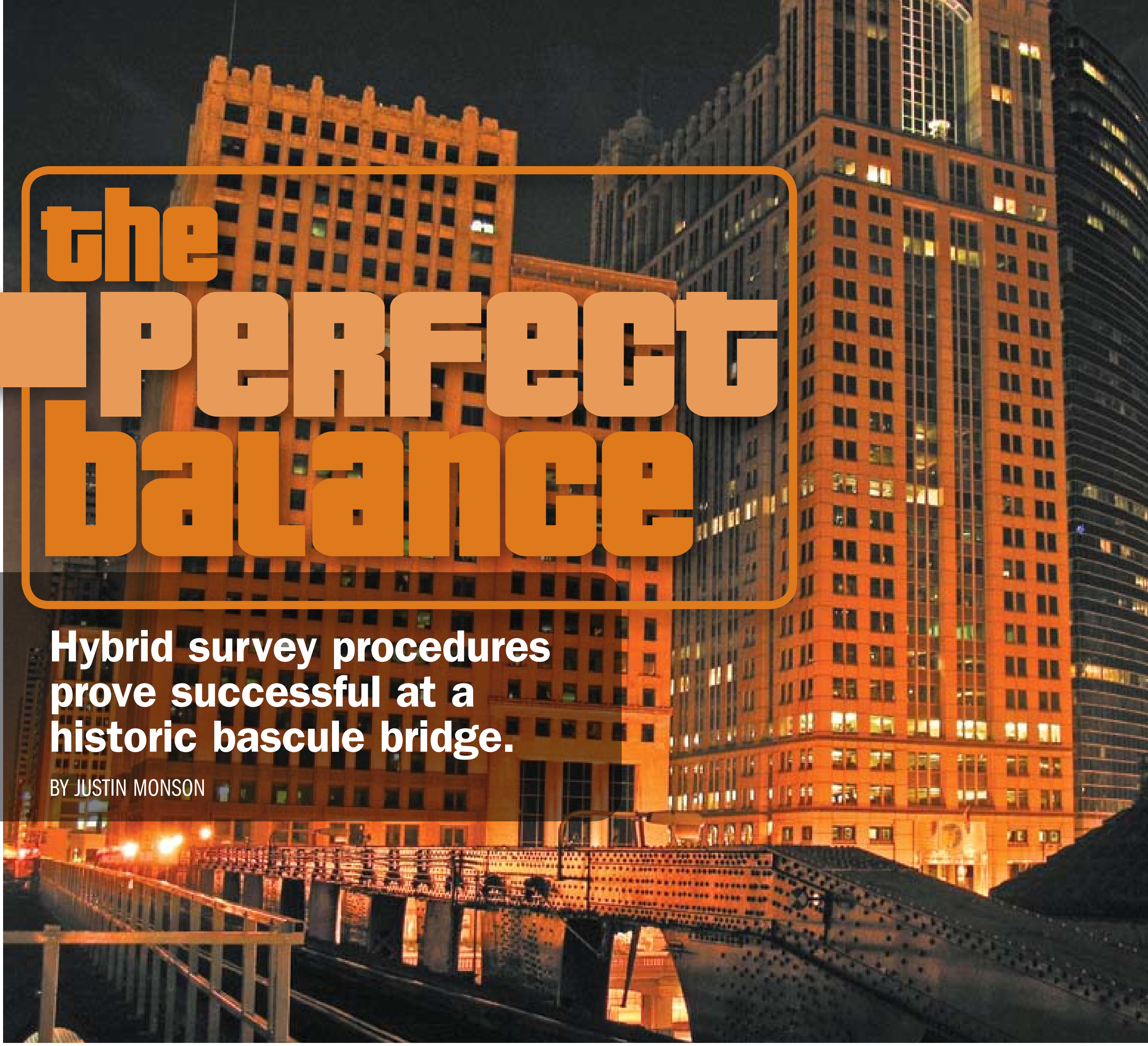


the PERFECT balance

Hybrid survey procedures prove successful at a historic bascule bridge.

BY JUSTIN MONSON

Surveyors and engineers face many challenges in the quest to present real-world 3D conditions in a manner that is functional for a broad spectrum of clients. This was the case in the summer of 2008 when the Chicago Department of Transportation (CDOT) commissioned Dynasty Group Inc. through CTE|AECOM (known today as AECOM) to provide professional survey services at the Wells Street Bridge over the Chicago River in downtown Chicago.

Designed by architect E.H. Bennett and built in 1922, this nationally recognized bascule bridge is a double-decker structure that carries vehicular, pedestrian and train traffic into and out of Chicago's "Loop" business district. The bridge is a fixed-trunnion bascule or "Chicago bascule" design with two individual spans called leaves. The leaves pivot on fixed points known as trunnions, which are located at each end of the structure. With the aid of large concrete counterweights located below the roadway at each end of the bridge, the leaves can be raised and lowered to accommodate boat traffic on the Chicago River. On the top level of the bridge are the Chicago Transit Authority's (CTA) Purple Line and Brown Line trains. The Chicago elevated track system, or "L," is the third busiest mass transit rail system in the United States. The roadway level of the bridge holds three lanes of southbound vehicular traffic as well as one bike lane. Two sidewalks flank the roadway and allow pedestrian traffic to cross the Chicago River. The bridge operations are controlled from two bridge houses located at the northwest and southeast corners.

To consider a full documentation of the bridge and surrounding area, Dynasty looked at the task from both a creative and practical standpoint. If the bridge were surveyed and documented by traditional means using a total station, level and measuring tape, weeks of field time would be spent cataloging the entire 350-foot-long structure, which stands 30 feet tall and includes two 30-foot-deep subterranean counterweight pits and two bridge control houses. This process, in turn, would invoke unacceptable interruptions to a vital artery in one of the country's busiest metro-

Opposite: Scans of the CTA tracks and the upper level of the bridge were acquired at night.

Left: Dynasty Group surveyors use the Leica HDS6000 to collect data at the track level of Wells Street Bridge.

Below: The Wells Street Bridge in Chicago is a nationally recognized double-decker bascule bridge.

politan business districts. Additionally, the scope of the project was liable to adapt to ongoing bridge inspection findings.

Ultimately, Dynasty determined that a combination of 3D laser scanning, total station surveying and nontraditional post-processing techniques would yield the best results. "We broke the project into tasks and used the most effective tools we have to complete each task" said Zhong Chen, PE, PLS, president of Dynasty Group Inc.

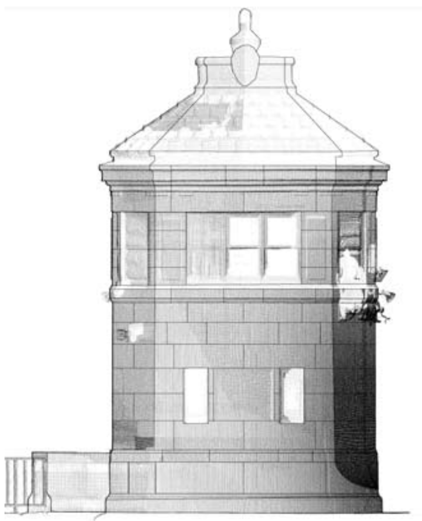
Capturing Data in High Resolution

In 2001, Dynasty first broke into the laser scanning market with a Cyrax 2500 from Cyra Technology (now Leica Geosystems HDS), which was purchased to catalog a mile-long stretch of Wacker Drive's historical stonework so that it could be disassembled, conditioned and reinstalled in exactly the same position after the reconstruction of the adjacent Wacker Drive viaduct. Since then, the firm has enjoyed the benefits of 3D laser scanning in a broad spectrum of survey projects, including roadways, bridges, buildings, petrochemical plants and historical documentation both in the United States and China. With eight years of field experience has come a broad knowledge of the laser scanning technology that allows Dynasty to offer clients an alternative to a traditional survey.

Executing a successful 3D laser scanning project relies on a thorough planning process prior to the first scan. In other words, as effective as the laser scanner can be, it will only yield usable results if a proper "game plan" is established before the scanner is turned on. Considerations include the type of scanner to be used, scanner positioning, target type and placement, control network, required scan density and an idea of how to take the scan data from the field to the final product. The fact that Dynasty's Chicago office is mere steps from the Wells Street Bridge made site visits convenient, which eased the planning enormously.

For the survey of the Wells Street Bridge, Dynasty chose a hybrid approach using both the Leica HDS6000 (phase-based) and Leica ScanStation (time-of-flight). These instruments were chosen based on Dynasty's successful project experiences, years of internal research and development of work flow, as well as Leica's reputation as a leader among scanner manufacturers. The entire bridge structure and surrounding area were to be scanned and referenced to a local coordi-

Above: The bridge's fixed-trunnion design allows its leaves to be raised and lowered to accommodate boat traffic on the Chicago River. Below: An orthophoto and line work of a bridge house.



nate system. Once the local control system had been established, a single two-person crew consisting of a scanner operator and an instrument person spent four nights collecting 3D data on the bridge structure.

The phase-based scanner collects large amounts of high-density data in a relatively short amount of time. Dynasty surveyors were able to set up and scan 360 degrees of roadway, train track and bridge steel in about seven minutes. The CTA trains run in 10-minute intervals leaving approximately three minutes to move between scan setups. The entire first level of the bridge, including approaches, required 44 phase-based scans.

The short scan time was ideal for the roadway and sidewalk; however, the limited range (± 80 feet) of the phase-based scanner was not sufficient for the data capture of some of the more remote areas of the structure. For the inaccessible areas of the bridge–particularly the underside of the roadway portion–the longer range (± 300 feet) of the ScanStation was useful. Dynasty used four ScanStation setups, one at each of the four corners of the bridge at the river-walk level, to capture the necessary data at the stringers and floor beams located beneath the driving surface of the bascule bridge. To avoid excessive vibrations and bouncing due to the effects of vehicular traffic on the cantilevered leaves during scanning, CDOT allowed for a nighttime road closure. Targets were affixed to the bridge steel in strategic locations and were shared between the phase-based and time-of-flight scan sets allowing for ease of registration later.

The top portion of the structure posed more of a hurdle as train traffic limited work to a five-hour span of time between 1 a.m. and 6 a.m. Additionally, a third rail that carries a 600-volt direct-current powering the CTA trains is located adjacent to each set of train tracks and poses a precarious situation for anyone working around them. Laser scanning allowed the surveyors to avoid the electrified rails. "Using the scanner in any hazardous environment such as this keeps my crew at a safe distance from personal injury hazards and provides peace of mind that we are out of harm's way," says Max Nelson, a Dynasty crew chief.

In order to gain clearance to occupy the CTA tracks, Dynasty personnel were first required to attend a safety training class and procure a CTA rail safety card. A Sunday night was chosen for the scan work to coincide with the lightest volume of train and vehicular traffic. Dynasty surveyors worked through the night to execute 14 scans with the HDS600 and were able to capture data for the entire 1,200 feet of track–including the upper portions of the trusses and steel members–in the allotted five-hour window.

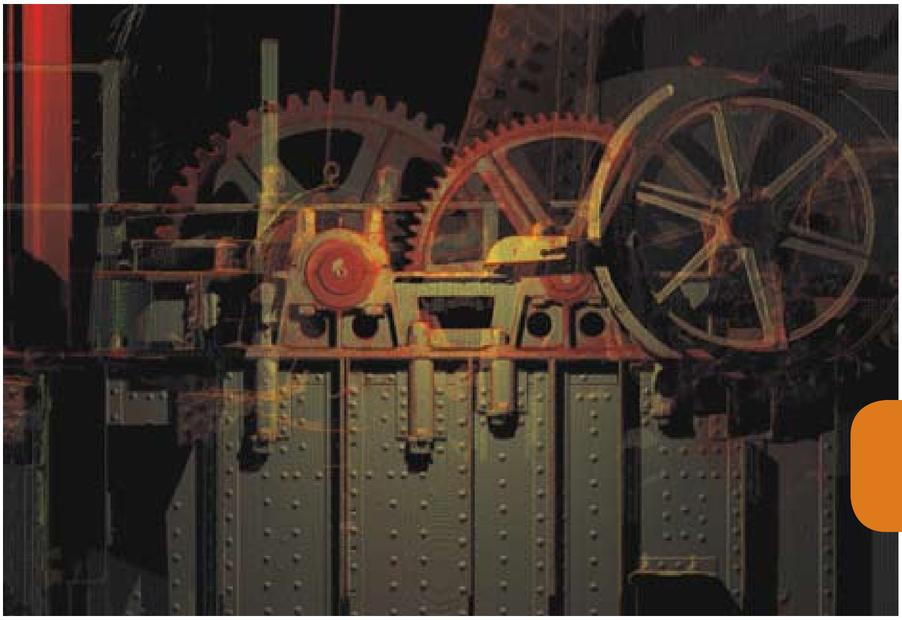
The final piece of the puzzle was surveying the pair of counterweight pits and machine rooms that were located to the north and south of the Wells Street Bridge. Each massive housing structure occupies an area 75 feet wide, 65 feet long and 30 feet deep. Located within are the pinion, rack, machinery, enormous counterweight and cavernous pit below. The use of conventional survey methods would prove not only challenging but also dangerous. It took two days to transfer the project control into both bridge pits and conduct the scans. These areas required a total of 22 phase-based scans that captured the machinery with very fine detail–a fact that would prove helpful in data acquisition later.

Streamlining with Georeferenced Orthophotos

Once the fieldwork was completed, a total of 88 scans were registered in Dynasty's office using Leica Geosystems' Cyclone 5.8 software, which provided an easy means for registering, viewing and transitioning point cloud data to CAD platforms. A shared network and multiple Cyclone licenses allowed more than one person to work with the data at any given time, which streamlined the project turnaround. Once the scans were completely registered, the result was a 34 GB .imp file. To ease working with the large amount of data, the primary model was broken up into components. Each secondary model space emphasized a particular constituent of the whole, allowing easier data manipulation and extraction.

A thorough bridge inspection by structural engineers from AECOM was occur-

Scan data from the bridge machine room in a lower-level bridge pit.



ring simultaneously with the field survey procedures to identify some of the more dilapidated steel in the 96-year-old structure. An advantage of laser scanning is the ability to revisit the site in virtual 3D as many times as necessary long after the field work is completed. Once a structure is scanned, a return visit is rarely needed since all of the data is captured at once and stored on file. Dynasty engineers met and worked with the structural engineers involved with the bridge inspection and subsequent repairs on numerous occasions in order to produce the required drawings and data sets. "Using the point cloud to orient many of the repairs was an invaluable tool and [provided] an enormous time savings," says Matt Barkley PE, SE, a structural engineer with AECOM.

The project deliverables would need to meet the needs of civil and structural engineers as well as architects. A challenge facing the Dynasty engineers was producing line drawings that would be a true representation of the extremely complex makeup of the bridge's steel, machinery and architectural stonework. The two main trusses, in particular, presented a scenario that would have normally required countless survey shots to capture the curved beams and individual steel plates that are riveted together to form the massive composition of the bridge. To solve this problem, georeferenced orthogonal images (orthophotos) of the scan data were generated and then referenced directly into Bentley MicroStation, which is a popular CAD environment used by many DOTs throughout the country.

To produce an orthophoto, Dynasty first isolated a segment of the point cloud that contained an area of interest in a separate model space. Once this portion of the point cloud was isolated, the 2D view of interest was situated perpendicular to view. An image or photo was then created and exported from Cyclone along with a World file (.twf) that associates the photo to the user-defined coordinate system (UCS) in the model space.

To facilitate the creation of an elevation view drawing, the UCS was created so that the Y axis was in the "up direction," which, in turn, allowed the orthophoto to have true elevation values in reference to the project coordinate system. Orthophotos that represent a plan view were aligned so that the UCS was fixed to the bridge centerline alignment. The amount of detail that comes through in the orthophoto depends on the size of the element that was being captured in the photo. The Dynasty team realized the importance of limiting the extent of each photo so that the quality of the point cloud would be available in the CAD model. Through trial and error, the team found that if approximately 30 feet of point cloud data were shown in each orthophoto, the resulting resolution allowed more than enough detail to be displayed in the CAD program.

To further validate the results, surveyors verified the dimensions and elevations of the actual structure against those yielded by the orthophotos. "Photorealistic images without distortion may be the quickest and easiest way to present a 2D projection view from the point cloud data. With the data density from a phase-based scanner, like the Leica HDS6000, we were able to generate the fine images of project components that our downstream users desired," Chen says.

Dynasty took advantage of these orthophotos in the presentation of the two trusses as well as the historic bridge houses, bridge stringer and floor beams and even typical cross sections of the entire bridge. In some cases, lines and dimensions were used to enhance the detail of the orthophotos in the CAD file; in other cases the orthophoto alone was sufficient. Not only did the orthophotos save much time in the field and office, but also produced an end result that was a dimensionally accurate drawing in a photo-quality rendering. As Barkley describes, "We were able to pull highly accurate dimensions and elevations on a wide variety of members without having to step foot out of the office."

At first glance, the Wells Street Bridge appeared to be a survey task that would take weeks of fieldwork and require imminent disruptions to a crucial traffic route for the everyday Chicago commuter. In the end, Dynasty surveyors and engineers called upon their past experiences as well as their ability to adapt with "on-the-fly" creative solutions to develop a work flow that reduced field time by 20 percent and also delivered high-quality drawings that would appeal to all facets of the engineering and architectural world. "Working with Dynasty on the Wells Street job was a great experience and opened our eyes to the enormous advantage of working in 3D," AECOM's Barkley says.

Justin Monson is an engineer with Dynasty Group Inc. For more information, visit www.dynastygrp.com or www.leica-geosystems.com.

Editor's note: *Dynasty Group received second place in Leica Geosystems' 2008 Civil/Survey Plan Contest for its work on the Wells Street Bridge project. The award was presented at the 2008 Leica Geosystems HDS World Wide HDS & Airborne User Conference in San Ramon, Calif.*