

## GIZA FIELD SEASON

### Mark Lehner

Ancient Egypt Research Associates (AERA)'s 2008 fieldwork included projects at three of Egypt's main archaeological sites: Giza, Saqqara, and Luxor. At Giza, excavations, survey, and mapping in the Khentkawes Town began on March 1 and continued until April 24, 2008. Due to a high water table, no excavations occurred in 2008 at Giza Plateau Mapping Project's flagship Lost City site south of the Wall of the Crow (which we refer to in short as HeG, after *Heit el-Ghurab*, "Wall of the Crow" in Arabic). Additionally, and in tandem with Egypt's Supreme Council of Antiquities (SCA) and a Japanese consortium, we completed laser scanning and 3-D modeling of the Step Pyramid in Saqqara between late May and early June 2008. The following report summarizes the 2008 work of these two projects. A third 2008 project, the joint AERA-ARCE Salvage Archaeological Field School at Luxor, took place from January through March. The results of the Luxor excavations are being published by the SCA.

### The Khentkawes Town

All the while we were excavating the Lost City of the Pyramids south of the Wall of the Crow, we knew of a neighboring community, roughly contemporary with the final days of the ancient city, on the other side of the Wall of the Crow and about 300 m west. This was the town attached to the tomb of Khentkawes, a queen who ruled at the end of the Fourth Dynasty (fig. 1). Our Lost City settlement must be assessed in the context of this town and of an adjacent settlement attached to the Menkaure Valley Temple (MVT).



**Figure 1.** *The Tomb of Queen Khentkawes stands in the center of the photo. Behind are the Pyramids of Khufu (right), Khafre (center), and Menkaure (left). The Khentkawes Town (KKT) extends east (right) of the queen's tomb. The modern Muslim cemetery fills the foreground. View to the north*

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Realizing the importance of the Khentkawes Town (KKT) for understanding our own site, we applied in 2004 for the concession to survey it, but we only began work in 2005, when the site was under threat from the construction of a new road and the high security wall around the Muslim cemetery nearby.

### ***Town First Revealed***

Selim Hassan excavated the KKT in 1932 and found an L-shaped mudbrick settlement with modular houses arrayed 150 m (492 feet) east–west along a causeway leading to the Khentkawes tomb (Hassan 1943). He produced little more than a map from his work. He did not retrieve or publish pottery and other cultural remains in a way that would inform us as to how long the site was occupied. Egyptologists currently assume the town dates to the late Fourth Dynasty.

### ***AERA Discoveries of Earlier Seasons***

In 2005 Pieter Collet and Mark Lehner found that the builders created the “foot” of the town on two terraces. The upper terrace included a water tank, round granaries, and magazines. Many of the mudbrick walls were eroded down to the last few centimeters or millimeters, or completely scoured away. Hassan’s crew found many of the walls waist-high or taller seventy-six years ago.

In 2007, working at the eastern end of the town, Lisa Yeomans and Collet found definitive evidence of two phases, despite the severely eroded walls. Most surprisingly, they discovered the remains of a building to the east founded on a lower terrace. This building was not included on Selim Hassan’s map. Nor does it show in any archival photographs from Hassan’s work, or those of George Reisner, who also worked at Giza during the 1930s.

### ***Goals of Season 2008***

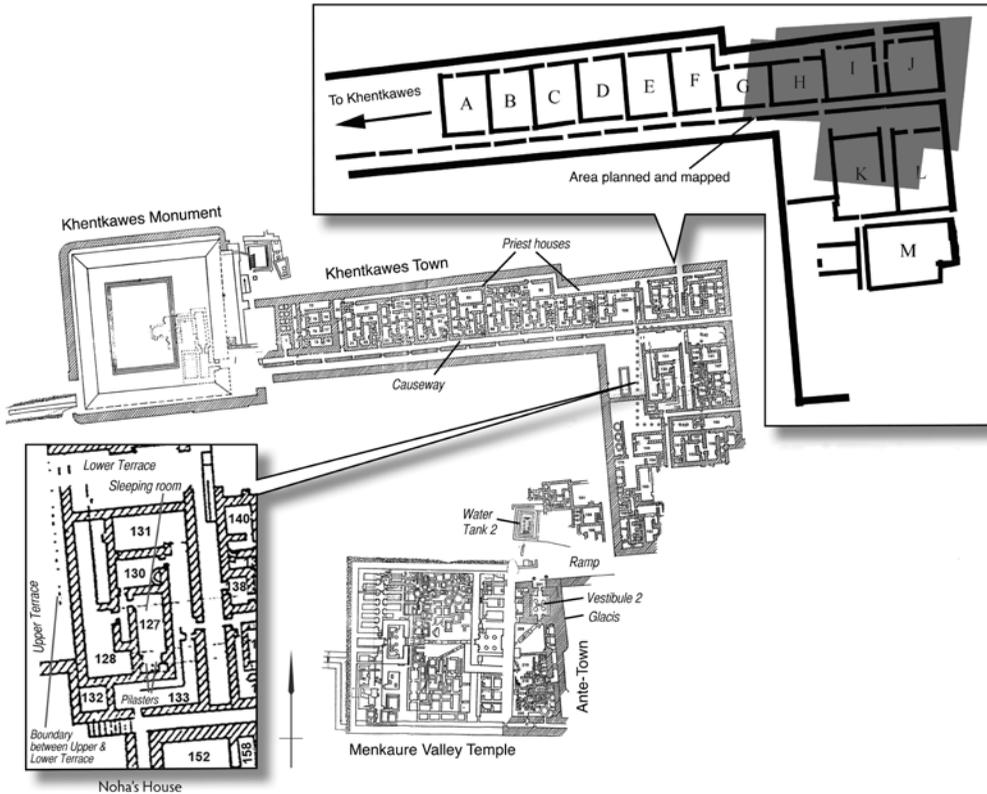
We began a six-week season at KKT (March 1–April 24) with the following goals:

- Study the previously undocumented buried building.
- Continue mapping whatever remained of the leg of the town, westward along the causeway to the queen’s tomb.
- Trace the stratigraphic relationships between the south end of the KKT settlement and the MVT, and investigate the road leading east between them.
- Complete a geophysical survey of the MVT in order to get a geophysical record of what might remain of the temple and surrounding unexcavated structures.

## **Exploration and Discovery 2008**

### ***Mapping Houses in KKT-North (KKT-N)***

The KKT consists of one row of large “priest” houses lined along the northern side of the causeway, which leads from the funerary monument to a large building (the valley temple?) on the east (fig. 2). This northern strip has six large houses on the west and four smaller houses on the east. Yeomans and Collet recorded the scanty remains of the eastern houses in 2007. During the 2008 season Collet continued mapping adjacent to this area. In House F he found evidence of at least two phases of use and rebuilding. Houses G and F show characteristic features of Giza



*Figure 2. Selim Hassan's map, published in 1943, of the Khentkawes Monument, Khentkawes Town (KKT), Menkaure Valley Temple (MVT), and Ante-town. Above right: Letter designations for houses in KKT. Pieter Collet and Lisa Yeomans recorded the shaded area in 2007. In 2008 Collet worked in a 10 m wide zone that took in the eastern half of House F and the western half of House G*

houses such as zigzag entrances, secluded rooms with sleeping(?) niches, and long, narrow storage magazines.

### *Noha's House*

On the lower terrace of the foot of KKT, Giza Inspector and 2007 Field School graduate Noha Bulbul recorded what appeared to be a discrete house unit: House K (dubbed "Noha's House"), set apart from a larger complex by an open court on the north, a corridor on the south, and a street on the east (fig. 3). Although the house is large — 137 sq. m (1,475 sq. feet) — it is much smaller than the largest house identified in our Lost City settlement, House Unit 1 in the Western Town, which is 400 sq. m (4,306 sq. feet).

Although smaller, Noha's House shares some features with House Unit 1, such as a room with a "sleeping" niche. The niche in Room 127 is defined by pilasters, like Room 125 in House Unit 1. Both the niche and the "sleeping room" were smaller than those of Room 125. Were it not for the severe erosion in House K, the niche might have enclosed a bed platform, such as the one in Room 125. House K and House Unit 1 were also similar in that one passed through several turns and doorways to reach the sleeping room. To access Room 127, one passed through a doorway through the eastern wall, turned right into Corridor 133, then left into Room 130, left again into

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the long, narrow vestibule, and finally left into the sleeping room. In House Unit 1, one had to likewise pass through room after room and make multiple turns before entering Room 125.

Hassan's excavators found traces of earlier walls, suggesting that the core of House K had been nearly leveled and rebuilt during the life of the settlement. The older walls belonged to a general earlier phase of the KKT, which predated the causeway. Traces of House K's western wall continued north across and under the remains of the causeway where the wall aligns with



*Figure 3. Left: Noha Bulbul excavates in the eastern part of House K, a.k.a. "Noha's House." Above: Noha's House cleared. The southeast corner of the core house shows an underlying, older phase projecting into Corridor 133 (foreground). View to the northwest*

the western wall of House I. This suggests that Houses I and K belonged to a common north–south complex on the east that predates the causeway.

#### ***"Dan's Cut": The Terraced Town (KKT-F)***

We discovered in 2005 that the builders founded the western part of the foot of the southern town (KKT-F) on a higher terrace of dumped limestone debris. To sort out the sequence of construction here, Daniel Jones excavated two trenches along the large north–south wall that separates the upper and lower terraces. He found that the builders cut into the limestone fill of the upper terrace and then erected the lower terrace mudbrick walls flush against the vertical cut through the debris. This indicates that the debris existed before the construction of the brick wall. It might be the case that the builders did not create the upper terrace by dumping limestone quarry debris, but rather they cut into an existing debris fill in

the area between the east–west leg of the KKT and the MVT. They leveled this fill to create the upper, western terrace, and cut down into it to make the step down to the lower terraces. Jones revealed details of the building sequence of the lower terrace mudbrick wall (fig. 4). To the north it consists of two thick mudbrick faces with a rubble core, while in the south it is built entirely of brick. During the occupation, the residents repaired the wall, which, along with repairs and rebuilds of other structures, suggests that the town was long-lived.

### *The KKT-MVT Interface*

One of the main aims this season was to make a stratigraphic link between the KKT and the MVT in order to determine how they were related to each other chronologically (fig. 5).

In 1908 Reisner excavated the Valley Temple of Menkaure, recovering magnificent artifacts and statuary. At the time, little was known of the elements that comprised a pyramid complex (which is typically an upper temple, causeway, valley temple, boat pits, and



*Figure 4. Daniel Jones in Trench A along the boundary between the lower terrace (left) and upper terrace (right)*



*Figure 5. Area KKT-AI and MVT from Hassan's 1943 map overlaid onto a geo-referenced Royal Air Force aerial photo*

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subsidiary pyramids). Reisner, a visionary archaeologist, established that Menkaure had conceived his valley temple on a massive scale comparable to the monolithic valley temple built to the northeast by Khafre. However, the masonry work of large limestone blocks, weighing several tons, stopped with the pharaoh's premature death. Workers under his son and successor Shepseskaf finished the project in plastered mudbrick. Reisner investigated two major phases of temple building and of the residential structures that pressed against the facade and invaded the courtyard. In 1932, twenty-two years after Reisner's work here, Hassan extended his excavations of the KKT southward to the front, eastern part of the MVT.

### *The MVT Ante-town*

Hassan found more residential structures, small mudbrick chambers and bins, as well as an open court in front of the MVT, in a thick-walled enclosure we refer to as the Ante-town (as in "in front of the town"). The doorway through the thick northern wall provided a northern access to a vestibule similar to one just inside the original MVT entrance. When we cleared the face of the eastern wall of the Ante-town in 2005, we found a stout, formidable structure dropping dramatically — 3.5 m (about 10.5 feet) to a much lower level than the vestibule floor, prompting us to dub it "the Glacis." We wonder how one approached and climbed up to the original MVT entrance before the Ante-town was built.

In 2008 Amelia Fairman supervised work in the area from the southern end of the KKT foot to the vestibule in the Ante-town. We called this area KKT-AI, for "Amelia's Interface" (fig. 6). Mike House, Kelly Wilcox, and Amanda Watts also worked in KKT-AI.



*Figure 6. The Ramp in area KKT-AI with a shallow cross trench excavated by Amelia Fairman and Mike House. The uppermost alluvial silt-paved concave surface shows a faint channel parallel to the southern wall. Two other channels show in the lower surface, exposed in the trench. View to the west*

### ***The Ramp***

Hassan's map shows both the KKT and the MVT with its Ante-town, but leaves them unconnected, separated by a blank strip. He wrote that access into this area "is gained by means of a broad causeway running westwards from the valley and lying between a thick mudbrick wall attached to the Khentkawes Valley-Temple," by which he meant the vestibule, "and the [southern] girdle wall of the City [KKT]" (Hassan 1943: 53).

In 2005 we exposed 9 m (29.5 feet) of this causeway, an east–west monumental ramp composed of silt paving over a limestone debris core held between thick mudbrick walls. This season we exposed 21 m (69 feet) of the ramp, from the east, where it disappears under the modern road, to the northeast corner of the MVT. Rising at an angle slightly more than 3°, the Ramp widens as it climbs to the west, broadening to 10.40 m (34 feet) about midway into our cleared area.

The builders appear to have designed the ramp with a concern for rainwater runoff. The surface is concave, with a long gradual slope descending from the north to the lowest point on the south side, where runnels and a built channel drained rainwater down the slope to the east. The channel runs northwest–southeast across the Ramp. It is formed over a bedding of crushed limestone and lined with alluvial mud, similar to the channel we discovered in Main Street in our Lost City settlement.

Ana Tavares supervised work at the western end of the Ramp where someone in the past excavated a deep pit, exposing the foundation for the upper, western end of the Ramp. The pit cut through the Ramp and exposed layers of limestone rubble 2.46 m (about 8 feet) thick, probably dumped as a foundation for the Ramp. The large limestone rubble of the lower layer is similar to the fill of Fourth Dynasty construction ramps elsewhere at Giza, which prompts us to ask: was this ramp first constructed to deliver building materials from the east, such as the granite blocks used to clad the Upper Temple?

### ***The Vestibule***

After the development of the Ante-town and Glacis, there was no direct approach into the first vestibule in the center front of the MVT. Instead, people entered from the north through a small portico and a swinging double-leaf door, as suggested by the pivots and socket in the limestone threshold, and then through the second vestibule in the northern end of the Ante-town.

The village that developed within the MVT spans 300 years, from the time when our Lost City site was occupied to the end of the Old Kingdom. Fairman and House excavated through an intricate sequence of wall remodeling and floors, exposing round sockets for pottery vessels, including a nearly intact vessel, put in by the residents during a long occupation. They discovered that the occupants thickened the walls up to 1.69 m (5.5 feet) with a series of accretions, possibly to support the roof after they had removed four columns that once stood on four round alabaster bases, each about one meter in diameter (fig. 7). Just outside the vestibule, they



*Figure 7. The second vestibule floor, quartered, with floors that were excavated in diagonal quarters. Amelia Fairman and Mike House excavated through a thick rebuild or accretion of the interior eastern wall. View to the north*

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examined the Ramp and found evidence of repairs and resurfacing. It appears that the Ramp and vestibule functioned together in at least the later phases of occupation.

### ***Water Tank 2***

Water Tank 2 is a rectangular basin located north of the MVT. An important feature of Water Tank 2 is that two massive limestone revetments shore up the quarry debris on its southern side to a height 1.40 m (4.6 feet) higher than the silt-paved roadbed of the Ramp. The sides of the tank are therefore higher than the floor levels of the top of the Ramp and the MVT and Antetown. The interior sinks in three steps through the debris and down into the limestone bedrock. The builders designed Water Tank 2 as a higher reservoir from which water could be let down, like modern water towers. We exposed the southern terrace and retaining wall of the basin and the mouth of a drain at the level of the Ramp. Hassan related this drain to a plastered mudbrick building that he designated as the embalming tent for Khentkawes' funerary rites.

### ***The Enigmatic AI Cut (AIC)***

A long ragged trench cuts north-northwest to east-southeast through the fieldstone house just west of the KKT foot, through the upper terrace of the KKT and along the northern side of the Ramp. It impedes our understanding of the stratigraphic relationships in the interface between the KKT and the MVT. We believe that flowing water, perhaps from wadi flooding, scoured out the cut

during the time people occupied the KKT-F and the settlement within the MVT. This would be consistent with Reisner's observation that a flashflood destroyed the first mudbrick phase of the temple, after which it was rebuilt in the Sixth Dynasty. Reisner thought that people added thick fieldstone walls, which he found appended to the western and northern sides of the temple in its second phase, as protection against another violent flood. In fact, the AIC begins about on line with the path that Reisner projected for the flashflood. Water Tank 2 might have been intended as a catchment basin and reservoir for floodwater.



***Figure 8. Surveyor Azab Ahmed Hassan stands with his total station on a massive core block of the MVT, which we exposed when we cleared a large hole at the northeast corner of the MVT. Each day when he set up on survey point GIII.1 of our Giza Plateau Survey grid, he rose higher and higher as we cleared deeper and deeper***

### ***The Northeast Corner of the MVT Exposed!***

The work that Ana Tavares supervised in the large hole (NEH) cut through the Ramp surface at the northeastern corner of the MVT provided valuable evidence about the MVT architecture and the structure of the Ramp. The pit cut through the massive limestone debris of the foundation and fill of the Ramp and through the mudbrick casing at the northeast corner of the MVT, exposing five massive core blocks of the temple foundation (fig. 8). These huge core blocks, stacked in three courses,

make it clear that Menkaure intended a colossal stone valley temple like that of his predecessor, Khafre.

As a result of this season's work, we have a new understanding of the MVT. At the end of its use and occupation it presented a blank eastern facade, dropping dramatically to the east (the Glacis), with a broad access road (the Ramp) rising to the vestibule and Ante-town, and continuing westward along the northern side of the valley temple.

### ***KKT-E: The Buried Building***

In 2007 Yeomans made three important discoveries to the east of the KKT: 1) Along the eastern foot of the eastern KKT enclosure wall the bedrock drops; 2) The wall enclosing the KKT on the north continued east beyond the bedrock edge and beyond the limits of the complex as previously mapped; 3) A large mudbrick building, which had never been documented, stood on the lower level (fig. 9).



*Figure 9. Evidence of 1932 trenching along the bedrock drop. The worker in the upper left corner cleans the scant remains of the KKT eastern enclosure wall. Selim Hassan's workers left narrow, shallow trenches along the face of the bedrock edge as they tracked the run to the south of the edge and the underlying mud mass. They cut down into the mud mass to find the marl lines marking the northeast corner of the building (background). Then they sunk a trench across the western wall of the buried building (ending at the worker on the right closest to camera). View to the north*

### ***KKT-E Goals in 2008***

A principal goal was to find how the lower building related to the eastern end of the Khentkawes causeway. As far as we knew from the 2007 work, the causeway ended abruptly at the bedrock edge. How did people ascend from the lower level up over the bedrock face to the causeway?

### ***Finding the Lower Terrace***

Mark Lehner and Kasia Olchowska supervised the removal of overburden between the two trenches that Yeomans had excavated in 2007. They determined that Selim Hassan's workers had found the lower building. But, for reasons unknown, the structure was not mapped. It may be that Hassan's cartographer mapped the KKT later than his 1932 season (he continued to excavate at Giza until 1938). In fact, the map may have been based on Royal Air Force aerial photos. By then, rapidly drifting sand might have already filled the probe trenches, obscuring them from RAF cameras and from surveyors working on the ground.

In clearing a deep, exploratory pit of Hassan's workers, Olchowska found the bedrock floor of the lower eastern terrace at elevation 16.53 m above sea level, a vertical drop from the KKT causeway threshold of nearly 2 m (about 6.5 feet). This discovery only increased the mystery of how one ascended from the lower terrace up to the causeway.

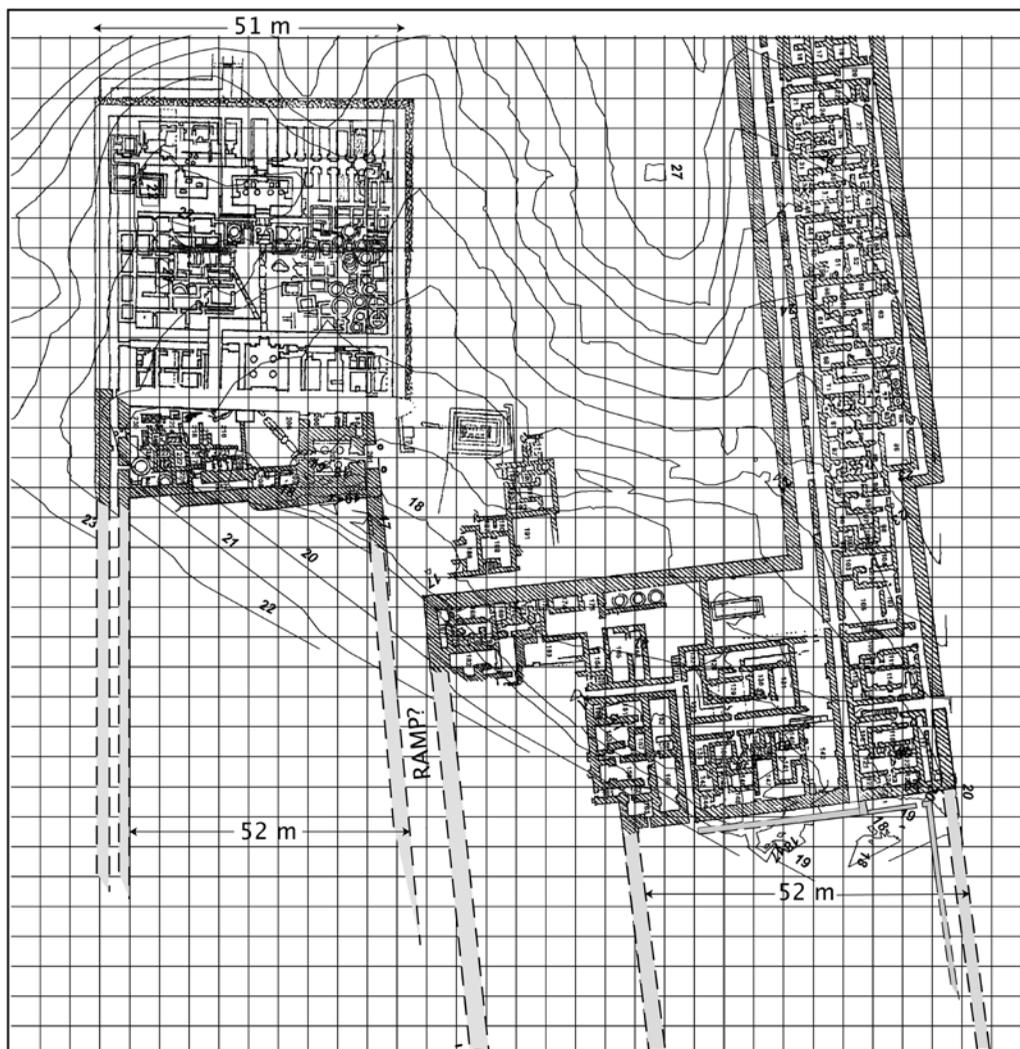
### ***Stairway to Heaven?***

Once the team members worked through the pits and upcast deposits of previous digs and sand deposited post-1932, they uncovered the eroded remains of another ramp, composed of a limestone debris core encased in mudbrick. This one was only 2 m (6.6 feet) wide, and rose in a gentle gradient along the bedrock face from the south up to the causeway threshold. To enter the Khentkawes causeway, one ascended from south to north on this ramp, then turned 90° west to enter the causeway. There might have been a straight-on stairway to the causeway in this sloped, deteriorated mass. It would have been very steep, but steep stairways were not usual in ancient Egyptian architecture. We are certain of the ramp, which may have been used until the end of the Old Kingdom. At its base we found a bread pot common to the Sixth Dynasty, some 300 years after the Fourth Dynasty and the heyday of our Lost City settlement.

### ***Valley Approach, Future Work***

The Ramp at the MVT-KKT interface and our discovery of another ramp in front of the Khentkawes causeway draws our attention to access into the whole complex and into the Giza Necropolis as a whole. If we project the lines of both ramps downslope, they point to the southeastern part of the KKT, which is toward the low end of the dip of bedrock into the central wadi between the Moqattam and Maadi formation outcrops at Giza (fig. 10). It is just this part of the settlement, the southeastern corner of the KKT, which was unobtainable already in 1932 because of the proximity of the modern cemetery, hence leaving it missing from Hassan's map. In our next season we hope to gain a little more of this low corner.

We will also begin excavations into the buried building in KKT-E. Is it in fact a discrete building, or just an enclosure around a broad, open reception area? Hassan's map appears to show the eastern wall of the KKT projecting slightly to the east at a point south of our newly discovered ramp. This hints that the whole foot of the town might have turned to the east and continued in that direction. With the northern KKT enclosure wall continuing eastward, it is possible that it and a southern wall enclosed a rectangular space 52 m (100 cubits, 170.6 feet) broad. This is about the width of the MVT (51 m [167 feet], probably intended to be 100 cubits). If the buried building is indeed a discrete building, it is most likely the true valley temple of Khentkawes, possibly of a size equal to that of Menkaure's valley temple.



*Figure 10. A projection of the possible arrangement east of the MVT and KKT. The MVT, measured off the geo-referenced 1:1,000 map, is 51 m (167 feet) wide north to south. The angle of the northern Ante-town would place its northern face 52 m (100 cubits, 170.6 feet) from the northern wall of the MVT causeway, if both walls are projected about 50 m (164 feet) east, roughly on line with the eastern wall of the KKT foot. Hassan's map shows a turn to the east of the eastern KKT enclosure wall. If projected, the distance from the northern face of this wall is 52 m from the northern face of the eastward extension of the northern enclosure wall of the KKT. The MVT would fit within this space, which contains what remains of a mudbrick building, possibly the Valley Temple of Queen Khentkawes*

### Saqqara Laser Scanning Survey

On June 3, 2008, Dr. Zahi Hawass, Secretary General of Egypt's Supreme Council of Antiquities (SCA), announced in a worldwide press release that the SCA collaborated with AERA and a Japanese consortium to use laser scanners to map the Step Pyramid in Saqqara (fig. 11). Dr. Hawass requested AERA's help in creating the Saqqara Laser Scanning Survey (SLSS) with the aim of producing a 3-D map of every millimeter of the Step Pyramid. Built around 2700 B.C. for the Third Dynasty king Djoser (or Zoser), this is Egypt's oldest pyramid and first gigantic



*Figure 11. The Step Pyramid of Djoser at Saqqara, southern side*

stone monument. The laser survey is part of the SCA’s salvage archaeology and restoration project for the Step Pyramid, which is threatened by centuries of erosion as well as the fragility of the stone and clay core masonry, exposed in ancient times by stone robbers who removed the protective outer casing.

#### ***Prelude at Giza: Laser Scanning Khentkawes***

At the end of our 2006 season AERA collaborated with a Japanese team from the Tokyo Institute of Technology, Gangoji Institute; Osaka University; and the Tohoku University of Art and Design to launch the Giza Laser Scanning Survey (GLSS). In three weeks the team scanned the gigantic funerary monument of Khentkawes and produced elevations, plans, and a 3-D model. They also produced a 3-D record of the Worker’s Cemetery for Dr. Zahi Hawass, who has directed work there since 1990.

With the powerful new technology of laser scanning, researchers use microwaves or infrared signals to gather the coordinates and elevations of points on a monument. As a light beam sweeps over a surface it “captures” tens of thousands of points per second, each located to x, y, and z coordinates. The product is a “point cloud” of the subject, an image that is highly accurate and highly detailed. A print of a point cloud could even be mistaken for a photo. The 3-D point cloud records the monument as it is at one point in time, which is especially useful in monitoring the condition of the structure. With the effects of weathering, tourism, and conservation and restoration efforts, ancient monuments are continually changing.

The plan for the GLSS as a sub-project of the Giza Plateau Mapping Project (GPMP) is to capture and conserve the state of major structures of the Giza Necropolis as “set pieces.” Our next choice was the Sphinx Temple.

#### ***Scanning Egypt’s Oldest Pyramid***

However, prior to our 2008 fieldwork at Giza, Zahi Hawass asked AERA and the Japanese team to help with laser scanning the Step Pyramid at Saqqara. In 2007 an Egyptian construction company under the supervision of the Supreme Council of Antiquities had begun to restore the monument. Dr. Hawass urgently needed an intensive and comprehensive survey of the pyramid exterior, as soon and as quickly as possible, ahead of the changes effected by the restoration

program. In response, the Japanese team and AERA shifted their focus from the GLSS to the Saqqara Laser Scanning Project (SLSS) with the goal of scanning the entire Step Pyramid in three weeks (late May to early June).

AERA joined a new collaboration with the Egyptian SCA, Osaka University, Tokyo Institute of Technology, and the Ancient Orient Museum for the development and deployment of the custom-made “Zoser Scanner.” Prof. Kosuke Sato, from Osaka University, led the SLSS team. AERA’s Yukinori Kawae acted as SLSS Field Director (fig. 12). Carrying out most of the organization and fielding of the SLSS on AERA’s behalf, he worked closely with Afifi Roheim, chief SCA inspector and head of the Step Pyramid restoration project.

### ***The Complex Topography of the Step Pyramid***

The Step Pyramid posed special challenges to laser scanning. At  $109.02 \times 121.00$  m ( $358 \times 397$  feet) and 58.63 m (192 feet) high, it is much larger than the Khentkawes monument, and it presents a far more complex topography. Five or six major building phases embedded within the fabric can be seen on the eastern and southern sides where some of the outer masonry was removed before modern times. The pyramid masonry overhangs a long, rectangular recess punctuated by large gaps and by columns of stone left by recent restoration efforts to support the overhang. Also, there are deep gaps and irregularities in the pyramid core. When we scan the Step Pyramid from the ground with commercially available scanners, the laser beams do not reach the topsides of the stones, and when we scan from above, the beams miss the underside of overhanging masonry. Thus each course is left partly in shadow, resulting in an incomplete scan.

To survey and map this challenging surface, the SLSS team used multiple laser scanners in two basic systems. Katsunori Tomita and Kazuto Otani, from the Topcon company, Tokyo, employed conventional ground-fixed laser scanners to scan all four sides and the top of the pyramid. This ensured basic, overall coverage of the pyramid, but did not resolve the problem of numerous small shadows left by the tilt of stones and larger shadows caused by recesses and gaps in the pyramid body.

To resolve the issue of shadows, Takaharu Tomii, of Develo Solutions, Osaka, designed and manufactured the “Zoser Scanner,” which is, by itself, a multiple scanner system. Like the wings of Icarus, the Zoser Scanner was carried on the backs of professional climbers, Yoshihiko Yamamoto and Risei Sato (fig. 13). Instead of flying toward the sun, they rappelled, carrying the Zoser Scanner, down six gigantic steps on each face of the pyramid. As they descended, four miniature scanners, two on each wing, projected infrared signals that brushed the pyramid fabric and gathered coordinates and elevations at the exceedingly fast rate of 40,000 points per second (fig. 14). The radiating cone of infrared beams projected by each mini-scanner assured that the entire surface of the pyramid masonry would be swathed and points thereby captured. Gyroscopes measured its position, orientation, and velocity at the rate of 10 hertz (100 times per second).

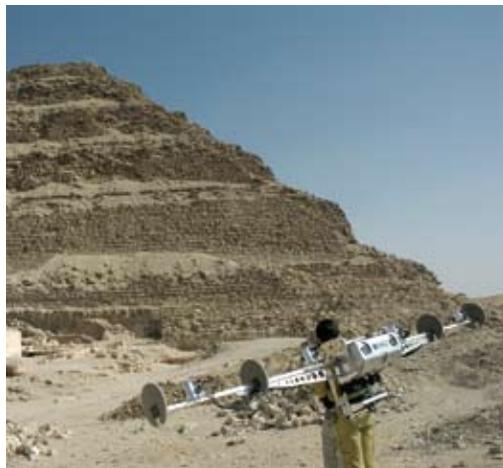


*Figure 12. Yukinori Kawae, who organized the SLSS for AERA, at one of two Topcon GLS-1000 laser scanners that the team used for the preliminary overall survey of the Djoser Step Pyramid*

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*Figure 13. Rappelling with the Zoser Scanner down the Step Pyramid southern face*



*Figure 14. A climber about to ascend with the Zoser Scanner mounted on his back. Each wing of the device carries two miniature laser scanners and two miniature macro cameras. The scanner also sports a cooling system, a gyroscope, and a prism for tracking location*

The width of the wings required that the climbers rappel each face about twenty-five times. A miniature macro-camera accompanied each scanner, taking rapid-sequence photographs of the pyramid fabric. The result is complete photographic coverage of the pyramid, in addition to the x, y, and z coordinates of thousands of points on the surface.

The SLSS team members who sat at computers tested the data and assembled the scanned points into position, thereby forming the greater point cloud model. They were aided by GPS and survey points taken by a total station (theodolite and electronic distance measurer) set on the ground. The total station telescope moved automatically with the Zoser Scanner as the climbers rappelled the pyramid. A GPS timer eventually synchronized all the data.

### ***Rebuilding the Step Pyramid: Thousands of Points of Light***

Thanks to the SLSS visualization team, the point data were assembled into a ghostly 3-D image of the pyramid (fig. 15). Five hundred million points combine like spores into a cloud that is an abstraction of the physical structure of the pyramid. This “point cloud” pyramid is the first true, scaled, extremely detailed, 3-D model of the Step Pyramid, and actually, the first time the real fabric of any of Egypt’s gigantic pyramids has been mapped in facsimile. In modern archaeology we try our best to make facsimile maps of any freshly excavated ancient surface. Yet, such mapping “as is” has never been done for the pyramids — because of their sheer size, for one thing — and so most of the theorizing about pyramid building has been based on mental template pyramids, usually of well-squared blocks (which is never the case in the physical reality of a pyramid core).

The miniature cameras on the Zoser Scanner were set up to take one photo per second. The team did not quite finish scanning all four sides with the Zoser Scanner (as they did with the Topcon scanners). When they do, the Zoser will have yielded around 400,000 photographs, each precisely located. The scanned points are far more numerous and far more evenly distributed



*Figure 15. Point cloud model of the Djoser Step Pyramid, eastern side. Looking like an infrared photograph or negative image, the model is assembled from five hundred million points located precisely in space and arresting the pyramid in time: late May–early June 2008*

than those from the GLSS 2006 Khentkawes survey. The Zoser Scanner eliminated most of the shadows and gave an accuracy of scanned data within  $\pm 25$  mm.

It is amazing that the Japanese scanned the Step Pyramid so intensively in less than a month. After they completed the scans, much work remained and still continues in order to resolve the data and compile the 3-D model and its visual presentations.

From the point cloud model of the Djoser pyramid, architects, restorers, and archaeologists can produce detailed models, plans, profiles, elevation drawings, and ortho-photographs for scholarly and scientific studies. The SLSS recorded the effects of current restorations, already a *fait accompli* before the May–June 2008 survey, as well as the untouched fabric of the pyramid. Conservators can use this detailed model of the Step Pyramid for monitoring future restorations and the condition of the Step Pyramid in the long term.

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