Statewide Mapping in the Digital Age

JOHN WELTER, KRISTIAN MORIN, North West Geomatics Inc., Calgary, Canada

ABSTRACT

NorthWest Geomatics has been operating a Leica Geosystems ADS40 sensor for aerial survey mapping for over 6 months. Projects have been rapidly growing in size and have lead to the instigation of a mission to map the state of Nebraska. Mapping with a digital three line scanner presents some new challenges to the photogrammetric workflow however. This paper discusses considerations for flight design, field crew deployment, computer processing requirements, schedules and quality control.

1. INTRODUCTION

The Leica Geosystems'ADS40 is fast becoming a proven technology. Since the acquisition of the sensor in late 2002, North West Geomatics of Calgary, Canada, has undertaken several county wide mapping projects in Florida and successfully delivered imagery in all areas. The rapid gain in experience has resulted in a new undertaking: the mapping of the entire State of Nebraska using the ADS40. This will be the first state-sized large format digital mapping project in North America and its results will likely form a benchmark for future digital missions. From planning to delivery however, there is much work and processing. This paper will discuss the statewide mapping project workflow using previous North West missions as a practical touchstone. This will include flight line planning, acquisition, digital product management, the ADS40 workflow, quality control and delivery. In the end, not only is the client's product available, but also additional features of the ADS40 are exploited to provide enhanced delivery.

2. PROJECT PLANNING

In any photogrammetry mission, the goal of flight planning is to minimize time and exposures while still maintaining ground resolution and sufficient overlap. In principal this is the same for ADS40 missions, but with some additional criterion. Because the nature of push-broom sensors is such that the along track spacing is created through aircraft motion, more burdens are placed on the pilot than in conventional film photography. The pilot must maintain a constant speed and altitude, as well as being consistently 'on-line' in the flight management system. Unlike conventional missions, there is no time between exposures to adjust the position of the aircraft. Although it is possible to fly the entire state of Nebraska from one end to the other in single flight lines, the strain on the pilot to maintain the position of the plane within 30 metres for over an hour may prove detrimental to flight safety. Therefore at the planning stage flight lines are broken into smaller blocks.

The smaller blocks have additional benefits. The post processing of the data is much easier to address if they are split into smaller workable blocks. By breaking the flight plans into these blocks we also ensure data acquisition over a given block in a shorter period of time which helps with the radiometric processing discussed later.

3. DATA ACQUISITION AND FIELD REVIEW

Imagery is acquired from the ADS40 using the method promoted by Leica: the operator switches on the sensor and simply monitors the light levels recorded. Data is stored on-the-fly using Leica's custom 540GB Memory Management Unit (MMU) which generally provides 2 or more days of mission storage space. North West employs 2 MMUs to provide sufficient in-field storage while data is couriered back to the main office. Regardless of client requirements, all spectral channels are recorded for each mission in order to provide additional deliveries should the need arise.

The state of Nebraska covers an area of 77,000 square miles (200,000 km^2) and has a rough rectangular shape (Figure 1). To map the entire state at 1 metre resolution is projected to take approx. 90 hours of flight time. During data capture, the ADS40 collects imagery at a rate of 50GB/hour. The raw imagery is compressed; but none-the-less the total amount of raw data is projected to 4.5TB. Thus the need for multiple memory units becomes clear.

Figure 1: State of Nebraska

Upon landing, data is immediately transferred to a field computer for backup and field review. This includes a review of the raw imagery to ensure no storage or processing problems occurred during flight. To date, reliability of data capture and storage has been very high, with only 1 line rejected out of 200. Due to the immediate review, data can be recaptured while the crew is still located on site. Depending on operator experience, navigation data can be processed on-site and reviewed for problems. Additional in-field processing is constrained by the need for large computer storage of intermediate files. The 4.5TB of raw data will consume approx. 13TB of data uncompressed, and an additional 13TB will be needed to store final product. Thus field work is restricted to preliminary checks only. After the initial quality assessment, data is transferred to a portable media (200GB firewire hard drive) and couriered to the main office for final processing.

4. THE ADS40 PROCESSING WORKFLOW

The amount of post-processing of ADS40 imagery has often been identified as a weakness of the sensor. Although processing load is significant, North West has helped drive software development of a distributed processing system from Leica. This, along with key off-the-shelf hardware components has dramatically reduced processing times and is integral in the ability to process a statewide project.

The raw data from the ADS40 contains spatial-temporal distortions that make it unsuitable for final production. The goal of processing is to remove the distortions and triangulate the imagery. The navigation data is used to "untwist" the distortions and create a product that can be triangulated. Once triangulated, the raw imagery is ortho-rectified. These tasks are time consuming, but they are largely automated and their repetitive nature can be exploited in parallel processing.

Parallel processing has been achieved by deploying a computing cluster; i.e. a group of computers which are coordinated by a central computer. North West has realised this cluster by using our existing workstations along with some additional dedicated computer nodes (Figure 2). Jobs are submitted by the operator to an automated central manager, which distributes the tasks to the available computer resources. The system is intelligent enough to detect when a computer is busy, and will wait until resources are free. This allows us to run jobs on dedicated processing machines during the day, and to exploit every computer within the company at night. With North West's current configuration, we are able to process data at a minimum rate of 25GB/hr (daytime) and more than double that at night. Although tasks such as rectification or automated point measurement take different amount of times and computer power, these rates are an average throughput.

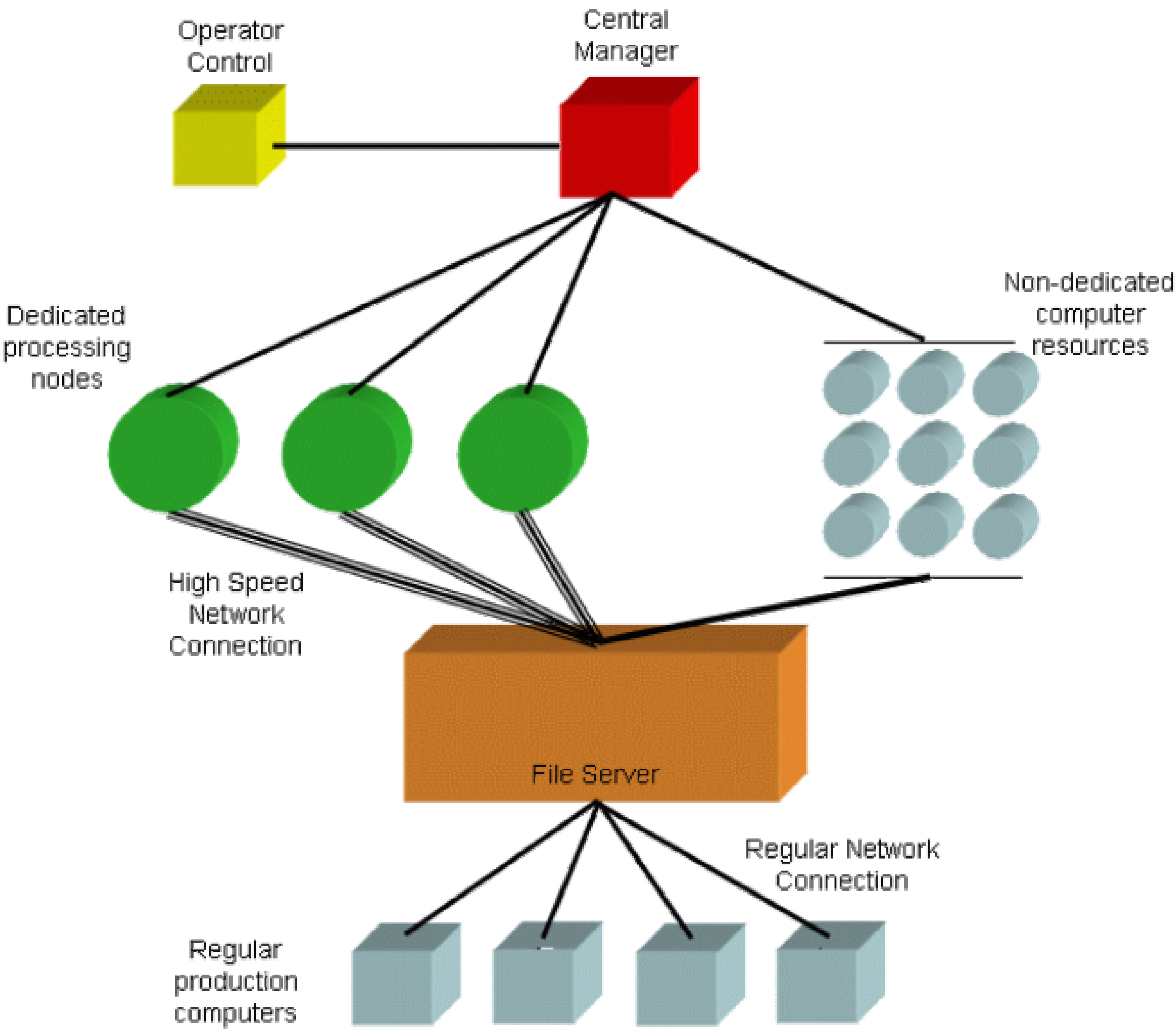

Figure 2: Computer Cluster Layout

5. ORTHO TILE GENERATION

After ortho-rectification, ADS40 imagery can start to enter the conventional production workflow. Radiometric correction, tiling and quality control can then proceed. However, the size of the image files and the nature of 12 bit imagery still poses challenges.

The ADS40 sensor captures image data with 12bits of colour depth per channel; the same as many photogrammetric scanners. However the histogram of an ADS40 tends to be populated more widely then a scanned image (Figure 3). At first this seems like an advantage – more bits means more information. But this quickly becomes a problem when faced with computer display systems that can only render 8bits per channel. This is further complicated by the fact that ADS40 12 bit imagery is stored in a standard 16bit format. This format facilitates image handling in the few software packages that can read 16bit images, but the unused bits can cause viewing problems in programs that expect fully populated image planes. Further, most clients request 8bit data as it is widely supported by virtually all software packages.

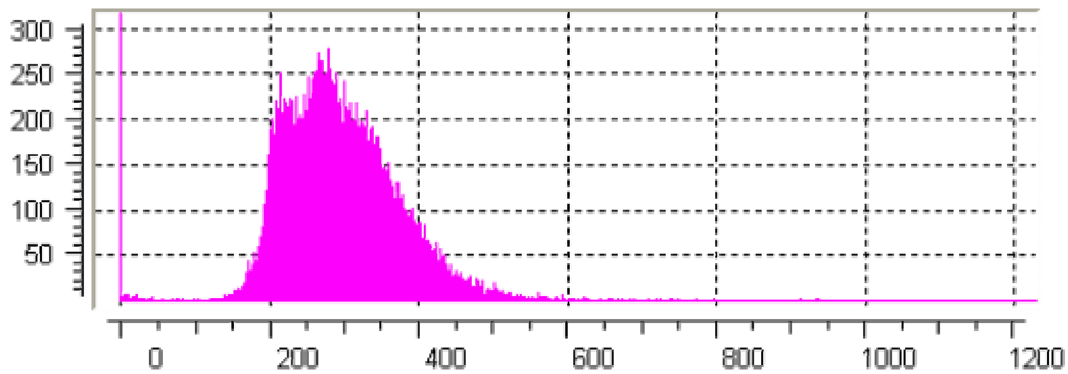

Figure 3: Typical histogram from ADS40 imagery

The most common and logical approach is to resample the 12bit data to 8bits using a mathematical stretch or a user defined tonal transform curve. This solves the image depth problem, but leads to a loss of information. Choosing what part of the histogram to compress or preserve is a difficult issue. Criteria can be placed on the maximum number of saturated pixels, but to achieve these numbers often means compressing digital numbers on the other side of the histogram where a greater percentage of the information lies. Ultimately the client must be aware of the issues and choose a 'spectral area of interest' that the imagery can be guided to. For Nebraska, a series of test images will be produced that will emphasize different areas of the spectral space. This will allow the client to specify what they prefer.

With radiometry corrected, tiles can be cut out of the ADS40 strips. Before cutting, seam lines must be chosen to preserve the appearance of buildings and topological features. In this area the ADS40 imagery excels. Due to its continuous nature, seam lines are only required in the along track direction and not in the cross track. This effectively halves the time required and the continuous imagery means that there will be no spatial distortions in the cross track direction.

With tiles cut quality control can be undertaken. In this process topological features that are inconsistent with the DEM are fixed. This often means bridges. An advantage of the Leica ADS40 software is in its ease of use – and this is illustrated in its use by North West's photo technicians. When a distorted bridge is identified (easily observable by its twisted nature in the ortho-rectified tiles – see Figure 4), the source image can be brought up in stereo. The local elevation at the bridge deck is measured and recorded. The ADS software allows any arbitrary area to be re-rectified, such as the local bridge area, and the rectification can be done to a fixed height (in this case, the height of the bridge deck). This permits accurate and fast correction of DEM induced image distortions. Such a fix can be performed in minutes; which permits its application on a statewide level.

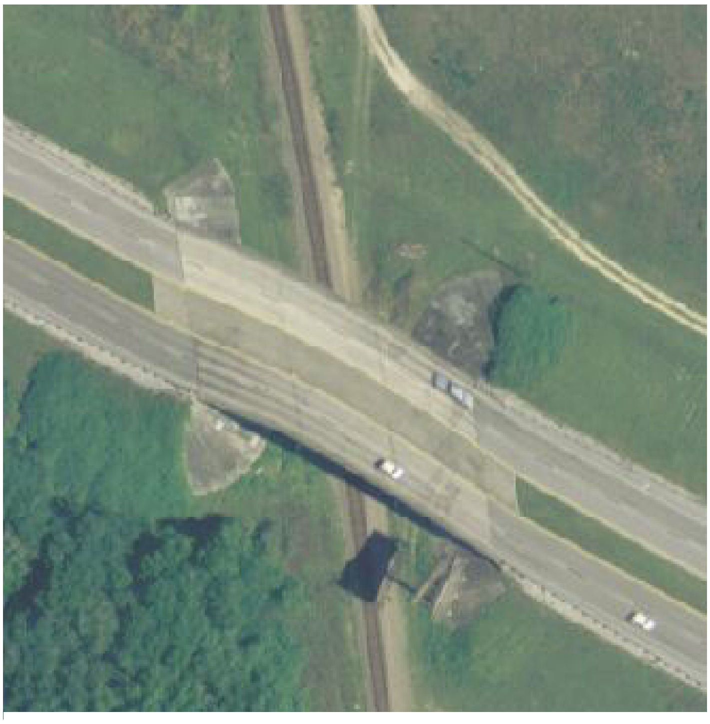

Figure 4: Distorted bridge

6. ACCURACY ASSESSMENT

North West's accuracy assessment regime begins at the aerial-triangulation (AT) phase, but for the client accuracy is often manifested solely in the final ortho-tiles. For our purposes accuracy assessment can be broken into before and after tile generation.

At the AT stage the results of the adjustment are monitored and aposteriori statistics are reviewed for accuracy compliance. Residuals of tie points and control are verified – all of which are standard features of the adjustment software (in the case of ADS40 imagery, Leica Geosystems' ORIMA). When the adjustment is complete, the updated orientations are verified in the imagery by viewing the strips in stereo. Overlapping strips are checked to see in any misalignments are minimized and non-systematic. The photo package SOCET SET also permits stereo images to be reviewed while driving the elevation values to a known DEM. By selecting the DEM to be used in ortho-production, a preview of the rectified strip alignment can be obtained to ensure that a poor DEM will not degrade the final product. North West has found that a 'good' adjustment from ORIMA should result in overlapping strips agreeing to within 1-2 pixels.

After ortho-rectification, images are again checked for discontinuities by the quality control photo technicians. A problem area triggers an investigation in reverse to the above methods; i.e. the images are reviewed in stereo and the DEM is checked in the local area. A DEM issue has been the most frequent issue to date. If the problem was not identified there, the investigation would continue to the AT solution. A good DEM has tended to induce a 0-2 pixel error in the final ortho tile.

For the statewide Nebraska project, the accuracy criteria are relatively low. Rather than aim for accuracy in a known reference system, the client has requested that the new imagery conform to an older set. This will permit an easier integration with existing vector data. Control will be taken from image data with a relatively low spatial accuracy. To achieve the most reliable fit, a large control data set will be used to achieve a high level of redundancy. This should ensure sufficient matching to the reference system.

7. DELIVERIES

The survey of the state of Nebraska for this project will involve over 6000 Digital Ortho Quarter Quads (DOQQs). The final requested delivery are colour DOQQs. Due to the large file sizes of these images, conventional recordable media such as CDs and DVDs are insufficient; thus North West has begun using large capacity hard drives in portable enclosures with IEEE1894 (FireWire) interfaces. The firewire provides cross-platform transfer ability while the hard drives are a fast and easy storage media.

The Nebraska client requested only colour orthos, but due to the simultaneous acquisition of colour, infrared and panchromatic data, additional products can be delivered in the same area. All channels are co-registered on the sensor image plane thus a triangulated solution for one channel can be applied to the others. This results in various ortho products which are automatically co-registered with each other. Thus vector data from one product can be immediately integrated with another.
Further, each channel has the same spatial resolution, thus there is no degradation from one channel to the next.

In addition to imagery, the very strong geometry from the ADS40 configuration (forward and backward looking imagery) creates and excellent base to extract DEM information. This can be performed manually or preferably automatically using tools such as SOCET SET's Automatic Terrain Extraction.

8. SUMMARY

Statewide mapping using a digital sensor is an exciting task. The ADS40's innovation places new challenges are every operator in the workflow; from pilot to technician. To overcome these new problems requires consideration from the very beginning of the mission design phase. A serious investment in computer power is required to process data in a timely fashion and a good team of engineers and technologists are needed to handle the quantity of information. North West Geomatics has risen to this challenge and is staged to set the benchmark in digital mapping age.