Rapid Build and Space Qualification of CubeSats

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Overview

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• Objective
• Systems Engineering
• Electrical Engineering
• Mechanical Engineering
• Test Fixtures
• Conclusions
Objective

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• Build and space qualify a CubeSat in 18 months
• Standard “Vee” model in which system requirements drive design decisions

• MORE important on short time scale
  • As much as mechanical and electrical engineering
Mission Phases

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- Pre-Commissioning
  - Start: Ejection from P-POD
  - Purpose: start flight processor and radio; deploy solar arrays and antennas
  - Exit: First contact w/ ground
- Commissioning
  - Start: Contact with ground
  - Purpose: Verify subsystem functionality, orient ALICE into space dart configuration
  - Exit: Functionality of all subsystems

- Normal Operations
  - Start: Completion of commissioning phase
  - Purpose: Data collection and downlink
  - Exit: Telemetry out of range
- Safety
  - Start: Telemetry out of range
  - Purpose: Diagnose problems with ALICE
  - Exit: Ground Command
Designing Subsystems

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- Telemetry, tracking, and command radio and antennas
- Command and data handling software to control main bus functions
- Additional serial ports for communicating with peripheral devices
- Deployment mechanism for deployable solar arrays and antennas
- External watchdog timers to monitor system and reset if necessary
- Temperature-compensated crystal oscillator (TCXO) for more accurate system timing
Integrating Additional Electronics

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- Needed area for additional electronic components
- Decided to redesign BIOM as Payload Interface Board to conserve volume
Payload Interface Board Design

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- Selected low-outgassing and extended temp components
- Schematics and Printed Circuit Board (PCB) designed in Altium Designer
Prototyping

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- Custom 2-layer boards manufactured in-house
- Prototyped individual sub-circuits to test design
  - I²C-to-UART and TCXO sub-circuit
  - Watchdog timer sub-circuit
  - Radio interface sub-circuit
- Refined Payload Interface Board design sent out for manufacturing
Payload Interface Board

Watchdog Timers

I²C-to-UART Device

Bus Extender Module Connector

TCXO

Carbon II Radio

Payload Connector

Deployment Relay and Connectors

-z Solar Array Connector

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Antenna Type Decision

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- Antenna types considered
  - Monopole, Dipole, Patch, and Loop
- Comparison done based on set of design criteria
  - Omni-directionality, simplicity, wavelength compatibility, deployability

<table>
<thead>
<tr>
<th>Criterion\Type</th>
<th>Monopole</th>
<th>Dipole</th>
<th>Patch</th>
<th>Loop</th>
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<tr>
<td>Omni-Directionality</td>
<td>Good</td>
<td>Very Good</td>
<td>Poor</td>
<td>Good</td>
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<tr>
<td>Simplicity</td>
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<td>Very Good</td>
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<td>λ Compatibility</td>
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<tr>
<td>Deployability</td>
<td>Very Good</td>
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<td>Very Good</td>
<td>Poor</td>
</tr>
</tbody>
</table>
STK Access Analysis

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• Determine whether dipole or monopole design provided best opportunity for satellite access
• Simulated in STK using modeled antenna gain patterns
• Designs compared based on total access time
STK Monopole Simulation

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Educational Use Only

`SC_TX-To-GS_RX Link Budget`
Time (UTC)
EIRP (dBW)
Rcvd. Frequency (GHz)
Rcvd. Iso. Power (dBW)
Flux Density (dBW/m²)
g/T (dB/k)
C/No (dB/Hz)
Bandwidth (kHz)
C/N (dB)
Eb/No (dB)
BER

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`GS_TX-To-SC_RX RX Summary`
Time (UTC)
Azimuth (deg)
Elevation (deg)
Range (km)

ALICE ICR Axes
2 Oct 2011 14:30:57.000
Time Step: 1.00 sec

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STK Dipole Simulation

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Alternate Antenna Design

• Quad-monopole turnstile antenna
  • Similar to antenna design used on RAX mission
  • Produces circularly-polarized farfield pattern which is nearly omni-directional with no nulls
  • Will require changes to ground station antenna
Chassis Modifications

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- Accommodates antenna, deployment mechanism and payload
- -Y face modified to allow the payload access to space and to mount deployment mechanism
- -Z plate mounting holes moved to accommodate antennas

-Antenna pass-through
-Deployment mechanism pass-through and mounting holes
-Payload cut-out for experiment space access
-Z mounting holes

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Deployment Mechanism

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• Required non-outgassing deployment mechanism
  • Guillotine type cutter designed to cut fishing line that retains solar arrays
  • Space rated shaped memory alloy based pin-puller used

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Test Fixtures

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• Test Pod
  • Vibe 3U CubeSats in P-POD like structure
  • Interior dimensions same as P-POD
  • Machined from 6061 AL
  • Removable front face with adjustable plate to secure CubeSat
  • Interface plate mates to AFIT’s vibe tables
Test Fixtures

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• Vibe Block
  • Vibe individual PC-104 cards or stacks
  • Mounting holes to test 3-axes without moving block
  • Machined from 6061 Al
  • Interface plate mates to AFIT’s vibe tables
Test Fixtures

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- Mechanical Aerospace Ground Equipment (MAGE)
  - Accommodate CubeSat during full system and deployment testing
  - Holds CubeSat on rails
  - MAGE rotates about Z axis for easy access
  - Head Machined from 6061 Al
  - Stand: 80/20 kit
Conclusions

The AFIT of Today is the Air Force of Tomorrow.

• With testing and qualification standardization, the custom equipment described here, and sufficient workforce it is possible to design, build, qualify, and deliver a CubeSat for launch in 18 months

• Many capabilities added to AFIT’s infrastructure
  • CubeSat manufacture at the machine shop
  • Ground station
  • Custom testing equipment
  • Leverage the experiences gained by the technicians, professors, and students to design and integrate more advanced experiments into CubeSats for future cutting-edge science and technology missions
Questions?

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Payload Interface Board Changes

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• Pumpkin
Radio Choice

• Carbon II Radio
  • Same radio used on Colony II CubeSat
  • Would ensure ground station equipment and software compatibility with Colony II CubeSat
  • Manufactured by AstroDev
  • Mounted on Payload Interface Board

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Chassis Modifications

- First design permanently bent antenna while stowed between chassis and –Z plate during assembly
- Antenna passthroughs changed to slots to eliminate problem