Cape Hatteras Lighthouse Relocation

One Man, Two Robotic System Make History

It's not really the application developers had in mind when they introduced the powerful, speedy and accurate Leica one-man robotic survey system -nor did they envision that one man might have reason to operate two at the same time. But that's exactly what happened during three surprising weeks this summer on the North Carolina shores during the historic Cape Hatteras Lighthouse relocation.

A Leica TCA1103 was used to align the rails." Centerline" was held with 0.01 ft for all seven rails.

A customer of Earl Dudley Associates, Leica's local dealer in North Carolina, called and said he wanted to try a Leica Robotic on a series of lot surveys. The survey specialists at Earl Dudley Associates sent a Leica TCA1103 with RCS1100 to the client. After receiving the unit, the customer called and mentioned that he was at a lighthouse and he needed a little help!

Within several hours, Earl Dudley Associates' Tom Dudley found himself standing next to the historic 129-year old Cape Hatteras Lighthouse on the shores of North Carolina's barrier islands near Buxton.

Cape Hatteras is the tallest brick lighthouse in the world standing 208 feet tall and weighing 4,800 tons. Over the years, the sea eroded the surrounding sand and pressed to within 160 feet of the lighthouse foundation. The U.S. National Park Service

A Leica TCA1103 monitors the settlement as the lighthouse is pushed off the original wooden timbers by five hydraulic jacks.

stepped in to save it. They called on surveyors, engineers and a construction team to move the landmark 2,900 feet from its original location and 1,600 feet from the sea.

In summary, this required construction crews to cut the lighthouse from its foundation, raise it six feet, insert a steel support system and then hydraulically move the lighthouse along steel tracks to a new foundation. Pretty straightforward, at least in theory.

Monitoring Tilt: Robotics System #1

Clearly, a key concern throughout this process would be the lighthouse's stability. Modeling systems demonstrated that the 208-foot tall lighthouse could tip in any one direction no more than 6.5 degrees before it was in danger of serious damage or falling.

Operating as a back-up resource, one surveyor from a local survey firm moved on-site to perform necessary analysis during the lighthouse move. It was his job to closely monitor this tilt from the time the foundation was cut until the lighthouse moved onto its new foundation 2,900 feet away. As he was usually working alone, robotics offered the only viable, effective solution. New to the application of the powerful technology, he called on Earl Dudley Associates to support the on-site efforts. Earl Dudley Associates arrived with two of Leica's TCA 1103 robotic systems with coaxial Automatic Target Recognition.

After several hours of training, the real work began.

The riggers attached two prisms to the main shaft of the lighthouse structure: one near the bottom and one attached near the top. The riggers then cut the granite substructure and began transferring load to 100 hydraulic shoring jacks (each capable of lifting 100 tons). Once the shoring jacks were in place, the steel beams and lifting jacks would be inserted to lift the lighthouse an additional six feet.

Prior to the move, one of the engineering firms had also installed a $250,000 electronic system designed to monitor tilt and tip of the lighthouse during the move. Its system gauges recorded inside wall temperatures and outside wall temperatures on the black and white stripes. Some strain gauges were set inside to measure changes in shape and roundness. In addition, gauges were attached to a number of the existing cracks to see if they widened or closed. Finally, two tilt sensors were mounted on the inside walls at the top and bottom. Unfortunately, electrical storms, power outages and damp weather plagued the sophisticated system. The system malfunctioned and occasionally failed.

Thus the survey system was to be used as a backup mechanism in case the engineering system failed. During this transfer, the surveyor used the TCA1103 to monitor the lighthouse movement in two directions: the tilt and distance differential. Operating in a stakeout mode, the robotic equipment continuously recorded cut-fill quantities and

The Hatteras lighthouse on its steel base and seven track rails as its nears the new location.

distance as the lighthouse inched higher. If the lighthouse tilted, the robotic readout would display a come-and-go, similar to a traditional stakeout operation.

About two weeks into the move, near disaster shifted the robotic responsibilities dramatically. On this day, computer readouts suggested the lighthouse was leaning slightly to the left. Engineers adjusted the jacks to compensate. A few minutes later, the computer readout suggested the lighthouse was leaning a little further to the left. Engineers compensated again. The surveyor using the robotic system recorded data reporting the exact opposite conditions!

It turns out the engineering system was malfunctioning, giving engineers exact opposite information as to the tilt. Within an hour, Leica's robotic system became the primary lighthouse watchdog.

Sitting side-by-side, the engineers controlling the lifting jacks watched the robotic LCD readout for slight changes. When the lighthouse tilted slightly, they would pressurize the appropriate jack to rebalance the lighthouse to vertical. Throughout this six-foot lift, the robotic system did not monitor more than a 0.3"movement at the top prism.

Once lifted, the construction crews installed the steel rail track beneath the lighthouse foundation, shifted the structure to the track and prepared for the horizontal move. Once again, the robotic system was used to monitor tilt. Engineers moved the lighthouse just 4 inches along the steel track on the first try. They then went forward with two full strokes, totaling 10 feet the first day.

Steel Track Alignment: Robotics #2

Besides the lighthouse monitoring, the surveyors needed to track the alignment of the roll beams attached to the steel rail track from the center point to the new location. On any given day, the lighthouse moved along this rail from 10 feet to 355 feet.

In the meantime, while one robotic system continued to monitor the lighthouse throughout the move, the survey firm was also required to monitor the elevation and alignment of the roll beams or the steel track roadbed. Now very comfortable with the robotic system, he borrowed the second Leica TCA1103 system, locked onto a Leica 360"prism and began recording data. The surveyor was operating two TCA1103's at the same time!

It took 23 days to move the lighthouse 2,900' to its new home on a 60' x 60' x 4' concrete and steel slab, designed so the leading edge would take the entire weight of the lighthouse as it rolled into position. Engineers were concerned about the back of the slab tipping up as a result of the weight.

By now, the surveyor's job was to monitor the movement of the slab – not the lighthouse. He propped a free-floating, 360"prism pole on the slab so it could move up and down. Once again, locked the robotic station on to the prism, set it in stakeout mode and measured cut-and-fill quantities during the entire process. According to the surveyors, the slab never deflected more than 0.025 feet.

Today, the lighthouse stands a safe 1,600 feet from the sea, well away from the dangerous erosion. For Earl Dudley and the lighthouse survey team, the monument represents an historic event of their own – the successful operation of dual one man survey systems.

Earl Dudley Associates gives special thanks to Greg Wagstaff and Mike Carlyle from the Leica Product Support Group (Norcross, GA) for their on-site help in evaluating the situation and supporting this historic use of robotic technology.

Vicki Speed

Leica prisms were mounted on the top and the base of the lighthouse and checked every day. The black box is the housing for the Internet site camera.

The Leica TCA 1103 was also used to monitor the settlement as the lighthouse was pushed off," and the settlement of the new foundation as the lighthouse was pushed on"(0.1 ft on the old wood timbers and 0.02 ft on the new concrete foundation).