U.S. Military Maps Panama Canal with Airborne Interferometry in Preparation for Transition

By Kevin P. Corbley

Nearly 90 years after its construction, the Panama Canal is still considered one of the greatest engineering feats ever attempted. The 82-kilometer long passage is without a doubt one of the most important transportation routes in the world. And it is also considered one of the most difficult structures to defend.

This final point was not lost on the United States or Panama in 1977 when the final Panama Canal Treaty was negotiated. Neither country wanted such a critical commercial and strategic resource left unprotected. This is why the United States will continue to take responsibility for the canal's defense even after its operation officially changes hands to Panama on December 31, 1999.

As is often the case with large geographic areas, proper defense planning requires up-to-date, detailed maps. The U.S. Department of Defense requested its National Imagery and Mapping Agency (NIMA) to obtain new topographic maps for the canal and its surrounding regions before the turnover occurs.

The mapping project is noteworthy, not just for the role it plays in the historic transition, but because it is one of the first high-profile, commercial applications of radar interferometry, an elevation modeling technique considered experimental little more than a year ago.

"There was a lot of skepticism about interferometry in the U.S. government and around the [mapping] industry, but the Panama project proved that airborne interferometry is a very cost-effective and efficient way to collect mapping information," said Michael Bullock, President of Intermap Technologies Inc., the Denver company that performed the mapping and provided the digital products.

Intermap, the wholly owned U.S. subsidiary of Intermap Technologies Ltd. of Calgary, Alberta, delivered digital elevation models (DEMs) and orthorectified synthetic aperture radar (SAR) images for a 11,600 square kilometer area encompassing the Canal Zone.

The DEMs have three-meter vertical accuracy and 10-meter postings, and the SAR images offer 2.5 meter spatial resolution.

Officials at NIMA -- usually tight-lipped -- are said to be extremely impressed with the results.

Preparing for Transition

Built between 1904 and 1914, the Panama Canal is one of the world's most impressive engineering accomplishments. Its construction involved building what was the largest dam on Earth and cutting a 15-kilometer long channel through a mountain range. Today, nearly 50 ships per day carry grain, ore, automobiles, liquid gas, coal and lumber through the passageway between the Atlantic and Pacific Oceans.

The U.S. DoD's interest in mapping the canal may seem out of place, but that is because few realize the passage was built by the United States primarily for military purposes to give its naval vessels quick access to both coasts. Even today, the DoD is closely involved with the Panama Canal Commission which oversees operations.

"DoD planned to map the Canal Zone with commercial airborne optical sensors," said Bullock, "but after several months of frustration due to near-constant cloud cover in the tropical region, they began looking at other options."

Working on behalf of the Pentagon, NIMA made arrangements with Intermap, though an existing data acquisition contract with EarthWatch Inc. of Longmont, Colorado, to get the job done using its airborne STAR-3*i* system flown aboard a Lear 36 aircraft.

"Commercial radar satellites were not an option in this project because they can't provide the image resolution and DEM accuracy required by NIMA," said Bullock.

Shortly after the contract was approved, Intermap moved its aircraft from Venezuela, where another tropical mapping project had just been completed, and stationed it at Howard Air Force Base in Panama. The crew needed only a day to set up a GPS differential correction base station at Howard and begin planning the flights. Data collection over the entire Canal Zone was completed in 10 days.

Interferometry Explained

The technology of SAR interferometry has been enthusiastically embraced by the geotechnology and mapping industries for its ability to make extremely accurate measurements of terrain elevation. In general, the procedure involves imaging the target area with two SAR signals. The phase differences in the reflected signals can be processed to determine variations in the height of surface features.

Interferometry is probably best known for its association with commercial radar imaging satellites, but the Intermap STAR-3*i* system differs from the orbiting platforms and offers several distinct advantages.

Operational radar satellites have one SAR antenna, which means they must image an area on two passes to collect the two data sets required for interferometric measurement of elevation. STAR-3*i*, on the other hand, utilizes two radar antennas rigidly mounted on the aircraft. The enables it to collect two signals over a target area on a single pass.

"The advantage of the one-pass system is that there is no time lapse between acquisitions in which ground conditions could change and reduce the accuracy of the elevation measurements," said Ken Rath, Intermap Marketing Director.

The other main advantages of the airborne system are the superior accuracy and resolution that can be achieved from a high-quality SAR sensor flown aboard an aircraft at a comparatively low altitude.

In recent years, many of the newest GIS applications and modeling packages have begun to require input of horizontal and vertical coordinates, but unfortunately accurate elevation data has been difficult to obtain commercially. Development of the STAR-3*i* system has been driven by intense interest among public and private sector organizations to quickly and accurately obtain digital terrain elevation information.

For instance, military agencies have long sought DEMs to model terrain in flight simulation and mission planning software. In the private sector, three-dimensional viewing software has given exploration geologists, wireless communication designers and civil engineers a voracious appetite for "z" map coordinates.

In response to this market demand, the Environmental Research Institute of Michigan (ERIM) developed the system in the mid-1990s under contract with the U.S. Advanced

Research Project Agency (ARPA). After extensive successful testing, ERIM formed a partnership with Intermap in Calgary to establish the U.S. Intermap and commercialize STAR-3*i* in 1997.

"Contracts for DEM and SAR image products have come from all sectors of the GIS and mapping markets," said Rath. "Natural resource management -- especially forestry applications in the tropics -- environmental change research and hydrocarbon exploration are the largest end user groups for the technology."

Mapping the Canal

The Intermap Learjet was airborne by 5 a.m. each morning to take advantage of smooth air over the tropical jungle. SAR imaging systems can operate in rain, clouds, fog and darkness due to the X-band radar signal, enabling the crew to conduct flights regardless of weather conditions.

Each afternoon, the crew plotted the coordinates of every flight line for the next day’s mission. This was conducted on a laptop computer equipped with STARPlan, a mission planning software developed by Intermap on top of the popular MapInfo desktop mapping package.

"Mission planning is critical in rugged mountainous terrain like we encountered in Panama," said Bullock. "The software automatically determines the optimal overlap of flight lines and plans opposite look imaging so that mountains are imaged from two sides. This eliminates void areas in the data due to the shadow or layover effects inherent in imaging."

Once the flight was planned, the Intermap flight crew fed the flight line coordinates into an onboard autopilot which actually controlled the plane during data acquisition. The jet itself is equipped with both a GPS and Inertial Navigation System to ensure that planned flight lines are flown precisely.

Intermap flew the Canal Zone at 35,000 feet, the optimal altitude required to obtain the standard three meter vertical accuracy in the DEMs. And because the project progressed so quickly, they had extra time to refly the area immediately surrounding the canal at a lower altitude of 20,000 feet.

"Image resolution remains the same regardless of altitude, but at the lower altitude the noise level in the elevation model was cut in half, which resulted in DEMs with higher accuracy," said Bullock. "We have included these in our Global Terrain archive for commercial sale to clients."

STAR-3*i* also carries a GPS to record coordinates of each SAR data set during acquisition. These coordinates were post-processed at the Air Force Base using differential correction ground control data collected by the GPS base station during the mission.

"Our field laptops have quality control software so we can make sure flight lines were collected correctly and that data quality meets our specifications," said Bullock. "If not, we can refly an area the next day."

The flight crew then shipped the data on digital tapes by courier to the Intermap processing facility in Denver. There the data was downloaded to a networked string of 12 Sun Ultra SparcStations. In this phase, the raw SAR interferometric data sets were processed to create separate DEM and orthorectified image files, which were sent to an Intermap facility in Ottawa, Ontario, for final product generation.

"The DEMs and images arrive in Canada in flight line strips," explained Rath. "Another in-house software, called STARPro, registers and radiometrically balances the strips and then mosaics them into a continuous data set."

Normally, the DEM and image products would then be shipped directly to the client. But NIMA has adopted a special file format called Controlled Image Base (CIB), which is a new standard for all U.S. military images and GIS layers. Intermap sent the completed Panama products to ERIM for conversion to CIB.

Making Data Available

In addition to having the mapping products collected on time and delivered at the accuracy level required by military specifications, NIMA is pleased the project could be completed at a reasonable cost -- about $500,000 -- using commercially available technology.

"This is also an example of NIMA's use of commercial solutions to fulfill the imagery and geospatial requirements of our customers," said a NIMA official.

NIMA's use of the STAR-3*i* system for this project has also contributed to the archive of data available to other commercial users. Intermap retained rights to the Panama digital maps, both the high-altitude data provided to NIMA and the low-altitude data acquired on speculation. This digital map data is available in Intermap's Global Terrain archive.

The company has been filling this archive with DEMs and SAR imagery acquired in projects all over the world during the past year and a half. Because the digital maps have already been produced, Intermap offers them for sale at a fraction of their original cost. Orders can be filled in a matter of days because the data is already processed.

"The Learjet is in use nearly all the time, so we are populating the archive very quickly," said Bullock. "We view STAR-3*i* as an important elevation mapping tool that cuts across all vertical GIS markets, and we are trying to make the data as available and accessible as possible."

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