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NASA’s Pathfinder Technology Demonstrator

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ABSTRACT

NASA's Pathfinder Technology Demonstrator (PTD) is a technology development project that will test the operation of a variety of novel CubeSat subsystems in low-Earth orbit, providing significant enhancements to the performance of these small and effective spacecraft. Each Pathfinder Technology Demonstrator mission will consist of one 6-unit (6U) CubeSat weighing approximately 12 kilograms and measuring approximately 30 centimeters x 25 centimeters x 10 centimeters. Each mission will be able to fulfill its objective of demonstrating the functionality of its payload and characterize the technology within 90 days of release from the deployment system. A sequence of five PTD spacecraft are expected to be deployed at near 6 month intervals, each demonstrating a novel, key small satellite technology. The first PTD spacecraft is expected to be ready for flight by August of 2018.

The PTD project, led by NASA's Ames Research Center at Moffett Field, California, in collaboration with NASA's Glenn Research Center in Cleveland, Ohio and Tyvak Nano-Satellite Systems, Inc. in Irvine, California as the spacecraft vendor, will benefit future missions by demonstrating the operation of new subsystem technologies on orbit. These technologies are expected to include propulsion systems that provide the capability to maneuver small science platforms and send small spacecraft to deep space; novel technologies to stabilize spacecraft, and laser communications systems that will greatly increase the amount of data that can be transmitted from the spacecraft to the ground. As small spacecraft increase in mobility and capability, NASA benefits by flight-qualifying these commercial subsystems, providing access to low cost, highly capable, science and technology platforms that can operate from the near-Earth to the deep space environment.

NASA’s Ames Research Center in Moffett Field, California leads the Pathfinder Technology Demonstrator project in collaboration with NASA’s Glenn Research Center in Cleveland, Ohio. The project is part of the Small Spacecraft Technology program within the NASA Space Technology Mission Directorate. SST is chartered to develop and demonstrate technologies to enhance and expand the capabilities of small spacecraft with a particular focus on enabling new mission architectures through the use of small spacecraft, expanding the reach of small spacecraft to new destinations, and augmenting future missions with supporting small spacecraft. A PTD overview incorporating the Tyvak spacecraft bus concept and status will be presented.

INTRODUCTION

The small spacecraft platform has provided an ideal opportunity to develop, mature and demonstrate technologies for the space community. Government and commercial technology developers can take advantage of the Cubesat standard and the rideshare access to space to test, demonstrate and validate their technologies in the space environment for a relatively low cost. NASA's goal with the Pathfinder Technology Demonstrator is to infuse technologies that will enable future small spacecraft missions. Technologies demonstrated on PTD may be applicable to larger spacecraft either in same form factor, or as a basis of technology for a more appropriately sized subsystem.

Small Spacecraft missions, particularly those with important scientific objectives have the same need for flight proven hardware that larger, traditional missions have. While the CubeSat community has shown a greater tolerance for risk and for using flight hardware without a proven heritage, future missions, especially those intended for deep space, interplanetary and extended operations, will require higher reliability, extended and/or higher performance subsystems than current technologies that are now operating in Low Earth Orbit (LEO).

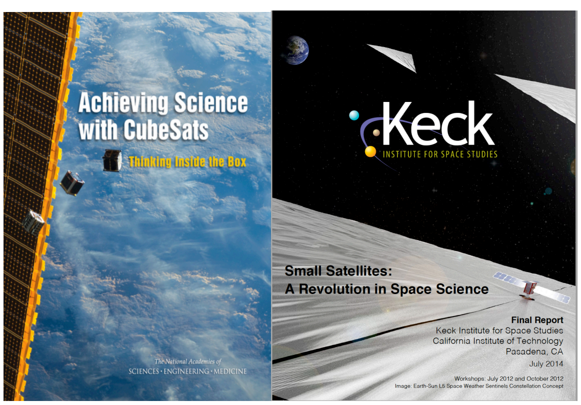

Figure 1: PTD Motivation

Recent reports from the National Academy of Sciences and the Keck Institute, have highlighted that several key science missions can be accomplished using the small spacecraft platform. Those reports described the technologies necessary to enable small spacecraft based scientific and exploration missions. These include Attitude Determination and Control Systems (ADCS) with improved knowledge and pointing accuracy, communication systems for deep space, high bandwidth and cross-linking applications, and propulsion systems for station keeping, orbital manuevering, and interplanetary transit.

The SSTP Office will utilize the PTD Technology Demonstration Missions to demonstrate the operation of those key mission enabling technologies in the space environment.

The PTD missions will be short duration missions whose overall time will be sufficient to test, evaluate and validate the performance of the technologies. Mission operation planning will be prescribed and guided by the principle researcher for the given technology, the spacecraft bus vendor and the mission operations provider. In this case, mission operations for the PTD Missions will be conducted by the spacecraft vendor as part of their PTD spacecraft bus and integration contract.

The current PTD program calls for five spacecraft and one spare to be provided by the spacecraft vendor. The current contract also includes payload assessment, payload integration into the spacecraft, environmental testing and integration activities with the flight services provider. The current flight readiness milestone calls for the first fully integrated spacecraft and payload to be ready approximately eighteen months after authority to proceed. The subsequent buses will be delievered in sequence on six month centers after the first bus is delivered.

In addition to the demonstration of the selected technologies, PTD will investigate the feasibility and application of the GlobalStar communications network. The goal of this task is to evaluate the use of the Globalstar network for in-space communications for commanding and low speed data downloads. Each PTD spacecraft will incorporate a Globalstar GSP-1720 Duplex Modem. This will allow for multiple opportunities to test and assess the performance of this commercial network when performing low cost communications.

A standard interface between the spacecraft and potential payloads was created to allow for the development of a single standard bus that can be used to test multiple technologies without requiring a custom bus design for each mission. This, when combined with the wide range in technical performance (e.g. mass, power, attitude control) provided by the bus, will allow 6U buses built to this standard to be used for future NASA missions requiring a spacecraft of similar size.

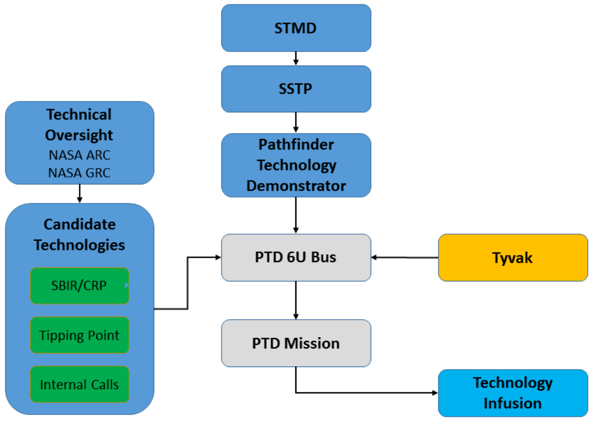

Figure 2: The PTD Mission

TECHNOLOGY SELECTION

Candidate technologies chosen for the Technology Demonstration Mission opportunities are selected via the STMD Integration Panel process. The Integration Panel consists of representatives from the three Mission Directorates, Science Mission Directorate (SMD), Human Exploration & Operations Mission Directorate (HEOMD) and Space Technology Mission Directorate (STMD). Technologies that are considered for flight opportunities are drawn from several NASA programs such as, Tipping Point public private partnerships, the Commercial Readiness Program, Small Business Innovation Research, Early Career Initiative and other internal research and development projects at NASA. A list of candidate payloads are provided in Table 1.

Table 1. Candidate Payloads for Flight

Technology Name	Company or Sponsoring Center
Busek 100uN Electrospray Propulsion	Busek, Inc.
HYDROS H2O Propulsion	Tethers Unlimited, Inc.
Hyper-XACT ADCS	Blue Canyon Technologies

The technologies currently planned for the first several PTD missions were selected based on their advanced state of development, their need for on-orbit testing and their likelihood of providing a significant enhancement in the capabilities of CubeSat-class spacecraft. Two propulsion technologies and one advanced attitude control system were selected for the first three missions. These were:

- The BET-100uN micro-electrospray thruster from Busek Space Propulsion and Systems. Enables station keeping and orbit maneuvers.
- The HYDROS thruster from Tethers Unlimited. Enables station keeping and orbit/plane changes.
- The Hyper-XACT attitude control system from Blue Canyon. Enables extended duration and deep space missions. Supports missions that require accurate knowledge and pointing.

BET-100uN Thruster

The Busek BET-100uN electrospray propulsion system is a low thrust, high specific impulse electrospray thruster that uses the same flight proven propellant demonstrated by Busek on the ESA LISA Pathfinder Mission. The thruster is designed specifically for low power, mass and volume constrained CubeSat and NanoSat missions. Each module fits in a volume that is less than 0.5U, can be configured to deliver 5-100 uN of thrust and requires less than 6 W of power. The thruster is throttlable, requires no moving parts or valves and uses a non-volatile propellant.

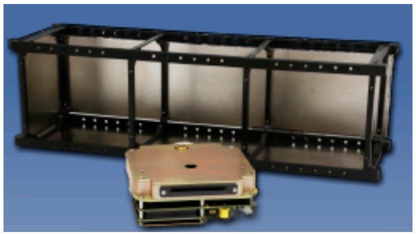

Figure 3: BET-100uN Thruster

HYDROS Thruster

The Tethers Unlimited HYDROS thruster will provide a safe, reliable option for CubeSat and microSat missions requiring thrust of up to one N in magnitude for orbit raising, deorbit and stationkeeping operations. The HYDROS thruster electrolyzes water, stored in a low pressure tank, to create gaseous hydrogen and oxygen, storing them in separate gas storage tanks. The oxygen and hydrogen are then burned in a simple bipropellant thruster. By storing the "propellant" as water, the HYDROS thruster eliminates much of the concern associated with CubeSat thrusters that use either a pressure vessel, or a caustic propellant.

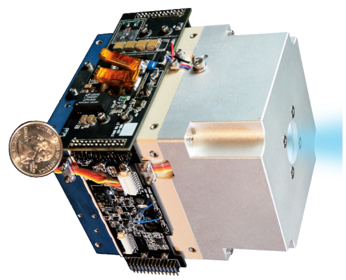

Figure 4: HYDROS Thruster

Hyper-XACT ADCS

The Hyper-XACT attitude control from Blue Canyon is a complete attitude control solution based on their current XACT attitude control subsystem. The Hyper-XACT offers superior attitude control performance by making improvements to their Nano Star Tracker, reaction wheels and control algorithms. The ADCS processor has been redesigned to have greater radiation tolerance, thereby providing lifetime improvements and the ability to operate in geosynchronous orbits and on deep space trajectories.

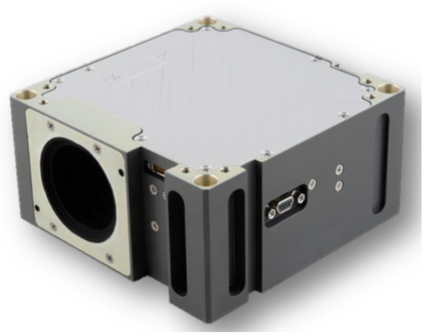

Figure 6: Hyper-XACT ADCS

PTD DEVELOPMENT AND STATUS

The commercial small spacecraft industry has been able to take advantage of advances in manufacturing, state of the art commercial technologies and the ability to demonstrate their respective capabilities in space. This ability has spawned a number of commercial companies who can provide anything from small subsystems to fully integrated spacecraft in a relatively short amount of time. Based upon this current trend, the SST Program Office concluded that it was feasible to baseline a commercial spacecraft bus to be used to as a platform to support technology demonstration missions. An RFI and a subsequent RFP were released to established interested companies who could provide a space ready small spacecraft platform based on their existing 3U and 6U offerings. All responses to the RFP were evaluated by an internal NASA Ames Research Center Source Evaluation Committee, Procurement Division and Legal Office. Final selection for the spacecraft provider was based upon an established several key evaluation criteria.The final selection was based upon a vendor's score against the criteria.

Tyvak was selected from a group of qualified respondents to provide the spacecraft bus and integrated space vehicle integration and test services. The Tyvak bus (Figures 7, 8 and 9), is based on existing Tyvak subsystems that are currently in use on their 3U and 6U spacecraft.

The bus occupies approximately half of the 6U spacecraft, providing communications, command and data handling, attitude control and power generation and distribution services. The technology payload under test is bolted to the "aft" of the spacecraft bus and nominally points in the anti-velocity direction when the spacecraft is in its nadir pointed, local vertical, local horizontal (LVLH) configuration. Payload switched main power, switched survival heater power and RS-422 serial communications are provided through bulkhead connectors between the payload and the spacecraft.

Power is generated from two solar panel wings that are initially folded along the 6U faces of the spacecraft body. When deployed, these articulated solar panels are designed to provide 62 W of total orbit average power with 44 W of power available to the payload on average.

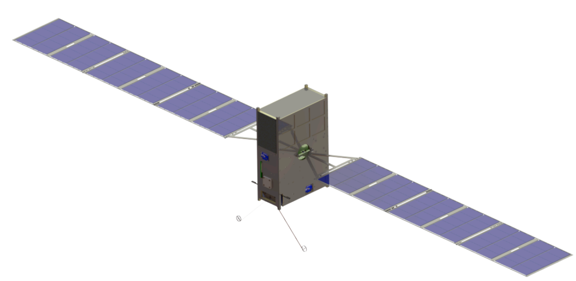

Figure 7: PTD Bus (Tyvak) in Deployed Configuration

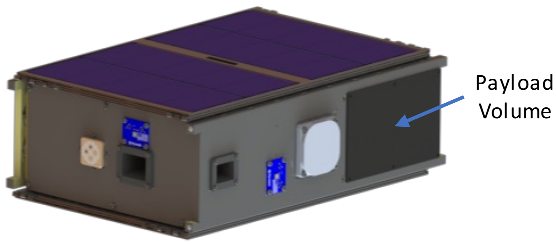

Figure 8: PTD Bus (Tyvak) in Stowed Configuration

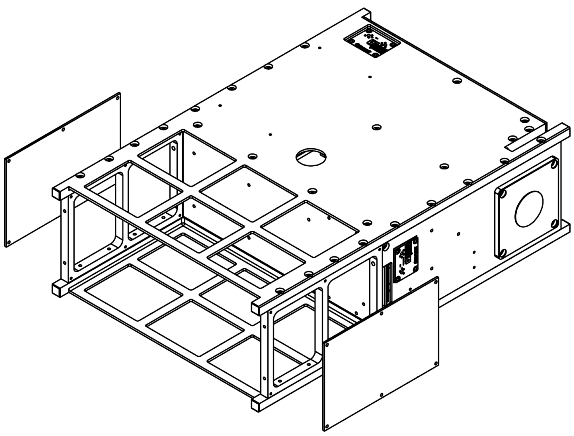

Figure 9: PTD Bus Cutaway

Size	6U (10 x 20 x 30 cm)
Mass	12 kg
Power	62 W OAP, deployable tracking arrays
Communications	UHF/S-Band
C&DH Heritage	From PROPCUBE

Table 2: PTD Bus Characteristics

The first PTD mission is well on its way to an August, 2018 delivery for launch. The first launch has been secured through the CubeSat Launch Initiative (CSLI) program. It is anticipated that the subsequent PTD spacecraft will be launched through the same program on six month centers. The technologies slated for first three PTD demonstration have completed their Critical Design Reviews and are completing their qualification units. Tyvak has completed the bus System Requirements Review and is moving to a combined Preliminary/Critical Design Review in August 2017.

PTD MANAGEMENT APPROACH

The management of the PTD project will be performed used NASA Procedural Requirements (NPR) 7120.8, "NASA Research and Technology Program and Project Management Requirements", as directed by STMD and SSTP. This allows the PTD team to be flexible in creating the Technology Development Plan (roughly equivalent to a Project Plan) and in its approach to the oversight of subcontractors. Traditionally, management of NASA orbital flight projects has been done according to NPR 7120.5, "NASA Space Flight Program and Project Management Requirements", regardless of the size and complexity of the spacecraft or the cost of the mission. SMD missions that are in the "U-class", or are suborbital missions have been managed under NPR 7120.8. Rather than starting with 7120.5 and seeking waivers to tailor requirements down to an appropriate level for PTD, the project will use 7120.8 to apply an appropriate level of oversight for the project. This allows the SSTP Program Office to push the decision making responsibility down to the Project Manager, Systems Engineer and the development team. In essence, PTD tailors up from 7120.8 to ensure mission success, rather than tailoring down 7150.2.

There are several reasons that 7120.8 management approach is more appropriate for PTD than the 7120.5 approach:

- The goal of PTD is to demonstrate the physics of the technology PTD will provide the technology the opportunity to test and demonstrate its technology readiness level in the space environment.

- 7120.8 allows the flexibility and guidance necessary to develop and mature technology that will eventually be infused into future NASA missions. This approach provides a low cost test and evaluation methodology that guides technology maturation through the appropriate Technology Readiness Levels (TRL) prior to incorporation into a science or exploration mission.

- The spacecraft is based on existing hardware with flight heritage from 3U and 6U size spacecraft. The pace at which CubeSat missions are flown in comparison to more traditional, large missions, means that these subsystems often can have a large number of flights completed in just a few years. In addition, Tyvak has a number of spacecraft on the shelf that use the same subsystems, awaiting launch. The PTD project is structured to support the accelerated vehicle delivery timelines of every 6 months by leveraging mature bus hardware and by providing a standard payload interface definition to streamline system-level integration and test efforts.

- The 7120.8 approach makes the best use of NASA Ames' and contractor experience in building small spacecraft with compact, highly motivated teams.

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