GEOMETRIC CORRECTION SYSTEM CAPABILITIES, PROCESSING, AND APPLICATIONS*

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ABSTRACT

The U.S. Department of Energy's Remote Sensing Laboratory developed the geometric correction system (GCS) as a state-of-the-art solution for removing distortions from multispectral line scanner data caused by aircraft motion The system operates on Daedalus AADS-1268 scanner data acquired from fixed-wing and helicopter platforms. The aircraft attitude, altitude, acceleration, and location are recorded and applied to the data, thereby determining the location on the earth with respect to a given datum and projection. The GCS has yielded a positional accuracy of 0.5 meters when used with a 1-meter digital elevation model. Data at this level of accuracy are invaluable in making precise areal estimates and as input into a geographic information system. The combination of high-spatial resolution and accurate geo-rectification makes the GCS a unique tool in identifying and locating environmental conditions, finding targets of interest, and detecting changes as they occur over time.

1.0 INTRODUCTION

A critical requirement for the entry of remote sensing data into a geographic information system is that the data be spatially referenced to a common datum and projection (Ehlers, 1997). Although distortions of space-based multispectral scanners have been acknowledged and well characterized in the literature (Williams, 1985), (Davison, 1986), distortions caused by fixed-wing and helicopter-based airborne systems have not been as widely reported.

Errors inherent in an airborne system result from changes in aircraft altitude and attitude caused by the surrounding turbulent atmosphere. As the mirror in the line scanner rotates and acquires multispectral data, additional distortions are recorded. These distortions vary with the angle of the mirror from nadir and the topography of the portion of the earth being imaged at that instant. Figure 1 illustrates some of the possible distortions. Although it is relatively easy to characterize the correction required for any single distortion, the problem is the additive nature of the multiple distortions caused by the continuous aircraft motion through the atmosphere.

For the past five years, the U.S. Department of Energy's Remote Sensing Laboratory (RSL) has been developing and testing a geometric correction system (GCS) for removing these distortions. The system is used successfully to correct Daedalus 1268 multispectral data acquired with various airborne platforms (Lewis-King et al, 1998).

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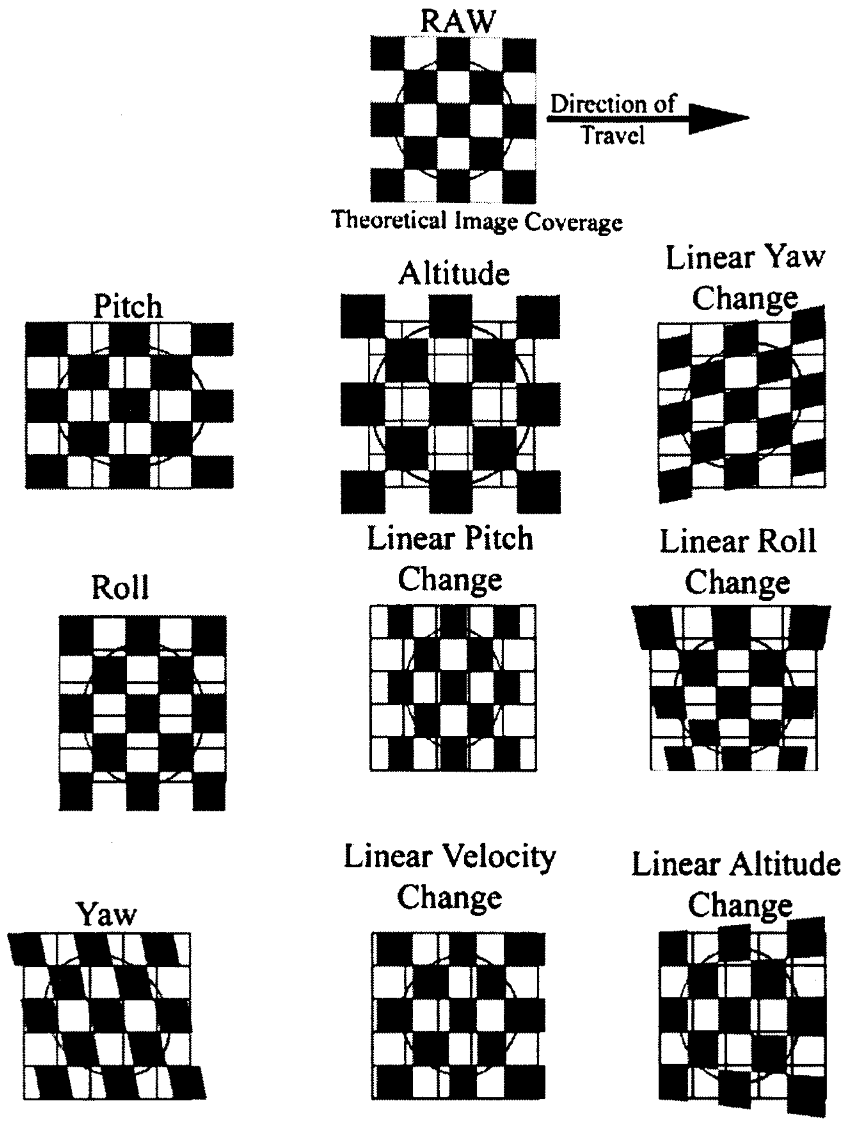

Figure 1. Scanner Distortions

2.0 THE GEOMETRIC CORRECTION SYSTEM

The geometric correction system consists of an airborne element and a ground processing element.

2.1 AIRBORNE ELEMENT

An airborne element records precise aircraft position, orientation, and time. RSL's airborne element uses an inertial measuring unit (IMU) operating at 200 Hz, two global positioning system (GPS) receivers (Trimble 4000se), a TrueTime encoding system, and a ruggedized PC-based data recording system with a removable hard drive. Figure 2 shows the components of the airborne element.

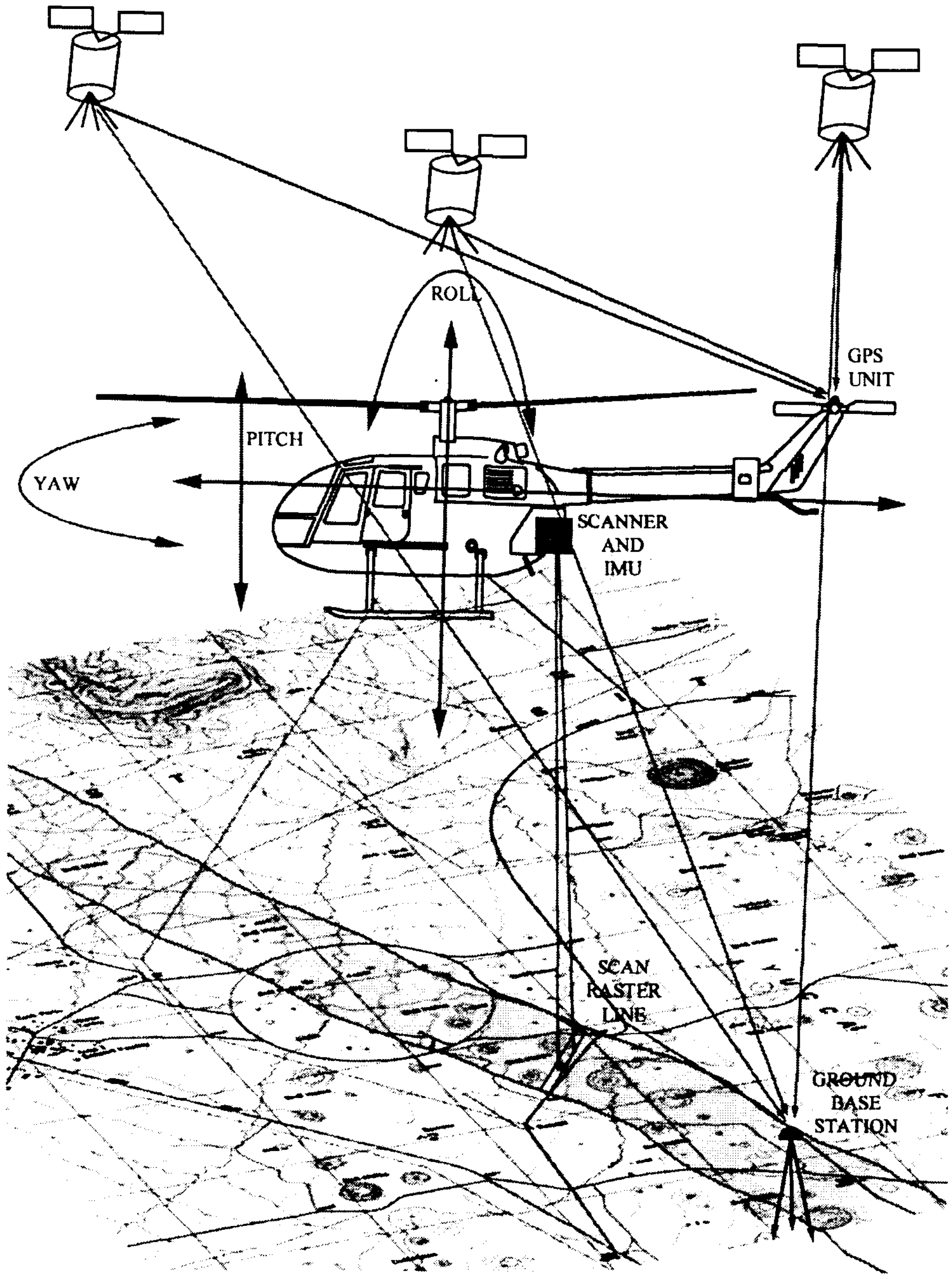

Figure 2. GCS Airborne Element

Aircraft position is established using a differential GPS. One (rover) receiver is placed in the aircraft and a second (master) station is placed at a known or surveyed location on the ground. Aircraft orientation is determined by a Litton LN-200, a lightweight IMU based on a triad of fiber optic gyros and silicon accelerometers. The TrueTime encoding system provides a timestamp to synchronize the position and orientation data with the multispectral scanner data. The IMU and timing information, as well as the GPS receiver data, are recorded onto the removable hard drive for processing once the aircraft has landed. The timing information is also recorded into the Daedalus 1268 housekeeping data for each line. At the same time, GPS information from the base station is recorded separately at the base station to allow for differential GPS processing.

2.2 GROUND PROCESSING ELEMENT

The ground processing element uses RSL-developed software to process the IMU data (GCSProcess) and commercial-off-the-shelf software to differentially process the GPS data (GrafNav), blend the IMU and GPS solutions (PosProc), and finally geometrically correct the data (GEOCOR). The first three parts of the ground processing element are PC-based and are accomplished in the field immediately following data collection. This allows the IMU and navigational data to be assessed for quality and the data to be re-acquired if necessary. The final part of the ground processing element is performed on an SGI workstation which has sufficient power to process the very large data sets.

The GCSProcess software, which is written in C++, combines individual IMU data files, checks the integrity of the IMU data and repairs it if necessary, converts the IMU data into PosProc-compatible format, and inserts the actual time (seconds past midnight) into multispectral data. The software also puts the multispectral data into a format compatible with the GEOCOR program.

GrafNav is a kinematic differential code and carrier phase GPS post-processing program. It processes the GPS data recorded by the rover and master receivers to yield a differentially corrected GPS position at sub-meter accuracy. The GrafNav program utilizes kinematic ambiguity resolution to remove errors introduced when a serious loss-of-lock condition occurs. Loss of lock usually occurs when an aircraft body blocks the signal from a satellite during a turn.

PosProc accepts differentially corrected GPS position and velocity data from GrafNav and raw angular rate and acceleration data from the LN-200 and computes an optimally accurate, blended navigation solution or single best estimate trajectory. PosProc contains a strapdown navigator that solves equations of motion on a rotating earth from accelerations and angular rates sensed by the IMU. A Kalman filter matches the strapdown navigation solution against the GPS data to obtain estimates of the significant navigation sensor errors. A modified Bryson-Frazier algorithm computes the smoothed blended navigation solution based on past, present, and future data.

The final section of the ground processing element is a commercial version of the GEOCOR package developed by the Canada Center for Remote Sensing and licensed through Applanix Corporation. GEOCOR uses the navigation solution data output by PosProc with the timed multispectral scanner data to eliminate distortion in the imagery caused by aircraft motion.

2.3 PROCESSING FLOW

The actual processing flow is found in Figure 3.

GCS GROUND ELEMENT
DATA FLOW DIAGRAM

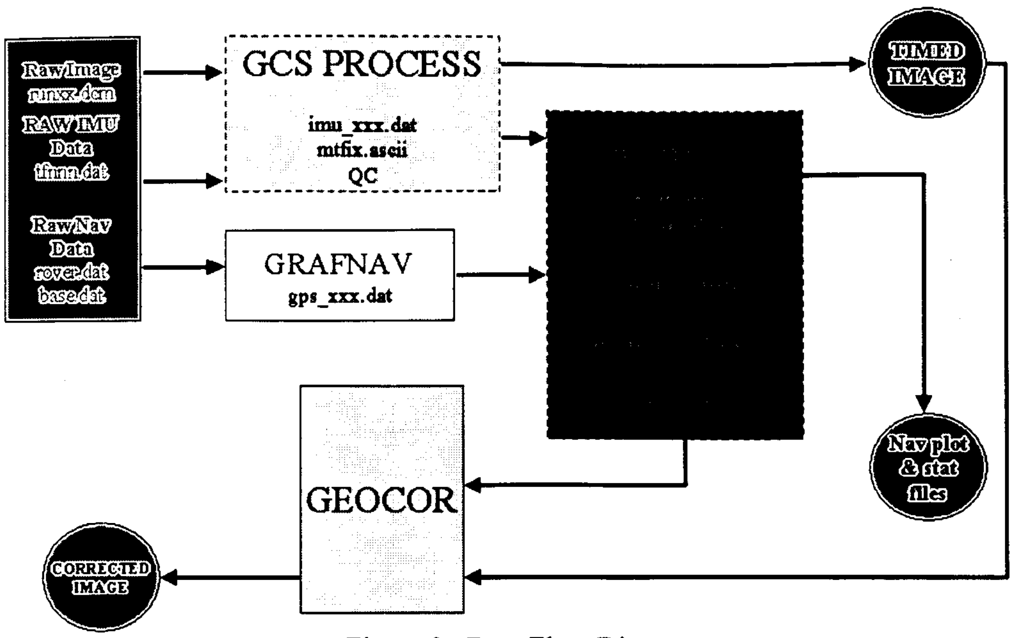

Figure 3. Data Flow Diagram

2.4 GCS PROCESSING LEVELS

The GCS produces corrected multispectral scanner imagery at three levels of precision. These levels are a combination of corrections for platform variation (pitch, roll, yaw, altitude), topography using a digital elevation model (DEM), and rectification to map accuracy.

Level 1 GCS: Scanner imagery is corrected for high frequency platform variation, but positional accuracy with respect to map coordinates is not guaranteed.

Level 2 GCS: Scanner imagery is corrected for platform variation and referenced to a datum and projection. The topographic correction is applied using a DEM.

Level 3 GCS: Scanner imagery is corrected for platform variation and topography and referenced to a datum and projection. The topographic correction is applied using a high-resolution DEM. The scanner imagery is then rectified to an orthophoto and can be mosaicked, if required. This technique uses standard numeric processing techniques and requires the selection of 15-20 ground control points.

A residual error attributed to scanner misalignment from nadir in each of the aircraft necessitates this Level 3 process. The goal is to remove the misalignment vector by flying a known grid and calculating misalignment coefficients that can be applied during GEOCOR processing. This process will effectively eliminate the final step and turn the orthophoto into a quality control mechanism.

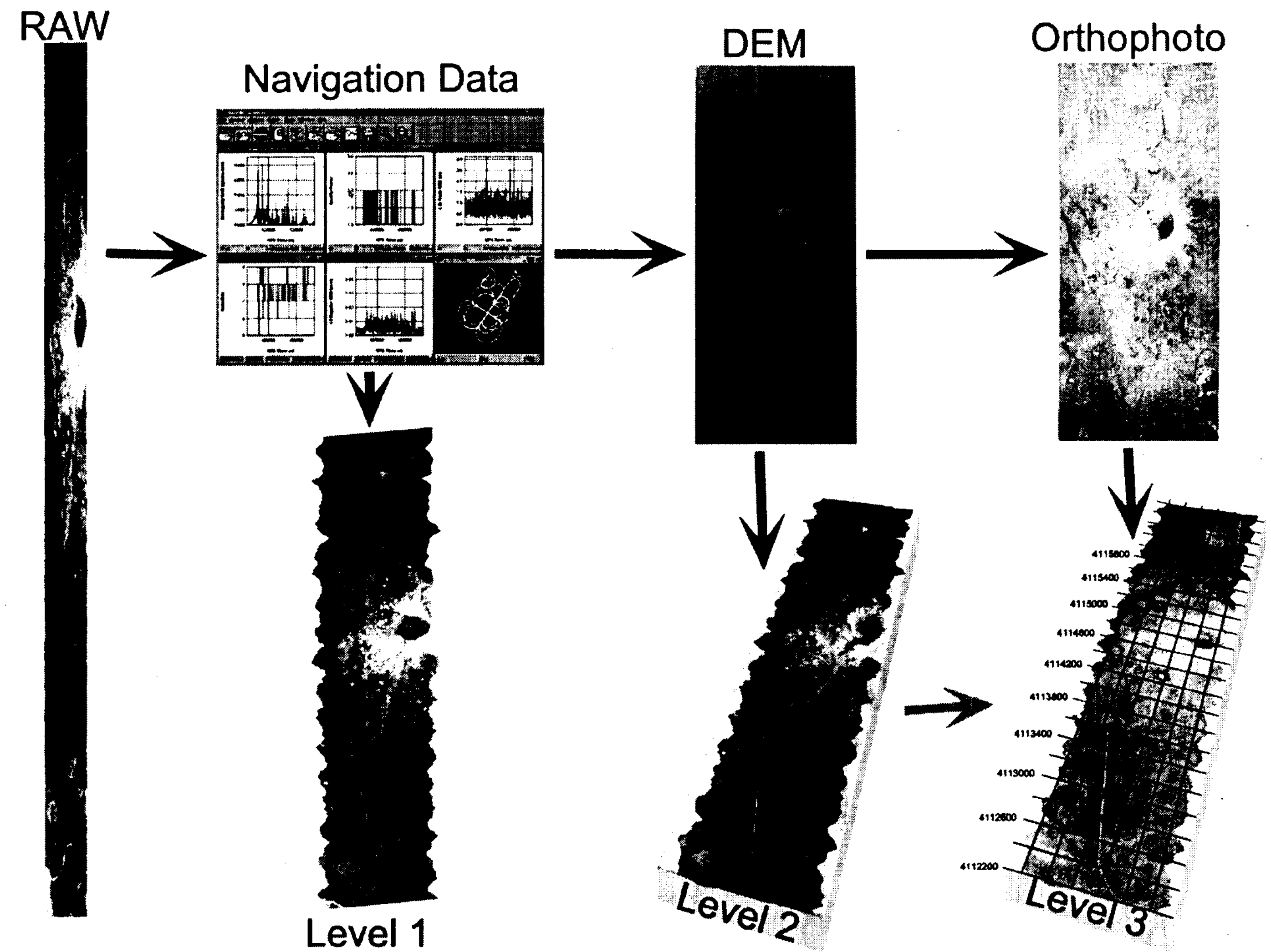

Figure 4. Three Levels of Processing

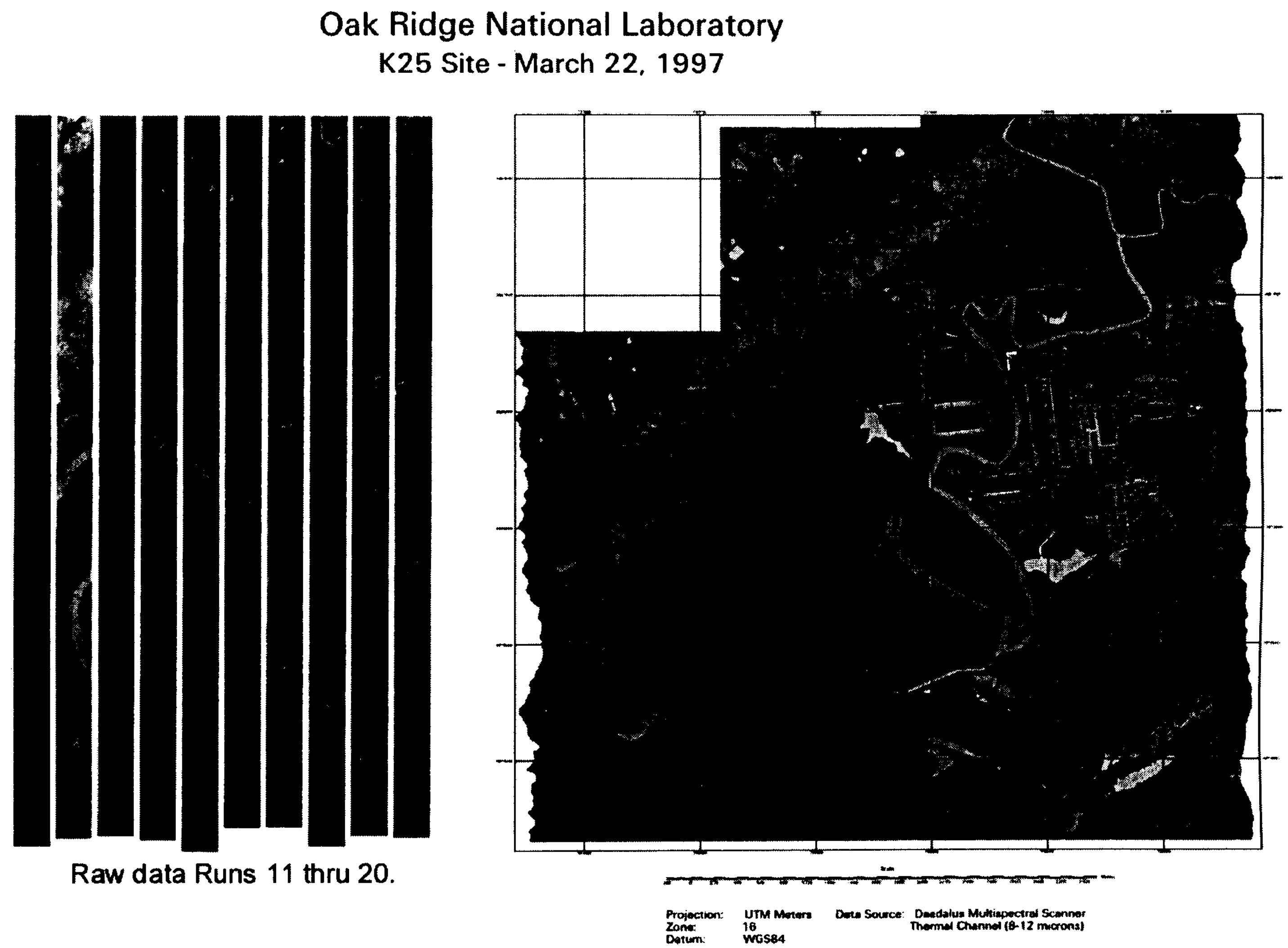

Figure 5. Oak Ridge Example

3.0 APPLICATIONS AND FUTURE WORK

The integration of airborne remote sensing data and geographic information systems has many applications including agricultural change detection, hazard assessment, forestry management, emergency response, and precise object detection and location.

The RSL has used airborne multispectral imagery processed through the GCS to identify and locate buried trenches, perform roof damage assessment, provide baseline data for hazardous waste transportation routes, and identify and delineate seeps and springs. Figure 5 gives an example data set that has gone through the GCS process. The image on the left shows 10 of the 27 raw data flightlines of predawn thermal data. The image on the right shows all 27 flightlines corrected to GCS Level III and then mosaicked into the final product.

As mentioned earlier, the third level of GCS processing is required to remove the distortions caused by the offset of the scanner mount from the nadir position. To facilitate characterizing this scanner offset, a specially built calibration grid and corresponding software generate the necessary correction coefficients. Once the installation has been characterized, the coefficients are applied and the third level of GCS processing is achieved without the need for ground control point selection. Then, the orthophoto is no longer used as an active registration mechanism but becomes a useful quality control measure.

4.0 ACKNOWLEDGMENTS

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5.0 REFERENCES

G.J. Davison, "Ground Control Pointing and Geometric Transformation of Satellite Imagery," *International Journal of Remote Sensing*, Vol. 7, No. 1, pp. 65-74, 1986.

M. Ehlers, "Rectification and Registration." In *Integration of Geographic Information Systems and Remote Sensing,* eds. J.L. Star, J.E. Estes, K.C. McGwire, Cambridge University Press, Cambridge, UK, Chap. 2, pp. 13-36, 1997.

E. Lewis-King, L. Tinney, D. Brickey, D. Eckhardt, "An Automated Geometric Correction System for Airborne Multispectral Scanner Imagery." In *Proceedings of the Second International Airborne Remote Sensing Conference and Exhibition*, 24-27 June 1996, San Francisco, CA, Vol 1, p 162.

J. Williams, "Integration of Geocoded Satellite Images in Geographic Information Systems." In *Geographic Information from Space,* John Wiley and Sons, Chichester, Chap. 6, pp. 144-181, 1995.

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