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Previous filling and attempts at stabilizing fragile plaster surfaces in KV 62
PHOTO: FACTUM ARTE

Unbroken seal and cord on the third shrine; Burton P0631 (colorized)
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Unlocking Tutankhamun

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On page 50 of Scribe Issue 8, we printed a photo of Robert Ritner with the note: “If you took this photo and gave a copy to Janet Johnson, please identify yourself so we can credit you.”

This photo was taken by Brian Muhs, Associate Professor of Egyptology at the Oriental Institute at The University of Chicago, in 2014 at the ARCE Annual Meeting in Portland, OR, and shared with his colleagues, including Johnson.

Thank you, Brian!
The color was printed on Factum Arte’s flatbed printer onto flexible “skins”.

PHOTO: FACTUM ARTE
I have often said I believe that the tombs of the pharaohs in the Valley of the Kings could be completely destroyed from modern activities in less than one hundred years. But there are tombs that we can replicate which contain magical, beautiful scenes. These are the tomb of Tutankhamun, the tomb of Seti I, and the tomb of the great Queen Nefertari. Therefore, I am supporting this important project to create facsimiles of these great tombs in order to save the originals. People can visit the exact replicas and experience the beauty of the tombs and know that they are preserving the past.

– DR. ZAHI HAWASS, 2009
A Sea of Change in the Valley of the Kings

A century is fraction of the 3,346-year history of the tomb of Tutankhamun, but even in the short time since Howard Carter made his discovery, the world has profoundly changed and these changes have accelerated in the past two years. The unavoidable specter of climate change and the COVID-19 pandemic have drawn a line between the past and the future, forcing us to urgently address how we experience, understand, and preserve our cultural heritage.

Now is the time to focus attention on sustainability, and Pharaonic natural philosophy has a great deal to offer: the tombs in the Valley of the Kings were built as part of a quest for eternity. Similarly, finding a way to avoid the irreparable loss of cultural heritage requires imaginative solutions and confronting some of our most deeply held prejudices about how we experience heritage. The relationship between vulnerable original objects that require constant maintenance to keep them intact, our experience of these changing objects, how they communicate, and what is being communicated must be reassessed.

It is in this context that I reflect on work that began in 2001* and that resulted in the high-resolution digital recording (in 3D and color) of the burial chamber, sarcophagus, and sarcophagus lid in the tomb of Tutankhamun – an initiative launched in 2009 by Factum Foundation with the Supreme Council of Antiquities (SCA), the Friends of the Royal Tombs of Egypt, and Basel University. From this collaboration and with the same partners, Factum Foundation also launched the Theban Necropolis Preservation Initiative (TNPI) in 2015, which is now based in Stoppelaere House on a hill above Howard Carter’s house (Carter House) at the entrance to the Valley of the Kings.

Factum’s recording of the tomb of Tutankhamun in 2009 began on the instruction of Dr. Zahi Hawass and Dr. Mostafa Waziry with the support of the SCA. This work was undertaken by Factum Arte and led to the formation of Factum Foundation. The quality of the digitization demonstrated that it is possible to record the surfaces and structure of the tombs at a resolution that can be rematerialized with a close correspondence between the original and the replica. The resulting facsimile of the burial chamber of Tutankhamun was given to Egypt in November 2012 by Baroness Ashton on behalf of the European Union. In 2013, then-Minister of Antiquities, Dr. Mohamed Ibrahim, took the decision to install the facsimile adjacent to Carter House. In 2014, Factum Foundation commissioned Tarek Waly to design an underground space and the physical facsimile was installed, as planned, later that year. It attracted extensive media attention and now plays a

* 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. 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 Thutmose III was produced by Factum Arte, demonstrating the level of accuracy that is possible when the application of technology is combined with high-skill mechanical and manual labor.
significant role in the discussion around the future of heritage preservation.

The Challenge
The technical skills of the pharaonic craftsmen ensured the survival of Tutankhamun’s tomb. In 1922, Carter discovered the tomb in very good condition and filled with objects but in the 100 years since then it has suffered serious decay. When Carter opened the tomb, he found that the painted walls were covered in dark brown spots of microbacteria (more easily visible once the tomb had been emptied of its contents), which revealed that the tomb had been painted and sealed quickly. With the opening of the tomb, the young Tutankhamun emerged from obscurity and captured the public imagination. The painted chamber and its treasures are among the most celebrated cultural artifacts in the world and the stories that surround them continue to infuse generations with the draw of Pharaonic Egypt. In the years following his discovery, Carter expressed concern that large numbers of visitors would damage the fabric of the tomb – he likely never imagined that eventually over 1,000 visitors a day would pay considerable money to enter it!

The fragility of the surface of the tomb is clear to see. Every morning a thick layer of dust is wiped off the sheet of glass that covers the sarcophagus. Removal of dust from the walls is a delicate task and any method causes some paint loss. Airborne pollutants, bacteria, micro-organisms, and general wear and tear add to the problems, but not as dramatically as the visitors whose bodily presence creates dynamic changes in the tomb’s temperature and humidity, leading the plaster surface to expand and contract and gradually detach from the surface of the rock. The New Yorker described the atmosphere in the tomb as a “swampy mist of breath and sweat” in a 2016 article titled ‘The Factory of Fakes - How a workshop uses digital technology to craft perfect copies of imperiled art’ by Daniel Zalewski. In the same article, Bahaa AbdelGaber, now the Director of the West Bank, remarked on the smell, especially on hot days.

Previous restorations are visible and reveal different methods to disguise the interventions. On the north wall there is a large area, of about one square meter, that has been restored and repainted with dark brown paint flicked onto the surface to mimic the bacterial growth. When was this restoration carried out? Was it instructed by Carter or is it a more recent change? In Burton’s photos the area appears intact but there is not enough detail when enlarged to see if it was an early infill. While Tutankhamun’s tomb is one of the best documented of all archaeological sites, this is just one instance that highlights the importance of, and need for, written, drawn, and photographic documentation. In the 21st century, digital records of the highest resolution become a new resource.

The Critical Need for Documentation
Carter was an artist with a deep appreciation of the
articulate nature of material evidence. He looked
and he drew, and through drawing his thoughts took
form. Carter’s drawings and notes, now preserved
in the Griffith Institute, Oxford University, and
freely available online, were supplemented by Harry
Burton’s photographs. Burton worked in Egypt for the
Metropolitan Museum of Art from 1915 until his death
in 1940, producing over 12,000 large format glass plate
negatives. Institutions at that time saw the profound
importance of documentation and so ensured that it
was provided and funded. Sadly, this is not the case
today. Burton was ‘loaned’ by the museum to help
Carter, and the photographs he took in the tombs of
Tutankhamun and Seti I are at once documents and
works of art; his ‘eye’ and cinematic skills are now
part of the tombs’ histories. Chicago House developed
its complex and technically beautiful documentation
system to overcome subjectivity and provide accurate
data for academic study using the technologies of
the 20th century. The recordings carried out by
Factum Foundation use 21st century technologies
to ensure even greater objectivity. They complement
the scientific studies done by the Getty Conservation
Institute (GCI) during the recent ten-year program
(2009-2019) that focused on research, restoration,
and the upgrading of the infrastructure in the tomb.

Our in-house development of new technolo-
gies has enabled Factum’s current methodology for
recording fragile and vulnerable sites. All the work
carried out is completely non-contact. Our mission is
to digitize at the highest resolution, securely archive
the data, and ensure that the Ministry of Tourism and
Antiquities owns and benefits from the archive. The
agreement with the Ministry ensures that the data is
made freely available for the study and preservation of
the tomb. Using specially designed software interfaces,
the walls of the burial chamber were put online in
2012, allowing the tomb to be studied remotely at
high-resolution as 3D surfaces and composite color
images. The two can either be examined separately
or overlaid. We are currently working on an interface
that will add the 2019 color recording to facilitate
condition monitoring. The online data has attracted
significant attention and raised new speculation about
the tomb. In response, ongoing research is being led
by Dr. Mamdouh Eldamaty using ground penetrating
radar (carried out by Japanese, American, Italian, and
British teams). This is leading to a new form of digital
connoisseurship and forensic study that is helping to
reveal the complex histories of the Theban Necropolis
and the dynamic nature of originality.

Part of the purpose of recording is to encour-
age exactly this: we want people to look! New

ABOVE: The facsimile of Tutankhamun’s sarcophagus installed and Harry Burton’s
photograph of the original (Burton Po646; © GRIFFITH INSTITUTE, UNIVERSITY OF OXFORD), taken
from a similar angle with a different lens
PHOTO: FACTUM ARTE
observations continue to be made, and these in turn contribute to a deeper understanding of the making, significance, and ongoing history of the tombs. They can also inform future preservation and restoration protocols. One area of study now emerging is focused on the bacterial growth in the tomb. What initially appears to be everywhere, on closer inspection seems to prefer some areas and colors to others. The density of the microbacteria implies the presence of moisture or organic material in the binding agent used in the paint. Binding agents are more difficult to analyze than mineral pigments, but gum arabic has different qualities to an animal glue or a casein. Microbacterial patterns could lead to information about the thickness of the walls and the nature of the rock behind the plaster, while binding agents may offer insights into methods of paint application, especially in the black lines delineating the main figures.

The Process of Recording and Preserving Heritage in an Age of Mass Tourism

Recording the tomb of Tutankhamun presented specific challenges. It is a small space and the sarcophagus and sarcophagus lid reduce the available working area. The distance between the sarcophagus and the wall is 126 cm at the narrowest point. Work to record the tomb was carried out in 2009 without interrupting the normal flow of visitors and used non-contact and entirely safe imaging technologies. On busy days over 1,000 people visited the tomb. Most showed a great interest in the work that was being carried

The system used to ensure accurate color matching during the production of the facsimile uses specially-prepared color sticks that are matched to the exact tone and sheen of the color on the wall. 

PHOTO: FACTUM ARTE

PHOTO: FACTUM ARTE

Nub3D structured light scanner recording the west side of the sarcophagus
out, while many expressed their concern that their presence was having a destructive impact on fabric of the tomb. There is a growing realization among the public that they are, in fact, a big part of the problem as the system is currently structured. This calls for imaginative rethinking.

The Lascaux, Altamira, and Chauvet caves located in France and Spain that contain Paleolithic cave paintings are closed to the public and have been replaced with copies. While the Lascaux copy was made by hand, the copy of the Cave of Altamira’s aspired to a level of objective accuracy: it was recorded with photogrammetry with approximately one measured point per five centimeters, i.e., 400 measured points per square meter. By comparison, Factum’s work in Seti’s tomb in 2001 demonstrated it was possible to record one measured point every 100 microns, or 100 million per square meter.

The recording of Tutankhamun’s tomb used different systems, some developed by Factum Foundation while others are commercially available. A Nub 3D white light scanner captured all the walls with one measured point every 600 microns. A Lucida scanner (designed by Manuel Franquelo and developed with Factum’s engineering department) was used in some places on the rough plaster walls and recorded the relief on the sarcophagus at a resolution of 100 microns. Composite photography produced images of all the walls of at least 500 DPI at a 1:1 ratio. During the second photographic recording that took place over five days in late 2019, 1,626 photos were taken of the walls. These were later stitched together at sub-pixel accuracy to produce an archive of 427 GB. The total digital archive recorded in the tomb of Tutankhamun by Factum Foundation in 2009 and 2019 is 854Gb (379Gb in 2009 between 3D and color + 475Gb for the color in 2019).

**Local Transfer of Global Knowledge, Skills, and Technology**

Factum Foundation’s approach in Egypt, as elsewhere, is to initiate a transfer of skills and technology to a fully trained local team. Carrying out the full restoration of
4 The specially designed photographic system recording the walls of the tomb of Tutankhamun in March 2009.

5 Abdo Ghaba and Amany Hassan scanning in the tomb of Seti I using the Lucida 3D Scanner.

6 Trainees from the Theban Necropolis Preservation Initiative recording the tomb of Seti I using the Lucida 3D Scanner and composite photography.

PHOTOS: FACTUM ARTE
1-2 In 2001, the side chambers were filled with fragments, many painted, used bulbs and waste. One of the distinguishing features of the project is that all known fragments of the tomb are being recorded in their current location. When complete the eventual digital models and physical facsimiles will be more complete than the original tomb itself. There are also a large number of fragments of different sizes, some painted, some not, that were found in or near the tomb. The excavations carried out by Susanne Bickel and Florence Mauric Barberio from the University of Basel, near the adjacent tomb of Ramses X (KV 18), brought to light roughly 8,000 fragments from the Tomb of Seti I between.

PHOTO: FACTUM ARTE

Hassan Fathy’s precariously placed mud brick building (Stoppelaëre House) not only saved the historic and important architectural work, but also provided a base from which this local team could work. In 2015 Factum Foundation set up a training program focused on sustainability and knowledge transfer. Under the direction of Aliaa Ismail, the Egyptian team – Abdo Ghaba, Mahmoud Abdellah, Mahmoud Salem, Mina Fahim Razik, Amany Hassan, Hager Ahmed, and Mosa el-Sayed – has been working from Stoppelaëre House since it was opened in 2017 by Egyptian Minister of Tourism and Antiquities, Dr. Khaled El-Enany, and Irina Bokova, then-Director-General of UNESCO. In 2020, this team was the first ‘mission’ back in the Valley of the Kings following COVID-19 closures. By the end of 2021 they had finished the complete documentation of the tomb of Seti I, the largest area of carved and painted walls ever recorded at high-resolution in 3D and color. The iconography within this tomb constitutes the most complete account of pharaonic beliefs, knowledge, and philosophy, as well as being the highpoint of low-relief polychrome decoration.

When Factum’s team started this work in 2001 the aim was to prove that the technology existed to produce an exact record of the tombs at a resolution that enables the creation of an identical replica. The digitization carried out in 2001 demonstrated it was possible to capture data that can be used in many different ways – both virtual and physical. The computer power and software to handle this data did not exist at the time and no-one understood where it would lead. 20 years later the quality of this data is still unmatched, and it has been used to raise both awareness and money for the Ministry through exhibitions in Basel and Lausanne. The copyright on all commercial applications of the data belongs in full to the Ministry for all current and future applications. The potential value of this data is significant as new uses and markets emerge.

Possible Future Applications

Virtual, mixed, and augmented realities are generating new uses for the data. In the exhibition Deep Fakes: Art and its Double at EPFL Pavilions, Factum’s recordings were used in an animation by Scan Labs that linked the inside of the tomb to the high-resolution data recorded from the alabaster sarcophagus of Seti I at Sir John Soane’s Museum in London. Events of this kind reach a new audience and draw attention to the importance of the high-resolution data that has been recorded since 2001.

The same 3D and color recordings may result in a new revenue stream for the Ministry. Non-Fungible
Tokens (NFTs) use blockchain, the technology behind cryptocurrencies, to certify the uniqueness of digital data in different forms. This has created a new market for digital collectibles. NFT sales exceeded $11 billion in the third quarter of 2021, but no-one yet has found the right way to channel this money into the preservation and documentation of cultural heritage. If this is done correctly it could become a major new revenue stream for the Ministry. The celebrity of Tutankhamun’s tomb should make different forms of the data ideal as collectible digital assets while turning the purchaser into both collector and philanthropist.

The Next Phase of Work in the Theban Necropolis
Following the completion of the recording of the tomb of Seti I at the end of 2021, TNPI and its partners, the University of Basel, and Friends of the Royal Tombs of Egypt have requested that the Ministry of Tourism and Antiquities allow for the continuation of the work launched in 2009. Once permission is granted the TNPI will:

- Undertake a complete high-resolution composite color and sub-millimetric 3D recording of the Tomb of Nefertari Finish the work in Stoppelaëre House to increase its potential as a 3D scanning, training, and archiving center.
- Launch training courses to expand the capabilities of the local recording team. To this end, a MOU has already been signed with the Institute of Restoration and Conservation of Antiquities in Luxor.
- Produce a facsimile of the tomb of Seti I and all parts of the tomb removed since its discovery in 1817.
- Create an innovative visitor center near Carter House explaining the preservation of the Theban Necropolis, the recording of the tombs and the production of exact facsimiles that are identical to the original tombs. The production of the facsimiles will be part of the visitor experience.
- Install the facsimile of Seti I below Stoppelaëre House followed by the installation of a locally produced facsimile of the complete tomb of Nefertari.

Towards a Sustainable Future
To date, millions of tourists have already visited the tiny burial chamber of Tutankhamun. From Carter to
Hawass, Egyptologists, guardians, scholars and other interested parties all agree that the tomb will not survive this kind of continued exposure without undergoing continuous maintenance, significant damage limitation, and ongoing interventions. Constant restoration will be needed to counteract the impact of vast numbers of visitors, which will take the existing tomb further away from its original state. Many have argued that there are effectively two choices: that the tombs in the Valley should either be sealed up to preserve them for posterity and future generations or continue to be exploited for much needed short-term financial gain. But there are other options and imaginative solutions. Over the past 21 years of working in the Valley of the Kings, Factum has demonstrated, developed the technology, and set up protocols for the following:

- Documentation and data input: high-resolution, non-contact, objective digital recording using close-range laser scanning, photometric stereo recording, photogrammetry at different resolutions and LiDAR scanning can be merged with composite photography and other forms of digital data. There is a significant difference between data for screen viewing and recordings that can be re-materialized as exact facsimiles.

- Uses and data output: to act as a permanent record of the tombs, a resource for condition monitoring, in-depth study and remote online access, for the re-materialization of exact facsimiles, AR and VR applications and more.

- Skills and technology transfer: to a local team, with training and remote support. This will eventually include the transfer to a trained local team of the means of manufacture of facsimiles of the tombs.

- Improved visitor experience: facsimiles can provide enriching and educational experiences under controlled and comfortable conditions while taking pressure off the original tombs.

- Ownership of the data: remains with the Ministry, with all commercial gain to stay in Egypt for the upkeep of the cultural heritage assets and to support the local economy.
• Open access: the data will remain openly and freely accessible for study, academic, and non-commercial uses.

The facsimiles of the tombs will help redefine the relationship between originality and authenticity and offer a partial solution to the protection of tombs that were built to last for eternity but never to be visited. To date, the training and creation of a team (almost entirely from the West Bank) has already generated a new local economy. If a new combined visitor center and workshops can be created next to Carter House and the replica of the tomb of Tutankhamun, it will make a dynamic attraction at the entrance to the Valley of the Kings. Plans for the renovation and improvement of Carter House have been developed by ARCE and will be implemented in 2022 in time for the centennial.

When the facsimiles of Seti I and Nefertari are installed next to that of Tutankhamun’s tomb, the Ministry will be able to demonstrate that it is leading the way in the application of technology for preservation. We hope the 100-year anniversary of the discovery of Tutankhamun’s tomb will attract new interest, encourage reflection, and reveal the optimism and positive change that is leading to a sustainable future for the Theban Necropolis.

To learn more about the Factum Foundation’s work, visit: www.factumfoundation.org/ind/46/the-theban-necropolis-preservation-initiative