Power Propulsion Element

For Deep Space Gateway Concept

Request for Information & Synopsis
Virtual Industry Forum

July 24, 2017

Forum Purpose

- Provide an overview of NASA's goals for developing a Power and Propulsion Element for the Deep Space Gateway concept
- Provide an overview of the Power and Propulsion Element Request For Information (RFI) and the Synopsis for NextSTEP BAA Appendix-C: Power and Propulsion Element Studies
- Address questions from participants

Agenda: 11 a.m. - 12 p.m. EDT

Topic	Speaker	Affiliation
Welcome, Introductions, Review of Ground Rules, and Deep Space Gateway Overview	Michele Gates	Director, Power Propulsion Element
Power Propulsion Element Overview	Mike Barrett	Manager, Power Propulsion Element
Power Propulsion Element RFI	Kathy Schubert	Senior Project Manager, GRC Space Flight Systems
NextSTEP BAA Appendix C Synopsis Overview	Mike Barrett	Manager, Power Propulsion Element
Wrap Up, Concluding Remarks	Michele Gates	Director, Power Propulsion Element
Q&A	All	

QUESTIONS?
Press *1 to be added to the queue or email HQ-PPE-RFI@mail.nasa.gov

Web Event Ground Rules

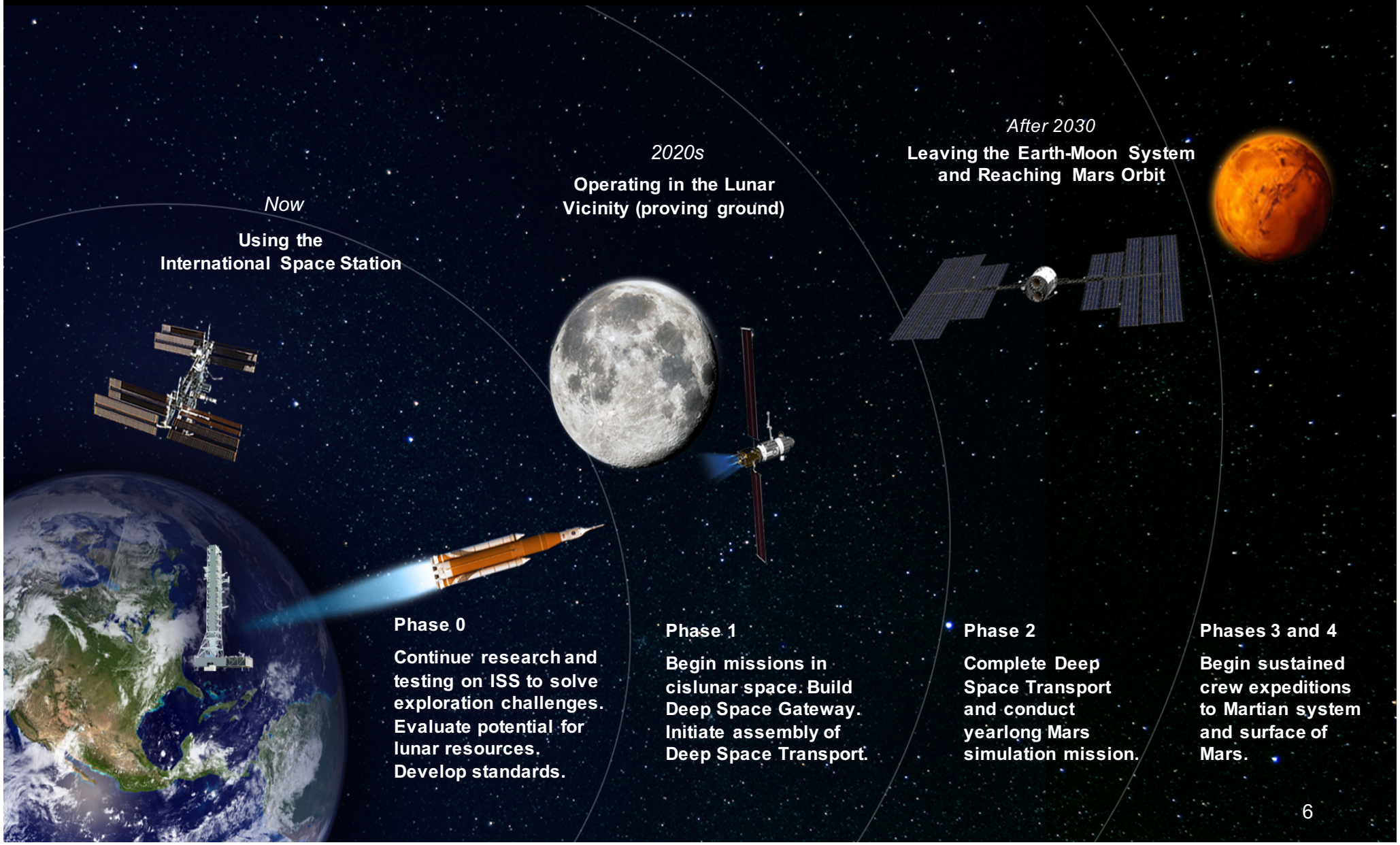
- NASA will address questions during this forum to clarify the content of the Announcements
- Virtual participants, please submit questions via **WebEx Chat** or by email at **hq-ppe-rfi@mail.nasa.gov**
- Questions that require further assessment to address will be resolved as soon as possible after the forum, and the answers will be included in the Q&A log
- NASA will not provide evaluations, opinions, or recommendations regarding any suggested approaches or concepts
- **Deadline for written technical questions is Wednesday, July 26, 2017 at 5 pm EDT – submit questions to hq-ppe-rfi@mail.nasa.gov**

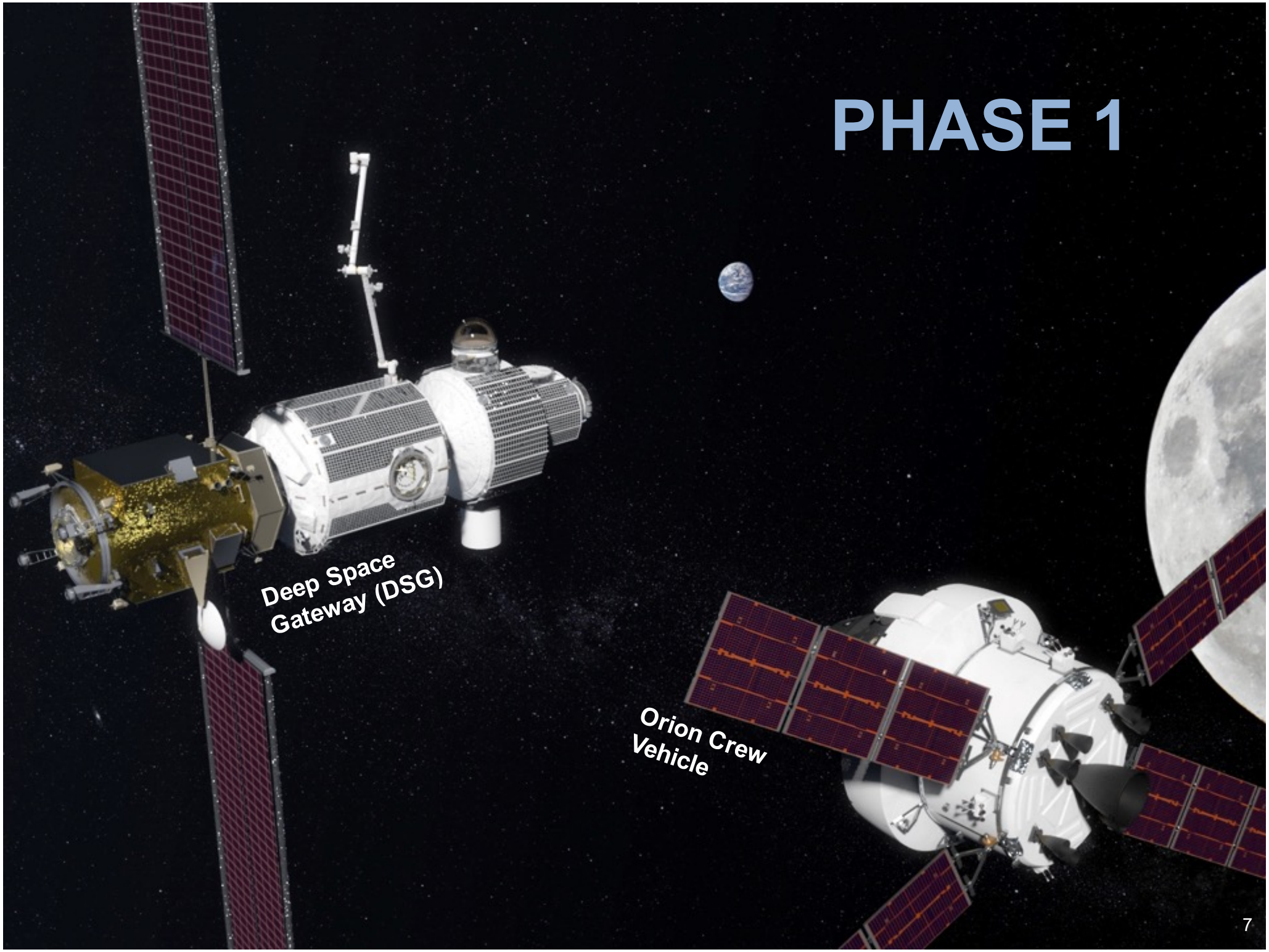
Key NASA Representatives

- **Michele Gates**, Director, Power Propulsion Element
- **Mike Barrett**, Manager, Power Propulsion Element
- **Kathy Schubert**, Senior Project Manager, GRC Space Flight Systems
- **Eve Lyon,** HQ Office of General Counsel
- NASA Ancillary Staff Representatives

EXPANDING HUMAN PRESENCE IN PARTNERSHIP

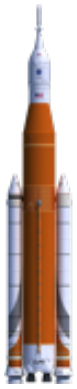
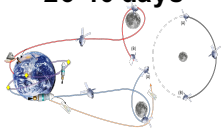
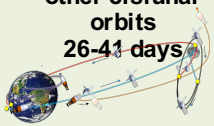
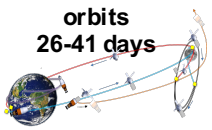
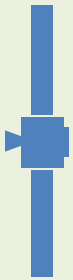
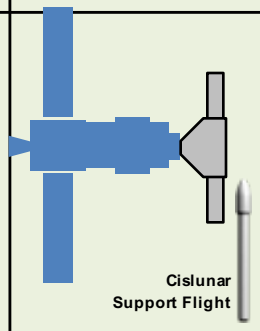
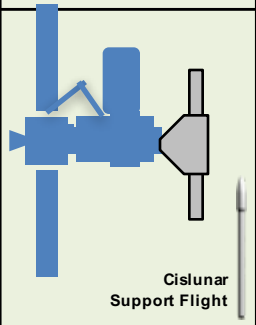
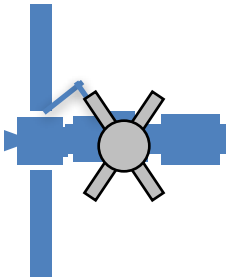
CREATING ECONOMIC OPPORTUNITIES, ADVANCING TECHNOLOGIES, AND ENABLING DISCOVERY




PHASE 1
Deep Space Gateway (DSG)
Orion Crew Vehicle

Phase 1 Plan

Establishing deep-space leadership and preparing for Deep Space Transport development

		Deep Space Gateway Buildup			
EM-1	**Europa Clipper**	**EM-2**	**EM-3**	**EM-4**	**EM-5**
2019 - 2025					**2026**
SLS Block 1 Crew: 0	SLS Block 1B Cargo	SLS Block 1B Crew: 4 CMP Capability: 8-9t	SLS Block 1B Crew: 4 CMP Capability: 10t	SLS Block 1B Crew: 4 CMP Capability: 10t	SLS Block 1B Crew: 4 CPL Capability: 10t
	 Europa Clipper (subject to approval)	  40kW Power/Prop Element	  Habitation	  Logistics	  Airlock
Distant Retrograde Orbit (DRO) 26-40 days	Jupiter Direct	Multi-TLI Lunar Free Return 8-21 days	Near Rectilinear Halo Orbit (NRHO) 16-26 days	NRHO, w/ ability to translate to/from other cislunar orbits 26-41 days	NRHO, w/ ability to translate to/from other cislunar orbits 26-41 days
					
Gateway (blue) Configuration (Orion in grey)			 Cislunar Support Flight	 Cislunar Support Flight	

These essential Gateway elements can support multiple U.S. and international partner objectives in Phase 1 and beyond

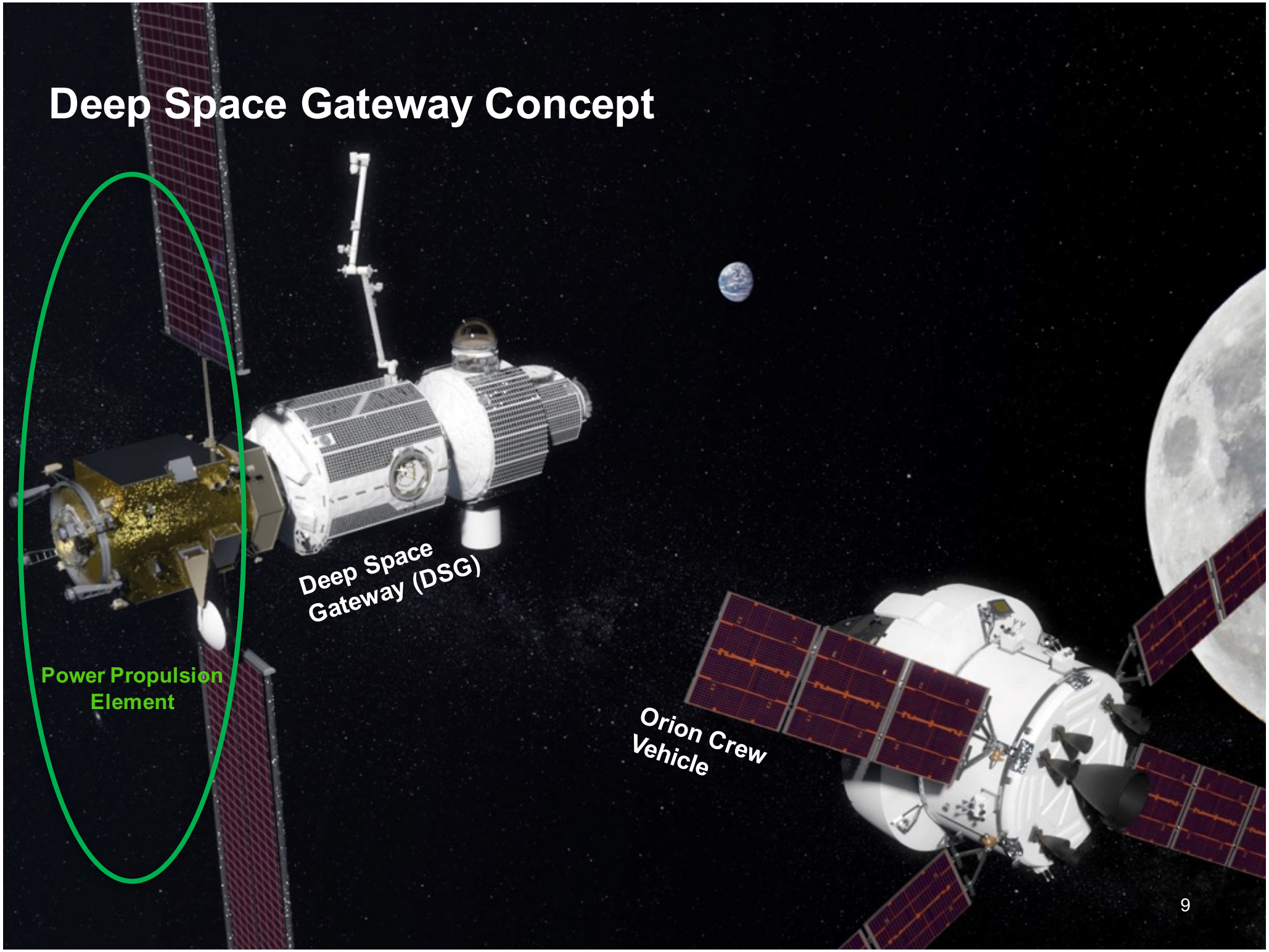
Known Parameters:

- Gateway to architecture supports Phase 2 and beyond activities
- International and U.S. commercial development of elements and systems
- Gateway will translate uncrewed between cislunar orbits
- Ability to support science objectives in cislunar space

Open Opportunities:

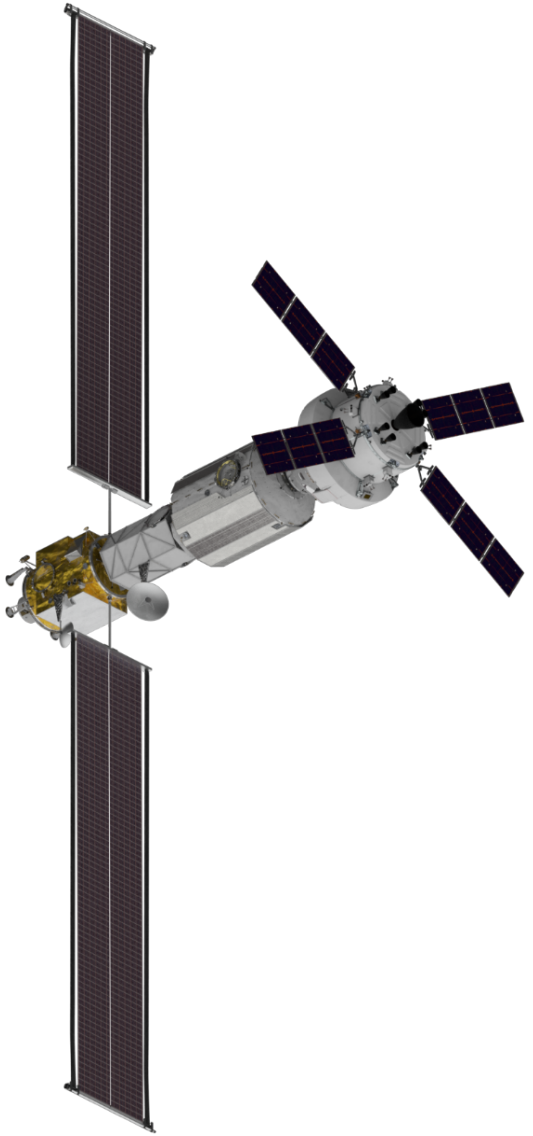
- Order of logistics flights and logistics providers
- Use of logistics modules for available volume
- Ability to support lunar surface missions

Deep Space Gateway Concept



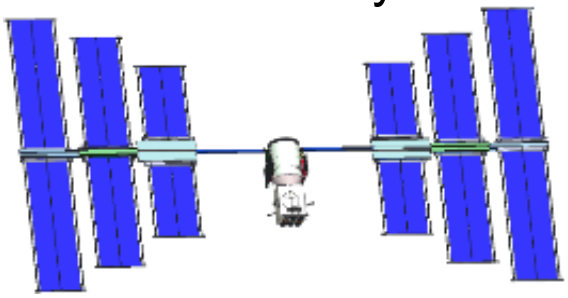
Advantages of Solar Electric Propulsion (SEP) in Cislunar Space

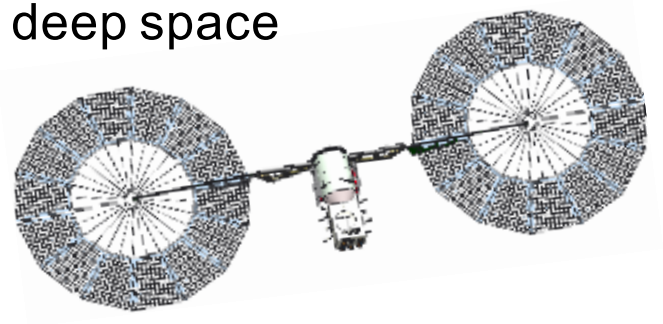
- **Fuel is storable, does not boil off, and can be resupplied**
- **Advanced SEP provides the ability to move habitat systems to various orbits around the moon**
  - Halo, Lagrangian, or other Earth-Moon orbits
- **Analyses of in-space orbit transfers in the lunar vicinity shows a 5 to 15 fold savings 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



Scalability to Higher Power Systems for Deep Space Human Exploration

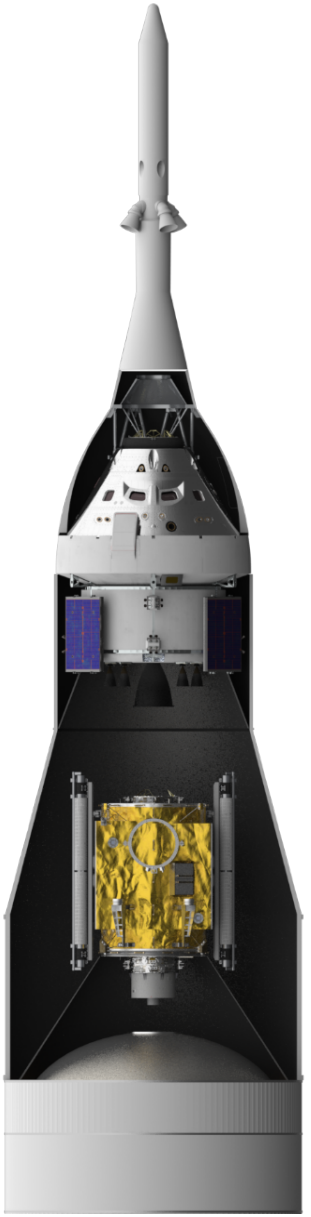
- **High-power, 40-kW class system would be a step up from current technology and on the path to much higher power systems.**
  - Range of powers: 150 kW to 300 kW
- **Electric propulsion technology scalable**
  - Several Hall thrusters of higher power (~50kW) have been validated in a laboratory environment
  - 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 SEP system capability in deep space





Power & Propulsion: 1st Element in Gateway

- Start deep space gateway when we fly crew to vicinity of the moon
- A power propulsion element (PPE) would be the first element in a cislunar gateway
  - Also would host communications and command/control functions
  - Potentially a partner system/payload contribution
- PPE launch co-manifested on SLS with Orion on EM-2

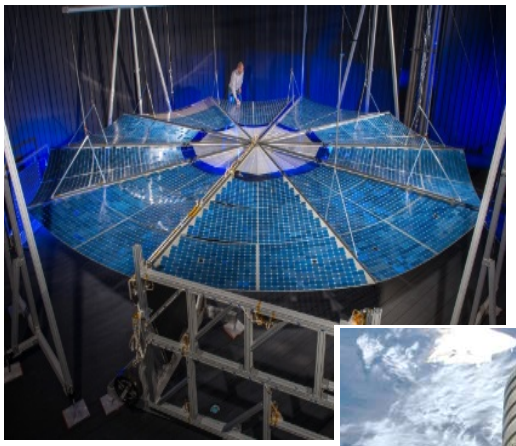


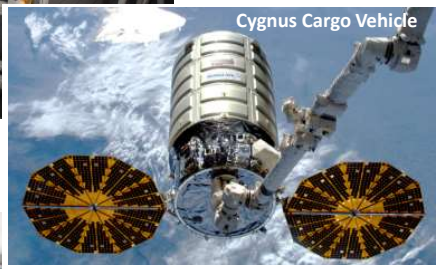
Approach to PPE Development

- **PPE will leverage advanced solar electric propulsion (SEP) technologies developed and matured during ARM activities**
  - **Directly use commercially-available U.S. flight hardware**
  - **Infuse SMTD-developed advanced SEP technology**
  - **Align with U.S. industry plans for future use of SEP**

Solar Electric Propulsion Progress (Solar Array)

- **Solar Array Development Contracts Fully Successful**
  - MegaFlex Engineering Development Unit
  - Rollout Solar Array (ROSA) Engineering Development Unit
  - Both arrays achieved all SOA-related goals including 4x rad tolerance, 1.7x power/mass (kW/kg), 4x stowed volume efficiency, and 20x deployed strength





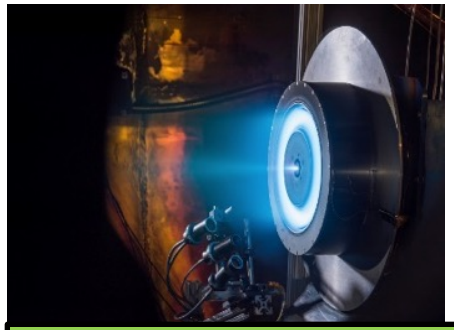
- **Subsequent commercial infusion of solar array technology:**
  - Orbital ATK using smaller version of similar technology to Megaflex on the Cygnus cargo vehicle to ISS
  - Space Systems Loral and Deployable Space Systems are flight qualifying a 12.5 kW ROSA for use on commercial satellites
  - ROSA flight experiment on ISS successfully completed its science objectives: unfurl for the first time on-orbit; measure structural dynamics and power generation performance

NASA SEP technology development led by Space Technology Mission Directorate

Solar Electric Propulsion Progress (Electric Propulsion)

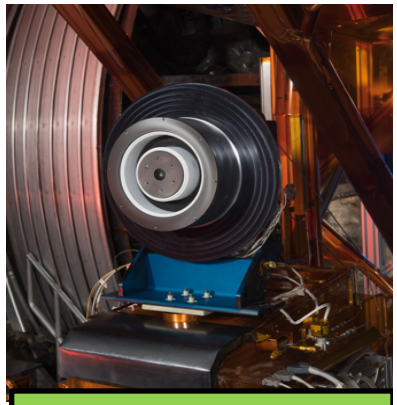
Risk Reduction

- **Technology Development Unit Thruster (TDU-1) and Power Processing Unit (PPU) Risk Reduction Tests at NASA-Glenn**
  - Confirmed thruster magnetic shielding (enables long-life operation)
  - PPU vacuum tests successfully completed
  - Conducted 12.5 kW thruster integrated tests w/ 300-V & 120-V PPUs
  - 2200 hours of testing completed
- **TDU-2 vibe and thermal balance testing**
  - Successfully completed random vibe, will run thermal test in chamber at JPL after sputter test and graphite chamber risk reduction tests are completed
- **TDU-3 wear testing in Vacuum Facility 5 at NASA-Glenn**
  - Represents flight-like configuration of downstream thruster on Advanced EP System (AEPS)
  - Final short duration risk reduction test segment completed at 600 V, 12.5 kW, 250 G
  - Over all four risk reduction test segments, the thruster was operated for 940 hours and consumed a total of 75 kg of xenon. Long duration 3000 hour wear test to follow.



Demonstrated full performance compatibility between thruster and PPUs

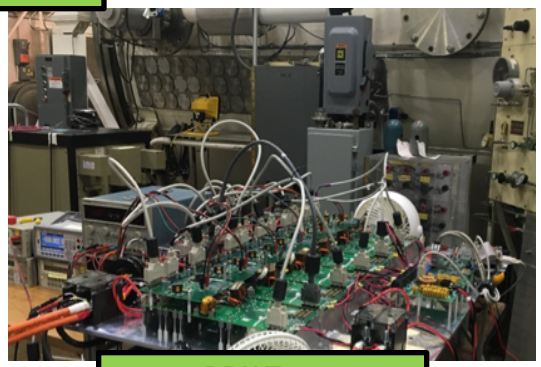
TDU-2 on Vibe table



TDU-3 Test Preparations

AEPS Contract

Early Integrated System Test in Vacuum Facility 6 - successfully conducted a series of hot-fire tests to demonstrate stable operation and characterize performance of Aerojet's PPU discharge module, a key PPU assembly. Test results inform AEPS design leading up to August Preliminary Design Review (PDR).



PPU Test

Asteroid Redirect Mission (ARM) Transition to Power & Propulsion Element

- **The Asteroid Redirect Robotic Mission (ARRM) portion of the ARM made substantial steps towards developing a highly efficient, large scale SEP capability that will be needed in NASA's emerging plans for deep space exploration.**
- **ARM studies and mission development of a SEP capability for future exploration is directly applicable to the planned cis-lunar power and propulsion capability.**
- **Deployment of 50kW class SEP as an initial step:**
  - Offers highly efficient power and propulsion capability to support longer duration human habitation
  - Provides a platform for communications and other lunar vicinity services for extended crew presence
  - Completes needed SEP integrated flight demonstration
  - Advanced systems use aligned with emerging commercial and other Government needs
  - Ensured the extensibility of these capabilities for Mars transport

RFI Content – Reference Capabilities

Capability Title	Reference Capability Description
1. PPE Lifetime	The PPE will have a minimum operational lifetime of 15 years in cis-lunar space.
2. PPE Power Transfer	The PPE will be capable of transferring up to 24kW of electrical power to the external hardware.
3A. PPE Propulsion Capability	The PPE will be capable of providing orbit transfers for a stack of TBD mass with a center of gravity of TBD.
3B. PPE Propulsion Capability	The PPE will be capable of providing orbit maintenance for a stack of TBD mass with a center of gravity of TBD.
4. PPE Xenon Capacity	The PPE will have 2,000 kg-class tank Xenon capacity.
5a. PPE Launch Vehicle	The PPE will be compatible with the SLS vehicle co-manifested launch loads on the Exploration Mission -2 (EM-2) flight.
5b. PPE Mass	The PPE will not exceed a mass of 7,500 kg including the payload adaptor.
6. PPE Attitude Control	The PPE will be capable of providing attitude control for external hardware up to (TBD) mass and (TBD) Center of Gravity location.

RFI Content – Reference Capabilities (cont.)

Capability Title	Reference Capability Description
7. PPE Interfaces	The PPE will be capable of integrating two International Docking System Standard (IDSS) compliant systems.
8A. PPE Communication	The PPE will be capable of providing X-Band, Ka-Band, S-Band and UHF communications.
8B. PPE Communication	The PPE will be capable of accommodating an optical communication demonstration
9A. PPE Crew Compatibility	The PPE will be crew compatible.
9B. PPE Crew Compatibility	The PPE will provide a minimum translation path for EVA.
10. PPE Refuelability	The PPE will be on-orbit refuelable.
11. PPE Extensibility	The PPE will demonstrate an advanced integrated solar electric propulsion system including a 50kW class Solar Electric Propulsion capability that is extensible to future human Mars class missions.
12. PPE Lunar Orbit	The PPE will insert into a crew-accessible Near Rectilinear Halo Orbit (NRHO) in no longer than 100 days (TBR) after launch.

Power Propulsion Element RFI Overview

NASA is seeking ideas and information from U.S. Industry on their current commercial capabilities, concepts and development approaches, and potential for future commercial applications that support a cost-effective partnership model for possible use in the potential development of the Propulsion Element (PPE) for NASA's Deep Space Gateway (DSG) concept.

- Intent is for U.S. Industry to provide **readily available information** responding to one or more of the requested items.
- Feedback is requested on preliminary PPE capability descriptions, including the identification of areas requiring further study.
- Industry ideas on possible approaches that would enable a successful partnership between the government and industry.
- Other specific topics of interest as listed in the RFI, e.g., use of green propellant, commercial satellite reliability data, etc.
- ***It should be understood that there is no explicit or implied commitment for future procurements in this action.***
  - No solicitation exists at this time. If a solicitation is released in the future, it will be synopsized in FedBizOps and on the NASA Acquisition Internet Service.

Power Propulsion Element Requested information

A. A description of your ability to leverage U.S. industry plans for use of SEP in future commercial applications. Identify any additional government or commercial markets or applications of a 50-kW-class SEP spacecraft or its components/subsystems/systems

B. A description of Commercial Communication Service Providers' approaches to acquiring communications spacecraft. (e.g., copies of relevant RFPs)

C. A conceptual schedule, rough order of magnitude engineering cost estimate, and recommended contract vehicle type for completing the PPE flight unit build, test and delivery. For planning purposes, the current target date for the PPE flight unit delivery to KSC is December 2021.

D. A summary of a conceptual PPE technical development approach that utilizes advanced SEP technology and any progress made under the Asteroid Redirect Mission efforts. Identify a conceptual design you would use as a starting point and what changes you believe are warranted to address PPE capability statements.

E. Identification of U.S. industry commercially available spacecraft bus capabilities for potential use in development of the PPE. Specifically, NASA is interested in receiving and reviewing any related existing commercial bus specifications that could inform programmatic planning for future development of the PPE.

Power Propulsion Element Requested Information (cont.)

F. Input on green-propellant propulsion system technologies or developments that could be considered as an alternative to the baseline hydrazine system. Please include the impacts of development and integration of a green propulsion system, including costs, timeline and risks.

G. Identification of any NASA-provided PPE capability descriptions that need further clarification and/or rationale. (PPE capability descriptions to be included in RFI)

H. Identification of any key trades or additional studies that may be required to address differences between PPE capability needs and existing commercial capabilities.

I. A description of potential cost contributions and/or cost share approach(es) and scope(s). Include recommendations on procurement approach that would enable successful partnership between the government and industry. Describe potential industry based business models, including potential innovative approaches to a partnership model including milestone based payments; contract cost and fee types; phased development approaches; approaches to ownership, intellectual property and data rights.

J. Reliability data for long duration and reliability of the commercial satellite capabilities.

PPE RFI Schedule

✓ FedBizOpps Posting Date:	July 17, 2017
✓ Virtual Web Event:	July 24, 2017
• Deadline for Written Questions:	July 26, 2017
• Response Due Date:	July 28, 2017

- Ongoing exchanges of information between potential offerors and the Government are encouraged per FAR Part 15.201, "Exchanges with Industry before Receipt of Proposals"
- The dates shown above provide a timely response for supporting NASA's near term planning activities
- Note: NASA has the option to accept responses after the RFI Response due date of July 28, 2017

QUESTIONS?
Press *1 to be added to the queue or email HQ-PPE-RFI@mail.nasa.gov

RFI Responses

- All responses will be thoroughly reviewed by NASA
- The information received as a result of this RFI may be utilized by NASA in developing its acquisition strategy for the PPE and/or Gateway.
- Respondents are encouraged to provide information that is not constrained by limited/restricted data rights. However, if proprietary data is included in a reply, Respondents should clearly and properly mark any propriety or restricted data contained within its submission so it can be identified and protected.
- NASA intends to evaluate all data received and respondents may be contacted for further discussion on an as needed basis.
  - NASA as well as support contractors and/or their sub-contractors working on behalf of the Government may be reviewing the information.
- Responses to this RFI will not be returned, and Respondents will not be notified of the result of the review and evaluation of material received in response to this RFI.

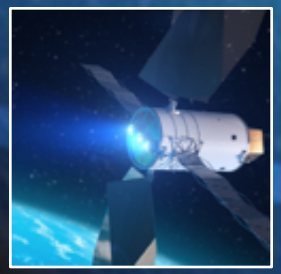
Synopsis Overview: NextSTEP Appendix C - Power and Propulsion Element Studies

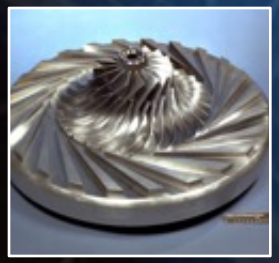
- NASA intends to release a solicitation under the Next Space Technologies for Exploration Partnerships – 2 (NextSTEP-2) Broad Area Announcement (BAA) in the near future to seek proposals from industry for the conduct of studies relevant to a Power and Propulsion Element (PPE).
- This NextSTEP Appendix C, targeted for release in the August 2017 timeframe, will seek proposals for areas necessitating further study for this specific application of advanced solar electric propulsion (SEP).
- Studies are anticipated to be brief (3-4 month duration) with succinct products to assist in the development of the PPE concept and approach.

Synopsis Overview: NextSTEP Appendix C - Power and Propulsion Element Studies

- **Studies will be identified and performed by industry that address key drivers for PPE development such as (but not limited to) potential approaches to:**
  - Meeting the intent of human rating requirements;
  - Concept and layout development;
  - Addressing PPB capabilities and concepts in specific areas such as attitude control, propulsive maneuverability of the gateway, power generation, power interface standards, power transfer to other gateway elements, ability to host multiple International Docking System Standard (IDSS) compatible docking systems; batteries/eclipse duration, 15 year lifetime, communications, and/or avionics
  - Assembly integration and test
  - Extensibility
  - Accommodations of potential (partner provided) hardware such as robotic fixtures, science and technology utilization and other possible elements
  - Options and ideas for cost share/cost contributions approaches

Industry Partnerships in Pursuit of NASA's Strategic Goals





- **NextSTEP solicits studies, concepts, and technologies to demonstrate key capabilities on the International Space Station and for future human missions in deep space. Focus areas include:**
  - life support systems, advanced electric propulsion systems, small satellites, commercial lunar landers, and in-situ resource utilization (ISRU) measurements and systems
- **Most NextSTEP efforts require some level of corporate cost-sharing.**
- **This cost-sharing model of public-private partnerships stimulates the economy and fosters a stronger industrial base and commercial space market.**

Questions

- Questions in this forum may be submitted in two ways:
  - Verbal/chat questions during Q&A period of the forum
  - E-mail questions to: hq-ppe-rfi@mail.nasa.gov
- Please limit questions to clarifications of the RFI only

QUESTIONS?
Press *1 to be added to the queue or email HQ-PPE-RFI@mail.nasa.gov

Conclusion

Thank you for your participation today.

We appreciate your interest and look forward to receiving your responses to the RFI.

This presentation will be posted to the RFI webpage: https://www.nasa.gov/feature/nasa-power-propulsion-rfi

Please submit questions about this Announcement no later than July 26th , 5pm EDT to:

hq-ppe-rfi@mail.nasa.gov

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