Solar Electric Propulsion: ARRM & Evolvable SEP

NASA Community Workshop on the Global Exploration Roadmap

Kurt Hack
NASA Glenn Research Center

4/10/14
SEP Cross-Cutting Applications

ARRM

Exploration

SEP Building Blocks

Science

Commercial
Asteroid Robotic Redirect Mission Concepts

- NASA developing concepts for demonstrating initial SEP capability:
  - Reference concept: captures small, free-flying asteroid in the ~3-10m range
  - Alternate concept: captures a 1-4 meter boulder off a large asteroid

Both concepts based on a 50kW SEP spacecraft

Reference Configuration

Alternate Configuration
ARRM Spacecraft SEP Module Concept

- Asteroid Redirect Vehicle (ARV) reference configuration developed
- SEPM is modular element of the ARV based on max capability with new tech currently under development

Reference configuration
40 kW (3+1 -13.3kW strings) electric propulsion subsystem; $I_{sp} \leq 3000 \text{s}$
$\leq \text{10,000 kg of Xe in 8 – 0.5m x 3.3m seamless-aluminum lined COPVs}$
2 - 25kW (BOL) SA Wings compatible $\geq 6 \text{ yr deep space operation}$

Solar Arrays & Electric Propulsion technologies currently under development
Solar Array Systems Development

- Two different 15-25kW Solar Array Wing concepts are being developed:

  *MegaFlex Solar Array Engineering Development Unit - ATK Aerospace*

  *Roll Out Solar Array Engineering Development Unit - Deployable Space Systems*

Low-mass, low-cost solar arrays extensible to higher powers
Electric Propulsion Development

- 13kW Hall thruster propulsion subsystem under development
- Subsystem designed to have cross-cutting applicability

NASA developing high-power, high-specific-impulse, long-life EP technology with extensibility to higher powers
Approaches for Evolution of SEP

- Options include:
  - Include future needs in initial vehicle
    - E.g.: Added docking ring to aft of ARV
  - Scar initial vehicle to allow use in extended applications
    - E.g.: Power transfer to other exploration vehicles
  - Block-upgrade approach keeping same family of fundamental SEP systems
    - Following charts
  - Modular SEP where multiple ARRM-derived SEP elements can be combined
    - Following charts

Trades on-going to find best fit of approaches for future uses within ARM constraints
Asteroid Redirect Mission Builds upon Orion/SLS to enable Global Exploration Roadmap

Asteroid Exploitation Missions

Lunar Vicinity Missions

Deep Space Missions
Notional ARM Derived Phobos Mission Option

Mars Orbit

Pre-Deploy Cargo

Cargo via Solar Electric Propulsion

Earth Return Stage and Phobos Transfer Stage (~40 t class payloads)

High Mars Orbit

Phobos Habitat

Solar Electric Propulsion (100-250 kW)

High-Earth Assembly Orbit

3 Years to Mars

4 Years to Mars

Lunar Gravity Assist

Trans-Earth Injection

Mars Inser-Fon Stage

Transit Habitat

Mars Insertion Stage

Orion: Mars ops and Earth Entry

EUS for Earth Departure

~16 Months in Mars System

7.9 Months to Mars

7.9 Months to Earth

Direct Earth Entry

Mars habitat and return stage will confirmed to be in place before crew departure.
Use of ARM-derived SEP for Mars

• Previous assessments have shown that human Mars missions utilizing a single round-trip monolithic habitat requires very high power SEP (approaching 1 MW total power)

• As part of on-going Mars architectures analysis, we are developing scenarios that have evolvable ARM SEP supporting cargo delivery for human missions into deep space and the Mars Surface
  – Pre-deploy crew mission assets to Mars utilizing highly-efficient SEP, such as
    • Orbit habitats: Supports crew while at Mars
    • Return propulsion stages or return habitats
    • Exploration equipment: Unique systems required for exploration at Mars
  – High thrust chemical propulsion for crew
    • Crew travels on faster-transit, minimum energy missions: 1000-day class round-trip
    • Low-thrust SEP too slow for crewed Mars missions
Summary

• NASA pursuing high-power solar electric propulsion to support range of future human exploration architectures

• A solar electric propulsion module is part of the reference configuration configuration for the Asteroid Redirect Vehicle

• Developments of extensible 25kW-class solar arrays and 13kW class EP underway to support NASA’s future needs

• These investments are designed to be cross-cutting to support additional SEP applications