Revealing Angkor Wat's Secrets

by Chris Cromarty

Angkor Wat is one of the world's most recognizable temples. Designated as a UNESCO world heritage site in 1992, this temple was built by the ancient Angkorian civilization in the 12th century under King Suryavarman II. Angkor Wat was the center of a once massive and powerful nation suspected of being the largest in the world at the time with up to one million citizens. Supporting such a population required a large infrastructure of water works during the arid Cambodian dry season. In the past, archaeologists have used radar and remote sensing data to try to make sense of the greater Angkorian civilization. It is suspected that a sophisticated water infrastructure consisting of reservoirs, canals and dams captured the water flow from the highlands and distributed it throughout the rice paddies of the lowlands.

Archaeologists studying this civilization face many challenges while trying to map out these features. The remote areas in the hills are hampered by jungle and are still spiked with landmines from the Khmer Rouge era. PT McElhanney Indonesia proposed flying over these areas with a helicopter-mounted Leica ALS60 LiDAR scanner and Leica RCD105 medium format digital aerial camera to pinpoint and model key features for the archaeologists. This would enable them to isolate the subtle topographical changes of water infrastructure and other urban civilization planning to identify areas of interest and then organize landmine-clearing crews to make ground inspections safe.

A consortium was necessary to put a project of this scale together. PT McElhanney worked closely with Professor Roland Fletcher and Dr. Damian Evans from the University of Sydney's archaeology department to organize this group.

Preparing the Project on the Ground

Before mobilizing the equipment a ground reconnaissance trip was made and time was spent with the archaeologists to understand what information they were hoping to gain from the data. Another important aspect of this trip was to assess the terrain and vegetation on site to maximize LiDAR's potential.

PT McElhanney spent a few days travelling to various sites with the archaeologists to understand the challenges they faced. In the lowlands and built up areas, site inspections of excavation sites were conducted.

In these areas the archaeologists were hoping to get a better understanding of where the "occupation mounds" were located. These are subtle rises in topography that usually indicate some extent of habitation above the rice fields or drainage areas. Understanding that the inhabitants, including the King, lived in wooden structures made it clear that there was no possibility of identifying remaining residential building foundations. This was critical in designing a LiDAR dataset that would identify these subtle topographical changes. Only temples were made of stone so being able to identify possible stone debris was also very important. The combination of high-resolution aerial photography and LiDAR was going to help locate and identify these areas of high interest in the lowlands.

The vegetated areas posed a greater challenge. Even though the requirements for subtle terrain change were the same as in other areas, the dense Cambodian forests coupled with the random locations of the landmines meant that the archaeologists could not freely investigate areas of interest. Instead, the very time consuming and costly requirement of sending in landmine-clearing crews to clear these areas was a necessary prelude to any investigation. Identifying these areas under the forest canopy with satellite imagery and radar data was virtually impossible so LiDAR had been proposed to give them the best possible Digital Terrain Model (DTM) so they could concentrate future inspections on specific locations. The high accuracy LiDAR DTM could also aid in modeling features that were previously incorrectly identified such as roads, which were in fact reservoir walls.

Due to the danger of landmines throughout Cambodia and the relatively little exploration that has been conducted in remote areas, it is presumed that to this day there are still many undiscovered temples. LiDAR was also identified as the technology to help identify additional temples that may be in the project areas of interest.

Data Acquisition with Highest Accuracy Level

The total project had three main areas of interest around Siem Reap, covering an area of 270 km^2 (104 mi^2). Due to the high level of accuracy required, it was proposed that two main GPS base stations would be used for acquisition. The helicopter was also ideal since one particular area was approximately 100 km (60 mi) from the nearest airport so on-site refueling would be required during the acquisition of that block.

Award Winning Project

The project was nominated and declared the winner of Asia Geospatial's Award of Excellence – Archaeological Application, which was handed out in September 2012. Further nominations and regional recognition will hopefully follow and revolutionize the technology's use in archeology throughout the region and the world.

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In the forested areas, acquisition was flown using a cross hatched pattern to maximize opportunity for LiDAR penetration to the forest floor. These areas were acquired with a LiDAR point density of up to 16 points per square meter, which was essential for the modeling required beneath the forest canopy. Over temples, this approach also maximized the 3D modeling ability of the LiDAR scanner. Full waveform LiDAR was also collected over the areas of interest to ensure the best DTM would be available in the heavy grasses and vegetation present on some of the sites.

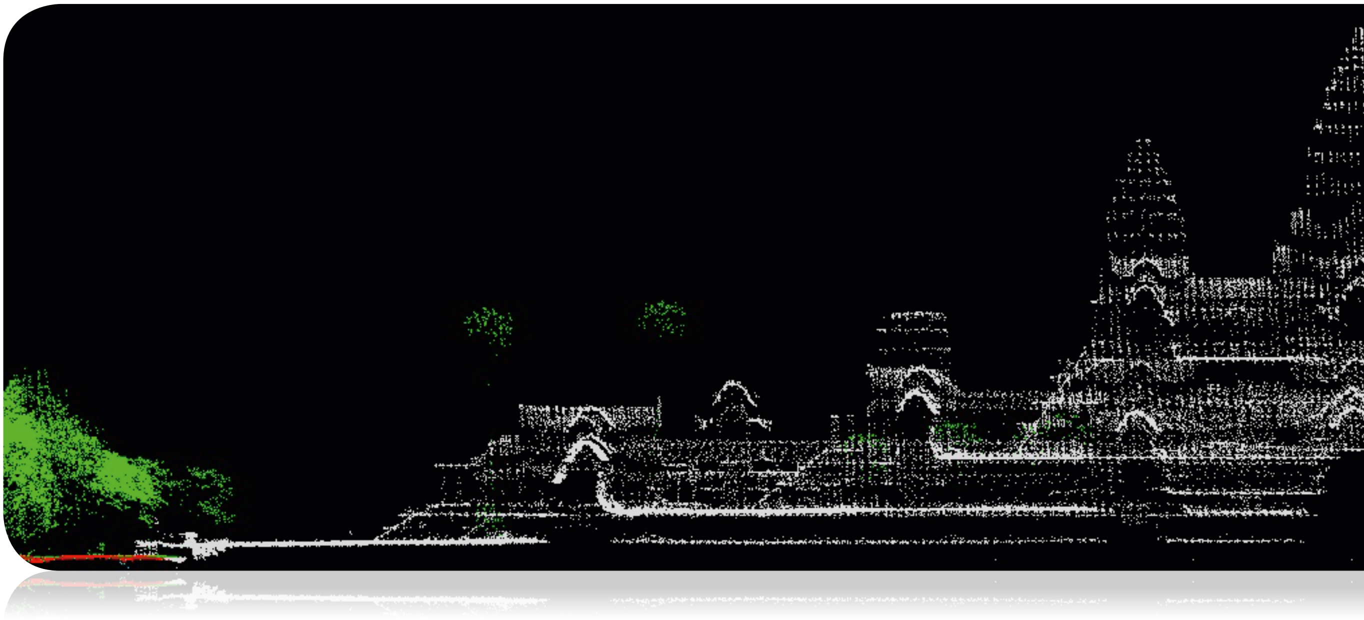
Digital aerial photography was simultaneously collected with the LiDAR data. Even though the aerial photography was a secondary product to the LiDAR, this was collected as a stereo image and had complete overlap of all the LiDAR for downstream products and viewing. This high-resolution imagery would be invaluable when completing the LiDAR modeling.

All of this data and the collected densities amounted to a very large dataset being acquired on a daily basis. Even with current, state-of-the-art computing power data management is one of the biggest problems during data acquisition. A daily challenge was to have all of this data backed up and the drives ready for acquisition the following morning.

Aerial acquisition hurdles also had to be taken during the arid Cambodian summer. Afternoon temperatures often exceeded 45°C (113°F), pushing the limits of the equipment's' operating temperatures. Summer slash burn by local farmers caused difficulties to ensure capture of the highest quality of photography. All of this was overcome without major delays and the project remained on schedule.

Tracing Angkor's History

Preliminary analysis is already revealing amazing new discoveries. According to archeologist Dr. Evans, the LiDAR survey has produced "a lifetime" of data in



a short period of time. LiDAR's ability to penetrate dense vegetation has meant that the temple complexes can be seen without vegetation for the first time since the habitation period. Subtle topographical changes have traced out road networks, occupation mounds and other urban planning signs that were previously undetectable even from the ground. Archaeologists are already speculating that the data will provide a completely new insight in the Angkor civilization and revolutionize the history of the Khmer Empire. ■

About the author:
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