MAPPING DAMAGES CAUSED BY THE OCTOBER 2003 WILDFIRES IN CALIFORNIA

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ABSTRACT

EarthData, in coordination with ESRI and Horizons, collected aerial imagery for the assessment and mapping of damages caused by the October 2003 wildfires in Southern California, to support rapid response and recovery efforts. Within 14 days, EarthData and Horizons acquired color-infrared imagery with ADS40 digital sensors over the worst affected areas totaling 3,143 square miles. ISTAR-derived orthoimages and digital elevation models (DEM) were delivered to ESRI within 4 weeks of acquisition. State and local authorities had immediate access to these map products to assess damages caused by the fires. The DEM was used for drainage analysis to assess the risk of mudslides over the scorched terrain.

1 INTRODUCTION

In October 2003, California suffered one of the worst and deadliest wildfires in its history. The fires raged through more than 750,000 acres from San Diego to Ventura County in Southern California, causing significant damage to property and loss of life.

EarthData has experience providing emergency-response mapping services, most notably during the recovery efforts following the terrorist attacks at World Trade Center in New York in September 2001 and more recently in the aftermath of the Hurricane Isabel disaster on the North Carolina coast. On October 30, 2003, Congressman Jerry Lewis's office in San Bernardino, California, contacted EarthData to ask if we would acquire aerial imagery to help fire fighters on the ground. Once we made the decision to mobilize our aircraft, we immediately contacted the Southern California fire fighting command centers where ESRI already was working closely with emergency personnel to clearly understand to etheir requirements.

2 CHOOSING THE RIGHT TECHNOLOGY

A quick needs analysis revealed an urgent requirement for accurate and current post-fire imagery to serve three main purposes:

- To provide a reliable, photogrammetrically accurate base map, which we could use to compile new and existing datasets from county, state, and federal agencies, to a common imagery source.
- To observe and capture the extents of burned areas accurately: Imagery provides the most accurate and efficient means to map the extent of burnt areas more precisely than the GPS traces that were used operationally during the fire-fighting operations. Delineating the burnt perimeters on foot is time consuming and error prone.
- To support flood control modeling: With vegetation on mountains and hillsides completely destroyed (see figure 1), the scorched terrain was prone to erosion, flash floods, and mudslides

from excess water running down the slopes. The ability to project and model the extent of flooding and debris flows relies on having excellent DEM as well as imagery to show the type of ground surface (vegetated or unvegetated) in a catchment.

Figure 1: Image of scorched terrain on a hillside. Rainwater cannot be absorbed into the ground.

As a result, EarthData was tasked with acquiring aerial imagery to produce accurate orthoimages and DEMs over the worst-affected areas. Given these requirements and the urgency of the situation, EarthData decided to use the multispectral Leica ADS40 digital imaging sensor. The use of the Leica ADS40 combined with EarthData's exclusive ISTAR® processing technology presented several advantages compared to conventional aerial photography:

- All-digital acquisition, processing, and delivery/distribution
- Simultaneous acquisition of both color and infrared stereoscopic imagery
- Highly-automated ISTAR® processing for fast turnaround
- High vertical and horizontal positional accuracy of orthos and DEM

3 INITIAL PLANNING AND IMAGE ACQUISITION

Given the urgent need for aerial imagery, the main challenge for the aerial acquisition operations was to be able to rapidly mobilize aircraft and crew on site, in order to start acquiring imagery as soon as possible, and then to be able to complete acquisition of all areas of interest in the shortest possible timeframe.

During the next 48 hours, EarthData's Maryland-based aviation group worked day and night to develop flight plans, mobilize aircraft and crew, and obtain all flying clearances, a process which normally takes several weeks. On Monday, November 3, the first ADS40-equipped aircraft arrived on site, ready to acquire digital imagery over the disaster area. To expedite acquisition, a second aircraft and ADS40 sensor mobilized from EarthData's affiliate company, Horizons, Inc., of Rapid City, South Dakota.

The project area comprised three separate areas in Southern California, covering a total of approximately 3,140 square miles:

- Camarillo, CA (825 square miles)
- San Bernardino, CA (973 square miles)
- San Diego, CA (1,345 square miles)

The basis for defining these areas was derived from the GPS traces captured by helicopters overflying the fire lines every night throughout the burning period. Every day during the crisis, ESRI received the GPS traces in the evening and produced maps all night. In the morning the fire crews came in to pick up the maps and develop their workplan for the day.

The mountainous terrain within this area, combined with the weather patterns and smoke from the fires, required special consideration in the flight-planning phase, which ultimately yielded shorter daily flying windows. These considerations were constant factors during the acquisition phase and flight plans were reviewed and modified continually to account for these variables.

During the entire project, EarthData and Horizons aerial operations were based out of airports in Camarillo, San Bernardino, and Ramona.

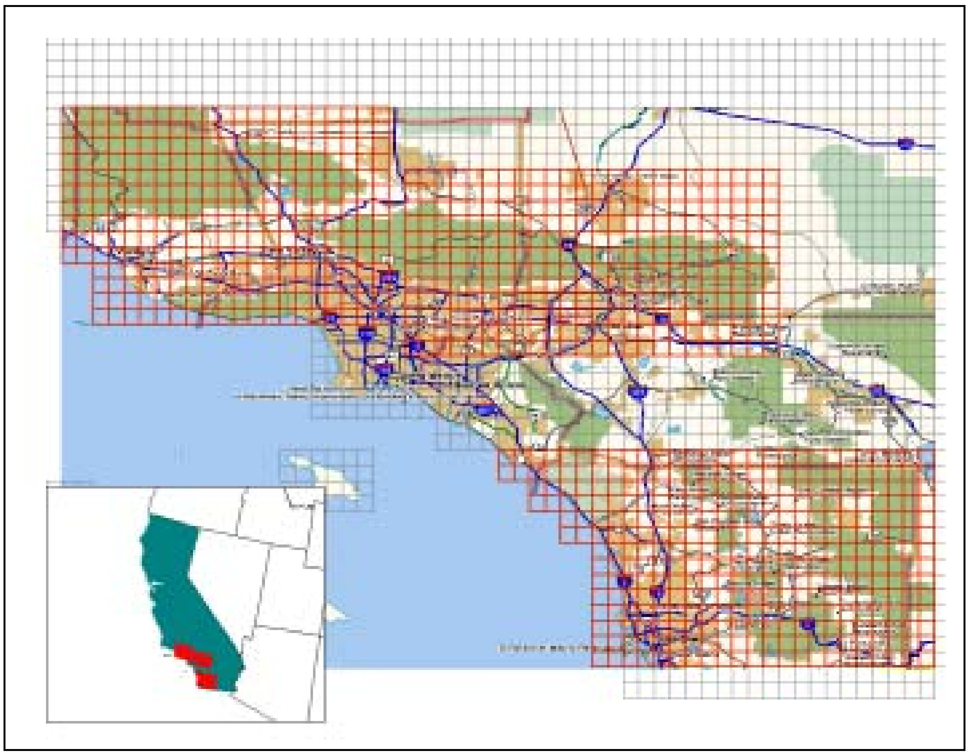

Figure2: Map of the three areas chosen for imagery acquisition shown in red (over USGS DOQQ layout).

4 GROUND CONTROL

Control of the digital orthophotography and DEM was accomplished through a network of GPS ground control points. Emphasis was placed on selection of photo-identifiable points that were located on public property. The use of photo-identifiable features also allowed planners to supplement the control network with additional points if necessary to strengthen the aerotriangulation adjustment (AT). An average of 5 ground control points were used per lift (or sortie).

Airborne GPS operations were supported using GPS base stations that were deployed by the aircrews prior to a data collection sortie. These base stations were located at the airport where the aircraft was locally based.

5 IMAGE ACQUISITION

The ADS40 sensor is a digital push-broom sensor that collects image data in panchromatic, red, green, blue, and near-infrared bands simultaneously and from different viewing angles as shown in the figure below. The imagery is generated from seven parallel arrays of charged couple devices (CCDs) in the focal plane of a single lens system. The characteristics of the sensor are as follows:

- Focal length 162.5 mm
- Pixel size 6.5 µm
- 12,000 pixels (CCD) per band
- Dynamic range of CCD – 12-bits for all arrays

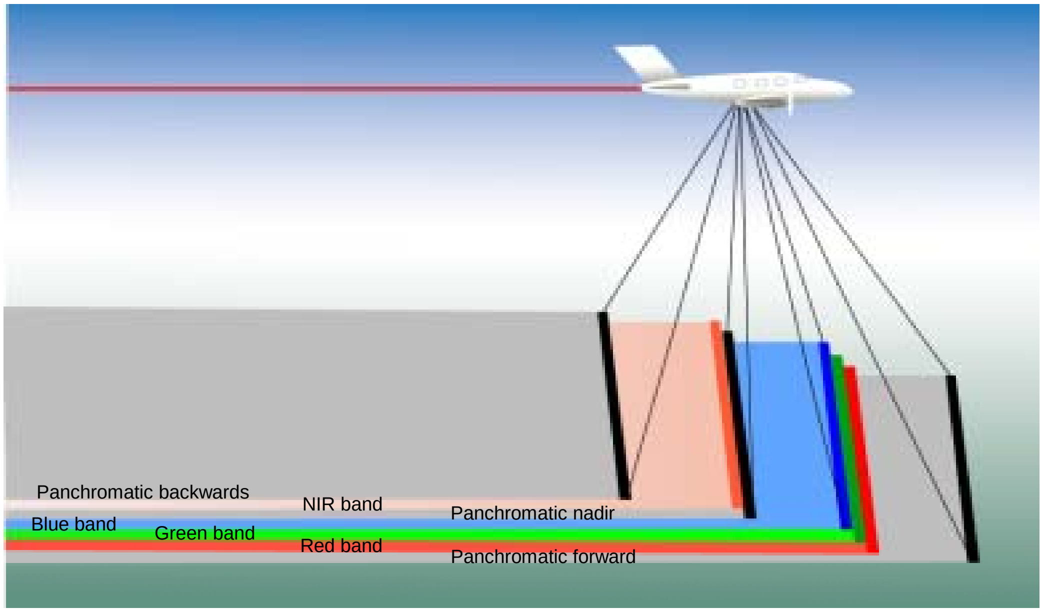

Figure 3: Multispectral band configuration of the Leica ADS40 "push-broom" sensor (courtesy of Leica Geosystems).

The entire area was collected at an altitude of approximately 18,000' for a 50 cm pixel resolution image product. The imagery was collected with a minimum 30% overlap between image strips. The two ADS40-equipped aircraft flew more than 20 sorties and collected aerial imagery of all 3,143 square miles in 13 days between November 4 and 16 2003.

The digital imagery plus GPS and IMU position and orientation data are recorded during each sortie and are written to the mass memory system that is part of the camera control unit. On completion of a mission the hard disk is removed and the data is offloaded onto a storage system at the aircraft's base of operation. The ADS40 can store 540 gigabytes of data, which represents approximately 4 hours of collection time.

As part of the team's quality control process, the aerial data were reviewed on site for coverage and anomalies (e.g. clouds) after each sortie. If deficiencies were identified, a reflight was immediately scheduled. This resulted in a much more streamlined workflow than is found in conventional imagery, wherein reflights may only be identified during film development. When the initial review was completed and the imagery accepted, airborne GPS and IMU data processing was performed to check for anomalies before initiating full production.

6 DEM AND ORTHOIMAGE PRODUCTION

From the acquired ADS40 imagery, EarthData produced and delivered two separate products: a 50 cm resolution color-infrared orthoimage and a 2-meter post-spacing DEM. These products were generated using EarthyData's exclusive ISTAR® processing system, which is a very robust and efficient system. In this project, the system handled data from two separate providers, EarthData and Horizons, and created a fully integrated process with no significant breaks in the workflow or final product.

Using the ISTAR® system, orthoimage and DEM production times were reduced by as much as 40 percent compared to conventional orthophoto generation methods. The ISTAR® processing system is highly automated. At its core lies a series of algorithms that use auto-correlation techniques to produce an accurate surface model of the observed terrain by exploiting data from every ADS40 stereo look-angle. The more processing power, the faster the system can produce orthoimages. EarthData's processing farm dedicated to ISTAR® processing consists of 96 processors (3.2 GHz each) and 16 TB of disk space.

6.1 <u>DEM and Orthoimage Processing</u>

Aerial imagery acquired in each sortie was placed onto the ISTAR® processing farm. The first step in the process is the AT, which is performed per data collection sortie. The ADS40 and ISTAR's effective use of airborne GPS and IMU reduces the number of ground control points needed to only 5 points per lift. Using methods that are similar to AT procedures used for conventional aerial photography, common points between flight lines were selected to tie the adjacent image swaths together. The number of required tie points is minimal, particularly when compared to conventional methodologies. The efficiency of this process greatly reduces the time required for the AT phase.

Using several tools that are part of the ISTAR® workflow, a digital surface model (DSM) is produced at a post spacing of 2 m, using an auto-correlation algorithm that computes the X, Y, Z values for each DSM post utilizing every stereo angle that is available. EarthData removed above-ground features (vegetation, buildings, etc.) using in-house software, initially designed to process lidar data, to produce a bare-ground elevation model for digital orthoimage production.

The digital imagery for each acquisition sortie was then differentially rectified to produce orthoimagery in the false color-infrared rendition (composite of the near infrared and nadir-viewing panchromatic bands) at a ground resolution of 0.5-m per pixel. Mosaic lines were placed between the flight lines running down the entire length of the strip. The process for mosaic line placement follows the same methodology as that used with conventional aerial photography. However, with ADS40 imagery, the time that this process takes is reduced, because the entire image strips can be mosaicked along a single seam line.

6.2 <u>Project Deliverables</u>

A total of 364 ortho tiles of color-infrared orthoimages (see figure 4) and DEM (tile size: 5000 m x 5000 m) and associated metadata were delivered to ESRI within 29 days of receiving the first ADS40 data acquisition. From the onset it was decided that, to facilitate the distribution among all the relevant local users and state and federal agencies, all data products would be delivered without any restrictions. Completed digital orthoimages were referenced to the North American Datum 1983, Universal Transverse Mercator (UTM) Zone 11 projection. The orthorectified images were produced for each area as a single seamless mosaic with a ground resolution (pixel size) of 0.5 m. The DEM was delivered at a 2 m post-spacing.

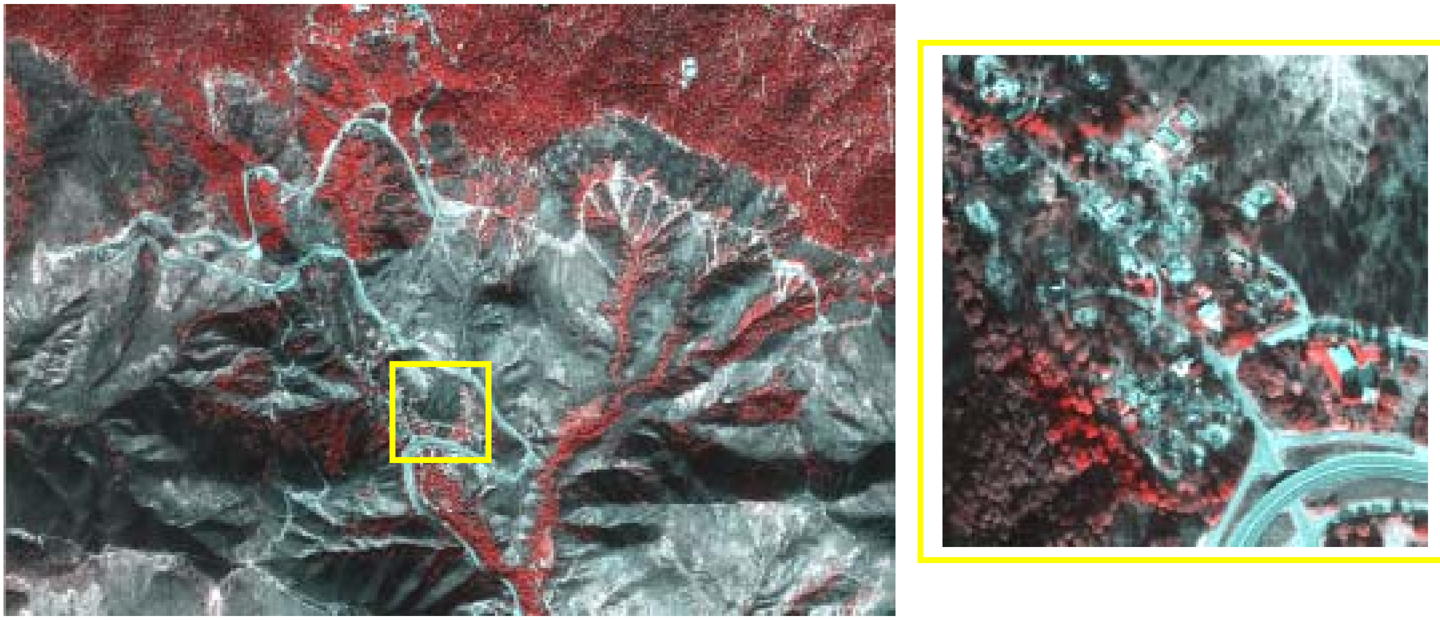

Figure 4: Example of color-infrared orthoimage near Crestline, CA. Healthy vegetation appears in bright red; burnt areas appear in dark gray tones. The inset (outlined in yellow) shows an area where houses were destroyed by the fires.

7 DATA APPLICATIONS

The orthoimage and DEM datasets provided by EarthData were subsequently used by ESRI, fire fighting command centers, and local end-users such as the California State Parks, the Forest Service, the California Governor's Office for Emergency Services, and counties, to support a number of applications, including short-term analysis of damage and recovery efforts, long-term analysis of regrowth of habitats, development of plans to mitigate risks of flash floods, and potentially to reduce damage during future fires of this magnitude. At the time of writing, many of these applications and studies are still ongoing. Following is an overview of some of the initial applications of the products delivered by EarthData during and immediately after the crisis.

In August 2003, ESRI established the Mountain Area Safety Task Force (MAST) GIS laboratory to assist Southern California agencies in managing its drought-stricken national forests (www.calmast.org/mast/public/default.htm). MAST is a consortium of 45 government agencies, private organizations, and volunteer groups concerned about the condition of the forests in the San Bernardino and San Jacinto Mountains.

Two months after the lab was set up, wildfires erupted in the mountains of Southern California and the GIS lab's resources were used to manage and coordinate the emergency services for the wildfires in the foothills of the San Bernardino Mountains. EarthData's high-resolution imagery and DEM registered perfectly with existing vegetation data, land parcel data, and asset location data. This enabled ESRI to provide the San Bernardino County Sheriff's Department, local police agencies, and fire-fighting command centers with ArcGIS-generated maps (see figure 5) based on these datasets, which were used to help carry out evacuations, assess damage, and plan community reentry.

Specifically designed to handle and display very large volumes of raster data, such as the orthoimage and DEM databases provided by EarthData (approximately XXX TB of raster data just for the San Bernardino area), ESRI's ArcGlobe visualization package was used by county authorities to build 3D views of the color-infrared imagery to visualize debris from burnt-out houses and to coordinate clean-up and recovery activities.

The Forest Service and the California State Parks used the color-infrared imagery to delineate areas of public land that were damaged by the fires. Now that the fires are extinguished, the priorities for these agencies are long-term timber management, removal of dead trees, and the restoration of protected habitats. Information derived from the color-infrared imagery and the DEM combined with other data layers within the GIS database, currently provide a tool to address these issues.

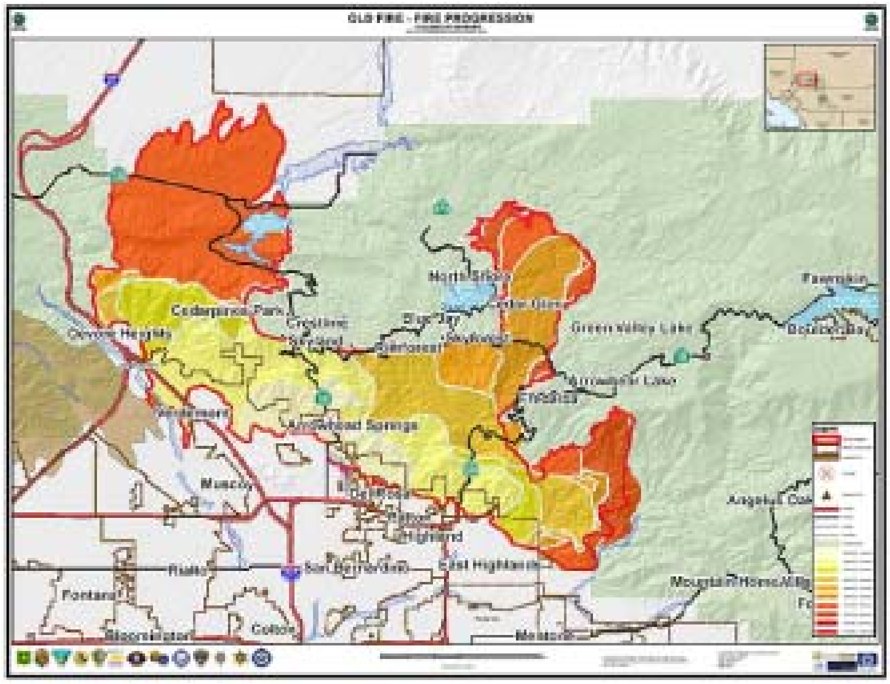

Figure 5: Fire progression map produced by ESRI.

8 SUMMARY

The success of this project was a result of close coordination between EarthData, Horizons, ESRI and local end-users during the planning and production phases. The immediate access to two ADS40-equipped aircraft enabled EarthData to respond rapidly to the urgent need for aerial imagery of the areas devastated by the wildfires. The unrestricted use and distribution of the resulting color-infrared images and DEM provided access to vital geospatial information, which ultimately helped local end-users to make more informed decisions regarding recovery activities as well as for long-term planning and risk mitigation. This project once again demonstrated the suitability of combining ADS40 digital acquisition with the highly effective ISTAR® processing system for rapid-response mapping over large areas.

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