National Aeronautics and Space Administration

The Evolvable Mars Campaign - The Moons of Mars as a Destination

July 30, 2014

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Shout Outs

- **Mike Gernhardt**

  Leading HAT work on designing Mars moon missions

- **Josh Hopkins**

  Lockheed Martin – Mission design across Phobos & Deimos

- **Dan Mazanek**

  Led Original HAT work on Mars moon missions

WHY Send Humans into Space?

According to me…….

To expand the human sphere of influence beyond Earth in order to further knowledge, enhance our quality of life, and assure humanity's survival

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 to Mars and beyond**
- **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**

Not THE plan, but a framework for guiding strategy and investments that will mature as technology, discovery and programmatics evolve

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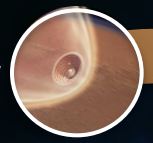
Evolvable Mars Campaign – Capability & Mission Extensibility

EARTH RELIANT | PROVING GROUND | EARTH INDEPENDENT

Capabilities

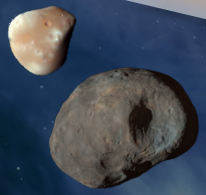


Mars Surface

Transportation

Staying Healthy

Working In Space



All Paths Through Mars Orbit

ISS Deep Space & Mars Risk Reduction

Deep Space Mars Preparation

Missions

WHY Send Humans the Moons of Mars??

Phobos
27x22x18 km

Deimos
15x12x10 km

2 km

The Moons of Mars are Unexplored and Intriguing!

Where did they come from?

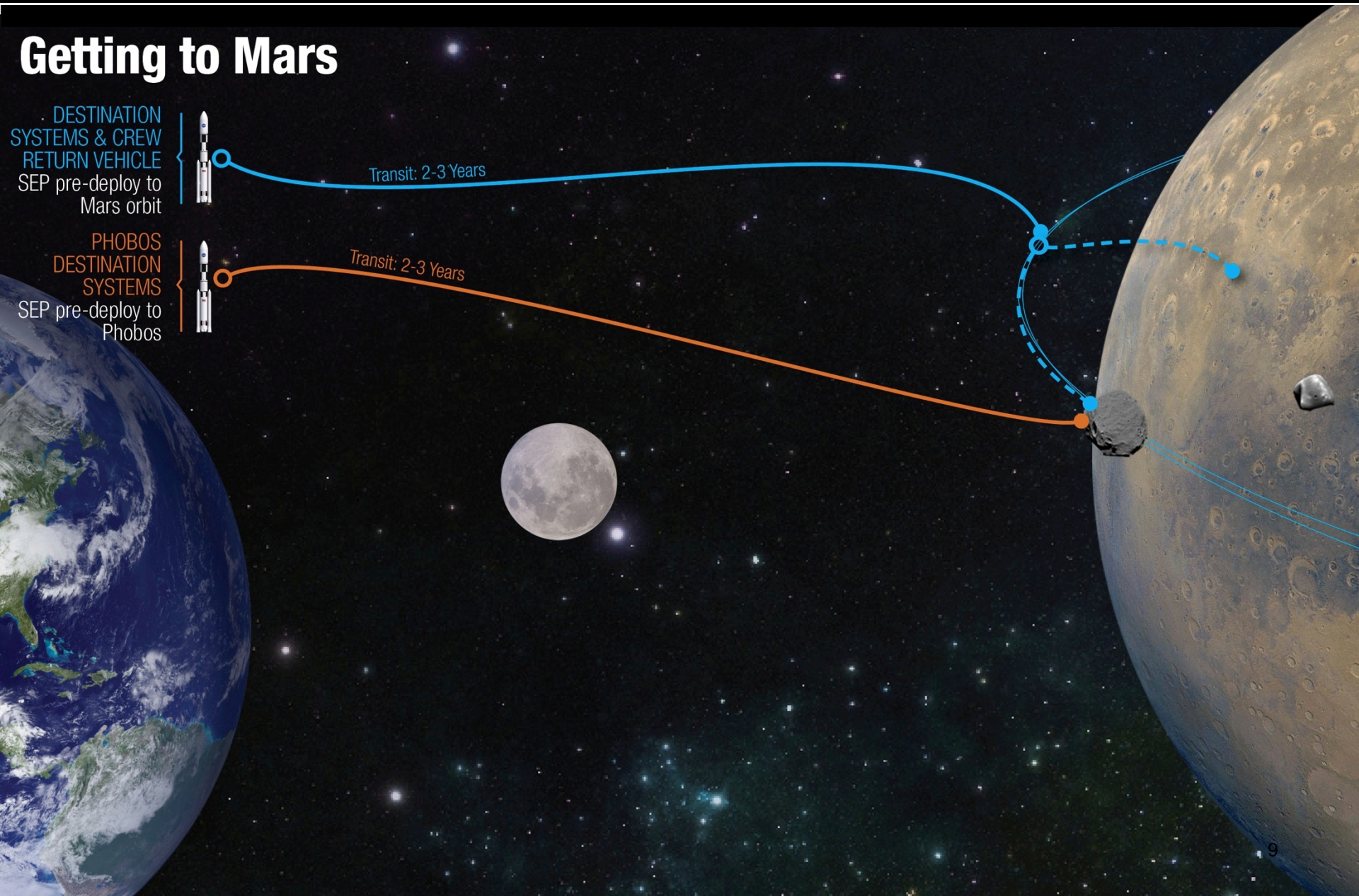
What can we learn about Mars from them?

What do they mean for the future of Mars?

Potential Science Activities

- Determine the nature of the surface geology on Phobos / Deimos and age of materials
- Constrain the conditions of formation of Phobos and Deimos materials
- Characterize the regolith on Phobos / Deimos in its geological context, and interpret the processes that have formed and modified it
- Identify and characterize the presence and distribution of any potential volatile or organic species
- Determine the near surface and interior structure at global and regional scales
- Find and analyze presolar grains
- Characterize Phobos' and Deimos' energy budget
- Perform astrophysics, heliophysics and Mars observations
- Add probably much more

The Moons of Mars are More Accessible than the Surface of Mars



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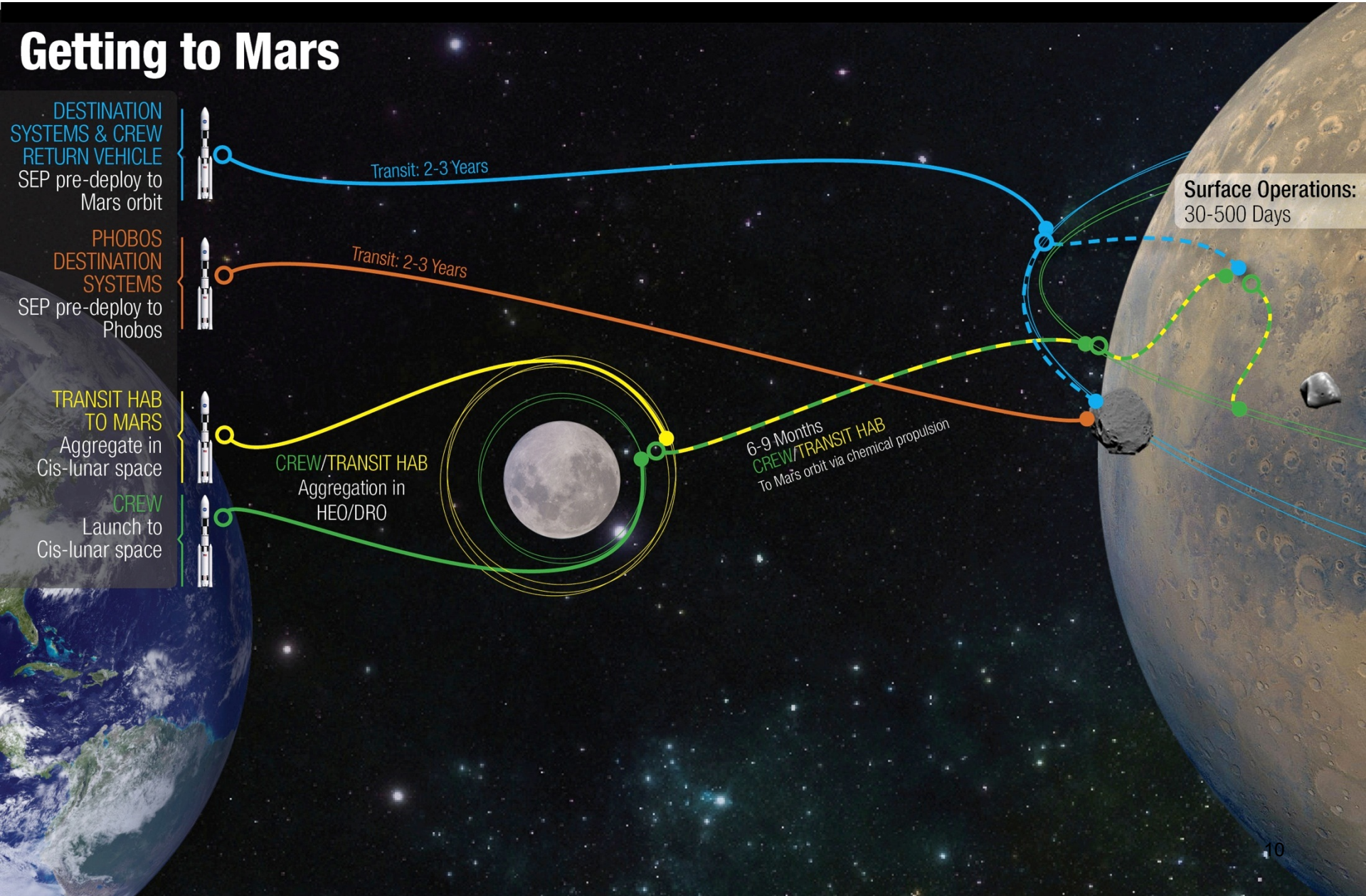

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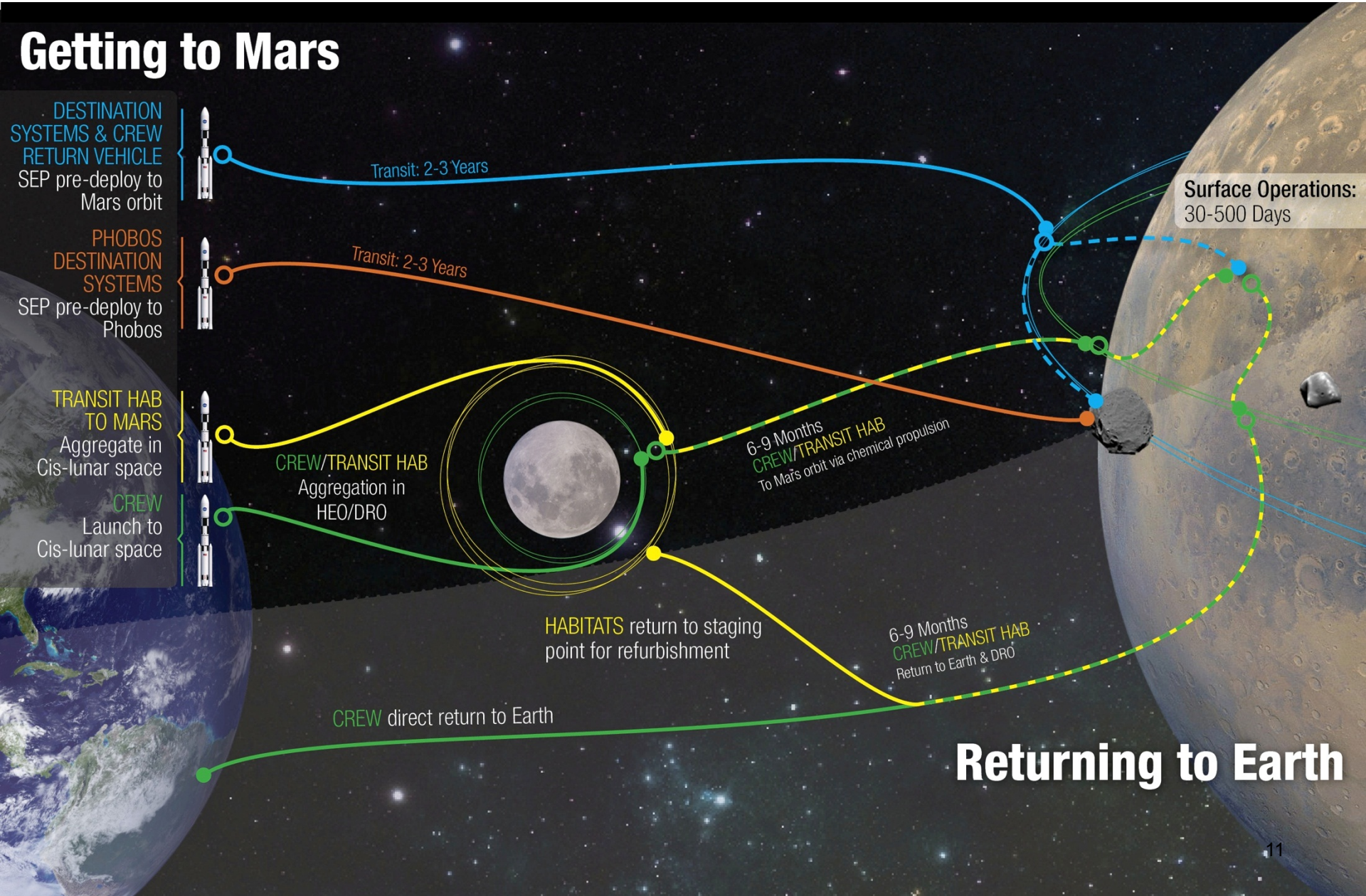


Preliminary Comparison of Surface Habitat vs. Parking Orbit Options

Effective Dose Equivalent					
	1977 Solar Min	1991 Solar Max		Percent of Free Space	
Free Space	0.8264	0.3987	mSv/day	100%	100%
L4/L5	0.798	0.385	mSv/day	97%	97%
20 km DRO	0.763	0.368	mSv/day	92%	92%
L1	0.623	0.300	mSv/day	75%	75%
Lunar Surface	0.4299	0.21	mSv/day	52%	53%
Phobos Surface	0.401	0.196	mSv/day	48%	49%
Mars Surface	0.3323	0.1728	mSv/day	40%	43%
Phobos Surface w/ 10 deg Crater Rim	0.326	0.159	mSv/day	39%	40%

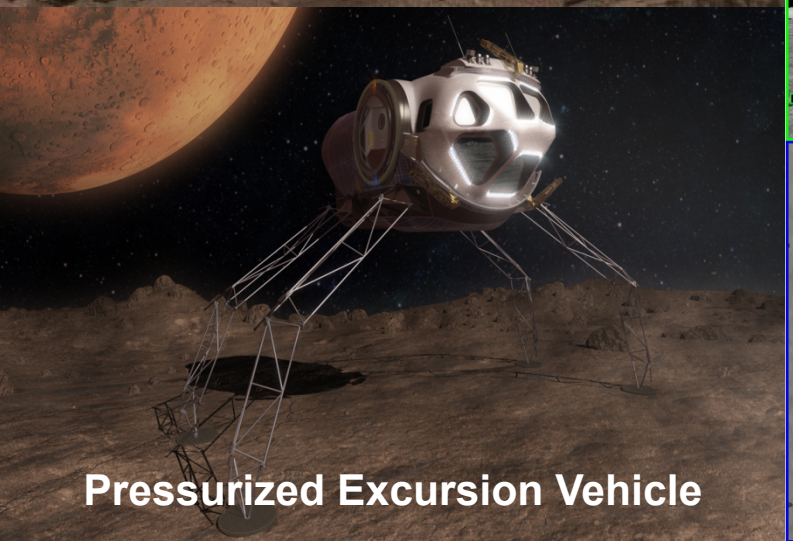
Location	Station-keeping Delta-V per Day (m/s)	Roundtrip Delta-V per Transfer (m/s)	Cumulative Delta-V * (m/s)	Roundtrip Time per Transfer (hrs)	Cumulative Transfer Time (days)
L1 (1 m Position Error)	0.22	8	457	4	4.7
L1 (10 m Position Error)	1.30	8	1537	4	4.7
20 km DRO, 0 incl.	Very Low	24.6	738	4.1	5.1
L4		64.0	1921	140.5	175.7
150 km DRO, 0 incl.		63.8	1914	10.0	12.5
150 km DRO, 10 deg incl.		76.9	2307	10.9	13.6
200 km DRO, 0 incl.		82.1	2464	10.1	12.6
200 km DRO, 10 deg incl.		99.4	2982	11.0	13.7

- **L1 may be acceptable from DV, crew time, and radiation perspective but unstable orbit and potential surface impact is a concern**

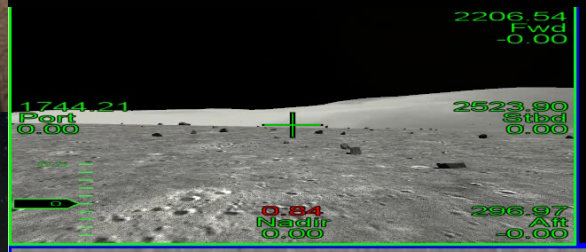
Low Gravity Has its Advantages……..

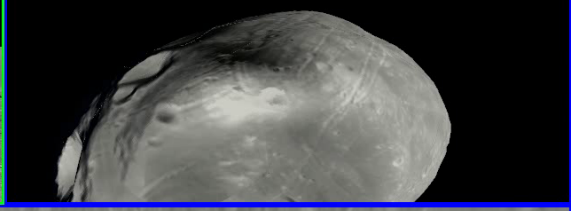
Weight on Phobos	lbf
Crewmember in a Suit	0.3
PEV (6,000 kg)	7.7
Habitat (15,000 kg)	19.2
Lander (50,000 kg)	63.9

Unpressurized Excursion Vehicle



Pressurized Excursion Vehicle





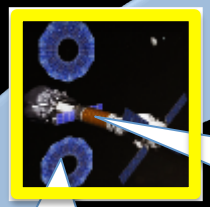
EMC Progressive Expansion of Capabilities and Distance

Low-Earth Orbit

- International Space Station: **Answer the question: Can humans live & operate ~900 days in micro-G?**
  - Zero-g, human factors research platform
  - Highly reliable life support, adv. logistics, low maintenance
  - Environmental monitoring
  - Supportability & maintenance concepts

Phobos/Deimos/Mars Orbit

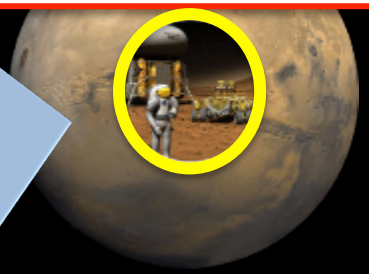
- Deep Space Port plus:
  - High power SEP (xxx kW)
  - ~900 day deep space habitat(s)
  - Deep space countermeasures
  - Mars vicinity propulsion



Continued Leveraging of Commercial & International Partnerships

4. Mars Surface

- Phobos/Deimos plus:
  - Mars entry & landing systems
  - Partial-gravity countermeasures
  - Long duration surface Systems (ISRU, fission power)



Deep Space Proving Ground

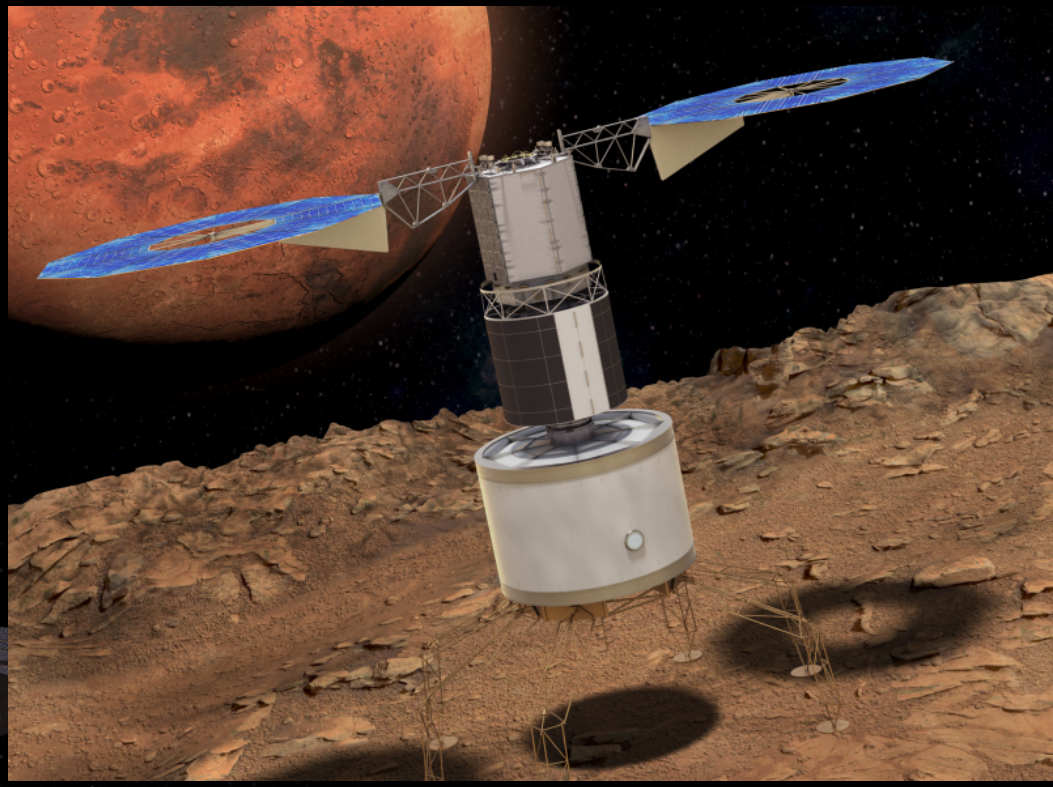
- SLS, Orion & ARM plus:
  - Exploration Augmentation Module
    - Crew support for 30-60 days (habitat)
    - Uncrewed for up to 11 months
- **Answers the question "Can human class systems operate in a deep space environment in a crew tended mode for long durations**
  - Advanced EVA (Suit, PLSS)
  - In-Space Propulsion (EUS)
  - Deep space long duration systems and operations testing
  - Aggregation of Mars Mission Vehicles

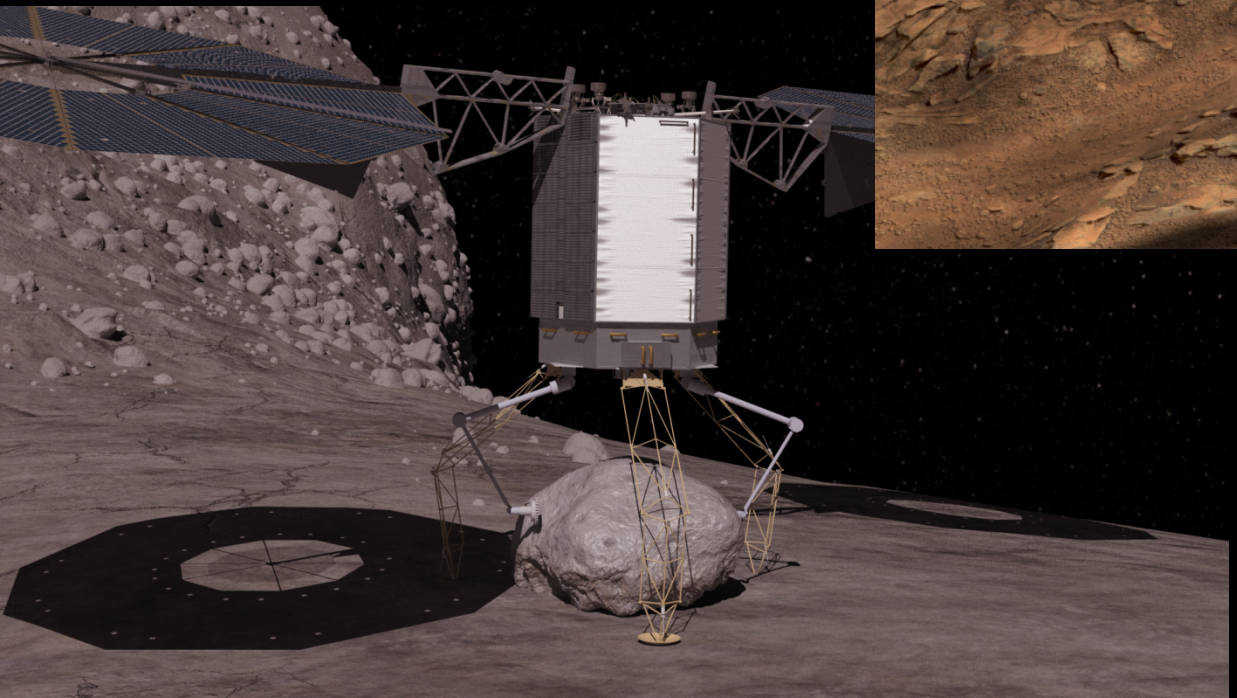
SLS, Orion & ARM

- Distant Retrograde Orbit
  - Heavy lift launch (SLS), Orion
  - Crew support for up to 30 days (Orion)
  - Deep-space propulsion (Orion)
  - SEP demonstration (40 kW)
  - AR&D

Asteroid Redirect Mission Synergies with Mars Moon Missions

ARM could yield an enhanced understanding of proximity and landing operations associated with uncooperative, low-G targets as will be experienced with Mars Moons

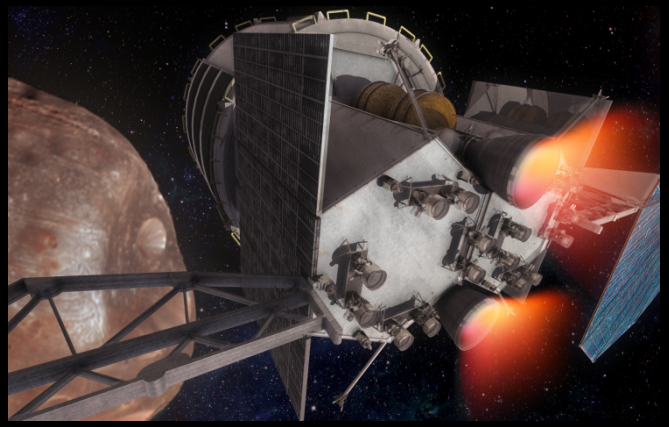




The Moons of Mars are Potential Enablers for Mars Surface Exploration

Mission Flexibility

- Opens up conjunction class mission modes where the crew and time spent shift from a Mars moon to the surface of Mars with equal radiation protection
- Offers “abort to moon” option as a contingency for Mars surface emergencies

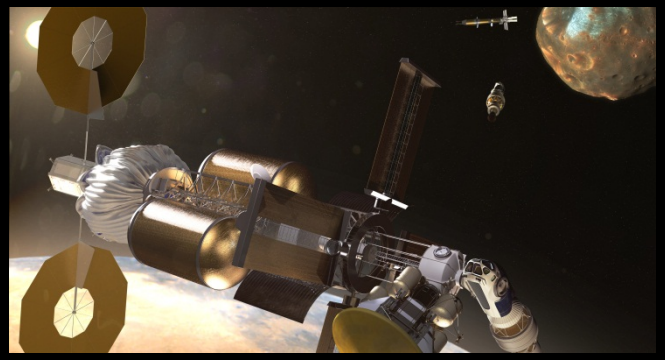


Tele-operation of Mars Surface Assets

- Human presence extended to the surface of Mars safely using the best of humans and robots together
- Conjunction class mission to Mars moons offer ~500 days of low-latency tele-operations on the Mars surface in support of Science, reconnaissance and infrastructure deployment

ISRU

- To be truly Earth Independent and sustainable, ISRU beyond Mars atmosphere will have to be leveraged
- The Moons of Mars may offer a source of propellant for landers, taxis and Earth return vehicles



Summary – Why the Moons of Mars as a Human Destination

Unexplored and Intriguing

- Rich science
- A link to Mars past and its future
- Incredible views

A More Achievable Step

- Same crew transportation system as Mars surface
- Low gravity environment for access and exploration
- Less investment than Mars surface required

An Enabler for Mars Surface Exploration

- Alternate mission modes opened up
- Low latency tele-operations of Mars surface assets
- ISRU potential for sustainable pioneering of Mars