Integrity ★ Service ★ Excellence

A Tale of Two CubeSats: GEARRS & VPM

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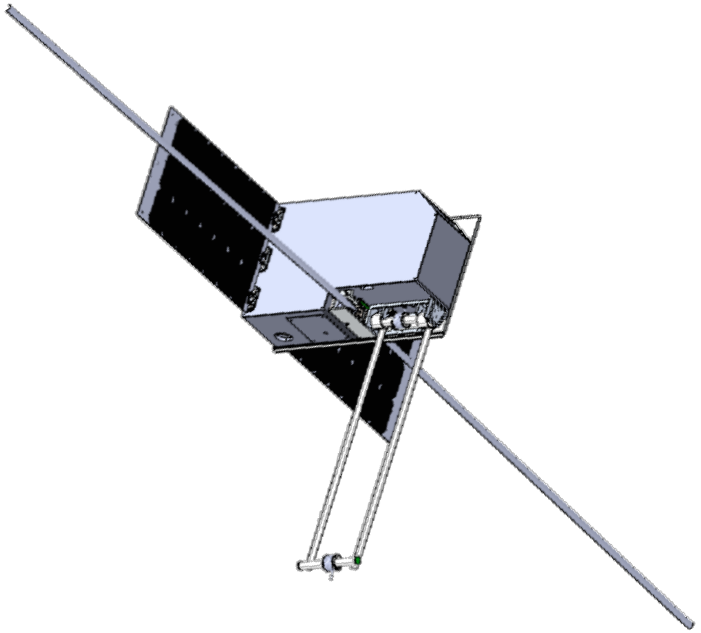
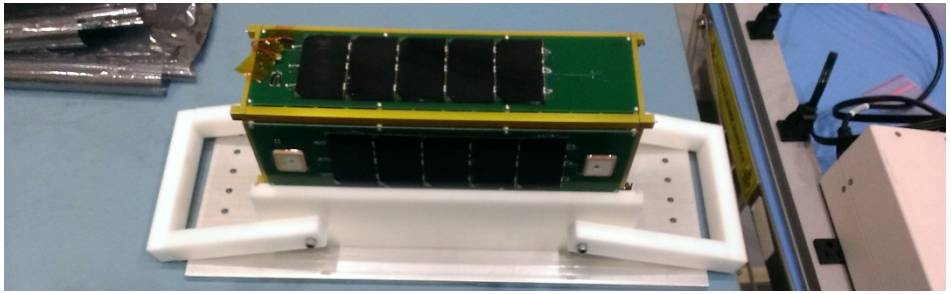
James Meub
ATA-Aerospace
AFRL/RVEP

Introduction

- Two different CubeSat Programs
  - VPM
    - Highly capable
    - Long term program
  - GEARRS
    - Quick turn
    - Specifically scoped mission
- How do you manage each end of the spectrum?
  - Tailoring mission assurance to mission scope, goals, and constraints





VPM

- Very Low Frequency and Particle Mapper
  - 6U CubeSat (2Ux3U)
  - 4 year development
  - Payload: VLF dipole receiver, High energy particle detectors
    - Correlate VLF events to electron precipitation
  - Large program effort
  - Low risk posture
- Approaching CDR stage in design
  - Currently building Flat-Sat/EM
  - Developing payload maturity

GEARRS

- GlobalStar Experiment and Risk Reduction Satellite (GEARRS)
  - Two radios
    - GlobalStar Duplex
    - GlobalStar Simplex
  - Characterize and map GlobalStar duplex and simplex coverage for LEO assets
    - Provide 98% orbital TT&C capability for spacecraft @ 9600 bps
    - Demonstrate NSL commercial product for future AFRL missions
- 90 Day CubeSat
  - December 2013 to March 2014
- Collaboration between AFRL, Near Space Launch, Space Test Program, and NanoRacks
  - NSL is the sole space GlobalStar Value Added Reseller (VAR) and built the satellite leveraging a previous bus design
  - AFRL performed misssion planning, launch interface, and environmental stress screening
  - Space Test Program and NanoRacks

Early December

- AFRL learned of a quick launch opportunity through the Space Test Program
  - March 2014 Delivery (~3 months from kickoff)
- AFRL was aware of the GlobalStar payload from a University NanoSat Program mission
- Hesitant to fly the radio on higher value programs without better understanding the on-orbit performance
- Perfect quick turn mission with well scoped payload and a documented user need (AFRL flight programs, UNP programs)
  - Can we fly a risk reduction in the required time frame?
  - How do we scope the mission assurance to accept risk, while still setting us up for mission success?

GEARRS

- **Kick-off**
  - **December 17th 2013, D - 94**
  - **Decided that the only way to converge on a March delivery:**
    - **Perform very targeted mission assurance**
    - **Focused (i.e. reduced) documentation and analysis**
    - **Increase hardware testing**
    - **Nano-team format**
      - **Everyone-knows-everything mentality**
      - **Everyone present at daily meetings**
      - **Only possible with a well scoped effort**
    - **Leverage prior hardware designs and COTS components**
    - **KISS**

Kickoff Program Decisions

1. **We don't have the time or budget to do all of this.**
2. **How do we pick and choose?**

- ❑ Goddard Gold Rules
- ❑ MIL-STD-1540C
  - ❑ Random Vibration
  - ❑ Shock
  - ❑ Thermal Cycling
  - ❑ Thermal Vacuum
- ❑ Cleanliness
- ❑ ESD safe-guarding
- ❑ Requirement definition
- ❑ Requirement V&V
- ❑ Configuration control
  - ❑ Documentation
  - ❑ Software
  - ❑ Revision Control
  - ❑ Signatures
- ❑ Design Reviews
- ❑ Configuration Control Boards (CCB)
- ❑ Management structure
- ❑ Engineering Change Requests (ECR)
- ❑ Functional Testing
  - ❑ Go/No-Go Tests
  - ❑ Day-in-the-life (DITL)
- ❑ Mate/De-mate logs
- ❑ Conformal Coating
- ❑ Etc.

Focus on the Essentials

GEARRS: Think Sputnik

- Target for 72 hour operations
  - Required coverage map fidelity can be generated in the first 72 hours
- Simple Payload
  - Leverage simplicity of mission
    - What is the bare minimum to achieve the required data products?
    - Don't overcomplicate it
- Soft-stow vibe loads

VPM: Not Sputnik

- Target for 1 year operations
  - Required measurement conjunctions with larger space systems
- Complex Payload
  - 3 deployables
  - Specific FoV requirements
    - Strict attitude pointing during science mission phases
  - Low data latency requirements

A simple payload allows for quick assessment of mission assurance trades

Documentation

GEARRS: Focus on essential documents

- Small, 4 man tiger team
- Everyone CC'd on every email and at every teleconference
  - Contributed to low-overhead and more face-to-face discussions
- Critical items still produced
  - SWaP Budgets
  - CONOPS
  - Mission Success Criteria
  - Requirement Verification Matrix
  - Integration and test procedures

VPM: Very document heavy

- Configuration control policies
  - PM/CE Signatures
  - Subsystem lead reviews
  - Configuration control boards after CDR -2 Months
- In-depth document production schedule
  - Design review oriented

A small team decreases documents and configuration control overhead

Analysis & Testing

GEARRS: Trade for testing

- One well scoped test is worth a 1000 simulations
  - For GEARRS, it was faster and cheaper to make an EM and ESS
- Exceed mission levels
  - Vibe to 9 grms
  - Thermal +/- 15
- PV Array I/V curve with controlled light source
- Leveraged known analysis from previous missions

VPM: Analyze everything, then test it

- Structural
- Thermal
- ADCS
- GNC
  - GPS antenna pointing analysis and gain patterns
- Science Data
  - Compare to MLTB and mission success criteria

Analysis *and* testing is preferred if resources allow, however testing alone *can* be a valid alternative

CONOPS

GEARRS: Simple software design

- Two modes
  - Fast Beacon
  - Slow Beacon
- Always power positive
- Limited Commanding
  - Commands are restricted to changing a parameter
    - Change reported via simplex beacon
- Run DITL many, many times

VPM: Robust software scheme

- Safe mode accounts for most error sources
- Autonomous 'Lights-out' operation paradigm
- Various mission stages
  - LEO checkout
  - Payload checkout
  - Operations

Simple payloads mean simple CONOPS

Targeted Mission Assurance

- One size does not fit all
  - Cannot apply one level of mission assurance to all CubeSats
  - Use the scope of the mission to determine
    - Risks that can be accepted
    - Risks that need to be mitigated or avoided
- Constantly re-evaluate
  - Need to be flexible
  - Keep the mission goals in mind and don't be afraid to cut pieces to meet them
- GEARRS paradigm doesn't work for every system
  - It can be done with the right payload, but not all of them
  - Many satellites require a lower risk posture
- VPM paradigm doesn't work for every system
  - It's applicable to some systems, but not most
  - Sometimes it's more than what the mission requires