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Michele RUSSO, Marta ACIERNO (Eds.)

DEFENSIVE ARCHITECTURE OF THE MEDITERRANEAN

Vol. XXIV

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Defending the Venetian Lagoon: Digital Reconstruction of the Early Modern Fortress at the *Lido*

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Abstract

Since the 13th century, the Lido inlet—strategically positioned between the Adriatic Sea and the Venetian lagoon—served as Venice's principal stronghold for the defence of the capital. Two medieval castles, Castel Vecchio at the northern tip of the Lido and Castel Nuovo on the opposite island of Sant'Andrea, guarded the entrance to the city's main port and defined the area known as *Do Castelli*. Amid the mounting Ottoman threat in the Mediterranean, this fortified zone became the focus of the Republic's increasingly ambitious program to reorganise, modernise, and expand the lagoon's defences in response to evolving siege warfare. While scholarship has largely concentrated on the construction of Fort Sant'Andrea, far less attention has been devoted to its counterpart, the fortress of San Nicolò, now largely demolished. Conceived through a protracted and complex series of construction campaigns, the fortress involved some of the leading figures in Venetian military architecture, who for decades debated the most effective strategies for defending the Serenissima's final outpost before the city. Building on recent archival, cartographic, and iconographic discoveries, combined with an integrated 3D survey, this paper examines the long-term history, strategic configuration, and architectural character of a defensive outpost that epitomised the transition from medieval to early modern Venetian fortification. Using Historic Building Information Modelling (HBIM) techniques, the ERC *Venice's Nissology* research group digitally reconstructed the fortress as it appeared in the mid-17th century, tracing its main construction phases and innovative design features, thereby reviving a form of military architecture that has largely disappeared.

Keywords: Lido fortifications, digital reconstruction, HGIS, HBIM.

1. Introduction

A climate of uncertainty and apprehension pervaded 16th-century Venice. After the War of the League of Cambrai, the growing threat of Ottoman expansion in the Mediterranean unsettled Venices's long-standing military strategy, which had hitherto relied primarily on naval supremacy and the protective waters of its lagoon (Concina & Molteni, 2001). From the

early 1530s, the Lido inlet—the city's main gateway—became the stage for an intensive programme of renovation, modernisation, and rationalisation of the Republic's defences, prompted by the evolution of siege warfare and the looming prospect of a direct seaborne assault. Confronted with the urgent need to strengthen the area known as *Do Castelli*, the *Serenissima* convened some of the most prominent minds in military architecture to upgrade the medieval defensive system formed by Castel Vecchio at San Nicolò del Lido and Castel Nuovo on the opposite island of Sant'Andrea (Morachiello, 1991). Among those involved were Michele Sanmicheli; duke Francesco Maria della Rovere, governor general of the militias; Sforza Pallavicino, captain general of the *Serenissima*; Antonio da Castello, colonel general of artillery; Francesco Malacreda; and Giulio Savorgnan, general of artillery. For decades, these military leaders and technicians engaged in an ongoing—and at times contentious—debate over the optimal strategy for fortifying the two shores of the inlet, torn between applying the *fortificazioni alla moderna* developed on the mainland and adapting defensive solutions to the lagoon's unique environmental conditions. While the first approach led to the construction of Fort Sant'Andrea on the site of Castel Nuovo, the design of a new fortification at San Nicolò proved far more complex. Its history was marked by aborted attempts, repeated reconsiderations, and four decades of uncertainty over whether to modernise the old castle, erect defensive barriers, build a citadel, or embark on a completely new fortress. The latter option eventually prevailed, though only in successive stages, with different designers implementing divergent solutions.

Archival documents provide a detailed account of the design debates—partially explored by scholars (Malagola, 1909; Manno, 1988)—but remain silent on the fortress's final configuration, particularly its elevations and architectural features. The limited survival of 16th- and 17th-century drawings (Fig. 1), combined with extensive 20th-century alterations, further complicates interpretation. The fragmentary and heavily modified surviving fabric has so far precluded a comprehensive reconstruction. Recent investigations by the ERC project *Venice's Nissology* (VeNiss) have documented and measured previously unstudied remains, enabling the reconstruction of the mid-17th-century fortress layout in plan and elevation (1). The digital survey—integrated with textual and iconographic sources and georeferenced within a Historic Geographic Information System (HGIS) environment—has allowed researchers to reconstruct the original curtain walls and trace vestiges of the ancient bastions embedded in later buildings. Using Historic Building Information Modelling (HBIM) methodologies (Murphy, Mcgovern & Pavia, 2009), the team also developed an interoperable 3D model supporting detailed analysis of construction phases, compositional features, techniques, and technological aspects of a military architecture closely aligned with the most advanced principles of early modern fortification.

2. A long construction history: San Nicolò at the crossroads of knowledge and practice

The first proposals for San Nicolò date to January 1535, when the Council of Ten commissioned Sanmicheli to inspect the medieval fortifications at *Do Castelli*. His survey found the twin castles wholly inadequate and led him to propose two new enclosed forts, linked by a heavy chain. Following Venetian practice, his designs were reviewed by Duke della Rovere and Colonel da Castello, who were tasked with suggesting improvements or alternatives. Della Rovere, in particular, rejected Sanmicheli's idea of a large intramural fortress, deeming it unnecessary and potentially damaging to the Republic's civic image. He instead advocated a more restrained scheme: two outward-facing defensive barriers on either side of the port, intended solely to resist seaborne attack while leaving the city-facing fronts unfortified (Concina, 1983: pp. 97-104).

Fig. 1- Map of the fortress with the moat, ca. 1646 (Rome, Istituto Storico e di Cultura dell'Arma del Genio, *Forti e Castelli*, *Venezia*, FT 10 A 641)

Assuming a seaborne landing at San Nicolò to be unlikely, della Rovere proposed isolating the Lido's head from the rest of the island with a curtain wall along its southern edge, severing the narrow strip of land between lagoon and sea to prevent any advance from Malamocco. For the other fronts, he recommended laying only foundations, upon which light but reinforced walls could be quickly erected if needed—strong enough for temporary defence yet easily dismantled if the outpost fell (Manno, 1988: p. 195). Eschewing mainland-style fortification in favour of a site-adapted design, his proposal effectively turned San Nicolò into an 'island', a strategy long employed by the Republic along the Dalmatian coast, as well as at Gallipoli and Chioggia. Da Castello offered a similar approach, advocating a single 'sturdy' front, strengthened with a glacis and counterscarp and isolated by a moat—a faster, more economical alternative (2).

The opposing arguments of Sanmicheli and della Rovere were debated extensively but ultimately set aside. Despite experts' reservations, the modernisation of San Nicolò was postponed in favour of Fort Sant'Andrea, begun in 1543 (Jacobone, 2001). The War of Cyprus reignited the debate, introducing new proposals ranging from renovating the old castle to building an entirely new fortress. In March 1570, the Council of Ten appointed Pallavicino to design a new fortification while recalling Malacreda to repair Castel Vecchio. The siege of Famagusta accelerated deliberations, and on 20 December 1570, the Council decided to proceed with Pallavicino's design (Manno, 1988: p. 198). Surviving records leave the project's specifics unclear, though a deposition by the hydraulic engineer Silvio Belli indicates that it was intended as a remarkably modest citadel—so small, in fact, that he questioned whether "such a small fortress […] could be defended against a powerful enemy" (3).

Belli's criticisms likely convinced Pallavicino, once work had begun, to abandon the compact stronghold in favour of a larger fortress that encompassed the monastery of San Nicolò. The project was conceived in phases. The initial stage envisaged the construction of a *traversa*—a bastioned front about 300 Venetian feet long—with a central bastion flanked by two half-bastions with orillons, followed by a *trincea* (trench) facing the sea (4). Shortly thereafter, in the governor's absence, the Republic entrusted Malacreda—assisted by military expert Latino Orsini—with the execution of the bastions, which by May 1571 were already nearing completion (Zavatta, 2020). Pallavicino, however, sharply criticised Malacreda's design, faulting the choice of terrain, the cramped proportions of the orillons, and, above all, the lack of a protective scarp (5). As a result, the Veronese engineer was dismissed, and responsibility passed to Savorgnan. His intervention on the *traversa* was limited: he raised the curtain wall to 15 Venetian feet (5.2 m), reinforced it with a double-sloped scarp, and added an *incamiciatura* (revetement).

Fig. 2- Surviving fortress elements: a) Northern curtain wall; b) Castel Vecchio; c) Austrian portal; d) SE *trincea* corner; e) SW orillon; f) SW *traversa*; g) SW lagoon-facing corner (photos by the authors, 2025)

His most distinctive contribution was the *trincea dentata* (saw-toothed trench) along the seaward side—a curtain wall articulated into six teeth, with sally ports and a central tenaille. Unconventional in Venetian practice at the time—previously confined to theoretical treatises (Maggi, 1564: p. 8)— this design proved influential in subsequent decades. Records suggest a phased, rather than fully coherent, construction: as late as September 1574, Andrea Bernardo, the official overseeing the Lido fortifications, sought Savorgnan's instructions on whether and when to complete the parapet—which, 18th-century reports confirm, was never realised (6).

Sources are laconic on the inlet-facing side and the western entrance, marked by a gateway (rebuilt in the 19th century) and a ramp leading to the parade ground. Documents confirm that the fortress was finished by 1576 and remained largely unchanged until 1646, when, following da Castello's idea, a wide moat was added before the bastioned front, complete with a covered way and glacis. By contrast, proposals by Pallavicino and Orsini to lay out a grid of houses within the fortress—intended for sale to offset construction costs—were never realised. The interior remained unbuilt, crossed only by parallel poplar-lined paths for artillery manoeuvres (7). The combined efforts of Pallavicino, Malacreda, and Savorgnan ultimately followed the approach advocated half a century earlier by della Rovere. The fortress encompassed the entire San Nicolò site in fragmented sections: a bastioned front facing Malamocco, a saw-toothed seaward trench, and a massive curtain wall along the port's shoreline. As encouraged by the Duke of Urbino, the city-facing frontage remained open and undefended, preserving Venice's symbolic image as a capital both threatened and yet unbowed.

3. A hidden fortress: Vestiges of a lost military architecture

Today, the fortress presents a highly fragmented and challenging interpretation, a condition largely resulting from extensive urban transformations during the 20th century. Among the most significant interventions was the construction of the Giovanni Nicelli air terminal, begun in 1926 and inaugurated on 4 February 1935. This project required the near-complete infilling of the trench to accommodate the new runway, which still exhibits pronounced unevenness, visible even in contemporary satellite imagery. Simultaneously, aircraft and naval workshops were built atop the first two teeth of the defensive wall. While these structures partially obscure the original fortifications, the surviving elements offer valuable insight into the site's former layout. However, the workshop construction necessitated the complete demolition of the half-bastion facing the sea and a section of the eastern face of the central bastion. In the 1930s, the opening of via Morandi further transformed the site, creating a breach in the westernmost section of the *traversa* and necessitating the removal of part of the eastern half-bastion's flank, whose vestiges are now entirely concealed beneath dense vegetation. The wall marking the fortress entrance has largely survived, although its height was modified due to ground-level alterations. In contrast, the frontage facing the inlet remains comparatively well preserved. Rising to approximately 6 m and topped with an Istrian stone cordon, this section—now within an Italian Navy military area—provides the clearest indication of the curtain walls' original scale and stature (Fig. 2).

4. Historical sources for digital reconstruction

Although a substantial body of historical and archival sources documents the decision-making process and construction of the fortress—including deliberations of the *Consiglio dei dieci* and reports by the engineers involved— evidence regarding the complex's morpho-dimensional characteristics and construction techniques remains limited. The few 16th and 17thcentury maps produced by Venetian offices shortly after the fortress's completion show only the planimetric layout, offering no information about the elevation or topology of the curtain walls.

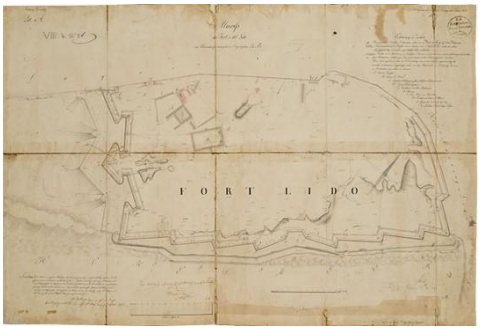

Fig. 3- Austrian survey of fortress, 1828 (Rome, Istituto Storico e di Cultura dell'Arma del Genio, *Forti e Castelli*, *Venezia*, FT 10 A 636)

Likewise, no visual representations survive of the external façades. Therefore, the reconstruction has relied almost entirely on later surveys, mainly from the 19th century, notably the 1828 map (Fig. 3). Compiled by French and Habsburg officers to assess the condition of newly acquired structures and propose restorations, these surveys also include sectional views—covering both the *traversa* and the *trincea*—which, despite minor discrepancies, have been crucial for comparing the current state with the original height and slope of the fortress walls.

5. Integrated digital survey and georeferencing of historical documentation

Given the fragmentary state of the curtain walls and bastions, architectural surveying was pivotal for virtually recomposing the fortress, comparing these with historical cartography, assessing the elevation of surviving 16th-century walls, and understanding long-term transformations of both preserved and lost elements.

An integrated digital survey was conducted to analyse the extant elements and establish connections where possible. Access to the northern curtain wall was limited by the airport and water, so its lagoon-facing side was surveyed photogrammetrically from a boat. These data, currently the sole reference, will be supplemented by future laser scanning in the restricted military area, producing a complete high-resolution point cloud of the northern sector and enabling further study of architectural transformations.

The site's conditions—including invasive vegetation, architectural barriers, wall sections incorporated into modern buildings, and land reclamations—required a multi-technique survey. Terrestrial laser scanning, GPS surveys, and photogrammetry ensured accurate integration and georeferencing of individual point clouds (8). Initially organised as two separate datasets, the point clouds were unified via GPS alignment, enabling integration into a single reference system within a shared working environment (Parrinello, Picchio & La Placa, 2024).

This integrated dataset supported the creation of general plans and elevations, as well as detailed sectional views, which were essential for identifying ground control points (GCPs). It also enabled direct correlation with ground-penetrating radar surveys along the current runway, revealing previously buried structures. The survey plans provided a basis for georeferencing historical maps through a reverse-mapping approach, allowing assessment of the visibility of early modern fortress remains. GCPs were defined using prominent historical elements (e.g., bastions' corners and curtain wall flanks), topographic markers (e.g., coastlines and urban landmarks), and discernible traces in the landscape, such as the remnants along the airport runway corresponding to the *trincea* (Fig. 4). Beyond visualising long-term transformations, these operations proved crucial for identifying additional areas that preserve wall fragments, later confirmed and surveyed (Fig. 5). Notably, the south-eastern angle of the fortress—the junction of the semi-bastion and the first tooth of the trench— remains recognisable despite 20th-century constructions, identifiable through finely dressed Istrian stone rustication. Its alignment with other *traversa* elements was confirmed in the digital plan.

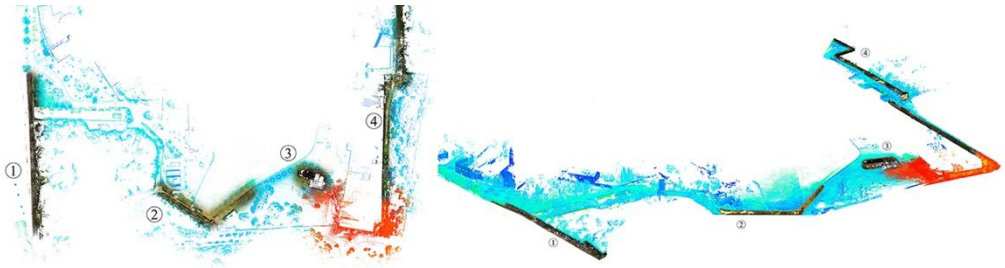

Fig. 4- Plan (left) and axonometric view (right) from the point cloud: 1) stone portal and SW curtain wall; 2) bastion on via Morandi; 3) modern building over SE bastion; 4) NE curtain wall, partly overbuilt (graphic elaboration by Gianlorenzo Dellabartola, 2025)

Fig. 5- Point cloud details: 1) bridge and eastern curtain wall; 2) bastion orillon, via Morandi; 3) building on the SE bastion orillon (graphic elaboration by Gianlorenzo Dellabartola, 2025)

Georeferenced maps show that part of the south-eastern bastion orillon survives in its foundations, integrated into a curved-ended modern building that preserves the original cordon. In the south-west, the link between the western bastion tip and its orillon was verified, though interrupted by via Morandi. The survey recorded both opposite corners, clarifying the curtain wall's original line and confirming earlier reconstructions.

For the northern front, only the external walls overlooking the lagoon were accessible. These better-preserved portions allowed verification of overall height and architectural details, including revetement, and enabled validation of Austrian sections, informing the modelling parameters for earlier construction phases (Picuni, Cilis & Statuto, 2019). After segmentation and decimation, the dataset was optimised for Scan-to-HBIM workflows, opening new possibilities for research, documentation, and analysis.

6. Digital HBIM reconstruction

The digital reconstruction of the fortress results from a complex interpretative process, integrating documentary analysis with the digital survey of surviving fragments. The outcome is a 3D model (LOD 200) that conveys the overall configuration of the defensive complex in its mid-17th-century layout, including the moat and glacis in front of the bastioned front (Fig. 6).

The first stage of the work focused on analysing the digital survey of the surviving structures. The fragmentary nature of the data—due to the particular conditions of the site—complicated comparison with the geomorphological context and necessitated a detailed plano-altimetric analysis, based on the study and cross-referencing of different portions of the point cloud. Particular attention was given to the altimetric data, which revealed that most of the extant remains—except for the northern portion facing the inlet—represent only the upper part of the original defensive wall.

This condition likely results from massive soil deposits added over the past century: on the southern side to support the construction of via Morandi, and on the seaward side to accommodate aircraft and naval workshops. This hypothesis is supported by historical sections, indicating an original wall height of about 5.5 ÷ 6 m (9), compared to the current 3 m. On this basis, the surviving portions were modelled by considering the present walls as the upper section of the original structure, with the lower sections reconstructed accordingly (Fig. 7).

Fig. 6- a) Digital reconstruction on the 1646 map (graphic elaboration by Federico Panarotto, 2025); b) 1940s photo before infilling; c) current view (Google Earth, 2025)

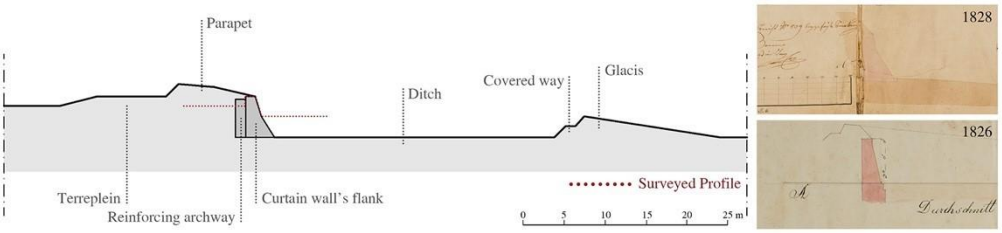

Fig. 7- Cross-section of the central bastion, shown alongside historical sectional drawings (graphic elaboration by Federico Panarotto, 2025)

This interpretation is further supported by early 20th-century excavations along the saw-toothed trench, which revealed the wall's continuation beneath the present ground level. In particular, the walls of the ear-shaped bastion and adjoining half-bastions reveal a scarp with two distinct slopes (10), a feature still visible in the surviving southwestern stretch facing the lagoon and clearly documented in historical sections, notably those from 1806 and 1826.

Direct modelling, based on the survey's dimensional data, was applied to the southern part of the bastioned front, a section of the trench, and most of the intact wall on the northern inlet. Once these portions were reconstructed, attention turned to the missing areas by combining digital survey evidence, analogies with preserved walls, and data from georeferenced historical maps. This process enabled the recovery of the fortress' entire wall system and its internal streets and features. Additional elements—parapets, ramparts, and sally ports—were then added. The first two, documented in 17th-century sources, were concentrated in the southern bastioned front. While plans and sections show varying dimensions, reconstruction relied on the plans for layout and the sections only for altimetric reference. The sally ports were inserted along the saw-toothed trench, as indicated in historical cartography. These were modelled with covered galleries and stepped entrances, set about 10 ft (about 17 m) from the outer perimeter (Fig. 8).

7. Conclusions

Despite lengthy decisions, construction delays, and phased campaigns, the fortress of San Nicolò emerged as an advanced military complex, fully integrated into the landscape and paired with its twin across the inlet—a defensive machine conceived to operate in concert with Fort Sant'Andrea as the capital's ultimate stronghold.

While the fortification has undergone extensive transformations, complicating a full appreciation of its architectural innovations, the project presented here allows a clearer understanding of both the typological features of the individual curtain walls and their integration into a cohesive tactical-operational system. The 2D and 3D reconstructions of this now "invisible" fortification demonstrate that the apparent heterogeneity of its four fronts—their varying heights and forms, the selective deployment of scarps, parapets, and terrepleins, and the internal arrangement of sally ports and manoeuvring routes—should not be interpreted as evidence of a disjointed design. On the contrary, they reflect a project that, although carried out in phases, meticulously adapted to the distinctive lagoon environment and fully aligned with the military and political strategies of the *Serenissima.*

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Author contributions: Introduction and Paragraphs 1-4: LG; Paragraph 5: GD; Paragraph 6: FP. Conclusions authored by all contributors.

Notes

(1) The project VeNiss was awarded an ERC Starting Grant (G.A. 101040474) by the European Research Council: https://veniss.eu.

(2) Archivio di Stato di Venezia (from now on, ASVe), *Consiglio di dieci*, *Deliberazioni*, *Segrete*, reg. 5, cc. 105v-106r (3 September 1543).

(3) Ivi, filza 14 (23 January 1571).

(4) Ivi, reg. 9, c. 132v (7 February 1571).

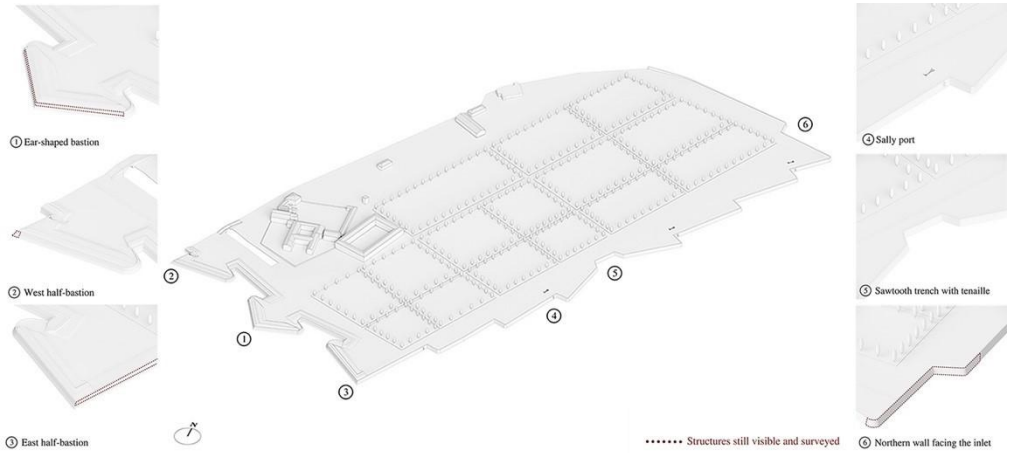

Fig. 8- San Nicolò Fortress 3D model and detail views (graphic elaboration by Federico Panarotto, 2025)

(5) ASVe, *Archivio proprio di Giacomo Contarini*, b. 8, c. 14r-v.

(6) ASVe, *Miscellanea miste e notabili*, b. 11, cc. 185v-186r (1576) and *Provveditori alle fortezze*, b. 44 (1790) for the 18th-century records.

(7) ASVe, *Consiglio di dieci*, *Deliberazioni*, *Segrete*, filza 18 (12 October 1573).

(8) Conducted by the DARWIN Lab (UniFi), the survey used BLK360 and FARO Focus 4 terrestrial laser scanners (RGB and B/W), supplemented by a Leica GNSS station and terrestrial photogrammetry.

(9) Data were compared with sections from sources dated 1715, 1826, and 1828.

(10) The lower scarp has an inclination of 32°, while the upper scarp measures 16°.

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