NEXTMap®: NEW NATIONAL MAP DATA FOR THE USA AND EUROPE

Garth Lawrence, Senior Vice President
Dean Hancock, Integrated Product Management Document Administrator
Intermap Technologies, Inc.
8310 South Valley Highway, Suite 400
Englewood, CO 80112-5809
glawrence@intermap.com
dhancock@Intermap.com

ABSTRACT

NEXTMap® USA and NEXTMap® Europe provide new mapping data for +8 million km^2 of the continental USA and Hawaii and 2.2 million km^2 of 17 Western European countries. NEXTMap® programs were undertaken to resolve the problem of outdated, incomplete, or insufficient accuracy of national data sets that did not meet the requirements for applications in the public and private sectors. Additionally, few of the previously available data sets used the same geodetic datum types from country to country or even in different regions of the same country. The significant interest from government and commercial organizations in uniformly accurate, consistent, and up-to-date elevation products provided the impetus to develop the NEXTMap® programs as an alternative to a variety of disparate, fragmented, and outdated datasets.

For NEXTMap, Intermap used its airborne interferometric synthetic aperture radar (IFSAR) technology to provide data that meets a vertical accuracy of 1m RMSE, a data point every 5m, and fully orthorectified imagery with a 1.25m pixel correct to 2m. NEXTMap represents the first time that a self-funded company has successfully collected and produced countrywide datasets to such specifications. The datasets include digital terrain models (DTMs), digital surface models (DSMs), and orthorectified radar images (ORIs), as well as derivative products such as contours, TINs and enhanced imagery.

Intermap faced a variety of challenges when planning and implementing the collection of data on two different continents simultaneously, while ensuring that the resulting data adhered to strict standards of accuracy. The company developed new methodologies to dramatically increase its data collection rates as well as processing and editing technologies.

This paper describes the NEXTMap® challenge.

Key words: NEXTMap®, DTM, elevation, accuracy, IFSAR

INTRODUCTION

The October 2003 ASPRS/MAPPS Terrain Data conference in Charlotte included an announcement that may have been a bit astonishing to some. It was there that Brian Bullock, CEO of Intermap Technologies, declared that his company had embarked on an effort to map all of the contiguous United States, plus Hawaii. That such an announcement might have startled some is easily understood, given the origins of most of the national data sets that were in use at the time. One might have been forgiven for assuming that the Intermap effort was unprecedented. In point of fact, even as the announcement was being made, Intermap was putting the finishing touches on the creation of a comprehensive data set for Britain. That said, the decision to map the United States would certainly result in a project of much broader in scope.

The project, entitled NEXTMap® USA, would prove to be remarkable in a number of respects. Firstly, it would map one of the world's largest countries in an effort to create a national data set of unprecedented consistency. In the past, national data sets have often been cobbled together from a wide variety of sources. This has resulted in data of inconsistent age and reliability. NEXTMap USA was intended to change that, at least for the United States.

The second remarkable quality of the NEXTMap USA project was its resolution. Though nation-wide in scope, Intermap's goal was to produce something significantly better than the existing 20 or 30 meter digital elevation model (DEM) data. More precisely, Intermap had set a target of mapping the 49 states involved at a resolution of 1m RMSE. This added significantly to the breadth of the goal.

NEXTMap USA also included a third noteworthy characteristic; it was to be a totally commercial enterprise. Although it was reasonable to expect that government agencies might purchase NEXTMap data, the collection, processing, editing, and marketing were, in this case, to be a strictly private venture. Assembling a national data set is of such scope that it has generally been the exclusive province of national mapping agencies. Traditionally, such organizations have been the only parties with the needed resources to take on such a challenge. NEXTMap USA was to challenge that.

The collection of high-resolution digital elevation data has not traditionally been attempted for entire countries owing to both technical and financial limitations. Generally, this has resulted in much smaller projects which were often funded by a single client and limited in area. In that context, the NEXTMap USA project was ground-breaking. That said, Intermap would eventually expand upon even this lofty goal. Increased efficiencies in both the collection and processing of its data led Intermap's management team to what may seem like a second unlikely decision. It was determined that Intermap would collect and market digital elevation data for several West European countries, while still working to complete the North American project. The second project, known as NEXTMap® Europe, would consist of collecting data with the same accuracy standards and national scope as NEXTMap USA. In the end, no fewer than 17 European countries would be included in the project.

Figure 1. Intermap Learjets.

At the time they were announced, such goals might have been seen by some as overreaching. But these very goals have been met. Collection of NEXTMap Europe data was completed in July of 2008 and the processing of that data wrapped up the following December. NEXTMap USA data collection was concluded in March of 2009; the finished product is expected to be on the shelf by early 2010. In total, more than 10 million km^2 of digital data has been produced for the 18 countries involved in the two projects.

NEXTMap®: The Details

NEXTMap®: The Beginnings

Figure 2. NEXTMap® Britain Orthorectified Radar Image.

Long before the 2003 announcement of NEXTMap® USA, Intermap had engaged in a number of other projects that utilized its proprietary "STAR" technology. This technology employs interferometric synthetic aperture radar (IFSAR) to generate high-resolution DEMs and orthorectified radar images (ORIs). The DEMs produced are available as either digital surface models (DSMs) or digital terrain models (DTMs). These early efforts proved to be far more than routine data collection jobs; they also served as test efforts for the refinement of the processes employed in the collection, processing, editing, and marketing of high-resolution IFSAR derived elevation data.

While this paper will not focus on IFSAR technology itself, a few words are in order. The qualities possessed by IFSAR were integral in the timely completion of the NEXTMap USA and NEXTMap Europe projects. These qualities include the capacity to collect data that is relatively high in accuracy, and to do so very quickly. These qualities arise, at least in part, because IFSAR systems can be operated from fast aircraft at high altitude. Flight levels are generally in the 34,000 ft range, and two of Intermap's radar systems are mounted in Learjets that can collect data while traveling at up to 750 km/hr. This means that Intermap systems can collect as much as 23,000 km^2 of data during a single flight, even at the one-meter level of accuracy. This technology was thoroughly tested and improved in the years leading up to the commencement of the NEXTMap projects.

The most important of these early projects was initiated in 2000. It was then that Intermap decided to engage in a comprehensive mapping project of the United Kingdom. The project began as an effort to map the Thames River basin for the sake of creating improved flood plain models. This effort grew out of a desire for improved risk assessment on the part on the British insurance industry. At that time, high-resolution DEM data collection projects were generally restricted to relatively small areas, and Intermap's initial efforts in the British Isles started along those lines.

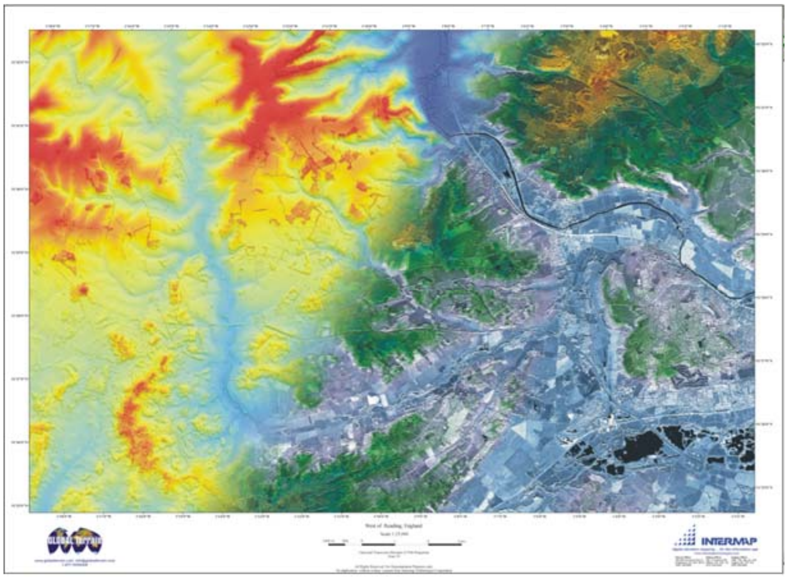


Figure 3. Digital Elevation Model of West Reading, U.K.

As the project proceeded, however, Intermap management began to consider the possibility that the Thames River basin project could serve as the stepping stone to something much larger. At that point in history, most countries had national elevation data sets that were inconsistent at best. Often, these data sets were the product of numerous distinct data collection efforts, with results that varied greatly with respect to age, resolution, and completeness. At times, they were not even based on a single datum. With the commencement of NEXTMap® Britain, Intermap Technologies was making a commitment to change that. Never before had a commercial entity embarked on a project to generate a high-accuracy DEM of national coverage without public funding.

Intermap's willingness to embark on such an effort was based largely in its long-range plans. These plans included the acquisition of national data sets for even larger countries. In essence, NEXTMap Britain was to evolve into a test case for the practicality of creating national data sets. NEXTMap Britain, which included all of England, Scotland, and Wales, was completed in October of 2003. By then, NEXTMap USA was already in its early stages. A comprehensive accounting of all of the challenges encountered during the NEXTMap projects is well beyond the scope of this paper, but we might benefit by considering just a few of them.

NEXTMap USA

Figure 4. Interferometric Processing Technician at work on NEXTMap® USA data.

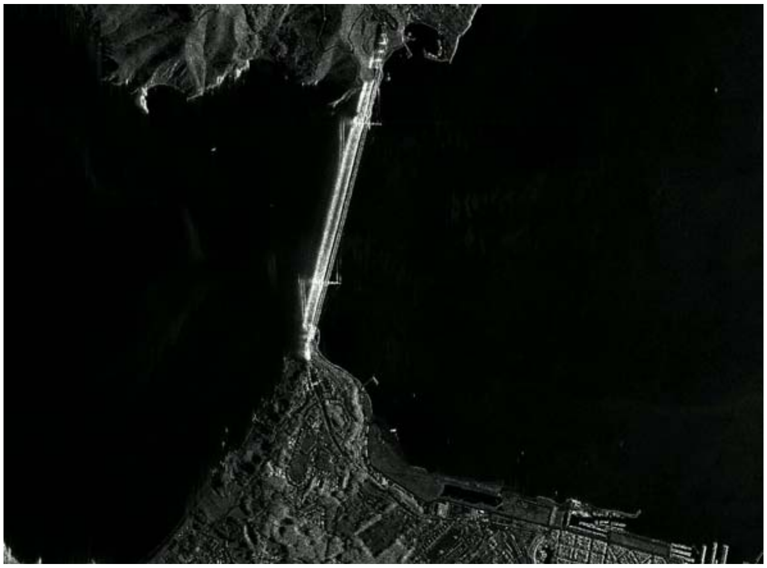


Figure 5. Orthorectified Radar Image of the Golden Gate Bridge.

NEXTMap USA data collection commenced in California in 2003, even though the company was still involved in the ongoing collection of elevation data in Asia. As was the case with NEXTMap Britain, the early work completed in Asia was to help Intermap prepare for the challenges to come. This was certainly true for the field staff, many of whom faced tasks that proved to be far more challenging in Asia than in North America or Europe. Such was the case with the establishing of Ground Control Points (GCPs). While both NEXTMap USA and NEXTMap Europe required extensive ground control, the associated logistical problems were relatively straight-forward. The GCP technician was able to drive from one point to another which, though time consuming, was manageable. The same is not always true in an island nation such as Indonesia or the Solomon Islands, where adequate ground control might require traveling to an outlying island. This might mean going to a work site that lacked adequate electrical power, or that suffered from poor communication services or limited travel options.

By successfully resolving such problems, the field staff developed a culture of self-reliance – a kind of confidence that was to pay dividends in the larger projects to come. Although the Asian projects were of limited scope when compared to NEXTMap USA or NEXTMap Europe, they were of great value as a sort of "spring training" that prepared field teams to play at a higher level. NEXTMap Britain, on the other hand, helped demonstrate that projects of national scope could be completed in a timely fashion. This included the development of data processing capabilities that could handle a steady stream of input without bogging down. In the end, both NEXTMap Britain and the various Asian projects would serve as important preliminaries to the NEXTMap USA and NEXTMap Europe efforts.

It goes without saying that the decision to map the 48 contiguous states plus Hawaii led to a wide variety of challenges. The problems associated with flight operations exemplified a broader set of concerns that were confronted throughout the project. Coordination with the Federal Aviation Administration (FAA) at the national level started well before the collection of any data. Early planning was then supplemented by ongoing interactions with local Air Traffic Control (ATC). Given that IFSAR data is collected at altitudes where one expects to find commercial air traffic, the need for detailed plans and ongoing communication was paramount. The situation was exacerbated by the requirement that Intermap aircraft fly straight and level during data collection; any deviation from the flight plan interrupts the collection of usable data. It was clear that the best possible relations had to be maintained with ATC if they were to remain as allies.

Not long after data collection began in the United States, it became clear that weather could also prove to be a problem. The challenge was met in two ways. Firstly, it became clear that seasonal weather patterns had to be considered. Essentially, an effort was made to answer the question: Which regions should be flown at a given time of the year if we were to maximize the chances of finding suitable weather? Secondly, Intermap flight planners initiated a practice whereby they produced a two or three distinct flight plans for any given sortie. Because these "weather alternates" were located in different regions, a last-minute selection could be made on the basis of developing weather.

The requirement for multiple "weather alternates" was to have consequences regarding the number of staff on the ground. The high-resolution nature of the data being collected demanded that Differential Global Positioning System (DGPS) technology be employed. DGPS consists of comparing GPS data recorded by ground stations with that captured by a receiver on board the aircraft. As such, a small army of surveyors was deployed to engage in the operation of base stations. In any case, the decision to plan flights with weather alternates meant having the resources on the ground to cover the various possible alternatives. This meant that the small army had to be a bit larger, and that the coordination of their efforts became a bit more complicated.

Not surprisingly, new challenges continued to pop up. Regional issues and turnover in staffing invariably present problems that must be dealt with. On balance, however, these problems were more than offset by improvements in technology and increased efficiencies. The result was an increased data flow, which itself had to be managed if the company was to avoid a logjam of unprocessed data. Improvements in data processing and editing were facilitated by more and faster computers, but there was more to the story than just "better equipment." Increased efficiencies also arose from ongoing efforts to improve the proprietary software that Intermap employees use when turning the raw radar data into a sellable product. Efforts to manage that dataflow came from every quarter, but at no time was data quality allowed to suffer. At the far end of the pipeline, Intermap's sales force was hard at work finding clients to use the data as it hit the shelf. Such efforts were themselves important in that they helped Intermap to better understand the market, and to refine priorities.

In fact, an important customer was to purchase some of that early California data. The Coastal Services Center Branch of the National Oceanic and Atmospheric Administration (NOAA) purchased data covering the coastline of California. It was to be used in shoreline mapping, watershed and wetlands mapping, and shoreline and wetland change detection. These are merely a few examples of the types of applications to which high-accuracy DEM data is suited.

In the end, the NEXTMap USA project resulted in the mapping of 8 million km^2 of land. This included all of the 48 contagious states and Hawaii. The last of this data should be on the shelf during the first quarter of 2010. NEXTMap USA data has the following specifications: DSMs and DTMs have 5m post spacing, and a vertical accuracy of 1.0 m RMSE. The ORI has a pixel size of 1.25 m, and horizontal accuracy of 2.0 m RMSE.

NEXTMap Europe

Although the NEXTMap USA project was far from completed, the decision was made to build upon the early success of NEXTMap Britain. Intermap had decided to collect data for the remaining countries of Western Europe. It's worth adding that the NEXTMap® Europe project benefitted from what might seem an unlikely benefactor. While it's common to discuss digital elevation data in a cartographic context, the range of applications to which it is being applied is growing daily. Although the creation of high-accuracy elevation data sets of national extent is a worthwhile goal in its own right, such projects can also benefit from some "prime mover" that adds to the urgency of the situation. In the case of NEXTMap Europe – at least early on – that prime mover was the desire on the part of the European auto industry to further its development of "smart car" technology.

Figure 6. Intermap King Air 200.

It's all too easy when reflecting upon projects such as those discussed here to focus on technological advancements and the data itself. The technology evolves, but so too can the forces that sustain the effort to bring a project to fruition. With respect to Intermap's efforts, these forces included the growing realization that the potential uses for elevation data were rapidly changing. In short, market awareness and proactive participation in those markets were essential factors in determining the course that Intermap should follow. This fact leads us to conclude that the completion of these projects can only be truly understood if seen as an accomplishment for the entire company.

Figure 7. NEXTMap® Europe.

The first flight in the NEXTMap Europe project took place in Germany, in June of 2006. Just as mapping in the United States had led to a wide range of administrative and logistical challenges, so too would working in Europe. In total, the NEXTMap Europe project resulted in the mapping of 17 countries – each with its own distinct rules and requirements. Britain, being an island, had presented none of the problems that arise from flying data collection missions over international borders. Likewise, permitting for border flights in North America was relatively straight-forward. Mainland Europe was a different story. The convoluted nature of the international boundaries on the continent, and the large number of different agencies involved in the permitting processes, resulted in the need for a full-time staff member whose sole responsibility was to secure the needed permissions. In some countries the permitting process proved to be fast and efficient; in others, paperwork languished for months in the offices of officials whose primary function appeared to be to that of slowing things down. In the worst case, the permitting process was nearly a year from start to finish. In some countries, mapping activities had to be coordinated with military officials; and in others not. There was no single template that applied; each new country presented unique challenges. Even Switzerland, the very model of efficiency, introduced unexpected airspace restrictions near soccer stadiums that were hosting World Cup matches.

Once data collection commenced, however, the level of cooperation tended to improve. That said, new problems were lurking around every corner. In some cases these challenges were actually a result of Intermap's ongoing efforts to increase efficiency. One of the most significant improvements came as a result of efforts to increase the length of the flight lines. That initiative, known in the company as Ultra Long Lines (ULL), will be discussed in due course. At this point it's sufficient to point out that as flight lines grew longer, the number of international borders to be crossed also increased. In some cases, flight lines extended from the North Sea to the Mediterranean. Flying such a line, from Amsterdam to Marseilles for example, might require coordination with as many as seven different ATC agencies. If ATC issues were a challenge in the U.S., they were, on occasion, a nightmare in Europe. European airspace is crowded, and the decision was made that Intermap aircraft would be upgraded to Reduced Vertical Separation Minimum (RVSM) standards. This meant retrofitting aircraft with the Traffic Collision and Avoidance System II (TCAS II). This was a costly upgrade, but it allowed for the utilization of higher flight levels in both Europe and American airspace.

Working in Europe also introduced new challenges for the ground surveyors. They had to cross international borders, just as the aircraft did. Not surprisingly, one big problem was the language barrier. Establishing GCPs routinely requires negotiation with private land owners, often in rural settings. As one might imagine, these facts conspired to produce a number of difficult and lengthy negotiation sessions.

The last data was collected over the French Alps in July of 2008. When completed, the NEXTMap Europe effort had netted no fewer that 2.4 million km^2 worth of data. This included 80 billion elevation measurements and resulted in 1.3 trillion image pixels. The 153 terabytes of raw radar data was turned into 17,925 tiles of final product. NEXTMap Europe produced data with the same specifications as that of NEXTMap USA: DSMs and DTMs have 5m post spacing, and a vertical accuracy of 1.0 m RMSE. The ORI has a pixel size of 1.25 m, and horizontal accuracy of 2.0 m RMSE.

As was the case in the United States, it did not take long for European agencies to find uses for the newly available data. An interesting example from the NEXTMap Britain project was a biodiversity study by the United Kingdom’s Staffordshire County Council. The project sought to correlate hill slope with lizard species distribution. In Germany, a wireless provider was to be an early user of Intermap data. In that case, the data was utilized for infrastructure and telecommunications network planning. The variety of applications to which NEXTMap data has already been applied is merely the tip of the iceberg. Support for this view can be found in a mandate from the executive branch of the European Union. It clearly supports the use of uniform data sets as part of a program known as *INSPIRE* (Infrastructure for Spatial Information in the European Community). That effort recognizes the importance of using national spatial databases that extend beyond the national borders.

The Numbers

Not surprisingly, the completion of the NEXTMap projects left behind a residue of interesting, and at times amusing, statistics. These numbers are derived from an extensive and detailed set of records kept by Intermap’s acquisitions staff. Consider the following:

The number of Ground Control Points utilized in the NEXTMap USA project was no fewer than 1100. Four hundred and fifty GCPs were required in Europe. Forty surveyors established and monitored base stations in the United States, while 17 were needed in Europe. These same surveyors also deployed a number of trihedral corner reflectors. These reflectors are placed at the intersections of flight lines in such a way that they help to increase the quality of the data. Made of heavy-gauge aluminum, they are designed to be sturdy and reusable. That said, they are subject to both the elements, and the wear and tear that results from being repeatedly assembled and disassembled. By the end of the NEXTMap projects, Intermap surveyors had constructed approximately 450 corner reflectors in the U.S. and 190 in Europe. The aluminum used totaled 11,250 pounds and 4,750 pounds respectively, which in total equates to about a half a million empty soda cans.

Figure 8. A corner reflector placed in the desert.

Figure 9. GPS Field Technician establishing a Ground Control Point.

It's not uncommon for a single surveyor to be responsible for several GCPs and/or corner reflectors at the same time. Given that these points may be widely dispersed over the countryside, the surveyors are often required to spend lots of time travelling between them. Such travels led to the following: the surveyors put 1,020,000 miles (in the U.S.), and 258,500 miles (in Europe), on a fleet of rental cars. These distances equate to two return trips and a single one-way trip to the moon. But the GCP surveyors were not the only ones to rack up impressive statistics.

Mapping the 3,100,000 square miles in the United States required 2,530 sorties, for a total of 10,324 flight hours. No fewer than 1,992,000 gallons of fuel were consumed during those flights over the United States. The European project, by comparison, required 416,000 gallons of fuel burned over 2,155 flight hours. Collection of data over Europe required 505 sorties, and resulted in 923,000 square miles of data. Two flight permits were required from the FAA in completing the U.S. project; 17 from the various European agencies. In Europe, three aircraft were used to collect data along 484,430 km of flight lines. This equates to 301,000 miles, or 38 times around the equator. Lastly, during the completion of the NEXTMap projects the aircraft involved utilized the services of 33 different ground bases in the U.S., while the European project needed only ten.

In the 34-month period during which editing of the European data occurred, a total of 780 data production staff – working in three different facilities (Ottawa, Jakarta, and Bangkok) – racked up a total of 754,000 production hours (about 64,000 of which were "overtime")! To put it another way, production staff committed approximately 470 person-years to NEXTMap® efforts! By the end of 2008 production was proceeding at a rate of 60,000 hours per month. To get the job done, these production facilities operated on a "24 hours a day/seven days a week" schedule.

Suffice it to say that these production capabilities did not exist at the outset of NEXTMap data collection. In fact, both of the Asian facilities experienced significant "ramp-ups" in response to NEXTMap program requirements. The Jakarta office experienced a 425% increase in staffing levels, and the Bangkok facility went from seven employees to 170. To hire and train such a workforce was itself a task of vast proportions, as was the effort to provide the required infrastructure. Moreover, one of these offices would be forced to contend with terrorist attacks, earthquakes, and a difficult relocation. The need to be flexible and agile clearly extended well beyond the field staff.

DATA VALIDATION

Intermap makes every effort to ensure that its data meets the quality specified. In point of fact, the quality of the data has been verified via both internal and external resources. Such efforts date back to early data collection in the U.K., and continue today. From the very beginning of the NEXTMap Britain project, external checks were being conducted to confirm that Intermap's stated accuracy was achieved. One of Intermap's initial clients, Norwich Union Insurance, engaged the University College of London (UCL) to conduct an evaluation of the data. This effort was entirely external to Intermap's own validation process. An additional independent evaluation was conducted by The Environment Agency of England and Wales. In both cases Intermap's data met the accuracy standards as specified.

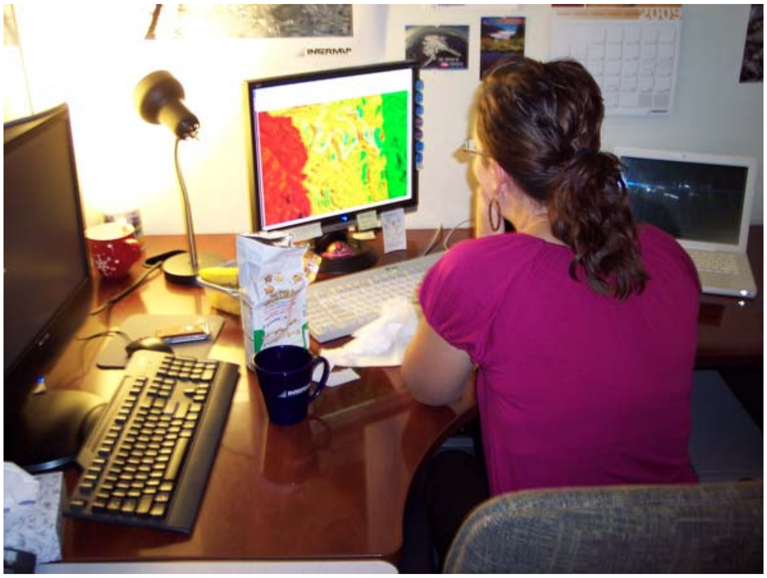


Figure 10. Mosaic Technician working on NEXTMap® USA data.

Although Intermap staff is always pleased to discover that an external agency has confirmed its quality standards, the company does not rely upon those assessments alone. Given the nature of Intermap's product line, it should come as no surprise that a proper Quality Management (QM) system is in place. But over and above the policies, procedures, and documentation that comprise the QM system, Intermap also utilizes an autonomous group known as Independent Verification & Validation (IV&V). IV&V exists apart from the departments responsible for data collection, processing, and editing, so as to avoid any "conflict of interest." As such, it serves as an objective "check" on data quality that utilizes external tools and resources. This is accomplished by referencing ancillary data from a variety of sources, and employing a host of GIS packages to conduct both visual and statistical inspections.

Specific IV&V procedures include checks on base stations and corner reflectors, a review of aircraft motion, and analysis of both pre-edit raw data and post-edit finished data. Software and procedures that are different from those utilized in the production pipeline are employed as to provide a cross-check on all variables. The findings of IV&V's efforts are made available to all Intermap employees so as to provide transparency.

Essentially, IV&V engages in a series of checks that confirm the accuracy of the data throughout the collection-processing pipeline. This pipeline starts with the data's collection in the field, and then passes to the processing of both "navigation data" (i.e., GPS and IMU data) and the raw radar data. The processing of the raw radar data is known as "Interferometric Processing," and is quite complicated. A single flight can collect up to one terabyte of raw radar data, and it obviously requires a significant amount of processing power to deal with such quantities. Once the data has been processed, it moves to the mosaic team where seams are dealt with and tiles created. It then passes on to the editing group, where careful scrutiny is applied in the search for unwanted artifacts. IV&V keeps a watchful eye at every part of the pipeline in an effort to ensure data quality. Along the way, IV&V also offers a unique assessment of the processes themselves.

Additional automation is often applied when seeking increased efficiencies, but some activities – such as editing and IV&V itself – require the careful attention that comes from human scrutiny. As such, many of the processes mentioned here remain labor intensive. To introduce too much automation runs the risk of reducing quality. As such, IV&V serves as more than a mere data quality check. It also offers the tools and techniques with which process improvements can themselves be monitored. Increased productivity has been attained by Intermap's processing and editing activities, but all the while these improvements have been carefully scrutinized by the IV&V team.

Intermap's attention to consistency of quality has paid off in the adoption of its data by a number of governmental agencies on both side of the Atlantic. In fact, the National Mapping Agency of France, *Institut Geographique National* (IGN), has selected off-the-shelf Intermap data as a source for upgrading its DTMs for the seven departments in southeast France that encompass the French Alps.

INNOVATIONS

That the NEXTMap® projects spanned seven years is testament to their scope. Not surprisingly perhaps, Intermap devised a number of ways to increase efficiency along the way. The goal was to expedite the collection and processing of the data, while maintaining a consistently high quality. We would do well to examine a few of the more important innovations that took place, as they are an essential part of the narrative. Some improvements resulted from mere volume increases: more aircraft, more and faster computers, more employees, etc, but efficiencies were also increased.

Data collection efficiencies are clearly a function of the percentage of the flight that is actually dedicated to the collection of data. Data can be collected during neither the takeoff, nor the climb up to a specified altitude. The same is true for the descent and landing, as well as any additional "ferry distance" that might exist between the base of operations and the survey area. Of the remaining portion of the flight – that part that occurs at altitude and in the survey area – usable data can only be collected while the aircraft is flying straight and level along a pre-determined flight line. In short, no data is collected while the plane turns from one flight line to the next. Unfortunately, that turn must be a wide one. If the aircraft makes a steeply banking turn, the onboard GPS receiver may lose sight of one or more of the GPS satellites, which would result in the failure to collect essential "navigation data."

When NEXTMap USA began, the standard line length was 200 km. At that time, only about 50% of any given flight was likely to be devoted to data collection. Not long after that, the line length was doubled to 400 km. But that decision brought with it a risk. As line length increases, so too does the likelihood that the data collected will be unusable. The IFAR radar is a type of "side-looking radar." As such, the desirable antenna position is perpendicular to the flight line. At the very least, it must be within a few degrees of that position. Unfortunately, changes in wind speed and direction alter the aircraft's yaw angle, which in turn changes the antenna point. Moreover, the antenna cannot be repositioned during data collection due to calibration issues. This complicated set of factors results in the following conundrum: If the flight lines are too short, too little time and fuel are spent collecting data. The cost of data on a line-kilometer basis goes up and the project makes very slow progress. But if the flight lines are very long, a significant portion of the data collected is likely to be unusable, with the result that efficiency remains low.

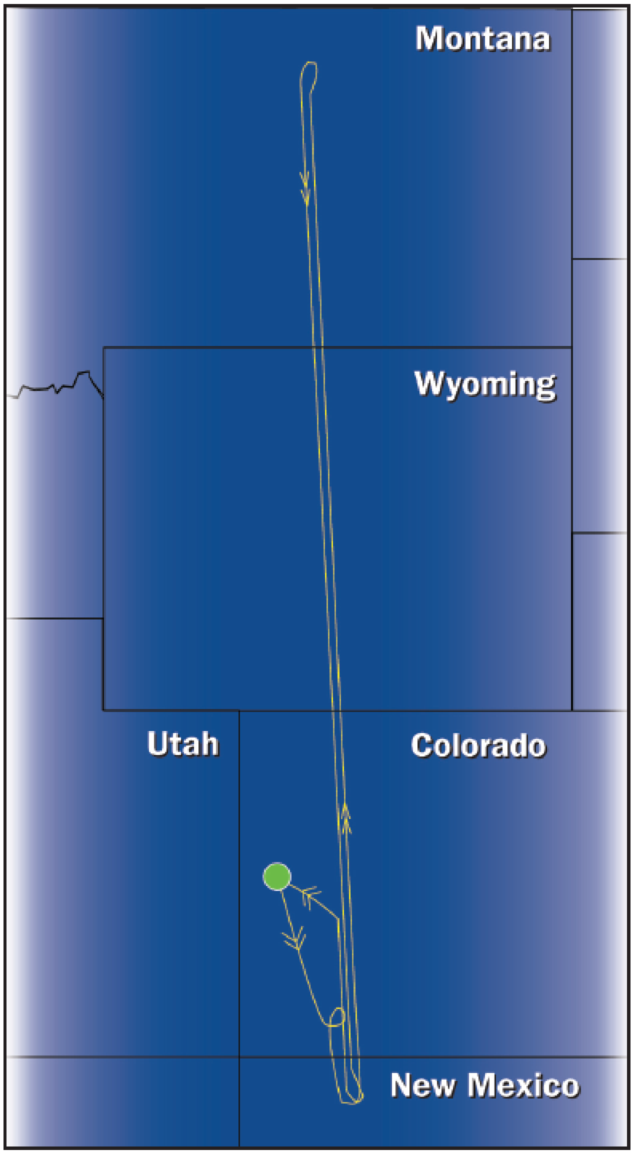


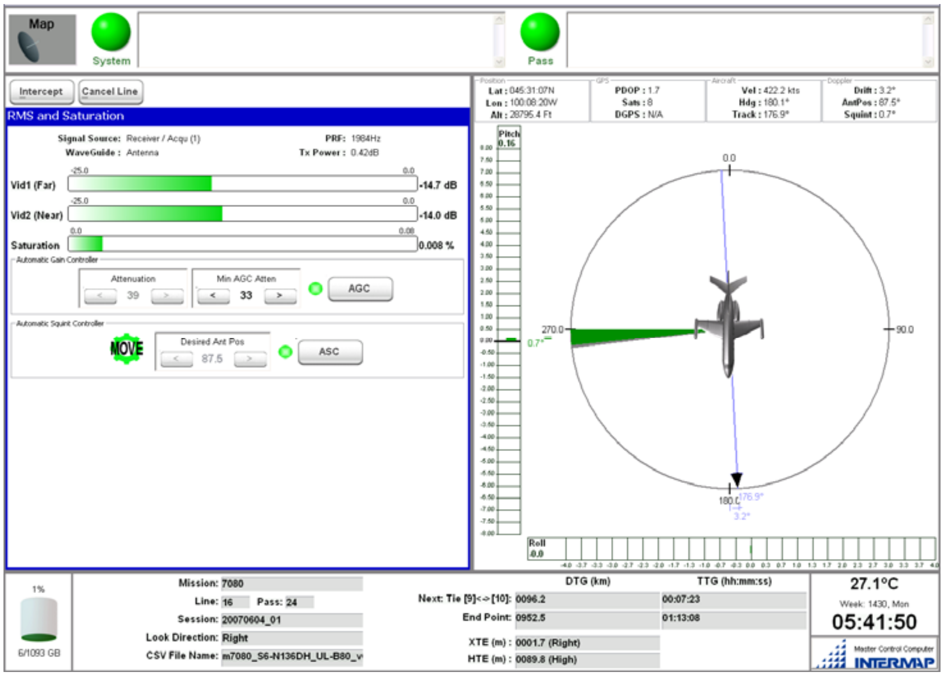
Figure 11. Track of sortie based in Grand Junction, Colorado. Data was collected continuously from northern New Mexico to northern Montana.

This problem was attacked at more than one level. Firstly, since wind is clearly a contributing factor, the mission planning process was reassessed to ensure that likely wind patterns were considered when determining flight line orientation. An understanding of seasonal weather patterns was of use here. Secondly, and as mentioned above, the practice of generating multiple "weather alternates" became part of the flight planning process. This allowed for a near real-time response to changing weather patterns. Lastly, and most importantly, Intermap's engineering staff embarked on a long project that would eventually allow for the repositioning of the antenna during data collection. This change required that the flight lines be subdivided into segments. At the end of any given segment, there was a brief window during which the antenna could be repositioned so as to compensate for the impact of the changing winds. This may sound like a trivial modification, but it was not. It required that data collection efforts would overlap in such a way that nothing would be lost during the antenna repositioning. This had implications for the mission planning, flight planning, and ground control processes. It also meant that every process that handled the resulting data had to change. This was truly a sweeping upgrade in the way Intermap conducted its business. The software that drives the radar had to be rewritten so as to allow for a rapid, timely, and precise antenna repositioning. In fact, this new software was so sophisticated that it actually monitored changes in the aircraft's yaw angle, calculated the resulting squint angle, and automatically selected a new antenna position that anticipated trends in the changing wind.

So effective were these techniques that Intermap was able to alter its data collection significantly. In fact, data collection efficiency was pushed to its logical limit: the fuel capacity of the aircraft. An aircraft could fly a single line until it had consumed half of its allowable fuel, and then turn around and fly one line back home. Just two lines would be flown on any given flight: one out and one back. This meant that fuel would be "wasted" making only one turn. The increase in collected data was more than significant. These "Ultra Long Lines," as they came to be known, were up to 1,200 km in length. With lines of this length, some sorties resulted in data collection during nearly 80% of the flight.

Not surprisingly, increased efficiencies in data collection meant similar improvements elsewhere in the data pipeline. A comprehensive accounting of all of them is beyond the scope of this paper, but such improvement resulted throughout the company. Some of these changes boosted data processing speeds so that the throughput of data was maintained. As mentioned previously, efforts to improve propriety software were constant throughout the NEXTMap projects. At no point were data processing or editing speeds deemed "good enough." But it was never merely enough to add new computers or create faster software. Literally the entire data pipeline was affected by the improved application of production metrics, an increased focus on employee training, and countless other changes. During the NEXTMap projects, data processing and editing achieved monthly bests of 350,000 km² and 300,000 km² respectively. While these totals never matched the maximum figures achieved in data collection (460,000 km² in one very exceptional month), they remained close enough to minimize the impact of any minor backlogs. Moreover, improvements continue to be implemented to this day. Just a few months ago, Intermap's Interferometric Processing group successfully processed over 500,000 km² of data in a single month – an unimaginable feat at the outset of the NEXTMap projects.

Intermap's editing capabilities were also to undergo significant improvements over the course of the NEXTMap projects. The development of proprietary editing software known as the "Interferometric Editing System" (IES) was to greatly enhance the productivity of the editing group. Editing is a labor-intensive activity, especially when done with care. This helps to explain the large number of hours logged by employees, as described above. The high resolution-high accuracy nature of the data makes it all the more important that all artifacts be removed before the final product is put on the shelf. Given the quantities of data involved, the result was lots of time spent editing. The IES software/environment package was to prove a boon to editing efforts. Produced by Intermap's engineering group, IES offered literally hundreds of editing tools. Moreover, IES itself was to be improved, with the result of three versions being released over the course of NEXTMap Europe, and utilized on more than 150 workstations.



Signal Source: Receiver / Acqu (1)
WaveGuide : Antenna
PRF: 1984Hz
Tx Power : 0.42dB
Vid1 (Far) -14.7 dB
Vid2 (Near) -14.0 dB
Saturation 0.008 %
Attenuation 39
Min AGC Atten 33
Desired Ant Pos 87.5

Lat : 045:31:07N
Lon : 100:08:20W
Alt : 28795.4 Ft
PDOP : 1.7
Sats : 8
DGPS : N/A
Vel : 422.2 kts
Hdg : 180.1°
Track : 176.9°
Drift : 3.2°
AntPos : 87.5°
Squint : 0.7°

1%
6/1093 GB
Mission: 7080
Line: 16 Pass: 24
Session: 20070604_01
Look Direction: Right
CSV File Name: m7080_S6-N136DH_UL-B80_v

	DTG (km)	TTG (hh:mm:ss)
Next: Tie [9]<->[10]:	0096.2	00:07:23
End Point:	0952.5	01:13:08
XTE (m) :	0001.7 (Right)	
HTE (m) :	0089.8 (High)	

27.1°C
Week: 1430, Mon
05:41:50

Figure 12. Graphical Interface for proprietary radar software.

One might add that the NEXTMap projects have benefitted greatly from technological improvements made by external sources. The application of Precise Point Positioning (PPP) and the increased availability of Continuously Operating Reference Station (CORS) – and the various European equivalents – are but two of the many improvements that might be cited. It goes without saying that these efforts have also been aided by general advancements in the computing world, and in Geographic Information

Systems (GIS) technology. But it’s not enough to acknowledge innovations made in the areas of data collection, processing, and editing. Each of these areas has benefitted from the significant resources that have been invested in related support activities. A failure at any point in the production pipeline could have resulted in a horrendous backlog of stalled data. It’s all too easy to imagine how any of a number of potential failures in the data pipeline might have brought the entire activity to a halt. History indicates that such disasters were averted, lending support to the contention that supporting activities continued to evolve and innovate along with the rest of the organization. This would include the previously mentioned improvements made in the IV&V group. Continual improvement of procedures and techniques in that area has helped to ensure the consistently high quality of the final product.

It’s also essential that we repeat our previous mention of the ongoing effort to better understand the markets that will eventually utilize NEXTMap data. New uses for digital elevation data are being discovered (or invented) at a rapid pace, and it’s essential that a company like Intermap keep its eye on the ball with respect to such issues. As such, acknowledgement of innovative thinking must also be directed at the sales and marketing departments. In fact, innovative thinking is required in every corner of the company. Ongoing reassessments of core products and value-added projects are just the beginning. There must also be an ongoing search for ways to put data products to work. Areas of interest range from engineering and the automotive world, to Personal Navigation Devices (PNDs) and risk management.

CONCLUSION

The completion of the NEXTMap® USA and NEXTMap® Europe projects would be cause for notice under any circumstances. The mere scope of the projects would warrant attention, but they may also be seen as truly watershed events. We have entered a new era: one in which the collection of high-resolution elevation data can take place on a nation-wide scale. The implications for the existence of such data sets are great. DEM users now have the option of using data sets that cover large areas, and that possess a known and consistent character. This data will be consistent as it crosses borders, and it will be consistent from an age perspective, both of which can be of great importance. But the completion of these projects is significant from another perspective. They remind us that the timely completion of projects that are of such great scope requires that the organization involved remain focused on increasing efficiency, while maintaining quality. They also illustrate the importance of maintaining flexibility; the organization must be able to respond with agility when unforeseen problem arise. Lastly, we are reminded that these increases in efficiency and this agility must exist in every portion of the company.