Mapping Great Britain at 1-Metre Z Values

By Hugh MacKay

Imagine having access to over 14 billion individual high-accuracy elevation points of Great Britain. Imagine having access to over 176 billion individual high-resolution image pixels of orthorectified imagery of Great Britain. Impossible? No, not at all, not with the introduction of NEXTMap Britain, an ambitious commercial program to provide 230,000 square kilometres of detailed digital mapping for all of England, Scotland and Wales.

Headquartered in Calgary, and with its major production facility in Ottawa, Intermap Technologies completed the entire program in less than 18 months in 2003 / 2004.

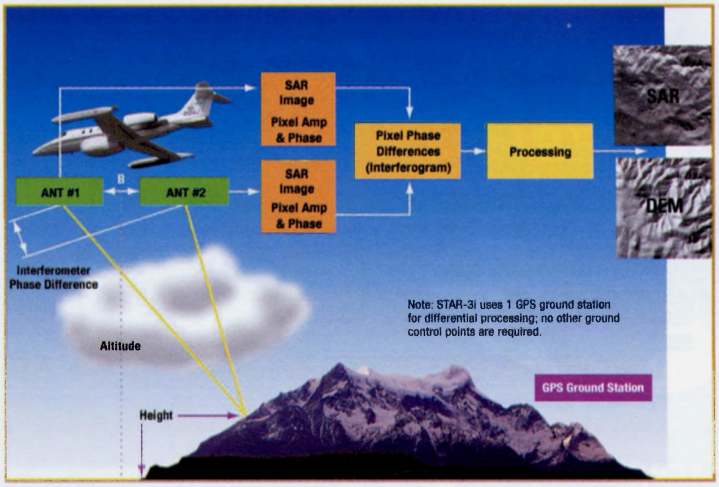
The NEXTMap Britain project marks the first time detailed elevation mapping of an entire nation has been funded and executed by a commercial organization on behalf of commercial interests. With a proven track record in Great Britain and 28 other countries, Intermap's unique airborne interferometric synthetic aperture radar (IFSAR) mapping capability is particularly well suited to the large-area regional and national elevation mapping programs.

IFSAR Technology

The need for improved remote sensing technologies that can quickly determine accurate terrain elevations over large areas evolved from military requirements. Operational requirements dictate the need for an all-weather, day/night, high-speed collection and processing capability. To address these needs, the United States Defense Advanced Research Projects Agency (DARPA) initiated a program in 1993 to develop operational airborne IFSAR capability.

In response to DARPA's mandate to ensure commercial utilization of the technology, Intermap invested several millions of dollars in the IFSAR technology. Intermap, which has been involved in airborne radar mapping since the mid-1970s, recognized the commercial benefits of interferometric radar to generate Digital Elevation Models (DEMs) and thus topographic map products, as well as fully Orthorectified Radar Images (ORIs). Since acquiring the technology in 1997, Intermap has been responsible for producing 3.1 million square kilometres of IFSAR generated DEMs and ORIs.

The interferometric technology is based on utilizing two radar antennae displaced by a known distance. This antenna separation is referred to as the interferometric baseline. One antenna acts as both a transmitter and receiver; the second as a receiver only. The baseline provides a slightly different path length in the reflection of the radar pulses from terrain points back to the antennae. This path length difference, or phase difference, coupled with precise aircraft positional data, provides the information required to measure the terrain elevation points.



The IFSAR concept is illustrated to show aircraft positional information, baseline separation of the radar antennae and the interferometric phase difference combining to provide the high accuracy DEM and image data.

Interferometry is probably best known through the radar imaging satellites such as ERS 1 & 2 and the Canadian RADARSAT, but the Intermap IFSAR systems differ from the orbiting platforms and offer several distinct advantages.

Operational radar satellites have one antenna, which means that they must image an area on two passes to collect the two data sets required for interferometric measurement of elevation. The Intermap systems, on the other hand, utilize two radar antennae, enabling single pass data collection. The importance of a single pass system for commercial airborne operations is the significant reduction in time and resources expended.

The other main advantages of airborne IFSAR systems are the superior vertical accuracy and image resolution. The Intermap systems are capable of collecting +/- 1.0 metre vertical data from a flight altitude of 28,000 feet and +/- 50 cm from a flight altitude of 20,000 feet. The image resolution, 1.25 metres, remains constant, regardless of the flying altitude.

STAR-3i IFSAR System

Intermap's STAR-3i IFSAR system is mounted in a Learjet Model 36. The Lear has a speed of 375 knots (730 kilometres/hour), enabling gross data acquisition rates of greater than 100 km^2 per minute on line.

Intermap's STAR-3i Interferometric Radar (IFSAR) mapping system collects a swath width of 9-kilometres from a flight altitude of 28,000 feet AMGL. The radome, extended fuel tip-tanks and lower stabilizer fins are evident.

Unlike aerial photography, STAR-3i is not dependent upon sunlight for viewing the target area, using instead the microwave energy transmitted from the aircraft for target illumination. This allows data capture by day or night. The ability to acquire data at night is a significant benefit when operating in an area of exceptionally heavy daytime air traffic. In fact, for the NEXTMap Britain program, STAR-3i collected data during two 5-hour missions per day, primarily at night. IFSAR technology also avoids the schedule delaying data acquisition window of aerial photography, which is confined to just 2 hours +/- solar noon to prevent shadows in the imagery.

The system is also reasonably weather independent. This capability permits data capture in cloudy and rainy conditions that would ground optical systems, a significant advantage, not just in Great Britain, but also in any coastal or tropical environment. The only significant weather limitation is severe wind aloft.

Mission planning is a critical component of the data acquisition activity. Intermap has developed proprietary mission planning software that 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 radar imaging. Flight coordinates are fed into an onboard autopilot that actually controls the plane during data acquisition. The Learjet itself is equipped with both a GPS and Inertial Navigation System to ensure that planned flight lines are flown precisely and that accurate positional information can be recovered for data processing.

The elevation and image data sets, which are collected simultaneously and are fully georeferenced to each other, are stored on an array of disks onboard the aircraft and run through quality assessments in the field before being shipped to the Intermap offices for processing. In Ottawa,

the data strips are merged and mosaicked into 10 km x 10 km tiles, or map sheets, based on the Ordnance Survey National Grid.

NEXTMap Britain

Intermap's NEXTMap Britain program began with a pilot project undertaken in 1999 / 2000. Willis Consulting, a flood risk consultant to the insurance industry, hired Intermap to acquire elevation data in the River Thames drainage basin for use in a new flood risk analysis system. The STAR-3i system was used to collect approximately 22,000 km^2 of DEM and image data in support of the project. Intermap's ability to use IFSAR for collection of a wide area in a short time at an affordable price made the project an unqualified success. Subsequently, every insurer with commercial or residential property portfolios in the Thames basin made use of the risk analysis system. In 2002, the insurance industry, led by Norwich Union Insurance, approached Intermap about flying all of the rivers and coastal areas in the country, as they were dissatisfied with the inconsistent data coverage and accuracies available from traditional data sources.

Intermap recognized that there would be wide spread interest in many other markets for a consistent, high accuracy national DEM. This prompted the firm to announce the NEXTMap Britain program. The NEXTMap Britain program is one of a series of NEXTMap programs being undertaken by Intermap. The firm's intent is to capture high accuracy elevation data of the G-8 nations. The NEXTMap USA program, announced in 2003, has already collected more than 1 million square kilometres of data in the United States. The complete re-mapping of the lower 48 states will be achieved within the next four years.

The STAR-3i Learjet was based at Manchester for the NEXTMap Britain program. Intermap divided Britain into seven rectangular blocks for the purpose of data acquisition. A total of 221 flight lines, comprising 40,077 line kilometres of acquisition, were undertaken. Intermap placed 56 precisely positioned radar reflectors throughout the project area to act as ground control for the data sets. To support the positional accuracy of the aircraft, a total of 35 GPS base stations were employed.

Most of the acquisition was flown at 28,000 feet to provide a 9-kilometre swath with a 1.5-kilometre overlap in flight lines. The resulting vertical accuracy for the elevation data is +/- 1.0 metres RMSE. Intermap lowered the flying altitude to 20,000 feet for the southeast of England and captured approximately 50,000 km^2 of elevation data with a vertical accuracy of 50 cm RMSE. The data acquisition

took only 120 days in total, spread over two deployments.

Both data sets have a DEM posting of 5.0 metres, resulting in over 14 billion sample points. The ORI resolution is a consistent 1.25 metres, resulting in over 176 billion image pixels. The elevation data and the ORI are fully georeferenced to each other, allowing the ORI to be draped over the DEM to support analysis in a 3-D environment.

Intermap processing generates two elevation products – digital surface models (DSMs) and digital terrain models (DTMs). The DSM is a first-surface measurement, including the elevations of trees, houses and buildings on the landscape. But in response to increasing demand for DTMs, Intermap has developed a proprietary algorithm that removes the surface features and produces a bald earth DTM.

The range of applications for the data is as broad as the entire geomatics market. 3-D viewing and elevation modeling now play a major data analysis role for flight simulation, mission planning software, security, civil engineering, wireless communication, flood mapping and modeling, auto navigation, orthorectification of airborne and satellite image data, exploration geology and map updating.

To validate the NEXTMap program, Norwich Union Insurance engaged Professor Ian Dowman of the Geomatics Department at the University College London (UCL) and President of ISPRS, to undertake extensive testing of the IFSAR elevation data. Professor Dowman took field measurements of two test areas in Britain, one for the 1 metre and another for the 50 centimetre elevation data. UCL determined exact elevations in the test areas using both photogrammetry and ground-based GPS for comparison with the Intermap NEXTMap products. The NEXTMap data was validated and verified to be superior to the 1 metre and 50 centimetre specifications.

Digital Elevation Model of Great Britain. This image is a mosaic of over 2,800, ten-by-ten kilometre tiles of the digital surface model. It has been resampled from the original 5-metre postings to 50-metre postings and shaded to highlight relief.

Obtaining NEXTMap Products

The data products are offered online at Intermap's digital data store (www.intermap.com). This site can be used to search order and download NEXTMap Britain products, as well as data from other countries mapped by Intermap.

Elevation data products are delivered in 32-bit generic binary Band Interleaved by Line (bil) file format. This generic file format is easily ingested into the majority of image processing, GIS and visualization software packages. ORI products are delivered in 8-bit GeoTIFF format. Data sets are delivered on ISO 9660 standard CD-ROM media. Tape media (8-mm or DLT) available upon request.

Intermap developed NEXTMap Britain subscription relationships with several other firms in Britain that have helped reach a variety of vertical markets. The data has been licensed nationally and regionally by defence and aerospace firms, air and rail transport simulation and visualization firms, mobile telecommunications companies and virtual tourism organizations. Although the project is noteworthy for its private funding and operation, Intermap has subsequently worked closely with the central government agencies in exploiting the data. The Environment Agency of England and Wales, The Scottish Environmental Protection Agency and the British Geological Survey have each purchased national data licenses.

BIOGRAPHY

Hugh MacKay is Canadian and Western European Sales Manager for Intermap Technologies (www.intermap.com). He has worked at Intermap and its predecessor company, Intera Technologies, since 1980. Hugh completed his studies at Dalhousie University and the College of Geographic Science in Canada. He has specialized in airborne remote sensing, working with a variety of optical, infrared and microwave sensor systems over the course of his career. He can be reached at **hmackay@intermap.com**

Sites to See

www.yorku.ca/yfile/archive/index.asp?Article=3638

SAME enables virtual views of anywhere on Earth

Imagine having the ability to view, in real time, downtown Paris, and to be able to identify cars driving on the street. York University Professor, Vincent Tao has developed innovative satellite mapping technology that enables users to visually zoom in on – or fly over – any place on the planet in real time. Called SAME (an acronym for See Anywhere – Map Everywhere), it is an Internet-based technology that provides 3-D imagery with ground resolution of a half-metre to one metre - close enough to identify automobile makes, for example, but not the human face. Professor Tao is director of York's Geospatial Information and Communication Technology Lab (www.geoict.net).