Pathfinder Technology Demonstrator
Small Satellite Conference 2016

NASA Space Technology Mission Directorate
NASA Small Spacecraft Technology Program
NASA Ames Research Center | NASA Glenn Research Center
Pathfinder Technology Demonstrator (PTD)

**To demonstrate and characterize novel satellite technologies in Low Earth Orbit**

“Enabling commercially marketable products to advance the capabilities for CubeSats and other small spacecraft to support a wide variety of science, exploration and commercial space missions.”

*Representative image only. Subject to change based on PTD spacecraft bus developer solution.*
PTD Tentative Milestones

Initial Flight Milestones

- **BET100uN Kick Off**: 2/3/16
- **BET 100uN SRR**: 3/7/16
- **BET100uN PDR**: 6/29/16
- **BET100uN CDR**: 10/28/16
- **BET100uN Delivery**: 5/15/17
- **I&T**: 5/25/17 - 11/10/17
- **Environmental**: 11/13/17 - 2/6/18

Initial Launch Capability (ILC) Milestones

- **LC BET100uN**: 3/14/18
- **ILC Hyper-XACT**: 8/15/18
- **ILC HYDROS**: 2/14/19
- **ILC GREEN PROP**: 8/23/19
- **ILC PL#5**: 2/14/20

PTD Milestones Subject to Change Based on SC Vendor Schedule
PTD Spacecraft RFP Background

A Request for Proposal (RFP) NNA16574335R was issued for the delivery of a spaceflight qualified 6U CubeSat spacecraft to be operated by NASA for its Pathfinder Technology Demonstrator (PTD) Project to accommodate technology subsystems, hereafter referred to as the payload. One flight demonstration is planned for a low thrust propulsion system with options for four follow-on technology demonstrations. Follow-on missions may include payloads such as higher thrust propulsion systems or payloads such as optical communications or high precision attitude determination and control systems.

RFP Release Date: 02.12.2016
RFP Response Date: 04.04.2016
Busek BET-100uN

- Rugged Design
- Non-volatile propellant
- No moving parts, no valves
- No pressure vessel
- Low power
- Integrated Digital Control
- Throttleable performance
- Clustered or distributed units

Busek’s BET-100 electrospay propulsion system is the result of over 10 years of pioneering research and development, enabling low-power CubeSat and NanoSat missions.

The 9 cm x 9 cm x 4 cm module consumes 5.5W to deliver between 5 - 100 uN thrust with a specific impulse of up to 1,800 seconds. Lower specific impulse configurations are available for extremely power limited applications (<3.5 W). A single module can deliver 45 m/s to a 4kg CubeSat.

Busek’s electrospay thrusters utilize non-volatile flight proven propellant, first characterized for the ESA LISA Pathfinder Mission (NASA ST-7).

- Rugged design
- Non-volatile propellant
- No moving parts, no valves
- No pressure vessel
- Low power
- Integrated Digital Control Interface Unit (DCIU)
- Throttleable performance
- Multiple units can be clustered or distributed within a spacecraft for primary propulsion and attitude control (ACS)
Hyper-XACT will extend the considerable SWaP and cost improvements of XACT (vs. traditional ADCS systems) to longer missions with tighter performance requirements and more conservative risk postures.

XACT sensor/actuator suite
- 1 Nano Star Tracker
- 3-4 Reaction wheels
- 3 Torque rods
- 1 Magnetometer
- 1 IMU
- 1-4 Quad-diode coarse sun sensor packages

Performs high-level commanded behaviors including multiple pointing reference frames: Inertial, LVLH, Earth-Fixed Target Tracking, Solar, Moon, etc.

Low-jitter 3-axis reaction wheel control
Tethers Unlimited, Inc.

Address: 11711 N. Creek Pkwy S., D113
Bothell, WA 98011

# Employees: 40

Description: TUI develops transformative technologies for space and defense missions:
- Propulsion
- Communications
- In-space manufacturing

Teaming Partners:
- Millennium Space Systems (cost-share customer)
- Air Force Institute of Technology

HYDROS Technology Overview:
- Hybrid chemical/EP technology to provide safe, high-performance propulsion for secondary payloads
- Uses electrolysis cell to split water propellant into gaseous hydrogen and oxygen, pressurizing separate gas storage volumes
- Burns hydrogen and oxygen in simple bipropellant thruster to provide up to 1N @ 258s

Required Development:
- Optimize system designs for CubeSat and Microsat applications
- Integrate flight-configuration control electronics
- Functional, Environmental, & Lifetime testing to establish TRL necessary for commercial sales

TRL:
Start: SBIR & post-SBIR testing in vacuum established TRL-5
End: Functional, Qual, & Lifetime testing will establish TRL-6

High-Thrust, High-Isp Propulsion with Non-Toxic, Non-Explosive, Non-Pressurized, ISRU-Compatible Propellant: WATER

Market Value:

Commercial Applications:
- Orbit raising, deorbit, & stationkeeping of LEO constellations –
- HYDROS baselined for 3 government-funded missions

NASA Applications:
- Science & Exploration missions conducted using ride-share secondaries and requiring orbit maneuvering, stationkeeping, or drag makeup
Aerojet Rocketdyne MPS-130

**MPS-130**
Innovative Propulsion Solutions for SmallSats

**Green High Delta V Propulsion for Cubesats**
3D Printed Cubesat Propulsion for Constellation Deployment, Orbit Maintenance and Stationkeeping

**1U Configuration Pictured**

**Expected Performance**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value (1U)</th>
<th>Value (2U)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throughput Limit</td>
<td>0.5 kg</td>
<td>1.0 kg</td>
</tr>
<tr>
<td>Pulse Limit</td>
<td>5000</td>
<td>1000</td>
</tr>
<tr>
<td>Impulse Limit</td>
<td>600 N-s</td>
<td>1200 N-s</td>
</tr>
<tr>
<td>SS BOL Thrust*</td>
<td>1.5 N (~0.4 lbf)</td>
<td>3.0 N (~0.6 lbf)</td>
</tr>
<tr>
<td>SS isp</td>
<td>240 seconds</td>
<td>480 seconds</td>
</tr>
</tbody>
</table>

**System Specifications**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value (1U)</th>
<th>Value (2U)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propellant</td>
<td>AF-M315E</td>
<td>AF-M315E</td>
</tr>
<tr>
<td>Operation Pressure</td>
<td>34.5 - 59 bar (500 - 860 psi)</td>
<td>40.0 - 70 bar (580 - 1000 psi)</td>
</tr>
<tr>
<td>Dry Mass</td>
<td>1.9 kg (4.2 lbm)</td>
<td>2.3 kg (5.1 lbm)</td>
</tr>
<tr>
<td>Wet Mass</td>
<td>2.4 kg (5.3 lbm)</td>
<td>3.3 kg (7.3 lbm)</td>
</tr>
<tr>
<td>Usable Propellant</td>
<td>0.6 kg (1.3 lbm)</td>
<td>1.1 kg (2.4 lbm)</td>
</tr>
<tr>
<td>Dimensions</td>
<td>10 x 10 x 11.4 cm</td>
<td>10 x 10 x 22.4 cm</td>
</tr>
<tr>
<td>Operational Temp</td>
<td>5 - 60 °C</td>
<td>5 - 60 °C</td>
</tr>
<tr>
<td>Valve Power</td>
<td>Startup: &lt;4 W</td>
<td>Startup: &lt;4 W</td>
</tr>
<tr>
<td>Requirements</td>
<td>Operation: &lt;1 W</td>
<td>Operation: &lt;1 W</td>
</tr>
<tr>
<td>Valve Voltage</td>
<td>Startup: 6-8 Vdc</td>
<td>Startup: 6-8 Vdc</td>
</tr>
<tr>
<td>Catalyst Bed</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Heater Power</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Number of Thrusters</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>MRL / TRL</td>
<td>6 / 6</td>
<td>6 / 6</td>
</tr>
</tbody>
</table>

**Delta-V Capabilities based on Payload Mass**

<table>
<thead>
<tr>
<th>Payload Mass (kg)</th>
<th>1U ΔV (m/sec)</th>
<th>2U ΔV (m/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>340</td>
<td>753</td>
</tr>
<tr>
<td>1.5</td>
<td>284</td>
<td>685</td>
</tr>
<tr>
<td>2.0</td>
<td>258</td>
<td>596</td>
</tr>
<tr>
<td>2.5</td>
<td>230</td>
<td>539</td>
</tr>
<tr>
<td>3.0</td>
<td>208</td>
<td>493</td>
</tr>
<tr>
<td>3.5</td>
<td>190</td>
<td>454</td>
</tr>
<tr>
<td>4.0</td>
<td>174</td>
<td>420</td>
</tr>
<tr>
<td>4.5</td>
<td>161</td>
<td>392</td>
</tr>
<tr>
<td>5.0</td>
<td>150</td>
<td>367</td>
</tr>
</tbody>
</table>

**Pathfinder Technology Demonstrator**
PTD Operational Concept

Launch (power off) → Deploy (350-800km) → Safe Hold → Ground Contact → Commission (7 days)

- 98 or 51 or 45 degree inclinations
- Wait 45 minutes to radiate
- Survival heating
- One monitored pass per weekday
- Up to 14 Lights out TLM passes/day
- One CMD upload/weekday

Characterize → Demo → Data Processing → Data Handling → Command Planning

Repeat Characterization up to 83 days
PTD Status

❖ Focus Areas
  • Busek BET-100uN Development
  • Blue Canyon Hyper-XACT Development
  • Tethers HYDROS Development
  • Aerojet MPS-130 Development
  • PTD SC RFP Evaluation/Down-select

❖ Busek BET-100uN
  • 1/2016 Authority To Proceed (ATP)
  • 3/2016 System Requirements Review (SRR)
  • 6/2016 Period Technical Review-1 (PTR-1)

❖ Blue Canyon Hyper-XACT
  • 6/2016 Authority To Proceed (ATP)

❖ Tethers HYDROS
  • 6/2016 Authority To Proceed (ATP)

❖ Aerojet MPS-130
  • 7/2016 Authority To Proceed (ATP)

❖ PTD SC RFP
  • 2/2016 RFP Release Date
  • 4/2016 Response Date
  • TBD ATP
PTD Key Requirements and Interfaces
<table>
<thead>
<tr>
<th>Req#</th>
<th>Requirement</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1-PTD-01</td>
<td>The purpose of the Pathfinder Technology Demonstrator (PTD) mission is to demonstrate novel satellite technologies in Low Earth Orbit (LEO).</td>
<td>The primary purpose of these flight demonstrations is to raise the Technical Readiness Level (TRL) from 5 to 7 of a variety of payloads provided to the project that meet the Pathfinder Technology Demonstrator system interface specification.</td>
</tr>
</tbody>
</table>
## Driving L2 Payload Requirements

<table>
<thead>
<tr>
<th>PTD L2 Requirement</th>
<th>PTD Spacecraft to Payload ICD</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Payload shall not exceed the total volume defined in the Spacecraft to Payload ICD.</td>
<td>2.4U</td>
</tr>
<tr>
<td>The Payload shall conform to CG and total mass limits specified in the Spacecraft to Payload ICD.</td>
<td>3kg with CG along X-axis</td>
</tr>
<tr>
<td>The Payload shall be capable of operating from spacecraft-supplied power as specified in the Spacecraft to Payload ICD.</td>
<td>The Payload subsystem on-orbit-average continuous electrical power required shall be less than or equal to 20W (TBD), 5.5a max current, unregulated power 12-15v (TBR)</td>
</tr>
<tr>
<td>The Payload shall be configured to communicate signals and data to the Flight System as specified in the Spacecraft to Payload ICD.</td>
<td>RS-422 Asynchronous</td>
</tr>
<tr>
<td>The Payload shall support a 90 day mission lifetime on orbit.</td>
<td>Payload thermal environment is independent and isolated from the Avionics volume and the responsibility of the payload.</td>
</tr>
<tr>
<td>The Payload shall be thermally controlled as specified in the Spacecraft to Payload ICD.</td>
<td>Payload thermal environment is independent and isolated from the Avionics volume and the responsibility of the payload.</td>
</tr>
<tr>
<td>The Payload shall be designed to withstand the maximums allowed for the LV dynamics (vibration, shock, acoustics) as per GEVS (GSFC-STD-7000A) levels</td>
<td>GSFC-STD-7000A</td>
</tr>
<tr>
<td>The Payload shall provide harnesses and cabling for the Payload System as specified in the Spacecraft to Payload ICD.</td>
<td>Provide the electrical harness and connectors required for operation of the Payload subsystem</td>
</tr>
<tr>
<td>The Payload shall be developed to allow for a one year shelf-life prior to launch.</td>
<td></td>
</tr>
<tr>
<td>The Payload shall be responsible for supplying mounting structures as specified in the Spacecraft to Payload ICD.</td>
<td>Provide Payload volume end-plate and mounting components or NASA-approved bonding agents.</td>
</tr>
<tr>
<td>The Payload shall provide EMI/EMC test data and analysis.</td>
<td>Shall be self-compatible with the Spacecraft</td>
</tr>
<tr>
<td>The Payload shall be delivered VC + UV for contamination levels.</td>
<td>Payload subsystem components shall be delivered VC+UV (Visibly clean, plus ultraviolet) at a cleanliness Level of 500 B.</td>
</tr>
<tr>
<td>The Payload shall provide a safe plug to inhibit unsafe operation on the ground per the electrical interface in the Spacecraft to Payload ICD.</td>
<td>Same</td>
</tr>
</tbody>
</table>
PTD Geometric View

*Notional design, TBS after RFP award