CubeSat/Small Satellite Lessons Learned

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5th UNISEC Global Meeting, Rome, Italy
December 3rd, 2017
CubeSat Community Current State

- Thousands of developers worldwide
  - Across academia, industry, and government agencies
- 750+ CubeSats have been launched
- No longer only an academic training tool or industry testbed
- Constant new entrants
  - New countries, new universities, new companies
New Entrants Common Issues

- Common failures include deployable failures, power system failures, comm system failures
- First time university developers have low mission success rates
  - Most CubeSats are not able to be contacted
    - Difficult to determine cause of anomaly
- New entrants tend to make the same ’first-timer’ mistakes
  - Most are easily avoidable
- How do we increase new entrant mission success?
Lessons Learned Discussion Main Topics

- Set Appropriate Scope for the Mission
- Establishing Program Structure
- Schedule
- Risk Management
- Design, Production, and Assembly
- Assembly
- Test, Test, Test
- Operations
Group Discussion Summary

• Establish minimum baseline mission with modest success criteria
  ✷ Stick to and defend these minimum requirements and goals
    • Do NOT allow requirements to be added after requirements have been decided

• Build an experienced team

• Rigorous documentation and reviews are important
  ✷ Helps to maintain continuity of knowledge

• Reviews are very important
  ✷ Independent reviewers are very helpful
Group Discussion Summary

- Maintain Schedule and Margin
  - Most on orbit anomalies attributed to lack of testing on the ground

- A good risk management process is very important for CubeSats

- Design for simplicity and robustness

- Test Early and Often
  - Performing fully integrated testing early will catch the most anomalies, greatly increases mission success
Group Discussion Notes
Set an Appropriate Scope for the Mission

• Establish a minimum baseline mission with modest success criteria
  ☞ May have de-scope plan in place should one be needed
  ☞ Stick to and defend these minimum requirements and goals
    • Do NOT allow requirements to be added after requirements have been decided

• Develop simplest spacecraft to fulfill mission
  ☞ Cal Poly/JPL IPEX mission, started as a 3U with 3-axis ADC, ended as a 1U with no ADC
    • Met all mission requirements

• Stick with your expertise, don’t do new science
Establishing Program Structure

- Build an experienced team
  - Teams with more experience tend to have higher success rates
    - Mentors from industry help apply best practices and lessons learned to academic programs
    - Focus on the team’s strengths and interests
    - Systems engineering is very important, must have during all phases of the project from conceptual design through operations
  - Rigorous Documentation
    - University teams have high turnover rates, helps maintain continuity of knowledge
- Reviews
  - Necessary evil, don’t need to be formal but do need to be rigorous
    - Independent reviewers are very helpful
- Have a small core team that communicates regularly
- At the university level, plan for turnover of students (they will graduate eventually)
  - Senior students should always train a younger student on their tasks
Schedule

• Assembly, Integration, and Test should be a large portion of the schedule
  ➤ Maintain this portion of the schedule, as this is where anomalies are found

• Launches don’t wait for CubeSats, be ready for the schedule crunch that will happen as delivery gets closer
  ➤ Puts extreme pressure on the latter half of the schedule, usually on AI&T
  ➤ Have margin and contingency plans to maintain mission success
  ➤ Work with Launch Integrator to find more schedule in case necessary

• Stick to your schedule, create milestones and stick to them
Risk Management

• A good risk management process is very important for CubeSats
  ✅ Do a risk assessment at the beginning
    • What is new? What is single point of failure?

• Purchase multiple sets of hardware
  ✅ Use for ’drop in’ replacements in case of failure, minimize schedule risk

• Software is always risk
  ✅ Early functional testing is necessary

• Risk to cost ratio
  ✅ When choosing analyses or tests to perform, focus on easiest to solve and work up from there
Design, Production, Assembly

- Design for simplicity and robustness
  - Minimize deployables and keep them simple
  - Design for the worst case environment
- Employ fail-safes built into the satellite electronics
  - Watch-dog timers, planned resets
  - Define what your safe mode, make sure your satellite can recover from safe mode
- Design for disassembly and re-work
  - Many issues are not discovered until the satellite is fully assembled
- Overdesign and overbuild for risk reduction
  - Manufacture or purchase extra parts, testing anomalies or mishandling of equipment will happen
  - Don’t design to the specifications in COTS components datasheets, apply values to de-rate them as appropriate, also test them to see how they behave
- Always have an omni directional antenna, at least as a back up
Design, Production, Assembly

• Perform inspection of all parts when they are received
• Clearly define tolerances
• Use 2 back out prevention methods for all fasteners
• Always check
   Electronics that CubeSat become obsolete quickly
   Don’t underestimate lead time for any component no matter how simple
Test, Test, Test!

- Subsystem testing important, integrated system testing is the most important
  - Most on orbit failures attributed to lack of integrated system testing
  - No matter how much time you have scheduled for testing, it won’t be enough
  - Cal Poly develops a ‘flatsat,’ engineering test unit, and flight unit for most missions

- Performing full end-to-end system testing is important to perform as early as possible
  - Examples include: Command execution testing, Day In the Life tests, End-to-end Comms testing, Full Power system charge cycle

- Thermal Vacuum Testing best simulates space environment
  - Resource intensive, if T-vac not available, perform testing at temperature extremes in ambient conditions
Operations

• Don’t underestimate the difficulty of tracking and commanding a CubeSat
• Ground segment should be developed in parallel or before the CubeSat
• Analyze trends of your satellite
  - Battery degradation, temperatures, etc.
• Practice operations on your own CubeSat and other CubeSats
  - Insert errors to see how operators respond