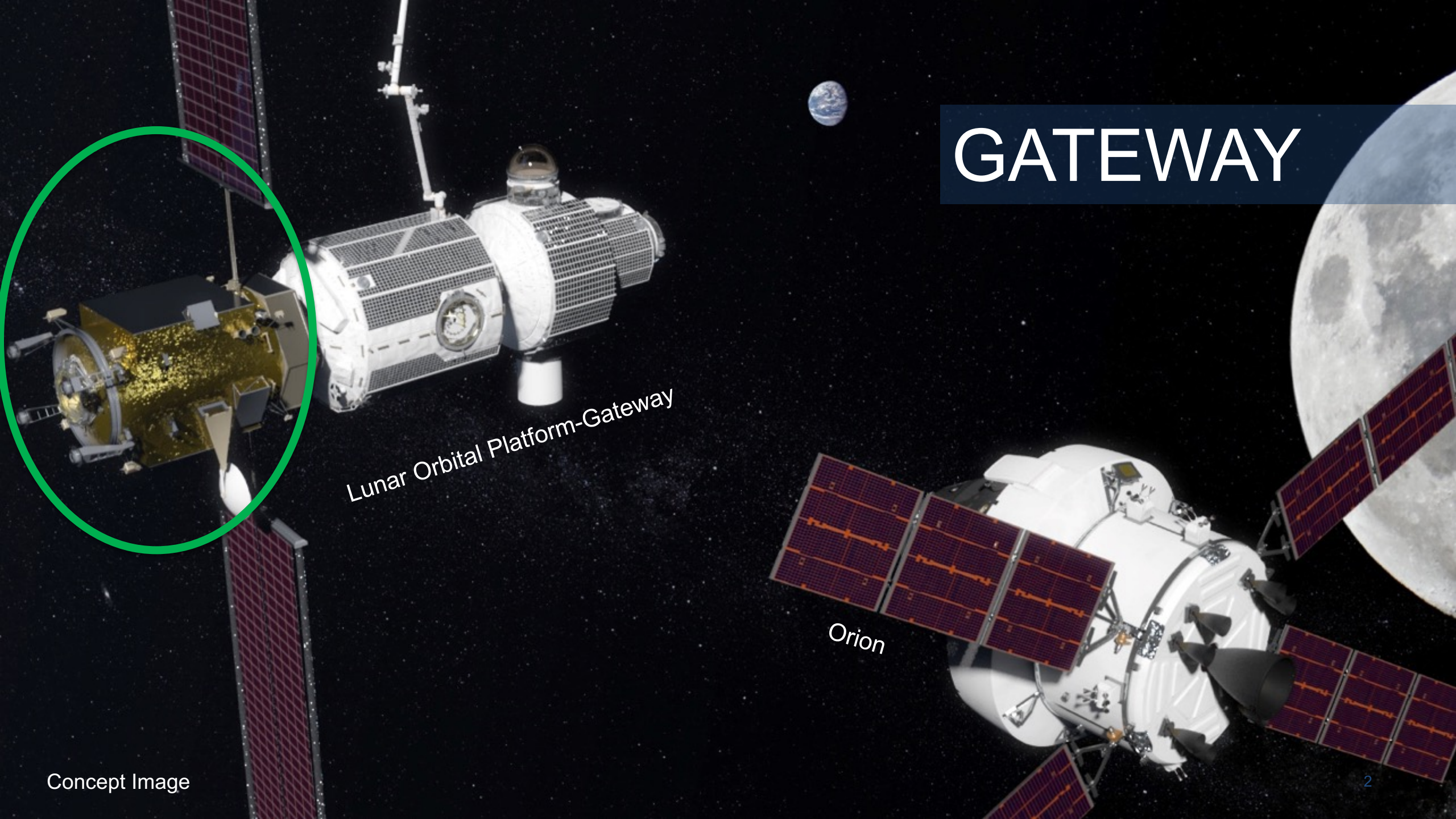
# Status of Power and Propulsion Element for Lunar Orbital Platform-Gateway

Michele Gates, Director, Power and Propulsion Element
NASA HQ
March 27, 2018

# GATEWAY




Concept Image

# Power and Propulsion Element (PPE): Previous Update to NAC HEOC

- **Advantages of solar electric propulsion in cislunar space and extensibility to higher power systems.**

- **A power & propulsion element (PPE) in planning as the first element in a cislunar gateway concept**
  - **Also would host communications and command/control functions**
  - **Potentially a partner system/payload contribution**

- **Industry partnership studies solicited through NextSTEP BAA Appendix C. Five industry study contracts selected and under contract Nov 1.**
  - Studies completed March 23

# PPE Near Term Milestones from Previous Update to NAC HEOC
as of Mar 6, 2018

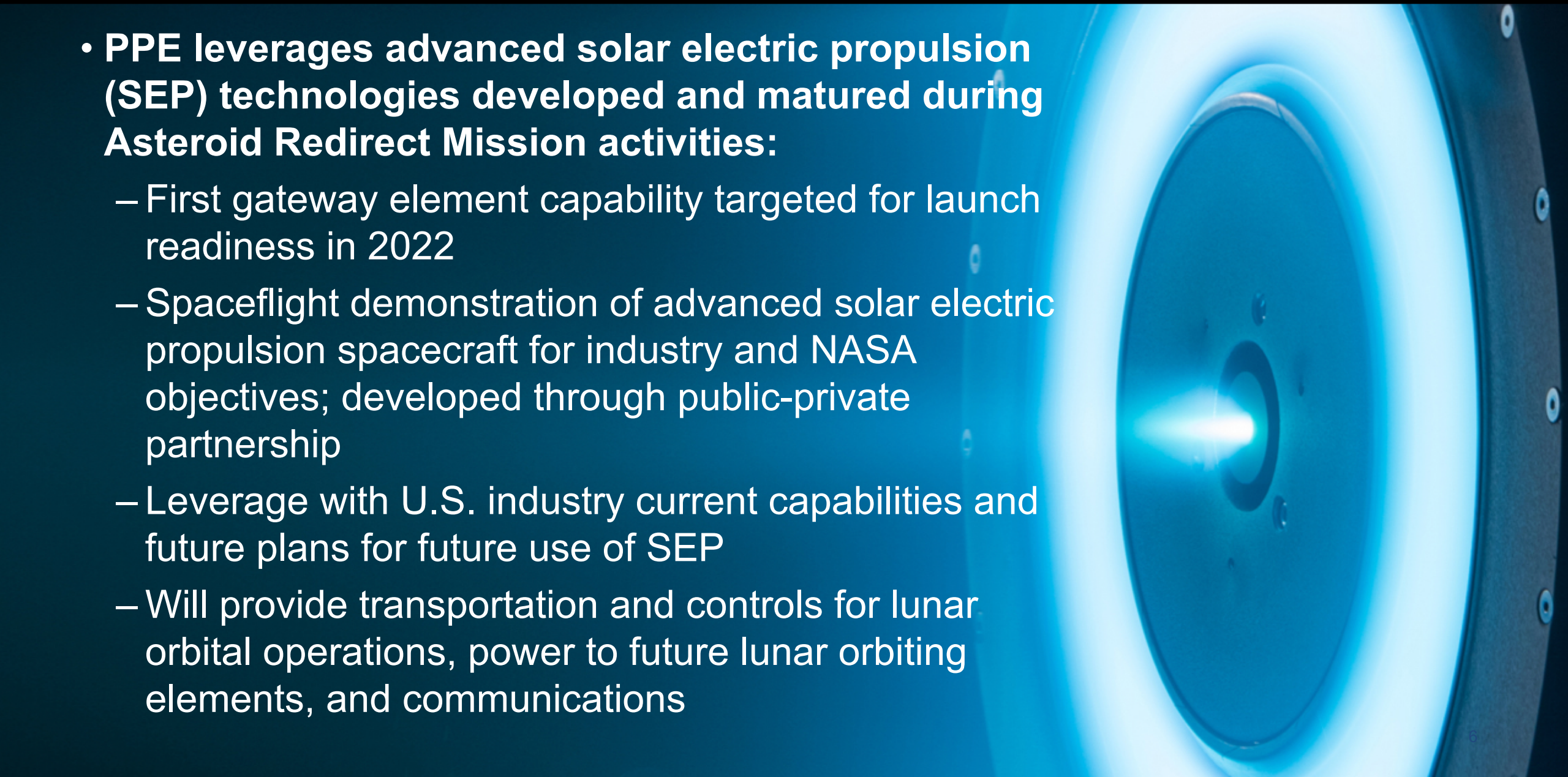
| | |
|---|---|
| ✓International interactions on potential hosted system | Aug 2017 – Feb 2018 |
| ✓PPE Industry Study Contracts Awarded | Nov 17, 2017 |
| ✓Kickoff Review of Interoperability Standards | Nov 17, 2017 |
| ✓Orbital ATK PPE study kickoff | Nov 27, 2017 |
| ✓PPE rqmts/con ops synthesis cycle 1 close | Nov 28, 2017 |
| ✓Space Systems Loral PPE study kickoff | Nov 29, 2017 |
| ✓Sources sought public release | Nov 30, 2017 |
| ✓Sierra Nevada Corp PPE study kickoff | Nov 30, 2017 |
| ✓Boeing PPE study kickoff | Dec 4, 2017 |
| ✓Lockheed Martin PPE study kickoff | Dec 5, 2017 |
| ✓PPE rqmts/con ops synthesis cycle 2 close | Dec 13, 2017 |
| ✓PPE rqmts/con ops synthesis cycle 3 close | Jan 10, 2017 |
| ✓Industry study 45 day reports completed | Jan 2018 |
| ✓Synopsis public release | Feb 20, 2018 |
| ✓Industry study final briefings completed | Mar 23, 2018 |

# FY19 Budget Request for Gateway Power and Propulsion Element

| | FY18 | FY19 | FY20 | FY21 | FY22 | Total |
|---|---|---|---|---|---|---|
| Budget Authority (total $M) | 51.5 | 327.9 | 210.9 | 108.4 | 43.4 | 742.1 |

# Approach to Power and Propulsion Element Development

- **PPE leverages advanced solar electric propulsion (SEP) technologies developed and matured during Asteroid Redirect Mission activities:**
  - First gateway element capability targeted for launch readiness in 2022
  - Spaceflight demonstration of advanced solar electric propulsion spacecraft for industry and NASA objectives; developed through public-private partnership
  - Leverage with U.S. industry current capabilities and future plans for future use of SEP
  - Will provide transportation and controls for lunar orbital operations, power to future lunar orbiting elements, and communications



# PPE Industry Studies

*NextSTEP BAA Appendix C Release Aug 2017*

**Industry studies focused on examining differences between prior solar electric propulsion (SEP) mission concepts, expected industry capabilities, and potential needs supporting NASA's gateway concept**

- **Overall objectives:**
  - **(Obj. #1): Identify and understand significant potential synergies between PPE specific capabilities and current and/or future commercially available capabilities**

    Includes identification of PPE specific capabilities that may be beyond current and/or future planned commercial capabilities. This could also include a variety of topics such as but not limited to the use of advanced solar electric propulsion, innovative ideas for partnership business models including intellectual property, asset ownership, and timing of delivery of the asset and/or services to the Government.
  - **(Obj. #2): Evaluate and understand driving technical differences and implications between prior concepts and approaches developed under the Asteroid Redirect Robotic Mission (ARRM) and the proposed concept for the PPE**

    Includes items such as implications to meeting reference technical requirements and/or drivers for validating a concept of operations.
  - **(Obj. #3): To obtain data that supports NASA's ability to define, derive, and validate the PPE requirements and a baseline mission concept**

    Includes identification of options and approaches to meeting PPE specific capabilities (as described in Attachment B of NextSTEP BAA Appendix C) and for contributing reliability and verification/validation data for a PPE approach that supports a human-rated DSG system.

# Study Topics – Brief Descriptors

#1 – Approach for PPE Design and Verification

#2 – Minimize the Probability of the Occurrence of Failure Modes

#3 – Orbit Maintenance

#4 – Rendezvous and Docking of Crewed/Uncrewed Visiting Vehicles

#5 – Uncrewed Autonomous Orbit Transfer

#6 – PPE Power Generation and Power Transfer Capability

#7 – Two International Docking System Standard (IDSS) Interfaces

#8 – PPE 15-Year Lifetime

#9 – Long-Term, Autonomous Operations Approach for PPE

#10 – PPE High-Reliability Communications

#11 – Optical Communication Demonstration

#12 – Assessment of NASA Standards for a PPE in a Human-Rated DSG

#13 – PPE Extensibility to Current and Future Commercial Capabilities

#14 – Impacts of Acquiring EP Strings As Part of the Commercial Bus

#15 – PPE Accommodations for Hosting Hardware

#16 – Managing Battery Charge/Discharge During Eclipse Durations

#17 – Conceptual Layout, Potential Clearance and Blockage Issues

#18 – Crew Exercise and Implications of Extended Stay Durations

#19 – PPE Assembly, Integration and Test

#20 – PPE Extensibility to Future Exploration Support Systems

#21 – Attitude Control of the DSG Stack

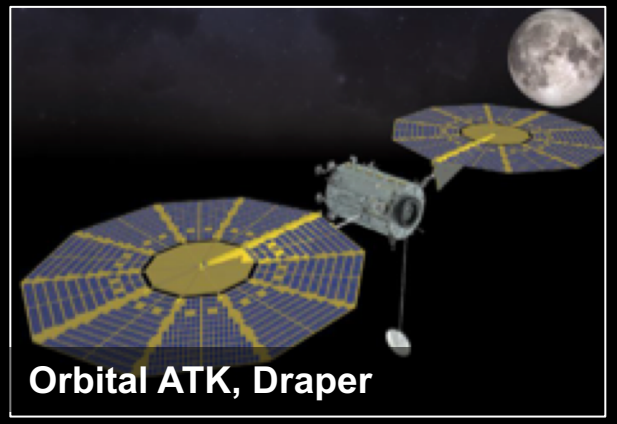
#22 – Transferring Additional Power to DSG Elements

#23 – Avionics and Software

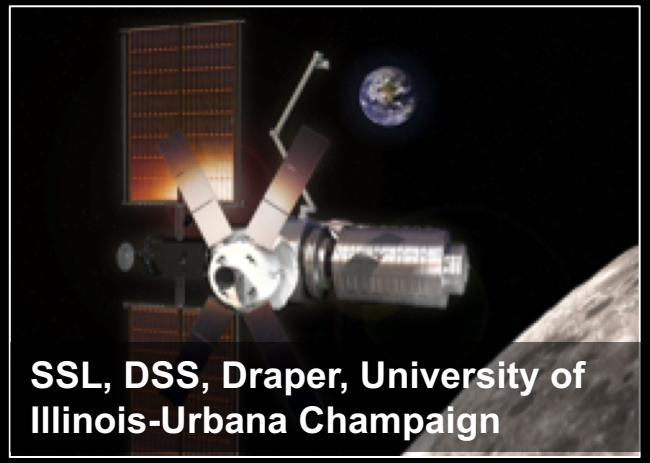
# Power and Propulsion Element Industry Studies

**<u>NextSTEP Appendix C:</u> Issued Aug 11, 2017 | Selections announced Nov. 1, 2017**

- U.S. industry-led studies for an advanced solar electric propulsion (SEP) vehicle capability.
- Four-month studies commenced late Nov 2017.



# PPE Sources Sought Notice

Released 30 Nov 2017

- **Sources sought notice refers to a potential PPE design, development, build, and flight demonstration with contemplated future use on NASA missions**
- **Potential industry/NASA partnership for development and spaceflight demonstration of spacecraft capabilities, including advanced solar electric propulsion, communications, and controls**
- **Strategy to stimulate and utilize U.S. commercial space industry while leveraging those same commercial capabilities through partnerships and future contracts to deliver NASA mission capabilities**
- **PPE provider to perform a demonstration of the PPE to the set of joint industry partner/NASA-developed demonstration objectives**
- **NASA currently envisions the PPE will be fully owned and operated by the PPE developer through completion of an industry partner/NASA spaceflight demonstration, the duration of which would be up to 1 year (TBD). After completion of the demonstration, and if NASA determines that the PPE meets its future needs, NASA would have the option to acquire the PPE for potential future operational use on NASA missions for a period of over a decade**

# Synopsis for the Spaceflight Demonstration of a PPE

Released 20 Feb 2018

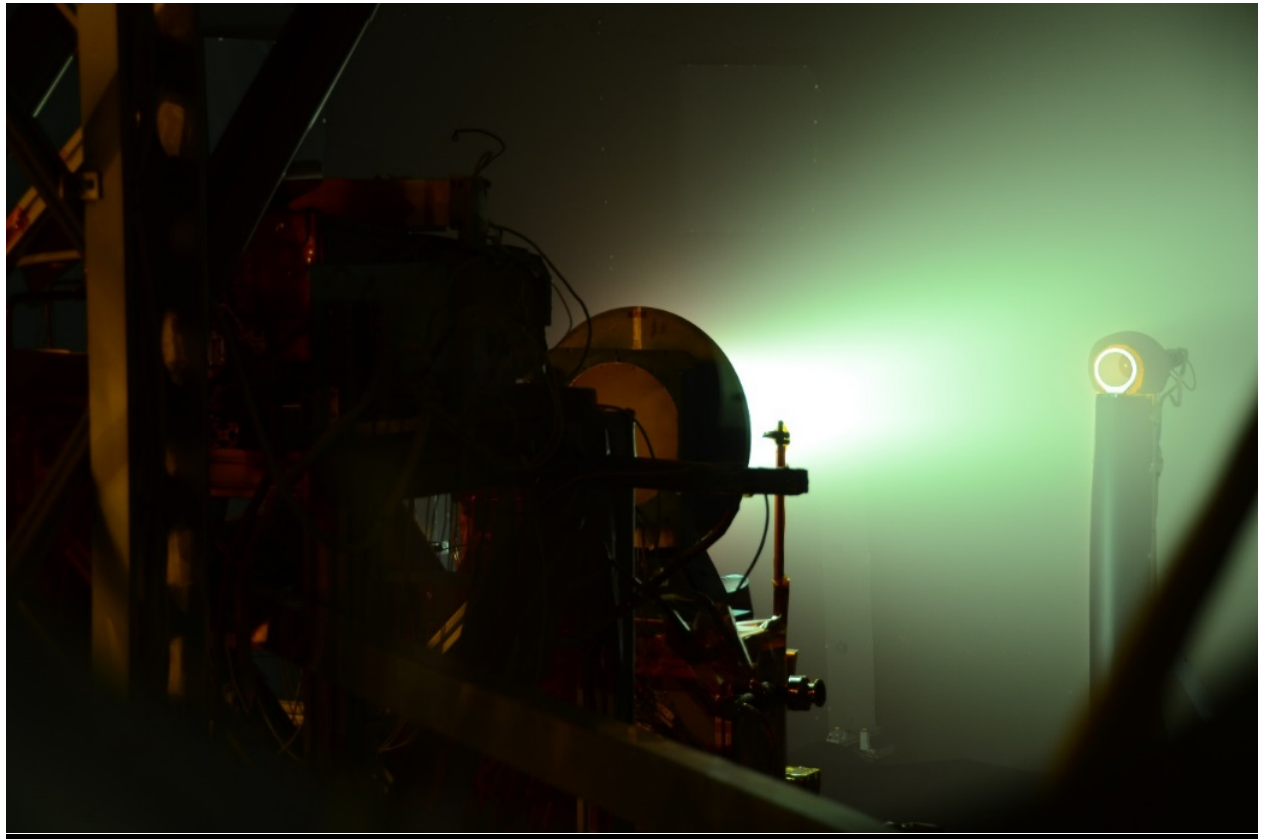
- **NASA Glenn Research Center intends to release a Broad Agency Announcement (BAA) in the near future to seek proposals from industry that could lead to potentially one or more contract awards for an industry/NASA partnership for the development and spaceflight demonstration of a PPE**
- **Through one or more partnerships with U.S. commercial companies, NASA intends to demonstrate advanced technology of SEP that leverages U.S. commercially available spacecraft bus capability that aligns with anticipated industry needs.**
- **NASA will potentially seek an in-space demonstration of PPE capabilities for a joint set of industry partner and NASA demonstration objectives.**
- **NASA is purposely defining only its unique requirements to allow industry to propose a bus and spacecraft and also meets industry's need for future commercial spacecraft. This requirements relaxation is being done to obtain shared risk and shared benefit.**
- **NASA currently intends to issue one solicitation encompassing the entirety of the scope of this effort for undertaking both the demonstration with an option to acquire the remaining in-flight asset for NASA's use.**
- **NASA currently envisions the PPE will be fully owned and operated by the PPE developer through completion of an industry partner/NASA spaceflight demonstration.**

# Synopsis for the Spaceflight Demonstration of a PPE (cont'd)

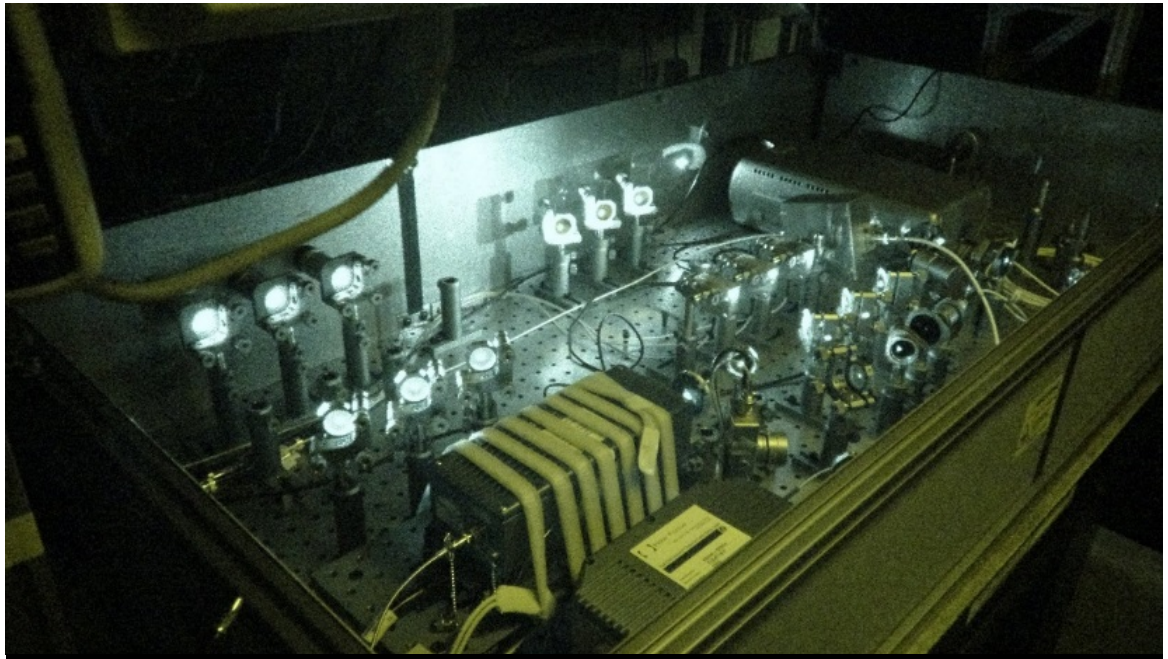
Released 20 Feb 2018

- **At the completion of the demonstration, and if NASA determines that the PPE meets its future needs, NASA intends to have the option to acquire the end item PPE for NASA use, specifically as the first element of the cislunar gateway concept.**
- **The PPE is envisioned to be launched in 2022. Proposals are to include an Offeror provided commercial launch vehicle for the launch of the PPE.**
- **The targeted release of the draft solicitation will be in the April 2018 timeframe with final proposals anticipated to be due in the late July 2018 timeframe.**
- **An Industry Day is planned to be held within two weeks following the release of the draft BAA.**

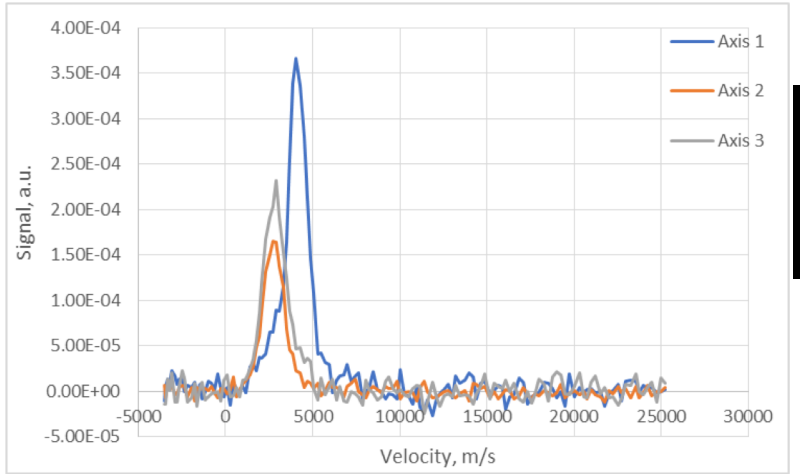
# STMD* High Power, High Throughput Electric Propulsion Technology Development Progress (1/4)



TDU-1 operating Vacuum Facility-6 during Laser Induced Fluorescence test



Laser setup in operation

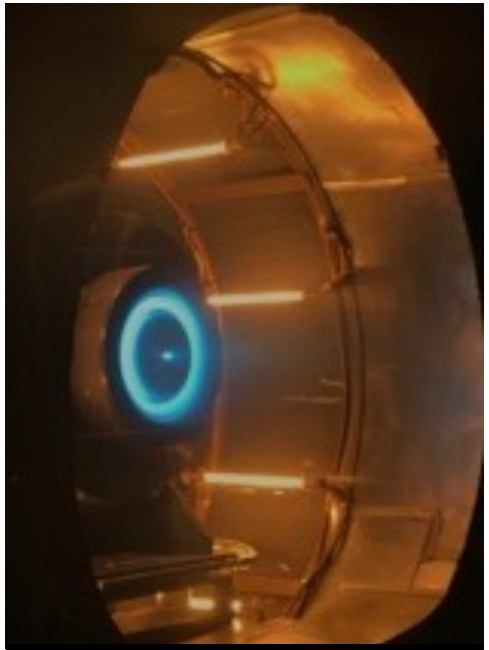



Example preliminary data

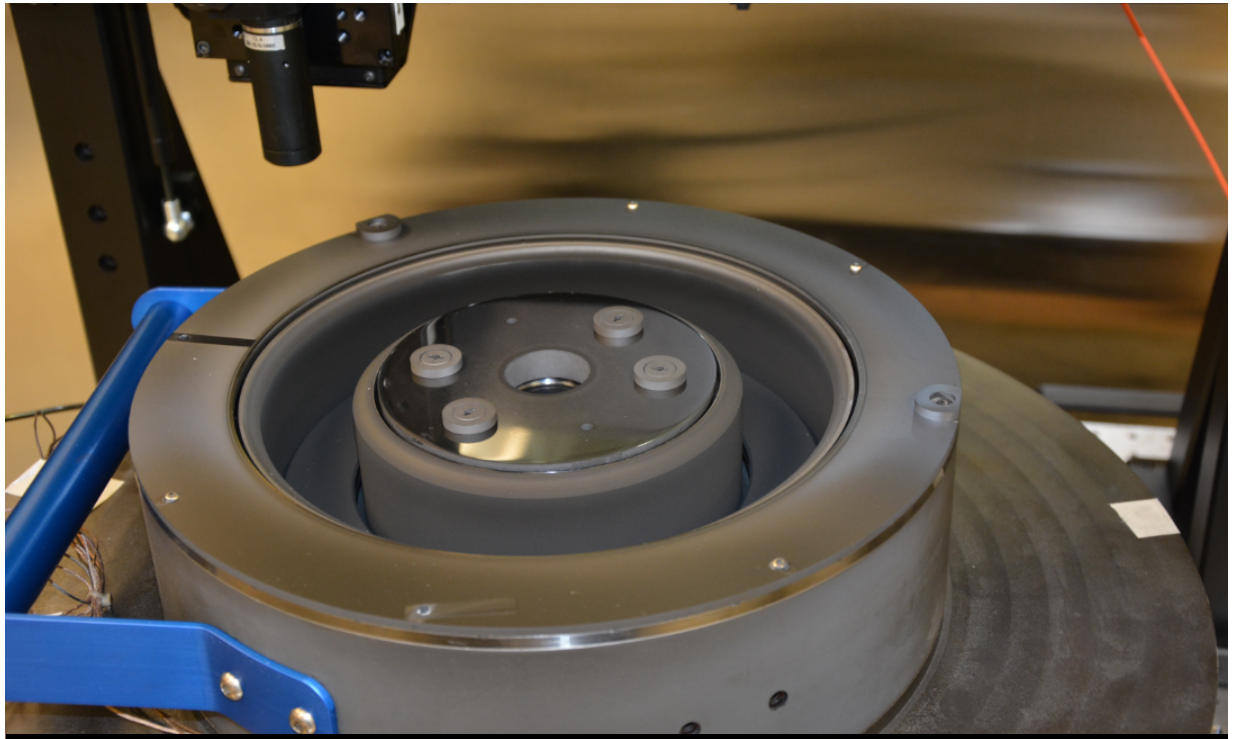
* Space Technology Mission Directorate

# STMD* High Power, High Throughput Electric Propulsion Technology Development Progress (2/4)


SEP Solar Array Electrical Simulator Unit #1

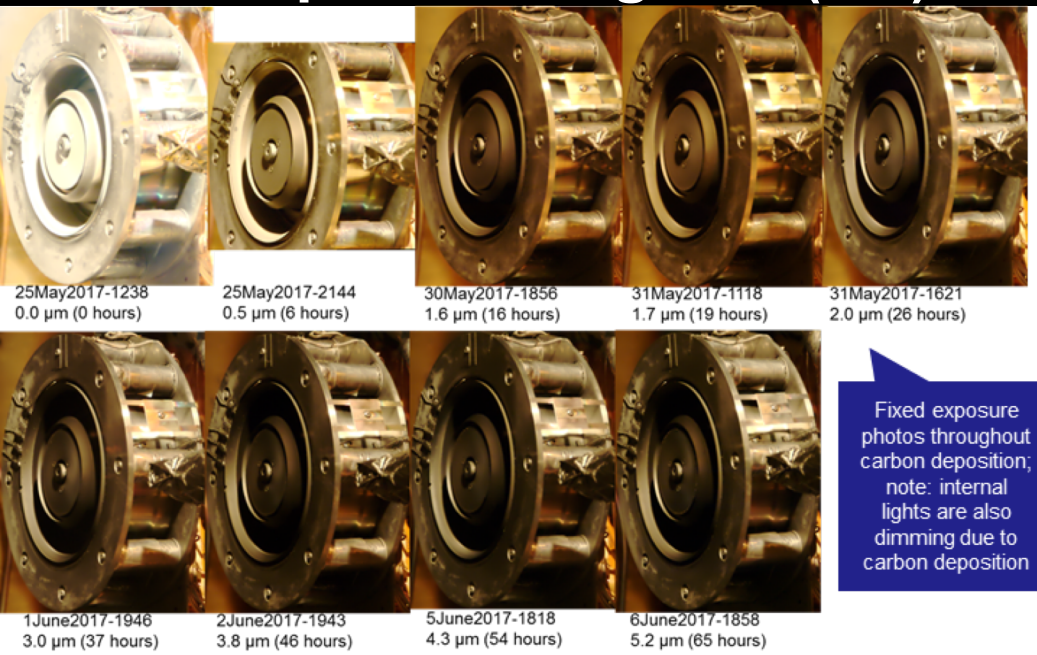


TDU-2 during initial TVAC operation

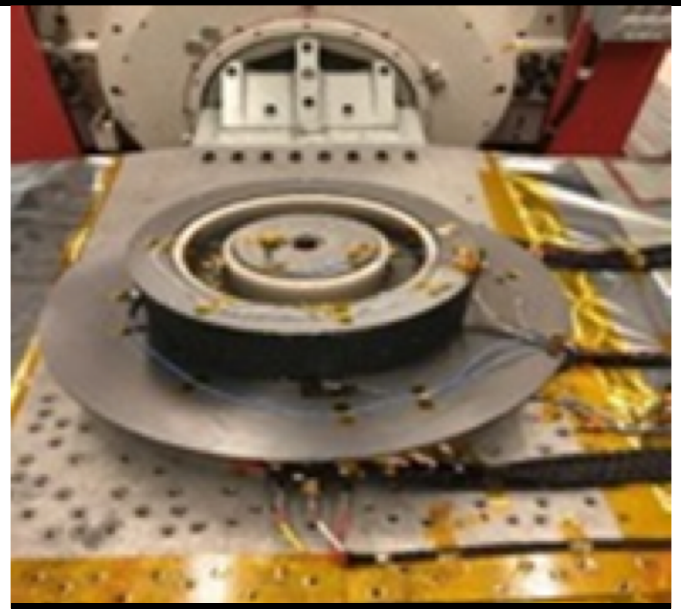


Profilometer scan of TDU-3 to measure erosion

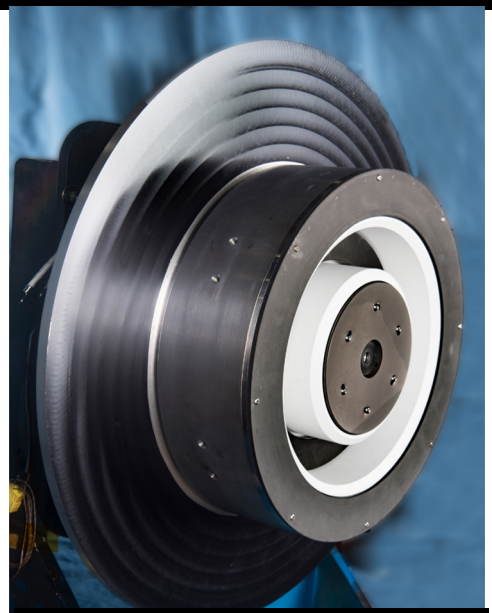
# STMD* High Power, High Throughput Electric Propulsion Technology Development Progress (3/4)



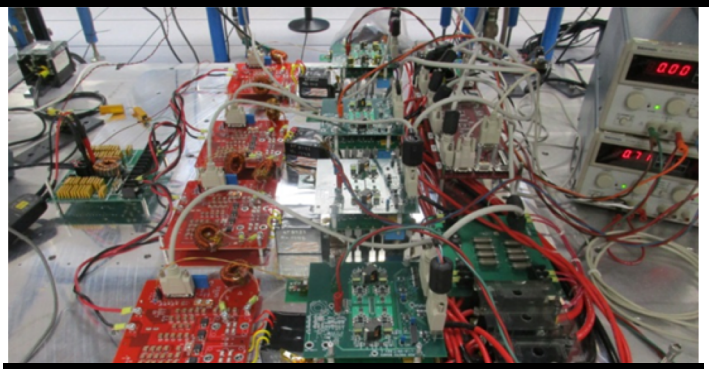

Carbon deposited on the discharge channel simulating space conditions



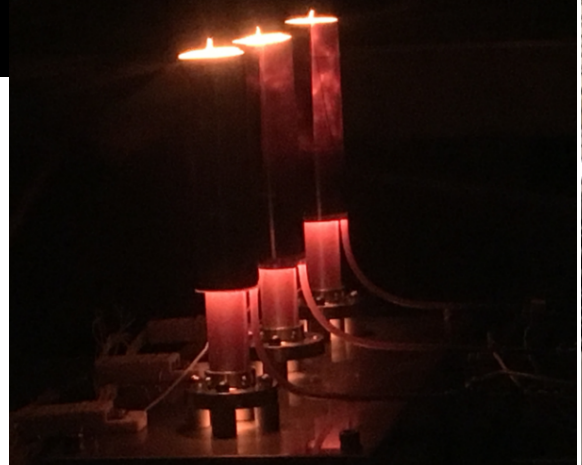
TDU-2 on vibe table



TDU-3



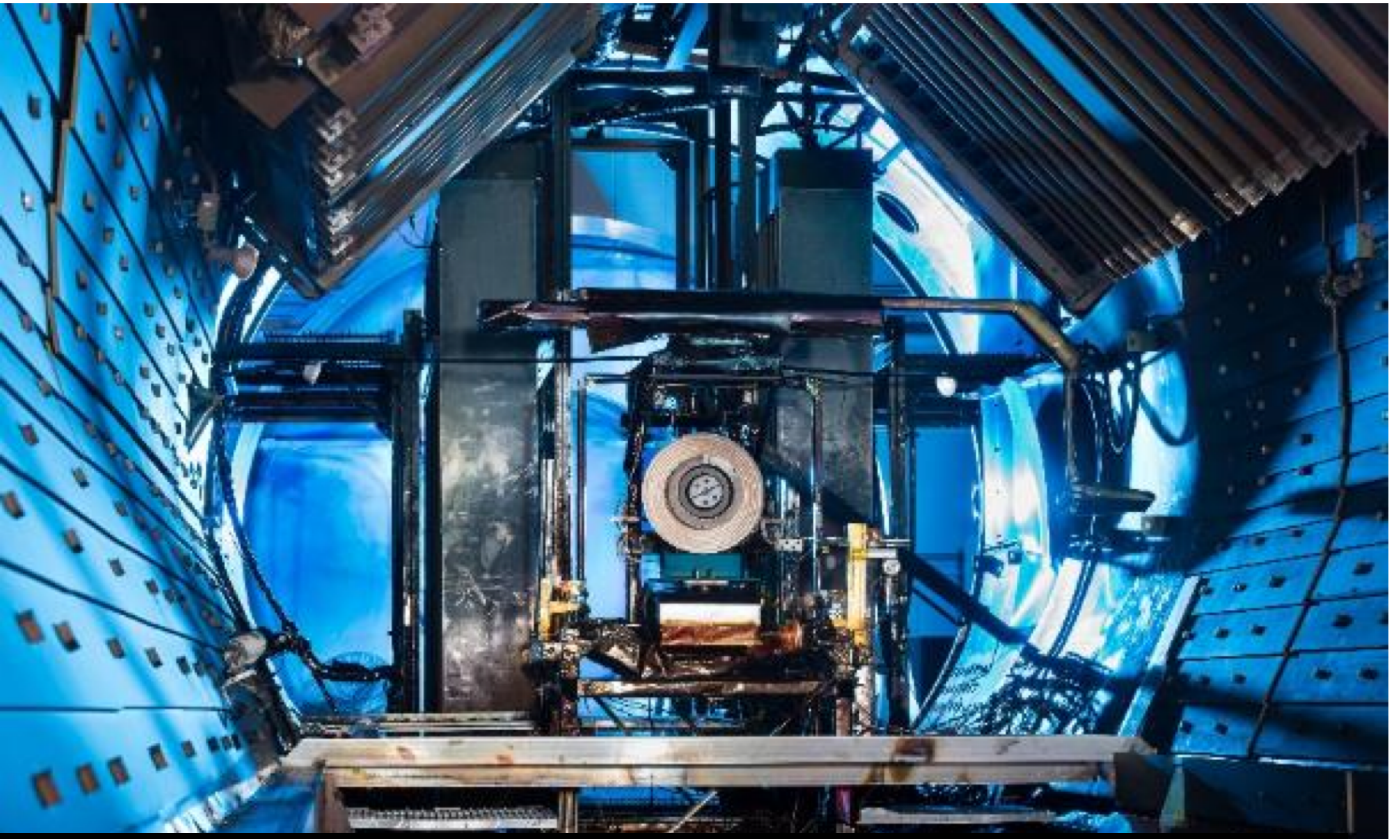
PPU Discharge Supply Unit breadboard testing



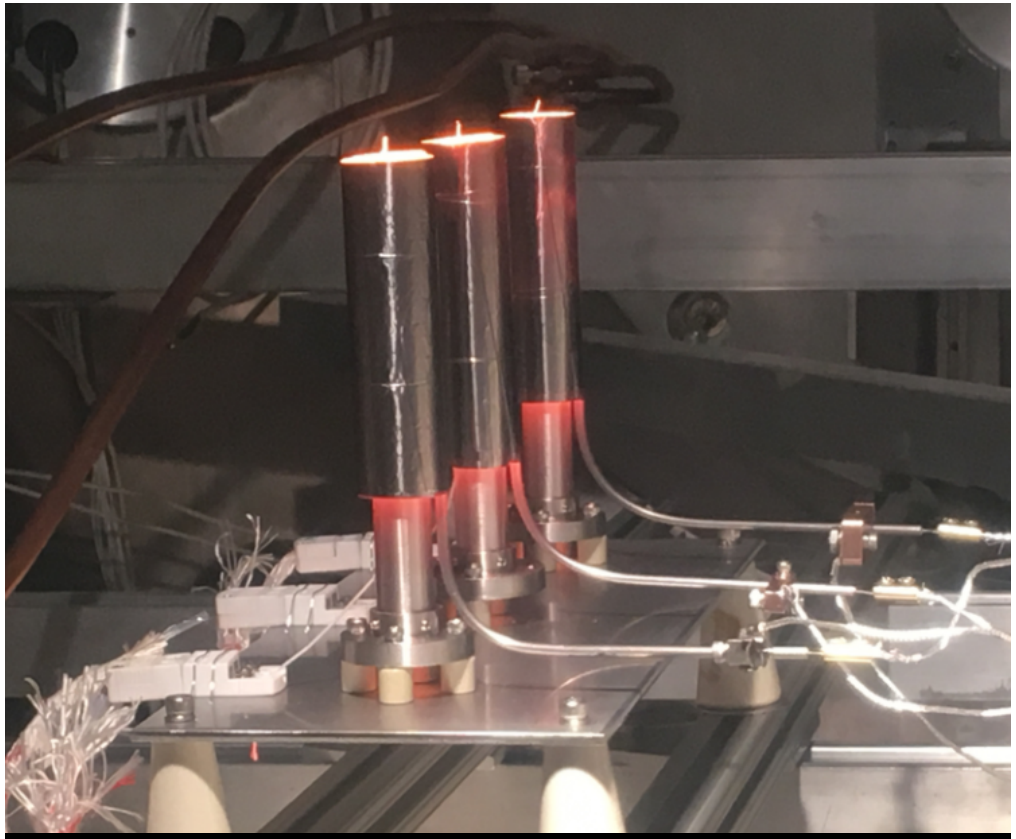
Cathodes under test

Power Processing Unit (PPU) #2

# STMD* High Power, High Throughput Electric Propulsion Technology Development Progress (4/4)



TDU-3 in Vacuum Facility-5



Cathodes under test

# PPE Upcoming Events

| | |
|---|---|
| • PPE NASA performance requirements refinement close | Apr 5, 2018 |
| • Support international interactions on gateway plan | Apr 10-13, 2018 |
| • PPE draft solicitation release | Apr 2018 |
| • PPE Industry Day | late Apr/early May 2018 |
| • International Space Development Conference panel participation | May 24, 2018 |
| • Space Ops Conference panel participation | May 28, 2018 |
| • PPE proposals due target date | late Jul 2018 |


NASA

# Advantages of Solar Electric Propulsion (SEP) in Cislunar Space

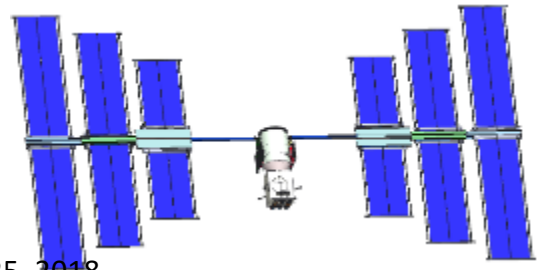
- **Fuel is storable, does not boil off, and can be resupplied**
- **Advanced EP provides the ability to move habitat systems to various orbits around the moon**
  - Halo, Lagrangian, or other Earth-Moon orbits
- **Analyses of in-space orbit transfers in the lunar vicinity shows a 5 to 15 fold savings in propellant with this system as compared to chemical-only systems with equivalent trip times**
- **Early use supports ensured extensibility to Mars class system**
  - Also directly applicable to a wide range of robotic and human spaceflight missions

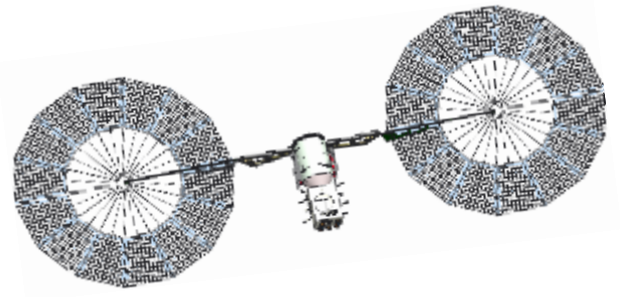


* Chart reference NAC HEOC presentation July 25, 2018

# Scalability to Higher Power Systems for Deep Space Human Exploration

- **High-power, 40-kW class system would be a step up from current technology and on the path to much higher power systems.**
  - Range of powers: 150 kW to 300 kW
- **Electric propulsion technology scalable**
  - Several Hall thrusters of higher power (~50kW) have been validated in a laboratory environment
  - Power Processing Unit (PPU) design is modular
- **The solar array is scalable beyond the 90kW class with the use of additional wings.**
- **The power per thruster/PPU string is a mission dependent system-level trade between fewer higher-power strings and more numerous lower-power strings.**
  - Current technology to demonstrate large scale SEP capability and performance also scales to the higher power vehicles to validate higher power generation and EP system capability in deep space





* Chart reference NAC HEOC presentation July 25, 2018

# Approach to PPE Development

- **PPE would leverage advanced solar electric propulsion (SEP) bus formulation progress from ARM**
  - **Directly use U.S. industry current commercially available spacecraft capabilities**
  - **Infuse STMD developed advanced SEP technology**
  - **Align with U.S. industry plans for future use of SEP**



* Chart reference NAC HEOC presentation July 25, 2018