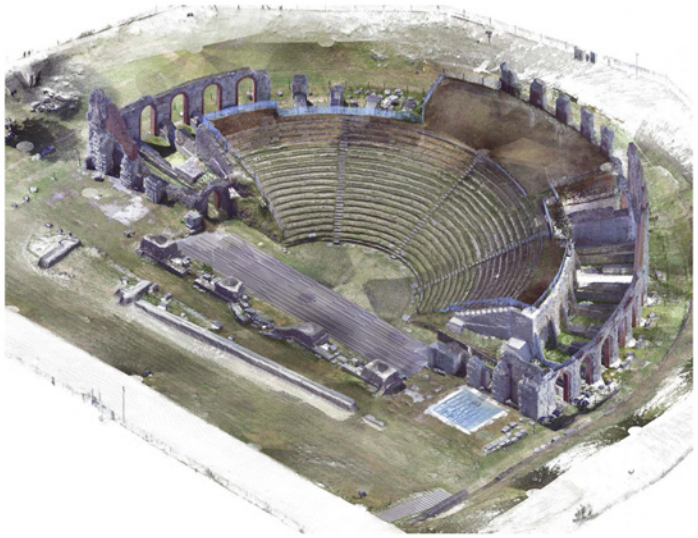
REALITY CAPTURE WORKSHOP



Digital Technology
in service of
Historical Research and Preservation

REALITY CAPTURE WORKSHOP OBJECTIVES

TEST THE 3D DIGITAL DOCUMENTATION TOOLS IN COMPLEX HISTORICAL ARCHITECTURAL AND URBAN ENVIRONMENT

DEVELOP A SYSTEM FOR 3D DATA ACQUISITION AND MANAGEMENT AT THE URBAN SCALE

PROVIDE NEW 3D TOOLS AND METHODOLOGY FOR ARCHAEOLOGICAL AND ARCHITECTURAL RESEARCH

WHY VOLTERRA?

COMPLEX, HISTORICAL URBAN ENVIRONMENT WITH STRUCTURES FROM ALL PERIODS OF THE 3,000 YEARS OF HISTORY

CLOSE RELATIONSHIP WITH THE CITY DEVELOPED THROUGH 30 YEARS OF COLLABORATION

SUITABLE SCALE OF THE HISTORICAL CITY FOR THE EXPERIMENTAL PROJECT

ON-SITE WORKSHOPS AND YEAR-ROUND, SYSTEMATIC COLLABORATION

REALITY CAPTURE WORKSHOP IS A LONG-TERM PROJECT TO CREATE A COMPLETE DIGITAL DOCUMENTATION OF A HISTORICAL CITY AND A METHODOLOGY FOR THE INFORMATION DISSEMINATION.

VOLTERRA

The city of Volterra was established more than 3,000 years ago and contains historic sites dating back to the fourth century BC. As well as being one of the oldest continuously inhabited cities in the world, it also is home to the world's oldest standing Etruscan arch. The city also contains one of the best examples of a Roman Theatre, excavated just 60 years ago, and continues to reveal new archaeological treasures such as a Roman Amphitheatre discovered in 2015. An international team of architects, engineers, and historians are using innovative technologies including drones, photogrammetry, and laser-scanning reality capture techniques to digitally record the city's buildings, archeological sites and artifacts.

Digital preservation of this type is important to better document and monitor important architectural treasures as they deteriorate over time. It provides highly accurate three dimensional digital replicas which support more in-depth detailed examination of the structures, opening the door to discovering new aspects of their designs and construction not understood before. These techniques also provide a basis for a faithful reconstruction in case of a natural disaster or to preserve the memory of the structures if they cannot be rebuilt.

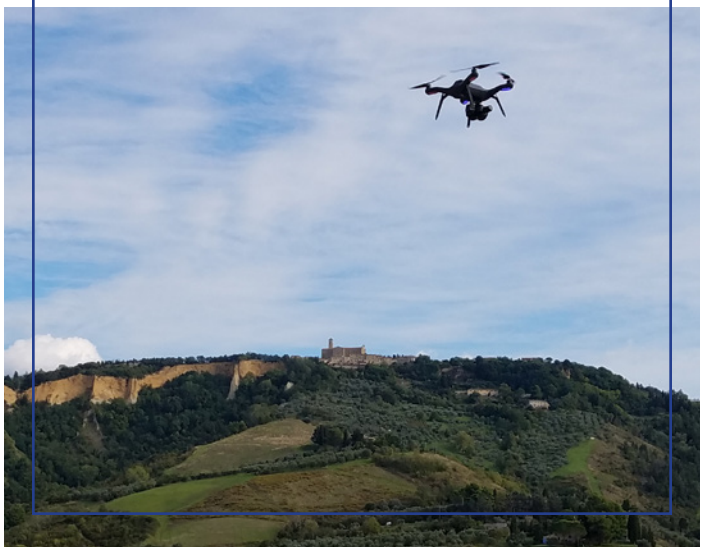
+ DIGITAL TECHNOLOGY

LASER SCANNING

Terrestrial laser scanners are used to perform highly accurate scans. Laser scanners record millions of measurements along the irregular surfaces providing incredibly accurate virtual replicas including every stone, joint and crack. Many scans are needed to record the surfaces from multiple angles which are then registered together into a comprehensive three dimensional point cloud using Autodesk ReCap software. ReCap is also used to clean up overlapping points as well as any unwanted objects such as people or cars. Finally, the point cloud may be submitted to an Autodesk cloud service which converts the points to a triangulated and photo textured mesh model which may be used for real time navigation and virtual reality applications. Point clouds may also be linked to Autodesk Revit software and used as a dimensionally accurate underlay for the production of a Building Information Model.

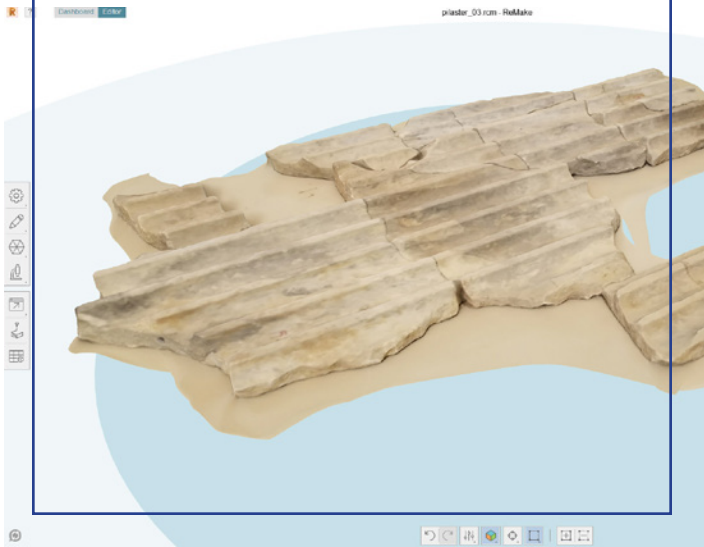
AERIAL PHOTOGRAMMETRY

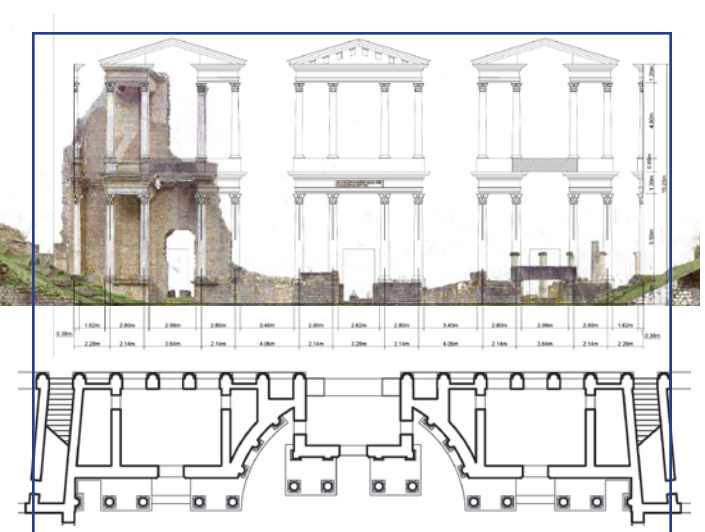
Unmanned Aerial Vehicles (UAV's or Drones) equipped with high resolution cameras are utilized to photograph large sites and sections of the city from many angles including overhead. The digital photos are then uploaded to Autodesk's ReCap 360 photogrammetry web service which stitches them together into a three dimensional model. The resulting model may then be downloaded as a point cloud and/ or a photographically textured mesh model and used for the same purposes as the laser scan. Furthermore, point clouds produced from UAV's have been combined with ones from laser scanners providing complete models from ground level and air.



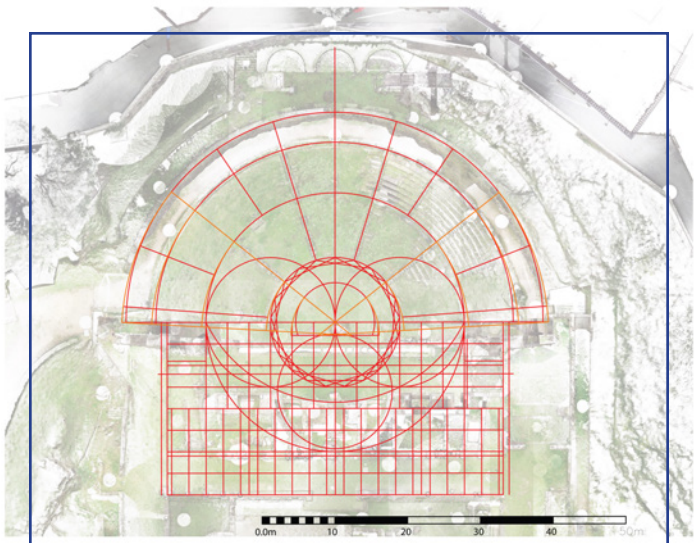
PHOTOGRAMMETRY

Smaller objects such as sculptures, ornamentation and building fragments are recorded with high resolution digital cameras or even cell phone cameras. Photographed from many angles with overlap, objects are then reconstructed digitally using photogrammetry process built into Autodesk ReMake software, or by uploading to a cloud service. The resulting three dimensional textured mesh model may then be cleaned up in ReMake using mesh modeling tools. The final object models may be incorporated into larger contextual models such as a statue in a church and may also be reconstructed physically through three dimensional printing.





Existing documentation of the ancient sites and structures is often very poor, if it exists at all. Therefore, if a structure is damaged and is needed to be rebuilt (Volterra lost part of the medieval wall to a landslide in 2014), the virtual models produced from the scans will provide the city extremely accurate and photo-realistic three dimensional documentation which it may utilize to rebuild faithfully to the original condition. Furthermore, this new three dimensional virtual model documentation will be utilized to present the assets of the city through web-based exhibits and virtual reality applications allowing anyone in the world to experience and study these important archeological treasures. Finally, the virtual models will be used by the Etruscan Museum in Volterra as part of their quest to provide better education to its visitors on these historically and culturally significant landmarks.



Understanding the design and construction principles along with the geometrical systems employed by architects and builders of significant ancient structures has always informed future generations in their quests to create their own beautiful structures. We have discovered through this project that the incredibly rich and detailed models produced from scans provide a far better tool to research these structures in an in-depth, multi-dimensional way, leading to discoveries that were not possible using traditional documentation. Furthermore, the models produced from scans of archeological remnants make it far more efficient to accurately create virtual replicas of the structures at the time they were built. These techniques have already led to new, exciting research discoveries, and will undoubtedly lead to many more as we engage others in the research efforts.

Preserving these historically significant structures for as long as possible so that they may be experienced in person by as many people as possible is obviously an important objective. However, deterioration and settlement over time is inevitable. By scanning these sites again in the future, we will be able to perform comparison analysis to identify and study better the severity of deterioration. We believe that these comparison analyses will provide insight into what may be causing more significant deterioration and study ways to prevent or at least slow the process down. We also hope to be able to identify significant shifts in the structures that may then be proactively fortified, heading off collapse.

DOCUMENTATION and PRESENTATION RESEARCH PRESERVATION

ON-SITE WORKSHOPS OCTOBER 2016 AND JULY 2017

VOLTERRA 2016

VOLTERRA 2016


VOLTERRA 2016


GUBBIO 2017

DOCUMENTATION and PRESENTATION

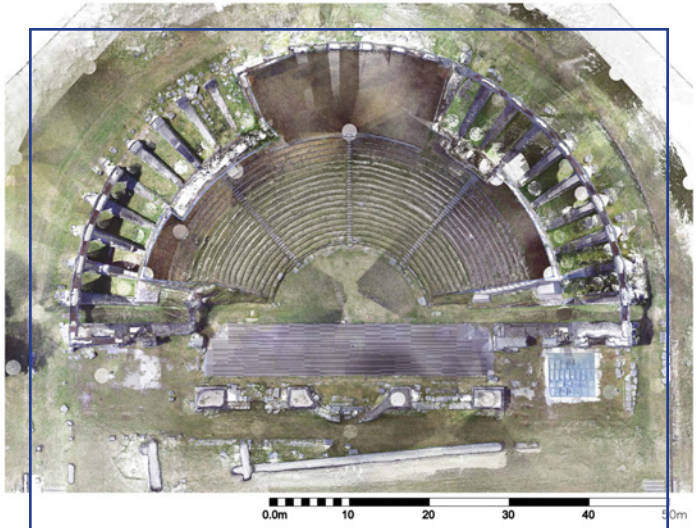
The point cloud model of a historical structure is a complete, faithful 3D digital replica of the original form, in full scale. As such, it allows to create a perfectly faithful documentation of the building, as well as become a source of any type of 3D information that can be required.

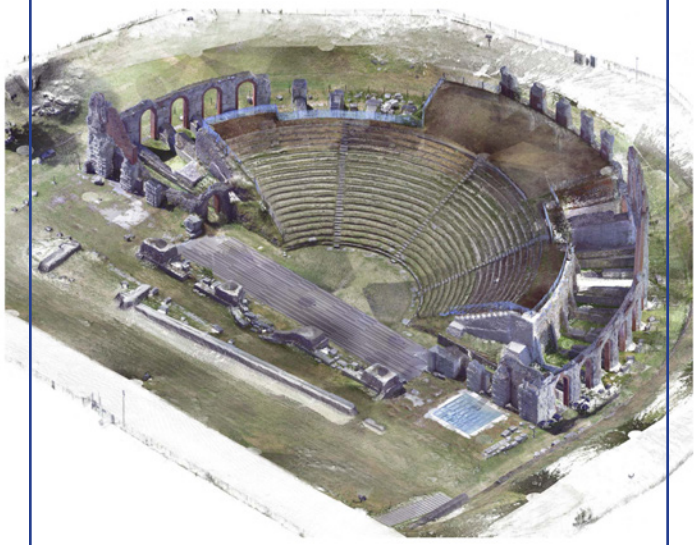
In case of the ruins of the ancient structures, the precise documentation fo the existing condition allows to research also the original design and form.

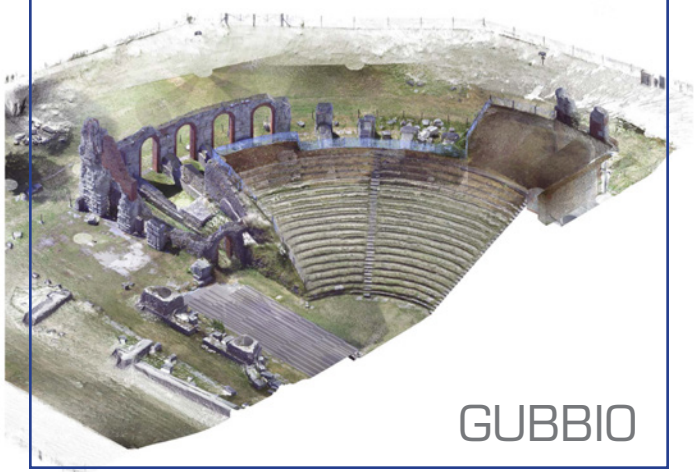
During the first on-site event in October 2016, a laser scan was done of the Roman Theater in Volterra. Based on the data obtained this way, a new and important discovery was made about the design techniques in antiquity (see the RESEARCH page). The discovery inspired further research on the subject of the Roman Theater design, as well as branching off the Reality Capture Workshop. **The benefits of access to the faithful 3D replica of the ancient structure became most evident in this case**, and therefore the study was followed with scans of two more Roman Theaters: in Gubbio and iin Fiesole. The other two theaters were selected because of their similar scale and geographic and historical proximity.

Comparative data and documentation from all three scans (and potentially more in the future) became the foundation of the new interpretation of the historical information. Thus created documentation will become also a basis for a study of ancient building techniques, as well as 3D digital reconstructions of the structures.

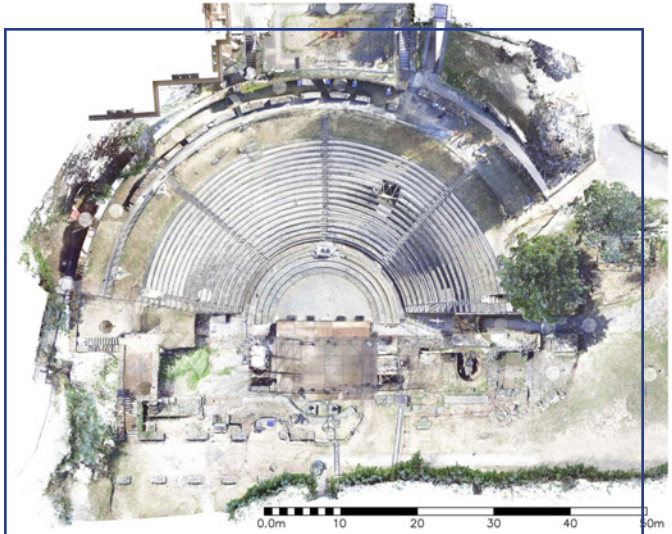
The process of 3D digital documentation and reconstruction provides invaluable input about the construction logic and techniques, as well as function and composition of the ancient structures.

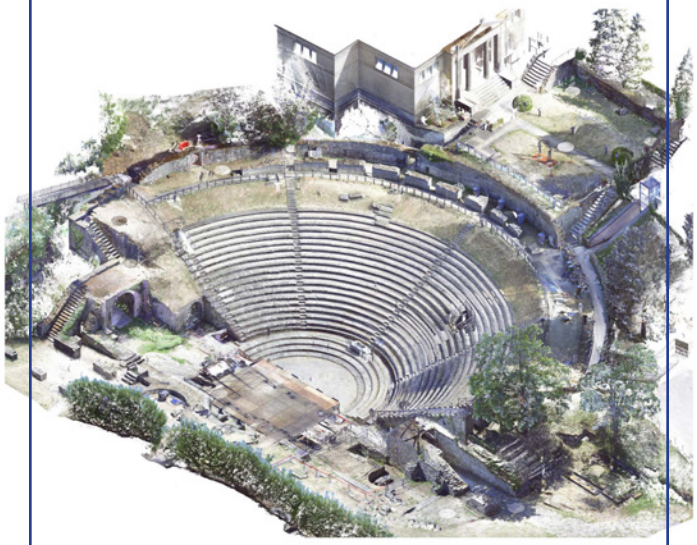






GUBBIO



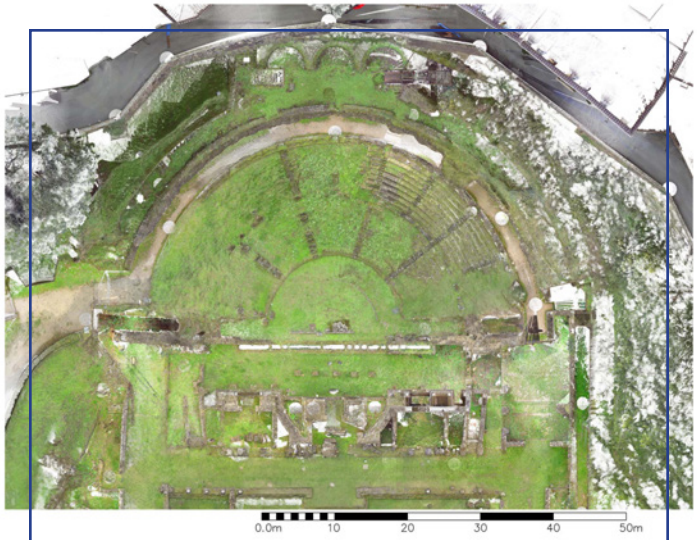


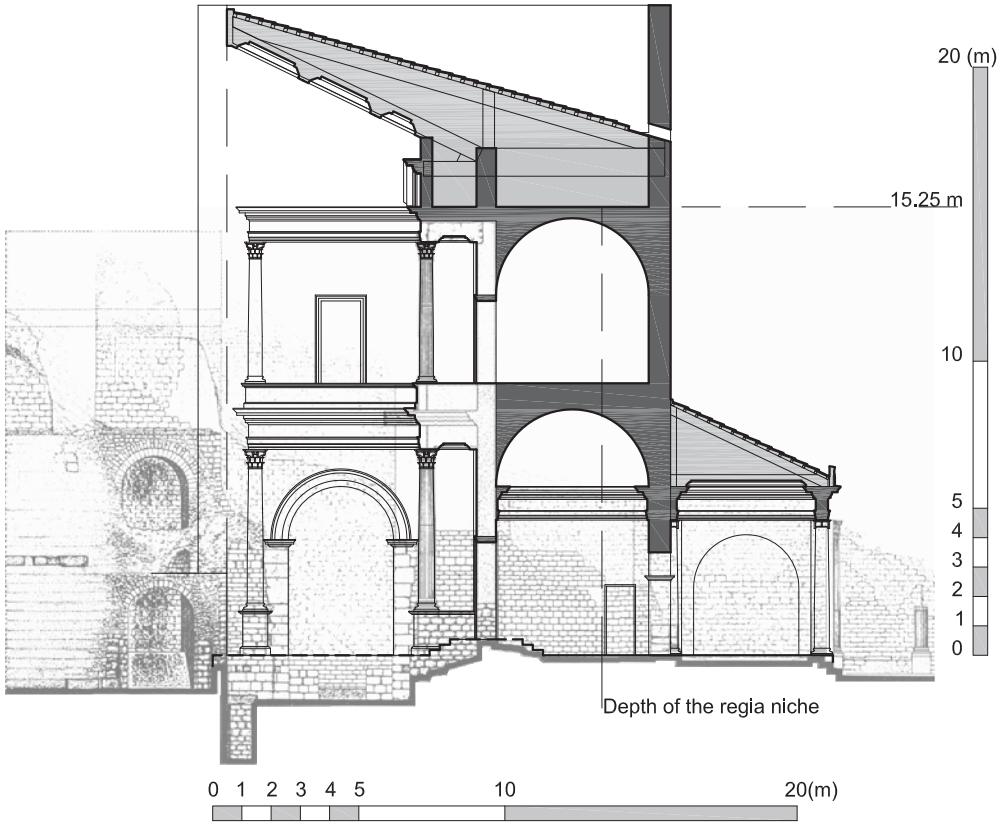
FIESOLE

DOCUMENTATION and PRESENTATION

VOLTERRA

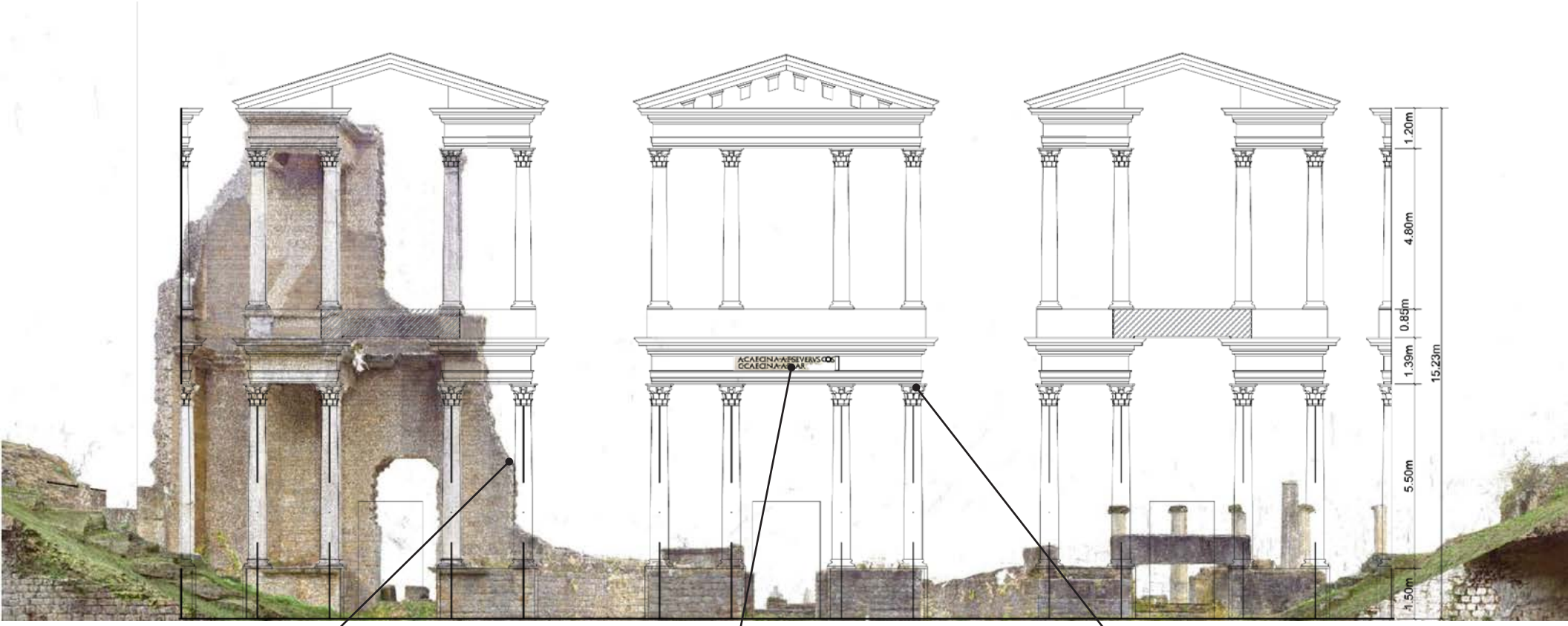
Original 3d laser scan and the documentation and interpretation drawings, cross section of the restored *scaenae* building, and the 3D model superimposed over the 3D point cloud.





DOCUMENTATION and PRESENTATION

ROMAN THEATER in VOLTERRA Individual pieces of the marble decoration of the Roman theater, found in various locations and often in multiple pieces, are being recorded in 3D with use of photogrammetry. They are being virtually restored to their original location in the 3D model of the structure. The complete catalog of the decoration fragments is developed in collaboration with the Sopraintendenza della Archeologia in Florence.



Pilaster fragment (in 7 pieces), Tunisian marble (yellow), Current location: Museo Guarnaci

Plaque fragment (in 4 pieces), Carrara marble (white), Current location: Archeological storage

Corinthian capitel (built into a wall), Carrara marble (white), Current location: Pieve Corbano

DOCUMENTATION and PRESENTATION

ROMAN THEATER in VOLTERRA For the purpose of presentation, the digital 3D model of the reconstruction Roman Theater was rendered in 3DS MAX as well as processed in Revit Live and Stingray software, to create a Virtual Reality experience of the original structure.

Volterra Roman Theater - 3D digital reconstruction

Virtual Reality system in Volterra - July 2017

Volterra Roman Theater - Virtual Reality model and rendering

R E S E A R C H

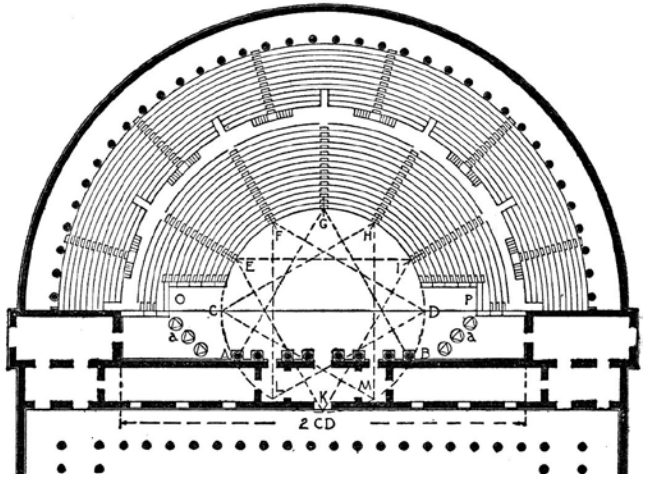
ROMAN THEATER DESIGN METHODOLOGY

The simplicity and elegance of the Vitruvian geometric system of the Roman-style theater was for centuries one of the primary examples of the Roman architectural design methodology. The 12-pointed star inscribed in the circle of the orchestra became an icon of the modern knowledge of the classical architecture.

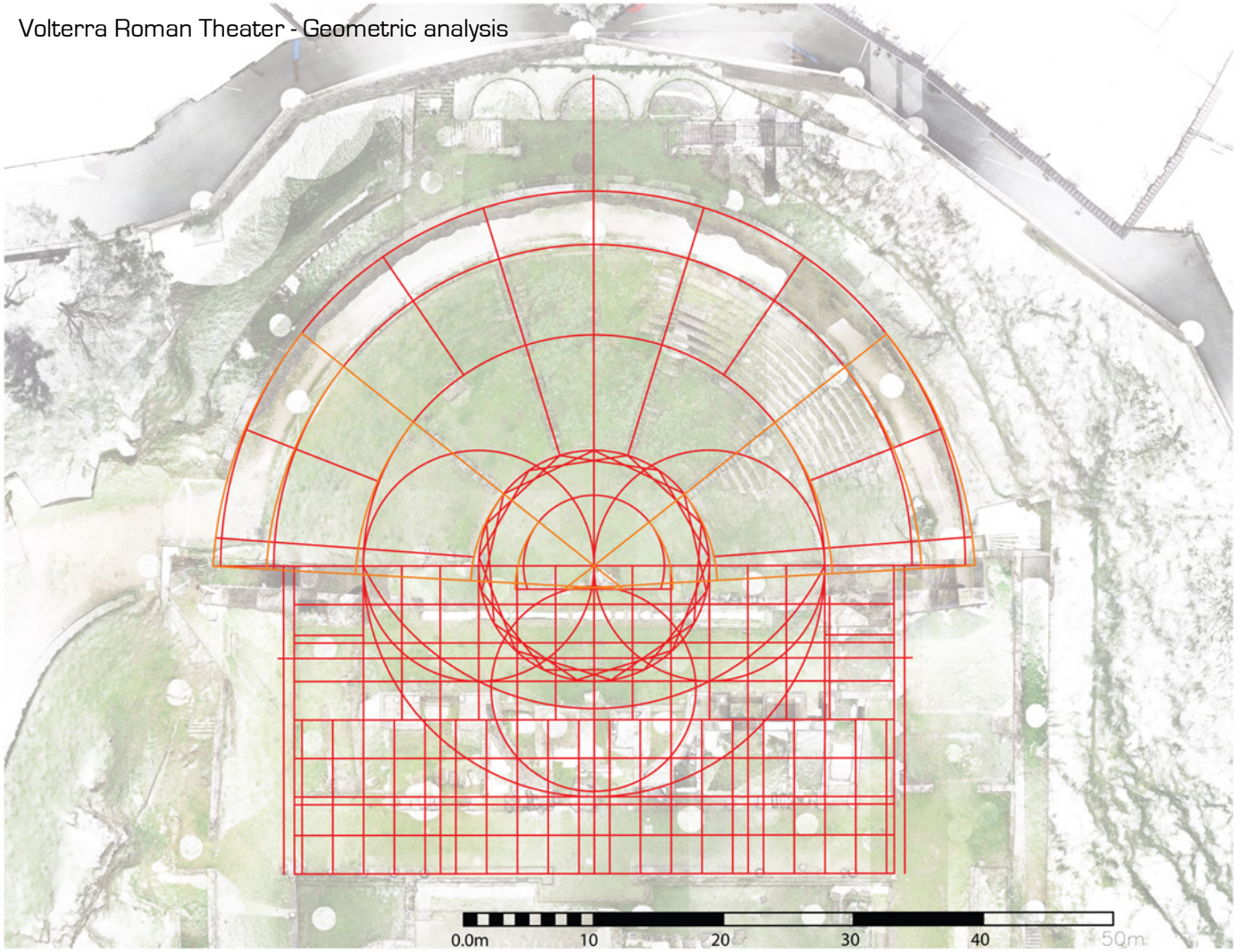
The theater archetype is clearly recognizable in all extant structures of this type, though their layouts vary significantly. However, the geometric model described by Vitruvius fails to explain all of them. It has been believed nevertheless that the ancient architects generally followed the Vitruvian principles, adjusting them where needed.

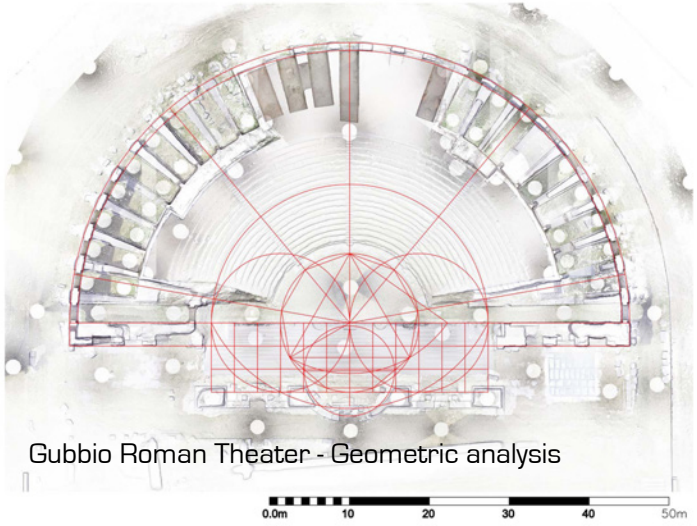
The three-dimensional laser scans and thus obtained data of unprecedented precision show that Roman architects in fact did not use the Vitruvius guidelines, but utilized in the design process a much more flexible and adaptable geometric system.

Below: Vitruvian diagram of the geometric system of the Roman Theater design.

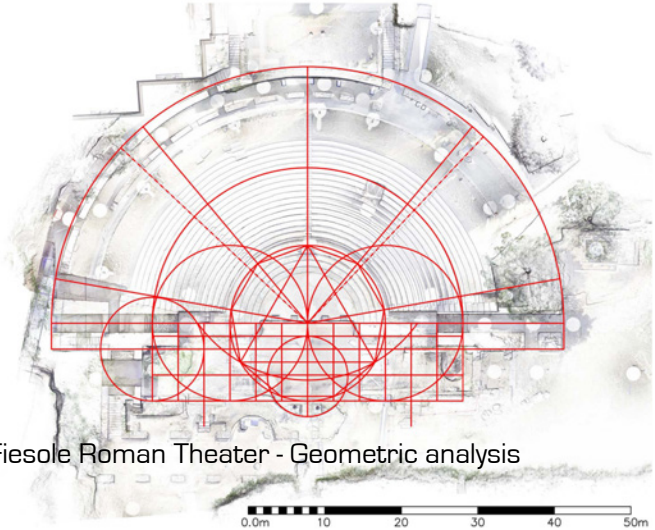


Volterra Roman Theater - Geometric analysis





Gubbio Roman Theater - Geometric analysis



Fiesole Roman Theater - Geometric analysis

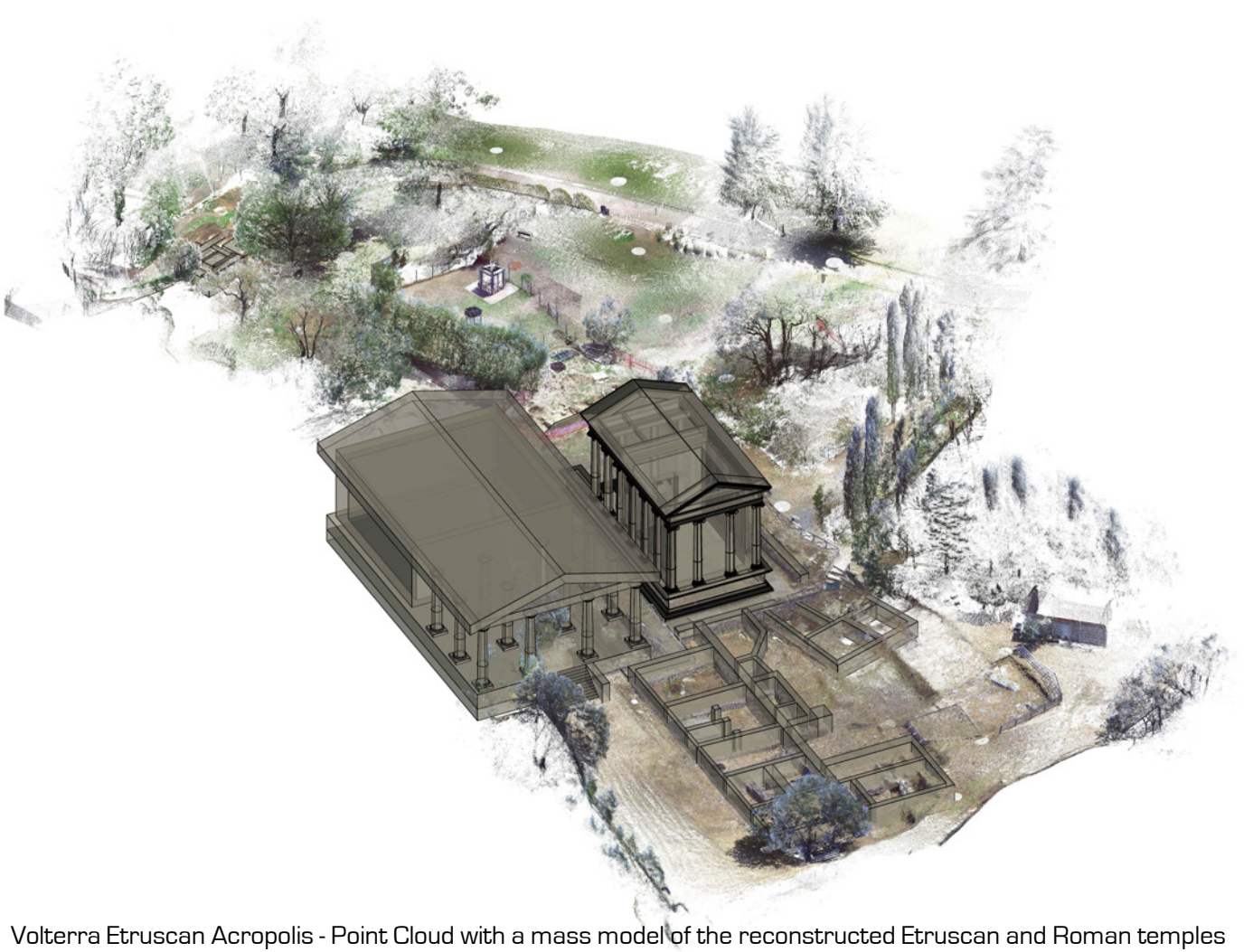
RESEARCH

VOLTERRA ETRUSCAN ACROPOLIS

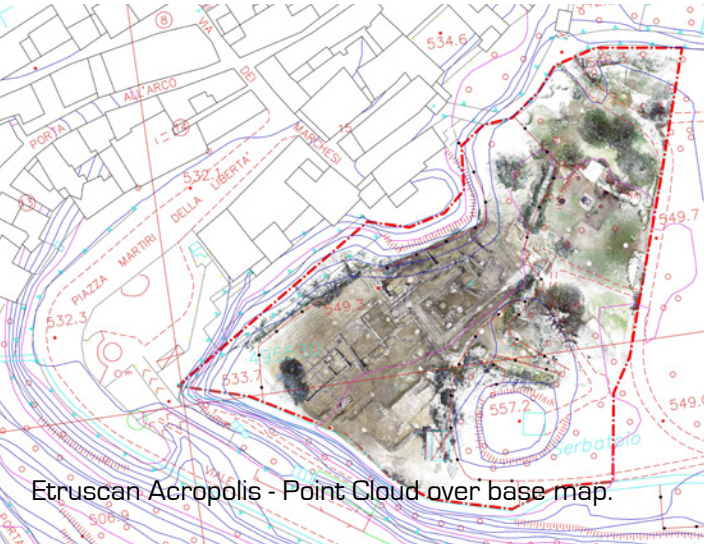
The archaeological zone of the ancient Acropolis in Volterra is located in one of the highest points of the city, at an elevation of over 550m above the sea level. The excavations in the Volterra Acropolis have uncovered an area dedicated to religious activities, dating back to 7th century BCE. Several religious buildings and other structures, were built there during different periods of time.

The laser scan of the Acropolis, including the most recent excavations, revealed the mutual relationships between the structures of the hilltop which had not been recognized before. Following the research, the Soprintendenza della Archeologia of Tuscany has revised its previous plans for future excavations in the area. The new interpretation of the urban composition of the Acropolis will likely generate new research of this area, as well as reevaluation of the historical significance of the site in Volterra, and in the entire Etruscan culture.

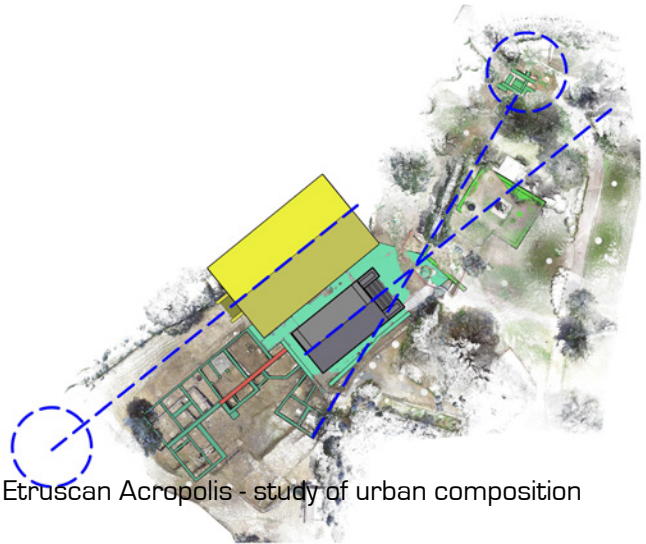
The Etruscan Acropolis site was also used as the topic of the International Design Workshop in July/ August 2017



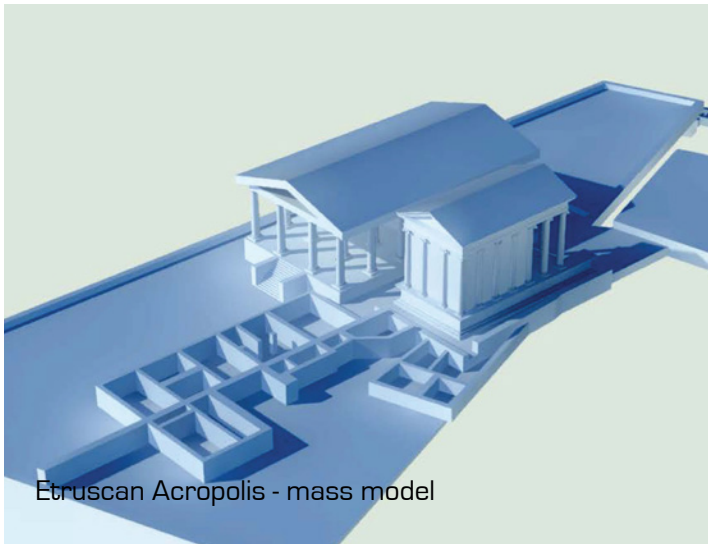
Volterra Etruscan Acropolis - Point Cloud with a mass model of the reconstructed Etruscan and Roman temples



Etruscan Acropolis - Point Cloud over base map.



Etruscan Acropolis - study of urban composition

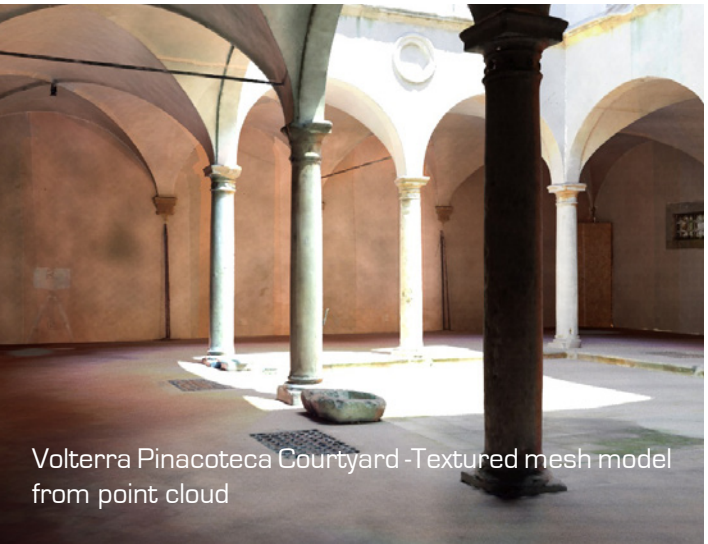


Etruscan Acropolis - mass model

PRESERVATION

Etruscan Gate - Textured mesh model from point cloud

Volterra Palazzo dei Priori Council Room - Textured mesh model from point cloud



Volterra Pinacoteca Courtyard -Textured mesh model from point cloud

Preservation is a long term process. It is based on a profound understanding of the past, and it is aimed for the future.

Preservation has to deal with the effects of the past, and the present, on the historical environment.

Preservation has to prepare also for the problems which may arise in the future.

Preservation combines the material from Documentation, with the knowledge obtained from Research, as well as the expertise of responsible agencies (in case of theis project the Soprintendenze della Archeologia in Tuscany and Umbria).

The 3D Laser scanning process will certainly replace the traditional methods of documentation through measured drawings. The systematic, periodical laser scanning of the historical built environment can provide invaluable data about the changes in the physical condition of the structures, and therefore become the most essential tool in the future historical preservation methodologies.

Volterra has seen multiple natural disasters in the past, the most common of which are landslides. The 3D replica of the city may become a critical tool for controlling the earth movements, as well as - if needed - resore the damaged structures to their original condition.

Volterra land slide 2014

Volterra Le Balze - huge landslide from 17 century

COLLABORATION

The Reality Capture Workshop is an international collaborative project, which connects the needs, the expertise, the software and hardware support and research potential into a dynanmic, flexible entity, which benefits all parties.

The Professional and Corporate partners can test their tools againts the most demanding practical applications and built environment.
The Educational and Research partners have an opportunity to work with the latest professional digital tools, and gain access to the most comprehensive data.

The Community partners learn new facts about the built environemnt in their care and new tools of their preservation and management.
They also obtain a new ability to present the historical and artistic value of their cities to the local community and to the world.

Professional Partner*

Soprintendenza della Archeologia Toscana (Italy)

Soprintendenza della Archeologia Umbria (Italy)

International (Italy-US) Educational Foundation*

Comune di Fiesole (Italy)

Comune di Volterra (Italy)

Comune di Gubbio (Italy)

US University School of Arcihtecture*

3D ROBOTICS - hardware support: UAV (Unmanned Aerial Vehicles - drones)
FARO - hardware support: Laser Scanners.
AUTODESK - software support and software development opportunities.
PROFESSIONAL PARTNER (*) - Provides connection with the corporate support and practicing professionals and their experience.
INTERNATIONAL FOUNDATION (*) - Provides support in organizing the on-site events, as well as connection with the Italian partners.
US UNIVERSITY (*) - Provides interpretation and research support, as connection with the student body and testing of the project outcome in the academic environment.
COMUNE DI VOLTERRA (and other) - City administration, which provides access and basic information about the sites.
SOPRINTENDENZA DELLA ARCHEOLOGIA - Provides research knowledge and support, as well as critical interpretation of the data.

Professionals and students who participate in the on-site events and workshop collaboration

*** Name of the organization is not shown to preserve the anonymity of the submission.**

WORKFLOW

WWW
DATA PRESENTATION
AND ACCESS

3D DATA
CATALOG
& ARCHIVE

VIRTUAL REALITY PRESENTATIONS AND DISPLAY

ASSEMBLY AND ANALYSIS OF THE 3D DATA, SYSTEMATIZATION, DOCUMENTATION AND RESEARCH
AUTODESK AUTOCAD
AUTODESK REVIT

DUE TO THE EXTREMELY LARGE QUANTITY, COMPLEXITY, AND VARIETY OF DATA, THE WORKFLOW IS SUBJECT TO CONTINUOUS EXPERIMANTATION AND CHANGE. NEW PATHS FOR WORKFLOW ARE BEING DEVELOPED TO ALLOW FOR EXCHANGE AND INTEGRATION BETWEEN FILE FORMATS.

3D MODEL CREATION AND EDITING

AUTODESK RECAP
AUTODESK REMAKE

PHOTOGRAPHS

3D SCANNING

A C T I V I T Y

EVENTS AND PRESENTATIONS:

OCTOBER 10-22 2016
FIRST REALITY CAPTURE ON-SITE WORKSHOP IN VOLTERRA

JANUARY 2017
PAPER PRESENTATION OF THE VOLTERRA ROMAN THEATER RESEARCH AT THE ARCHEOLOGICAL INSTITUTE OF AMERICA CONFERENCE IN TORONTO

JUNE 25 - JULY 5 2017
SECOND REALITY CAPTURE ON-SITE WORKSHOP IN VOLTERRA, GUBBIO AND FIESOLE

JUNE 28 2017
PRESENTATION OF THE REALITY CAPTURE WORKSHOP PROJECT OUTCOME TO THE COMMUNITY OF VOLTERRA

JULY 25 - AUGUST 6 2017
INTERNATIONAL DESIGN WORKSHOP IN VOLTERRA BASED ON THE 3D LASER SCAN OF THE ETRUSCAN ACROPOLIS

SEPTEMBER 2017
PRESENTATION OF THE ROMAN THEATER RESEARCH AT THE CONFERENCE IN VOLTERRA

3D DATA CREATED:

2016:

VOLTERRA:
ROMAN THEATER (1 century BCE)
ETRUSCAN GATE (4 century BCE)
BAPTISTERY (11 century CE)
PALAZZO DEI PRIORI (13 century CE)
THE GATE AND THE FOUNTAIN OF SAN FELICE (13 century CE)
PINACOTECA COURTYARD (15 century CE)

MULTIPLE INDIVIDUAL OBJECTS THOUGHOUT THE CITY.

2017:

VOLTERRA:
ETRUSCAN ACROPOLIS (7-2 century BCE)
ROMAN ROOM IN THE GUARNACI MUSEUM

MULTIPLE DECORATIVE ELEMENTS FROM THE ROMAN THEATER.

GUBBIO:
ROMAN THEATER (1 century BCE)

FIESOLE:
ROMAN THEATER (1 century CE)

NEXT STEPS

EVENTS AND PRESENTATIONS:

JANUARY 2018
PAPER PRESENTATION OF THE ROMAN THEATER RESEARCH AT THE ARCHEOLOGICAL INSTITUTE OF AMERICA CONFERENCE IN BOSTON (Paper submitted)

APRIL 2018
THIRD REALITY CAPTURE ON-SITE WORKSHOP IN VOLTERRA

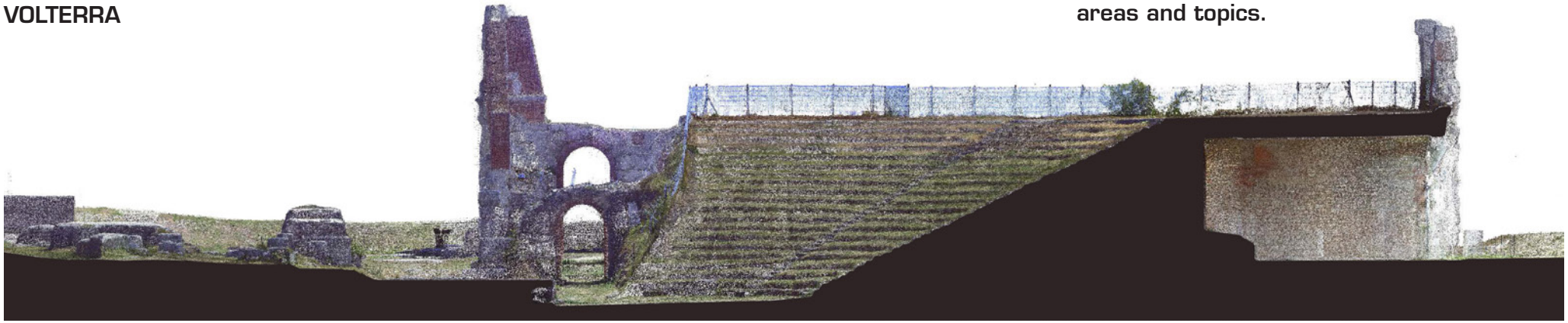
RESEARCH AND INTERPRETATION:

Volterra Carta Archeologica (complete archeological database of the city). In collaboration with the Soprintendenza della Archeologia in Tuscany. Create the tools for the 3D archeological database of Volterra.

Continue research of the Roman Theaters, their design technique and principles.

Continue research of the Roman Theater in Volterra, the 3D database of the extant structure and decorative elements (in collaboration with the Soprintendenza della Archeologia in Tuscany).

Support and facilitate research of other areas and topics.



CONCLUSION

SINCE THE FIRST EVENT IN OCTOBER 2016, THE REALITY CAPTURE WORKSHOP ALREADY SUPPLIED DATA WHICH BECAME THE FOUNDATION OF VERY SIGNIFICANT RESEARCH IN THE AREA OF ARCHEOLOGY AND ARCHITECTURAL HISTORY.

THE SAME DATA IS BEING USED BY THE CORPORATE PARTNERS TO FURTHER THEIR RESEARCH ON THE NEXT GENERATION PRODUCTS.

WE ARE CERTAIN, THAT AS WE CONTINUE TO WORK ON THE PROJECT, THE WORKSHOP WILL OFFER NUMEROUS OPPORTUNITIES FOR NEW EXCITING DEVELOPMENTS.

THE REALITY CAPTURE WORKSHOP HAS BECOME AN INNOVATIVE AND UNIQUE INTERDISCIPLINARY RESEARCH TOOL, CONNECTING ACADEMIA, HISTORICAL PRESERVATION ADMINISTRATION, PROFESSIONALS AND THE CORPORATE PARTNERS.