**Technology Title:** Micro Satellite Solar Electric Propulsion

**Affiliation:** ExoTerra Resource

### Assumptions: Technology required to be at TRL 5 by 2021

**Technology Description, Current Performance Metrics, and Performance Goals**

**Micro Hall Effect Thruster**
- 4-33 mN Thrust, 700-1500 s Isp, .65 kg, 7.2 cm OD, 85-450 W, 200 kNs Impulse

**CubeSat PPU**
- 95-98.5% Efficiency, <.4 kg, PC104 form factor

**135W Deployable Solar Array**
- 130 W/kg, .16 W/cm^3, scales to 500 W.

<table>
<thead>
<tr>
<th>Industry State of the Art Technology Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hall Effect Thruster</td>
</tr>
<tr>
<td>12.8 mN, 1375 s Isp, 1.2 kg, 10.1 cm OD, 200W, ~50 kNs Impulse</td>
</tr>
<tr>
<td>PPU</td>
</tr>
<tr>
<td>92-94% Efficiency, ~1 kg</td>
</tr>
<tr>
<td>Solar Arrays (Microsat Scale)</td>
</tr>
<tr>
<td>&lt;100 W, 60-90 W/kg</td>
</tr>
</tbody>
</table>

### Technology Development Challenges to Meet TRL Goal

- **Hall Thruster:**
  - Lifetime Testing, Vibration Testing
- **CubeSat PPU**
  - Radiation Testing, SEE Testing
- **Solar Array**
  - Vibration Testing, 0g Deployment

**Current TRL**
- **4-5**

**Industry State of the Art Technology Performance**

- **Hall Effect Thruster**
  - 12.8 mN, 1375 s Isp, 1.2 kg, 10.1 cm OD, 200W, ~50 kNs Impulse
- **PPU**
  - 92-94% Efficiency, ~1 kg
- **Solar Arrays (Microsat Scale)**
  - <100 W, 60-90 W/kg

### Potential HPD Science Application (Optional)

- High delta-V missions with micro satellites
- Delivery from LEO or GTO to Lagrange Points or Earth Escape at reduced launch cost or more frequent rideshare opportunities.
- Increased power availability for instruments, cryo-coolers, or telecommunications.

### Contact Information

- **Michael VanWoerkom**
  - mvanwoerkom@exoterracorp.com
Halo Hall Effect Thruster

- 72 Hrs of testing to date
- Currently in Life Testing. Test Target: 500 hr. Lifetime target >2000 hr.
- Measured mass <.65 kg
- 7.2 cm OD x 5 cm
- Centerline Cathode
- Recently awarded NASA SBIR to qualify and deliver a flight test unit by Q1 2020
Hall Thruster Performance
Power Processing Unit

- Measured Efficiency of 96-98.5%
- Completed integrated testing with thruster
- Measured mass below .25 kg/card
- Designed for 100 krad w/ 300 krad upgrade option
- To be qualified as part of NASA SBIR award
Radiation Tolerant CubeSat Power Distribution

- Developing a radiation tolerant CubeSat EPS board under NASA SBIR
- >100 kRad TID
- Currently at breadboard level development
- 30 software programmable switches
- 96-98% Efficiency
- >300 W throughput

Phase I Rad Tolerant PMAD Breadboard
Deployable Solar Array

- 135 W measured power
- 130 W/kg measured specific power
- Random Vibration, Shock and Thermal Cycle testing conducted under NASA Ph II SBIR.
- .16 W/cm$^3$ Stowed Power Density

Solar Array Vibration Testing

Solar Array Blanket Test Article
ExoTerra Team

- **Michael VanWoerkom** – Founder, MBA, 20 yrs Experience. System Design, SEP, Mechanical Design. XSS11, Genesis, Orion
- **Greg Hegemann** – Systems Engineer, 20 yrs Experience at Lockheed & Sierra Nevada. Stardust, Orbcomm, Classified
- **Tom James** – Mechanical Lead, 18 yrs Experience on Shuttle, Orion and X-33
- **Carl Gross** – Mechanism Design, 10 yrs Experience on Orion, Dream Chaser
- **Mike Krohn** – Stress Analysis – 30 yrs Experience, Atlas, Orion
- **Jake Hogan** – Thermal Analysis – 4 yrs Experience, Orion
- **Heather Swenson** – Guidance & Nav – 11 yr Experience
ExoTerra History

<table>
<thead>
<tr>
<th>Year</th>
<th>Sponsor</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>NASA</td>
<td>Direct Drive SEP Microsatellite</td>
</tr>
<tr>
<td>2014</td>
<td>NASA</td>
<td>EPIC: Electrically Propelled Interplanetary CubeSat</td>
</tr>
<tr>
<td>2015</td>
<td>NASA</td>
<td>SEP CubeSat Power Module</td>
</tr>
<tr>
<td>2016</td>
<td>NASA</td>
<td>SEP CubeSat Power Module (Ph II)</td>
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<tr>
<td>2017</td>
<td>Air Force</td>
<td>GEO CubeSat Observer</td>
</tr>
<tr>
<td>2018</td>
<td>NASA</td>
<td>Xenon Micro EP Module</td>
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</tbody>
</table>

Asteroid Redirect Mission Study

Mars Aerosol Tracker