An Integration of Remote Sensing, GIS, and Information Distribution for Wildfire Detection and Management

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Abstract

A disaster mitigation feasibility study, entitled "WILDFIRE," was initiated in 1997. Project WILDFIRE demonstrated the feasibility of integrating civil and commercial communications and information technology to provide operational resources to fire-fighters attacking wildland fires. The demonstration of various technologies occurred during an actual "controlled" burn in a wildland environment in northern California. Real-time data transfer of thermal line scanner data from an airborne platform via a cellular data phone transmission was accomplished, and near-real-time map integration and development was demonstrated using portable uplink/downlink systems to "move" data and asset information (such as vehicle and personnel locations) to a fire camp and a disaster control center. Vehicle tracking was accomplished with the Global Positioning System (GPS) and radio communications to track both fire equipment and field personnel in real time. We focus on the utility and melding of these "off-the-shelf" and emerging technologies in the context of disaster mitigation and response.

Introduction

The Project WILDFIRE Demonstration was designed by the Western Disaster Center (WDC) to demonstrate how a national Natural and Environmental Disaster Data Center (NEDDC) could rapidly process and disseminate data to emergency response personnel in the field. The primary goal of the WILDFIRE demonstration was to demonstrate how airborne fire imagery can be transmitted in near-real-time, geo-corrected, combined with ancillary map information data, such as hydrant locations and structures at risk, and disseminated to fire-fighters in a manner consistent with the California Standardized Emergency Management System (SEMS) and the California Incident Command System (ICS).

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In the event of an emergency, the ICS communicates with an Incident Command Center (ICC), the Operations Section, and Division Commanders. When a forest fire occurs in a remote location, an Incident Command Center is typically established at a location readily accessible by road near the occurrence. The ICC is staffed by fire management personnel as well as support staff consisting of communications personnel, fire behavior modelers, mapping specialists, and, in some cases, photo-interpreters. The ICC maintains contact with the other supporting agencies and coordinates the allocation of resources against the fire. Division Commanders located in the field closer to the fire then receive and use data provided by the ICC to direct their task force operations.

This project focused on demonstrating how these information and communications procedures can be streamlined by providing timely, accurate fire condition data to the ICC staff. This reduces the mitigation and response time, resulting in saved resources and manpower requirements.

Background

Early efforts employing remote sensing data for forest fire assessment relied on aerial photography to map fire damage (Arnold, 1951). Johnson and Thomas (1951) used a Polaroid Land Camera to assess forest loss due to disease and fires. The data were used in "real time" by dropping the prints to fire camps minutes after being acquired. The fire fronts and hot spots were then located on available maps, although logistics problems sometimes slowed the process or led to inaccurate mapping. In the early 1960s, the U.S. Forest Service initiated a fire detection program at the Northern Forest Fire Lab in Missoula, Montana (Hirsch, 1963) to develop a system capable of detecting fires through all normal atmospheric conditions, allowing quick suppression response. The result was an airborne thermal infrared line-scanning device. In 1964, Hirsch listed the attributes of an ideal fire monitoring remote sensing system: (1) detection of fire in its early stages; (2) effective operation day and night; and (3) ability to prioritize fires, distinguishing between dangerous fires and those of no significant consequence. Hirsch noted that the most important characteristic of a fire-mapping remote sensing system was the ability to detect fire size and location in relation to ground features (topography) and forest resources (vegetation and fuel) (Hirsch, 1968; Hirsch *et al.*, 1971). Functionally, all the information must be communicated to fire management personnel for timely fire management decisions. Although these data timing issues were raised over 30 years ago, they are just be-

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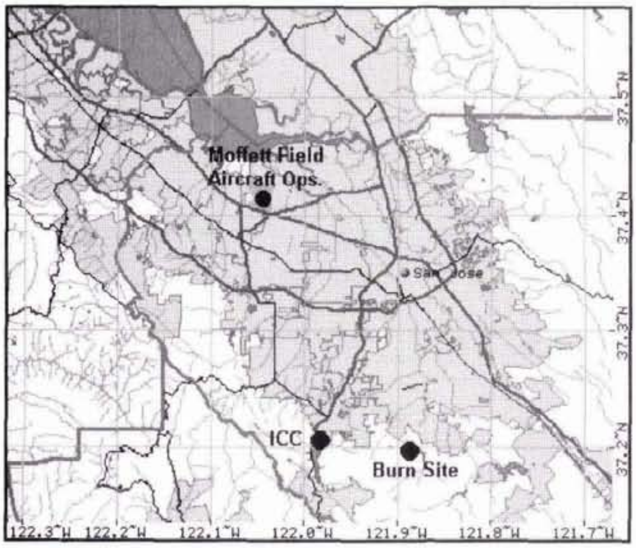

Figure 1. The location of the prescribed burn site, the Incident Command Center (ICC) site, and NASA-Ames Research Center at Moffett Field, the site of the aircraft operations. The water body to the north of Moffett Field is the southern extreme of San Francisco Bay.

ginning to be addressed by the fire suppression agencies. The delay was due to limitations of data communication technologies and to the lack of sufficient experience in the fire suppression agencies in the implementation of sophisticated airborne reconnaissance systems.

More recently, NASA-Ames Research Center (ARC) has cooperated with other federal, state, and local agencies on numerous real-time fire-mapping efforts, including the Ventana Cone, California fire in the early 1970s; the Ojai, California fire in 1985 (Ambrosia and Brass 1988; Brass *et al.*, 1987); the massive efforts in Yellowstone National Park in 1988 (Ambrosia, 1990); the Oakland Hills, California fire in 1991; the Murphy, California fire in 1991; the Dome Fire, Los Alamos, New Mexico in 1996; and the more recent Fork Fire and Lake Castaic fire complexes in California in August 1996. The early NASA-Ames involvement centered on delivering a single spectral band (usually 10.4 to 12.5 μm) of image data via a 915 MHz communications link to a ground-based CRT and video recorder located at NASA-ARC. The data were then interpreted, and fire locations were drawn on a map. Because the data were not geo-rectified, map control was approximate and based solely on an image interpreter's ability to recognize distinguishing features on the recorded data and the paper topographic map. The information was then relayed via overnight mail to the fire manager, a time period too long to assist in active fire management and control efforts. During the 1988 Yellowstone fires, the data link station was set up at Fire Command Headquarters in West Yellowstone, Montana (Ambrosia, 1990; Brass *et al.*, 1996). This allowed an interpreter to provide the same mapped fire information, on-site, in approximately four hours. Although this was a significant improvement, it still was not sufficient for timely deployment of equipment and manpower. The need still exists for the timely distribution of fire location information, geo-referenced to a map base, in a visual format, within one hour or less of actual data collection, as Hirsch predicted in 1964.

After overcoming difficulties in transmitting information to the ground, the greatest hindrance to rapid image exploitation has been the inability to geo-rectify data in real time. Automated geo-rectification requires that platform position and orientation information (metadata) be collected and maintained with the imagery (Buechel and Nichols, 1997; Buechel, 1996). The more precise and frequent these metadata are, the more accurately the image data can be rectified. Highly accurate, automated geo-rectification depends on differential Global Positioning System (GPS) data and a very high precision inertial measurement unit (IMU) providing sensor and aircraft attitude information at high data rates (≤1 sec). However, high relative accuracies may be obtained using selective availability (S/A) 3D GPS where absolute errors on the order of 25 to 90 metres are tolerable. In most cases, these positional inaccuracies are too large to effect disaster suppression efforts. Geo-located data allows immediate integration with geo-referenced based information to enhance visualization, as well as mensuration capabilities. Integration may include "draping" of fire perimeters on digital terrain which has been enhanced with fuels information.

Geo-correction, integration with a digital map base, and information transfer can be accomplished in minutes, rather than hours. The application of these technological improvements will save resources, time, and manpower requirements, and can be accomplished utilizing off-the-shelf components. To be successful, the technologies must place no additional burden on the system operator or aircraft crew; must produce data compatible with current GIS, modeling, and image processing systems; and must result in information readily interpreted by fire management personnel. The demonstration of these technologies for use in fire identification, fire condition, asset tracking, and fire suppression will be the focus of this paper.

Goals of Demonstration

The Project WILDFIRE Demonstration goal was to test civil and commercial satellite communications and information technologies to show that existing capabilities can be used in near real time for fighting wildland fires. Three key technologies were addressed: real-time fire image visualization and data fusion, asset tracking, and data communications. In order to accomplish these goals, a framework was established to simulate an Incident Command Center (ICC) with access to a Regional Disaster Center for the "exchange" of vital information and data sets in near real time during a prescribed fire. The objectives were to demonstrate the ability to obtain airborne coverage of fire and transmit it to the ICC, to track remote assets at a realistic ICC, and to process and communicate associated fire status information to the incident site within 15 minutes.

A prescribed burn was initiated over 16 km from NASA-Ames in the Sierra Azul Range near Los Gatos, California to serve as a target incident. The Incident Command Center was staged over four miles from the burn at the Lexington Reservoir, while aircraft activities were staged from Moffett Field in communication with the ICC (Figure 1).

During the burn, a NASA-Ames Learjet (Model 23) carrying the Airborne Infrared Disaster Assessment System (AIRDAS) line-scan sensor flew racetrack patterns over the fire site, and collected thermal-infrared line-scanned imagery of the burn and surroundings. Imagery from the on-board display was relayed in near real time from the aircraft to the ICC where the imagery was acquired, rectified, and fused in a GIS system. Fusion of the data sets and information on the fire condition were to be accomplished in under 15 minutes from data acquisition in order to achieve the stated goals of combating and controlling disasters in a manageable amount of time.

WILDFIRE Demonstration Site Description

The area selected for the prescribed burn lies at the western edge of the California Coastal Mountains (Sierra Azul Range) at an elevation of 365 m near the town of Los Gatos, California (USGS Los Gatos 7.5-minute quadrangle map). The region is characterized as an open oak and brush woodland with moderate slopes. The area receives an average annual precipitation of approximately 500 mm, with most occurring in the winter months, falling as rain. Summers are dry, and fire potential is greatest from June through late October. The prescribed fire was ignited 5 June 1997 on grassland adjacent to a small man-made reservoir. Due to recent precipitation (morning of 5 June), fire perimeters were small and easily contained by the fire crews on site.

Airborne Thermal Infrared Data Collection

The real-time airborne scanner data collected over the WILDFIRE Demonstration prescribed burn was acquired from a NASA Learjet operating at 2000 m above ground level (AGL). Flight tracks were flown in a repetitive racetrack pattern over the site. This pattern allowed data transmission to the ground receiving station on down-track runs. The altitude and flight pattern were critical in order to transmit the data from the aircraft via a local cellular tower. At higher altitudes (3000 m above mean sea level), no hindrance in cellular transmission is noted and signal strength is adequate for data and communications relay to virtually any location in the continental United States.

The AIRDAS thermal line scanner was flown for this field demonstration. The AIRDAS is a four-channel scanning instrument designed for the specific task of filling a critical gap in airborne imaging of wildland fires and other natural and man-induced disasters. The AIRDAS has been laboratory calibrated to accurately resolve fire intensities up to 873°K (600°C). The integration of two-step linear response pre-amplifiers for the near-infrared and thermal infrared bands allows for a greater range of temperature discrimination than standard linear calibrated pre-amplifiers. AIRDAS data are collected in four filterable EM channels: band 1, 0.61 to 0.68 μm; band 2, 1.57 to 1.70 μm; band 3, 3.60 to 5.50 μm; and band 4, 5.50 to 13.0 μm. Each of the specific AIRDAS bands provides useful information for fire analysis. The visible band 1 is suitable for monitoring smoke plumes as well as distinguishing surface cultural and vegetative features not obscured by smoke or clouds. Band 2 is suitable for analysis of vegetative composition, as well as very hot fire fronts, while still penetrating most associated smoke plumes. Band 2 is sensitive to fires and hot spots at temperatures above 573°K (300°C). Band 3 is specifically designed for analysis of distinct fire temperatures while penetrating the associated smoke column. Band 4 is designed to collect thermal data on Earth ambient temperatures and on the lower temperature soil heating conditions behind fire fronts, as well as the minute temperature differences in pre-heating conditions. Each of the four bands can be filtered to narrower bandpass regions.

The AIRDAS system is composed of a Texas Instruments RS-25 thermal line-scanner, the two-step linear pre-amplifiers, a 16-bit digitizer, dichroic filters for the band passes, an Ampro 386 system control computer, an Exabyte 8500 tape output device, an integrated Trimble TN2000 Global Positioning System (GPS) unit, and a two-axis gyro. The GPS unit is integrated into the scanner output and delivers encoded location information on aircraft position to the header file for each flight segment (scan line). The two-axis gyro sends encoded information on pitch and roll to the control system in order to allow for post-flight correction. A magnetic compass assists in determining heading, allowing for geometric correction. The barometric altimeter data are also incorporated in the header. The system accommodates additional serial interfaces to integrate other avionics navigation systems on airframes that acquire such information.

The field-of-view (FOV) of the scanning optics is 108° cross-track, with an instantaneous field-of-view (IFOV) of 2.62 milliradians. The system, at a designed scan rate of 5 to 24 scans/second, can operate in a flight envelope of 900 to 10,400 m AGL, at aircraft ground speeds of 50 m/sec to 130 m/sec or greater. The AIRDAS has a digitized swath width of 720 pixels in the cross-track direction, with continuous data flow acquired in the along-track direction. These parameters provide a ground resolution of 8.0 metres at an aircraft altitude of 3000 m AGL.

Airborne Data Telemetry System

The configuration for real-time data telemetry for the WILDFIRE Demonstration involved a Flitefone™ 800 air-to-ground digital cellular phone system, a 486 laptop computer, Very Small Aperture Terminal (VSAT) hardware and software provided by Hughes Corp., and intra-ICC computer systems communications linked into the VSAT connection with an Ethernet hub. The system provided AIRDAS scanner data, via a wireless data link, to an Internet site shortly after collection. The data were then accessed and moved to a receiving station on the ground at the Incident Command Center. A single spectral band (black-and-white) image of the current frame of data containing border and header information particular to that image is collected by the AIRDAS operator, and JPEG compressed (~85KB). The data set includes collection time, platform altitude, heading, GPS location on the first line in the image, scan rate, aircraft speed, and platform pitch and roll, again, all for a single point in time. Frame information, such as gain, offset, and spectral channel information, are also displayed (Figure 2). The image file is then transferred to the Flitefone™ and transmitted to the ground. File transfer is on the order of one to two minutes and is accomplished while the aircraft is preparing for subsequent data collection overpasses. Data were collected for three overpasses of the fire. At the time of the demonstration, GPS information was only transmitted for one point on the "freeze-framed" scene, compromising the full geo-rectification capabilities of the system. The future intent is to provide an associated data stream, or file of the vital GPS and platform attitude scan line header information, with the file.

The AIRDAS data were transmitted to a NASA-Ames Research Center controlled file transfer protocol (FTP) site on the Internet. The image files were then sent to the ICC via a geo-synchronous communications satellite (GE-1 positioned at 103° west longitude). The Very Small Aperture Terminal (VSAT) equipment at the ICC consisted of a 2-watt Ku Band ComStream DT4000 transceiver and a 1.2-metre dish antenna. This link operated at 128 kbps, resulting in about a 64-kbps single-session user throughput data transfer rate between the ICC and an Internet gateway located in Vail, Colorado. The VSAT receiving station was co-located with the local area network (LAN) at the portable ICC (Figure 3). Data were transferred onto the local LAN computer system in preparation for geo-rectification. Upon receipt at the ICC LAN computer, the data sets were ingested into the Terra-Mar Data Acquisition Control System (DACS) for further overlay, geo-rectification, and processing.

Information Processing—GIS Data Processing System

Terra-Mar's DACS software, running on a SUN SPARC 5 with 62 Mb of memory and 4 Gb of disk storage, provided the data logging and image processing capabilities for the ICC. DACS consists of an object oriented, spatially referenced, relational database; a raster image processing engine provided by the Interactive Digital Image Manipulation System (IDIMS) software; and a data acquisition control component for managing incoming ephemeris data for the system. The database is designed to ingest streams formatted (and modeled in the

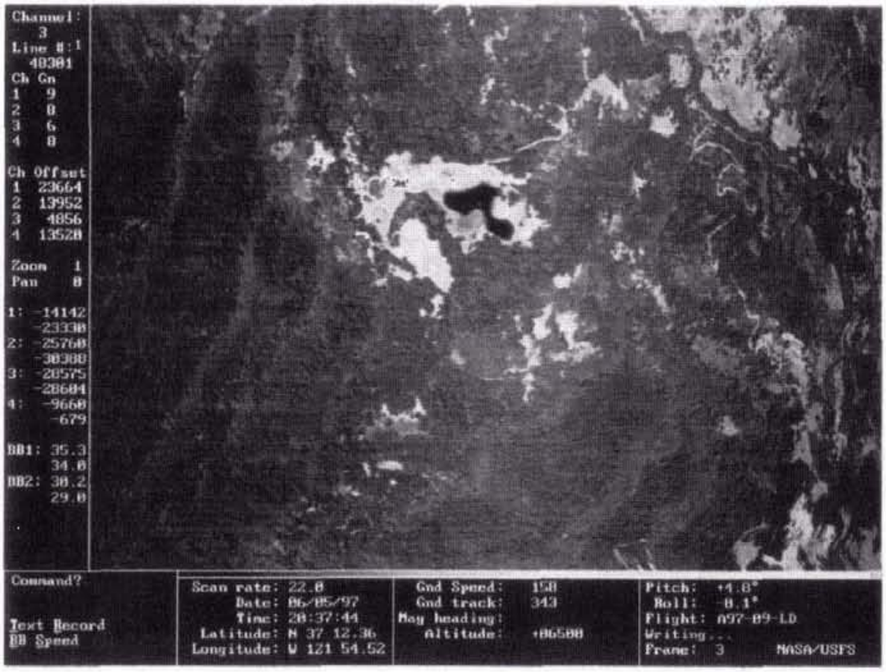

Figure 2. Image captured with the AIRDAS scanner over the prescribed fire. The ancillary data concerning flight and sensor parameters are displayed around the perimeter of the "freeze-framed" scene. The small fire is barely visible to the left of the reservoir near the upper scene-center. The flight and sensor parameters are used to geo-rectify the scene for merging with ancillary information.

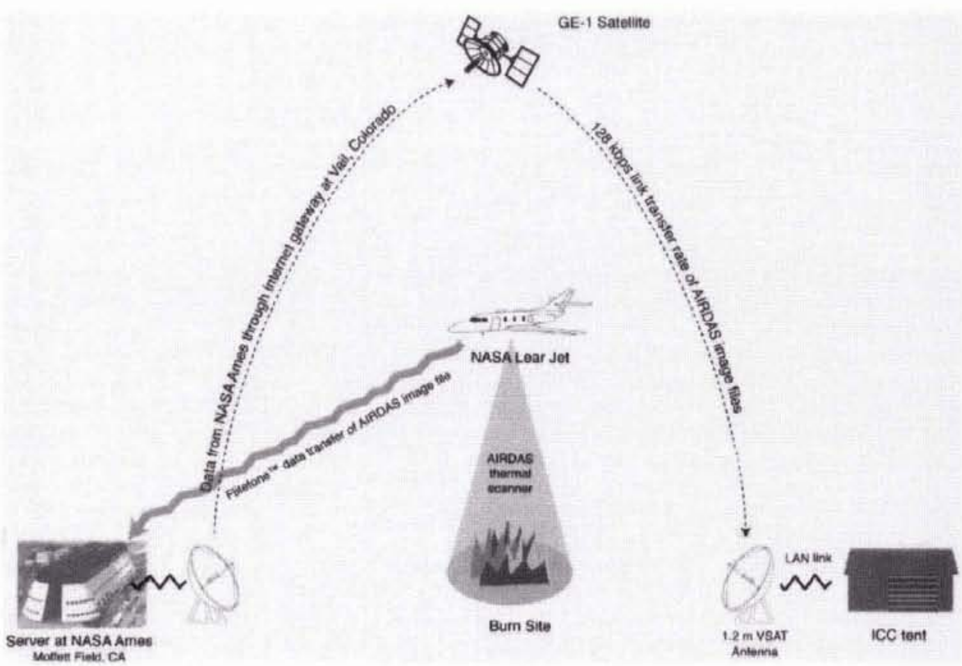

Figure 3. Graphic illustrating the data transfer and connectivity issues involved with real-time aircraft-acquired thermal infrared data. Communications links and computers can be set-up in under four hours at a remote location, such as an ICC.

case of two- or three-dimensional data) by the data acquisition control, and to map them to the display in real time to assist the response team in visualizing incident activities. Formatted streams may be position points, as in the case of vehicle tracking, or calculated image coverages based on sensor geometry models customized for the particular airborne sensor system being used. Once logged, this information, in vector form, may be redirected for overlay on geo-referenced raster imagery managed by the IDIMS image processing component of DACS, used to select imagery for processing, and used to automatically map acquired imagery to create fire status maps.

The Geographic Information System

The geographic information system developed by Terra Mar for use in fire response scenarios illustrated a range of static data types potentially available to a response team. A variety of vector and raster information was converted to a common projection and integrated into the system. These data provided pre-incident condition information as well as incident site data sets (Table 1). Data included the Santa Clara County Fire District (SCCFD) vector database, digitized USGS 7.5-minute quadrangle maps of the region, digital panchromatic ortho-photography at 2.0 m and 0.27 m resolutions, and a Landsat Thematic Mapper-based vegetation classification interpreted into fuels classes. The topographic data of the area were provided by Terra-Mar's digital elevation model mosaic of California produced from USGS 30-m DEMs.

The Santa Clara County Fire District provided it's extensive database in DXF format. These included hydrant locations and detailed parcel and roadway information, among other data elements. Data were re-projected and ingested into the DACS system.

Digital USGS 7.5-minute quadrangles were purchased from the California State Teale Data Center, mosaicked, and re-projected. Quad coverage metadata were stored in the database, allowing searches by specifying quadrangle names. The quads provided a familiar base map for the ICC personnel and response team, particularly for visualizing slope and elevation information in a simple format.

The digital ortho-photography was produced by Terra-Mar from it's photo library. The photography was produced to two resolutions: two metres for an overview and 0.27 metres for selected areas. The digital photography mapped to a two-metre pixel resolution was available for the entire study area. The photography, projected to a 0.27-m resolution, was designed to illustrate the potential detail available to emergency response teams in residential areas from a high resolution imagery source. The higher resolution data set was produced for the Lexington Reservoir region (ICC location) as well as for the prescribed burn site.

Fuels information is a key component of wildfire response decision making. To provide fuels information for the demonstration, a vegetation classification was created for the potential study site from Landsat Thematic Mapper imagery. The unsupervised clustering, based on field checks, was allocated into eight categories: urban, grassland, conifers, two classes of mixed evergreen, oak woodland, mixed built/vegetation, and chaparral. These were then allocated into five fuel classes based on the National Fire Danger Rating System (NFDRS), and the classes were color-coded relative to flammability. This was considered a preliminary map because no accuracy assessment was undertaken. The purpose was to illustrate the use of this particular data type.

Current meteorological data were not collected during the burn and therefore were not used in factoring the fire spread calculations. Meteorological data are an important component of fire behavior modeling but were beyond the intended scope of this technology demonstration. Meteorological data, when collected as point or vector information, can be easily ingested into the GIS to assist in fire behavior modeling.

TABLE 1. WILDFIRE DEMONSTRATION DATABASE

Vector Layers	
Static Layers	**Dynamic Layers**
Roads including widths	Fire perimeters
Parcels with addresses	Hot spot locations
Hydrant locations	Moveable asset location
Water tower locations	
Contour lines	
Hydrology	
Fire History	
Other miscellaneous features	
Raster Layers	
Static Layers	**Dynamic Layers**
Panchromatic ortho-photography	Thermal imagery – time series
Preliminary fuels map	Burned-in fire perimeters
Merged photo and fuels	Burned-in asset locations
Digital USGS 7.5-minute quads	
DEM 30-m data	

Real-Time Information — Vehicle Tracking

A key element for emergency response is quickly updating the database with current information. The asset management and vehicle tracking demonstration illustrated real-time updating for vehicle positions and fire status coverage. The location and status of vehicles involved in wildland fire suppression is required for the tactical and strategic elements of the operation. Placement of these resources is usually ordered by the Incident Command Center by means of verbal instructions over radio networks. The availability of GPS position information makes the determination of asset position relatively easy. The capability to transmit GPS information over a radio network allows the position information to be incorporated into and displayed on a GIS system.

Two days of vehicle tracking demonstrations were planned. The first day's operations involved short-range movement of one moving unit (fire truck) while other vehicles were stationary. The second day, during the remote ICC demonstration, vehicle tracking demonstrations occurred in hilly terrain near the prescribed burn and three moving vehicles were deployed. The complex terrain created frequency "shadow" areas and prevented desirable unit networking, but this situation would normally be anticipated, and signal relay units would be positioned on various ridges or hills to eliminate frequency "shadow areas."

Automatic vehicle position reporting using this technique was successful. A larger network of mobile nodes would both improve and degrade the operation of the system. Additional nodes would improve the inter-connectivity in the rugged terrain, resulting in a more reliable real-time vehicle tracking and mapping capability. Too many modes result in transmissions occurring simultaneously—a communications collision—resulting in re-transmission of vehicle locations and a concurrent reduction in the efficiency of the process. Further study of this method of vehicle tracking is needed to define the optimum solution.

In large wildland fires the number of vehicles can easily reach into the 1000s. An automated position reporting and messaging system would support both the logistical and tactical requirements but may also necessitate the use of multiple frequencies to spread out the communications load.

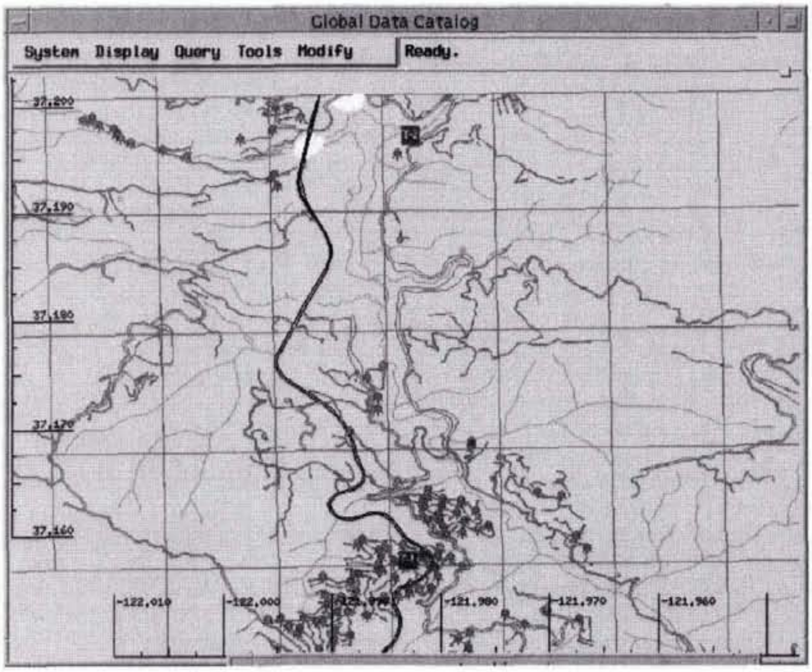

Figure 4. Vehicle position information merged with a vector map base. Two tracked vehicles are identified as "T-1" and "T-2" and can be seen depicted as small squares in the frame. The vehicle movements can be tracked in real time to ascertain their position in relation to the disaster event. Road networks and fire hydrant locations are also displayed in the vector map, indicating potential access routes and water availability.

While this is feasible, the coordination and maintenance effort becomes significant. This is the situation where the amateur radio community could play a role. The techniques and equipment are relatively common within the "ham" bands and, because "hams" usually support the communications efforts, this would be a somewhat natural extension of the role they already provide.

The vehicle position information was transferred to the SUN SPARC computer workstation where it was interpreted, logged, and displayed as an icon on the database vector map (Figure 4). Three vehicles were tracked during the field demonstration with ten-second update rates. The system operator had the option to overlay the position information on the current active raster map on request. This tracking proved extremely useful in identifying a lost vehicle and re-directing it to the appropriate fire location during the demonstration.

Airborne Tracking

The DACS system is designed to receive ephemeris streams from airborne platforms and to map the imagery acquisition coverage in real time. The DACS system requires platform position (GPS), pitch, roll, heading, and altitude information in order to automatically project and map the imagery in a georeferenced format. This information is used in conjunction with a sensor geometry model, which defines the geometric characterization of the imaging system, and digital elevation information. These data elements are then used to geo-correct the resultant scene to a ground coordinate system. Fire status information such as perimeter, area, and hot spot locations can then be interpreted from the imagery. The time required for data processing varies depending on the particular image size, desired output mapping resolution, and computer used. In general, the process may vary from five to fifteen minutes from data acquisition. The geo-referencing of the frame grabs sent to the ICC via the VSAT link took approximately five minutes. This time included that necessary to manually enter the metadata, which was required for this particular sensor configuration.

In this demonstration, no airborne metadata were transferred to the ground as file header information. The available metadata were derived from the quick-look file and were integrated with an AIRDAS image frame grab. Band 3 (3.60 to 5.50 μm) was found the most useful for delineating the active fire locations and was transferred from the Flitefone™ system on-board the aircraft to the Internet FTP site at NASA-Ames in JPEG format and transferred to the ICC using VSAT satellite communications. DACS was modified to allow manual entry of the metadata from the frame grab, at which point the data were logged as a footprint in the database and mapped to a geo-referenced image (Figure 5). Three coverages of the prescribed burn were acquired and mapped during the field demonstration over a 40-minute period.

Fire perimeters were delineated directly on the image data based on the spectral characterization of the burn areas. Areas and perimeter lengths were determined (Table 2). These vector perimeters were logged to the database for use in modeling efforts with other information such as current weather conditions, should those data elements be available.

Results—Data Products Produced

The data flow for the WILDFIRE Demonstrations was highly successful. From data collection overflights at an altitude of approximately 2000 m, three fire status maps were produced at a "wireless" Incident Command Center, powered (as if under actual fire camp conditions) by a generator on-board a Santa Clara County Fire District Hazardous Materials (HAZ-MAT) vehicle.

The three mapped frame grabs of the fire were obtained over a forty-minute period; all produced from AIRDAS channel 3. The images show the short term progression of the actively burning fire in near real time. Fire position and perimeter were determined from the geo-referenced output. Both the dynamic fire perimeters and static vector database were overlaid on the various raster base maps, and hardcopy output was produced. Reports on fire area and perimeter, and a vehicle activity history, were concurrently produced.

Hardcopy output was considered desirable for an incident situation because the prints and maps can be easily handled and shared among ICC personnel. Annotated prints were produced in the field using a Codonix color printer for the three mapped images generated by the overflights. Fire perimeters were overlaid on the merged fuels-photography base map as vector polygons, and printed (Figure 6). The latter was hindered by the poor geo-location information and required manual correction to align with the high resolution base maps. In addition to the hardcopy output, the data files that were produced were transferred in JPEG format to an Internet site for use by the general public.

Vehicle and crew management activities benefited from the live vehicle status information, suggesting significant potential for increasing the safety of field crews in true hazardous conditions. A vehicle in transit from the Incident Command Center at Lexington Reservoir (ICC) to the burn site was determined to be lost based on the vehicle's icon location on the digital map. That vehicle was contacted and redirected via a two-way communication system.

TABLE 2. FIRE STATUS INFORMATION FOR THE 5 JUNE 1997 SIERRA AZUL PRESCRIBED BURN

Image GMT	Perimeter (m)	Area (sq m)	Comment
20:14:05	177 (1st fire)	1979	single hot spot
20:37:44	381 (1st fire)	2416	two hot spots
	94 (2nd fire)	136	noted (1) (2)
20:51:52	187 (1st fire)	905	first fire declining
	202 (2nd fire)	2073	second fire increasing

As a by-product of the asset tracking process, a log of vehicle activity was produced. This is valuable for post-incident analysis and assessment. The entire database is useful for managing and reviewing the data collected both for post-incident analysis and tracking multi-day incidents through time. Over time, the fire history of an area can be automatically constructed and readily available. This would be a significant improvement, as efforts to obtain fire history information for this project were discouraging. In the end, the fire history information was obtained utilizing a hand sketch from an eyewitness on earlier burns in the area.

As part of the demonstration, the image data that had been processed at the ICC were incorporated into a command data file. This was transmitted in voice and/or text form to the Division Commander at the location of the fire using conventional Forest Service radios and SKYCELL transportable mobile satellite phones. Each of these mobile satellite phones is the size of a briefcase and supports 9600 bps data transmission. Using this capability, field commanders can also receive "finished product" imagery and annotated maps from the ICC

Figure 5. The geo-corrected AIRDAS scanner, channel 3 (3.60 to 5.50 µm) data collected over the fire on 5 June 1997. The image file was corrected and displayed in under 15 minutes, allowing the ICC Commander time to deploy resources to combat the fire. Due to precipitation on the morning of the burn, fire size was very small and detection of the "hot spots" was difficult in this scene.

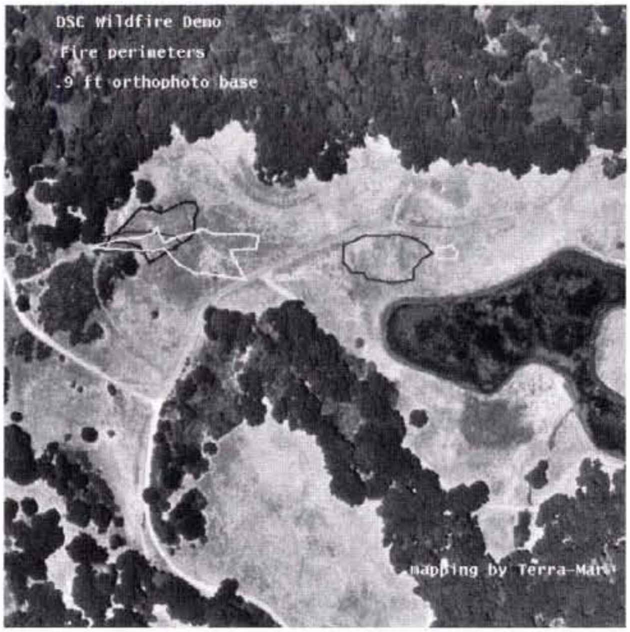

Figure 6. Final fire perimeters from the prescribed burn overlaid on the 0.27-m orthophoto base. The outlined polygons on the left and right represent the two fire areas summarized in Table 2. The black outlined area represents the fire perimeter (Fire 1) ascertained from the first AIRDAS overpass; the white outlined areas (Fire 1 and 2), the second overpass, and the gray perimeter, the third overpass data collection. This information can be used post-event to ascertain the fire movement through various fuel conditions. This information assists the re-vegetation team in speeding the recovery of the affected area.

showing where the fire currently is and where each of their units are presently located. Image files were not transferred to the Field Commanders during the demonstration.

A back-up satellite connection linking the ICC to the "outside world" was also tested during the demonstration using the SKYCELL mobile satellite phone in conjunction with DirecPC and a 0.6-metre receiving dish antenna. DirecPC is capable of downloading files from the Internet at 400 kbps and can be used at remote locations when a lower data rate cell phone or mobile satellite phone is used for the uplink portion of the connection. This makes it possible to download large image files to the ICC if the primary VSAT terminal becomes inoperable.

Verbal reporting to field crews from softcopy analysis for fire movement prediction would be a future goal. This would include incorporating the most recent fire status with fuels, micro-climate, and property information, to allow the Incident Commander to make more informed decisions in allocating resources. This step was beyond the scope of this demonstration.

The image geo-rectification methodology employed is dependent on accurate sensor/platform geometry data to produce highly accurate ground position information. Without P-code or differentially corrected GPS, absolute positions of airborne sensor-acquired data can be expected to be off by approximately 90 metres, as was found with this effort. Compounding this error was the limited amount of airborne platform position and orientation information transferred with the imagery to the ground station. One-second updates are minimal requirements in order to approach high accuracy geo-rectifying and mapping for airborne platform sensors. Two solutions to this issue are to improve the quantity and quality of position information transfer, and/or to provide the operator with tools to improve the information based on manual input of control points. The former is desirable whenever possible to eliminate human error and to support cases where control point location may be difficult to ascertain and select.

Vehicle position and fire imagery were successfully logged, incorporated into, and displayed within, a raster/vector geographic information system, and reported via mensuration information and visual overlay with relevant base maps. Due to the small size of the prescribed burn and the absolute position discrepancies, the subsequent steps incorporating the information provided into possible incident command decisions were not attempted.

The AIRDAS data tapes from the overflights were post-processed using all four spectral bands and metadata sets available. Multispectral data were found to provide improved fire status information. Viewing a composite of AIRDAS bands 3, 2, and 1 as an RGB image revealed significant charred areas not apparent in AIRDAS band 3 (the data band transmitted to the ground station), when viewed alone. The hot spot "snapshots" acquired with the single-band imagery missed the earlier fire conditions which could have been surmised from multi-band imagery.

Final Remarks

The project WILDFIRE Demonstration showed the potential for analyzing and managing data and mitigating disasters in near-real-time using digital data, GIS, electronic data transmission, and current communications technology. Data sets, transmitted from an airborne platform, were mapped and geo-rectified in under 20 minutes. Ancillary information was overlaid with the raster airborne imagery to assist firefighters in allocating resources against the fire. The goal of 15 minutes from "aircraft to map" was hindered somewhat by the data stream of aircraft positional data and sensor characteristics, although these tasks were accomplished within a few minutes of the stated goal. Improvements in the positional data stream information are currently being developed. This will assist in reducing the time allocated for geo-correction of the airborne data. A new methodology is currently being incorporated into the data collection package to better "model" the platform/sensor geometry package to speed geo-correction.

Although the Flitefone™ system proved extremely reliable, data rates are slow due to the bottleneck encountered with data transmission speeds. Other methods for improving transmission speeds are under investigation. One of these methods, incorporating a local area network (LAN) card in the onboard computer proves promising and useable, but data transmission is limited by signal strength to about five miles (line of sight) from the transmitting location to the ground. In instances where various ICCs want to share data or monitor an event simultaneously, that methodology proved flawed. Output products need to be generated more quickly in order to assist in resource allocations. The ICC commanders, gathered around a computer screen, do not provide an optimal situation for information exchange. Without the ability to studio- or theater-project the data to large gatherings, decision making is slowed. The output hardcopy products that were generated were produced slowly, due to limitations of color printers available for this project.

The WILDFIRE Demonstration was beneficial to federal, state, and local resource and disaster agencies responsible for responding to natural disasters, such as wildland fires. Further improvements are needed to optimize the complete system, although the technology is currently in-place, at a low, off-the-shelf price, to affect mitigation efforts under emergency conditions. The authors and their agencies continue to cooperate in correcting shortcomings in the various elements of this demonstration, and continue to assist in dispelling the "mystique" of data collection, remote transmission, geo-correction, and analysis of spatial information.

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