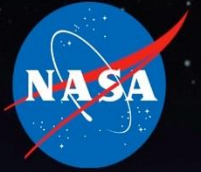


National Aeronautics and Space Administration



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

National Aeronautics and Space Administration

Small Spacecraft Technology Program
SPACE TECHNOLOGY MISSION DIRECTORATE

Advance the capabilities of small spacecraft to support NASA missions in science, exploration and space operations

PTD
New Subsystem Demonstrations - Microfluidic Electro-spray Propulsion

iSat
Electric Propulsion

ISARA
High Data Rate Reflectarray Antenna

Nodes
Autonomously Configured In-Space Network

CPOD
Rendezvous, Proximity Operations and Docking

OCSD
Proximity Operations and Data Transmission

EDSN
Cross-Link Communication

www.nasa.gov/smallsats
www.nasa.gov

Pathfinder Technology Demonstrator (PTD)

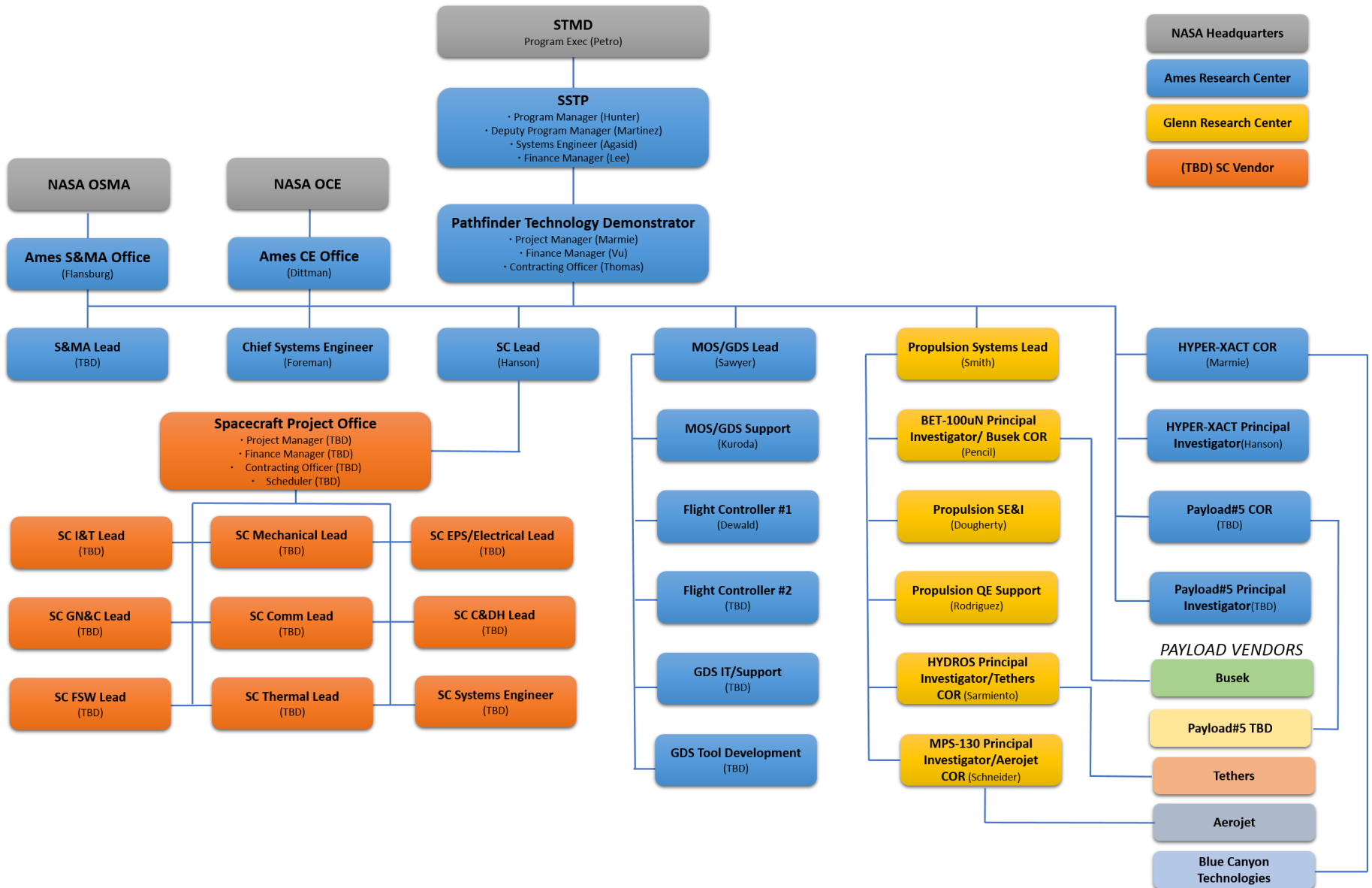
To demonstrate and characterize novel satellite technologies in Low Earth Orbit

“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.*



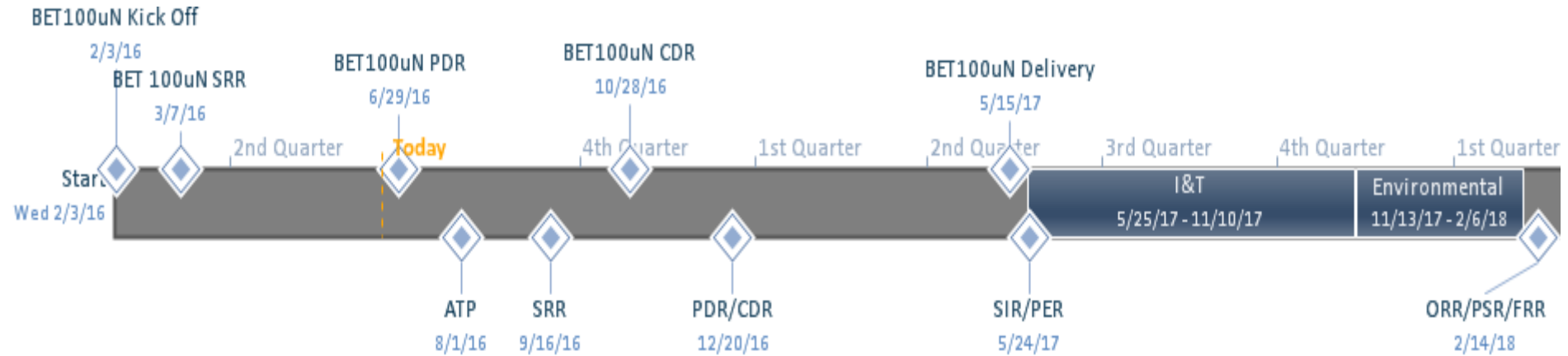
Organizational Chart



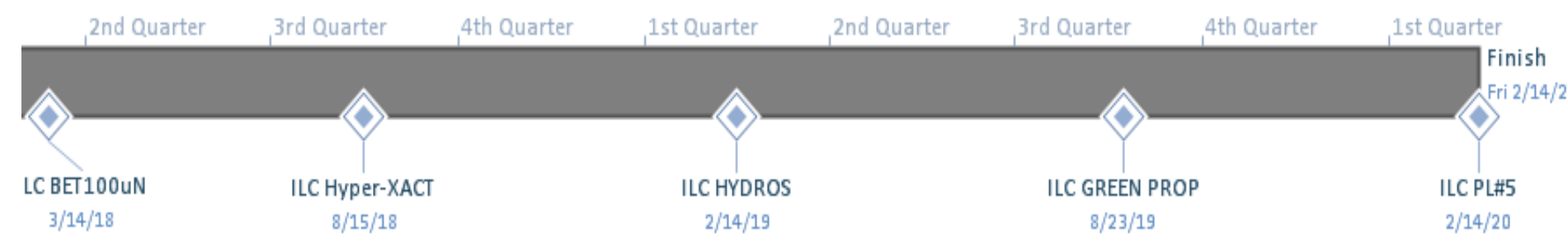


PTD Tentative Milestones

Initial Flight Milestones



Initial Launch Capability (ILC) Milestones



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

Evaluation and Down-Select Process is Progressing



Busek BET-100uN

BET-100
Busek Electro Spray Thruster



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

Busek's BET-100 electro spray 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 μ N 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 electro spray 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 Electro Spray Thruster



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

Photo credit: ESA/CNES/Arianespace
Optique Vidéo du CSG - G. Barbate

- 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

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:

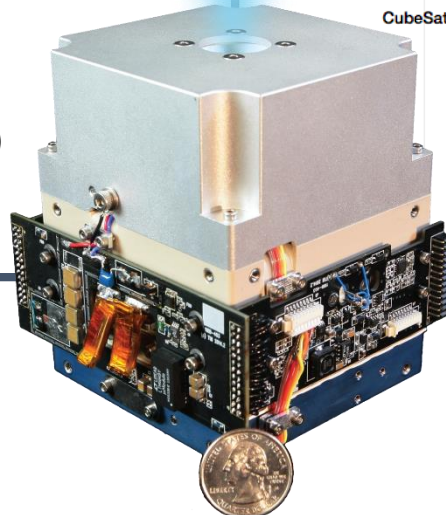
- Propulsion
- Communications
- In-space manufacturing

Teaming Partners:

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

Company Overview

Project Overview

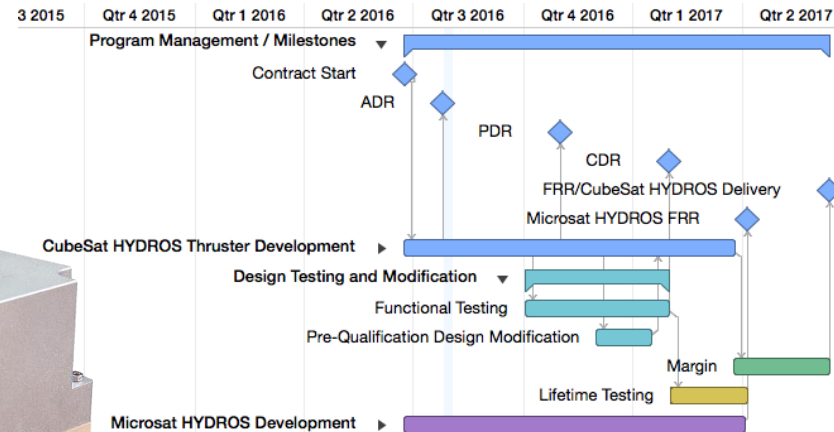


High-Thrust, High-Isp Propulsion with Non-Toxic, Non-Explosive, Non-Pressurized, ISRU-Compatible Propellant: WATER

Technology Overview

Commercialization Overview

Schedule & Milestones:



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:

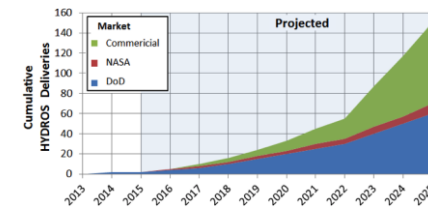
- Optimize system designs for CubeSat and Microsat applications
- Integrate flight-configuration control electronics
- Functional, Environmental, & Lifetime testing to establish TRL necessary for commercial sales

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



www.rocket.com

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

1U Configuration Pictured

Expected Performance



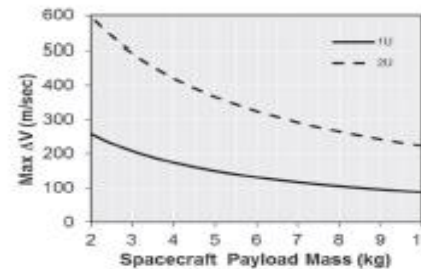
Individual Thrusters (1U and 2U)

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	Startup: <4 W	
Requirements	Operation: <1 W	
Valve Voltage	Startup: 6-8 Vdc	
Requirements	Operation: 1-2 Vdc	
Catalyst Bed	N/A	
Heater Power	N/A	
Number of Thrusters	4	
MRL / TRL	6 / 6	

Delta-V Capabilities based on Payload Mass

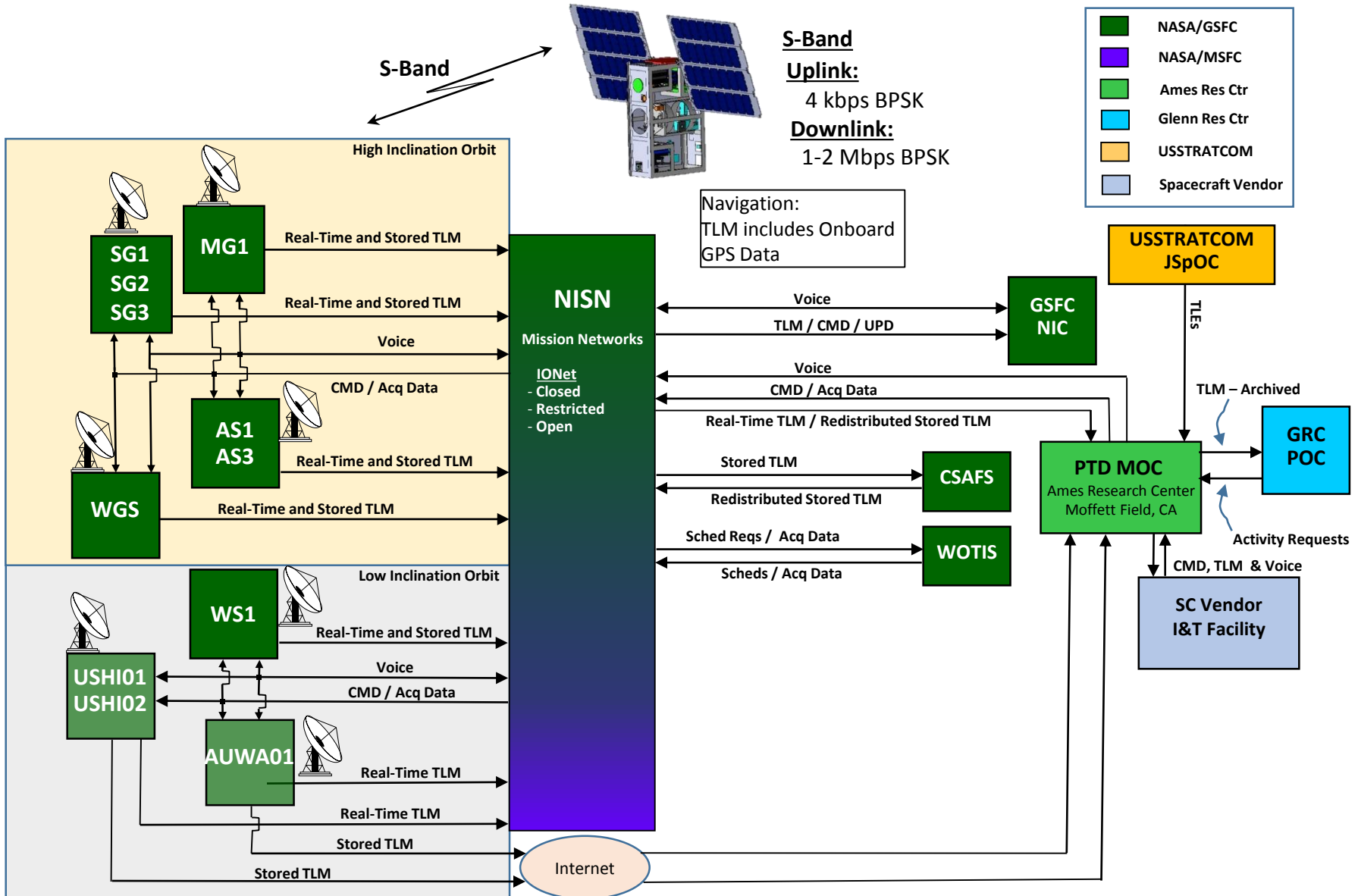


Payload Mass (kg)	1U ΔV (m/sec)	2U ΔV (m/sec)
1.0	340	753
1.5	294	665
2.0	258	595
2.5	230	539
3.0	208	493
3.5	190	454
4.0	174	420
4.5	161	392
5.0	150	367

10/07/16

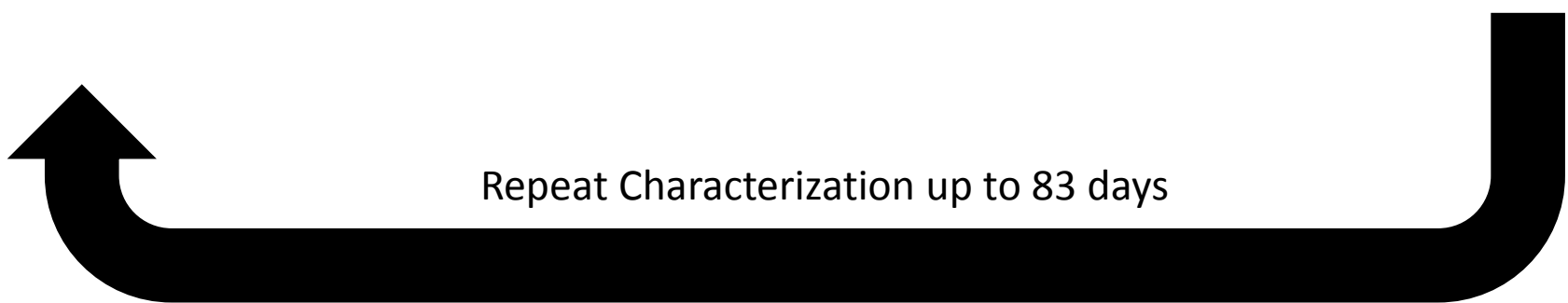
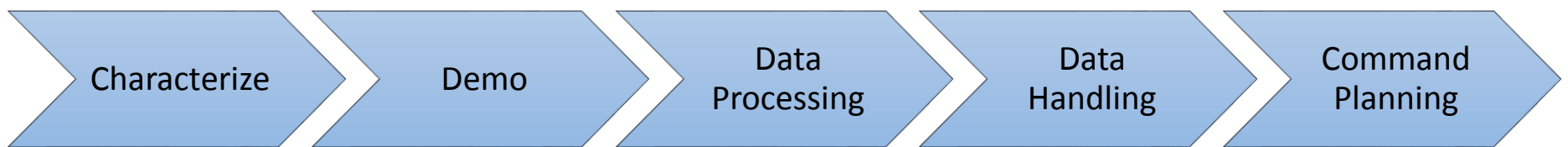
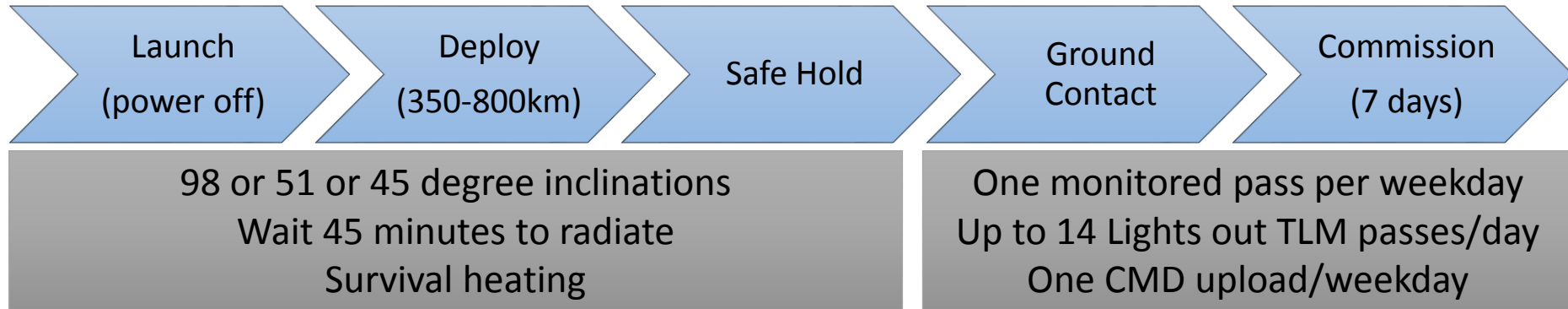


NEN Ground Data System Option





PTD Operational Concept





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



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.

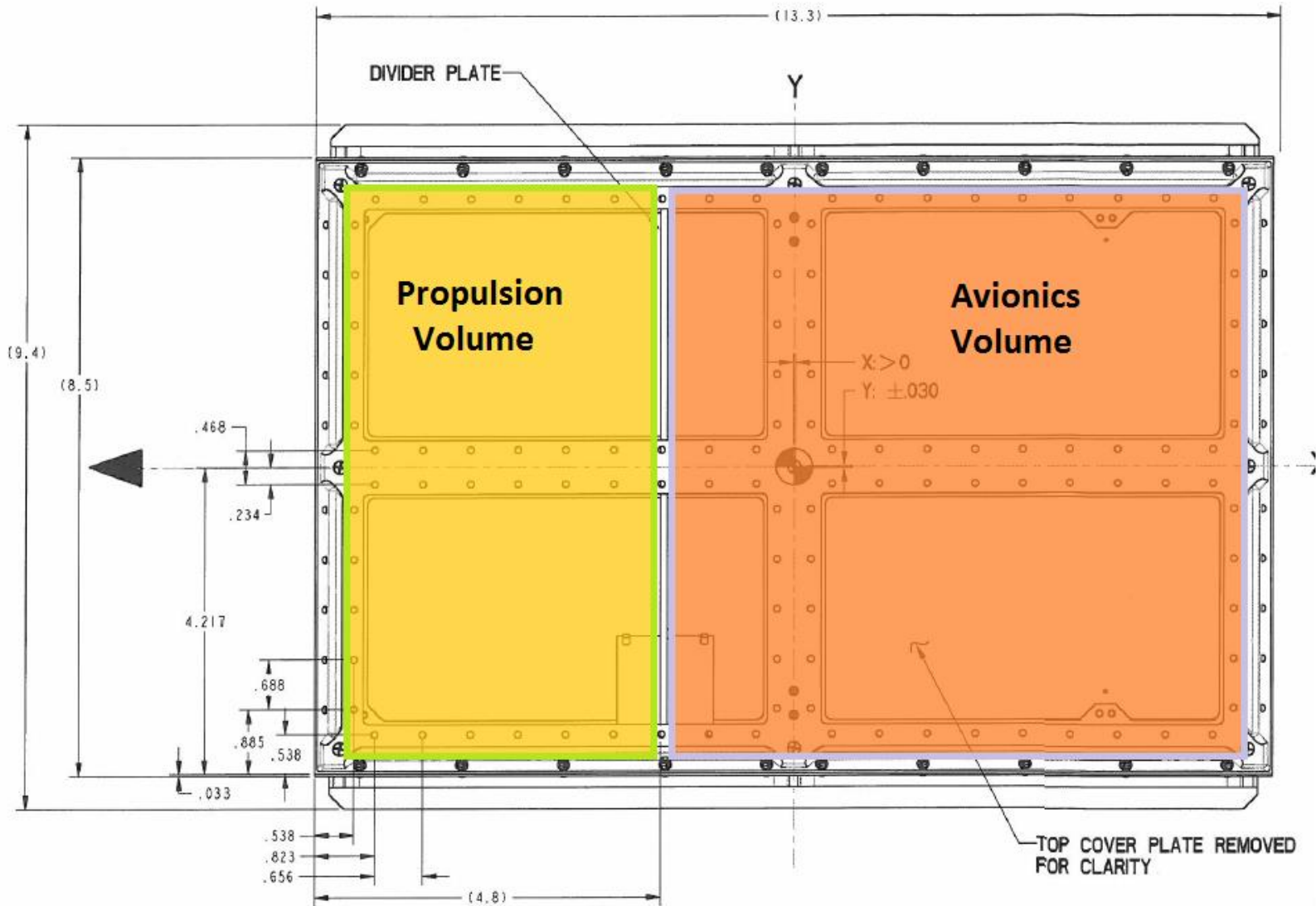


Driving L2 Payload Requirements

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



PATHFINDER TECHNOLOGY DEMONSTRATOR

