Digital Aerial Sketchmapping and Downlink Communications: A New Tool for Fire Managers

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Abstract

Aerial sketchmapping is the geolocating of features that are seen on the ground below an aircraft and the subsequent recording of those features. Traditional aerial sketchmapping methods required hand-sketching on hardcopy maps or photos and the translation of that information to a digital file. In 1996, the U.S. Department of Agriculture (USDA) Forest Service embarked on a project to develop a digital aerial sketchmapping system (D-ASM) to replace or augment the traditional (manual) methodology. Advances in microprocessor speed and Personal Computer (PC) system performance made possible the use of PCs to aid in aerial sketchmapping. The USDA Forest Service Remote Sensing Applications Center (RSAC) and the Forest Health Technology Enterprise Team worked with a software vendor to develop a product that would meet the needs of aerial surveyors. Several hardware and software options were investigated.

The Remote Internet Protocol Communications System (RIPCom) culminated from a successful 2-year collaboration between National Aeronautics and Space Administration (NASA)-Goddard and RSAC to develop a cost-effective, multitask communications solution for the Forest Service based on NASA expertise. The RIPCom consists of commercial off-the-shelf components that were each chosen because of their desirable performance characteristics. The 2003-2004 field tests demonstrated that the RIPCom would deliver the required data throughput (1 Mbps) up to a range of 20 mi. A contractor constructed the second generation RIPCom system incorporating the lessons learned from flight testing and operational deployments.

The planned integration of the D-ASM and RIPCom systems will enable firefighting experts to collect information about an incident (fire perimeter and hotspot locations) on the D-ASM and rapidly disseminate this information, via wireless devices, to the incident's geographic information system (GIS) technician or directly to firefighters on the ground. Potential system users within the wildfire community include Air Attack, Helitack, Situation Unit Leaders, Operations Chiefs, and Incident Commanders.

Keywords: GIS, global positioning system, pen-tablet, Remote Internet Protocol Communications System (RIPCom), wildland fire monitoring and suppression.

Introduction

Aerial Sketchmapping

Aerial sketchmapping for Forest Health Protection has been conducted since the 1940s. Typically, sketchmapping surveyors fly the area to be surveyed in a high-winged, high-performance aircraft at elevations of 1,000 to 3,000 ft above the ground. The surveyor tracks the plane's location on a hardcopy map (typically several maps that are trimmed, edge-joined, and taped together) or aerial photographs, then sketches areas of the forest that have been damaged during the past year (Figure 1). The sketched features (points and polygons) are then registered and digitized into a geographic information system (GIS). Finally, the resulting GIS data are used to create maps and reports at forest, regional and national levels.

Although skilled surveyors have successfully employed manual sketchmapping techniques for years, there is great potential for error in the process. Some examples of the sources of error are:

- Not knowing the aircraft's location on the map.
- Reinking map data upon completion of the day's flying.
- Inaccurate registration, line following, and attribute capture when digitizing data into the GIS.

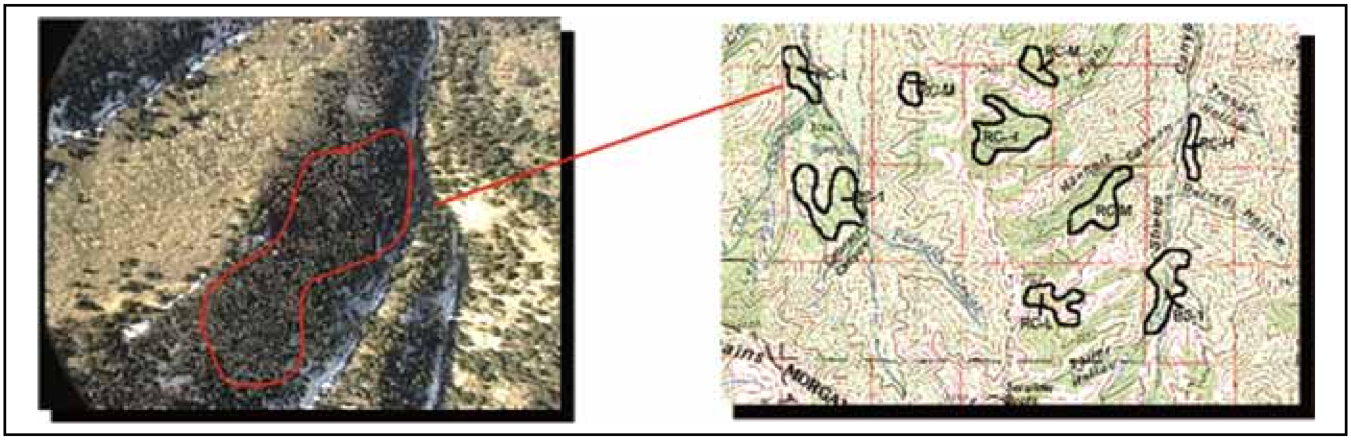

Figure 1—The principle of aerial sketchmapping—observing ground features and annotating those features on a paper or digital map—is displayed in the aerial photograph and accompanying map.

In addition to the potential for error, some of the processes used in manual sketchmapping require additional time to complete. Examples of those processes that can be eliminated with a digital system are:

- The reinking of map data upon completion of the day's flying.
- The management of numerous taped and folded maps in the cockpit.
- The taping and folding of maps prior to the mission, the cutting apart of those maps prior to digitizing, and the retaping of the maps after digitizing, but prior to proof-checking the digitizing results.
- The digitizing process itself.

The positional accuracy of sketched features is largely determined by the ability of the sketchmapper to keep track of the aircraft's position on the map and to correctly relate features seen on the ground to the map. This can be especially difficult in unfamiliar or flat terrain or both. At typical airspeeds of 100 to 140 miles per hour (mph), a sketchmapper has approximately 15 sec/mi^2 to accurately locate, sketch, and attribute features (assuming a visual mapping distance of 2 mi from the aircraft). Accuracyare a relative term, and the end use of the data must be considered. If the data collected during a sketchmap mission are for general monitoring purposes, then more error can be tolerated than if field crews need to locate the affected stands using the sketchmapped data.

To be favorably compared against manual sketchmapping, a competent digital aerial sketchmapping system should address the problems listed above and should meet the following list of requirements, which were compiled for early system development:

1. The map display must be linked to a global positioning system (GPS) receiver so that an icon on the display represents the current position of the aircraft on the movable digital map.
2. The map display must update quickly at ground speeds of 130 mph and reorient when turning, if desired by the surveyor, based on the GPS position and heading of the aircraft.
3. The screen must be viewable under a variety of lighting conditions including full sunlight and must also display, at minimum, full (256) color.
4. The viewable screen size must be at least 10 inches measured diagonally.
5. The software must have the capability to:
    - Digitize points, lines, and polygons – including nested and overlapping polygons.
    - Attribute digitized features (points, lines, and polygons) quickly and easily.
    - Allow editing of feature attributes quickly and easily.

- Allow the user to predefine the feature attributes to be collected during that day's mission.
- Collect the GPS log file of the flight.
- Allow the user to zoom quickly to different map scales.
- Retrieve and display common raster and vector data types as background maps quickly and seamlessly (including the U.S. Geological Survey 1:100,000-scale digital roster graphics DRG aerial surveyors currently use in hardcopy form).
- Export files in a format that is easily imported into ESRI Arc/Info software, thus eliminating the intermediate digitizing step
- Save data automatically to the computer's disk.

6. The hardware should be operational in moderately harsh conditions (32 to 120 °F, high humidity, dusty conditions).
7. The primary input device must be a touch screen with stylus.

After a great deal of testing and evaluation, the Forest Service successfully met these requirements, and two systems emerged and are in common use today; a two-screen system and a pen-tablet system. Advantages of the Digital Aerial Sketchmapping System (D-ASM) include automatic tracking of the aircraft's position on a map base through a link to a GPS receiver and a significant reduction in the time spent moving data into a GIS. The D-ASM greatly speeds data collection and processing and improves the positional accuracy of the data being collected. Now a mature system, the D-ASM has been widely embraced by the sketchmapping community with over 90 systems in service with Federal and State forest health agencies.

Following initial system development, a D-ASM was shown to wildfire air attack crews who liked the concept, but wanted the system to be smaller and for it to include a means to get the information down to the incident command in real time. Two technological developments solved these requirements: commercially available touchscreen pen-tablet computers and the National Aeronautics and Space Administration (NASA) developed long-range high-speed data link named RIPCom. or Remote Internet Protocol Communication.

The Forest Service is now working to further expand the utility of the D-ASM by adding live downlink capabilities to the existing system.

D-ASM Mapping Software

For the D-ASM, the Forest Service selected the consumer off-the-shelf (COTS) mapping software that most closely met the system requirements, and the software provider agreed to make necessary modifications to their product to meet our sketchmapping needs.

With this software, feature type keys (point, line, and polygon) are used to display the aircraft's position on the on-screen map, and a user-defined keypad is used to attribute features. The observer selects the type of feature to be sketched, sketches the feature on the screen, and then assigns attributes to the feature using the keypad. The screen remains frozen while the feature is being sketched and is updated after the enter key is pressed. When the aircraft icon advances to the edge of the window, the map display updates and moves the aircraft icon to the center of the window. Upon completion of the sketchmapping mission, a translation step converts the sketched features into ESRI shapefiles. These shapefiles are then copied to an external disk for transfer to a GIS.

Aerial surveyors often want to display large shapefiles over their raster map data; these shapefiles may be the previous seasons' survey data, administration boundaries, or section lines. Fire managers may want to see the previous day's fire perimeters shown on top of raster aerial imagery or digitized raster maps. The software can display many different types of geospatial data as the background map and thus can accommodate a variety of user preferences.

The software provider continues to enhance the software by developing modifications such as editing of polygons, multiple user-defined keypad sets for attributing features, display of feature attributes, and editing of feature attributes.

Figure 2—Forest Service digital sketchmapping systems are displayed. At left is the two-screen system with external global positioning system (GPS) receiver. At right is the pen-tablet sketchmapping table with built-in GPS receiver (the windshield-mounted antenna is shown in the lower right).

D-ASM Mapping Hardware

Two computing options have been tested and are in use in Forest Service sketchmapping systems: a two-screen laptop-based system with a separate touchscreen, and a pen-tablet sketchmapping table (Figure 2). Because of the potential for bright sunlight on the screen, the visibility of the map image on the touchscreen display is critical. We evaluated several touchscreens, which varied in screen size, brightness, and touchscreen technology. Resistive touchscreens have a membrane layer installed over a fine wire mesh grid in the screen; when this membrane is pressed on to the grid, a signal is sent to the computer, and the cursor jumps to that spot on the screen. Virtually any object can be used on the screen—a finger, an eraser, stylus, etc. This can be a disadvantage for sketchmapping, because any inadvertent touch to the screen may result in undesired actions. Many touchscreens have a rather small screen size (10.4 diagonal), which limits the amount of map area visible on the screen.

A supplier manufactured several screens to Forest Service specifications for early testing. These screens have 800 by 600 resolution, 12.1-in diagonal screen size, 1,500 nits brightness, and capacitive touchscreens. This type of touchscreen is activated by completion of an electrical circuit using a tethered stylus. There is no inadvertent activation of the resistive touchscreen because the screen can be activated only with the tethered pen. It should be noted that this system is quickly becoming obsolete and will no longer be supported by the Forest Health Technology Enterprise Team (FHTET).

Pen-tablet Personal Computers (PCs) were also tested as an alternative platform for the D-ASM. The advantages of the pen tablet for use in sketchmapping include a smaller, simpler hardware profile and fewer cables. The disadvantages include a smaller screen area and decreased screen visibility in full sunlight.

We have tested many GPS receivers, and it seems that any receiver capable of producing an National Marine Electronics Association 0813 output string will be compatible with the software. Expensive, survey-grade receivers are not necessary; various recreation-grade units are adequate for the task. The GPS signal enters the PC via a COM port Universal Serial Bus ([USB] or Serial) connection. Newer USB GPS units have the advantage of drawing power from the laptop PC. Wireless GPS receivers provide an attractive alternative, and testing of such receivers is ongoing.

RIPCom Background

The RSAC has been working with NASA Goddard Space Flight Center (GSFC) on adapting technology NASA has developed for unmanned aerial vehicles (UAV) to Forest Service applications. The RIPCom system that is being developed by NASA-GSFC is of particular interest to the Forest Service because it can be used to download fire imagery during flight, which will save the Forest Service

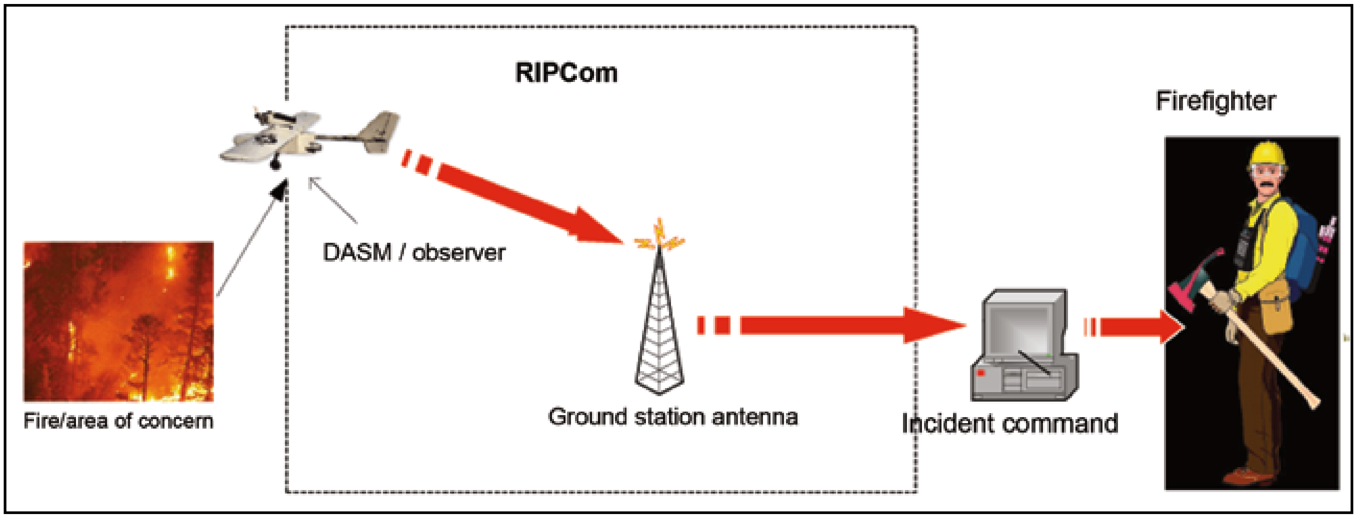

Figure 3—RIPCom concept is shown in detail.

time and money while enhancing safety. RIPCom is a wireless communication system that makes any RIPCom-equipped aircraft look like a network node in the sky. RIPCom-provides an Ethernet to Radio Frequency (RF) connection solution for real-time data transmission, and its design allows the end points of the communication system to become nodes on a network with assigned IP address. RIPCom's versatility makes it valuable for any system that requires a high-speed, digital wireless network.

The NASA-GSFC has modified the original RIPCom design so that it meets Forest Service requirements. These include the ability to dump data at much faster rates and at greater ranges.

Specific Forest Service requirements include:

- Providing a wireless network connection at distance of at least 10 mi.
- Supplying a data rate of at least 1 Mbps.
- Providing a long-distance wireless network that can also maintain a connection with a moving target.
- Design for aircraft that is 10,000 ft above-ground level.
- Data acquired at the ground station from an aircraft operating at 300 mph.

The RIPCom consists of COTS components from different vendors chosen because of their unique performance characteristics to meet Forest Service goals. Numerous wireless network technologies currently exist that are candidates for RIPCom, and many factors such as frequency, RF power output, size, and cost were considered for the Forest Service system design. The aircraft and ground station nodes were designed individually owing to the unique conditions of each environment. Figures 3 and 4 illustrate the major components of the RIPCom concept and details of the system's ground station and aircraft components.

The major consideration for the airborne components is the antenna, which must be very aerodynamic while still providing a workable radiation pattern for this implementation. In addition, the antenna must be placed so that shadowing by the wings or other aircraft components is minimized. A 2.4 GHz, 5dB gain blade antenna (Figure 5) has been installed on the aircraft's fuselage just aft of the forward landing gear bay, which gives the antenna an excellent field of view.

RIPCom's ground station is designed so that it is able to provide bi-directional communication with a lower gain antenna 10 mi away. The ground station accomplishes this by utilizing a three-sector, omni-directional antenna. The resulting system is able to provide a point-to-point connection for high-speed data transfer at an affordable cost ($7,500 for the ground station, less tripod, and $3,200 for aircraft station, less installation). Because RIPCom is platform independent, (it does not matter which operating system is used), the only requirement is that ground station

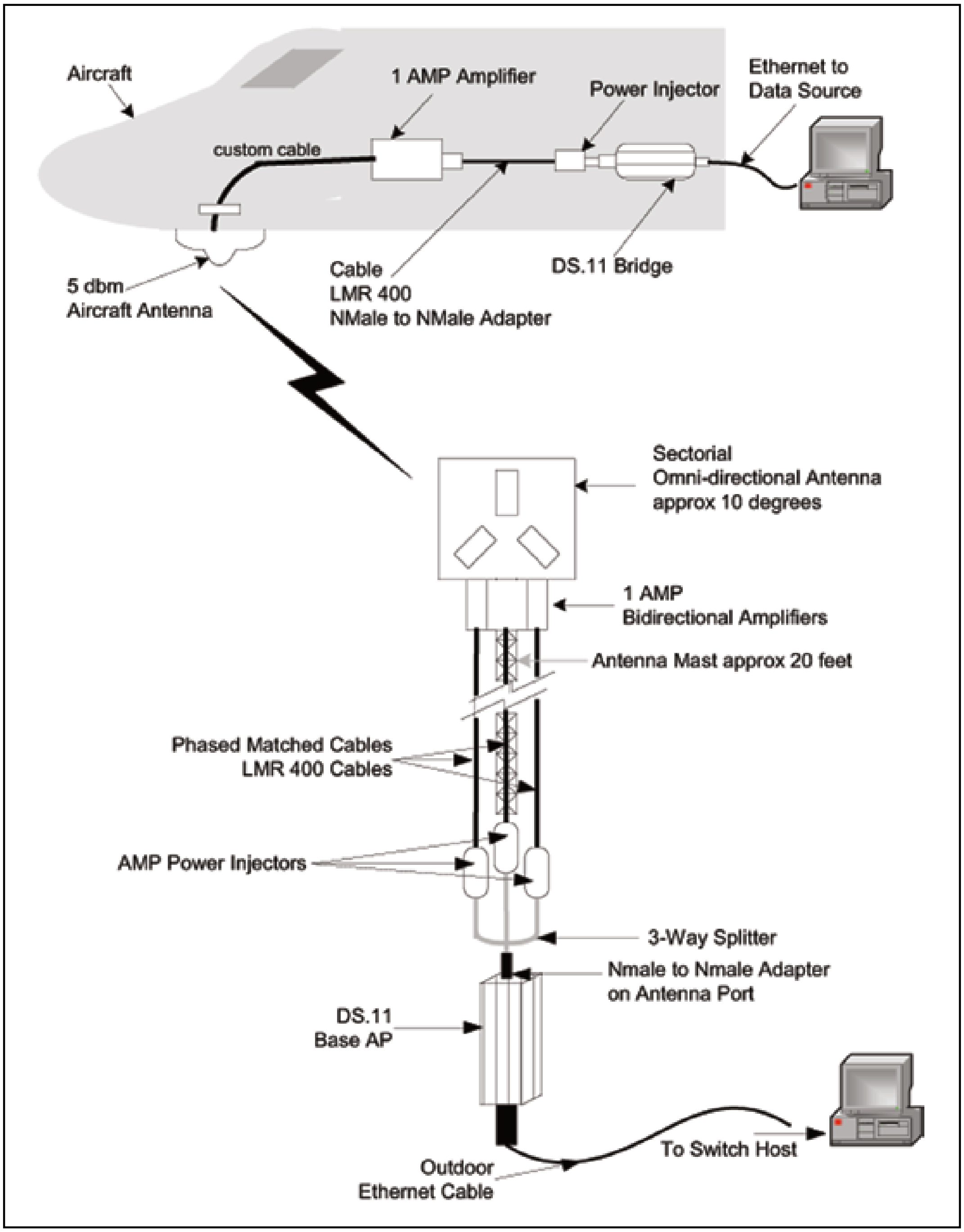

Figure 4— Detailed diagram of Forest Service RIPCom solution is shown.

and aircraft have a Transmission Control Protocol/Internet Protocol connection.

Flight Tests

Initial flight-testing of the RIPCom system took place near Boise, Idaho, the week of April 14-19, 2003. Tests were conducted for 6-, 8-, 9-, 10-, 11-, 12-, and 15-mi orbits. During the flight test, several issues were evaluated, checked, and recorded:

- Determine the strongest channel (One is able to choose among 11 channels.).

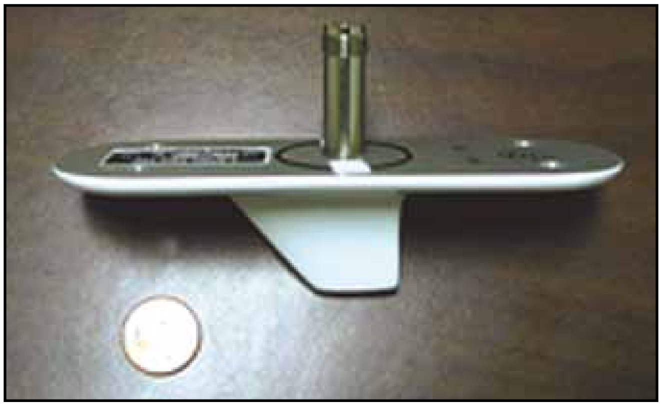

Figure 5— View of the aircraft gain blade antenna that is attached to the aircraft's fuselage.

- Ping each network device for each throughput setting (11, 5.5, 2 Mbps), and transmit a 36 Mb and 77 Mb file from the plane to the ground station.
- Determine the time it took to transmit the data.
- Characterize the location and duration of any data drops during data transmission.

Other tests included having the pilots fly elliptical orbits, flying directly over or to the sides of the ground station to characterize the radiation pattern of the ground station and to determine if there was any Doppler interference in the data transmissions.

The RIPCom exceeded expectations during flight-testing as it had with the ground tests. Performance was very good. Data rates of 2 to 3 Mbps were achieved at a range of 30 mi. The system was robust; File Transfer Protocol transfers could be completed without errors even if the transmission was interrupted (up to 45 sec). We also found that the jet could fly directly to and from the ground station at 300 mph without the data transmissions being affected by the Doppler Effect.

RIPCom 2

The April 2003 flight tests were an unqualified success based on the National Infrared Operations requirement for long-range broadband real-time transmission of high-resolution imagery acceptable by the Infrared Interpreter. Upon later assessment, it was decided that the current state of technology could not fulfill both the performance and updated portability (single suitcase as carry-on luggage) requirements.

The NASA/GFSC and the Forest Service went back to work to develop a self-contained unit that could be easily transported by one person. It was a conscious decision to sacrifice both range and data bandwidth in order to meet the portability requirement. This collaborative effort resulted in a second generation RIPCom unit that utilizes a 36-in omni-directional antenna and a single radio. The portable approach yields a much lighter package that can be transported in two pelican cases. One case contains the modem, radio, and laptop computer. The second contains the antenna, mast, and cables (Figure 6). The bottom line for the end-user is that the portable RIPCom ground station is capable of 1 Mbps data rate at a range of 8 to 10 miles.

Summary

By integrating two successful technologies, the Forest Service is working to create a new tool that will allow fire managers to relay critical fire information to dispersed field units in real time. The Remote Sensing Applications Center will be working with NASA GSFC and wildland fire personnel to integrate the RIPCom sketchmapping system into wildland-fire operations during the 2007 fire season. The ultimate goal is to increase firefighter safety and to improve overall operational effectiveness in wildland fire monitoring and suppression.

Figure 6— (Left) Case 1, (Center) Case 1 with computer tray removed, (Right) Case 2.

Continue