Remotely Sensed Wildland Fire Data and Information Product Processing and Delivery Report

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Due to the quickly-changing nature of various websites referenced in this report, some HTTP locations may not be accurate over time.
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EXECUTIVE SUMMARY

This report provides an overview of current and potential data processing and delivery options for airborne imaging of wildfires. The first section (1.0) of this report focuses on the Fire Incident Command structure, needs, and capabilities, as related to the delivery of fire information products from remote sensing instrumentation. Section 2.0 provides a comprehensive summarization of current airborne research systems and operational systems currently in use or contracted by the resource agencies in the U.S. Various systems and their capabilities are described in detail, as well as an assessment of products generated from the systems, telemetry capabilities (if any) and contact information for further details. Much of this information was coalesced from various reports by the USDA-Forest Service and contacts with company providers and vendors. Section 3.0 provides a comprehensive, detailed, summarization of data telemetry options that are available or in use by organizations, private companies or government agencies. Aircraft –to-satellite-to-ground and aircraft-to-ground telemetry options are reviewed. Section 4.0 includes a review of “non-imaging systems” as a potential information source for fire response needs. Section 5.0 covers new technologies for ground-based data delivery and data access. This section focuses on satellite communications, wireless LAN technologies, handheld (PDA, etc) devices, information access via the Internet and issues related to the employment of each of these methods for data sharing. Section 6.0 provides details on data processing and delivery scenarios for WASP. The section covers issues related to the WASP image product, including data information characteristics, data volume and data format issues. Section 7.0 provides two case studies of actual wildfires and the information access and use by fire personnel and the IC structure. The two fires covered in detail are the Biscuit Fire of Oregon / California and the Croy Fire (California). The two wildfire case studies are presented to give context to the proposed scenarios for WASP data processing and delivery. Section 8.0 focuses on WASP scenarios for data processing, delivery, and product options. The section references the two fire scenarios as examples. Section 9.0 provides a summary and conclusion, while the remaining two sections (10.0 and 11.0) provide a bibliography, references, and works-cited materials, relevant websites and URL information.
1.0 SUMMARY OF CURRENT INCIDENT COMMAND DATA AND INFORMATION INTEGRATION

Map products in paper form have been used extensively to assist in wildfire fighting efforts. Remotely sensed imagery has been a component of these products with delivery for incorporation originally via airdrop. As geospatial technology and improved data delivery methods have arrived in the Incident Command Centers, the options for these products, both in content and quantity, have increased. The need for standardization of these products has been a key recent finding of the Geospatial Task Group, a sub-group of the multi-agency Information Resource Management (IRM) Working Team (Sorbel et al., 2002) and significant efforts to achieve this goal are already evident through published standards, the briefing Maps presented on various web sites, and the advent of standardized fire perimeter databases such as provided by the US Geological Survey (USGS) GeoMAC web service (http://www.geomac.gov).

Information needs for products have been divided into three categories:

- the Public
- the Field Crews, and
- the Incident Command.

Efforts to provide information to the public have expanded in the last few years via a myriad of web sites providing daily updates and perimeter maps in addition to evacuation status, road closures and shelter information. During the Biscuit Fire in Oregon, 2002 each Type 1 Team provided a daily written status report via web site and telephone. Photos are provided as available and these sites are used by the families of the fire crew to keep in touch with the situation. Television access in the Incident Command Center may be used to monitor the information being provided to the public for accuracy. (Note: During the Oct / Nov 2003 Southern California wildfires, the general CDF incident information was a day or two behind so these sites must not be the “tactical” ones. Also the GeoMAC web site sustained continuous heavy connection volume use during the event making dial-up connections very slow).

Field crews require accurate maps for orientation and escape and safety zone access. Their current access to immediate fire status beyond their visual field is via radio. Field crews include ground teams such as strike, dozer, engines, as well as air-access crews such as hotshots and rappel teams. Field crews may return daily to the Incident Command Center or create camps in closer proximity to the fire to minimize travel time. The ground-access crews may be vehicle based, or may have to hike in as was done in portions of the Biscuit Fire where there was no other access. Both night and day shifts may be staffed if necessary. In addition to the fire fighting field crews, Field Observers travel to the fire specifically to record information for incorporation into the Incident Action Plans. They may travel by truck or by aircraft, generally a helicopter collecting fire status information. They may be equipped with GPS, digital cameras and notebook computers or hand held computers.
The Incident Command manages both tactical and strategic operations. They require information on dynamic factors such as the current state of the fire (perimeter, fire front, hot spots, behavior), asset location and status, and weather information in as timely a manner as possible. They need information on static factors such as the fuels in the region, water sources, jurisdiction, features to protect, hazards etc. For fires which continue uncontained beyond the initial attack (first 24 hrs.), formal daily strategic assessment is required each morning with pertinent materials prepared during the previous night / early morning hours. Remote Sensing thermal-infrared flights have traditionally been flown at night to minimize the effects of solar radiation on image brightness (false positive detections). The current procedure is for these data to be processed and manually transferred to base maps by Infra-Red Interpreters (IRINs) for incorporation into the mornings briefing maps by the GIS technician. When assigned, the Incident Meteorologist (IMET) is responsible for monitoring the local weather and is usually brings mobile equipment which must be set up. The Fire Behavior Analyst (FBA) is responsible for using all this information to predict the fire behavior.

This report, addressing issues related to data processing and delivery for support of wildfire suppression, focuses on the latter two needs i.e., information needs for field crews and the Incident Command Center.

1.1 SUMMARY OF THE INCIDENT COMMAND STRUCTURE

The Incident Command Structure consists of an Incident Commander with a general staff consisting of the chiefs of logistics, planning, operations, and finance. Some Type 1 Incident Commands are also including an Information Section with a Web Manager position.

The Planning Section oversees the Geographic Information Systems (GIS), Fire Behavior Analysts (FBA) and the Infra-Red Interpreters (IRINs) as well as the Incident Meteorologist (IMET) if one is assigned. The Situation Unit Leader directly manages these efforts. This is the section to which data are delivered and in which the processing and interpretation for map preparation occur. Information provided by the Planning Section feeds the strategic planning efforts. Every National Type 1 Incident which is not contained within the first 24 hours is required to run the standardized WFSA (Wildfire Situation Analysis) nightly which is a formalized system for generating various scenarios for fighting a fire based on current conditions, predicted conditions, available resources, and associated cost. This results in an Incident Action Plan, which the Operations Section carries out. The IR data acquisition will involve the Air Operations Group. Tactical data delivery, such as asset tracking, would also likely fall under the Operations section.

Several recent reports have examined the incorporation of GIS in ICCs (Albright et al, 2003; Burchfield et al, 2002; Sorbel et al, 2002; Zajkowski, 2003; Hardwick and Fox, 1999; The Incident Command Handbook, 2002; Andrews and Bradshaw, 1997). The facilities are currently often “rented” including a trailer complete with computers, printers, and networking equipment. The staff may be contracted or federal employee personnel. Some Teams have a GIS technician assigned and others request one as...
needed. There has been interest expressed in providing the facilities in-house in the future due to the high cost of contracting GIS technology and labor. The Oregon Department of Forestry and Minnesota Department of Natural Resources have outfitted mobile trailers specifically for mapping and spatial analysis (Needs Assessment, 2003; Kinslow, 2001). The Geospatial Task Group report (Burchfield, et al. 2002) found a wide variety of skills and success levels in five fire camps they visited in 2002 resulting in recommendations for standardization in products, data formats, and training. Consistent facilities provided in-house should help with system standardization issues.

Federal Government agencies have defined standards for processing software and data formats. The majority of the resource agencies have “contracted” the use of the Environmental Science Research Institute (ESRI) products (ArcInfo, ArcView, ArcGIS, and ArcIMS) and standardized on the GeoTIFF image format, and the ESRI shapefile vector format for their products. There are standards for meta-data in support of products (ISO 19115 for example), though full implementation of these standards is moving slowly. The States and local groups may use different information processing tools including in-house developed software. The standard projections and datums used for base maps vary between states, which can be an issue for incidents crossing state boundaries.

The Fire Behavior Analysts (FBA) studies the fire and attempt to predict its behavior to assist in strategic planning. There are several models employed by the fire fighting community, most commonly BEHAVE, which has no spatial component, and FARSITE, which has a spatial component. For a review of various models see FIRES Final Needs Assessment Report (IAGT, 2003). A current fire perimeter can potentially be a useful information layer for this process (Buechel, et al. 2000).

As mentioned, the IR Interpreters (referred to as IRIN) are the current means of producing fire perimeters from infrared imagery. An IRIN is a requested resource, not a permanent member of a team in the IC structure. They interpret the fire perimeters by eye from the non-rectified imagery, transferring the information to a line on a map. Because infrared imagery is traditionally flown at night, the perimeters are interpreted to produce maps for the morning briefing. Though the IRIN’s manually interpret the imagery, they use computers and software in doing so and are probably the closest to remote sensing analysts available at the fire.

1.2 INFORMATION NEEDS
Information needs can be divided into the three categories defined above, public, field crews, and incident command.

The public needs to know where the fire is, what roads are affected, what evacuation warnings are in effect, air quality conditions, evacuation details and shelter locations. Innovative warning systems have been suggested and prototyped to assist in individual home notification (IAGT, 2003). Door to door notification was used in the 2002 Croy Fire for mandatory evacuations and is still common.
The field crews need topographical details for their work area including safety zone locations and escape routes. Fire location and behavior, changing weather conditions and fire behavior predictions help insure crew safety. It would be useful for the camp to know their position via GPS allowing constant monitoring. It would be useful for the crew to have their position overlaid on a map in real-time, particularly the air-access group.

Incident Command needs static information such as terrain, structures and hazards, water sources, and key resources (such as endangered species, habitat or critical watershed), items available for most GIS applications and generally downloadable once, for example, to CD-ROM for use at the ICC. Dynamic information needs such the fire perimeter, front, characteristics and behavior, fire lines, and asset locations require continuous timely delivery and are the focus of this report.

1.2.1 Current Product Standards
Standards are emerging. According to the GIS Technicians (GIST) Handbook the following products will be produced:

- Travel maps
- Briefing sketch maps
- Incident Action Plans
- Fire Progression Maps (secondary)
- 3-D shaded relief (secondary)

Web sites are commonly used to post this information for public access, and also for within team exchange. The CDF Incident sites (http://www.fire.ca.gov/cdf/incidents/) and others are beginning to show consistency in presenting travel maps, briefing sketch maps, and occasionally the two secondary maps. Based on the postings during the Southern California Wildfires of 2003, there does seem to be a trend to replace these with more generic “public” maps simply showing a perimeter overlaid on a base map with roads and locations, keeping the working maps in private space requiring a login. The web sites of the National Incident Management Teams (IMT’s) show similar working maps in addition to daily status information reports (see example: http://www.nartc.net/pnw_t2). Sometimes a satellite image will be posted for large fires, but airborne IR imagery is not, at least on the publicly accessible sites, probably because it is often currently provided as a paper strip map, or because it is not considered a product in itself. Satellite imagery of fires is provided on ancillary sites such as GeoMAC and http://activefiremaps.fs.fed.us/index.html, which provides MODIS imagery for fires greater than 10,000 acres.

1.2.2 Data Presentation
Status and plan maps are currently printed in large format and displayed on the briefing room wall and central locations of camps (GIS Technicians Handbook, 2002; Figures 66,67). Digital versions are later posted later to web sites. The Biscuit Fire web site (http://www.biscuitfire.com) has a gallery of pictures many of which depict the map displays in the camps.
1.2.3 Base Map Information (Static)
In order to produce the products certain “static” (in the time frame of the fire) base information is required. These appear to be generally downloaded to CD-ROM for a particular incident and transported to the incident by the GIST (Burchfield, 2002). State, County or federal repositories may be the source.

Raster data sources include Digital Raster Graphics (DRG’s) that are basically scanned USGS Quads, value added DRG’s such as the National Geographic TOPO! product and the DeLorme TOPO product, Digital Elevation Models (DEM’s) generally a USGS 30 meter product though SRTM 1 arc second products have become available, and possibly USGS Digital Ortho Quarter Quads (DOQQ’s) though these have not appeared in the examples posted to web sites, and Single Edition Quadrangles (SEQ) which are DRG’s which have been updated by the Forest Service. A fuel classification is a very useful and necessary product for fire behavior prediction, which may or may not be available.

Useful vector information includes roadways, ownership boundaries, hydrology and water sources, key resources such as endangered species habitat or public watershed boundaries, addresses, hazard locations such as power lines or power plants. This information may be maintained by county or even local fire departments or planning agencies.

1.3 CURRENT COMMUNICATIONS - CHAIN OF COMMAND ISSUES
Fires are generally reported locally, often by a citizen, but sometimes by an aerial observer. Initial response is local with responsibility determined by land ownership. When local resources are depleted, the Geographical Area Command Center (GACC) of responsibility comes into play with a national level of support serving as the final resource through the National Incident Command Center (NICC) located at NIFC in Boise, ID. In the case of fires with mixed land ownership responsibilities, Unified and Inter-agency Commands may be formed to co-operate in the strategic aspects of battling a fire. In this case all agencies are represented, with one assigned the Command.

An Area Command, or other coordinating group may manage resource allocation and logistics during high fire periods, while the Incident Command Center manages both strategic and tactical planning (among other things). Large and complex fires, such as the Biscuit Fire in Oregon/California, 2002 may have separate Incident Management Teams (IMT’s) for different sections of the fire.

Airborne IR coverage will generally be requested only for fires under management by a Type 1 Team. Type 1 Teams represents the greatest training and expertise level and respond to the more complex fires. Efforts are being made at the federal level such that one can assume a Type 1 Team will include both GIS support and, at least a dial-up Internet connection (Greenfield, 2003). The fire will be relatively large already, and a “Base” structure will be in place. In cases of large fires covering multiple jurisdictional areas, Unified Commands may be created including members from each jurisdiction. One Team will be assigned the command. In extreme cases, a very large fire will be
divided into zones, each with its own command. The “Area” Command prioritizes and coordinates resources in such situations. Any level of command may be “unified” to deal with multiple jurisdiction situations. To request federal infrared support, the Incident makes a written request to the appropriate GACC who forwards a request for IR coverage to NIFC where the order is processed (http://www.fs.fed.us/fire/niiced/Infrared/). According to this web site the cost of obtaining a federal IR flight is $5000 - $10,000.

1.3.1 Voice Communications
Radio dispatch is used for asset requests and assignments. Radio is used for aerial observer communications (see the Biscuit Fire chronology) as well as field crew communications. CDF has five statewide MCC (Mobile Communication Centers) that support dispatch consoles, a HAM station, three scanners, four cell phones, a satellite phone, a TV and VCR (as well as computers, printers etc.). The vans are stocked with 12 different kinds of hand-held radios. Local HAM radio operators may be called upon to assist in communications. The Final Needs Assessment (IAGT, 2003) discusses general communications systems in section 5.2.7 (p. 150). Radio communications are of interest because it is possible for appropriate radios to be used to transfer small amounts of data such as a location or perhaps a vector fire perimeter.

1.4 Current Geospatial Information Technology Capabilities
Current geospatial information technology at the fire camps has been well documented (Burchfield et al., 2002; IAGT, 2003). GIS trailers complete with computers, printers, and network capability are generally rented though the trend is toward providing mobile capabilities in-house due to the high cost of rentals (see Section 2.2.4.3 and 2.2.4.9. for examples of costs). Capabilities vary by state. Both Oregon and California have GIS support for Type 1 Teams. NIFC has a goal for every National Type 1 Team to have GIS capability (Greenfield, 2003). The Minnesota Department of Natural Resources has had a GIS trailer, the “Mapmobile”, in operation since 2000 (Figure 1). It was first employed at the World Trade Center Disaster where it provided GIS support for two weeks (http://www.ra.dnr.state.mn.us/mapmobile/). The trailer is equipped with a DirecPC satellite Internet receiver and dish, along with two Dell workstations, digital cameras, ArcGIS™, ArcView™, and ERDAS Imagine™ among other support software and hardware items.

The current IR interpretation methodology has been described (Section 1.1). The IRIN position is not a member of a particular team, but is ordered as needed. On some national inter-agency teams (IMT’s) the GIS technician (GIST) position works similarly. Others have one assigned in their roster. As previously mentioned, many of the West Coast IMT’s have a web manager assigned.
GPS use is prevalent, though not formally incorporated into the ICS system, and perimeter definition using GPS (either ground or helicopter) is an accepted means of acquisition. The fire perimeter standard includes an item for method of acquisition, which is either IR interpretation or GPS derived. GPS use has been described in the Final Needs Assessment section 5.3.3.1 (IAGT, 2003, p 159). As described there, GPS was incorporated with hand held computers for fire perimeter mapping of the Viejas Wildfire in 2001. This effort is further described in Section 5.1.3.

The Pacific Northwest Interagency Incident Management Team 3 has been experimenting with satellite communications between field observers and base camp and between base camp and their web managers. A satellite Internet connection, for this group, is the norm. See Section 1.5 for more details.

1.4.1 Trends

Many of the current problems identified in the Burchfield et al. (2002) study point to issues that are related to standardization and training (projections used, consistent units, procedural). As an indication of the direction things are heading, the Interagency Fire and Aviation Management Information Systems Workshop in 2002 listed as their recommendations for Fire GIS:

- Perform a cost analysis of GIS services on fires,
- Setup an interagency FTP site to facilitate sharing of data,
- Ensure reliable Internet access on scene,
- More IRIN and GIST cooperation, and
- Data standard development.

Discussions also addressed the possibility of a central website to manage information from all incidents and improve consistency. Hand held computers are seen as increasingly useful along with GPS tracking of assets. At the national level, analog radios are being, or have been replaced with digital radios.

A 2003 Resource Management Tools Conference (BLM, 2003) program focused on issues related to new technologies for data management in the Fire section. Vendors such
as Spatial Data Technologies, California CAD Solutions, and AutoDesk presented their products for web served data management and visualization. Government speakers addressed new program developments such as GIST training programs and the “required interaction procedures between IRIN’s and GIS specialist on large files” (BLM, 2003).

1.5 **HISTORICAL AND CURRENT REAL-TIME DATA DELIVERY**

The first fire imagery delivery methods involved IR film, dropped in canisters into camp from aircraft. Phoenix data is currently delivered on CD-ROM after landing. CDF’s AIRIS system experimented with using satellite phone to transfer vector perimeter data with the alternative via removable hard disk after landing. A system developed by Terra-Mar for CDF used wireless LAN technology in 1997 to deliver vector perimeters to a ground station (though this did not get beyond the testing phase due to funding issues) and removable disk for raster imagery. NASA Ames has demonstrated satellite telemetry and wireless LAN imagery transfers for raster imagery. Section 2 lists all the systems currently recognized by the USDA-FS and their processing and delivery methods where known.

Visual observation and reporting can be a large portion of current “data delivery”. The Incident Command system incorporates the position of Field Observer whose job is to collect information in the field. Visual aerial reconnaissance was used extensively in the early stages of the Biscuit Fire from fixed wing planes as well as helicopter in the case of remote fires.

The Pacific Northwest Interagency Management Team 3 discusses efforts they have made to test and implement new technologies ([http://www.nartc.net/pnw_team3](http://www.nartc.net/pnw_team3)). Their “Techno-Tips” listing (see References section) describes successful use of a private vendor two-way satellite connection to provide ICP access to their web staff during the Lakeview Complex Incident near Medford, OR in 2001 (Figures 2 and 3). They also successfully employed internal wireless LAN’s within the ICP. This effort resulted in a “Cut the Wire” vendor specification for requesting such support on an Incident (this spec is available on the Team 3 web site noted above). They specified access bandwidth no less than 200kbps down and 30kbps up.

This Team has also experimented with the transfer of documents and photos from the field to the ICP using Glentel mobile satellite/radio phones (ST200 Mitsubishi terminal phones) attached to notebook computers and developed a detailed written guide for the process which is available on their website. The maps were edited in PowerPoint and transferred as jpeg images. The photos from the digital cameras were processed using LvPro software to reduce them to 10-50k for transfer. Information on the software they use for image processing, including animated fire progression displays is provided on the website. They established a central web site ([www.agencydocs.com](http://www.agencydocs.com)) to be used by all incident personnel.
Figure 2. Lakeview Fire Complex
From PNW Team 3 web site. Note the DeLorme product used. First use of satellite for Internet access by Team 3 in 2001.

Figure 3. Lakeview Fire Complex ICC
Located at the Lakeview Fairgrounds and Lakeview Airport with Mobile FAA Tower.

Web sites are being used in many situations to quickly make data and information accessible to people. The GeoMAC site provides a means for fire personnel to upload fire perimeters, and the NASA Ames FiRE website provides access to AIRDAS telemetered data within minutes of its acquisition. Non-imaged data, such as RAWS, is available over the Internet from NIFC (or directly via NESDIS). NIFC provides an ftp site for transfer of imagery from their IR systems (ftp://ftp.nifc.gov).

1.6 PERCEIVED NEEDS – THE WASP SPECIFICATIONS
The WASP system specifications (Project Overview, 2003) call for output imagery no coarser than 5m resolution and a one-hour product delivery window, with 15-meter
locational accuracy. Imagery is to include .5 kilometer of coverage outside the current fire perimeter. Tactical needs require coverage in as close to real-time as possible, but strategic needs are currently met with daily overflights so the inability to meet tactical timelines does not fail strategic needs. No fixed wing imaging system currently feeds directly into tactical level strategy. This is a factor of accuracy as well as timeliness.

The requirement regarding detection of small hot spots is a search issue rather than a monitoring issue (WASP specification of detection of fire size of 0.25 m at 600°K). It isn’t required for general monitoring of the perimeter and fire front and fire characteristics (flame, intensity, burned area, smoke). It is key in mop-up operations when it is important to detect any possible re-ignition locations. Re-ignition has been a factor in several deadly fires including the Oakland Hills Fire of 1991 and the Arrowhead Fire (San Bernardino National Forest, CA, 2001), which was a prescribed burn that re-ignited to become an uncontrolled wildfire. It may also be an issue in fire detection efforts for regions of known hazard such as the Kalimopsis Wilderness Area in July 2002 when high fire danger combined with predicted lightening storms to create the complex of fires that became the Biscuit Fire.
2.0 CURRENT AIRBORNE FIRE IMAGING SYSTEMS

There is an increasing number of fire imaging systems in various stages of development and use within the United States and Canada. These systems can be categorized as either “research” instrumentation or “operational” instrumentation (some systems are categorized as both research and operational). The following sections categorize and discuss the capabilities of each of these known research and operational systems. Included also is a description of the design characteristics, products, capabilities and processing scenarios for each airborne instrument.

2.1 RESEARCH INSTRUMENTATION

Research instrumentation is defined as those airborne imaging systems that are primarily utilized for scientific investigations of fire phenomenon (or other thermal analysis). A few of the instruments described here are also categorized as operation instrumentation due to programmatic, software, or hardware modifications that allow their use for supporting wildfire imaging on an “as needed” basis. Most of the systems described herein are line scanner systems, except for one thermal video system and one microbolometer detection system.

2.1.1 Airborne Infrared Disaster Assessment System (AIRDAS)

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 system is composed of a Texas Instruments RS-25 thermal line-scanner, the two-step linear pre-amplifiers, a sixteen-bit digitizer, dichroic filters for the band passes, and a Pentium system control computer. The AIRDAS contains an integrated Motorola® chassis-mounted Global Positioning System (GPS) unit, and a Kennedy® two-axis gyro. The GPS data are integrated into the scanner output and provide 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 integration of improved heading information has also been undertaken on various aircraft integrations of the AIRDAS system. The GPS altitude information is also included in the header stream. The system accommodates additional serial interfaces to integrate other avionics navigation systems on airframes that acquire such information. INS data is encoded into the data stream and the AIRDAS allows for incorporation of high precision information (IMU) via minor modifications to the data stream.
Table 1. AIRDAS System Configuration and Characteristics for Payload Operations

| System Composition: | Texas Instruments® RS-25 thermal line-scanner optics; Non-linear detector pre-amplifiers; Sixteen-bit Digitizer; Dichroic filters for spectral channel separation. |
| Control Computer: | Pentium® I Pro 233 MHz system; On-Board ETHERNET; SCSI; High-speed serial ports running QNX OS; Kingston® 18.0 GB removable hard drive storage device; Integrated Motorola® Chassis-Mounted GPS Receiver; Kennedy® 2-axis gyroscope |
| Weight and Power: | Scan Head: 95 lbs.; Control computer and peripherals: 70 lbs.; Requires 28V DC @ 20 amps |
| Sensor Parameters: | Quantization: 15-bit true (signed 16 bit) FOV: 108 degrees IFOV: 2.62 milliradians Scan Rate: 4-23 scans/second Digitized Swath Width: 720 pixels Spatial Resolution: 26 ft. (8m) at 10K ft. NEΔT: Band 2 and Band 3: <0.5°C @ 500°C Temperature Sensitivity: 1.0°C/DN / 0.2°C/DN (non-linear two-step pre-amp; below and above breakpoint) Thermal Calibration Temp: ~700°C |
| Spectral Configuration: | Channel 1: 0.64 – 0.71 µm 2: 1.57 – 1.70 µm 3: 3.75 – 4.05 µm (narrowing filter available) 4: 5.50 – 13.0 µm |
| Airframe Compatibility: | UAV ALTUS, UAV ALTAIR, Cessna Citation, USFS Piper Navajo, NCAR King Air, Lear Jet (Model 23 and 25), NASA C-130B, P-3 Orion, other aircraft options. |

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 5-24 scans/second, can operate in a flight envelope of 3000 to ~40,000 foot AGL, at aircraft ground speeds of 100 to 260 knots 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 meters at an aircraft altitude of 10,000 feet AGL (Table 1).

AIRDAS data is collected in four filterable EM channels: band 1, (0.61-0.68µm); band 2, (1.57-1.70µm); band 3, (3.60-5.50µm); and band 4, (5.50-13.0µm). Band 2 is sensitive to fires and hot spots at temperatures above 573°K (300°C)(Riggan et al., 1993). Band 3 and Band 4 are calibrated for high temperature resolving.

The AIRDAS is laboratory-calibrated to resolve fire intensities up to 973°K (700°C). Accurate higher temperature discrimination of the thermal channels is possible but is restricted by the peak temperature efficiency of the laboratory calibrated thermal source.
in use (max at ~700°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. The NEΔT of band 2 and 3 is <0.5°C at 500°C. A narrowing band-pass filter can be integrated for channel three, narrowing the channel to 3.95-4.05 µm, allowing for accurate temperature discrimination, but restricting the energy transfer to the sandwiched detector channel 4. Integration of non-linear response pre-amplifiers for the near infrared (channel 2) and thermal-infrared (channel 3) allows for a greater range of temperature discrimination than standard linear calibrated pre-amplifiers. The pre-amplifiers allow for two distinct, non-linear temperature discrimination curves to be developed. For low temperatures (30-100°C), discrimination is approximately 1.0°C/count, while in the higher temperature portion of the non-linear curve (500-600°C), discrimination is approximately 0.2°C / per count in the mid-infrared thermal channel 3.

This design allows for discrimination for low temperature earth ambient targets, and also discrimination of discrete temperatures emitted by a variably hot target. The AIRDAS has been flown on numerous platforms and can be integrated into both manned and unmanned aircraft with modifications. Three versions of the control electronics exist to allow for various operational considerations (manned vs. unmanned). Two of the operational versions are shown above in Figure 4.

The NASA-Ames team has been experimenting with increasing the real-time information flow and data type of the AIRDAS instrument. This research has involved the investigation of different band combinations for real-time telemetry, data compression and transmittal methodologies, and development of large-area image flight-line georectification and mosaicing techniques. The AIRDAS can provide 3-band color composite imagery in near real time (via telemetry) by transmitting a “screen grab” from a large array buffer. The image file is generally generated as a 640x720 pixel image.
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(although larger files can be generated), saved as a JPEG-format file and transmitted to a ground station (ftp server at NASA-Ames)(Figure 5).

![Figure 5. Typical Three-Band Color Composite of AIRDAS Data](image)

This image of bands 4, 2, 1 was generated onboard the acquiring aircraft and transmitted to a ground station. This JPG image has no geo-rectification applied when transmitted. Collected over the Old Fire, Southern California, 5 November 2003.

Geo-rectification of image files is completed once the image data is telemetered to the NASA-Ames FTP server. The data are ingested along with a navigation file into the geo-rectification process, and the correction algorithm is run. The navigation data are received as a coincident text file with the *jpeg* image (same file name with *.nav* extension. The navigation file contains information on the sensor configuration and platform positional information for use in geo-rectification. The navigation information is collected (at the sensor) for every scan line, although the *.nav* file is further compressed to a transmittal of every fifth line. This process is being adapted to allow every line of navigation information to be transmitted, allowing for increased precision on geo-rectification. The *.jpg* image files are generally 110-170 KB in size, while the navigation information file is 9 KB in size. The correction algorithm allows for terrain correction if DEM or SRTM data are available for the area of interest. Total processing time (from collection to transmittal to geo-rectification) approaches 10-15 minutes (Figure 6).

Post-flight processing of large AIRDAS data sets requiring multiple-line mosaicing is accomplished by off-loading the “raw” AIRDAS data from the instrument’s removable hard drive and then geo-correcting the full four-band data sets. This process involves extracting the navigation information from the data stream and providing a DEM or SRTM data for terrain correction of the spectral data. This process (large-area, multi-
flight line data sets) cannot be done in real-time due to the file structure size and telemetry capabilities currently being utilized.

![Figure 6. Geo-Rectified and Terrain-Corrected AIRDAS Image](image)

*This JPG image data of Figure 5 (above) was terrain-corrected using USGS DEM data. Data was collected over the Old Fire, So. California, 5 November 2003. Geo-correction took under 5 minutes and data was redistributed to the web. Processed using Terra-Mar DACS software.*

An example of AIRDAS multiple flight line, mosaicked, geo-rectified (including terrain correction) fire data can be seen in Figure 7. The processing of this data set collected over the Cedar Fire, covering over 230,000 acres of burned area (~200 Mb of data) took approximately 1.5 hours of computation time.
2.1.1.2 AIRDAS Telemetry Capabilities

AIRDAS system data have been telemetered to the ground via two distinct methodologies: aircraft-to-ground-direct (via Flitefone™ 800 cellular technology) and aircraft-to-satellite-to-ground (via INMARSAT). Recent telemetry methodologies for the AIRDAS involve the use of a NERA WC M4 flat panel antenna mobile communication phone integrated on the airframe. This system was derived from a wireless mobile handheld telecommunications system that communicates through the INMARSAT series of geo-stationary satellites. The NERA World Communicator M4 was selected for integration simplicity, cost and adequate functionality (see section on telemetry). Data speeds are 64Kbs. These antenna systems have been integrated on both manned and unmanned platforms (Figure 8).
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Figure 8. The NERA World Communicator M4 Flat Panel Antenna Modified for Telemetry Options
The left figure shows the flat panel antenna. The center figure shows the NERA WC M4 pre-positioned in the USFS Navajo aircraft window. The right figure shows the location of the NERA WC M4 panel integrated into the forward payload fairing (under the FiRE logo) of the ALTUS II UAV.

The AIRDAS scene data and navigation file are sent from the AIRDAS control computer to the NERA system onboard the aircraft. Data are telemetered through a phased-array antenna, pre-positioned (in elevation) to acquire signal lock with an appropriate INMARSAT geo-stationary communications satellite. To attain an antenna intercept angle of 90 degrees (between antenna and satellite), the aircraft has to be oriented in an appropriate flight track. Proper intercept angles are determined from known fixed locations of the nearest INMARSAT satellite in the constellation. When signal strength is maximized (through an indication at the payload engineer’s workstation), a TCP/IP network connection was established and the image data were transmitted to the antenna panel.

NASA-Ames is also investigating and the use of an omni-directional, gimbaled antenna for telemetry capabilities. The gimbaled system precludes the need for intercept-angle flight profiling. Data can be transmitted during aircraft data collection, flying any flight orientation. Communication “lock-on” allows continuous collection and telemetry during a mission event. Also under development (by start of FY05), is the porting of geo-rectification procedures to the on-board computer. This will allow the data to be automatically geo-rectified (including terrain correction) in real-time, with data telemetry of a fully geo- and terrain-rectified scene to the ground (researcher or Incident Command Center (ICC)).

Further information regarding telemetry options is covered in a later section of this document. Further utility of the AIRDAS airborne imaging system is described in the Operational Instrumentation section.

2.1.2 California Department of Forestry - AIRIS
The California Department of Forestry flew an airborne fire imaging system in 2002 known as the Airborne Infra-Red Imaging System (AIRIS). The system was composed of a co-mounted 4-band Positive Systems camera and a thermal infrared video camera. GPS and aircraft attitude information were recorded on-board and utilized in correcting the scene geographic positioning. The AIRIS utilized in-house custom developed software for fire perimeter extraction of the TIR data, and Positive System’s DIME for orthophoto mosaic production.
The AIRIS was used for emergency response as well as resource missions such as the mapping of Sudden Oak Death extent. Though it never got past the research mode prior to the loss of funding, it flew 33 fire flights and 17 resource missions. The aircraft operated from McClellan Air Base in Sacramento, where the ground processing station was located. The AIRIS specifications are shown in Table 2.

<table>
<thead>
<tr>
<th>Sensors</th>
<th>Thermal IR video camera; 4-Band Positive Systems, Inc. camera</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position / Attitude</td>
<td>GPS and aircraft attitude information</td>
</tr>
<tr>
<td>Software</td>
<td>Custom software for fire perimeter extraction; ERDAS IMAGINE for mosaic production</td>
</tr>
<tr>
<td>Products</td>
<td>Fire perimeter overlay on base map; color / CIR orthophoto mosaics</td>
</tr>
</tbody>
</table>

2.1.2.1 AIRIS Products
The AIRIS system delivered fire perimeters overlain on a base map, along with color/color-infrared orthophoto mosaics from the Positive System camera equipment. The data was used for emergency response as well as resource management missions, such as the mapping of Sudden Oak Death extent (Figure 9). Though it never got past the research mode prior to the loss of funding, it flew 33 fire flights and 17 resource missions. The aircraft operated from McClellan Air Base in Sacramento, California where the ground processing station was located.

Figure 9. AIRIS Fire Perimeter Data Overlain on Map (at Left). AIRIS Thermal / CIR Composite Showing Sudden Oak Death Mission Data Over California (at Right).
2.1.2.2 AIRIS Telemetry Capabilities
Plans for air-to-ground data transfer had been tested, but not operationalized during fire missions. The primary data delivery mode was via CD-ROM or transfer to an FTP site at the ground processing station after the aircraft had landed.

2.1.2.3 Status of AIRIS
The program was discontinued in 2003. The reason for the program discontinuation was lack of funding due to failure to support itself through non-emergency projects.

2.1.3 FireMapper™
Space Instruments Inc. (Encinitas, CA) built the FireMapper™ as part of a Joint Research Venture, Small Business Innovative Research (SBIR) program proposal supported by the USDA Forest Service, Riverside Fire Laboratory. FireMapper™ is a high precision, airborne imaging system with 3 selectable infrared and 2 selectable visible bands. The infrared bands utilize a single uncooled microbolometer detector array and operate without mechanical scanning. The infrared sensor features a through the lens, absolute calibration system and automatic drift correction to obtain stable, highly calibrated radiometric measurements. Its signal processor features 16-bit encoding to allow fires to be imaged without saturation. The two visible bands use Megaplex 1.6i digital cameras which each contain 1.6 million pixels. The operating system utilizes a rack mounted Micron server which holds up to six 36 GB hard drives for data storage. The system records all data, with GPS co-ordinates, speed and heading and allows real time display and playback of the images (Figure 10). Performance characteristics can be seen in Table 3.

The FireMapper’s instrument micro-bolometer detector array requires no cryogenic cooling, as do conventional mercury-cadmium-telluride detectors, and thus the FireMapper offers a less complex and expensive thermal imaging system. The use of an uncooled microbolometer makes the instrument a promising candidate for future developmental guidelines in thermal instrument enhancement. The FireMapper features internal calibration, user-selected channels based on removable spectral filters, and real-time image viewing and enhancement. Field demonstrations of the technology show that the FireMapper can provide a large-field view of fire activity through long-wave infrared measurements alone. The instrument provides low spatial resolution (327 x 245 pixel) thermal data, which restricts its usefulness for large fire imaging missions. Given the narrow FOV (34.7°), the FireMapper has not been used extensively for supporting fire mapping efforts, but has shown great promise in fire research (discrimination of high temperature variations). The system is being enhanced to improve delivery of fire imagery in readily interpretable products, and will be deployed for fire research and operational missions supporting fire mitigation.
The system is composed of two Megaplus 1.6i digital cameras which each contain 1.6 million pixels (two visible bands) and an infrared microbolometer array allowing capture of three infrared bands (see Table 3). The microbolometer assembly is contained in the gold “canister”.  

Table 3. FireMapper System Configuration and Characteristics for Payload Operations

<table>
<thead>
<tr>
<th>Sensor Performance:</th>
<th>Infrared Bands</th>
<th>Visible Bands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline Spectral Bands*</td>
<td>8.0 to 12.5 µ</td>
<td>0.615 to 0.685µ</td>
</tr>
<tr>
<td></td>
<td>8.2 to 9.0 µ</td>
<td>0.815 to 0.885µ</td>
</tr>
<tr>
<td></td>
<td>11.5 to 12.5µ</td>
<td></td>
</tr>
</tbody>
</table>

*Note: Spectral bands can be changed with new filters

<table>
<thead>
<tr>
<th>Number of pixels</th>
<th>327 x 245</th>
<th>1528 x 1024</th>
</tr>
</thead>
<tbody>
<tr>
<td>Encoding, bits</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>Spatial resolution, mrad</td>
<td>1.85</td>
<td>0.375</td>
</tr>
<tr>
<td>FOV, crosstrack, deg.</td>
<td>34.7</td>
<td>32.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sensor Physical Parameters:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight, pounds</td>
</tr>
<tr>
<td>Size, inches</td>
</tr>
<tr>
<td>Power, watts</td>
</tr>
<tr>
<td>Data/Image, MBytes</td>
</tr>
</tbody>
</table>
The FireMapper provides a low-resolution (though high temperature calibration / discrimination) image (327x245 pixels) that is stored on the system in collection and processed on the ground following landing and off-loading of the data stored on the removable hard drives. The thermal data (low spatial resolution) is sometimes combined (through co-rectification) with the digital camera visible band data to form a composite image. These images are then post-processed, geo-rectified and distributed to USFS investigators (Figure 11).

![Figure 11. FireMapper Thermal / Visible Color Composite of the Pines Fire, Southern California](image)

Imagery was collected 2 August 2002. The image on the left is a geo-corrected image file overlain on a DRG map sheet. The image on the left is the same image in 3-D draping over terrain data.

### 2.1.3.1 FireMapper Telemetry Capabilities

Currently the FireMapper data does not have telemetry capabilities, although the USDA-Forest Service, Riverside Fire Lab (who own the instrument), is attempting to develop a telemetry option. All geo-rectification is accomplished after landing and the data has been off-loaded from the removable hard drives. A “remote” analyst does most image processing within one day of collection.

Further information about the use of the FireMapper is available in the Operational Instrument section.

### 2.1.4 DACS / Terra-Mar

Terra-Mar Resource Information Services develops customized systems based on their DACS and PCDACS software. The system has supported input from digital cameras,
video cameras, radar, FLIRs, and line scanners. It includes logging and management of GPS and attitude information, as well as automated logging to a spatial database. Automated direct geo-rectification software is available for framing and line scanning systems including pointable sensors. Imagery footprints are automatically logged to the spatial database for ease in data management. Functions are provided for integrating imagery with maps, graphical capabilities, and projection conversions among others. Figures 6 and 7 provide examples of geo-rectified line scanner imagery.

### 2.1.5 MODIS Airborne Simulator (MAS)

The MODIS Airborne Simulator (MAS) is a multispectral scanner configured to approximate the Moderate-Resolution Imaging Spectrometer (MODIS), an instrument orbited on the NASA EOS-AM1 platform. MODIS is designed to measure terrestrial and atmospheric processes. The MAS was a joint project of Daedalus Enterprises, Berkeley Camera Engineering, and Ames Research Center. The MAS instrument is a line scanning system based on a Daedalus Enterprises scanner, outfitted with a Berkeley Camera Engineering fifty-channel digitizer (Figure 12). The MODIS Airborne Simulator records fifty spectral bands, configured as shown in Table 4.

![Figure 12. The Scan Head of the NASA MODIS Airborne Simulator (MAS) Scanning Instrument](image)
### Table 4. Spectral Channel Configuration of the MODIS Airborne Simulator

<table>
<thead>
<tr>
<th>Spectral Channel</th>
<th>Band Center (µm)</th>
<th>Bandwidth (µm)</th>
<th>Spectral Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.4649</td>
<td>0.0397</td>
<td>0.4451-0.4848</td>
</tr>
<tr>
<td>2</td>
<td>0.5494</td>
<td>0.0417</td>
<td>0.5285-0.5703</td>
</tr>
<tr>
<td>3</td>
<td>0.6550</td>
<td>0.0511</td>
<td>0.6294-0.6805</td>
</tr>
<tr>
<td>4</td>
<td>0.7024</td>
<td>0.0415</td>
<td>0.6816-0.7231</td>
</tr>
<tr>
<td>5</td>
<td>0.7431</td>
<td>0.0420</td>
<td>0.7221-0.7641</td>
</tr>
<tr>
<td>6</td>
<td>0.8248</td>
<td>0.0427</td>
<td>0.8034-0.8461</td>
</tr>
<tr>
<td>7</td>
<td>0.8667</td>
<td>0.0414</td>
<td>0.8460-0.8874</td>
</tr>
<tr>
<td>8</td>
<td>0.9072</td>
<td>0.0409</td>
<td>0.8867-0.9276</td>
</tr>
<tr>
<td>9</td>
<td>0.9476</td>
<td>0.0397</td>
<td>0.9277-0.9674</td>
</tr>
<tr>
<td>10</td>
<td>1.6422</td>
<td>0.0519</td>
<td>1.6163-1.6682</td>
</tr>
<tr>
<td>11</td>
<td>1.6975</td>
<td>0.0505</td>
<td>1.6722-1.7228</td>
</tr>
<tr>
<td>12</td>
<td>1.7499</td>
<td>0.0506</td>
<td>1.7245-1.7752</td>
</tr>
<tr>
<td>13</td>
<td>1.8014</td>
<td>0.0491</td>
<td>1.7768-1.8259</td>
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<td>0.4579</td>
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<td>0.3763</td>
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<td>13.041-13.500</td>
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<td>0.5347</td>
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<tr>
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<td>14.2395</td>
<td>0.3775</td>
<td>14.051-14.428</td>
</tr>
</tbody>
</table>

**MAS Sensor/Aircraft Parameters:**

- **Spectral Bands:** 50 (16-bit resolution)
- **IFOV:** 2.5 mrad
- **Ground Resolution:** 163 feet (50 meters at 65,000 feet)
- **Swath Width:** 19.9 nautical mi (36 km)
- **Total Scan Angle:** 85.92 degrees
- **Pixels/Scan Line:** 716
- **Scan Rate:** 6.25 Hz
- **Ground Speed:** 400 kts (206 m/second)
- **Roll Correction:** Plus or minus 3.5 degrees (approx.)

The MAS operates as a research instrument in support of NASA and other funded program research. The instrument data are available to the science community through requests to the NASA-Ames Airborne Sensor Facility ([http://asapdata.arc.nasa.gov/](http://asapdata.arc.nasa.gov/)), and include a number of data sets collected over fires in the western US. The MAS operates on the NASA ER-2 aircraft as well as the Department of Energy King Air B200 and Cessna Citation. The MAS has been used to collect thermal channel data over a number of “fires of opportunity” in the Western US. These data collections were special requests made by the USDA-Forest Service or were collected during other scientific investigations within the vicinity of the mission. Recent MAS images collected over fires can be seen in Figure 13.
2.1.5.1 MAS Telemetry Capabilities

The MAS currently does not provide for telemetered data distribution in real-time from the aircraft. Post-processing the data after landing provides data distribution of both rectified and unrectified data. Generally, the MAS data is not geo-rectified except under previous arrangements and special occurrences and missions. Turn-around time for data is approximately 24-hours at best.

The NASA-Ames Airborne Sensor Facility has experimented with a “high-end” data telemetry system for data distribution from the ER-2 platform (Figure 14). The system, known as STARLINK provided a 294/400 Kbs return/forward link with INMARSAT. Data was uplinked from the aircraft (via 294 Kbs link) to INMARSAT, down-linked to White Sands Complex, uplinked to DOMSAT via a 48 Mb link, then down to the Ames Research Center STARLINK Ground Station and Payload Operations Control Center, where it was available at a local investigators workstation (on-site) or for data storage (Figure 15). Data could be further distributed from there via Internet or dial-in. The system was employed to collect fires data with the NASA Thematic Mapper Simulator (TMS) 12-channel scanner. These missions were to demonstrate capabilities and the system was cost-prohibitive for integration on other platforms.
Fires data, collected from the Thematic Mapper Simulator (TMS), a twelve-channel Daedalus AADS1268 scanner, aboard the NASA ER-2 was telemetered through the STARLINK system to NASA-Ames Research Center. The data collected over the Lake Castaic (Marble) Fire was then distributed to a fire command center for use by infrared interpreters. An example of that STARLINK telemetered data can be seen in Figure 16.
2.1.6 MODIS / ASTER Airborne Simulator (MASTER)

The MASTER is similar to the MAS, with the thermal bands modified to more closely match the NASA EOS ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) satellite instrument. It is intended primarily to study geologic and other Earth surface properties. Flying on both high and low altitude aircraft, the MASTER was
The Institute for the Application of Geospatial Technology

operational in early 1998. The MASTER instrument is a line scanning system based on a Daedalus Enterprises scanner, outfitted with a Berkeley Camera Engineering fifty-channel digitizer (Figure 17). The MASTER Airborne Simulator records fifty spectral bands, configured as shown in Table 5.

Table 5. Spectral Channel Configuration of the MODIS Airborne Simulator

<table>
<thead>
<tr>
<th>Spectral Channel</th>
<th>Band Center (µm)</th>
<th>Bandwidth (µm)</th>
<th>Spectral Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.460</td>
<td>0.04</td>
<td>0.440-0.480</td>
</tr>
<tr>
<td>2</td>
<td>0.500</td>
<td>0.04</td>
<td>0.480-0.520</td>
</tr>
<tr>
<td>3</td>
<td>0.540</td>
<td>0.04</td>
<td>0.520-0.560</td>
</tr>
<tr>
<td>4</td>
<td>0.580</td>
<td>0.04</td>
<td>0.560-0.600</td>
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<td>5</td>
<td>0.660</td>
<td>0.06</td>
<td>0.630-0.690</td>
</tr>
<tr>
<td>6</td>
<td>0.710</td>
<td>0.04</td>
<td>0.690-0.730</td>
</tr>
<tr>
<td>7</td>
<td>0.750</td>
<td>0.04</td>
<td>0.730-0.770</td>
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<td>8</td>
<td>0.800</td>
<td>0.04</td>
<td>0.780-0.820</td>
</tr>
<tr>
<td>9</td>
<td>0.865</td>
<td>0.04</td>
<td>0.845-0.885</td>
</tr>
<tr>
<td>10</td>
<td>0.905</td>
<td>0.04</td>
<td>0.885-0.925</td>
</tr>
<tr>
<td>11</td>
<td>0.945</td>
<td>0.04</td>
<td>0.925-0.965</td>
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<tr>
<td>12</td>
<td>1.625</td>
<td>0.05</td>
<td>1.600-1.650</td>
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<td>13</td>
<td>1.675</td>
<td>0.05</td>
<td>1.650-1.700</td>
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<td>0.05</td>
<td>1.700-1.750</td>
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<td>15</td>
<td>1.775</td>
<td>0.05</td>
<td>1.750-1.800</td>
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</table>
### MASTER Sensor/Aircraft Parameters:

<table>
<thead>
<tr>
<th>Spectral Bands:</th>
<th>50 (16-bit resolution)</th>
</tr>
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<tbody>
<tr>
<td>IFOV:</td>
<td>2.5 mrad</td>
</tr>
<tr>
<td>Ground Resolution:</td>
<td>12-50 meters (variable with altitude)</td>
</tr>
<tr>
<td>Total Scan Angle:</td>
<td>85.92 degrees</td>
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<tr>
<td>Pixels/Scan Line:</td>
<td>716</td>
</tr>
<tr>
<td>Scan Rate:</td>
<td>6.25 – 25 Hz</td>
</tr>
</tbody>
</table>
The MASTER sensor has been used to collect data over fires, but not routinely. The various data sets that are available have been through missions that were collected as “fires of opportunity”. An example of the MASTER (low level data type) imagery collected over one of the Southern California wildfires is shown in Figure 18.

2.1.6.1 MASTER Telemetry Capabilities

The MASTER currently does not provide for telemetered data distribution in real-time from the aircraft. Post-processing the data after landing provides data distribution of both rectified and unrectified data. Generally, the MASTER data is not geo-rectified except under previous arrangements and special occurrences and missions. Turn-around time for data is approximately 24-hours at best.

2.2 Operational Instrumentation

The USDA-Forest Service has developed an Infrared typing system to identify various operational fire imaging systems available for their use either through direct “ownership” (such as the Phoenix system) or through contracting from private sector systems. The descriptions in the following section details the guideline used by the Forest Service to
define and “categorize” systems and is further referenced in Zajkowski (2003c). The following sections are abstracted from that document for ease of information ingestion.

2.2.1 Infrared Typing System
During the past decade, a number of advancements in thermal IR remote sensing have occurred, and a growing number of these systems are available in aircraft for use in fire management. The IR typing system is a guideline designed to help incident command teams determine the best system for their situation. The typing system informs fire managers about the capabilities and limitations of the available IR systems. They can then use this information to choose a system that will be cost-effective for their situation. Choosing the right IR system ensures that this valuable fire intelligence is obtained in a safe, timely, and cost-efficient manner. Infrared systems are the combination of the detector, data recorder and processor, Global Positioning System/Inertial Navigation System (GPS/INS), platform, and operator. These components determine which mission profiles the system can accomplish effectively.

Infrared systems can be classified in various ways; we have classified them in a manner relevant to the wildland firefighter. The following four components are used to sort the various IR systems in to five categories (Table 6). These characteristics, outlined by Zajkowski, define the necessary elements of a classification scheme for TIR fire imaging systems.

<table>
<thead>
<tr>
<th>Components</th>
<th>Multiple Incident/Large Fires</th>
<th>Single Incident</th>
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</thead>
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<tr>
<td></td>
<td>Type 1</td>
<td>Type 2</td>
</tr>
<tr>
<td>Aircraft Mount</td>
<td>Nadir</td>
<td>Nadir</td>
</tr>
<tr>
<td>Geo-corrected Products</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Thermal Band(s)</td>
<td>2+</td>
<td>1</td>
</tr>
<tr>
<td>Production Rate (acres/hour)</td>
<td>100,000</td>
<td>10,000</td>
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</table>

2.2.1.1 Infrared System Mounts
Infrared systems can be mounted in several different ways: nadir, gimbaled, or hand. Hand-mounted units are designed to be operated similar to a camcorder. With gimbaled mounts (widely known as forward looking IR (FLIR) balls), the IR sensor is mounted on a stabilized turret that can be pointed in nearly any direction unimpeded by the aircraft. With nadir mounts, the sensor is pointed directly below the aircraft.
2.2.1.2 Geo-Corrected Products
The deliverable product(s) are corrected for applicable sensor distortions and set to a specified map projection with associated map coordinates. Typically, an IR interpreter or image analyst manipulates the data to a point where it can be integrated into an incident’s GIS. It is important to check with the infrared provider to determine if an infrared interpreter or extra GIS specialist will be needed.

2.2.1.3 Thermal Bands
IR sensors can detect a number of thermal bands, or ranges, within the electromagnetic spectrum between 3 - 5 µm and 8 - 14 µm. Systems that detect more than one thermal band are better suited to reject false positives that occur when flying over hot rocks, a metal roof, etc.

2.2.1.4 Production Rate
The production rate is the area the sensor can cover in one hour stated in acres per hour. Note that the stated value for a particular sensor is the best case and will decrease significantly due to turns, flight-line overlap, mission type, etc. Production rates are determined by the instrument’s field of view (FOV) in conjunction with the aircraft’s speed and altitude. The values listed for production rates do not include the amount of time it takes to deliver and process the imagery.

The thermal fire imaging systems are defined by the Forest Service as belonging to one of three types: Type 1, Type2, and Type 3. Each of these types is further defined here and the various operational imaging systems are then detailed.

2.2.2 Type 1 Systems Overview
These systems are best used to detect very small heat sources distributed over vast areas and to map large fires. Type 1 systems are capable of imaging a large incident quickly so that fire managers get a snapshot of the situation. Strategic information may be gathered for planning and general assessment of conditions over large areas. They are also useful for a final look before an incident is turned over to the local agency. These systems, mounted on twin-engine or jet aircraft, can cover large areas quickly.

2.2.3 Type 2 Systems Overview
These systems are best for gathering data for tactical and near-real-time decision-making and should be coupled with products that do not require an on-the-scene IR interpreter. These systems can often be used for multiple purposes, including infrastructure and forest condition mapping and burned area assessment. Unless specifically stated by the vendor, a qualified analyst is required to create the desired data products. Possible platforms are fixed-wing aircraft or helicopters.

2.2.4 Type 3 Systems Overview
These systems are valuable for close-in IR viewing, coupled with visual observation and judgment by on-the-scene fire managers. Type 3 systems are very useful for fire-line mapping and mop-up operations. Because these systems are gimbaled mounted, they can typically view an object from multiple angles, thus detecting heat that may elude nadir-
mounted systems. Type 3 systems are generally mounted on helicopters that travel with their own processing centers but a few are mounted on fixed winged aircraft.

Table 7 classifies IR vendor capabilities by these three types. These vendors have voluntarily submitted their information through a Request For Information (RFI-51-03-018). This information has been checked for technical feasibility by the NIROPS and RSAC staff. This list of vendors does not constitute an official evaluation, conclusion, recommendation, endorsement, or approval by the Forest Service of any product or service to the exclusion of others that may be suitable.

<table>
<thead>
<tr>
<th>Type</th>
<th>Company Name</th>
<th>Thermal Bands</th>
<th>Mount</th>
<th>Hourly Acquisition Rate (Acres per hour)</th>
<th>Fire Experience</th>
<th>Platform</th>
<th>Geo-rectified Products</th>
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<tr>
<td>3</td>
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<td>BE200, Cessna Citation Bravo</td>
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<td>USDA-FS PSRS, Riverside Fire Lab</td>
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<td>PA31-310</td>
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<td>2</td>
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<td>Blue Skies Consulting, LLC</td>
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<td>Nadir</td>
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<td>Cessna T210N, Antonov AN-2P</td>
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<td>Range and Bearing Corporation</td>
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<td>Nadir</td>
<td>22,000</td>
<td>Tests</td>
<td>Cessna 337</td>
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### 2.2.5 Type 1 Systems: USDA-Forest Service Phoenix System

The USDA Forest Service has a history of evaluating, developing and deploying new technology to detect fires and provide imagery for fire containment efforts. Among these efforts is the use of line scanner technology to provide accurate fire detection capabilities along with images useful for managing fire containment. Evaluation of a bi-spectral scanner detection system started with “Project Fire Scan”. This effort was headed under the DOD, Office of Civil Defense along with foresters and fire experts from the Forest Service Fire Laboratory. At the time this group provided the best technical team to apply cutting edge technology developed by the DOD under guidance from the foresters and fire scientists. Commercial efforts at this time did not exist. DOD technology was held tightly by the program offices responsible to employ that technology for national

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<th>3a</th>
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<th>Nadir</th>
<th>5,600</th>
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<th>Piper Aztec</th>
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<td>Bell 206 Jet Ranger</td>
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<td>Mid-Valley Helicopters</td>
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<td>San Joaquin Helicopters</td>
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<td>Gimbaled</td>
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<td>MD 530F or UH-1H</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Vision Air Research</td>
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<td>Gimbaled</td>
<td>20,826</td>
<td>Tests</td>
<td>Cessna 206, PA-31-310 Navajo</td>
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<tr>
<td>3a</td>
<td>Helicopter Applicators Incorporated</td>
<td>1</td>
<td>Gimbaled</td>
<td>500</td>
<td>Yes</td>
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<td>Yes</td>
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<td>3b</td>
<td>Oilton Remote Detection Technologies (ORD-TECH)</td>
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<td>Gimbaled</td>
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<td>No</td>
<td>Bell 206 Jet Ranger</td>
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<tr>
<td>3c</td>
<td>Advanced Building / M.I.R.S</td>
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<td>Hand</td>
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<td>Various</td>
<td>Yes</td>
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<td>John Newman (I R Mapping)</td>
<td>1</td>
<td>Hand</td>
<td>900</td>
<td>Yes</td>
<td>Various</td>
<td>Yes</td>
</tr>
</tbody>
</table>
defense. Transfer of this technology to another US department is common in support of civil defense and emergent events.

The driving factors for use of imaging technology for fire management are: 1) ability to detect fire accurately with a low false report rate, 2) fast data collection, and 3) timely delivery of information. The Forest Service determined as early as 1967 that an airborne 2-channel IR line scanning system is the optimal choice for forest fire surveillance. Project Fire Scan and related activities have resulted in the operation systems today, FLAME, Firefly, and Phoenix. Current and planned upgrades to line scanner systems at NIFC are really technology upgrades to the early Project Fire Scan system. For example, the Doppler radar and compass components were replaced to include GPS technology, which was not available in earlier designs. System upgrades and maintenance is performed by NIFC technicians along with in-house engineers and contractors operating in authority for the US Army Aviation and Missile Command at Redstone Arsenal. The FLAME, FIREFLY and PHOENIX system are described here, although the Phoenix is the primary system in use now, with the others serving as necessary backup systems in event of heavy utility or PHOENIX malfunctions.

2.2.6 Type 1 Systems: FLAME System
The FLAME (Fire Logistics Airborne Mapping Equipment) system was developed in the early 80's at JPL-NASA. The system was new in that it had a digital interface for mission storage on a 37MB Twinchester Tape Drive System. This storage system weighed 87 lbs and stood about 36" tall and 24" wide. The Flame system (w/o the storage system) is still in use today. The analog electronics has been completely upgraded by SAIC (Science Applications Integration Corporation). The system utilizes a 2-IR band detector in the 3-5 µM and the 8-14 µM range with 1.0-mrad detectors. This allows automatic fire detection through a discrimination algorithm that makes this system very sensitive to small fire occurrences. The scan head collects data at 200 lines per second (each pixel size dependent upon the altitude above ground level, i.e. 1.0-mrad at 10,000 Ft AGL = 12.5 ft/pixel) at 1024 pixels per line output. This system used to output to an EDO 5" Film strip but now outputs a continuous strip image from a TDU-850 Thermal Paper printer.

2.2.7 Type 1 Systems: FireFly System
The FireFly system is a follow-on effort from FLAME. It is designed and built on a new scanner, Daedalus ABS3500 System Aerial Bi-Spectral System, provided by SenSyTech Inc. (formally Daedalus Corp.). Firefly was developed by NASA/JPL in 1989-1992. It is NIFC's first digital system that provides first order geo-correction in real-time. The scan head uses a 2-band TIR system in the 3-5 µM and the 8-14 µM range. The detectors provide an instantaneous field of view of 2.5 milliradians. The National Infrared Operations Group currently has 2 of these systems. The output is also provided on a continuous strip image from a TDU 850 Thermal Paper printer that has edge marks to locate fire in that particular scan line and GPS readout along the edge. The system also stores missions on an 8 mm tape. The data collected on this tape includes image information from both detectors, navigation data (per line per channel), and aerial platform attitude information. This data is importable to ERDAS Imagine on UNIX Systems.
2.2.8 Type 1 Systems: Phoenix System

The Phoenix system is an upgrade to the Firefly system (new sensor head and IMU) and has been in development since 1998 with cooperators from NASA-Ames, US Army Aviation and Missile Command, National Infrared Operations, Remote Sensing Applications Center, and USDA Fire & Aviation. The Phoenix is a repackaging of existing equipment from the FLAME system with the addition of a digital signal processor digitizing analog sensor output. The Phoenix is a Windows 98-based computer with a single Data Acquisition Card. This system runs on a Microsoft Windows NT 4.0-based PC system from ICS Advent (formerly Industrial Computer Source), has a data acquisition system that is based on an Innovative Integration M67 series data acquisition card, runs on software that was developed by Computer Sciences Corporation (CSC) in Huntsville, AL., and utilizes the same scan head as the Flame System. Its output is a continuous image strip from the TDU 850 Thermal Paper printer and a mission log data file that includes Navigation data, aerial platform attitude information (provided by an Applanix POS/AV 210), and 2 channel image data. Efforts are underway at this time to make this log file compatible with US Government GIS systems. The strip image has 1st order geometric correction while the log files provide accurate enough data for 2nd and 3rd order geometric correction. Plans are to provide a raw log file with scanner output, aircraft dynamics and GPS data along with playback software on a CD-ROM that is provided to the interpreter at the same time as the paper image product is provided. This CD-ROM product may be used to generate GeoTIFF if the interpreter has access to GIS resources. Phoenix is the NIICD’s primary line scanner. The Phoenix system is shown in Figure 19.

![The Phoenix System Fire Scanner](image_url)

*Figure 19. The Phoenix System Fire Scanner*

*The scanhead assembly can be seen on the left and the control electronics on the right. Image courtesy of NIFC-NIROPs.*
The Institute for the Application of Geospatial Technology

The Phoenix operates with a wide FOV to allow large area coverage over major fire complexes while reducing the amount of aircraft time spent over individual events. The system operates on various platforms operated by NIFC. Phoenix is capable of producing geo-referenced (not geo-corrected) digital products in either *.gif or *.tiff format. Trained interpreters can create GIS products for an incident by “transferring” fire “hot pixel” locations to a map base.

The various IR systems in use by the NIFC are configured to fly in two of the agencies main platform aircraft, the Cessna Citation Bravo II and the Beech King Air B-200. These aircraft can be seen in Figure 20. The Citation is a recent addition to the fleet (July 2001) and is the main acquiring aircraft for TIR fire missions.

Table 8. Phoenix Performance Characteristics

<table>
<thead>
<tr>
<th>Total Field-of-View</th>
<th>Ground Coverage</th>
<th>Detectability</th>
<th>Fire Location Method</th>
<th>Aerial Platform</th>
<th>Pixels/Scan Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>120°</td>
<td>6.5 Statute Miles at 10,000 Ft AGL</td>
<td>8” 600° Hot Spot @ 14,000 Ft AGL</td>
<td>Edge Marks</td>
<td>King Air B200 King Air B90 Citation Jet Lear 35/36 (with modifications)</td>
<td>1680</td>
</tr>
</tbody>
</table>

Figure 20. The Two Main NIROPS Used for Fire Imaging.

The Cessna Citation Bravo II (on left) and the Beech King Air B-200 (on right). The NIROPS also utilize an older King Air aircraft.

2.2.8.1 Phoenix Imagery Product

Example line printer imagery is shown in Figure 21. This imagery is collected as a strip file and handed-off at fire camp as a paper product (upon landing) or saved to a CD-ROM and ingested into a GIS system by an Interpreter (if digital data processing is available in the ICC). The imagery is formatted with easy to interpret black tic marks along the image perimeter to demote the location of hot pixels that exceed a temperature threshold.
The pixels in the interior of the image file are colored red to denote the hot locations. The perimeter tics are used simply to indicate quickly the presence of hot pixel areas in the scene.

![Image of Phoenix Data Collected Over a Fire During a 2003 Test Mission](image)

**Figure 21. Phoenix Data Collected Over a Fire During a 2003 Test Mission**

This is a typical product delivered as a paper product or digital file to an IR interpreter at the ICC. Note the black tics along the image perimeter to denote locations of fire in the scene. Pixels that exceed a predetermined temperature threshold are colored red, as demonstrated seen in this image.

### 2.2.8.2 Phoenix Telemetry Capabilities

A Wireless LAN telemetry system was tested in 2003. This system should operate up to 50 miles away from the ground site to the aircraft. NIICD Infrared is looking into the availability of a satellite telemetry system. Issues include bandwidth availability and equipment size. Primary delivery of data in 2003 was through paper or CD-ROM handoff of TIR fire information. The NIICD and RSAC are working closely with NASA-Ames to define telemetry issues and test various configurations for use with Phoenix. Further testing of telemetry options will occur in early 2004.

### 2.2.8.3 Phoenix System Contact Information

Derived from Zajkowski, 2003c.

<table>
<thead>
<tr>
<th>Company Name:</th>
<th>USDA-FS National Infrared Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mailing Address:</td>
<td>3833 S. Development Ave., Boise, ID 83705</td>
</tr>
<tr>
<td>Primary Contact:</td>
<td>Darrel VanBuren</td>
</tr>
<tr>
<td>Telephone:</td>
<td>208.387.5647</td>
</tr>
<tr>
<td>Fax:</td>
<td>208.387.5560</td>
</tr>
<tr>
<td>Email Address:</td>
<td><a href="mailto:jvanburen@fs.fed.us">jvanburen@fs.fed.us</a></td>
</tr>
<tr>
<td>Website:</td>
<td><a href="http://nirops@fs.fed.us/">http://nirops@fs.fed.us/</a></td>
</tr>
<tr>
<td>Emergency Contact:</td>
<td>208.859.4475</td>
</tr>
<tr>
<td>General Sensor Description:</td>
<td>Phoenix Dual Channel Line Scanner</td>
</tr>
<tr>
<td>Cost:</td>
<td>Aircraft: $485-685/hr; IR Interpreter ~$500/day</td>
</tr>
</tbody>
</table>
2.2.9 Type 1 Systems: FireMapper (Operational Mode)

The FireMapper was recently (2003) designated as a Type 1 Operational fire mapping instrument system. A description of the FireMapper can be found in the section on Research Instruments. FireMapper is an R&D project instrument funded by the National Fire Plan and managed by the USDA-Forest Service, Region 5, Riverside Fire Research Lab. It is dispatched by the South Zone Coordination Center. PSW is now flying the FireMapper™ thermal-imaging radiometer to map and monitor major wildfires in partnership with the Forest Service’s Pacific Southwest Region. Based on modern night-vision technology, the FireMapper is designed to accurately map fire intensity and provide fire intelligence to improve firefighter safety, make fire fighting more effective, and reduce wildfire damage to natural resources and society. Imaging with the FireMapper system is also being tested for use in burned-area rehabilitation. FireMapper and associated mapping cameras are deployed aboard the PSW Airborne Sciences Aircraft, N70Z, which is a twin engine Piper Navajo.

2.2.9.1 FireMapper Imagery Product

FireMapper imagery depicts color-coded surface temperatures, which are readily interpretable as fire intensity or activity, on a geo-registered, shaded relief map. Major fire lines are also shown in 3D on a topographic relief view. An image depicting the FireMapper product can be seen in Figure 22.

![Figure 22. FireMapper Mosaic Flight Line Data Overlain on a Topographic Map Base](image)

Multi-pass mosaic over the Old Fire, San Bernardino National Forest. Ground surface temperatures as viewed from above at 11.9 micrometers wavelength on 27 October 2003, between 3:27 and 4:04 PM PST.

2.2.9.2 FireMapper Telemetry Capability

The FireMapper product is off-loaded from the removable hard drive after aircraft landing and forwarded to a Forest Service analyst (in Seattle area) for manual geo-rectification, fitting to map base, and redistribution to the primary user. The total process
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can take up to 24-48 hours for imagery processing. There are currently no telemetry
capabilities involved in the data exchange, although the Forest Service primary contact
for the instrument is exploring such (probable integration in ~2005).

2.2.9.3 FireMapper System Contact Information
Derived from Zajkowski, 2003c)

<table>
<thead>
<tr>
<th>Company Name:</th>
<th>USDA-FS PSRS, Riverside Fire Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mailing Address:</td>
<td>4955 Canyon Crest Dr., Riverside, CA 92507</td>
</tr>
<tr>
<td>Primary Contact:</td>
<td>Robert Lockwood</td>
</tr>
<tr>
<td>Telephone:</td>
<td>909.680.1535</td>
</tr>
<tr>
<td>Fax:</td>
<td>909.680.1501</td>
</tr>
<tr>
<td>Email Address:</td>
<td><a href="mailto:rlockwood@fs.fed.us">rlockwood@fs.fed.us</a></td>
</tr>
<tr>
<td>Website:</td>
<td><a href="http://www.fireimaging.com/">http://www.fireimaging.com/</a></td>
</tr>
<tr>
<td>Emergency Contact:</td>
<td>27/7 909.315.0181</td>
</tr>
<tr>
<td>General Sensor Description:</td>
<td>Space Instrument FireMapper</td>
</tr>
<tr>
<td>Cost:</td>
<td>Aircraft: $500 /hr; Image processor ~$500 / day</td>
</tr>
</tbody>
</table>

2.2.10 Type 1 Systems: AIRDAS (Operational Mode)
The configuration of the AIRDAS was described in the Research Instrumentation section.
The AIRDAS instrument has also been utilized significantly for operational missions in
support of fire mitigation agencies and managers. This section describes the operational
use of the instrument, the differences in the type of data delivered and the telemetry
options. A NASA Space Act Agreement between NASA-Ames Research Center
(instrument developer and manager) and Sky Research, Inc (private firm) allows for the
loan of the AIRDAS instrument. Sky Research provides operation management,
consulting services, and aircraft modifications for organizations involved in emerging
remote sensing technologies. Sky Research operates the AIRDAS, a four-channel line
scanner designed and built by NASA-Ames Research Center, Moffett Field, CA. The
AIRDAS output is similar to the images produced by the NIROPS Phoenix and can be
readily interpreted by interagency IR interpreters. Sky Research has incorporated minor
modifications to the instrument software to allow for generation of a fire product similar
to that currently available from the NIFC Phoenix Dual Channel Line Scanner system.
Sky Research in support of the Forest Service, flew the AIRDAS extensively in 2003
during critical fire season when their aircraft and imaging capabilities were either stressed
(out of area on other fires, etc.) or down for maintenance.

Sky Research has modified software to provide a fire temperature threshold image file
similar to the Phoenix product. This “data continuity” allows ease of interpretation by
the infrared interpreters. The AIRDAS, operated by Sky Research, is integrated on a
Cessna Caravan (Figure 23). The instrument is loaded in the belly baggage pod and the
control electronics are operated from an instrument engineer’s seat aft of the pilot station.
Figure 24 depicts the AIRDAS system onboard the Caravan aircraft.
2.2.10.1 Sky Research AIRDAS Product

Imagery from the AIRDAS was previously shown in the Research Instrumentation section. The products in development by NASA-Ames and the USFS-RSAC team are those previously viewed image data sets. Sky Research produces AIRDAS fire products that are similar in appearance to the Phoenix system product. The Sky Research AIRDAS fire product produced as a paper product on the aircraft, although primary data product output is as a CD-ROM delivered to ICC infrared interpreters upon landing. The data are not geo-rectified on board, but are geo-referenced (i.e., Lat/Long tics along the image perimeter allow general orientation. The information is generally saved as a *.jpg image (with minimal compression) or as a *.tif file. The data are depicted as fire threshold pixels derived from an algorithm run on band 3 (3.75 – 4.05 μm) and 4 (5.50 –
13.0 µm). The threshold-calculated pixels are then displayed on the AIRDAS channel 2 single band background image plane. Channel 2 (1.57 – 1.70 µm) provides a strong “orientation” background image for ease of interpretation. Roads, terrain features and other vegetative cover can easily be discerned in the data set. The product also contains a series of information tables in the top part of the image file. The information block contains the following information:

- File Name
- Flight Line No.
- Average Track Direction
- Average Altitude
- Number of Scan Lines
- Start Date and Time
- End Date and Time
- Pixel Size
- Display Band
- Threshold Band
- Sensor Name
- Threshold Value

The second information block contains the histogram distribution (temperature guide) of temperature (hot pixels) vs. Lat / Long location.

The Sky Research AIRDAS fire data product can be seen in Figure 25.

Figure 25. Sky Research-Acquired AIRDAS Data Collected Over the Beaver Fire, Montana on 4 September 2003

The background image plane is a single channel band (band 2), while the hot spots are depicted in red. Similar to the Phoenix system, black tics along the image perimeter provide a quick locational reference to red pixel hot spots in the image. The information table at the top of the image (left side) contains data on collection parameters, while the adjacent temperature guide provides a histogram of temperature gradients by Lat / Long coordinates.
2.2.10.2 Sky Research AIRDAS Telemetry Capabilities

During 2003, NASA-Ames funded Sky Research to install and test an omni-directional, gimbaled, tracking antenna (INMARSAT satellite communication), onto the Cessna Caravan. No AIRDAS data products were operationally delivered to the ground through such a system although all testing indicated that the system was ready for operational distribution of AIRDAS data. NASA-Ames has also installed the NERA World Communicator M4 flat panel antenna in the belly pod and has operated this system on a routine basis for telemetry of AIRDAS imagery through INMARSAT to the ground. Sky Research is also experimenting with a wireless LAN system (in conjunction with NASA-Ames) and has tested and operated this system successfully on the Caravan (although not with AIRDAS; with a digital camera and spectral interferometer). Current plans for Sky Research are to deliver CD-ROM products to the ground as well as to initiate distribution of AIRDAS data through the omni-directional antenna in 2004. These efforts are funded through the NASA-Ames successful REASoN CAN project.

2.2.10.3 Sky Research AIRDAS System Contact Information

Derived from Zajkowski, 2003c.

<table>
<thead>
<tr>
<th>Company Name:</th>
<th>Sky Research Inc</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mailing Address:</strong></td>
<td>445 Dead Indian Memorial Rd., Ashland, OR 97520</td>
</tr>
<tr>
<td><strong>Primary Contact:</strong></td>
<td>Sue Gray</td>
</tr>
<tr>
<td><strong>Telephone:</strong></td>
<td>541.482.7603 ext. 105</td>
</tr>
<tr>
<td><strong>Fax:</strong></td>
<td>541.488.4606</td>
</tr>
<tr>
<td><strong>Email Address:</strong></td>
<td><a href="mailto:sue.gray@skyri.com">sue.gray@skyri.com</a></td>
</tr>
<tr>
<td><strong>Website:</strong></td>
<td><a href="http://www.skyri.com/">http://www.skyri.com</a></td>
</tr>
<tr>
<td><strong>Emergency Contact:</strong></td>
<td>Sky or Anne Sky 541.448.1333</td>
</tr>
<tr>
<td><strong>General Sensor Description:</strong></td>
<td>AIRDAS</td>
</tr>
<tr>
<td><strong>Costs:</strong></td>
<td>Ferry: $1680 /hr; Operations: $2200 / hour (min of 3 hrs/day; IR interpreter at ~$500 / day</td>
</tr>
</tbody>
</table>

2.2.11 EarthData International of Md: Airborne Bispectral Scanner (ABS)

The line scanner that the EarthData and SenSyTech team operates is almost identical to the Daedalus ABS 3500 system that has been operated by NIROPS since the early 1990s. Therefore, the raw data output would be identical to those produced by the Daedalus system. EarthData provides a range of airborne cameras and/or sensors mounted on a fleet of aircraft to create and deliver geospatial data in multiple forms.

EarthData's aircraft operate throughout the United States as well as internationally. Currently, aircraft are based in Hagerstown, MD; Reno, NV; and Argentina. The company’s fleet consists of 3 Piper Navajo Chieftains, a Helio Courier STOL, and a Gulfstream II aircraft.
2.2.11.1 EarthData International ABS Product

The information provided by the EarthData International, Daedalus ABS (Airborne Bispectral Scanner) consists of two-channel TIR data with spectral bandpass information in the 3-5 µm and 8-11 µm portion of the spectrum. The system is not set for high temperature discrimination and therefore has some temperature saturation anomalies when collecting over higher intensity fires. The ABS has been optimized for temperature calculations on standard thermal earth features (steam pipe discrimination, power leakages in urban areas, etc.). The authors have not seen any product collected over fires to allow a determination of capabilities.

2.2.11.2 EarthData International Telemetry Capabilities

No known telemetry capabilities are available. Data are processed upon landing and delivered as a product following correction.

2.2.11.3 EarthData International of Maryland, LLC System Contact Information

Derived from Zajkowski, 2003c.

<table>
<thead>
<tr>
<th>Company Name:</th>
<th>EarthData International of Maryland, LLC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mailing Address:</td>
<td>45 West Watkins Mill Rd., Gaithersburg, MD 20878</td>
</tr>
<tr>
<td>Primary Contact:</td>
<td>Robert C. Barnard</td>
</tr>
<tr>
<td>Telephone:</td>
<td>301.948.8550</td>
</tr>
<tr>
<td>Fax:</td>
<td>301.963.2064</td>
</tr>
<tr>
<td>Email Address:</td>
<td><a href="mailto:cbarnard@earthdata.com">cbarnard@earthdata.com</a></td>
</tr>
<tr>
<td>Website:</td>
<td><a href="http://www.earthdata.com/">http://www.earthdata.com/</a></td>
</tr>
<tr>
<td>Emergency Contact:</td>
<td>24/7 301.529.6312</td>
</tr>
<tr>
<td>General Sensor Description:</td>
<td>ABS Airborne Bispectral Scanner / AMS &quot;Multispectral&quot;</td>
</tr>
<tr>
<td>Costs:</td>
<td>Mobilization: $9705; Rate: $5955 /day; Flight: $805 /hr.</td>
</tr>
</tbody>
</table>

2.2.12 Type 2 Systems: Airborne Data Systems (ADS) Spectra-View®

Airborne Data Systems’ sensor creates five-band, multi-spectral, digital, ortho-rectified mosaics. Visible bands can be used to map infrastructure, and the NIR band is useful for mapping forest condition, fuel load, or moisture content. The thermal band creates a map of fire line hot spots. This data can be viewed as color, color IR with thermal overlays, or individual bands. Data can be used digitally when imported into GIS software, or printed using a printer or plotter. The Spectra-View® system has been in production for 10 years.

Spectra-View® is an airborne, multi-spectral digital remote sensing system complete with differential GPS and precision Inertial Measurement Unit (IMU) attitude system. It can accommodate up to eight bands of spectral data at resolutions from 1/4-meter-per-pixel to two-meters-per-pixel and at speeds in excess of 250 MPH. With power consumption under 300 watts and weight less than 68 pounds, this system is easily installed in both fixed wing aircraft as well as in helicopters (Figure 26). Images are acquired
automatically using pre-planned flight grids. The on-board laptop computer may be used to control scene spacing, line spacing and flight line grids during flight and is also used to set camera shutter-speeds for image quality control. The pilot yoke mounted Course Deviation Indicator (CDI) assists the pilot in maintaining flight course and image acquisition control. System specifications can be found in Table 9.

Figure 26. Airborne Data Systems Spectra-View Imaging System
*In the left image, note the digital camera systems lens for the visible/near-IR channels. The right image shows the Spectra-View system mounted in the Seneca aircraft.*

Table 9. Airborne Data Systems Spectra-View System Specifications

| Can be configured as 4 to 8 band multi-spectral |
|---|---|
| **Cameras:** | |
| 1K X 1K Multi-Spectral | |
| 2K X 2K Multi-Spectral | |
| 4K X 4K Multi-Spectral | |
| 4K X 7K Panchromatic | |
| 4K x 7K Color | |
| **Detector Range:** | 400 nm to 8 Microns |
| **Geo-Accuracy:** | ±2 m on the fly |
| **Speed:** | 250+ MPH at 1° resolution |
| **Laptop Controls:** | Set Shutter Speed |
| | View Histograms |
| | View Scenes |
| | Guidance Information |
| **Dimensions:** | 15 X 17 X 24 inches |
2.2.12.1 Airborne Data Systems Spectra-View Product

In flight data is stored on a removable data drive that is brought directly into a PC for processing after acquisition. Stored data includes a raw band sequential raster file (BSQ) with a separate header file for each image containing positional information and camera settings. Images are processed into GeoTIFF files very rapidly after flight. The five-band system contains a single thermal detector that captures data in the 3-5 micron range, as well as four other detectors equipped with filters in the visible and near-infrared range. Fire can be detected during daylight or nighttime hours - with the added benefit of some background imagery during the day - and captured with the near-infrared band, with complete background imagery displayed in true color (RGB) if smoke has not obstructed the view. The thermal “camera on the Spectra-View is a 3-5 micron, Indium-Antimonide (InSb)-detector focal-plane array, built by Cincinnati Electronics (http://www.cinele.com/ired.htm). The detector has a 256x256 pixel array dimension. The other spectral bands (from individual cameras) are co-united into a series of multiband “frames” and can be co-rectified on-board the aircraft. This processing is done through proprietary software provided by ADS. The data are geo-corrected for elevation and further processed for delivery after landing (Figure 27). The small-array size of the TIR band precludes large area coverage (or high resolution coverage) of fire events. Calibration of the InSb detector in the Spectra-View is unknown.

<table>
<thead>
<tr>
<th>Weight</th>
<th>68 lbs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power:</td>
<td>300 Watts</td>
</tr>
<tr>
<td></td>
<td>10-30 VDC</td>
</tr>
<tr>
<td>Configuration Dependent</td>
<td></td>
</tr>
</tbody>
</table>

Figure 27. Airborne Data Systems Spectra-View Near-IR / TIR Frame Composite

These data were collected over the Alder Fire, Montana on 30 August 2000.
2.2.12.2 Airborne Data Systems Spectra-View Telemetry Capabilities
Airborne Data Systems does not currently rely on telemetry systems for data delivery. Hand-off of digital (CD-ROM) products occurs after landing at a nearby field. Data ingestion is mostly accomplished with ERDAS Imagine image processing software. ADS has also had Forest Service fire personnel onboard the aircraft during Spectra-View acquisition and they have relay (via radio and satellite-phone, the Lat / Long coordinates of assumed fire positions derived from the thermal band product. They are interested in telemetry concepts, but primarily for vector data downlink (fire perimeters) (Fuhr 2003).

2.2.12.3 Airborne Data Systems Spectra-View Contact Information
Derived from Zajkowski, 2003c.

<table>
<thead>
<tr>
<th>Company Name:</th>
<th>Airborne Data Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mailing Address:</td>
<td>25338 290th St., Wabasso MN 56293</td>
</tr>
<tr>
<td>Primary Contact:</td>
<td>David Fuhr</td>
</tr>
<tr>
<td>Telephone:</td>
<td>507.984.5419</td>
</tr>
<tr>
<td>Fax:</td>
<td>507.984.3150</td>
</tr>
<tr>
<td>Email Address:</td>
<td><a href="mailto:dfuhr@airbornedatasystems.com">dfuhr@airbornedatasystems.com</a></td>
</tr>
<tr>
<td>Website:</td>
<td><a href="http://www.airbornedatasystems.com/">http://www.airbornedatasystems.com/</a></td>
</tr>
<tr>
<td>Emergency Contact:</td>
<td>David Fuhr, 507.984.5419</td>
</tr>
<tr>
<td>General Sensor Description:</td>
<td>Airborne Data Systems Spectra-View</td>
</tr>
<tr>
<td>Costs:</td>
<td>Ferry: $375-495 /hr; Operations: $675-775 /hr; Additional equipment and processing personnel required</td>
</tr>
</tbody>
</table>

2.2.13 Type 2 Systems: Blue Skies Consulting, LLC
Blue Skies Consulting a woman-owned emerging small business based out of Belen Alexander Airport in Belen, New Mexico. Blue Skies specializes in aerial photography and remote sensing for mapping and surveying. Its expertise includes primary data acquisition, system integration, and remote sensing applications. Blue Skies has 15 years experience on missions throughout the United States and in Mexico, the Caribbean, and South America for public and private institutions. This operation is a collaboration of three firms: Blue Skies Consulting, Spectrum Mapping (formally EnerQuest), and Kestrel Corporation. The collaboration operates an IR system in the 3 - 5 and 8 - 12 micron range.

Blue Skies utilizes two turbo-charged Cessna T210 aircraft and an Antonov An-2 for its camera platforms. The Cessna T210 is a 1979 "N" model equipped for large-format aerial photography and remote sensing applications. It has a 17"x19" camera hole and contains a real-time kinematic-capable GPS system for flight-line navigation. The second Cessna T210 is a 1978 "M" model and is capable of small-format film and digital photography and remote sensing applications. Both the Cessna aircraft can stay aloft for up to 4.5 hours between fuel stops. An average cruising speed of 180 miles per hour gives them an effective range of more than 800 miles. The aircraft are certified for continuous operations at altitudes up to 27,000 feet mean sea level. They are maintained and
operated in accordance with all applicable regulations of the U.S. Department of Transportation's Federal Aviation Administration (FAA). The Antonov An-2 is a 1985 model equipped for remote sensing applications. It has three sensor ports and a real-time kinematic-capable GPS system. The aircraft has a maximum cruising speed of 120 knots, and can accomplish data acquisition at speeds between 50 and 100 knots. Its normal operating altitude for data acquisition is between 1,000 to 14,500 feet MSL (Figure 28).

![Figure 28. Blue Skies Consulting Aircraft Fleet](image)

*Two Cessna T210 aircraft and an Antonov An-2 used for remote sensing data gathering.*

Blue Skies Consulting provides aircraft and flying services. Spectrum Mapping (formally EnerQuest) partners with Blue Skies Consulting on project consultation, custom remote sensing and GIS applications development and training. They have a suite of digital camera systems, mapping camera systems, two Airborne Imaging Spectroradiometer for Applications (AISA) hyperspectral sensors, and three DATUS LIDAR systems. Kestrel Corporation, a third partner in the collaboration, provides advanced remote sensing systems. Kestrel Corporation's AirCam multispectral imaging system is a compact, low-cost electronic imaging system suitable for a wide range of surveying, mapping, and imaging missions (Figure 29). Based on modern CCD camera technology and Kestrel's innovative control system, software and packaging. The AirCam's small lightweight implementation is readily accommodated by a wide range of aircraft. Key features of AirCam include:

- True multi-band performance, with up to five user-selectable bands (UV to Mid Wave IR).
- 1-meter spatial resolution at typical operating altitudes.
- Full geo-referencing, including line of sight to the ground.
- On-board data storage for over 2,000 frames (expandable - disk size limitation only).
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- Complete software for image acquisition, post processing, image mosaicking and color balancing.
- Self-contained design, incorporating DGPS, attitude reference and pilot's "fly-to" display.
- Compact, lightweight, low power consumption.
- Simple installation in light aircraft.
- Rugged construction - Components come with commercial shipping cases that are easily transported as airfreight or checked baggage.

Figure 29. The Kestrel Corporation (a Partner of Blue Skies Consulting) Multi-Spectral AirCam Instrument

The instrument is shown on the left, while the instrument control station is on the right.

2.2.13.1 Blue Skies Consulting Product
The Blue Skies / Kestrel imaging system, AirCam provides 4-5 channels of CCD camera data with spectral coverage in the visible and near-IR portion of the spectrum. There is also a capability for a mid-wave-IR (MWIR) channel configuration for fire discrimination. Kestrel does not state the spatial resolution of the TIR band, but other similar systems do not exceed 256x256 pixel arrays, and we suspect this is the case with the Kestrel AirCam (Table 10). No known fire image product is available from Blue Skies Consulting, Spectrum Mapping, or Kestrel. Kestrel’s website does provide thumbnail images of various vegetation mapping efforts, but no information about fire imaging capabilities and data.

Table 10. Kestrel AirCam Instrument Specifications

<table>
<thead>
<tr>
<th>Imager:</th>
<th>4 (or optionally 5) large format progressive scan CCD cameras</th>
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<tbody>
<tr>
<td>Spectral Coverage:</td>
<td>350-1100 nm in 4 bands. Landsat TM Bands 1,2,3,4 standard. MWIR 1.7 - 3.0, 1.7 - 5.0 or 3.0 - 5.0 selectable (Optional full-color camera in lieu of one camera)</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Spatial Resolution:</th>
<th>1.0 milliradians</th>
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</thead>
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<tr>
<td>FOV:</td>
<td>0.8 steradians</td>
</tr>
<tr>
<td>Shutter Speed:</td>
<td>1/60s - 1/16,000s</td>
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<tr>
<td>Position Accuracy:</td>
<td>&lt;100m with GPS selective availability (SA) &quot;on&quot;, &lt;35m with SA &quot;off&quot;</td>
</tr>
<tr>
<td>Operating System:</td>
<td>PC-based, MS-DOS interface</td>
</tr>
<tr>
<td>Output Data Format:</td>
<td>Band Sequential &amp; band interleaved by pixel, TIFF 7.0 with header</td>
</tr>
<tr>
<td>FOV:</td>
<td>0.8 steradians</td>
</tr>
<tr>
<td>Shutter Speed:</td>
<td>1/60s - 1/16,000s</td>
</tr>
<tr>
<td>Position Accuracy:</td>
<td>&lt;100m with GPS selective availability (SA) &quot;on&quot;, &lt;35m with SA &quot;off&quot;</td>
</tr>
<tr>
<td>Operating System:</td>
<td>PC-based, MS-DOS interface</td>
</tr>
<tr>
<td>Output Data Format:</td>
<td>Band Sequential &amp; band interleaved by pixel, TIFF 7.0 with header</td>
</tr>
</tbody>
</table>

| Operating Environment: | 0-15,000ft pressure altitude, -20 to +50 deg C. Passive vibration isolation |
| Size (in):             | Imager: 13(L)x9(W)x11(H); Pwr & Display Module: 23(L)x17(W)x30(H); Control & Rec Module: 23(L)x11(W)x28(H) |
| Power Requirements:   | 480-600Watts at 14VDC (dependant on # of bands) |
| Display:              | Imager: SVGA Monitor; Control: SVGA Monitor; Pilot Display: Backlite LCD |
| Data Archive:         | CD ROM or 4mm DAT tape |
| Attitude Sensor:      | Solid State, heading, pitch and roll |
| Software:             | Custom software for data and image acquisition, post mission review and processing, archival support |
| Radiometric Calibration: | NIST traceable |

2.2.13.2 Blue Skies Consulting Telemetry Capabilities
The AirCam equipment is mounted in a fixed-wing aircraft and can produce highly accurate, ortho-referenced, GIS-ready polygon and point files that represent the fire perimeter and/or hot spots. Data can be downlinked to technicians, air-dropped, or hand-delivered. Hardcopy maps and color and IR imagery can also be provided if requested. No indications of their downlink capabilities or methodology are currently available.

2.2.13.3 Blue Skies Consulting Contact Information
Derived from Zajkowski, 2003c.

<table>
<thead>
<tr>
<th>Company Name:</th>
<th>Blue Skies Consulting, LLC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mailing Address:</td>
<td>P.O. Box 19012, Albuquerque, NM 87119</td>
</tr>
<tr>
<td>Primary Contact:</td>
<td>Tami Wiggins</td>
</tr>
<tr>
<td>Telephone:</td>
<td>505.842.8555</td>
</tr>
<tr>
<td>Fax:</td>
<td>505.842.8555</td>
</tr>
<tr>
<td>Email Address:</td>
<td><a href="mailto:tami@blueskies.aero">tami@blueskies.aero</a></td>
</tr>
<tr>
<td>Website:</td>
<td><a href="http://www.blueskies.aero/">http://www.blueskies.aero/</a></td>
</tr>
<tr>
<td>Emergency Contact:</td>
<td>(D) 505.842.8555, (E) 505.301.4040, (N) 505.857.9968</td>
</tr>
<tr>
<td>General Sensor Description:</td>
<td>Multiple (LIDAR, CIR Camera, Hyperspectral Sensor)</td>
</tr>
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</table>
2.2.14 Type 2 Systems: Range and Bearing Environmental Resource
Mapping Corporation AWIS System
The Range and Bearing Corporation has performed fire management work in Alberta since 1999. The company has developed the Airborne Wildfire Intelligence System (AWIS). The AWIS is a fifth generation advanced airborne remote sensing system, specifically designed using proven components and technology, which captures, mosaics, processes and analyzes digital thermal infrared imagery of wildfires in near real-time. AWIS is an automated, digital system delivering GIS integrated, complete fire intelligence and extensive analysis products via the Internet. AWIS is a Canadian owned, operated and developed system. The system has integrated cutting-edge technology in the areas of aircraft navigation, thermography, image processing, and geomatics.

2.2.14.1 Range and Bearing AWIS Product
The AWIS mission statement is to deliver service oriented, accurate, timely and comprehensive wildfire intelligence in order to facilitate effective and efficient wildfire management. AWIS has the capability to report the precise location of the spot on an image map (using positional coordinates) with vector information overlaid on the image mosaic. As well, detailed intelligence regarding the terrain characteristics, fuel type, and proximity to watercourses and roads can be supplied. The company’s AWIS is really a comprehensive imaging data delivery package, and little or no publicly disclosed information is available on their imaging systems, capabilities, or telemetry standards, equipment or methodology. The company says they will do whatever the client wants, without specifying the type of data they can provide (spectral bands, calibration of such, resolution, etc.) The services offered under the AWIS package include: Detection (Hotspots (active or hold-over), burned areas, water and saturated conditions, vegetative surface changes, fire suppression features, interface structures); Wide-area hot spot detection, Fire perimeter mapping; Temperature analysis; Spatial analysis; Temporal analysis; Fire behavior prediction support; Visualization tools; and Fire intelligence development (Figure 30).

Figure 30. AWIS Imagery for Fire Detection
Image on left shows fire activity, with active fire in red. The center image shows a mosaic of data scenes used to create a fire burned area perimeter map, post-fire. The image on the right shows a 3-D rendition of AWIS data draped over terrain for the Sooke Fire.
2.2.14.2 **Range and Bearing AWIS Telemetry Capabilities**
Products are delivered via a secure website or through FTP (file transfer protocol). Products are in ESRI GIS format and include perimeter and hot spot images, tractor lines, and GPS-formatted file locations. Also included is a hot spot rating tool that ranks hot spots on their escape potential. Escape potential is calculated using a spatial model that considers fire behavior indices, proximity to perimeter, proximity to volatile fuels, values at risk, etc. A three dimensional visual fly-through is also available. Electronic products are delivered via Internet website, Hard copy, CD-ROM and/or by “drop tube. No digital telemetry capabilities are currently used. Data is delivered to analysts after the aircraft has landed. AWIS-ims-based tools can be used to visualize the data sets.

2.2.14.3 **Range and Bearing AWIS Contact Information**
Derived from Zajkowski, 2003c.

<table>
<thead>
<tr>
<th>Company Name:</th>
<th>Range and Bearing Environmental Resource Mapping Corporation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mailing Address:</td>
<td>3747 Privateers Rd., Pender Island, B.C. V0N 2M2 CANADA</td>
</tr>
<tr>
<td>Primary Contact:</td>
<td>Doug Cambell</td>
</tr>
<tr>
<td>Telephone:</td>
<td>250.629.3447</td>
</tr>
<tr>
<td>Fax:</td>
<td>250.629.3557</td>
</tr>
<tr>
<td>Email Address:</td>
<td><a href="mailto:doug@range-bearing.com">doug@range-bearing.com</a></td>
</tr>
<tr>
<td>Website:</td>
<td><a href="http://207.102.122.235/awisweb/index.htm">http://207.102.122.235/awisweb/index.htm</a></td>
</tr>
<tr>
<td>Emergency Contact:</td>
<td>24/7 604.816.6655</td>
</tr>
<tr>
<td>General Sensor Description:</td>
<td>AWIS</td>
</tr>
<tr>
<td>Cost:</td>
<td>Standby: $3695 /day; Flight: $468 /hr; Processing: $2,540 /hr</td>
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2.2.15 **Type 2 Systems: SennaBlue LLC Long-wave thermal frame imager**
SennaBlue currently has operations in the United States of America, Canada and Australia. SennaBlue uses a fixed-wing aircraft to fly over a fire with a single-band (8 - 9 micron) sensor in a nadir position. Aircraft are sub-contracted, USFS-carded Piper Navajo and are equipped with a pilot and mechanic within the stated costs. The system is composed of a 640x512 long-wave (8-12 um range) sensor. The system is Sterling-cooled (rather than cryogenically-liquid cooled). The system produces 14-bit dynamic range information, and has an NedT of <35 milli-Kelvin

SennaBlue’s system operates with an inertial measurement unit and a DGPS navigation system. This provides the capabilities of generating geo-referenced data.

2.2.15.1 **SennaBlue Product**
SennaBlue’s web page is currently under construction (as of 30 November 2003), but the following information was provided by the company president via conversations and email exchanges.
SennaBlue’s processing is broken into two categories; (1) the image ortho rectification process and (2) image analysis, feature extraction and final map production. The company’s primary product is a thermal image mosaic with hot spots highlighted. Fire perimeter and hot-spot location data is also available for incorporation into GIS. Hot-spot coordinates (Universal Traverse Mercator (UTM)/Latitude Longitude) are provided for input into GPS. SennaBlue can provide geo-referenced / ortho-rectified 16-bit thermal image maps (preserving the full dynamic range); extracted hot spot data via custom analysis routines - delivered in GPS format; and complete image maps with hotspot locations and thermal imagery background in pdf format. Maps may also include desired GIS data base information such as roads, creeks etc as well as fire perimeter, area, digitized suppression features or other imagery as a background; and data in GIS format for all of the above (Figure 31).

Figure 31. SennaBlue Thermal Frame Imager Composite Data of an Active Fire
Geo-corrected infrared imagery with hot spots (red) and fire front (green) shown. Tic marks along image side are provided in post-production registration.

2.2.15.2 SennaBlue Telemetry Capabilities
All products can be delivered to the incident command post electronically through e-mail, FTP, or a secure website. Hardcopies can also be delivered. SennaBlue has initiated a development phase to compress the image rectification process and consider using telemetry to transfer this data direct to our analysts. They are evaluating the end result of this processing (time/cost analysis). Data telemetry may occur in 2004 with the full dynamic range being compressed for the transfer. They would like to explore options with NASA on these issues.

2.2.15.3 SennaBlue Contact Information
Derived from Zajkowski, 2003c.
2.2.16 Type 2 Systems: VeriMAP PLUS, Mitsubishi IR-M700 system
VeriMAP Plus Inc. is an aerial imagery/aerial photography and digital mapping company with International office in Calgary, Alberta, Canada. VeriMAP is located in the NW North America to service the Forestry and Fire mapping needs of western Canada and NW USA. In the United States, they operate as VeriMARC Plus Inc. a partnership of VeriMap and MARC Inc, (Mississippi Aircraft Rental Company). The company partnership holds 6 Cessna 337 SkyMaster Survey Mapping Aircraft for data collection missions. The VeriMARC MK IV system includes:

- OmniStar DGPS 1m accurate moving map display for pilot navigation
- Profile LiDAR, (soon to be a 16Khz scanning LiDAR)
- Litton LN200 INS (navigation 400hz data rates)
- Tightly-coupled to real-time differential GPS,
- Mitsubishi M700 thermal infrared camera
- Kodak Color Infrared digital camera (covering 3-spectral band options from true color visible RGB to CIR)

The Thermal Infrared Imager, is the IR-M700 from Mitsubishi Electronics. The IR-M700 produces ultra-high commercial resolution from a Focal Plan Array (FPA) 801 x 512 pixel dimension. Ground sample image dimensions of 30cm pixels are achieved from a 500m-flight altitude. The wide dynamic temperature range of -20 C to 2000 C is well suited to fire mapping requirements. The system can resolve thermal intensity sections of the advancing fire front to classify the hottest sections of the fire. The IR-M700 uses a cryogenic, Stirling cycle cooler for continuous operation for its high-resolution imagery and operates in two filter settings between (1.2 µm to 5.9 µm) or (4.9µm to 5.9µm)(Figure 32).
2.2.16.1 VeriMAP PLUS Product

The VeriMARC thermal infrared fire mapping system is capable of providing a single-channel TIR scene of an area collected. The data can be integrated to create mosaic image maps of active fires for fire management operations and suppression efforts. Missions are deployed for lightning strike verification, active fire line intensity mapping, post main burn mop-up hot spot detection and vegetation mapping looking for live vegetation areas spared by the fire with the color CIR camera. Thermal intensity is resolved to classify the hottest sections of the active fire, therefore pinpointing the areas of most intense thermal energy. These digital aerial maps are loaded to hand-held GPS devices at aircraft landing to enable ground teams to navigate directly to the hotspots most rapidly... by walking, driving or flying by helicopter. The imagery sets are fully ortho-rectified and tiled. Imagery can be processed on board the aircraft or onsite by the vendor. The false-color, post-burn analysis is a larger file size and takes an additional day for processing (Figure 33).
2.2.16.2 VeriMAP PLUS Telemetry Capabilities

Imagery can be processed on board the aircraft and delivered upon landing as a CD-ROM data set. Hot spot coordinates can be relayed to the ground (via radio) for use in attach. No digital telemetry capabilities are currently being utilized.

VeriMAP PLUS Contact Information (derived from Zajkowski, 2003c)

<table>
<thead>
<tr>
<th>Company Name</th>
<th>VeriMap PLUS Inc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mailing Address</td>
<td>4100 Airport Rd., Raymond, MS 39154</td>
</tr>
<tr>
<td>Primary Contact</td>
<td>David Stonehouse</td>
</tr>
<tr>
<td>Telephone:</td>
<td>601.857.8197</td>
</tr>
<tr>
<td>Fax:</td>
<td>601.857.8177</td>
</tr>
<tr>
<td>Email Address:</td>
<td><a href="mailto:david_s@verimap.com">david_s@verimap.com</a></td>
</tr>
<tr>
<td>Website:</td>
<td><a href="http://www.verimap.com/">http://www.verimap.com/</a></td>
</tr>
<tr>
<td>Emergency Contact:</td>
<td>24/7 403.606.0412</td>
</tr>
<tr>
<td>General Sensor Description:</td>
<td>Mitsubishi IR-M700, Kodak CIR, Profile LIDAR</td>
</tr>
<tr>
<td>Cost:</td>
<td></td>
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2.2.17 Type 3 Systems: Angiel EnviroSafe, Inc., Daedalus ABS
Angiel EnviroSafe uses the Daedalus ABS (Airborne Bispectral Scanner) system mounted in the camera hole of a Piper Aztec twin-engine airplane. The ABS has a wide 86-degree field of view. It collects data in the 8 to 12 micron band (Long Wave IR) and in the 360-to-380-nanometer band (UV). Therefore it only has one thermal band to collect data over fires. This unit is similar to the Daedalus units (now used as backup for the Phoenix systems) used by the NIROPS except that the Angiel EnviroSafe ABS unit presently uses only one thermal band (8 - 12 micron).

2.2.17.1 Angiel EnviroSafe, Inc. Product
Angiel has no example products at their website, except for a copy (not credited) of the FireMapper product (which is NOT produced from a Daedalus (now SenSyTech) ABS instrument). The Angiel EnviroSafe Daedalus ABS sensor system is shown in Figure 34.

![Figure 34. The Angiel EnviroSafe, Inc. Daedalus (now SenSyTech) Airborne Bispectral Scanner](image)
The two-channel scan head is shown on the left and the operator’s electronic control rack is shown on the right.

2.2.17.2 Angiel EnviroSafe, Inc. Telemetry Capabilities
No known telemetry capabilities for digital data distribution from the acquiring aircraft.

2.2.17.3 Angiel EnviroSafe, Inc. Contact Information
Derived from Zajkowski, 2003c.
2.2.18 Type 3 Systems: Fireball Information Technologies (Wescam 12-DS90)

Fireball is a nationally registered contractor to provide incident support services for wildland fire. Over the last four years, Fireball has developed a real time mapping and GIS system. This proprietary technology allows Fireball to provide accurate and immediately available situation information to incident managers and their crews. When Fireball is ordered for an Incident, managers get a package of three logically integrated services: Reconnaissance Platform; Thermal Mapping; GIS Services. The company utilizes helicopter aircraft support through a contract with Redding Air Services. The foundation of the system is based upon a Wescam 12DS, dual-sensor, gimbaled camera system. The dual sensor system features a high sensitivity, 3-5µm, 3 field-of-view FLIR, with Indium Antimonide staring array, and a low-light color daylight CCD camera with 10x zoom lens. The Wescam system is mounted on the belly of the Bell 206 Jet Ranger (Figure 35).

![Figure 35. The Wescam 12-DS90](image)

The Wescam 12-DS90 is a dual-sensor, gimbaled camera system (on left) and the system mounted on the underside of the Redding Air Service’s Bell206 Jet Ranger.
The Fireball System consists of two parts: an aircraft unit and a ground support station. These are detailed in the following:

**Aircraft**
- Bell 206 Jet Ranger owned and operated by Redding Air Service
- High end computer workstation running Fireball's proprietary software
- Wescam(R) 12DS gyro-stabilized, gimbal containing co-aligned: daylight TV with 10X zoom and modified InSb infrared imager.
- Differential GPS receiver
- Inertial Navigation Unit with proprietary modifications (for accurate navigation solution)
- High-bandwidth microwave downlink (to ground station)
- Moderate-band microwave satellite uplink (to Internet Server)

**Ground Station**
- Self-sufficient GIS trailer
- Multiple computer workstations
- HP plotters for printing medium and large-format maps
- High-bandwidth microwave link

### 2.2.18.1 Fireball Information Technologies (Wescam 12-DS90) Product
Fireball provides a number of paper and digital products. After receiving flight instructions and important issues for a particular incident, Fireball will fly the designated portions of the incident in a Bell 206 Jet Ranger (operated by Redding Air Services) to map the fire perimeter, active areas and hotspots. Since all the data processing occurs in the aircraft during the flight, paper and digital products are available almost immediately after the flight.

![Figure 36. Fireball Information Technologies Wescam 12-DS90 Derived Paper Map Product](image)

*This product displays fire perimeter plotted on a USGS DRG and hot spot detection in various shades of color denoting intensity.*
The typical printed map Fireball produces consists of USGS DRGs (topographic maps) as a base layer with fire perimeter and hotspot data overlaid (Figure 36). Additional printed products include zoom-in printouts of individual hotspots for mop-up crews. These smaller size (8.5x11" or 11x17") printouts include an aerial photograph with infrared overlay, perimeter line and GPS coordinates (Figure 37).

During the flight, fireball's proprietary system will capture video and still frames (both infrared and visual). The aircraft's position and fire perimeter are displayed to the operator and observer in a flight-following format. As the flight is in progress, the system uses its onboard navigation system, camera parameters and digital elevation models (DEM) to accurately geo-reference and ortho-rectify the incoming images. Next, the images are analyzed by the onboard computer for heat. A specialized algorithm extracts coordinates for all hot spots in the imagery automatically. These coordinates are available immediately for transmission to ground crews. The aircraft and fire perimeter are displayed over a base map that can consist of USGS DRGs, DEM's, DOQQ’s or satellite imagery (topographic maps, hill shades, aerial photos). As the flight progresses, processed imagery appears on the map and can be clicked for inspection.

All data from each flight is available digitally in a format usable by ArcView, so GIS groups can use it in their own maps and presentation materials. Typical data sets consist of:
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- Perimeter (as a shapefile)
- Hotspots (as a shapefile indexed by size/intensity)
- Flight path (as a shapefile)
- Area of coverage (as a shapefile)
- Geo-referenced images (as Geo-JPEGs)
- Historical index of all maps on CD-ROM (for transition packages)

Fireball’s IR and visible imagery is geo-referenced and ortho-rectified. The size and intensity of heat sources are extracted on the fly. IR overlays detailing hot spots and GPS coordinates for use by mop-up crews are also available. Video recordings (both IR and TV) of the flights are available. Digital data can be delivered through Fireball’s FTP site or one of the dedicated fire FTP sites.

### 2.2.18.2 Fireball Information Technologies (Wescam 12-DS90) Telemetry Capabilities

When line-of-site communication is in place, data on location and intensity of heat sources can be viewed on the ground in real time. During the flight, imagery and flight information are transmitted to the ground station over a high-speed data link. Fireball ground crew receives imagery and perimeter data from the flight and begun processing it into hard copy. Data can be displayed in less than a minute and printed maps are available on the ground with a minimum amount of time. All the images are geo-referenced on the fly, so accurate ground coordinates are produced for each image. Fireball geo-references images by taking into account aircraft attitude and location, camera direction and zoom, and ground topography.

Fireball has a high-bandwidth microwave downlink (to ground station) from the acquiring helicopter platform, and a moderate-band microwave satellite uplink (to Internet Server). No further information on the telemetry equipment is available.

### 2.2.18.3 Fireball Information Technologies Contact Information

Derived from Zajkowski, 2003c.

<table>
<thead>
<tr>
<th>Company Name:</th>
<th>Fireball Information Technologies, LLC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mailing Address:</td>
<td>1240 Fairfield Ave., Reno, NV 89509</td>
</tr>
<tr>
<td>Primary Contact:</td>
<td>Tim Ball</td>
</tr>
<tr>
<td>Telephone:</td>
<td>755.848.4462</td>
</tr>
<tr>
<td>Fax:</td>
<td>775.328.0694</td>
</tr>
<tr>
<td>Email Address:</td>
<td><a href="mailto:info@fireballit.com">info@fireballit.com</a></td>
</tr>
<tr>
<td>Website:</td>
<td><a href="http://www.fireballit.com/">http://www.fireballit.com/</a></td>
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<tr>
<td>Emergency Contact:</td>
<td>24/7 775.848.4462</td>
</tr>
<tr>
<td>General Sensor Description:</td>
<td>Wescam 12-DS90</td>
</tr>
<tr>
<td>Cost:</td>
<td>Flight: $491 / hour; System: $7172 / day</td>
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</table>

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2.2.19 Type 3 Systems: Mid-Valley Helicopters

Mid-Valley Helicopters operates the Radiometric Airborne Mapping (RAM) system. This system has been developed by RAM Systems Incorporated and sold to several IR mapping vendors throughout the United States. The RAM system has an emissive code which is set for a specific heat index on the ground, giving it the capability of discriminating between burning wood, hot rock, cars, etc. RAM systems come with a GIS support trailer that can create map products from the IR data. The Agema 1000 Radiometric Infrared Heat Intensity mapping radiometric/DTV imaging system is a lightweight, compact, gimbal mounted, gyro stabilized imager. The system provides digital temperature information (minimum, maximum and average). The information can be of spot or area locations. The temperature information is operational in Centigrade, Fahrenheit, and Kelvin. Ambient surface temperatures do not affect the high temperature readings. This is accomplished by inputting of emissivity, atmospheric temperature, ambient temperature, objective distance, relative humidity, computed transmittance and estimated transmittance. Additionally, a synchronized digital video image is recorded along with the temperature readings. This provides quality digital imagery in addition to the thermal readings. This imagery is recorded with the same field-of-view as the thermal readings, imprinted with GPS coordinates, and time encoded for frame grabbing. This provides another tool for the incident command team. The gimbal camera is mounted on the belly of a helicopter and is controlled from an operator’s station on board (Figure 38).

The RAM system provides computerized maps plotted to scale from GPS, with GIS information, including the actual fire perimeter as well as power lines, fuel breaks, new road or cat line construction, water source levels, suitable helispot locations, homes, etc. The system can plot the fire perimeter with the heat intensity. The mobile GIS lab’s (which accompanies the RAM for mission data ingestion) primary purpose is to process radiometric data. But, the lab is also equipped to provide complete GIS services in remote locations (i.e., planning maps, incident action maps, fire progression maps, fire spread prediction, processing satellite images, and aerial photos)(Figure 39)(Table 11).

Figure 38. RAM Gimbal-Mounted Agema 1000 Radiometric Infrared Camera System

Shown mounted on the belly of a helicopter (left image).  
Control station for the RAM system in the helicopter (right image).
Figure 39. The RAM Mobile GIS Lab trailer at the Curve Fire, Angeles National Forest, September, 2002

*Image on left shows the MotoSat dish communication antenna on the roof. The interior of the Mobile GIS Lab is shown on the right.*

<table>
<thead>
<tr>
<th>Table 11. Capabilities of the RAM Mobile GIS Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wired for Phone/Modem</td>
</tr>
<tr>
<td>Wired for Internal Network</td>
</tr>
<tr>
<td>Wired for External Network Link</td>
</tr>
<tr>
<td>One or Two computer stations, depending on trailer size</td>
</tr>
<tr>
<td>Computer will be state-of-the-art with the following components:</td>
</tr>
<tr>
<td>Fast processor, based on current technology</td>
</tr>
<tr>
<td>Advanced Video Graphics Card</td>
</tr>
<tr>
<td>Internal Modem</td>
</tr>
<tr>
<td>Adequate RAM, 1 GB or greater</td>
</tr>
<tr>
<td>Large capacity HD</td>
</tr>
<tr>
<td>Internal zip drive, on request</td>
</tr>
<tr>
<td>CD/DVD Rom drive</td>
</tr>
<tr>
<td>CD/DVD Writer</td>
</tr>
<tr>
<td>1.44-megabyte floppy disc drive</td>
</tr>
<tr>
<td>10/100 Base-T Ethernet</td>
</tr>
<tr>
<td>Two independent USB ports</td>
</tr>
<tr>
<td>Keyboard and mouse</td>
</tr>
<tr>
<td>17” flat screen monitor</td>
</tr>
<tr>
<td>36-inch large format inkjet plotter</td>
</tr>
<tr>
<td>Windows XP Professional Operating system</td>
</tr>
<tr>
<td>ESRI ArcView 3.x GIS</td>
</tr>
<tr>
<td>ESRI ArcView or ArcInfo 8.x</td>
</tr>
<tr>
<td>ESRI ArcPress</td>
</tr>
<tr>
<td>ArcView Extensions</td>
</tr>
</tbody>
</table>
2.2.19.1 Mid-Valley Helicopters (Agema 1000 Radiometric Infrared) Product
The RAM system provides a fire hot spot GPS location, derived from the Agema / FLIR 1000 calibrated camera system. The GPS location is derived from the attitude of the helicopter data and the pointing vector calculations of the gimbaled sensor. The hot spots are recorded as a “text” file (in GPS coordinates) and downlinked to the ground via a satellite phone system (see Telemetry capabilities in following section).

2.2.19.2 Mid-Valley Helicopters Telemetry Capabilities
Also, a data downlink system was implemented in 2003. The telemetry system is based on a satellite cellular phone/data system, communicating through the Iridium satellite constellation. The system operated at 9.6 Kbs (9600 baud). The RAM data is sent as simple text files of GPS locations of hot spots detected from the Agema / FLIR 1000 camera. The low data rate is sufficient for this text file (GPS locations) data transmission.

The MotoSat dish communication antenna mounted on the roof of the RAM Mobile Lab trailer is to provide local area wireless Internet services to fire camp locations (where the trailer would be located).

2.2.19.3 Mid-Valley Helicopters Contact Information
Derived from Zajkowski, 2003c.

<table>
<thead>
<tr>
<th>Company Name:</th>
<th>Mid-Valley Helicopters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mailing Address:</td>
<td>P.O. Box 993, Jefferson, OR 97352</td>
</tr>
<tr>
<td>Primary Contact:</td>
<td>Jill Johnson</td>
</tr>
<tr>
<td>Telephone:</td>
<td>541.327.1169</td>
</tr>
<tr>
<td>Fax:</td>
<td>541.327.2910</td>
</tr>
<tr>
<td>Email Address:</td>
<td><a href="mailto:jill@ramsystemsllc.com">jill@ramsystemsllc.com</a></td>
</tr>
<tr>
<td>Website:</td>
<td><a href="http://www.ramsystemsllc.com/">http://www.ramsystemsllc.com/</a></td>
</tr>
<tr>
<td>Emergency Contact:</td>
<td>Jill Johnson, 541.327.1169, 541.327.2910</td>
</tr>
<tr>
<td>General Sensor Description:</td>
<td>Agema 1000 Radiometric Infrared</td>
</tr>
<tr>
<td>Cost:</td>
<td>Aircraft Availability: $1960/day; Flight: $500/hr; Camera: $2500/day; Trailer: $2500/day</td>
</tr>
</tbody>
</table>

2.2.20 Type 3 Systems: San Joaquin Helicopter
San Joaquin Helicopter contracts out to USFS, BLM, and CDF, for fire suppression. San Joaquin Helicopters provides Infrared hot spot locating and GPS/GIS mapping. By merging Geographic Information Systems “GIS” and Forward Looking Infrared “FLIR” Mapping, the Aerial Infrared Mapping (AIM) system provides hot spot detection via a FLIR Systems Model 2000AB mounted on a Bell 206B3 Jet Ranger helicopter. A GIS technician rides left-seat during mapping flights, alongside the pilot, ensuring accurate, efficient data gathering through a heads-up display in the cockpit.
2.2.20.1 San Joaquin Helicopter (FLIR System Model 2000AB) Product

The Company also provides an associated Mobile GIS Lab trailer and service truck for fire mapping missions. The trailer is fully-contained with ARCVIEW software, with desired layering for direct transfer to local GIS systems, large wall maps for display and interpretation at briefings, durable pocket maps for out on the line, and other useful formats. The equipment is capable of producing geo-referenced, panchromatic IR photos, GIS-ready polygon and point files representing fire perimeters, and hot spots and hardcopy GIS-generated map products. The GIS-created maps have thumbnail versions of the geo-referenced panchromatic IR imagery located on a USGS 1:24,000 topographical base map (Figure 40).

![Figure 40. Video Frame Grab of Fire Data Collected from the FLIR Systems Model 2000AB (on Left) and the GIS-Derived Map (on Right)](image)

The GIS map is a USGS 1:24K topo base map combined with thumbnail, geo-referenced panchromatic IR imagery located on it. GPS reference information is provided in the image “text box”.

2.2.20.2 San Joaquin Helicopter Telemetry Capabilities

Digital information, including the video frame “grab” imagery, is copied to CD and hardcopy maps and photos, or can be provided over a LAN (local area network) as e-mail. There is no digital transmission from aircraft to ground.

2.2.20.3 San Joaquin Helicopter Contact Information

Derived from Zajkowski, 2003c.

<table>
<thead>
<tr>
<th>Company Name:</th>
<th>San Joaquin Helicopters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mailing Address:</td>
<td>1407 S. Lexington St., Delano, CA 93215</td>
</tr>
<tr>
<td>Primary Contact:</td>
<td>Jay Koch</td>
</tr>
<tr>
<td>Telephone:</td>
<td>916.966.8181</td>
</tr>
<tr>
<td>Fax:</td>
<td>916.354.0547</td>
</tr>
<tr>
<td>Email Address:</td>
<td><a href="mailto:jkoch76@hotmail.com">jkoch76@hotmail.com</a></td>
</tr>
</tbody>
</table>
### 2.2.21 Type 3 Systems: Ventura County Sheriff Aviation Unit / SAR

Ventura County operates a FLIR Systems Mark II infrared and color video camera that views energy in the 8 - 12 micron range.

#### 2.2.21.1 Ventura County Sheriff Aviation Unit / SAR Product

The equipment is capable of producing IR and color videos, and GPS-generated, GIS-ready polygon and point files representing fire perimeter and hot spots. The GPS-created data is differentially corrected, meaning that the system records the location of the helicopter as it flies over the fire.

#### 2.2.21.2 Ventura County Sheriff Aviation Unit / SAR Telemetry Capabilities

Digital information, including video, can be downlinked to technicians, air-dropped, or hand-delivered. Color and infrared imagery can also be provided if requested. No indication of telemetry method is described or provided.

#### 2.2.21.3 Ventura County Sheriff Aviation Unit / SAR

Derived from Zajkowski, 2003c.

<table>
<thead>
<tr>
<th>Company Name:</th>
<th>Ventura County Sheriff Aviation Unit/SAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mailing Address:</td>
<td>375 Durley Ave. #A, Camarillo, CA 93010</td>
</tr>
<tr>
<td>Primary Contact:</td>
<td>Captain Arve Wells</td>
</tr>
<tr>
<td>Telephone:</td>
<td>805.338.4212</td>
</tr>
<tr>
<td>Fax:</td>
<td>805.338.4380</td>
</tr>
<tr>
<td>Email Address:</td>
<td><a href="mailto:Arve.Wells@mail.co.ventura.ca.us">Arve.Wells@mail.co.ventura.ca.us</a></td>
</tr>
<tr>
<td>Website:</td>
<td><a href="http://www.fire.countyofventura.org/Services/Mapping/mapping.html">http://www.fire.countyofventura.org/Services/Mapping/mapping.html</a></td>
</tr>
<tr>
<td>Emergency Contact:</td>
<td>24/7 805.654.5161</td>
</tr>
<tr>
<td>General Sensor Description:</td>
<td>FLIR Mark II IR &amp; color video system</td>
</tr>
<tr>
<td>Cost:</td>
<td>Approximately $400/day, plus per diem for crew, plus $1.47/mi (fuel tender), plus $734/hr</td>
</tr>
</tbody>
</table>

### 2.2.22 Type 3 Systems: Vision Air Research

Vision Air Research was founded to specialize in wildlife surveys using advanced aerial infrared sensor technology (commonly called forward-looking infrared – FLIR). They do not provide much service to the fire imaging community, focusing on animal surveys. Vision Air utilizes a PolyTech Kelvin 350 II sensor, which is a high resolution FLIR Thermovision® 1000 and a SONY FCP 470 video camera (Figure 41).
Figure 41. PolyTech Kelvin 350 II Gimbaled Infrared System

This system includes a SONY video camera and a Thermovision (an infrared radiometer).

### 2.2.22.1 Vision Air Research Product

Output includes both color and infrared video in analog or digital videotape. The video includes an overlay of the GPS data. The Vision Air collects frame-by-frame data at up to one frame per second in an on-board computer. This computer has the capability to geo-rectify the data frame by frame. The geo-referenced mosaics can be incorporated into a GIS data product. Data can be exported to ArcView shapefile for import into your GIS, html format for web based publication or to a CD, excel spreadsheet for further analysis, or a range of graphics formats. The video and still images can be exported as html or shapefile format.

### 2.2.22.2 Vision Air Research Telemetry Capabilities

No telemetry capabilities noted.

### 2.2.22.3 Vision Air Research Contact Information

Derived from Zajkowski, 2003c.

<table>
<thead>
<tr>
<th>Company Name</th>
<th>Vision Air Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mailing Address:</td>
<td>904 E. Washington St., Boise, ID 83712</td>
</tr>
<tr>
<td>Primary Contact:</td>
<td>Susan Bernatas</td>
</tr>
<tr>
<td>Telephone:</td>
<td>208.841.9566</td>
</tr>
<tr>
<td>Fax:</td>
<td>208.345.0595</td>
</tr>
<tr>
<td>Email Address:</td>
<td><a href="mailto:wildlife@visionairresearch.com">wildlife@visionairresearch.com</a></td>
</tr>
<tr>
<td>Website:</td>
<td><a href="http://www.visionairresearch.com/">http://www.visionairresearch.com/</a></td>
</tr>
<tr>
<td>Emergency Contact:</td>
<td>24/7 208.841.9566</td>
</tr>
<tr>
<td>General Sensor Description:</td>
<td>PolyTech Kelvin 350 II</td>
</tr>
<tr>
<td>Costs:</td>
<td>Ferry: $250-440/hr; Acquisition: $275-575/hr; Sensor support: $1850-2500/day</td>
</tr>
</tbody>
</table>

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2.2.23 Type 3 Systems: Helicopter Applicators Inc.
Helicopter Applicators Incorporated utilizes a Kelvin 350 II Radiometric Infrared Camera System. It covers the thermal range (wavelengths of 8 \( \mu m \) through 12 \( \mu m \)), resolving 4096 levels of heat radiation. The Thermovision 1000 sensor is housed in a gyro-stabilized ball and is mounted on the belly of a Bell 206 Jet Ranger. The system includes two monitors with daytime and infrared video, a data acquisition system consisting of a computer, switch panels for heat indexes and a GPS unit; accurate to within three meters.

Helicopter Applicators Inc. also is currently equipped with a PolyTech Pixel 275 II\textsuperscript{®} system. Designed on a gyro-stabilized platform, the Pixel 275 II\textsuperscript{®} is a highly capable airborne surveillance / inspection system. This system contains a visible light three-chip camera (Sony DCR-VX1000\textsuperscript{®}) mounted within a gyro-stabilized turret. Sony's VX-1000\textsuperscript{®} is a high-resolution digital video camera with high zoom capability. The VX-1000\textsuperscript{®} incorporates Sony's Super Steadyshot\textsuperscript{®} picture stabilization technology, reducing shake without compromising picture quality. Our Pixel 275 II\textsuperscript{®} is also equipped with a GPS unit for real-time onscreen time and location information. Easy to use controls allow the operator to position the turret through a full 360° range of motion. We fly our system using a Bell Helicopters Jet Ranger\textsuperscript{®} allowing accurate slow and low flights.

2.2.23.1 Helicopter Applicators Inc. (FLIR Thermovision 1000) Product
Helicopter Applicators, Inc. operates a RAM system, similar to the one used by Mid-Valley Helicopters (see above listing for Mid-Valley).

2.2.23.2 Helicopter Applicators Inc. Telemetry Capabilities
No current telemetry options listed by company.

2.2.23.3 Helicopter Applicators Inc. Contact Information
Derived from Zajkowski, 2003c.

<table>
<thead>
<tr>
<th>Company Name:</th>
<th>Helicopter Applicators Incorporated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mailing Address:</td>
<td>1670 York Rd., Gettysburg, PA 17325</td>
</tr>
<tr>
<td>Primary Contact:</td>
<td>Jason Cole</td>
</tr>
<tr>
<td>Telephone:</td>
<td>717.337.1370</td>
</tr>
<tr>
<td>Fax:</td>
<td>717.337.1527</td>
</tr>
<tr>
<td>Email Address:</td>
<td><a href="mailto:jcole@helicopterapplicators.com">jcole@helicopterapplicators.com</a></td>
</tr>
<tr>
<td>Website:</td>
<td><a href="http://www.helicopterapplicators.com/">http://www.helicopterapplicators.com/</a></td>
</tr>
<tr>
<td>Emergency Contact:</td>
<td>Glen Martin, 8AM - 5PM EST 717.337.1370</td>
</tr>
<tr>
<td>General Sensor Description:</td>
<td>FLIR Thermovision 1000 Radiometric Infrared Camera System</td>
</tr>
<tr>
<td>Costs:</td>
<td>Flight: $497/hr; Aircraft Availability: $2100; Trailer: $5000/day</td>
</tr>
</tbody>
</table>
2.2.24 Type 3 Systems: Oilton Remote Detection Technologies AIRDS Sensor
The Airborne Infrared Detection System (AIRDS) was developed and is owned by Oilton Remote Detection Technologies of St. Paul, MN. The high-resolution sensor was developed to detect and map land mines and other unexploded ordnance. AIRDS is a FLIR 2000AB gimbaled, thermal infrared sensor filtered to the 8 - 14 micron wavelength. ORD-TECH has developed and successfully demonstrated AIRDS technology for both surface and buried unexploded ordnance, as well as petroleum product contamination. AIRDS is based on thermal infrared imaging technology and on a proprietary process to analyze the data. The AIRDS can be used either on a fixed wing airplane or a helicopter, depending on the project and the target of interest. The forward-looking infrared or FLIR ball is located on the belly of the helicopter. The FLIR ball is connected to a monitor inside the helicopter where an engineer utilizes the display to define areas of (fire) interest (Figure 42). Oilton uses EL Aero of Elko, NV, for its fire contract ships.

Figure 42. The Oilton Remote Detection Technologies Sensor, Composing the Airborne Infrared Detection System (AIRDS)

2.2.24.1 Oilton Remote Detection Technologies AIRDS Product
This system utilizes on-board Differential Global Positioning System (DGPS) and a laser ranging system for calculating the positions of hot spots.

2.2.24.2 Oilton Remote Detection Technologies AIRDS Telemetry Capabilities
The AIRDS system is also equipped with digital line-of-site communication for real-time image downloading. No known characteristics of the system are known. The company does not maintain a web page for information.

2.2.24.3 Oilton Remote Detection Technologies AIRDS Contact Information
Derived from Zajkowski, 2003c.
2.2.25 Type 3 Systems: Advanced Building / M.I.R.S. (Raytheon IR 400DX Pro)

The Mobile Laser-Designated InfraRed Multimedia Mapping System (MIRS) is composed of a Raytheon IR 400DX Pro. This system can operate on any aircraft with a 3-pin or 2-pin power connector; however, helicopters are the preferred platform. The system can operate on a Jet Ranger (all models), Hughes 500 (all models), Cessna 206 (w/ spoiler kit), Hueys and any other USFS carded aircraft(s) w/ power connector. The Raytheon IR 400DX Pro provides digital data storage combined with the power of a personal digital assistant (PDA), which can store over 150 images. The camera produces 320 x 240 pixel thermal images and offers an interface with its on-screen menu and NTSC or Pal video output. In addition, the Pro 400 Digital is capable of using interchangeable lenses to fit a wide variety of applications. The unit is a hand-held system (Figure 43).

![Figure 43. The Advanced Building MIRS (Raytheon IR 400DX Pro) Handheld Thermal IR Camera System](image)

The system is used to fly and define fire perimeters by coupling with a laser-designated GPS measurement of the pointing vector of the instrument.

2.2.25.1 Advanced Building / M.I.R.S., (Raytheon IR 400DX Pro) Product

The system provides a view of the fire’s perimeter overlaid over a USGS 1:24,000 topographical map for hot spots within 300 feet of the fire perimeter. Also included are infrared photos, a correlating natural color photo with GPS/time/date information on the
The Institute for the Application of Geospatial Technology

photo, and a 7-10 second IR video for each hot spot. The system provides a full color (256 color) Thermal infrared imaging camera with a temp range of 32 degrees F to 572 degrees F., and sensitivity of 1 degree Celsius. All data is embedded with laser designated GPS info with a margin of error less than 15cm from target. All targets on maps (i.e. hotspots, water sources) will have a minimum of 7-10 seconds of IR thermal video, an IR thermal still photo with GPS and Time Code embedded, a digital still photo with GPS info embedded to correlate with TIR imagery, and an integrated temperature analysis of all hot spots (Figure 44). The company provides a Mobile GIS trailer with necessary computers, printers, and a high-speed satellite-Internet dish (Figure 45).

Figure 44. Fire Perimeter Map Derived from the MIRS System Handheld Device

While flying the general perimeter, the Raytheon IR 400DX Pro is pointed at the fire perimeter. A coincident laser pointing GPS provides feedback of the burn area edge GPS values. These are used on the ground to produce the map seen here.

Figure 45. The MIRS Mobile GIS Lab Trailer and the Interior of the Lab

The antenna on the trailer roof is for wireless satellite / Internet connectivity in fire camp.
2.2.25.2 Advanced Building / M.I.R.S., (Raytheon IR 400DX Pro) Telemetry Capabilities
All data is exported to ArcView 3.x format, or HTML for presentations. No known telemetry capabilities are provided. Data are shared from the Mobile GIS trailer via a wireless satellite / Internet system.

2.2.24.3 Advanced Building / M.I.R.S., Contact Information
Derived from Zajkowski, 2003c.

<table>
<thead>
<tr>
<th>Company Name:</th>
<th>Advanced Building/M.I.R.S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mailing Address:</td>
<td>2810 Highway 32, Chico, CA 95973</td>
</tr>
<tr>
<td>Primary Contact:</td>
<td>Dave Chaplin</td>
</tr>
<tr>
<td>Telephone:</td>
<td>530.895.1836</td>
</tr>
<tr>
<td>Fax:</td>
<td>530.895.1741</td>
</tr>
<tr>
<td>Email Address:</td>
<td><a href="mailto:chaparelli24@aol.com">chaparelli24@aol.com</a></td>
</tr>
<tr>
<td>Website:</td>
<td><a href="http://www.mobile-ir.com/">http://www.mobile-ir.com/</a></td>
</tr>
<tr>
<td>Emergency Contact:</td>
<td>Dave Chaplin, 530.321.6445</td>
</tr>
<tr>
<td>General Sensor Description:</td>
<td>Raytheon IR 400DX Pro</td>
</tr>
<tr>
<td>Costs:</td>
<td>$2500/day, plus the cost of “call when needed” aircraft</td>
</tr>
</tbody>
</table>

2.2.25 Type 3 Systems: John Newman (IR Mapping)
John Newman IR Mapping uses a Raytheon Digital PalmIR 250 camera in a nadir mount. IR Mapping relies on the incident management team to provide the aircraft. The equipment can be mounted in a helicopter already assigned to the incident.

2.2.25.1 John Newman (Raytheon Digital PalmIR 250) Product
The camera is designed as a hand-held unit but the company has mounted the system in a nadir mount. The NightSight PalmIR 250 Digital is a digital upgrade of Raytheon's NightSight PalmIR 250 camera providing clearer images through digital signal processing and adds features such as 2X zoom and automatic contrast. The camera is designed around an uncooled ferro-electric, 320x240 pixel array detector (Figure 46). The camera has a spectral response of 7-14 µm. The capabilities of the Raytheon Digital PalmIR 250 camera are shown in Table 12.
Figure 46. The Raytheon Digital PalmIR 250 Thermal Camera

John Newman (IR Mapping) has configured this hand-held system as a nadir-mount camera for fire imaging. The camera operates in the 7-14 µm TIR range.

Table 12. Specifications of the Raytheon Digital PalmIR 250

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physical Dimensions</strong></td>
<td>9.5&quot;L x 4&quot;W x 4&quot;H</td>
</tr>
<tr>
<td><strong>Weight without Battery</strong></td>
<td>2.6 lbs</td>
</tr>
<tr>
<td><strong>Ergonomic Design</strong></td>
<td>One hand operation</td>
</tr>
<tr>
<td><strong>Mounting Provisions</strong></td>
<td>Tripod mount</td>
</tr>
<tr>
<td><strong>Operating Temperature</strong></td>
<td>-20°C to 49°C</td>
</tr>
<tr>
<td><strong>Storage Temperature</strong></td>
<td>-40°C to 80°C</td>
</tr>
<tr>
<td><strong>Water Resistance</strong></td>
<td>Splash-proof IEC pub. 529 IPX4</td>
</tr>
<tr>
<td><strong>Operating Humidity</strong></td>
<td>0-95 percent non-condensing</td>
</tr>
<tr>
<td><strong>Power Source</strong></td>
<td>Rechargeable camcorder battery (6VDC)</td>
</tr>
<tr>
<td><strong>Power Consumption</strong></td>
<td>&lt;5 watts</td>
</tr>
<tr>
<td><strong>Power Conservation</strong></td>
<td>Standby mode</td>
</tr>
<tr>
<td><strong>Operating Time per Charge</strong></td>
<td>&gt;3 hours (varies with batteries and environmental conditions)</td>
</tr>
<tr>
<td><strong>Interfaces</strong></td>
<td></td>
</tr>
<tr>
<td><strong>VCR Compatible Video Output</strong></td>
<td>NTSC &amp; PAL (RCA jack)</td>
</tr>
<tr>
<td><strong>External Control</strong></td>
<td>RS-232 serial communications port</td>
</tr>
<tr>
<td><strong>Performance</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Detector Type</strong></td>
<td>Uncooled ferro-electric (320 x 240)</td>
</tr>
<tr>
<td><strong>Spectral Response</strong></td>
<td>7 to 14 microns</td>
</tr>
<tr>
<td><strong>Thermal Stabilization</strong></td>
<td>Thermoelectric cooler</td>
</tr>
<tr>
<td><strong>Frame Rate</strong></td>
<td>30 Hz NTSC, 25 Hz PAL</td>
</tr>
<tr>
<td><strong>Time to Operation</strong></td>
<td>&lt;30 seconds (typical) &lt;90 seconds (max)</td>
</tr>
<tr>
<td><strong>Standard Lens</strong></td>
<td>75mm, f/1.0</td>
</tr>
</tbody>
</table>
IR Mapping maps a fire's perimeter location and hot spots using GPS aboard a helicopter (or airplane). The system is generally mounted in a helicopter (nadir mount), flying the perimeter of the fire. The camera records the hot spots and is united with the coincident GPS track data to define the location of the perimeter. The camera resolution is small (320x240 pixels) and the spectral response is in the 7-14 µm range (TIR).

### 2.2.25.2 John Newman Telemetry Capabilities

After landing, perimeter and hot spot information are printed on USGS maps and delivered to the incident management team. No telemetry capabilities are stated, although GPS data could easily be sent via radio communication. Data are off-loaded upon landing and digital GPS locations of the perimeter are placed as vectors on maps (assumed GIS integration capabilities at the ICC).

### 2.2.25.3 John Newman Contact Information

Derived from Zajkowski, 2003c.

<table>
<thead>
<tr>
<th>Company Name:</th>
<th>John Newman (IR Mapping)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mailing Address:</td>
<td>P.O. Box 391, Kernville, CA 93238</td>
</tr>
<tr>
<td>Primary Contact:</td>
<td>John Newman</td>
</tr>
<tr>
<td>Telephone:</td>
<td>760.376.2861</td>
</tr>
<tr>
<td>Fax:</td>
<td>760.376.2861</td>
</tr>
<tr>
<td>Email Address:</td>
<td><a href="mailto:johnlinda@lightspeed.net">johnlinda@lightspeed.net</a></td>
</tr>
<tr>
<td>Website:</td>
<td>N/A</td>
</tr>
<tr>
<td>Emergency Contact:</td>
<td>24/7 760.549.3292</td>
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<td>General Sensor Description:</td>
<td>Raytheon Digital PalmIR 250</td>
</tr>
<tr>
<td>Costs:</td>
<td>$1750/day plus the cost of “call when needed” aircraft</td>
</tr>
</tbody>
</table>
3.0 DELIVERY SYSTEMS

3.1 TELEMETRY
Data telemetry involves “moving” data through wireless connections between the acquiring imaging system and platform and a “ground receiving station”. There are a number of methodologies to support the telemetry of data from an acquiring platform, and they involve varying “paths” for “wireless” communication. Two primary focus directions are: 1) Direct from acquiring aircraft to a “ground receiving location” and, 2) data transmission from an acquiring aircraft, up through a telecommunications satellite, and down to a ground network system location. There are advantages and disadvantages to each method, which are discussed here.

3.1.1 Satellite Telemetry Communication
This telemetry method permits the data transmission from the acquiring aircraft up to a commercial geo-stationary communications satellite system such as INMARSAT. The advantage to this telemetry methodology is that data can be sent to any location on the globe. The aircraft is not required to stay within the airspace confines of a “ground” receiving station like the wireless short-range LAN methodologies. The data telemetry rates for this method are currently limited although an implementation of new technologies on the INMARSAT-series of platforms will dramatically increase telemetry rates. Currently this telemetry option performs at 64 Kb/s, with an “actual” throughput of between 48 and 54 Kb/s. Planned enhancements to INMARSAT in late 2004 or 2005 will increase this capacity to approximately +384 Kb/s, which will make this method very beneficial for large data set telemetry.

3.1.1.1 Inmarsat
Inmarsat was the world's first global mobile satellite communications operator and is still the only one to offer a mature range of modern communications services to maritime, land-mobile, aeronautical and other users.

Formed as a maritime-focused intergovernmental organization over 20 years ago, Inmarsat has been a limited company since 1999, serving a broad range of markets. Starting with a user base of 900 ships in the early 1980s, it now supports links for phone, fax and data communications at up to 64kbit/s to more than 250,000 ship, vehicle, aircraft and portable terminals. That number is growing at several thousands a month.

Inmarsat Ltd is a subsidiary of the Inmarsat Ventures plc holding company. It operates a constellation of geo-stationary satellites designed to extend phone, fax and data communications all over the world. The constellation comprises five third-generation satellites backed up by four earlier spacecraft (Figure 47).
The satellites are controlled from Inmarsat's headquarters in London, which is also home to Inmarsat Ventures as well as the small IGO created to supervise the company's public-service duties for the maritime community (Global Maritime Distress and Safety System) and aviation (air traffic control communications). Inmarsat has regional offices in Dubai, Singapore and India.

Forthcoming from Inmarsat is the new Inmarsat I-4 satellite system, which from 2005 will support the Inmarsat Broadband Global Area Network (B-GAN) - mobile data communications at up to 432kbit/s for Internet access, mobile multimedia and many other advanced applications (Inmarsat, 2003).

3.1.1.1.1 **Inmarsat Satellite Functioning and System**

Inmarsat's primary satellite constellation consists of four Inmarsat-3 satellites in geostationary orbit. Between them, the main ("global") beams of the satellites provide overlapping coverage of the whole surface of the Earth apart from the poles. So, thanks to Inmarsat, it has become possible to extend the reach of terrestrial wired and cellular networks to almost anywhere on Earth (Figure 48).
Figure 48. Inmarsat-3 Global Coverage Map

The four Inmarsat satellites in geo-stationary orbit above the equator provide worldwide coverage for voice and data communications. For operations in North America, the Atlantic Operating Region – West (AOR-W) satellite located at 54° West longitude over the equator and the Pacific Operating Region (POR) satellite at 178° are the main satellites providing service.

A geo-stationary satellite follows a circular orbit in the plane of the Equator at a height of 35,600km, so that it appears to hover over a chosen point on the Earth's surface. Three such satellites are enough to cover most of the globe, and mobile users rarely have to switch from one satellite to another. Other mobile satellite systems use larger numbers of satellites in lower, non-geo-stationary orbits. From the user's point of view, they move across the sky at a comparatively high speed, often requiring a switch from one satellite to another in mid-communication and risking the possibility of an interrupted call or data telemetry feed.

The initiation of a “call” from an Inmarsat mobile terminal goes directly to the satellite overhead, which routes it back down to a gateway on the ground called a land-earth station (LES). From there the call is passed into the public phone network.

The Inmarsat-3 satellites are backed up by a fifth Inmarsat-3 and four previous-generation Inmarsat-2s, also in geo-stationary orbit.

A key advantage of the Inmarsat-3s over their predecessors is their ability to generate a number of spot-beams as well as single large global beams. Spot-beams concentrate extra
power in areas of high demand as well as making it possible to supply standard services to smaller, simpler terminals.

Launched in 1996-8, the Inmarsat-3s were built by Lockheed Martin Astro Space (now Lockheed Martin Missiles & Space) of the USA, responsible for the basic spacecraft, and the European Matra Marconi Space (now Astrium), which developed the communications payload.

The Inmarsat-3 communications payload can generate a global beam and a maximum of seven spot-beams. The spot-beams are directed as required to make extra communications capacity available in areas where demand from users is high.

Inmarsat-3 F1 was launched in 1996 to cover the Indian Ocean Region. Over the next two years F2 entered service over Atlantic Ocean Region-East, followed by F3 (Pacific Ocean Region), F4 (Atlantic Ocean Region-West) and F5 (back-up and leased capacity).

3.1.1.1.2 Inmarsat 4

Inmarsat is now building its fourth generation of satellites. The company has awarded European spacecraft manufacturer Astrium a US$700 million contract to build three Inmarsat I-4 satellites. Astrium is the European company that includes the former Matra Marconi Space, which built the Inmarsat-2 satellites and the payload for the Inmarsat-3s.

The job of the satellites will be to support the new Broadband Global Area Network (B-GAN), to be introduced in 2005 to deliver Internet and intranet content and solutions, video on demand, video-conferencing, fax, e-mail, phone and LAN access at speeds up to 432kbit/s almost anywhere in the world. B-GAN will also be compatible with third-generation (3G) cellular systems.

The satellites will be 100 times more powerful than the present generation and B-GAN will provide at least 10 times as much communications capacity as today's Inmarsat network. The spacecraft will be built largely in the United Kingdom. The bus will be assembled at Astrium's factory in Stevenage and the payload in Portsmouth. The two sections will then be united in Toulouse, France, together with the US-built antenna and German-built solar arrays. This configuration will far surpass any publicly available satellite communications capabilities and will allow large data telemetry capabilities.

3.1.1.1.3 Communications Antenna Configuration

An operation with Inmarsat as a telemetry communications satellite requires a communications antenna configuration on the acquiring aircraft, which can be expensive and possibly require airframe modification to the platform. Connectivity is established through ISDN functionality and a pure digital interface and is via a TCP/IP network connection to a “ground” computer connection (through Inmarsat as a relay). Currently, costs for data transmission are moderate (approximately $7.00 / minute), although experimentation has proven that minimal “connect” time is required for large data telemetry (<5 minutes).
3.1.1.2 Inmarsat-Capable Communications Devices, Specifications and Capabilities

There are a myriad of options for aircraft/satellite/ground telemetry systems. A representative number of these are reviewed here. Some of these systems can operate “off-the-shelf”, and are designed for aircraft or maritime installations. Other systems may be modified for use in aircraft to provide very good telemetry options for much less cost. Any technical, engineering, operational, or installation experiences with an individual system are addressed in this section. This section will address the satellite communications systems that can be adapted for use in aircraft data telemetry operations as well as systems that are designed for aeronautical applications. Maritime systems, although configurable for aircraft installations, are not covered extensively, due to the complexity of modification for performance on airframes.

3.1.1.2.1 NERA World Communicator M4

Nera SatCom is a major supplier to Inmarsat. All Nera SatCom's products and land earth stations are linked via Inmarsat satellite systems. The antenna communicates with Inmarsat communications satellites at 1626.5 to 1660.5 MHz. Data throughput is currently (late 2003) 64 Kbs with planned upgrades to ~384 Kbs by 2005. By linking two units together you can double the throughput to 128 kbps, delivering large data transfer and video transmission at high speed. For maximum security, the Nera WorldCommunicator can be linked to proprietry encryption devices. The NERA World Communicator M4 is a portable satellite terminal offering ISDN functionality and pure digital interface (NERA, 2001). The M4 was designed primarily for the mobile remote satellite voice and data communications market. The M4 functions as a “suitcase phone” with a modem, phone handset and folding, lightweight antennas (Figure 49).

![NERA World Communicator M4](image)

**Figure 49.** NERA Telecommunications M4 World Communicator Portable Satellite Terminal, Phased-Array Antenna

*The antennas are approximately 340mm by 774mm by 12mm (depth).*
The Nera WC M4 has been outfitted to operate on at least three aircraft by NASA-Ames Research Center for telemetry use, with no major problems encountered. Experimentations with a NERA Communicator M4 “satellite suitcase” telephony antenna (and phone), provided adequate telemetry capabilities without the need for major structural modifications. The three integrations that have been performed with the Nera WC M4 include designing an adjustable frame bracket (to change intercept angle) mounted to the interior of a Piper Navajo window frame. This unobtrusive mount operated with no signal loss (and continues to operate well). It also requires no exterior aircraft mounting. This configuration does require the aircraft to fly angular intercept “routes” to provide “signal lock” during transmission of the image data to the INMARSAT constellation platform and, ultimately to the ground. NASA-Ames has also integrated and used a second WC M4 on a Sky Research, Inc. Cessna Caravan. This installation was integrated immediately behind the fiberglass doors of the belly pod of the aircraft. The same flight pattern constraints are required. The third integration and use for the WC M4 was for the General Atomics (GA-ASI) ALTUS II UAV platform. Opposing antennas were mounted directly into the fiberglass forward payload fairing on either side of the airframe. The antennas were angled at the proper orientation to allow signal intercept with Inmarsat. The same flight constraints (at 90 deg. to satellite) were required of the UAV for data transmission. In operation, when signal strength was maximized (through an indication at the payload engineer’s workstation), a TCP/IP network connection was established and the image data were transmitted to either of the appropriate transmitting antenna remotely (depending on flight orientation and best signal strength intercept angle)(see Figure 8 in section 2.1.1). The NERA World Communicator M4 is priced through various outlets at ~$8400 (US$).

3.1.1.2.2 NERA WorldPhone Voyager
Nera WorldPhone is one of the smallest, lightest global phones in the world. Besides telephony you can also send and receive faxes, data, scanned images and e-mail. The WorldPhone comes with different antennas. The Voyager vehicle-mounted option allows use of the WorldPhone while motoring. You can clip the WorldPhone to the dashboard and it connects to a special antenna, which maintains accurate satellite when in motion. This system, although small, only allows 4.8 Kbs throughput (voice) and 2.4 Kbs throughput (data). This system is not optimal for telemetry of large data sets, but should prove useful for telemetry of vector files or text files (fire perimeter or GPS locations). A WorldPhone Marine Model exists as well, but the data rates are the same as for the Voyager (Figure 50).
The Voyager, although small and inexpensive, only offers 2.4 Kbps data throughput. The Marine Model, ruggedized for ships and with an omni-antenna encased also offers the same low data rates.

3.1.1.2.3 Saturn BT2
Saturn BT2 is a ruggedized portable terminal that provides high quality global access to the international telephone, fax, telex and data networks. The Saturn BT2 was designed primarily for maritime applications and as such will not be covered in detail in this section. A number of systems offered by NERA and Thrane & Thrane are designed for maritime applications and can be modified for use in aeronautical. The maritime systems are generally geo-stabilized for satellite tracking capabilities in a moving, pitching platform (Figure 51).

The Saturn BT2 can operate at data throughputs of 64 Kbps. The system is constructed primarily for maritime applications and is complete with a gyro antenna (tracking) assembly.

The Saturn BT2 is another in a line of maritime applications communication devices. These systems offered by NERA are similar in data relay speeds, and only vary slightly in design. The other maritime communications devices include: the NERA F33, F55, and F77.
3.1.1.2.4 Thrane and Thrane TT-3024A Inmarsat-C Aeronautical Capsat®
An improved (though more expensive) option is the installation of a tracking antenna (such as the Thrane & Thrane system) in the aircraft. The compact TT-3024A Aeronautical Inmarsat-C/GPS transceiver is designed for automatic data reporting and message transfer of position reports, performance data and operational messages on a global basis, from sea level to 55,000 feet and all the way from 70° north to 70° south. The TT-3024A operates through the established network of Inmarsat and GPS satellites with interconnection to the international telex and packet switched data networks, offering fast and reliable transfer of information 24 hours a day. The system is fully FAA and INMARSAT approved for aeronautical use. Data collecting equipment may be connected to the TT-3024A via an RS422/423 port, enabling all selected data to be transferred as data reporting packages. The system is composed of an omni-directional antenna, RHC polarized. Data rates are very low, one the order of 600 bits/second. The on board message-interface can handle up to 9.6 Kbs., still rather low for data transmission, though sufficient for vector or fire perimeter GPS locations data transfer. This system requires CAPSAT Manager Tracking software on a PC in a “receiving” office location (Figure 52).

![Thrane & Thrane TT-3024A INMARSAT-C Aeronautical Capsat System](image)

*Figure 52. Thrane & Thrane TT-3024A INMARSAT-C Aeronautical Capsat System*

*The blade antenna is omni-directional and is built for use on aircraft. Low data rates may make this system valuable for small data transmissions only.*

3.1.1.2.5 Thrane and Thrane Aero-HSD+
The T&T Aero-HSD+ combines the functionality of the Aero-H+ and the Swift64 (Figure 53). The Aero-H+ part provides three channels for global beam operation of voice, fax, PC modem data and cockpit communications (SATAFIS, UniLink™, ACARS etc.). The Inmarsat Aero-H+ service is an evolution of the Aero-H service, which takes advantage of the Inmarsat-3 spot beams when operating within the spot beam area. When operating outside these areas, the terminal operates using the global beam as a standard Aero-H system. Aero-H+ supports the same services as Aero-H. The Swift64 component provides a fourth channel, dedicated to high-speed data requirements. The Swift64 channel may operate using the Integrated Services Digital Network (ISDN @ 64 kbps) or the IP-based Mobile Packet Data Service (MPDS up to 64 kbps). The Swift 64 Integrated Services Digital Network (ISDN) offers up to 64 kbps for voice, G4 fax, data
communications etc. ISDN is the preferred option for transmitting large files (e.g. compressed video, digital images, graphics etc.), live videoconferences, real-time visual intelligence transmissions, 64 kbps G4 fax, or Secure Telephone Equipment (STE). ISDN traffic is charged by the length of time the user remains on-line. This is probably preferable to paying a per/bit cost for large fire image data sets.

![Image](image.png)

**Figure 53. Thrane and Thrane Aero-HSD+ Aeronautical Satellite Communications System**

*Includes the Aero H+ and the Swift64 for high-speed (64kbs) data transmissions. The system can operate as either ISDM or MDPS data provisioning at 64kbs. This system is an improvement over the Aero-HSD by providing a smaller antenna system, reducing weight and drag.*

Other systems offered by Thrane and Thrane for aeronautical applications are primarily oriented towards the telephony market and only provide data rates at up to 9.6kbs. High-speed data links (64 kbs) are only offered on the Aero-HSD+ system. Adaptations of other systems (i.e., Marine Applications communications systems from Thrane and Thrane) can be accomplished and provide high-data rates (64 kbs).

### 3.1.1.2.6 EMS Cyclone GAN Terminal

EMS SATCOM's CYCLONE GAN (Global Area Network) Land Mobile Terminal extends the capabilities of the STORM portable GAN terminal. The system is designed for mobile (vehicle) operations, but could possibly be modified for aircraft use. The terminal, a power supply and a high performance land mobile steerable antenna - enables 64K data transmissions. CYCLONE interfaces include: ISDN, X.21, RS449, USB, RS232, and two RJ11 ports. Operating over the Inmarsat's Global Area Network, the CYCLONE GAN Land Mobile Terminal is ideally suited to data functions that require the highest bandwidth and are time critical in transmission - for example, video conferencing, data streaming and telephony. Costs for the EMS Cyclone are approximately $14,500 per unit.
The various EMS Technologies products for aeronautics can be custom tailored for various aircraft and offer up to 128 kbs of data throughput using two independent 64Kbps channels (part of one unit; Viper Terminal). Various satellite antenna configurations are possible allowing modification to fit any platform. By configuring a low profile, tail-mounted antenna (such as the EMS AMT-50G satellite antenna), and the EMS Technologies HSD-128 High Speed Data Terminal, capabilities for 128 kbs are possible. Various exterior aeronautical radome-mounting kits are available for the EMS products (Figure 54).

![Image](https://via.placeholder.com/150)

**Figure 54. Example of Aeronautical Radome Mount for Use with Various EMS Tracking Antenna for Satellite Telecommunications**

### 3.1.1.3 TDRSS Communications Satellite

The Tracking and Data Relay Satellite System (TDRSS) is a communication signal relay system that provides tracking and data acquisition services between low earth orbiting spacecraft and NASA/customer control and/or data processing facilities (Figure 55). The system is capable of transmitting to and receiving data from customer spacecrafts over 100% of their orbit (some limitations may apply depending on actual orbit). The Goddard Space Flight Center receives programmatic direction from NASA Headquarters Office of Space Flight (Code M) regarding all aspects of the Tracking and Data Relay Satellite System and the Space Network. At Goddard, the Mission Services Program Office, provides the day-to-day management and operations of TDRSS and the Space Network. The TDRSS space segment consists of seven on-orbit Tracking and Data Relay Satellites (TDRSs) located in geo-synchronous orbit. The spacecraft constellation is distributed to provide global coverage. The TDRS constellation of spacecraft to provide ready backup in the event of a failure to an operational spacecraft and in specialized cases, resources for target of opportunity activities or dedicated operations. The TDRSS ground segment is located near Las Cruces, New Mexico and consists of two functionally identical ground terminals collectively known as the White Sands Complex. Customer forward data is uplinked from the ground segment to the TDRS and from the TDRS to the customer spacecraft. Return data is downlinked from the customer spacecraft via the TDRS to the ground segment and then on to the customer designated data collection location.
The TDRSS system is primarily for NASA mission support (Space Shuttle and Space Station) and is infrequently used for “partner” operations. Therefore it is not a viable telecommunications system for other groups. It may be possible to allow use of TDRSS by other Federal Agencies (USDA-Forest Service) during missions of critical importance (such as large wildfires).

![TDRSS Communication Satellite Schematic for Data Flow](image)

3.1.2 Direct From Acquiring Aircraft to “Ground Receiving Location”
This method can involve sending data over a wireless Local Area Network (LAN) type connection using 802.11b protocols. This involves sending data from the acquiring aircraft to a computer workstation on the ground at the Incident Command Center (or other location). This wireless LAN communication method is an inexpensive telemetry option that can provide high data communication rate (11 Mb/s). Disadvantages to this wireless LAN telemetry include the limited range of transmission, requiring the acquiring aircraft to maintain near-vicinity airspace lingering to maintain LAN connectivity and interference from other local radio sources. This wireless LAN option has been tested successfully out to about 5 miles line-of-sight (LOS) from the ground workstation. In remote, rugged terrain this can be a limiting obstacle, given constraints imposed by terrain, smoke obscuration and complex airspace issues related to other aircraft in the vicinity at similar altitudes. The wireless LAN technology is probably the least cost-prohibitive while data rates are excellent, although data transmission range options are limiting.
Another option for direct aircraft / ground station telemetry involves the use of spread spectrum radios (such as Freewave). Experiments involved in this technology yielded transmission rates of 115 Kb/s and LOS coverage out to approximately 20 miles with the aircraft at ~10K feet altitude over non-complex terrain. This methodology typically requires the installation of a small blade antenna on the belly of the acquiring aircraft with connectivity to the sensor or “onboard data preparation” computer.

3.1.2.1 Cisco Aironet 340 Series Ethernet Bridge

The CISCO Aironet 340 Series Ethernet Bridge has been tested and demonstrated for data telemetry from a solar-powered UAV equipped with digital cameras and scanning instruments. The system can provide large data telemetry capabilities at short-range distances and provide a solution to moving fire image data to fire camps directly.

The line-of-sight wireless local area network (LOS-WLAN) is based on commercially available wireless hardware configured for imaging system control and data download. The telemetry system comprising the LOS-WLAN is based on the high-speed data link provided by Cisco Aironet 340 Series Ethernet bridges. These Ethernet bridges, which function at 2.4-2.5 GHz and adhere to IEEE 802.11b standards (unlicensed under FCC regulations), were originally designed for spatially fixed building-to-building links. Their use on moving airframes was not originally a consideration although they have successfully adapted for such.

The airborne side of the Ethernet bridge serves as the link between the airborne system payload computer and an omni-directional stub antenna positioned on the underside of an aircraft. The ground-based side of the bridge is equipped with an omni-directional “rubber duck” antenna, which served as the link to a portable laptop computer. Each side of the bridge was amplified to 1-Watt using bi-directional amplifiers with automatic gain control.

During tests on UAV aircraft, continuous broadband wireless Ethernet connectivity using TCP/IP was successfully established between the moving aircraft-based WLAN and the fixed ground control station WLAN. The slant range distance of wireless air-to-ground network connectivity reached 17 km. Error-free 16 MB Kodak/Hasselblad digital images were transmitted with no data dropouts to the ground-based laptop computer at transfer rates ranging from 1 to 4 Mbit s⁻¹. At a distance of 11 km with the data transfer rate exceeding 2 Mbit s⁻¹, each acquired digital image was transmitted in less than one minute. During mission tests and operations, the ground system used an Ethernet bridge attached to a 21-db-gain dish antenna. Tracking was performed deterministically based on GPS information on aircraft position.

3.1.2.1.1 Results of Experiments with Cisco Bridge at NASA-Ames

Maximum observed operating range of the WLAN telemetry link was 29km line-of-sight with image data downlink rates of 3-4 Mbit s⁻¹. Best system throughput (>6 Mbit s⁻¹) was achieved with the aircraft flying tangential to the antenna at a range of 5-10 km. The directional antenna used for the data telemetry (see Figure x) replaced the small omni-
directional antennas on the Ethernet bridge, and provide a tighter focused beam for telemetry. The directional tracking antennas allow a significant increase in S/N ratios, as well as an increase in telemetry distance capabilities (Figure 56).

Figure 56. Directional Tracking Antenna Assembly for Imaging Payload Command-and-Control
An Ethernet bridge is located on the backside of each dish antenna. The two antennas were used for command and control of two separate sensors on the UAV. Each sensor sent data to the two Ethernet Bridges on the antenna backs.

3.1.2.2 FreeWave Technologies (DGR-115H)
FreeWave Technologies was founded in 1993, and provides and manufactures spread-spectrum radios. The company offers radios and transceivers in the 900 MHz and 2.4 GHz frequency areas. They also offer radios in the military frequencies (138-144 MHz, 225-400 MHz, and 1.4 GHz) spectrum regions. The 225-400 MHz frequency can be used for government agencies (i.e., USDA-Forest Service), under some agreements. FreeWave Technologies suggests the use of the 900 MHz frequencies, because at 2.4 GHz there's more attenuation and achieving line-of-sight is even more important. Therefore, for a given antenna gain, you can achieve longer links at 900 MHz. Also, the 900 MHz radios have more features than the 2.4 GHz radios. The industry is moving to 2.4 GHz because the 900 MHz band is becoming crowded; however, this is less of a concern for FreeWave radios, because FreeWave radios are not affected severely by interference at 900 MHz.

The FGR-series products (FGR-115) offer features including high-speed (115.2 Kbps) continuous throughput, long-range (60+ mile) line-of-sight range, error-free communications (32 bit) CRC with automatic retransmission, an RS232 interface and a whip antenna (Figure 57)(Table 13). The ratings for data speed (115.2 Kbs) were never achieved in our tests, with common data throughput on the order of ~16 Kbs. For aircraft modifications, an exterior, small blade antenna can be mounted on the acquiring aircraft for use with the FGR-series products. As distance of line-of-sight transmission increases
there is a slight drop-off of data transmission rates. NASA-Ames has tested data transmission from an aircraft out to 35 miles line of sight in a cluttered urban environment. Data transmission rates decreased down to 9.6 Kbs when distance increased to 35 miles from the ground unit. NASA-Ames did not test telemetry of large image data sets through the FreeWave system. Transmission test included normal sized, jpeg-compressed AIRDAS3-band color-composite data that were ~160 kb file size (typical scene size). Data transmissions of aircraft GPS values (text files) were also accomplished out to ~35 miles before signal loss. Those GPS files were small and did not require the full “published” telemetry rates of the FreeWave system.

Figure 57. FreeWave Technologies FGR-115, 900 MHz Spread Spectrum Wireless Radio
The unit on the left is the milled box version while the unit on the right is plastic. Note the whip antenna. This antenna can be replaced with a blade antenna for use on the exterior of the aircraft (belly mount is most efficient).

Table 13. Specifications for the FreeWave Technologies RS232, 900 MHz Spread-Spectrum Data Transceiver, Model FGR-115

<table>
<thead>
<tr>
<th>Radio link:</th>
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<tr>
<td>Frequency Range</td>
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<tr>
<td>Method</td>
<td>Frequency hopping spread spectrum</td>
</tr>
<tr>
<td>Hopping Patterns</td>
<td>15 per band, 105 total, user selectable</td>
</tr>
<tr>
<td>Hopping Channels</td>
<td>50 to 112, user selectable</td>
</tr>
<tr>
<td>Hopping bands</td>
<td>7, user selectable</td>
</tr>
<tr>
<td>Range, Line-of-sight</td>
<td>60 miles</td>
</tr>
<tr>
<td>Occupied Bandwidth</td>
<td>230 KHz</td>
</tr>
<tr>
<td>Modulation</td>
<td>GFSK, 144 ~ 188 Kbps</td>
</tr>
<tr>
<td>RF Connector</td>
<td>Reverse SMA female (both models)</td>
</tr>
<tr>
<td></td>
<td>Whip antenna</td>
</tr>
<tr>
<td>System Gain</td>
<td>140 dB</td>
</tr>
</tbody>
</table>
**Transmitter:**

| Output Power | 100 mW to 1 Watt (+30 dBm) |

**Receiver:**

| Sensitivity | -108 dBm for $10^{-6}$ BER  
|            | -110 dBm for $10^{-4}$ BER |

**Data Transmission:**

| Error Detection | 32 bit CRC, retransmit on error |
| Data Encryption | Substitution, dynamic key |
| Link Throughput** | 115.2 Kbps |

** Uncompressed , measured assuming 75% frequency availability

**Data Interface:**

| Protocol | RS-232,  
|          | 1200 Baud to 115.2 Kbaud, DCE |
| Connector | DB9-female |

**Diagnostics Interface:**

| Connector | Part of DB9 connector |

**Power Requirements:**

| Voltage | 6-30 Vdc |

**Environment and mechanical:**

| Operating temperature | -40 °C - +75 °C |

| Dimensions | Plastic  
|            | 7.40 L x 3.90 W x 1.60 H ["]  
|            | 188 L x 99.1 W x 40.6 H [mm]  
| Milled     | 8.05L X 4.00 W x 1.08 H ["]  
|            | 204.5 L x 101.6 W x 27.5 H [mm] |
| Weight     | Plastic - 340 g  
|            | Milled - 560 g |

The FreeWave system(s) have moderate data rates (at 115.2 Kbs; better published rates than current INMARSAT (64 Kbs)), but the rates to do not approach those provided by CISCO Ethernet bridge capabilities (3-4 Mbs).

### 3.1.2.3 Aero Telemetry Corp

The Aero Telemetry Corporation specializes in the design, manufacture, integration, and deployment of airborne video/data telemetry systems, high-reliability, ruggedized, airborne radio/data communications systems, and theater-deployed satellite communication systems for military and aerospace applications. Aero Telemetry Corporation also supports UAV flight operations. Currently, Aero Telemetry products are in use on university level research and development projects, in commercial aviation
flight-test programs, and in tactical, theatre-deployed air vehicle systems used for reconnaissance and low cost payload delivery missions by the U.S. Military. The company has a wide range of military, university and government clients including NASA. The company is involved directly with most of the major UAV providers for video-type data telemetry. The company provides transceivers, receivers and modems for telemetry.

The AT-S3™ series airborne satcom telemetry system is a fully integrated portable SATCOM system offering a highly versatile video, voice, and data satellite communications data link that can operate from an airborne platform to a geo-synchronous satellite and back to an earth station. The typical satellite communication is through MEXSAT. The AT-S3™ Ku-band is capable of high speed, high data rate (up to 15MBps) uplink/downlink communications. It features the ASATS™ high-speed, bi-directional, airborne satellite tracking antenna Ku-band satellite data link system, capable of pointing accuracies of ±1°. The airborne system components are lightweight and modular. The earth terminal systems can also be modular or rack mounted and both are configured for rapid deployment. General Atomics Aeronautical Systems, Inc (GA-ASI) uses this same system in the Predator UAV aircraft for communications and Command and Control (C&C). The ASATS aircraft antenna is an airborne type, radome-enclosed, 24-inch parabolic reflector assembly. It can be fitted in large UAV’s or manned aircraft. As mentioned earlier, the communications link is through commercial communications satellite providers.

The ground station is a mobile dish, approximately 1-meter in size allowing data collection from the airborne system through the commercial communications satellite (Figure 58). A transceiver is required for operation of the data stream through to the antenna (on board the aircraft). Aero Telemetry provides the Ku-band transceivers as well.

![Figure 58. The Aero Telemetry Corporation, Single-Hop FTSAT Ground Station Antenna](image)

No pricing is given for provisions of the Ku-band system, although it is known to be an expensive alternative. The aircraft Ku-band transmitting antenna (and the supporting peripherals) are on the order of ~$500,000, while the ground station is approximately...
These costs may preclude use in the commercial community (private data providers).

3.1.2.4 Other Issues to Consider for Satcom Data Telemetry
For systems that operate with geo-synchronous orbiting communications satellites, the “look-angle” for the satellite is low on the horizon (~15 degrees elevation for parts of the western U.S.). This could be an issue for fire camp regions where mountainous obstructions preclude low-horizon satellite signal intercepts. When INMARSAT launches its next series of satellites (Series 4), by 2005, the company will be able to provide ~384 Kbs data rates. Until that time determinations have to be made on the trade-offs involved in each of these data telemetry methodologies. Consideration should be given to various on-board image compression technologies to allow a reduction in the image data transfer sizes. Those data-sharing technologies are covered in the following section.

3.2 Data and Information Sharing Via the Internet
The Internet provides an easy and inexpensive way to share data among a large, dispersed group. Issues of concern include bandwidth, security, and reliability. Bandwidth issues are discussed in detail in Section 5.2. Great progress has been made in improving bandwidth options in recent years. Security is an issue. Viruses must be protected against and access managed as with any network. Many incident and fire management sites are requiring logins to restrict general access. Firewalls can be a problem in providing too much protection making it difficult for those needing access to get in from external and temporary locations. Virtual Private Networks (VPN) are being utilized by several groups to protect data in the wireless world. The public can overwhelm communication channels during a disaster situation making it imperative that critical communications be protected. In the unlicensed frequencies it is illegal to block interference though spread spectrum technology has helped with this problem. The trend, on paper, is toward a centralized overall incident management site though what is gained in consistency may be lost in lack of redundancy and the ability to support the large access requirements.

The fire community is extensively using the Internet to share information with the public as well as within the fire community. The Appendix includes lists of web sites for various IMT’s at the state and the national level in addition to those highlighted here. Most of the sites contain fire status updates and a selection of maps either actual briefing maps or simplified perimeter maps intended for the public. Photos of the incidents are popular. In the case of likely evacuations pertinent information is posted. Some sites provide access to actual IAP and AIR-OPS maps though there is a trend toward requiring a password to access the actual incident documents/maps. The Biscuit Fire of 2002 still maintains a web site, which is now used for tracking the post-fire recovery process and well as providing an extensive chronology of the events of the fire. The content and organization of these sites varies tremendously by the group. Within a group, such as the Pacific-Northwest Type 1 Teams, the sites are consistent. Some sites provide simply a list of the team members and current incident information only while active with no archive of past incidents, while others provide extensive incident histories and photo
galleries, and still others provide innovative efforts such as 3-D views, shaded relief, and animated fire progression displays. A selection of key or representative sites are reviewed:

3.2.1 GeoMAC
The GeoMAC web site (http://www.geomac.gov) provides on-line maps of current fires at various scales as well as an upload facility, for the fire community only, to provide fire perimeter information (see Figure 69 in Section 7). The site is based on ArcIMS™ technology and is designed to handle many different imagery types including MODIS and Landsat. The evolution of this site has been described in the Final Needs Assessment Section 5.3.6 (IAGT, 2003, p. 163). This multi-agency effort uses Sanz technology to serve the imagery and support varied output projections. It performs marginally on slow dial-up particularly during heavy access times. Imagery can be downloaded as well as viewed. The ArcIMS™ product is used by many GIS oriented web sites. It provides a common look and feel, which can be helpful for ease of use.

3.2.2 Automated Flight Following (AFF)
An interesting site being developed by NIFC (http://aff.nifc.gov) involves a system for Automated Flight Following (AFF) intended to allow tracking of lightening strikes and airborne resources. Up to 50 platforms can currently be tracked. Unlike many of the map oriented web sites, this site is based on WebTracker™ software rather than ESRI’s ArcIMS, ArcSDE software. Access to the actual flight following is restricted as of this year. The site, to the extent it can be currently accessed, performs well on dial-up access.

3.2.3 CDF Incident Web Site
The California Department of Forestry maintains web sites (http://fire.ca.gov/cdf/incidents) on each incident they are involved in. Status, maps, and further information phone numbers are included. These sites are increasingly oriented toward public information needs though travel, briefing, and fire progression maps can be found. The maps presented are sometimes inconsistent in terms of type and quantity, which may be a factor of the rank of the Team responding to the fire. Archived incidents are maintained. During the 2003 Southern California wildfires the sites were slow to present maps (i.e. the maps did not appear on the day they were made) suggesting that these were not the primary sites.

3.2.4 California Type 1 Interagency Incident Management Team 1
The web site http://www.fs.fed.us/r5/fire/ciimt1/ is an example of a national interagency team effort which presents much of the actual response data including the IAPs and briefing maps and maintains the archived fire information from several years. Of the sixteen national teams currently available, thirteen maintain web sites. Links to the other IMT’s can be found on this site. The sites are somewhat consistent within a region, but vary greatly in terms of organization and content between regions. The example presented is an exceptional one in terms of archived information. This site was the source of the Biscuit Fire working maps in Section 7.1.1.
3.2.5 AIRDAS FiRE Web Site
The AIRDAS FiRE web site (http://geo.arc.nasa.gov/sge/UAVFiRE/) is of interest in that it provides near-real time access to imagery acquired and telemetered via satellite to a site at Ames Research Center. When the files arrive at the ftp site the images automatically become accessible via the web site. A simple file system interface is currently provided which in the past automatically displayed the jpeg images.

With all the web sites out there it may be prudent to consider incorporating the WASP products into an existing serving system such as GeoMAC or a site similar to the Southern Sierra Geographic Information Cooperative (http://ssgic.cr.usgs.gov), which appears to be based on the GeoMAC system.
4.0 NON-IMAGING SYSTEMS
There are data useful in producing certain fire information products which are not imaged but rather point source information such as RAWS weather information, instrumentation designed to measure fire characteristics, and asset location signals. This information may be used in modeling fire behavior or in assisting in calibrating image classifications, or as in the case of asset location, as a stand alone product. Delivery options for these data may follow the same paths as imagery but their small size allows for some interesting alternatives.

4.1 WEATHER INFORMATION
The Remote Automated Weather Stations (RAWS) are managed by NIFC. There are 1150 permanent ones and 22 mobile ones in California (http://www.fire.blm.gov/FactSheets/raws.htm, http://www.fs.fed.us/raws/) (Figure 59).

RAWS transmit their information via GOES telemetry to NIFC. The data can also be obtained directly through NESDIS. In 2001, transmission capability was upgraded from 100-baud every 3 hours, to 300 baud every hour for incident support (Fire Danger Working Team, 2001). RAWS observations are generally retrieved via the Internet from NIFC by an Incident Meteorologist if used in incident forecasting. According to the BLM web site RAWS data are used for environmental monitoring and sometimes for early-alert warning systems, in addition to their use in wildfires. Monitored parameters include wind speed and direction, wind gusts, precipitation, air temperature, relative humidity, and fuel moisture. RAWS locations can be found through the USFS URL above. A field unit is pictured below (Figure 60).
The MicroREMS is a similar unit without satellite telemetry capability, which is being phased out or converted to a RAWS. These units use phone telemetry.

4.2 REMOTE EVENT MONITORING
Remote monitoring systems have been implemented for hazard management for many years by the USGS. Systems have also been implemented more recently for scientific study requiring remote data logging (Hughes, 2002). Similar efforts, specifically for fires, include Dr. Bob Kremens Autonomous Fire Detectors (Kremens et al., 2003) and the HPWREN program’s auto-triggered video cameras. The company Dust, Inc. is developing tiny inexpensive environmental sensors with two-way radio capabilities that may have applications for remote fire parameter measurement.

U.S. Geological Survey has been using GOES or cell phone telemetry for monitoring geological and hydrological field sensors for years but as neither of these provides truly real-time data, they have been looking into other options (http://wwwhif.er.usgs.gov/Public/needs). Their complaints regarding GOES include that its one way, there is a 3-4 hour delay, the bit rate is to slow and the transmit window too small. They consider the system over used. Cell phone access cannot be always on. The USGS office in Menlo Park, CA instituted a program of automated ground water saturation measurement designed to alarm via radio communication when saturation levels associated with debris flows were reached. When the system triggered a false alarm, the program was discontinued.
The HPWREN program, described in Section 5.1.2.1 has set-up video cameras that are triggered to turn-on in response to motion. These cameras provided video recording of the 2003 Southern California fires. The fire crews remotely directed the wide-angle field of view. Video clips are available on the HPWREN web site.

Dave Hughes, Principal Investigator on the Biology Science by Wireless Project describes his efforts using radio technology to retrieve remote data for scientific study in this NSF funded study (http://wireless.oldcolo.com). Final Reports are available on his website. In addition to information on field trials of various experiments, some findings of relevance to remote fire data collection include the lack of a need for high bandwidth (except for video applications) and the better performance of radios which operate in the 902-928MHz range over the 2.4GHz or 5.8GHz frequencies for penetrating vegetation. Radios in this frequency range are less common and more expensive.

Another strategy is to simply retrieve data logged to a web site by another group to implement a possible near real-time display of information. RAWS data, for example, might be used in this fashion.

These efforts are useful in terms of communication methodologies but did not have to address the requirement for real-time, temporary set-up.

Resistance to set-up issues could be overcome on large and complex fires. There is considerable set-up and prep work going on and it seems possible to incorporate and consolidate tasks and activities. During the Biscuit Fire they helispots were created using bulldozers, and the IMETs have to site their equipment. DUST, Inc. is developing inexpensive sensors that can be dropped from an aircraft, which would solve the set-up issue.

4.3 ASSET TRACKING
Asset tracking has been demonstrated (see for example Ambrosia et al., 1998). The main impediment to this technology is tree cover and hilly terrain blocking signals. Airborne asset tracking doesn’t suffer from these problems and has been implemented as a semi-operational system in NIFC’s AFF product (see Section 3.4.2.).

4.4 INTEGRATION INTO PRODUCTS
IAGT’s VMOC (Virtual Management Operations Center) product has demonstrated real-time presentation of data from hydrology monitoring sites displayed in web enabled ArcGIS with text readout of values at their geographical location. Asset tracking has been demonstrated by Terra-Mar using HAM radio signals processed by Terra Research and delivered via serial port on a Unix machine running DACS (Ambrosia et al, 1998). The positions were displayed using a spatial database (GDC). This application was not web enabled. In the demonstration, trucks were tracked and displayed as icons in real-time over the global vector based display. The AFF product works similarly but with display to a web enabled base map. Access to the actual tracking display requires a login. RAWS is logged at NIFC as text or point/line data on a state outline map (see Figure 59.). GPS locations logged directly into a computer (or PDA) for overlay on a map are
being used by some Incident Teams for fire perimeter development. One methodology is
described in Section 5.1.3 and examples of products produced from GPS data can be seen
in Section 2.
5.0 NEW TECHNOLOGIES FOR DATA DELIVERY

Recent developments in communications technology are opening doors for new modes and higher data rates for wireless data transfer. As PDA’s turn into mini-hand held map displays, cell phones send pictures and wireless bandwidth grows, new opportunities for providing wildfire assistance become possibilities. In addition, a recent FCC rule change opened up additional unlicensed spectrum for wireless communications that will impact system development.

5.1 DATA TRANSFER

Data transfer rate and distance are the limiting factors in data delivery for imaging systems which produce large datasets. Luckily, the bandwidth problem is of concern to the general population and concerted efforts are being made to continually increase the bandwidth for data transfer. The last few years have seen huge increases in bandwidth and distance parameters for Wi-Fi systems and continual increases in satellite bandwidth. Third party systems are being offered that make satellite access set-up much easier and affordable. In addition to the air to ground applications described in Section 3, terrestrial wireless LAN’s are being demonstrated for custom set-up to provide high bandwidth in emergency situations. Following is a review of some current developments of interest.

5.1.1 Satellite Systems

Key developments in this area involve increased bandwidth, increased ease of set-up and decreased cost.

5.1.1.1 VSAT

Very Small Aperture Terminal (VSAT) satellite communications system can be used directly or through a service such as DirecPC. The system can provide data rates from 128kbps to at least 4Mbps. The antennae and RF equipment is essentially the same as is used by satellite TV remote trucks. There may be vans in the emergency response community already equipped with VSAT equipment. Alternatively, a VSAT ground station can be purchased for about $3000, with a minimum service cost of $200 per month. Ground station set-up and linking to the service provider’s Network Operations Center requires a trained technician. (Kruse, 2003).

5.1.1.2 DirecWay

Hughes Network Systems DirecWay service can be purchased directly. The service offers .5 – 1 Mbps upload speeds and at least 1 Mbps download speeds (Kruse, 2003). When purchased directly the user must set up the antenna, which can be challenging. Their web site lists the monthly cost for home users at $59.00/month with about $600 of equipment. DataStorm, below, provides software to make this set-up easy for mobile applications using an auto-pointing antenna.

5.1.1.3 Third Party Solutions

The following represent third party solutions for satellite data transfer.
5.1.1.3.1 DataStorm (http://www.groundcontrol.com)
The DataStorm product provides mobile Internet service via DirecWay satellites, with a rooftop pointable antenna and software that makes setup automated. The equipment cost is $3995 with service starting at $99/month. The auto-pointing antenna is the expensive component. The low-end data rates are 30-90kbps up and 400kbps down with higher end service available as well at higher cost.

5.1.1.3.2 Tachyon (http://www.tachyon.net)
Tachyon has demonstrated their Mobile Network Access™ system for fire application in San Diego. They describe their product as “the first cost-effective Internet or enterprise network connectivity service for organizations that need transportable broadband network access for temporary field locations, special events, or emergency response teams”. Setup time is listed as about 30 minutes. They offer a VPN solution for security. The system is designed to TCP/IP standards to provide compatibility with terrestrial networks. They provide the network service using independent satellite operators and report that they have optimized their satellite transmission to provide data rates of 2Mbps down and 256Kbps up. Their web site includes a good discussion of problems associated with using TCP/IP over satellites and the solutions they have come up with. Oriented toward enterprise customers, this option is most likely more costly. The ground station that connects to the satellite is about $5000. Quoting Dave Hughes of Old Colorado City Communications in a July, 2000 interview (http://wireless.oldcolo.com), full rate service was $2000/month while 300Kbps down and 64Kbps up is $795.

5.1.1.3.3 NetAcquire (http://www.netacquire.com)
NetAcquire™ provides a small system (“toaster-sized”) designed to work with either satellite telemetry or aircraft. It reads serial or analog telemetry signals and publishes the result to any Ethernet network. A simple Web browser is used to manage the box. Their open programming environment allows one to develop extensions.

5.1.2 Wireless LAN’s
Two studies will be described in which “portable” wireless LAN’s are set-up to provide broadband Internet access for emergency situations.

5.1.2.1 HPWREN (http://hpwren.ucsd.edu)
The HPWREN (High-Performance Wireless Research and Education Network) project was jointly undertaken by the University of California, San Diego (UCSD) National Laboratory for Applied Network Research (NLANR) and Scripps Institute of Oceanography (SIO). The National Science Foundation awarded the three-year research grant. The co-principal investigators include Hans-Werner Braun of NLANR and Frank Vernon of SIO. The project addressed “the need for high-speed network access from hard-to-reach sites” (http://www.nlanr.net/nlanrpackets/v2.1/hpwren.html). The backbone and nodes of the system created in San Diego can be seen at http://hpwren.ucsd.edu. The backbone, a “45 Mbps full-duplex wireless backbone” (NLANR Packets New Updates Nov. 29, 2000) was completed in 2000. The system was originally designed to assist researchers in remote areas by allowing the transfer of large images and for real-time monitoring of environmental parameters. UCSD’s Mt.Laguna
Observatory fell into the former category. They were presented with the problem of a single dial-up connection and 8 Megabyte images produced by their telescope, similar to the problem of delivering IR imagery to Incident Command Centers. Recognizing the need for higher band access by the fire community, HPWREN connected the CDF Ramona Air Attack Base and the Red Mountain fire station to the backbone in July, 2003. Their original objective was to connect to high-resolution still and controllable video cameras along with other sensors throughout San Diego County (HPWREN News 7/16/03). High-speed access to the Internet was an added bonus.

Soon after the connection was established, the opportunity presented to test it with the outbreak of the Coyote Fire in northeastern San Diego County. The HPWREN Team provided the remote Incident Base with high speed Internet access throughout the week long, 18,000-acre event. The set-up process “probably did not take much more than eight hours after the request was made” according to Braun (HPWREN News 7/25/03) (Figure 61).

The HPWREN project has collected extensive data on wireless connection performance (degraded in correlation with weather and window size) as well as specifically evaluating satellite versus terrestrial network access. They concluded that satellite provided more
rapid access while the terrestrial wireless access provided higher bandwidth at lower per minute cost. They suggested that a combination might be appropriate starting off with a quickly deployed satellite link, which would be turned over to the terrestrial connection as it came on-line (http://hpwren.ucsd.edu/incidentmgt.html).

The HPWREN networks use 802.11b (Wi-Fi) technology along with some licensed spectrum. The networks require line-of-site and frequently use mountaintops to extend access. They have experimented with solar power to run the remote antennae, an effective but currently costly approach (Luna, Wireless Review 1/1/03).

The HPWREN group has also experimented with IQeye3 90+ degree field of view solid-state 1288x968 video cameras with built in web servers and Ethernet connections that trigger on motion for monitoring environmental conditions (http://www.npaci.edu/online/v7.5/hpwren.html). The CDF has written grants to obtain a similar camera for monitoring regions from mountaintop or lookouts in Santa Clara County (Morgan, 2003).

On Nov. 16, 2003 the HPWREN group published video clips of the Cedar Fire obtained through these network cameras and other video systems to their web site.

5.1.2.2 Virginia Tech CWT project
Virginia Tech’s Center for Wireless Telecommunications (CWT) and SAIC have collaborated on a project to demonstrate rapidly deployable wireless communications for emergency management (Bostonian and Midkiff, 2002). Their project focused on a 9/11-type situation rather than a wildfire scenario. Their original system used commercial Local Multi-point Distribution Service (LMDS) and 10/100BaseT Ethernet interfaces. After 9/11 they fielded this demonstration system at 10Mbps data rate but faced funding difficulties in transferring the system from the research realm to the operational. The particular research questions they addressed included broadband channel sounding and adaptive zero-administration wireless networks. The system uses a base station to illuminate the disaster area with high data rate connectivity, which the field units then access. The base unit connects to a larger network via either terrestrial or satellite connection. The field units provide a connection point for various network devices. According to the authors, the system is deployable within several hours once the equipment is at the site. The base station to field station range is reported to be 2-3 km using COTS radios with 10-15 km possible with custom radios. They feel that a data rate goal of 120 Mbps is possible. The spectrum used is the licensed 28 – 31 GHz range (LMDS). They cite the reasons for this selection as the high data rates supported, accessibility in that Virginia. Tech owns licenses in this spectrum, and the availability of COTS RF products. The design is based on Ethernet frames and IP protocol. Security, though less of a problem at the LMDS wavelengths than the Wi-Fi wavelengths, is addressed with Virtual Private Networks (VPN). They note that common personal computer operating systems and low cost routers are supporting VPNs. Unique aspects of their system include a built-in sounder, which simplifies system set-up, and an adaptive response to changes in the quality of the connection. They incorporated the use of a GIS “viewshed” program to determine optimal placement of the units in the field as
the base and field units require line-of-sight. They presented the pros and cons of 802.11 technologies versus licensed technologies. The pros included distance, bandwidth, and non-line-of-sight possibilities. The cons included interference, security, and reliability. They note that their innovative technology can be applied to other spectra as the low-cost 802.11 technologies have made it difficult for them to fund development in the licensed spectrum. The article cited above includes detailed diagrams of the set-up they used for their demonstrations.

5.1.3 Handheld Systems (PDA, Cell Phones, Satellite Phones)

Cell phones are a fairly unreliable option for wildfire data transmission due to the remoteness of many wildfires. For locations where they are an option data rates vary from 9.6kbps (GSM and TDMA) to 14.4kbps (CDMA networks). Ricochet, a dedicated data service, goes up to 128kbps and Venturi (a compression system) cites speeds to 56kbps. See [http://cellphones.about.com](http://cellphones.about.com) for the latest information on cell phone capabilities including WAP for browsing a “stripped down” version of the Internet. AT&T announced recently improved cell phone data access using a new service called EDGE (Enhanced Data GSM Environment), which industry claims is twice as fast as GPRS networks (General Packet Radio Service). These are both advancements from the GSM (Global System for Mobile Communications). AT&T is claiming data rates of 100-130kbps. They list the cost at $80/month (reported by Reuters at [http://money.excite.com](http://money.excite.com)).

The Pacific Northwest IMTeam3 has experimented with data transfer using satellite phones. Despite the 2400 to 4800 baud rates, they claim success in speeding up IAP preparation by 2 hrs. See Section 1.5 for further discussion.

PDA’s have been used on fire locations for collecting GPS data and displaying it on digital maps (IAGT, 2003, p.161) ([http://spatialnews.geocomm.com/features/viejasfire/](http://spatialnews.geocomm.com/features/viejasfire/)). Providing ready access to digital maps with GPS overlay they can also be used to obtain weather information, text messages, and even voice communication if supported wireless communications are an option. The Compaq iPAQ© unit in particular was a big success used during the Viejas Fire in 2001. Versions of the iPAQ come with both Bluetooth and 80211.b wireless connections. Bluetooth is very short range but the Wi-Fi connection may allow for somewhat remote access. The software used in the Viejas Fire work included ESRI’s ArcPAD© and topographic base maps obtained from the ERM Tactical Mapping System program. This technology may be useful for transmitting small maps or information derived from imagery between the ICP and the field crews, or for transmitting field crew locations back to the ICP. Spatial Data Technologies offers a similar product integrating raster and vector data display with a GPS receiver for Windows CE devices.

DeskArtes ([http://www.deskartes.com/Wireless/techdata.htm](http://www.deskartes.com/Wireless/techdata.htm)) of Finland has developed what they call the “First Wireless CAD Viewer”. This product is of interest because it displays raster images that would be useful in fire response. The PDA/Smart phone connects to the server via a GSM/modem/Internet connection. The commands are sent to the server which carries them out and sends back a highly compressed video capture of
the screen result. Using this methodology allows commands such as zooming to be “performed”. They are also using the Compaq (iPAQ 3630/3850) with a modem card and communicate with a Windows NT server.

5.2 INFORMATION ACCESS – THE INTERNET

Internet access has become faster and cheaper and more readily available. For the sake of quick reference a comparison table of data rates is included (Table 14). It is generally safe to assume that a dial-up Internet capability can be provided at the ICC and increasingly safe to assume that a satellite connection will be provided. New turn-key systems and lower cost make satellite access a reasonable assumption, if not today, than for the near future. High-speed wireless systems are possible, as demonstrated by UCSD and Virginia. Tech, though the set-up overhead may currently make this a less viable alternative. Higher data rates make this option worthy of continued scrutiny.

Table 14. An example for the Transit Time of a Four-Megabyte Image for a Range of Bandwidth Options

<table>
<thead>
<tr>
<th>Bandwidth</th>
<th>Image Size</th>
<th>Approximate Time</th>
<th>Megabytes/sec.</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 Mb/s</td>
<td>4 Mg</td>
<td>2.92 sec.</td>
<td>1.37</td>
</tr>
<tr>
<td>115 Kb/s</td>
<td>4 Mg</td>
<td>4.75 min.</td>
<td>.014</td>
</tr>
<tr>
<td>64 Kb/s</td>
<td>4 Mg</td>
<td>8.55 min.</td>
<td>.0078</td>
</tr>
<tr>
<td>24 Kb/s</td>
<td>4 Mg</td>
<td>23 min.</td>
<td>.0029</td>
</tr>
</tbody>
</table>

Connections from a 56K modem and faster should be able to support data turn around on the order of 1 hour for data quantities of this size assuming the data must be transferred from a central receiving center of some sort to the incident base. File transfer protocols such as the ftp family can be used to transfer files in batch mode without the “overhead” of browser access.

5.3 ISSUES AFFECTING DISSEMINATION OPTIONS/CHOICES

Value added satellite systems have made mobile set-up in the field much easier and faster than in the past. Setting up a wireless network in the field, as demonstrated in the two efforts reviewed, is going to be a several hours to daylong process, possibly longer if access issues need resolving. The effort, however, is rewarded with significant gains in bandwidth. Satellite and terrestrial wireless may be combined to service a fire camp and possibly the “field” as well.

Security issues are of concern in any network situation. In addition to protecting data in transit, care must be taken to provide appropriate access through institutional firewalls from the external fire camps if a central processing facility is used. VPNs are being used by several of the services described to provide security on wireless networks. WEP (wired equivalent privacy) mandated by the 802.11 standard may be adequate for a closed community like a management team. It requires a single password per network.
discusses these security issues in an evaluation of 802.11 for campus service (see http://wireless.oldcolo.com). The application is different, but the options the same.
6.0 DATA PROCESSING AND DELIVERY SCENARIOS FOR WASP

6.1 ISSUES RELATED TO PROCESSING AND DELIVERY
The character of the data itself will influence possible processing and delivery scenarios for the imagery produced by the WASP sensor as well as the requirements of the user community.

6.1.1 Data/Information Characteristics
Imagery provided for emergency response must be easy to integrate into the system. To that end certain characteristics have been identified.

6.1.1.1 Channels/Bands
The WASP sensor produces 3-channel color images and three single channel infrared images. For ease of use, the end product should be either a single banded or three-banded image. Often viewing and manipulation software are only set up to process one or the other. Older tiff reading software may only support 1 or 3 bands as well. Possibilities include IR color composites or possibly a classified image derived from the three resulting in a single band image. In general, products will tend to be one or the other since map products are meant for direct viewing.

6.1.1.2 Geo-Rectification
Geo-rectification of imagery for use in emergency response is increasingly becoming an expectation. The most common method of aligning imagery with a ground projection involves “point picking” of co-locations to generate coordinates for warping the imagery to a map base, a capability provided by most image processing software packages. The ready availability of more accurate GPS data and lower cost inertial navigation systems (INS) has spurred the development of automated geo-rectification software. Whatever the method, geo-rectification is key to creating readily usable products. Processes for automated geo-rectification will be discussed here. Note that the term geo-referencing is sometimes used to indicate that location information has been collected with an image, but not necessarily that the image has been reprojected to ground coordinates, hence the use of the term geo-rectification to indicate the latter.

Approaches to automated geo-rectification can be divided into two groups. One a photogrammetric approach and the other a matching approach. The former gathers position and attitude information from various sensors and uses it to project the image into ground coordinates (Grejner-Brzesinska, 2002; Buechel, 2000; Skaloud, 2002). This is generally referred to as direct geo-referencing as opposed to the traditional aero-triangulation approach in which the sensor position and orientation is estimated from overlapping imagery itself. In the latter approach image matching algorithms are used to automatically align the image with an existing ortho-image and “inherit” the geo-referencing from it. (Wildes et al., 2001, Positive Systems DIME™ software)
In the photogrammetric category there are varying levels of automation. Many involve some minimal operator interaction, usually point selection, to assist the process and adjust for errors in the orientation parameters; some use only “meta-data” collected regarding the platform/sensor exterior orientation to project the image to the ground via the projective transformation equations. (Note that the term meta-data here refers to the platform position and orientation information, not the standard ISO meta-data definition). This method is dependent on the errors in the position, attitude, and altitude sensors being minimized to achieve good accuracies. The transformation for the projection may be 2-D for framing sensors such as digital cameras or video frame grabs or 1-D for line scanning sensors. Interior orientation parameters are required in addition to the exterior parameters to correct for lens distortions.

The automated matching approach frees one from the need to collect and manage meta-data and DEM’s, however it requires an existing ortho-imagery base to match to. The USGS Digital Ortho Quarter Quads (DOQQ’s) may provide adequate base maps for this methodology and application. An advantage here is that the fire camps rely heavily on USGS base maps. These maps contain their own error, but by matching to them, things line up and confusion is minimized in that the errors are the same. See the TerraServer Imagery database (http://www.terraserver.com) as a possible source. Matching may prove to be a more time consuming method than the direct approach from a processing standpoint.

One group (Wildes, et al., 2001) has combined these two methods, using a direct approach followed by a matching to improve the accuracy. By getting the imagery close first, the matching is more effective.

Terrain adjustment is essential to produce accurate maps when variation exceeds about 200 feet. Even in less hilly areas it provides a means of automating AGL altitude calculations when a laser rangefinder or equivalent is not flown on the aircraft. USGS Digital Elevation Models (DEM) at 30-meter resolution (in some locations at 10-meter resolution are available for an increased fee). One arc second SRTM DEM’s are available for free on the Internet. Both these data sets have issues but their coverage and availability make them useful for wildfire applications. Another source of DEM’s to consider is the National Geographic TOPO! product. In addition to the standard product, they offer an ArcView extension with a seamless set of DEM’s as well as DRG’s sold by the state based on the USGS products. If higher resolution and more accurate terrain information is available it should be used. Terra-Mar’s DACS™ software manages DEM’s using a spatial database (GDC™) to automatically determine which DEM should be used for a mapping. The DEM’s are logged to the database and must be stored on-line for full automation.

Mapping software can be divided into three general groups. Custom mapping systems such as Terra-Mar DACS, purely ground based systems requiring a technician such as Positive Systems DIMET™, and ERDAS Imagine™ Orthophoto production suite which are not oriented toward real-time applications, and services which offer a geo-rectified (not to be confused with a merely geo-referenced) end product such as Fireball.
Information Technologies or San Joaquin Helicopters (see Section 2). The Phoenix system has proposed an interesting approach in which they provide the data, meta-data, and geo-rectification software on a CD-ROM for ground processing. In considering geo-rectification software, issues to consider include processing speed, automation, accuracy, and data management tools.

It is important to be able to support multiple map projections for wildfire applications, or to involve a party that can handle them in that different states work in different projections. UTM (Universal Transverse Mercator) is perhaps the most common at the national level, but State Plane and Albers Equal Area are also common. With GIS capabilities in most fire camps, reprojecting is possible but distracting from real-time efforts if unexpected.

6.1.1.3 Extracted Information
Products may consist of information extracted from the collected imagery rather than the imagery itself. For the purposes of processing and delivery it is useful to consider the characteristics of various extractions. Extractions may involve fire feature thresholding or classification, fire feature delineation, or fire feature by value. Thresholding or classification will result in a raster file of class values representing a range of temperature or intensity for example. These files will compress well due to the long value run lines. Feature delineation will result in a vector file of polygons and possibly lines (e.g. fire perimeter, fire front, fire lines). Vector files of fire perimeters are inherently smaller than the raster image. The feature by value would include a raster representation and a look-up table of actual parameter values or an integer or floating point valued raster. This would be the largest product and perhaps unnecessary detail for fire response efforts.

6.1.2 Data Volume/Format Issues
Data volume is critical both for turn around processing time and delivery of the product through networks. Methods to reduce the volume of data transmitted include on-board processing to reduce and optimize the information sent, data compression, and reduction of the bit and pixel resolution of the final product.

6.1.2.1 On-Board Versus Ground Processing
On-board processing provides the opportunity to turn the imagery into products of lower volume. Disadvantages include the need to carry DEM’s on board, the need to develop software fully automated or easy to operate under flight conditions, the need to design the processing computer into the system. The only real disadvantages to ground processing are the time and volume issues of getting the data there and the added transfer time from the ground station. Keep in mind the cost of an airborne technician to trouble-shoot problems will be costlier than a ground technician. The fastest scenario would be to collect imagery, process it and telemeter it directly to the fire camp. To linger in the area giving time for this to happen may be expensive and difficult however. If processing can occur during transit time to the next fire with delivery to a web site accessible to the camp, this may be the optimal solution. An alternative is to process the imagery as much as possible (reduce the bit range, minimize bands, and compress) and telemeter to a central site for further processing to the product level. This allows the production of
multiple products from the dataset and reprocessing if problems occur or issues arise without impacting the flight plan. A disadvantage for ground processing is that for geo-
rectification, the associated position and attitude meta-data must be sent with the image if
ground based direct processing is to be used. This is less of an issue with framing
cameras since there is one set per image. For line scanners such as AIRDAS, meta-data
must be included for each line, or at least a representative subset. The AIRDAS system
telemeters the meta-data in a separate text file. Alternatively, this may be included in a
line or image header.

6.1.2.2 Data Compression
Discussion of data compression options is beyond the scope of this report, but this could
be key making certain scenarios possible. The compression scheme should be “loss-less”
and well supported. JPEG, with quality set to 100 (highest quality; least compression) is
a common option but can be improved on.

6.1.2.3 ISO Meta-Data Requirements
Standards have been developed for Meta-data describing imagery such as where it came
from and how it has been processed. These Meta-data support geo-location information
in a descriptive sense as well. If imagery is delivered directly from the plane, the ISO
Meta-Data should ideally, accompany it. Information on ISO Meta-Data was presented
in Task 4b.

6.1.2.4 Data Management
A large number of images will be collected and a large number of mosaics made if the
system becomes operational. Some type of data management will be needed for the
system to keep track of things. There must be a file-naming scheme for either the
computer or the operator, there should be a standard directory structure to facilitate image
location, and there must be a way for the computer or the operator to select the images
that are to be mosaicked. There must be a way to record the processing history of an
image. Some systems such as AIRDAS and Terra-Mar’s DACS system include a lot of
information in the image name itself. In addition Terra-Mar’s spatial database, GDC,
automatically logs image meta-data for collected imagery in real-time if run on-board,
and during post processing if run as a ground station. This Linux based system creates a
database of image footprints on the fly and can be used to spatially delineate camera
frames to be mosaicked and select images for display among other things (Figure 62). As
previously mentioned it manages DEM files for use in mapping. It has been demonstrated
historically for logging Landsat and SPOT coverage and is used by NASA-Ames
Airborne Sensor Facility for managing their aerial photography and digital data
collection. GDC is not an SQL database. It uses the SQL precursor Quel. It uses the 2D-
ISAM spatial indexing method.

Other image database software exists for logging geo-rectified imagery so it can be easily
retrieved. Oracle has spatial data types and can be used for such an application (see
Informix has collaborated with ESRI to offer spatial data types and queries in their
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database product offering a Java spatial data viewer and data loader as well. They use an R-tree spatial index.

The Image Data Acquisition and Sharing (IDAS) utility developed by IAGT with GST are based on RODIN technology (Figure 63). To quote from the user manual, “This software was developed specifically for sharing and accessing public remote sensing data. The IDAS was created for the IAGT’s Northeast Affiliates Group (NEAF) and other IAGT partners. A network of image libraries can be created and made available to selected users. The network is based on technology initially developed for Code 935 of the NASA Goddard Space Flight Center and provides a scalable, data-format-neutral system for ingesting, archiving, and accessing geo-referenced data. The IDAS leverages this existing technology to accommodate HDF, generic binary, and ERDAS Imagine raster format. Users can search and download archived image data as well as upload image data from their own image data archives.” This product is not currently available outside the NEAF group.

Sanz (http://www.sanz.com) offers an interesting data management solution for large datasets, specializing in automatic re-projection upon request. They partnered with ESRI and the ArcIMS™ tools to provide data serving for the GeoMAC.

GDC is a Linux product oriented toward real-time data logging and fast retrieval of geographic data. It is not currently web-enabled. The other products are oriented toward post acquisition loading but are web-enabled.
Other data management issues include a plan for removing imagery from the aircraft whether it is telemetered or handed off on a CD-ROM or flash disk. Removable drives simplify this process. Getting ground power to do any processing on the plane after a mission is a tedious and unpopular activity (Buechel, personal experience).

Figure 63. IAGT’s IDAS
This image is zoomed into a location showing the retrieval of ASTER imagery
7.0 CASE STUDIES

Two case studies follow describing the organization, facilities, and landscape of actual wildfires against which to consider the data processing and delivery options for the WASP sensor. The Biscuit Fire of 2002 was an extremely large and complex fire in a predominantly wilderness area that burned from July through September at the Oregon/California border. The vegetation in the main area of the fire was fir and pine forest with 40-50% crown closure. 29% of the area is open serpentine (Figure 64). The fire involved land jurisdictions from five different organizations and two States.

![Figure 64. Biscuit Fire View of the General Landscape (on left) and a Fire Line Being Built (on right)](image)

The Croy Fire was a relatively small fire in oak grass and scrub that became a serious wildland-urban interface fire when it burned towards inhabited areas in the region. The general statistics for each fire are presented in Table 15.

Table 15. Statistics on the Two Case Study Fires; the Biscuit, OR/CA Fire Complex and the Croy, CA Fire

<table>
<thead>
<tr>
<th>Fire</th>
<th>Acreage</th>
<th>Structure Loss</th>
<th>Personnel</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biscuit Complex</td>
<td>499,965 a.</td>
<td>14 + recreation</td>
<td>&gt;7000</td>
<td>$153 million (est.)</td>
</tr>
<tr>
<td>Croy Fire</td>
<td>3127 a.</td>
<td>46</td>
<td>&gt;1900</td>
<td>7.5 million</td>
</tr>
</tbody>
</table>

7.1 BISCUIT FIRE SUMMARY

The fires, which were to coalesce into the Biscuit Fire, began in July 2002 following a lightening storm. The “stage” for the scenario considerations will be the situation as of August when Type 1 Teams finally took over. The events up to that time will be summarized, based on the extensive day-by-day chronology published on the Biscuit Fire web site (http://www.biscuitfire.com/).
7.1.1 Situation Description

In July of 2002, following a predicted lightening storm several fires were reported in southern Oregon. A citizen in the Siskiyou National Forest reported the first, a human caused fire. Lightening strikes were reported the same day in the Kalmiopsis Wilderness (within the Siskiyou) and both ODF and CDF aerial observers reported several fires. Requests for support, to the Northwest Interagency Coordination Center in Portland, OR, and the Grants Pass Interagency Fire Center, and the Fortuna Interagency Coordination Center in Northern California (Fortuna) were not filled due to commitments created by the many fires burning around the western U.S. at the time and the lower priority location of the Oregon fires in predominantly wilderness areas, i.e. no immediate human impact. Normally available assets were serving on other fires. Requests circulated among various interagency groups none of who could fill them. Meanwhile more fires were reported including ones in CA and the Oregon Florence Fire grew from 50 acres to 600 acres in one afternoon. The Forest Service Pacific Northwest Region got involved. Aerial observers provided information on size and possible safety routes for setting up a defense. Access was a problem and bulldozers were employed to improve road access as well as create helispots. A multi-agency coordinating group was set-up to help prioritize asset allocation. There were not enough crews for all the fires and reconnaissance aircraft were used to patrol those without. Coordinated planning efforts began. A request for a Type 1 Team was turned down but another Type 2 Team was assigned. The second team established Area Command in Medford to coordinate all the Southwest Oregon fires. ODF began structure protection efforts as the fire approached residential areas. The Florence Fire doubled in size overnight to 15,300 acres. A new Incident Command Post was established at Lake Selmac to have more space and be closer to the fire. The McCaleb Boy Scout Camp was overrun and evacuation plans for residential communities began. With the threat to populated areas, the fire priority was bumped up and new Teams were added to the efforts. As a Type 2 Team was assigned to the California sections, inter-state coordination began. This involved coordinating strategies as well as air traffic radio frequencies. The chronology specifically mentions that “while communities were under pre-evacuation notice high use of phone, fax, and Internet overloaded communications systems” in Oregon. In August, Type 1 Teams began to be assigned. An additional ICP was established at the Gold Beach Fairground in Gold Beach, OR (Figure 65).

Figure 65. Gold Beach ICP
From CIIM Team 1 web site photos by Alfie Blanch.
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Figures 66 and 67. Briefing at Gold Beach and Lake Selmac ICP

Left image (Figure 66) is from Calif. Team 1 web site and right image (Figure 67) of the Lake Selmac ICP is from the Biscuit Fire web site.

Two teams were assigned to the Sour Biscuit Fire (one OR and one CA) with an ICP set up in Crescent City, CA. New spike and staging camps were established or expanded at various campsites.

Aerial observers played a large role in the identification and monitoring of the individual fires. Inaccessibility and lack of assets had allowed the fires to grow. As the Florence Fire began to threaten human habitat, it gained in priority and resources began to be redirected but it wasn’t until August 7 after the Florence and Sour Biscuit fires had merged and several communities overrun that Type 1 Teams were available for assignment. In August they inherited a fire so huge it was divided into four zones each with its own Incident Command Post (ICP): Lake Selmac, Gold Beach, Chetco (east of Brookings), and Crescent City (Figure 68). Each of the camps had its own GIS team and facility with computers, printers and satellite Internet access (Figures 65, 66, 67). A large auxiliary camp was established at Charles A. Sprague Seed Orchard in Merlin, OR, replacing a camp set-up. The fire overran the Snow Camp Lookout and destroyed the forest radio repeater there. IR coverage was requested and NIFC began flying nightly overflights with their Phoenix instrument (see Section 2) based either at Klamath Falls Air Attack Base, 57 miles east of Selma, or (more commonly) its home base in Boise (Zajkowski, 2003). Usually the entire fire was imaged nightly. The infrared imagery was retrieved by the ICP IRINs via an ftp connection. The paper products were scanned in to digitize them for transfer (Malcolm, 2003). The IRIN’s coordinated via the Situation Unit Manager with the GIS teams to produce fire perimeters. Figure 69 shows the GeoMAC representation of perimeters, while Figure 70 shows a portion of a working perimeter.

In addition to Phoenix coverage, requests for helicopter IR support are recorded in the flight log of the IAPs.

With cooperating weather and over 7000 personnel involved, the fire was slowly contained starting with Zone 2 on August 15, Zone 1 on August 22 and finally for the
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entire fire on September 5. The fire was not declared controlled until Nov. 8 with the arrival of fall rains.

Figure 68. Biscuit Fire Vicinity Map

Biscuit Fire vicinity map showing perimeter, zones and key locations. From the Biscuit Fire Chronology
http://www.biscuitfire.com
7.1.2 Data Processing and Delivery

The Biscuit Fire was large by any standards. The Forest Service Phoenix system generally flew the entire fire each flight (as opposed to the perimeter or sections) and provided the data, scanned print outs, via an ftp site. To deliver a single band 8-bit, 5m resolution mosaicked and geo-rectified WASP image would require transferring 125.9Mg or about 70Mg compressed. To try to send the raw data frames in this case would be prohibitive. Not accounting for obliquity, and not optimizing the flight pattern, it would require 7.4 lines of 70 across track swaths each to cover the fire at 10,000 feet AGL. This would be over 600Mg after scaling to 8-bit. This represents a higher end case, the opposite of the imaging requirements for the Croy Fire. This fire would be a candidate for land and hand-off, to be broken into sections (in this case the zones would be appropriate), or to be flown at a higher altitude. Once the data have been mosaicked and geo-rectified it would be simple to break it into zones, but that information would have to be available on-board in some sort of standardized fashion. High-speed wireless connectivity both for air to ground and for central site to the fire camp if a centralized scenario was implemented would be helpful in this situation. At 3Mbps, a conservative estimate for an 11Mbps wireless LAN, 70Mg could be transferred in about 3 minutes and multi-band IR composites would become an option.

Though the Phoenix system appears to have been used to image the entire fire frequently, the characteristics of the WASP sensor (WDMS System Specification Rev. 2) may suggest alternative imaging strategy involving more detailed coverage of particular areas, with higher altitude total coverage for reference. The particular imaging objectives of an incident and the available delivery options should be evaluated to determine the methodology.

Figure 70 shows the layout in detail for Zones 3 and 4 with some key objects such as Lookout towers, helispots and the westside airports shown in relation to the Gold Beach.
and Chetco ICPs. Staging areas, indicated by an S, where fire crew communications might be important, appear as well. Two RAWS stations (X) can be seen and two radio repeaters on Lookout Towers (R). Both ICPs are about 10 miles from the fire perimeter at the time of this map. The blue spots represent Helispots.

Figure 70. An AIR-OPS Map From the CIIM Team 1 Web Site
AIR-OPS served on the Biscuit Fire at the Gold Beach ICP in Zone 4 during August. Some of the mentioned locations can be seen including the Snow Camp Lookout Tower that burned.
This information is presented in the interest of determining potential inter-incident data transfer via wireless communications, however such an analysis is beyond the scope of this report.

7.2 THE CROY FIRE
The Croy Fire was a relatively small fire in the San Francisco Bay Area of California, of importance due to its proximity to inhabited areas. It was a several week event as opposed to the months of effort that went into containing the Biscuit Fire. It involved just two agencies, CDF and the USDA-FS.

7.2.1 Situation Description
A citizen reported the Croy Fire, caused by an electrical malfunction, at 2:15p. on September 23, 2002 along Croy Rd. outside of Morgan Hill, CA. The vegetation in this area is oak, brush and grass (Figure 72). The CDF Santa Clara Unit based in Morgan Hill initially responded. A CDF Type 1 Team (#5) was assigned on September 25th as residential areas were threatened and evacuations became mandatory. The Incident Command Center was set up in Christmas Hill Park in Gilroy (Figure 73). Two communications vans were assigned. One was a CDF MCC (see Section 1.3.1) and the other a smaller locally owned but similarly equipped van. A local HAM radio group, Mountain View Amateur Radio Emergency Service assisted with communications September 25 through October 3. Eight HAMS contributed 28 shifts to support communications. There was a field repeater and communications worked well (Stoneham, 2003). The fire had GIS and Meteorological support. The GIS team was from CDF’s FRAP group. Helicopters were used as well as Air Tankers for water drops. Helicopters were not used for IR or perimeter delineation. The Alma Helitack base, near Lexington Reservoir provided helicopter support. The closest Air Attack Base was in Hollister. Infrared coverage was provided daily, Sep. 24-26 and Sep. 29 by CDF’s AIRIS system flying out of McClellan Air Base outside Sacramento. The data was delivered via ftp from McClellan to the Morgan Hill CDF office on a T-1 link and by hand to the GIS team in the I.C.P. It was considered too poor in resolution and was not used to produce perimeters (Wood, 2003). Fire perimeters were produced by ground based GPS measurement (Figure 74).

Standardized briefing maps (Figure 74), a fire progression map and travel maps were all created and posted to the CDF Incident Web Site. Over 1900 personnel were involved in battling the fire. The fire was declared contained on September 29 when foggy weather gave firefighters the upper hand, and finally controlled on October 11. This 3100-acre fire was relatively small but serious due to the proximity to residential and commercial zones, as well as important watershed lands. Exploding propane tanks created additional hazard as structures burned. The terrain was steep and access difficult.

7.2.2 Data Processing and Delivery
Using the WASP specifications from the Project Overview presented at the Forest Service Geospatial Conference 2003, and not accounting for oblique coverage in the non-nadir frames, the Croy Fire, 8.9 km long by 2.8 km wide along its axis (Figure 71), would require 9.2 swaths of IR coverage. Assuming only full frames were used and that the
data were scaled to 8-bit, the raw images would be 9.8 Mg of uncompressed imagery per camera to deliver (approximately 4Mg using the gzip utility though the actual data content will effect the result). This would be feasible but begin to stress delivery systems, given current bandwidth, except for the wireless LAN option, or the soon to be satellite telemetry bandwidth >300kbps (air to ground), or a VSAT type satellite telemetry system (for non-airborne transfers).

If the images were geo-rectified and mosaicked on-board the aircraft to create a 5 meter resolution “map” of the site, a single band file, compressed and scaled to 8-bit, of about 1Mg could be created. The gzip utility was used to estimate the compression. This size file can easily be managed for telemetry purposes. Application of a classification algorithm could further reduce the data to transfer. A three-band composite image mapped to 5m-pixel resolution would be approximately 3 Mg compressed and scaled to 8-bit.

Figure 71. Croy Fire Perimeter from AIRDAS (in Red)

The ICP in Gilroy is off the map towards the blue at the lower right. Base DRG is from the TOPO! software with geo-referencing and graphics added using Terra-Mar DACS tools. The black lines indicate the measurements for the map product (rectangular) vs. the raw frames (along axis).
Figures 72 and 73. The Croy Fire from the Air
Note the topography and vegetation cover (photos by Chris Larkin).

Figure 74. The Croy Fire in Relation to the ICP
Base 7.5” DRG by TOPO! AIRIS data was received in the Morgan Hill office and delivered by hand to the ICP.
The ICP for the Croy Fire was located in Gilroy (Figure 73) more than ten miles away from the fire. The proximity to urbanization and the open vegetation suggest good wireless communication potential as well as ready access to fast wired internet connections. Though IR coverage was obtained, it was not used, suggesting that airborne imaging of a fire this size is not essential though it fits well with the system specifications. Whether the costly structure loss could have been minimized with useful IR coverage is unknown.
8.0 WASP SCENARIOS

The two case studies in Section 7.0 give a range of data volume and facility layouts to consider in proposing scenarios for WASP. Though each fire will be unique there are some generalizations that become apparent. The Incident Command Centers were located relatively far from the fire, in both cases over 10 miles away. This may improve loitering feasibility for wireless LAN data delivery and is also well within the realm of emerging wireless LAN technologies for potential field data transfers. Incident Command Posts are frequently located on Fairgrounds which could possibly have traditional higher speed Internet connections though these have not been considered in our scenarios since low-end satellite Internet connections appear to be the norm for west coast teams with a minimum of 200-Kbps specified. For possible remote field data communications, lookout towers existed in the vicinity of both fires and were used for communication support. The movement of the camps in the Biscuit Fire situation is relevant and must be considered in efforts to set up a both a field wireless LAN, and less so but still relevant for within camp set-up for an incident. Frequency of coverage and area of coverage gives a suggestion of data management needs as well as the Biscuit Fire example suggesting that large fires will require creative data acquisition and processing strategies. The rental of computers for incidents is common so ground processing requirements, for example for the client end of the 3-D fly-throughs should not be an issue.

8.1 DELIVERY LOCATION

Two scenarios are considered but many combinations of processing location, data products, and delivery method are possible. Flexibility is important in supporting varied fire camp conditions particularly while introducing new technology.

The centralized solution (Figure 75) telemeters data via satellite to either NIFC or perhaps a GACC location or even an image-processing center such as RSAC. The site should have processing facilities and a high-speed served ftp site. NIFC already supports an ftp site so this might be the preferred location. A centralized delivery location does not preclude using a wireless LAN transfer methodology. It might be easier to set-up a loiter zone away from the fire and the receiving station could be permanent.

In the dispersed solution (Figure 76) the imagery is delivered via wireless LAN directly to the Incident Command Center. This requires the Incident to manage the data. GIS teams and trailers appear to be capable of supporting some image processing particularly the ones tied to the image acquisition groups (Section 2). This would be limited to inserting IR derived information into base maps, running raster to vector extractions, and building 3-D capable sets of imagery for overlay in Skyline 3-D views, activities which could be significantly automated. By having such a group responsible for receiving the data prior to submitting it to the camp, a QC opportunity is provided for the direct approach.
Figure 76. Scenario 1 – Centralized Delivery.

Figure 77. Scenario 2 – Direct to ICC.
Airport option if high-speed link is set up. ICC-2 represents a second ICC on the same fire.
8.2 DATA PROCESSING
The pros and cons of on-board versus ground processing have been discussed. To ease telemetry load, some on-board processing will be required. Supporting on-board processing does not preclude ground processing as conditions dictate. An intermediate level of on-board processing is proposed here (reduce to 8-bit, geo-rectify and mosaic, and possibly “classify”) with further product development occurring on the ground to simplify the airborne operation. Further development includes incorporating derived information into DRG’s, raster to vector conversions and building the 3-D viewing file for use with the Skyline component of IAGT’s VMOC software. This allows the ground crew to make decisions such as which type of base maps to use and whether vector versions are necessary which may vary from situation to situation.

8.3 DATA PRODUCTS
A series of proposed products were described in Task 4b. Those products consisted of raw data, data mosaicked and geo-rectified, data mosaicked and geo-rectified with hot regions highlighted, hot regions extracted and placed in a base map. These data will be accessed and analyzed via the 2-D ArcGIS component of VMOC. Access to this level of product should be usable with dial-up or satellite Internet connection if desired in the centralized processing scenario and provides a familiar interface. The highest level of processing is the 3-D view and flythrough capability demonstrated in Task 4b using the Skyline product component of IAGT’s VMOC software. The 3-D flythrough requires some extra preparation, processing, computer power, and network bandwidth if used over the Internet and may not be feasible in some fire camps. The MS Windows product client will run on any recent computer with performance improved the faster the processor. The more RAM the better and a higher end graphics card will improve performance. At least a Cable or DSL level Internet connection is recommended (Pieper, 2003). Computer equipment at fire camps is often rented, so specifying a computer for this application is probably not a problem if performance issues are encountered. MS Windows, including components such as Internet Explorer are standard for National IMT’s. A cable or DSL connection is unlikely, though satellite service is probable. In the fires considered here, the ICC is frequently relatively far from the fire itself and often on Fairground sites that might be supplied by cable or other wired connections. Building the terrain base of DRG’s, Satellite imagery or DOQQ’s and a DEM, processing the collected imagery for 3-D display and serving the data require a higher end machine. This scenario works best with a centralized experienced facility to prepare the base, but a trained GIS group could perform the preparation as well in camp with service on a LAN. They will have already gathered the base information for their 2-D maps (note that products such as TOPO! can provide DRG plus DEM data). The imagery data can be “built” for 3-D display after downloading.

The WASP sensor is capable of providing higher spatial resolution and greater dynamic range than most imagery is currently providing. In order to reduce bandwidth, it has been proposed that reduced quality of image be telemetered. If high band width telemetry capabilities do materialize, or for land and hand-off scenarios, an interesting option exists in a web access solution from Spatial Data Technologies (http://spatialdatatech.com). Their DataGATE© product allows the user to select the data quality level for download.
over the Internet based on use requirements and bandwidth. This concept may be useful for “degrading” the WASP product to network limits determined by the particular fire camp.

8.4 Flexibility in Processing and Delivery Options

Due to a constantly changing technical environment and a potentially large variation in fire camp capability across the nation, support for low or high tech situations seems prudent. To land and hand-off a flash disk or CD-ROM will always be an option if conditions dictate. If a fire camp has only a dial-up Internet connection and no GIS support, a centralized telemetry option, with full processing capability provided at that facility could deliver any level of product desired. At least 2-D access via VMOC will be possible. Fully processed data products should compress very well for downloading.

A technically savvy camp with broadband wireless can make full use of data and process locally allowing possible near real-time production and multiple overflights rather than the traditional nightly one.

Both situations could be supported by a single centralized solution combined with an adaptive data delivery tool such as DataGATE© which allows the data degradation to be determined based on the download capability of the fire camp.
9.0 SUMMARY/CONCLUSIONS

The Incident Command Systems Planning Unit with GIS support as well as IRIN support will be the direct users of any products developed from the WASP system. Increased coordination between these two technical specialists can provide the skills needed to interpret imagery from different sources and do basic image manipulation if required. Traditional fire image products have been well defined and standards are being implemented within the fire management community. New technologies will provide improved products as processing and algorithms demonstrate reliable fire temperature calculations for active fire, hot spots, smoldering components, and other measurements. Meanwhile, the Incident Command can benefit significantly by more frequent timely delivery of fire perimeters, fire intensity, and hot spots locations.

The Incident Management Teams in the western United States have already been experimenting with improved fire data exchange communications. Satellite Internet connections, wireless LAN’s within the camps and significant web use have all become common with high-speed capabilities in the demonstration phase. Field to camp image transfer has been attempted, albeit at very low data rates. There has been an emphasis on the incorporation of GIT capabilities and innovative applications are emerging.

Current airborne data delivery of the thermal fire products is frequently a “land and hand-off” procedure of either a digital product or a printed strip map (which may later be scanned for ftp transmission). Other methods include fire perimeter interpretation by a Field Observer recorded by digital camera and GPS enabled PDA devices. Operational telemetry efforts mainly involve small data sets such as vector perimeter strings or hot spot locations. Satellite telemetry and wireless LAN transmission from an airborne system has been demonstrated by Ames Research Center projects for image data sets, and proves feasible for data delivery.

Terrestrial data and information delivery methods include satellite phone transfers from laptop computers of small compressed images, and both broadband transmission of video data, and high-speed Internet connections by the HPWREN project. Wireless LAN’s have been employed within Incident Command Centers. Hughes’ “Biology Science by Wireless” project has demonstrated remote data retrieval in harsh environments using radio technology in the unlicensed frequencies (or in combination with licensed frequencies) for several projects, which have application for fire efforts in field data retrieval. The potential to set-up wireless LAN’s from field to camp warrants exploration.

A comprehensive presentation of the airborne imaging systems available to the Forest Service indicates that several companies are offering complete imaging service from acquisition through processing including the GIS trailer and satellite connection. A variety of products are offered from strip maps to fully geo-rectified mosaics and interpreted imagery.
The Internet is being heavily utilized for fire incident information sharing. Sites are managed by organizations in some cases (e.g. CDF) or by individual teams (e.g. National IIMT). The layouts and information provided vary greatly. Their primary purpose is public communication and the trend is away from providing the working documents. In some cases these can only be accessed via a password-protected, secure login. Web sites are also being used by Incident Teams for providing within-team documents. The GeoMAC utility, while not operational in this sense, comes close to prototyping a potential centralized data server for incident imagery and other information. NIFC’s AFF product is a noteworthy attempt to provide real-time web based information.

Recent and “on-the-horizon” improvements in bandwidth capabilities will impact data delivery capabilities. The 11Mbps Wi-Fi radios and improvements in satellite telemetry rates will allow some scenarios that weren’t possible several years ago. Decreased cost and increased distances are opening up new opportunities for data sharing. Mobile and easy to set-up satellite Internet access (such as DirectPC) is currently available and getting cheaper and should stimulate many communication options.

The RIT WASP system can fill a critical niche in the USFS and NIFC’s desired fire imaging capabilities as a Type 1 sensor system. These systems are the most critical for providing large incident coverage over numerous fires while providing fire information rapidly. By providing a suitable fire product from the WASP, the acceptability of the system by the USFS and NIFC will be greatly enhanced.
10.0 BIBLIOGRAPHY, REFERENCES AND WORKS CITED


Greenfield, P., personal communication, USDA Forest Service Remote Sensing Applications Center (RSAC), Salt Lake City, Utah, 9 September 2003.


Wood, E. personal communication. Morgan Hill Unit, CDF.


11.0 RELEVANT FIRE WEBSITES AND URL INFORMATION

11.1 FEDERAL AGENCY SITES

National Interagency Fire Center: http://www.nifc.gov/


Interagency Coordination Centers: http://www.nifc.gov/news/nicc.html


USDA Forest Service RSAC MODIS Active Fire Mapping Program: http://activefiremaps.fs.fed.us/index.html

USDA Forest Service, Fire and Aviation Management: http://www.fs.fed.us/fire/

USDA Forest Service, Fire and Aviation Management, Geospatial Tools For Incident Support: http://www.fs.fed.us/fire/gis/incident-support/incident-support05.htm


National Interagency Remote Automated Weather Station Network: http://www.fs.fed.us/ra w/

USDA Forest Service Rocky Mountain Research Station, Missoula Fire Science Lab: http://www.firelab.org/

USDA Forest Service Wildland Fire Assessment System: http://www.fs.fed.us/land/wfas/

USDA Forest Service, Riverside Forest Fire Laboratory: http://www.rfl.psw.fs.fed.us/

USDA Forest Service, Eastern Area Coordination Center: http://www.fs.fed.us/eacc/

Eastern Great Basin Coordination Center: http://www.blm.gov/utah/egbcc/

Northern Rockies Coordination Center: http://www.fs.fed.us/r1/fire/nrcc/
Northern California Geographic Area Coordination Center: 
http://www.fs.fed.us/r5/fire/north/

Northwest Area Coordination Center: http://www.or.blm.gov/nwcc/index.htm

Rocky Mountain Area Coordination Center: 
http://www.fs.fed.us/r2/fire/rmacc.html

Southern Area Coordination Center: http://www.r8web.com/sacc/

Southwest Area Coordination Center: http://www.fs.fed.us/r3/fire/swamain.htm

Southern California Coordination Center: http://www.fire.r5.fs.fed.us

Western Great Basin Coordination Center: http://www.nv.blm.gov/wgbcc/

Fire Research and Management Exchange System: http://www.frames.gov/tools/

Fire Research and Management Exchange System (FRAMES) Fire Management Tools: 
http://frames.gov/tools

PLUMP: A one-dimensional plume predictor and cloud model for wildland fire and smoke managers: http://www.fs.fed.us/database/plump.htm

California Wildfire Coordination Group, Interagency Fire Weather Center: 
http://www.fs.fed.us/r5/fire/south/fwx/

Southwest Area Wildland Fire Operations: http://www.fs.fed.us/r3/fire/


BLM Office of Fire and Aviation: http://www.fire.blm.gov/index.htm

Bureau of Indian Affairs Fire and Aviation Management: http://www.bianifc.org/


USGS GeoMAC: http://www.geomac.gov/

USGS Rocky Mountain Mapping Center, Front Range Wildfire Response: 
http://rockyweb.cr.usgs.gov/wildfire/
National Park Service, Fire and Aviation Management: http://www.nps.gov/fire/

National Park Service, Yosemite National Park Fire Information: http://www.nps.gov/yose/now/fire/projects.htm


NOAA Fire Weather Information Center: http://www.noaa.gov/fireweather/

NOAA OSEI Fire Events: http://www.osei.noaa.gov/Events/Fires/


National Association of State Foresters: http://www.stateforesters.org/

US Office of Aircraft Services: http://www.oas.gov/


National Fire Plan: http://www.fireplan.gov/content/home/

NASA-Ames Research Center – UAV FiRE: http://geo.arc.nasa.gov/sge/UAVFiRE/

NASA-Ames Research Center – Wildfire Response Team: http://geo.arc.nasa.gov/sge/WRT/

NASA-Goddard Space Flight Center, MODIS web page: http://modarch.gsfc.nasa.gov/cgi-bin/texis/search/search


Canadian Interagency Forest Fire Center: http://www.ciffc.ca/
11.2 STATE, LOCAL, AND UNIVERSITY, RESEARCH INSTITUTES AND PRIVATE SITES

California Department of Forestry and Fire Protection: 
http://www.fire.ca.gov/php/index.php

California Department of Forestry and Fire Protection, Fire and Resource Assessment Program: http://frap.cdf.ca.gov/

Southern California Wildfire Hazard Center: 
http://www.icess.ucsb.edu/resac/resac.html

Los Angeles County Fire: http://www.lacofd.org/

Alaska Fire Service, Interagency Wildland Fire Management: 
http://fire.ak.blm.gov/default.htm

Florida Division of Forestry, Fire and Forest Protection: http://flame.fl-dof.com/


University of Maryland, Web Fire Mapper: http://maps.geog.umd.edu/

Arizona Pyrogeography Research Laboratory: 
http://climate.geog.arizona.edu/~yool/

University of Montana – Missoula, Global Fire Net: 
http://www2.umt.edu/ccesp/global/

University of Wisconsin-Madison, Biomass Burning Monitoring Team: 
http://cimss.ssec.wisc.edu/goes/burn/abba.html

Desert Research Institute, Western Regional Climate Center: 
http://www.wrcc.dri.edu/
Desert Research Institute, Program for Climate, Ecosystem and Fire Applications: 
http://www.cefa.dri.edu/

Desert Research Institute and Scripps: California Applications Program, Wildfire: 
http://www.cefa.dri.edu/Other_Links/links_index.htm

Western Fire Center, Inc.: http://westernfire.com/


### 11.3 Imaging Systems Sites

USFS National Infrared Operations: 
http://nirops.fs.fed.us/

USFS Fire and Aviation Management – Infrared Group: 
http://www.fs.fed.us/fire/niicd/Infrared/Infrared.html

NASA-Ames Research Center, AIRDAS: 
http://geo.arc.nasa.gov/sge/brass/Brass.AIRDAS.html

Space Instruments, FireMapper: 
http://www.rumford.com/SpaceInstruments/index.htm

USFS, Riverside Fire Lab, Fire Mapper: 
http://www.rfl.psw.fs.fed.us/prefire/firemapperhtml/, also 
http://www.fireimaging.com/

NASA-Ames Airborne Sensor Facility: 
http://asapdata.arc.nasa.gov/

NASA-Ames Airborne Sensor Facility – MODIS Airborne Simulator: 
http://mas.arc.nasa.gov

NASA MODIS / ASTER (MASTER) Airborne Simulator: 
http://masterweb.jpl.nasa.gov/

Sky Research, Inc. – AIRDAS: 
http://www.skyri.com/

Airborne Data Systems Spectra-View: 
http://www.airbornedatasystems.com/

EarthData International of Maryland, LLC: 
http://www.earthdata.com/
SenSysTech Inc. (formally Daedalus Corp.):  
http://www.sensytech.com/

Blue Skies Consulting, LLC:  
http://www.blueskies.aero/

Spectrum Mapping, LLC. (formally EnerQuest):  
http://www.enerquest.com/

Kestrel Corporation:  
http://www.kestrelcorp.com/advanced.html

Range and Bearing Corporation (AWIS System):  
http://207.102.122.235/awisweb/index.htm

SennaBlue LLC:  
http://www.sennablue.com/

VeriMAP PLUS Inc.  
http://www.verimap.com/

Angiel EnviroSafe, Inc:  
http://www.angielenvirosafe.com/

Fireball Information Technologies, LLC:  
http://www.fireballit.com/

Mid-Valley Helicopter:  
http://www.ramsystemsslcc.com/

San Joaquin Helicopters:  
http://www.hhcopters.com/

Ventura County Sheriff Aviation Unit / SAR:  
http://www.fire.countyofventura.org/Services/Mapping/mapping.html

Vision Air Research:  
http://www.visionairresearch.com/

Helicopter Applicators Incorporated:  
http://www.helicopterapplicators.com/

Oilton Remote Detection Technologies (ORD-TECH):  
Not Available

Advanced Building / M.I.R.S.
http://www.moble-ir.com/

John Newman (IR Mapping):
Not Available

Cincinnati Electronics (Infrared Detectors):
http://www.cinele.com/ired.htm

WESCAM 12DS-MAR Camera:
http://www.wescam.com/products_services_1c.asp

FLIR Systems:
http://www.flir.com/airborne/

PolyTech Kelvin 350 II FLIR system:
http://www.polytech-us.com/kelvin350II.htm

Raytheon IR Cameras:
http://www.raytheoninfrared.com

11.4 DATA COMMUNICATION AND TELEMETRY SITES

Inmarsat Satellite Communications:
http://www.inmarsat.com/

NERA Satellite Phone (telemetry) Systems:
http://www.nera.no/01154339C51CEA7DC1256A2A0031D9DB.html