Pathfinder Technology Demonstrator
“Demonstrating Advanced Technologies for Advanced Missions”

CubeSat Developer’s Workshop
April 26th, 2017

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.”

RFP issued and contract awarded for a 6U bus leveraging existing CubeSat industry developments and experience to provide a low-cost, low-risk bus.
### PTD Level 1 Requirement

<table>
<thead>
<tr>
<th>Req#</th>
<th>Requirement</th>
<th>Rationale</th>
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</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>
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</tbody>
</table>
## Driving L2 Payload Requirements

<table>
<thead>
<tr>
<th>PTD L2 Requirement</th>
<th>PTD Spacecraft to Payload ICD</th>
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</thead>
<tbody>
<tr>
<td>The Payload shall not exceed the total volume defined in the Spacecraft to Payload ICD.</td>
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<tr>
<td>2.4U</td>
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<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>
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<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>
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<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>
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<td>The Payload shall support a 90 day mission lifetime on orbit.</td>
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<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>
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<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>
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<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>
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<td>The Payload shall be developed to allow for a one year shelf-life prior to launch.</td>
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<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>
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<tr>
<td>The Payload shall provide EMI/EMC test data and analysis.</td>
<td>Shall be self-compatible with the Spacecraft</td>
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<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>
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<td></td>
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<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

Propulsion Volume

Avionics Volume

*Notional design, TBS after RFP award
**PTD BUS SOLUTION**

**Overview**
- Tyvak selected to provide PTD bus and I&T services
- Options for up to 5 missions included
  - Common bus design
- PTD-1 will test Busek MEP
- GlobalStar demo included

**Implementation**
- 6U, 12 kg, 62 W OAP
- Based on existing, proven Tyvak hardware
- Deployable tracking solar arrays
- UHF/S-band Comms
- PROPCUBE based C&DH

**Status**
- Jan, 2017: Tyvak Kick-off held
- Feb, 2017: CSLI proposal accepted
  - Likely sun-synch orbit
- Mar, 2017: SRR held
- Aug, 2018: Launch of PTD-1
- Nov, 2018: PTD-1 mission complete
PTD Tentative Milestones

Initial Flight Milestones (PTD-1 Payload)

- BET100uN Kick Off: 2/3/16
- BET 100uN SRR: 3/7/16
- BET100uN PTR-1: 6/29/16
- BET100uN PTR-2: 6/14/17
- BET100uN Delivery: 10/25/17

Start: Wed 2/3/16
ATP: 1/9/17
SRR: 3/16/17
PDR/CDR: 7/24/17

Initial Launch Capability (ILC) Milestones

- SIR/PER: 3/29/18
- ORR/PSR: 7/12/18
- Ship PTD1(BET-100uN): 7/25/18
- Ship PTD2: 12/21/18
- Ship PTD3: 5/7/19
- Ship PTD4: 10/25/19
- Ship PTD5: 4/9/20

Finish: Thu 4/9/20

PTD Milestones Subject to Change Based on SC Vendor Schedule
PTD-1: 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

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

- One monitored pass per weekday
- Up to 14 Lights out TLM passes/day
- One CMD upload/weekday

Repeat Characterization up to 83 days
PTD-1: 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
Blue Canyon Hyper-XACT

• 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**

**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

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-M815E</td>
<td></td>
</tr>
<tr>
<td>Operation Pressure</td>
<td>34.5 - 5.9 bar (500 - 85 psia)</td>
<td></td>
</tr>
<tr>
<td>Wet Mass</td>
<td>1.9 kg (4.2 lbm)</td>
<td>2.2 kg (4.9 lbm)</td>
</tr>
<tr>
<td>Usable Propellant</td>
<td>0.5 kg (1 lbm)</td>
<td>1.3 kg (2.9 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 – 50 °C</td>
<td></td>
</tr>
<tr>
<td>Valve Power</td>
<td>Startup: &lt;4 W</td>
<td></td>
</tr>
<tr>
<td>Requirements</td>
<td>Operation: &lt;1 W</td>
<td></td>
</tr>
<tr>
<td>Valve Voltage</td>
<td>Startup: 6-8 Vdc</td>
<td></td>
</tr>
<tr>
<td>Requirements</td>
<td>Operation: 1-2 Vdc</td>
<td></td>
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<tr>
<td>Catalyst Bed</td>
<td>N/A</td>
<td></td>
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<tr>
<td>Heater Power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Thrusters</td>
<td>4</td>
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</tr>
<tr>
<td>MRL / TRL</td>
<td>6 / 6</td>
<td></td>
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</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>294</td>
<td>685</td>
</tr>
<tr>
<td>2.0</td>
<td>258</td>
<td>595</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>
PTD: INFUSING CUBESAT TECHNOLOGY

- **Pathfinder Technology Demonstrator**
  - First Technology Payload Selected
    - Busek MEP
  - Standard Bus Provider Under Contract
  - PTD-1 Selected for CSLI Provided Launch
  - First Flight in 2018
  - Four Subsequent Flights on Six Month Centers

- **Example Technologies**
  - Busek BET-100uN Development (PTD-1)
  - Blue Canyon Hyper-XACT Development
  - Tethers HYDROS Development
  - Aerojet MPS-130 Development
  - Future Tipping Point or SBIR/CRP
  - Internal Technology Calls

- **Tyvak Spacecraft Bus**
  - 01/09/2017 ATP
  - 01/30/2017 Kick-Off
  - 03/16/2017 System Requirements Review