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Study and 3D survey of the Roman baths in the archaeological site of *Lilybaeum* (Marsala, Italy)

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Study and 3D survey of the Roman baths in the archaeological site of Lilybaeum (Marsala, Italy)

- *Case Study and Scope of Work*
- *The Archaeological Park of Lilibeo-Marsala and the Roman domus*
- *Methodology*
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  - *Data Processing and Integration*
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Case Study and Scope of Work

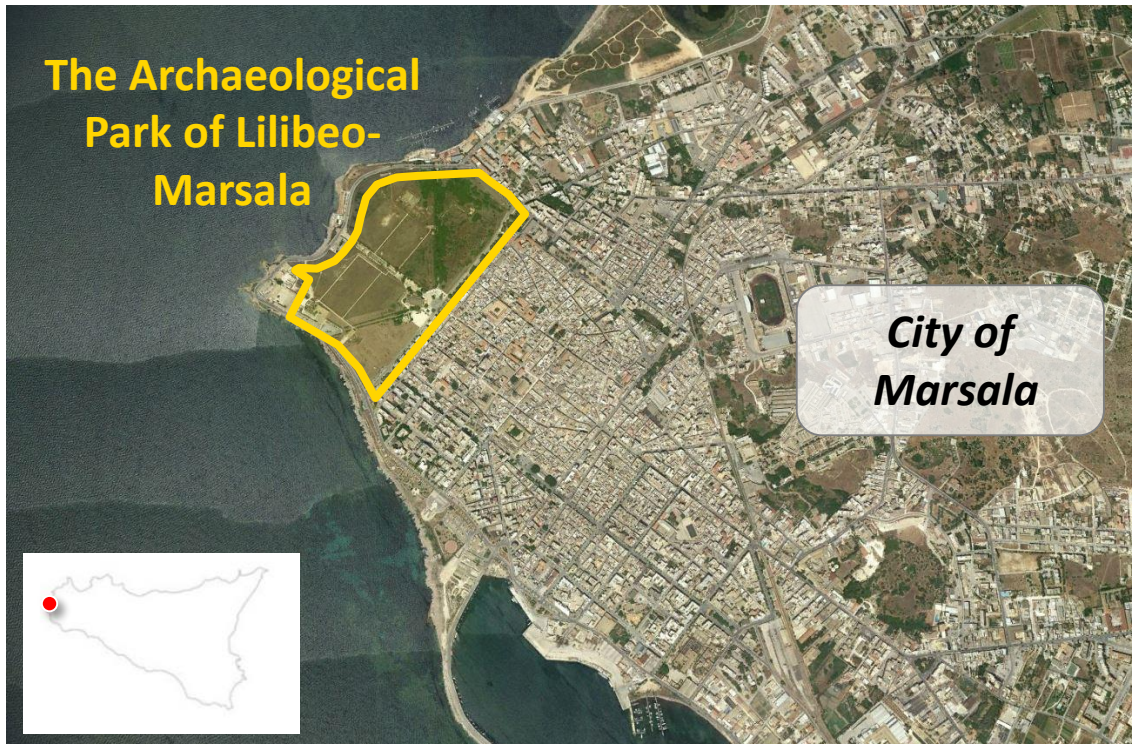
The **thermal baths** of the Roman *domus* in the Archaeological Park of Lilibeo-Marsala (Italy)

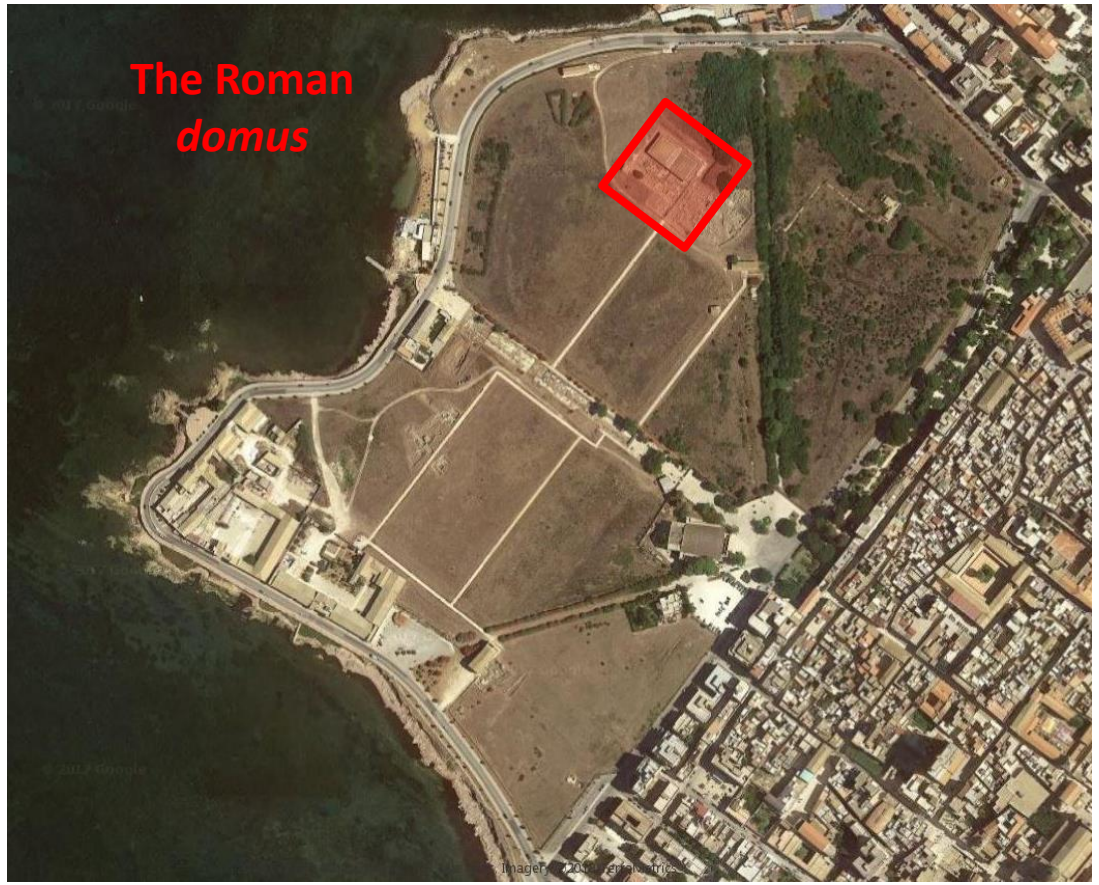
Scope of Work

- Describe **the large and complex archaeological areas** of the thermal baths through an integrated 3D survey.
- Develop a complete 3D model and a high-resolution orthophoto **for archaeological documentation and conservation purpose.**

The Archaeological Park of Lilibeo-Marsala

- The Archaeological Park of Lilibeo-Marsala **preserves the remains of the ancient city of Lilybaeum**, the modern city of Marsala.
- The north-east area of the Park is occupied by the ruins of ***insula* I**, that **holds ruins of a large and rich private residence, the so-called Roman *domus*.**





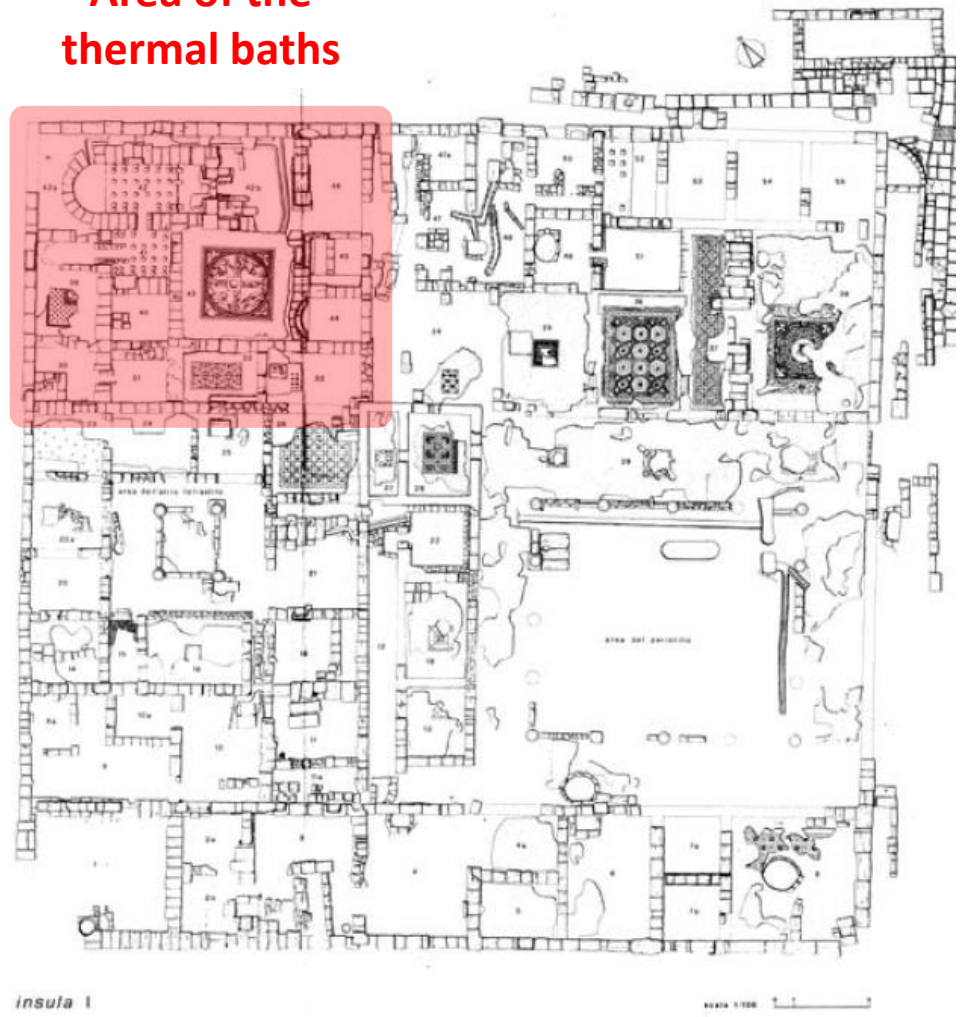
- At the end of the II century-beginning of the III century A.D., **north-western sector of the Roman *domus* was completely converted in thermal baths.**

The Archaeological Park of Lilibeo-Marsala

The Roman *domus*

- To protect the archaeological area, **the Roman *domus* was covered with a concrete roof.**
- The **presence of modern barriers,** as a wooden walkway that crosses the entire site and large pillars, **was a challenge for the surveying**.

Area of the thermal baths



- The *domus* shows an articulated structure with **many rooms decorated with polychrome mosaics, marbles and paintings.** The thermal baths are located in the north-western area.

The Archaeological Park of Lilibeo-Marsala

The Thermal Baths

- The Roman baths were generally supplied with water coming from an adjacent natural river or stream, or from an aqueduct.
  - The **water management**, in connection with the urban water distribution system and the implications of this for the location of baths, **offers an interesting example of how the water disposal of bath houses was integrated into a city's water management system**.

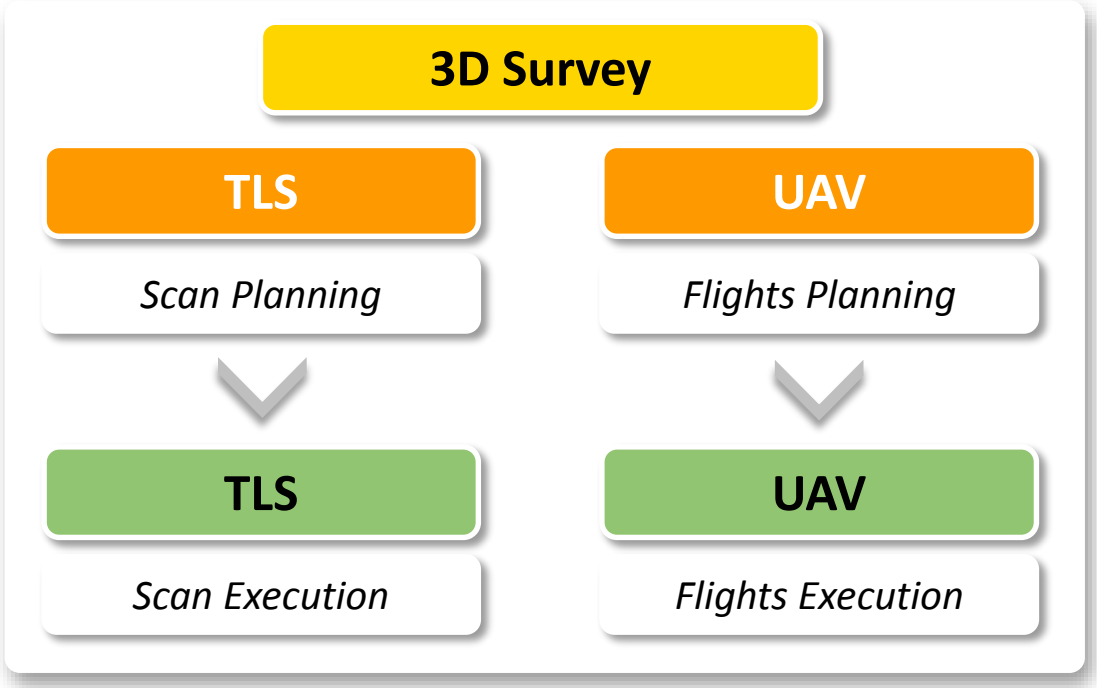
- Roman baths were organized according to a path in a clear sequence of rooms, which generally
  - started with a cold room (*frigidarium*)
  - crossed an intermediate one (*tepidarium*)
  - and ended in the hottest room (*calidarium*)

- The heating system was very sophisticated and hot air could circulate thanks to a system of *tubuli* and *suspensurae*, by heating floors and walls of the rooms

Methodology

- **Integration of Terrestrial Laser Scanner** (TLS) **and Unmanned Aerial Vehicle** (UAV) **methodologies** to record the thermal baths of the Roman *domus*.

Data Acquisition

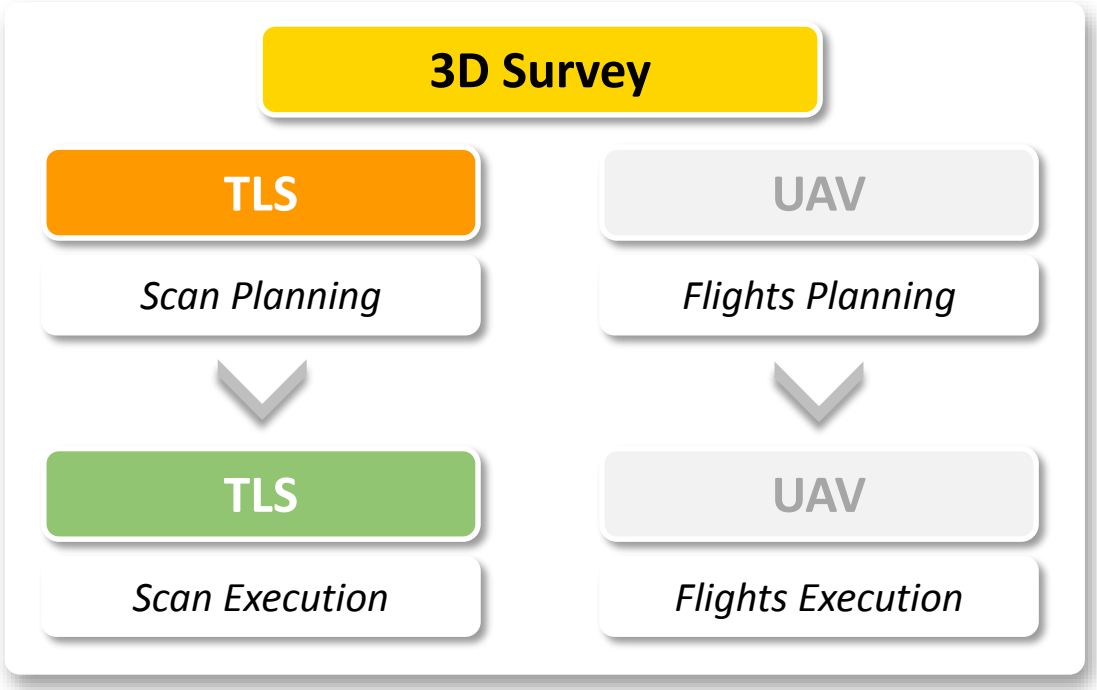


Data Processing and Integration

Data Acquisition

Terrestrial Laser Scanner (TLS) 1/2

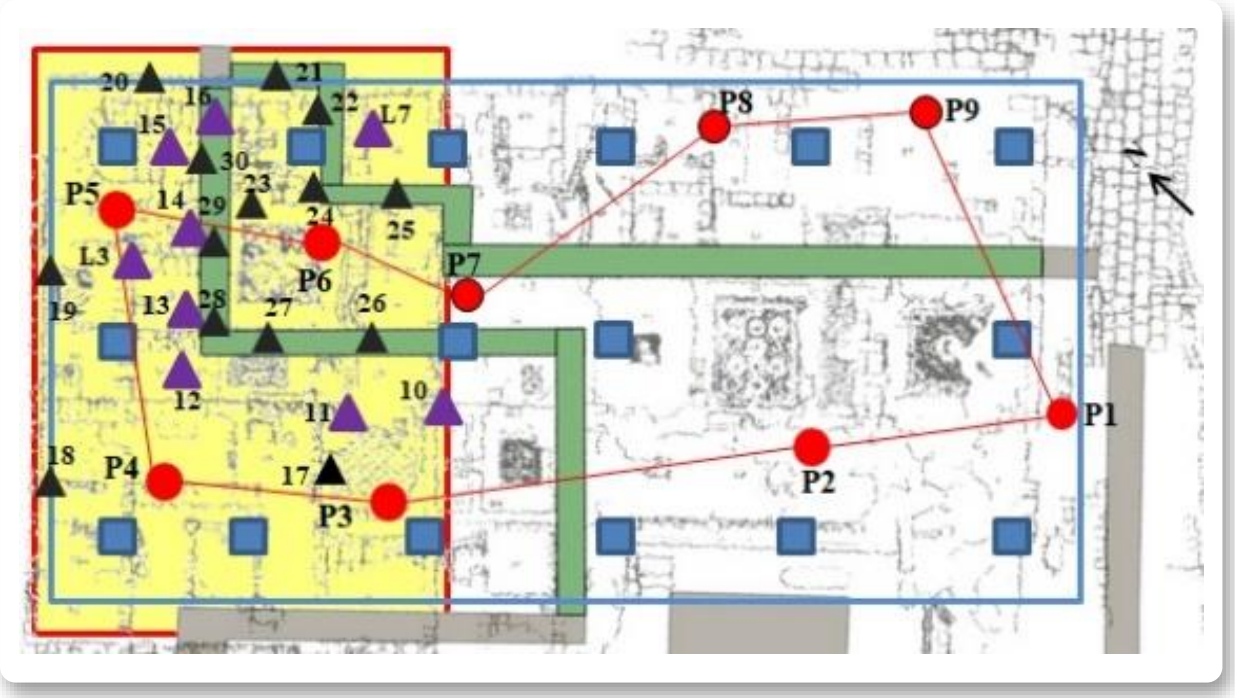
- In order to have the same reference system for all data **a topographic survey with a total** station was carried out to measure a topographic network inside the archaeological Park.
- To overcome logistical difficulties, **a first TLS acquisition of the *domus* was carried out with a Topcon GLS-2000 laser scanner**.
  - The device allows **using a topographic approach** by planning scan points along a traverse path.
  - In this way, scans are automatically registered in a topographic way, even without large overlapping areas.
- The GLS-2000 survey was planned to have **a reference point cloud** of the whole *domus*.

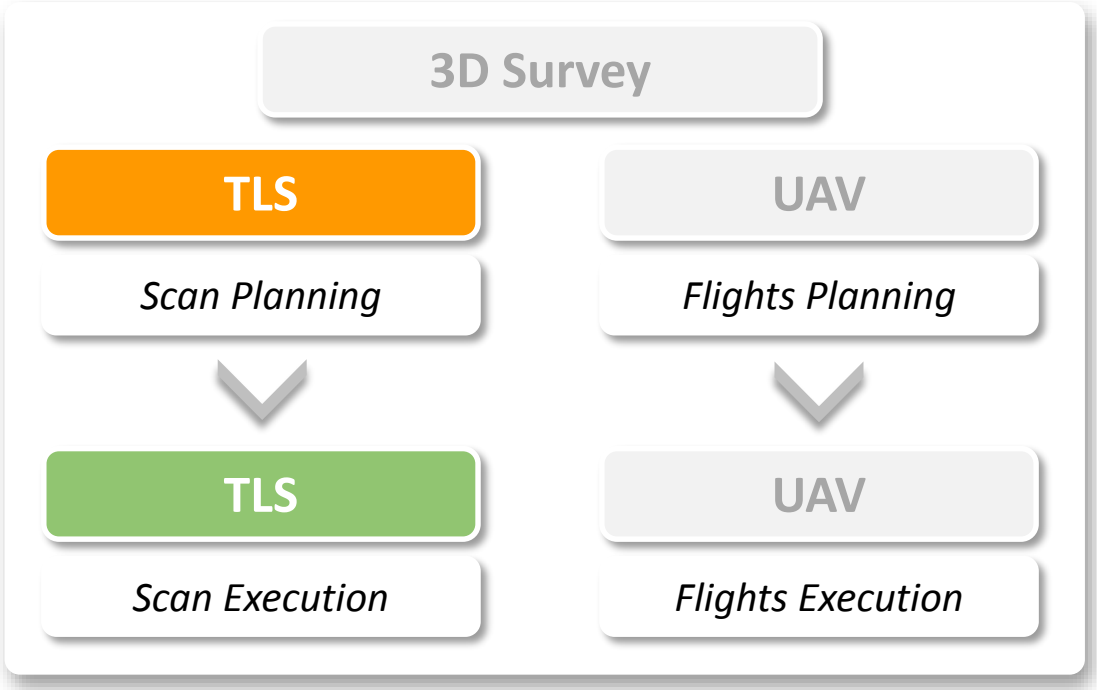


Data Acquisition

Terrestrial Laser Scanner (TLS) 2/2

- The **complexity of the preserved thermal structures**, with different heights and shapes, **caused many shaded areas that forced to complete this survey with other TLS surveys.**
- **To acquire in detail the thermal area**, additional scans were planned.
- **Two additional scan surveys** were planned with **high overlap with the reference point cloud:**
  - additional single scans were acquired **with the GLS-2000** too;
  - a **third scan survey** was realized **with a Faro Focus 3D.**



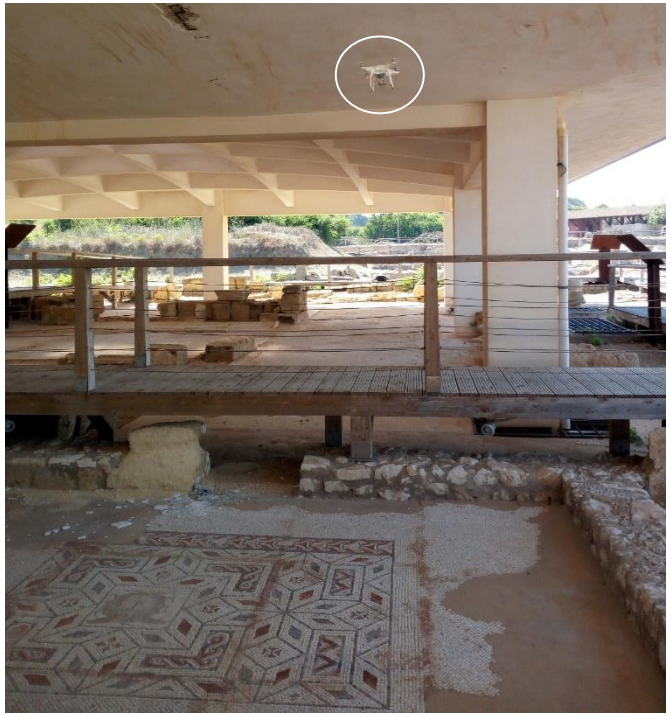


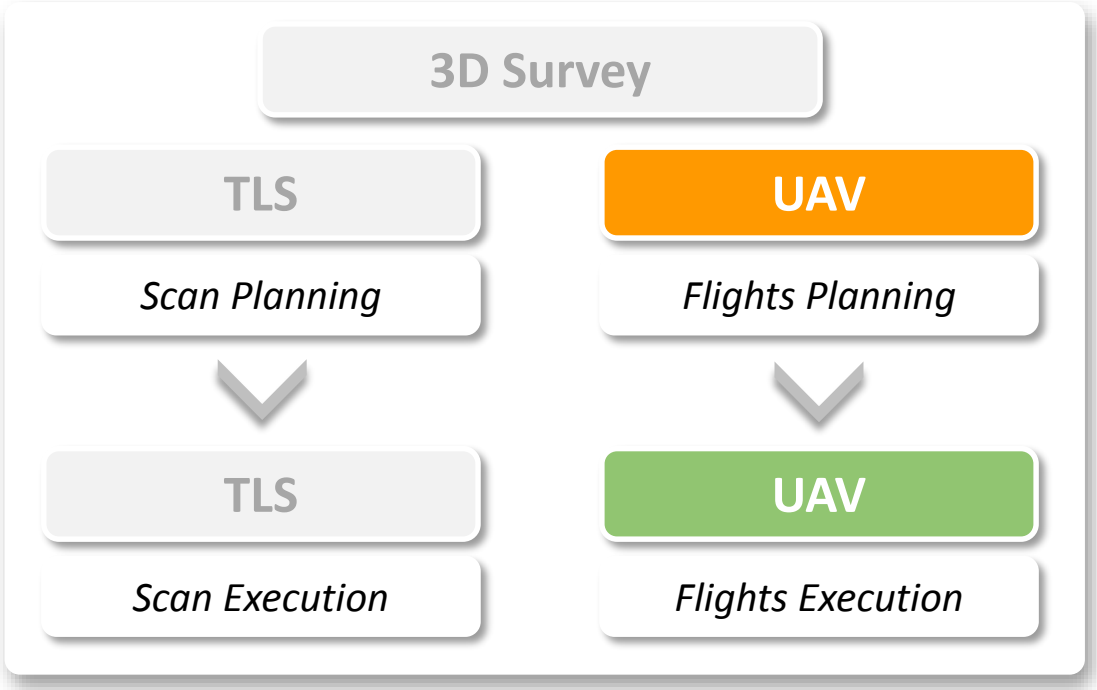
- GLS-2000 scans position along the traverse path
- Additional GLS-2000 scan positions of the thermal rooms
- Faro Focus 3D scan positions

Data Acquisition

Unmanned Aerial Vehicle (UAV)

- **To integrate** the TLS point cloud of the thermal rooms, **a low-altitude UAV survey** was carried out to generate a **detailed photo-realistic 3D model** and **a high-resolution orthophoto**.
- **The most significant difficulty** during all field recording operations **was determined by light conditions of the site.**





- **Due to the complexity of the area** (presence of large pillars) and the difficulty of maintaining GPS signal under the roof it was decided to **fly in manual mode.**
- Nadiral images were acquired at an approximate altitude of 3 m: a **total of 1590 images** were collected with a Ground Sample Distance (GSD) of about 0.8 millimeters.

Data Processing and Integration

3D Products - TLS

- In the first data processing phase, **the TLS and photogrammetric data were separately processed** and two 3D models were produced.

- All GLS-2000 scans along the traverse path were **automatically registered** due to the topographic approach (Topcon Positioning Magnet Collage software). A reference point cloud of about 8 million points was achieved.

- Additional single GLS-2000 scans were registered with a **cloud-to-cloud approach with the reference point cloud.** Root Mean Square Error (RMSE) between the reference point cloud and every single scan was in the order of 4÷5 millimeters. **A final point cloud of about 14 million points was generated.**

- **The GLS-2000 point cloud** was imported in Autodesk Recap in order to **carry out an automatic registration with the Faro scans.**

Final Point Cloud

- **A final points cloud** (GLS-2000 and Faro scans) of the Roman *domus* **of about 60 million points was produced.**

Data Processing and Integration

3D/2D Products - UAV

- In the first data processing phase, **the TLS and photogrammetric data were separately processed** and two 3D models were produced.

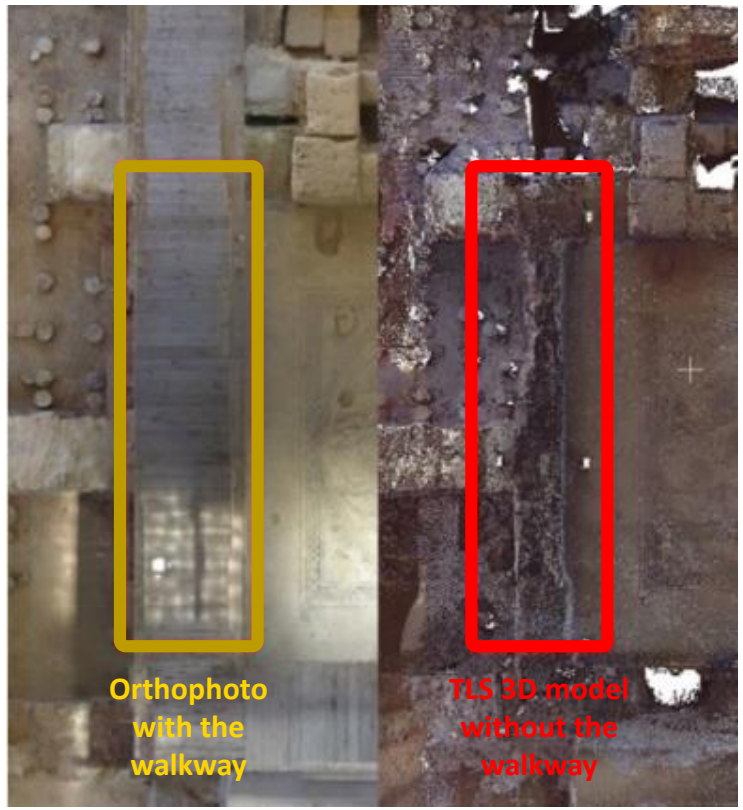
Final Ortophoto

- The photogrammetric dataset was processed with Agisoft MetaShape software. Accuracies of about few millimeters for north and east coordinates and of about 1 centimeter for height were obtained.
- The surface model of the thermal rooms was generated and textured to provide **a photorealistic representation of the archaeological area.**
- An orthophoto with a resolution of 2 mm was generated.
- Even though all images were modified before the post-processing step, light differences were still visible in the final product.

Data Processing and Integration

3D/2D Products - TLS and UAV Combination

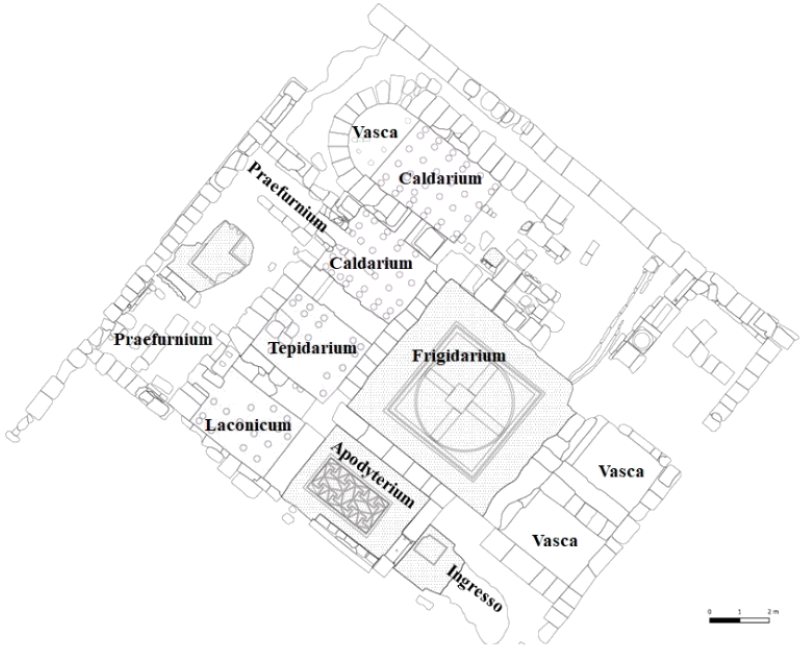
- In the second data processing phase, **both the TLS 3D model and the orthophoto of the thermal baths were used for the production of a 2D plan.**



Final drawing of archaeological structures

The TLS 3D model became useful to complete the items located under the wooden walkway, not visible in the orthophoto

Complete plan of the thermal structures was realized for research and conservation purposes



Conclusions

- The paper describes **an integrated TLS and low-altitude UAV survey** of the thermal baths of the Roman *domus* in the Archaeological Park of Lilibeo-Marsala.

- The work took advantage of the **multi-source approach** to describe, with a very high resolution, the remains of the archaeological site and its mosaics still in situ.

- The integrated survey has allowed achieving **a detailed and accurate 3D model and a high-resolution orthophoto** of the archaeological area in order **to document onsite structures**, with particular attention to mosaics documentation, and **to create an updated 2D and 3D documentation for future conservation and valorization projects**.

Thank You

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