Deep Space Transport (DST) and Mars Mission Architecture

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October 17 2017

Human Space Exploration Phases From ISS to the Surface of Mars

Today

Phase 0: Exploration Systems ***Testing on ISS***

Ends with testing, research and demos complete*

Phase 1: ***Cislunar Flight Testing*** of Exploration Systems

Asteroid Redirect-Crewed Mission Marks Move from Phase 1 to Phase 2

Phase 2: ***Cislunar Validation*** of Exploration Capability

Ends with one year crewed Mars-class shakedown cruise

Phase 3: Crewed Missions Beyond Earth-Moon System

Phase 4a: Development and robotic preparatory missions

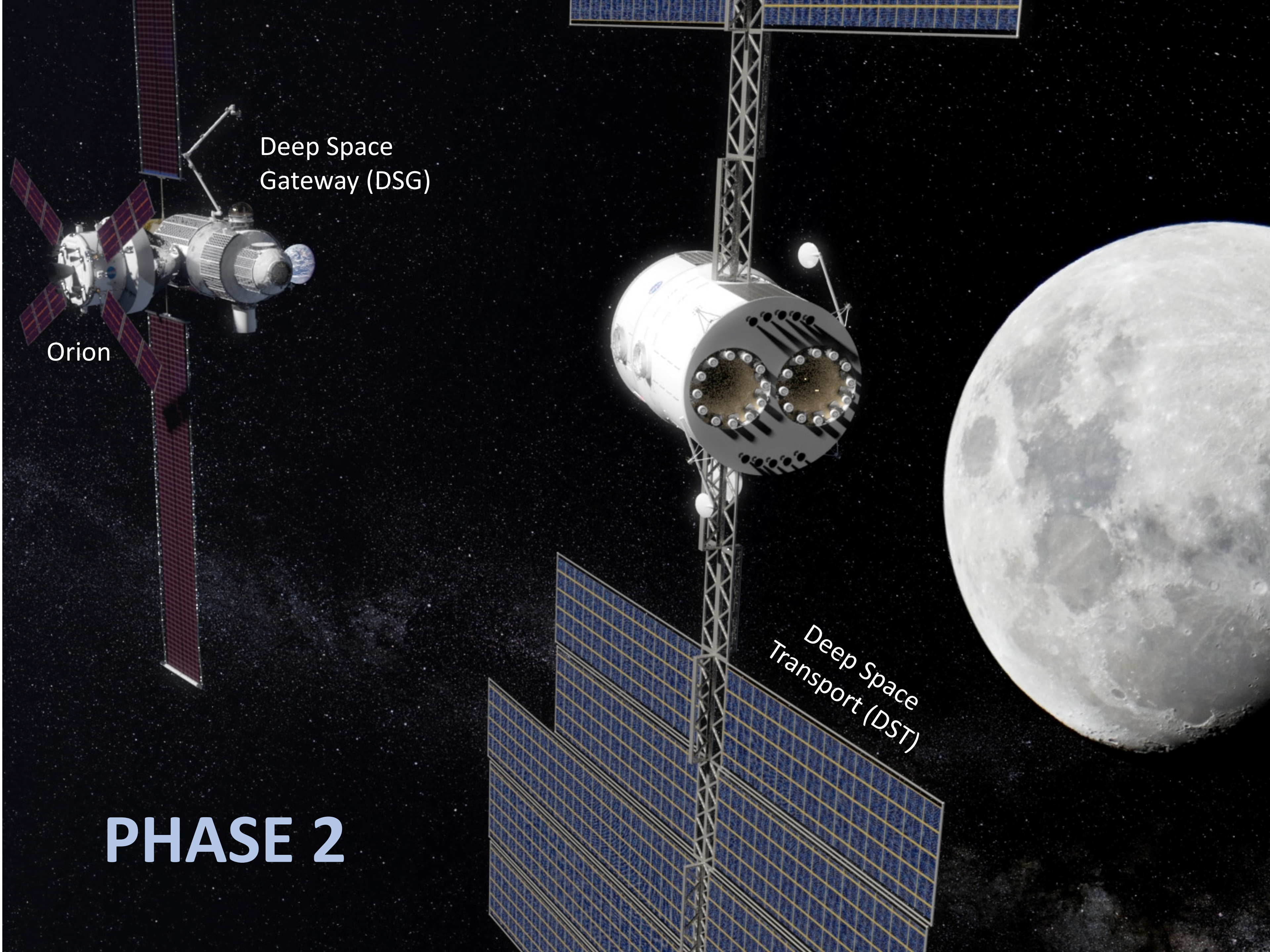
Phase 4b: Mars Human Landing Missions

Planning for the details and specific objectives will be needed in ~2020

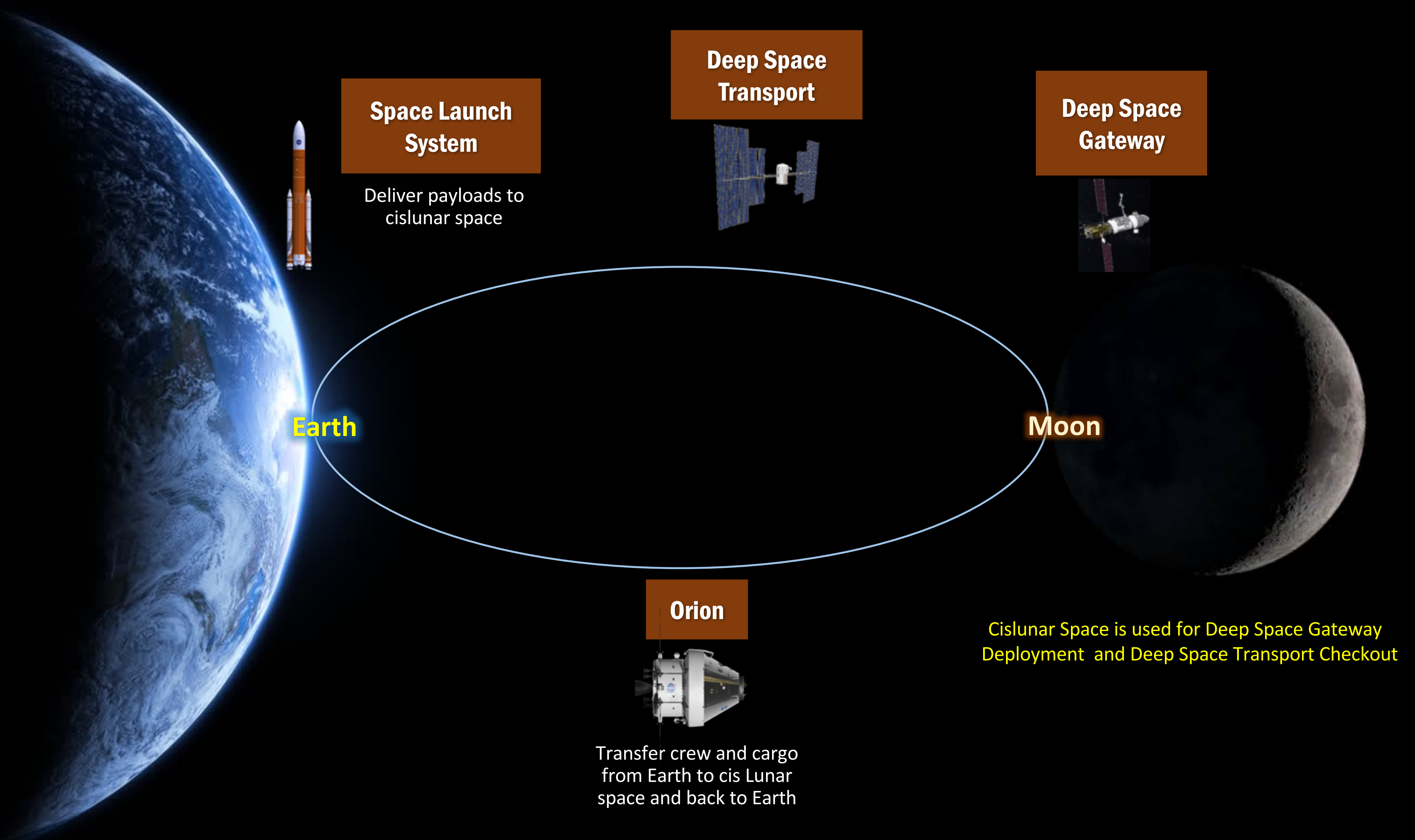
Mid-2020s

2030

* There are several other considerations for ISS end-of-life


Deep Space
Gateway (DSG)
Orion
Deep Space
Transport (DST)
PHASE 2

Phase 2 Mission Elements



Deep Space Transport Functionality

- **Emphasis on supporting shakedown cruise by 2029**
  - Shakedown cruise to be performed in lunar vicinity
  - Utilizes deep space interfaces and common design standards

- **Example Assumptions**
  - Deep Space Transport provides habitation and transportation needs for transporting crew into deep space including supporting human Mars-class missions
  - The Transport system life will be designed for:
    - Reused for 3 Mars-class missions with resupply and minimal maintenance
    - Crew of 4 for 1,000 day-class missions in deep space
    - Launched on one SLS 1B cargo vehicle - resupply and minimal outfitting to be performed in cislunar space

DST Driving Assumptions

	Assumption
Crew Number	4 Crew
Vehicle Lifetime/Dormancy	15 year lifetime with up to 3 years dormant operation
Dimensions Constraints	7.2 m diameter shell to meet 8.4 m payload shroud constraint. 0.95 eccentricity end domes to maximize useful volume
Habitable Volume	>25 m^3/person
Docking mechanisms	3 passive, 1 active ISS compliant docking mechanisms for cislunar aggregation
Extravehicular Activity	Contingency EVA only using modified Launch, Entry, and Abort (LEA) suits and an inflatable airlock

More complete set of assumptions in paper

Deep Space Transport EVA Assumptions

	Transit Habitat Guidelines and Assumptions
EVA Guidelines (Baseline set)	**<u>EVA Assumptions</u>**: Assume only contingency EVA for transit habitat utilizing modified Launch, Entry, and Abort (LEA) suits and an inflatable airlock. Assume TBD amount of spares/logistics for EVAs. Assume that surface EVA suits are delivered on the destination habitat and checked out in orbit prior to crew descent. After operations at the destination are complete, surface EVA suits are left at the destination if there is a pressurized IVA transfer capability available. Crewmembers then ascend in their LEA suits (brought with them during landing) for planetary protection (backward). Risks associated with cabin depress/docking failure to Mars Transit Habitat are future work. **<u>Number and Types of Suits:</u>** Assume the number of LEA suits = number of crew. Also assume 2 in-space Portable Life Support Systems (PLSSs). Crew brings these LEA suits along to the surface and on the return trip. **<u>Habitat EVA Services:</u>** The habitat has umbilical interface panels located where suit services or suited crewmember operations occur. Suit services/umbilical interface panels provide: Recharge capability for the suit includes: oxygen (3000 psia), water w/biocide (potable and cooling) resupply, and battery recharge and utility services: power, communications (wireless and hardline), and vacuum lines (if required).

Interior Layout Features

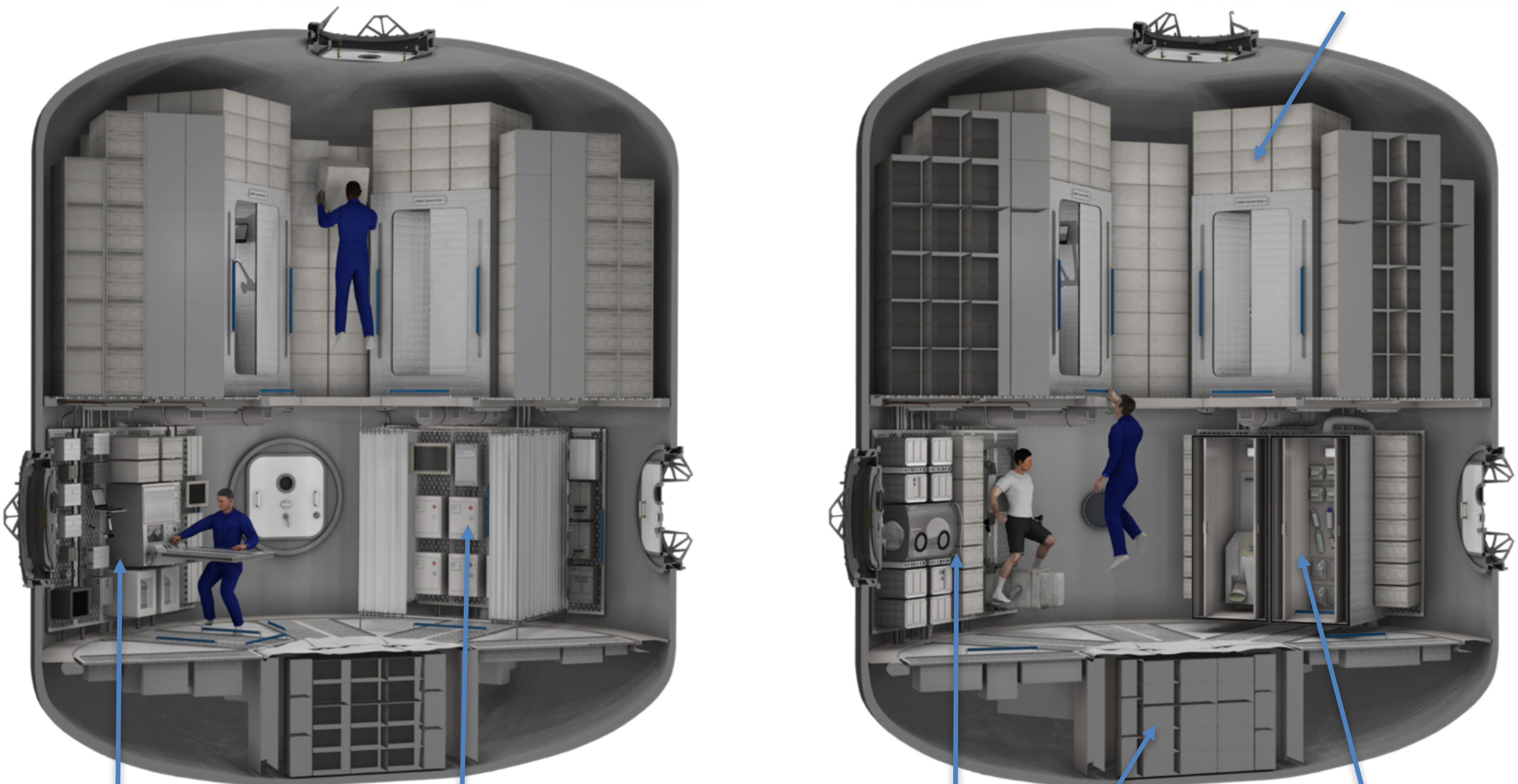
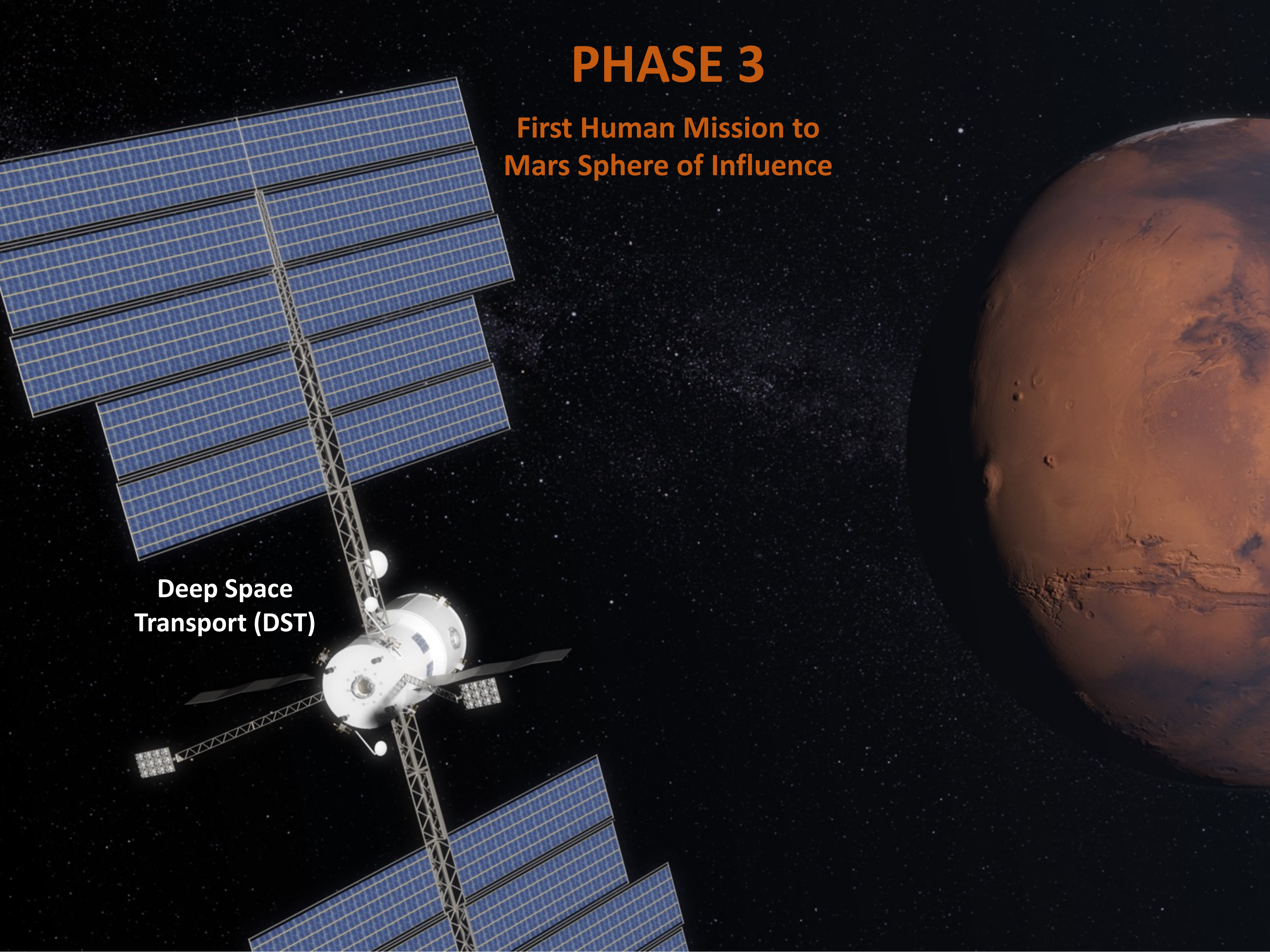


Image credit: NASA

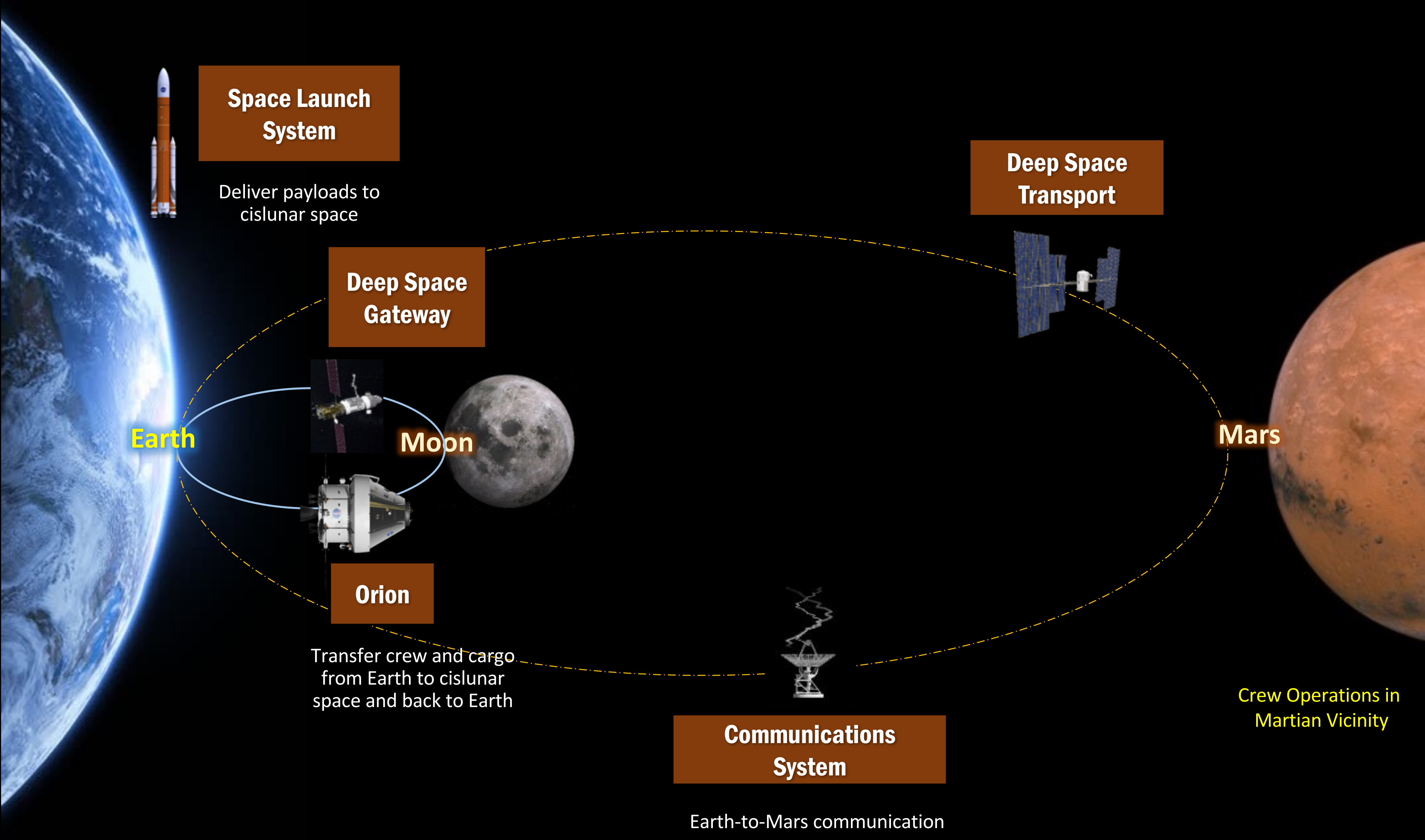

PHASE 3
First Human Mission to
Mars Sphere of Influence
Deep Space
Transport (DST)

Mission to Mars Sphere of Influence (Phase 3)

- **Emphasis on first human mission to Mars' sphere of influence**
  - First long duration flight with self sustained systems
  - Autonomous mission with extended communication delay
  - First crewed mission involving limited abort opportunities

- **Example Assumptions**
  - 8.4 m Cargo Fairing for SLS launches in Phase 3
  - Crew of 4 for Mars class (1000+ day) mission independent of Earth
  - Orion used for crew delivery and return to/from cislunar space
  - Re-usable DST/Habitat and Propulsion Stage
    - Hybrid (SEP/Chemical) In-Space Propulsion System
    - Gateway used for aggregation and re-fueling of DST

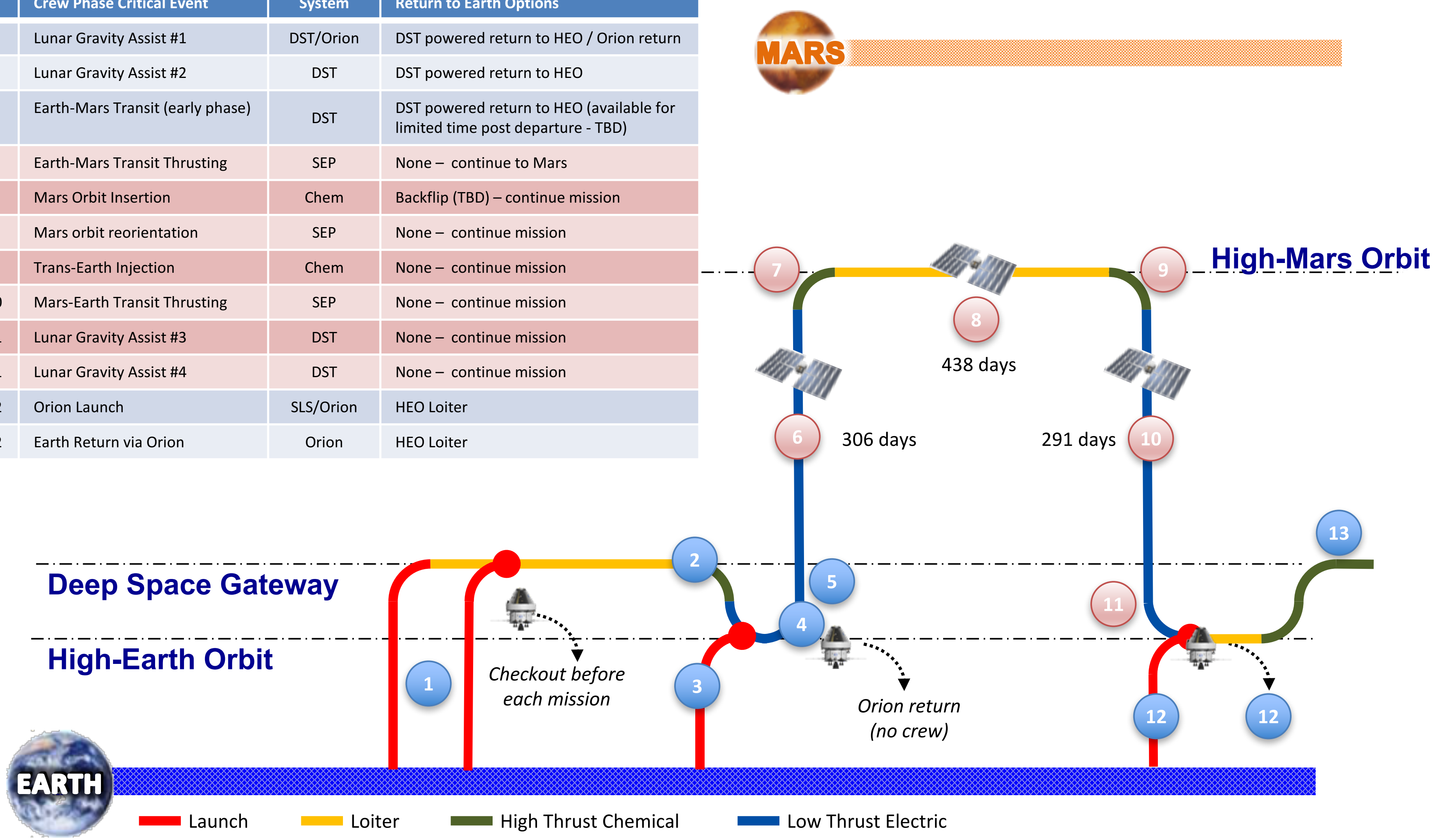
Example Phase 3 Mission Elements



Mars Orbital Mission

Example Operational Concept

#	Crew Phase Critical Event	System	Return to Earth Options
4	Lunar Gravity Assist #1	DST/Orion	DST powered return to HEO / Orion return
5	Lunar Gravity Assist #2	DST	DST powered return to HEO
5	Earth-Mars Transit (early phase)	DST	DST powered return to HEO (available for limited time post departure - TBD)
6	Earth-Mars Transit Thrusting	SEP	None – continue to Mars
7	Mars Orbit Insertion	Chem	Backflip (TBD) – continue mission
8	Mars orbit reorientation	SEP	None – continue mission
9	Trans-Earth Injection	Chem	None – continue mission
10	Mars-Earth Transit Thrusting	SEP	None – continue mission
11	Lunar Gravity Assist #3	DST	None – continue mission
11	Lunar Gravity Assist #4	DST	None – continue mission
12	Orion Launch	SLS/Orion	HEO Loiter
12	Earth Return via Orion	Orion	HEO Loiter



Mars Orbital Mission

Overview – 2033 Mission Example

Deep Space Transport

~ 300 kW Electric Propulsion (EP) power

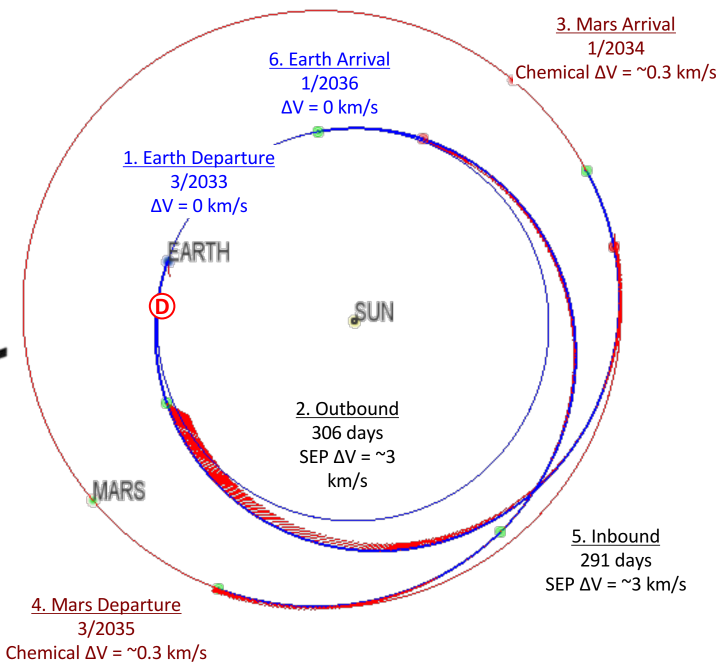
~ 470 kW solar array power at start of the mission

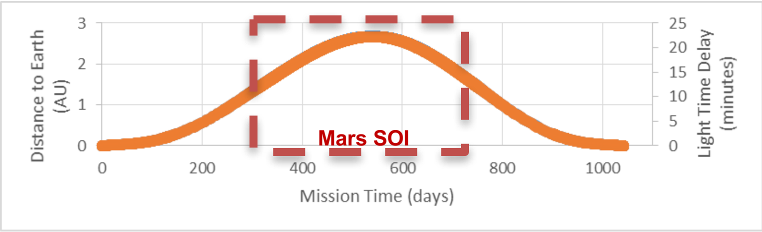
~ 20 kW power to the spacecraft and payload

~ 24 t EP propellant and ~ 16 t chemical propellant

~ 48 t Payload

- ~ 21.9 t habitat with 26.5 t logistics and spares to support 4 crew





Mission Concept of Operations

1. After crew rendezvous with the Transport in high elliptical Earth orbit it catches lunar gravity assists for Earth Departure
   – Most opportunities don't require a chemical departure burn but some harder outbound opportunities do
2. Transport uses EP in heliocentric space to complete transit to Mars
3. Transport captures into Mars orbit with chemical propulsion
4. Crew performs remote observations of Mars vicinity for 438 days (88 orbits)
5. Transport departs Mars via a chemical propulsion departure burn
6. Transport uses EP to return to Earth
7. Lunar gravity assists to recapture into Earth sphere of influence.

PHASE 4

Mars Surface Missions

Mars Surface Mission Feasibility (Phase 4)

- **Emphasis on establishing Mars surface field station**
  - First human landing on Mars' surface
  - First three missions revisit a common landing site

- **Example Assumptions**
  - Re-use of Deep Space Transport for crew transit to Mars
  - 4 additional, reusable Hybrid SEP In-Space Propulsion stages support Mars cargo delivery
  - 10 m cargo fairing for SLS Launches in Phase 4
  - Missions to Mars' surface include the following:
    - Common EDL hardware with precision landing
    - Modular habitation strategy
    - ISRU used for propellant (oxidizer) production
    - Fission Surface Power
    - 100 km-class Mobility (Exploration Zone)

Mars Surface Mission

Example Operational Concept

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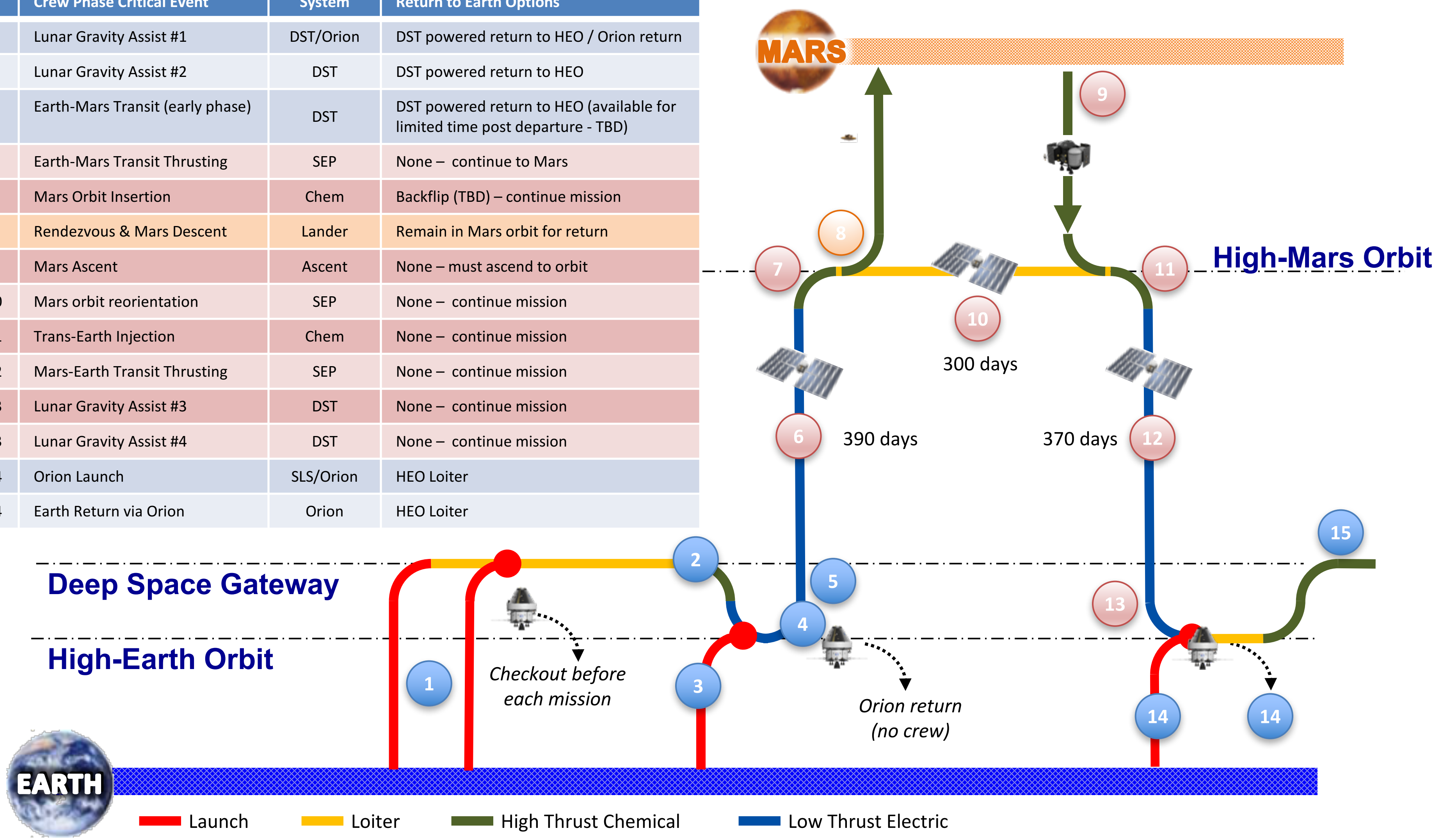
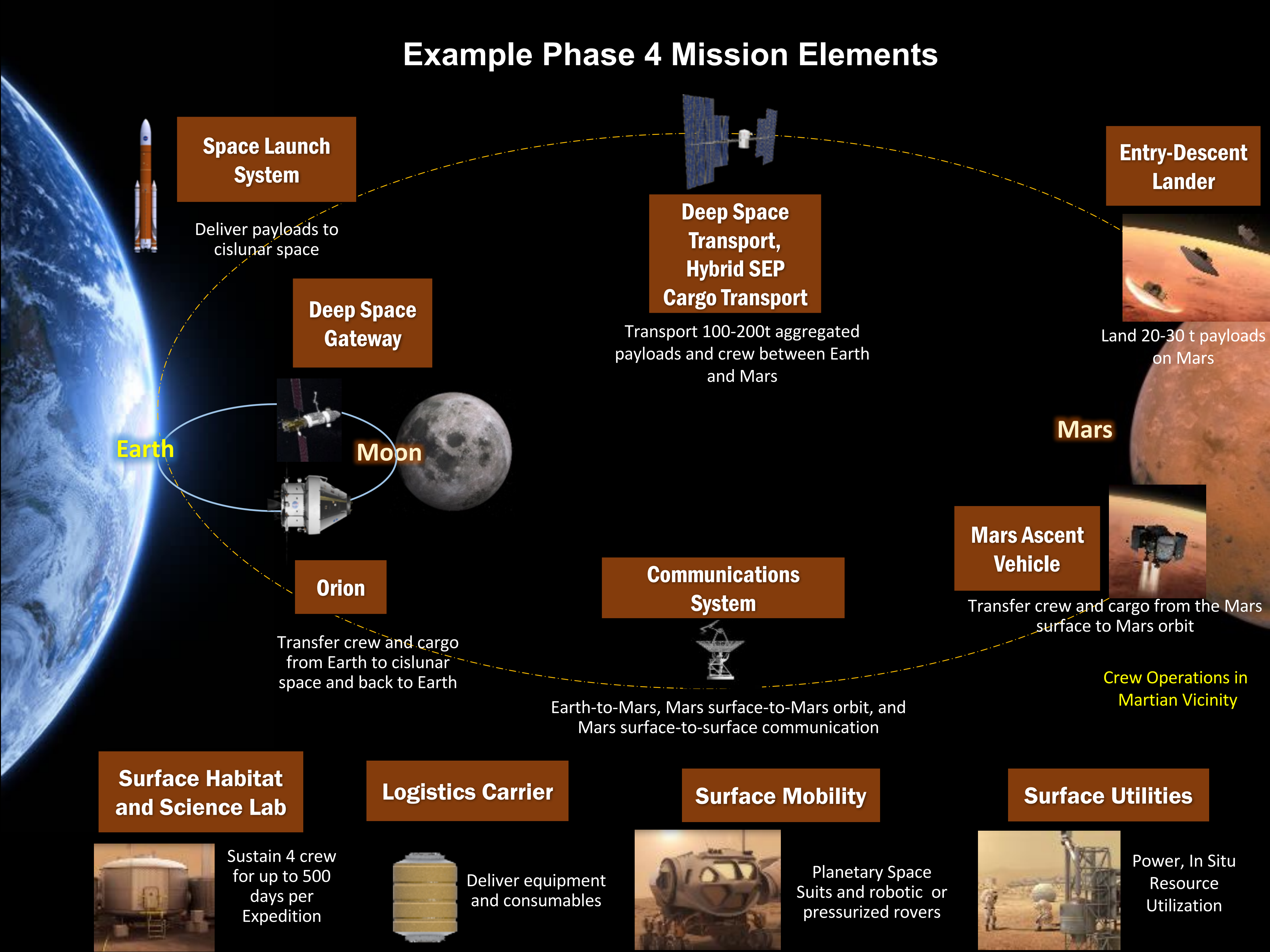
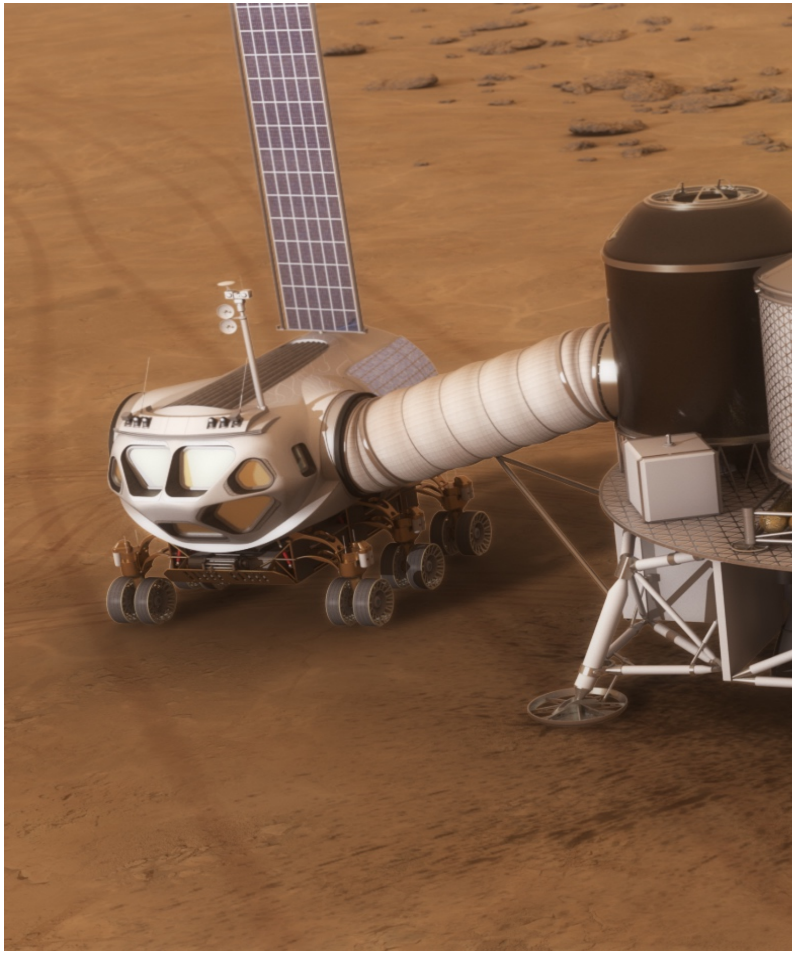
6	Earth-Mars Transit Thrusting	SEP	None – continue to Mars
7	Mars Orbit Insertion	Chem	Backflip (TBD) – continue mission
8	Rendezvous & Mars Descent	Lander	Remain in Mars orbit for return
9	Mars Ascent	Ascent	None – must ascend to orbit
10	Mars orbit reorientation	SEP	None – continue mission
11	Trans-Earth Injection	Chem	None – continue mission
12	Mars-Earth Transit Thrusting	SEP	None – continue mission
13	Lunar Gravity Assist #3	DST	None – continue mission
13	Lunar Gravity Assist #4	DST	None – continue mission
14	Orion Launch	SLS/Orion	HEO Loiter
14	Earth Return via Orion	Orion	HEO Loiter




Example Phase 4 Mission Elements
Space Launch System
Deliver payloads to cislunar space
Deep Space Transport, Hybrid SEP Cargo Transport
Transport 100-200t aggregated payloads and crew between Earth and Mars
Entry-Descent Lander
Land 20-30 t payloads on Mars
Deep Space Gateway
Earth
Moon
Mars
Mars Ascent Vehicle
Transfer crew and cargo from the Mars surface to Mars orbit
Orion
Transfer crew and cargo from Earth to cislunar space and back to Earth
Communications System
Earth-to-Mars, Mars surface-to-Mars orbit, and Mars surface-to-surface communication
Crew Operations in Martian Vicinity
Surface Habitat and Science Lab
Sustain 4 crew for up to 500 days per Expedition
Logistics Carrier
Deliver equipment and consumables
Surface Mobility
Planetary Space Suits and robotic or pressurized rovers
Surface Utilities
Power, In Situ Resource Utilization

Human Mars Architecture Decisions Related To EVA

- **End State**
  - "Lewis and Clark"
  - Field Station (revisit)
  - Towards permanent habitation
- **Mission Duration**
  - In-Space
  - Surface
- **Mars Descent and Ascent**
  - Duration
  - Scale/capabilities of descent and ascent vehicles
- **Transfer Among Surface Elements**
  - Pressurized vs unpressurized
  - Dust control
- **Spacesuit Commonalty**
  - Launch/In-space EVA/Mars EDL/Mars Surface/Mars Ascent/Earth Entry
  - Volumetric constraints
- **ISRU**
  - Availability of locally produced consumables
- **Maintenance and Spares**



NASA

Human Mars Mission Design Decisions

The current big picture design choices offers up 5.3 x 10^{37} possible combinations

Mission Architecture / End State

Transportation – Earth-to-Orbit

Transportation – Cis-Earth Infrastructure / Deep Space

Transportation – Deep Space / Earth Return

Human Health / Surface

Surface														
ISRU	Power	Habitat Type	Life Support	Planetary Outpost	Excursion Radius/ Exploration Zone	Length of Surface Stay	Planetary Sciences	Laboratory Sciences	ECLSS	Trash	Robotics	Landing Zone Surveys	Cargo Handling	Surface Communication
None	Solar	Monolithic	Open	Different for Each Expedition	< 10 km	7 sols	Teleoperation of Instrument / Networks	None	Open	Containers	Low Latency Telerobotics	Orbital	Crane/ Hoist	Line of Sight
Demonstration Only	Nuclear	Modular	Closed	Single Outpost	10 - 100 km	14 sols	Recon Geology / Geophysiology	Basic Analysis / No Lab	50 - 75% Closed	Recycle	Autonomous	Robotic	Ramp	Relay Satellite
Atmospheric Oxygen	RTG	Inflatable		Multiple Outposts	> 100 km	30 sols	Field Work	Moderate Geochemical + Life Science	75 - 90% Closed	Combination	Crew Partnered		ATHLETE	
Water from Regolith	Combination	Rigid				90 sols	Drilling / Geophysical Tests	Full-Scale Life Science	> 90% Closed				Other	
Water from from Subsurface Ice		Local Features and Resources				300 - 500 sols								
Fabrication / Manufacturing						500 - 1000 sols								
Combination						> 1000 sols, overlapping crews								
Export														