CYGNSS: Lessons We are Learning from a Class D Mission

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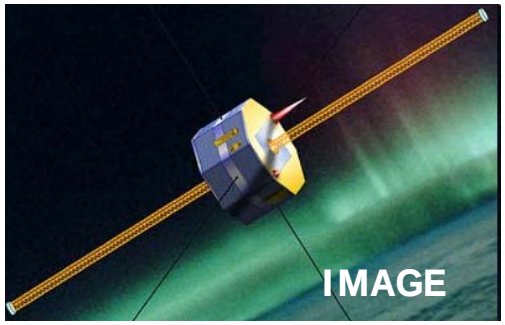
Agenda

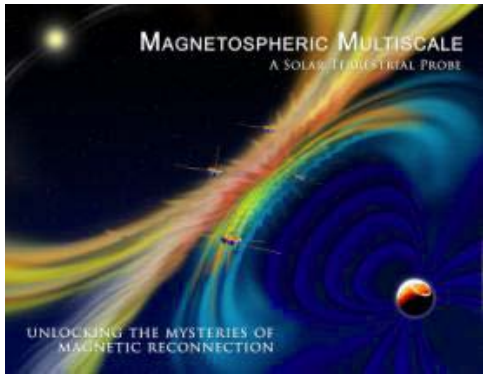
- **Who is SwRI?**
- **What is CYGNSS?**
- **How CYGNSS compares**
- **Factors in defining CYGNSS parts program**
- **CYGNSS Parts Control Board**
- **Parts selection for CYGNSS**
  - The details aren't as important as the how and why
- **Additional challenges experienced**
- **Tips for success**
- **Conclusions**

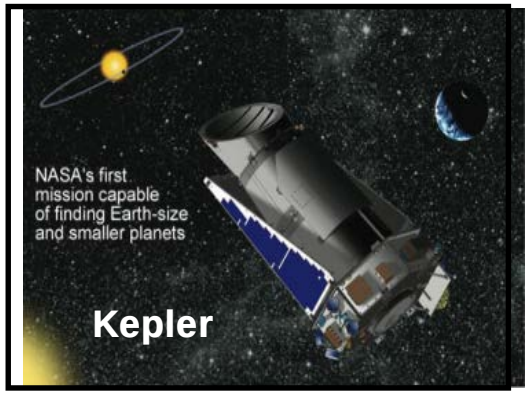
Who is Southwest Research Institute (SwRI)?

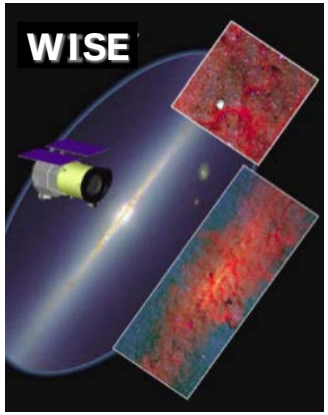
- **Independent, nonprofit applied research and development organization**
- **Space Science and Engineering Division one of 10 technical divisions with a dedicated focus in the physical sciences**
- **World Class Space Science Research, Space Avionics, and Instrument Development**
- **Mission level expertise includes large and small Mission Project Management and/or Mission Systems Engineering**
- **Stand alone services include project management, systems engineering, manufacturing, parts engineering, and earned value management (EVM)**
- **Extensive experience and expertise in the design and build of spacecraft electronics, instrument electronics and instruments for NASA, non-NASA US Government, international, and Commercial customers**
  - Parts requirements run the gamut from Class B (Level 1 parts, DX rated) projects to Class D
    - Historically, EEE-INST-002 Level 2 is most common parts program

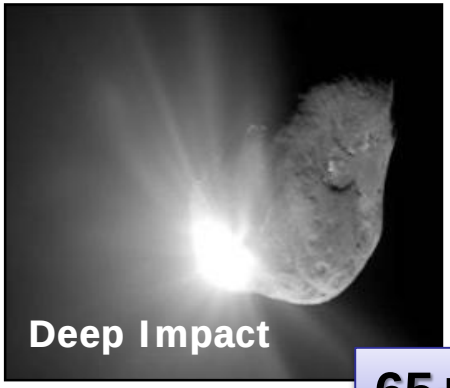
Sample of Missions SwRI has Supported

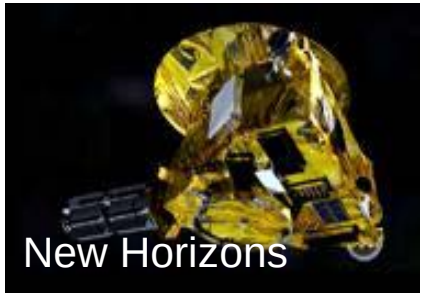


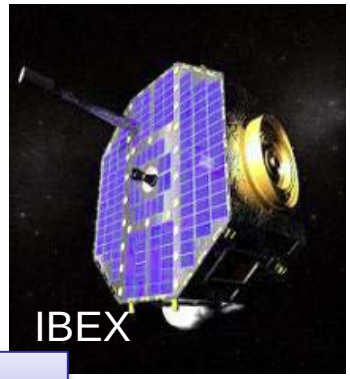








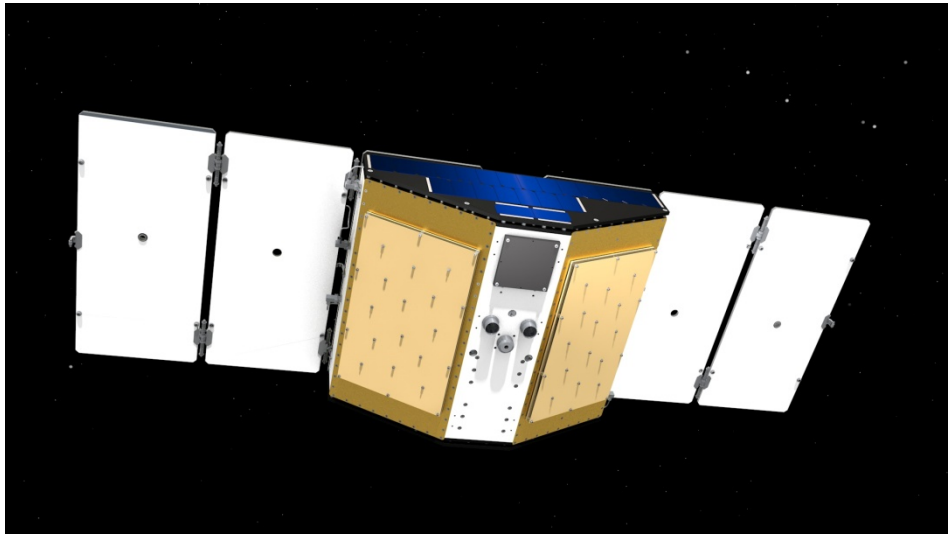


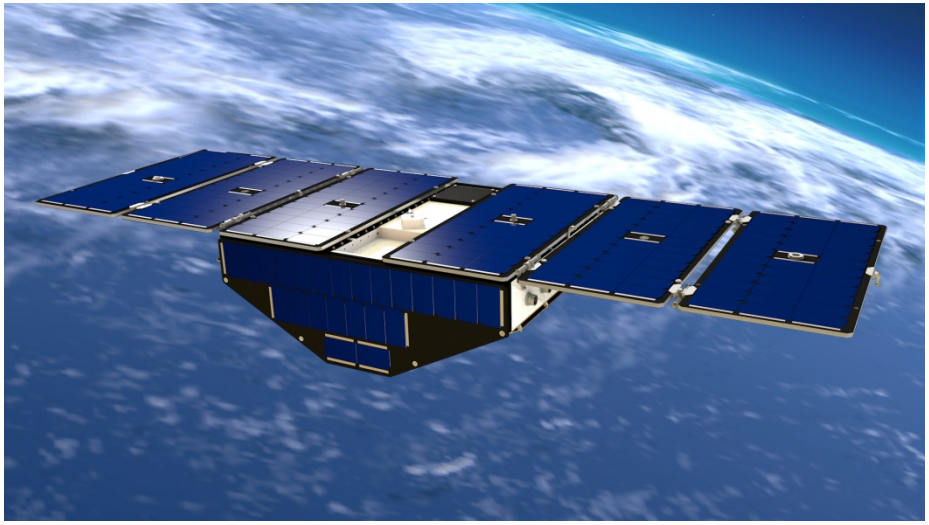


65+ missions with 100% mission success

What is CYGNSS?

- Cyclone Global Navigation Satellite System
- CYGNSS consists of 8 Global Positioning System (GPS) bi-static Global Navigation Satellite System Reflectometry (GNSS-R) receivers deployed on separate micro-satellites



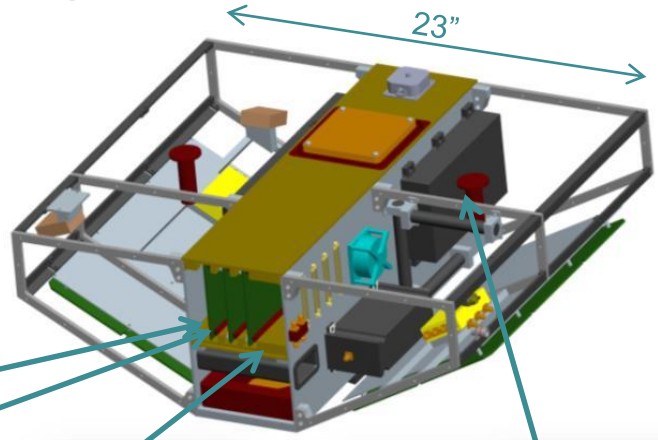


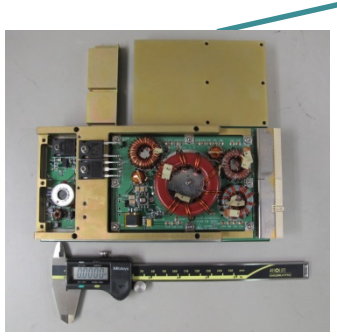
CYGNSS Science Goal

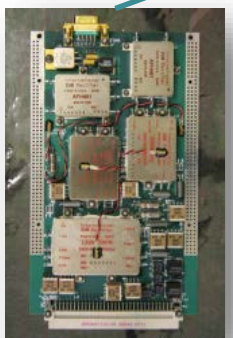
Understand the coupling between ocean surface properties, moist atmospheric thermodynamics, radiation, and convective dynamics in the inner core of a tropical cyclone

What is CYGNSS?

- **The CYGNSS mission is the NASA Earth Venture 2 Mission selected in June 2012**
- **PI-led mission**
- **CYGNSS is classified as Category 3 Class D**
  - Low cost, highest level of acceptable risk
- **Cost and schedule capped**
- **Project currently in EM I&T**
  - CDR scheduled for January 2015
  - Launch scheduled for October 2016







Comparison of CYGNSS to other kinds of Projects

	SwRI Designed CubeSat	CYGNSS	MMS
Mission Category	CubeSat	Class D	Class B
# of S/C	1 CubeSat	8 MicroSats	4 satellites
Mission Profile	<1 year LEO Orbit	2 years LEO Orbit	2 years Elliptical Earth Orbit
Size	4-16 kg	28.9 kg/ satellite	1326 kg/ satellite
Customer	Variety	PI	NASA GSFC
NASA Center	Varies, none in some cases	LaRC	GSFC
Payload	N/A	1	25 instruments
Mission Success	3 months science data	6 months of data with 4 uSats	As defined by NASA MMS Level 1 requirements; some instruments can be lost, case by case basis

Comparison of CYGNSS to other kinds of Projects

	SwRI Designed CubeSat	CYGNSS	MMS
Mission Budget	$2-5M	$100M	$1B
Cost per satellite	$2-5M	$4.9M, not including payload	$165M
Parts Cost	$25-100K; 20% of total cost	$281K not including payload; 6% of total cost	$50M/ satellite; 30% of total cost
Mission Assurance Approach	Best practices and design reviews; no formal QA	SMA delegated to PI; NASA is reviewer; Significant negotiation during Phase A for requirements with NASA	Customer provided MAR; limited flexibility during negotiations
Contractual EEE Parts Requirements	None	None	EEE-INST-002 Level 2
Customer provided Parts Control Plan?	No	No	Yes

How did CYGNSS select a Parts Program?

- **Careful balance between cost constraints and mission risk profile**
- **CYGNSS needed more reliability and radiation than traditional CubeSat parts programs**
- **The CYGNSS mission achieves reliability through mission and system level factors rather than through simple piece part reliability such as the traditional Level 2 or Level 3 parts program**
- **Approach similar to LADEE, System F6, various commercial S/C programs**
- **Aims to find the balance between**
  - Cost
  - Risk
  - Schedule (short development cycle)
  - Technology available
    - We could not meet the technical requirements imposed using currently available space qualified components
- **Team chose to be aggressive given Class D mission and functional redundancy**

CYGNSS Parts Control Board

- **There is still a mission level Parts Control Board**
  - Consists of Mission Parts Engineer, Mission Radiation Engineer, Mission QA and Hardware Developer Parts Representative
  - NASA LaRC is not a voting member
- **There is still a mission level Parts Control Plan**
  - Generated by SwRI
  - Includes requirements for
    - Comprehensive GIDEP searches of all flight parts
    - Procurement from OEMs or authorized distributors to mitigate the risk of counterfeit parts
- **Approval broken into two categories**
  - Parts Quality
    - Approach based primarily on part reliability rather than traditional screening
  - Radiation
    - ICs and transistors only for this environment
  - A part cannot be fully approved until both categories have been satisfied
- **PIL, PAPL, ADPLs and ABPLs still required**
  - Formats less prescribed, vendor format acceptable for many
- **Additional approaches at higher levels of assembly to assure necessary reliability**
  - Avionics required to undergo burn-in for infant mortality screening
    - Project expects to see more part failures during initial board level testing
  - System redundancy at microsat level is key

Parts Selection for CYGNSS

- **Determination of what is appropriate occurs on a part by part basis and considers:**
  - Existing radiation data (Radiation Approval)
  - Existing reliability data (Parts Quality Approval)
  - Part Application and Criticality (Both)
- **For active devices, radiation evaluation is paramount**
  - If data is not available, project must decide between changing parts and testing the part (or assembly)
  - Only after that has been determined, can parts quality be reviewed
- **Heritage can factor largely into parts selection**
  - Does not automatically guarantee approval, but does carry weight especially for similar mission durations and orbits

Additional Challenges

- **We've encountered additional challenges brought on by extensive use of commercial parts**
  - Pure tin finish is the rule, rather than exception
    - Mitigation approach must be determined and accepted
  - PEDs (plastic encapsulated devices) are the rule, rather than exception
    - Outgassing may be an issue for particular missions
  - Complications to thermal design and analysis at the circuit board level
  - Definition and implementation of derating requirements must be carefully considered
  - Introduces unique manufacturing considerations at the circuit board level
    - Component packages often different from traditional space parts
    - Introduction of plastic packages to a manufacturing process designed for ceramic packages

Tips for Success

- **Negotiate parts program early on and ensure customer buy in**
  - Ideally during proposal phase
- **Supplier engagement can have significant benefits**
  - Reach back into the manufacturing processes utilized by suppliers for process, test, reliability, etc
- **Ensure design engineers understand the kinds of parts available for use and the limitations**
  - Not all commercial parts are acceptable
- **Get creative with parts selection**
- **Part obsolescence may need to be more carefully managed**
- **Don’t discount lead times, they may still be an issue relatively**

Conclusions

- **The CYGNSS team is still learning how to operate in this Class D world**
- **This approach isn't appropriate for all missions, even all Class D missions**
- **Class D missions have to find the balance between cost constraints and risk profile**
- **Still have to apply lessons learned from projects with a more traditional parts program, where reasonable**
- **Have to be willing to accept more risk than we have been trained to accept**
  - Risk still has to be quantified