Di Teodoro, Francesco P., Matthew A. Cohen, and Maarten Delbeke. "Leonardo Da Vinci: The Proportions of the Drawings of Sacred Building in Ms. B, Institut De France". *Proportional Systems in the History of Architecture* / Edited by Matthew A. Cohen and Maarten Delbeke. 2018. pp. 381-396.

The reconstruction described in this chapter takes into account these contributions and uses the classification rules defined in Chapter 3. Being the first step in the digitalisation, the architectural details were kept in a low level of detail, sticking mainly to the level of information contained in the drawings, that sometimes appear to be small and schematic. The specific architectural reference that can be related to every church, however are pointed out and will be later used in order to reach a higher level of detail. The approach is thus aimed at systematically comprehending the proportions and the recurring elements in order to try to make a classification based on volumes, rather than on plans. For this purpose, understanding the previous classifications of the churches was fundamental as it constitutes the starting point for any development and will be discussed in detail for each church.

2. Methods of reconstruction

The process starts with the representation of the plan and its deconstruction, in order to define the geometric construction process that Leonardo could have used to design the church. So, at first, the main attention was given to the relationships and proportions between guidelines and base objects.

Then, the elevation is analysed, trying to find a relation between the dimensions of the elements in the plan and their height (in order to do so, first of all it's necessary to scale the bird's-eye view drawing on the basis of the plan). Moreover, the fact that the perspective views are almost cavalier axonometrics represents a useful characteristics to derive the measures of objects, since the façade is almost an orthographic elevation. However, in most of the cases there isn't a perfect consistency between plan and perspective view and, moreover, the absence of a section view makes it impossible to have certainties about the structure of the interior.

To overcome this issue, in case of uncertainty, more solutions have been explored, referring to the architectural examples that Leonardo might have seen during and before the writing of Ms.B. As we will see, more variants were modelled also in that cases where Leonardo draws different solutions in the same drawing.

3. Analysed churches and pairing of drawings

The following list enumerates the churches that were digitalised[6] and, when necessary, the pairings that have been done in order to have always a plan and an exterior perspective view to analyse. The number of output variants is indicated in square brackets. When the same folio contains more than one church, its study has been divided using a letter.

6 In this work, only churches that had the characteristic of having a plan view along with a perspective view were considered. All the cases where Leonardo depicts just a plan were discarded from the process of digitalisation.

1. 17 v - 18 r (A) [2];
2. 17 v - 18 r (B) [4];
3. 18 v - 19 r [24];
4. 21 r (A) [3];
5. 21 r (B) [1];
6. 21 v [2];
7. 22 r [8];
8. 25 v (A) [1];
9. 25 v (B) [2];
10. 39 v [2];
11. 93 v (A) [5];
12. 93 v (B) [4];
13. 93 v (C) [1];
14. 93 v (D) [1];
15. 93 v (E) and 56 v [1];
16. 93 v (F) [6];

The folii that were discarded from the operation are ff. 3r-4v, since they are in fact sketches for the Tiburio of Milano's Cathedral, f. 24 r, since it has a longitudinal layout, f. 95 v, because it was already studied and three-dimensionally built by Jean Guillaume in occasion of the Montreal exhibition and f. 94 r, since it differs from the ones here analysed and would require a separate analysis. Regarding the latter, only some considerations were produced and it certainly constitutes an interesting element to digitalize in future studies.

3.1. Folios 17v and 18r (A)

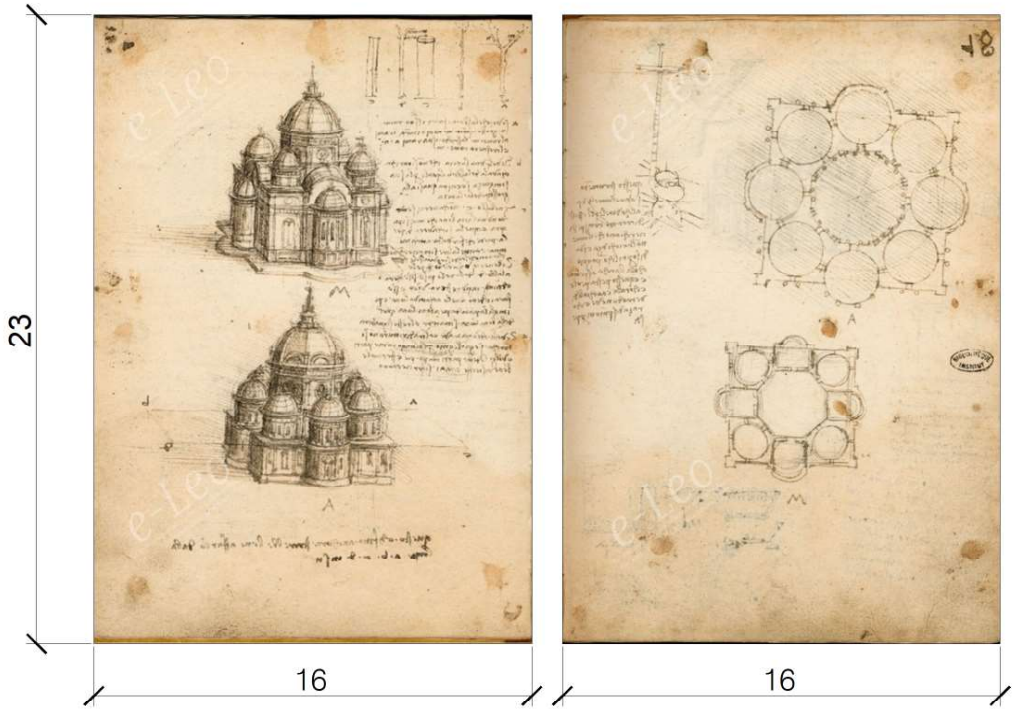


Fig. 1 - Folios 17v and 18r with the indication of their dimensions in centimetres

Folio 17v depicts two bird's-eye perspectives, each one matching one of the two plans drawn in folio 18r (fig. 1). Therefore, the two churches, named A and B, have been considered separately in order to proceed with their digitalization. Leonardo himself distinguished the churches labelling them underneath with the letters M and A[7].

The elevation of the church here reported is accompanied by the note *"Questo edifizio ancora starebbe bene a farlo dalla linia a b c d in su"* referring to the plane indicated with the letters *a b c d* in the drawing. In this case the resulting building would resemble, with some little differences, the one depicted in the upper part of f. 25v. It is interesting to notice how Leonardo is, in fact, exploring in the same drawing two different possibilities (a tendency that will be highlighted also in other drawings of the manuscript)

The church is characterized by an octagonal domed drum with ribs set into its corners and into the ones of the dome. Around the octagonal nucleus there are eight equal circular domed chapels, connected by the square-based volume placed under the plane *a b c d* and placed along a circle. The chapels are connected through a narrow passage, element that associates even more this spatial layout with that of Brunelleschi's Rotonda.

Using the nomenclature defined in Chapter 3 we could classify this church as R/C/A-C D-C/

7 Regarding the nomenclature used in this chapter, the church labelled by Leonardo with the letter A corresponds with the A one, while the one labelled with M corresponds to the B one.

BY, since the octagon is Regular, the chapels are distributed along a Circle, the shape of the chapels on the main Axes is Circular as well as that of the one on the Diagonals and a surrounding square-based volume is present.

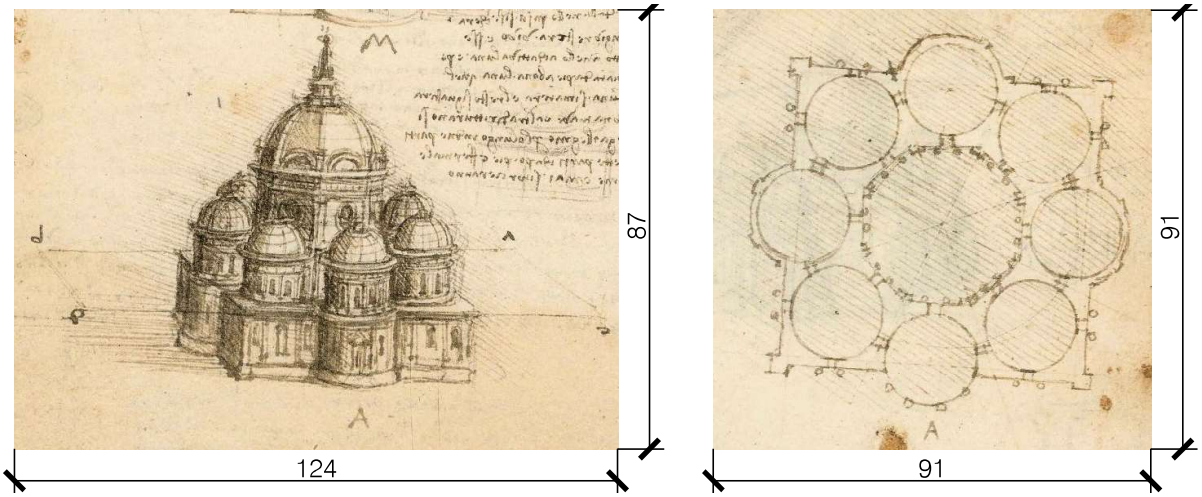


Fig. 2 - Ms. B, f. 17 v and 18r. Detail of the church "A" with the dimensions of the drawing in mm.

As will be later pointed out, in this case plan and three-dimensional representation are almost coincident, except for two elements that are not matching: the position of the single-arched windows in the façade.

In his article Francesco di Teodoro[8] analyses the proportions of plan and elevation and proposes the process to draw the plan. One of the most interesting contribution of his work is certainly the consideration of the proportional connections between plan and elevation.

Di Teodoro's process will be now presented and discussed since it shows some slight inconsistencies that will be explained in detail. Then, a different process to draw the plan will be proposed, with the intent to obtain the most accurate matching possible with Leonardo's sketch.

3.1.1. Di Teodoro's process

Di Teodoro proposes to start the drawing process from the square circumscribing the chapels and defines of the central octagon using a golden section relationship between the side of the square and the diameter of the octagon itself. Then he imposes that the diameter of the octagon should be equal to the distance from the centre of the octagon to the extreme opposites of the diameters of the circular chapels and that the distance between each side of the octagon and the corresponding chapel should be defined by the circumference that circumscribes the octagon.

Using this process however, it is not possible to respect the constraints of tangency between the circular chapels and the circumscribing square, and, moreover, the diameter of the chapels, if compared with the original drawing, seems to be slightly shorter than the original one.

8 Di Teodoro, Francesco P., Matthew A. Cohen, and Maarten Delbeke. 2018. pp.390-391

In Fig. .. it is possible to see this process and, on the right, the problems that were just described.

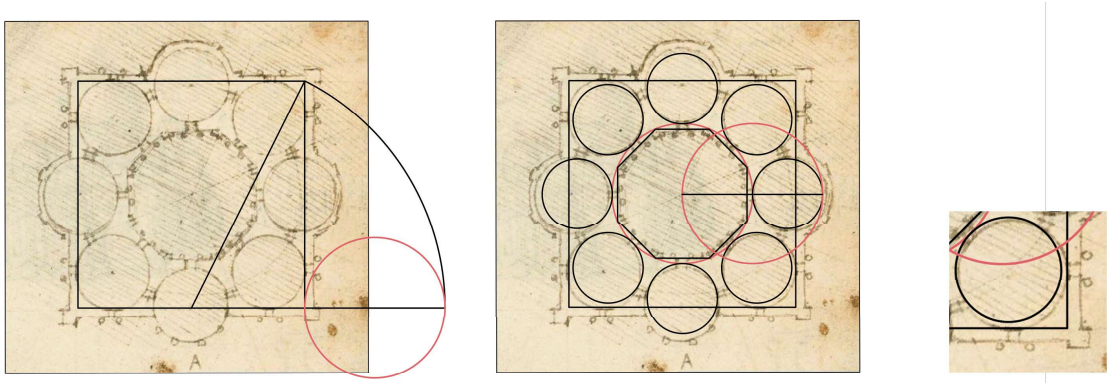


Fig. 3 - Process for the reconstruction of the plan as proposed by Di Teodoro

3.1.2. Plan and elevation analysis

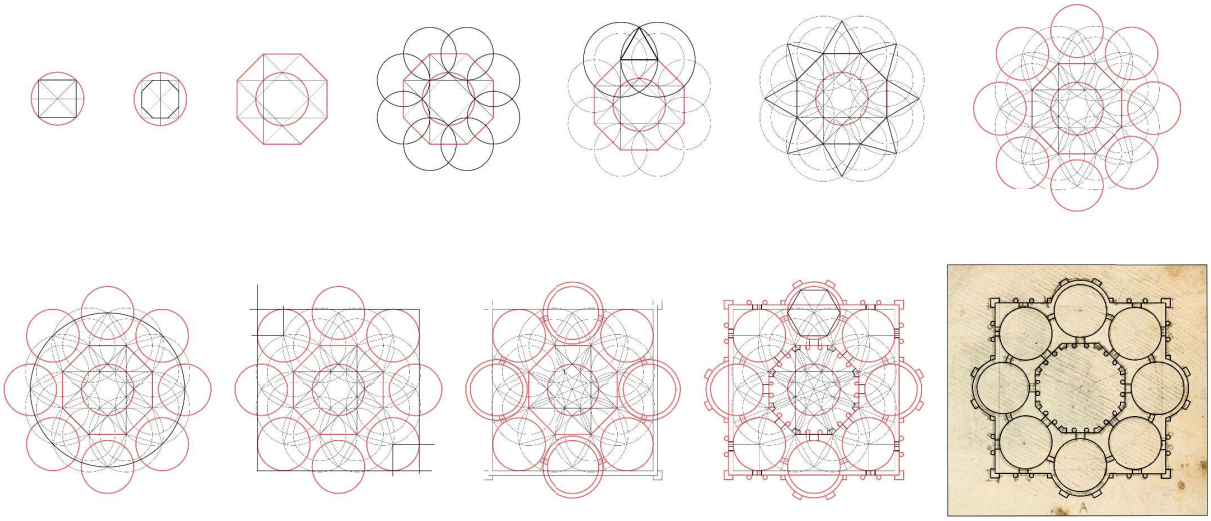


Fig. 4 - Alternative process based on the diameter of the chapels.

The process here proposed starts from the diameter of the circular chapels and derives from it the dimensions of the other elements. One interesting element of using this approach is that doing so, we are in fact imposing the length of the side of the central octagon[9] and in the recto of f. 17 Leonardo describes how to construct an octagon over a given line.

In Fig. 4, starting from the circumference of the chapels(1), the inscribed square is drawn along with the regular octagon inscribed in the square(2). This is likely to be a process Leonardo could have used, because another process described in Ms. B is the one for dividing the sides of a square inscribed in a circumference, in order to obtain a regular octagon[10].

9 When we construct the next octagon in the Pell Series starting from the regular octagon inscribed in the starting circumference we are in fact constructing a regular octagon that has a side equal to the side of the square inscribed in the circumference.

10 See Ms. B f.12 v "*Qui si dimostra la brevità di fare un quadro e quello dividere in 8 parti equali.*" i.e. "*here the conciseness of drawing a square and dividing it in eight equal parts is discussed*"

Then (3) the sides of the octagon are extended until they touch one another, thus constructing the next octagon in the Pell series of regular octagons. Then, a circumference, equal to the first we have used, is drawn on each of the vertices of the obtained octagon (4) and on each of its sides an equilateral triangle is constructed (5 and 6). Drawing an equilateral triangle, as can be seen from the bigger circumferences drawn in (5) and (6), is in fact equal to trace a circumference with a radius equal to a side of the octagon and the center in one of its vertices.

The vertices of the triangles are used as the centres of eight circumferences equals to the previous ones (7). Then a square circumscribing the circumferences on the diagonals has been constructed (8) and the circumferences drawn in phase (4) were used as a guide for drawing the openings that connect the chapels with each other (9), along with the circumference with the centre coincident with the one of the octagon that connects the centres of each chapel. These two circumferences have been used to define also the offset for the thickness of the walls (9 and 10). Moreover an hexagon inscribed in the chapels placed on the x,y axes has been used to place the pilaster strips (i.e. the *lesene*) that surround the chapels themselves (9).

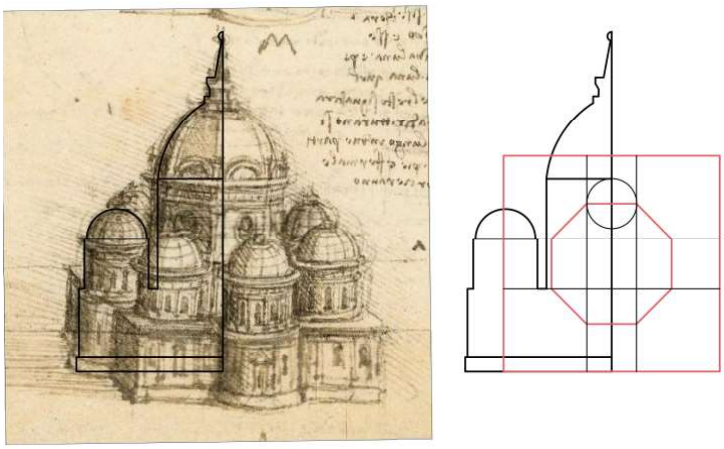


Fig. 5 - Study of proportions in the elevation view

The reconstruction of the bird's-eye views of the manuscript is more difficult than the one of the plans, as it was already pointed out, since they are usually free-hand drawings and show more variability in the measures. In this case, after scaling the drawing, in order to make the external boundaries of the building coincident with the ones in the plan, the height of the elements was analysed, looking for connections with the geometrical elements used to draw the plan.

3.1.3. Consistency between plan and perspective view

Plan and perspective view, in this case are almost consistent, apart from the main entrance and the position of the openings. For this reason two options were analysed (Fig. 4) in order to consider all the possible variables in the process of digitalization.

The entrance to the building in Leonardo's plan view is made of four columns placed along a semicircle (1), while in the perspective view Leonardo represents the main entrance with a door

surmounted by a triangular pediment in one of the chapels, each of which is surrounded by two pilaster strips (2).

Regarding the windows, in the plan Leonardo draws only one opening per chapel on each side, between two columns (1), while in the perspective view he draws three of them (2). The second solution, however, leads to some issues in the corners as, respecting the dimensions obtained from the perspective view, two of the windows show an intersection.

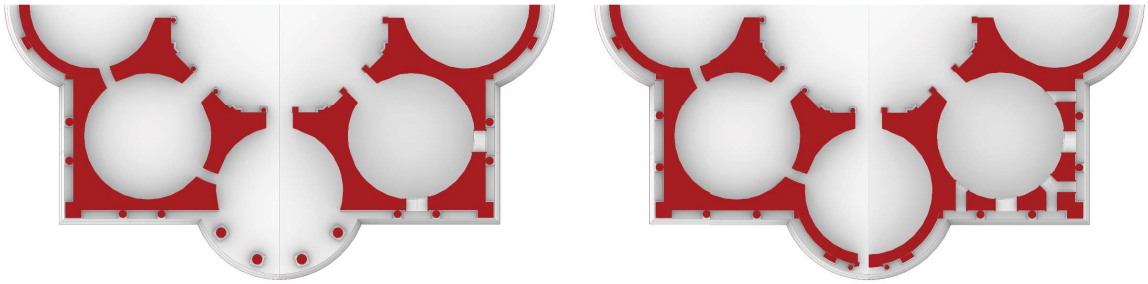


Fig. 6 - A comparison between the plan obtained giving precedence to the information contained in the plan (1) and the perspective view (2). In each plan, the left-hand side is obtained sectioning the building at the doors' level, while the right-hand side is the section at the windows' level

Later on, for each of this solutions we explored the different possibilities for the dome, as the dimensions of Leonardo's perspective are not sufficient to determine with certainties its features. In the next sections the reconstruction process is then divided between the one that starts from the plan and the one that gives precedence to the perspective view, exploring all the possible variations and referring, when necessary, to external references (architectural or from other manuscripts).

3.1.4. Types of domes

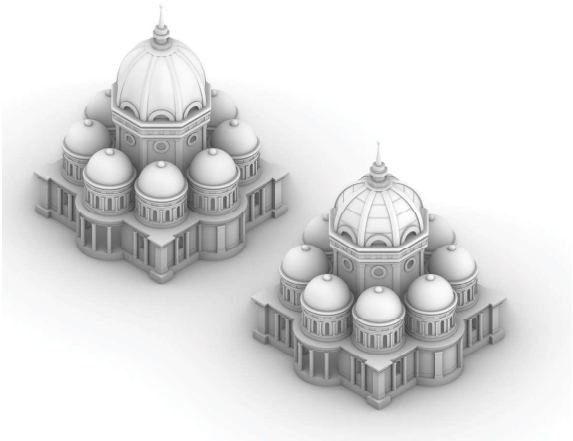


Fig. 7 - Comparison between the types of domes modelled: umbrella domical vault (1) and cloister domical vault (2)

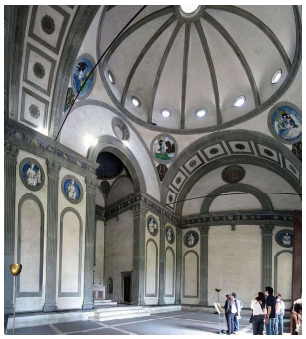


Fig. 8 - Photography of the umbrella vault in Cappella Pazzi, Florence

Fig. 9 - Photography of the drum and of the cloister vault in Pavia's Cathedral

The dome represented by Leonardo in the perspective view seems to be an octagonal cloister

vault, but in order to explore all the possibilities given by other solutions and since the dimension of the drawing isn't sufficient to define the type of dome with certainty, we also decided to consider the case of an umbrella vault.

The two types of domes are related to specific architectural references (see Chapter [...] for further explanations about the choice of the references), that Leonardo probably saw and from which he was likely to be influenced in his reasoning.

The first case, an octagonal umbrella domical vault, is referred to the domes designed by Filippo Brunelleschi in Sagrestia Vecchia, Cappella Pazzi (Fig. 7) and Santo Spirito in Florence, even though in those cases the base of the vault was dodecagonal and not octagonal like in the case of this church.

The second one, an octagonal cloister vault, refers especially to the dome of Pavia's Cathedral (Fig. 8), which is as well octagonal and has single curved parts between two ribs.

However, the presence of the semicircular openings at the base of the dome represents a solution that better fits with an umbrella dome, rather than a cloister vault. For this reason, the cloister vault variant was discarded from the proposed solutions.

3.1.5. Results

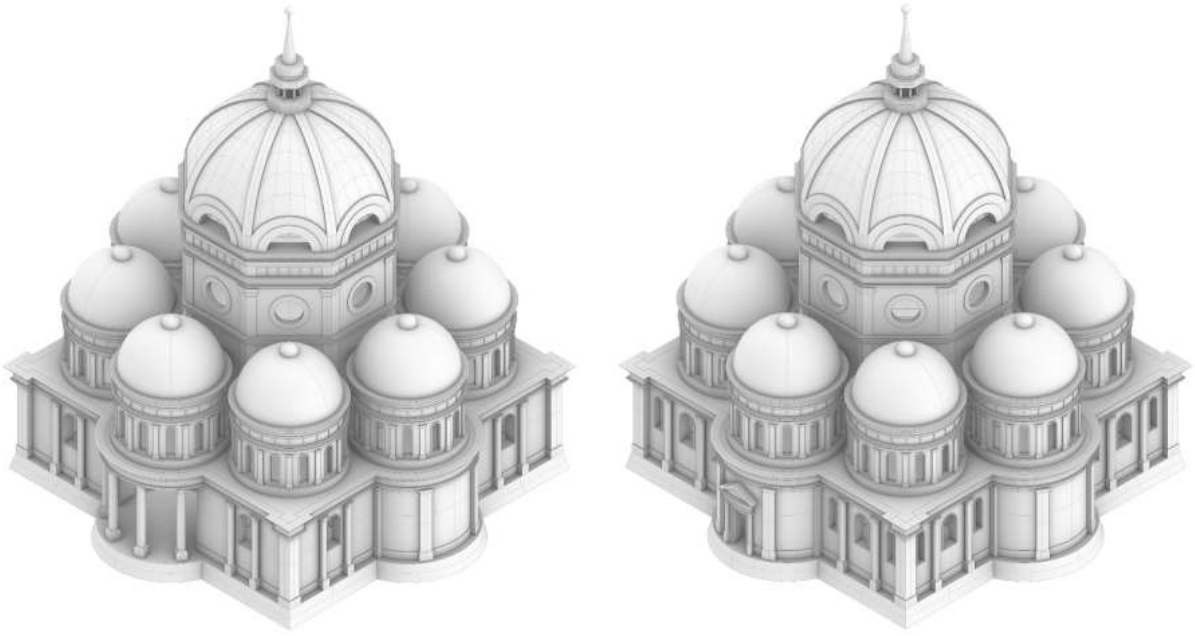


Fig. 10 - Comparison of the two proposed solutions: on the left the one derived from the plan and on the right the one mainly based on the bird's-eye view

In the following page all the explored variants are shown and listed.

The first solution privileges the information contained in the plan view, so that the main entrance

of the church is realized with four columns placed along a semi-circle and the wall portions on the corners show just a window per side, placed between two columns.

The second solution, on the other hand, is mainly based on the information given by the perspective view (only, of course, in the parts that show inconsistencies between plan and elevation), and thus shows an entrance made up by a door with a triangular pediment and three windows per side on each corner wall.

The estimated scale and the interior decorations were hypothesized using the architectural references listed in the previous chapters.

Fig. 11 - Axonometric section

As it was already pointed out, the drawings lack of any scale or dimensional reference, so, in order to make some realistic assumptions regarding the dimensions of the church it was necessary to consider the interior and exterior openings and apply the examination carried out in Chapter 2.

From a practical point of view, the reference dimensions previously found for the various categories of openings - single and double arched windows, circular windows, interior and external doors - were used to scale the object and try to find the solution that could make the dimensions of all these elements plausible.

In this case, it was imposed a minimum width equal to 1 meter for the windows and 1.2 meters for the interior doors. For the latter - in absence of any information regarding their height - a 2:5 ratio was used. Both the minimum dimensions and the ratio used were based in particular on Brunelleschi's Rotonda, because of the similarities, already underlined, in the spatial layout.

The interior decorations, on the other hand, are based in particular on the examples of Santa

Maria della Passione in Milano and on the reconstruction work of f.95 v of the same manuscript, done in the past by Jean Guillaume. Those two were particularly useful also for the interior details of the other digitalized churches, since they present a particular affinity in the interior articulation of space. All the details, however, are characterized by a low level of detail, given the lack of information, and must be considered as hypotheses made in order to make the interiors more plausible.

Fig. 12 - Plan, section and elevation of the variant obtained following the plan view in a representation scale equal to 1:500 (in the appendix it is possible to see also the other output). The plan views are obtained by sectioning at the level of the windows (on the right) and at the level of the doors (on the left).

3.2. Folios 17v and 18r (B)

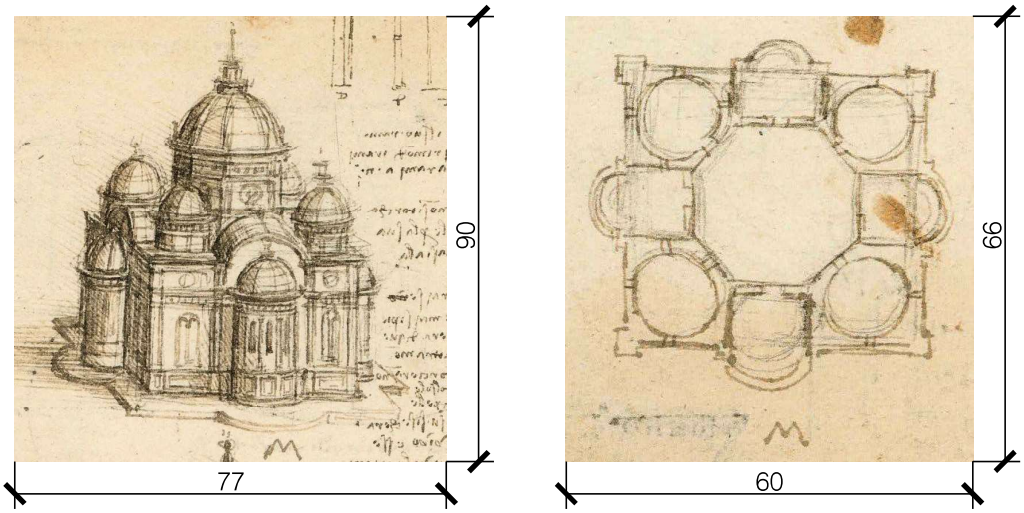


Fig. 13 - Ms. B, f. 17 v and 18r. Detail of the church "B" with the dimensions of the drawing in mm.

The second church drawn in folios 17v and 18r, labelled by Leonardo with the letter M, shows an alternation in the shapes of the chapels, which are distributed along a circle: on the main axes the chapel is made up by the combination of a rectangular space and a semicircle, while on the diagonal axes they are circular. Using the nomenclature explained in chapter 3, this layout could be classified as I/C/A-RSC D-C/BY.[11]

Leonardo doesn't give any indication about the entrance for this church, neither in plan nor in the bird's-eye view. This is a tendency that we will later see in many of the digitalized churches, since the definition of an entrance constitutes a breakage in the symmetry of the layout and, thus, represents a difficult problem to solve. It could be interesting to notice that the church in the same folios, which we analysed just before, the entrance is drawn both in the plan and in the elevation and that moreover this one was drawn with more attention. In fact, while the plan of church A is clearly drawn using instruments, we cannot say the same for church B, which, on the contrary, seems to be free-hand drawn and shows several irregularities and *pentimenti*, showing that he was probably still reasoning on this solution while drawing it.

Like in the church A, the chapels are connected through narrow passages and were consequently associated with the reference of Brunelleschi's Rotonda, which was used in order to define a minimum width for these passages (1.2 m) and a ratio for their elevation (2:5).

The width of the passages that connect the chapels with the central octagonal space, varies in the drawing, so it was proposed a solution with wider passages on the main axes and 1.2 m wide passages for the ones on the diagonals. However, the difference in width between single and double arched windows, as drawn in the bird's-eye view is too great to achieve the reference

11 I, since the octagon is slightly irregular, C since the chapels are placed along a circle, A-RSC because the chapels on the main axes are made up by a Rectangular shape plus a Semi Circle, D-C for the Circular shape of the chapels on the Diagonals, BY for the presence of a square-based volume.

width for both (respectively 1 and 2 metres). The scaling solution here proposed shows a width of 0.7 m for the single arched windows in the semicircular niches and a width of 2.8 m for the double arched windows in the façade. Regarding the circular windows in the drum, a width of 2 m was imposed, in order to respect the measure previously found in the references of Cappella Colleoni at Bergamo and of Brunelleschi's Rotonda.

Regarding the production of multiple solutions, in this case, as we will soon see in detail, four variants were explored: two for the type of dome and two for the inconsistencies between plan and elevation view.

3.2.1. Plan and elevation analysis

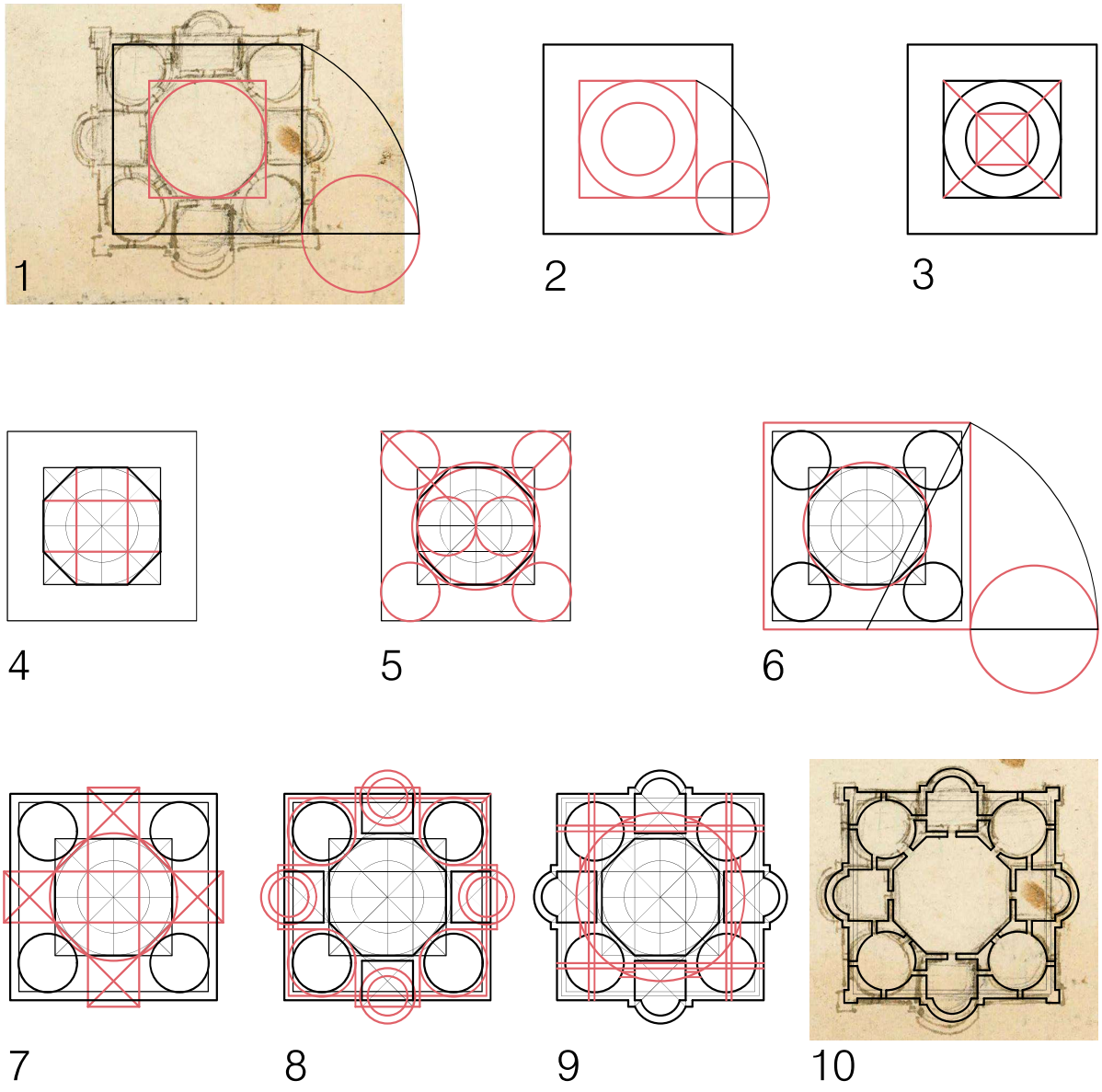


Fig. 14 - Geometrical process for the reconstruction of the plan.

The geometric construction of the plan starts from the square that is tangent to the circular chapels placed on the diagonals. The square circumscribing the central octagon is related to this perimeter square by a golden section relationship between their sides (1). The golden section is then applied once again to the smaller square - the one that circumscribes the octagon - in order to obtain a smaller circumference (2) and the square inscribed in it (3). Lengthening the sides of the latter it is possible to obtain the central octagon (4). Then, four circumferences, whose diameter equals half of the diameter of the octagon, are placed on the diagonals, tangent to the circumference that circumscribes the octagon (5). This last circumference is related to the external perimeter of the building by a golden ratio (6). In order to define the main axes' chapels, the sides of the octagon were lengthened (7) and the obtained rectangle was completed with semicircular niches (8). The position of the openings was defined through the circumference that joins the points of intersection between the oblique sides of the octagon (9).

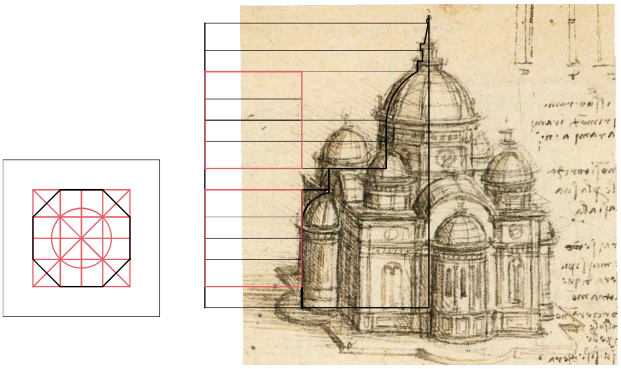


Fig. 15 - Relationship between the geometry in plan and the proportions in elevation.

The elevation was related to the inner octagon and its interior subdivisions. What emerges is a possible relationship leaded by the parts of the octagon between the heights of the elements in the perspective view. The octagon itself was obtained through the application of the golden ratio, and it seems plausible that Leonardo might have used it even working free-hand, even though we must keep in mind that the small dimensions of the sketch make it difficult to have certainties in the analysis of the proportions in the elevation.

3.2.2. Consistency between plan and perspective view

There is a slight inconsistency between plan and bird's-eye view which regards the semicircular niches. In the plan view, in fact, Leonardo draws a rectangular exterior protrusion where the niche meets the rectangular shaped space, that was interpreted as an angular *lesene*, while in the perspective view this element is missing. Therefore, the differences in this case are very slight and the two view can be considered almost consistent.

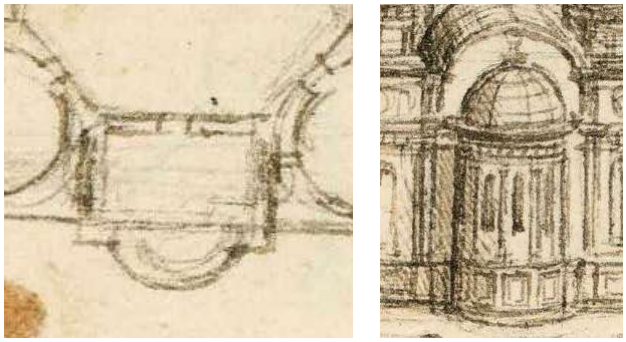
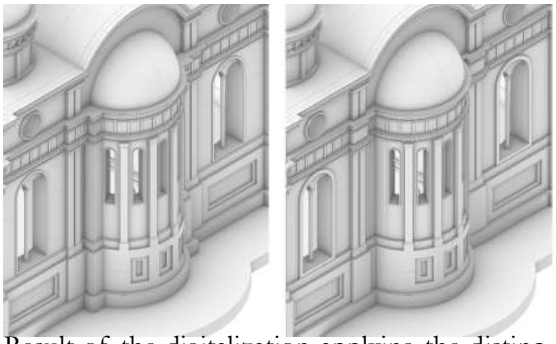


Fig. 16 - Focus on the differences between the views: in the plan view the rectangular volume emerges, while in the perspective view it seems to be at the same level of the façade.



Result of the digitalization applying the distinction between plan and perspective views

3.2.3. Types of domes

The dome drawn by Leonardo is likely to be a cloister domical vault on the example of Brunelleschi's dome, however it is not certain whether it is pointed or rounded shaped, so both solutions were modelled in order to define what seemed to be more visually matching. The solution that was considered the most suitable in this case is the rounded shaped cloister dome.

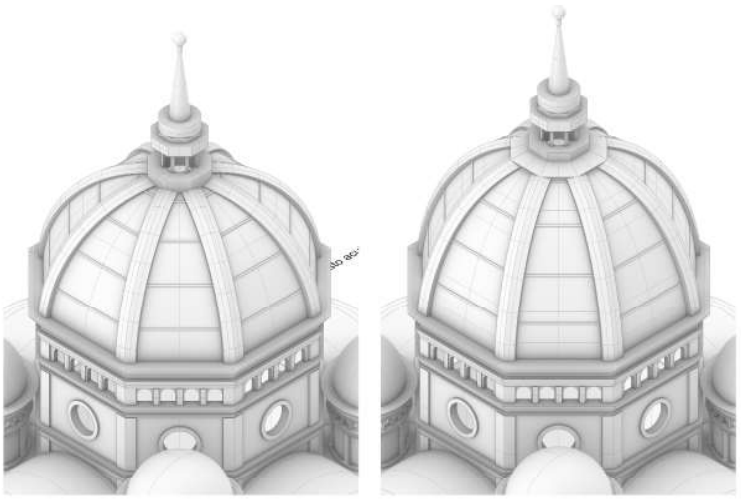


Fig. 17 - Comparison betweeen the two types of domes that were considered. On the left (1) the dome has a rounded shape, while on the right (2) it is pointed.

3.2.4. Results

In conclusion, the solutions that were produced are four in number and depend, on one hand, on the type of dome considered (rounded-shaped or pointed-shaped) and, on the other hand, on the main source of information (the plan view or the bird's-eye view).

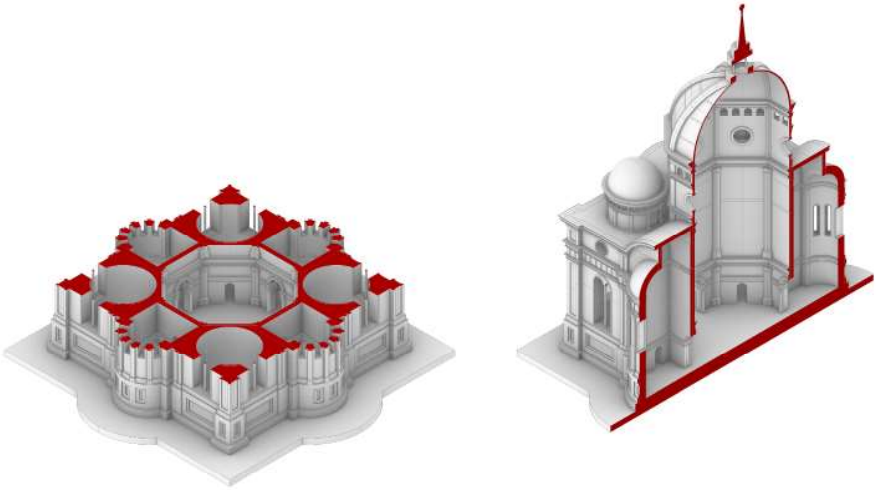


Fig. 18 - Axonometric sections of one of the four modelled solutions.

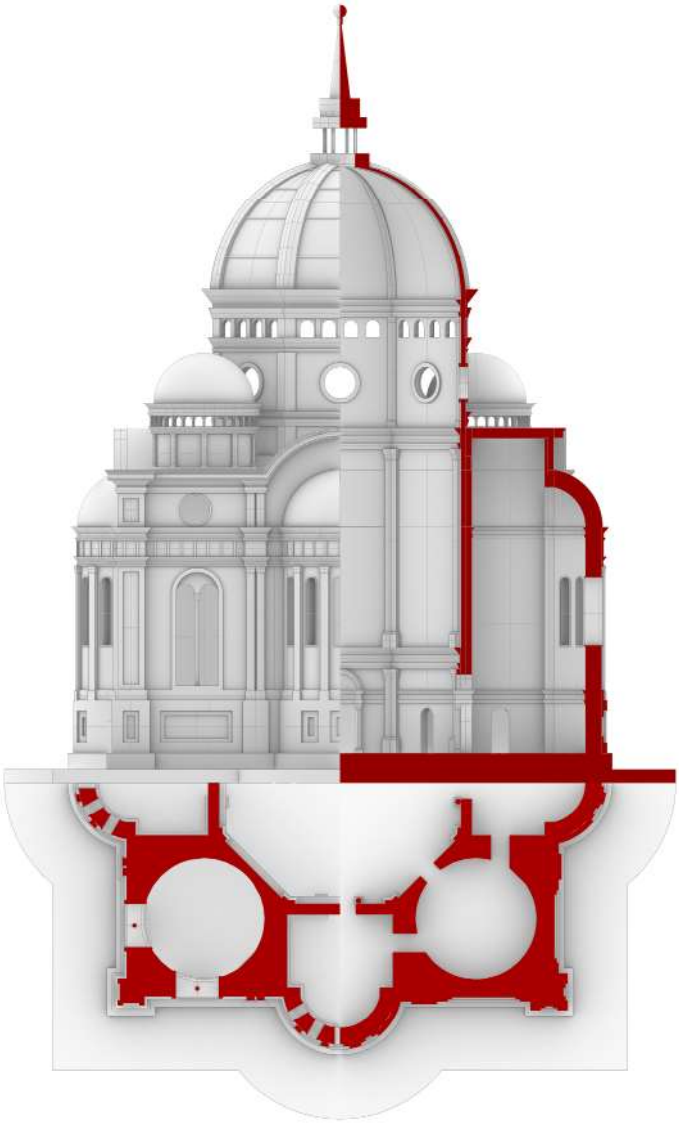


Fig. 19 - Plan, section and elevation of the variant obtained by the bird's eye view, with a rounded shaped cloister dome (1:500).

3.3. Folios 18v and 19r

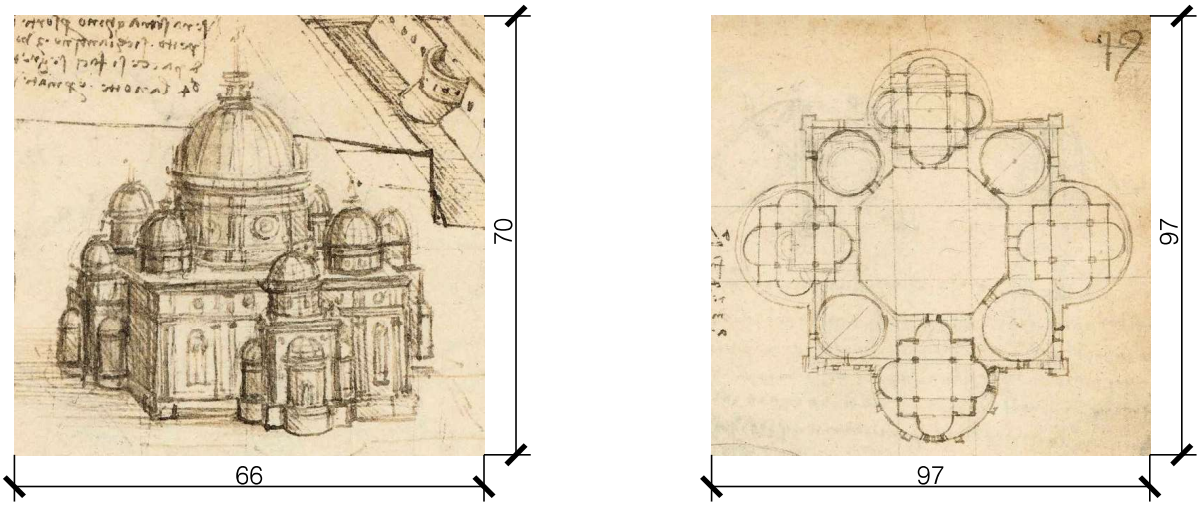


Fig. 20 - Ms. B, ff. 18 v and 19r with the dimensions of the drawing in mm.

This church, like in the ones just analysed, is drawn in two different facing folios, and not in the same one, as many churches that we will later analyse in this work.

The church here depicted shows two type of chapels alternated, placed around an irregular octagonal-based central space, around a circumference. The chapels on the xy axes belong to the "QC" classification in the nomenclature defined in Chapter 3, i.e. they are made up by a square combined with semicircular niches. In particular, following the methods previously defined for the analysis of this type of chapel, it belongs to the "A" type, i.e. the one with pilasters in the intersections between the lengthening of the niches and a dome on four spherical pendentives, and the ratio D/L is equal to 0.5. The chapels placed on the diagonal axes, on the other hand, are circular. Given all these observation and using the nomenclature method previously defined, this layout can be classified as I/C/A-QC(a) D-C/BY[12].

The type of chapel used in the xy axes is a recurring element in many churches of this manuscript, both as independent edifice[13] and as chapel, and also in the drawing of interiors made by Leonardo in other manuscripts[14]. This solution is almost identical to the one found in one of the reference listed in Chapter 2, i.e. the Sacello Carolingio in the church of Santa Maria presso San Satiro at Milan (see fig. 20, on the next page). The interior drawings made by Leonardo and the example of the Sacello Carolingio were the reference that was used to make assumptions on the articulation of voids inside the four-lobed chapels, as will be thoroughly described in the section about the explored variants.

12 I since the central octagon is Irregular, C since the chapels are placed following a circumference, A-QC(a) since - as it was just explained - the chapels on the main axes belong to the QC(a) classification, D-C since the ones on the diagonal axes are circle-based and BY for the presence of an external square based volume that joins the chapels.

13 See the analysis conducted for f. 93v, which shows many variants of this layout solution used for churches.

14 Leonardo uses this layout in the interior views depicted in Codex Atlanticus, f. 104 r and Royal library, Windsor Castle, f. 12609 v. See Chapter 2 for specific consideration regarding these drawings.

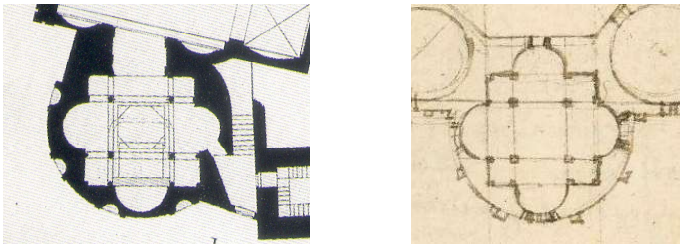


Fig. 21 - Comparison between the Sacello Carolingio's plan view and that of the church depicted in ff. 18v-19r

The plan view is more detailed and accurately drawn, also thanks to its greater dimensions (approximately 97x97 mm) compared to that of the perspective view (approximately 66x70 mm) and to the use of drawing tools, but it shows some evident *pentimenti,* on the upper left corner, where the chapels were previously designed to be smaller. Also in the perspective view - even though they are less evident - it is visible the trace of some modifications occurred to the drawing (mainly in the drum and in the dome of the left and the right chapel).

Another peculiarity of this drawing is that, even though it is among the most accurately drawn churches, the differences between plan and perspective view are evident and show some kind of reconsideration or reasoning in process for the layout. For this reason it was necessary to develop two different solutions according to these differences.

3.3.1. Plan and elevation analysis

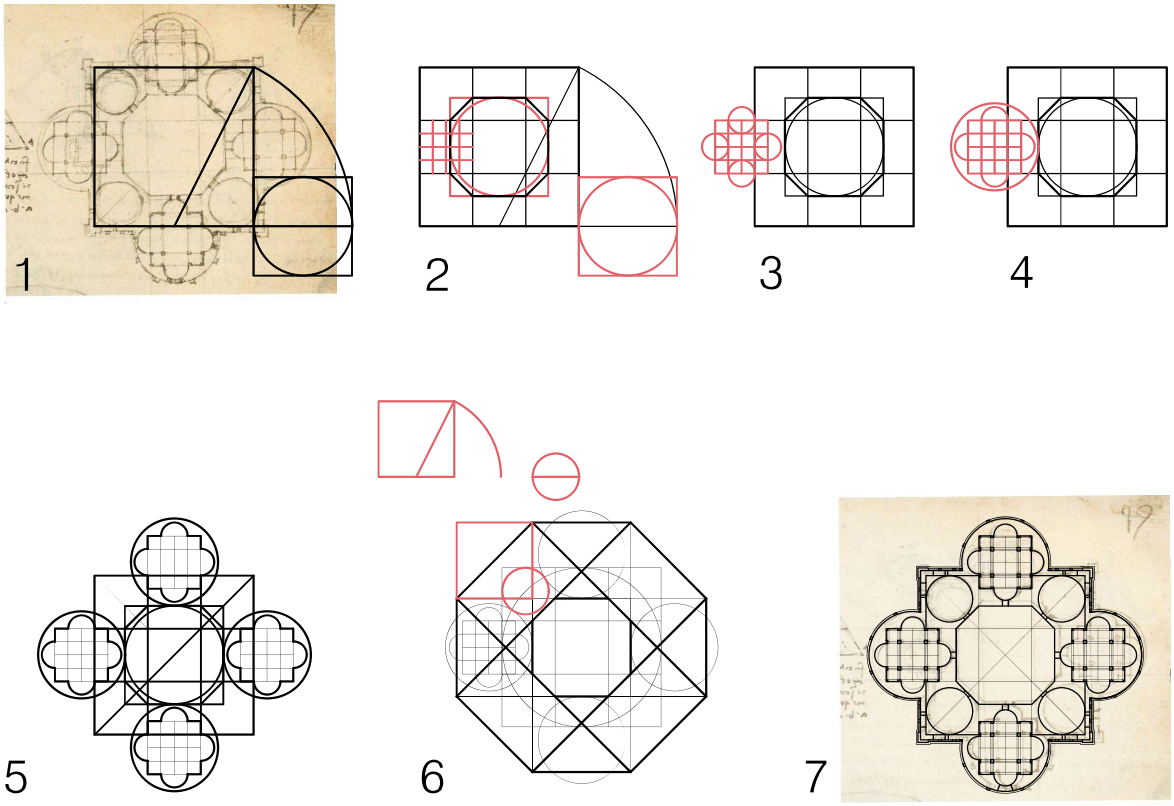


Fig. 22 - Geometrical process for the reconstruction of the plan.

The construction of the plan starts from the application of the golden ratio to the perimeter square (1), as in the previous case (f. 17v 18r B). The square that was just defined, circumscribes the central octagon, which is obtained dividing each side of the perimeter square in three parts. The intersections between the subdividing lines and the smaller square constitute the vertices of the central octagon (2).

The four-lobed chapels are then drawn by dividing one of the nine squares obtained in the last step in sixteen parts and translating it (3). Then, the circle-based external perimeter of the chapel can be drawn as the circumference centred in the chapel and tangent to the octagon (4).

In order to draw the circular chapels placed on the diagonal axes, the sides of the octagon were lengthened, in a process used many time by Leonardo and connected to the Silver Ratio[15]. The resulting square obtained in the corner was then used to draw the circumference related to it by a golden ratio (6). This constitutes the base of the chapel and can be placed in tangency both of the chapels on the xy axes and of the perimeter square.

As we will describe in the next section, also F. P. di Teodoro studied this plan and suggested a geometrical process to construct it. Nevertheless his solution differs from the one that was just described for the last step and leads to a slightly different output.

Regarding the proportions in the elevation, to the contrary, the solution proposed by di Teodoro was used without any adjustments: as can be seen in Fig. the total height of the building and that of its parts is related to half the length of the perimeter square's side and its golden section.

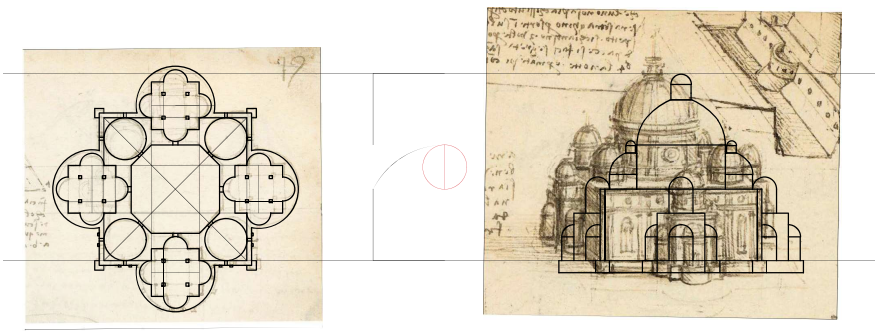


Fig. 23 - Relationship between the geometry in plan and the proportions in elevation.

3.3.2. Di Teodoro's process

The process proposed by F.P di Teodoro differs from the one described in the previous section in the last step (6). In fact, in his work, he suggested that the diameter of the circular chapels was equal to half of the diameter of the circumference that surrounds the four-lobed chapels.

However, by applying this hypothesis it is impossible to obtain a perfect tangency between the chapels and the circumscribing perimeter square, while, in the previous case the tangency is obtained.

15 In fact, lenghtening the sides of the octagon, the result is the next regular octagon in the Pell Series.

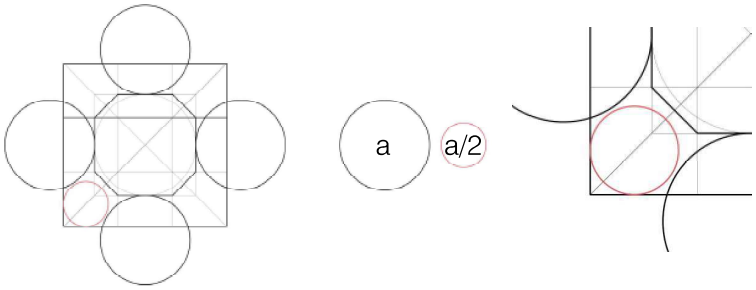


Fig. 24 - Illustration of the process proposed by F. P. di Teodoro and result (on the right).

3.3.3. Consistency between plan and perspective view

As we mentioned before, there is an evident lack of consistency between representations in plan and in perspective of the four lobed chapels. In fact, while in plan Leonardo draws a circle-based volume that encloses the voids of the chapel, in the bird's-eye view the interior shape emerges outside and is visible with the articulation of niches.

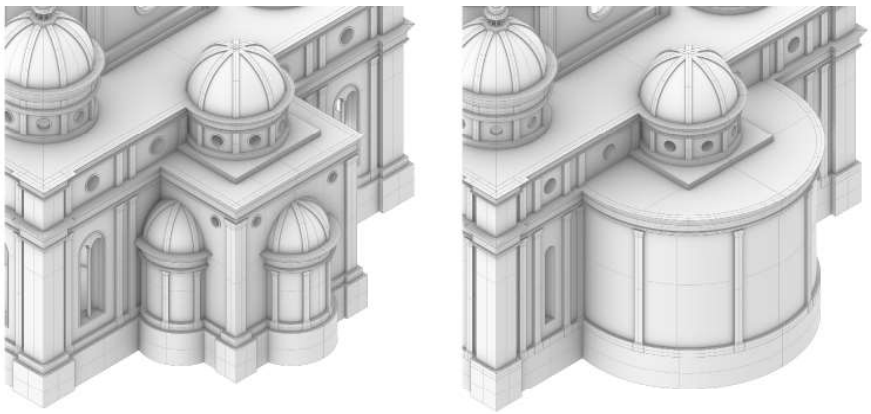


Fig. 25 - Comparison between the exterior shapes of the chapels in the bird's-eye view (1) and in the plan view (2).

The first solution recalls that - already mentioned - of the Sacello Carolingio in Santa Maria presso San Satiro. However, as explained in Chapter 2, the external circular volume that surrounds the niches is not a pre-Romanesque feature of the church, but was in fact added by Bramante. We know that the previous external appearance of the Sacello, before Bramante's alteration, showed instead the internal articulation of volumes through niches, in a way that should have looked more like the solution proposed by Leonardo in the bird's-eye view of this church.

The inconsistencies between plan and perspective view however also regard the diameter of the chapels' drums. In fact it is not possible - starting from the plan - to obtain exactly the same distance between the elements, as depicted in the perspective view. In this case the solution was the one that made it possible to obtain the maximum level of consistency between the views, but the possibility of modifying the plan was excluded. In fact, being the latter the element drawn with the maximum accuracy, it seems likely that this last difference is caused by involuntary errors that free-hand drawing can lead to.

3.3.4. Types of dome

The dome drawn by Leonardo seems to be spherical, but its *tiburio* is octagonal. For this reason two solutions were explored: one with a cloister vault, on the example of Santa Maria del Fiore, and one with an umbrella vault. Using the latter, it is possible to reach a better level of visual correspondence with Leonardo's drawing.

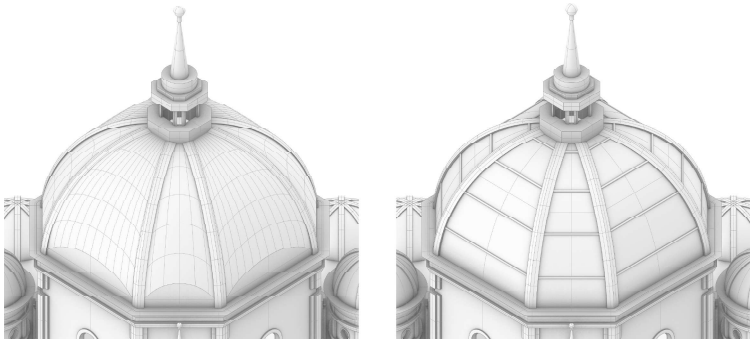


Fig. 26 - Comparison between the solution with an umbrella vault (1) and with a cloister vault (2)

3.3.5. Results

The solutions that were explored in this case involve several variables, that will be now listed for the sake of clarity:

1. Source of information (plan or perspective view);
2. Type of dome (cloister or umbrella);
3. Reference used for the interior of the four-lobed chapel (the Sacello Carolingio or f.104 r C.A.);
4. Type of vault in the corners of the four-lobed chapel (sailing vault, groin vault or a flat ceiling).

Therefore the total number of combinations explored is equal to 24.

While the first two groupings were already discussed, the last two variables shall now be further explored. Both the distinctions come from the lack of information about the interiors.

Regarding the distiction between the reference that was used, this emerges from the necessity to find a way of increasing the voids in the chapels' interior space. This goal can be achieved in several ways, so, it was important to choose some references useful to support any hypothesis. The first solution presents a matroneum overlooking the central space, as in one of Leonardo's drawing of Codex Atlanticus (f.104 r) and in the hypothesis made by J. Guillaume for the church in f.95v, while the second one is based on the example of the Sacello Carolingio, in which the barrel vaults' imposts are higher than that of the niches, and in that of f.12609 v of the Royal Library collection.

Fig. 27 - Comparison of the variants generated for the interior possibilities and references. The first solution takes inspiration from CA, f.104r and Guillaume's work, the second one from Windsor Castle, f. 12609v and Sacello Carolingio.

Fig. 28 - Comparison between the solutions: axonometric section.

The elements of uncertainty, however, also include the type of ceiling used in the corners of the four-lobed chapels. Three types have been considered: sailing vault, groin vault or a flat ceiling. In the drawings of interiors considered in Chapter 2, in fact Leonardo used a flat ceiling solution (in Royal library, Windsor Castle, f. 12609 v) and a solution with arches that could hide behind a groin or sailing vault (in Codex Atlanticus, f. 104r).

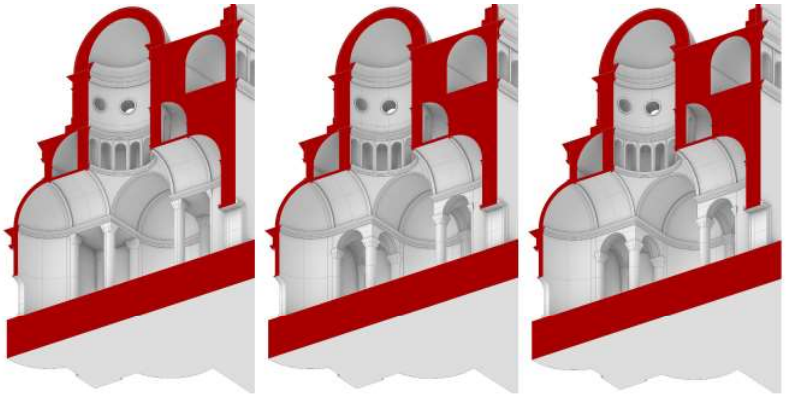


Fig. 29 - Comparison between the three possibilities for the corners of the chapel.

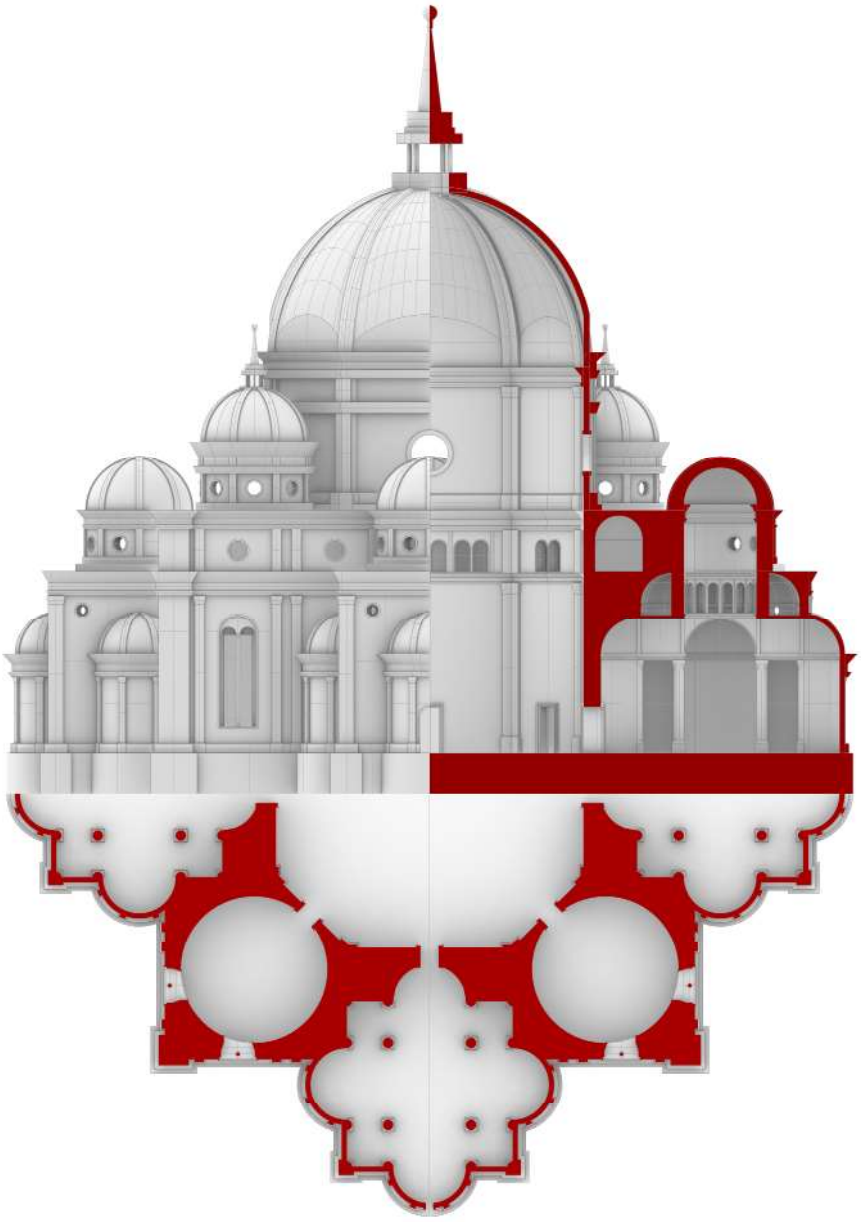


Fig. 30 - Plan, section and elevation of the variant obtained by the bird's eye view, with an umbrella dome and a chapel with flat ceilings in the corners and a central *matroneum* (1:500).

3.4. Folio 21r (A)

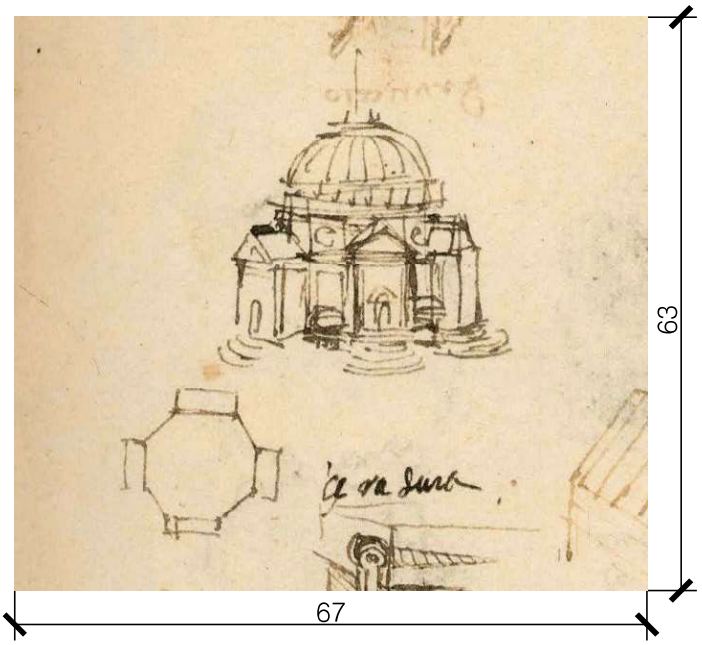


Fig. 31 - Ms. B, f. 21r: Detail of the church "A" with the dimensions of the drawing in mm.

F. 21r contains the drawing of two churches, that share a similar layout, since they do not present any chapel on the diagonal axes. In the first one, that we named "A", the design is one of the simplest and the drawing is really quick and synthetic. The plan, in fact, only contains the main guidelines, while the bird's-eye view is evidently drawn really quickly and the drawing overall measures just approximately 51 mm x 59 mm.

As regards the layout of the church, it is made up by an octagonal central space surrounded by four rectangular chapels on the main axes, therefore it can be classified as I/C/A-R/BN. In this case, nevertheless, the chapels are not connected through an opening, but are completely merged into the central space - almost resembling a Greek cross plan. An element of interest is represented by the presence of entrances, in the bird's-eye view, on four sides. This way Leonardo solves the problem of the entrance, that would otherwise break the symmetry.

The lack of accuracy in the drawing makes it necessary to rely on references. The principal one, in this case, is represented by the church of Santa Maria delle Carceri at Prato (even though it is later than the period when Leonardo wrote Manuscript B). The reference was used in particular for the interior definition of the chapels, that were covered internally with a barrel vault. The octagonal central space, nevertheless, makes it impossible to use the same solution visible in Santa Maria delle Carceri (a circular drum on four spherical pendentives at the crossing of the vaults), so, for the central element, the reference was instead Cappella Chigi at Rome.

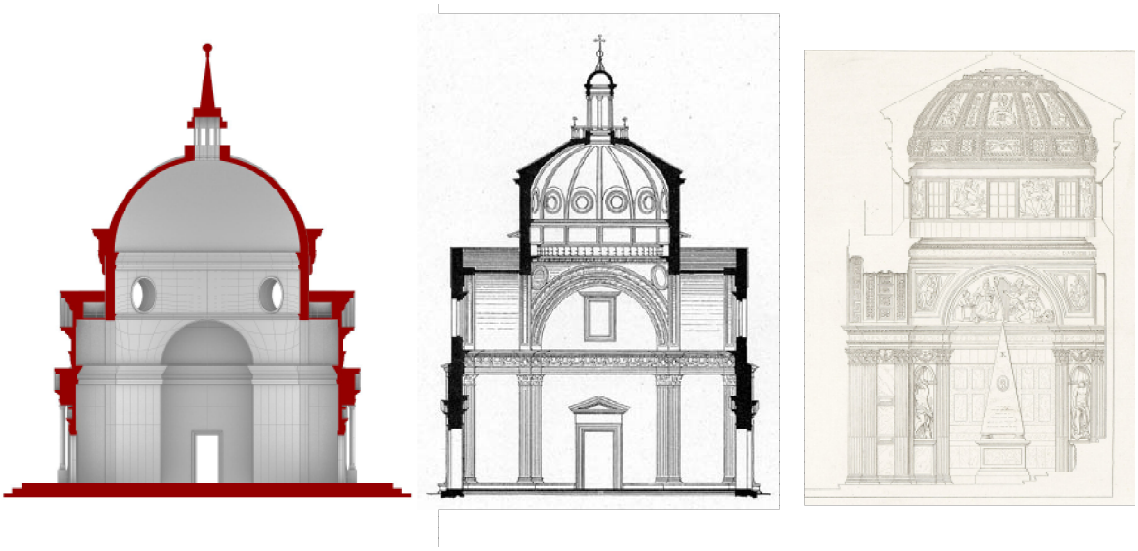


Fig. 32 - Comparison between our solution (1), that of St. Maria delle Carceri at Prato (2) and Cappella Chigi (3).

In this case, as we will see, the variants only differ from the type of entrance, since the level of detail of the drawing only let us know the approximate dimension of the opening compared to the façade and the fact that it should be surmounted by a *tympanum*.

The overall dimensions of the church were hypothesized on the basis of the width of the entrance doors, that was assumed to belong to a range of 1.5 to 2 metres (like in the example of Cappella Colleoni at Bergamo) and on the width of the circular windows in the drum, that should not be much greater than 2 metres in order to respect the observations made in Chapter 2 (in this case it has a width equal to 2.2 m).

3.4.1. Plan and elevation analysis

The process of reconstruction of the plan in this case is deliberately very simple, since Leonardo's drawing itself is systematic. Moreover the drawing is not easily measurable because it was drawn free-hand. The hypothesis we make is that the octagon is constructed dividing each side of a square in four parts, and that the extension of the chapels is equal to the side of the regular octagon that is inscribed in the square obtained joining the opposite vertices of the first octagon (this square has therefore a side equal to half the diameter of the bigger octagon).

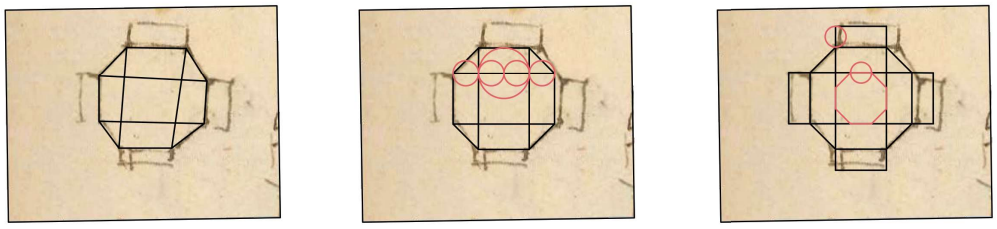


Fig. 33 - Geometrical process for the reconstruction of the plan.

Regarding the elevation, on the other hand, the variability of the drawing makes it impossible to

get some reliable results of proportion. For this reason, in this case, I simply tried to find a scale for the birds'-eye view that could be compatible with the lines of the plan (used as reference for the interior of the building), and then I proceeded with measurements of the parts.

3.4.2. Consistency between plan and perspective view

In this case it is pointless to find the differences between plan and perspective view, because the first one constitutes just a systematic drawing, as it was already stated before.

3.4.3. Results

In this case three solutions were modelled, on the basis of the entrance. This one was modelled according to coeval architectural references and the assumption made for this architectural element were later used also for the other churches, when facing the same problem.

The overall reference used to model the portal's cornice and define the proportions between its elements is, in all the solutions, the church of Sant'Andrea at Mantova, by Leon Battista Alberti. Then, in order to define the specific elements of the portal, three solutions were made following some references for each one[16]:

1. A detail of the painting "The Ideal City" of Baltimore
2. Raffaello's drawing for a scenography
3. The portal of the Reggio Emilia Cathedral

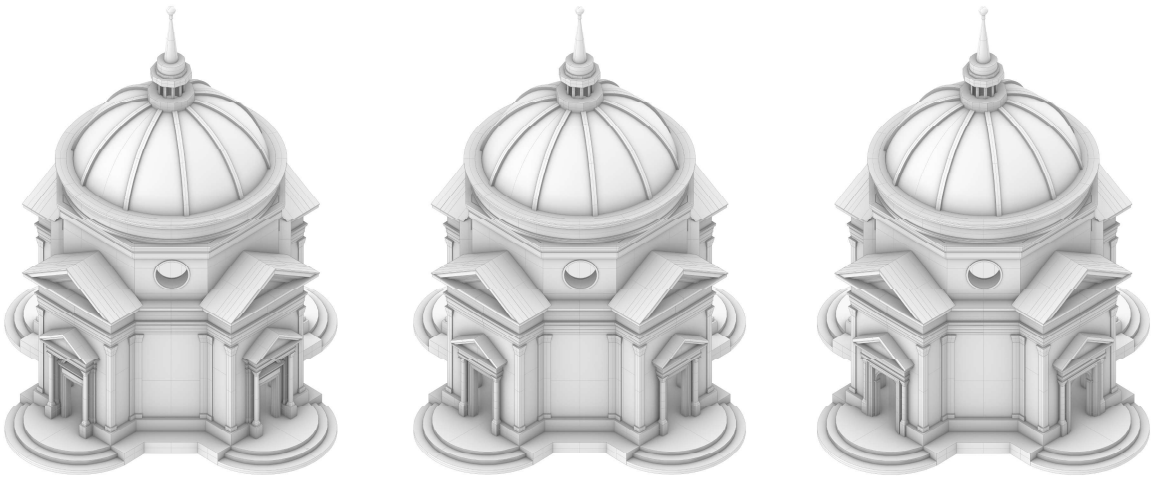


Fig. 34 - Comparison between the three modelled variants: axonometries.

16 In order to understand the elements that compose the church, also the three-dimensional model of Giuliano da Sangallo's Mausoleum for Giulio II made by Alice Cancilla and Elena Masina was considered, for its similarities with this case.

Fig. 35 - The variants of the entrance portal and the relative reference (from left to right): (1) "The Ideal City" of Baltimore, (2) Raffaello's drawing for a scenography and (3) The portal of Reggio Emilia Cathedral.

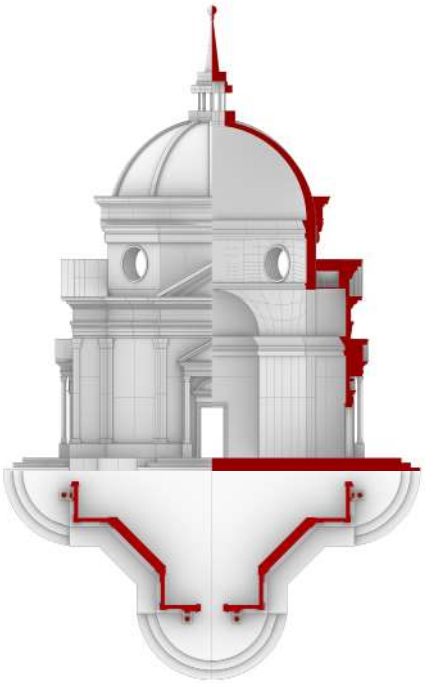


Fig. 36 - Plan, section and elevation of the first variant (1:500)

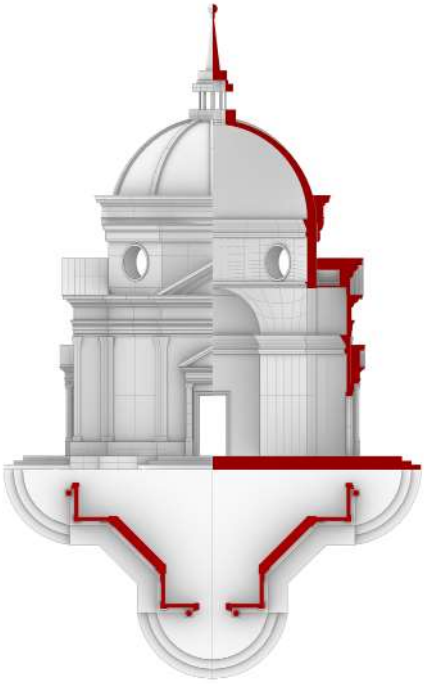


Fig. 37 - Plan, section and elevation of the second variant (1:500)

3.5. Folio 21r (B)

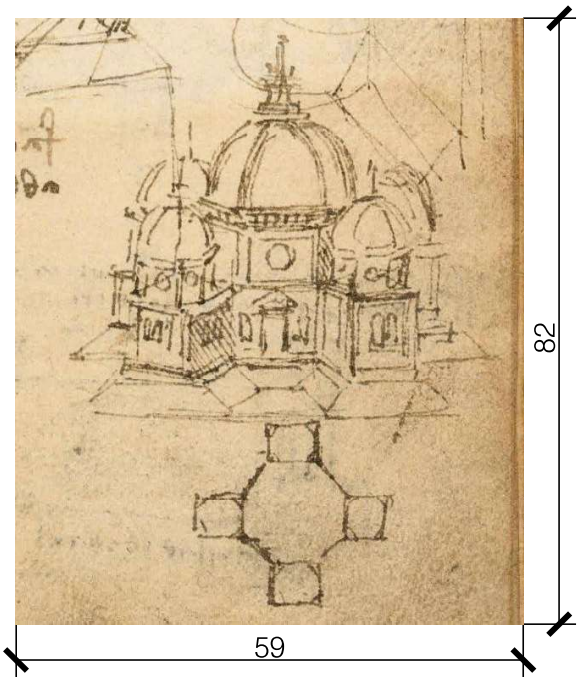


Fig. 38 - Ms. B, f. 21r: Detail of the church "B" with the dimensions of the drawing in mm.

The second church depicted in folio 21r, here named "B", is, as well as the previous case, quickly sketched in both plan and bird's-eye view. However, the dimension of the drawing is slightly greater than in church "A" (about 59 mm x 79 mm), so it was at least possible to try to analyse the proportions in the elevation, as will be soon presented.

The layout of the church is composed by an octagonal central space surrounded - on the main axes - by four square-based chapels, therefore it can be classified with the code R/C/A-Q/BN. It is similar to that of one of the references described in Chapter 2: the church of Santa Maria della Croce in Crema.

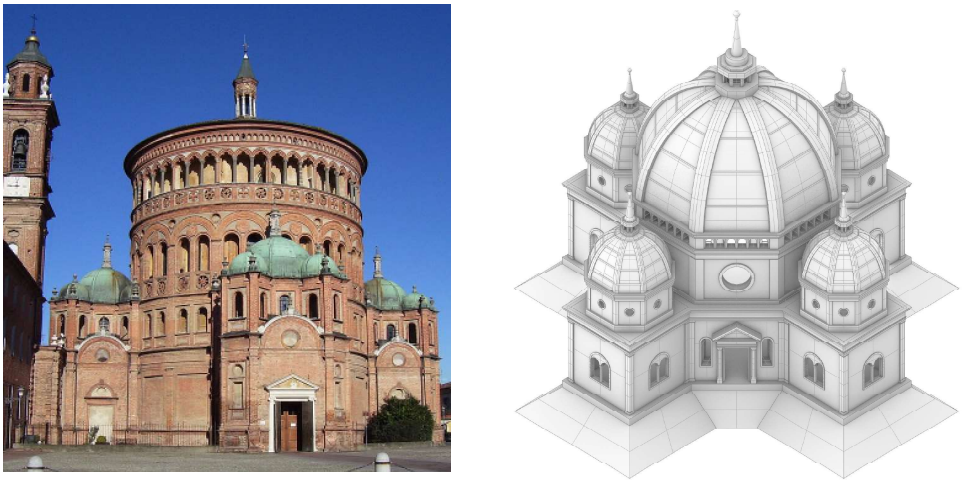


Fig. 39 - Similarities with the four chapels layout of Santa Maria della Croce at Crema.

There are, as will be thoroughly described, some inconsistencies between plan and perspective view, that are probably related to the feature of the plan's drawing, which is just systematic, and therefore did not lead to the production of two variants, but only to some adjustments in plan. In this case, this procedure was considered correct, because of the lower level of detail in plan, rather than in the perspective view.[17]

3.5.1. Plan and elevation analysis

The central space is a regular octagon, while the squares' sides of the chapels have the same length of the octagon's side. Dividing the latter in sixteen smaller square it is possible to obtain an octagon that has later been used as reference for the interior of the chapel.

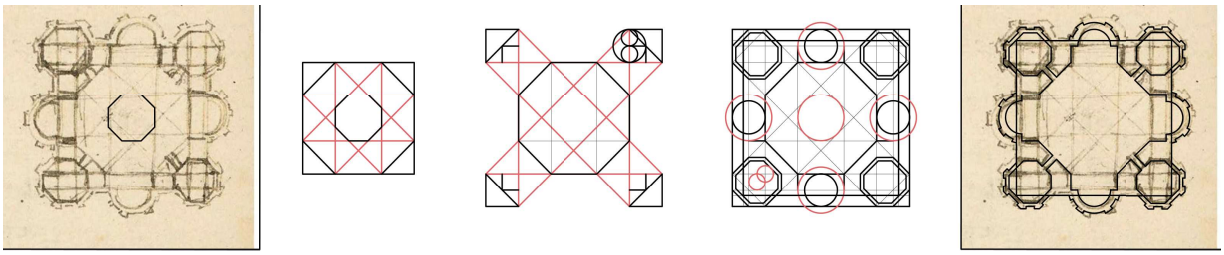


Fig. 40 - Geometrical process for the reconstruction of the plan.

Once scaled the bird's-eye view according to the plan, it is possible to relate the total height of the church and that of its parts to the diameter of the central octagon.

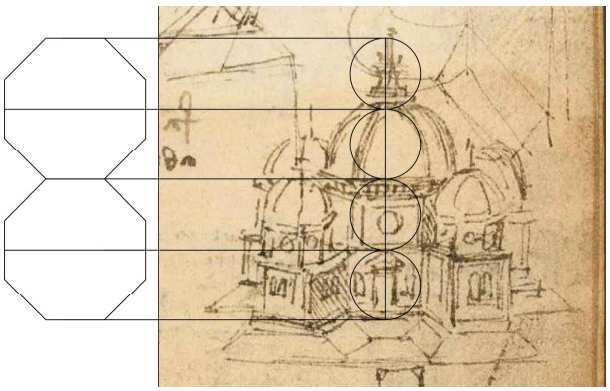


Fig. 41 - Relationship between the geometry in plan and the proportions in elevation.

3.5.2. Consistency between plan and perspective view

While in the perspective view the octagonal drums of the chapels are separated from the main octagonal drum, in plan the chapels are depicted as perfectly tangent to the octagon (like in the

17 This constitutes, in fact, a peculiarity in the drawings of the Manuscript, since in the majority of cases, the plan is bigger and or drawn with the help of drawing tools, while the birds'eye view is often just free-hand sketched.

case of church "A" of the same folio), making it impossible to separate the drums in their development in height. For this reason, I decided to consider the plan just as an indication for the interiors of the elements that assemble the church, and to slightly distance the chapels from the central octagonal space.

3.5.3. Results

In this case it was not necessary to produce any variant, as it was already explained in the previous sections. However, the considerations made for the other church of this folio were used in order to model the portal of this church. In this case the drawings is slightly more accurate about the entrance and let me use just one of the solutions previously found for the entrance.

In this case, the scale of the building was hypothesized according to both exterior doors, round windows, single and double arched windows, using the reference dimensions identified in Chapter 2 and trying to find the scaling solution that could fit best all the architectural element listed above. In particular the width obtained for each element will be now listed for clarity, along with their reference dimension in brackets[18]:

1. Single-arched windows: 0.8 m (1.0 m)
2. Double-arched windows: 2.1 m (2.0 m)
3. Rounded windows: 2.3 m (2.0 m)
4. Exterior door: 1.9 m (2.0 m)

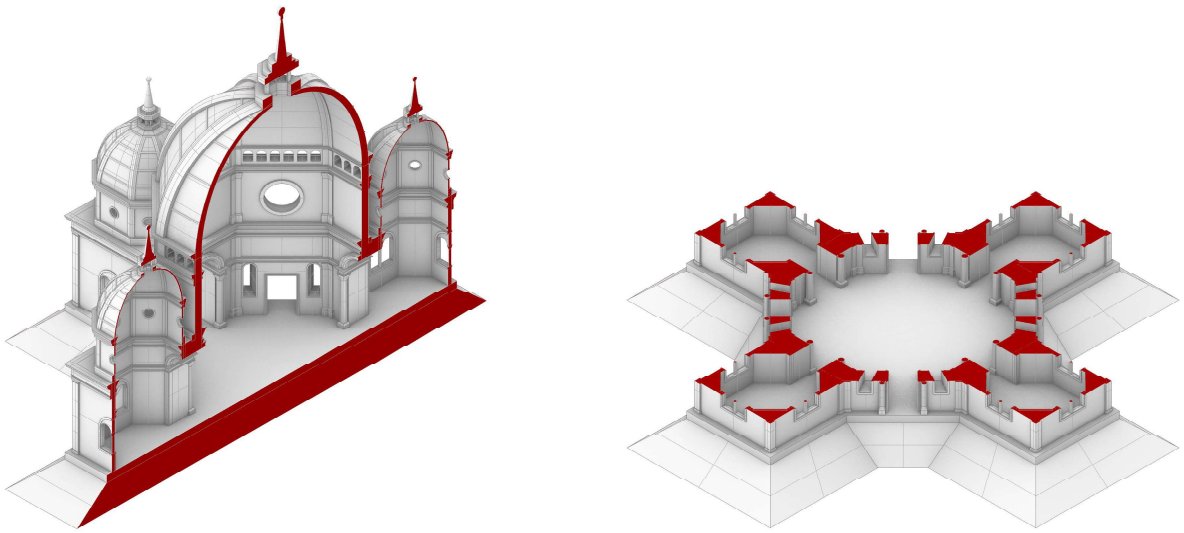


Fig. 42 - Horizontal and vertical axonometric sections.

18 See Chapter 3 for further explanation about the dimensions used as reference.

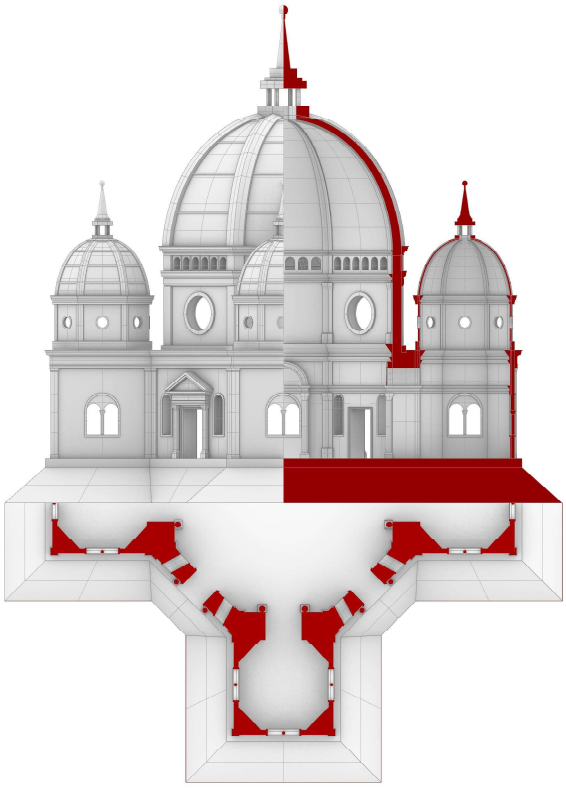


Fig. 43 - Plan, section and elevation (1:500).

3.6. Folio 21v

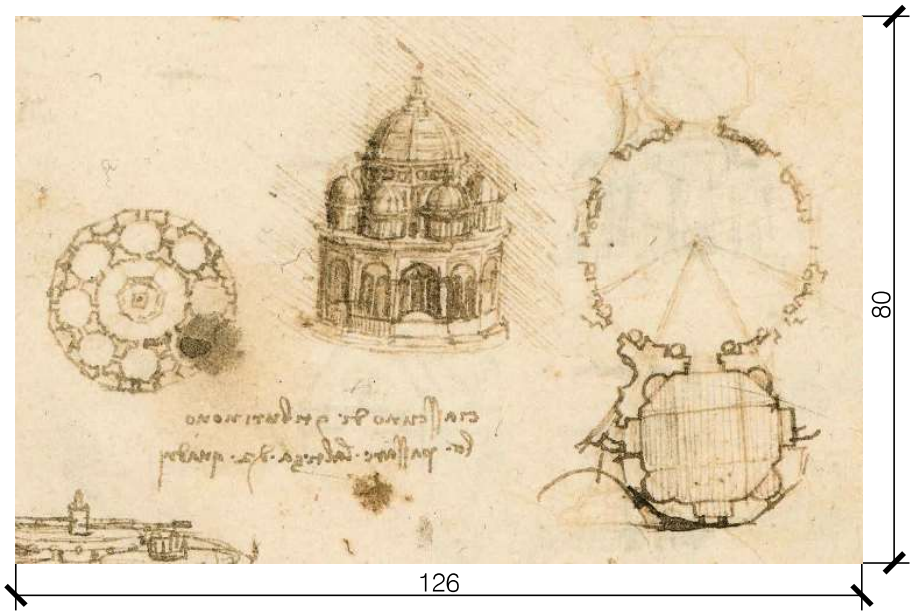


Fig. 44 - Ms. B, f. 21v: drawing of the church with its dimensions in mm.

The church depicted in f. 21v has some interesting peculiarities: Leonardo added some details to the plan by drawing an enlarged portion of it, thus taking advantage of the multiple axes of symmetry of the church, below which he annotates *"Quest'è come le 8 cappelle hanno a essere fatte"* (i.e. this his how the eight chapels have to be done"). The drawings however are particularly small, since the plan measures just 30 mm x 30 mm, the bird's-eye view 34 mm x 45 mm and the detail of the plan 42 mm x 64 mm.

Moreover this is the only church - along with the one in f. 94r - where Leonardo added a note regarding the dimensions of the building. In fact the annotation below the perspective view says:

"Ciascuno de' 9 tiburi non vole passare l'altezza di due quadri"[19]

I have not found, however, any hint of what unit of measure Leonardo could have meant by "quadri" , so the overall dimension of the church was decided - like in the other ones - on the basis of the width of doors and windows.

The layout of the church is characterised by eight equal octagon-based chapels, placed around the central octagonal space along a circumference, joined by an hexadecagon-based volume and thus can be classified as R/C/A-O D-O/BN[20].

The octagonal chapels, thanks to their niches on the smaller sides of the octagon, resemble one of the examples identified in Chapter 2: Cappella Chigi at Rome. This example, thus was used

19 I.e. "each of the 9 *tiburi* must not be higher than two *quadri*"

20 R since the octagon is Regular, C since the chapels are placed along a Circumference, A-O and D-O because the chapels placed on both the xy axes and the diagonal ones are octagonal and BN because there is not any square based volume embracing the chapels.

in order to solve the transition between an octagonal base and a circular drum. Regarding the overall layout, the influences from the Brunelleschi's Rotonda are many: the narrow passages between the chapels, the articulation of niches around the perimeter of the chapels themselves, the octagonal central space.

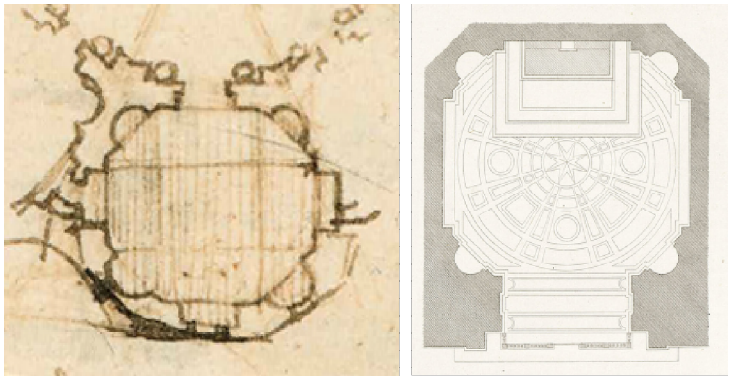


Fig. 45 - Comparison with the plan of Cappella Chigi.

3.6.1. Plan and elevation analysis

The analysis of the process suited to obtain the plan, was conducted on the detail drawing, since it is more accurate and easier to measure. The geometric construction stars from the central octagon of the church: its sides are lengthened[21] and the intersections define a greater octagon (1). The distance between the sides of the two octagons is used to draw a circumference and a square, circumscribed to it. The sides of the square are then divided in three parts (2), joining the endpoints just obtained it is possible to draw an octagon inscribed in the square, that will be used as a guide to draw the interior boundaries of the chapel itself. To obtain that, the square whose vertices are on the midpoints of the oblique sides of the octagon is drawn. Then, each side of the square was divided into four segments and the octagon with the niches could be drawn (3). Then, the diameter of the niches was used in order to define that of the internal passages between the chapels (4).

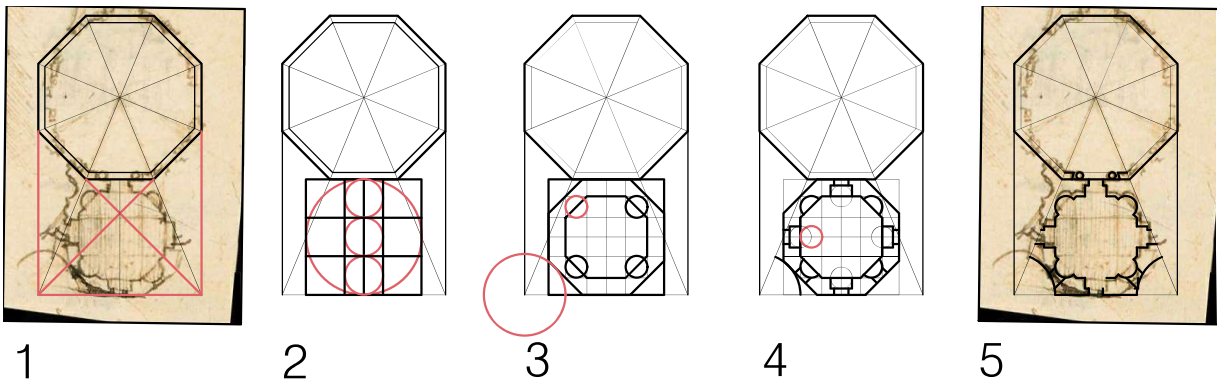


Fig. 46 - Geometrical process for the reconstruction of the plan.

21 Every time the sides of a regular octagon are lengthened in order to find the intersections between horizontal/vertical and oblique sides the result is the next regular octagon in the Pell Series, which, once again, demonstrate the recurrence of this geometric construction in Ms. B.

After scaling the perspective view according to the plan just obtained[22], it is possible to find some correlation between them. In particular, there seems to be a relationship between the overall height of the building (until the upper end of the drum) and the overall extension in plan and, moreover, the height of the single parts, as the drums of the chapels, can be seen in relation to fractions of the overall extension in plan.

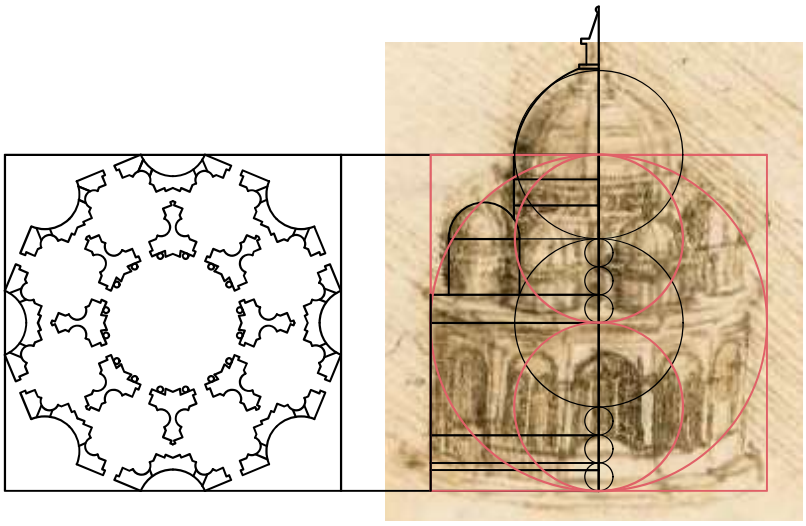


Fig. 47 - Relationship between the geometry in plan and the proportions in elevation.

3.6.2. Consistency between plan and perspective view

Plan and perspective view show some inconsistencies and this led to the production of two variants. These inconsistencies involve two elements: the windows and the extension of the niches in the façade.In the bird's-eye view, in fact, Leonardo draws some really large double-arched windows in correspondence of each chapel (so big that it may appear oversized if compared with the other elements of the church), while in the plan he just draws a narrow opening that may be a single arched window. The second element of inconsistency is represented by the extension of the niches, that in plan seems to be equal to the width of the side itself, while in the perspective views it appears slightly smaller than the side of the wall where it is placed.

As anticipated there is one element in this representation that makes it difficult to obtain with enough certainty the correspondence in scale between plan and perspective view. The perspective view, in fact just shows five sides of the external hexadecagon (instead of seven), so it is impossible to use the overall extension of the edifice in plan. as reference for the scaling process. Instead, the width of the front side of the hexadecagon was used, making it equal to its width in plan.

22 In the next sections I will make some observations regarding this procedure, since, for this church, there are some problems in the representation that makes it more difficult to evaluate the right scale to give to the perspective view.

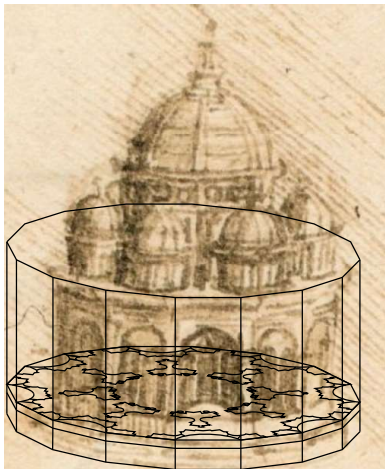


Fig. 48 - Comparison between the number of sides that should be visible and those that were drawn.

3.6.3. Results

The solutions produced differ, in this case, for the main source of information (plan or perspective view). Both of them, however, had to be scaled according to the dimension of windows and doors (both interior and exterior). In particular, single arched windows show a width that varies between 0.8 m and 1.0 m, interior passages have it between 1.0 m and 1.5 m, rounded windows measure 1.0 m. The element that may be considered oversized, if compared with the architectural references, is the double-arched window, that measures approximately 3.0 m.

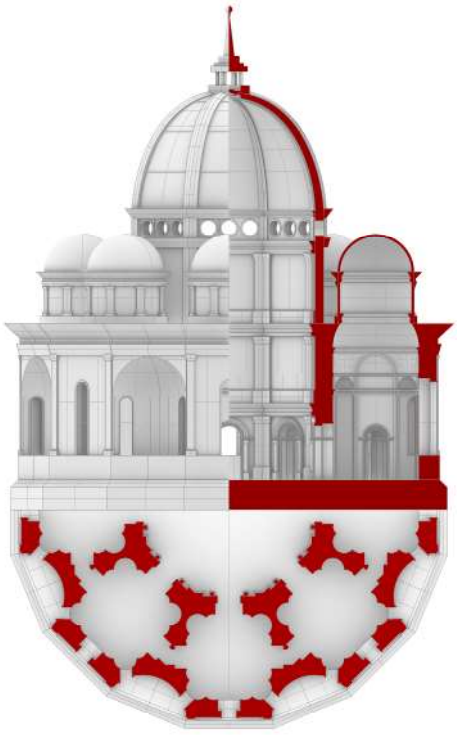


Fig. 49 - Plan, section and elevation (1:500) of the solution derived from plan.

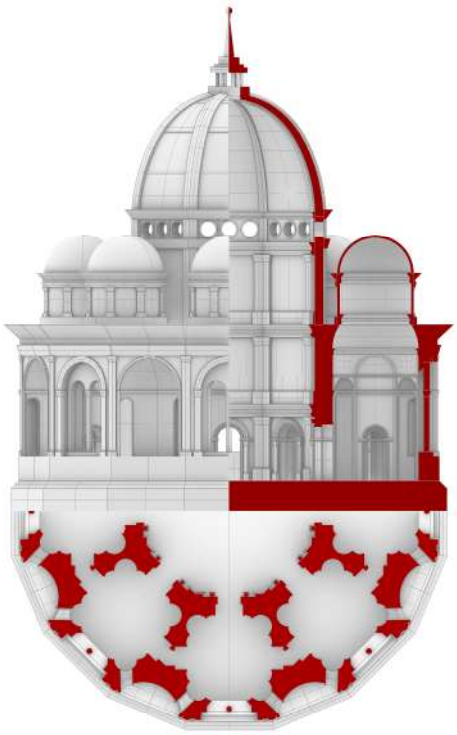


Fig. 50 - Plan, section and elevation (1:500) of the solution derived from the bird's-eye view.

3.7. Folio 22 r

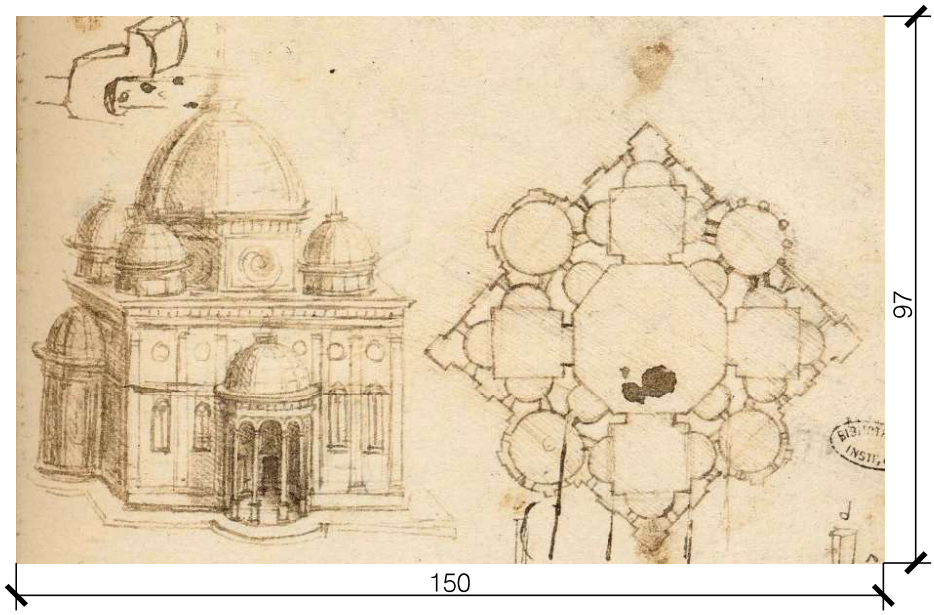


Fig. 51 - Ms. B, f. 22 r: drawing of the church with its dimensions in mm.

The church here depicted consists of a central regular octagonal space, with niches on its oblique sides, connected with eight chapels, alternated in shape, that are disposed around it along a square and that are enveloped by a square based volume. The chapels on the diagonal axes are circular, while the ones on the xy axes are a variant of the four-lobed chapel already analysed, even though it is not clear whether they should be classified as type B (i.e. a square central space with niches in its sides and the drum leaning on spherical pendentives) or type C (i.e. an octagonal space with niches on the major sides of the octagon and a drum that leans on pendentives, which are modelled as the example of Cappella Chigi in Santa Maria del Popolo at Rome and solve the transition between the octagon and the circumference).

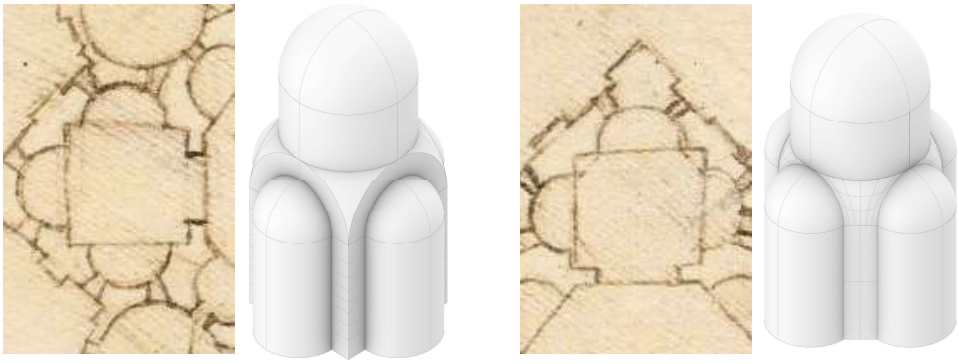


Fig. 52 - Comparison between the two variants modelled for the interior of the chapels: type B (1) and type C (2),

The inability to classify exactly the interior shape of the chapels is due to the fact that Leonardo draws them in two different ways in the plan view: in two cases the interior is octagonal, and thus was interpreted as type C, and in the other two chapels the interior is square-based, and therefore

is compatible with type B. For all these reasons this church can be classified as R/Q/A-QC(b) D-C/BY and R/Q/A-QC(c) D-C/BY (depending on the type of chapel QC is considered on the main axes).

The difference just pointed out leads to the production of two variants. However, there are also two more variables to consider: the inconsistencies between the plan and the perspective views and the height of the double-arched windows. This is due to the fact that Leonardo draws the latter in two different ways in the bird's-eye view, as we will describe in detail in the section about the solutions that were produced.

One other element of interest, besides the fact that Leonardo represented multiple solutions in the same drawing, is that for this church, whose representation is among the wider in the manuscript (about 80 mm x 80 mm for the plan and 72 mm x 97 mm for the bird's-eye view), he drew an entrance, consisting in a *portico*, in both plan and perspective view. It also may be noted that the representation in plan and in perspective are reciprocally rotated by 45°.

3.7.1. Plan and elevation analysis

The construction of the plan starts from the regular octagon at the centre of the plan, whose sides were lengthened (1), thus using once again the geometric construction of the silver section. The intersections between these are used in order to draw the perimeter square and, in the midpoints of its sides, four circumferences, whose diameter equals the length of the octagon's side. Then, the circumference that circumscribes the octagon was drawn and it was used to draw a larger octagon, that, in turn circumscribes the circumference. This last octagon was used to place the centres of the niches (2).

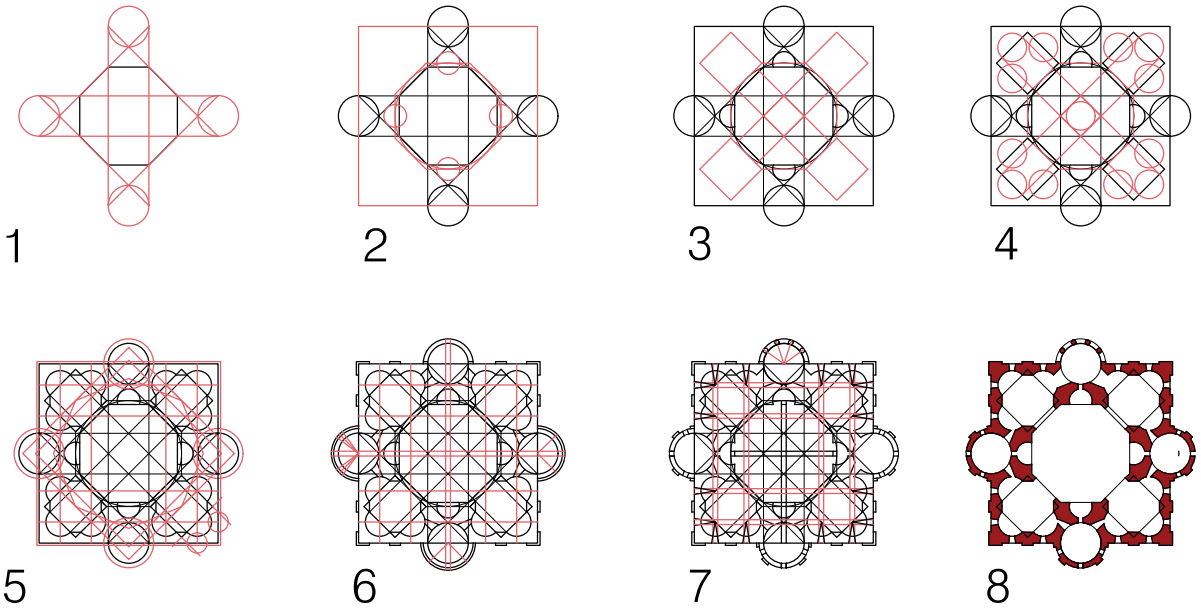


Fig. 53 - Geometrical process for the reconstruction of the plan.

Then, the squares for the second type of chapels, were drawn in tangency with the bigger octagon and with the same side length (3). Drawing the square whose vertices are positioned on the midpoints of the lines that divide internally the first octagon, it is possible to obtain the diameter of the niches in the chapels and also the width of the interior connection between these and the central space (4). Some of the interior doors (the one connecting the chapels) were drawn using as guidelines the square with its sides passing through the centres of the niches and the octagon with its vertices on the midpoints of the square's sides (5). Then, a vertical and horizontal grid, connecting the centres of the niches, was drawn and used to position the remaining windows and the interior passages (6 and 7).

Regarding the analysis in elevation, the height of the edifice up to the end of the drum is equal to the side of the perimeter square, and the total height seems to be equal to that plus its golden section.

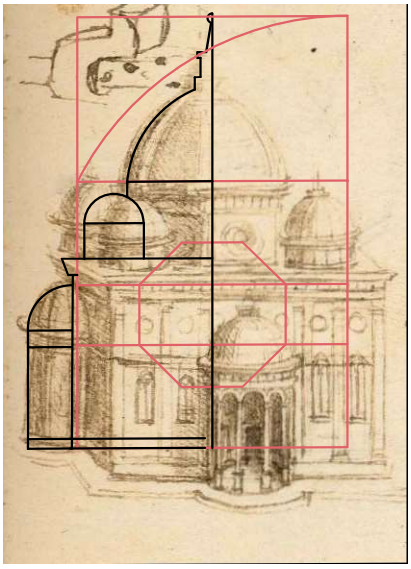


Fig. 54 - Relationship between the geometry in plan and the proportions in elevation.

3.7.2. Consistency between plan and perspective view

The differences between plan and perspective view just regarded the extension of the lesenes in the façade and thus led to two slightly different solutions. However, there is another inconsistency, that is impossible to solve, which is represented by the diameter of the chapels' drums and their distance from other elements in the perspective view. In fact, it is impossible, respecting the plan, to obtain this result in an exact way. However, since the plan is very accurate and made using drawing tools it was not considered the possibility to largely modify it (for example it would be necessary to modify the interior of the chapels in order to obtain such a large drum that stands so near to the edge of the roof without any intersection with the main *tiburio*).

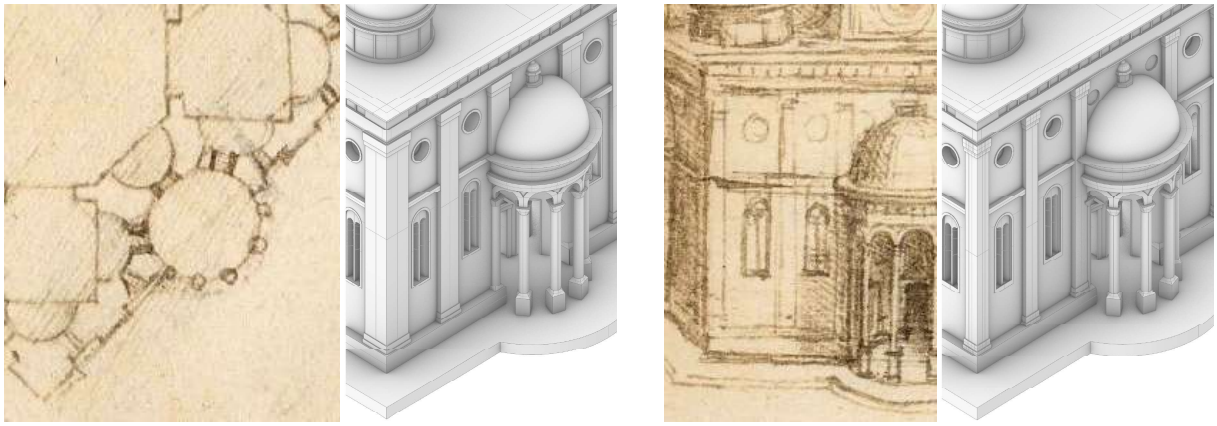


Fig. 55 - Highlight of the inconstencies between plan and perspective views and relative result in the 3D model (see the width of the *lesenes* and the position of the double-arched windows).

3.7.3. Results

The overall number of solutions produced is eight, each one related to the modification of one of the variables listed before.

In particular, as anticipated, one of these variables is represented by the height of the double-arched windows. In fact, in the perspective view, Leonardo draws two different solutions: on the right-hand side of the façade the windows are higher, while on the left-hand side they are shorter and above them there is a *cornice*.

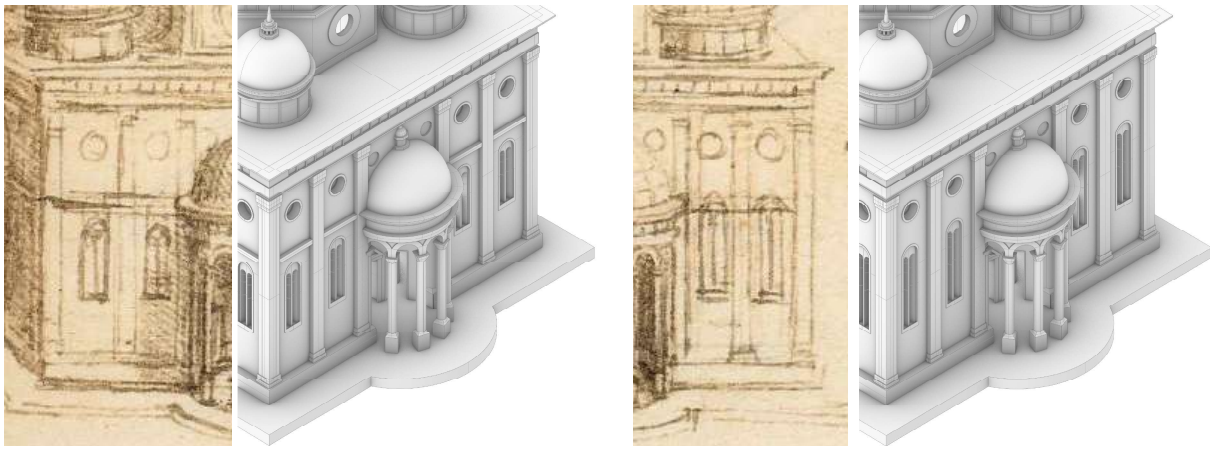


Fig. 56 - Comparison between the different height of the double-arched windows in façade.

For all the solutions, it was attempted to make an hypothesis for the dimension of the building, on the basis of the architectural elements' width. The process is the same already described and used for the other churches here analysed. The width obtained for each element will be now listed for the sake of clarity:

1. Single-arched windows: 1.0 m
2. Double-arched windows: 1.7 m
3. Rounded windows (in the drum): 2.5 m

4. Interior doors (minimum): 1.2 m
5. Entrance portal: 2.35 m

All of these measures are consistent with the ones defined in Chapter 2.

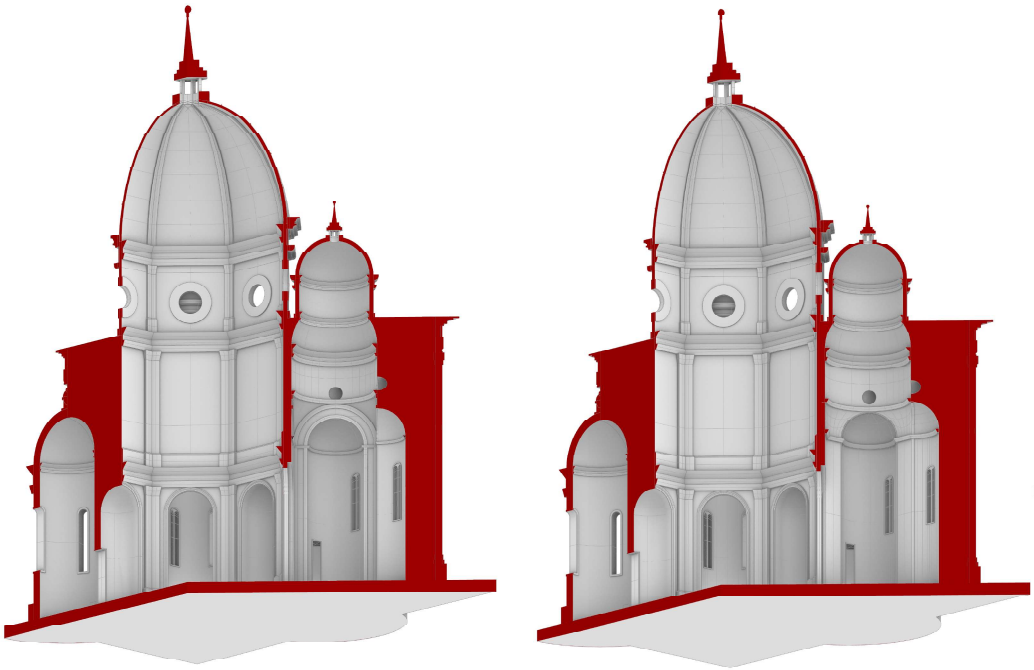


Fig. 57 - Comparison between the interior differences in the chapels in the final output (axonometric section). On the right hand side the chapel is square-based (type B), on the left it is octagonal (type c).

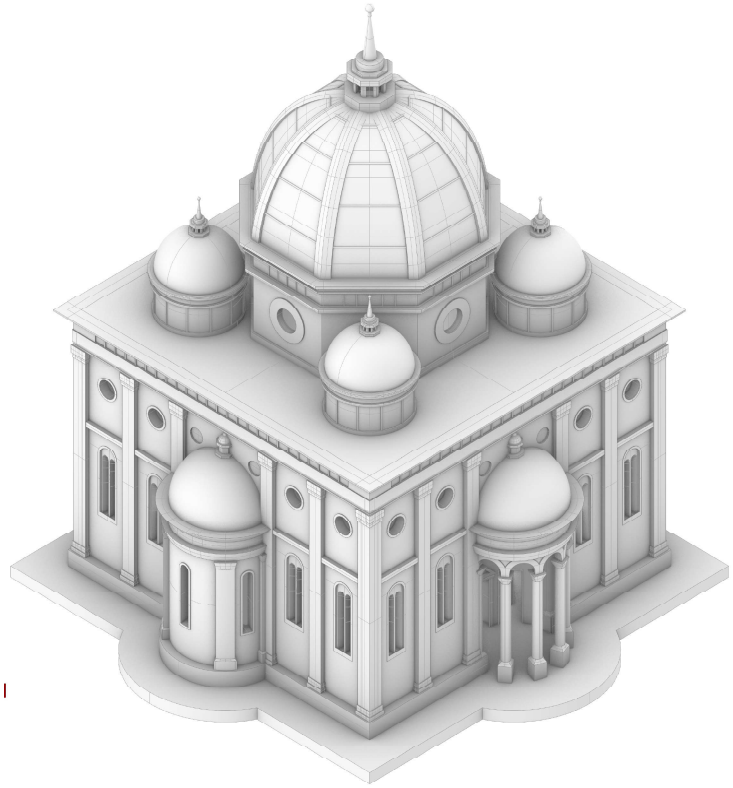


Fig. 58 - Axonometry of one of the eight outputs modelled.

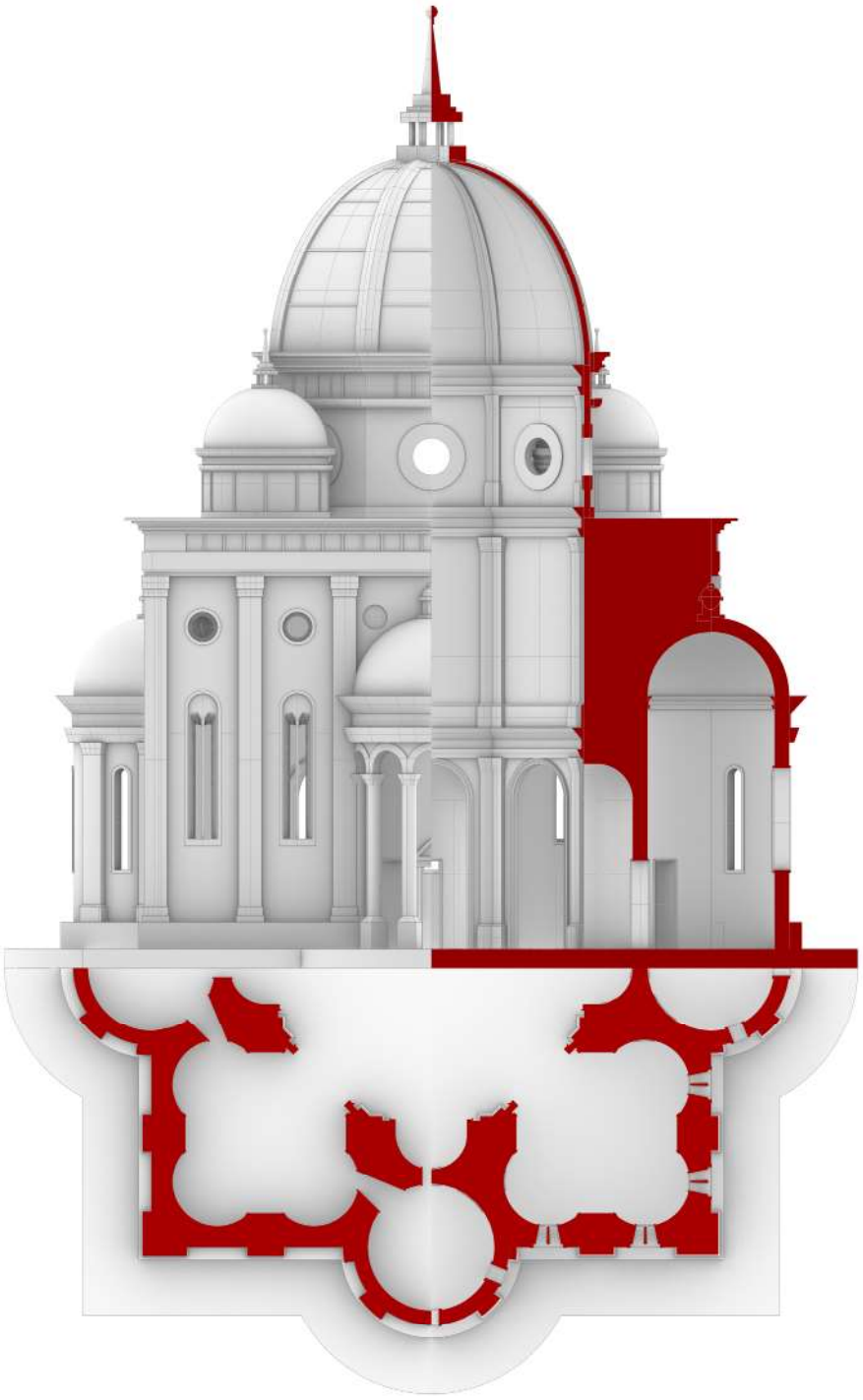


Fig. 137 - Plan, section and elevation of the variant obtained following the bird's-eye view, with type C chapels and high double-arched windows (scale 1:500 - in the appendix it is possible to see also the other 7 outputs). The plan views are obtained by sectioning the edifice at the level of the windows (on the right) and at the level of the doors (on the left).

3.8. Folio 25v A

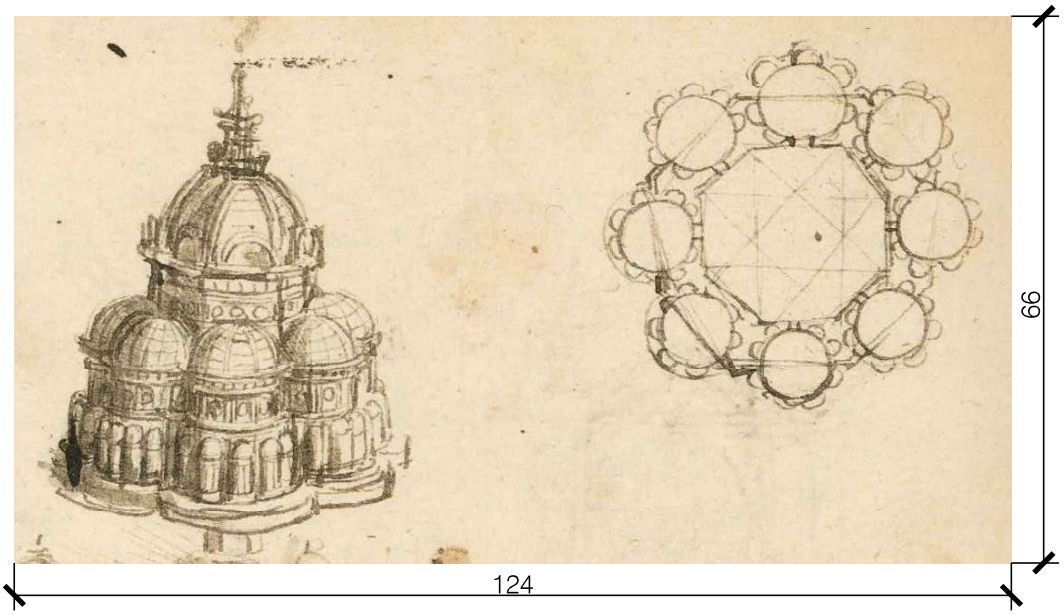


Fig. 59 - Ms. B, f. 25v: drawing of the church "A" with its dimensions in mm.

The folio 25v contains the drawing of two churches, along with two other plan views. The one drawn in the upper part of the folio will be here named "A" and the one drawn just beside it, "B".

Church A seems to be free-hand drawn in both plan and perspective views. It consists of a central octagonal space surrounded by eight equal chapels, which are circular and feature multiple niches on their perimeter (in this case the classification of the layout would be R/C/A-CC D-CC/BN). Neither the plan view nor the bird's-eye view show an entrance.

Given that the plan view is a schematic drawing, there wasn't any necessity to produce variants. In fact, the inconsistencies between the views are not so relevant in this case and the drawings can be easily adapted to be compatible.

However, it is likely that Leonardo drew this plan very quickly, since the number of niches in each chapel varies in the plan view.

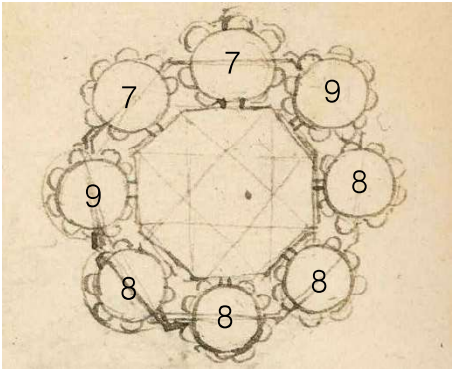


Fig. 60 - Number of niches in every chapel

In order to proceed with the three-dimensional modelling, it was decided to choose the number of niches that could allow to avoid their mutual intersection and that was the most frequently recurring in the plan view, that is eight.

However, the presence of consecutive niches, that completely surround the external perimeter of the church, resembles one of the main features of the church of Santo Spirito in Florence, whose niches were originally visible from the outside (but they were later incorporated into a thick wall).

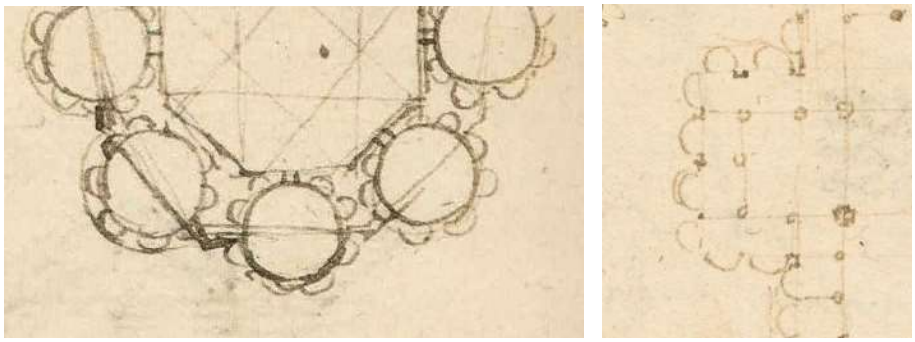


Fig. 61 - Comparison with the system of niches of Santo Spirito, as drawn by Leonardo in f. 11v of Ms. B.

Given that there are semicircular windows at the base of the dome, as in the case of the church in f. 17v - 18r (A), an umbrella dome was used. The references, as in the case just recalled, are the church of Incoronata in Sabbioneta and the several examples of churches with an umbrella dome in Florence.

Fig. 62 - Detail of the two domes of the manuscript that show semicircular windows and the interior of the dome of the church of Incoronata at Sabbioneta. In both cases the shape of dome more fitting was the umbrella one.

3.8.1. Plan and elevation analysis

Also in this case, Leonardo uses the silver section in order to draw two subsequent octagons (1). This construction is visible also in the drawing, since the guiding lines are visible. Then, the smaller octagon (the one obtained in step (1) by joining the opposite vertices of the bigger octagon) was used to draw the circumference inscribed in it(2). This circumference represents

the base of the circular chapel and it is possible to derive the diameter of the niches from the smaller octagon. Then a circular array with nine elements has been applied to place the niches around the chapel's perimeter, and this group of elements was placed in tangency to the bigger octagon (3). The niche that was tangent to the side of the octagon was then converted into an opening on the central space (4).

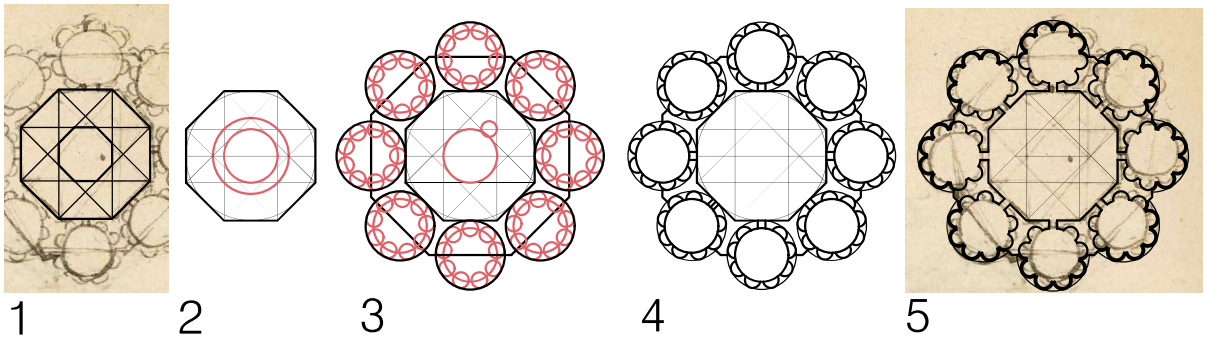


Fig. 63 - Geometrical process for the reconstruction of the plan.

As regards the analysis of the proportions in the perspective view, it is possible to find a relation between the height of the parts and the extension of both the perimeter square and the central octagonal space.

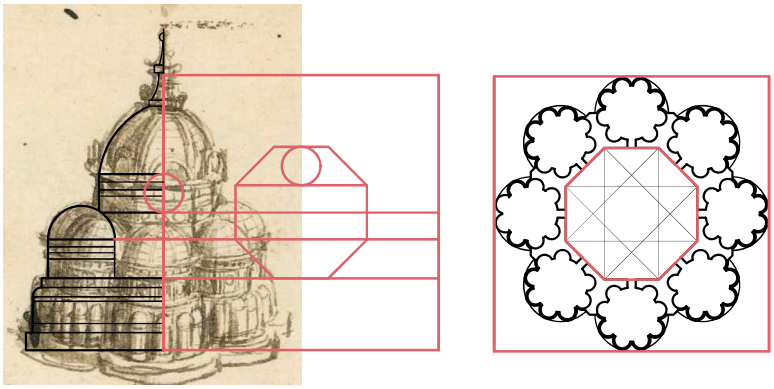


Fig. 64 - Relationship between the geometry in plan and the proportions in elevation.

3.8.2. Results

In this case, an unique solution was produced.

As seen for the other churches, the model was then scaled in order to hypothesize its dimensions on the basis of the windows' and doors' width. However, the only reference elements are the semicircular windows at the base of the dome and the interior doors, so, in this case, the scale could have a great variability. In particular, in the proposed solution, the semicircular windows have a diameter equal to 3.2 m, while the interior doors have a width of about 1.5 m.

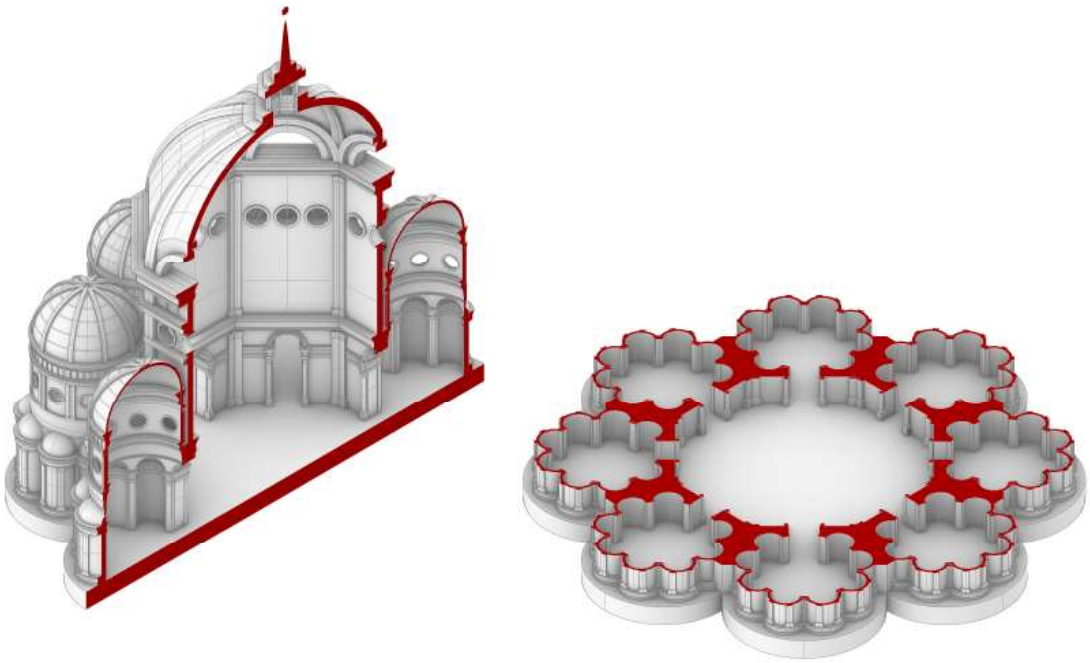


Fig. 65 - Axonometric sections of the model.

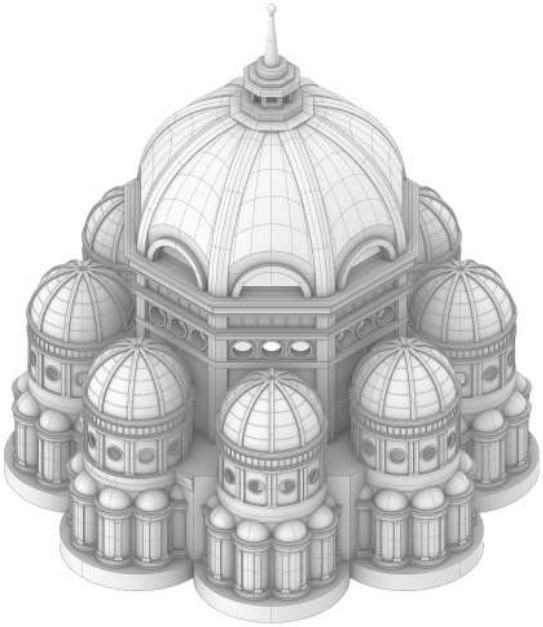


Fig. 66 - Axonometry of the model

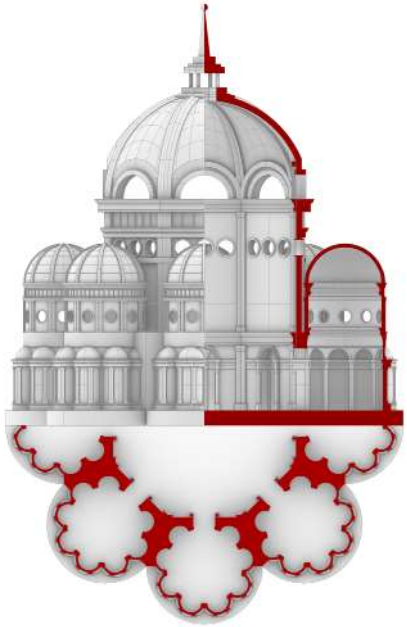


Fig. 67 - Plan, section and elevation (1:500).

3.9. Folio 25v B

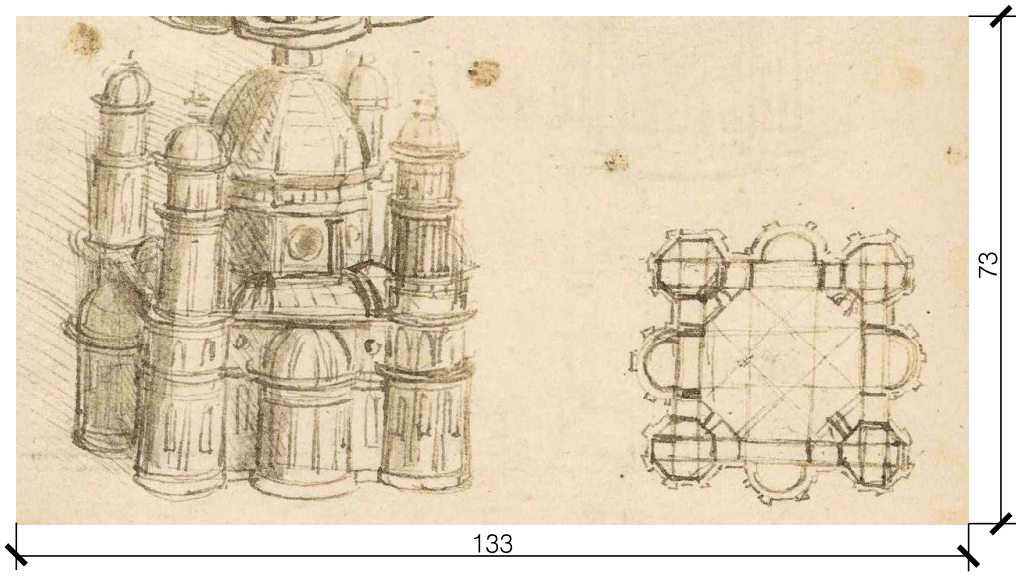


Fig. 68 - Ms. B, f. 25v: drawing of the church "B" with its dimensions in mm.

The second church depicted in f. 25 v has a layout which is very similar to that of f. 39 v. It consists in an octagonal central space surrounded by eight chapels, that are placed along a square. The chapels on the xy axes are composed, in plan, by a rectangle combined with a semicircle, and are completely opened on the central space. The ones on the diagonal axes, instead, are octagonal and are connected with the latter through a narrow passage, even though in the upper right corner of the plan is still visible a niche, then not repeated in the other corners (this element, as we will see, is used in f. 39 v). Given these observations, we can classify this layout, on the basis of the nomenclature previously defined, as R/Q/A-RSC D-O/BY. Also, regarding the layout, Leonardo does not indicate any entrance for the church, both in plan and in perspective views.

This church, along with that of f.39 v, resembles many elements of the Duomo of Sforzinda drawn by Filarete (see, for example, the four high towers on the corners and the octagonal domed central space with circular windows on the drum's sides).

Fig. 69 - Comparison with Filarete bird's-eye view of Sforzinda Cathedral

There is, however, an element of peculiarity, which is the curved ceiling that connects the edges of the square based volume and the octagonal, central drum. It was hypothesized to carve it with a matroneum running all around the central space and opened to it through double arched windows. This is similar to what was done for the church in f.18v -19r and takes inspiration from the drawing of interiors made by Leonardo that we already examined, along with the reference of the church of San Lorenzo in Milan.

Fig. 70 - On the left hand side the matroneum is highlighted in red, on the right the 3D result is visible.

In the perspective view, the tower on the right is slightly different from that on the left, since there is a sketch of a dome with a lower impost, likely to have been drawn at an earlier date, still visible under the main lines of the drawing. However, this difference did not produce any variant, because this previous solution is only outlined and was then covered. There was, nevertheless, the need to consider the inconsistencies that exist between plan and perspective views and produce two different solutions, as we will later see in detail.

3.9.1. Plan and elevation analysis

The construction of the plan view starts from the two consequent regular octagons in the Pell's series (1 and 2), as it was done for the church that is drawn in the same folio. Then the vertical and horizontal sides of the bigger octagon are lengthened, along with the oblique lines that connect the opposite vertices of the octagon. The intersections between them define the guidelines (3) that allow the construction of the chapels (4).

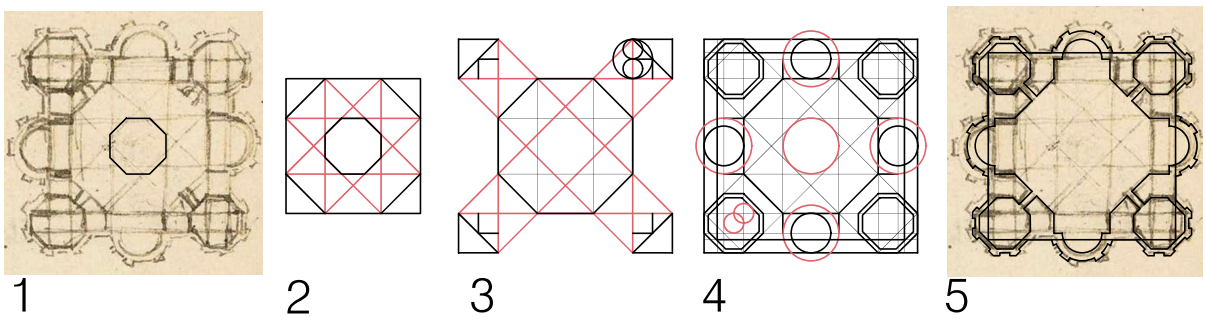


Fig. 71 - Geometrical process for the reconstruction of the plan.

The elevation can be obtained, starting from the division in subsequent parts of the total exten-

sion of the plan, by means of progression. All the elements, thus, can be analysed as fractions of this total length and the overall height of the bell towers is equal to it.

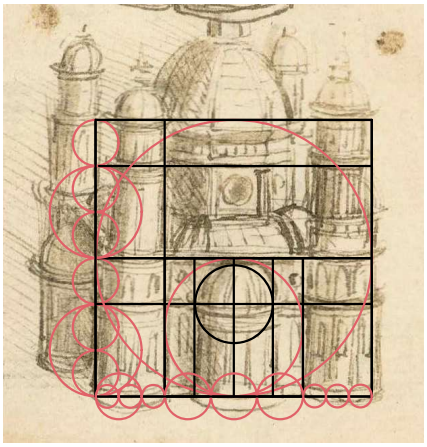


Fig. 72 - Relationship between the geometry in plan and the proportions in elevation.

3.9.2. Consistency between plan and perspective view

Plan and perspective views show some differences regarding the exterior shape of the bell towers: while in plan Leonardo draws an octagonal wall with angular *lesenes*, in the perspective view the wall is circle-based. For this reason - keeping the same shape for the interiors - two solutions were modelled.

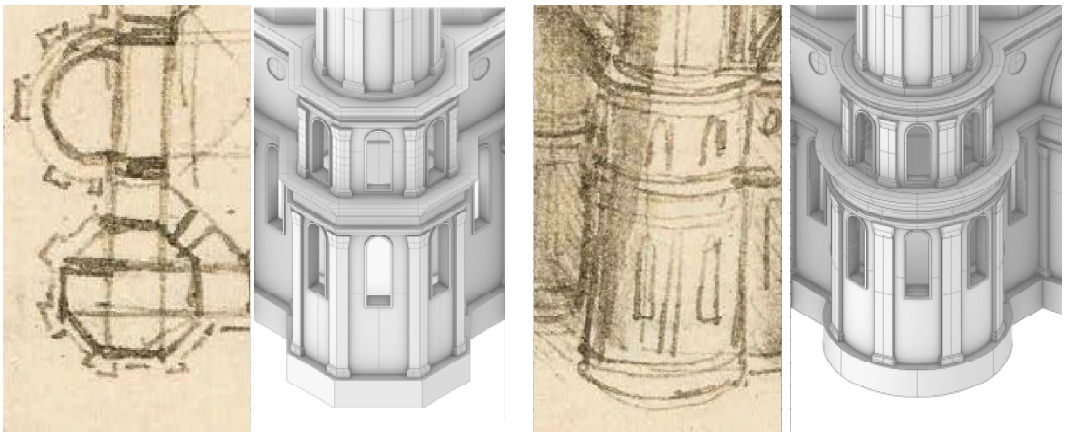


Fig. 73 - Detail of the differences between the bell towers.

3.9.3. Results

The result of the digitalization process is made up by two different solutions, depending on the main source of information (plan or perspective view). ‚Regarding the dimension of the building, in this case the elements that were used in order to make hypothesis are the interior doors and the single-arched windows on the façade and on the bell towers. The first ones have a width that spans from about 1.6 m to 1.8 m, while the windows are 1.0 m wide.

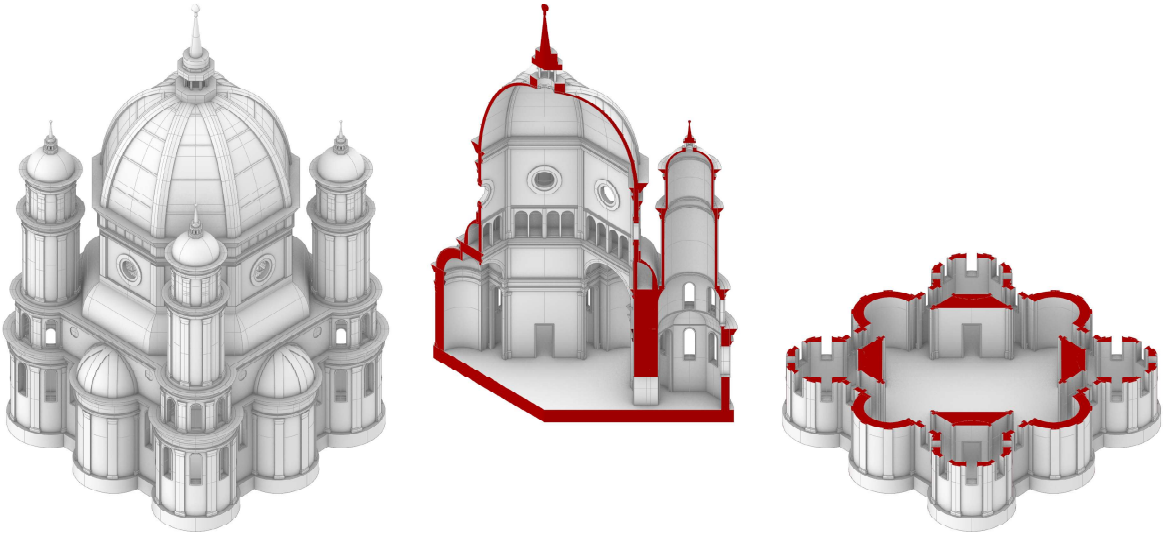


Fig. 74 - Axonometry and axonometric sections of one of the solutions.

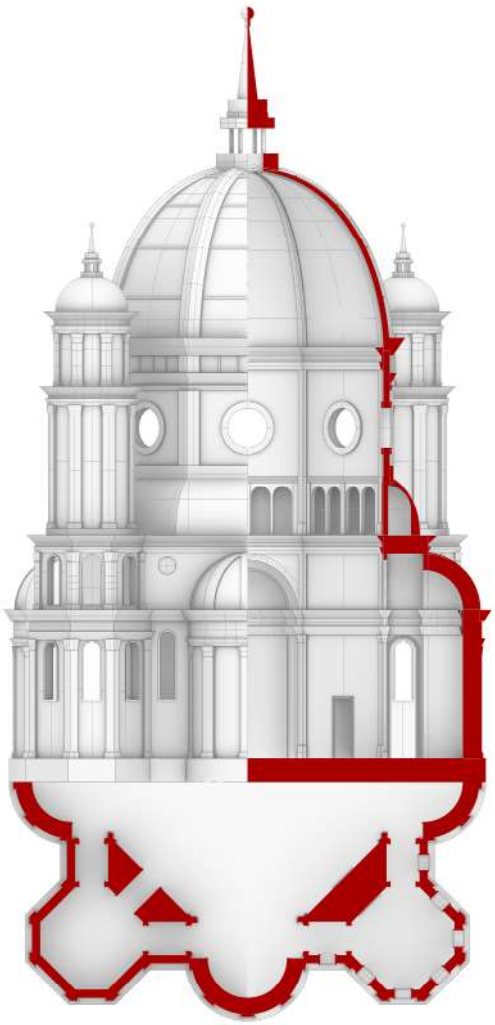


Fig. 75 - Plan, section and elevation (1:500) of the solution derived from the plan view. The plan views are obtained by sectioning the edifice at the level of the windows (on the right) and at the level of the doors (on the left).

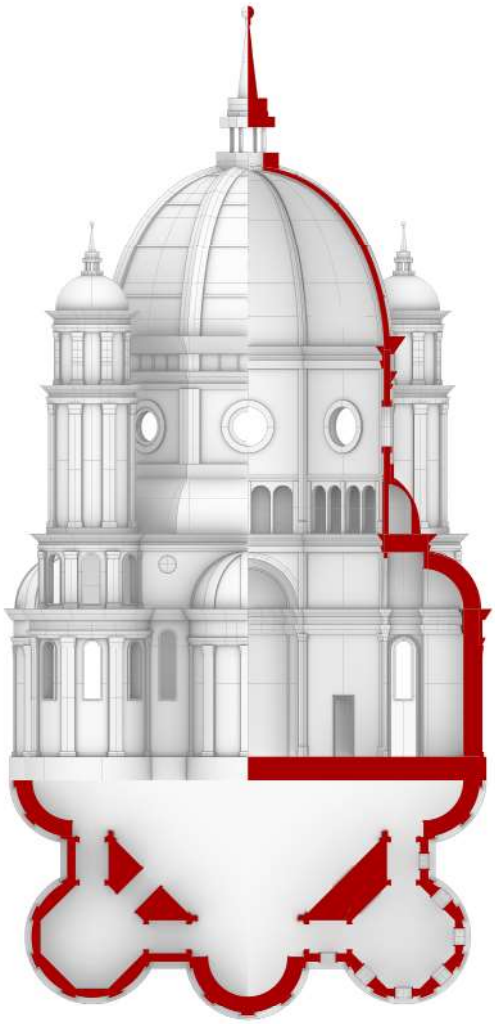


Fig. 76 - Plan, section and elevation of the solution derived from the bird's-eye view.

3.10. Folio 39v

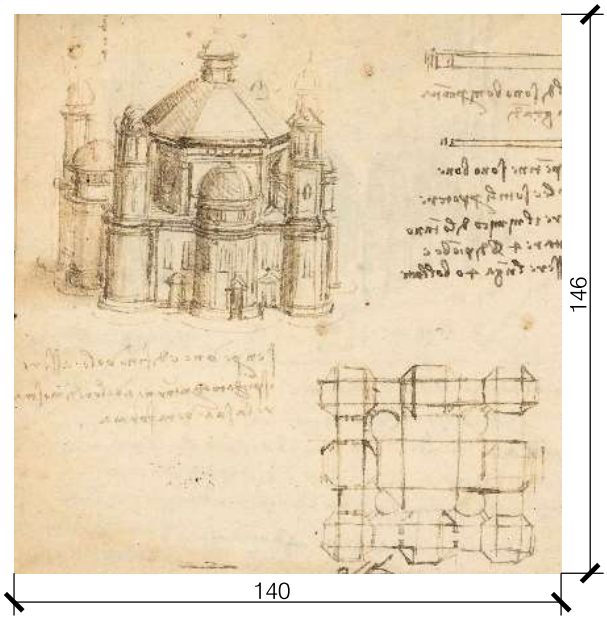


Fig. 77 - Ms. B, f. 39v: drawing of the church with its dimensions in mm.

In this folio Leonardo writes an annotation that states his ideas about the importance of the base in churches:

"Senpre uno edifitio vole essere ispichato dintorno a volere dimostrare la sua forma"[23]

This church has many characteristics in common with the previous one (f.25 v B): it is, as well, composed by an octagonal central space surrounded by chapels that are placed along a square. This time, however, all the chapels are octagonal (at least internally) and the ones on the diagonal axes are connected with the central space through a niche and a narrow passage. The layout can thus be classified as I/Q/A-O D-O/BY.

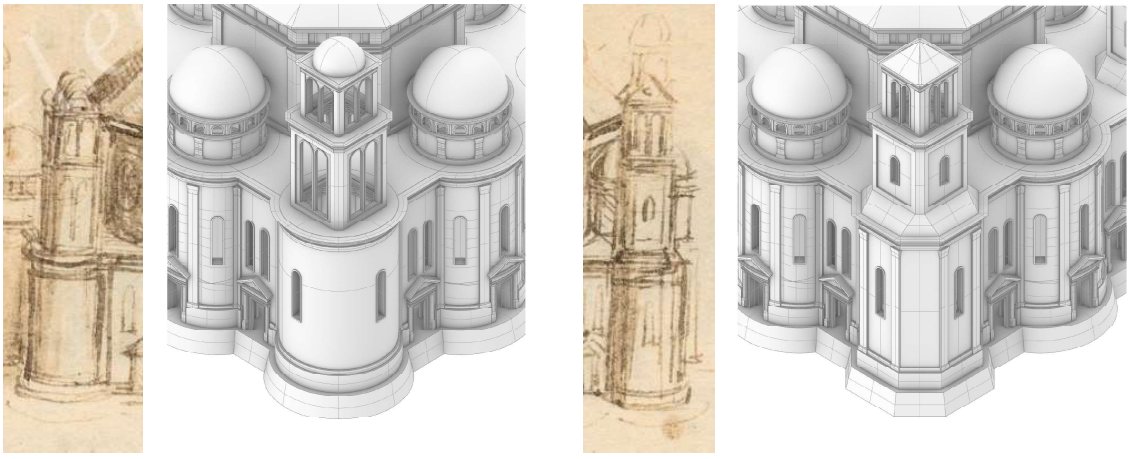


Fig. 78 - Comparison between the variants that were produced for the bell towers.

23 I.e. "a building should always be detached on all sides so that its form can be seen"

This layout corresponds in elevation to an alternation of bell towers and protruding niches. The bell towers, however, are drawn with two different solutions in the right and in the left part of the façade, so, two variants had to be modelled in order to represent both of them (see fig. 114 on the previous page).

The central octagonal space is covered with a pyramidal roof that recalls the reference of the Baptistery of San Giovanni in Florence.

As in the previous case, another useful reference is Filarete's Duomo of Sforzinda. In this case, the similarities can be found, for example, in the entrances, that are three in number and show a *tympanum,* and in the bell towers.

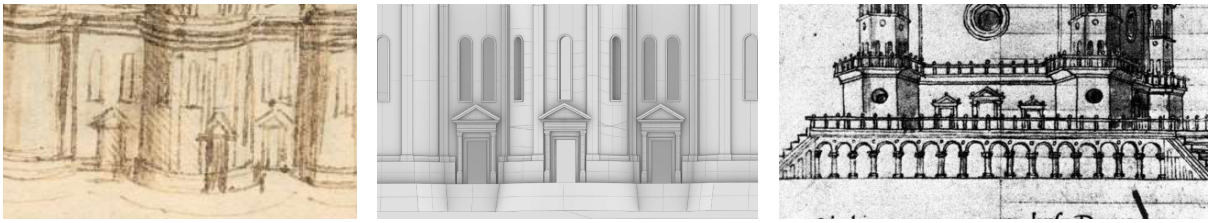


Fig. 79 - Comparison between the entrance portals in Leonardo's drawing (1), in our 3D model (2) and in Filarete's drawing of Sforzinda Cathedral.

The plan view just contains schematic guidelines, that have been interpreted, in the process of digitalisation, as reference for the interiors.

There are, however, some inconsistencies between plan and perspective view, that are probably simply imperfections and thus did not led to the definition of a variant. We will analyse them thoroughly in the next sections.

3.10.1. Plan and elevation analysis

Francesco P. di Teodoro produced a reconstruction hypothesis for this church, it is slightly different in the passages used, since it starts from one of the chapels in the corners, but it leads almost to the same output. The only difference is represented by the diameter of the niches (but even in Leonardo's drawing it varies from side to side). In particular, in the solution presented here it was considered shorter than the octagon's oblique side, while in di Teodoro's hypothesis it was considered equal to it.

The construction process that I propose starts from the construction of an octagon by the lengthening of the sides of two squares (1 and 2), one drawn inside the other with its vertices on the sides' midpoints of the other. The niches are drawn tangent to the grid just defined (2). Then, the construction of the subsequent octagon in the pell series is applied in order to find the exterior square boundary of the drawing (3). Drawing an additional smaller square inside the first one (4) it is possible to draw the grid that will serve as guideline for the definition of the chapels and of the elements of connection between them (5).

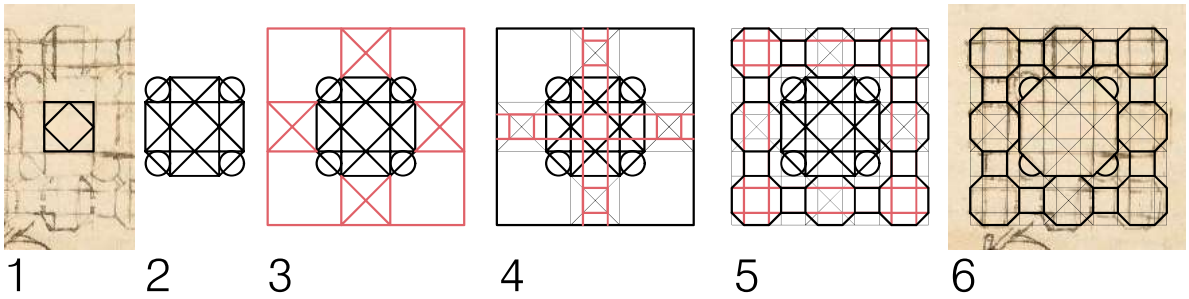


Fig. 80 - Geometrical process for the reconstruction of the plan.

As regards the elevation, it is possible to relate the height of the elements to multiples of a reference measure.

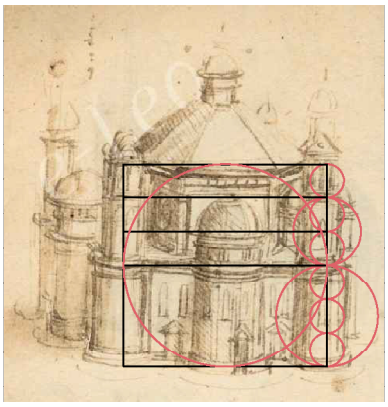


Fig. 81 - Relationship between the geometry in plan and the proportions in elevation.

3.10.2. Consistency between plan and perspective views

While in plan the chapels are perfectly aligned and have the same interior width, in perspective the ones on the corners are smaller in diameter than the ones in the middle of the façades and they are not aligned.

Moreover, in plan, the chapels on the xy axes have a side that is perfectly tangent to that of the central octagon. If so, it would not be possible to obtain - like in the perspective view - a separation between the drums on the xy axes, so it was necessary to slightly distance them from the octagon.

3.10.3. Results

Two models were produced in order to represent the two solutions for the bell towers that Leonardo draws in the bird's-eye view.

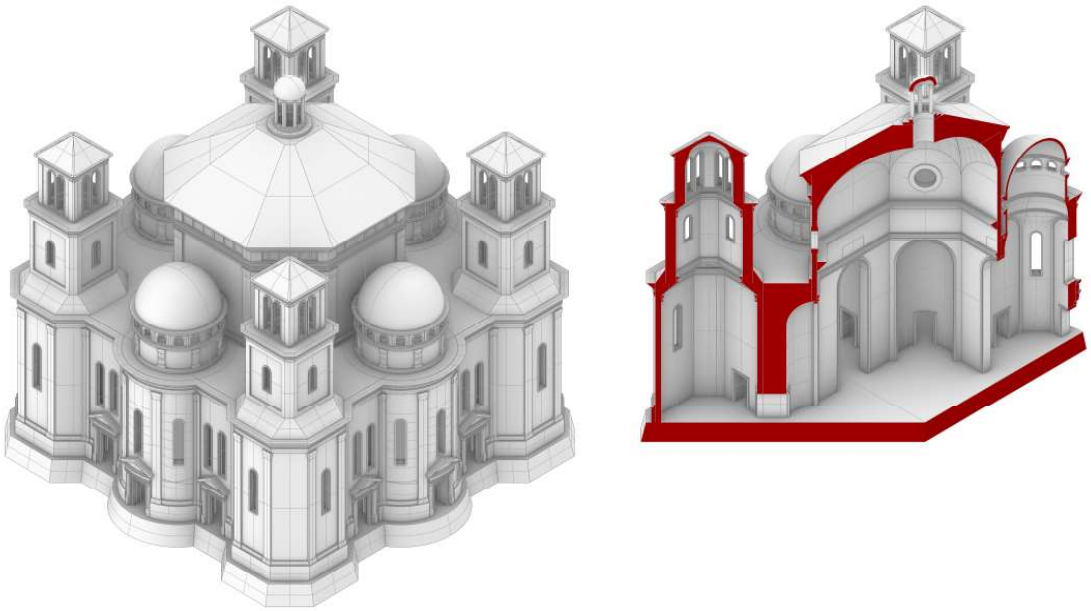


Fig. 82 - Axonometry and axonometric section of one of the two solutions.

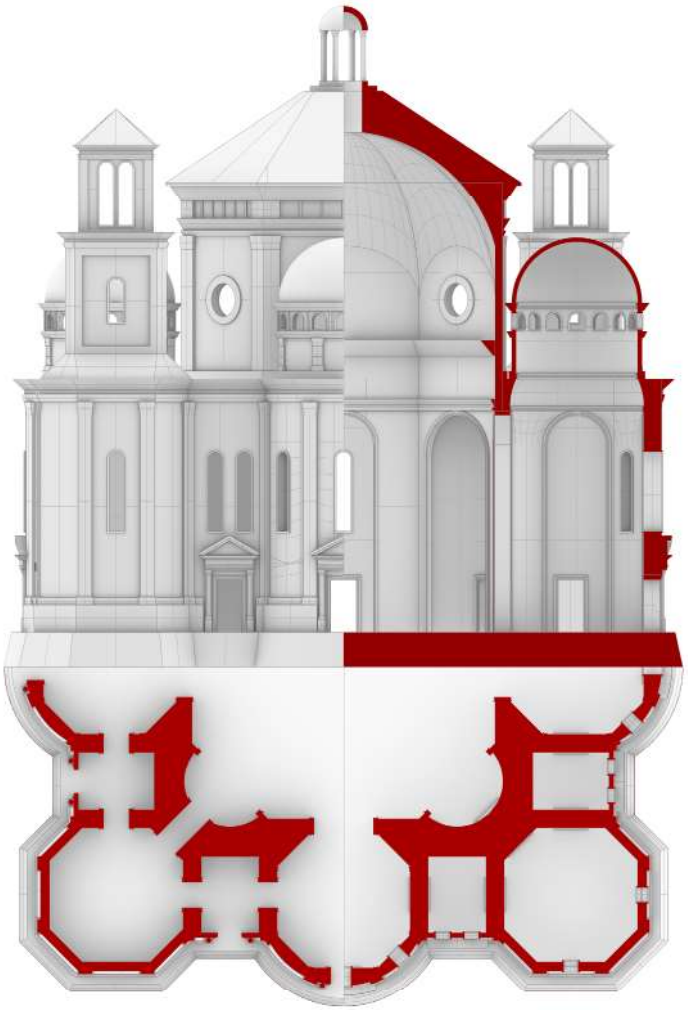


Fig. 83 - Plan, section and elevation (1:500) of one of the two solutions. The plan views are obtained by sectioning the edifice at the level of the windows (on the right) and at the level of the doors (on the left).

3.11. Folio 93 v

Folio 93v represents one of the most peculiar ones, since it depicts multiple variations for the same layout. In particular, six pairings of drawings were identified and called with letters from A to F.

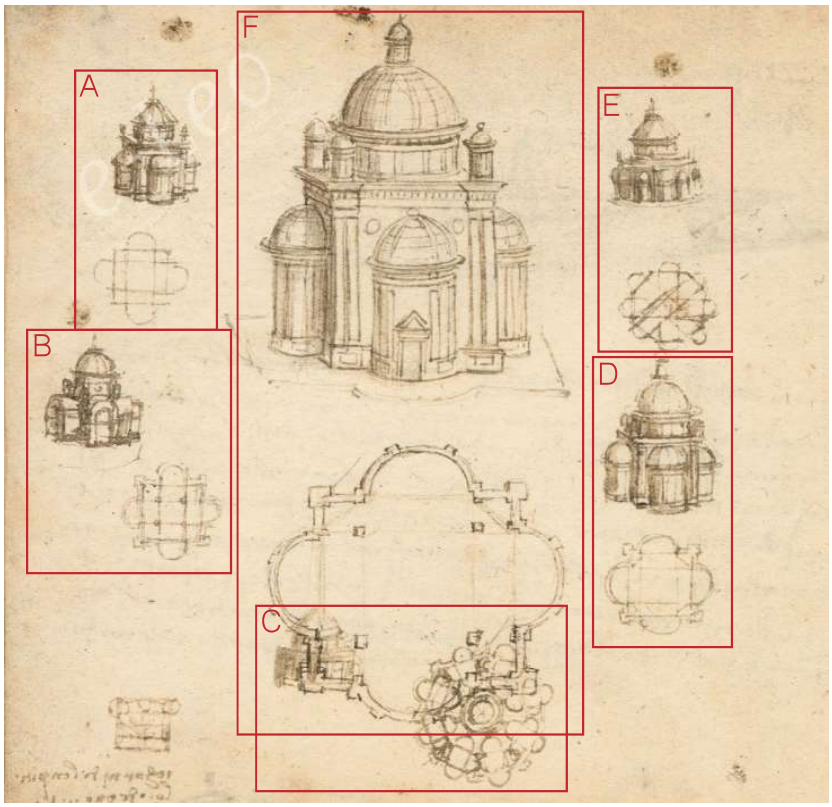


Fig. 84 - Ms. B, f. 93v: indication of the nomenclature used in order to distinguish the different edifices.

Among these six churches, that will be soon thoroughly analysed, four depict the variations of the four-lobed layout that Leonardo used in other churches as a chapel. In this case, instead, this element stands alone as an independent building. The work produced in order to study the aggregation of elements will be useful to better understand how the buildings vary one from another.

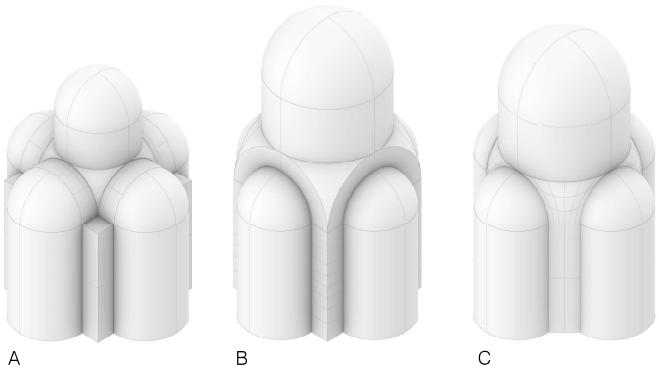


Fig. 85 - Variants of the -QC chapel as studied in Chapter 3.

Another element that can be noticed is that the church depicted in the middle of the page is much bigger and more accurate than the others. An hypothesis that could explain this is that maybe the other drawings were part of a process of trial and reasoning, and the one in the middle could be the result of this process (still, it is not so easy to determine with certainty what drawing was drawn before).

3.12. Folio 93 v A

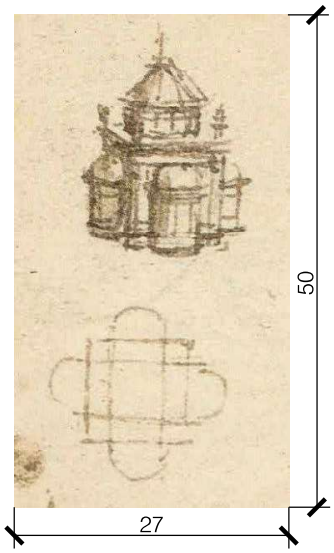


Fig. 86 - Ms. B, f. 93v: drawing of the church "A" with its dimensions in mm.

The drawing of this church is very small, since the plan view measures about 19 mm x 19 mm and the perspective view 18 mm x 24 mm. The plan, moreover, is just made of the main guiding lines, that were used as reference for the interior[24]. This way, the result we obtain is made up of a central square space with niches, surmounted by a spherical dome with a circular drum on spherical pendentives, thus this church could be classified as QC(b).

Given the small dimensions of the drawing it is difficult to tell whether the roof is pyramidal or conical. For this reason two possible solutions for the exterior have been produced.

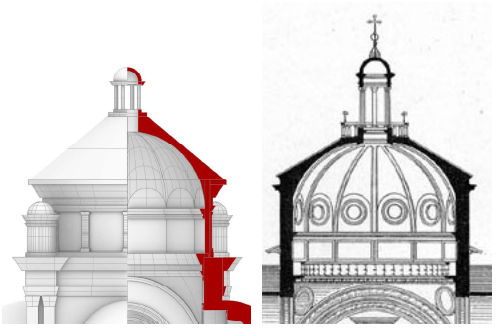
The first case consists externally of a conical roof and internally of an umbrella dome, as in the case of Santa Maria delle Carceri in Prato. In the second one, instead, the interior is similar to that of Santa Maria delle Grazie at Milan, since the drum is circular and the dome is spherical.

In the third, in the fourth and in the fifth variant, instead, the roof was modelled as pyramidal exteriorly, while interiorly it was hypothesized in one case as a cloister vault, in one as an umbrella

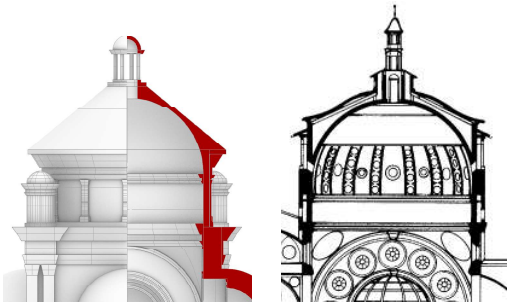
24 In fact, where using them as reference for the exterior it was impossible to obtain an external view that resembled the bird's-eye-view drawn by Leonardo

dome and in the last one as a pyramid as well.[25]

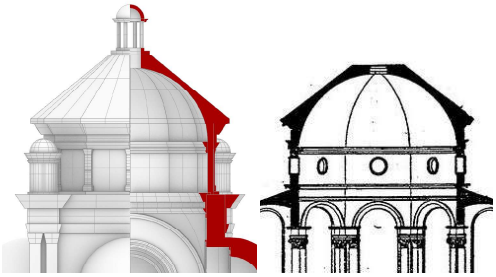
When exploring these solutions the examples that were used are respectively the Brunelleschi's Rotonda degli Angeli in Florence (for the roof made of an interior cloister vault and an exterior pyramidal roof), Cascina Pozzobonelli in Milan (where there is interiorly an umbrella dome and exteriorly a pyramidal roof and Vincenzo Borghini's drawing of the Baptistery of San Giovanni in Florence as an ancient temple (for the use of a pyramidal shape for both the interior and the exterior).



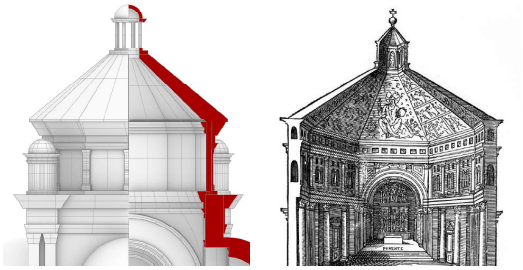
Santa Maria delle Carceri, Prato



Santa Maria delle Grazie, Milan



Rotonda degli Angeli, Florence



Baptistery of San Giovanni in Florence as an ancient temple by Vincenzo Borghini

Cascina Pozzobonelli, Milan

Fig. 87 - Variants for the dome and relative reference.

Moreover, there is an example, among the ones pinpointed in Chapter 2, where a polygonal drum is placed upon spherical pendentives, that is the church of Santa Maria dei Miracoli presso San Celso in Milan. This solution was used as a reference to solve the problem of the combination of a circular base (obtained at the end of the spherical pendentives) and a polygonal drum through a *cornice*. In both our case study and Santa Maria dei Miracoli, in fact, the drum has

25 Of course, all the combinations of those interior and exterior elements could be explored, but it would be just a combinatory work.and I decided to just model four of these combinations.

twelve sides, so the solution is perfectly fitting.

Fig. 88 - Comparison with the interior of San Celso.

3.12.1. Plan and elevation analysis

The construction of the plan, in this case, is very simple, also given the small dimension of the drawing. The main square was divided in sixteen smaller squares. By dividing the side of one of this smaller squares in eight parts it is possible to define a further grid (1) that lets us define the diameter of the niches (2). Then, the square that circumscribes all the niches was offset of a distance equal to 1/4 of one of the smaller squares (3). Each circumference was moved with its centre on the square obtained in the previous step (4).

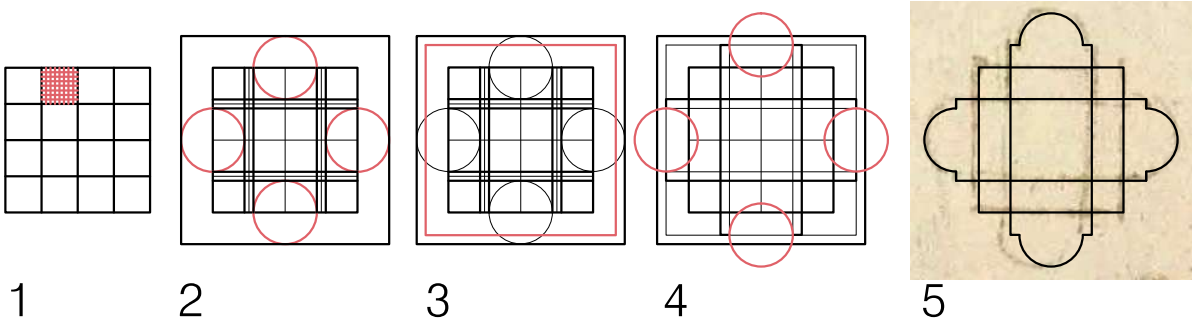


Fig. 89 - Geometrical process for the reconstruction of the plan.

The importance and recurrence of the fraction 1/4 in this drawing can also be traced back to the note written by Leonardo in the lower left corner of the folio:

> *"I corni del capitello deono essere la quarta parte d'uno quadro"*

Regarding the proportional study in elevation, the façade can be put in relation with a square, while the niches show a 4:7 ratio between the diameter and the total height.

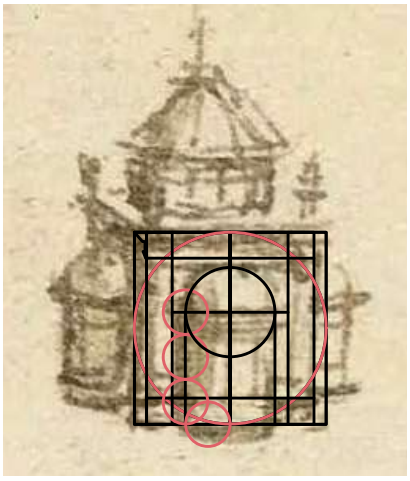


Fig. 90 - Relationship between the geometry in plan and the proportions in elevation.

3.12.2. Consistency between plan and perspective views

As has been already pointed out, in this case there isn't any problem regarding the consistency between the views, as long as the guidelines in plan are used as reference for the interior of the church. This is also due to the fact that both views are very small and systematic.

3.12.3. Results

Overall, six solutions were produced, on the basis of the type of roof and drum. For all of these, since we will later see that the proportions in façade are the same for the church F (the central and more detailed one), the exterior elements of detail were taken from it (for example the *cornices* and the double columns in the corners). The interior decorations, instead, were modelled using as reference Cappella Pazzi.

Fig. 91 - Comparison with the interior decoration of Cappella Pazzi.

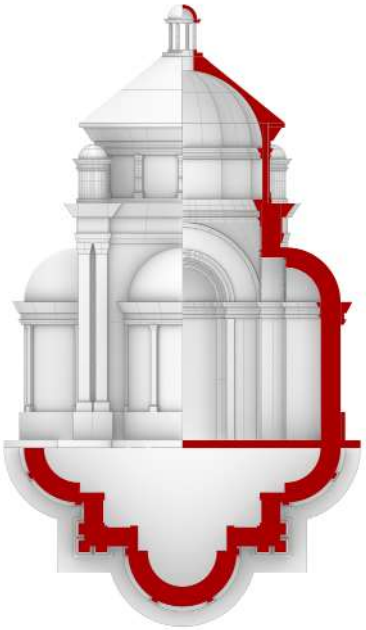


Fig. 92 - Plan, section and elevation (1:500) of the solution with a cloister dome and an exterior circle-based drum.

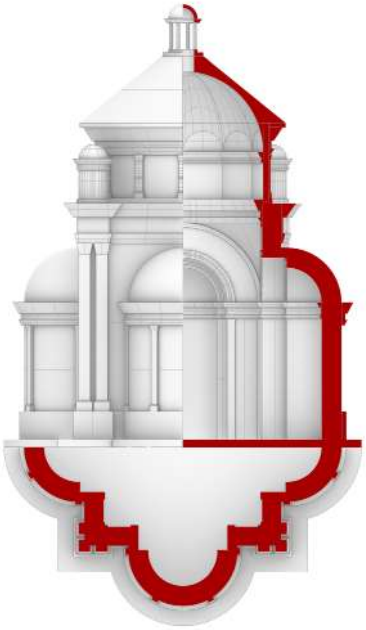


Fig. 93 - Plan, section and elevation (1:500) of the solution with an umbrella dome and an exterior circle-based drum.

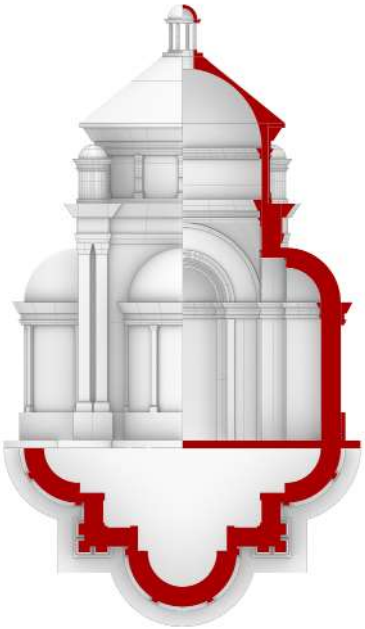


Fig. 94 - Plan, section and elevation (1:500) of the solution with a spherical dome and an exterior circle-based drum.

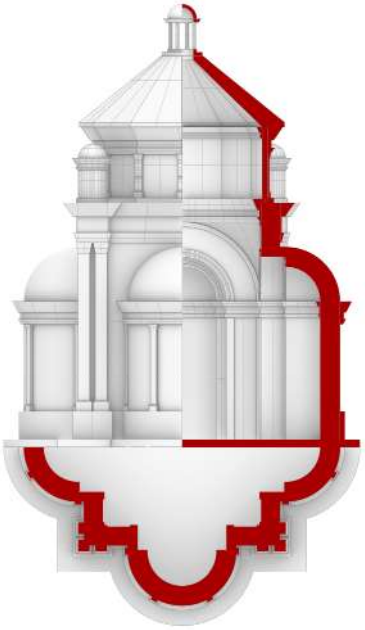


Fig. 95 - Plan, section and elevation (1:500) of the solution with a pyramidal ceiling and an exterior dodecagonal drum.

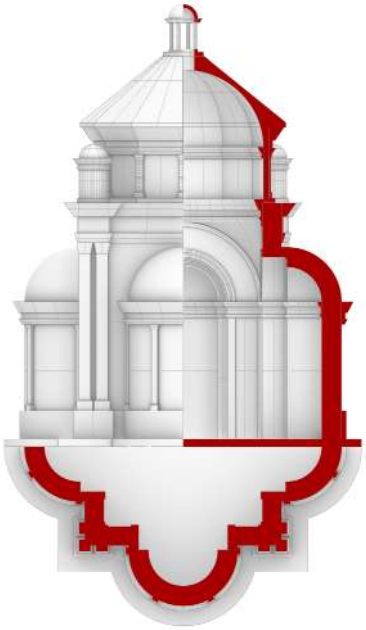


Fig. 96 - Plan, section and elevation (1:500) of the solution with a cloister dome and an exterior dodecagonal drum.

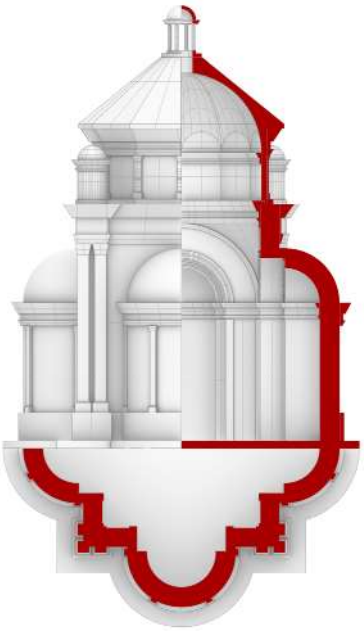


Fig. 97 - Plan, section and elevation (1:500) of the solution with an umbrella dome and an exterior dodecagonal drum.

3.13. Folio 93 v B

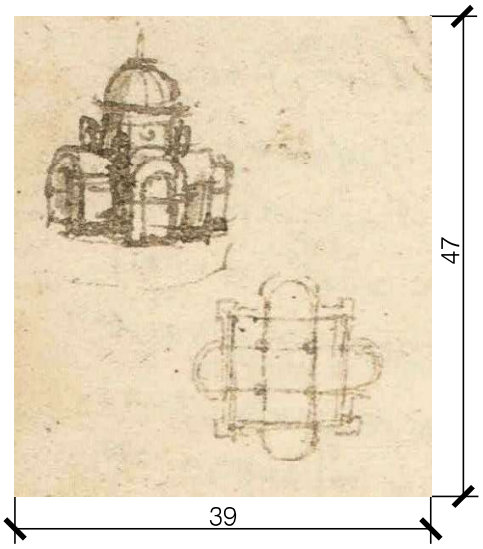


Fig. 98 - Ms. B, f. 93v: drawing of the church "B" with its dimensions in mm.

This is the only case where plan and perspective views are completely incompatible. For this reason, it was impossible to associate them and proceed with the digitalisation. Instead, they were considered separately: the plan was studied with attention to the geometric process for its construction (without producing any three-dimensional model related to it), while a model was created on the basis of the bird's-eye view alone, trying to derive a plan just from it.

In order to do so, another Leonardo's drawing, f. 362 b-r of Codex Atlanticus, can be a useful reference. However, despite the similarities between the bird's eye views, the plan is not really compatible with the one we are considering, because the barrel vault has a longer diameter in the example of C.A. and because they intersect without having any space for the pinnacles in the corner of the central element (that are instead visible in Ms.B's drawing). Even so, it still can be a guide for some of the elements that have to be modelled and it is interesting to notice that the proportions in elevation are the same.

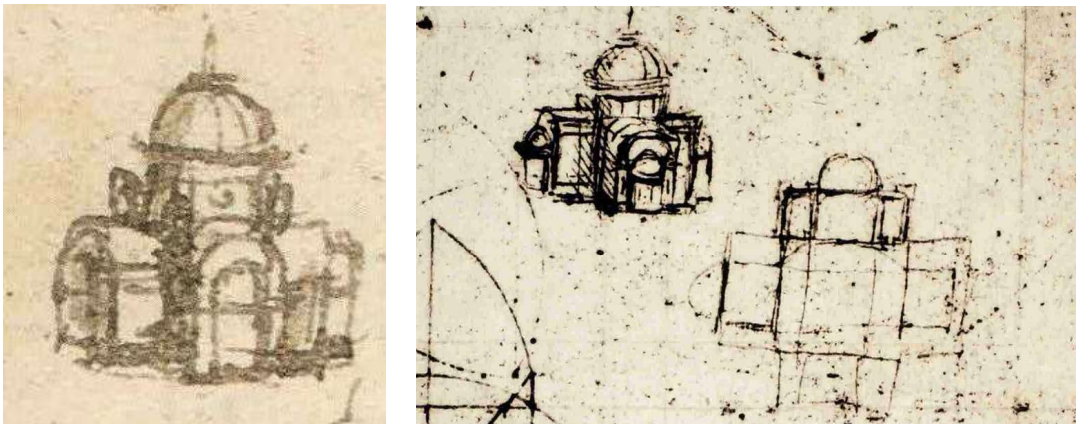


Fig. 99 - Comparison with the church depicted in f. 362 b-r of Codex Atlanticus.

However, given the small dimension of the drawing (the plan and the perspective views measure respectively about 20 mm x 20 mm and 22 mm x 27 mm), it is difficult to tell with certainty the proportions between the sides of the central octagon, as well as the type of dome. For these reasons a variant was produced on the basis of the shape of the drum, and another one for the type of dome. The types of dome that were modelled are the umbrella and the cloister vault because they are compatible with the octagonal drum. In the drawing however Leonardo seems to have drawn a spherical dome, as well as in C.A. f.362 b-r, but, while in the latter the drum is circular, in the church we are considering the drum has the shape of an irregular octagon, which does not allow a smooth transition with a circumference[26].

3.13.1. Plan and elevation analysis

The plan can be constructed by dividing the sides of a square in four parts (1). As it was done for the church "A" of this folio, the dimension of the elements is derived from a further group of guidelines that is drawn offsetting the first ones of 1/8 the length of the sixteen smaller squares (2). The circumferences that constitute the bases of the chapels are then moved with their centres on a bigger square, which was obtained using the grid just described (3).

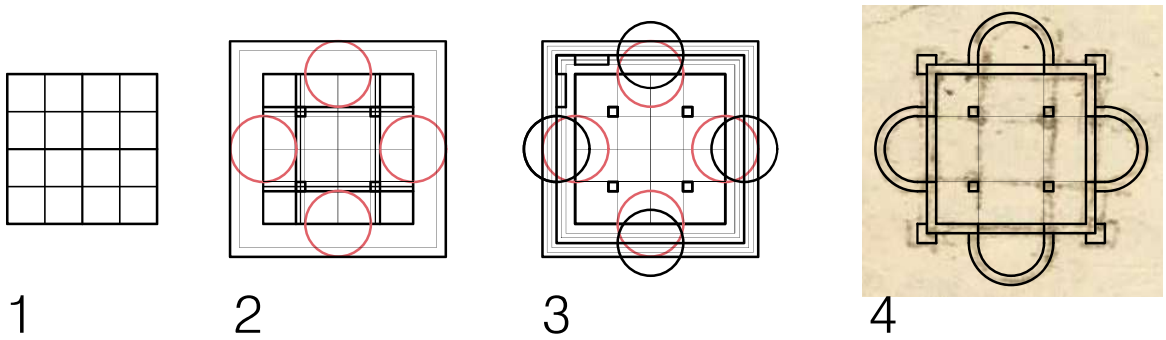


Fig. 100 - Geometrical process for the reconstruction of the plan.

The plan view in the Codex Atlanticus, similarly to many drawings in this folio, is constructed by dividing in four parts each side of a square. Then all the other dimensions of the elements of the drawing are derived from this division.

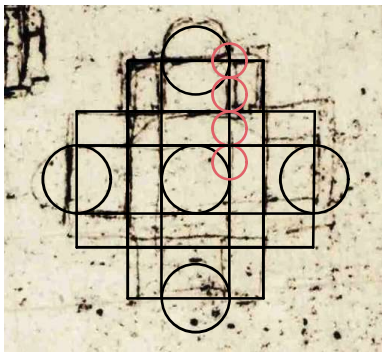


Fig. 101 - Deconstruction of the plan depicted in C.A., f. 362 b-r.

26 Thus, the case of a spherical dome could be modelled only assuming that the drum has a circular shape.

Regarding the bird's-eye view, as anticipated, there are several elements that have the same proportions that can be found in the folio from the Codex Atlanticus. In particular, the proportions that characterize the niches are the same that are present in churches A and F of this folio (ratio 4:7). Moreover, the height of the drum is equal to that measurable from the base up to the top of the barrel vault.

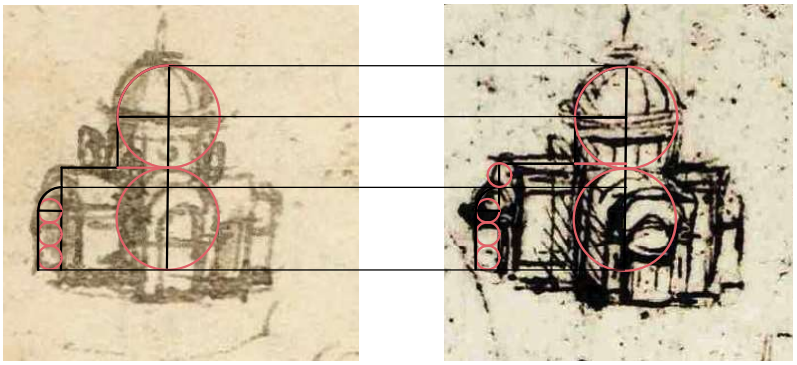


Fig. 102 - Relationship between the proportions in elevation in the two drawings

3.13.2. Consistency between plan and perspective views

As it was already pointed out there is a total lack of compatibility between plan and perspective views: the plan, in fact, depicts a four-lobed edifice very similar to the "F" one (i.e. the one in the centre of the folio), while in the bird's-eye view the church has an octagonal central space (almost a square) and a greek-cross layout made up by four barrel vault completed with smaller niches.

Moreover, as it can be noticed, the plan from the Codex Atlanticus shows some problems of compatibility and couldn't be used for dimensional problems (the layout however, is very similar).

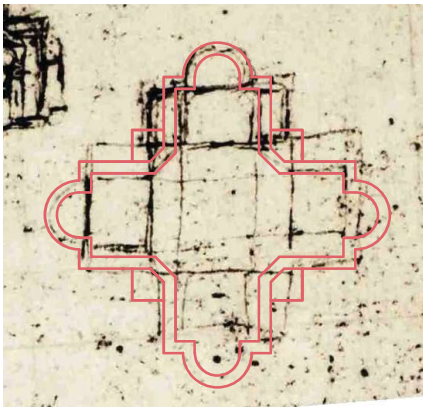


Fig. 103 - The main lines of the plan were drawn upon the drawing contained in Codex Atlanticus. The width of the rectangular chapels is greater in the latter.

3.13.3. Results

Four solutions were produced overall, each one on the basis of the variables that were just pinpointed:

1. Type of dome (cloister or umbrella dome)
2. Proportion between the sides of the octagon that defines the exterior perimeter of the drum

The dimension of the building was hypothesized on the basis of the diameter of the drum's circular windows, that was imposed equal to 2 m.

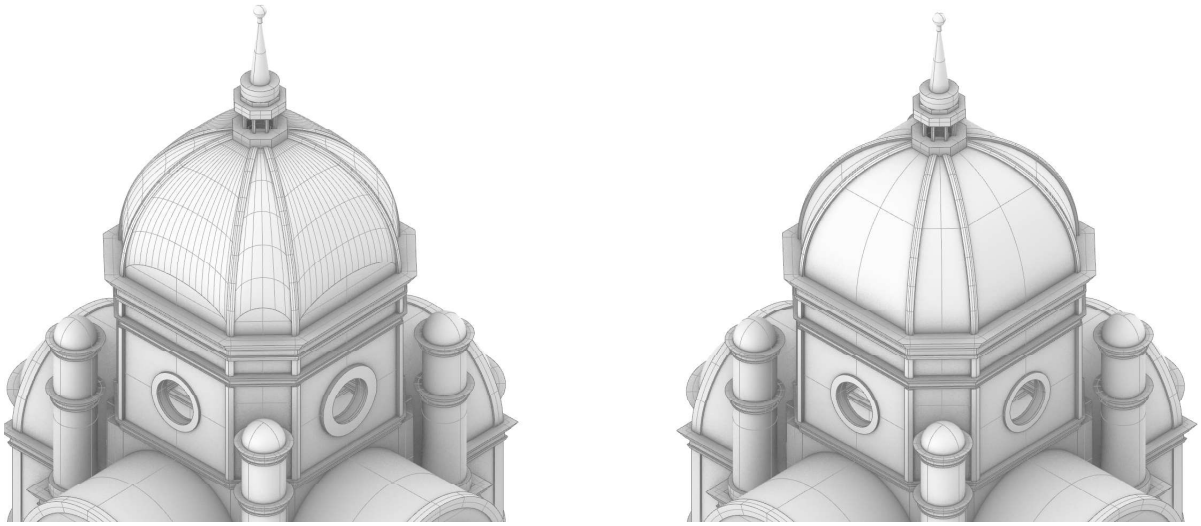


Fig. 104 - Comparison between the umbrella dome (1) and the cloister dome (2).

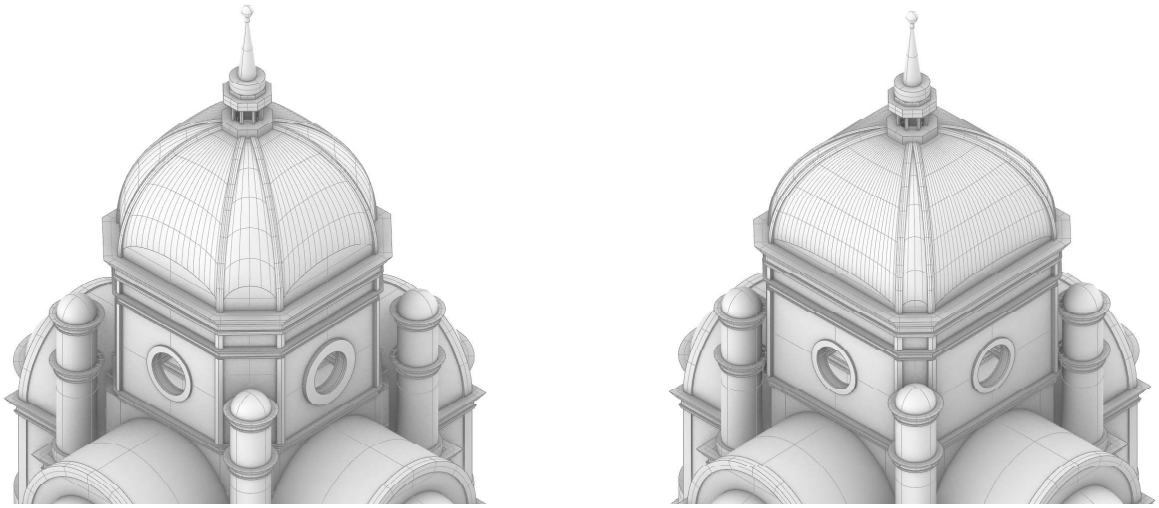


Fig. 105 - Comparison between the variants hypothesized for the drums.

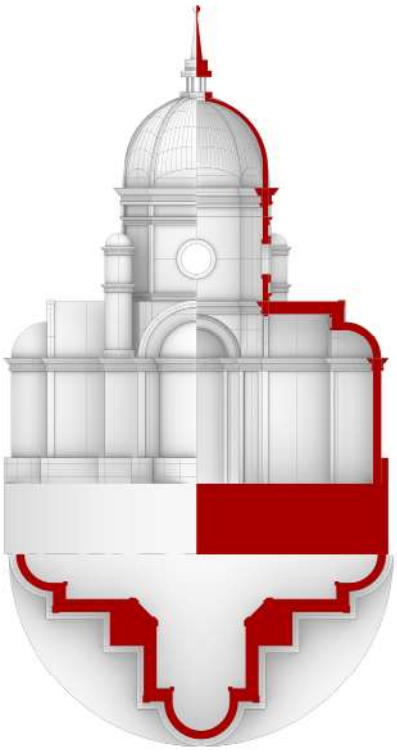


Fig. 106 - Plan, section and elevation (1:500) of the solution with a wider diagonal side of the drum and an umbrella dome.

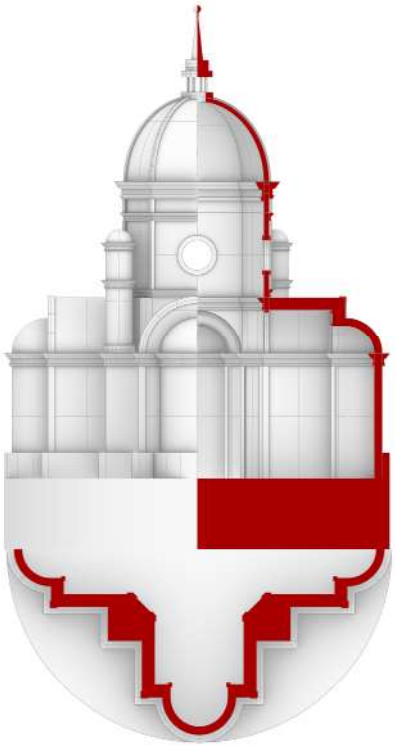


Fig. 107 - Plan, section and elevation (1:500) of the solution with a wider diagonal side of the drum and a cloister dome.

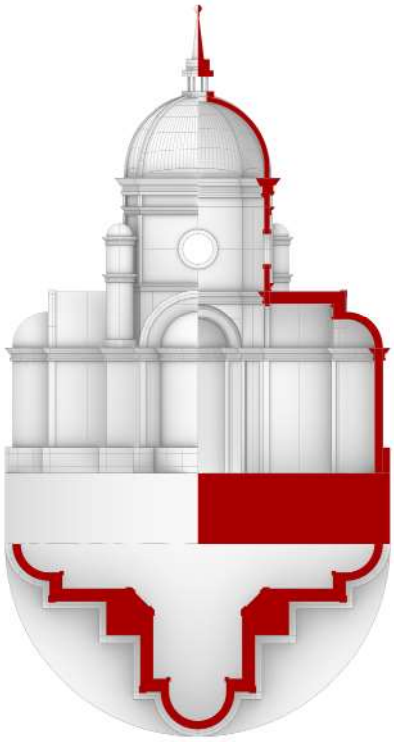


Fig. 108 - Plan, section and elevation (1:500) of the solution with a smaller diagonal side of the drum and an umbrella dome.

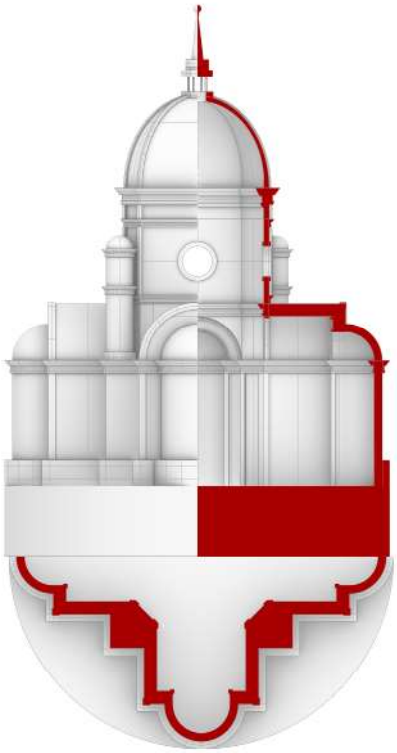


Fig. 109 - Plan, section and elevation (1:500) of the solution with a smaller diagonal side of the drum and a cloister dome.

3.14. Folio 93 v C

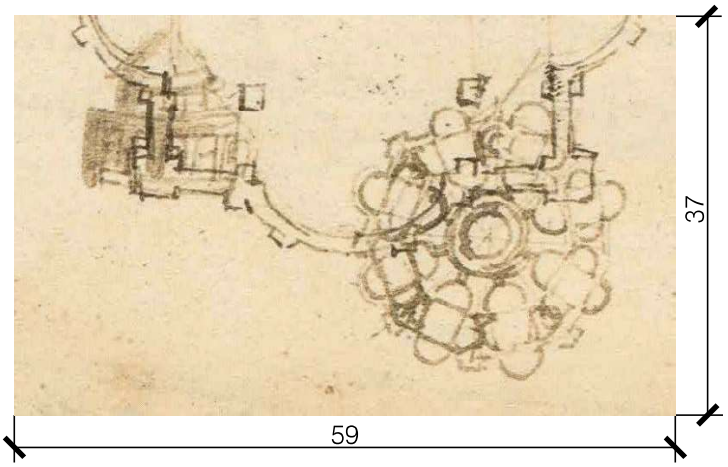


Fig. 110 - Ms. B, f. 93v: drawing of the church "C" with its dimensions in mm.

The drawing in this case is extremely small and sketchy. Moreover it is partially covered by the bigger drawing of church "F", thus its legibility is very difficult. For these reasons, the model that was produced is schematic and only contains the main elements.

The layout, however, consists in an octagonal central space covered with a pyramidal roof and surrounded by eight equal four-lobed chapels. This structure recalls that of Brunelleschi's Rotonda degli Angeli, which was used as a reference, even though the definition of the plan does not make it possible to see whether there are passages between the chapels. Given this layout, the church can be classified as R/C/A-QC(b) D-QC(b)/BN, since the four-lobed chapels can be catalogued under type b.

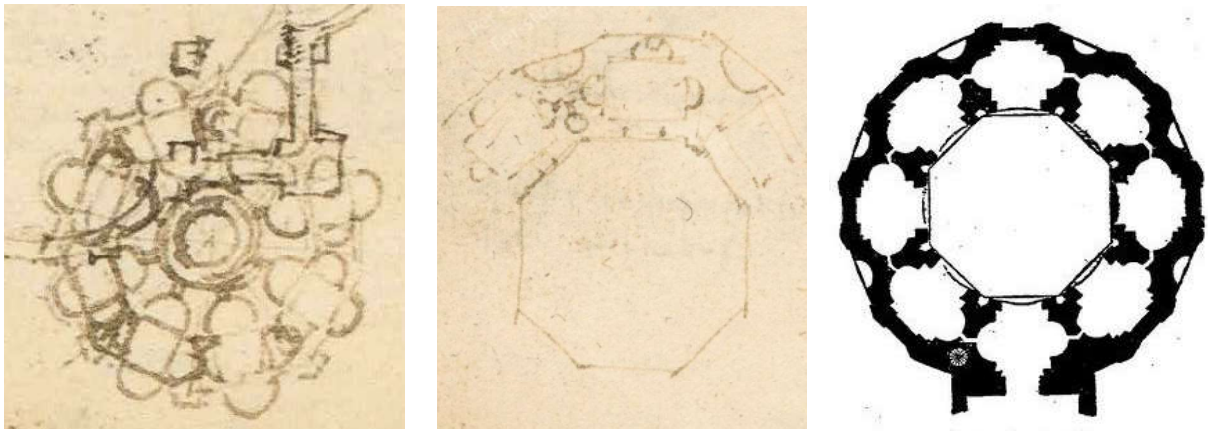


Fig. 111 - From left to right: (1) the plan of the church in f. 93v, (2) the plan of Brunelleschi's Rotonda as depicted by Leonardo in f. 11v of Ms. B, (3) its actual plan.

3.14.1. Plan and elevation analysis

The construction of the plan starts from the exterior octagon. A square, with its vertices on the midpoints of the oblique sides, was drawn, along with the octagon inscribed in it (1). The oppo-

site vertices of this last octagon are then joined and the intersections were used in order to draw a circumference passing through them. Vertical and horizontal lines were drawn in correspondence with the intersections between the circumference and the radii that connect the centre with the vertices of the octagon (2). Those lines were then used as guides to draw the boundaries of the chapels (3).

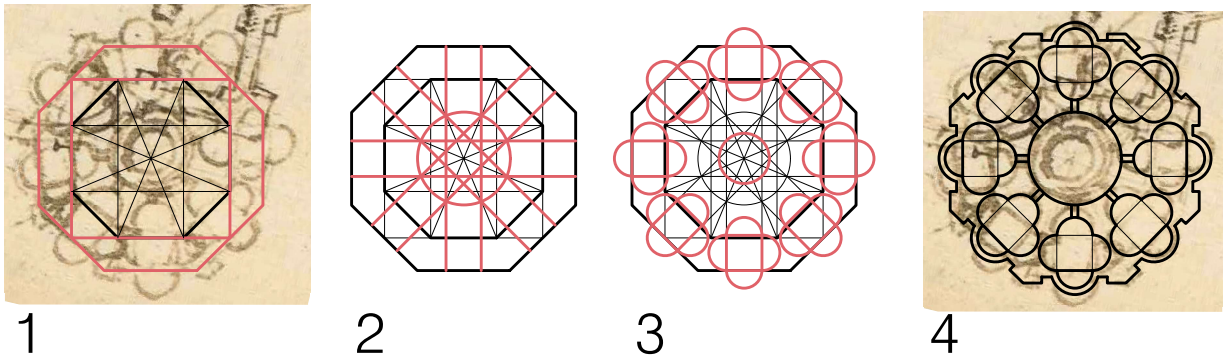


Fig. 112 - Geometrical process for the reconstruction of the plan.

As regards the study of proportions in the elevation, the small size of the drawing only makes it possible to hypothesize that the lower part and the upper part are equal in height.

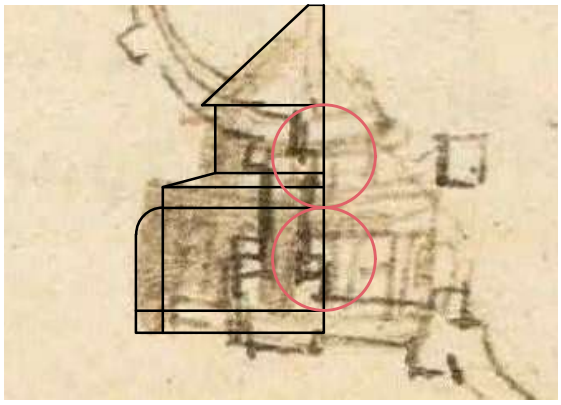


Fig. 113 - The proportions in elevation.

3.14.2. Consistency between plan and perspective views

Given the small dimension of the drawing, no inconsistencies between plan and perspective views were found.

3.14.3. Results

Because of the reasons explained in the previous sections, only one solution was produced. Given the absence of any exterior opening, it was necessary to scale the building on the basis of the interior doors' width alone, which was imposed to be equal to about 1.3-1.4 m. Along

with it, after having put the lesenes in the niches exterior perimeter (as Leonardo did in the other churches of the Manuscript), also the distance between them was considered, by checking that it was greater than 1.0 m. This way, since it is likely that single arched windows could be positioned there, they could respect the reference dimensions defined in Chapter 2.

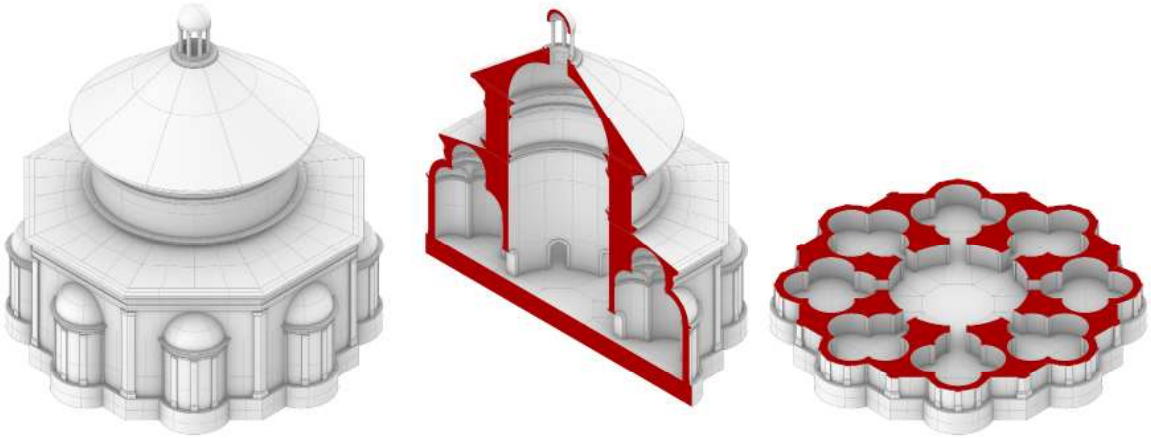


Fig. 114 - Axonometry and axonometric sections of the 3D model.

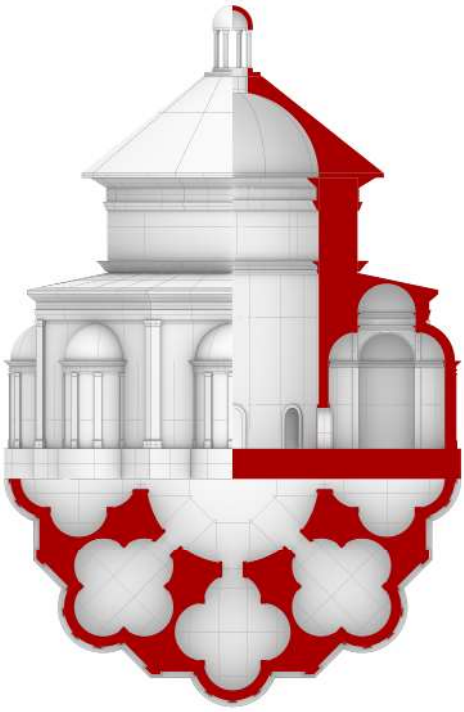


Fig. 115 - Plan, section and elevation (1:500) of the 3D model.

3.15. Folio 93 v D

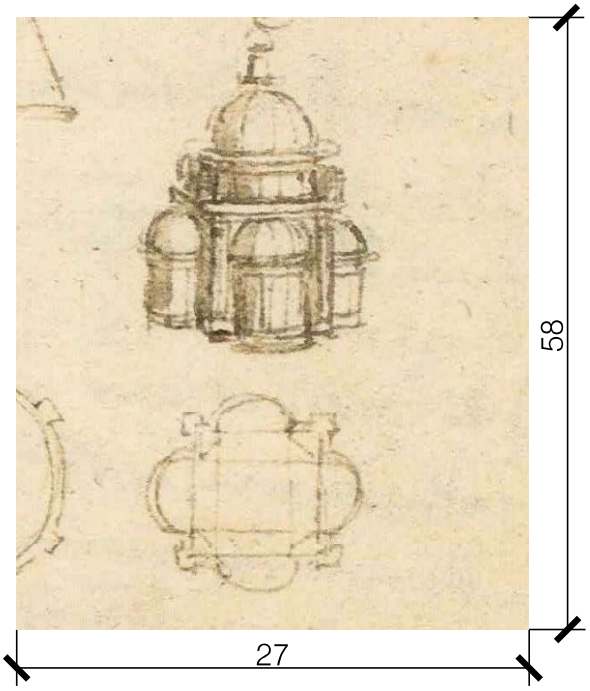


Fig. 116 - Ms. B, f. 93v: drawing of the church "D" with its dimensions in mm.

Also in this case, the drawing is very small since the plan view measures about 21 mm x 21 mm and the perspective view has an approximate extension of 24 mm x 33 mm. The layout is once again the one based on a four-lobed shape.

In this church, nevertheless, the niches are connected through an oblique side, that makes the interior of the church octagon-shaped. The vertical development has been modelled as in the reference of Cappella Chigi, in order to solve the interior transition between an octagon and a circumference. Given the previous observations, we can classify this church as QC(c).

The small dimension of the drawing makes it impossible to find any relevant inconsistency between plan and perspective views, so only a solution was modelled.

3.15.1. Plan and elevation analysis

First of all, each side of the external perimeter square is divided in four parts, thus defining a first grid (1). Then, the intersections between the grid and the inscribed circumference are used draw the interior octagonal boundary. The intersections between the oblique sides of the octagon allows to draw a square with its vertices passing through them (2). The circumference that defines the chapel's interior boundaries have as endpoints the vertices of the latter square and its centre (3). Then, the details are drawn following the guidelines previously defined (4).

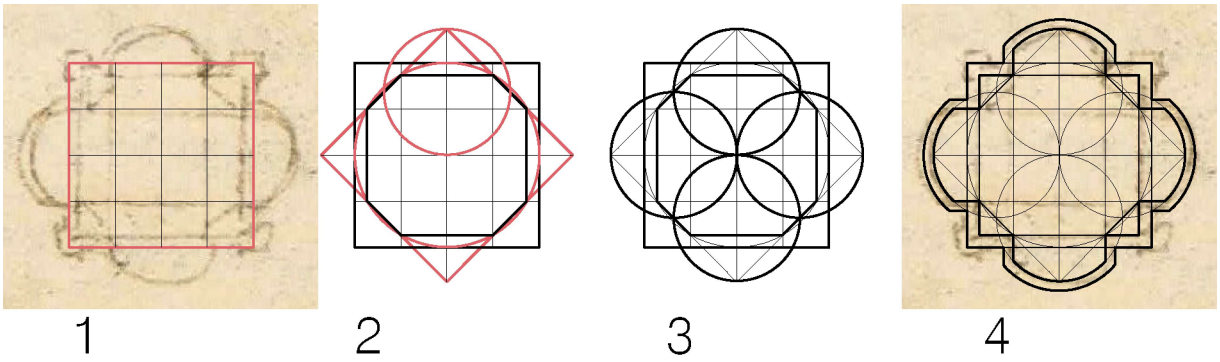


Fig. 117 - Geometrical process for the reconstruction of the plan.

As can be seen in fig. 156, the height of the parts of the church was put in relation with the guidelines defined for the plan. The height of the niches, in fact, is equal to the distance in plan between its interior extreme and the centre of the plan, and the height of the edifice is related to the square that led to the construction of the plan.

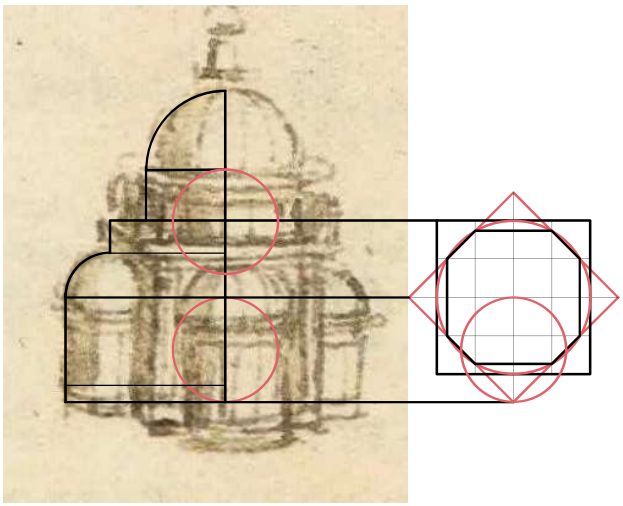


Fig. 118 - Relationship between the geometry in plan and the proportions in elevation.

3.15.2. Results

In this case only one three-dimensional model was produced, because, as it was already highlighted, no need to create variants emerged during the study of the church. Obviously, this is related to the low level of detail of this small drawing.

As regards the dimensions of the edifice, the hypotheses were made on the basis of the niches, since there is no indication of openings, and the result is akin to the one obtained for church "A" (even though it is a slightly smaller than the latter).

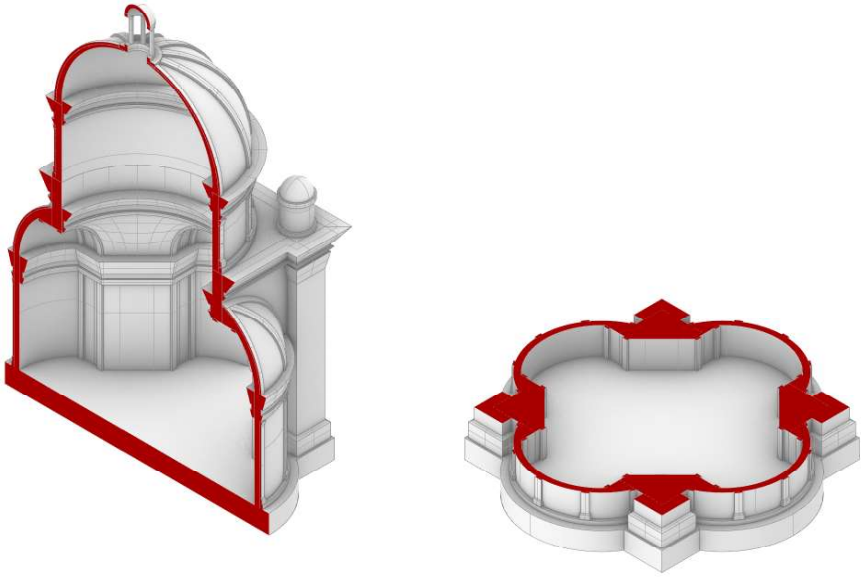


Fig. 119 - Axonometric sections of the 3D model.

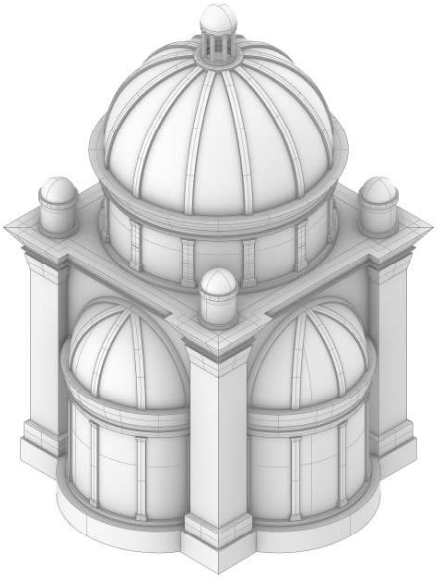


Fig. 120 - Axonometry.

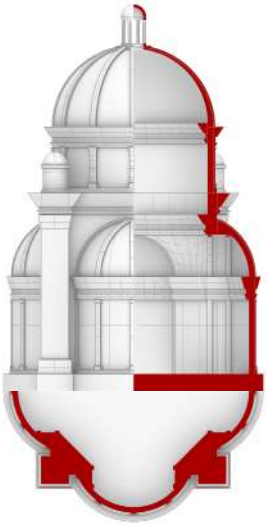


Fig. 121 - Plan, section and elevation (1:500)

3.16. Folio 93 v E - 56 v

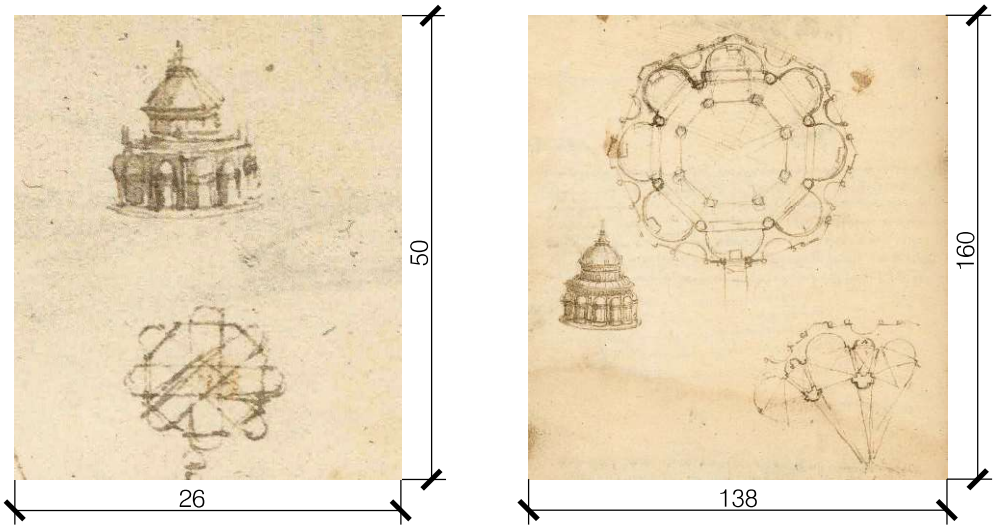


Fig. 122 - Ms. B, f. 93v (D) and f.56v: drawings of the churches with their dimensions in mm.

The small drawing of church "E", in folio 93 v, shows some peculiarities that made it necessary to try and apply a different approach for its digitalisation.[27] The reason is that while the plan view represents the scheme of an octagonal layout, the perspective view depicts a twelve-sided edifice, so, there is an inner incompatibility between the views that does not make it possible to obtain, starting from the plan, exactly the same result in elevation. The layout is however the same: a central polygonal space surrounded by semicircular niches.

Another problem is that the plan view is so schematic that it only shows guidelines. For instance, we do not have any information regarding the presence of interior columns, but nevertheless their presence is likely in order to allow the lower structure to support a smaller drum like the one drawn in the perspective view.

For all these reason it was decided to rely on the information of another folio's drawing, that is f. 56v and that as we will see, has a lot in common with the one just described and is far more detailed. The folio contains three drawings - a bird's aye view, a plan and the portion of a plan - accompanied by a note. The perspective view is very similar to that of f.93 v (the only differences are in the ceiling around the drum, which is curved, and in the dome, which is spherical) and similarly depicts a twelve-sided building. The first plan is, instead, octagonal and the second one is dodecagonal, as demonstrated by Leonardo's note:

> *"Questo vole avere 12 facce con 12 tabernaculi come a b"*[28]

However, not even the two dodecagonal views could be compatible, since in plan the semicircular niches are incorporated into a the wall, which is marked by smaller external niches, while in the perspective view the niches are completely visible externally and surround the whole perim-

27 For this reason, this case should be seen as an attempt to understand the three-dimensional layout of the buil

28 I.e. "this edifice has to have 12 sides with 12 tabernacles like a b"

eter of the building.

So, after studying all the plan views, they were combined, in order to obtain a three-dimensional model that could resemble the church depicted in f. 93 v.[29] In particular, in order to stick with the recurring elements of the manuscript, the church was modelled as octagonal. The plan of f. 93 v is thus the general guide for the modelling, while the octagonal plan in f.56 v was used in order to place the interior columns. The bird's-eye view, instead, was used for the information about the height of the elements, and scaled on the basis of the width of the niches. The final result could be classified as R/C/A-SC D-SC/BN.

3.16.1. Plan and elevation analysis

Starting from the plan depicted in f.93 v, its construction is based on the construction of two regular octagon linked by the Silver Ratio (and thus obtained by lengthening the sides of the inner one). Then, a further octagon is obtained by offsetting the exterior one by a distance equal to that between the two first octagons. The diameter of the niches is then equals twice the inner octagon's apothem.

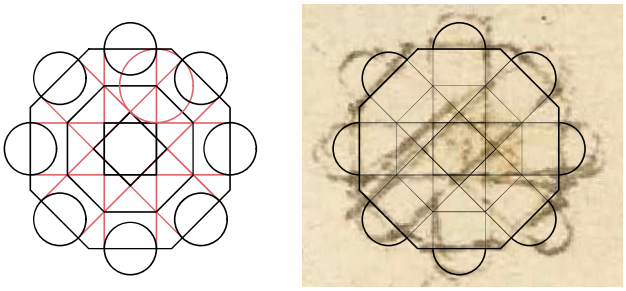


Fig. 123 - Geometrical process for the reconstruction of the plan in f.93 v (E).

The elevation views of the two churches demonstrate once again the similarities between them, since the proportion is almost the same and in both cases can be put relation with the previous geometric construction of two consecutive octagons.

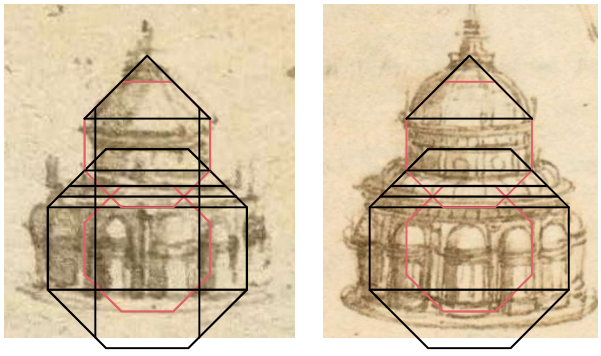


Fig. 124 - Relationship between the geometry in plan and the proportions in elevation.

29 The process could also be done for the perspective view of f. 56v, but since this process is itself a particular hypothesis, I decided not to explore all the possible combination, although this could leave other future possibilities of exploration.

The construction of octagonal based church in f. 56 v starts, once again, with the use of the Silver Ratio. A first inner octagon was drawn, then its sides were lengthened and the next octagon in the Pell Series could be constructed. By joining the midpoints of its sides it is possible to draw the exterior perimeter of the church (1). Then a circumference was drawn with its centre on one of the inner octagon's vertex and passing through the intersection between the horizontal and vertical sides of the octagon (2). The intersections between the circumferences and the radii connecting the centre and the vertices of the octagon was used in order to draw a third octagon, placed between the two ones that were drawn before. This octagon was then offset using as reference the intersections between the circumferences (2). The diameter of the exterior niches is then determined on the basis of the radii that connect the centre with the intersection of the grid based on the inner octagon and the one in the middle (3 and 4). The interior niches were drawn using one of the octagons previously defined to place the centres and an octagonal star to determine their radii (5). Then, the columns were placed in the vertices of the inner octagon and the other architectural details were drawn using the guidelines determined by the elements previously drawn (6).

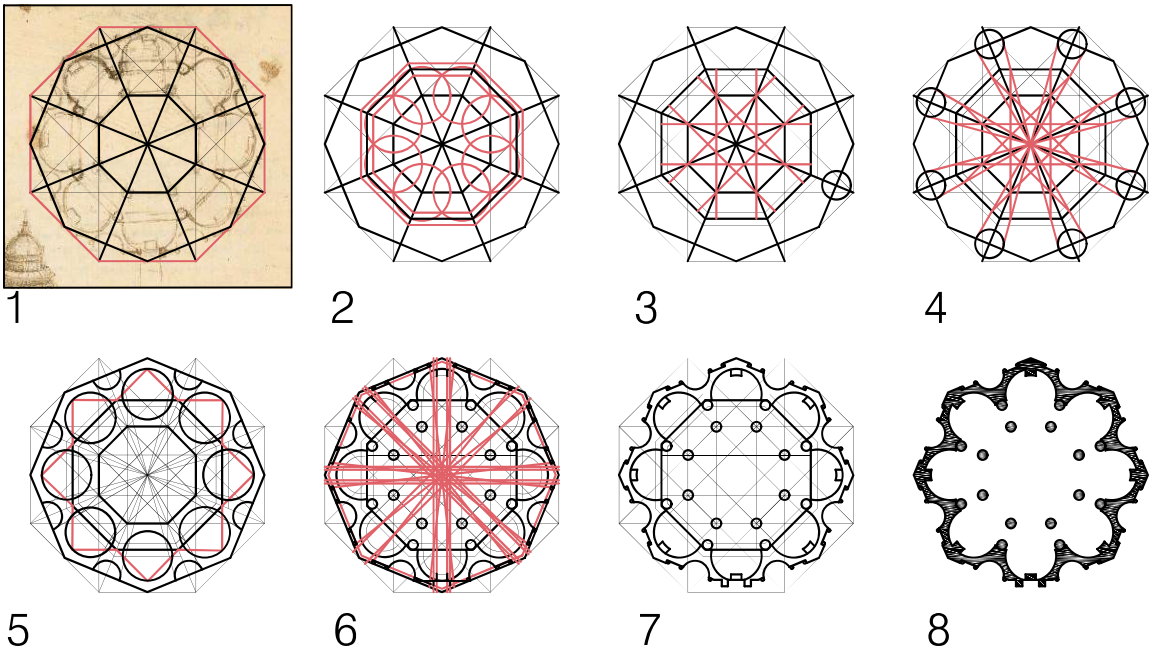


Fig. 125 - Geometrical process for the reconstruction of the octagonal plan in f. 56v.

The construction of the dodecagonal plan starts from an inner dodecagon. Then two sides were lengthened and the circumference, centred in their intersection and tangent to the first polygon, determined the offset to give to the exterior dodecagon (1). The diameter of the interior niche is determined drawing a circumference that passes through the intersection between the lengthening of two sides of the latter octagon and that has its centre in the midpoint of its side (2). The exterior perimeter was then drawn, using the construction of other dodecagons on the basis of the latter (3) and drawing radii from the centre to the tabernacles (4). Using the guidelines defined by all these elements it was then possible to define all the interior and exterior details (5 and 6).

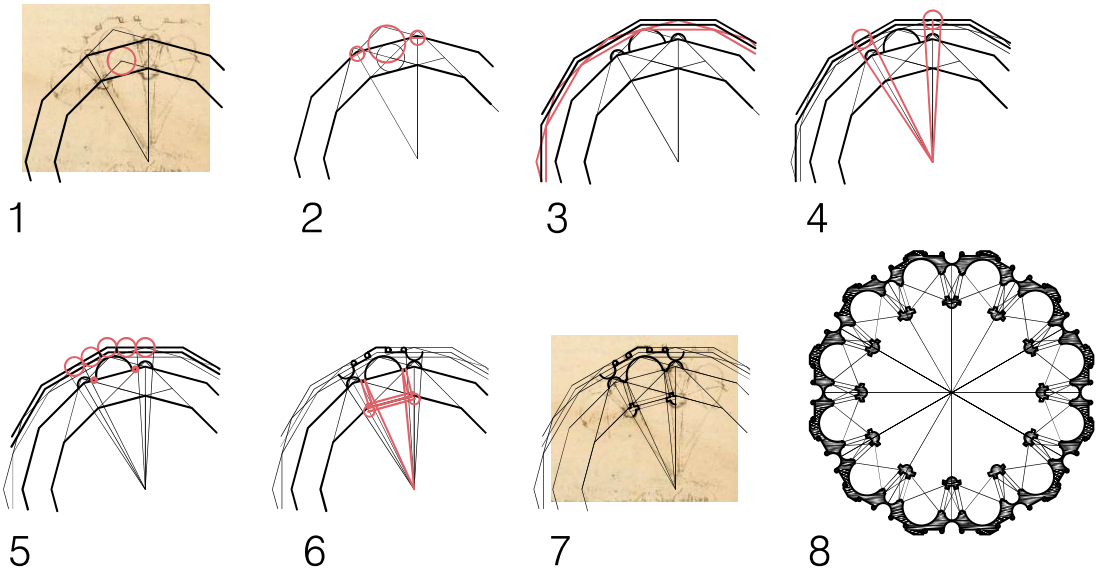


Fig. 126 - Geometrical process for the reconstruction of the dodecagonal plan in f. 56v.

3.16.2. Consistency between plan and perspective views

As it was pointed out, there are multiple problems of inconsistency between the views in bot f. 93 v and f. 56 v. Those inconsistencies rely on two levels: the number of sides of the building, which varies from eight to twelve in both folii, and the exterior visibility of niches (for what regards f. 56 v).

3.16.3. Results

The result is a single 3D model. By hypothesizing the presence of single arched windows on the niches' perimeter (as Leonardo did in many other churches), it is possible to make an assumption on the dimension of the edifice by imposing a width equal to approximately 1.0 m.

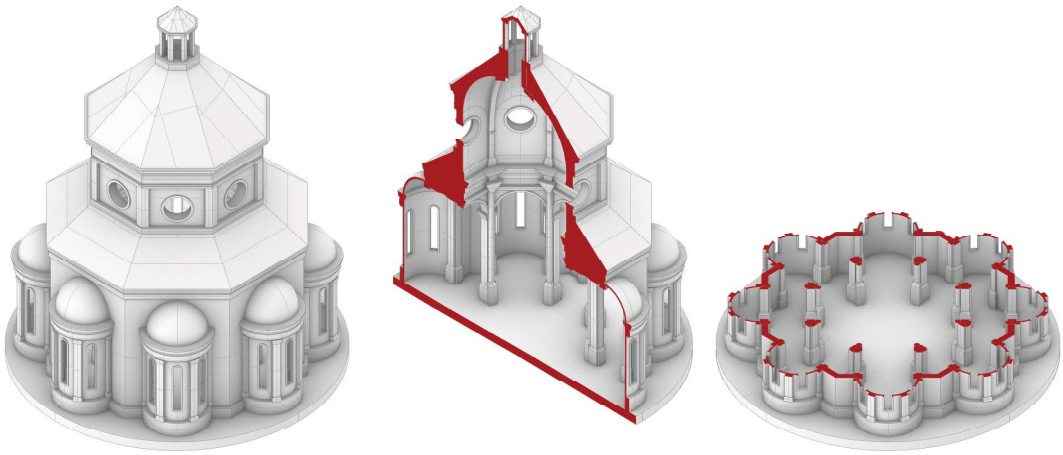


Fig. 127 - Axonometry and axonometric sections of the 3D model.

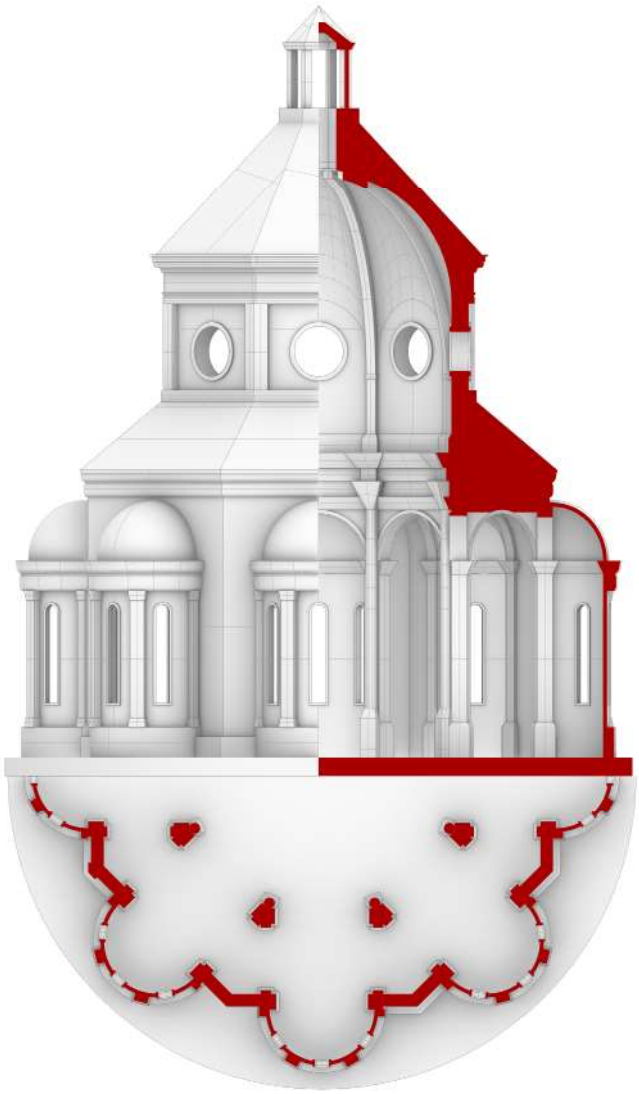


Fig. 128 - Plan, section and perspective view (1:500).

3.17. Folio 93 v F

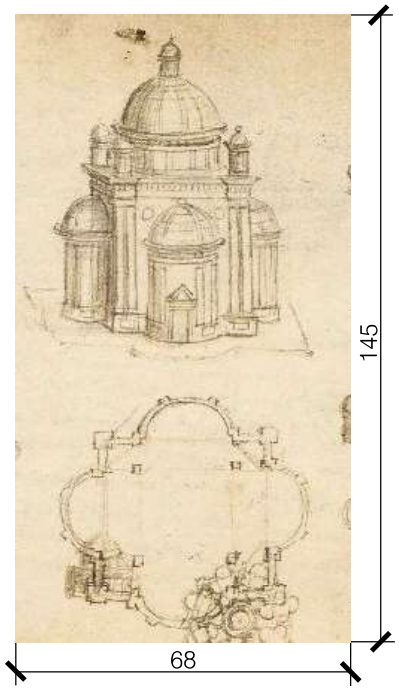


Fig. 129 - Ms. B, f. 93v: drawing of the church "F" with its dimensions in mm.

The drawing of this church is the bigger one of the folio, since the plan view measures about 60 mm x 60 mm, while the perspective view measures approximately 70 mm x 82 mm. It is, therefore, the most accurate drawing of the folio and among the ones where the details are better visible in the whole manuscript. For this reason, the detail information contained in it were used also for the other churches of f.93 v.

The layout of the church is made up of a central square space with niches, surmounted by a spherical dome with a circular drum on spherical pendentives. The latter are positioned in correspondence of the intersections between the barrel vaults. Thus, this church could be classified as QC(a). As it was done for f. 18v-19r we don't have any certainty about the type of ceiling covering the corners of the four-lobed structure, so three different possibilities were modelled.

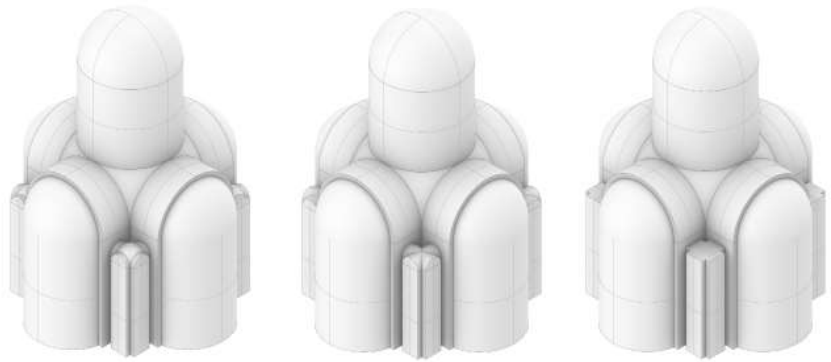


Fig. 130 - Comparison between the shape of the interior voids of the variants.

Moreover there are a few inconsistencies between plan and perspective views that led to the definition of two variants.

3.17.1. Plan and elevation analysis

The reconstruction of the plan view starts from the square that defines the interior perimeter. Applying the geometric construction of the golden section a smaller circumference is defined, and the position of the interior columns can be defined by tracing the horizontal and vertical lines tangent to this circumference (1). The latter also allows to define the boundaries of the chapels by translating the circumference itself of a distance equal to half its diameter (2). Then through the construction of a grid based on sub-multiples of the main elements it's possible to define all the remaining details.

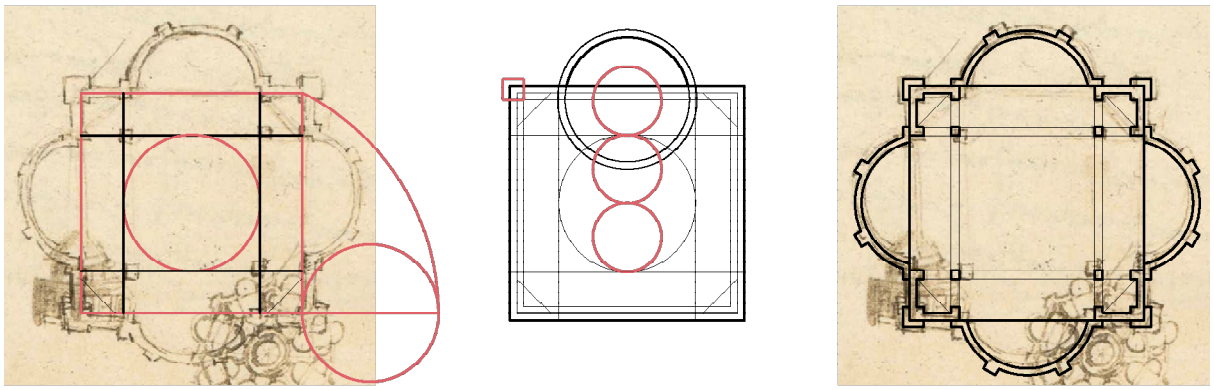


Fig. 131 - Geometrical process for the reconstruction of the plan.

Regarding the proportional study in elevation, the façade can be put in relation with a square, while the niches show a 4:7 ratio between the diameter and the total height (as in churches A and B). Moreover its possible to put in relation the height of the drum and the guidelines defined for the plan.

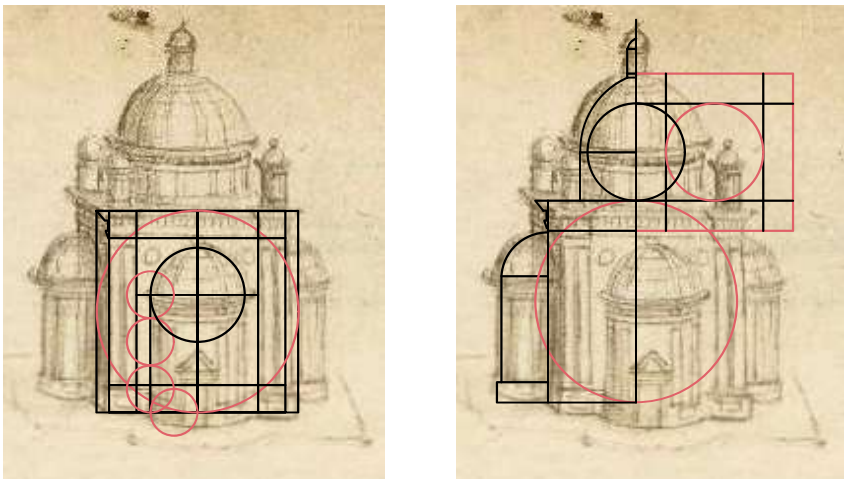


Fig. 132 - Proportions in the façade (1) and the relationship between the geometry in plan and the proportions in elevation (2).

3.17.2. Consistency between plan and perspective views

Plan and perspective views differ only for the extension of the angular lesenes and for the fact that in plan they are not drawn ad double columns (as in turn they are in the perspective view). This is, for this reason, just a slight difference that could be traced back to a decision of keeping the plan schematic.

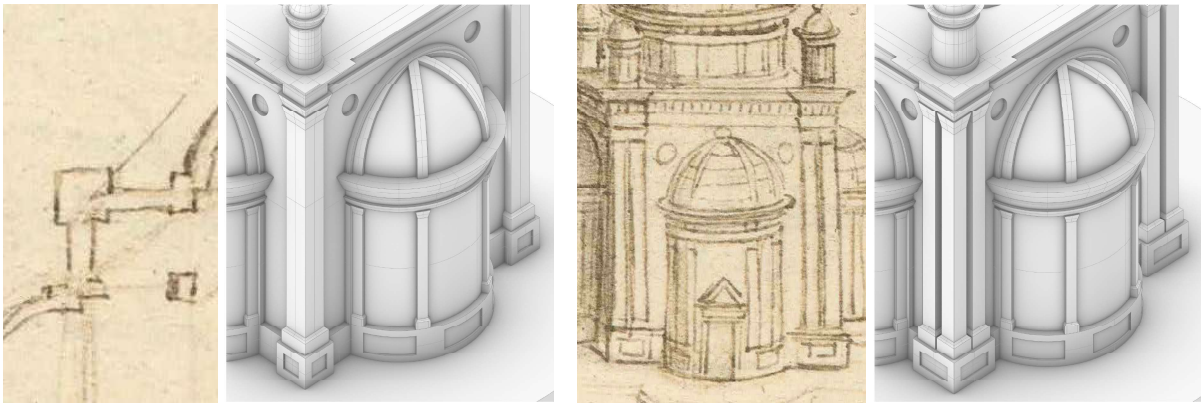


Fig. 133 - Detail of the differences in the corner *lesenes*.

3.17.3. Results

Overall, six solutions were produced, on the basis of the two variables that were previously pinpointed:

1. Source of information (plan or perspective views)
2. Type of ceiling in the corners (sailing vault, groin vault or a flat ceiling)

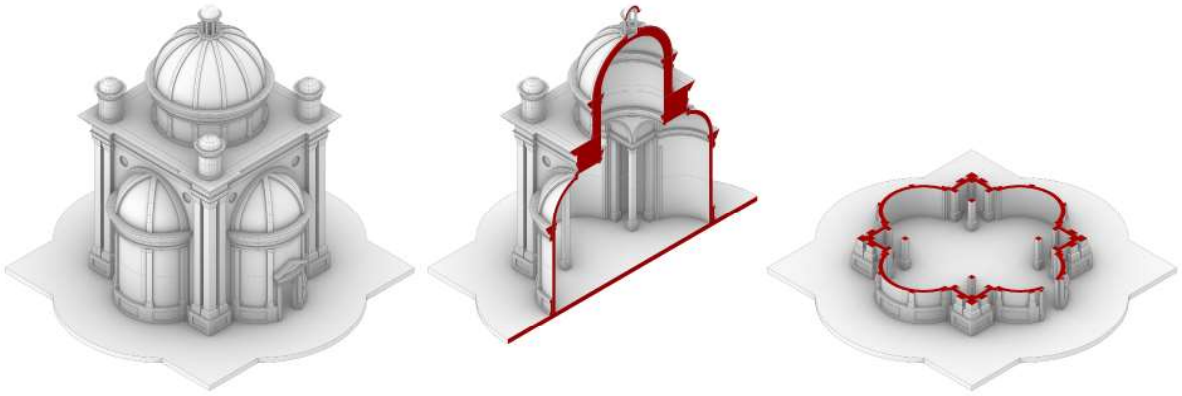


Fig. 134 - Axonometry and axonometric sections of one of the six variants.

3.18. Folio 94 r

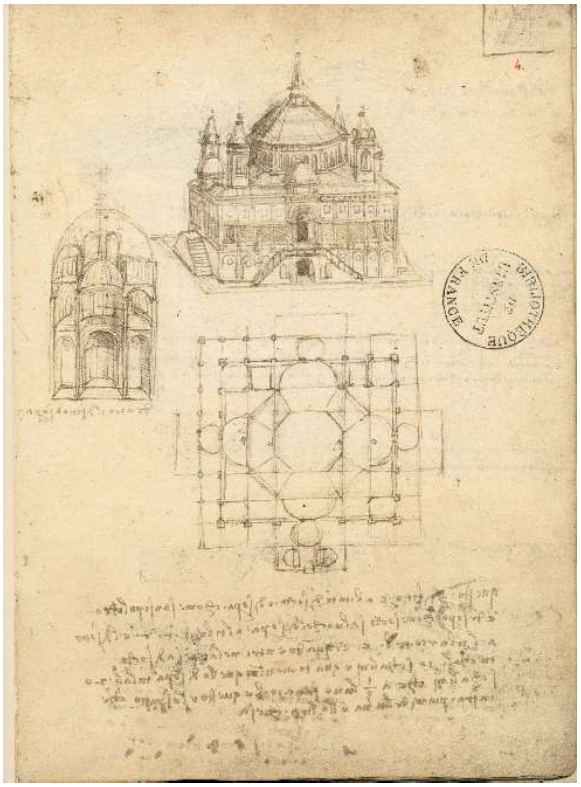


Fig. 135 - Folio 94 r.

The church depicted in folio 94r constitutes an *unicum* in Leonardo da Vinci's production of centrally planned churches: not only it is the only one that is equipped with a perspective section of its interiors, but it is also the only one that presents the plan of two storeys and one of the few accompanied by a written description[30]. Moreover it is the only church that is equipped with information regarding its dimensions and, on a compositional point of view is not related with any of the previous churches and doesn't follow their aggregative rules.

We shall here better explain what we mean saying that it contains the plan of two floors. What apparently is just a plan contains in fact two plans in it as Leonardo explains in his note:

> *"Questo edifizio è abitato di sotto e di sopra, come San Sipulcro. È di sopra come sotto salvo che 'l disopra ha 'l tiburio c d e 'l disotto ha 'l tiburio a b; e quando entri ne la chiesa di sotto, tu cali 10 scalini, e quando tu monti quello di sopra, tu sali 20 scalini che a 1/3 l'uno fanno 10 braccia. E questo è lo spazio ch'è in fra i piani dell'una e l'altra chiesa."*

Let's consider the given dimensional information. Leonardo expresses the dimensions in *braccia*

30 The fact that in one of the final pages of the manuscript Leonardo uses a written description to better explain the features of a church could be in my opinion an important element to understand the purpose of these studies. In particular this could well relate to the techniques of treatise-writers in case he intended to write a corpus or a treatise about centrally planned churches with a dome and use the content of Ms. B as a basis for it. Filarete, for instance uses text in order to give all the dimensional information of his drawings (for further information about the traditional features of Leonardo's coeval treatise-writers see SCHOFIELD, RICHARD. 1991. *"Leonardo's Milanese Architecture: Career, Sources and Graphic Techniques"*. Achademia Leonardi Vinci. 4, pp. 140-142).

fiorentine (one *braccio fiorentino* corresponds about to 0,5836 metres). This could mean that the distance between the floors is equal to 5,8 m (i.e. ten *braccia*) and the height of every step of the stair is equal to 29 cm (590/20), which is plausible.

The layout of this church differs from the pattern that we noticed in all the other churches of the manuscript and is not classifiable using the method that we defined in Chapter 3. In this case we decided to limit our study to the reconstruction of the plan, but the three-dimensional reconstruction of this church could certainly be an interesting element to develop in future analysis of the manuscript.

The construction of the plan starts once again from a combination between Golden and Silver Ratio, which are used to create a grid of guidelines for the drawing. An interesting element is the fact that this plan is drawn differently in the upper part and in the lower part, maybe indicating in the same drawing the information for two different floors[31].

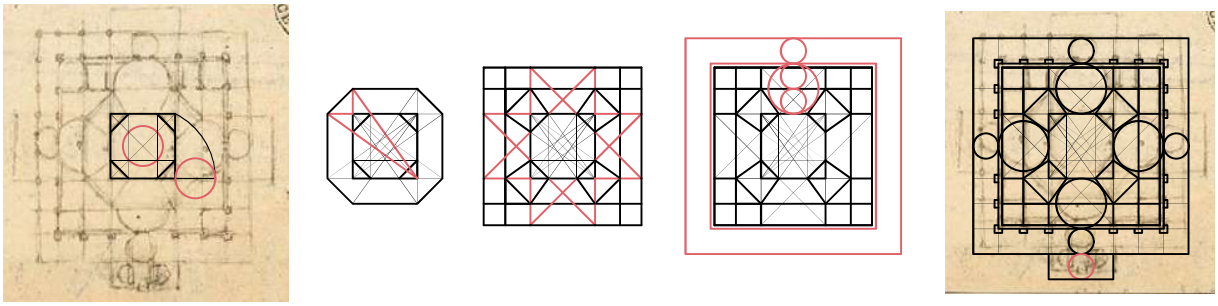


Fig. 136 - Geometrical process for the reconstruction of the plan.

31 This, however is an hypothesis that could be verified trying to create its 3D model.

Conclusion

To conclude, we summarize the main goals reached in every chapter and try to point out a general result of the whole work.

In the first chapter we illustrated a complex historical context for the manuscript and, given the contacts that Leonardo had with other coeval artists, we proposed an approach that was inclusive towards the examples that could have influenced Leonardo during and before his Milanese period. This was done in contrast with the tendency of analysing Leonardo's oeuvre as that of a solitary genius, devoid of his context. Of course, our selection does not claim to be thorough: other examples could be added and this could certainly constitute a further possible development of this research.

This selection was used in Chapter 2 in order to define some guiding elements for the digitalization. In particular, this was done classifying the topic for which each reference could be useful and then collecting in parallel all the edifices that were related to the same subject. Doing so, it was possible to obtain a casuistry for the drum and dome system, for the exterior and interior decoration (which however was always considered in a low level of detail), for the interior layout in elevation or for the interior and exterior openings. The latter were particularly useful as guides for making assumptions regarding the real scale dimension of the building.

In the third chapter we analysed on one hand J. P. Richter's work[1], pointing out some problems that could be related to an approach of classification that is focused on the analysis of the domes, and on the other hand, that of J. Guillaume[2], who instead carried out a study that starts from the aggregation of elements. On the basis of considerations about those works we developed a personal proposal for the classification of churches based on a code that assigns a letter for each variable in the definition of the layout. This approach is highly compatible with parametric methods of modelling, even though it was only used to define the fundamental elements of the model due to the computational complexity that rises when trying to create a single, comprehensive script for all the churches.

One of the most interesting results that we can observe from the digitalisation work carried out in Chapter 4 is that for the majority of the churches it was necessary to produce more than one three-dimensional solution. This is related to two different kind of variables:

1. Leonardo draws in different ways the same architectural element inside the same drawing;
2. There are inconsistencies between plan and perspective views.

The first variable is deeply related to the fact that these drawing are personal annotations and prove that, by drawing, Leonardo is exploring solutions and testing them. The fact that these drawings

1 Richter, Jean Paul. *The Notebooks of Leonardo Da Vinci. Vol. 2. / Compiled and Edited from the Original Manuscripts by Jean Paul Richter*. New York: Dover, 1970. pp. 41-51

2 2 Guillaume, Jean. "Léonard et l'architecture". *Montreal Museum of Fine Arts. Léonard de Vinci, ingénieur et architecte* [Catalogue]. Montréal: Musée des beaux-arts de Montréal, 1987. pp. 207-286

were meant for personal annotations is also proven by the lack of accuracy in many of them, in fact, the more the churches are characterised by a simple layout, the more their representation is just schematic.

The second variable concerns both of the previous elements. In fact, as emerged from the digitalisation process, there are some inconsistencies that are evident and are related to the exploration of a different solution[3], while others are due to problems of imprecision or schematism in the drawings[4].

Another result that emerges from the study of the drawings is that there is a recurrent use of Golden and Silver Ratio[5] in the construction of plan views, and that the fundamental elements of this process is almost always related in some ways to the height of the parts in the perspective view. This showed the presence of a relatively complex geometrical construction also behind designs that are apparently very simple and sketchy. It is interesting to note that all these peculiarities could not be noticed without a thorough work of combined analysis and deconstruction of the two views.

As regards the layout of churches, we saw that Leonardo does not converge, through the pages of the manuscript, on a particular solution. Instead, he explores multiple possibilities in a nearly combinatory work. This, along with the other results previously pointed out, weighs in favour of the theories that want this speculation not to be meant for the design of any particular church[6]. It is in fact more likely, in our opinion, that a work of this kind could constitute the basis for a later creation of a treatise on centrally planned churches.

Lastly, all these results enable us to make some considerations about the representation techniques used in the manuscript. We anticipated that the use of a plan and a bird's-eye view is in contrast with what was claimed by L. B. Alberti and Raffaello regarding the representation tools for architecture[7], and we will try to give an explanation to this difference. First of all, it is interesting to notice that the method used by Leonardo could in turn show some affinities to the drawing instruments listed by Vitruvio: *ichnographia*, *orthographia* and *scaenographia*. In fact, Leonardo's bird's-eye views could be considered as a combination of the two last instruments, since they show a façade

3 The case of the church in ff. 18v - 19r is an example of this possibility, since the differences between plan and perspective views depict, in fact, two different solutions for the exterior wall of the chapels on the xy axes.

4 Just think, for example, of the differences in the measure of single elements, or of the impossibility to obtain the exact distance between the elements in perspective starting from the plan view.

5 This was also noticed by F. P. di Teodoro in his work about the proportions in the churches of Ms. B and can be seen in almost all the plan and elevation analyses carried out in Chapter 4. See Di Teodoro, Francesco P. *Leonardo Da Vinci: The Proportions of the Drawings of Sacred Buildings in Ms. B, Institut De France*. Architectural Histories / European Architectural History Network, EAHN. 2015. pp.381-396.

6 In his article R. Schofield demonstrates that it is unlikely that the drawing in Ms. B could be an attempt to create a project for Santa Maria delle Grazie or for Pavia Cathedral, and he also excludes the possibility for them to be regarded as "real plans" (See Schofield, Richard V. . "Leonardo's Milanese Architecture: Career, Sources and Graphic Techniques". *Achademia Leonardi Vinci* / the Armand Hammer Center for Leonardo Studies at UCLA, . 1991. pp. 139-140.). On the contrary, S. Lang claimed that the drawings constitute a progressive series for the creation of a Sforza Sepulchre (Lang, S. "Leonardo's Architectural Designs and the Sforza Mausoleum". *Journal of the Warburg and Courtauld Institutes* / Ed. E.H. Gombrich [U.a.], 1968. pp. 218-235.).

7 As it was pointed out in the Introduction, in fact, L.B. Alberti thought that the architectures should be represented through a plan view and an elevation view, while Raffaello added to them the section view (in both cases, only orthographic views).

which is almost an orthographic view of the elevation (*orthographia*) together with a perspective view that gives information about the volumes (*scaenographia*), and those are paired with a plan view (*ichnographia)*. Of course, as it was claimed[8], the perspective of which Vitruvio writes about might be different to that of Leonardo and may be a central perspective with the observer placed at a lower height. However, with this disposition, Leonardo manages to add also information about the roof in the same drawing.

It is reasonable to think that the graphical decision of Leonardo ultimately has to be related to the purpose of the drawings, and thus to the information they are able to convey, and also to the features of the edifices. First of all, the bird's-eye view enables to obtain a synthetic overview of the whole, with attention to the way the volumes are spatially assembled, and this is particularly fitting for the recurrent layout of the churches, which is made by the aggregation of elements around a central space. Then, as we anticipated, the drawing is also able to give information about the roof and about the proportional measures in the façade, while the plan associated is fundamental to know about the circulation inside the edifice. Moreover, the final effect is very similar to that of a model placed on a table, as was noticed by Pedretti[9] and we know that the combined use of a plan view with a wooden model was not something rare in terms of architectural communication in Renaissance. Moreover also L. B. Alberti claimed the importance of the creation of a model[10] in order to be aware of the problems of a project, and our analysis showed once again that Leonardo was using the drawings as a reasoning instrument.

To conclude, the representation technique developed by Leonardo appears to be on one hand extremely effective for rapidly annotating ideas and testing solutions, and also a powerful tool to convey immediate volumetric information along with measurable, ortographic views.

8 Xavier J.P. "Leonardo's Representational Technique for Centrally-Planned Temples". *Nexus Network Journal*. 10, no. 1. 2008. pp. 84-85

9 See Pedretti, Carlo. *Leonardo architetto.* Milano: Mondadori Electa, 1996. p. 12-14.

10 Alberti, Leon Battista, Cosimo Bartoli, and Giacomo Leoni. *The Ten Books of Architecture*: The 1755 Leoni Edition. New York: Dover Publications, 1986. p. 22.

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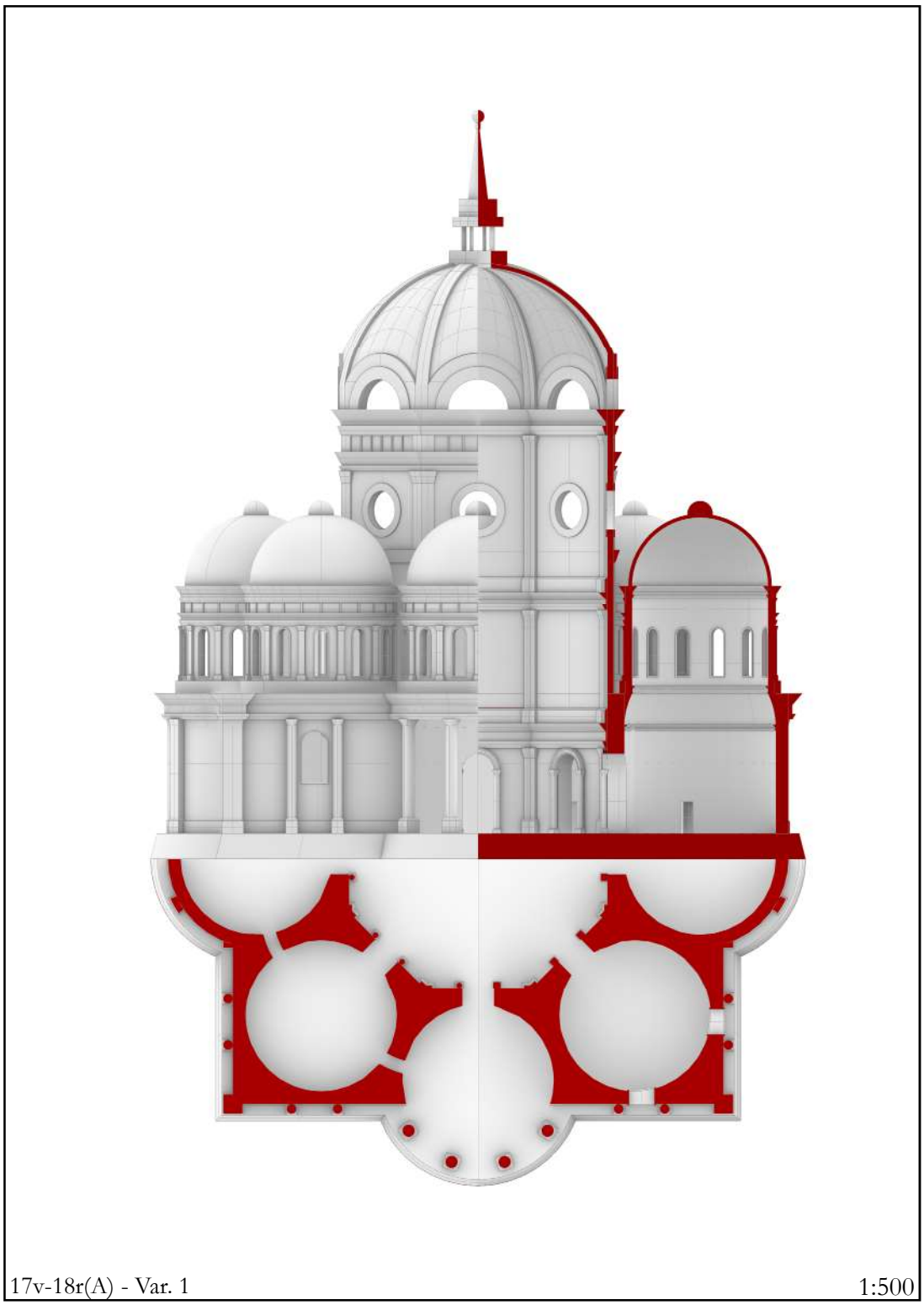
Appendix

This appendix contains the representation in plan, section and elevation of the churches that, having many variants, could not be represented in their totality in Chapter 4. These churches are:

1. 17v - 18r (A): 2 variants;
2. 17v - 18r (B): 4 variants;
3. 18v - 19r: 24 variants - 8 reported here;
4. 21r (A): 3 variants;
5. 22r: 8 variants;
6. 39v: 2 variants;
7. 93v (F): 4 variants.

In the case of ff. 18v-19r only eight variants are reported, that are the ones with a groin vault in the corners of the chapels, since the variation of the corners leads to results that are really similar and the possibility with a flat ceiling was already presented in the relative section of Chapter 4.

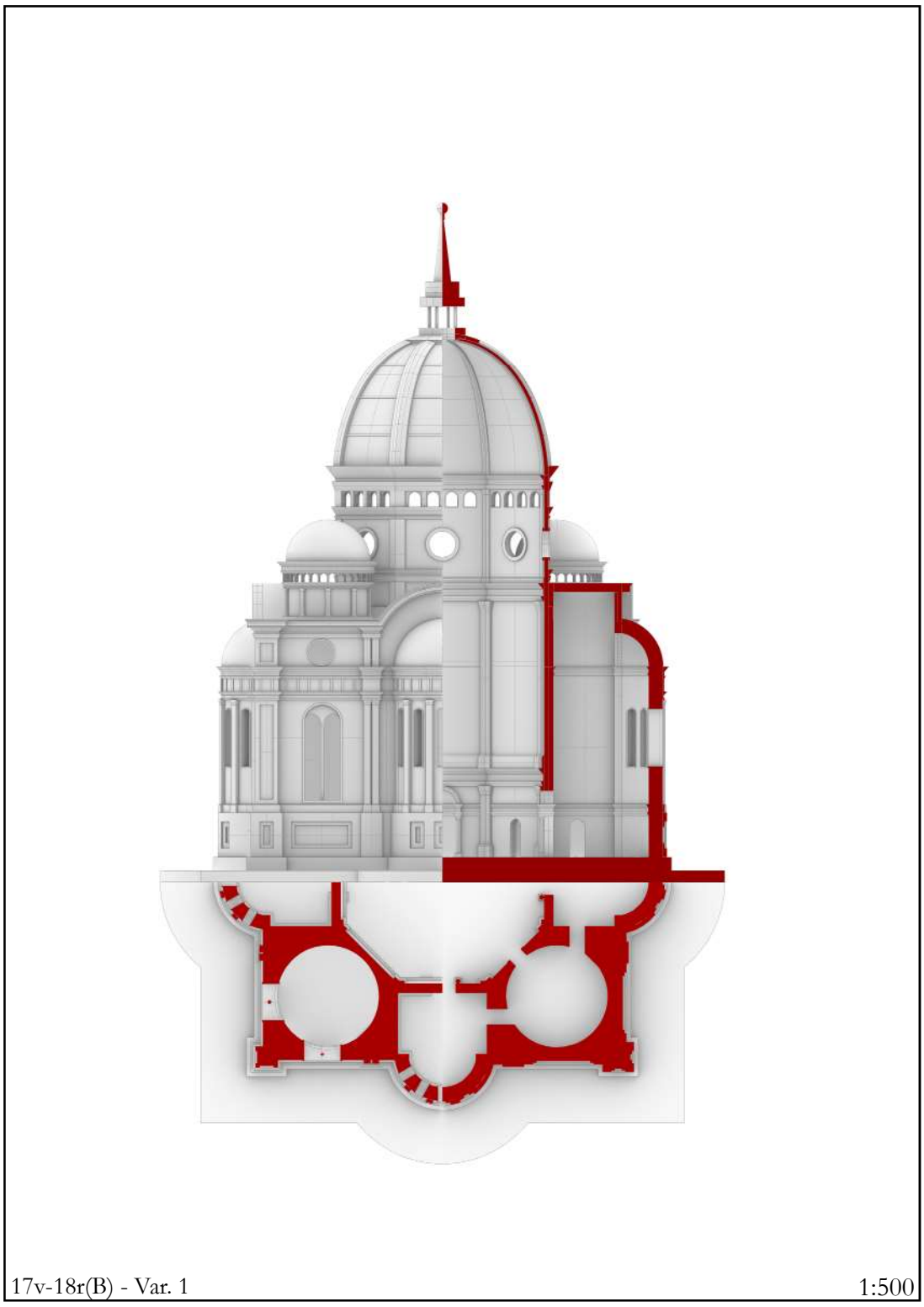
1. F. 17v - 18r (A)



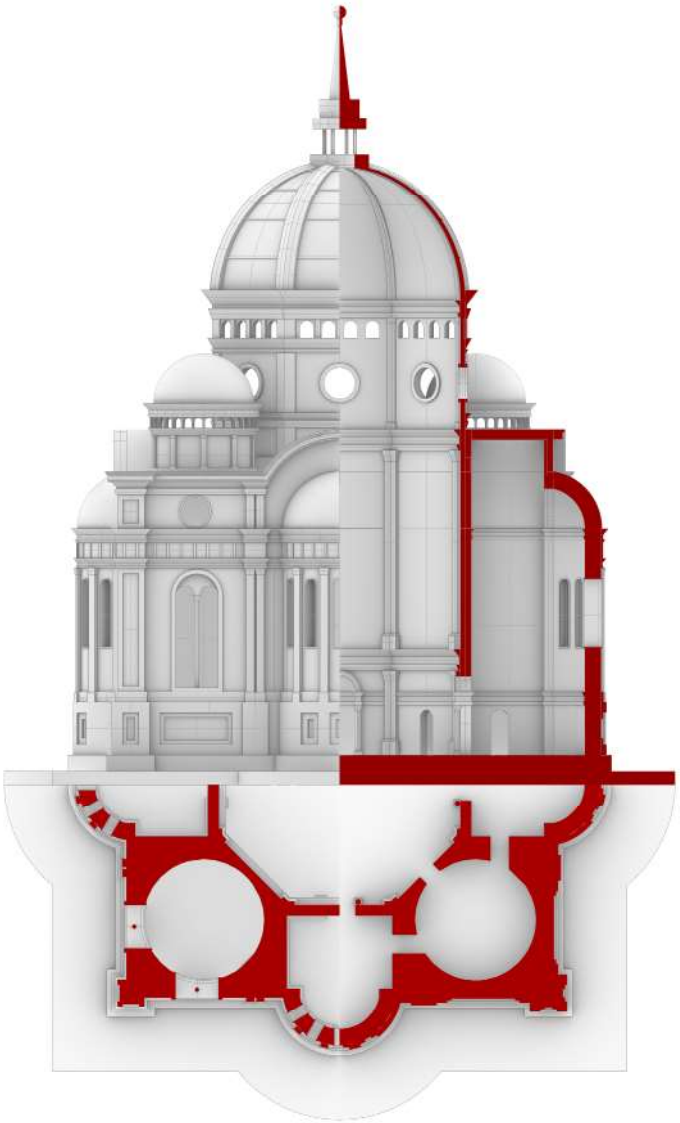
17v-18r(A) - Var. 1 1:500

17v-18r(A) - Var. 2 1:500

2. F. 17v - 18r (B)



17v-18r(B) - Var. 1 1:500



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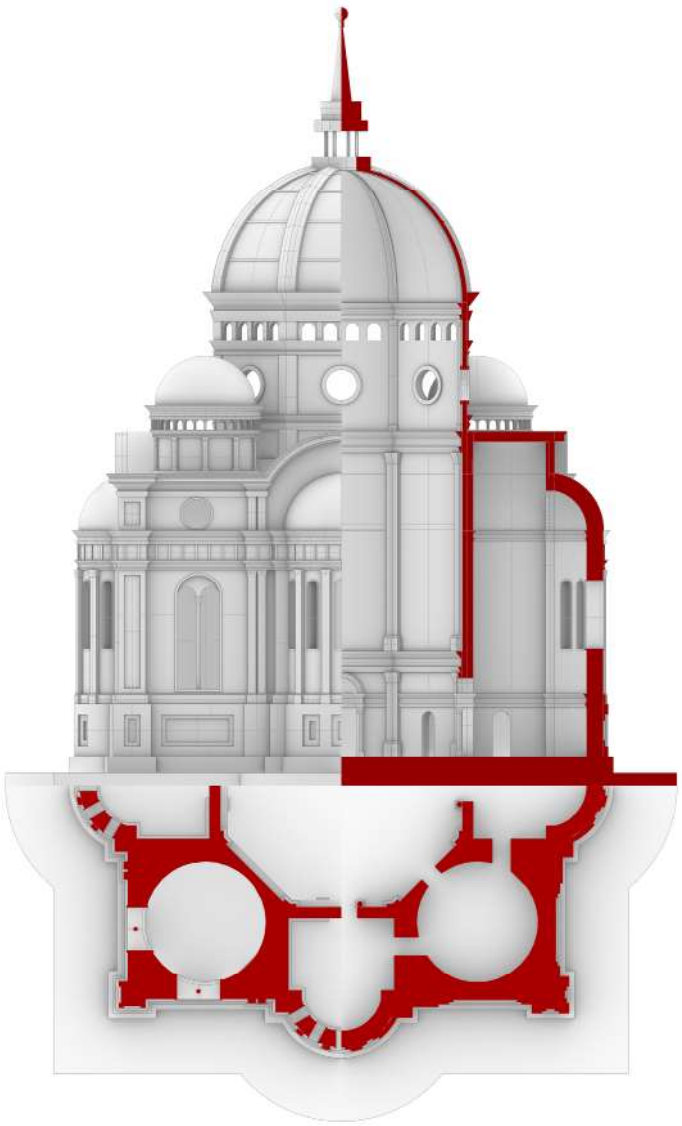
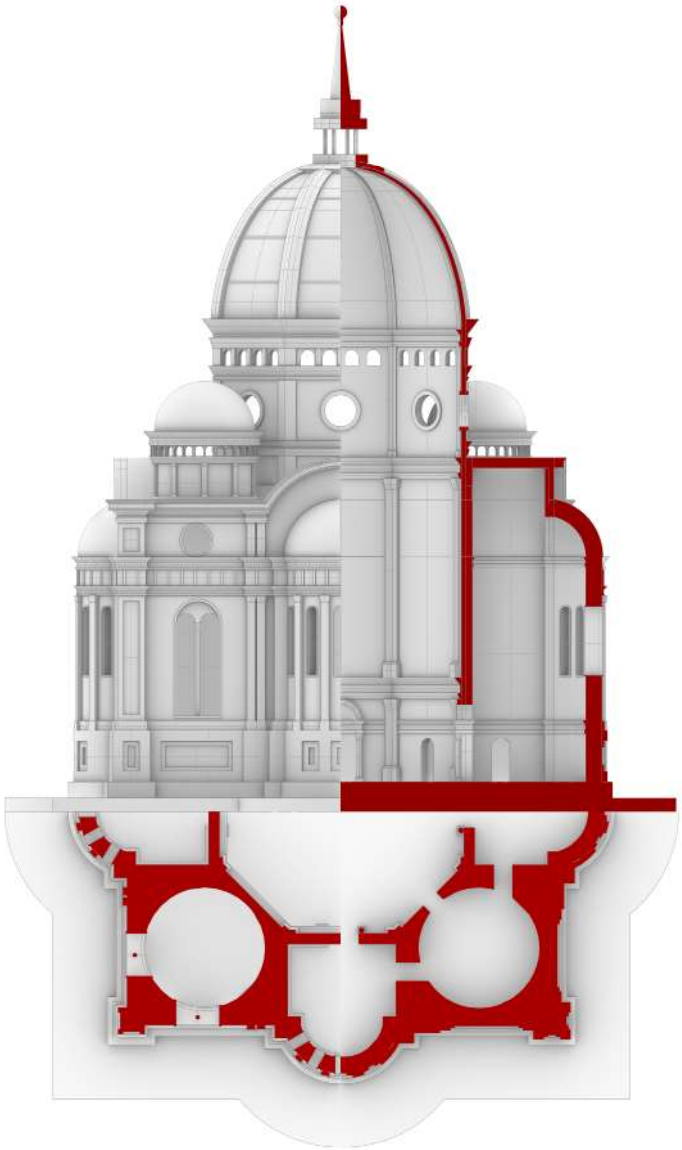
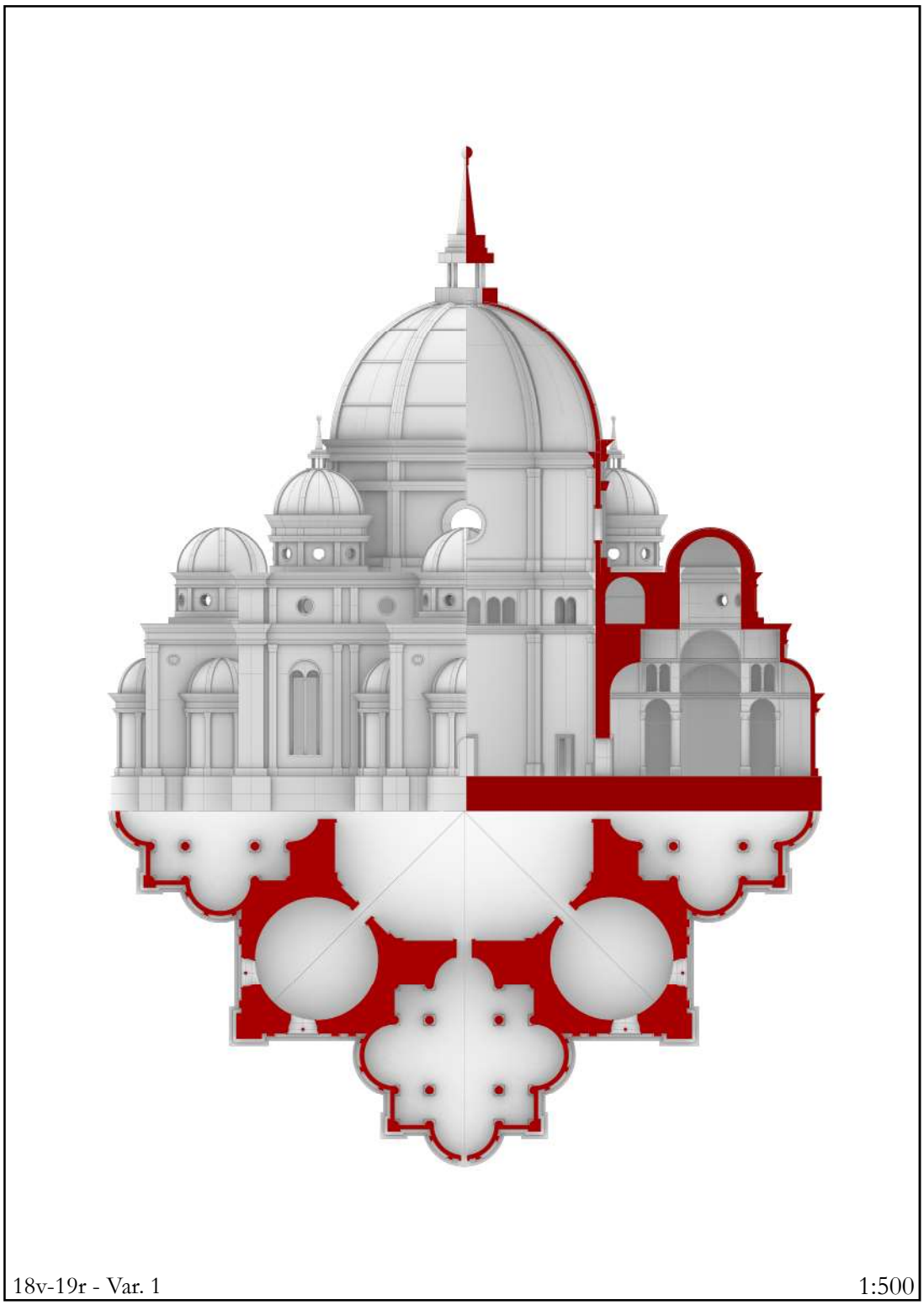


17v-18r(B) - Var. 3 1:500

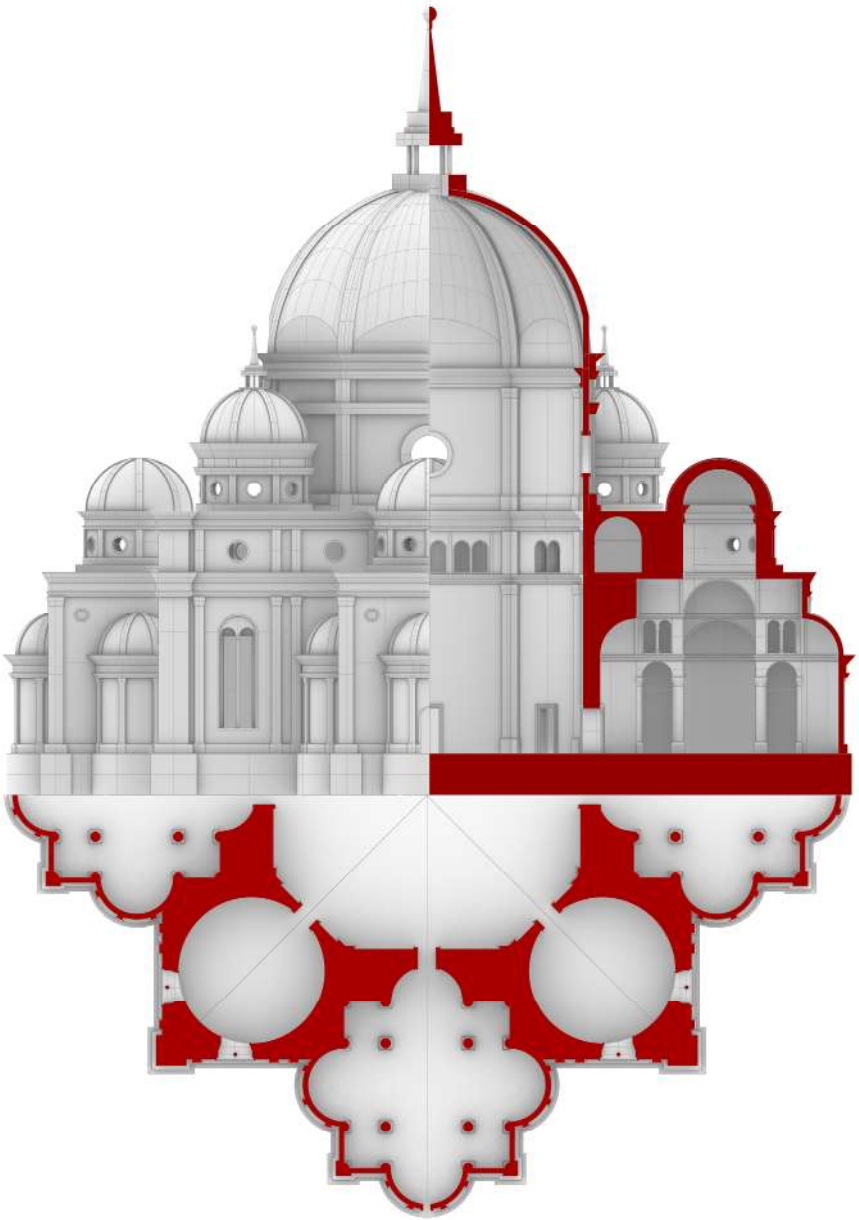


17v-18r(B) - Var. 4 1:500

3. F. 18v - 19r



18v-19r - Var. 1 1:500



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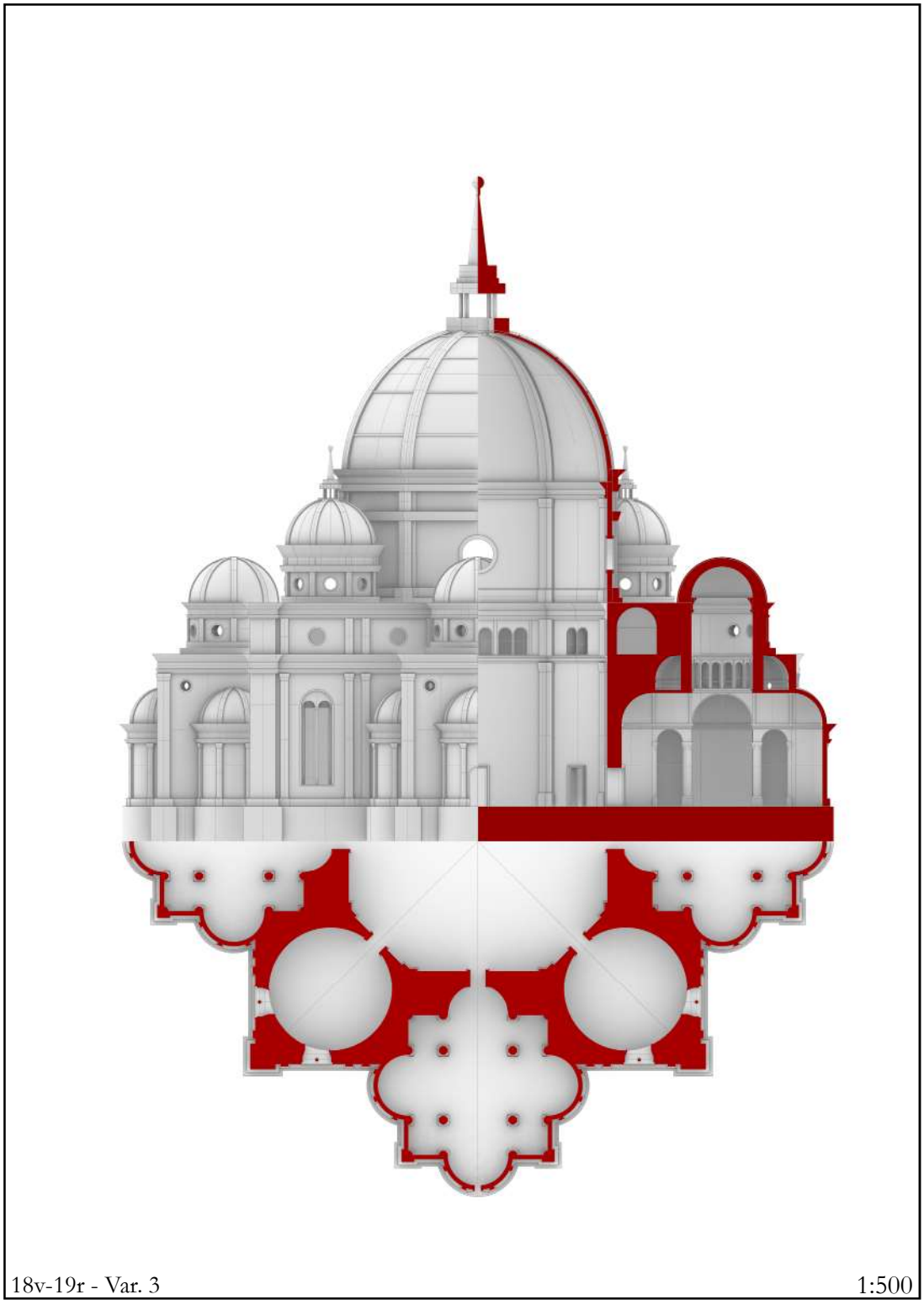
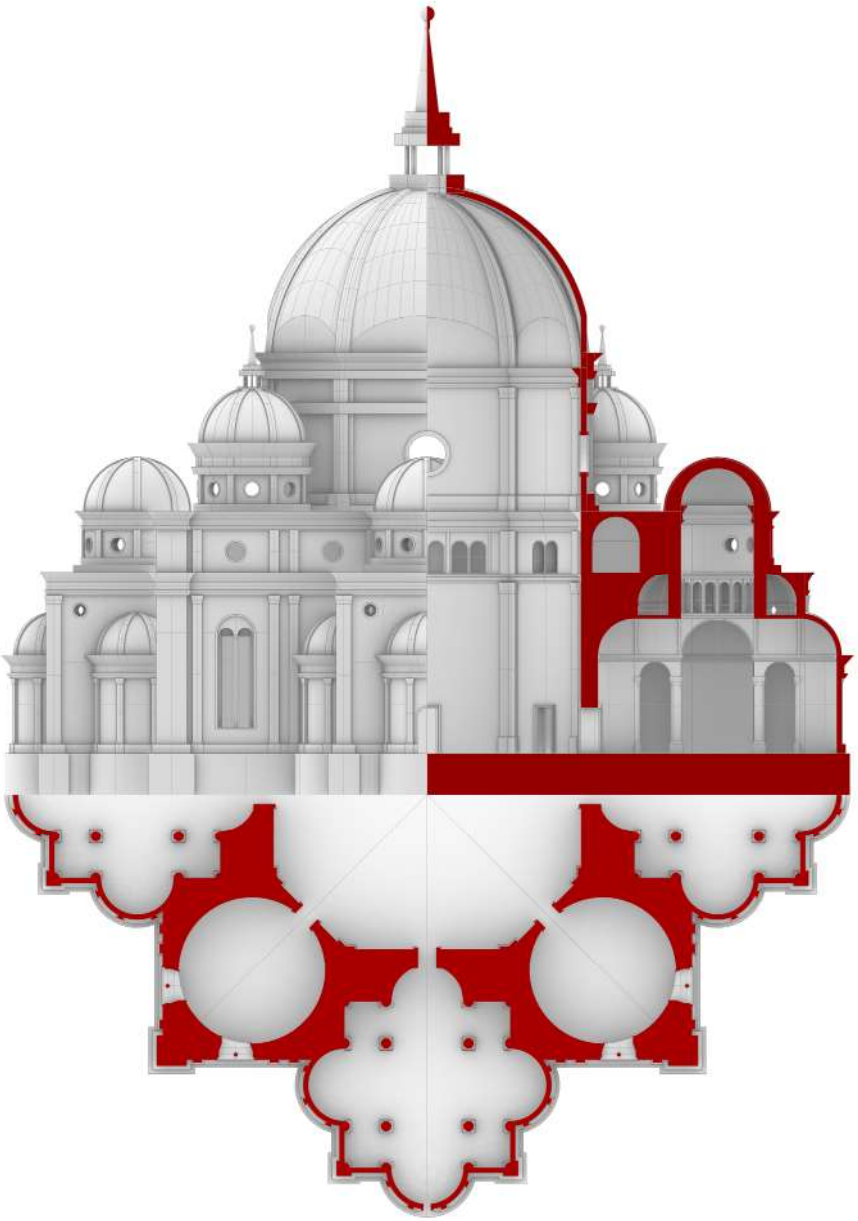


18v-19r - Var. 3 1:500



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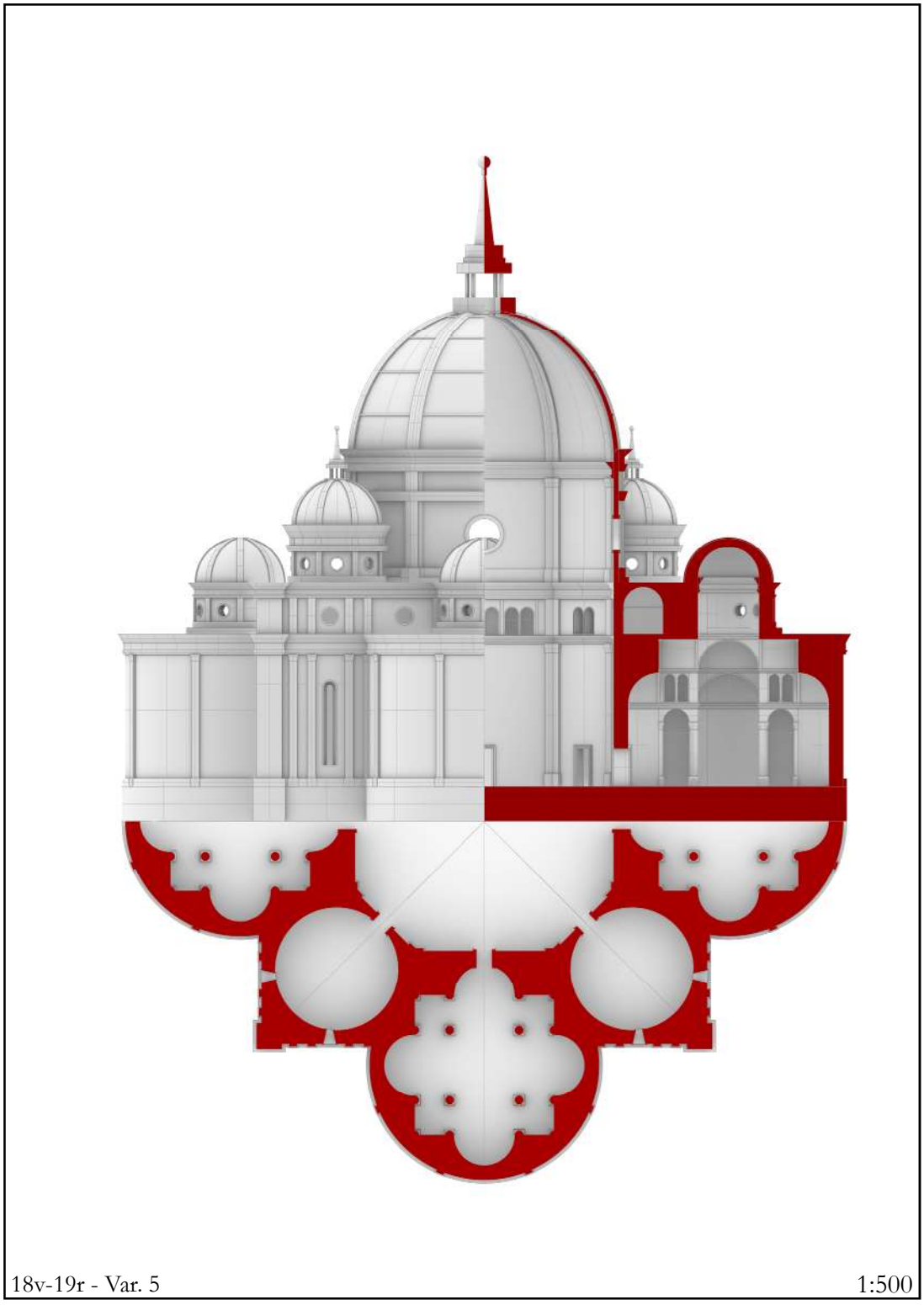
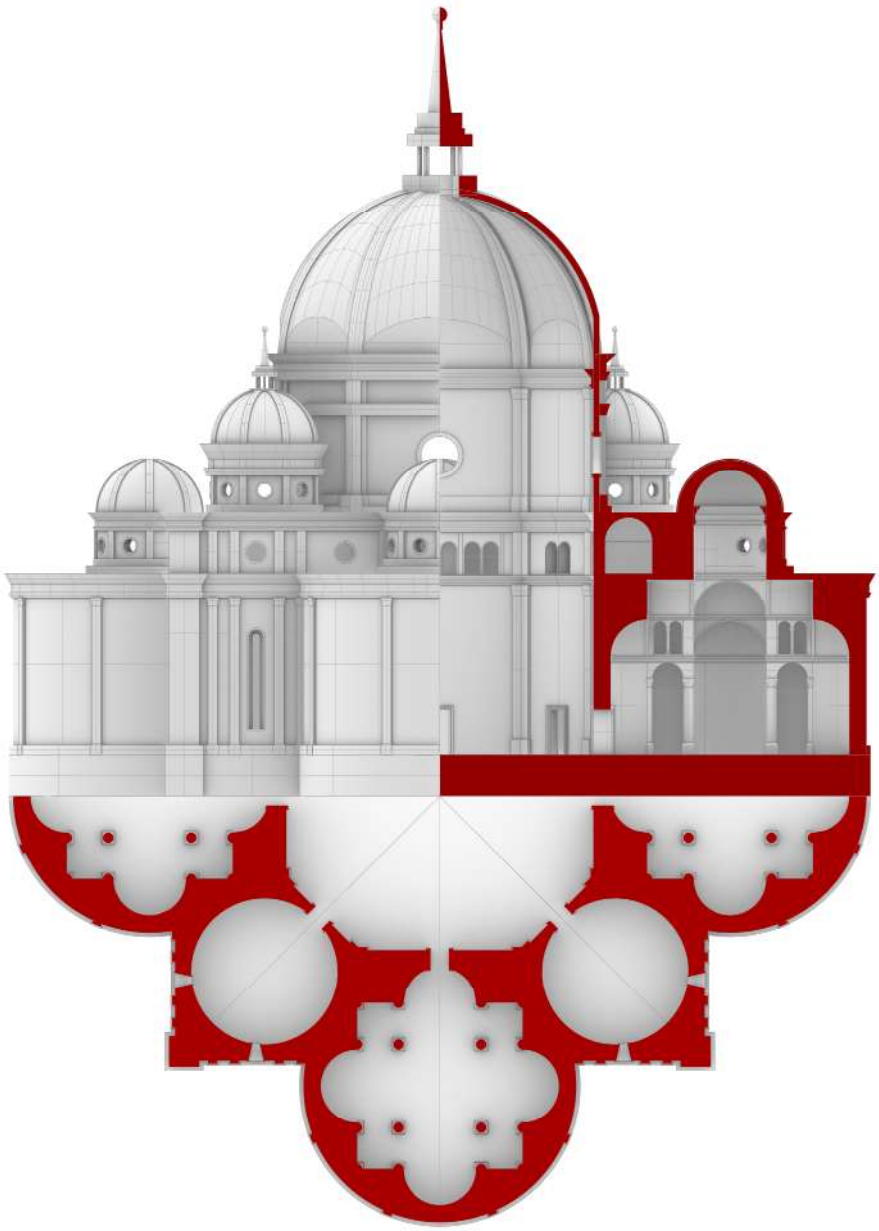
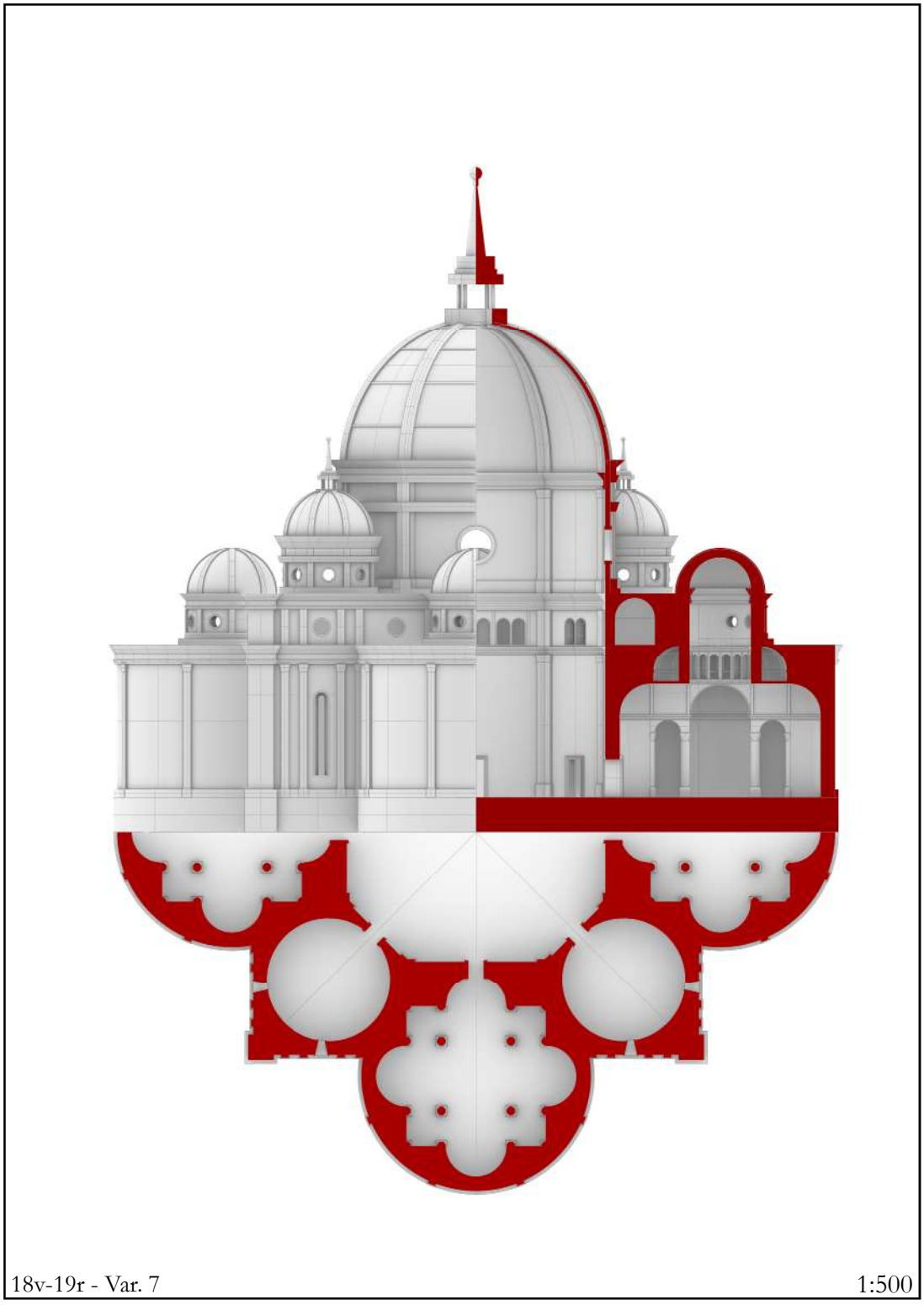


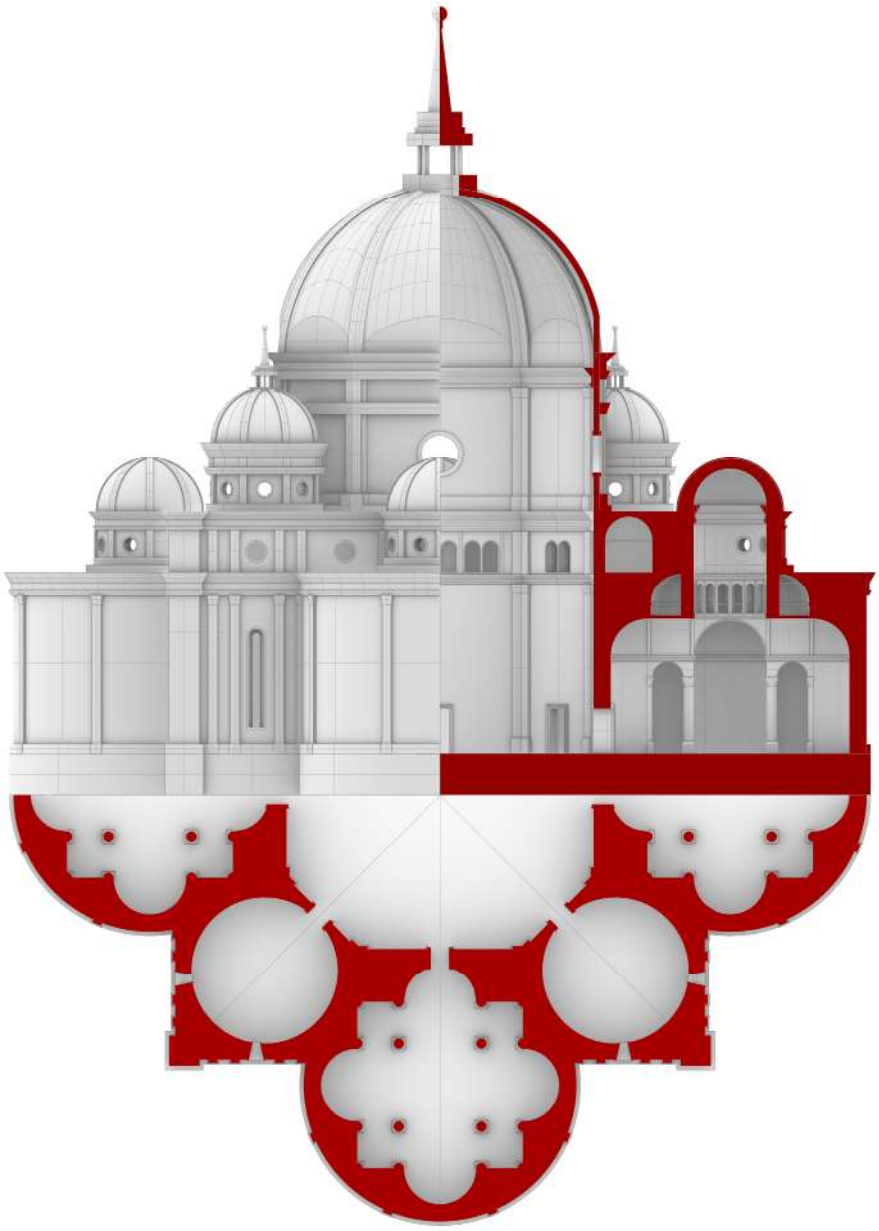
18v-19r - Var. 5 1:500



18v-19r - Var. 6 1:500

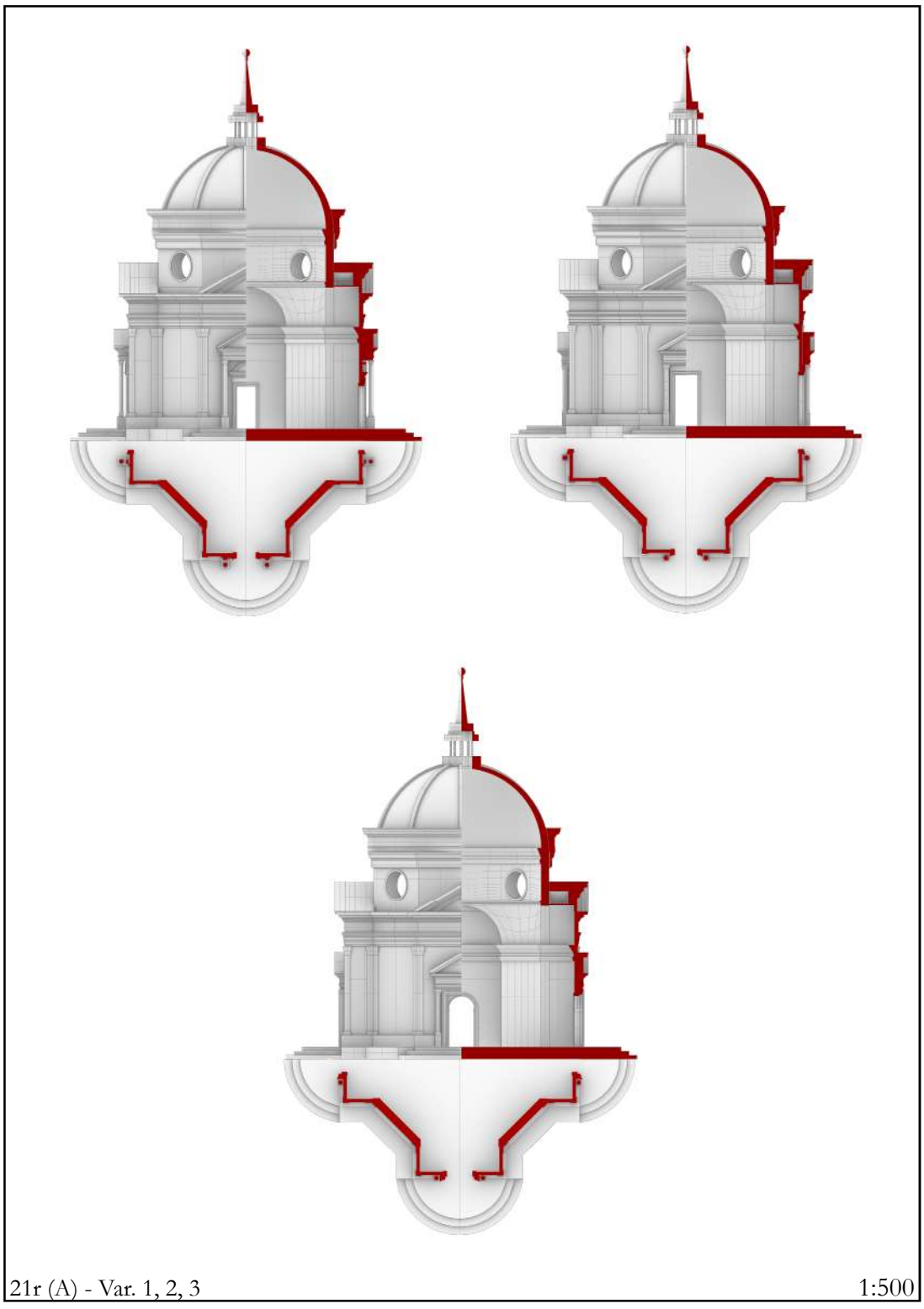


18v-19r - Var. 7 1:500



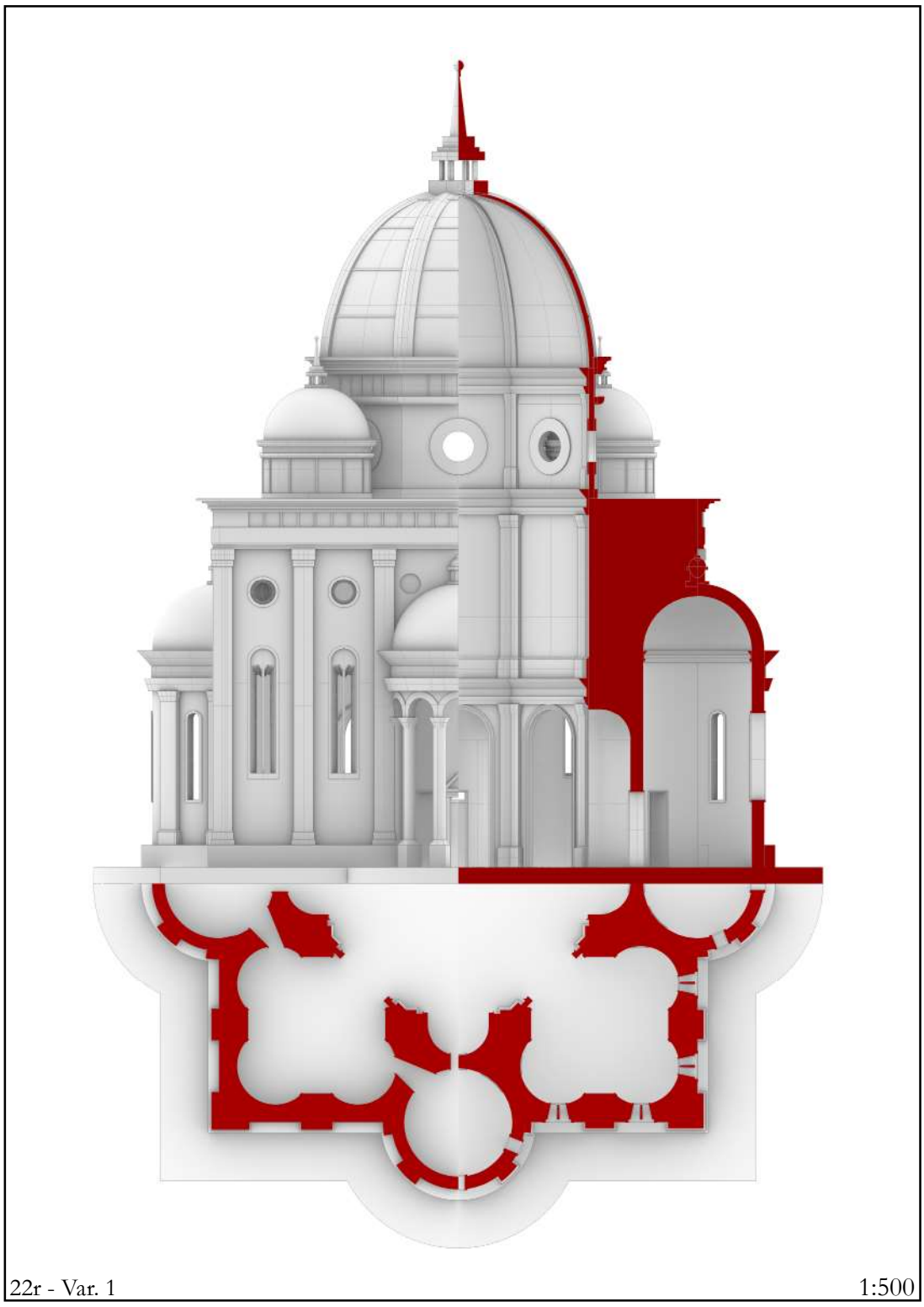
18v-19r - Var. 8 1:500

4. F. 21r (A)

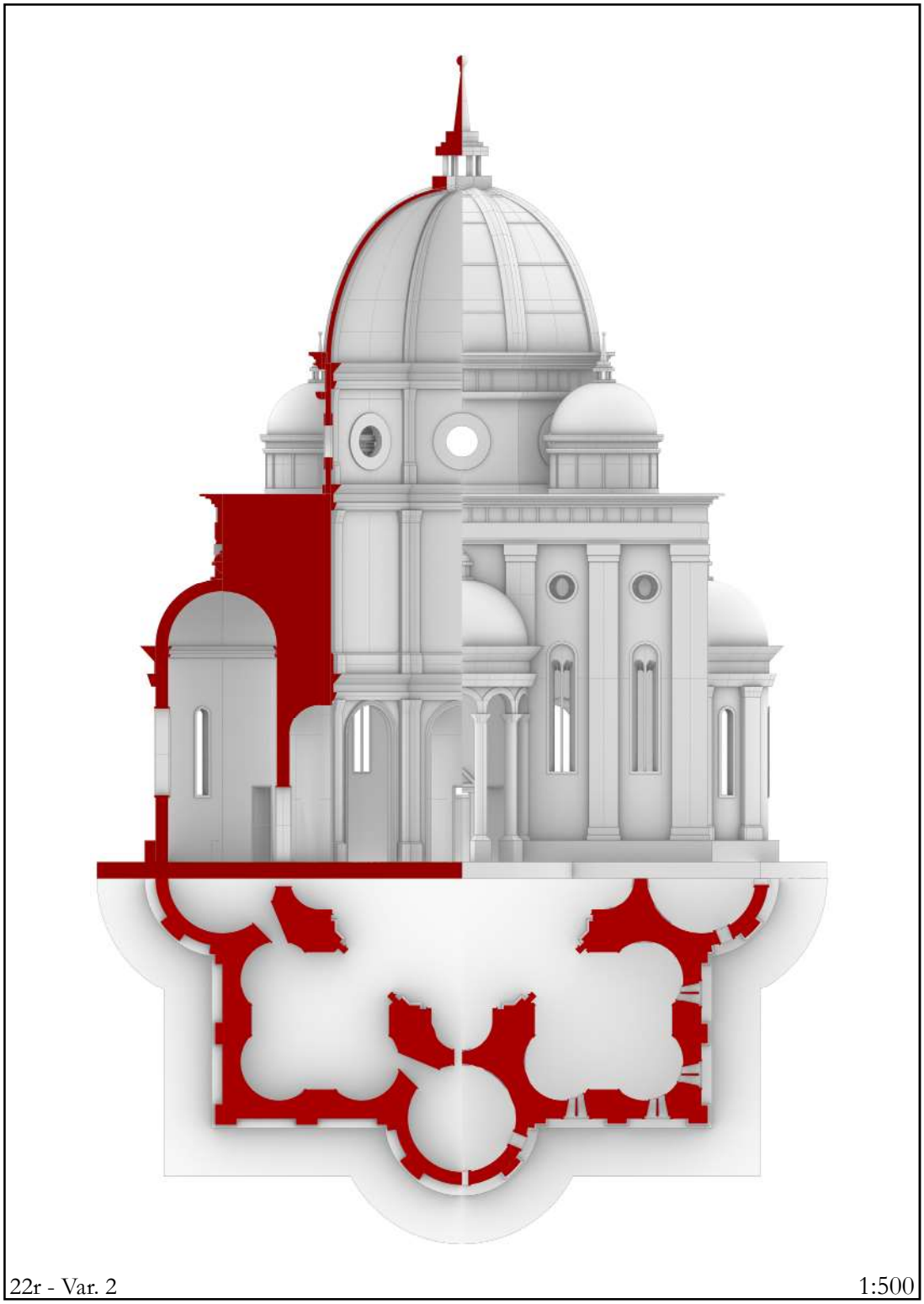


21r (A) - Var. 1, 2, 3 1:500

5. F. 22r

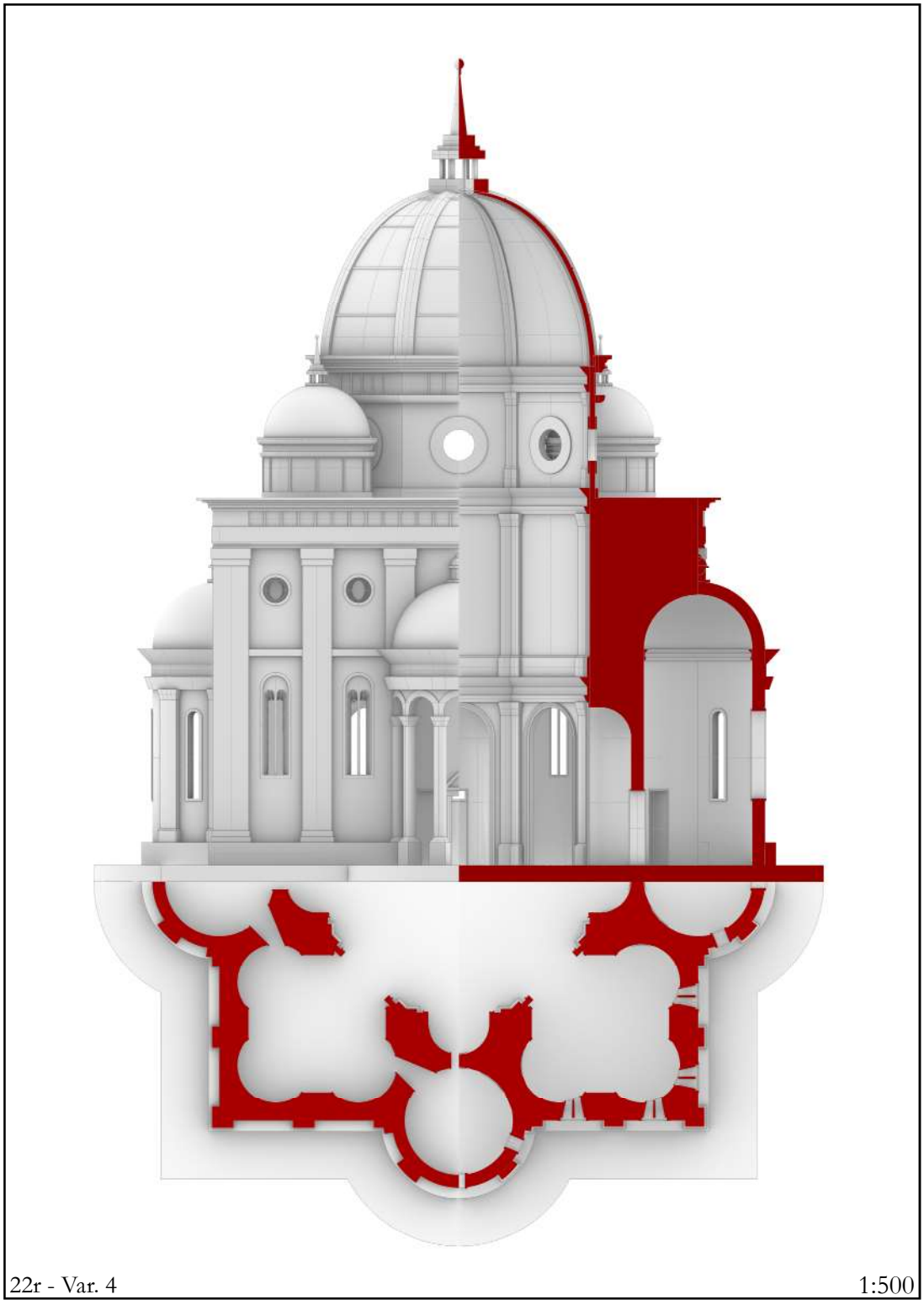


22r - Var. 1 1:500



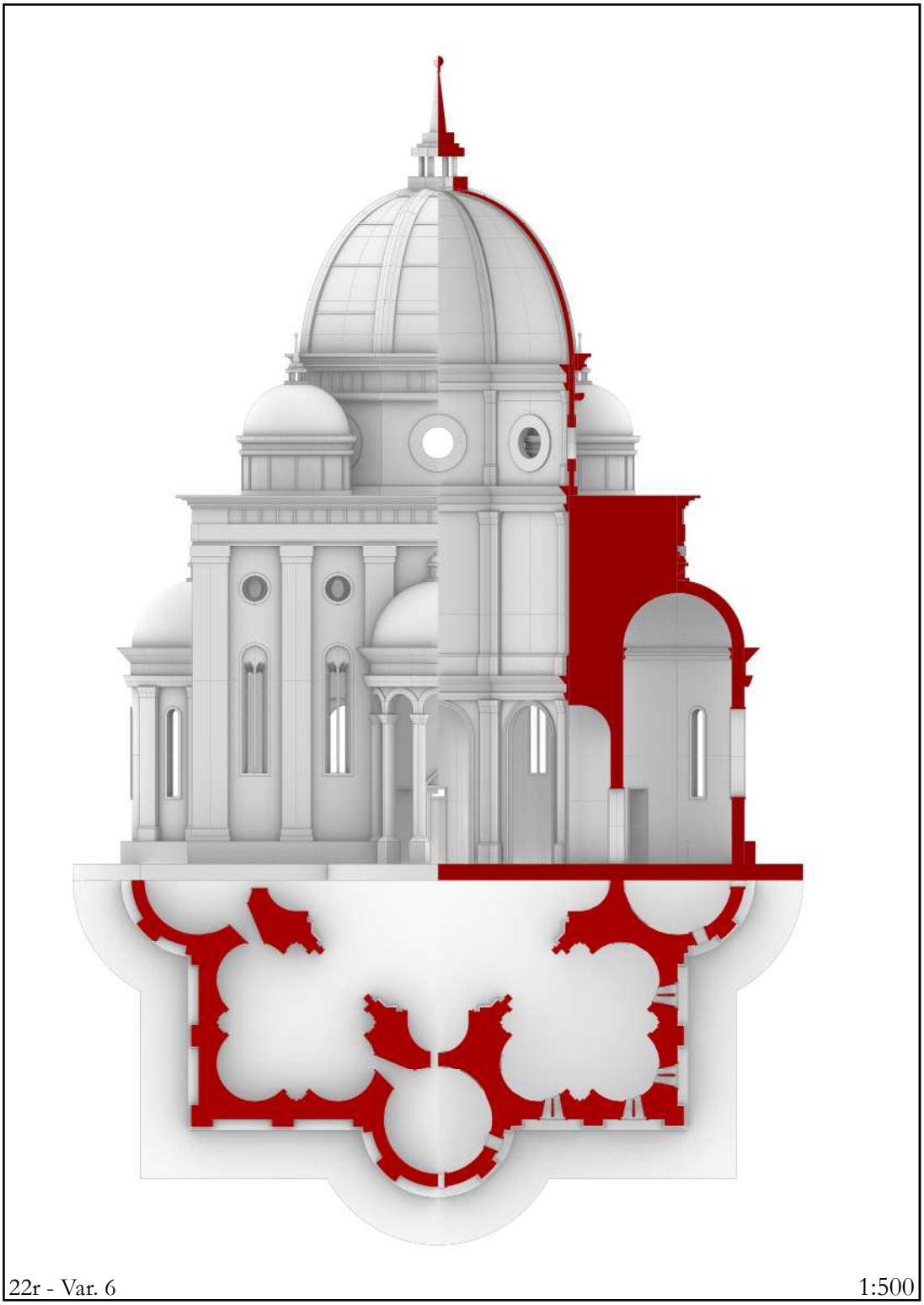
22r - Var. 2 1:500

22r - Var. 3 1:500



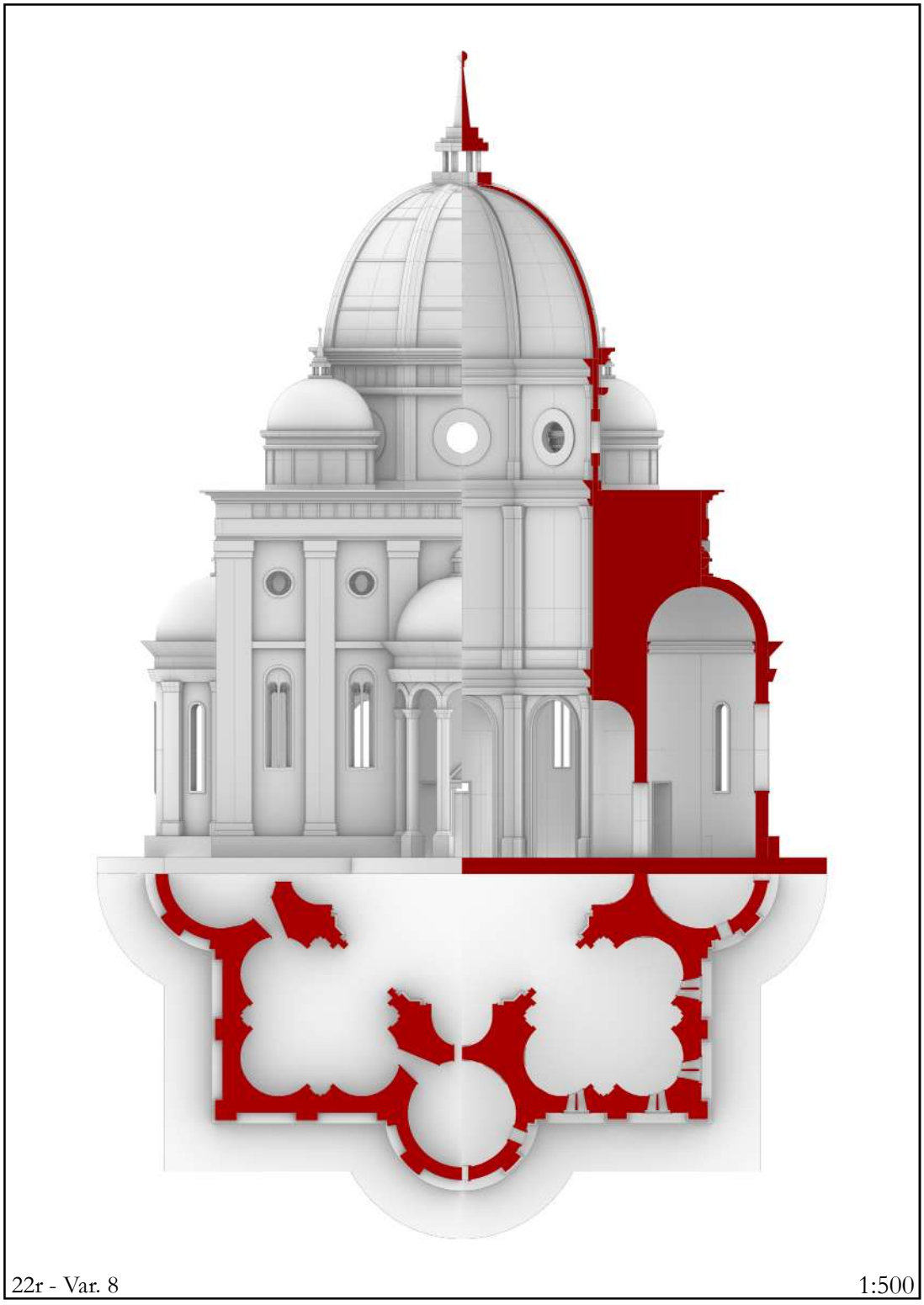
22r - Var. 4 1:500

22r - Var. 5 1:500



22r - Var. 6 1:500

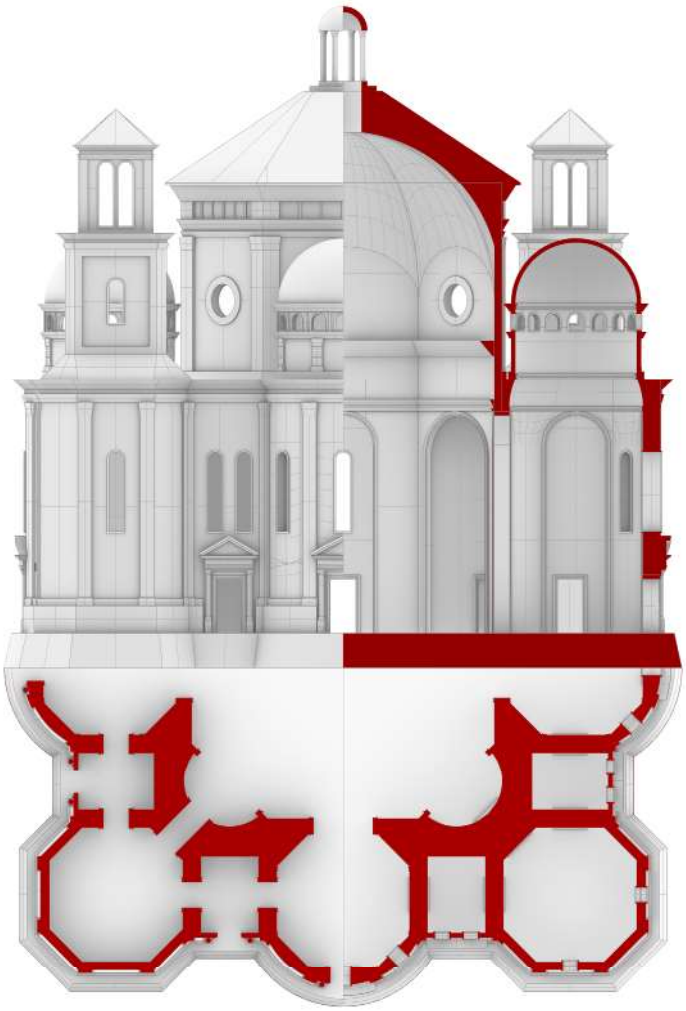
22r - Var. 7 1:500



22r - Var. 8 1:500

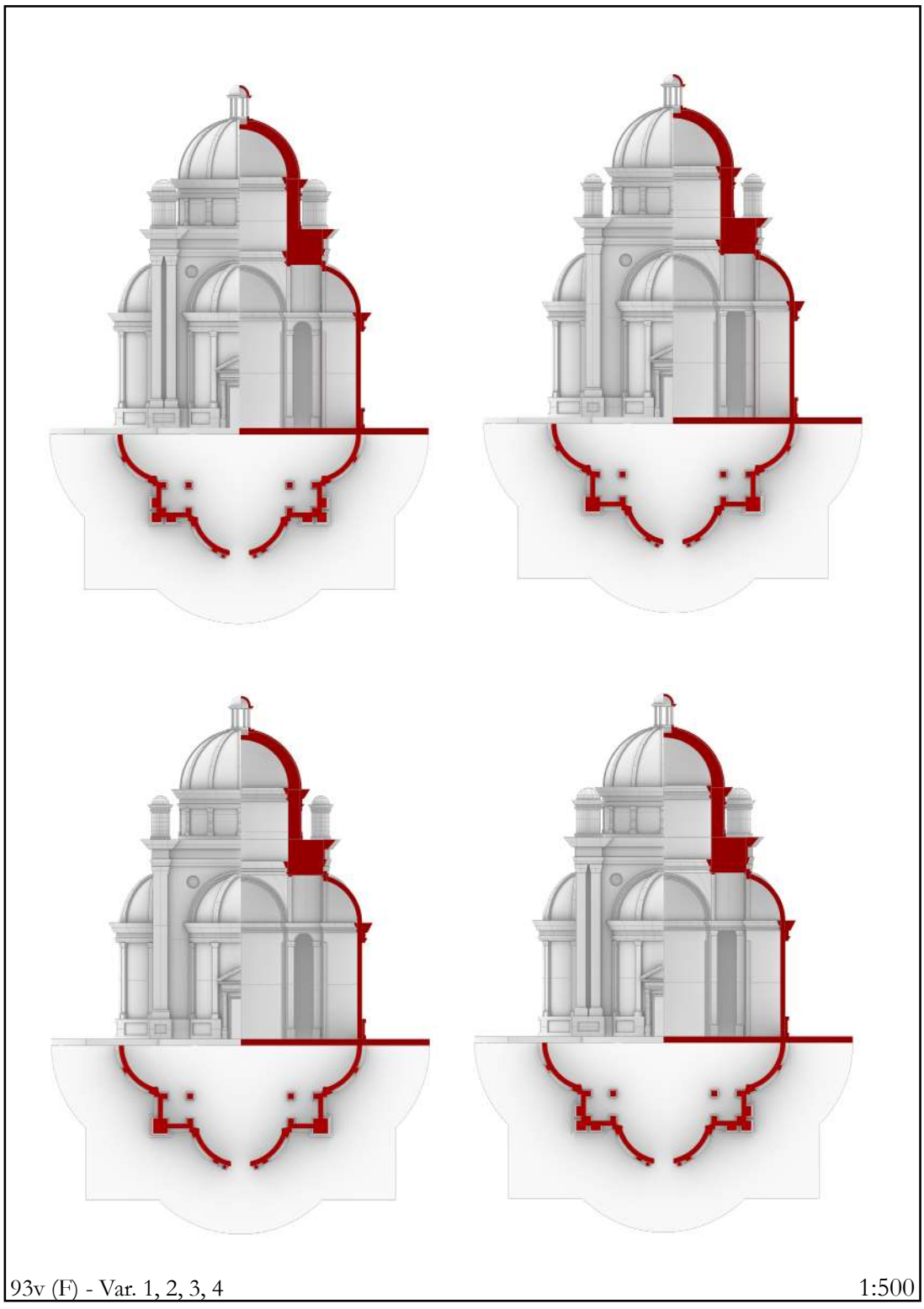
6. 39 v

39v - Var. 1 1:500



39v - Var. 2 1:500

7. 93v (F)



93v (F) - Var. 1, 2, 3, 4 1:500