Sands of Time

The Business of Surveying
People, Product and Profits

JAVAD GNSS Conference
1st annual meeting a success

Gear Review
Spectra Precision EPOCH 25
Finding My Inner Indiana Jones

Using Carlson SurvCE to Survey History

>> By Rob Rosa, LSIT
very day as I headed to my job, the theme from Indiana Jones kept running through my head. I even had the hat! The site I was surveying was older than any piece of property I had ever worked on before.

I was working in the dry, barren desert sands of Sudan, surveying for an archeology team from the United States with the National Corporation for Antiquities and Museums (NCAM-Sudan). The site was located at the base of Jebel Barkal, a sandstone table-mountain close to the Nile River, and a one-time sacred site for both the Egyptians and Nubians.

It all started in January of 2007. I had been making plans to go into business with the registered land surveyor who got me interested in surveying. After talking for weeks, we decided that new equipment was needed. I purchased a Topcon robot, a Topcon RTK GPS system and a Carlson Explorer II. Carlson SurvCE worked the best with the instruments I chose.

Later that month, the sales manager from where I purchased the equipment contacted me and asked if I was interested in renting the robot for a month. My original business plans had fallen through, so with a rather large equipment loan hanging over my head, I decided that a rental was not out of the question. This is how I met Tim Kendall, archeologist.

I met with Tim in February 2007 to go over the functions of SurvCE and how to use the robot. This is when Tim told me where he was going. The Jebel Barkal site in the country of Sudan is about 390km south of the Egyptian border, and about 1.5km northwest of the Nile River (Lat 18°32'9.07"N Long 31°49'41.14"E).

I had always been interested in archeology, but never pursued it, so I was very interested in his project from the start.
Even though it was freezing that February morning, I was able to get him going very quickly, due to the ease of use of the SurvCE program. Two weeks into the archeology season, I got an e-mail from Tim saying that due to personal differences, their surveyor walked off the site, in the middle of Sudan. "The job is yours next year, if you want it." Upon reading the words, I almost fell out of my chair.

Leaving the Country
Fast forward to February 29, 2008. There are no direct flights to the country of Sudan, so Tim and I took a six and a half hour flight to London where, due to a scheduling mix-up with the travel agency, we ended up staying two nights.

Another seven-hour flight, with a 45-minute layover in Lebanon, and we were in the Khartoum airport at 4 a.m. Customs kept both the GPS system and the robot for a day, but we went back the next morning to retrieve them. A five-hour bus ride and we were in the sandy desert of Karima.

As we came upon the small mud brick structures that made up the town, there it was, Jebel Barkal is a very imposing figure. Tim had described the mountain as "small" before, and in the distance it was. The closer we got, however, the more I got to see of the mountain I had viewed on Google Earth so many times before. After arriving at the compound where we would be staying for the next four weeks, we decided to venture out to the site. It was amazing. After some 4,000 years, many of the walls of some of the oldest religious temples were reduced to nothing more than two meters high. Many columns were still standing, some elaborately carved. Many relief blocks, carved with figures and icons I had only seen in books, movies, and at the Museum of Fine Arts in Boston, were sitting right in front of me. I was standing in the middle of history.
My first day on the job, I began by setting up the GPS base station. There were no survey stakes or hubs available, and rebar was nowhere to be found. Once everything was operating correctly, I walked down to a shop near our compound in search of a soda. Along the way, I found a valve from a truck motor. It was about 15 centimeters long, with a head about 4 centimeters in diameter—a perfect monument. I set it as the GPS base point, took ties to the nearest building corners, and set up the tripod, which did not move the entire four weeks.

We took location shots of this granite ceremonial relief block.
The Mission
Tim had three main objectives on this trip: 1) to complete excavation of the small temples on the site; 2) to examine the inner structure of the Great Amun Temple and other smaller sanctuaries on the site; and 3) to continue the survey and mapping of the temple site, showing each structure, block-by-block, and all loose stones.

It was for this third objective that I, working with Carlson SurvCE, was asked to join the expedition. There are at least 24 important structures extending out from the mountain, with 11 of them partly or wholly excavated.

In the beginning, Tim was wary of the GPS, having never used the technology before. I found myself sketching that familiar diagram with the four satellites sending signals to the base station, then explaining about geosynchronous and non-geosynchronous orbits. I had to stop at L1/L2, because I was losing him. I don’t think I even got to GLONASS.

The Team
Our team consisted of Tim Kendall, director (USA); Pawel Wolf, field director (Germany); Manja Wtendorf-Lavall, archaeological assistant and ceramicist (Germany); Heather Wilson, archaeological assistant (New Zealand); El-Hassan Ahmed Mohamed, Inspector for NCAM, 14 local men as excavators and myself as surveyor. We met up with Heather and Hassan the day after we arrived in Khartoum. One week later, Pawel and Manja arrived at the compound.

The Mornings
Workdays began at 7 a.m. We each took turns making the morning tea, a process that involved heating a kettle on the propane grill, then straining loose tea through a small cone-shaped filter. Fresh fruit was available for a quick snack, as well as what was left over from the night before. Fortunately for us, the owner of the compound had purchased a refrigerator two days after we arrived. Mornings were cool, 60 to 70 degrees.

The Site Conditions
The first week or so it was tough, with high temperatures ranging in the 100s. After a while one gets accustomed to the arid climate. A typical day involved working from 7 to 10 a.m., then eating breakfast, working again from 11 a.m. to 1 p.m., then resting. Around this time, the electricity would be shut off to our side of the town, and due to the heat, with the sun directly overhead, the safest thing was to stay under cover and stay hydrated. Some would nap in the shade, others would read. As the sun went down, around 4 p.m. or so, the temples were in the shadow of the mountain, so a final round of survey and excavation would commence, and we would finally wrap up around 6:30 p.m.

Surprisingly, none of the equipment was affected by the sun or the heat. Some of the anodizing on the aluminum brackets faded, but there were no failures. We experienced two sandstorms. The first, within the second week, was not bad, and we were able to work. The sand is extremely fine. I inspected all ports on the equipment every day, and a routine cleaning was necessary every night. The second sandstorm was much worse, whipping sand through the air like millions of minuscule needles piercing unprotected skin. We stayed in that day.

A Day’s Location
Each morning, after a 500-meter walk to the site, a quick meeting was held to keep everything on track, and also to know where everyone was working. Tim would travel to each of the work areas, inspecting the progress. On the dig sites, he was more that willing to pick up a shovel, or clean the foundation blocks, or with me, walk the blocks and take shots.
Using SurvCE, I was able to accomplish all necessary tasks, including all the field location work as well as laying out previously located, but now reburied blocks, switching between GPS, conventional total station and robotic total station at a moment’s notice. Topo shots averaged between 1,000 to 1,500 points per day in a six-hour window because of the quickness and intuitiveness of the Carlson software.

By the end of the season, I was able to fully map temples B600 and B700 myself. The temple B500, which had been worked on in previous seasons, was brought closer to completion with Tim’s help. In addition to mapping two large spoil piles that were left from the original excavation of the site in 1913, Tim and I were also able to tie in a completely ruined temple, called B1100. In a previous season, Tim had put together a roughly scaled drawing of the remaining blocks, but since that time, vandalism had taken its toll, and most of the temple was demolished. Between the locations of the blocks that were left, and using a digital insert of Tim’s sketch, we were able to piece together the location of B1100 in relationship to the rest of the site.

The Jebel in 3D
Another task that I gladly took on was to compile the previous year’s data, incorporate the new topographical surveys, and then create a 3D model of the mountain. Using Carlson Survey, I was able to piece together earlier 3D polyline data and the spot shot data per day to create a 3D model including the landscape. Pawel was then able to take a DXF of my model, and incorporate five separate artistic 3D renderings of the temples he had done in previous years. By matching the temples to the baseline coordinates, he created a picture of what the site may have looked like thousands of years ago. While not complete—the top 15 to 20 meters of the mountain will need to be surveyed to complete the picture—the current terrain model is very true to life.

Small GPS Base Lines
Traditionally, smaller excavations were surveyed and then documented with hand-drawn scaled renderings, drawn on millimeter grid paper, and surveyed using parallel and perpendicular base line and offset dimensions. A right triangle would be laid out using steel tapes and chaining pins. In order to facilitate the second half of the team, I was asked to locate their base line control points to put their work on the base plan. I enjoyed seeing chaining pins still being utilized. The only problems involved the lengths of the baselines. The minimum base line that I usually process is well over 150 feet long. The longest base line on this site was 3 meters.

The first base line that was located came in within 1cm over 3m, but the third shot, the one that created the right angle, was out 5cm along the hypotenuse of the triangle. Not pleased with the results, I re-plumbed the rover rod, and relocated the three base line points three separate times during the next day, once
at 8 a.m., once at noon, and once at 3 p.m. The initial locations were an average of 15 shots per point. The later locations were 50-shot averages per point, per location time. At the end of the day, I processed the three locations per control point, and performed a manual least squares adjustment averaging the center of each of the three locations. The end result was much better. Point-to-point relationships along the adjacent sides of the right angle were within 5mm, while the hypotenuse measured to within 15mm. While I would have preferred to incorporate redundancies from at least three different base station points, I was limited by time.

**Trying Something Different**

In addition to surveying temples B500, B600, B700, and B1100, our group also found three temples that archeologists had known about, but they had no real data on, because the temples had not been fully excavated in 1913. We finished the excavation of the three smaller temples during the last week of site work, but were running out of time.

Over a long dinner conversation about how we should proceed, Pawel was adamant about doing a rendering of each of the temples in the manner that is recognized in the archeological field. While the base line and offset method is tried and true, there was not enough time to complete all three small temples. The decision was reached to use individual scaled plots of the block-by-block temple locations as templates. After checking individual block measurements, Manja was able to trace over the plots to then enhance them by hand.

**The Results**

In a report to sponsor Northeastern University of Boston, Tim wrote, “Mapping the site block by block, while tedious, gave us the ability to show the site as it really was and to locate by map any carved or inscribed stone, whether on a wall or lying on the ground.” He added that working with a robotic total station and a GPS surveying system greatly increased the speed of the surveying.

With the discoveries the mission made, which included gold leaf, a sign of the royal ceremonies carried out, and a ritual deposit of unique pebbles, Tim reported that our work during this quick season “created a remarkable new picture of the late Eighteenth Dynasty layout of the site.” All in all, more than 300 new artifacts were discovered this season.

**Final Thoughts**

All modern archeological projects begin with a survey, ranging from the utilization of satellite imagery to find varying tree canopy types and density, signifying possible ancient building sites, to on-the-
ground site survey. As with property surveying, it’s interesting to consider how archaeology has progressed from transits, levels, tape measures and chaining pins to magnetometry, total stations with data collectors, and now GPS.

While preparing for our trip, I had been given a November 1990 issue of National Geographic to research our destination. The writer (none other than Tim Kendall himself), had referred to Jebel Barkal as a “little mountain with big secrets.” In his words, “...ancient people must have been overcome with awe, bewilderment, and fear. Little wonder that this mountain became a sacred place, the residence of a god, and the birthplace of a dynasty.” In his overview about the NCAM mission, Tim stated that the mountain appears to have derived its sacred and political importance from its “peculiar shape—especially the shape of its pinnacle, a natural wonder.”

There is a unique correlation between the property line surveyor and the archeologist. Both must be able to prove a point based on research, field measurements, calculations and monuments found. In order to find out more about the ancient site and those who lived and worshipped there, Tim and I have begun planning for 2009. There’s no question that the trip and the job were one of the most exhilarating experiences of my life. My Indiana Jones hat is ready to go, and a cerebral sandstorm of thoughts about next year’s season are already swirling in my head.

Rob Rosa is a Massachusetts LSIT working towards licensure. Currently working as an independent sub-contractor for several surveying offices, civil engineering offices, and site work/construction companies, he has also been attending UMASS Lowell part time with additional education through UMAINE Orono and MALSCE. He will be returning to Sudan next month to continue the archeology project.