Mission Concept and Design for the Orbiting Aerosol Observatory

Presenters: Frank Rutherford, Erica Jenson, Kieran Wilson
Faculty advisor: Riccardo Bevilacqua
University of Florida, Gainesville, FL
Mission Overview

• March 4, 2011 – NASA Glory satellite failed to reach orbit
• December 2020 – 6U CubeSat carrying hypothetical, miniaturized version of Glory’s Aerosolized Polarimetry Sensor begins 2-year mission in the Afternoon Constellation
Mission Objective

• Determine the concentration of atmospheric aerosols
• Miniaturized aerosol polarimetry sensor (mAPS) will take measurements of sunglint scattering
• Sunglint – sunlight reflected off the Earth’s oceans
Initialization CONOPS

**Orbital Insertion**
- Deploy from launcher at 12:00 GMT 1 Jan 2020
- T+0

**Detumbling**
- Magnetorquer
- T+0 to T+27 hours

**Startup**
- Solar panel deployment
- Contact ground station
- T+27 to T+72 hours

**Phasing Maneuver**
- Phasing burn 1: +ΔV
- T+72 to 76 hours
- Phasing burn 2: -ΔV
- T+76 to 80 hours
**CONOPS, continued**

**Lunar Calibration**
- T+168 to 169 hours

**Science Mode**
- Sunglint tracking 23430 seconds/day
- Relay spectral data to ground
- T+240 hours to T+2 years

**Deorbit**
- Retrofire thruster
- T+2 years
Orbital Mechanics

• STK simulation of operational orbit, environments

Orbital Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eccentricity</td>
<td>0.00125</td>
</tr>
<tr>
<td>Semimajor axis</td>
<td>7071 km</td>
</tr>
<tr>
<td>Inclination</td>
<td>98.22°</td>
</tr>
<tr>
<td>MLTAN</td>
<td>13:41</td>
</tr>
<tr>
<td>Arg Perigee</td>
<td>69°</td>
</tr>
<tr>
<td>Altitude</td>
<td>700 km</td>
</tr>
</tbody>
</table>
Phasing Maneuver

• Injection orbit 160° out of phase with operational position
• Continuous thrust modeling
  • Performed in MATLAB, with J2 orbital perturbation and thrust
  • Requires 13,233 second long firing followed by matching retrofire
Position keeping and deorbit

• Cumulative drag effects after 1 year:
  • $\Delta a = 0.3 \text{ km}$
  • $\Delta V = 0.17 \text{ m/s}$
  • $\Delta T = 0.21 \text{ s}$

• Positional lag >4000s relative to Aqua after 2 years

• Boost burns every 74 days to maintain position in A-Train to within 15s
  • 604s burn, 10 required during mission

• Drag insufficient to guarantee deorbit within 25 years
  • Deorbit burn to lower altitude to <490 km ($\Delta V = 140 \text{ m/s}$)
Attitude Determination and Control

• Criteria:
  • Detumbling
  • mAPS calibration maneuver
  • Sun glint, ground station tracking

• System selected:
  • Blue Canyon Technologies XACT
  • Pointing accuracy ±0.003° for 2 axes; ±0.007° for 3rd axis

\[
\dot{\omega} = I^{-1}(\ddot{\tau} - \omega \times I\dot{\omega}) \\
\ddot{\tau} = \vec{m} \times \vec{b} \\
\vec{m} = \frac{-k}{\|\vec{b}\|^2}(\vec{b} \times \vec{w})
\]
ADACS Simulink Model

• Verify that XACT meets torque and momentum storage requirements

• Closed-loop PD control algorithm:

\[
\begin{bmatrix}
\alpha_x \\
\alpha_y \\
\alpha_z
\end{bmatrix} =
\begin{bmatrix}
k_{p1} q_{e2} \\
k_{p2} q_{e3} \\
k_{p3} q_{e4}
\end{bmatrix} - k_d
\begin{bmatrix}
\omega_x \\
\omega_y \\
\omega_z
\end{bmatrix}
\]

• Gain scheduling: \( k_{p_i} = k_o - q_{e_i} k_o k_g \)

• Input sunglint tracking quaternion from STK
Sun Glint Tracking

- High initial error corrected in ~100 seconds
- Max torque
  - Allowable: 4 mNm
  - Predicted: 3.6 mNm
- Max angular velocity
  - Allowable: 630 rad/s
  - Predicted: 500 rad/s
mAPS Calibration Maneuver

• The mAPS will be swept over the moon four times at 0.01333°/sec
• Maneuver is performed about the spacecraft z-axis
• The moon-pointing orientation was determined using STK
Telemetry, Command and Data Handling

• Single ground Station
  • Thule Tracking Station
  • Access every orbit
  • Minimum 8.96 Mbps transmission rate

• Components selected:
  • Syrlinks EWC27 X-band transceiver
    • Up to 100 Mbps
  • AntDevCo X-band patch antenna
  • SkyFox Labs GPS Receiver and patch antenna
  • NanoMind Z7000 onboard computer
Solar Panel Configuration

Normalized Power Intensity vs Time (h)

-+Y -Y +X -X +Z -Z

mAPS line of sight
Electrical Power System

- Maximum power requirement during phasing maneuver:
  - 21.3 W
  - 14.86 Wh per orbit
  - 33 Wh in total

- Components selected:
  - NanoPower P60 EPS
  - GOMspace BPX Batteries
    - 87.4 Wh storage
  - ClydeSpace deployable solar panels
    - Four 3U panels, two 2U panels
    - Estimated output of 30.6 Wh per orbit
Structure

- ISIS 6U Structure
- Total estimated mass: 11 kg
- Thrust vector aligned with center of mass

<table>
<thead>
<tr>
<th>Direction</th>
<th>Distance (cm)</th>
<th>Tolerance (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>-0.36</td>
<td>4.5</td>
</tr>
<tr>
<td>Y</td>
<td>0.34</td>
<td>2.0</td>
</tr>
<tr>
<td>Z</td>
<td>-1.37</td>
<td>7.0</td>
</tr>
</tbody>
</table>
Environments and Test Plan

• Two complete articles constructed
  • Qualification and flight units
  • Components have full flight heritage
  • Only system-level qual required

• Shock, Vibration and Acoustic
  • Qual unit to +6 dB, full duration in each axis
  • Acceptance test to max flight environment

• Thermal
  • Minimum of 350 hours of operation during thermal cycling
  • -20 °C to +50 °C estimated with aluminized Kapton insulation layer

• Radiation
  • STK simulations estimate radiation dose of ~0.5 rad/day
  • Expose electronics to 120% of anticipated total accumulated ionizing dose
Acknowledgements

• Dr. Riccardo Bevilacqua
• Justin Treptow and Laurence Fineberg, NASA Kennedy Space Center
• Sanny Omar
• Stanley, Marianne, Valerie, and all the judges
Budget

Mission Budget (USD)

- 5,000,000
- 2,000,000
- 2,000,000
- 3,000,000

Projected vs. Budgeted Cost (USD in millions)

- Build
- Launch
- Operate

Projected | Budgeted
--- | ---
Build | 2
Launch | 2
Operate | 1