

# SCANNING SETI: THE RE-GENERATION OF A PHARAONIC TOMB

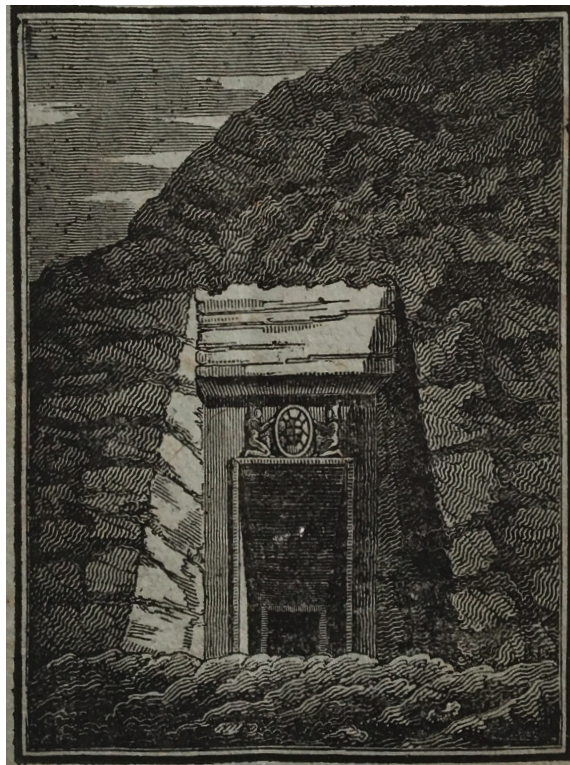
## 200 YEARS IN THE LIFE OF A TOMB

DIGITAL RECORDING IN AN AGE OF MASS TOURISM AND ANTI-AGEING.

ADAM LOWE, FOUNDER, FACTUM ARTE & FACTUM FOUNDATION

*'Tradition is not the worship of ashes, but the preservation of fire'.*

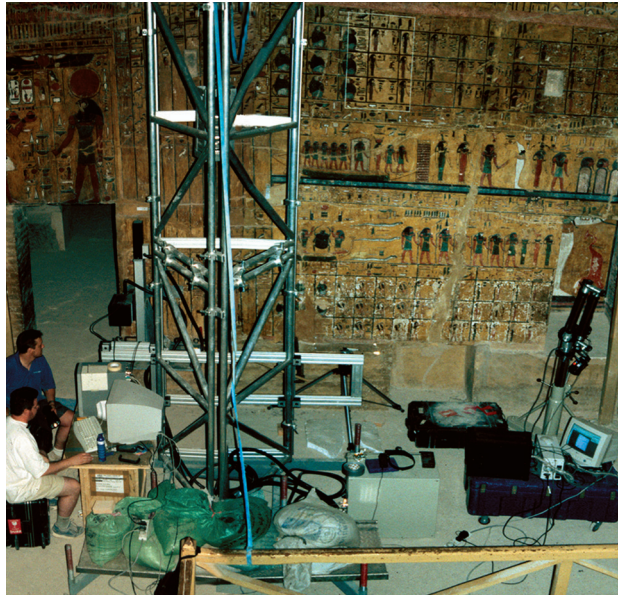
Attributed to both Thomas More and Gustav Mahler



## INDEX

|   |    |
|---|----|
| Introduction  | 4  |
| Originality and Authenticity  | 5  |
| Belzoni's Copy - 1821   | 5  |
| 'Squeezed to death'   | 7  |
| The Process of Originality  | 9  |
| A Future for the Past – The New Facsimile of Seti I                       | 10 |
| The Facsimile and The Tomb  | 13 |
| Recording   | 14 |
| 3D Scanning   | 14 |
| LiDAR SCANNING - The Faro Focus 3DX 330                                   | 14 |
| LASER SCANNING –The Lucida Laser Scanner                                  | 15 |
| PHOTOGRAMMETRY – Canon EOS 5DSR   | 16 |
| Composite Colour Photography  | 17 |
| Panoramic Recording   | 18 |
| Optical Colour Matching   | 19 |
| Data Processing   | 20 |
| Data Archiving and Ownership  | 21 |
| Digital Restoration   | 21 |
| Physical Reintegration of Missing Area into the Facsimile                 | 22 |
| Re-materialising  | 23 |
| Making an exact facsimile   | 23 |
| Topographic correction  | 23 |
| Routing   | 25 |
| Elevated printing   | 25 |
| Elastic printing support  | 27 |
| Printing the walls of the facsimile                                       | 27 |
| Positioning the skins   | 28 |
| Stitching the colour skins of the relief surface                          | 29 |
| Vacuuming the skins   | 30 |
| Retouching the final facsimile  | 30 |
| Ceiling   | 31 |
| Sarcophagus   | 32 |
| Fragments   | 33 |
| Final facsimile   | 34 |
| The physical reconstruction of the Hall of Beauties in its 1817 condition | 35 |
| The Theban Necropolis Preservation Initiative                             | 37 |





2001 Room J- the Sarcophagus Room.



2009 Room G – Book of Gates.



2016 Room I- Hall of Beauties.

## INTRODUCTION

*Scanning Seti: The Re-generation of a Pharaonic Tomb* celebrates the 200<sup>th</sup> anniversary of the discovery of the tomb of Seti I – perhaps the most important and complete record of the art, science, philosophy, theology, poetry and magic of Ancient Egypt. The first serious facsimile was the re-creation of parts of the tomb made by Giovanni Battista Belzoni and shown at the Egyptian Halls in London in 1821. It caused a sensation, building on the excitement generated by Napoleon's *'Discovery of Egypt'*. It can be seen as a critical moment in the European love of the Pharaohs and their civilisation. It was one of many events that fuelled the imagination and led Thomas Cook to form the travel agency that made it possible for the general public to first visit Egypt. In the 1880's, the tourism trade in the Middle East was effectively invented by Thomas Cook's son, John Mason Cook, who became described as 'the second greatest man in Egypt. An initial trickle of tourists led to a vast industry that grew throughout the 20<sup>th</sup> century and reached its peak at the end of the first decade of the 21<sup>st</sup>. But political upheaval in Egypt dramatically reduced the number of visitors to the Theban Necropolis, causing real hardship for those people who depended on them.

The 19<sup>th</sup> century production of Belzoni's facsimile seriously damaged the fabric of the tomb, as did the hacking out of cultural artefacts and souvenirs. But later so did the presence of millions of visitors a year. Since 2009 the Theban Necropolis Preservation Initiative has been working to rethink the relationship between tourism and preservation, and the facsimiles of rooms I and J are an important part of this work. In contrast to the destruction caused by Belzoni and others, this work is re-uniting with the tomb all the fragments that are scattered in museums around the world. It is a major undertaking that has required the support and involvement of many museums and the Egyptian Ministry of Antiquities. Hopefully it will allow the tomb to once again provoke wonder, interest and amazement, and stimulate a new wave of a different kind of tourism to Egypt. Through an awareness of the extraordinary history of the Valley of the Kings, and the complex task of conserving it, this new generation of tourist will help preserve the tombs rather than contribute to their gradual destruction.

## ORIGINALITY AND AUTHENTICITY

At a time of increasing awareness of the dangers to cultural heritage, the ability to accurately record – and when necessary re-create – cultural artefacts has never been greater. The application of multi-spectral composite photography and 3D scanning to the field of cultural protection offers huge opportunities. Factum Foundation has been applying these technologies on the West Bank in Luxor and transferring skills and equipment to local people.

First it was necessary to demonstrate it was possible to record the surface and colour of the Tomb of Seti I with enough resolution to make an exact copy. Then it was necessary to make one that people could see and experience. Factum Foundation has already made exact copies of the burial chambers of Thutmosis III and Tutankhamun. Both of these have demonstrated what can be done when people work together with a common goal. Now, with the facsimile of Seti I, the aim is to go further and to reintegrate all the fragments removed in the 19<sup>th</sup> century and housed in museums and collections around the world. This will result in a facsimile that is more complete than the original. The work around the Tomb of Seti I seeks to address the difference between the materiality of original object and the information that object contains. It aims to reveal the difference between originality and authenticity.

### BELZONI'S COPY – 1821

Giovanni Battista Belzoni was not thinking about preservation when he discovered the Tomb of Seti I on the 16<sup>th</sup> October 1817. Many of the locals who showed him where it was will have known that this was one of the largest and most important tombs in the area we now know as the Theban Necropolis. They were probably amazed that Belzoni and his colleagues had travelled so far to see these underground sites that belonged to a distant past. Belzoni was on a mission; he was a traveller and discoverer, a practical man of action open to the potential benefits that could be gained from cultural discovery. He needed to earn a living. He knew the British were keen to acquire things that could be housed in a new museum of world culture that was being planned in London to cement the importance of the British Empire and educate the people of England about the wonders of other cultures. That institution is now called the British Museum.

The French, Italians, English and others were carrying things back in the excitement that accompanied the “discovery of Egypt”. Knowledge was preserved by careful scholarship and rigorous documentation. Objects were preserved by their removal and installation in the emerging museums in Europe’s capital cities. The protection of the site in an age before mass tourism was not high on the list of priorities. Their aim was to find great things to fund their next adventure. London was hungry for evidence of Pharaonic Egypt. Belzoni was in the right place at the right time.

Belzoni was a circus strongman and a water-pump salesman who had successfully moved the colossal statue of Ramesses II to London without damage on the instruction of Henry Salt and with the authorisation of Muhammad Ali, the Pasha of Egypt. He was in the company of the great figures who followed Napoleon’s ‘discovery of Egypt’ including Jean-Francois Champollion, Bernardino Drovetti, and Johan Ludwig Burckhardt. Their lives and interests reveal a great deal about the values of their time. Gaia Servadio’s forthcoming biography of Belzoni will reveal more about his life and character but the focus now is on the tomb of Seti I and it is clear that it was in remarkable condition when he entered. A few years later it was not. It was painted to last for eternity and it had survived 3,096 years without the significant decay that would change its meaning and function.

The importance of the tomb of Seti I, even in its current condition is immediately obvious to anyone who enters. It contains, in its purest and most condensed form, the philosophy, knowledge and understanding about what happens after death and before life starts again. There is a complex cast of characters, all with their own iconography, but with the ability to slide between one form and another as in a dream. They carry the multi-layered narrative laid out in bands across the walls like an innovative graphic novel with images and hieroglyphic text. Egypt is ‘the land of infinite impossibility’ and while Belzoni may have stumbled upon the most complete

tomb with the most detailed account of Pharaonic philosophy by chance, it is also possible that he charmed and inspired the local guides and was taken to the most revered part of the valley. The tomb of Seti I is the holy grail for anyone interested in the passage between life and death. We don't know what Belzoni was thinking about when he started to engage with the extraordinary space he had discovered, but a few years later he was an avid Freemason. His head was filled with esoteric thoughts about symbols, transformation, the temple of Solomon, alchemy, secret knowledge and magic. The three main Abrahamic religions all have roots that can be found in ancient Egyptian philosophy and religion. Those ideas are contained in the texts that make up the 'Books of the Dead' that decorate the walls. Alchemy has its roots here too, but these remained hidden and seldom translated from the Arabic sources that guarded their secrets. They are only now being revealed by the work of the *Corpus Alchemicum Arabicum* that was initiated by Marie-Louise von Franz and Theodor Abt in Zurich. Their aim is to bring a deeper understanding of alchemy as window into the inner world of the collective unconscious. C. G. Jung realised that the natural philosophy of the Pharaonic civilisation contained a profound understanding of the human condition and placed value and importance on the journey through the 'dark hours of the sun' when the human soul is rejuvenated and reborn in a continuous cycle.

We don't know the depth of Belzoni's knowledge, but he was a close friend of Johan Ludwig Burckhardt, the Swiss Muslim orientalist who rediscovered Petra in 1812 and found the ruins of Abu Simbel in 1813. We do know that he was interested in phantasmagoria and magic lanterns, dioramas and theatrical displays that were popular at the time. The idea of making a copy of the most spectacular part of the most important tomb appears to have struck him the moment he entered the Hall of Beauties. With Alessandro Ricci, he immediately started documenting the walls with watercolours that are now housed in the Bristol City Museum. They reveal a questioning and curiosity, and have a charm but they are not sophisticated works of art. Neither are they objectively accurate copies but have different colour schemes in certain key details like the Pharaoh's head-dress. They are timid in their line and struggle with the proportion of the figures. I remember the first time I entered the tomb. I had a deep sense that I simply did not understand where the importance lay when the walls were being painted. There are always many things that only reveal themselves over time. The pigments are important as is the method and order of application. So are the tools used in the application, the binding agents and surface qualities, the relationship between the relief surface and the colour, the under-painting and the way each line begins and ends. All of these details reveal a great deal about the intention of craftsmen who painted the tombs, their values, their understanding of materials and the transformations that are possible. Their knowledge and skill was remarkable and will still reveal more insights into their ways of thinking.



## **‘SQUEEZED TO DEATH’**

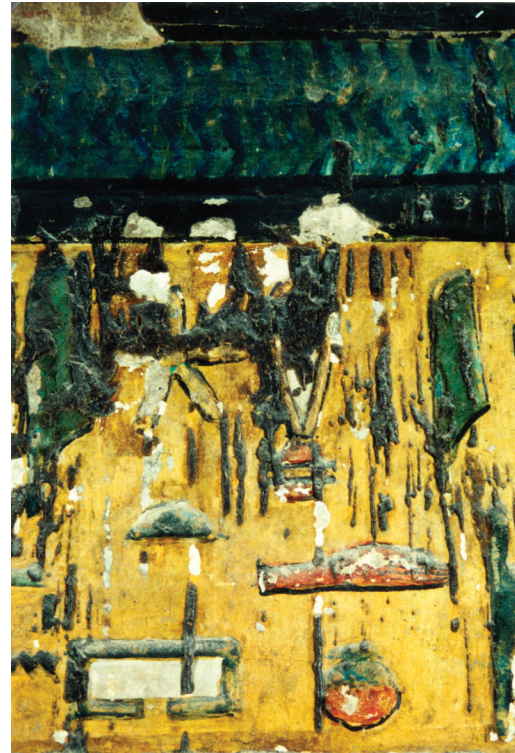
After copying the walls by hand Belzoni began to make ‘squeezes’; casts taken with wax reinforced with vegetable fibres to add rigidity. The wax was applied directly to the paint and gradually built up to become stiff – It was then removed and used to make plaster-casts. The results were amazing but the cost was high. The moulds in the Museum of Fine Arts, Boston and the British Museum still contain significant amounts of the original paint. The damage is clear as soon as you look at the walls. The worst affected areas have an almost polished, stained surface, and with only vestigial traces of paint.





Sometimes the evidence of a squeeze is revealed by a change in colour on a section of the wall (the Huntite white pigment becomes transparent in contact with wax or varnishes) in other places wax can still be found on surrounding areas. Following Belzoni's example, taking squeezes in the tomb became common practice and there is evidence of plaster and paper as well as wax moulds.

Belzoni was very busy. In 1817 he was excavating Abu Simbel but within a space of a couple of years he had also made casts of most of the Hall of Beauties and of Room G – the columned room containing the text of the Book of Gates. He had secured a deal with William Bullock to hold an exhibition at the Egyptian Halls in Piccadilly: he shipped the casts and moulds back to London, made the facsimile and painted it. In 1821 the exhibition was open to the public. It caused a sensation.



Graffiti, fragments, evidence of paper squeezes and wax can be found in many parts of the tomb.



## THE PROCESS OF ORIGINALITY

All things change over time, yet the commonly held idea of an 'original object' is of something with fixed qualities that are integral to its being and character and are unchanging. The tombs were created at a specific moment to provide the pharaoh with all the information required to complete the transformation from death to life, from old to young, from tired to rejuvenated. They were intended to provide the knowledge needed to save both the memory and the physical body of the occupier from falling into oblivion. In the Tomb of Seti I, there have been periods of dramatic and rapid change since its discovery. Actions and decisions that reflect the values of their time have resulted in a devastating loss of paint in many parts of the tomb. The removal and relocation of numerous fragments has resulted in severe damage. It is hard to look at the gaping holes and not feel a sense of shock. To remove a cartouche of less than 25 x 25 cm (often not particularly well) required an area of damage to the wall of over twice that.



Harry Burton, detail from the Hall of Beauties, 1921.

The tomb is covered in graffiti that has been incised into the walls with sharp tools and written on ceilings with candle soot. Dust generated by visitors and excavations was (and remains) a serious problem, and its removal is never simple.

More recently the large numbers of visitors to the Theban Necropolis created dynamic conditions inside the stable environment of the tomb. This expansion and contraction accompanied by fluctuations in humidity places the walls under stress resulting in paint loss and a collapse. Conservation and restoration attempts can solve some problems but they can also be problematic. There is evidence of repainting and of the addition of acrylic materials that alter both the reflectivity and colour. In some cases this can conceal the original intention of the craftsman who originally painted the walls, acting as a veil partially obscuring the evidence of the past. Restoration work can be essential to arrest decay but it can also have serious consequences, especially when paint and consolidants are added. Originality is not a fixed state of being, it is a process in which many agents work together. In a digital age, diverse recording methods can accurately fix the state of an object in a moment of time. The resulting archive acts as a record against which change can be monitored and measured.

## A FUTURE FOR THE PAST – THE NEW FACSIMILE OF SETI I



Plastercast of a routed panel of the Hall of Beauties.



Plastercast with the colour transferred onto the surface in its current condition.

While Belzoni's Facsimile caused major damage to the tomb, the work of the Theban Necropolis Preservation Initiative is part of a wider project to safeguard the tombs of the Theban Necropolis through the application of new recording technologies, and the creation of exact facsimiles of tombs that are now either closed to the public for conservation, or in need of closure to preserve them for future generations.

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, who have consistently helped develop this project since its inception. Factum Arte's involvement began in 2001 with the approval of a research project by Dr Gaballa Ali 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*, which opened at the National Gallery of Art in Washington in 2002. The facsimile demonstrated the level of accuracy that was possible when the application of technology was combined with high-skill mechanical and manual labour.

In 2009 the recording of the tomb of Tutankhamun began on the instruction of Dr Zahi Hawass with the backing of the Supreme Council of Antiquities (now the Ministry of Antiquities), who have long supported the idea of building replicas of the closed tombs. The facsimile was given to the people of Egypt in November 2012 by Baroness Ashton as a gift from the European Union and Factum Foundation. 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. The installation took place in early 2014 and the didactic exhibition and facsimile were opened to the public on 1<sup>st</sup> 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.

In an age that holds so many threats to our cultural heritage, 3D scanning and composite photography are changing the way cultural artefacts are recorded, but different scanning systems do different things. Some are mainly for screen-based visualisations while others for re-materialising objects in three dimensions. The techniques are still unfamiliar to most of the heritage managers charged with their use. There is still not enough agreement about how and when to apply which technology, the terminology used to discuss the work and usage of the resulting data. Factum Foundation is dedicated to the use of new recording technologies, and is addressing the political and philosophical questions raised by digital recording in both virtual and physical forms.





Left: *The Goddess Hathor welcomes Seti I* (approx. size: 235 x 103 cm), Museo Archeologico di Firenze. Right: *The Goddess Hathor welcomes Seti I* (226 x 105 cm), Musée du Louvre. The panels at Paris and Florence were originally located in Gate G (entrance to corridor G), facing each other. The Paris fragment on the West wall, the Florence fragment on the East wall.

It is now possible to record objects in colour and 3D and to re-materialise them in forms that are almost indistinguishable from the original. Achieving this requires digital and physical artisans to work together, uniting technology and craft skills. Currently, the most dramatic technical developments with relevance to cultural heritage preservation are going on with software used in photogrammetry (the extraction of 3D information from 2D images), composite photography (blending data from multiple images of the same object) and 3D output devices (both additive and subtractive technologies). The 19<sup>th</sup> century was a similar time of technological progress in which photography, electro-forming and plaster-casting were changing attitudes to originality and museum collections. The year 2017 is not only the 200<sup>th</sup> anniversary of the discovery of the tomb of Seti I it is also the 150<sup>th</sup> anniversary of Henry Cole's Convention for Promoting Universally Reproductions of Works of Art for the Benefit of Museums of all Countries. Evidence of the success of this convention can still be seen in the Cast Courts at the Victoria and Albert Museum. To celebrate the anniversary the V&A in collaboration with the Peri Foundation, have launched ReACH (Reproduction of Art and Cultural Heritage) 'a year long programme of events devoted to the drafting of a new convention regarding the role of museums in digital preservation and the dissemination of works of art and culture'. We are again living in an age of copying, and there is a realisation that the importance of cultural artefacts lies in the complex stories they communicate about people who lived in different places at different times, held different views and often believed in different gods. Museum objects are a means to access knowledge and understanding; they are not primarily things of commercial and aesthetic value.

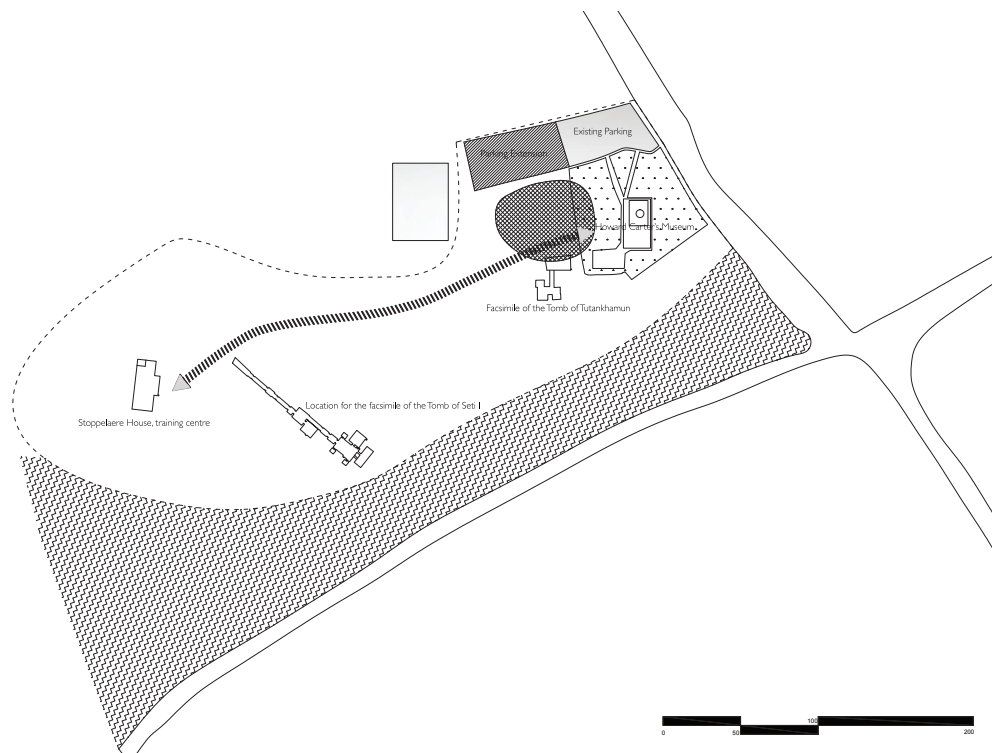
Before cheap flights and mass tourism, it was easier to move copies of architectural sculptures to London, Berlin or Paris than it was to move people to remote sites. Now the situation is reversed. Millions of people each year want to visit sites of cultural interest. Many of those sites, like the tombs in the Valley of the Kings, were never

intended to be visited – and cannot take vast crowds without incurring significant damage. Tourism, which is vital for local economies, is now one of the main causes of the change and decay of our shared cultural heritage. It is increasingly difficult to balance the complex demands of protecting heritage sites while providing access to them.

Tourists are not the only threat to our cultural heritage. Other causes of damage and destruction include war, natural disasters, climate change, pollution, political apathy, vandalism, accidental damage, fire, iconoclastic attacks and theft. Cultural protection needs to address each of these destructive factors, as well as acknowledging the inevitable changes that occur to objects and buildings over time. Done properly, accurate recording of cultural heritage can facilitate a deeper understanding of the articulate artefacts left by previous generations.

Over recent years it has been difficult to raise money for the documentation and the development of technologies to digitally record cultural heritage – both objects and sites. Sponsors and institutions have instead preferred to support restoration projects and high-profile interventions, but as attitudes to originality and authenticity emerge from a century of modernist ideology, the role of non-contact preservation and digital restoration are attracting attention. It is essential that we work together to record as many things as possible quickly and at the highest resolution possible. The technology exists and it is now time for the politicians to hand over to the technicians and to set demanding targets. The best way to do this is through the transfer of skills and technologies to the places that are most in need. The high-resolution recording of the Theban Necropolis is a clear example of this approach in action.

The Theban Necropolis Preservation Initiative, run by Factum Foundation in collaboration with the University of Basel under contract to the Egyptian Ministry of Antiquities, is now working to create a long-term, self-financing model for heritage preservation in the Valley of the Kings. The initiative focuses on sustainability and knowledge transfer and is dependent both on specifically developed technologies and human skills. The recording of the vast and important tomb of Seti I is a central part of this initiative.

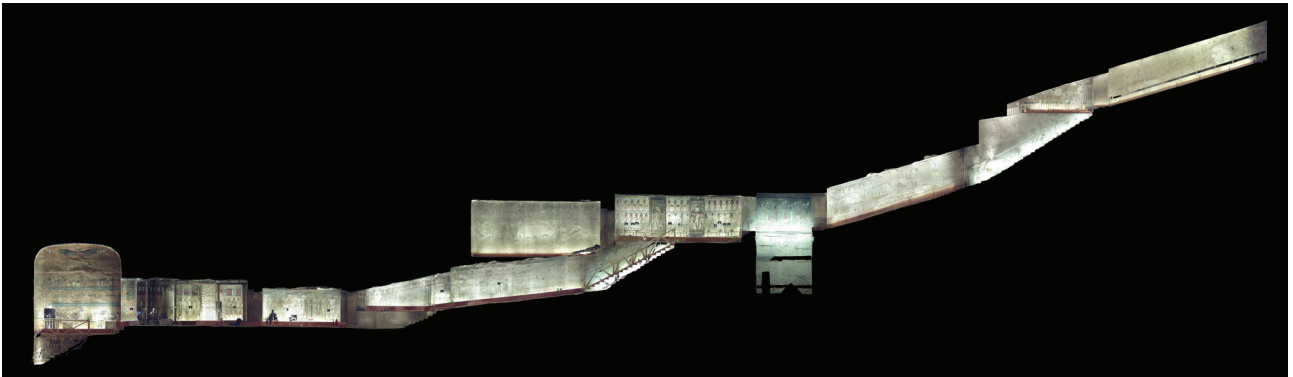


The facsimiles of the tombs of Tutankhamun and Seti I will form the core of the 'Visitor Centre' located at the entrance to the Valley of the Kings. The purpose of these facsimiles is to inform the visitors about the complex task of preserving the tombs of the Theban Necropolis for future generations while continuing to generate the revenue that is vital for the local economy.

## THE FACSIMILE AND THE TOMB

*“The gift of the facsimile (of the burial chamber of Tutankhamun) 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, November 14<sup>th</sup> 2012, Cairo.  
On the occasion of the facsimile of the Tomb of Tutankhamun being given to Egypt.



Faro LiDAR scan of the whole tomb recorded in 2016.

The following images with extended captions document the key stages of the work required to produce an accurate facsimile. A mixture of different technologies and manual skills are required to record, mediate, transform and replicate the tomb of Seti I. The Hall of Beauties and the pillared part of the sarcophagus room have been recreated with all the known fragments we have been able to record returned to their correct place. For study purposes this has been a valuable way to focus the knowledge of different specialists on the task of understanding the tomb. I remember Erik Hornung, at the end of three days filming in the facsimile of the burial chamber of Thutmosis III, commenting that he had never been able to spend so much time in the original tomb due to its heat and humidity. It is only with time to reflect that the evidence of the past freely offers itself to our understanding.

After the exhibition at the Antikenmuseum in Basel, the facsimile will be installed on the site between Stoppelaere's House and Carter's House at the entrance to the Valley of the Kings as part of the Theban Necropolis Preservation Initiative. The installation of a facsimile close to the original site will help to explain to the visitors the complex task of preserving a site that was made to last for eternity but not to be visited.

In the 200 years since the discovery of the tomb of Seti I, pharaonic culture has emerged from obscurity and captured the public imagination worldwide. The Theban Necropolis is justifiably one of the most celebrated and popular tourist destinations and the tomb of Seti I is one of the most important cultural artefacts in the world. The stories and knowledge contained on its walls have inspired generations. But it is important to be aware that the tomb has changed dramatically since Belzoni produced his watercolours to capture the scenes on its walls soon after it was reopened in 1817. The paint surface of the tomb has been damaged by repeated casting. Many sections of the intricate painted carvings were cut from the walls and are now in museums around the world. Tourists en masse create a dynamic environment, generating dust, introducing air born pollutants and causing mechanical wear and tear. A partial collapse of the celestial ceiling led to the closure of the tomb in the 1980's. It has recently re-opened to limited numbers of visitors. Its documentation and long term preservation are essential.



## RECORDING: 3D SCANNING

A number of different 3D scanning methods exist, each with their own advantages and limitations. The challenge is to identify the right system for the right application. No single system can do everything. 3D data can be recorded on a vast scale, capturing the topography of a landscape from great distances or it can be captured at close range with enough accuracy to document the flaking paint and the surface of a carving, revealing marks that are not easily visible to the human eye.

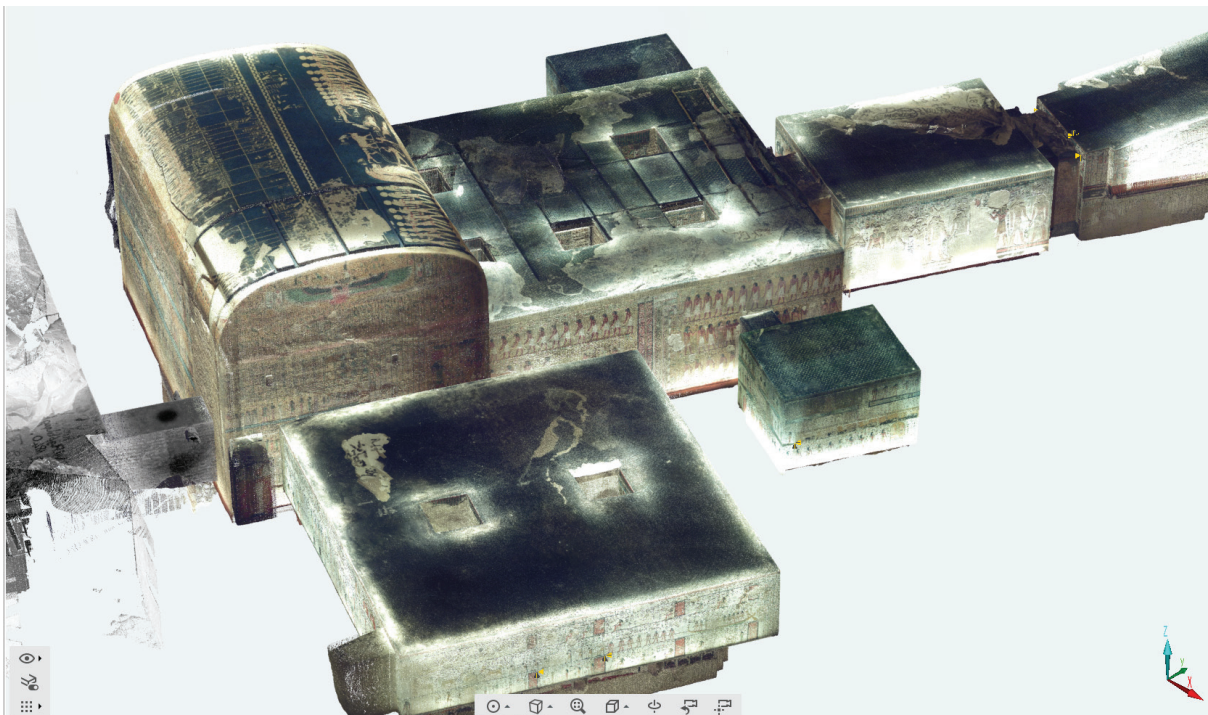
It is essential that the right type of 3D recording is undertaken and that the resulting data is safely archived and processed so that it can be made accessible for study, conservation and re-materialisation as a replica. To make a facsimile it is essential to acquire high-resolution data, with particular attention paid to the surface of the object. The better the data, the more uses it has for academic, conservation and research purposes.

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.

Outlined below are the three main techniques and scanners used by Factum Foundations team to record the tomb of Seti I.

### LIDAR SCANNING - THE FARO FOCUS 3DX 330

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 0.6 m up to 130 m. It can capture millions of 3D measurements at up to 976,000 points per second, with a ranging error of  $\pm 2$  mm. The integrated colour camera records a photographic overlay. Seti I tomb was surveyed from 70 different positions. The accurate point cloud obtained of the entire tomb is 2.132 million points. The recording of the whole tomb took one week. The recording was done with visitors present in the tomb. This data needed extensive post processing work to remove their ghostly images, recorded as they moved around the tomb.



Faro LiDAR scan of the area beyond the Hall of Beauties.



Faro Generates a low to midium resolution, textured 3D model (point clouds of accurate values but variable sampling intervals of from 1- 10 mm, depending on the distance to the target. This provides the general geometry and texture, used later in the process as the reference in terms of absolute positions and scale for the high-resolution relief (Lucida) and colour (Panorama) data. The photogrammetric and Faro data are integrated together using *Reality Capture* software.

## LASER SCANNING –THE LUCIDA LASER SCANNER



Comparison between the maximum resolution possible with the Faro LiDAR scanner (left) and a normal recording with the Lucida Laser Scanner (right). The file preparation and CNC strategy are constant.

The Lucida Laser Scanner was specially developed by Manuel Franquelo for recording the relief in the tomb of Seti I. The system and its operating software is made by Factum Arte. The Lucida is a close-range scanning system that works at 8 cm from the surface of the wall. The scanning head is mounted onto a lightweight mast and the horizontal and vertical movement (X and Y axis) is regulated by a Computer Numerical Control(CNC). The scanner has a depth of field of 2.5 cm and records an area of 48 x 48 cm in one hour.

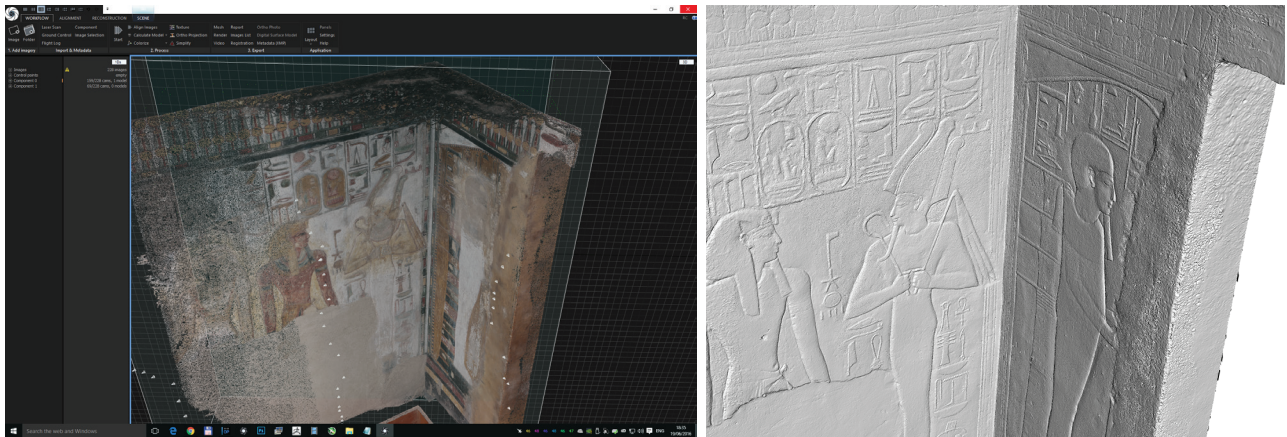
The Lucida records tonal video using two precision cameras placed either side of a low-intensity laser. The scans are Depth Elevation Model (DEM) files in tiff format: grey scale images where each pixel represents a tiny square of 0.1 x 0.1 mm with the grey value representing the distance to a ground plane. This black and white information is then converted into 3D data. 100 million independently measured points per sq meter can be extracted from this depth map. The video data is stored as raw video. In the future this could be processed at even higher resolutions. This representation is an ortho-projection related to a ‘virtual’ plane derived from the Lucida scanner’s orientation and position.

The main areas of each wall in the Tomb of Seti I were recorded with the Lucida Scanner. In 2016 three Lucida scanners were working in the tomb at the same time. After scanning, the tiles generated by the Lucida need to be aligned and merged together. The data is not compatible with Faro or photogrammetric information and the protocol to merge the three data sets has been developed in Factum Arte.



3D recording with the Lucida Laser Scanner on the left, and panoramic colour recording on the right.

## PHOTOGRAMMETRY – CANON EOS 5DSR



Photographs have been used to provide colour information, but now they are capable of recording both colour and shape. Multiple images are taken with a constant, diffuse, light-source using an SLR camera and following a clearly defined protocol with significant overlap between each image. The multiple images are processed using Reality Capture, a software package by Capturing Reality from Bratislava. The results still don't match the data recorded with the Lucida scanner but they are improving rapidly and are starting to match the best results that are possible with more expensive 3D systems. Photogrammetry is playing an important role in the recording the tomb of Seti I – It will become more important as the work proceeds.



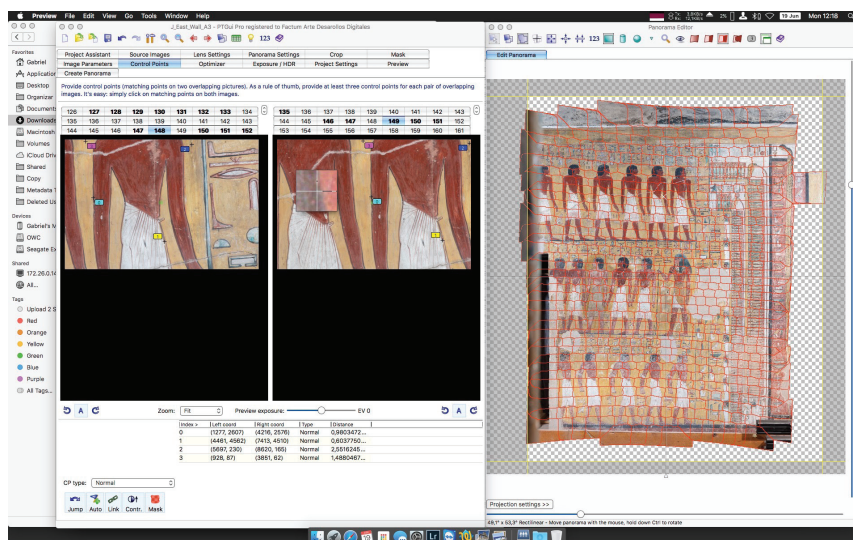
## RECORDING: COMPOSITE COLOUR PHOTOGRAPHY

Composite Colour photography is often referred to as Gigapixel photography due to the vast amount of data that is recorded. The entire tomb will be recorded with a Canon 5DSR (50 megapixel sensor). The aim is to record the entire tomb at 600 PPI at a scale of 1:1. At this resolution one square meter is 23,662 x 23,662 pixels, around 1 Gigabite of data.

In some areas there is enough space to work to achieve the resolution of 600 PPI after the perspectival distortions are removed. In other areas with limited space the resolution will not exceed 300 PPI. The composite photographs are stitched using PTGui software at sub-pixel accuracy and the resulting files are aligned to the 3D data. They can be prepared as layers in viewers that can be accessed via the internet. They can be viewed together or separately facilitating study. They can be enlarged to about five times actual size without any loss of image quality. This means that the tomb can be studied in greater detail from the photographic data and can complement on-site observations by conservation specialists. The floors, walls, pillars and ceilings of the tomb are being recorded using a variety of different lenses at different resolutions.



Recording composite colour images.



Screenshot of PTGui stitching process. On the left, a pair of overlapping images with control points to help the alignment of a panorama with less than 1 mm error. On the right, a preview of the panorama with the limit of each shot marked in red.

## RECORDING: PANORAMIC RECORDING



The Panoramic approach is based on keeping the camera in a fixed position on a computer controlled pan and tilt head and knowing the distortion that occurs as multiple shots are taken and stitched together. Once these are 'undistorted' in the software and merged together, the whole image can assume the correct shape and high-resolution. Colour space, depth of field and sharpness of focus are critical in all macro-photography but the distortions in panoramic photography require specific lighting techniques to overcome.

A Clauss Rodeon HD panoramic head is used with a Canon full-frame 5DSR with a variety of lenses and a 'slave' flash unit supporting a UV filtered Elinchrom high-speed flash head. This makes it possible to record in a coherent way while exposing the tombs to lower light levels and ensuring maximum image sharpness.

Panoramic photos are stitched using PTGUI and Lightroom/Photoshop software. This provides accurately registered, high-resolution colour information that can be merged to the 3D data using orthophoto applications in GIS software.



## RECORDING: OPTICAL COLOUR MATCHING



In order to produce a facsimile that has accurate colour, it is necessary to be able to compare colours of the original with colours of the facsimile. This is achieved using specially made colour swatches (referred to in-house as 'colour sticks'). These are compared directly to known points on the walls and fixed onto diagrammatic line drawings or photocopies of the walls prepared by Factum. It is critical to know the precise location on the original of each colour reference. When printing the facsimile, the colour sticks are used to check the exact character of the colour. Printed sections were taken into the tomb with small windows cut into the surface and held directly in front of the wall for comparison. The facsimile of the burial chamber of Seti I has been made so that the colour looks identical under the same lighting conditions that existed in the tomb at the time of recording.

The main difficulty when recording the colour of the tombs is to understand the extreme complexity of the painted surface. The paintings were executed as broad areas of paint with a limited palette but a combination of centuries of ageing and modern interventions has resulted in an inconsistent and intricate surface.

Research was carried out into the pigments and binders used by the painters of the tomb in order to understand the surface characteristics and fragility of the surface. A partial understanding of their techniques can be gained from studying the colour and 3D information, but this supplements, rather than replaces, close observation of the painted surface in the tomb. A detailed, non-contact observational survey of surface characteristics was carried out and focused on the variations within each colour, the surface texture, the varieties of matt and gloss surface, evidence of under-painting, corrections, the character of the cracking and flaking, the presence of deposits or residues and the method of application of the colour.

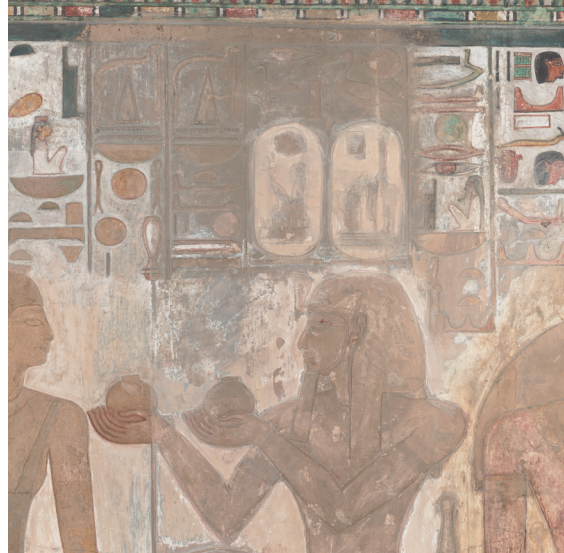


## DATA PROCESSING

As the data is recorded, it is downloaded to a server where it is organised and stored. The time consuming work of processing then begins. As a rule of thumb, every hour spent recording in the field requires one day of processing. Powerful computers or server farms are essential. 'Big data' recorded with diverse technologies raises many technical issues as software and data formats are often incompatible.



3D recording with the Lucida Laser Scanner.



Composite Colour Photography.



The colour and 3D data merged.



## DATA ARCHIVING AND OWNERSHIP

To ensure long-term archiving it is essential that there are distributed servers capable of storing data in a secure format for many years. Long term digital storage cannot be taken for granted. The thought of what would happen to all the digital archives if there was an extended period of time without electricity is a chilling one.

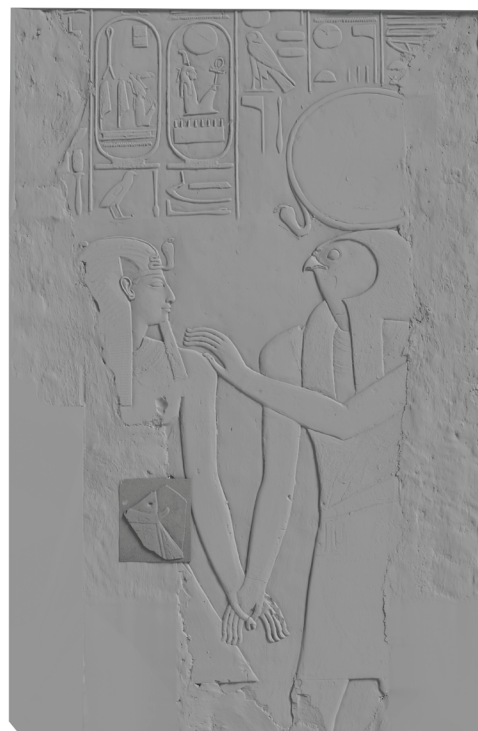
Ownership of data is a critical issue. Its dissemination is vital but who has access to it, how it can be used, when it is made freely available, when should it be commercialised, how it is used in restoration in the event of damage and to what extent should it be used to replicate damaged areas are some of the issues for top-level heritage managers. The data recorded in the tomb of Seti I belongs to the Ministry of Antiquities who will benefit from all current and future commercial uses. With their permission it can be encrypted and made freely available for conservation, monitoring purposes and academic study.

## DIGITAL RESTORATION

Digital restoration is a fast growing field that is both a subject in its own right and a means of introducing objectivity into restoration treatments. Through digital manipulation, various hypotheses can be tested, different data sets compared, the surface and what lies under it can be analysed, fragments can be brought from different locations and reintegrated and a multitude of visualisation techniques and virtual recreations can be carried out before any interventions are made on the original surface. This approach nurtures in-depth investigations and conversations. Restorations tend to reveal a great deal about the place and time that they were carried out in and can obscure or overlay important information contained in the original artefact. To some degree all interventions turn the original into a reproduction of itself.

Digital restoration techniques can play a significant role not only as a conservation tool, but in imagining how this tomb would have looked when it was first sealed in 1279 BC, or when it was discovered in 1817.

Thousands of small fragments have been recovered from the tomb and the rubble around the tomb by a team from the University of Basel. Working with Florence Baberio and Susanne Bickel, Factum Foundation will apply visualisation techniques to assist in the location and integration of these fragments.



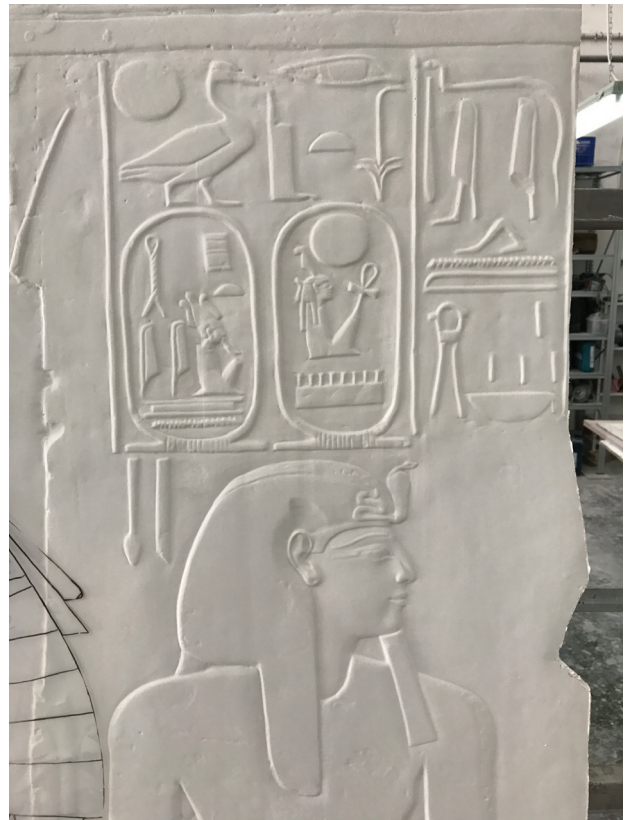
## PHYSICAL REINTEGRATION OF MISSING AREAS INTO THE FACSIMILE

There are two versions of the Hall of Beauties in the Antikenmuseum exhibition. One showing it as it is now in 2017 and the other showing how it might have looked when Belzoni first entered in 1817. This has involved extensive reconstruction based on Belzoni and Ricci's drawings, Erik Hornung's notes and Andre Wiese's research. The reintegration of original elements or the mix of original facsimile elements is a complex subject. But the potential of facsimile reconstructions is again attracting public interest as it did in the second half of the nineteenth when the cast courts opened in the V&A. The re-generation of damaged and dispersed objects assists understanding without putting the original object at risk. It focuses attention and results in a deeper appreciation both of the object and of the reasons it looks as it does today. Many people comment that this is about falsification. In reality it is more like an interpretation of a musical score. There will be different performances of the same object. They can be compared, discussed and understood.

In the exhibition there is also a section showing the east wall of the Hall of Beauties as it was in the early C20<sup>th</sup> based on Harry Burton's photographs.



Hall of Beauties in 1921 from an image by Harry Burton. It seems likely that the cartouche was removed before the walls were squeezed as the figure retains its colour.



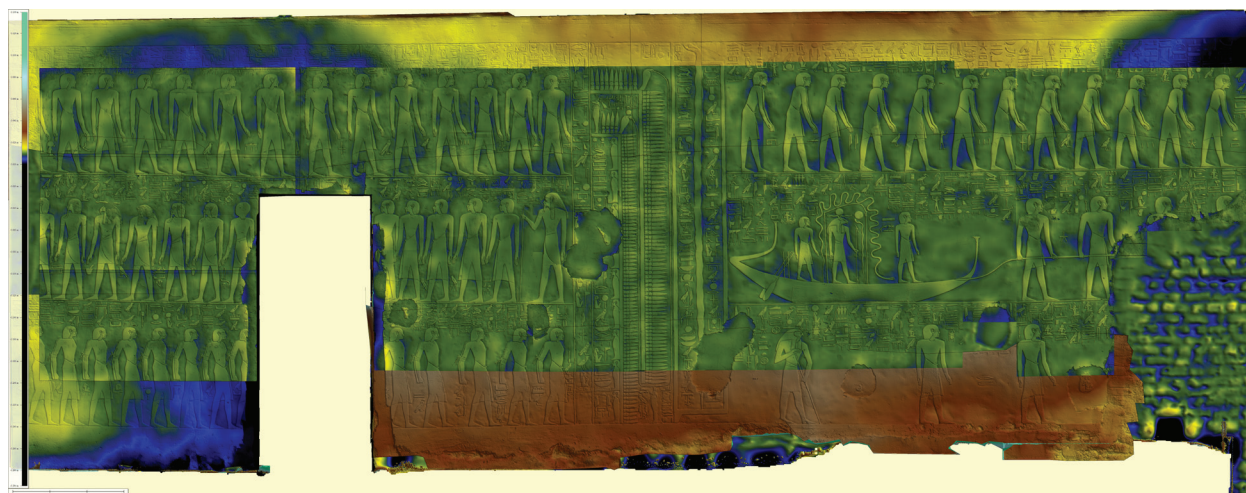
The same area with the cartouche and hieroglyphs replaced following the instructions of Erik Hornung and André Wiese.

## RE-MATERIALISING: MAKING AN EXACT FACSIMILE

At a time when many people are just starting to understand the role virtual models can play in studying and preserving cultural heritage, Factum Foundation has gone one stage further. The work that is being undertaken in the Valley of the Kings is a two way process – from the real world to the digital archive and then from the digital files back into the physical world without significant change or loss of detail. This work has theoretically been possible for a while but the costs have been prohibitive. Now, due to a highly focused and motivated period of research and development the protocol has been put in place to vastly reduce the costs and break down all stages of the work into tasks that can be taught to a local workforce in Luxor. A fundamental outcome of this is the recasting of local perceptions of value. Enabling local communities to change their relationship to their own cultural heritage, through deepening understanding and knowledge, while making them the direct guardians and beneficiaries of it, is a vital form of preservation in itself.

## RE-MATERIALISING: TOPOGRAPHIC CORRECTION

The specific challenge of integrating Photogrammetric, LiDAR and Laser scanned data has required innovative solutions working across different software packages.



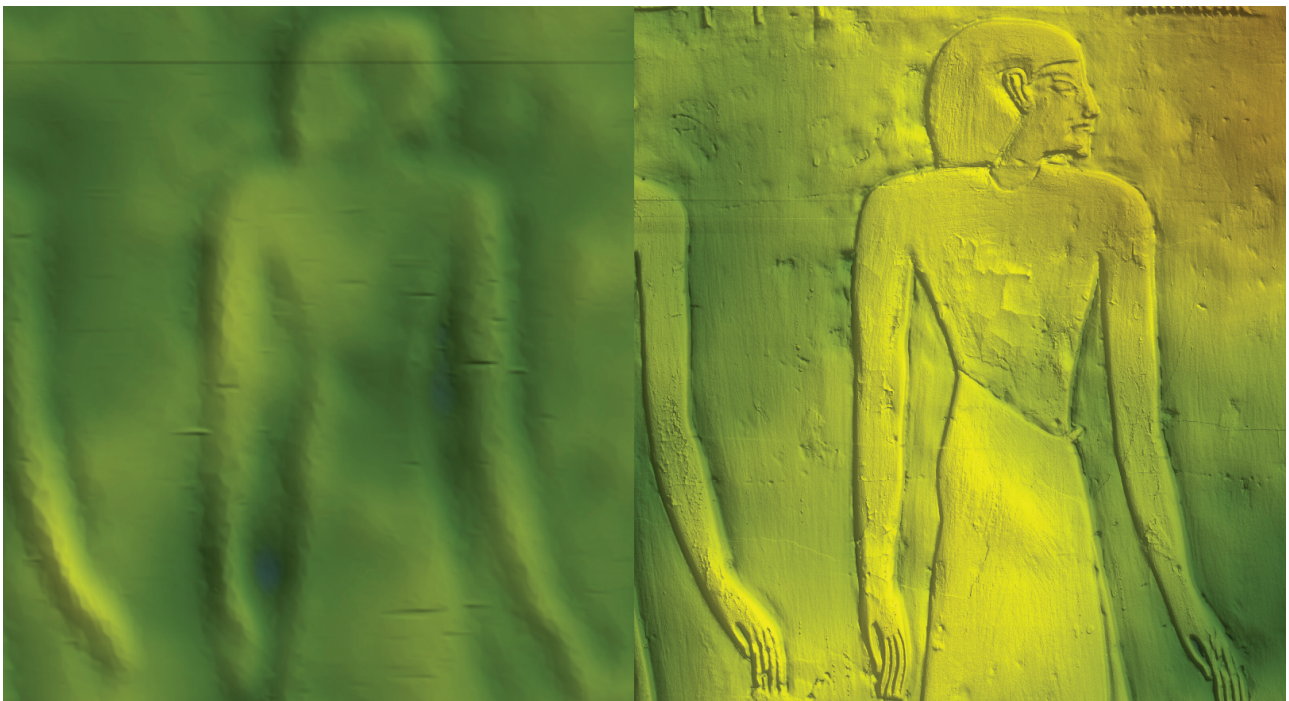
GIS (Geographical Information System) software facilitates the integration of 3D data from Faro, Photogrammetry and Lucida systems. Having all the data scaled, positioned and merged in one system allows us to export the resulting panels with precision to the CNC routing system or to the Océ elevated printer. Joining three different types of data in two dimensions can be complicated. Joining, in three dimensions, without any reduction in the quality of the data or any visible artefacts is a significant challenge. Cartographic software developments will make it possible to publish all the 3D and colour data online in an easily accessible form.

The methodology and processing algorithms have been developed by Factum Arte to make this possible. Various commercially available and free software packages were used. *Global Mapper* is fast and powerful, known as the ‘Swiss penknife’ of the GIS software. Intuitive and efficient, it is based on a user-friendly and graphic user interface. *Grass Gis* is a free, open-source alternative to *Global Mapper*. It is more technical and slower, but it works well and it can be ‘scripted’ and modified. Time consuming processing tasks can be automated and carried out at night. Factum also uses *QGIS* which is a free, open-source software for visualisation and data analysis.



The low to mid-resolution DEM from Faro/Photogrammetry is imported into the GIS software and provides the base reference in scale and position for stitching all the Lucida scans in place. First of all, we adjust the Lucida tiles to fit in the X- and Y- axes to the low res Faro/Photo DEM. This is done by classic point registration control. Once the scans are aligned in the X- and Y- axes, we need to align the depth (Z values in the orthographic space). We have developed an algorithm to digitally subtract a thin layer of micro relief (a low relief of sub-millimetric accuracy) from the Lucida scans which allows them to be pasted over a smoothed base surface processed from the Faro and photogrammetric data. In this way, we superimpose the low-relief, high-resolution surface detail from the Lucida data onto the general geometry generated by the other systems.

Finally, the high-resolution colour image can be imported into the GIS software as a colour layer to create a 'layered map' in which the depth and colour information is registered. Using GIS software these 'maps' can be augmented with vectorial layers and textual information. These maps can be shared online using powerful online map viewing platforms like Carto.



Left: Surface from Lidar 3D scanner: accurate geometry. Right: Surface from Lucida 3D Scanner: texture information.

## RE-MATERIALISING: ROUTING

Over the years Factum has run many tests to find the best and most economic way to turn digital information back into a physical object. A combination of CNC milling and Océ 3D printing has been used to produce the facsimile the tomb of Seti I.

Most of the tomb has been carved into boards of polyurethane using CNC routing machines. To rout a 1 m<sup>2</sup> panel in 3D at a resolution of 250 microns takes approximately 120 hours. The walls were routed into panels of approximately 1 x 2 m that are then joined together. Once complete, these panels were assembled to form complete rooms. These are then cut into irregular shaped sections that can be transported and bolted together with invisible joints.



## RE-MATERIALISING: ELEVATED PRINTING

The elevated printing technology of Project EIGER (a development of Océ - A Canon Company), is a form of additive 3D printing. It can create full-colour, textured prints with a maximum size of 2.44 x 1.19 m and a height





up to 5 mm. As the walls in the tomb of Seti I exceed the 5 mm, the research and development department of Océ-Technologies created an experimental slicing algorithm and modified the print processes to create monochrome prints with the required relief while maintaining the accuracy.

The technology makes use of a UV curable ink. Multiple layers of ink are stacked on top of each other. After each layer the ink is fixed and cured before the next layer is applied. The thickness of each layer varies between 2 and 40 microns. This results in texture with an extremely high precision in all dimensions. To create full colour elevated prints, the texture layers are covered with a white layer. On top of this white layer a colour layer is applied.

Full colour texture data consists of a CMYK or RGB bitmap for colour and a 16-bit gray-scale height map for elevation and texture. The full colour texture data is fed into the elevated print Raster Imaging Processor (RIP). The RIP creates a stack of image files that are then printed one by one on top of each other to create the full colour textured print.

Factum Foundation has been collaborating with Océ since 2015 to develop applications of this technology for heritage preservation. The Lucida 3D Scanner generates relief information as 254 dpi tiff, grey-scale depth maps, which makes it suitable for the Océ technology. In the process of the collaboration, a number of issues have been resolved to guarantee the maximum quality of the resulting surface and the closest correspondence to the original texture.

Factum produced a monochrome printing of the tomb of Seti I, and added colour later. The Océ prints were created as negative moulds of the walls of the tomb from which casts were taken. Had Belzoni had access to this non-contact technology, the walls of the tomb might retain their original colour today.



Océ 3D printing as a mould (right) from which the plaster cast is taken (left).



3D printed mould (right) and plastercast taken from the mould.



## RE-MATERIALISING: ELASTIC PRINTING SUPPORT

Factum Arte's approach to the production of high-resolution facsimiles is dependent on the merging of the 3D information of the surface with the high-resolution, colour photography recorded in the tomb. This work is time consuming and highly focused. As technologies develop it is becoming more automated but still requires high levels of human intervention to ensure that there is a perfect fit between colour data and surface data. While this is done for virtual applications when the printed data is mapped onto the physical relief, a second process of alignment needs to take place. This is done using slightly elastic 'skins'.

The preparation of an elastic printing media was a direct response to practical need. Factum Arte's flatbed digital printer can overprint in perfect register but it cannot print a detailed and focused image onto an undulating surface. A layered mixture of three different materials has been developed and is made as required. It is an ultra-thin, flexible, slightly elastic material suitable for inkjet printing with pigmented ink. It is made of two thin layers of ink-jet ground backed with an acrylic gesso and then an elastic, acrylic support. It is built in seven layers rolled onto a slightly textured silicon mould. The skins have a short working life and need to be made freshly to ensure that they stretch and fit the surface in the correct way. The skins can be printed in sheets that are one and a half metres wide and up to three meters long, minimising the number of joints in the final facsimile.



## RE-MATERIALISING: PRINTING THE WALLS OF THE FACSIMILE

The printing of colour on the surface of the facsimile is done using a flatbed inkjet printer designed and built by Dwight Perry at Factum Arte. For many years this printer has been at the centre of Factum Arte's approach to the production of facsimiles that can close the gap between the look of the original object and the look of its copy. With this printer the image can be built up of layers of colour printed in perfect registration. This approach means that both the colour and the tone can be controlled and locally altered to ensure a perfect match. The colour is corrected both digitally using image processing software and in the printing process. This can seem counter intuitive to many people experienced in reprographic printing techniques. Most commercially available colour

management and profiling systems are designed to ensure standardisation with specific printing systems, inks and material coatings. With Factum's approach the adjustments made to the colour in the virtual space of the image management software can also be made in the physical space of the printed image. This multi-layered approach changes the way the files are managed. It is dependent on shared experience and constant comparison with the physical colour notes made in the tomb.



## RE-MATERIALISING: POSITIONING THE SKINS

Working with a raking light, the skin is positioned and re-positioned until all details in the printing correspond to the underlying surface. The fit between the paint and the relief surface is seldom obvious and therefore clearly defined registration points need to be identified. A sharp angle of flaking paint, a defined crack, the edge of a damaged area provide clear registration points. In the case of the tomb of Tutankhamun the slight relief and clearly defined edges of the micro-bacteria were the dominant positional guides. The Tomb of Seti I is more complicated. The elastic nature of the support means the colour data can be stretched or compressed to ensure a perfect fit.







## RE-MATERIALISING: STICKING THE COLOUR SKINS TO THE RELIEF SURFACE

When the flexible skins are in the correct position they are pinned in place and locally folded back. A contact adhesive is applied to both sides. A slow-cure contact adhesive ensures that the skins do not move but the bond is not strong so they can be repositioned as required. Sight and touch are essential to ensure the exact relationship between the surface and the colour.





## **RE-MATERIALISING: VACUUMING THE SKINS**

Once the skins have been positioned, pressed down in place and held by contact adhesive they are put into a vacuum bag with a polyester blanket. A uniform pressure is applied using a vacuum pump insuring full contact and adhesion between the skin and the support. Due to the gossamer-like, elastic nature of skin, it takes on the character of the underlying relief resulting in a surface where the colour and texture are fused together.



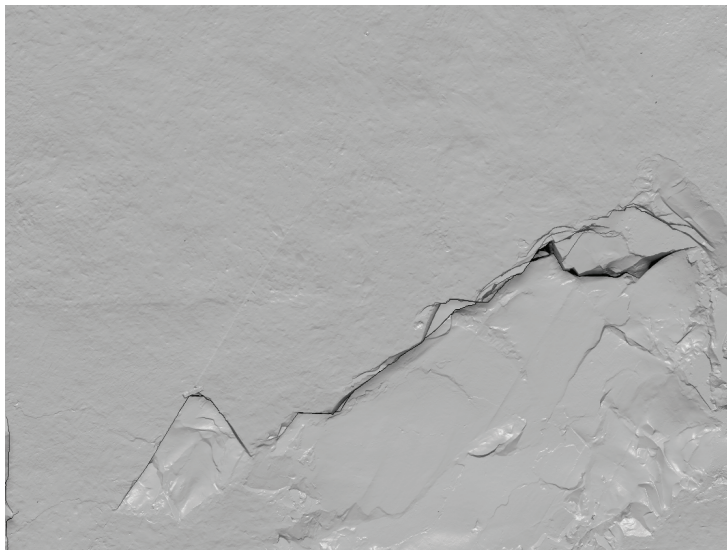
## **RE-MATERIALISING: RETOUCHING THE FINAL FACSIMILE**

Once the skins are fixed to the surface, there is some retouching required to ensure perfect contact and no visible artefacts. This work is done by a team working under Factum's restoration specialist.



## RE-MATERIALISING: CEILING

The ceiling was recorded using composite photography at a resolution of 300 dpi at 1:1. The 3D form is derived from the Faro data and photogrammetry. It was CNC milled and finished by hand. The colour was added using Factum's elastic skins.





## RE-MATERIALISING: SARCOPHAGUS

Working in the confined space of the crypt in Sir John Soane's museum, over 4,500 images were taken with a Canon 5DSR over a five-day period. The team employed a motorised rig onto which the camera was mounted, with two flashes mounted at a 45° angle to spread an even light on the exterior of the surface. The interior of the sarcophagus was difficult to reach, and was recorded using a hand-held setup and a blue laser system that minimises the diffraction of the beam on the translucent alabaster surface.

The stitching of the images was done in collaboration with Capturing Reality, to form a 3D model that will facilitate an in-depth study of the surface and shape of the sarcophagus. The model is made from an uncompressed file of 2.7 billion polygons, each polygon describing a change of plane. It can be viewed with or without high-resolution colour data.



## RE-MATERIALISING: FRAGMENTS

Eight fragments have been recorded in Museum of Fine Arts Boston. One large relief of Hathor and Seti was recorded in the Musée du Louvre. Three large fragments were recorded at Ägyptisches Museum und Papyrussammlung Staatliche Museen zu Berlin - Preußischer Kulturbesitz. Two large fragments have been recorded in the Archaeology Museum in Florence. Eighteen fragments of differing sizes were recorded at the British Museum in London. Two small fragments from a private collection were also recorded.

Many of these pieces come from rooms I and J. As the facsimile develops, the re-integration of facsimiles of the fragments into the facsimile of the tomb will become increasingly important.

Thousands of small fragments have been recovered from the tomb and the rubble outside the tomb by a team from the University of Basel. Working with Florence Baberio and Susanne Bickel, Factum Foundation will apply visualisation techniques to assist in the location and integration of the fragments. As soon as permission is obtained, a major digital recording project will produce 3D scans of all of these fragments. Facsimiles can then be reintegrated into their original location in the facsimile of the tomb.



Recording the fragment of Hathor welcoming Seti in the Musée du Louvre with the Lucida Laser Scanner.



A fragment in the Museum of Fine Arts, Boston.



## RE-MATERIALISING: FINAL FACSIMILE

Understanding the transformations that happen as the physical world is digitised and then re-materialised is key to the production of a facsimile that aspires to forensic accuracy. This begins by understanding the layers of mediation in both the hardware and software used in high-resolution recording and replication techniques. This is essential and informs every decision as the data moves from one state to another right up to moment it becomes a finished, physical object.

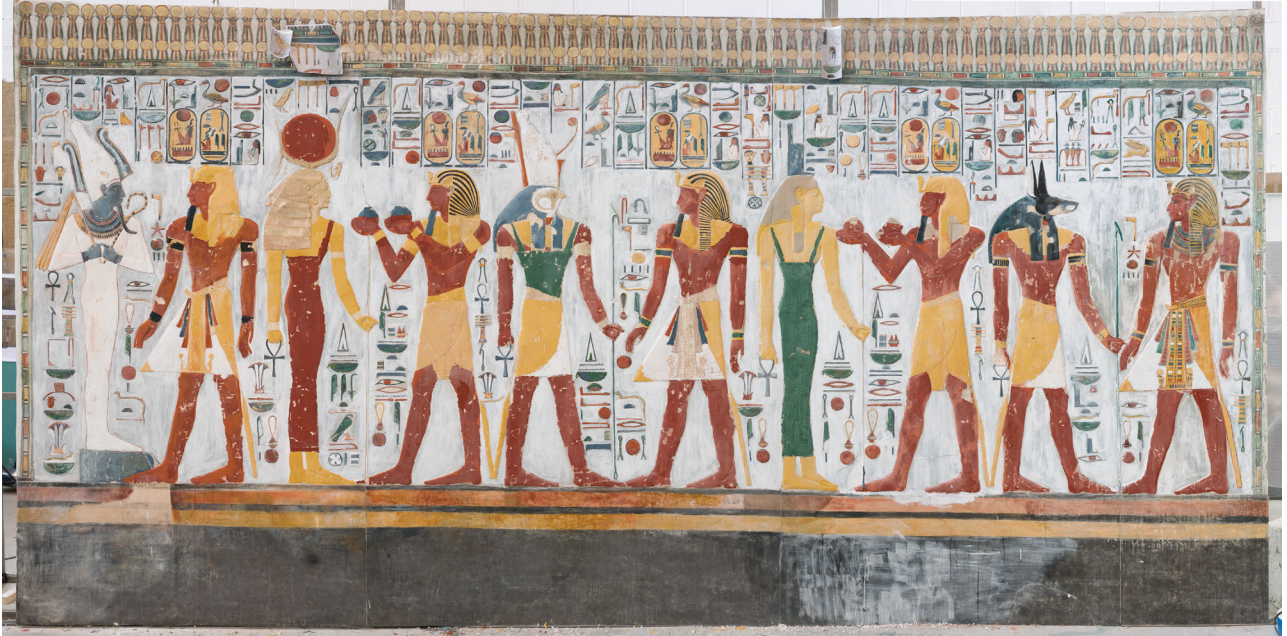
For many years facsimiles have been dismissed as the tourists and the general public focussed on the need to have access to the originality. As recording technologies change the relationship between originality and authenticity and facsimiles become identical to the original they are finding a new role. The facsimile can be used in theatrical and didactic ways to enhance visitor experience. The importance of the tomb of Seti I is undeniable and its preservation essential. By visiting the facsimile the cultural tourist can understand the problems of conserving a site, that was built to last for eternity but was never meant to be visited. In a world of more than seven billion people, all with increasing mobility, this is critical.



The West wall of the Hall of Beauties in Factum Arte's workshop after the transfer of the colour showing the wall in its current condition.



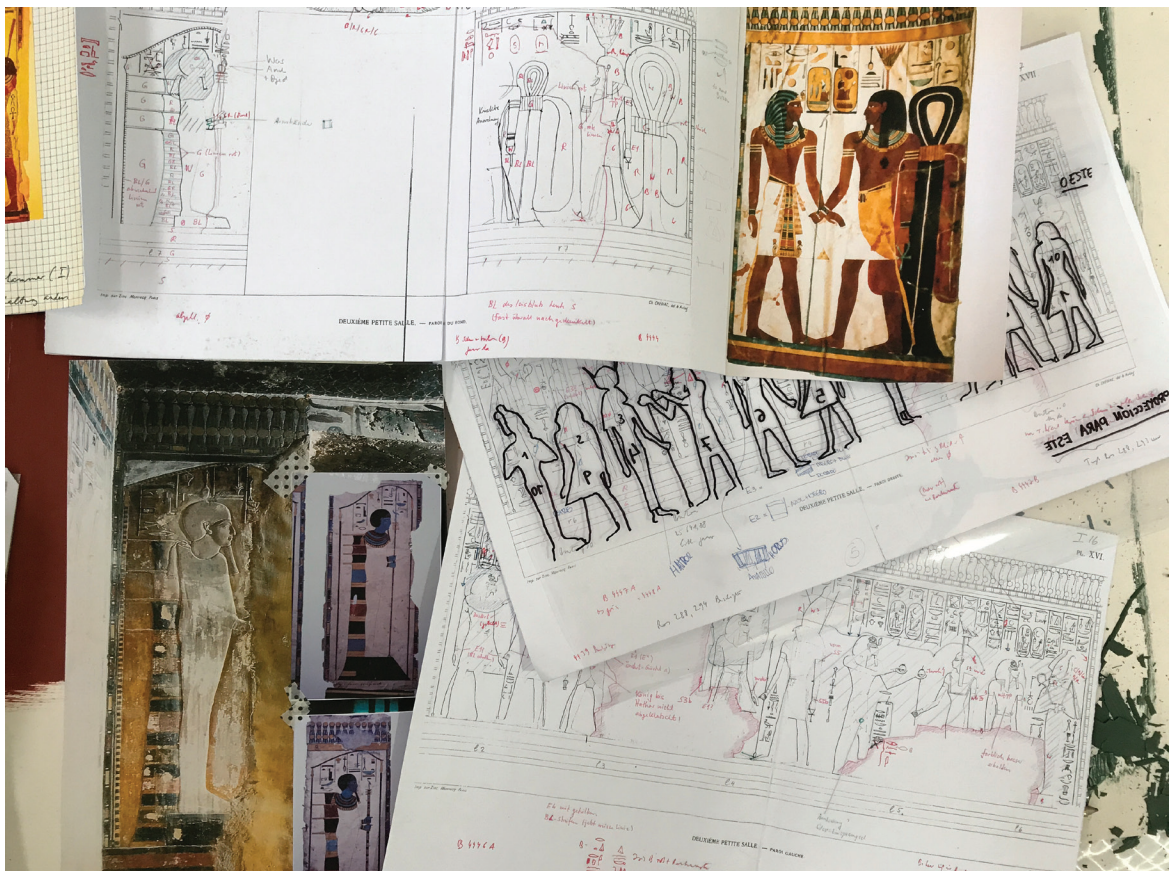
**RE-MATERIALISING:  
THE PHYSICAL RECONSTRUCTION OF  
THE HALL OF BEAUTIES IN ITS 1817 CONDITION**



West wall of the Hall of Beauties during the application of the colour to recreate the effect of the tomb in 1817.







Re-generating the missing hieroglyphs and figures is dependent on scholarship and expert advice. Erik Hornung's notes supplement and correct the drawings by Belzoni and Ricci.

## THE THEBAN NECROPOLIS PRESERVATION INITIATIVE

The Theban Necropolis Preservation Initiative (TNPI) is a collaboration between Factum Foundation for Digital Technology in Conservation and the University of Basel. It has been operating for seven years. In 2009 Factum Foundation employed Factum Arte to record the Tomb of Tutankhamun. It was through a close study of this data in its virtual form that led Nicholas Reeves to publish his paper in August 2015 about the possible discovery of a new tomb behind the north wall of the burial chamber.

In 2012 the physical facsimile of the burial chamber was given to the people of Egypt at a special task force organized by the European Union. In 2014 the facsimile of the Burial Chamber was installed in a building specially designed by the *Tarek Waly Center for Architecture & Heritage* for a site next to Carter's House at the entrance to the Valley of the Kings. The facsimile and the associated exhibition have been open to the public since 2014 with the Ministry charging 50LE for a ticket to visit Carter's House and the facsimile. In 2016 the complete restoration of Stoppelaere House was carried out by Tarek Waly. The 3D Scanning, Archiving and Training Centre in Stoppelaere House was officially opened in February 2017 by Irina Bokova, the Secretary General of UNESCO with the Swiss Ambassador, Markus Leitner, and the Egyptian minister of Antiquities, Dr. Khaled El Enany. In 2016 the complete recording of the tomb of Seti I began and the first local Egyptian operators were trained. In 2016 the recording of fragments removed from the tomb began at the Museum of Fine Arts in Boston. In 2017 further fragments have been recorded at the British Museum, the Sir John Soane's Museum, the Louvre, the Pergamon and the Museum of Antiquities in Florence. The exhibition, *Scanning Seti: The Re-generation of a Pharaonic Tomb*, is the most recent evidence of the success of this collaboration.

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 re-materialized 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 ordered, spatial points per square metre; key skills and technologies are simultaneously transferred to the local community. As the project develops, the data generated will be stored locally and disseminated globally. The copyright belongs to the Egyptian Ministry of Antiquities for all current and future applications. The data is essential 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 itself.

The next phase of the Theban Necropolis Preservation Initiative work will start as soon as security permission has been granted. Its aim will be:

- to continue the recording of the tomb of Seti I (estimated completion date: end of 2019)
- the recording of all the fragments discovered by the University of Basel in the Tomb of Seti I. (during 2018)
- the transfer of equipment to create a fully operational 'documentation centre' at Stoppelaere House and the full training of local teams capable of carrying out all aspects of the recording, processing and archiving work (during 2017 and 2018)
- the opening of this technology to other missions working in the area leading to high-resolution recording of other sites
- the creation of a visitor centre where facsimiles are made at a standard that is unmatched world wide (estimate: the end of 2020).

The 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 professions. The people we have had the privilege to work with are extremely capable (and often more ingenious and resourceful) than Oxford or Harvard graduates. This project is one of the most ambitious, coherent and advanced example 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 TNPI 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.



Hassan Fathy's mudbrick building that was completely restored in 2016 by Tarek Waly. Built for Alexandre Stoppelaere in 1951 the building will be used as the 3D scanning, Archiving and Training Centre.





Facsimile of the Tomb of Thutmosis III. Made by Factum Arte in 2002.



Facsimile of the Burial Chamber of Tutankhamun. Made by Factum Arte in 2012, and funded by Factum Foundation. Installed at the entrance of the Valley of the Kings, 2014, and now part of the Carter's House Visitor Centre.



Text © Adam Lowe.

Image of an engraving from the cover of the booklet that accompanied the exhibition of Belzoni's facsimile in Paris in 1822, page 1 © Adam Lowe.

Image pages 9 and 22 © Harry Burton, The Griffith Institute, Oxford.

Images page 25 © Océ - A Canon Company.

Image of the construction of the building for the facsimile, page 38 © Tarek Waly  
Center for Architecture & Heritage

All other images ©Factum Foundation for Digital Technology in Conservation.