

A composite space image featuring Earth, the Moon, Mars, Jupiter, a comet, a satellite, and a galaxy. The Earth is on the left, showing the Americas. The Moon is in the center. Mars is below the Moon. Jupiter is on the right. A comet is in the upper right. A satellite is in the upper left. A galaxy is in the top right.

**Science Mission
Directorate**

Using UAS for Earth Science

An Overview of NASA UAS Activities

Brenda L. Mulac

*Airborne Science Program UAS Program Lead
Earth Science Division/Science Mission Directorate
NASA Headquarters*



NASA UAS Platforms

- UAS used to augment current manned fleet capabilities
- UAS primarily used for Airborne Science:
 - SIERRA
 - Ikhana
 - Global Hawk
- Many smaller platforms
 - Sensors with Wings
 - Build airframe around a given sensor
 - Aeronautics Research
 - Controls, payload directed flight, failure modes
- Catalog of aircraft - BPA
 - Aerosonde, Viking, and others



SIERRA II UAS

- Science Instrumentation Evaluation Remote Research Aircraft (SIERRA)

- Airframe designed by NRL; systems development by NASA Ames Research Center (ARC)

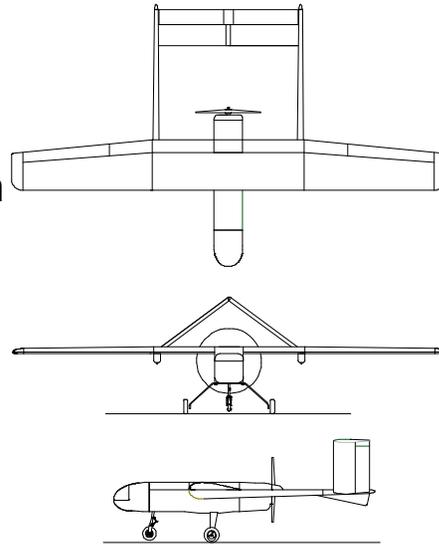
- Capabilities compliment other NASA Airborne Science UAS

- Low altitude missions
- ~100lb payload capacity

- First flight October 2008

- Payloads flown to date:

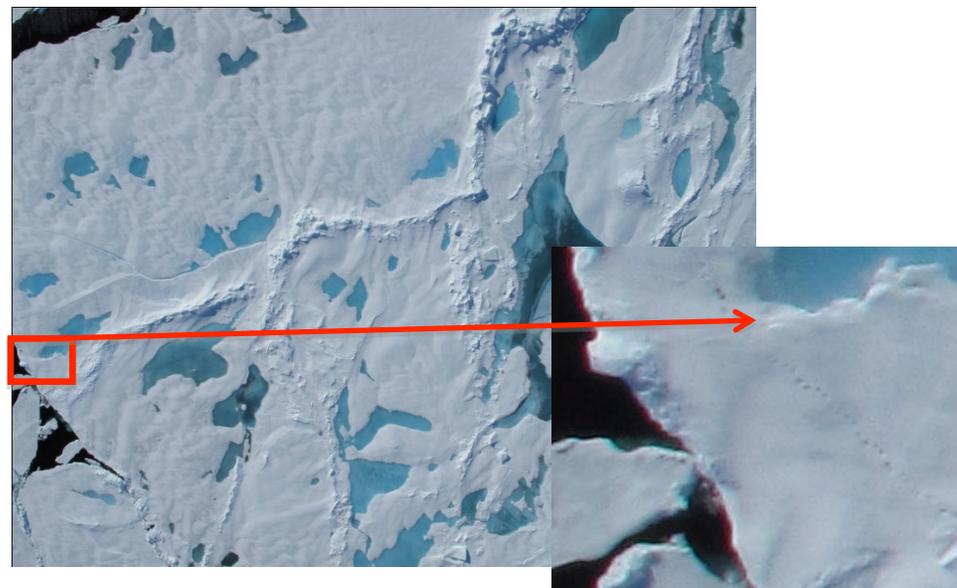
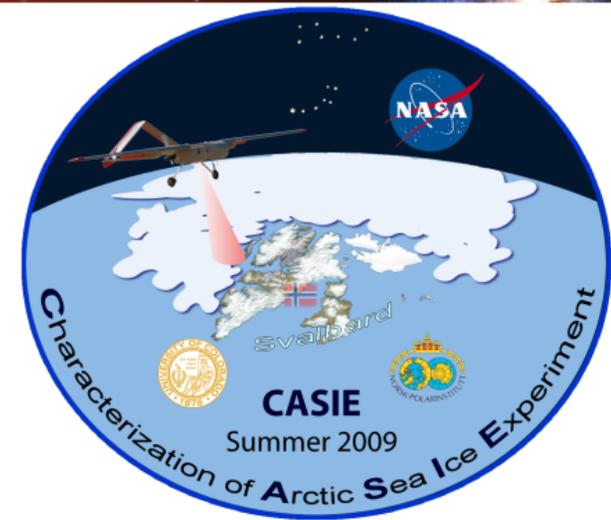
- CIS/NIR Hyperspectral Imager (NASA Ames)
- LIDAR Profilometer (CU-Boulder)
- Ocean Color suite (NASA GSFC)
- MMS (NASA Ames)
- CO₂/CH₄/H₂O (Los Gatos Research)
- C-Band SAR (Artemis/BYU)
- UHF/L-Band SAR (Mirage Systems)



Wing span	20ft
Length	11.8ft
Height	4.6ft
Wing Area	42.4ft ²
Empty weight	215lb
Gross Weight	445lb
Max Speed	79kt
Cruise Speed	55kt
Stall Speed (clean)	30kt
Aspect Ratio	9.43
Rate of Climb	545ft/min
CG Position	29-32% Chord
Payload Weight	~100lb
Payload Power	28V DC
Duration	8-10hr

Characterization of Arctic Sea Ice Experiment (CASIE)

- SIERRA aircraft and mission team based at Ny-Alesund, Svalbard, Norway; July 2009
- **Sea ice roughness measurements and reflectance**
- Payload: laser altimeters, C-Band SAR, micro-spectrometers, radiation sensors, digital cameras, and temp/humidity sensors
- Summary of science flights:
 - July 16 - 5hr, 49min
 - July 22 – 7hr, 57min
 - July 24 – 10hr, 7min
 - July 27 – 8hr, 39min
 - July 29 – 8hr, 15min
 - 2923 km of sea ice flown



Ikhana (NASA's Predator B equivalent)



Assets/Capabilities

- Modified MQ-9 with digital engine control
- Mobile ground control station
 - Ku Satcom for over the horizon missions
 - 6 engineering monitoring stations
 - Modified from standard configuration
- Ground support equipment and spares
- Trained pilots
- External pods for sensors
- Experience conducting flight ops in the NAS

Mission

- Airborne Science mission support
 - Western States Fire Missions (WSFM)
 - Research Opportunities for Space and Earth Science (ROSES) Missions (tentative FY11-12)
 - Operation Ice Bridge (tentatively FY12 or 13)
- Test-bed for UAS technology & sensor development
 - Collision avoidance
 - Sensor characterization
 - CONOPS development.validation
- Fundamental Aeronautics Research Validation Platform
 - Fiber-optic Wing Shape Sensing (FY08)
- UAS technology development and flight demonstration
 - Supporting various customers with the development and integration of new technologies onto UAS





NASA Ikhana UAS Supporting Wildfire Observations

Partners and Objectives

- **Partners:**
- NASA-ARC (Project Lead)
- USDA-Forest Service and CalFire (Partner Agencies)
- NASA-DFRC (UAS Flight Management Lead)
- **Objectives:**
- Demonstrate UAS, advanced NASA sensors, and data fusion to support disaster (wildfire) management.
- Support emergency wildfire events with real-time NASA data to allow improved rapid response.
- Demonstrate safe UAS integration into NAS allowing ease-of-use for future NASA UAS mission utility.
- Partners operationalize capabilities to support nation.

Wildfire UAS Missions Summary

MISSION	YEAR	PLATFORM	FLIGHTS	HOURS	FIRES FLOWN
Small UAS Demo 1	2005	various (3)	3	3	2 (test fires)
Small UAS Demo 2	2006	various (4)	10	15	1 (prescribed fire)
WSFM 2006	2006	Altair	4	68	2
WSFM 2007*	2007	Ikhana	12	89	37
WSFM 2008	2008	Ikhana	4	21	16
WSFM 2009	2009	Ikhana	2	11	2 (post-fire flts)
TOTALS:			35	207	60

* UAS missions encompassed flights in the NAS over eight western US states: California, Nevada, Oregon, Washington, Utah, Idaho, Wyoming and Montana.



Ikhana UAS

Operations: to ~45K ft; >4000 nm
Endurance: ~24-hours
Speed: 170-200 kts
Payload: 2400 lbs of instruments
C&C and sensor telemetry: C-band (local) & Ku-band (global)

AMS-Wildfire Sensor

- Multispectral (VIS / IR / SWIR / TIR);
- Remotely operated / autonomous;
- On-board-developed geo-rectified, sensor-derived images and model products, delivered real-time
- Reconfigurable (in-flight) data / product capability to support changing mission metrics.



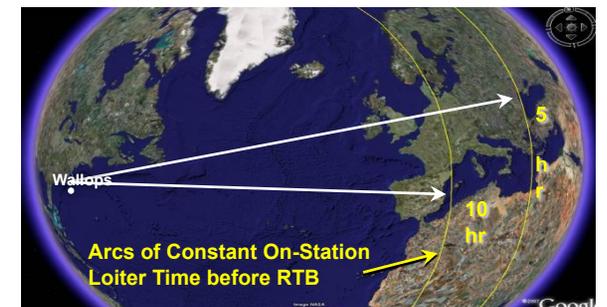
Success Metrics and Outcomes

- **Success Metrics:**
- **Technology Transfer:** USFS operationalized the NASA data-telemetry technology on their aircraft assets (2009); operationalized the NASA-developed Collaborative Decision Environment (CDE) to support the wildfire National Incident Command Center (2009).
- **NASA Science Serving Society:** +200 mission hours supporting 60 major wildfire events in western US, including: Esperanza Fire (2006), Idaho Fire Siege (2007), multi-state fires (2007), So. California Firestorms (Oct. 2007), No. California lightning fire storm (2008), So. CA. Station Fire burn assessment (2009).
- **Continuation through 2011 via NASA ARRA funds.**

NASA Global Hawk System

- Two USAF pre-production Global Hawk aircraft transferred to NASA, September 2007
 - A third aircraft arrived Jan 2010
- 5-year partnership with Northrop Grumman team for maintaining, modifying, and operating the UAS (2008-2013)
- First flight of NASA Global Hawk: 23 October 2009
 - Flight time of 4 hours
 - Flight altitude of 61,400 ft
- First science mission: GloPac, April 2010
- Future capability with mobile ground station
- New missions: ATTREX and HS3

Endurance	>30 hr
Range	>11,000 nmi
Service Ceiling	65,000 ft
Airspeed (55k+ft)	335 KTAS
Payload	1,000-1,500 lb
Length	44 ft
Wingspan	116 ft

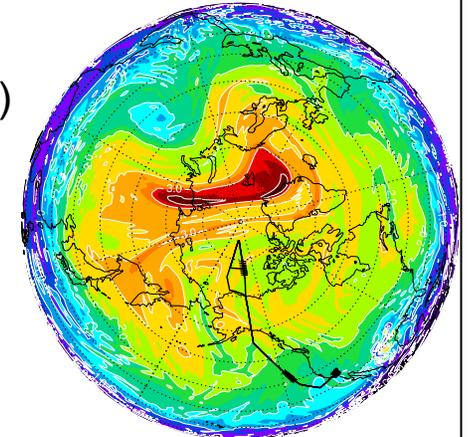


Recent Global Hawk Missions

Global Pacific Mission (GloPac)

- Campaign took place April 2010
- First demonstration of the Global Hawk unmanned aircraft system (UAS) for NASA and NOAA Earth science research and applications
- Exploration of trace gases, aerosols, and dynamics of remote upper troposphere and lower stratosphere regions
- Calibration and validation of satellite instrumentation
- Sample polar vortex fragments and atmospheric rivers
- Risk reduction for future missions that will study hurricanes and atmospheric rivers

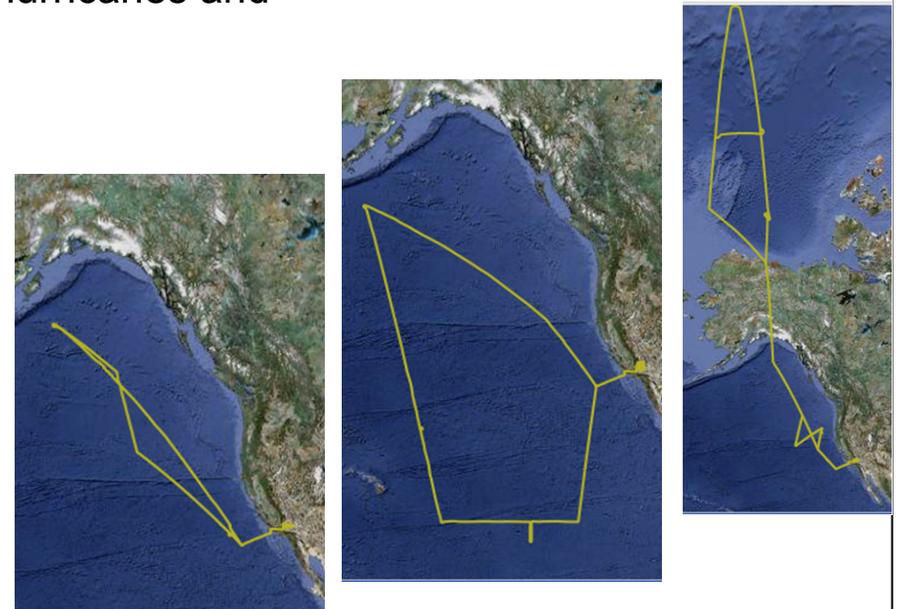
GEOS-5 valid 2010-04-24 00 Z
EPV (10^{-2} K kg¹m²s¹) 70.0 mbar



Courtesy of NASA Goddard



5 flights
82.6 total flight hours



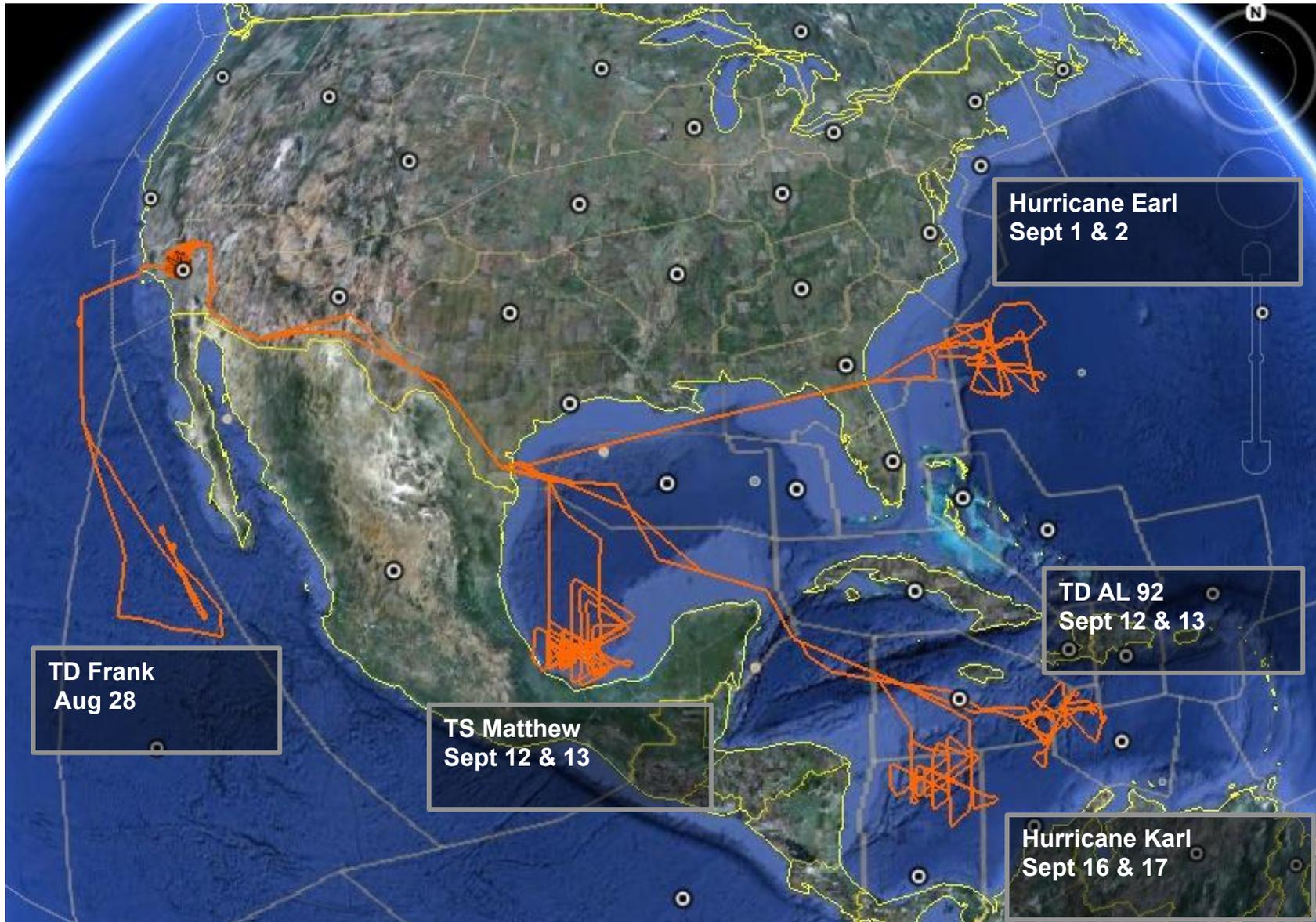
Recent Global Hawk Operations

Genesis and Rapid Intensification Processes (GRIP)

- Improve intensification forecast models and satellite calibration/validation
- Campaign took place August 15 – October 1
- Multi-agency, multi-aircraft research campaign
 - NOAA P-3, G-3
 - NSF G-5
 - NASA Global Hawk, DC-8, WB-57
- Demonstration of Global Hawk capabilities for science
- Integration of new Global Hawk payloads:
 - Radar, Microwave Radiometers, Dropsondes, Electric Field Measurements

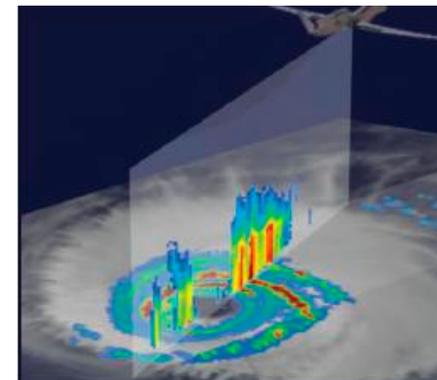
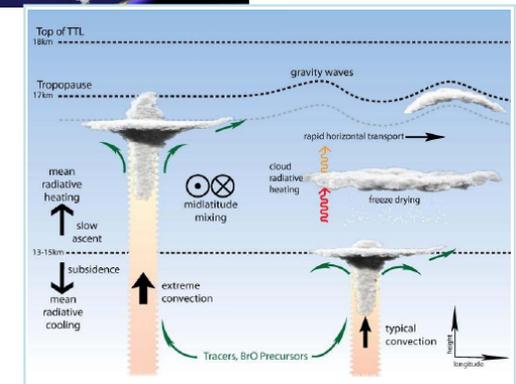
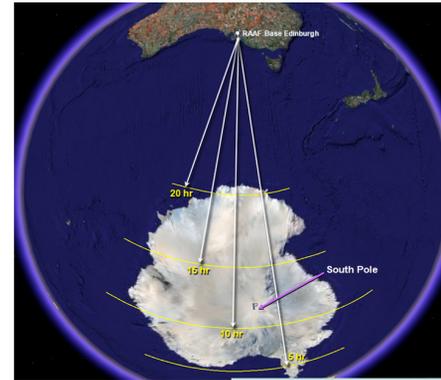


GRIP Flight Tracks



Future Missions

- **Operation IceBridge: *Global Hawk* and *Ikhana***
 - IceSat no longer functional
 - IceSAT 2 won't be ready until at least 2015
 - Airborne campaign for gap filling measurements
 - DC-8 and P-3 currently being used over Antarctica and Greenland
 - Plan to start using both *Global Hawk* and *Ikhana* by 2012
- **Airborne Tropical Tropopause Experiment (ATTREX): *Global Hawk***
 - Study of water vapor chemical composition in tropopause/stratosphere and impacts on climate
 - 5 year project, missions start 2012
 - Basing tentatively in Guam and Australia
- **Hurricane and Severe Storm Sentinel (HS3): *Global Hawk***
 - Hurricane intensity change study
 - 5 year project, first mission September 2012
 - Basing at Wallops Flight Facility
- **Proposal call for UAS for Earth Science (ROSES A-40)**
 - 2 year projects, missions start in 2012
 - Required to use SIERRA, *Ikhana*, or *Global Hawk* and another UAS of different class





Other NASA Science UAS Activities

- Participation Small UAS Aviation Rulemaking Committee
- On-site Liaison in FAA Unmanned Aircraft Program Office
- Participation in UAS ExCom
- Over \$14M in ARRA invested in Global Hawk and UAS sensors
 - Includes wing pylons and Mobile GCS
- Representation on Arctic Monitoring and Assessment Program UAS Expert Working Group
- NASA-NOAA-DOE MOU for using UAS for Earth science
- Representation to new Aeronautics Research Mission Directorate's UAS Integration into the National Airspace System project

Parting Thoughts on the Future

- Unmanned aircraft will not replace manned aircraft but will be used to augment existing fleets, filling gaps in observing capabilities
- Unmanned aircraft technology will continue to mature, driving more instrument development and expanding science application options.
- New platforms such as the Global Observer will challenge the traditional relationship between satellites and aircraft
- Observing networks will be created using all sizes of unmanned aircraft.

