

**The Airborne Data Acquisition and Registration (ADAR)  
System 5000: A CCD-Based System  
for High Resolution Multispectral Remote Sensing**

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**ABSTRACT**

This paper discusses the features and applications of the Airborne Data Acquisition and Registration (ADAR) System 5000. The ADAR System 5000 is a multispectral imaging system which integrates CCD-based sensors with advanced computer technology and the global positioning system (GPS). This full frame imaging system provides four user-selectable spectral bands within the visible/near IR range (400 - 1000 nm).

The ADAR System 5000 was designed to provide users of raster imagery with a flexible source of image data. The key system features are rapid turnaround between acquisition and availability of data, spatial resolution from 50 cm to 3 m/pixel, and user selectable spectral coverage. First available in November, 1991, the system has been successfully used for a variety of applications, including forestry, marine biology, agriculture (insect management and soil chemistry studies), environmental impact studies, resource management, ecosystem science, and urban land use and land cover classification. Highlights of a few typical applications are presented.

**KEY WORDS:** Digital Image, Remote Sensing, Spatial, Multispectral, Raster, GPS.

**THE ADAR SYSTEM 5000**

The Airborne Data Acquisition and Registration (ADAR) System 5000 was designed for collection of digital multispectral image data and other associated geographic data. Charge coupled-device (CCD) sensors are used to provide four user-selectable spectral bands within the visible/near infrared range (400 - 1000 nm), and the global positioning system (GPS) is used to identify the location of each image captured with the System 5000. The following sections describe the performance and features of the System 5000.

**1.0 System Performance.**

**1.1 Spatial Resolution.** Using optics with a 22 degree field of view (FOV), spatial resolution of images collected with the System 5000 varies from 1/2 to 3 meters per pixel at aircraft elevations from 3,000 to 18,000 feet above ground level (AGL). Higher resolution images (at 25 centimeters/pixel) have been successfully captured with the System 5000, but minimum airspeed requirements make collection of imagery at this resolution difficult using a fixed wing aircraft. For very high resolution applications (higher than 1/2 meter/pixel), the System 5000 must be carried in a slower platform such as a helicopter. Figures 1 through 3 show individual spectral images from a multispectral scene captured at a spatial resolution of 2/3 meter per pixel.



Figure 1. Sample Image (Blue: 450 +/- 40 nm)



Figure 2. Sample Image (Red: 650 +/- 40 nm)



Figure 3. Sample Image (Near Infrared: 850 +/- 40 nm)

1.2 Spectral Resolution. Spectral sensitivity of the standard CCD image sensors used in the ADAR System 5000 ranges from 200 nanometers (nm) to 1000 nm. Current system optics do not allow imaging in the ultraviolet, resulting in an effective spectral range of 400 nm to 1 micron, covering the visible and near infrared bands. Each sensor can be configured to view distinct spectral bands ranging from 300 nm to 12 nm in bandwidth. The sample images shown in Figures 1 through 3 show 80 nm spectral bands centered at 450, 650, and 850 respectively.

1.3 Rapid Turnaround from Data Collection to Processing. Since all data recorded by the System 5000 is in digital format, no post-processing is required before image processing can begin. Image data is converted from ADAR System 5000 format to a file format compatible with the image processing system, using software resident on the System 5000. The reformatted data is then written onto permanent storage media (1/4" tape, 8 mm tape, floppy diskette, etc.) accessible

to the destination system. Both of these steps may be completed quickly, in some cases before the host aircraft returns to its home airport.

## 2.0 Features of the System 5000.

2.1 Modular Design. The ADAR System 5000 is a modular system designed for collection of digital multispectral image data and other associated geographic data. The modular design was employed to allow utilization of industry standards for interfaces between subsystems, to simplify addition of new sensors and subsystems required to meet special needs, and to expedite system maintenance.

2.2 CCD Image Sensors. The primary function of the System 5000 is to collect digital image data in multiple spectral bands. The standard configuration for the System 5000 is to employ four charge coupled device (CCD) sensors measuring 739 columns x 478 rows, with spectral coverage as described in section 1.2. Because of the System 5000's modular

design, larger format sensors (up to 1024 x 1024) can be utilized as an option. One important feature of the CCD sensors used in the System 5000 is that each spectral image is captured in a full-frame format, as opposed to building an image in a line-by-line scanning format.

**2.3 Alternative Image Sensors.** The System 5000 includes a programmable image sensor interface, capable of recording digital image data directly or digitizing analog signals carrying image information (RS-170 standard or non-standard video). This enables the System 5000 to accept input from other image sensors if required. For special projects, thermal infrared sensors have been successfully integrated into the System 5000. Thermal infrared images have been collected using a platinum silicide (PtSi) solid state sensor, sensitive to the high temperature 3 to 5 micron spectral region. Images in the lower temperature thermal infrared band (8 to 14 micron wavelengths) have been captured using a pyroelectric vidicon tube sensor, although the ability of this sensor to obtain quality images from an airborne platform was limited above 6000 feet AGL.

**2.4 Image Data Format.** All airborne data is buffered on the System 5000 hard disk and recorded in a proprietary format on high speed tape. Upon completion of imaging, the images may be rewritten into formats compatible with common image processing or geographic information systems (GIS) such as band sequential (BSQ), band interleaved by line (BIL), and other formats as necessary.

**2.5 Global Positioning System (GPS).** In addition to storing digital image data, the System 5000 continually monitors a GPS receiver, recording latitude, longitude, and elevation data to provide the location of the host aircraft at the time each image is acquired. Based on the status of the constellation of GPS satellites, uncertainty in the location of the centerpoint of each image can range from +/- 100 meters to +/- 1000 meters. For most applications, raw GPS data is adequate to assist post processing activities by providing approximate location information as well as a record of the host aircraft's flightlines. With the current configuration of the System 5000, visible ground control points are required to complete ground registration. As additional technology is incorporated into the System 5000, accuracy of the image location data will be improved dramatically.

### **3.0 Data Correction and Image Registration.**

For many applications, geometric corrections must be applied to the raw data collected by the System 5000. As with any optical system, the imaging geometry creates geometric distortions, and scale distortions due to ground relief and variations in aircraft

altitude and orientation are also inherent in the digital images. Established methods for geocorrecting digital image data (from satellites or scanned aerial photographs) may be applied to System 5000 images to provide the necessary corrections.

Again based on the requirements of the application, radiometric corrections may also be required. For projects which do not require radiometrically accurate data, the System 5000 may be configured to maximize the contrast in each scene. For those projects which will compare spectral intensities between scenes collected in different regions or at different times, the gain, exposure, and aperture on each spectral channel are held constant to allow radiometric corrections to be applied to the image data.

### **4.0 System Operation.**

**4.1 Pre-flight Planning.** A custom software tool, developed for the ADAR System 5000, is used to calculate all flight parameters prior to the flight. Parameters which must be predetermined include aircraft groundspeed and altitude, image frequency, total data volume to be collected, etc. These parameters are based on the specific requirements of the project, such as spatial resolution, image overlap, sun angle, etc.

Once the flight parameters have been calculated, latitude and longitude coordinates of the region to be imaged are used to establish flightlines, monitored by GPS while in flight. GPS is also used to assist navigation from the flight's point of origin to the imaging site, minimizing the total project flight time.

**4.2 Flight Operations.** The ADAR System 5000 may be operated with a minimum of two people on board the aircraft: the pilot and the system operator. A video monitor is used to provide a real time display, either of the terrain within the field of view of the System 5000 or in a forward looking configuration to assist with accurate overflight of specific targets. In many cases, the lead researcher for the project participates in the flight, allowing additional parameters of importance to the project to be noted at the time the images are acquired.

### **EXAMPLE APPLICATIONS FOR SYSTEM 5000 IMAGE DATA**

#### **5.0 Introduction.**

Digital image data is available from a variety of sources. Remote sensing satellites, airborne scanners, aerial photography, and airborne videography all have unique advantages, but none can serve all applications. Similarly, the ADAR System 5000 has its own set of advantages which make it a suitable

source of data for many applications. Several past applications for this image data are described briefly below. The variety of applications is intended to illustrate how the unique features of the System 5000 apply to real-world problems.

#### 6.0 Erosion Studies.

ADAR System 5000 images are being used by the Bureau of Indian Affairs (BIA) to aid in efforts to combat erosion. In this research effort, multispectral digital images (at 1/2 and 2 meter per pixel resolution), GPS data, and aerial photographs are being integrated into an existing GIS. The research will attempt to identify the causes of and possible solutions for erosion problems occurring on two separate river drainages on the Blackfeet Native American Reservation in northwestern Montana.

On the first river, researchers are studying a problem area where erosion is undercutting a hillside which supports a road and irrigation canal. Previous research has indicated that the river is currently following a channel different from its original meandering path. In the new channel, the swifter flow of the water has resulted in increased erosion. The main objectives of this study are to:

- 1) identify and map the original river channel.
- 2) determine what caused the river to alter its path.
- 3) determine if any method can redirect the river back into its original channel.

In the second river, sediment from upstream sources is affecting the fish population in the downstream system of lakes and rivers. The main objective of this study is to determine the source(s) of sediment in the river and then attempt to identify methods for minimizing the sedimentary load.

Although these projects are still in the analysis stage, initial efforts indicate that the results of computer image analysis of these two erosion problems are very promising.

#### 7.0 Classification and Mapping of Grasshopper Habitat.

The Agricultural Research Service is conducting a study to determine the effectiveness of using high resolution multispectral data to classify grasslands and thus map preferred habitats for several species of grasshoppers. In this project, the vegetation types which support the grasshoppers are known, but spatial variations of the vegetation types are too great to be observed in commercially available satellite data. During the summer of 1991, high resolution images were collected with the ADAR System 5000 of sites which had already been mapped using ground-based methods. This research hopes to determine whether or not ADAR System 5000 data can be used to map large areas of grasshopper habitat.

#### 8.0 Forestry Applications.

Forestry studies have made extensive use of satellite image data, and the availability of high resolution data from the ADAR System 5000 has resulted in numerous applications.

One project involves analysis of images of conifer forests acquired in Oregon and Washington at .5 and 2 meter per pixel resolution (Benkelman, Verbyla, and Cohen 1992). The data were used to characterize proportions of various scene components (e.g., sunlit and shaded tree canopy and sunlit and shaded background) in forest inventory plots and long term Ecological Research (LTER) sites, and

thus to facilitate more accurate modeling of forest canopy reflectance using satellite data.

In a related study, the high resolution imagery was also used to characterize riparian vegetation conditions, locate streamside forest gaps, and map patterns of riparian canopy disturbance. The objective is to determine dissimilarities between forest fragmentation along stream corridors versus the fragmentation up slope. Results of this study have significant implications on issues related to global and regional biodiversity.

The ADAR System 5000 also has potential for mapping trees that are dead or dying from insects, disease, air pollution or other stress agents. The University of Idaho Department of Forest Resources is currently testing this application by analyzing ADAR imagery acquired during the summer of 1991 at the University of Idaho Experimental Forest (Benkelman, Verbyla, and Cohen 1992). For this project, early-morning images were collected of sites with trees exhibiting two classes of stress. In the first class, trees were deliberately stressed by severing sapwood with a chainsaw. The second set of sites includes trees known to be infected with root rot. Previous research (Ahern 1988) was used to select the spectral bands used for this study. Although this work is still in progress, early analysis of the multispectral images indicates that standard classification techniques can successfully delineate trees which are stressed from healthy trees in the same scene.

#### 9.0 Semiarid Vegetation Mapping.

In this project, conducted by the Department of Geography at San Diego State University, vegetation properties such as percentage vegetation cover and above ground green and woody biomass of semiarid regions are being quantified (Benkelman et al., 1992). The researchers hope to develop procedures for quantifying the spatial distribution

of above ground plant biomass and net primary production of grassland, shrubland and playa (high runoff accumulation) sites.

High resolution imagery was collected of an LTER site in the Jornada Basin near Las Cruces, New Mexico. The research in progress seeks to derive spatial patterns of vegetation properties at high spatial frequency and temporal patterns at seasonal and interannual time scales. An advantage of the high spatial resolution imagery achievable with the ADAR System 5000 is the potential to detect the generally low vegetation abundance signal of a desert landscape.

#### SUMMARY

This paper describes the features of the Airborne Data Acquisition and Registration (ADAR) System 5000, an imaging system which uses four full-frame CCD sensors and the global positioning system (GPS) to acquire multispectral image data at spatial resolutions from 1/2 to 3 meters per pixel. In comparison to remote sensing satellites, the ADAR System not only provides higher resolution images but also allows the user to select the spectral bands acquired and to begin processing the image data as soon as the images are acquired. While spatial resolution of images from the System 5000 is comparable to that provided by airborne scanners, the full-frame format of the System 5000's CCD sensors improves on many spatial inaccuracies which can exist in scanner data, such as line-by-line misregistration and variable pixel resolution caused by airborne turbulence affecting the scan pattern and sensor IFOV dwell time. Although aerial photography and videography provide alternatives to the System 5000 for some applications, the spectral accuracy and direct digital format of the image data provided by the System 5000 yield critical advantages for projects requiring multispectral image data which is rapidly available and easy to use.

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