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The integrated digital survey of the Florence Air Warfare School. HBIM-based protocols for documentation and information management

This paper presents the results of a long-term research project focused on the documentation and digitization of the Florence Air Warfare School, a 1938 important Italian Rationalism architectural complex designed by Raffaello Fagnoni.
The study highlights the methodological protocols employed in the project and presents the several activities carried out for documenting the complex and developing specific digital elaborations.
The research project involved first the study of archival documents related to the original executive project, and historical-multimedia materials, such as newspaper, magazines, site photos and audiovisual newsreels.
In order to obtain a reliable description from the metric-morphological point of view of its current state, integrated reality-based surveying techniques, such as TLS and SfM photogrammetry, were used to acquire and process data.
The data results from these surveys, a global point cloud and high-poly 3D models, were thus integrated and optimized, thus making them a morphologically and metrically reliable support for the development of a graphical atlas of 2D digital drawings descriptive of the elevations of each building and the general plan layout of the architectural complex.
On the basis of the digital survey outputs, a specific coded and semantic classification of the elements in the complex was finally studied through a functional subdivision of it.
These analyses allowed the development of a multiscalar digital repository that, thanks to an appropriate naming-convention, could become a semantic support for *HBIM-based* and VR systems on which enhancing the management of Florence Air Warfare School Heritage and guide its re-discovery.

Keywords:
Raffaello Fagnoni, digitization, workflow, virtual reconstruction, semantic classification

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INTRODUCTION

The paper aims to present the results of a long-term research project dedicated to the documentation and digitization of the architectural complex of the Florence Air Warfare School [1]. In particular, the paper will focus not only on the outcomes actually obtained, but also on the methodological protocols adopted within the project, delving for each aspect into the operational workflows through which the several activities of data acquisition, processing and management were carried out. [Fig. 1] The case study, the *magnum opus* of architect Raffaello Fagnoni and one of the most significant monuments of Italian Rationalism, appears in fact as an emblematic tester for this kind of digital documentation experience, as it perfectly conjugates a heterogeneous Architectural Heritage and an articulated territorial system. Each of these aspects has addressed the research project toward specific activities aimed at its documentation with the goal of developing digital elaborations – historical, multimedia and metric-morphological – on which proposals for HBIM and XR systems can be developed to improve its management and guide its re-discovery.

THE FLORENCE AIR WARFARE SCHOOL

With Raffaello Fagnoni's School of Aeronautical Application, the apex of that fruitful and innovative design phase that Florence experienced from 1929 to 1938 is reached, during which were conceived and built "three non-rhetorical architectures in the rampant Piacentinism that accompanied our country until the World War" (Gurrieri, 1988, p. 18), all of them sharing an intense search for mediation between the reality of the time and the culture of the place: the Municipal Stadium by Nervi, the new Railway Station of Santa Maria Novella by the so-called "Tuscan Group," and finally, precisely, the Air Warfare School. (Pagani, 1984) [Fig. 2]

The design of the military complex was entrusted to Fagnoni in 1936 directly by Mussolini, who at the time was the head of the Ministry of Aeronautics itself, whose technicians preliminarily set up not only its urban layout, but also many design aspects typical of the regime's works of which the architect would have to take into account. Thus, it was requested by the Aeronautic State Property Office that the typical features of the constructions already built by the Ministry should be respected, i.e., facades clad in red brick with travertine finishes and flat roofs covered with turf so as to camouflage their presence. Finally, in relation to anti-aircraft defense regulations, it was required that the buildings should be placed as far apart from each other and as close as possible to the green areas on the lot. The latter is located on the northern boundary of the Cascine Park and is circumscribed to the west by the Le Molina Racecourse, to the east by the Agricultural Technical Institute, to the north by the Macinante ditch, and to the south by the Viale dell'Aeronautica, formerly Viale del Re. (Fagnoni, 1937) [Fig. 3] The area covered by the project was about 11 hectares and presented a geometric conformation consisting basically of two quadrilaterals of different sizes juxtaposed to form a kind of "L," within which the pre-existing Experimental Arboretum of Silviculture was incorporated. This features an area of about 2.5 hectares and its preservation within the project made it a nodal element for the distributional layout of the complex. The plan layout of the School turns out to be divided according to four sectors, each of which presents a certain operational function. The main section intended for Command and Administration is followed in

Fig. 1 - Integrated digital survey of the Air Warfare School

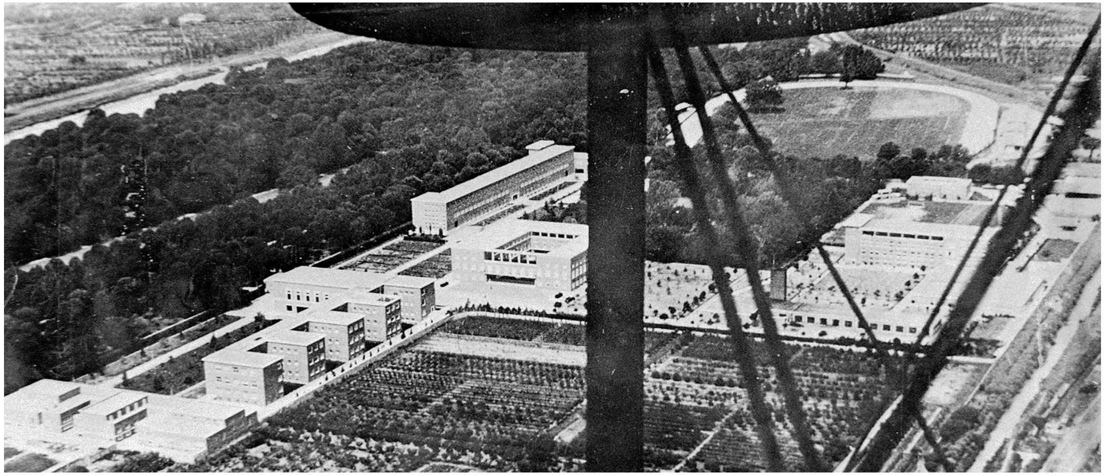

Fig. 2 - Airplane historical view of the architectural complex of the Florence Air Warfare School

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counterclockwise order by sectors for Education, for Services and Armed Guard, and finally for the Officers' quarters and sports-military training. The primary axis that departs from the main entrance, located along Viale del Re, describes a cardus-decumanus layout at the center of which is the Forum, the fulcrum of the complex, the Command building, around which the other functional cores and green areas spread out. The second sector is articulated through a series of volumes characterized by a marked "comb" plan, with the first one being intended for Didactic, the so-called Palazzina Italia, while the second (built years after) is assigned to the Institutes of Aerodynamics and Thermodynamics. Symmetrically positioned to these with respect to the Piazza d'Armi facing the compact Command building and the entrance pavilion, extends the longilinear structure destined for the Officers' quarters, which, developing entirely along the fence, concludes by connecting to the blocks of the infirmary and sports facilities. In addition, this third sector includes both the green areas and paths of the surrounding Arboretum and the sports fields that extend beyond it. The fourth sector, instead, destined mainly for services, is located in the northern part of the complex and consists of three buildings arranged in an inverted "U" shape that house the Airmen's Barracks, warehouses, the Chapel, the garage and the thermoelectric power plant. [Fig. 4]

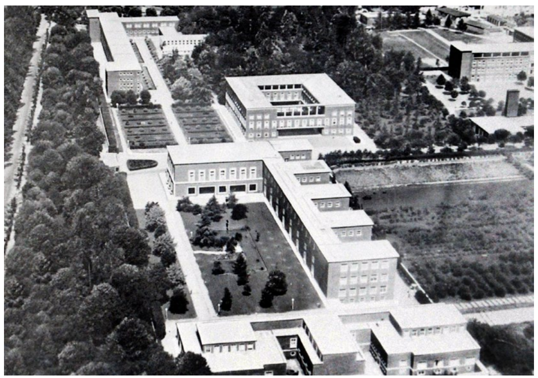
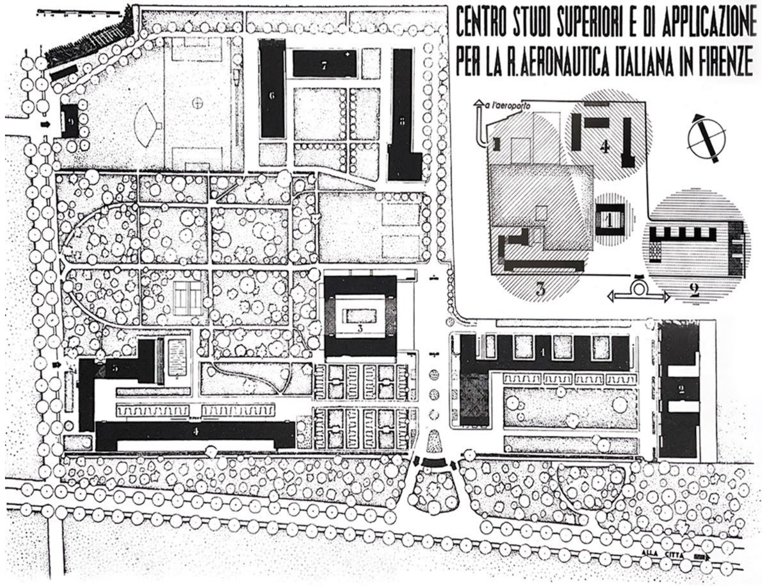


Fig. 3 - The Air Warfare School and its environmental context



SECTOR 1
Command and Administration
Command building (3)

SECTOR 2
Didactic
Didactic building (1)
Institutes of Aerodynamics and Thermodynamics (2)

SECTOR 3
Residence
Officers' quarters (4)
Sports facilities (5)

SECTOR 4
Services
Airmen's Barracks (6)
Warehouse and Chapel (7)
Parking garage and thermal power plant (8)
Guardhouse (9)

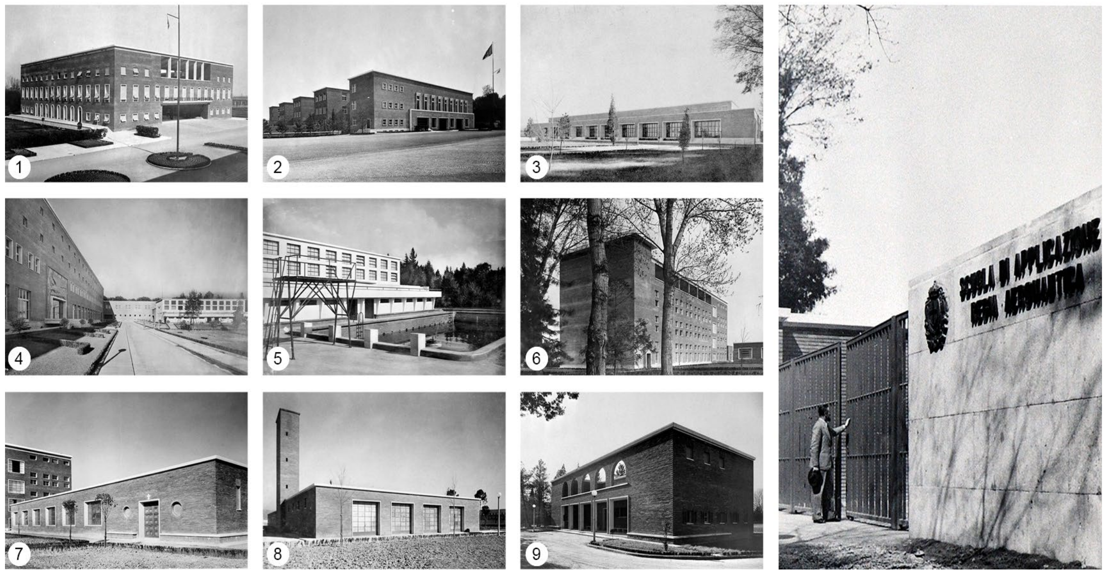


Fig. 4 - Project urban scheme and historical photos of the main buildings

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Finally, it is necessary to emphasize the design respect and meticulous study carried out for the insertion of these considerable volumes within such a relevant environmental context. In fact, Fagnoni knew how to skillfully approach both the pre-existence of the monumental Arboretum, and the more general organization of landscaping, distributing its paths according to orthogonal patterns defined by hedges, avenues, gardens and lawns, through a modern interpretation of the Renaissance garden concept and exploiting it for its sole function of connecting and harmonizing the buildings. (Podestà, 2006)

The executive project was delivered by Fagnoni in 1937, and the construction site that followed, entrusted to the construction company Igliori, laid the foundations in April of that same year and was completed in a record time of eleven months: in fact, on March 28, 1938, the Regia Aeronautica Application School complex was officially opened. (Fagnoni, 1937) [Fig. 5]

Fig. 5 - Grand opening of the architectural complex

STUDY AND DIGITIZATION OF ARCHIVAL AND HISTORICAL MULTIMEDIA SOURCES

At a preliminary level, an extensive study of historical-archival sources was carried out, through which it was possible to outline a precise excursus on the design processes and distinctive features of the architectural complex. In particular, documents and graphic drawings related to the Fagnoni executive project found within the *Fagnoni Fund* and in the *Genio Civile Fund*, both housed in the Florence State Archive, were analyzed and digitized through photographic acquisitions.

The study of the numerous documents contained in these funds has made it possible, on the one hand, to be aware of the impressive design work carried out by the designers and, on the other, to obtain an exact picture of the actual state of the project actually carried out. This latter aspect turned out to be extremely relevant from the point of view of architectural documentation, since it made it possible, thanks to the high detail of the executive drawings, to integrate those parts that during the digital survey phases of the complex had not been acquired by the instrumentation. Moreover, to each of these drawings it was assigned detailed graphic caption consisting of a series of informative parameters related to the data on the original sheet. [Fig. 6]

The drawings of the Executive Project were also subjected to a comparative analysis between the dimensions on paper and those found in the surveys, highlighting sometimes some discrepancies. This analysis of the documentary corpus was followed by that concerning the editorial sources produced by the magazines and newspapers of the time. These were found to be extremely relevant from the point of view of content, although they substantially cover a very short period of time from 1937 to 1938. The main editorial source was found to be that relating to an extract from the magazine "Architettura" of June 1938, within

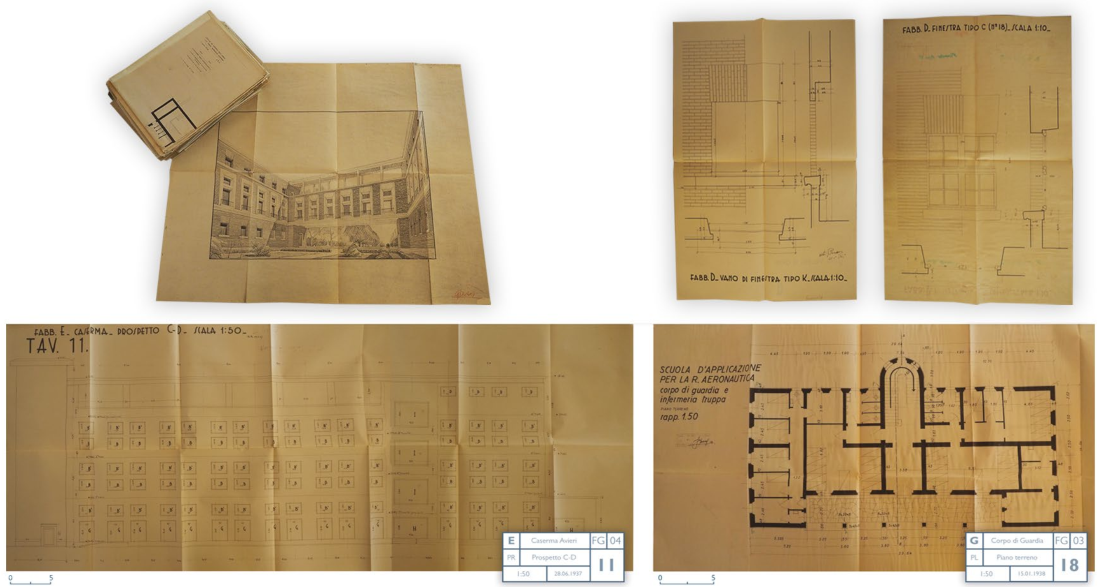

Fig. 6 - Photographic acquisition, digitization and cataloging of graphic sheets from the original Executive Project present in the Fagnoni Fund

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which architect Fagnoni's report on the design and construction of the School was published in its entirety, and for the first time, with photos and graphical drawings at different scales of representation also attached. (Fagnoni, 1938).
The architecture of the complex and Fagnoni's work for the regime were of interest not only to periodicals but also to numerous newspapers and magazines, both national and local (such as "La Nazione", "Il Giornale d'Italia" or the "Rivista Illustrata del Popolo d'Italia"). In fact, from 1937 there were published articles on the subject in a considerable manner, within which the various construction phases that the project was going through were announced or described.
Complementing the editorial and archival research carried out, also the multimedia sphere has been deepened through a study – and cataloging – of the photographic and audiovisual heritage. Regarding the first, photographic acquisitions in the archives of the Barsotti Studio and the Air Warfare School Photographic Laboratory were recovered, which described both the newly completed complex and, more importantly, its building phases.
The massive amount of photographs developed by the Barsotti brothers during the building site phases made it possible to obtain a visual and absolutely reliable documentation for the global knowledge of the work, through the acquisition of all those construction and technological information otherwise unknown.
Within this photografic record the works-progress was thus graphically "noted" through the dating and stamping of each photograph taken. In this sense, this type of photographic documentation represents a fundamental source for examining all the structural elements of the buildings that nowadays remain substantially hidden by the external facings. [Fig. 7]
Finally, with regard to the audiovisual heritage, the sources recovered and catalogued basically refer to those of the newsreels shot by the Istituto LUCE and currently preserved in its online cinematographic archive. Within the latter, punctual research was thus carried out on some of the various events recorded and broadcasted concerning the School complex, for which information such as title, ID, date, duration and brief descriptions of the sequences were noted. (Istituto LUCE, 1937) (Istituto LUCE, 1938a,b) [Fig. 8]

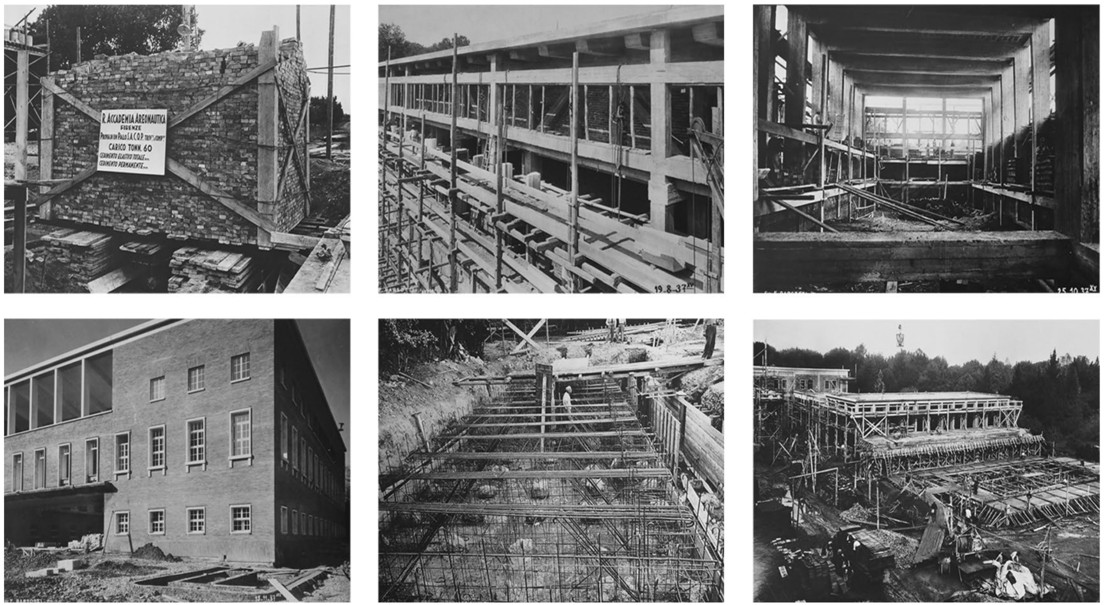

Fig. 7 - Historical photos of the construction site taken by the Barsotti brothers

Fig. 8 - Screenshots from Istituto LUCE newsreels

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INTEGRATED DIGITAL SURVEY METHODOLOGIES FOR THE ARCHITECTURAL HERITAGE DOCUMENTATION

Acquisition and data processing through reality-based systems

Since beginning in 2017, the architectural complex of the Air Warfare School, now the Institute of Air Force Military Sciences (ISMA), has been the subject of a series of metric-morphological documentation campaigns carried out by the LRA [2] laboratory of the Department of Architecture in Florence in collaboration with the administration of the Institute.

The methodological approach involved the use of integrated non-invasive reality-based acquisition techniques, pairing *Terrestrial Laser Scanning* (TLS) systems with specific detailed *Structure from Motion* (SfM) photogrammetric applications, in order to obtain a comprehensive picture of the current state of the architectural complex. [Fig. 9]

Given its extensive land area and the daily occupation of its environments by members of the Air Force, whose activities could not overlap with those of surveying, it was established that these survey campaigns would be carried out mainly outdoors, with a few exceptions for some buildings, setting as the primary objective to obtain a globally descriptive image of the relationship between the architectural and environmental systems.

Fig. 9 - Range-based data acquisition phase using TLS

Data acquisition was undoubtedly the most time-dilated phase, taking into account that the first survey missions, referring to the biennium 2017-18, had been carried out within a series of educational workshops [3] whose purposes were basically to familiarize students with the methodologies and applications of digital surveying in architecture. (Ricciarini, La Placa, 2019) These data were thus retrieved and integrated into the missing parts starting in 2019, through additional integrated survey campaigns, temporally outlining a total of 5 operational missions, each of which was intended to acquire a portion of the large architectural complex. [Fig. 10] Thanks to the approximately 1,000 scans made during the various missions, it was possible to link the various portions surveyed by ensuring that the main polygonals were closed, so that any misalignment errors following the registration phase could be appropriately quantified.

The survey campaigns described were conducted by exploiting the potential of two different types of laser-scanner instrumentation: a *Z+F Imager 5006H* was used for the first three missions, while a *Z+F Imager 5016* was used for the last two. The data acquired through these instruments were subsequently processed according to a methodological protocol widely adopted by the LRA research group (Bertocci et al., 2015), consisting of a series of processing steps of the acquired metric data, one propaedeutic of the other and aimed at the development of a 3D model in the form of a point cloud highly descriptive of the morphologies of the architectural complex. Previously, however, a procedure was conducted to filter out the "noise" present, caused by the instrument's massive acquisitions, during which excess points were eliminated, mainly related to vegetation, humidity or reflections, which could have led to errors in the subsequent alignment phase. The following registration phase was instead developed within *Leica Geosystems Cyclone* management software, where the filtered point clouds were processed using a *Visual Alignment* procedure, consisting of performing a series of rigid rototranslations between adjacent point clouds, identifying their homologous points in order to determine their alignment. This *cloud-to-cloud* registration thus made it possible to obtain a single global point cloud of the Air Warfare School complex that included all the data acquired during the instrumental survey phase.

The next step involved verification of the reliability of the developed survey, during which any misalignment errors present in the registered point cloud were checked. For this validation step, the scale of representation of the graphical drawings was taken into account, which for this study was defined as 1:50, and for which, according to ISO 4463-3:1995, accuracy limits with a tolerance of ±12 mm are provided. (Pancani, 2016) The results of this verification were positive, with maximum errors of less than 10 mm, thus establishing the clear reliability of the TLS survey developed, and making it a reliable morphometric support for the digital elaborations and analyses to be carried out on. [Fig. 11]

Fig. 10 - Summary plan scheme of the 5 laser-scanner survey missions

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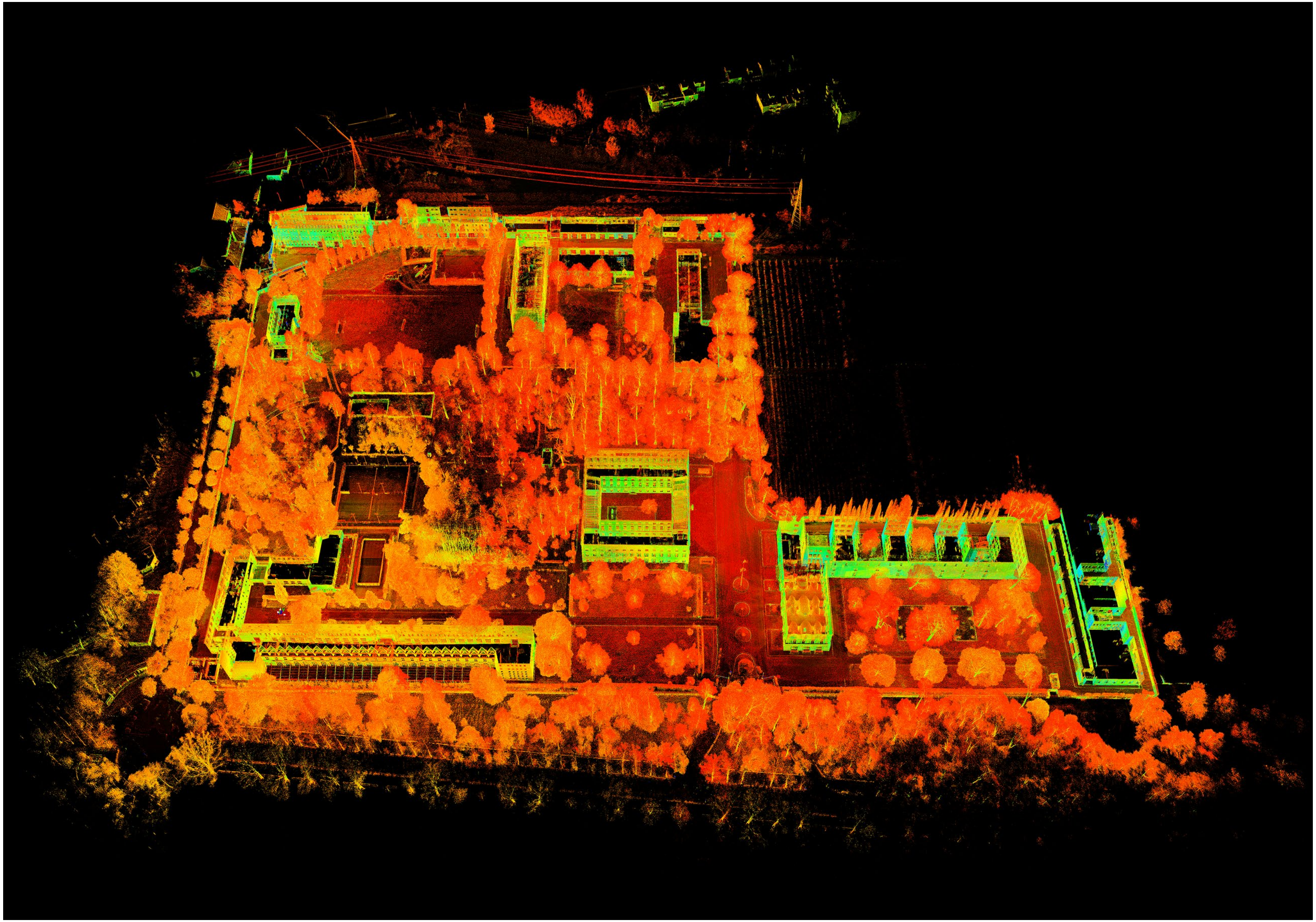

Fig. 11 - Global point cloud view of the architectural complex of the Air Warfare School

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As for the SfM photogrammetric survey, conducted during the last mission, it focused only on the architectural buildings and some valuable elements. These activities were organized according to different levels of scale and detail; in fact, proceeding from the general to the particular, first in a close-range shooting mode, the morphologies of the various buildings were surveyed, and then the individual decorative and architectural elements that most characterized them.

These photographic acquisitions were carried out through the use of various instrumentation and photographic optics, including a *Nikon D3100* DSLR and an *Olympus OM-D EM-1 Mark II* mirrorless camera.

The subsequent processing phase of the photographic data was based on a well-tested methodological practice. (Pancani, Bigongiari, 2020) This was carried out within *RealityCapture*, through specific SfM photogrammetric processes, a series of textured three-dimensional models describing the current state of buildings and elements were obtained.

In particular, within this paper are presented the results considered most interesting, namely those obtained from the photogrammetric processing of the massive façade of the Palazzina Ufficiali, placing particular emphasis on the front gable above the portal: a sculptural artwork created by artist Mario Moschi representing a brick bas-relief of a darting eagle. [Fig. 12]

The photomodeling obtained, although qualitatively adequate in terms of surface textures, presents a pixel-scale that does not correspond to the actual scale in meters. Therefore, in order to unify the results of the two survey techniques, *range-based* and *image-based*, the models developed through the latter methodology were referenced and calibrated according to the coordinates of specific homologous control points identified on the point cloud processed by the laser-scanner survey. The various models obtained were then exported as point clouds and aligned within *Cyclone* to their respective façades by homologous control points, showing misalignment errors with respect to the range-based data of less than 15 mm.

This procedure thus made it possible to integrate the two digital survey methodologies, obtaining two types of results, one based on mapped *high-poly* 3D models, and the other represented by a global point cloud descriptive of the entire complex. [Fig. 13]

These architectural assets will thus become the metric-morphological support both for the development of the canonical two-dimensional descriptive graphic drawings of the current state of the surfaces, and for their eventual and subsequent implementation in the HBIM environment, on the basis of which a *Scan-to-BIM* modeling workflow can be structured.

Fig. 12 - SfM photogrammetric acquisition phase and detail of the entrance

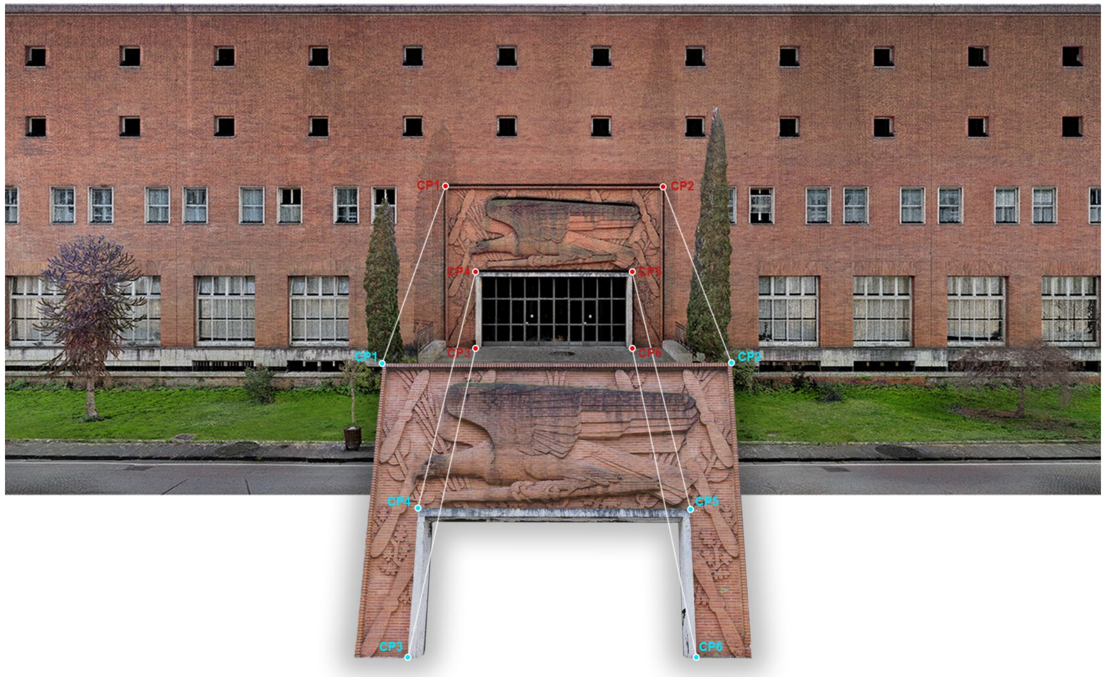

Fig. 13 - Integration phase between point clouds and 3D photogrammetric models using homologous control-points

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Processing of a 2D graphical atlas

In order to obtain an overall documentation of the surveyed architectures, the graphical 2D representation of the general plan layout of the complex and the various elevations related to each pavilion was considered extremely relevant. The procedure started within *Cyclone* software, where a system of cutting planes was initially structured (horizontal for plan development and vertical for that of elevations) and then, based on these, the process of exporting the so-called *orthoimages* [4] from the point cloud was initiated.
These were subsequently imported into the CAD environment, where, once inserted and mosaicked according to their respective coordinates in order to recompose the overall image, they became the support on which to develop the wireframe drawing process. The aim of this 2D vectorization procedure was thus to obtain a graphic atlas of highly descriptive drawings in which every aspect of the study objects was morphologically identifiable and consequently measurable.
In addition to the creation of this vector database containing the elevations relating to each building, drawn, as mentioned, with an accuracy corresponding to the scale of representation of 1:50 and becoming themselves the support for the calibration of the respective photoplans, it is of particular relevance for the purpose of knowledge of the architectural complex, the elaboration at the same scale of its extensive general plan layout. [Figg. 14-15]
The latter in fact made it possible to analyze and comprehensively understand the articulated relationship between the architectural system and the environmental one. In this sense, the external profiles of all the buildings and elements of man-made origin present were primarily identified on the planimetry, which also made it possible to establish the distributive layout of the external paths, for which the finish of the pavements, the presence of technical installations and horizontal signage were studied and catalogued. These technical-architectural investigations were then combined with those related to landscape analysis, for which a mapping of the Plant Units present in the complex was developed. Within CAD environment each tree was represented not only through the location and horizontal section of the stems, but also through the identification of the average crown perimeter.
In summary, it can be stated that the creation of these graphical elaborations enabled a threefold result. The first obviously refers to the development of a digital documentation of the complex, useful for further study of its urban, architectural and environmental apparatus, through the reading of geometric and functional relationships.
The second relates to the possibility of carrying out a comparison between these drawings and the existing documentation, both the historical one obtained from the digitization of archival data and the management documentation made available by the administration's technical offices, in order to record any inconsistencies and to understand the architectural and environmental transformations that have occurred over the years.
The third, finally, refers to the opportunity to exploit this processed two-dimensional documentation, particularly the planimetric one, as a graphic and informative support for the elaboration of a functional classification, based on specific parameters and descriptors. Through these it is thus possible to preliminarily organize and categorize the various elements that compose the complex, in the perspective of setting up a general framework aimed at improving its management and oriented toward an eventual implementation of the data in a BIM environment.

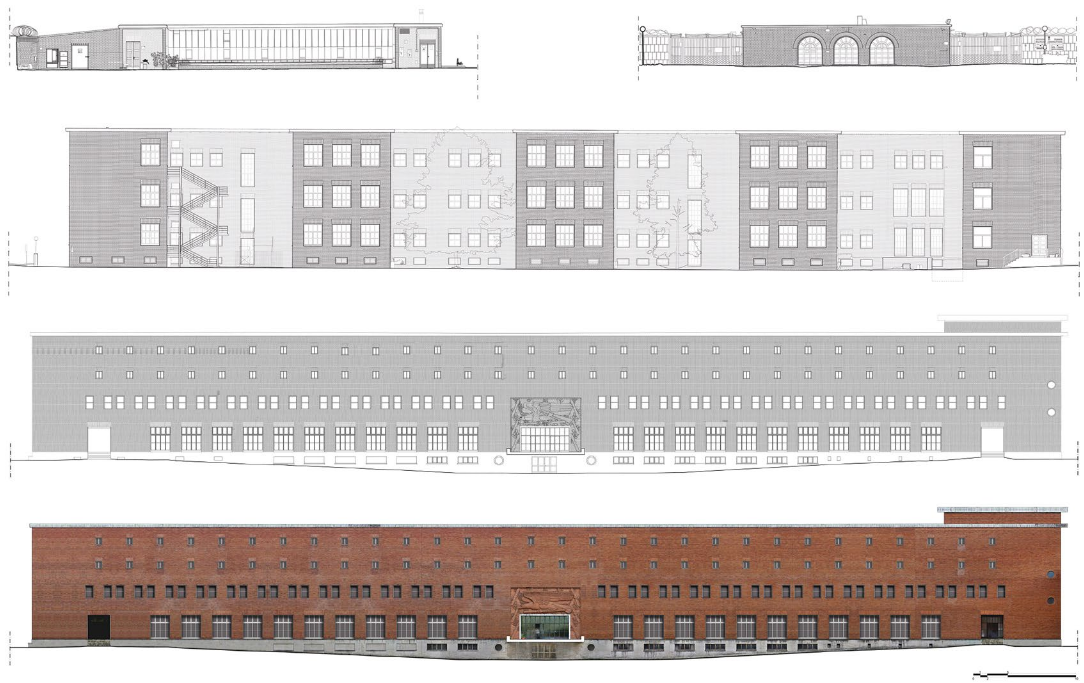

Fig. 14 - 2D graphical atlas of the elevations of the various buildings: wireframes and orthophotoplans

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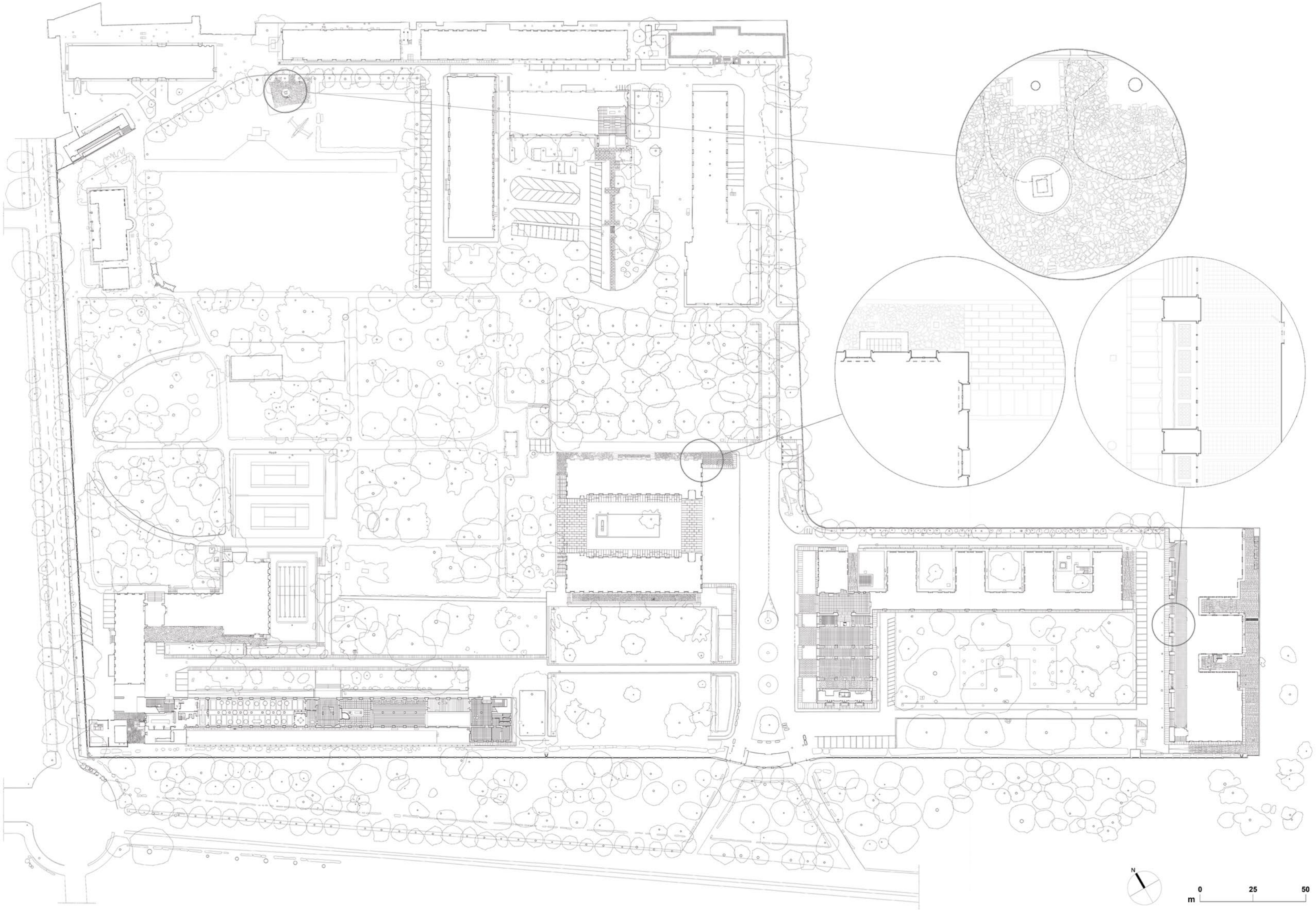

Fig. 15 - General plan layout and details of some pavings of the Air Warfare School complex

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ANALYSIS AND CLASSIFICATION OF THE ARCHITECTURAL SYSTEM

Within this updated knowledge framework, developed from the graphical restitution of the large amount of data collected, it was foreshadowed the need to elaborate a system of organization and cataloguing of the elements present in the Architectural complex, in order to make them univocally identifiable and referable to a specific functional category. Thus, with this classification activity, it was intended to investigate the organization of functional systems related to the architectural context and the mutual relationships between them. For this purpose, the discretization of the planimetric scheme played a key role in this research. Based then on the current plan configuration, a hierarchical classification of the most relevant elements was prepared, structuring a codified breakdown of the architectural complex first into "sectors" and subsequently into homogeneous functional "units."
The proposed classification indeed takes up the functional concepts of the one contemplated by Fagnoni, where the scheme was divided into 4 "sectors": Command, Didactic, Residence and Services, but refines its segmentation and contents by splitting the large Residence sector into two, in the perspective of taking into consideration the new buildings present and their uses. [Fig. 16] The "sectors" have thus become 5 and each of them has been assigned a new name and an alphanumeric identification code consisting of two digits "Sn": where "S" is a fixed string to indicate "Sector," while "n" is a variable number.

Fig. 16 - Classification of the 5 functional sectors

The next classifying activity of the system involved the breaking down of the architectural complex into homogeneous "units," hierarchically dependent on the "sectors" and categorized according to their functional characteristics. On the basis of the information documentation obtained from the surveys, 9 functional categories were thus identified, within which it is possible to frame all the relevant elements in the complex. The coding of these was designed according to two combined semantic levels. The first focuses on identifying the functional category of "unit" and consists of two "UF" digits: where "U" is a fixed string to indicate "Unit," while "F" is also a string but with variable values depending on the related "Function." The functional units encoded and exemplified according to their first semantic level are listed below.
The second semantic level related to "Units" focuses instead on the definition and enumeration of the individual instances present. The coding of this level is composed of three progressive numeric digits "XYZ" with domain [001,999] and is valid for all categories of "Units" with the exception of "Building," which presents instead a code composed of a single digit string type "E" whose values belong to the English alphabet [A-Z]. The reason why this differentiation was established lies in the intention to place architectural works on two different planes, with different relevance, from those subordinate to them, so as to enhance them from the point of view of identification and research.
For the same reasons, the classification of "UE" was further set up while maintaining the possibility of being further subdivided through the introduction of "sub-units, in order to optimize the identification of the distinctive "sub-functions" present in most buildings. In particular, a coding similar to that of regular "units," namely, consisting of two progressive numerical digits "XY" with domain [01,99] was developed for these. [Tab. 1]
As an exemplification of this functional breakdown, an example of coding related to the sub-unit of the " Carabiniers Station", namely "S4-UE-N-01", is presented. The decryption of this code firstly allows to state that the sub-unit "01" is part of the "Building Unit" "N", which corresponds to the "Guardhouse" that is located within the "Sector 4", and subsequently makes it possible to search for it on the plan scheme. [5] [Fig. 17]

ID	Description	Exemplification	Condition [6]
UE	Building Unit *(Unità Edilizia)*	Architecturally significant and recognizable building *(Command building, Palazzina Italia ...)*	*host*
UI	Facility Unit *(Unità Impiantistica)*	Building or relevant facility element *(borehole, air conditioning room ...)*	*host*
UL	Logistics Unit *(Unità Logistica)*	Building or area intended for warehouse or storage *(fuel storage, vehicle wash yard ...)*	*host*
UD	Distribution Unit *(Unità Distributiva)*	Area designated for road distribution *(pedestrian paths, driveways ...)*	*host*
UP	Landscape Unit *(Unità Paesaggistica)*	Landscape area descriptive of a portion of the territory *(gardens, Arboretum sections ...)*	*host*
UM	Border Unit *(Unità Marginale)*	Relevant element with a boundary function *(boundary wall, garrets ...)*	*guest*
US	Sport Unit *(Unità Sportiva)*	Relevant building or area with sports function *(skeet shooting building, soccer field ...)*	*host*
UA	Artistic Unit *(Unità Artistica)*	Artistically relevant elements *(statues, fountains ...)*	*guest*
UV	Plant Unit *(Unità Vegetale)*	Relevant plant element or group *(trees, hedges ...)*	*guest*

Tab. 1 - Classification of the various types of Functional Units identified

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Fig. 17 - Planimetric classification of the architectural system and coded-functional breakdown of the elements present

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Subsequent to this process of classifying the architectural system of the complex, it was deemed appropriate to proceed to a further semantic decomposition, extending the coding, so far developed at the territorial scale only, to a more detailed one related to the ultimate components of the individual architectural area or building.
First, therefore, the spatial aspects of the building system were considered, for which a specific classification was developed intended for the identification of the reference floor levels and the intended uses of the individual rooms in the buildings.
Next, a break-down of the building system according to technological units was set up, assigning each element a unique identification code to recognize its function.
In conclusion, the development of this classification structure sorted by hierarchically dependent classes and subclasses has made it possible to create a preliminary knowledge and management support that can be extremely advantageous in procedural and informatization terms during a future modeling phase in a BIM environment.
Below is shown the list – illustrative but not exhaustive – of codes and descriptions of the corresponding main technological and spatial units of the building system. [Tab. 2]

SPATIAL UNIT		TECHNOLOGICAL UNIT	
Rooms		Element	
ID	Description	ID	Description
MG	Warehouse *(Magazzino)*	MU	Wall *(Muro)*
DP	Storage room *(Deposito)*	PO	Door *(Porta)*
HW	Hallway *(Corridoio)*	FI	Window *(Finestra)*
IN	Entrance *(Ingresso)*	PV	Floor *(Pavimento)*
BA	Bathroom *(Bagno)*	PI	Pillar *(Pilastro)*
CU	Kitchen *(Cucina)*	SC	Stair *(Scala)*
...	...	...	...

Tab. 2 - Classification of spatial and technological units

DEVELOPMENT OF AN *HBIM-BASED* MULTISCALAR DIGITAL REPOSITORY

As widely discussed above, the large amount of information collected during the data acquisition phase made it essential to catalog it within a series of dedicated digital archives. These, for their part, required precise coding of the elements present, which was carried out through careful classification of the architectural and environmental system.
The results of the functional and hierarchical breakdowns of the complex thus made it possible to define a broad knowledge framework of the Architectural Heritage and its territorial articulation. This made it possible to lay the groundwork for the first considerations regarding the search for the most appropriate cataloging structure in order to develop a single multiscalar repository, which would include the combination of the architectural and environmental apparatuses, in order to assign to each instance present (technological, spatial, vegetal, etc.) a set of descriptors belonging to the different systems studied but linked by a common feature or function.
For the development of this *HBIM-based* repository, 5 general criteria for identification and analysis have thus been outlined, which will become the basis for the composition of a kind of overall "filing" for collecting and reading the information of the various instances.
In this regard, for their cataloguing, the following sections have been identified:

- *Anagraphic:* contains descriptors designed to collect the main information useful for uniquely identifying the element
- *Localization:* contains descriptors that gather information about the spatial setting of the element, identifying its location within the various functional-spatial subdivisions
- *Dating:* contains descriptors related to the identification of the temporal data of each element
- *Details:* contains descriptors that identify the physical characteristics of various elements
- *Dimensions:* Contains descriptors related to the geometric characteristics of the element, derived directly from range-based metric surveys

Finally, as exemplification, the cataloging of a *UT* (a double-hung window from the Guardhouse) according to the previously outlined macrocategories and their descriptors is given below. [Tab. 3]

0.00 - ANAGRAPHIC	
0.01 - Category	Window
0.02 - Element	FI-005
0.03 - Description	Double-hung window
1.00 - LOCALIZATION	
1.01 - Sector	S4
1.02 - Unit	UE-N
1.03 - Sub-unit	01
1.04 - Level	01
1.05 - Local	HW
2.00 - DATING	
2.01 - Creation date	1938
2.02 - Survey date	2021
3.00 - DETAILS	
3.01 - Material	Wood
3.02 - Material finishes	White cypress wood
3.03 - Conservation status	Good
3.0n - …	…
4.00 - DIMENSIONS	
4.01 - FI_width	1,45 m
4.02 - FI_height	2,45 m
4.03 - FI_frame thickness	0,08 m
4.0n - …	…

Tab. 3 - Example of digital repository classification

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CONCLUSIONS

From the latter exemplification, the potential of implementing this cataloging protocols in both HBIM and VR environments are evident. In fact, its enumerative-hierarchical as well as integrable-updatable over time structure, based on highly reliable 3D assets, allows not only to improve content management through the development of homologous shared parameters, but also to define coordination guidelines that support potential Scan-to-BIM modeling steps.
In fact, as can be seen in the adjacent image, it is possible and quite easy to associate to the single architectural elements (in this case Revit families) the descriptors developed within this classification proposal, and consequently to obtain a multiscalar digital repository where information can be stored and optionally queried. These information models can also as well become media supports that can be integrated within specific VR platforms where the various information metadata can be interactively displayed in a well-organized and easily readable manner.
In conclusion, the activities and results presented within this paper for the Florence Air Warfare School case study, are intended to emphasize the importance of setting up synergistic and multidisciplinary methodological protocols based on the digitization of historical-archival sources and integrated digital surveying techniques, in order to develop, in a scientific and reliable manner, multiscalar repositories that could address interventions for digital documentation, VR interactive experiences and management of the Architectural Heritage.

Fig. 18 - Implementation potentialities of the digital repository within an HBIM environment. Case study: double-hung window from the Guardhouse

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NOTE

[1] The data and results of this research project were processed and finalized within the doctoral dissertation of A. Lumini titled "*L'HBIM per la fruizione virtuale interattiva del Patrimonio Architettonico e dei metadati informativi. Il caso studio della Scuola di Guerra Aerea di Firenze*" *(HBIM for the interactive virtual fruition of Architectural Heritage and informative metadata The case study of the Florence Air Warfare School)*, University of Florence, Department of Architecture (DIDA), Italy, 2023, Tutor: Prof. S. Bertocci

[2] Laboratory of Architectural Survey

[3] The workshops were organized within Prof. S. Bertocci's Architectural Survey courses held in the A.A. 2017/18 and 2018/19.

[4] They represent a "mirror" of the three-dimensional point cloud datum in the form of a 2D raster image at a metric scale and referenced according to a user-defined point of origin.

[5] It should be noted that for the abbreviations in the "ID" columns of the following tables – as well as in some of the images – the Italian wording has been retained, as it was considered more appropriate for illustrating the logic of the proposed naming convention.

[6] Further differentiation has also been placed in the condition of individual "units": some are in fact intended to "host" elements within them (*guest*), while others are intended to be "housed" in other "units" (*host*).

CREDITS

The following are the credits related to the images. All images not expressly listed are intended to be entirely by the author.

Fig. 2 - Graphic reworking by the author on a Barsotti Brothers© photo

Fig. 3 - *Ibidem*

Fig. 4 - Graphic reworking by the author from Podestà, 2006, pp. 50-51 and on Barsotti Brothers© photos

Fig. 5 - Graphic reworking by the author on a Barsotti Brothers© photo

Fig. 6 - Graphic reworking by the author on ASFi, Fondo Fagnoni, b. 1-4 and Fondo Genio Civile, b. 260

Fig. 7 - Graphic reworking by the author on a Barsotti Brothers© photos

Fig. 8 - Graphic reworking by the author from Istituto LUCE, 1937, 1937a,b

Fig. 14 - Graphic reworking by the author with drawings developed within the research project "Architectural Documentation and Integrated Digital Survey of the Florence Air War School" carried out within didactic workshops from 2017 to 2021 by the Department of Architecture of Florence (DIDA) under the Scientific Responsibility of Prof. S. Bertocci and the Scientific Coordination of PhD M. Ricciarini and PhD A. Lumini

Fig. 15 - *Ibidem*

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