Development of Instrumented Unmanned Airborne Systems (UAS) for Air-Sea Interaction Research
&
Ship-Based UAS Measurements of Air-Sea Interaction and Marine Atmospheric Boundary Layer Processes in the Equatorial Indian

Update on the AGOR / UAS Scientific Demonstration Integration for Project DYNAMO

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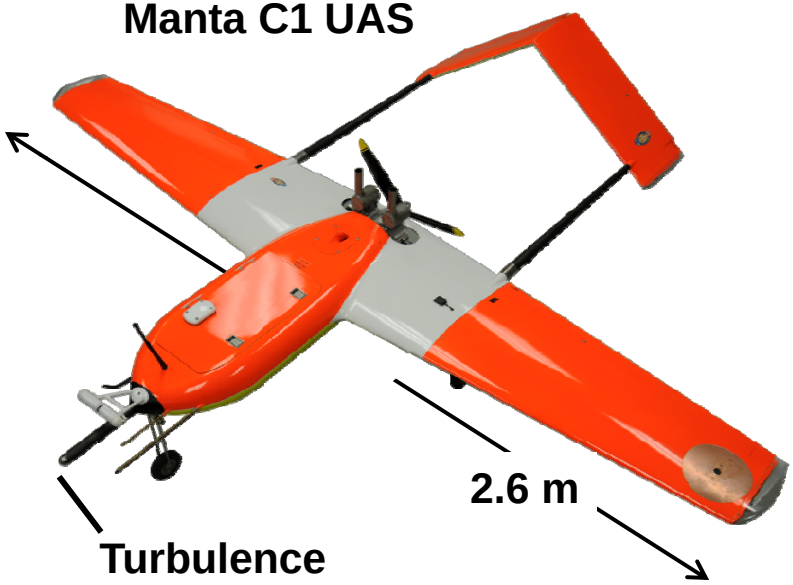
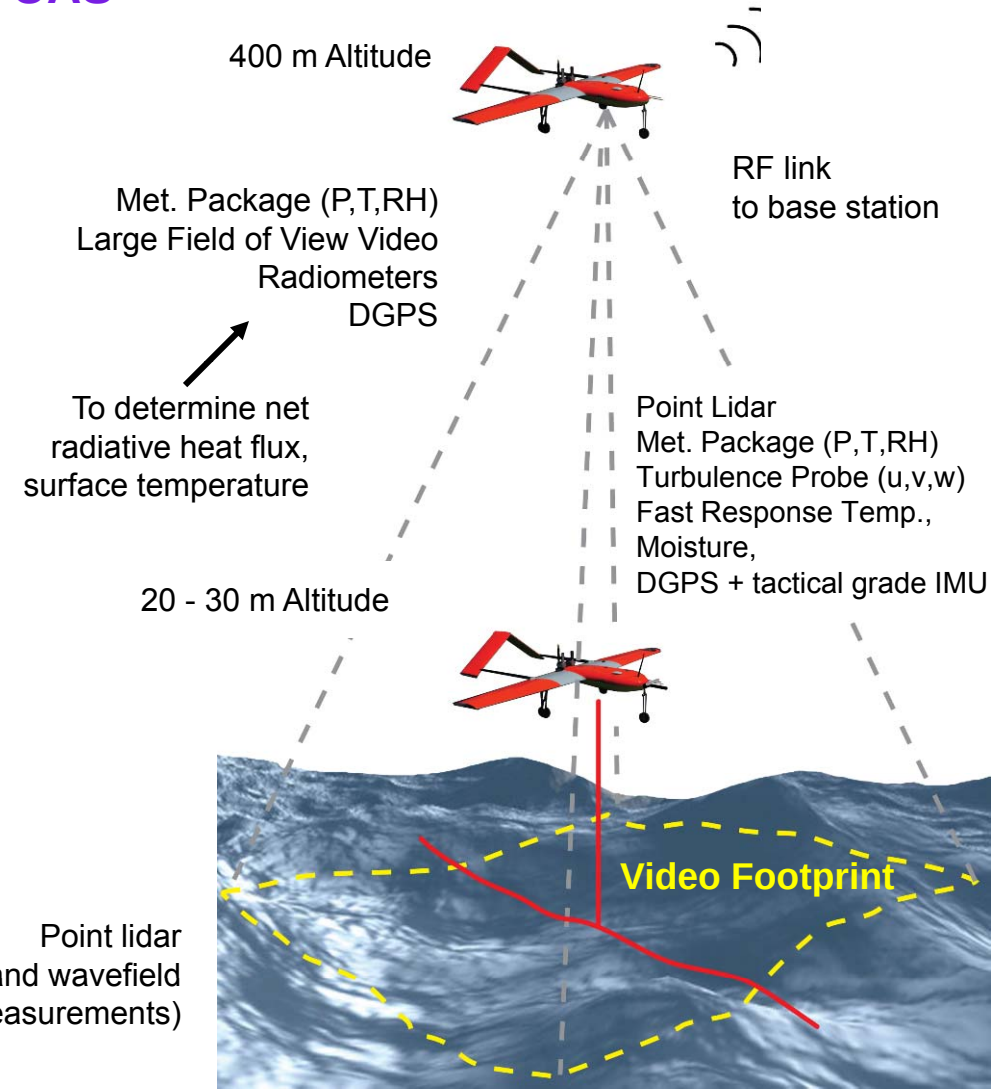
Update on UAS instrumentation development for Air-Sea Interaction Research - BAE Manta UAS

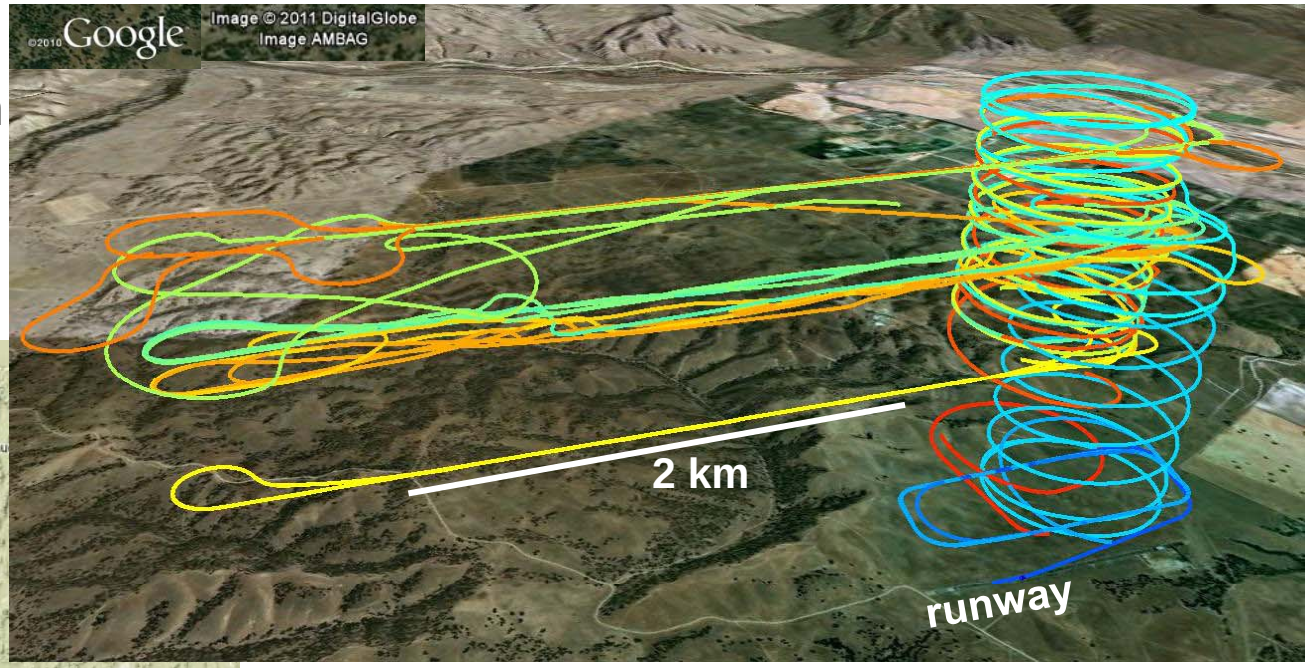
Instrumented BAE Manta C1 UAS

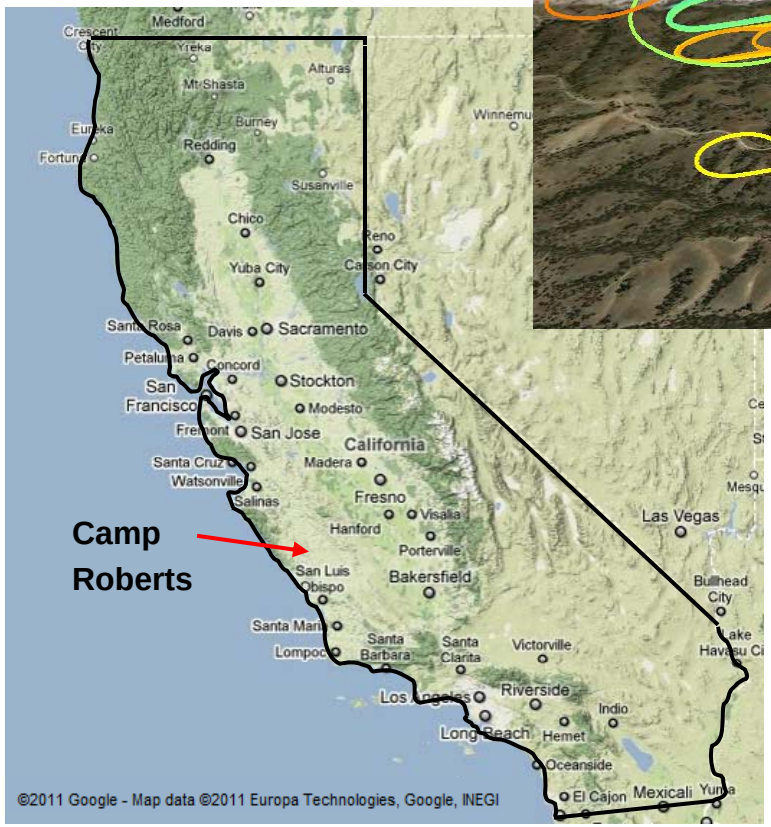




Camp Roberts 01/2011

- McMillan Airfield, run by CIRPAS (NPS)
- Restricted airspace



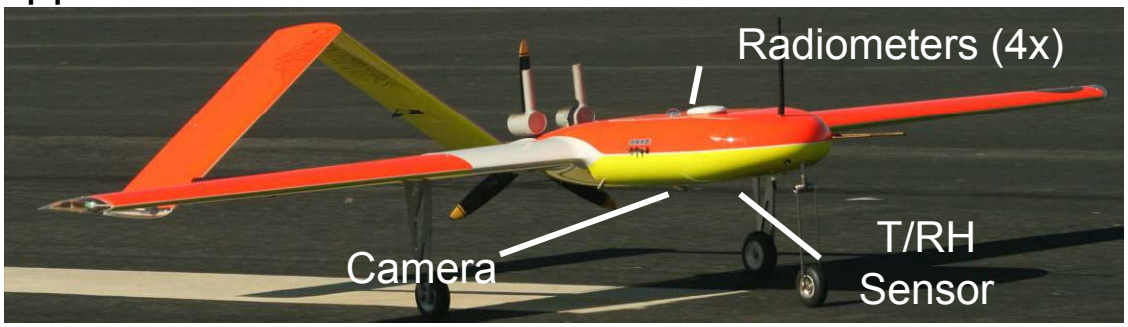


Sample flight paths (sample vertical soundings and "flux runs") from lower Manta, total time ~2 hrs

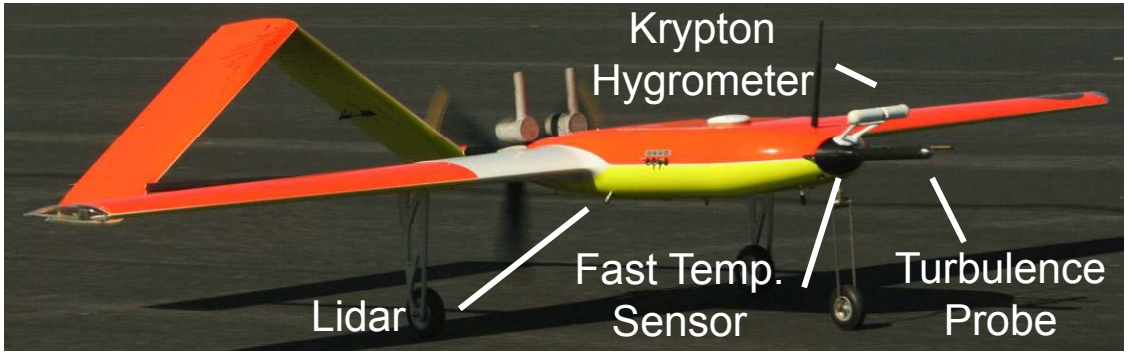
- 18 hours of flight time (two UAS):
  - Laser range finder implemented in stacked flight
  - Calibration maneuvers
  - Helical vertical soundings
  - Constant altitude 2-3 km “flux runs”

Instrumented Manta UAS – Camp Roberts 01/2011

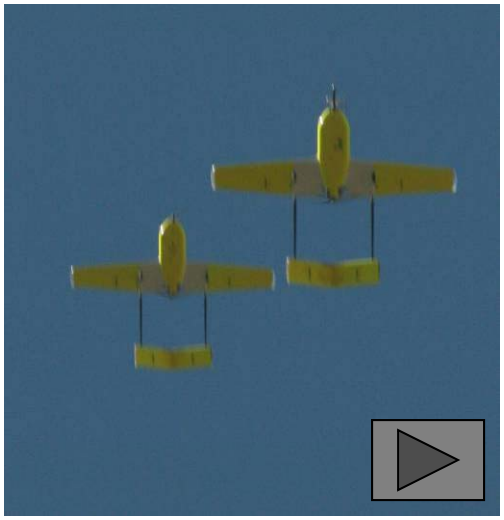
Upper Manta



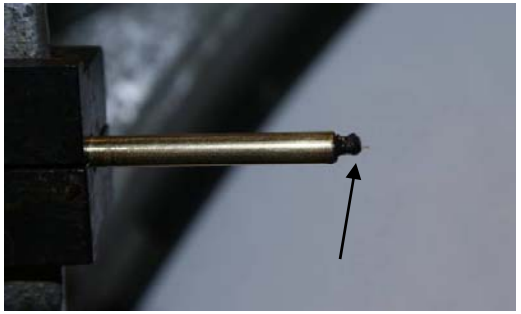
Lower Manta

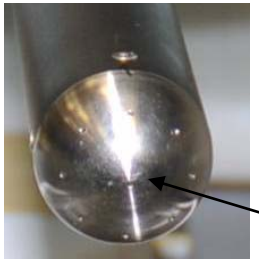


Automated
Stacked flight)

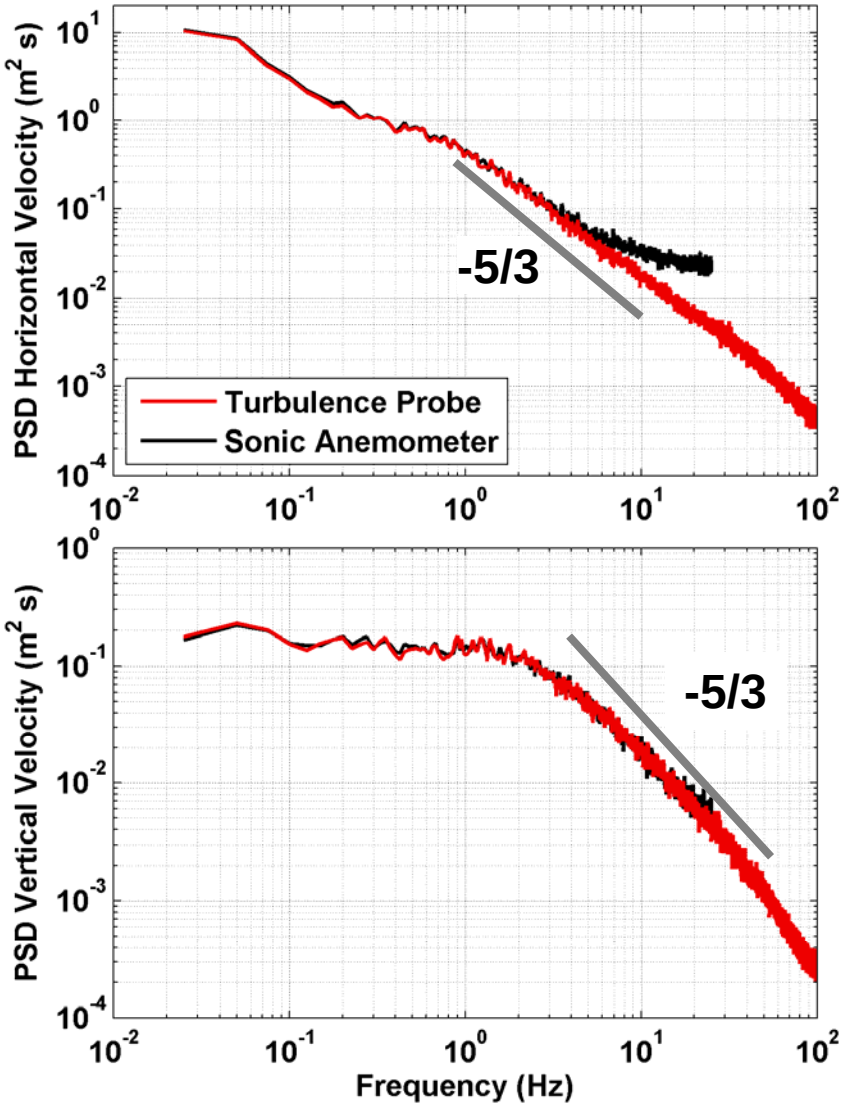


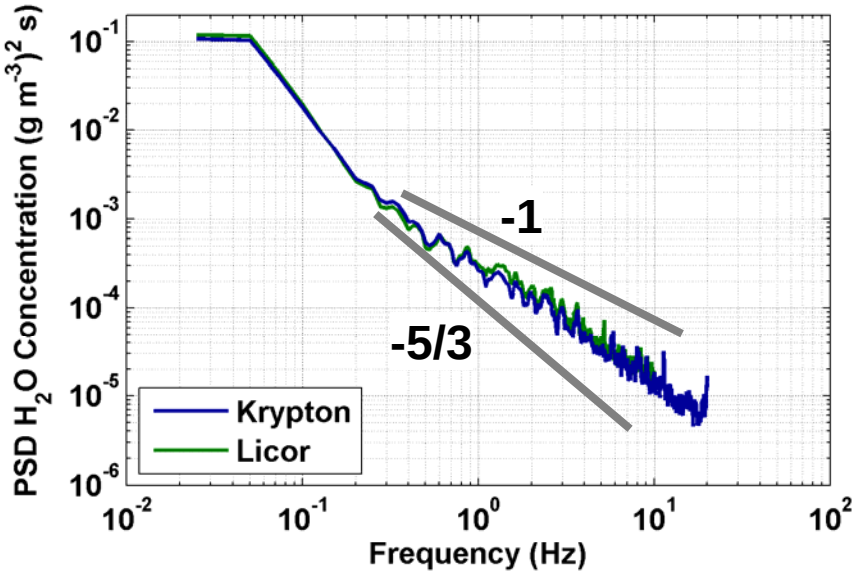
Fast response
T-sensor
(fiber optic)





Water vapor and turbulence probe calibration – Vehicle test



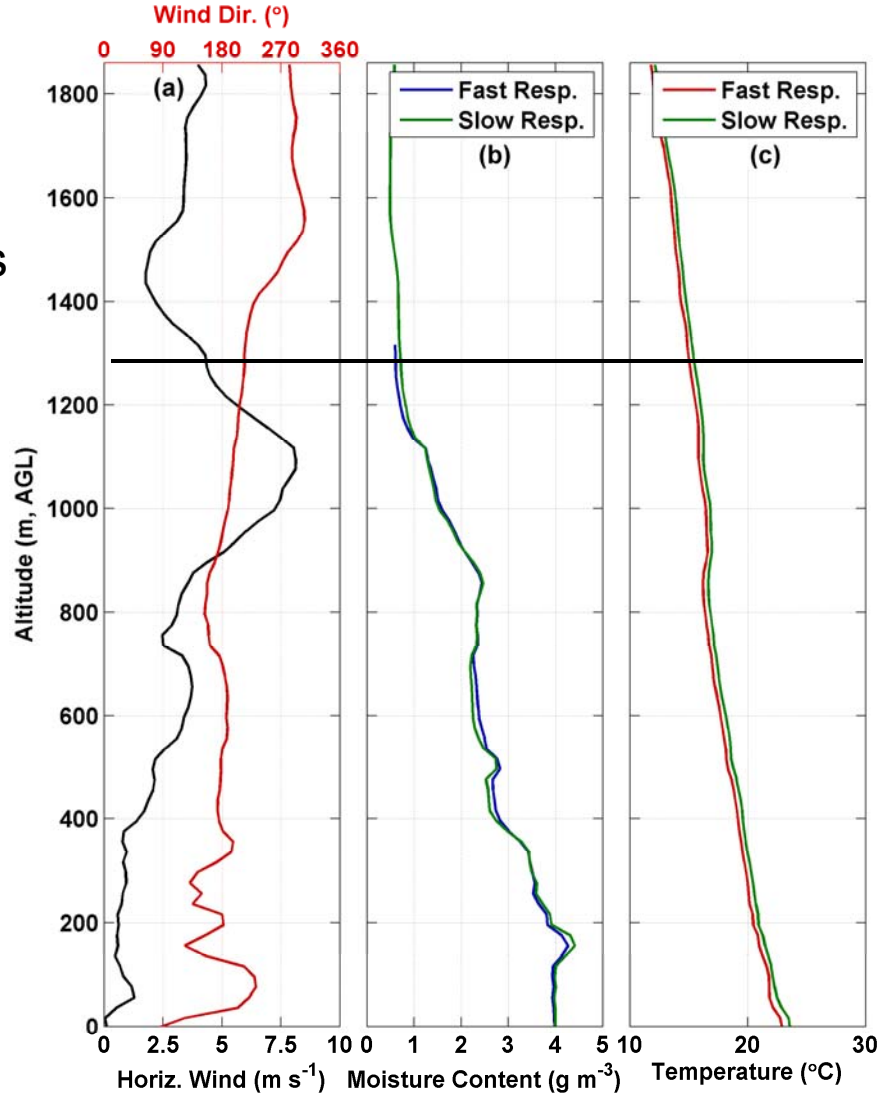


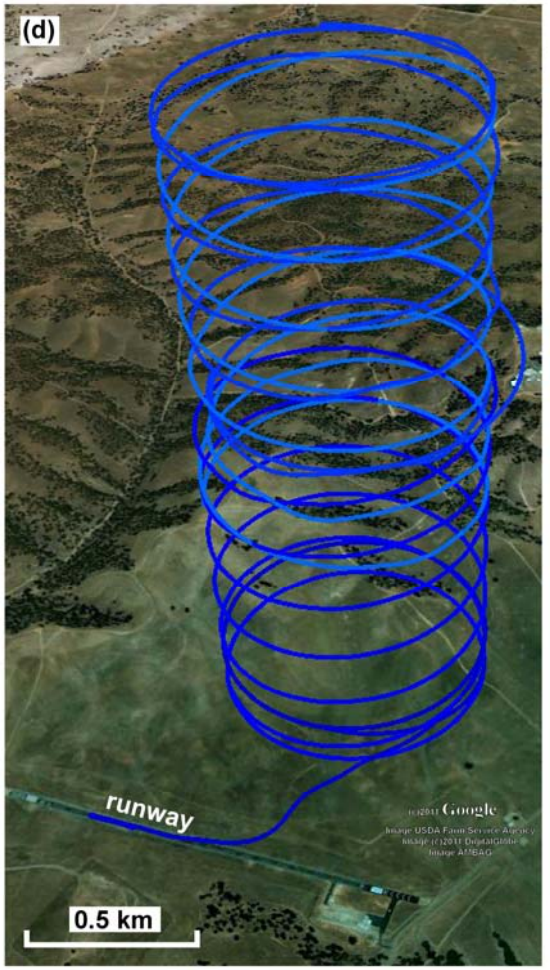
- 30-minute record, 40-s Hanning windows
- Water vapor spectra of the modified Krypton Hygrometer and the Licor 7500
- Wind: assuming isotropic turbulence, should follow a -5/3 slope in the inertial subrange

Sample vertical profiles of Wind, water vapor, Temperature Camp Roberts 01/2011

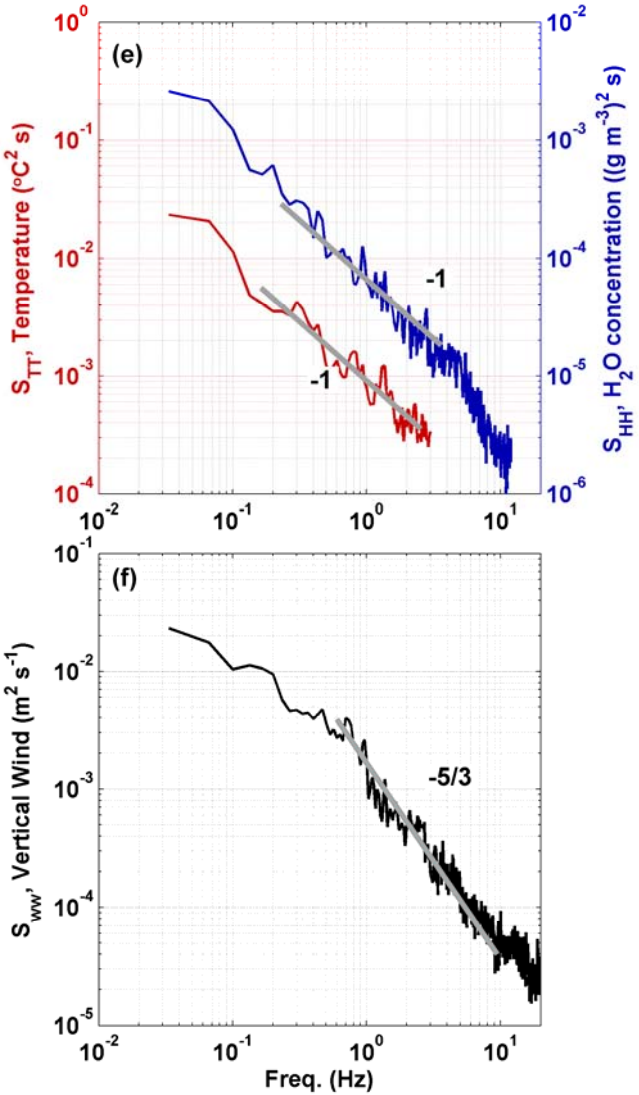
- 27 Jan 2011
- begin: 1526 PST
- 40-m vertical bins
- 50% overlap

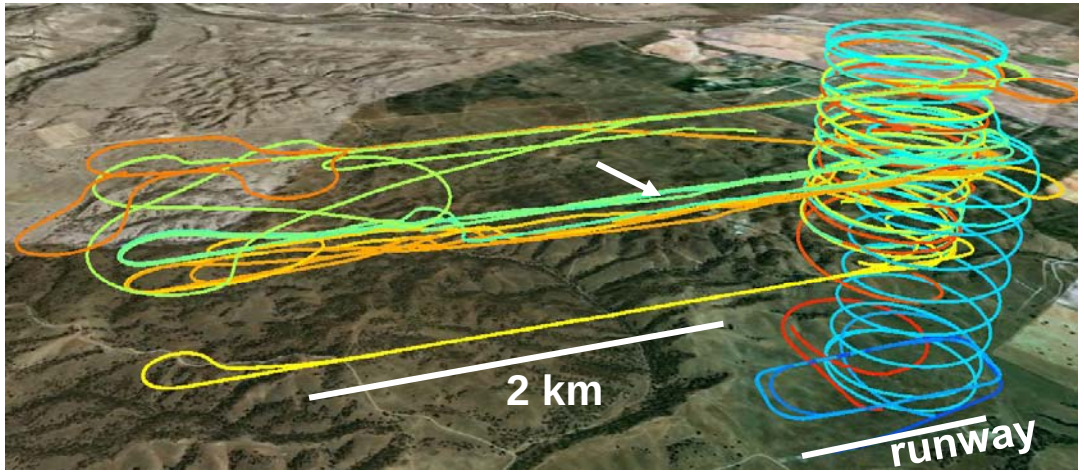
wind jet





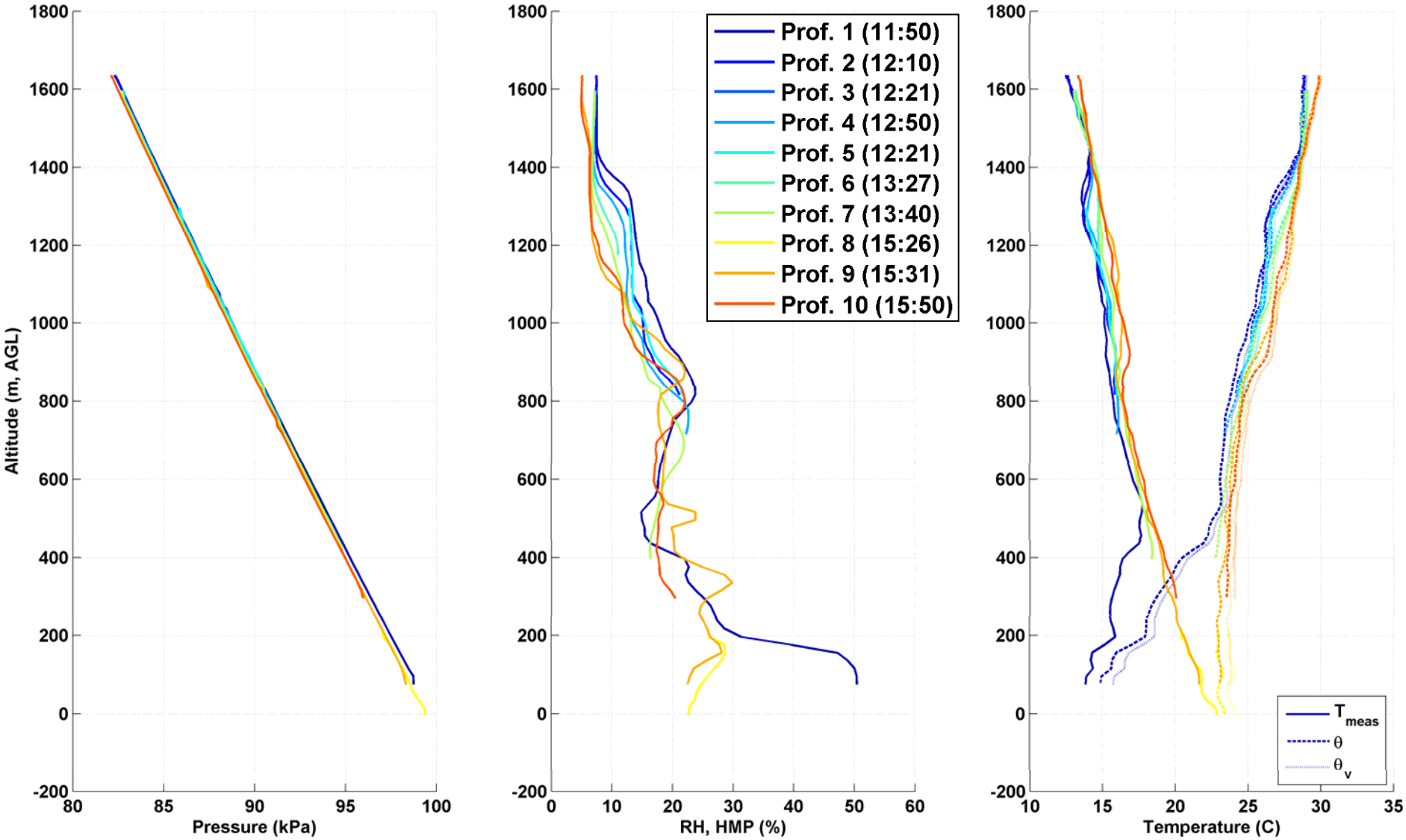
Sample spectra of vertical wind, temperature, water vapor – Camp Roberts 01/2011



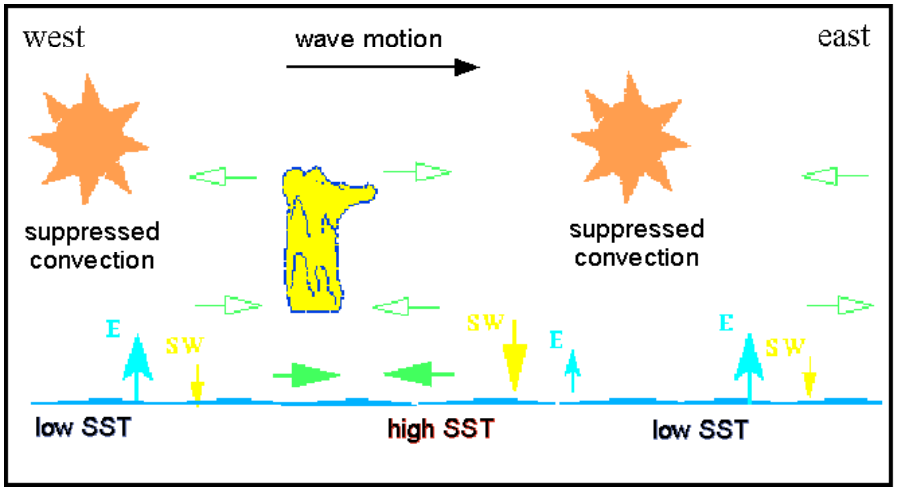


- using Earth-referenced vertical wind
- Calculated from five level flight segments at 1280 m AGL, 430 s total (shown with white arrow, above), begin: 1225 PST
- 30-s Hanning window is used for the spectral calculation.

Evolution of vertical profile of T, virtual potential temperature – Camp Roberts 01/2011



Dynamic of the Madden Julian Oscillation - DYNAMO (nsf)
Air-Sea Coupling in the Indian Ocean ONR DRI



Schematic of the MJO. The cross section represents the equatorial belt around the globe, or just the eastern hemisphere. E stands for evaporation, SW for net shortwave radiation absorbed by the ocean. The converging bold green arrows indicate the location of strongest moisture convergence. The hollow green arrows show the anomalous circulation associated with the MJO. The areas of enhanced convection are indicated by the yellow schematic thunderstorm. (adapted from Elleman 1997)

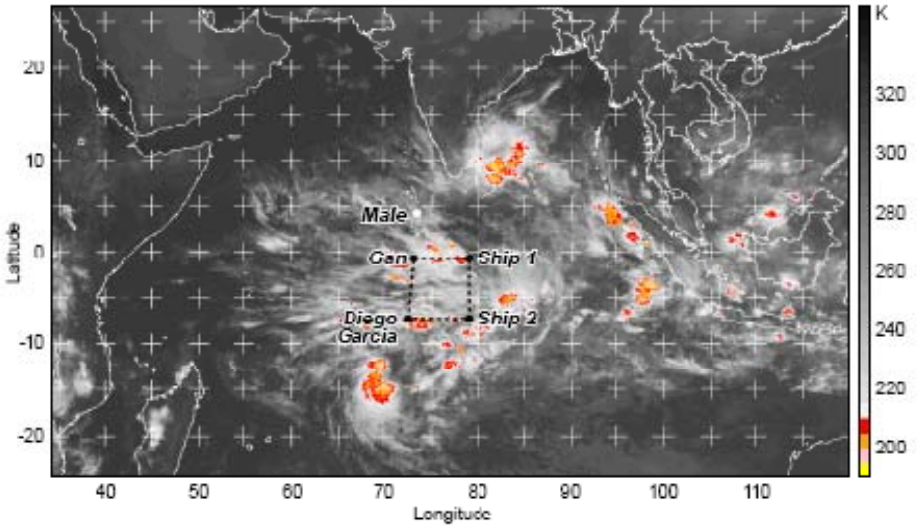


Figure 1. Some of the important elements of DYNAMO, an experiment in the region of MJO initiation in the Central Indian Ocean. The shaded contours show the cloud top temperature. The lower values (shown in white, red, orange, pink, and yellow) indicate areas of deep convection on 21 UTC 12 Dec 2007. The square box is the DYNAMO area of interest, with key measurements planned at four primary DYNAMO observing sites (black dots).

MJO effort overview

Deployment of ScanEagle UAVs from the R/V Revelle during the Tuticorin-to-Tuticorin cruise (12/2011-01/2012, Rob Pinkel/Jerome Smith, Chief Scientists) as part of the joint field program with NOAA/NSF (DYNAMO) and International partners (CINDY 2011: Japan, India, Australia).

To enhance the capabilities of research vessels in the Coupled Air-Sea Processes DRI , these capabilities include the measurement of air-sea fluxes, marine atmospheric boundary layer (MABL) variables, and surface signatures of ocean boundary layer (OBL) processes.

A - Air-sea Fluxes and the Marine Atmospheric Boundary Layer

(Eddy Momentum, heat, moisture fluxes, atmospheric soundings, surface wave measurements)

- To measure spatial decorrelation scales of the air-sea fluxes and related MABL variables relative to the research vessel.

B - Atmospheric Convection & Precipitation

- In conjunction with weather radar, measure horizontal entrainment velocities approaching the perimeter of the convective cell.
- Correlation of recently precipitated pools of cooler fresher water at the surface with the convective activity.

C - The Diurnal Surface Layer

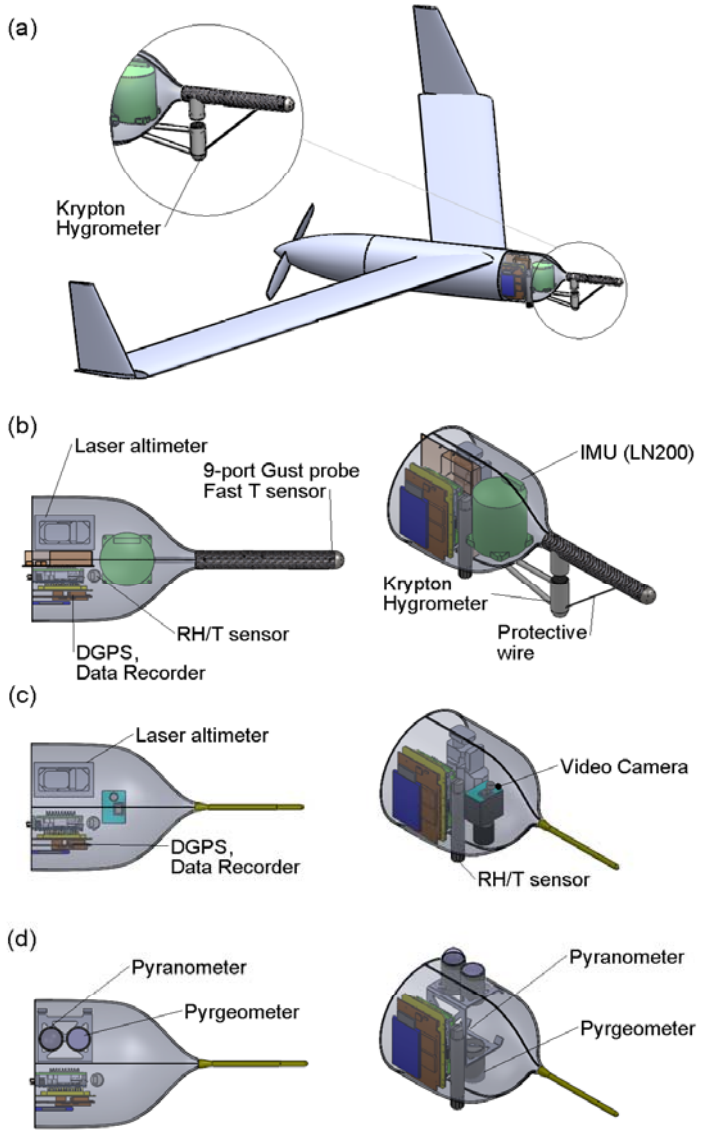
Coordinated flights with the tethered array of wirewalkers profiling the DSL (air-sea fluxes, waves, met.)

D - Surface Wave Processes and Mixing

ScanEagle UAS for Air-Sea Interaction Research

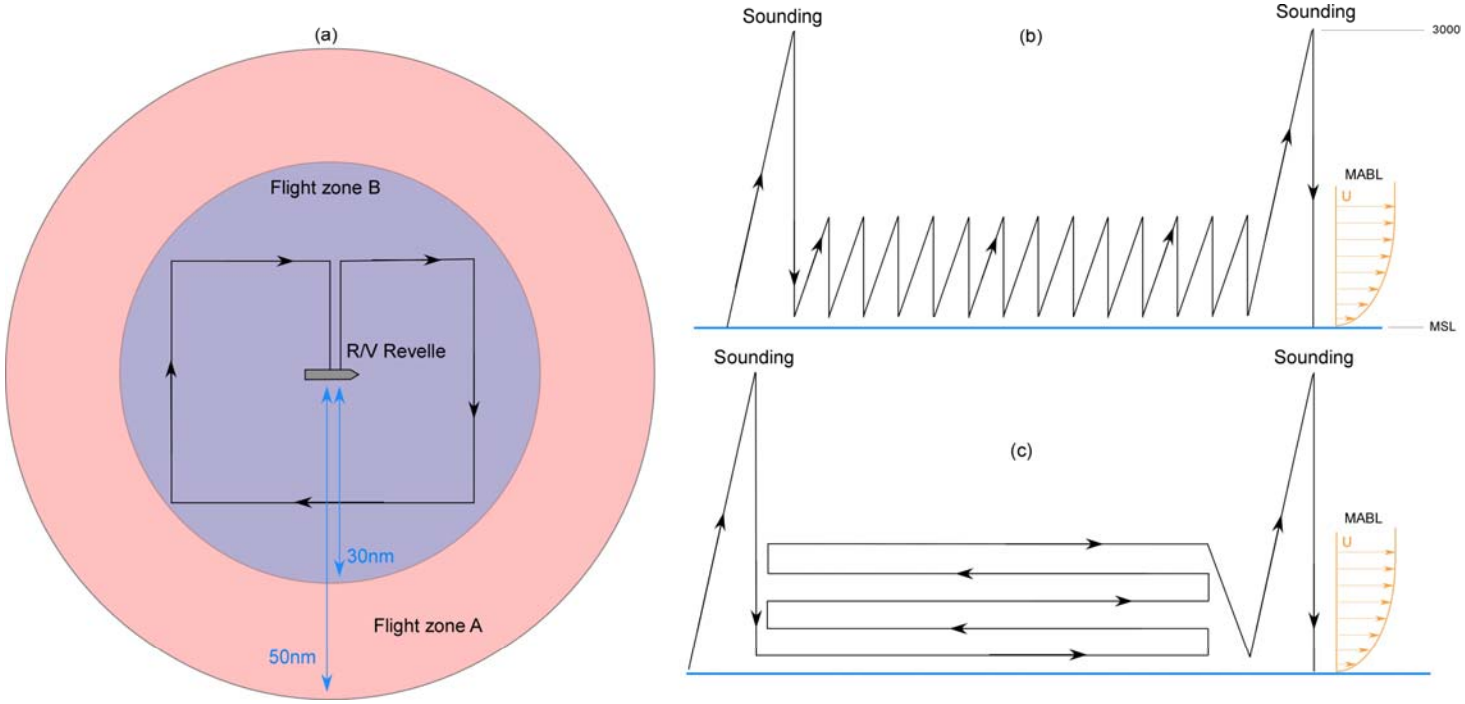
Table 1: Boeing InSitu ScanEagle specifications

	Boeing Insitu ScanEagle
Mission Endurance	Up to 24 hours
Fuel Type	Gasoline (100 octane unleaded non-oxygenated gas) or Heavy fuel (JP5, JP8, Jet-A)
Mission Airspeed	48 kts
Dash Speed	80 kts
Stall Speed	36 kts
Navigation System	Insitu
Service Ceiling	5 km
Command and Control Radio	900 MHz UHF datalink
Control Radio Range	20 nm LOS / "unlimited" with Satellite
Payload Capacity	2 kg (<8 hrs endurance) 6 kg total fuel and payload combined (24 hrs endurance with 5.4 kg fuel)
Power available for payload	Battery (included in payload)
Fuel Capacity	N/A
Engine	1.9 hp (1.4 kw), 2-stroke engine
Wing Span	3.11 m
Fuselage length	1.37
Tail Height	N/A



(a) ScanEagle UAS equipped with one of the air-sea interaction payloads. (b) example of proposed payload, for MABL lower altitude that includes 9-port turbulence probe, laser altimeter, fast response fiber optic temperature sensor, water vapor, RH/T. Upper altitude packages are shown in (c) equipped with laser altimeter and digital camera and (d) with a set of downward/upward looking pyranometers and pyrgeometers for SST and net radiation measurements. (In (b) to (d), plan views of payloads are in the left column.)

ScanEagle UAS flight zone around R/V Revelle

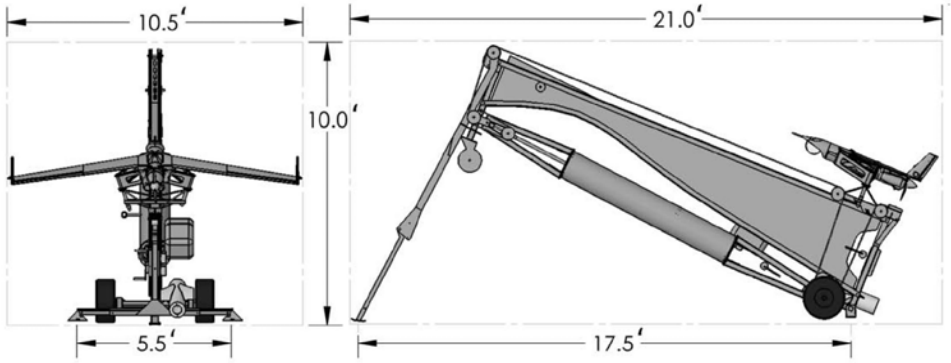


ScanEagle UAS Launch & Recovery

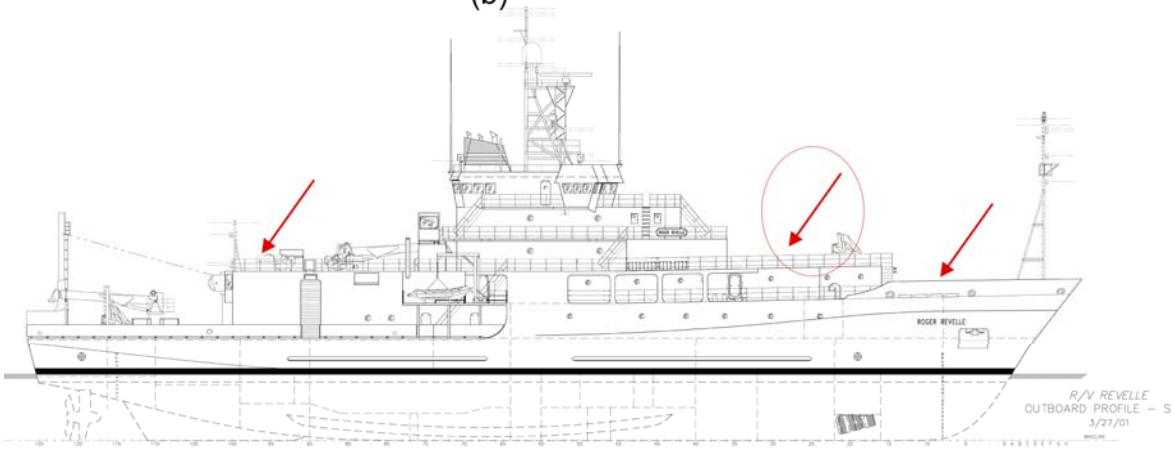
ScanEagle approaching a ship for its autonomous landing. The UAV is recovered using Boeing InSitu's SkyHook system, in which ScanEagle catches a cable hanging from a 50ft-high pole (Photo credit: Evergreen).

ScanEagle launched from vessel (photo credit: Boeing)

(a)

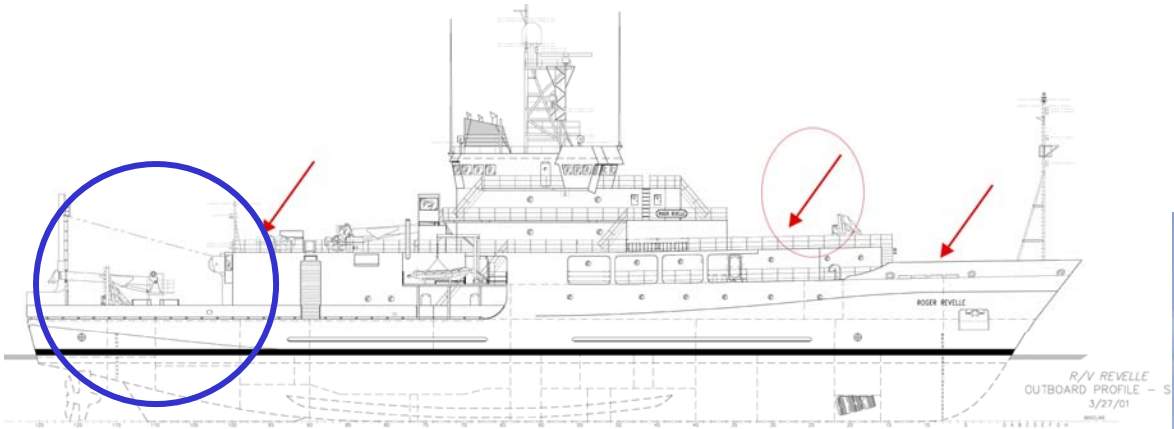


(b)

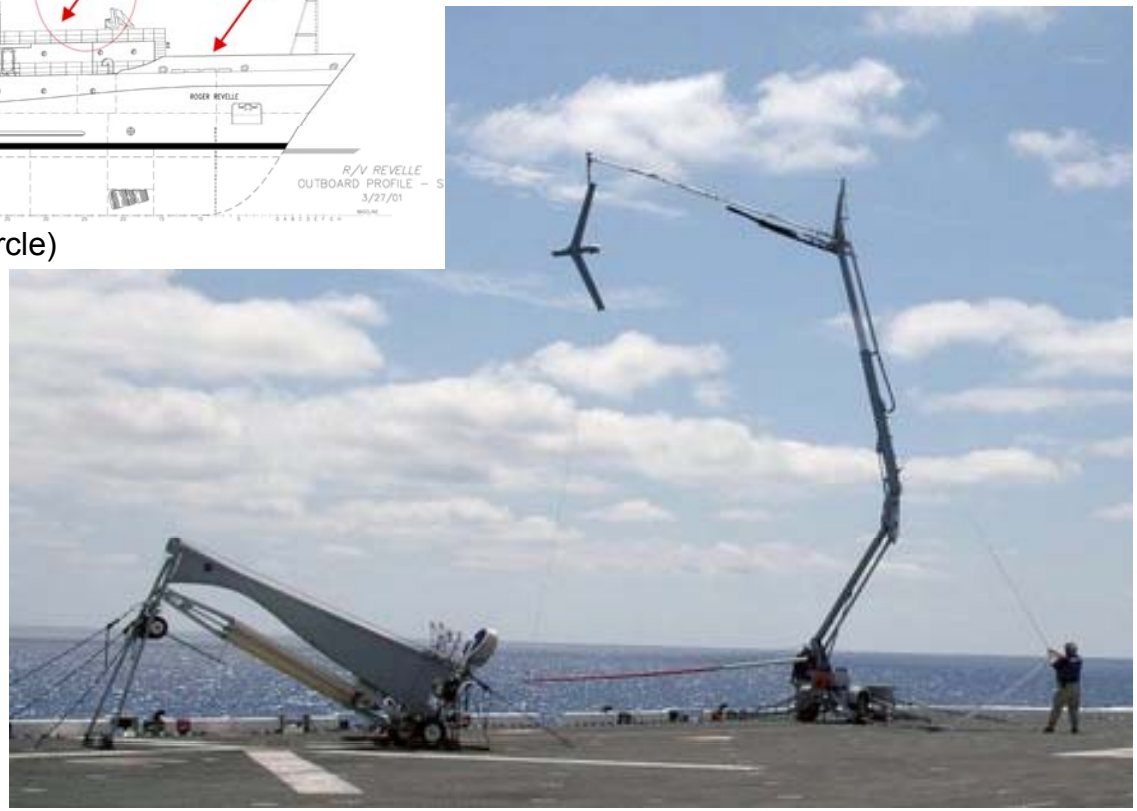


Proposed launcher location (red arrow, preferred location circled)

ScanEagle UAS Launch & Recovery



Proposed Recovery unit location (blue circle)



Program status – ScanEagle Platform

Original plan:
Use NPS ScanEagles (managed by Bob Bluth) operated by Evergreen.

BUT…..

- NPS ScanEagles are no longer available for this effort (03/2011)
- Evergreen, now VT group is no longer interested in supporting this effort (03/2011)

Two options identified:
- ISR group, UAS operator could provide flight support, launch and recovery equipment, 3 ScanEagles (05/2011)

- Naval Surface Warfare Center Dahlgren Division (NSWCDD) able to provide flight support, launch and recovery equipment, 5-6 ScanEagles for the DYNAMO AGOR/UAS scientific demonstration (06/2011)
Statement of work & schedule due 06/24

Program status – Payload and experiment preparation

Payload preparation:
11/2010: Science proposal submitted (start date: 02/11), funding started 06/01/2011
05/2011: Order submitted to Insitu for payload bays and blank noses (needed asap for instrumentation integration. Lead time 3+mo.
06/2011: DURIP Instrumentation award announced.
06/2011: Dahlgren NSWCDD has access to spare payload bays and blank noses