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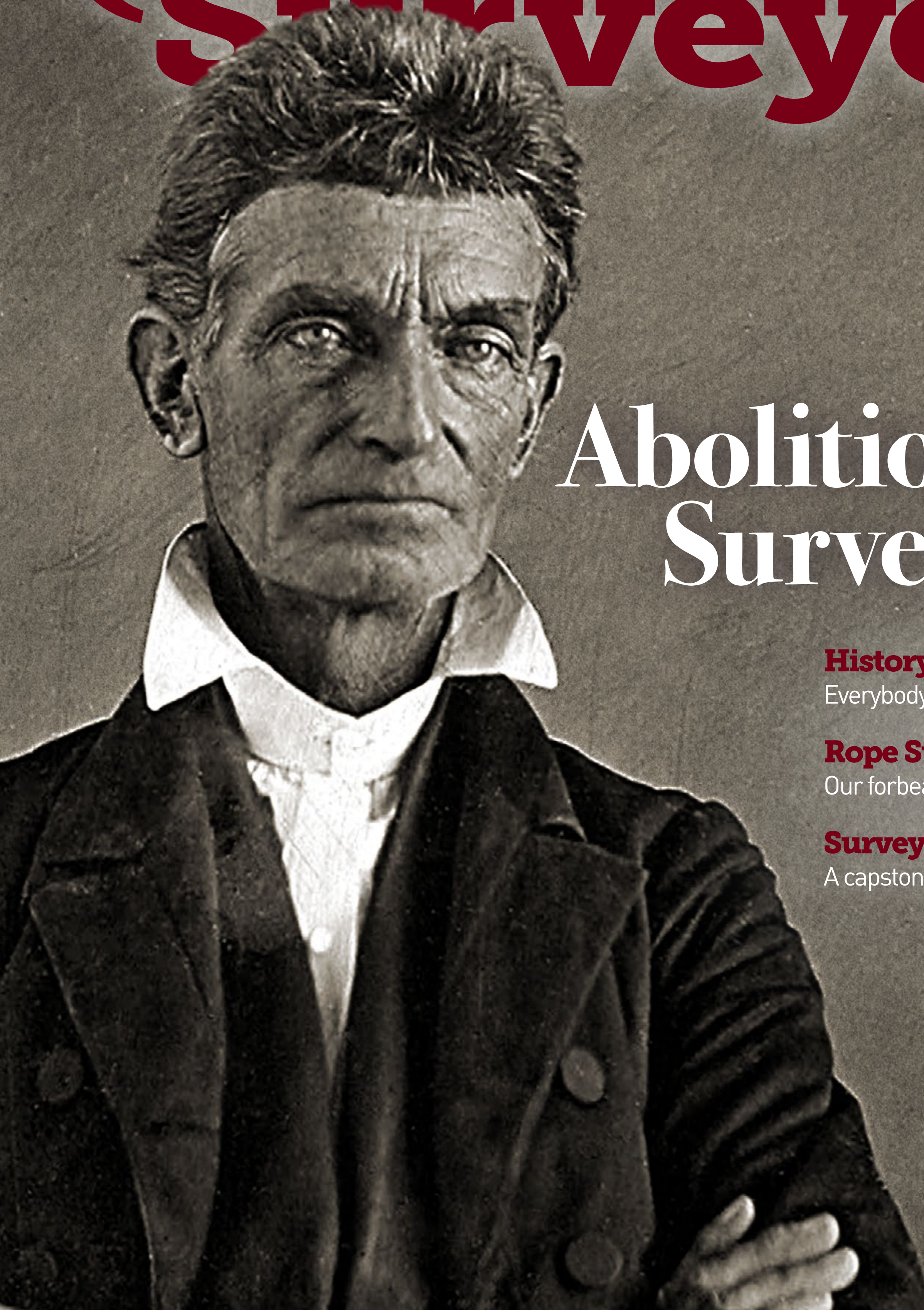

# Abolitionist, Surveyor

**History of RTK**
Everybody wanted it

**Rope Stretchers**
Our forbears

**Survey Education**
A capstone project

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Daguerreotype of John Brown, famous abolitionist and surveyor.



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MARC CHEVES / PS

editorial

# In This Issue

I hope you are having a pleasant summer and the heat and smoke is not too bad where you are. The Olympics just wrapped up and the United States made a good showing. While I've never been a big fan of pro sports, I'm a nut when it comes to the Olympics, binge-watching and simultaneously recording on four channels. Hats off to all our athletes who worked so hard to reach the pinnacle and represent our country.

We've got another great issue for you, starting off with Joe Fenicle's eloquent account of his surroundings for his new position at the University of Akron. Joe has been writing for the magazine since 2017, and lucky for us, even though he could easily write about technology or education, has chosen to write about our history. No matter which side you are on, given the racial turmoil our country is experiencing, I feel having John Brown on the cover is apropos. Who knew he was also a surveyor?

Continuing with our series on the history of RTK, Stacey Hartmann informs us that everybody wanted it: for hydrography, photogrammetry, machine control and more. Even though our piece of the pie is tiny in comparison, could you do your job without RTK? Some of you remember the days of lengthy observations at odd times of the day just to get a single point position. Now look at us! And thanks to scientists who brought us this marvelous capability, there's no telling what's next in positioning and measurement.

Moving on, Mary Jo Wagner provides an application story about how Trimble technology aided in the construction of twin tunnels in Norway. After that, the program chair of the survey program at Cincinnati State shows how future survey professionals helped the Archaeological Research Institute bring past cultures to light. I'm encouraged by the success of these programs all across the country. There's still work to be done in encouraging young folks to consider surveying as a career, but the opportunities for education are there.

The last feature by Emily Pierce is about the rope stretchers. How many times have you had a non-surveyor ask you what you do? We often start by telling them how old surveying is and use the rope stretchers as an example. Emily dives deep into the subject and goes beyond ropes into geometry and other surveying techniques employed by the Egyptians. So, the next time someone asks, you'll have more facts for your explanation. As an aside, just last week, it was revealed that the Pythagorean Theorem was used 1,000 years before Pythagoras. You can do a web search and read all about it.

Rounding out the issue is an article from Wendy Lathrop about the implementation of the latest changes to the National Flood Insurance Program. If you are involved in flood management, it will behoove you to pay attention. Finally, Gary Kent is starting a series on the state of surveying. Gary is a national seminar presenter and has noticed a disturbing trend among attendees. It goes without saying that boundary surveying is not a math problem, and furthermore cannot be completely taught in school. Schools such as Cincinnati State and the University of Akron can provide an excellent start, but experience is the best teacher.

I hope you enjoy the issue and that you have plenty of work. Still having trouble finding employees? The answers are all around you, but one thing's for sure: these folks do not grow on trees. ■


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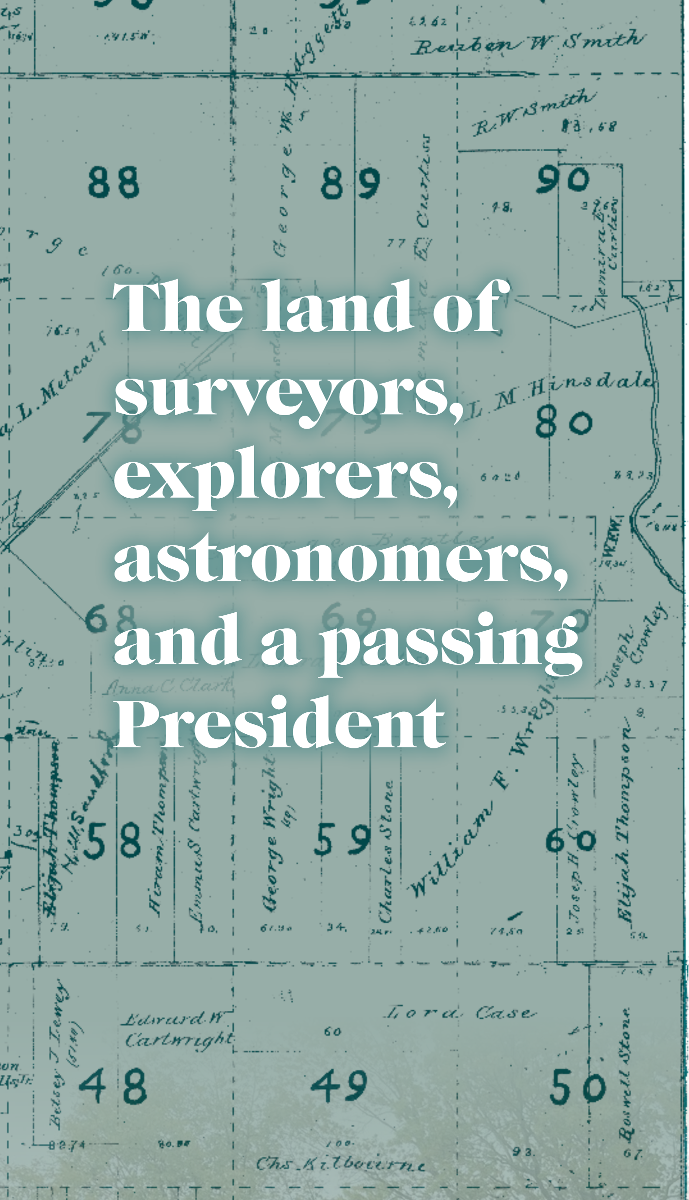
# Hudson, Ohio

» JOSEPH D. FENICLE, PS


Plat of Hudson Township.
COURTESY OF THE SUMMIT COUNTY ENGINEER, AKRON, OHIO.

U.S. Coast & Geodetic Survey Benchmark Designation Hudson 1934, PID MB1083.
PHOTO BY THE AUTHOR.

The 1838 Loomis Observatory on the Campus of Western Reserve Academy, Hudson, Ohio.
PHOTO BY THE AUTHOR.




# The land of surveyors, explorers, astronomers, and a passing President

On Monday, April 13th, 2020, I was granted an offer letter from the University of Akron for a full-time faculty position. I was given the opportunity to give back and teach at the great University who gave me the surveying education I worked so hard for 20 years prior. The decision was a difficult one, a life changing one. We had three small children, a large farm, and a new house. We had great jobs and great friends. We chose to walk away and start fresh leaving our jobs, our friends and the State of Michigan. I chose to abandon my commute which crossed not only the current Ohio/Michigan State Line, but the old one as well. We chose to settle in Hudson, Ohio—the land of surveyors, explorers, astronomers, and a passing President.

## David Hudson

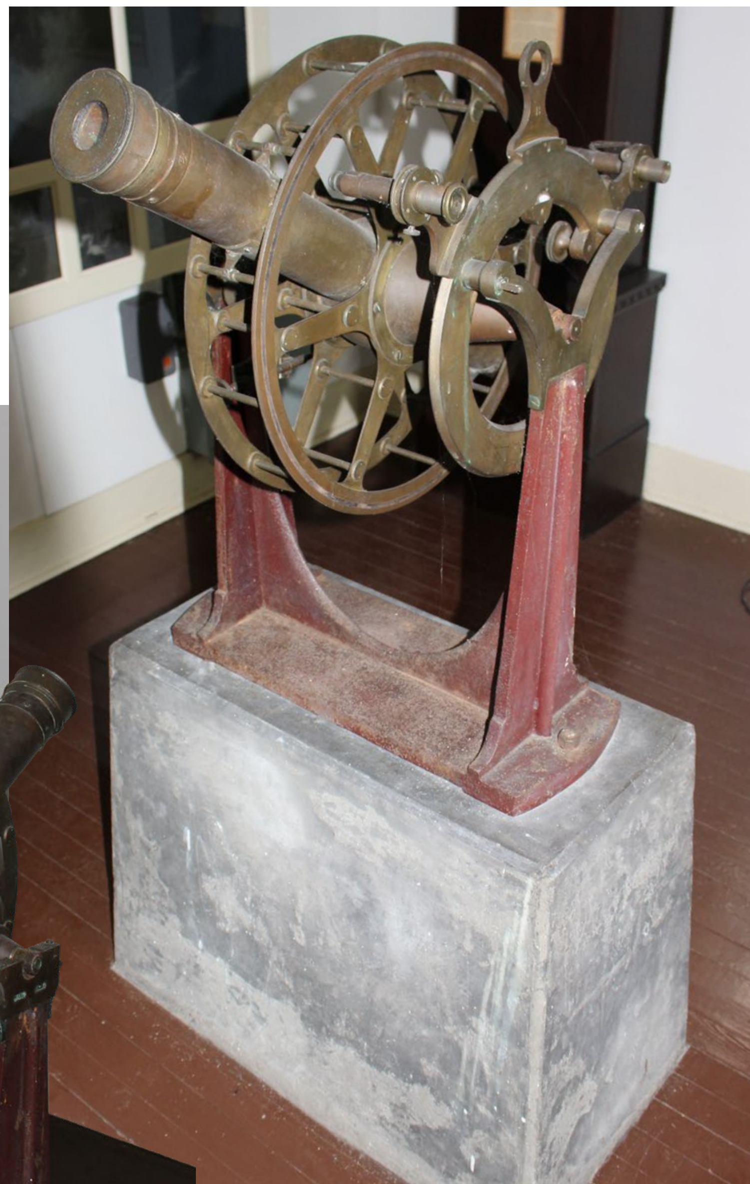
David Hudson left Goshen, Connecticut in April of 1799 to survey, settle, and found Hudson, Ohio. Alongside, Birdsey Norton, and others, they purchased thousands of acres of land in the newly formed Connecticut Western Reserve. Although technically in Northeast Ohio and part of the Northwest Ordinance, the land was reserved for Connecticut. This land was sold to the Connecticut Land Company and comprised roughly 3 Million Acres. From there the land was further surveyed and subdivided in five-mile square townships with the Meridian being the West line of Pennsylvania and the Baseline being the 41rst degree of North Latitude. Connecticut's claim was about 71 miles wide and extended 120 miles West of Pennsylvania. The remainder was ceded to the Federal Government for relinquishment of debt after the Revolutionary War, as their original claim extended West to the Pacific Ocean.

The West line of Pennsylvania (Meridian) was surveyed by legends like Andrew Ellicott, David Rittenhouse, and others. The South line of the Connecticut Western Reserve (Baseline) was intended to lie on the 41rst parallel, but surveyor Seth Pease introduced some error and did the best he could at the time. Prior to settlement and subdivision there were also groups of initial surveyors sent to explore the new territory. This included names like Moses Cleaveland (City of Cleveland) and Joseph Tinker (Tinker's Creek). Tinker drowned while piloting a boat on an early surveying expedition in late 1797.

When Hudson, and others, first left Goshen they followed Indian trails on the most direct route to Irondequoit Bay on Lake Ontario, present day Rochester, New York. This was roughly a 300-mile journey. They then took flat row boats across Lake Ontario, portaged Niagara Falls and across Lake Erie to the mouth of the Cuyahoga River, now present-day Cleveland. During this time, they encountered massive ice floes, rolling waves and thieves. They paddled upstream until the Cuyahoga became ankle deep by Brandywine Falls. Hudson then traveled by foot, heading Southeast, and searched feverishly for the Southwest corner of Township 4 North, Range 10 West, later to become Hudson Township. This corner was set by Nathan Redfield in July of 1797 during the subdivision of the Reserve. Hudson found the corner on June 17, 1799 and proceeded to the center of his township. Although each township in the Reserve was further subdivided differently, this township was divided into 100 square lots. The village of Hudson was chosen to lie within lot 55 and 56 in the dead center of the township. Hudson surveyed the area and laid out the village in typical New England style with an extensive village green, or town center, with roads radiating thereafter. This closely resembled the towns surrounding Goshen like Branford, Litchfield, Winchester and Warren. Hudson traveled back to Connecticut that November and quickly returned with his family and an allotment of settlors eager to start a new life in the West. David's wife soon gave birth to their eighth child, being the first white child born in Summit County, Ohio. Furthermore, David's original 1806 house still stands and is the oldest structure in Summit County. Hudson continued to grow and became home to the Western Reserve College, also known as the Yale of the West. Today, the remarkable City of Hudson is home to a vibrant residential, commercial and industrial community that is highly sought after in Northeast Ohio.

## Elias Loomis

David Hudson was instrumental in bringing the Western Reserve College to Hudson. He petitioned the State of Ohio long and hard to have the University built in Hudson. Hudson himself donated 160 acres in his township that would be sold to jumpstart the school. The school was architecturally designed and built after Yale, especially the Old Brick Row. To meet the high standards of Yale, the administration had to hire the best. They hired Elias Loomis. Loomis was a genius; he was the best. He attended Yale at the age of 14 and excelled. He was hired away from Yale to be the new chair of Mathematics and Natural Philosophy. The College sent him to Europe to study astronomy and purchase the necessary supplies to build a world class observatory. Loomis bought a transit, equatorial telescope and a sidereal clock. When he returned, he designed and had built an astronomic observatory with



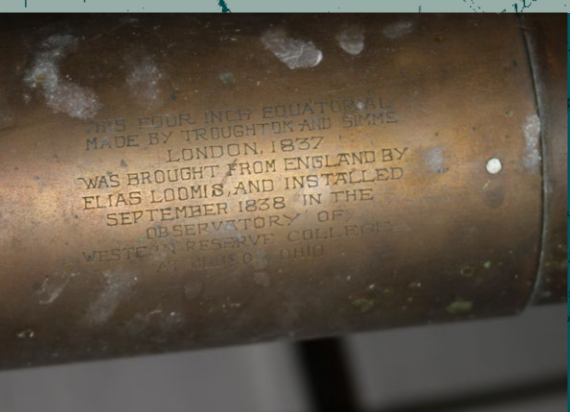
Western Reserve Academy Archivist & Historian Tom Vince with the 1837 Troughton & Simms Transit.
PHOTO BY THE AUTHOR.

his equipment in mind. It is a quaint brick structure, designed by the same architects that aided with the original College buildings. The building measures 37 feet long and 16 feet at the widest portion. It has a sandstone foundation and one-foot thick brick walls. The transit room, with its 15-inch wide opening in the roof, lies to the East end. It has a massive cut piece of sandstone in the center of the room lying six feet below grade. The block of stone is totally detached from the building itself. At the time of its installation the transit had an unobstructed view of the night sky. The transit has a 30-inch focal length and was purchased in London. The center room, under the copper dome, is a 5.5 feet focal length equatorial telescope atop a ten feet diameter raised sandstone column, also six feet below grade and detached from the building. Both instruments are from London and are Troughton and Simms. The clock was also purchased in London and was built by Robert Molyneaux. The clock was visible between the walls of the East and center room so it could be used with both instruments. Loomis thought of everything here and spent the next seven years of his life observing the stars in this small building. He determined, with the greatest precision, the latitude and longitude of the instruments. At this time measuring Longitude by Telegraph was not an option, as he had to rely on the clock. He calculated that he was 5 hours, 25 minutes and 42 seconds West of Greenwich. Currently there is a first order position on the center of the equatorial telescope as established by the National Geodetic Survey (PID MB2757) in 1977. The published Latitude by Loomis is perfectly accurate, and the longitude differs by 44 seconds, which equates to only 3 seconds in actual time and is well within explanation for an sidereal clock in 1838. Loomis went on to publish multiple textbooks on algebra, geometry and trigonometry, selling upwards of 600,000 copies. One of his most famous was *Elements of Plane and Spherical Trigonometry with their applications to Mensuration, Surveying, and Navigation*. The little observatory is still there today and is oldest observatory in the United States still standing on its original foundation. Hopkins Observatory at Williams College, Massachusetts was the first by three months but has been relocated multiple times.

The College was politically acquired in 1882 and relocated to Cleveland and eventually renamed Case Western Reserve. Western Reserve College became Western Reserve Academy, an independent, coed, boarding and day school. In 1903 the Academy closed due to financial difficulties. It was not until 1916 that the doors reopened thanks to local coal multi-millionaire James Ellsworth. It would be his son, Lincoln, who would go on to be a Polar Explorer—hence the school's symbol—the Hudson Explorers.


## Lincoln Ellsworth

Lincoln Ellsworth was born in Chicago but grew up in Hudson. One of his early idols was Ernest Shackleton for his polar explorations. He grew to become a railroad surveyor in Canada and then surveyed in his father's coal mines. At first his father refused to entertain the idea of Lincoln being a Polar Explorer, but later in life donated $85,000 to fund his first, failed, polar expedition. Alongside Roald Amundsen and crew, Ellsworth attempted to fly over the North Pole in a pair of Donier-Wal flying boats, named *N24* and *N25*, but due to mechanical issues were later rescued. Ellworth would not give up though. After his father's passing, Lincoln dedicated his large inheritance to Polar Exploration. His next mission he successfully flew the airship *Norge* over the Arctic Ocean and the North Pole. Later, he would retrace the steps of Polar Explorer Richard Byrd and explore the Antarctic. Ellworth




Engraving on the 1837 Troughton & Simms Equatorial Telescope.
PHOTO BY THE AUTHOR.

Detail of the 1837 Equatorial Telescope.
PHOTO BY THE AUTHOR.

Engraving on the 1837 Transit.
PHOTO BY THE AUTHOR.

bought a Norwegian ship, renamed the *Wyatt Earp*, and a new plane named the *Polar Star*. After multiple attempts he flew over Byrd's Little America and then landed and placed an American flag in the snow and claimed Ellsworth Land. He continued flying and landing, for a total of almost 2500 miles and being the longest transantarctic flight in history, at the time. Lincoln was awarded multiple prestigious metals, mostly for discovering two mountain ranges and helping the United States claim 350,000 square miles of Antarctic Territory. Today the Antarctic Ellsworth Mountains and Lake Ellsworth are named after him as well as the former Antarctic base Ellsworth Station. The Ellsworth Mountains are the highest mountains in Antarctica and Lake Ellsworth is a hidden, natural freshwater subglacial lake only recently discovered in 1996. The *Polar Star* was brought back to New York on the *Wyatt Earp* and rests today at the Smithsonian National Air and Space Museum in Washington, DC.

## John Brown

John Brown came to Hudson with his parents when he was five years old. As a teenager, John taught himself how to survey by reading Abel Flint's *A System of Geometry and Trigonometry, with a Treatise on Surveying*. In the early 1850's he moved to Kansas employed as a land surveyor to gain knowledge of pro-slavery movements. At this time government surveyors were assumed to be pro-slavery, so this let John in as a spy. Sparked by the assault of abolitionist Charles Sumner on the floor of the U.S. Senate, Brown and his sons brutally murdered five pro-slavery men on the banks of the Pottawatomie Creek. This incident led to the "Bleeding Kansas" period between both sides of the slavery movement. Brown was good friends with Henry David Thoreau and they met and wrote extensively up to John's raid on the Federal Armory in Harper's Ferry, West Virginia. John was captured, tried for treason and subsequently hanged soon thereafter. His radical beliefs of violence against the pro-slavery movement, and his death, no doubt changed the opinion of many. Lincoln at the time watched Brown cautiously. Although they both agreed on the same end goal, they had far different ways of going about it. Some say that John Brown started the war that ended slavery and that President Abraham Lincoln finished it.

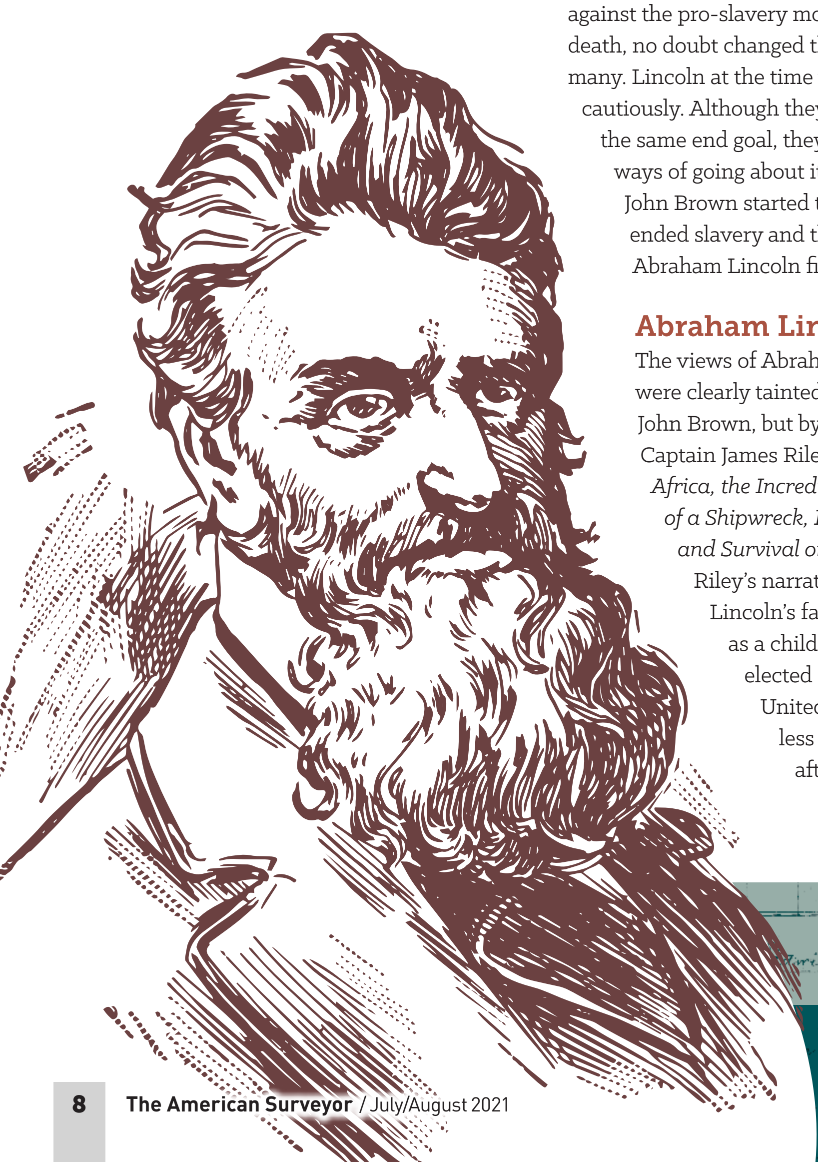
## Abraham Lincoln

The views of Abraham Lincoln were clearly tainted not only by John Brown, but by the story of Captain James Riley in *Sufferings in Africa, the Incredible True Story of a Shipwreck, Enslavement, and Survival on the Sahara.* Riley's narrative was one of Lincoln's favorite books as a child. Lincoln was elected President of the United States in 1861, less than two years after John Brown was hanged. Lincoln was a well-known, and well-respected surveyor in his early career. Aboard the Lincoln Inaugural Train, on the Cleveland and Pittsburgh Railroad Line, Lincoln stopped in Hudson, Ohio on February 15, 1861 to give a speech to around 6,000 on lookers. Lincoln did not say much in Hudson, as he was ill and hoarse, but to the people of Hudson it meant everything.

## Conclusion

The Cleveland and Pittsburgh Railroad tracks are now long gone, but the rail bed lies literally visible across the street from our new home. There is no doubt we chose the right place to live. The rich history of President Lincoln going by on a cold February day in a snowstorm brings me warmth. As I walk past the Loomis Observatory, I think of Elias take observations all night long in that tiny building. As I drive down Owen Brown drive, I think of John Brown and his radical ways that impacted our young country. As I pick up my young son up at Ellsworth Hill Elementary, I think of Lincoln who defied his father and chased his dream of being a Polar Explorer and placing hundreds of thousands of square miles of ice on the map. Lastly, I compare myself to David Hudson, who picked up his family and left it all behind to pursue bigger dreams, dreams that include a long career at the University of Akron teaching the next generation of surveyors. I am proud to live in Hudson, Ohio—the land of surveyors, explorers, astronomers, and a passing President. ■

**Joseph D. Fenicle, PS** is a Professor at the University of Akron for their award winning Surveying/Mapping program. Immediately prior, he was the Chief Surveyor at the Office of the Fulton County Engineer in Wauseon, Ohio for 15 years. He also owns Angular By Nature, LLC, a company specializing in Continuing Education for Surveyors and Engineers. Joseph has a BS in Surveying/Mapping, and is working on his PSM at the University of Maine. He obtained his FAA license in 2019.



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HISTORY OF RTK—PART 3

# "EVERYBODY WANTED IT"

Smart minds around the world race to develop the dynamic capabilities necessary for RTK

» STACEY HARTMANN


USACE Dredging Research Program RTK design reports.
SOURCE: STEVE DELOACH

When considering historically significant technology, it's tempting to try to pinpoint one particular breakthrough that marks the start of a new era, but Real-Time Kinematic (RTK) revealed itself as a wave of innovation rather than a particular moment in time.

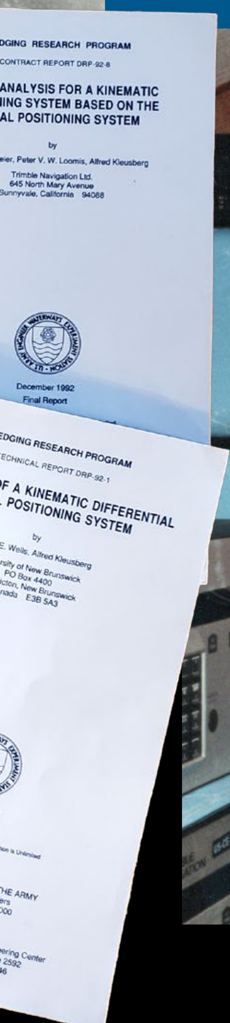
The wave formed from the convergence of ripples of software and hardware development and testing by geodesists, mathematicians and scientists from government, academic and commercial entities around the world.

Seeing significant potential benefits in marine and land surveying by leveraging a new constellation of satellites known as the Global Positioning System (GPS), these technology pioneers were pulling in a similar direction in the late 1980s and early 1990s to attain three-dimensional, centimeter-accurate kinematic positioning in real time, or RTK. This era also brought new GPS signals, the launch of more GPS satellites, and improved receiver development.

Although these pioneers pursued RTK to improve cumbersome and costly surveying techniques on land and water, they didn't fully imagine the multitude of ways the technology would eventually change the world and make precise positioning available in a growing list of applications.

In this third article on the history of RTK, we focus on the most intense period of RTK development, a fast-paced and heady time when highly motivated individuals sought to solve integer ambiguities reliably so the system could work dynamically, or "on-the-fly" (OTF), a key that would unlock its full potential.

The USACE Coastal Research Amphibius Buggy (CRAB) was one of the many OTF-RTK test platforms.
SOURCE: STEVE DELOACH




Dale Jarvis, senior geodetic technician for the Corps, provided important guidance for data campaigns for RTK development.
SOURCE: STEVE DELOACH

## The push to create a working system

Before RTK, which processes in real time, users could do a continuous kinematic survey, logging raw observations from the satellites, and then go back to the office and process that data to get centimeter-accurate positions, said Mark Nichols, general manager at Trimble and one of the company's early RTK development leaders. "This post-processing step would typically take several hours and generally required some form of static initialization. Sometimes there were so many cycle slips that you could not get a reliable answer."

In the early 1990s, there were simultaneous efforts to develop algorithms to initialize the carrier integer ambiguities while in motion, identify and resolve cycle slips automatically, and develop the data formats for transmission from a base station to a computing station and formats for real-time processing. The naming conventions had not matured, and limited effort was going toward a full system integration.

The U.S. Army Corps of Engineers launched its high priority, multi-year project to develop a complete operational prototype RTK system in 1988 with the goal of vastly improving

The Trimble 4000SSE receiver represented a major reduction in size and power consumption, and vastly improved dual frequency signal measurement.
SOURCE: TRIMBLE

the economies, accuracies and timeliness of dredging and hydrographic surveying, in particular to benefit the $400 million annual maintenance of the nation's waterways.

The Corps' intent was to develop a prototype system that could be immediately put to work. "We wanted to demonstrate an operational system that could be interfaced to multiple hydrographic and dredging systems, run experiments for new applications and develop the geodesy to use GPS for tidal measurements on the survey boat," said Steve DeLoach, a civil engineer and land surveyor who led the program for the U.S. Army Corps of Engineers. "Our goal was to prove the capability, to develop the OTF algorithms and data formats, and solve problems the industry had not yet recognized."

When the program was done, the hope was that a market would be created, and industry would step in and create a more robust, reliable and operational toolset, DeLoach said. "What we were doing was developing, testing, publishing—unabashedly putting information out—and hoping the industry would pick it up, and they did. They rewrote it, changed it, commercialized it, and made it usable for everybody."

OTF would open up the use of RTK for marine and machine control while also simplifying the use for surveyors, because it automated the initialization without the need for a point of beginning each time the receiver lost lock. It would also provide a data analysis and processing tool to continuously and automatically look for cycle slips, repair them and back-process the data for the correct solution—all automatically and processed without operator intervention. With the addition of data transmission between a reference station and the roving station, RTK could be realized in a robust way.

## Corps sparks flurry of research and testing

To help understand the intricacies of every component of a system, and what other groups were doing, the Corps asked the University of New Brunswick, Canada, to conduct a feasibility study in 1988-1989 (*described by authors David E. Wells and Alfred Kleusberg*). The study found the concepts feasible, identified key components and determined that, at that time, no similar system or work was available.

The Corps then launched several efforts to examine the primary components for the hydrographic surveying and dredging case; a contract with Trimble to conduct a detailed system analysis (*described by authors G. Jeffrey Geier, Peter V. W. Loomis and Alfred Kleusberg*;) a contract with Worcester Polytechnic Institute to investigate data link alternatives (*described by Per K. Enge and Keith Pflieger*;) and a contract with the University of Maine to investigate the use of GPS to measure tides, by Alfred Leick and Quanjiang Liu.

In May 1991, Dr. Benjamin W. Remondi, a GPS technologist for the National Geodetic Survey (NGS) (see History of RTK - Part 2), coined the term "On-The-Fly (OTF)" following many months of trials and updates to his software to allow kinematically collected data to be processed without static initialization. The testing followed the idea of using GPS in non-OTF mode to verify OTF; after all, how else would you test a moving system with accuracy at the centimeter level?

Under the careful guidance of Dale Jarvis, senior geodetic technician for the Corps, many data campaigns were well underway in early 1990 with processing, analysis and revision on a continuous cycle. The data would be processed using kinematic techniques and require a static initialization to determine the true antenna trajectory, then reprocessed using the OTF algorithms removing any static initialization data.

USACE Coastal and Hydraulics Laboratory Field Research Facility in Duck, N.C.
SOURCE: USACE

Data campaigns were aggressive, vigorous and often. They ranged from Holloman Air Force Base's high-speed sled track with its millimeter-level positioning system, to a Corps hydrographic survey vessel operating in the Chesapeake Bay, to a shopping cart (borrowed from a nearby grocery store) pushed around a paved course by a then-young engineer, Bryn Fosburgh, now Trimble's senior vice president.

The Corps also surrounded Remondi with young physicists and computer scientists, including Rob Fischer and Jeff Walker, to ensure the latest algorithms and search techniques were quickly coded to align with Remondi's analysis and thoughts. This work is described in "Decimeter Positioning for Dredging and Hydrographic Surveying," by DeLoach and Remondi.

The Corps also worked hard to remain abreast of industry and academic progress. It advertised via a Request for Information, offering to pay for OTF solutions and design review of their systems' design alternatives. The data collections and processing, with Remondi's software, the academic studies and the design review all helped the Corps make development decisions that recognized what was occurring within the industry and academic world.

Only two entities responded to the RFI: Magnavox and the University of the Federal Armed Forces in Munich. At that time, Magnavox was not able to deliver operational software, although Dr. Ron Hatch—who had a 50-year career in satellite navigation systems with Johns Hopkins Applied Physics Laboratory and companies including Boeing, Magnavox and John Deere—proved to be a valuable colleague and thought leader on the subject, DeLoach said.

In 1991, Dr. Herbert Landau, now vice president of GNSS technology at Trimble, was heading a lab at the Institute for Earth Surveying and Navigation at the University of the Federal Armed Forces in Munich. Working under Dr. Günter W. Hein, Landau and Hans-Juergen Euler published "A System for Precise Real-Time Differential GPS Positioning in the Decimeter Range," presented at the June 1991 Institute of Navigation annual meeting. It was based on six-channel low-cost C/A code receivers reaching accuracies in the decimeter range in real-time and in the centimeter range for post-mission. The receivers were controlled by separate processors, which were communicating via a radio link in the UHF band. This team presented OTF software and further design review comments to the Corps, under the RFI.

## Project moves toward implementation

By early 1991, the first phase of the Corps' Dredging Research Program was complete and successful. It showed encouraging results from actual OTF data collection and testing campaigns; a complete system definition was in place; and the idea of using RTK GPS for tidal datum measurement on a survey vessel had been validated. During the summer of 1991, the team continued experimentation, now including a second OTF software from the University in Munich. This work led to Phase 2 of the project to develop proper guidance for the ultimate users and to define operational criteria in the marine environment. Remondi continued updating his algorithms with every test.

At the time, other researchers, including Hatch, also were making great progress. Dr. Peter Teunissen of Delft University of Technology, The Netherlands, was explaining how to improve the efficiency and reliability of integer searches. "His contributions were at the highest level," Remondi said. "His 'LAMBDA method' was a breakthrough that achieved universal acclaim."

Both Remondi and Hatch started with a doppler approach to OTF initialization, Remondi recalled. "It was not long before that was abandoned for a grid-like search for the 'best' integers. This worked very poorly at first because we had only single frequency receivers. Later, we added a weak second frequency (half cycle L2 data) and achieved improved results. At this point, many were skeptical about searching for integers. This was understandable as better GPS signals, and more GPS satellites were needed."

Soon, the development of full-cycle L2 GPS receivers would make searches easier.

"Fred Gloeckler (senior electrical engineer at the Corps) was an important contributor, as he was both brilliant and insightful," Remondi said. "As our search methods were getting better and our optimism grew regarding better signals and more satellites, Steve contracted with John E. Chance to implement RTK for real."

## Trimble's first commercial RTK system makes its debut

In 1991, Nick Talbot joined Trimble's engineering team in Sunnyvale, California, after completing his doctoral thesis—"Real-Time High Precision GPS Positioning Concepts: Modelling, Processing and Results"—at RMIT University, Melbourne, Australia, which followed completion of his degree in surveying.

"I'd read many times with great interest Ben Remondi's Ph.D. thesis," Talbot said. "Ben developed theoretical techniques for post-processing GPS data to produce centimeter-level baseline vectors over long range. His research laid the groundwork for centimeter-level GPS positioning."

Although Remondi's well-known thesis only dealt with static GPS data post-processing, he later published papers discussing the possibility of producing results in real time, Talbot notes.

During his early employment at Trimble, Talbot began working on the company's first RTK product and was responsible for the algorithmic aspect of the development, together with Dr. Timo Allison, who had been with Trimble from the start and had developed the positioning engine in the very first Trimble GPS products. Allison was also responsible for signal tracking firmware. Other members of the RTK development team worked on GPS receiver data communications and the data collector communication interface.

The resulting product, Trimble's Site Surveyor RTK system, was based on the 4000SSE receiver. The 4000SSE receiver represented a major reduction in size and power consumption compared with earlier models, and this enabled it to be easily carried in a backpack. Importantly, the 4000SSE used a new digital signal processor, the Maxwell chip, that delivered high quality dual-frequency measurements that would become an enabler for robust OTF real-time kinematic.

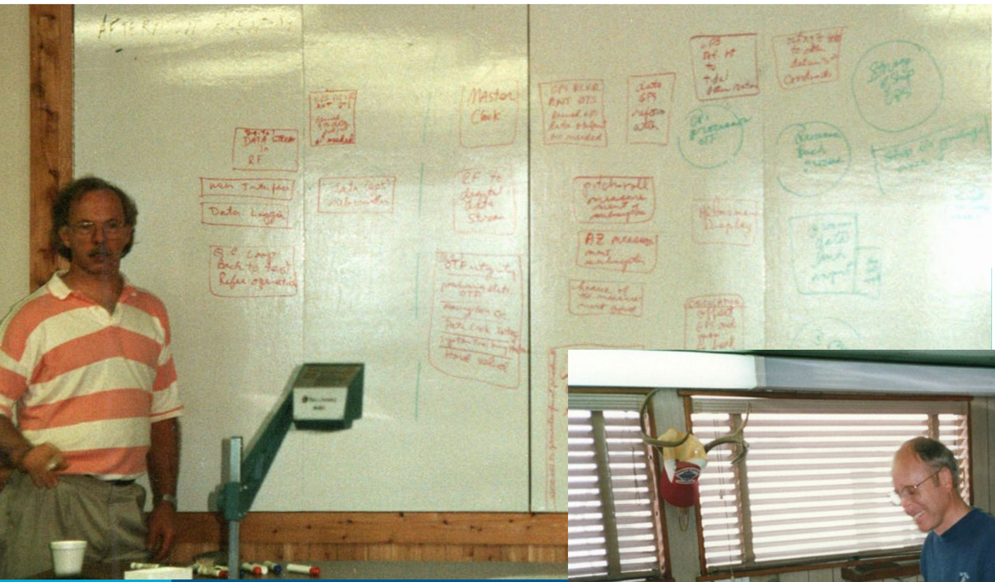
## Corps partners with JECA on final steps to working system

In the 1980s, marine positioning remained a tough, risky and expensive endeavor, which Kurt Maynard knew first-hand from his research and development role for John E. Chance & Associates (JECA), founded in 1957 by its namesake, a surveyor who had worked in the Texas oil industry.

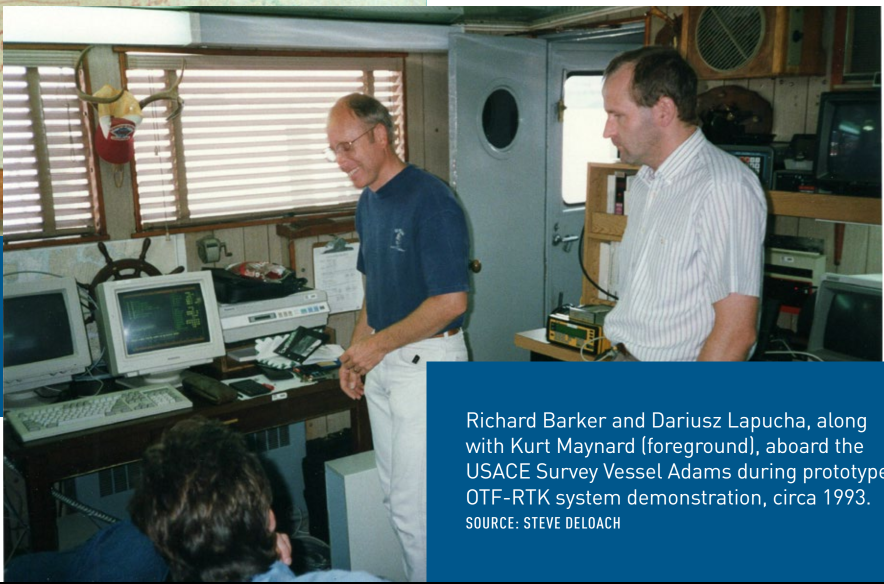
"We used everything we could use, because positioning was not like it is today," said Maynard, now of Trimble. During that era of oil-field navigation, the best positioning accuracy was several meters in real time. "You couldn't go down the street and grab a survey point and start your survey."

Maynard became part of the Corps' RTK project when DeLoach hired JECA for its history of developing real-time, satellite-based positioning and communications systems and using those tools on board their own fleet of ships to support the Gulf of Mexico oil industry.

JECA initially relied on systems such as Loran-C or Raydist, which had limited accuracy, but was able to develop its own



Benjamin Remondi at the white board at the USACE Field Research Facility in 1992.
SOURCE: STEVE DELOACH



Richard Barker and Dariusz Lapucha, along with Kurt Maynard (foreground), aboard the USACE Survey Vessel Adams during prototype OTF-RTK system demonstration, circa 1993.
SOURCE: STEVE DELOACH


Survey vessel Adams is ready to sail on an RTK test.
SOURCE: STEVE DELOACH

'GPS like' system, Starfix, which was basically GPS on HBO satellites. JECA also owned the database for oil leases and pipeline locations in the Gulf of Mexico. "Any time an oil company wanted to drop an anchor or drill a well, they had to call JECA to provide positions for their ships," DeLoach said, "and JECA designed and built Starfix for that purpose."

This relationship between JECA and the Corps enabled both entities to innovate, Maynard said, because "they had things we needed, and we had things they needed, and we'd work together on different contracts." The Corps was interested in Starfix because it was much better than land-based, line-of-sight positioning systems. And while Starfix didn't have the potential of GPS for centimeter-level positioning, its designers (including Maynard) had the magic of transmitting data between land stations and ships and computing positions in real time, "and we needed that expertise on our team," DeLoach said.

The Corps, in turn, "brought the algorithms to actually do the task of OTF-RTK with three-dimensional accuracies at the centimeter level," Maynard said. But for the Corps, "it needed to be real time and it needed to be one program that ran on a laptop that could be used in the field."

In addition, Gloeckler, who served as chair of the Radio Technical Commission for Maritime Services (RTCM) differential carrier phase working group, collaborated with Hatch, Hein and Remondi to develop the data standard for transmission of the signals from a base station to allow OTF-RTK to occur.

## Research with JECA puts prototype over finish line

The movement of the post-processing versions of the software onto a real-time platform and interfacing the hardware components into a working prototype would be a significant challenge. In July 1992, the entire team from the Corps and JECA sequestered itself for a week in a conference room (on the beach) at the Corps Field Research Facility in Duck, N.C.

There, the team learned each other's strengths and weakness, and who could design and build each component part. Team members also had to establish trust so they could exchange intellectual details of their contributions.

Another meeting soon followed at JECA's facility in Lafayette, La., where Remondi, Dr. Dariusz Lapucha and Richard Barker revised the libraries and software for the prototype. Remondi and Lapucha worked for nearly a month in a closed room almost day and night converting the multitude of research software programs into something portable enough to use on a laptop to plug into a Trimble receiver to get RTK out of it, Maynard said. The Trimble receivers were used because the Corps already owned them for static geodetic work, and Ron Hyatt, an original member of Trimble's executive team, had a hand-shake deal with DeLoach, providing the internal device code to the team—with nothing asked in return.

"Everybody wanted it," Maynard said. "I think it was about a two-to three-month period to blend it into a working system. The working system consisted of a laptop computer, a Trimble 4000 receiver, and a radio communication link that would take the raw data from a base station to the user to be able to do real-time kinematic."

Use of the system began sometime around March 1993 with demonstrations on the Corps' survey vessels Adams in Norfolk, Gillette in Wilmington, and Hickson in Portland. These and many other tests—including important vertical accuracy checks on the Adams during a full tidal cycle—proved the system worked.

"The experience we have with the OTF system over the last few months has convinced us that we can obtain centimeter level accuracy in real time with current GPS receiver and computer hardware using the software developed for this project," wrote the project team in "Results of Real-Time Testing of GPS Carrier Phase Ambiguity Resolution On-The-Fly" for the Institute of Navigation Satellite Division's 6th International Technical Meeting in September of 1993.

"As soon as we had the prototype OTF-RTK system working we immediately began demonstrating the system on hydrographic survey boats," DeLoach said, "and working on photogrammetric aircraft, an R&D project with Caterpillar, and working out the geodesy for real-time tides."

Check out our next issue for History of RTK—Part 4 ■

***Link to part 1:*** *https://amerisurv.com/2021/04/18/history-of-rtk-part-1-a-really-tough-problem-to-solve/*
***Link to part 2:*** *https://amerisurv.com/2021/06/20/history-of-rtk-part-2-rtk-roots-run-deep/*

**Stacey Hartmann** writes about surveying and geospatial topics for Trimble's Geospatial division.

# LIGHTING THE WAY

When professional surveyor Sylvia De Vuyst arrived in the northern edges of Norway in March 2021 for a significant tunnelling project, she wasn't sure what to expect. Freshly hired as the tunnel surveying manager for Mesta, a civil engineering construction company based in Lysaker, Norway, De Vuyst would be the lone surveyor responsible for the NOK $211 million (US $24.8 million) renovation of the Maursund and Kågen Tunnels, two critical passageways that connect the cities of Nordreisa on the mainland and Skjervøy on Kågen island.

Each about 2 kilometers long, the Maursund Tunnel (Maursund) travels under the North Sea, reaching a depth of –92.5 meters (–303 ft) below sea level and a 10-percent grade in some areas; the Kågen passes through Kågen mountain, which is vulnerable to avalanches and landslides. Built in 1991, both structures will undergo extensive upgrades including widening their carriageways, installing new LED lighting, Co / No2 gas meters, new water and frost protection, and new drainage systems, and building new road surfaces.

After one week in the dark, damp tunnels, one project requirement became abundantly clear to De Vuyst: she'd need to be agile.

"A major challenge with the Maursund is that it needs to stay open 24/7 to allow traffic to pass through at set times," says De Vuyst. "This means that many times a day the diggers and bolt riggers need to move to the side, big trucks need to drive out and sometimes I need to stop my survey work. So when we're clear to work, we have to maximize our productivity. To ensure construction stays on target and pace, I need to be efficient, reliable and precise."

Instead of using the traditional total station—the typical domain of tunnel surveys—De Vuyst opted to replace convention with a scanning total station. Combining the high accuracy total station point measurement with the speed and precision of 3D scanning, De Vuyst is managing two tunnel environments where tolerances are tight, space is at a premium, visibility is low and expectations are high—on her own. And she's matching the frenetic pace of the digging, blasting and bolting at six times the speed of multiple-person crews.

» MARY JO WAGNER


The SX12's green laser shines brightly in the Maursund tunnel. On the walls are reinforcement materials. The red discs with cross bars are the bolts that hold the mats on and the steel grid is for extra reinforcement. Concrete will then be sprayed onto the the steel grid.

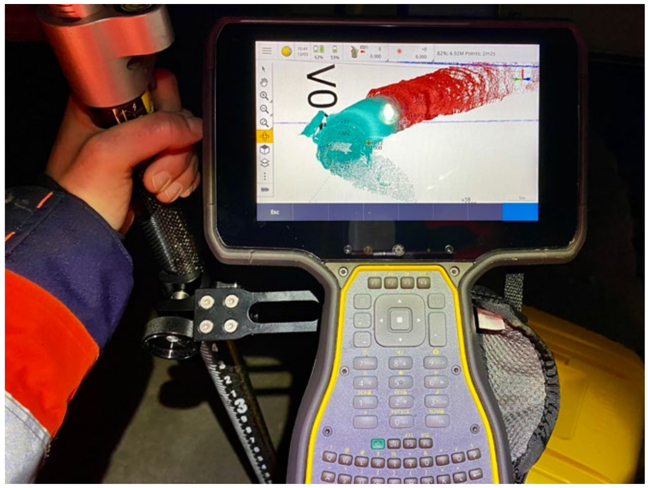
## Change in plan

Tunnel surveying is a specific breed of project that requires unique techniques and skill sets. It's challenging to create and manage a geodetic control network, operate in a GNSS-restricted environment and maintain high accuracy over a long, linear distance underground. It also requires a solid understanding of geodesy to anticipate how the vertical alignment of the tunnel is affected over its length.

Not only do the Maursund and Kågen tunnels have these general complexities, they have multiple layers of challenges in addition to the 24/7 traffic flow issue. Neither one has been designed with a pre-defined shape, making it more difficult to guide construction. All the rock material that is extracted is immediately reused by other firms so there isn't the option to measure stocks and calculate volumes. None of the machinery—save one grader with a Trimble SCS900—is equipped with machine control. And in the Maursund tunnel, a technical building, measuring 5.4-m wide, 4-m high and 19-m long, needed to be constructed and assembled into a confined space with a tolerance of 0.5 m.

When the renovation first began in January 2021, the original plan was to run one, two-person survey team with a total station and occasional scanning, and they would alternate every week. However, given the scale, setting and project deadlines, this approach proved problematic within the first two months of work.

"Measuring and establishing control for the carriageway—one of the most essential jobs to ensure we create the required width and height—with a total station requires constant setting up, measuring and setting out, which is quite time consuming," says De Vuyst. "So in order to keep up, they had



Above: Viewing two scans on the TSC7. The smoother green scan captures a section of the Maursund where reinforcement materials have been installed. The rougher red one doesn't yet have reinforcements installed.

Center: The SX12 outside the Maursund tunnel.

Drilling out space for Maursund's technical building. On the rig's screen the operator can see the driving box to help guide the drilling.

to be on site every day and night taking measurements. Laser scanning is far more efficient. With my scanning total station, I can scan 500 meters to measure control at a precision of .005 meters in four hours; that would take the total station team two days. That efficiency has not only enabled me to manage all surveying tasks by myself, it's allowed me to limit my time on site to only four days every other week, saving us survey costs and positively impacting the project's budget."

The scanning total station that De Vuyst is referring to is the Trimble SX12, a total station and scanner combination that is particularly well suited for underground projects like tunnels. It can scan a full dome at 100 m with a point density of 0.1 m in 11 minutes, lock onto a prism in five seconds, and pinpoint a 3-mm diameter spot at 50 m with its green, eye-safe laser pointer.

"We chose the SX12 based on extensive demos we received on it as well as our experience with previous Trimble SX models," explains De Vuyst. "The combination of surveying and scanning technology makes it incredibly versatile—I can perform multiple functions from the same set up. It's fast and precise which is important for such a dynamic environment. With its ease of use, short learning curve, simple and intuitive functionality and seamless workflow integration, I felt I would be in good hands with the SX12 for my first project with Mesta,"

Based on progress to date, it seems the SX12 and the surveying tasks have been in good hands with De Vuyst.

## Where are we

As darkness is the one constant in the tunnels, it has been crucial for crews to have reliable reference points to know where they are physically in the tunnel and where specific work needs to be done. So one of De Vuyst's main tasks has been to seamlessly switch between the SX12's total station and scanner to provide that guidance. Using the instrument's robotic total station, she has been establishing ground control by setting out prisms at 80-m intervals along the tunnel walls. With those fixed points, De Vuyst maintains a project control network accurate to 0.005 meters.

To easily and reliably guide the four teams of 40-50 people working in the tunnel, De Vuyst uses the total station scanner to establish and measure a "meter line", a horizontal line sprayed every 10 m that indicates the 1-meter mark above the Maursund's future new road. "The existing road has steep grades descending down around 80 m and it curves so it isn't a reliable reference," says De Vuyst. "We know the elevation and design of the new road so I can use that theoretical data and the SX12 to measure and set out the meter line, which not only gives crews a physical position in the tunnel, it provides a marker to follow for determining their own work such as laying cables or installing reinforcing materials on the walls. To lay that out with a traditional total station would require hours of multiple set ups but with the green laser range and speed of the SX12, I can capture the survey data in minutes from one position."

## Volumes of volumes

If there is one word that often dominates De Vuyst's day, it is "volume". With the routine blasting and digging to both widen and heighten the Maursund, De Vuyst is constantly checking and calculating volumes to confirm teams have removed enough material to create a 6-m-wide carriageway with a 1.2-m shoulder on each side and a clear height of 4.6 meters.

And she has had to be creative with machine control since none of the diggers on site are connected to universal total station (UTS) positioning technology. To resolve this, De Vuyst first created a 3D model of the tunnel's "driving box", the predefined height and width needed to allow vehicles to safely drive through. Scanning 60-m sections of the tunnel, she imported the 3D data into Trimble Business Center (TBC) to create a model of the road and then input the 6-m-wide and 4.6-m-high driving box dimensions to produce a linear 3D drawing of the box. She imported it into Trimble Access Tunnels software and saved it as master file on a Trimble TSC7 controller, enabling her to quickly check

The all-female survey team. Sylvia De Vuyst (right) and her trainee Sofie Kolsum.

earthworks progress any time by positioning the SX12, measuring any point, and immediately identifying any underbreak in relation to the driving box perimeter visible on the controller's graphical interface.

She has also been creating 3D "profile prints", drawing files that provide the tunnel shape, tunnel bottom, driving box, and a numbered position marker for tunnel orientation. Once a section has been blasted or dug out, De Vuyst positions the SX12 and captures a full-dome scan to collect a georeferenced point cloud of the 60-m area. She integrates that data into TBC and using the software's specialized Tunnel module, she uses a classification tool to automatically clean and process the data to create a tunnel shape—a process that takes 3 minutes per scan.

"The scanner captures everything it sees—people, cars, even water droplets—as well as the tunnel shape," says De Vuyst. "Without the automatic classification tool in TBC, I'd have to manually select each bit of noise and delete it. That feature, along with the automatically georeferenced scans, saves me hours of processing time. And because I know I can eliminate noise automatically, I don't worry about passing traffic or objects in the way."

De Vuyst uses the SX12 to set out ventilation bolts.

Once she has the tunnel shape, she can combine survey controls with the density of points to calculate and verify earthwork volumes as well as convert the 3D model to a tunnel profile drawing, indicating precisely where more sediment needs to be removed and how much. Digger operators then use the prints in their cab as a machine control guide.

"I make profile prints of the tunnel at every half meter," says De Vuyst. "That allows everyone to monitor progress at set intervals. Crews can not only see how the tunnel looks now, I can provide historical views to show how the tunnel looked a week ago or even at the beginning of construction. It's incredibly helpful for measuring and monitoring progress."

The ability to efficiently produce tunnel profiles was particularly beneficial for preparing and positioning Maursund's technical building, which is set in the tunnel center, 93 m below sea level.

Teams needed to blast out a space 5 m deep by 20 m long. Precision was paramount because the building's pre-fabricated construction was designed to within only a half-meter of the tunnel wall and the top of two of the building's corners. De Vuyst used the SX12 to as-built and calculate the excavation volumes based on two profile prints for the same area to ensure the space was correct. In early June, crews successfully constructed the technical building.

## Locked and bolted

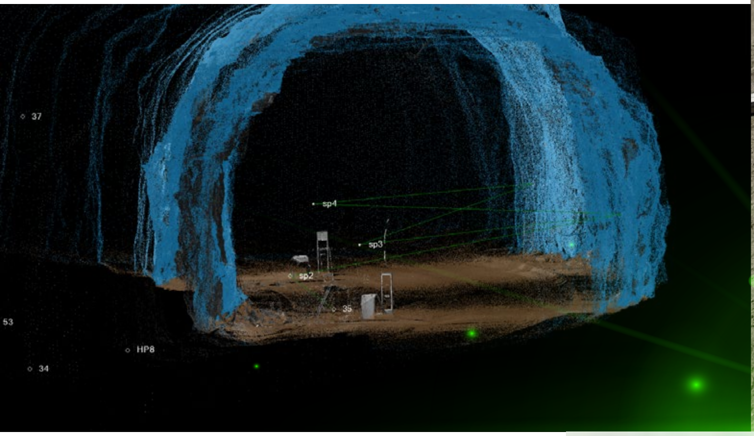
In addition to checking and calculating volumes, De Vuyst has also been consumed with bolts—prism bolts, reinforcement bolts, lighting bolts and signage bolts, all of which she has either been taking as-builts of or setting out.

Of the roughly 170 bolts she has set out, the most challenging to precisely position were the bolts for road signs that will be

installed in the tunnel. The bolts needed to be set at a minimum height of 2.2 m above the finished road but at the time, a ditch for underground cables had been dug, making access to properly mark the positions difficult. De Vuyst resolved this with the SX12's green laser and a truck with a hydraulic bed.

With a tunnel shape model as a base, she used the defined design plans and national height specifications to determine and draw set-out lines indicating where the bolts should be placed. She then imported that 3D file into the TSC7's Access software. Setting up the SX12 about 20 m from the

The SX12 stands at the ready outside one of the Maursund's technical buildings.




The blue tunnel shape created with TBC. SP stands for station point and the two green lines show where the SX12 locked on to two fixed prisms to measure De Vuyst's position.

truck, she used the set-out function and let the scanner's green laser navigate to the corresponding line. From there she used the controller to move the laser along the line until it hit the precise break point. The person on the truck could then mark the tunnel ceiling at the exact bolt position.

"The clarity, precision and range of the green laser made the task so much easier," says De Vuyst. "Even at 100 meters away, points are crystal clear."

With one kilometer of the Maursund tunnel now complete with installed bolts, reinforcement materials, concrete fire protection, and 8.5 billion 3D points, De Vuyst will continue to do more of the same for the last half of the Maursund and the full length of the Kågen to meet the completion deadline of fall 2022. De Vuyst may still not know what to expect as work continues, but she's confident the versatility of the SX12 will light the way. ■

The view of the project site from above. The red lines indicate the two tunnels—Maursund on the left and Kågen on the right.

**Mary Jo Wagner** is a freelance writer who's covered the geospatial industry for 25 years. Email: *mj_wagner@shaw.ca*.

# Cincinnati State Land Surveying Capstone 2021

» EDITED BY CAROL MORMAN, EDD, PS, PE

Marcus Schulenberg showing the Cincinnati State students the scope of the project.

**Group members:**
Luke Strotman,
Emerson Hoeweler,
Jared Foster,
Frank L. Sellinger, II,
Rakeem Wright.

**Also shown:**
Marcus Schulenburg, MS, RPA, Senior Archaeologist, The Archaeological Research Institute

The 2021 Land Surveying Graduates at Cincinnati State have been busy bringing history back to life near the city of Lawrenceburg, Indiana. This team of students from Ohio was lucky to have the opportunity to survey a pre-contact village site. The site, located in Dearborn County, Indiana, is the current focus of the Archeological Research Institute, also known as ARI. The stated mission of ARI is to educate present and future generations about the past cultures of the Indiana, Ohio, and Kentucky tri-state region through research archeology and cultural preservation efforts. To accomplish this mission, ARI needed to identify the boundaries of their diggable area, gather topographic information about that area to identify ancient structures and features on the land, establish control to lay out features on the site as needed, and to make the dig site both accessible and enjoyable for the public.

To help ARI pursue their mission, Carol Morman Ed.D., P.E., P.S., Program Chair and Professor of Land Surveying at Cincinnati State Technical and Community College, arranged for a team of five Land Surveying students to take on the project as the culmination of their degree program.

While the project was presented as a simple retracement and topographic survey, there was a unique obstacle in the make-up of the team. Each member was working full time and was also a student. This meant all work would be performed on weekends with smaller tasks needing to be completed after everyone's day job. This limited timeline quickly became problematic as several weekends were lost when the site was entirely underwater, due to its location in the floodway of the Great Miami River.

After overcoming and outlasting the elements, the fieldwork began to take shape. The topography was handled by two crews running Trimble S3 instruments simultaneously with one crew working on the wooded area of the site and another focused on the open areas. The topographic survey was necessary to be able to see the differences in the elevation of the ground to find more artifacts and other features of the ancient settlement. Three-wire level loops were run to the site to establish elevation from a nearby NGS benchmark. With the help of the ARI's Executive Director, Liz Sedler, and Senior Archeologist, Marcus Schulenburg, the Cincinnati State students were also able to map the locations of known buildings around a Native American settlement, and what is thought to be a protective perimeter wall.

Site flooded after rainfall and snow thawing in the spring.

Cincinnati State students meeting at ARI to go over work for the day.

> “I gained so much by being able to take a small part in the mission of ARI as they nurture appreciation of what happened in the past!”
>
> — Frank L. Sellinger, II

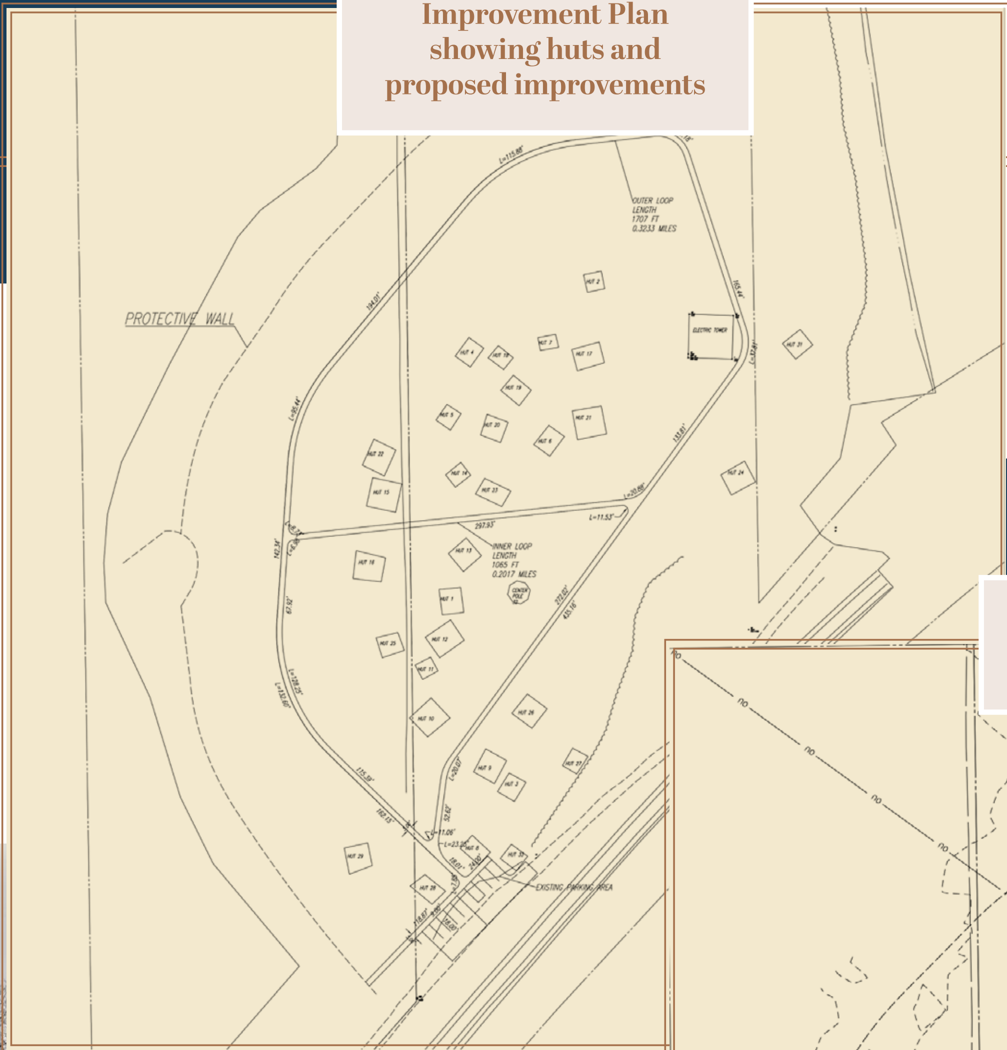
These structures had been discovered by an earlier magnetic survey conducted by ARI that was able to uncover evidence of the settlement and which helped establish where the huts and the protective perimeter wall are in the ground. To provide a more interactive format for the topographic map, a secondary survey of the site was performed by Cincinnati State cooperative education partner, LJB, Inc.'s survey department. A drone specially fitted for survey work was utilized to create a 3D picture of the project site and allowed for a check to the topographic data collected by robotic total stations and GPS. The drone survey data will be an invaluable teaching aid for ARI's work in educating the Lawrenceburg community about the history of the area. The students of Cincinnati State also set control points for ARI to use for future mapping of dig sites. These points were concentrated toward the eastern portion of the property to provide enough space for work to continue while mapping is taking place in the future.

With the establishment of control and the topographic mapping of the area being completed, the boundary was the next concern. The area being studied by ARI is surrounded by Oxbow, Inc., who leases the fields for agricultural use, an active rail line, and the old riverbed of the Great Miami River. The property also sits in the existing floodway of the Great Miami River. Despite there being a plowed field to the west of the property being utilized by ARI, the class was able to find an undisturbed rebar in the middle of the field and were able to utilize it to help define the western line of the property. There were also several monuments found that proved to be less than helpful in defining the boundary. Near the southeast corner of the property, there were three existing features that could reasonably be considered corner monumentation. Two of these were rebar set in concrete and encased in PVC piping, and the other was an angle iron. None of these could be fit neatly into the deeded area, the closest being more than two feet from the deeded corner. The boundary of the project was eventually established using the rebar found in the west line of the adjoining property, original concrete monuments in the west line of the subject property, and a rebar located at the north east corner of the property.

With the retracement and the topography of the property completed, it was then the goal of the class to show ARI how the land could be used to allow for guided access to the dig site for tours and information sessions. An improvement plan was prepared for this purpose. Part of the land that had not been marked as a building location was chosen as a possible site for a small

Frank L. Sellinger, II calibrating GPS as fellow students wait to discuss next steps.

Improvement Plan showing huts and proposed improvements




Topographic Map


Marcus Schulenburg, Rakeem Wright, Frank L. Sellinger, II, Luke Strotman, Jared Foster, Emerson Hoeweler. Not pictured: Carol Morman, Liz Sedler

parking lot and a walking path was shown that would follow both the perimeter of the village and a row of ancient building sites through the village. The exact location will not be provided as per safety and preservation concerns but is available upon request.

Emerson Hoeweler and Luke Strotman reviewing level-loop notes

As the students finish their time in Cincinnati State's Land Surveying Program, they can add this unique experience to their ever-growing body of knowledge. By locating and mapping the sites of these ancient buildings, they have helped preserve the information under the surface. This is information about a culture that could have been lost, and can be used to teach us about society and humanity.

This project was completed as part of the requirements of the Bachelor of Applied Science Degree in Land Surveying at Cincinnati State. The Surveying Capstone course is one of the final courses that students in the program take to show their proficiency in land surveying before graduation.

The Archaeological Research Institute (ARI) is a non-profit organization based in Lawrenceburg, IN, near an Ohio River site occupied by past cultures. Under the guidance of ARI's staff-archaeologists, volunteers and students of all ages have unique and immersive hands-on opportunities to unearth site artifacts and features, document and preserve them, and learn about and appreciate the cultures that lived on our Tristate land long before us ■

**Carol Morman, EdD, PE, PS** is Program Chair and a Professor in Land Surveying at Cincinnati State. She is a licensed land surveyor in Ohio and Indiana and a licensed civil engineer in Ohio, Indiana, and Kentucky.

Luke Strotman locating possible corner monumentation.

A rope being used to measure fields. Taken from the Tomb of Menna, an Egyptian official interred in the Theban Necropolis on the west bank of the Nile, opposite Luxor.

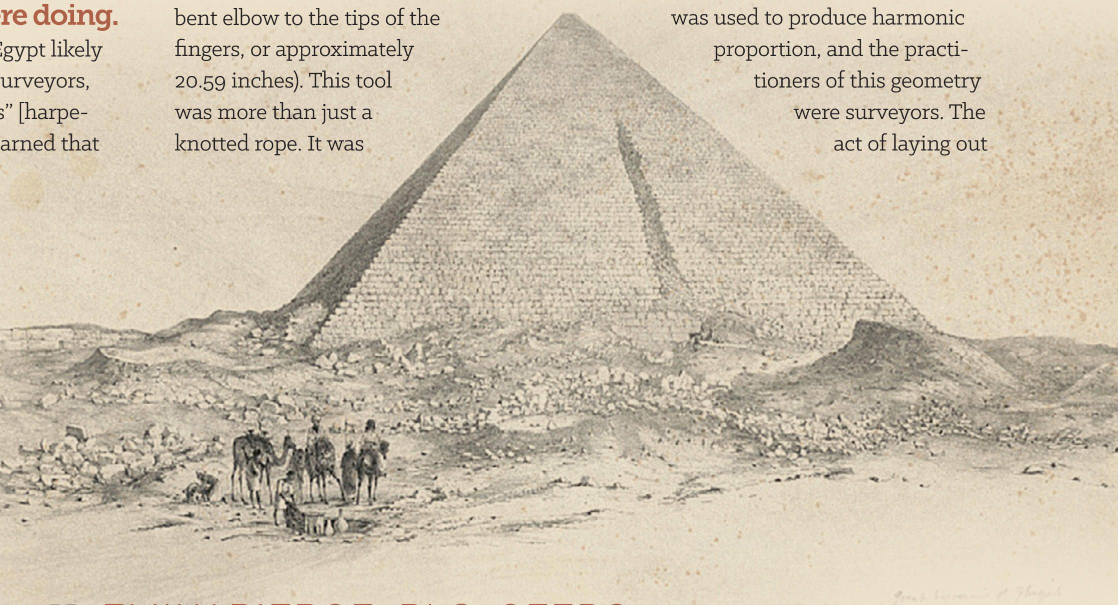
# WHAT'S A ROPE-STRETCHER?

Every year our field bags get increasingly loaded with technology—total stations, GPS units, lidar, drones, apps, and software—tools that make things easier, allow us to generate more data, and expand our reach. It makes me wonder how difficult things were for surveyors of the past to complete their jobs!

## However they did it, they sure knew what they were doing.

As most surveyors know, Egypt likely produced the first known surveyors, known as "Rope-Stretchers" [harpedonaptae in Greek]. They earned that name because one of the tools used in surveying was a calibrated rope. These ropes were specially-treated to hold their length by being stretched out taut between stakes and then rubbed with a mixture of beeswax and resin. They were graduated by 13 knots tied at equal intervals (small or large, depending on the intended use). A commonly-used rope was made up of 12 royal cubits (a cubit is the length from the bent elbow to the tips of the fingers, or approximately 20.59 inches). This tool was more than just a knotted rope. It was the key to practicing sacred geometry, the purview of priests and royalty.

The inherent harmony in geometry was accepted by the ancient Egyptians as evidence of the divine plan that upholds the entire world. The use of geometry allowed humans to determine and incorporate this pre-existing divine order into their structures. Sacred geometry, where all figures can be drawn or created using a straight line and a compass, was used to produce harmonic proportion, and the practitioners of this geometry were surveyors. The act of laying out



» EMILY PIERCE, PLS, CFEDS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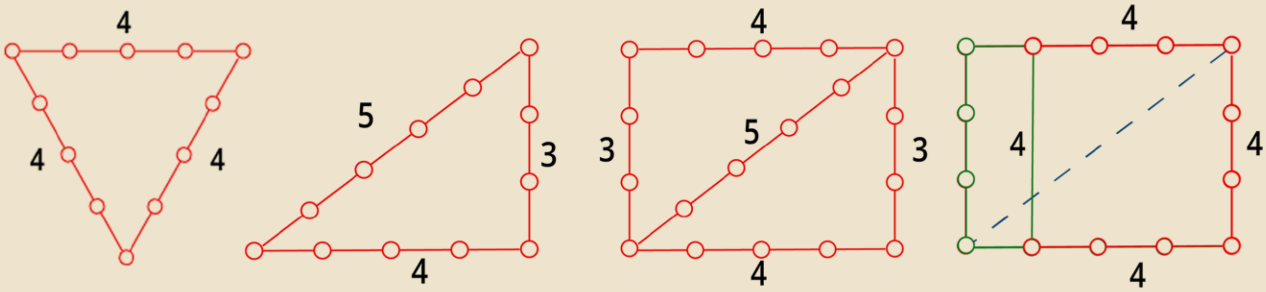



buildings was literally done religiously—with an elaborate ceremony. Royal tombs, temples, pyramids and palaces, even the Pharaoh took part in the ceremony, playing the part of the chief surveyor.

> *"The most famous depiction of the ceremony comes from the temple of Edfu. Here the king is shown with the goddess Seshet, who is the personification of the art of writing and knowledge. Alongside the image is an inscription that reads, "I take the stake and I hold the handle of the mallet. I hold the measuring cord with Seshet." So the king basically acts as a chainman in the ceremony. The king also took part in the celestial observations, at least ceremonially, to establish the alignment of structures."*
> *—Surveying in Ancient Egypt, Joel F. Paulson, presented at FIG Working Week 2005 GSDI-8*

Hatshepsut with Seshat founding the Red Chapel @Lothar Derstroff

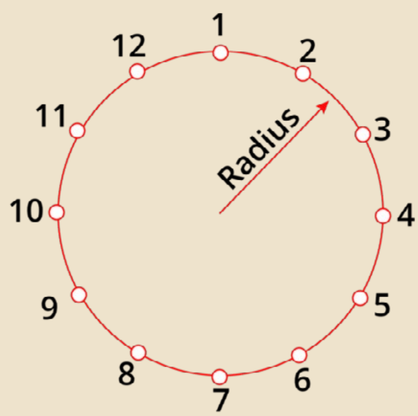
So for special occasions, the Pharaoh got to pretend he was a suveyor! That sounds pretty harmonious to me.

## More than a knotted rope

The equally-spaced 13-knot cord was the basic tool used to establish various geometric shapes. For example, the rope can be used to create an equilateral triangle, where the three sides are made up of four units each. It can also create a right-angle triangle with sides 3, 4 and 5 units.

Of course, once you have a right triangle with the proportion of 3:4:5, you have the basis for rectangles and squares, which can be used to design almost any building.

Most important of all, this rope can be used to create a circle, which is the symbol for the Egyptian god Re (the cosmic creative force). When the cord is looped as a full circle, that radius is 1.91 cubits . . . which also happens to be a meter. Did those ancient surveyors know something prescient?




## How did they make sure the pyramid was level?

A water level was used to create a level base. The bedrock was networked with narrow trenches, then filled with water. The waterline was marked on all the trench walls, the protrusions cut down, and the trenches re-filled with stone to create a level base.

The second type of level was an A-frame with a plumb bob suspended from the apex. Since the Egyptians understood the isosceles triangle, stones could be cut and chiseled square, then mortared into place using this instrument for precision. With these tools, the Egyptian surveyors were able build structures that are testaments to their understanding of geometrical harmony and complex engineering principles.

Using the simple knotted rope, and two types of levels, the Egyptian surveyors were able to create structures that are acknowledged as wonders of the world to this day.

The geometry of the Great Pyramid of Giza remains a hot topic of conversation today. The facts are pretty straight-forward. The Pyramid was the largest monument of its kind ever constructed and remains one of the Seven Wonders of the Ancient World. It was built with approximately 2.3 million blocks of stone, many of which weigh more than 3 tons, with the total weight calculated to be about 6 million tons.

## However, its geometry is the pyramid's most stunning aspect.

- If 2pi is multiplied by the perimeter of the Pyramid, that sum is equal to its height.
- The azimuth of the Pyramid during summer solstice sunrise measures from true north (with only a 3/60th of a degree of error), and the sides seem to case a shadow effect to make it appear to have eight sides instead of four.
- The base of the Pyramid is level to within just 2.1 centimeters; the average deviation of the sides from the cardinal direction is 3 feet 6 inches of arc.
- The greatest difference in the length of the sides of the Pyramid is 4.4 centimeters.

That's some amazing surveying!

However, not all Egyptian surveyors worked on building pyramids—there was a great deal of work surveying nearby fields. Most of the land was owned by the Pharaoh, which meant that the Pharaoh was very interested in collecting rents and taxes on the land. (After all, there were tombs and pyramids to build, and they didn't come cheap). What's interesting is that this dichotomy of survey roles is still true today. Surveyor duties can range from new construction on large projects like skyscrapers to residential property line marking. Like the Pharaoh understood back in the day, both skills are the bedrock of a successful culture.

In those days, surveying had to be done yearly, due to the annual flooding of the Nile. Some monuments survived the flooding, but the land would have to be re-surveyed and so the Rope-Stretchers were brought in to put order to things.

Herodotus (484-425 BCE) wrote in Item 109 of Book II Enerpre as follows:

Egypt was cut up: and they said that this king distributed the land to all the Egyptians, giving an equal square portion to each man, and from this he made his revenue, having appointed them to pay a certain rent every year: and if the river should take away anything from any man's portion, he would come to the king and declare that which had happened, and the king used to send men to examine and to find out by measurement how much less the piece of land had become, in order that for the future the man might pay less, in proportion to the rent appointed…

In learning more about how ancient Egyptian rope-stretchers did their work, I became aware of one elementary theory. "The more things change, the more they stay the same." In other words, even though the ancient Egyptians' tools seem rudimentary today, the principles of measuring and construction are still the same as it was then. We rely on the same sacred geometry, trigonometric formulas, and universal mathematic language, and it will continue to be the fundamental principles that will be relied upon centuries into the future. ■

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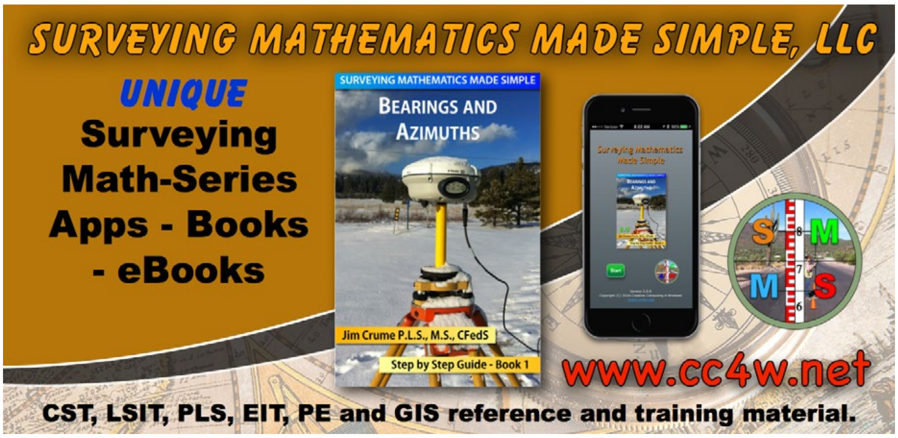
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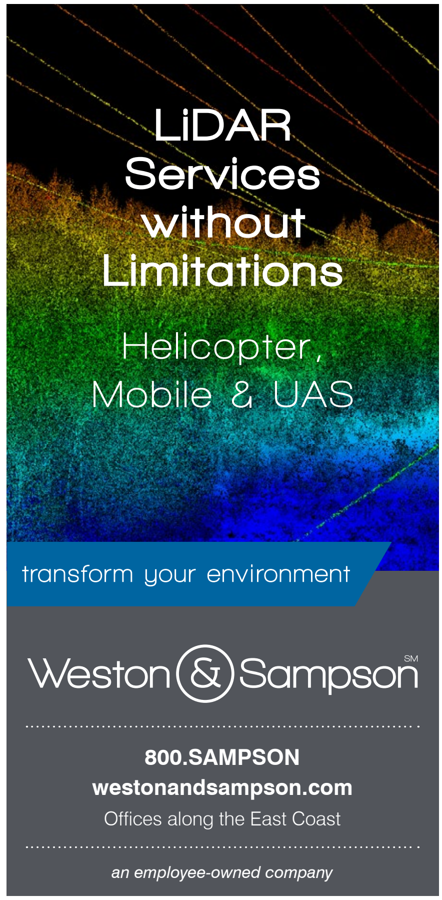
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# Risk Rating 2.0 Launches

The chasm between the two parallel worlds of the National Flood Insurance Program (NFIP) is about the widen and deepen.

October 1, 2021 marks the start of Phase One for Risk Rating 2.0, a transition away from "in/out" determinations of relationships between structures and Special Flood Hazard Areas (SFHAs), where mandatory flood insurance and regulations apply and toward what FEMA hopes is a more equitable and more accurate assessment of flood risks. The maps showing the various risk levels (Special, Moderate, and Minimal) will still play a central role in floodplain management. But when it comes to assigning premiums, new software will take the place of the tables that flood insurance agents have relied upon for decades.

True, the tables had in recent years been updated to accommodate non-coastal structures with their lowest floors more than the paltry one to three feet below Base Flood Elevation (BFE) that had for decades been the standard cut-off before needing individualized evaluation. Tables in the last two or so years have shown rates for structures with lowest floors up to 15 below BFE before being sent off to the Special Rating Guide.

Risk Rating 2.0 does away with all those tables and instead bases premiums on a range of factors intended to more accurately and more fairly calculate the risk for each individual structure. Individualized risk rating and gradients of risk rather than stark "in/out" determinations are concepts that have been argued for (and against) for years. It was the 2016 Annual Report by the Technical Mapping Advisory Council to FEMA (TMAC) that finally advocated it strongly enough at a time when reform to the insurance side of things was strongly needed that seems to have pushed the concept of structure-based risk assessment from fringe to center stage. Recommendation 23 stated:

> *"FEMA should develop, in conjunction with others in the public and private sectors, flood risk-rated insurance premiums for all structures within and outside the identified Special Flood Hazard Area. These premiums should be based on the nature and severity of the flood hazard, structure elevation, and other characteristics, as well as structure damage functions and vulnerability."*

This recommendation was rooted in 2015 Annual Report recommendations intending to better prepare our nation for flooding, improve transparency of the insurance rating process, and to try to minimize creating future risk problems as we build.

Now policy premiums will consider the cost to rebuild and include additional rating variables. No longer will insurance agents rely solely on the map zone, BFE, foundation type and elevation of structures in the SFHA. Zone and BFE will be replaced by distance to flooding source and the type of flooding (riverine, urban flooding, coastal storm surge). Other rating factors include a broader range of flood frequencies than just the 1% annual chance event; the use of the building; ground elevation; first floor height; number of floors; and prior claims. Foundation type is still evaluated as an element of structural integrity and resistance to flood damage.

Where will this data come from? FEMA is relying on not just its own data but also other federal government-source data and commercially available third-party data. As one example of an outside data source, readers may have heard of First Street Foundation (https://firststreet.org), but there are others.

Is everything changing? No, some basics will remain as we are used to them. Requirements for flood insurance remain in place for structures within SFHAs serving as collateral for any mortgage issued by a federally-regulated lender. Increases in premiums are still limited by federal statute to a maximum of 18% per year. And FEMA-issued flood mapping, no matter whether under the current name of "Flood Insurance Rate Map" or something else not tied to insurance, is still the basis for floodplain management building requirements and mandated flood insurance purchase. One improvement to a retained basic is that discounts to flood insurance

> "... our clients need us to help them navigate the two separate universes of flood insurance and floodplain management."

*continued on page 38*

**Lathrop,** *continued from page 36*

policies in communities participating in the Community Rating System (which awards points for proactive floodplain management adding up to premium reductions for policy holders) will now apply to *all* policies, not just those in SFHAs.

What about Elevation Certificates? They will play a diminishing role in the assessment of insurance premiums. But that doesn't mean they will disappear. The maps identifying the mandate for flood insurance, local building regulation, and floodplain management will still need updating with Letters of Map Change. Alterations to structures not reflected in the databases still require on-site data collection. Disputes over database accuracy still need surveying services. Local communities may still require Elevation Certificates for consistency in keeping records of lowest floor elevations, data that is required for communities to participate in the NFIP. Building permits and interim checks to assure that construction is according to plans will still rely on Elevation Certificates.

Besides renaming products, FEMA will need to revise language in some of its regulations as well. For instance, references throughout Title 44 of the Code of Federal Regulations (CFR) referring to "Flood Insurance Rate Maps" will need to change as this product changes focus and is renamed, and some definitions specified for insurance applications may need to be rewritten (such as "structure" in 44 CFR 59.1).

The start of the road may be rocky, and surveyors need to keep up to date on the NFIP because our clients need us to help them navigate the two separate universes of flood insurance and floodplain management. Read more about Risk Rating 2.0 at *https://www.fema.gov/flood-insurance/work-with-nfip/risk-rating*. Find out about discussions leading to Risk Rating 2.0 under the link for "Annual Reports & Recommendations" at *https://www.fema.gov/flood-maps/guidance-reports/technical-mapping-advisory-council*. ■

**Wendy Lathrop** is licensed as a Professional Land Surveyor in NJ, PA, DE, and MD, and has been involved since 1974 in surveying projects ranging from construction to boundary to environmental land use disputes. She is a Professional Planner in NJ, and a Certified Floodplain Manager through ASFPM.

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# Infinite Squares

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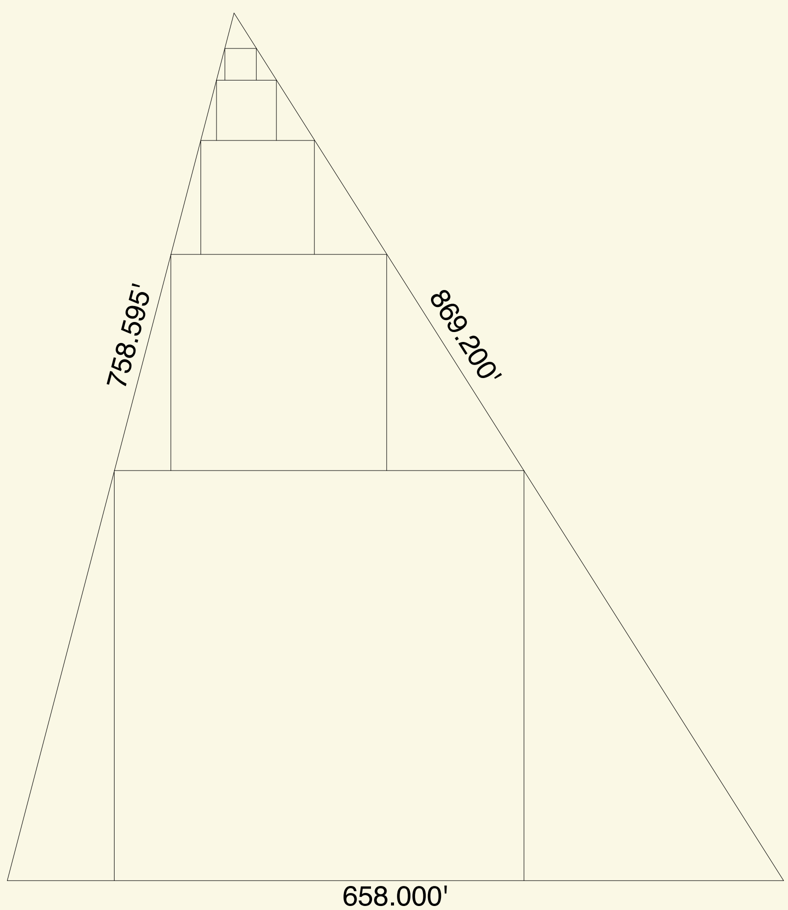
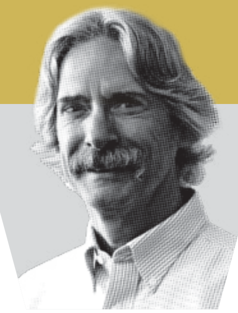
**Dave Lindell**, PS, retired after 36 1/2 years with the City of Los Angeles. He keeps surveying part time to stay busy and keep out of trouble. Dave can be reached at *dllindell@msn.com.*





# The State of the Surveying Profession, Part 1

Recently, a colleague wrote to tell me that some concepts covered during my programs are perceived as advanced and often go over the heads of some in the audience. I found that thought disturbing because one of the things I work very hard at is taking complex ideas and conveying them in a way that is understandable and meaningful. But after actually talking with my colleague—who is an educator—I understood that the issue was *not* that I wasn't doing a good job breaking down complexities. The problem was that I was simply wrong in taking for granted that everyone in the audience was familiar with some of the basic concepts that I mention only in passing. Thus the greater message in my programs are lost when attendees do not grasp certain ideas that I know to be fundamental to boundaries and boundary law.

I have been a student of surveying since I graduated out of the Purdue University Land Surveying program in 1976. (I will readily admit that I have been much more of a student since graduation than before.) Once I started my employment at the Marion County Surveyor's Office in Indianapolis, I instantly realized that I did not learn everything I ever needed to know about surveying at Purdue. I could not, for example, conduct proper section corner perpetuation without understanding the history of the USPLSS, the rules outlined in its various instructions/manuals, the practices of its surveyors (who did not always follow those rules), and without having a distinct grasp of the differences between existent, obliterated and lost corners.

From there, I very quickly recognized that in order to be able to write a proper land description—and in order to interpret a poorly written one—and to properly locate the described boundaries on the ground, I needed to have an in-depth understanding of boundary law and its history.

The doctrines that form the basis of boundary law in the United States are complex. By their very nature the concepts are advanced. It takes study and work to develop even a fundamental understanding. It takes the ability to work with imperfect evidence, and flexibility in thinking to conduct a proper boundary survey. Boundaries are not a math problem.

If we are to meet our legal obligation as boundary surveyors to protect the health, safety welfare and property of the public we must understand the law. This means we have to be life-long students because the law and our understanding of it changes. It requires that we have the ability to be humble and realize that what we think we understand about law and evidence will evolve. My personal understanding of my responsibilities as a boundary surveyor most assuredly has evolved, even in the last several years. Your's should have too.

How do we support and encourage professional growth in this 30-second attention-span world (I know—30-seconds is optimistic)? Certainly the pandemic has forced us to find ways to engage virtually, but hopefully in-person conferences and seminars are not a thing of the past; we need the networking and in-person learning experience.

> "It takes the ability to work with imperfect evidence, and flexibility in thinking to conduct a proper boundary survey. Boundaries are not a math problem."

There are so many issues to discuss regarding the state of our profession: technology and its effect, de-licensure, comity, education requirements, the concept of minimal competency, unlicensed practice, the definition of surveying, and more. It is my intent to probe these and more in upcoming columns. Stay-tuned for Part 2. ■

**Gary Kent** has been a professional surveyor with Schneider Geomatics since 1983 and is also owner of Meridian Land Consulting, LLC. He has chaired the joint ALTA/NSPS Committee on the Land Title Survey standards since 1995. He also sits on the Indiana State Board of Registration and lectures nationally.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