EDICULA

Educational Digital Innovative Cultural heritage related Learning Activities

Project Code: 2020-1-EL01-KA203-079108

NATIONAL TECHNICAL UNIVERSITY OF ATHENS [GREECE]

SAPIENZA UNIVERSITA DI ROMA [ITALY]

BEZALEL ACADEMY OF ARTS AND DESIGN [ISRAEL]

PerpetielSI SRL

PERPETIELSI SRL [ROMANIA]

ISRAEL ANTIQUITIES AUTHORITY [ISRAEL]

HELLENIC RESEARCH INSTITUTE OF THE ALEXANDRIAN CIVILIZATION [GREECE]

The EDICULA Project | MULTIPLIER 1 [E1]:
The Historic City of Jerusalem, The Holy Sepulchre: A Hands-on Experience

The Rehabilitation of the Holy Aedicule of the Holy Sepulcher

NATIONAL TECHNICAL UNIVERSITY OF ATHENS
Chief Scientific Supervisor, Prof. Antonia Moropoulou

NTUA Interdisciplinary Team:
Prof. E. Korres, Prof. A. Georgopoulos, Prof. A. Moropoulou, Prof. C. Spyrakos, Assist. Prof. Ch. Mouzakis, Deputy Construction Site Manager

Co-funded by the Erasmus+ Programme of the European Union

NATIONAL TECHNICAL UNIVERSITY OF ATHENS

INTERDISCIPLINARY RESEARCH GROUP FOR THE MONUMENTS PROTECTION

The Rehabilitation of the Holy Aedicule of the Holy Sepulcher

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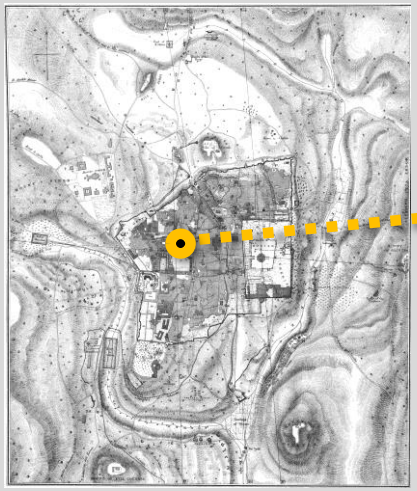
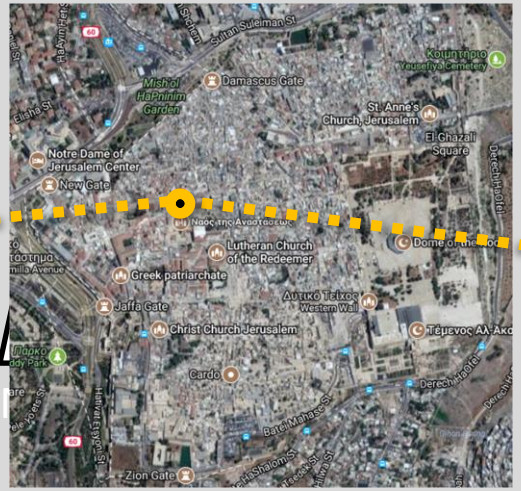
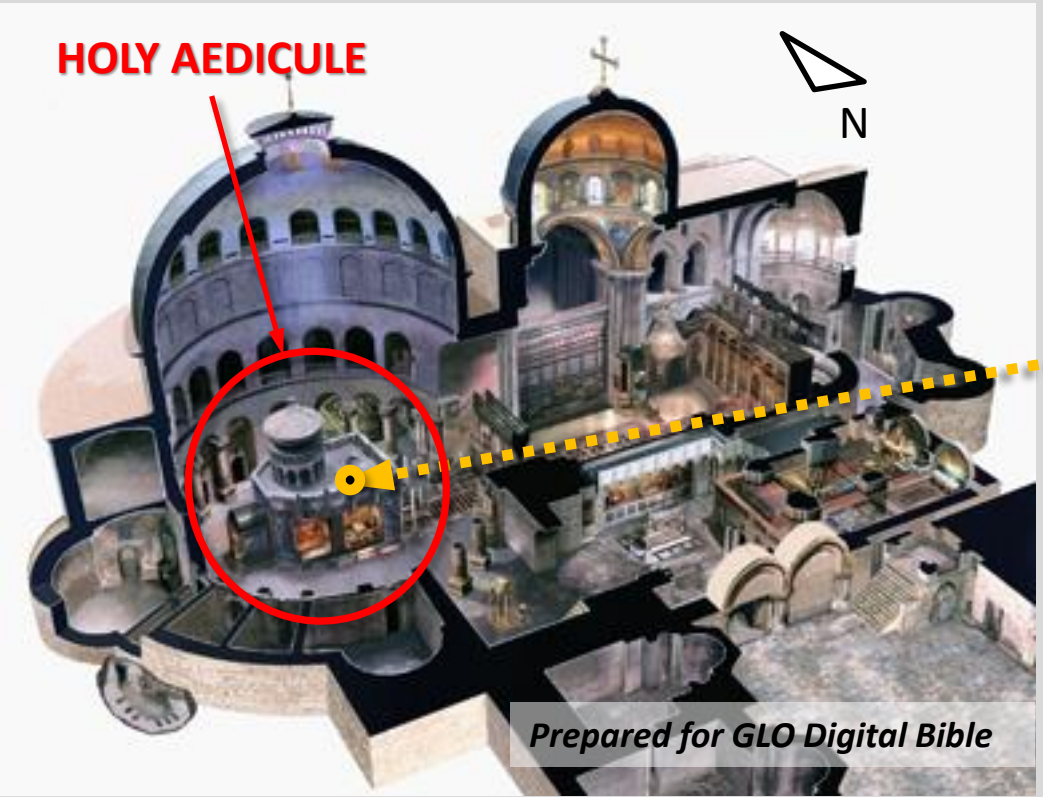
Assist. Prof. Ch. Mouzakis, *Deputy Construction Site Manager*

THE CHURCH OF THE HOLY SEPULCHRE IN JERUSALEM



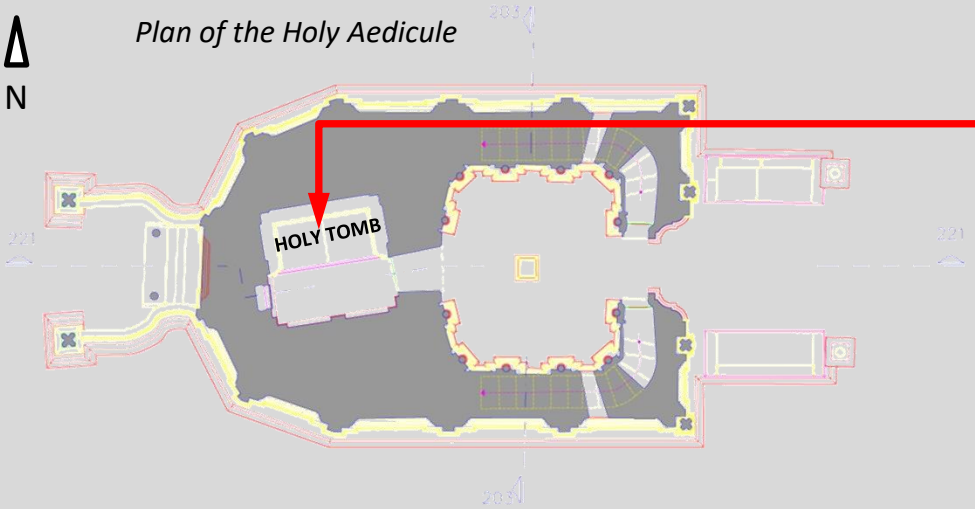


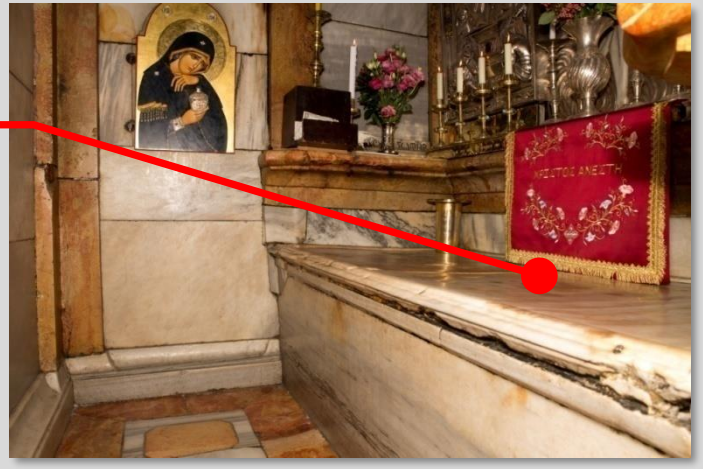


Prepared for GLO Digital Bible

N

Plan of the Holy Aedicule



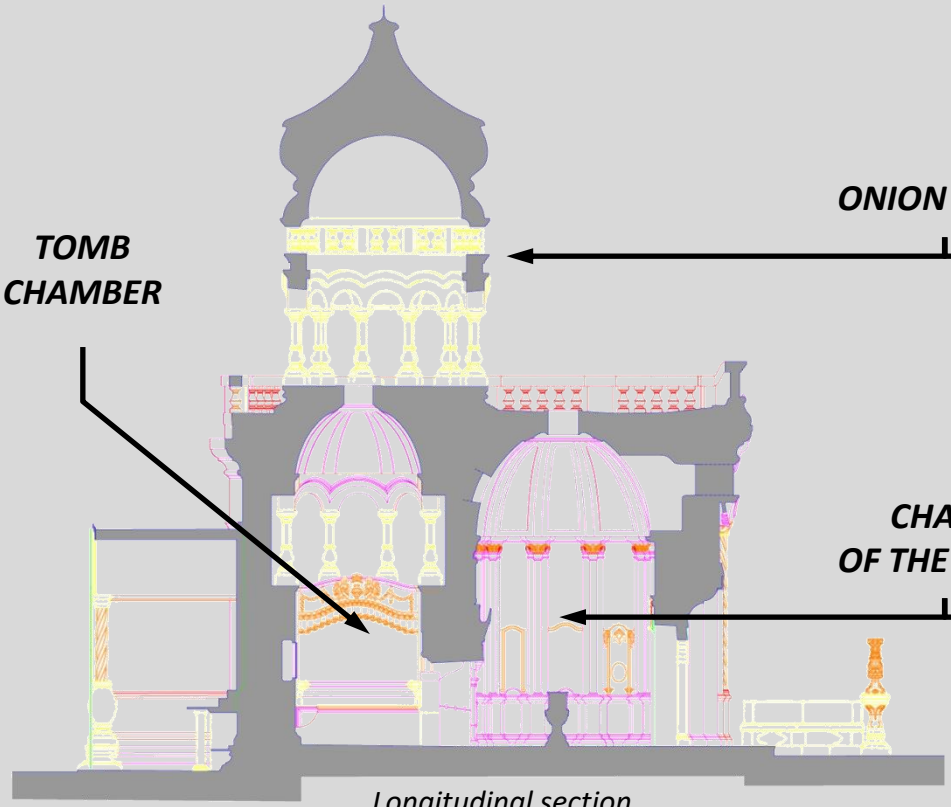


THE HOLY TOMB WITHIN THE HOLY AEDICULE

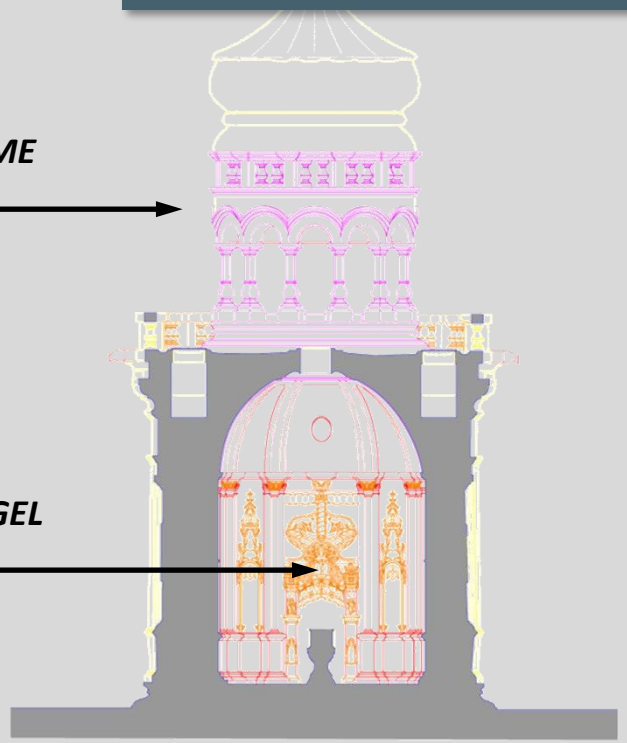
TOMB CHAMBER

ONION DOME

CHAPEL OF THE ANGEL

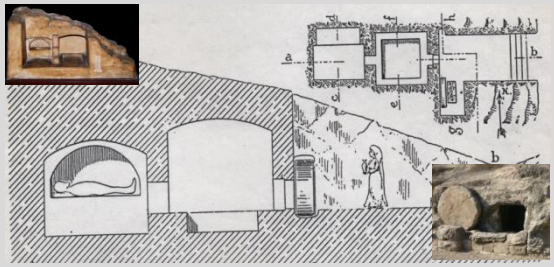


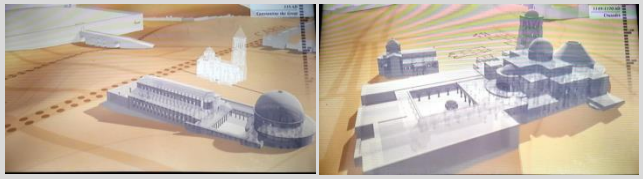
Longitudinal section



Transverse section

Historical aspects related to the Aedicule of the Holy Sepulchre





1st PHASE

- **Period of Constantine the Great and construction of Constantinian institutions (326-614 AD)**
- **The destruction of the Holy Shrines by the Persians (614 AD). The reconstruction of the Church of Resurrection by Patriarch Modestos**
- **The destruction of the Holy Shrines by Caliph Hakem bi-Amr-Illah on 1009 AD**
  The reconstruction of the Church of Resurrection of the Byzantine Emperor Constantine IX Monomachos (1042 - 1048).

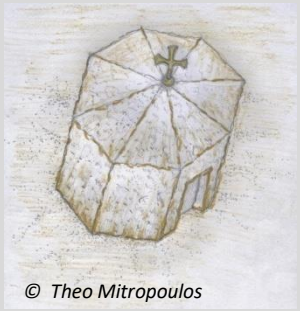
2nd PHASE

- **11th c. Byzantine period**
- **First Crusaders period (1099 - 1187)**

3rd PHASE

The restoration intervention of the Crusaders in the late Romanesque style, gives a new character to the previous intervention of Monomachos, integrating all Holy Shrines below a single building

From the Constantinian, to the Byzantine, to the Crusaders to the Renaissance, to the Komnenos period which we restore



The Holy Aedicule (326 AD)

(614AD) after its partial destruction by the Persians

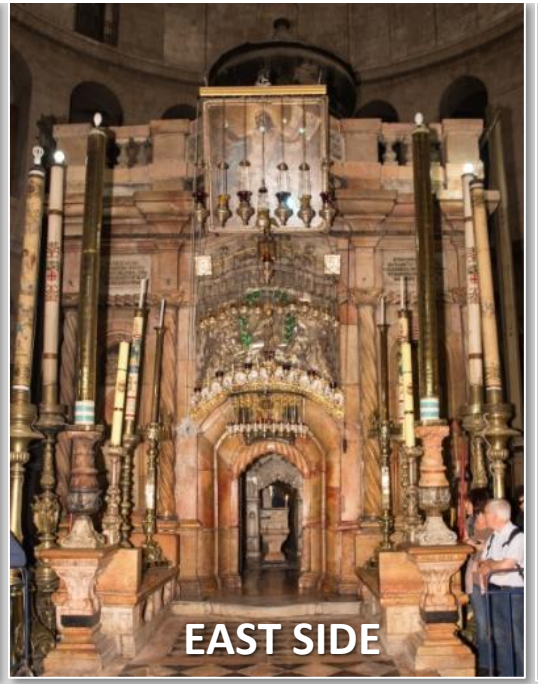
8th c. AD. The rehabilitation of the core of the Aedicule by Patriarch Modestos

(11th c. AD). The rehabilitation in the shape of "pulpit" by Monomachos 1045 AD

Crusaders' phase 12th c. AD De Brun 16th c. AD

The current state of the reconstructed Aedicule by architect Komnenos in 1810 (after the fire of 1808) and the addition of the iron frame from the British rulers, 1947

The Holy Aedicule before rehabilitation interventions



Historic initiative of the Greek-Orthodox Patriarch of Jerusalem to invite the NTUA

The project was initiated, became possible and is executed under the governance of His Beatitude, the Greek-Orthodox Patriarch of Jerusalem, Theophilos III.

His Beatitude, the Greek-Orthodox Patriarch of Jerusalem, Theophilos III invited Professor Antonia Moropoulou (March 2015) and signed a programme agreement with the National Technical University of Athens in order to conduct a study regarding *"Materials & Conservation, Reinforcement and Rehabilitation Interventions in the Holy Edicule of the Holy Sepulchre"* with the consensus of all three Christian Communities

NATIONAL TECHNICAL UNIVERSITY OF ATHENS
Interdisciplinary Research Group for the Monuments Protection

Materials & Conservation, Reinforcement and Rehabilitation Interventions in the Holy Edicule of the Holy Sepulchre

Final Report Presentation,
27 January 2016, Consulate General of Greece in Jerusalem
19 February 2016, Greek-Orthodox Patriarchate of Jerusalem
8 March 2016, Zappeion Hall, Athens

Scientific Coordinator:
Prof. A. Moropoulou

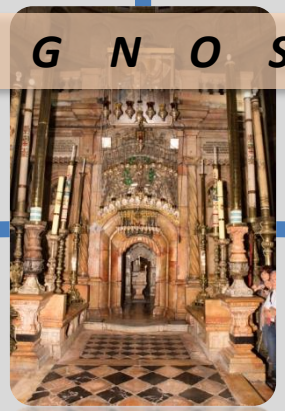
Interdisciplinary Research Group NTUA**:**
Prof. E. Korres, School of Architecture Engineering NTUA, Former Director of the Interdisciplinary Postgraduate Programme "*Protection of Monuments*"
Prof. A. Georgopoulos, School of Rural and Surveying Engineering NTUA, Laboratory of Photogrammetry
Prof. A. Moropoulou, Director of Studies in the NTUA Interdisciplinary Postgraduate Programme Direction «*Conservation Of Building Materials*», School of Chemical Engineering NTUA,
Laboratory of Materials Science and Engineering
Prof. C. Spyrakos, School of Civil Engineering NTUA, Laboratory for Earthquake Engineering

Aim and interdisciplinary methodology of Research

D O C U M E N T A T I O N

- Integrated documentation of the problem
- Geometric, Structural, Architectural documentation
- Documentation and characterization of building materials

D I A G N O S I S

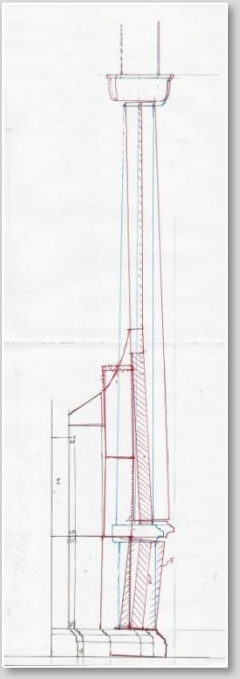


- Prospection of building phases and decay diagnosis and pathology
- Assessment of current state against static and seismic loads

P R O P O S A L

- Principles, ethics, requirements and instructions for conservation reinforcement and rehabilitation materials and interventions
- Continual update of the three religious communities of the Holy Church of the Resurrection in Jerusalem and organization of scientific and institutional debate for decision making regarding the most appropriate solution.

DEFORMATION OF THE HOLY AEDICULE

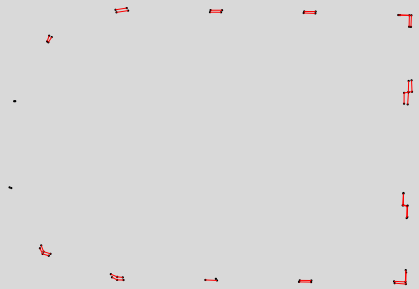


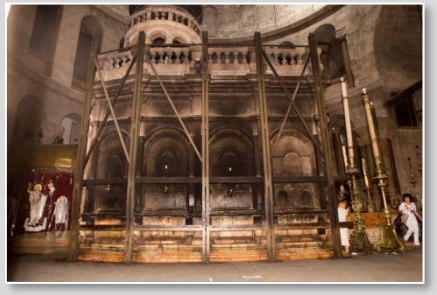
Drawing of deformations at the east façade (Emm. Korres, 2015).

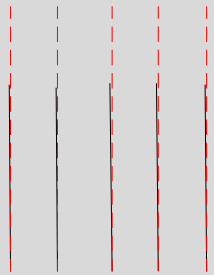
Cause of the deformation: Deterioration of the mortars & masonry swelling:

- Mortars characterization: **slightly hydraulic mortars** produced from **marly** limestone and **lime-gypsum mortars**, susceptible to swelling, dissolution & degradation
- A historic **cause of the swelling was the water precipitation** through the open oculus of the dome above the Aedicule, until 1868
- Thereafter, as investigated by NTUA, the **main source of humidity is the uptake through capillary rise from the surrounding water canals and underground voids**

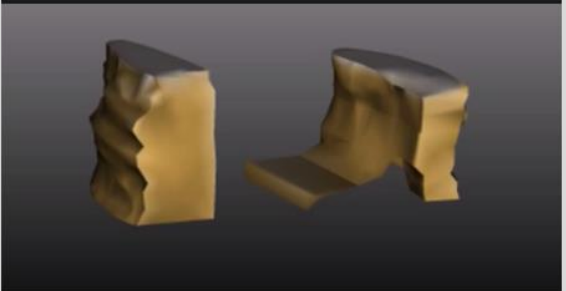
Deformations of the metal supportive beams





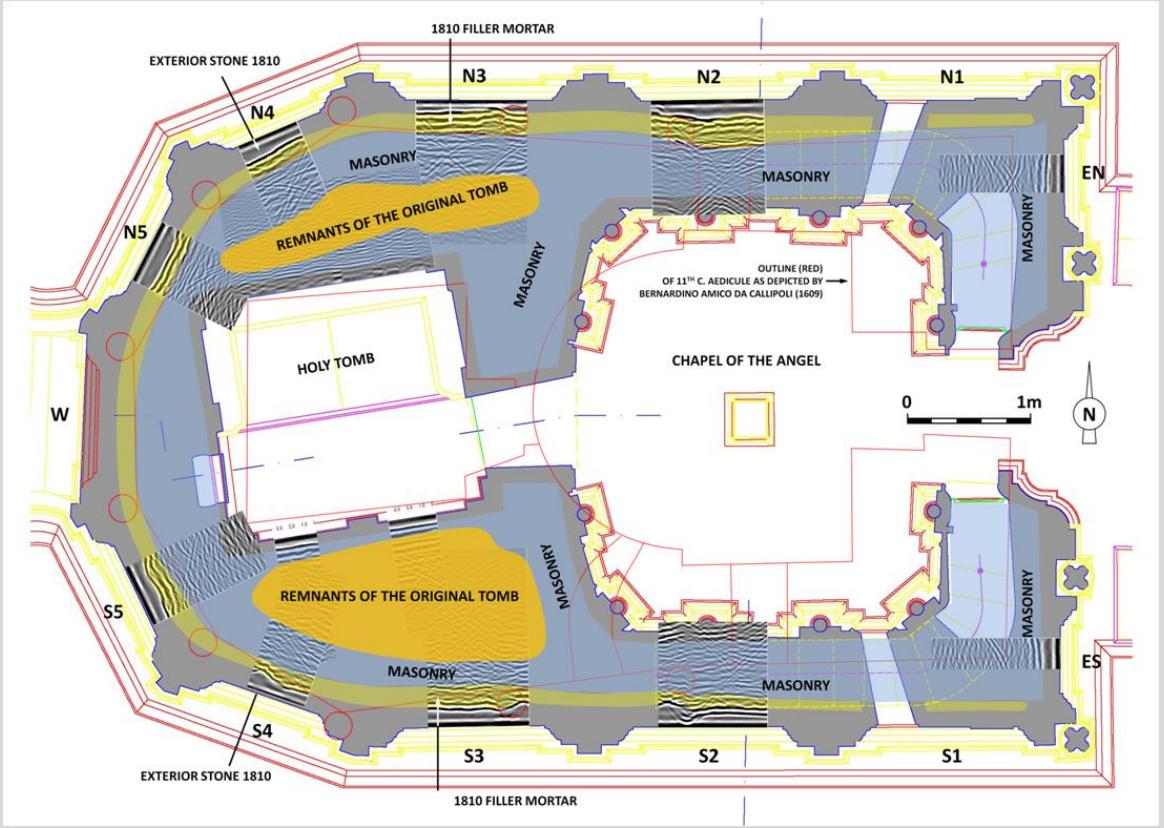


Even the iron frame is deformed, 4-9cm. Significant deviations of the columns from the vertical plane



INNOVATIVE PROSPECTION OF THE NON-VISIBLE LAYERS OF THE AEDICULE AS A MAJOR TOOL FOR ITS REHABILITATION

Integrated Non-destructive Prospection, Architectural and Geometric Documentation Digitally Render the Internal Structure of the Holy Aedicule and Reveal its Construction Phases



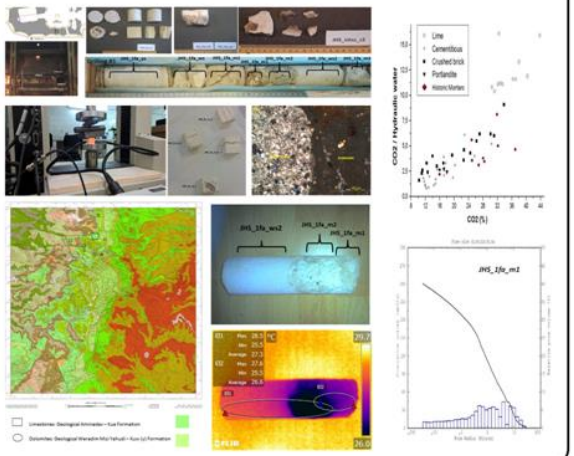
3D SUPPORT TO THE DESIGN AND QUANTIFICATION OF MATERIALS AND REHABILITATION INTERVENTIONS

INTERRELATED GEOMETRIC, ARCHITECTURAL, MATERIALS AND STRUCTURAL DOCUMENTATION

How **architectural, historical and materials** characterization **geometrical** documentation and **structural** assessment act as **knowledge based digital infrastructure to support the design of the rehabilitation**

GEOMETRIC DOCUMENTATION

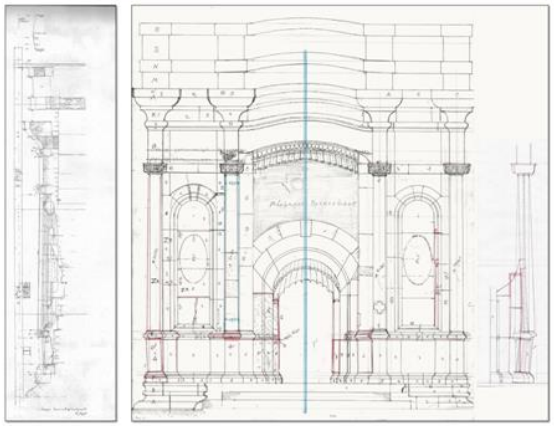
MATERIALS DOCUMENTATION



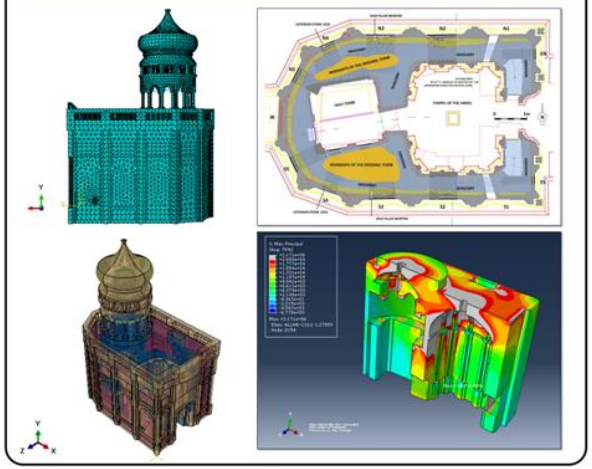
NATIONAL TECHNICAL UNIVERSITY OF ATHENS

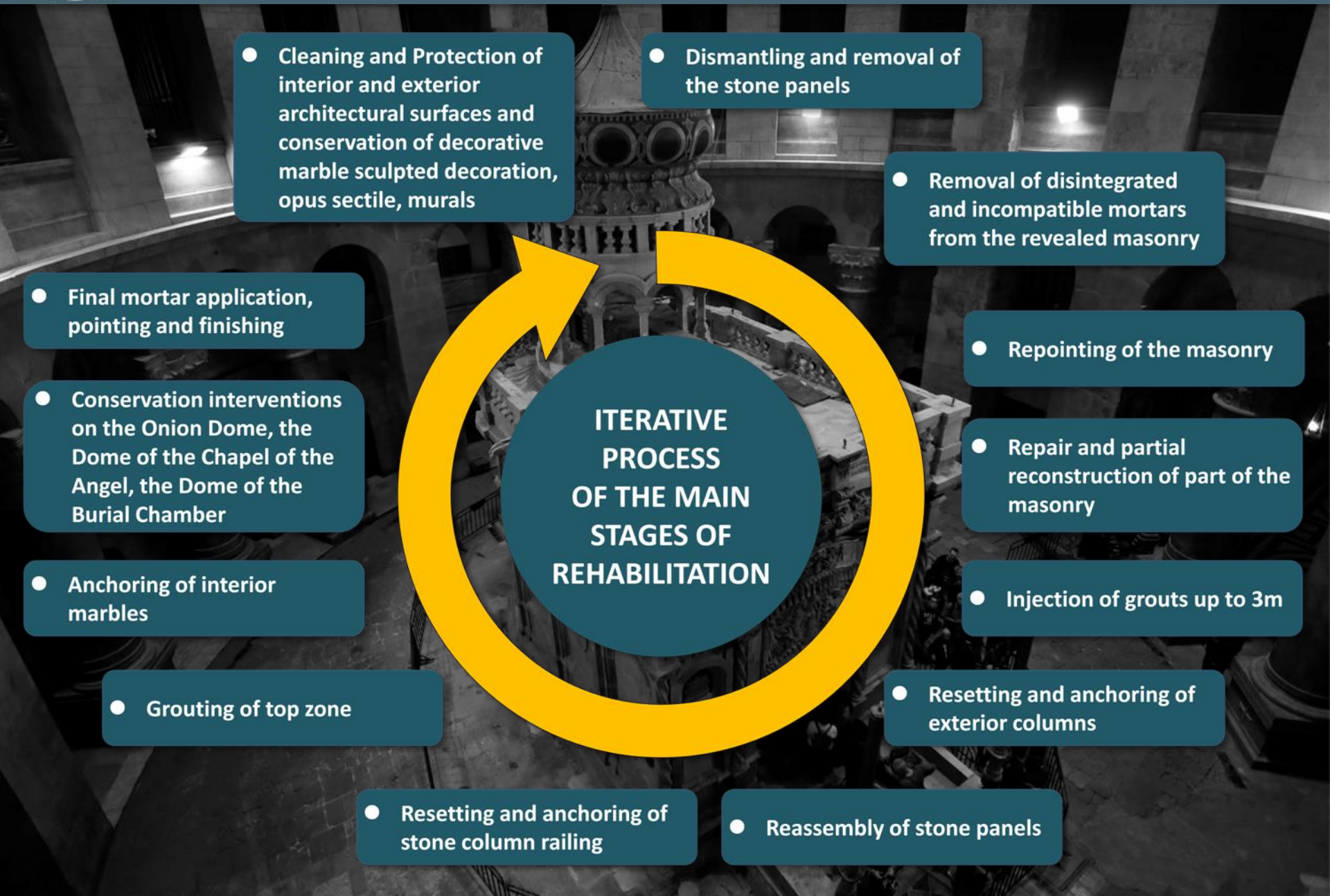
DIAGNOSTIC INTERDISCIPLINARY STUDY

ARCHITECTURAL DOCUMENTATION



STRUCTURAL DOCUMENTATION




ITERATIVE PROCESS OF THE MAIN STAGES OF REHABILITATION
Cleaning and Protection of interior and exterior architectural surfaces and conservation of decorative marble sculpted decoration, opus sectile, murals
Dismantling and removal of the stone panels
Removal of disintegrated and incompatible mortars from the revealed masonry
Repointing of the masonry
Repair and partial reconstruction of part of the masonry
Injection of grouts up to 3m
Resetting and anchoring of exterior columns
Reassembly of stone panels
Resetting and anchoring of stone column railing
Grouting of top zone
Anchoring of interior marbles
Conservation interventions on the Onion Dome, the Dome of the Chapel of the Angel, the Dome of the Burial Chamber
Final mortar application, pointing and finishing

PROPOSAL FOR REHABILITATION

Minimum invasive
Maximum compatibility & performance with historical materials and structures

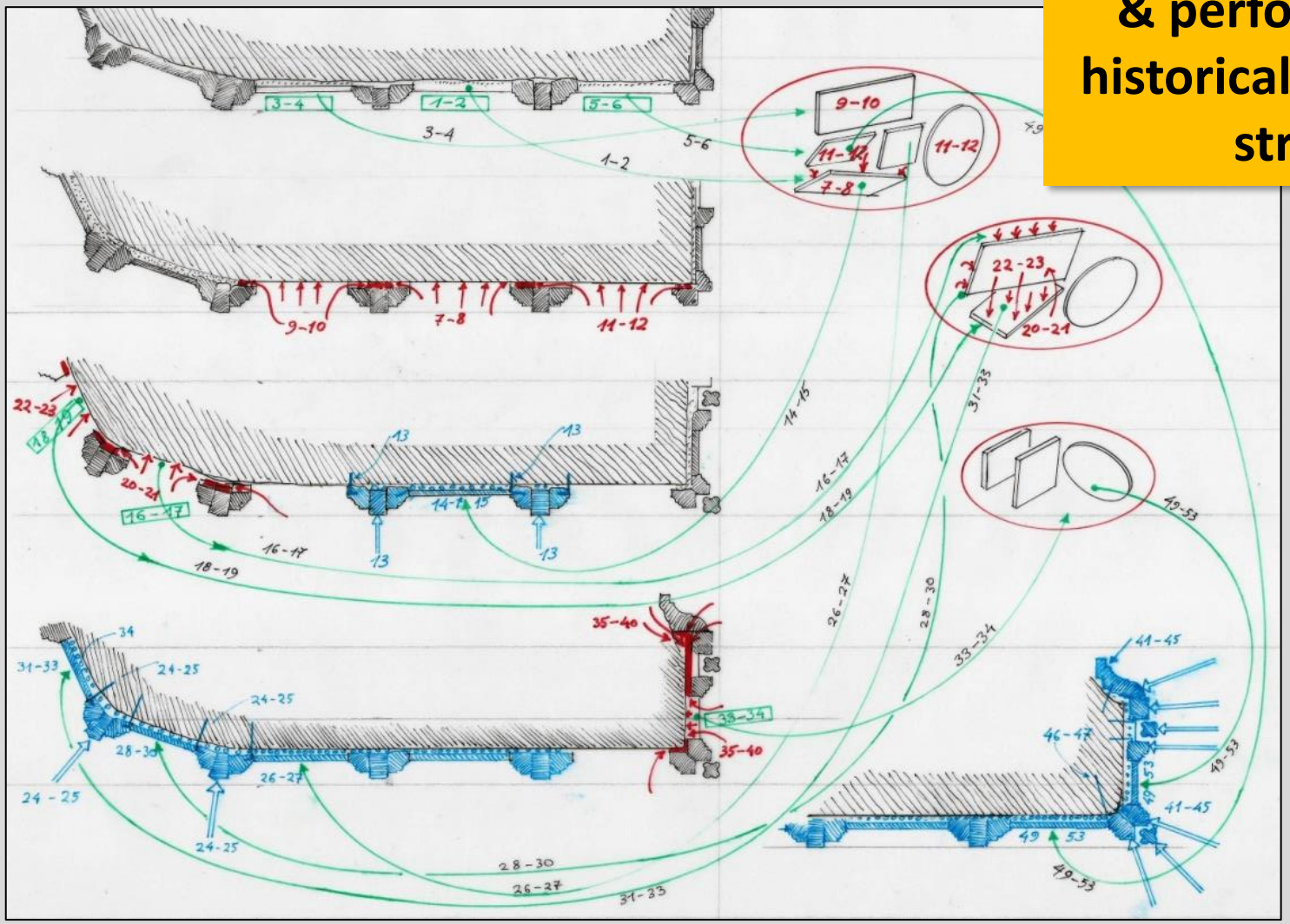
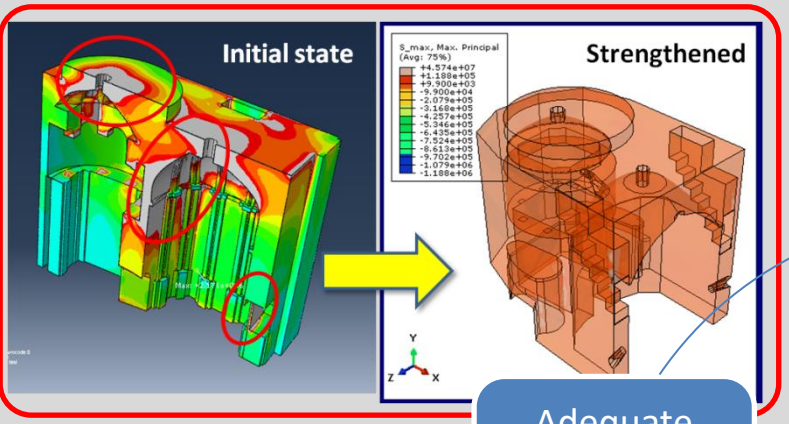


Diagram of the work's progress
(design by Prof. Em. Korres)

COMPATIBLE AND PERFORMING MATERIALS – NDTs TO SUPPORT ASSESSMENT



Assessment of mechanical performance through FEM

Digital in situ microscopy to evaluate microstructural compatibility

Do not induce anistropy

Adequate mechanical performance

Similar thermohygric behavior

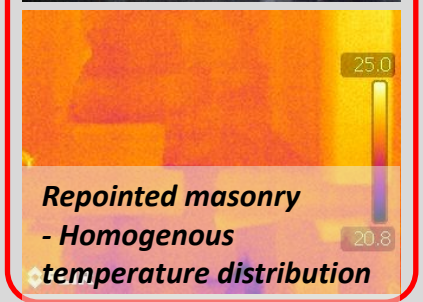
COMPATIBLE AND PERFORMING MATERIALS

Specific conductivity measurement: <80µS/cm

Do not introduce soluble salts

Ensure breathability

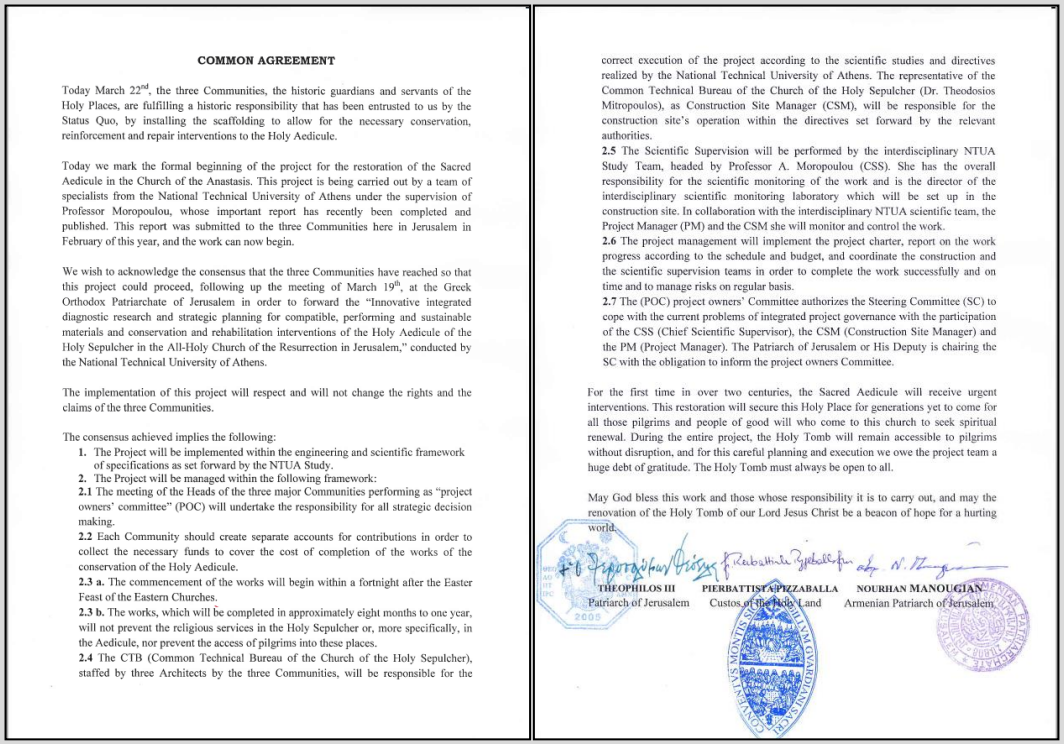
Revealed masonry
- Inhomogeneous temperature distribution due to the presence of incompatible materials



Repointed masonry
- Homogenous temperature distribution

HISTORIC AGREEMENT BETWEEN THE THREE CHRISTIAN COMMUNITIES

The Common Agreement of the Status Quo provides him with the authority, in constant collaboration with the Leaders of the Christian Communities, the historic Guardians of the Holy Sepulchre, consisting of the Greek-Orthodox Patriarch of Jerusalem, Theophilos III, the Custos of the Holy Land of the Franciscan Order, Pierbattista Pizzaballa (until May 2016), today the Apostolic Administrator of the Latin Patriarchate of Jerusalem, and Francesco Patton (from June 2016), as well as the Armenian Patriarch in Jerusalem, Archbishop Nourhan Manougian, to **coordinate** all scientific, technical and administrative aspects of the project.



COMMON AGREEMENT

Today March 22nd, the three Communities, the historic guardians and servants of the Holy Places, are fulfilling a historic responsibility that has been entrusted to us by the Status Quo, by installing the scaffolding to allow for the necessary conservation, reinforcement and repair interventions to the Holy Aedicule.

Today we mark the formal beginning of the project for the restoration of the Sacred Aedicule in the Church of the Anastasis. This project is being carried out by a team of specialists from the National Technical University of Athens under the supervision of Professor Moropoulou, whose important report has recently been completed and published. This report was submitted to the three Communities here in Jerusalem in February of this year, and the work can now begin.

We wish to acknowledge the consensus that the three Communities have reached so that this project could proceed, following up the meeting of March 19th, at the Greek Orthodox Patriarchate of Jerusalem in order to forward the "Innovative integrated diagnostic research and strategic planning for compatible, performing and sustainable materials and conservation and rehabilitation interventions of the Holy Aedicule of the Holy Sepulcher in the All-Holy Church of the Resurrection in Jerusalem," conducted by the National Technical University of Athens.

The implementation of this project will respect and will not change the rights and the claims of the three Communities.

The consensus achieved implies the following:

1. The Project will be implemented within the engineering and scientific framework of specifications as set forward by the NTUA Study.
2. The Project will be managed within the following framework:

2.1 The meeting of the Heads of the three major Communities performing as "project owners' committee" (POC) will undertake the responsibility for all strategic decision making.

2.2 Each Community should create separate accounts for contributions in order to collect the necessary funds to cover the cost of completion of the works of the conservation of the Holy Aedicule.

2.3 a. The commencement of the works will begin within a fortnight after the Easter Feast of the Eastern Churches.

2.3 b. The works, which will be completed in approximately eight months to one year, will not prevent the religious services in the Holy Sepulcher or, more specifically, in the Aedicule, nor prevent the access of pilgrims into these places.

2.4 The CTB (Common Technical Bureau of the Church of the Holy Sepulcher), staffed by three Architects by the three Communities, will be responsible for the correct execution of the project according to the scientific studies and directives realized by the National Technical University of Athens. The representative of the Common Technical Bureau of the Church of the Holy Sepulcher (Dr. Theodosios Mitropoulos), as Construction Site Manager (CSM), will be responsible for the construction site's operation within the directives set forward by the relevant authorities.

2.5 The Scientific Supervision will be performed by the interdisciplinary NTUA Study Team, headed by Professor A. Moropoulou (CSS). She has the overall responsibility for the scientific monitoring of the work and is the director of the interdisciplinary scientific monitoring laboratory which will be set up in the construction site. In collaboration with the interdisciplinary NTUA scientific team, the Project Manager (PM) and the CSM she will monitor and control the work.

2.6 The project management will implement the project charter, report on the work progress according to the schedule and budget, and coordinate the construction and the scientific supervision teams in order to complete the work successfully and on time and to manage risks on regular basis.

2.7 The (POC) project owners' Committee authorizes the Steering Committee (SC) to cope with the current problems of integrated project governance with the participation of the CSS (Chief Scientific Supervisor), the CSM (Construction Site Manager) and the PM (Project Manager). The Patriarch of Jerusalem or His Deputy is chairing the SC with the obligation to inform the project owners Committee.

For the first time in over two centuries, the Sacred Aedicule will receive urgent interventions. This restoration will secure this Holy Place for generations yet to come for all those pilgrims and people of good will who come to this church to seek spiritual renewal. During the entire project, the Holy Tomb will remain accessible to pilgrims without disruption, and for this careful planning and execution we owe the project team a huge debt of gratitude. The Holy Tomb must always be open to all.

May God bless this work and those whose responsibility it is to carry out, and may the renovation of the Holy Tomb of our Lord Jesus Christ be a beacon of hope for a hurting world.

THEOPHILOS III Patriarch of Jerusalem

PIERBATTISTA PIZZABALLA Custos of the Holy Land

NOURHAN MANOUGIAN Armenian Patriarch of Jerusalem

NATIONAL TECHNICAL UNIVERSITY OF ATHENS

INTERDISCIPLINARY RESEARCH GROUP FOR THE MONUMENTS PROTECTION

SCIENTIFIC SUPERVISION, MONITORING AND DECISION MAKING

PROJECT FOR THE CONSERVATION, REINFORCEMENT AND REPAIR INTERVENTIONS FOR THE REHABILITATION OF THE HOLY AEDICULE OF THE HOLY SEPULCHRE IN THE ALL-HOLY CHURCH OF RESURRECTION IN JERUSALEM

National Technical University of Athens

Chief Scientific Supervisor:

Prof. Antonia Moropoulou

A Collective Work by

NTUA Interdisciplinary Team

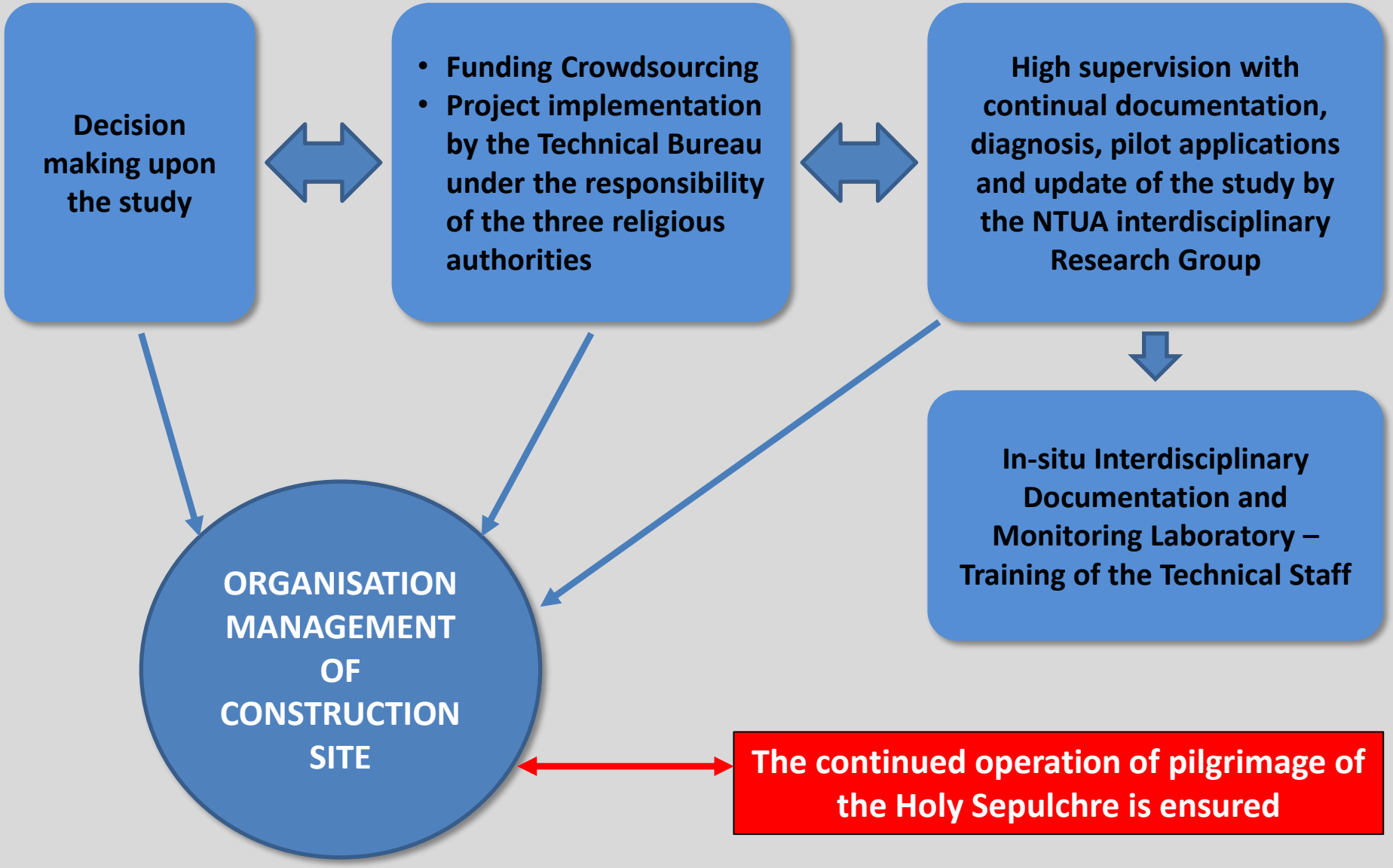
Prof. E. Korres, Prof. A. Georgopoulos, Prof. A. Moropoulou, Prof. C. Spyrakos,

Assist. Prof. Ch. Mouzakis, *Deputy Construction Site Manager*

An exemplary project highlighting Greek and European Innovation and Expertise in the field of Cultural Heritage protection

Exploiting a multilevel integrated interdisciplinary approach

Implementation methodology



Project Funding

N. Moropoulos, Project Manager

- The Holy Edicule project raised a total of Euro 3.7 million in funds, including cash contributions and self-funding by the three ”Status Quo” communities, as shown in the Table below.
- Total expenditure is Euro 3.5 million (Project Closure is pending).

Funding - Cash	Amount in Euro
Donations	1,680,779
World Monuments Fund	1,156,202
Communities - Cash Contributions	384,180
Cash Funds Total	***3,221,161***
Funding - Non cash	**Amount in Euro**
Self funding activities	324,495
Aegean	159,000
Non-cash Funds Total	***483,495***
Total funds	**3,704,656**

IOANA MARIA (MICA) ERTEGUN
Great Benefactor

JACK SHEAR
Benefactor

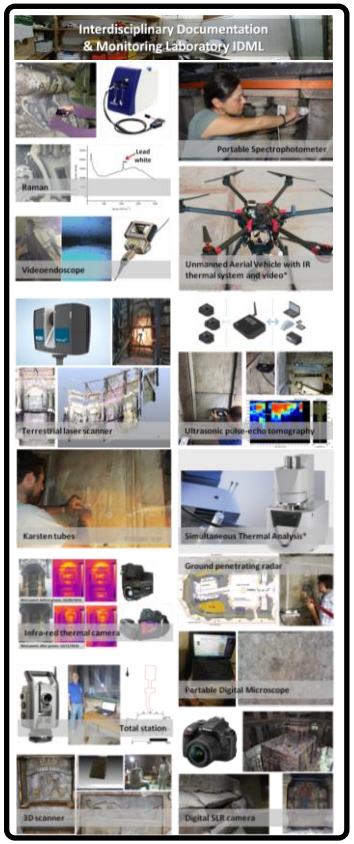
through World Monuments Fund
WMF total 1,156,202 Euro

MICA ERTEGUN: Great Benefactor through WMF

Mica Ertegun and Linda Wachner

Under the blessing of Father Alex from the Greek Orthodox Archdiocese of America and with the active participation of WMF (prior president Bonnie Burnham)

SCIENTIFIC SUPPORT TO INTEGRATED GOVERNANCE



INTEGRATED GOVERNANCE OF THE PROJECT

Project Owners' Committee

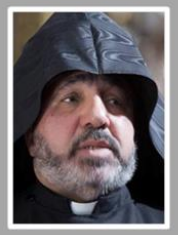
Custos of Franciscan Order

Apostolic Administrator of Jerusalem

Pierbattista Pizzaballa *(until May 2016)*

Francesco Patton *(Since June 2016)*

Patriarch Theophilos III (Chairman)



Armenian Patriarch Nourhan Manougian

Common Technical Bureau (Dr. Theodosios Mitropoulos, Osama Hamdan, Carla Benelli, Irene Badalian)

Project Steering Committee (5-7 members)

WMF/Mica Ertegun Fund/ Greek Orthodox Archdiocese of America (oversight)

Patriarch Theophilos III (Chairman)

Chief Supervising Scientist & Director of Materials & Rehabilitation Interventions Prof. Antonia Moropoulou

Project Manager Ir. Nikos Moropoulos

Site Manager Dr. Theodosios Mitropoulos

Director of Restoration Prof. Emmanouil Korres

Director of Reinforcement Prof. Kostantinos Spyrakos

Direct. of Geometric Documentation Prof. Andreas Georgopoulos

Deputy Site Manager Assist. Prof. Charalampos Mouzakis

Asst. Deputy Site Manager, Head of Restorers Vasileios Zafeiris

Administrative **Scientific** **Construction site management**

Scientific support to decision making

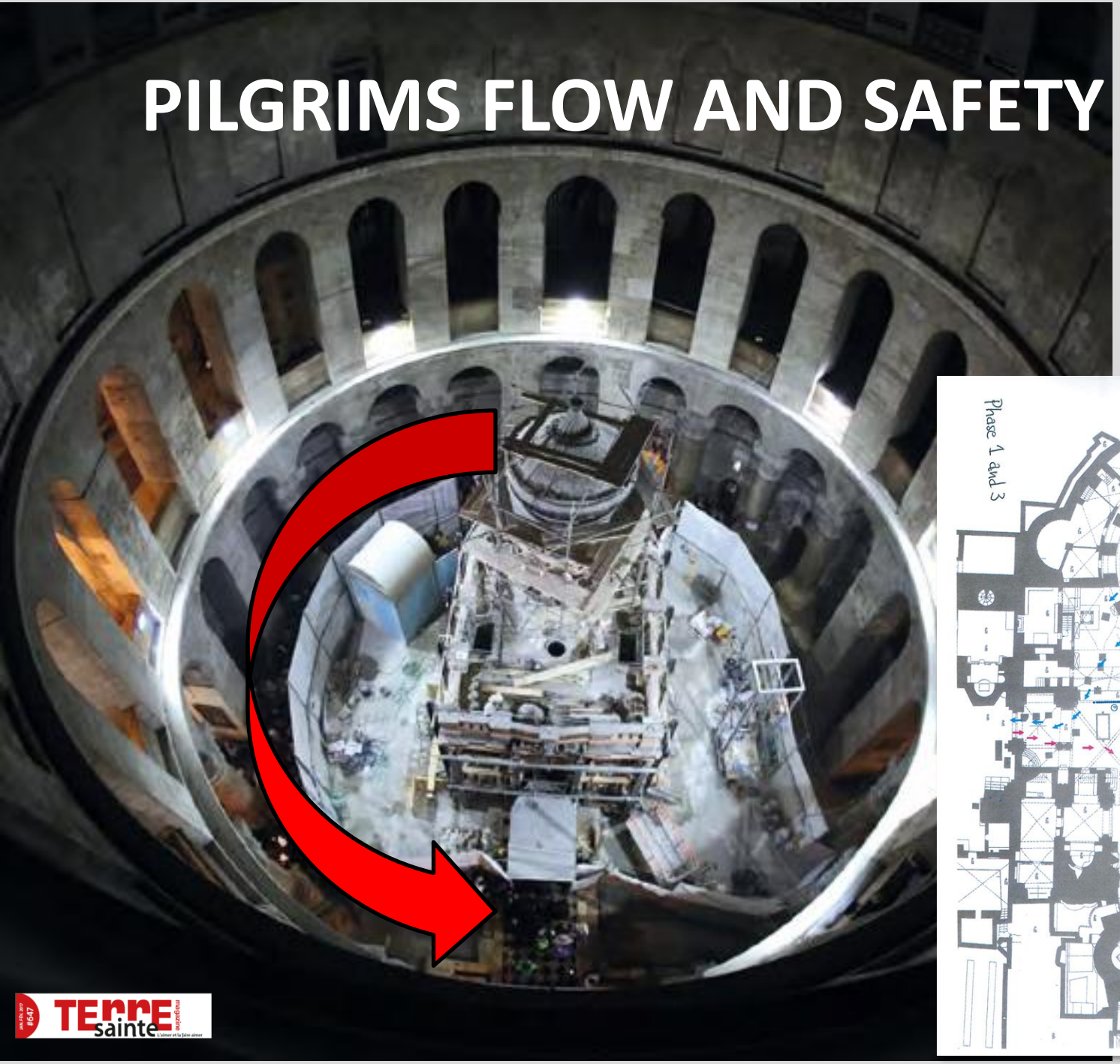
*The **integrated scientific management of the project** is recognized as the only prerequisite that can successfully face the risks and uncertainties that arise during the progress of the Works.*

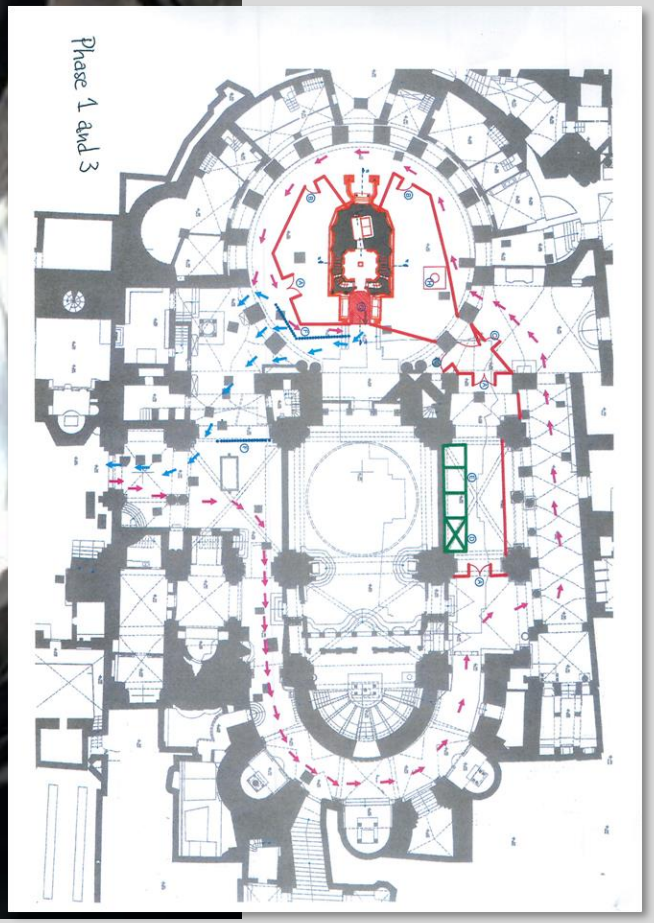
*Continuous scientific documentation, monitoring and assessment of all acquired data, in real scale and real time comprises the **scientific support to decision making**. Hence, the **integrated governance** of the project is achieved on the **basis of the NTUA study**, as well as the **NTUA scientific reports** throughout the implementation of the study*

The work site is successfully organized without disrupting the flow of pilgrims or religious functions

ADDITIONAL LATERAL SUPPORTS (⬇) TO THE 1947 IRON FRAME OF THE BRITISH MANDATE (⬇)

PILGRIMS FLOW AND SAFETY PLAN

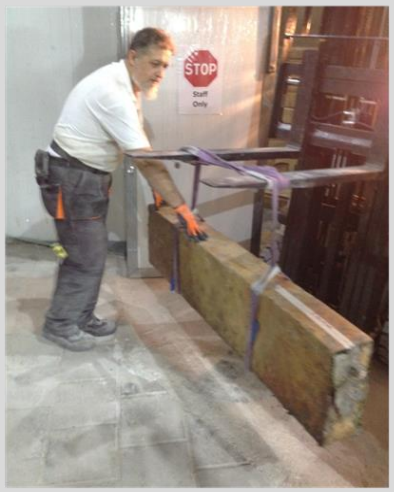




The Conservation lab is established and functions at the Franciscan gallery

At two rooms of the Rotunda, belonging to the Greek-Orthodox Patriarchate, the Interdisciplinary Documentation and Monitoring Laboratory has been established, continuously functioning under the NTUA interdisciplinary team's scientific responsibility

Jerusalem Patriarchate – National Technical University of Athens

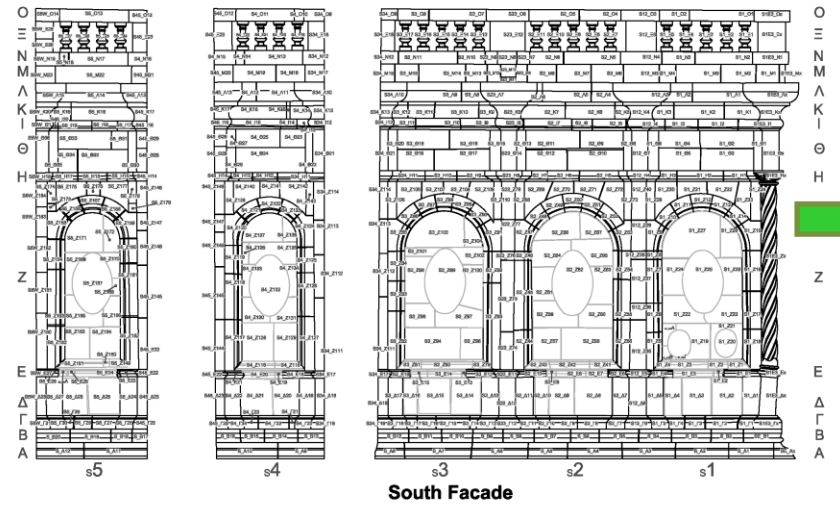


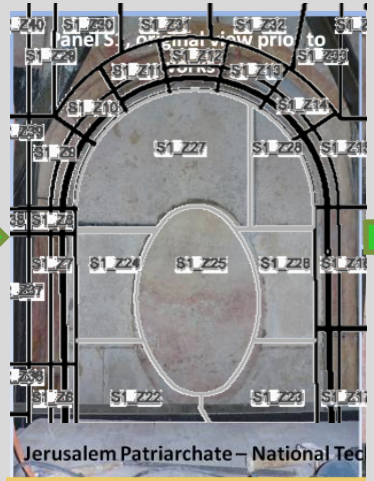
The Greek teams of restorers and conservators working in full capacity in two shifts day and night

DISMANTLING AND REMOVAL OF THE STONE PANELS

☑ 20.07.2016

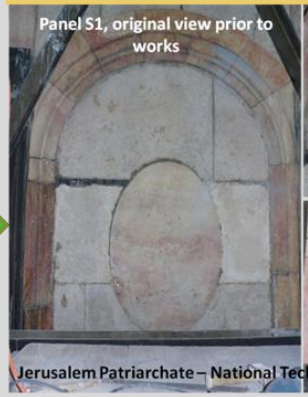
Architectural design from 3d geometric representation





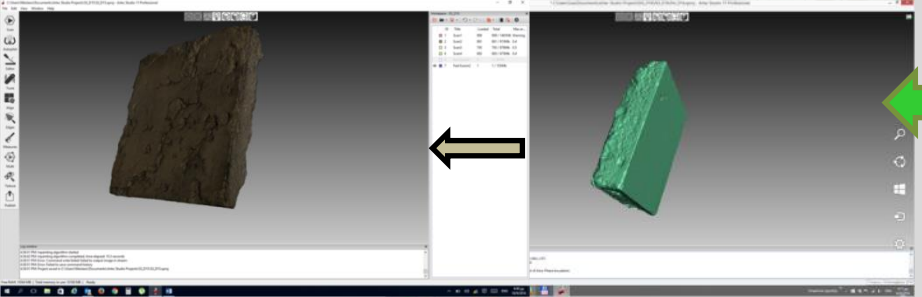
Codes are assigned to each stone

Dismantling process



Jerusalem Patriarchate – National Technical University of Athens

3d Documentation of each stone slab

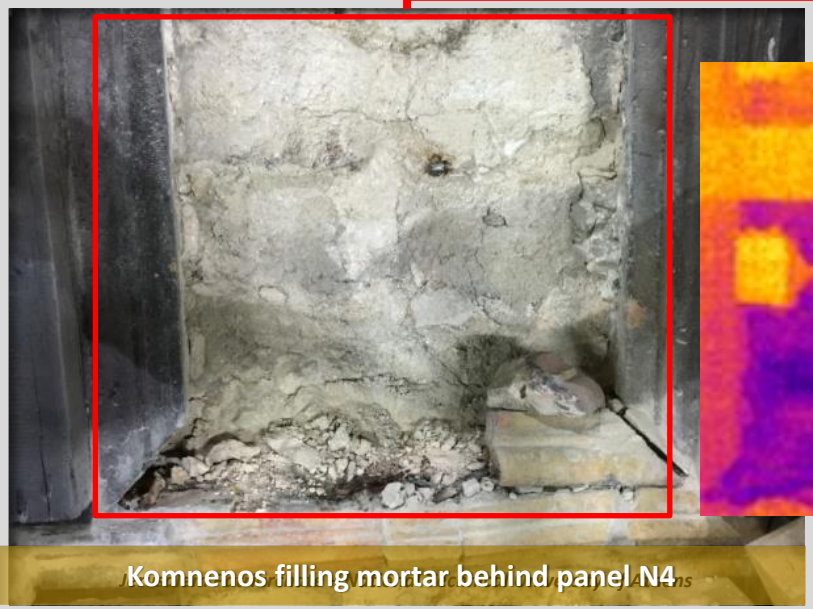


Data was used for the assessment of interventions

Removal of stone slab, transportation to conservation lab

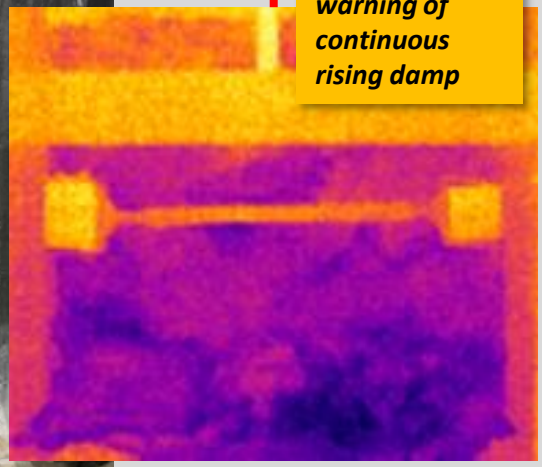
REMOVAL OF DISINTEGRATED AND INCOMPATIBLE MORTARS

☑ 30.07.2016



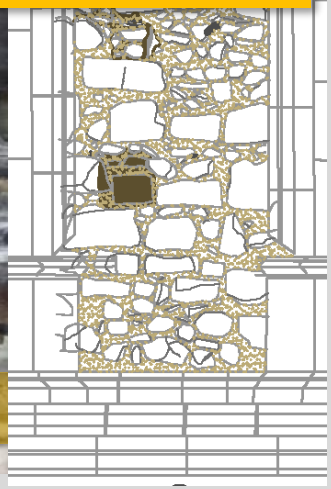
Komnenos filling mortar behind panel N4

Monitoring of thermohygric performance – warning of continuous rising damp



Cleaned masonry

Architectural and geometric documentation of historic masonry



REPOINTING OF MASONRY WITH RESTORATION MORTARS

☑ 7.10.2016

STUDY PROPOSAL

Compatible to the original mortars: Lime-pozzolan mortar (High reactivity metakaolin), with river quartz origin aggregates of 2 mm maximum gradation&inorganic mineral fibers. **Performing to the structural integrity of the original structure, according to FEM results: compressive strength >15 MPa**

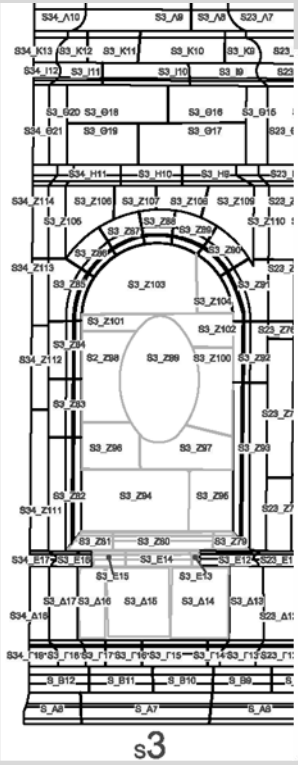
IMPLEMENTATION STUDY

MasterEmaco S 285 TIX
Lime-metakaolin mortar (with high reactivity metakaolin), without the presence of cement, with river quartz origin aggregates of a maximum gradation of 2mm and with the addition of mineral inorganic fibers. It guarantees compressive strength >15 MPa

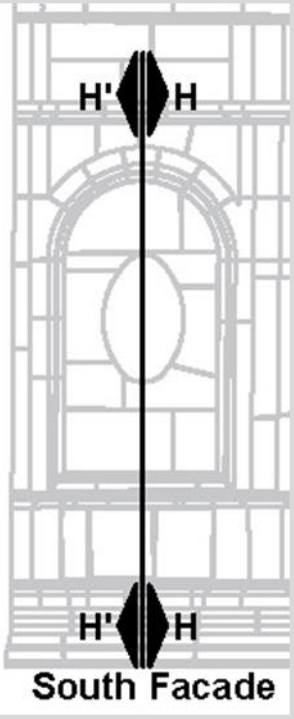
PARTIAL RECONSTRUCTION OF MASONRY AREAS TO ADDRESS SWELLING, STRUCTURAL INEFFICIENCY AND DAMAGE OF THE MASONRY

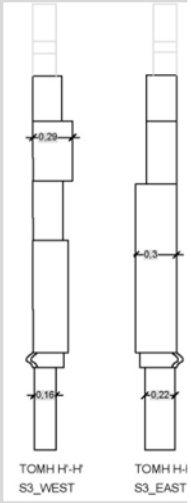
☑ 24.08.2016

Geometric and architectural documentation



Exterior stone panels prior to disassembly





Exterior stone panels after removal of slabs

Interior historical masonry after removal of slabs

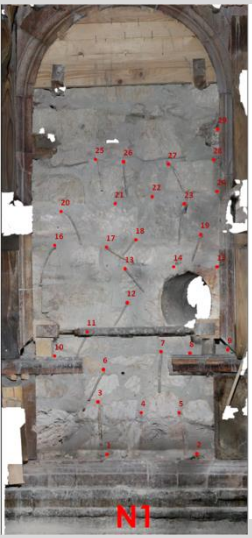
*The new masonry was **constructed using orthogonal stone blocks** with largely standardized dimensions, to ensure compatibility and to enhance mechanical performance and homogeneity. Jammain stone, a beige limestone from Palestine, is a type of Mizzy and was selected as the most compatible and performing stone (F_c 70MPa)*

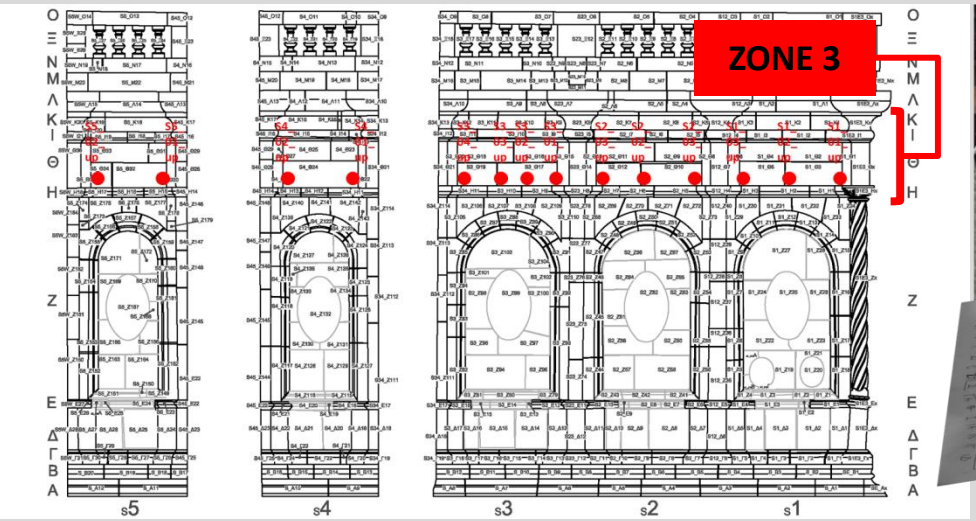
Basic requirements fulfilled:

- *Safety - structural integrity of the aedicule.*
- *New building stones compatible with the historic materials*
- *Preservation of the Holy Rock*

*The design of the repair masonry was based on data from geometric and architectural documentation **to ensure that the repair masonry conforms to the shape of the Holy Rock** and **does not protrude** such that it hinders the final reassembly of the exterior panels*

HOMOGENIZATION OF STRUCTURAL LAYERS AND CONSOLIDATION OF THE HOLY ROCK BY THE INJECTION OF COMPATIBLE GROUTS

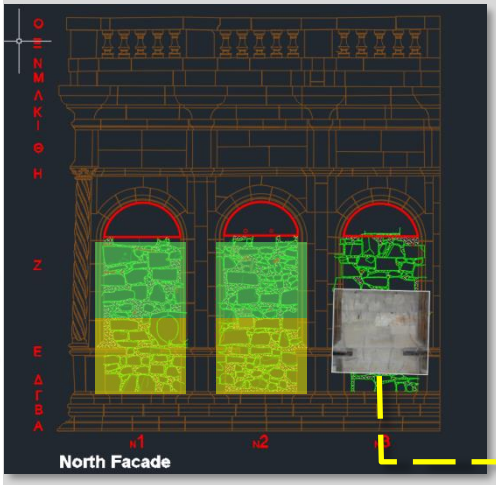




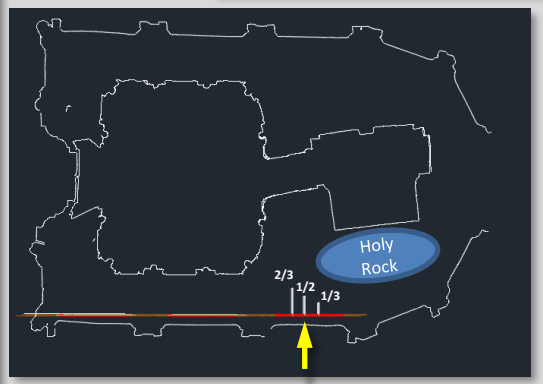
☑ 06.02.2017

Geometric and architectural documentation data facilitated grout injection tube design and documentation

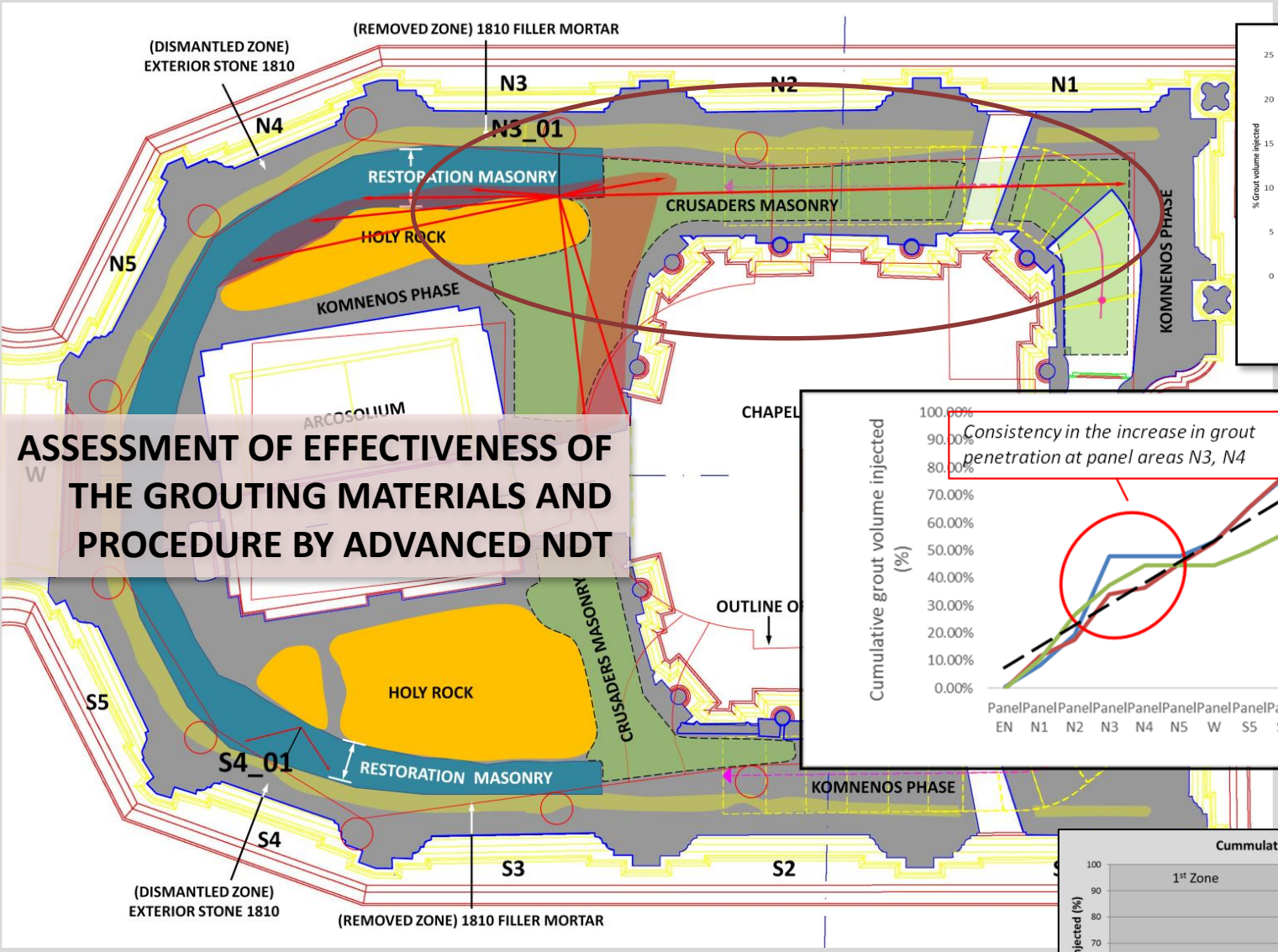
Installation of injections pipes, creating a matrix at different depths, based on sections of the geometric model

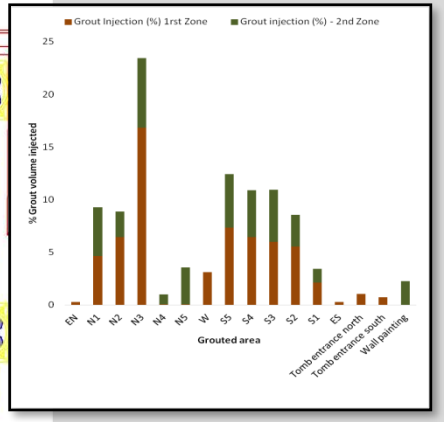


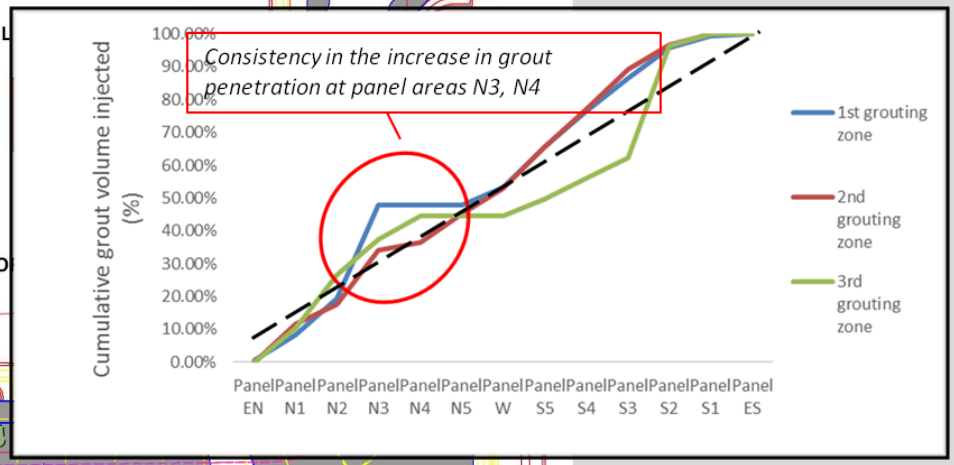
☑ 28.10.2017

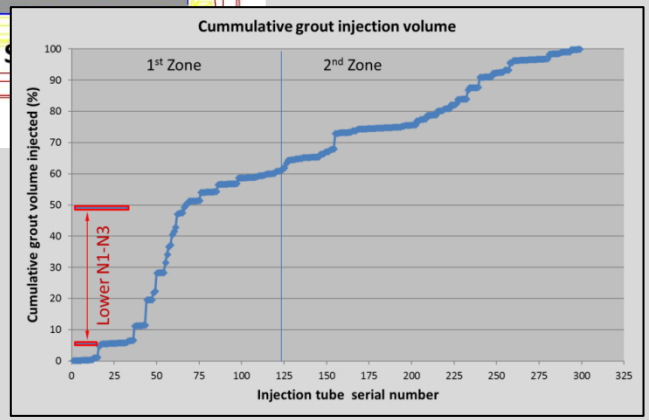


ASSESSMENT OF EFFECTIVENESS OF THE GROUTING MATERIALS AND PROCEDURE BY ADVANCED NDT

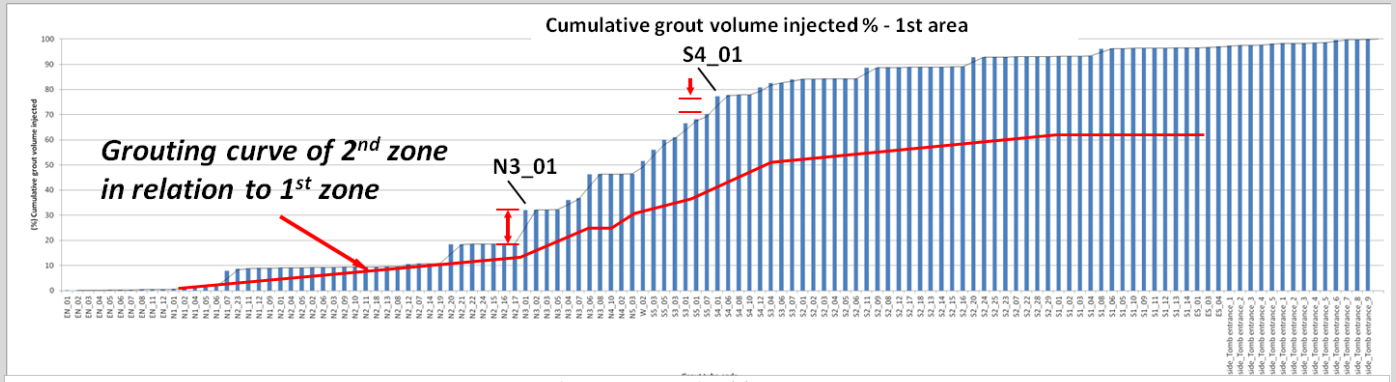


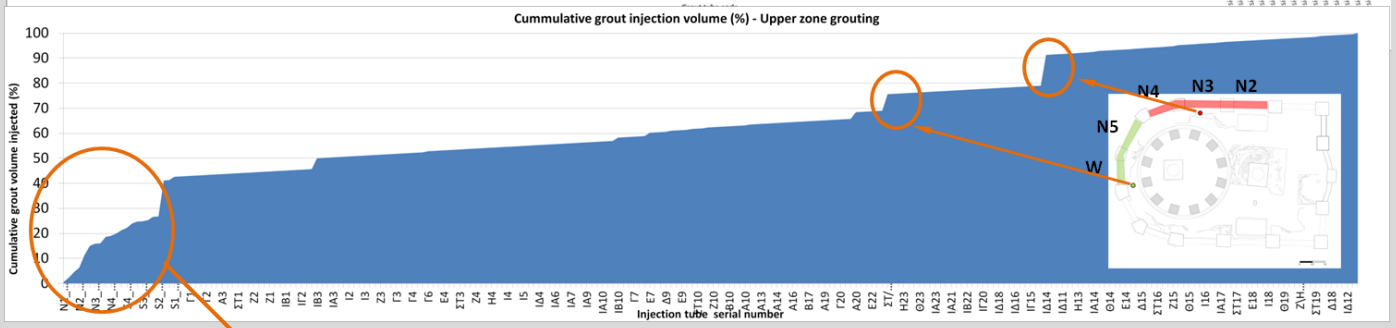


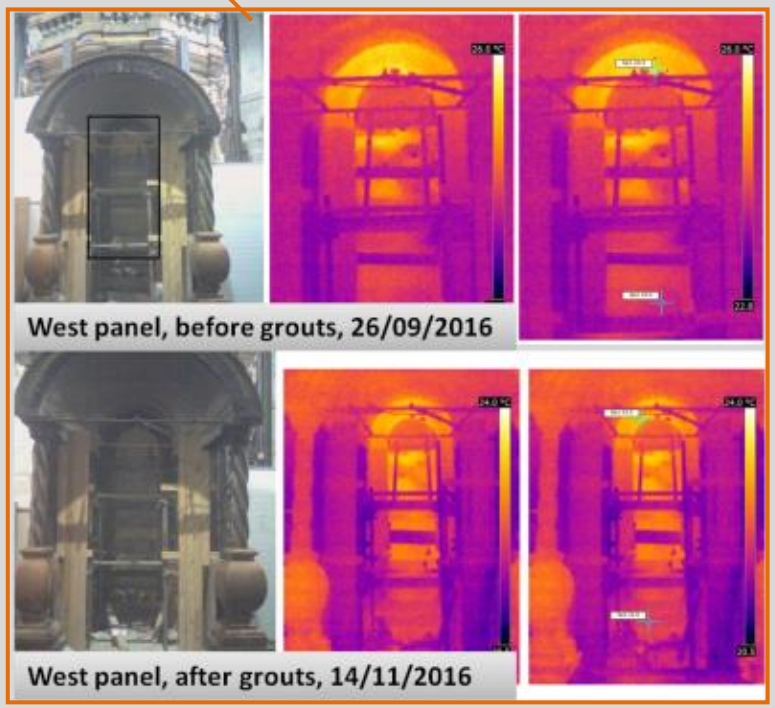




Analysis of the relative location of the exit tubes in the case of insertion tube N3_01, based on the internal structure of the Aedicule as revealed by GPR analysis, shows that ***grouting was successful in homogenizing the interface between the restoration masonry and the north block of Holy Rock as well as the other construction phases***







NDTs FACILITATE DECISION MAKING

The higher areas of the panels consumed a significant volume of grout ~40%; this is in accordance with IRTh results conducted after the lower part grouting, which ***showed the presence of voids at the higher panel levels and indicated the necessity of the upper zone grouting***

RESETTING OF EXTERIOR COLUMNS

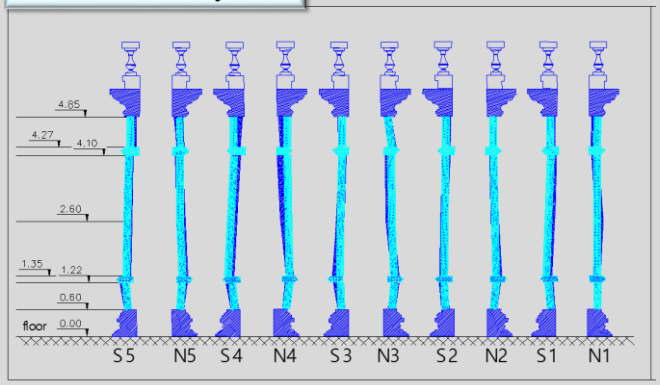
☑ 11.11.2016

Process of a column repositioning

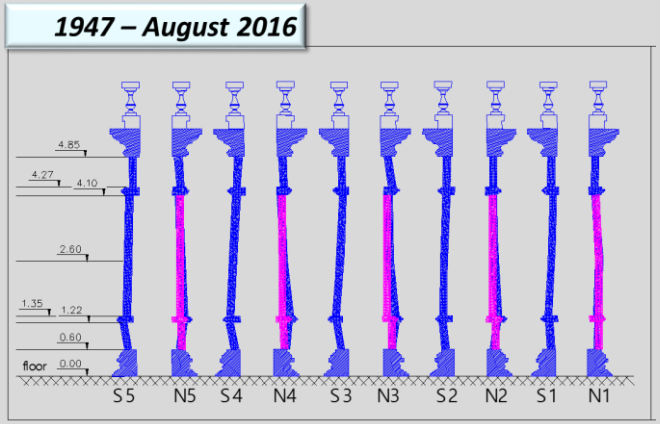
One of the basic requirements, **prior to the reassembly of the panel slabs and the addition of the filling mortar**, between the masonry and the stone panels, is the **resetting of the dislocated columns**.

Assessment of reduction of deviations from verticality during the works

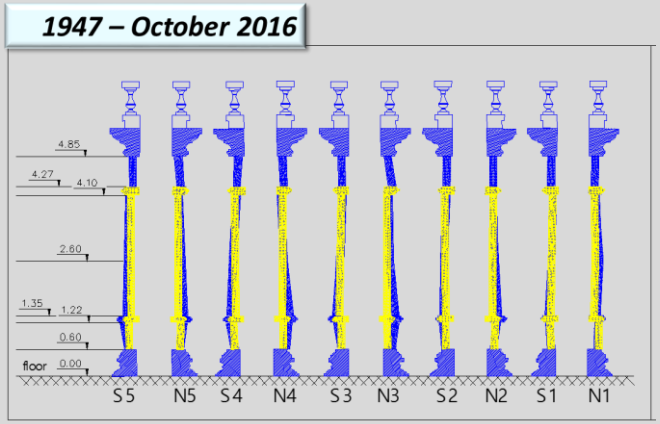
1947 – January 2016



1947 – August 2016



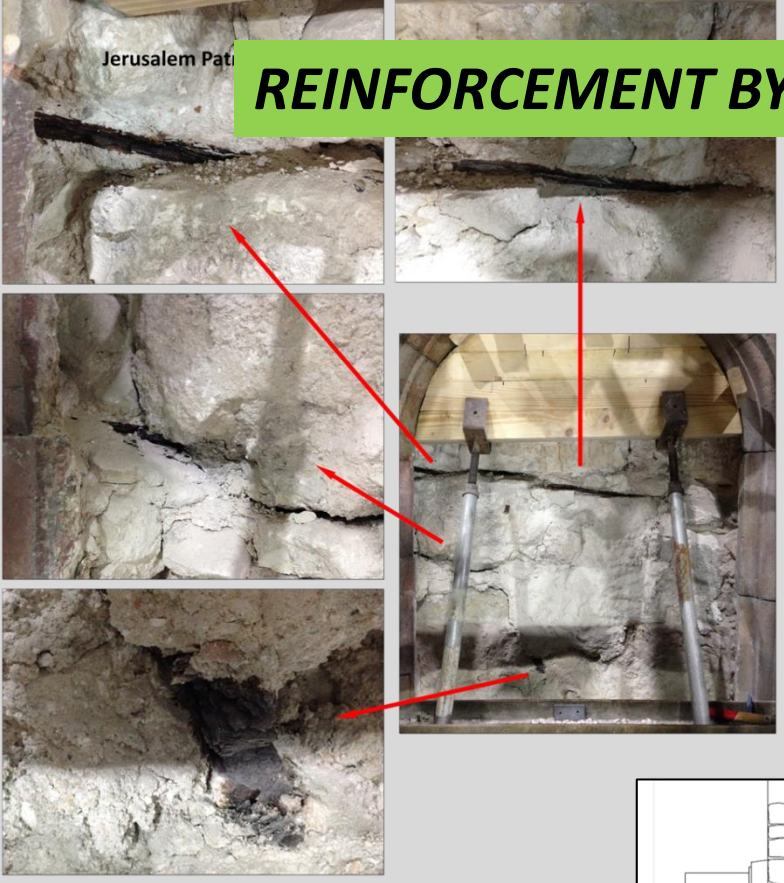
1947 – October 2016



REINFORCEMENT BY TITANIUM

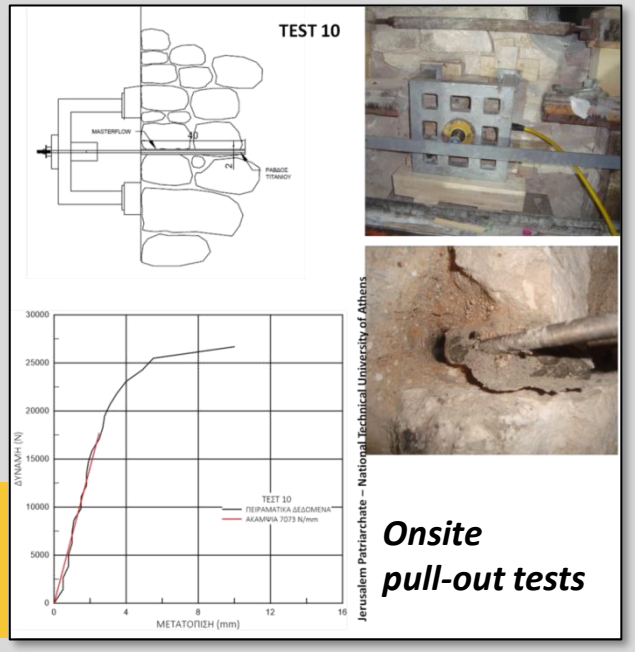
☑ 28.01.2017

The finding of corroded iron support bars necessitates the use of titanium, as proposed by the NTUA interdisciplinary team, in order to avoid such phenomena and ensure the longevity of the structure



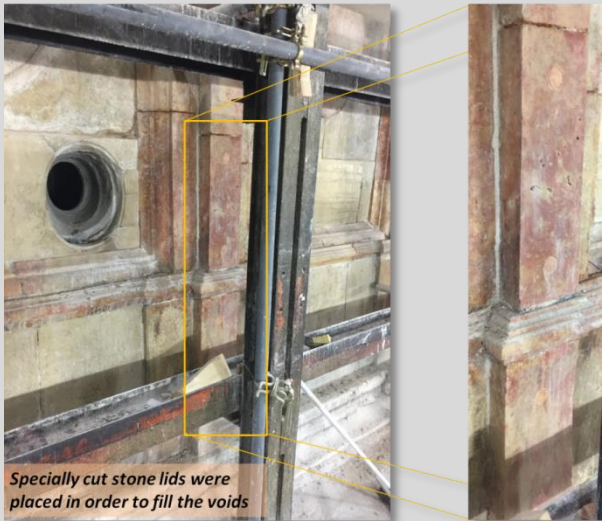
Examples of fully corroded iron support bars in area N1

Holes were drilled at the columns for the installation of titanium anchors



Onsite pull-out tests

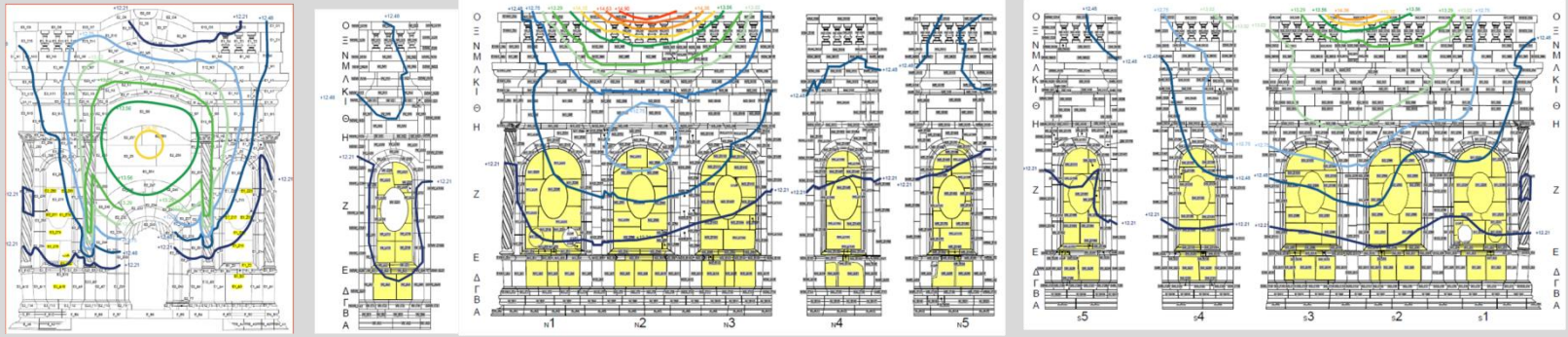
In-situ validation of titanium anchors and bolts design and implementation study



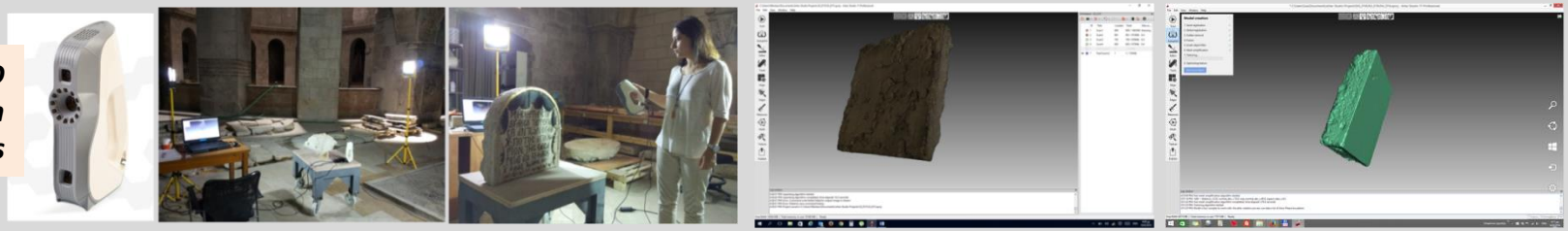
Specially cut stone lids were placed in order to fill the voids

DIGITAL DOCUMENTATION IN COOPERATION WITH THE RESULTS OF EXPERIMENTAL TESTS AND FEM PERMITS THE DESIGN OF SLABS ANCHORING

Calculation of seismic loads for the design of marble slab attachments by Finite Element Modeling analysis

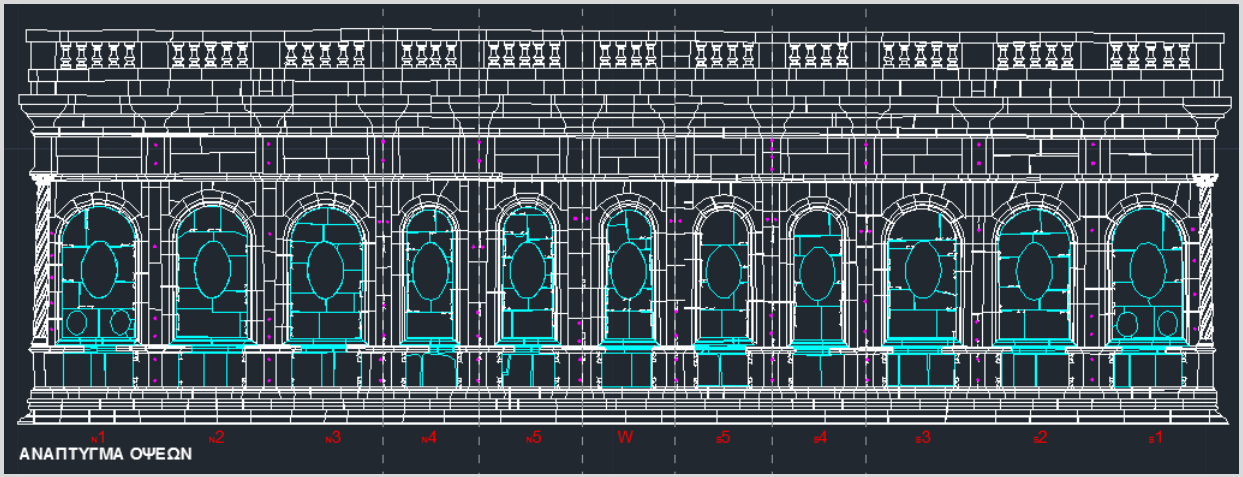


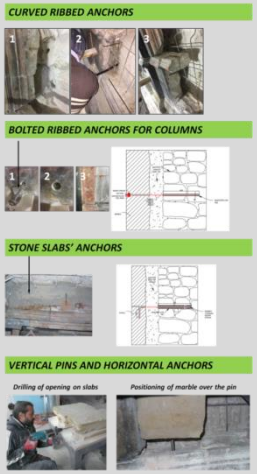
3D documentation of stone slabs



DESIGN OF REINFORCEMENT POSITIONS

Architectural and geometric documentation allows for the design of the anchors and bolts positions





RESETTING AND ANCHORING OF INTERIOR MARBLES

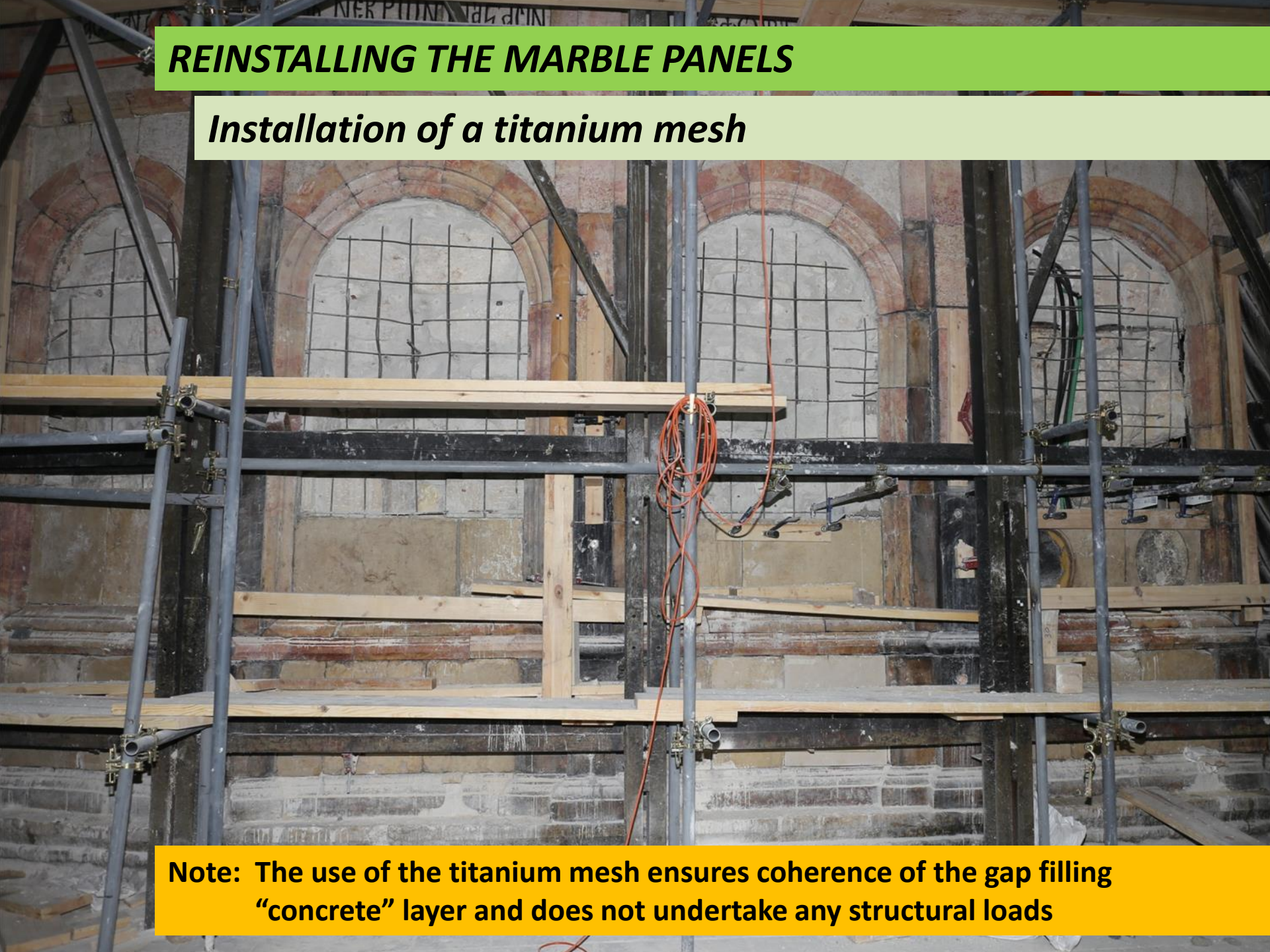
☑ 06.02.2017

Plan for anchoring of columns in the interior of the Chapel of the Angel (by Assist.Prof. Ch.Mouzakis)

3D reconstruction of the interior of the Chapel of the Angel

REINSTALLING THE MARBLE PANELS

Installation of a titanium mesh



Note: The use of the titanium mesh ensures coherence of the gap filling "concrete" layer and does not undertake any structural loads

REINSTALLING THE MARBLE PANELS

Reassembly of the stone slabs

Process of stone slabs reassembly

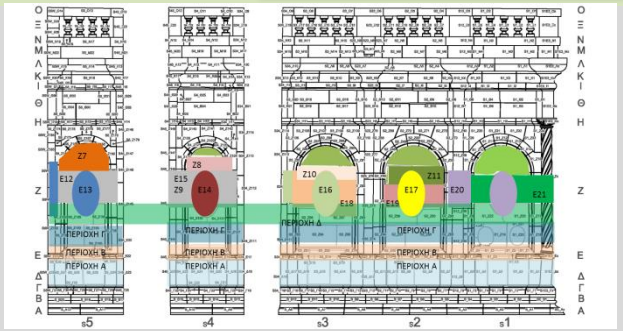
REINSTALLING THE MARBLE PANELS

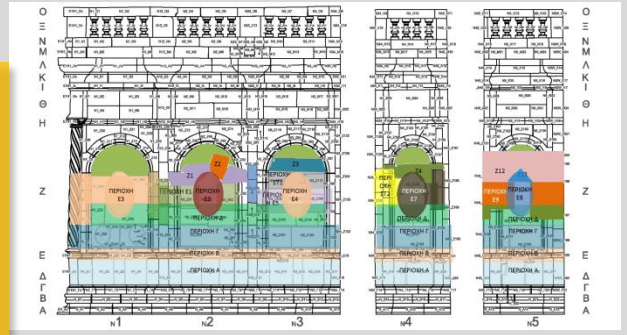
Application of the optimized filling mortar

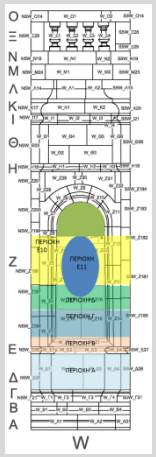
☑ 19.01.2017

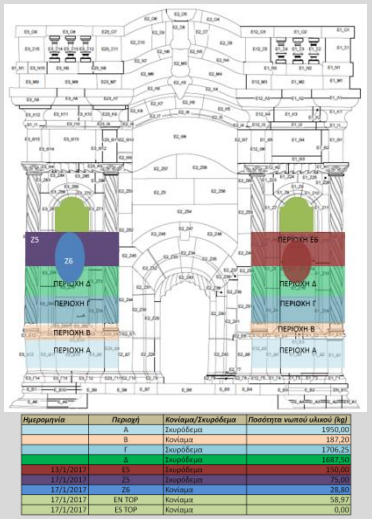
Use of compatible and performing "concrete" in order to fill the gap between the masonry and the reassembled stone slabs. Where the gap was less than 12 mm, the restoration mortar was applied

*All data was **digitally documented** and **validated by NDTs** in order to act as input data for the FEM analysis*





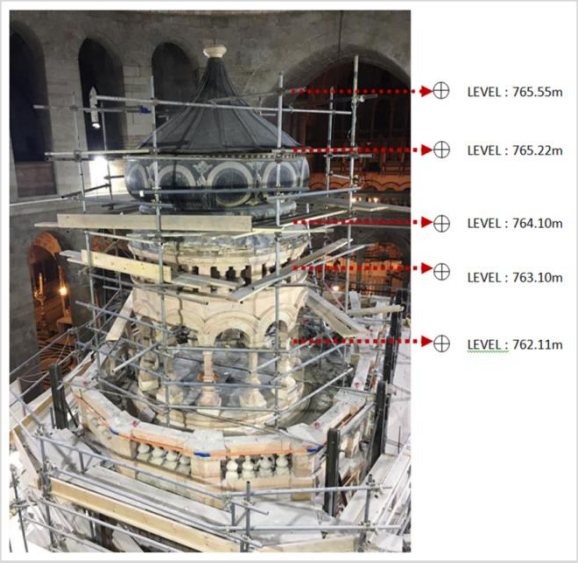


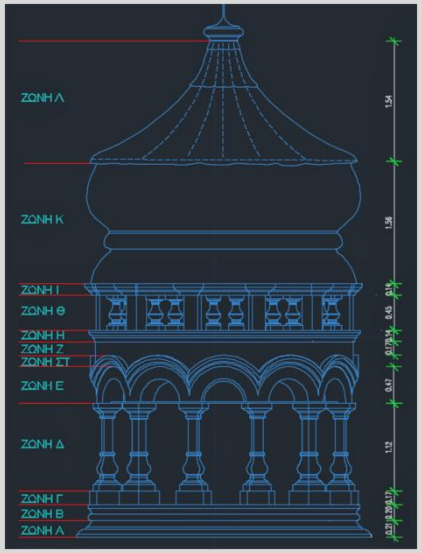


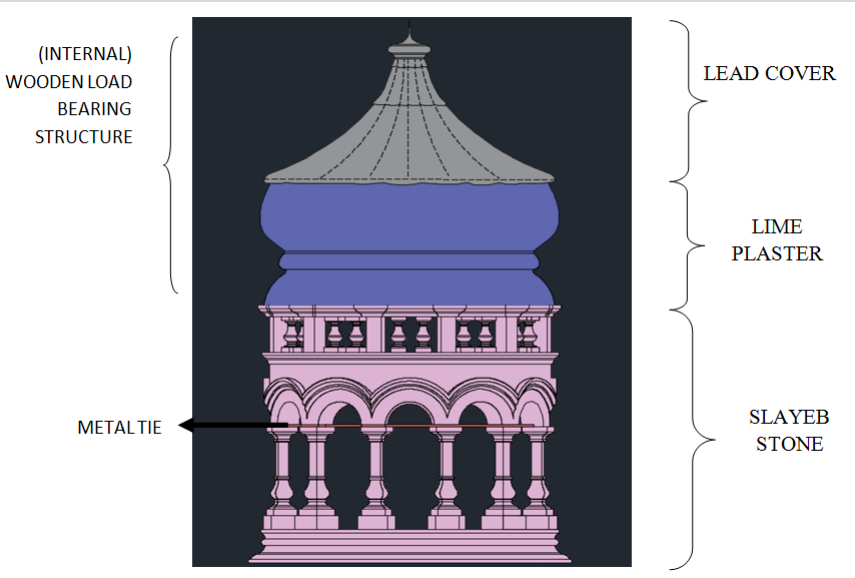
Ημερομηνία	Περιοχή	Κονίαμα/Σκυρόδεμα	Ποσότητα νωπού υλικού (kg)
	A	Σκυρόδεμα	1950,00
	B	Κονίαμα	187,20
	Γ	Σκυρόδεμα	1706,25
	Δ	Σκυρόδεμα	1687,50
13/1/2017	E5	Σκυρόδεμα	150,00
17/1/2017	Z5	Σκυρόδεμα	75,00
17/1/2017	Z6	Κονίαμα	28,80
17/1/2017	E4 TOP	Κονίαμα	58,97
17/1/2017	E5 TOP	Κονίαμα	0,00

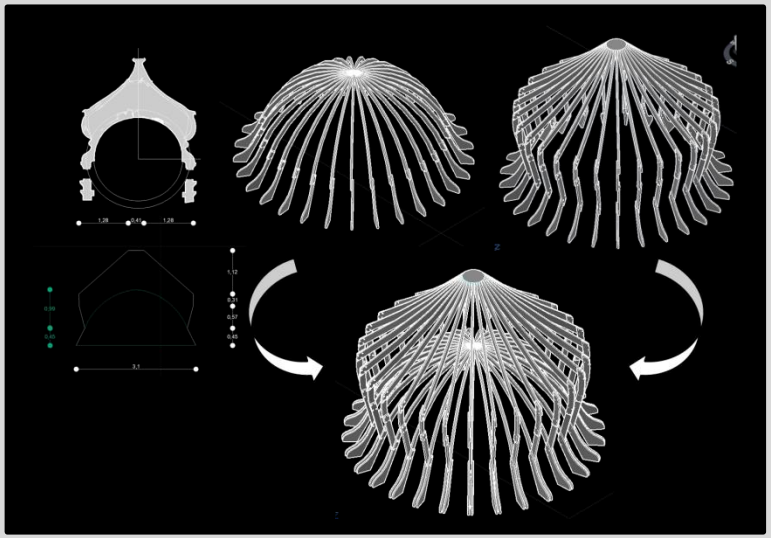
DESIGN OF CONSERVATION, REINFORCEMENT AND RESTORATION INTERVENTIONS

3D REPRESENTATION AND STRUCTURAL ANALYSIS





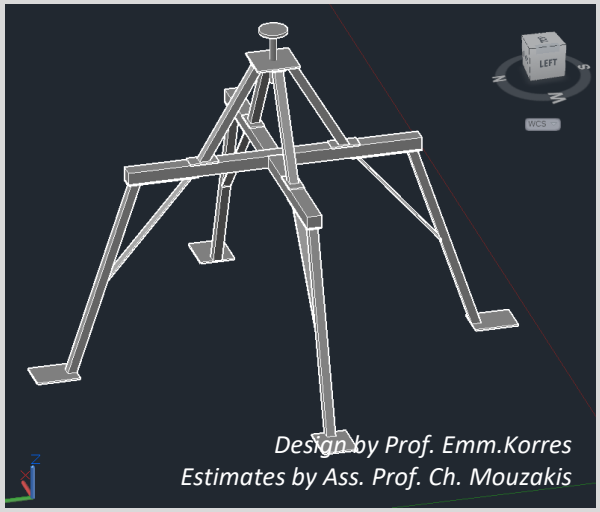




Georeferenced architectural analysis coupled with geometric and materials characterization data

3d Representation of the Onion Dome internal wooden structure

ONION DOME OUTER CUPOLA METAL SUPPORT



DISINFECTATION OF THE HOLY AEDICULE'S ONION DOME WOODEN ELEMENTS OF WOOD-BORING INSECTS AND FUNGHI


Disinfectation process


Ventilation system in the dome

Prof. A. Moropoulou, Dr. E.T. Delegou*, Antonios E. Tsagkarakis, MSc, PhD***

* *Sch. Chem. Eng., National Technical University of Athens,*

** *Laboratory of Agricultural Zoology and Entomology, Agricultural University of Athens, Greece*


Infested Wooden Pieces

CLEANING

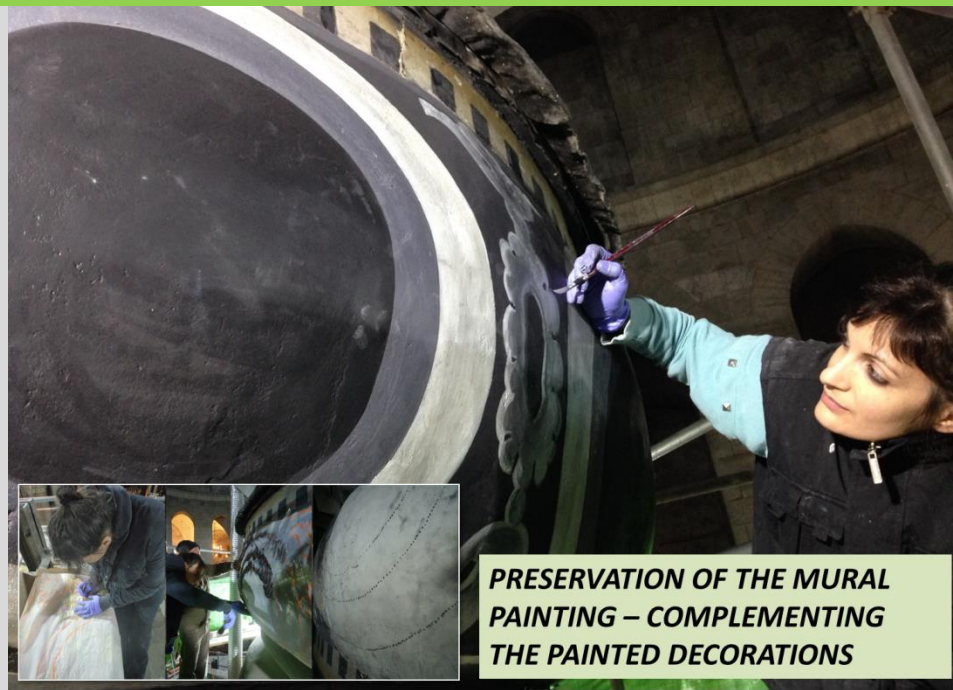
REINFORCEMENT AND CONSOLIDATION OF CRACKS

- Primal 3% acrylic emulsion

CONSERVATION INTERVENTIONS AT THE ONION DOME

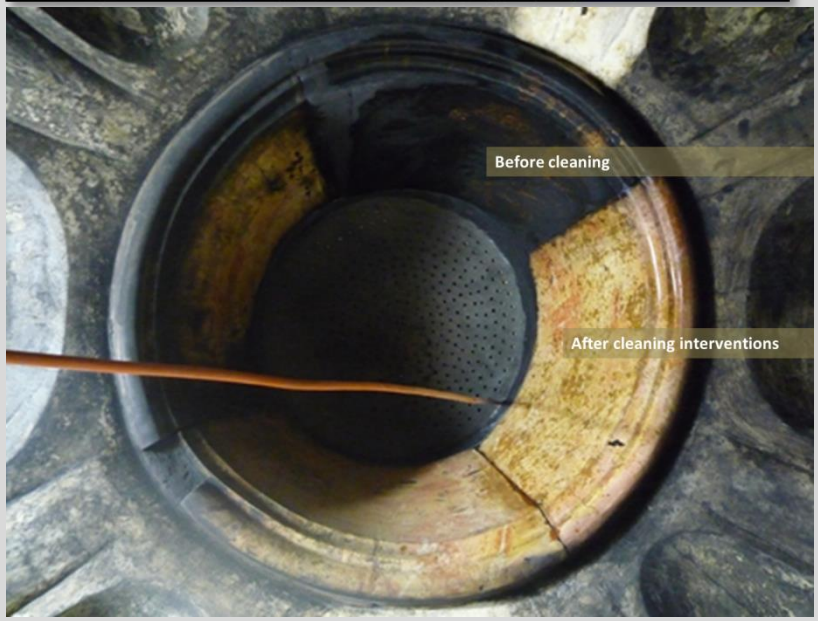
APPLICATION OF PLASTERS (TWO LAYERS)

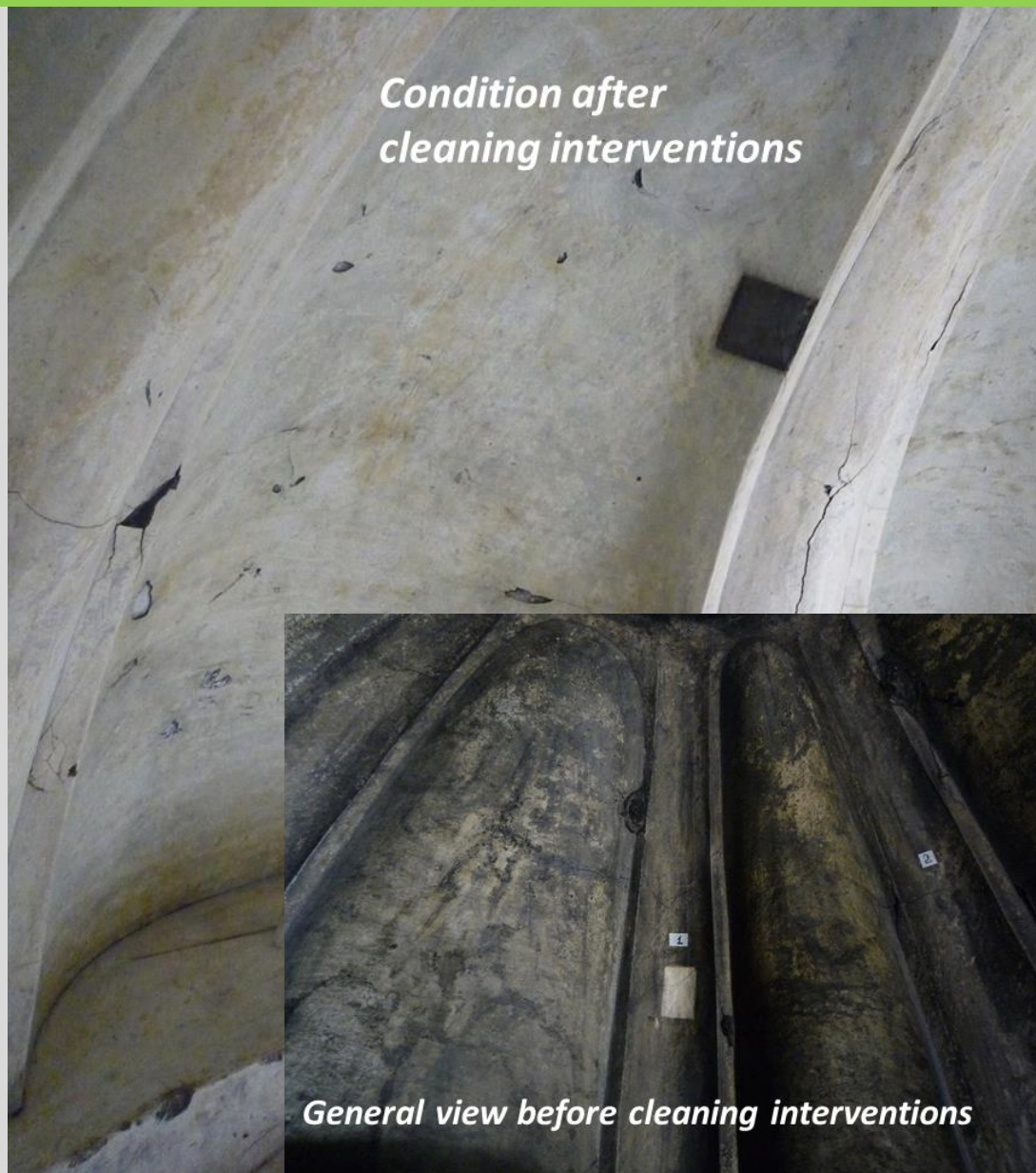
1st layer: MasterEmaco S TIX 285
2nd (top) layer: MasterEmaco S TIX 285 sieved at 1mm

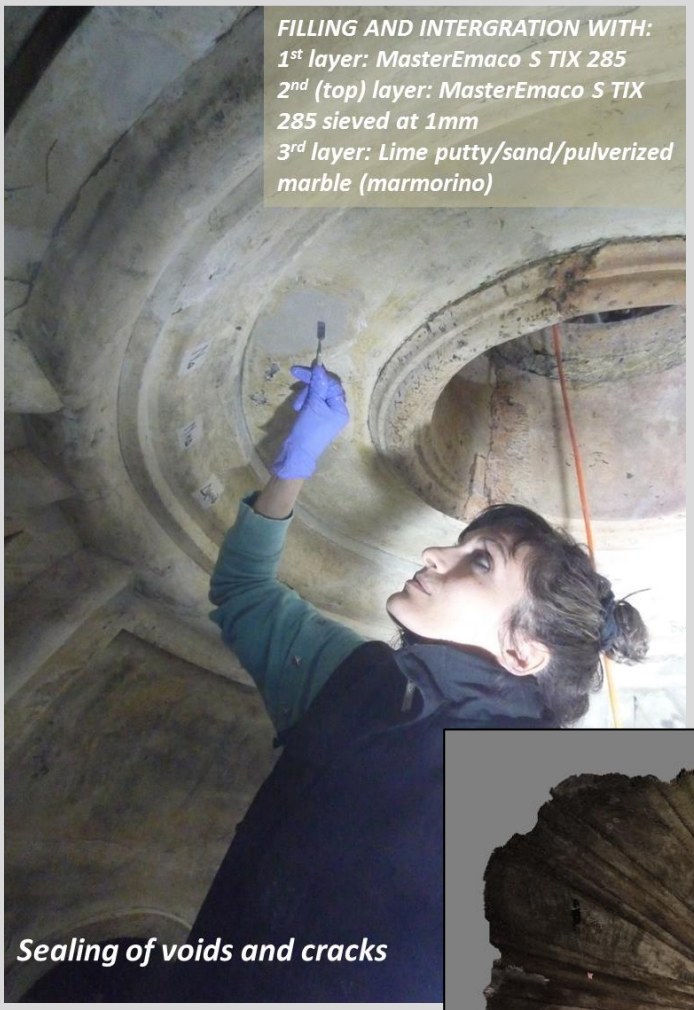


PRESERVATION OF THE MURAL PAINTING – COMPLEMENTING THE PAINTED DECORATIONS

CONSERVATION INTERVENTIONS AT THE DOME OF THE TOMB CHAMBER

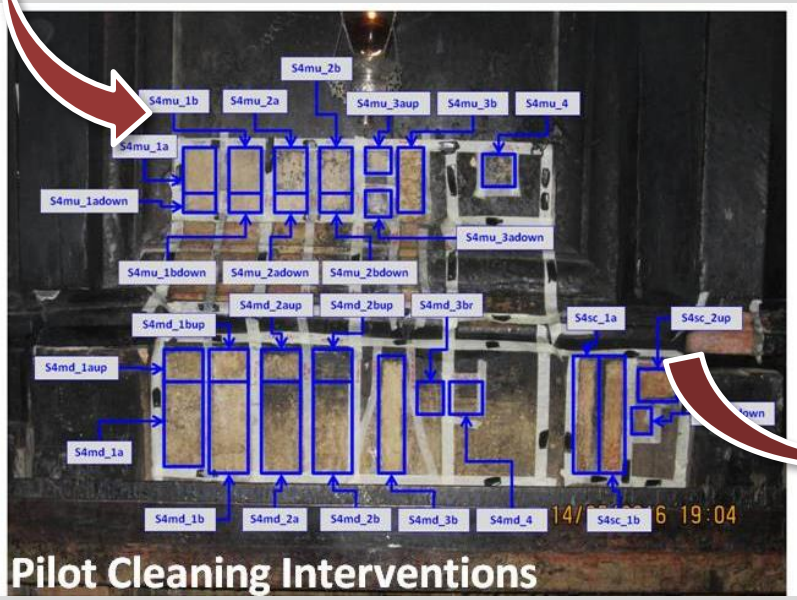






CONSERVATION INTERVENTIONS AT THE DOME OF THE CHAPEL OF THE ANGEL

CLEANING INTERVENTIONS



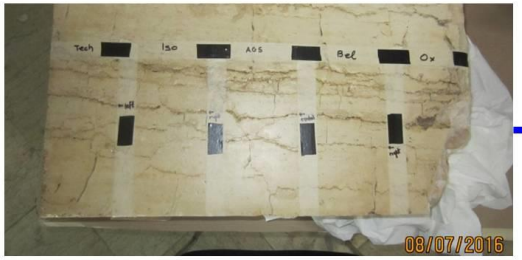
FROM PILOT TO FINAL APPLICATION

PROTECTION INTERVENTIONS

FROM PILOT APPLICATION

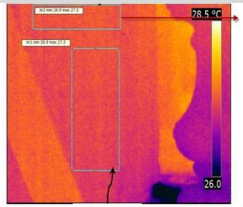
TO FINAL APPLICATION

Pilot Protection Interventions



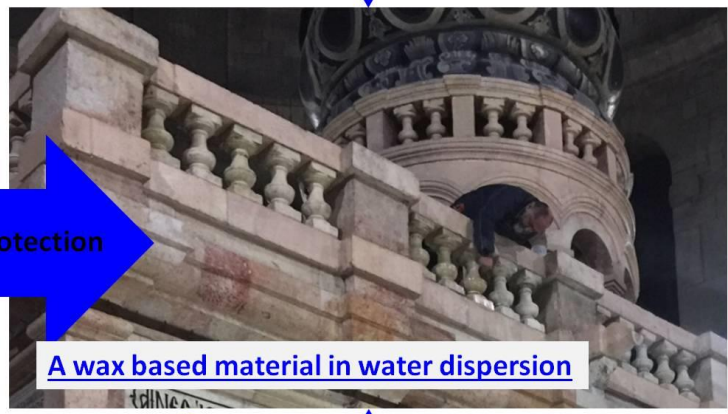
Assessment

FOM Raman Karsten Tubes



IRT

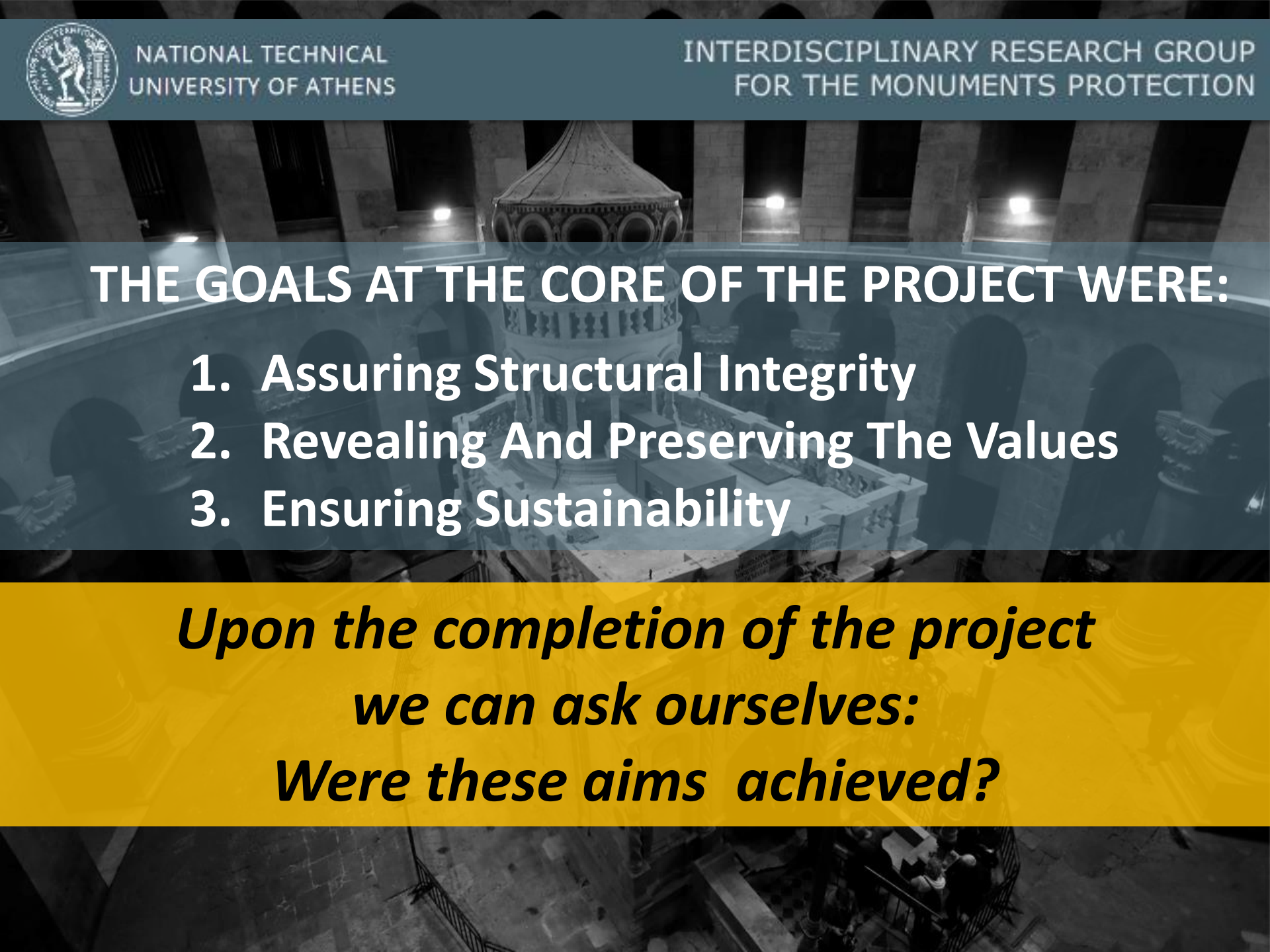
Final Protection



A wax based material in water dispersion

Decision making

In order to ensure sustainability, a cultural rehabilitation of the pilgrims' attitude is required. The extinguishing of the candles onto the Aedicule's exterior facades, must stop

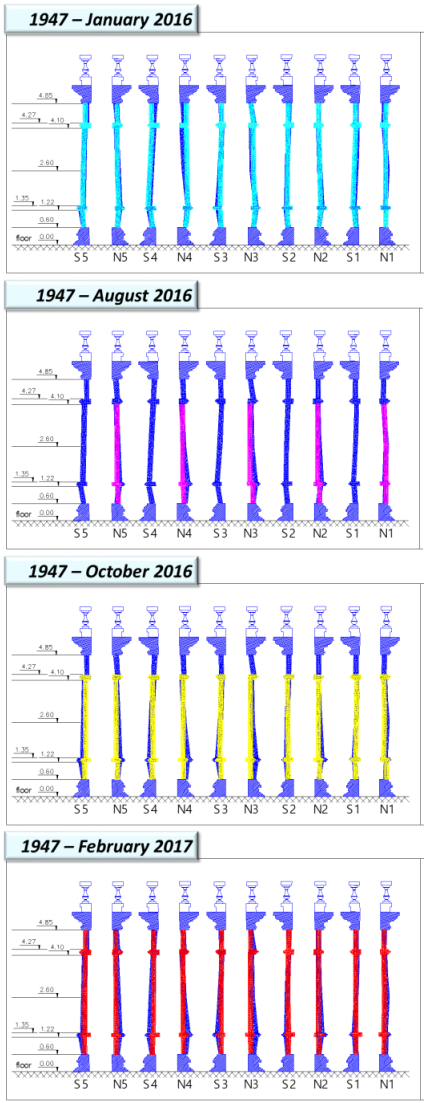


THE GOALS AT THE CORE OF THE PROJECT WERE:

1. Assuring Structural Integrity
2. Revealing And Preserving The Values
3. Ensuring Sustainability

Upon the completion of the project we can ask ourselves: Were these aims achieved?

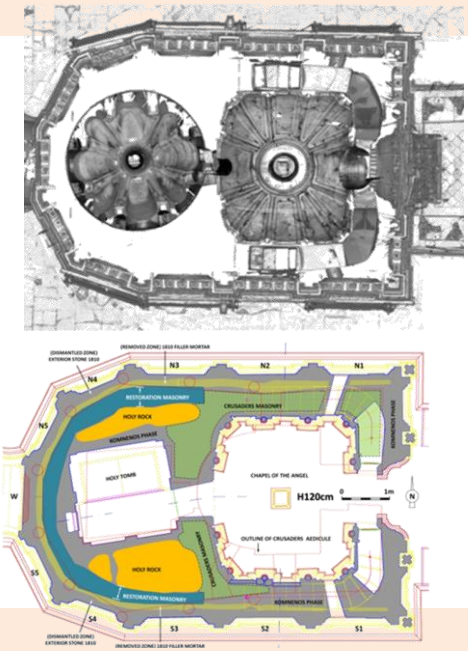
Time Evolution of the columns' Deviations from verticality



Diminution of the deformations

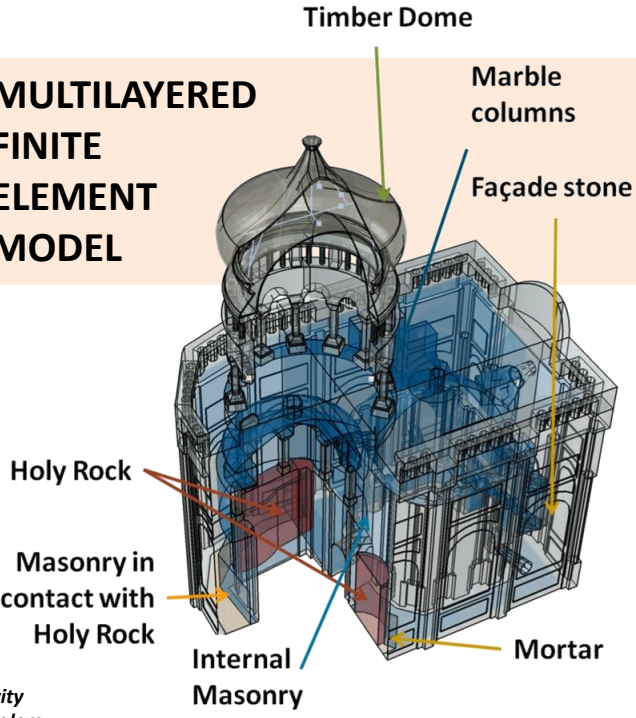
ACHIEVING THE PROJECT'S GOALS:
1. ASSURING STRUCTURAL INTEGRITY

DIGITAL GEOMETRIC DATA

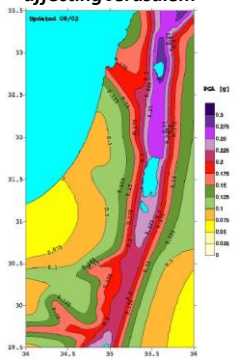


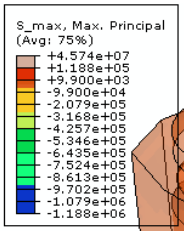
DIGITALIZED MATERIAL DATA

MULTILAYERED FINITE ELEMENT MODEL

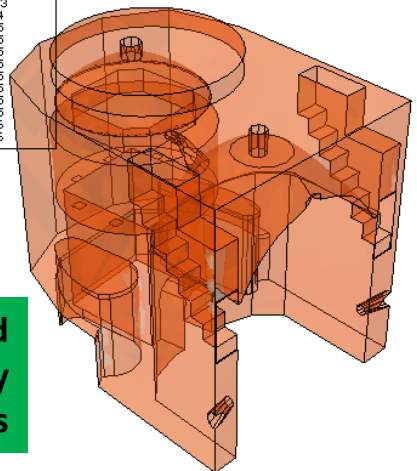


Seismic activity affecting Jerusalem





Strengthened Holy Aedicule



THE RESPONSE OF THE RETROFITTED STRUCTURE IS VALIDATED

*The **retrofitted structure** fulfills the **damage limitation performance level** for the design seismic action.*

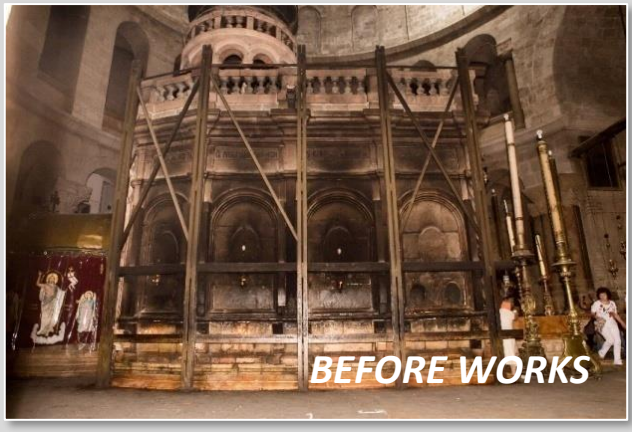
Bearing efficiently and homogeneously max principal stresses

*As a result, **the iron frame** installed by the British Mandate in 1947 (Freeman), in order to negate the deformation of the Aedicule and ensure safety, was **removed***

REMOVAL OF IRON FRAME

The Holy Aedicule is free again after 70 years

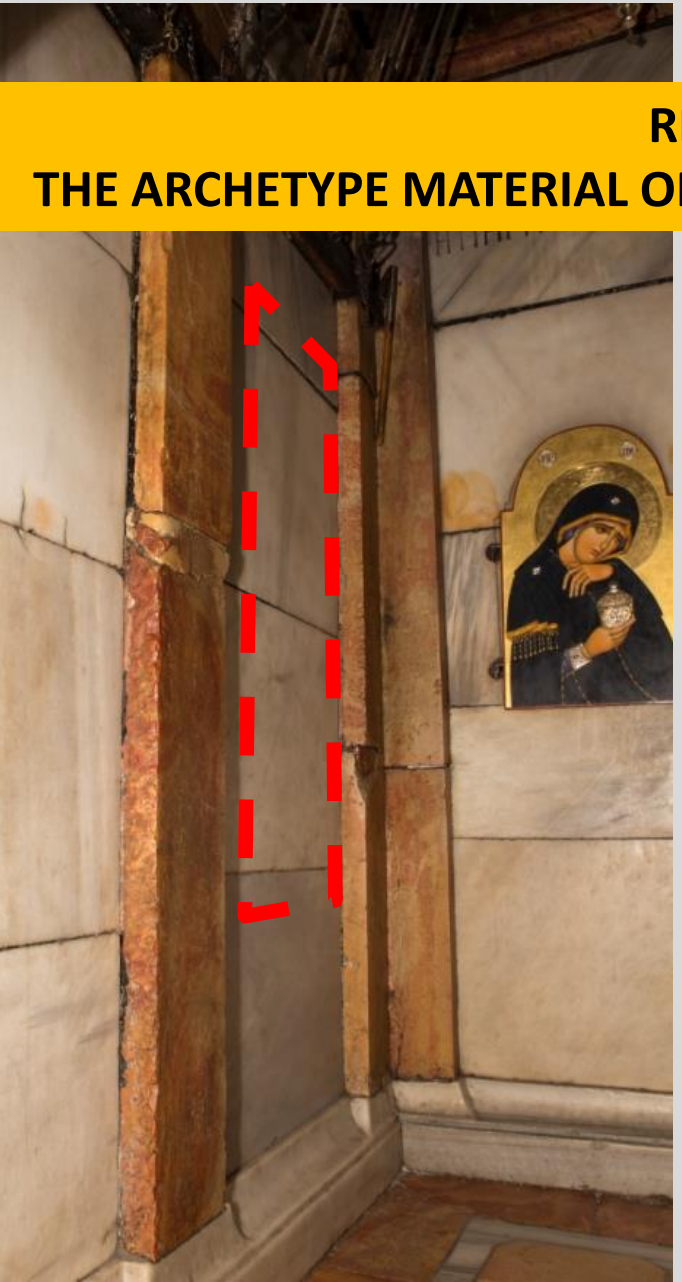
It is now only in the hands of the three Christian Communities, entrusted with its safeguard under the framework of the Status Quo

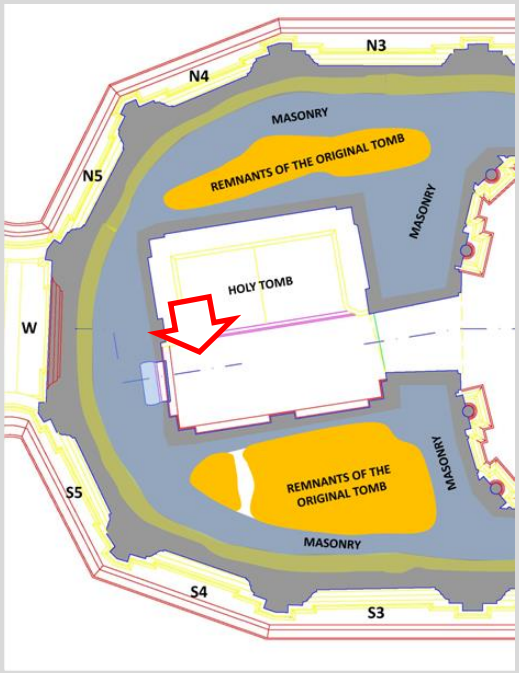


REVEALING OF VALUES

ACHIEVING THE PROJECT'S GOALS:
2. REVEALING AND PRESERVING VALUES

REVEALING THE HOLY ROCK, THE ARCHETYPE MATERIAL OF THE BURIAL MONUMENT





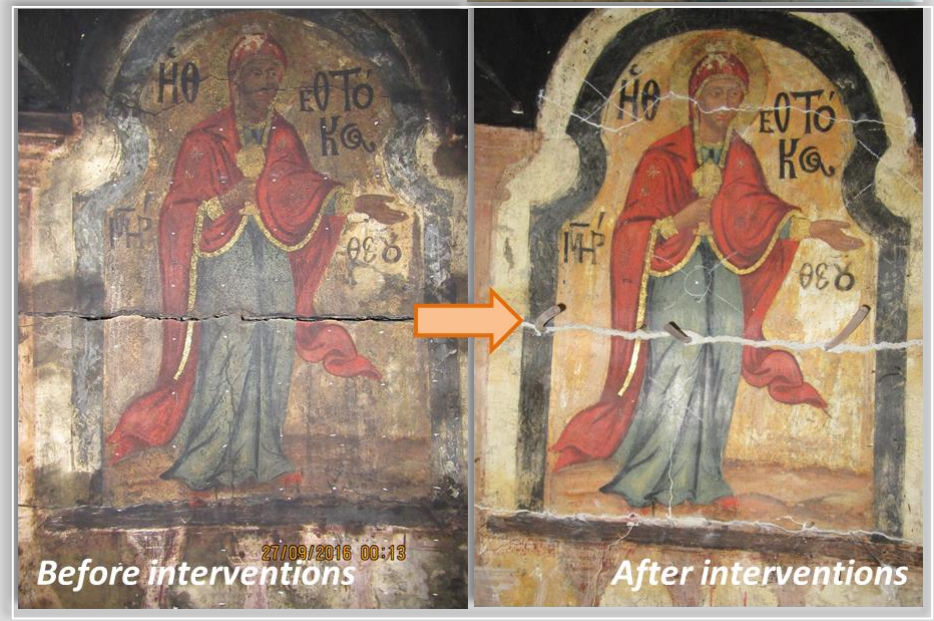
ACHIEVING THE PROJECT'S GOALS:
2. REVEALING AND PRESERVING VALUES

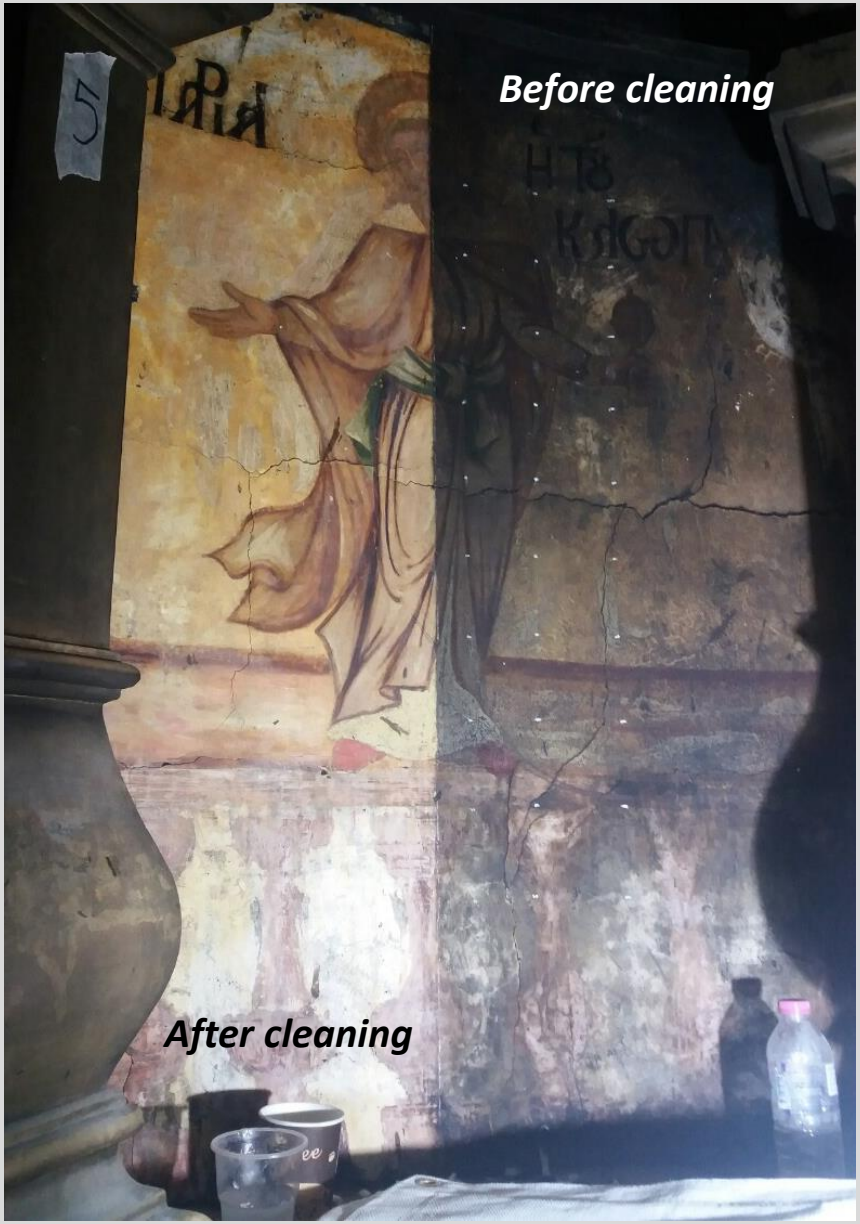
PRESERVATION OF THE EXISTING GILDING DECORATIONS OF THE SCULPTED MARBLES OF THE HOLY AEDICULE

The existing gilding decorations of the sculpted marbles of the Holy Aedicule will be conserved and preserved, but not reproduced

REVEALING & CONSERVATION OF THE FRESCOES: CHAMBER OF THE TOMB

ACHIEVING THE PROJECT'S GOALS: 2. REVEALING AND PRESERVING VALUES



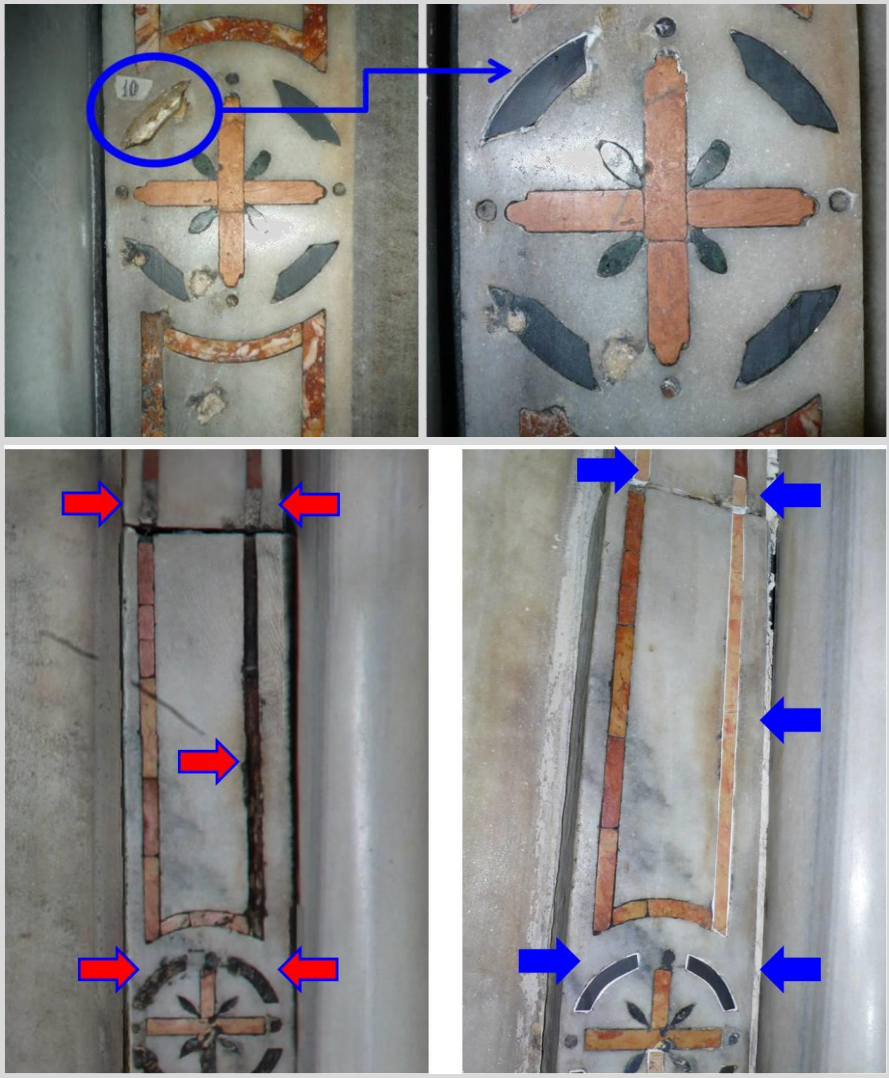


AESTHETIC CONSERVATION OF THE OPUS SECTILE DECORATIONS IN THE CHAPEL OF THE ANGEL

ACHIEVING THE PROJECT'S GOALS: 2. REVEALING AND PRESERVING VALUES

Cutting the restoration parts of opus sectile

Aesthetic conservation of the opus sectile replacing slayeb and black limestone missing parts



REVEALING, CLEANING AND PROTECTION OF THE ONION DOME EXTERIOR SURFACES

May, 2015

March, 2017

ACHIEVING THE PROJECT'S GOALS:
2. REVEALING AND PRESERVING VALUES

REVEALING, CLEANING AND PROTECTION OF THE LOWER INNER CUPOLA OF THE ONION DOME

Revealed fresco in the Onion Dome inner cupola

In the process of cleaning

Before cleaning

Radiant sun

After cleaning

Moon

Detail of revealed fresco

Rainbow

REVEALING, CLEANING AND PROTECTION OF THE EXTERIOR FAÇADE INSCRIPTIONS

ACHIEVING THE PROJECT'S GOALS: 2. REVEALING AND PRESERVING VALUES

Northwest façade

- *Before: left* (May 2015)
- *After: right* (March 2017)

South façade

- *Before: upper* (May 2015)
- *After: lower* (March 2017)

KOMNENOS' RESTORATION SIGNATURE FOUND AT THE SOUTH-EAST CORNERSTONE OF THE HOLY AEDICULE (15 OCTOBER 1809)

Komnenos cross after conservation interventions by the conservators

Area where the cross was discovered

Design by NTUA team through reverse photogrammetry, Prof A. Georgopoulos

A golden cross, copy of the Komnenos cross, installed on the top of the rehabilitated onion dome of the Holy Aedicule of the Holy Sepulchre

PRESERVATION OF VALUES

FINDINGS

ACHIEVING THE PROJECT'S GOALS:
2. REVEALING AND PRESERVING VALUES

3D RECONSTRUCTION OF THE CHAMBER OF THE TOMB BEFORE THE OPENING

ACHIEVING THE PROJECT'S GOALS:
2. REVEALING AND PRESERVING VALUES

Lifting of the stone of the Tomb revealing the burial monument

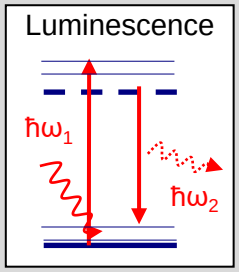
ACHIEVING THE PROJECT'S GOALS:
2. REVEALING AND PRESERVING VALUES

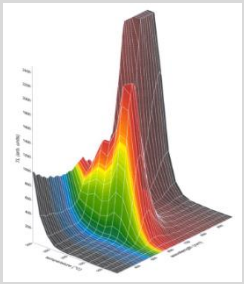
ACHIEVING THE PROJECT'S GOALS:
2. REVEALING AND PRESERVING VALUES

LUMINESCENCE DATING RESULTS - TL/OSL DATING

Inter-calibration of results

Prof. A. Moropoulou*, Dr. E.T. Delegou*, PhD Cand. M. Apostolopoulou*, Prof. N. Zacharias**
**** Sch. Chem. Eng., Nat. Techn. Univ. Athens, **Lab. Archaeometry, Univ. Peloponnese***





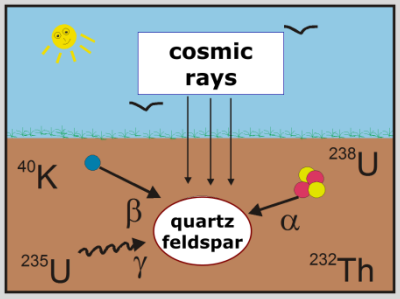
$$\frac{\text{Absorbed radiation dose (Gy)}}{\text{Dose rate (Gy/ka)}}$$

AGE = ED/DR

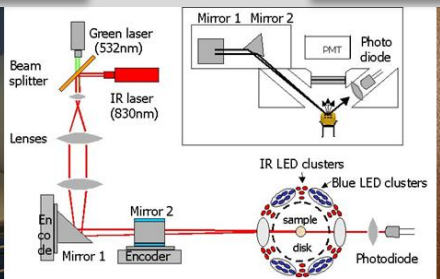
10 parameters are required, such as:

- *Luminescence signal*
- *Signal correction*
- *Signal attenuation form*
- *Sample moisture content*
- *Calculation of cosmic rays*
- *Calculation of uranium, thorium and pottasium*

*Use of the phenomena of **Thermoluminescence** (TL; stimulated by heat) and **Optically Stimulated Luminescence** (OSL; stimulated by light) to result in an **ABSOLUTE AGE***



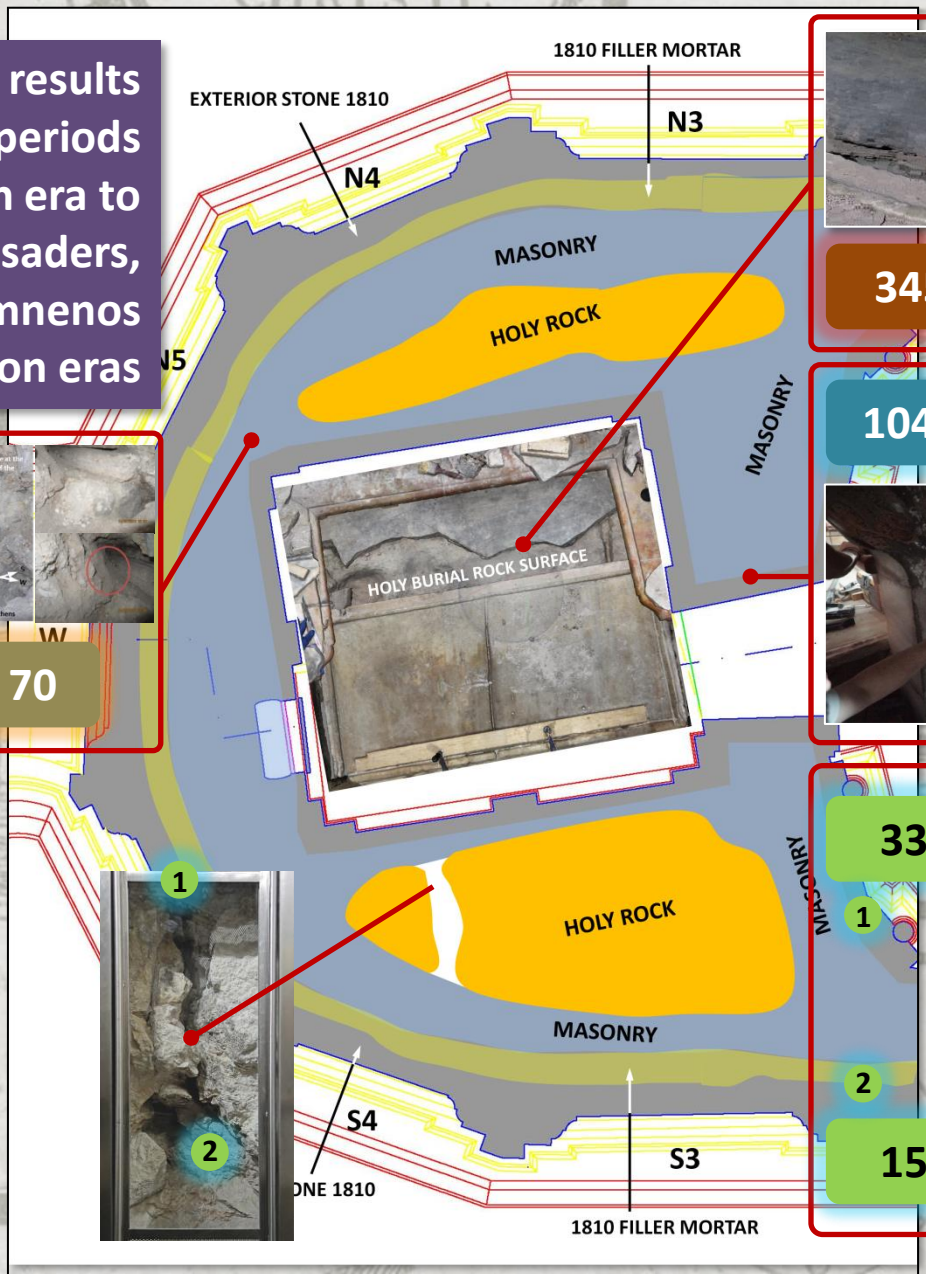
TL/OSL instrumentation



Holy Aedicule samples

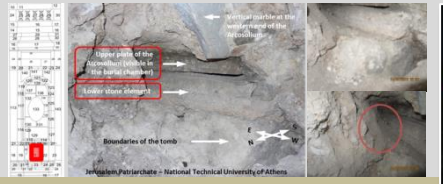
ACHIEVING THE PROJECT'S GOALS:
2. REVEALING AND PRESERVING VALUES

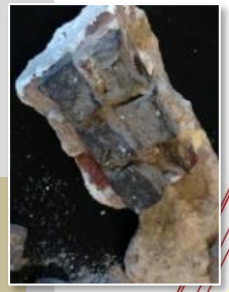
Archaeometric results stemming all historic periods from the Constantinean era to Byzantine, Crusaders, Renaissance and Komnenos restoration eras



Moropoulou, A., Zacharias, N., Delegou, E. T., Apostolopoulou, M., Palamara, E., & Kolaiti, A. (2018). OSL mortar dating to elucidate the construction history of the Tomb Chamber of the Holy Aedicule of the Holy Sepulchre in Jerusalem. *Journal of Archaeological Science: Reports*, *19*, 80-91.

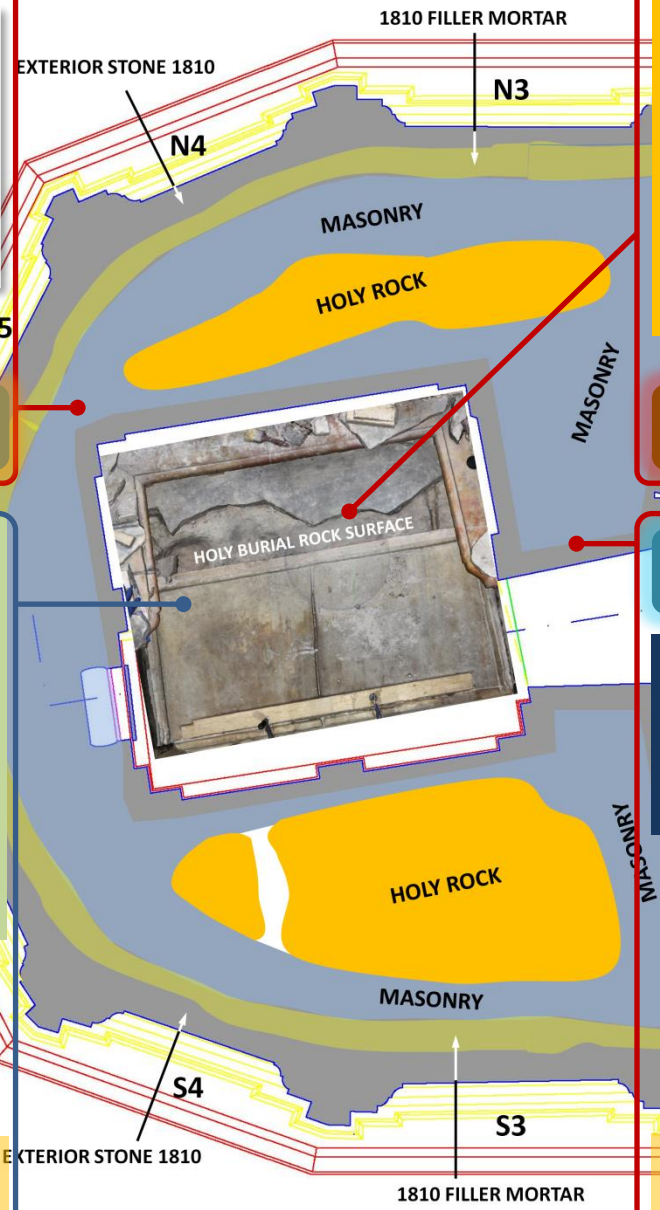
ARCHAEOMETRIC INVESTIGATION OF DIFFERENT TYPES OF MORTARS





The mortar sample from the north-west area of the Tomb, bearing red mosaics was dated to the ***Bonifacio restoration period***

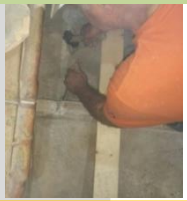
1560AD ± 70



Archaeometric analysis estimates the age of the mortar connecting the gray plate with the bedrock at the ***Constantinean era***

345AD ± 230

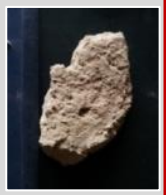
A comparative study of the mortar remnant sample taken from beneath the orange hued plate with other samples enhances the historic representations estimating the provenance of the upper plate in the period between the ***sack of Jerusalem by the Khwarazmian Turks (1244) & Bonifacio's restoration period (1555)***



"English pilgrim in 1345….decorated with a porphyry slab, that had lips on the sides, and in the middle of the slab there was cut a streak", Biddle M. "The Tomb of Christ", p.88, (1999)

1040AD ± 150

Michael IV Paphlagonian or Constantine Monomachos restoration / Crusaders' interventions



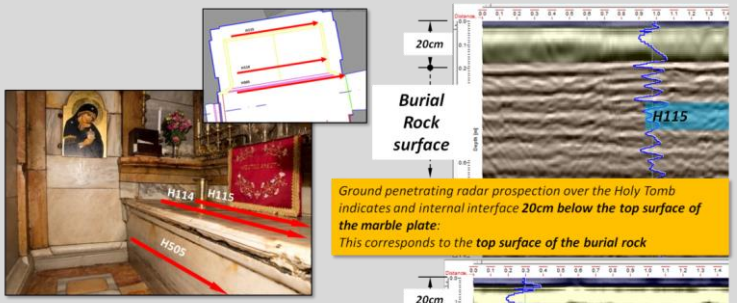
"…some time before 1106/8 the Tomb Chamber was rebuilt….the limiting dates are 1009 and 1106/8", Biddle M. "The Tomb of Christ", p.85, (1999)

NATIONAL TECHNICAL UNIVERSITY OF ATHENS

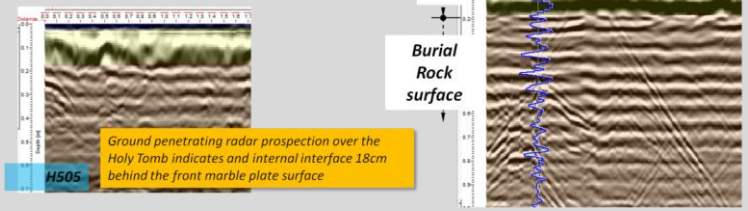
ACHIEVING THE PROJECT'S GOALS:
2. REVEALING AND PRESERVING VALUES

INNOVATIVE NON-DESTRUCTIVE INSPECTION BY NTUA TO REVEAL THE BURIAL MONUMENT'S MORPHOLOGY

Georadar prospection over the closed tomb

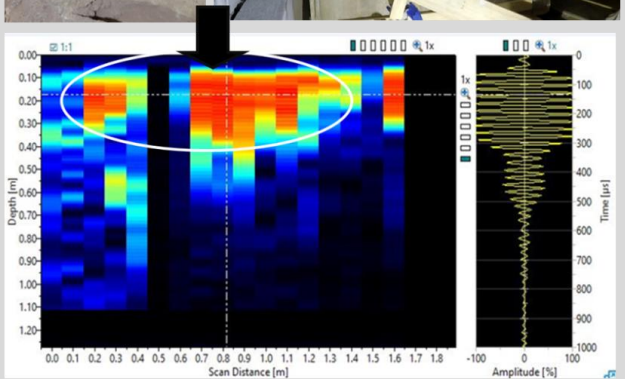


Ground penetrating radar prospection over the Holy Tomb indicates and internal interface **20cm below the top surface of the marble plate**:
This corresponds to the **top surface of the burial rock**

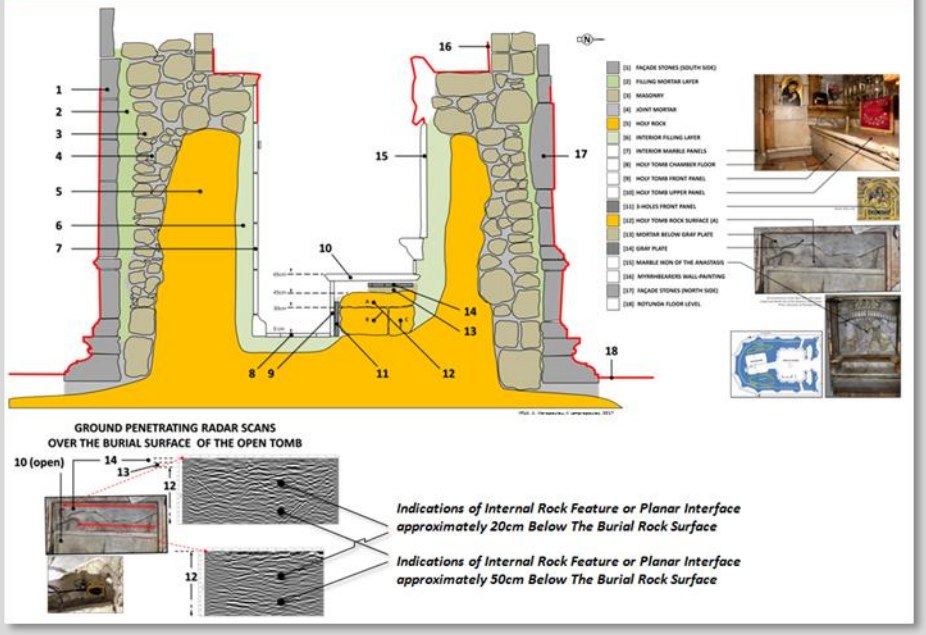


Ground penetrating radar prospection over the Holy Tomb indicates and internal interface 18cm behind the front marble plate surface

Digital portable microscopy over the burial surface



CONCEPTUAL DESCRIPTION OF HOLY TOMB BASED ON GEORADAR FINDINGS



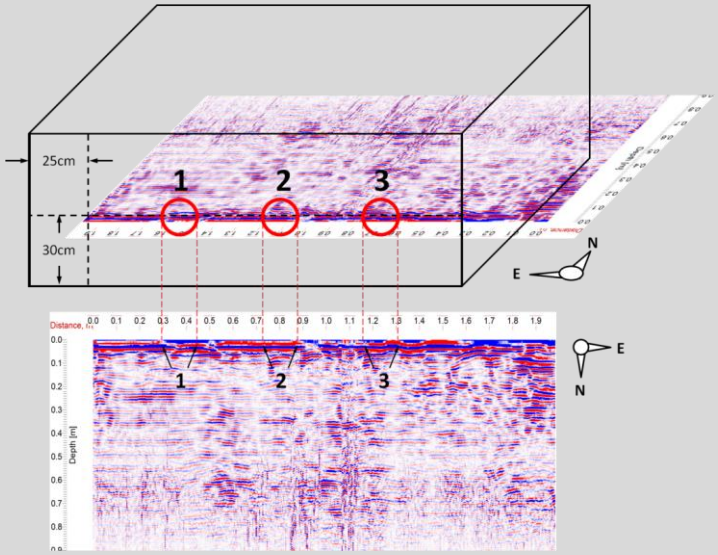
ACHIEVING THE PROJECT'S GOALS:
2. REVEALING AND PRESERVING VALUES

(A. Moropoulou, K. Lampropoulos, M. Apostolopoulou 2017) based on recent findings and GPR survey

Verdun Altar, 1181
Nikolaus von Verdun

Battistero di San Giovanni in Tumba
Tomba di Rotari

THREE LARGE ROUNDELS REPRESENTING THE 'PORT-HOLES' which were a key feature of the burial couch in the Aedicule from c. 1100 or before until the 14th century



Ground penetrating radar indicates the presence of remnants of the **earlier front marble panel of the Holy Tomb**, between the current one and the Tomb.

REFLECTIONS CORRESPOND TO THE EDGES OF THE THREE HISTORICAL PORTHOLES.

The Holy Rock evidenced from the Constantinean era to the Bonifacio restoration

Holy Rock observation window

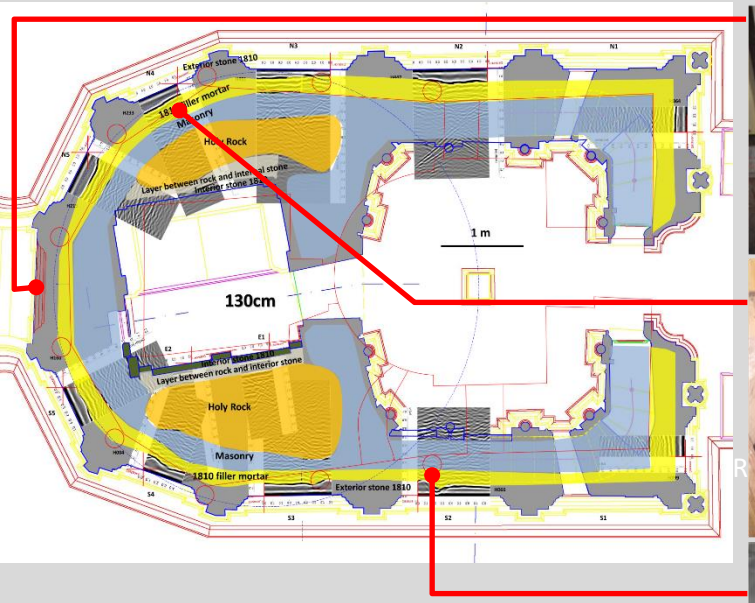
335AD ± 235

Archaeometric investigation of the two types of historical mortars found in the crack, reveal the application of mortars over a large period of time, from the Constantinean construction till Bonifacio's restoration period

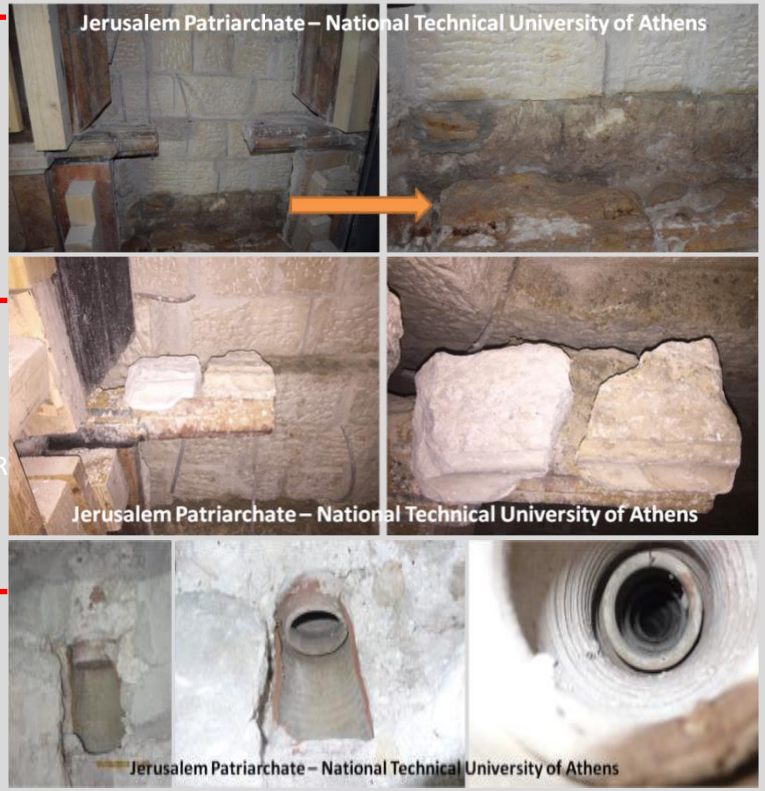
1570AD ± 68

ACHIEVING THE PROJECT'S GOALS:
2. REVEALING AND PRESERVING VALUES

Did Komnenos built a completely new Aedicule around the remains of the Holy Rock or did he embedded parts of the earlier Aedicule that survived the destructive fire?



Architectural and Ground Penetrating Radar analyses were verified, regarding the predicted internal layers



Possible remains of an earlier construction phase

Triangular shaped marble pieces with decorative cymatia

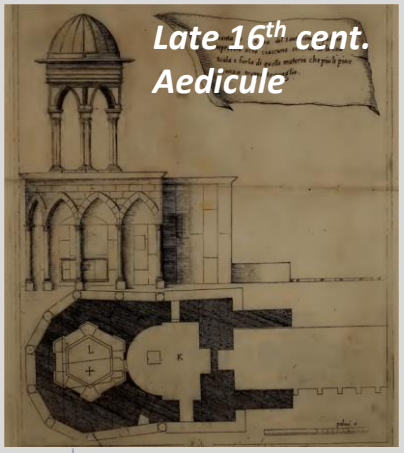
Archaeometric analysis dates the ceramic drain tube within the masonry to early 19th c.

Komnenos most probably preserved the core of the masonry, at least at its lower height, which is presumed to have been erected by Monomachos with later interventions, **embedding primary materials in his own construction phase**. Moreover, **the roughly reconstructed masonries of the Komnenos phase**, are proof that the reconstruction **was implemented in conditions of great haste**

ACHIEVING THE PROJECT'S GOALS:
2. REVEALING AND PRESERVING VALUES

(A. Moropoulou, K. Lampropoulos, 2017) based on recent findings and ground penetrating radar survey

HISTORIC REPRESENTATION OF THE HOLY AEDICULE EVOLUTION BY DIGITAL CORRELATIONS: LATE 16th & EARLY 19th CENT. AEDICULE

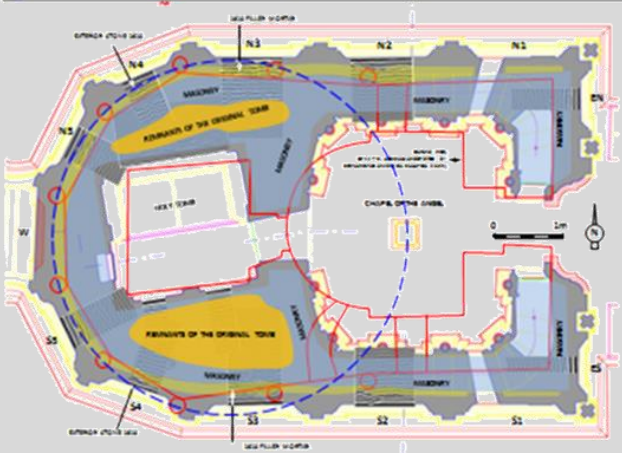


Late 16th cent. Aedicule

Early 19th cent. Aedicule

The digital correlation, (NDT prospection, and architectural, geometric and historic documentations) of the late 16th and the early 19th c. Aedicule indicates the probability of embedded parts of the earlier structure:

- *At the western part, up to the Myrrhbearers area*
- *At the eastern part, up to 1.5m of the northern masonry of the Chapel of the Angel*

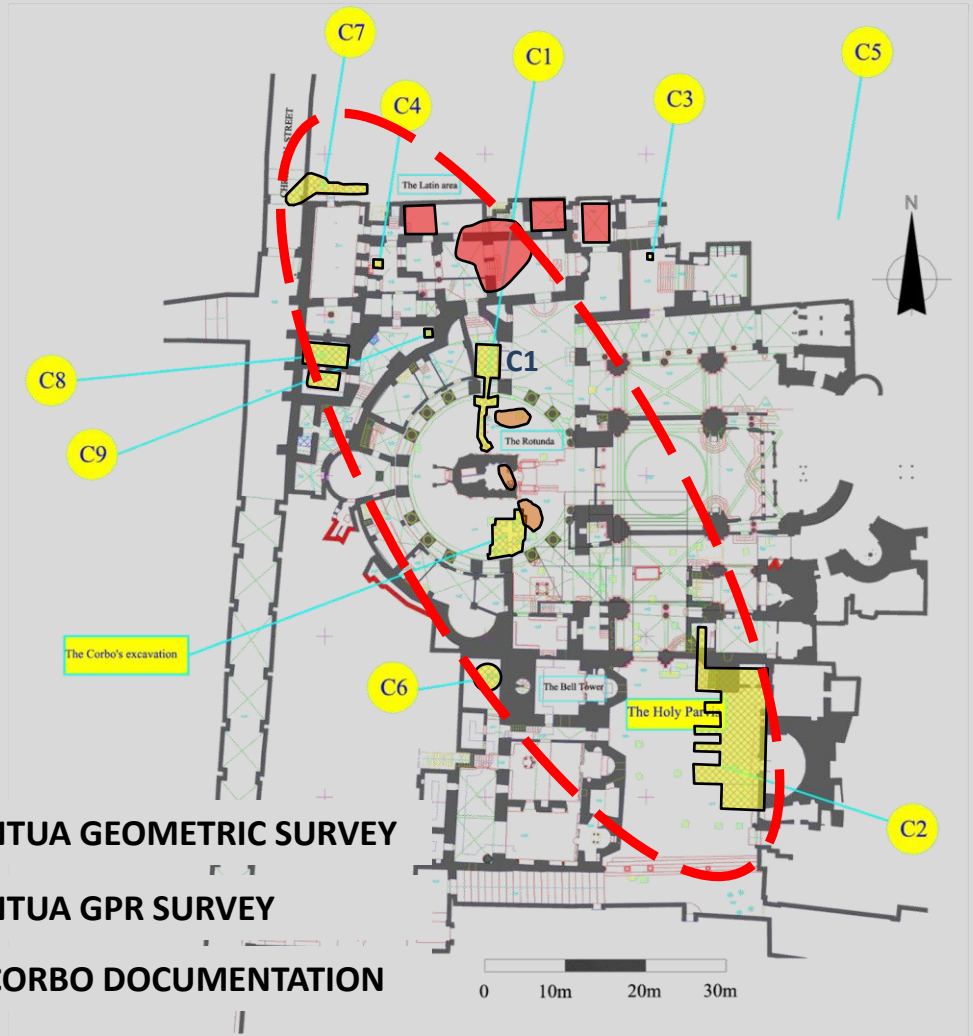


ACHIEVING THE PROJECT'S GOALS:
2. REVEALING AND PRESERVING VALUES

ARCHAEOLOGICAL SEMANTICS OF THE UNDERGROUND AREA OF THE CHURCH OF THE HOLY SEPULCHRE

NATIONAL TECHNICAL UNIVERSITY OF ATHENS
INTERDISCIPLINARY RESEARCH GROUP FOR THE MONUMENTS PROTECTION

The Holy Aedicule is located at the center and above a **cluster of underground cisterns**, and natural and manmade **underground voids** and spaces

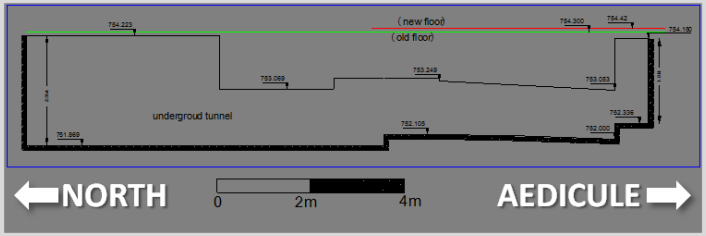


NTUA GEOMETRIC SURVEY

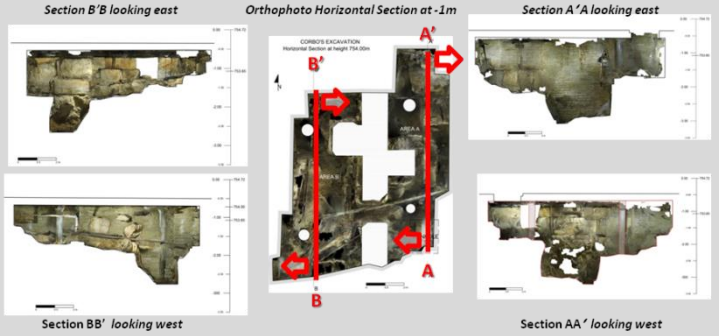
NTUA GPR SURVEY

CORBO DOCUMENTATION

Geometric documentation (vertical section) of cistern C1

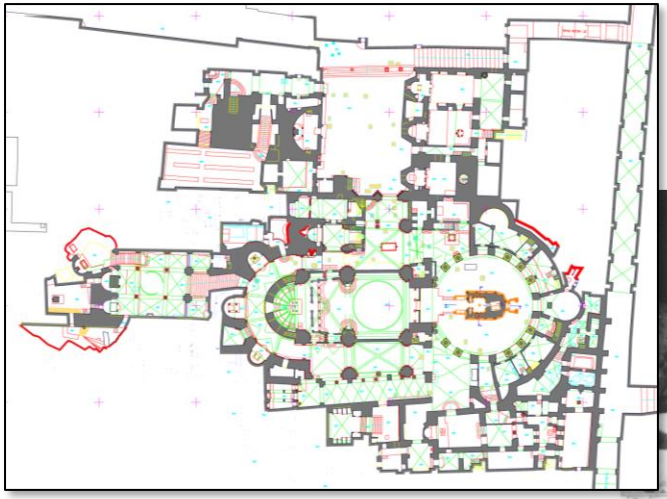


Geometric documentation of Corbo's Excavation

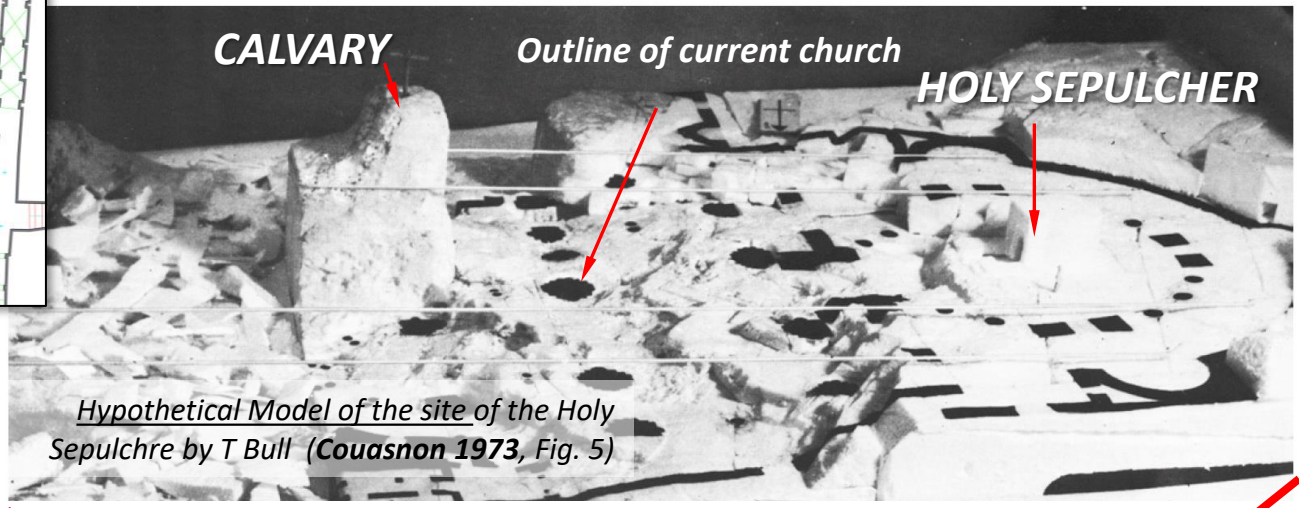


ACHIEVING THE PROJECT'S GOALS:
2. REVEALING AND PRESERVING VALUES

SEMANTICS OF THE BEDROCK MORPHOLOGY OF THE SITE OF THE HOLY SEPULCHER - NEW FINDINGS

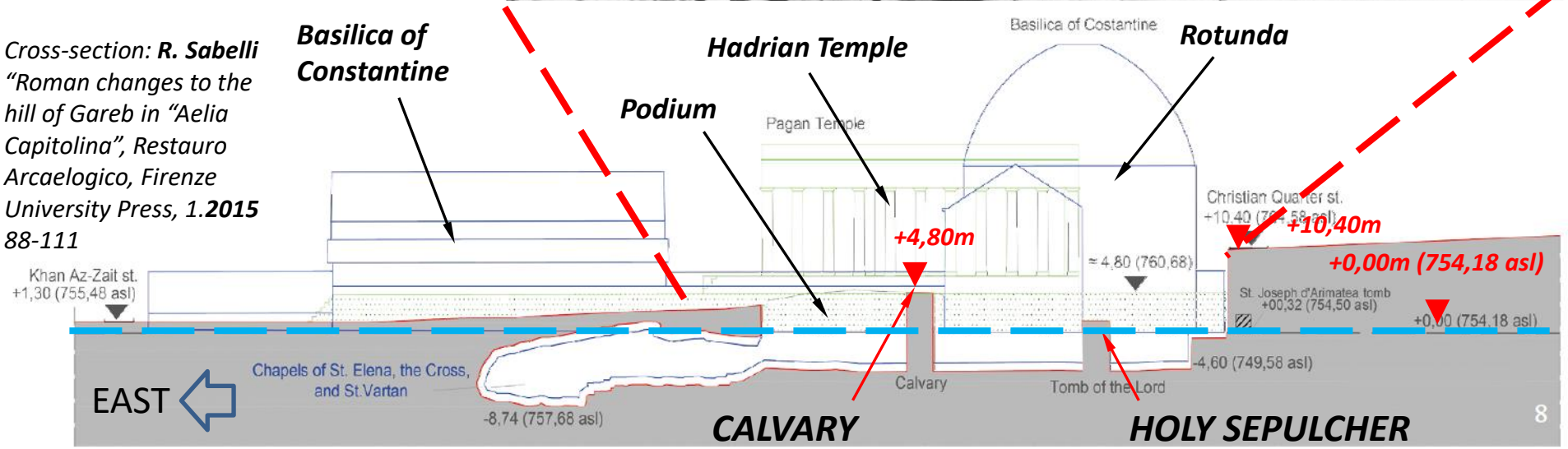


*General ground plan of the Holy Sepulchre, courtesy of **D.-D. Balodimos, A. Georgopoulos and G. Lavvas, 2003***



*Hypothetical Model of the site of the Holy Sepulchre by T Bull (**Couasnon 1973**, Fig. 5)*

*Cross-section: **R. Sabelli** "Roman changes to the hill of Gareb in "Aelia Capitolina", Restauro Arcaelogico, Firenze University Press, 1.**2015** 88-111*

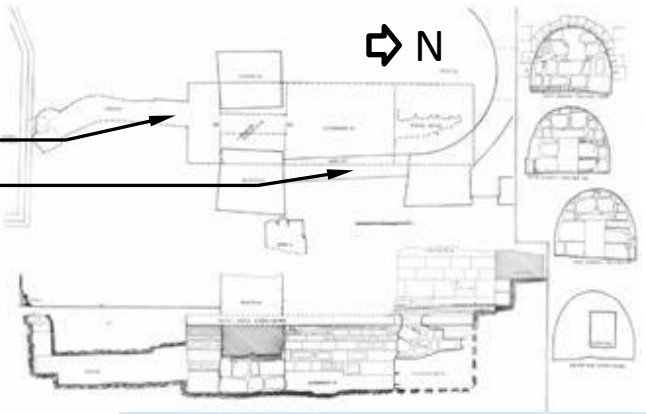


ACHIEVING THE PROJECT'S GOALS:
2. REVEALING AND PRESERVING VALUES

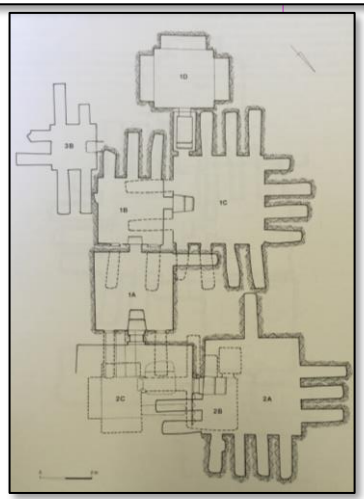
(A. Moropoulou, K. Lampropoulos, 2017) based on recent findings and ground penetrating radar survey

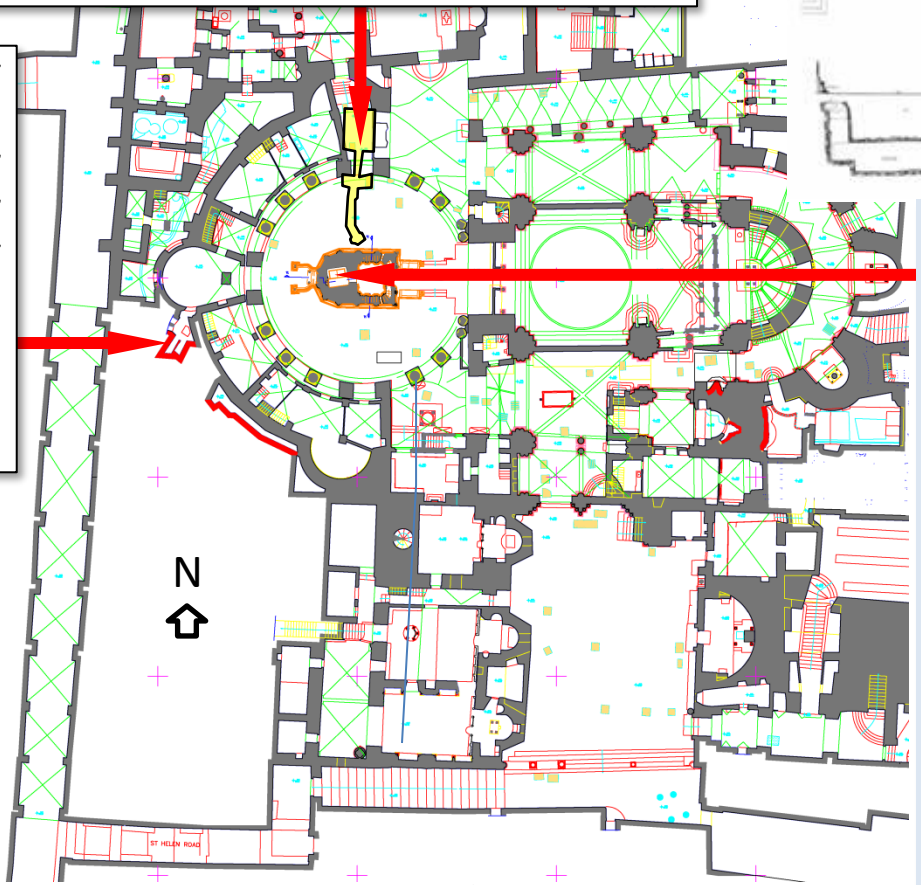
*The Cistern may be the **remnants of a Tomb**, its roof cut-off during the leveling of the area by Constantine.*

- *The tunnel towards the Aedicule could be a southward extension of one of the burial openings of the Tombs*
- *The other openings may have been blocked by the stone lining*



*The Tomb of Joseph of Arimathea (+0.30m level) may be the **remnants of a multilevel cluster of Tombs**, as in the case of the Alkedama Tombs, Jerusalem, after the construction of the Constantine Rotunda.*





***Akeldama Tombs complex**, Plan 1.1 from G. Avni , Z. Greenhut , The Akeldama Tombs, IAA 1996*

1. The facts that:
   - *"Cistern" is at -2.37m level*
   - *Tomb of Joseph of Arimathea is at +0.3m level*
   - *Tomb of Christ is a +0.9m level with an eastern entrance*

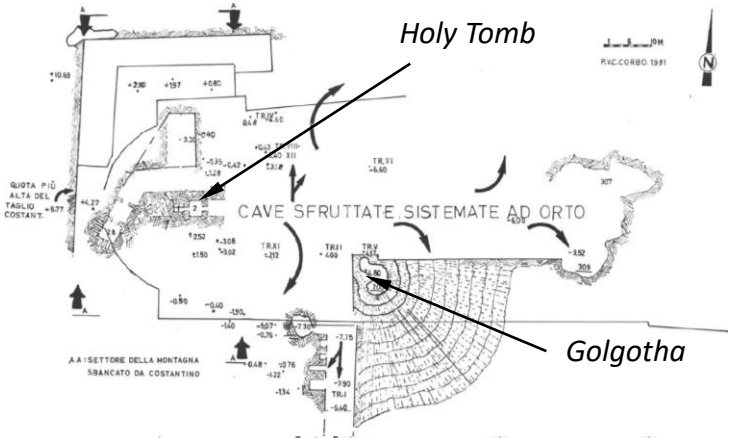
2. Taking into account Corbo's excavations and recent GPR findings

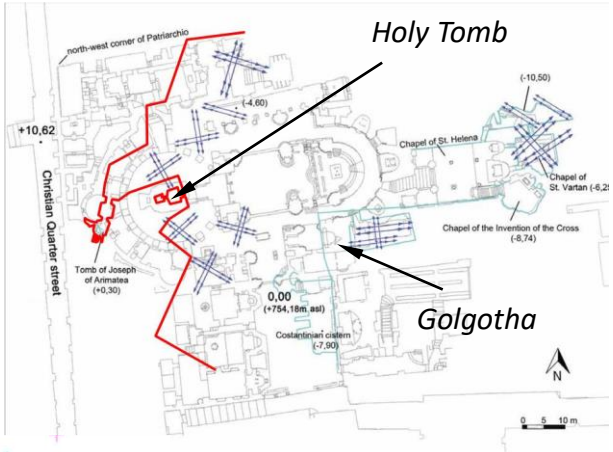
are indications that the western boundary of the quarry may have had a north-west direction during the Hadrian era

ACHIEVING THE PROJECT'S GOALS:
2. REVEALING AND PRESERVING VALUES

(A. Moropoulou, K. Lampropoulos, 2017) based on recent findings and ground penetrating radar survey

The abandoned quarries partially used as a garden ***V. Corbo 1981/1982****, III, Pl. 67*





Outline of western boundary of the quarry according to ***R. Sabelli (2014),*** *based on directions of quarrying according to Corbo's indications*

Potential Tomb corresponding to Hadrian Cistern

Cluster of Tombs (including Tomb of Joseph of Arimathea). Potential entrance at the surface of the rock volume removed by Constantine or from the western street level (also removed)

(A. Moropoulou, K. Lampropoulos, 2017) ***<u>POTENTIAL OUTLINE OF WESTERN BOUNDARY OF THE QUARRY</u>*** *based on recent findings and ground penetrating radar survey*

SUCH A NORTH-SOUTH BOUNDARY CONFIGURATION BETTER JUSTIFIES WHY HADRIAN BUILT THE TEMPLE WITH ITS WESTERN SIDE RIGHT UP TO THE HOLY TOMB

NATIONAL TECHNICAL UNIVERSITY OF ATHENS
Interdisciplinary Research Group for the Monuments Protection

UNDERGROUND INTERVENTIONS AT THE HOLY SEPULCHER ROTUNDA AREA TO ASSURE SAFETY AND SUSTAINABILITY OF THE HOLY AEDICULE REHABILITATION

Geometric documentation of the cisterns and the underground tunnels in the Church of the Holy Sepulchre

Chief Scientific Supervisor: Prof. A. Moropoulou

Scientific Responsible: Prof. A. Georgopoulos
School of Rural and Surveying Engineering

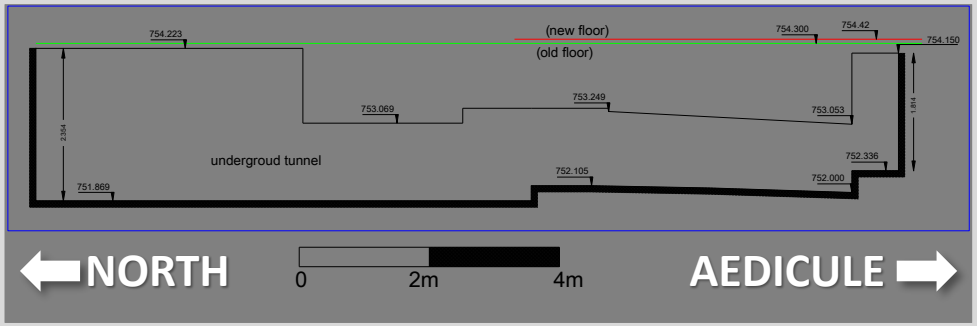
Research Team: ***Assoc. Prof. E. Lambrou***, ***Assoc. Prof. G. Pantazis***, ***S. Tapinaki***, *Rural & Surveying Eng., Msc,*
E. Tsilimantou, *Rural & Surveying Eng, Msc*

Greek Orthodox Jerusalem Patriarchate
Franciscan Order
Armenian Jerusalem Patriarchate

National Technical University of Athens

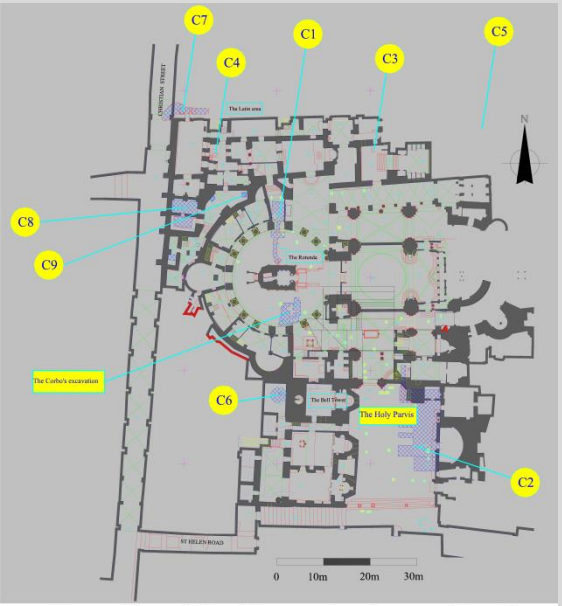
Geometric documentation *determined the* ***depth of each cistern*** *determined its* ***positional relation to the Holy Aedicule*** *in order to assess its eventual impact and* ***documented in detail*** *the most important cisterns*

C1 ***Geometric documentation (vertical section) of cistern C1***



1 *Detailed documentation of underground cisterns*

The position of the cisterns &underground tunnels on the ground plan of the Holy Sepulchre Complex.



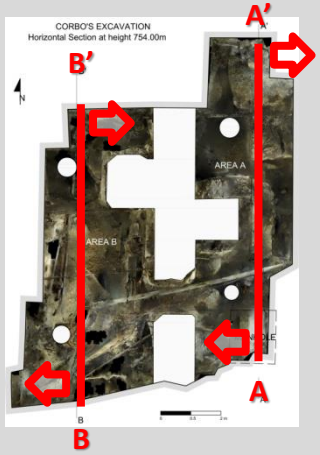
The positions of the cisterns and underground tunnels are presented on the ground plan of the Holy Sepulchre Complex

Cistern	Depth (m)	Situation	Minimum distance from the center of the Holy Aedicule (m)
C1	2.43	without water	3.40
C2	7.30	without water	32.45
C3	-	-	34.00
C4	-	-	29.85
C5	-	-	-
C6	11.40	water (0.90m)	23.07
C7	4.79	without water	38.38
C8	0.50	without water	21.38
C9	1.75	without water	18.76
Corbo's excavation	1.00 - 2.65	without water	5.31

Section B'B looking east

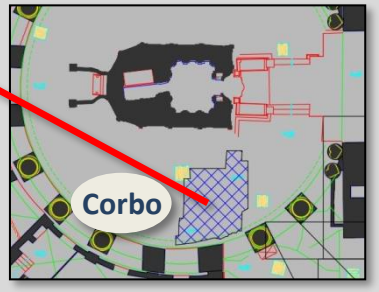
Section BB' looking west

Orthophoto Horizontal Section at -1m



Section A'A looking east

Section AA' looking west



2 *Depth, state and relative position of cisterns and underground tunnels in relation to the Holy Aedicule*

ENSURING SUSTAINABILITY

In order for the Holy Aedicule to achieve sustainable equilibrium with its environment, monitoring is mandatory

A five-year monitoring period is necessary in order to monitor the environment and the response of the monument

Monitoring will enable scientifically based decision making and will give the directions for the ensurance of sustainability

NATIONAL TECHNICAL UNIVERSITY OF ATHENS
Interdisciplinary Research Group for the Monuments Protection

Interdisciplinary scientific support for the onsite monitoring concerning critical performance parameters as well as the proper management to assure safety and sustainable protection of the Holy Aedicule of the Holy Sepulchre

- *Hydrothermal Simulator of the Holy Aedicule*
- *Dynamic Monitoring*
- *Monitoring of verticality and movements of the Holy Aedicule*
- *Presentation of the Interdisciplinary Documentation and Monitoring Laboratory (IMDL)*

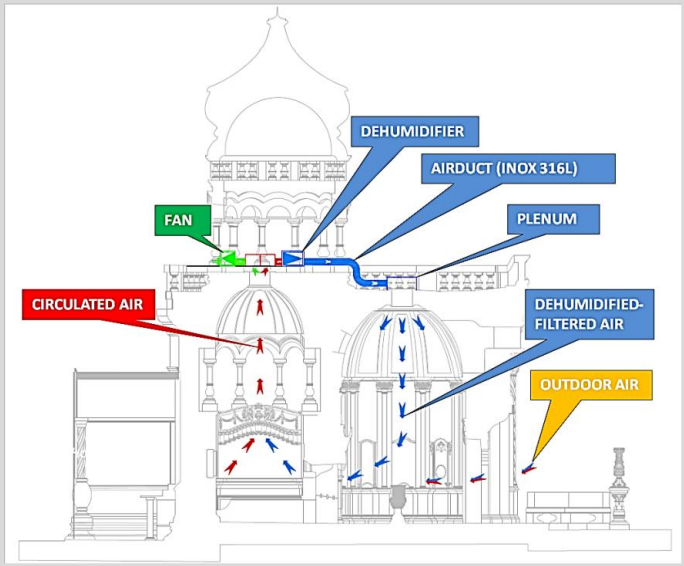
Scientific Coordinator:
Prof. A. Moropoulou

Interdisciplinary Research Group:
Prof. E. Korres, School of Architectural Engineering,
Prof. A. Georgopoulos, School of Rural and Surveying Engineering NTUA, Laboratory of Photogrammetry
Prof. A. Moropoulou, Director of Studies in the NTUA Interdisciplinary Postgraduate Programme Direction «*Conservation of Building Materials*», School of Chemical Engineering NTUA, Lab. Materials Science & Engineering
Prof. C. Spyrakos, , School of Civil Engineering NTUA, Laboratory for Earthquake Engineering
Assist. Prof. Ch. Mouzakis, , School of Civil Engineering NTUA, Laboratory for Earthquake Engineering

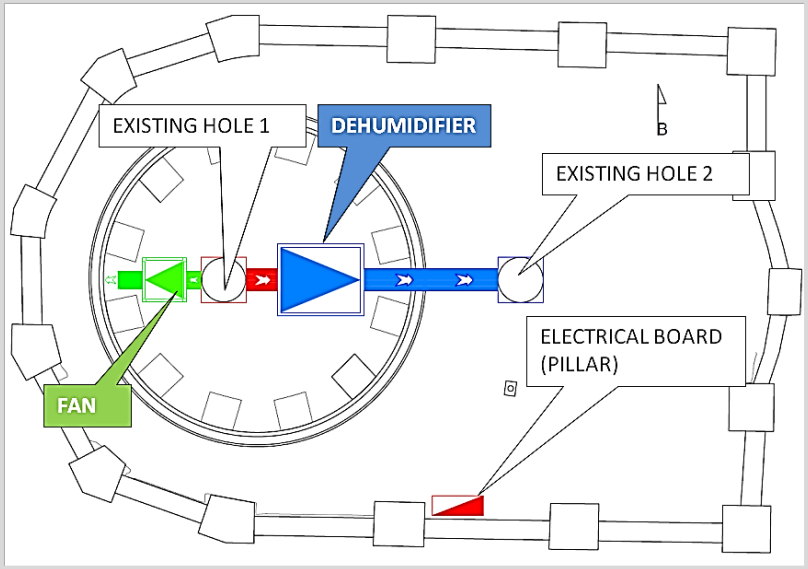
ACHIEVING THE PROJECT'S GOALS:
3. ENSURING SUSTAINABILITY

INSTALLATION OF VENTILATION AND DEHUMIDIFICATION SYSTEM

*National Technical University of Athens, Prof. A. Moropoulou, M. Agapakis**, A. Fragkiadoulakis****
*** Mechanical Engineer*



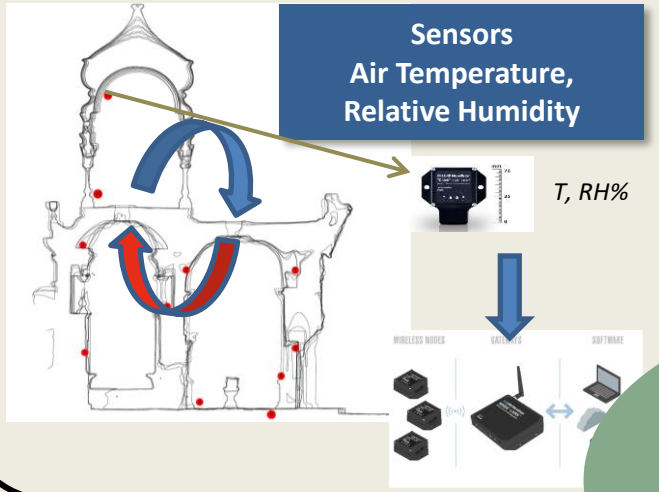
Schematic operation section of air ventilation and dehumidification system



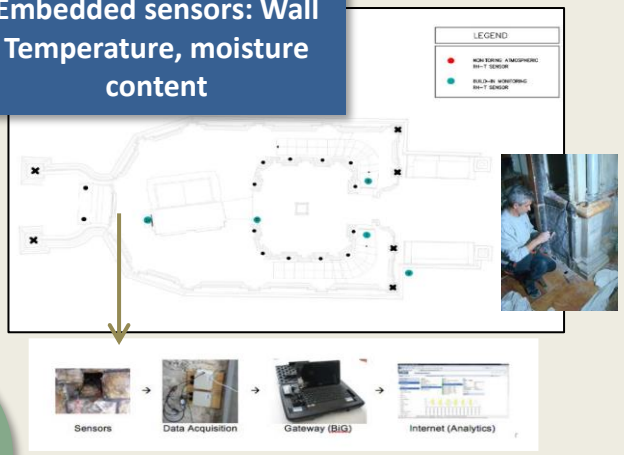
Rooftop of Holy Aedicule

ACHIEVING THE PROJECT'S GOALS:
3. ENSURING SUSTAINABILITY – MULTISENSORS

HYGROTHERMIC RESPONSE MONITORING

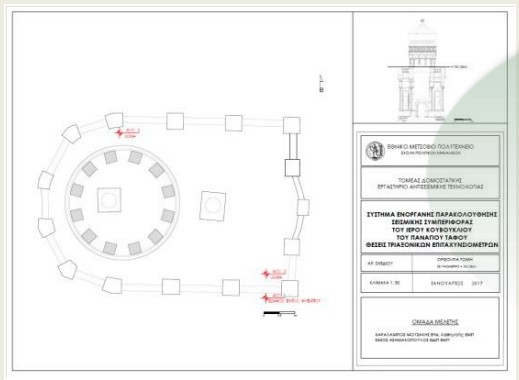


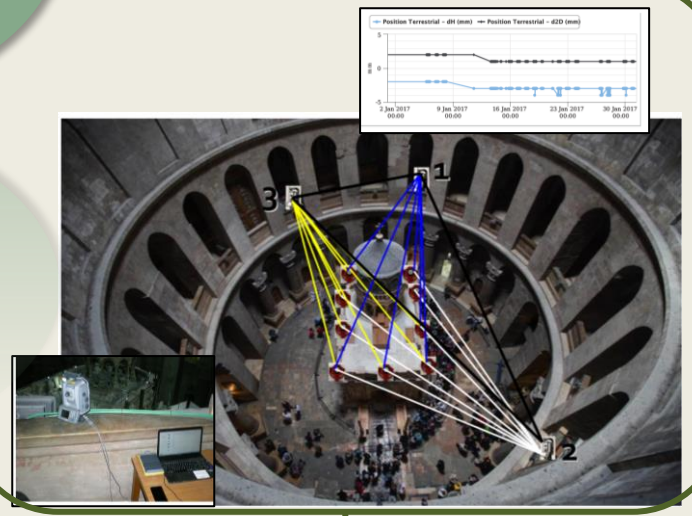
REMOTE DATA ACQUISITION



MULTIMODAL PERFORMANCE HEALTH MONITORING

Accelerometer



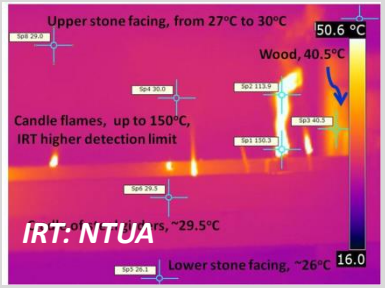


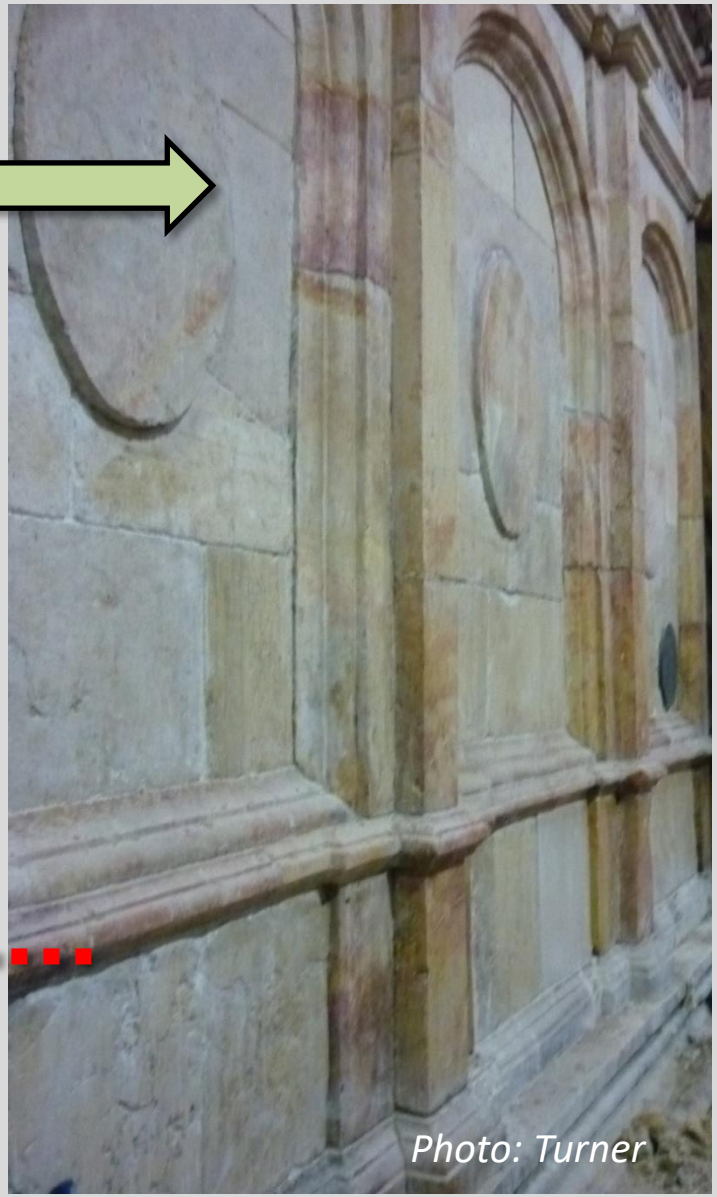
STRUCTURAL HEALTH MONITORING

3D PRECISE GEODETIC NETWORK

OVERALL SUSTAINABILITY OF THE REHABILITATED HOLY AEDICULE IN THE ENVIRONMENT OF THE CHURCH OF THE HOLY SEPULCHRE

New pilgrims' attitude is required for the adoration of the Aedicule in order to sustain it

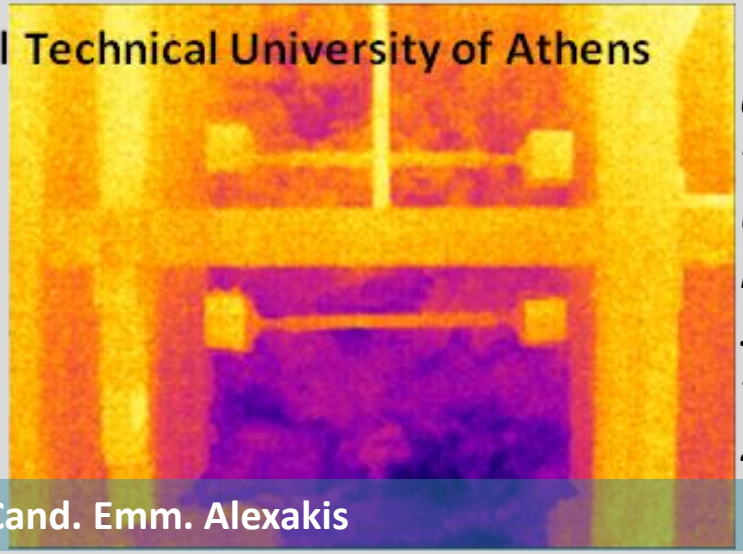




RISK TO SUSTAINABILITY:
INTENSE RISING DAMP FROM THE UNDERGROUND

Immediately after the removal of the external stone slabs intense rising damp phenomena were observed

The revealed masonry behind panel N2



The temperature difference between the lower and the upper part of the masonry is suggested from the thermograph (July 2016)

Prof. A. Moropoulou, Dr. E. Delegou, PhD Cand. Emm. Alexakis

We undertook the investigation of these issues and the study of a proposal to **reverse the connected risks** and **ensure sustainability**

Proposed interventions

- *Foundation Interventions for the Underpinning, Reinforcement, Water and Humidity Control of the Holy Aedicule*
- *Control of the rising damp and installation of proper sewage and water drainage system*
- *Pavement preservation and rehabilitation*

NATIONAL TECHNICAL UNIVERSITY OF ATHENS
Interdisciplinary Research Group for the Monuments Protection

UNDERGROUND INTERVENTIONS AT THE HOLY SEPULCHER ROTUNDA AREA TO ASSURE SAFETY AND SUSTAINABILITY OF THE HOLY AEDICULE REHABILITATION

Non-destructive prospection of the underground structures and water and humidity sources (canals, cisterns and voids)

Chief Scientific Supervisor: Prof. A. Moropoulou

Prof. A. Moropoulou, Dr. K. C. Lampropoulos*, PhD Cand. Em. Alexakis*, P. Sotiropoulos**
**School of Chemical Engineering, National Technical University of Athens, ** Terra Marine, Greece*

In cooperation with Athens Water Supply and Sewerage Company (EYDAP S.A.):
A. Aggelopoulos, E. Karampelas and D. Tamvakeras

Greek Orthodox Jerusalem Patriarchate
Franciscan Order
Armenian Jerusalem Patriarchate

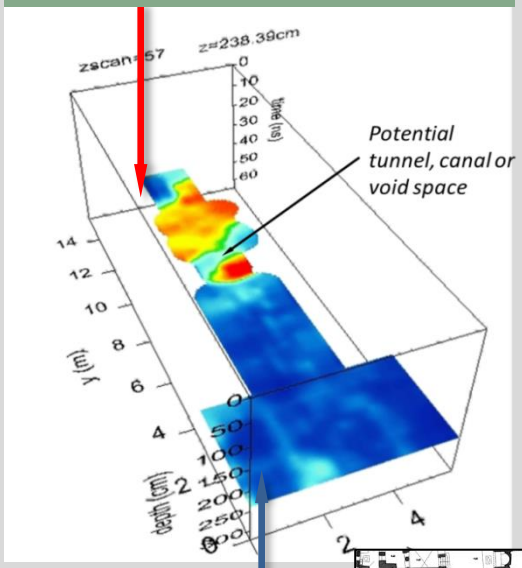
National Technical University of Athens

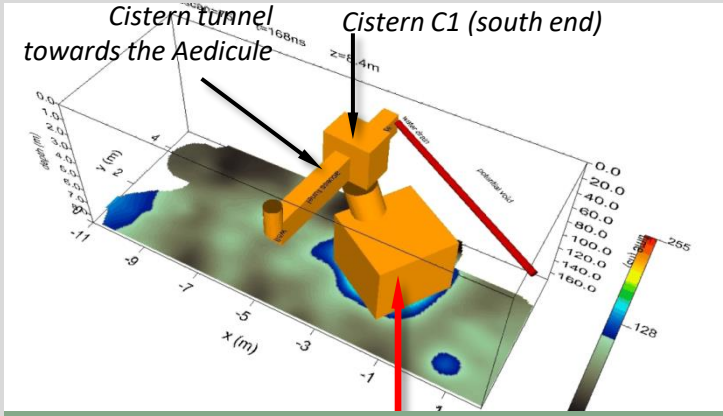
NATIONAL TECHNICAL UNIVERSITY OF ATHENS

SUSTAINABILITY AT RISK: 3D DIGITAL NDT PROSPECTION OF UNDERGROUNDS RISKS

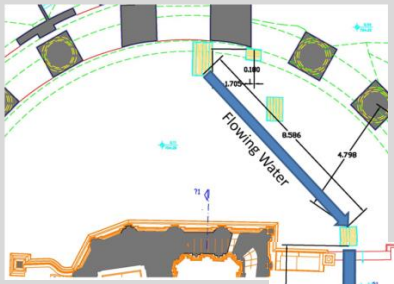
Ground penetrating radar, ***Electrical Resistivity Survey***, ***Electromagnetic Probe Systems***, and ***Robotic Cameras*** identified and documented the nature and state of all underground features related to water and humidity transport phenomena below and around the Holy Aedicule and neighboring areas

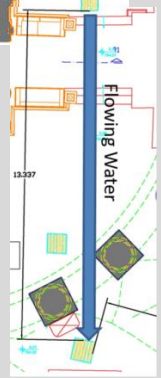
Presence of a potential void space under the Chapel of the Angel



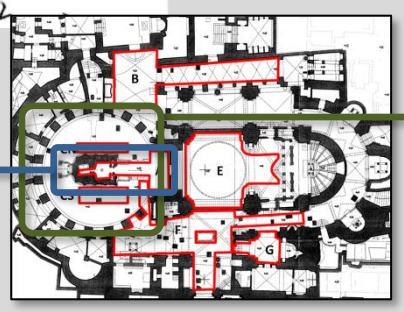


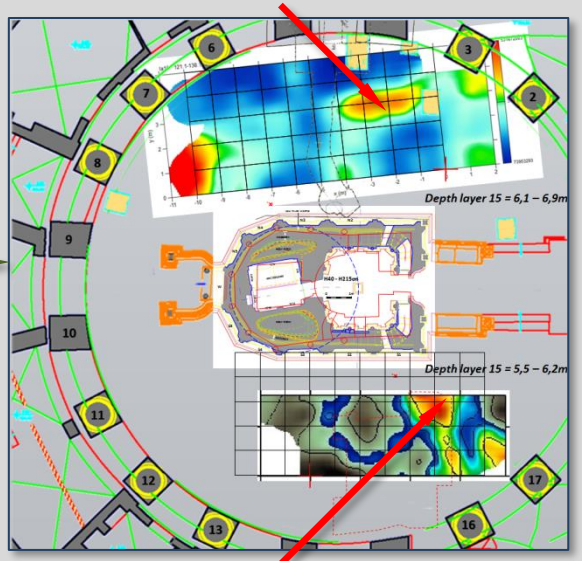
Large underground void *below cistern C1*





The underground canal that runs at the north east and east sides of the Rotunda floor, is active, full of water, and passes in front of the Aedicule





Underground feature in correlation with *the north* ***void space***

Underground water and drainage channels in *need* ***proper design, reconstruction*** *and* ***maintenance***

NATIONAL TECHNICAL UNIVERSITY OF ATHENS
Interdisciplinary Research Group for the Monuments Protection

Underground interventions at the Holy Sepulcher Rotunda area to assure safety and sustainability of the Holy Aedicule rehabilitation

- *Foundation Interventions for the Underpinning, Reinforcement, Water and Humidity Control of the Holy Aedicule*
- *Control of the rising damp and installation of proper sewage and water drainage system*
- *Pavement preservation and rehabilitation*

Scientific Coordinator:
Prof. A. Moropoulou

Interdisciplinary Research Group:
Prof. A. Georgopoulos, School of Rural and Surveying Engineering NTUA, Laboratory of Photogrammetry
Assoc. Prof. M. Kavvadas, School of Civil Engineering NTUA, Department of Geotechnical Engineering
Em. Prof. P. Marinos, School of Civil Engineering NTUA, Department of Geotechnical Engineering
Prof. A. Moropoulou, Director of Studies in the NTUA Interdisciplinary Postgraduate Programme Direction «*Conservation of Building Materials*», School of Chemical Engineering NTUA, Lab. Materials Science & Engineering
M. Agapakis, Mechanical Engineer

INVERSING THE RISK TO SUSTAINABILITY:
DIGITAL DESIGN OF UNDERGROUND INTERVENTIONS IN THE ROTUNDA AREA

FOUNDATION PROBLEMS AND PROPOSED INTERVENTIONS

***PROBLEM 1: FOUNDATION ON RUBBLE OF OLDER STRUCTURES AND/OR QUARRY STONES**, providing heterogeneous foundation with voids and weak spots. This condition appears to occur at the north and part of the south sides of the ante-chamber.*

INTERVENTION: **Grouting of the foundation**, using ALBARIA-based grout, with the objective to fill and/or consolidate voids in the rubble.

***PROBLEM 2: FOUNDATION ON NATURAL ROCK** (usually via a thin layer of bedding mortar), **BUT VERY CLOSE TO A STEEP SLOPE**. This condition appears to occur at the south side of the ante-chamber.*

INTERVENTION: A ***slope inclination 2:1 is considered as minimum for the stability of the foundation***. If the slope of the natural rock is steeper than 2:1, the **rubble between the rock and the red dashed line will be grouted or removed and replaced** by ALBARIA-based mortar and/or stonework (using local Jerusalem red Slayeb limestone).

***PROBLEM 3: FOUNDATION ON NATURAL ROCK VIA A THIN (20-30CM) BEDDING LAYER OF LOW SILICATE MORTAR** which has degraded, mainly due to the long-term effects of moisture.*

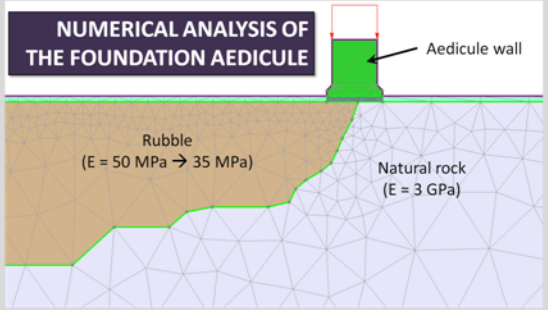
INTERVENTION: **Removal of the degraded mortar** (in short lengths of the order of 25-30cm to avoid disruption of the foundation of the wall) and **replacement with ALBARIA-based mortar**

***PROBLEM 4: RISING WATER AND MOISTURE**, as leakages from cisterns and water conduits seep through cracks of the natural rock towards the foundation of the Aedicule.*

INTERVENTION: : Corbo's south excavation will be **drained**, **ventilated** and the present reinforced **concrete slab** covering the excavation will be **replaced by a 15cm thick Glass Fibre Reinforced concrete slab**, supported on the perimeter and on the Constantinian stylobate crossing the excavation in the N-S direction (via special bedding to prevent damage to the stylobate). **A glass opening may be left, for antiquities inspection**

FOUNDATION INTERVENTIONS FOR THE UNDERPINNING, REINFORCEMENT, WATER AND HUMIDITY CONTROL OF THE HOLY AEDICULE

NUMERICAL ANALYSIS OF THE FOUNDATION AEDICULE



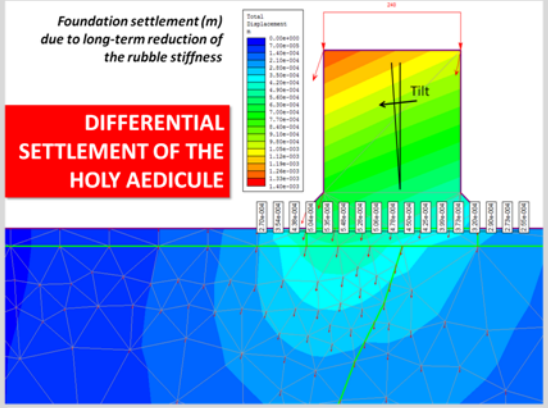
NUMERICAL ANALYSIS OF THE EFFECTS OF LONG-TERM DETERIORATION OF THE RUBBLE

(30% reduction of stiffness) on ground settlement and tilt of the aedicule walls.

- Analysis with finite element computer program PLAXIS.
- Modelling stages : Initial (ground and church loads) & deterioration of rubble under load (30% reduction of rubble stiffness)

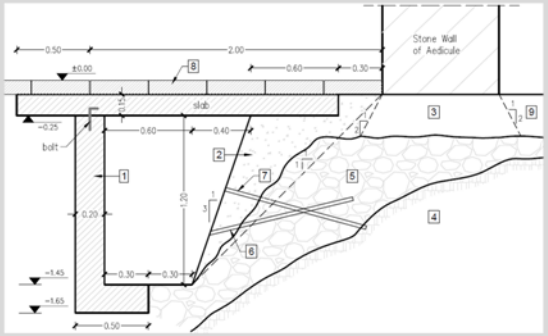
DIFFERENTIAL SETTLEMENT OF THE HOLY AEDICULE

Foundation settlement (m) due to long-term reduction of the rubble stiffness

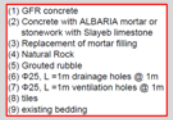


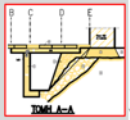
SETTLEMENT at left edge** of footing : 0.5 mm , Settlement **at right** edge of footing : 0.3mm, Tilt : $\theta = (0.5 - 0.3) / 800mm = 2.5 \times 10^{-4}$, Rotation of the top of the Aedicule wall (H=10m) : $\Delta y = H\,\theta = 10000 \times (2.5 \times 10^{-4})$ = **2.5mm

PERIPHERAL DRAINAGE & VENTILATION GALLERY

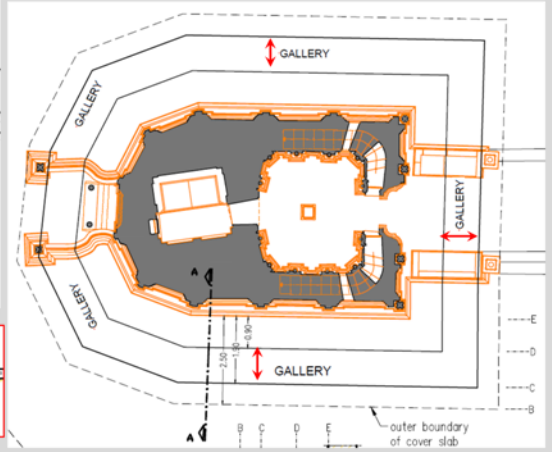


Case 5 : Gallery excavated in rubble overlying the natural rock. The rubble is partly excavated and removed, away from the 1:1 stability line



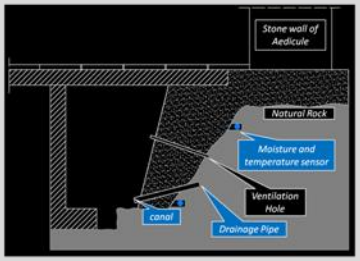


PLAN OF THE PERIPHERAL DRAINAGE AND VENTILATION GALLERY

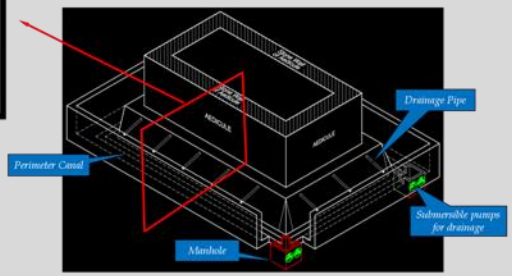


INVERSING THE RISK TO SUSTAINABILITY:
DIGITAL DESIGN OF UNDERGROUND INTERVENTIONS IN THE ROTUNDA AREA

1. DRAINAGE & VENTILATION SYSTEM OF UNDERGROUND PERIMETER CORRIDOR

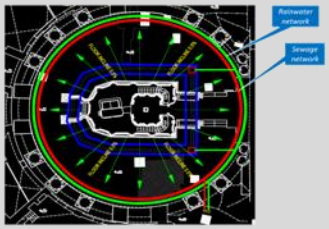


A drainage canal will be constructed for the protection of the foundation of the Holy Aedicule from the rising underground water.



- *Drainage system, which consists of an open canal constructed at the bottom of perimeter corridor close to the new Foundation.*
- *Drainage pipes placed at the perimeter of the new foundation to drain the rising underground water between the new foundation and the natural rock.*

2. NEW PERIPHERAL PIPPING NETWORK AT THE ROTUNDA'S AREA

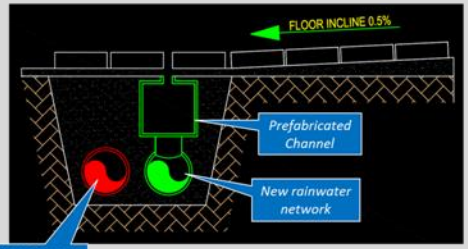


A new functional sewage and rainwater network will be constructed within the perimeter of Rotunda to replace the complex existing network

- *Two parallel circular networks in the proximity of Piers' foundation*
- *Connection of the underground gallery's manholes with the circular rainwater network*

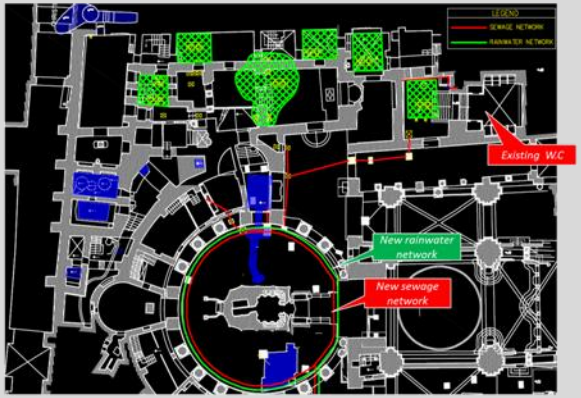
Prefabricated channel above the perimeter rainwater network for the collection surface water

Inclinations for the best drainage of the surface water towards the new perimeter rainwater network.



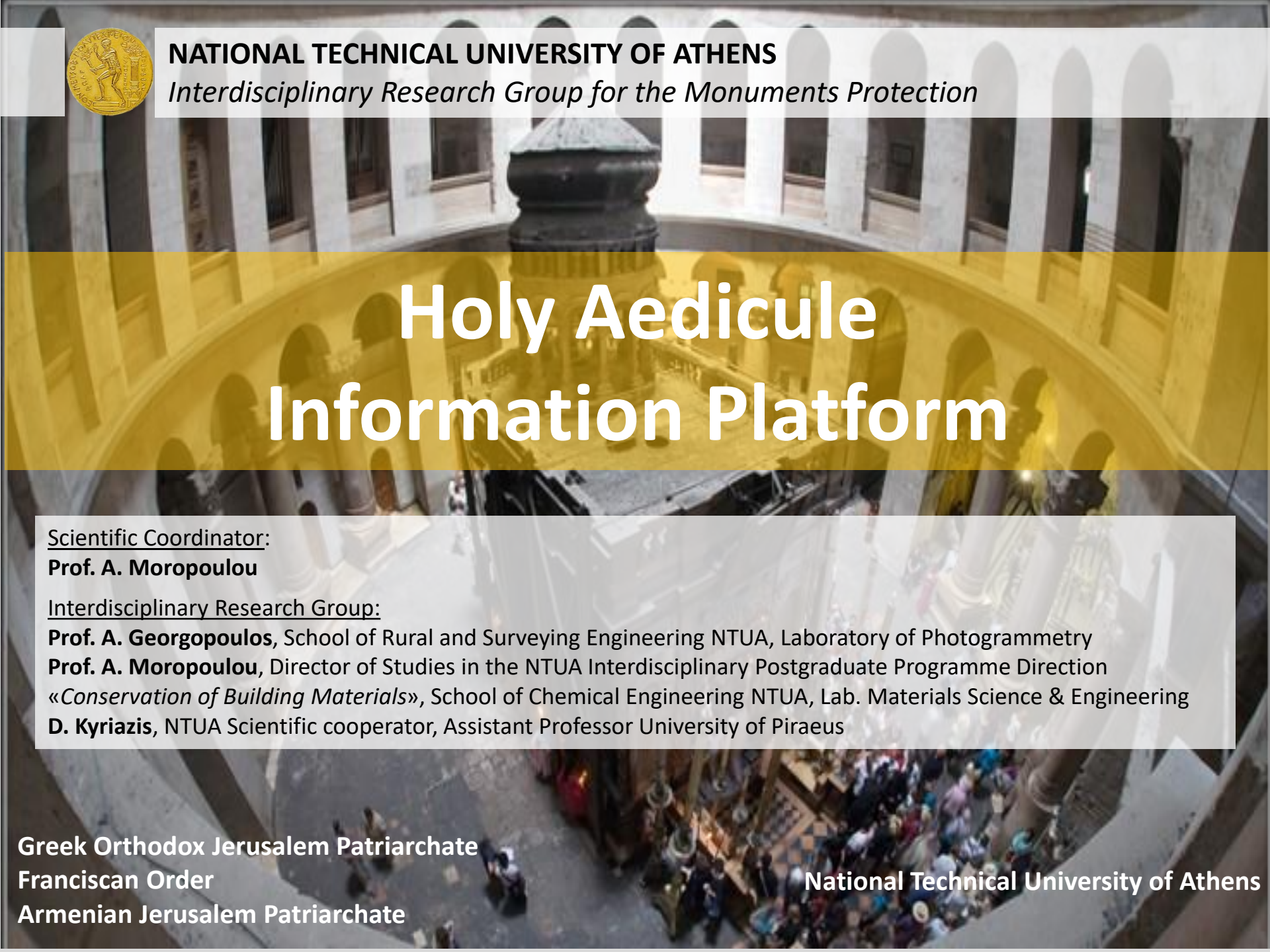
Section of the new perimeter rainwater and sewage network.

3. INSTALLATION OF NEW SEWAGE AND RAIN WATER NETWORK



Interventions for the arrangement and modernization of the All-Holy Church's sewage and rainwater networks.

CONTROL OF THE RISING DAMP AND INSTALLATION OF PROPER SEWAGE AND WATER SYSTEM



NATIONAL TECHNICAL UNIVERSITY OF ATHENS
Interdisciplinary Research Group for the Monuments Protection

Holy Aedicule Information Platform

Scientific Coordinator:
Prof. A. Moropoulou

Interdisciplinary Research Group:
Prof. A. Georgopoulos, School of Rural and Surveying Engineering NTUA, Laboratory of Photogrammetry
Prof. A. Moropoulou, Director of Studies in the NTUA Interdisciplinary Postgraduate Programme Direction «*Conservation of Building Materials*», School of Chemical Engineering NTUA, Lab. Materials Science & Engineering
D. Kyriazis, NTUA Scientific cooperator, Assistant Professor University of Piraeus

Greek Orthodox Jerusalem Patriarchate
Franciscan Order
Armenian Jerusalem Patriarchate

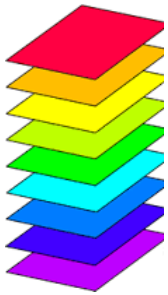
National Technical University of Athens

Multilayer Data Management – Platform Architecture

Content-Based Management through Semantic Data Integration

Multilayer Management of Information – Big Data Integration

- Non destructive Testing
- Analytical Techniques
- Spatial
- Historic
- Time, etc.



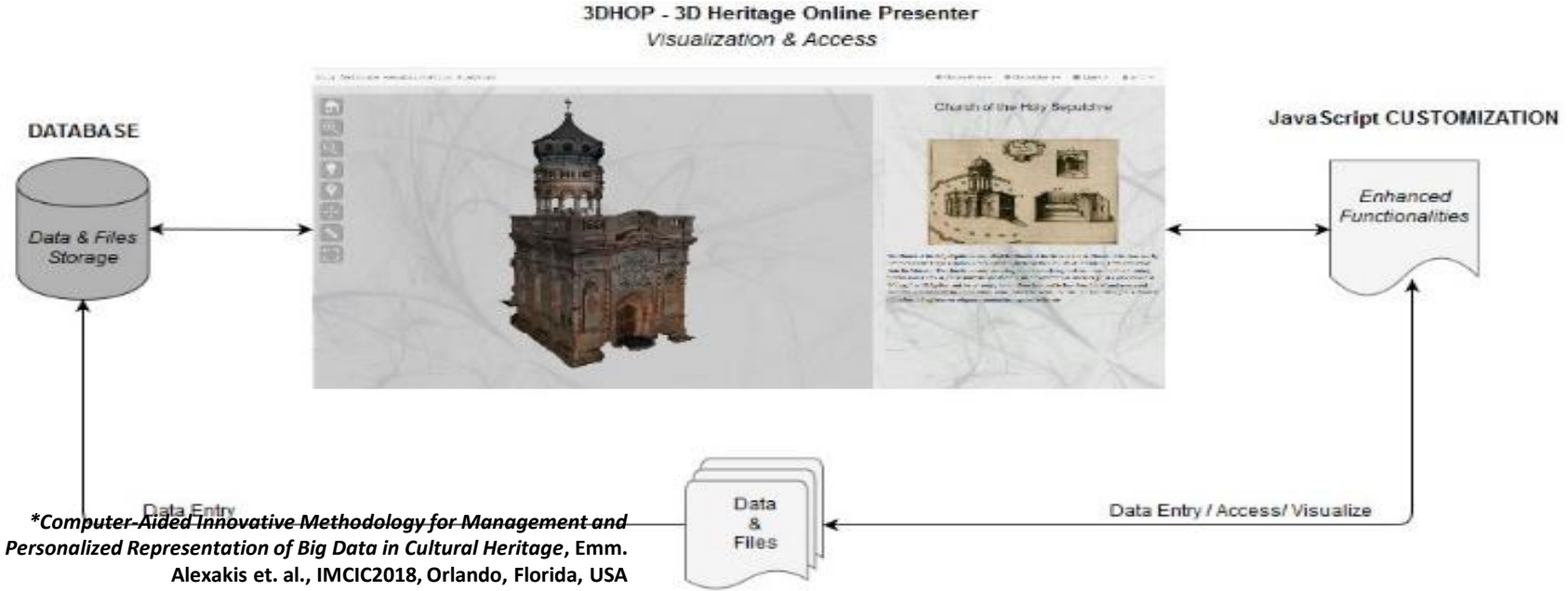
Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης

RESPECT:

An Exemplary Information System and Methodology for the Integrated Management, Analysis and Dissemination of Digital Cultural Heritage Data from the rehabilitation of the Holy Aedicule of the Holy Sepulchre Project

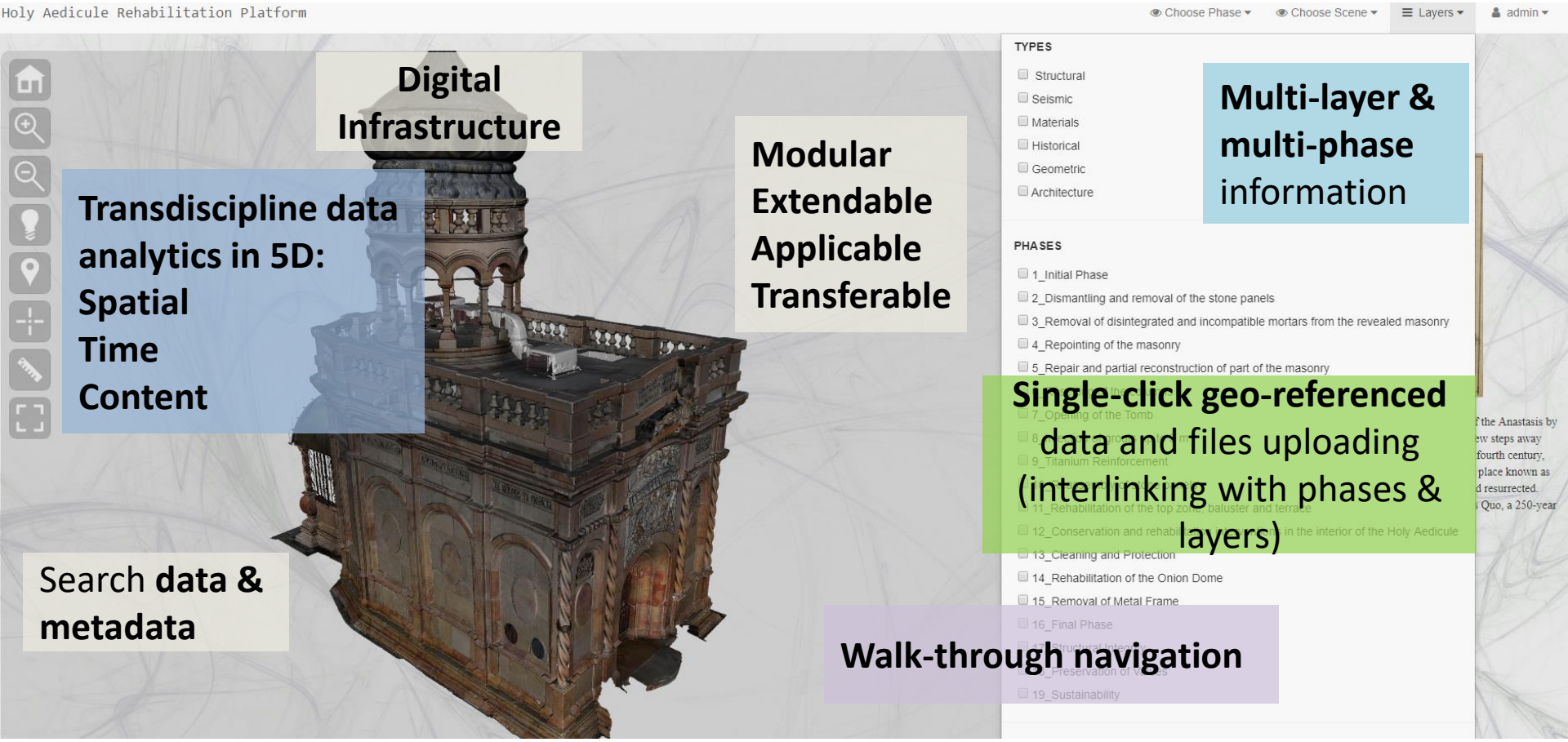
Partnership Agreement 2014-2020, Operational Programme "Competitiveness,Entrepreneurship and Innovation" (MIS 5129424)

*Architecture of the Information System**



**Computer-Aided Innovative Methodology for Management and Personalized Representation of Big Data in Cultural Heritage*, Emm. Alexakis et. al., IMCIC2018, Orlando, Florida, USA

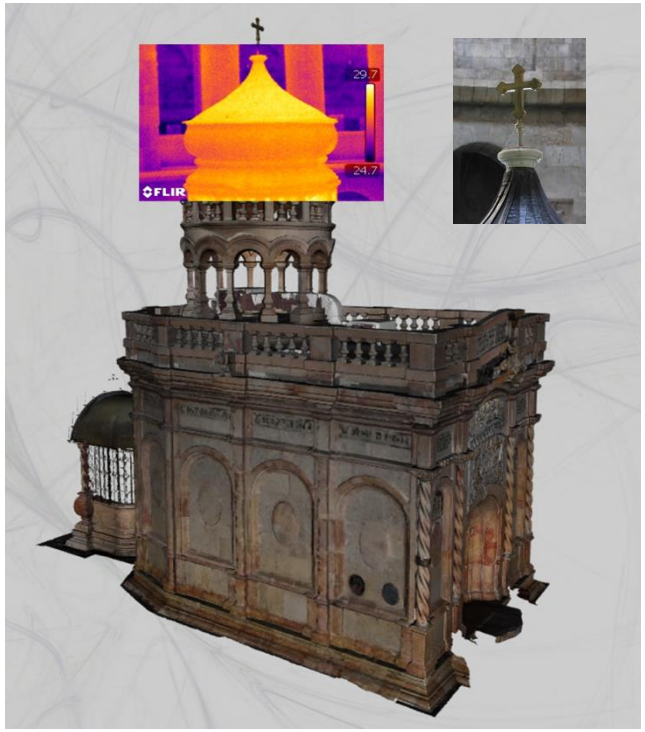
The Holy Aedicule Integrated Information System Platform



Platform as the **cornerstone** for data management, knowledge acquisition and information sharing

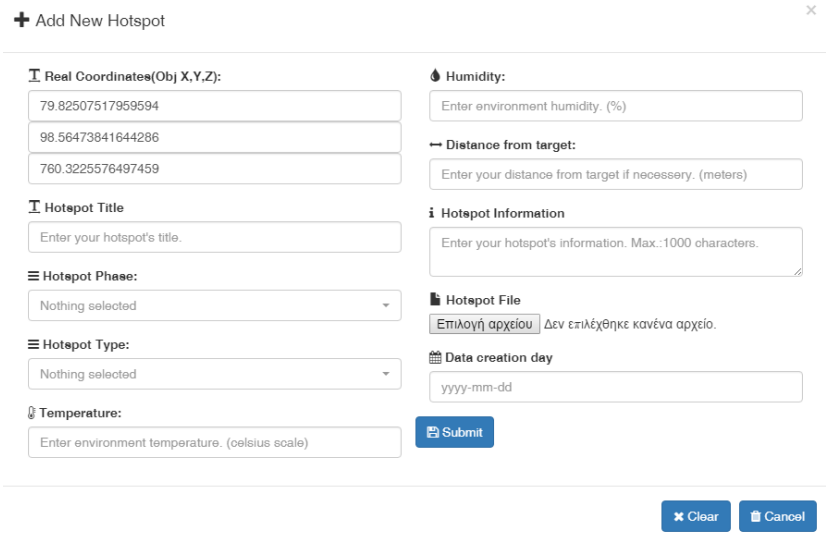
The Holy Aedicule Integrated Information System Platform

Multilayer Data Fusion

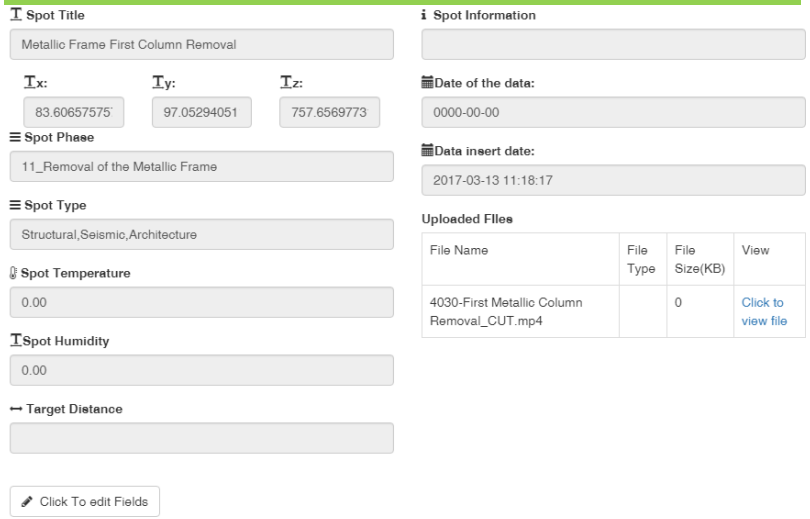


In cooperation with Assist. Prof. Dimosthenis Kyriazis

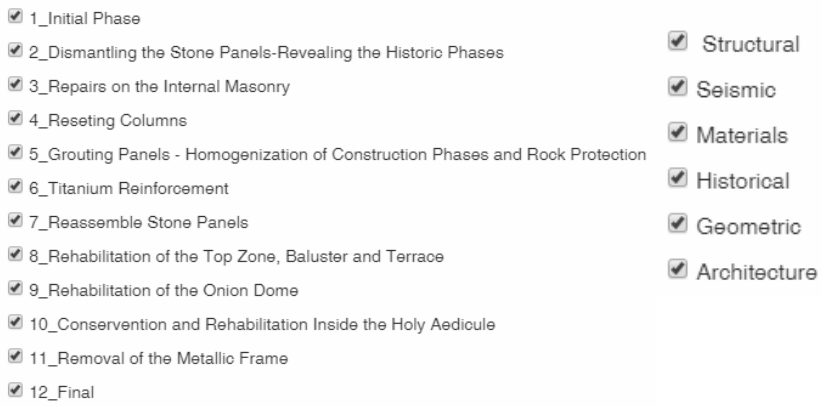
Add Data on certain areas



Retrieve Data from certain areas



Data Filtering based on Data Content and Phase



*This challenging project was implemented and completed with Innovation, marking **future trends in the protection of monuments**, as declared in Brussels 14.03.2017 by the representatives of the DG: Research & Development, Education & Culture, ICT/Connect*

CEREMONY MARKING THE COMPLETION OF THE HOLY AEDICULE REHABILITATION PROJECT

The Ceremony Marking the Completion of the Conservation, Restoration and Rehabilitation of the Aedicule of the Holy Sepulcher.

PROGRAMME

March 22nd 2017

Holy Sepulcher Church
JERUSALEM

9:00 a.m. Arrival and seating of clergymen and guests at the Holy Sepulcher Church before ceremony commences

9:45 a.m. Church Heads meet at top of Holy Sepulcher courtyard, descend, and enter into the Church together

10:00 a.m. Ceremony commences

Choir: Hymns by the respective choirs of the Greek Orthodox, Franciscan, and Armenian Communities

- **Address of His Beatitude Greek Orthodox Patriarch Theophilos**
  Choir: Hymn by the Greek Orthodox Choir
- **Address of the Custos of the Holy Land Fr. Francesco Patton**
  Choir: Hymn by the Franciscan Choir
- **Address of His Beatitude the Armenian Patriarch Archbishop Nourhan Manougian**
  Choir: Hymn by the Armenian Choir
- **Address of His Excellency the Latin Apostolic Administrator Archbishop Pierbattista Pizzaballa**
- **Address of His All Holiness the Ecumenical Patriarch Bartholomeos**
- **Message of His Eminence Cardinal Leonardo Sandri, Prefect of the Congregation for the Oriental Churches**
- **Message of His Holiness Garegin II Catholicos of all Armenians**

"The Lord's Prayer" led by the Heads of the Churches in their respective languages *(the faithful may join)*

Conclusion of the Ceremony

The Church Heads, followed by clergymen and invitees proceed to the ***Greek Orthodox Patriarchate*** *for the* ***final presentation of the completed works***

HOLY AEDICULE
MARCH 22ND 2017


photwww.jp-newsgate.net


photo: Garo Jerusalem

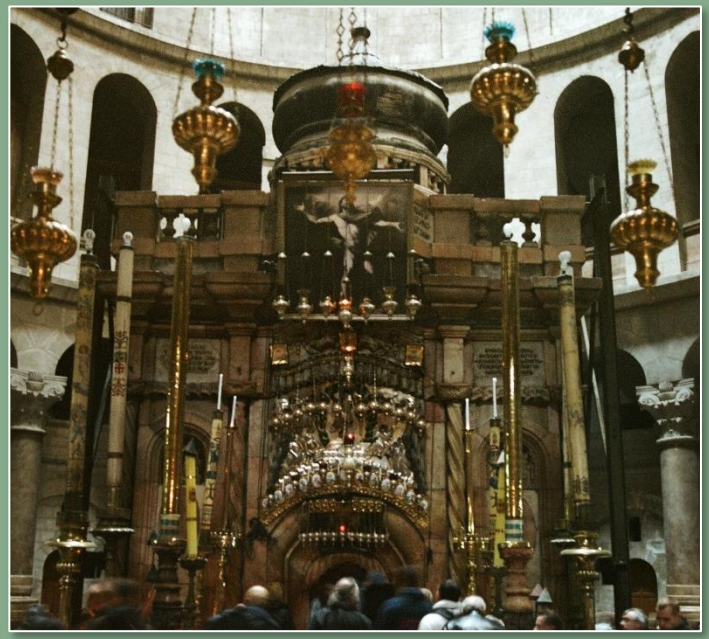

photo: Garo Jerusalem

The Holy Aedicule Before and After Rehabilitation Interventions

Before Rehabilitation Interventions

Panoramic View

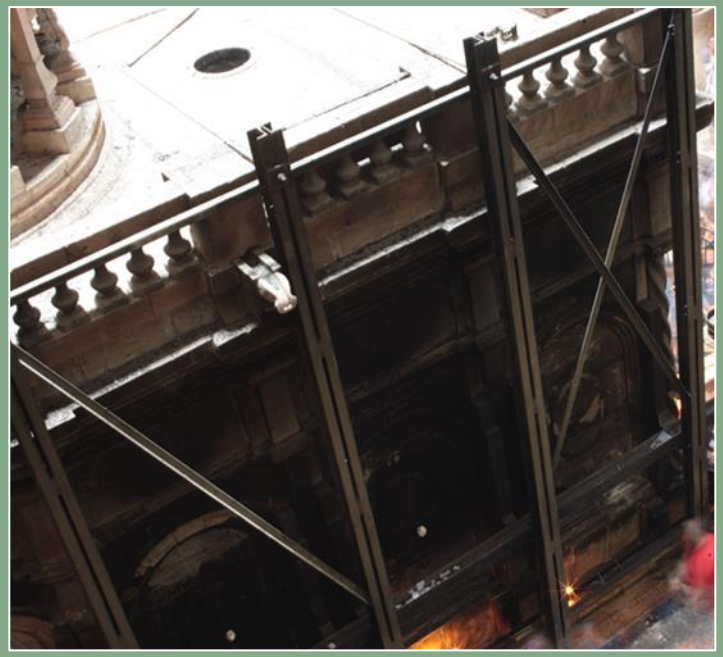
After Rehabilitation Interventions



East Side

The Holy Aedicule Before and After Rehabilitation Interventions

Before Rehabilitation Interventions



South Side View

After Rehabilitation Interventions

North Side View

PERSPECTIVES

The Holy Aedicule has been rehabilitated and ensured

Research continues

- Concerning historical materials in relation to technology, provenance, archaeometry, archaeogenomics, etc
- The development of all data on the platform in 5 dimensions with layers of scientific information

→ *Representation of the historical phases of the monument according to the data*

Sustainability has to be ensured

- Monitoring
- Underground works

Dissemination


© PHOTO/GALI TIBBON

Communication strategy of the project

The National Geographic Society and the Media were present and disseminated to the rest of the world critical, stages of the project, in conjunction with the Steering Committee Meetings:

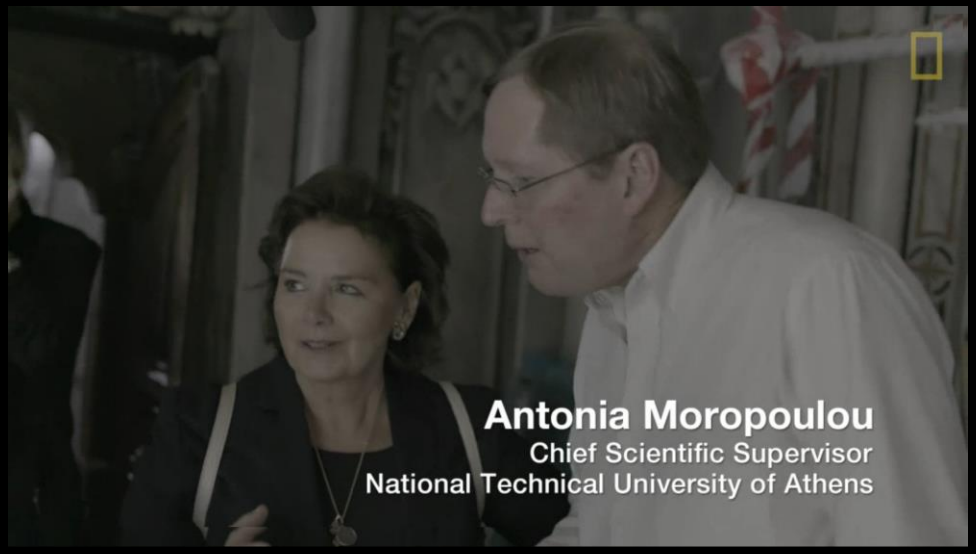
- July 2016 Dismantling and removal of the stone panels
- October 2016 Lifting of the stone of the Tomb
- December 2016 Resetting of columns, homogenization of structural layers and consolidation of the Holy Rock by the injection of compatible grouts
- February 2017 Removal of iron frame
- March 2017 Completion of the restoration of the Holy Aedicule

Strategic cooperation of the National Technical University of Athens, the three Christian Communities and the National Geographic Society on the news for the opening of the Tomb of Christ and on to the Tomb of Christ Exhibition

Fredrik Hiebert, *National Geographic Archaeologist-in-Residence*
Kristin Romey, *staff writer covering archaeology and paleontology for National Geographic*

Exclusive: Christ's Burial Place Exposed for First Time in Centuries
by Kristin Romey, published October 26, 2016
https://news.nationalgeographic.com/2016/10/jesus-tomb-opened-church-holy-sepulchre/

Unsealing of Christ's Reputed Tomb Turns Up New Revelations
by Kristin Romey, published October 31, 2016
https://news.nationalgeographic.com/2016/10/jesus-christ-tomb-burial-church-holy-sepulchre/

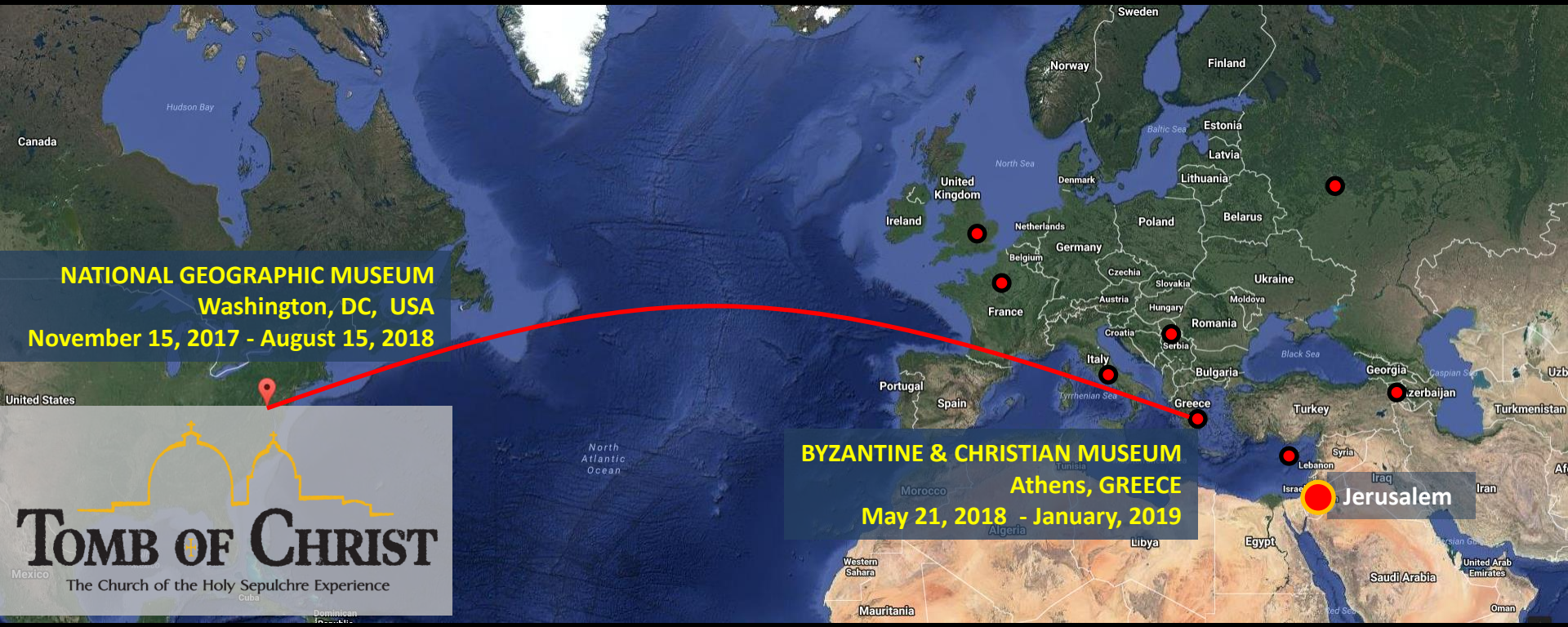


Fredrik Hiebert, *National Geographic Archaeologist-in-Residence*

CULTURAL HERITAGE BEYONG BORDERS

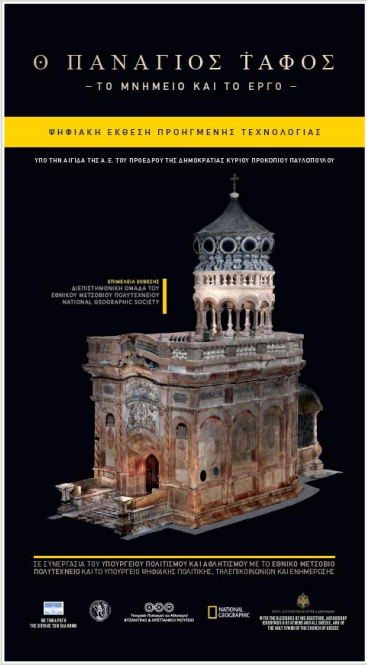
DIGITAL EXPERIENCE EXHIBITION

The digital solutions and multi layer data innovations in the rehabilitation of the Holy Aedicule are presented in emblematic museums all over Europe and the World towards creating a modern, open and pluralistic society building on Europe's cultural diversity, creativity and respect of creators' rights and its values, in particular democracy, religions & values diversifications, freedom of expression and tolerance




PRESERVING OUR SHARED PAST
Saving Sacred Cultural Heritage Sites Around the World


TOMB OF CHRIST
The Church of the Holy Sepulchre Experience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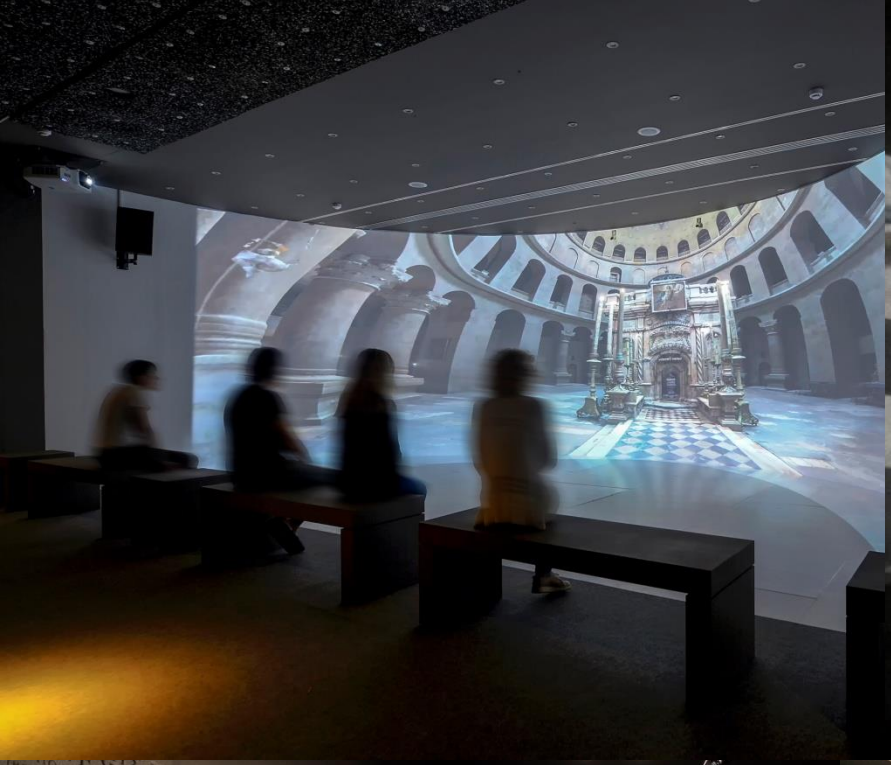

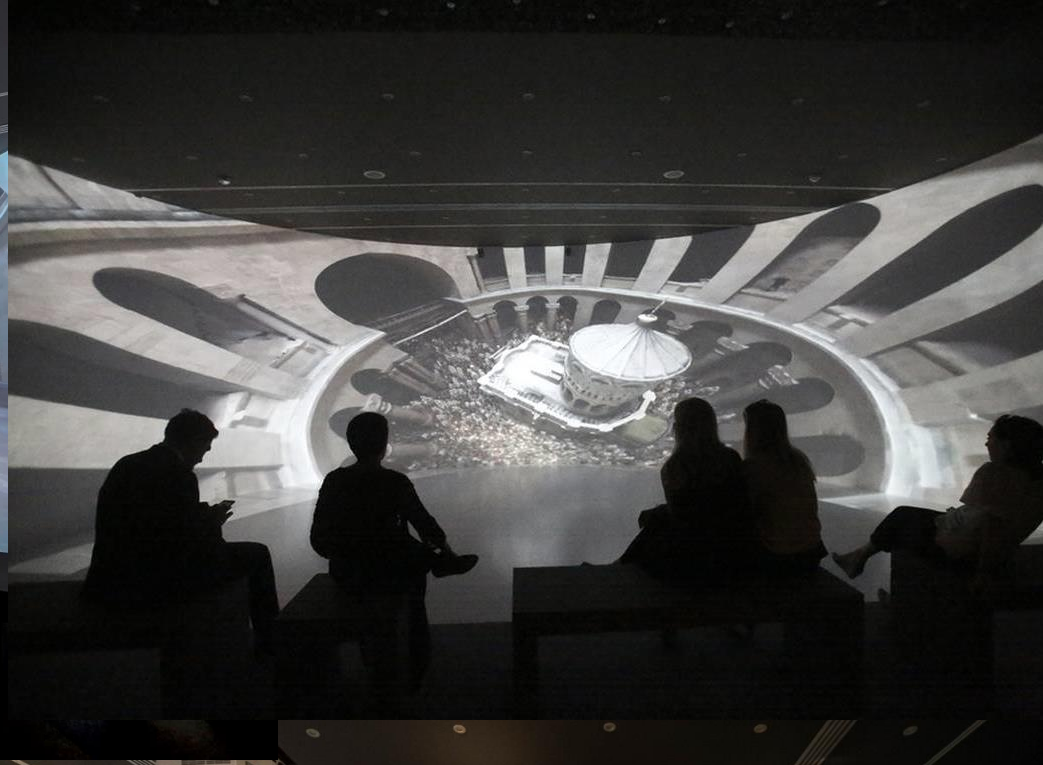

TMM 10 1 10 8 CH

1st International Conference on

Transdisciplinary Multispectral Modelling and Cooperation for the Preservation of Cultural Heritage

October 10-13 2018, Eugenides Foundation, Athens, Greece

Under the Auspices of the Presidency of the Hellenic Republic
with the support of the Hellenic Parliament

Καινοτόμος, Διεπιστημονική, Ψηφιακή Διατήρηση της Πολιτιστικής Κληρονομιάς

Organized by the **National Technical University of Athens** and the **Technical Chamber of Greece** in cooperation with the **Ministry of Culture and Sports** and the **Ministry of Digital Policy, Telecommunications and Media of Greece**, the **National Geographic Society**, **ECTP** and other Greek and International major organizations and networks in the field of cultural preservation.

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With the support of Greek Parliament

ΤΕΕ Technical Chamber of Greece

Ministry of Culture and Sports

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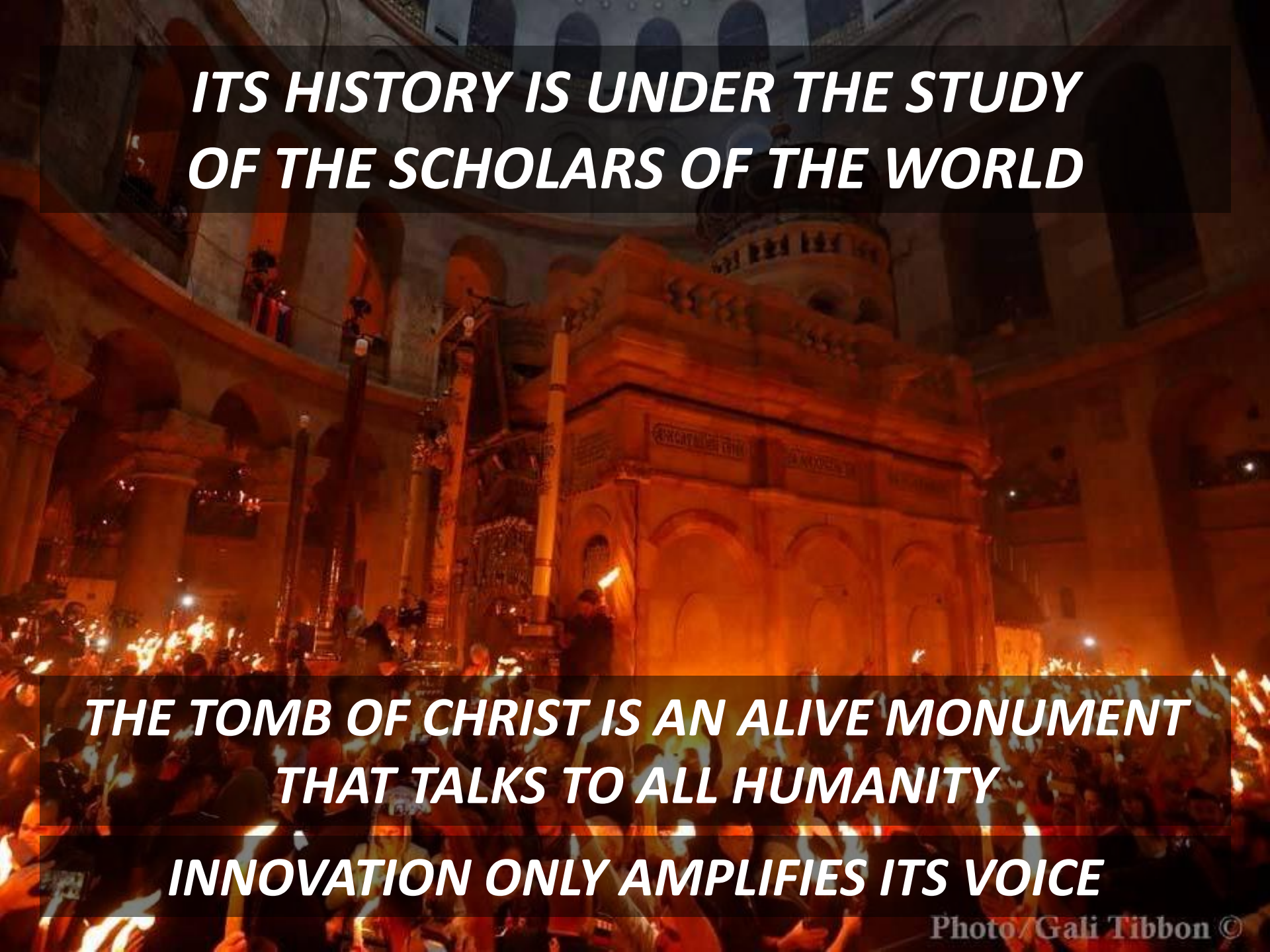
NATIONAL GEOGRAPHIC


ITS HISTORY IS UNDER THE STUDY
OF THE SCHOLARS OF THE WORLD
THE TOMB OF CHRIST IS AN ALIVE MONUMENT
THAT TALKS TO ALL HUMANITY
INNOVATION ONLY AMPLIFIES ITS VOICE
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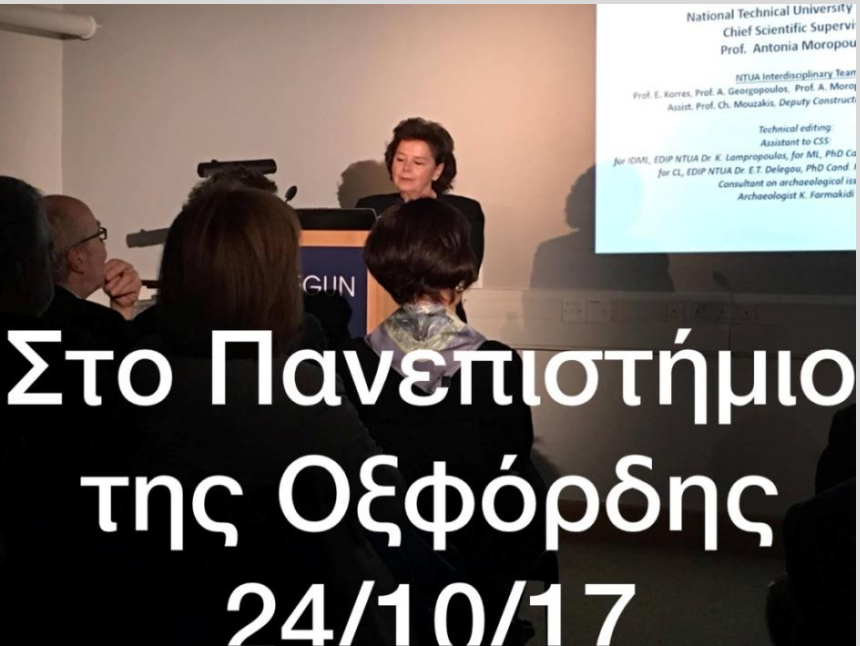
TRANSDISCIPLINARITY: BRIDGING ENGINEERING WITH HISTORY, ARCHAEOLOGY AND THEOLOGY

OXFORD, October 2017

5th aniversary of the Mica and Ahmet Ertegun Graduate Scolarship Program in the Humanities



***LECTIO MAGISTRALIS,* Biblioteca Ambrosiana, Milano, Maggio 2017, GIORNATE DI ARCHEOLOGIA E STORIA DEL VICINO E MEDIO ORIENTE**

https://www.tmm-ch.com/

The Conference is organized under the patronage of H.E. the President of the Hellenic Republic, Ms Katerina Sakellaropoulou, by the National Technical University of Athens in cooperation with the Technical Chamber of Greece and the organization AHEPA Hellas. Distinguished scientists and representatives of the National Geographic Society, the Cultural Heritage Finance Alliance, the International Council of Monuments and Sites ICOMOS, the Organization of World Heritage Cities OWHC, the European Society for Engineering Education SEFI, the European Construction Technology Platform ECTP, the International Federation of Surveyors FIG, the International Committee CIPA Heritage Documentation, the World Monuments Fund and other major International and European Organizations, Associations, networks Universities and Research Centers, participate in the International Steering and Scientific Committees.

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2nd International Conference TMM-CH

Transdisciplinary Multispectral Modelling and Cooperation for the Preservation of Cultural Heritage

Recapturing the World in Crisis through Culture

13-15 December 2021 Eugenides Foundation Athens, Greece

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3rd International Conference TMM-CH

Transdisciplinary Multispectral Modelling and Cooperation for the Preservation of Cultural Heritage

20-23 March 2023 Eugenides Foundation Athens, Greece

Members of the National Technical University of Athens Interdisciplinary Team for the "Protection of Monuments" contributing to the Project:

Chief Scientific Responsible: *Prof. A. Moropoulou*

Scientific Responsibles of the Interdisciplinary Team: *Prof. A. Moropoulou, Prof. Emm. Korres, Prof. A. Georgopoulos, Prof. C. Spyrakos, Asst. Prof. Ch. Mouzakis*

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