National Aeronautics and Space Administration

NASA Advisory Council
HEO Committee

June 23, 2014

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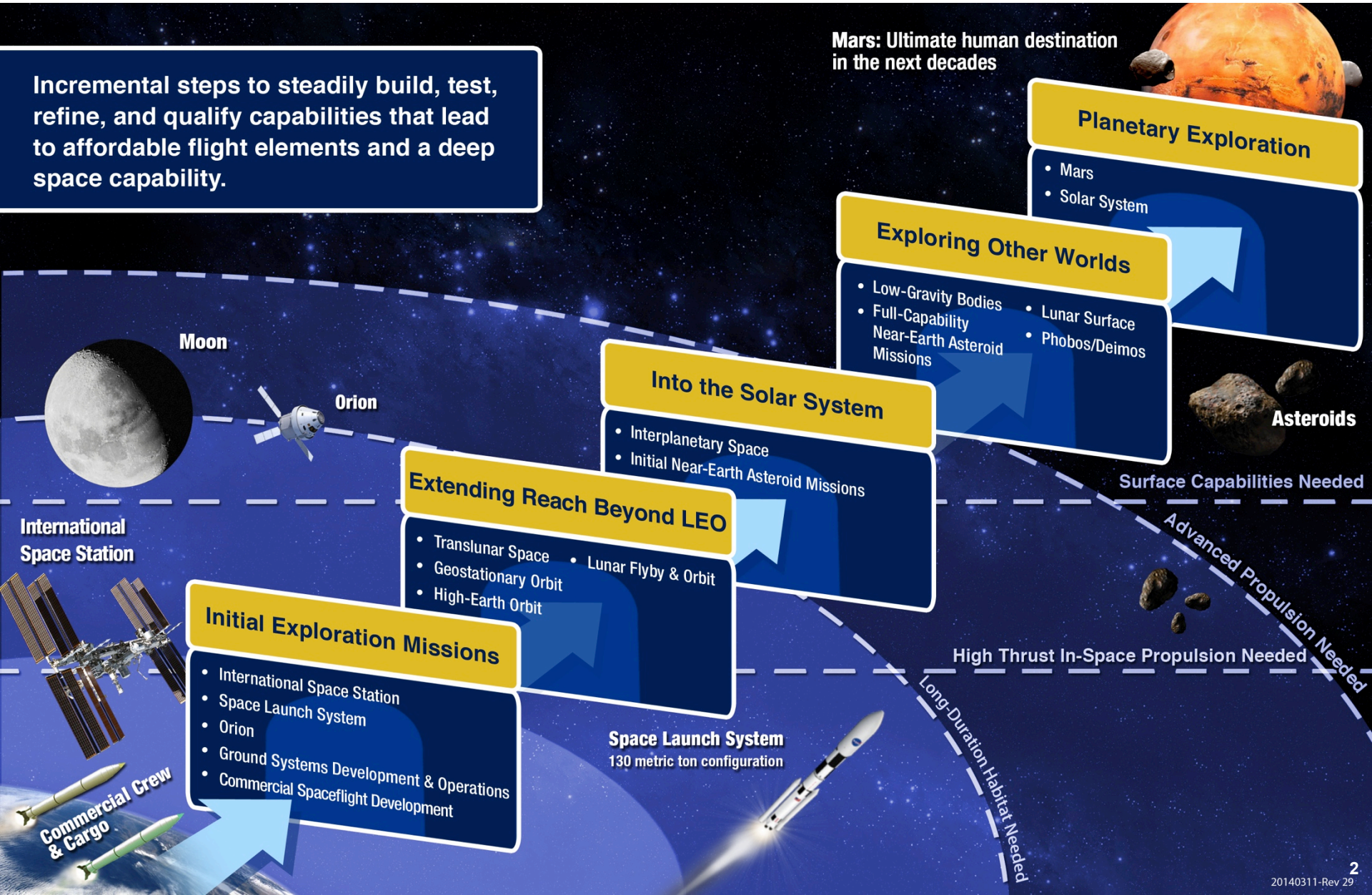
NASA Human Exploration and Operations

The Capability Driven Framework



Strategic Principles for Exploration Implementation

Six key strategic principles to provide a sustainable program:

- Implementable in the ***near-term with the buying power of current budgets*** and in the longer term with budgets commensurate with economic growth*;*
- Application of ***high Technology Readiness Level*** (TRL) technologies for near term missions, while focusing sustained investments on ***technologies and capabilities*** to address challenges of future missions;
- ***Near-term mission opportunities*** with a defined cadence of compelling human and robotic missions providing for an incremental buildup of capabilities for more complex missions over time;
- Opportunities for ***U.S. commercial business*** to further enhance the experience and business base learned from the ISS logistics and crew market;
- ***Multi-use, evolvable*** space infrastructure;
- Substantial ***international and commercial participation***, leveraging current International Space Station partnerships.

Evolvable Mars Campaign: Guiding Philosophy

- **Leverages strong linkage to current investments in ISS, SLS, Orion, ARM, EAM, technology development investments, science investments**
- **Develops Earth independence for long-term human presence leading to the surface of Mars, starting in the Proving Ground, through the cis-lunar environment, enabling science along the way, and providing infrastructure for human exploration missions beyond Mars**
- **Accommodates a realistic budget, both in escalation and peaks coupled with a cadence of significant missions**
- **Starts off minimalist, grows as resources and capabilities permit**
- **Emphasizes prepositioning and reuse/repurposing of systems when it makes sense**
- **"Provides a basis for architecture development and identification and analysis of trade studies with our partners and stakeholders and incorporates the flexibility to adjust to changing priorities across the decades. From this work will emerge the roadmap we will follow through cis-lunar space to pioneer Mars." (from Pioneering Space paper)**
- **Not to develop "the plan" but develop different options to provide a range of capability needs to be used as guidelines for near term activities and investments**

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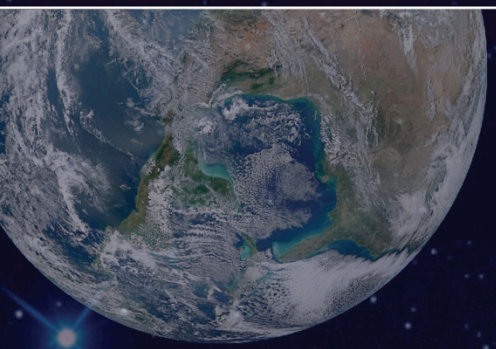
Evolvable Mars Campaign Study Trades



THE TRADE SPACE

Across the Board | Solar Electric Propulsion • In-Situ Resource Utilization (ISRU) • Robotic Precursors • Human/Robotic Interactions • Partnership Coordination • Exploration and Science Activities

PROVING GROUND

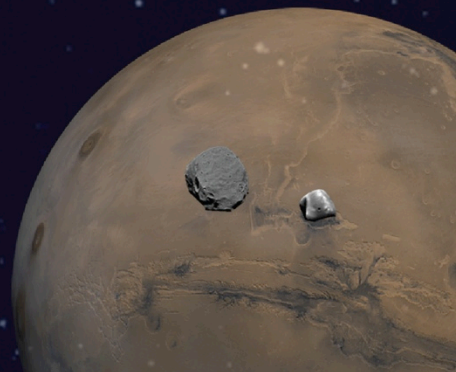
Cis-lunar Trades

- Deep-space testing and autonomous operations
- Extensibility to Mars
- Mars system staging/refurbishment point and trajectory analyses

EARTH INDEPENDENT

Mars Vicinity Trades

- Split versus monolithic habitat
- Cargo pre-deployment
- Mars Phobos/Deimos activities
- Entry descent and landing concepts
- Transportation technologies/trajectory analyses



Key Thrusts for Advancement

THERE & BACK

- The ability to launch a very powerful rocket
- High-reliability spacecraft systems
- Size requirements of crew capsule
- Validation of performance of SLS and Orion in the deep space environment *(hotter, colder, radiation)*
- Deep space navigation
- Rendezvous and docking
- Life support systems
- High speed re-entry

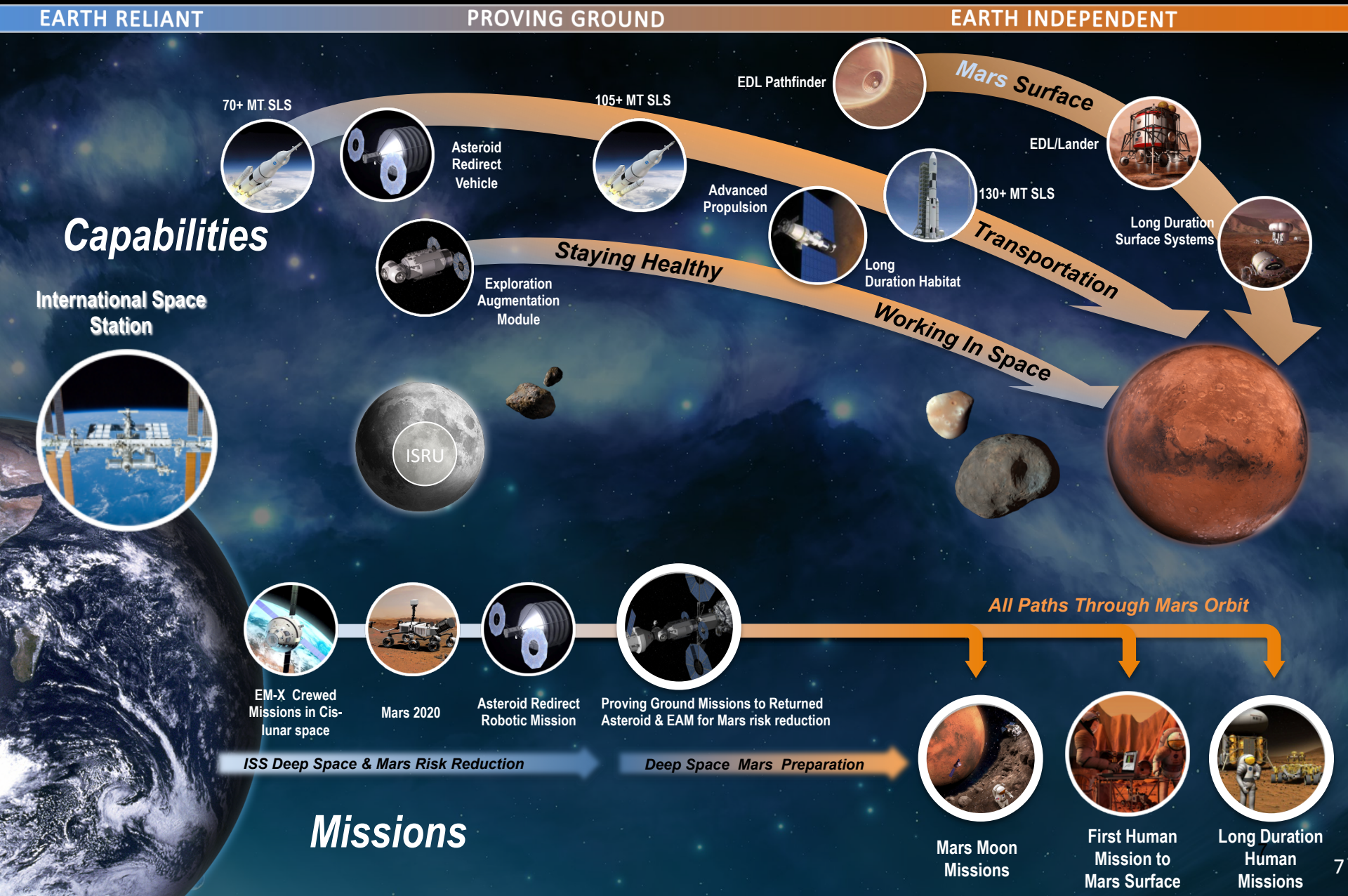
HAPPY & HEALTHY

- Air, water, food
- Waste containment
- Psychological impact
- Low- / no-gravity
- Medical emergencies
- Bone loss
- Radiation
- Ocular degeneration
- Hygiene

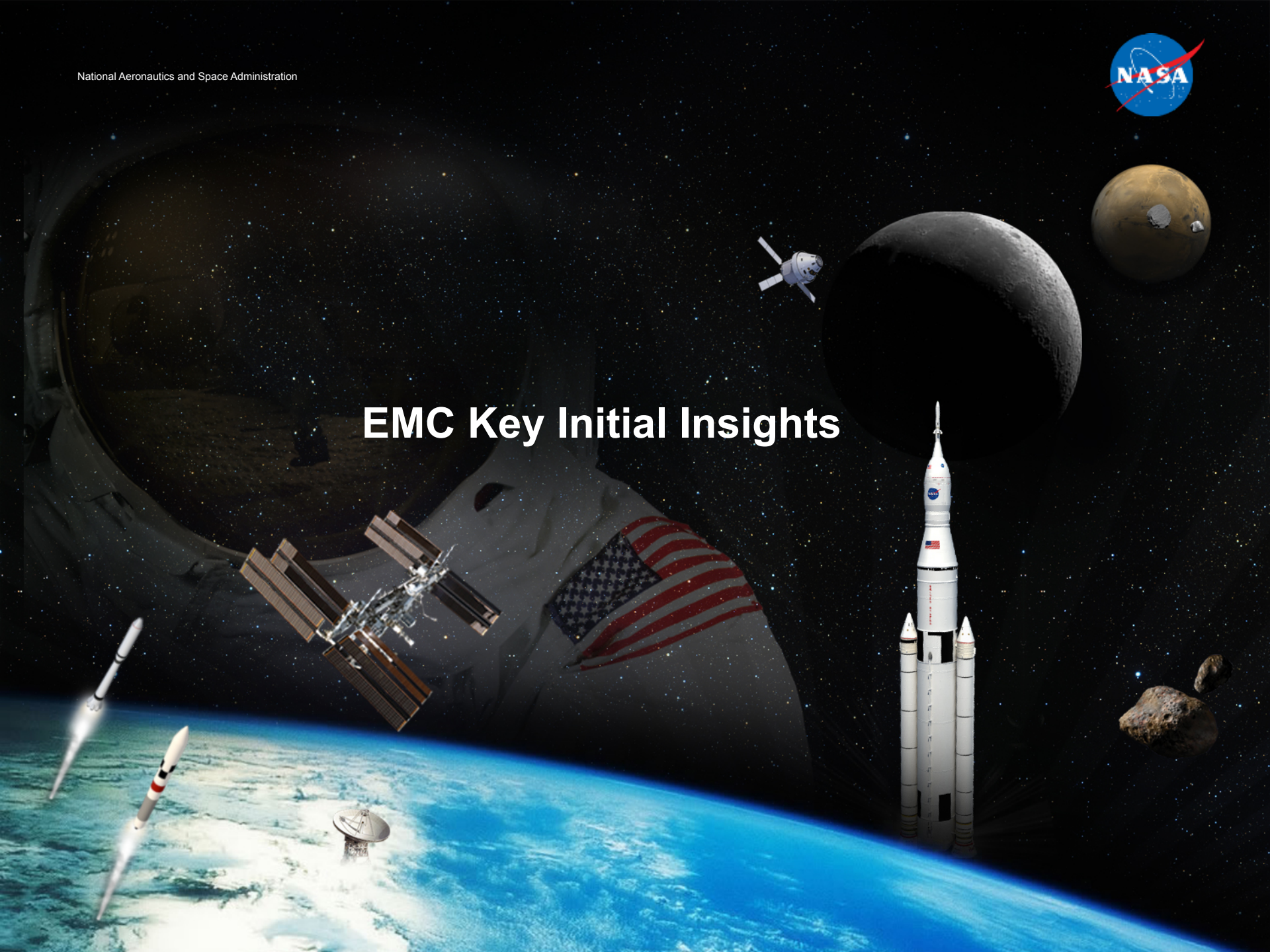
WELL EQUIPPED & PRODUCTIVE

- Sample handling
- Microgravity operations
- Space suits
- Advanced training and tools
- Mission planning
- Situational awareness and decision making
- Crew relationships

Evolvable Mars Campaign – Capability & Mission Extensibility

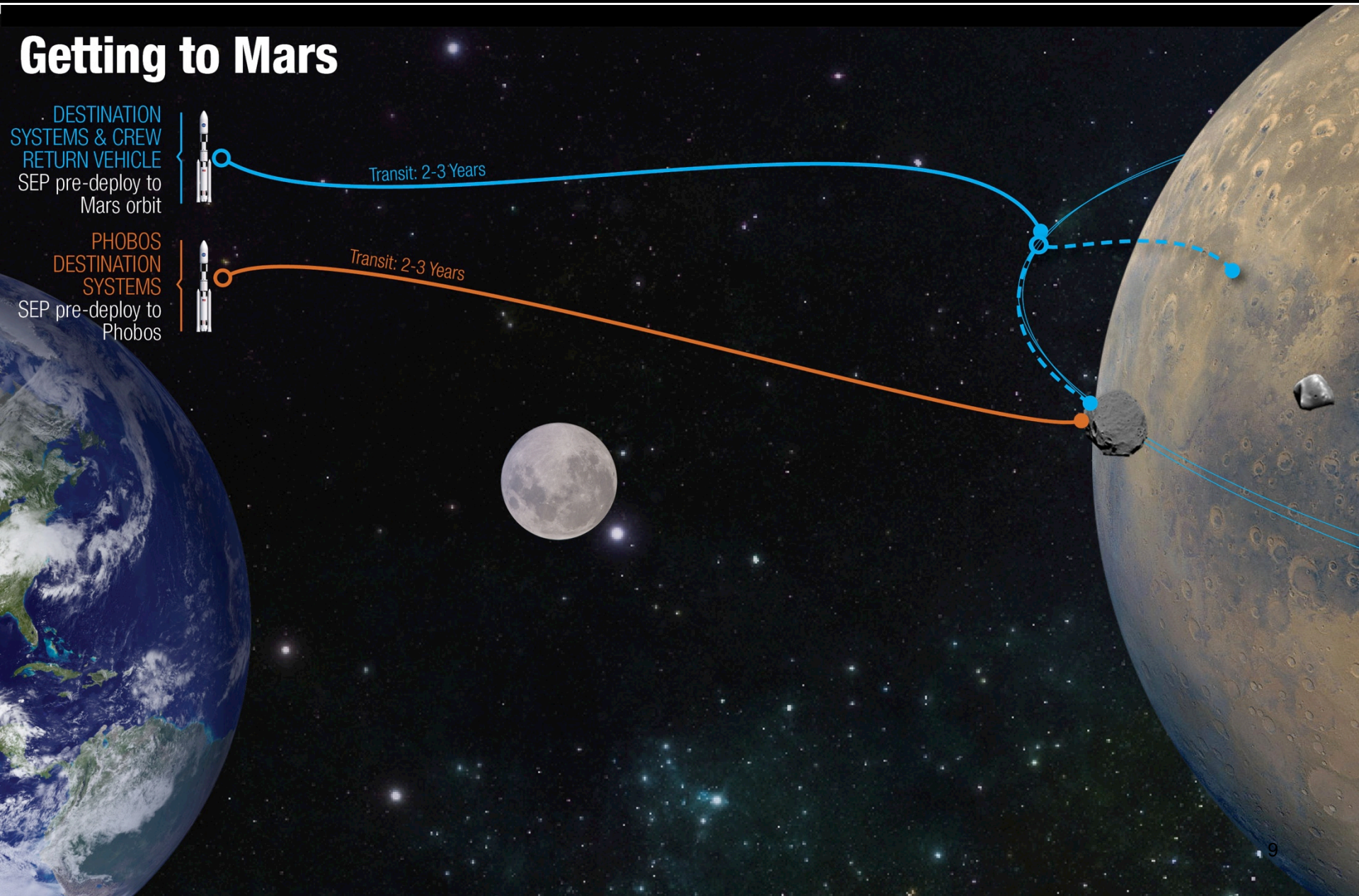


National Aeronautics and Space Administration



EMC Key Initial Insights

1: Mars Split Mission Concept



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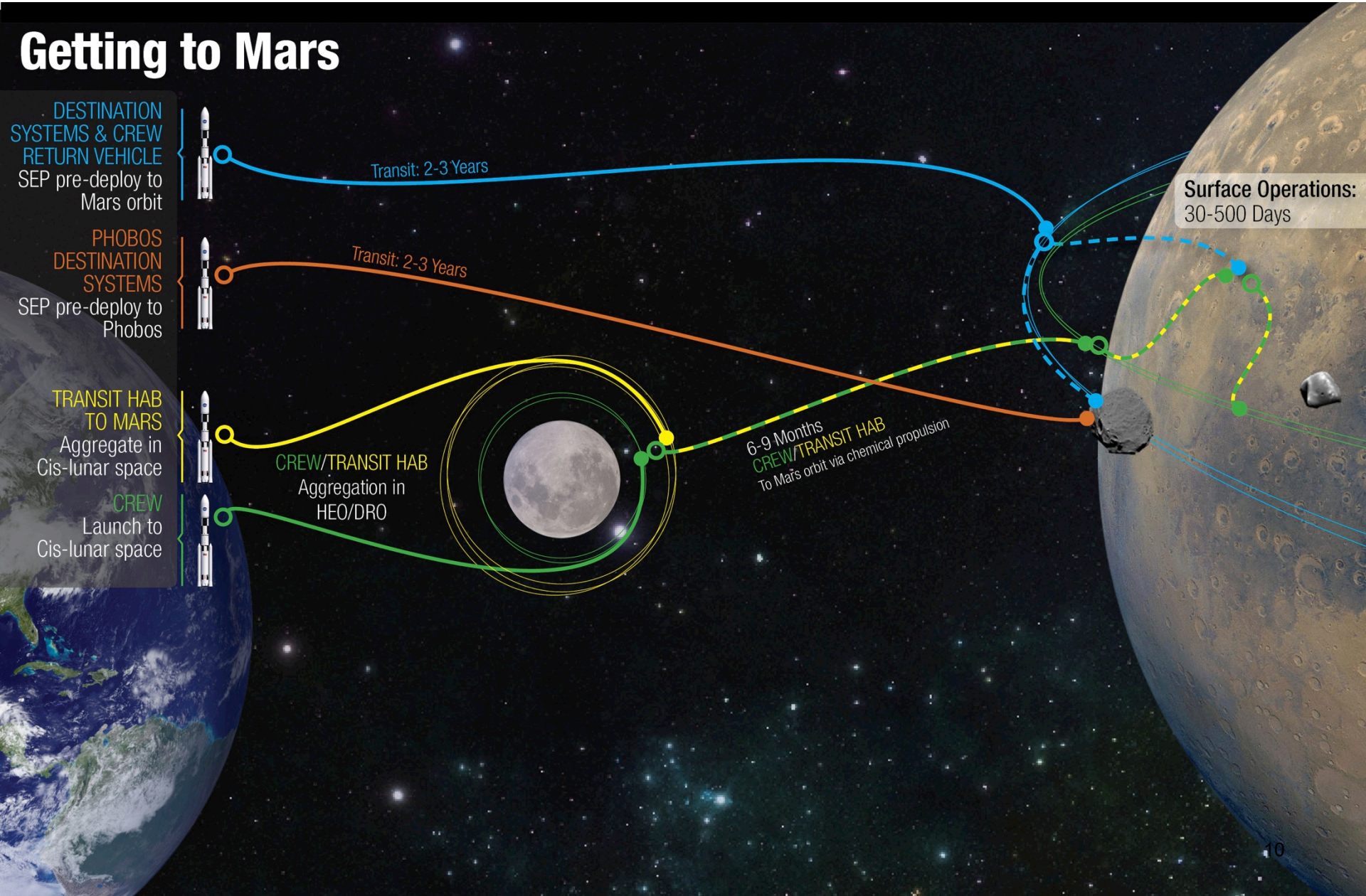

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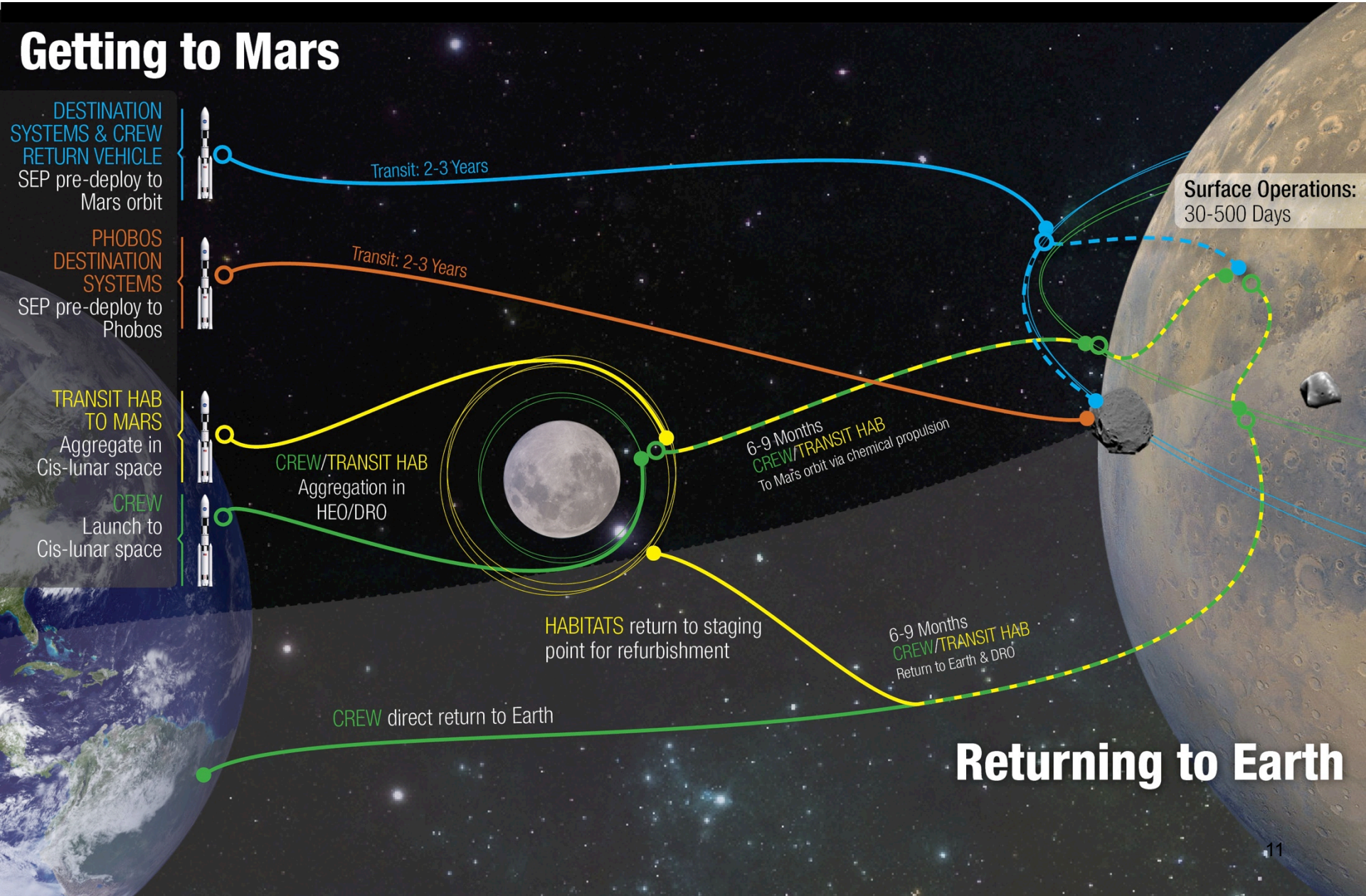
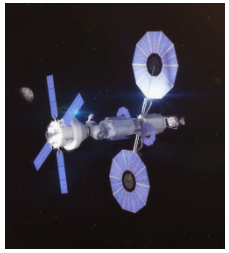
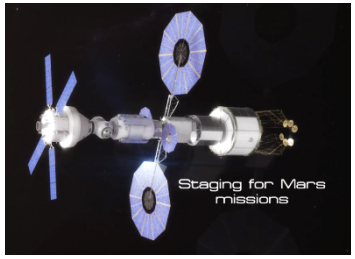


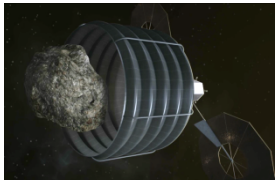
2: ARM Risk Reduction for the EMC

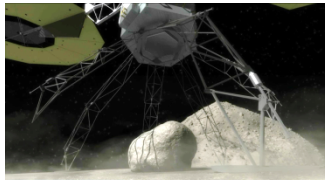
Sensor suites and proximity operations required for aggregating Mars mission vehicle stacks in deep space, deep space rendezvous and docking with Orion



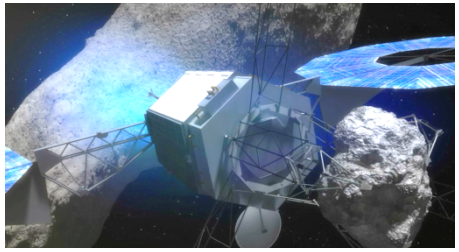


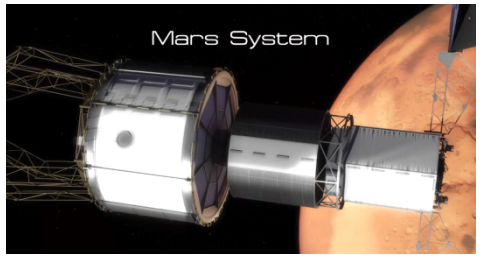
Enhanced understanding of uncooperative, low-G targets as will be experienced with Mars Moons





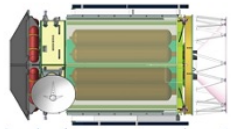
Long duration human scale systems operating in deep space thermal / radiation environment. Pre-deployment of crewed mission elements via solar electric propulsion with long quiescent periods





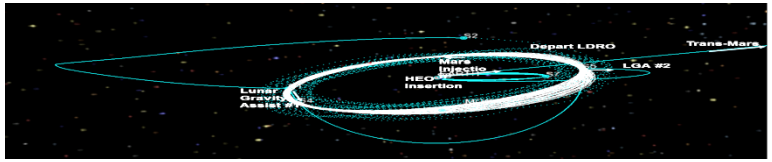
Solar Electric Propulsion (SEP)

Solar arrays, thrusters, PMAD, Xenon storage.



Mission Operations

Deep space trajectory guidance, rendezvous and docking, pre-deployment of systems,



Advanced EVA ops on micro-g body (Phobos), sample handling, and ISRU

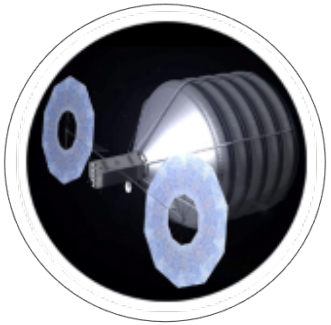
3: Proving Ground Planning

Exploration Transportation Systems BEO

- Provide Heavy Lift transportation of crew and cargo to deep space testing
- Deep Space Navigation for deep space crew missions

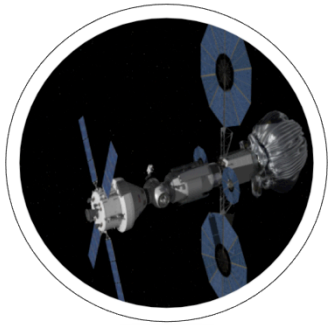
Capability/ SKG Pathfinders

- Resource Prospector
- Mars 2020
- Phobos precursor
- EDL /Lander / ISRU / Surface Power
- Pathfinder of deep space chemical stage



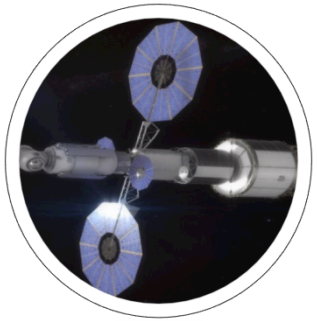
Asteroid Redirect Mission

- Deep space navigation and automated rendezvous and docking
- Solar Electric Propulsion testing
- Research on asteroid composition and associated crew and robotic operations on these micro-g bodies



Exploration Augmentation Module

- Deep Space System and Operational Testing including long duration of robotic tended spacecraft
- Deep space testing on radiation mitigation techniques for long duration human missions
- Tele-operations in space and on lunar surface
- Sample handling and return
- Docking for international/ commercial partners



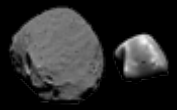
Mars Transit Habitat

- Spacecraft life testing in deep space
- 500-900 day Deep Space Habitat including long duration dormancy time periods
- Advanced maintenance & logistics packaging

Human Exploration Pathways

Mastering the Fundamentals

- Extended Habitation Capability (ISS)
  - High Reliability Life Support
- Deep-space Transportation (SLS and Orion)
- Exploration EVA
- Automated Rendezvous & Docking
- Docking System



On to Mars

Land on Mars

Toward Earth Independent

Crewed Orbit of Mars or Phobos/Deimos

Pushing the Boundaries

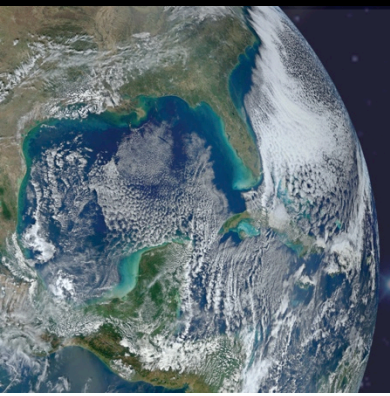
- Deep Space Operations
  - Deep Space Trajectories
  - Deep Space Radiation Environment
  - Integrated Human/Robotic Vehicle
- Advanced In-Space Propulsion (SEP)
  - Moving Large Objects
- Exploration of Solar System Bodies

To Moon And Beyond
(International and/or Industry Partners)

To Mars

Bringing the moon within Earth's economic sphere.

EMC Forward Work



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- **Across the Board**
  - SEP sizing, ISRU benefits
  - Study potential of a common small pressure shell that could be used for the Mars ascent cabin, the Mars moons taxi, the Phobos exploration vehicle, and EAM component
  - Pathfinder mission developments (Phobos precursor, capability pathfinder missions for EDL and in-space propulsion)
  - Global Exploration Roadmap
  - Identify key near-term decisions
  - End of Year Report – support development of Pioneering Space and development of capability roadmaps

- **Cis-lunar Trades**
  - ARM, ISRU, sample management extensibility
  - Exploration Augmentation Module concepts

- **Mars Vicinity Trades**
  - Refined element concept development activities to drive out technology/capability key performance metrics, packaging needs, configuration layouts and refined mass estimates
    - Long duration habitat systems, exploration mobility systems, surface power, in-space stages, landers, ascent modules, taxis, etc. to include SLS packaging
  - Fission reactor requirements
  - Mars surface operations and site selection
  - Impact of small Mars lander on surface ops and EDL capability

Engagement Product Development: *Pioneering Space*

Pioneering Space

Update *Voyages* (2011) to incorporate Evolvable Mars Campaign study results and provides additional details in the HSF plans for the pioneering of Mars.

Pioneering Space development schedule:

Dec 2013	- **Evolvable Mars Campaign** kickoff
May	- **Pioneering Space White Paper** released
June	- **EMC** study interim status #1
July	- NAC meetings
Aug	- **EMC** study interim status #2
Sept	- **EMC** FY14 outbrief
Sept	- **EMC** FY14 findings integrated into draft
Sept-Oct	- Stakeholder discussions
Fall	- NAC meetings
Dec	- Final ***Pioneering Space*** document ready for publication