Interplanetary CubeSat Design
System Challenges and Architectures

Austin Williams
Cal Poly / Tyvak Nano-Satellite Systems

iCubeSat Workshop
Cambridge, MA
May 29th, 2012
Biological Evolution as a Model: 1 Species

- Born
  - Sufficient Resources
  - Risk Tolerance

- Reproduce
- Survive

- Are you alive and attractive?
- A large gene pool can produce new Abilities

- Effectiveness of Intrinsic Abilities
- Ability to do more with less (η)
Biological Evolution as a Model: Many Species

- Are you alive and attractive?
- A large gene pool can produce new Abilities
- Sufficient Resources
- Risk Tolerance
- Effectiveness of Intrinsic Abilities
- Ability to do more with less ($\eta$)
Biological Evolution made analogous to Satellites

- Developed
  - Sufficient Resources: Gov $
  - Risk Tolerance: Very Low

- Reproduce
- Survive

- Is there demand?: Yes
- Can it be easily tweaked with new components?: Given very low risk required? No.
- Effectiveness of Designed Abilities: Great
- Ability to do more with less ($\eta$): Poor

Results:
- Shallow gene pool (Components)
- Inbreeding (System Designs)
How do CubeSats change the model?

Developed

- Sufficient Resources: Gov / University $
- Risk Tolerance: Highly Variable

Reproduce

- Is there demand?: Yes
- Can it be easily tweaked with new components?: Generally, Yes.

Survive

- Effectiveness of Designed Abilities: Good and getting better
- Ability to do more with less (η): Excellent and getting better

Results:
- Highly variable Gene Pool!
- Tons of innovation!
Where will CubeSats eventually be?

Tons of Variety, Tons of Competition.

We’re going Darwinian

Larger Variety of Designs

Born

Reproduce

Survive

Large production runs drive down costs of successful platforms

Competitiveness will drive performance
What is “Selecting” CubeSats

• Access to Space for CubeSat developers of all forms.
  – Pulling from the collective creativity of a large base.
  – Relatively quick feedback on design approaches (Did it survive….?)
  – Will eventually lead to science instruments designed specifically for CubeSats.

• Modern COTS are an absolute treasure drove.
  – Change in Risk posture allows judicious use.
  – This provides the solution for Volume, Mass and Power constraints.
What’s working against CubeSats?

- **Volume, Mass, and Power**
  - A solvable problem.

- **Radiation**
  - Total Ionization Dose
  - Single Event Effects
  - A more challenging problem

- **Cultural Bias**
  - Resistance to change?
  - Marriage to “Rules of Thumb”
  - Broad access to space helps
Blank Page CubeSat System Design

• **Bottom up approach: Let available components drive the design**

  – We are repurposing components from a different industry, allow their design practices and built in features to have proper influence.

  – E.x. Selecting 3.7V, 7.4, 12.1V nominal unregulated battery voltage. Besides the power generation and supply benefits of one vs the other, what typical operating voltages are supplied, and what type of efficiencies will result? Depends on components used.
Blank Page CubeSat System Design

• High level of integration. A clear understanding of the complete capability, and the components that allow it result in the most efficient designs. Take the mm and mW seriously.
Blank Page CubeSat System Design: Radiation

• **Total Ionization Dose**
  – Shielding goes a long way to solve this problem

• **Single Event Effects**
  – HW Redundancy?
  – SW Redundancy?
  – Rad Hard?
  – Power Cycle Hardware Periodically?

• **Part of increased acceptance of risk, is acceptance of higher radiation effect rates.**

Lots of potential solutions, each with a big Impact to the system design. We will learn a lot about the effectiveness of different solutions in LEO over the next decade.
What are some first steps we could take?

• Encourage every CubeSat to fly a TID sensor.
  – Accumulate approximate TID heritage by compiling collective CubeSat BOMs in a public database.
  – Very low telemetry and power requirements (monitor a voltage, and report its change over time).
  – Either use a calibrated RadFet (more expensive, more accurate), or a simple PMOS device (cheap, not accurate)

• Encourage CubeSat’s to record SEE rates.
  – Not trivial to implement
  – Potential for lots of false positives.
What are some first steps we could take?

• **Simple Mission Concept: Environmental Monitor and Avionics Test Bed.**
  - Deploy a 3U with TID, UV, X-Ray, and Temperature Sensors.
  - Include a large variety of component types (Memories, Processors, Logic Chips, etc) and record performance telemetry and SEE related events.
  - Low amount of telemetry produced, low power requirements, high value data return.

• **For a step up in complexity**
  - Test different avionics processing architectures (not just chips, but full computing systems)
Thanks!

Questions?