

## CONSTRUCTION HISTORY AND DIGITAL HERITAGE. EXPERIMENTATIONS ON RENAISSANCE DOMES IN CAMPANIA (ITALY)

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### ABSTRACT:

The paper describes an ongoing research project granted by the University of Naples Federico II (2017-2020) concerning masonry domes considered as visual poles in the historic urban landscape and as a constructively vulnerable built heritage. Studies focus on Renaissance domes in Campania region (Naples included) and combine established strategies with innovative ones for the knowledge of visible/invisible parts. Verticals and curved structures are investigated with a unitary approach, together with the pre-reinforcements placed during the construction phases or for later strengthening. These topics deal with issues crucial for the domes' study: firstly, the overlapping of inner and outer surfaces that hide structural elements and do not enable their comprehension. In addition, we must consider the recurring difficult inspection or inaccessibility due to the big dimensions and heights from the ground. All these factors, together with the fact that decorated surfaces are a limit for the traditional diagnosis, require new investigation strategies – remote and by non-destructive methods – so as to document the invisible both for emerging and for underground parts. A model for knowledge characterized by the interlacement of 'humanistic' interpretation and bottom-up/bottom-down surveys is discussed. The understanding of what is invisible to direct inspection is considered a stimulating frontier for proposing innovative dissemination tools for the comprehension of cultural heritage, able to reach new communicative horizons related to the construction of complex forms of architecture. The transposition of the research outcomes into digital "accessible" data aims at having impacts for sharing a broader cultural awareness of the built heritage historical constructive significance.

## 1. INTRODUCTION

### 1.1 Domes as palimpsests

Domes, if intended as symbols and centuries-old landmarks in the urban landscape, take part in the continuous and dynamic process of transformation of the cityscape. They are often perceived as immovable icons in everyday life but indeed are the result of interventions that add, subtract, replace or adjust new and old parts (Figure 1). This process characterizes their building and transformation over the centuries, to give in the present-day images that are frequently other than what was designed in the ideation phase. This circumstance is shown by truncated artefacts, that is without the final splendour of the lanterns, or chromatically different from the original decorative design. It is worth considering the substitution of the enamelled terracotta coverings with industrially produced sheaths or the variations in the design of the finishing, often with the loss of the skilled initial shades (Casiello et al., 2007).

Recent earthquakes occurred in Italy – in Abruzzo in 2009, in Emilia Romagna in 2012 or Umbria and Marche regions – or less recent events (as evident in the aftermath of the Irpinia earthquake) demonstrated how the domes are highly vulnerable parts of the architecture. This is caused by the endogenous lack of a concept of "aggregate" that would improve their strength and by vaulted sections whose horizontal stresses increase the thrust factors.

In many cases these conditions correspond to the absence or unavailability of data concerning the specific features of the construction, the material discontinuity, the presence or lack of components, even *post operam*, able to reinforce the dome or, on the contrary, to trigger potential damages.

### 1.2 The state of the art in Campania region

Studies have started since the late 1990s recurring to traditional instruments for the investigation of domes, dating from the 16th to the 19th centuries, in Campania region in central-southern Italy and with reference to Naples, Capua and Salerno, together with the areas of Ischia, Pozzuoli and Procida, converging in a catalogue of 112 artefacts (Casiello, 2005).

The researches highlighted the great variations in construction systems and the different ways of responding to static and dynamic actions. They also showed the limits of direct inspections, although essential, if not combined with complementary approaches which can be able to clarify what cannot be captured through the eyes. These aspects emerged, for example, when double shell domes were investigated (Russo, 2012; Russo, 2016) or when dealing with the difficult acquisition of construction data in presence of vertical and sub-horizontal coatings, at the intrados with frescoes or stuccoes and at the extrados with metal or terracotta tiles (Casiello et al., 2007). As a result, it became clear that the same architectural elements that strongly mark the identity of the urban landscape and are icons for local communities, still provide, paradoxically, an insufficient framework of knowledge of the construction properties and, hence, of potential risk indicators.

Moreover, there is a gap between urban iconography – which, as a whole, reserved long-term attention over the centuries to the representation of architecture with a domed conclusion – and the graphic documentation of the single buildings, at least for the context of Campania, which is still very limited.

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Figure 1. Naples, skyline. In the background, the high Treasury of San Gennaro Chapel and the Church of Santa Caterina a Formiello dome at the back.

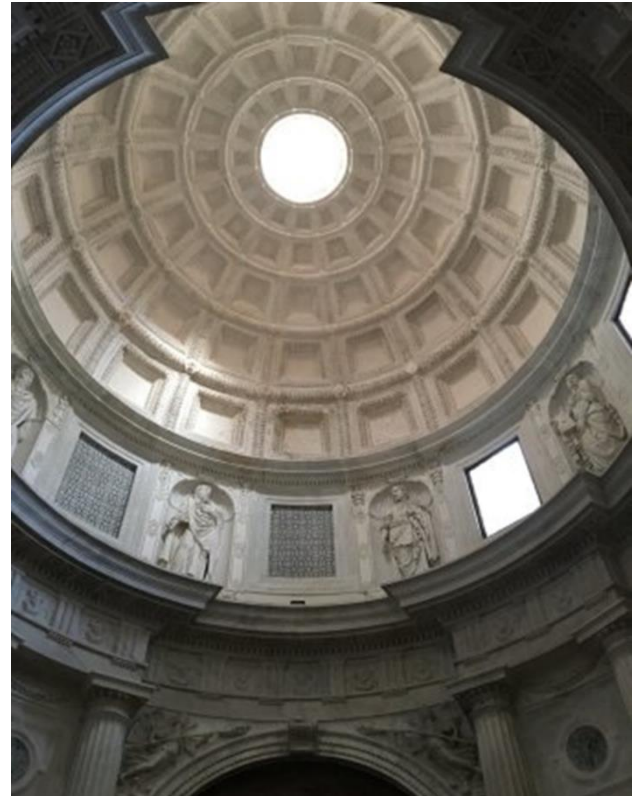


Figure 2. Naples, San Giovanni a Carbonara Church. The calotte of the Caracciolo di Vico Chapel (about 1499-1516)

Renaissance, as is well-known, is a composite period that has been the subject of extensive studies in the past decades for Southern Italy, too. These focused on the relations between the local, the Catalan and the Tuscan culture (Pane, 1975-1977; Gambardella, Jacazzi, 2007) or on that with the new religious Orders. At the same time, they focused on the iconography – e.g., in the case of the *Tavola Strozzi* dating to 1472 – or on archival sources giving the reconstruction of social assets, of designers and of corporations of arts and crafts.

## 2. MAKING ACCESSIBLE THE HISTORY OF CONSTRUCTION

### 2.1 The *iDome* research project

The research project *iDome-Invisible | Accessible. Masonry domes between the 15th and 16th century in Campania. Innovative strategies for the inclusive and multi-thematic interpretation and fruition of vulnerable architectures* aims at deepening the data collected in previous studies in chrono-spatial terms and at focusing on the first diffusion of forms of architecture with domes in Campania region, dating between the 15th and the whole 16th century.

The methodological research approach aims at going beyond a centralistic interpretation concentrated only on the main historic towns such as Naples, paying attention to the regional spreading of an often neglected building know-how.

The 16th century is a crucial chronological key-node of the research that is, thus, in progress starting from a phase when the historic-constructive studies concerning the topic still need in-depth analysis. This has been recently pointed out about the Southern Renaissance (Di Teodoro, 2015) in comparison with historiographical advancements related to other contexts such as the Tuscan and Roman ones.



Figure 3. Naples, Sant'Anna dei Lombardi Church. Tolosa Chapel (about 1492-1495).



Figure 4. Capua, Annunziata Church with its massive 16th century dome.

The diffusion of treatises and the building yards in the Late 15th century demonstrate the overcoming of the late-Gothic language in favour of a spatial design influenced by an expressive universe permeated by an antiquarian afflatus. This reflects both on architectural and on decorative arrangements to result, in the second half of the century, in the Counter-Reformation culture, strongly prevailing in post-Tridentine Naples (Savarese, 1986; Russo, 2008). We can refer as examples of a fine sensitivity towards the Antique as “model” the Caracciolo di Vico Chapel in San Giovanni a Carbonara Church (Figure 2), with its coffered dome (Migliaccio, 2008; Aceto, 2010), or the Tolosa Chapel in Sant’ Anna dei Lombardi Church with terracotta reliefs in the pendentives (Figure 3).

Some important building yards that occur before the wide diffusion of the domes during the 17th century are documented in Naples both for the first decades of the 16th century – e.g., in the iconic Santa Caterina in Formiello dome, subject of the applied research activities – and for the Tridentine phase, in relation to the yards of the churches of Donnaromita or San Gregorio Armeno. The spreading of these artefacts, in turn, reveals evident variations in their structural concept: more composed in the first part of the century and considerably more experimental since the end of the 16th century – as happens in the Annunziata in Capua (Figure 4) – probably also thanks to the migration of the skills learned for the dome of St. Peter in Rome. Stimulating themes emerge from the work on a regional scale: from those related to the clients, as in the case of the Ave Gratia Plena and Loreto buildings which spread in the mid-sixteenth century, to that relating to the Tuscan and Roman influences.

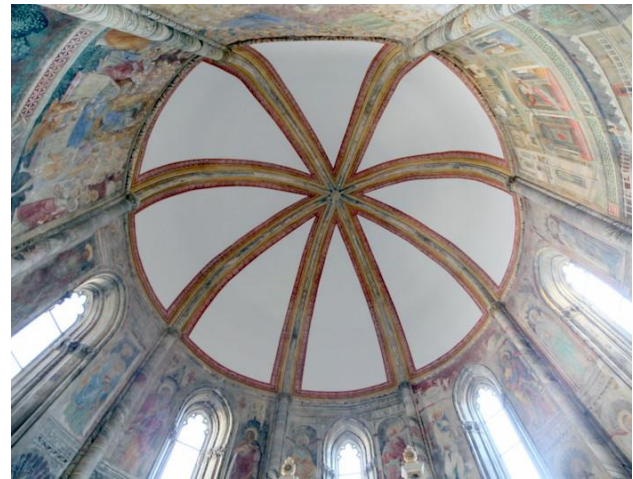


Figure 5. Naples, San Giovanni a Carbonara Church. The ribbed calotte of the Caracciolo del Sole Chapel.

The use of domed apses in the second half of the fifteenth century – as in the case of the ‘centric’ roofing of the cathedral tribune in Naples (Russo, 2017) is of some interest, too, and can be referred to the Caracciolo del Sole Chapel in San Giovanni a Carbonara Church (Figure 5). Some more considerations can be made looking at the adoption of the polygonal, three-domed presbytery and to ‘trullo’ domes or, again, at domes with a fascinating vernacular character, frequent in the Sorrento-Amalfitan context.

The scope of the revitalization of a wide field of studies combines with the need to go beyond a “pure visibility” approach to the fabric and to render “accessible” the invisible in immaterial terms: this “invisible” made of the interlacing of constructive factors, expedients for damage prevention, repair techniques, closures, consolidation and covered decorations. Indeed, it means thinking of a innovative declination of the history of construction, focused on the relations between appearance and structure, and considered not as separate entities but rather as the two sides of the same coin.

This methodology is largely characterized by the purpose of overcome isolated interpretations of local historical-constructive data in order to reach a unified dimension of the building phenomenon. The nature of the project is, in this sense, collaborative and aimed at strengthening the dialogue between humanistic and technical skills, e.g. between consolidated knowledge strategies and emerging technologies; at the same time, reinforcing the dialogue among the history of science, building skills, compositive factors and spatial outcomes.

Another methodological goal stands in the intersection of historical-documentary and direct data emerging from on-site explorations, innovative dimensional surveys and 3D restitutions: this is a further step the research project has taken in consideration to assess the intersections between documentary information and the concreteness of architecture. Consequently, the research aims at highlighting the role that a careful detection of invisible construction parts, of details and techniques not immediately identifiable assumes in the design of a sustainable prevention of natural risks today: this by means of an interdisciplinary approach, the use of diagnostic evaluations and interpretative models of historically sequential vulnerability.

All this can find innovative technical refinements for culturally based structural strengthening operations “within” the intrinsic characteristics of the historical building system. In this sense, historical knowledge and conservation are intended as absolutely intertwined by making the former exist because of the need of the latter and vice versa (Russo, 2017).



## 2.2 Santa Caterina a Formiello Church. The “first” dome in Renaissance building yard in Naples

The research team has progressively advanced with a deductive approach from a wide recognition to individual case-studies and to the *Demonstration Research Project*. This by firstly collecting the thematic bibliography, both concerning Italian contexts as well as about Campania ones and focusing on indirect sources, on the informative system creation and the starting of dimensional surveys.

A second step, still in progress, focuses on the “demonstrative” case-study chosen in consequence of the first part of the research and in cooperation with the local Superintendence. In this sense, the research focuses the attention of the multidisciplinary team on the dome of Santa Caterina a Formiello Church in Naples. This latter is an artefact of remarkable interest within the historical-architectonic panorama because considered as the “first” dome built in the Neapolitan Renaissance. The dome of Santa Caterina a Formiello has consequently assumed a symbolic and iconic significance in architectural and urban historiography, as the symbol of the affirmation of the ascendancy of the Tuscan language in the capital of the Spanish Viceroyalty (Figure 6).

The historical documents point out its construction yard starting in 1519 (Ceci, 1900, p. 70) or 1523 (Celano, 1692, I, p. 189) with the prosecution of the enlargement of a pre-existing church dedicated to Santa Caterina, too, located on the eastern edge of the city and contiguous to the city walls (Canonico, 1996). The design of the new church – «la quale per lo suo adeguato modello e proportionata altezza viene giudicata la più bella di Napoli» («that for its adequate model and proportionate height is considered the most beautiful in Naples») (De Lellis, ante 1689, p. 343) – was attributed to Antonio Fiorentino from Cava dei Tirreni in late 17th century (Celano, 1692, I, p. 190), confused with Antonio Marchesi from Settignano; otherwise, Roberto Pane recognized the influence of Francesco di Giorgio Martini on the design, directed for the construction by the Tuscan Romolo Balsimelli from Settignano (Ceci, 1900 and 1901; Pane, 1975-1977, II, p. 203-205; Petreschi, 1991; Ghisetti Giavarina, 2002, 471; Rusciano, 2006).

The church, ended in 1577 (Celano, 1692, I, p. 189), with its structures in Neapolitan Yellow Tuff (NYT) and cladding in Piperno stone and grey tuff, has a Latin cross plan with five chapels on each side, a not protruding transept, choir and a rectangular apse. The intersection of the nave with the transept is dominated by the dome, sustained by pillars and arches with Piperno stone cladding (Figure 7), characterized by a slender drum about ten metres high and a vault with an oval profile and twinned ribs. The internal diameter, equal to about 11 metres, corresponds to the nave’s width and to the height of the dome from the cornice to the key; this means that the vault can be inscribed in a parallelepiped whose height is double the side of the base square. The structure, in bricks and tuff, externally rhythmized by twinned pilasters corresponding to the massive ribs, is closed by a lantern, resulting from the replacement of a much heavier one in Piperno stone.

Despite the importance of the artefact in the history of Italian Renaissance architecture, very little is still known about its construction history, somehow “obfuscated” by the main interest for the figural value of the work. However, the construction yard of Santa Caterina’s dome is a very important node in the history of Neapolitan architecture: it is in this building, in fact, we can record a strong upward energy both in the drum and in the ribbed vault, at that date almost absent in Southern Italy.



Figures 6 and 7. Naples, Santa Caterina a Formiello Church. The right side of the transept, the bell tower and the massive dome. Below, an internal detail of the crossing.



Figure 8. A. Baratta, *Fidelissimae urbis Neapolitanae...*, Naples 1629. Detail with the Church of Santa Caterina a Formiello, the city walls and Porta Capuana.



Figure 9. Giacino Gigante (fourth decade of 19th century). Porta Capuana and the dome of Santa Caterina Formiello in the background.

In consideration of this knowledge gap, the research is using direct and indirect means to understand the structure of the Neapolitan fabric. An in-depth study has been undertaken in the large documentation preserved in the State Archive of Naples that contains a large archive of the Dominican convent, with data precious for understanding the construction features and the phases of modification of the dome of Santa Caterina. The iconographic sources that show the building between the 16th and 20th centuries have a significant importance, too, by confirming the visual “weight” the dome has maintained in the urban skyline over the centuries (Figures 8, 9 and 10).

The research activity interlaces different skills in an interdisciplinary way, aiming at the characterization of the subsoil and of the elevations. A non-invasive investigation campaign with the Ground Penetrating Radar (GPR) system has been done on the floor of the nave, presbytery and choir. It has verified the crypt, anomalies attributable to burial cavities and the probable traces of unknown pre-existing masonries.

The survey of the crossing by laser scanner and 3D photo modelling has had a significant relevance. From their results the overall section of the dome has been defined, and excluded the presence, in its current state, of a double calotte as hypothesized in a first phase considering the highly pointed shape. It has been highlighted the prosecution of the vertical drum for about a third of the height of the dome and, consequently, the upward translation of the thrust section.

A crucial phase in the study of the Renaissance dome has involved the use of drone surveys whose acquisition provided detailed images of the drum (Figures 11, 12 and 14) and the ribbed vault. As experimented in other buildings under investigation – e.g., in the churches of Santa Maria Donnaromita in Naples and the Annunziata in Capua – the use of the drone was also tested for the survey of the internal parts, with different rotations of the camera. This operation aimed at integrating drone imaging with thermographic and magnetometric surveys in relation with the overall goals of the research project.

In the church of Santa Caterina a Formiello, as in the other above mentioned cases, it proved impossible to obtain close photo recordings of parts arranged at high elevations such as vaults and drums because of the loss of the signal that occurs in the upward flight of the drone. The research group is experimenting with the combined application of photographic, magnetometric and radarstratigraphic survey in addition to thermographic imaging of the exterior (Figure 13) by using a drone aiming at mapping non-visible metal elements – hoops, anchorages, etc. – and heterogeneities in masonries due to historical reinforcing and restorations. The latter goal is highly complicated because of the interaction between the instrument support and magnetic radiation.



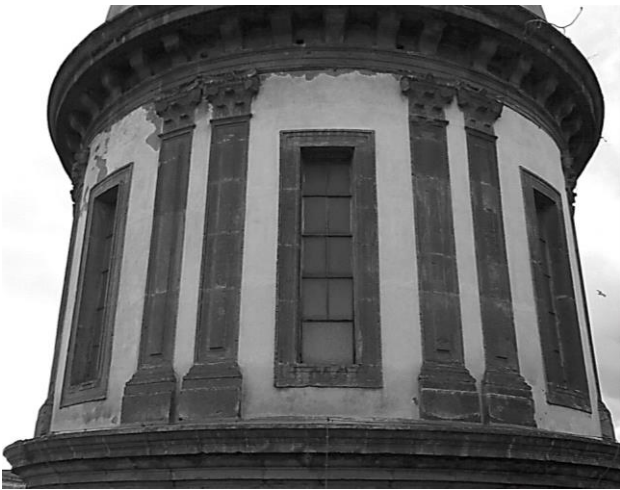
Figure 10. Santa Caterina a Formiello Church. In the upper part, the brick curtain of the drum (Archive *Superintendence Archeologia, Belle Arti e Paesaggio per il Comune di Napoli* (middle 20th century).

### 2.3 Digital documentation and ICT

The ongoing experimentations test diagnostic technologies “on remote” without causing invasive impacts for historical materials. This aims at combining the specialized scientific knowledge with innovative and wider horizons for the dissemination of the constructive values of the historical heritage. The interlacing of light drones and thermal imaging, 3D cameras, geophysical surveys from the ground up to the top gives added values to the traditional historical and construction interpretations: closed windows, variations in materials for arches, drums, vaults or ribs can be detected and give new perspectives to knowledge for conservation.

The results of the research will converge both in the *iDome* information system and in a communication tool that can also be accessed by mobile instruments and installed into Santa Caterina a Formiello Church. This goal is intended as a start-up testing that can use thematic apps and, above all, interactive virtual and augmented reality reconstructions. In this sense, the experimentation of innovative methodologies for the survey, the analysis of 3D representations of construction systems, the testing of interactive imaging techniques, such as 360° immersive photos and 3D PDFs support the exploration of the potentials of Augmented Reality systems able to “represent the invisible” and to make comprehensible the aspects of architectural heritage usually not accessible to visitors (Figure 15).





Figures 11 and 12. Santa Caterina a Formiello Church. The elevation of the drum and, below, detail of the cornice in Piperno stone at the base (photo M. Facchini, DiARC MLab, 2019).



Figure 13. Santa Caterina a Formiello Church. Thermal photography of a span of the drum (R. Amore and M. Facchini, DiARC MLab, 2019).



Figure 14. Santa Caterina a Formiello Church. The brick lantern rebuilt after the earthquake of 1688.

Moreover, an *Atlas of Masonry Domes in Campania. The Fifteenth and Sixteenth Centuries* will be published. It will explore the interweaving of architecture, techniques, ancient construction expedients, dimensional and formal features, constitution and origin of materials, spatial imagery and will highlight the characteristics – e.g., lightning systems, joints of the structures, reinforcements – with an innovative and integrated methodology.

As already mentioned, a very important tool for the dissemination of the project is the *iDome* database designed and implemented since the beginning of the research, open accessible at the end of the project (late 2020) by mobile tools, linked to the aforementioned *Atlas* by QR codes and directly explorable in Santa Caterina a Formiello Church with an immersive and interactive touch screen. Together with the *Atlas*, the web resource (Figure 16) will show the methodology of the research, its contents and goals, the activities and the publications carried out by the team members. A specific section will correspond to selected regional contexts, with an interactive map referring to case-studies (Figure 17).

The informative system will collect all the documentation concerning the demonstrative case-study of Santa Caterina a Formiello dome at the end of the project, too: literary, iconographic and archival sources, dimensional surveys, information about the construction expedients and restorations, applied diagnostics results, immersive photos and reports about its state of conservation.

### 3. CONCLUSIONS

The understanding of what is invisible to direct inspection in a multi-disciplinary way stands as a challenging horizon for a wider and in-depth comprehension of historic built heritage. This seems to be much more evident when affording issues concerning high parts of historical architecture as domes and vaults. Although deeply studied from the historical point of view, these latter still need to be better understood in relation to hidden construction and strengthening expedients. This lack of knowledge is quite evident in relation to many Italian domes, too, as the ones dating to Renaissance and investigated by the *iDome* research team with reference to Campania area and to an 'iconic' object as the dome of Santa Caterina a Formiello Church in Naples.

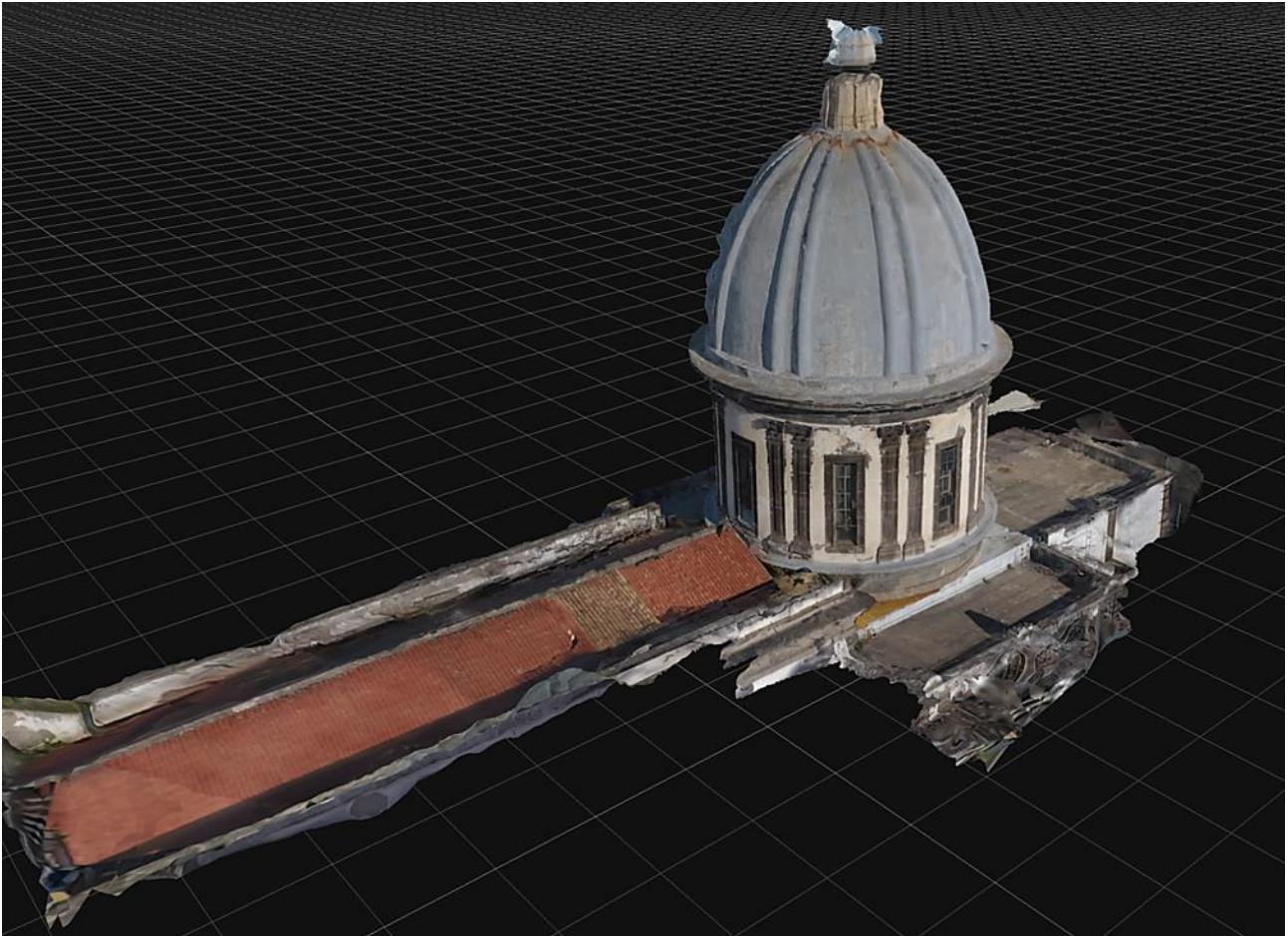
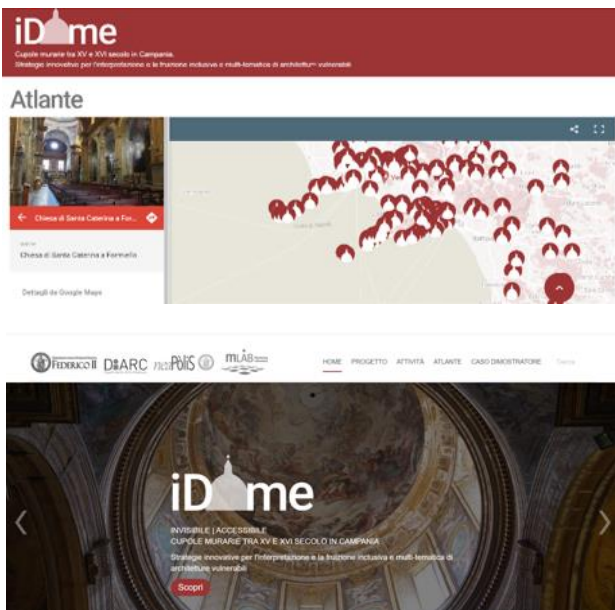


Figure 15. Santa Caterina a Formiello Church. Photomodelling of the roof and the dome elaborated from drone acquisitions (R. Amore, M. Facchini, M. Venanzio, DiARC MLab, 2019).



Figures 16 and 17. The *iDome* website homepage. Below, the domes' mapping in Campania with the interactive information database (S. Pollone, 2018-2019).

In parallel, the outcomes of the direct and indirect studies – that means information about technical inventions of the past, preventive expedients, hidden systems and traces of transformations – can be expanded from more traditional scientific dissemination tools to digitally accessible ICT and mobile systems. Such a frontier can have positive impacts on the sharing and consequent spreading of a cultural awareness about the constructive features, often sacrificed, of historical built heritage. Informative tools descending from robust and multidisciplinary researches can be intended both as sources for a scientific historical knowledge and means for enhancing the sensitivity towards the conservation of historical construction skills in public administrations and in a wider community of people.

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