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Historical and 3D Survey Analyses for an Informative Database on the Venetian fort of Sant'Andrea

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Abstract

This paper focuses on the Venetian fort of Sant'Andrea, also known as Castel Nuovo, located at the entrance of Venice's lagoon, in front of the inlet of San Nicolò del Lido. Redesigned in 1543 by the architect Michele Sanmicheli with the assistance of a series of military experts appointed by the Republic, at the time it represented the most relevant modern fortress of the city, embodying the image of the defence and political-institutional power of the Serenissima. Over the centuries, the building complex was profoundly altered by several restoration works and it is now in a state of disrepair and at risk for sale. In April 2023, a new digital survey of the whole structure was developed within the ERC project *Venice's Nissology* (VeNiss), a research that seeks to reconstruct digitally the history Venice's lagoon islands – from the sixteenth century onwards – through a geospatial semantic infrastructure. The survey campaign was conducted with mobile and TLS laser scanners and drones (flying and submarine) to generate digital archives, point clouds, and three dimensional models integrated and interwoven with historical and archival data in the informative system. While the elaboration of architectural drawings (sections and maps) is fundamental to describe the state of conservation of the fort, it also comprises the essential reference point for analysing its change over time. The digital twin of the fortress, accessible through the interactive 3D online map, constitutes a crucial opportunity to visualise its long-term architectural transformations as well as promoting strategies of valorisation of this important and almost neglected monument to a broad public.

Keywords: Venice's fortresses, 3D survey, integrated database, semantic infrastructure.

1. Introduction

Ne quid urbi natura omnium
munitissimae deesset

"So that nothing is lacking for a city made, by nature, more defensible than any other" reads the inscription affixed on the façade of fortified tower of Sant'Andrea, installed by the doge Alvise Mocenigo in the aftermath of the reconstruction of the military fort that would be later known as Castel Nuovo (1543-1570). This new fortress constitutes the first significant military intervention carried out by the Republic for the defence of Venice in the early modern period. Given the natural protection offered by the lagoon and its 'impregnable' water walls, throughout the Middle Ages the whole security of the city was entrusted only to a series of small fortified outposts located close by strategic sites, in particular along the lagoon inlets of San Nicolò, Malamocco, and Chioggia (Caniato, 2012).

Starting from the sixteenth century, the Serenissima begun to conceive a systematic renewal of its defence system to upgrade and enhance the existing structures – forts, garrisons, and watchtowers – of both the mainland and the lagoon (Concina & Molteni, 2001). Important military architects and engineers, such as Michele Sanmicheli (1484-1559) and his nephew Giangirolamo (1510/14-9), the duke Francesco

Maria della Rovere (1490-1538), Antonio Gambello (active 1458-1481) and Antonio da Castello (before 1499-1549), were involved to define the new strategic imaginary of the city as well as delineating a far-reaching functioning system to preserve the State's invulnerability.

Due to its proximity to the city centre, in the first place the debate focused on the inlet of San Nicolò del Lido, the site referred to as the Two Castles (*Do castelli*). There, from the fourteenth century, two facing castles – one located in the northern tip of the Lido and the other in the opposite island of Sant'Andrea – watched over the principal entrance to the lagoon. In the eyes of the Republic, the ancient fifteenth-century fort of Sant'Andrea, consisting of a central keep and two smaller towers connected by a curtain, was particularly insufficient. For this reason, on December 25, 1534 the Council of Ten instructed the Veronese architect Michele Sanmicheli to visit the island and the opposite area of San Nicolò as well as inspecting the whole lagoon for developing an advanced plan for the modernisation of the exiting outposts "dalla vetustà consumpti e del tutto inutili" (worn out by the age and completely useless). In his alarming report presented on January 21, 1535 the architect confirmed the necessity to protect the inlet with two mighty fortresses and to connect them with a long chain to block the port (Tosato, 2016, pp. 30-35). Aware of the urgency of the matter, only six days later the Council of Ten resolved to reconstruct the two castles based on the models developed by the architect and authorised the stone purchase for the considerable price of 3,000 ducats (1). Despite the exigency, however, a series of afterthoughts and withdrawals about the shape and military organisation of the fortification slowed down its construction, which took more than 35 years for the final completion.

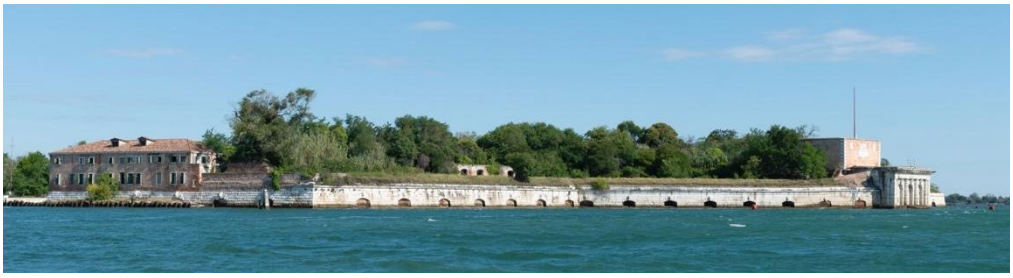

Fig. 1- The fort of Sant'Andrea at the inlet of San Nicolò del Lido in Venice (© Roberta Orio)

2. A collective endeavour: Sanmicheli's project and the critical role of Francesco Maria della Rovere and Antonio da Castello

From the beginning, Venetian local officers appeared reluctant to embark on Sanmicheli's project and in August 1536 they called upon the duke Francesco Maria della Rovere, *capitano generale* in charge of Venice's military strategy, to express his opinion on the granted model (2). In his negative judgement of Sanmicheli's plan to erect two citadels, the duke of Urbino considered these structures militarily worthless as well as inappropriate for a city like Venice that had always boasted its reputation of freedom. On the contrary, he recommended constructing a building that in its strengths meets the requirements of defence and its "weakness" reflects the peaceful life of the Republic. Displaying an outline proposal, he advised building powerful structures only on the fronts facing the inlet, thus leaving the rear side of the fortification, which overlooks the city, unprotected. This design decision, albeit grudgingly, was accepted and introduced by Sanmicheli in his new version of the project (Davies & Hemsoll, 2004, pp. 253-254).

After Sanmicheli's journey down the Adriatic, in August 1543 the Council of Ten finally commissioned the architect to elaborate a final project, which was most likely ready by the end of the month (3). However, this new proposal was called into question again due to the reservations expressed this time by the engineer Antonio da Castello, the Republic's captain of artillery. In the aftermath of an inspection conducted together with Sanmicheli himself, da Castello developed a complete overhaul of the architect's design (Rusconi, 1906, pp. 159-160). He suggested keeping the existing *mastio* and transforming it into a cavalier equipped with two storeys for the artillery piece. His advice also concerns the demolition of all the walls and buildings located around the fortified tower and the construction of

a new curtain (*parapeto*), 8 Venetian feet tall (c. 2,78 metres) and 10 feet thick (3,47 metres), to accommodate – solely along the front facing the lagoon – cannons and other artillery (4). Measurements of the existing buildings have revealed that all the above-mentioned technical proposals were carefully fulfilled. Despite his reluctance, in fact, Sanmicheli presented an additional version for the fort that, as he declared, attended to both della Rovere and da Castello's recommendations (5). One can say that the built fortification epitomises the expertise of the most updated early modern military technicians of the Peninsula: if the plan is adherent to the precepts conjured by Francesco Maria della Rovere, the refined architectural design refers to the knowledgeable work of Michele Sanmicheli. In addition, this complex incorporates the skilful technique of Giovanni da Zon, proto of the Arsenal, in charge of the piled foundations celebrated by Vasari (Concina 1995, p. 254) as well as the ballistic expertise of the captain da Castello.

A sixteenth-century dimensioned plan sketch, published for the first time by Rodolfo Gallo without specifying its archival reference (Gallo 1960, fig. 2), embodies this collective endeavour. Over time, the drawing was variously attributed to Francesco Maria Della Rovere (Ghisetti Giavarina 2013, 28) or Michele Sanmicheli (Tosato 2016, 128-129) and dated between 1536 and 1549. In our perspective, this map displays a rather advanced solution for the general plan of the Castel Nuovo and encloses all previous decision-making discussions carried out by the three technicians. The fort, shaped as an isosceles trapezium, is preceded by a large curved bastion that ends in a protruding portal with three arches arranged in a tripartite composition schema. Only the curtains facing the lagoon are equipped with two rows of gun emplacements for the artillery while the town side is only partially protected by a rather thick wall.

The digital survey fielded by the VeNiss team in April 2023 allows for an accurate comparison between the designed plan and the existing building and reveals a high level of agreement of the two structures, both in terms of physical dimensions and the arrangement of the cannon turrets and casemates. One main difference lies, however, in the organisation of the square behind the fortified tower. At the rear of the *mastio*, six thick columns are aligned to form a sort of large belvedere loggia facing directly toward the city. These elements, roughly sketched and most likely added at a later time, may represent the "square divided by pilasters and arches of rustic order" described by Vasari (Vasari, 1568, p. 515) as a marvellous novelty introduced by Sanmicheli but ended up unrealised (3).

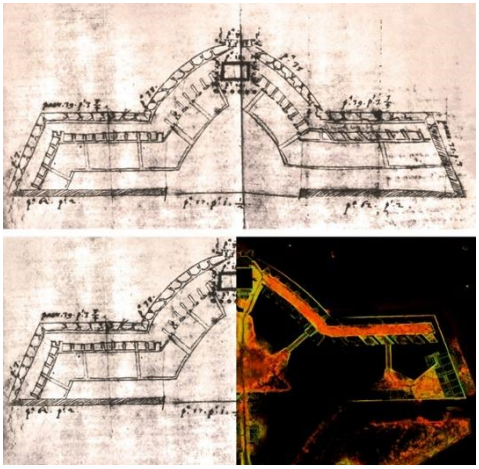

Fig. 2- Design project for the fort of Sant'Andrea, 1536-1543 (Venice State Archives) and comparison with the digital survey

The proposal presented to the Council of Ten by Sanmicheli on September 12, 1543 was finally accepted and the building works began without further delay. They proceeded steadily until May 1549, when the construction of the fort was interrupted for more than two decades by a State decree. Fearing an impending attack by the Ottomans, however, the building complex was rapidly completed between 1570 and 1571, under the guidance of the marquis Sforza Pallavicino and with the direction of Francesco Malacreda. On that occasion, concerned about the possible suffocating fumes produced by the cannons, the Veronese engineer ordered the demolition of the system of vaults connecting the gun emplacements with the casemates, thus leaving the intermediate gallery completely exposed (Marchesi 1988).

3. Castel Nuovo: A landscape military architecture

Following the directives of its many creators, the fort of Sant'Andrea resulted in a 'terrible' (*terribile*) while 'wonderful' (*maravigliosa*) fortress, a fortified machine intended to "serve in times of war and do not serve in times of peace" (Concina & Molteni, 2001, p. 143). Its narrow and

elongated irregular isosceles trapezium shape was a novelty for the Venetian environment, as well as for traditional military architecture. Extending for more than 300 metres with curtains rising only 6 metres from the water level (while the height of the fortified tower reaches up to 15 metres), the Castel Nuovo does not even reflect the regular canons of proportion of common defence structures. On the contrary, its marked horizontality seems inspired by the lagoon context as much as by an ideological concept of "armed neutrality", which revolves more around the intention of 'frightening' the enemy than as an actual protection.

The defensive apparatus is in fact entirely assigned to the central front of the fortification with its martial and rusticated façade. The side facing those approaching from the sea is equipped with two orders of gun emplacements. The inferior level presents forty cannon turrets arranged radially at water level and decorated with lion heads in Istrian stone as keystones, elements that blazon fierceness more than intimidation. A second line of defence is provided by the casemates with cannons mounted en barbette, enclosed in a rampart located in a retracted position (Marchesi, 1978).

The main bastion, built upon the fourteenth-century *mastio*, serves as a cavalier with two levels for the artillery. This is characterised, in its protruding central part, by a three-bay façade covered with white square blocks of Istrian stone. The triumphal portal, which reminds of a city gate, is organised with a central arch and two smaller openings recessed within blind arches to either side, and half columns paired with pilasters at the corners.

Behind the fortified tower and across the inner courtyard, the town side of the fort remains open and 'vulnerable' as suggested by Francesco Maria della Rovere. The current ravelin was actually constructed only in 1646 and equipped with pitches and a covered street, but it was never armed with artillery guns pointed at the city (7).

This intervention appears as the only modernisation carried out by Venetian officers in later centuries. As Damiano Jacobone demonstrated, at the end of the seventeenth century an anonymous military expert was called upon by the Republic to present a project for reinforcing the fortification (Jacobone, 2001). In his report, accompanied by three sketch drawings, the master firmly recommended no architectural changes as the existing buildings were considered absolutely adequate to their purpose. As he explained, the defensive capacity of the fort should necessarily be considered in relation to the landscape of the lagoon. Positioned right in front of a series of minor islands much more easily convertible into military outposts suited to face a siege, the role of the fort of Sant'Andrea was essentially reduced to prevent any potential attack only through offensive actions. This interpretation of the building's function supports the choice of militarising exclusively the front of attack.

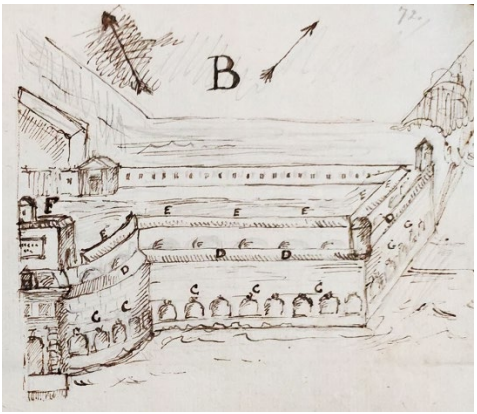

Fig. 3- Foreshortened bird's-eye-view of half the fort, 1690 c. (ASVe, *Archivio proprio Contarini*, filza 24)

The unconventional shape of the fort and its 'landscape' architecture are then justified not only by the morphology of the terrain and the peculiar configuration of Venice's basin but also by the strategic role of the castle within the broader network of islands forming the archipelago.

4. The fort's architectural transformations visualised in a geospatial infrastructure

Only from the nineteenth century onwards, the fort underwent major interventions for both modernising its defence system and restoring its structures. In 1833, a new powder magazine was constructed in the first gallery to the right of the *mastio* – which connects the casemates with the square – while a series of garrisons were placed in the ravelin. The officials' quarters on the south-western corner of the island were remodelled to accommodate more soldiers and, in 1884, a narrow-gauge railway route was installed to facilitate the movement of the military equipment within the fort (Marchesi, 1978, pp. 39-42).

The main restoration works, however, focused on the complex system of wooden piles used as the building foundation and largely celebrated by Vasari (Vasari, 1568, 515). As early as 1845, a map prepared by the Krieg Fortification Local

Direction zu Venedig denounced the state of its disrepair due to the erosion caused by water currents but only timely interventions were carried out (8). This lack of maintenance, along with the change of the lagoon conditions, profoundly damaged the foundation structures.

After the Canale della Giudecca was deepened to accommodate more intense shipping activity, its current heavily increased and began to erode the fort's north-east corner, so much so that it collapsed on June 26, 1950 for a length of over 40 metres. After much consultation, the restoration started only in 1965 and was finished five years later. Following this action, no other interventions were performed and today the complex lies in a state of disrepair. In December 2022, the Agenzia del Demanio issued an exploratory notice to sell the fort, which is now waiting for a project of valorisation.

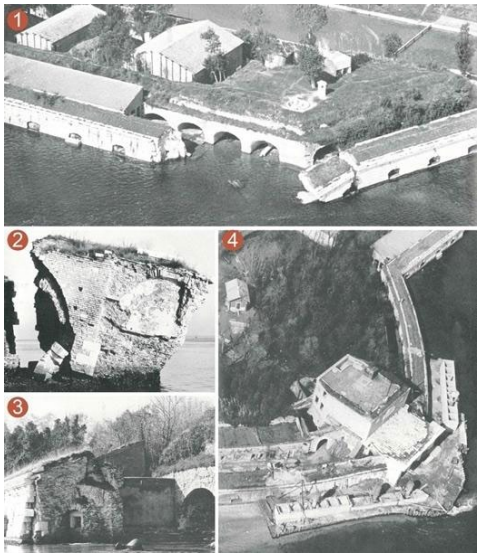

Fig. 4 - The collapse of the north-east corner of the fort in 1950

The history of the fort as well as the visualisation of its architectural transformations over time have a compelling place within the ERC Starting Grant *Venice's Nissology* (VeNiss). This research, developed at the Università degli Studi di Padova in partnership with the Università degli Studi di Firenze, and Harvard University, aims to investigate, map, and visualise the urban, political, and cultural patterns connecting Venice with its lagoon archipelago through a web interactive 3D map, intended for researchers and the wider public alike (9). This is a geo-spatial semantic infrastructure that enables a journey through time and space to discover, from the sixteenth century onwards, the layered histories of Venice's over sixty islands. Allowing users to navigate across the digital historical lagoon, the research platform brings the once densely-populated islands to life in their physical appearance as well as in their social arrangement. Through HGIS and HBIM models interwoven with pertinent historical information, the infrastructure helps investigate, interpret, and represent the long-lasting dynamics of the archipelago, blending physical and functional dimensions together and displaying them as an on-going flow (Galeazzo, forthcoming).

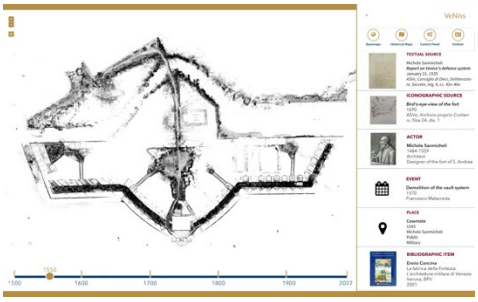

Fig. 5 - VeNiss digital research infrastructure

5. Digital documentation and survey project

The survey fielded by the VeNiss team for the fort of Sant'Andrea aimed at acquiring morphometric information and experimenting with data for understanding and analysing the material traces left by history on the wall structures. Designing a digital documentation system for this military complex required taking many complexities into consideration. First of all, the relationship with the water, the high and low tides as well as the continuously changing surrounding conditions. The bond between the fort and the island is expressed, indeed, by its boundary, a blend that makes the fort and the island an unicum with respect to the lagoon system. The fort is, to all extents, an island and this island has been transformed over the centuries into a fort.

This strict relationship heavily influenced the design of a new survey: from the way of defining data acquisitions to the more general issue of semantically reading the architecture itself, which in this case has a territorial relevance. As for many smaller islands of the Venetian archipelago, the limit between the naturalistic and artificial system coincides with an undefined line, the wet sign on a wall partially immersed in the water. This margin

varies hourly and is not clearly marked as many substructures or ruins of pre-existing buildings are located below the water level. Over the centuries, the contours of the settlement have profoundly changed. Whether it was the island or the naturalistic system that modified the fort or, on the contrary, the different architectural growth phases that changed the landscape and its shoreline's edges, the fort – like any other military architecture – dialogues and should dialogue with this naturalistic environment.

Speaking of military architecture requires to consider distances, paths, angles and inclinations in order to shape an architecture in perfect harmony with the culture and the place that it represents. In this sense, military architecture gives form to an ornamental as well as decorative model that embodies a cultural identity to be defended, thus resulting, within the economy of the project, in the most adequate strategic and formal solution to oppose the enemy. The fort of Sant'Andrea has an extremely complex structure that originates from the central nucleus and extends over two large curtains characterised by an approximately symmetrical layout. In this solution, the horizontal dimension prevails over a limited vertical extension. With respect to the survey, this anomalous configuration rather complicates the geometric arrangements necessary to stabilise the net of topographic cornerstones. Therefore, we carried out many acquisition campaigns using different instruments, with the idea of creating a single 3D database in which data obtained from each individual survey coexist. For the measurement activities conducted with laser scanners, we ended up combining a traditional survey with a series of scans developed with mobile tools. The slam technology proved to be very efficient for this case study, in particular for moving acquisitions such as circumnavigating the whole island with a small boat and creating closed circuits. Internal walkways were also treated with the same methodology as this allowed us to easily interconnect architectural elements separated by thick vegetation.

Slam technology was also integrated with static terrestrial laser scanners: stations were placed in strategic points so that the acquisition of angular complexities fell within a single station. Lasers were positioned on the top of the *mastio* and along the walkways as well as on the parapet of the fort's curtains in order to strengthen the point clouds with control points as cornerstones. Static laser scanners were also used to build two paths crossing the island perpendicularly, thus creating a geometric rigid system that further optimises the recording of the scans.

The 3D database, which includes data from GPS systems, laser scanners, terrestrial SfM photogrammetry, and close range inoffensive drones, was finally integrated with a photographic database. In order to organise this digital archive, the island, the fort and its various buildings were semantically broken up into several components. By using an alphanumeric code, information on each building element, architectural component, room, environment or area of the fortress were stored, hence structuring a complex level system. Moving from the general building to details, this methodology enabled us to describe the way in which the fort's complex is usually analysed and understood. This organisation of documentation encompasses the means through which every dialogue on the fortress is articulated. Folders containing the files are labelled with a specific code so that any photographs, annotations or information can be archived with respect to the described object. The code thus becomes the key to understanding the fortress but, above all, a useful tool to interweave data with future 3D modelling activities.

6. 3D Database

The point cloud of a monumental complex, if reliable and well created, constitutes a crucial document as it embodies the starting point for

Fig. 6- 3D colorimetric point cloud of the fort

developing any digital drawings or models. Today, documenting a cultural heritage means to create data that not only describe the state-of-the-art of a place, but also deeply support the design process of the architectural heritage, which includes its valorisation, knowledge, control, and management. To this extent, in this research the distance between a survey and a project or between documentation and planning has been shortened. The database and related models appear as a temporal projection that accompanies the building in its digital life.

This is not just about representing the past. On the contrary, it means building a tool capable of digitally qualifying the identity of a space. These instruments and methodologies are not comparable to 'adjectives' but rather to 'nouns' that give the digital architectural heritage its own value. This value is different from that of the real good and it lives on its own temporal dimension or, in other words, on its ability to dialogue with the community. This depends on the capacity to adopt a 'digital language' where drawing, in its broadest sense, has a renewed communicative value, which is comparable to that of the great Renaissance artworks. In the digital age, the media impact of digital works potentially knows no boundaries, but it requires achieving a sort of 'digital notoriety' in which the model itself encompasses a utopian universalisation of the language.

Drawings and models thus embody a critical synthesis of the reality's complexity: by reinterpreting shapes and constructing geometries that derive directly from point clouds, they give life to three-dimensional spaces integrated with data. At any rate, a 3D model is an information model, whether the information is explicit or implicit. The exploring approach through which we grasp the meaning of this model is similar to a path or a story that we need to experience by keeping in mind the relationship between man and the model as well as the bond between man, the model, and its contents.

Communicating through a narrative or a story thus requires that signs and symbols are codified and made accessible to any user of the digital work. To all extents, the point cloud, a discrete model that contains measures, is a sort of digital 'identity card' of a real object, the DNA from which to begin a series of processes as exhaustive or reliable as more reliable the point cloud data will be.

7. Possible readings for a critical comparison of historical models

Within the ERC project VeNiss, three-dimensional databases become the building blocks for developing models that enable the researcher to move back in time. The HBIM models constitute the support base for a formal typological investigation of the main studied and surveyed buildings. This corresponds to a typification of historical phases, hence allowing scholars to associate each architecture with a repository of information accessible through a fairly intuitive platform (Galeazzo, 2022). One of the very first questions to answer, however, was the level of detail described by the point clouds. If this argument is cogent for determining the right limit between details and the descriptive capacity of a model – in particular with respect to decorative elements –, this also affected the speed of the surveying procedures, which needed to be considered within the overall project.

The VeNiss digital infrastructure is meant to be the container of all historical and architectural data, so much so that it revolutionises the very concept of digital archives. Here, in fact, the archive is embodied by the digital architecture itself. This research, however, is also oriented forward in time as 3D models are the repository for not only past events but also for current actions or future events. By all means, a model is comparable to a 'digital twin' of a building. While waiting to understand what model is the most efficient for this project, the information is currently read directly through the point clouds in order to align the methodological protocols standardised on the HBIM with analyses necessary to define not only the skin of the buildings, but also what is included inside its walls.

Fig. 7- Comparison between a eighteenth century drawing and the point cloud

Conclusions

This ongoing research project is thus orienting its activities on the reconstruction of the fort's history by evaluating the specificities of the generated point clouds in order to facilitate the construction of 3D models describing the Venetian military architecture. From a theoretical and methodological point of view, models and drawings are in line with former representations, hence underlying two parallel research paths: the first one refers to the fort and its history and evolution, the latter to the 'language' used to represent the architecture, which becomes the tool for communicating the project. The fort of Sant'Andrea is today in precarious conditions and it will undergo further modifications and changes in the near future. The activities of documentation of this cultural heritage as well as its translation into a digital format are therefore particularly relevant. Given the fort's forthcoming modifications, these procedures will be crucial to describe the current state of the building complex and, hopefully, support its protection and valorisation during the restoration works.

Notes

(1). Venice State Archives (hereafter ASVe), *Consiglio di Dieci, Deliberazioni, Secrete*, reg. 4, c. 52v (August 25, 1535).
(2). Ivi, c. 63r (August 16, 1536).
(3). Ivi, reg. 5, c. 102v (August 23, 1543).
(4). Ivi, c. 103v (September 5, 1543).
(5). Ivi, c. 106r (September 12, 1543).
(6). "Dentro poi vi fece Michele una piazza con partimenti di pilastri et archi d'ordine rustico, che sarebbe riuscita cosa rarissima se non fusse rimasa imperfetta" (Vasari, 1568, p. 515).
(7). ASVe, *Senato, Deliberazioni, Rettori, Registri*, reg. 16, c. 14r (January 1, 1646).
(8). Rome, Istituto Storico e di Cultura dell'Arma del Genio, *Disegni*, *Forti e Castelli*, *Venezia*, FT 10/C 681 (March 10, 1845).
(9). The project *Venice's Nissology. Reframing the Lagoon City as an Archipelago: A Model for Spatial and Temporal Urban Analysis (16th-21st centuries)* has been funded with a five-year grant (2023-2027) by the European Research Council (ERC-2021-StG, GA n. 101040474).

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