Human Missions to Mars
Surface Concept of Operations

National Aeronautics and Space Administration

EXPLORE MOON to MARS

M. Rucker, S. Hoffman
Mars Architecture Team
JSC Exploration Missions and Planning Office
1 December 2020

Presentation Overview

- **The purpose of this presentation is to provide insight into NASA's current thinking for human exploration on the surface of Mars**
- **Presentation outline**
  - Part 1: Human Mars Mission Overview
    - Major mission events
    - Range of Mars mission durations for human missions
  - Part 2: Surface Mission Operations
    - Expected environmental conditions and operations during the Mars surface exploration phase
    - Example Mars surface mission 30-sol timeline
    - Some Planetary Protection issues still open for discussion

Human Mars Mission Overview

Human Mars Mission Overview

Who

Up to 6 crew have been studied

Some could potentially remain in Mars orbit while others explore surface

Under Review

What

Mars Transit

Landing and Surface Exploration

Mars Ascent and Earth Return

Where

Cislunar, Deep Space and Mars orbit

Mars Surface

When

As Early as 2030's

Crew away from Earth 2 to 3 yrs

30 to 300 sols on Mars

Why

Science

How

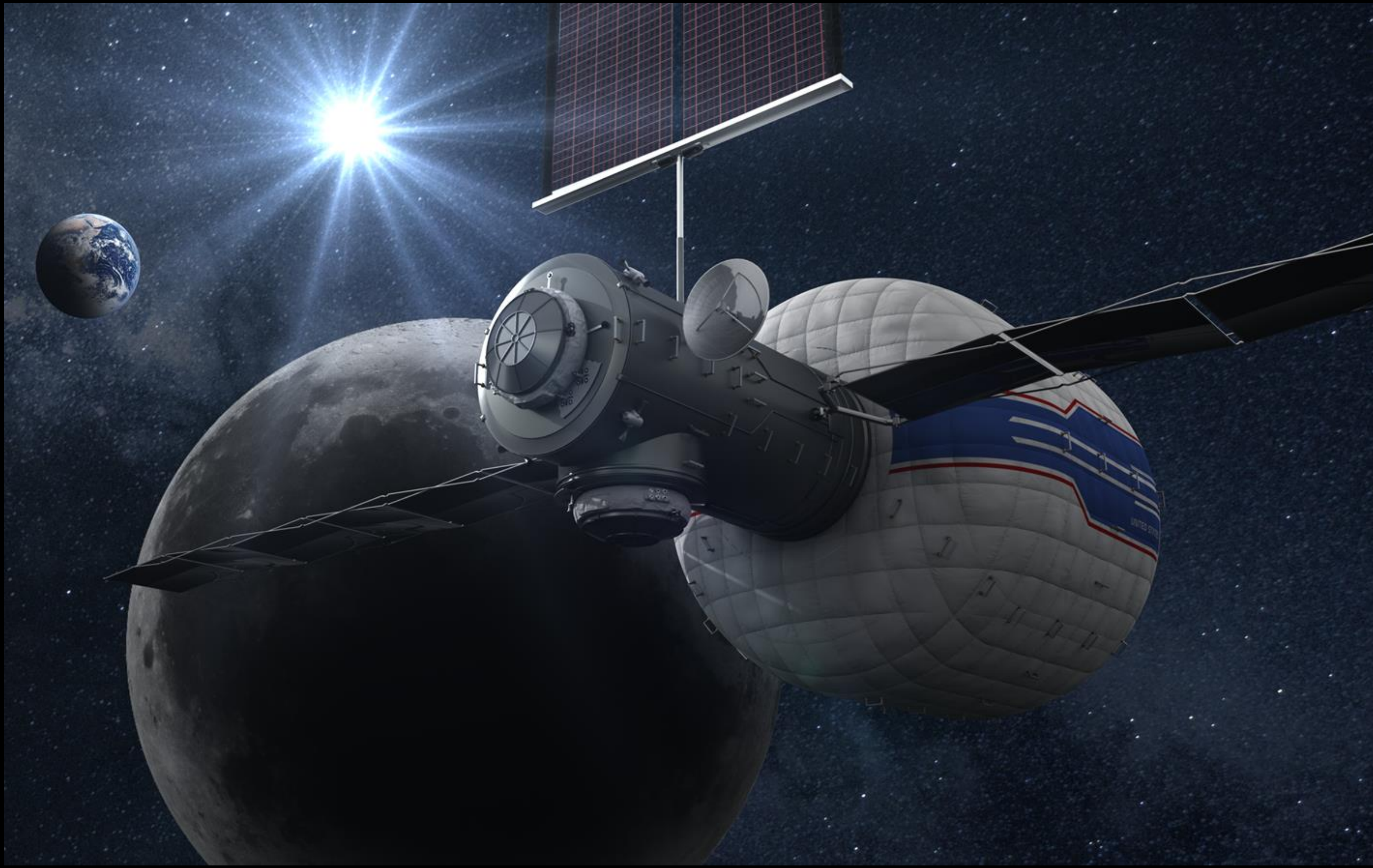
1 *Pre-Deployed Cargo Phase*

2 *Crewed Surface Exploration Phase*

General Human Mars Mission Concept of Operations

EXPLORE MOON to MARS

1. **Deploy Mars Transit Habitat for testing and validation at or near Gateway**
   - Opportunity to do practice planetary protection processes
2. **Pre-deploy surface cargo to Mars before crew departure**
3. **Crew transit to Mars**
4. **Rendezvous with crew descent lander in Mars parking orbit**
5. **Crew descend to Mars surface**
   - Crew transport loiters in orbit
6. **Crew completes surface mission then returns to orbit with Mars samples**
7. **Crew return transit to Earth**



Human Mars Mission Intersection with Planetary Protection

Surface Phase

- **Crew Ingress/Egress**
- **Waste management**
- **Excess heat creating a “special region”**
- **Science Operations**
  - Potentially sub-surface
- **End of Mission disposal of vehicles and infrastructure**
- **Contingencies**

Transit Phase

- **Return of Mars samples to Earth**

Ideally We Will Practice with Analogues

Analogue Comparisons

	6 days (4 + 2) *Artemis* Phase 1	30 days Gateway (extended)	60 days (30 on surface) *Artemis* (extended)	4-12 months ISS LEO	24+ months Mars transit CRA	22-30 months (1-18 on surface) Mars landing CRA
Exploration Atmosphere *TBR/TBD	Low Pressure (8.2 psi / 34% O_2, other options possible)*			Earth-like (14.7psi / 21% O_2)	Low Pressure (8.2 psi / 34% O_2, other options possible)*	
CO_2	Current ECLSS (2-4 mm Hg)		New ECLSS	Current ECLSS	New ECLSS (2 mm Hg)	
Microbes of Built Environment & Wetted Systems	Intermittent Occupancy, Limited Inputs			20 y Continuous Evolution/ multiple inputs	2-3 y Evolution, Single input	
Microbes Outside	Colonization		Colonization			Planetary Protection / Colonization
Food System						
Dust	Lunar Dust		Lunar Dust			Mars Dust, Storms

Surface Mission Operations

Crewed Mars Surface Exploration Phase

EXPLORE MOON to MARS

Conditions

- Partial Gravity
- Dust/Dust Storms
- Mass-Limited
- Communication Delays
- No Resupply
- Day/Night Cycle

Operations

- Science
- Frequent EVA
- Vehicle and Space Suit Maintenance

Duration

- 30 – 300 sols

Notional Phases of a Minimal Surface Mission

Short (30 sol) Example Shown

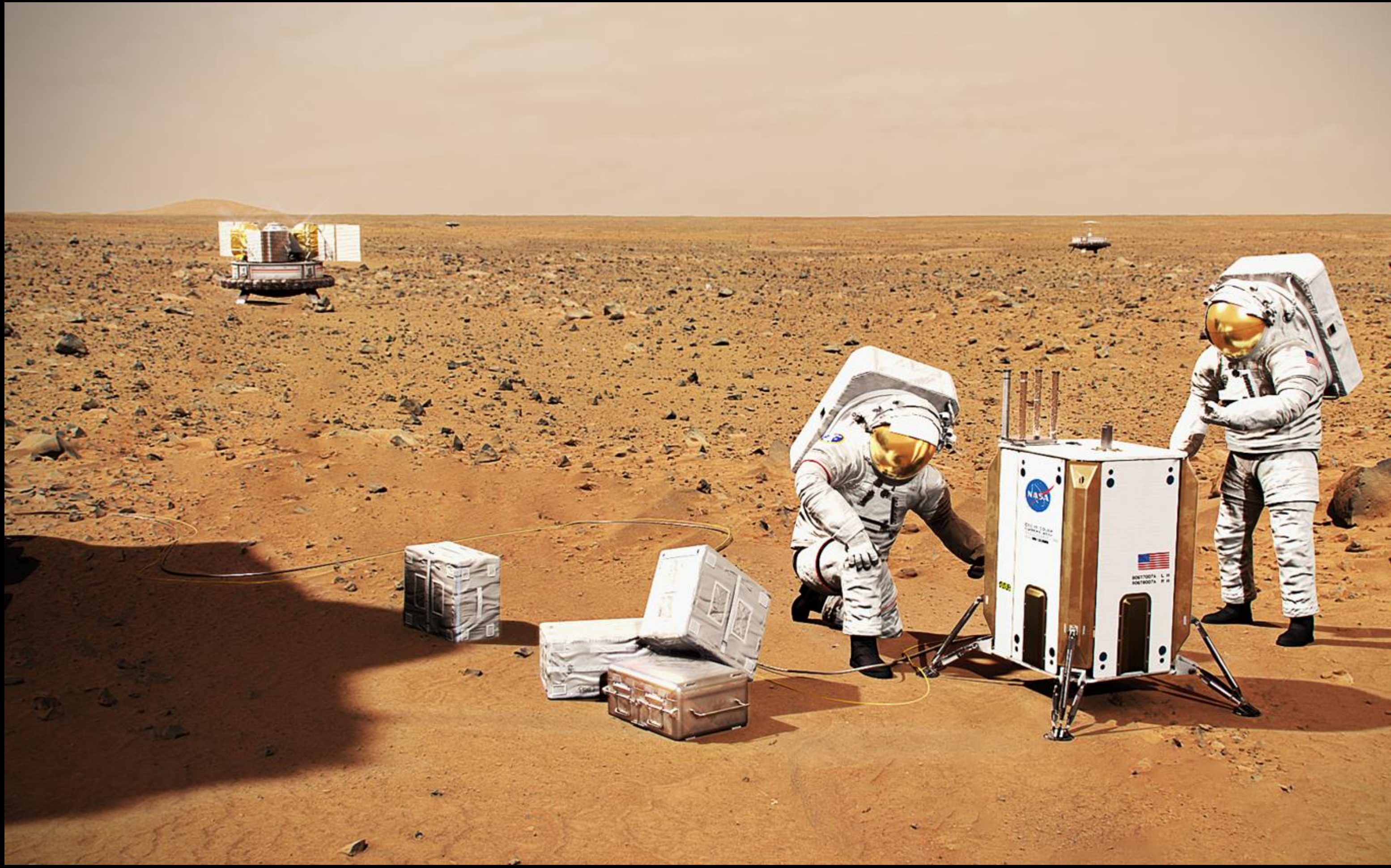
30 Sol Surface Mission

Crew Gravity Re-Adaptation **(7 sols)** Med ops Scout rover	Cargo Off Load and local ops **(2 sols)**	Surface Exploration **(19 sols)**	Launch Prep **(1 sol)**	Launch Opportunities **(1 sol)**

Maximum of 8-hour Extravehicular Activity (EVA) x 20 EVA sols = 190 EVA hours

Ingress and Egress

- **Crew land and ascend from Mars in different vehicles**
  - So crew must changes vehicles on the surface
- **Many EVA activities planned in-between these events**
- **There are several methods that can be used for these transfers**
  - Depressurize cabin and open a hatch (Apollo style)
  - Enter and exit through an airlock
  - Suitports: EVA suits remain on the outside of the vehicle cabin
- **All options have some amount of habitable cabin atmosphere escape**



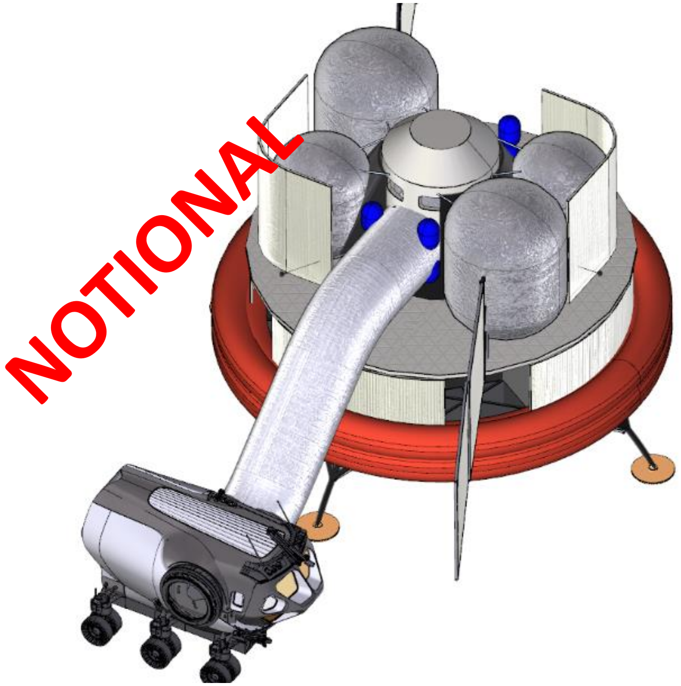
Mars Surface Ingress/Egress Events

Arrival Ingress/Egress

- Suits arrive with crew inside cabin
- Crew don suits and depress cabin
- Suit docked to Pressurized Rover suitport and crew enter cabin
- All nominal surface EVA uses suitport for rover exit and entry

Contingency Ingress/Egress

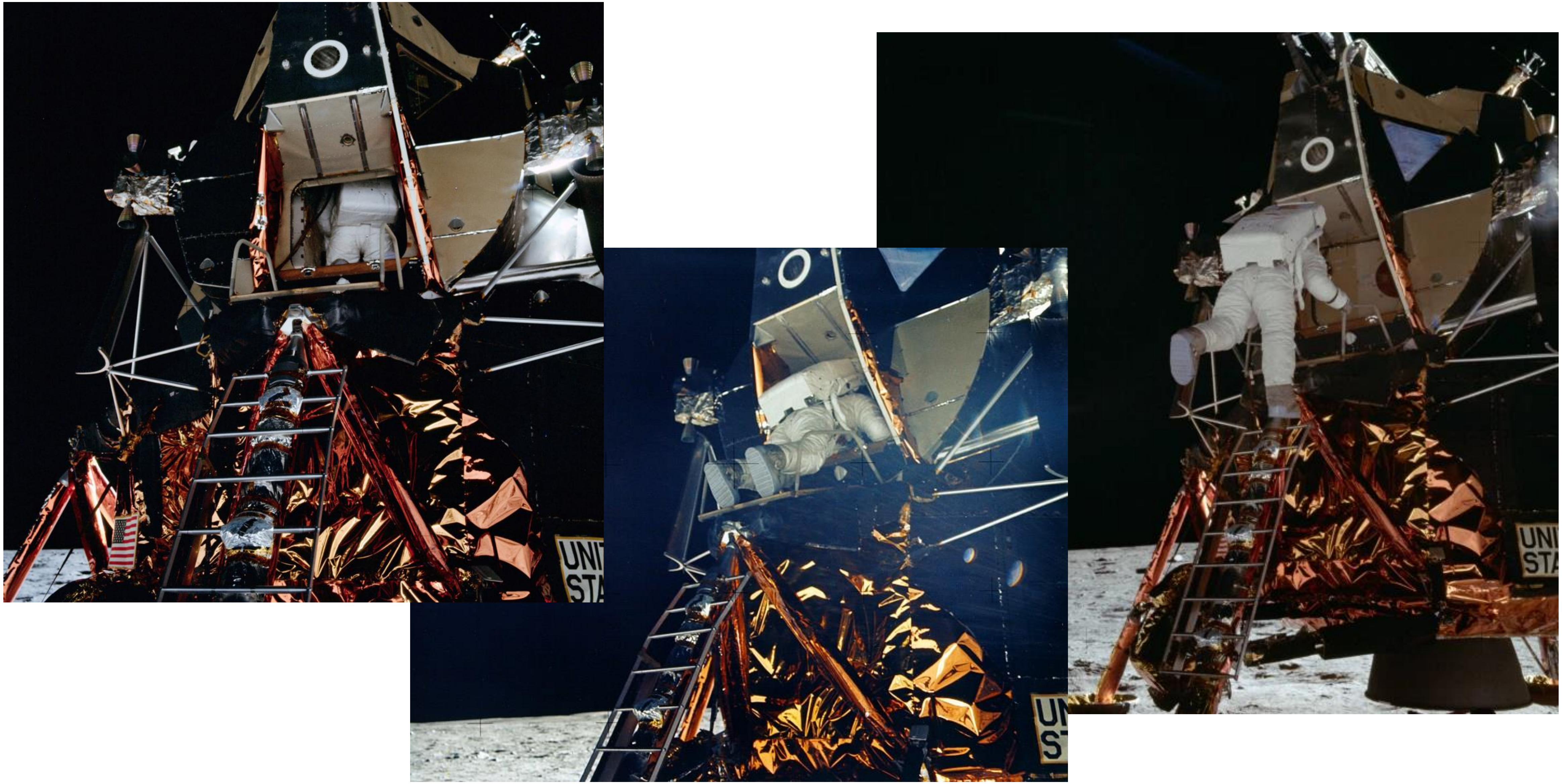
- Contingency scenarios in development
- Example: Incapacitated crew or damaged suit port requires crew to ingress/egress rover via hatch
  - Requires rover cabin depressurization/vent to surface



Nominal Departure Rover-to-MAV Ingress/Egress

- Inflatable tunnel integrated arrives with Mars Ascent Vehicle (MAV)
- Rover docks with tunnel
- Crew shirt-sleeve transfer from Rover to MAV
  - Minimizes Mars dust entering MAV

Apollo LEM Ingress and Egress



Planetary Protection Questions to Consider

- **Given that all hatches and EVA joints will leak (in both directions) how much leakage is acceptable?**
  - Leakage, by definition, is unfiltered
- **If an airlock is used or the entire cabin is depressurized, should there be some sterilization step prior to exiting and before reentering the habitat?**
  - What is the verification criteria?
- **What kind of monitoring of the habitable environment is necessary**
  - HEPA filtering is assumed for capturing airborne particles
  - What type of microbial or chemical detection is needed for air and water? What is the verification criteria?

Waste Management

- **Trash**
  - Consumables
    - Filters
    - Wet wipes
    - Packaging material
  - Broken or unused spare parts and maintenance items
- **Vented gases**
- **Liquids**
  - Grey water
  - Brines
- **Human waste**
  - Liquids
  - Solids

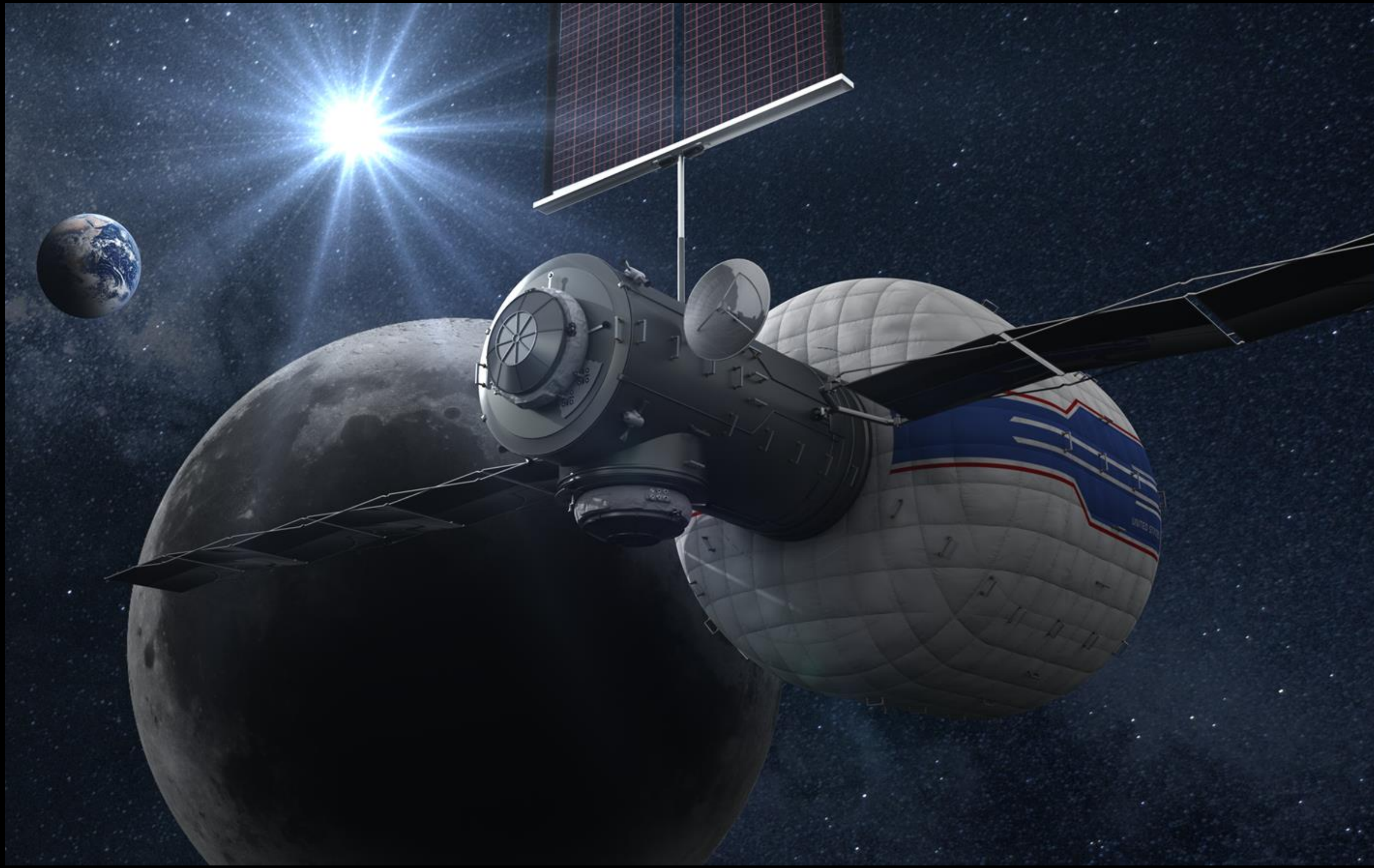
Planetary Protection Questions to Consider

- **What treatment of trash is required before disposal?**
  - Radiation? Antimicrobials? Other?
- **How long should any container be expected to provide its containment?**
- **What is the preferred location for trash disposal?**
  - Disposal below ground, on the surface, above the surface (e.g., lander deck)?
- **How much leakage/venting/etc. from fluid systems is allowable?**
  - All systems are assumed to leak
  - Containment vs special region segregation
- **If HEPA filtering is assumed for cabin atmosphere systems, is venting of CO2 or other cabin gases acceptable? Is additional sterilization of these gases necessary?**
- **Under what conditions can liquid waste be released into the environment?**

Crew Interaction with Science Experiments and Breaking the Chain with Mars

EXPLORE MOON to MARS

- **Experiments include subsurface sampling and searching for signs of life**
- **Samples from these experiments will be returned with the crew**
  - Placed in containment as part of experiment protocol
  - Transferred from surface to orbit as part of the MAV payload
  - Transferred from the MAV to the Transit Vehicle for the return flight to Earth-Moon space
  - Transferred from the Transit Vehicle to an Orion capsule for return to Earth surface



Planetary Protection Questions to Consider

- **Crew proximity to subsurface sampling and search for life experiments. For example:**
  - How close can the crew be to subsurface operations, especially ice?
  - How should these potential life-containing samples be returned with the crew?
- **What are the Mars biomarker or chemical markers for backward detection?**
- **How is backward contamination to be detected and measured?**
- **Should returned samples be stored inside the habitable environment with the crew? While on the surface? In the MAV? In the interplanetary Transit Vehicle?**
- **What microbial detection/monitoring of the surface and in-space habitat environment is required?**
- **Should the crew be allowed to interact with Mars samples during the return transit?**

End of Mission Infrastructure Shut-Down and Vehicle Disposal

EXPLORE MOON to MARS

- **At the conclusion of the surface mission, human-contaminated equipment will remain**
  - Whether these systems remain active or are deactivated will depend on subsequent mission strategy
- **After crew rendezvous with their interplanetary transit vehicle, their MAV will be left behind in orbit**

Planetary Protection Questions to Consider

- **What steps should be taken for the long-term disposal of surface systems?**
  - Remaining fluids (e.g., water, propellants, etc.) could freeze and burst containment without adequate heating or cooling
    - Sterilize as appropriate and abandon in place
    - Vent overboard
    - Drain into purpose-built long-term containment
  - Is long-term monitoring (for biological activity) of the landing site necessary? If so, for how long?
- **What steps should be taken for the long-term disposal of the Mars Ascent Vehicle (MAV) following crew departure from the vicinity of Mars?**
  - Maneuver into stable disposal orbit? What orbit lifetime is considered adequate?

Contingencies

- **Unplanned leaks or spills (outside habitable spaces)**
  - Do we clean it up?
  - What are the standards for deciding the spill has been sufficiently cleaned or remediated? How will the crew verify?
- **Inadvertent opening of sample container inside a habitable space**
  - How is contamination to be detected and measured?
  - How should any sample material released be collected, contained, and stored? How will the crew verify that the release has been sufficiently cleaned?

Testing Opportunities on the Moon

- **What aspects of Planetary Protection would benefit from testing on the Moon?**
  - High level guidance for testing Mars mission systems and operations on the Moon
- **Opportunities exist for testing equipment or protocols for most (all?) of the topic areas discussed above**
  - Ingress/Egress
  - Biological characterization
  - Waste management
  - Cleaning/sterilization techniques
  - Clean sampling protocols
  - Impacts on drilling and subsurface sampling

Backup