CEOI-ST Technology Conference 2015
Cosener's House, Abington
April 22nd 2015

The NASA CYclone Global Navigation Satellite System (CYGNSS) Mission

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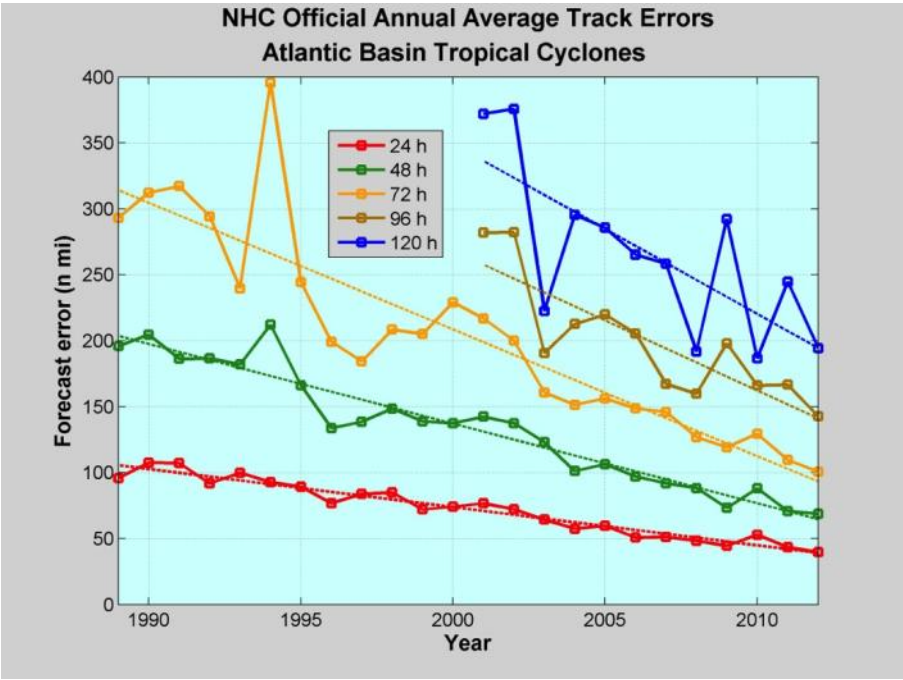
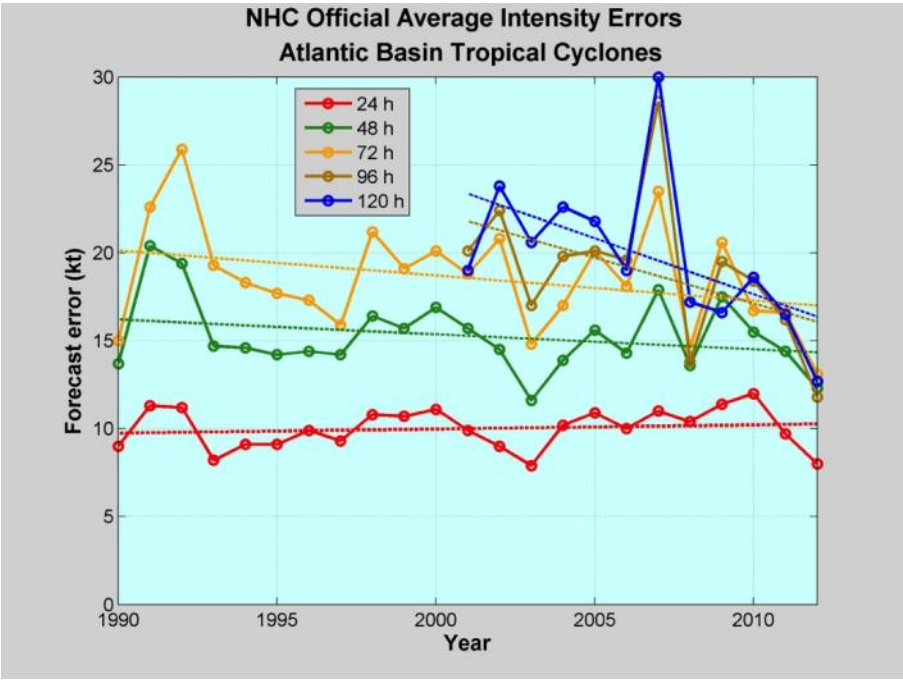
CYGNSS Science Motivation

- Tropical cyclone track forecasts have improved in accuracy by ~50% since 1990, largely as a result of improved mesoscale and synoptic modeling and data assimilation. In that same period, there has been very little improvement in the accuracy of intensity forecasts.

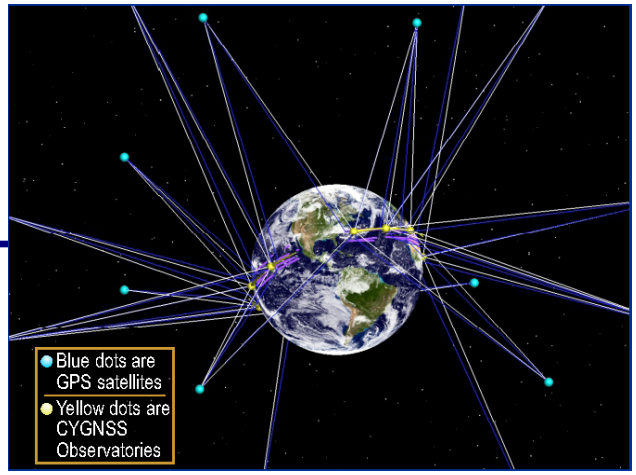


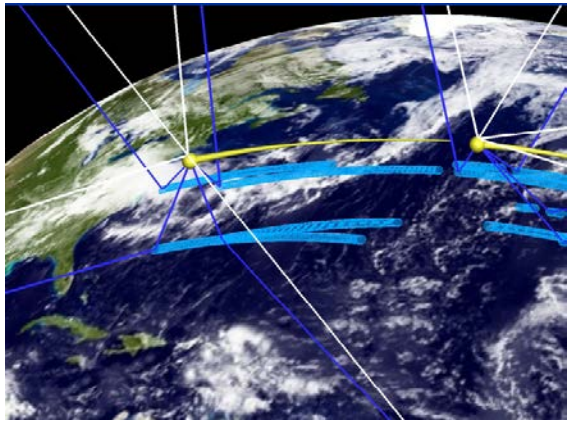


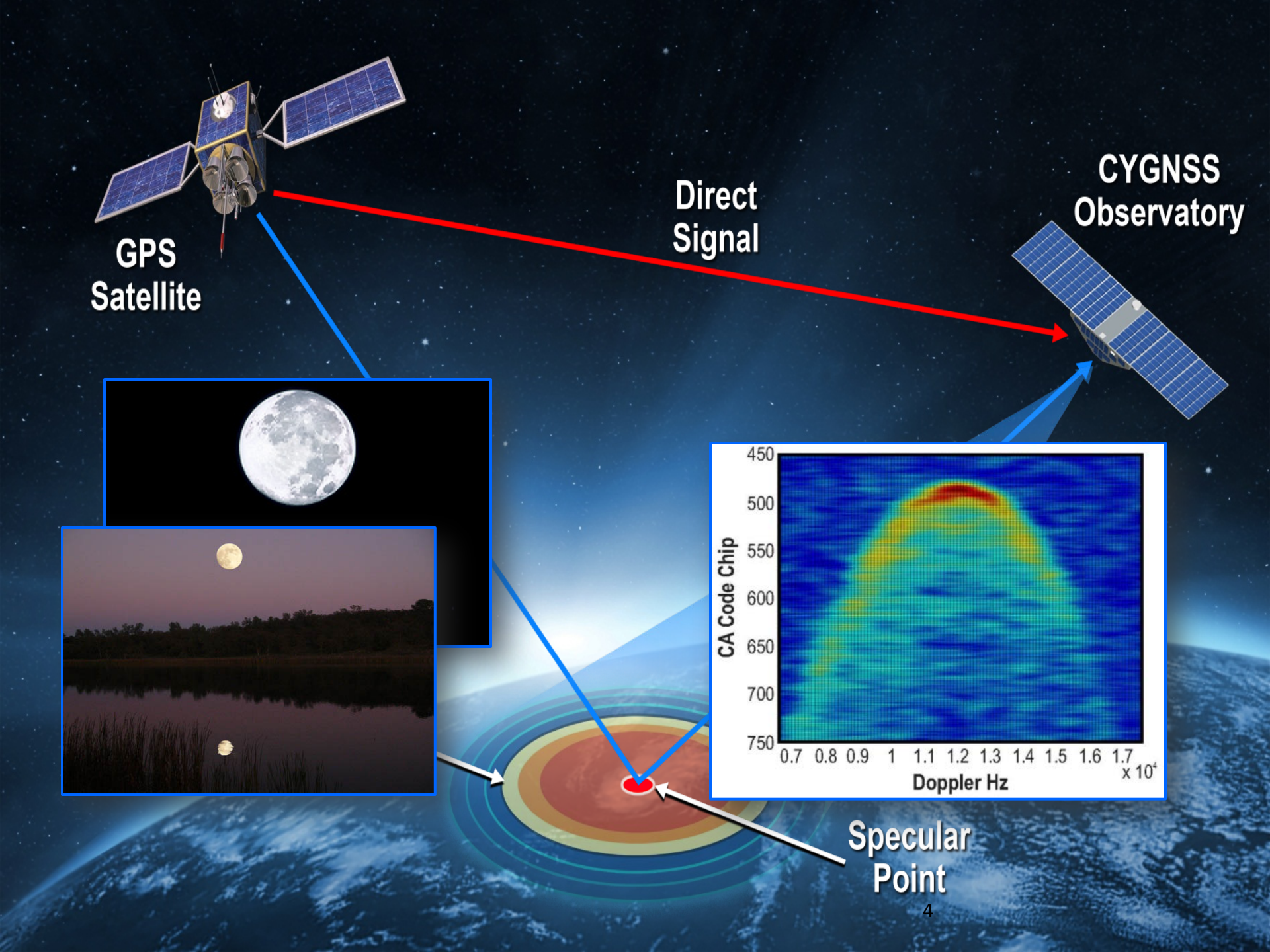
National Hurricane Center, http://www.nhc.noaa.gov/verification/verify5.shtml

CYGNSS Objectives and Mission Design

- CYGNSS Objectives
  - Measure ocean surface wind speed **in all precipitating conditions**
  - Measure ocean surface wind speed in the TC inner core **with sufficient frequency to resolve genesis and rapid intensification**
- CYGNSS Mission Design
  - Eight microsatellites in low earth orbit at 35^{o} inclination, each carrying a modified L-Band GPS receiver capable of bi-static scatterometer measurements of GPS signals reflected by the ocean surface



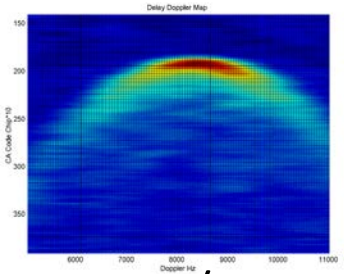



GPS
Satellite
Direct
Signal
CYGNSS
Observatory
CA Code Chip
450
500
550
600
650
700
750
0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7
x 10^4
Doppler Hz
Specular
Point

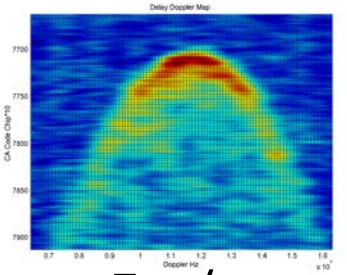
Spaceborne Empirical Demonstration of Ocean Wind Speed Retrievals by GNSS-R

DDMs measured by GNSS-R instrument (early version of CYGNSS science payload) deployed on UK-DMC-1 mission (launch 2003) with co-located NDBC buoys for wind speed ground truth

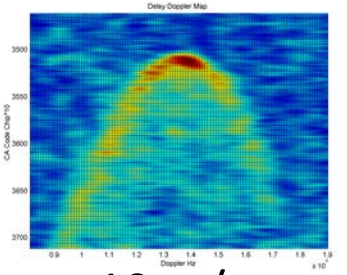
Software-based generation of DDMs in ground processing with <<1% duty cycle



2 m/s



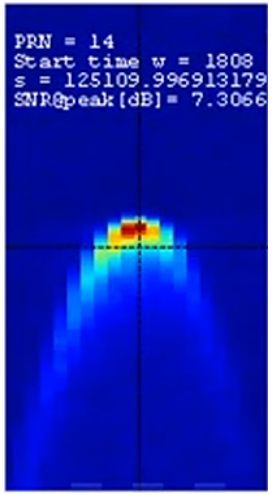
7 m/s

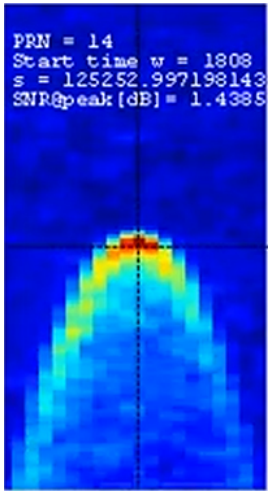


10 m/s

DDMs measured by GNSS-R instrument (nearly identical to CYGNSS DDMI science payload) deployed on TDS-1 mission (launch 2014). Ground truth co-location and intercomparison analysis in progress

Firmware-based generation of DDMs in real time with 100% duty cycle





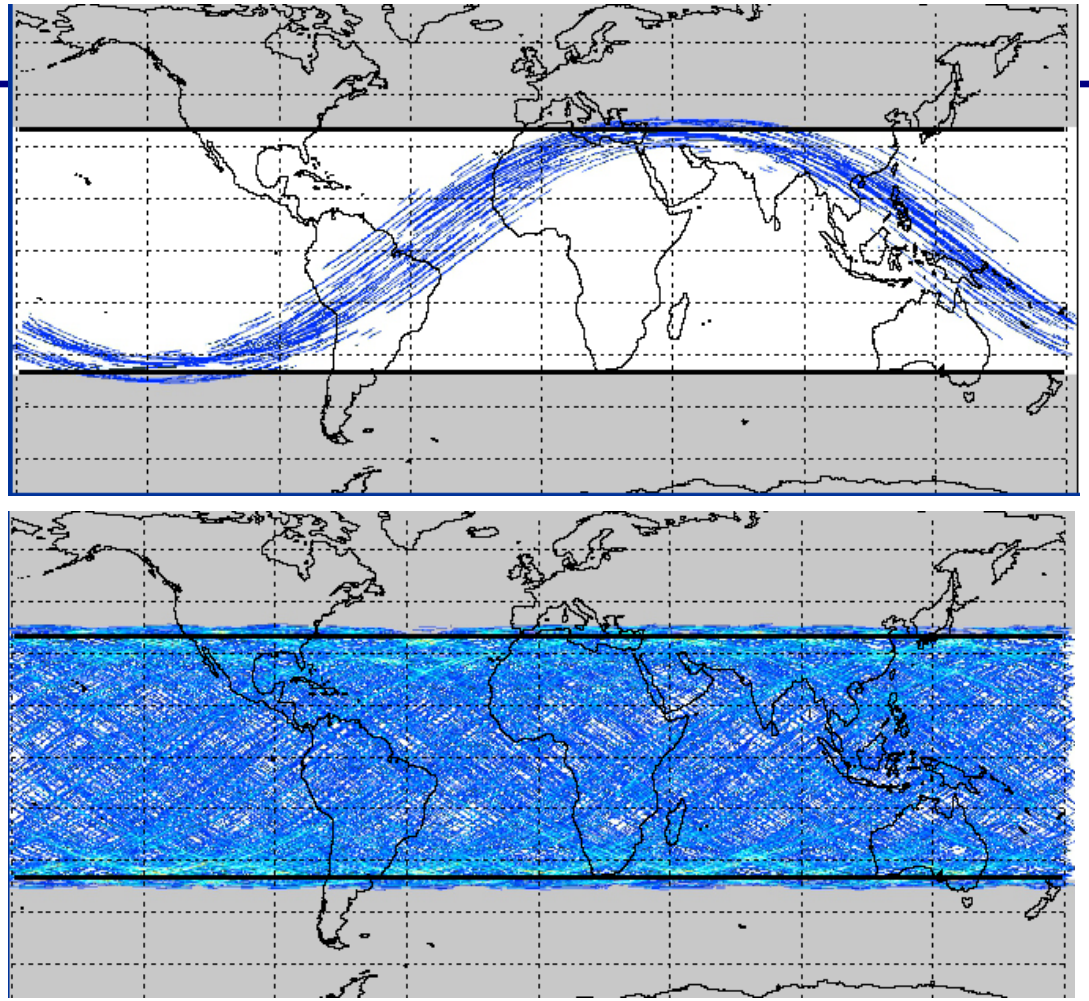
CYGNSS Measurement Performance

Science Objective	Scientific Measurement Estimated Performance	
	Parameter	Performance
Measure ocean surface winds under TC conditions	"Operate through" Precip	< 100 mm/hr (25 km footprint)
	Windspeed uncertainty	Greater of 2 m/s or 10% of windspeed
	Spatial resolution	Variable 15-50 km (ground processing)
	Windspeed dynamic range	< 70 m/s (Cat 5)
Measure ocean surface winds in TC inner core with high temporal frequency	Revisit time	~3 hr (median); ~7 hr (mean)
	Earth coverage	> 70% coverage of all historical TC storm tracks

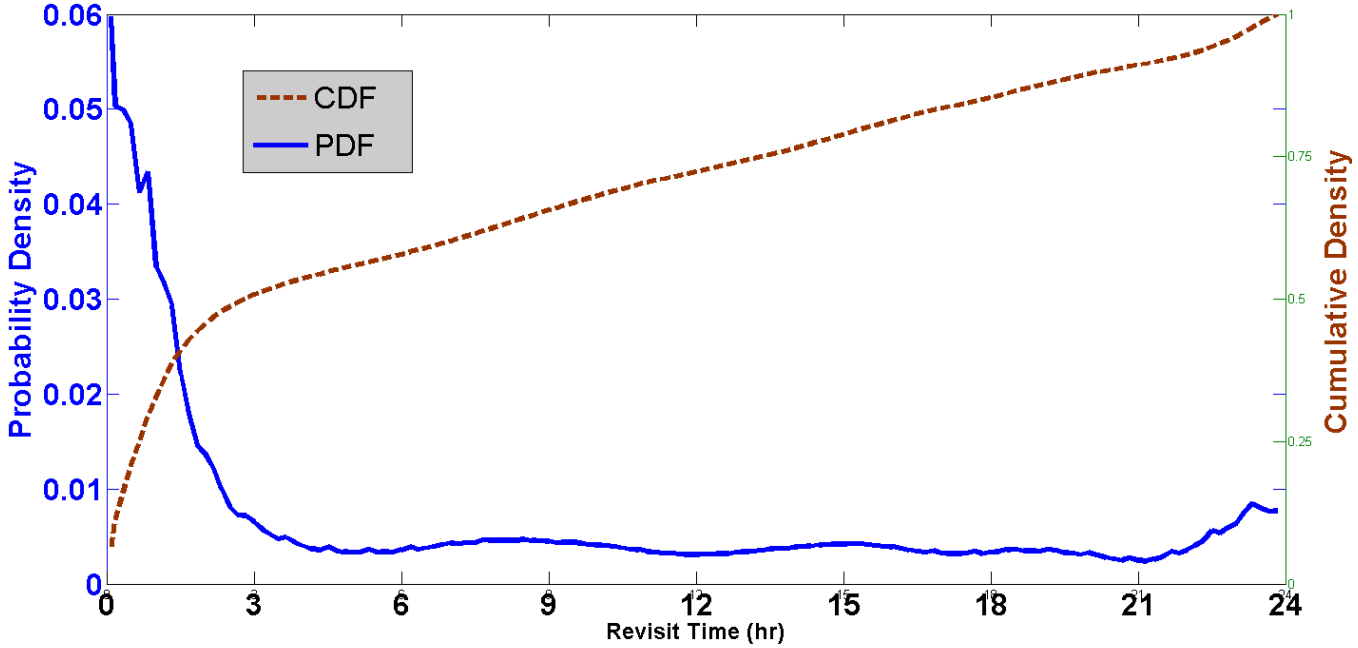
CYGNSS Spatial Sampling

CYGNSS Earth Coverage

- 90 min (one orbit) coverage showing all specular reflection contacts by each of 8 s/c
- 24 hr coverage provides nearly gap free spatial sampling within +/- 35 deg orbit inclination

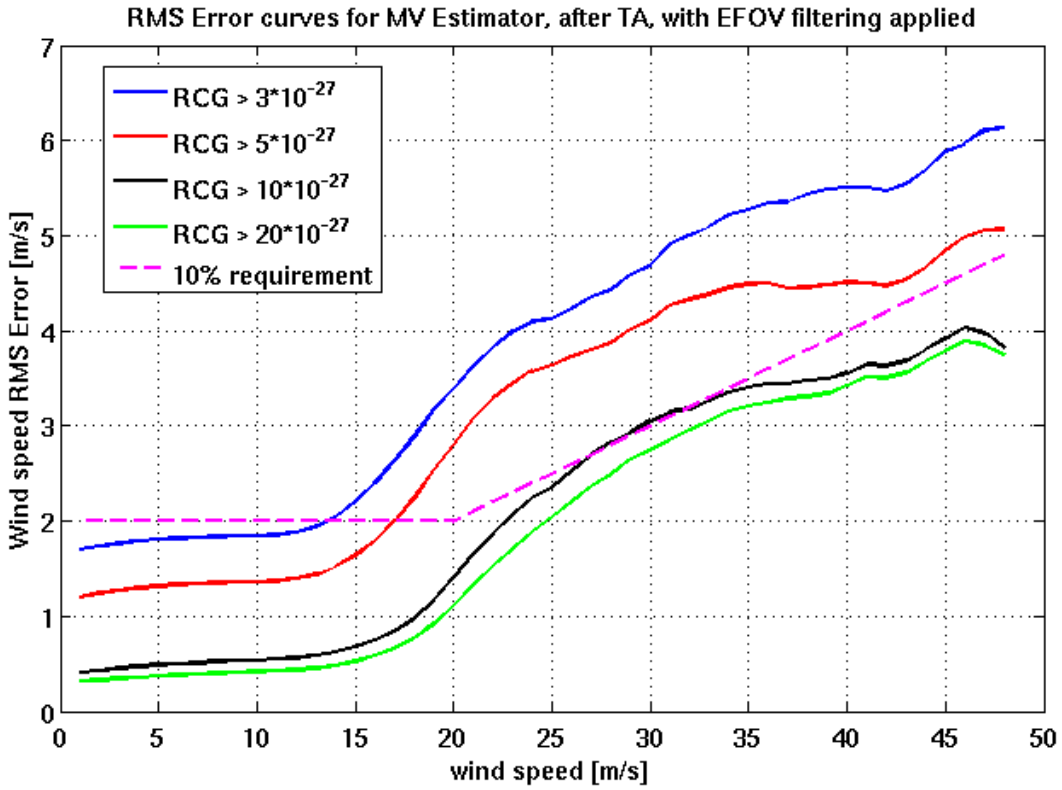


CYGNSS Revisit Time



- Probability distribution of revisit time for all Earth samples within +/-35°
- Revisit stats derived from PDF demonstrate **<u>7.2 hr</u>** mean storm revisit (requirement is 12 hr)

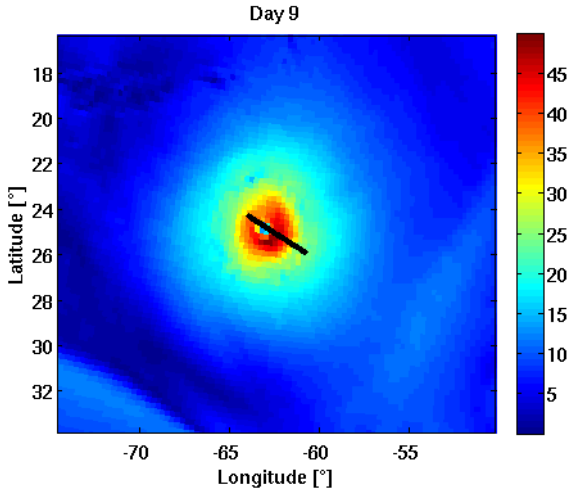
RMS Error for different RCG thresholds (25 km spatial resolution)

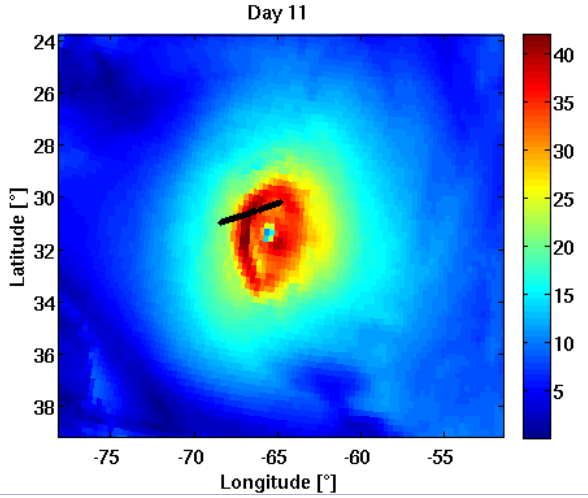


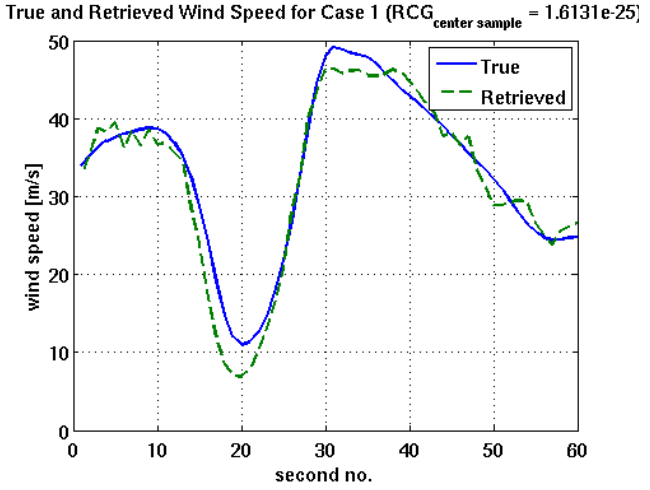
RCG = Range Corrected Gain

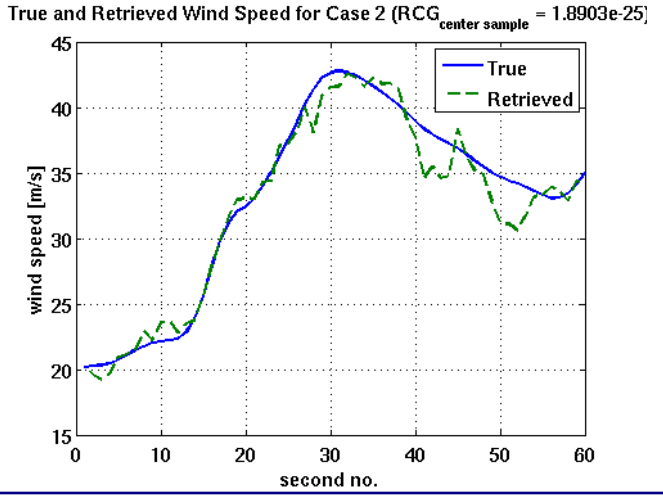
Wind speed range	<20m/s	>20m/s
RCG lower bound	**>5**	**>10**
Avg. RMS error	**1.4 m/s** (req. is 2 m/s)	**9.2%** (req. is 10%)

True vs. Retrieved Winds for Storm Center Transects







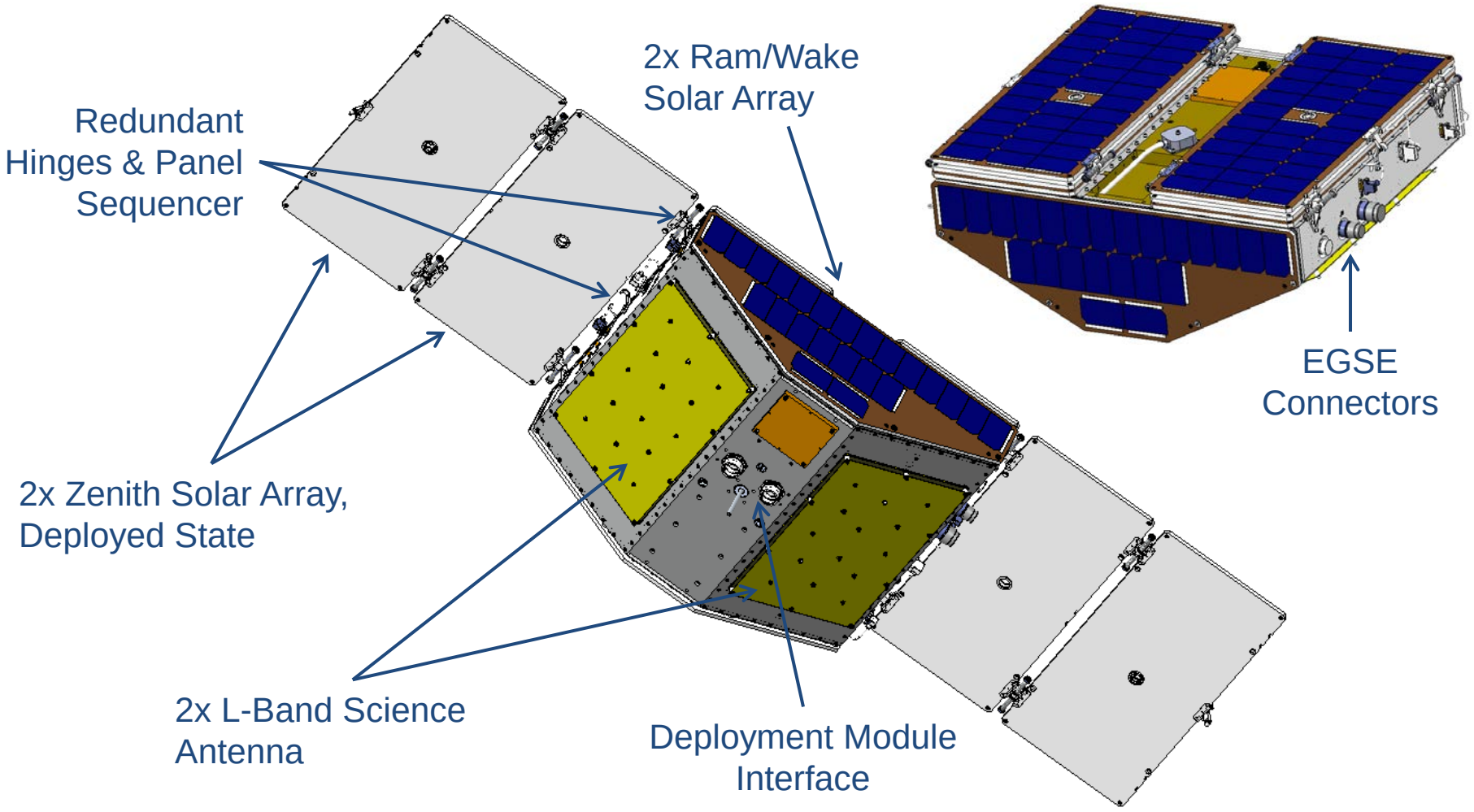


Performance Summary

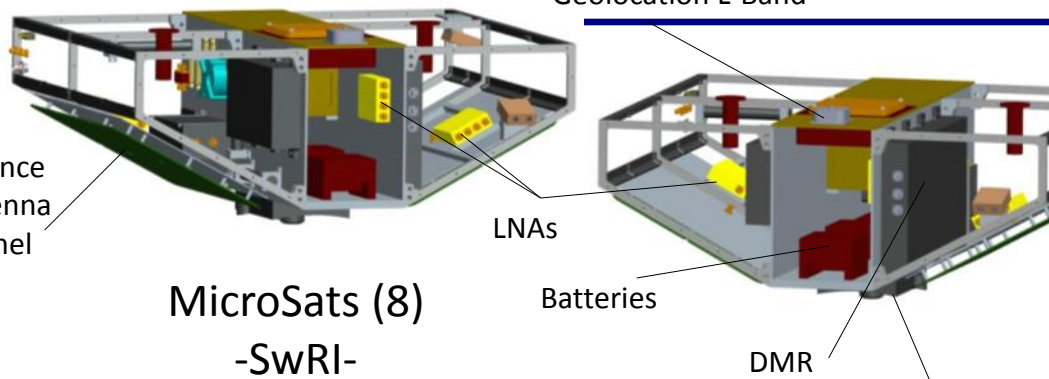
- Level 1 baseline science requirements are all met with margin

Requirement		Projected Performance
Spatial coverage	> 70%	78.9% (8 s/c), 74.3% (7 s/c)
Temporal revisit (mean)	< 12 hr	7.2 hr
Spatial resolution	25 km	25 km
Wind speed uncertainty <20 m/s	< 2 m/s	1.4 m/s
Wind speed uncertainty >20 m/s	< 10%	9.2 %

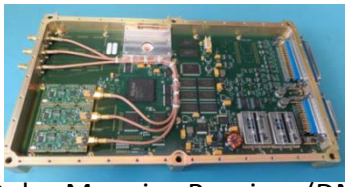
Observatory Configuration (underside)



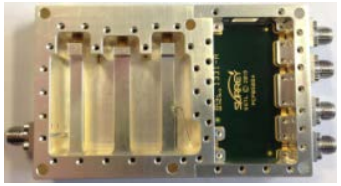
Key Mission Elements (1/2)



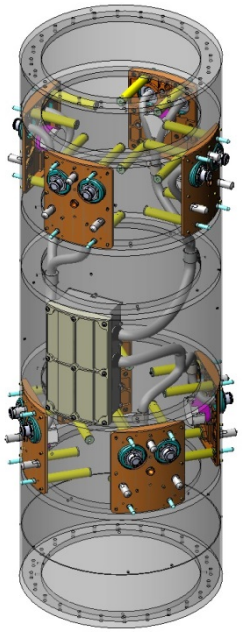
MicroSats (8)
-SwRI-



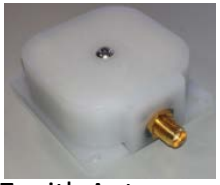
Delay Mapping Receiver (DMR)



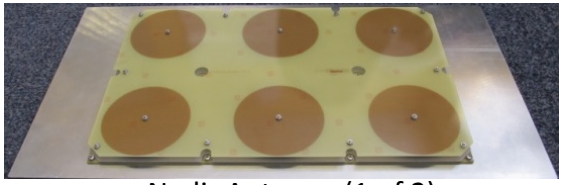
Low Noise Amplifier (LNA, 1 of 3)



Deployment Module (DM)
-SNC-



Zenith Antenna



Nadir Antenna (1 of 2)

Payload: Delay Doppler Mapping Instrument (DDMI)
-SSTL-

Launch Vehicle: Government Furnished Pegasus XL

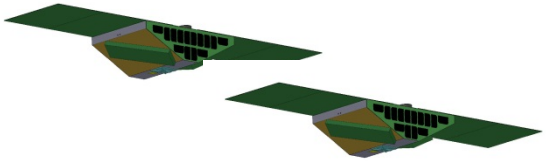
Key Mission Elements (2/2)

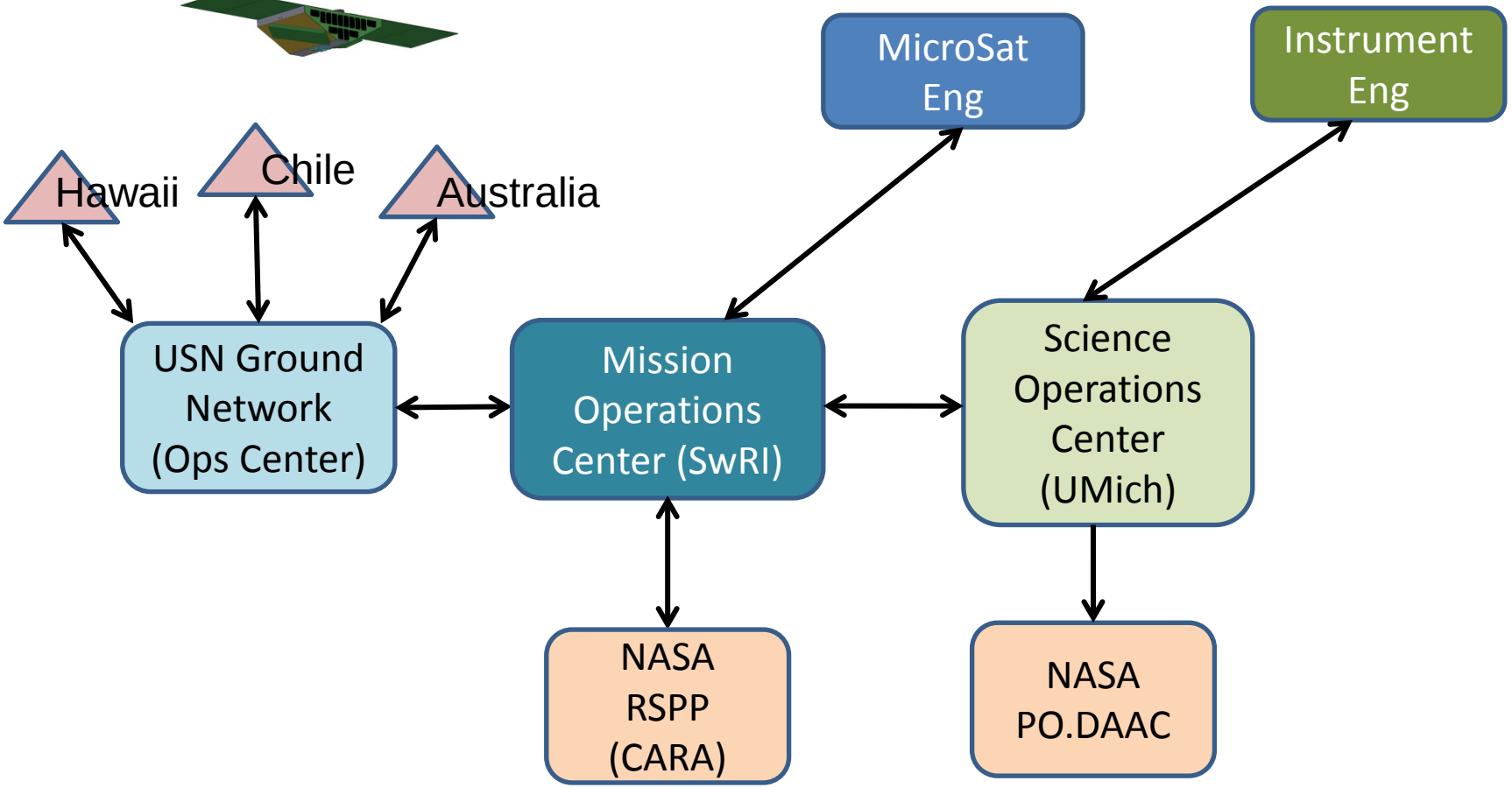
Ground Network
-USN-

Mission Operations Center (MOC)
-SwRI-

Science Operations Center (SOC)
-UM-

Ground System Block Diagram





Science Data Products

Data Product	Description	First Data Delivery after IOC	Maximum data latency after first release
Level 0	**Raw data** of total system power (received signal + instrument noise)	2 Months	**6 days**
Level 1a	**Calibrated DDMs** of received power	2 months	**6 days**
Level 1b	**Cal'd DDM** of bistatic radar cross section	2 months	**6 days**
Level 2a	**Spatially averaged windspeed** (plus uncertainty) over a 25 x 25 km2 region centered at the specular point, geolocated, in spacecraft time & space coordinates	2 months	**6 days**
Level 2b	**Spatially averaged mean square slopes** (plus uncertainty) over a 25 x 25 km2 region centered at the specular point, geolocated, in spacecraft time & space coordinates	2 months	**6 days**
Level 3a	**Wind speed, gridded** in space and time (1/4° lat and long, 3 hours)	3 months	**6 days**
Level 3b	**Wind speed, gridded and optimized** for observing system experiment data assimilation (optimised spatial and temporal resolution)	3 months	**6 days**

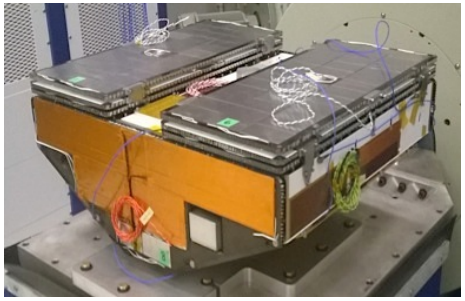
Project Schedule

Date	Milestone
Dec 2012	Project start
Jun 2013	System Requirements Defined
Jan 2014	Overall System Design Completed
Jan 2015	Detailed Design Completed
Mar 2015 – Jun 2016	Build, Assemble & Test the Spacecraft
Jul-Aug 2016	Integrate Spacecraft and Launch Vehicle
Oct 2016	LAUNCH
Oct 2016 – Mar 2017	Spacecraft commissioning, Science payload and algorithm calibration and validation
Oct 2016 – Sep 2018	On-orbit Mission Lifetime
After Sep 2018	Extended mission

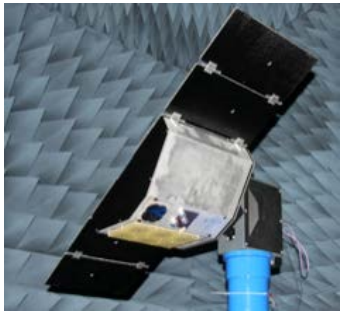
Outcome of CYGNSS Critical Design Review (CDR)

- The observatory design has been validated by building and testing three complete prototypes:
  - Electrical Model (EM)
  - Structural Thermal Model (STM)
  - Radio Frequency Model (RFM)
- The payload (DDMI) design has been validated with simulated signal benchtop testing and TDS-1 on-orbit performances
- **The design is mature, and we have entered the flight hardware build phase**

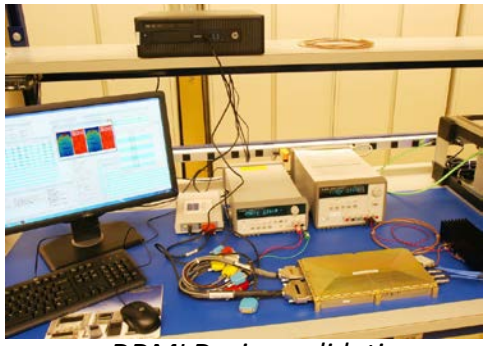
Electrical Model



Structural Thermal Model



Radio Frequency Model



DDMI Design validation

Thank You

for more information visit **http://cygnss-michigan.org**

email us : **clarizia@umich.edu**, **cruf@umich.edu**

or work with us:

We are currently looking for a Post-Doc/ Research Scientist to support the activities of the CYGNSS Science Operation Center (algorithm development, cal/val activities, special modes of operation) and to conduct research related to the CYGNSS mission.

The position requires a Ph.D. degree in a related field (*e.g.* Atmospheric Science, Meteorology, Physics, Engineering), and familiarity with tropical meteorology and Earth remote sensing.

Talk to me if you are interested !