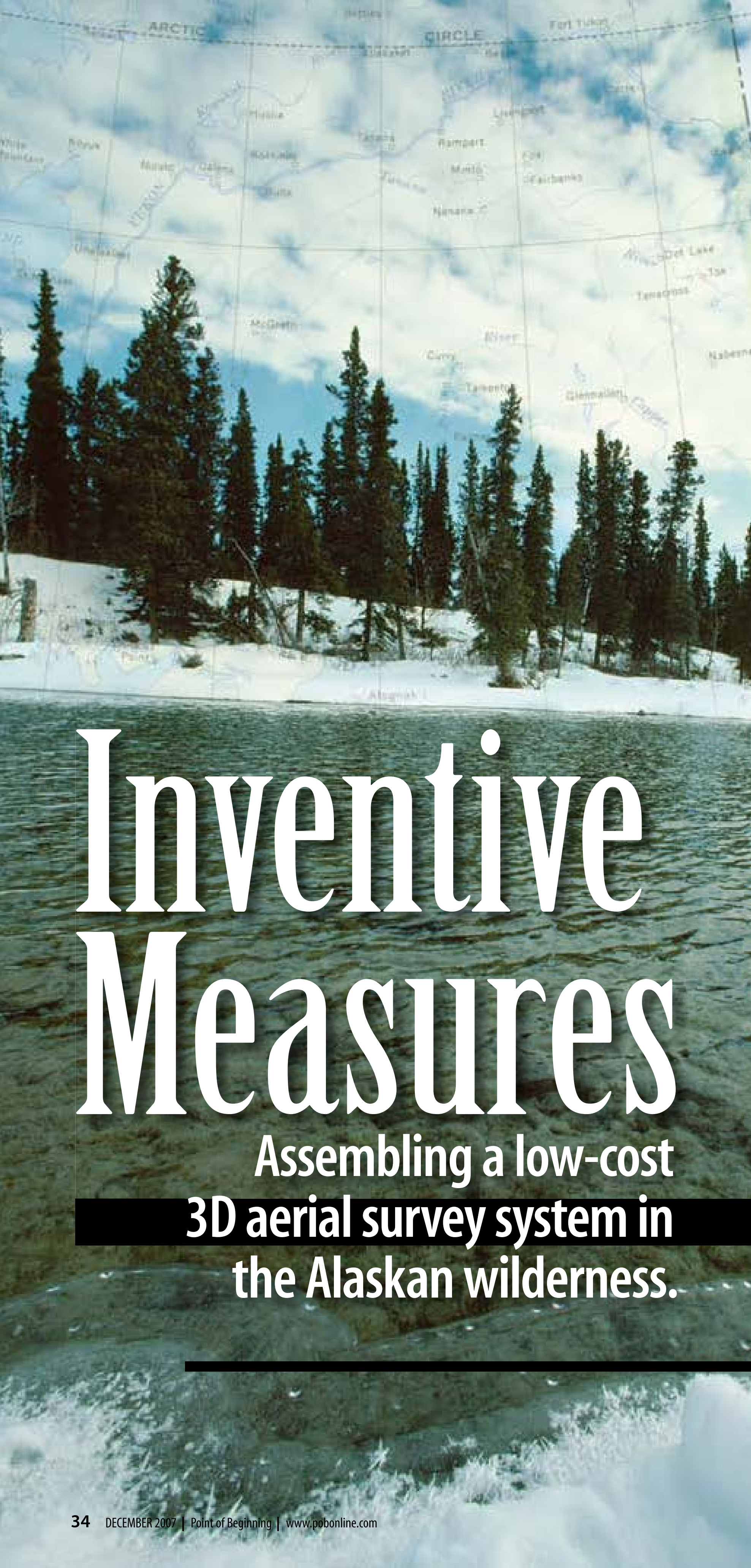


Inventive Measures

Assembling a low-cost 3D aerial survey system in the Alaskan wilderness.

BY C. JASON SMITH, PHD

Hanging out of a helicopter with a 5-pound camera and gyroscope contraption in hand is not a common measuring method for a surveyor, but that is what survey manager Eric Stahlke, LS, found himself doing in May 2007. Stahlke and his survey team from Alaska's Tanana Chiefs Conference were trying to solve a problem that had plagued them for years: how to conduct low-cost, three-dimensional aerial surveys for isolated native villages where most of the surveying work is difficult and pro bono. The decision to pull off the almost acrobatic stunt with consumer to high-end advanced equipment was based on a need for quality surveys on slim budgets.

The Case of the Unknown Boundaries

Founded in 1962, Tanana Chiefs Conference (www.tananachiefs.org) is a non-profit corporation based in Fairbanks, Alaska, that consists of 42 member Athabascan Indian villages located in an area of 235,000 square miles in the Alaskan interior. The primary function of the corporation is to administer health and social services assistance to the outlying villages. Most of the professionals outside the administrative units are doctors, dentists and social workers.

The primary work of the Tanana Chiefs surveyors is to survey the boundaries of tribal lands, surveys that are prohibitively expensive for most residents. As they work in the Alaskan Bush, the teams generally base themselves in one of the local villages where they are often called on to survey subdivisions for new housing and solve local boundary disputes. Calling in a survey crew generally entails chartering a flight into areas with few, if any, roads and local budgets that simply cannot bear the burden of such an expense. Therefore, much of the work Stahlke's team completes is pro bono.

There are few places more challenging to survey than the Alaskan Bush. One of the difficulties working in this area is that much of the monumentation from the original government surveys—conducted primarily between 1920 and

All photos courtesy of Nick Russill and Eric Stahlke, LS, except opening image.

1960—has been lost. For the Athabascan people of the Alaskan interior, property lines have traditionally been more a matter of practical need than legal ownership. As Stahlke describes it, "the Athabascan culture is not one that abides fences. People are used to sharing both their food and their land. In a culture that recycles nearly everything, any open space not taken up by buildings is often filled with old trucks, snowmobiles and dog yards."

The Athabascans tend to think of property along occupational lines—how much space is needed for their possessions—rather than along actual surveyed property lines. Even streets and utilities may wander off the original right of way lines and across personal property. Occasionally, residents will approach the surveyors working in the area complaining that a neighbor is encroaching on their property, Stahlke says. "[But] few people have a clue where the actual boundary is."

To make matters worse, the monumentation markers have a tendency to disappear: "In a typical village," Stahlke says, "your garden variety lot corner is either located under a pile of used equipment, in the middle of a dog yard, under a building or is missing completely." Sometimes villagers build dog pens or pile snowmobile carcasses on top of them. Sometimes a property owner doesn't want the boundary line to be exact.

Missing monumentation pushes the cost of the surveys even higher. In many villages so few of the original survey corners remain in place that it may take two or three days just to recover enough control to re-establish lost boundaries. All things considered, the typical boundary survey in these villages can run upwards of $20,000 in an area where the average annual income is around $15,000.

Though traditional survey methods have worked, they were time consuming, particularly for pro bono work (sandwiched between larger projects) that needed to be completed as efficiently as possible. Considering the difficulties of the village surveys, Stahlke realized that the ability to conduct detailed cost-effective aerial surveys onsite was what was really needed. High-quality orthorectified images could be merged with vector information showing controlled lot and block lines, and most boundary disputes could be solved immediately. But how was this going to be accomplished?

Common Sense Meets Trial and Error

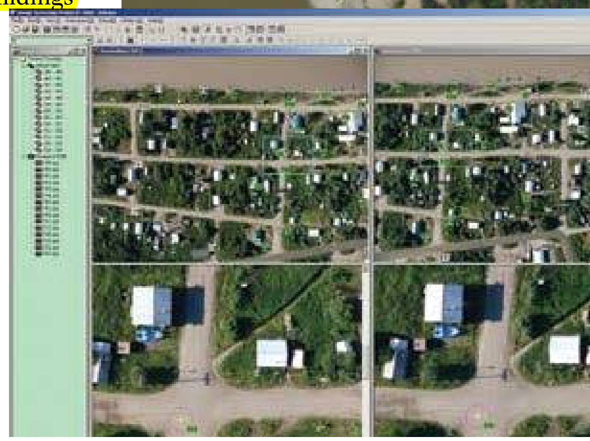
Traditional aerial surveys were out of the question for the team because the one pixel per half-meter upper limit for true color photography was considerably less than the two to three centimeters per pixel they wanted. The Tanana Chiefs did possess a helicopter, though—a Robinson R44 Raven leased every summer for work in remote areas. Could a helicopter be used for aerial survey photography of the quality the group needed?

The Robinson R-44 seemed perfect for aerial photography with one notable exception: the vibration. The Robinson is extremely "noisy" for the camera and likely to produce blurred images. There was one way to find out for sure: buy an aerial camera and take some test photos.

Stahlke's team did not want to find simply another method for producing GIS-style depictions of approximate boundary line locations. "Our goal is to produce something new," Stahlke says, "an aerial survey plat that approaches the accuracy of an actual boundary survey plat." If they could use the helicopter, the photos could be taken at a much lower altitude, allowing for much more detailed photos. Traditional aerial cameras employ the use of a large format 23 cm x 23 cm image plate and need a lens with an aperture that will capture enough light for the exposure. Because of this limitation, the best shutter speed is 1/500 of a second or faster. At that speed the forward motion of low-flying, fixed-wing aircraft inevitably impacts the resulting image.

A helicopter, on the other hand, can hover in place eliminating the distortion due to motion and improving resolution. And, Stahlke thought, why spend $500,000 on a top-end digital aerial camera designed for airplanes when a $1,000, 10 megapixel, off-the-shelf camera might work just as well, or better, at a lower altitude?

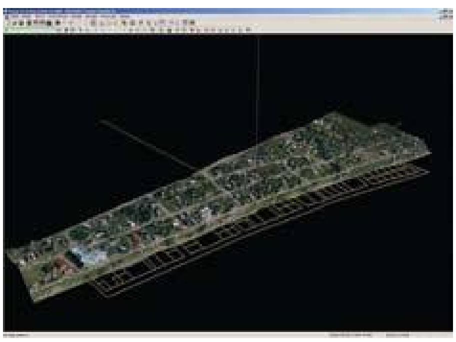
The team settled on the Lumix DMC-FZ50 due to its buffer speed of two photos per second, 10 megapixel image quality, focus and aperture locks, and variable zoom function. Since aerial photography cameras use an external gyro stabilizer to isolate the camera from aircraft vibration, and they rightly expected the vibration to



Above: A raw image taken by the Lumix DMC FZ50 that shows complex road patterns in the unsurveyed village of Huslia. Left: This Topcon PI-3000 software screenshot depicts the measurement of control and tie points of a registered stereo pair.

Albert Macica, LS, shoots aerial photos from the R44 above the village of Minto.

be severe, they also ordered a gyro stabilizer. "There were a number of other questions that had to be answered besides what kind of camera to buy," Stahlke says. "For example, what would be the best focal length, what was the optimum aperture setting, at what height above ground should we fly? Also, how much ground coverage could be expected at different focal lengths and at different altitudes, and what size ground targets should be used? While there are formulas that can be used to calculate all the above param-



This PI-3000 screenshot shows a completed 3D model of the village of Tanana.

eters, for us it seemed more intuitive to answer these questions by common sense combined with trial and error."

By far, the most difficult problem aside from money was the computer programming to quickly convert digital images into a precision orthorectified mosaic. The software packages used by photogrammetrists run upwards of $50,000, well beyond the budget of the Tanana Chiefs. Stahlke, however, eventually stumbled across reference to a program, Topcon's (Livermore, Calif.) PI-3000 software, that seemed ideal to solve the imaging problem. Best of all, the program would run on a conventional laptop so if it worked, the team could complete the images onsite. Stahlke got on the phone with Topcon distributors and was put in contact with the managing director of TerraDat Geophysics, Nick Russill, based in the U.K., and the software was soon in the mail to Stahlke.

Going Above and Beyond

With only a few days left before the supply boat set out for the interior, it was time to test the camera. Team members cut up some makeshift circular targets of varying diameters and scattered them on the tarmac in front of the hanger at Quicksilver Air at the airport in Fairbanks. Since they did not have the remote control or special mount for an aerial camera, they improvised. "We removed a rear door from the helicopter," Stahlke explains, "and I flopped down in the back seat and hooked into the airframe with a safety strap. The technique was simple: lean out the door as far as possible, point the camera straight down and start taking pictures. We flew the target sight over and over again, from different altitudes and using different focal lengths on the variable zoom lens. This took about a half hour, which was about all my body could take, as handling the gyro stabilizer with one hand uses more muscles than one can imagine."

The team was able to determine the optimal resolution and target size from the resulting images. They were ready for the next step—practical application.

Up the River and Through the Air

On June 1, 2007, the survey team sailed upriver on the *Selooghe* (an archaic Russian-Eskimo word meaning "large boat"). The boat boasts a full office with computers, living quarters, a shower and a washer with space to carry food and supplies for two months as well as enough helicopter fuel for several weeks of flying.

The team's first stop, the village of Huslia, on the Koyukuk River, is about 10 days or 700 miles by river from Fairbanks. Huslia is a village with few existing surveys. The village council wanted the team to create lots for about half of the village occupants, based entirely on current occupation lines. Given the entangled nature of what constitutes occupation lines in remote native villages in Alaska, a traditional as-built survey to gather all improvements, roads, trails and utilities would easily take a week to complete. And it would take another week to work out all the new boundary locations by consulting each villager as to who owns what. With a good, high-resolution orthophoto, one capable of showing small objects, the team imagined they could get the villagers to help thread the needle, so to speak, by creating new lot lines that traverse between identifiable objects that people could visualize.

With a lot of time on their hands during the river trip, the team put two trainees to work making 50 donut-shaped 3D aerial markers out of 18-inch white vinyl and packed sand. A hole was punched in the center to affix the markers with spikes. About a day out of Huslia, the helicopter carrying Russill and the PI-3000 software caught up with the *Selooghe*. About five miles below the village, they sent a small boat upriver with the survey crew to lay out the markers.

June 9 was a beautiful sunny morning and the air was crystal clear—perfect flying conditions. Stahlke and Russill piled into the helicopter and made a number of flight lines over the village to ensure they could obtain the needed coverage. Each shot was followed by another of the same area with a slightly different central focal point to produce a stereopair of photos that would be used to generate a three-dimensional image using

Orthophotographs generated by Topcon's PI-3000 photogrammetric software is combined in this AutoCAD screenshot with townsite boundary lines generated by proportioning the GPS recovery of surviving village monumentation.

the PI-3000 software. The digital photos turned out crisp and clear. Stahlke and Russill printed the photos on a color LaserJet and spread them out on the office table to select the best images.

They chose the best 14 photos of the part of the village to be surveyed. The stereo-pair photos were then loaded into the software, which registers all stereo pairs and indexes them with the coordinates of the aerial targets. They chose three "control points" for each stereo pair and four to six "tie points," distinct, uncoordinated points easily identified in both images such as stove-pipes on flat roofs. "As tie points are added, the accuracy of all selected points can be examined with a bundle adjustment routine," Stahlke says. "This is very helpful as the integrity of the network can be followed step by step as one progresses, allowing for re-measurement of wayward tie points or elimination of questionable control points. This calculation also provides camera position coordinates, a base to height ratio of the stereo pair, as well as the standard deviations for each control and tie point."

The next step was to define the digital terrain model (DTM) boundaries and breaklines in a set of stereo images created by the software. Finally, they began to create the DTM.

A Surveyor's Dream

Within four hours they had a finished product: a high-resolution orthorectified image of the village in brilliant color, as well as a three-dimensional model of the village that could be zoomed, rotated and examined in computer space. "One unexpected but pleasant result was that the resolution of the image was so tight that individual wires of overhead power lines could be identified, eliminating the need for time-consuming utility as-builts," Stahlke says. The resulting rectified photograph, nearly the size of a ping-pong table, was hung on the council office wall. It will be used by individuals and local government officials to confidently locate property lines in relation to large and small physical features.

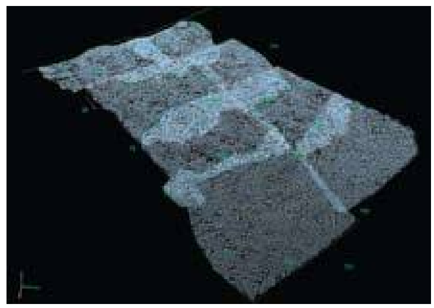
Stahlke could now start the process of creating new lot boundaries based on the occupation lines of the inhabitants. He met with village Chief Orville Huntington at the council office and encouraged him to get the word out. Each house in Huslia, which has a population of about 200, is connected to a live chat room via VHF radio, so it didn't take long to drum up a crowd.

"The giant orthophoto, which consisted of a dozen or so printer sheets held together with cellophane tape, was rolled out on a big folding table at the council hall, and the villagers gathered around and offered up comments as we examined different areas of the mosaic," Stahlke explains. "'This is George's stuff, his line needs to go to here; this is Thelma's dog yard; that old shed and snow machine belongs to Henry' and on and on." As the group collaborated, Stahlke sketched in the boundary lines based on general consensus. "It took only 30 minutes to create the new boundary locations, and more importantly, everyone who was interested had participated in the process. They were in general agreement with the placement of the new lot lines, and they had a good time doing it. It was a surveyor's dream."

True to Ground

The orthophoto from the PI-3000 software was then downloaded into AutoCAD and new subdivision boundary lines were created that matched the village markup. By the following morning they had the necessary stakeout data loaded into GPS receivers and the survey crews proceeded, using RTK, to set the 150 or so monuments needed to define the new lots. By day's end the subdivision was finished and all that remained was to pull the aerial targets. "We couldn't have hoped for better results," Stahlke says. "The combination of in-house digital photography and PI-3000 produced the perfect solution to a very difficult problem. An added benefit was a significantly reduced cost and time investment for this survey compared with the use of our normal methods."

Within the next month, the *Selooghe* moved on to a number of other sites including the villages of Galena and Tanana. Both of these villages had at their core a townsite survey, which is an



A TIN model of the village of Huslia.

entire village property layout of about 100 lots each, originally surveyed by the federal government in the late 1950s. In both villages only scant remnants of these original surveys remain, and there is general uncertainty about the location of boundary lines.

The situation at Galena and Tanana exemplified typical problems found in Alaskan villages that they hoped to solve by performing photogrammetric resurveys. Considering their progress so far, Stahlke and his team might just redefine both aerial photography and land surveying.

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