GigaPan Imagery and Archaeology at the Sanctuary of the Great Gods, Samothrace

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ABSTRACT
In this paper we describe the use of gigapixel imagery at the Sanctuary of the Great Gods, an archaeological site on the island of Samothrace, Greece. The Sanctuary was the home of a secret cult that was a particular favorite of Macedonian royalty during the 4th and 3rd centuries BC. Despite the lack of any current structures remaining erect, the dozen buildings are remarkably well preserved and are spectacular examples of classical Greek architecture. We are employing a number of sophisticated advanced visualization tools, including a 3-D reconstruction of the site, computer-animated fly-throughs, and an interactive map. We have undertaken a topographic survey and are integrating georeferenced GigaPans into a geographic information system (GIS). This system will allow us to return to the site in future years, capturing the same scene, thus better informing the upcoming site management plan and allowing us to observe change over time.

Keywords
Photography, GigaPan, archaeology, Sanctuary of the Great Gods, ancient Greece, classical Greek architecture.

INTRODUCTION
The Sanctuary of the Great Gods (Figure 1) on the tiny, windswept island Samothrace (Figure 2) in the northeastern Aegean Sea, was home to one of the most important mystery cults of antiquity (Lehmann, 1998). Initiation was open to male and female, slave and free, and promised the initiated salvation at sea as well as the opportunity to become a better and more pious person. The Sanctuary rose to prominence at the time of Philip II of Macedon, who allegedly met his future wife Olympias during their initiation on Samothrace. (Their son, Alexander the Great, would later complain about his father’s devotion to the island.) In the later 4th and 3rd centuries BCE, the Sanctuary became an international center for Macedonian royalty; in subsequent centuries it became a pilgrimage place for Romans, who traced their legendary ancestry to the island. Cult activity remained strong until the late 4th century CE, when the Byzantine emperor Theodosios banned pagan cults. The rituals of the cult were not to be revealed, and the initiates kept their silence well. Today, we know very little from ancient texts about the actual rituals the initiates experienced. We must rely instead on the complex and sometimes contradictory archaeological record.

Figures 1 and 2 (left to right). Figure 1. The Sanctuary of the Great Gods is situated above and to the left of the center of the picture. Figure 2. Islands in the Aegean Sea. Samothrace is in the northeastern Aegean.
The fame of the mysteries was never totally forgotten and the island drew European travelers and antiquarians of the Renaissance. The site itself rose from obscurity in the mid-19th century with the discovery of the spectacular statue of the Winged Victory, or Nike, found by the French and now in the Louvre Museum. Subsequent investigations by French, Austrian, and Czech teams revealed key parts of the Sanctuary, but American archaeologists under the aegis of New York University, working from 1938 to the present, have been responsible for the main excavations that have revealed the extraordinary originality of the site, even when considered against the many spectacular sanctuaries of ancient Greece.

While the sacredness of the place has long been apparent to modern as well as ancient pilgrims, new discoveries reveal the complex way in which architects manipulated the landscape to heighten the experience of initiation. In particular, recent research in the area of the Entrance Complex on the Eastern Hill (using traditional methods of survey, drawing, and reconstruction on paper, with BDW, archaeologist and project director), demonstrated both the dramatic and the subtle ways designers controlled the experience of entering the place of a mystery cult, which relied on privileged revelation. As the pilgrims descended a steep ramp from the Propylon (entrance gate), they were met by dozens of bronze statues and a prominent building, which framed a circular gathering space (view Walkthrough 1 at this site for a reconstruction of this experience). In this remarkable configuration (unique in the history of Greek architecture, planning, and sacred space), the entrance court, statues, and structures were placed to welcome the pilgrim, but also to screen the view into the most sacred part of the Sanctuary, for which the pilgrims were not yet ready. Our continued research reveals that at each subsequent stage moving into and out of the Sanctuary, the designers developed the interaction of architecture, sculpture, and landscape to create dramatic moments of revelation.

The extensive ancient remains allow us to make very accurate reconstructions. However, the site itself suffers especially from degrading erosion and harsh climate. Both maintaining the site and demonstrating its original appearance remain a challenge. Therefore, our team from Emory has been working for the last three years on developing various means of visualization for the following three purposes: 1) as a way to better understand the ancient site and the experience of the initiate; 2) as a way to record the condition of the site to aid in conservation and site management; and 3) as a way to communicate the dramatic terrain and the monuments of the Sanctuary to scholars and the interested public more broadly.

The Sanctuary has a spectacular setting, nestled in a cleft in the earth where the north Aegean Sea meets the base of the Ayios Giorgios ridge of the mile-high Mt Fengari, the highest point in the northern Aegean. More than a dozen extraordinary major marble buildings and a host of ancillary structures were deftly positioned within the complex and rugged terrain to frame and heighten the experience of the initiate within the sacred landscape. Combined, nature and architecture justifiably make Samothrace one of the most important expressions of Hellenistic sacred space in the ancient Mediterranean. None of the buildings is standing, however (although, paradoxically, they are actually very well preserved), and the landscape has suffered two millennia of harsh erosion and degradation. The artifacts are scattered among museums in four countries. Travel to the site remains a challenge even today, even for the privileged few who can do so. For these reasons we have developed Samothrace.emory.edu in order to enable and enhance public access to the physical site as well as to create new ways to understand it. This site is linked to 3-dimensional model reconstruction, computer animation, and an interactive site map. It also serves as a repository of content through which we can quickly communicate results to the archaeological audience as new developments arise at the site.

Beginning with the 2009 field season we began taking georeferenced photographic surveys at Samothrace to inform the topographic survey, provide site and situation information for the research, to aid in site management and conservation efforts, to add to the historical record, and to create Web content for education. Many of the panoramic photos are gigapixel images enabled with deep zoom capabilities that allow the user to interact with the image by panning and zooming in on high detail. By compiling the data within a GIS the researchers will be able to track observation and conduct spatial analyses over time as well as consider the Sanctuary in the context of how it is situated on the island of Samothrace.

In this paper we describe our work using GigaPan technology on Samothrace, beginning with an overview of the project as a whole. In the next section we describe our methods. Following that we present representative panoramas to highlight the site. We conclude with a discussion, describing the issues that arose over the course of the 2009 and 2010 field seasons, depicting future uses of this technology at the site, and cataloguing our wishes for future technology enhancements and advances for both hard- and soft-ware.
METHODS

During the 2009 field season, we (VSH and MP) joined the project director (BDW) on Samothrace from July 24 to August 6. During this period we shot over two dozen GigaPans. We used standard point-and-shoot cameras (Canon A720 IS (VSH), Canon SX100IS (MP), and Canon G-10 (MP)) in combination with 3 robotic mounts (GigaPan EPIC 100 (MP) and two Beta units (VSH and MP)). Photographs were taken at the benchmark locations used for topographic survey and three GPS units (Juno Trimble (MP), and two Garmin GPS 60 sx (MP and VSH)) were used to tag the locations of these and other shots around the site. These geotagged images were then stored in a GIS that also includes basemap data of the island and site, an elevation model, and other thematic layers.

While on site we stitched images together using the GigaPan Stitcher 0.4.3865. Some of the resulting panoramas (VSH; username vherzb) were then published to gigapan.org using GigaPan Uploader 0.4.3865 with links to Google Earth 4.2. A MacBook Pro (VSH) and MacBook Air (MP), both using Mac OS X, v 10.5.8, were used for these initial post-processing steps. Additional post-processing of the images was conducted once back in the US. The stitched images had been saved in .raw format, and these were imported to both Mac's and PC's for post-processing using Adobe Photoshop CS4. After cropping and modest attempts to correct color, the images were saved in Zoomify format. Some of the larger gigapixel images took over 8 hours to process and would often crash during processing. Select images have since been uploaded to the site.

In 2010 we again returned to the site in order to capture additional panoramas as well as to record additional data for the topographical survey. Some panoramas were taken for the express purpose of replacing images with poor color correction taken during the 2009 field season. We also added other new images that provided additional perspectives or recorded additional monuments. The same methods described above were used.

RESULTS

We present here several representative shots around the site. Panorama 1 (MP) shows a view from atop the theater looking northeast into the central Sanctuary. The columns are a partial reconstruction of the Hieron (Lehmann, 1969), a building of major importance during initiation rituals (Figure 3). Closer in lies the foundation of the Altar Court (Figure 4), a near contemporary of the Hieron that faces suggestively toward the Theater and may have served as its backdrop. Thus this panorama gives the context within one can view details such as the inscription on the Altar Court epistyle block as seen in Figure 4. A view of the central Sanctuary from due north is shown in Panorama 2 (VSH). Together, the two GigaPans capture a full architectural record of the buildings individually and show how they are knit together in plan.

Looking southwest from the same point as Panorama 1, Panorama 3 (VSH) shows a view of the Nike Monument, the place where the famous Winged Victory originally stood. Note the platform in the center of the niche (Figure 6), on which the statue was mounted atop a ship’s prow. We see the Monument from atop the wall on the eastern side in Panorama 4 (VSH). We note that capturing a true vertical GigaPan of this area, and hence enabling true photogrammetry of it, is virtually impossible at present.
Figure 6 (left). Base for statue of Nike, Winged Victory. For fully zoomable version, go to http://gigapan.org/gigapans/30326/.

Figure 7 (right). Southern retaining wall of Stoa. Niche for Nike, Winged Victory, is behind trees to left in photo. For fully zoomable version, see http://gigapan.org/gigapans/30188/.

In Panorama 5 (VSH) we see the southern half of the site’s western hill where the Stoa was situated. This building served as sleeping quarters during rituals held at the site. Note retaining walls in the rear (Figure 7), which adjoin the Nike niche. We see the Stoa from another perspective in Panorama 6 (VSH). These two shots are discussed in more detail below.

In Panorama 7 (VSH) we view the northern half of the western hill. The Milesian Dedication can be seen in Figure 6, and can be seen from multiple different perspectives in GigaPans 30169, 30208, 30234, and 30350. Also note the ship monument (Figure 9), which can be seen from another perspective in panorama 8 (VSH).


Figure 9 (left). Mount for prow of ship, Ship Monument, western hill, Sanctuary of the Great Gods, Samothrace. For fully zoomable version, see http://gigapan.org/gigapans/56404/.

Figure 10 (right). A portion of the batteries used by one of the authors (VSH) during the 2009 season.

**DISCUSSION**

The GigaPan is proving to be a powerful tool in our technological armamentarium, despite our need to overcome several issues in image capture and photoprocessing.

Our biggest challenge has been one of power. We found that each image required the installation of a fresh set of new or newly recharged batteries in both robot and camera. In our first season we had difficulty keeping up with the appetite for freshly recharged batteries. We also experienced difficulties with generic brand, non-U.S. batteries available on the island. We (in particular, VSH) used up many non-rechargeable batteries over the course of shooting over a dozen Gigapans (see Figure 10 above). In future trips we need to bring sufficient rechargeable batteries, battery chargers and extension cords to ensure that we can supply 4 shots per day for each camera / robot combination. In 2010 we (MP and VSH) each brought 2 chargers for 4 batteries each, along with 16 rechargeable batteries. This amount, along with 8 Gb cards for our cameras, seemed to be sufficient for at least 4 shots per day per camera / robot combination, about 500 individual photographs per “shooting session”.

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Wind is also an issue – it is always windy on the island, and there is not much we can do to avoid it and its subsequent effects on our panoramas. One of the authors (MP) had a great deal of difficulty maintaining the tripod, and hence the robot and camera settings, while attempting to shoot Mt. Phengari due to the wind.

The length of time required for all of the processing – stitching, Adobe Photoshop, and uploading – is enormous. This would not be such an issue if the MacBooks were also not necessary for other tasks at the site, including statistical analysis of the block data. The panoramas that we have taken are composed of 175 images on average and take hours to stitch, and many minutes to upload, with or without Zoomify, another time sink. Photoshop processing of the .raw files is also very time-consuming, taking about an hour to import the file, crop, do any other processing, and save. We are saving the .raw files locally so that as the stitching software advances we can take advantage of new features. Each GigaPan image linked from our website takes about 2 Gb of storage space, which is another element of cost to the user. There is even one panorama of Mt. Phengari that is so big that we have so far only been able to manipulate it as two halves.

The process has been a learning curve, both in getting the settings for the camera correct, as well as for post-processing for color-correction. About two months after returning to the US in 2009, one author (VSH) finally stumbled upon the proper settings for her camera in manual mode. Although the gigapans she took in 2010 are much improved over those of 2009, color correction is still an issue (see upper right corner of panorama 7; also note the streakiness of the sky in middle to left). Do these issues arise due to the direction in which the camera is pointed, or are they due to the method of pixel interpolation used in the software, or does it boil down to the manner in which some places are illuminated? We are now experimenting with AutoPano Giga for processing as well, but do not have adequate experience yet to report on its utility.

Having identified these issues then, of what value is this technology? We believe there are three aspects that give value beyond ordinary photography: 1) experience of place; 2) conservation and site management; and 3) open access opportunity.

The GigaPans help the viewer to understand the experience of the space by capturing peripheral vision. With our animated walk-throughs we have already demonstrated the way in which the architects maneuvered the placements of sites for rituals within the terrain in order to heighten the experience of the initiates. The GigaPans do this as well, albeit 2.5 millennia after the heyday of the cult. By hyperlinking GigaPans (an item remaining on our task list for the off-season as of this writing) we can explore the experience of initiation by passing between the 3-D model and the deeply zoomable imagery. The GigaPans also allow us to understand an object or a building in context, which is very important in reconstruction. As an example, consider the Stoa, one of the longest such buildings in northern Greece, as viewed from the southeast. Its size is apparent enough in this view, but its scale and dominance over the Sanctuary, as well as a clearer understanding of its internal foundations, are reinforced when viewed from the northeast. In the former view we find no evidence of the internal foundations, the boulders covered with red clay roof tiles that are so evident in the foreground of the latter view. The GigaPans also allow a researcher to study the materials not only in context, but also at her/his own pace, which technologies such as videos do not easily afford.

GigaPan technology can also aid in conservation and site management by providing a record of the ancient material in context. The GigaPans afford the viewer with a wider and far more detailed view of the actual ground state in the field than ordinary photography affords. By capturing full records of the monuments at regular intervals, the conservator can use the GigaPans to view, compare, and assess any changes that may have occurred in the condition of the site. Because the GigaPan is capable of extreme zoomability, the conservator can easily observe every stone. This task would be impossible in ordinary photography. To optimize its contribution to site management, there should be a list of standard GigaPan shots to be taken from fixed points at the site at regular intervals. Currently we are building a geodatabase that will contain the GigaPans as one element.

The open access of gigapan.org allows us to share the experience of the Sanctuary with others at different times and places. For instance, the panoramas can be used in classes to give students a better idea of the space under consideration. Ultimately, we see real value to scholars and students who will be able to use GigaPans to compare structures from different places (be they in Greece, across the Mediterranean, or across continents), because the GigaPans provide a much richer record of preservation, architectural detail, and geographic context than ordinary photography or traditional panormamics.
As this technology continues to develop, there are a few things that we hope will be included in future models of the robot and future versions of the software. These include the following: 1) improved photogrammetry, with true vertical and oblique angle photography; 2) a memory card for the robot to capture meta-data about each shot, including location information; 3) boosting the computing power of the robot; 4) a way to access the camera battery while it is mounted on the robot without disturbing the robot settings; 5) more user control over the Stitcher program settings for choices such as pixel interpolation; 6) ability to link within the cyberinfrastructure to GigaPans by other researchers, so that common threads can be identified and explored; and 7) improved methods for annotation on the GigaPan, such as rollover notes.

You can read more about our work at the following sites:

- [Samothrace.emory.edu](http://Samothrace.emory.edu) Our main site
- [www.isamothrace.org/blog/](http://www.isamothrace.org/blog/) Our dig blog for teens
- [samo00.wordpress.com](http://samo00.wordpress.com) Another of our dig blogs (VSH)

Our future goals for work at the site include:

- Produce new maps, both paper and digital, of the Sanctuary site as well as of the island;
- Integrate the 3D models with a geographic information system, including the greater site and situation;
- Use cyberinfrastructure and GIS to inventory artifacts, make calculations, and establish a repository for preservation;
- Explore how new technologies can be used to aid our research and disseminate our digital media and raw data;
- Acquire new funding to support all of the above.

REFERENCES
