High Power Advanced Solar Electric Propulsion Development under NASA's NextSTEP Project

Panel EXPL-06: Electric Propulsion for the Gateway

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NextSTEP BAA: Advanced Electric Propulsion Background

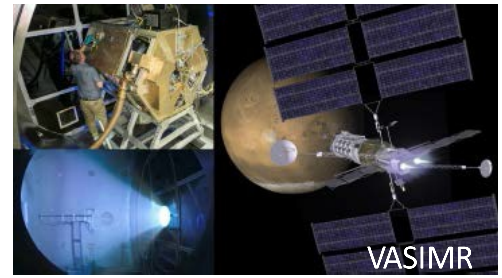
- Developing propulsion technology systems in the 50- to 300-kW per thruster range to meet the needs of a variety of long duration, deep-space mission applications beyond capabilities being developed for 50-kW SEP Tech Demo Mission.

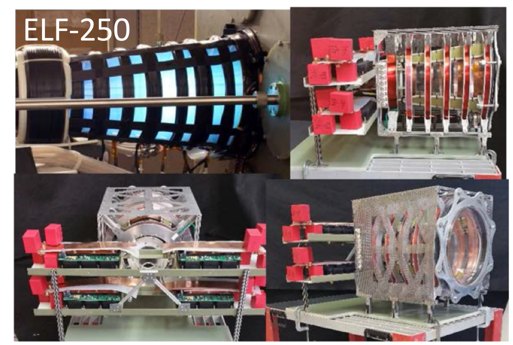
- NASA Broad Area Announcement (BAA) was released in 2014.

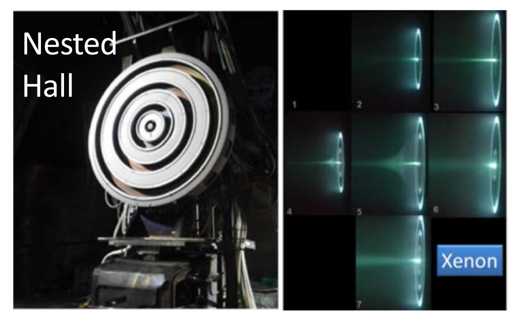
- 3 proposals were selected to develop and demonstrate NextSTEP (Next Space Technologies for Exploration Partnerships) advanced electric propulsion (EP) subsystems.
  - Ad Astra - VASIMR (Variable Specific Impulse Magnetoplasma Rocket)
  - MSNW - ELF-250 (Electrodeless Lorentz Force)
  - Aerojet Rocketdyne - Nested Hall Thruster

- Primary goal is, during the third year, to demonstrate 100-hours of continuous, steady-state operation of propulsion subsystem at 100-kW in a relevant TRL 5 environment.
  - Subsystem includes thruster, power processing unit, feed system, and other key components.

- A 50% cost-sharing requirement was stipulated in the BAA.







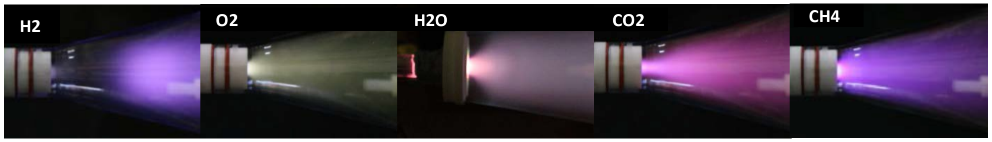
NextSTEP BAA: Advanced Electric Propulsion Background

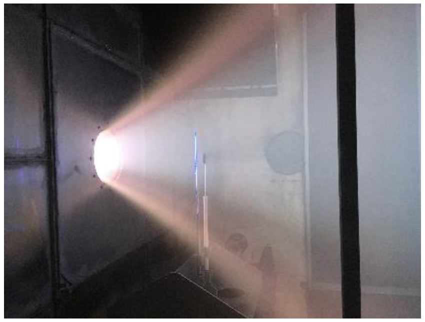
- Key performance goals include Isp range of 2,000 to 5,000s, total system efficiency> 60%, operational life> 10,000 hrs, total system specific mass < 5kg/kw, and scalable to MW levels.

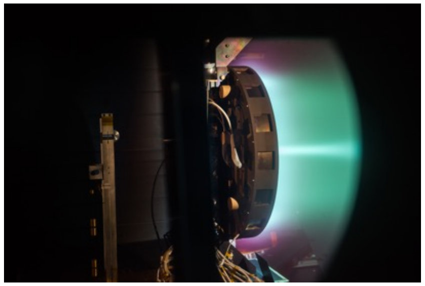
- Variety of mission concepts could use NextSTEP advanced EP systems including Earth-orbiting tugs, Earth-cislunar tugs, Earth-Mars Cargo Transfer Vehicles, Earth-Mars Human Transfer Vehicles, and other human exploration mission vehicles/spacecraft.

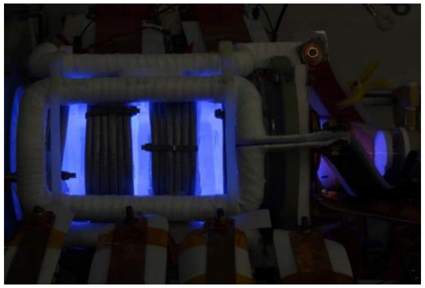
- With early investments, could jump directly to higher power EP flight development and obtain more advanced EP systems sooner.

- Offers the potential for use of alternate propellants (hydrogen, oxygen, water, carbon dioxide, methane, etc.), including those ISRU derived.





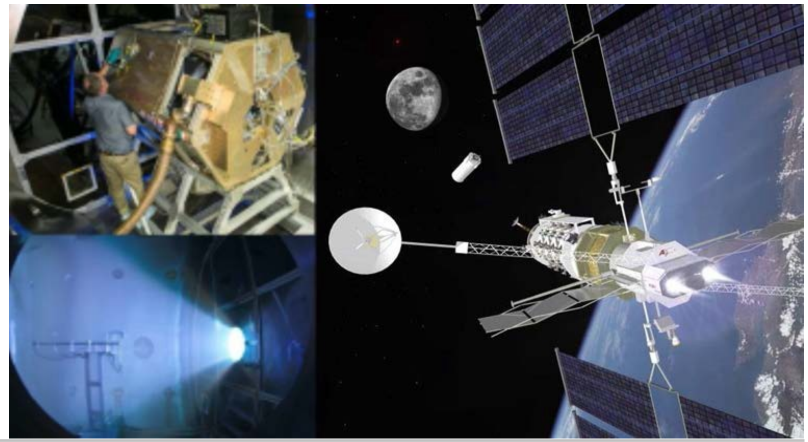




Ad Astra's Variable Specific Impulse Magnetoplasma Rocket (VASIMR ®)

Objectives & Technical Approach:

- Demonstrate a TRL-5 single core VASIMR® thruster with PPUs, the VX-200SS, in thermal steady-state for at least 100 continuous hours at 100 kW
- Leverage Ad Astra's privately funded superconducting magnet, propellant management system, power processing units, and unique vacuum capabilities to test the steady-state performance of its integrated thermal design



Team:

- Dr. F.R. Chang Díaz, Ad Astra, CEO, Strategic Guidance, Private Investment Leveraging

Key team members, organization, and role

- Dr. M.D. Carter, Ad Astra, Engineering Development and Principal Investigator
- Dr. J.P. Squire, Ad Astra, Experimental Implementation and Measurement, co-Principal Investigator
- Mr. L. Dean, Ad Astra, Director of Manufacturing
- Ms. Yamaris Lopez-Nieves, Ad Astra, Contracts Manager

Schedule/Objectives

Milestones	Year 1	Year 2	Year 3
System Design Mfg & Assembly			
1st Stage, 2nd Stage pulsed Low-T plasma tests			
2nd Stage & Plasma Dump Preparation Complete			
1st & 2nd Stage Integrated Low-T plasma tests			
VX-200SSTM Integrated Duration High-T plasma tests			

Multiple Ad Astra papers were recently published at AIAA Propulsion and Energy Forum. (AIAA-2018-4416, x-4417, x-4503, x-4507)

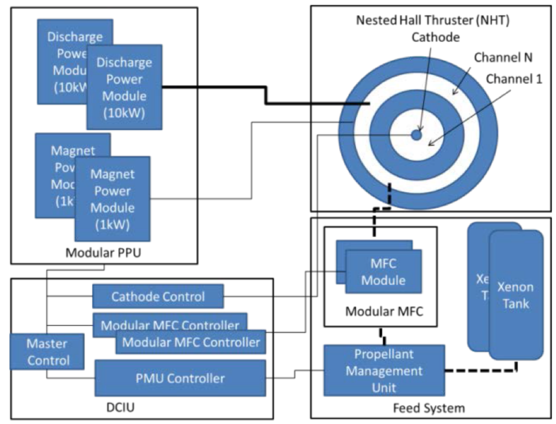
Aerojet Rocketdyne's Nested Hall Thruster

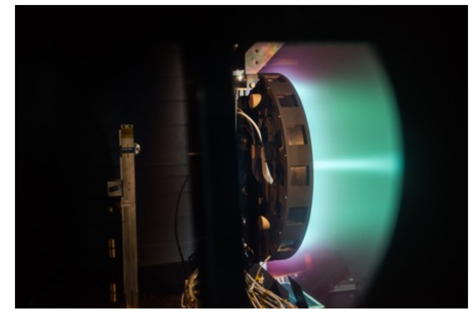
Objectives & Technical Approach:

- Demonstrate performance capabilities to TRL 5 with 100 kW input power for 100 h at thermal steady-state
- Implement the X3, Nested Hall thruster
- Demonstrate the XR-100, 100 kW system extensible to MW class systems

Metric	XR-100 Objective
Specific Impulse	~2,000 to ~5,000 s
In-space lifetime capability	>50,000 h
Operational lifetime capability	>10,000 h
System efficiency	>60%
Power per thruster	250 kW
System kg/kW	<5 kg/kW

Image:





Team:

- Propulsion System Development: Aerojet Rocketdyne
- Propulsion System Testing: NASA GRC (VF-5)
- Feed System: Aerojet Rocketdyne
- PPU Engineering: Aerojet Rocketdyne
- Thruster Development:
  - Aerojet Rocketdyne
  - University of Michigan
  - Jet Propulsion Laboratory

Schedule/Objectives

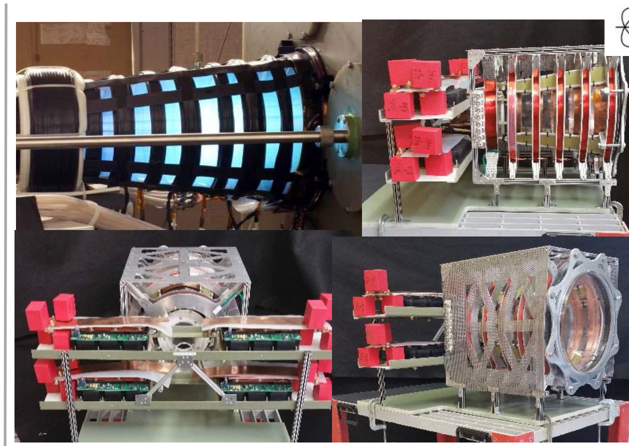
- Year 1: Component demonstration testing
- Year 2: TRL 4 System Demonstration Test
- Year 3: TRL 5 System Demonstration Test

Multiple Aerojet-Rocketdyne and U Michigan papers were recently published at AIAA Propulsion and Energy Forum. (AIAA-2018-4418, x-4419)

Electrodeless Lorentz Force (ELF) Thruster

Electrodeless Lorentz Force (ELF-250) Thruster

- Lightweight, highly variable, highly scalable EP thruster
- One Thruster, 250 mm diameter
  - 1,500-8,000 s Isp
  - 100-1000 kW input power
- ELF-250 electromagnetically forms, accelerates and ejects a high-density magnetized plasmoid – no electrodes
- Operation on Water, Argon, Xenon, and other propellants
- Science & Technology demonstrated in the laboratory
  - Multi-Pulse and complex propellants demonstrated
  - 0.1-2K Joule, 100 W -2 MW discharges demonstrated
    - at 1 kHz for duration of ~50 microseconds



Team:

MSNW LLC

- Design high power thruster geometry
- Design and qualify PPU
- Thermal design and modeling

University of Washington

- Provides testbed extension and facility support
- Operate ELF-250 at 100 kW for 100 hrs

Helion Energy Inc.

- Design and implement advanced, lightweight PPU systems

Schedule/Objectives:

- 6 months – Thruster Assembly
- 12 Months – Pulsed operation 100 kW thruster and PPU
- 15 months – Full thermal engineering model
- 24 months – Steady thermo-vac thruster and PPU operations
- 27 months – Pulsed High power facility upgrades completed
- 36 months – 100 hr, 100-200 kW integrated test

NextSTEP Advanced Propulsion

Technical Challenges and Status

- **Major technical challenges include:**
  - Thermal management
  - Performance characterization and direct thrust measurements
    - Each vendor is addressing performance characterization with varying approaches.
  - Design, preparation, and execution of the high power, long-duration tests
    - Facilities capable of long duration testing of high power systems are a challenge.
    - May require investment for advancing the state of the art.

- **Milestone test status:**

Year 3: 100-hr, 100-kW System Demonstration Test	Anticipated Completion Date
Ad Astra Variable Specific Impulse Magnetoplasma Rocket	9/30/18 (existing RF PPUs) 11/30/18 (new RF PPUs)
Aerojet Rocketdyne Nested Hall Thruster	11/30/18
MSNW Electrodeless Lorentz Force thruster	TBD