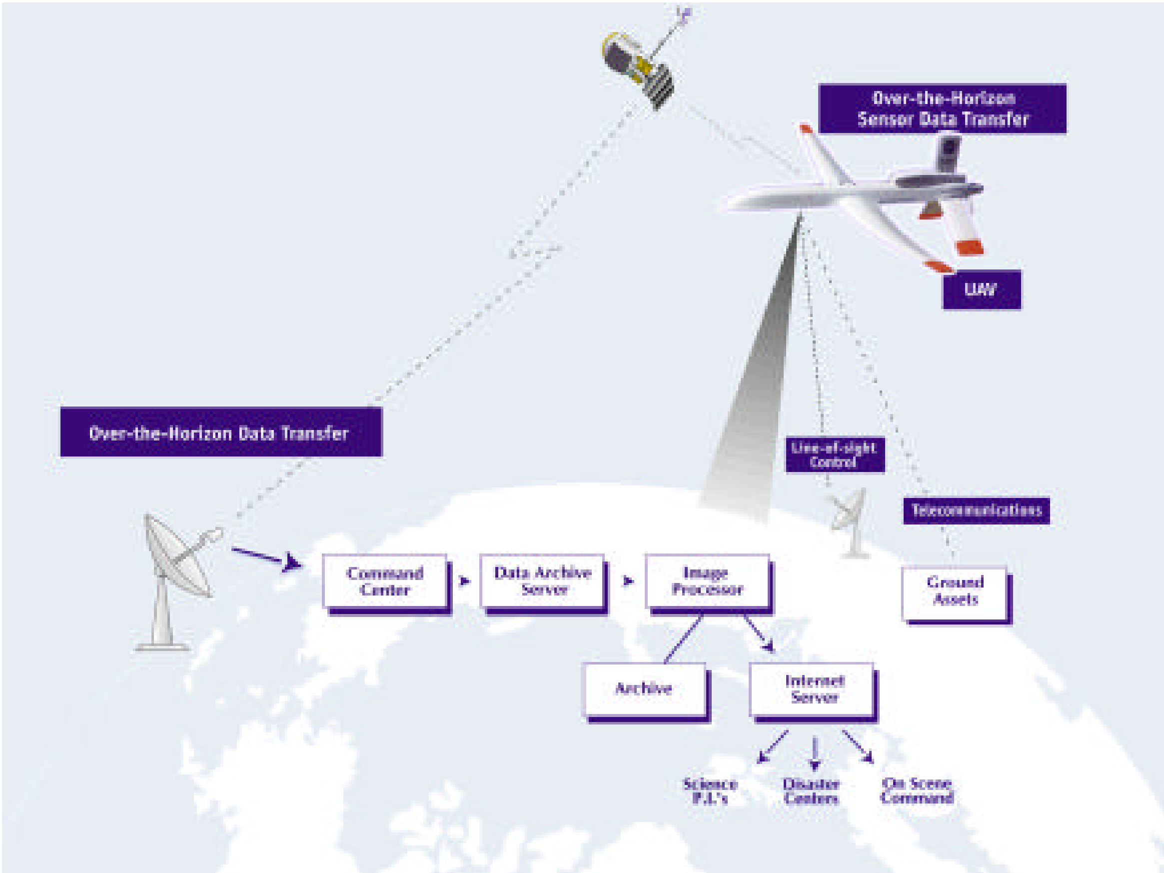
UAV Over-the-Horizon Disaster Management Demonstration Projects



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White Paper: UAV Over-the-Horizon Disaster Management Projects

(prepared by Susan Schoenung, with input from Steve Dunagan, Don Sullivan, Jim Brass and Steve Wegener)

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FY2000 ERAST Disaster Management Demonstration: Fire Management Mission

(prepared by Steve Dunagan and Steve Wegener)

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White Paper on
UAV Over-the-Horizon Disaster Management Demonstration Projects

INTRODUCTION: THE NEED

There exists within the disaster management community an on-going need for real-time data and information, especially during catastrophic events. Currently, much of the data is collected by twin engine or jet aircraft with limited altitude and duration capabilities. Flight safety is also an issue. Clearly, much of the needed data could be delivered via over-the-horizon transfer through a UAV platform to mission managers at various locations on the ground. In fact, because of the ability to stay aloft for long periods of time, and to fly above dangerous situations, UAVs are ideally suited for disaster missions.

There are numerous situations that can be considered disastrous for the human population. Some, such as fire or flood, can continue over a period of days. Disaster management officials rely on data from the site to respond in an optimum way with warnings, evacuations, rescue, relief, and to the extent possible, damage control. Although different types of disasters call for different types of response, most situations can be improved by having visual images and other remotely sensed data available.

“Disaster Management” is actually made up of a number of activities, including:

- Disaster Prevention and Mitigation
- Emergency Response Planning
- Disaster Management (real-time deployment of resources, during an event)
- Disaster / Risk Modeling

All of these activities could benefit from real-time information, but a major focus for UAV-based technology is in real-time deployment of resources (i.e., emergency response teams), based on changing conditions at the location of the event.

Locating a UAV with the right capabilities at a disaster site affords an opportunity to impact disaster outcomes because it can provide to the right people the right information at the right time regarding the situation on the ground. To achieve this capability on an operational basis requires an ability to put a suitable platform with appropriate sensors in place above a disaster location and provide real-time, over-the-horizon data transfer to personnel who can put the information to use in a timely and helpful way. Figure 1 shows the demonstration elements.

With all these potential benefits, it is desirable to demonstrate to user agencies the ability to perform disaster management missions as described. The following demonstration project is the first in a program designed to prove the feasibility of supporting disaster missions with UAV technology and suitable communications packages on-board.. A several-year program is envisioned, in which a broad range of disaster-related activities are demonstrated to the appropriate user communities.

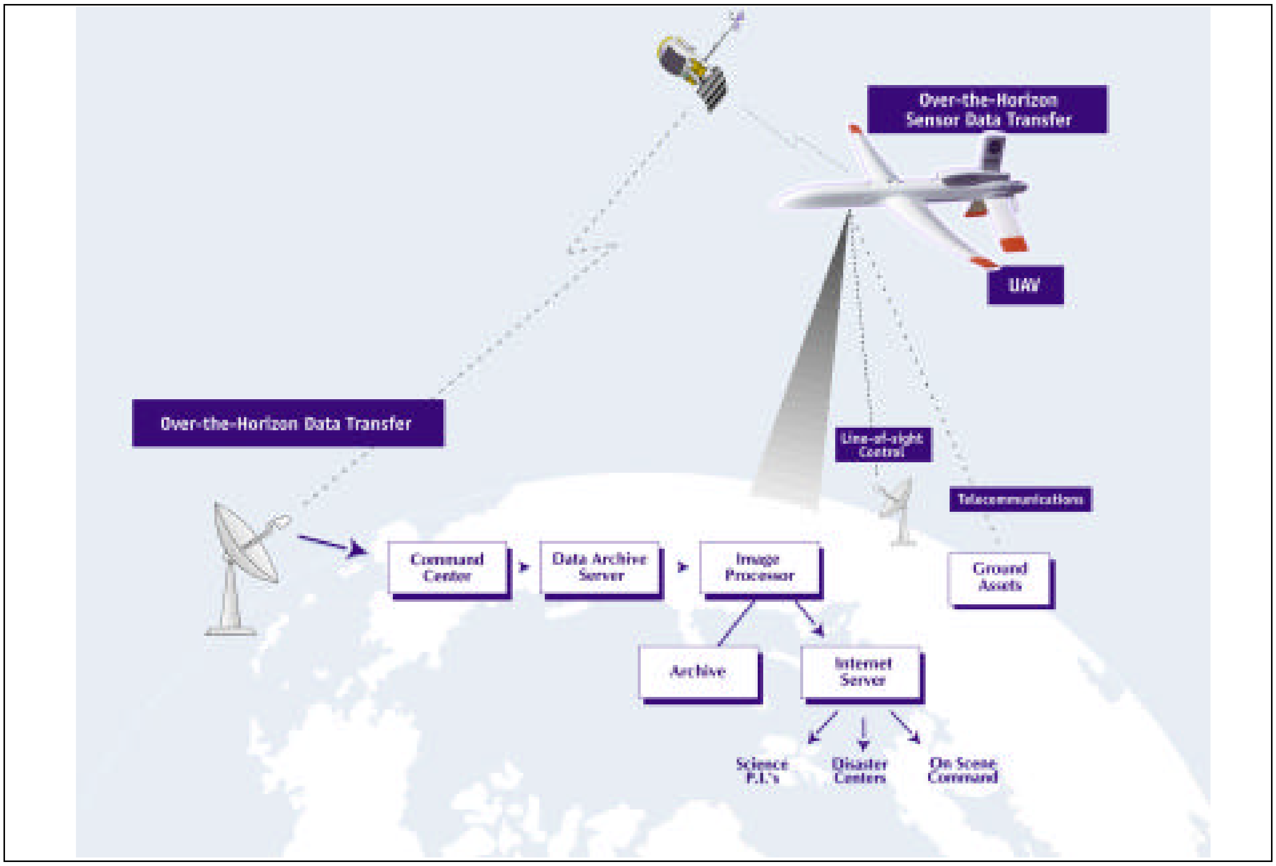

Figure 1 Demonstration Elements

GOALS OF THE DEMONSTRATION PROJECT

The goals of carrying out disaster management demonstration missions are:

- To demonstrate the ability to provide safe, timely, critical information to disaster managers
- To enhance the value of disaster data.
- To refine the process for planning such demonstration missions, enabling future operations

OBJECTIVE / CHARACTERISTICS OF THE DEMONSTRATION PROJECT

The objective of the demonstration missions is to successfully integrate the following capabilities into a system and operate in a disaster management scenario:

- UAV platform providing safe, flexible, long endurance operations
- Suitable remote-sensing payload
- Over-the-horizon data downlink to data hub
- Real-time or near-real-time disaster data analysis
    - Real time disaster information distribution to users in the field
    - Real-time tasking of system to optimize information value
- Real or simulated disaster situation with user agencies participating
- Asset tracking
- Communications

POTENTIAL MISSIONS, PAYLOADS, DATA AND PLATFORM REQUIREMENTS

There are many potential missions. These are listed below:

- Fire (wildfire, urban, urban/wildland interface, prescribed)
- Flood mapping / monitoring
- Hurricane tracking / landfall characterization / damage assessment
- Tornado, other weather-related tracking / assessment
- Earthquake monitoring / damage assessment
- Volcanic eruption plume sampling / flow field mapping / damage assessment
- Toxic plume, or other man-made chemical release
- Terrorist, military, or other social disaster
- Loss of communications / provide communications support

The matrix in Table 1 indicates for each type of mission, the most suitable sensors, and accompanying data and flight profile requirements.

Table 1. Mission Parameters

Disaster Mission	**Data Type**	**Sensors**	**Data Link Rate (kbaud) (up/down)**	**Flight Profile / Time on Station**	**Response Time**
Fire	Imagery, temperatures	Thermal, IR, possible vis	4.8-9.6 / 64	Above traffic, >12 hours	1-2 hours
Flood	Imagery, terrain elevation	Vis, possible IR, SAR	4.8-9.6 / 64	Above traffic, > 12 hours	1-2 hours
Hurricane	In-situ wind, pressure, etc., general imagery	Dropwind-sondes, LIDAR, vis	4.8-9.6/4.8-9.6 for sondes	Above weather, 12 – 36 hours	12 - 24 hours
Earthquake	Imagery, 3D resolution	High resolu-tion vis, DEM	4.8-9.6 / 64	Above traffic, > 12 hours	< 2 hours
Volcanic eruption	Imagery, chemisty	Chemical analyzers, IR	4.8-9.6 / 64	Range determined by extent of event	1-6 hours
Toxic plume	Chemistry	Chemical analyzers, possible vis	4.8-9.6 / 64	Range determined by extent of event	< 2 hours
Loss of comm-unications	Telecomm	Receiver /Transmitters	9.6 / 9.6	High altitude loiter, long endurance	< 2 hours

TECHNOLOGY STATUS DISCUSSION

UAV Status and Opportunities

NASA has access to a number of UAVs that are available or becoming available for disaster demonstration missions. Table 2 below lists the status of several platforms.

Table 2 UAV Platforms

Platform	**Supplier**	**Status**	**Maximum**	**Endurance**

			Altitude	
Altus DT	General Atomics	Available	60,000 ft	6 hrs
Altus TM	CIRPAS	Available	40,000 ft	36 hrs
Predator	General Atomics	Available	26,000 ft	40 hrs
Predator B	General Atomics	In development	52,000 ft	24 hrs above 45,000 ft
Perseus	Aurora	In repair	65,000 ft	6 hrs
Sky Watch	Aurora	In development	62,000 ft	32 hrs
Pathfinder Plus	AeroVironment	Available	80,000 ft	14 hrs
Centurion	AeroVironment	In development	100,000 ft	14 hrs
Helios	AeroVironment	In development	60,000 ft	Indefinite, with fuel cells
Global Hawk	Ryan Aeronautical	Available,negotiate with from AF	65,000 ft	36 hrs

O-T-H Status and Opportunities

Over-the-Horizon data transfer is a major goal of this demonstration program. At present there is very limited commercial service available for OTH applications. Previous NASA experiments have used TDRSS, a NASA satellite normally restricted to special use. Military systems have been used in some experiments that had joint military sponsorship. The available commercial systems are listed in Table 3 below, along with their availability for UAV demonstrations. For early demonstrations, it is likely that some compromise will be needed to achieve some degree of OTH communication.

Table 3 Commercial Over-the-Horizon (OTH) Systems

System	Orbit / Coverage	Data rate	Availability / suitability for UAV use
Inmarsat	GEO / worldwide	4.8 – up to 64 kbps	Aeronautical systems available, others adaptable.
Iridium	LEO / worldwide	2.4 kbps	Aeronautical systems available
GlobalStar	LEO /worldwide	9.6 kbps	Operational
Orbcomm	LEO / limited at high latitude	2 kbps	Operational for ground systems

Sensor Status and Opportunities

Although many sensor payloads are available, in principle, for disaster management demonstration missions, in reality only a few are supportable by the current UAV community. Weight, power and size are issues; integration is required to make use of limited space; many payload areas have little or no environmental control; and payloads must be controlled autonomously for UAV applications. Table 4 below lists several disaster management payloads and their characteristics.

Table 4 Sensor Payload Characteristics

Sensor	Data Type	Operator	UAV Readiness
Airborne Infrared Disaster Assessment System (AIRDAS)	Thermal/IR fire images	NASA-Ames	In redesign for UAV demo
Airborne Real-time Imaging	Digital imagery	NASA-	Demonstrated

Spectrometer (ARTIS)		Ames, HSI	
Digital Array Scanning Interferometer (DASI)	Multispectral imagery	NASA-Ames	Demonstrated
HiMetSonde	Meteorological data: pressure, temperature, wind speed and direction	CIRPAS	Initial demonstration from CIRPAS Altus
Airborne Large Format Imager (ALFI)	Scene camera	NASA-Ames	Must be automated
Harvard / Perseus packages	Chemical analyzers (sniffers)	Harvard Univ.	Demonstrated on balloons
LightSAR	Digital elevation or terrain data	General Atomics	Ready for demonstration

Real-time telemetry and analysis: Status and Opportunities

ERAST demonstration missions provide the opportunity to address several challenges that NASA is facing as the quantity of data produced with new sensor technology and the scientific data requirements from space or airborne missions tax the bandwidth of present telemetry downlink systems. The basic physics of transmission favor the investment of electrical power assets not in higher bandwidth transmission but in intensive low power on-board data processing, where Moore's law promises ever improving computational capability. The development of "smart sensors" will reduce the volume of the downlinked data stream.

In the near term, several strategies may be exploited. A starting point is the development of algorithms that select only data that is relevant to very specific scientific objectives. This may be as simple as selecting specific targets or not transmitting images from clouded areas. Another technique that is common with image data is compression, which may be categorized more generally as the use of mathematical tools to compress information into a minimum lossless (or prescribed lossy) volume as limited by information theory. Often remotely sensed image data is processed with sophisticated classification software to identify the spatial domain of a specific phenomenon. As an example, a huge multi- or hyperspectral data set might be reduced to a single binary image mapping a particular vegetation type. At a more complex level, algorithms may be developed to select elements from a large data set based on optimal scientific content as measured by a field programmable merit function.

For the future, it is possible to envision the use of neural networks or rule-based artificial intelligence tools to maximize the acquisition of useful data, particularly if autonomous direction of the aircraft flight path is incorporated into a full robotic mission concept. This concept is described below as real-time retasking.

Real-time data distribution: Status and Opportunities

Real time data distribution is currently planned to be handled in three different ways, depending on the tools and internet connectivity available. Scenarios 1 and 2 could reasonably be carried out today. Scenario 3 is in development and should be available within the next year or so, depending on funding profiles.

Scenario 1, Field Access:
A field commander would access the internet server with a standard web browser, and download the most recent incident image or relevant data, or any historical (archived) images or data.

Scenario 2, Command Access:
A regional commander in the command center would have access to either processed or raw image or instrument data, and, additionally, ancillary data sets, available in different formats, on the internet.

Scenario 3, Digital Earth Augmented Access:
A field commander with a reasonably high speed internet access, a regional commander in the command center, and (possibly) distributed disaster center personnel could, using freeware tools being co-developed by NASA and the OpenGIS Consortium, utilize resources on the "Digital Earth" in concert with real time imagery or other data. In this scenario, a user could, for example, overlay a road layer from one "Digital Earth" server over the real time incident assessment image, which was, itself, overlaid on a USGS digital orthophoto that was retrieved and re-projected by another server. At any time, current asset locations and descriptions can be downloaded and displayed.

Real-time data availability makes possible real-time retasking, as described below.

Real-time system retasking: Status and Opportunities

The most important goal of providing real-time data to users on the ground is to support disaster response by allowing real-time decision making regarding flight coordinates and data acquisition functions of the UAV and its payload. The concept is to allow observers at a mission control station to task or retask the UAV and its payload by directing it while in flight to a specific location for a desired measurement or observation. Some examples:

- Send the UAV back to collect more images of a given scene
- Fly lower or higher for better resolution or a wider view, or to take a sampling profile
- Return for a measurement if data were lost for any reason
- Loiter at a location for ground communications purposes

Real-time retasking of payload instruments may also be helpful in some situations, such as:

- Switching spectral bands / data type
- Turning on and off in situ sensors
- Calibrating sensors
- Dropping sondes more or less frequently

These activities require real-time understanding of the incoming data, and real-time ability to redirect the platform and payload. Several experimental flights have demonstrated real-time data downlink capability, although much needs to be done to reach mature, operational status. Some previous flights are indicated in Table 5.

Table 5 Real-time Data Demonstrations

Mission	Objective	Sponsor	Downlinked Sensor
Atmospheric Radiation Monitoring	Cloud radiation measurements	DOE	Radiometers, meteorology package

(ARM)			
Pathfinder	Vegetation imagery	ERAST	ARTIS, DASI
OshKosh / Proteus	Real-time demo	HSI	Multispectral Camera
GDIN demo	Forest Fire observations	ERAST	Pointer videocam
ARGOS (Navajo flight to Hawaii)	Sea surface temperature	ERAST	PRT-5 Radiometer
TDRSS/Raptor D2	Demonstrate OTH, measure temperatures	ERAST	InSb camera (Thermal IR)
Hawkeye ER2	Demonstrate Starlink	Code Y	Thematic Mapper Simulator (TMS)

PROCESS OF SELECTING DEMONSTRATION MISSIONS

The goal of UAV disaster management demonstrations is to show the feasibility not only of the technological components, but the integration of the UAV system and interface with likely users. A general process for selecting missions is described below. The first demo, to be carried out in 2000, is also described briefly below. Details of the 2000 mission, prepared by Steve Dunagan of NASA-Ames, are appended to this white paper.

General selection process

A number of attributes of the desired disaster management mission and the available technology must be considered when preparing for a demonstration. The key element is to define an exercise that can succeed, both technologically, and in serving the needs of the user community.

Some items to consider:

- user priorities and requirements
- matching missions: payloads (sensor performance, weight, data rate) and platforms (altitude, endurance, payload capability, climb rate, availability, etc.)
- communications: OTH data links, etc.
- data processing and distribution capabilities
- schedule;
- budget;

Plan for first (2000) demonstration

Having created a matrix of possible missions, the items listed above as selection criteria were considered. Primarily on the basis of limited time and budget, and previous experience with the fire management community, it was decided to proceed with the following disaster management demonstration:

- wildfire management
- summer 2000
- California-based (most likely location is San Gabriel mountains)
- AIRDAS payload, redesigned to minimize weight and for remote operation; possible camera
- Platform: Altus

- OTH communications: likely Inmarsat

DEMONSTRATION MISSION MANAGEMENT

This section describes the process under which demonstrations will be carried out. The FY2000 mission is used as an example.

Overview

One goal of the ERAST sensor element, managed by NASA Ames, is to integrate UAV and sensor technology with the intention to provide an extended UAV user base and to identify new regulatory and technology needs. Limited resources require highly leveraged demonstrations. Disaster management missions have been identified as being very well suited to UAV operations and hence are highlighted.

Demo mission objective

FY2000 and 2001 UAV demonstrations will utilize existing platforms, sensors, and analysis tools to provide relevant near-real-time disaster imagery products to personnel in the field. Multiple missions are envisioned. If appropriate, a quick-response capability will be demonstrated.

Demo mission approach

Altus will be equipped with the AIRDAS system (utilized by fire researchers) and standard communications connections for data download. Imagery combined with various other parameter relevant to the demo mission, such as GIS products, will be provided to disaster professionals. Opportunities will be explored to support real disasters.

Resources and Personnel

Project manager – Steve Wegener
UAV Flight Operations – General Atomics Aeronautical Systems
Payload development and integration – Steve Dunagan
Real-time data products, communications, internet – Don Sullivan
Fire disaster incident response simulation – U.S. Forest Service

Demo mission schedule

The schedule for the 2000 mission is shown in Figure 2 below.

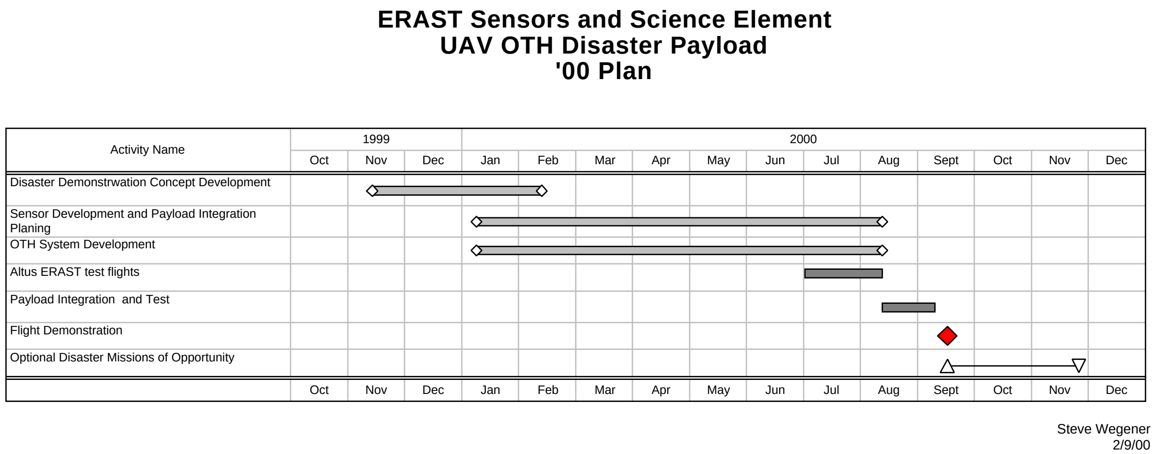

Figure 2 FY 2000 Disaster Mission Plan

Demo mission budget (follows final section)

LONG-TERM PLANS

The long term plans for UAV disaster mission demonstration include:

- a preliminary schedule for the next three years,
- a vision for demonstrating diverse types of disaster missions,
- a plan to work with agencies who might take on such operations in the future,
- background analysis required to define and understand the most viable missions, including both technology performance and economic considerations.

The schedule is shown in Figure 3 below.

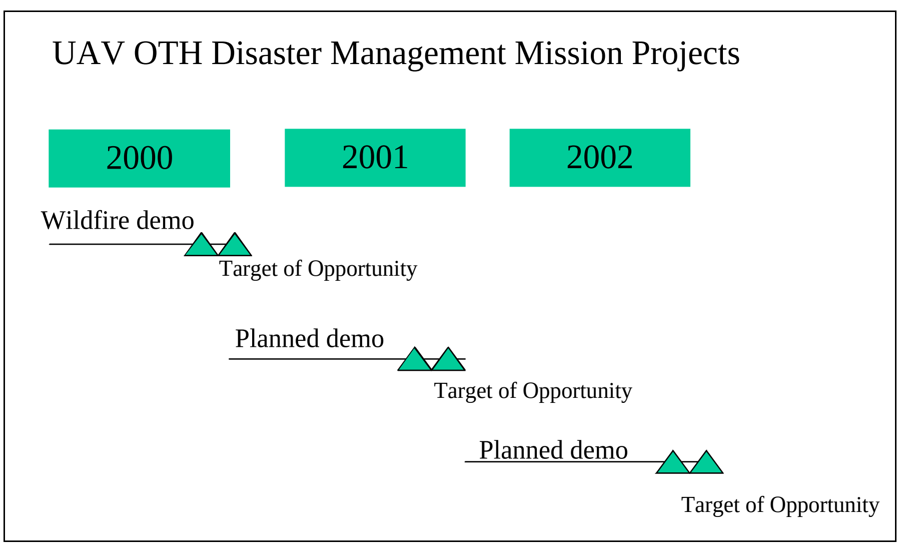

Figure 3 Long-Term Schedule

Plans for 2001 and 2002 include upgrades to sensor telemetry and real-time analysis capabilities. Disaster response opportunities will be pursued with the U.S. Forest Service, FEMA, NOAA, California Resources Agency, California Office of Emergency Services, CalSip and the insurance industry.

Along with future disaster missions, improved technology and system operation are anticipated. Some identified future technology and system development needs are listed in Table 6 below.

Table 6 Summary of identified future technology / system development needs

User Interface: addresses user data/information requirements – what, when, where, in what format
Technology
- advanced instrumentation for remote sensing - generally smaller, lower power requirements - remote operation - smart sensors - autonomous reasoning - artificial intelligence - onboard processing - telemetry to move date to the ground - support emergency communications
Product Generation
- quick look images - GIS context / data overlay - asset tracking
Monitoring
- control architecture - mop-up/damage assessment
Environmental impact
- assessment - recovery

FY2000 ERAST Disaster Management Demonstration:
Fire Management Mission

System Requirements Document: Rev B 12-2-99

I Disaster Mitigation Demonstration Objectives:

A. Demonstrate real time over the horizon (OTH) uncrewed aerodynamic vehicle (UAV) disaster assessment mission capability
C. Demonstrate a mission package that is realistic (in terms of cost and technical complexity) to the specific disaster management community (customer). This must be balanced by the need to deliver data that is of adequate quality to meet the mission requirement.
D. Include total mission from data acquisition through delivery of the data product. (RPA flight costs not included, RPA modification costs must be included)
E. The demonstration budget is $200K.
F. The schedule is for a flight demonstration during the summer of 2000.
B. Highlight unique mission capabilities of UAV's
G. Design sensor system to be compatible with both manned and unmanned platforms

II Fire Management Mission Objectives:

A Develop strategic (rather than tactical) mission
- A.1 Stay out of tactical airspace [below 7 km (10,000 ft)] to avoid interference with air tankers.
- A.2 Provide synoptic view of fire, fuel, structures at risk, and smoke plume.
- A.3 Track and display local meteorological station data , and locations of fire fighting assets

B Remote sensing measurements
- B.1 Image location of active fire front at full range of temperatures.
- B.2 Image background in immediate region of fire to identify structures, roads, water resources, fuels, and the extent of the smoke plume.
- B.3 Provide useful data both during the day and at night.

C Tracking and communications:
- C.1 Automatically monitor and downlink locations of fire-fighting assets.
- C.2 Automatically monitor and downlink local ground station meteorological data
- C.3 Relay local voice communications

D Mission parameters
- D.1 Be on station in time to provide crucial data
- D.2 Generate and provide internet access to GIS data products as separate layers ready to insert into customer's GIS.
- D.3 Deliver products within an effective time frame

III System Requirements:

1 Measurement Requirements:

1.1 (Objective B.1,2) The sensor package shall measure emitted thermal radiation in the 1.5-1.7, 2.2-2.5, 3-5, and 8-14 micron wavelength bands, with at least 10 meter spatial resolution and a swath of at least 8 km. This imagery shall be geo-registered to within 10-20 meters.

1.2 (Objective B.2) The sensor package shall measure reflected solar radiation in the 0.4 to 0.9 micron wavelength band, with at least 10-20 meter spatial resolution and a swath of at least 8 km.
1.3 (Objective A.2) The sensor system shall be designed to assess a fire having a spatial area of 16 km by 16 km.
1.4 (Objective C.1,2) The sensor system shall be capable of receiving up to 20 telemetry uplinks providing GPS position information or local ground station meteorological data. This information shall update once every 3 minutes. This information shall be incorporated into a GIS layer data product.
1.6 (Objective D.1) The aircraft shall be on station ready to acquire data within 4 hours of notification.
1.7 (Objective D.3) GIS registered imagery and tracking information shall be available to the user within 1 hour of acquisition.

2 Operational Requirements
2.1 The sensor system shall be remotely controllable over a continuous telemetry (OTH??) link providing least 4800 baud data rate.
2.1.1 Instructions for data acquisition, data processing, and data transfer shall be supported.
2.1.2 The system shall have means to verify proper sensor operation and flightline orientation prior to data acquisition.
2.1.3 Moderate communications dropout (5% of packets) is tolerable (to be managed with packet checking communications protocols).
2.2 The sensor system shall monitor operation of critical components and provide feedback to the ground operator via telemetry link on command, with 1 minute update rates.
2.3 The sensor system shall be capable of storing the entire fire scene image for each band between telemetry data downlink sessions.
2.4 Data downlink shall be accomplished using an OTH link operating at 64000 baud or faster.
2.4.1 The sensor system shall have means to process and transmit a compressed image of the fire scene, containing adequate information to assemble a synoptic view with all data properly indexed in space and time.
2.4.2 The aircraft heading may be aligned to the relay satellite during data downlink telemetry sessions.
2.4.3 Moderate dropout (5% of packets) of this connection is tolerable.

3 Interface Requirements:
3.1 The sensor system shall weigh no more than 180 kg (400 lbs)
3.2 The sensor system power requirements shall not exceed 60 amps at @ 28VDC.
3.3 The sensor system volume shall not exceed 58" long x 26" high x 27" wide instrument envelope of the aircraft.
3.4 The sensor system telemetry interface shall be independent of the line-of-sight telemetry link used for aircraft operation.
3.5 The sensor system shall mount to the aircraft by means of the bolt pattern identified in Figure 3 of Appendix B of the Altus Aerial Vehicle Payload Integration Manual.
3.6 The electrical power connector shall conform to the pin-out defined in ICD TBD.

4 Airworthiness Requirements

4.1 The sensor system shall not generate EMI which interferes with UAV telemetry or electronic systems operation.
4.2 The sensor system shall operate in extreme pressure and thermal environment of the aircraft and mission altitude profile.
4.3 The sensor system design shall conform to mechanical and electrical design standard of aircraft manufacturer.
4.4 Modifications to the aircraft required to support this mission shall conform to the requirements of the aircraft operator airworthiness review board and shall be subject to their review and approval.

IV AIRDAS Flight Operator Mode Requirements

1 One meter spatial resolution at 150 kts ground speed.
2 Sensor package to include:
2.1 Instrument head
2.1.1 Operates at external ambient conditions
2.1.2 Optical instrument includes scan optics, scan motor and controller, optical filters, detectors, pre-amps, digitizers.
2.1.3 Ancillary equipment includes 2 blackbodies and temperature controllers, gyroscope, pressure altimeter, power supplies, electronic filters
2.1.4 Cable to chassis up to 40?? ft in length
2.2 Data acquisition computer chassis
2.2.1 Operates at cabin pressure and temperature.
2.2.2 Data acquisition computer includes CPU, EPROM boot partition with op sys, PCI bus, digital I/O board, SCSI controller, Serial I/O board, SCSI removable hard disks
2.2.3 Autonomous systems health datalogger with 8 temp, pressure, or voltage inputs.
2.2.4 Hard disks may require pressurized housings for reliable operation above 10K ft.
2.3 Ancillary equipment includes:
2.3.1 28V to 400 Hz inverter and synchro to digital resolver (for gyro),
2.3.2 Frequency multiplier to convert motor encoder to digitizer trigger
2.3 Operator interface screen (at least 640 x 800), keyboard, and pointing device
3 Installation to be compatible with the following aircraft:
3.1 USDA Forest Service Piper Navajo, 120-200 Kts airspeed, altitude to 15000 ft.
3.2 NASA/Brazilian LearJet, 250-380 Kts airspeed, altitude to 40000 ft

V Software requirements

1 Operating system features
1.1 Load and boot from EPROM (8?? Mbytes or less)
1.2 Recover from random power loss in any state.
1.3 Watchdog features to detect hung processes or I/O
1.4 Multi-tasking with task prioritization
1.5 Remote session login for RPA operation

2 Set operational parameters
2.1 Adjust Scan rate
2.1.1 Read altitude and airspeed and set mirror scan rate to achieve desired sampling along track.
2.1.2 Adjust digitizers to maintain 720 across track samples per scan.
2.1.3 Verify that light levels are properly matched to scan rate
2.2 Set blackbody temperature according to values in initialization file, adjust as required.
2.3 Enter flight sequence designation

3 Ingest data stream:
3.1 Switch and read detector A/D converters
3.1.1 Detector 1/2 digitizer:
- 1 TTL trigger waveform in
- 1 channel select line in
- 16 digital lines out

3.1.2 Detector 3/4 digitizer:
- 1 TTL trigger waveform in
- 1 channel select line in
- 16 digital lines out

3.1.3 Verify light levels are within the linear range of detectors
3.2 Read GPS data stream (time, date, x, y, z, ground speed) at 1 Hz (RS232)
3.3 Read gyroscope pitch and roll from synchro to digital resolver for each scan line
3.4 Read pressure altimeter at 1 Hz
3.5 Read magnetic compass at 1 Hz
3.6 Read black body temperatures at 0.1 Hz

4 Store data
4.1 Assemble data into 32 kByte blocks
4.2 Write data to hard disk

5 Monitor system health
5.1 Stand alone data logger computer to boot up and monitor up to 8 temperatures, pressures, or voltages (0-5V) at 1Hz update rate.
5.2 Datalogger may be polled periodically from main data acquisition computer to display systems health data.
5.3 Comparator program may run in background to evaluate temperatures and pressures against operating limits and send warning message to operator.

6 Remote operator mode control functions

6.1 Maintain un-interrupted command and control satellite communications over 4.8 kbaud communications link.

6.2 Initiate remote session on flight data acquisition system from ground control station computer with PPP packet handling.

6.3 Monitor instrument systems and operation

6.3 Adjust elevation of antenna (in conjunction with aircraft bearing) to enable reliable 64 kbaud INMARSAT communications for data downlink.

6.4 Establish 64 kbaud satellite communications for downlink session.

6.5 Compress each channel of image data with JPEG compression to reduce data volume by at least 50%

6.4 Terminate satellite communications to end each downlink session.

7 Flight Operator Mode quick-look data evaluation

7.1 Real time data display to verify target acquisition, signal strength.

7.1.1 Select one of the 4 detector channels and write to 800 pixel screen within 1 second of acquisition.

7.1.2 Normalize data for brightness and contrast (integrated histogram linearization) and map to 6-bit output for display.

7.1.3 Identify pixels with values above the upper limit and mark as red in real time output.

7.1.4 Incorporate roll correction into real-time image.

7.1.5 Display/record flight log data including:

- mission number
- optical filter configuration
- run and line numbers
- flight line start and stop time and numbers
- operator comments

7.2 Transfer data to downlink device via serial connection.

Schedule