SCAN PYRAMIDS MISSION

HIP.INSTITUTE HERITAGE INNOVATION PRESERVATION

ARAB REPUBLIC OF EGYPT MINISTRY OF ANTIQUITIES

FACULTY OF ENGINEERING CAIRO UNIVERSITY

Press Release
Cairo, October 15th 2016

#ScanPyramids – First conclusive findings with muography on Khufu Pyramid

On October 13th, The #ScanPyramids team met at the Egyptian Ministry of Antiquities, with the Scientific committee of Egyptologists appointed by H.E. Dr. Khaled El-Enany, Minister of Antiquities, in order to present the first conclusive results of the muography survey conducted on the Khufu Pyramid since June 2016.

The Scientific committee of the Ministry is led by the former minister of antiquities Dr. Zahi Hawass and is composed of Dr. Mark Lehner, Director of Ancient Egypt Research Associates (AERA); Dr. Miroslav Barta, Director of the Czech Archaeological Mission in Saqqara and Dr. Rainer Stadelmann, former director of the German Archaeological Institute and and Dr. Mahmoud Afifi, Director of Egyptian Antiquities sector, Supreme Counsel of Antiquities, Ministry of Antiquities.

The findings:

North Face of Khufu Pyramid

Among several thermal anomalies that have been detected back in November 2015 by the infrared specialist Jean-Claude Barré (France), a significant one was found on the Northern Face of the Great Pyramid, in the area where 4 visible chevrons overhang the descending corridor.

Another in depth thermal survey was conducted over 3 x 24 hours, by Laval University (Canada) to confirm that this area was a point of interest, where different blocks comprised of the same material in the same orientation were supposed to exhibit similar behavior, which was not the case.

Image 1 - Infrared short survey

Image 2 - Infrared 3 x 24 hours survey

This analysis convinced the #ScanPyramids team to expand the survey of this interesting area with complementary techniques.

A 3D reconstruction and analysis of the area has been done with the competency support of “La Fondation Dassault Systèmes” and “Emissive”.

The many questions raised in this area motivated the team to invest in a complete Muography process through the descending corridor of the pyramid (which is just below), keeping in mind that when the pyramid was finished 4500 years ago, the chevrons of this area were not visible, as they were hidden under casing stones that were dismantled throughout centuries.

Today we still see the remains of those chevrons and oblique stones which most probably are parts of propped missing chevrons covering a kind of void that might have existed before stones were dismantled.

We have also to keep in mind that inside the Great Pyramid there are other chevrons covering the King and the Queen Chambers. In ancient architecture, chevrons were not used for decoration, but they have had a very practical purpose: to protect a void and prevents the roof from collapsing. The question posed here was: why so many chevrons are put to protect such a small area at the beginning of the descending corridor?

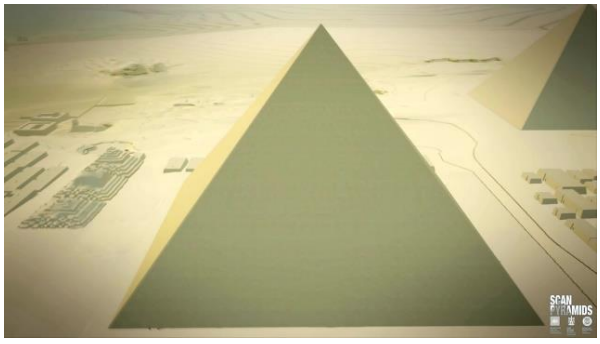

Image 3 - Khufu with casing stones 4500 years ago

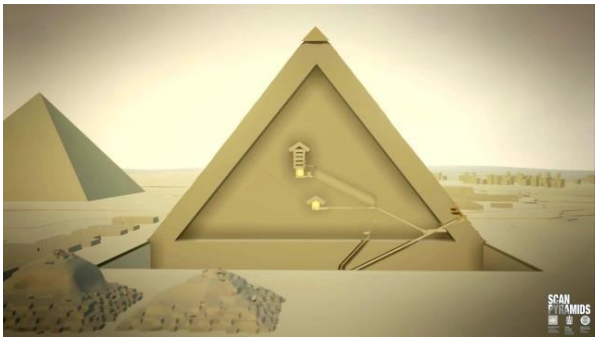

Image 4 - Khufu's internal view of known structures

Image 5 - 3D reconstruction - Khufu Pyramid's chevrons zone

Image 6 - 3D reconstruction - Remains of chevrons

Image 7 - 3D reconstruction - Oblique Stops

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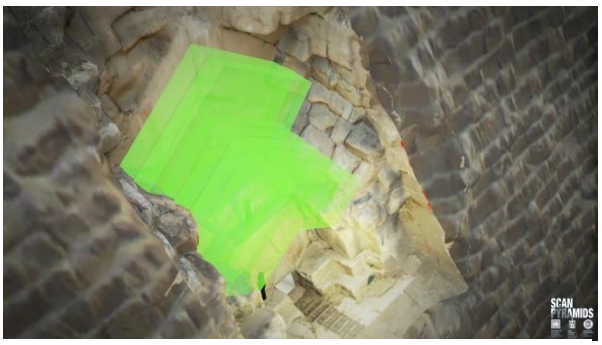

Image 8 - 3D reconstruction - Reconstitution of disappeared chevrons

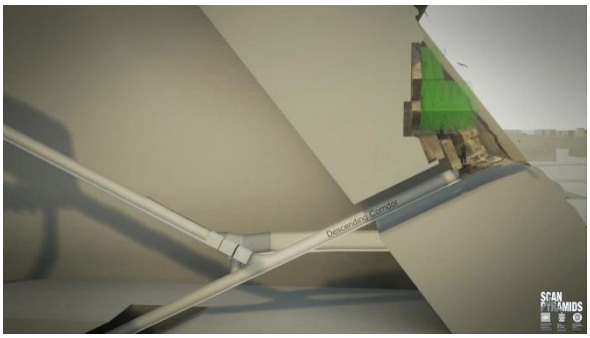

Image 9 - 3D reconstruction - Cut view of disappeared chevrons above descending corridor

Since the team has validated the use of Muon Cosmic rays to observe internal structures of pyramids (on the Bent Pyramid in Dahshour in April 2016). Muography has proved that it is very efficient for detecting voids in massive and thick structures (volcanoes, power plants, pyramids, …). The #ScanPyramids team decided to use Muography to observe the space behind the chevrons.

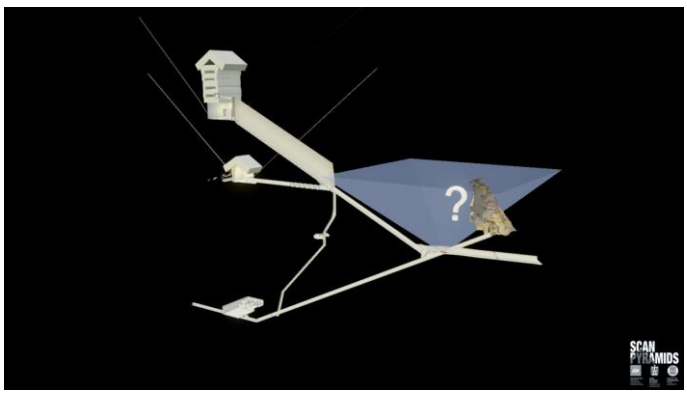

Image 10 - 3D reconstruction - Area analyzed by Muon sensitive plates positioned in the descending corridor

In June 2016 3 aluminum plates containing emulsion films that are sensitive to Cosmic Muons were installed at the bottom of the descending corridor in order to “see” potential voids above them. The films collected Muon information during 67 days before being analyzed at Nagoya University (Japan).

Image 11 - Nagoya University Muon sensitive plates in descending corridor that have been analyzed

Image 12 - Nagoya University emulsion film setup in the descending corridor

Each plate revealed significant excess of muons in the same direction. Several studies were then conducted to prove that this excess of muons, which could be interpreted as a void, was not statistical fluctuation or noise. The comparison with detailed simulations shows that this excess is largely above 5 sigmas. A 5 sigma excess corresponds to an effect with a probability above 99.9999%. This value is commonly used in high energy physics as a discovery threshold. This excess has the shape of a straight line. This feature strongly suggests that it cannot originate from inhomogeneities along the viewing lines, but from one or several voids.

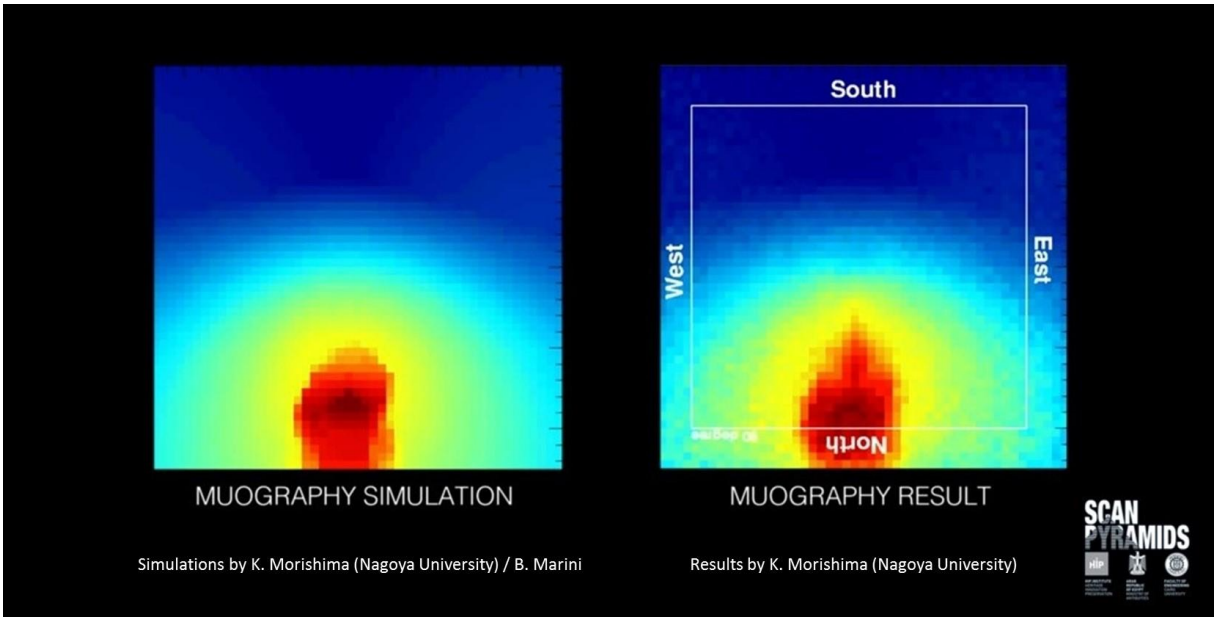

Image 13 - Comparison of muography simulation and results for descending corridor

Having conducting those three complementary techniques, we are now able to confirm the existence of a “void” hidden behind the North Face, that could have the form of at least one corridor going inside the Great Pyramid. The precise shape, size, and exact position of this void is now under further investigation. It should be done with the help of 12 new Muon Emulsion plates that are installed in the descending corridor, and will be collected by the end of October 2016.

The #ScanPyramids team is also completing the investigations by 3D simulation of different architectural hypotheses, with the aid of Muography simulators.

Image 14 - 3D reconstruction - Schematic view of the void behind north face (shape exact position and size to be tuned)

North East Edge of Khufu Pyramid

Beginning of June, Muon gas detectors (telescopes) were deployed outside the great pyramid, around the North Eastern edge; two on the Eastern side and one on the Northern side. They were pointed at a notch located 150 m away (height of 83 m), with the goal to validate their performance of detecting a known cavity (C2) of 9m² that scholars have reported previously.

Image 15 - CEA Muon telescope setup on Khufu

These innovative instruments built at CEA/Irfu operated smoothly during three months and accumulated altogether around 50 million Muon cosmic particles.

The analysis of the collected data revealed 3 known notches (N1, N2, N3).

Around the zone of notch N2, a statistically significant muon excess (6.3 sigma) revealed a correspondence to the cavity already known, i.e. perfectly compatible with the size of the known “room” (C2), and thus fully confirms the performance of the telescopes. This cavity is known to be 6m deep from the edge of the Pyramid.

In addition, another statistically significant excess (5.1 sigma) has been detected close to the edge, at around 105 m high, in the vicinity of another, small notch (N1) invisible from the ground. This excess corresponds to an unknown cavity (C1) with around the same volume of the known room (C2). Further data analysis is still in progress to check for additional cavities of that sort.

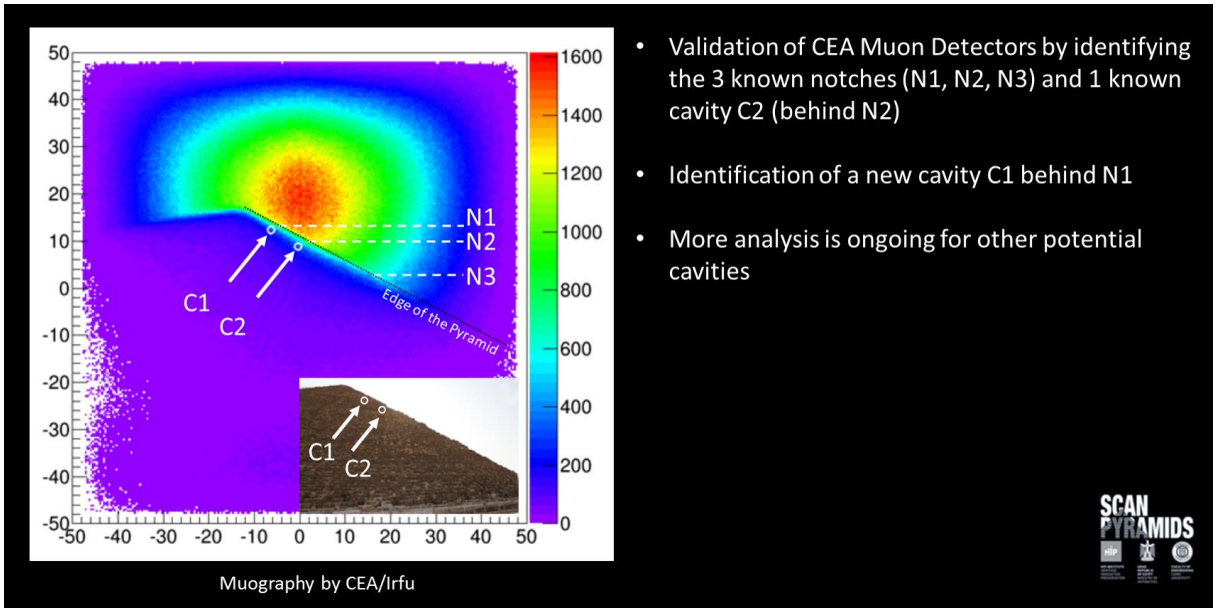

Image 16 - CEA Muography results for Khufu's north east edge

In the forthcoming months, the telescopes will be placed again and pointed towards the other edges of the pyramid for further data acquisition.

Khufu's Queen Chamber

The ScanPyramids team is still acquiring muon data inside Khufu's Queen Chamber with other emulsion films and an electronic scintillator installed by KEK (Japan). We expect to have the results of the analysis of those instruments during the first three months of 2017.

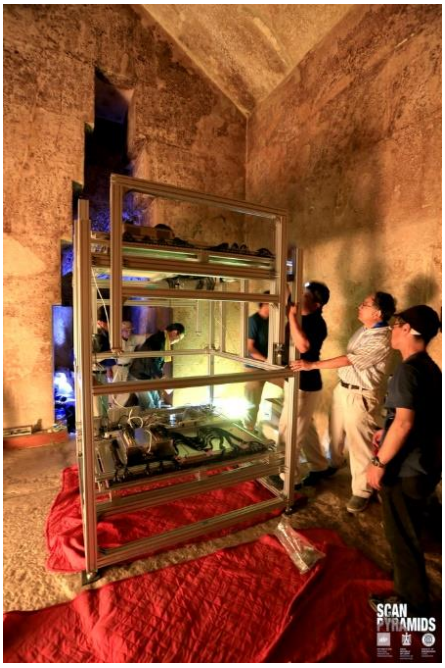

Image 17 - KEK Muon electronic scintillator in Khufu's Queen chamber

Conclusion:

The team presented to the Scientific Committee of the Ministry of Antiquities the conclusive findings of the first year of operation of the #ScanPyramids project, which could be summarized as follows:

1. This is the first time in history that three complementary techniques using Muography, Thermography and 3D simulation are used to "scan" the Great Pyramid of Giza.
2. The #ScanPyramids team is able to confirm the presence of an unknown cavity on the North Eastern edge of the Pyramid, at a height of about 105 m from the ground.
3. The #ScanPyramids team is able to confirm the presence of an unknown void behind the chevrons of above the descending corridor of the great pyramid, while its shape, size and extension are still under further investigation by the team.

More information on muography

Muon particles permanently reach the Earth with a speed close to the speed of light and a flux around 10,000 per m² per minute. They originate from the interactions of cosmic rays created in the Universe with the atoms of the upper atmosphere. Similar to X-rays which can penetrate the body and allow bone imaging, these elementary particles, also called “heavy electrons”, can go through hundreds of meters of stone before being absorbed. Judiciously placed detectors (for example inside a pyramid, below a potential, unknown chamber) can then record particle tracks and discern cavities (which muons cross with practically no interactions) from denser regions in which some muons are absorbed or deflected. The challenge of such measurements consists in building extremely precise detectors and in accumulating enough data (over several days or months) to increase the contrast.

This muography technique is frequently used in volcanology, in particular by research teams of Nagoya University. Within the ScanPyramids mission, three types of detectors have been developed. Nagoya University uses chemical detectors based on silver emulsion films. The KEK has built an electronic device that works with muon-sensitive, scintillating plastics. Such instruments allowed the imaging of nuclear reactor interiors in Fukushima. The muon telescopes of CEA, which joined the mission on April 15th, are made of gaseous detectors based on an argon mixture. In contrast to chemical emulsions, electronic instruments (plastic or gas) allow for real-time imaging.

About #ScanPyramids

#ScanPyramids mission (www.scanpyramids.org) was launched on 25 October 2015 under the authority of the Egyptian Ministry of Antiquities and is led by Faculty of Engineering, Cairo University, and HIP.Institute (www.hip.institute) , Paris (Heritage, Innovation and Preservation Institute). This project aims at scanning, some of the Egyptian Pyramids: Khufu, Khafre, the Bent and the Red Pyramids. #ScanPyramids combines several non-invasive and non-destructive scanning techniques in order to try to detect the presence of any unknown internal structures and cavities in ancient monuments, which may lead to a better understanding of their structure and their construction processes / techniques. This mission is currently using Infrared thermography, muon tomography and 3D reconstruction techniques.

Several international scientific institutions are part of #ScanPyramids: Nagoya University (Japan), KEK (High Energy Accelerator Research Organization – Tsukuba – Japan) and CEA (French Alternative Energies and Atomic Energy Commission – Saclay - France) for muon techniques and Laval University (Quebec – Canada) for infrared thermography.

PICTURES

You can request pictures at contact@hip.institute or - patricia.attar@gen-g.com

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Image 18 - ScanPyramids team inspecting North Face Chevron Area