DOCUMENTATION

# Revealing Tyndaris: a Technological Approach to Archaeological Conservation and Study

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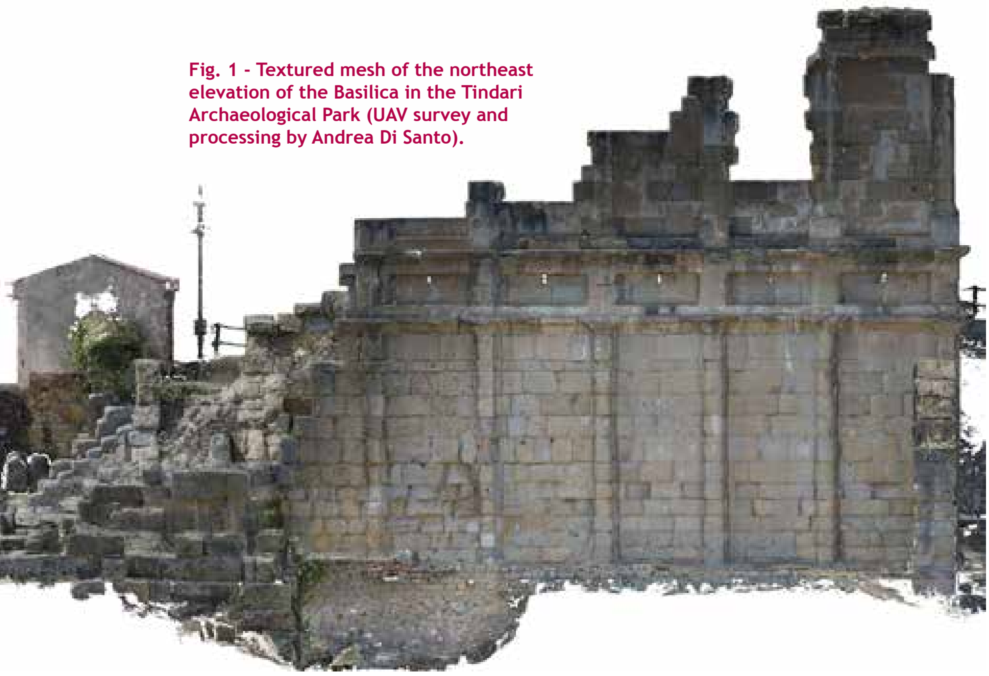

Fig. 1 - Textured mesh of the northeast elevation of the Basilica in the Tindari Archaeological Park (UAV survey and processing by Andrea Di Santo).

The archaeological site of Tyndaris (currently Tindari, municipality of Patti, province of Messina, Italy) served as the backdrop for an important technological and cultural initiative organized by mediaGEO on May 30, 2024: the "TECHNOLOGYforALL OnTheRoad".

The event brought together university professors, experts in geomatics, archaeology, and engineering, as well as industry professionals engaged in applying advanced surveying methodologies. The main objective was to create precise and detailed digital documentation of a site useful for conservation, study, and tourism enhancement.

During the event, a series of state-of-the-art surveying technologies were employed to map and meticulously document the topography and monuments of the ancient Greek, and later Roman, city in Sicily—an area for which a complete survey is still lacking.

According to Diodorus Siculus, the foundation of Tyndaris dates to 396/395 B.C., when Dionysius I of Syracuse allocated a territory on the northern coast of Sicily, opposite the Aeolian Islands, to six hundred Messenean mercenaries who fought under his command in a victorious campaign that led the Carthaginians to abandon the island in 393 B.C. This stable and formidable garrison of professional soldiers, adopting a mythical Messenean poleonym, established control over a territory taken from the Sicel city of Abakainon, an ally of Carthage. The area was inhabited and surrounded by largely hostile Sicel populations and centered on a promontory overlooking the sea.

Simultaneously, likely as a consequence of this new settlement, the nearby Hellenized indigenous center of Gioiosa Guardia nearly lost all vitality. From the Tyndarian promontory, an important pass along the coastal route was controlled, coinciding with the coastal terminus of a significant inland route. This position also allowed for the interdiction of a port area, possibly comprising two harbors, strategic for dominating the maritime routes of the southern Tyrrhenian Sea.

The chronological data of the foundation provided by the historical source, however, has not yet found confirmation in archaeological research. Both the oldest structures of the settlement, identified during excavations in the 1950s, and the earliest data from necropolis areas do not date beyond the second half of the 4th century B.C. Consequently, both the dating of the urban plan and the related chronological issue concerning the city walls remain uncertain and controversial in scholarly studies.

After over a century of conflict, with only a few decades of independence—amidst struggles involving Syracusans, leaders like Timoleon and Agathocles, Carthaginians, Mamertines, and Romans—in 254 B.C., a few years after the naval battle of Atilius Regulus against Hamilcar in the nearby waters, Tindari surrendered in fidem et amicitiam populi Romani, subsequently maintaining loyal conduct. From the 2nd to early 1st century B.C., evidence indicates lively public and private building activity in the city, adhering to experiences and models of Hellenistic and Italic architectural and figurative culture. Between the late Republican and early Imperial periods, coinciding with the arrival in Sicily of increasingly numerous and entrepreneurially aggressive Italian groups, villae began to appear in the territory.

Following the military events that pitted Sextus Pompey against Octavian in Sicily, the Imperial era saw the establishment of the Colonia Augusta Tyndaritanorum, with a probable widespread transfer of properties from the old local aristocracy to members of the new and victorious Augustan ruling class. This period also saw an intensification of presence in the surrounding countryside, as highlighted by systematic and intensive surface surveys conducted between 2010 and 2012 (Fasolo 2013, 2014). Among these new owners, Grypianus might be included, possibly connected with Iucundus Grypianus, who had land holdings in Egypt; the name of one of his freedmen emerged from an inscription reused centuries later in the Tyndarian territory at Patti, possibly in what was once his estate. Certainly, to him or another unknown prominent supporter of Octavian belonged a marble slab with a bas-relief depicting Apollo before the Temple of Victory on the Palatine, found during excavations in the area of the Roman villa of Patti Marina and probably displayed in a room of the dwelling that preceded the late antique villa.

However, Augustus's plans—envisioning a revival and significant role for the new Roman colony compared to a state of abandonment and depopulation (oliganthropia), as reported by Strabo—seem to have been abruptly interrupted due to a catastrophic event recalled by Pliny the Elder. Studies have not yet clarified the nature or the area affected by the disaster, but certainly, in the city, after an initial series of urban interventions in the early Imperial age, signs from the second half of the 1st century A.D. indicate a slowdown in building activity, both private and public, a financial crisis, and later evidence of a progressive decline in urban life. At the beginning of the 3rd century, stratigraphic data show a definitive abandonment of some urban building complexes and perhaps temporary abandonment of many others, also indicating a significant demographic contraction, likely exacerbated by epidemics.

A significant seismic event, identified by most scholars with the earthquake of 365 A.D.,

Fig. 2 - Textured mesh of the southeast elevation of the Basilica at the Tindari Archaeological Park (UAV survey and processing by Andrea Di Santo).

then led to the residential abandonment of the western and northwestern quarters of the city. Even in the countryside, stable settlement shrank, and if it did not disappear entirely, it certainly did not concentrate in Tindari. In the late antique or proto-Byzantine period, some scholars attribute the restructuring of the original Greek city walls to this time, in connection with Vandal incursions in Sicily between 440 and 475 A.D. In the southeastern sector of the city, this intervention incorporated the northwest wall of the so-called "Basilica" and marked a general narrowing of the urban perimeter.

From the 6th century onward, the settlement seems to lose any urban character, beginning to assume a rural aspect. In the last Byzantine phase of Sicily, Tindari, although still an episcopal seat (in the Basilica perhaps) , is perhaps reduced to merely a fortified outpost of the territory and a stretch of coast. A terminus ad quem for the end of the city could be derived, if we accept the identification of the toponyms M.d.nar or D.ndarah with Tindari, from the report of the city's conquest by Arab invaders in the year 835/836. Between the end of the 11th and the end of the 12th century, under Norman rule, Tindari was supplanted by Patti in the role it had held for centuries as the territorial center. In historical sources, it is not mentioned except indirectly as vetus civitas, reappearing as sedes Helene Tindaree only in 1282.

Archaeological research at Tindari began as early as the 18th century, with initial studies conducted by the Prince of Biscari and other contemporaries of the time. During the 19th century, further excavations were promoted by the Commission of Antiquities and Fine Arts, which led to the discovery and study of numerous artifacts and structures. In the 20th century, under the guidance of Paolo Orsi and Luigi Bernabò Brea, investigations became more systematic, revealing significant details about the urban planning and history of the site, including the discovery of the theater and the basilica.

## AMONG THE MONUMENTS SURVEYED WITH ADVANCED TECHNOLOGIES: THE BASILICA

The so-called "Basilica" is one of the most imposing monuments in Tindari, but its function remains a subject of debate. Some scholars identify it as a Hellenistic gymnasium, while others see it as a Roman basilica later reused as an episcopal residence. The building features a rectangular hall divided into eight sections, each separated by transverse arches supported by pillars. The interior had a vaulted roof and may have had one or more upper floors. The construction exhibits techniques typical of the Imperial Age, with the use of squared blocks and some elements in concrete work, indicating a chronology between the Hellenistic and Roman periods.

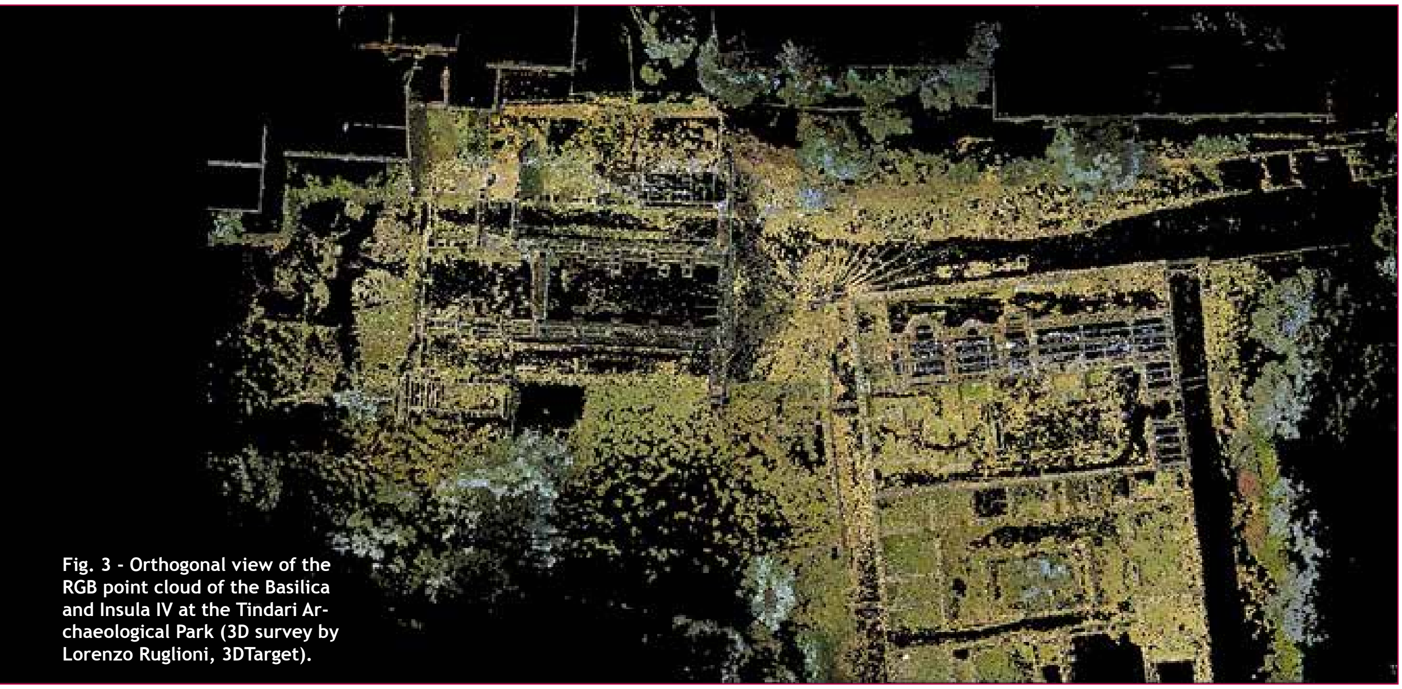

**Fig. 3 - Orthogonal view of the RGB point cloud of the Basilica and Insula IV at the Tindari Archaeological Park (3D survey by Lorenzo Ruglioni, 3DTarget).**

## THE GRECO-ROMAN THEATER

The theater of Tindari is one of the best-preserved monuments and has undergone several restoration campaigns, especially in the 20th century. Originally built in the Hellenistic period, it was expanded and modified in the Roman era to host circus performances. The cavea (koilon) has a diameter of about 76 meters and could accommodate up to 3,000 spectators. The structure rests against the hillside, while the wings are supported by massive substructure walls. The stage features typical elements of Greek theaters with paraskenia and a channel (euripus) for water drainage.

## THE FORTIFICATIONS

The defensive walls of Tindari, still visible today, display multiple construction phases. They are built with parallelepiped sandstone blocks in a double-faced structure. Some sections of the walls have been dated to the 3rd century B.C., likely constructed to protect the city from the threats of the Mamertines. Typical elements such as towers and gates have been identified, including a dipylon gate with a semicircular tenaille entrance, flanked by towers. The city walls include a sophisticated water drainage system and showcase various construction techniques that reflect Punic influences and subsequent Roman interventions.

## INSULA IV AND THE BATHS

Insula IV, located in the southeastern sector of the city, is one of the best-preserved blocks in Tindari. It comprises residential houses (including the so-called Houses B and C), baths, and tabernae. The baths are renowned for their mosaics, decorated with geometric patterns and figures such as the Trinacria and symbols of the Dioscuri. These mosaics attest to the stylistic influence of North African and local workshops active between the 2nd and 3rd centuries A.D. The houses were organized around porticoed courtyards, featuring cisterns and rainwater collection systems.

The collected data are currently being processed by mediaGEO:

- Processing of Point Clouds
- Creation of BIM Models
- Structural Analyses (Insula IV)
- Geographic Information Systems (GIS)

Some preliminary results are already promising:

The combined use of these technologies can offer an unprecedented view of the monuments. Not only does it digitally preserve the heritage, but it also makes it accessible and attractive on a global scale.
The "Technology for All" event in Tyndaris offered a unique opportunity to field-test a series of advanced tools, each with its own peculiarities, advantages, and some limitations. Below is a report that compares these instruments, highlighting their features and providing insights into their performance during the event.

## THE TECHNOLOGIES

*NavVis VLX 3 Wearable Mobile Laser Scanner*

The NavVis VLX 3 is a portable mapping system designed for scanning complex environments, both indoors and outdoors, while in motion. It is equipped with two 32-layer LiDAR sensors, four cameras for 360° imagery, and an integrated display for real-time monitoring.

• Main Features
Portable and wearable, it utilizes SLAM technology to capture detailed point clouds and can be integrated with georeferencing systems for increased accuracy.

• Advantages
Portability and Ergonomics: Being wearable, it allows smooth movement through complex archaeological sites.
Continuous Scanning. Ensures uninterrupted coverage without the need to reconfigure the scanner. Geospatial Data Integration. Compatible with global coordinates for integrated mapping.

• Possible Disadvantages
Challenges with Uniform Surfaces: SLAM technology may struggle in environments with few distinguishable features.
Limited Range: Not ideal for long-distance scans.
Sensitivity to Sudden Movements: Unexpected movements can compromise scan quality.

• Post-Processing:
Reliance on Automatic Software Cleaning: Although the software

can clean point clouds, residual artifacts in crowded environments may require manual corrections.
Complex Data Integration for Large Projects: When using data from multiple sources or sessions, integration can become complex and require advanced expertise.

• Post-Processing Considerations:
Supporting Software: NavVis IVION
Automatic and Real-Time Registration: Immediate visualization to identify any gaps.
Integrated Georeferencing: Improved accuracy thanks to compatibility with GNSS systems.
Automatic Point Cloud Cleaning: Automatic removal of moving objects.
Advantages: Reduced editing times, easy integration with CAD/BIM software for analysis and modeling.

*Leica BLK2GO*
Compact and Portable Laser Scanner: The BLK2GO is a lightweight and easy-to-use device designed for rapid and dynamic 3D data acquisition in indoor environments. It features a horizontal field of view of 360° and a vertical field of 270°, along with wireless data transfer.

• Main Features
Portable, fast, capable of 360° scans, includes an integrated imaging camera.

• Advantages
Extreme Portability: Ideal for exploring tight and narrow spaces.
360° Scanning: Complete coverage in a single pass.
Ease of Use: Autonomous startup, wireless data transfer.

• Possible Disadvantages
Medium Precision: Does not offer the same quality as more advanced scanners.
Limited Range: Suitable for short distances, not for larger structures.
Battery Life: Limited to short sessions without interruptions.
• Post-Processing
Dependence on Wireless Data Transfer: The connection can suffer interference, delaying data acquisition and transfer.
Less Advanced Noise Filtering: Filtering capabilities may not completely remove noise, necessitating manual cleaning.

• Post-Processing Considerations
Supporting Software: Cyclone REGISTER 360 (BLK Edition)

• Peculiarities
Wireless Transfer and On-Site Management: Real-time control to avoid coverage errors.
Point Cloud Optimization: Automatic filtering and enhancement.
Advantages: Efficient merging of scans, reduced editing times thanks to dynamic on-site previews.

*Leica RTC360*
High-Speed and High-Precision 3D Laser Scanner: The RTC360 is designed for rapid acquisition of extremely detailed data. It integrates HDR imaging and a VIS (Visual Inertial System) that automatically aligns point clouds.
Main Features: High precision, scanning speed up to 2 million points per second, automatic real-time registration.

• Advantages
Speed and Precision: Ideal for quickly covering large archaeological areas.
Automatic Registration: The VIS system reduces the need for complex post-processing operations.
HDR Images: Provide detailed and realistic models.

• Possible Disadvantages
Heavy and Expensive: Heavier and more costly than other scanners.
Requires Accurate Setup: Demands detailed installation and maintenance.

• Post-Processing
Large Volume of Data to Manage: High-resolution scans generate large files that require powerful systems for processing and storage.
Dependence on VIS Automatic Registration: In specific environments, automatic registration may not work perfectly, requiring manual alignments.

• Post-Processing Considerations
Supporting Software: Cyclone FIELD 360 and REGISTER 360

• Peculiarities
On-Site VIS Automatic Registration: Minimizes the need for manual alignments.
HDR Processing: Enhances the visual quality of models.
Advantages: Efficient merging of scans, seamless integration with CAD/BIM software for conservation and reconstruction projects.

*Stonex X70GO Model*
Portable 3D Laser Scanner with Dual Mode: The X70GO combines SLAM mode for dynamic scanning and static mode for detailed scans, integrating a 12 MP RGB camera to colorize point clouds.
• Main Features: SLAM and static modes, real-time processing, integrated georeferencing.

• Advantages
Dynamic and Static Modes (X-Whizz): Adaptability to precision and speed requirements.
Real-Time Processing and Preview: Reduces time for corrective actions on-site.
Georeferencing: Improves the accuracy of acquired data.

• Possible Disadvantages
Variable Precision in SLAM Mode: Scans may be less precise in challenging environments.
Limited Battery Life: Prolonged scanning sessions may require frequent battery replacements.

• Post-Processing
Complexity in Combining Different Modes: Integrating data acquired in dynamic and static modes may require additional steps, slowing down point cloud merging.
Dependence on Dedicated Software: If the software is not well-managed, obtaining precise alignments can be difficult.

• Post-Processing Considerations
Supporting Software: GOpost and Cube-3D

• Peculiarities
Flexible Data Processing and Optimization: Filtering and enhancing scans.
Dual-Mode Scanning: Facilitates the combination of dynamic and static data.
Advantages: Advanced point cloud optimization and management, precise georeferencing, and easy integration for detailed models.

*Lidaretto H32X on DJI Matrice 350 Drone*
UAV-Mounted Lidar System (Drone): The Lidaretto H32X, integrated with a GARMIN VIRB360 camera, is a versatile scanning system that can be mounted on drones, vehicles, or backpacks for aerial or mobile acquisitions. Ideal for large-scale mapping.
• Main Features: Mountable on drones, rapid aerial acquisition, point cloud colorization through 360° images.

• Advantages
Versatile Aerial Acquisition: Covers extensive areas difficult to explore on foot.
Integration with 360° Images: Adds visual information to point clouds for photorealistic models.
Speed and Efficiency: Rapid and detailed scanning of large areas.

• Possible Disadvantages:
Weather Conditions: Wind, rain, and other factors can affect flight stability and data quality.
Drone Regulations: Require special permits, which can delay operations.
Drone Battery Life: Limited battery duration requires frequent recharging breaks.

• Post-Processing:
Complexity in Managing Large Volumes of Aerial Data: Large amounts of data collected during flights may require considerable processing and management time.
Synchronization of Images and Point Clouds: Accurately combining lidar data and 360° images can be complicated, especially in case of alignment issues.


Fig. 4 - Orthomosaic of the tomb at Cercadenari, Tindari Archaeological Park (UAV survey and processing by Andrea di Santo).

• Post-Processing Considerations Supporting Software: Dedicated software from Alma Sistemi

• Peculiarities:
Multi-Source Processing and Point Cloud Colorization: Combines lidar and 360° images for photorealistic models.
Automated Flight Planning: Optimizes data collection to uniformly cover large areas.
Advantages: Enhanced visual models and efficient data management for large areas, ideal for presentations and detailed analyses.

## FINAL CONCLUSION

Post-processing is a critical phase in archaeological surveying. Each tool offers different solutions for data optimization and management:

• *NavVis VLX 3*: Efficient with automatic registration and cleaning, but complex when integrating data from multiple sources.
• *Leica BLK2GO*: Quick transfer and on-site control, but with limitations in automatic noise filtering.
• *Leica RTC360*: Minimizes manual alignments but requires complex management of large data volumes.
• *Stonex X70GO*: Flexibility with dynamic and static modes, but difficulties in integrating mixed data.
• *Lidaretto H32X on Drone*: Excellent for covering large areas with photorealistic models, but requires precise management of data synchronization.

The choice of the right tool should consider the specific needs of the project, balancing speed, precision, and data integration capabilities to create accurate and useful models in the field of archaeological conservation and presentation.

The "Technology for All on the Road 2024" event in Tindari demonstrated how technological innovation can serve culture. The integration of advanced surveying techniques offers powerful tools for the conservation, study, and promotion of cultural heritage. With data processing underway, the community eagerly awaits the final results, which promise to shed new light on Tindari's rich history and become a model for future similar initiatives.

| Tool | Manufacturer | Type and Description | Precision | Acquisition Speed | Main Features | Possible Disadvantages | Post-Processing Peculiarities | Recommended Uses |
|---|---|---|---|---|---|---|---|---|
| NavVis VLX 3 (used by Dyna-Tech) | NavVis GmbH | Wearable Mobile Scanner | High | Scanning in motion | Real-time wearable feedback | Challenges with uniform surfaces, limited range, complex data integration from multiple sources | Automatic registration, data cleaning | Complex surveys, indoor and outdoor |
| Leica BLK2GO (used by 3DTarget) | Leica Geosystems | Compact and Portable Scanner | Medium | 420,000 points/s | Compact scanning, fast, wireless transfer | Medium precision, limited range, battery life limitations, noise filtering limitations | Wireless transfer, dynamic optimization | Complex indoor spaces, dynamic surveys |
| Leica RTC360 (used by GEOMAX) | Leica Geosystems | High-Speed and High-Precision 3D Scanner | Very High | 2 million points/s | Rapid and automatic registration, HDR images | Heavy, expensive, requires complex setup, large data volume | Automatic VIS, detailed HDR models | Large-scale documentation, high precision |
| Stonex X70GO Model | Stonex | Portable 3D Scanner with Dual Mode | High | SLAM/Static Modes | Portable real-time preview, integrated georeferencing | Variable SLAM precision, battery limitations, complex data integration | Advanced filtering, dual dynamic mode | Dynamic and detailed surveys, speed and precision |
| Lidaretto H32X + DJI Matrice 350 | Lidaretto | Mobile Scanner on UAV (Drone) | High | High (varies with drone flight) | Versatile, UAV-mounted, 360° image integration | Weather conditions, drone regulations, battery life, data synchronization complexity | 3D colorization, automated flight planning | Aerial surveys, mapping complex terrains |


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### Abstract

*The archaeological site of Tyndaris (currently Tindari, municipality of Patti, province of Messina, Italy) served as the backdrop for an important technological and cultural initiative organized by mediaGeo on May 30, 2024: the "Technology for All on the Road 2024".*
*The event brought together university professors, experts in geomatics, archaeology, and engineering, as well as industry professionals engaged in applying advanced surveying methodologies. The main objective was to create precise and detailed digital documentation of a site useful for conservation, study, and tourism enhancement.*
*During the event, a series of state-of-the-art surveying technologies were employed to map and meticulously document the topography and monuments of the ancient Greek, and later Roman, city in Sicily—an area for which a complete survey is still lacking.*



### Keywords

Archaeology; Technologies; survey; Lidar; scanner 3D;



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