Cyclone Global Navigation Satellite System Lessons Learned

PI Masters Forum #7

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SPACE PHYSICS RESEARCH LABORATORY

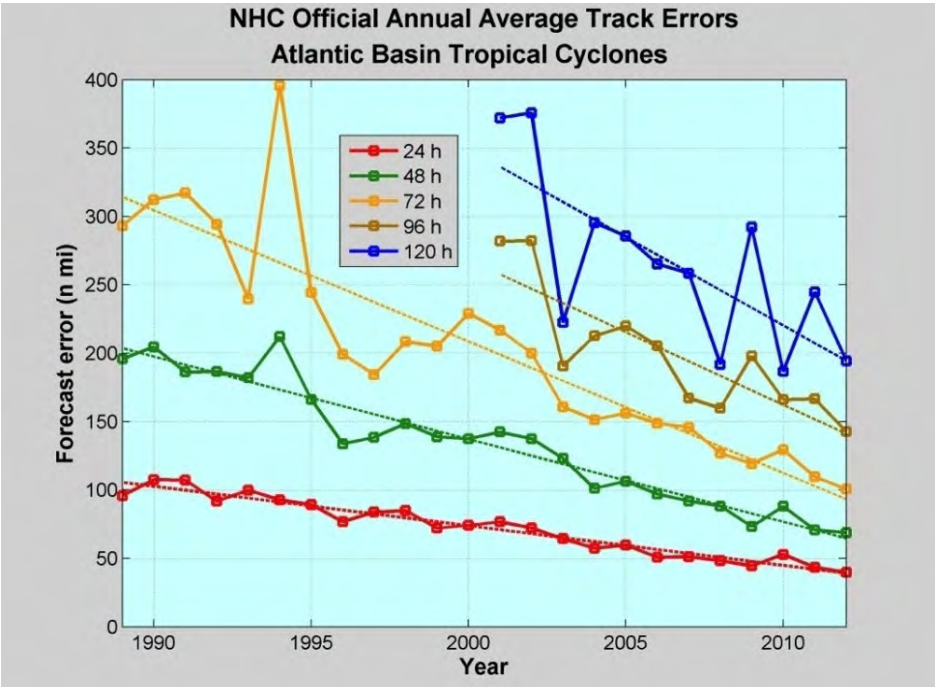
SwRI

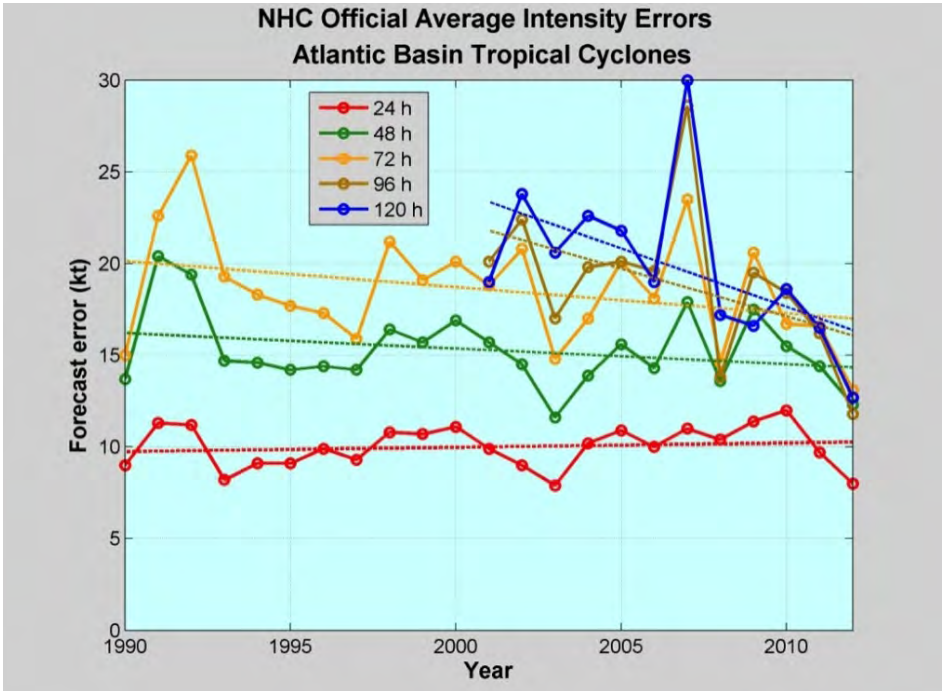
SURREY SATELLITE TECHNOLOGY

NASA

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 essentially no improvement in the accuracy of intensity forecasts.





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

CYGNSS Objectives and Mission Design

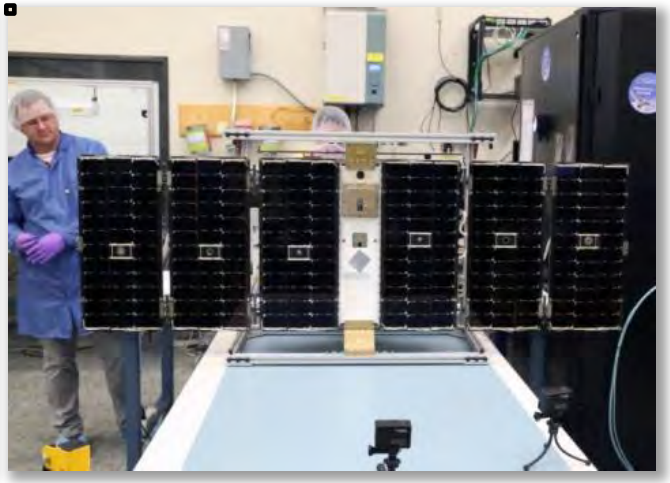
- CYGNSS Objectives
  - Measure ocean surface wind speed in ***all precipitating conditions***, including those experienced in the tropical cyclone (TC) eyewall
    - *Drove the measurement technique*
  - Measure ocean surface wind speed in the TC inner core with ***sufficient frequency*** to resolve genesis and rapid intensification
    - *Drove the mission to be a constellation*
- CYGNSS Mission Design
  - Eight satellites in low earth orbit at 35° inclination, each carrying a four-channel modified GPS receiver capable of bistatic radar measurements of GPS signals reflected by the ocean surface

Implementation

- Team:
  - Univ. of Michigan (PI C. Ruff)
    - Lead, thermal, SOC
  - SwRI
    - Mission PM, SE, SMA, Spacecraft, I&T, MOC
  - Surrey
    - Payload (FFP procurement)
  - SNC
    - Solar Arrays and Deployment Module
- Overview
  - First ESSP Earth Venture Mission
  - Cost cap: $100M, not including GFE LV
  - Non-competitive Phase A
  - 48 months from start of Phase A to launch (with 2 months of launch delay ironically caused by Hurricane Matthew)

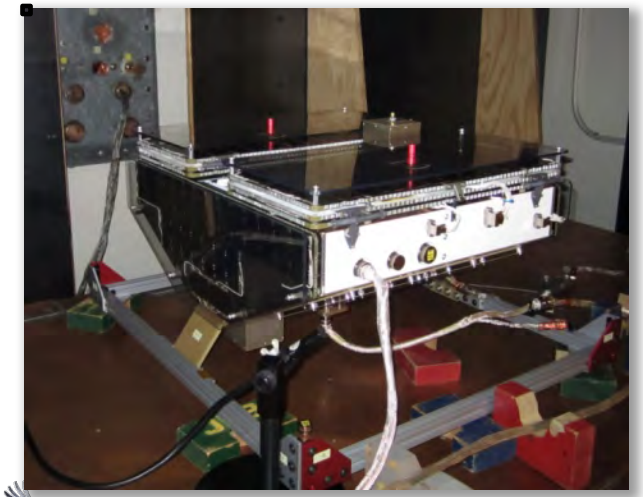
Observatory Photo Gallery

Microsat Integration

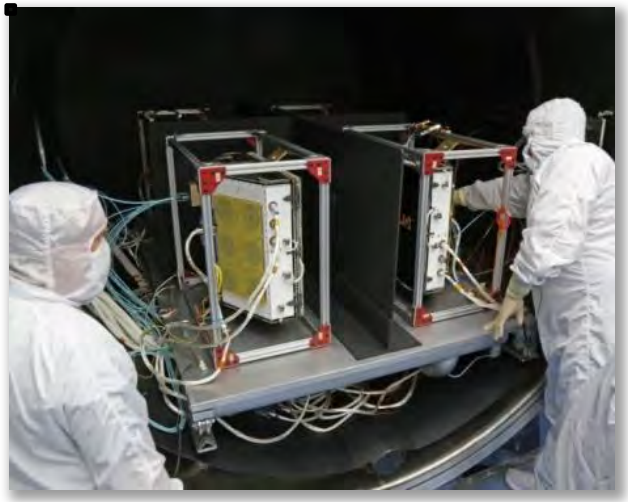


Solar Array Deployment

FM2 Random Vibe



Obs EMI/EMC Test



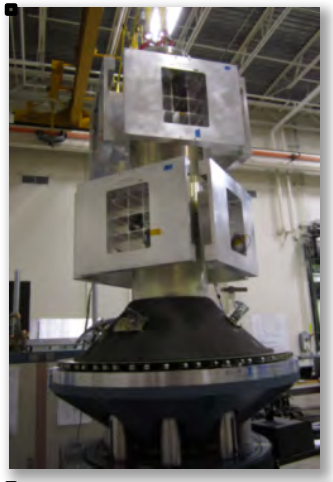
4 Obs in Thermal-Vac Chamber

L-Band NFT in RF Chamber

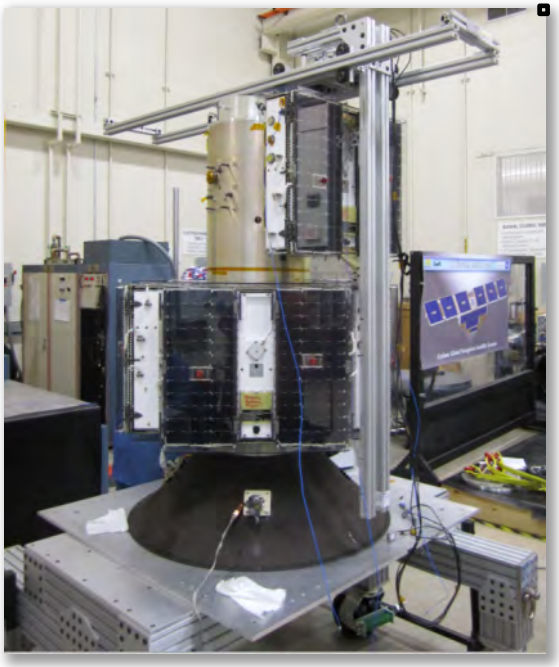
Flight Segment Photo Gallery

DM in Turn-over Fixture

MM install on DM



DM+MM Vibe



Obs install on DM

FS Shock Test

FS Vibe

FS Horizontal Lift Dry-Run

VAFB, Ferry and Launch

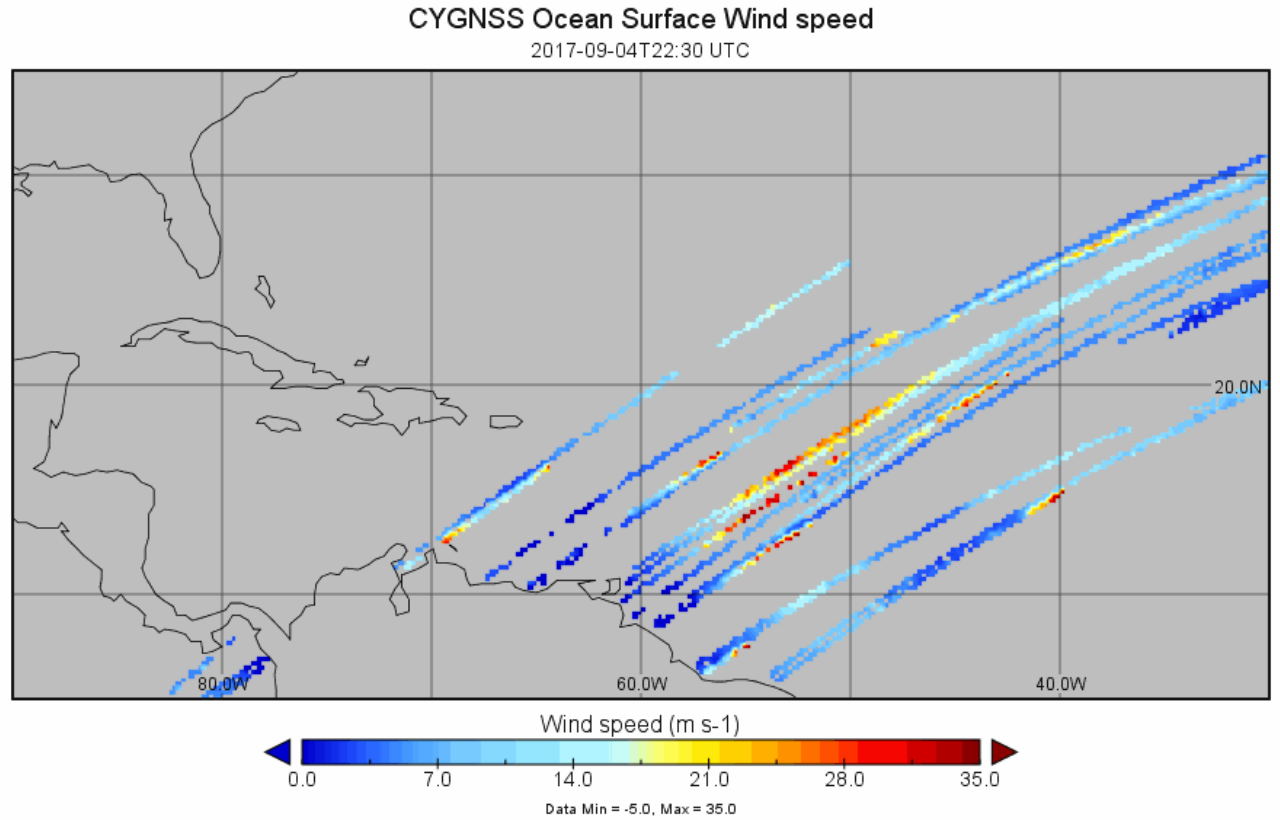
Incoming Inspection at VAFB

Fairing Installation

Lift off!

CYGNSS Overpass of Hurricane Irma

- CYGNSS Level 3 gridded surface wind speed data product (v1.1) at 12:30 on 4 Sep 2017



(v1.1 calibration is still preliminary)

Cyclone Global Navigation Satellite System

Lessons Learned

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Major Issue 1: Cost Cap

After selection, one of the major subsystem suppliers more than tripled its cost.

The Fix

- We immediately told the supplier that was not acceptable and re-opened the subsystem to bidding from other suppliers.
  - LaRC was kept in the loop throughout this process.
- We received two other competitive bids and an update to the original supplier's bid.
- PI informed ESSP that we wanted to switch providers, and they wholly agreed (as did NASA HQ).

In Hindsight

- We were correct in the proposal, and ultimately we were correct in changing providers.
- Keeping ESSP in the loop was key, and after the decision was made, we received compliments from NASA HQ.
- Changes should be expected over the life of the project.
  - NASA will have your back.

Major Issue 2: CubeSat Vendors-1

A month after CDR and after EMs had been received, the Torque Rod manufacturer sent an email that they were going out of business: “the doors were locked”. We had 27 flight units on order due in 6 months.

The Fix

- First: Panic, than assessment of options
  - We knew that we did not have the time to go through the typical procurement and contractual process.
- Viable options were:
  - UM build a flight set
  - Go with an existing vendor that was already under contract
- We ended up doing both as risk mitigation (UM rods are flying).

In Hindsight

- Again, be flexible because “stuff” happens that is out of your control.
  - That is what reserves are for
- When making a procurement, it is good (if possible) to have a hot backup.
- Moral of the story: CubeSat community is full of new, entrepreneurial start ups, some of which will not be around in 5 years.

Major Issue 3: CubeSat Vendors-2

Due to the newness of some CubeSat vendors – small size, fast growth, etc., their in house processes and procedures may not meet the rigors of typical NASA missions.

The Problem

- Not at all universal to all CubeSat vendors. On CYGNSS some vendors had many more issues than others, and many had no issues.
- Problems include:
  - Interface Suggestion Document vs. ICD, lack of CM, slow response to issues
  - Hardware not meeting spec'ed performance, and spec'ed performance changing with time
  - On orbit issues due to lack of rigor in design process (lack of fault detection)

The Fix and In Hindsight

- More oversight and insight
- Beefed up S/C FDC
  - This has been a key CYGNSS driver since launch.
- More thorough component-in-the-loop verification testing
- Reserves to handle component "features"
- CubeSat component price tag is not the total price.

Major Issue 4: LV Loads

Catch-22 of KSC/LV wanting test verified analytical model vs. the project not wanting to overstress hardware with overly conservative loads

The Fix

- This is a universal issue that is compounded with constellations because of additional interfaces between LV and S/C that are difficult to model.
- Fix is mission unique, but goal is to maximize time after flight segment vibe for CLA work by KSC/LV.

In Hindsight

- We probably should have done S/C TVAC after flight segment vibe; that would have bought a month for CLA work.
- Not really a good solution to speeding this up much more than that

Major Issue 5: Dealing with 8 S/C (Advantages and Disadvantages)

Not always an issue. There are advantages and disadvantages.

Disadvantages / Complications

- CM, CM, CM!
  - Impacts virtually all aspects of the project from manufacture and procurement to operations
- A systemic problem found on FM-8
- More complicated LV separation analysis
- Commissioning with a small team

Advantages / Simplifications

- Recurring activities are greatly increased, which is a good thing.
  - increased efficiency due to repetition
- A non-systemic issue does not “stop the train”; team can move to another S/C.

Additional Issue

- Certified Earned Value Management (EVM) now required
  - CYGNSS did EVM while being validated; the level of rigor, documentation, etc. that is currently required is a huge increase in scope from just 10 years ago.
  - Don't underestimate this effort. On CYGNSS, we had ~2 FTEs for schedule and financial reporting, which is probably not enough for fully compliant EVM.

Last Suggestions

- Reserves: Dollars and schedule should not be allocated to subsystems upfront. PI/PM should control and jealously guard them.
- Scope: Likewise, this is not the time for "it sure would be nice if". Fight against any new / increased scope.
  - Guaranteed, the issues you encounter in achieving your primary goals will be enough of a challenge for your cost and schedule without adding new scope.
- Word to PMs: Explorers Mission Manager is your closest ally.
  - Mission Manager will help diffuse and buffer you from NASA's high-gain, undamped system.
  - Key is to keep Mission Manager in the loop and with no surprises.

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Good Luck!

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