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

- Cassini
- IMAGE
- MSL
- Swift
- Magnetospheric Multiscale
- Kepler
- WISE
- WorldView 1 & 2
- Deep Impact
- JPSS
- New Horizons
- IBEX

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
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

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

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