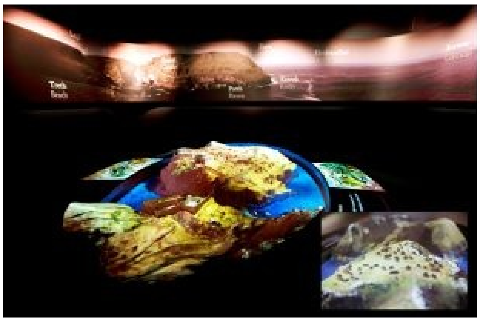
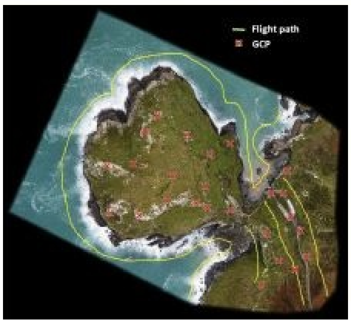
# CREATING A PRINTED 3D MODEL OF TINTAGEL ISLAND FROM UAS PHOTOGRAMMETRY

# Reconstructing a Mythical Past in 3D




UAS photogrammetry has been used to create a printed 3D model of the area around Tintagel Castle in Cornwall, UK. The model is on display in the new visitor centre at the castle. Vertical images were taken with a fixed wing and oblique images with a multirotor. Data capture faced two major challenges: the weather and steeply rising cliffs. Working in the winter, in windy and gloomy conditions, proved tricky for obtaining sharp and vivid images so the use of high-quality cameras was a must. In contrast, the legal limitations were modest.

*(By Andrew Blogg, Future Aerial Innovations, UK)*

The ruin located on Tintagel Island, Cornwall, UK, was once a castle. It was built by Richard, Earl of Cornwall in the 13th century, after Cornwall had been subsumed into the Kingdom of England (Figure 1). The castle has long been associated with the legend of King Arthur; in the 19th century the ruin became a tourist attraction and archaeological investigations started. A new exhibition at Tintagel Castle brings King Arthur and Tintagel's mysterious past to life for tourists and shows the island changing over 1,500 years of history – from a thriving Dark Age settlement, to medieval fortress, through to romantic ruin. The centrepiece of the new visitor centre is an accurate and detailed 3D model of the island and nearby mainland (Figure 2). The 3D model has been created using UAS photogrammetry.

## Challenges

Data capture by UAS faced two major challenges. Firstly, Tintagel faces the Atlantic Ocean and is thus windy and gloomy in the winter months, which is when the data had to be captured due to project deadlines. The multirotor used was the Falcon 8 from Ascending Technologies. This UAS can handle much more wind than the available fixed wing, the eBee from senseFly, but the air dynamics require a high camera shutter speed. Table 1 compares the characteristics of both UASs. To avoid blurred imagery due to poor light conditions the standard camera on the fixed wing, a Sony A7r, was swapped for an upgraded Canon with shutter priority mode. To obtain sharp images with as little noise as possible it is essential to shoot in RAW. RAW image formats help to preserve the radiometric characteristics of the scene by capturing a wider dynamic range or colour gamut than the ultimate image. The final image is created through white balancing and colour grading. A short exposure time decreases blur but also decreases grain as a high ISO setting is required. The ISO setting defines the sensitivity of the sensor to light: the lower the number, the less sensitive the sensor and the finer the grain. The high ISO setting produced insufficient crispness of the building edges (Figure 3). To resolve this issue, the buildings were captured again with the Sony A7r on board the multirotor. A second challenge was that vertical images alone were not sufficient to create a full, uniformly detailed 3D model of the island and adjoining mainland. Terrestrial laser scanning (TLS) could have been an option to capture the steeply rising cliffs of the island and the ruins but this is a time-consuming surveying method. Furthermore, only a small area was accessible on foot due to the steep and dangerous terrain. Therefore, the cliffs and the ruins were captured with a camera on board a multirotor taking oblique images. Since capturing the entire island by multirotor alone would have taken too long, a fixed wing was used to capture vertical images of the relatively flat parts of the area.

| Type | **Fixed Wing** | **Multirotor** |
|---|---|---|
| Brand | eBee | Falcon 8 |
| Camera | Sony WX220 | Sony A7r |
| Weight [kg] | 0.4 | 2.3 |
| Max. payload [kg] | 0.15 | 0.8 |
| Max. stay in the air [min] | 45 | 22 |
| Max. speed [km/h] | 57 | 54 |
| ø / wingspan [cm] | 96 | 82 |

*Table 1, Basic features of the fixed wing and the multirotor used to capture the area around Tintagel Castle.*

## Legal Issues

The UK's Civil Aviation Authority (CAA) allows the commercial use of UASs for flights of up to 500m in the line of sight and not above 400 feet (122m). These conditions were easily met. Furthermore, there was no risk of harming people as the flights were conducted during times when the castle was closed to the public.

## On-site Work

Work got underway with the multirotor until the weather allowed the fixed wing to be used. The multirotor can fly autonomously but, to give the camera operator time to frame photos correctly, the UAS was flown manually. This required extra care to ensure proper overlaps. The flight plan set the multirotor 100m out to sea at a height level with the top of the island and looking back towards it, always focusing on a central point (Figure 4). A distance of 100 metres ensured the island was fully framed in one shot whilst maintaining the best possible ground sampling distance (GSD) of less than 4cm. To keep the UAS in sight and within 500m, both the camera operator and the pilot followed it on foot.

The challenging weather conditions necessitated considerable testing to determine the correct height, shutter speeds and distances. The capturing of the oblique images required 15 flights. When weather conditions became more favourable a follow-up visit was arranged to capture vertical imagery with the senseFly eBee. To ensure maximum coverage and overlap, the flights were conducted in two perpendicular directions; the waypoint abilities made flying much simpler compared to the multirotor. Due to the steep cliffs and rugged ground, it took a full day to lay out the ground control points (GCPs). Removable markers were used to leave no trace of the survey afterwards. Figure 5 shows the 25 GCPs distributed over the area. They were measured with an accuracy of 1cm in all three dimensions.

## Processing

The data was processed using Agisoft Photoscan and resulted in a root mean square error (RMSE) of less than 5cm for the x, y and z coordinates. The point cloud contained 42 million points. Creating a printed 3D model from such a large point cloud is challenging; earlier experiments with 3D printing showed that photogrammetrically created meshes need to be cleaned as they are full of small spikes, tunnels, holes and non-manifold faces and intersecting polygons. Tests were carried out with three meshes of varying densities with high and low resolution textures. The full resolution version with around 42million faces proved too difficult to work with. The best mesh was the medium one with around 15 million faces.

**Acknowledgements**

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**Biography of the Author**

Following an MSc in GIS, Andrew Blogg started his career as a GIS professional and subsequently explored the opportunities of UAS technology for GIS use. He started one of the world's first UAS mapping companies and is now director of Future Aerial Innovations.

Email: andrew@futureaerial.com

*Figure 1, Location of Tintagel Castle in Cornwall, UK.*

*Figure 2, Exhibited 3D model and detail (inset). (Image Courtesy: Emily Whitfield-Wicks)*

*Figure 3, Crisp, defined building model (right) taken with a Sony A7r camera compared to the Canon on the eBee.*

*Figure 4, Diagram showing the oblique images captured.*

*Figure 5, Flight paths of the multirotor for capturing oblique imagery and ground control points.*