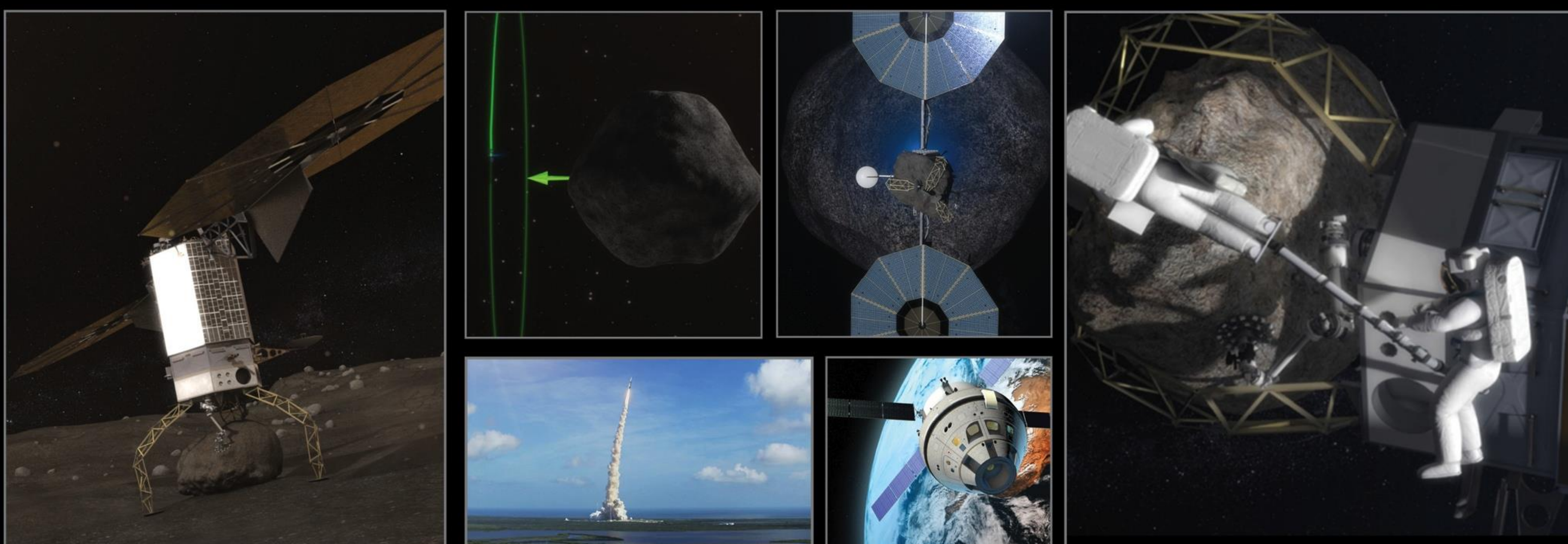
National Aeronautics and Space Administration

Asteroid Redirect Mission Concept Overview

Michele Gates

13th Meeting of the NASA Small Bodies Assessment Group
June 29, 2015



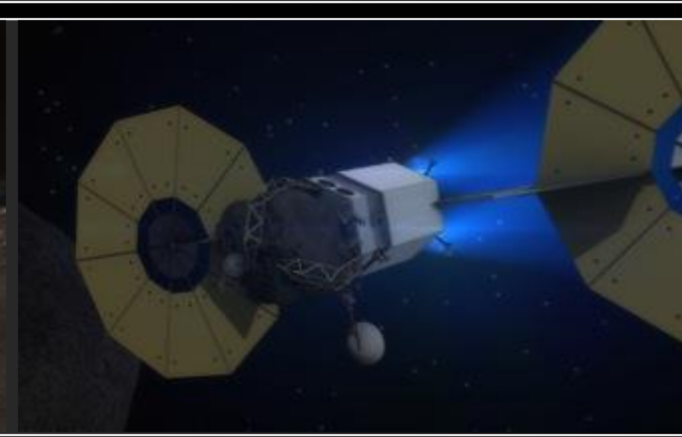
Asteroid Redirect Mission: Three Main Segments

IDENTIFY

Ground and space based assets detect and characterize potential target asteroids

REDIRECT

The Asteroid Redirect Robotic Mission (ARRM) uses solar electric propulsion (SEP) based system to redirect asteroid to cis-lunar space.

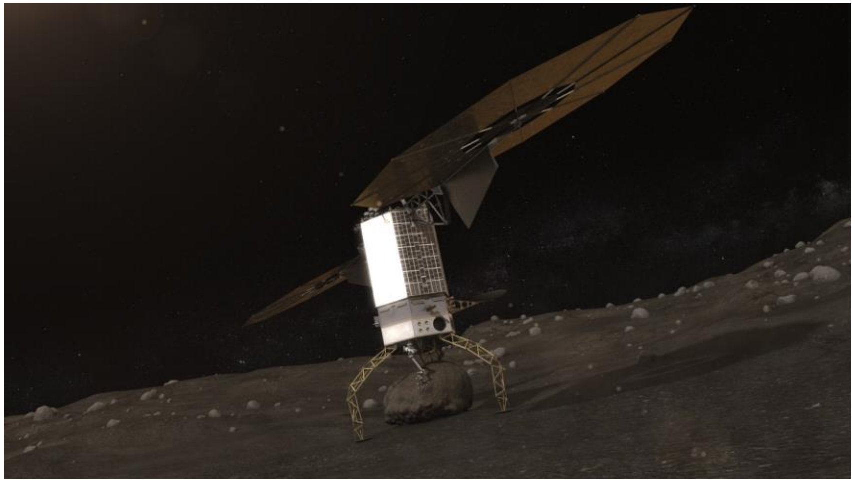


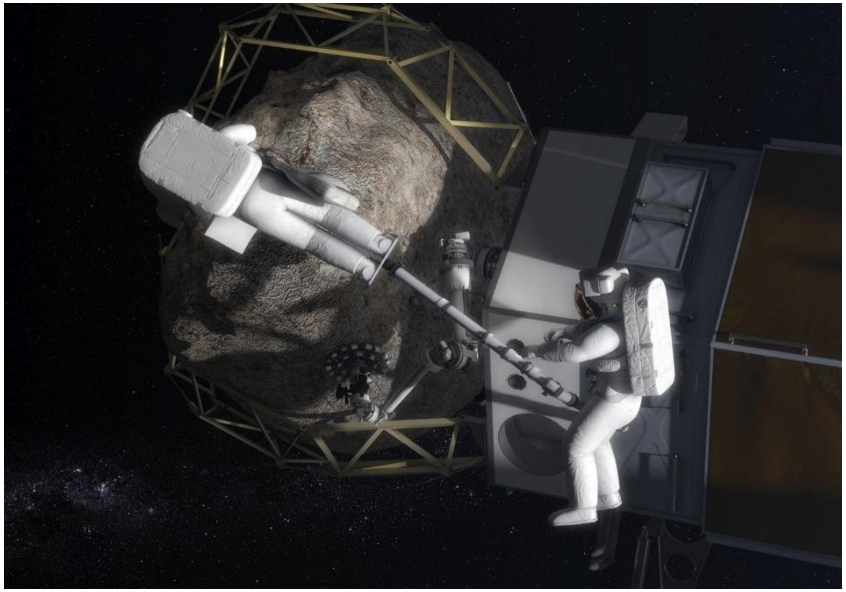
EXPLORE

Crew launches aboard SLS rocket, travels to redirected asteroid in Orion spacecraft to rendezvous with redirected asteroid, studies and returns samples to Earth

Key Aspects of ARM

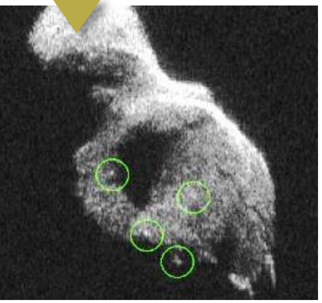
- **Moving large objects through interplanetary space using SEP**
- **Integrated crewed/robotic vehicle operations in lunar distant retrograde orbit (LDRO)**
  - Integrated attitude control, e.g., solar alignment
  - Multi hour EVAs
- **Lean implementation**
  - Clean interfaces, streamlined processes
  - Common rendezvous sensor procurement for robotic vehicle and Orion
- **Integrates robotic mission and human space flight (HSF) capabilities**
  - HSF hardware deliveries to and integration and test with robotic spacecraft
  - Joint robotic spacecraft and HSF mission operations

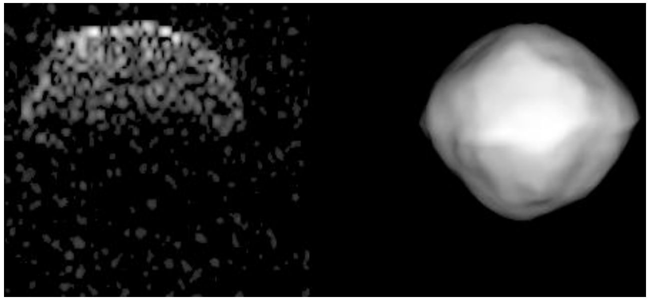


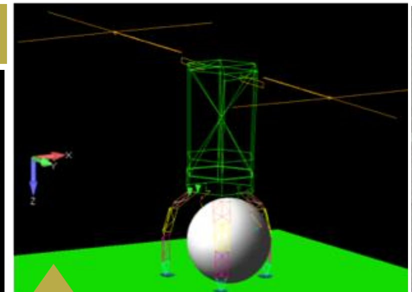


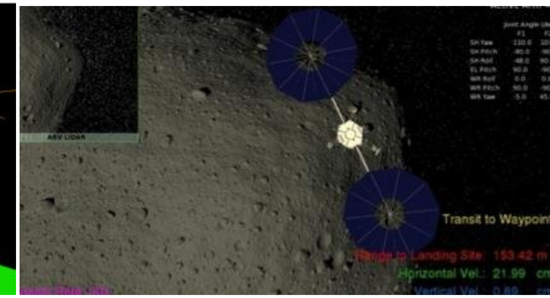
Asteroid Redirect Mission: 2015 Advancements

IDENTIFYING CANDIDATE ASTEROIDS







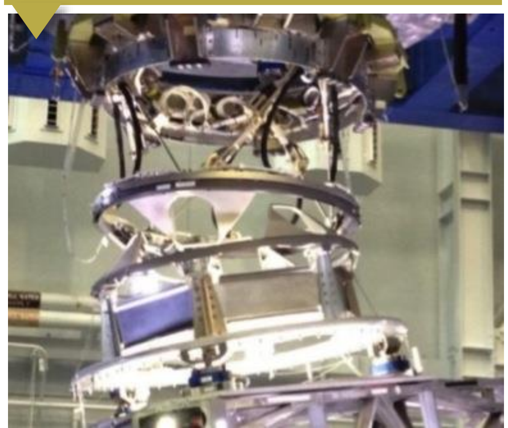


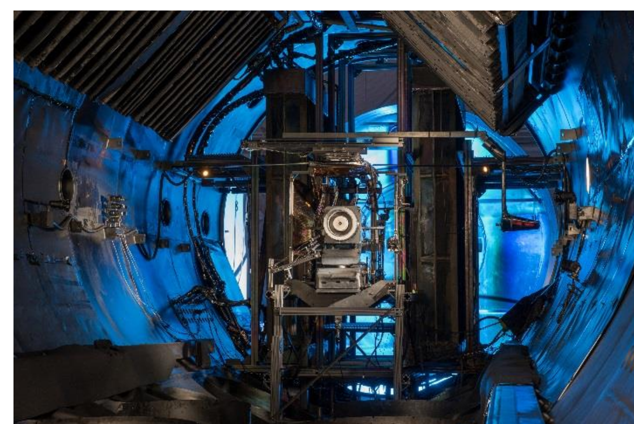
MISSION DESIGN AND SIMULATION OF CRITICAL MISSION OPERATIONS

PROTOTYPING AND TESTING CAPTURE OPTIONS

VACUUM PRESSURE INTEGRATED SUIT TESTING

INTERNATIONAL DOCKING SYSTEM





SOLAR ELECTRIC PROPULSION

Objectives of Asteroid Redirect Mission

1. **Conduct a human spaceflight mission involving in-space interaction with a natural object, 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.**

3. **Enhance detection, tracking and characterization of Near Earth Asteroids, enabling an overall strategy to defend our home planet.**

4. **Demonstrate basic planetary defense techniques that will inform impact threat mitigation strategies to defend our home planet.**

5. **Pursue a target of opportunity that benefits scientific and partnership interests, expanding our knowledge of small celestial bodies and enabling the mining of asteroid resources for commercial and exploration needs.**

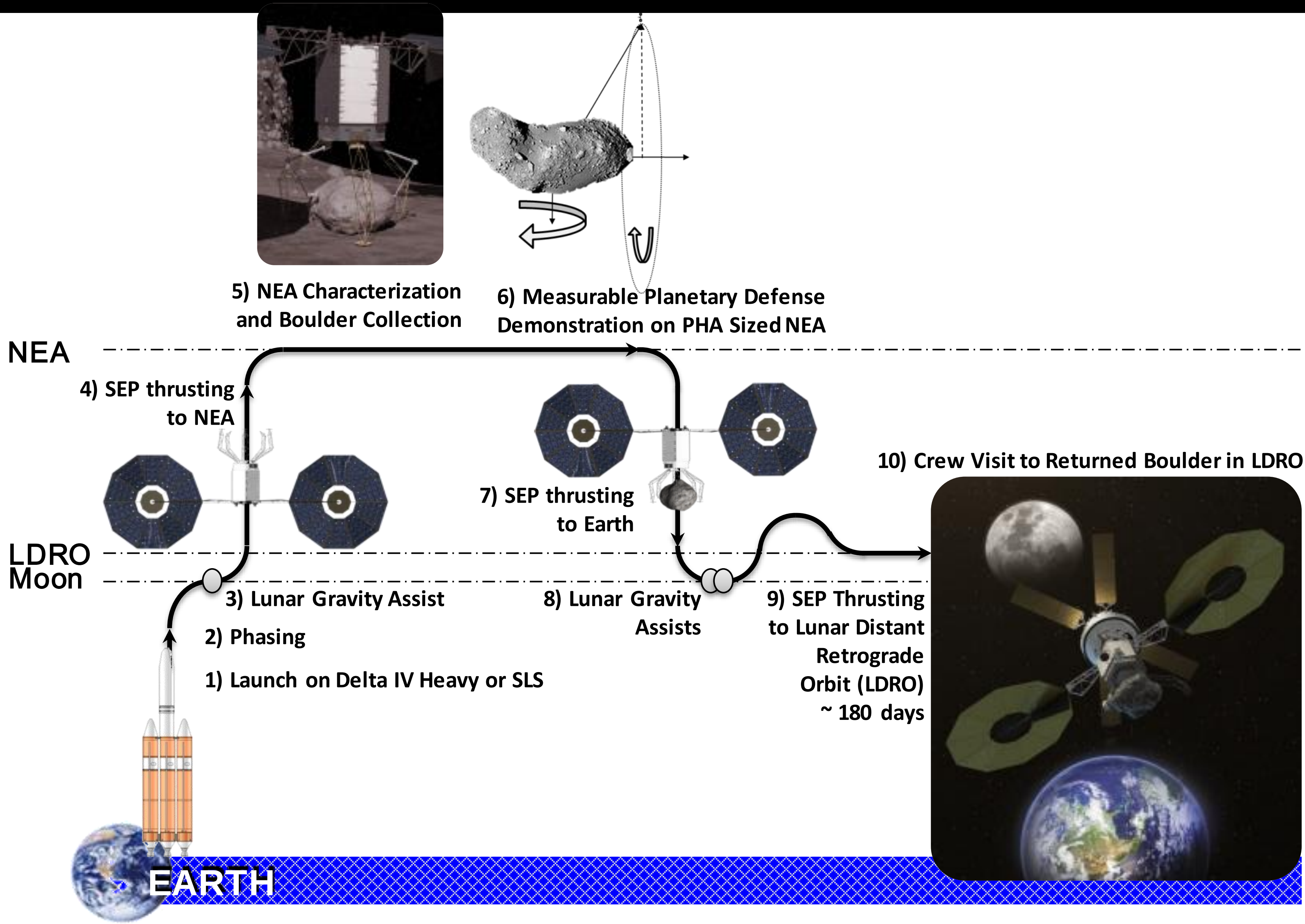
External Engagement (1)

- **June 2013: NASA issued a Request for Information (RFI) to seek new ideas on how to implement the ARM and AGC, alternative ARM concepts, and innovative approaches to broaden participation from partners and the public.**
- **Fall 2013: Ideas Synthesis workshop for public synthesis of highest rated responses**
- **March 2014: NASA issued the Asteroid Redirect Mission Broad Agency Announcement (BAA), soliciting proposals for concept studies in areas including asteroid capture systems, rendezvous sensors, adapting commercial spacecraft for the Asteroid Redirect Mission and feasibility studies of potential future partnership opportunities for secondary payloads and the crewed mission.**
  - In June 2014, NASA announced it selected 18 of the 108 BAA proposals for six-month studies, totaling $4.9 million in awards.

External Stakeholder Engagement (2)

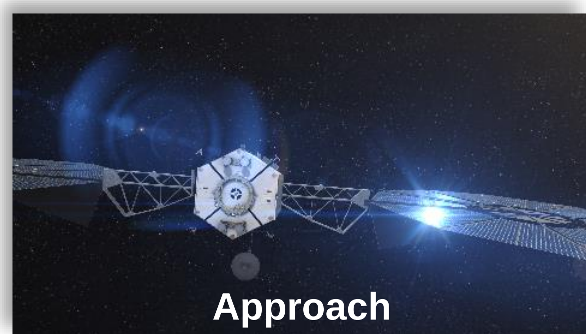
- **Other assessments, information during pre-formulation**
  - Several briefings with feedback
  - SBAG Special Action Team – August 2014
  - CAPTEM input – December 2014
- **May 2015: NASA issued another RFI for Spacecraft Bus Concepts to Support the Asteroid Redirect Robotic Mission and In-Space Robotic Servicing**
- **June 2015: Formulation Assessment and Study Team invitation**
- **Sept 2015: Community workshop**

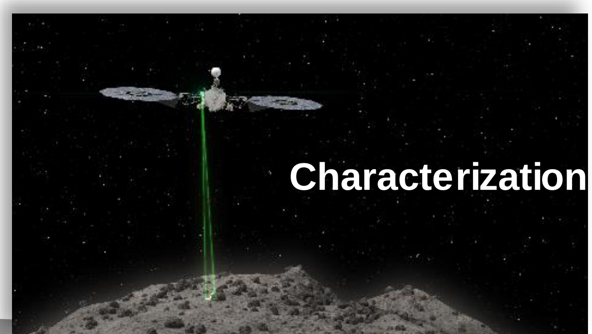
ARRM Mission Concept Overview



ARRM Capture Phase Introduction

Approach	Characterization	Boulder Collection	Planetary Defense Demo
14 days	72 days	69 days	150 days (30 deflection + 120 hold & verify)

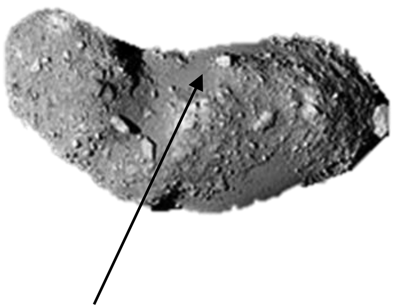




Note: Asteroid operations timeline varies depending on target asteroid. Times shown are for 2008 EV_5: total stay time of 305 days with 95 days of margin.

Current Candidate Parent Asteroids

ITOKAWA

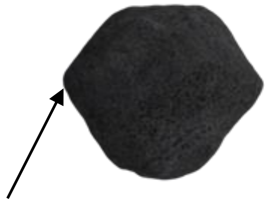


Muses C –
Hayabusa landing

BENNU

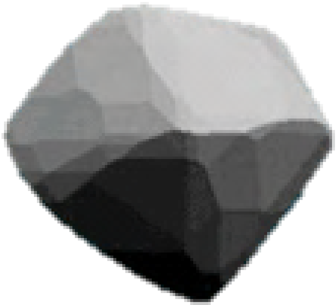
Radar –
OSIRIS-REx target

2008 EV5



Radar – boulders and extremely pronounced bulge at equator suggests movement of loose material

1999 JU3



Expected valid target -
Hayabusa 2 target

Asteroids not to scale

Comparison of current candidate parent asteroids

	Itokawa	Bennu	2008 EV_5	1999 JU_3
Size	535 x 294 x 209 m	492 x 508 x 546 m	420 x 410 x 390 m	870 m diameter
V_∞	5.68 km/s	6.36 km/s	4.41 km/s	5.08 km/s
Aphelion	1.70 AU	1.36 AU	1.04 AU	1.42 AU
Spin Period	12.13 hr	4.297 hr	3.725 hr	7.627 hr
Type	S	B (C-grp volatile rich)	C (volatile rich)	C (volatile rich)
Precursor	Hayabusa (2005)	OSIRIS-REx (9/2016 launch, 8/2018 arrival)	None currently planned (boulders implied from 2008 radar imaging)	Hayabusa 2 (launched 12/4/2014, 7/2018 arrival)

NASA continues to look for additional targets in accessible orbits.

Reference ARRM Target

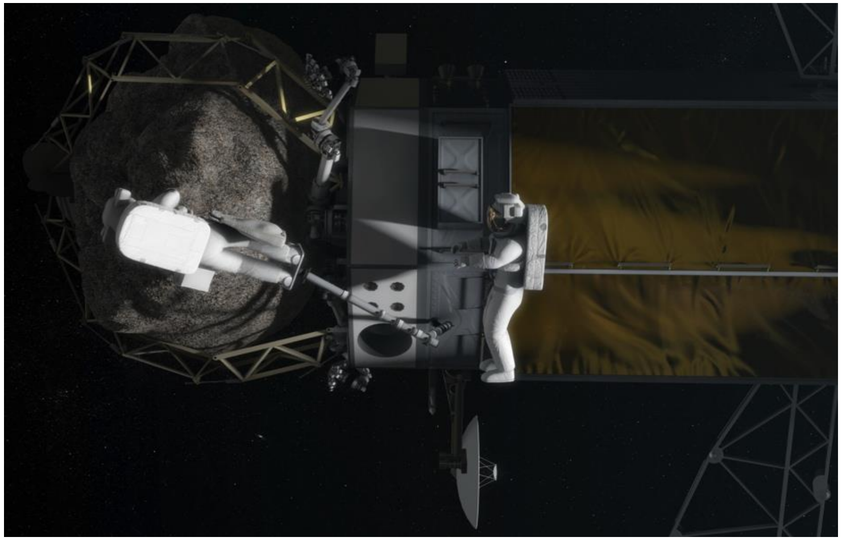
ARRM Formulation Guidance

- Capture option B
- Draft Level 1 requirements
- Target robotic mission launch date Dec 2020
- Cost cap $1.25B not including launch vehicle and mission operations (Phase E)
- Internal and external dependencies
- Define capability demonstration implementation approach
- Target crewed mission launch date Dec 2025

NASA Approval to Proceed to begin Phase A Formulation for Robotic Mission

Pre-formulation of Crewed Mission

- **Will continue through FY2016**
- **Will involve community and potential partnerships**
- **The ARRM Flight System will support visits by crewed missions:**
  1. Carry GFE hardware to make docking and EVA possible, such as
     - International Docking Mechanism (passive) with:
       - FRAM-type connectors for data and power transfer
       - Retro-reflectors
     - 24" EVA Handrails mounted to the spacecraft exterior
     - Attach for Orion-to-ARRM Telescopic Boom
     - Attach for EVA Boom Installation
     - EVA Telescoping Booms
     - EVA Tool Box with tools
  2. Carry robotic systems which could have multiple purposes
  3. Provide resources to crewed and future vehicles
     - 125 V unregulated power
     - Data transfer to Earth via X-band or
     - Optical Communications demonstration
  4. System is crew safe



ARM Investigation Team Introduction

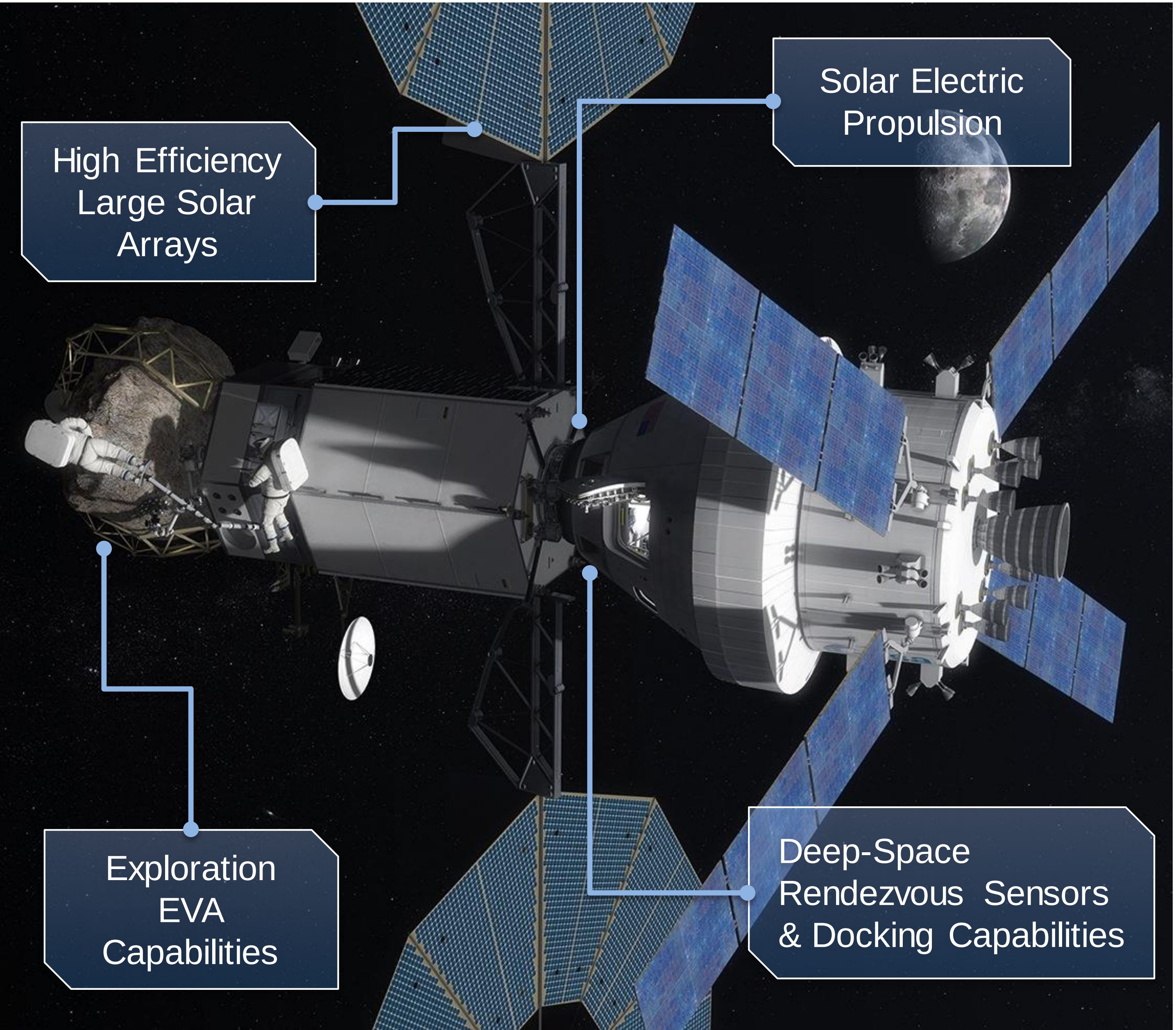
- **The Investigation Team will operate similar to a science team**
- **Will provide input on the following four areas:**
  - science benefit
  - planetary defense deflection demo
  - in-situ resources utilization benefit
  - technology demonstrations
- **International partners and/or commercial partners may wish to have membership on the investigation team also.**
- **Supports the robotic mission project manager, and early formulation of the crewed mission, concept of operation, mission requirements, partnerships development, etc.**
- **Dan Mazanek, of LaRC is the lead, and Paul Abell, of JSC, is deputy**
- **Dan is calling the first phase the FAST (Formulation assessment and support team)**

ARM milestones

- ARRM Implementation Approach Agency discussion #1 — Jun 22
- Formulation investigation team* courtesy letter released — Jun 24
- Spacecraft bus Request for Information responses due — Jun 29
- Small Bodies Assessment Group — June 29
- ARRM Implementation Approach Agency discussion #2 — Jul 6
- NewSpace Conference — Jul 16-17
- NASA Advisory Committee HEO Committee Meeting — Jul 27-30
- Draft common visible/Infra-Red camera spec release — Jul 30
- ARRM lean implementation approach action due — Jul 31
- SEP 2nd thruster test unit fab and assembly complete — Aug 3
- ARRM Acquisition Strategy Meeting — Aug 4
- Exec Session – management structure discussion — Aug 5
- Requirements Closure Technical Interchange Meeting — Dec 15

* Formulation Assessment and Support Team (Sept - Dec 2015)

ARM: A Capability Demonstration Mission



IN-SPACE POWER & PROPULSION:

- High efficiency 40kW SEP extensible to Mars cargo missions
- Power enhancements feed forward to deep-space habitats and transit vehicles

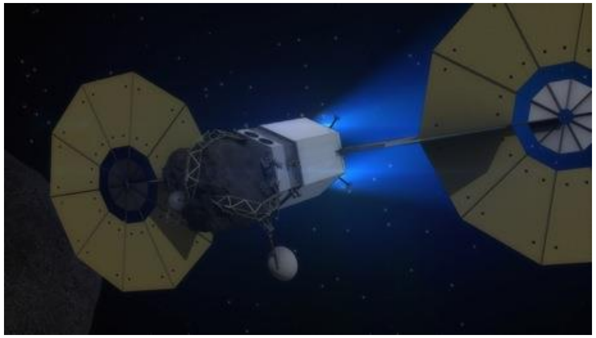
EXTRAVEHICULAR ACTIVITIES:

- Primary Life Support System design accommodates Mars
- Sample collection and containment techniques
- Follow-on missions in DRO can provide more capable exploration suit and tools

TRANSPORTATION & OPERATIONS:

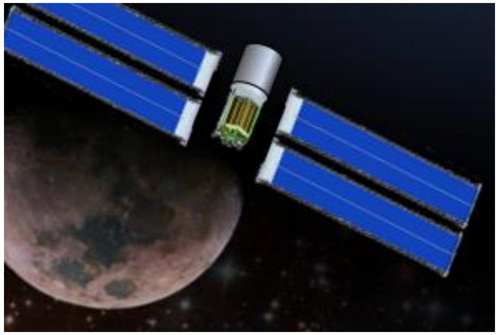
- Capture and control of non-cooperative objects
- Rendezvous sensors and docking systems for deep space
- Cis-lunar operations are proving ground for deep space operations, trajectory, and navigation

SEP Module Extensibility Concept for Mars



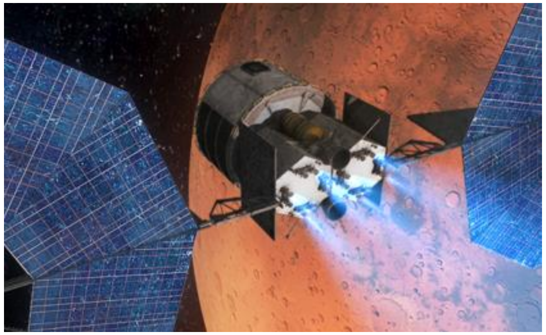
Asteroid Redirect Mission

- 50-kW Solar Array
- 40-kW EP System
- 10-t Xenon Capacity with Refueling Capability



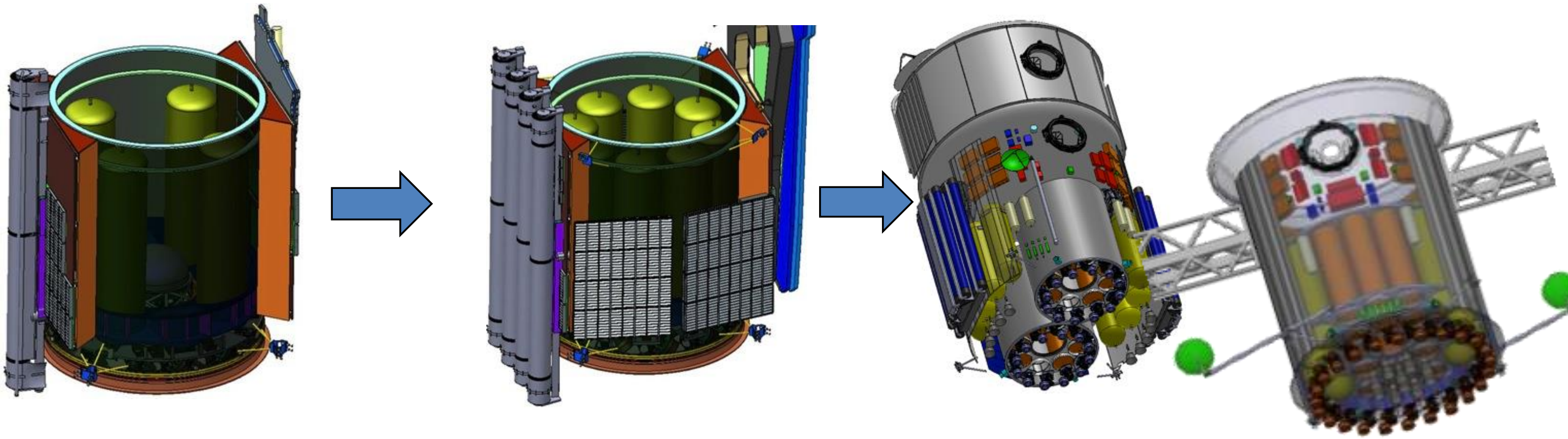
SEP/Chemical

- 190-kW Solar Array
- 150-kW EP System
- 16-t Xenon Capacity

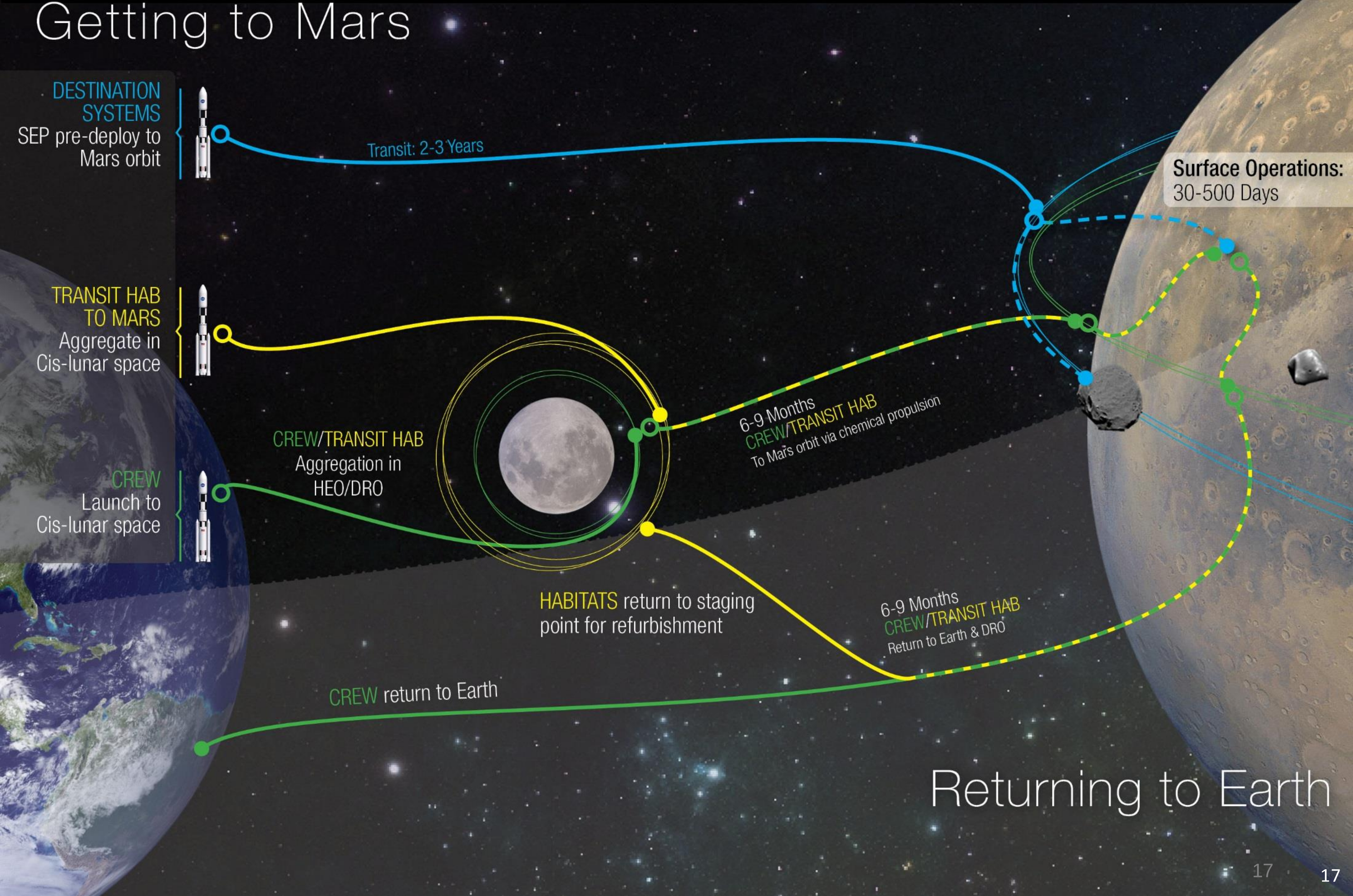


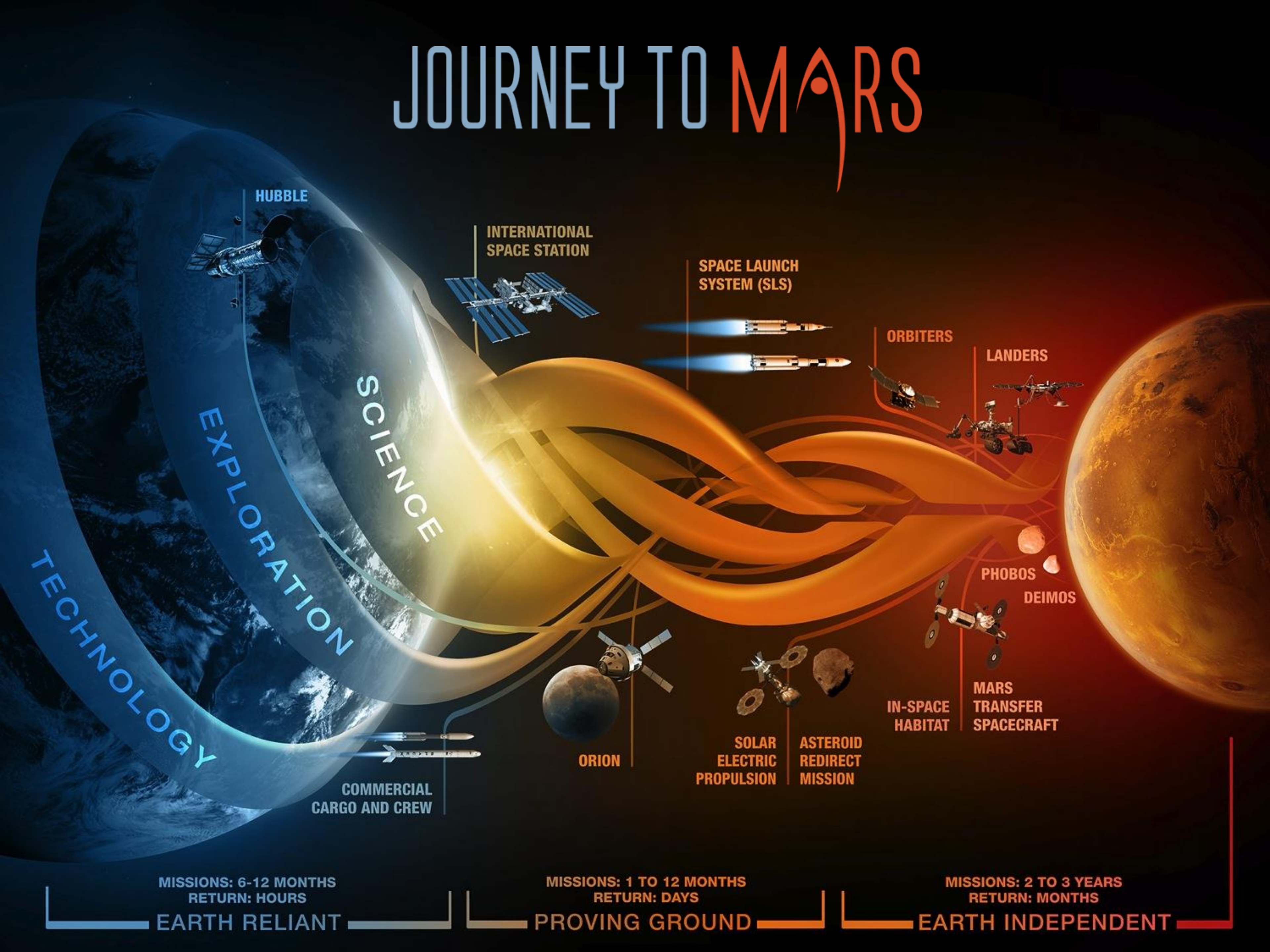
Hybrid

- 250 to 400-kW Solar Array
- 150 to 300-kW EP System
- 24-t Xenon Capacity With Xe Refueling Capability



A Sustainable Exploration Approach
Mars Split Mission Concept




JOURNEY TO MARS
HUBBLE
INTERNATIONAL SPACE STATION
SPACE LAUNCH SYSTEM (SLS)
ORBITERS
LANDERS
SCIENCE
EXPLORATION
TECHNOLOGY
PHOBOS
DEIMOS
MARS TRANSFER SPACECRAFT
IN-SPACE HABITAT
SOLAR ELECTRIC PROPULSION
ASTEROID REDIRECT MISSION
ORION
COMMERCIAL CARGO AND CREW
MISSIONS: 6-12 MONTHS
RETURN: HOURS
EARTH RELIANT
MISSIONS: 1 TO 12 MONTHS
RETURN: DAYS
PROVING GROUND
MISSIONS: 2 TO 3 YEARS
RETURN: MONTHS
EARTH INDEPENDENT

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