Dynamic integrated geometric documentation of the monument before, during and after the rehabilitation

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NATIONAL TECHNICAL UNIVERSITY OF ATHENS [GREECE]

NTUA PH [O] TO GRAMMETRIC COMPUTER VISION

National Technical University of Athens
Interdisciplinary Research Group for the Protection of Monuments

Integrated Program of Diagnostic Research and Strategic Planning of Materials and Interventions, Maintenance and Restoration of the Holy Aedicule of the Holy Sepulchre in the Church of the Resurrection in Jerusalem

Scientifically Responsible:
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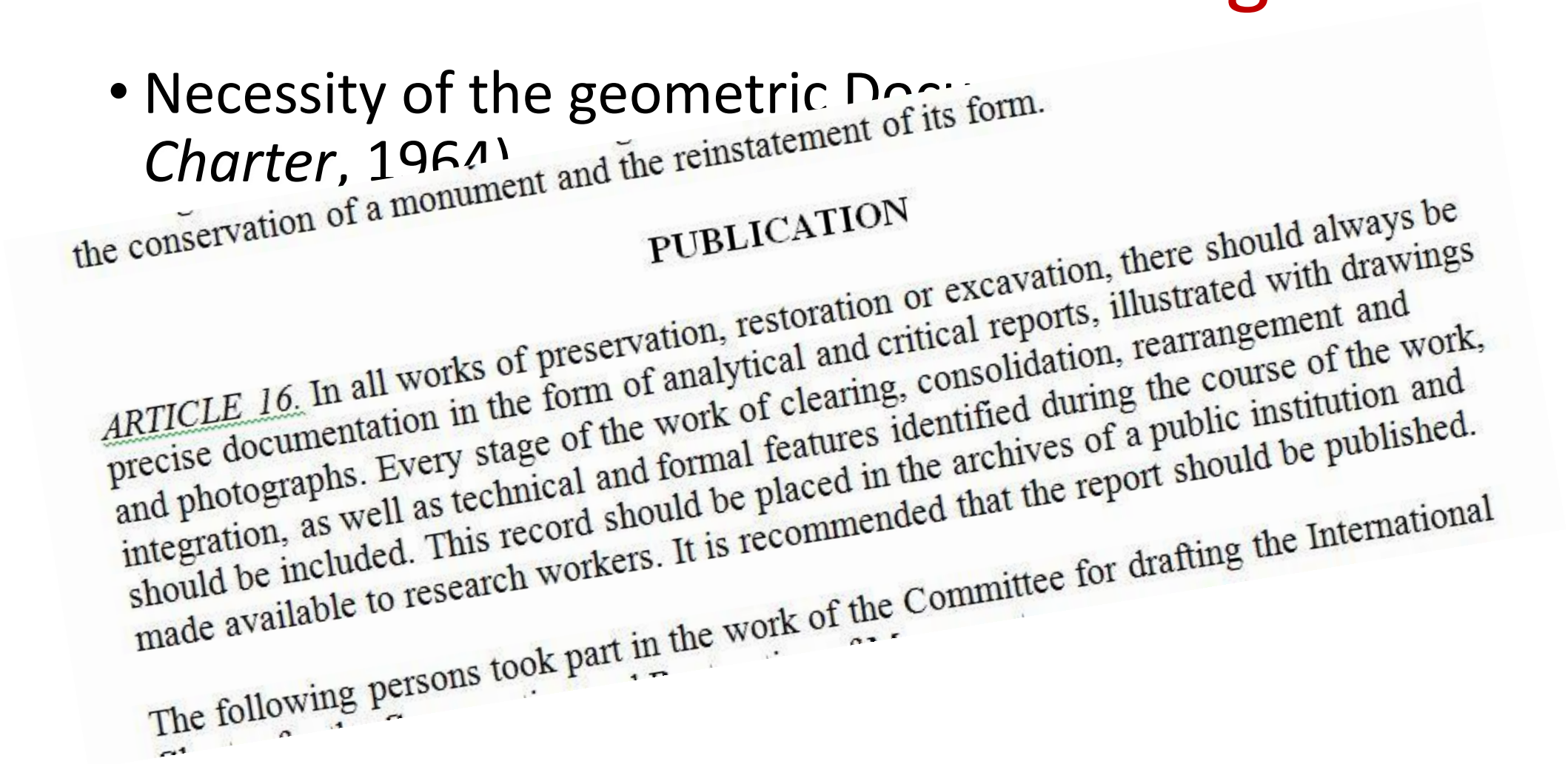
Protection of Cultural Heritage

- Necessity of the geometric Doc
  Charter, 1964)



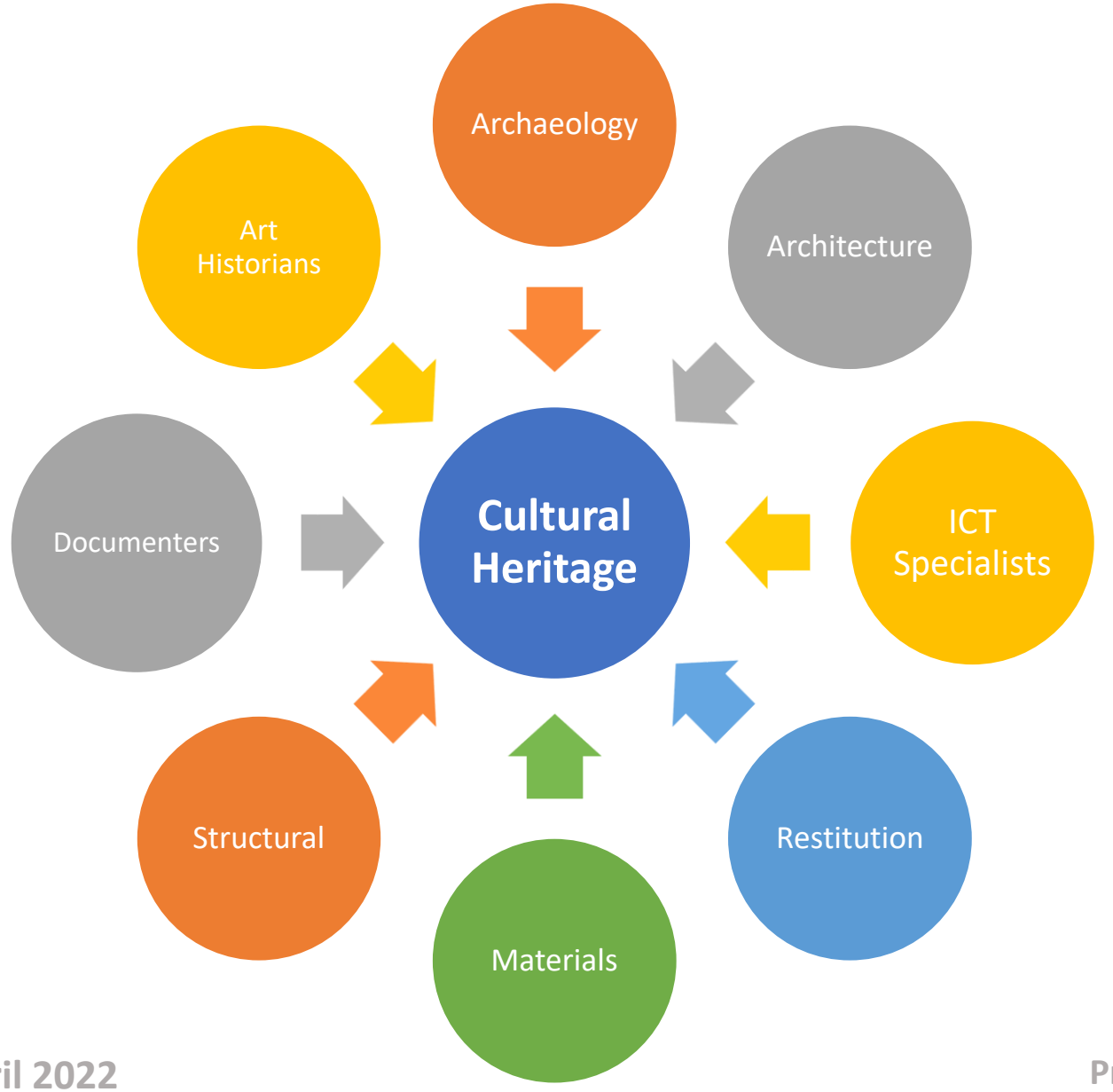
the conservation of a monument and the reinstatement of its form.

PUBLICATION

ARTICLE 16. In all works of preservation, restoration or excavation, there should always be precise documentation in the form of analytical and critical reports, illustrated with drawings and photographs. Every stage of the work of clearing, consolidation, rearrangement and integration, as well as technical and formal features identified during the course of the work, should be included. This record should be placed in the archives of a public institution and made available to research workers. It is recommended that the report should be published.

The following persons took part in the work of the Committee for drafting the International

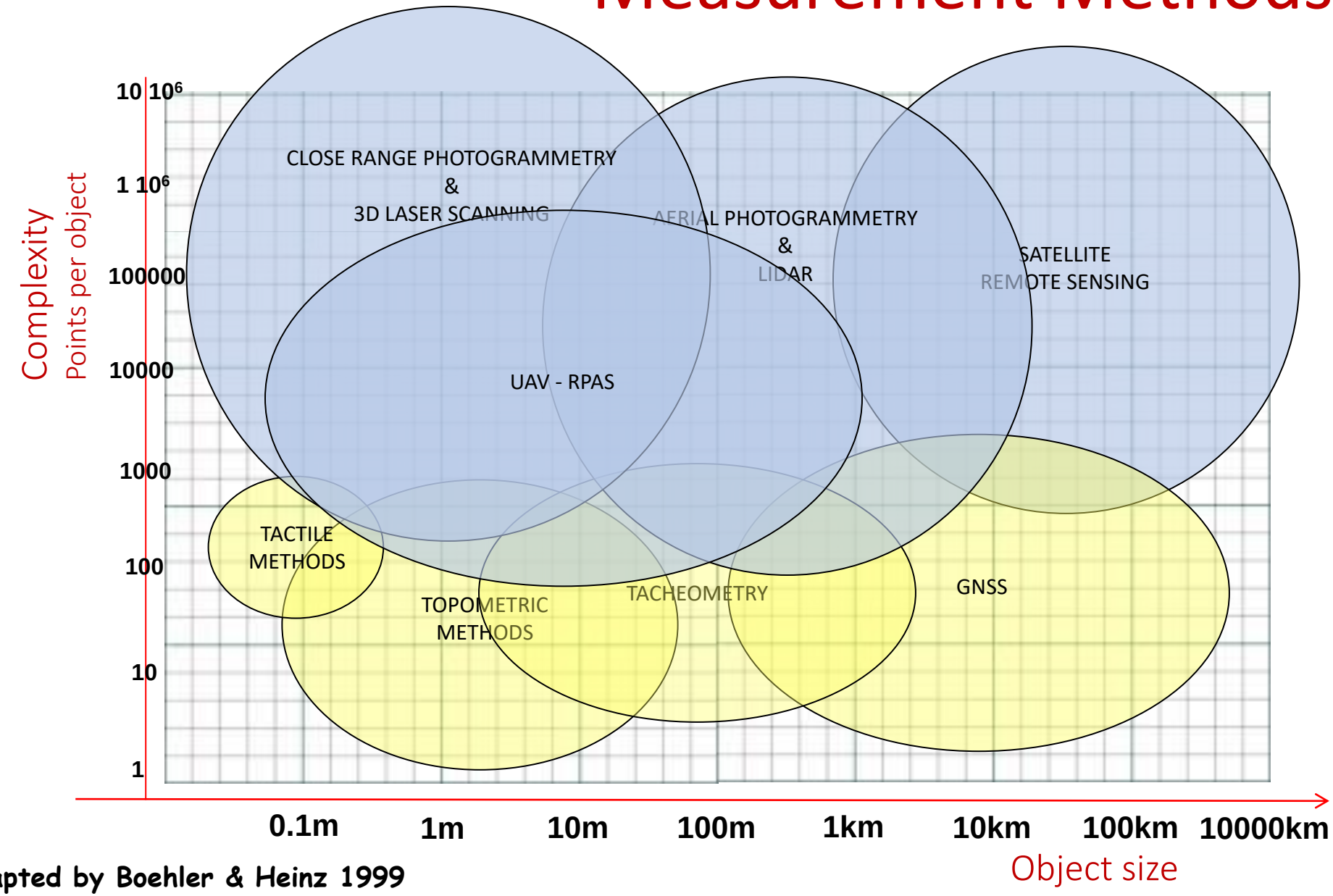
Interdisciplinarity



Geometric Documentation of Monuments

- The geometric documentation of a monument is the procedure of acquiring, processing, presenting, archiving and storing of data adequate to determine the position, the true form, shape and size of the monument in the 3D space at a given moment in time.
- The geometric documentation of monuments using the topographic – photogrammetric methodology actually is the orthogonal projection of a carefully selected set of points on (usually) horizontal or vertical planes, in order to record all geometric properties of the monument in the best possible way
- This implies that all the determined points lie in a common reference system in the 3D space

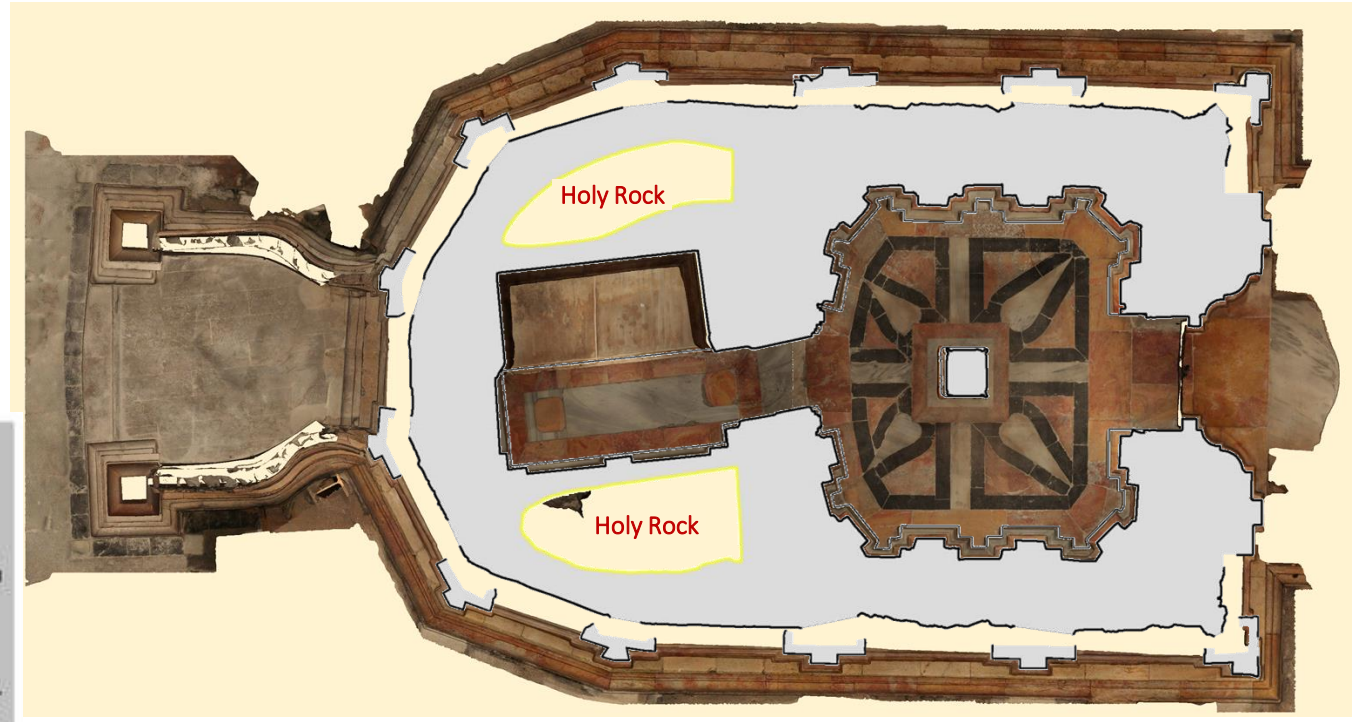
Measurement Methods

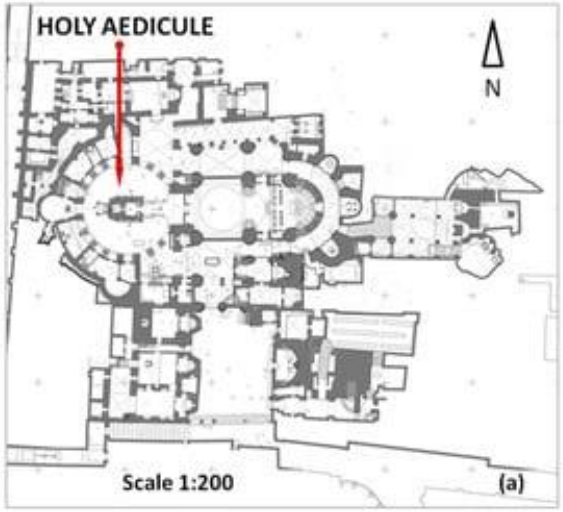


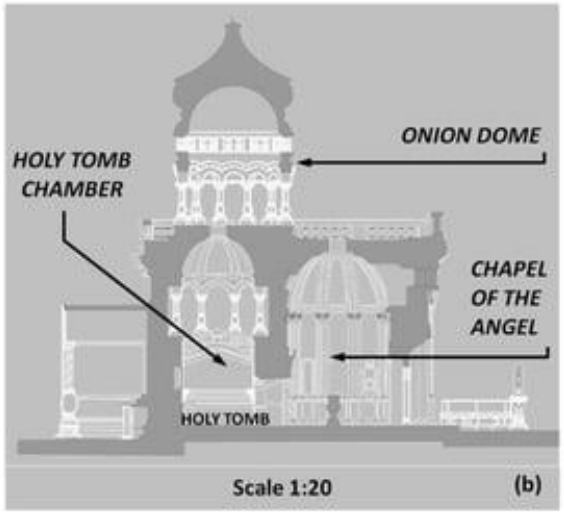
Adapted by Boehler & Heinz 1999

The Holy Aedicule of the Tomb of Christ in Jerusalem

Complex construction
Rich exterior and interior decoration
Length = 13m
Width = 6m
Height = 12.5m
Covers and protects the Holy Rock







Moropoulou A, et al., 2019. The White Marbles of the Tomb of Christ in Jerusalem: Characterization and Provenance Sustainability. 2019; 11(9):2495. https://doi.org/10.3390/su11092495

The Rehabilitation of the Holy Aedicule

Data acquisition

Important phases of the project

Project Phases-Interventions		Data acquisition
0	**Documentation of Initial Sate**	**05/2015 & 01/2016**
1	Initial Phase	
2	Dismantling and removal of the stone panels	
3	Removal of disintegrated and incompatible mortars from the revealed masonry	
4	**Repointing of the masonry**	**7-13/10/2016**
5	Partial reconstruction of part of the masonry, where deemed necessary	
6	Resetting and anchoring of exterior columns	
7	**Opening of the Tomb**	**25-29/2016**
8	**Injection of grouts up to 3m**	
9	**Reinforcement with anchors, rods and titanium grid**	**11-15/01/2017**
10	**Reassembly of stone panels**	**02/2017**
11	Grouting of top zone and terrace	
12	Anchoring of interior marbles	
13	Cleaning and protection of interior and exterior surfaces and conservation of decorative elements	
14	Conservation interventions on the Onion Dome	
15	Removal of the metal frame	20-23/02/2017
16	**Final Phase**	**5-9/03/2017**

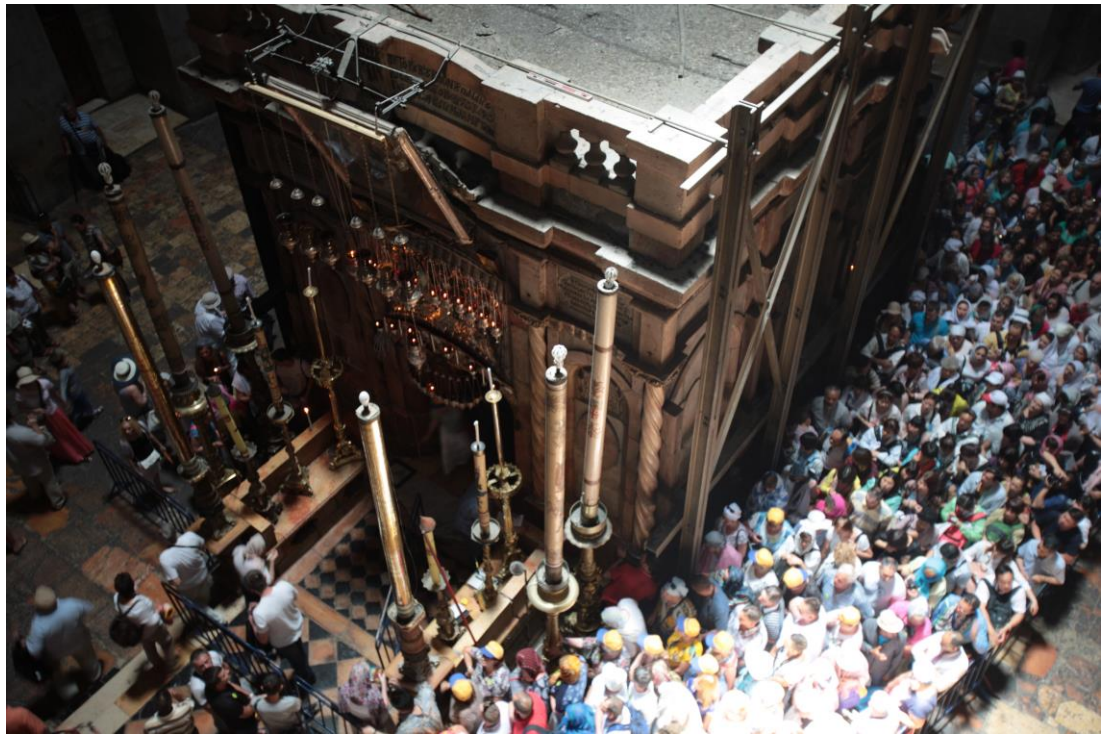
Data acquisition

	Date	Area	Scans	Images Captured
1	05/2015	Interior & Exterior	-	916
2	01/2016	Exterior	58	-
3	7-13/10/2016	Interior	-	1.050
		13 Panels	50	2.463
4	25-29/10/2016	Tomb chamber	-	860
5	11-15/01/2017	Excavation of Corbo	-	576
		13 Panels	18	1.735
		interior of the onion-shaped Dome	2	-
6	02/2017	13 Panels	28	389
7	20-23/02/2017	Exterior (Photographic Documentation)	-	about 10.000
8	5-9/03/2017	Interior & Exterior	57	1.283 1.800
		Total	213	11.183+10.000

Data management, storage, preservation, maintenance!!!

Data acquisition

- According to the specifications and methods
  - Topography - Surveying
  - Photogrammetry - Image-based modelling
  - Terrestrial Laser Scanning
- Adapted to certain restrictions:
  - Complexity
    - Complicated building, with a variety of architectural styles
  - Attendance of Pilgrims
    - 2000-5000 Pilgrims per day
    - 07:00-20:00
  - The intervention works never stopped

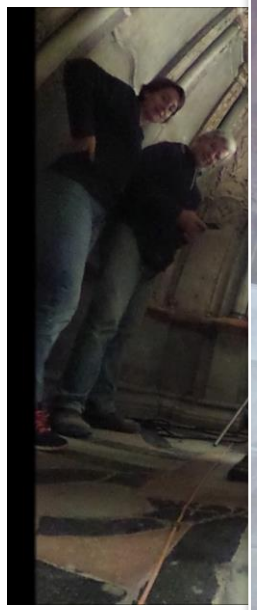


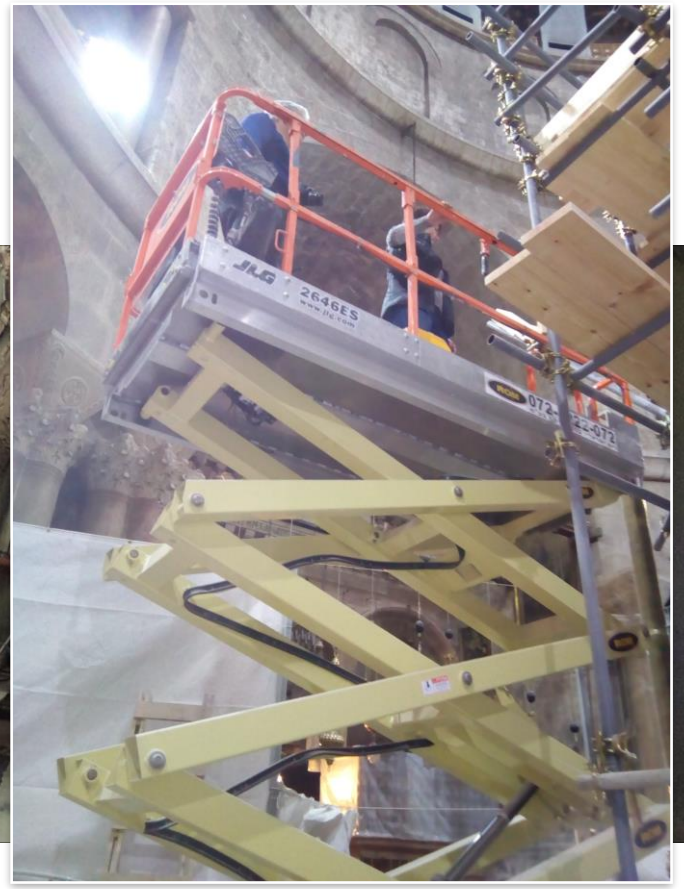
- Mainly during night hours
  - Interior 20:00-05:00
  - Exterior – 24 hours
- Short period of time between the rehabilitation phases

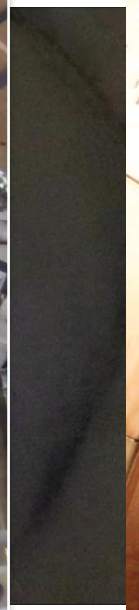
Data acquisition procedures

Image Acquisition

- Canon Mark III
- Canon 6D
- Lenses 24mm, 16mm, 35mm
- Studio Flash
- GoPro camera







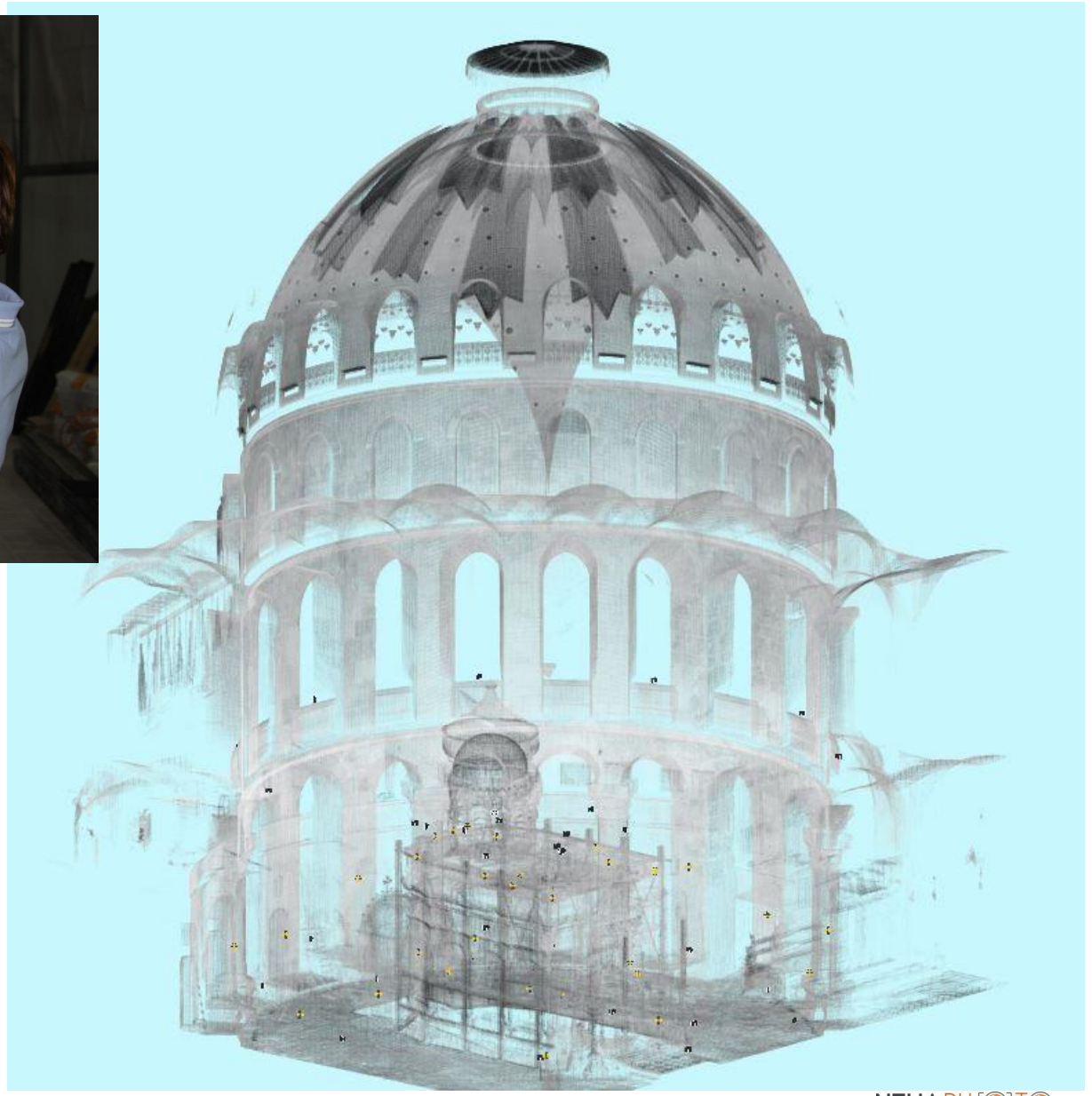
Data acquisition procedures

Laser scanning

FARO Focus 3D X 330

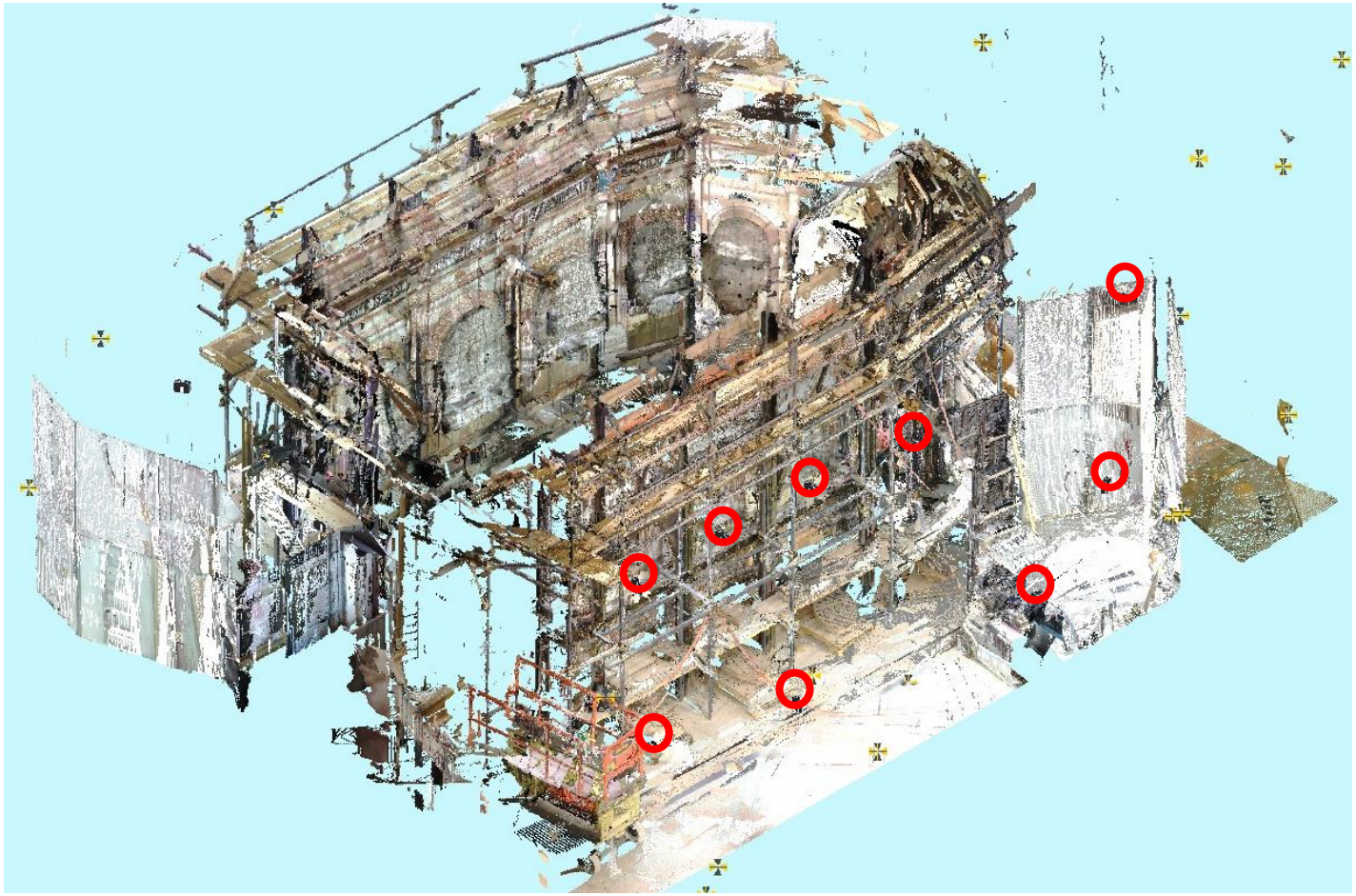
Scan density 5mm

Scan overlap >70%



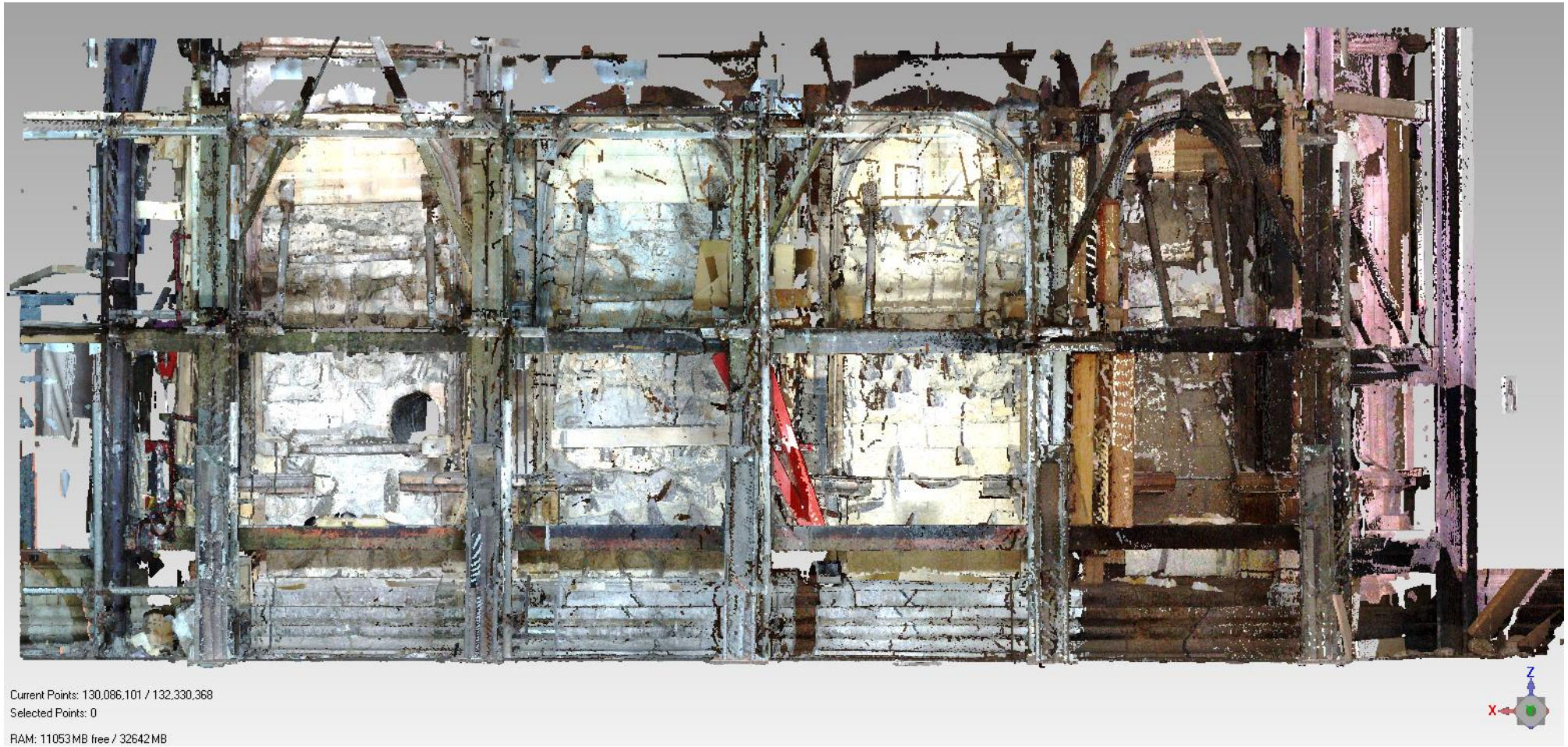
Data acquisition

- October 2016 - Scans of 13 Panels
- 50 scanner positions



Data acquisition

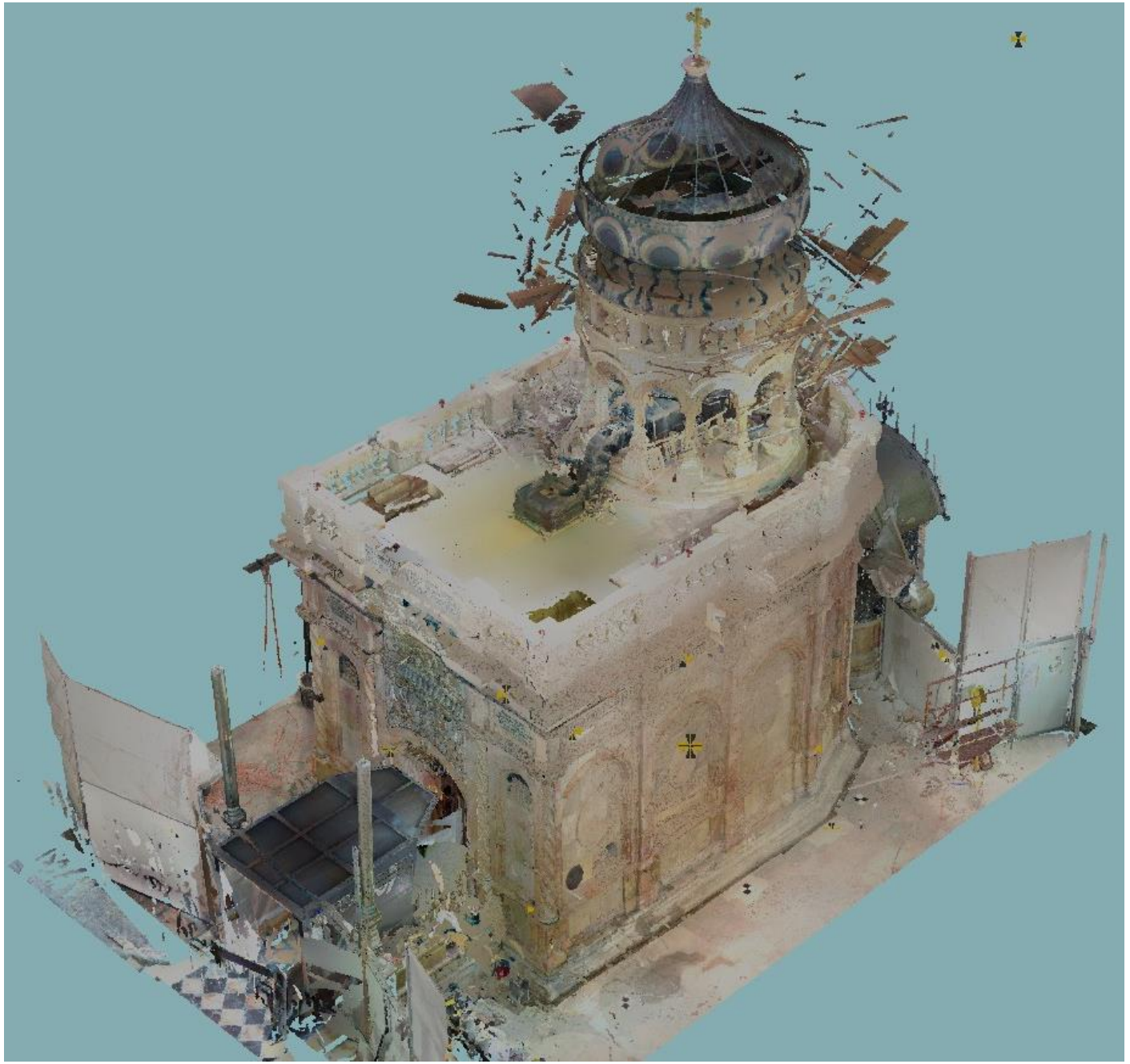
- October 2016 - Scans of North façade's panels
- 17 scanner position



Data acquisition

March 2017

57 scan positions



Data processing

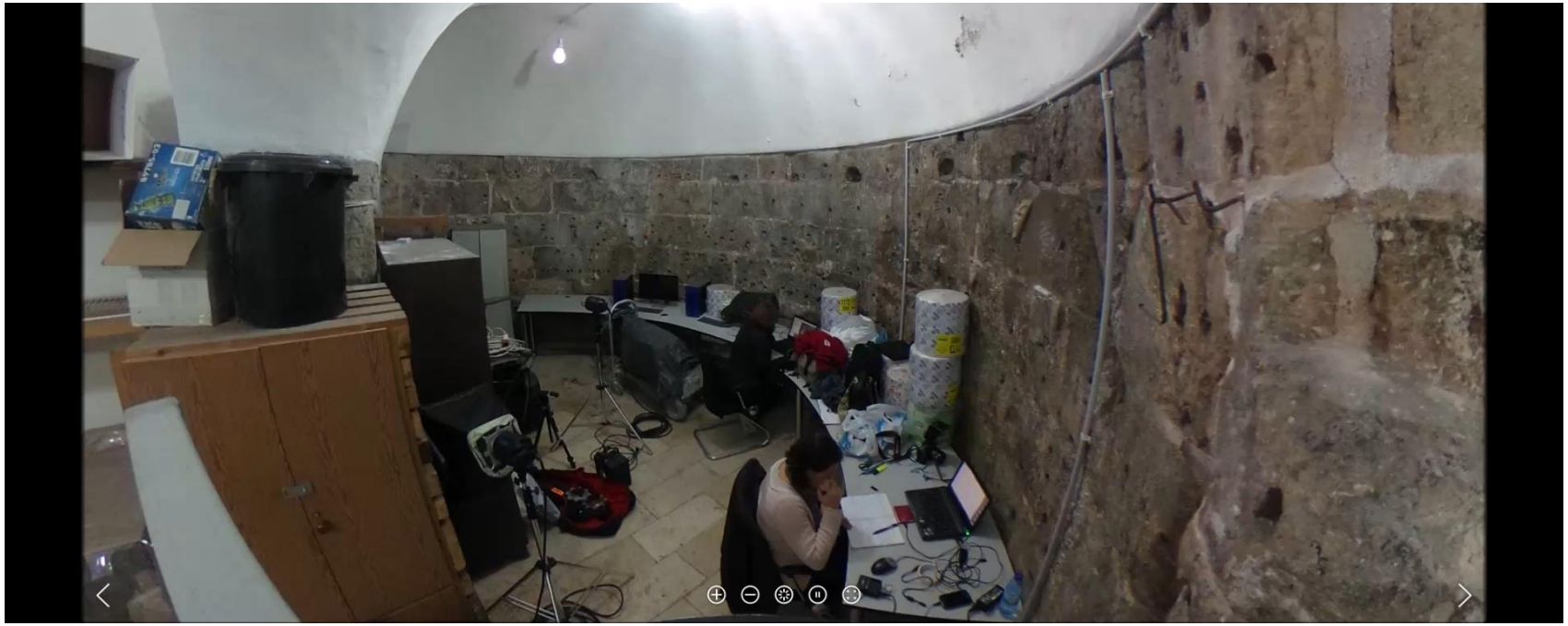
Auxiliary areas of the Church were used as offices

Team coordination and work planning

Equipment storage

Initial processing immediately after acquisition

- data checking - detection of omissions - additional measurements



Data processing

methods and procedures

Images

Image Based Modelling Software

Orientation → Georeferencing

high accuracy
Structure from Motion (SfM)

targets coordinates
accuracy ≤ 1.2cm

Initial Scanned point clouds

3D data processing software

Registration → Georeferencing

Cloud-to-Cloud
Iterative Closest Point (ICP)

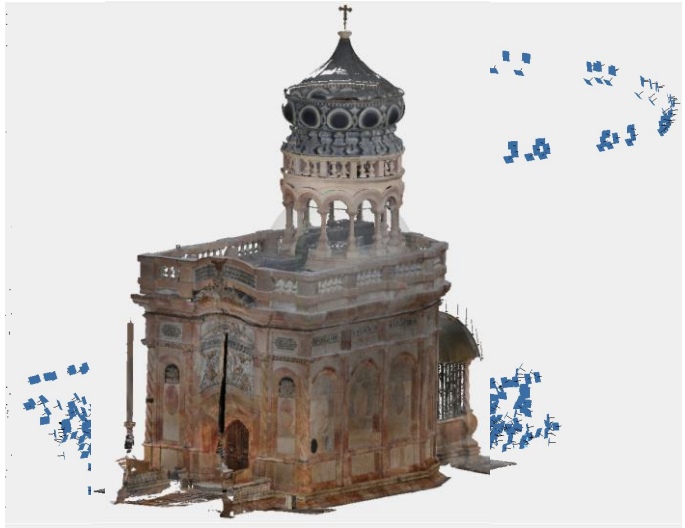
targets coordinates
accuracy ≤ 1cm

Multi-View Stereo (MVS) reconstruction algorithms

Dense point clouds

Noise Cleaning
Merging

Final Scanned Point Clouds



Final integrated georeferenced point cloud

Accurate 3D models
(Surfaces)

→ Results

Detailed 3D textured models
Stereo video

decimation →

light 3D models
for visualization purposes

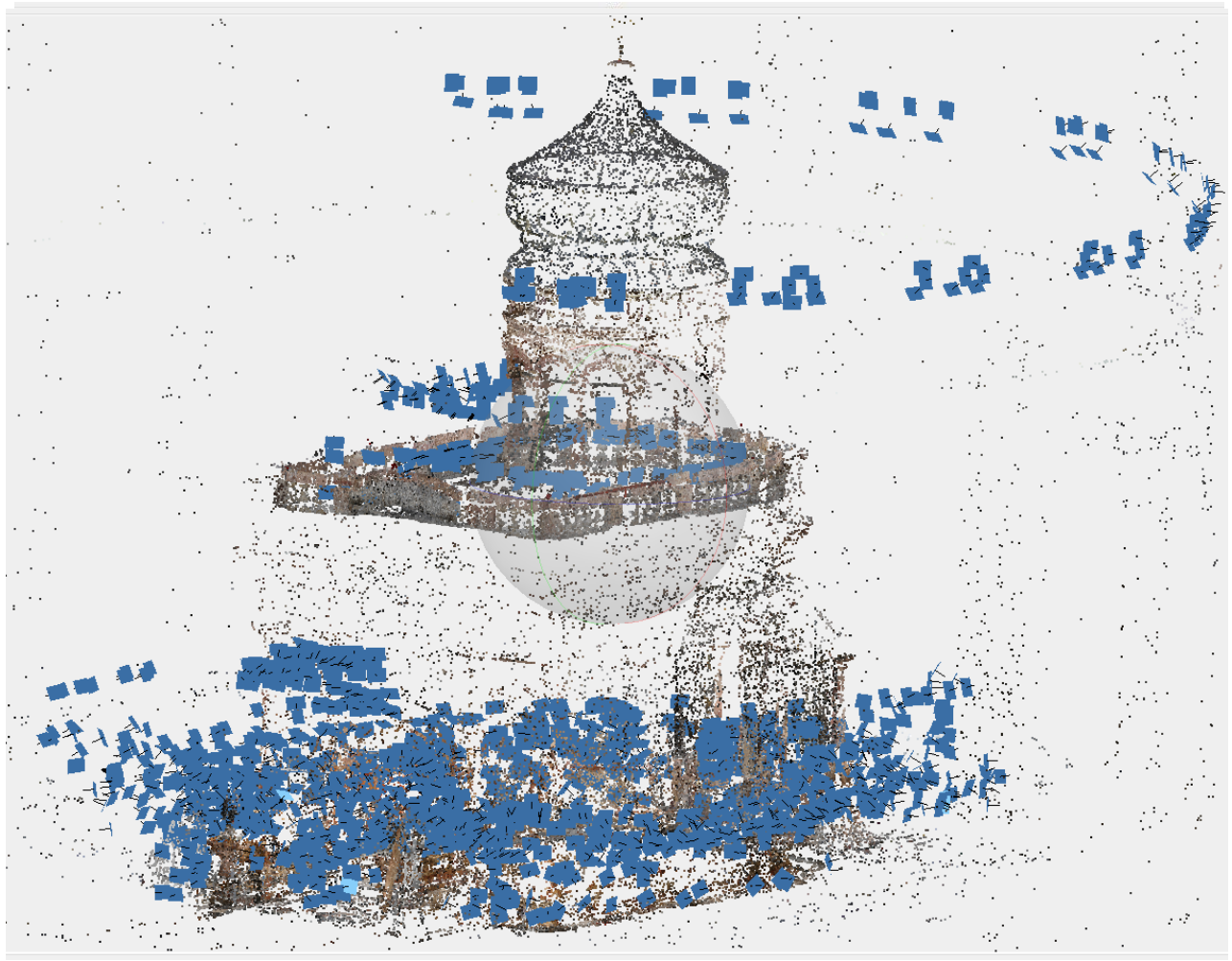
Data processing
Images

Image Based Modelling Software

- Agisoft® PhotoScan Professional Edition (now Agisoft Metashape)

Structure-from-motion (SfM)

Dense point cloud (MVS)



Data processing Scans

3D data processing software

- FARO® SCENE Software

Point Cloud Registration

- Cloud-to-cloud
- Target-to-target

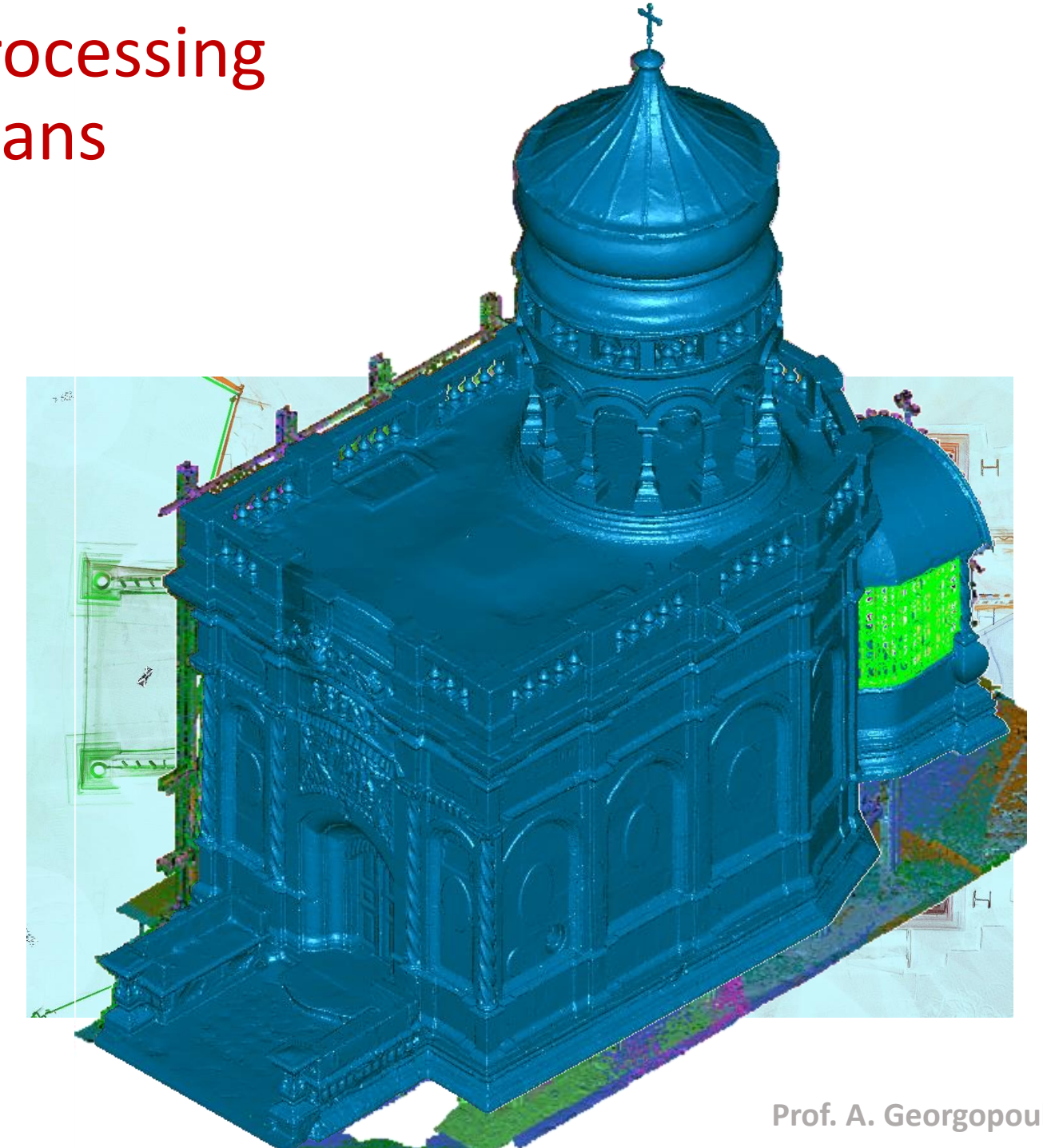
- Geomagic® Studio Software

Point Cloud processing

- Noise reduction
- Delete outliers

3d Surface Modelling

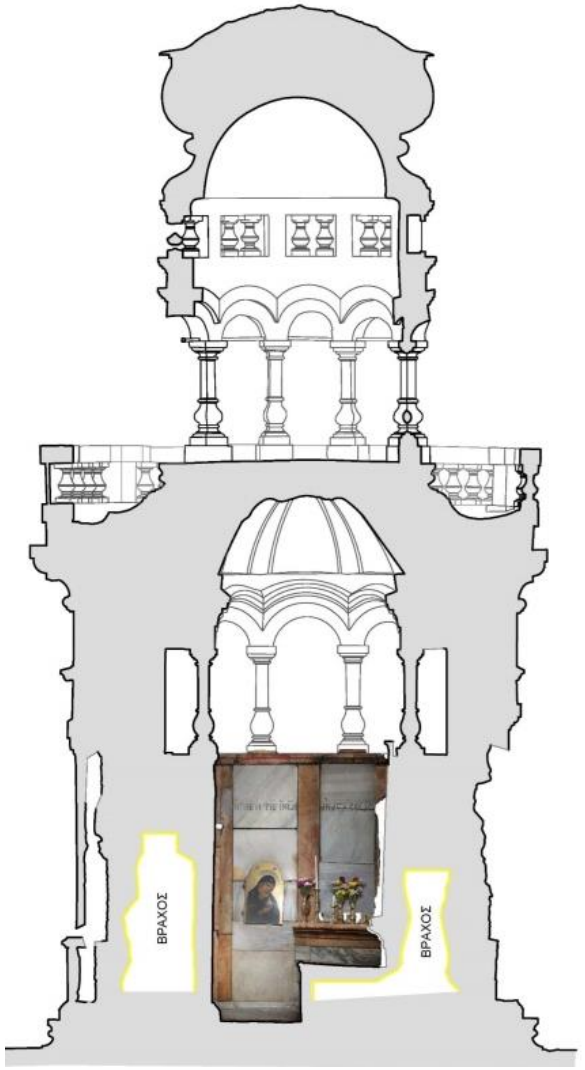
- TIN
- Fill holes



Orthophotos

May 2015

March 2017



October 2016

Orthophotos

May, 2015

May, 2015

March, 2017

March, 2017

High Resolution 3D Textured Models

Image Based Modelling Software

Automated method using digital images

March 2017
Opened Tomb 26/10/2016
Orthophoto of opened Tomb

Lessons learnt

- High accuracy fully controlled geometric documentation is achieved with the application of a suitable combination of documentation techniques
  - Scans – Point cloud processing
  - Image capture – Image based modelling
  - High accuracy geodetic measurements
    - Coordinate System - Control - Accuracy

- Interdisciplinary Approach is absolutely necessary

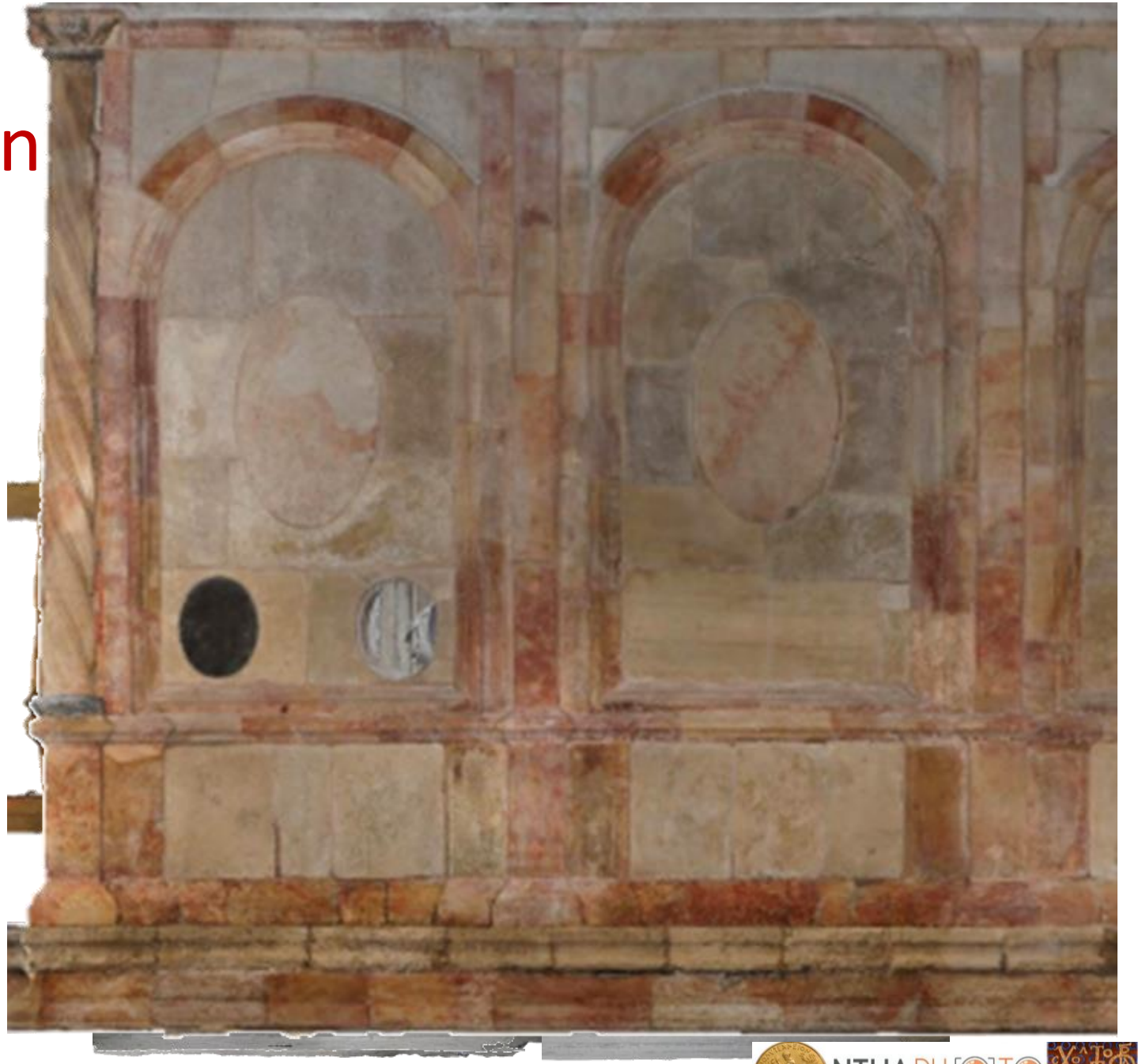
- 4D Documentation of the Monument during the rehabilitation project:
  - Geometric documentation (3D data)
  - @ different phases of the project (7 moments of time)

4D Documentation

May 2015

4D Documentation

- *May 2015*
- *October 2016*
- *January 2017*
- *March 2017*



4D Documentation

May 2015

March 2017

3D Printing

3D Models: May 2015 – March 2017

Geometric Documentation Team

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