

THEBAN  
NECROPOLIS  
PRESERVATION  
INITIATIVE

FACTUM FOUNDATION  
AND THE UNIVERSITY  
OF BASEL WORKING WITH  
THE MINISTRY OF ANTIQUITIES

A REPORT ON THE WORK  
COMPLETED IN THE TOMB  
OF SETI I UP TO APRIL 2019



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*That immaculate eye for detail is typical of the work of Factum Arte, a Madrid-based studio whose combination of digital analysis with assiduous craft is transforming the way we see art. I have been watching their work develop for nearly a decade. I am now convinced it is the most important thing happening in 21st-century art – because it can quite literally save civilisation.*

Jonathan Jones, *The Guardian* - February 2017

## TABLE OF CONTENT

Factum Arte can be translated from the Latin as ‘made with skill’. Factum's practice lies in mediating and transforming material. Its approach has emerged from the ability to read subtle visual information manifest in the physical world around us. Hundreds of decisions are embedded as material evidence in the process of making an object of any kind. Archaeologists are trained to read this evidence, as are forensic detectives at a crime scene. Patrick Blackett, an experimental physicist, wrote that his work was to *cultivate an intimacy with the behaviour of the physical world*; this is an equally good description of Factum's aims.

Theban Necropolis Preservation Initiative	
What is it?	5
The Partners	7
Background	9
Contracts Signed - Work Restarts	11
Aims of TNPI	13
Work in 2019 Luxor and Madrid	15
Work Completed April 2019	17
Summary	19
Systems Used for Data Capture and Storage	
Technology in Action	21
LiDAR Scanner	23
Lucida Scanner	25
Photogrammetry	29
Composite Colour Photography	31
Reference Photography	33
Data Processing and Archiving	37
Recording the Fragments of the Tomb of Seti I	39
Recording the Sarcophagus	43
Rematerialising the Sarcophagus	45
Restoration of Stoppelaëre House	
Outline	47
Interventions and Use as Training Centre	49
The Creation of the Facsimile of the Tomb of Seti I	
The Need for a Facsimile	51
Burton Photograph from 1920's	52
Factum Composite Image from 2016	54
Factum's Reconstruction	56
Facsimile of Room J	58
Facsimile of East Wall of Room I	60
Appendix	64

## THE THEBAN NECROPOLIS PRESERVATION INITIATIVE

What is it?



Top: Carlos Bayod and Aliaa Ismail scanning with two Lucida 3D Scanners in 2016.

Bottom: Abdel Raheem Ghaba, Amany Hassan Mohamed and Mahmoud Salem scanning with two Lucida 3D Scanners in 2019.

Right: A view of the restored Stoppelaëre House with a render of the proposed signage for the training centre.

The Theban Necropolis Preservation Initiative (TNPI) is a collaboration between the Madrid-based Factum Foundation for Digital Technology in Conservation and the University of Basel under the aegis of the Egyptian Ministry of Antiquities. It works on conservation and sustainability of the Egyptian cultural heritage using non-contact digital technology with Egyptian staff in charge of all operations on the ground and external involvement focussed on capacity development, training, support and technology transfer.

This project is one of the most ambitious, coherent and advanced examples of Digital Preservation currently being undertaken. The work that is being carried out is of importance both to heritage management in general and to the people of the West bank in Luxor. The Theban Necropolis Preservation Initiative is making a real difference to the way cultural heritage is preserved and demonstrates what can be achieved when heritage managers work with technical specialists to provide the optimum data for conservation monitoring, in-depth analysis, dissemination and replication. The aim is to develop a sustainable structure that will help the Egyptian Ministry of Antiquities to preserve the Valley of the Kings for future generations in an age of mass tourism. UNESCO is being kept informed about the progress of the TNPI.





## THE THEBAN NECROPOLIS PRESERVATION INITIATIVE

Partners

### Factum Foundation:

The Factum Foundation for Digital Technology in Conservation is a not-for-profit organisation, founded in 2009 in Madrid. The Foundation is dedicated to the preservation of cultural heritage through the promotion of digital documentation, the production of facsimiles and sharing/archiving high-resolution files. Through research and collaborations, the Foundation is committed to the development of new technologies for heritage recording and re-materialization. Factum Foundation trains technicians across the world in digital documentation. It is currently running projects in Egypt, Saudi Arabia, Daghestan, Italy, US, Spain, UK, Nigeria and Brazil. It has worked with institutions such as the National Gallery of Art (Washington DC), the National Gallery (London), the Museo del Prado (Madrid) and the Musée du Louvre (Paris). The Factum Foundation has designed and produced exhibitions for the Royal Academy (London), the Fondazione Giorgio Cini (Venice), Waddesdon Manor, Museo Arqueológico Nacional de Madrid and the Antikenmuseum Basel.

### University of Basel

Factum Foundation has been working with the University of Basel as its academic partner since 2009. Originally with Erik Hornung, the Professor emeritus of Egyptology and from 2015 - 2017 Professor Dr Antonio Loprieno and Professor Dr Susanne Bickel. Since 2017 the main contact has been with Susanne Bickel. In March 2019 we received permission from the Ministry to scan about 8000 fragments found by the University of Basel team in and around the Tomb of Seti I. This collaboration will be a major addition to the scholarship relating to the tomb.



Architect Tarek Waly talking to then Director-General of UNESCO, Irina Bokova, and the Minister of Antiquities, Khaled El Ennany, at the opening of the *3D Scanning, Archiving and Training Centre* in the newly re-stored Stoppelaëre House.



A workshop in Stoppelaëre House lead by Aliaa Ismail (left) changing the laser in one of the scanning heads. April 2019.

*The gift of the facsimile is a metaphor for the relationship between Europe and Egypt - the skills and technology that have been developed in Europe to create the facsimile are going to be transferred to Egypt where the local workers will be trained and those very skills and technology will become Egyptian.*

**Baroness Ashton**, EU High Representative on the occasion of giving the facsimile of the Tomb of Tutankhamun to Egypt; Cairo - November 14th 2012.

## THE THEBAN NECROPOLIS PRESERVATION INITIATIVE

Background

Following Factum Arte's work in the Tomb of Seti I in 2001 and a project in 2002 to build a replica of the tomb of Thutmose III for a touring exhibition starting at the National Gallery of Art in Washington D.C, Factum Foundation was formed to record the Tomb of Tutankhamun in 2009.

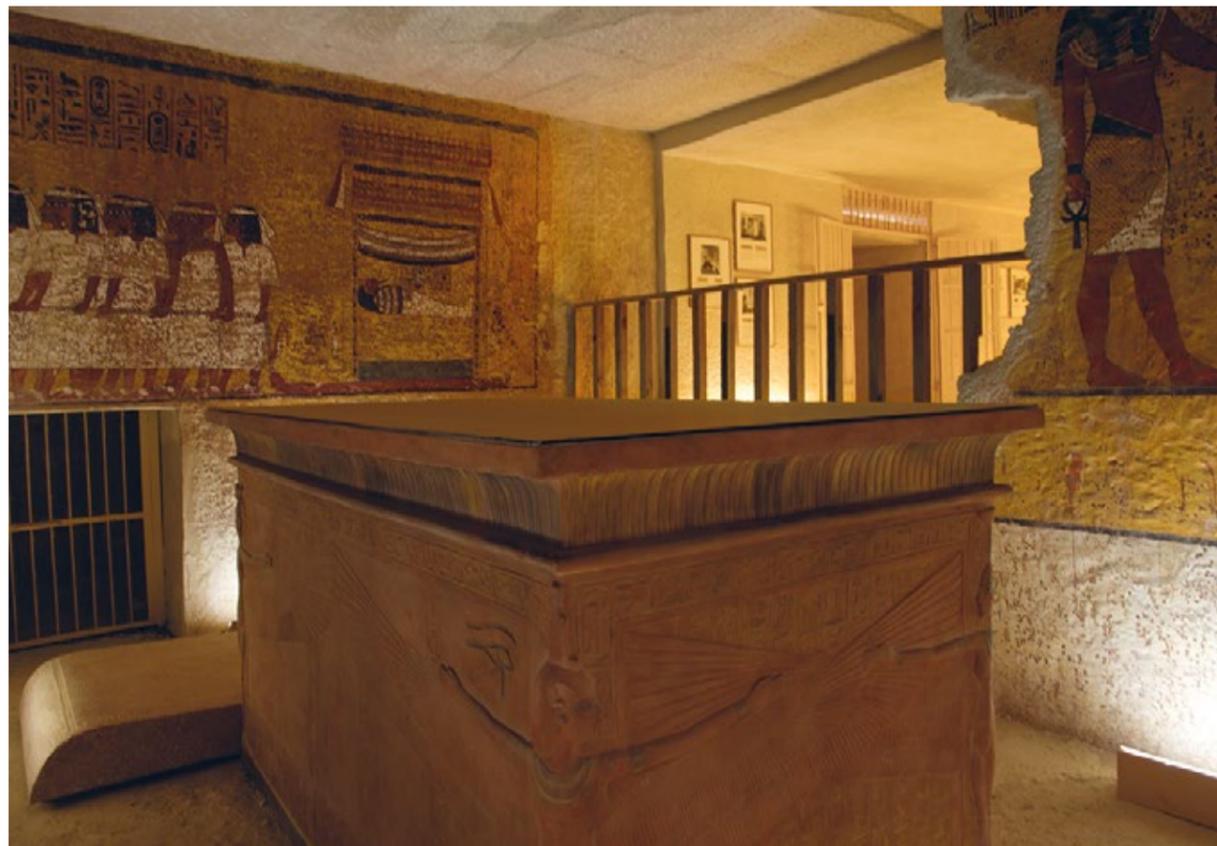
The recording of the tomb of Tutankhamun was carried out with the University of Basel as our academic partner and in collaboration with Erik Hornung and Professor Dr Theodor Abt from the Society of Friends of the Royal Tombs in Egypt.

In 2012, the physical facsimile of the burial chamber of Tutankhamun was given to the people of Egypt by the EU High Representative Baroness Ashton. It was presented to the Prime Minister of Egypt at a special event at the Conrad Hotel in Cairo, organized by the European Union.

In an ambitious development funded by Factum Foundation, the facsimile was installed in an underground building designed by the Tarek Waly Center for Architecture and Heritage next to Carter's House at the entrance to the Valley of the Kings in 2014. Tutankhamun's burial chamber and the associated exhibition have been open to the public since 2014, allowing many tourists to see both the original tomb and its facsimile and understand the problems of preserving sites that were never meant to be visited.

In 2016, the complete recording of the Tomb of Seti I began and the first local Egyptian operators were trained. In parallel, the recording of painted wall fragments and objects removed from the tomb began at the Museum of Fine Arts Boston, the British Museum London, the Musée du Louvre Paris, the Museums of Archaeology in Florence and Bologna, Sir John Soane's Museum in London, the Pergamon Museum in Berlin and in private collections. In October 2017, the University of Basel and Factum Foundation with support from the Ministry of Antiquities showed the first results of their partnership in the exhibition *Scanning Seti: The Regeneration of a Pharaonic Tomb*, at the Antikenmuseum in Basel to mark the bicentenary of the discovery of the tomb.

In 2017, the restoration of the Stoppelaëre House was completed. The prominent building at the entrance to the Valley of the Kings was designed by architect Hassan Fathy and the restoration was carried out by Tarek Waly with traditional local builders. This restoration was totally funded by Factum Foundation in exchange for free use for 10 years. It was inaugurated in February 2017 by Irina Bokova, then Director-General of UNESCO, the Egyptian minister of Antiquities, Dr. Khaled El Enany and the Swiss ambassador to Egypt.



Top: Production of an exact facsimile of the tomb of Tutankhamun 2012.  
 Bottom: Finished replica installed at the entrance of the Valley of the Kings 2014.

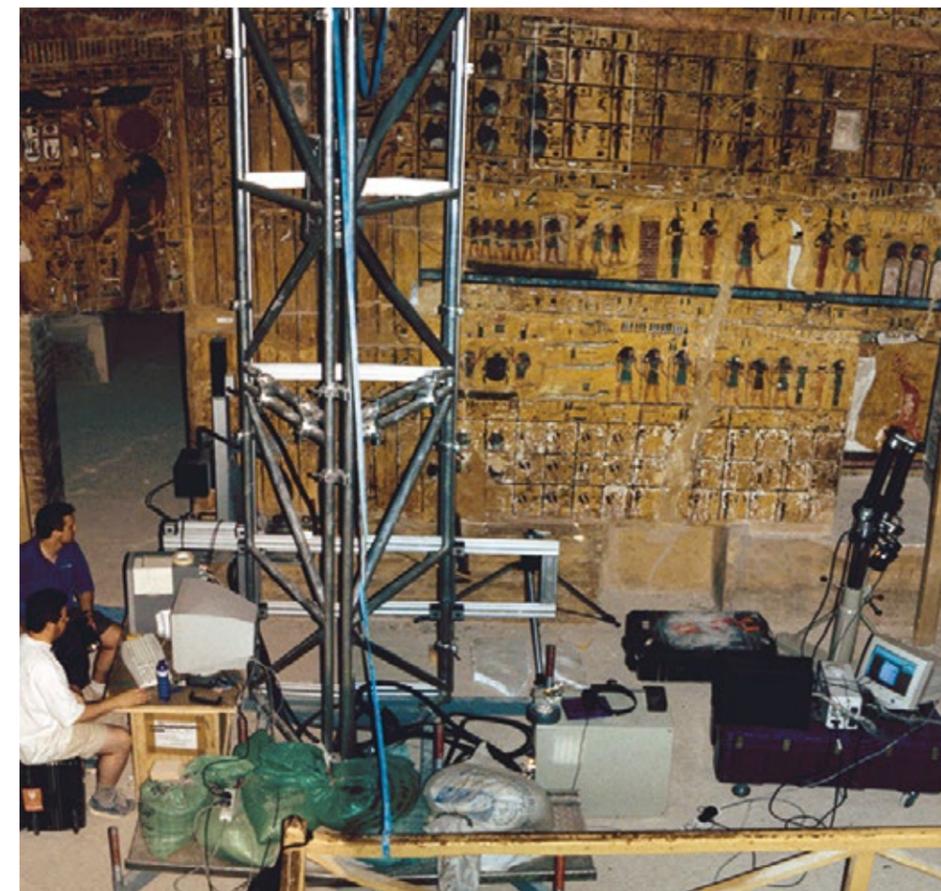
## THE THEBAN NECROPOLIS PRESERVATION INITIATIVE

Contracts Signed  
 and Work Restarts

In 2018, all the contractual agreements were completed and Factum Foundation began equipping the *3D Scanning, Archiving and Training Centre* in Stoppelaëre House with state of the art scanning, data processing and archiving equipment. This work is ongoing and the server to store the data will be installed in October 2019.

In February 2019, the Theban Necropolis Preservation Initiative team moved into Stoppelaëre House and work restarted in the Sarcophagus room within the Tomb of Seti I. Factum Foundation, University of Basel and the Ministry of Antiquities selected two inspectors of the Ministry to be trained in 3D recording. This training is ongoing with two more trainees starting in October. The objective is to train ten persons in total.

The work will continue until the completion of the high-resolution recording of the tomb. The *3D Scanning, Archiving and Training Centre* could also offer services to the Ministry of Antiquities and other foreign Missions working in the area. This would provide a sustainable work flow and economic security for members of the local community who are trained in the documentation of cultural heritage.



A team from Factum Arte demonstrating that it was possible to 3D scan the relief carving in the Tomb of Seti I in 2001.



## THE THEBAN NECROPOLIS PRESERVATION INITIATIVE

Aims of TNPI

The Theban Necropolis Preservation Initiative is committed to high-resolution documentation, training and technology transfer. The definition of 'high-resolution' is that the data is sufficiently accurate to enable the tombs to be rematerialized at a scale of 1:1 so that, to the naked eye, from a normal viewing distance, they are indistinguishable from the original.

Not only are the surfaces of tombs being recorded in colour and three dimensions with over 100 million measured spatial points per square metre but the key skills and technologies are simultaneously transferred to the local community. As the project develops, the digital data generated will be stored locally, owned by the Ministry of Antiquities and made accessible globally.

The copyright belongs to the Egyptian Ministry of Antiquities for all current and future commercial applications. The data will be made available for monitoring the condition of the tomb and will provide objectively accurate evidence of changes to the surface, paint loss and alterations caused by the impact of tourism and interventions to halt the tomb's decay. Hopefully, it will also lead to new discoveries about the Tomb of Seti I and other tombs.

The main goal of the Theban Necropolis Preservation Initiative is to ensure that the local community benefits financially from the preservation of cultural heritage through the provision of new skills and employment to reinforce their sense of ownership. Members of the local community who are working with Factum Foundation in Luxor are extremely capable and often more ingenious and resourceful than graduates of the best western universities. Basel University ensures that the work is academically coherent while informing cutting edge research in archaeology and Egyptology. Factum Foundation for Digital Technology in Conservation is a leading force in the field of non-contact recording, data processing and re-materialization providing access to advanced technology that will assist in the preservation of Egyptian heritage. At the same time, it will generate income at a local level resulting in the safe and sustainable study and display of tombs and other artefacts in Luxor and elsewhere.

Left: A shaded render of 3D information recorded using the Lucida Laser Scanner, designed by Manuel Franquelo specifically to record the relief surfaces in the tomb. It records black and white information that is converted into 100 million measured spatial points per square meter.



Top: Aliaa Ishmail leading a training session in Stoppelaëre House in March 2019.  
 Bottom: At the start of 2019 Factum Foundation shipped an exact facsimile of the funerary herb garden discovered by José Gallan (Proyecto Djehuty, CSIC). The original is very vulnerable and has been reburied. The facsimile will be placed on top of the original site. This approach will mean it is both preserved and visible. Sadly, it was delayed in customs and will not be installed until next year.

## THE THEBAN NECROPOLIS PRESERVATION INITIATIVE

Work in 2019  
 in Luxor and Madrid

A contract between the Ministry of Antiquities, Factum Foundation and the University of Basel covers all the work being carried out. TNPI has received practical support from the Swiss Embassy and the Delegation of the European Union.

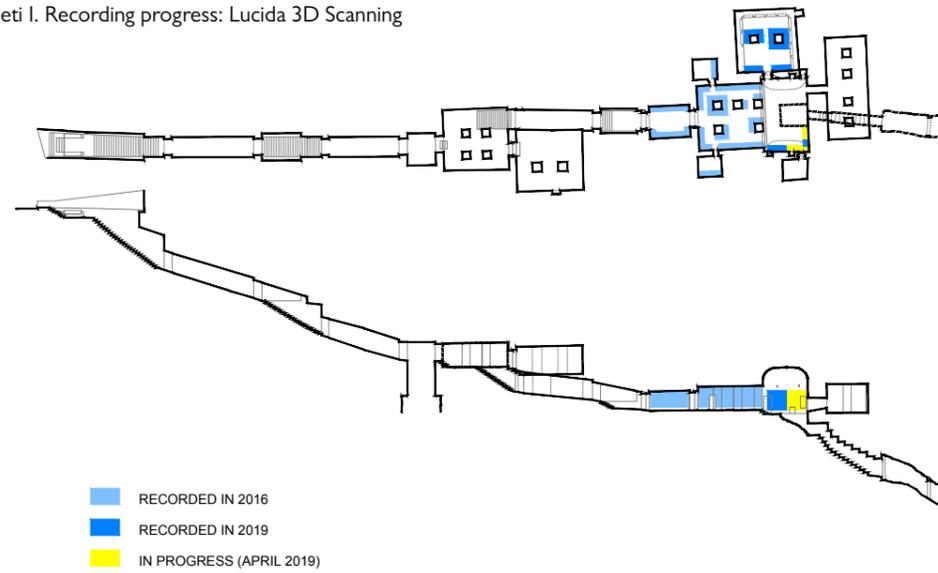
The signing of a trilateral agreement in December 2018 has enabled work to restart on the West bank in Luxor. A team of four people under leadership of Aliaa Ismail, an Egyptologist trained at the American University in Cairo, is running day to day operations at the *3D Scanning, Archiving and Training Centre* at Stoppelaëre House. She is also supervising Abdel El Reheem Ghaba and Mahmoud Salem who are carrying out the scanning with two Lucida Scanners in the Tomb of Seti I. They are working alongside Factum Foundation's specialists who supply additional knowledge and training.

Two trainees, Amany Hassan Mohamed and Mahmoud Abdellah Mohamed Ammar, from the Luxor branch of the Ministry of Antiquities are now receiving hands-on training from Aliaa Ismail. Over the coming months, Factum Foundation staff will continue to supplement this work locally and by remote access from Madrid. The trainees will be taught laser scanning, photogrammetry, color recording, data processing, archiving and dissemination. On completion of their training they will become part of the recording team sharing their knowledge with the new trainees. It is anticipated that by 2022 a total of ten Egyptian women and men will have been trained and will be able to perform preservation recording work with technical and material support from Factum Foundation. Their skills and competence will be available to the Ministry of Antiquities and will also be available for the numerous foreign archaeological missions that work in Luxor and other locations in Egypt.

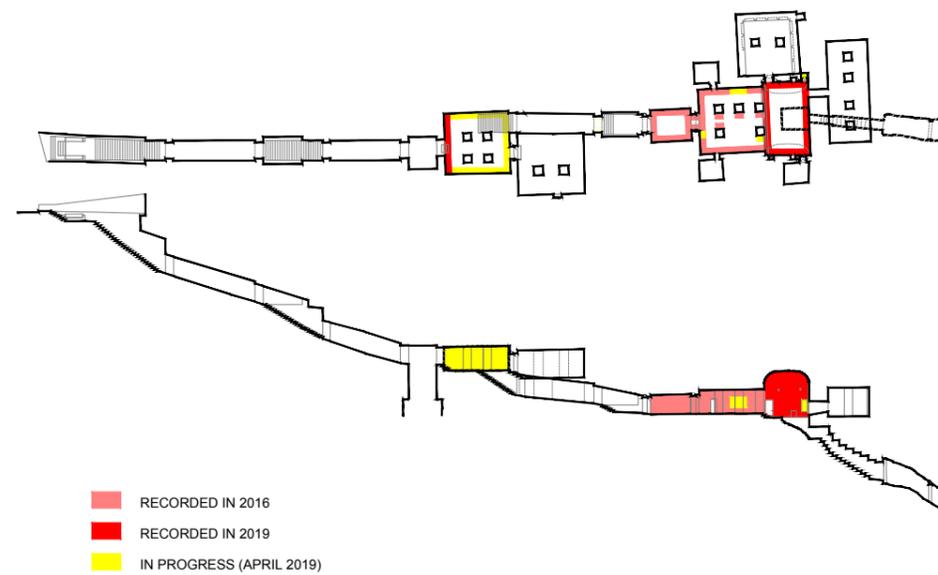


José Galan standing beside Factum Foundation's reconstruction of the Djehuty stela at the public event at the Temple of Debod in Madrid, October 2018.

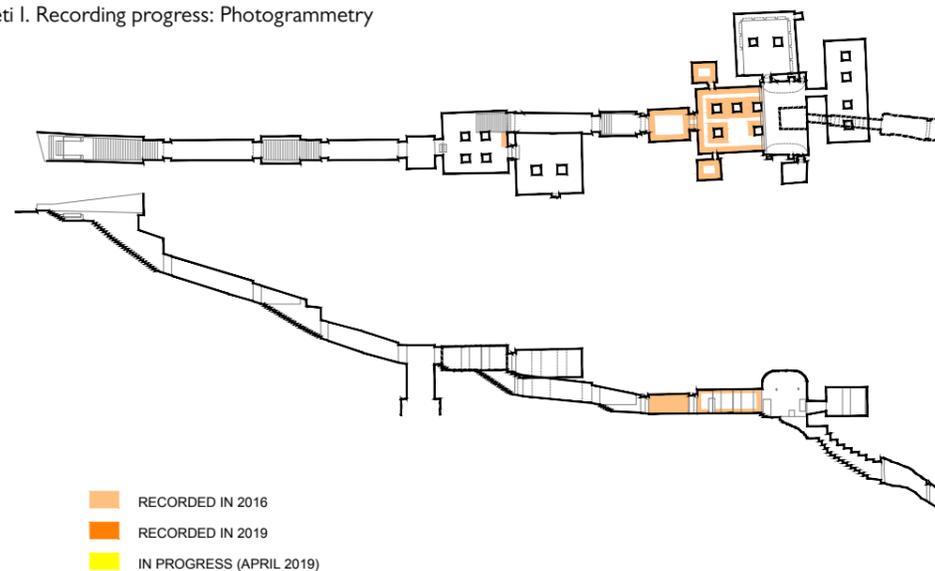
KV 17 - Seti I. Recording progress: Lucida 3D Scanning



KV 17 - Seti I. Recording progress: Panoramic colour photography



KV 17 - Seti I. Recording progress: Photogrammetry



## RECORDING THE TOMB OF SETI I

Work Completed  
by April 2019

The letters used to identify the rooms are those used by Erik Hornung.

- The entire tomb has been accurately surveyed and measured in 3D using a FARO Focus 3D x 130 Scanner: a Terrestrial Laser Scanner that also records colour.
- A section of the south wall of Room F has been recorded with high-resolution photogrammetry. All of Room F has been recorded with composite photography
- The Hall of Beauties (Room I) has been entirely recorded in high-resolution 3D Laser scanning, composite colour and some parts have been recorded using photogrammetry.
- The Connecting passage between Room I and Room J has been entirely recorded in composite colour and photogrammetry.
- 100% of Room J has been recorded: 80% using high-resolution Lucida 3D Laser Scanner, the remaining 20% was recorded using photogrammetry. Five pillars were recorded in composite colour. Five of the twenty sides of the pillars have been photographed. Most are missing and are being recorded elsewhere. The entire room has been recorded with composite photography
- Room M and L were recorded in composite colour photography for photogrammetry.
- The entire Sarcophagus Room (Room K) has been photographed using composite photography. Scanning continues in the room with two scanners. Due to the height of the walls the lower part (below 3 meters) will be recorded in 3D using Lucida Laser Scanner. The areas above 3 meters will be recorded using Photogrammetry.
- Some areas from west wall of Room N have been scanned with the Lucida. The 2 pillars have been scanned. Some areas have been recorded with composite photography.
- Detailed photographs were taken to produce a record of the rooms before and after recording.

Working hours in the tomb are 9 – 3pm five days a week.

During Ramadan working hours are reduced. Work will stop in the tomb during the summer months and focus on data processing at Stoppelaëre House.

The reconstructed Hall of Beauties as it may have looked in 1817 illuminated with candle light. When seen with this light the relief carving is critically important in creating the form, the white paint is matt and absorbs the light while the colours have varying degrees of reflectivity.

## THE THEBAN NECROPOLIS PRESERVATION INITIATIVE

Summary of the Current  
and Next Steps:

Work re-started in the Tomb of Seti I in February 2019 with full support from the Ministry of Antiquities. Training at the *3D Scanning, Archiving and Training Centre* started at the same time. Factum Foundation and the University of Basel are working increasingly closely with the Ministry and will begin the recording of 8000 fragments found by the University of Basel team in and around the Tomb of Seti I. The work will continue until the full recording of the Tomb of Seti I and all the fragments removed from the tomb is complete. It will result in a fully trained local team that will establish a world leading centre for 3D scanning and high-resolution recording.

Theban Necropolis Preservation Initiative is functioning and needs a long-term strategy with secure funding until it can become fully self-supporting.

The following things have been achieved and are ongoing:

- a.) A fully functional *3D Scanning, Archiving and Training Centre* at Stoppelaëre House with a local Egyptian team.
- b.) The training of the local staff (2 trainees per semester) selected by the Ministry over the next 4 years. After training they will be able to carry out all aspects of the recording, processing and archiving work. This scheme started on 7 February 2019.
- c.) The recording of the Tomb of Seti I and the processing of all the data.
- d.) The complete archiving of all the data.
- e.) Starting in September 2019: The recording of approximately 8000 fragments discovered by the University of Basel in or near the Tomb of Seti I which are now stored in the tomb of Rameses X; The *3D Scanning, Archiving and Training Centre* will provide the technical means for the University of Basel project in the Valley of the Kings, led by Dr Elina Paulin-Grothe and Susanne Bickel, to record the fragments they have discovered in colour and 3D. These will then form an important part of the archive relating to the Tomb of Seti I.
- f.) In planning phase: Providing recording facilities to other missions working in the area leading to high-resolution recording of other sites under supervision of the Ministry of Antiquities. Building connections to ensure the work continues after the completion of the scanning in the Tomb of Seti I is of great importance. The goal is long-term digital recording and archiving that can be viable and self-sustaining while bringing new skills to the West bank in Luxor.



THE SYSTEMS  
USED  
FOR DATA  
CAPTURE

Technology in Action

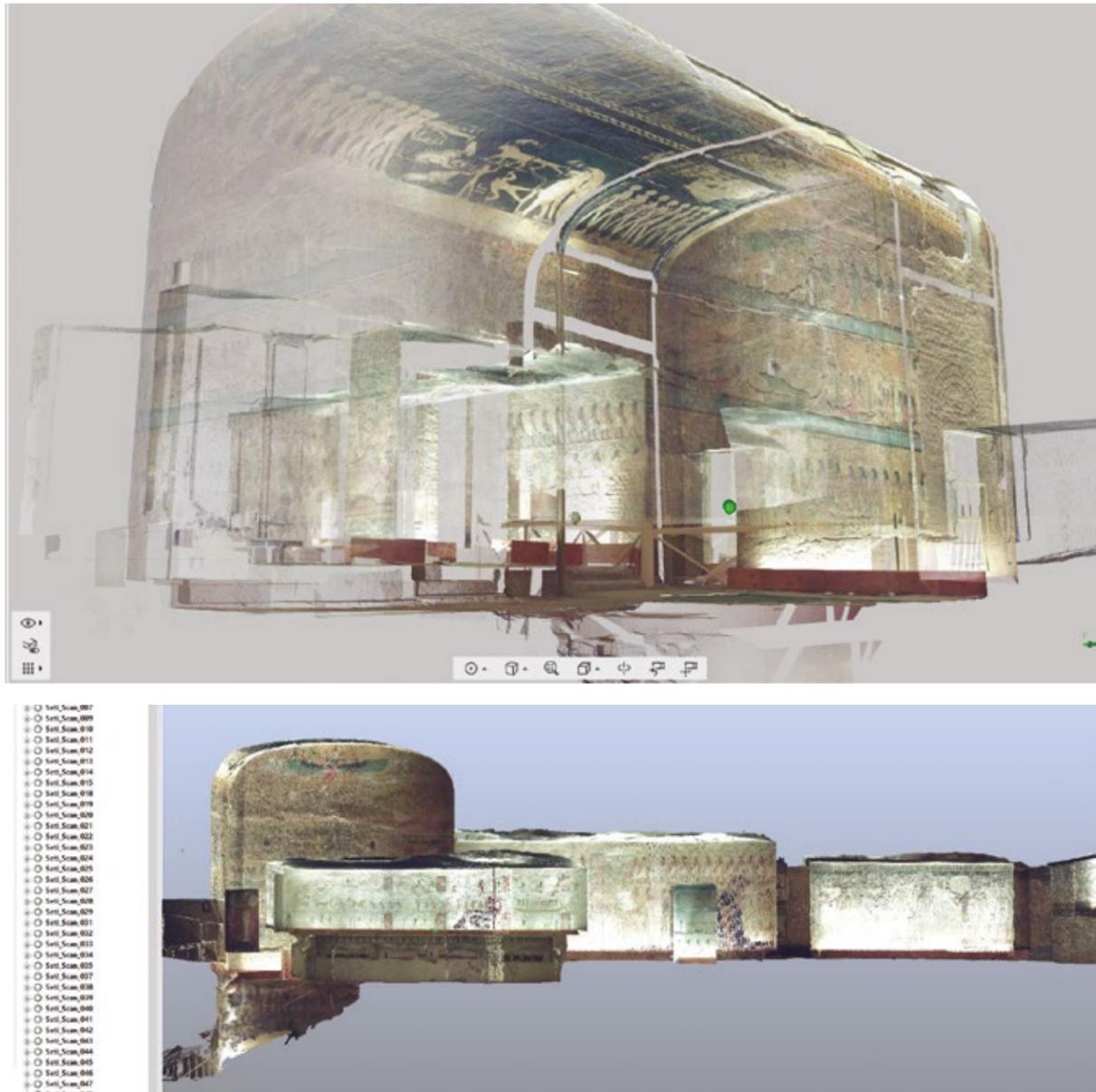


Hathor, Osiris, the Pharaoh Seti I and Horus from Room F of the Tomb of Seti I. Recorded using photogrammetry and composite colour recording.

All systems used by Factum Foundation are 100% non-contact and meet the highest conservation standards. At no time during the recording is there any physical contact with the wall. No markers or colour charts are attached to any part of the wall at any time.

## THE SYSTEMS USED FOR DATA CAPTURE

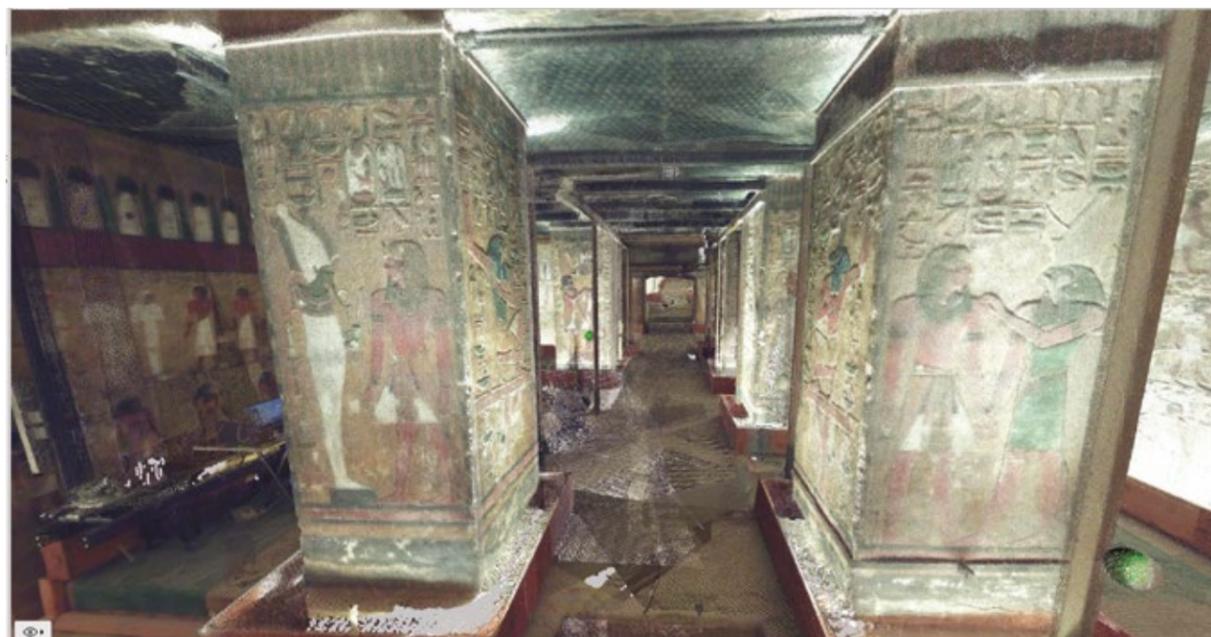
LiDAR Scanner



FARO Scanner at the entrance of the tomb.

The Terrestrial Laser Scanner (TLS) FARO Focus 3D x 130 HDR is a mid-range device that uses phase shift technology, offering accurate scanning from 0.6m up to 130m. It can capture millions of 3D measurements at up to 976,000 points/second, with a ranging error of  $\pm 2$ mm. The integrated colour camera records a HDR photo overlay of up to 165 megapixel colour.

The tomb of Seti I was surveyed from 70 different scan positions. The accurate point cloud obtained of the entire tomb is about 2.132 million points, with an average distance between measured points of 1.5 mm to 3 mm.





**THE SYSTEMS  
USED  
FOR DATA  
CAPTURE**

Lucida 3D Laser Scanner



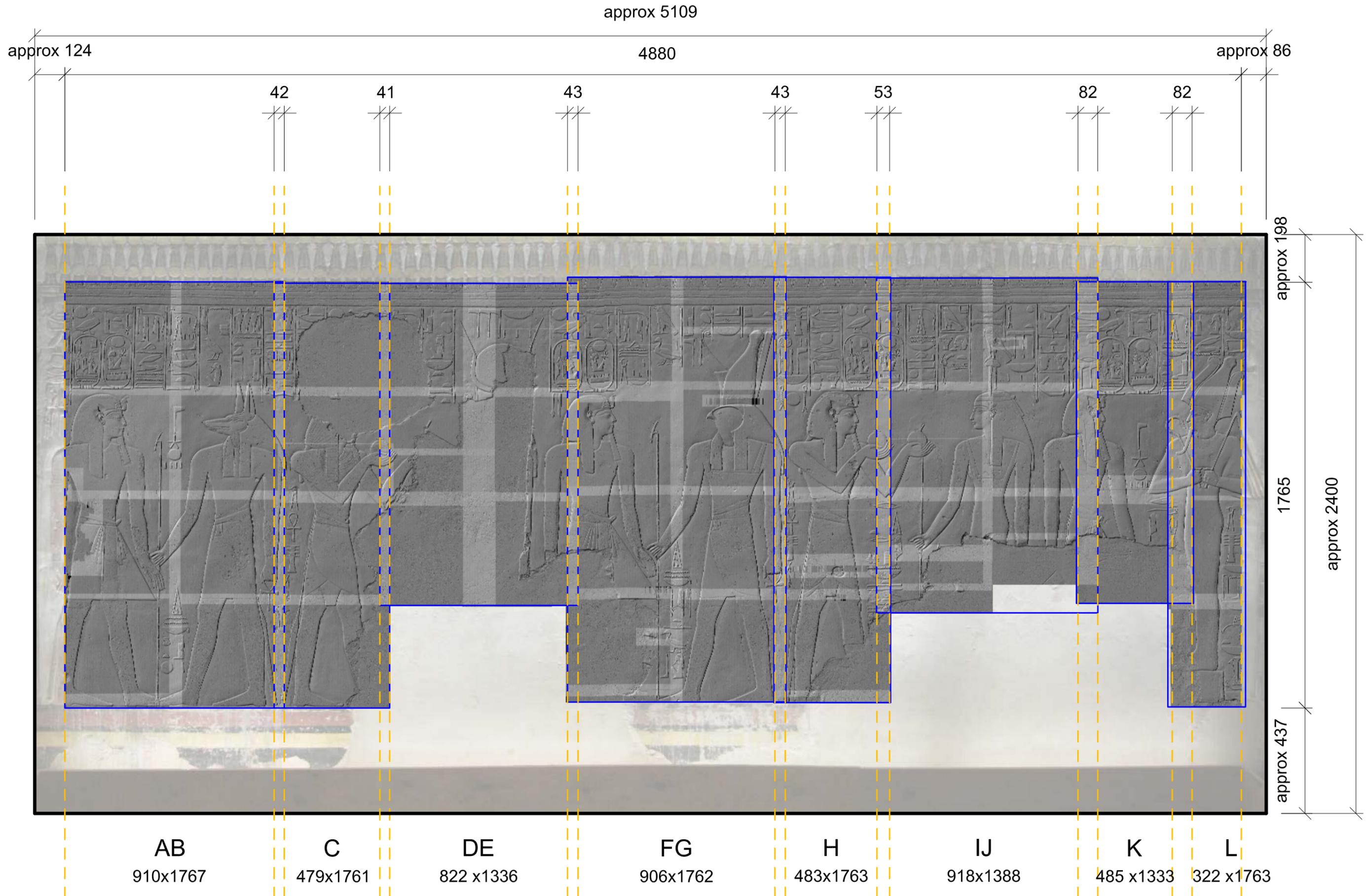
Abdel El Reheem Ghaba recording in the Tomb of Seti I using the Lucida Scanner. Keeping detailed and accurate records is a vital part of the documentation work.

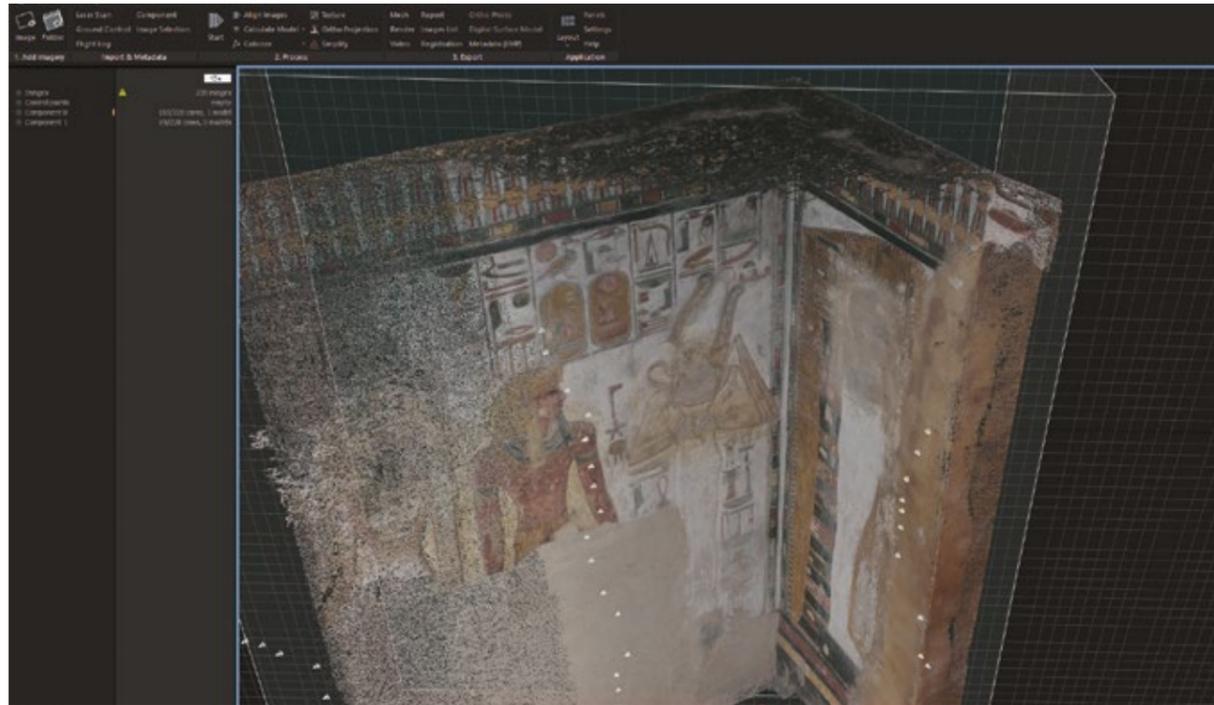
The Lucida Laser Scanner was designed and developed by Manuel Franquelo and the team at Factum Foundation for recording the coloured 3D relief in the Tomb of Seti I. The software has been specially developed for simplicity and ease of use without compromising its quality of working applications. The main advantage of writing software in-house is that it gives the operator complete control and bypasses the normal commercial constraints imposed on software usage.

The black and white video recorded with the Lucida Scanner is processed into a point cloud consisting of 100 million independently measured points per sq meter. The Lucida Laser Scanner is a close-range scanning system that works at 8 cm from the surface of the wall. It can record an area of 48x48cm in about an hour. It can be repositioned to record surfaces with a relief of more than 2.5 cm and automatically merges the two sets of data.

The Lucida is the main scanning system used for high-resolution recording of the tomb.

# I\_E Diagram





Both 3D information and colour can be obtained using composite photography. For colour recording the main aim is to keep the light constant and record accurate colour information. For 3D, data overlap and the correct approach to the photography is critical.

Top - 3D and colour.

Bottom 3D data recorded with a 35mm lens camera.

## THE SYSTEMS USED FOR DATA CAPTURE

Photogrammetry



Photogrammetry is a 3D recording technique that employs 2D images to create a 3D model of an object or a surface. It involves taking hundreds of overlapping photographs of an object from many different angles. Capable of extracting data with sub-milimetric resolution, photogrammetry is an emerging technology. Factum Foundation currently employs a software developed by Capturing Reality to maximise the quality of the data, the processing time and the ease of use.

Factum Foundation works closely with the software provider Capturing Reality who are supplying software at greatly reduced cost. *Reality Capture* is a powerful software capable of processing thousands of images to produce high-resolution 3D files.

Continuous development and research into ways of improving quality while reducing the recording time are ongoing in Madrid and with our technical partners.

## THE SYSTEMS USED FOR DATA CAPTURE

## Composite Colour Photography

Composite colour photography is often referred to as Gigapixel photography due to the vast amount of data that is recorded. The aim is to record the entire tomb at a scale of 1:1 with image files of about 500 PPI at 1:1. These files can be enlarged to about 5 times actual size without loss of image quality. The floors, walls, columns and ceilings of the entire tomb are recorded using a variety of different lenses.

The process of mapping the composite colour images onto the 3D recording of the surface requires powerful computers and great attention to detail. It requires time, concentration, skill and sensitivity.



Detail.



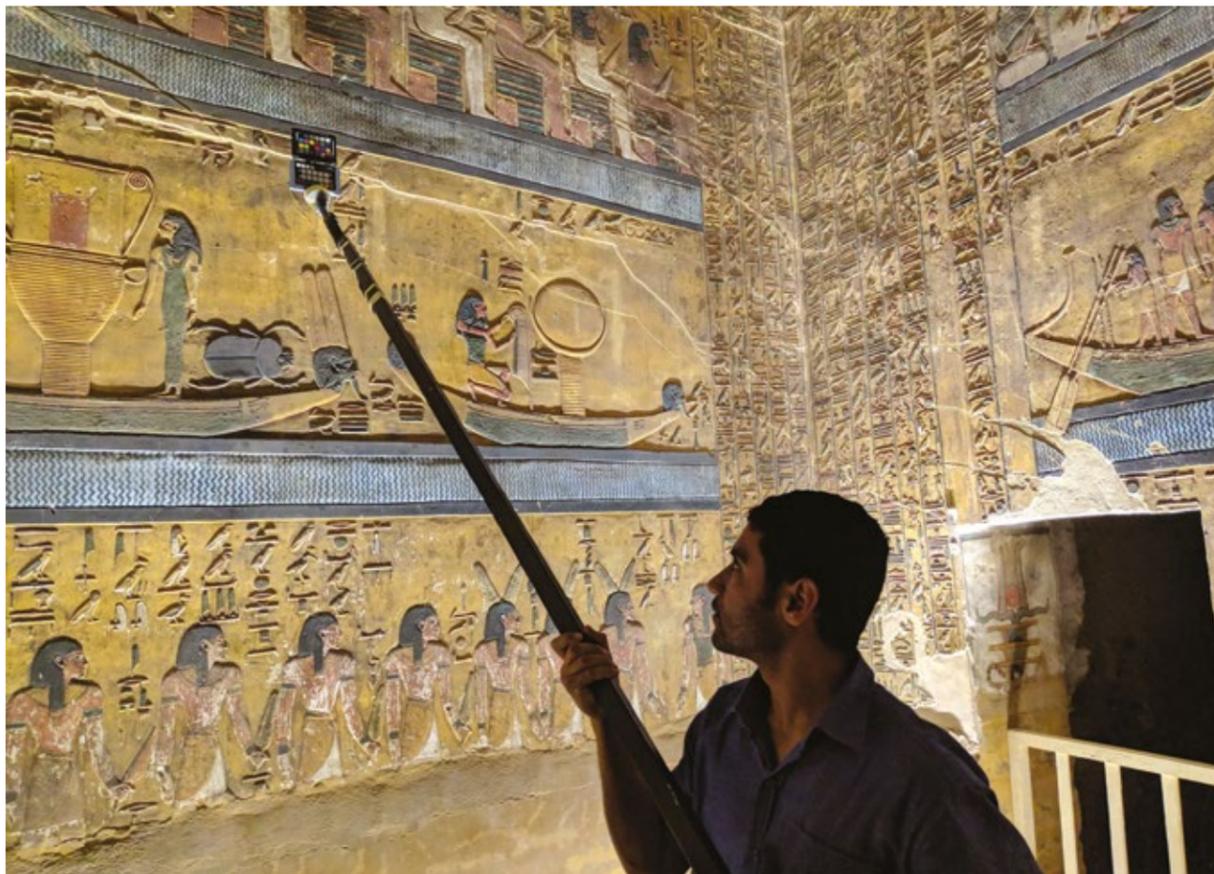
Detail: 1:1 at 400 pixels per inch.



Automatic stitching of hundreds of overlapping high-resolution images using *PTGui* software. This is the first stage of the merging process that is dependent on software and human skill.

THE SYSTEMS  
USED  
FOR DATA  
CAPTURE

Reference Photography



Top: specially made colour bar held close to the wall.

Bottom: Mahmoud Salem using a standard colour checker.

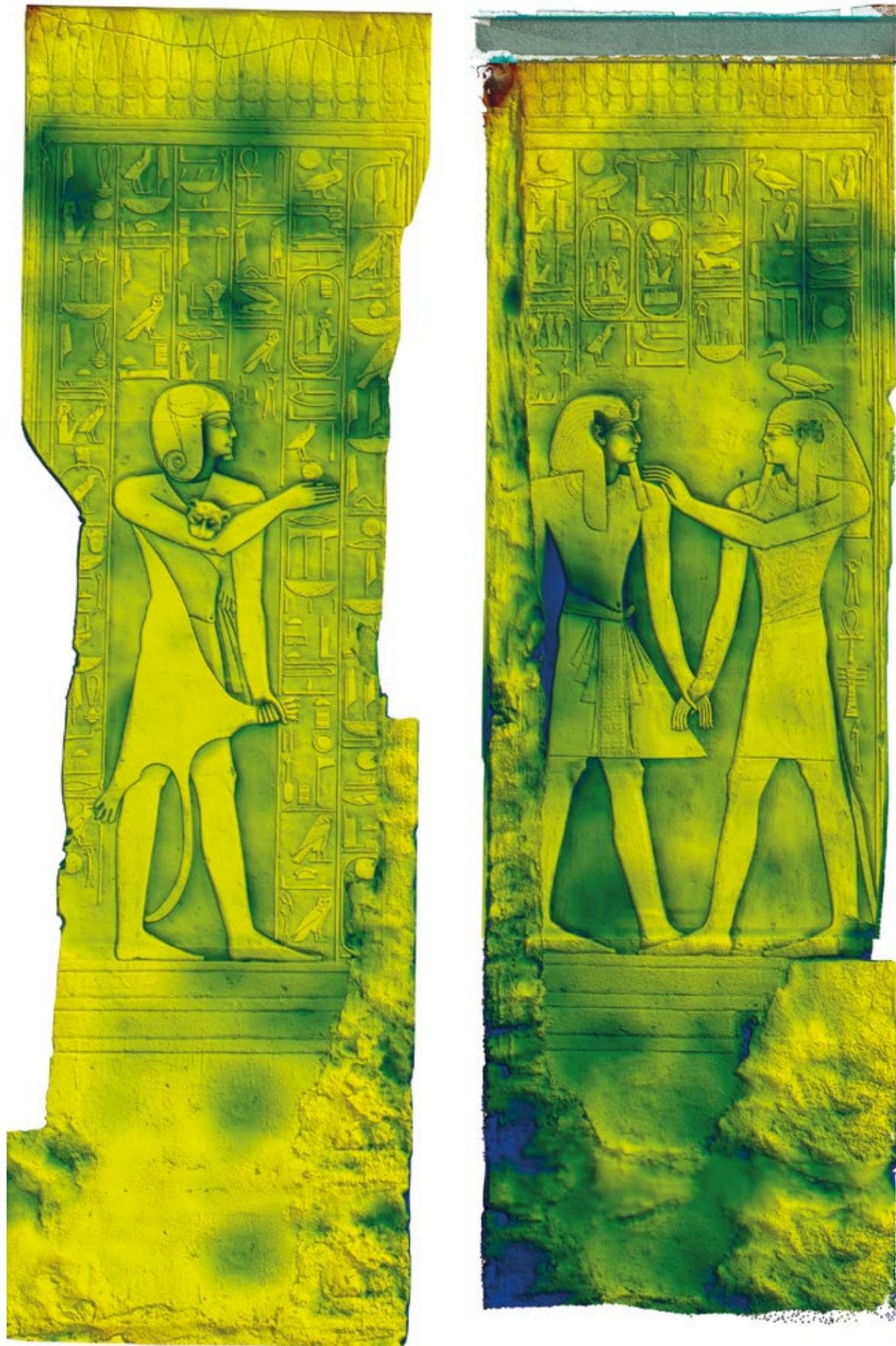
Right: Moussa Sayd Mohamed using a specially prepared colour chart in the Sarcophagus room.

**Colour Reference:** Colour appears different under different lighting conditions. Factum Foundation's aim is to record data that will be of such high quality that the whole tomb can be replicated in its present condition. To do this we must have accurate references about the colour of the tomb under the current lighting conditions. Both standard photographic colour charts and physical colour reference sticks are used. These are held close to the surface of the wall but not in contact with it. The colour reference sticks are made specially for each area of the tomb. These are vitally important when the facsimile is being made - At present the facsimiles are made in Madrid but the aim is to create workshops on the West bank near Carter's house where the facsimiles can be produced as a visitor attraction.

**Reference Photography:** In addition to the high-resolution composite photographs an archive of reference images is also being made. This records the condition of the tomb before and after scanning, the work that is taking place, the individuals involved and any detail that is relevant for research or for facsimile production.



A panoramic composite photograph stitched together before perspectival correction.



Depth map of two faces of pillars from Room J produced with *Global Mapper* software as part of the data processing.

## DATA PROCESSING AND DATA ARCHIVING

All the data recorded in the Tomb of Seti I is stored and archived in its raw format. It requires processing in different ways for use for different applications. Screen viewing requires one approach, the production of a facsimile another.

The high-resolution Lucida Scanner records raw video that must be processed into tonal-range image files and then converted into a 3D point cloud. All the raw video data is currently stored on external hard drives. An archival storage system will be installed in Stoppelaëre House before the end of 2019. Storing digital data in different forms and in different places is critical to its long term survival.

Photogrammetry is processed using *Reality Capture* software. Composite colour photographs are stitched together in *PTGui* and transformed in *Adobe Photoshop*. Factum Foundation has developed its own approach to ensuring perfect focus and the removal of all glare or reflection keeping the images uniform.

Composite images are merged at sub-pixel accuracy and registered over shaded renders generated from the 3D tonal images recorded with the Lucida Scanner. 3D Photogrammetric recording is used to complement the areas where the high-resolution 3D scanner has not been able to record. Mixing different types of data is a complex part of the process that is constantly evolving. Laser scans, LiDAR recording, Photogrammetry and composite colour are all required to ensure an accurate facsimile.

The data processing is done in Stoppelaëre House and in Madrid. As more members of the local community are trained, more processing will happen on the West bank with remote access management supporting from Madrid. The aim is to use computer vision technology and Artificial Intelligence to analyse and evaluate the recorded data, working with *Analysis and Recording of Cultural Heritage in Venice (ARCHiVe)* a partnership between Factum Foundation, the Cini Foundation and École Polytechnique Fédérale de Lausanne.

Data storage and access are emerging subjects that require new skills. All the data will be stored in a digital archive in Stoppelaëre House where it will be freely available for study and condition monitoring. The copyright on the data will belong to the Ministry of Antiquities for all commercial benefits on current and future applications.

## RECORDING FRAGMENTS OF THE TOMB OF SETI I



A fragment showing Hathor offering her neck decoration to Seti I, Archaeological Museum, Florence (left) and a matching panel from the opposite door post now in the Musée du Louvre, Paris, demonstrating two very different approaches to restoration made in separate places and times. These panels look neither like each other, nor like the original tomb, and demonstrate changing fashions in the treatment of cultural heritage.

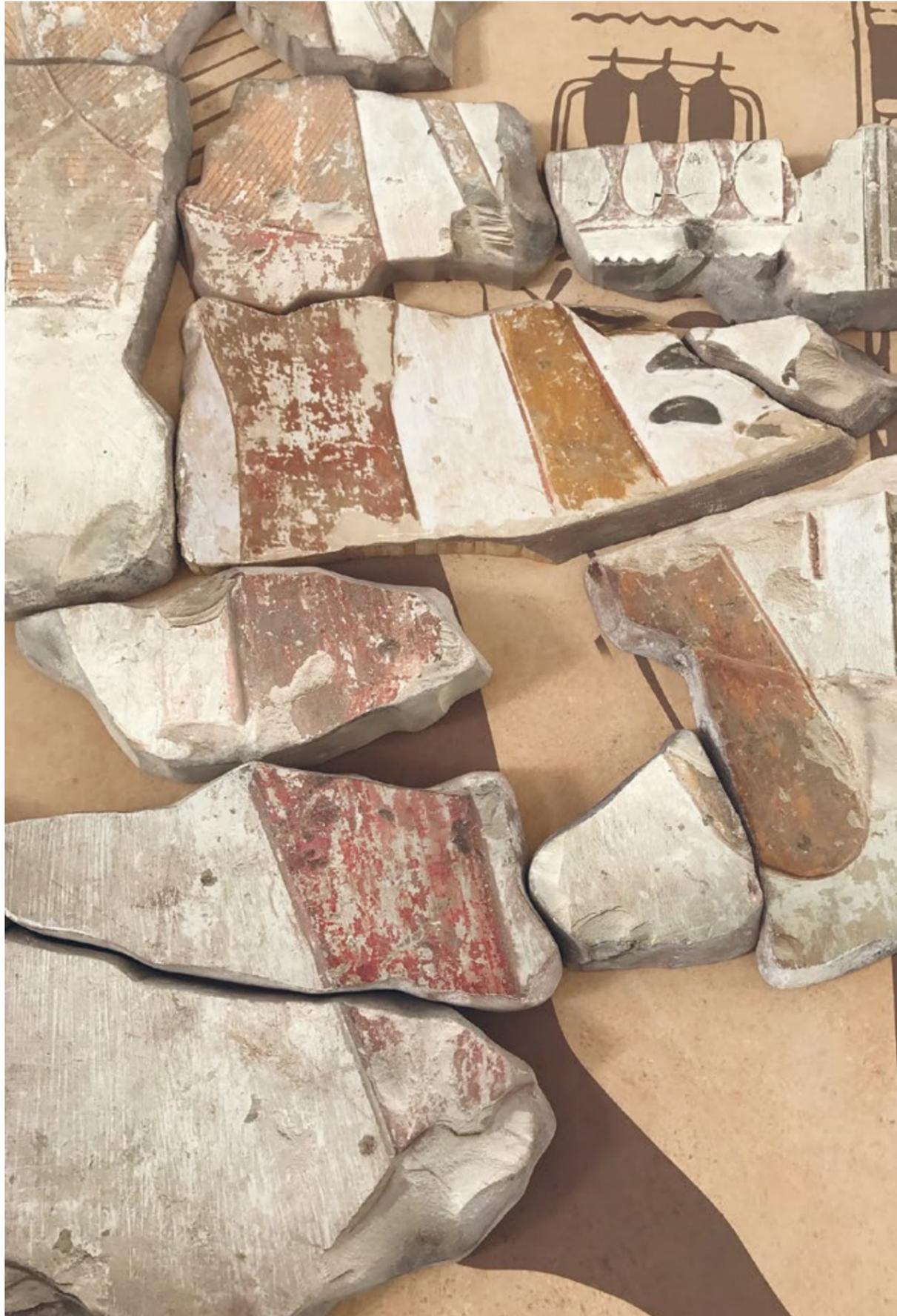
In the years following the discovery of the tomb, sections of the decoration were removed and there are now many fragments of varying sizes in museums and collections around the world. The largest are in the Musée du Louvre in Paris and the Archaeological Museum in Florence. There are also a large number of smaller fragments that were found in, or near, the tomb by a team from the University of Basel led by Susanne Bickel and Dr Florence Mauric Barberio (Institut Khéops, Paris).

A fundamentally important part of the work that is being carried out by Factum Foundation and Basel University is the complete recording of all the fragments that were removed since its discovery in 1817. Since 2016 fragments have been recorded at the Museum of Fine Arts, Boston, the Louvre (Paris), at the British Museum, the Sir John Soane's Museum (London), the Archaeological Museum (Florence), The Archaeological Museum in Bologna and in a private collection.

Research conducted by the University of Basel in the Valley of the Kings has expanded our knowledge on the Tomb of Seti I (KV 17). The excavations carried out near the adjacent tomb of Ramesses X (KV 18) between 1998 and 2005 brought to light roughly 8,000 decorated fragments from the Tomb of Seti I. Larger fragments were found inside Seti's tomb where they had been stored for more than a hundred years.

Factum Foundation is committed to recording these fragments and assisting with the computer visualisations that will help with their study and re-integration. Digital restoration is a fast-growing area of digital humanities. Both recording hardware and analytic software are changing the way academia functions. In recent years, Florence Mauric Barberio and the team from Basel University have pieced together many fragments. As objectively accurate technologies are applied to the understanding of the past, new discoveries are constantly being made. Digital technology is playing an increasingly important role in medicine, now it is starting to have a real impact on the preservation of the past.

Factum Foundation is also seeking to record any existing squeezes; wax squeezes are thought to exist at the Museum of Fine Arts, Boston, the Griffiths Institute and in the British Museum. These objects contain vital evidence about the surface of the tomb and also help to understand the damage that can be found in the tomb. Understanding why the tomb looks like it does is an important part of understanding its meaning and relevance.



Fragments found in the Tomb of Seti I by Florence Mauric Barberio.

**RECORDING FRAGMENTS  
OF THE TOMB OF SETI I  
THE FOLOWING FRAGMENTS HAVE BEEN RECORDED**

Museum of Fine Arts, Boston

Reference 72.645ab; 300 x mm

Reference 72.646; 70 x 80mm

Reference 72.647; 160 x 140mm

Reference 72.649; 220 x 150mm

Reference 72.650; 100 x 40mm

Reference 72.651; 130 x 100mm

Reference 72.653; 180 x 180mm

Reference 72.661; 90 x 120mm

Musée du Louvre, Paris

Reference B7; 2260 x 1050mm

Ägyptisches Museum

und Papyrussammlung, Berlin

Reference ÄM 2058; 2610 x 880mm

Reference ÄM 2079; 1050 x 530mm

Reference ÄM 2079; 1060 x 540

Museo Archeologico Nazionale, Florence

Seti and Hathor; 2350 x 1030mm

Maat; 740 x 470mm

British Museum, London

Reference EA855 (Side A); 1660 x 630mm

Reference EA855 (Side B); 1660 x 200mm

Reference EA884 (Side A); 490 x 400mm

Reference EA884 (Side B); 490 x 210mm

Reference EA5602; 240 x 180

Reference EA5603; 250 x 240mm

Reference EA5604; 110 x 70mm

Reference EA5605; 130 x 100mm

Reference EA5606; 100 x 180mm

Reference EA5608; 280 x 200mm

Reference EA5610; 250 x 380mm

Reference EA35499; 80 x 110mm

Reference EA35500; 50 x 80mm

Sarcophagus lid fragments

Reference EA37928; 100 x 160mm

Reference EA29948; 350 x 240mm

Reference EA37927; 120 x 140mm

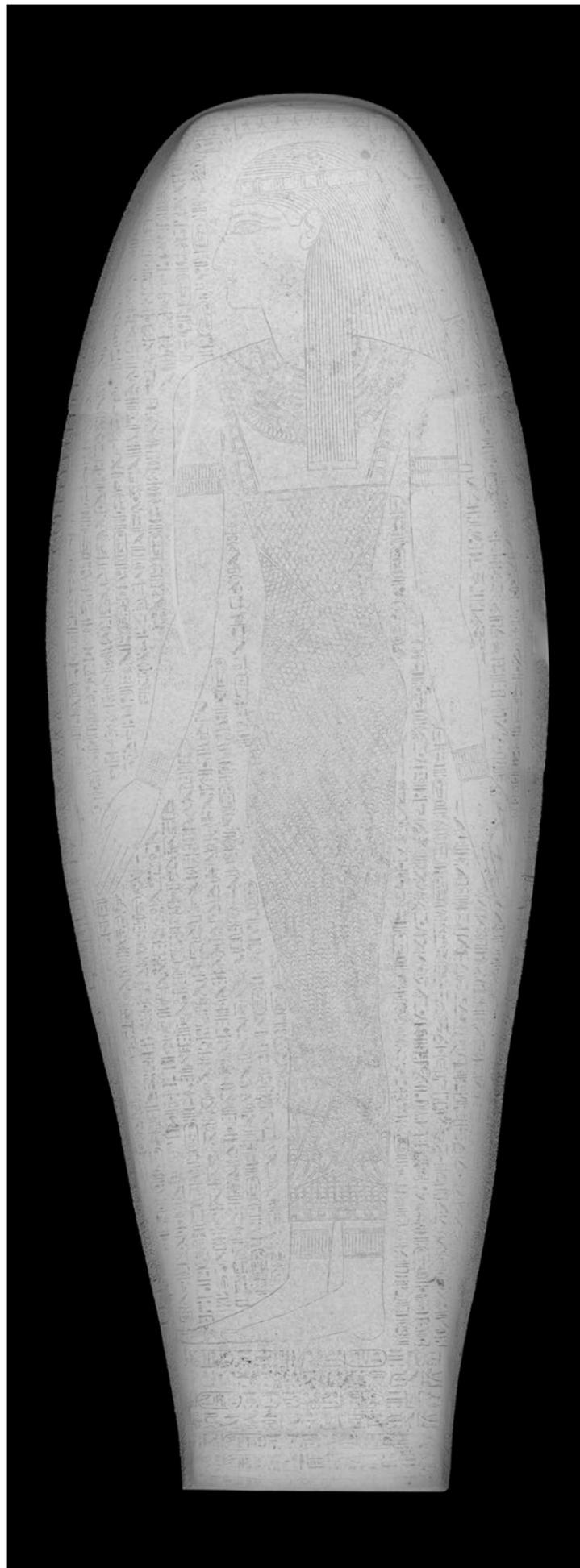
Sir John Soane's Museum, London

The entire sarcophagus housed in Sir John Soane's Museum has been recorded in high-resolution and replicated using cutting-edge technology. 18 fragments of the sarcophagus lid of different sizes have also been recorded. Two are presented in a glass case while the others are set into plaster and housed in four wooden cases with glass protection designed by Joseph Bonomi the Younger.

Museum of Archaeology, Bologna

8 Shabti's in the collection of the Museum of Archaeology from Seti's tomb have been recorded.

Ongoing research is bringing new fragments to light - One was recently recorded at Gallery Eberstein in Paris and another has been located through a dealer in London. The aim is to create a database of all existing fragments and to keep updating it as new pieces emerge.

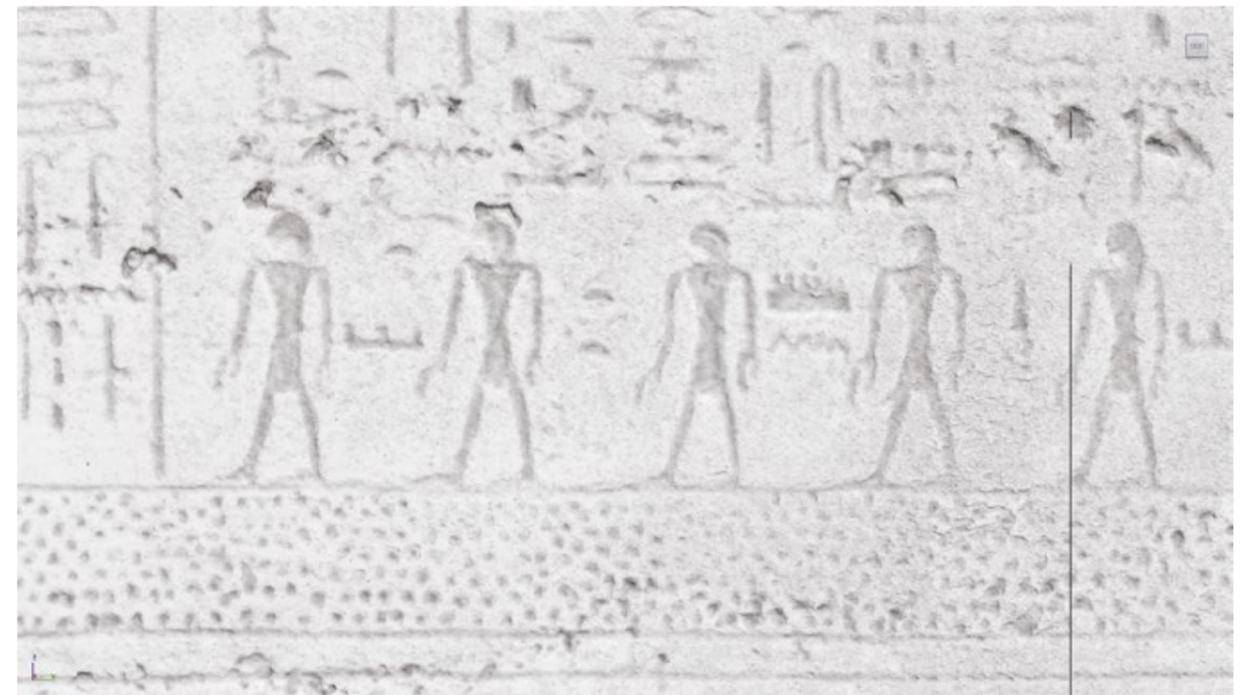


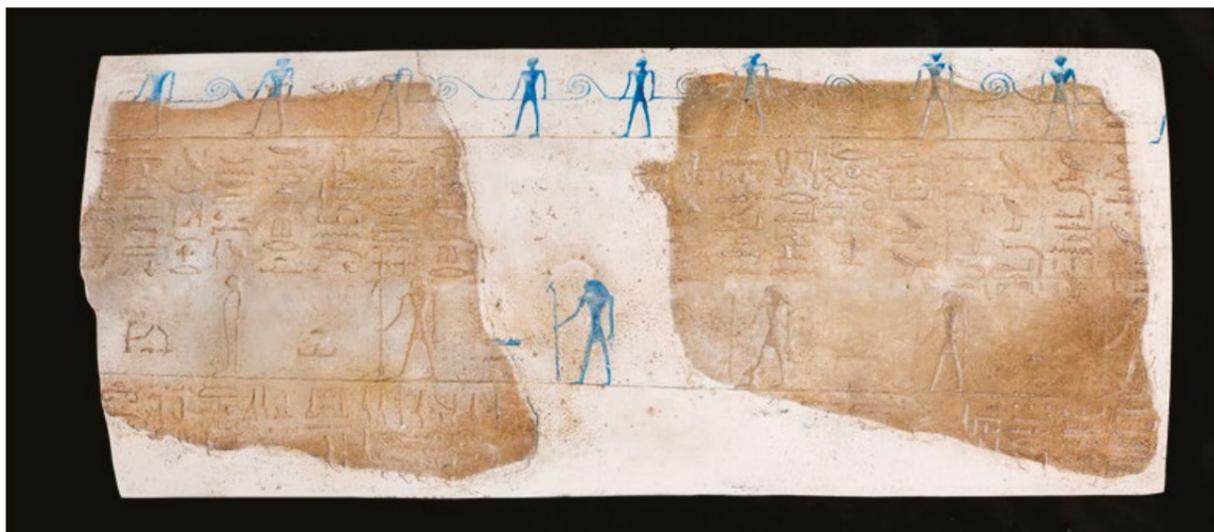
Left: render of the interior of the sarcophagus.  
Above: Images in Sir John Soane's Museum during the recording.  
Right: Render of a detail of the outside of the sarcophagus.

## RECORDING THE SARCOPHAGUS AND THE FRAGMENTS OF THE SARCOPHAGUS LID.

The photogrammetric recording of the Sarcophagus of Seti I in Sir John Soane's Museum, London was carried out between the 14th and the 19th March 2016 by Adam Lowe, Pedro Miro, Manuel Franquelo and Ferdinand Saumarez Smith from Factum Foundation,

Almost 5000 high-resolution photographs were stitched together using *Reality Capture* software with extensive support from the team at Capturing Reality in Bratislava. The resulting 3D model will facilitate an in-depth study of the surface and shape of the sarcophagus. Recording the sarcophagus cemented the close relationship between the museum and Factum Foundation and an animation of the recording was part of their bi-centenary exhibition about Belzoni, the discovery of the tomb and the arrival of the sarcophagus at the museum. The 3D file of the sarcophagus also forms part of Digital Soane, a freely accessible interactive website.





## REMATERIALISING THE SARCOPHAGUS

Factum has developed a variety of specialist methods and techniques that allow for the reproduction of the most diverse materials. Alabaster is particularly difficult. To re-materialise Seti's sarcophagus we used a method which combines 7-axis CNC routing with Océ's elevated printing technology. Océ's new printer builds 5 micron thick layers of UV cured ink into a 3D surface up to 2 cm in depth and with maximum dimensions of 2.4 x 1.4 meters. Focused work by both Océ and Factum engineers resulted in the separation of local surface details from the general shape, enabling the surface of the sarcophagus to be printed and mapped back onto the 3D routed form without distortion. The result of combining these two technologies was a copy that perfectly captures the colour and relief of the sarcophagus's surface. The movement between the digital and the physical realm is characteristic of Factum's approach and is based on our in-depth understanding of the transformations required to create a meaningful object. The technology is always dependent on skilled people who understand materials and the way they can be manipulated. This approach is capable of helping to preserve, archive, share and study the world's heritage. The facsimile of the sarcophagus was exhibited at *Scanning Seti: The Regeneration of a Pharaonic Tomb*, (October 2017 to May 2018) at the Antikenmuseum in Basel and at *Images of Egypt* at the Museum of Cultural History, Oslo (September -December 2018). Work to locate more fragments of the sarcophagus lid is ongoing. Currently about 20 fragments have been scanned and hopefully more pieces will emerge.





## THE RESTORATION OF STOPPELAËRE HOUSE

Outline

Stoppelaëre House was built in 1951 by the Egyptian architect Hassan Fathy for Alexandre Stoppelaëre, the Belgian chief restorer of the Department of Antiquities at this time. The house was designed to be a guest house for the Department of Antiquities and the headquarters/apartment for Alexandre Stoppelaëre. It occupies a prominent position at the entrance to the Valley of the Kings, perched on the top of a hill near Carter's House, the Facsimile of the Tomb of Tutankhamun and the Japanese Mission house. The house provides ample evidence of Fathy's mastery of mudbrick vaulting techniques, and contains many architectural details that are characteristic of his work. Like the earlier houses on the West bank, Stoppelaëre House was expressly designed to house an archeological mission and contained spaces for drafting and working.

The work to restore the building and convert it for its new use was carried out by Tarek Waly Center -Architecture and Heritage using local builders and other workers. All finance to realise this work was provided by Factum Foundation and Tarek Waly Centre -Architecture and Heritage.



Images of Stoppelaëre House before, during and after restoration.





The TNPI team on the roof of Stoppelaère House in 2016 at the start of the work to restore the building.

## THE RESTORATION OF STOPPELAÈRE HOUSE

### Preservation status at the start of the restoration

The house has been subjected to various forms of decay caused by the weather, settlement in the surrounding soil and the erosion of the hill. Due to poor plumbing there has also been ground water erosion under the building. It had been empty for a unknown period of time and was left without adequate maintenance. This resulted in a severe deterioration in the condition of the house. Many problems were visible to the naked eye, others were revealed in the surveys that were carried out.

### Interventions

Due to the poor condition of the building significant interventions were needed to rehabilitate the building and convert it for use as the *3D Scanning, Archiving and Training Centre*. Structural interventions were essential. The first critically important work was to stabilise the existing structure through the insertion of a reinforced concrete ‘ring beam’ that ties the building together. The domes, external walls and the entire structure were then restored and everything possible has been done to prevent future deterioration. The restoration was made using the same techniques and recycling natural materials previously used in building the house. Some modifications were made to enhance the functionality of the building. New German ‘dust-proof’ windows were installed. The doors and lattice work have all been remade by local carpenters. The entire interior has been restored to the highest standard and new electrical wiring, plumbing and air-conditioning has been installed to adapt the house for its new use. Exterior elevation restoration and landscape redesign has also been carried out. All the interventions took into account the need to provide the conditions for advanced digital recording technologies and archiving systems. The contemporary needs were always considered in conjunction with the necessity of preserving the architectural importance of the house.

### Use as a Training Centre

The 3D documentation training centre at Stoppelaère House was inaugurated in February 2017, in presence of then Director-General of UNESCO, Irina Bokova. In the time since the launch a contract covering the use of the building has been signed with the Ministry of Antiquities. In February 2019, the TNPI started using the building for training and processing data. More equipment is being sent and the aim is to equip and run a centre that will become a practical example of how technology can be used to preserve and disseminate cultural heritage. More work still needs to be done to ensure that the centre has secure water and electricity supply and that it can function with maximum efficiency.



Top: The reconstruction of the Hall of Beauties with the colour and missing sections digitally and physically restored.  
 Bottom: The character and application of the paint is a mix of matt colours that absorb the light and glossy surfaces that reflect.

## THE CREATION OF THE FACSIMILE OF THE TOMB OF SETI I

The need  
 for a facsimile

The creation of a facsimile of the Tomb of Seti I was first imagined in 1988 by the Society of Friends of the Royal Tombs of Egypt. Since this time the copy at Lascaux (1983) and the reconstruction of the Cave of Altamira (2001) have proved that facsimiles can become major visitor attractions if people understand the conservation issues. The challenge for the Valley of the Kings is unique - the Theban necropolis is one of the world's leading tourist attractions. It was built to last for eternity but not to be visited.

Factum Arte's involvement began in 2001 with the approval of a research project by Dr. Gaballa to develop the techniques needed to scan the tomb. In 2002, an exact facsimile of the tomb of Thutmosis III was produced by Factum Arte for a touring exhibition, *The Quest for Immortality: Treasures of Ancient Egypt*, (National Gallery of Art, Washington 2002). This was followed by the facsimile of the burial chamber of Tutankhamun that now forms *Carter's House and the Replica of the Tomb of Tutankhamun* visitor centre. The Facsimile of the Tomb of Seti I has now started. When complete it will form the largest and most detailed facsimile ever made. The first rooms have been produced and were exhibited at the Antikenmuseum, Basel, in an exhibition that examined the 200 years in the life of the tomb since its *discovery* by Belzoni on 16th October 1817 (when he was shown the site by a local).

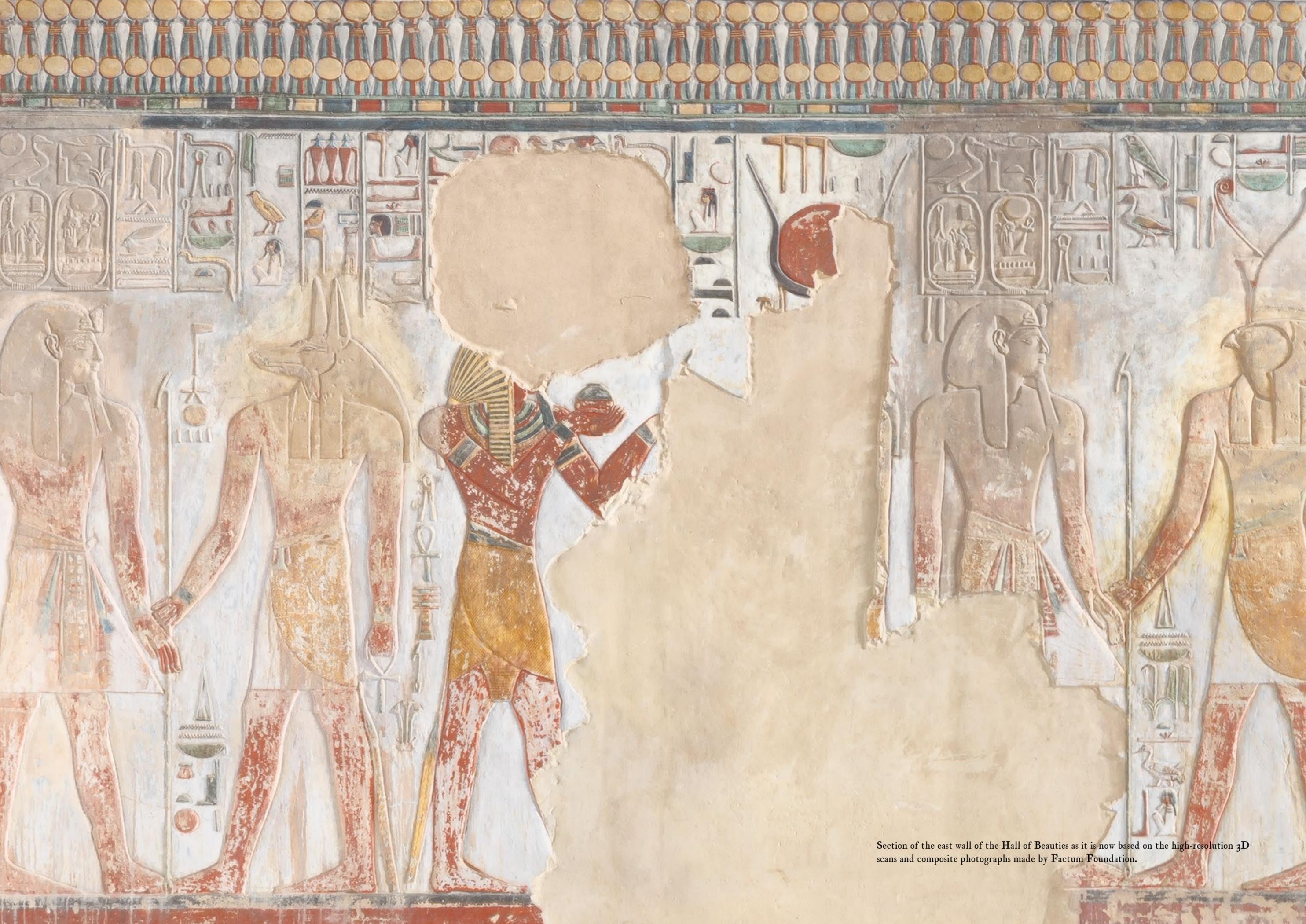
The facsimile will not only show the tomb in its current state, it will also reintegrate all the fragments removed in the 19th century. The fragments will be shown in their current condition focusing attention on the dynamic nature of originality. The facsimile will also incorporate all the painted fragments discovered by the University of Basel. The result will be a facsimile that is more complete than the original.

Factum has also made an interpretive reconstruction of the *Hall of Beauties* as it looked before sections were removed and the walls were moulded removing most of the paint. Viewing this copy with candle light reignites the emotional excitement Belzoni described in his pamphlet to accompany the exhibition of his *facsimile* at the Egyptian Halls in Piccadilly in 1821. This led to the first phase of Egyptomania in the UK - a passion that is still alive today.

In an age that holds so many threats to our cultural heritage the new facsimile of Seti I seeks to help preserve, protect and communicate the importance of this remarkable tomb. The aim of the TNPI is to give future visitors a choice; do they want to understand the tomb in depth and grasp the complexity of its biography and why it looks as it does or do they insist on visiting the original and contributing to its destruction. The relationship between originality and authenticity requires rethinking as technology develops. It is time we question our prejudices about what we value and why we attribute value; what we expect to experience and what we actually experience.



Section of the east wall of the Hall of Beauties photographed by Harry Burton during his documentation of the whole tomb. Courtesy of Metropolitan Museum of Art, New York.



Section of the east wall of the Hall of Beauties as it is now based on the high-resolution 3D scans and composite photographs made by Factum Foundation.



Factum Arte's reconstruction section based on Belzoni and Ricci's watercolours and the 3D recording of the tomb carried out by the Theban Necropolis Preservation Initiative. The aim was to recreate the feeling described by Belzoni as he was transfixed by the pristine condition of the paintings he was looking at in 1817. Upon entering the tomb Belzoni 'perceived that the paintings became more perfect as we advanced further into the interior. They retained their gloss, or a kind of varnish over the colours which had a beautiful effect'.



Facsimile of Room J displayed in *Scanning Seti*  
at the Antikenmuseum in Basel 2017-2018



Facsimile of the west wall of Room I displayed in *Scanning Seti* at the Antikenmuseum in Basel 2017-2018

### Training Course:

The training of a local team is at the heart of TNPI and is being run by Aliaa Ismail. Aliaa and the first two fully trained operators, Abdel Raheem Ghaba and Mahmoud Salem started the training of Amany Hassan Mohamed Ahmed and Mahmoud Abdellah Mohamed Ammar in February 2019. They were selected from 26 applicants proposed by the Ministry of Antiquities. The in-depth training is carried out over a six-month period.

- Setting up the Lucida,
- Operating the Lucida,
- Processing the data as a tonal render,
- Stitching the data into tiles,
- Converting the tonal render into a 3D file (an image into a form),
- Learning the principles of composite photography,
- Using composite photography to record colour,
- Using composite photography to record 3D (photogrammetry),
- All stages of processing the colour and 3D photographic data,
- Merging Laser scanned and photogrammetric data,
- Using Lidar Scanners,
- Understanding the different recording systems and when to use them,
- Training individuals to work in vulnerable heritage sites,
- Offering advice to other missions in the area.

### In Summary the TNPI is focused on:

- Transferring skills and technologies to a local community (on the West bank in Luxor). This is both empowering and supporting a local economy.
- Scanning vulnerable sites and objects at the highest realistic resolution.
- Recording fragments that are on site and in museums around the world.
- Building exact facsimiles that can be shown and seen in sites where original objects cannot be lent.
- Helping to store, share and disseminate information while protecting the Ministry of Antiquities's rights to the data recorded by Factum Foundation.
- Appealing to the next generation of *Digital Natives* in a way that adds knowledge and understanding while provoking curiosity.
- Re-negotiating the relationship between originality and authenticity.
- Presenting digital data in both virtual and physical forms. This is leading to new display technologies that are facilitating forensic analysis.
- Developing digital passports to help identify and track objects.

### Thanks to:

Our gratitude to His Excellency the Minister of Antiquities in Egypt, Dr. Khaled El Enany, extended also to former Ministers Dr. Mamdouh Eldamaty and Dr. Zahi Hawass, as well as the Secretary General of the Supreme council of Antiquities Dr. Mostafa Waziri. Additionally, we would like to thank, Dr. Nashwa Gaber, Dr. Osama El-Nahas, Dr. Mahmoud Afifi, Dr. Hisham El Leithy, Dr. Mohamed Ismail and all the staff in the Ministry of Antiquities who are providing constant assistance for this project. Furthermore, we would like to thank the authorities in Upper Egypt; Dr. Mohamed Abdul Aziz, Dr. Mohamed Yehia, Dr. Fathy Yassin, Bahaa Gabr, Mohamed Khalil, Abd El Nasr, Ayman Mohamed Ibrahim, Adel Arfan, Sheik Hassan. We would also like to thank inspectors Badawy Idrees, Mohamed Ali, Amany Hassan Mohamed, Samir Sayed Hadad, Mahmoud Salem and Mahmoud Fawzy, who joined us during our work in the Tomb of Seti I.

Erik Hornung and Theodor Abt have been a constant support since their first contact with Factum in 2001. We are grateful to the support of Markus Leitner, Jean-Pierre Reymond, Antonio Loprieno, Fayza Haikal, Salima Ikram, Maria Golia, James Moran and many others both in Luxor and elsewhere.

This work involves many people and has already had significant impact on the documentation of the Valley of the Kings. The team who have worked on the project since 2016 include: Adam Lowe, Carlos Bayod, Aliaa Ismail, Gabriel Scarpa, Pedro Miró, Moussa Sayd Mohamed, Abdel El Reheem Ghaba and Mahmoud Salem, Eduardo López Rodrigues, Manuel Franquelo, Otto Lowe, Amany Hassan Mohamed Ahmed, Mahmoud Abdellah Mohamed Ammar and many more.

### The installation of Tutankhamun's burial chamber and the restoration of Stoppelaëre House

Tarek Waly Center -Architecture and Heritage: Tarek Mohamad Waly, Shima Abdul Aty Shaheen, Dina Alaa Al Araby, Ehab Mohammed Zaqouq, Mohamed Safwat Attia.

Construction team: Mohamed Salem Abdel Wareth, Mahmoud Mohammed Salem, Sayed Hamdi Al-Dawy, Ahmed Haggag Mohamed, Mohammed Abdel Wareth Salem, Abdullah Jamal Salem, Yasser Abdel Wareth Salem, Syed Mohammed Salem, Hassan Mohammed Haggag, Hassan Abdel Alrhman Al-Hefni, Abdel Rahim Mohamed Ibrahim, Abdul Rahim Hassan Al- Azab, Mustafa Ali Ramadan, Abdel Shafi Mohammed Fahim, Gomaa Abdel Shafi Fahim, Mohammed Gomaa Mohammadayn, Ahmed Mahmoud Hassan, Mohamed Sayed Al-Tayeb, Hassan Tayea Hassan, Ahmed Al-Azab, Mohammed Abu Elewa, Mahmoud Reda Fahim, Salah Abdul Majid Mohamed.

## TIMELINE

2001: Factum Arte begins work in the Tomb of Seti I in collaboration with Dr Ahmed Baghat, Michael Mallinson, the University of Cambridge, and the SCA. First meeting with Eric Hornung.

2001: First meeting with Theodor Abt and the Society of Friends of the Royal Tombs of Egypt. Presentation of the test facsimile of Seti I at Museo Arqueológico Nacional, Madrid in collaboration with Museo Tifológico, Madrid.

2002: The production of the Facsimile of the Tomb of Thutmosis III.

2004 Video about Thutmosis with Eric Hornung and Theodor Abt with an introduction by Christian Loeben. *Las horas oscuras del sol* exhibition opened at Museo Arqueológico Nacional.

2005 and 2006: Exhibition tours to Edinburgh and Basel.

2009: Formation of Factum Foundation for Digital Technology in Conservation as a not-for-profit charity registered in Spain.

2009: the recording of the Tomb of Tutankhamun began on the instruction of His Excellency Dr Zahi Hawass with the backing of the Supreme Council of Antiquities (now the Ministry of Antiquities).

2012: The facsimile was given to the people of Egypt in November by Baroness Ashton as a gift from the European Union and Factum Foundation.

2013: The decision to install the facsimile on the site next to Carter's House was taken by the Minister for Antiquities, Dr Mohamed Ibrahim in 2013.

2014: The installation took place in early 2014 and the didactic exhibition and facsimile were opened to the public on 1st May 2014. The Factum Foundation for Digital Technology in Conservation was awarded Apollo Magazine's 2014 prize for 'Digital Innovation of the Year' for the work they carried out to produce the facsimile. This approach to the preservation of at-risk cultural heritage in Egypt captured both the press and public interest.

2016: Extensive period of recording in the Tomb of Seti I

2017: Creation of a facsimile of two rooms from the Tomb of Seti I (Rooms I and J) and the realisation of the exhibition *Scanning Seti* at the Antikenmuseum. Scanning fragments in several European and American museums. The opening of Stoppelaëre House and the *3D Scanning, Archiving and Training Centre*.

2018: Finalisation of permission and security clearance.

2019: In February Factum Foundation restarts work in Seti's tomb. Work is ongoing.

### News videos:

CBS News - February 2019: <https://vimeo.com/315491231>

Patek Philippe - June 2018: <https://vimeo.com/274852503>

CNN - April 2018: <https://vimeo.com/264433112>

CNN: <https://edition.cnn.com/videos/design/2017/11/09/egypt-seti-tomb-style-orig.cnn>

CNN Arabic: <https://arabic.cnn.com/travel/video/2017/11/07/v14882-tr-071117-factum-scanning-seti>

Egypt Today - August 2017: <http://www.egypttoday.com/Article/4/15746/Alia-Ismail-1st-Egyptologist-to-use-3D-technology-in-documentation>



