MASTER THESIS

Meta-Representation

Potentialities of representation in the restitution of complex architecture, the case study of the Pantheon.

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POLITECNICO MILANO 1863

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Graduation session April 2022
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Before proceeding with the discussion, I would like to dedicate a few lines to all those who have been close to me on this path of personal and professional growth.

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A special thank you to my better half, without her at my side this path would not have been the same. Constanza is my strength to face the most difficult moments, the peacefulness to look to the future with hope and wish and the security of a genuine confrontation at all times.

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Thank you all, without you I would never have made it.

Politecnico di Milano
Scuola di Architettura Urbanistica e Ingegneria delle Costruzioni

Master Degree in Architecture and Urban Design

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Meta - Representation
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Meta - Rappresentazione
Le potenzialità della rappresentazione nella restituzione di un architettura complessa, il caso studio del Pantheon.

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Image by Jad Limcaco, Jun 2017.

ABSTRACT

The theoretical incipit of the thesis is the study and analysis of four surveys carried out on the Pantheon in Rome. The particularity of these sources examined is their temporal location and consequently the methods and purposes of the survey, but also the methods of representation in communicating the data collected.

But first of all, there is a chapter devoted to the historical and architectural analysis of one of the ancient and most important monuments in the world. The historical stratigraphy in fact tells us of a previous Pantheon, built under the emperor Marcus Agrippa, as reported by the inscription on the entablature supporting the pediment of the present monument. The main components of the architecture are then defined, their geometric and material characteristics, and their architectural and stylistic attributes.

At the same time, given the historical urban context in which the monument is located, an analysis of the urban fabric and the variations it has undergone during the Pantheon's millennial history is reported. In particular, four urban resources of the area surrounding the monument have been analysed and redesigned and then compared with each other in order to understand the evolution of the built and unbuilt fabric in close contact with the city and the monument itself. The peculiarity of these urban planning sources is that each of them is linked at a temporal level with one of the four surveys of the Pantheon analysed, so as to create an overview at an urban planning level of the historical, social and cultural context in which each surveyor worked and by which the vision of the monument was inevitably influenced.

A fundamental process in achieving the objective of this thesis is the three-dimensional modelling of the four historical surveys.

In fact, after an analysis of the sources from which they are extracted, a digital redesign of the technical drawings of each survey (plans, sections and elevations) was carried out, so as to make it possible to create a digital model using three-dimensional modelling software for each of the survey campaigns. This made it possible, first of all, to provide a detailed and immediate representation of each of the historical sources, in order to represent the particularities that characterise each individual survey campaign, such as the methods used to collect the data or the purpose of the work carried out.

It has also made a direct comparison of historical resources possible, despite their incompatibility, due to methodological and representative differences. By means of plans and sections in axonometric views we can have a three-dimensional representation of the vision of the monument of each individual surveyor, maybe what previously took place only in a theoretical way through the study of iconographic sources, here has an immediate and clear development.

Finally, we obtained a model based on the design derived from the most recent survey source, which uses more precise survey methodologies, but which in some particular points of the architecture also refers back to the other sources.

This model is the basis to explore all the most complex characteristics of the Pantheon, the geometric composition of the single elements that compose it and the spatial relationships between them, but also the stratigraphy of the wall thickness in which the structural solutions that allow the dome to be still currently the largest concrete dome in the world are inserted.

From the optimized model the representations that recreate the process of geometric construction of the internal coffer of the dome, which creates a level of perception of interior space unique in its kind, have been obtained.

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1. OBJECTIVE OF THE THESIS

The main objective of this thesis is to investigate different forms of architectural representation in order to extend the immediately perceptible knowledge of a complex architectural object, the metamorphic potentialities of representation in the restitution of complex architecture, the case study of the Pantheon. The prefix **mèta** (from Gr. μετά) generally indicates the change, the transformation of a given element, in various branches of the biological sciences, this is defined as a maturative evolution, a more advanced or more complex growth. This research into the transformative capacity of representation in architecture was carried out in **parallel** with the process of analysing the architecture itself, that is the Pantheon.

The analysis of four different surveys of this monument, and the urban context in which the construction was inserted at the time of the above-mentioned surveys, made it possible to elaborate four three-dimensional models that represent the different degree of perception and knowledge, and consequently the spatial and visual relantioship that the surveyors had with the monument. The language of representation is brought into direct contact with the generative power of architecture. In the case of a building as iconic and historic as the Pantheon, it is important to define the sense of representation beyond its possible forms, but also the way in which it provides knowledge and perception of architectural and urban space, even to a non-professional user.

"In un certo senso allora, come la storia, la teoria e la tecnica, anche la rappresentazione dovrà avere una funzione veritativa: non solo non le è concesso di non tradire la "verità" dell'opera, ma deve rivelarcela, dimostrarcela, costruirla, ponendosi in rapporto sia con la storia, che con la teoria,

che con la tecnica; e la sua verità deve dispiegarsi a un doppio livello: rispetto all'opera, come fedeltà della "copia" prodotta nei confronti di un "originale" attualmente assente; e rispetto alla rappresentazione stessa come interna coerenza del procedimento riproduttivo"[1].

Representation intended as language is the direct form and realisation of an abstract thought in a concrete and spatial concept, even if only in two-dimensional form. To quote Vittorio Gregoretti, "in our socio-economic context the architect does not produce houses, but designs houses". With the evolution of systems of representation (three-dimensional models, augmented reality), not only is the relationship between the architect and the design of new buildings changing, but also the reading of existing buildings, both at urban and architectural level. The work presented here is therefore not intended to be a simple analysis of the proposed architecture, but an overview of the representative possibilities arising from the three-dimensional modelling of the historical architectural heritage. The reading of the monument in all its complex characteristics has made it possible to develop a representative process that goes beyond the architecture itself, but at the same time is inextricably linked to it.

This is what is meant by "meta-representation": the relative simplicity of adapting the representation to the complex architectural character that you want to report and analyze, through the use of a three-dimensional model. The representation is adapted through the complexity, the number of dimensions on which it operates, thus overcoming the need for architectural knowledge in reading a complex architecture.

1. Vittorio Ugo, *Fondamenti della Rappresentazione Architettonica* (Milan, Esculapio,1994), p.11.
"In a certain sense then, like history, theory and technique, representation must also have a truthful function: not only is it not allowed to betray the "truth" of the work, but it must reveal it to us, demonstrate it to us, construct it, placing itself in relation to both history, theory and technique; and its truth must unfold on a double level: with respect to the work, as fidelity of the "copy" produced with respect to a currently absent "original"; and with respect to the representation itself as the internal coherence of the reproductive process."

Image by Gabriella Marino, Feb 2021.

2.FRAMEWORK

2.1 The Pantheon

The Pantheon in Rome, commonly attributed to Hadrian, is one of the great iconic buildings of the western world, rivalled only by the Parthenon of Athens for its impact on subsequent architectural works in the classical tradition.

One of the best preserved ancient Roman buildings, it has remained in continuous use and boasts the largest unreinforced, solid concrete dome in the world today, with an interior diameter of 43.56 m[1].

The archetype of architecture, the model of every central-plan space, the Pantheon is perhaps the only ancient building that has always remained in use since antiquity.

Since the Middle Ages, the Pantheon has been an important architectural model and influenced the shape of new buildings. During the Renaissance, this position obviously became more pronounced and it was the real reason for so many of the sketches and studies on the monument.

In the later centuries, the rotunda was the main architectural feature and an inexhaustible source of inspiration. In many Italian cities, churches and monuments are a proof of the influence of the Pantheon[2].

"The most beautiful remnant of Roman antiquity is undoubtedly the Pantheon. This temple has suffered so little that it appears to us as the Romans must have seen it in their time"[3].

As the best preserved example of Roman monumental architecture, the Pantheon had an enormous influence on European and American architects (one example above all, Andrea Palladio with his famous villa La Rotonda in Vicenza), from the Renaissance to the 19th century, with Neoclassicism. Numerous churches, civic halls, universities and libraries echo its structure with portico and dome. There are many famous buildings influenced by the Pantheon: in Italy the *Pantheon famedio* in the monumental cemetery of Staglieno in Genova, the facade of the *Teatro Massimo* in Palermo, the church of San Carlo al Corso in Milan, the basilica of San Francesco di Paola in Naples, the church of San Simeon Piccolo in Venice, the *Tempio Canoviano* in Possagno, the church of the Gran Madre di Dio and the mausoleum of Bela Rosinin in Turin. Abroad, the *Pantheon of Soufflot* in Paris and, in the Anglo-Saxon countries, the rotunda of the British Museum, the villa of Monticello and the rotunda of the University of Virginia wanted by Thomas Jefferson through Palladio's reinterpretation of the Pantheon, the *Low Memorial Library* of Columbia University in New York and the *Jefferson Memorial* of Pope in Washington D.C.

However, the fundamental structure in the broadest sense (a building with a central plan and a dome with an added façade inspired by a Greek temple and facing a square built especially for the building) has been found, since Renaissance architecture, in countless buildings, first and foremost St Peter's Basilica.

1. Albers, Jon, Gerd Graßhoff, Michael Heinzelmann, and Markus Wäfler.Introduction. In: *The Pantheon in Rome: The Bern Digital Pantheon Project* (Bern, eds. Gerd Graßhoff, Michael Heinzelmann, Nikolaos Theocharis, and Markus Wäfler, 2013), p.7-13.
2. De Fine Licht K, *The Rotunda in Rome: A Study of Hadrian's Pantheon* (Edición Gyldendal,1968), p.24.
3. Stendhal, *Promenades dans Rome* (Paris, Delauny,1829), p.4.

Figure 1: Iscription at the entrance of the Pantheon

2.2 Hystorical investigation

If we are able to reconstruct the history of its more recent past, thanks also to the studies, descriptions and drawings depicting its transformations, more complex is instead the reconstrcution of the first centuries of the ancient temple.

Agrippa's Pantheon

The present monument was built on the remains of an older pantheon.
The first Pantheon was built in 27-25 BC by ***Marcus Vipsanius Agrippa***, friend and son-in-law of *Augustus*, within the framework of the monumentalisation of the *Campus Martius*, entrusting its construction to *Lucius Cocceius Aucto* [1]. It stood between the *Saepta Iulia* and the Basilica of Neptune, built at the expense of Agrippa himself on an area he owned, where Agrippa's baths, Neptune's Basilica and the Pantheon itself were aligned from south to north[2].

It seems likely that both the Pantheon and Neptune's basilica were *sacra privata*(private buildings for sacred use) of *Agrippa* and not *aedes publicae* (temples for public use)[3]. This less solemn function might help to explain why the memory of the original name and function was lost so early and easily[4].

The original dedication inscription of the building on the later Hadrianic reconstruction reads: M-AGRIPPA-L-F-COS-TERTIVM-FECIT, i.e.:

"Marcus Agrippa, Lucii filius, consul tertium fecit'.

("Marcus Agrippa, son of Lucius, consul for the third time, built it'.)

From the remains found at about 2.50 metres below the building at the end of the 19th century, it is known that this first temple was rectangular (43.76x19.82 metres[5]) with a transversal cella, wider than long (like the temple of Concordia in the Roman Forum and the small temple of Veiove on the Campidoglio hill), built in travertine blocks covered with marble slabs. The building faced south, opposite to the *Adriano*'s reconstruction, and was preceded by a pronao on the long side measuring 21.26 metres wide.

In front of it was a circular open area, a sort of square separating the temple from the basilica of Neptune, enclosed by a small wall in *opus reticulatum* and with a floor of travertine slabs. On top of these slabs, other marble slabs were laid, perhaps during the *Dominiziano*'s restoration.

The central axis of Agrippa's building, however, coincided with that of the newer building, and the width of the cella was equal to the inner diameter of the rotunda. The entire depth of the Augustan building also coincides with the depth of the Adriano's pronaos.

The temple overlooked a square (now occupied by the *Rotonda adrianea*) bordered on the opposite side by the Basilica of Neptune.

Cassius Dione Cocceiano states that the "Pantheon" had this name perhaps because it housed the statues of many deities, or more likely because the dome of the building recalled the vault of heaven (and therefore the seven planetary deities), and that Agrippa's intention was to create a place of dynastic worship, dedicated to the gods protectors of the *Gens Iulia* (Mars and Venus), and where a statue of *Octavian Augustus* would be placed, from which the building would derive its name. As the emperor was opposed to both, Agrippa had a statue of *Divus Julius* (deified Caesar) placed inside, and one of Octavian and one of himself outside in the pronaos, to celebrate their friendship and his zeal for the public good[6].

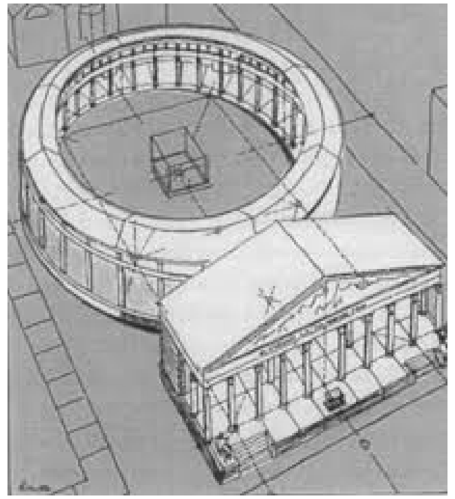


Figure 2: The Pantheon of Agrippa according to the reconstruction of Gerd Heene - G.Heene 2008

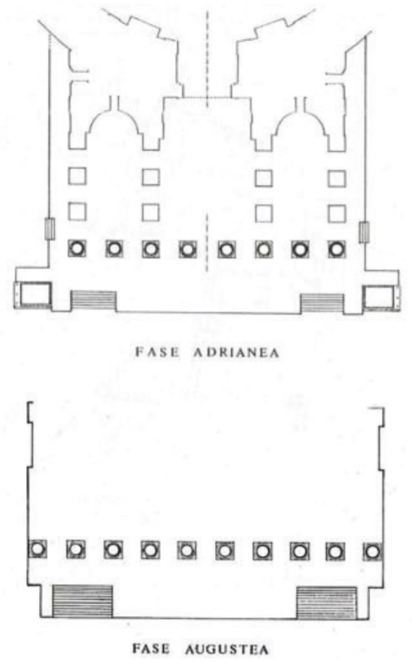


Figure 3: Reconstructive plan of the podium in the two phases of the monument - G. Joppolo 1997

Destroyed by fire in 80, it was restored under Dominiziano (Dominitian), but suffered a second destruction in 110 AD under Traiano(Trajan) due to lightning[7].

Adriano's Pantheon

Under *Adriano* (Hadrian) the building was entirely rebuilt between 112-115 and 124, while an earlier hypothesis placed the reconstruction between 118 and 128[8].It can be assumed that the temple was dedicated to the emperor during his stay in the capital between 125 and 127.

The brick stamps (annual factory marks on the bricks) belong to the years 115-127[5].

According to some, the project, drawn up immediately after the destruction of the previous building in *Traiano*'s time, is attributed to the architect *Apollodoro di Damasco* (Apollodorus of Damascus)[9]. It is also possible, based on considerations on the irregularities and peculiarities of the construction, that the building was started under *Traiano,* resumed at his death by *Adriano*, interrupted for some time, then completed with some variations to the initial project, in particular related to the reduction of the height of the columns of the pronaos from 15.24 to 12.19 meters[10].

The building consists of a pronaos connected to a large round cella by an intermediate rectangular structure. Compared to the previous building, the orientation was reversed, with the façade facing north. The great pronaos and the structure connecting it to the *cella* (interior chamber) occupied the entire space of the previous temple, while the rotunda was built almost to coincide with the enclosed circular Augustan square that divided the Pantheon from the Neptune's basilica. The temple was preceded by a square porticoed on three sides and paved with travertine slabs.

1. Jean-Pierre Adam, *La construction romaine*, 3ª ed. (Paris, Picard, 1984), p. 306-307.
2. Cassio Dione, Roman History, su penelope.uchicago.edu, p. 3,23,33.
3. Adam Ziolkowski, *Lexicon topographicum urbis Romae 4* (Rome, Quasar, 1999), p. 55-56.
4. Adam Ziolkowski, *Was Agrippa's Pantheon the Temple of Mars 'In Campo'?*, in Papers of the British School at Rome, vol. 62, 1994, p. 275.
5. Ranuccio Bianchi Bandinelli e Mario Torelli, *L'arte dell'antichità classica, Etruria-Roma* (Turin, Utet, 1976) p.124.
6. Cassio Dione Cocceiano, Storia romana, LIII 27.
7. Paolo Orosio, *Historiarum Adversum Paganos*, Libri VII , VII,12: *Pantheum Romae fulmine concrematum*.
8. Giorgio Cricco e Francesco Paolo Di Teodoro, *Itinerario nell'arte – Versione Arancione, vol. 1*, 4ª ed. (Zanichelli, 2016), p.241.
9. Richard Poulin, *Graphic Design and Architecture, A 20th Century History: A Guide to Type, Image, Symbol, and Visual Storytelling in the Modern World* (Rockport Publishers, 2012),p.31.
10. Mark Wilson Jones, *Who Built the Pantheon? Agrippa, Hadrian, Trajan and Apollodorus*, in Thorsten Opper (by), *Hadrian: Art, Politics and Economy, British Museum Research Publication*, vol. 175, (London, British Museum, 2013), p. 31-49.

2.2.1 Urban Context

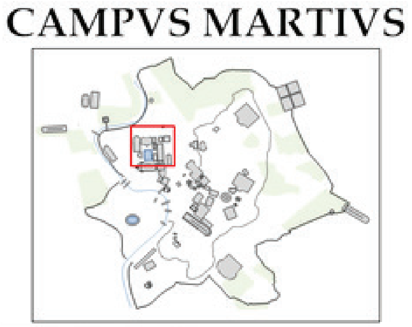


Figure 4: Cassius Ahenobarbus

Obviously, the monument is located in the historic centre of the city, in an area that nowadays, as well as at the time of its construction, is called Campo Marzio.

During the millennial life of the Pantheon, the urban context in which the monument is located has undergone countless changes, facing epochs, wars, epidemics and natural catastrophes.

The perception of an architecture has always been influenced by the urban context that surrounds and characterises it. Economic, urban, social and architectural development can vary the importance within the urban social context of even such an important piece of architecture.

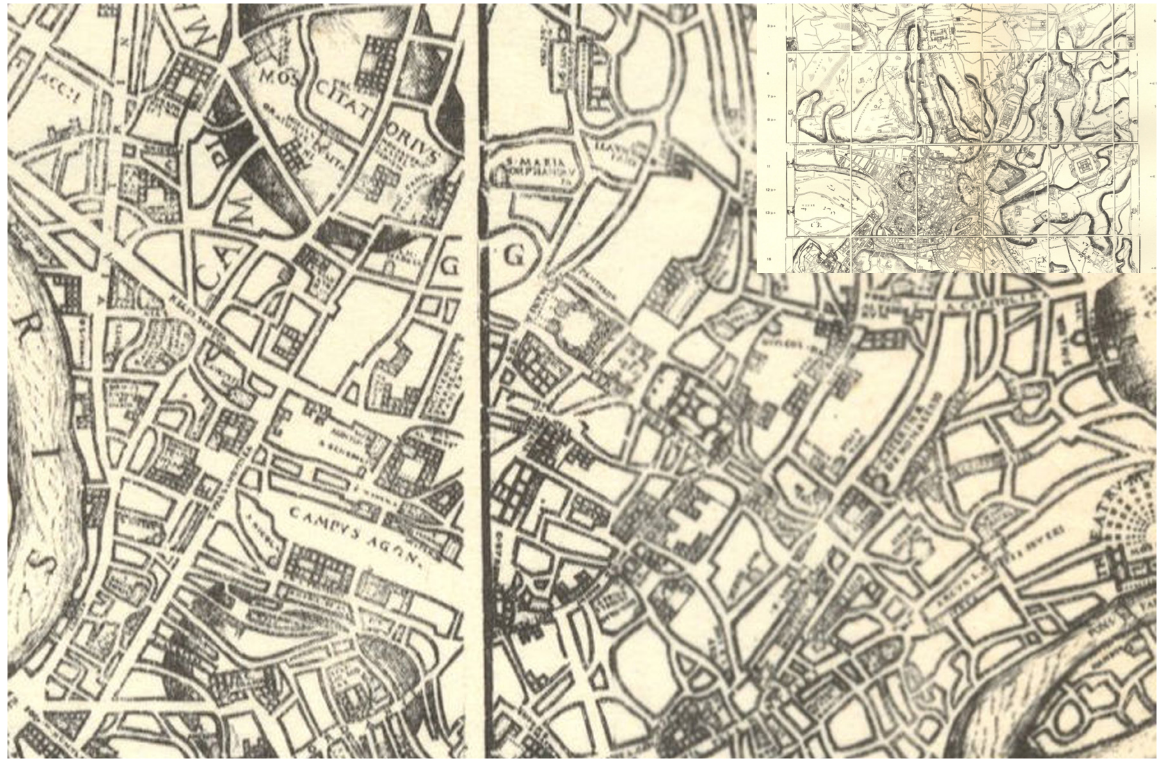
For this reason, in parallel with the analysis of perception through the study of the texts of the architectural surveys, the following pages provide representations of the urban context that characterised the monument in the same historical periods.

The following pages contain four historical maps of the centre of Rome, in particular of the district around the Pantheon.

The chosen cartographies go hand in hand with the historical surveys that will be reported below and on which the central part of the thesis is based. This cartographic comparison reinforces the idea of the subjectivity of the representation, which we will see for the reliefs of the monument, despite the variation in scale obviously used.

The different techniques of drawing, representation and presentation of the historical stratigraphy of the urban fabric once again underline the role of Representation in the reading of a context, be it urban or architectural, and the consequent interpretative key in the hand of whoever produces such cartography or survey.

- The map designed and carved by **Leonardo Bufalini** in 1551 (carpenter, carver, measurer and military architect) bears the title: ROME. It is a very drawn map. The projection and figuration are vertical, icnographic and orographic. The toponymic indications are partly in Latin and partly in Italian, but are not always correctly written. The Aurelian walls bear numbers relating to measurements. The orientation is indicated with North on the left. Around the 4 edges of the map the 24 winds are drawn, with symbolic faces. At the bottom there are a warning to the reader, a dedication to Julius III, a portrait of Bufalini with the date of the first edition [1].



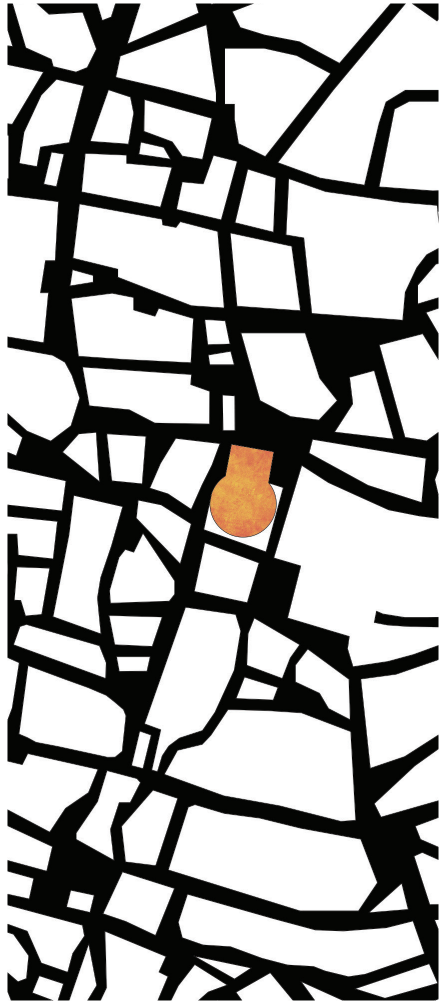
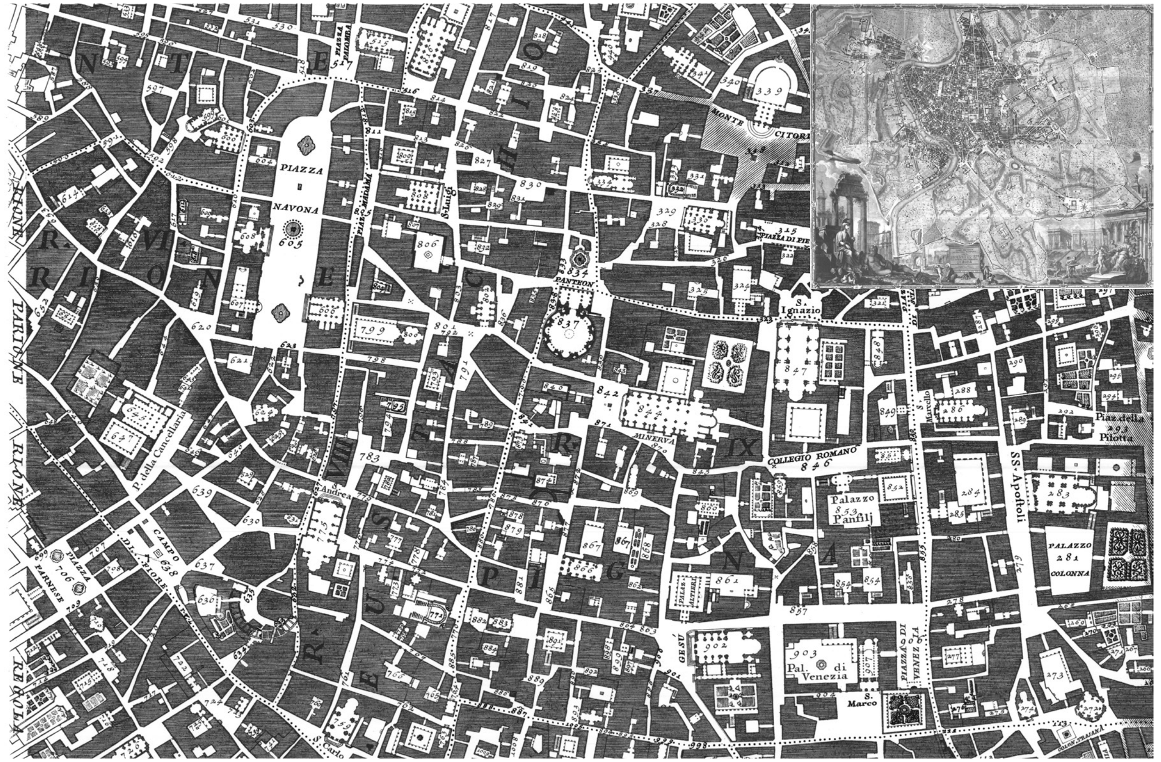


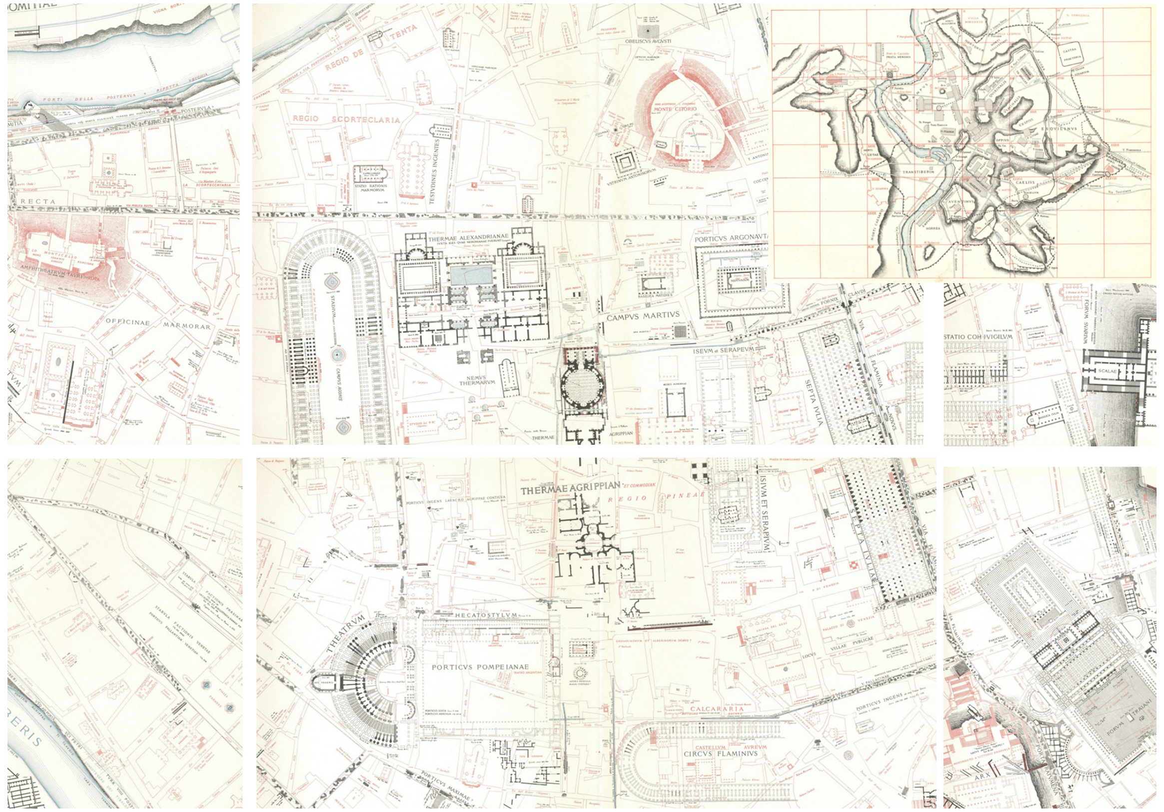
Figure 5: Leonardo Bufalini (1551)

Figure 6: Giovanni Battista Nolli (1748)

- When he arrived in the city, **Giovanni Nolli** realised that, unlike other major European capitals, Rome lacked a modern and detailed map. He therefore had the idea of filling this gap, and in 1736 began to draw up a map detailing the streets, the monuments and the surrounding area. With the help of his son Carlo, who was joined over time by other illustrious personalities such as the young Venetian engraver Giovanni Battista Piranesi and the Sicilian Giuseppe Vasi, Nolli set up a working group that initially financed itself to cover the daily expenses of the work. The result was a prestigious and extraordinary large map (176 x 208 cm), the New Topography of Rome[1], consisting of 12 sheets and accompanied by detailed indexes of streets, churches and monuments, which was completed and published in **1748**. The map also shows the new division of the city of Rome into 14 districts, established in 1744 by Benedict XIV[2] (to whom the map is dedicated), which led to the creation of splendid stone plaques indicating streets and squares, many of which are still present in the streets of the capital [2].



- **Rodolfo Lanciani**’s *Forma Urbis Romae* was published between **1893** and **1901**. The work is still an indispensable tool for the study of the ancient city and also for the organisation of the modern city. The map was drawn up at a time of great transformation for Rome, which had just become the capital (1870). The work consists of 46 colour plates and a dense series of captions indicating the date and sometimes the bibliographical reference of the various findings, which were destined to be included in Lanciani’s other monumental work, *“Storia degli Scavi di Roma - Volume Quarto, 1566-1605”* (History of the Excavations in Rome - Fourth Volume, 1566-1605). With the approval of the first urban development plan on November 28, 1871, followed by a second one in 1883, the gutting of the city began in order to create new arteries, and build new residential areas. As a result, whole sectors of the ancient city, previously completely unknown, came to light and had to be explored, documented and preserved [3].



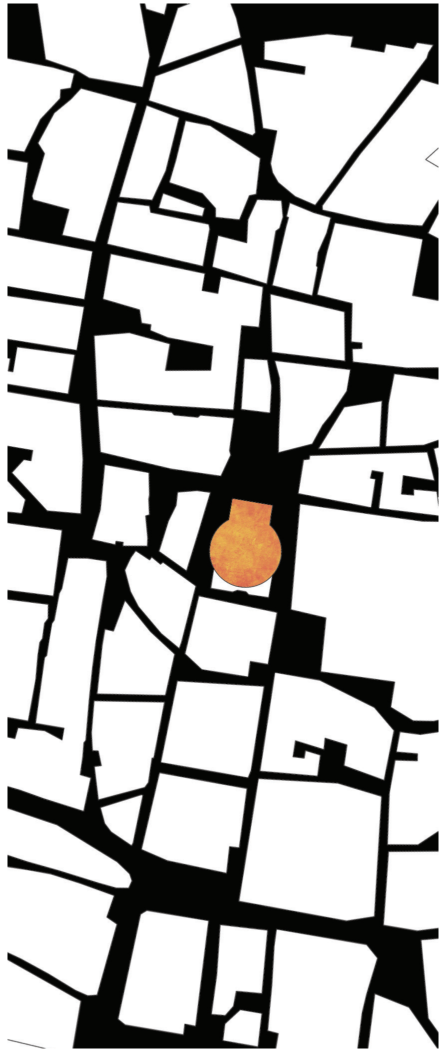


Figure 7: Rodolfo Lanciani (1893-1901)

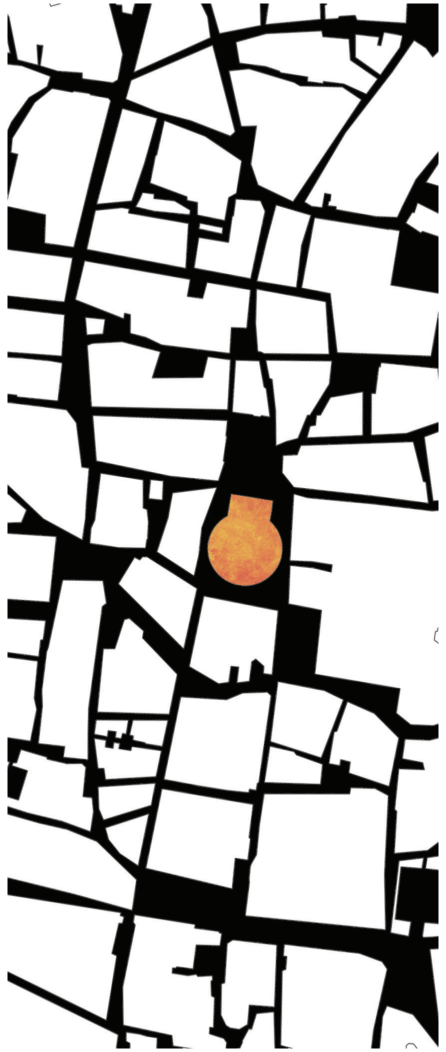
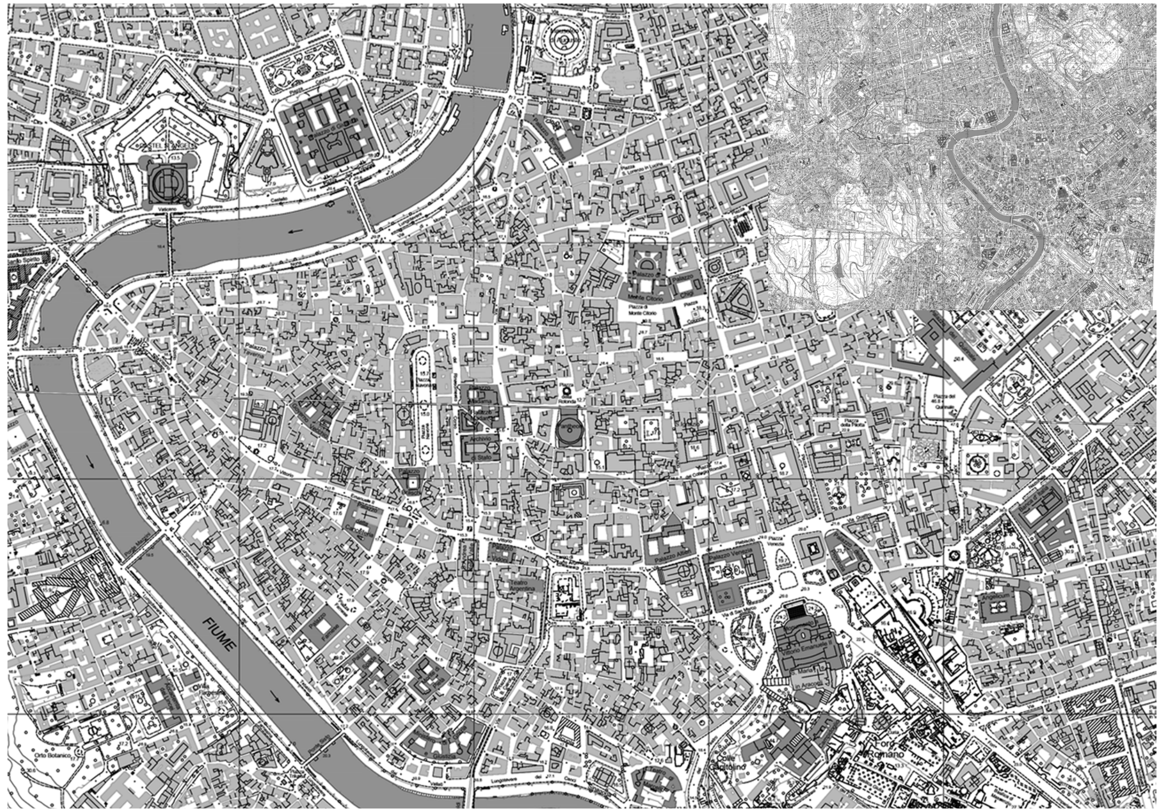


Figure 8: CTR (2014)

- The last map corresponds to the Regional Technical Map of the Province of Rome, updated in **2014**, made by the Project Centre of the Department of Architecture and Design.

  The regional technical map (abbreviated CTR) is a type of topographic map produced by Italian regions to represent their territory. They are called “technical” maps because they represent elements without changing their size and position, but showing their actual projection. Objects such as buildings and roads are therefore represented with the true shape of their perimeter seen from above, and not by replacing them with conventional symbols. It is in fact a map with a scale large enough to appreciate these details; the standard scales are 1:5 000 and 1:10 000, but larger scales are also available. This makes them suitable for large-scale land use and urban planning activities, hence the name technical maps. They are also suitable as the basis for various types of thematic maps [4].



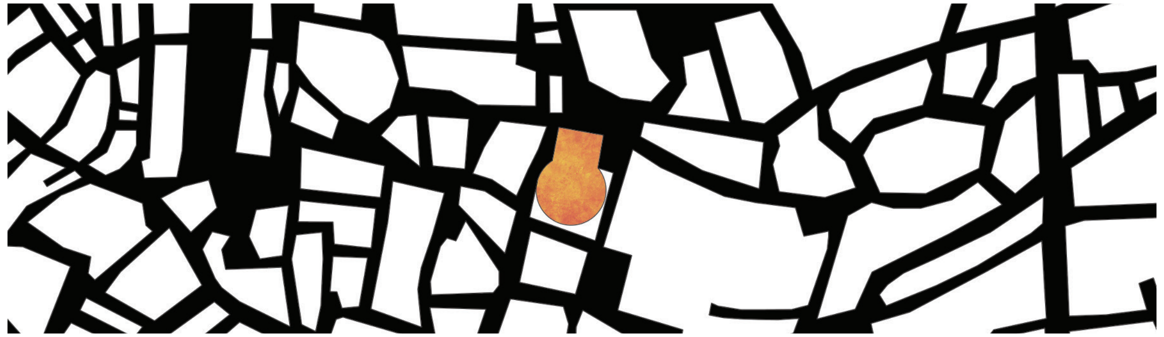


Figure 9: schematisation of the urban map by Leonardo Bufalini (1551)

Figure 10: schematisation of the urban map by Giovanni Battista Nolli (1748)

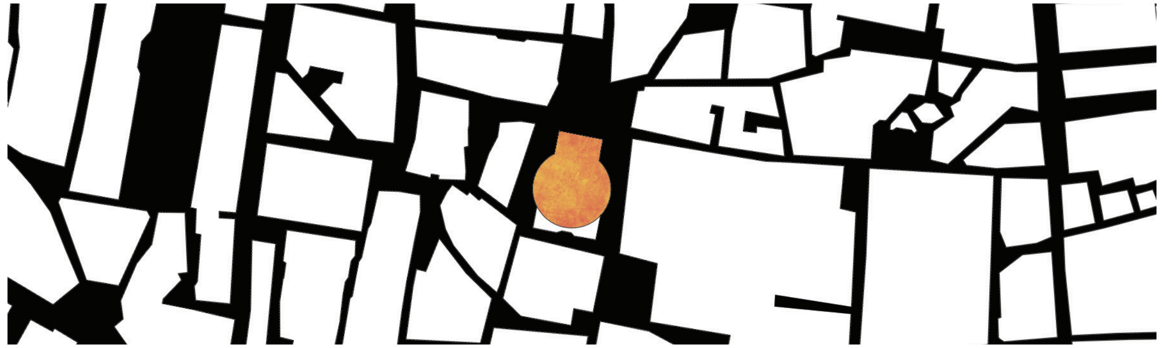


Figure 11: schematisation of the urban map by Rodolfo Lanciani (1893-1901)

Figure 12: schematisation of the urban map CTR (2014)

On the facing page are schematisations of the historical maps presented above. The area of interest has been resized on the monument and on the urban fabric surrounding it, in particular the urban development around the road axis that runs parallel to the main façade of the monument.

In order to obtain an immediately visible and clearly comparable result, the representation is based on a negative representation of the built space, marking the streets with a black fill. We can therefore observe how the fragmentation of the urban built environment has varied over the centuries around the Pantheon and the urban grid has gone through a process of transformation with the aim of regularising the urban space.

At the same time, we can see the impact that, even in the field of town planning, representation can have in providing information about a built environment, whether it be at the level of the city fabric or architectural survey. In fact we can observe how the character of each cartography changes according to the choices of its creator, for example the level of detail of representation of the spaces inside the built blocks.

The historical context in which each cartography has been represented has influenced the techniques of survey of the urban environment and its relative representation. In particular, we can note that the first diagram reported is characterised by a fragmentation of the built blocks and a very approximate and irregular definition of them.

1. Aimé-Pierre Frutaz, *Le piante di Roma*, Roma 1962, II, CXXVI, p.168-169.
2. Simona Ciofetta, *Lo Studio d'Architettura Civile edito da Domenico De Rossi* (1711, 1721), in *In Urbe Architectus*, p.214–228.
3. Rodolfo Lanciani, *Rovine e scavi di Roma antica*, new edition (Roma, 1985), (ed. or. The ruins & excavations of ancient Roma, London 1897), p.48, 78.
4. Camillo Berti, *Produzione cartografica in Italia*, in Topografia e cartografia, Università degli studi di Firenze, a.a.2010-2011.

2.2.2 Architectural heritage

The pronao

Figure 13: front view of the pediment from the square.

Figure 14: internal view of the pronao. Christopher Czermak, Rome, 2018.

The octastyle pronaos (16 columns, 8 columns of grey granite from the island of Elba and 8 columns of pink granite from the quarry of Mons Claudianus in Egypt) measures 34.20 m x 15.62 m and was raised 1.32 m above the level of the square[1], accessed by means of five steps.
The total height of the order is 14.15 m and the shafts have a diameter of 1.48 m at the base[1].

On the facade the *fregio* (frieze) bears Agrippa's inscription in bronze letters, while a second inscription, in smaller characters, related to a modest restoration carried out in 202 AD by Septimius Severus and Caracalla, was engraved on the architrave below the first one[2]. The *frontone* (pediment) must have been decorated with bronze figures, fixed on the bottom with pins whose seats can be seen in the marble[3].

Inside, four rows of two columns (placed at the first, third, sixth and eighth column of the first row) divide the space into three naves: the wider central one leads to the great doorway of the *cella* (interior chamber), while the two lateral ones end in large niches that must have housed the statues of Augustus and Agrippa transferred here from the Augustan building[2].

The shafts of the columns were made of grey granite (eight on the façade) and pink granite (eight, distributed in the two rows behind), coming from the Egyptian quarries of Aswan, and the shafts of the porticos of the square were also made of grey granite, although smaller in size. The Corinthian capitals, bases and elements of the *trabeazione* (entablature) were made of white Pentelic marble from Greece. The last column on the eastern side of the pronao, which had been missing since the 15th century, was replaced by a grey granite shaft under Pope Alexander VII, and the column at the eastern end of the façade was also replaced by a red granite shaft under Pope Urban VIII: the original alternation of colours in the columns has therefore been altered over time. The new columns both came from the Nerone's Baths[2].

The *tympanum* (which is not calibrated according to the canonical Greek proportion) has become smooth due to the loss of the bronze decoration, of which, however, the holes for its supports are still visible[2].

The double-pitched roof is supported by wooden trusses, supported by block walls with arches resting on the rows of internal columns. The bronze covering of the wooden truss of the pronaos was removed in 1625 under pope Urban VIII for the construction of 80 cannons of Castel Sant'Angelo[4] and maybe a small part for the building of St. Peter's Baldachin, by Gian Lorenzo Bernini[39]: it was for this "recycling" that the famous pasquinade "quod non fecerunt barbari, fecerunt Barberini" was written[5].
The pronaos is paved with coloured marble slabs arranged according to a geometric pattern of circles and squares. The sides of the pronaos are also covered with marble.

Avant-corps

The intermediate structure connecting the pronaos to the cella is a brickwork *avancorpo* (avant-corps) consisting of two massive pillars resting on the rotunda, connected by a vault that seamlessly continued the original suspended bronze vault of the central part of the pronaos. Stairs leading to the upper part of the rotunda are inserted in the pillars [3]. The wall is covered with slabs of pentelic marble and decorated on the outside and on the sides of the door of the cella by an order of pilasters that continues the order of the pronaos[2].

Figure 15: detail of the column.
Moritz Kindler, Rome, 2020.

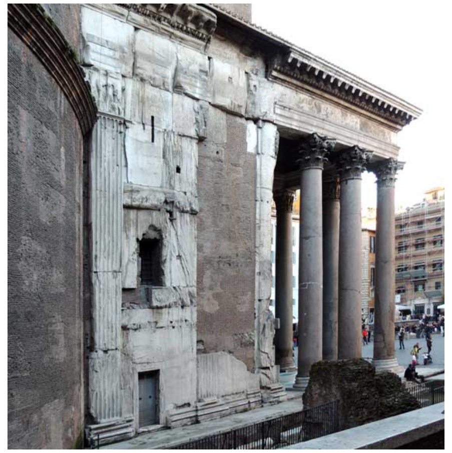


Figure 16: detail of the column.
Moritz Kindler, Rome, 2020.

Figure 17: exterior of the rotunda.

On the outside, the structure has the same height as the cylinder of the rotunda and, like the rotunda, was probably covered with *stucco* and plaster, which has since disappeared.

On the façade, a brick pediment repeats that of the pronaos at a greater height, and is related to the divisions of the string-course cornices on the rotunda, which continue without interruption on the outer walls of the rectangular structure above the order of pilasters. The pediment, hidden by the pronaos, could be seen only from a great distance. The bronze gate, the oldest and most imposing of those still in use in Rome, measures 4.45 m wide by 7.53 m high[3].

The exterior of the rotunda

The exterior of the rotunda hides one third of the dome, building a cylindrical body that is nothing more than a vertical continuation of the drum. Between the dome and the outer wall there is a large cavity where a double system of windowed chambers has been created, organised in an annular corridor, which also serves to lighten the weight of the vaults.

The external body of the rotunda, except for the dome, was not visible in ancient times, as it was hidden by the presence of other adjacent buildings; for this reason it does not have any particular decoration, apart from three cornices with brackets at different heights: at the entablature of the first internal order, along the line of the dome and on the crowning.

Each of these three bands also corresponds to different materials used in the building, progressively lighter[2]; more in detail, from bottom to top:
Band I: layers of concrete alternated with flakes of travertine and tuff;
Band II: layers of concrete alternated with tuff flakes and bricks;
Band III: layers of concrete with only brick flakes.

The interior of the rotunda

“I wanted this sanctuary of all the gods to represent the terrestrial globe and the celestial sphere, a globe within which are enclosed the seeds of eternal fire, all contained in the hollow sphere”[7].

The inner space of the round cell consists of a cylinder covered by a hemisphere. The cylinder has a height equal to the radius (21.72 m) and the total height of the interior is equal to the diameter (43.44 m[1] ; 43.30 m[3]).

On the lower level, there are six large style niches (i.e. with two columns on the front), with an alternating rectangular (actually trapezoidal) and semicircular plan, plus the entrance niche and the apse.

This first level is framed by an architectural order with columns at the niche openings and pilasters in the intermediate wall sections, supporting a continuous entablature. Only the apse opposite the entrance is flanked by two columns protruding from the wall. The continuous entablature of the body of the rotunda continues into the apse; the semi-domed absidal bowl rests on it.

Between the pilasters, in the spaces between the niches, there are eight small aedicules on a high base, with alternating triangular and curvilinear pediments. The walls are covered with slabs of coloured marble.

The upper order, in *opus sectile*, had an order of porphyry pilasters framing the windows and a covering of coloured marble slabs. The windows faced the first inner annular lightening corridor.

The floor of the rotunda is not the original one because it was rebuilt in 1873, but the effect is that of the Hadrianic period: it is slightly convex towards the sides,

Figure 18: interior of the rotunda.
Stefan Bauer, Rome, 2005.

Figure 21: detail of the coffers.
Dimitry B., Rome, 2021.

Figure 19: view from the entrance.
Evan Qu, Rome, 2017.

with the highest part (moved about 2 metres north-westwards from the centre) raised by about 30 cm, while it is concave in the centre to allow the rain falling inside the temple through the oculus on the top of the dome to flow towards the 22 drainage holes in the centre of the rotunda.

The floor covering is made of slabs with a pattern of squares in which smaller circles or squares are inscribed alternately. The materials used are porphyry, antique yellow, granite and *pavonazzetto* marble[3].

The dome

The dome, with a diameter of 43.44 m[1] (43.30 m according to Cinti & al.[3] and Coarelli[2]), and weighing more than 5 000 tons, is the archetype of the domes built in the following centuries in Europe and the Mediterranean, both in Christian churches and Muslim mosques.

In terms of diameter, today, if one does not consider the roof of the CNIT (Centre des nouvelles industries et technologies) in Paris as a dome (it is actually a cross vault), the Pantheon dome is still the largest dome in the world, surpassing both St Peter’s dome (diameter 42.52 m[3]) and Brunelleschi’s dome in Florence (smaller diagonal 41.47 m [3]) and the dome of St Sophia in Constantinople (largest diameter 31.24).

Inside it is decorated by five orders of twenty-eight coffers [2]; twenty-eight was a number that the ancients considered perfect, since it is obtained by the sum 1+2+3+4+5+6+7 and seven is a number indicating perfection, being seven the planets visible to the naked eye [8]. The coffers are of decreasing size proceeding upwards, and they are absent in the wide smooth band near the zenith oculus, which measures 9 m in diameter[1].

The oculus, which gives light to the dome, is surrounded by a frame of bronze banded tiles fixed to the dome, which perhaps continued internally to the highest row of coffers.

The construction was made possible thanks to a series of expedients contributing to the lightness of the structure: from the use of coffers to the use of materials that are progressively lighter towards the top. In the layer closest to the cylindrical drum there are layers of concrete with brick flakes, going upwards there is concrete with tuff flakes, while at the top, near the oculus, there is concrete mixed with volcanic lapilli[2].

On the outside, the dome is hidden by a raised wall of the rotunda, and is therefore articulated in seven superimposed rings, the lower of which still has its marble slab covering. The remaining part was covered with gilded bronze tiles, removed by the Byzantine emperor Constant II in 655, with the exception of those surrounding the oculus, still in place[3].

In the 8th century Pope Gregory III restored the roof with lead plates [3]. Restoration works on the roof were then carried out by popes Nicholas V and Gregory XVI. The thickness of the masonry tapers upwards (from 5.90 m below to 1.50 m around the central oculus[1]).

Figure 20: the dome and the oculus
Lode Lagrainge Rome, 2017.

1. Adam Ziolkowski, *Pantheon*, in Eva Margareta Steinby (by), *Lexicon Topographicum Urbis Romae*, 4ª ed. (Rome, Quasar, 1999), p.57-59.
2. Filippo Coarelli, *Roma*, in *Guide Archeologiche* (Milan, Mondadori, 2002), p.280-284.
3. Siro Cinti, Federico De Martino, Andrea Carandini, Marco De Carolis e Giovanni Belardi, *Pantheon. Storia e Futuro / History and Future* (Rome, Gangemi Editore, 2007) p.4,27,29,31,33.
4. Tina Squadrilli, *Roma* (Milan, Rusconi editore, 1997), p.386.
5. Guglielmo Audisio, *Storia religiosa e civile dei papi per Guglielmo Audisio*, vol. 5 (Roma, G. Aureli, 1868), p.77.
6. Paul Davies, David Hemsoll e Mark Wilson Jones, *The Pantheon, triumph of Rome or triumph of compromise?*, in *Art History*, vol. 10, n. 2 (Association of Art Historians, 1987), p.133-153.
7. Marguerite Yourcenar, *Mémories d'Hadrien suivi de Carnets de notes de Mémories d'Adrien*, (Parigi, Libreairie Plon, 1951) p.12.
8. Christiane L. Joost-Gaugier, *Pitagora e il suo influsso sul pensiero e sull'arte* (Rome, Arkeios, 2008), p.211.

Image by Gabriella Marino, Feb 2021.

3.STUDY AND COMPARATIVE MODELING FROM THE RESOURCES

3.1 Resources

The following are testimonies of some of the many surveys carried out over the course of history on the Pantheon. This journey through time in the art of survey and its representation spans centuries and eras that are completely different from each other: from the Renaissance to the Enlightenment, from the Belle Epoque to the present day.

Over the centuries, not only have surveying techniques evolved and progressed, but so have the motivations for studying an ancient building and the role of the surveyor within the society in which the final result was presented.

But what we are going to explore in the next paragraphs, through three-dimensional modeling, are the differences that emerge from the representations of the four surveys examined: the interpretation of the author of the monument, through the technical choices on the most important parts to be surveyed and represented, and the most effective representative techniques in returning on paper the volumetry of such a complex object.

The surveys were selected to represent a wide time span in the history of architecture and the monument itself, and to have the necessary graphic resources for the theoretical and practical development of each survey.

Andrea Palladio - Geometry and harmony of shapes

The first historical survey was carried out by Palladio, one of the masters of the Italian architecture, in his publication "*I quattro libri dell'Architettura*"(1576), in which he sets out his absolute views on architecture and the architectural method and, just as Vitruvius did, reports the survey of several ancient monuments in Rome. He lived in Rome for several years during his training period, and this in-depth study of the capital's historical resources will be fundamental to his training as an architect.

Figure 22: front cover of *I quattro libri dell'architettura*, 1576.

Already from the introduction, the author begins to analyse the geometric forms used by architects of the past, always relating them to the historical and religious context in which these buildings were constructed. The circular form, according to Palladio, is but the most obvious architectural representation of the time in which such buildings were constructed, a time in which paganism was a direct consequence of the world that surrounded men, the Moon and the Sun as absolute elements influencing and characterising life as it was known.

"Hebbero gli Antichi riguardo a quello, che si convenisse à ciascuno de' loro Dei non solo nell'eleggere i luoghi, ne' quali si dovessero fabricare i Tempij, come è stato detto di sopra, ma anco nell'elegger la forma; onde al Sole, & alla Luna, perché continuamente intorno al Mondo si girano, & con questo lor girare producono gli effetti a ciascuno manifesti, fecero i Tempij di forma ritonda." [1]

Continuing the introduction, again in Chapter II, Palladio explains the change in the concept of decoration and form from the time of the surveyed buildings to the time of the architect. The ancient Romans used the decoration on the elements of a temple, based on the divinity to whom the temple was dedicated: the architectural stylisation of the forms and ornamental enrichments, had importance not only for the practical aspect of the building, but also and above all for the relationship with the oneiric context to which it referred. In the contemporary 16th century, with the absolute predominance of Christianity, in which God is unique, in his perfection, in his representations and in his doctrine, the circular form expresses a simple and effective spatial synthesis. Circularity represents God's creation, in fact as it has neither a beginning nor an end, the geometric element is unique and indivisible, as is the Christian religion according to the author.

"E però ancora noi, che non habbiamo i Dei falsi, servare il Decoro circa la forma de' Tempij, eleggeremo la più perfetta, più eccellente, e conciosiache la Ritonda sia tale, perché fra tutte le figure è semplice, uniforme, equale, forte, e capace, faremo i Tempij ritondi, a quali si conviene massimamente questa figura, perché essendo essa da un solo termine rinchiusa, nel quale non si può ne principio, ne fine trovare, ne l'uno dall'altro distinguere, e havendo le due parti simili tra di loro, e che tutte participano della figura del tutto, e finalmente ritrovandosi in ogni sua parte l'estremo egualmente lontano dal mezzo, è attissima a dimostrare la Unità, la infinita Essenza, la Uniformità, e la Giustizia di Dio".[1]

Antoine Desgodetz - Survey for proportion and measure

Antoine Desgodets' Journey to Rome in 1674 places him as one of the first French students of the Academy of Architecture to survey and design the Pantheon. His survey were marked by precision and he carried out his work with great resourcefulness, having excavations and soundings, building ladders and scaffolding to measure the architectural details himself[3].

In the preparation manuscript, Desgodets includes drawings of forty-eight buildings, but only twenty-five were included in the edition of ***Les edifices antiques de Rome mesurés et dessinés très exactement,*** published in Paris in 1682.

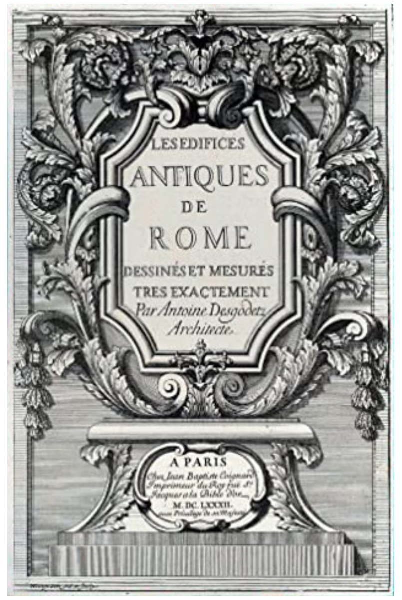


Figure 23: front cover of *Les edifices antiques de Rome mesurés et dessinés très exactement*, 1674.

The work soon became a topic of discussion for the *Académie Royale d'Architecture* [2] and on his return to France in 1678 he was given several commissions by Louis XIV.
His *Les edifices antiques*[...] was the subject of many lectures, commented on, criticised and in some cases verified by comparison with the drawings of students at the Academy in Rome.

To verify his declared objective scientific survey, that is the representation of how the buildings really looked, he compared his work to the previous surveys in the treatises by Serlio, Palladio, Antonio Labacco and Roland Fréart, highlighting the differences found.

"*J'ay vérifié le tout plusieurs fois pour me confirmer dans une certitude dont je pûsse répondre, ayant fait fouiller ceux qui estoient enterrez, & fait dresser des eschelles & autres machines pour approcher de ceux qui estoient beaucoup élevés, afin de voir de prés & prendre avec le Compas les hauteurs & les saillies de tous les membres, tant en general qu'en particulier jusqu'aux moindres parties*".[3]

In his work, Desgodets chose to use only orthogonal projections, and plans, elevations and sections are drawn using the *acquaforte* technique, with very fine and precise strokes. The units of measurement adopted throughout his work are the *toise du Châtelet*, the *pied de Roi* and the *pouce*.

Despite the intention to redesign the buildings as they really are, which explains the total absence of reconstructive hypotheses, Desgodets nevertheless makes numerous "corrections", for example in the case of the Pantheon it appears isolated from the context and cleared of all modern additions, including the famous bell towers erected in 1626.

George Chedanne - Aesthetics of archaeology

Towards the middle of the 19th century there was a slow move away from the study of the stylistic features of classical architecture, and an approach to new models which opened up to eclecticism, often evidenced by tendencies towards the picturesque, but there were also some examples of a real archaeological passion in the second half of the 19th century, one of which was the work that George Chedanne undertook in 1892 for the Pantheon.

Figure 24: front cover of *Panthéon de rome: étude générale de la structure*, 1892.

Georges Chedanne came from a modest background but thanks to his talent as a designer he obtained a departmental scholarship and in 1881 entered the *École des Beaux-Arts* in Julien Guadet's studio. He won the first prize in the Grand Prix of 1887, and stayed at the Villa Medici until 1892. In the early years of his stay in Rome, he devoted himself to the study of ancient monuments [4].

For his fourth year in Rome, in 1891, he chose the Pantheon, starting to survey the orders of the portico. At the end of his stay in Italy, his career was marked by important works, but above all by exhibitions of his works on the Pantheon throughout Europe.

These works comprise more than 30 drawings of which only 6 were delivered to the École des Beaux-Arts and are still visible today.

His survey must have contained several drawings, among which certainly: a general planimetry, framing the temple among the surrounding buildings; a plan with an indication of the floor and a plan of the foundations and excavations. In all these and many other drawings made by Chédanne are not kept in the Académie library, it was possible to examine the elevations, sections and an axonometric view of the sections and an axonometric view showing the construction hypotheses that emerged from the 1892 excavations.

Among the lost drawings there are some in which Chedanne's reconstructive hypotheses go as far as to hypothesise an entrance portico to Agrippa's Pantheon composed of 10 columns, and an axonometric cross-section called "General study of the structure" in which the construction of the new Pantheon under the emperor Hadrian is shown [5].

Due to the lack of preservation of many of the works produced by Chedanne, including the plan of the monument, the survey campaign was supplemented by the use of the plan drawn by Pier Olinto Armanini in 1892. In fact, Chedanne worked on the monument at the same time as Armanini and Luca Beltrami were carrying out studies and restoration work on the building and in particular on the dome, working in close contact with each other and on a perfectly identical state of conservation of the monument.

Bern Digital Pantheon Project- Survey 3.0

The collection 'Digital Pantheon' is based on research data of the Bern Digital Pantheon project. This project - directed by Gerd Graßhoff, Michael Heinzelmann and Markus Wäfler of the University of Bern - created a digital 3d scan of the Pantheon in Rome using a laser scanner in several scanning campaigns in the years 2005 to 2008 [6].

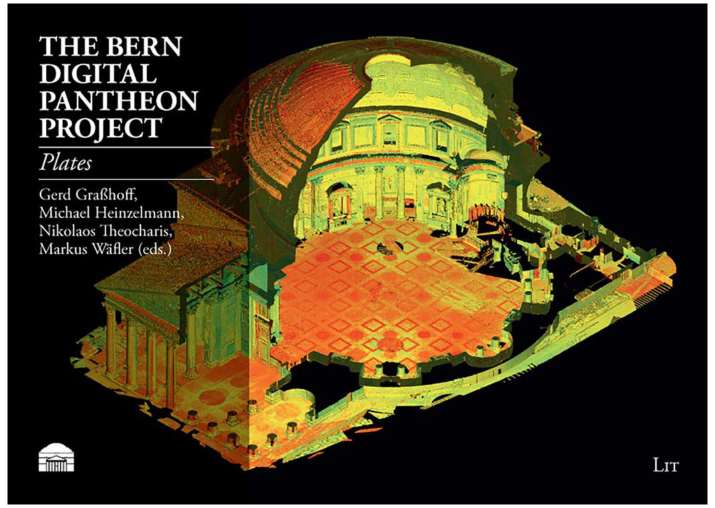


Figure 25: front cover of the *Bern Digital Pantheon Project*, 2014.

The objective of the institute was to create a pilot project, applied to the the fields of art history and archaeology, in which different and new methods of scientific research could be integrated [6]. The Pantheon was chosen, and among the first operations conducted, towards the end of 2005, there was a laser scanning survey campaign.

The peculiarity of this project is that all survey data, including point clouds, were made available to researchers through a complex web database system so that everyone could access it, download and process the data according to different interpretations. Point clouds allow us to immediately carry out measuring operations. In a software environment that allows us to "navigate" within the cloud, it is possible to select vertices and obtain a real time measurement. The point clouds, oriented and segmented with respect to the main parts of the monument, were acquired and oriented with respect to the geolocated reference system, using a series of common points relative to the interior of the dome. The different structure of the points cloud from this study allows us to address the issue of colour in point clouds.

The fully automatic procedure consists in the acquisition by the instrument of a certain number of photographs of the scene taken exactly at the point of emission of the wave. The overlapping between the photos and the point cloud allows each point in space to be associated with a point on the photograph and, consequently, with its given colour. In this way, the clouds also take on a new characteristic that opens up new types of investigation and analysis of the colour data [7].

From the point cloud it is possible to extract the classic methods of architectural representation: plans, sections and elevations. This has made it possible to directly compare this innovative form of survey with the others previously illustrated, despite the extremely different methods of data collection [7].

1. Andrea Palladio, I quattro libri dell'Architettura (Venezia, 1570), 4° Libro, Capitolo II.
2. Wolfgang Herrmann, *Antoine Desgodets and the Académie Royale d'Architecture*, in The art bulletin (New York, 1958) p.23–53.
3. Antoine Desgodets, *Edifices antiques de Rome dessinés et mesurés très exactement par Antoine Desgodets architecte* (Paris, 1682) p.32, 74, 119.
4. Pierre Pinon, Francois Amprimoz, *Les envois de Rome, 1778-1968: architecture et archéologie* (Roma, 1988), p.423.
5. William Loerke, *Georges Chédanne and the Pantheon: A Beaux-Arts Contribution to the History of Roman Architecture*, in "*Modulus: University of Virginia, School of Architecture Review*", (Charlottesville, 1982) p.44–50.
6. Gerd Graßhoff, Michael Heinzelmann , Markus Wäfler, Christian Berndt, Jon Albers, Oskar Kaelin, Bernd Kulawik, Ralph Rosenbauer, Nikolaos Theocharis, Michael Lustenberger , Bernhard Fritsch, *Digital Pantheon* (2016, Edition Topoi), p. 5,6,7.
7. Stefano Bertocci, Marco Bini, *Manuale di rilievo architettonico e urbano*, (CittàStudi, 2012), p. 134, 175.

3.2 From the survey to the model

The central development of this thesis is the modelling of four three-dimensional models, based on the resources presented in the previous paragraph. In order to obtain models that are as representative as possible of the surveys examined, in this paragraph we will define the practical steps that characterised the process of transition from two-dimensional to three-dimensional, from paper to virtual.

This series of processes is the achievement of the fundamental step in the development of the thesis. The realisation of a three-dimensional model for each survey examined allows the spatial realisation, even if only on a virtual level, of historical evidence on the state of the art of a monument of immense cultural and archaeological importance, in different historical periods.

Moreover, the uniqueness of the three-dimensional language allows for a direct comparison between historical surveys works that would otherwise be impossible, due to the different representation and survey techniques that the course of history has inevitably brought about.

As well as giving shape to the technical and practical aspect of the survey, this phase, through its three-dimensional transposition, provides a spatial dimension to the inevitable subjectivity of the survey. The decisions and choices made during the survey campaign, from the preliminary phases to the production of the drawings, provide a sort of subjective interpretation of the historical and architectural features of the monument, especially in the three least recent surveys.

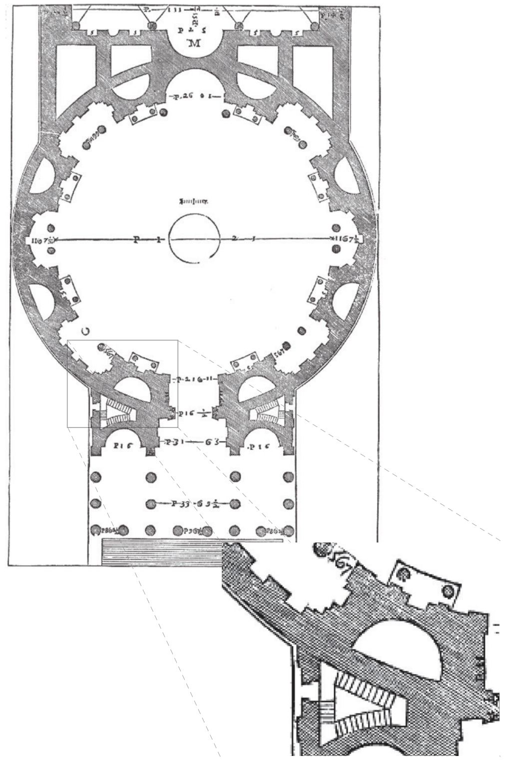


Figure 26: plan of the Pantheon, Andrea Palladio, 1576 (original dimension 25.6 x 15.6 cm).

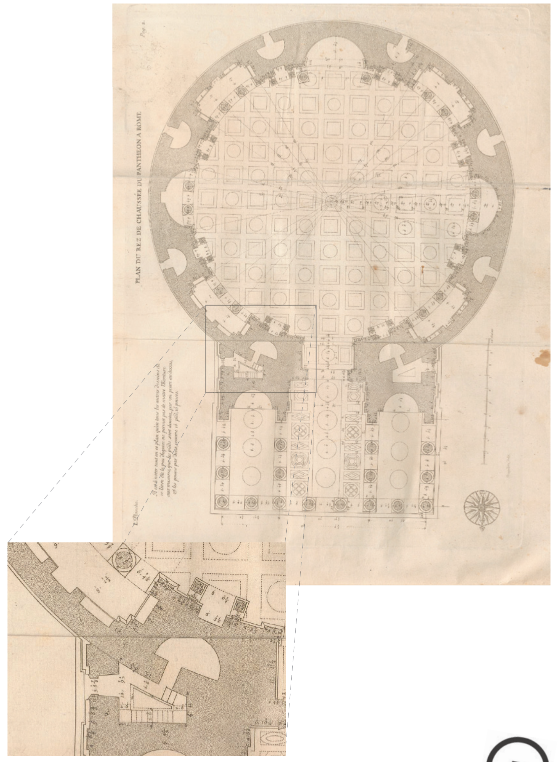


Figure 27: plan of the Pantheon, Antoine Desgodets, 1674 (original dimension 20.2 x 27.1 cm).

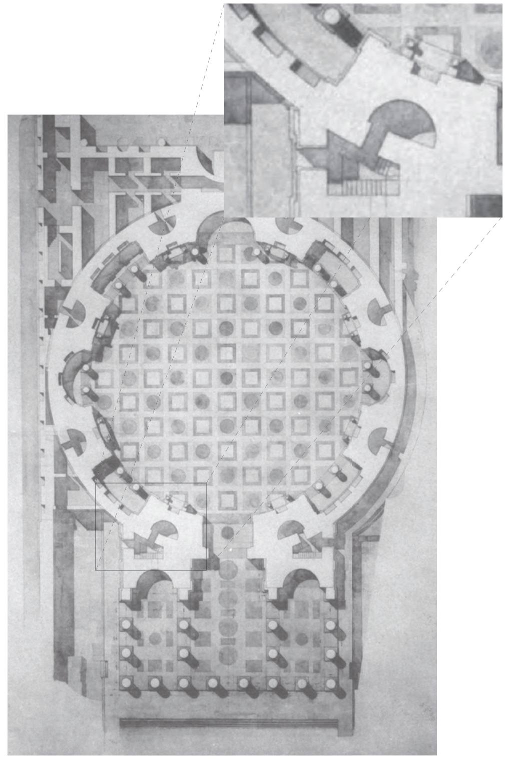


Figure 28: plan of the Pantheon, Pier Olinto Armanini, 1892 (original dimension 28.4 x 18.3 cm).

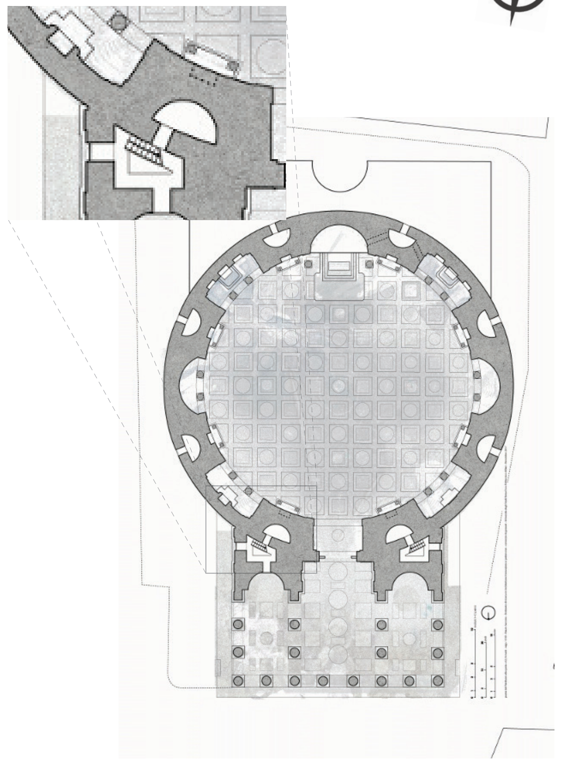


Figure 29: plan of hte Pantheon in *Bern Digital Pantheon Project*, 2014 (original dimension 19.4 x 28.6 cm).

Image acquisition from sources

The first fundamental step is to obtain the technical drawings from the reference texts of the four surveys. These treatises in fact complete the representation tables of the monument with extensive descriptions of the methodologies used and particular notes on details and problems encountered during the survey campaign [1].

The reference texts have been obtained in digital form since, given their historical value, they are not widely available in paper form, but they are widely available on the web in their digital forms, obtained by authorised scanning in order to preserve their academic value and make them accessible to students and professionals.

A special case is the most modern historical survey, the Digital Pantheon Project, whose use is free and immediate through a special web page because, as introduced in the previous paragraph, it is an academic project that uses innovative methods of surveying and therefore of sharing the works.

The survey drawings were then extrapolated as individual elements from the digital texts, in the form of raster images and subsequently standardised in resolution using Adobe Suite Photoshop software. Here two examples images are reported.

Here are two example images of the technical drawings of the surveys, obtained from the digital texts and used in the next step of the process.

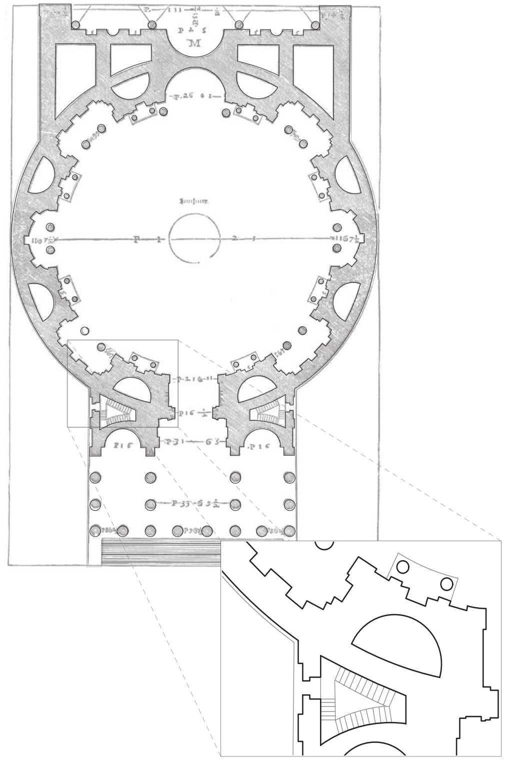


Figure 30: retrace of plan of the Pantheon, Andrea Palladio, 1576.

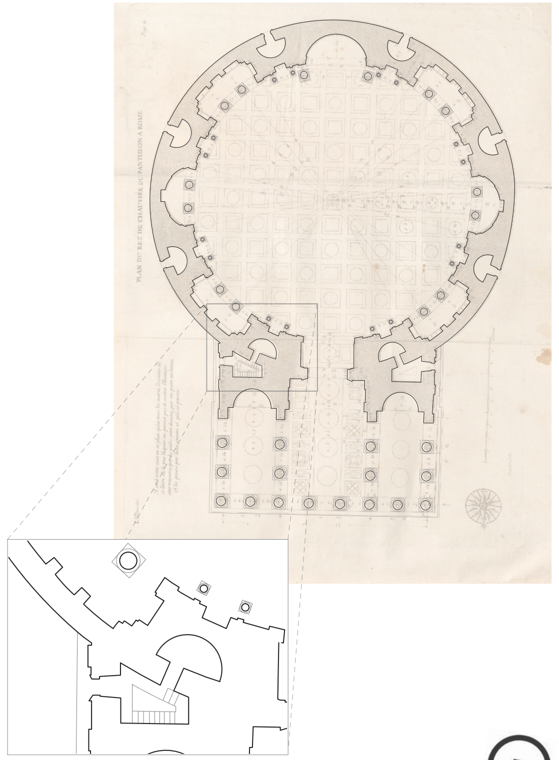


Figure 31: retrace of plan of the Pantheon, Antoine Desgodets, 1674.

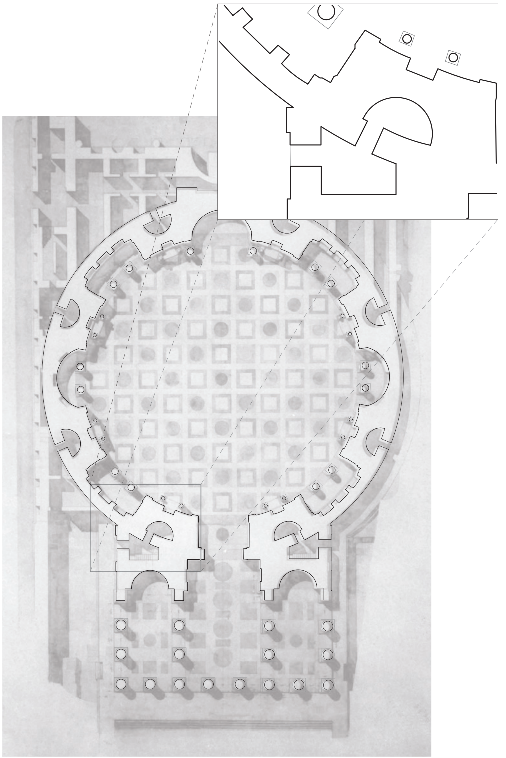


Figure 32: retrace of plan of the Pantheon, Pier Olinto Armanini, 1892.

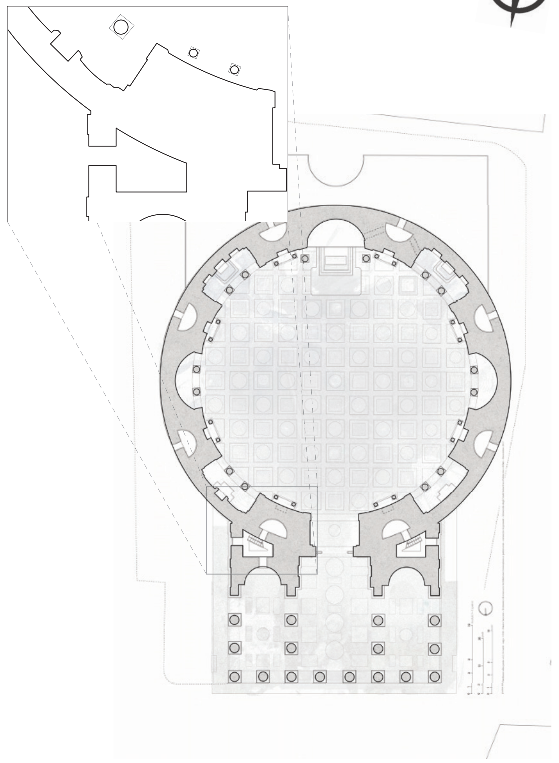


Figure 33: retrace of plan of hte Pantheon in *Bern Digital Pantheon Project*, 2014.

Digital retrace

Subsequently, the images obtained were imported into a digital drawing software, in order to trace and return in digital form the graphic designs that the surveyors had returned.

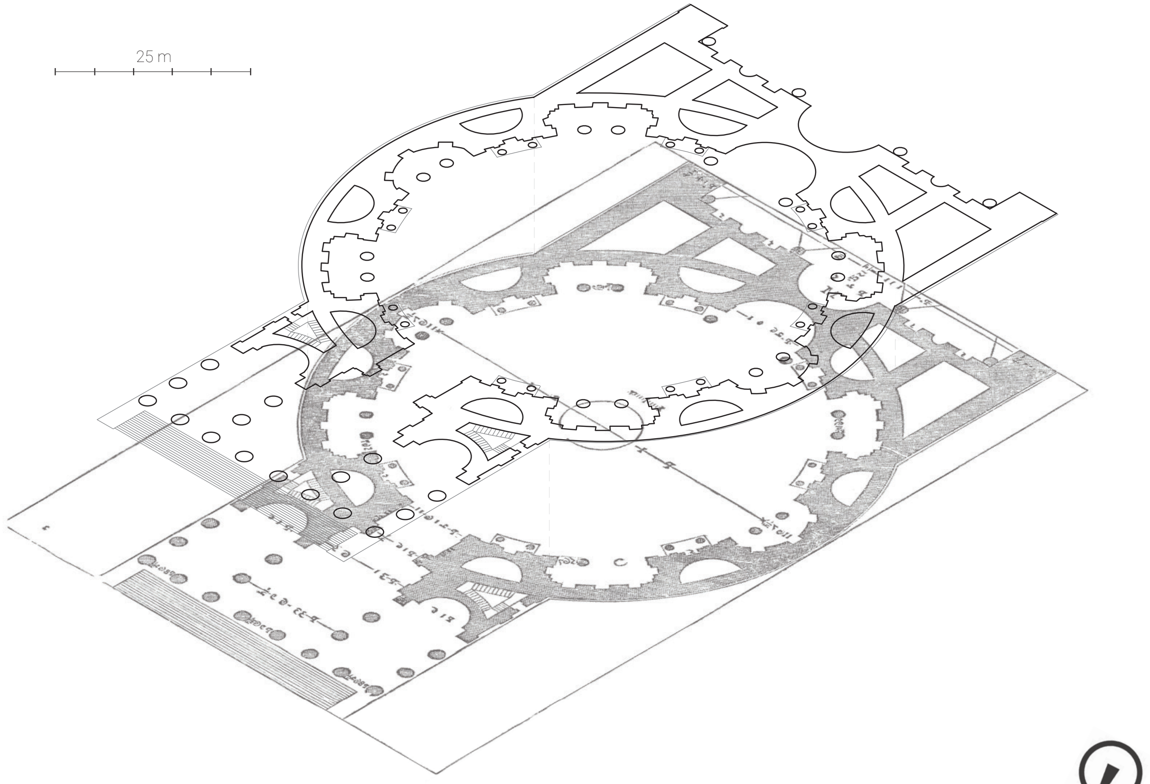
This procedure was mainly used for plans and sections of the monument, in order to obtain the thickness of walls and partitions, dimensions and shapes of the internal spaces.

In this phase two layers were created to control and report the plans, one for the sectioned parts of the monument, the other to distinguish the parts of the monument that were immediately visible but not cut by the section plan, i.e. it allowed in the following modelling phase to obtain a more accurate level of detail.

On the facing page, the overlaps between the original sources and the retrace obtained from them are presented so that a direct comparison can be made, and the previously analysed portion of the plan is reported in detail.

Once the tracing is complete, it is essential to scale the work according to the dimensioning in the original drawings. As well as the techniques of survey and representation, the units of measurement used to dimension the spaces in the original drawings vary according to the period in which the survey was carried out, and we will go into this aspect in the next paragraph [3].

On the following pages the same comparison is shown from a different point of view: an isometric axonometry view allows a dynamic comparison of the result obtained.



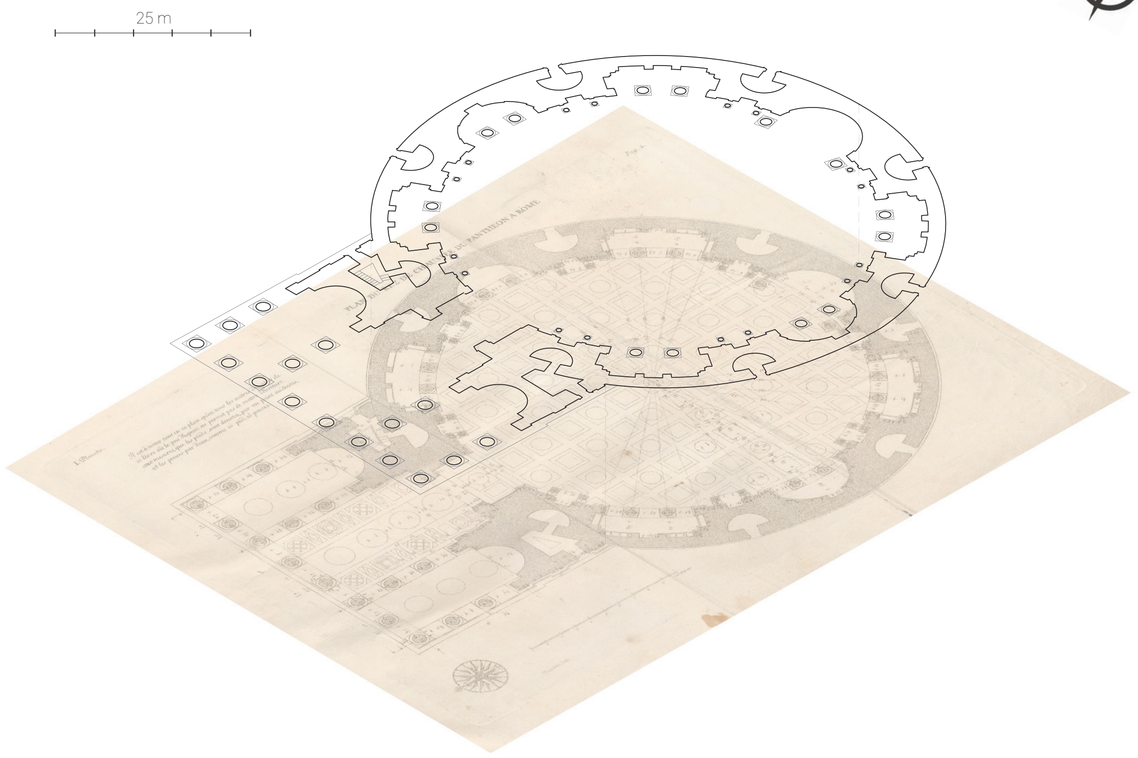
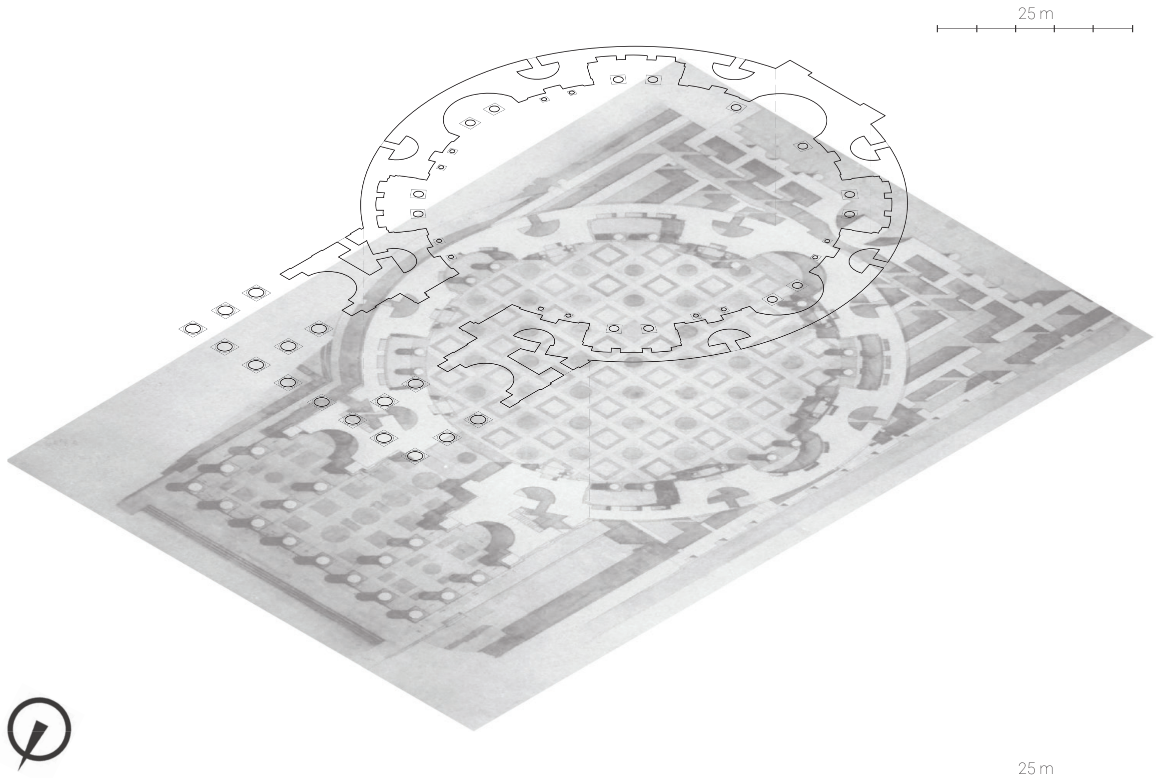


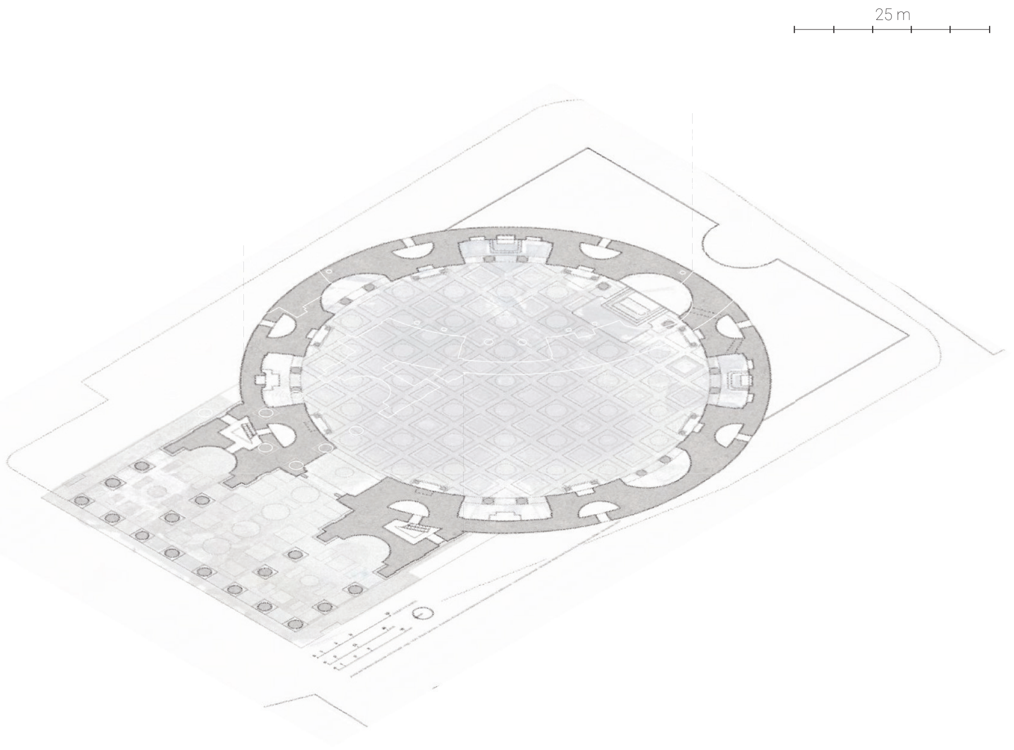
Figure 34: axonometrical comparison of the retrace on the plan by Andrea Palladio, 1576.

Figure 36: axonometrical comparison of the retrace on the plan by Pier Olinto Armanini, 1892.

Figure 35: axonometrical comparison of the retrace on the plan by Antoine Desgodets, 1674.

Figure 37: axonometrical comparison of the retrace on the plan by Digital Pantheon Project, 2014.





Threee-dimensional modeling and shaping

Once the drawings have been transformed into digital format, they are imported into 3D modelling software, in our case Rhinoceros 7.
In order to identify the heights of the individual architectural elements that make up the work, we refer to the elevations and sections corresponding to the plans, carrying out the same redesign procedure as before for the latter.

The three-dimensional modelling of the monument consists of several phases. The fundamental process concerns the extrusion of the lines obtained from the digital tracing, to obtain the internal masonry, the extent of the extrusions is based on the dimensions obtained from sections and elevations.

Then the vertical elements were modelled which present different characters along their development, the columns, both those inside the rotunda and those that constitute the pronaos.

Once the modelling of what can be defined as the first level was finished, again using sections, the vault of the main niche and the roof of the entrance were defined, as well as the second level of the rotunda up to the beginning of the dome.

The construction of the interior of the dome is presented here in rough form, without the geometric design of the coffered ceiling, obtained through a revolution of the section line that defines the shape of the dome. The various levels of the entablature and the tympanum covering the pronaos have been modelled in the same way.

Finally, the section of the outer wall of the rotunda and the dome's roof, with its relative cornice around the oculus, were also obtained by revolutionising the section line and then adapting it to the information provided by the plans of the successive levels.

1. Sander Munster, Kristina Friedrichs, Florian Niebling, Agnieszka Seidel-Grzesinsk, Digital Reserach and Education in Architectural Heritage, (Dresden: Springer, 2017). p.28-37.
2. Stefano Bertocci, Marco Bini, *Manuale di rilievo architettonico e urbano*, (CittàStudi, 2012), p. 134, 175.

3.3 Methodology

The surveys examined cover a time span of more than five centuries, resulting in inevitable differences in the survey methodologies and units of measurement used. For this reason, in this paragraph we are going to define in more detail the working methodology adopted to overcome these differences and obtain a result that is as truthful and comparable as possible.

Unit of measurement

Almost all the authors of the surveys examined by this study use different units of measurement related to the historical and political events of their time.

The metric system, which was introduced in France between 1775 and 1791 [2], had a decisive influence on the design of architecture112 [3]. As already highlighted by Luigi Vagnetti in his 1973 lectures [4], the introduction of the meter into the study of ancient architecture, on the one hand, facilitates dimensional comparison, on the other, it imposed a break between classical and modern architectural culture.

When surveying an architecture, the very same dimensioning in centimetres and meters distances perception and understanding, since the numbers we quote are no longer the original numbers.

Therefore, a "translation" of the number becomes indispensable, in order to return that meaning, that has been expressed for centuries and that risks disappearing behind exact but increasingly abstract numbers.

For this reason, the analyses conducted in the following text follow the suggestions made by Maria Teresa Bartoli in her 2014 essay: "the first requirements of analysis are that the investigation be made:
1) only of findings whose degree of reliability is known;
2) when there is either certain knowledge of the unit of measurement or the possibility of verifying it on the basis of information of a historiographic nature "[3].

Beginning with Palladio's survey, the latter indicates a series of dimensions and proportions in the plans. In particular, two measurements are given: the first indicates the measurement using the Vicentine foot as a unit, corresponding to 0.356 m, the second indicates the ratio between that dimension and the diameter of the columns of the pronaos.

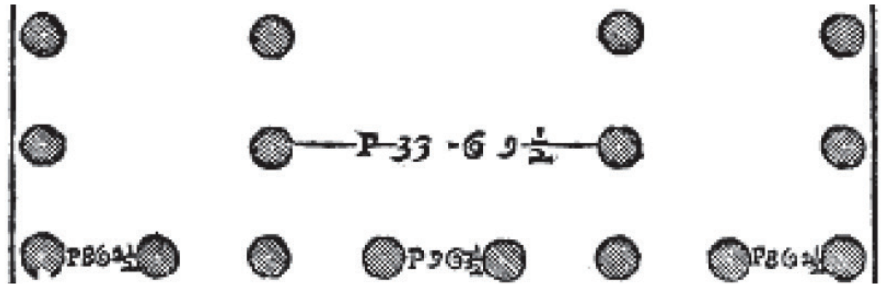


Figure 38: detail of the dimension reported in the plan by Andrea Palladio.

This double indication shows us once again the spirit of the survey carried out by Andrea Palladio. Everything we read about a building, the dimension of the elements that compose it and of the spaces that are created, are related to the dimension of a key element, of an architectural and decorative detail that regulates the proportions of the spaces.

The search for a dimensional module is an attempt to read architecture as the maximum expression of proportion and harmony of the elements that make it up; this vision is explicitly legible in all of Palladio's projects.

Desgodets, for example, went through a reform of the system of French units of measurement. His mentor, Jean Baptiste Colbert, founder of the Académie de France, introduced the pied de Roi (32.4 cm) and the toise du Châtelet (194.3 cm), which remained in use until the advent of the metric system [5].

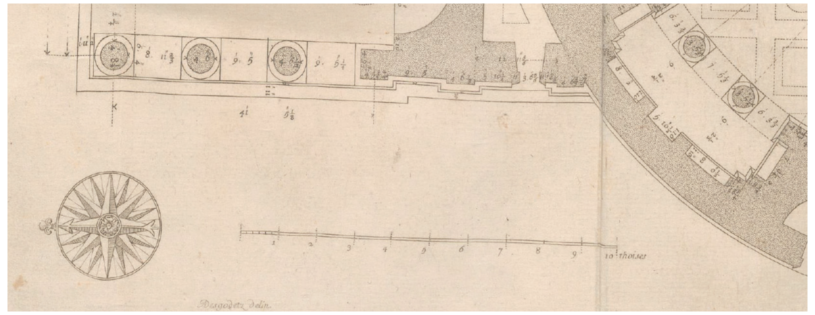


Figure 39: detail of the grphic scale reported in the plan by Antoine Desgodets.

In Armanini's plan, merged with Chedanne's drawings, the metric system is used for the first time, which is why we do not find any graphic scale on the table, but only the metric scale that frames the work at a scale of 1:100. Similarly, the drawings that make up the survey carried out by the Bern Digital Pantheon Project work using the metre as a unit of measurement, all the more so since the survey uses modern scanning technology.

Author	Year	Unit	Equivalence
Palladio	1576	piede vicentino	0.352 m
Desgodetz	1674	toise pied de Roi pouce	1.943 m 0.324 m 0.027 m
Chedanne	1892	metre	
Digital Pantheon project	2014	metre	

Figure 40: graphical comparison of units of measurement addressed in the collection of resources

Retrace methodology

The process of digital tracing is based on digital sources, derived from paper sources, this additional step inevitably worsensing the quality of the work. Moreover the error between the paper and digital stroke works at completely different scales. We will therefore report on the method used for the practical choice on the dimension of the stroke, followed for the creation of the digital drawing.

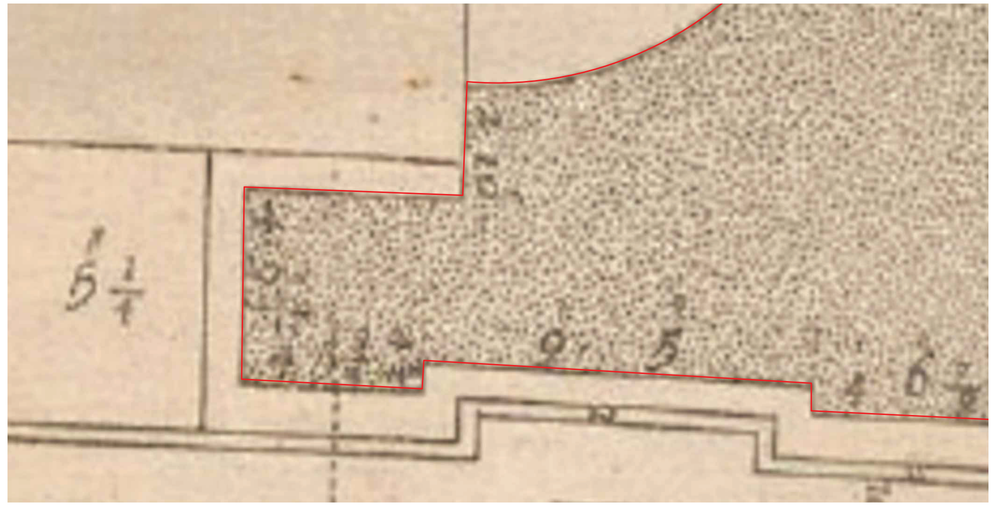


Figure 41: detail of the retrace of the plan by Antoine Desgodets.

Above are some tracing details of one of the four plans used for the development of the three-dimensional models. We can see the technical compromise used to compensate for the low quality of some of the sources used, while in some case the mark follows the stroke perfectly as it is clearly more distinguishable.

The retouching of the plans was carried out using a layer division, to differentiate the sectioned parts and the elevated parts, in order to obtain a different stroke and characterise certain construction details [6].

The process of tracing the sections follows the same guidelines as those defined for the plans, with particular attention paid to the warping of the dome and its division into coffers. However, the less than excellent quality of the sources did not allow for a tracing of the decorative parts of the second level of partitions, as most of the sections were not sectioned.

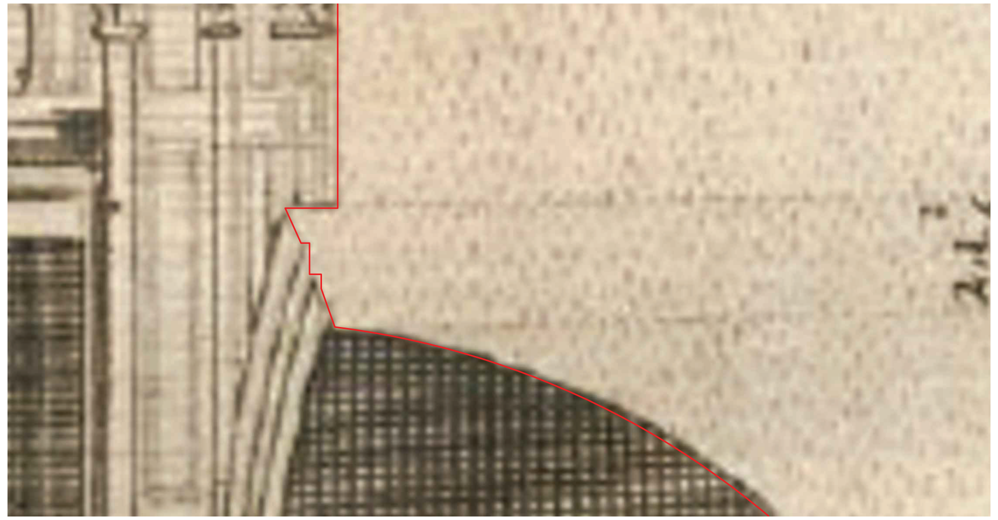


Figure 42: detail of the retrace of the section by Antoine Desgodets.

Above is a detailed tracing of the section corresponding to the plan previously illustrated; it can be seen how the discreet level of detail has allowed the restitution of the decorations that mark the succession of the macro levels inside the monument.

Generally speaking, the tracing phase was based on the most faithful restitution possible of the manual trait reported by the historical sources; the variations that inevitably occurred in this process were partly corrected during the modelling phase, by means of a direct comparison with all the documents that make up the state of the art of the monument in each historical period.

1. Stefano Bertocci, Marco Bini, *Manuale di rilievo architettonico e urbano*, (CittàStudi, 2012), p. 134, 175.
2. Henri Moreau, *Le système métrique: des anciennes mesures au Système international d'unités*, (Paris: Chiron, 1975).
3. Maria Teresa Bartoli, *La misura nella geometria che disegna l'architettura*, in *La geometria descrittiva dalla tradizione alla innovazione*, C.Cundari, M.Migliari, (Aracne, 2015), p. 53-70.
4. Luigi Vagnetti, *L'architetto nella storia di Occidente*, (Padova: Cedam, 1980).
5. Jean-Claude Hocquet, *La métrologie historique*, (Paris, PUF, 1997), p.389–391.
6. Sander Munster, Kristina Friedrichs, Florian Niebling, Agnieszka Seidel-Grzesinsk, Digital Reserach and Education in Architectural Heritage, (Dresden: Springer, 2017). p.28-37.

Painting by Ippolito Caffi, 1830.

4. REPRESENTATION

4.1 Representation as a theme

In the process of analysing representation, from its ancient to its contemporary forms, which characterises this thesis, a fundamental step is the one presented in this chapter. In the following pages, in fact, we will present the four models of the Pantheon obtained, in relation to the historical sources from which they were generated.

The preceding chapters and paragraphs: the historical and urbanistic introduction of the monument, the philological work of description of the historical sources, the presentation of the practical processes for the realisation of the digital models, with annexed clarifications on the methodologies and problems encountered during this process; these are necessary phases for the creation of the experimental and technical context that leads to the presentation of the work carried out.

The classical representation that characterises the surveys under consideration therefore takes on a different language, more complex and immediate but at the same time more prone to errors. Modelling a historical survey on a three-dimensional level means giving a form to the dimensional interpretation that the surveyor inevitably transposes in the production of the architectural survey drawings.

Representation therefore no longer becomes just a means of communicating spatial and geometric data, but a tool for characterising a virtual space, the three-dimensional transposition of a survey method, a historical period or the phases in the life of a building or monument. This allows us not only to observe this phenomenon, but also the possibility of an immediate comparison on the perception of the Pantheon that the four historical surveys intrinsically contain.

4.2 From two to three dimensions

The transition between the two-dimensional resources and the three-dimensional models obtained from them was introduced in the previous chapter. The modelling method is based on the comparison between the different outputs of each historical survey.

In order to obtain a model that is as faithful as possible to the historical resources, the parts of the monument that are not represented in the survey have not been included in the three-dimensional model. However, the level of detail for the decorative parts in the drawings are addressed as subjects of special interest, for historical and academic reasons, while at the three-dimensional modelling level these elements have not been recreated with a similar level of detail, in order to keep the model comprehensible in its entirety and even at a reduced scale, as can be seen in the following pages.

The possibilities of creating a three-dimensional model, in terms of representation, are endless. The comparison with reference paper resources is as immediate as it is effective. The three-dimensional model thus becomes a container of information on the architecture that can be extrapolated on the basis of representative needs, whether these be technical or merely aesthetic.

The comparison of three-dimensional models with graphic sources allows an immediate relationship between three-dimensional space and its planar counterpart. In addition, the survey drawings are placed in relation to the three-dimensional models respecting their real relationship with the structure of the building. For example, the plans section the model at the height to which they refer, the sections are placed on the axis of the sectioning plane that ideally generated them, this allows to build at a perceptive level the visual depth that is obviously absent in a two-dimensional work.

4.2.1 Geometry and harmony of shapes - Palladio

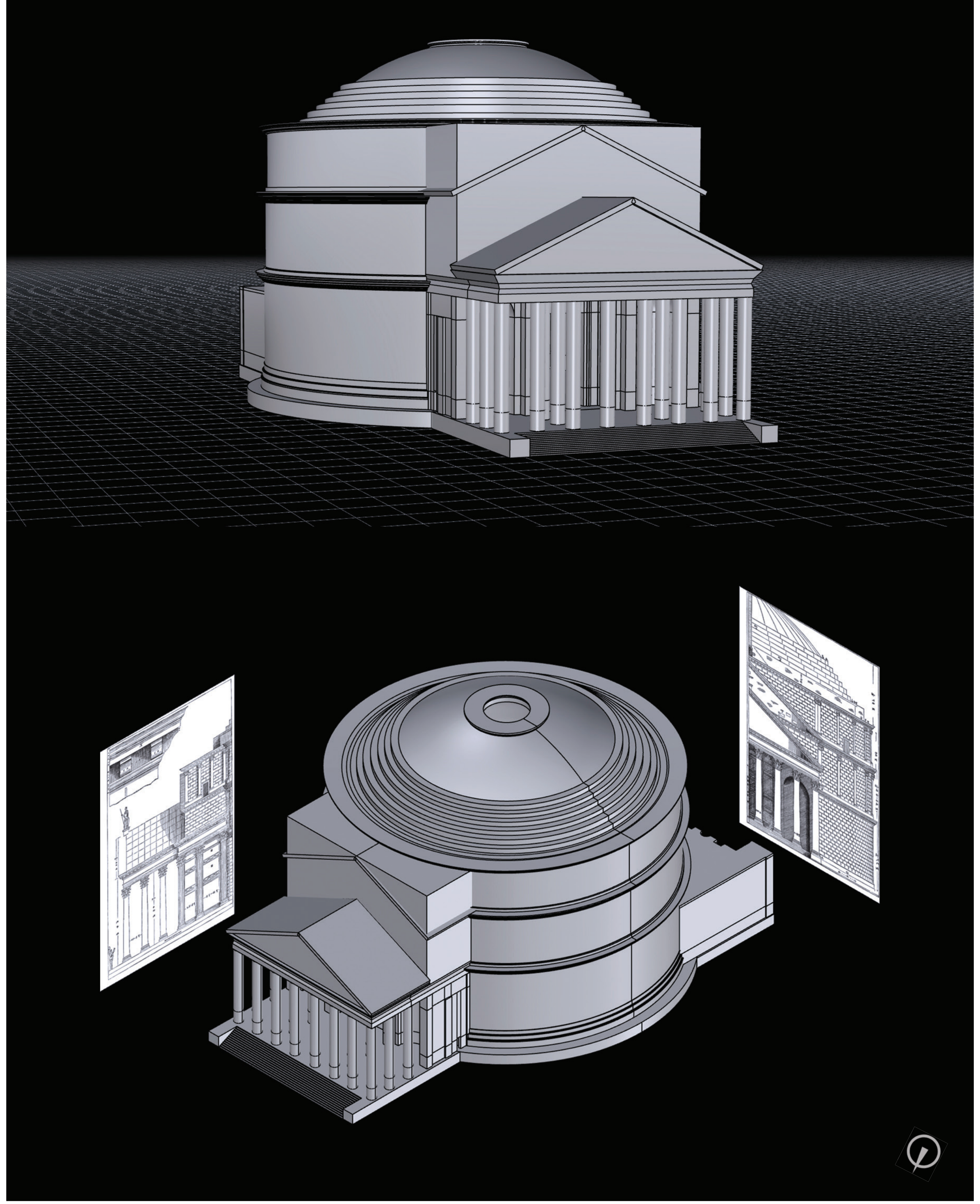


Figure 43: tridimensional model of the Palladio's survey, perspective view and related to the original elevations.

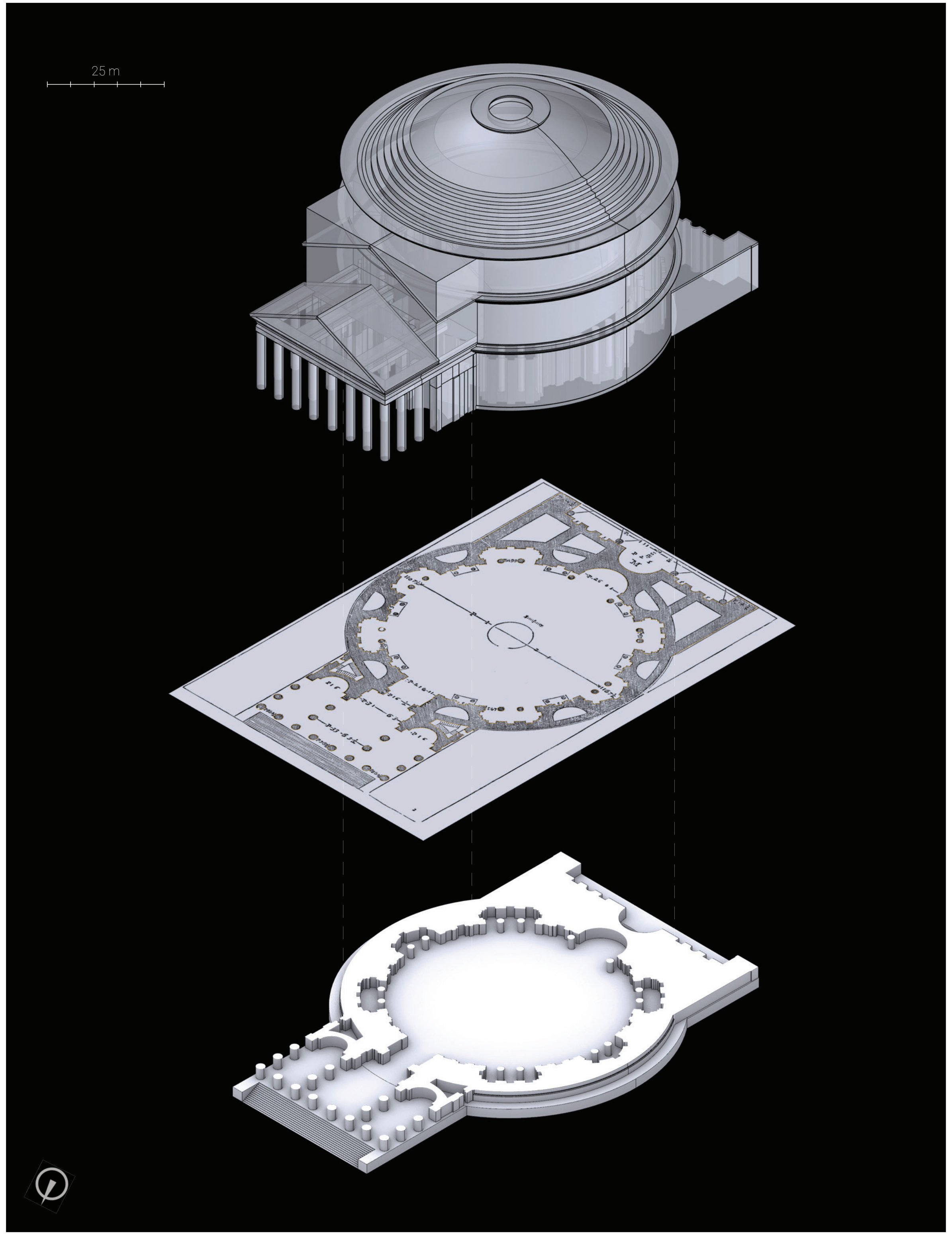


Figure 44: tridimensional model of the Palladio's survey, related to the original plan.

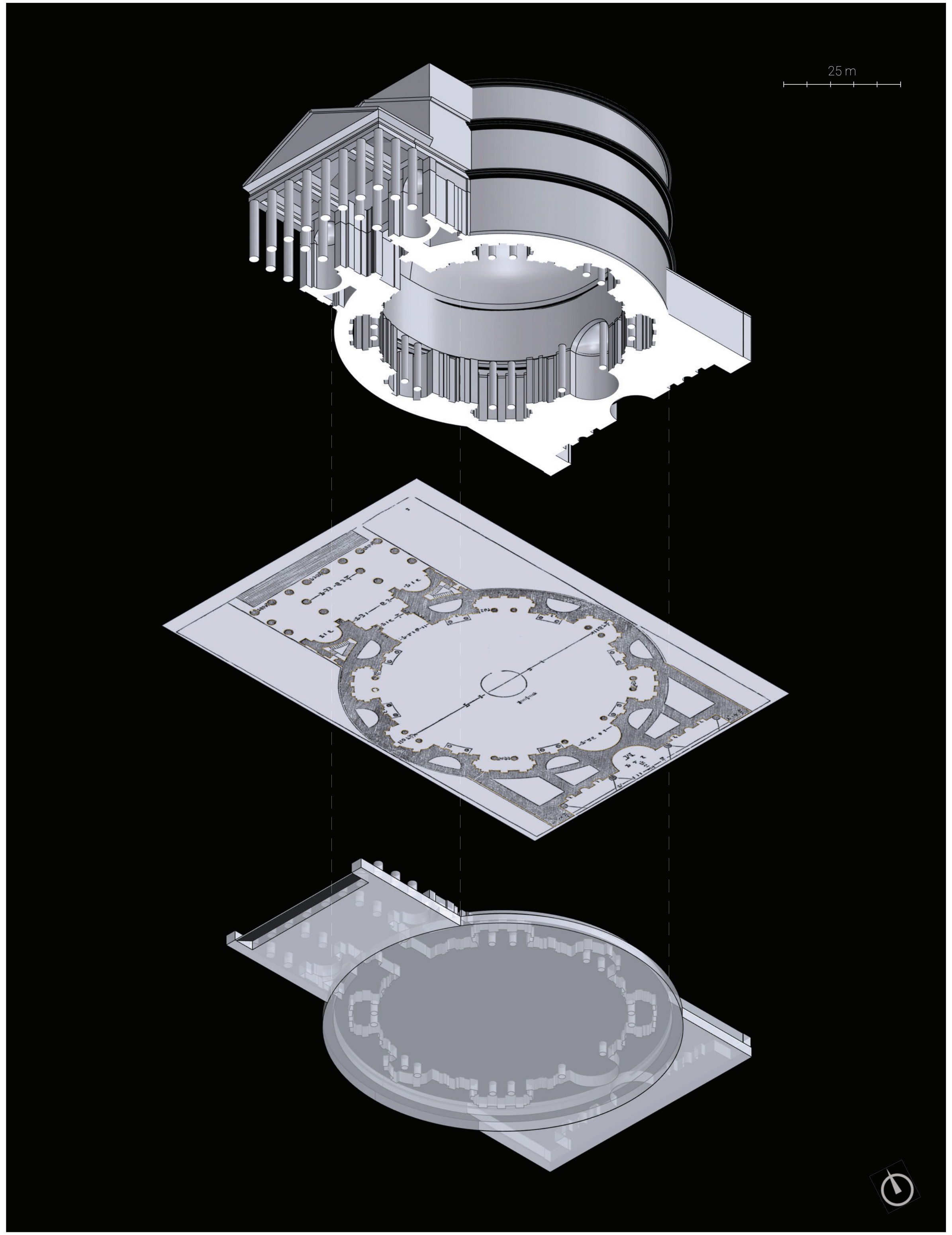


Figure 45: tridimensional model of the Palladio's survey, related to the original plan.

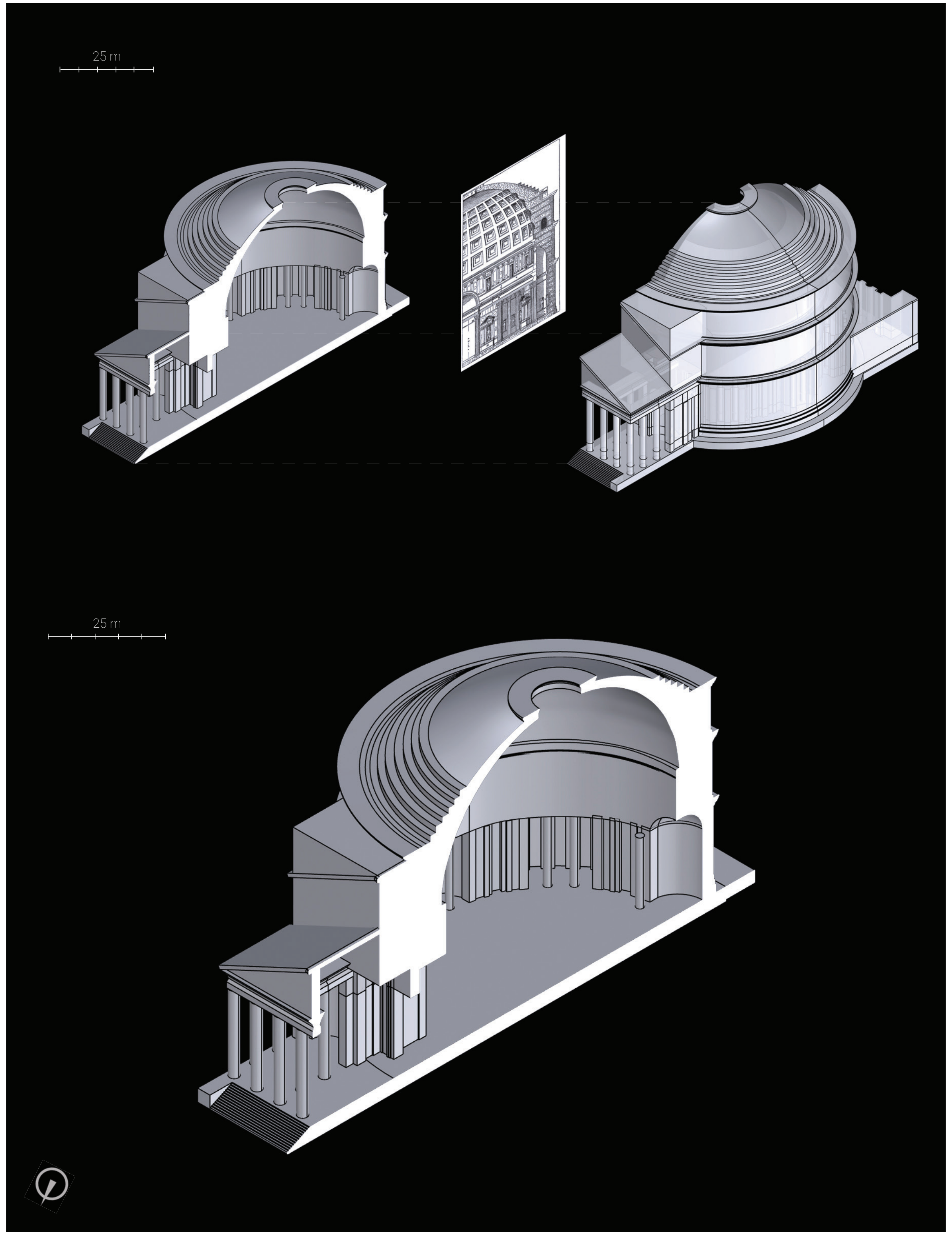
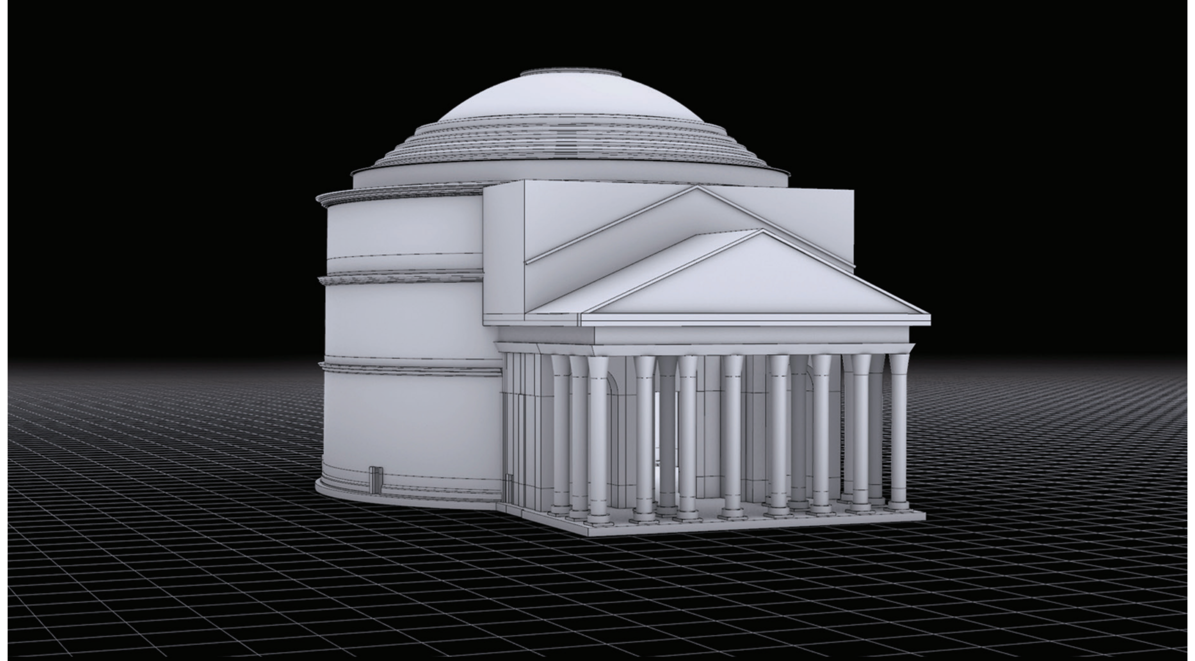


Figure 46: tridimensional model of the Palladio's survey, related to the original longitudinal section.

4.2.2 Survey for proportion and measure - Desgodets



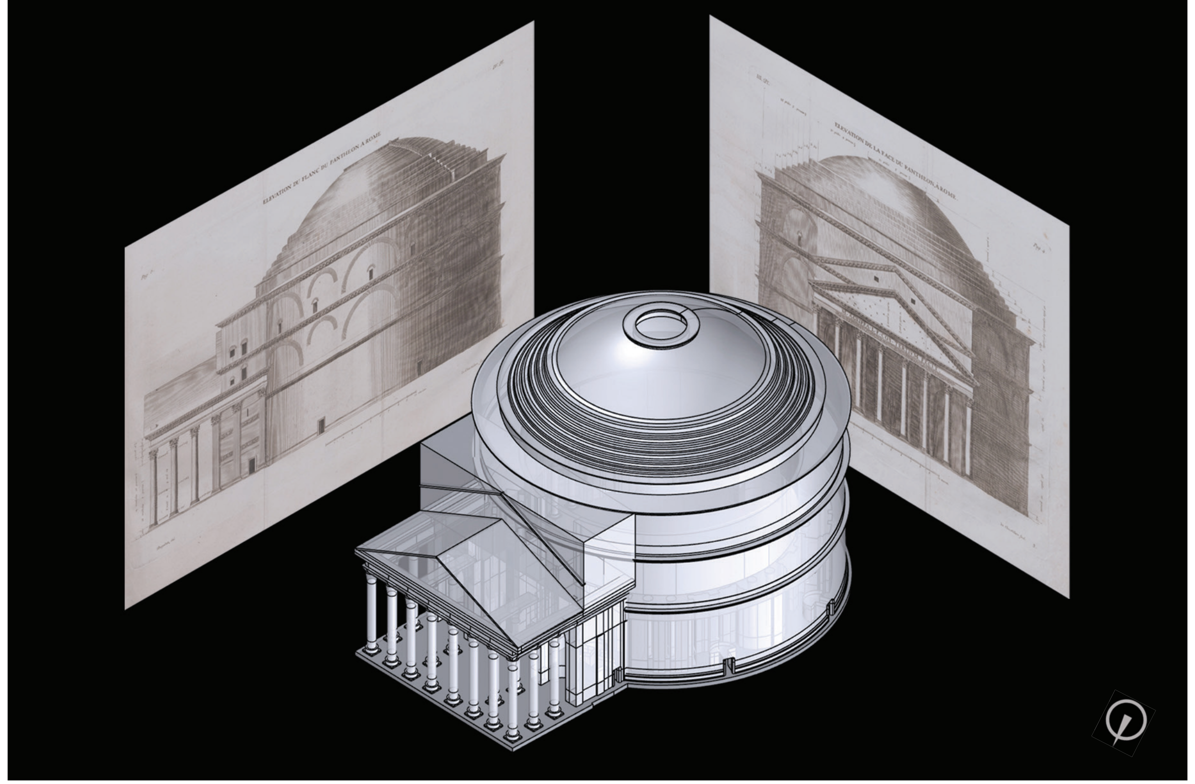


Figure 47: tridimensional model of the Desgodets's survey, perspective view and related to the original elevations.

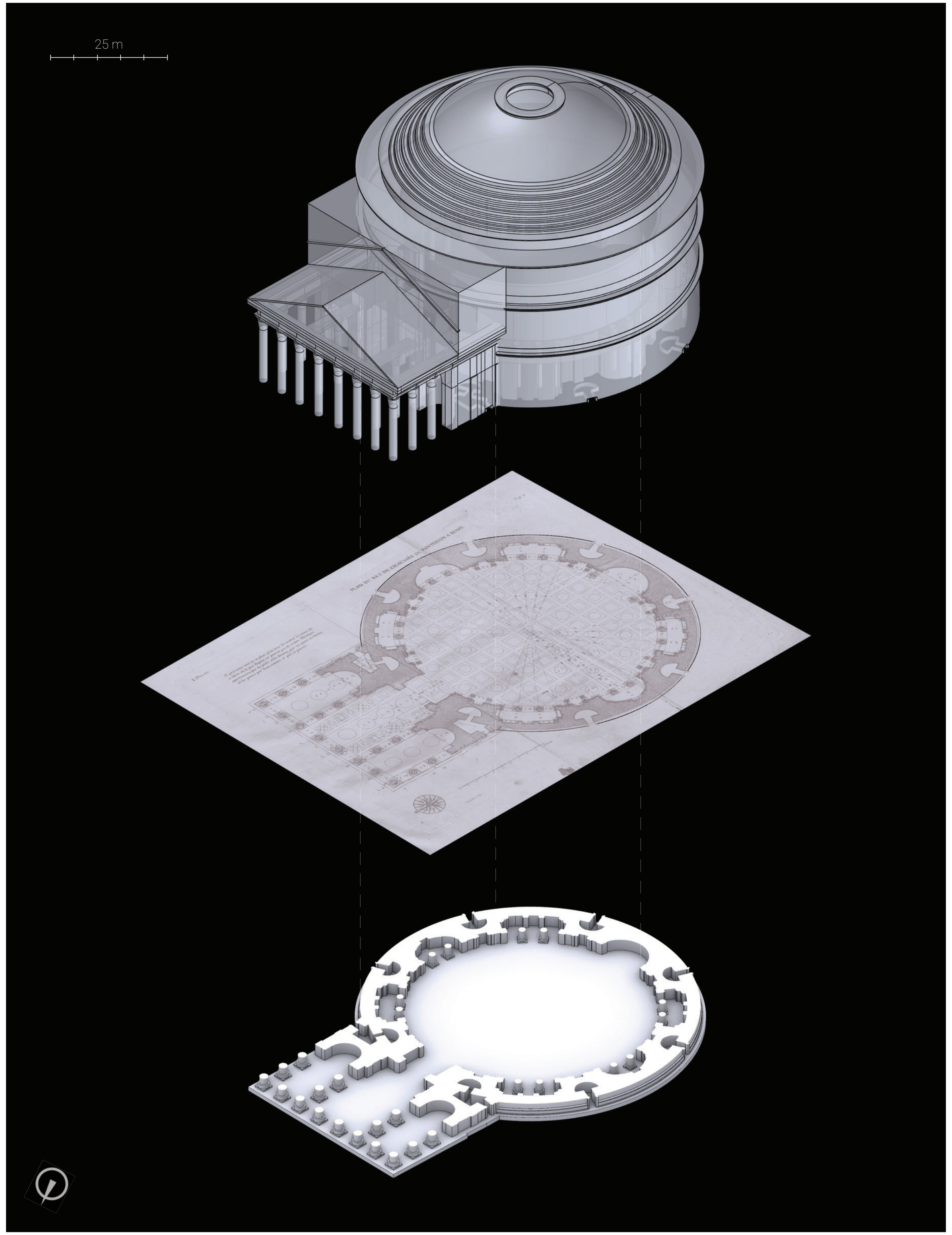
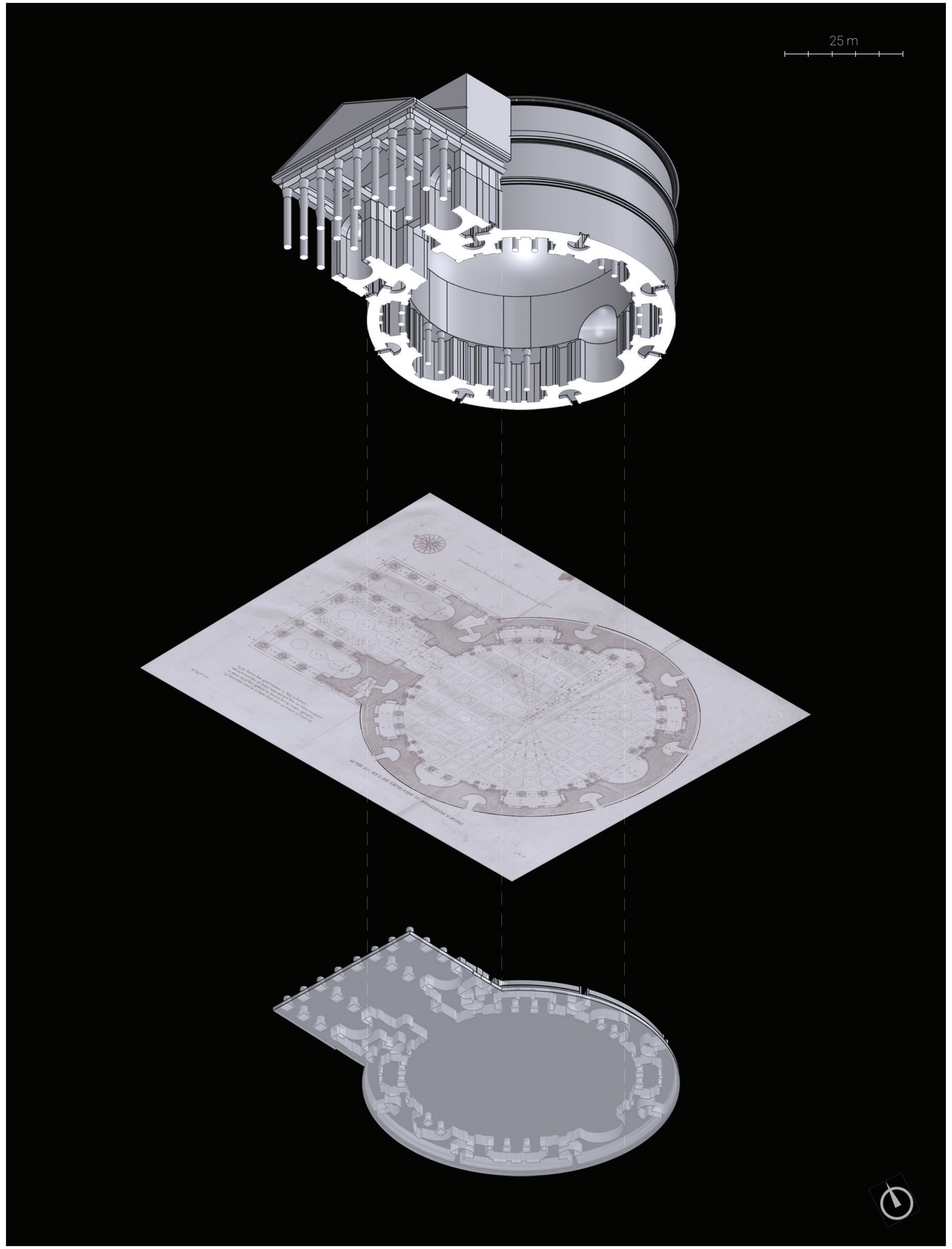


Figure 48: tridimensional model of the Desgodets's survey, related to the original plan.

Figure 49: tridimensional model of the Desgodets's survey, related to the original plan.



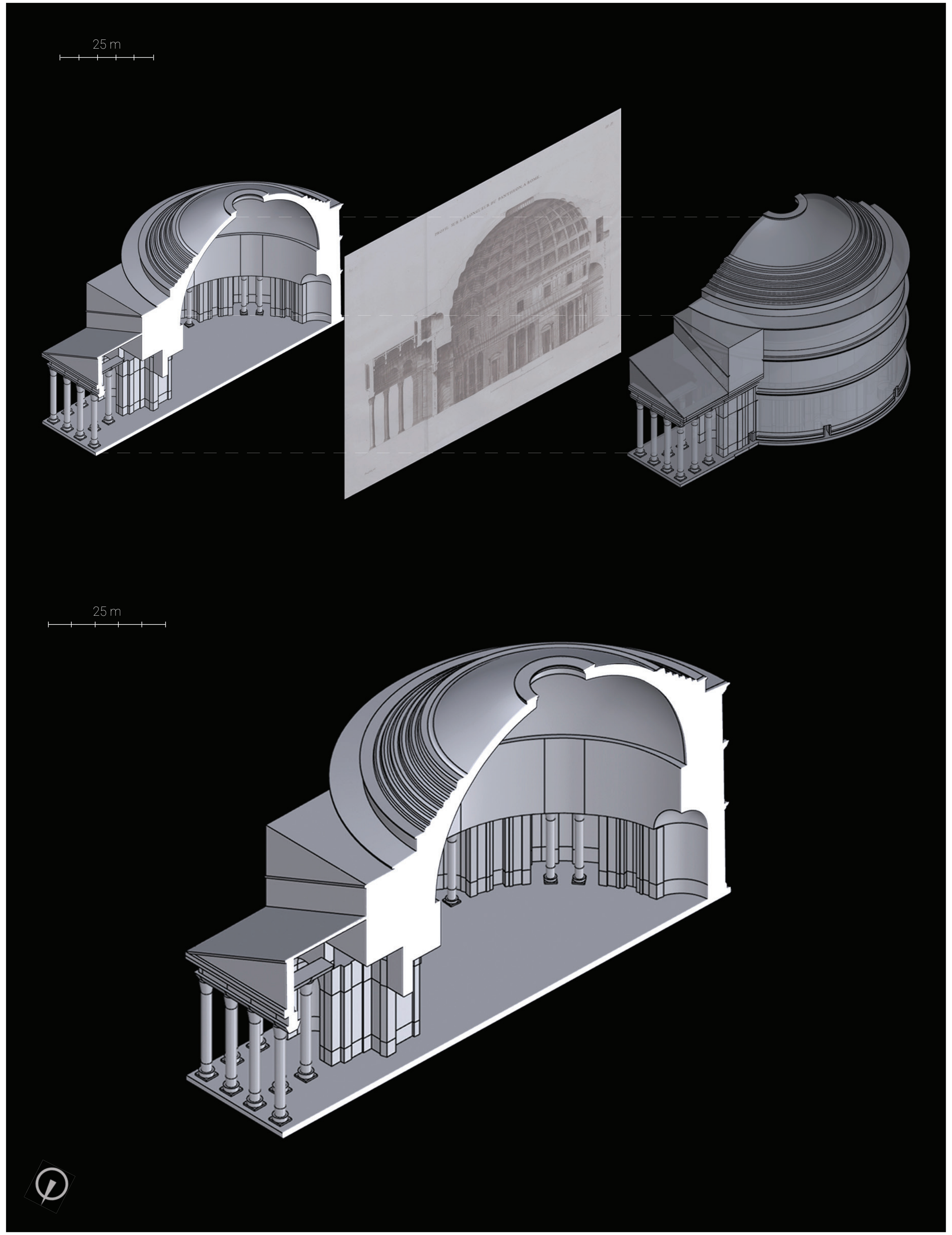


Figure 50: tridimensional model of the Desgodets's survey, related to the original longitudinal section.

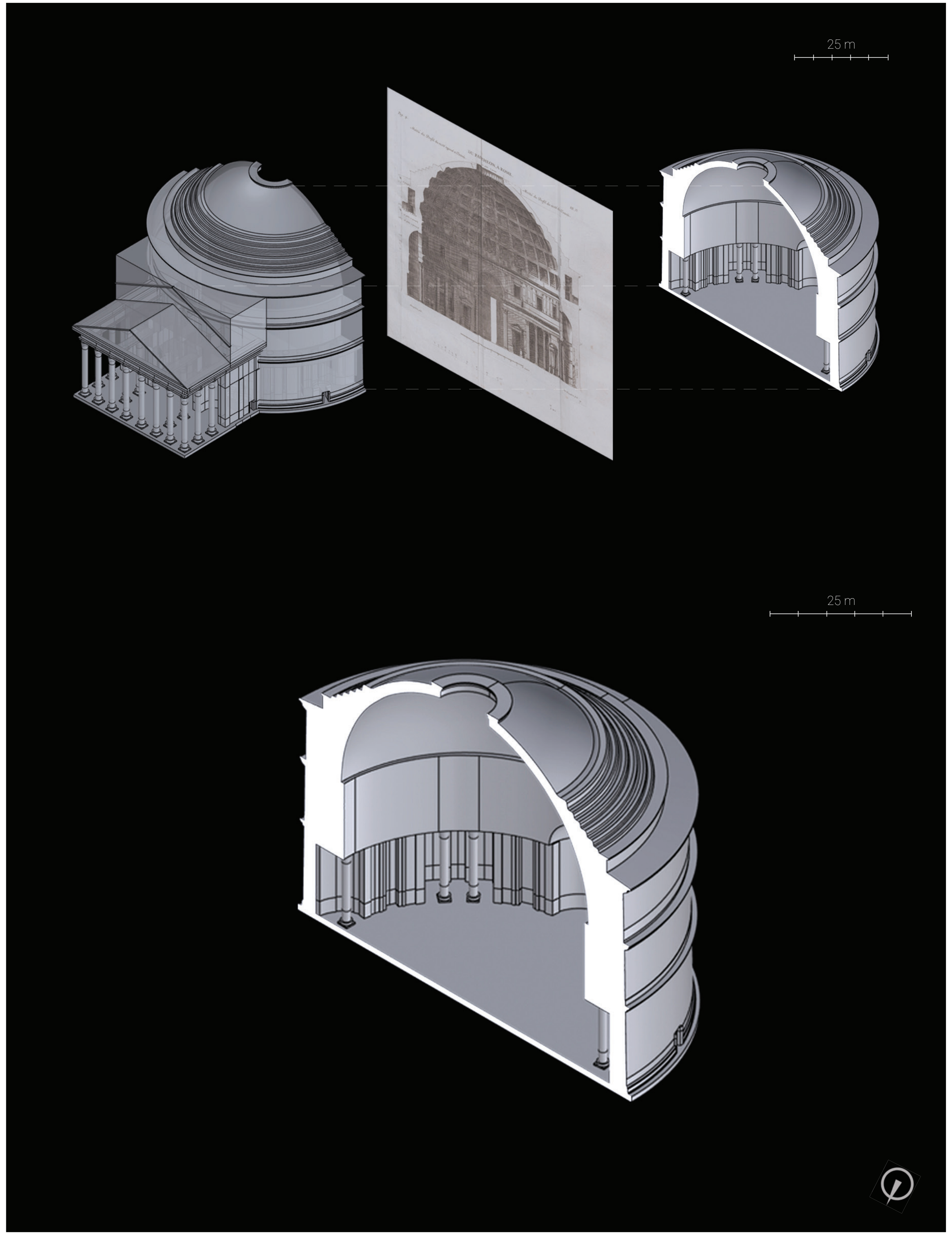


Figure 51: tridimensional model of the Desgodets's survey, related to the original trasversal section.

4.2.3 Aesthetics of archaeology - Chedanne

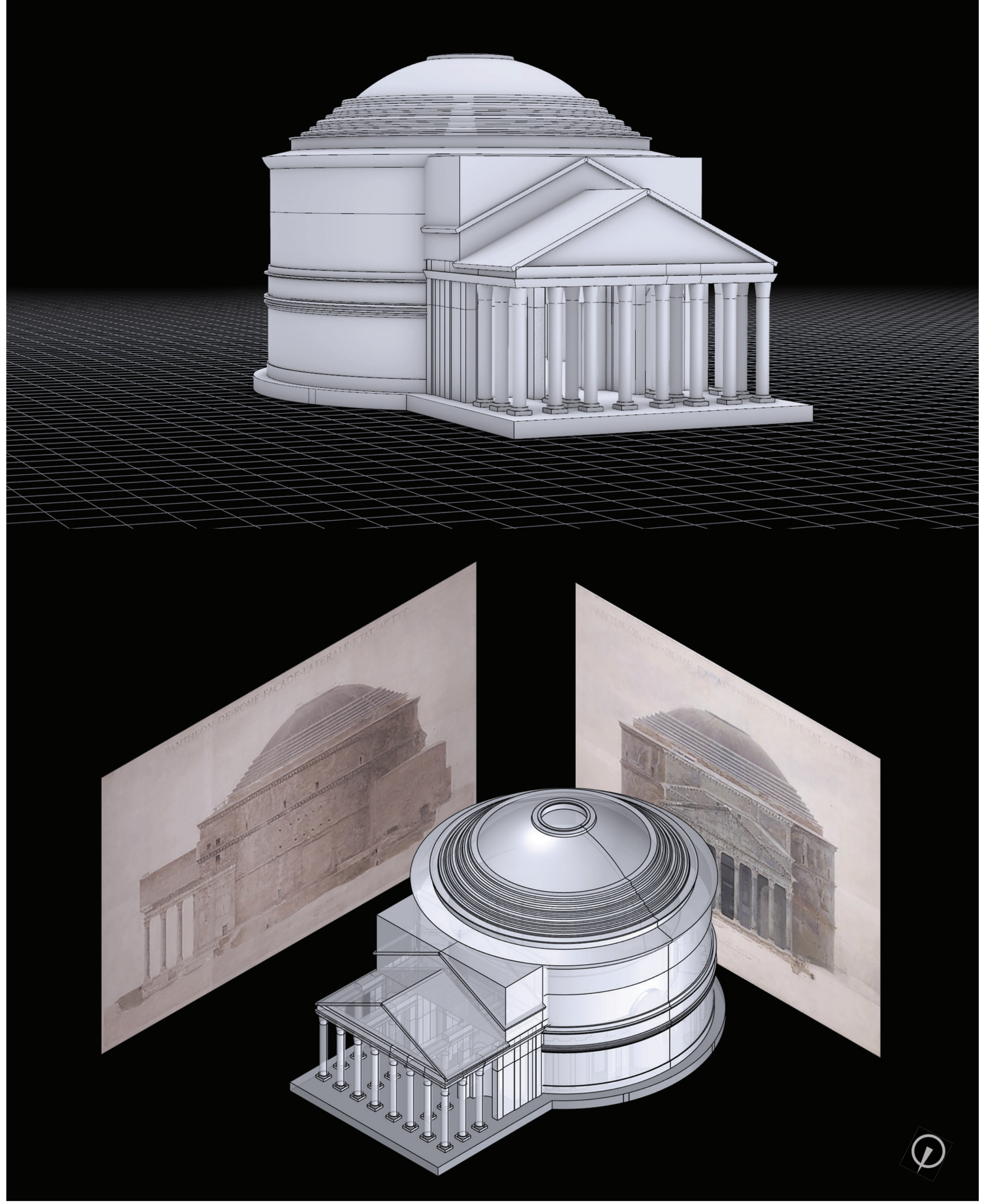


Figure 52: tridimensional model of the Desgodets's survey, perspective view and related to the original elevations.

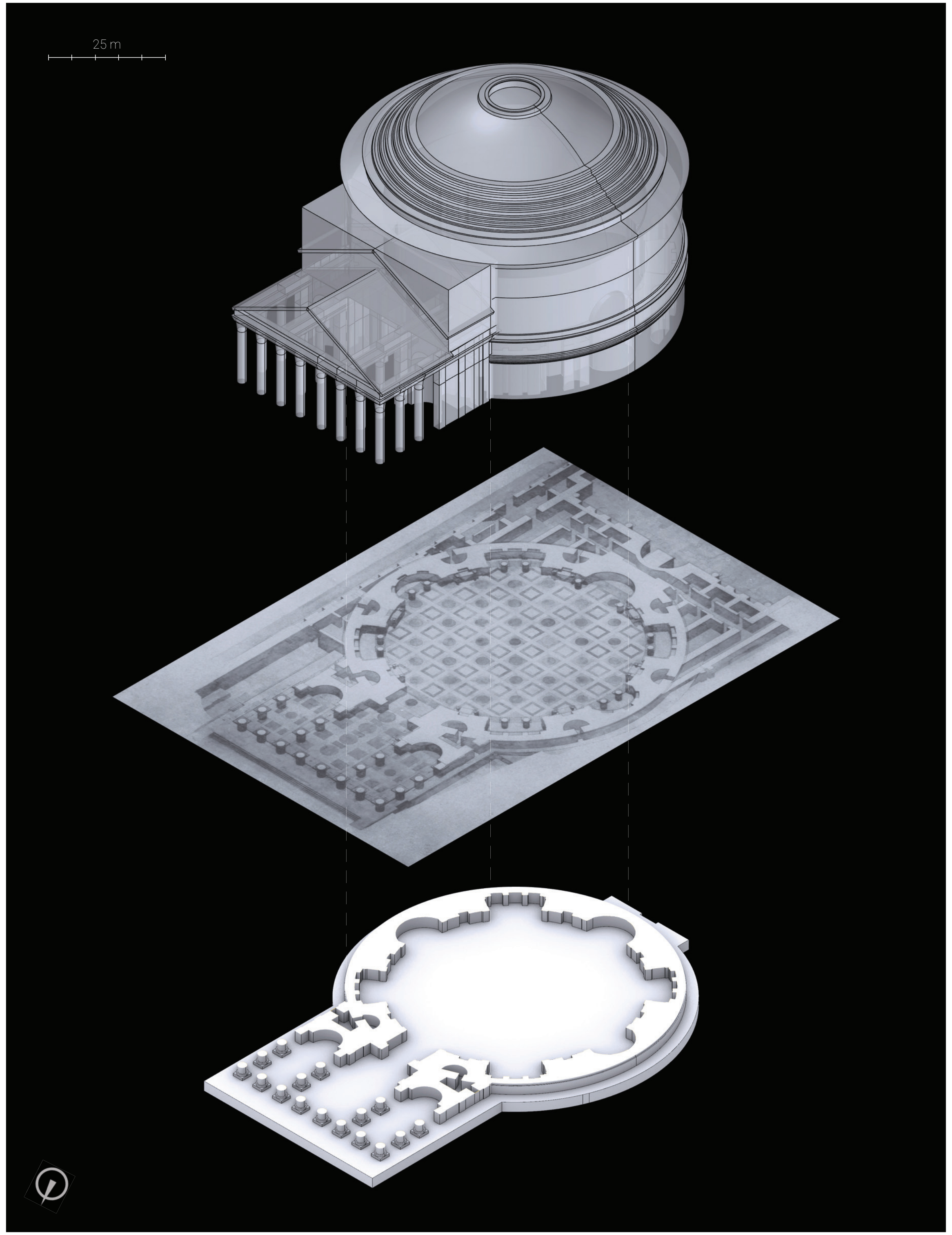
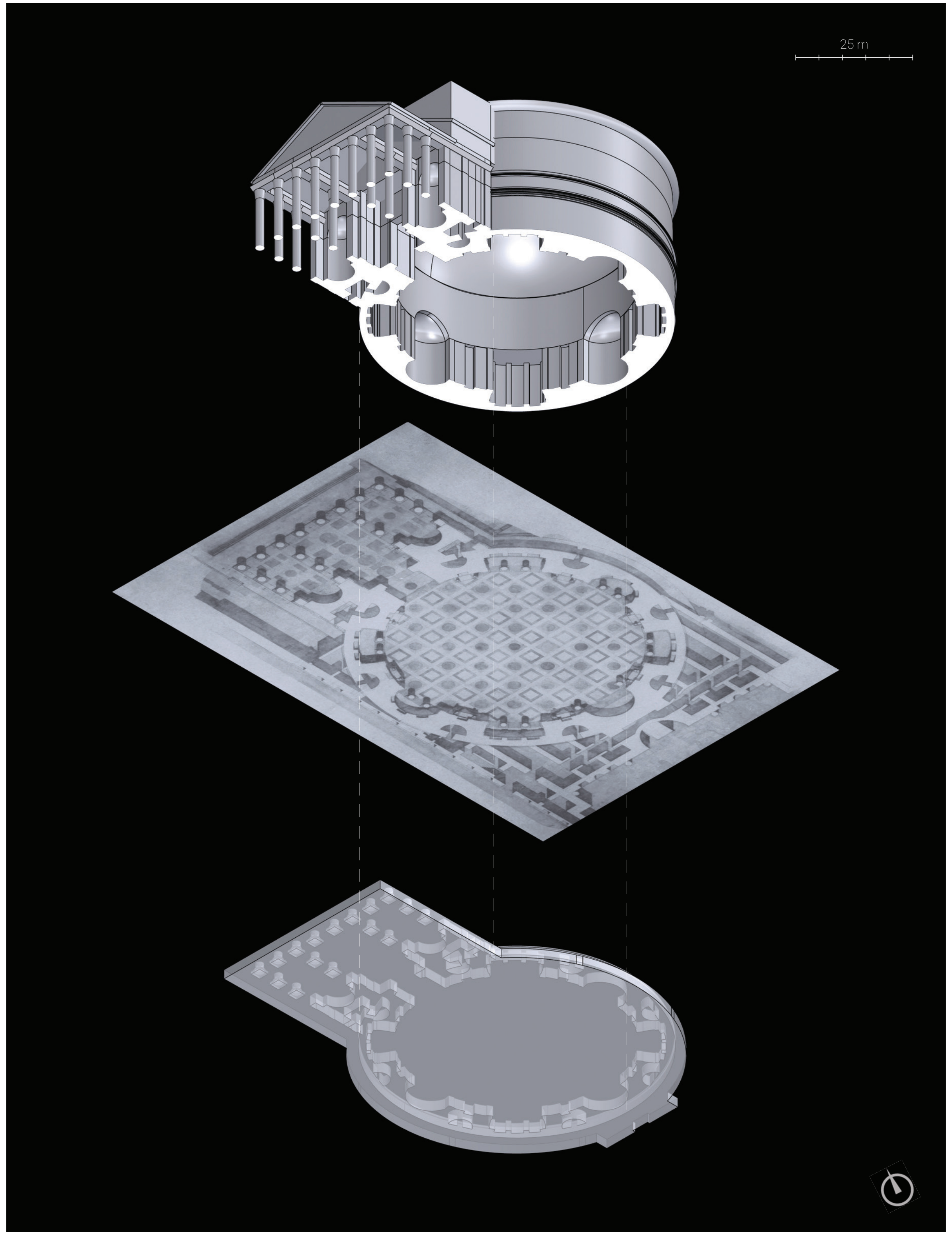


Figure 53: tridimensional model of the Chedanne's survey (plan by Armanini), related to the original plan.

Figure 54: tridimensional model of the Chedanne's survey (plan by Armanini), related to the original plan.



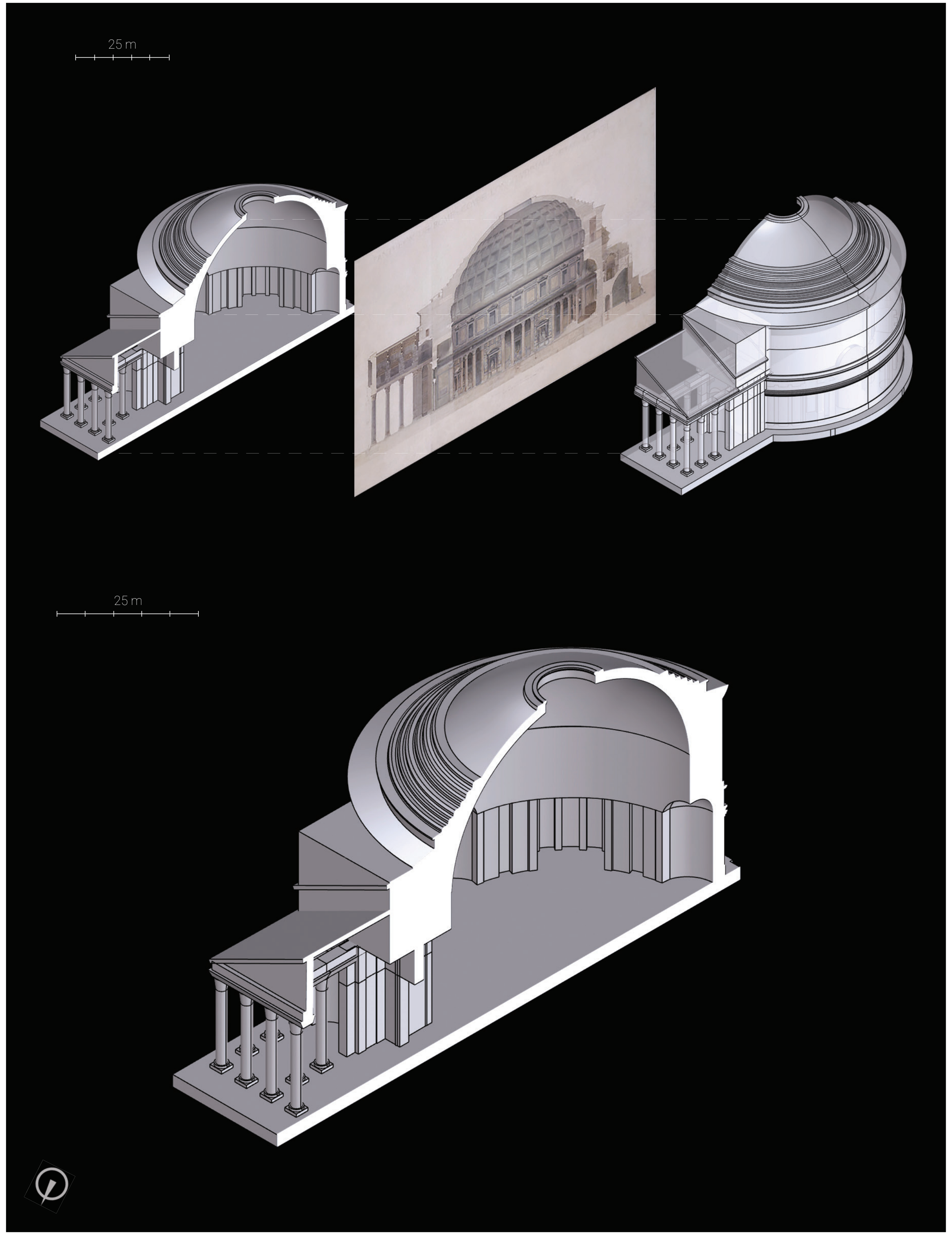


Figure 55: tridimensional model of the Chedanne's survey, related to the original longitudinal section.

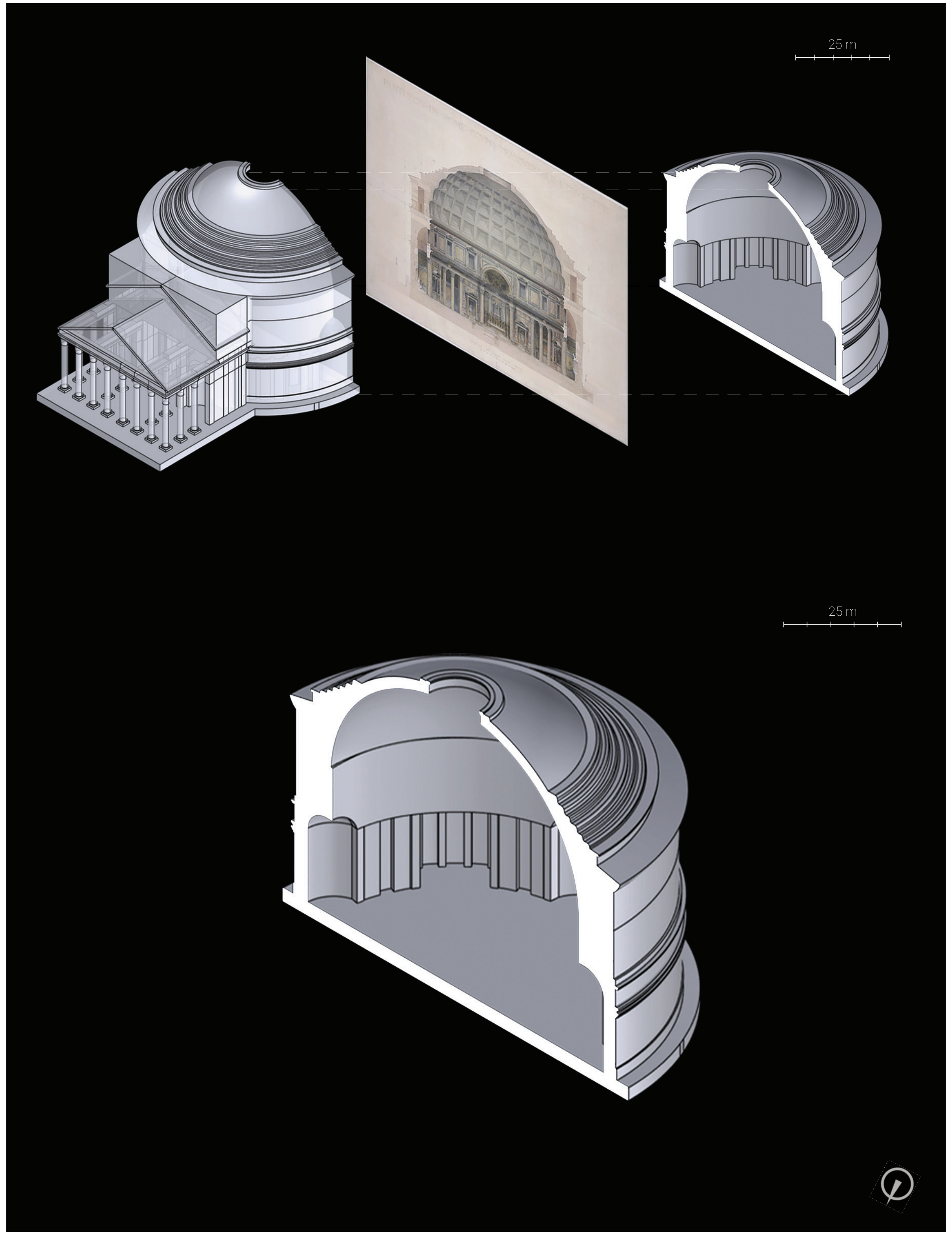


Figure 56: tridimensional model of the Chedanne's survey, related to the original trasversal section.

4.2.4 Digitisation of the monument - Digital Pantheon Project

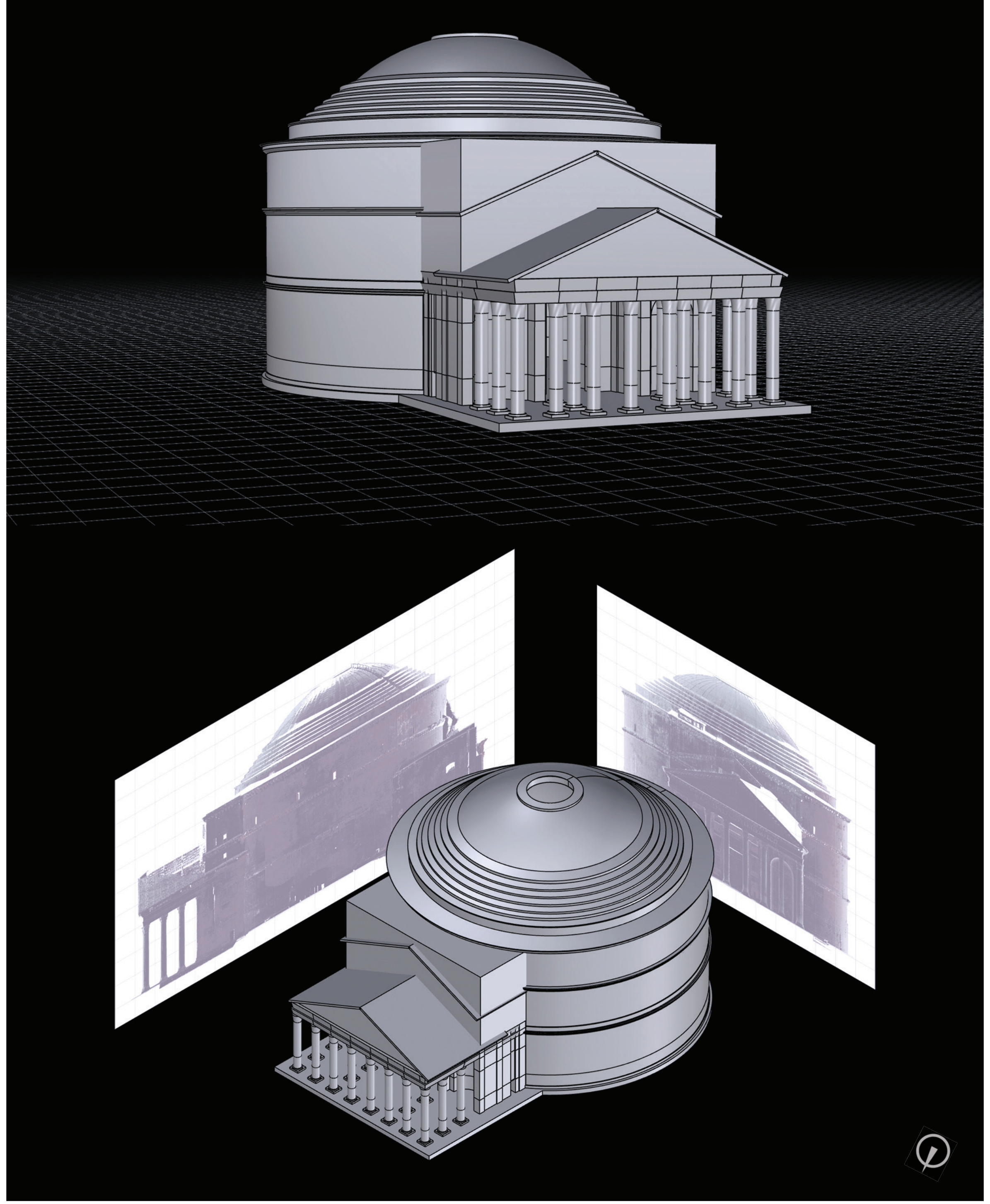


Figure 57: tridimensional model of the Digital Pantheon Project's survey, perspective view and realted to the original elevations.

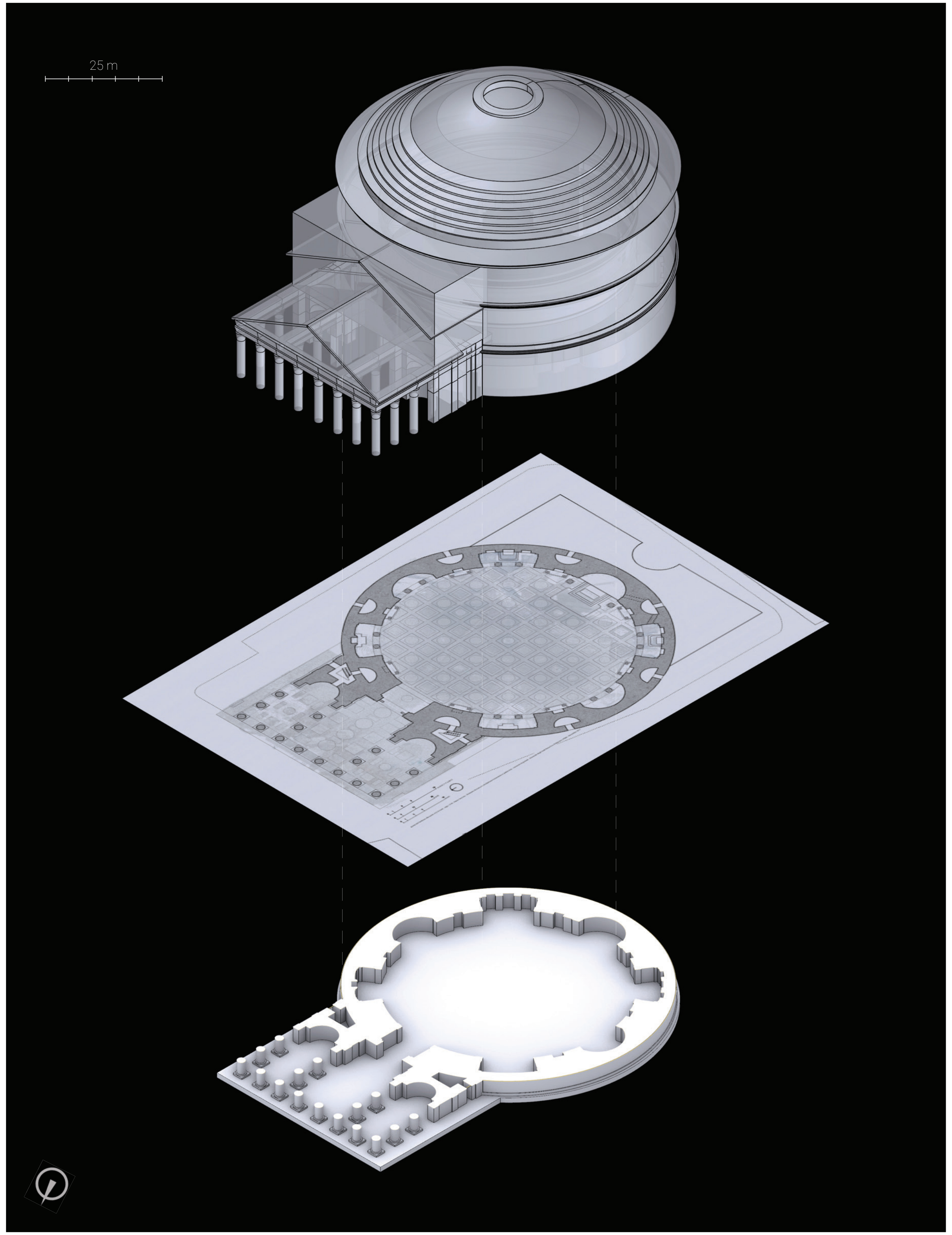
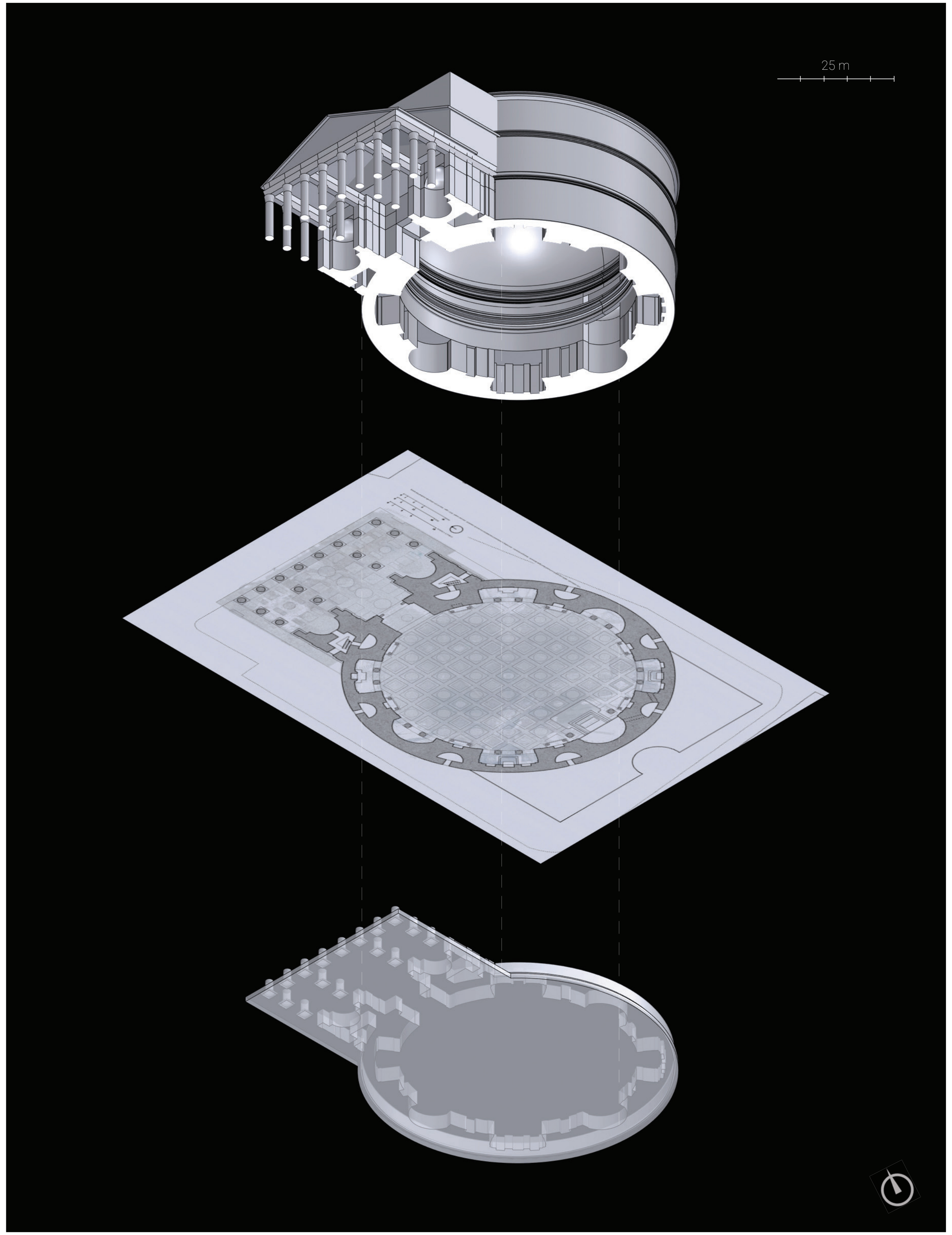


Figure 58: tridimensional model of the Difital Pantheon Project's survey, related to the original plan.

Figure 59: tridimensional model of the Difital Pantheon Project's survey, related to the original plan.



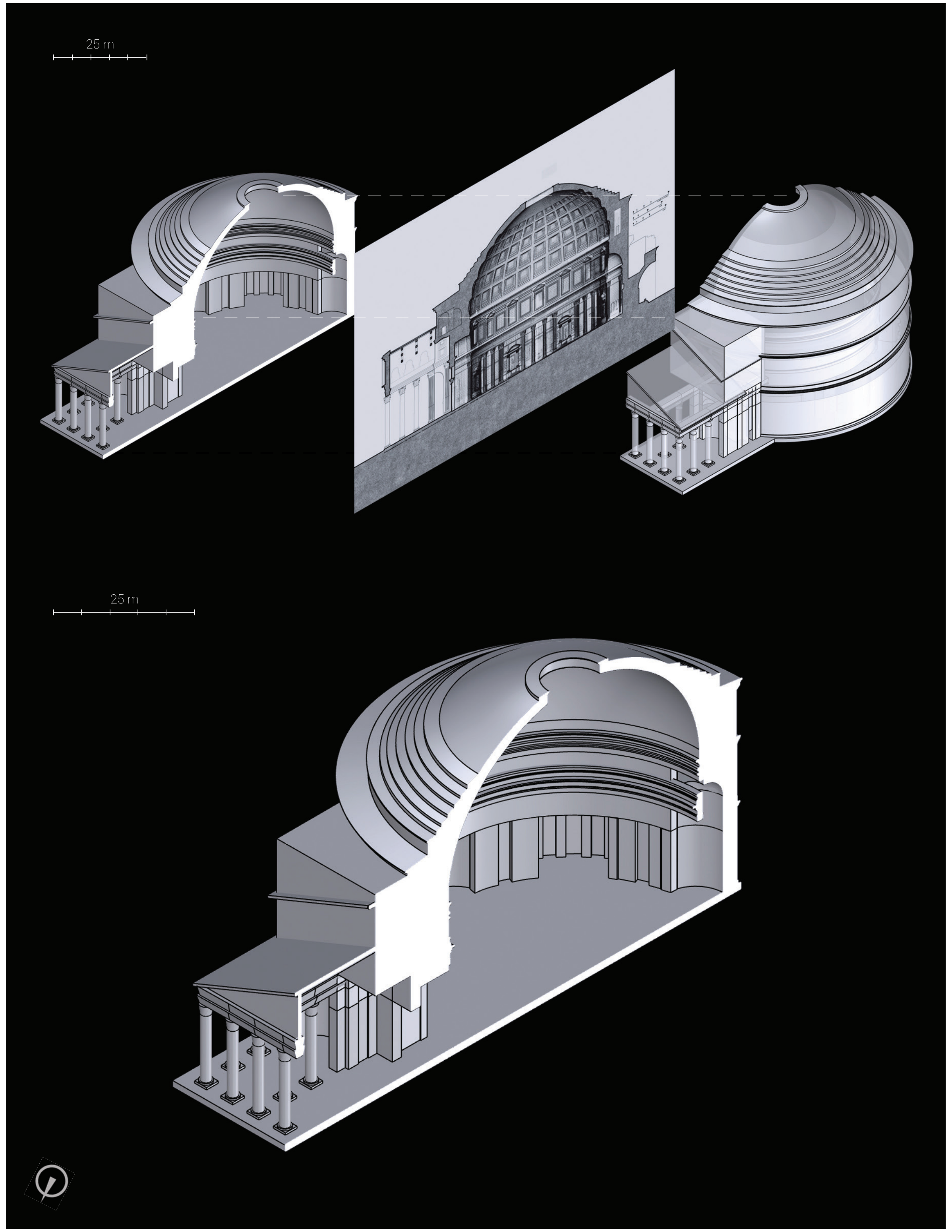
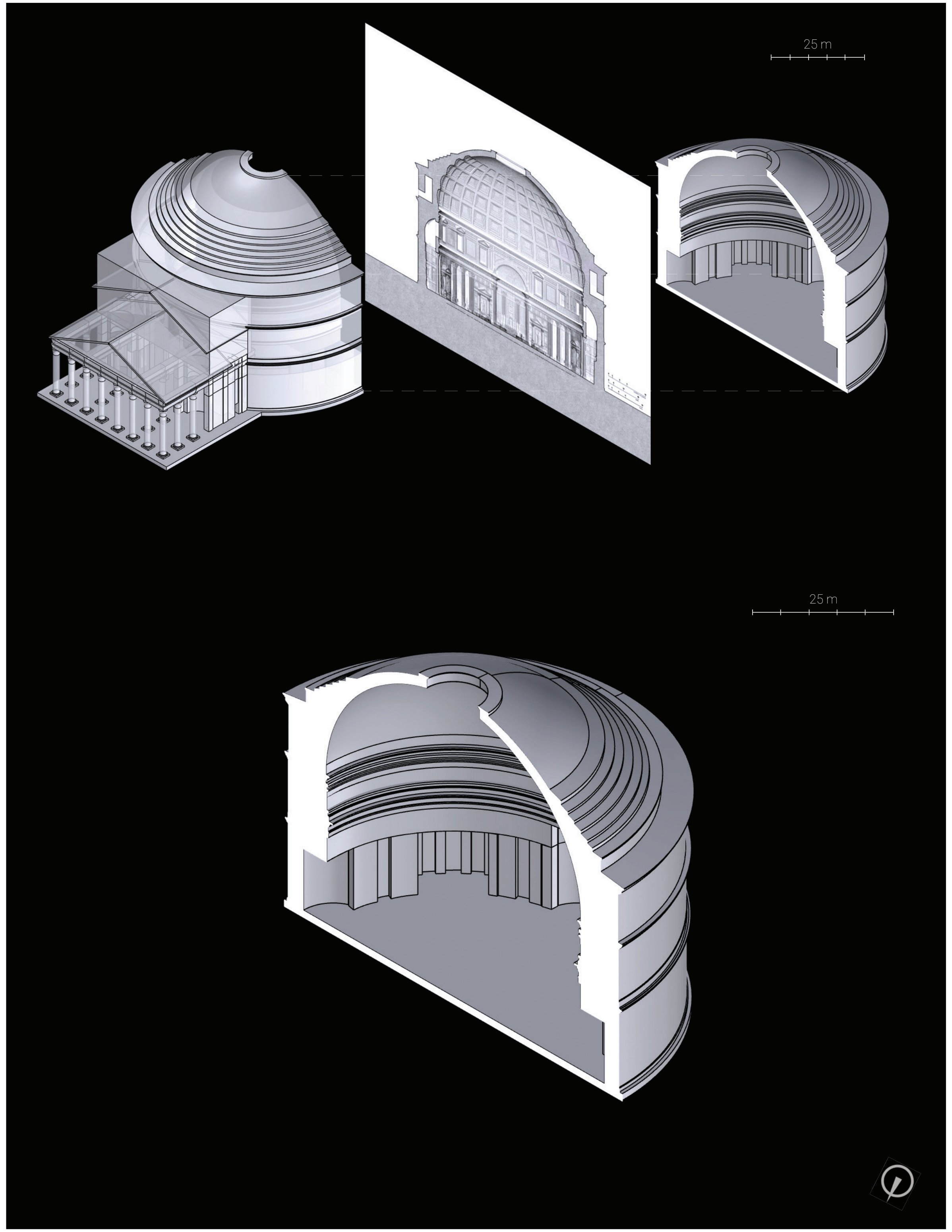


Figure 60: tridimensional model of the Difital Pantheon Project's survey, related to the longitudinal section.

Figure 61: tridimensional model of the Difital Pantheon Project's survey, related to the trasversal section.



4.3 Direct comparison

In the previous chapter, the digital redesign phase, carried out on the elaborations obtained from the selected sources, led to a process of theoretical comparison of the contents and representations of each survey.

Gradually this process progressed and evolved into the phase of creation of a three-dimensional model for each of the funds, the construction of the volumes and spatiality that each elaboration represents inevitably led to an indirect comparison of the three-dimensional results obtained for each survey.

However, it was precisely the creation of these models that made it possible to implement these comparison phases at a practical level and consequently to extrapolate a series of useful representations to report the differences found in the developments of the initial resources. This type of comparison and the methodology of the previous processes made it possible to go beyond the differences of a technical and historical nature that inevitably condition each individual survey.

In particular, the geometry and proportions defining the internal space are a point of particular interest in this phase of comparison. The task carried out in the development of each three-dimensional model was to try to minimise the error linked to the digital transposition of the graphic works, in order to obtain as truthful a result as possible. However, inevitably, due to the complexity of the monument and the slight inaccuracy of the graphic digitisation of the historical sources, some elements of the models are not representative of the constructional state of the monument. But for volumetric, proportional and dimensional comparative purposes, the resources obtained are certainly propaedeutic to such use and in making it graphically immediate.

For the visual immediacy of the volumetric differences of the models obtained, the three-dimensional correspondents of the fundamental technical drawings that make up the surveys, i.e. plans and longitudinal sections, are represented for comparison, but always in relation to the three-dimensional counterpart that generates them and to which they are inextricably linked.

What emerges gives an idea of the different perceptions of space, of the different level of detail according to the areas of interest, which each surveyor has intentionally or unintentionally transposed onto the paperwork that constitutes the survey.

Moreover, the differences tend to be accentuated in the way in which the individual surveyors accessed the various parts of the architecture, in particular the areas that make up the base of the dome and the order of decorations immediately below.

4.3.1 Comparison through plan

The four three-dimensional models are initially compared by means of a planar section. Uniforming the floor height, the models were sectioned at the same height to analyse the differences at a given height.

To allow a simultaneous comparison of all four models, each one was divided into sectors according to the longitudinal and transversal section lines intersecting the centre of the oculus.

In the second image, the geometries above the cut-off level are also replaced, again in order to maintain the relationship between the two-dimensional part and its three-dimensional counterpart.

We can immediately see that the greatest differences are to be found in the way the basement layer on which the architecture rests is represented, which for some surveyors is fundamental to the monument's dialogue with its past (in fact, under the current building are the remains of the previous Pantheon, as illustrated in chapter 2) and with the rest of the city, while for others it is a negligible element whose only function is to frame the volume above it.

Other less marked differences can be found in the level of detail in the definition of the walls and in the general proportions between the minor decorative elements.

However, since the plans were analyzed at a height easily accessible in all periods in which the surveys were carried out, regardless of the methodologies and techniques applied for the surveys, the differences are less marked than in other parts of the monument, which are more difficult to reach and therefore surveyable.

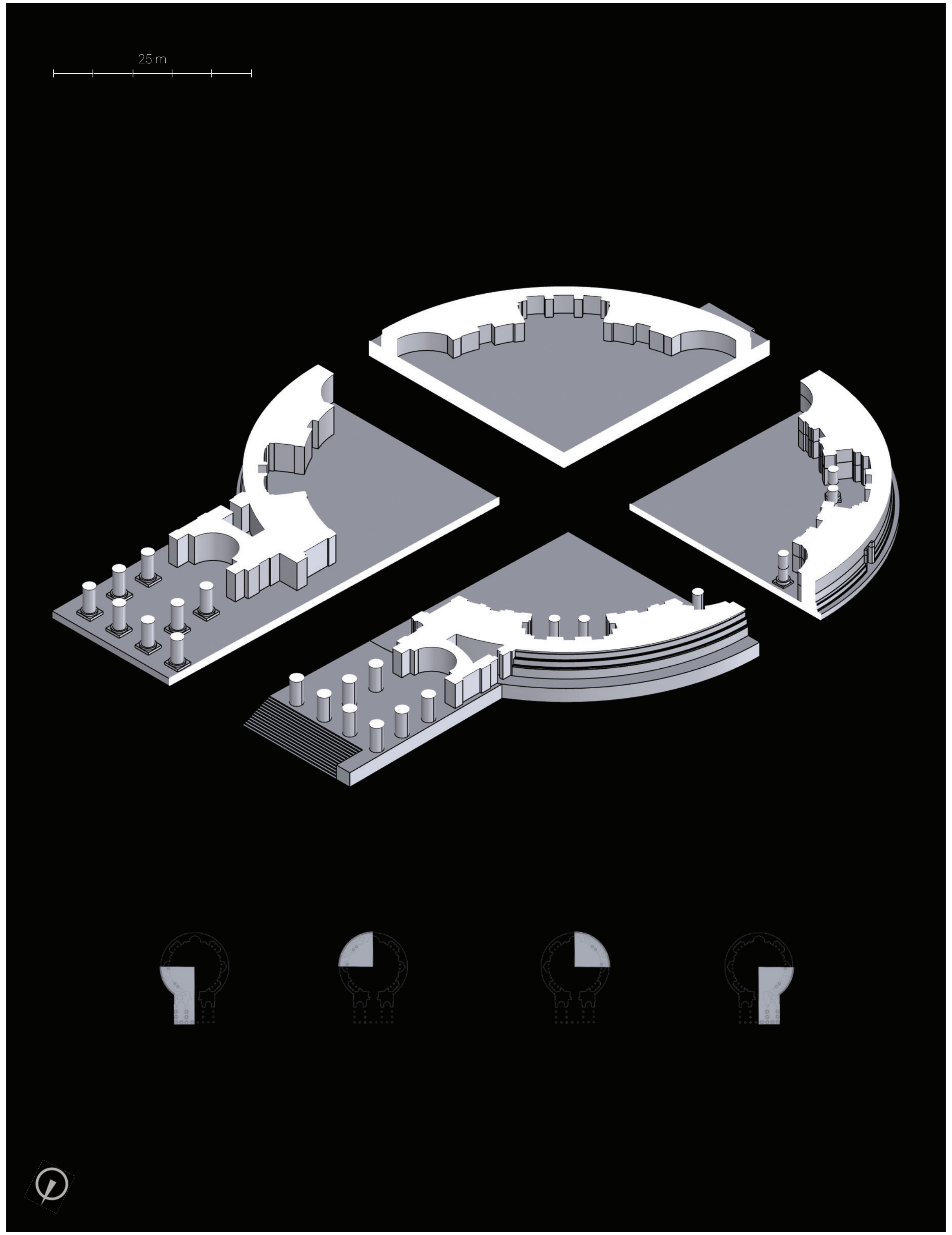
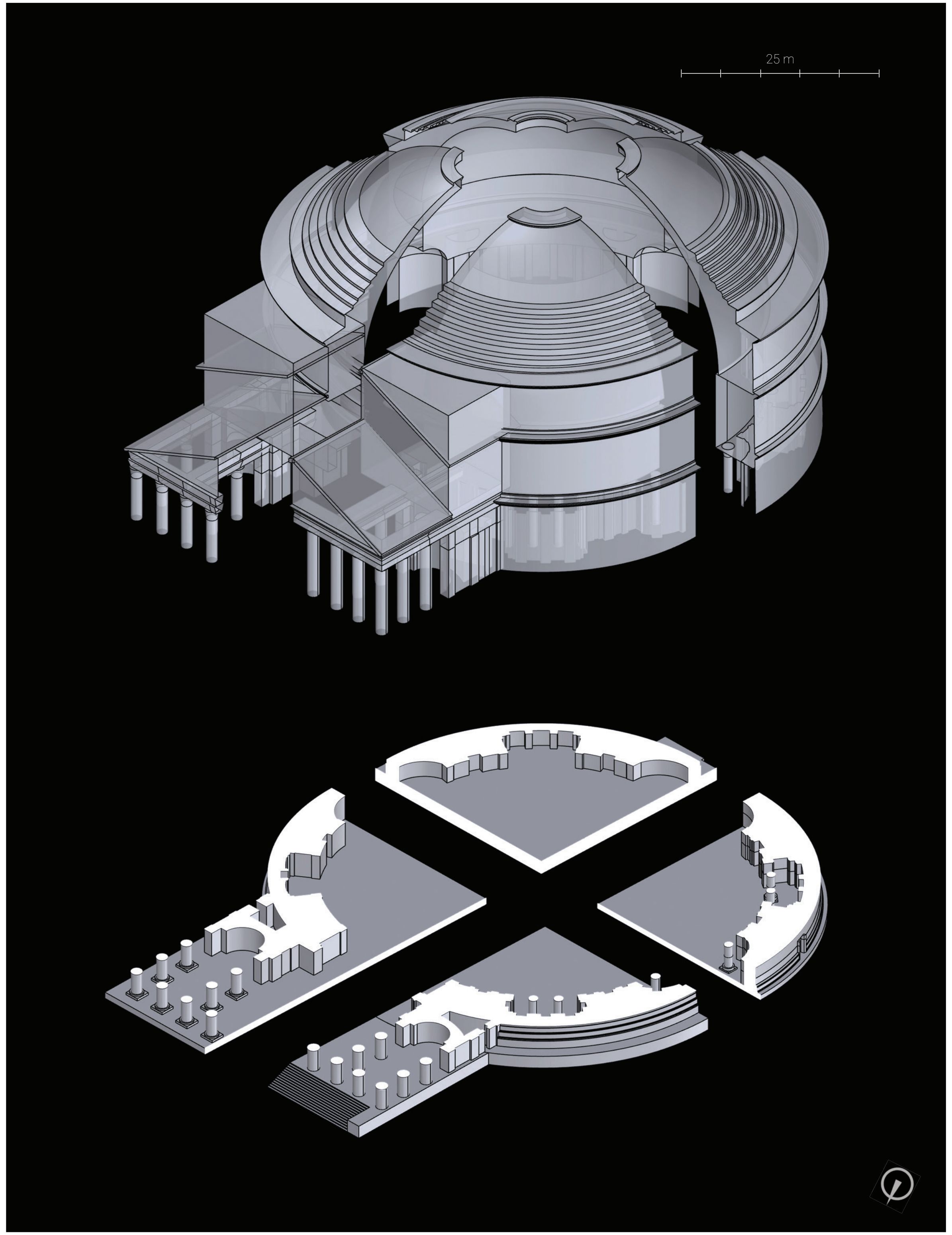


Figure 62: direct comparison of the plans, through the four three-dimensional models, obtained by the longitudinal and trasversal axis.

Figure 63: direct comparison of the plans, through the four three-dimensional models, related to each corresponding volume.



4.3.2 Comparison through sections

The second level of comparison is based on a direct comparison of sections, both longitudinal and transversal. The alignment of the two section planes when overlapped coincides with the division into sectors used for comparison through the plans. In the following pages we can therefore observe the sections carried out for all 4 models, ordered chronologically, subdivided by section orientation.

In addition, a further comparison by exploded view is given on the next page. Here the concept of the relationship between technical detail (in this case the sections) and its three-dimensional relationship with the model is reiterated.

The sections are made up of the same sectors identified in the comparison of the plans, but they develop completely in height and show the sectioned part. The element that ideally unites the individual elements is the central oculus, which acts as a common denominator and pivot for the realisation of this representation.

This comparison allows us to detect more substantial and macroscopic differences, such as the different curvature of the dome, or the geometric composition of the secondary niches compared to the level of decoration immediately above.

These differences allow us to observe how the difficulty in surveying a monument such as the Pantheon may lie in the understanding of its complex geometries, the relationships between the various macro elements that make up the structure and all those so-called "hidden" parts from a limited, although scrupulous, survey campaign.

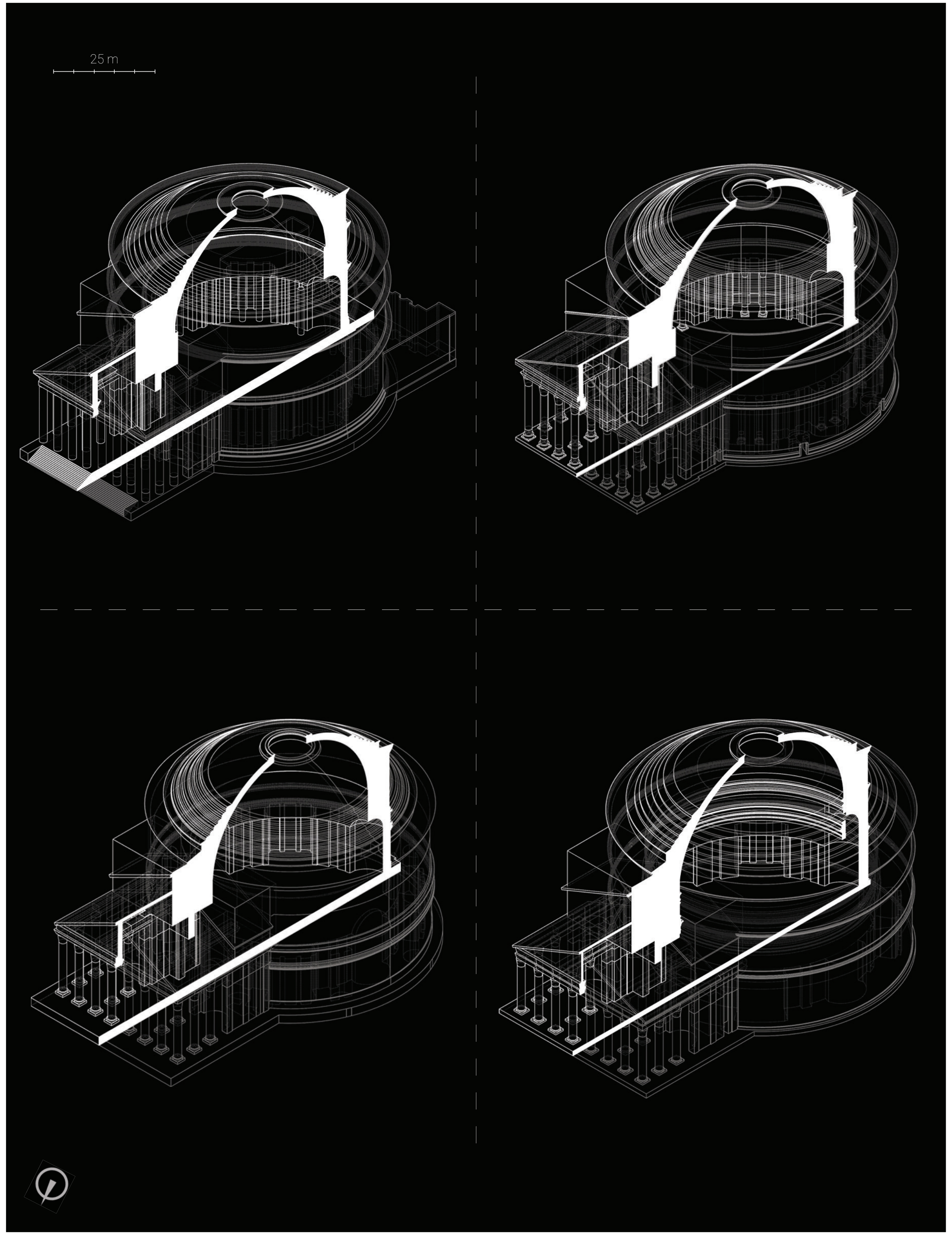
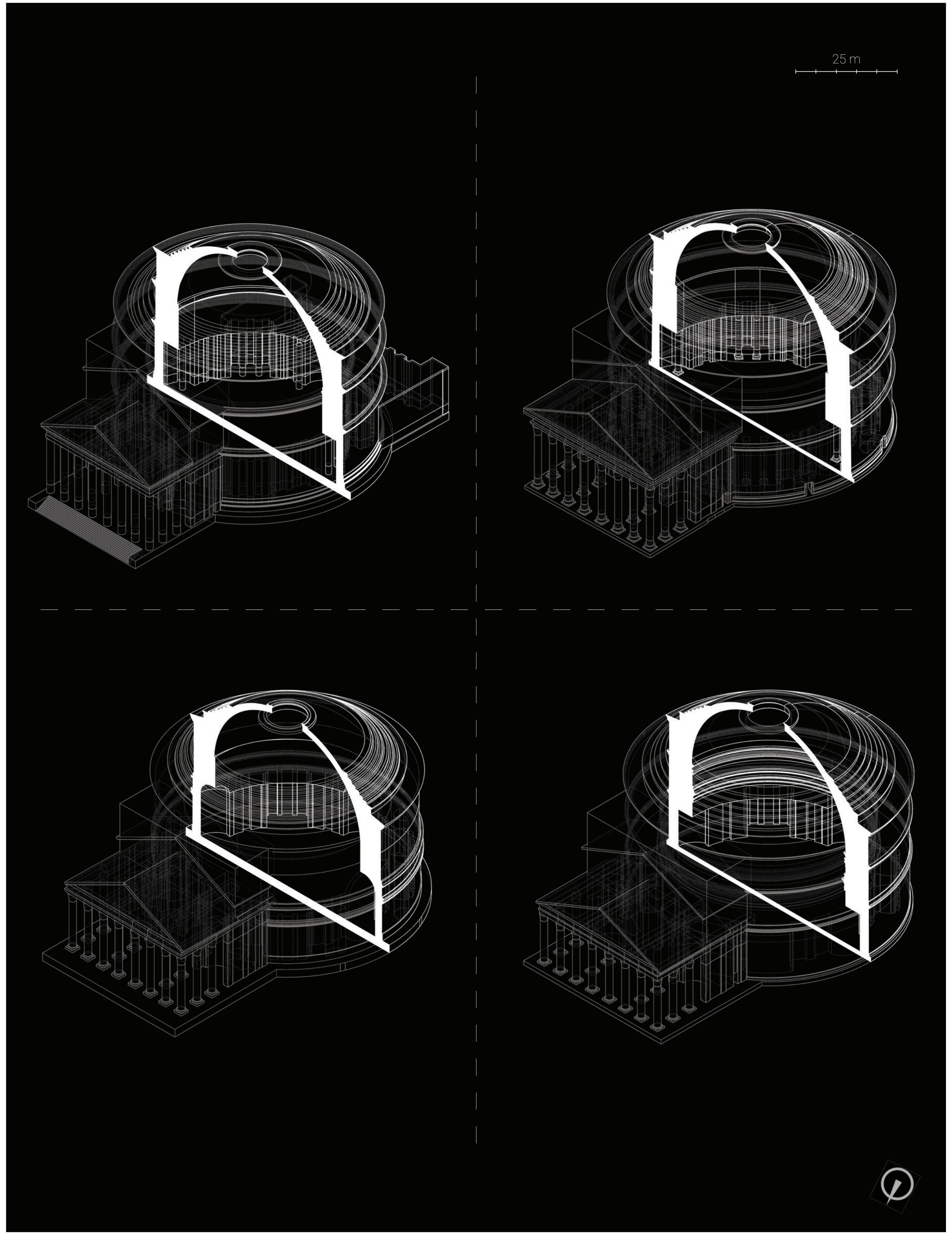


Figure 64: direct comparison of the longitudinal sections, through the four three-dimensional models.

Figure 65: direct comparison of the trasversal sections, through the four three-dimensional models.



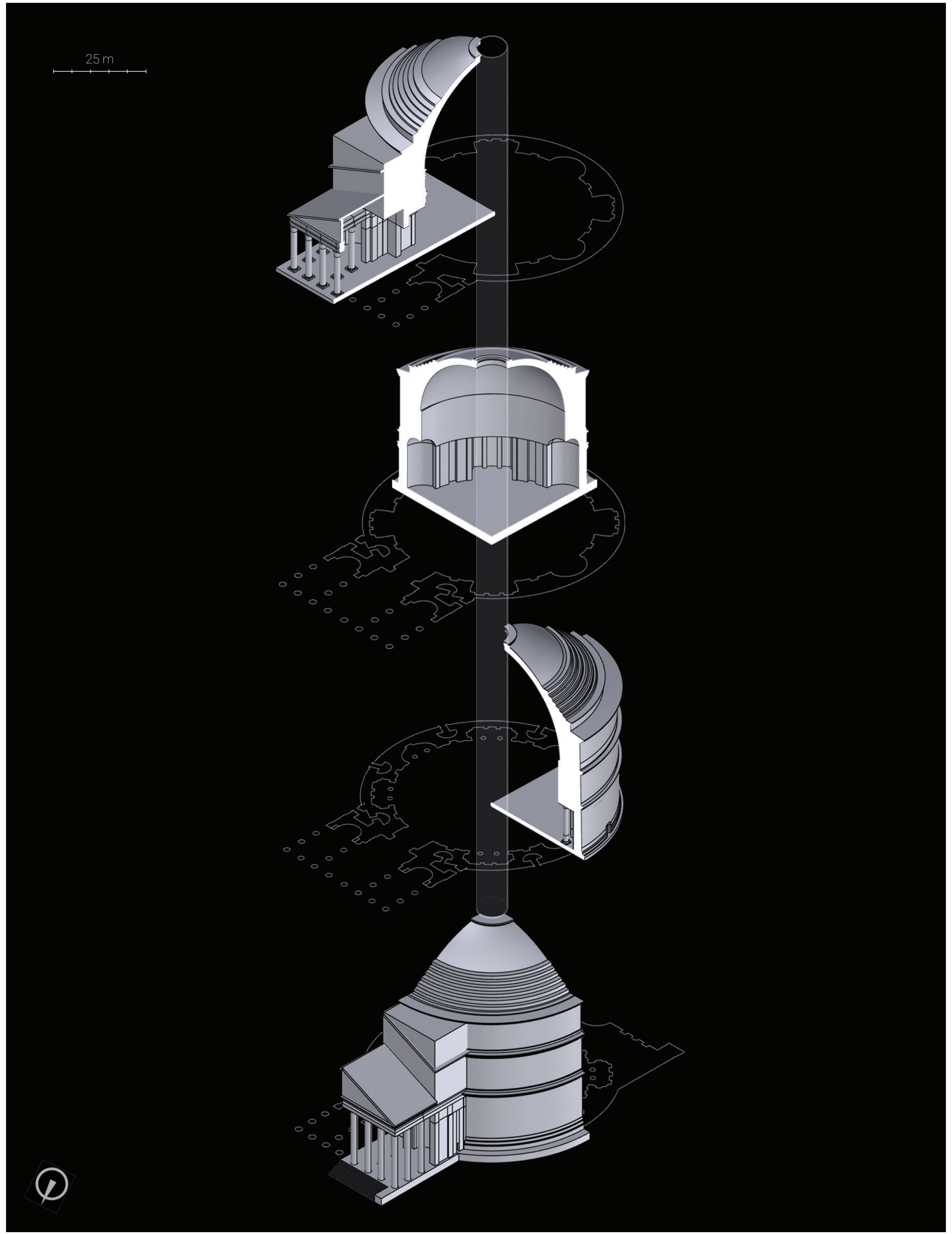
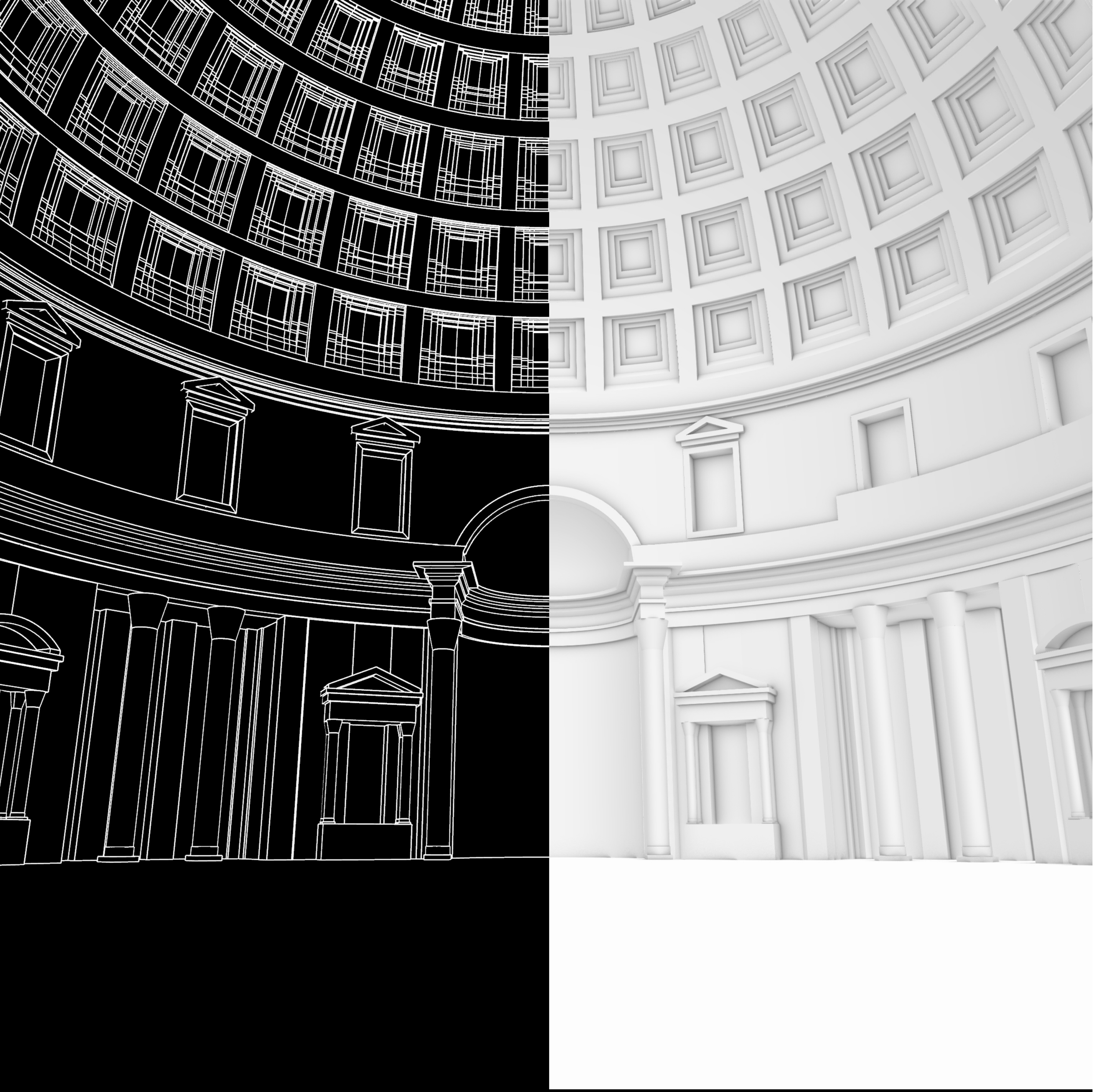


Figure 66: exploded direct comparison of the four sectors, obtained by the two main axis, realated to their origianl plans



5.META-REPRESENTATION

5.1 Representation applied to the restitution of complex architectures.

Up to this point, the analysis carried out and the consequent representations of the Pantheon are based on classical representational forms of architecture, especially in the analysis of monuments of major historical importance. Elements such as plans, sections and axonometric views are legacies of an analytical and representative method that is at the basis of architecture and consequently of its representation.

The analysis of the historical surveys of the Pantheon shows how the uniformity of the drawings, as a result of the survey campaigns, has allowed an analytical and volumetric comparison of the monument through the centuries in which it has been represented, despite the fact that the techniques and interpretations of the surveys inevitably present differences.

However, paying particular attention to the most recent survey source, carried out with 3D digital scan techniques, infinite possibilities in representing the information gathered open up. In fact, in terms of the accurancy and immediacy of the data collected, this technology has no comparison with the others historical surveys examined.

Just as surveying techniques have adapted and evolved, especially in the analysis of complex architectural artefacts of historical importance such as the Pantheon, the methods of representing and communicating the data collected must be adapted to the technology of our time.

The process that began with the analysis of the four surveys examined, the subsequent digitalisation of the graphic components that constitute them, and finally the modelling of the corresponding three-dimensional volumes, led to the creation of a model that best represents the monument in its complexity and in its current state.

The comparison phase of the previous chapter has also allowed the complete understanding of each element that composes the architecture and consequently, the way of how each surveys analize the relationship between them.

The final model, used for the representations obtained in this chapter, is mainly based on the survey carried out during the Bern Digital Pantheon project by Professors Gerd Graßhoff, Michael Heinzelmann and Markus Wäfler of the University of Bern.

This choice is due to the level of accuracy and reliability, which inevitably comes with a 3d digital scan survey. However, the limitation of this technology, i.e. the lack of data acquisition in areas not directly visible due to the working principle of the laser scanner, was overcome by integration with other survey sources taken into consideration.

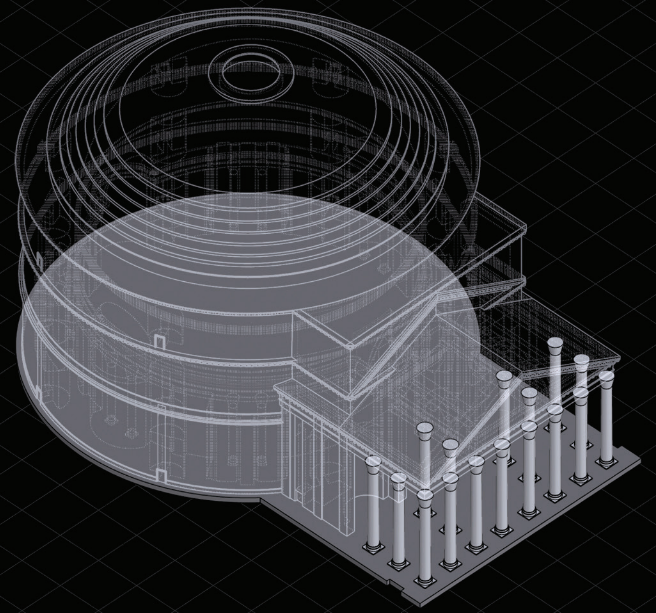
5.2 Decomposition of the geometrical and architectural elements

In this paragraph, a de-structurisation of the monument into its formal macro-components is given, which constitute this complex volumetric geometry that is the Pantheon.

This decomposition was fundamental in the modelling phase for the understanding of the dimensional relationships between the various parts and the presence of hidden volumes functional to the static nature of the structure. In the same way it can help the reader, even the least expert, to understand the complexity of the work, which in the following paragraphs will be examined in depth in its most important elements.

The main division on a structural, as well as compositional and geometric level, is dictated by the forepart and the rotunda. In spite of all the interventions throughout history that have transformed the main characters of these two macro elements, the spatial relationship between them has made the monument famous [1]. As complex elements, the perception of them and the volumetric and spatial relationship they generate varies according to the point of observation. If we consider the external volumes, the two elements stand out clearly and almost vainly interrupt each other's harmony. At the level of the plan and therefore the interior space, the forepart, with its wide and imposing colonnade, creates an architectural and spiritual filter between the sacredness of the inner space of the rotunda and the outside world.

The subsequent decomposition not only makes the volumetric relationships of the monument more visible to us, but their functioning in terms of hidden spaces, ancillary to the structure supporting the enormous dome or merely decorative: this make the sensation of crossing the interior space unique.



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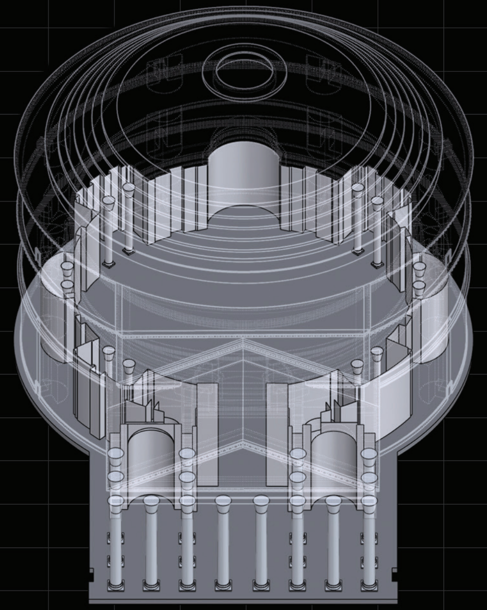

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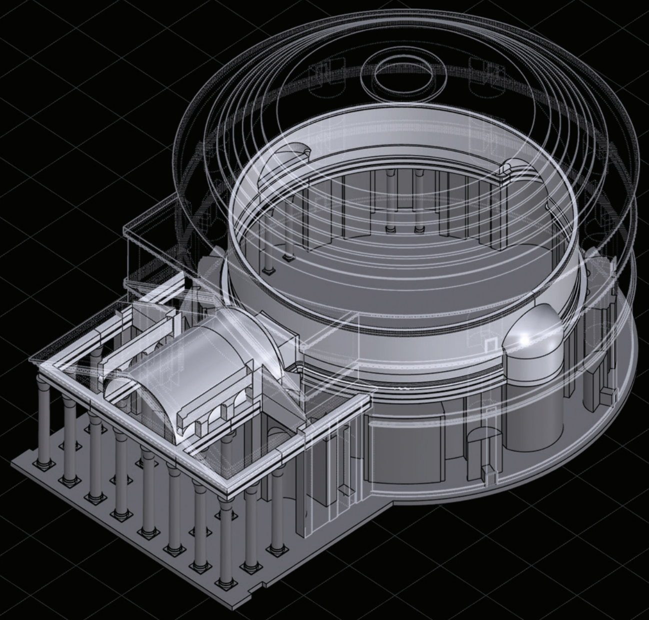

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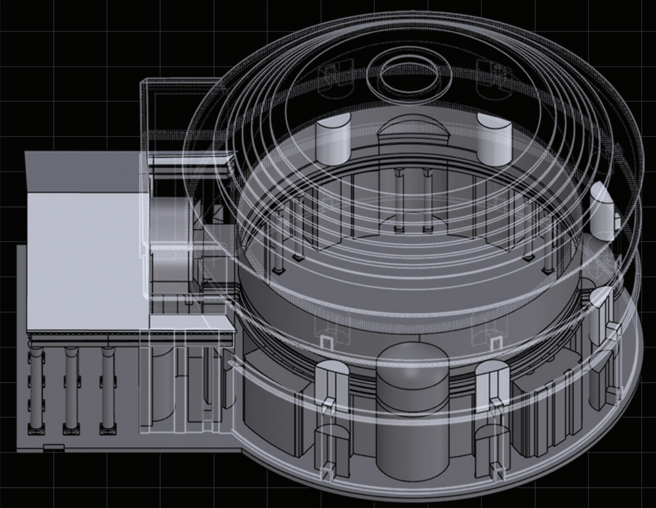

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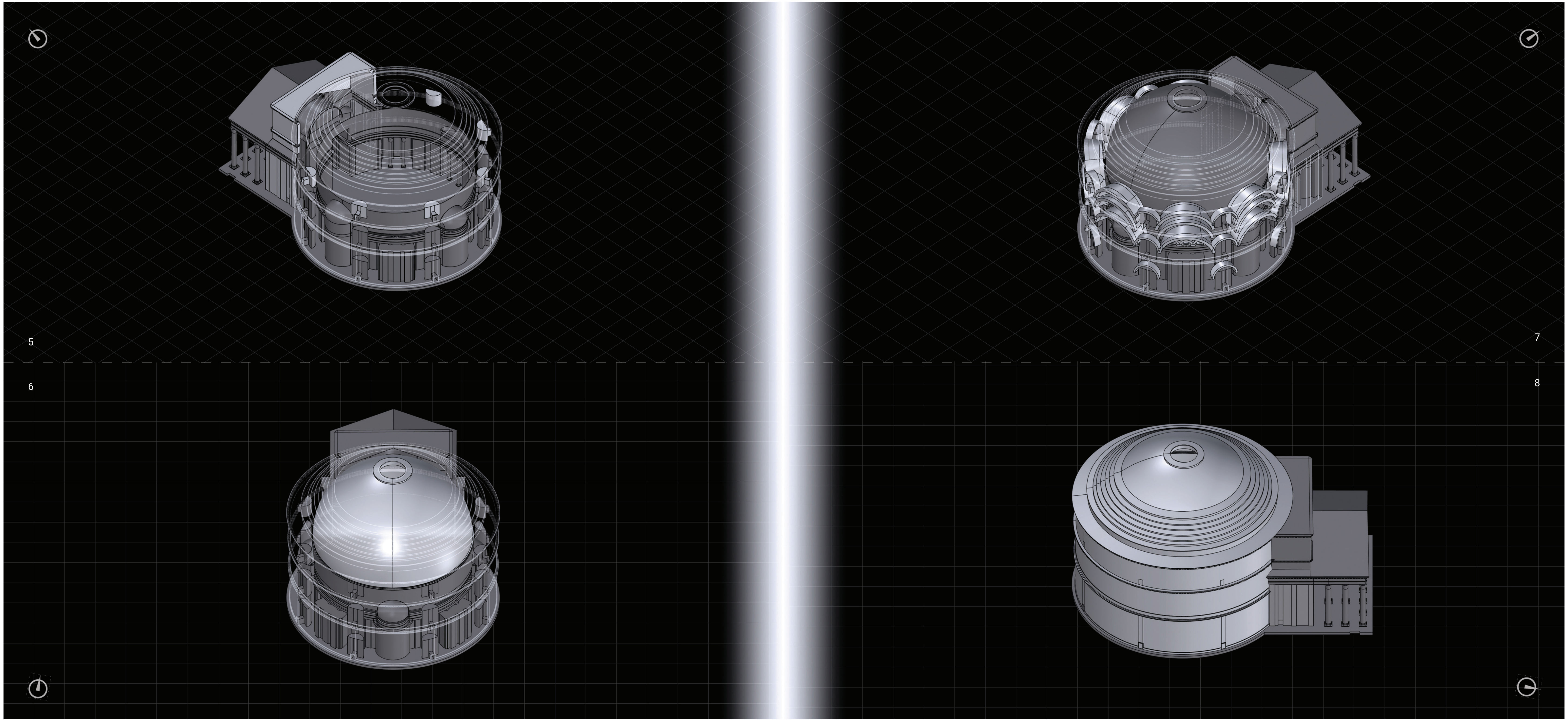
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5.3 Disassembly of the structural elements that compose the hidden geometry.

The masonry portion of the structure has an important thickness that varies along the perimeter due to the presence of niches in the interior space, which considerably reduce the thickness of the supporting masonry. This is made possible by the presence of several orders of arches within the masonry package, which vary in size and function.

As we can see in the exploded view presented in the following pages, opening the wall from the outside, we find first of all an order of 7 brick arches that support the weight above the niches and the apses and unload it in the thickest points of the bearing wall. At the same time, a tripartite system of blocks and arches at the base of the main arches contributes to the distribution of the weight lost on the entablature, which creates the empty space of the apses and niches [2].

Going up along the height of the supporting wall we find a second order of masonry arches, perfectly aligned with the one below. Placed directly under the weight of the heavy roof, each structural discharge point consists of two overlapping arches.

And finally, in the cavities that alternate between the main structural elements, we find three orders of smaller arches, called drainage arches, which contribute to the uniform distribution of the structural load and allow the creation of niches within the masonry for the lightening of the masonry block.

On the last two pages we can see a closer schematic of the structural system inside the masonry and how it works in distributing the structural load at precise points shown on the facing page.

Figure 67: radial exploded view, scomposition of outer shell and cover.

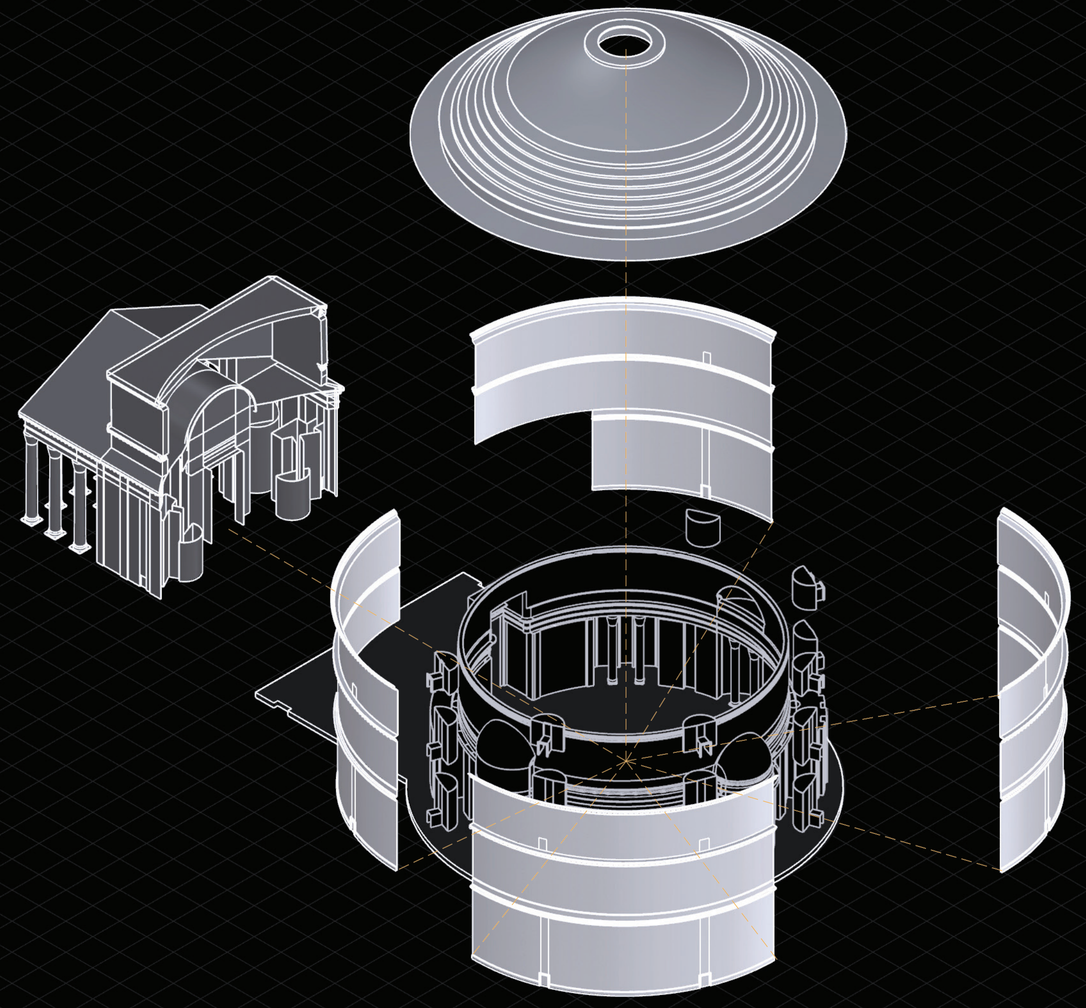


Figure 68: radial exploded view, support arches of the internal niches and their supporting relieving arches.

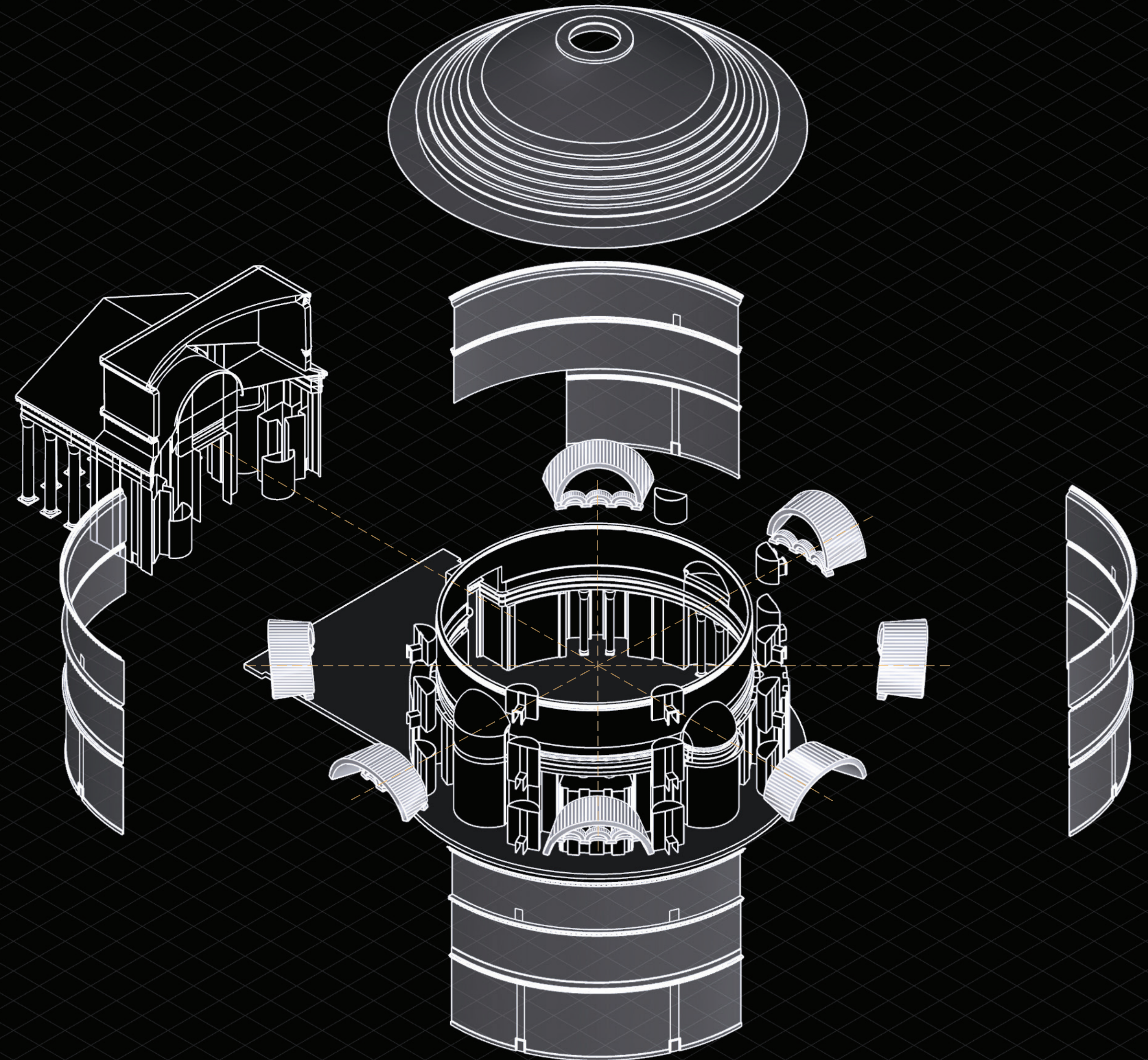


Figure 69: radial exploded view, structural arches supporting the covering.

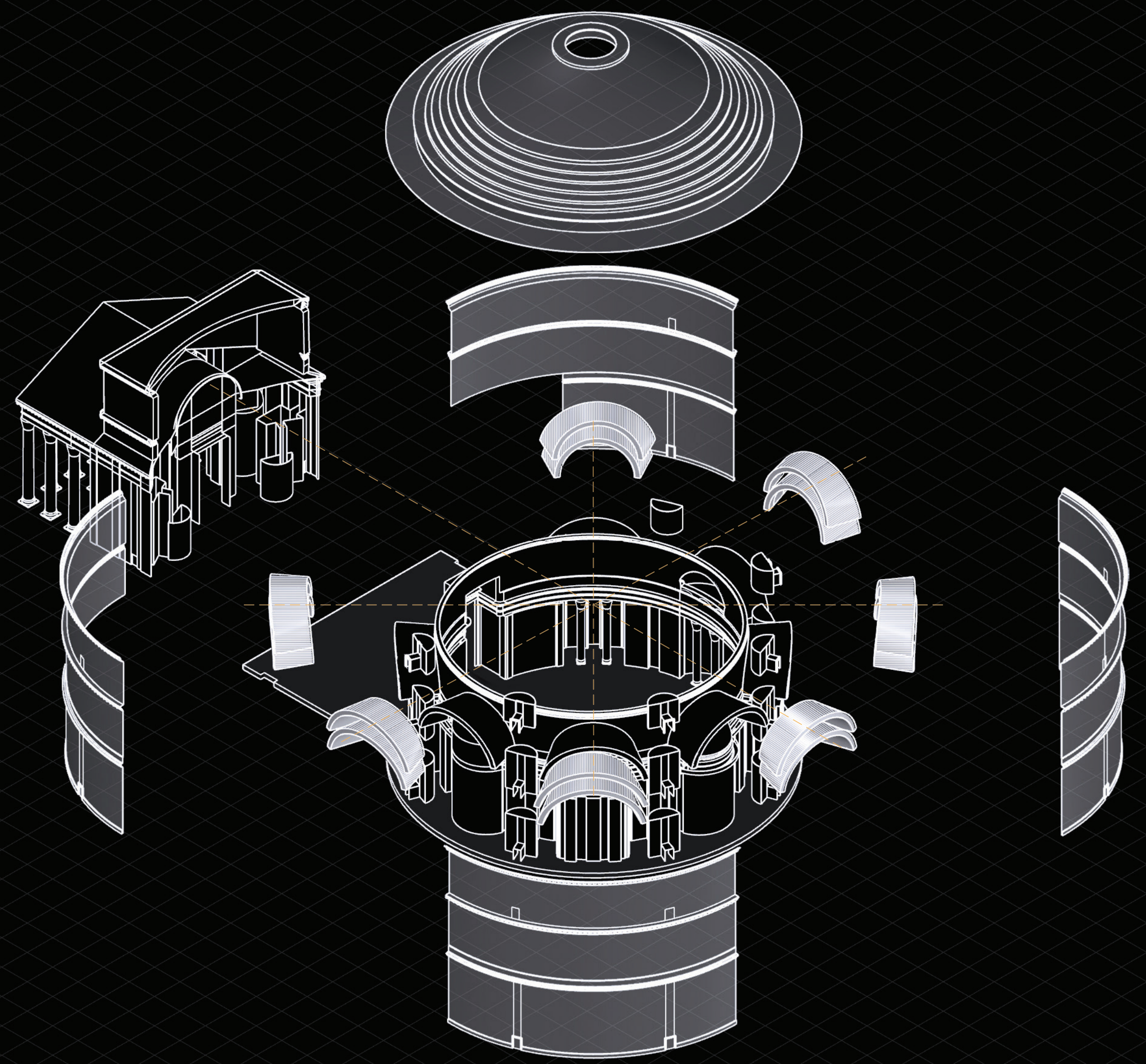


Figure 70: radial exploded view, secondary system of relieving arches.

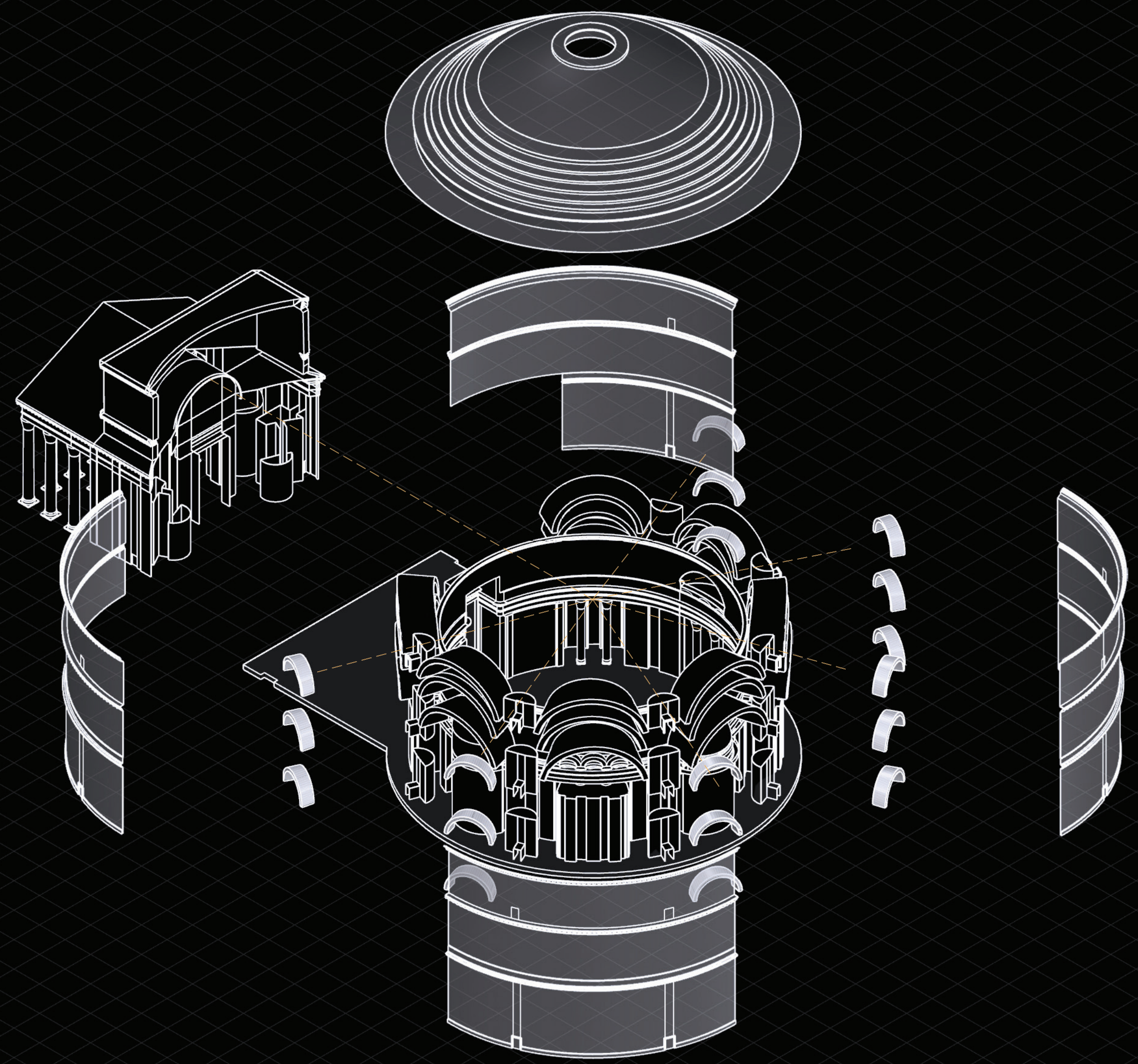


Figure 71: representation of the connection system of arches inside the masonry.

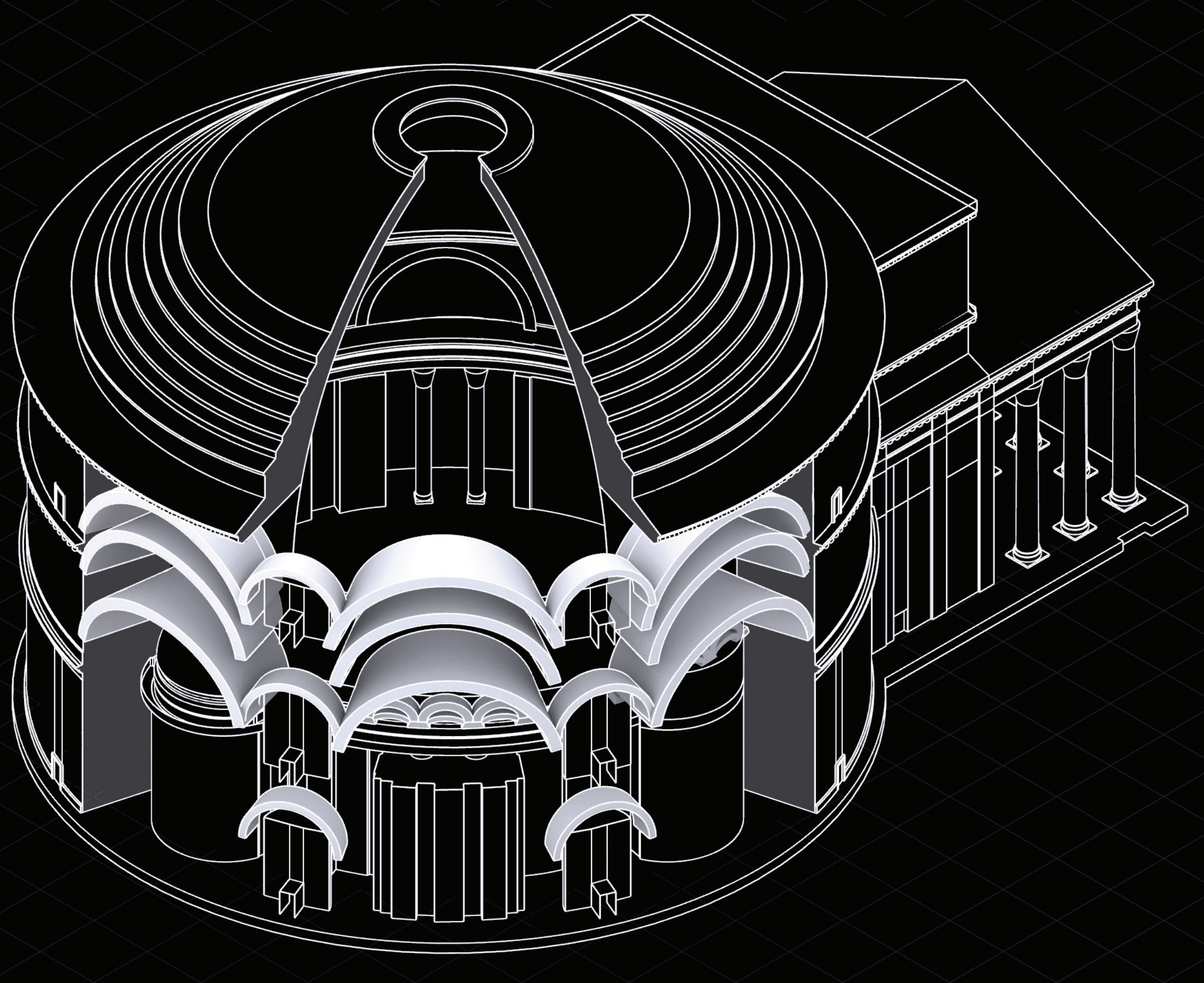
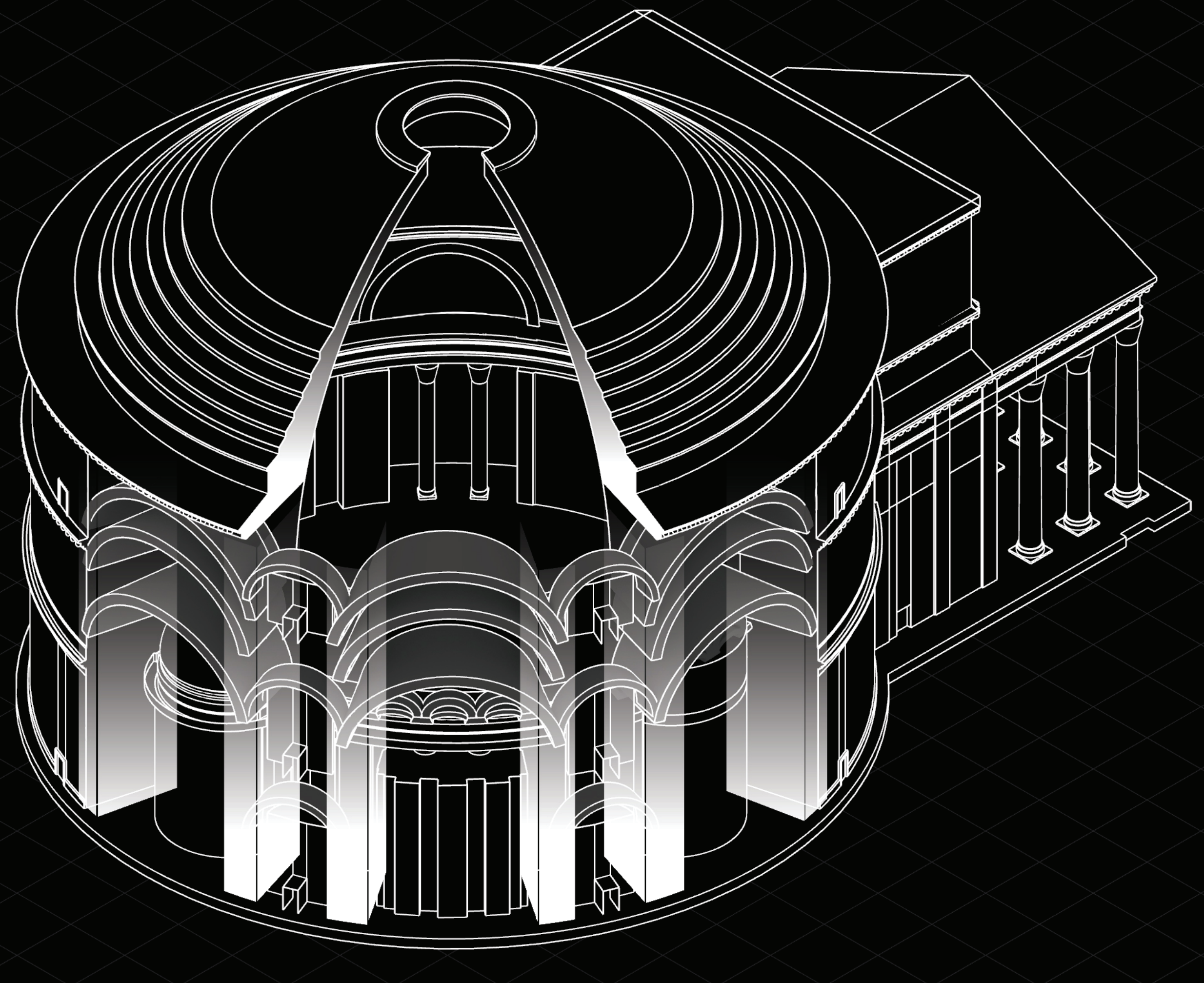


Figure 72: representation of the distribution of the structural load of the roof, inside the masonry.



5.4 Geometric composition of the dome's coffered ceiling.

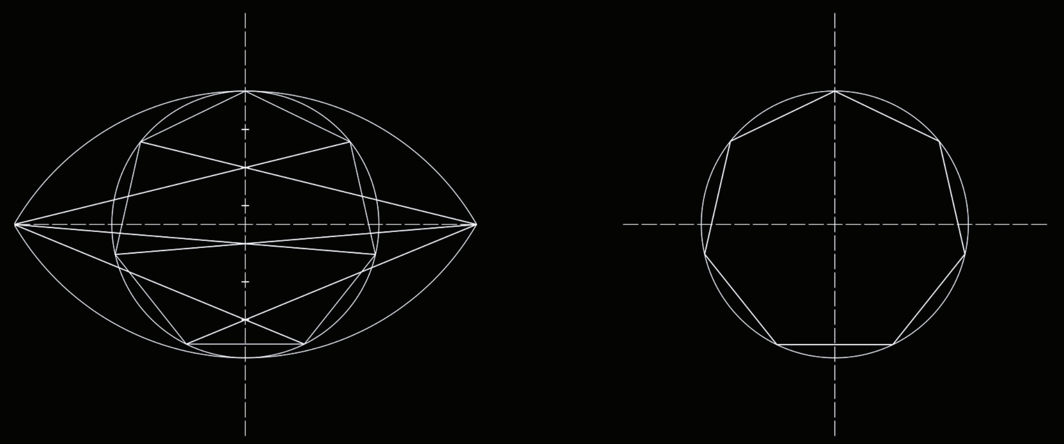
The coffered ceiling of the Pantheon's dome is one of the elements that makes this architecture unique. Although it has a purely decorative function, this element contributes to making the interior space solemn but at the same time concrete and tangible. The regularity of the roof from all points of view accentuates the uniformity of the space, defined in plan and emphasised in elevation [3].

In this section we will analyse the basic geometric composition, which creates the coffered pattern, and their subsequent three-dimensional development.

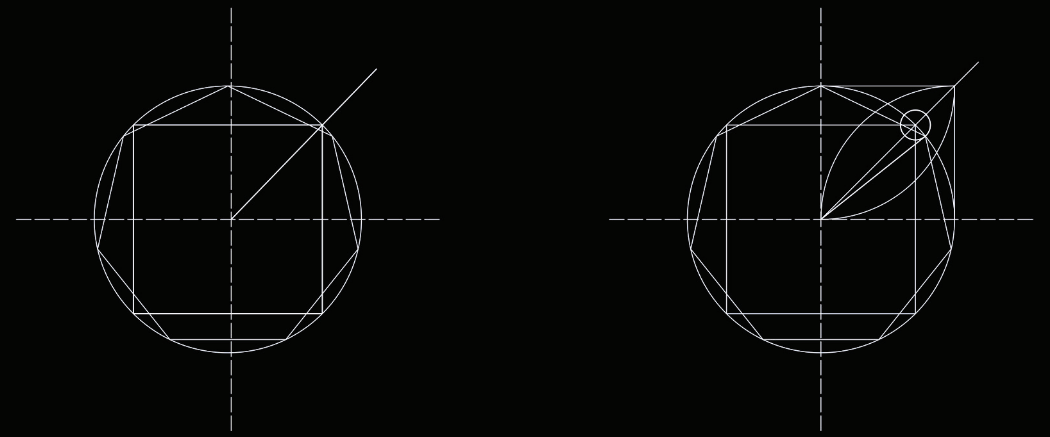
The division by 7 is somewhat unusual in the Roman world, but it was quite familiar in the Pythagorean milieu, and was not without a certain esoteric character. The cylindrical drum level follows these proportions and Roman symmetries; even the oculus measurement (1/5 of the dome diameter) fits in the Roman world. The five coffer courses also fit into this series. Only the partition into twenty-eight segments of the equator is out of the norm and uses number 7, while placing it in agreement with the 8: a curious combination [4].

On the following pages, the constructional hypotheses at the geometric and compositional level to arrive at the creation of the coffered dome, used to achieve this objective in the three-dimensional model, are shown. This has also made it possible to obtain various representations with the aim of rendering the perspective and geometric functioning of this particular instrument immediate, being decorative but alters the observer's perception of space.

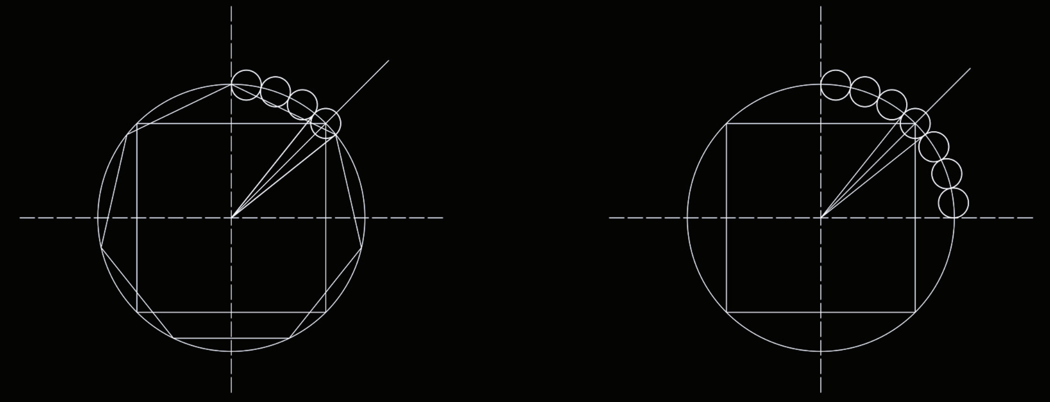
1 - geometric construction of the heptagon inscribed in a circle of the diameter of the dome.



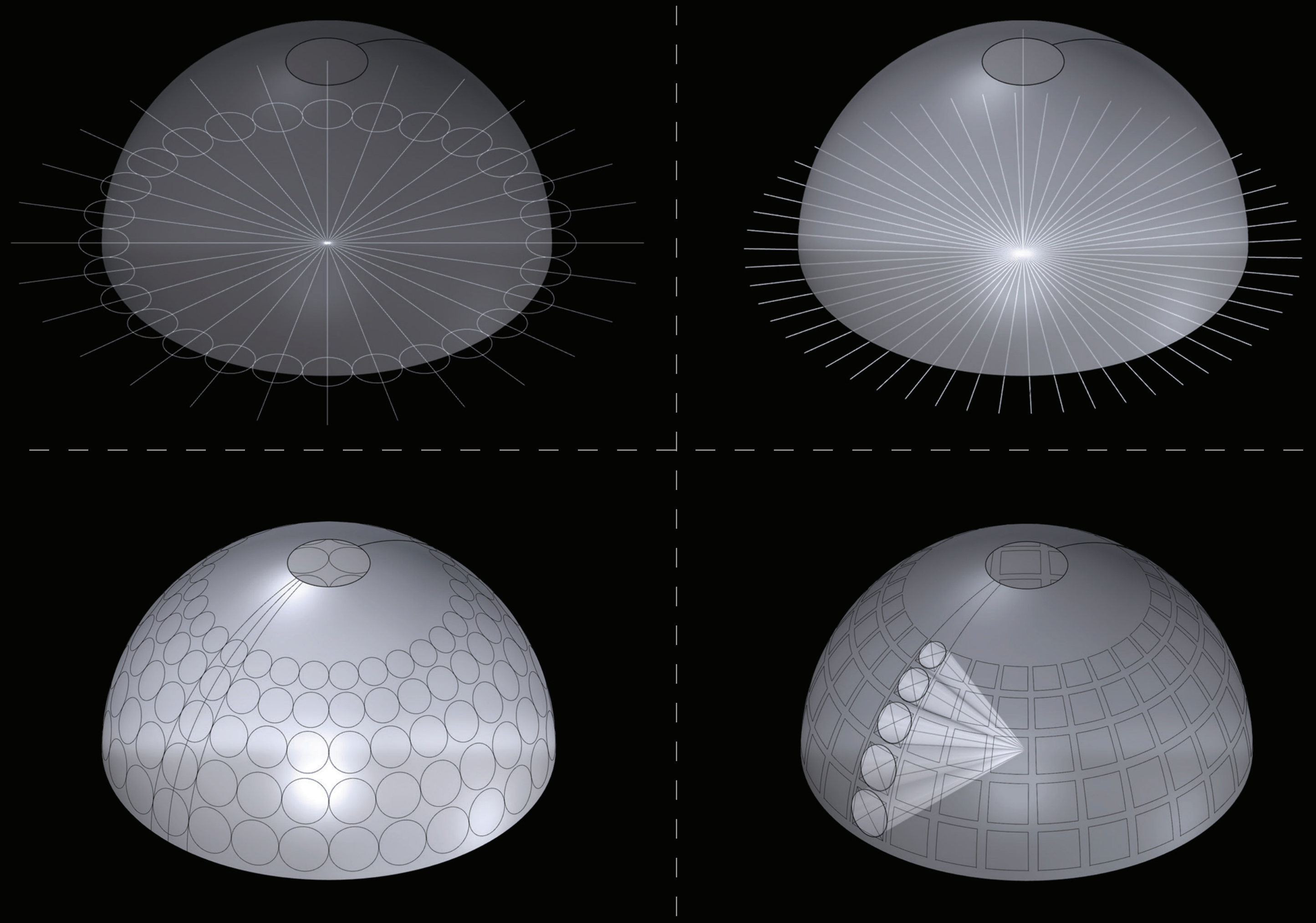
2 - corresponding 4-sided polygon inscribed in the same circle and corresponding first division of the sector.



3 - complete partitioning of the circumference sector into 7 parts, resulting in an order of 28 coffers for the entire circumference

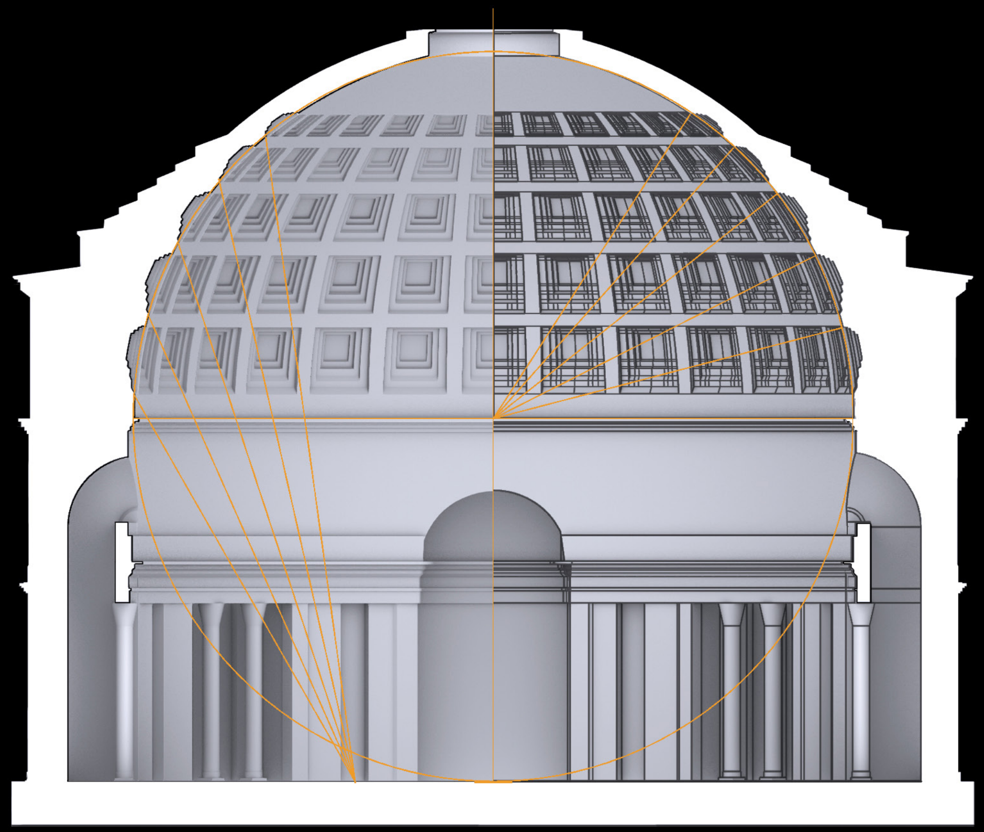


The division into 28 sectors of the circumference at the base of the dome, obtained previously, is carried over to the three-dimensional development of the hemisphere. Subsequently, by extending the points of tangency towards the vault of the dome, the development of the upper orders of coffers is obtained.



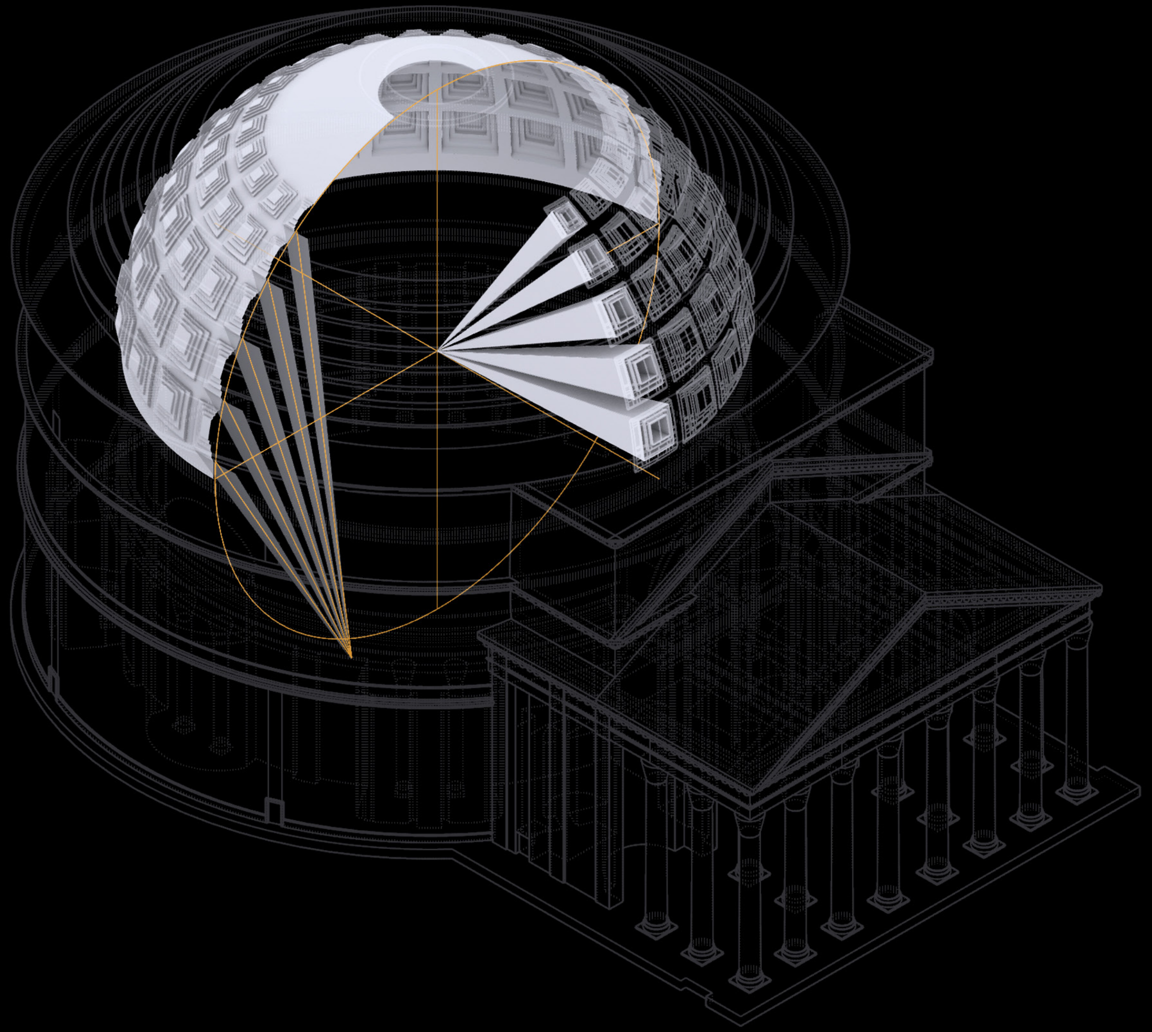
From the circumferences intersecting with the dome's vault we obtain the central points on which the external profiles of the coffers are built, which follow the distribution previously created, obtaining a regular pattern in terms of proportions and distribution. We can also observe how the extrusion of the limits that constitute the geometry converges towards the centre of the base of the dome, obtaining what can be defined as ghost geometry.

The development in depth of the coffers creates the fundamental expedient to obtain a sense of homogeneous perception of the internal ceiling. In the diagram shown here we can first of all identify the geometry of the dome and its perfect dimensional relationship with the part below described by a perfect circle. We can also observe how the internal extrusion of the coffers differs in how it develops in the lower or upper edges of each order of coffers.



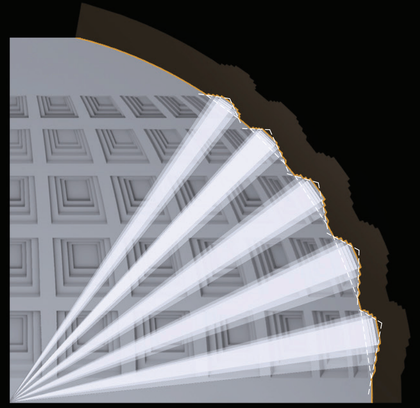
The upper edge of the coffers extrudes towards the interior of the dome, aligning with the centre of the circumference at the base of the dome, corresponding to half the total height of the interior.
The lower edge, on the other hand, follows a direct alignment towards the floor level of the interior, with varying precision, this alignment converging at the median point between the centre of the plan and the outer limit where the walls and niches are located.

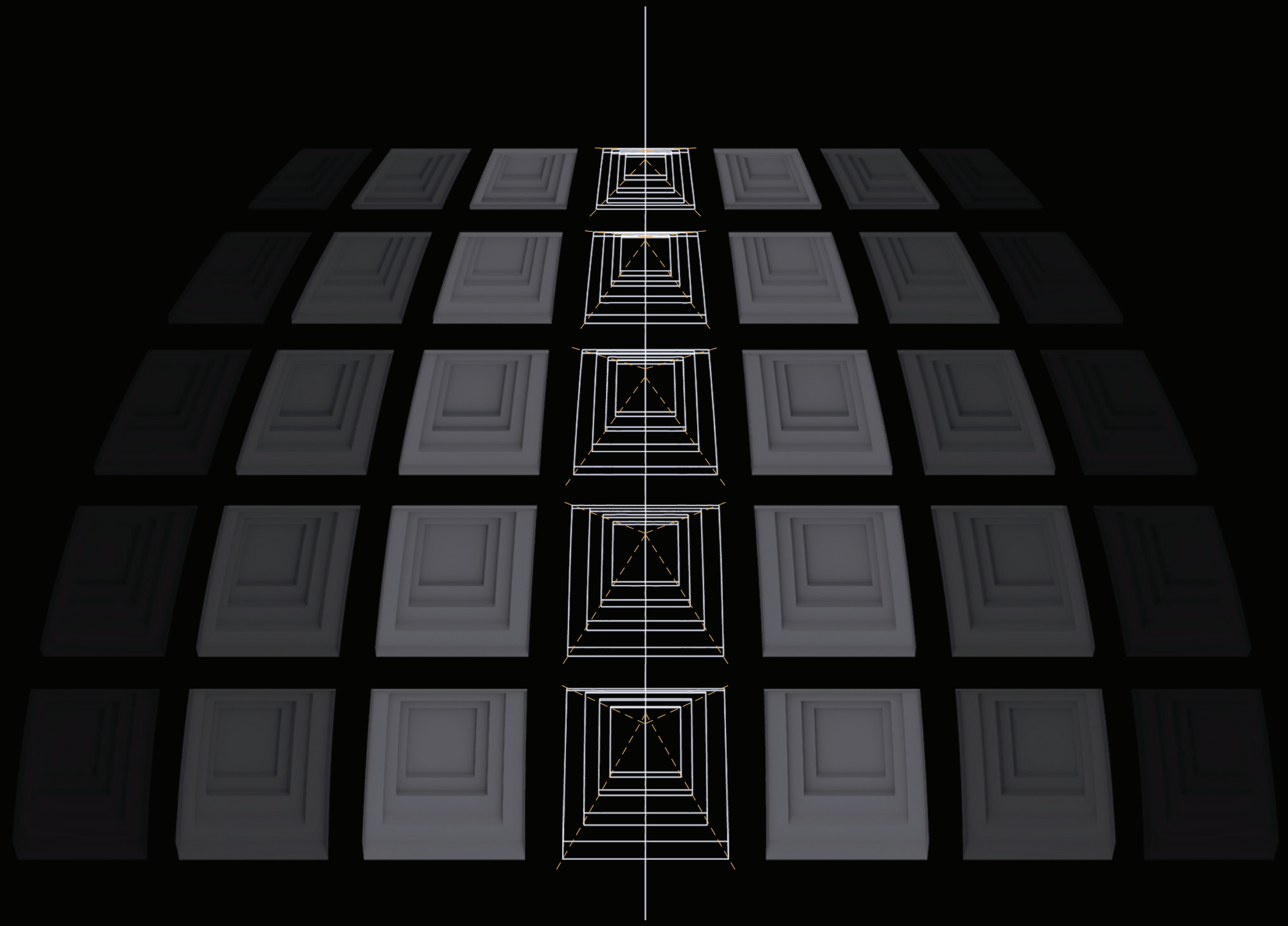
In an axonometric view we see how the geometric details contribute to the development of the architectural element in its totality and complexity. Moreover, here we can observe the ghost geometry of a vertical coffer sector with its consequent internal development.



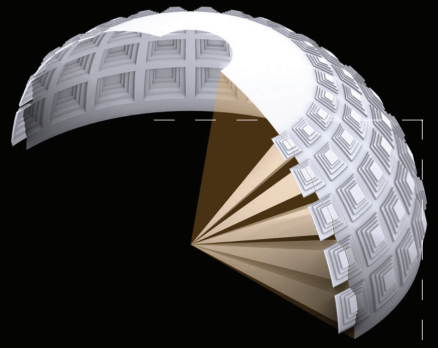
In detail, we can first observe the course of the section that cuts through an order of coffers and their direct connection with the centre of the base circle that forms the dome.

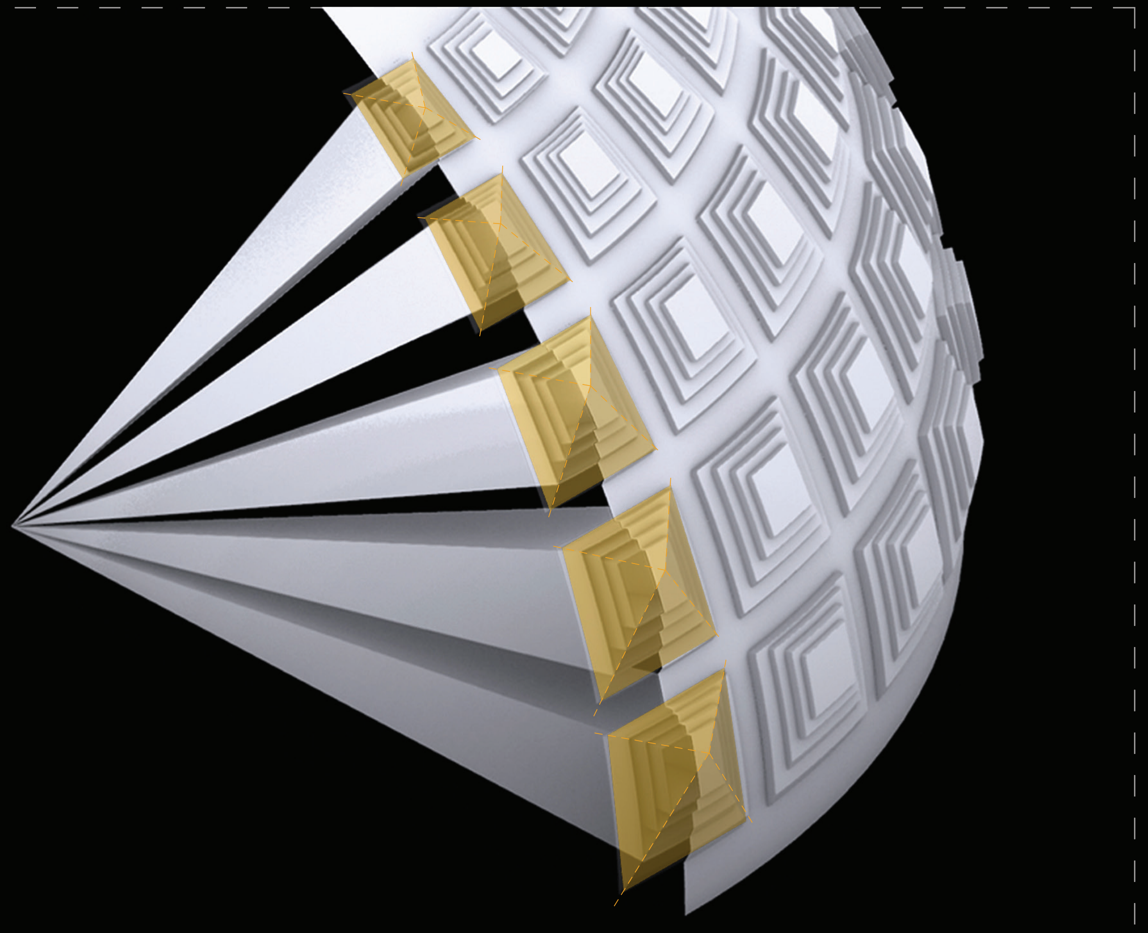
Furthermore, from a schematic view of one order of coffers, we can observe how the convergence of the lower and upper sides of the five coffers that make up one of the 28 sectors varies as the height varies, increasing the perspective effect of homogeneity.





Still in detail, but from an axonometric point of view, we have a direct observation of the alignment of the orders of internal coffers for each sector with the centre of the circumference that forms the base of the dome. We can note how the surfaces that make up the bottom of the innermost coffer tend to remain orthogonal with respect to the centre of the circumference and the cutting plane passing through it.





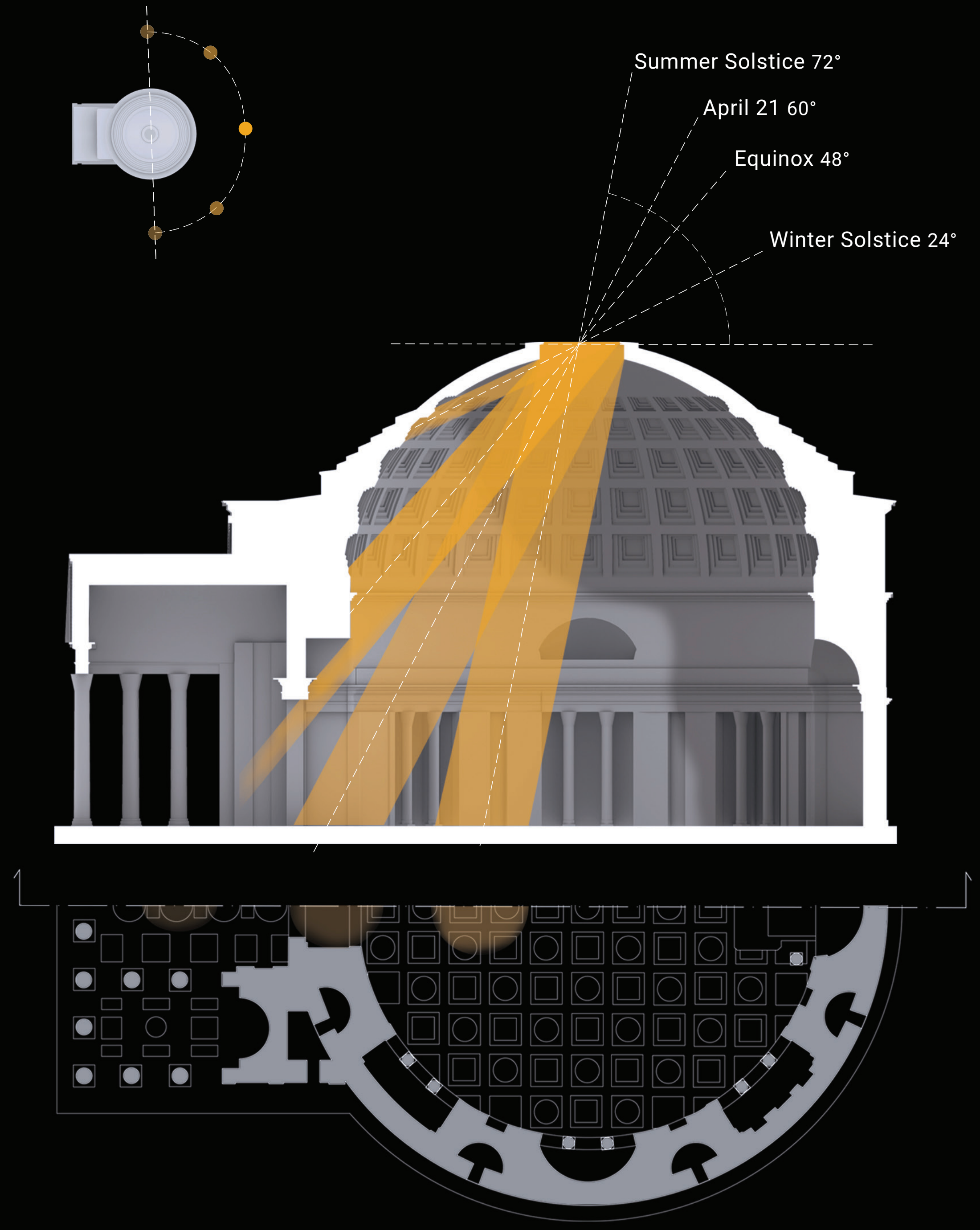
5.5 Pantheon as a solar system

Recent studies have put forward the hypothesis that the orientation of the Pantheon was similar to that of the spherical or hemispherical sundials with a hole at the top, through which the sun's rays entered, which were in fact turned towards the north; thus the oculus and dome would be a monumental version of the hemispherical garden sundials [5].

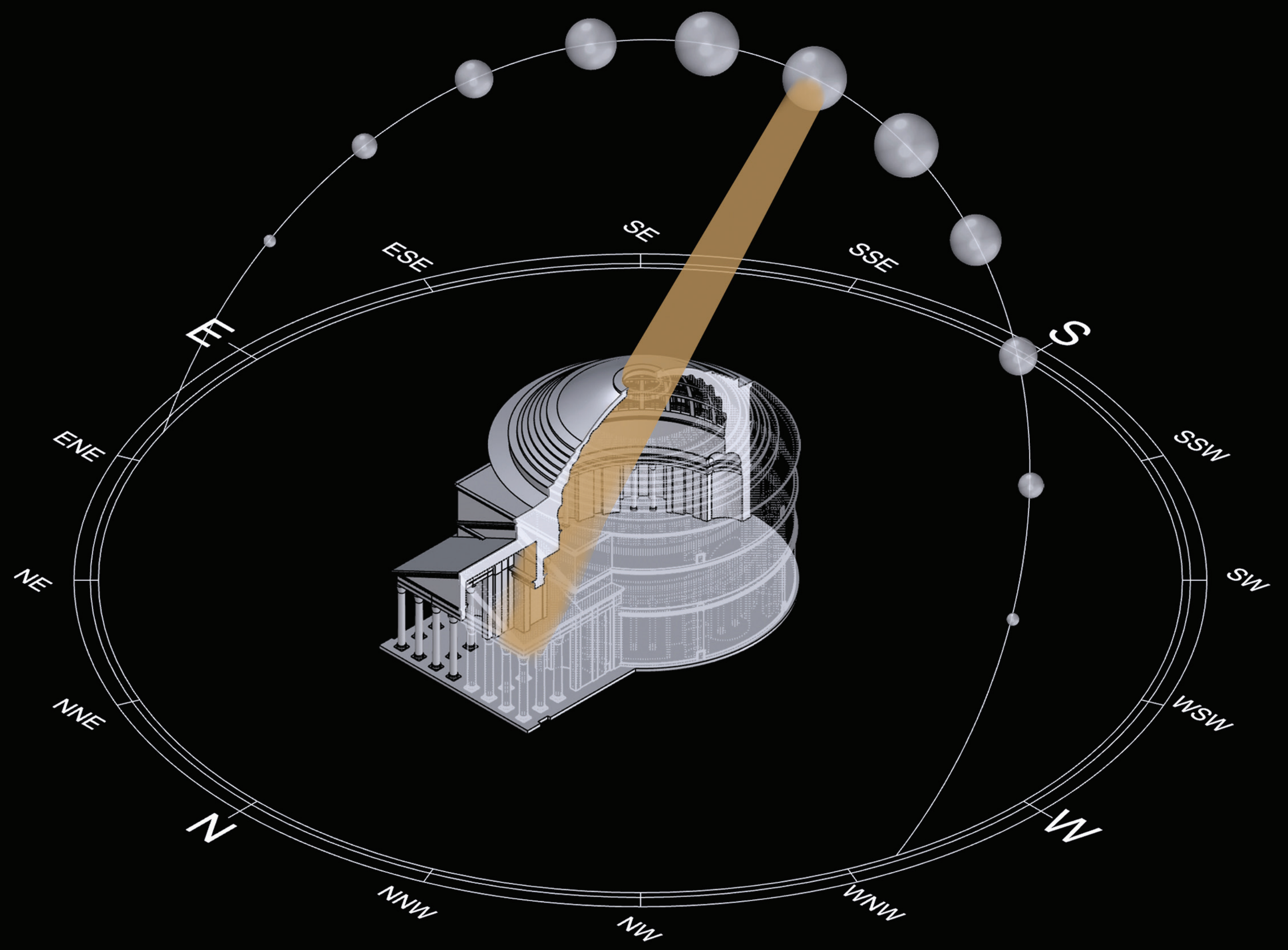
Starting from this assumption, scholars began to investigate the different 'plays of light' in the Pantheon, noting that during the winter months, when the sun is lower, the light entering from the oculus illuminates the coffers of the dome, while during the summer months it reaches the lower part of the walls and the floor.

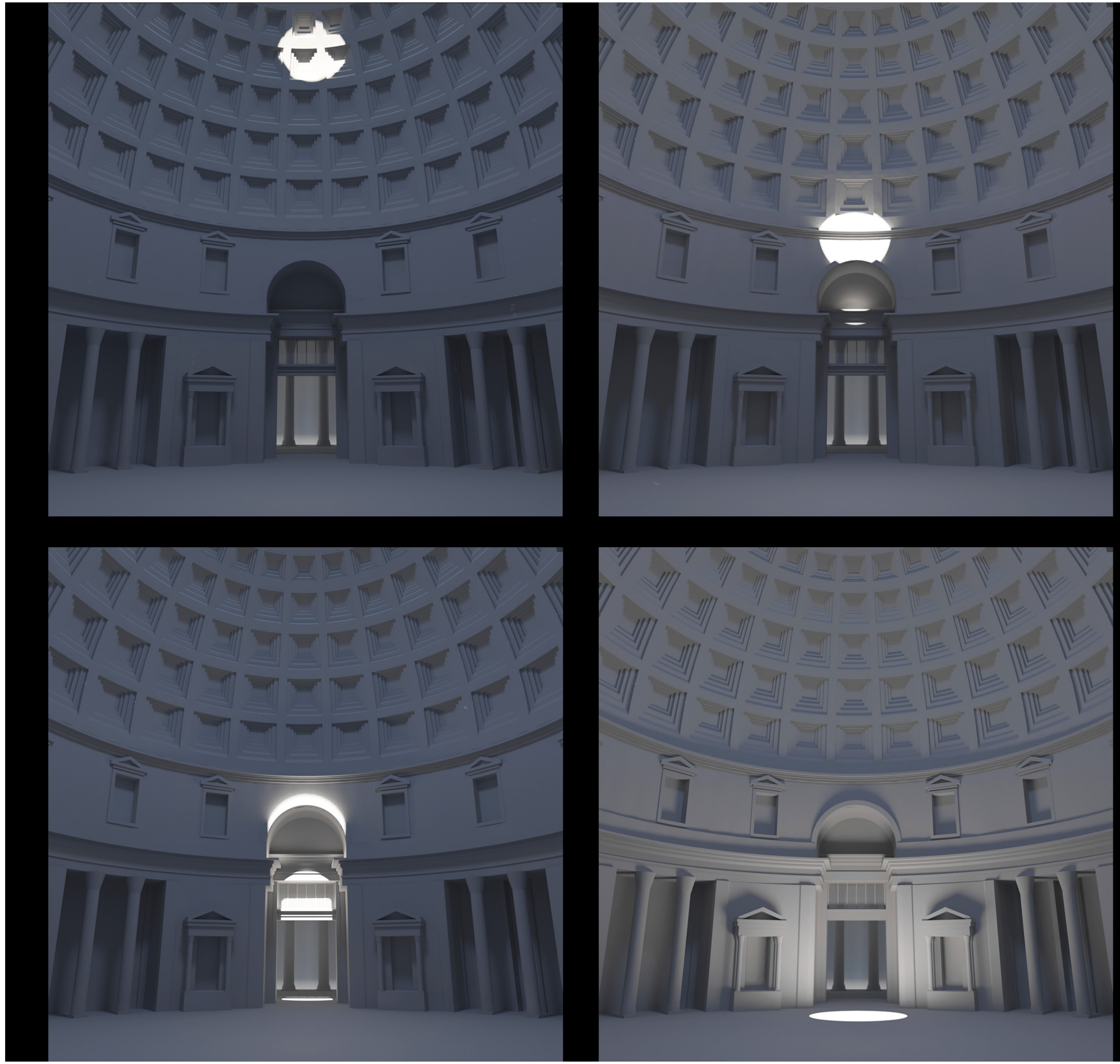
These special "beacons" created by the Pantheon's eye and which strike precise points of the monument at different times of the year have a very precise symbolic meaning, which Emperor Hadrian mastered and skilfully used to express his connection with the Cosmos and the Universe [5].

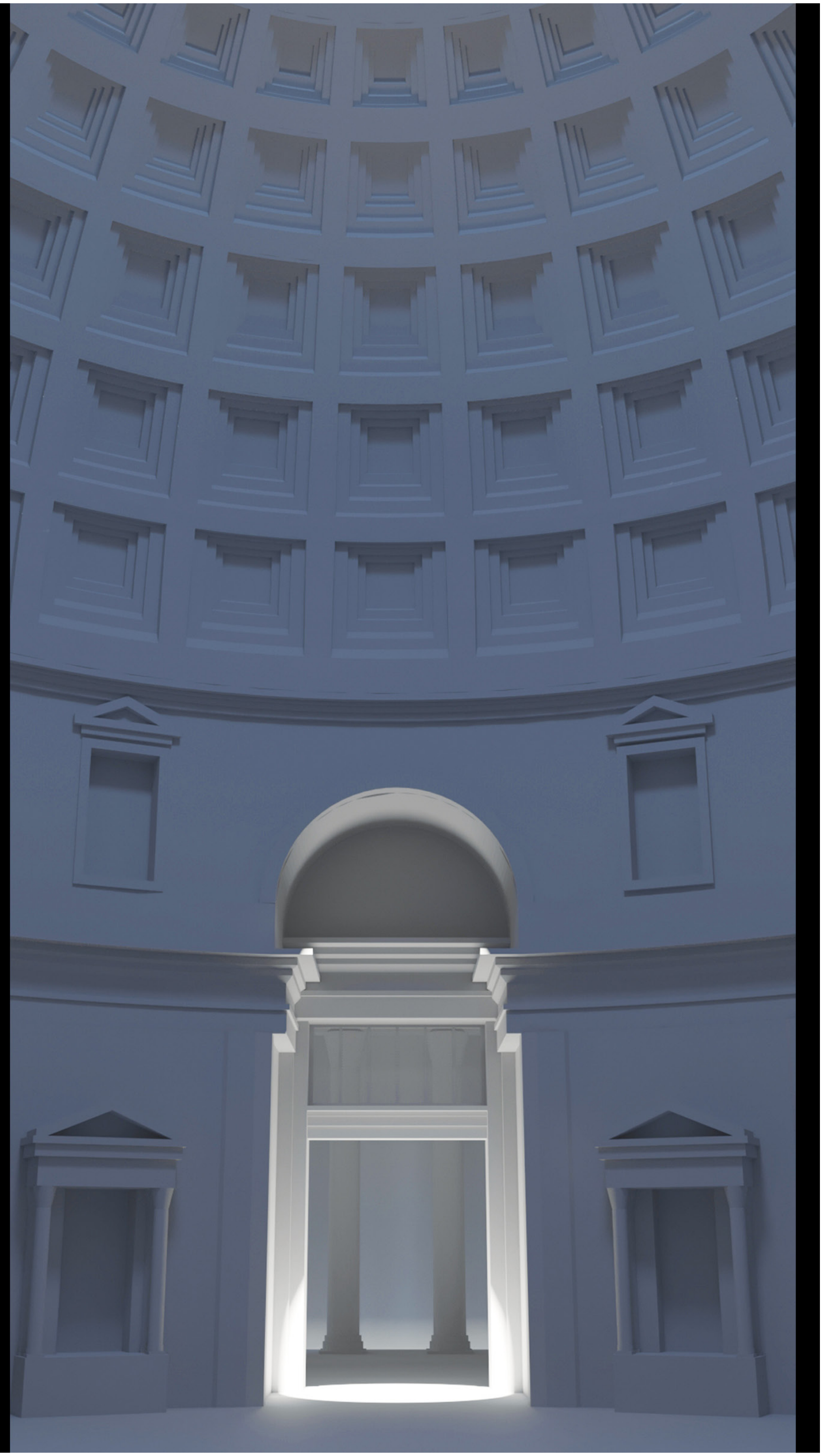
The representations on the following pages show first of all a diagram of the solar alignment with the oculus of the dome, on the most significant dates of the ancient Roman calendar. We observe how, starting from the winter solstice, the light of the sun travels through the architecture at various points, until it almost illuminates the central part of the pavement [5]. However, the event that certainly speaks volumes about the design skills and astronomical knowledge of the architects who built this incredible monument almost two thousand years ago is the 21st of April. This date in fact had a fundamental symbolic importance in ancient Rome, being the day, according to legend, on which the eternal city was founded.



On this date, precisely at noon, the emperor crossed the bronze doors that gave access to the temple, at that precise moment the sun in perfect alignment hit the entrance enveloping the emperor in an almost divine light. Being built initially as a temple dedicated to all the gods, this particular tradition and design feature of the Pantheon elevated the emperor to divinity, increasing the sacred and functional significance of the Pantheon.







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6.CONCLUSIONS

6.1 The role of representation in a contemporary context

The path of analysis, carried out at different levels and in different ways, developed in the writing of this thesis has inevitably conditioned my own vision and understanding of architectural representation in the communication of built space.

In a historical period in which visual content abounds in quantity and speed, representation, particularly architectural representation, must adapt to the speed of use and fruition that characterises contemporary graphic content, while at the same time focusing on the features that make a given architecture or urban complex unique in its genre.

Representation does not remain a simple means of reproducing an architectural entity, but an effective manifestation of the architectural character of a given building. This makes it possible and necessary to broaden the type of user who wishes to explore an architectural project through its representation, from the professional or scholar of the subject, to potentially any person interested in understanding an architectural project.

What we have tried to show in this text are the various forms of architectural representation and the consequent adaptability in reporting the characteristics of a complex architecture.

6.2 Adaptation of representation in the case study of the thesis

The case study under consideration, the Pantheon, is perfectly suited to the purpose, despite the fact that it may appear to be a simple piece of architecture, both in terms of forms and the spaces it generates. In reality, the compositional, structural, geometric and material aspects it hides are unique.

The investigation of architecture and the adaptive possibilities of representation in reporting it have evolved hand in hand in the development of this thesis. Each structural, compositional or spatial feature of the monument needed to be represented with a method that would make this information as quickly perceptible as possible to the reader.

In the initial phase, the basic tools of architectural representation, such as plans and elevations, were fundamental both to restore the historical and architectural heritage of the surveys examined and to lay the foundations for modelling a virtual three-dimensional counterpart of the monument. This subsequently made it possible to create a more immediate visualisation of the historical sources and a direct comparison between them despite the inevitable technical and theoretical differences.

This also led to the optimisation of an ideal three-dimensional model of the Pantheon, formed and created on the basis of the experience gained from modelling on such heterogeneous technical and representational bases.

The development of the fifth chapter is based on this volumetric basis, where the aim is to report on some of the more complex, technical and theoretical peculiarities that characterise the monument.

And it is here that the representational qualities are adapted to the necessary purpose: through the use of axonometric views, characterised by a visual hierarchy of the elements constituting the model, which allow an infinite exploration and consequent representation of the architectural and conceptual space.

Polygonal modelling has also made it possible to broaden the means of presenting the content of the work carried out, by attempting to go beyond the representative limits of the two dimensions of the paper medium and inserting an animated representation that incorporates the variable of the fourth dimension, i.e. the dimension of time, in order to create a dynamic animation that represents the most important themes reported in this text.

6.3 The physical limits of dimensions in representation

The ability of representation to adapt and transform itself, as presented in the title of this thesis, has its greatest expression in the variation of physical dimensions in which the representational medium operates. This text itself and the boards presented as a manifesto of the graphic contents it contains, are representations that inevitably work on a two-dimensional level. As much as perspective and the use of perspective views attempt to represent the three-dimensionality of an architectural object, they are static representations that imitate or replicate the concept of spatiality in three dimensions.

For centuries of human history this has always been the limit of the transmission of the perception of an object, an architecture, a landscape operating in the real world of three dimensions through its two-dimensional representation. Over the centuries, the main innovations to overcome this representational limit were the discovery of perspective in 1400 at the dawn of the Renaissance by artists such as Filippo Brunelleschi and Masaccio, and the invention of cinema by the brothers August and Luis Lumière.

The consequences of these advances in the field of representation or imitation of reality were not only technical and artistic, but mainly cultural and social. When a means of expression is made readable by the masses and not primarily by intellectuals and artists, this leads to the dissemination of a representative method and consequently of the content that is intended to be represented and diffused.

6.4 Future scenarios for meta-representation

In modern architectural and urban planning, the representative medium used to compensate for the limitations of communicating the project or the architectural heritage is the creation of scale models capable of reproducing the object to be represented.

Despite the fact that technology has significantly improved the creation of such real models, making it a more accurate, efficient and accessible process, there are still obvious limitations to the use of this medium of representation.

First of all, the scale inevitably fails to convey the perception of the built volumes and the space created by them, and secondly, the physical uniqueness of these models makes them accessible to a limited number of observers and users. This is in contrast to the representation as a theme of large-scale diffusion of the artistic and architectural content that is to be reported.

This type of limitation can be overcome by making the virtual three-dimensional model the main representative object. This is already widely used to some extent in the field of commercial construction, the navigation of virtual models by potential clients in the real estate field makes it possible to finance architectural projects through the clients who, once the project has been completed, will live in it. However, this poses economic and commercial interests that go beyond the representative intention of the architectural project.

What has been represented in this text in the form of graphic works can be contained in a single meta-verse, a container of historical, architectural and geometric information, which uses a single three-dimensional model as a method of representation. A collection of the heritage of an architecture usable by a wide audience of users, from professionals to students to explorers of meta-universes.

At the time of the diffusion of this thesis, the only technological limitation to the creation of such a representative and divulgative possibility remains the complexity of the architecture under examination. The high number of polygons that inevitably make up a representative model of a complex architecture such as the Pantheon, do not make this content exploitable through a technology in its infancy such as the meta-verse.

However, a possible interest of institutions dedicated to the preservation and divulgation of the architectural heritage of individual states, could create the conditions for collaboration with developers of this type of technology, in order to obtain a representative method adapted to the current communication needs with possible educational purpose and awareness of the historical architectural heritage.

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