Press Kit

Khufu Reborn

The adventure continues...

Kheops Renaissance
L'aventure continue...

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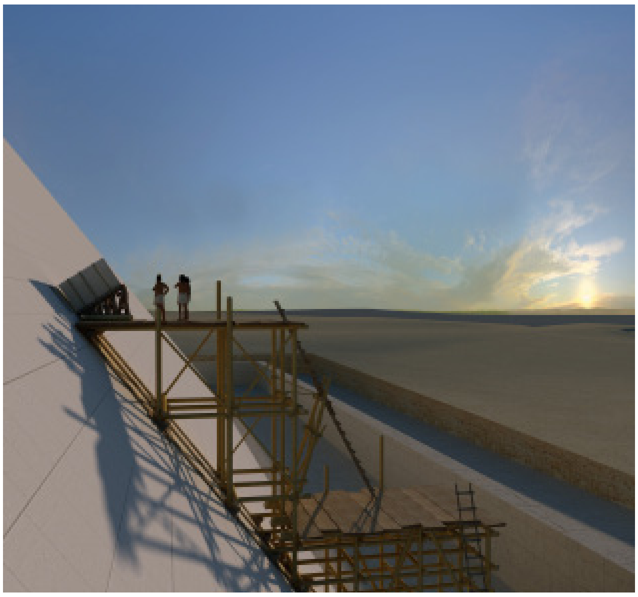


Exploring the past using tools of the future: the adventure continues

On March 30, 2007, an incredible journey back in time took place in the futuristic surroundings of La Géode. The French architect Jean-Pierre Houdin led a packed auditorium into a virtual Egypt to recreate the construction of the Khufu Pyramid with a degree of realism that only 3D relief can offer. In front of 400 people wearing 3D glasses, he revealed his theory about how the pyramid was built. Houdin's theory is the only one to explain each and every phase in the construction of the sole surviving member of the seven wonders of the ancient world.

The inspirations for this event

Were one man's obsession with a 4,500 year old enigma, and collaborations with other enthusiasts whom a priori would never expected to have found themselves working together on this project. The Great Pyramid first became a part of Jean-Pierre Houdin's life in 1999. The so far unexplained mystery of its construction became an obsession for this architect hooked on new technology and 3D. As an experienced architect, Jean-Pierre was already thinking about the pyramid in full 3D in order to better understand it. This original approach enabled him to gradually develop his theory. But he needed powerful tools in order to cultivate it further. Here entered Dassault Systèmes, world leader in "real time 3D" software.

In 2005,

the software editor launched "Passion for Innovation", a technicalsponsorship programme designed to support original projects by contributing its software solutions. Dassault Systèmes has new 3D tools that make it possible to design and simulate some of the most impressive manufacturing projects of our time in three dimensions. Previously "unachievable" projects now continue to defy reason and turn established practice on its head. By making it possible, for example, to design a giant plane, a futuristic building or even just a car in record time, industrial 3D tools encourage new ways of thinking and, therefore, of innovating.

But should the concept of innovation automatically be linked with the future? Could it not be used to go back in time to help formulate new ideas?

Fascinated by Jean-Pierre Houdin's obsession

and rigorous approach, and motivated by the challenge, Dassault Systèmes accepted the architect onto its "Passion for Innovation" programme. For two years, teams of Dassault Systèmes engineers worked tirelessly in order to examine the entire theory through the critical lens of scientific 3D tools. Everything from 3D modelling to mechanical simulations was implemented in order to ascertain the theory's scientific validity. In doing. so, the engineers took the opportunity to review the story of the cracks in the King's Chamber for the first time, and to put an end to all the doubts surrounding the talent of the Egyptian builders. It was also the first time that a theory explaining the pyramid's construction from A to Z had been endorsed by the 3D software tools used by leading manufacturing groups. Such results had to be shared with the masses. Once more, Dassault Systèmes had the right tools: interactive 3D as a universal language. Isn't it said that a good picture is worth more than a long story? Dassault Systèmes was convinced that creating an experience and immersing the general public in the process of the pyramid's construction would rival any speech or image. Hence the theory that premiered on 30 March 2007, which has since been shown at La Géode three times a week and online to millions of internet users every day.

But the adventure didn't stop there.

The 3D interactive show was received to such widespread acclaim that a TV documentary about Jean-Pierre's theory was made. Shots taken in Egypt were combined with computer generated images from the 3D universe created by Dassault Systèmes.

During filming,

the American Egyptologist Bob Brier went to examine a notch located on the north-east corner of the pyramid, the same one that Jean-Pierre had always considered as evidence supporting his theory. Bob returned with video, photos and observations. This was all Jean-Pierre needed to resurrect his thought process. On the basis of these findings, he worked once more on honing his theory in conjunction with the teams from Dassault Systèmes. Using the data collected by Bob Brier, the teams modelled what would henceforth be known as "Bob's Room" in 3D, and carried out new simulations under the supervision of Jean-Pierre Houdin, who was now interested not only in Khufu but in all of the pyramids from the 4th Dynasty. By examining the collection, he had identified a logical relationship from an architectural point of view.

At the same time,

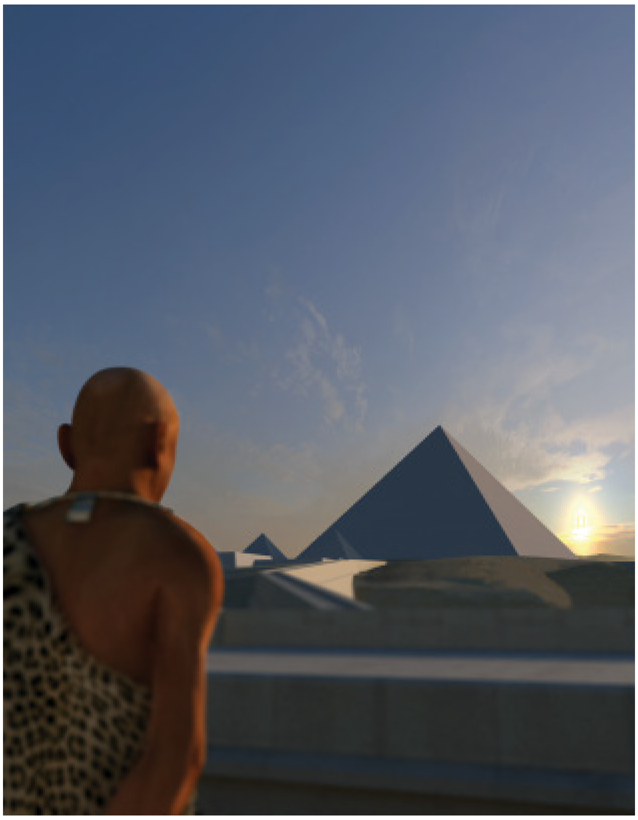
in their quest for non-destructive investigation methods capable of locating conclusive evidence to support the theory, the team also carried out thermal simulations in order to be sure that infrared thermography technology could be used. It was also important not to forget the person who inspired the pyramid as a resting place for the afterlife: Khufu. Writings confirm that the Great King was buried there. The funeral and the route taken by the procession is equally fascinating to Jean-Pierre Houdin, as are several additional complications concerning the monument's internal architecture.

Another mystery on which the architect has worked tirelessly to solve, so far without having shared anything about it.

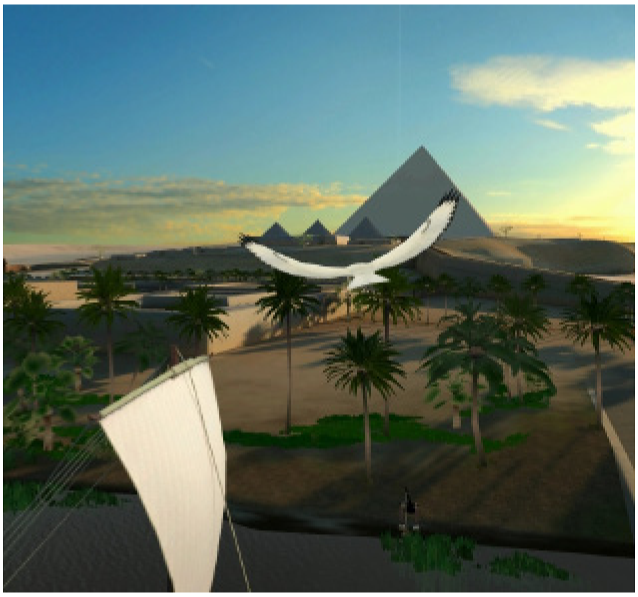
After another two years of intensive effort

coordinated by an increasingly motivated Jean-Pierre, it was time once again to share the results of what had become a veritable quest. The quest of one man, an architect fascinated with the engineering feats of his Egyptian predecessors. The quest, too, of a team of engineers mindful of the remarkable intelligence of these builders who, using methods that were truly basic in comparison with modern computers and machines, designed and built the Great King's pyramid. Jean-Pierre Houdin and Dassault Systèmes were about to introduce us to a spatial experience; to a new and exciting journey through time, which would change the way we viewed the Khufu masterpiece for ever. Once again, the tools of the future would enable us to explore the past.

The Khufu adventure was firmly underway.



Khufu: a giant in the desert



The last remaining wonder of the world

By definition, a pyramid is a monument with triangular sides with a polygon for a base and a common summit. For historians, a pyramid is a royal burial tomb from ancient Egypt. For the rest of humanity, the three pyramids of Khufu, Khephren and Mykerinos that stand on the Giza plateau just outside Cairo are both a treasure and an enigma.

What do we know about these pyramids?

We know that they were designed to guard the remains of three pharaohs, almost three thousand years ago. Whilst the most impressive of these colossal stone structures, the Khufu Pyramid, has been studied and photographed an incalculable number of times, its insides remain a mystery that evokes rich treasures and mythical curses. It is said that the Great Pyramid is the only one of the seven wonders of the world still standing, the only one that, until now, has withstood the folly of humankind and the wrath of the elements.

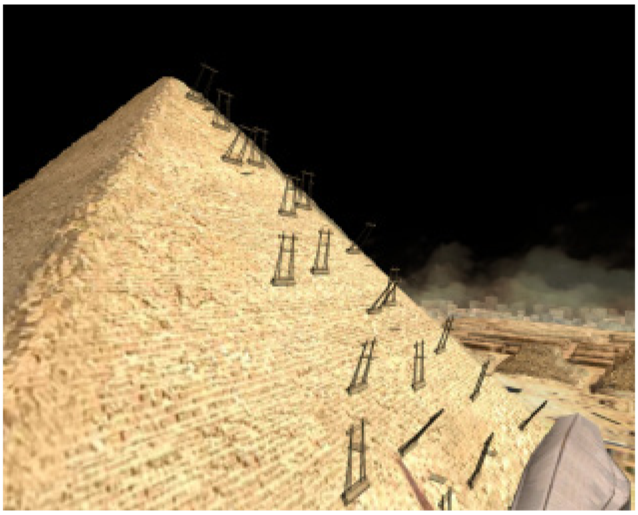
Standing 146 metres high,

it was the tallest monument in history until the Eiffel Tower was built. However, we still don't know how it was built by these men who had no iron, no wheels and no pulleys, nor how long it took. Neither do we know what secrets it could still be hiding within its stone walls.

A witness to 4,500 years of history,

the Khufu Pyramid has been visited by the world's most important figures: those who have admired the mesmerising scale of all that it symbolises; those who have dreamed of endless conquests or immortal life. Over the centuries, powerful men and ordinary people have surveyed its stones. Some, intoxicated by this strange sensation, are convinced that a work on such a scale could not be of human doing, and that only an unknown and faraway civilisation could have created such a wonder.

The mystery of the Great Pyramid



The Great Pyramid: between myth and reality

Through the ages, the secret of how the Khufu Pyramid was built has been lost. As surprising as this sounds, no writings exist from that era explaining how the seventh wonder of the world was constructed. If we dispense with the sensational theories of extraterrestrial activity and the lost world of Atlantis, our attempts to explain how the Great Pyramid was built focus on three main areas.

Machines /

Instruments similar to wooden cranes used to hoist stone blocks up the side of the pyramid. With the slopes of the Khufu Pyramid exceeding 51°, how would it be possible to hoist blocks weighing up to 60 tonnes in such conditions?

Huge ramps on the outside /

One or more ramps built up against the sides of the pyramid would have made it possible to transport the blocks during construction. A simple idea, but in order to reach the summit, the volume of such a construction would have been double that of the pyramid itself, which seems extremely unlikely.

A spiral ramp wrapped around the pyramid /

A ramp wrapped around the outside of the pyramid like a spiral staircase, which would be built as the construction progressed. Unfortunately, such a ramp would interfere with the sight lines of the pyramid, making it difficult to monitor the project. In addition, turning the blocks around corners would have been extremely dangerous.

The main disadvantage with all these hypotheses is that none looks properly at how the monument was constructed as a whole. At some point, each theory hits one snag or another. The reason is beautifully simple: the problem has never been studied from a global perspective, nor presented in the right way.

When Jean-Pierre Houdin

began to tackle the "mystery" of the Khufu Pyramid, it was as an architect, with his expertise and building experience. This is what led him to identify three distinct issues concerning the construction of the Great Pyramid:

\ The construction of an enormous volume in a relatively short space of time

\ The construction of a chamber with a 43 metre high flat ceiling in the heart of the pyramid

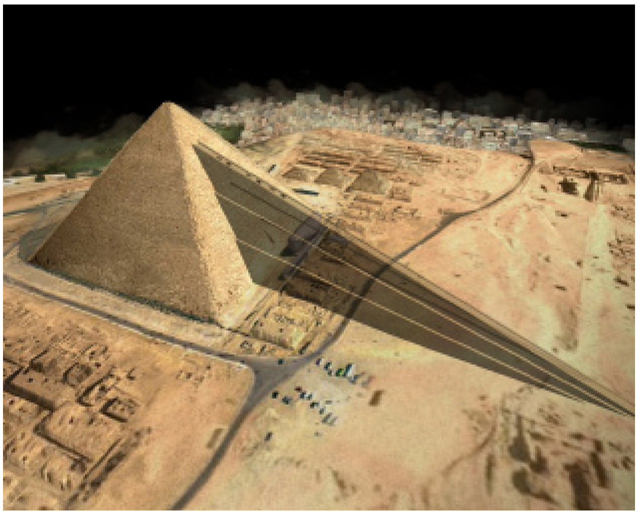
\ The construction of a 146 metre high monument

The volume, the King's Chamber and the height:

three phases of a unique construction project, which, examined one by one using the most suitable solution, would make it possible to explain how the entire construction was built by unravelling the mysteries that have continued to puzzle over such a long period of time.

The quest of one man:

an architect who, for more than twelve years now, has striven to tread the path of his illustrious predecessors...



The quest of one man

The man behind the theory: Jean-Pierre Houdin. A brief autobiography

I was born in Paris in 1951,
but grew up in Abidjan, in Africa, where my father managed a building and public works company. As a young boy, I spent my spare time on building sites, while my mother, who was a doctor, looked after patients in a bush dispensary. My interest in the world of construction probably stemmed from this first period of my life. Back in Paris, and following my baccalauréat, I went to the Fine Arts school to study architecture.

After graduating in 1976,
I set myself up as a freelance architect, a job that I did for twenty years. I helped with numerous construction projects, both residential and office buildings, in and around Paris, France. At the same time, together with my wife Michelle and our friend Laurent, we opened an art gallery for avant-garde events («Les Enfants Gâtés»), which hosted works by dozens of young artists for ten years, and became one of Paris' top artistic venues at the turn of the 90s.

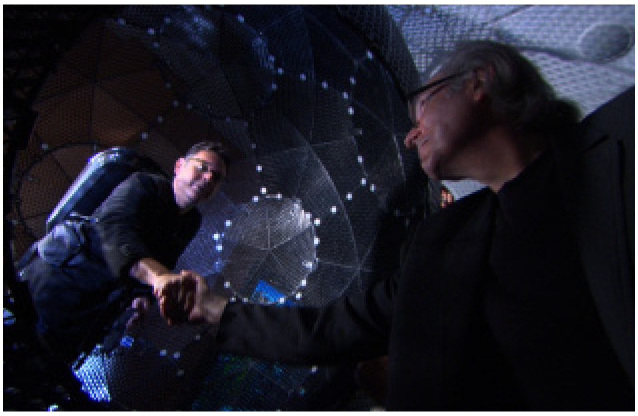
In 1996,
Michelle persuaded me to start a new chapter in our life, so we decided to take a year's sabbatical in New York. I went with no definite schemes, but plenty of ideas up my sleeve: I wanted to study again and to work freely, with no restrictions, but with passion. This was the perfect era to harbour such ambitions, as the Internet was to develop massively during these next few years.
This new state of affairs resulted in a new way of thinking in every area of life, including work. I learnt to use the Internet, to draw using the first ever digital drawing tools, and I started creating websites, firstly in New York, and then in France as I returned to Paris in 1998, with a new career and new experiences.

An enigma,
one man's intuition and the start of a quest.
On January 2, 1999, when I was in New York once more, my father, a retired engineer, was watching a programme presented by François de Closets, all about how the pyramids were built. He cast his construction engineer's eye over the theories put forward at the time. They didn't hold water. And then it struck him:
the pyramids had been built from the inside!

It was a revolutionary idea,
because it swept aside all other hypotheses that had been put forward until now. He asked me, as an architect, and well-versed in 3D technology, to help him with his research. In 2000, we met several members of a team that had carried out microgravimetric surveys in the Khufu Pyramid in 1986, as part of the EDF Foundation. They showed us their plans, which revealed a peculiarity in the construction; a detail in the drawings that could not be explained by any of the existing hypotheses. This peculiarity, dubbed "the spiral construction", concurs perfectly with the idea of a ramp built inside the pyramid, and which would have been used to help build it!

This was the start of my adventure with Khufu...

Jean-Pierre Houdin and Dassault Systèmes



A meeting and a first rate partnership.

Thoughts of a lone architect

Jean-Pierre Houdin would spend six years developing his theory based on his father's intuition: what if the pyramid had been built from the inside?

Jean-Pierre was an architect, which gave him every right to try and recreate the construction of the Khufu pyramid. After all, who understands an architect better than another architect? However, he was careful to avoid a common trap: all too often, architects and engineers allow themselves to be blinded by their own technical expertise. They put forward clever theories, but ones that are marred by anachronisms and which contradict the evidence available on the ground, and which Egyptologists would refuse to accept. Jean-Pierre took great care to avoid these pitfalls (no wheels nor iron back in Khufu's day!). Furthermore he adopted a radically different viewpoint of the pyramid by looking at it in 3D, in order to enhance his understanding of it.

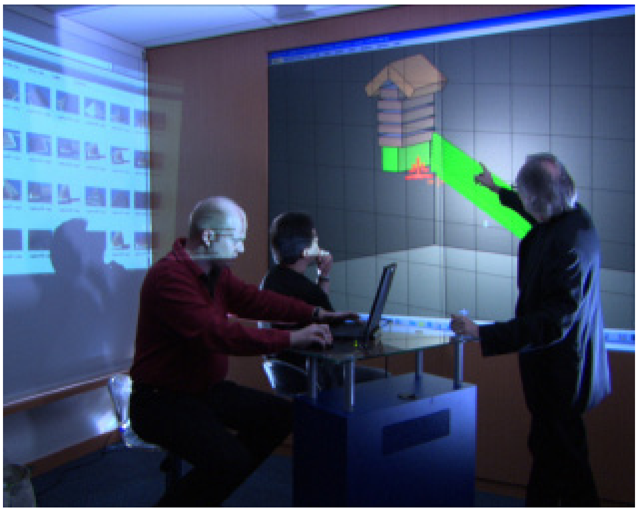
But he quickly exhausted the possibilities offered by the tools available to him. The meeting with Dassault Systèmes in 2005 would breath new life into his quest.

Passion and innovation: a shared interest

The solutions offered by Dassault Systèmes were ideal. 3D design and realistic simulations would enable him to pursue his work, whilst the theoretical and rational model supporting his theory was already well established and potential evidence from the site had been recorded. It turned out that Dassault Systèmes had recently launched a technical sponsorship programme called "Passion for Innovation". Destined to provide support for particularly innovative projects championed by individuals and not for profit associations, the programme seemed perfect for Jean-Pierre. He explained his theory for the first time, illustrating the basis for his ideas in front of Mehdi Tayoubi and Richard Breitner, both of whom lost track of time, so intriguing was his talk and convincing his demonstration. When Jean-Pierre added "If I had never seen the pyramid in 3D, I would never have been able to understand it," they exchanged a knowing look. Jean-Pierre Houdin joined the programme shortly afterwards. The theory was already so well structured that the modelling and simulations required to test it against Dassault Systèmes' scientific solutions were carried out with the greatest of ease.

For nearly two years,

a multi-disciplinary team of around fifteen people (including engineers, designers and developers) would support the research architect. The first task was to model the pyramid and simulate the various construction processes using Dassault Systèmes' scientific solutions. Used by some of the biggest industry names, these solutions integrate all the laws of physics. This means that a virtual pyramid is built and stored in computers, with all of its geometric (e.g. shape and dimensions) and physical (e.g. material density, elasticity, resistance) characteristics; a type of «electronic twin» on which the various construction stages are simulated in a realistic manner. The advantage of a 3D reality model is that it can be taken anywhere on just a laptop computer, examined from all angles and measured spatially. It is also possible to replay simulations as many times as required, changing the parameters each time. This enabled Jean-Pierre to explore the subject in more detail and to further hone his theory. Such is the great power of scientific 3D technology: simulating reality, adjusting the model accordingly and improving it until satisfied, all for the cost of theprocessing time and a small amount of electricity.



The simulations deliver their verdict

Jean-Pierre's theory was mechanically plausible. For the first time ever, the construction of the Great Pyramid had been explained in its entirety and each stage had been substantiated by scientific 3D software typically used by major manufacturers.

3D: a universal language to support sharing

Dassault Systèmes and Jean-Pierre Houdin were keen to share their findings with as many people as possible. 3D had once again proved itself to be the perfect tool. On 30 March 2007, La Géode was transformed into a time machine to take us back through the millennia. Transported to Khufu's Egypt, the audience were plunged into the construction site of the Great Pyramid as recreated by Jean-Pierre.

Following this conference,

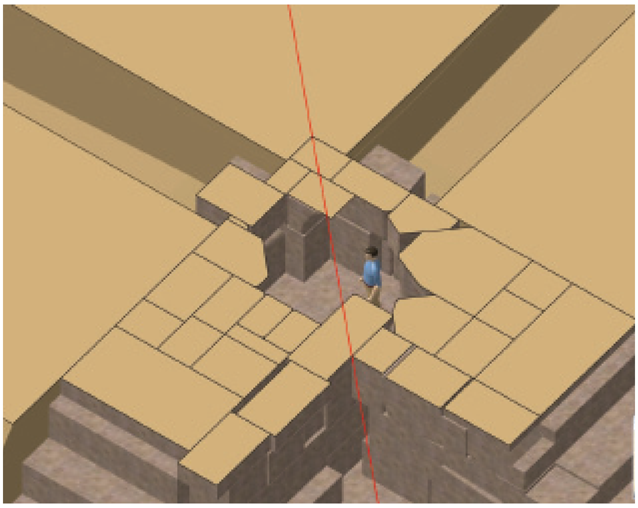
La Géode incorporated an hour-long 3D relief interactive show about the building of the Khufu Pyramid into its programme. It was shown three times a week, and aimed at schools and families. There would also be a special evening show every month, featuring Jean-Pierre in person. All of this had a huge impact. Both the ideas (the theory) and the technical means (a unique immersive experience) of the event were much reviewed and talked about in the world press. In terms of ideas, Jean-Pierre Houdin's theory was the first to offer a comprehensive explanation of how the pyramid was built and to withstand the scrutiny of scientific 3D tools. The "mysteries" of its construction had been consigned to the mists of time. Instead, we discovered highly pragmatic Egyptians working to a specific plan carefully established in advance: they were, after all, history's first engineers. The evidence was clearly presented by an observant Jean-Pierre who spots the most minute details that would go unnoticed by the layman, but that enlighten the architect as to the thinking behind the pyramid's construction. The way in which the stones are superimposed, the slightest sign of a corridor, an unexpected change of angle: all of these elements inspired the thinking of someone whose motto could well be "It's not just coincidence."
Jean-Pierre Houdin's theory about how the pyramid was constructed is extremely logical and breathtakingly simple, particularly when projected in 3D relief.

An idea already gaining ground

Two and a half years before the "Avatar" wave, 3D glasses made an appearance in a large Parisian cinema. There was one major difference, however. This was not a film with a fixed scenario and the 3D calculated in advance, but an interactive adventure where the 3D universe shown was calculated in real time according to the movements made within the virtual world. Alongside Jean-Pierre, a "3D jockey", or "3DJ" (a new term was needed after Disc Jockey and Video Jockey!) took the spectators around the Khufu site as instructed by the architect, who asked him to get closer to a specific detail or to enter a particular room. At one of these evenings, Jean-Pierre was directly questioned by someone asking for more specific information. The 3DJ immediately zoomed in on the area concerned, and Jean-Pierre gave detailed explanations about the point in question. This meant that each spectator could potentially take charge of their own experience, and no two sessions would ever be exactly alike. 3D immersion in a world of bewildering reality produces powerful emotions. Everyday frames of reference are replaced by those from the virtual world. These are used to create a unique and powerful experience that leaves a lasting impression. If we add to this incomparable impact the possibility of interacting with the conference speaker, we are able to exploit the full potential of such an experience: education, entertainment, and vocational and collective training.

A living theory:

the birth of computer-aided archaeology. Following the initial revelation of 30 March 2007, over 30,000 people have been able to re-live the building of the pyramid at La Géode, just as millions of Internet users have done online on the Dassault Systèmes website. This widespread visibility led practically seamlessly into the release of a documentary in 2008, called "Kheops Révélé" ("Khufu Revealed"), which combined images taken from the 3D virtual world with sequences shot in Egypt. Screened by over 30 channels across the world and awarded several prizes, this film tells the story of Jean-Pierre's quest and the partnership with Dassault Systèmes, exemplary on both a technical and a human level. It was during filming that a crucial event occurred. Amongst the observations recorded by Jean-Pierre in support of his theory, there was a notch approximately 80 metres high on the north-east corner of the pyramid, at the very place where the architect had predicted that one of the "platforms" of his internal ramp would be.



The Egyptologist Bob Brier

obtained permission to climb the pyramid and visit this notch. At Jean-Pierre's request, he brought back photos and measurements; the corresponding footage was included as a bonus on the DVD of the film.

How could the data from this visit that lasted barely twenty minutes be used to its best advantage?

The answer was obvious

and, once more, involved the use of 3D tools. Guided by Jean-Pierre Houdin as the project manager, the teams from Dassault Systèmes used the photos and measurements to model "Bob's Room" in 3D (even taking into account the distortion produced by the wide angle lens!). This enabled Jean-Pierre to come up with new hypotheses, and to test them in the 3D virtual world. He worked unflaggingly to correct and fine-tunethe model and the simulations. Soon, with the help of the 3D tools, the internal ramp and the process of turning blocks around corners had been simplified and become more logical.

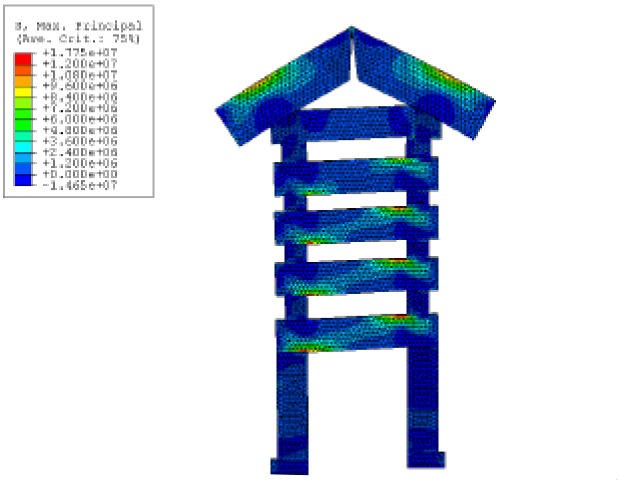
By making it possible to conduct in-depth analysis of data from a short exploration, both retrospectively and remotely, Jean-Pierre Houdin and Dassault Systèmes had laid the foundations for "computer-aided archaeology".

With 3D technology,,

it is now possible to study and enhance the findings of an observation mission and even prepare and simulate the next, which will be better focused and more effective, therefore shorter and less expensive. Better still, realistic simulation enables us to test investigation methods by virtual means, and to choose the most effective with a view to implementing them on the ground. This was how Jean-Pierre Houdin and the teams at Dassault Systèmes were able to make sure that infrared thermography would prove an effective, discreet and non-invasive technique with which to locate in situ - the experimental proof still required to corroborate the validity of the theory.

"Infrared thermography and the pyramid"
See section 10 further on.

3D'scientific contribution to the theory



Jean-Pierre Houdin's theory

is the first to explain each and every phase in the construction of the pyramid without shying away from any problematic issues, such as the question of how such a volume was built or how granite beams weighing over 60 tonnes were placed in the King's Chamber between 43 and 60 metres off the ground. The investigation method called on the architect's expertise, painstaking observation of the monument and the site (looking for evidence that revealed the thinking behind the pyramid's construction), and extensive documentation (so as to avoid any risk of anachronisms). This made Jean-Pierre's work perfectly suited to computer modelling.
The laws of physics that determine whether a wall stands up or not have not changed since the days of the Ancient Empire. Whilst the materials and the tools may have evolved, it remains no less true that a contemporary architect is extremely well placed to analyse the work of his distant predecessors, particularly now that he can rely on powerful software tools: 3D solutions from Dassault Systèmes. We were dealing with the laws of physics. These would be translated by equations that would be seamlessly integrated into this design and simulation software. The result? A virtual world played out in a computer's memory just as it would in the real world. This is precisely what we call modelling. This digital transposition of reality is carried out in three stages:

Geometric modelling /
Physical modelling /
Functional modelling /

\ Geometric modelling

is the vital first stage that makes it possible to draw the object being studied in three dimensions and on a life-size scale. As it happened, the pyramid was recreated using the exact measurements available and with the entire network of interior corridors and burial chambers. It was then possible to manipulate the geometric model as required: to rotate the pyramid in order to study it from all angles, to look at cross-sections, and to examine the layout of internal corridors and burial chambers etc. using see-through techniques, etc. It would obviously be impossible to manipulate the real pyramid in the same way as the 3D pyramid, the latter lending itself to a series of rapid observations. The 3D model also enabled Jean-Pierre Houdin to gain a clearer understanding of the monument and to establish relationships between certain measurements (for example, it is possible to instantly obtain the distance between two points on the model). Establishing the relationship between certain levels and the length of various internal structures of the pyramid can provide the architect with a lead or vital corroboration to help him develop his theory. The geometric model, however, is still no more than an "empty shell", void of any information that might enable the architect to apply the laws of physics to simulate its behaviour.

\ Physical modelling

aims to enhance the geometry with the physical characteristics of the materials making up the pyramid. It's easy to know where to find limestone or granite, but now we can also learn about their physical parameters (e.g. density, elasticity) and incorporate this data into the geometric model. It is then possible to simulate the behaviour of the virtual pyramid as if it were the real thing: material resistance, the effect that the weight of the pyramid has on itself, etc.

\ Functional modelling

Jean-Pierre Houdin's theory involves a certain number of mechanical systems such as sleds and trolleys moving along wooden rollers. These systems are well known in mechanics with their characteristics and their differences (friction would not be the same for a shoe sliding along a rail and a load moving on a roller). These characteristics are incorporated into the 3D model.

It is then possible to produce the entire model complete with dimensions as well as the physical and functional parameters of the real pyramid.

The result

A "digital twin" of the real pyramid that can be manipulated and simulated in any manner possible, anytime, anywhere, on a simple laptop computer. Only 3D modelling offers such a flexible and convenient way of quickly testing multiple hypotheses. By putting all of its solutions at Jean-Pierre Houdin's disposal, Dassault Systèmes had effectively provided him with a highly realistic virtual Egypt in which he could repeatedly test his theory to ensure that it was compatible with the laws of physics.

Since 2007,

he has used the same realistic 3D model to tweak his theory in the light of new information collected from the site and developments in his ideas. Such is the vital contribution made by scientific 3D to the project. Typically, Dassault Systèmes solutions enable manufacturers to invent the future. Product design and simulation, production line design and optimisation (from basic tasks to entire factories), information sharing between partners and subcontractors in real time: everything is developed in 3D in a virtual IT world, where errors are infinitely less expensive than in real life. The degree of detail even goes as far as to check the workstation ergonomics using virtual dummies! This genuine "antechamber of reality" paves the way for the most ambitious of inventions to be created at minimal cost, in complete safety and much more quickly. This explains why, for example, today's products are updated with increasingly high performance products far more quickly than in the past, a phenomenon that is true of all industries, including consumer goods, automobile and aviation. In Jean-Pierre's case, Dassault Systèmes' scientific 3D tools made it possible to understand the construction of the Khufu Pyramid after the event.

Any scientific process consists of three stages in a fixed order:

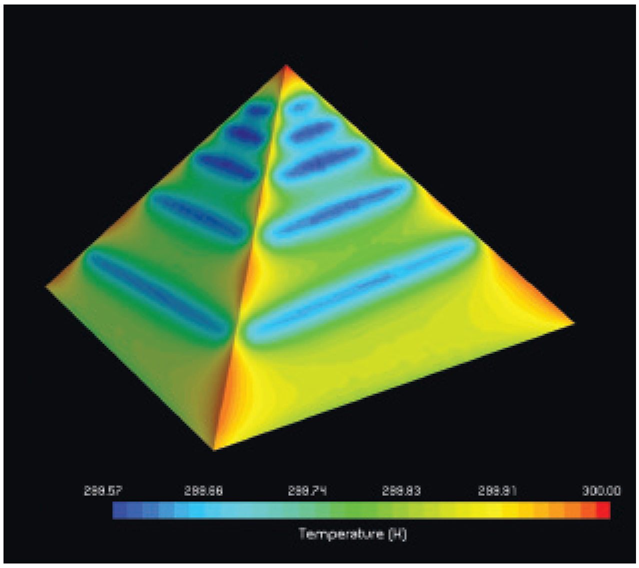
Intuition that leads to the theory /
"The pyramid was built from the inside"

Rigorous demonstration of the theory /

Experimental proof /

With 3D modelling and simulation having demonstrated that the theory was mechanically possible, it was now necessary to visit the site to test for the presence of an internal ramp. To do this, they required an investigation method that was both effective and respectful of the monument, its environment and the restrictions posed by tourism on the the Giza plateau. At this stage, the 3D model was still proving useful. A thermal simulation had shown that infrared thermography was an avenue worth exploring.

"Infrared thermography and the pyramid"
See section 10 further on.



Similarly, it was the flexibility of Dassault Systèmes' tools that had enabled Jean-Pierre Houdin to hone his theory since 2007 by incorporating data such as the "Bob's Room". Any change, whether to the model's geometry or to its associated data, would automatically generate an analysis of the various impacts on the overall model and propagate the corresponding changes within this model.

To put it simply,

there is no need to start from scratch as was customary in the era of drawing boards. Far from claiming to replace the observations recorded on site, the 3D model and its simulated behaviour have helped not only to nurture Jean-Pierre's thought process and bring his theory to life, but also to better plan observation missions in the future. It is clear that scientific 3D constitutes a vital tool for modern archaeology.

The University of Leeds

fully understood this. In order to lead a successful robotic exploration mission along the corridors of the Queen's Chamber in the Great Pyramid, the University joined the "Passion for Innovation" programme in 2009. Djedi the robot was then designed using SolidWorks solutions by Dassault Systèmes and its route simulated in the 3D reconstructed corridors.

A perfect illustration of the possibilities offered by 3D technology for archaeological investigations.

The interactive 3D revolution for the masses

The initial presentation of the theory in immersive 3D at La Géode demonstrated the relevance of another type of 3D: interactive 3D media.

Whilst scientific 3D was a crucial prerequisite for bolstering the theory, the sensory and emotional impact of 3D media and its universal appeal have illustrated just how suited it is to the sharing of information in an efficient, yet enthralling manner. The incomparable power of a live experience, three years before the arrival of mainstream 3D cinema, has demonstrated the power of Dassault Systèmes' 3DVIA solutions in the "Serious Game" arena.

The Museum of Fine Arts (MFA) in Boston and Harvard University knew what they were doing. After signing a strategic partnership in 2010, Dassault Systèmes and the MFA decided to model the Giza plateau in 3D in order to make use of the museum's substantial Reisner collection. By the end of this ambitious project, anyone and everyone will be able to navigate - in 3D and online - right across the plateau's necropolis, to visit the painstakingly recreated mastaba tombs and to gather information about those occupying the tomb, when it was discovered and what objects were found there, etc.

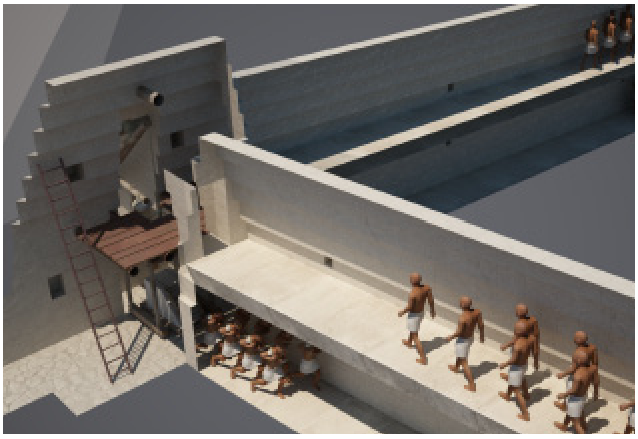
The virtual Giza plateau

will be for not just at the general public, with a guided tour of the most beautiful mastabas, but also at students and professionals, who would have specific access to the appropriate level of information. It's happening before our very eyes: interactive 3D has seen a new form of museography evolve: a modern museography, suited to the demands of a public that now lives and breathes multimedia, and who would no longer be satisfied with objects exhibited in cabinets and accompanied by a few explanatory texts. Interactive 3D, however, enables us to resurrect them within their natural environment, thereby achieving a perfect balance between scientific rigour and technological creativity. This is an experience that researchers and students can turn to their advantage.

The educational dimension

is undeniable. Moreover, Peter Der Manuelian, Philip J King professor of Egyptology at Harvard, is convinced of it. An enthusiastic manager of the Giza 3D project with Dassault Systèmes, he recently gave the University's first Egyptology course via immersive 3D, plunging students into the virtual necropolis of the Giza plateau! New forms of immersive interaction in the sphere of archaeology are emerging. The use of 3D technology is clearly inspiring new forms of communication and scientific investigation. In addition, and this was demonstrated in 2007 with Jean-Pierre's theory, the real strength of the 3D worlds available - thanks to the 3DVIA solutions created by Dassault Systèmes - is that they are multi-platform. By making a few adjustments to the user interface and to textures, the same 3D content can then be used in either 3D relief cinemas like La Géode, online, on 3D TVs, on games consoles, and so on, with the core 3D and the logic behind its animation remaining identical, thereby considerably optimising production costs. Mainstream 3D is now a reality!

Khufu Reborn: honing the theory



Underpinning the work of Jean-Pierre Houdin,

was the latest ingenuity and architectural challenge at the heart of the entire project: constructing the interior. The «Houdin method» was used to express the problem correctly. The architect summarised the construction of the Great Pyramid in three points:

1/ Construct the volume.

2/ Reach the summit.

3/ Construct the King's Chamber at the heart of the monument using a flat ceiling (a novel feature of the Khufu Pyramid, and a unique accomplishment that neither Khafre nor Menkaourê had reproduced in their pyramids).

The overwhelming advantage of this approach?

Treating each of these three points with the best possible technical solution given the constraints of each particular stage. This signalled the end of the "singular idea" based on the principle that the pyramid had been constructed from the outside. Furthermore, "traditional" theories were set in stone, suggesting only one hypothesis that might hold true for a particular stage, but never for the construction project. as a whole. It was necessary to segment the project and adopt a different viewpoint.

And so...

1. Most of the volume (85%) was constructed using a short external ramp that made it possible to supply the project with vast quantities of materials extremely quickly. It was of no use beyond the bottom third of the pyramid's height, as its proportions would become dangerously unfeasible.

2. For this reason, the remaining construction used an internal ramp spiralling upwards underneath the "skin» of the pyramid. Built from the base of the pyramid, it provided a means of transporting materials right up to the summit.

3. The choice of a flat ceiling for the King's Chamber meant that granite had to be used, the only material capable of covering the room. The heaviest beam weighed 63 tonnes! Human strength alone was insufficient to move and position such immense weights. Some form of traction system was needed: a counterweight moving around the Grand Gallery.

The external ramp in detail

Jean-Pierre's external ramp bore no relation to the immense one and a half kilometre long ramps put forward by certain theorists. By making clever use of a natural ridge on the plateau, the ramp began higher up than the bottom of the pyramid, which meant that, measuring just 325 metres long, it could reach the south face of the pyramid at a height of 43 metres (level with the base of the King's Chamber). This continued along an internal section inside the monument up to a height of 70 metres (updated from the 2007 theory), the whole ramp having a gentle slope of barely 8.5%. It served its purpose well, supplying this massive project with materials for as long as possible. At a height of 70 metres, there was only 15% of the volume left to build, which seemed fairly small. However, this task was trickier than it appeared. This upper section of the pyramid measured 76 metres tall, and was too far from the external ramp, unless the latter was lengthened to such an extent that it exceeded the volume of the pyramid itself.

The internal ramp in detail

The role of the internal ramp was to enable blocks to be hauled right to the top of the pyramid. Constructed at the beginning of the project, it was a straight quarter turn ramp with a gentle slope of 7% used to transport the façade's limestone blocks from the Toura quarry. Once the external ramp had served its purpose, it was dismantled, and its limestone blocks re-sized to make smaller blocks that could be used to complete the last 15% of the monument's volume. These reconditioned blocks were then hauled up on the internal ramp. The principle of the internal ramp and of turning the blocks around the ramp's corners remained the same. However, all of this was considerably simplified and streamlined in the wake of new research carried out by Jean-Pierre that resulted in, most notably, the 3D modelling of the «Bob's Room".

Gone was the external passageway for the workers to use. The ramp now had two levels: a lower level for sleds loaded with limestone blocks for the construction, and an upper level for "empty" sleds to make their return journey.

Such a configuration can be seen in the Meidum pyramid (whose descending corridor has a corbel vaulted ceiling forming a second level). Turning blocks at the corners was done in the "Bob's Rooms" with a system of wooden cranes identical to the shadoufs that were used to draw water from the Nile. Gone was the open-air platform seen in 2007.

The pyramid was therefore entirely built from the inside, starting with the sides, layer after layer, until it reached the top. The pyramid's sides, covering a total surface area of more than 84,000m, were placed in their final positions from the start, with no adjustments or finishing works required at the end. This simplified the task considerably and reduced the overall completion time by several years.

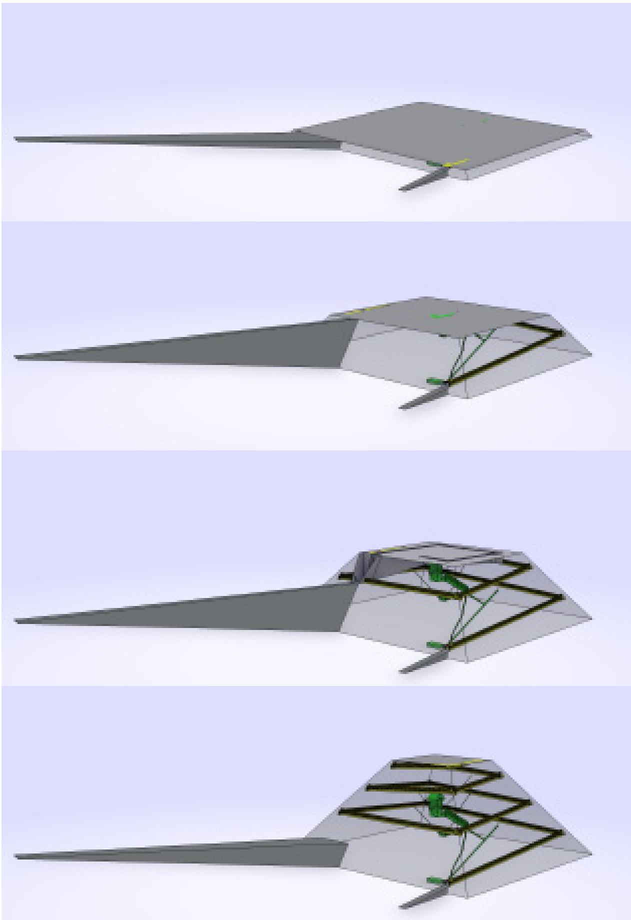
With the ramp and counterweight

on the Giza plateau fully dependent on the idea of the external ramp as a "fast track" stone haulage method and the counterweight as an "engine", Jean-Pierre Houdin installed a ramp on the Giza plateau that led from the port to the foot of the external ramp of the pyramid. This "plateau ramp" made it much easier and quicker to transport materials to the site, particularly heavy monoliths, even more so since the driving force for the transportation of said materials was provided by a system of counterweights identical to that suggested by Jean-Pierre in the Grand Gallery in 2007. This new counterweight operated within a shaft hollowed out of the rocky base (later on, this would have a major influence on the architecture of the Khafre pyramid, and its presence can be observed on site). The plateau ramp would then have been used as the base for the Khafre causeway. In fact, it is possible to observe a 23 metre wide base (for a mere 10 metre wide monumental walkway), unrivalled by any other pyramid causeway base. Along its course, this ramp served several of the plateau's quarries that supplied the majority of the materials used to build the pyramid. Once these materials had been transported to the site, the counterweight on the plateau ramp was dismantled and its components re-used elsewhere on the site.

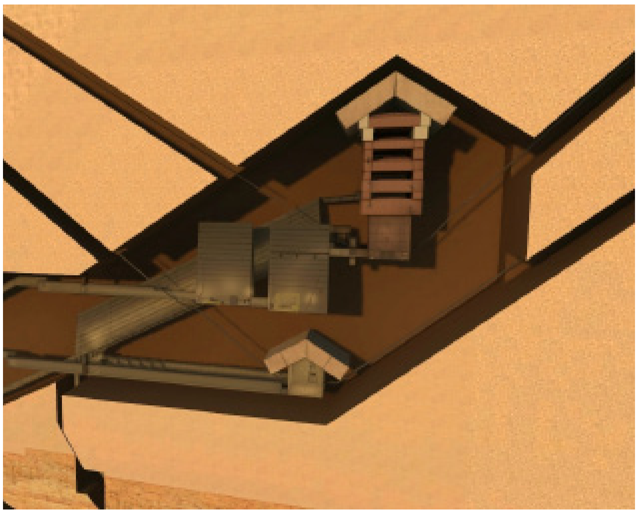
The Grand Gallery counterweight

To lay granite beams weighing between 27 and 63 tonnes in the King's Chamber could not be done by human strength alone. Around 600 people would have been needed in order to hoist the heaviest monoliths. It would have been impossible to coordinate such a number and, furthermore, there would have been insufficient room for them all. Therefore, a counterweight operated from the Grand Gallery, in order to reduce the number of men required to around 180. According to the principle of the lift (or funicular railway), as the counterweight went down into the Grand Gallery, the platform holding the beam to be moved went up. This "assistance" made it possible to haul up and position more than 70 beams. Compared with the original version of the theory back in 2007, when the ceiling was put in place, gone were the teams used to re-load the counterweight after traction. The entire beam transportation platform was made up of the same elements forming the counterweight that had been going up and down within the gallery on the plateau ramp axis and which were re-used for this very purpose. Each time a beam was unloaded at the level where it was to be placed, this platform would then act as a counterweight; loaded with around fifteen small blocks weighing almost 3 tonnes and easily transportable, in other words, sufficient to become a "counterweight for the counterweight» and replenish the Grand Gallery system.

Since the theory was initially advanced in 2007, not one single development has raised any question whatsoever over the fundamental principles. Quite the opposite: they have taken the theory further, in the sense that construction was more straightforward and required fewer resources, particularly human ones. It should be remembered that Jean-Pierre Houdin has always found evidence on site to support his ideas).



The antechambers in the Khufu Pyramid



The architectural lineage

Jean-Pierre Houdin did not consider the Khufu Pyramid to be an isolated monument, instead placing it in the architectural lineage of pyramids from the 4th Dynasty. After the first pyramid of Djoser created by the mighty Imhotep, Jean-Pierre noticed that the pyramids shared a certain architectural logic, including that of Khufu. For the architect, each pyramid designer had taken the innovations used in the previous structure and added others in order to improve it. This is how we moved from a step pyramid to a smooth pyramid, whilst burial chambers, firstly carved out of the bedrock, gradually began to rise higher and higher within the building, until the Khufu Pyramid with its impressive flat-ceiling chamber deep in the heart of the monument. A logical process of evolution perfectly mastered by the Egyptian builders whom Jean-Pierre considered to be the first engineers in history. Several things puzzled Jean-Pierre about this process. Firstly, there was the strange way in which the corridors of the Khufu Pyramid and the Grand Gallery were slightly misaligned in relation to the north-south axis.

Why this misalignment?

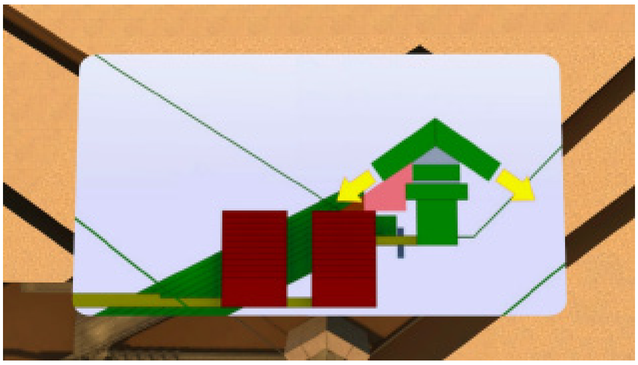
According to Jean-Pierre, the Egyptian architects never left anything to chance. The same applied to the strangely complex shape of the shafts from the King's and Queen's Chambers. They didn't seem to fit with the pragmatic approach that builders from the Ancient Empire seemed to demonstrate. There was also the block of granite present in the King's Chamber after the visit of the Caliphe Al-Ma'mun and until 1998, when it was removed during renovation works. It would have been impossible to have sealed up the King's Chamber with this block from the outside. Given its dimensions, this block could only have been moved from the inside. Which exit, then, had been used by the workers carrying out this operation? There was also the discrepancy between the size of the chevrons overhanging the entrance on the pyramid's facade and the size of the entrance itself. Most importantly, there was the Red Pyramid, the last pyramid by Snefru, the father of Khufu who had at least three built. The Red Pyramid has a flawless design. The burial chamber is inside the building, preceded by two antechambers. The access corridor, the antechambers and the burial chamber are perfectly aligned with the monument itself. The antechambers were used to store the possessions left to the deceased for the afterlife. This flawless plan and these antechambers led Jean-Pierre to ponder the question of Khufu's heritage. No antechambers in its pyramid, strangely misaligned corridors...Why this apparent inconsistency in the Khufu design? Why hadn't it repeated the technique of corbel vaulted antechambers, long since mastered to perfection? And wouldn't Khufu have had some burial possessions? Hard to believe of a king who left us the most imposing monument there has ever been! Firstly it was the mystery of its construction. Now it was the mystery of its heritage.

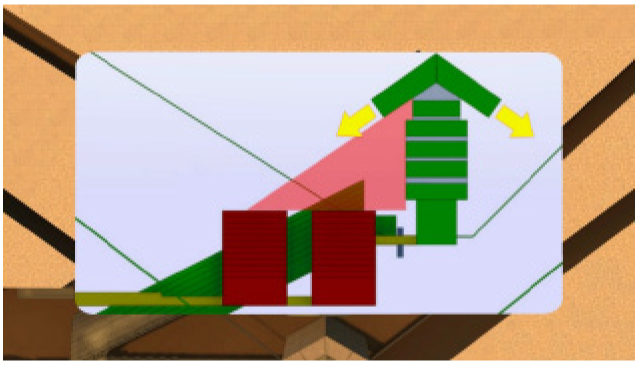
A case of intuition.

Jean-Pierre superposed the plans of the two pyramids. He traced the route through the corridor and the antechambers of the Red Pyramid so that they became those of the Khufu chamber. The superposition was perfect. Better still, it now explained the all-important misalignment of the descending and ascending corridors and the Grand Gallery: the corridor leading to the antechambers and the latter that were located on the north-south axis. The odd shape of the shafts from the burial chambers meant they were able to avoid this new group of structures. The ascending and descending corridors and the Grand Gallery were thought to have formed the route taken when burying Khufu inside his pyramid. Jean-Pierre had always argued that the Grand Gallery had never been intended for use as a burial chamber. For him, it was nothing more than a chute designed to accommodate the counterweight system. Furthermore, taking this passage would have made it decidedly impossible to seal up the King's Chamber. The famous block of granite removed by Al-Ma'mun could only have been put back in place from the inside, as had been witnessed. So, what did this mean? Were a few unfortunate workers buried alive alongside the king? It seemed unthinkable that Khufu would share his burial chamber with anyone at all!

The actual journey made by Khufu

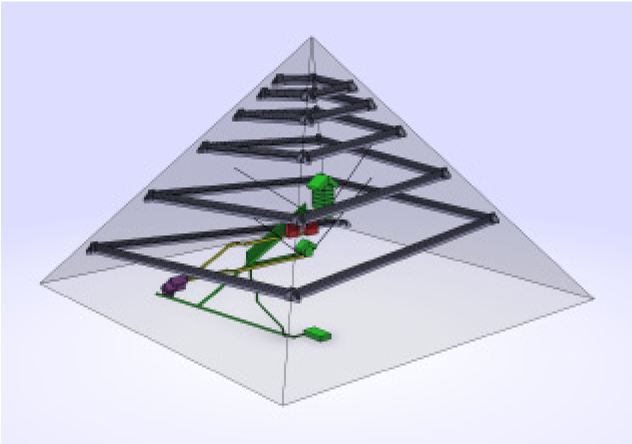
on his way to his eternal resting place would therefore have been through the corridor and the antechambers before finally reaching the King's Chamber. The beginning of the new route lies directly above the entrance to the descending corridor, in two successive rooms housed beneath the chevrons of the façade. The current entrance, used by anyone visiting the pyramid today, is further to the west and was opened up by the Caliphe Al-Ma'mun in 820 when he began his search for Khufu's treasure. As for the antechambers, these led to the King's Chamber via a short, horizontal corridor that finished behind a block of granite in the north wall of the Chamber, under a lintel cleverly concealed in the brickwork. Since then, the pyramid's plan has been revealed in a different light. Firstly, a consistent architectural link between the Red Pyramid and the Khufu Pyramid has been re-established; secondly, the strange discrepancy in the layout of the corridors identified thus far has been explained.





Relief chambers

Above the King's Chamber, these chambers would have been designed, for technical reasons, to pass the limestone chevrons up through the monument. These chevrons would crown the ensemble of chambers. Without this structure, the antechambers would have been crushed by the oblique load transferred from the north side of the roof made of chevrons, their corbelled ceiling only capable of withstanding a vertical load. This type of structure is only found in the Great Pyramid and is linked to the architects' decision to cover the King's Chamber with a flat ceiling. In any case, as the latter required a counterweight in order to haul it into place, laying other ceilings was just a question of money and time, which the architects accepted after due consideration. The idea of a secret chamber where Khufu or his treasure might still lie is not a new one. However, it has never been possible to back it up, through either logical reasoning or experiments. The new plan of the pyramid put forward by Jean-Pierre had the advantage of basing itself on historical fact, adopting a consistent argument, being geometrically accurate and explaining a number of unusual features in the pyramid's layout. Finally, he gave Khufu the antechambers for his burial possessions, which he sees as utterly logical and far removed from the fantastical notions of tomb raiders. We may not yet have experimental proof, but there is clearly no shortage of clues.



The search for evidence on site

Université Laval (Québec)-Dassault Systèmes

Infrared thermography and the pyramid

Ever since Jean-Pierre Houdin first advanced his theory in immersive 3D on March 30, 2007, a huge amount of public interest has been shown in this research architect and his quest. Among the questions most frequently asked during La Géode shows, the question of whether the theory would be proved with a mission to Egypt has undoubtedly been the most popular.

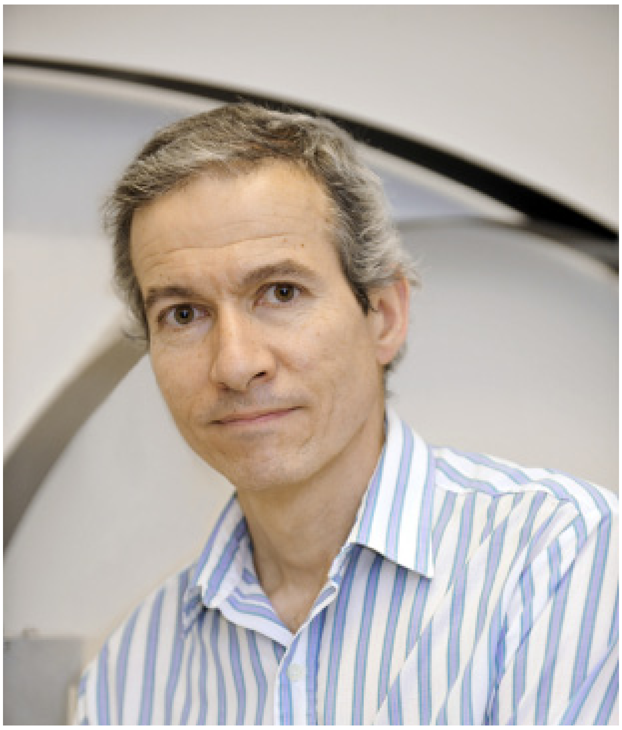
A veritable national symbol on the banks of the Nile, the Great Pyramid does not give up its secrets quite so easily. The Egyptian authorities are understandably fastidious about any requests to conduct missions involving the pyramid. Consistent with his utmost respect for the monument and for those who had designed and built it, Jean-Pierre Houdin had never considered exploring the pyramid using anything other than non-destructive techniques. Making holes in it would have been out of the question! Similarly, mindful of the potential economic impact on tourism, Jean-Pierre was keen to use the least invasive methods possible. That's why there was no question of considering technologies that would impede access to the pyramid during the mission. Recent progress in the miniaturisation of cameras could well make infrared thermography the technology of choice for a discreet and completely "painless" mission designed to verify the suspected presence of an internal ramp within the last resting place of Khufu.

In 2008,

Dassault Systèmes began conducting thermal simulations on a model of a solid pyramid (without a ramp) and a model of a pyramid with an internal ramp, in order to ascertain whether infrared thermography would be capable of providing experimental proof of Jean-Pierre Houdin's theory. In the event, the simulation revealed that the air trapped inside the internal ramp was causing an inversion of temperature at the top of the monument. In summer and during the daytime, for example, the pyramid would be colder at the top, whilst a solid pyramid would be warmer at the top. The simulation also showed that the internal ramp left a thermal imprint on the surface of the pyramid. The differences were small, but sufficiently encouraging to convince the team to delve deeper into the issue.

At the end of 2010,

Jean-Pierre Houdin met the team of the MiViM (Multipolar Infrared Vision Infrarouge Multipolaire) Research Chair at the Université Laval in Québec, a laboratory renowned for infrared thermography research and advanced processing. Fascinated by the theory and by the work already done by Jean-Pierre and Dassault Systèmes, members of the MiViM Chair found themselves bitten by the "Khufu bug" and decided to join the adventure through the "Passion for Innovation» programme run by Dassault Systèmes.

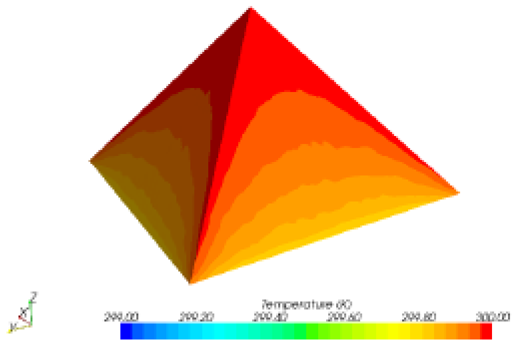


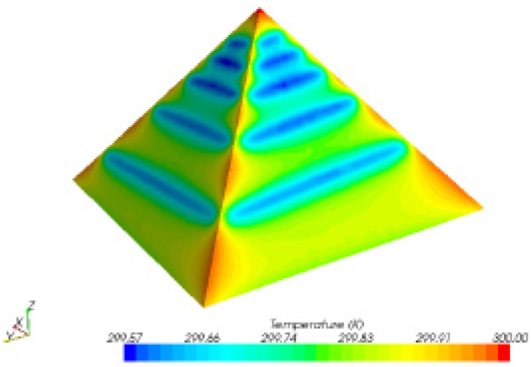
Xavier Maldague - Université Laval

This was the stuff of dreams! Their superb scientific expertise coupled with their experience made the members of the Université Laval the ideal partners. They wasted no time putting forward an experimental method that would form the key focus of their mission application to the Egyptian authorities, backed by Dassault Systèmes, who would provide them with their thermal simulation models from 2008, along with the various simulation and calculation methods.

Why infrared thermography?

Infrared rays are waves, just like visible light, but with much lower frequencies. Any object with a temperature above 0 will emit a certain amount of this electromagnetic radiation proportionate to its temperature. Visible light uses reflection to reveal the external shape of objects. It reveals their colour when the matter constituting the object absorbs part of the radiation. Infrared rays, however, are able to reveal the in-depth structure of objects as they emit heat. Depending on the matter and any sub-surface anomalies such as cracks and cavities, the heat sent back up to the surface is different, making it possible to obtain an image of the internal structure. This is infrared thermography, and it was clear that it would enable Jean-Pierre Houdin to supply evidence of his internal ramp.





The method

The cycles of variations in the external temperature from one season to another influence how the pyramid surface temperature changes over time. Fairly obviously, changes to the pyramid surface temperature, which scientific jargon refers to as the "thermal response", therefore almost exactly mirror the temperature changes in the seasons. But there's one tiny difference: the changes in the pyramid surface temperature will actually be affected very slightly by what exists under its surface, and, in particular, if there is a void beneath the surface, as there would be with the ramp hypothesis. Therefore, by observing not the surface temperatures directly, but rather the difference in the temperature change between two points on the surface of the pyramid, it should be possible to obtain some indication of whether or not there is actually an internal ramp. Temperatures taken in order to monitor changes in thermal response are done using an infrared camera, which has the advantage of being able to measure the pyramid surface temperature at any point, in just one go, without any contact at all, from a distance of over 300 metres. And the consequences? No damage, not one single hole, nor the tiniest grain of sand out of place. This method is non-invasive, and completely invisible to both the public and tourists alike. Neither is there a need for on-site operators. Data is collected remotely online and processed immediately in Canada in the MiViM laboratory of the digital vision and systems laboratory at the Université Laval, with the help of Dassault Systèmes.

This apparently straightforward technique is referred to as the rather monstrous-sounding "non-destructive testing of materials and NDT using modulated or lock-in active thermography». "The basic principle is linked to the subtle shift between the variations in solar heating and the pyramid's thermal response to this, the shift depending on the construction of the monument," explains Xavier Maldague, director of the Canadian chair for research into infrared vision, MiViM. This method is used, for example, when assessing composite materials in aviation, such as the wings of an aeroplane. The difference is that it is used here on an infinitely larger scale; a scale that has never been seen before. On such a scale, more time is required, and one or two whole years spent measuring 24 hours a day wouldn't be excessive in order to observe the extremely slow changes in temperature over time through the 3 to 6 metre thick wall that would cover any ramps. Over the last 4,500 years, however, the pyramids have taught us to be patient.

Matthieu Klein - Université Laval

Dassault Systèmes on the Giza plateau

The first presentation of the Khufu project in 2007 introduced many prestigious institutions to the powerful 3D solutions designed by Dassault Systèmes and their benefits for archaeology. Dassault Systèmes subsequently found itself on the Giza plateau for the purposes of two major new projects.

Djedi :

A robot designed to explore the shafts inside Khufu - a mission led by Leeds University and Dassault Systèmes.

Egyptologists

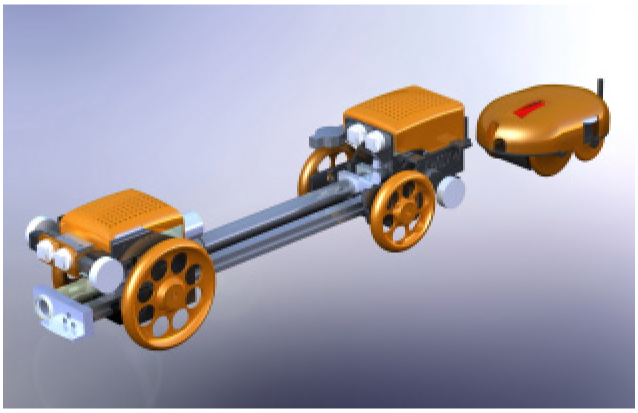
have always been fascinated by two pairs of narrow corridors leading away from the King's Chamber and the Queen's Chamber. Why had they been built? Where did they go? While those of the King's Chamber more than likely played some sort of ventilation role, the same could not be said for those of the Queen's Chamber, even if only because their point of exit in the pyramid's façade has never been found. What's more, their geometry is intriguing: the south shaft is straight, whereas the north shaft is curved. Exploring the shafts leading from the Queen's Chamber seemed inevitable. However, given their narrowness, it soon became clear that the best solution would be to use small robots.

And so it was that in 1993,

the engineer Rudolph Gantenbrink and his team developed Upuaut and Upuaut2 (the name means "he who paves the way" in the ancient Egyptian language). Equipped with cameras and measuring instruments, the robots bumped into a slab with copper fittings on its surface, which was obstructing both the north and south corridor.

In 2002,

the baton was picked up by Pyramid Rover, a robot funded by the National Geographic Society, who was to take over the exploration under the auspices of Egypt's SCA (Supreme Council of Antiquities) led by archaeologist Dr Zahi Hawass. Exploration of the south shaft concurred with that of Upuaut. As for the north shaft, a hole drilled through the slab in 1994 enabled a camera to locate a second block barring the way once more!
The Supreme Council of Antiquities then decided to continue exploring with a new international and multi-disciplinary team. The team from the University of Leeds called on specialists in robotics such as Shaun Whitehead (involved in the Mars Rover robot) as well as embedded sensor and camera experts from Canada and Hong Kong. The mission was dubbed "Djedi", after the magician whom Khufu is said to have consulted when deciding where to place his pyramid.



The main challenge

involved navigating the entire length of the north shaft which, aside from a steep slope of 50 degrees, featured a bend that would be difficult to negotiate. The University of Leeds decided to call on Dassault Systèmes with its 3D design and simulation solutions. This is how the Djedi project came to join the "Passion for Innovation" programme in 2009. Using SolidWorks, the team was able to design and simulate a robot specially adapted to cope with the shaft's unique geometry. Cleverly jointed and equipped with detectors, the robot was able to get a firm grip on the walls of the narrow north corridor and to haul itself up around the bend unhampered.

The first tests on site confirmed the result of the 3D simulations: the robot was perfectly suited to exploring the entire corridor. We can therefore be hopeful that the mission scheduled for 2011 will finally enable us to explore the entire length of the conduits leading from the Queen's Chamber.

La Géode: partner of Khufu 3D

In May 2010, La Géode celebrated 25 years

of exceptional programming by screening an exclusive version of Khufu 3D. A programme — or rather an experience — that it was delighted to offer as a particularly impressive demonstration of interactive 3D relief virtual reality applications and the "Passion for Innovation" programme run by Dassault Systèmes.

The Great Khufu Pyramid

was first showcased at the giant sphere of La Géode in 2008. Thanks to Jean-Pierre Houdin, Mehdi Tayoubi, Richard Breitner, Fabien Barati and their friends, such as Jean-Noël Kendirgi, and controllers and speakers at La Géode, it has become one of the most fascinating and high profile cinemas with more than 33,000 interactive visitors, whether students on educational trips or enthusiasts keen to hear the explanations and revelations provided by Jean-Pierre Houdin during the special evening performances.

With "Khufu Reborn",

La Géode is starting where it left off, showcasing an exciting programme, full of dramatic momentum; a mystery revealed yet so far unsolved. In doing so, it is reinforcing its reputation as a unique venue offering a world of spectacular discoveries and innovations; inspiring a taste for learning, enjoyment from knowledge and, above all, the sharing of one man's obsession.

NVIDIA

The world leader in visual computing technologies and inventor of the GPU, a high performance graphics processing unit, Nvidia has supplied La Géode with equipment since the Khufu adventure began, thereby making it possible to create an incomparable experience in 3D.

SCALABLE GRAPHICS

Scalable Graphics provide services and high performance software solutions for the purposes of 3D calculation and visualisation. Thanks to their Direct Transport Compositor, it is possible to coordinate multiple graphics cards on one single screen. It allows La Géode's Digital Cinema projector to be controlled in real time in order to immerse the audience in a three dimensional world.

Appendix 1

Key dates

1999 /

Henri Houdin, Jean-Pierre's father, is struck by the idea of an internal ramp after seeing a documentary on the Great Pyramid. He seeks the opinion of his son, who takes up the idea and begins investigating the theory..

1999-2005 /

Jean-Pierre Houdin documents and develops his theory.

2005 /

Meeting with Dassault Systèmes, accepted onto the "Passion for Innovation" programme.

2005-2006 /

Modelling and testing of the theory using Dassault Systèmes' scientific solutions.

march 30 2007/

The theory is revealed in 3D relief at La Géode in Paris.

2007-2008 /

Filming of the documentary "Kheops Révélé" ("Khufu Revealed"). Bob Brier takes this opportunity to investigate a notch on the north-east corner of the pyramid. He brings back pictures and observations about a certain room: "Bob's Room".

2008/

Dassault Systèmes conducts simulations showing that infrared thermography could be used as a non-destructive exploratory investigation method for detecting the presence of Jean-Pierre's internal ramp. At the same time, the "Bob's Room" is modelled in 3D and new simulations are carried out. Jean-Pierre incorporates the results of his work into his theory.

\ 2009

Dassault Systèmes and the University of Leeds join forces to conduct a mission on behalf of Egypt's Supreme Council of Antiquities led by the archaeologist Dr Zahi Hawass. The partnership designs and simulates a robot, Djedi, whose mission is to explore the shafts of the Queen's Chamber.

Several test missions are successfully completed on site. The actual exploration mission is scheduled to take place during the first quarter of 2011.

\ 2008-2010

Jean-Pierre Houdin continues to fine-tune his theory using the tools designed by Dassault Systèmes, and collects considerable clues on site to support his thinking.

\ 2010

The Museum of Fine Arts in Boston, Harvard University and Dassault Systèmes sign a strategic partnership agreement. The Giza plateau is to be modelled in interactive 3D technology using archaeological data and archives housed at the MFA (Giza 3D project). A new type of 3D experience will now be accessible by researchers, the educational world and the general public.

\ 27 janvier 2011

"Khufu Reborn" at La Géode unveils the revised theory and exclusive new revelations.

Appendix 2
Biographies

Jean-Pierre Houdin, architect /

Born in Paris in 1951, Jean-Pierre Houdin grew up in Abidjan, Africa, where his engineer father managed a building and public works company. As a young boy, he spent his spare time on building sites, which doubtlessly inspired his interest in the world of construction. Later, in Paris, he went to Fine Art school to study architecture. After graduating in 1976, he set himself up as a freelance architect, a job that he pursued for 20 years. He helped with numerous construction projects, both residential and office buildings, in Ile-de-France. At the same time, together with his wife Michelle and a friend, he opened an art gallery and salon de thé for avant-garde events. It became one of Paris' top artistic venues at the turn of the 1990s. At the end of 1996, he went to New York, at a time when the Internet was enjoying massive growth. He learnt to use the Internet and draw using the first ever digital drawing tools, and started creating websites, firstly in New York, then in Paris, when he returned in 1998. In 1999, whilst watching a TV programme about the building of the pyramids, his father was struck by the idea that the pyramids had been built from the inside. He asked his son, Jean-Pierre, well-versed in 3D technology, to help him with his research.

In 2005, Jean-Pierre Houdin met Mehdi Tayoubi and Richard Breitner under the "Passion for Innovation" sponsorship programme run by Dassault Systèmes. The Khufu adventure was underway.

\ Mehdi Tayoubi, Dassault Systèmes

Director, experiential and interactive strategy. With his multi-disciplinary team of autodictats, engineers, designers and business school graduates all busy innovating alongside each other, he works tirelessly to push back the limits of new 3D technologies and to identify new ways to use them. In 2005, he launched the "Passion for Innovation" programme with Richard Breitner. 3D, an interactive media for all, enabled him to use innovation projects to bring together the worlds of education, culture, research, business and the general public. His achievements include: the first community for sharing and conversing using 3D, www.3dvia.com (3D YouTube), the first ever 3D relief film in real time, "Kheops 3D", in 2007, and 3D documentaries made using virtual reality ("Kheops Révélé", "Rêve de Glace", etc.). He also manages numerous strategic partnerships involving content (Fine Art Museum in Boston, EuropaCorp, etc.)

\ Richard Breitner, Dassault Systèmes

Manager, "Passion for Innovation" program. A 48-year-old engineer, this aviation enthusiast began his career at SNECMA in 1987, where he was already an engineer for CATIA, the well-known CAD software created by Dassault Systèmes. After a brief spell at IBM in the international CATIA support centre, he joined Dassault Systèmes in 1992, where he held various positions in maintenance and industrialisation using UNIX. In 1997, he was fairly obsessed with the Internet, learning HTML language in two hours and creating his first websites.

He helped to develop the very first versions of Dassault Systèmes' websites. In 2001, he joined Mehdi Tayoubi's team and a disabled colleague who was single-handedly carrying out a personal project using CATIA gave him the idea for the "Passion for Innovation" technical spo sorship programme. This scheme was to take the Khufu project under its wing, and coordinate its scientific 3D simulations, as well as write the educational/mainstream version of the immersive Khufu 3D experience at La Géode. Aside from the Internet and Ancient Egypt, he is also passionate about music, Eastern philosophy and classic Japanese poetry. He likes to say that he would need nine lives to learn and do everything that he wants to.

Xavier Maldague/

Université Laval (Québec)

Xavier Maldague / PhD. Eng., has been a professor in the department of electrical engineering and computer engineering at the Université Laval in Québec, Canada since 1989, and was department director from 2003 to 2008. He has supervised or co-supervised over 50 students during their MSc. or PhD. courses and has over 300 publications to his name. Since 2004, he has held a Tier 1 Canada research chair, the MiViM chair (Multipolar Infrared Vision Infrarouge Multipolaire), a chair renewed in 2011. He is an active member of several international bodies involved in infrared vision, such as SPIE Thermosense and QIRT. In 2009, he was appointed Fellow of the Canadian institute of engineers (FICI).

\Matthieu Klein,

Université Laval (Québec)

After studying for an M.Sc. in electrical engineering in non-destructive testing at the Université Laval, Québec, Canada, Matthieu Klein went to work for Advanced Computer Communication Inc. (later bought by Ericsson Inc.) in the United States in 2001. On returning to Québec in 2005, he began a Doctorate (still ongoing) in infrared vision image processing with the MiViM research group of the Vision and Digital Systems Laboratory (LVSN), under the guidance of Prof. X. Maldague at the Université Laval. In 2008, he co-founded Visioimage Inc., a spin-off from MiViM, where he still works today, and earned an MBA in business management in 2009. He introduced Prof. Maldague and his MiViM laboratory to Jean-Pierre Houdin in 2010. He then worked to achieve a consensus between Jean-Pierre, MiViM, the Université Laval and Dassault Systèmes concerning the possibility of finding internal ramps in the great pyramids using modulated infrared thermography as predicted by Jean-Pierre's theory.

Kheops Renaissance
L'aventure continue...

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