Replication: Facsimiles are being used in cases where increased numbers of visitors are destroying the original sites. Lascaux and Altamira are two famous cases where painted caves have been replicated. The same approach has recently been applied to the Valley of the Kings. The aim is to provide visitors with an equivalent but authentic experience whilst at the same time protecting the original. The speed at which things are being destroyed is alarming!

Relocation: The Sala Bologna in the Vatican, rock art in Africa or sculptures high on the façade of a church are all examples where high-resolution recording and relocation may be applicable. Many things are overlooked because of their inaccessibility. Another use of relocation is for exhibition purposes when objects cannot be moved because of their size, fragility or material (for example Leonardo's Last Supper).

Return (a positive approach to repatriation): The return of Veronese's Wedding at Cana (torn out by Napoleon's troops) to Palladio's refectory on San Giorgio Maggiore, Venice was a collaboration between the Musée du Louvre, the Fondazione Giorgio Cini and Factum Arte from which everyone benefitted — especially the public and those interested in the meaning of the painting.

Re-unification: There are many cases in which an original work has been broken up and dispersed (The throne-room of Ashurnasirpal II, sections from the Tomb of Seti I or the Polittico Griffoni). When art was about aesthetic appreciation of discrete objects this was less problematic. When it is viewed as a complex subject revealed through the biography (career) of things a lot is lost. Re-unification of works or art can reveal a great deal about our ancestors' attitudes to originality, possession, and culture.

Re-visualisation: Re-visualising a painting like the Last Supper in new multi-media, multi- sensory displays like Peter Greenaway's interventions with paintings by Veronese and Leonardo da Vinci or Gregoire Dupond's animation or Piranesi's Carceri d'Invenzione reveal new insights into the original.

Reconstruction: a detailed study and re-construction of a missing object can help nurture our understanding about its relevance. The reconstruction of the 'missing panel' from the Tomb of Tutankhamun has resulted in observations about the micro-bacteria that covers the walls of the tomb.

Restoration: All the work supported by the foundation is non-contact and while we work alongside restorers and conservators our role is to provide them with information and monitor decay. Attention is being paid to the development of protocols for virtual restoration techniques.

Reversability: A word widely used in conservation that urgently needs revisiting. Looking after our heritage in a time of mass tourism is a difficult task but it is essential that the measures we take to protect, patch up and preserve an object don't result in further damage. The use of Paraloid on the painted surface of an Egyptian tomb will consolidate a flaking surface but it stops it breathing resulting in serious threats to its long-term preservation — it is not reversible without significant paint loss.

Redemption of Museum Loans: Objects move between museums, historical sites and collections. Sometimes they have been built into displays that make no sense without them (Gomez de la Serna at MNCARS, Madrid) at other times they have an important connection with a specific site (Princess Wallada's ivory box)

Re-evaluation: Re-evaluating the evidence of the past is an ongoing task. Treating originality as a dynamic process is resulting in significant insights and revelations.

Recording & Recovery: Documentation is essential for conservation and the development and application of non-contact recording systems is at the heart of the Factum Foundation mission.

Readymade: Culture and Nature are central to our concept of art and the development of museums. Some artworks appear ready-made and ready-formed but all are anachronic objects talking articulately across time.

Research: Bringing digital data together into one archive that can be stored and accessed in many places will transform the character of research.

Re-thinking the digital Archive: The storage of 3D information, the storage of colour data, locating and unifying historical photographs, revealing previous restorations, assembling X-ray and infra-red images that are often held by different institutions, generating meta-data and making this accessible requires a new type of archive and a re-thinking of the role of the archivist.

Re-creation: The role of high-resolution recording and facsimile re-creations using the same or equivalent materials in exhibitions and for conservation applications is one of the most important developments in the preservation of our cultural heritage. There are many motivations behind acts of recreation and they each raise different questions that require tailor-made solutions.

FACTVM
FOVNDATION
FOR DIGITAL TECHNOLOGY
IN CONSERVATION

'The projects of the Factum Foundation involve some of the most urgent and exciting developments in contemporary cultural heritage. Digital artisans and their collaborative skills are so impressive that it's easy to imagine that objects' conservation and reproduction simply leave things just as they are, unchanged and immortal. But the enterprise of documentation through advanced digital recording has the power entirely to transform the worlds of material culture and alter the forms of memory and artistry they sustain. The challenges of these new kinds of digital objects and cultural memories must be collectively understood and productively directed. Wounded artifacts may sometimes need heroic surgery, but they always need nursing, forms of artful care that sustain objects' lives and maintain their vivacity. This is why the Factum Foundation needs every support in its plans to encourage state of the art digital curatorship, and to use this curatorship to help transform the arts of the cultural state.'

Simon Schaffer,
Professor of History and the Philosophy of Science,
University of Cambridge,
author/presenter of *Mechanical Marvels: Clockwork Dreams*, A BBC documentary on automata.

The formation of the Factum Foundation

The Foundation was established in 2009 as a direct response to a number of very pressing demands; new innovations were making high-resolution panoramic photography faster and more affordable. Factum Arte's team was finishing the development of a 3D scanner to record the surface of paintings and was just about to start work on their own system that redefines the capture of surface and shape by using an unorthodox approach to the relationship between image and object. At the same time museums and heritage managers were realising that in order to attract new audiences in the C21st their collections needed to be viewed as archives capable of communicating the complex subjects embodied in the discrete objects in their care.

At this time Factum Arte was given the unique opportunity to record and make an exact facsimile of the Tomb of Tutankhamun. The aim of this work in the Valley of the Kings was to promote a new relationship between tourism and the preservation of a site of cultural importance to the world. The full 3D and colour recording of the burial chamber was completed in 2009 and in 2012 the finished facsimile was given to Egypt. The only funding available was provided by the Factum Foundation, Factum Arte and the Friends of the Royal Tombs of Egypt.

This was not the only project that required Factum Arte's unique mix of high-resolution documentation and the elaboration of the resulting information in innovative and inspirational ways. Several other works of importance were demanding action for different reasons: the rapid decline of the Romanesque cloisters in Tudela called for high resolution scanning, the restoration of the façade of San Petronio required high-resolution 3D documentation, the work on the reunification of the throne-room of Ashurnasirpal II was demonstrating what can be achieved with the right team and the right spirit.

This booklet focuses on some of the outcomes that have already resulted from the Factum Foundation's work – which has emerged from and been supported by Factum Arte. The Foundation's goals are to make the recording of surface a standard practice, to re-define the relationship between a facsimile and a vulnerable original, to create multi-layered archives to accelerate our understanding of the past and to find inspired ways to present digital data with emotional and meaningful impact.

Culture is not primarily a leisure activity – it is the only tool we have to ground us within our world – it defines our understanding of the past, conditions the way we act in the present and influences the shape of the future – without it we are lost. If we alter it in the wrong ways we diminish its importance. Once it is properly recorded we at least have a memory and as technology develops that memory can become more complete – The Foundation for Digital Technology in Conservation is committed to developing and applying technology to assist in the preservation of cultural heritage.

Adam Lowe

Factum Foundation's mission and aims

Advances in digital technology are dramatically and radically changing our understanding and appreciation of our shared cultural heritage. Science and technology are transforming the ways in which we see and think about art by providing forensically accurate information to both specialists and an increasingly interested public.

Factum Foundation is a registered foundation based in Spain, established in 2009 and dedicated to the development and use of non-contact high-resolution digital recording as part of a coherent approach to the preservation, dissemination and public exhibition of diverse types of cultural artifacts.

The Foundation is committed to developing the hardware and techniques required for high-resolution documentation in colour and in three-dimensions. The resulting data is essential for monitoring, study and conservation purposes. The accurate documentation of surface has never been successfully or systematically undertaken before and is the most glaring oversight in the management of cultural heritage. The recording of colour and things that lie under the surface is a rapidly developing field of expertise that needs to be integrated with the surface data – if we take our responsibilities to preserve the past seriously it is essential that this happens in the most effective, efficient and economical way.

The Foundation is dedicated to demonstrating that the way we understand the original object is as part of a dynamic process and not as a fixed state of being. When the dynamic nature of originality is successfully presented, works of art come alive – their complex biographies inform the present and influence the future. When viewed in this way they cease to be discrete objects to be viewed in museums and become complex subjects that can reveal their past and also reveal how they have been valued and cared for by previous generations in diverse locations and in very varied circumstances.

The conservation and preservation communities have realised the importance of high-resolution digital recording, which is now gaining wide acceptance. It is starting to be integrated into professional protocols and into the discourse that surrounds preservation. If developed in the right spirit, this change in attitude can, for instance, be used to turn cultural tourism into a pro-active force assisting in the preservation of important monuments and works of art. The aim of the Foundation is to ensure that future generations can inherit the past in a condition where it can be studied in depth and emotionally engaged with... can inherit what we inherited, with minimum and well documented interventions.

Mass tourism poses new challenges for the preservation of many great works of art. The concentration on documentation has also resulted in a fundamental re-appraisal of the role of exact facsimiles both installed in their original location and used in touring exhibitions. These facsimiles are clear evidence of the quality of the data, they are useful tools to monitor the changes that are happening to the original and they raise awareness amongst the growing number of visitors that the preservation of the past is a delicate, difficult and extremely important act.

James Macmillan-Scott

'At a time when control over big data is one of the most vital issues we face, Factum Arte is a leader in its field, providing cutting-edge technology and an ethical approach to conservation and artistic practice that offers international best practice for anyone working in the arts and humanities. Their remarkable fusion of art, science and digital technology has created unsurpassed methods of 3D scanning and printing that is transforming our understanding of originals and facsimiles. From the surface of an Old Master painting, to the recreation of Egyptian tombs and previously unrealised designs by Piranesi, Factum Arte leads the way in understanding how we can retain the integrity of the cultural heritage of the past, and preserve it for the future.'

Jerry Brotton,
Professor of Renaissance Studies,
Queen Mary's, University of London,
author of *A History of the World in Twelve Maps, The Sale of the Late King's Goods: Charles I and his Art Collection* and *The Renaissance Bazaar: from the Silk Road to Michelangelo.*

'[...] a vast network of artists, historians, technicians, and countless others, few of them known to one another, aggregate for the startling task, not of transcribing a 67m² painting almost half a millennium old, but of recreating it, re-originating it through many thousands of agonizing decisions, at dizzying degrees of fidelity. But fidelity not to some static original, but to a 'trajectory of transformations' set loose in the constantly changing run of social time. To fill a refectory wall at the height of the Renaissance with an ancient story of renewal is an act of mastery, faith, cohesion, exuberance, and conviction, To restore that same wall with that same painting of that same ancient episode – after Darwin, after Hiroshima, after the launch of interplanetary probes, after decolonization, after the onset of global warming and mass extinction, after nano-computing, after the discovery of the molecular basis of life – and to do so with technologies that have broken free of any individual's ability to understand now becomes an act of near-perverse regeneration. Those who had lost the ability to see anything at all in the aura-laden original will look again. New gatherings will be refreshed. Future pasts will be reformed. The reproduction awakens the original.'

Richard Powers,
Making things Similar,
a short story written about making the facsimile of Veronese's painting *The Wedding at Cana*,
read by the author at the Dialogo di San Giorgio, 2008.
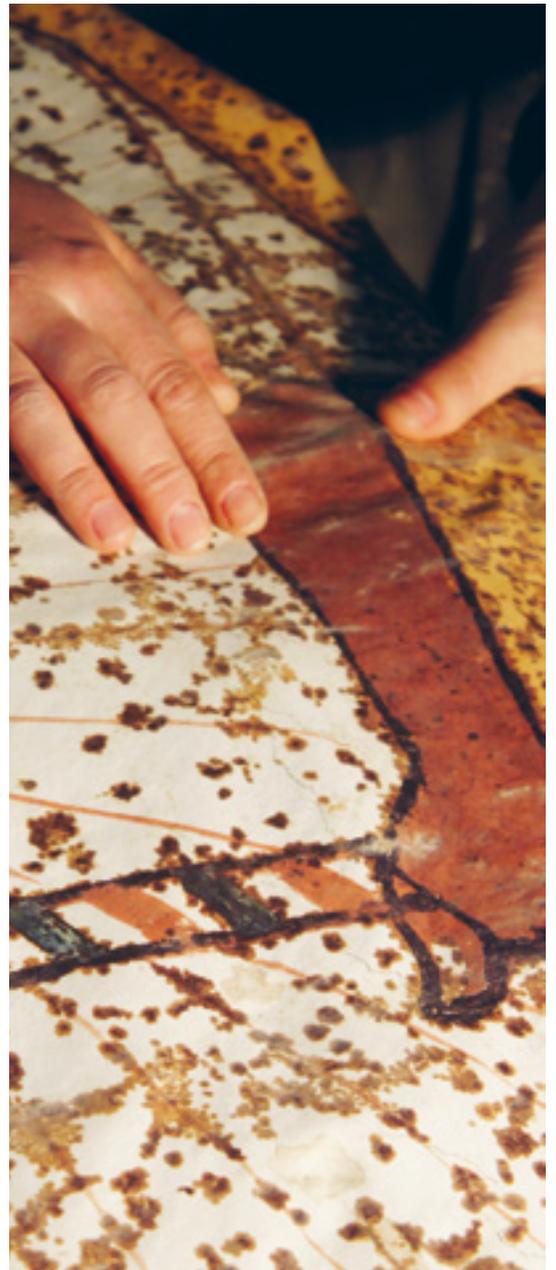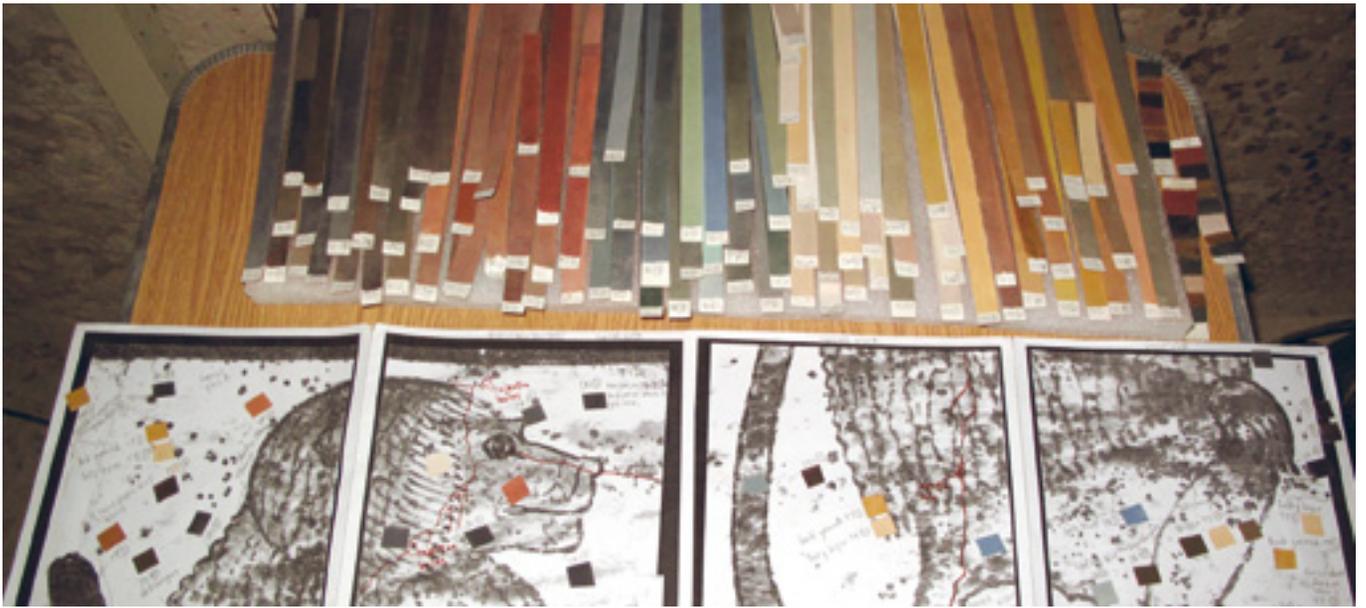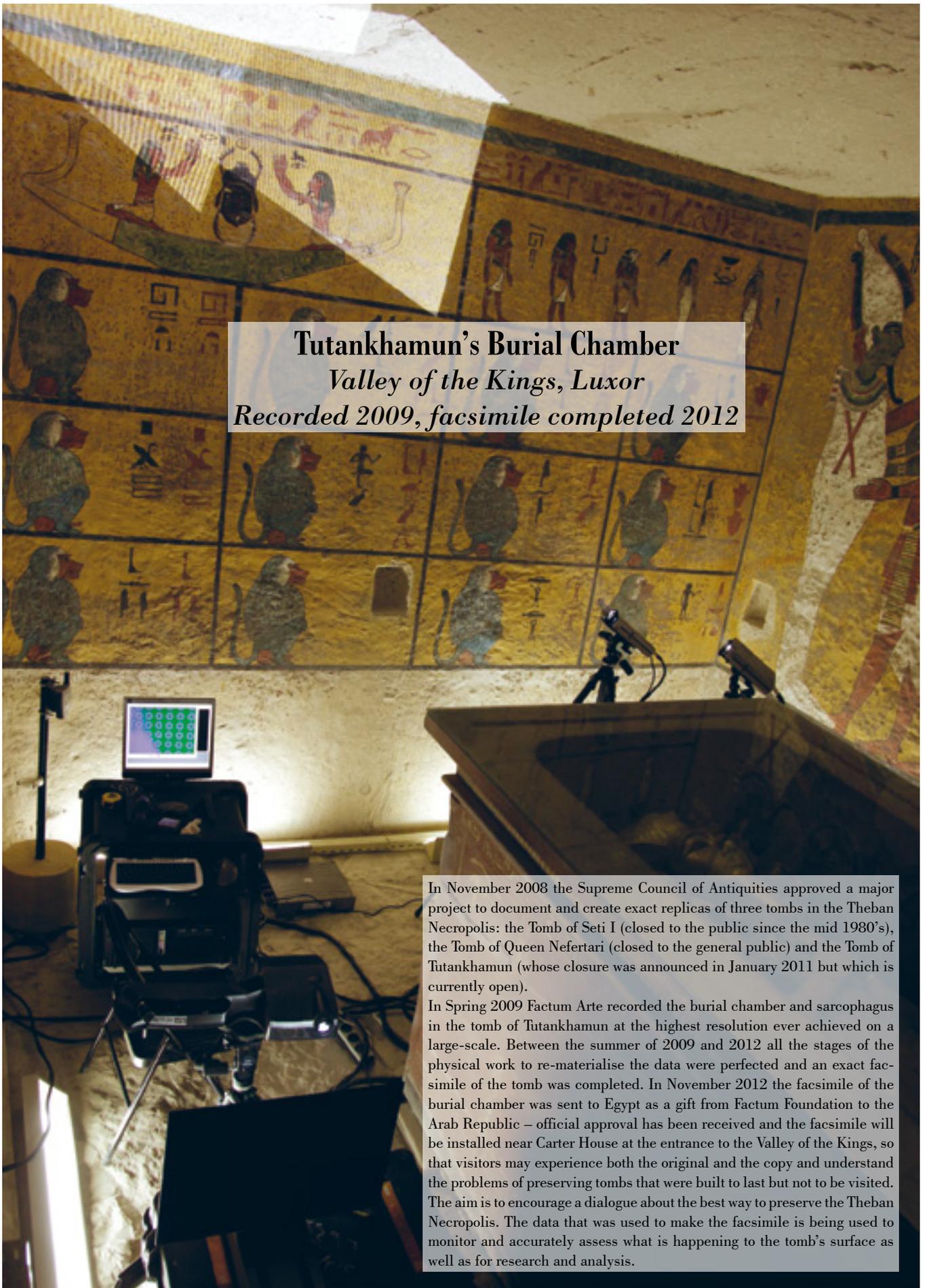
Tutankhamun's Burial Chamber
Valley of the Kings, Luxor
Recorded 2009, facsimile completed 2012

In November 2008 the Supreme Council of Antiquities approved a major project to document and create exact replicas of three tombs in the Theban Necropolis: the Tomb of Seti I (closed to the public since the mid 1980's), the Tomb of Queen Nefertari (closed to the general public) and the Tomb of Tutankhamun (whose closure was announced in January 2011 but which is currently open).

In Spring 2009 Factum Arte recorded the burial chamber and sarcophagus in the tomb of Tutankhamun at the highest resolution ever achieved on a large-scale. Between the summer of 2009 and 2012 all the stages of the physical work to re-materialise the data were perfected and an exact facsimile of the tomb was completed. In November 2012 the facsimile of the burial chamber was sent to Egypt as a gift from Factum Foundation to the Arab Republic – official approval has been received and the facsimile will be installed near Carter House at the entrance to the Valley of the Kings, so that visitors may experience both the original and the copy and understand the problems of preserving tombs that were built to last but not to be visited. The aim is to encourage a dialogue about the best way to preserve the Theban Necropolis. The data that was used to make the facsimile is being used to monitor and accurately assess what is happening to the tomb's surface as well as for research and analysis.

The Romanesque Cloister
Tudela Cathedral
Recording and facsimile production 2012

The Romanesque capitols in the cloister of the Cathedral at Tudela are crumbling to sand – the cause has been attributed to restoration work carried out in the 1950's. In January 2012 at the request of the Asociación de Amigos de la Catedral in Tudela, a team from Factum Arte recorded the complete capitol of *David y los Músicos* and one side of the capitol of *La Virgen*. The team used a NUB 3D Triple system to record the relief at a resolution of 240 microns. The aim was to evaluate potential problems and work out exactly what will be required to scan the complete series of capitols in the cloister as accurately as possible. At a public seminar in the Cathedral in January 2103, based on analysis of the data and findings it was decided that this work ought to be done immediatly, before further material loss inevitably occurs. To date no further recording has taken place and the material loss continues.

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The project to carry out a 'virtual' restoration of the vast bird's eye view map of Bologna's surrounding countryside, painted on the wall of the Pope's private quarters in the Vatican, began in April 2011. The original instruction was to record and recreate the map of the city of Bologna (the largest city map of the Renaissance) as the first stage of a plan to recreate the entire Sala Bologna. A physical facsimile of the map of the city of Bologna was created in 2011 for the entrance of the Museo della Città in Palazzo Pepoli in the centre of the city. During the recording it was observed that the adjacent landscape map was in poor condition – this lead to a focused discussion resulting in a digital restoration.

Factum Arte's team worked within the Vatican's Apostolic Palace to record, in high definition, images of the frescoes in the Sala Bologna – works originally executed under Lorenzo Sabatini's direction for Gregory XIII's Jubilee in 1575. The data was then processed and a digital restoration has been painstakingly and accurately completed. This virtual restoration can be used to understand the work in forensic detail and to develop an intimate understanding of the way the fresco has aged and changed. The virtual restoration was carried out with assistance from Francesco Ceccarelli and the University of Bologna. Great attention was paid to the historical and factual accuracy of the work. From this virtual restoration it is now possible to appreciate the beauty of the original wall painting and to analyse it in some depth – in order to form a clear and vivid idea of the appearance of the fresco at the time of its painting – without imposing anything onto the original.

Facsimile and Virtual Restoration of the Sala Bologna
Vatican City
Recording and facsimile production 2011
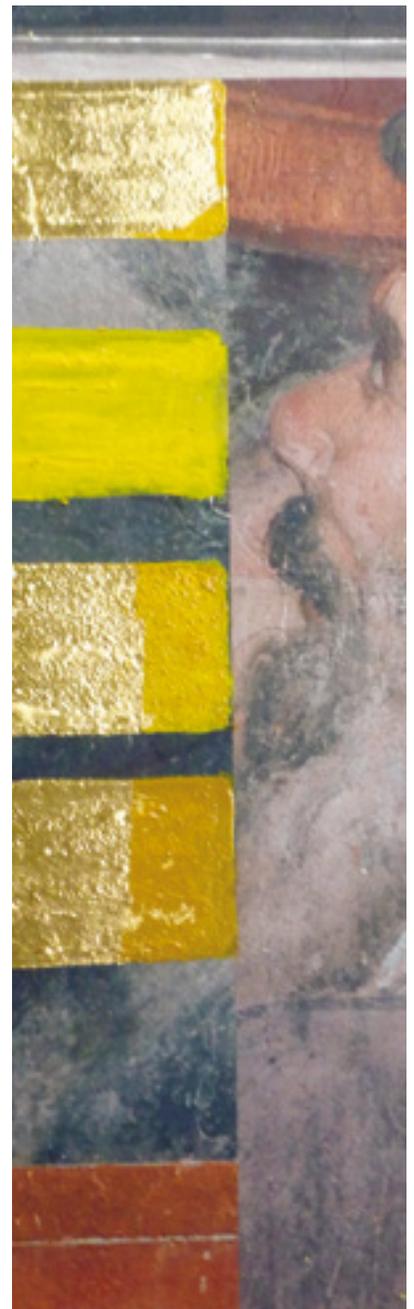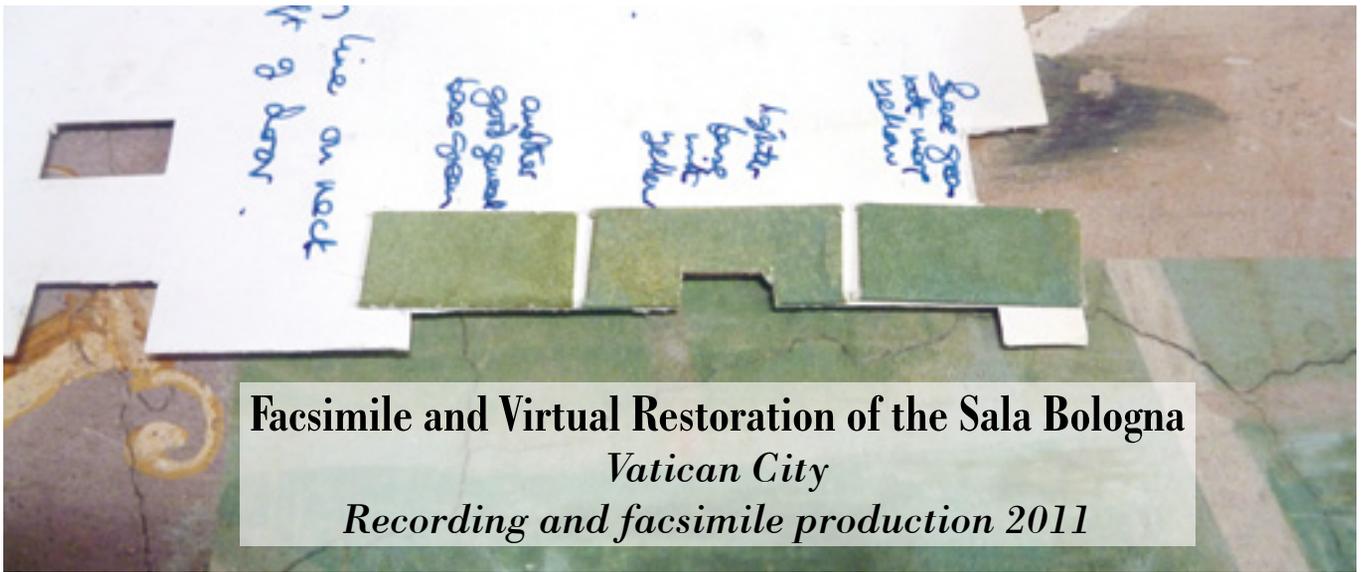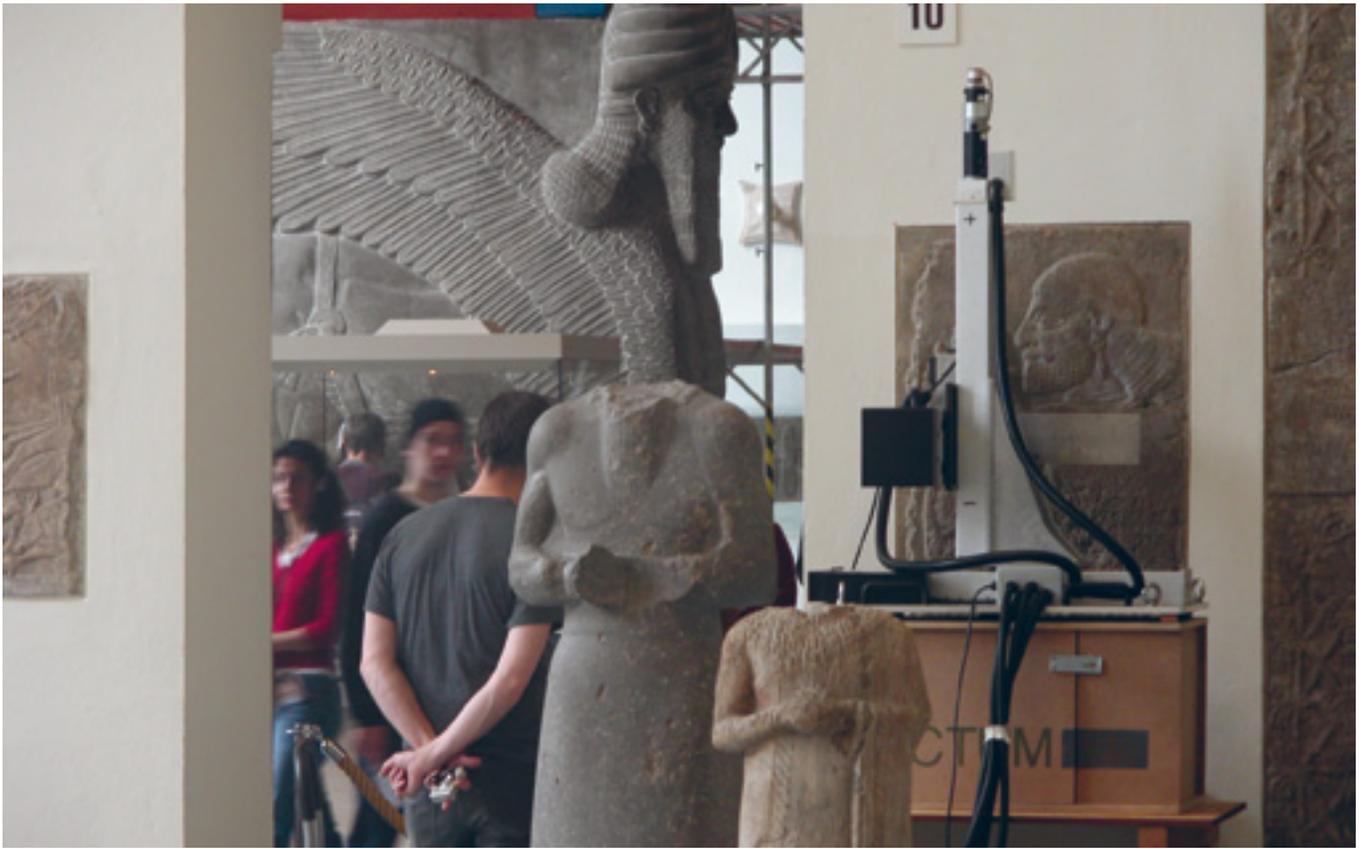
Recent and Current Projects

16
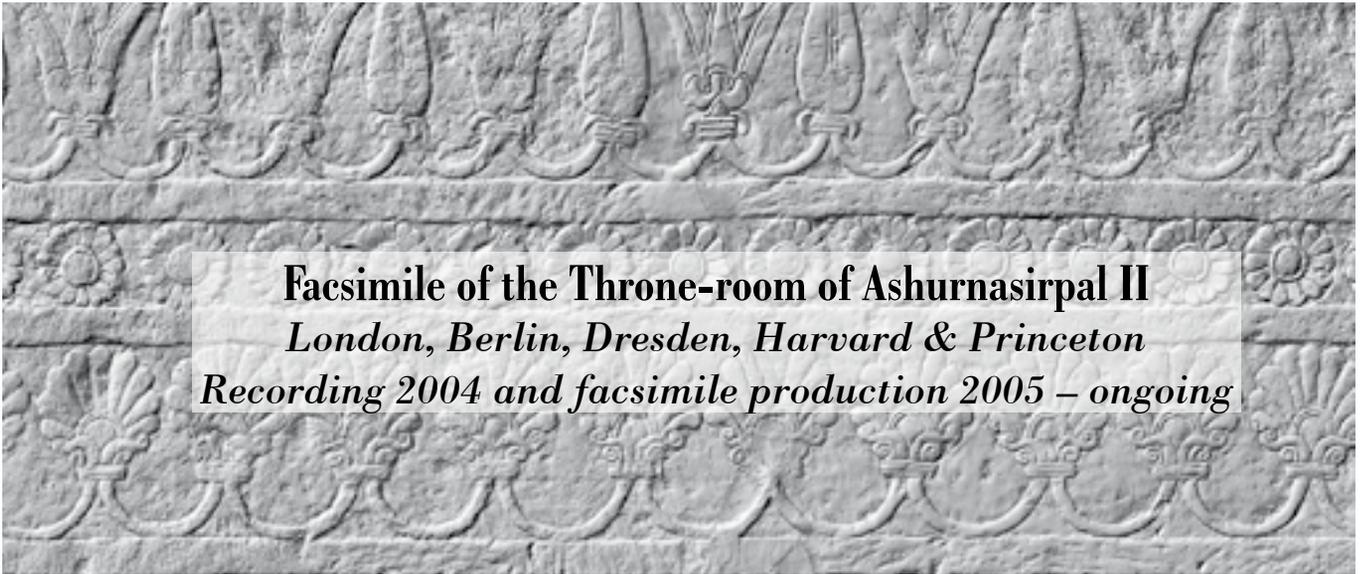
Facsimile of the Throne-room of Ashurnasirpal II
London, Berlin, Dresden, Harvard & Princeton
Recording 2004 and facsimile production 2005 – ongoing

The relief panels and vast human-headed lions from Ashurnasipal II's throne-room were discovered and painstakingly removed from the site by Austen Henry Layard in the mid C19[th] and sent to London – an extraordinary feat of archaeology and engineering but not one that would be encouraged now. The panels and sculptures gathered from Nimrud, in modern day Iraq, have had an interesting biography since their arrival in London still retaining traces of colour. Whilst many of them are still housed in the British Museum, others are now displayed as discrete objects in different museums around the world. Some were cast, some were shown at the *Great Exhibition* (from where they were sold to the Pergamon), one is now in Dresden after having spent almost 40 years in Moscow, and others went to America. The aim of this project is to re- unite and study a group of relief carvings that have been described as the greatest Assyrian narrative cycle.

These friezes from Nimrud were once part of a complex narrative that mixed polychrome relief carving and text. The impact of this has been lost both due to its dispersal and the C19[th] plaster casts which removed the last traces of colour. It is hoped that the work to reunite all the known parts of the Eastern end of the throne-room will lead to new insights and understandings about both Assyrian art and life. Revealing the biography (or career) of each of the fragments is an important part of the work – one that shows how attitudes to the preservation of culture are both constantly changing and geographically conditioned. The work started in 2004 with the support of the British Museum and is now largely complete, though parts of the palace not removed by Layard remain in Nimrud and are still in urgent need of documentation and preservation. Negotiations are now being completed to send plaster casts of all the recorded panels to the Ashurbanipal Library Project at Mosul University.

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The work in the church of San Petronio, Bologna is a collaboration with Felsinae Thesaurus and the Basilica di San Petronio. The original commission was to carry out high-resolution 3D scans of all the scultpures on the unfinished facade. This work will not only document the state of the sculptures now but it will facilitate a meaningful comparison with plaster casts made in the C19th.

A second project to record and reunite all sixteen panels of the altarpiece known as the *Polittico Griffoni* (1742-3) began in 2012 and is scheduled for completion in 2014. The polyptych (polittico) hung in the Griffoni family chapel in the basilica of San Petronio but was removed when the chapel was taken over by the Aldovrandi family around 1725. The paintings are now widely dispersed and the act of re-unification through virtual montage and physical facsimile is a slow but important task. The first five panels of the *Polittico Griffoni* have been recorded and made as facsimiles. Agreements have been made to record the panels in the National Gallery, London and the Pinacoteca Nazionale, Ferrara. Dates are being finalised to record in the Pradella in the Pinacoteca Vaticana. These three works will be recorded in the Autumn of 2013 and it is hoped that the remaining panels will be completed in 2014. A virtual reconstruction of the whole *Polittico Griffoni*, assembled with the help of different experts, will be supplied to each museum and will include the most up to date opinions about the configuration and design of the altarpiece. A physical facsimile will be installed in the recently restored Griffoni chapel in the basilica of San Petronio.

The following panels were painted by Francesco del Cossa:
- *St. Vincent Ferrer*, National Gallery, London
- *San Pietro*, Pinacoteca di Brera, Milan
- *St. John the Baptist*, Pinacoteca di Brera, Milan
- *San Floriano*, National Gallery of Art, Washington
- *Saint Lucia*, National Gallery of Art, Washington
- *Crucifixion*, National Gallery of Art, Washington
- *Angel of the Annunciation*, Villa Cagnola, Gazzada
- *Virgin of the Annunciation*, Villa Cagnola, Gazzada

The remaining panels were painted by Ercole de Roberti:
- *Predella with stories of St. Vincent Ferrer*, Pinacoteca Vaticana, Rome
- *St. Michael the Archangel*, Musée du Louvre, Paris
- *Apollonia*, Musée du Louvre, Paris
- *Sant'Antonio Abate*, Museum Boymans-van Beuningen, Rotterdam
- *San Petronio*, Pinacoteca Nazionale, Ferrara
- *Saint Catherine of Alexandria*, Fondazione Giorgio Cini, Venice
- *St. Jerome*, Fondazione Giorgio Cini, Venice
- *St. George*, Fondazione Giorgio Cini, Venice

Work in San Petronio
Recording Jacopo della Quercia's Principal Door
and making a facsimile of the 'Polittico Griffoni'
Bologna
2011 – ongoing
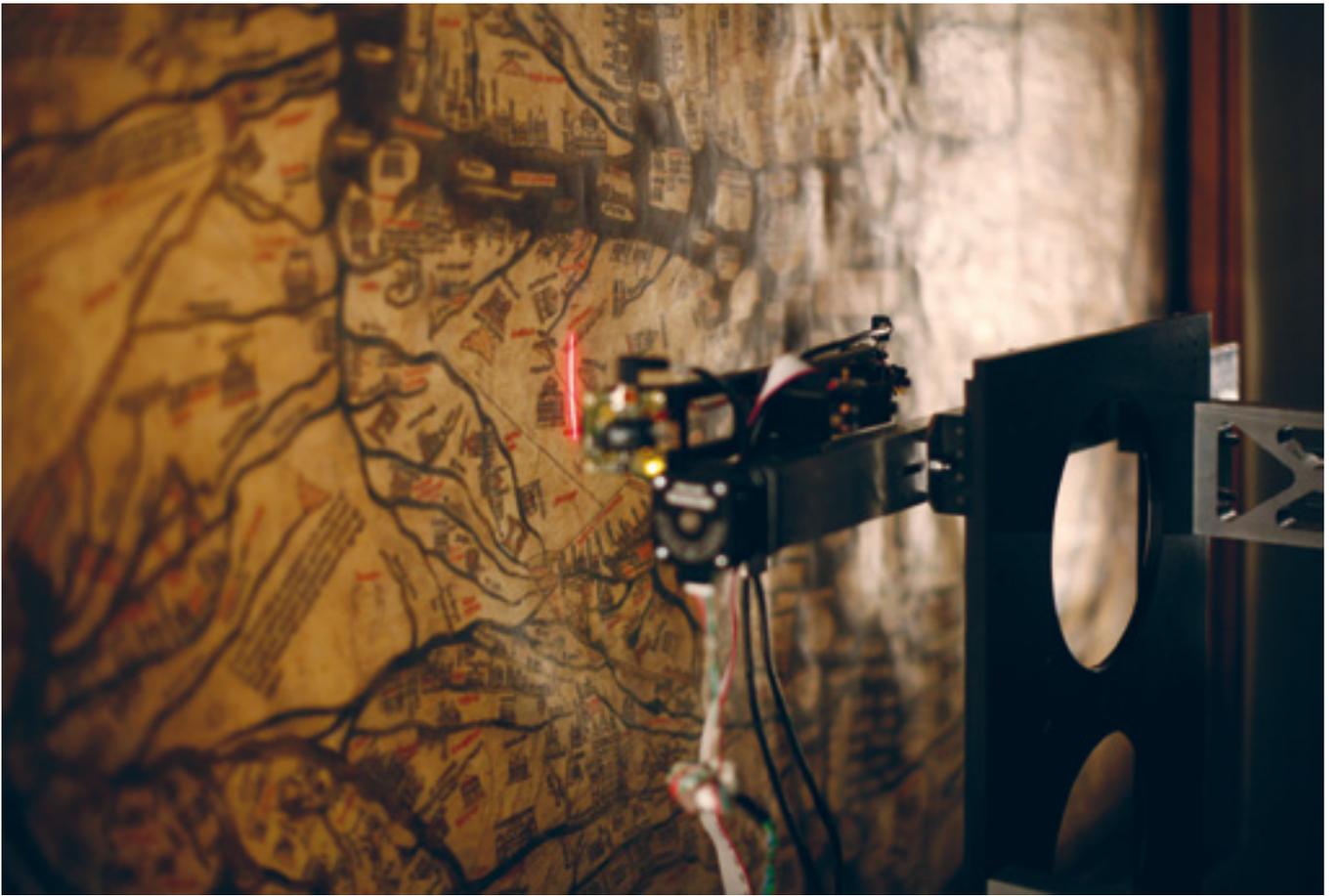
The Hereford Mappa Mundi
Hereford Cathedral
2013

The *Hereford Mappa Mundi* is one of the most significant maps in the world. It was written and painted on a single vellum sheet (calf skin) towards the end of the C13[th] and is attributed to 'Richard of Haldingham or Lafford' (Holdingham and Sleaford in Lincolnshire) though information arising from the recording might suggest it was made in Hereford. The map is 1.58 x 1.33 metres (64" by 52"). The skin is in the shape of an upright open envelope tapered towards the top. The central map is a circular, a two-dimensional globe, 1.3 metres (52") in diameter, with Jerusalem at its centre, as the medieval church envisioned the world. The East is at the apex, where the Garden of Eden sits on the edge of the world. It is in the form commonly called a T & O – the oceans forming the T internally and forming an O as they surround the land mass. The map is illustrated with colourful figures, animals and plants as well as Biblical and mythological events.

In January 2013, at the invitation of The *Hereford Mappa Mundi* Trust and The Dean and Chapter of Hereford Cathedral, a team from Factum Arte made a high-resolution recording of the *Mappa Mundi* whose sealed glass cover is only removed once every two years for inspection. The team used the Lucida 3D scanner designed and built by Manuel Franquelo for the Foundation. The data from the recording has been processed using the system's innovative software and has been used to create a routed impression of the surface of the map. The data has also been archived and supplied to the trustees so that a digital record will be available to future custodians, thus providing an accurate record of the surface as it was in 2013. This will become the benchmark to analyse and track any changes. The final impression – a white routed map representing the exact amplified surface relief – has been given to the Cathedral and is now on display near the *Mappa Mundi*. This relief version of the map will provide access to this wonderful artifact for the blind and partially sighted; coincidentally the College of the Royal National Institute for the Blind is based in Hereford.

Eye tracker laboratory UAL

Target Locking

B

A

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3. 5.2005
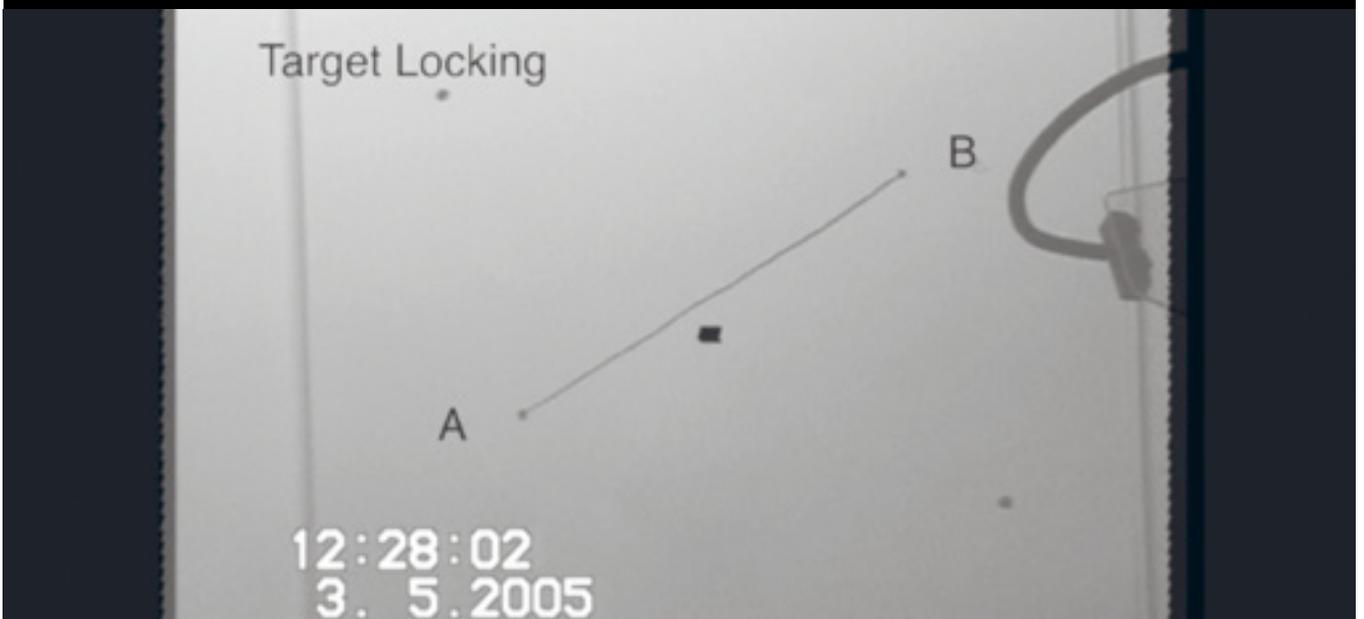
'Capturing Life', directed by John Tchalenko
London
2013

This is a new film about how artists look/see – using eye-tracking and brain-scanning technologies. It has been made in collaboration with the Musée Rodin, the School of Psychology, Birmingham and Camberwell College for the Arts, London. It is the summation of John Tchalenko's last 15 years of innovative research into the subject.

The eye, brain and hand interact during life drawing. The common explanation of this process is that the eye captures the visual information from the external world, the brain stores this as short-term working memory and transforms it into a programme of manual movements which the hand, assisted by the eye, executes to make the drawing. In this way, a vision of the external world becomes a physical picture on paper or canvas. However this film reveals that many of these assumptions are insufficient, incomplete or misleading. New discoveries about brain function, scanning and eye-tracking technologies are literally transforming our understanding of how we see.

In the film the drawing process is discussed with the help of four different experts. John Tchalenko, psychology researcher in eye-hand coordination, formerly at UAL; portrait painter Humphrey Ocean RA; Chris Miall, Head of the School of Psychology at the University of Birmingham and Nadine Lehni, Conservateur et Chef du Patrimoine, curator of the Musée Rodin 2011-2012 exhibition, Rodin, 300 Dessins, la saisie du modele.

The results are simply stated but profound in their implications. A series of shorter documentaries is now being planned. The aim is to make this important body of scientifically accurate research freely available to educational institutions, artists and medical researchers.

'The Guga Hunters of Ness', sound design by Nathaniel Robin Mann
Faroes Islands
2011

Nathaniel Robin Mann (composer in residence at the Pitt River's Museum Oxford) is completing the sound-track for a new film shot in the Faroe Islands using a multi-directional microphone.

With funding from Factum Foundation, Intrepid Cinema was able to secure additional 'match' funding and produce this film that captures the dramatic vistas of the islands, their people and the unique hunting activities of the Faroe islanders. The Foundation's specific interest is in the recording system being used and perfected by Nathan Mann to record the sounds of traditional Faroese ring dances and choral singing; these activities have now been documented with an unprecedented degree of spatial resolution using an ambisonic microphone, preserving these fading traditions for future study. This is a complex local story with international consequences and now has funding from Creative Scotland, The Wellcome Trust and is to be screened by broadcasters worldwide.

Acoustic archaeology is a rapidly growing area of research that has significant implications for the production of realistic facsimiles. Sound, temperature, humidity and smell all significantly effect our emotional engagement with sites and works of art.
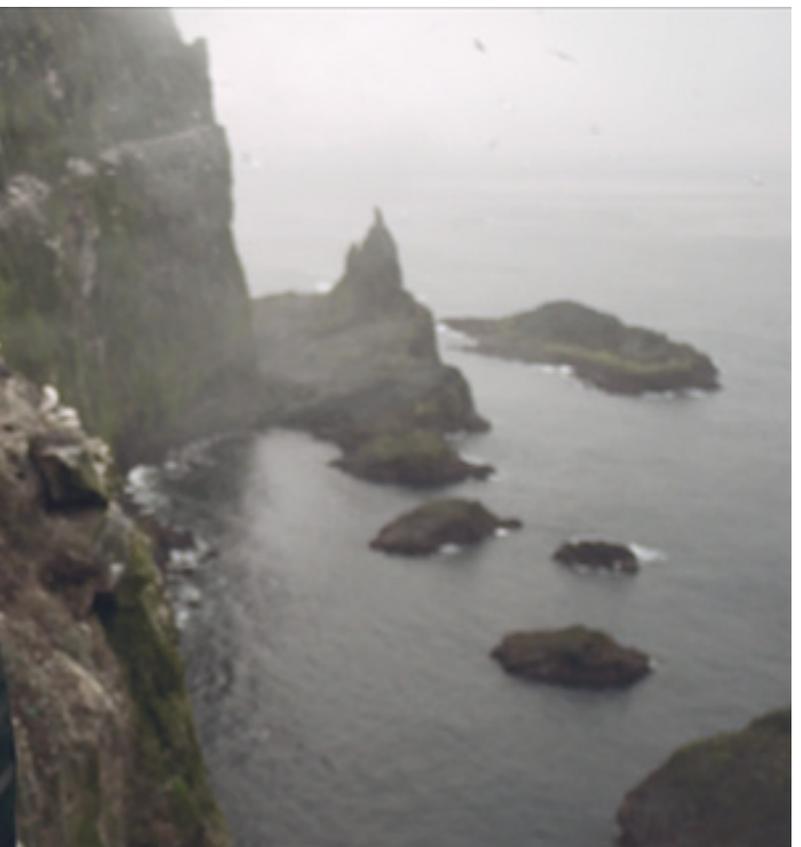
'Because it connects the most advanced technology with the deepest care for the materiality, history and intricacies of works of art, Factum Arte occupies now a central place at the cross-roads of all the issues concerning the restoration, conservation and politics of treasures spread in many different countries. What the Factum Arte team has managed to assemble allows for a set of skills impossible to find anywhere else to not only probe deeply into works so as to reproduce them, but also, to produce new works of art. Or rather, it has given to the words 'reproduce' and 'fac simile' a completely new sense and direction that has become synonymous with creation and innovation.'

Bruno Latour,
Sociologist of Science and anthropologist,
Professor at Sciences Po, Paris,
and recipient of the Holberg Prize in 2013.
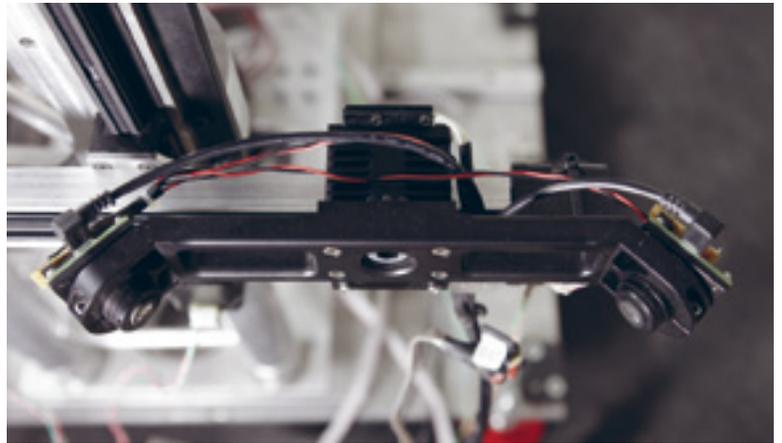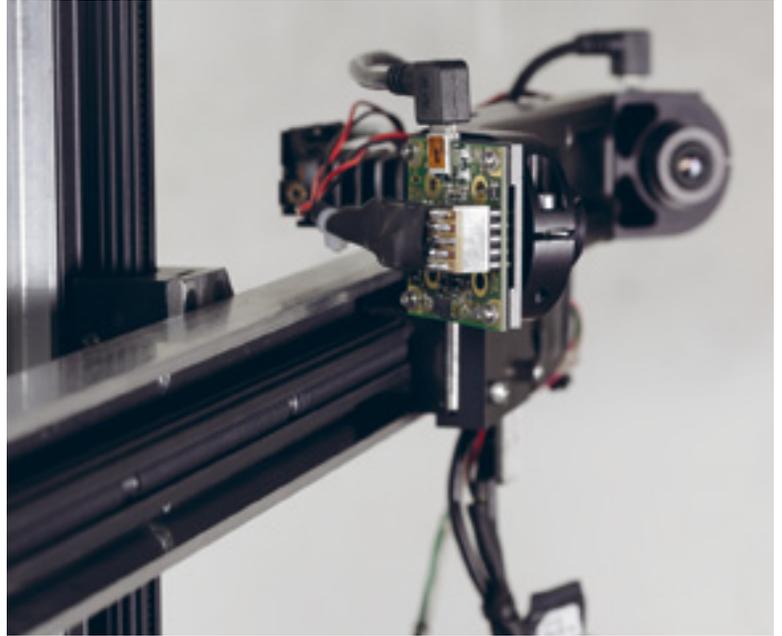
3D Scanning
Registering surface and shape

During the last decade Factum Arte has been involved with the recording of diverse works of art each presenting a different problem that had to be overcome. Ten years ago 3D scanning required a coat of a white matting agent and markers fixed to the surface in order to achieve good results. This was the first of many obstacles that had to be overcome. The experience of designing hardware, software and new practical methods is central to the Factum Foundation's work. The Lucida scanner, the flatbed inkjet printer, the concrete printer, the software for working with large 3D files, the use of raw black and white video to capture relief and recent experiments with 'focus-stacking' are just some of the examples of the ways that image and object are merging as the boundaries between 2, 3 and 4 dimensions are being radically and rapidly redrawn.

The Lucida Scanner
The Lucida 3D Laser Scanner has been developed by Manuel Franquelo for the Foundation to create contact-free, high-resolution images of the surface of paintings and low relief. It is a two camera, one laser system with bi-directional recording. It has a software application that under and over exposes each frame to record accurate data from both the dark and light areas of the surface. It can also record metallic and glossy surfaces. The scanning head is small and robust and mounted onto X and Y axis linear guides fitted to a light-weight, rigid aluminium structure. All the scanning processes are controlled from a portable computer and the bespoke software application allows the user to select a specific section of the target should re-scanning be necessary. The Z axis is manually controlled. All stitching is done as a depth-map, greatly reducing the size of the

files and time of processing while increasing the objectivity of the data. The graphic user interface is intuitive and easy to operate. The system is lightweight, powered by battery or mains electricity and stores the 3D information as raw black and white video data. This tonal data is currently processed to give measured depth measurements on a 100 micron grid – providing 100 million measured points per square meter. This approach to the recording and management of 3D information has significant implications for long-term data storage. The Lucida Scanner is in an advanced state of development and has already been used to record the surface of works of art in a number of different situations, all of which have significant implications for the protection and management of cultural heritage. The Foundation has developed the Lucida scanner for documenting highly detailed work that requires a close correspondence between the surface of the object and the data that is recorded from the surface. It is the intention of the Foundation that Lucida scanners are made available either by gift or loan to custodians globally to record the objects they are responsible for, in order to allow future generations to enjoy them and future researchers to analyse and monitor their condition.

White Light scanning
White Light scanning is used for the recording of volumetric form, it also records the surface of the objects but the noise/information ratio generally means that significant processing is required to extract the data from the noise – therefore reducing the correspondence between the data and the object. White light (structured light) scanning systems record
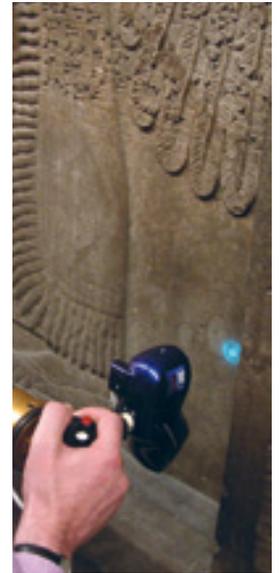
3D data by analysing the deformation of parallel lines of light projected onto the target. As they pass over the surface the deviation to a theoretically straight line reveals the shape. The patterned light is recorded by one or two cameras positioned just off the axis of projection and at a fixed angle from it. The principles of this system were originally developed in the 1920's in France by Claudius Givaudan but over recent years this method of volumetric recording has found many applications and developed rapidly.

Other methods of recording 3D information
There is a vast difference between close-range scanning to record high-resolution information of the surface that can be physically re-materialised, and long-range scanning that can capture a shape that is then rendered for screen applications. The Foundation is committed to the developing an understanding of both approaches. As part of this research a 'standard test' has been developed and recorded at the highest resolution possible with hand-held laser systems mounted onto 7 axis arms, white light systems mounted onto linear guides, medium and long-range scanners, photogrammetry and other methods. The aim is to demonstrate what is possible and to optimise the correspondence between the digital information and the surface of the object. In all this work the relationship between shape and surface, image and object, tone and form are constantly under analysis.

Tonal Depth Maps (Range images)

A 'range image' refers is a 2D greyscale image in which each pixel contains information about the actual 3D height of that point in the real world. A totally white pixel represents the highest point, while a totally black pixel represents the lowest – in between are shades of grey within a 32 bit greyscale range. The laser scanner can record a depth of 25 mm within a single scanning pass. The radical feature of this scanner is that the depth is being handled as tone and processed in Lucida's specially written TIFF 'image file exporter' application. If the relief is more than 25 mm, multiple scans can be merged together and the software is capable of ascribing depth co-ordinates up to a depth of 500 mm. This approach means the data can be stored as a raw TIFF file and reprocessed at higher resolutions as processing power becomes available. As a result of this technology the scanner can also record both light and dark tones, glossy surfaces and even gold at the same time without requiring repeated re-scanning at different exposures.

Manuel Franquelo's processing software makes it possible to edit the greyscale image with filters to reduce noise, eliminate spikes and fill holes, it also has tools that allow it to clone, smooth and bump. The data is worked as an image but the information corresponds to points in space. This is essential if the data is being physically routed or printed – previously it was only possible to work on very small areas at high resolution or to optimize and compress the data. This approach to editing is not possible even in the most expensive 3D software. For engineering applications metrology is more important than surface detail. For cultural applications it is the surface detail that is essential.
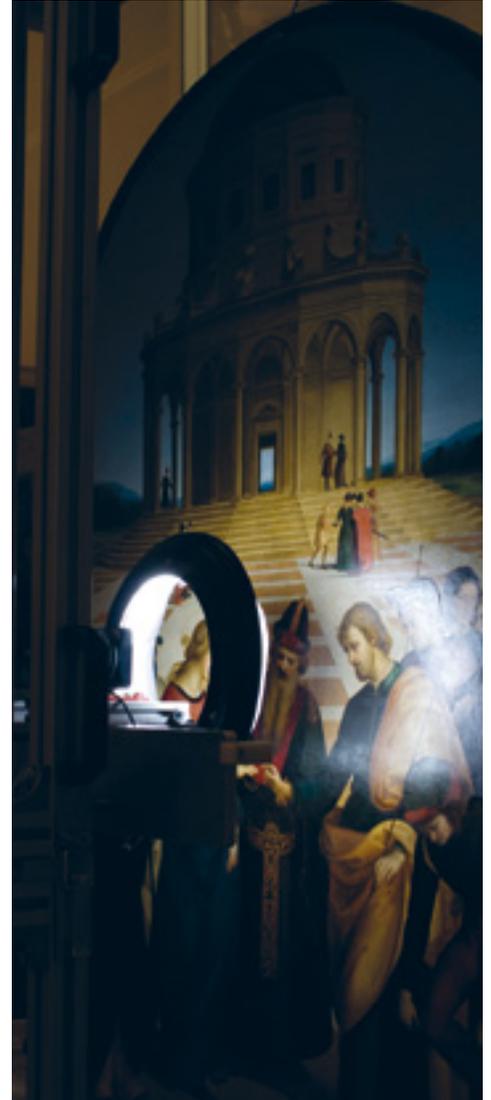
High Resolution Photography
Recording colour

High Resolution Photography

Colour photographic recording of works of art at high-resolution is a rapidly developing technology. One hundred years ago academics relied on small black and white reference prints of works of art – now photographic images can be made using visible light, X ray and infra-red at resolutions that can be printed and reviewed digitally at 1:1 without significant loss of quality. The processes used can be studio based or done on site, if the subject cannot be moved. High-resolution photography is achieved by stitching together thousands of smaller images in a seamless mosaic. This is done using cameras or scanners, parallel or panoramic systems.

Studio recording

In a photographic studio heavy immobile equipment can be used to create stable, high-quality recordings. The subject is brought to the equipment in order to be photographed or scanned. Most of the high quality equipment has been manufactured in Germany and Japan where there has been significant investment in CCD technology (charge coupled device). CCD technology is the digital equivalent of film.

A tri-linear CCD has 3 lines of luminance photosites or cavity arrays where photons collect upon exposure to light, rather like a solitaire board with indents that can take more than one ball – digital cameras have millions of them. Each of them is filtered for primary red, green and blue (RGB) colours (normally a Bayer Array), which move across the target recording the colour of the surface, which must be illuminated with the correct level and type of light.
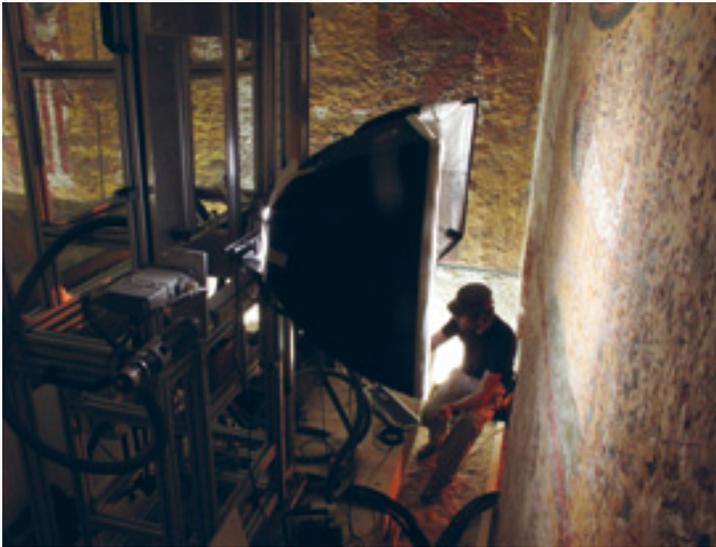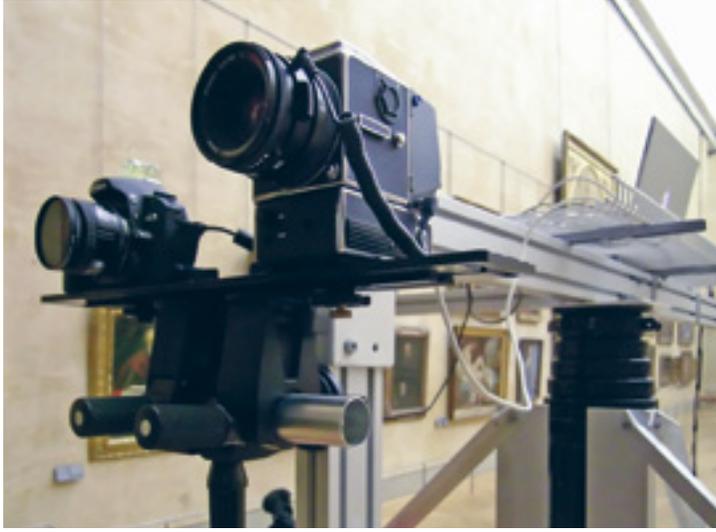
Parallel Photography

Parallel photography consists of mounting a recording system on a lightweight, modular structure so that it can be positioned and moved parallel to the surface that is being recorded. The Foundation has experimented with a number of systems including modified flatbed scanners (similar to desktop scanning machines) mounted onto telescopic masts, digital single lens reflex (DSLR) cameras with macro lenses on computer controlled linear guides, medium format cameras with digital backs on manual and motorized positioning systems and sonic depth sensors to ensure exact parallel positioning.

The method requires setting up a railed platform parallel to the surface of the painting (or 2D target), a vertical mast or frame is then moved along the rails, parallel to the surface. The recording device and lighting are fixed to the mast or frame. As the platform moves parallel to the surface of the target a number of image captures are made at fixed, overlapping positions to cover the whole of the surface. These are then assembled and digitally stitched together to produce a single large image file at resolutions of up to 1200 dpi (dots per inch).

This approach is practical when recording a flat surface with low relief. While portable, it takes time to install and operate. Time is very often the determining factor – museums and heritage sites are normally open to the public and keeping works on public display is an important part of their mission.

Panoramic Photography

Panoramic recording is carried out with the camera fixed in a single position on a two axis motorised cradle. Software is used to calculate the position and angle of a camera in relation to the target. The Foundation has been working with a Clauss system that has had several modifications including the projection of a laser pattern to assist the focusing and the use of a second 'slave' head for the flash lighting.

The recording device (usually a professional digital single lens reflex camera (DSLR) with a 600 mm telephoto lens) is mounted onto a motorised panoramic head that rotates around the perspective centre or nodal point. The surface is then recorded by rotating the head in a horizontal and vertical axis capturing overlapping images. The lighting is either by flash or a fixed constant source over the whole surface. When working with flash the unit is mounted onto a second motorised slave head controlled by the recording unit so that it follows and illuminates only the section being captured for each position. If the flash is installed on the same head as the recording system it results in unusual shadows and hotspots – the separation of the light-source from the recording system is essential to achieve the desired level of control. The use of flash units is prohibited in some museums but this prohibition stems from issues of copyright more than preservation of the object.

Each sequential image captured during panoramic recording has a known distortion that can be corrected using different mathematical projections. The resulting images are then stitched together at sub-pixel accuracy using specialist software applications. The resulting
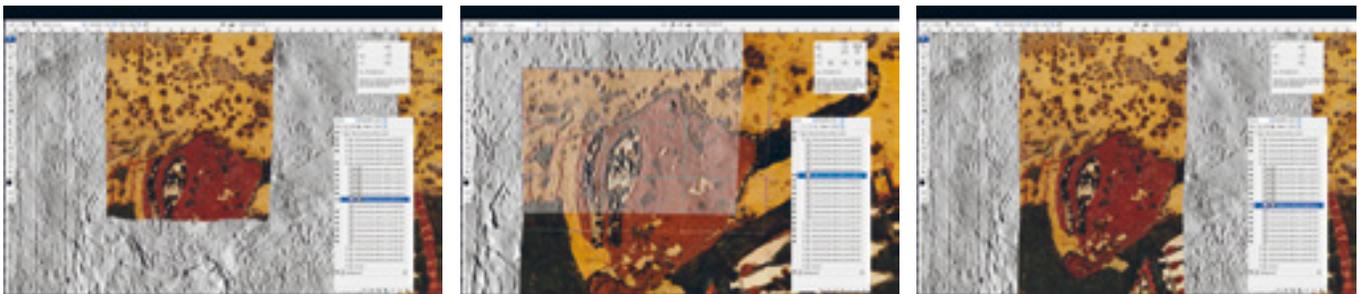
files facilitate intimate inspection of the surface of paintings and works of art and are helping to transform our understanding of the importance of the object and what is required to preserve it.

Stitching and Blending

Stitching is the process of combining several images with overlapping fields of view in order to produce one single image. The stitching process used to merge high-resolution images is mainly composed of two different processes: aligning and blending. Aligning is the matching of overlapping common areas of two or more images (the recommended overlapping area between images is usually 30%). This can be done in many ways using different aligning algorithms.

There is a lot of software on the market designed for this specific task, however, aligning data with sub-pixel accuracy requires a special approach that has more in common with medical or topographic applications. Currently, we use a software called PTGUI. This software is affordable as it is based on an open source library and can produce well-aligned composite images. Pre-positioning of the images is done manually and by eye. The task is not difficult but there are many decisions to be made and is best done by someone with a good visual awareness.

The blending process involves harmonizing the pixel combination in the overlapping area between each pair of images. If the recording is perfect this is not necessary but any shift in tone or colour will be visible. To remove this artifact and achieve an invisible transition between stitched images the greyscale and colour values require local and
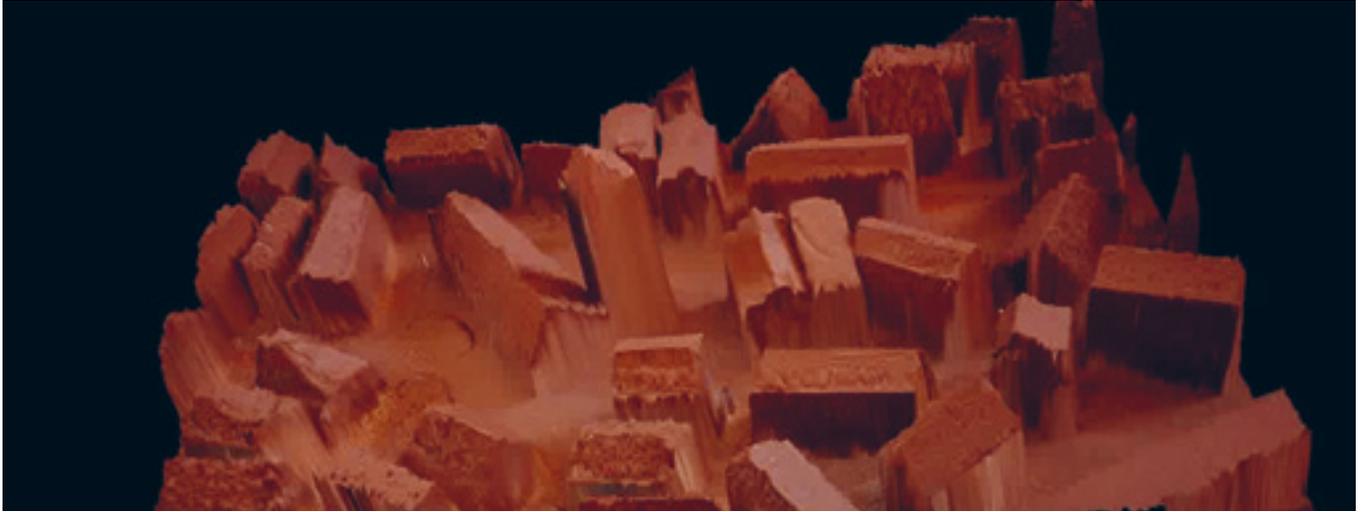
limited harmonisation. The preferred 'blending motor' is currently in Adobe Photoshop. This is the only part of the image merging process for which we do not currently have an open source alternative.

Focus-stacking

One of the current areas of research is focus-stacking – the use of a panoramic photographic system to record both across a surface and at different depths of focus in order to produce focused images or to extract three-dimensional co-ordinates. As with most innovations it arose from need. Google Culture, based in Paris were working to make a Google Earth type simulation of the vast 1:600 scale models made of all the fortified cities in France in the C18th and C19th. It was impossible to use the time of flight or phase based scanners that they normally use. In response the team at Factum Arte built a scale model and produced 3D data using focus stacking and stitching technologies. To date the results can record form but not surface – with more work who knows what can be achieved.
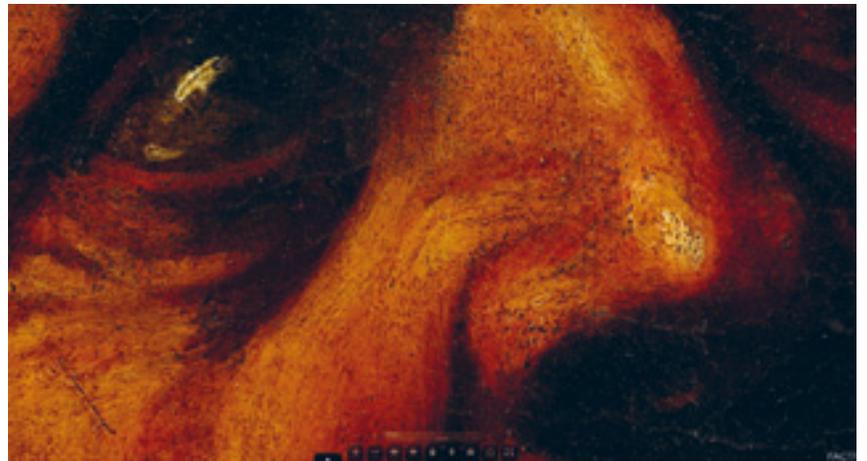
Storing Knowledge – Sharing Knowledge
Archiving, multi-layered files, high-resolution image browsers, virtual restoration and new methods of multi-media display

Archiving

The recording of vast amounts of colour and three-dimensional information is one thing – its storage, processing, presentation and accessibility require different skills and structures – both physical, intellectual and legal. A central part of the Factum Foundation's work is devoted to ensuring that the archives we are assembling will be permanent, accessible and managed in a transparent way. It is essential that the data that is recorded will be freely accessible for study and monitoring of works of art. It is equally important that any commercial applications that exist (or may emerge in the future) belong exclusively to the museums and guardians of our cultural heritage and that they are used for its long-term preservation.

The speed at which new developments are appearing show that imaging and recording technology are still far from fully developed.

The Foundation is focused on storing the digital data as securely as possible in a format that can generate revenue for the custodian but be accessible for monitoring and study. Future generations will continue to develop new technologies – these will hopefully be able to extract more information from the raw data we are gathering now. Un-abstracted raw data is the key to preserving the past. Future generations will find better ways of processing, analysing, viewing or applying the data. The aim is to make it available – a record of the past and present for the future.

Digital data is fragile and ephemeral – its long-term storage will be dependent on constant maintenance. Unlike works of art that are sometimes best protected by periods of negligence, digital data ceases to exist unless perfect conditions are maintained.

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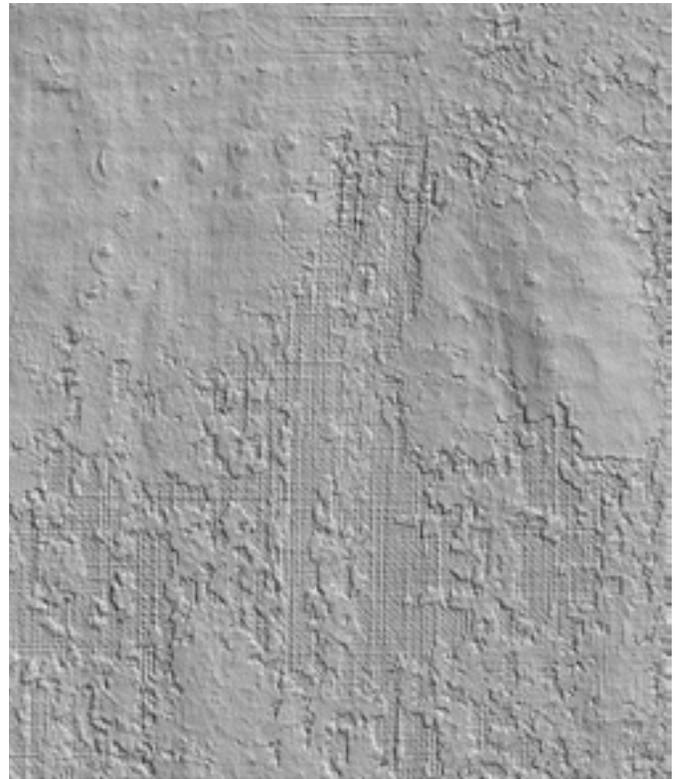
Access to the data can take many forms and in the coming years it will certainly take forms that cannot yet be imagined. The virtual and the physical co-exist just as words and objects have done in the past. It is the Foundation's assumption that physical locations will remain important as a focus for sharing and discussing information – the environment that has been developed at the Fondazione Giorgio Cini, Venice could be a good example of the model that will be needed in the future – open shelf libraries, residences, exhibition areas, scholarships and an inter-disciplinary emphasis.

Multi-layered archives
Monitoring of condition and decay is increasingly important in an age of mass tourism and increased visitor numbers.

It is one of the reasons why high-resolution recording is essential. Everything changes with time but these changes are significantly accelerated by the presence of large numbers of people.

The conservation and preservation communities are realizing the importance of high-resolution digital recording and this data is starting to be integrated into professional protocols. Data can be stored in a layered archive composed of different types of input – 3D scanning, X Ray, Infra-Red, colour photography, historical data, conservation notes, condition reports and diverse notations. An archive of this kind should be open-ended and constantly updated. In assembling a multi-layered archive the skill is to find the best way to integrate the various inputs so that the original object can be viewed as transparently and easily as possible in many ways. It is essential that all post-processing and mediation is clearly stated and

accurate. It is important to note that layered images depend greatly on skilled post-processing.

Advances in digital technology are rapidly and radically changing our understanding of our shared cultural heritage. The Factum Foundation is focussing resources on the creation of layered archives in the belief that we need to focus information and make it accessible in one place – this can be a virtual or a physical location.

Presentation and Education – Rethinking the home of the Muse
Will museums become more like libraries or more like theatres? What role will they play in the future? How will they display the objects they care for in ways that reveal and communicate their importance? Their role is constantly changing and many are finding innovative ways of connecting their 'objects' with a wider audience.

Many of these changes are only possible through the embrace of technology and the benefits it can bring. Practical examples are often the best way to answer these questions. To coincide with the 400th anniversary of the death of the Italian artist Caravaggio, the Municipality of Caravaggio began an ambitious and enlightened project. They commissioned the Fondazione Giorgio Cini and Factum Arte to develop a new type of research centre based around high-resolution recordings with facsimiles and material evidence of the quality and variety of the recording. The project began by focusing on three of Caravaggio's masterpieces – the cycle of paintings of St Matthew in the Church of San Luigi dei Francesi in Rome. The Research Centre opened in the church of John the Baptist in September 2010 with the 3 facsimiles

installed in the Sacristy of the church and high-resolution browsers (that allow the digital files to be viewed up to five times life) were installed in front of each painting. In their original location two of the paintings can only be viewed from an oblique angle – in the church in Caravaggio they can be seen from the front: one can move around, alter the intensity and colour of the light, shift gaze between painting and screen, zoom in – reflect. The programming and archiving work that has been completed since 2009 now opens up new possibilities to view historical prints and photographs, to read conservation notes during restorations, to access multi-spectral images – intimacy and depth are the key words – the results are compelling as the virtual and the material collide – but this is just the start.

Sala Bologna Virtual restoration
Digital restoration is emerging as an important new area that is dependent on the quality of the different types of recording to create virtual facsimiles revealing different points of view or theoretical ideas. Digital restoration refers to restoration projects carried out on digital archives. An important advantage of digital technology is the potential to manipulate the data. It is possible to digitally restore the object both by working with specialists to modify the data and by scanning fragments that have been dispersed in museums and private collections worldwide. In this way the data can be merged to produce a digitally restored facsimile of a damaged or dispersed original. The precise protocol for this has yet to be established. The Foundation is committed to this type of work.

The temporality and subjectivity of our point of view needs to be acknowledged. Any intervention is a reflection of its historical time and of the team responsible for the restoration. As recording technologies develop and the subjectivity of this approach is revealed, the Foundation is encouraging an approach that will result in more and more emphasis on virtual restorations and a greater period of time for reflection. To some degree all restorations turn the original into a reproduction of itself – it is as essential that all physical changes are
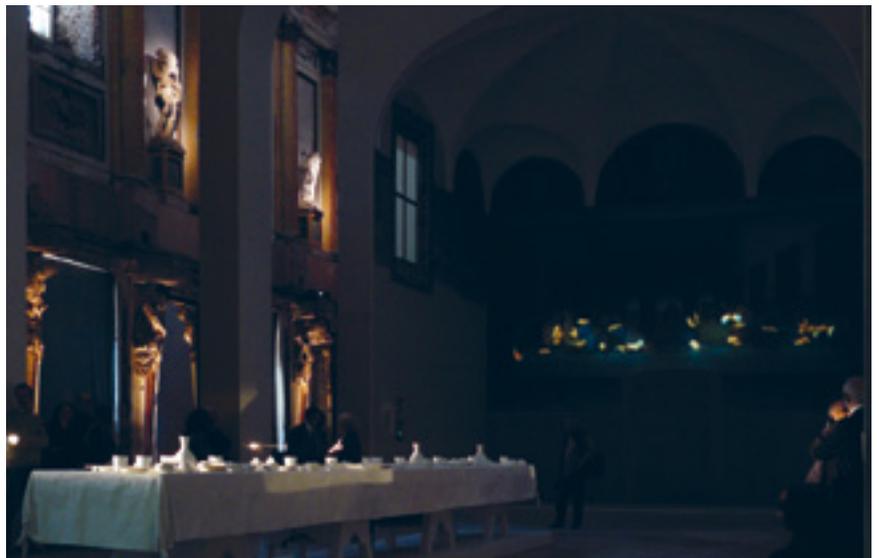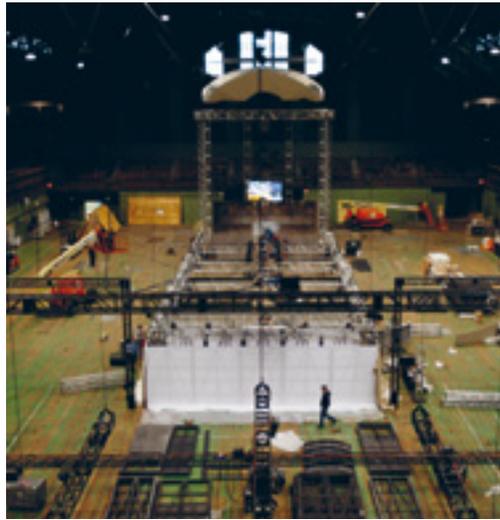
fully documented and fully reversible. The issue of reversibility is enshrined in conservation practice but is not as obvious as it seems. No action is 100% reversible and some are 100% not reversible without causing significant damage, paint-loss or changes to the appearance of the original.

Multi-media display
Multi-projector displays perfectly registered to architectural details or to the surface of paintings are becoming widely used for both didactic installations and theatrical investigations into works of art. Factum Arte was commissioned to produce of a 1:1 facsimile of Leonardo da Vinci's *Last Supper* in Santa Maria delle Grazie, Milan. The facsimile, derived from high-resolution colour photographs was taken by Haltedefinizione using a Clauss Panoramic system and careful colour notes made on site in Santa Maria della Grazie. The facsimile is an accurate colour copy of this heavily conserved original but without the 3D data it remains a theatrical prop. The final installation in the Palazzo Reale in Milan included sections of the ceiling, side walls and three dimensional objects as part of a live performance by Peter Greenaway and Reinier van Brummelen. It was originally planned to show from the 14th to the 21st of April 2008 but was extended due to popular demand and was later shown in the Melbourne Festival 2009, Australia. A similar multi-media event using multiple projections registered to the image took place on the facsimile of Veronese's *Wedding at Cana* on the island of San Giorgio in Venice in 2009.
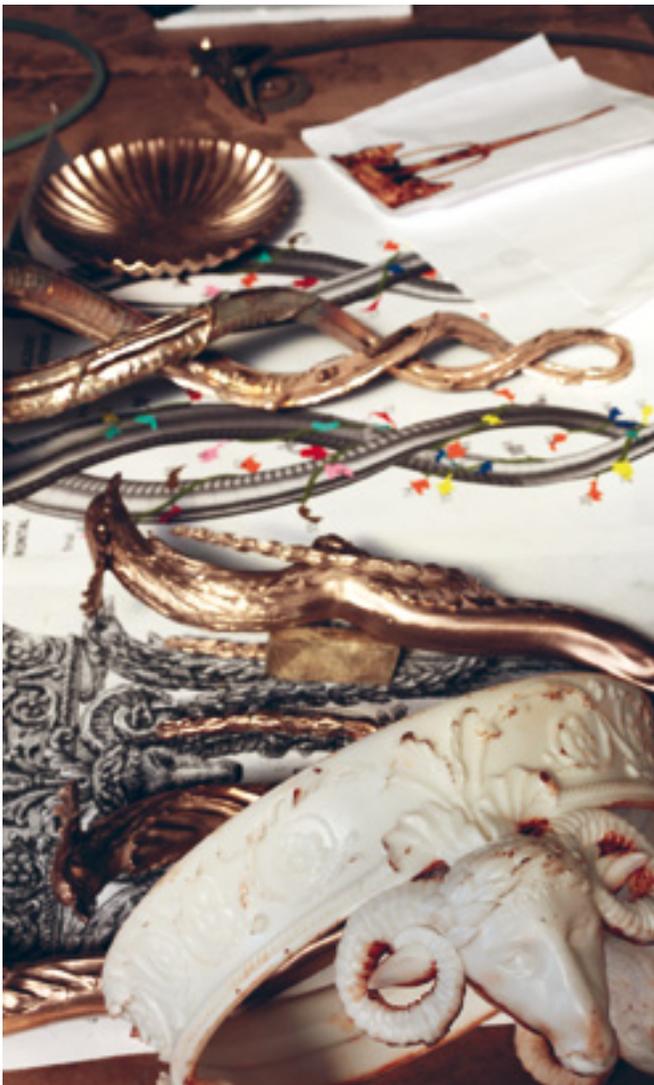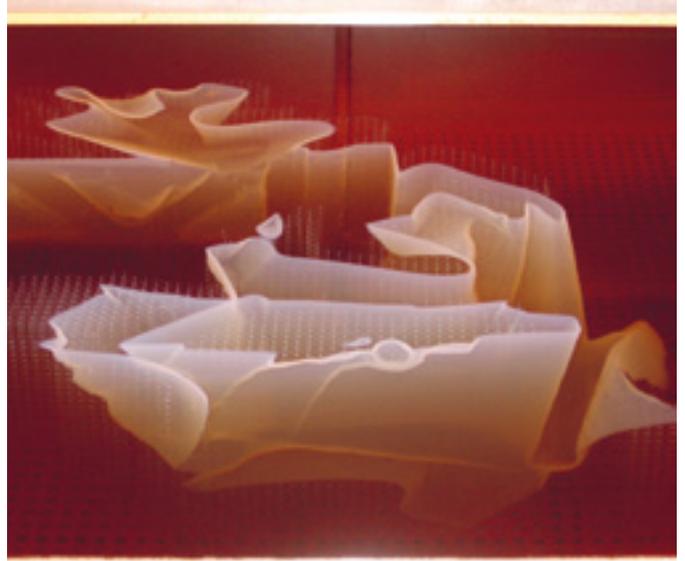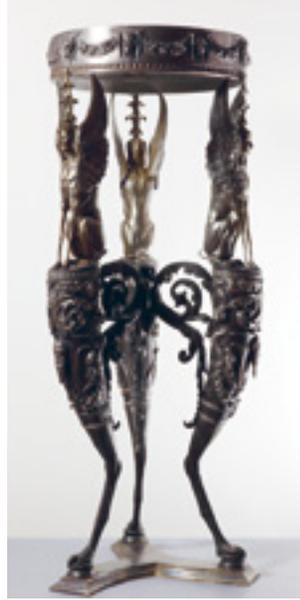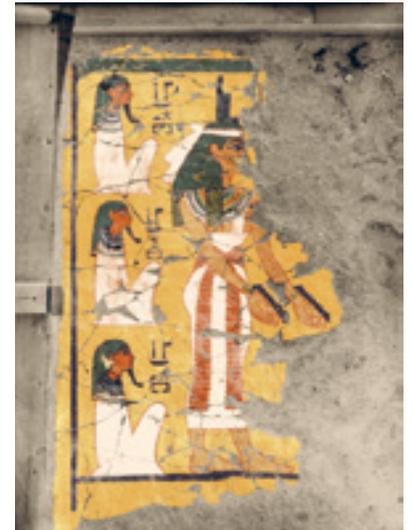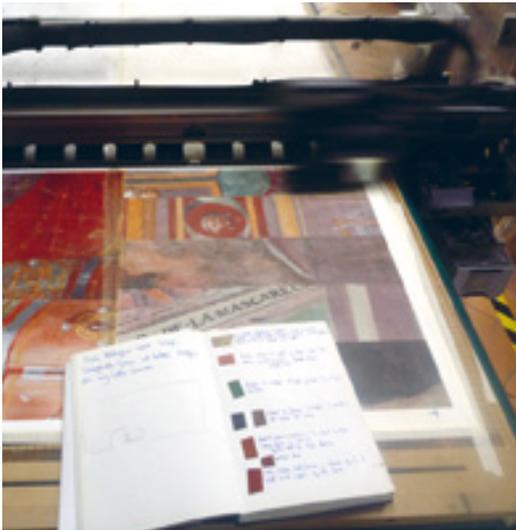
Dematerialisation – Transformation – Re-materialisation
The third industrial revolution?

New technologies nurture new ways of thinking and seeing, new insights and new perceptions shape the way we think about and care for things. Attitudes change – Factum Foundation is committed to non-contact recording – especially of the surface and colour of objects and paintings, a process of dematerialising the thing so it can be stored and used in different ways. The Foundation's concentration is on ensuring the data has a close correspondence to the original in as many ways as possible and can be used both to monitor the condition of the original and be used to produce exact facsimiles when required.

The production of an accurate facsimile requires a deep and detailed understanding of the information as it is mediated from one form to another, transformed and returned to the physical domain. The buzz word used to be virtual, but virtual realities are losing their celebrity as they become endemic and commonplace. The focus is now on 3D printing and diverse methods of rematerialising data. The work that is being done to make facsimiles at the right levels of detail is utilising these 'output technologies' and leading in their development.

Facsimiles

When Factum Arte was commissioned to make the facsimile of the Tomb of Thutmosis III there were many dissenting voices raising concerns about fakes, falsification, fraudulence, deceit – a theme park approach to culture. After it was unveiled at the National Gallery of Art in Washington in 2002 the tone changed to one of wonder and amazement at its veracity and detail – authenticity had separated itself from the tyranny of originality. Over three million people have paid to visit the facsimile, their money has directly helped both museums and the Supreme Council of Antiquities in Egypt.

Since then attitudes to facsimiles have slowly changed – there is a realisation that we cannot simply be part of a collective act of destruction as we visit cultural heritage. In 2004 Brian Fagan clearly presented the predicament in the Valley of the Kings:

'The authorities face agonizing decisions. Do they admit visitors to royal graves and witness the near-certain deterioration and perhaps disappearance of unique wall paintings from sheer people pressure? Or do they close everything to save it for future generations?... The dilemma pits the preservation of the priceless and finite archive that is ancient Egypt against the pressing economic needs of a developing country – altruism for future generations against short- term advantages.'

Brian Fagan, *The Rape of the Nile, Tomb robbers, tourists and archaeologists in Egypt*, 2004

By 2011 the mainstream press was starting to understand the challenges faced by the custodians of celebrated heritage sites. Referring to the facsimile of the tomb of Tutankhamun funded by

the Factum Foundation Mike Pitts wrote in The Guardian:

'Indeed, the replication process is so precise, it brings new insights to the original, helping academics and tour guides alike. No, it's not the real tomb. But it is a real facsimile, and when you visit you will become part of a cutting-edge research project. Before, you were just a pan scourer.'

Mike Pitts, *The Guardian*, 17th January 2011

In November 2012 the Foundation gave the facsimile to the people of Egypt in a ceremony organised by the EU. Baroness Ashton, the EU High Representative officially handed over the facsimile to the Minister of Tourism of Egypt, Mohammed Zaazou and confirmed its installation in the entrance to the Valley of the Kings with President Mursi and Prime minister, Hesham Qandil. The facsimile is now awaiting its final installation beside Howard Carter's house in Luxor. The intention is to encourage the tourists to visit both the facsimile and the original and enter into a dialogue about the best ways to preserve the Theban Necropolis. Display methods and techniques that can be used in the facsimile are not possible in the original tomb. The hope is that visitors will actually report that the experience in the facsimile was both more authentic and more informative than their visit to the rapidly deteriorating original.

A similar approach is being applied to other sites, monuments and paintings. A vast archive is being assembled and new understandings are emerging.

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The facsimile of the city map from the Sala Bologna is installed in the Museo della Città, Bologna.

The four walls and ceiling of the Sala Bologna, Vatican City were recorded and a facsimile of the city map of Bologna was produced. It now hangs in the entrance of the Museo della Città, Palazzo Pepoli Vecchio. The work was carried out with permission from the Vatican Museums over four days in May 2011. The complete room was recorded using a panoramic system designed by Clauss and a section of the south wall was scanned in three dimensions. A publication on the history of the Sala Bologna and the significance of cartography in the Renaissance was edited by Nadja Aksamija and Francesco Cecerelli, published by Marsillio. This publication contains a text by Adam Lowe; 'Mapping a Map: Factum Arte at the Sala Bologna'.

The Tutankhamun facsimile is awaiting installation on the West Bank, Luxor.

The high resolution recording and production of an exact facsimile of the Tomb of Tutankhamun was part of a major initiative by the Supreme Council of Antiquities to preserve the tombs in the Valley of the Kings. The project was run by the University of Basel with permission from the Supreme Council of Antiquities. The agreement covers the tombs of Seti I, Nefertari and Tutankhamun. The work was organised by The Friends of the Royal Tombs of Egypt (a Swiss foundation), the Factum Foundation for Digital Technology in Conservation and Factum Arte. The facsimile has been given to Egypt and is due to be installed at the entrance to the Valley of the Kings.

The facsimile of the 'Dama de Elche' is now in the collection of MARQ, Alicante.

In November 2002, Factum Arte was approached by MARQ and the Diputación de Alicante to make an exact replica of the *Dama de Elche*, which is part of the collection of the Museo Arqueológico in Madrid.

With the full support of the Museo Arquelógico Nacional, where the original sculpture is now shown, Factum Arte carried out digital 3D documentation of the *Dama de Elche*. This work turned into a research project involving direct comparisons between three different scanning systems. The digital data was then printed in 3D using a sintering system (Z Corp). A full-scale replica of the sculpture was made using pulverised limestone from quarries local to Elche. A film, 3D animation and the digital data itself was presented to the Museum MARQ and to the Museo Arqueológico Nacional as a digital archives to aid all future study of the *Dama de Elche*.

A facsimile of Princess Wallada's Box is in the Conjunto Arqueológico Madinat al-Zahra.

The Conjunto Arqueológico Madinat al-Zahra commissioned Factum Arte to make a facsimile of a small ivory box found in Madinat al-Zahra. It was originally made for Princess Wallada. The box has bronze hinges with traces of gold leaf and it is believed that it was made around 966 AD.

This box is now owned by the Fundación Instituto Valencia Don Juan, but it has been on loan to the museum at Conjunto Arqueológico Madinat al-Zahra since it opened. The return of the box to its owners in Madrid prompted the need for a facsimile. The box was recorded in both colour and three dimensions and a detailed condition report was compiled. The facsimile was then made from routed resin, which has the colour, transparency and characteristics of ivory.

A facsimile of the 'Schwittershytta' is in the Henie-Onstad Art Centre near Oslo.

An exact facsimile of Kurt Schwitters' only remaining *Merz* building, located on the island of Hjertøya, Molde, in Norway, was started in spring 2009. The work was commissioned by the Romsdal Museum and Littoral Arts and is now on permanent display at the Schwitters in Norway exhibition in the Henie-Onstad Art Centre near Oslo.

It is hoped that the facsimile will play an important role in providing a physical copy of the *Schwittershytta* at a specific moment in its life. The original is now being dismantled and will be reassembled in the Romsdal Museum. Eventually there might be an interesting comparison between the facsimile of the *Schwittershytta* and the re-assembled original. All objects change over time making both the object and the way we care for it a dynamic subject.

A facsimile of collage by Gómez de la Serna in MNCARS, Madrid.

Factum Arte was commissioned to undertake the scanning and facsimile production for a work by the Spanish poet Ramón Gómez de la Serna. The MNCARS (Museo Nacional Centro de Arte Reina Sofía) hosted this untitled work (referred to as *Window-Panel from the Ramón Gómez de la Serna's study on Hipólito Irigoyen street, Buenos Aires*) temporarily as a loan from the Museo de Arte Contemporáneo de Madrid. When the loan ended MNCARS wanted to retain an exact copy, which has now become part of the permanent collection.

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A facsimile in bronze of 'Seneca and Nero' is on public display in Córdoba.

The 'directly worked' plaster original of Eduardo Barrón's *Seneca and Nero*, made in 1904 is in the collection of the Museo del Prado. For many years it was on display in the Ayuntamiento de Córdoba. Despite the fact that the plaster was painted, it is assumed that Barrón intended the work as a bronze. In 2006, following a project involving 3D scanning and stereo-lithographic printing, a bronze version was made without touching the surface of the original at any point in the process. This copy (arguably the 'original' bronze) is now on permanent display in Córdoba. Following the completion of the facsimile, Factum Arte worked with the Museo del Prado to scan a maquette in Zamora and 3D print a hand that had been heavily restored on the original plaster sculpture. This approach raised important questions during the restoration work carried out by the museum.

The facsimile of a Golden Lion by Matteo de Bonarelli is on display in Museo del Prado, Madrid.

In 2005 the Museo Prado initiated a restoration project to replace the lost bronze lion that used to form part of the base of a pair of tables commissioned by Velázquez in 1651 from the Italian artist Matteo de Bonarelli. The original tables were in the Alcázar in Madrid until one of the bronze lions was destroyed in a fire and consequently replaced with a lead copy. Over time the lead deformed and it was decided that it should be replaced by a bronze cast.

Following conversations with Elena Arias and Gabriele Finaldi at the Prado it was decided to gild the lion using the same process originally used by Bonarelli in 1651 – mercury gilding (fire-gilding). In this process an amalgam of mercury and gold is applied to the surface of the bronze. The mercury is then volatised, leaving a thin layer of gold on the surface. The impurities in the mixture condition the final colour of the gold that was carefully matched to the originals.

A facsimile of 'La Defensa de Zaragoza' by José Álvarez Cubero is installed in Priego de Córdoba.

La Defensa de Zaragoza depicts an important event in Spain's struggle for independence from Napoleon's France. It represents a contemporary episode in which a son defended his father during the siege of Zaragoza. This classically inspired sculpture is a seminal piece of the Spanish Neo-Classical period.

For many years the sculpture stood outside El Casón del Buen Retiro and was covered with a thick crust of black pollution. Underneath this crust the marble was fragile and in places turning to a granular powder. The production of the facsimile for Cubero's hometown of Priego de Córdoba assisted the conservation team at the Prado in their restoration of the work. The facsimile is now on permanent display in Priego de Córdoba. The restored original is in the Moneo extension of El Prado.

John Stevens Henslow's teaching charts – recording completed, facsimile tests in process.

John Stevens Henslow (1796 – 1861) was an English botanist, and teacher at Cambridge University. He is best known as the friend and mentor of Charles Darwin. Henslow was originally meant to sail with Robert Fitzroy on HMS Beagle but due to personal reasons he recommended his student Charles Darwin instead.

George Loudoun provided the funding to cover the costs of recording the teaching charts for the Whipple Museum of the History of Science. The high-resolution recording (1:1 at 600 dpi) is an important documentation that can be used to monitor the condition of the fragile works on paper. It can also be used to disseminate the works in various forms and will hopefully generate income for the museum in the future.

Outcomes

The C19[th] was the time of the plaster-cast both as a didactic tool and as material archive. Few of the great plaster-cast collections have survived intact. The iconoclastic tendencies of modernism or financially-based political decisions destroyed many. Now, in the C21[st] high-resolution recording of various kinds and 3D output technologies are emerging as a central element in the preservation of cultural heritage. Factum Foundation seeks to nurture a new type of digital artisan who is both skilled in the practicalities of digital recording but is also equipped with the intellectual framework necessary for the application of technologies in new and innovative ways while also identifying and developing specific technologies for new challenges. Conservators, restorers, curators, managers, researchers, scientists, art historians, digital artisans, and anyone interested in preserving our history will find in the Factum Foundation a valuable body of knowledge – both theoretical and practical – from which to re-think our relationship with the sites and objects that define us through our shared past. The emphasis is on the application of affordable technology and the transfer both of equipment and skills to local communities. Factum Foundation is investigating and testing new ways to work with and disseminate the importance of cultural heritage, as well as identifying ways to generate funds that can be reinvested in the upkeep, maintenance and conservation of the many sites. With the potential to store vast amounts of information attention is turning to the diverse ways this can be elaborated, contextualised and applied.

Some of the ways it will be used may be developments of existing technologies that could range from virtual and physical printing to merchandising. But new opportunities are emerging that range from I-pad applications to projections onto painted and sculptural surfaces, virtual reconstructions/restorations and physical 3D prints. In the near future children, students and interested individuals will be able to download 3D files of museum collections and re-materialise them at home on low-cost 3D printers. Virtual restoration projects will be able to rely on willing volunteers to assist in the painstaking task of digitally reconstructing surfaces that have suffered as a result of mass tourism – the protocols for this will need to be established to ensure objectivity but these are no more complicated than those that have already evolved to cover the actual restoration of the objects themselves.

Touring exhibition: Immortal Pharaoh; the Amduat in the burial-chamber of Thutmosis III

Museo Arqueológico, Madrid 2004; City Art Center, Edinburgh 2005; Antikenmuseum, Basel 2006

The centrepiece of this exhibition was an exact replica of the burial chamber of Thutmosis III in the Valley of the Kings. The walls of the tomb contain a complete text of the Amduat: the text which chronicles the pharaoh's journey through the dark hours of the sun to his rebirth as the sun-rises in the morning. This text is the key to eternity – both for the Pharaoh and everything that is dependent on the continuation of the sun.

The exhibition consisted of a selection of original objects from Madrid, Hanover and Basel illustrating the themes of the Amduat and the rituals surrounding burial, mummification and resurrection.

Selected Exhibitions and Events
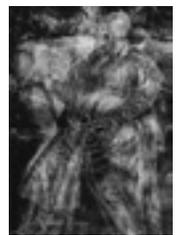
Facsimile, Exhibition and Dialogue: The Miracle of Cana; The Originality of the Re-Production
Fondazione Giorgio Cini, Venice 2007

In the autumn of 2006 the Musée du Louvre reached an agreement with Fondazione Giorgio Cini and granted Factum Arte access to record Veronese's great painting, the *Wedding at Cana* and make a facsimile. The recording conditions were strictly regulated but resulted in some innovative solutions to the recording of large-scale works at high-resolution. The resulting facsimile now hangs where the original used to hang before it was ripped off the wall of Palladio's refectory on the island of San Giorgio Maggiore, Venice by Napoleon's troops. Back in its original location the composition of the painting regained its sense of being, revealing insights that have been obscured during its time in Paris.

Multi-media presentation: Peter Greenaway responds to Leonardo's Last Supper
Palazzo Reale, Milan 2008; Melbourne Festival, Australia 2009; Armory, New York 2010

Factum Arte was commissioned by Change Performing Arts to produce of a 1:1 facsimile of Leonardo da Vinci's *Last Supper* in Santa Maria delle Grazie, Milan. The facsimile, derived from high-resolution colour photographs taken by the Novarra based company Haltedefinizione is an accurate copy of the colour of the heavily conserved original printed onto a distressed plaster surface. The complete facsimile, including sections of the ceiling, side walls and three dimensional objects was installed in the Palazzo Reale in Milan as part of a live performance by Peter Greenaway and Reinier van Brummelen. It was originally shown from the 14th to the 21st of April 2008 but was extended due to popular demand and was later shown in the Melbourne Festival 2009, Australia and the Armory, New York 2010.

Touring exhibition: The Arts of Piranesi. Architect, engraver, antiquarian, vedutista, designer
Venice Biennial of Architecture, Fondazione Giorgio Cini, Venice 2010; CaixaForum, Madrid 2012; CaixaForum, Barcelona 2012; San Diego Museum of Art, San Diego 2013

An exhibition curated by Michele de Lucchi, Adam Lowe, Giuseppe Pavanello and Alessandro Martoni that opened in Venice in May 2010 and has been touring ever since.
The exhibition is an innovative re-interpretation of Piranesi as one of the great designers of the C18th. In addition to over 250 prints from all stages of his work there are a group of objects realised by Factum Arte that use digital modelling, 3D printing and traditional fabrication processes to realise some of Piranesi's designs.

Dissemination and Communication: educational visits, courses, seminars and lectures

Dissemination and communication of the importance of technology in conservation is central to the Foundation's aims. Interns regularly spend time Madrid and Bologna. SPEAP (Sciences Po, Paris), IUAV (Venice), Complutense (Madrid), Cambridge University (Cambridge), the Architectural Association (London) have all been recent visitors.

Funding

All the projects that are documented in this booklet, all the technologies that have been developed, all the software that has been written take a vast amount of time, human skill, energy, focus and, above all care. They don't happen fast and they don't happen of their own accord. The team that works in Factum Arte and the Factum Foundation for Digital Technology in Conservation have come together to demonstrate that new technology and manual skill exist side by side and both are essential to help preserve, elaborate and understand the material evidence of our heritage. The way we work does not accommodate the accepted divisions between science and art, artist and artisan, technician and intellectual – skills are pooled and the labels move between people.

Interest in our heritage is a vast and growing industry. This can be a destructive force, or an extraordinarily powerful force for change in the way we view the past. With millions of cultural tourists each year enough money can be generated from our cultural heritage to ensure its preservation as long as the difficult and delicate task of managing sites and caring for objects is communicated effectively.

The Factum Foundation was never planned. It emerged from the interests and concerns of the people who have made it what it is. This initiative has been entirely self-financed – it has never received any public funds and yet it has already carried out the work shown and described on these sixty-four pages. The number of projects that are emerging, the assistance we are asked to provide and the developments we are involved in continue to multiply. We have now reached a point where we need some assistance – some genuinely altruistic support to ensure that we can respond to the need.

Everything changes with time – the real vision behind all the work we do is the realisation that works of art don't emerge fully formed, but they develop over time. In the era of anti-ageing treatments our interest lies in reading the trajectories of objects – helping people understand and be comfortable with where they came from and what shaped our past.

The task of the Foundation is to ensure that future generations can inherit the past as we inherited it and that a careful documentation and study of the material evidence will reveal its changing and dynamic biography.

The Foundation is committed to developing new technologies, communicating the role of high-resolution, non-contact documentation, elaborating the data in diverse ways and redefining the role facsimiles can play in preservation and conservation. To succeed in its aims Factum Foundation needs to raise funds from committed supporters through donations and project-specific funding. It already develops events, exhibitions, technological presentations to deliver a variety of projects to a large public. It is now establishing and developing its educational side.

The Foundation has so far managed to juggle its modest funds between different projects – but they have become too numerous. We are now seeking support to sponsor specific projects as well as more general individual and institutional assistance in order to continue to develop, innovate and be able to apply the technology and human skill we control to the projects that are in most critical need.

For more information please go to our website
www.factumfoundation.org
or to contact us please write to
info@factumfoundation.org

'La muestra que se exhibe ahora en Madrid, en CaixaForum, "Las artes de Piranesi, arquitecto, grabador, anticuario, vedutista y diseñador", es extraordinaria. Tiene, entre otros, el mérito de mostrar buen número de los objetos que Piranesi concibió y diseñó pero nunca llegó a ver materializados, pues eran demasiado excéntricos e insólitos para el gusto de sus contemporáneos. Los ha producido, con escrupulosa fidelidad y utilizando la tecnología más avanzada, el laboratorio madrileño Factum Arte que dirige Adam Lowe. Esos candelabros, trípodes, sillas, chimeneas, adornos, apliques, jarrones en los que Piranesi dio rienda suelta a su desbocada fantasía y su amor por las civilizaciones del pasado – Roma, Egipto, los etruscos – fascinan casi tanto como las invenciones carcelarias que lo han hecho famoso o las Vistas de esa Roma de los siglos grandiosos que él creyó documentar en sus grabados cuando en realidad la rehacía e inventaba.'

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Mario Vargas Llosa,
'El visionario', *El País*, 6th May 2012,
Nobel Prize in Literature 2010.

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