Exploring Space In Partnership

Using the International Space Station

2020s
Operating in the Lunar Vicinity

2030s
Leaving the Earth-Moon System and Reaching Mars Orbit

Now
Using the International Space Station

Phase 0
Solve exploration mission challenges through research and systems testing on the ISS. Understand if and when lunar resources are available

Phase 1
Conduct missions in cis lunar space; assemble Deep Space Gateway and Deep Space Transport

Phase 2
Complete Deep Space Transport and conduct Mars verification mission

Phases 3 and 4
Missions to the Mars system, the surface of Mars

Advancing technologies, discovery and creating economic opportunities
Approach

- NAC request for in-space power and propulsion
- This briefing is focused on applicability of solar electric propulsion (SEP) on ARRM for human exploration
• Relevant Asteroid Redirect Mission Objectives

1. ‘Conduct a human exploration mission’…. ‘providing systems and operational experience required for human exploration of Mars’.

2. Demonstrate an advanced solar electric propulsion system, enabling future deep-space human and robotic exploration with applicability to the nation’s public and private sector space needs.

• Relevant Asteroid Redirect Robotic Mission (ARRM) Level 1 Requirements

– AIRM shall develop and demonstrate a high-power, high-total impulse solar electric propulsion (SEP) system with an input power level of at least 40kW and a useable capacity of 5 t of propellant that is extensible to future human and robotic missions to Mars at a power level of at least 150 kW.

– AIRM shall demonstrate solar array technology with the power-to-mass ratio, stowed volume efficiency, deployed strength and radiation tolerance applicable for future robotic and human missions to Mars.
• Completed hardware installation for Vacuum Facility (VF-6) thruster testing.
  • New xenon flow panel, data acquisition, breakout box, cabling (power and sense), thrust stand, thruster and plasma diagnostics mounts, and power and instrumentation racks
  • Installed plasma diagnostics suite inside VF-6
  • Installed VACCO XFCM (Xenon Flow Controller Module) inside VF-6 to support AR AEPS early system test

• Completed Technology Demonstration Unit 3 (TDU-3) Thruster assembly and installed in VF6

• TDU-3 was successfully fired. Thruster operated up to 500 V, 12.5 kW with nominal performance
  • Minor issue with electrical isolation near the propellant isolator precluded operation at 600 V
    • Leak was identified in the propellant isolator and corrected
  • Chamber was opened to assess the electrical isolation, and to switch to the M26-BN (Boron Nitride) discharge chamber
    • TDU-3 will be fired in February, diagnostics checked-out
• Second M26 BN channel shipped to JPL
  • Will be used in TDU-2
• Started planning for Wear Test 2 with TDU-3 in VF-5
  • Main objectives are to quantify wear and performance trends to identify unknown failure modes and support validation of service-life models; quantify deposition rate of back-sputtered facility material
  • Currently planning for March through July (TBR) test
• A thrust vector probe concept was presented to the thruster team for use in VF-5 and VF-6.
  • The team agreed that the concept should proceed to detailed design and fabrication
  • The probe will to be ready for use in June.
• 6 total Developmental Anomaly Reports (DAR) being tracked by Safety & Mission Assurance (S&MA)
  • Tracks anomalies in developmental testing, helps identify trends, identifies cause and corrective action, not as rigorous as for flight HW
  • 1 closed, 5 open
ARM SEP Contributions

- Advanced SEP systems are part of the foundation for human exploration plans, including ultimately a transportation system for human exploration to and from Mars
  - STMD’s Advanced Electric Propulsion System thruster power level on ARM supports lunar vicinity early phase needs based on studies to date
  - Direct applicability to enhancing commercial spacecraft market, enabling NASA as a marginal buyer
- Advanced Electric Propulsion Systems, compared to chemical
  - 4-6 x higher Isp
  - 5-10 x less propellant mass for equivalent missions
  - Magnetic shielding design enables long life operation (years)
- High powered thrusters will operate at ~2.5 times the power level of the highest powered electric thrusters now in use
- Solar array systems, compared to current state of the art
  - 2x lighter
  - 4x less stowed volume
  - 4x greater radiation tolerance
  - 20x greater deployed strength
ARM SEP Technology Demonstration Contributions

• Demonstrate performance and operations in deep space
• Characterize high power (12.5 kW) next generation Hall thrusters
• Characterize solar arrays (high power density, >130 W/kg) > 30 kW beginning of life
• Integral HP-SEP system including thrusters, arrays, bus, and payloads as they operate as an integrated system
  – Quantify xenon plume and thruster electromagnetic interference effects
• Demonstrate ΔV
  – Confirm throughput EP capability and lifetime of overall flight system
  – Xenon 2600 - 3000s and >23,000 hr
• High-power, 40-kW system would be a step up from current technology and on the path to much higher power systems.
  • Range of powers could be as high as 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
  • HEOMD reference mission scenarios use Isp range ~2000-3000 seconds
• The solar array would be 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.
ARRM SEP bus planned to provide:

- NASA and industry design, building, test and operations of a 40kW SEP spacecraft
  - Solar array including packaging, deployment, and flight dynamics
  - End to end high power multi-string SEP system design and performance
  - PPU design
  - Cathode design
  - Power management system with high power and high voltage
  - Thermal design at various solar ranges including with eclipses
  - Spacecraft and xenon plume interaction analysis and design
  - Mission operations including autonomous operations and fault management

- Proof of a deep space operational capability that is directly applicable to wide range of robotic and human spaceflight missions