Performance Characterization of CubeSat Radiometer Optics
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Mission Overview

Create a 3D temperature profile of the lower atmosphere.

Mission Statement:

PolarCube will perform tropospheric temperature sounding using the 118.7503 GHz O$_2$ resonance, by using a radiometer.
PolarCube Design

- 3U CubeSat based on ALL-STAR concept
  - Design heritage
  - Second ALL-STAR mission
- Miniaturized, previously flown radiometer
  - MTS NASA ER-2 1986
  - Rotating mirror
MiniRad Overview

118.7503 GHz Radiometer
- Microwave frequency
- O₂ Resonance
  - Cloud Penetrating
- Rotating Parabolic Mirror
- 16.5 km ground spot size (410 km orbit altitude)

RAD FBD (TOP), RAD Mirror (B-Left), Feedhorn Antenna (B-Right)

Swaths of data collected on-orbit
MiniRad Structure

Critical Components:
- Deployment System
- Outer Structure
- Board Enclosure
- Radiometer Tower
- Receive Antennas

Design Drivers
- Small dimensions
- Fast adjustment
- Withstanding launch vibrations
- Exact positioning
- Minimal surface in x-/y-direction to minimize spillover effect
MiniRad Testing

• Split into three structural tests
  – Phase I (Deployment Verification)
  – Phase II (Deflections caused by Deployment)
  – Phase III (Optical Alignment)
Phase I: Test Objective

• Binary Deployment of MiniRad
  – Repeatability, and reliability

• Pin Trigger deployment - 10 consecutive deployments must be met for P/F assessment

• Successful testing conducted in 2014-2015

• New, preloaded bearing tested due to unknown friction effects
Phase 1 Testing

- MiniRad assembled with PEZ and EXO-Structure
- Mounted onto MGSE

- Procedure then repeated with Frangibolt
- Ensures system works with same deployment mechanism as flight
Results – Phase I

Passed Testing Criteria

• All ten consecutive tests successfully deployed MiniRad structure
• All STR pin trigger test requirements were met.
• Old hardware used but no effects due to same mass properties
• Repeatability Verification
• Ensure range of motion of sliders is sufficient
• Ensure rigidity of linear bearing
• Observe changes in final position of MiniRad after deployment.
  – 1.186 millimeters in the x direction
  – 1.186 millimeters in the y direction
  – 1.840 millimeters in the z direction
Phase II Testing Procedure

- MiniRad Mounted to Jig
- Clamped to Mill and Aligned with Mill Axes
- Dummies in place of Exo-panels
- Mill zeroed onto exterior of payload panels

- Exo-Panel dummies lowered to allow deployment
Phase II Testing Procedure

• Dial Indicator used to measure position of mirror in X, Y and Z positions
Phase II Testing
## Results – Phase II

### Passed Testing Criteria

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Measured Value in X</th>
<th>Measured Value in Y</th>
<th>Measured Value in Z</th>
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<tbody>
<tr>
<td>Test 1</td>
<td>0.0086 in</td>
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<td>Test 10</td>
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<td>0.0004 in</td>
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</tbody>
</table>

Max Deflection in X: **0.2464 mm**

Max Deflection in Y: **0.8255 mm**

Max Deflection in Z: **0.0787 mm**
Phase III Testing

- Optical Test to verify mirror alignment
- Procedure to iteratively adjust position of mirror with feedhorn prototype
- Alignment verification at NIST’s CROMMA facility
- Significant modifications to previous design
Alignment Risk Areas

- Set screws hold moving plate
- Risk of vibration loads causing set screws to shift
- Proper linear bearing to maintain alignment tolerances
Phase III Procedure

Previous Phase III Testing Setup using collimated light source

Current Phase III Testing Setup using alignment stages and image processing
Phase III Procedure

- Integrate Alignment Stack and Mounting Jig
- Integrate mechanism to optical table
- Mount MiniRad to MGSE and implement counter weight
Phase III Procedure

- Integrate dummy feedhorn with correct interfaces
- Integrate Mirror Holder and Restraint Mechanism
- Mount laser pointers and center with respect to surface mirrors
Phase III Procedure

- Mount laser pointers and adjust tip/tilt to reduce spot size on Target Screen 2
- Mount laser pointers and adjust translation stages to reduce spot size on Target Screen 1
- Repeat process for fine alignment
Phase III Procedure

- Collimated Light Source Alignment
- Track focal point via image post processing
- Repeat process for fine alignment and reduce off-axis rays
Phase III Preliminary Results

- Preliminary results verify that phase center is misaligned 2X the allowable distance.
- Lack of preloaded linear bearing, and incorrect integration of alignment pins may be contributing to phase center misalignment.
- Live post processing of focal and laser positions to be investigated.
Path Forward

• Continue Phase 3 in conjunction with NIST - CROMMA testing
• Manufacturing payload hardware in house
• Confirm phase center and outsource modified parabolic mirror
• Wing deployment verification
• Vibe Test of structure with all internal electronics
BACKUP