

Unmanned Airborne Systems Supporting Disaster Observations: Near-Real-Time Data Needs

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Abstract - Between 2004 and 2010, the Wildfire Research and Applications Partnership (WRAP), a joint NASA / US Forest Service project, matured, demonstrated and transitioned innovative technologies and capabilities for real-time information data delivery to Incident Management Teams on wildland fires in the United States. The capabilities included the development of innovative unmanned airborne systems (NASA Ikhana UAS), multispectral sensors (NASA Autonomous Modular Scanner), on-board, real-time processing /delivery through a satellite data telemetry system, and a COTS-driven visualization and common operating picture (COP) capability. All of these capabilities and their technology readiness levels are described. The wildfire management agency end-users are currently adopting these capabilities into operational utility, and an assessment of the gaps in adaptation will be addressed. Additionally, an assessment of appropriate UAS-derived technologies for disaster management support is also addressed.

Keywords: NASA, Ikhana, AMS, CDE, wildfire, disaster support.

1. INTRODUCTION

The Wildfire Research and Applications Partnership (WRAP) is a NASA Applied Sciences-funded collaborative project between NASA and the United States Forest Service focused on R&D, demonstration and infusion of innovative remote sensing, geospatial, and aeronautics capabilities into disaster management operations. Four major capabilities and technologies were selected to “mature” for infusion into operational status within the US wildfire management community. Those four technology arenas were:

- 1) Use of long-duration Unmanned Aerial Systems (UAS) as a sensor platform;
- 2) Improving wildfire sensor systems.
- 3) Mature Over-the-Horizon (OTH) data telemetry systems for real-time relay of UAS sensor-derived fire information;

- 4) Develop and enhance a decision support system to allow simplified visualization capabilities and integration of wildfire-related data sets.

These four technology arenas are described below. Following sections will describe the adaptation successes and gaps in adaptation for these technology arenas.

1.1 NASA UAS

The NASA *Ikhana* UAS is a modified General Atomics - ASI, Inc. Predator-B aircraft, designed to support NASA aeronautics and Earth science research missions. The platform, entered NASA service in January 2007. The *Ikhana* is capable of ~24-hour duration, ~45,000 feet altitude, and flight legs of over 4000 nautical miles. The *Ikhana* (Figure 1), flew its first science missions in support of wildfire observations in August 2007, and continued mission operations through 2009, supporting wildfire observations.



Figure 1. The NASA *Ikhana* UAS platform. The sensor is carried in a pod located under the wing, as can be seen in this image.

1.2 Autonomous Modular Sensor (AMS) -Wildfire Sensor

The 16-channel NASA WILDFIRE Scanner was developed for operations on-board both manned and UAV platforms. The instrument supports fire science measurements, with four mid-IR and TIR channels (two each of high gain / low gain mid-IR and TIR). The AMS-Wildfire scanner subsystems include the scan head, digitizer/data system, Applanix navigation system enclosure, Trimble DGPS / storage subsystem enclosure, power distributor, blackbody control subsystem, GPS antenna and assorted cabling (Figure 2).

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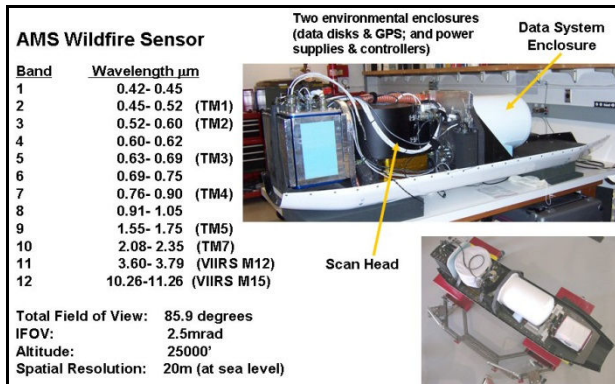


Figure 2. The AMS-Wildfire sensor system. The figure indicates the spectral channel characteristics and integration layout in the *Ikhana* UAS sensor wing-pod.

1.3 Over-The-Horizon (OTH) Data Telemetry

The OTH data telemetry system embedded in the NASA *Ikhana* UAS is used for bi-directional command and control (C&C) of the UAS as well as for bi-directional control of the AMS-Wildfire sensor system. The link allows imagery and Level 2 data products, developed on the payload processors to be sent from the UAS to a ground receiving station and then, through the Internet. The OTH telemetry system is capable of 3.0 Mb/s data throughput rates.

1.4 Wildfire Collaborative Decision Environment (W-CDE)

A simplified, fire data visualization tool was developed using NASA and Commercial-Off-The-Shelf solutions. GoogleEarth[®] free-ware package is used as a “back-end” to display AMS sensor-derived imagery and other fire data sets on a 3-D landscape, allowing ease of visualization use by Incident teams. The CDE is shown in Figure 3.

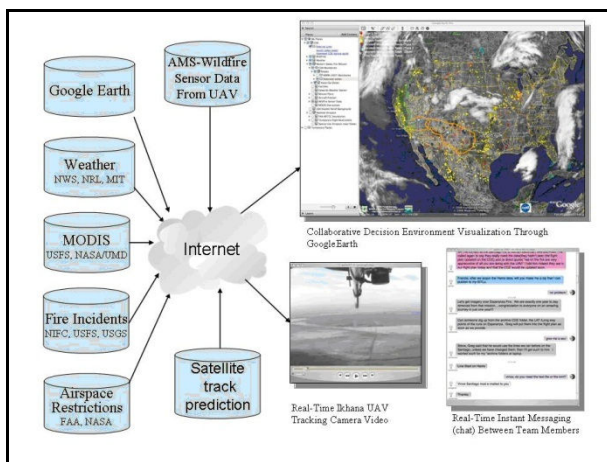


Figure 3. The Collaborative Decision Environment (CDE) tool for visualizing wildfire-related data and information. The CDE is based on the GoogleEarth free-ware package and allows various web-served data sets to be coalesced and viewed in a 3-D package perspective.

Each of these capabilities and elements was demonstrated during 2006-2010 over wildfire events in the western United States. The following section highlights those missions.

2. TECHNOLOGY DEMONSTRATIONS – 2006-2010

Between 2006 and 2010, a series of wildfire imaging missions were flown on the NASA *Ikhana* UAS with the AMS-Wildfire sensor system to demonstrate various technologies and also to support disaster managers with real-time data over wildfire events. The mission series is highlighted below.

2.1 2006 AMS-Wildfire Missions

On 28 October 2006, the AMS-Wildfire sensor, operating aboard the Altair UAS (*Ikhana* UAS predecessor), collected sensor data over the Esperanza Fire in southern California, providing real-time wildfire hot spot detection to the on-site Incident Command Team.

2.2 2007 AMS-Wildfire Missions

In 2007, the AMS-Wildfire was integrated on the new NASA *Ikhana* UAS, and eight fire observation missions occurred between August and October. The first four missions were operated over fires in eight western states. Mission operations over 27 fires were between 10-22 hours long and extended for 1400-3200 mile ranges. Real-time fire data were relayed to Incident Command Centers (ICC) through the W-CDE.

2.2.1 Southern California Firestorm AMS Missions

In late October 2007, a series of Santa Ana wind-driven fires erupted in the Los Angeles and San Diego regions of Southern California. The NASA *Ikhana* UAS / AMS-Wildfire sensor flew the first four mission-days over 11 major wildfire complexes in the region and provided real-time hot spot data to fire management teams, over a five day period..

2.3 2008 AMS Missions

In late June 2008, lightning ignited hundreds of fires in northern California and the AMS, operating aboard the *Ikhana* UAS, flew a series of four mission-days over the various complexes, completing the mission series in mid-September. Each of the fire management teams were provided near-real-time, on-board-derived fire LEVEL II data, as defined earlier in section 2.2.

2.4 2009-2010 AMS Missions

During the 2009 fire season, the NASA *Ikhana* UAS was unavailable to support missions until November. An AMS-Wildfire post-fire NBR data collection mission was flown over the Station Fire in Southern California on 19 November 2009.

In 2010, again due to the unavailability of the *Ikhana* UAS, the AMS team initiated installation on a NASA manned platform (Beechcraft B200 King Air). No wildfires were flown in the 2010 period. A summation of the AMS-Wildfire sensor missions is shown in Table 2.

Table 2. AMS Mission Summation.

YEAR	AIRCRAFT	FLIGHTS	HOURS	FIRES FLOWN
2006	Altair	4	68	2
2007	Ikhana	12	89	37
2008	Ikhana	4	21	16
2009	Ikhana	2	11	2 (post-fire)
TOTAL		35	207	60

3. TECHNOLOGY ADAPTATION SUCCESSES

Since the completion of the WRAP project fire imaging demonstration missions in 2009, a series of successful technology infusion elements have occurred. The following subsections describe those adaptation successes, while the next major section (section 4) describes the noted gaps in adaptation. During the project lifespan, a number of wildfire observation strategies and capabilities were enhanced (Figure 4). The following sections highlight the major USFS partner technology adaptations that resulted from collaborative R&D with the NASA WRAP project team.

Tactical Imaging of Fires	
<p>Capacity 2003</p> <p>Short aircraft mission duration. "Process" to structure mission configuration: time consuming. Fire / flight decision based on "best guess" conditions (fire / weather). Rotorcraft observations expensive and day-flight limited. Limited on-board / on-ground geo-processing with DEM data. No data telemetry to IC...nor NICC. Imagery received in a few hours. Fire / No-Fire "blobs" mapped (binary map). Data integrated in GIS in few hours.</p>	<p style="text-align: center;">NASA / USFS Collaboration</p> <p>Achieved 2008</p> <ul style="list-style-type: none"> • Showcase 24-hour capability. • IMM: Real-time platform / sensor control and mission configuration. • Integrate orbital resources (MODIS / GOES) to configure airborne mission. • Small UAVs: cost effective, day / night operations. • On-board, automated geo-processing with SRTM database. • Full OTH telemetry to NICC and LOS to IC. • Imagery received in 10 minutes. • Full real-time configurable multi-channel imagery of fire condition. • Data compatible with GIS immediately.

Figure 4. Wildfire Capabilities Enhancements achieved during the Wildfire Research and Applications Partnership (WRAP) project.

3.1 UAS Technology Adaptation

Since 2008, the U.S. Forest Service (USFS) has spearheaded an initiative to test, deploy, and integrate UAS into their operational tactical wildfire imaging arsenal. The USFS is exploring and investing in small UAS (hand- and catapult-launched) platforms for tactical fire observation strategies supporting crews on fire perimeters. The small UAS would provide gimbaled TIR / camera observations of local fire phenomenon (hot spots in mop-up operations, flaming fronts, etc.). The small UAS are seen as a gap-filler on wildfires during periods when rotorcraft fire observation platforms are not available to fly (night operations). In 2009, the USFS experimented with a small UAS system operating in and supporting a major wildfire in Northern California. Additional shake-down demonstration missions occurred in 2010 (Figure

5). The USFS is planning to test UAS platform integration on wildfire events in 2011 to help define parameters for integration into the USFS firefighting arsenal. The USFS has further established their own COA development system, and are of generating and supporting their own COA submissions.



Figure 5. AAI RS-16 catapult-launched (belly-recovered) small UAS employed by USFS in 2010 during a capabilities demonstration to support wildfire imaging. The USFS has organized and supported a series of these capabilities missions to look towards small UAS wildfire observation operations.

3.2 Wildfire Sensor Technology Adaptation

The USFS has an aging sensor suite operated by the National Interagency Fire Center (NIFC) - National Infrared Operations (NIROPS). The NIROPS operates two scanning systems on two manned aircraft (Citation Jet and B200 King-Air). The USFS has invested in the development of new sensor systems for the development of a sensor to replicate AMS capabilities. The USFS is also investing in an additional B200 King-Air to accommodate the AMS during a loan period in 2011 and 2012. That development will allow the NIROPS to operate three aircraft / imaging systems while development and integration of new replacement sensors is completed. One of the proposed sensors systems is the Wide Area Imager (WAI) developed by Xiomax Technologies, under a NASA Small Business Innovative Research (SBIR) contract and cost-shared with the USFS for final enhancements. The sensor will be flight tested in 2011

3.3 OTH Data Communication Technology Adaptation

In late 2008, the USFS invested in two Aircell[®] data telemetry systems for use on the two NIFC NIROPS aircraft platforms. The Aircell[®] system operates by interface to cellular network tower / stations located in the U.S. mainland. Currently, the system operates in the lower 48 states only (not AK or HI), and is functional for bidirectional communication / data transmission when the Aircell[®] system on the aircraft is operated at 10K feet AGL or higher. The Aircell[®] system is resident on numerous commercial passenger airline aircraft and is affordable to operate, compared to wide-band satellite communications systems. The successful implementation of NASA data telemetry capabilities, demonstrated on numerous Ikhana missions, led to this adaptation and significantly reduced the NIROPS data collection-to-user delivery time from hours to minutes! (Figure 6).

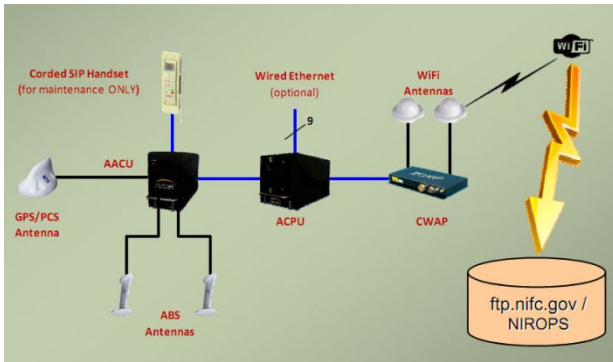


Figure 6. A schematic of the Aircell[®] data communications telemetry system operated on the NIFC NIROPS aircraft.

3.4 Decision Support Systems Adaptation

The GoogleEarth-based Collaborative Decision Environment (CDE), developed within the WRAP project to share, visualize and manipulate wildfire geospatial data, including sensor-acquired imagery data has been adapted by the USFS in operational fire support. The CDE is operational at the Remote Sensing Applications Center as well as at the NIFC National Incident Coordination Center (NICC). The CDE has been further enhanced by NIFC by the addition of all USFS operational aircraft positional information, to allow monitoring of all air resources in the US during wildfire events. Additionally, the CDE is used to serve up and display weather related information from the National Weather Service (NWS) during their daily fire weather briefings at the NICC during the fire season. New functionality, after testing at NASA and USFS, is added to the USFS CDE to enhance the operational utility of the decision environment.

4. GAPS IN ADAPTATION

The gaps in adaptation of the demonstrated technologies include the UAS (large and small) access to National Airspace, prohibitive costs of specialized fire imaging sensors, and costs related to data telemetry systems for relaying information from acquiring sensors to ground personnel.

4.1 UAS Adaptation Gaps

The FAA has not established guidelines yet for routine operations of UAS in the National Airspace. The USFS is working with the FAA to facilitate operational directives, focused on UAS missions in the context of supporting emergency operations within the closed airspace (TFR) of a wildfire event. This may prove to be the first adaptation of a small UAS into the wildfire imaging support role for the USFS, and is the most feasible approach to the slow integration of UAS into operations supporting wildfire monitoring.

4.2 Wildfire Sensor Adaptation Gaps

The cost-prohibitive nature of small-supply, specialized imaging systems to specifically support wildfire observation is a major deterrent to adaptation. The market-place for specialized, accurate wildfire sensors is small. Companies are adverse to develop units without a significant market force to ensure sustainability. The procurement and operational

integration of the sensor systems is also slow, taking up to 2-3 years of development and manufacturing before delivery. The wildfire management community also needs long-lead times to budget the necessary resources for procurement. The USFS is evaluating a new sensor for wildfire imaging use in 2011. If acceptable, further procurements of the system will probably follow in 2012-2013.

4.3 OTH Data Communication Adaptation Gaps

The USFS invested in an affordable solution for their data telemetry needs. The Aircell company has expanded their market share by offering commercial passenger airline companies the ability to procure systems allowing passengers to have real-time WiFi access aboard aircraft. This has allowed Aircell to “mass-produce” systems, and bring the costs to an affordable range for small-unit-procurement entities such as the USFS. Although the Aircell system is not operational outside the US, the USFS performs missions primarily in the lower 48 states, and the system is more than suitable for their needs. The cost structure of data-transmission time is very affordable to the USFS, compared to higher bandwidth throughput systems, such as the SatCom system utilized by NASA on the Ikhana UAS platform.

5. CONCLUDING REMARKS

The Wildfire Research and Applications Partnership (WRAP) Western States UAS Fire Mission series (2004-2010) demonstrated four critical components required to improve wildfire management and mitigation: 1) UAS platform utility 2) improved sensor imaging systems; 3) data telemetry technologies; and 4) real-time fire information integration into a decision support system. Each of these technology arenas and capabilities has been adapted by the USFS and wildfire management agencies into operational status, even though some implementation barriers still exist. The UAS wildfire missions demonstrated that the capabilities were at very high Technology Readiness Levels (TRL) and adoptable for integration as operational systems. The utility and employment of long-duration / range UAS, such as the *Ikhana*, make them invaluable for these disaster-related observation missions, where lingering and endurance are critical for full-time situation monitoring. The main barriers to full UAS implementation into operational utility in the National Airspace is their performance / reliability issues, and how those relate to perceptions by the FAA, and therefore the COA process and flight restrictions. The sensor, data telemetry and Collaborative Decision Environment are at very high TRL levels and are being individually integrated into operational status by NASA’s partners, the US Forest Service and the NIFC.

6. NEXT STEPS

The NASA WRAP team is continuing to partner with the USFS and the wildfire management community to further enhance and evaluate emerging technologies. The partnership has recently expanded to include the State of California fire protection agency, CalFire, as a technology partner. The project team is also expanding to engage the fire science community to share in technology enhancements and field experimentation that can help improve the knowledge of the role of wildfires in ecosystem functioning.