Busek SmallSat Technologies

Planetary CubeSats Symposium
Aug 17th 2018
NASA Goddard Space Flight Center

Dan Courtney
Michael Tsay
Nathaniel Demmons

Approved for public release; distribution is unlimited. Copyright 2018.
Cubesat & SmallSat Propulsion (6kg-220kg)
Busek CMNT on LISA Pathfinder: Successful Demonstration of Electrospray Thrusters for Precision Control

- <0.1μN resolution, <0.1μN/Hz$^{1/2}$ noise

BET-300-P / RCS Seeks to Provide Precision Control Electrospray Features to Small Spacecraft
BET-300-P Performance and Applicable Missions

**Performance:** High T/P, Precision Actuator

- Low noise (calculated) <0.1\(\mu\)N/Hz\(^{1/2}\) [10mHz – 10Hz]
- High impulse density ~1000Ns/U (1000s Isp)
- Low impulse bits ~2\(\mu\)Ns

**Deep space missions:**
- High impulse density
- Single RCS (vs. reaction wheels+CG)

**Precision pointing:**
- Arcsecond precision
- Vibration free
- Astronomy
- Laser communication

**Non-Keplerian orbits:**
- Nm scale control
- Inspection / service
- Occultation sources
- Distributed apertures

**Wide range** ~few to 150\(\mu\)N

**Control** <0.4\(\mu\)N

**T/P** > 55mN/kW
6U CubeSat observatory tasked with taking long exposure inertial-stare images

- Precision ACS via electrospray holds target centroid to sub-arcsec over 10’s of seconds
- Same ACS used to slew to next image position

<table>
<thead>
<tr>
<th>Images</th>
<th>100/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impulse /image</td>
<td>1.7mNs/img</td>
</tr>
<tr>
<td>Impulse /year</td>
<td>125Ns/yr</td>
</tr>
<tr>
<td>Margin</td>
<td>100%</td>
</tr>
<tr>
<td>Total impulse</td>
<td>250Ns/yr</td>
</tr>
<tr>
<td>$M_{\text{prop}} @ 65s$ lsp</td>
<td>400g/yr</td>
</tr>
<tr>
<td>$M_{\text{prop}} @ 1000s$ lsp</td>
<td>26g/yr</td>
</tr>
</tbody>
</table>
BIT-3 RF Ion Thruster

**Iodine Propellant**

**BIT-3 Features**
- Integrated, “plug-n-play” propulsion unit
- 1.6U volume, 2.9kg wet (1.5kg solid iodine prop)
- RF ion thruster and RF cathode
- 2-axis, ±10° thruster gimbal
- Propellant management system
  - Lightweight, heated iodine tank
  - NASA launch safety approved
- Mini Power Processing Unit (PPU), Smallest ion engine PPU; SOTA power conversion efficiency (>83%)
BIT-3 RF Ion Thruster Performance

**Thrust**

- ~0.7 to 1.2mN @ 55 to 80 W (system) power

**Specific Impulse**

- 1400-2160s $I_{sp}$
- ~31000Ns total impulse (19kNs/U)

---

Gimbal Demonstration

- +10°
- 0°
- -10°
BIT-3 RF Ion Thruster: Status and Missions

**Lunar IceCube** (led by Morehead State University)
- 6U CubeSat lunar mission, prospect for ice
- Deploy by NASA’s SLS on EM-1 (2020)
- BIT-3 applied with low energy manifold trajectory to achieve lunar capture and science orbit

**LunaH-Map** (led by Arizona State University)
- Deploy by NASA’s SLS on EM-1 (2020)

BIT-3 **flight hardware undergoing final preparation for delivery; presently booking orders for 12 month delivery.**

4,000-hr life test, funded by NASA for risk reduction; Test to begin in 2018
AMAC Features
Integrated propulsion system (propellant, PPU, thruster)
• 1.5 kg (wet)
• 565 Ns total impulse
• Single 0.5N thruster (BGT-X5)
Post-launch pressurization system (PLPS)

Integrated electronics / digital interface
• Rad-tolerant power electronics
• 20W input power
BMP-220 mPPT Thruster System

BMP-220 Features:
Co-axial PPTs, heritage from FalconSat 3 (2007)
Fully integrated system
  - <0.5U module + ‘tuna-can’
  - Avg. Ibit ~20μNs, <=2Hz repetition rate
  - 150-170Ns total impulse

12 selectable PPT ‘sticks’
BHT-200 Hall Thruster System

- Flight-proven Xenon propulsion system; first US Hall thruster in space (2006)
- Multiple deliveries of complete integrated systems; thrusters, cathodes, PPUUs, feed systems tank, harness, brackets; system hot-fire acceptance tests.
- Iodine compatible anodes & valves
- Compact 100kRAD PPU in active development; legacy PPU being sunset
- 2,000 hours demonstrated life, voluntarily terminated
BHT-600 Hall Thruster System

- BHT-600 actively advancing to flight status
- Compact 100kRAD PPU
- Xenon and Hybrid iodine variants
  - 5,000 hr all-Xe thruster duration test at GRC underway
  - 1,200 hr hybrid Xe + I variant successfully tested 1,200 hours (10kg iodine), GRC
Selected Customers: