Performance Characterization of the HYDROS™ Water Electrolysis Thruster

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HYDROS Overview

- Allows secondary payloads to launch with a safe, storable, non-toxic propellant: water

- Fuel cell electrolyzes water into oxygen and hydrogen on-orbit

- Modular design affords scalability to meet a wide range of mission and design imposed requirements
HYDROS Overview

• High performance bipropellant thruster capable of providing up to 1 N of thrust at 300 seconds of specific impulse

• Current total propulsion system volume 1U, including control electronics

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<thead>
<tr>
<th>Metric</th>
<th>Goal</th>
<th>Demo’ed To-Date</th>
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<tbody>
<tr>
<td>Thrust (Max)</td>
<td>1 N</td>
<td>0.8 N</td>
</tr>
<tr>
<td>Min. Bit Impulse</td>
<td>0.1 mN·s</td>
<td>&lt; 0.75 mN·s</td>
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<tr>
<td>Specific Impulse</td>
<td>300 s</td>
<td>258 s</td>
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<tr>
<td>Power Required</td>
<td>0.5 -10W</td>
<td>0.5 -10W</td>
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HYDROS Performance Metrics
HYDROS provides orbit-agility for both CubeSats and small satellites.
HYDROS System Architecture

- **Electrolyzer**
  - Generates gaseous O2 and H2 on-orbit

- **Gas Volumes**
  - Store evolved gases for use in bipropellant thruster

- **Thruster**
  - Bipropellant 1N thruster capable of 300s $I_{sp}$

- **Water Tank**
  - Scalable to meet mission performance requirements
Design History

- Developed HYDROS thruster prototype under a NASA SBIR
  - Phase I: Proof-of-Concept
  - Phase II: Technology Development

- Electrolyzer and thruster developed in parallel efforts
  - Extensive pre-integration test campaigns conducted for both sub-systems
  - Vacuum and gravity antagonistic testing used to validate design
Design History Cont.

- Initial integrated prototype designed for 0.5U footprint
  - No avionics integration
  - Length constrained for 3U+ volume
- Electrolyzer and thruster designs rev’d to improve performance
  - Gas generation rate doubled
- Improved system architecture incorporates improvements and provides expanded gas storage
- Engineering unit delivered to AFIT
  - Testing by AFIT and TUI matures design to TRL 5
HYDROS Test Program

• Testing conducted in-house utilizing TUI’s vacuum chamber and thrust stand

• Vacuum Chamber
  – Lifetime testing
  – Thruster/Electrolyzer characterization

• Thrust Stand
  – Torsion balance
    • Sub mN·s resolution
    • Measures thrust events up to 500 mN·s
Test Configuration and Error

- Thrust and Isp values are determined from impulse and pressure measurements

- Calibration
  - Thrust stand and pressure transducers are calibrated prior to data collection

- Error Analysis
  - Calibration and measurement errors propagated to characterize total error
  - ~6% error with given test configuration
Electrolyzer Characterization

- **Verify analytical models of electrolyzer performance**
  - Time required to pressurize gas volumes
  - Current and power levels

- **Understand how power levels and wetting of the electrolyzer impact performance**
**Electrolyzer Characterization**

- Understand driving properties of electrolyzer performance
  - Maximum electrolyzer performance requires adequate wetting of Proton Exchange Membrane
  - Drop in current draw correlates to reduction in gas evolution rate and indicates inadequate wetting
Electrolyzer Characterization

Power consumption testing:

- Fuel cell gas generation rate as a function of applied power
  - Used to refine analytical models for system and mission design efforts
Thruster Performance

• Initial characterization of the thruster has demonstrated:
  – Avg Thrust: 0.6 N
  – Total Impulse: 150 mN·s
  – 250 ms pulse
Thruster Performance

![Graph](#)

**Pressure Drop vs. Average Thrust**

- **Y-axis**: Average Thrust [N]
- **X-axis**: Pressure Drop [psi]

The graph shows the relationship between pressure drop and average thrust for thrusters.
Tethers Unlimited, Inc.

- TUI Develops Advanced Technologies for Space & Defense
- 20 years in operation, >80 contracts completed
- Clients: NASA, DARPA, Navy, Air Force, Army, & space primes
- Commercialized multiple SBIR technologies & supported multiple flight missions

### Core Technology Areas

<table>
<thead>
<tr>
<th>Tether Systems for Space and Defense</th>
<th>High-Performance SmallSat Components</th>
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<td><img src="image1.png" alt="Tether Systems" /></td>
<td><img src="image2.png" alt="SmallSat Components" /></td>
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<th>SmallSat Software Defined Radios</th>
<th>Additive Manufacturing For- &amp; In-Space</th>
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<td><img src="image3.png" alt="SmallSat SDR" /></td>
<td><img src="image4.png" alt="Additive Manufacturing" /></td>
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- AFSCN/S-band
- Wide-Band
- UHF

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