



NASA's Human Spaceflight Plans and the CCMC

**The 8th Community Coordinated Modeling Center Workshop
Community Workshop**

**John Allen
Crew Health and Safety
HEOMD
NASA Headquarters
April 11, 2016**

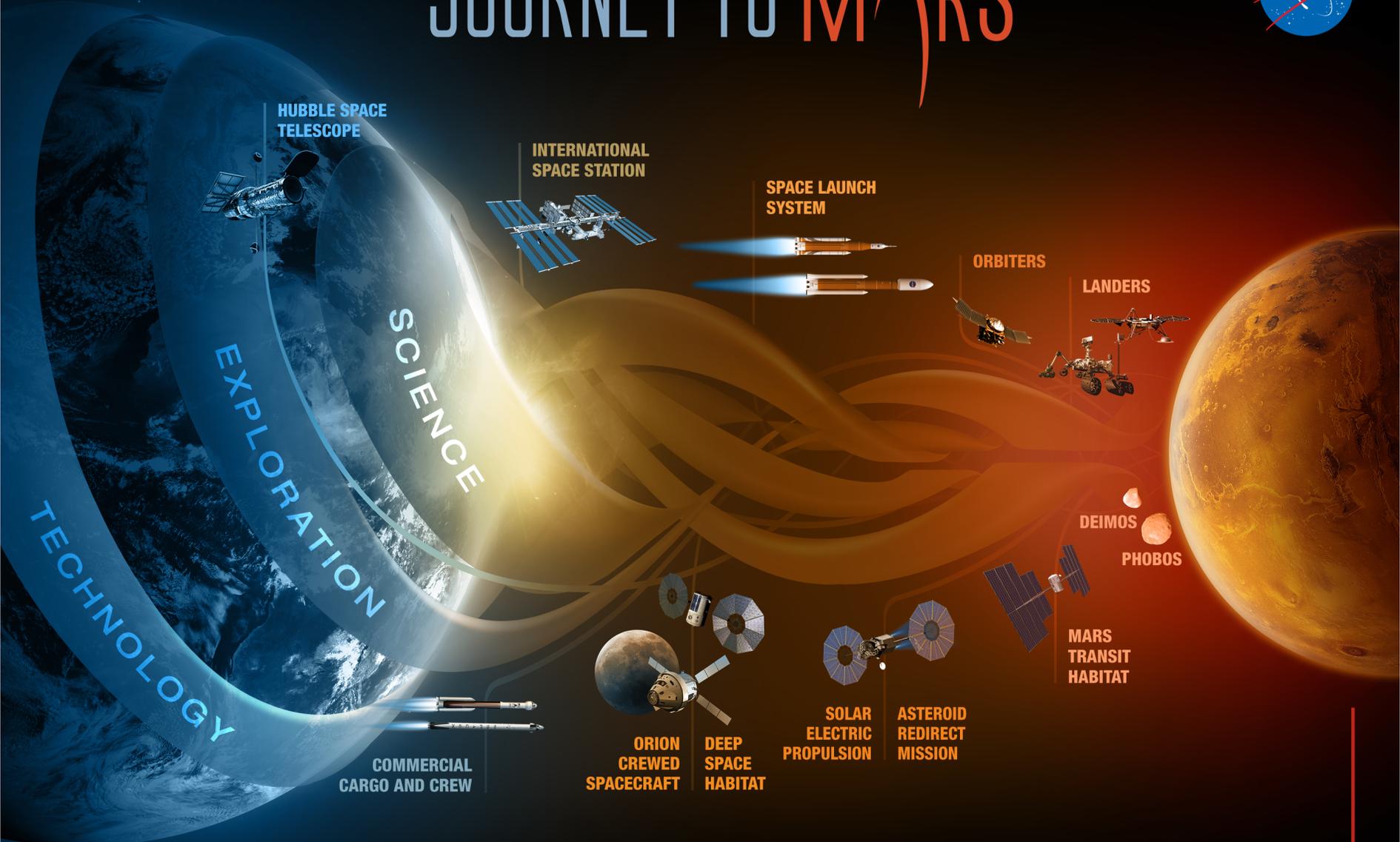


Our Purpose – NASA Strategic Goal 1.1

Expand human presence into the solar system and to the surface of Mars to advance exploration, science, innovation, benefits to humanity, and international collaboration.



JOURNEY TO MARS



HUBBLE SPACE TELESCOPE

INTERNATIONAL SPACE STATION

SPACE LAUNCH SYSTEM

ORBITERS

LANDERS

DEIMOS

PHOBOS

MARS TRANSIT HABITAT

SOLAR ELECTRIC PROPULSION

ASTEROID REDIRECT MISSION

ORION CREWED SPACECRAFT

DEEP SPACE HABITAT

COMMERCIAL CARGO AND CREW

MISSIONS: 6-12 MONTHS
RETURN: HOURS

MISSIONS: 1-12 MONTHS
RETURN: DAYS

MISSIONS: 2-3 YEARS
RETURN: MONTHS

EARTH RELIANT

PROVING GROUND

EARTH INDEPENDENT



Evolvable Mars Campaign **- *planning for human spaceflight***

Strategic Principles for Sustainable Exploration

- Implementable in the *near-term with the buying power of current budgets*
- *Exploration enables science and science enables exploration*
- Application of *high Technology Readiness Level (TRL) technologies* for near term missions
 - Focus on sustained investments on *technologies and capabilities* to address challenges of future missions
- *Near-term mission opportunities*
 - Defined cadence of integrated human and robotic

Strategic Principles for Sustainable Exploration

- **Opportunities for *U.S. commercial business***
 - Further enhance the experience and business base
- ***Resilient architecture featuring multi-use, evolvable space infrastructure,***
 - Minimize unique major developments
 - Each mission leaving something behind to support subsequent missions
- ***Substantial New International and Commercial Partnerships***
 - Leveraging International Space Station partnership
 - Building new cooperative ventures

EVOLVABLE MARS CAMPAIGN

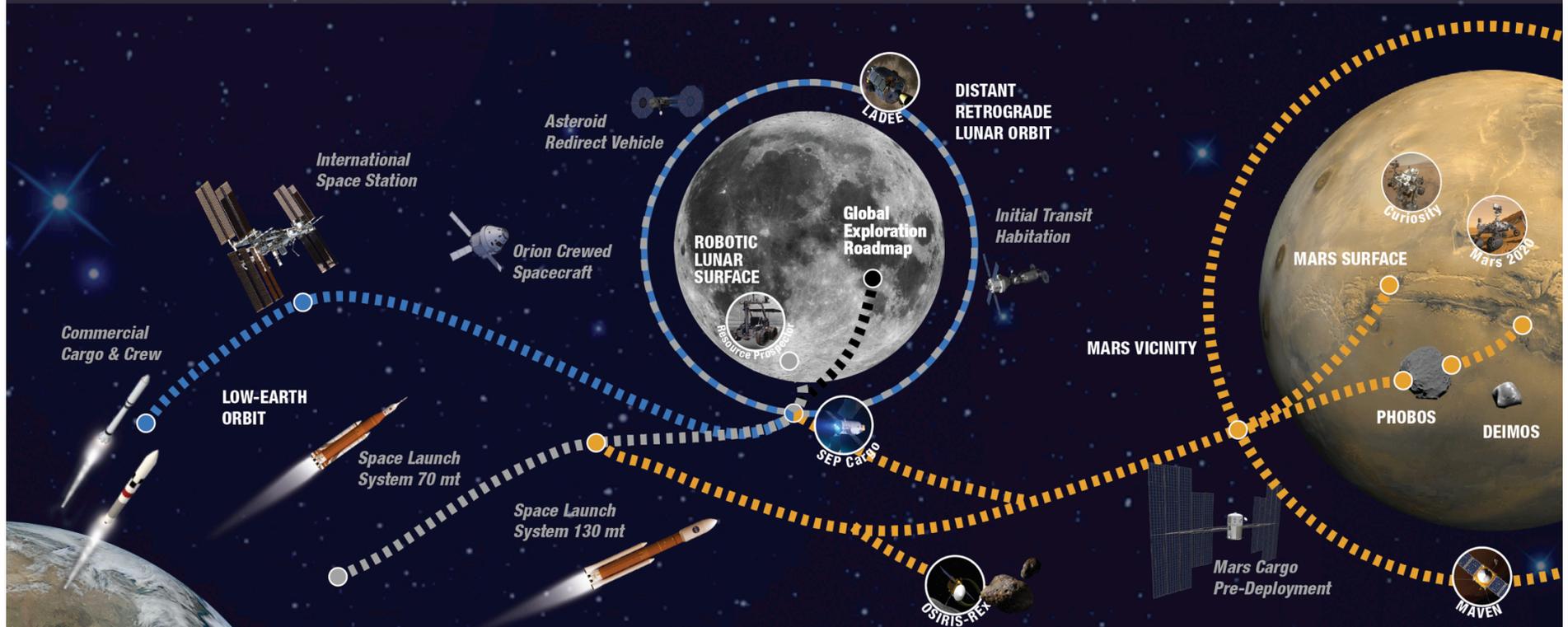
A Pioneering Approach to Exploration



EARTH RELIANT

PROVING GROUND

EARTH INDEPENDENT



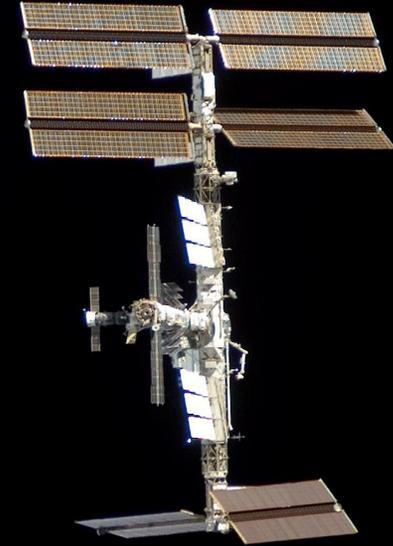
THE TRADE SPACE

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

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

Mars Vicinity Trades • Split versus monolithic habitat • Cargo pre-deployment • Mars vicinity activities • Entry descent and landing concepts • Transportation technologies/trajectory analyses

Earth Reliant Objectives





Earth Reliant Objectives

Near-Term Objectives in Low Earth Orbit

VALIDATE EXPLORATION CAPABILITIES IN AN IN-SPACE ENVIRONMENT

- Long-duration, deep space habitation systems
- Next-generation spacesuit
- Autonomous operations
- Communications with increased delay
- Human and robotic mission operations
- Operations with reduced logistics capability
- Integrated exploration hardware testing



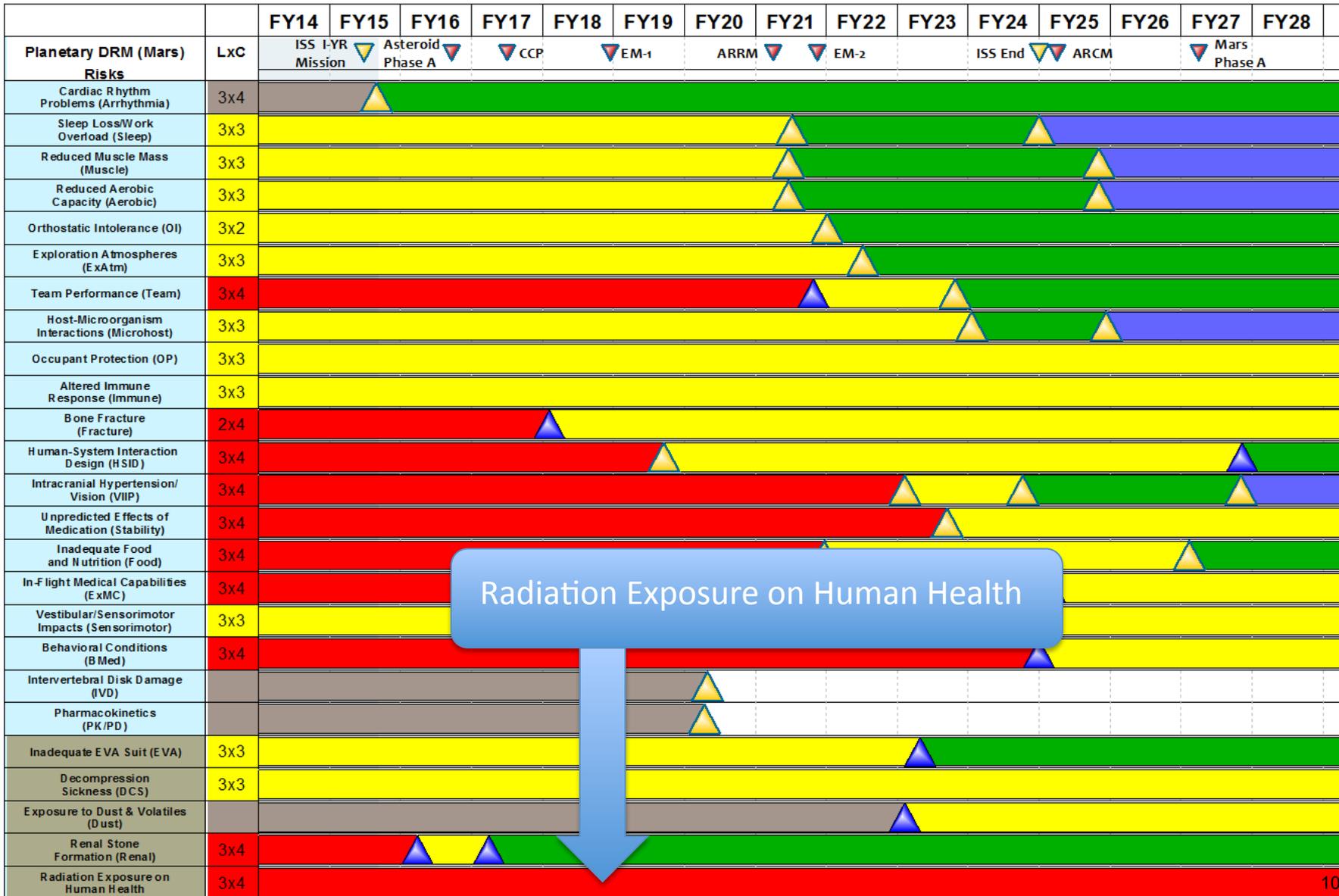
LONG-DURATION HUMAN HEALTH EVALUATION

- Evaluate mitigation techniques for crew health and performance in micro-g space environment
- Acclimation from zero-g to low-g

COMMERCIAL CREW TRANSPORTATION

- Acquire routine U.S. crew transportation to LEO

Human Research Program: Path to Risk Reduction



ISS Technology Demonstration Plan

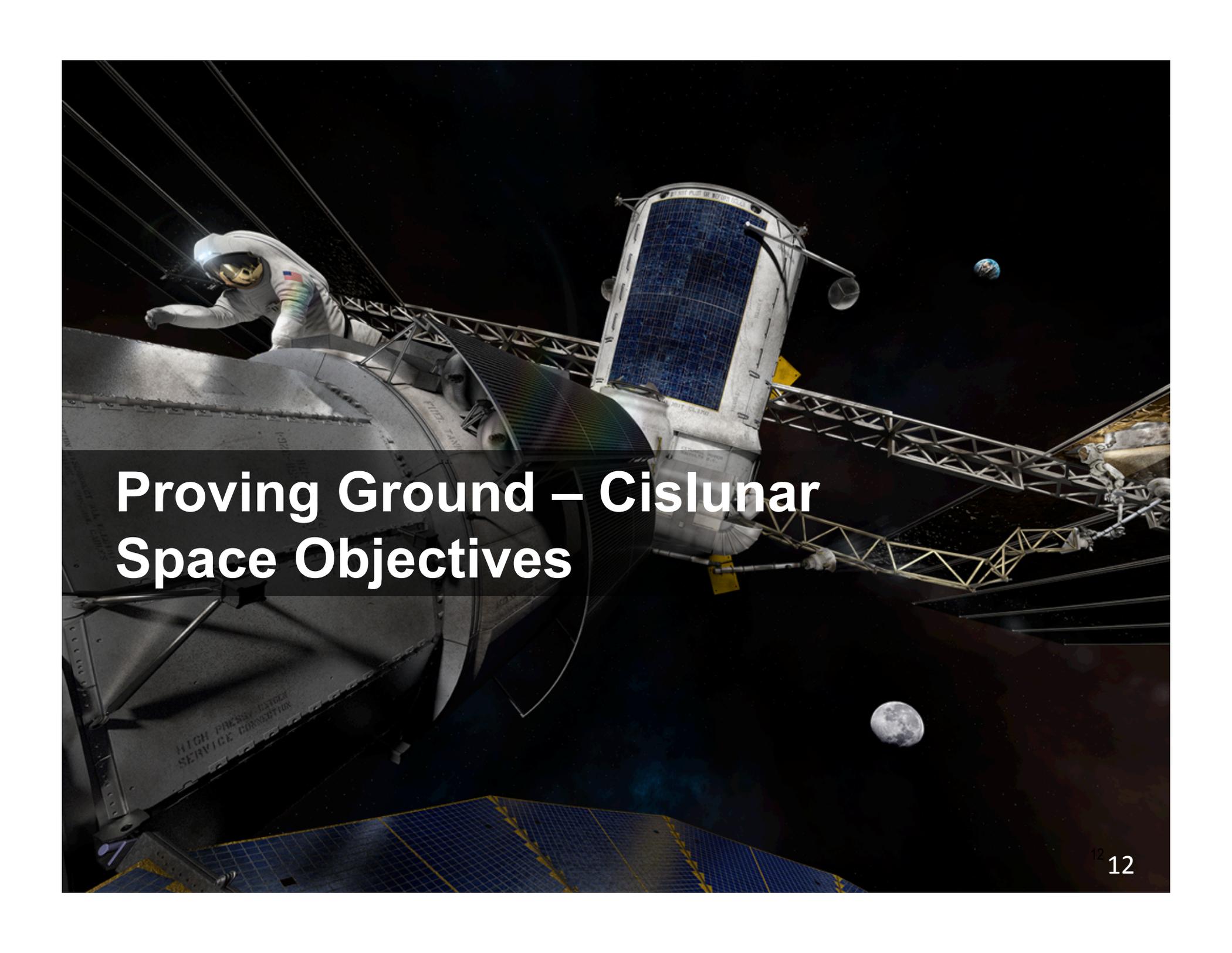


Capability Gap	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28
ECLSS															
Reliable CO2 Removal + ppCO2 < 2 mmHg	▲ CDRA-5	▲ LDST			▲	CDRA upgrades	▲	next gen system							
Smaller, simpler O2 Gen							▲	OGA upgrades							
High pressure O2 (3000 psi) for EVA & medical use							▲								
Reliable urine processing = 85% recovery			▲	▲	▲	PCPA upgrade	▲	next gen UPA							
Reliable water processing w/ reduced expendables						MF bed mod	▲	cat reactor mod							
Common biocide with on orbit replenishment															
Compact waste & trash mngmt, stable, 90% water recov						▲	UWMS	▲	HMC						
Additional O2 recovery from CO2 > 75%									▲	>75% recovery					
>90% recovery of water from urine brine						▲	demo candidates			▲	brine processor				
Condensing HX robust anti-microbial coating															
10:1 volume reduction logistical & clothing		▲	adv clothing	▲	RFID	Logistics Awareness				▲	laundry/sanitation				
Environmental Monitoring															
Trace Gas (on orbit, no grab sample return)	▲	AQM							▲	SAM					
Targeted Gases (fire products, NH3, hydrazine)			▲	MGM					▲	CPM on Saffire					
Water (individual compounds)															
Microbial (ID & qty species)															
Major Constituents (small, no maintenance)															
Particulates															
Acoustic (automated, alerting, no crew time)															
EVA															
Exploration PLSS/Microgravity Suit															▲
Fire Safety and Response															
Emergency Mask (single cartridge)	▲	dual													
Contingency Air Monitor (overlap with targeted gas)															▲
Smoke Eater															▲
Water Mist PFE															▲
Large fire behavior in ug															▲
Crew Health & Performance Technologies															
Exercise Equipment															
Medical Equipment															
Food System															
Thermal (including Cryo)															
Zero Boil Off Cryo															
Phase Change Material															
Variable Heat Rejection radiators, single loop															
Power & Energy Storage															
Solar arrays															
Energy Storage															
Comm & Navigation															
High speed comm/internetworking															
Position, navigation, and timing															
Structures & Materials															
Materials/In-space manufacturing															
Structures & Health Monitoring															
Radiation Monitoring & Shielding															
ISRU (trash processing, resource prospecting, in-situ manufacturing) Plans under construction.															
Autonomous Operations															
Autonomous Operations															
Automated Rendezvous & Docking															
Automated Rendezvous & Docking															
Robotics															
Robotic refueling															
Free flyer robots (IVA & EVA)															
Human assist robots															
Telerobotics															
Entry, Descent, Landing															
Entry, Descent, Landing															

Radiation Monitoring and Shielding

■ no committed funding
■ some \$, but insufficient funding for ISS demo
■ sufficient funding to ISS demo

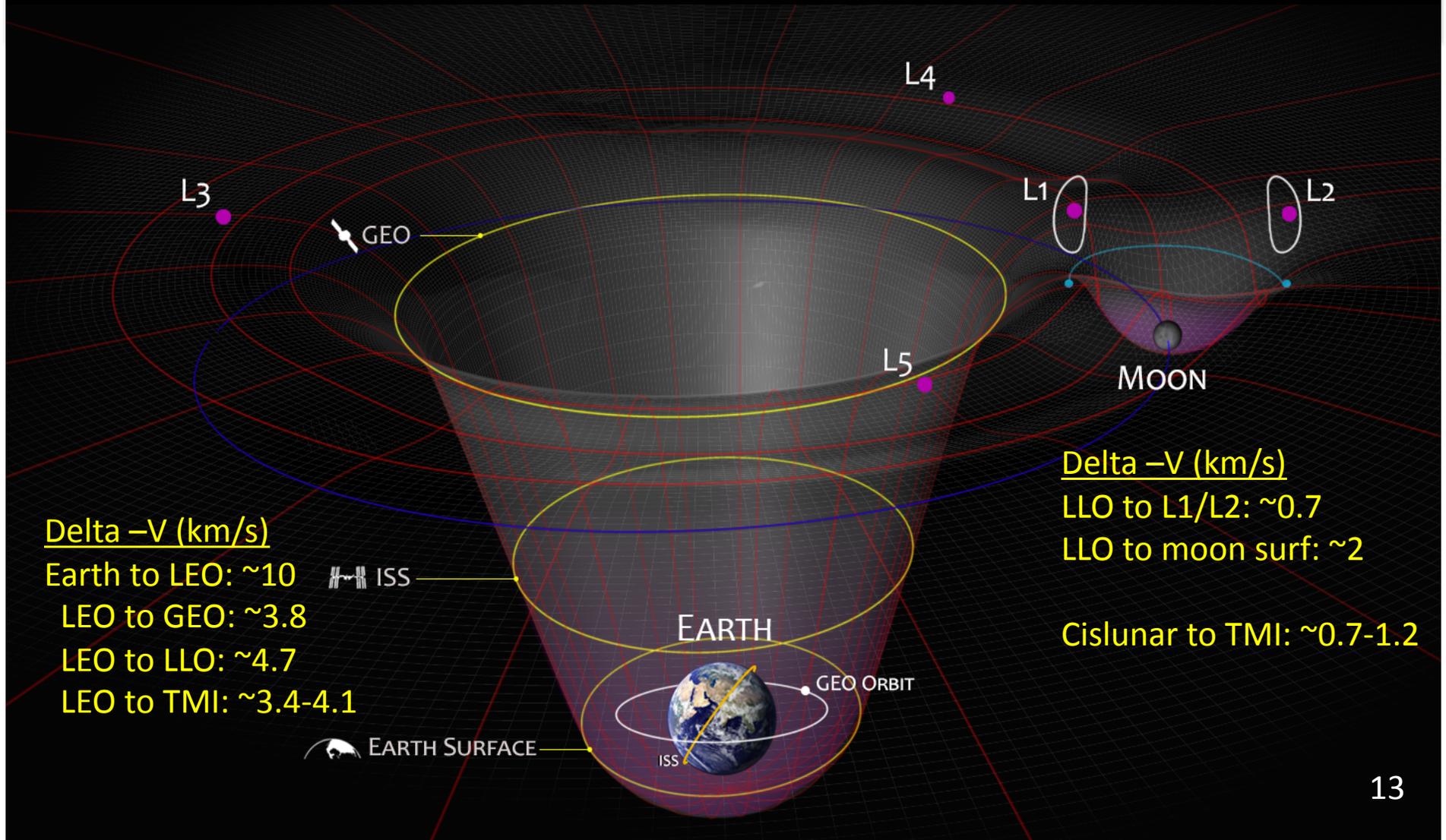
▲ Funded ISS demo
▲ Proposed ISS demo (not yet funded)

A detailed illustration of an astronaut in a white spacesuit working on a large, complex spacecraft structure in space. The spacecraft features various components, including a large blue solar panel array and a cylindrical module with a grid pattern. The background shows the Earth in the distance and the Moon in the foreground, set against a dark, starry sky. The overall scene conveys a sense of advanced space exploration and infrastructure development.

Proving Ground – Cislunar Space Objectives



Why Cislunar Space? The 'Gravity Well' Advantage



Proving Ground Objectives



Using Cislunar Resources to Enable Human Missions to Mars



TRANSPORTATION



WORKING IN SPACE



STAYING HEALTHY

- **Heavy Launch**

Capability: beyond low-Earth orbit launch capabilities for crew, co-manifested payloads, large cargo

- **Crew:** transport at least four crew to cislunar space

- **In-Space Propulsion:** send crew and cargo on Mars-class mission durations and distances

- **ISRU:** Understand the nature and distribution of volatiles and extraction techniques and decide on their potential use in human exploration architecture.

- **Deep-space operations capabilities:** EVA, Staging, Logistics, Human-robotic integration, Autonomous operations

- **Science:** enable science community objectives

- **Deep-Space Habitation:** beyond low-Earth orbit habitation systems sufficient to support at least four crew on Mars-class mission durations and dormancy

- **Crew Health:** Validate crew health, performance and mitigation protocols for Mars-class missions

Habitation Systems Goals



System	Includes	Today	Mars Goal
Life Support	Air revitalization, water recovery, waste collection and processing	42% recovery of O ₂ from CO ₂ ; 90% recovery of H ₂ O; <6 mo MTBF for some components	>75% recovery of O ₂ from CO ₂ ; >98% recovery of H ₂ O; >2 yr MTBF
Environmental Monitoring	atmosphere, water, microbial, particulate, and acoustic monitors	Limited, crew-intensive on-board capability; rely on sample return to Earth	On-board analysis capability with no sample return; identify and quantify species and organisms in air & water
Crew Health	exercise equipment, medical treatment and diagnostic equipment, long-duration food storage	Large, cumbersome exercise equipment, limited on-orbit medical capability, food system based on frequent resupply	Small, effective exercise equipment, on-board medical capabilities, long-duration food system
EVA	Exploration suit	ISS EMU's based on Shuttle heritage technology; not extensible to surface ops	Next generation spacesuit with greater mobility, reliability, enhanced life support, operational flexibility
Fire	Non-toxic portable fire extinguisher, emergency mask, combustion products monitor, fire cleanup device	Large CO ₂ suppressant tanks, 2-cartridge mask, obsolete fire products. No fire cleanup other than depress/repress	Unified fire safety approach that works across small and large architecture elements
Radiation Protection	Low atomic number materials including polyethylene, water, or any hydrogen-containing materials	Node 2 CQ's augmented with polyethylene to reduce the impacts of trapped proton irradiation for ISS crew members	Solar particle event storm shelter based on optimized position of on-board materials and CQ's with minimized upmass to eliminate major impact of solar particle event on total mission dose ¹⁵



Radiation Protection

- **Includes**
 - Low atomic number materials including polyethylene, water, or any hydrogen-containing materials
- **Current**
 - Node 2 Crew Quarters augmented with polyethylene to reduce the impacts of trapped proton irradiation for ISS crew members
- **Mars Goal**
 - Solar particle event storm shelter
 - Optimized position of on-board materials and Crew Quarters
 - Minimized upmass to eliminate major impact of on total mission dose



EMC Split Mission Concept *- series of missions*

Split Mission Concept

Pre-Deploy Cargo First

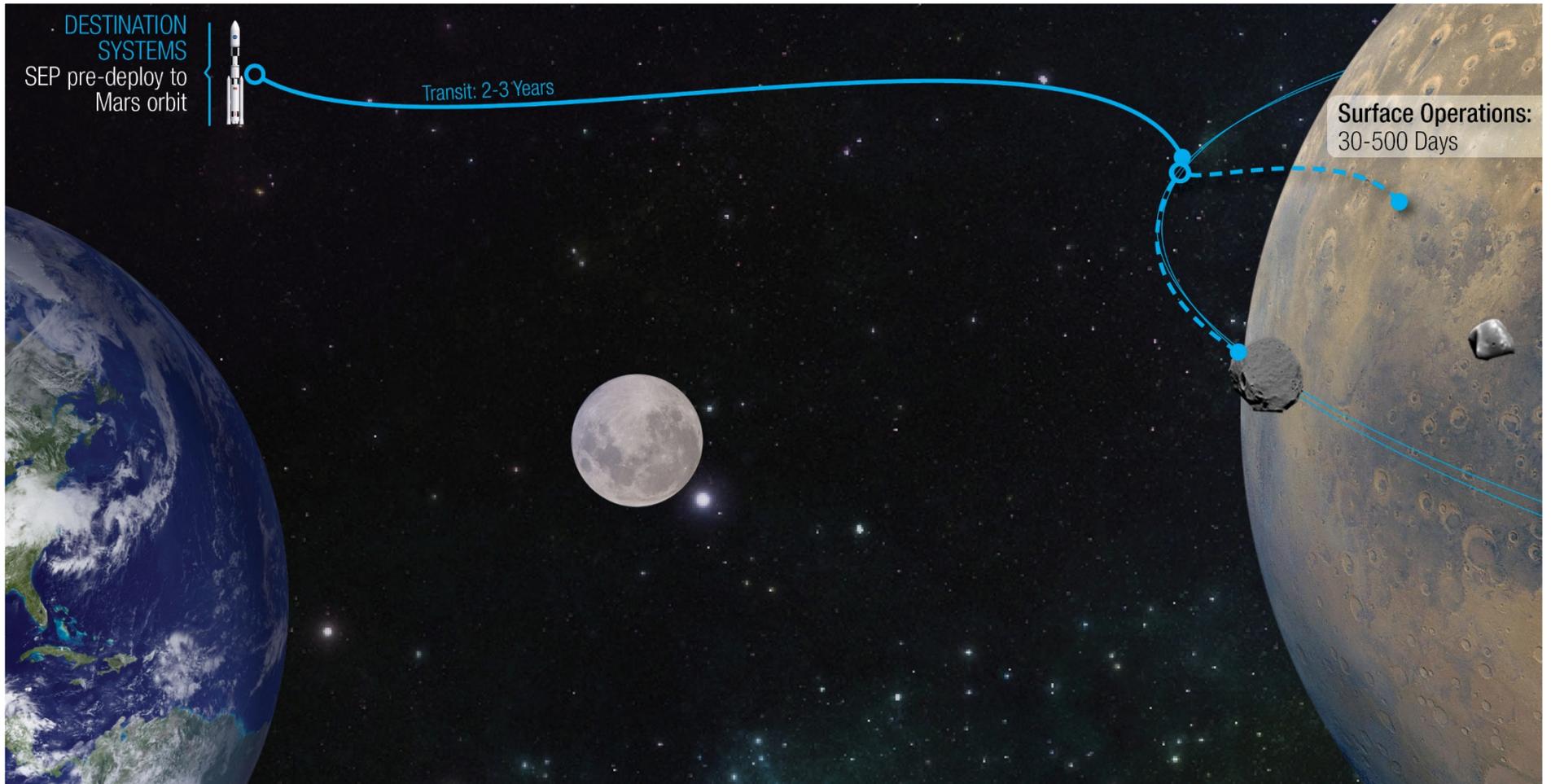


DESTINATION SYSTEMS
SEP pre-deploy to Mars orbit



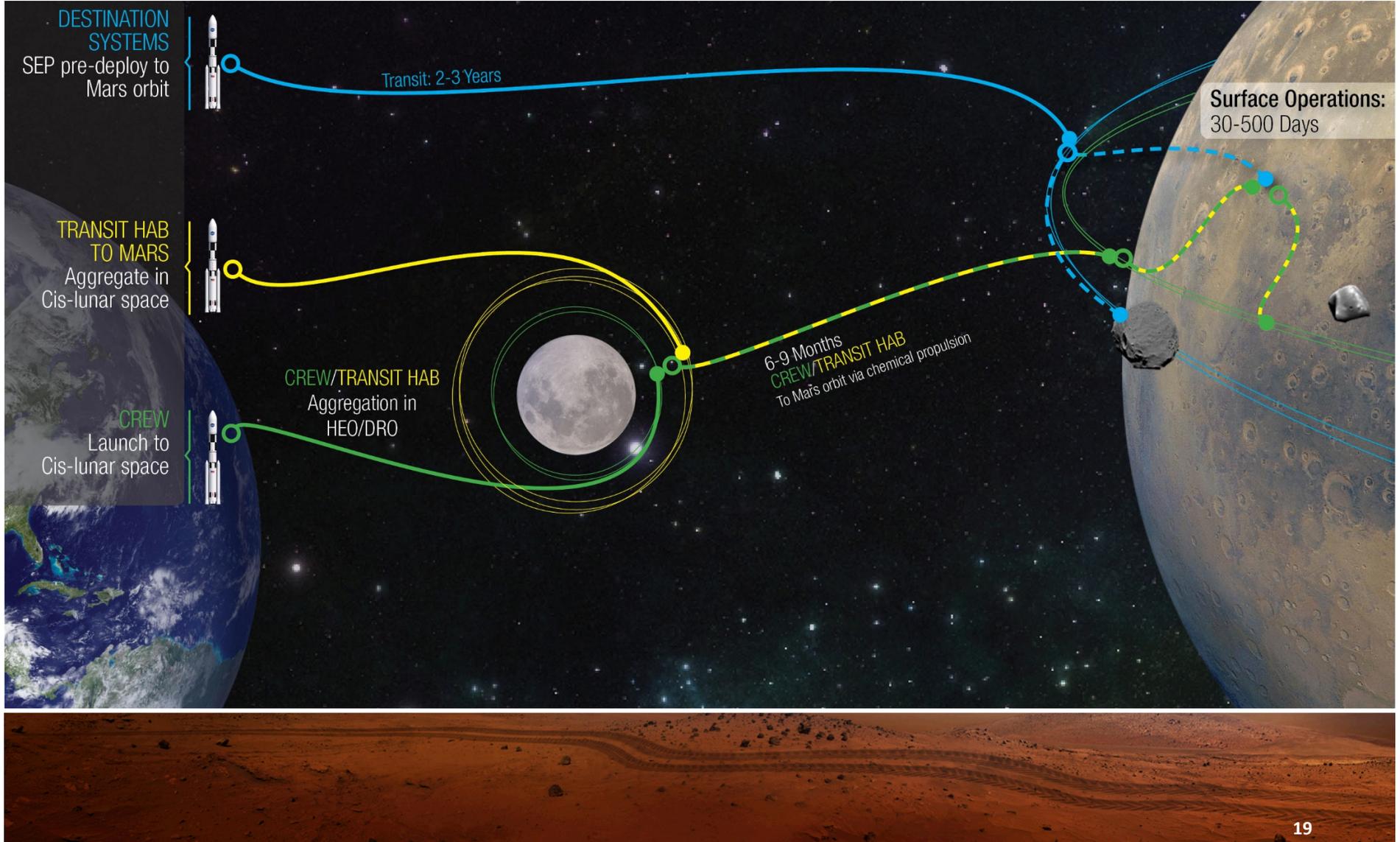
Transit: 2-3 Years

Surface Operations:
30-500 Days



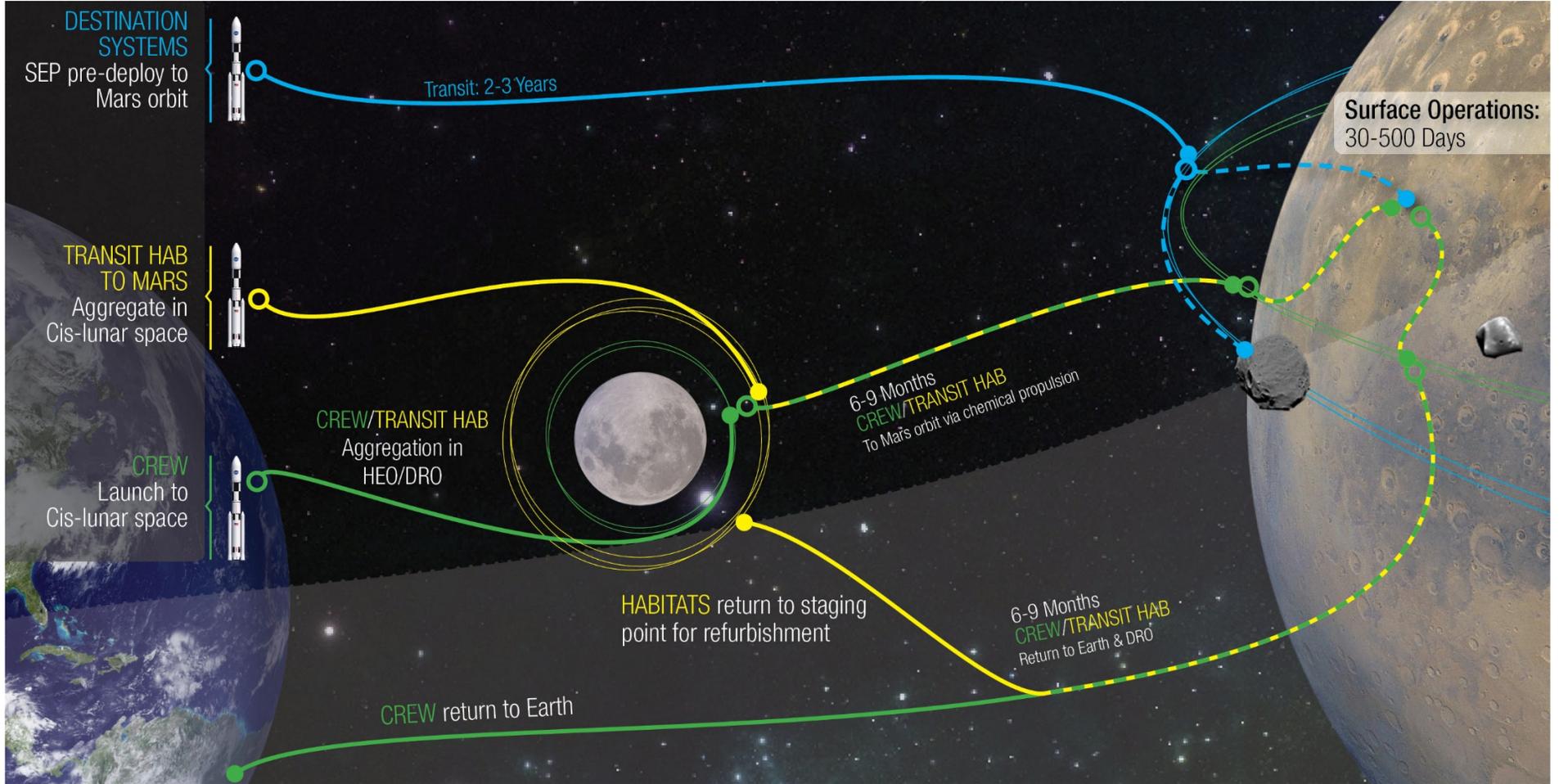
Split Mission Concept

Crew to Mars Orbit



Split Mission Concept

Crew Return to Earth



Journey to Mars - in Progress



2007
PHOENIX SCOUT

2003
MARS EXPLORATION ROVER

2011
CURIOSITY ROVER

2018
EXOMARS ROVER

2020
2020 MARS ROVER

International Space Station

The First Step in Exploration



Human Health Research



Advanced Life Support



Technology Demonstration



Logistics Management



Maintenance & Repair



International Collaboration



SLS, Orion, and Ground Operations

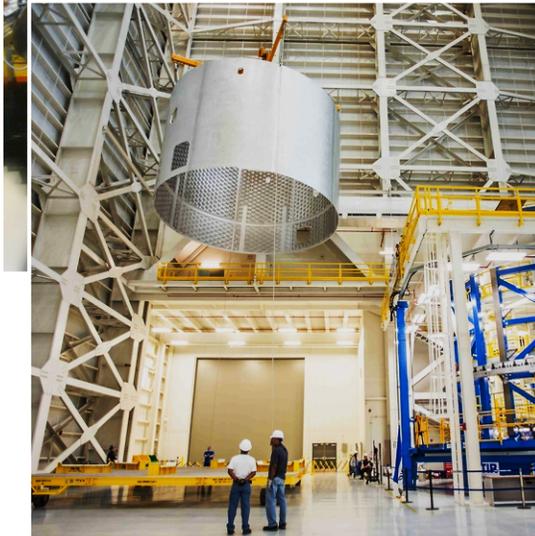
Making Real Progress



Orion



Space Launch System



Ground Operations



Space Launch System

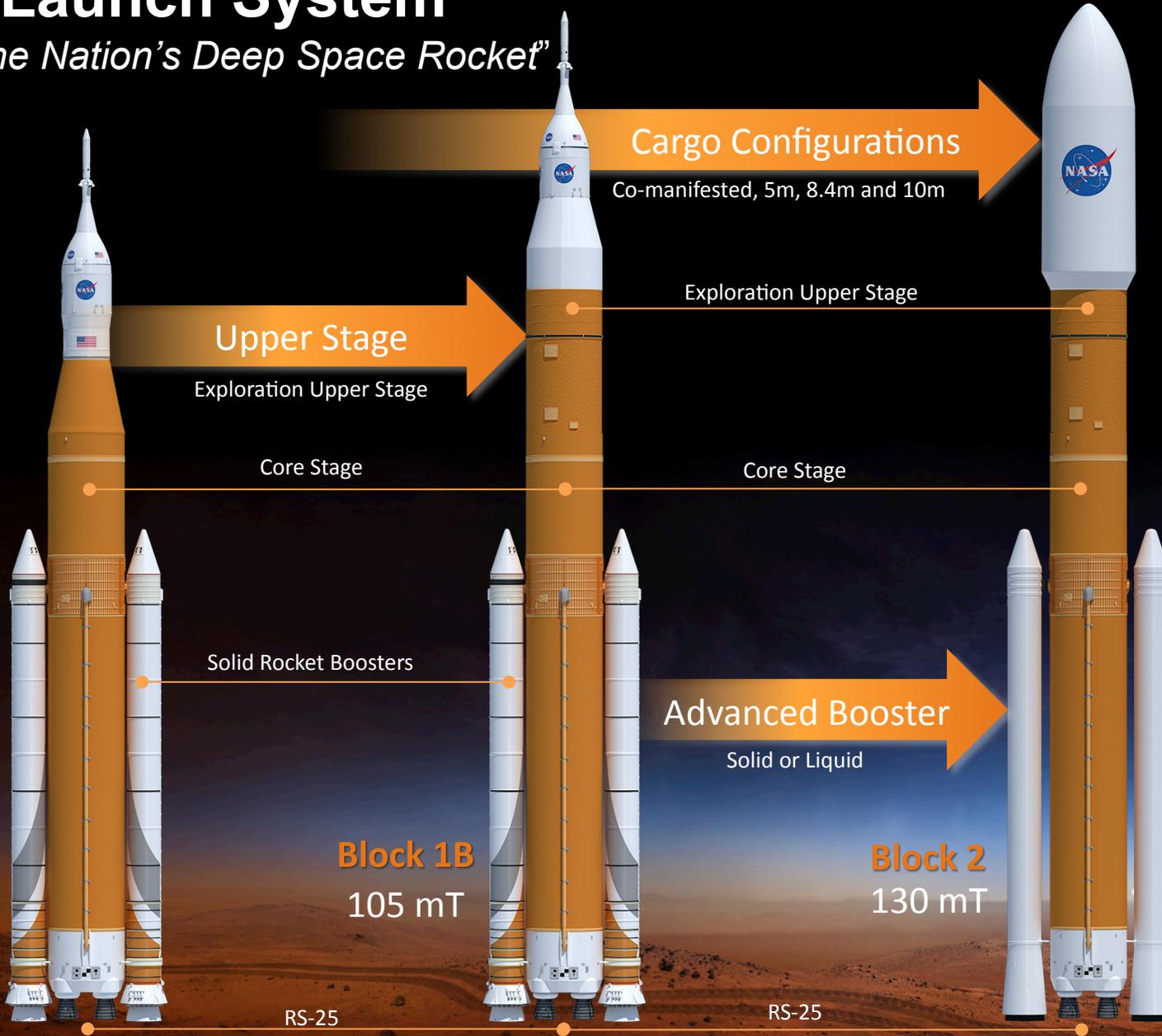
"Evolving the Nation's Deep Space Rocket"



Block 1
70 mT

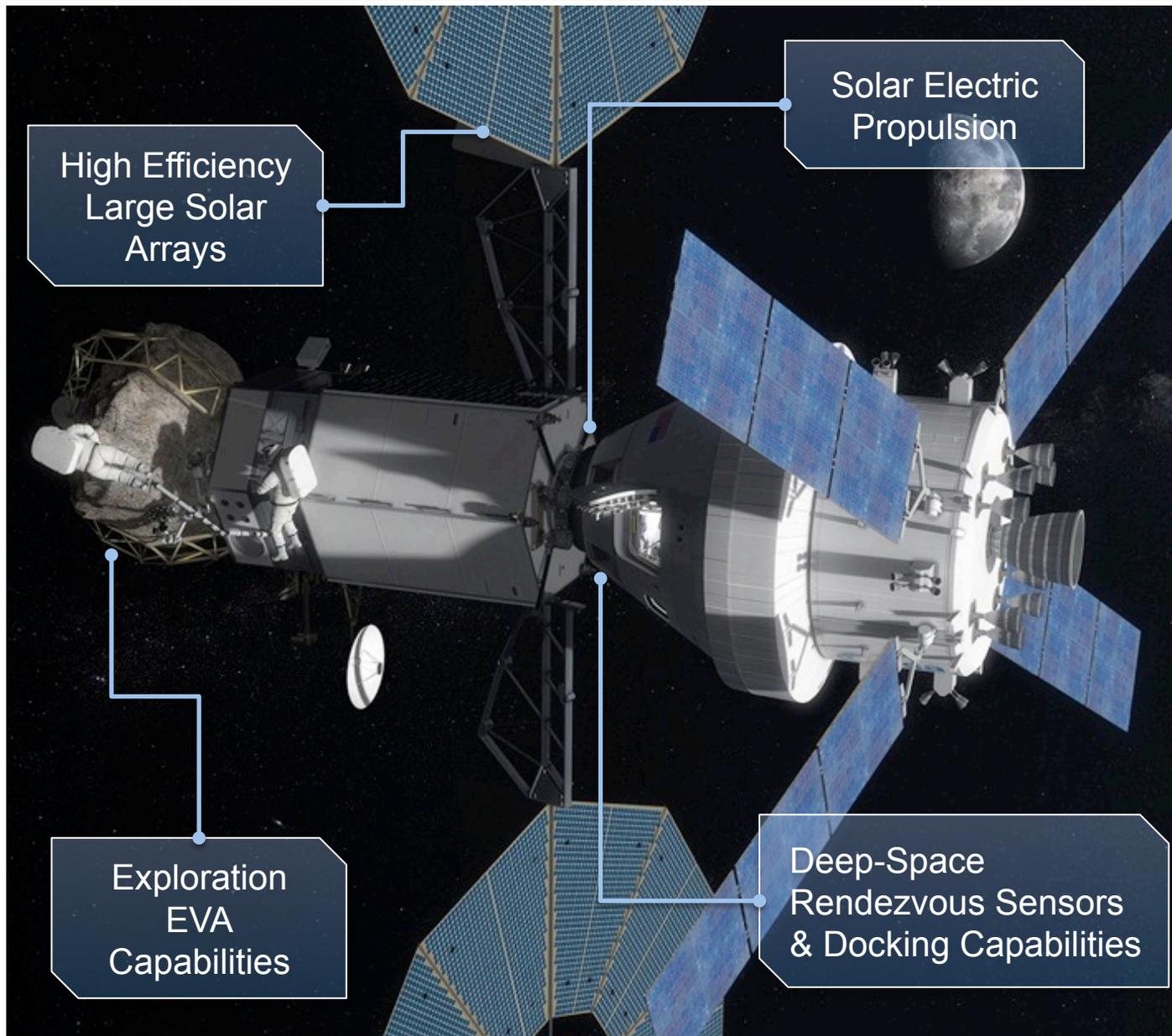
Block 1B
105 mT

Block 2
130 mT



As documented in "Pioneering Next Steps in Space Exploration"
https://www.nasa.gov/sites/default/files/atoms/files/journey-to-mars-next-steps-20151008_508.pdf

ARM: An Early Mission in the Proving Ground of Cislunar Space



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:

- Two in-space EVAs of four hours each
- Primary Life Support System design accommodates Mars
- Sample selection, collection, containment, and return

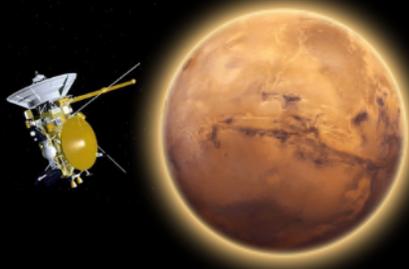
TRANSPORTATION & OPERATIONS:

- Capture and control of non-cooperative objects
- Common rendezvous sensors and docking systems for deep space
- Cislunar operations are proving ground for deep space operations, trajectory, and navigation

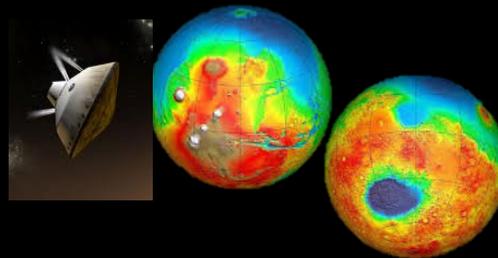
What We've Learned Thus Far and Still Need to Learn



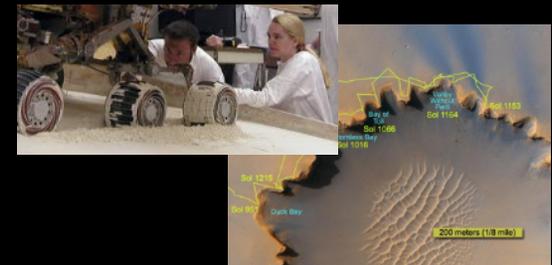
Orbital Environment and Operations



Capture, EDL, and Ascent at Mars



Surface Operations at Mars



Learned:

- Deep space navigation
- Orbit transfer near low-gravity bodies
- Gravity assist
- Aero-braking
- Gravitational potential
- Mars's moons' characteristics
- ISRU potential

To Learn:

- Return flight from Mars to Earth
- Autonomous rendezvous and docking
- ISRU feasibility
- Resource characterization of Mars's moons
- High-power SEP

Learned:

- Spatial/temporal temperature variability
- Density and composition variability
- Storm structure, duration, and intensity
- 1 mT payload
- ~10 km accuracy

To Learn:

- Ascent from Mars
- Large-mass EDL
- Precision EDL
- Aero-capture
- Site topography and roughness
- Long-term atmospheric variability

Learned:

- Water once flowed and was stable
- Global topography: elevation and boulder distributions
- Remnant magnetic field
- Dust impacts on solar power/mechanisms
- Radiation dose
- Global resource distribution
- Relay strategies, operations cadence

To Learn:

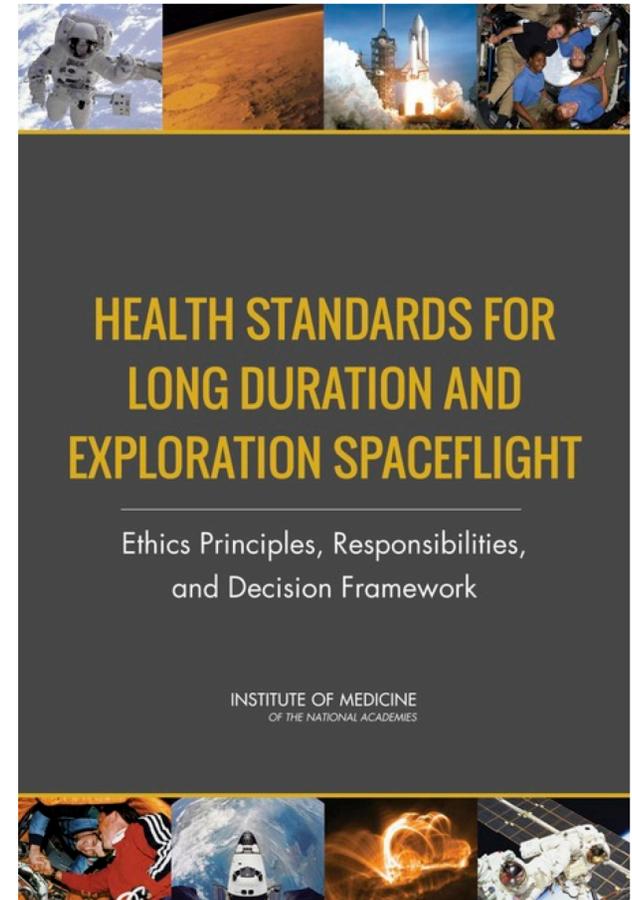
- Landing site resource survey
- Dust effects on human health, suits, and seals
- Rad/ECLSS in Mars in environment
- Power sufficient for ISRU
- Surface navigation



“Health Standards for Long Duration and Exploration Spaceflight: Ethics Principles, Responsibilities, and Decision Framework” (April, 2014)

The report makes 4 recommendations:

- The first 3 recommendations are directed at how OCHMO develops and implements health and medical standards.
- The fourth recommendation provides a tri-level decision-making framework based on the ethical principles and responsibilities that can be used when a health/medical standard(s) cannot be met, or when there are health/medical risks that are not fully understood for a proposed long duration or space exploration mission.





HEOMD view of CCMC??

WE WANT IT ALL, AND WE WANT IT NOW...

- We want to know
 - When we can safely launch
 - When we can safely operate
 - When will an event happen
 - How big will it be
 - How long will it last
 - Will it adversely impact humans
 - Will it adversely impact space-based and/or ground-based systems



HEOMD view of CCMC??

- Improved propulsion may reduce human exposure
- Improved shielding may improve our protection for humans and systems
- More and improved space weather models will benefit both humans and systems
- SWORM Strategic Plan and Action Plan point to the importance of R2O and O2R
- CCMC is such a place!
- TED



QUESTIONS?

#JOURNEYTOMARS

