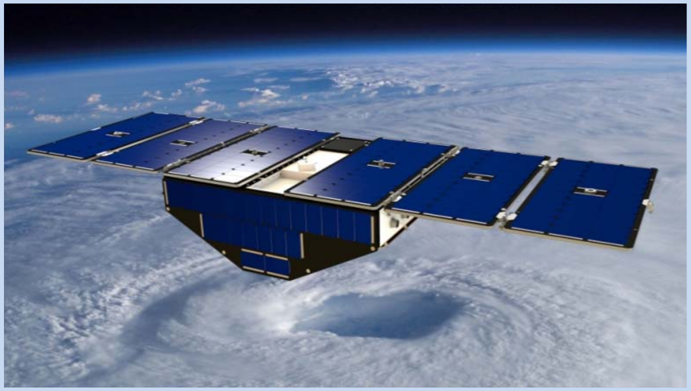

Cyclone Global Navigation Satellite System

Lessons (Being) Learned: Managing a More Cost-Effective NASA Mission

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Agenda

- Background
- CYGNSS overview
- Class D, really?
- CYGNSS specific efficiencies
- Overarching personal observations and suggestions

Southwest Research Institute (SwRI) Overview

- Independent, nonprofit applied research and development organization established in 1947
- Over 3,000 employees
- Broad Technological & Scientific Base
- Decentralized Organization
- Project Management Approach
- More than 1,000 patents

SwRI Space Program Overview

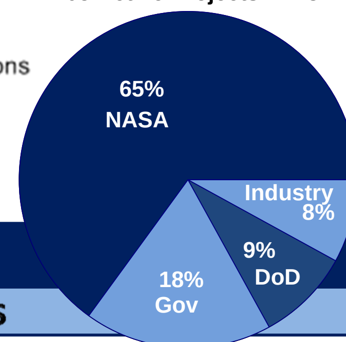
- World class Space Science Research and Instrument Development
- Industry leader in Mission Design and Management and Spaceflight Avionics
- Space Science and Engineering Division:
  - 344 Staff Members with Yearly Payroll of $33M (FY13)
  - Participation in over 85 missions since program started in 1977, with contracts totaling over $2B
  - $108M Total Revenue in FY13

Southwest Research Institute

SwRI Space Science and Engineering Division

- **Space Systems**
  - Space Engineering
  - Space Avionics
- **Space Science**
  - Instrument Systems
  - Science
  - Power
  - Software
- **Planetary Science**
  - Space Studies
  - Space Operations
- **Earth, Oceans and space**

205 Active Projects FY13



Projects Under Development

Avionics

(DreamChaser) Flight Control Computers

Actuator Control

Atmospheric Test 2015

Missions and Full Payloads

Cyclone Global Navigation Satellite System (CYGNSS)

Mission Management & Systems Engineering

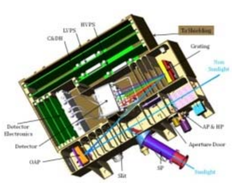
Launches 2016

Magnetospheric Multiscale (MMS)

Payload

Launches 2015

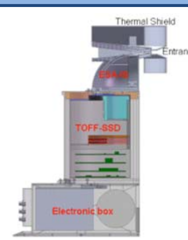
Instruments



Spectrograph (UVS) for Jupiter Icy Moons (JUICE)

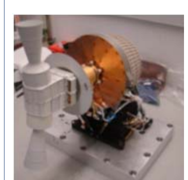
Energetic Particle Detector for Solar Probe +

Launches 2018



Heavy Ion Sensor (HIS) TOF for Solar Orbiter

Launches 2017



Strofio Mass Spectrometer for Bepi/ Colombo

Launches 2015

Hot Plasma Composition Analyzer (HPCA) for MMS

Launches 2015

Brief History of the Space Program at SwRI

1950-1980s

Late 1950s:
Improving Rocket Power Performance

1967-1970s:
Safeguarding Against Future Fires

1969-1970s:
Solving Tank Slosh Errors

1973/1974:
Monitoring Astronauts' Physical Condition

1980s: Failure Analysis Software for Shuttle Engine Components

NESSUS

1980s: Fracture Analysis Software for Space Systems

NASGRO

1981: Hot-Cold Plasma Interactions in the Magnetosphere

1983:
Attitude & Experiment Control Processing

1990s

1991:
Quantifying Global Ozone Change

1992:
Improving Performance of Spacecraft Computer

1992:
Creating Artificial Aurora

Instrument: SEPAC

1997:
Imaging the Hale-Bopp-Comet

1997:
Surveying Saturn and its Moons

1997:
Studying Liquid Motion in Rotating Tanks

1998:
Advancing Space Physics Measurement Technology

Instrument: PEPE

1999:
Searching for Vulcanoids

1999:
Command and Telemetry for Storm-Warning Mission

2000-2007

2000:
Imaging the Earth's Magnetosphere

2003:
Determining the Cause of the Columbia Accident

2004:
Analyzing a Comet's Composition

Instruments: IES (top), ALICE

2004:
Simplifying Spacecraft Computer Hardware Interfaces

2005:
Command & Control Computers for Deep Impact Mission

2006: Exploring Pluto-Charon and the Kuiper Belt

2006:
Avionics for Earth Climate Satellite

2006:
Capturing Stereo Images of the Earth's Ring Current

2007:
Spacecraft Control to Test Robotic Refueling

2008-2014

2008:
Mapping the Boundary of the Solar System

2009:
Spacecraft Avionics to Find Earth-Like Planets

2009:
Viewing Water-Ice in Polar Craters of the Moon

2009:
Command & Telemetry Processing for Multispectral Satellite Imagery

2009:
Spacecraft Command & Control to Identify Luminous Galaxies

2011:
Unlocking the Secrets of Jupiter's Origins

Instruments: JADE (top), UVS

2011:
Detecting Radiation from the Sun and Supernovae

Coming Soon:

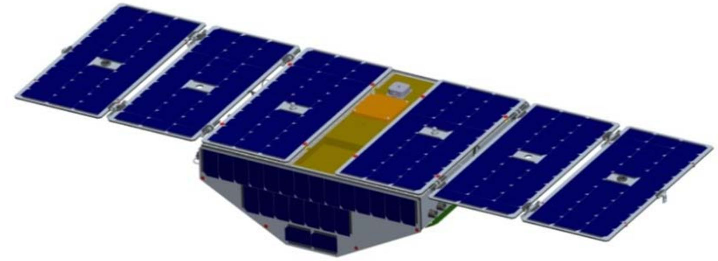
- Four-spacecraft Magnetospheric Multiscale Mission *(MMS)*
- Analyzing Mercury's Surface *(BepiColombo-STROFIO)*
- Exploring the Formation of Hurricanes *(CYGNSS)*
- Flight Control Computers for Manned Spacecraft *(Dream Chaser)*
- Analyzing the Solar Wind *(Solar Orbiter-HIS)*
- Flying into the Sun's Corona *(SPP-ISIS)*
- Exploring Galilean Satellites *(JUICE-UVS)*

Where I am coming from…

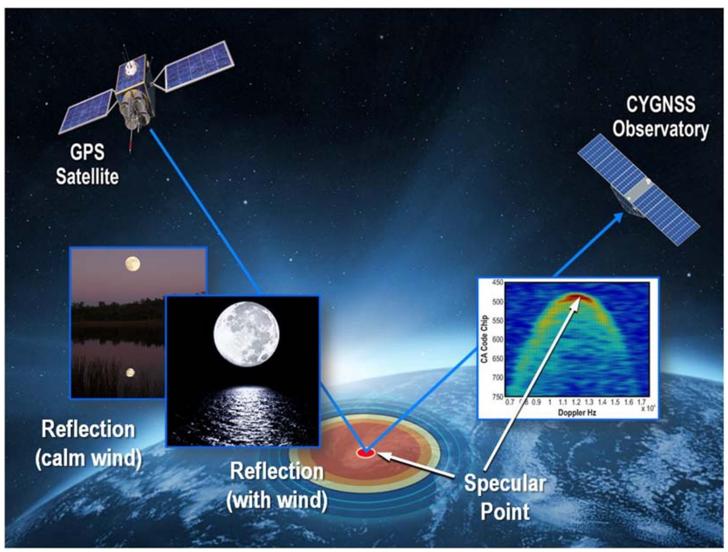
- SwRI employee for 31+ years
- Mechanical engineer
- Initially worked sounding rocket projects
- Moved into instrument design and project management
  - UARS, Cassini, Mars Express, Rosetta, New Horizons, MMS
- Then mission planning and management
  - Deputy Project Manager (PM) of IMAGE (Midex), PM of IBEX (SMEX) and CYGNSS (ESSP EV-2)

Cyclone Global Navigation Satellite System (CYGNSS)

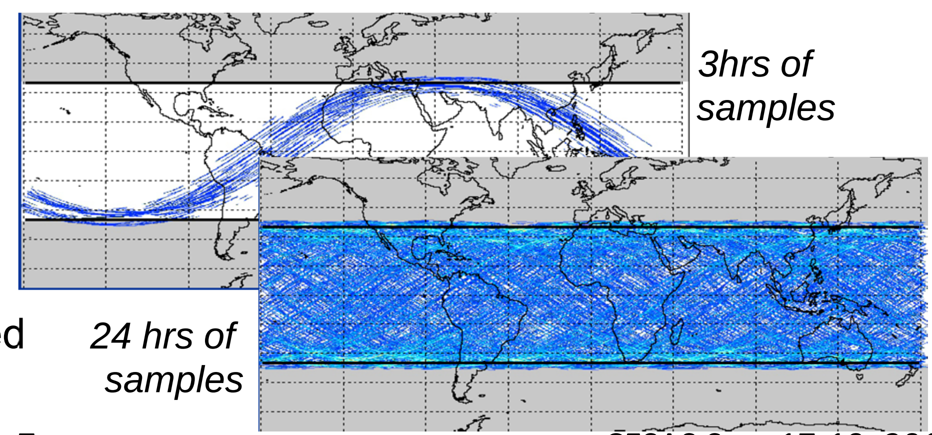
- **Problem**: 50% improvement in ability to predict the track of a hurricane in the past 20 years but no improvement in prediction of hurricane's future strength
- **Science Objective**: CYGNSS will measure ocean surface winds 300% more often than current technology to enable **better prediction of hurricane growth**



- SwRI provides overall mission Project Management, Systems Engineering, Mission Assurance
- SwRI responsible for spacecraft fabrication and test
- SwRI responsible for Mission Operations



- 8 Low Earth Orbiting spacecraft receive GPS signals reflected by Earth's surface
- Reflected signals respond to ocean surface roughness, from which wind speed is retrieved
- Valid in all levels of precipitation

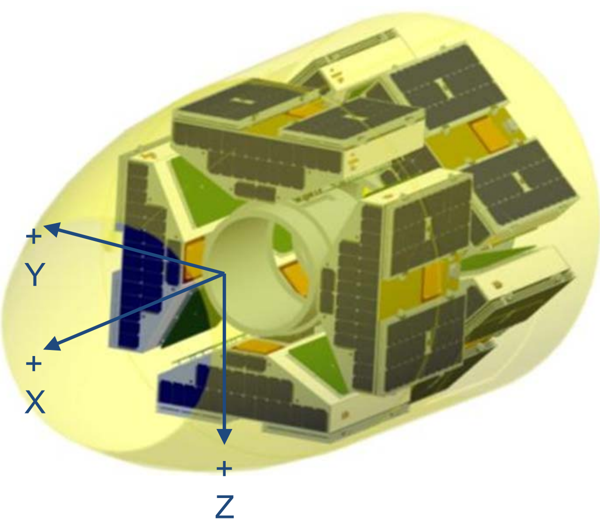


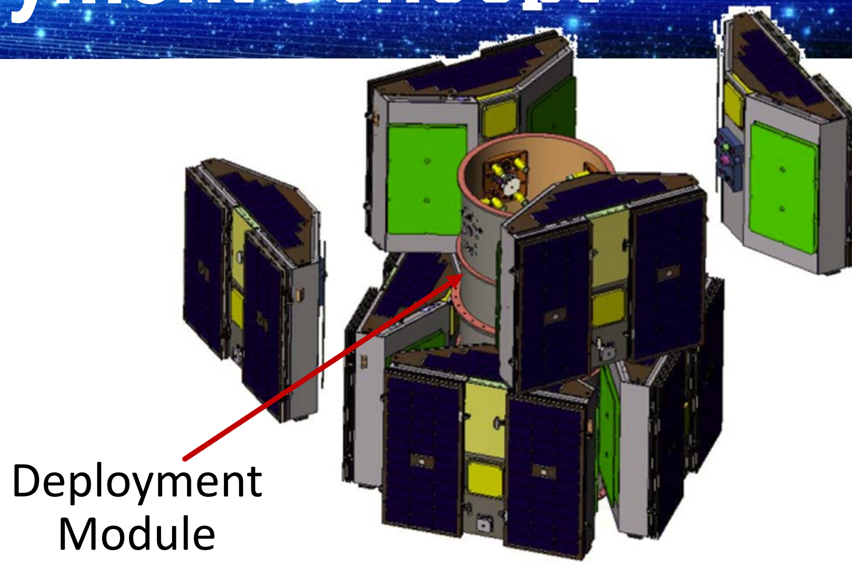
3hrs of samples

24 hrs of samples

Launch and Deployment Concept

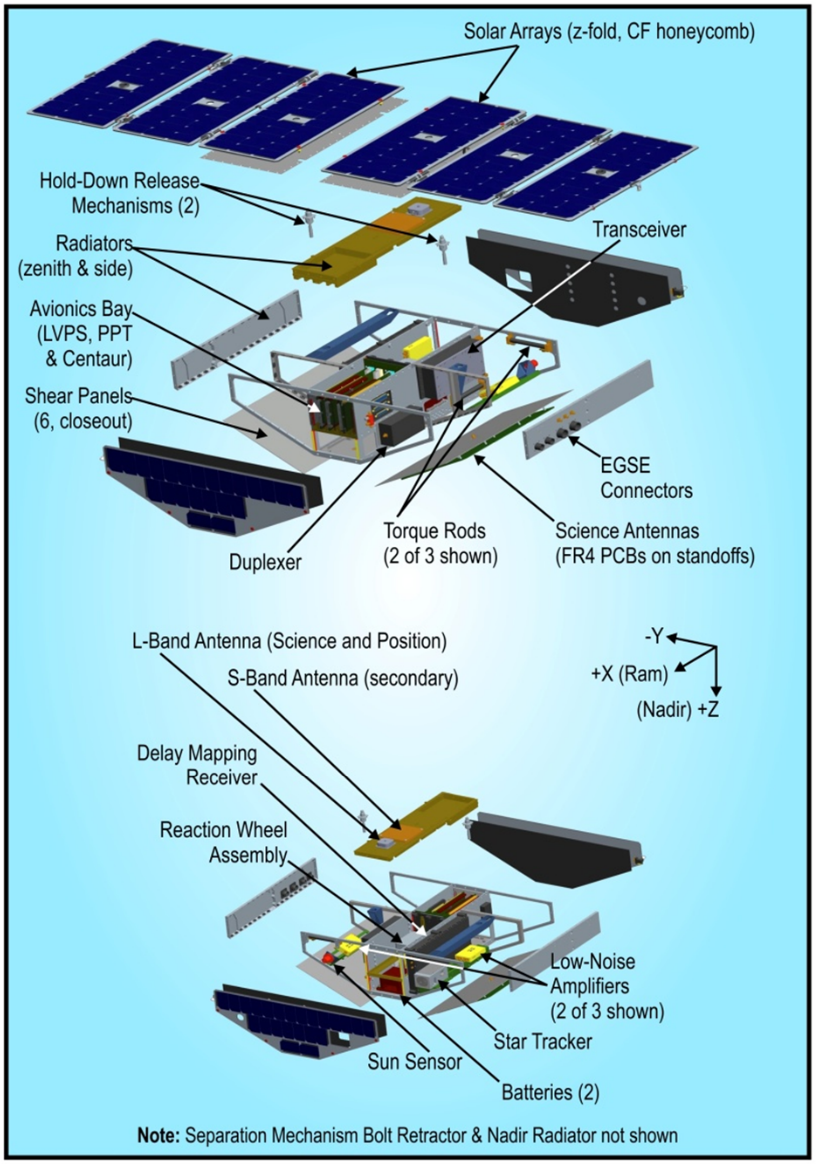
- Pegasus XL Launch Vehicle, GFE
- Altitude: 500 km
- Inclination: 35°
- Launch: Oct 2016
- Operations: 2+ years





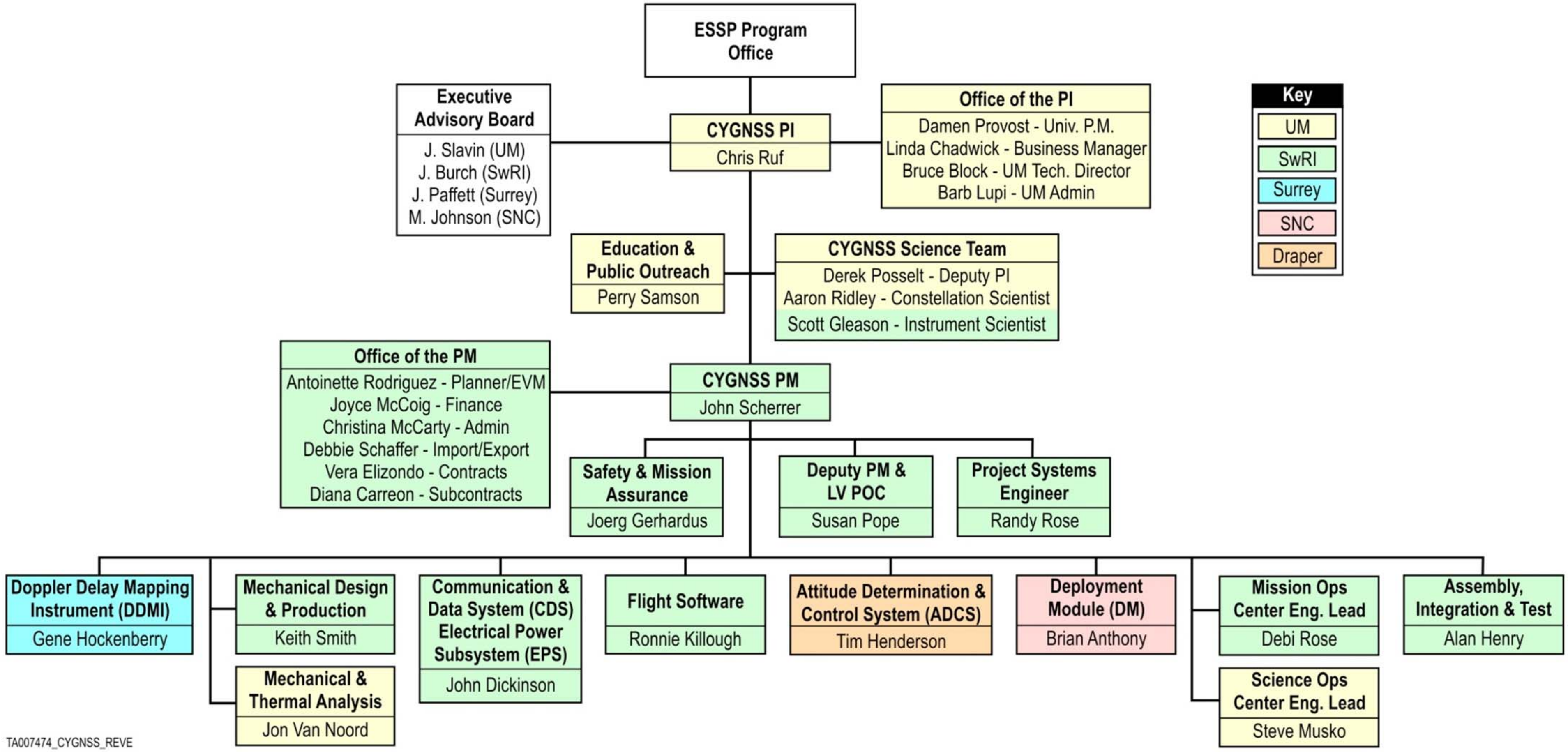
- 8 observatory deployment (solar array stowed)
- Observatories are separated in pairs to balance forces
- Each observatory ~29 kg incl. payload
  - Payload mass: 4 kg
- Total flight segment ~291 kg

CYGNSS Capabilities

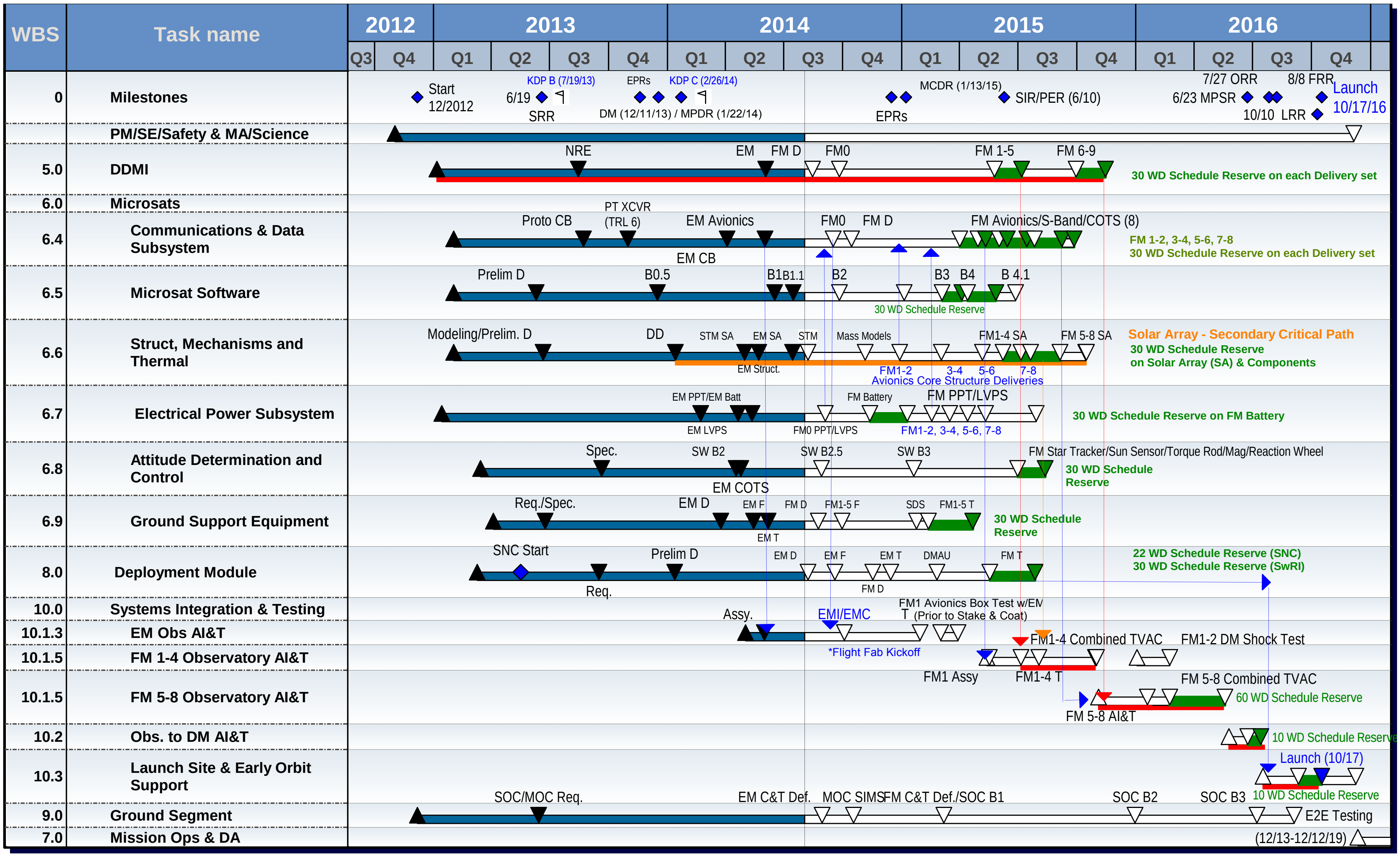


Parameter/Item		Value
Radiation Total Dose		>10 krad (RDM:2)
Design Life		2 yrs
Obs Mass		25.7kg (20% launch margin)
Attitude Determination		2.1 deg (29% margin)
	Star Tracker	6 arc-sec accuracy
	Magnetometer	10 nT sensitivity
Attitude Control		3-axis stabilized, 2.8 deg (79% margin)
	Reaction Wheel	18 mNms; 0.6 mNm
	Torque Rods	1 Am^2
Solar Array		59.2 W generation (23% margin)
	Type and Size	Fixed, 0.22 m^2
	Deployment	One-time Release
	Cell Type	Triple Junction
Battery	Type & Capacity	Li-ion, 4.5 Ahr total
	DOD-EOL, worst-case	19.3% (31% margin)
Thermal Control		Heaters, MLI
Comm	Uplink	S-band 2 kbps
	Downlink Sci	S-band 4Mbps (3.2dB margin)

Organizational Chart



Top Level Schedule



CYGNSS Programmatic Facts

- Principal Investigator (PI) - led mission
- Category 3 Class D mission
  - Low cost, highest level of acceptable risk
- Cost and schedule capped ($100M in $FY14, not counting launch vehicle)
  - Univ. of Michigan (UM) is prime contract and holds all reserves
  - SwRI contract ~$66M
- Project management (i.e. schedule, financial, earned value management) is truly a joint effort between UM and SwRI

Class D, really?

- CYGNSS statement of work, data requirements list (DRL) and data requirements descriptions (DRD): 143 pages
- 78 “paper” deliverables
  - Most have multiple drops
  - Several submitted monthly
    - Monthly Project Status Report (~80 pages) including status of technical resources delivered and briefed monthly
    - 533M’s to level 2 of Work Breakdown Structure (WBS)
    - Earned Value Management (EVM) Contract Performance Report (CPR) to level 2/3 of WBS with Cost and Schedule Variance Report
    - Integrated Master Schedule (currently over 3800 activities)
- Weekly highlights and briefing to ESSP program office and NASA HQ
- Aerospace Corp. has $26M contract to provide CYGNSS insight to NASA HQ and Standing Review Board
  - Remember, CYGNSS is cost capped at $100M

Not Class D enough?

- Review Teams consistently comment that CYGNSS is not “Class D enough”
- However, individual reviewers often request more requirements (e.g., analysis, testing, etc.) in their particular area of interest
- *The challenge of Class D is there is no clear definition*
  - Either HQ must more clearly define acceptable Class D procedures for reviewers, or
  - The project needs clearer authority to define Class D procedures

CYGNSS Efficiencies (1 of 4)

- Maximum use of Commercial Off the Shelf (COTS) components (especially nano and microsat)
  - System flows requirements up rather than down
    - Performance, electrical and software interfaces, environment qualification
- Single payload with known performance and interfaces
  - Near clone of payload currently flying on TechDemoSat
- PI and management team ruthlessly prevent scope creep
- Hold everyone accountable and take action if needed
  - Example: Deployment Module provider change

CYGNSS Efficiencies (2 of 4)

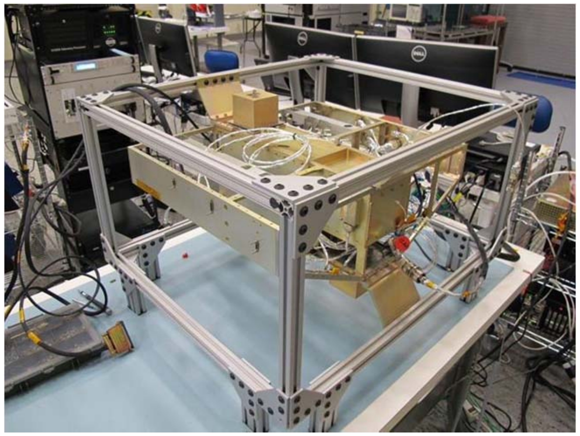
- Relaxed parts-quality requirements
  - Reliability achieved through mission/system level factors vs. traditional (piece-part) Level 2 or Level 3 parts program
  - Approach similar to LADEE, System F6, and various commercial S/C programs
  - Seeks balance between
    - Cost
    - Risk
    - Schedule (short development cycle)
    - Technology available
      - Currently available space qualified components would not meet requirements
  - Risk mitigation: All electronics undergo burn-in for infant mortality screening
  - Parts cost vs. spacecraft cost
    - CYGNSS: 6%
    - MMS: 50%

CYGNSS Efficiencies (3 of 4)

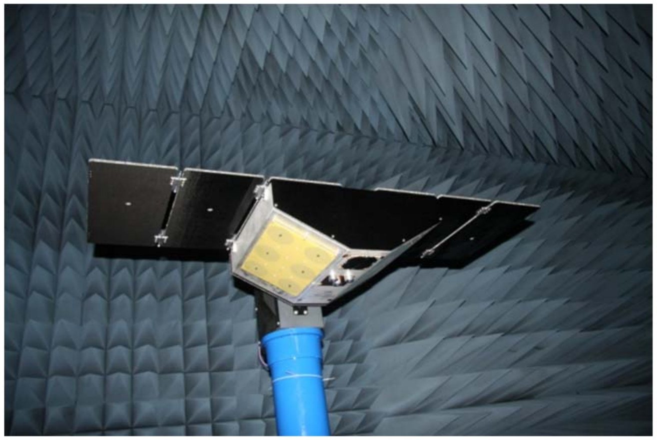
- Small focused team
  - 1 person at 100% is more efficient than 2 at 50%
  - Combine traditional subsystems and jobs
    - Structure, Mechanical and Thermal
    - Communications and Data System
    - System Engineer and I&T controller
- Protect technical and programmatic margin, but willing to use them judiciously to reduce risk
    - Example: We just made a contract mod ($75K) to buy long lead motors from an alternate vendor as a backup in case our currently selected reaction wheels fail life test

CYGNSS Efficiencies (4 of 4)

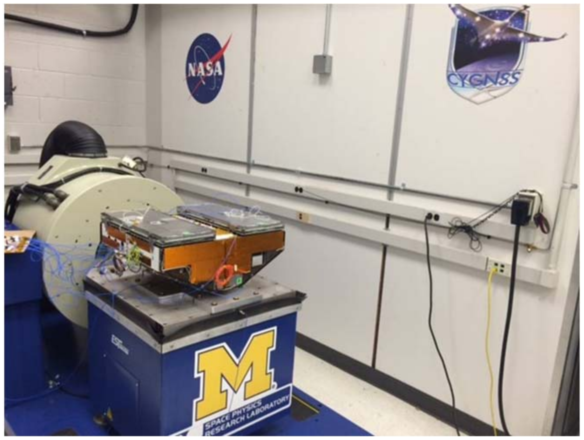
- Maximum use of physical engineering models to reduce flight build risk → spend money now to save later



Form, Fit, Function Microsat Eng. Model During Communication System Testing

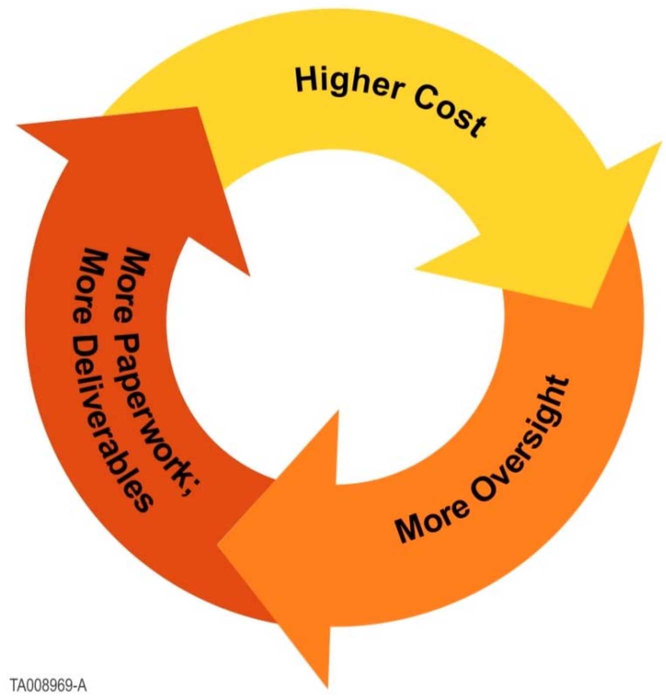


Antenna Pattern Mockup in Anechoic Chamber



Structural Thermal Model on Vibe Table

Overarching Philosophies



Increased Cost Cycle: A self-fulfilling paradigm that increases cost

Answer is less oversight – More project accountability

7120.5E: The Guiding NASA PM Document

- Theory: The requirements in NPR 7120.5E *NASA Space Flight Program and Project Management Requirements* are essential for a successful NASA project
- Theory: The requirements in NPR 7120.5E are tailorable (though it says "establishes a standard of uniformity for the process by which NASA formulates and implements space flight programs and projects")

NPR 7123.1B: The Guiding NASA SE Document

- Theory: Likewise, the requirements in NPR 7123.1B *NASA Systems Engineering Processes and Requirements* "establish the requirements on the implementing organization for performing systems engineering". Again, these requirements are needed for a successful project
  - **"COMPLIANCE IS MANDATORY"**
- 7123.1B also includes the recommended best practices for entrance and success criteria for the life-cycle and technical reviews

The Problem: Lack of Definition

- While NASA “classifies” projects, only one document actually acknowledges the distinction between the requirements of the different classifications: NPR 8705.4 *Risk Classification for NASA Payloads*
- 7120.5E includes a large compliance matrix which is silent to project classification
- 7123.1B literally uses the word “classification” only once in the whole document (and it is referring to software classification)
- ***A Class D project should not have the same programmatic (PM and SMA) or SE requirements levied on it as a Class A project***
- NASA however, falls back on “one size fits all” and that one size is the default for deliverables, oversight, reviews and review entrance and success criteria, etc.

Suggestions for More Efficiency (1 of 5)

- NASA should provide tailoring per project classification up front; eliminate one size fits all
- Reduce the number of deliverables
  - ~80% of the CYGNSS deliverables are never used again by the project once they are delivered
  - Some documents (i.e. parts lists, materials and processes, configuration management plan, etc.) should be available for onsite review but should not be a project deliverables
  - Eliminate separate deliverables for less complex control plans and roll these into the MAIP (i.e. Configuration Management Plan, Software Quality Assurance Plan, Electrostatic Discharge Plan,…)
  - Or, a deliverable could be an already-developed institutional document rather than a project-specific document
  - Ask: *Does the deliverable increase the likelihood of project success? If not, don't require it.*

Suggestions for More Efficiency (2 of 5)

- Clearly define requirements as part of the Announcement of Opportunity (AO) release.
  - Already tailored Mission Assurance Requirements (MAR) document and DRD's should be part of the AO.
    - Without these, proposers make assumptions that need to be corrected during Phase A/B negotiations
- Eliminate programmatic reviews in favor of table top reviews
  - Rely on a CDR and PSR formal Standing Review Board-chaired review (all other reviews are prime contractor chaired and are more like Engineering Peer Reviews with NASA technical experts in attendance)
  - NASA could provide subject matter experts for individual technical reviews of subsystems (Example: CYGNSS reaction wheel specific support from NESC during CYGNSS Phase C)
  - Reduce the number of PowerPoint reviews and focus on actual engineering documentation reviews (schematics, layout, mechanical configuration, etc.)

Suggestions for More Efficiency (3 of 5)

- Eliminate formal ANSI compliant or validated Earned Value Management System (EVMS)
  - Require EVM but not with the formality required by ANSI
  - The extra formality is expensive and adds no value
- Eliminate PowerPoint Monthly Status Reporting and rely on Weekly telecon between NASA program office and prime contractor
- Early selection of Launch Vehicle (LV) improves design/engineering decision making; i.e. tailoring to a specific LV vs. many LVs costs time and money…
- Emphasize the use of existing quality management systems (while creating new project specific plans and procedures as needed) and don't require new plans for all SMA disciplines; trust the supplier, but verify implementation

Suggestions for More Efficiency (4 of 5)

- Reduce oversight
  - Example 1: CYGNSS Launch Vehicle MSRR attendance
    - Orbital (launch vehicle provider) – 8
    - CYGNSS project – 7
    - NASA ESSP (the program office) – 1
    - NASA KSC (provides oversight of LV) – 19
    - Review board – 10 (most of which also are KSC)
  - Example 2: CYGNSS MIT telecon
    - Orbital (launch vehicle provider) – 3
    - CYGNSS project – 4
    - NASA ESSP – 1
    - NASA KSC (provides oversight of LV) – 13
- Have the project or program office select and manage the organization that is responsible for LV procurement
  - They are the ones with the most vested interest in the successful return of science

Suggestions for More Efficiency (5 of 5)

- During the selection process, place more importance on "can this project be done for the proposed dollars?"
  - Things that weigh heavily into this include: TRL, complexity, margins, project team, requirements, etc.
- And then after selection, if the project is going off course, make the hard decision…

Summary

- In today's fiscal climate, we have to do science for less dollars
- Less bureaucracy, less oversight, and more project accountability is the answer
  - For NASA: Put the money where it counts – Science and Engineering and manage the risks associated with less programmatic oversight by participating in value added technical activities
  - Be a part of the solution to technical reviews and challenges and not a bureaucratic burden
- Tailor the PM, MA and SE requirements and oversight to the class of mission: get rid of one size fits all