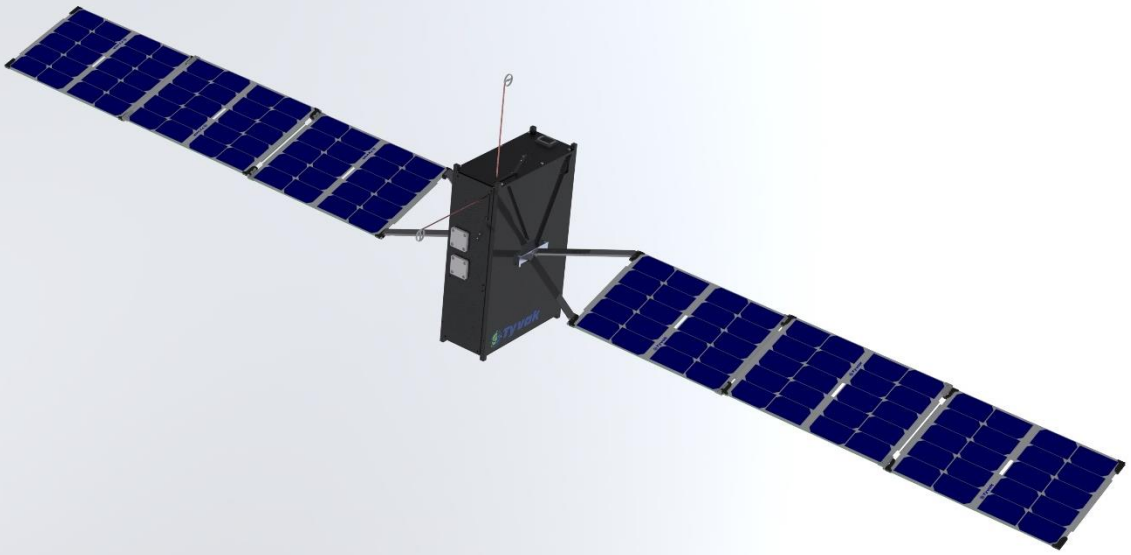
Pathfinder Technology Demonstrator

"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

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.

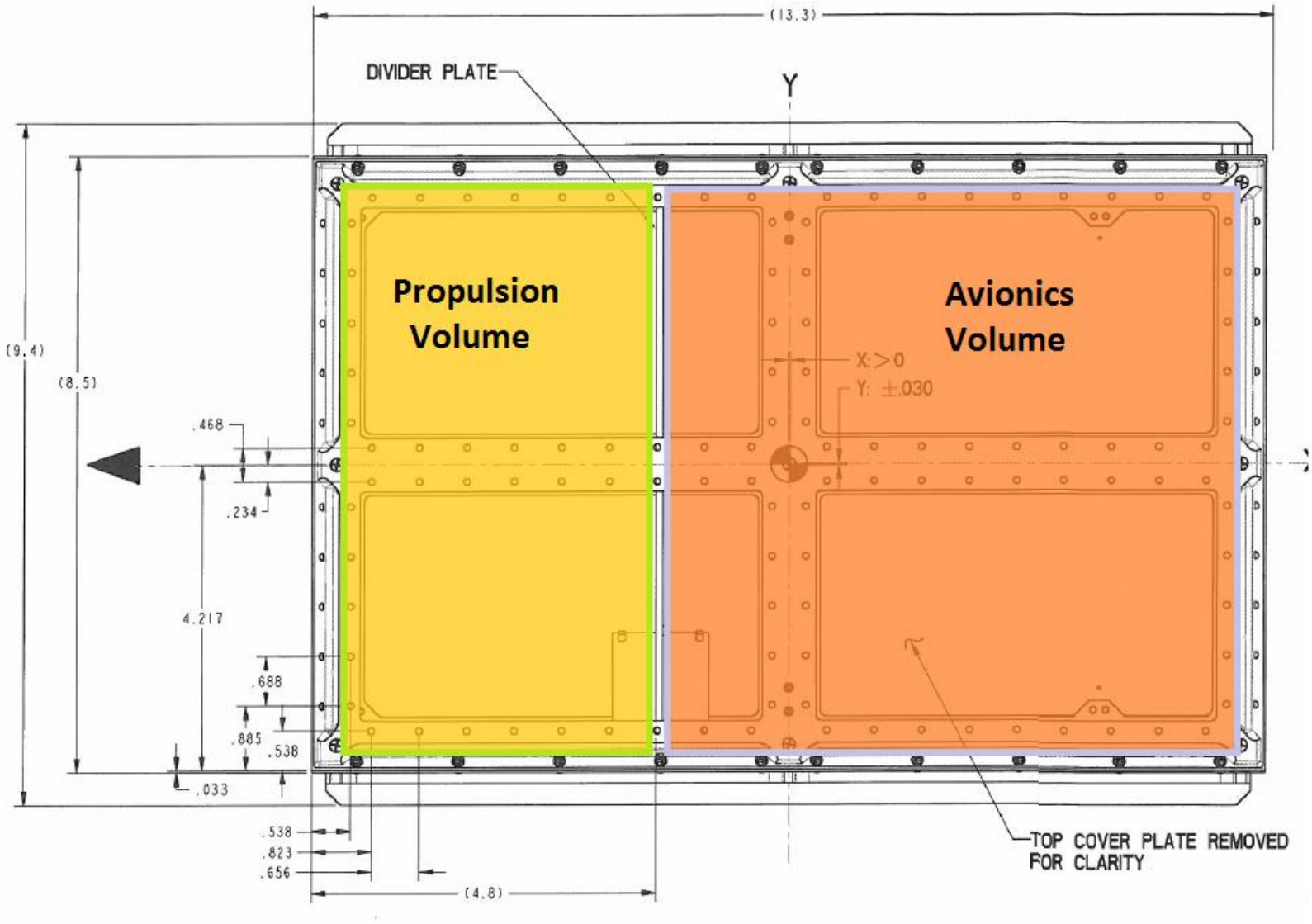
PTD Level 1 Requirement

Req#	Requirement	Rationale
L1-PTD-01	The purpose of the Pathfinder Technology Demonstrator (PTD) mission is to demonstrate novel satellite technologies in Low Earth Orbit (LEO).	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.

Driving L2 Payload Requirements

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

PTD Geometric View



*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

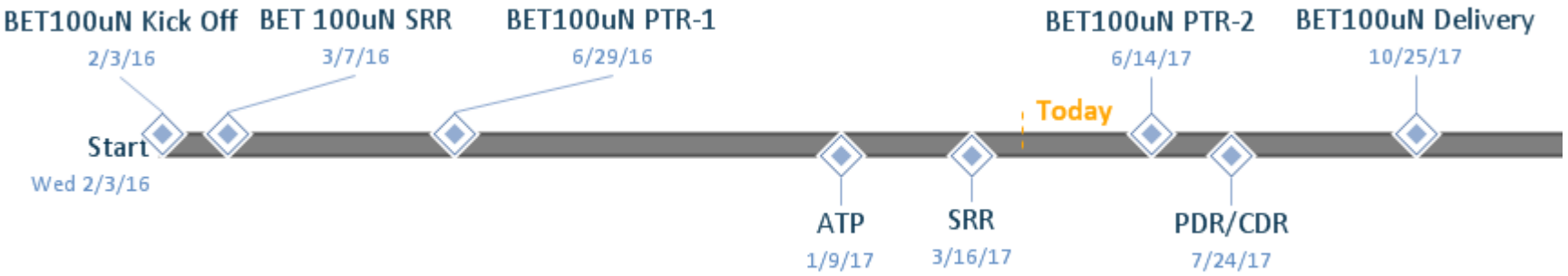
Tyvak
A Terran Orbital Corporation

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)



Initial Launch Capability (ILC) Milestones

PTD Milestones Subject to Change Based on SC Vendor Schedule

Tyvak GDS Solution

UHF / S-Band
Vendor chosen

Uplink:
Vendor chosen Rate

Downlink:
Vendor chosen Rate

- Ames Res Ctr
- Glenn Res Ctr
- USSTRATCOM
- Spacecraft Vendor

RF Link

Navigation:
TLM includes Onboard GPS Data

Any Inclination Orbit

NEN/Vendor Antenna(s) & Control Facilities

Real-Time and Stored TLM
Voice
CMD / Acq Data
Sched Reqs / Acq Data
Scheds / Acq Data

Secure Internet (VPN, SFTP, etc)

USSTRATCOM JSpOC

TLEs

Voice
CMD / Acq Data
Real-Time TLM / Redistributed Stored TLM
Sched Reqs / Acq Data
Scheds / Acq Data

PTD MOC
Ames Research Center
Moffett Field, CA

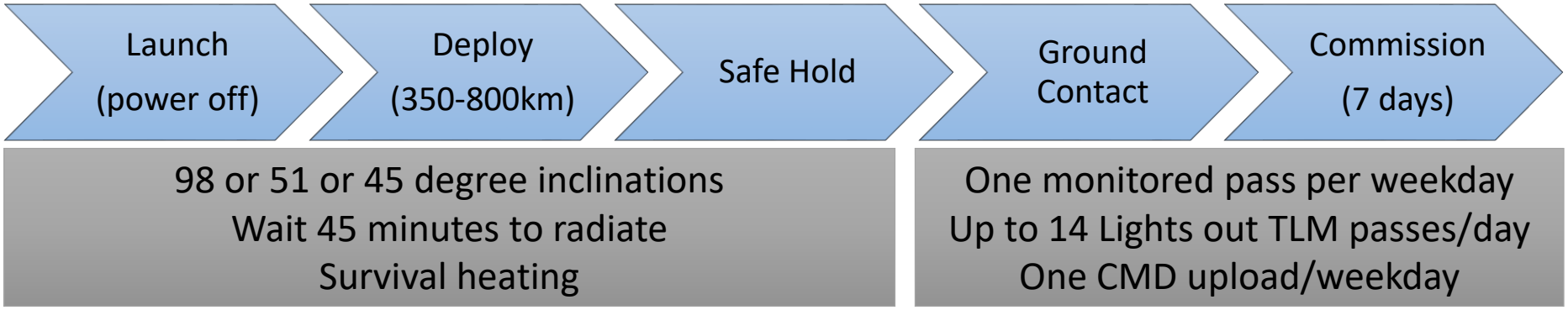
TLM – Archived
Activity Requests

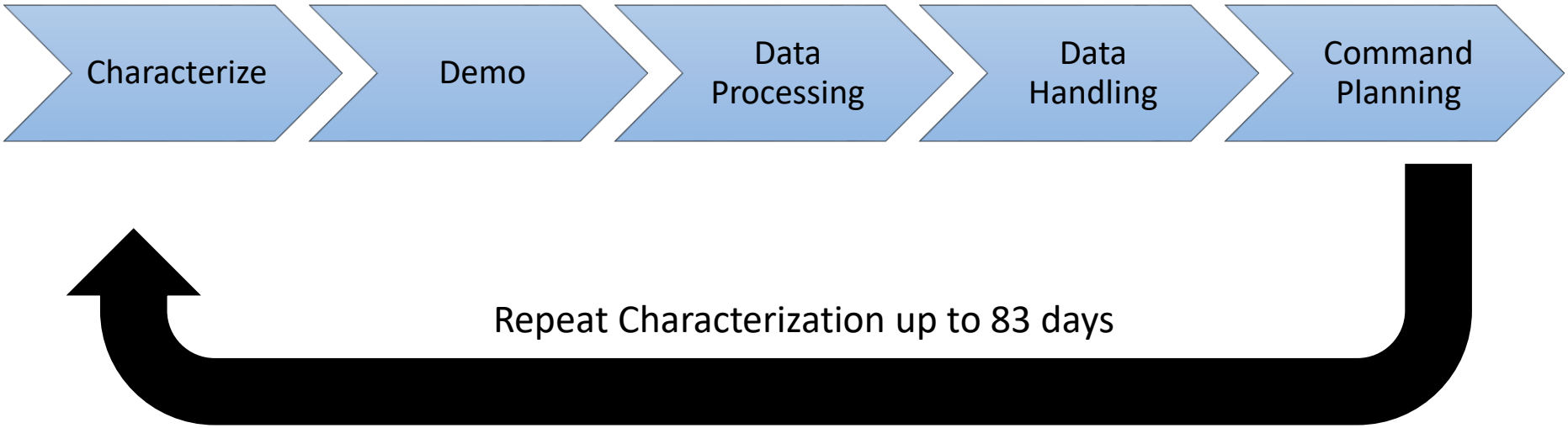
GRC POC

CMD, TLM & Voice

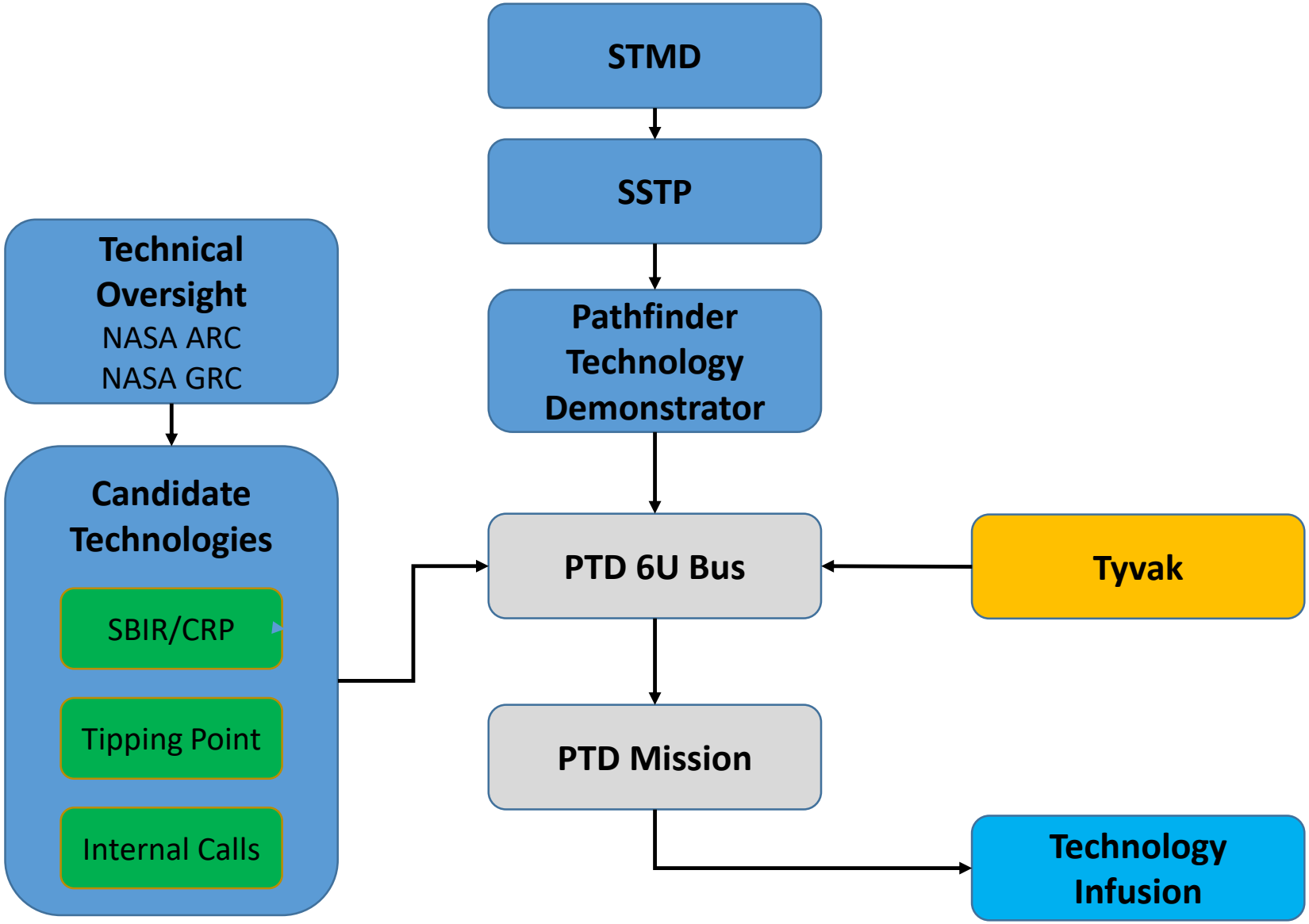
SC Vendor I&T Facility

PTD-1: Operational Concept





PTD: TESTING NOVEL TECHNOLOGIES



PTD-1: Busek BET-100uN

BET-100 Busek Electrospray Thruster

BUSEK Space Propulsion and Systems

Robust, modular propulsion for small satellites and CubeSats with low pressure, non-volatile propellant

Busek's BET-100 electrospray 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 µN 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 electrospray 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)

BET-100 Electrospray Thruster

Eight First-Generation Busek Electrospray Thrusters on LISA Pathfinder (NASA ST-7)

Photo credit: ESA/CNES/Arianespace
Optique Video du CSG – G. Barbaste

www.busek.com

- 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 HYDROS

Company Overview

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:

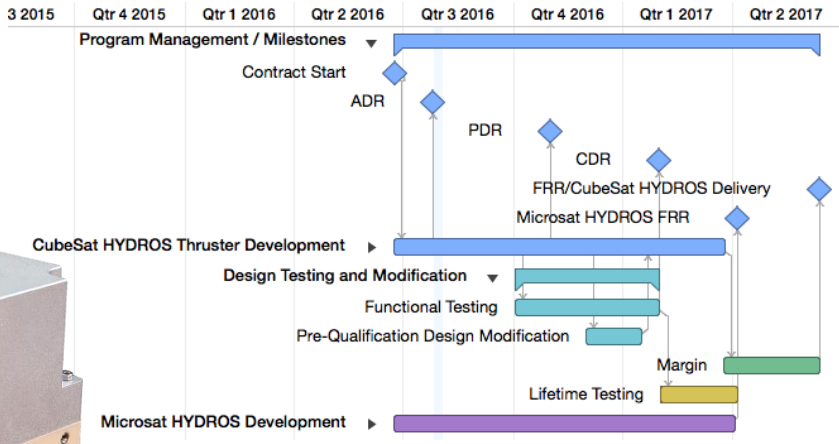
- Propulsion
- Communications
- In-space manufacturing

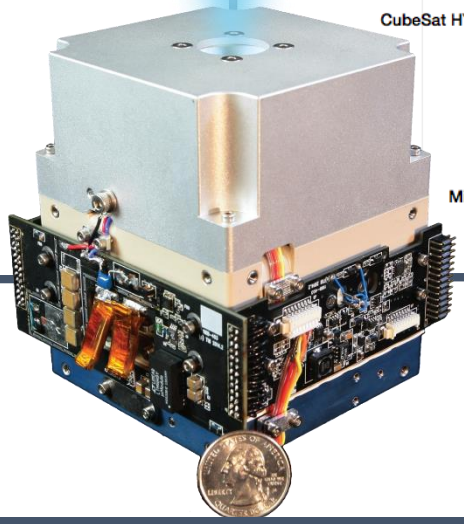
Teaming Partners:

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

Project Overview

Schedule & Milestones:





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

Technology Overview

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

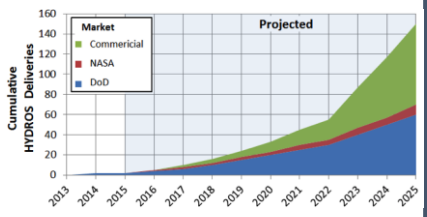
TRL:

Start: SBIR & post-SBIR testing in vacuum established **TRL-5**

End: Functional, Qual, & Lifetime testing will establish **TRL-6**

Commercialization Overview

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

Green High Delta V Propulsion for Cubesats

3D Printed Cubesat Propulsion for Constellation Deployment,
Orbit Maintenance and Stationkeeping

1U Configuration Pictured

Expected Performance

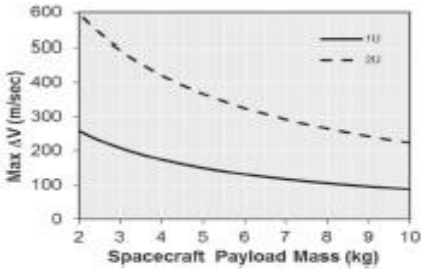
Individual Thrusters (1U and 2U)

Throughput Limit:	0.5 kg
Pulse Limit:	5000
Impulse Limit:	600 N-s
MIB (BOL):	0.003 N-s
SS BOL Thrust*:	1.5 N (~0.4 lbf)
SS Isp:	240 seconds

System Specifications

Parameter	Value (1U)	Value (2U)
Propellant	AF-M315E	
Operation Pressure	34.5 - 5.9 bar (500 – 85 psia)	
Dry Mass	1.9 kg (4.2 lbm)	2.2 kg (4.9 lbm)
Wet Mass	2.4 kg (5.3 lbm)	3.5 kg (7.7 lbm)
Usable Propellant	0.5 kg (1 lbm)	1.3 kg (2.9 lbm)
Dimensions	10 x 10 x 11.4 cm	10 x 10 x 22.4 cm
Operational Temp	5 – 50 °C	
Valve Power Requirements	Startup: <4 W Operation: <1 W	
Valve Voltage Requirements	Startup: 6-8 Vdc Operation: 1-2 Vdc	
Catalyst Bed Heater Power	N/A	
Number of Thrusters	4	
MRL / TRL	6 / 6	

Delta-V Capabilities based on Payload Mass



Payload Mass (kg)	1U ΔV (m/sec)	2U ΔV (m/sec)
1.0	340	753
1.5	294	665
2.0	258	595
2.5	230	539
3.0	208	493
3.5	190	454
4.0	174	420
4.5	161	392
5.0	150	367

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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

PATHFINDER TECHNOLOGY DEMONSTRATOR