

**THE  
AUTHORIZED  
FACSIMILE OF THE BURIAL CHAMBER  
OF TUTANKHAMUN**

**WITH SARCOPHAGUS , SARCOPHAGUS LID  
AND THE MISSING FRAGMENT FROM THE SOUTH WALL**

**1922 TO 2012  
THE 90<sup>th</sup> ANNIVERSARY  
OF THE DISCOVERY OF THE TOMB**



A CELEBRATION OF  
**THE 90<sup>th</sup> ANNIVERSARY**  
OF THE DISCOVERY OF  
THE TOMB OF TUTANKHAMUN  
AND THE ANNOUNCEMENT OF A NEW INITIATIVE  
TO SAFEGUARD THIS AND OTHER TOMBS

**THE  
AUTHORIZED  
FACSIMILE OF THE BURIAL CHAMBER  
OF TUTANKHAMUN**

**WITH SARCOPHAGUS, SARCOPHAGUS LID  
AND THE MISSING FRAGMENT FROM THE SOUTH WALL**

A GIFT TO THE REPUBLIC OF EGYPT  
FROM  
FACTUM ARTE,  
THE SOCIETY FOR THE FRIENDS OF THE ROYAL TOMBS OF EGYPT  
THE FACTUM FOUNDATION FOR DIGITAL TECHNOLOGY IN CONSERVATION,  
AND  
THE UNIVERSITY OF BASEL

PREPARED FOR THE EUROPEAN UNION TASKFORCE IN CAIRO NOVEMBER 2012

القطعة  
المصرحة  
المطابقة للاصل  
**لمقبرة توت عنخ آمون**  
مع التابوت و جوانبه

و الجزء المفقود من الحائط الجنوبي

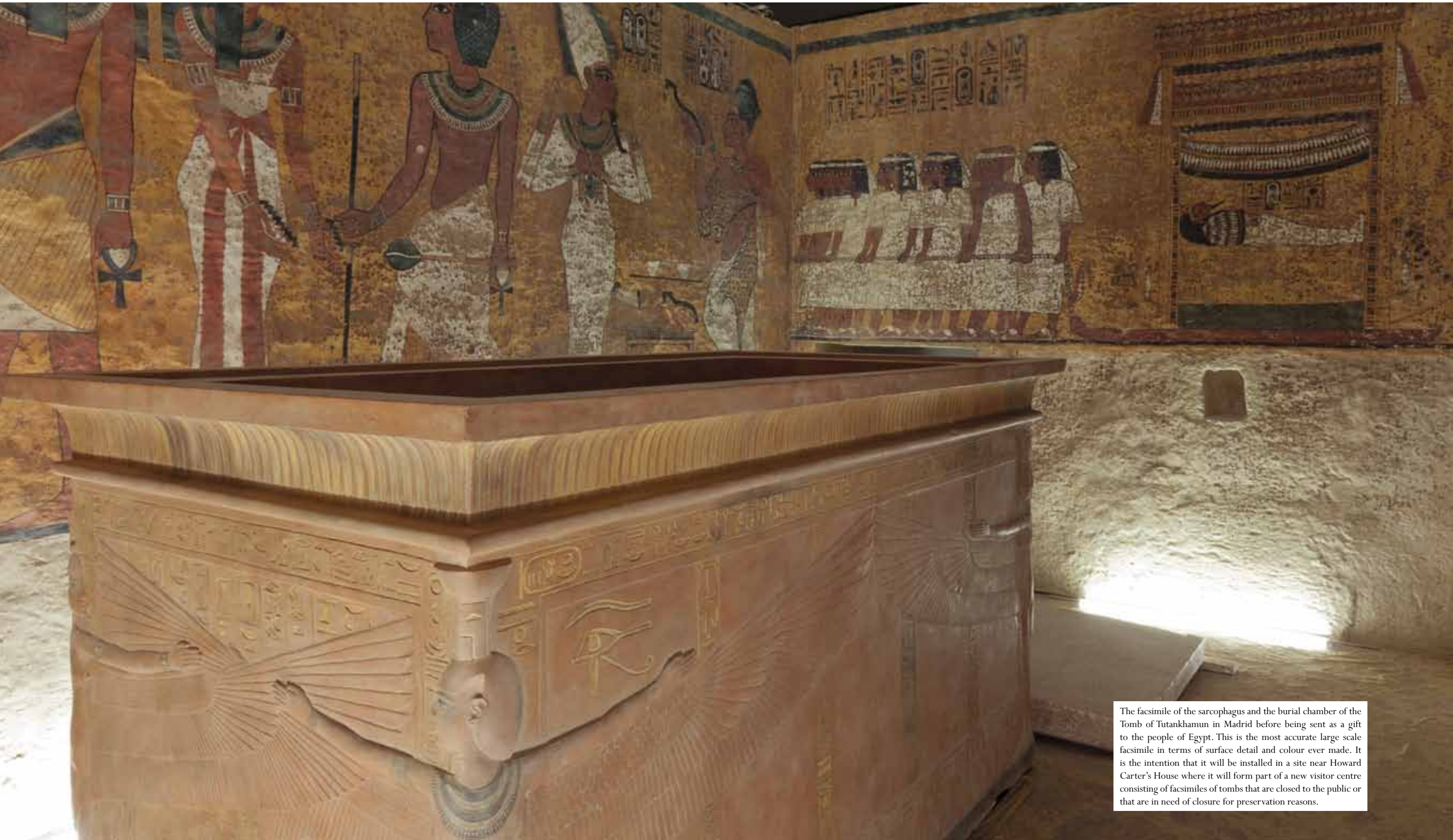
إهداء لجمهورية مصر العربية  
من  
فاكتوم آر تي  
وجمعية اصدقاء المقابر الملكية المصرية  
و مؤسسة فاكتوم للتقنيات الحديثة للترميم  
و  
جامعة بازل

تم اعدادها لصالح لجنة الخبراء الاوربية بالقاهرة نوفمبر 2012



On November 4<sup>th</sup> 1922 Howard Carter discovered evidence of the existence of a tomb near the entrance to KV9. During the month of November he cleared the way to a sealed door. On 25<sup>th</sup> November the sealed doorway at the entrance of the tomb was photographed. News spread rapidly and the discovery caught the world's attention. The next day the Antechamber was opened revealing 'wonderful things'. It took until the 16<sup>th</sup> February 1923 before they had accurately recorded the objects in the antechamber and were ready to open the next sealed door. Within minutes of opening a hole in the wall it was clear that Lord Carnarvon and Howard Carter had discovered an unrobbed royal burial chamber. Since that moment the young Tutankhamun has emerged from obscurity and captured the public imagination. The tomb and its treasures are now amongst the most celebrated cultural artifacts in the world and the stories that surround them continue to inspire generations with the magic of Pharaonic Egypt – attracting thousands of visitors every year to the Cairo Museum, the Valley of the Kings and various exhibitions of original objects and copies that are touring the world – adding to the celebrity and drawing new visitors to Egypt.

To celebrate the 90<sup>th</sup> anniversary of the discovery of the tomb an exact facsimile of the burial chamber is being sent to Cairo by The Ministry of Tourism of Egypt to be displayed in the Conrad Hotel for the meeting of the European Union task force. It is part of an initiative to preserve the Theban Necropolis through the application of new recording technologies and the creation of exact facsimiles of tombs that are either closed to the public for conservation reasons or are in need of closure to preserve them for future generations. This initiative will result in a major transfer of technology and knowledge. The work to record the tombs and build the facsimiles will be carried out by an Egyptian team in Luxor, initially working under the direction of a team from Factum Arte in order to implement the protocol that has been developed to digitize the tombs, archive and transform the data and then re-materialize the information in three dimensions at a scale of 1:1. The resulting facsimiles are redefining the relationship between the original and the copy – re-negotiating the complex relationship between originality and authenticity. This is essential if we are going to preserve our heritage in an age of mass tourism and if we are going to understand the importance of the past, its impact on the present and its influence in shaping our future. Our shared cultural heritage is a subject from which we can learn. It is not a fixed 'object' to be revered.



The facsimile of the sarcophagus and the burial chamber of the Tomb of Tutankhamun in Madrid before being sent as a gift to the people of Egypt. This is the most accurate large scale facsimile in terms of surface detail and colour ever made. It is the intention that it will be installed in a site near Howard Carter's House where it will form part of a new visitor centre consisting of facsimiles of tombs that are closed to the public or that are in need of closure for preservation reasons.



### INHERITING THE PAST – THE FACTUM FOUNDATION APPROACH

The management of cultural heritage sites is often a balancing act between protecting the monuments and allowing access to those who wish to study, admire and learn from them. The tombs in the Valley of the Kings are especially vulnerable because their well-deserved fame makes the Theban Necropolis one of the most visited sites not just in Egypt but in the World.

The Factum Foundation has proved that it is possible, through the use of digital technology, to record the surfaces and structure of the tombs in astonishing detail and reproduce it physically in three dimensions without significant loss of information. This work has involved the development of new technologies to record, inspect, archive and reveal the complex histories of Egyptian tombs. It is an approach that is rapidly gaining acceptance and has already proved very popular with the public in Europe. The Foundation's aim is twofold – to provide the data to satisfactorily monitor the condition of the tombs and to turn the public interest into a force assisting in the protection of the tombs.

The work undertaken in the tomb of Tutankhamun is an initiative instigated in 1988 by the Society of Friends of the Royal Tombs of Egypt (through its president Dr Theodor Abt and the highly respected Egyptologist professor Erik Hornung) with the full support of the Supreme Council of Antiquities (SCA) who have long supported the idea of building replicas of the tombs that are closed to the public or in need of closure for preservation. The re-creation we are now witnessing shows what can be achieved when politicians and conservators work together with experts in new technology and innovative craftsmen to achieve a common aim.

#### TECHNOLOGY IS MAKING TOURISM A POSITIVE FORCE

As the number of cultural tourists increases rapidly more people are becoming aware that each visit to a heritage site is almost an act of desecration – we want to turn that concern around and make each visit a positive story not just for the original site but also for the visitor. We can do this by using exact facsimiles that allow an experience of the original while at the same time providing funds to make sure the site is maintained and preserved.

The biography of any cultural artifact will reveal various levels of human intervention at different times in its life. Many of these interventions have been made to preserve the object. They are normally done with the best of intentions but the results often have unpredictable consequences. We want to record with forensic accuracy the things we have inherited, find innovative ways to study and analyse the information and ensure that no physical interventions are imposed on the works unless they are proved to be absolutely benign. It is anticipated that the facsimiles we have created will safely receive at least 500,000 paying visitors a year.



The facsimile of the burial chamber of Tuthmosis III (made by Factum Arte at the instigation of Theo Abt) was first shown in the National Gallery of Art in Washington as part of the exhibition *The Quest for Immortality* in 2003. Since then it has been visited by over 3 million visitors.

#### PAYING FOR THE PRESERVATION OF OUR HERITAGE

The facsimile of the tomb of Tutankhamun has been made by Factum Arte under the auspices of the Supreme Council for Antiquities. The work has been done under a licence to the University of Basel and with the support of the Society of the Friends of the Royal Tombs of Egypt, working alongside the Factum Foundation. It has been completed and is made as a gift to the Arab Republic of Egypt. The one condition is that it benefits the Valley of the Kings and provides work for people on Luxor's West Bank.

Factum Arte's work on the Theban Necropolis started in the tomb of Seti I in 2001. The ideas that are now presented here have been refined since then, in collaboration with many Egyptologists, technicians, cultural heritage managers and the SCA. The importance of this work and its implications for the sustainable management of world heritage sites cannot be overstated. The vision is to turn the interest of the millions of visitors into a force that will ensure the preservation of Egypt's heritage. But, only with the right financial structure can these important testimonies to the past be permanently protected for posterity. This project is about sustainable management of the world's cultural heritage at a time of mass tourism and vast popular interest. The aim is not only to safeguard the three most important tombs in the Valley of the Kings but to raise the initial funding and then to ensure that a percentage of the revenue generated by the new museum housing the facsimiles is used to continue the work of documenting other less famous but equally important tombs.

#### THE TOMB OF TUTANKHAMUN

It is important to note that each monument presents specific recording challenges. Tutankhamun's tomb is small and the sarcophagus and sarcophagus lid reduce the available working space, with the distance between the sarcophagus and the wall of 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 approximately 1,000 people visit the tomb. The visitor numbers have a dramatic effect on the temperature, humidity and dust in the space. Most visitors showed a great interest in the work that was being carried out and many expressed concern that their presence was having a destructive impact on fabric of the tombs.

There concerns are well-founded. The effect of the temperature changes, variation in humidity levels and dust are serious problems creating a dynamic response in the materials from which the tomb is made. Previous restoration and consolidation treatments are adding to the problems both in changing the appearance of the surface and creating

new problems to which there are currently no solutions. Conservation treatments are meant to be fully reversible but the use of Paraloid (a thermoplastic acrylic resin used as a consolidation agent) is a non-reversible treatment on an absorbent surface like the painted plaster in the tombs. Even a non-expert can see from photographic details that the walls are in a critical condition and are deteriorating fast. The Pharaonic craftsmen were skilled technicians and the tomb of Tutankhamun survived in good condition for 3245 years. In the 90 years since its discovery it has suffered serious decay.

We do not have the conservation techniques to allow multiple visits to the original without altering the appearance of the tomb or compounding the problems that will face future generations of conservators. One day we may have an answer but until then we must act with extreme caution and document what we have with great accuracy, archiving raw data that can be reprocessed at higher resolutions in the future.

#### THE SCALE AND PUBLIC ACCEPTANCE OF THIS APPROACH

A project on this scale has never been attempted before and the technical and practical challenges are considerable, but the research and development is complete and the results speak for themselves. Changing attitudes towards originality and the role and value of the past is a slow process. Ten years ago the thought of a facsimile tended to produce a reaction of scorn from the cultural elite and a sense of being cheated from the public. Since the unveiling of Factum Arte's extraordinary facsimile of Veronese's famous painting *The Wedding at Cana* in its original location in the Palladian refectory on San Giorgio Maggiore in Venice responses have begun to change. Many great art historians and journalists have declared that a copy of this accuracy, with all the surface details of the original, in its original location is actually more 'authentic' than the heavily restored 'original' that hangs framed, at the wrong height and in a location that it was not designed for, the Musée du Louvre.



Facsimile of Veronese's *The Wedding at Cana*,  
Fondazione Giorgio Cini, Venice.

#### EGYPT'S INNOVATIVE APPROACH

Egypt, through its long term relationship with the University of Basel, the Society of Friends of the Royal Tombs of Egypt, Factum Arte and the Factum Foundation, has demonstrated that it is at the forefront of this new approach to preservation – an

approach that puts the emphasis on documentation and on revealing the past as an active and dynamic force. The way we value and treat an object reveals as much about us as it does about the thing itself. Our past conditions how we see the present and influences the way we will shape the future.

#### FACTUM FOUNDATION'S WORK

Factum Foundation in collaboration with a wide range of specialists, is pioneering this approach. It has provided the funding for the technical innovations, software developments and the refinement of all stages of the process from the recording of the tombs in two and three dimensions to the production of facsimiles that are objectively accurate, physically present and capable of provoking an emotional response.

Work is now complete on the facsimile of the burial chamber of Tutankhamun (including a section of the south wall originally removed to get the objects out of the burial chamber), the sarcophagus and its lid. It is now time to present this work to the people of Egypt, install it near Howard Carter's house at the entrance to the Valley of the Kings and allow a new generation to visit both the facsimile and the original tomb. Visitors should be encouraged to share their views, opinions and experience in order that the facsimiles of the beautiful tomb of Nefertari and the vast tomb of Seti I can provide an even better visitor experience. This opportunity to visit Tutankhamun's tomb both in original and authentic facsimile will not be available for long as the closure of the original has already been announced – but it is a unique opportunity that will provide access to the two 'versions' allowing public and experts alike the chance to engage with and shape our relationship to the past and its future.

#### ACCESS TO THE DATA

Factum Arte has a clear policy towards the data that it has recorded in Egypt. Wherever possible it should be made freely accessible to scholars and the general public under a Creative Commons licence but all copyright and commercial benefits belong to the Supreme Council of Antiquities who have the responsibility of preserving and managing Egypt's cultural heritage. The new Lucida scanner, developed specifically by Factum Arte for work in the tombs in the Valley of the Kings has a unique feature, which is that it records raw video which is then processed using its own software. The advantage of this, if the data is correctly stored, is that it can be reprocessed at higher resolutions in the future when the technology becomes available. Future technologies may well develop some astonishing techniques that we can only now prepare for. In this way Egypt's heritage is conserved, recorded and made available generally to the public and Egypt will benefit from any revenue it generates.

The Factum Foundation is committed to demonstrating that new technologies have an important role to play in the preservation of Egypt's heritage, a heritage whose deserved fame means that it is in a position to have a partially self-financing conservation policy if it is handled sensitively. It can be a policy that leads the way for the rest of the world.

**James Macmillan-Scott.** President of the Factum Foundation





The visitors have a significant impact of the temperature and levels of humidity inside the tomb. This creates a dynamic situation in which the plaster surface is forced to expand and contract. This action will force it to detach from the rock.

### CULTURAL TOURISM – CAN IT BE A PRO-ACTIVE AND BENIGN FORCE?

The problems facing the Tombs in the Valley of the Kings are real: the photographic evidence is clear and alarming. The tombs were designed to last but were never intended to be visited. The presence of thousands of visitors a day causes accidental damage and changes in humidity and temperature that the 3,000 year old plaster walls cannot withstand. But the situation has been complicated by conservation attempts that have tried to consolidate the plaster to the bedrock – this treatment is not reversible and is now suffocating the tombs – the plaster can no longer breathe and is moving away from the rock. With time this will lead to a collapse unless the conditions within the tomb are kept constant.

Close inspection of the Tomb of Tutankhamun reveals that there have already been significant collapses that have been refilled and repainted. This approach turns the original into a reproduction of itself. This is not good for the past, the present or the future.

The new responsible tourist has a critical role to play in the preservation of the Theban Necropolis. Now it is time for cultural tourism to re-negotiate its relationship with cultural heritage.



At the top of the north wall the plaster is moving away from the rock to a dangerous degree. Some filling and painting has already been carried out but a large area is in imminent danger of collapse.

In some places this has already started. In southwestern France thousands of visitors each day pay to visit Lascaux II, a facsimile that was built in the 1983. The NeoCueva in Altamira (completed in 2001) now attracts three times the number of visitors of visitors that flocked to see the original cave near Santander in Northern Spain until it was closed in 1979. Visits to the Etruscan tombs in Tarquinia (facing many of the same problems that are faced by the tombs in the Theban necropolis) are now strictly controlled and rotated. Stonehenge, after years of discussions and negotiation is now undergoing a major transformation which will result in a new visitor centre and the re-landscaping of the local environment. These sites in France, Spain, Italy and England continue to attract vast numbers of paying visitors. Their ticket money contributes to the preservation of the sites. Many people are now directly and indirectly employed as a result of the popularity of these sites, just as they will be in Egypt as the Theban necropolis is recorded and re-created. Factum Arte has been at the centre of these new approaches for over 12 years and the work carried out in Egypt for the Supreme Council of Antiquities represents a quantum leap, both in terms of technology and software, but more importantly in terms of the fidelity and visitor experience.



### **MATERIAL FRAGILITY**

The fragility of the surface of the tomb of Tutankhamun is clear to see (top). Every morning a thick layer of dust is wiped off the sheet of glass covering the sarcophagus. Removal of dust from the walls (left) is another matter. Any method of removal will also cause paint loss. Blowing with air lifts the painted surface from the support, the use of a vacuum is impossible, a very soft brush will also cause paint loss.

Very little is known about the binding agents used by Egyptian craftsmen but from surface observation it seems that the vast majority of the tomb is painted with a mixture of pigment and animal glue. This effectively allows the surface to breathe. The black lines (left) have a different character and appear to be painted on top of the paint layer. The binding agent is probably a gum arabic. The method of application of the black lines is a matter of great interest. Many of the lines appear to have been made with a long continuous contact that is not possible with a bristle brush. The black areas are cracking in a different way from the majority of the tomb.

A large area of the north wall has been filled and repainted with the conservator going to great lengths to mimic the appearance of the micro-bacteria that form dark patches over the walls of this tomb. Also note the quality of line that forms the knees of the figure (above). These lines are painted with a fitch – a brush with long soft hairs. Their tapering ends are not found elsewhere in the tomb.



## THE WORK CARRIED OUT IN THE TOMB OF TUTANKHAMUN

In November 2008 and April 2009 the Supreme Council of Antiquities granted the University of Basel a licence to record and create exact replicas of three tombs in the Theban necropolis: the tomb of Seti I (closed to the public since the mid 1980s), the Tomb of Queen Nefertari (closed to the public following a major conservation initiative by the Getty Conservation Institute) and the Tomb of Tutankhamun (whose closure was announced in January 2011 but which is currently open).

In Spring 2009 the burial chamber and sarcophagus in the tomb of Tutankhamun were recorded in 3D and colour at the highest resolution ever achieved on a large-scale. Between the summer of 2009 and now all the stages of the work have been perfected and an exact facsimile of the tomb is now complete. The data that was used to make the facsimile is currently being used to monitor and accurately record the decay that is taking place in the tomb. The intention is to make the data public in such a way that everyone will be able to study it in great detail but only the SCA can benefit from any copyright fees it generates.

Every stage of this work has been undertaken by Factum Arte. Most of the equipment has been specifically designed or significantly adapted, specialist software has been written, a new flatbed printer has been built, new materials have been developed and old materials have been revived. The results speak for themselves. The technologies being developed for the Supreme Council of Antiquities are helping to preserve the tombs and communicate their cultural importance. They also enable conservators, academics and the public to understand the objects themselves in deeper and more objective ways.

This initiative focuses on sustainability and knowledge transfer. It is dependent both on specifically developed technologies but also on human skills. Both will be transferred to an Egyptian team working in Luxor who will carry out the recording of the vast and fundamentally important tomb of Seti I and the beautiful tomb of Queen Nefertari. The same technologies will be used in museums and collections around the world to record all known fragments that were removed from the tombs in the past and re-incorporate them within the facsimiles. As a result the facsimile will be more complete than the original – its narrative and meaning more accessible.

The finished facsimiles will form the core of a new visitor centre that will be located near the Valley of the Kings giving public access to tombs that are closed and facilitating the closure of tombs that are in critical condition. This way they can be saved for future generations while continuing to generate revenue that is vital for the local economy and enables documentation of less famous but equally important tombs.

This book, documenting the work to record, mediate, transform and replicate the tomb of Tutankhamun, also explains why this approach will work and how it will be funded. Attitudes are finally changing and originality is increasingly being seen as a process that changes over time, both through natural and human agency. The aim of all the projects developed by Factum Arte is to reveal the biography of cultural artifacts and to demonstrate that the past has the potential to influence the present and shape the future.



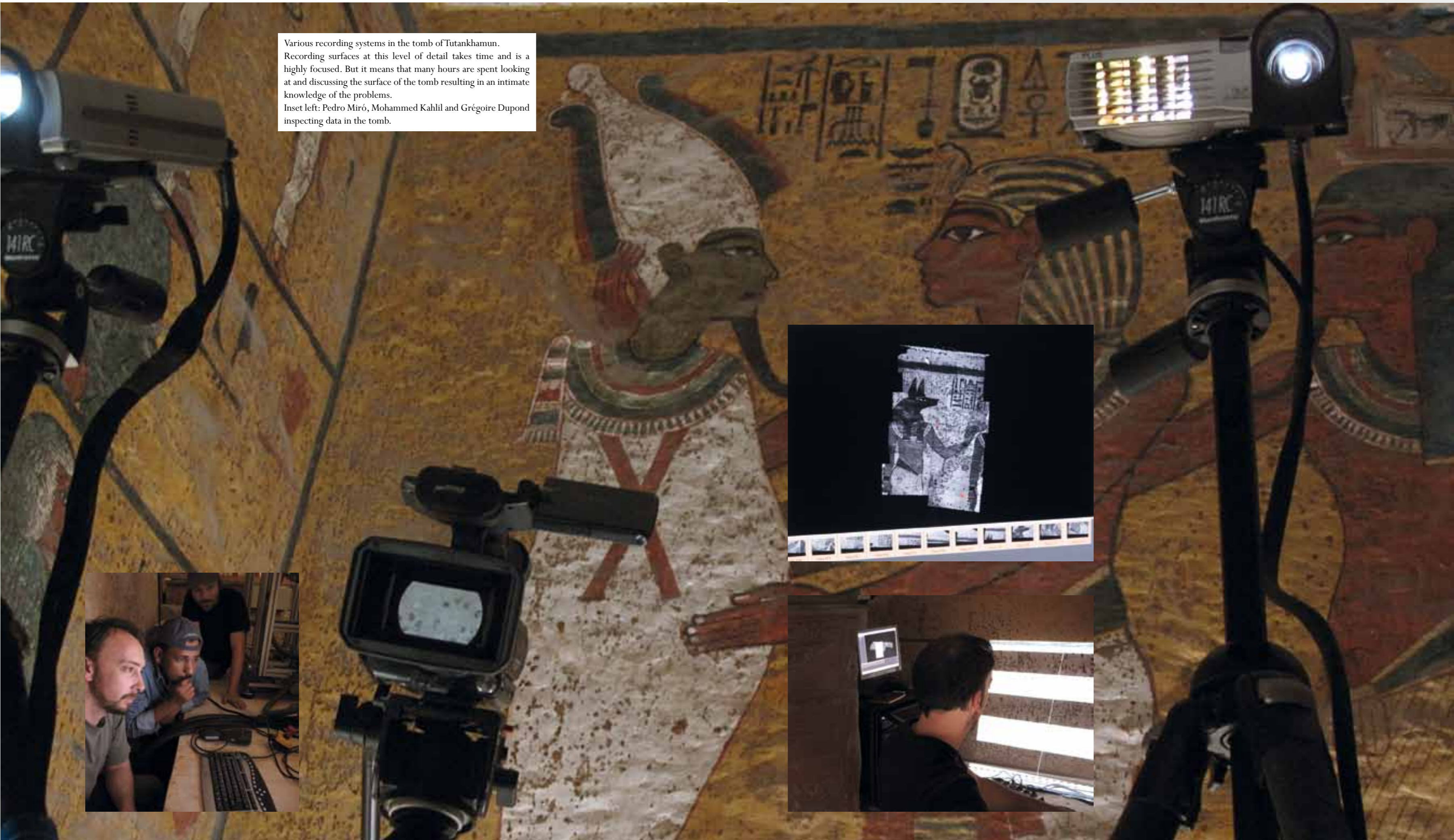
## A DESCRIPTION OF THE PROCESS



The following pages offer a visual description of the important stages of the process of making the facsimile of the burial chamber of Tutankhamun.

The starting point has been to develop the hardware and software specifically for use in the tombs. This has required a detailed evaluation of every aspect of the process from the Laser scanning system to the development of the system for printing high resolution images onto 3 dimensional surfaces. There have been many dead ends along the way but one point has become very clear: in the complex world we inhabit the only way forward is to work as a team. No-one can have all the skills and knowledge required to master all stages of the process. This is really a story of collective will, of teamwork, of multi-cultural collaboration and of a common purpose.

Various recording systems in the tomb of Tutankhamun.  
Recording surfaces at this level of detail takes time and is a highly focused. But it means that many hours are spent looking at and discussing the surface of the tomb resulting in an intimate knowledge of the problems.  
Inset left: Pedro Miró, Mohammed Kahlil and Grégoire Dupond inspecting data in the tomb.



## THE SETI SCANNER (LASER SCANNER)

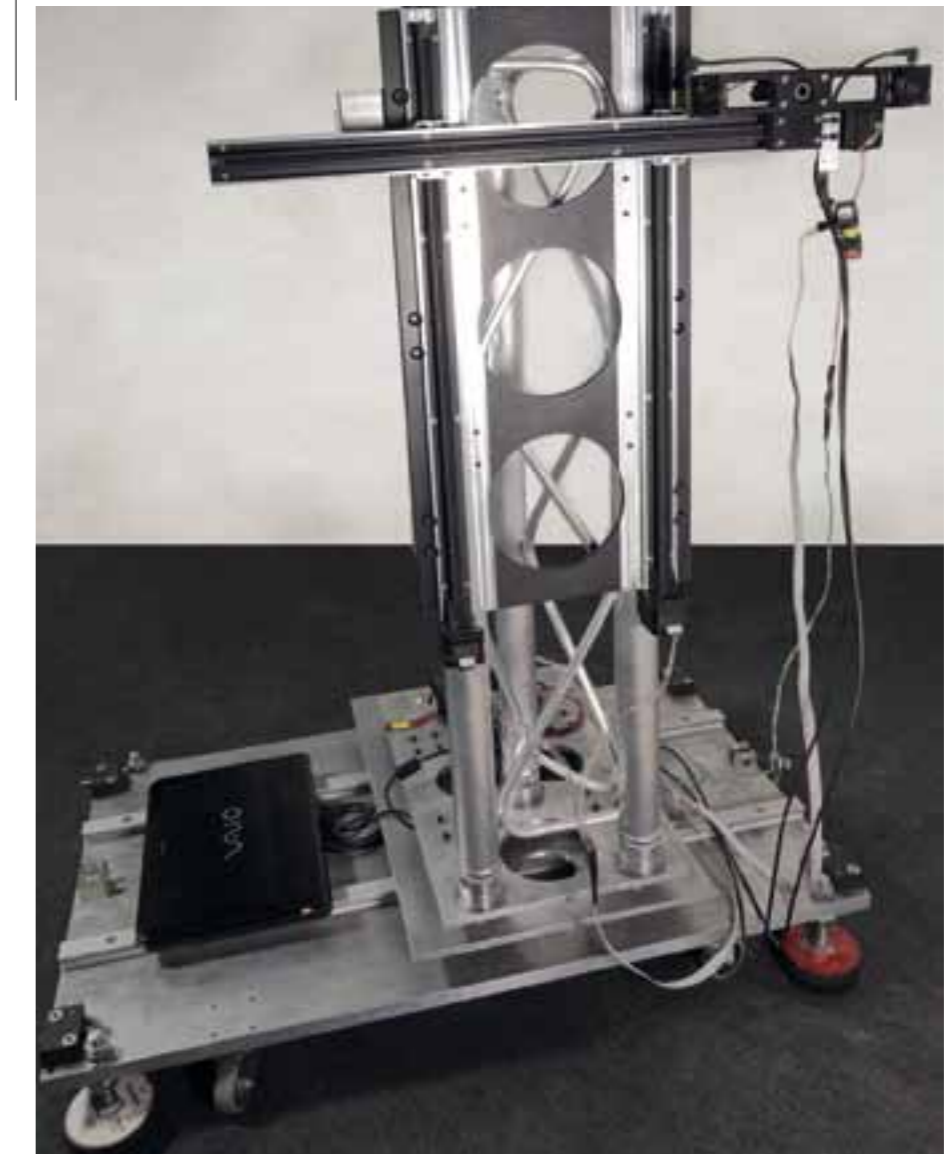


Piers Wardle working with the Seti Scanner (version 3) in the confined space of the burial chamber of Tutankhamun.

Seti Laser Scanner was originally developed for work in the tomb of Seti I in 2001. It was based on a two camera, one laser system designed by 3D Scanners UK and marketed under the name Reversa. It was initially selected because the correspondence between the actual surface and the recorded data was very close. This was due to the fact that it recorded the surface in an ordered grid of 100 million measured points per sq meter. Over the years it went through several significant improvements- both to the laser scanning head (in collaboration with Metris, Belgium) and to the frame that positions the head (with IPREM, Madrid).

After years working with laser scanning various practical issues have become very clear. The most significant is the need to control the costs of both the recording systems and the software used to post-process the data. This has resulted in significant research by FactumArte's engineers into the most efficient way to handle the data and also into the development of a high-resolution cost-effective lightweight scanner (the Lucida scanner). The scanner has been in development for the past two years and is now finished. The software, controlling both the operating system of the scanner and the processing of the data is also complete. The software handles the 3D information as a tonal depth map that is compatible with most existing software packages. This removes the need of expensive 3D software to handle the data while working.

## THE LUCIDA SCANNER (LASER SCANNER)



Lucida 3D laser scanner has been designed by Manuel Franquelo and made by Factum Arte specifically for work on high relief surfaces in the tombs in the Valley of the Kings. Its design has addressed many fundamental issues that relate to the 3D scanning of cultural heritage – cost, data storage, software and the correspondence between the surface of the original and the scan. The two most important features of the scanner are its automatic 'double scan' (so that it can record light and dark colours and glossy surfaces) and the fact that the data is recorded as raw black and white video. Recording raw video files is essential to the Factum Arte approach to high resolution scanning. Most laser scanners abstract the information as it is being recorded and rely on expensive 3D software to process the data. The Lucida scanner works with its own software. The un-abstracted data is archived in its raw form and then processed and supplied to the client in a form they can use. This will allow for the re-processing of the raw video files in the future, at a higher resolution and it dramatically reduces the operating costs and facilitates safe and simple data storage. The Lucida scanner can be operated by one person. The software's graphic user interface is intuitive and simple to use. It is light-weight and easy to transport. It has been designed for use recording sites with difficult access and extreme conditions. The whole system is battery operated.

In the Tomb of Tutankhamun all the walls were recorded with the white light scanning system at three different resolutions: 200 microns, 400 microns and 700 microns. While this level of accuracy was sufficient in this tomb it will not be adequate for the tombs of Seti I and Nefertari where we will also need to record relief. The scanner can operate at higher resolutions but this requires more time both in the recording and post processing. Factum Arte's approach is to use the white light system in tandem with the Lucida laser scanner.



### THE SIDIO PRO SCANNER (WHITE LIGHT SCANNER)



Factum Arte has been using a Nub3D Sidio white light scanning system (this page and overleaf). SIDIO is a scanning system that employs a mix of optical technology, 3D topometry and digital image processing to extract 3D coordinates from an object's surface. This technique is known as structured light triangulation. 3D information is acquired by analyzing the deformation caused when parallel lines are projected onto the surface of an object. A series of images are captured by a camera that is integrated into the recording head. This process is performed within seconds. From these images the scanner can calculate with great accuracy a co-ordinated XYZ point cloud relating to the surface of the object. Dense point clouds of millions of points or polygon meshes are generated describing the surface of the scanned object with precision. The recording in the tomb was carried out and processed by Pedro Miró. All data was archived as original TRI files, PIF files, Polyworks files and control tests.

High resolution photographic data is essential to monitor the conditions in the tombs and to develop a deeper understanding about how they were made and the dangers that they now face as a result of high levels of tourism. Inset – Grégoire Dupond and Pedro Miró working in the Tomb of Tutankhamun.



## PARALLEL PHOTOGRAPHY



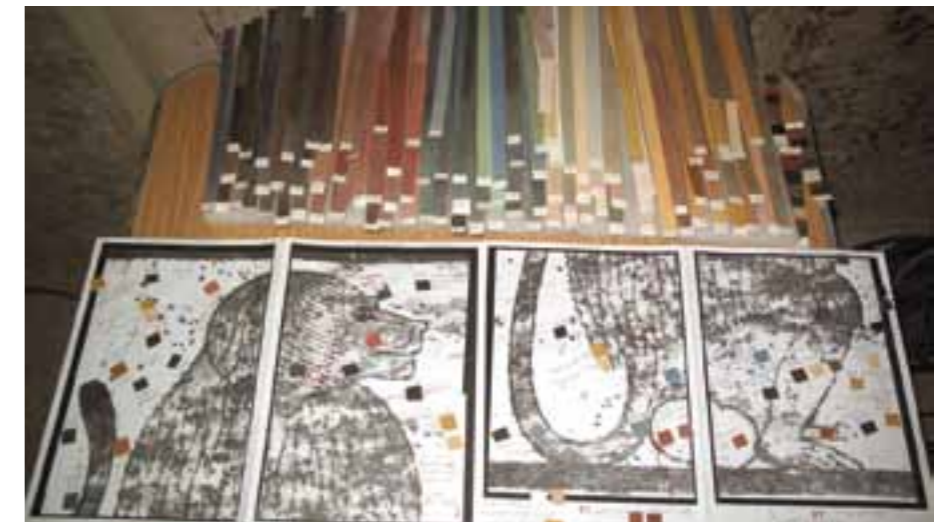
For the recording in the tomb of Tutankhamun two different computer-controlled structures were used to place the camera at a fixed distance parallel to the surface of the wall. The entire tomb was photographed using a Canon EOS5DII with either a 100mm or 180mm macro lens (above). Over 16000 photographs were taken providing a complete photographic map of the surface with a resolution of between 600 - 800 DPI at 1:1. The total photographic archive is approximately 300 gigabytes of data. This level of recording provides visual information about the condition of the tomb that will be essential to monitor the level of decay and rate of change that is taking place in the tomb (left). This photographic data was supplied to the Getty Conservation Institute with the permission of the SCA and is being used in the compilation of their report on the condition of the tomb.

Since 2009, Grégoire Dupond has been looking at ways to improve both the speed and accuracy of the photography. The solution is to mix panoramic photography with the parallel recording. For future recording a Dr Clauss HD panoramic head and a 'slave' flash unit working with a UV filtered Elinchrom high-speed flash head will make it possible to record in a more coherent way while exposing the tombs to lower light levels.





## COLOUR MATCHING

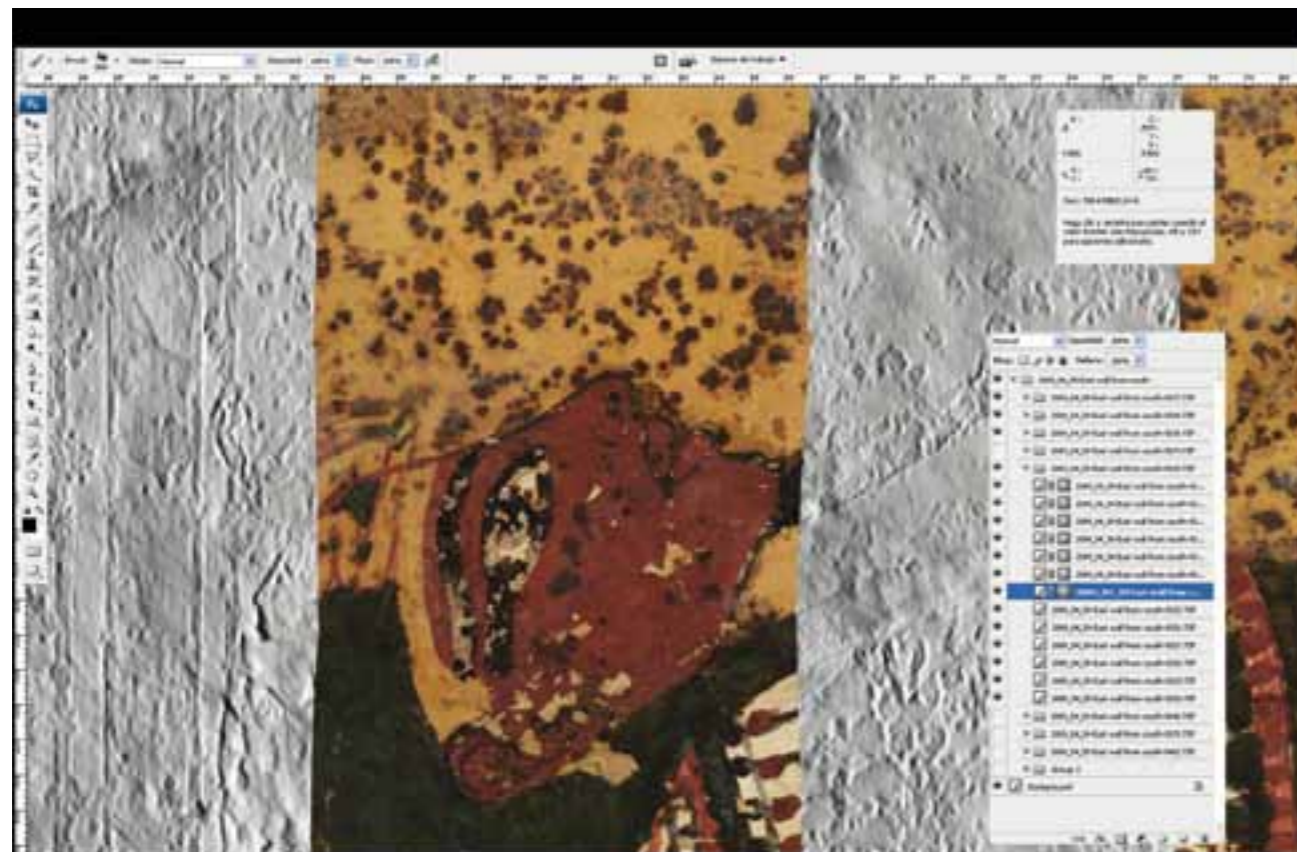
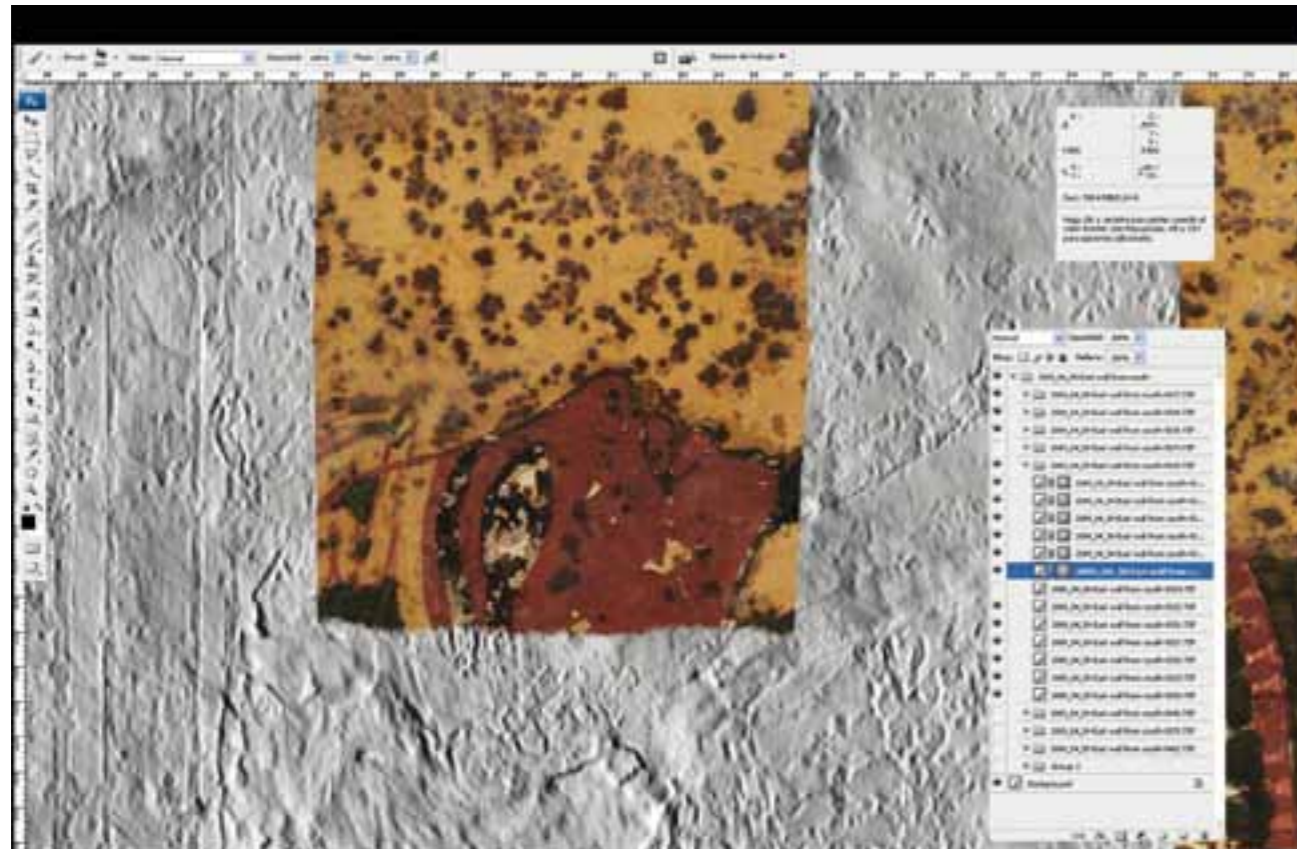


Factum Arte's conservator, Naoko Fukumaru (top), was in charge of making colour reference samples that are an important part in the production of the facsimiles. In order to produce a facsimile that has accurate colour it is necessary to be able to compare colours of the original with colours of the facsimile. The facsimile has been made so that the colour looks identical under the same lighting conditions that exist in the tomb (left).

The main difficulty of recording the colour 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 interference has resulted in an inconsistent and intricate surface. Even within a tiny area of colour there is a wide variety of hue and tone (above).

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 the 3D information, but this supplements rather than replaces, close observation of the painted surface in the tomb. A detailed survey of surface effects focused on recording 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.

MERGING 3D AND COLOUR DATA



Factum Arte's approach to the production of high resolution facsimiles is dependent on the merging of the 3D information of the surface and the high resolution colour photography recorded in the tomb. This work is time consuming and highly focussed. As technologies develop it is becoming more automated but it still requires high levels of human intervention to ensure that there is a perfect fit between colour data and surface data. The majority of the stitching of the colour and 3D data was undertaken by Grégoire Dupond, Pedro Miró, Blanca Nieto and Alicia Guirao who carefully assembled and archived the four walls of the tomb.



## ROUTING



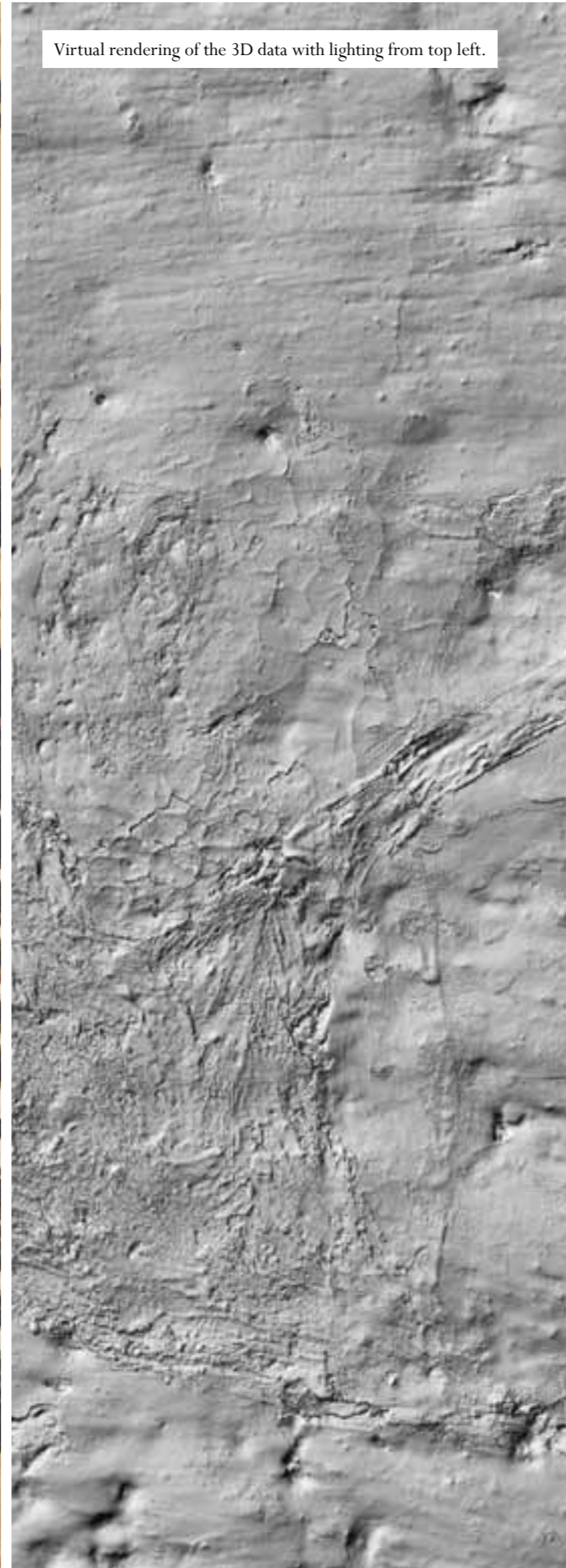
At a time when many people are just starting to understand the role virtual models can play in studying and presenting cultural heritage Factum Arte has gone one stage further. The work we are proposing for the Valley of the Kings is a two way process – from the real world to the digital archive and then from the digital files back into the physical world without significant change or loss of detail.

This work has been possible for a while but the costs have been prohibitive. Now, due to a highly focussed and motivated team 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. The most time consuming and expensive part of the process is routing the 3D data into polyurethane panels at high resolutions. The work within Factum Arte is carried out by Javier Barreno and Pedro Miró using ArtCam software and Victor 3 axis routing machines.

To rout a 1 x 1 sq meter panel in 3D at a resolution of 300 microns takes approximately 400 hours. In order to rout the entire surface of the tombs of Nefertari and Seti I in relief at this resolution will require 50 machines working for 10 hours per day for 3.5 years. It is intended that all this work will be done in Luxor with local people specially trained to carry out this work.



Original wall photographed at high resolution with and even light in order to flatten the relief and prioritised the colour.



Virtual rendering of the 3D data with lighting from top left.



Physical output from 3D data routed into polyurethane with lighting from the centre-right.



Final facsimile photographed with raking light to reveal the surface.





The preparation of an elastic printing media was a direct response to practical need. Factum Arte's flatbed digital printer cannot print a detailed and focused image onto an undulating surface. A layered mixture of 3 different materials was the final solution. It was developed by Rafa Rachewsky, Silvia Rosende and Adam Lowe. The resulting material is a thin flexible 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 mold. The work to make and position the skins was done by Aniuska Martín and María del Carmen Pascual.



## PRINTING



The printing of the facsimile was done by Rafa Rachewsky using a flatbed inkjet printer. For many years this printer has been at the centre of Factum Arte's approach to the production of facsimiles. With this printer the image can be built up of layers 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 materiality of colour presents a different set of challenges. The colour is corrected both virtually and in the printing process. The first step is to print the high resolution photographs onto the 'skins' and compare the result to the color samples made in the tomb by Naoko Fukumaru. The color adjustments are done with the use of Adobe Photoshop. Due to the fact that the image is multi-layered the approach to the preparation of the print files is based on experience and the skill of the operator.



### POSITIONING AND FIXING THE SKINS



Once printed the flexible skins are positioned using a slow-cure contact adhesive. Sight and touch are both essential to ensure the exact relationship between the surface and the colour. Working with a raking light the skin is positioned and re-positioned until all details in the printing correspond to the underlying surface. Once positioned correctly the skin and the relief are put into a vacuum bag and pressure is applied evenly until the adhesive has cured.





Due to the gossamer-like character of the skin when it is fixed to the surface it takes on the character of the wall of the tomb.



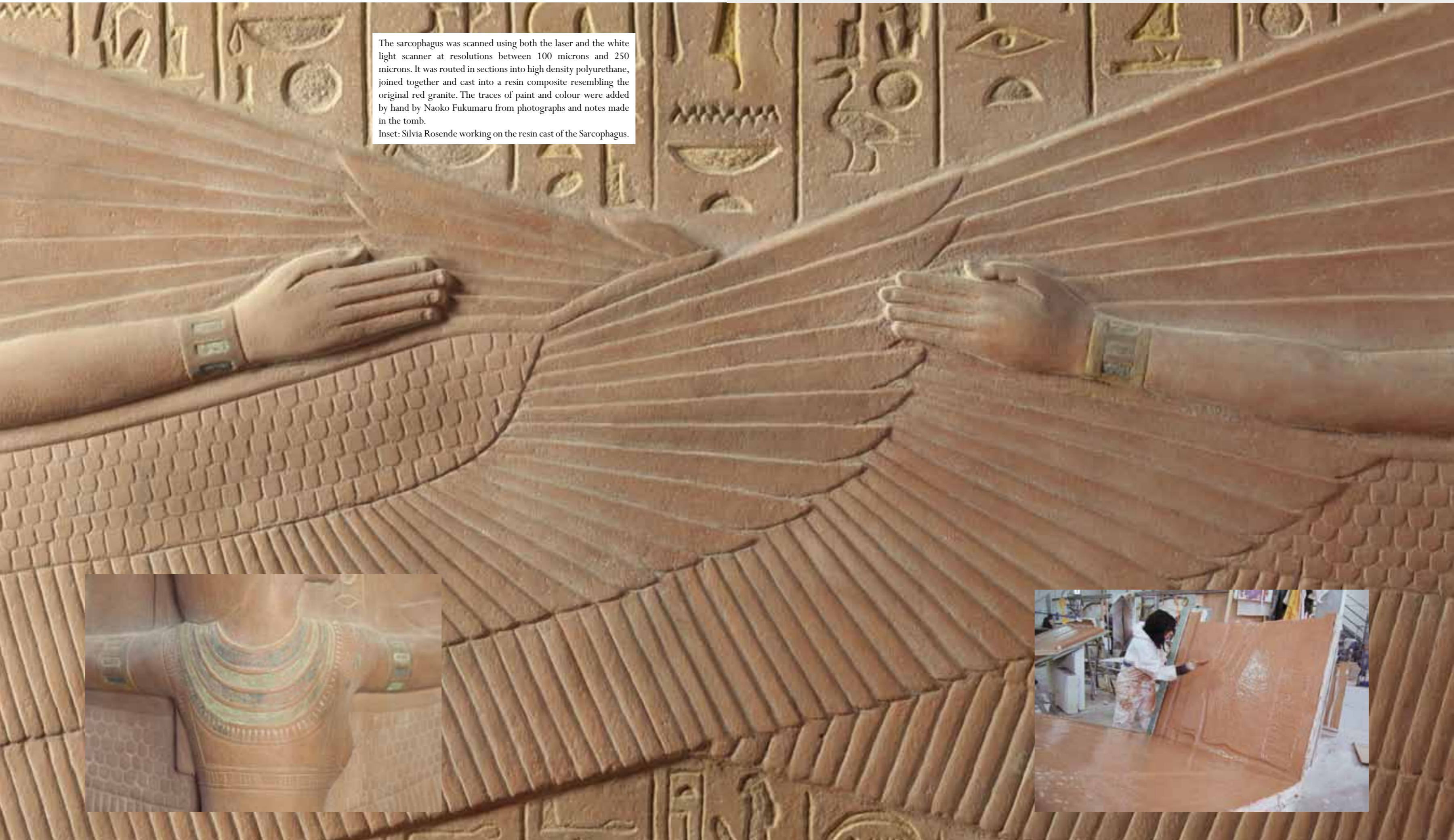
### ASSEMBLING THE FACSIMILE



The burial chamber is assembled from interlocking panels that are bolted together from the outside. It has been designed for ease of transport and assembly. Once the tomb is assembled the final joins are filled and re-touched. The proposed lighting for the facsimile is the same as the lights used in the Valley of the Kings. Once installed in its final destination it will be possible to work on the acoustics and temperature of the facsimile in order to increase the similarities between the original and the facsimile. The control of humidity and temperature can also be used to demonstrate to the visitor the impact of these dynamic conditions can have on the original tomb.



The sarcophagus was scanned using both the laser and the white light scanner at resolutions between 100 microns and 250 microns. It was routed in sections into high density polyurethane, joined together and cast into a resin composite resembling the original red granite. The traces of paint and colour were added by hand by Naoko Fukumaru from photographs and notes made in the tomb.  
Inset: Silvia Rosende working on the resin cast of the Sarcophagus.





The sarcophagus lid, made from a different granite to the rest of the Sarcophagus was scanned, routed and cast in scagliola, a composite substance made from selenite, glue and natural pigments, imitating marble and hard stone like granite – the material was used by the Romans but became popular in the C17<sup>th</sup>. Sebastián Beyró made many tests to match the grain and colour of the lid and to ensure that the final result has the character of the original.





## THE CEILING



The unplastered ceiling in the tomb of Tutankhamun reveals many details of the way the tombs were carved and prepared. Lines of chisel marks, each about 1cm wide, appear to have been made to level off protusions and irregularities in the surface prior to plastering.

A large fracture runs across the ceiling of the burial chamber and extends into the antechamber and there are also some restored areas of plaster infill. Traces of paint and plaster from the decoration of the walls extend onto the ceiling in a number of places. There is little evidence of the micro-bacteria that covers the wall suggesting that this was feeding off the animal glue which was probably not completely dry when the tomb was sealed.



## SOUTH WALL: RECOVERING THE MISSING PIECES



Working with assistance from the Griffith Institute in Oxford, who supplied a scan of Harry Burton's black and white photograph of a fragment removed from the south wall of the Tomb of Tutankhamun, Blanca Nieto has reconstructed its colour using the high resolution documentation of the south wall recorded in the tomb in 2009. In a painstaking process the photograph by Harry Burton was enlarged and closely studied. The fragments that remained after the wall between the antechamber and the burial chamber was removed were each defined and separated from the sand into which they were set by Howard Carter. The tones of the black and white photograph were carefully studied and matched to the colours used in the tomb. The figure of Isis has her own iconography so the colours on her necklace and bracelets are easy to identify. However the three gods on the left side of the panel are unknown. As it was impossible to confidently attribute colour they have been left in monochrome. The surface was carved by hand, prepared with plaster and gesso and printed on the flat bed printer.

The 'missing fragment' was taken out of the tomb in order to remove the objects, it's current whereabouts is unknown. The re-integration of missing sections of the tombs is an important part of the work that is being proposed. This will be especially important when recording the tomb of Seti I- there are well over 100 fragments in museums and collections around the world- the largest being two symmetrical door posts that were removed from corridor G and are now in the Musée du Louvre and the Museum of Archeology in Florence. These two fragments each have their own restoration history – they now look very different from each other and from the original tomb.

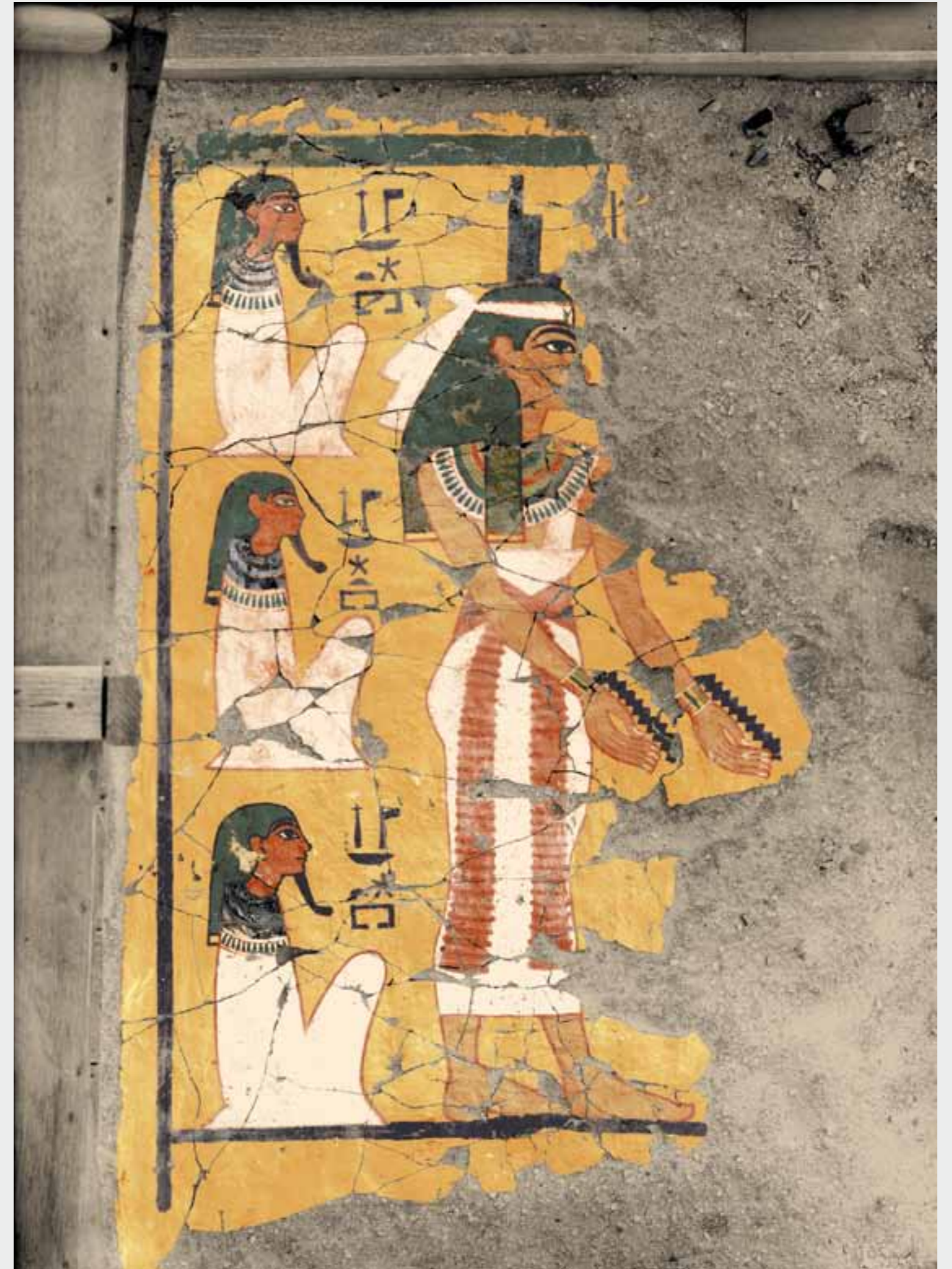


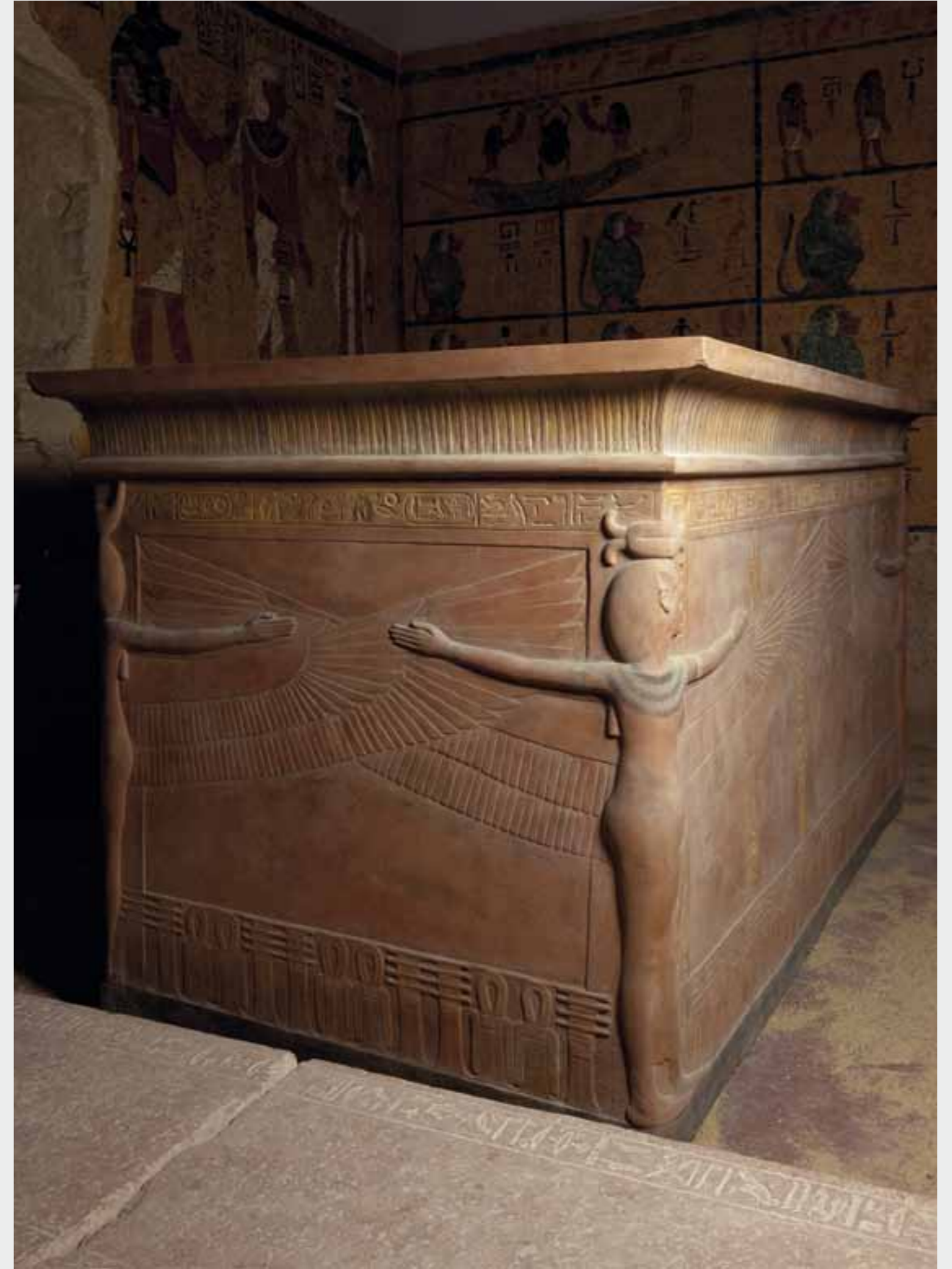
## COMPARISONS

BETWEEN PHOTOGRAPHS TAKEN BY  
**HARRY BURTON**  
AT THE TIME OF THE DISCOVERY OF THE TOMB IN 1922

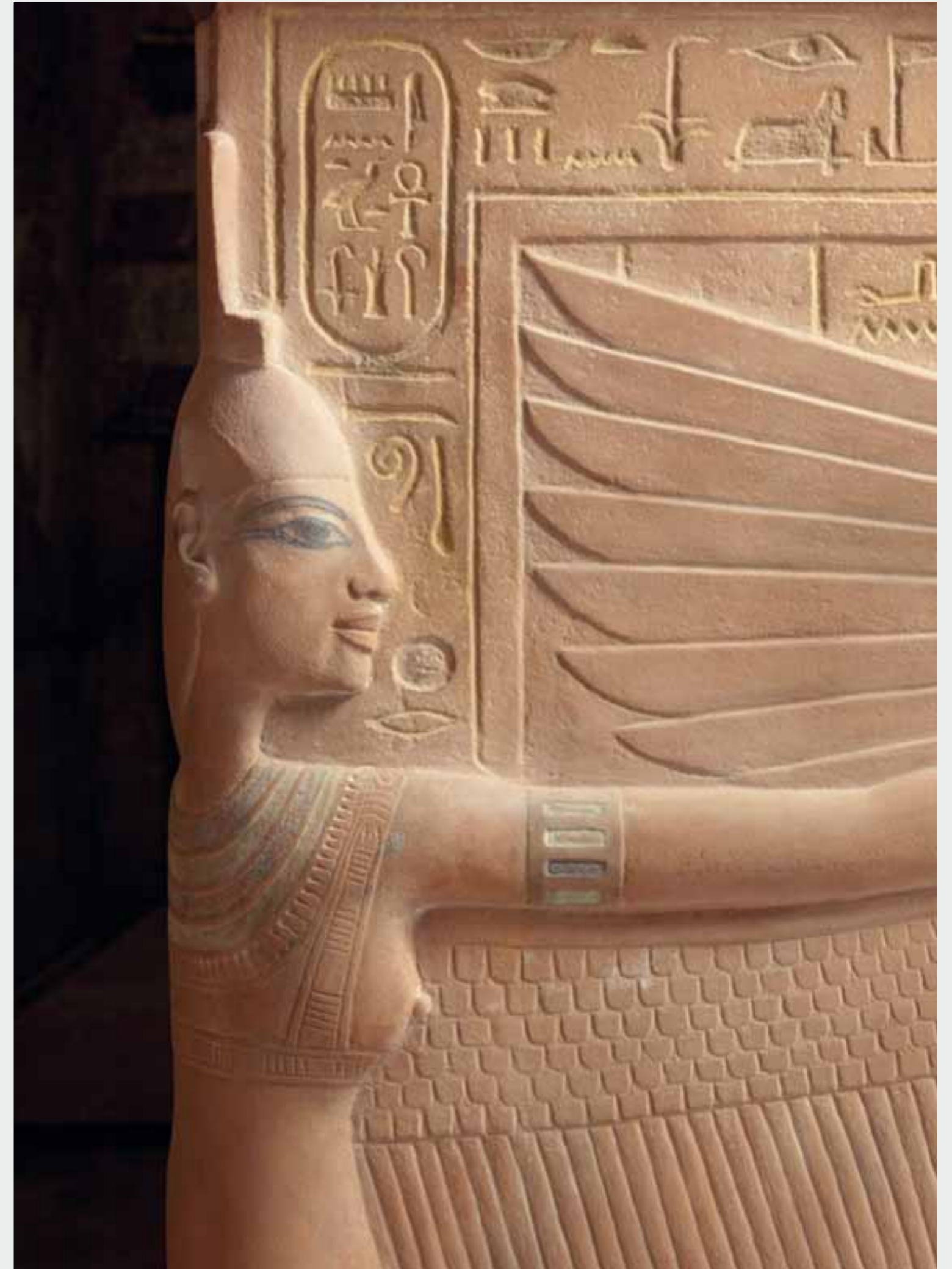
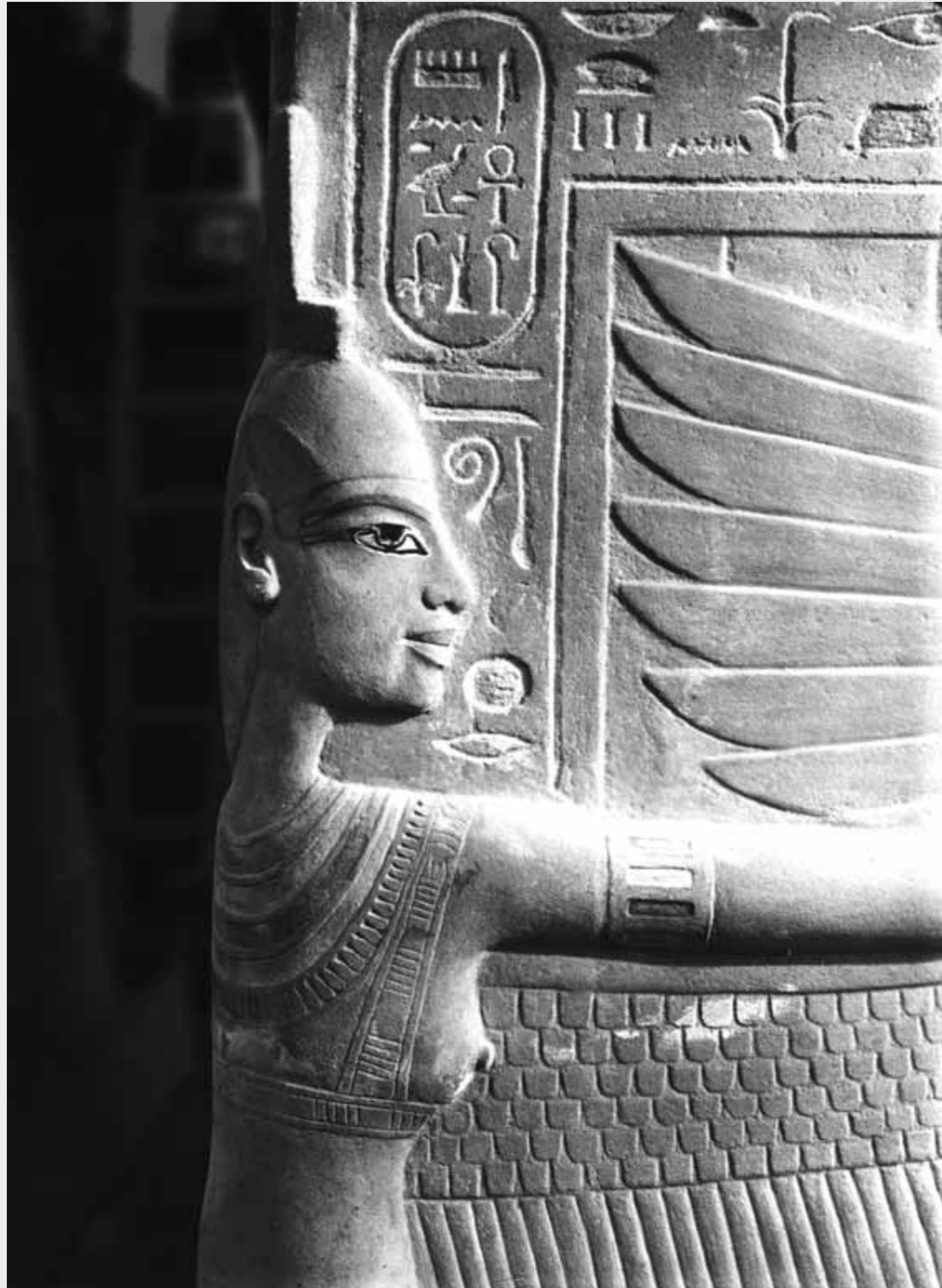
AND  
PHOTOGRAPHS TAKEN BY  
**ALICIA GUIRAO**  
IN 2012 OF THE FACSIMILE IN FACTUM ARTE'S WORKSHOP IN MADRID











## THE NEXT PHASE:

During the time spent working in the Valley of the Kings, Factum Arte has developed a number of significant innovations in both recording technologies and material processes that have resulted in some dramatic advances in our ability to record and re-create objects of cultural importance. It is now possible to work with the Arab Republic of Egypt to move to the next phase – the recording and re-creating the tombs of Seti I and Nefertari. Both of these tombs are closed to the public. The aim is to reopen them in facsimile form within the context of carefully designed exhibitions and with an emphasis on the reasons for their continued importance. At the same time the tourists visits to these facsimiles will generate extra revenues and provide funding to protect the originals and to pay for the documentation and preservation of other sites in Egypt that are less famous but no less important.

## NEW FACSIMILES:

The planned recording, archiving and facsimile construction for installation in a new visitor centre in the Valley of the Kings will be a major undertaking, but one that will not only save the greatest tombs for posterity but also build a level of skill and knowledge in Egypt that will allow for a continuing process of preservation of the cultural heritage. In this schedule of work Factum Arte and the Society of the Friends of the Royal Tombs of Egypt will manage the transfer of technology and skills to a local team in Luxor – providing all the equipment necessary to establish one of the most advanced workshops in the world. This will be done in a way that ensures a level of skill and knowledge so that employment in the area can increase as new projects are initiated.

This technology transfer has been at the heart of the relationship with the SCA since the start of the work in 2001: Factum Arte wants to share its technology and knowledge in such a way as to create a sustainable centre devoted to the use of new technology in conservation in Egypt. The hope is that, with such a wealth of cultural heritage in Egypt from Pre-Pharaonic times to the present day, a practical workshop of this kind will grow and develop. As a result it will not only preserve what we already know but the application of technology mixed with human skill will lead to new discoveries about the past and in doing so secure the future for both cultural heritage and the local community.

## COST, FUNDING AND SCALE OF THE TASK:

The magnitude of this task needs to be understood, as does the requirements in terms of plant and time. A lot has been achieved over the past 10 years. Now it is time for the practical application of this approach.

The Tomb of Seti I is approximately 2,300 m<sup>2</sup> of coloured relief carving. The complex surface reveals many different types of natural decay and human intervention that have taken place since it was discovered by Belzoni in 1817. The Tomb of Queen Nefertari is about 900m<sup>2</sup> and has a recent conservation history. Between 1986 and 1992 the Getty Conservation Institute undertook a condition assessment, analysis, emergency treatment, and conservation of the tomb. As a result there is a clear body of evidence of the condition of the tomb in 1992 that can be compared to the current condition of the decoration. Before 1989 the build up of salt crystals was pushing the plaster and pigment away from the limestone walls. However the consolidation methods have since been questioned and the tomb has been closed to the general visitor for several years.

These two tombs, of great importance for an understanding of the importance of the Theban Necropolis, need to be recorded and their condition monitored. The data that will be created by recording also creates the opportunity to create exact facsimiles that not only make them accessible again but will reveal the complex biographies of these famous sites. The recording at a resolution necessary for an accurate facsimile and for an archive of value to monitor the condition of the tombs will take a significant amount of time. In planning the work on these two tombs Factum Arte is assuming that the recording, archiving and practical fabrication of the facsimiles will be carried out in parallel. In this way the process will be accelerated and the time to completion reduced.

Factum Foundation and the Society of Friends of the Royal Tombs of Egypt intend to find the funding for the entire process. It is estimated that the total required will amount to €20 million (a detailed costing and workstream schedule has been prepared). The funding to carry out the recording and to make the facsimiles will be raised from global foundations, institutions, corporations and individuals. Ticket sales will fund a visitors' centre and the recording and conservation of other sites in the Theban necropolis. The hope is that this model will be extended to assist with the preservation of various of sites in different parts of the country.

The tombs will be recorded by an Egyptian team based on the West Bank, Luxor, working with the experts from Factum Arte. The data will be centrally archived and processed. It will be stored and supplied to the teams in Luxor working on the different processes required to make the facsimiles. The 3D recording will be done using six Lucida scanners provided by the Factum Foundation. The

local operators will be trained by a team from Factum Arte as part of a significant transfer of technology and skill. It is important that the recording and facsimile production is carried out locally and benefits the local community. The main employment will come from the installation of fifty high-specification routing machines located in the West Bank in workshops provided by the Supreme Council of Antiquities and the City of Luxor. These workshops will become a permanent facility for the preservation and conservation operations and it is anticipated that they will become a visitor destination themselves. The initial cost of setting up the workshop will be over €1,000,000 (the assessed cost of the routing machines alone is €750,000). Each of these machines will be operated for at least ten hours per day and will require one operator for every three machines with an overseer for the whole process. Routing at this high level of accuracy is time consuming (it takes a little more than four hundred hours to route a single square metre) but essential for the success of the facsimiles.

It is anticipated that the facsimiles of the tombs of Seti I and Queen Nefertari will take 5 years to complete.

## TRAVELLING EXHIBITIONS:

In addition to creating a facsimile of the tombs of Seti I, Nefertari and Tutankhamun within permanent visitor centres in Egypt, there is an opportunity to create second facsimiles for touring exhibitions. This will add considerably to the potential for sponsorship and the generation of additional returns to the people of Egypt. The scale and magnificence of the tomb of Seti I, in particular, is of such an order as to suggest that major capital cities around the world would vie to have the facsimile exhibited as a major attraction; this competition would provide the opportunity for front ended payment as well as a revenue trail lasting many years. The exhibition would focus on the text in the tomb, its history since its opening by Belzoni, the fragments that were removed in the c19<sup>th</sup> and the damage caused by the 'squeezes' that were taken from the walls (raising the subject of changing attitudes of tourists and tour operators). The facsimiles of the tombs of Seti I and Nefertari are a powerful medium to communicate an understanding of the conservation and preservation of Egypt's immense cultural heritage.

## SUSTAINABLE TOURISM:

This description of the work to provide the facsimiles for the visitor centre at the entrance to the Valley of the Kings, a touring exhibition and training and employment of many Egyptian nationals requires an investment of an estimated €20 million. This investment will offer a model for a new approach to sustainable tourism. The aim is to create a centre of such excellence that it will not only help educate the world to the challenges facing our heritage but it will also demonstrate that with careful management and political support a project like this can be self-financing and will generate revenues that will help preserve our shared cultural heritage for future generations to admire and study.

## CONCLUSION:

Society of the Friends of the Royal Tombs of Egypt, Factum Arte, the Factum Foundation and the University of Basel are committed to completing the work that has been started and to bring this innovative conservation project to a successful conclusion. A great deal of work has already been carried out. All the funding has been privately raised. The next phase requires a significant capital investment to equip and establish the workshops on Luxor's West Bank.

This Swiss/EU initiative will undertake the fundraising, the transfer of technology and skills to an Egyptian team and the management of all stages of the work up to the opening to the visitor centre containing the facsimiles of the tombs of Seti I, Nefertari and Tutankhamun. In return we require the the renewal of permissions granted by the Supreme Council of Antiquities and logistical support from the Ministries of Tourism and Antiquities. Working together we can achieve 'wonderful things' and ensure that the Tomb of Tutankhamun can be passed on to the next generation in good condition.

The work to produce facsimiles of tombs in the Valley of the Kings was started in 1988 by Theo Abt, Erik Hornung and the Society of Friends of the Royal Tombs of Egypt (Zurich). Since 2001 the Society of Friends of the Royal Tombs of Egypt has been working with Factum Arte (Madrid) to turn the idea into reality. Since 2009 the Factum Foundation has generated most of the funding required to produce the Facsimile of the burial chamber in the Tomb of Tutankhamun. All work in the Tomb of Tutankhamun was done under licence from the Supreme Council of Antiquities granted to the University of Basel on April 21<sup>st</sup> 2009. The recording in the Tomb of Seti I was carried out under a licence issued to the University of Basel on 30<sup>th</sup> October 2008.

The Factum Arte team involved in the production of the facsimile included;

Adam Lowe, Manuel Franquelo, Grégoire Dupond, Pedro Miró, Juan Carlos Arias, Rafa Rachevsky, Naoko Fukumaru, Carmen Figueras, Blanca Nieto, Dwight Perry, Lauren Canales, Aniuska Martín, María del Carmen Pascual, María González, Sebastián Beyró, Silvia Rosende, Damián López, Alicia Guirao, Gabriel Scarpa, Javier Barreno, Eduardo Corrales, Carlos Bayod, Mike Buffington, José Manuel Pellón, Teresa Solar, Celia Yllanes, Jimena Kato and Flavia Introzzi.

The temporary installation in the Conrad hotel, Cairo was done by: Michael Roberts, Michael Perry, Michael Ward, Otto Lowe, Alex Peck, Javier Barreno, Eduardo Corrales and Adam Lowe.

The Facsimile will be stored at the European Union Embassy until the site in Luxor is complete. It will then be officially gifted to the Arab Republic of Egypt.

All unattributed text by Adam Lowe.

Text © Adam Lowe

Text © James Macmillan Scott

Photo credits:

© Andreas F. Voegelin (Thutmosis III in Antikenmuseum Basel, page 11).

© Griffith Institute, University of Oxford for all the images taken by Harry Burton (pages 5, 62, 64, 66 and 68).

© Alicia Guirao, Grégoire Dupond, Juan Carlos Arias, Adam Lowe, Gabriel Scarpa for all the images taken by Factum Arte.

In a period of development that has taken over 10 years there are many people to thank both in Europe and in Egypt.

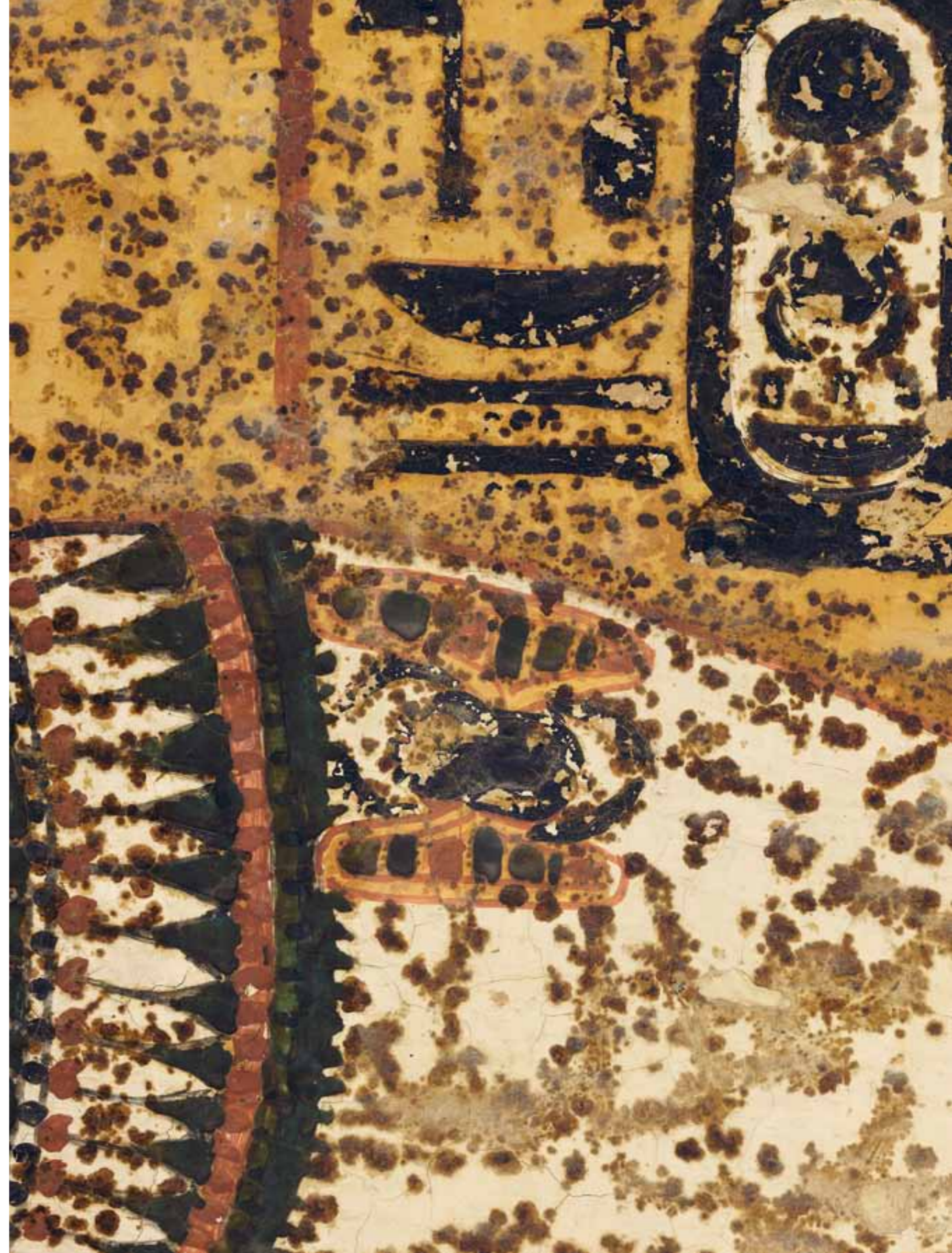
Thanks to: Soha Abboud, Mousa, Abdu, everyone at the Marsam and El Gazira Hotels, Mohamed Khalil, Mahmoud Mousa, Dr Magdy Mansour, Jess Ahmon, Dr Gaballah, Dr Hawass, Tarek Waly, Elhamy ElZayat, Lara Baladi, Charles-Edouard Held, Dr André Wiese, Dr Christian Loeben, Kent Weeks, Faiza Haikal, Ray Johnson, Francesco Bandarin, Dominic Asquith, Neville Agnew, Antonio Loprieno, William Owen, Jaromir Malek, Cat Warsi, Dominik Furgler, Nataliya Apostolova, Raquel Cabrera Alvarez, James Moran, Christian Leblanc, Salima Ikram, Mohamed Ismael, The Ministry of Tourism, Egypt Air and everyone from the Supreme Council of Antiquities both in Luxor and Cairo who have given so much assistance.



This book is dedicated to Piers Wardle who was at the heart of many things at Factum Arte until his sudden death in 2009, soon after finishing work in the tomb of Tutankhamun. His brilliant mind and true friendship are missed every day.

Designed by Blanca Nieto  
Printed by Julio Soto Impresor in Madrid, 2012  
Legal deposit: M-35006-2012

[www.factum-arte.com](http://www.factum-arte.com)  
[www.factumfoundation.org](http://www.factumfoundation.org)  
[www.slrte.ch](http://www.slrte.ch)





FACTUM arte

