Use of Unmanned Aircraft Systems for the National Weather Service

2012 Unmanned Aircraft Systems Workshop
OFCM
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In Affiliation with
NOAA/OAR?ESRL and Northrup Grumman

Use of UAS within NOAA

Monitoring of tropical storms

Monitoring of fires and analysis of PBL

Use of UAS for Tropical Storms

Scientists from NASA, NOAA and private sector & academia have been examining UAS for use in typhoons and hurricanes for over a decade

Will note low-level smaller UAS first…larger UAS to be discussed later (i.e., Hurricane and Severe Storm Sentinel or HS3)

Using the Aerosonde UAV During the the 2005 Atlantic Hurricane Season

Principal Investigator: Joseph J. Cione

NOAA's Hurricane Research Division

Co-collaborators: Jason Dunion (CIMAS/HRD); Eric Uhlhorn (CIMAS/HRD); Greg Holland(NCAR/MMM); Brenda Mulac (Aerosonde Corporation); Chris Sisco (NWS/NHC)

IHC 2005

March 10, 2005

Project Goal:

Successfully fly an Aerosonde UAV into a Tropical Cyclone during the 2005 N. Atlantic hurricane season

(low level boundary layer flight(s))

Funding:

Joint NOAA/OAR, NASA, Aerosonde Corporation effort…

Resources Available:

75h Aerosonde flight for the upcoming 2005 season…

(Originally slotted for 2004…carried over to 2005)

Other Key Participants:

NHC, CARCAH

Standard Dimensions and Ranges of Operation for the Aerosonde

The following are the specifications for the Aerosonde platform:

WINGSPAN:	2.9m
ENGINE:	24cc fuel injected
FLIGHT SPEED RANGE:	15m s - 60m s
MAX RANGE:	2500 km (less for high speed, low altitude missions)
MAX DURATION:	25 hr (less for high speed, low altitude missions)
MAX PAYLOAD:	2kg (w/full fuel complimen t)
AVAIL AUX POWER:	20-30 Watt sustained
ALTITUDE RANGE:	100m-5000 m (Š50m possible in certain cases)
COMMUNICATION:	radio com (line of site) and satom (Iridium)
MINIMUM DATA RATE	9.6 kbps
MAX WINDS (so far):	100kts+. (squall line convection)
LAUNCH /RECOVERY:	car/roof-rack system (55mph launch speed needed)
OPERATION LOCATION:	can monitor/modify flight track anywhere (see range map) (need: PC with Aerosonde's software and internet access)

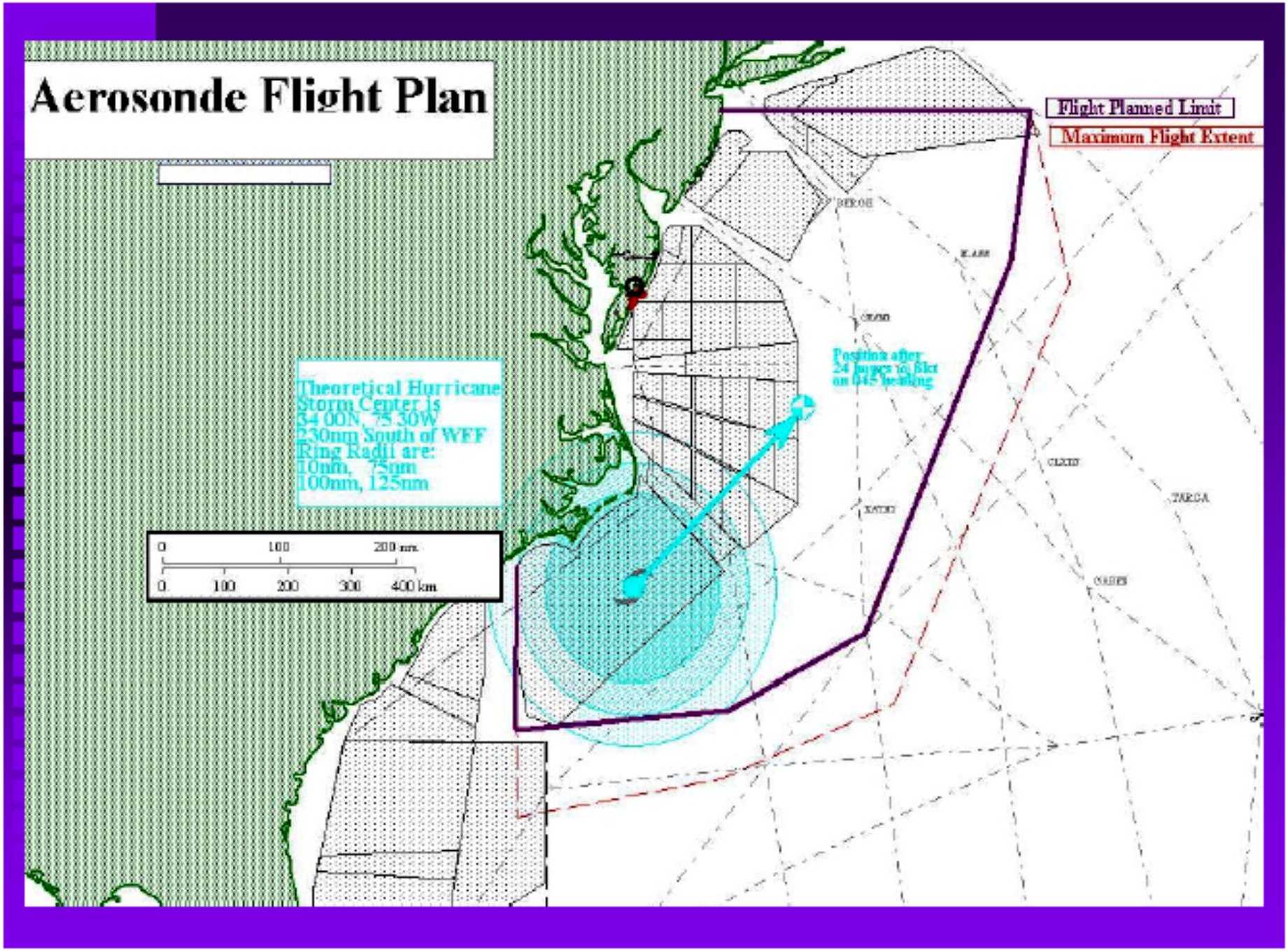
<u>Specific Aerosonde Instrumentation Requested for use in this study:</u>

STANDARD MET PACKAGE:

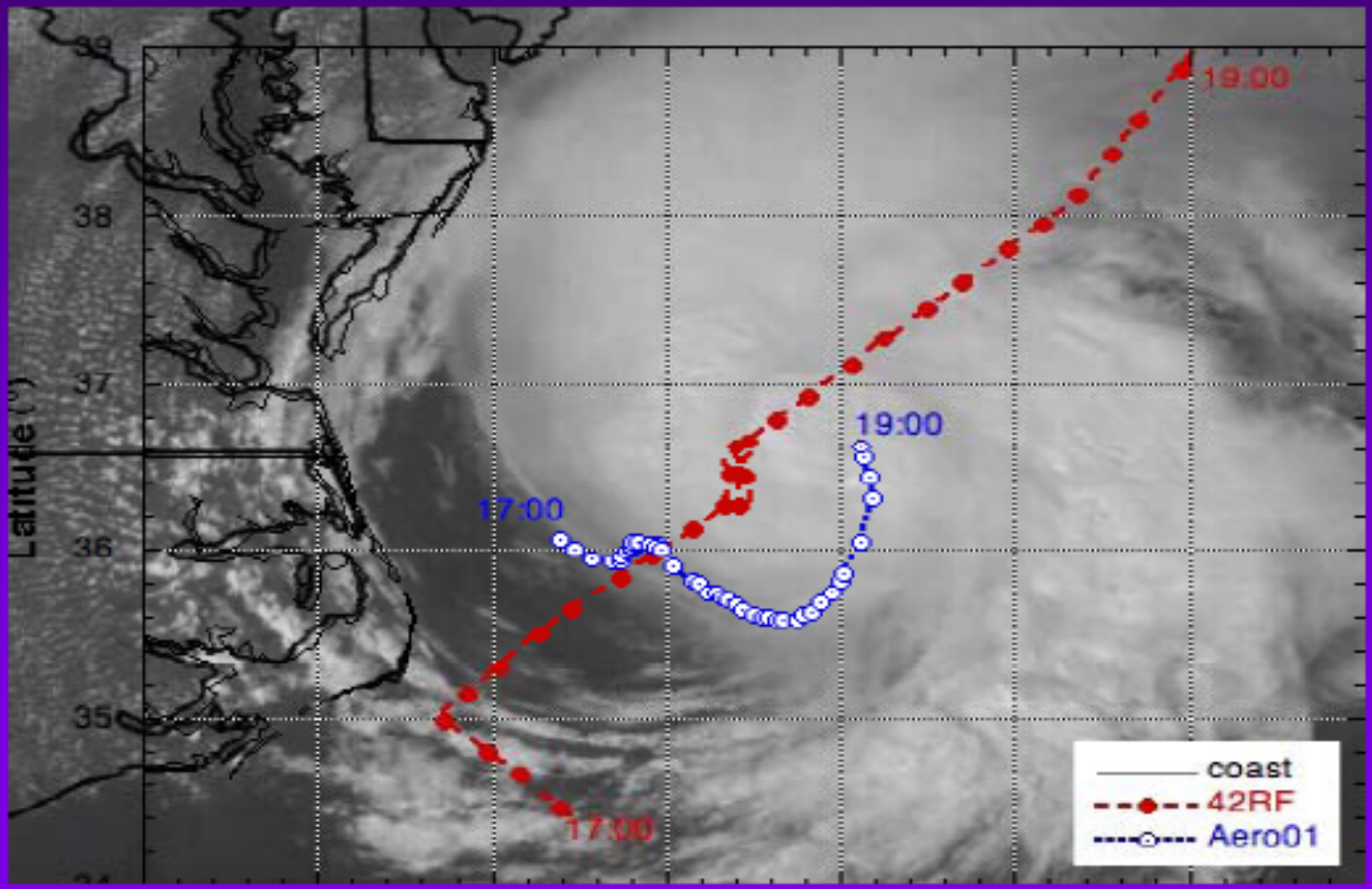
Pressure, Temperature, Relative Humidity and Winds (Viasala w/1 backup; Errors: 1hPa; 0.1 C; 2-5%RH; 1 m s^{-1})

OTHER REQUIRED SENSORS:

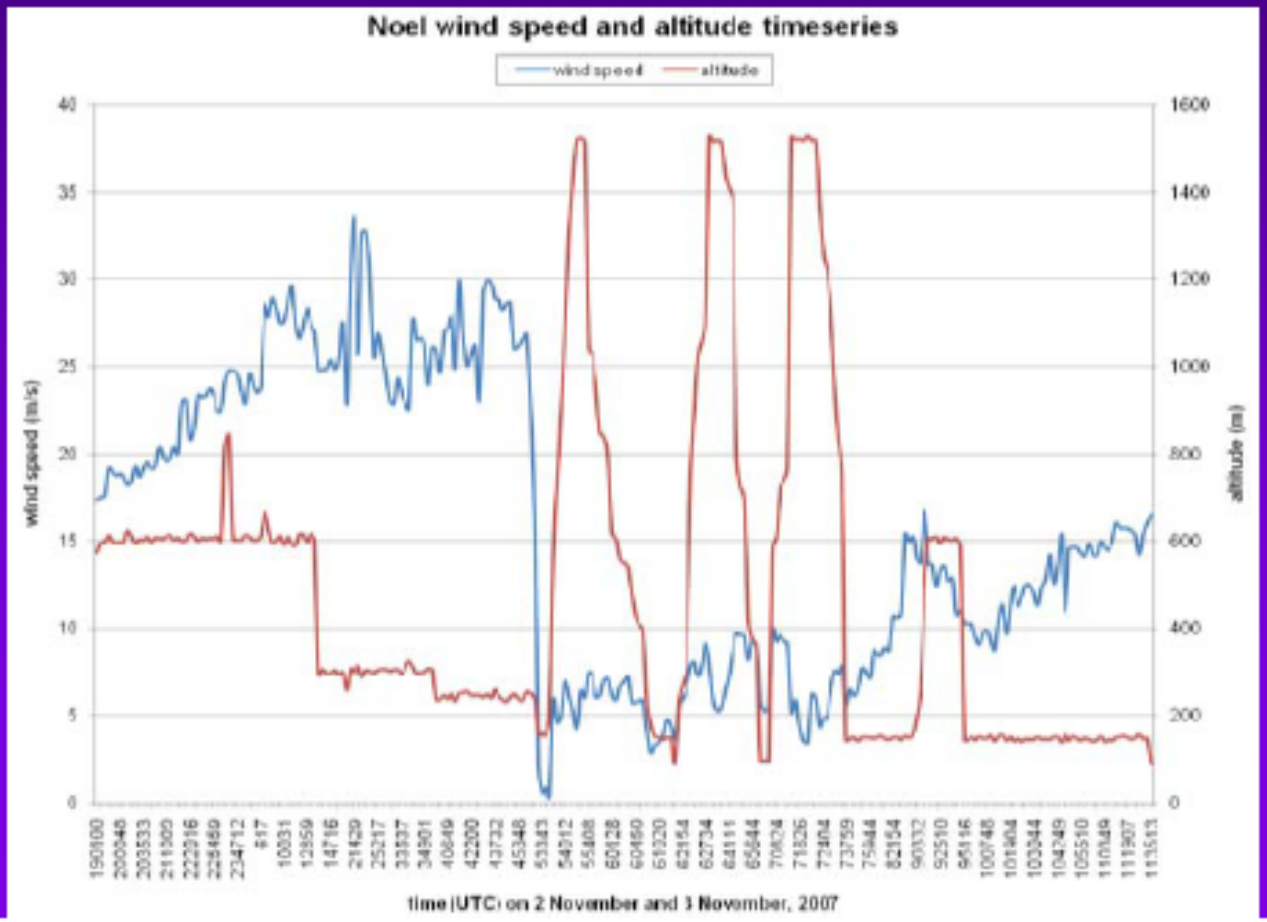
IR sensor (for surface T/SST); PMS (down to 10 microns);
Visible still imagery *POSSIBLE? ===> Mini PMS?*


Aerosonde Flight Plan
Flight Planned Limit
Maximum Flight Extent
Theoretical Hurricane
Storm Center is
34.00N, 75.30W
230nm South of WFF
Ring Radii are:
50nm, 75nm
100nm, 125nm
0 100 200 nm
0 100 200 300 400 km

P-3 (red) & Aerosonde (blue) tracks in Tropical Storm Ophelia, Sept 16, 2005



Aerosonde altitude & wind speed, showing transition into low winds of eye, Nov. 2, 2007, Hurricane Noel



Lessons Learned:

- UAS data continuous, better than dropsondes
- FAA CoA process >12 months, still requires instrument flight rules
- Important to streamline in-flight comms coordination among stakeholders
- Close coordination w USN, AF needed to deconflict their airspace use (including covert)
- Land-based launches reduce endurance on scene
- Nov.06- 1st ever lo-altitude CoA for UAS; useful to extend CoA NY Oceanic airspace N. of 18oN
- Barbados contacts in place, good for future use

Use of UAS for Wildland Fires

Scientists from NOAA and private sector & academia have been examining UAS for use in supporting firefighters for over a decade

There has been an examination of both monitoring fires as well as collecting data for model assimilation

Strategic and tactical examination

Major Motivations

Uncontained wildfires result in property losses averaging $1.2 B per year.

Of particular concern is the spread of wildfires into wildland-urban interface (WUI) areas

The weather plays a major, and often dominate, role in determining the magnitude of this kind of loss.

NOAA needs to take advantage of resources to monitor fires from above

Jesusita Fire, Santa Barbara, CA, May 7, 2009

The Unmet Need

Incident support forecasters require highly detailed and tailored forecasts for placement into incident action plans. Improved high resolution weather and fire behavior modeling. Adding in-situ observations above and near the incident area would provide greatly improved situational awareness and support improved high-resolution model forecasts of local winds, relative humidity and other sensible weather elements critical for fire suppression planning and tactical decision making.

These improved services are critical to executing NOAA's primary goal – protection of life and property.

Meeting the Need

Modeling and Sensing in The Fire Environment

Overview of Existing Fire Sensing and Modeling Technologies

Small UAV Capabilities/Opportunities
Barriers/Challenges

Looking at large UAS as well

Role of Modeling and Sensing

- Fire Science
  - Fire Behavior
  - Fire Effects
- Technology
  - Predictive Computational Models
  - Sensing
    - Quantify Fuel State, Active Fire Location and Intensity, Topography, Weather, Fire Effects, Recovery
    - Data for Model Validation
    - Initial/Boundary/Update Data for Prediction
    - Situation Awareness for Incident Management

Scales of Observations and Models

Fire Weather

900 km fire Domain
~8 km Model grid cell)

Coupled Models

20 km fire domain
100 m Model grid cell

Fire Behavior

10 m fire domain
~1 m (grid cell)

Current Gaps

regional

fire/landscape scale

residence

basic fire spread/fuels components

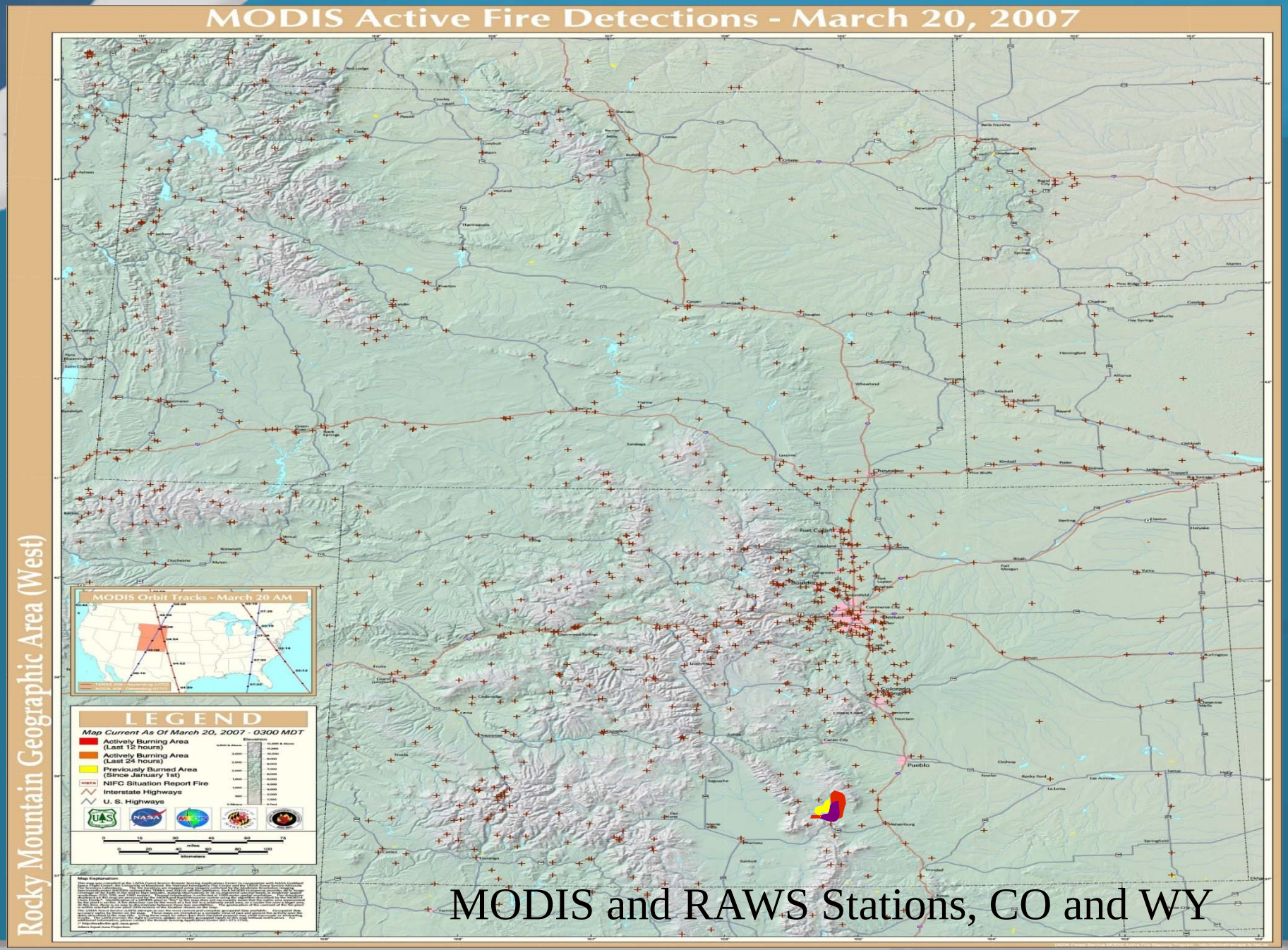
Observations Needed At the Fire Scale

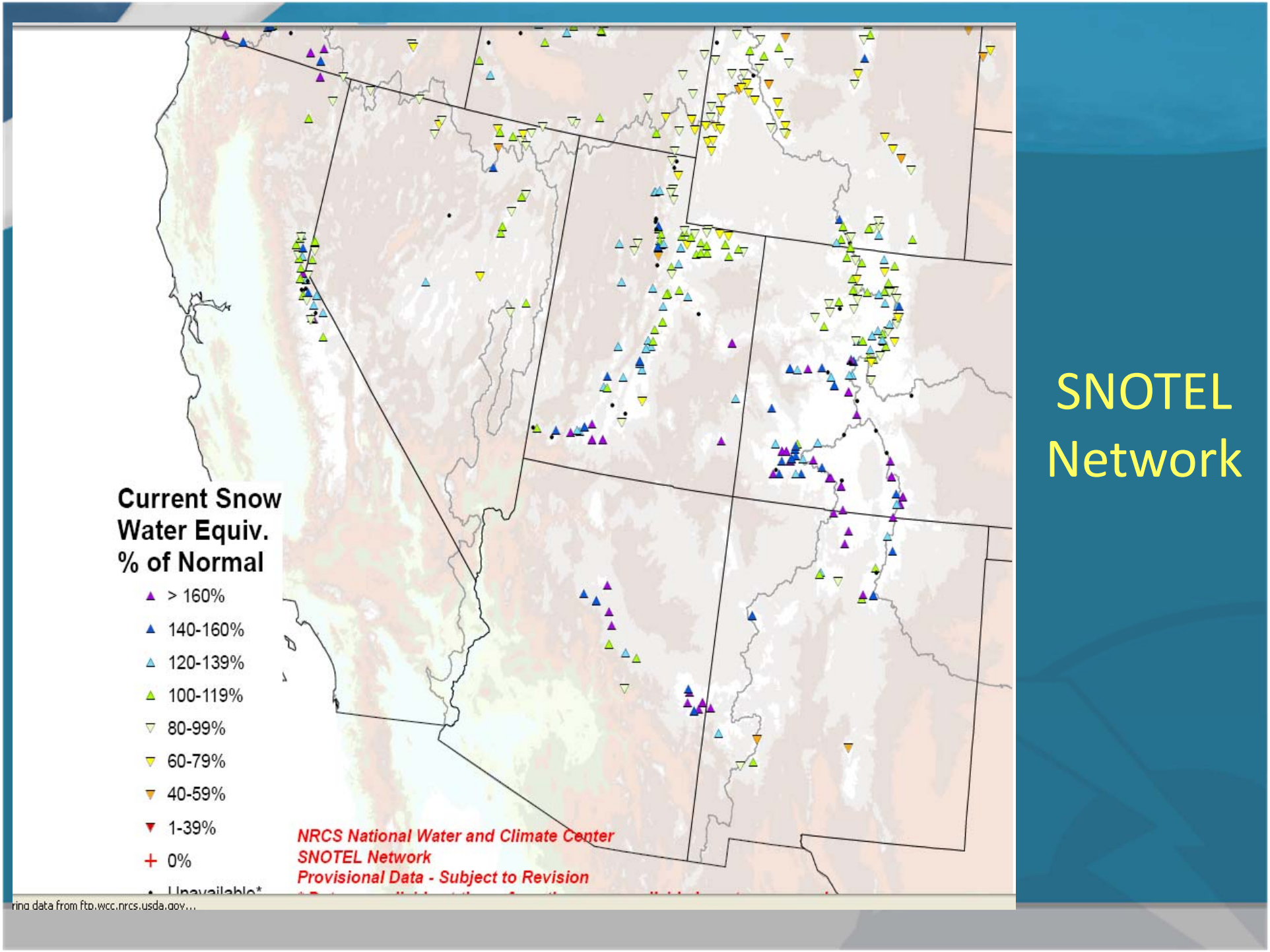
-Meteorological and optical data are lacking in and near wildland fires

-Lack of data, data assimilation, and forecasts result in poor diagnosis of fire environment

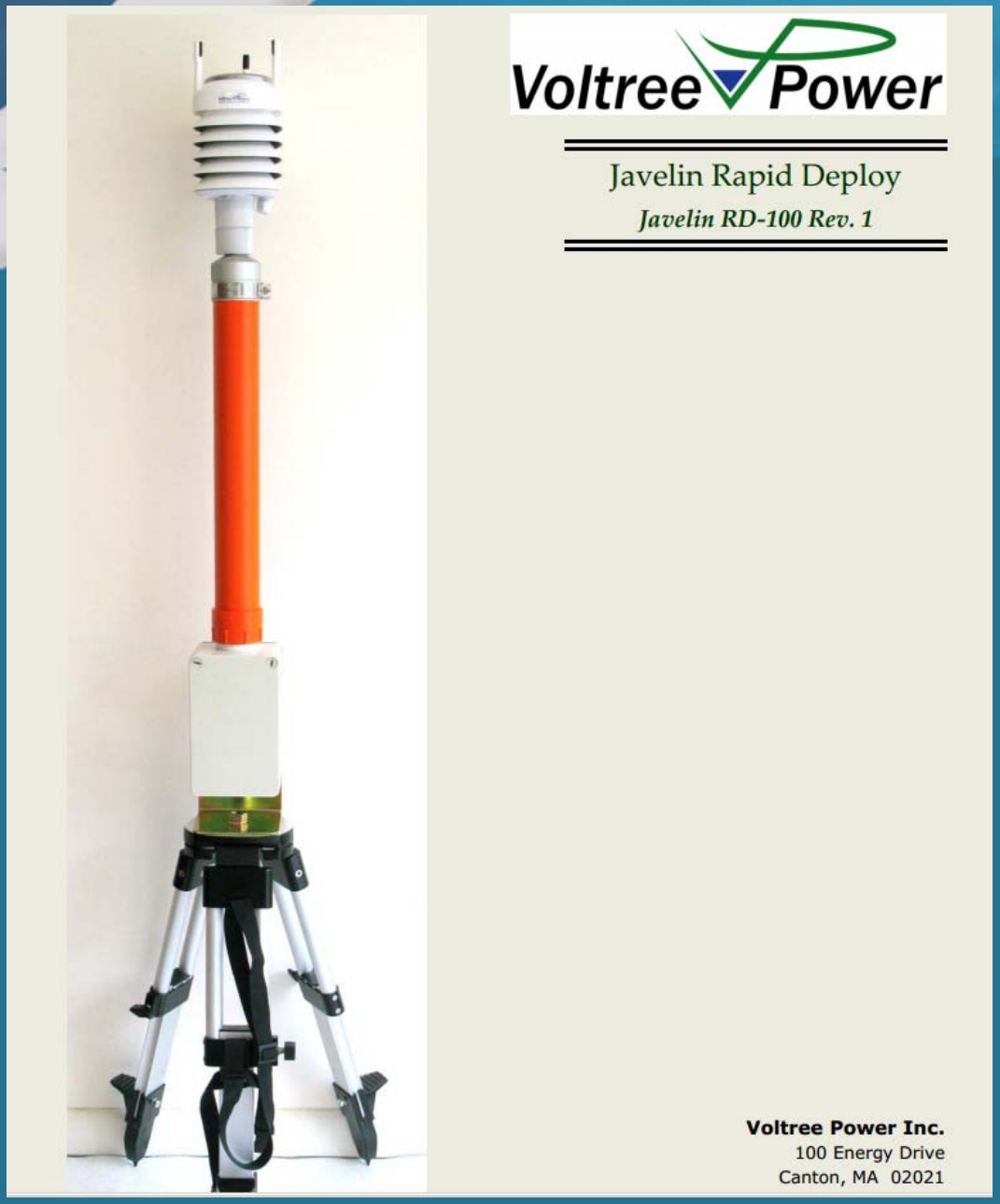
-Deficiencies in defining the environment reduce the effectiveness of fire behavior models

- Unrepresentative fire behavior modeling results in poor assessment of fuels effects on fire evolution


MODIS Active Fire Detections - March 20, 2007
Rocky Mountain Geographic Area (West)
MODIS Orbit Tracks - March 20 AM
LEGEND
Map Current As Of March 20, 2007 - 0300 MDT
Actively Burning Area (Last 12 hours)
Actively Burning Area (Last 24 hours)
Previously Burned Area (Since January 1st)
NIFC Situation Report Fire
Interstate Highways
U. S. Highways
Elevation
Pueblo
MODIS and RAWS Stations, CO and WY



SNOTEL Network



Javelin Rapid Deploy Surface System

- New observation tool
- Can deploy and network
- Uses LUFTT and Vaisala sensors
- Interfaces with RAWS
- Measures winds, rainfall (incl. duration & intensity), barometric pressure, air temp, RH

Interesting story with this one…

Current In-Situ Fire Scale Observations

ATMU

- **Atmospheric Theodolite Meteorological Unit**
- Composed of a theodolite, tripod, weather balloons and miscellaneous tools

Existing Active Fire Sensing Technologies

Aerostats (Balloons/Kites)

- Used for surveillance, atmospheric sensing
- Fixed location
- Large payload

Balloons and Dropsondes

- Pibals used by IMETs
- Sondes used regularly in weather sensing
- Could carry imaging sensors
- Could carry AFD ground sensors
- Non-controllable, non-recoverable

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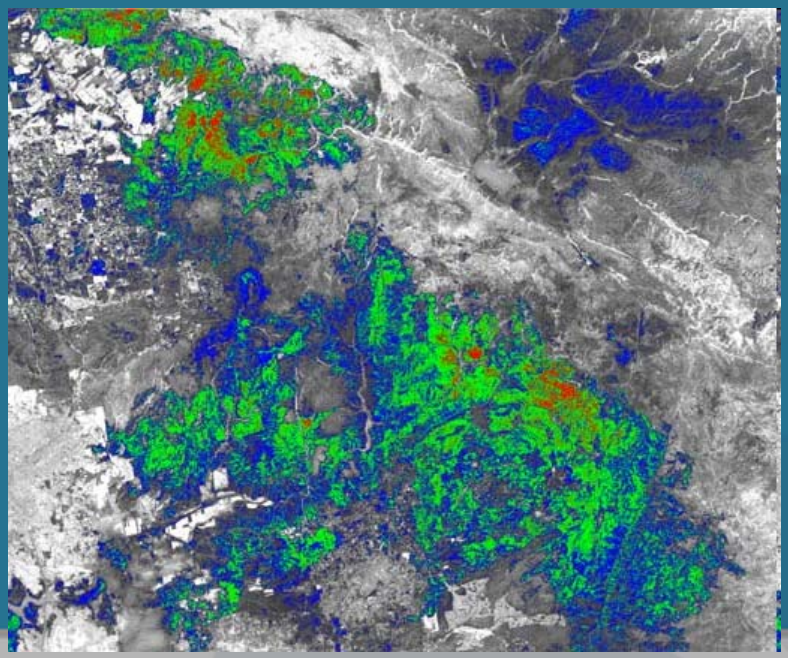
Aerospace Engineering Sciences
University of Colorado

Existing Active Fire Sensing Technologies

- MODIS (Terra/Aqua)
  - Visible to TIR in 36 bands
  - 250m to 1000m resolution
  - 2x daily coverage of mid and high latitudes, each spacecraft.
- ASTER (Terra)
  - Visible to TIR in 15 bands
  - 15m-90m ground resolution
  - 16 day repeat
- NPP VIIRS
  - Higher res than MODIS
  - IMETS/USFS evaluating
- Used in the Active Fire Mapping Program (4 and 11 μm bands), and for multi-spectral vegetation coverage mapping.



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Aerospace Engineering Sciences
University of Colorado

Existing Active Fire Sensing Technologies

Fire Spotting

- Limited visibility
- Limited coverage
- Non-quantitative

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University of Colorado

Existing Active Fire Sensing Technologies

GeoEye

- Multi-spectral (visible)
- 3 day repeat
- 0.5 m resolution

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Aerospace Engineering Sciences
University of Colorado

Existing Active Fire Sensing Summary

- Conventional aerial survey is familiar, but costly and difficult to arrange on short notice.
  - Helicopter hourly flight rates $1k - $6k, 50-400 gal./hr. fuel use
  - Airplanes sortie from distant airfields, have similar costs
- Pibals, balloonsondes, do not provide adequate spatial coverage without prohibitive numbers, and cannot be guided.
- Aerostats are not mobile, cannot follow evolution of the fire, but could be useful in protecting property on the WUI
- Spacecraft spatial and temporal capabilities are currently inadequate
  - Revisit times could be improved by additional spacecraft
  - Resolution will likely improve over time, but high spatial and spectral resolution in the IR requires a large aperture
  - Total costs are high, and lead times are long
  - End user costs are variable, but have been heavily subsidized.
- Conventional UAVs have potential for monitoring, situational awareness
  - Prohibitive acquisition and operation costs (opportunities to leverage though)

UAV Concepts for the Fire Environment

- Conventional UAV requirements
  - All weather operation → high cruise speed
  - Long duration and range → large size, IC or jet engines
  - Carry large, high-capability sensors
  - Large size/energy/cost requires assured control
    - High quality, redundant components
    - Sophisticated, fault tolerant flight computers
    - Extensive verification and test procedures
    - Costs of failure preclude autonomy (pilot still required)
  - Causes an upward cost spiral
- Alternative Approach
  - Fly with weather, not against it
  - Reduce Individual vehicle size, speed, sensor capability
  - Use many vehicles/sensors to cover large areas/periods
  - Increase autonomy to lower costs of training/operation
  - Manage costs of failure, accept attrition
  - Enable a downward cost spiral
  - Leverage from other agencies

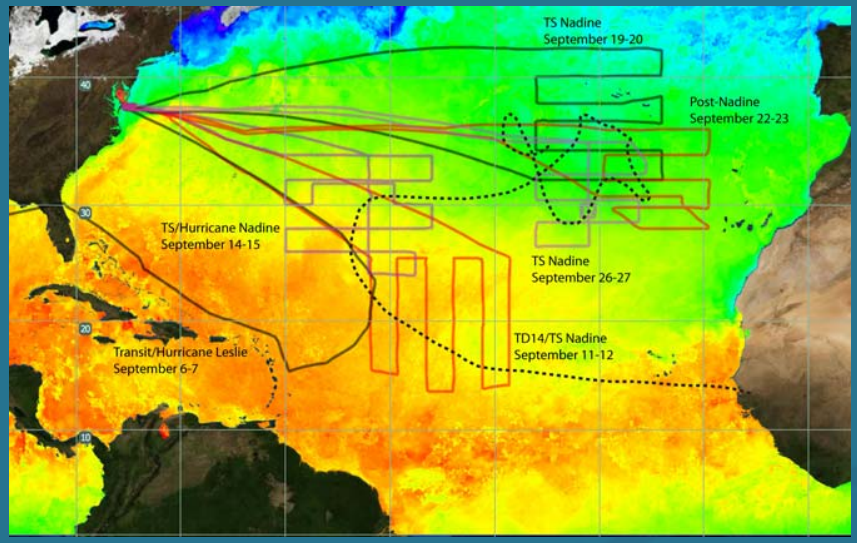
Large UAV Potential Advantages

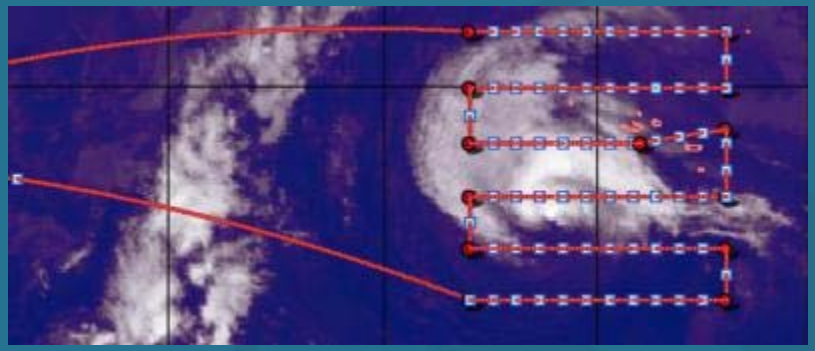
NASA has used Global Hawk for tropical systems…
Why not for monitoring of fires?

In 2007 NASA Dryden used the UAV Ikhana to monitor IR signatures of CA fires

"The success of these tests will help to refine the future direction of fire mapping for the wildfire management agencies," USFS rep

NASA Mission for Hurricane Nadine





Large UAV Potential Advantages

Properties of the GH make it uniquely suited for response for monitoring all high-impact, recurrent, randomly occurring, relatively-short-duration natural hazards. High Altitude Long Endurance (HALE) applies here!

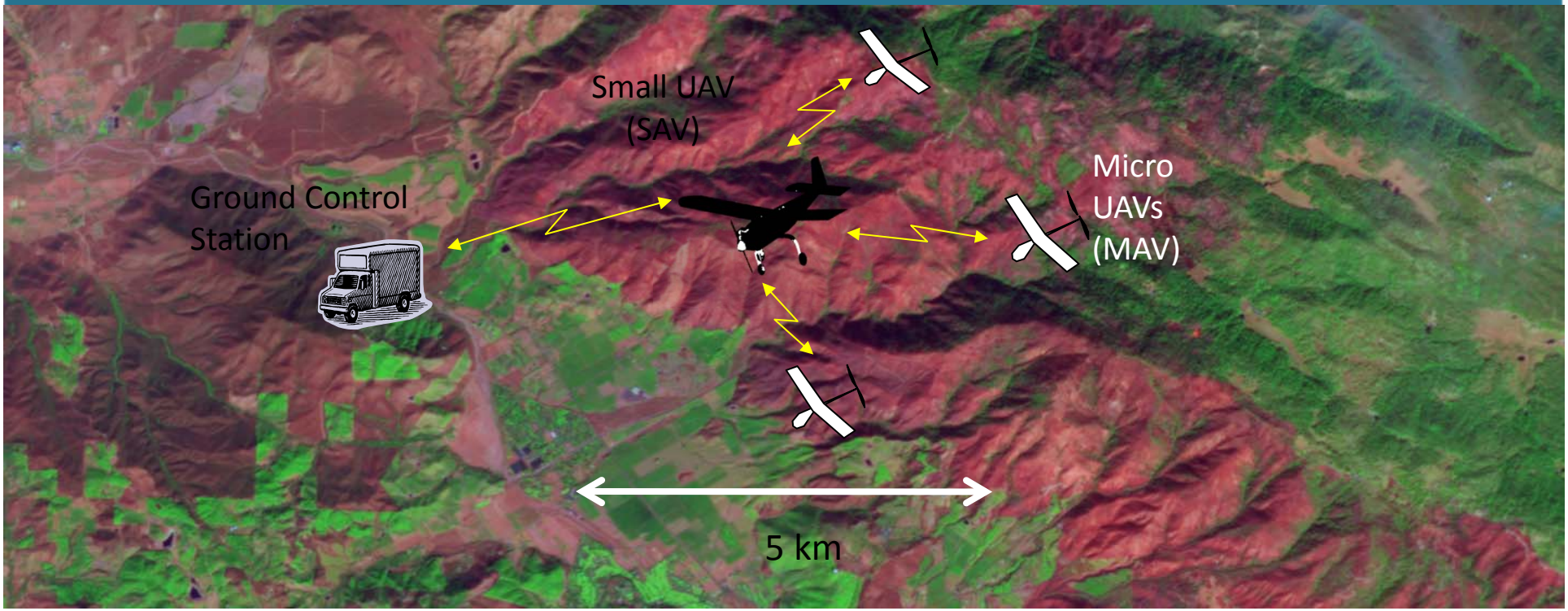
- Ability to fly quickly to the site (350 kt)
- Sustains a long mission (32 h or longer)
- Hovers well (7-km turning radius)
- Cruise well above historic and FAA-restricted definition of CONUS civil airspace
- Carries and powers a heavy payload (recent versions can carry a ton of sensors in many different bays, some pressurized and some not)
- Affords real-time readout of data, and admits in-flight reprogramming of the mission in response to surprises
- There is a large infrastructure in place for remotely piloting, repairing, and maintaining the aircraft, as well as many instrument designers who work with the GH platform explicitly in mind.

Small UAV Potential Advantages

- Small UAV aerial survey could provide an interesting alternative
  - Could provide on-demand, locally-controlled, high-resolution reconnaissance for acquiring data and incident management
  - Small vehicles have safety advantages
  - Can be launched and recovered anywhere
  - Lightweight “backpack” for ground support and transport to incident
- Low system cost requires a downward cost spiral
  - Individual vehicle capability and reliability (hence unit cost) is low
  - Attrition is part of the system cost calculation---vehicle loss is only a marginal cost
  - Multiple vehicles can provide extended spatial and temporal coverage
- New operational capabilities (research & evaluation needed)
  - Use in high winds
  - Close observation, even within smoke plumes
  - Multiple look angles
  - Organic operation by incident personnel

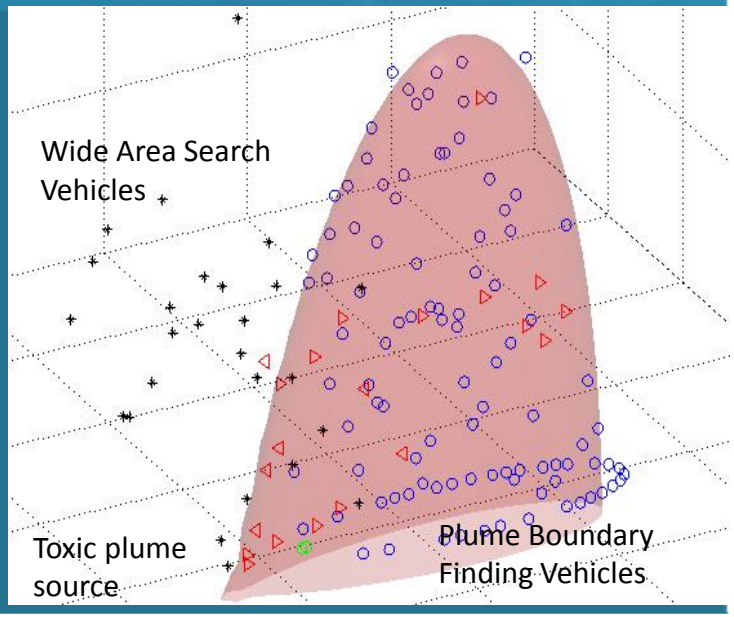
UAS Notional Scenario

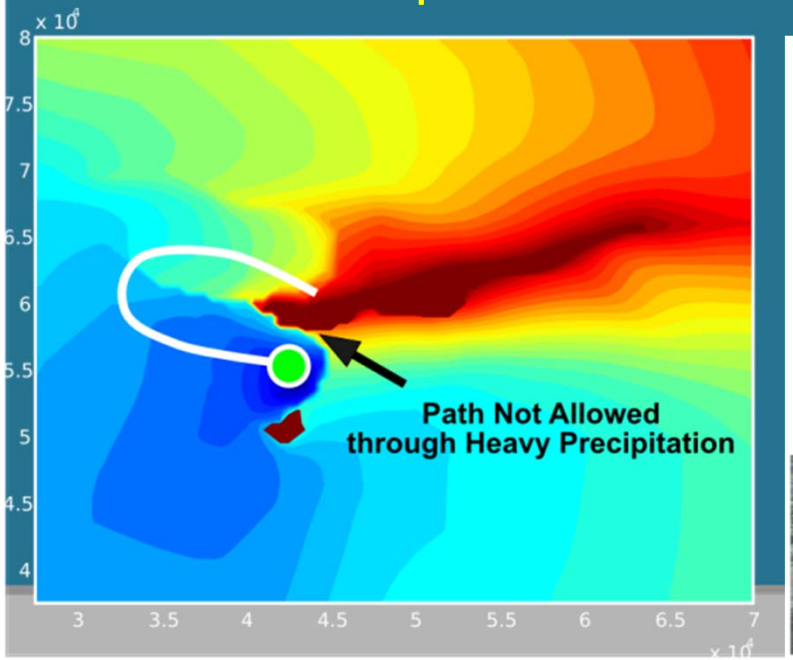
- SAV launched from ground station
- SAV carries MAVs to area of interest
- SAV relays MAV data to ground station, loitering at 1000ft. AGL (class G airspace)
- SAV provides strategic view of fire of fire at low resolution
- MAVs provide high resolution IR views of fire front for 1hr. each, < 500 ft. AGL
- MAVs return to ground station or a designated recovery zone
- SAV returns to ground station, recovered via parachute
- Vehicles are positioned by map designation: autonomous launch, flight, recovery

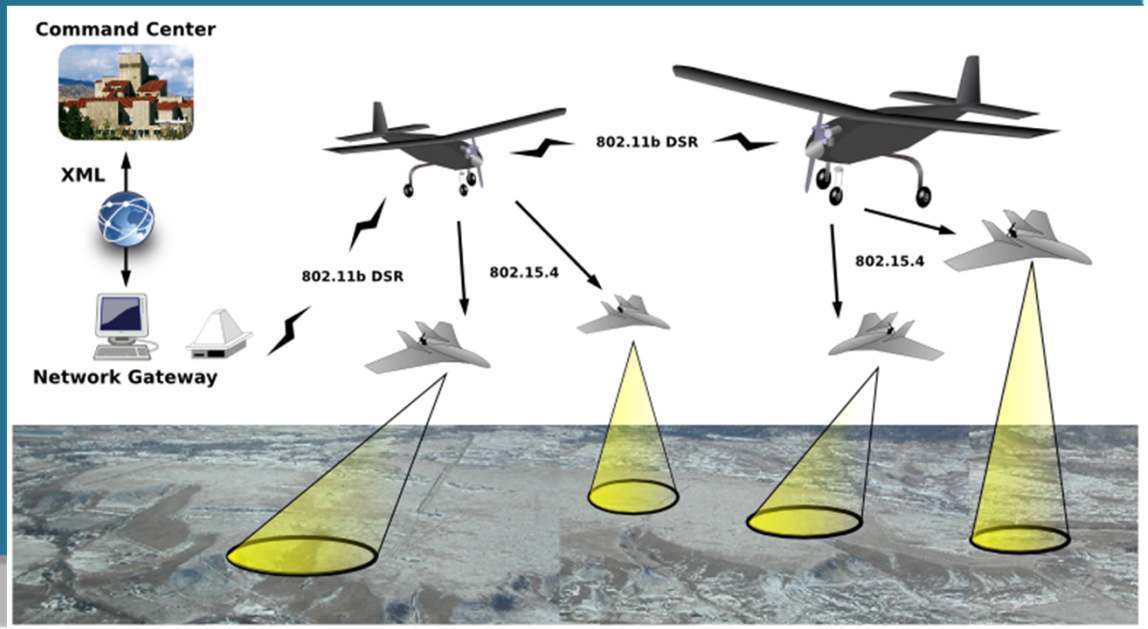


Possibilities

- Alternative Concepts of Operation
  - Flocks
  - Heterogeneous teams
  - Hierarchical automation
  - Simultaneous modeling and exploitation





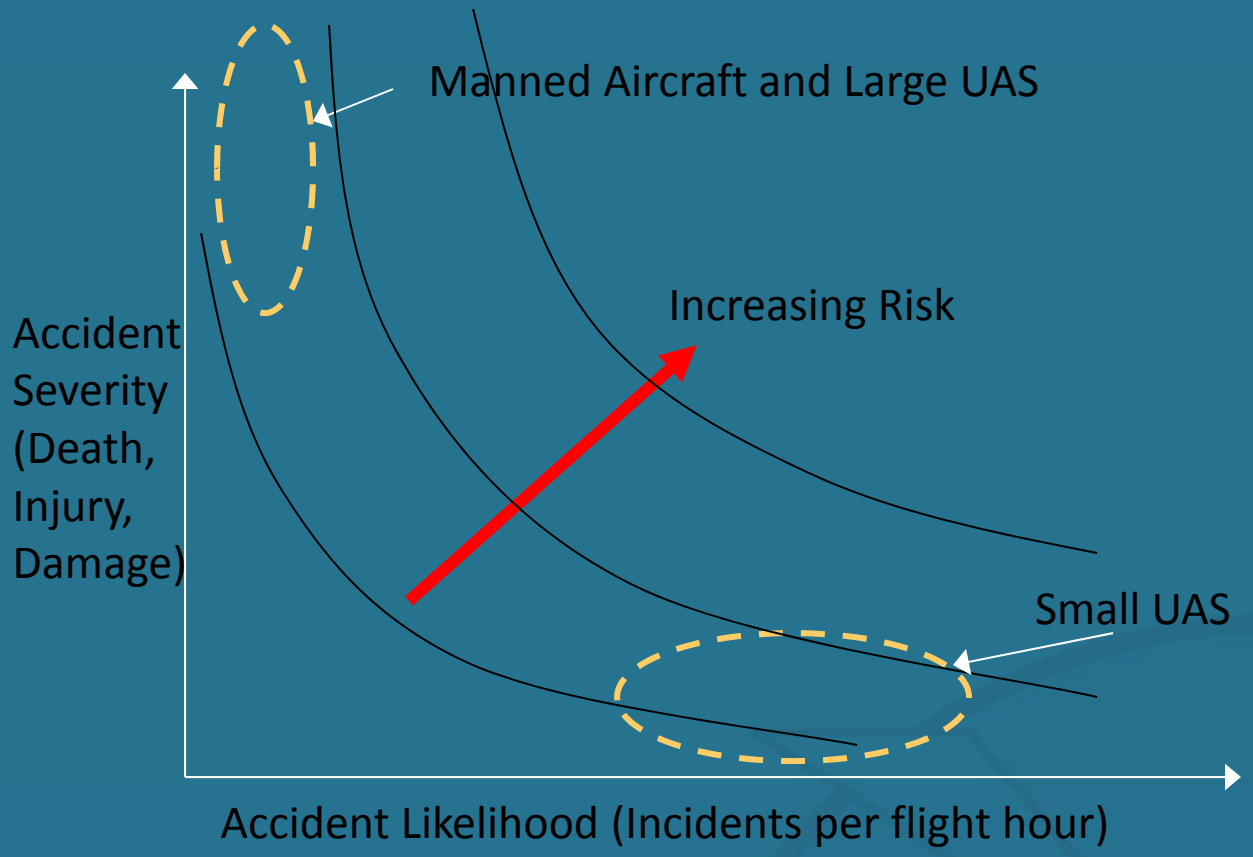


Air Traffic Issues

- Manned Aircraft
  - Controlled airspace above 700-1200 ft. AGL (Class E airspace up to 18000 ft. MSL, then Class A)
  - Uncontrolled below (Class G airspace)
  - All fires (with incident air traffic) have a Fire Traffic Area (FTA) structure
  - Large fires may have an additional Temporary Flight Restriction (TFR) perimeter
- Unmanned Aircraft
  - Public entities require a Certificate of Authorization or Waiver (COA)
  - Commercial entities require a Certificate of Airworthiness (Experimental tail number)

Key COA Issues

- De-confliction with other air traffic
  - Line of sight remote control
  - Sense and avoid capability
  - Air traffic control interoperability
- Lost link procedures
- Safe flight termination
- Personnel training
  - Emergency procedures
  - Intergroup communication
  - Defined roles

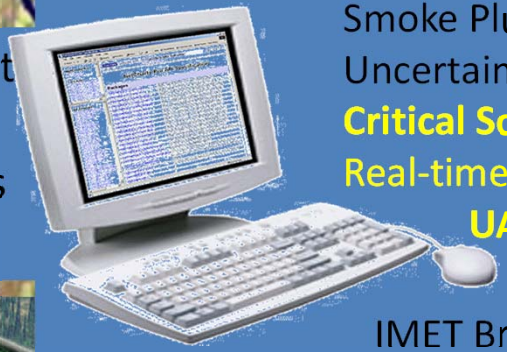


Incident Meteorologist Concept of Operations

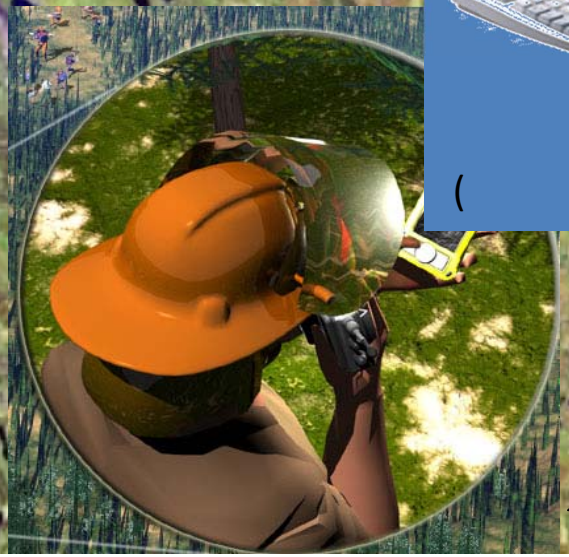
- Multiple UAS
- Fire Mapping
- Communications
- Weather Data Collection

Model Output: Fire Scale Winds, Temp, RH
Coupled Weather/Fire Behavior Forecasts

Model Products: Fire Weather/Behavior Forecast,
Smoke Plume and Dispersion
Uncertainty Guidance
Critical Scene UAS Observations
Real-time Model Verification **using**
UAS Observations



Intelligence Assistant
Thin Client
Distributed Products
Web Services



IMET Briefing
Incident Command
Fire Analyst (FBAN)
Fire Fighter Crew Chiefs
(

- Fire Perimeter Forecast Map
- GIS Smoke Dispersion map
- Sever Weather Impacts map