

# Aerial Image based 3D Documentation of Inaccessible Archaeological Sites using UAS

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The following paper refers to Large Scale Documentation of Cultural Heritage, in extreme regional and environmental conditions, with the use of Unmanned Aerial Systems (UAS) of IMANTOSIS team. Three large scale survey exhibitions in Greece will be presented, focusing on the workflow followed during a single documentation, the planning support for future monitoring, excavation and restoration campaigns, in addition with long – term accessibility to the 3D Data collected and produced. Case studies are, the Penteskoufi Fortress, the Acrocorinth Castle and the Old Philosofofou Monastery, all located in the Southern Greece, at the Peloponnese region.

## Penteskoufi Fortress

### Precise Documentation and Monitoring

The “Penteskoufi Fortress” project (Fig.1), encompasses all the methodology deployed on workflow during documentation of inaccessible Archaeological sites. The Fortress is located on one of the two unique elevations of the generally flat landscape near Ancient Corinth, at a height of 480m above sea level. It is a total area of 610m<sup>2</sup> with 110m of snakelike fortress walls and a rectangular tower of 100 m<sup>2</sup> (Castles of Argolid, Arcadia, Corinthia ,2013). The peak of the fortified rugged rock embraces an area of 8500sq.m. though it is only accessible on foot. An one-hour hike in a medium difficulty terrain is needed to reach the Fortress.

The survey expedition had to face the following challenges.

1. The dense, low vegetation on the fortress hid 80% of both the monument and its significant elements. A complete clean-up was decided to unveil the details. However, due to the rapid regrowth of the vegetation, detailed and precise documentation had to take place rapidly, regardless of weather conditions.
2. The use of 3D Terrestrial Laser Scanning was excluded, due to the distance from the provincial road, the hike needed to approach the monument and the inability of transporting heavy equipment. In addition, no suitable area existed for setting up such equipment.
3. Traditional time-consuming measurements supported by geodetics, could not cover the necessity of fully capturing all the details.

Facing the possibility of complete loss of details or even larger elements of the fortress (collapse of entire sections) due to lack of maintenance, a detailed three-dimension imprinting of the entire monument was required. It included the fortresses’ surrounding natural area, in order to collect all those necessary scientific evidences that would allow a restoration and reconstruction study to take place, in case of a complete loss. The use of a UAS, capable of lifting heavy loads and operating in difficult conditions of extreme wind resistance and light rain, was therefore considered as the optimum solution.

## Acrocorinthos Castle

### Precise Documentation and Excavation Planning

The steep rock of the Acrocorinth rises to the south west of ancient Corinth. It is dominated by the fortress, also called the Acrocorinth. It was the fortified citadel of ancient and medieval Corinth and the most important fortification work in the area, from Antiquity till the Greek War of Independence in 1821 (Ministry of Culture, Anastasia Koumoussi, 2010, p.7.). It lays 573m high above the sea level and its walls run for almost 5,500 km surrounding an area of 600,000 m<sup>2</sup>.

Three fortification zones lead to the interior of the Castle. Inside the Castle, Remains of various time periods such as Ancient Sanctuaries, Early Christian Basilicas, Byzantine Cisterns, a Frankish Tower, a Venetian

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Church, Mosques, settlements and fountains, reveal the significance of the settlement. Reused materials often make it difficult for experts to date and distinguish historical and construction phases. The team had to deal with common type of problems but on an enhanced scale .

1. Fortress is accessible by vehicle till the first fortification gate. A 40 minute hike is required to reach the top of the hill and more than two hours to walk around the main walls.
2. Weather conditions are particularly changeable and the winds are usually blowing in a scale greater than 5 Beaufort (40 km/h)
3. No natural or artificial shelters exist as the mountain is totally exposed to weather conditions.
4. Due to the vast area and the terrain difficulty, reaching equipment and supplies was of a great issue.
5. Lack of previous existing documentation (maps, plans, contour plans, 3d geoids etc) in order to organize the operations in advance.
6. Existence of many excavations, with many consecutive layers.
7. Particularly high data volume as a result

Once more the solution chosen as optimal for surveying was the use of a heavy lift UAV. More than 250 aerial missions took place with collected data of more than 100,000 ultra-high-resolution photos, fed in a photogrammetric station, producing a Dense Point Cloud of 3mm point spacing. The Accuracy of the Point Cloud was aided by a dense network of installed ground control points (GCPs) that was acquired with a total station and georeferenced by GPS/GNSS. Some areas were surveyed more than once during the excavations in order to record all the historical phases. The Photogrammetric procedure took place on a render farm, in order to produce the Point Cloud Data, the Digital Surface Model (DSM), the Digital Elevation Model (DEM), the Orthophoto maps and orthophotomosaics of the facades of the Walls. All these products contributed significantly in the organization of Historical Research, Organization of Excavations and Restoration Studies and the creation of an archaeological viewing route network.(Fig.2)

## Old Philosopher's Monastery

### Precise Documentation Restoration and Planning

The old "Philosopher's" Monastery is located in the gorge of Lousios river, south of Dimitsana in the Peloponnese region. The founding of the monastery and the first construction phase date back to the second half of the 10th century AD.

An one-kilometer narrow path through the gorge is the only way to access the monastery. It is built in a natural cavity of a vertical rock, with a total length of 320m. The Complex has a minimum width of 50cm, a maximum of 6m and a general average width of 2m. The smallest preserved height of the Monastery's walls is 3m high and the maximum is 10m.

The following issues had to be faced for the 3D documentation of the monastic complex:

1. Extremely dangerous frequently rock falling, led to the fastest possible documentation method to be chosen. Therefore, a 3D Terrestrial Scanner was used in the inner parts of the walls.
2. Dense vegetation inside the gorge (tall and thick trees) and the lack of satellite connection prevented the lift of a UAV from a spot close to the monastery.

The dilapidated condition of the monument, in conjunction to the fall of rocks and the difficulty of access, required a detailed documentation in the shortest possible time, including both the monastery and the surrounding environment of the natural rock.

The exterior of the monument was decided to be documented with the use of a UAS and photogrammetry. The monument was eventually approached from the opposite side of the gorge, although an automated UAV flight was impossible due to lack of satellites. Beyond Line of Sight (BLS) UAV skills of the expertise team were used, alongside with the aid of sporadic and low accuracy GPS tracking, of a hand held GPS unit. Many probationary flights took place in order to define the exact distance and height away of the monument for best results, all done without automated procedures with the aid of Goggles. Four routes at different heights were finally used, delivering more than 14000 close face shots, of both the monastery exterior walls and the rock formations beneath and above the complex.

The Photogrammetry procedure of the photos taken alongside with the processing of the 37 Scans (Laser Scanning) , delivered mapping products, billion numbered Point Clouds, Digital Surface Models (DSM), Digital Elevation Models (DEM) and orthophotomosaics of the facade with a pixel size of 3mm & accuracy of 1cm (Fig.3) . The Geotechnical Study, aiming for the stabilization of the falling rocks was significantly aided by the above. The 3D created rock model helped to determine the way of transporting building materials for the restoration of the monument. A cavity that was revealed, allowed to a special crane to move downwards all the materials needed for the restoration from the top of the gorge.

**Figures**

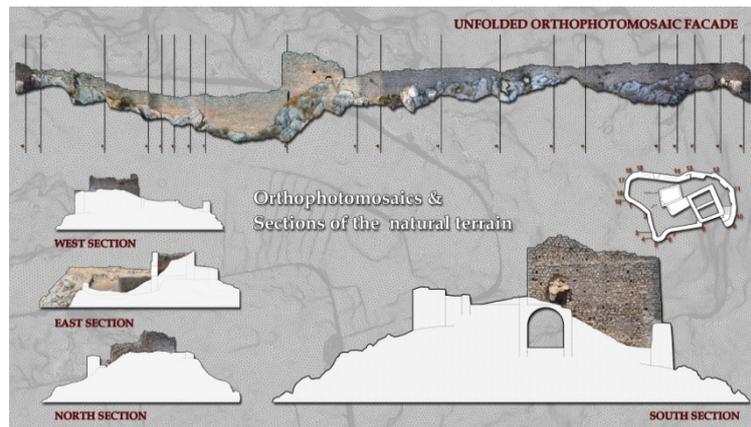


Fig. 1. Orthophotomosaics & natural terrain sections (© IMANTOSIS(2016)).



Fig. 2. Orthophotomosaic / Part of West Fortification of Acrocorinthos Castle (© IMANTOSIS (2016))  
 Details of original Orthophotomosaic: accuracy 1cm / pixel size 3mm / 50 artificial ground targets (GCPs) & more than 400 physical targets all measured by total station / Photogrammetric Station : Agisoft Photoscan , CapturingReality



Fig. 3. Orthophotomosaic / Facade of Old Philosopher's Monastery (© IMANTOSIS (2017))  
 Details of original Orthophotomosaic: accuracy 1cm / pixel size 3mm / more than 300 physical targets all measured by robotic total station & 3D Scanner / Photogrammetric Station : Agisoft Photoscan , CapturingReality

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