UASs: Utility for improvements in hurricane intensity and track forecasting in the Gulf of Mexico

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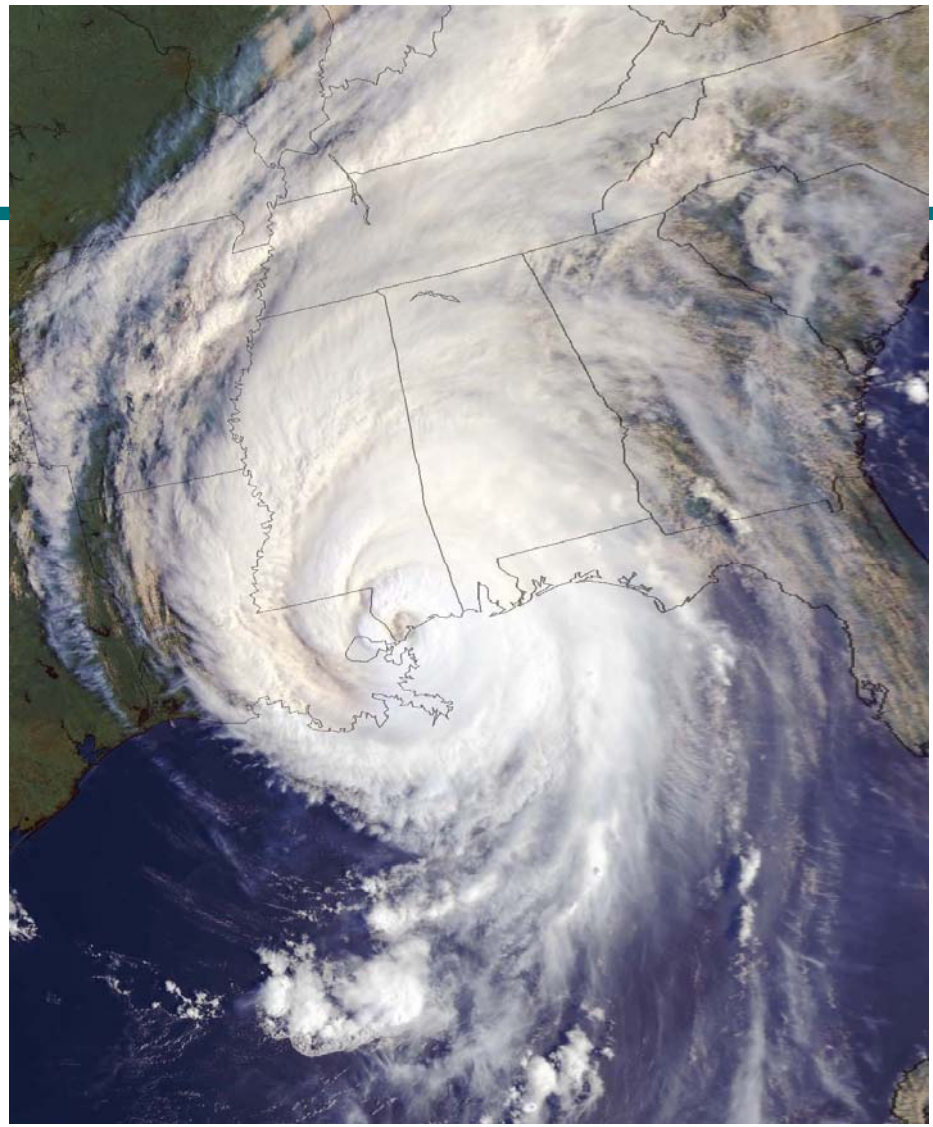
AIAA May 8, 2007



Requirement 1:
Assess and predict the intensity and storm-surge conditions at landfall

- **<u>Current Gap:</u>** Unable to accurately and continuously monitor atmospheric and oceanic conditions near/at the surface due to:
  - Severe safety constraints (manned flight not possible)
  - Observing platform failures near the surface due to 100kt+ winds, 60 ft waves (GPS, buoys)
  - Observational limitations of 'instantaneous/snapshot' platforms (GPS, SFMR, etc)

  Lack of routine low level hurricane observations leads to …
  - Limits in understanding-> boundary layer processes, cloud/spray microphysics, etc
  - An inability to assimilate low level inner core observations into coupled operational models
  - An inability to significantly & consistently improve hurricane intensity forecasts…

- **Role for UAS?** For hurricane reconnaissance, a low altitude long endurance (LALE) platform could help fill some of the gaps outlined above by:
  - Eliminating safety concerns (flights as low as 200m)
  - Utilizing 'continuous' observations- Greatly increases the likelihood of sampling stronger surface winds (vs. using 'snapshot' observations - e.g. GPS sondes).
  - Enhance hurricane inner core data coverage (& eventually data assimilation in a critical data void region)
  - Improve our physical understanding of the rarely observed hurricane upper ocean/boundary layer

    …hopefully leading to better operational models & improved forecasts of hurricane intensity change

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Requirement 2:
To more accurately predict the future *track* of hurricanes

- For hurricanes, the primary mission goal for NOAA's Gulfstream IV aircraft is to:
  - Conduct dropsonde flights around & ahead of the storm to minimize model uncertainty and materially improve forecasts of hurricane track.
- **Gap:** NOAA's G-4 manned aircraft is the key observing tool to help predict Hurricane track. NOAA owns and operates one G-4 platform. As such, finite range and operation limitations exist.
- **Role for UAS?** For Hurricane surveillance, a High Altitude Long Endurance (HALE) platform could help fill gaps & potentially enhance existing G-4 observing capabilities.
  - A Hurricane Hunter (G-4) flight w/ a concurrent HALE hurricane mission could significant enhance area coverage/data assimilation capabilities, and as a result, potentially improve hurricane track forecasts
  - Limited endurance G-4 missions could be enhanced by also utilizing HALE platforms (> lead time)
  - HALE remote sensor packages-currently not on the Hurricane Hunters [e.g. Microwave imager (surface winds), LASER (environmental moisture)] could help improve future forecasts of hurricane intensity (in addition to track)
  - HALE remote sensor payload could also aid satellite validation and calibration efforts (NESDIS/NASA) Could also potentially address existing satellite observational 'gaps'

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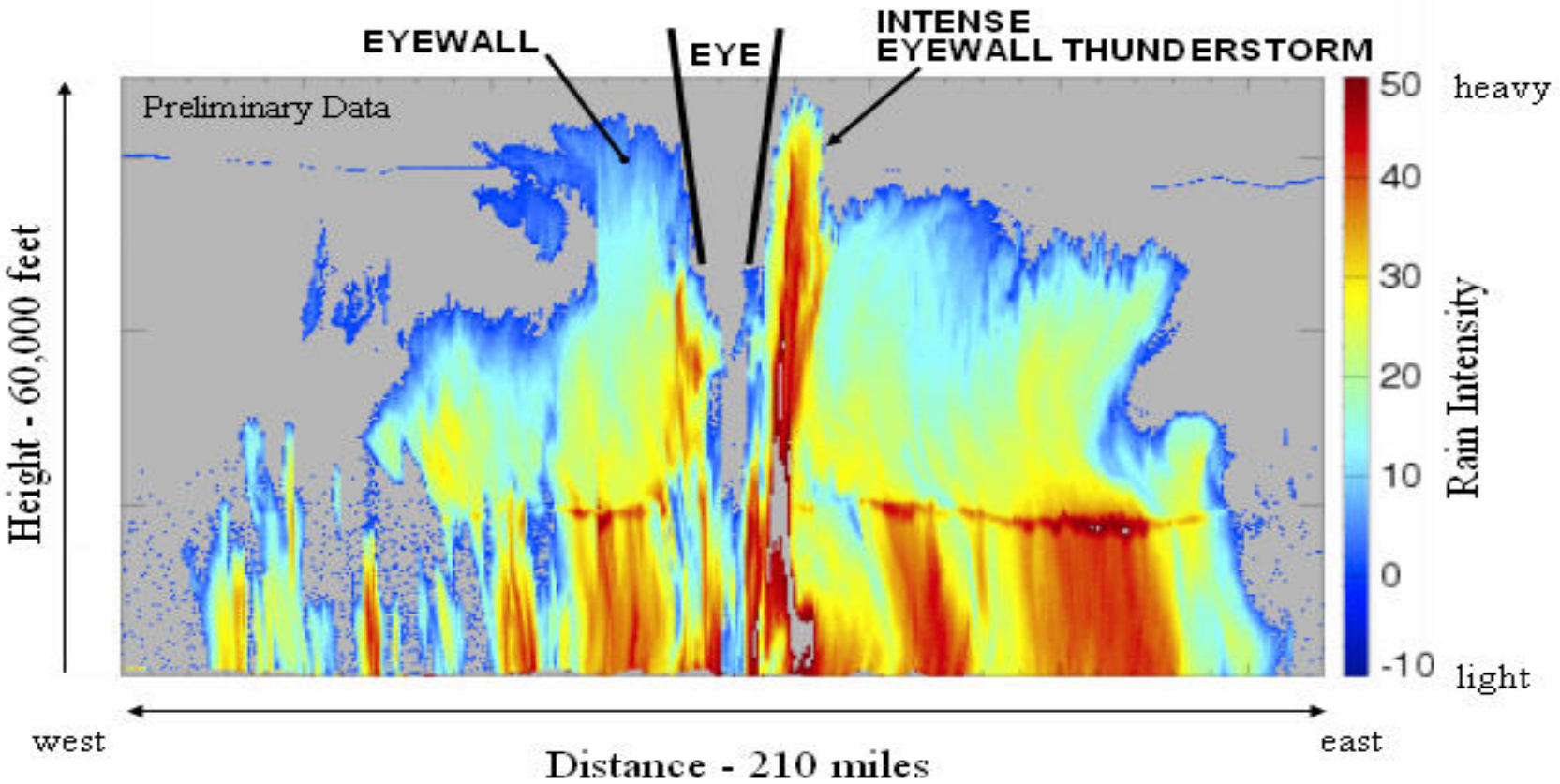
Harsh Environment

- Hurricanes present a harsh environment for any aircraft:
  - High horizontal/vertical winds
  - Icing
  - Intense Lightning
  - Heavy Rain
  - Problematic Comms.

ER-2 Doppler Radar (EDOP) Views Detailed Super-Anatomy Of Intense Hurricane Emily During NASA's TCSP Experiment

Principal Investigator: Dr. Gerald Heymsfield, NASA GSFC



Vertical slice showing rain structure across the entire storm - 1:30 - 2:00 AM CST July 17, 2005

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Potential Use of Low Level UAS

- **Low level hurricane environment too dangerous for manned planes**
- **Location of environment where the ocean's warm water energy is directly transferred to the atmosphere just above it**
- **Low-level in situ measurements will potentially enhance existing observational capabilities within the tropical cyclone environment**

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Low-Altitude Long-Endurance Typical Mission Profiles

- 30 hour flight, 6000 miles (11000 km)
- Varying altitude slices from 150 – 500m (surface) to 3,000m (higher for severe storms)
- Intercept eye at 3000m
- Fly 160km radius about the eye
- Onboard data collection
- Dropsonde down to surface

Current Aircraft

53rd Weather Reconnaissance Squadron

WC-130J Hercules

- Wing Span – 40.4 m
- Weight – 69,750 kg
- Range – 6437 km
- Endurance – 18 h
- Cruise – 480 kph
- Ceiling – 10 km

Hurricane Hunters into the storm

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Current Aircraft

Gulfstream IV "Gonzo" N49RF

Gulfstream IV

- Wing span – 23.7 m
- Weight – 33,900 kg
- Range – 7000 km
- Endurance – 10 h
- Cruise – 864 kmh
- Ceiling – 12 km

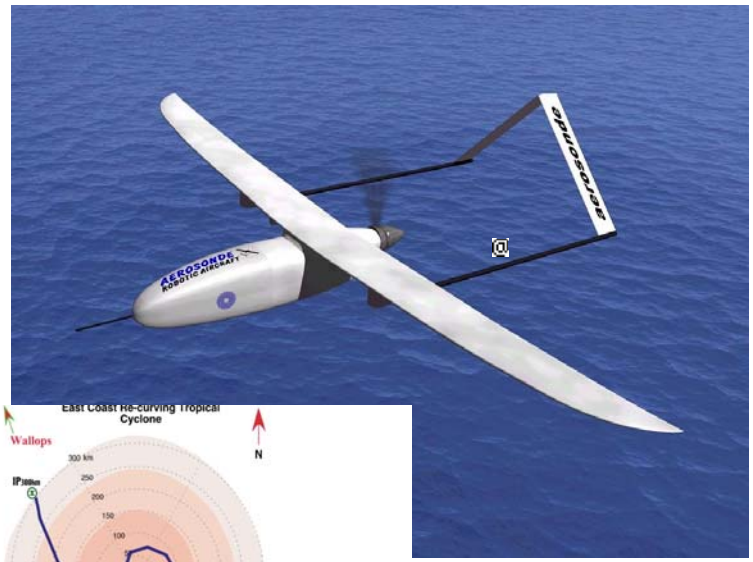
Current Aircraft

"Kermit" N42RF "Miss Piggy" N43RF

WP-3D Orion

- Wing span – 30.6 m
- Weight – 61,400 kg
- Range – 4100/6100 km
- Endurance – 8.5/10.5 h
- Cruise – 612 kmh
- Ceiling – 7.6 km

Development



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Aerosonde Unmanned Aircraft System

- Wing Span – 2.9 m
- Weight – 13-15 kg
- Range – 3,000 km
- Endurance – 30 h
- Cruise – 80-150 kph
- Ceiling – 7 km
- Payload – 5 kg

Low-level missions (< 300 m) into eyewall region

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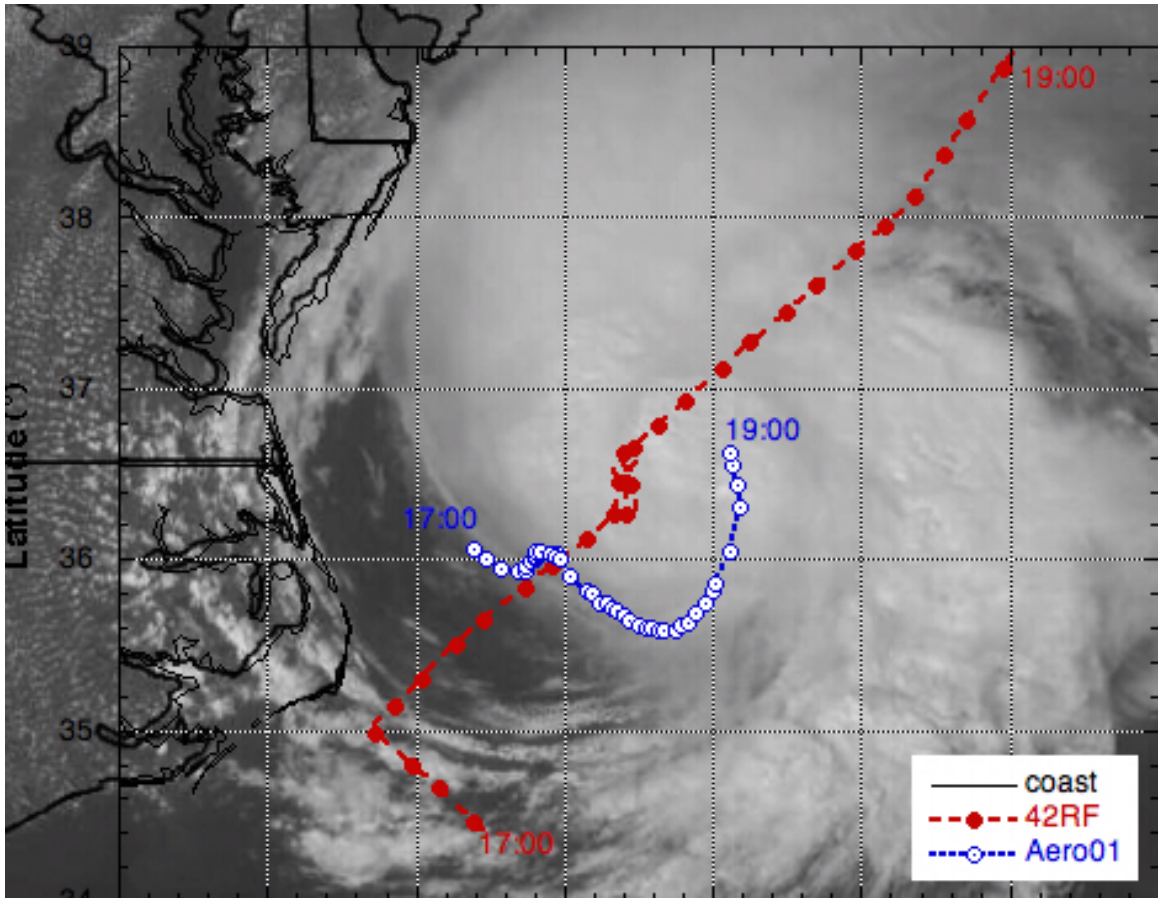
Aerosonde and NOAA P-3 Flight Tracks Tropical Storm Ophelia (September 16th, 2005)



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Potential Use of High Altitude Long-Endurance (HALE) UAS

- An aircraft like the Global Hawk or Ethereal could fly above the hurricane at 60 to 65 K, staying with the storm for extended periods

- It could use remote sensors (radar and Stepped Frequency Microwave) to continuously monitor hurricane surface winds

- It could drop sondes to continuously monitor storm central pressure, and expendable bathythermographs or AXCTDs to determine sea temperature and conductivity profiles

- It could carry repeaters so that it could maintain cell phone communications in the affected areas as the storm makes landfall

- HALE could possibly descend into the eye to make direct measurements using the strong updraft to conserve fuel

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High Altitude Long Endurance (HALE) Typical Mission Profile

- Ceiling – 18.3 km (above typical storm – 14 km)
- Radius – 5000 km (reach forming storms)
- Endurance – >48 h (stay on station 1 day minimum)
- Payload – GPSDropsondes, mini-UASs, Oceanographic Probes (AXBTs, AXCTDs)

HALE Typical Mission Profile (cont.)

- Cruise out to low pressure area (~10 hrs)
- Stay on station 24 hrs minimum (would need to send replacement every day for continuous coverage)
- Remote sensing, seeding with micro sensors
- Return to base (~10 hrs)

Global Hawk

Global Hawk

- Endurance – 24 h at 2000 km
- Weight – 11,612 kg
- Range – 22000 km
- Speed – 630 km/h
- Ceiling – 19.8 km
- Payload – 890 kg

Predator-Type

	PREDATOR B	ALTAIR	MARINER
	Military Multi-Mission	High-Altitude Scientific Research	Long-Endurance Border & Maritime Surveillance
Length:	66 ft (20.1168m)	86 ft (26.2128m)	86 ft (26.2128m)
Fuselage:	36 ft (10.9728m)	36 ft (10.9728m)	36 ft (10.9728m)
Weight:	10,000 lb (4536 kg)	7,000 lb (3175 kg)	10,500 lb (4763 kg)
Altitude:	50,000 ft	52,000 ft	52,000 ft
Endurance:	30+ hr	30+ hr	49+ hr
Payload:	Internal - 800 lb (363 kg)	Internal - 660 lb (300 kg)	Internal - 800 lb (363 kg)
	External - 3,000 lb (1361 kg)	External - 3,000 lb (1361 kg)	External - 3,000 lb (1361 kg)
Air Speed:	Over 220 kn		Over 220 kn
Customer:	U.S. Air Force	TBA	U.S. Navy, DHS
		NASA	

General Atomics – Aeronautical Systems

http://www.ga-asi.com/products/mariner.php

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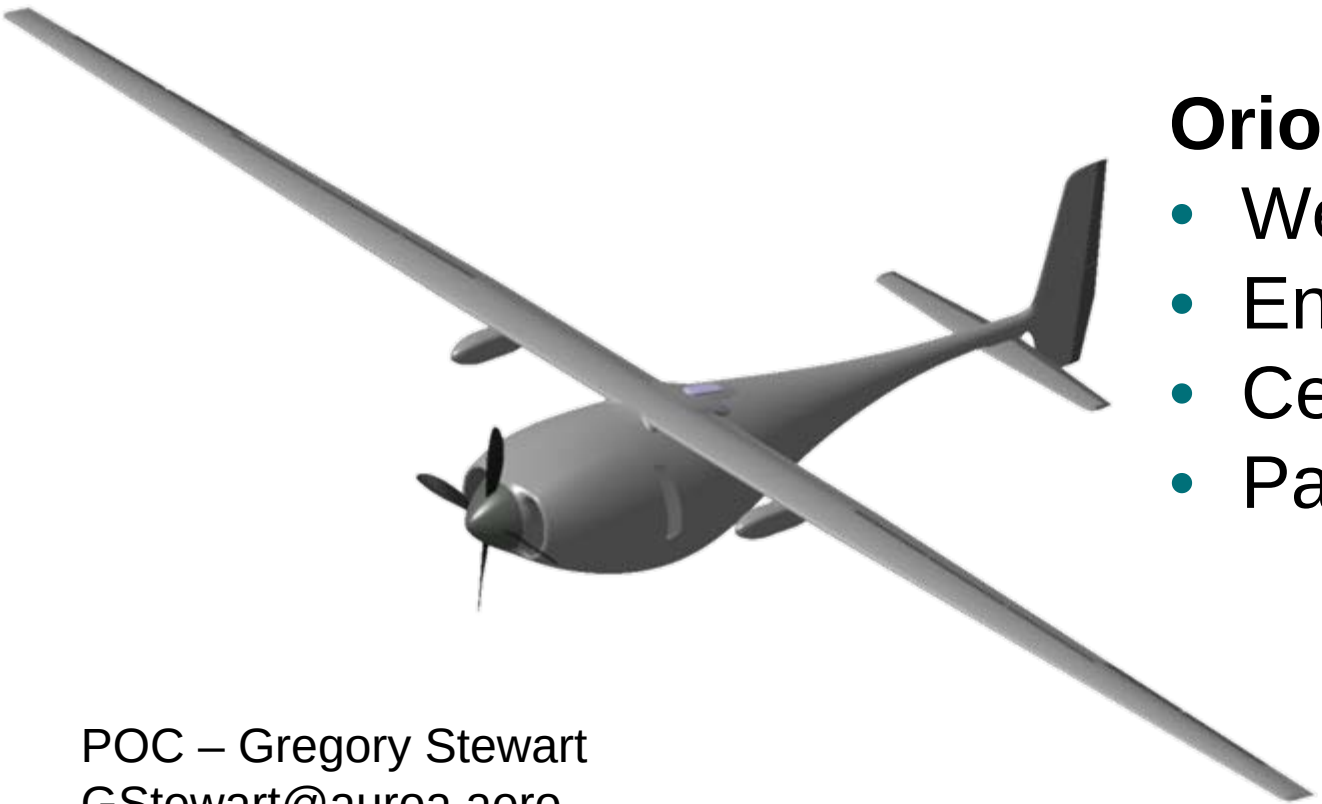
Development
Orion – Aurora



Orion

- Weight – 3060 kg
- Endurance – 100 h
- Ceiling – 19.8 km
- Payload – 182 kg

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Aurora FLIGHT SCIENCES

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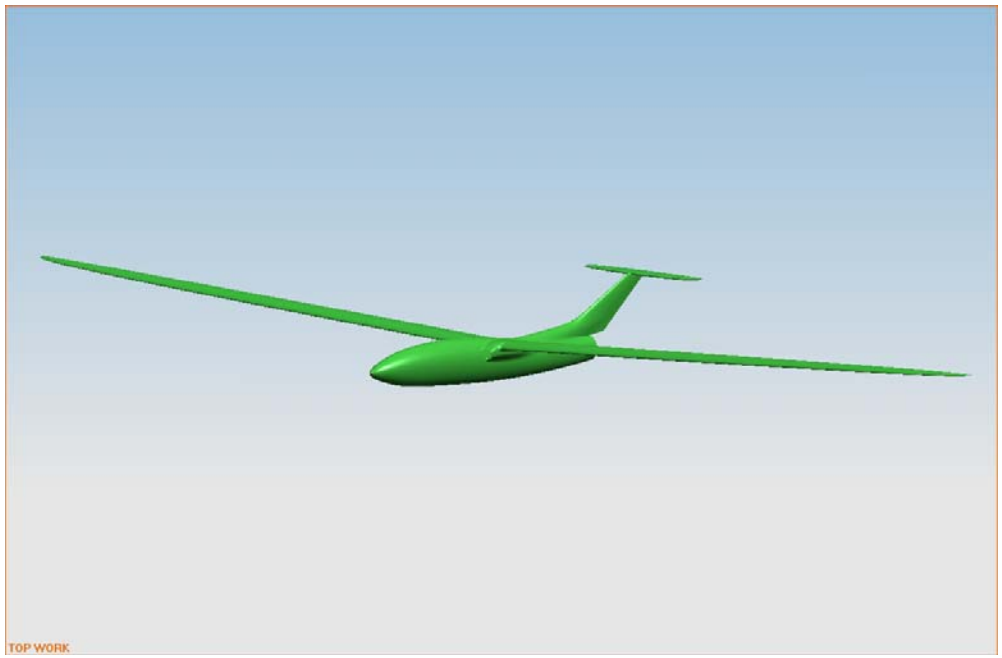
Development
Ethereal – Mississippi State University



Ethereal

- Wing span – 33.5 m
- Weight – 3770 kg
- Range – 22000 km
- Endurance – 48 h
- Cruise – 460 kmh
- Ceiling – 19.8 km
- Payload – 225 kg

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Aircraft	Range (km)	Payload (kg)	Max Altitude(m)	Endurance (h)	Dropsonde/XCTD Capability
WC-130J	6437	15909	10000	18	Yes
G4	7000	16000	12000	10	Yes
WP3D	6100	28000	7600	10.5	Yes
Aerosonde	3000	5	7000	30	Problematic
Global Hawk	22000	890	19800	42	Yes
Predator B	5100	1724	15244	42	Possible
Mariner	11000	1742	15850	42	Possible
Orion - Aurora		182	19800	100	Problematic
Ethereal	22000	225	19800	48	Problematic
LALE	11000	50	3000	30	Yes
HALE	20000	800	18300	48	Yes

Challenges

- Harsh flying conditions
- Communications
- Possible need for autonomous modes
- Mobility of launch and control systems
- Cost

Opportunities

- Significant improvement is prediction of intensity and location of landfall leading to:
  - Earlier decisions for governmental bodies
    - Better Evacuations
    - Longer time to put storm protection devices in place
- Other potential significant uses of UASs:
  - Post-storm evaluation
  - Monitoring river outflow
  - Tracking harmful algal blooms leading to better prediction of movement
  - Tracking toxic spills

Summary

- The ability to sample hurricanes during their early development and as they approach the shore is vital to protect lives and property.
  - **Assess and predict the intensity and storm-surge conditions at landfall**
  - **more accurately predict the future *track* of hurricanes**
- Certain missions are too dangerous (low-level) or outside the range of manned A/C.
- UASs present opportunity to overcome these issues.
- Other uses of UASs in oceanographic research and operations (ex., tracking harmful algal blooms or toxic spills) offer us the opportunity to mitigate or prevent ecological disasters.

Questions or comments welcome

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Background Slides