Six-Axis Monopropellant Propulsion System for Pico-Satellites

Mariella Creaghan, Orland Lamce, and Cody Slater

14 October 2015
Overview

• Background
• Spacecraft Capabilities
• Thruster System Design
• Ground Support Equipment
• Results
• Conclusion
A Wide Variety of Satellites

- **International Space Station**: 419,455 kg
- **Hubble Space Telescope**: 11,110 kg
- **Voyager 1 & 2**: 733 kg
- **“Small” Satellites**: < 500 kg

Images provided by nasa.gov
Small Satellite Categories

- **Pico** (<1 Kg)
- **Nano** (1-10 kg)
- **Micro** (10-100 kg)
- **Mini** (100-500 kg)
The Small Satellite Revolution

1 to 50 kg Satellite Launches

Data from SpaceWorks 2014 Market Research Assessment
Laboratory’s Approach to Propulsion

Propellant

Catalyst Bed

Decomposition Chamber

Thrust Chamber

Exhaust

Thrust
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System Concept

Cylindrical Fuel Tank

Dual Manifold Central Feeds

Notional Thrust Block

Triad Valve Arrangement

Honeycomb Mounting Shelf
### Propellant Selection

<table>
<thead>
<tr>
<th>Propellant</th>
<th>Volumetric Impulse (kg*s/m³)</th>
<th>Ground Infrastructure</th>
<th>Test Precautions</th>
<th>Attainability</th>
<th>Flight Proven</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen Gas</td>
<td>33,314</td>
<td>Moderate</td>
<td>Minimal</td>
<td>Easy</td>
<td>Often Used</td>
</tr>
<tr>
<td>Hydrogen Peroxide</td>
<td>215,298</td>
<td>Moderate</td>
<td>Highly reactive</td>
<td>Easy</td>
<td>Popular in 1960s</td>
</tr>
<tr>
<td>Hydrazine</td>
<td>234,600</td>
<td>Extreme</td>
<td>Carcinogenic</td>
<td>Moderate</td>
<td>Standard</td>
</tr>
</tbody>
</table>

**Hydrogen peroxide provides most versatile, economic performance for immediate space flight**
Picosatellite Propulsion Objectives

- Acceleration \( \sim 1 \text{ m/s}^2 \)
- Slew rate 32 °/s
- Response time < 1 second

Goal: To create an adaptable and reliable propulsion system concept for use in a wide range of picosatellite geometries.
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Objectives

5. Live-fire the complete system and characterize the resulting steady state performance
Catalyst Bed

- Increases reaction rate
- Pure silver catalyst
- Activation procedure
- Microchannel design
- Maximum surface area
- Length estimated with scaling
- Analytical model started

\[
\frac{\Delta X}{H} = \frac{H_2O}{O_2}
\]
Nozzle Configuration

AER = 10

Chamber
- Pressure: 689,000 Pa
- Temperature: 1219 K
- Diameter: $D_t = 1.162$ mm
- Length: $L = 3.862$ mm
- Angle: $\alpha = 18^\circ$

Atmosphere
- Pressure: 7,158 Pa

-.776 $\frac{g}{s}$

$D_2 = 3.670$ mm
Catalyst Block Design
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System Layout
Thrust Stand

Counter Weight

Torque Sensor

Reaction Force

Thrust Block

Thrust

y

x

.21 m
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System Check and Calibration

- Safety Precautions
- Calibrated:
  - In-line pressure sensor
  - Torque sensor
- Leak Tested:
  - Nitrogen gas
  - Helium gas
  - Water
- Valve Operation Test
Catalyst Test

![Graph showing temperature over time during a catalyst test](image-url)

The graph illustrates the temperature change over time for a catalyst test. The temperature is measured in degrees Celsius (°C) and the time is in seconds (s). The test appears to involve an initial rise in temperature followed by a decline, indicating the catalyst's activity over the measured period.
Integrated HTP Thrust Test

HYDROGEN PEROXIDE THRUSTER TEST
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Conclusions

1. Safety ✓
2. System setup ✓
3. System proof test ✓
4. Catalyst experiments ✓
5. Integrated system test ✓
Future Work

• Catalyst bed exploration
• Interface of flow into catalyst
• Continuation of thrust characterization
• Long term system improvement
Acknowledgements

• Jesse Mills
• Adam Shabshelowitz
• Kurt Krueger
• Sean Crowley
• Mark Seaver
• Sharon Hardiman

Additional thanks to: Mike Shatz, Dennis Burianek, Marc Brunelle, John Howell, Prof. Gatsonis, Prof. Clancy, Professor Blandino, Jocelyn O’Brien, Gerald Johnson, Andy Kalil, Ted Bloomstein
Questions?
Torque Sensor Calibration

Calibration Curve

\[ y = 343.13x + 0.3231 \]

\[ R^2 = 0.9977 \]
Mounting Plate