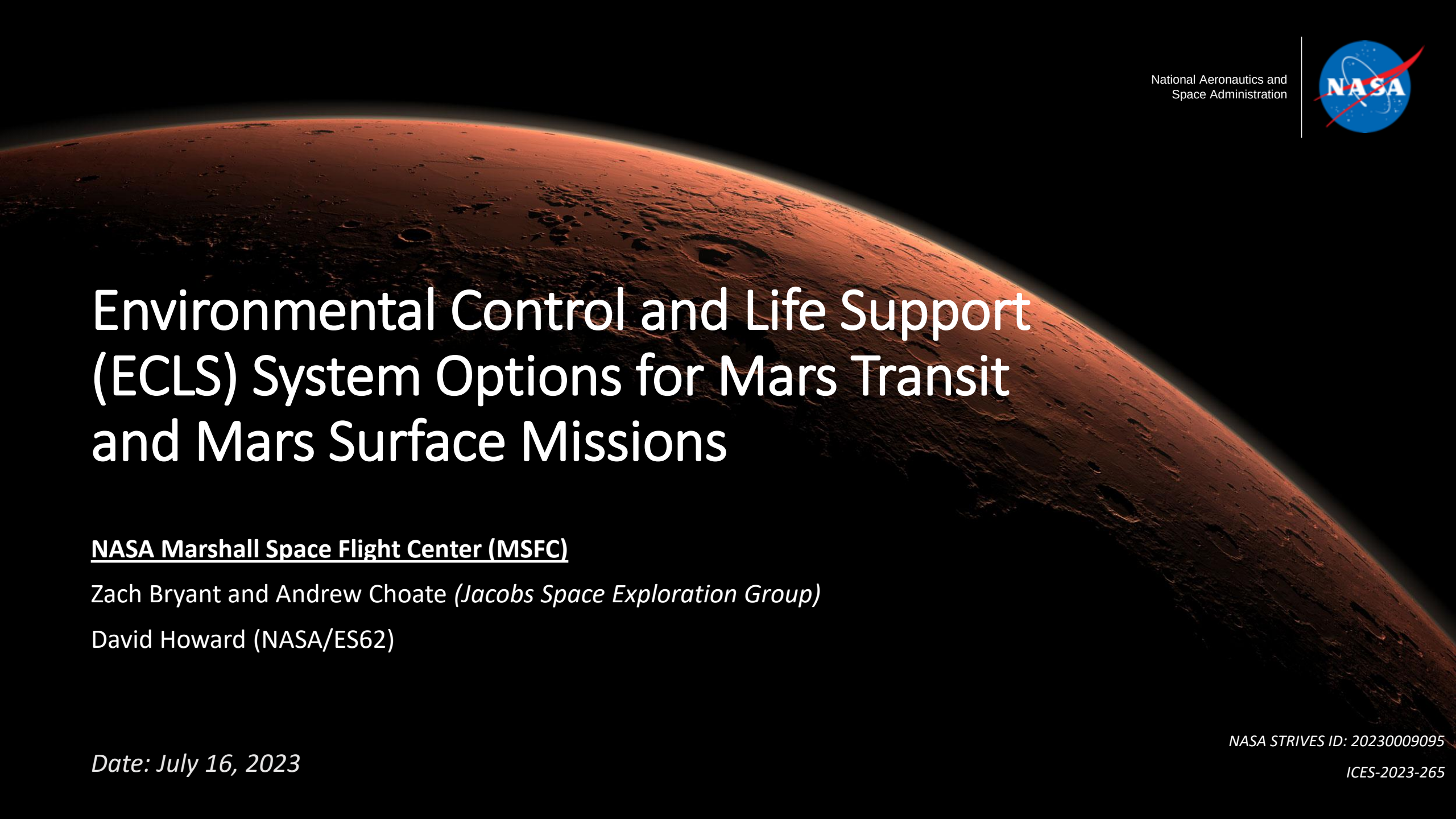
National Aeronautics and Space Administration



Environmental Control and Life Support (ECLS) System Options for Mars Transit and Mars Surface Missions

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David Howard (NASA/ES62)

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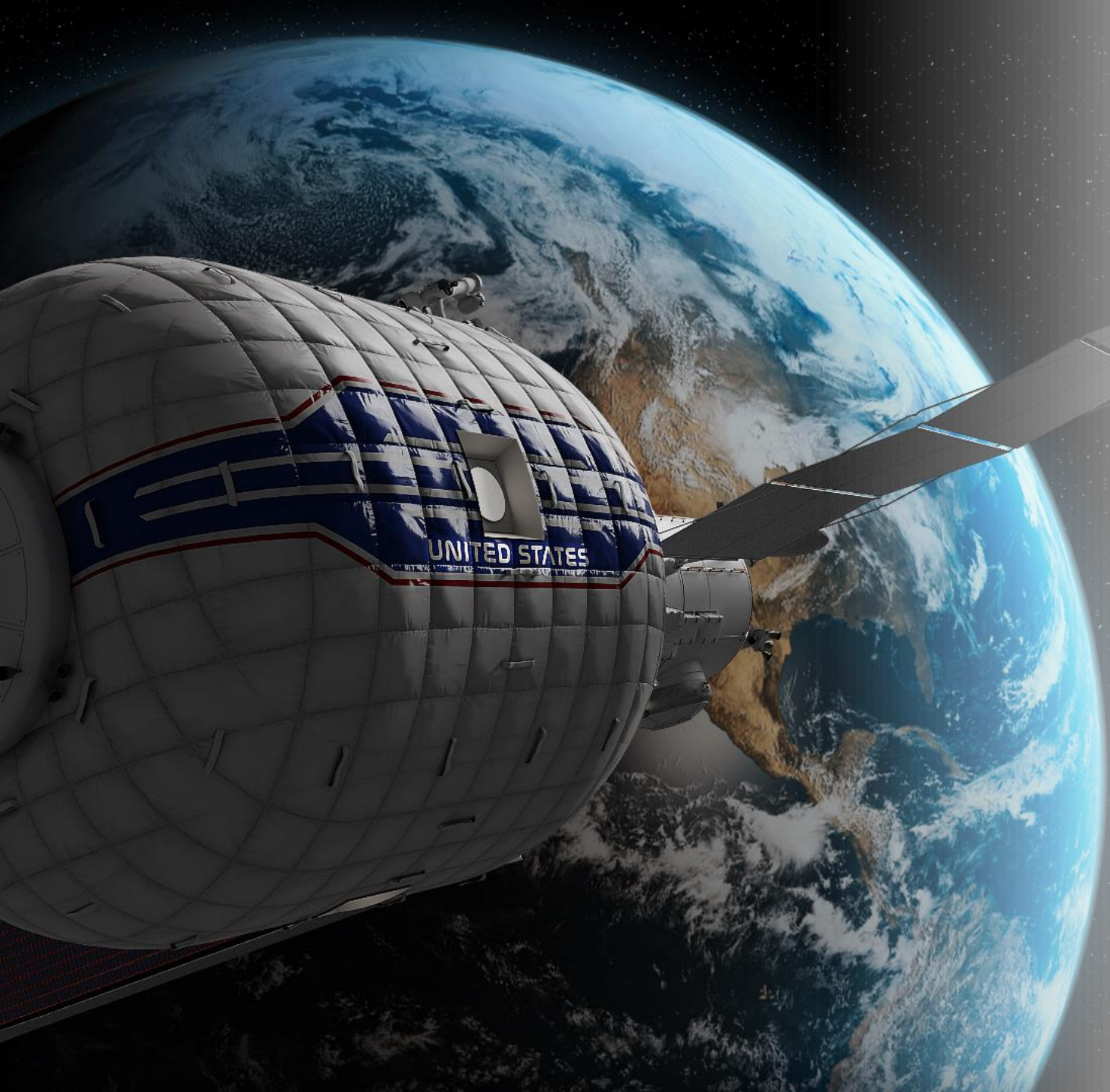
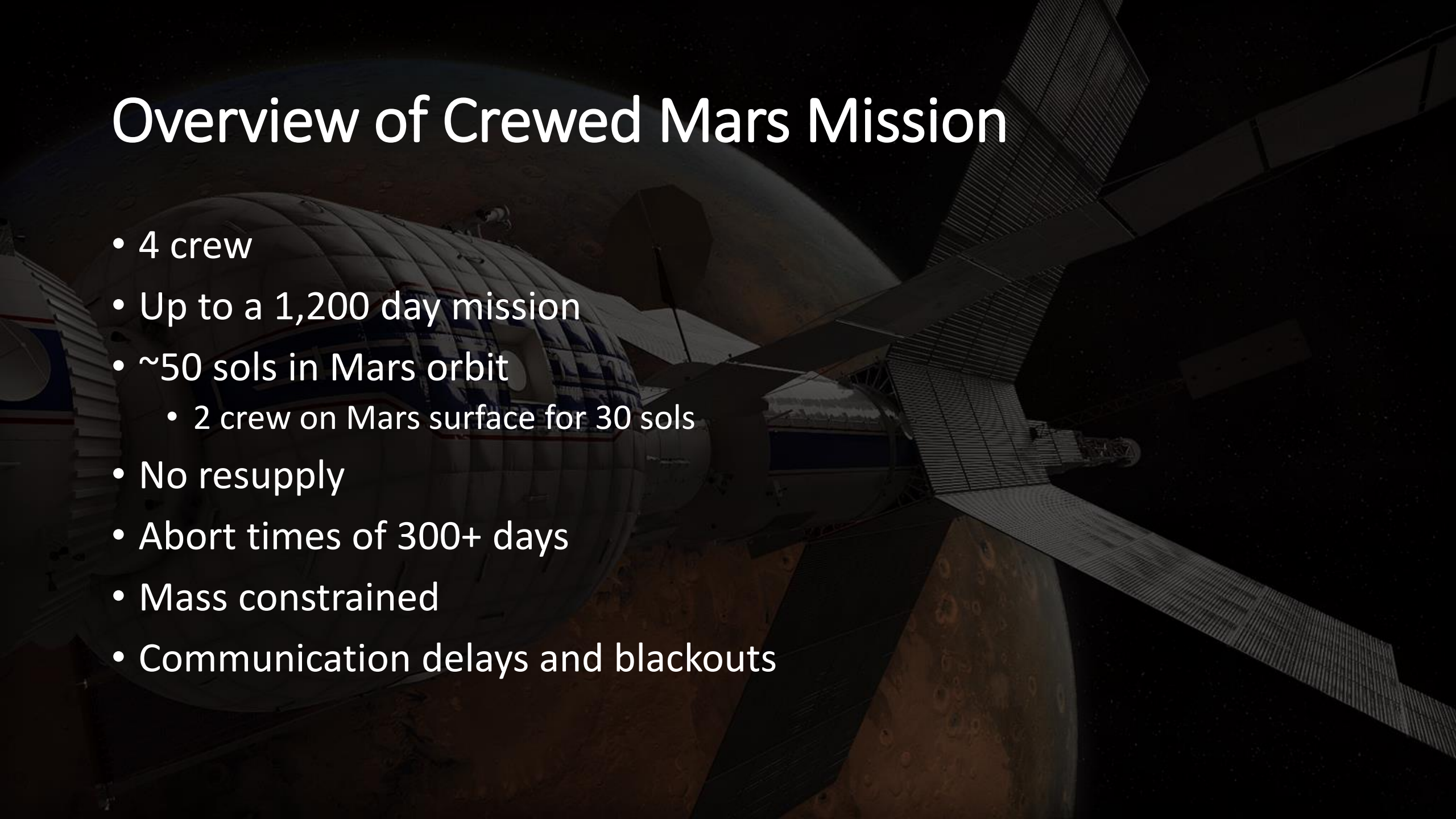


Objective

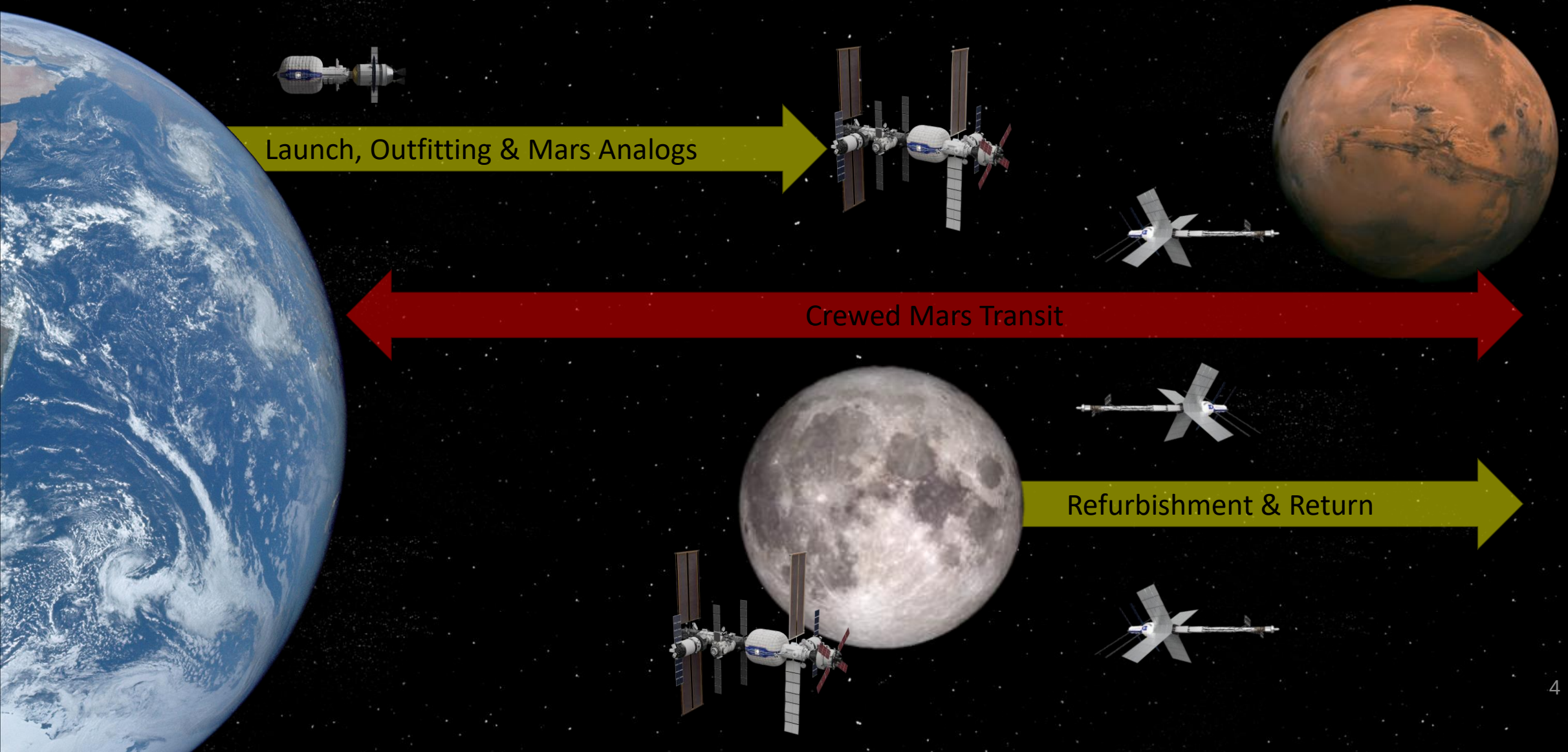
- Overview of Crewed Mars Mission
- Overview of Mars Transit Habitat (TH)
- Notional Mars TH ECLS
- Overview of Mars Surface Habitats
- Notional Mars Surface Habitats ECLS
- Conclusion

Overview of Crewed Mars Mission

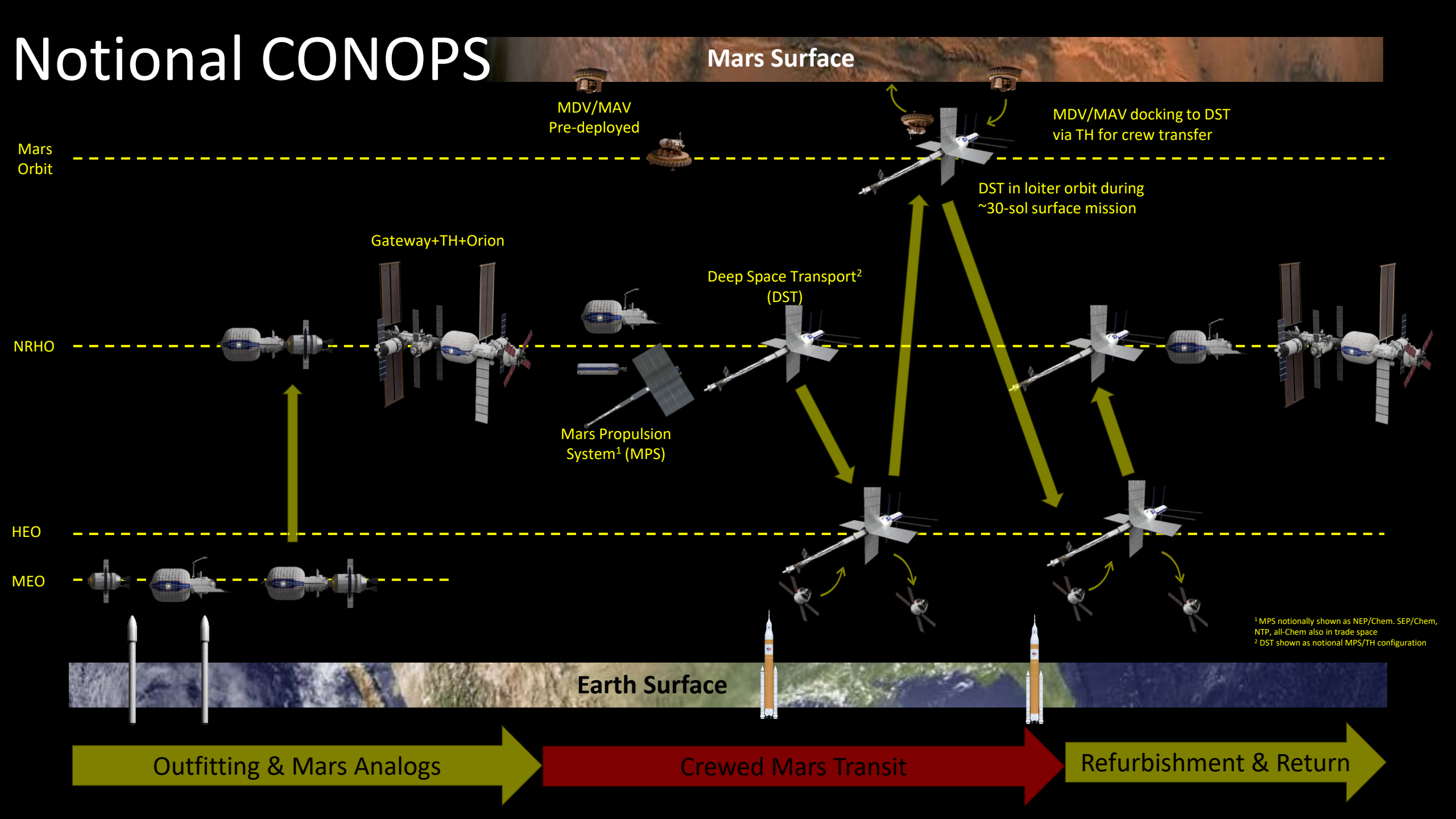


- 4 crew
- Up to a 1,200 day mission
- ~50 sols in Mars orbit
  - 2 crew on Mars surface for 30 sols
- No resupply
- Abort times of 300+ days
- Mass constrained
- Communication delays and blackouts

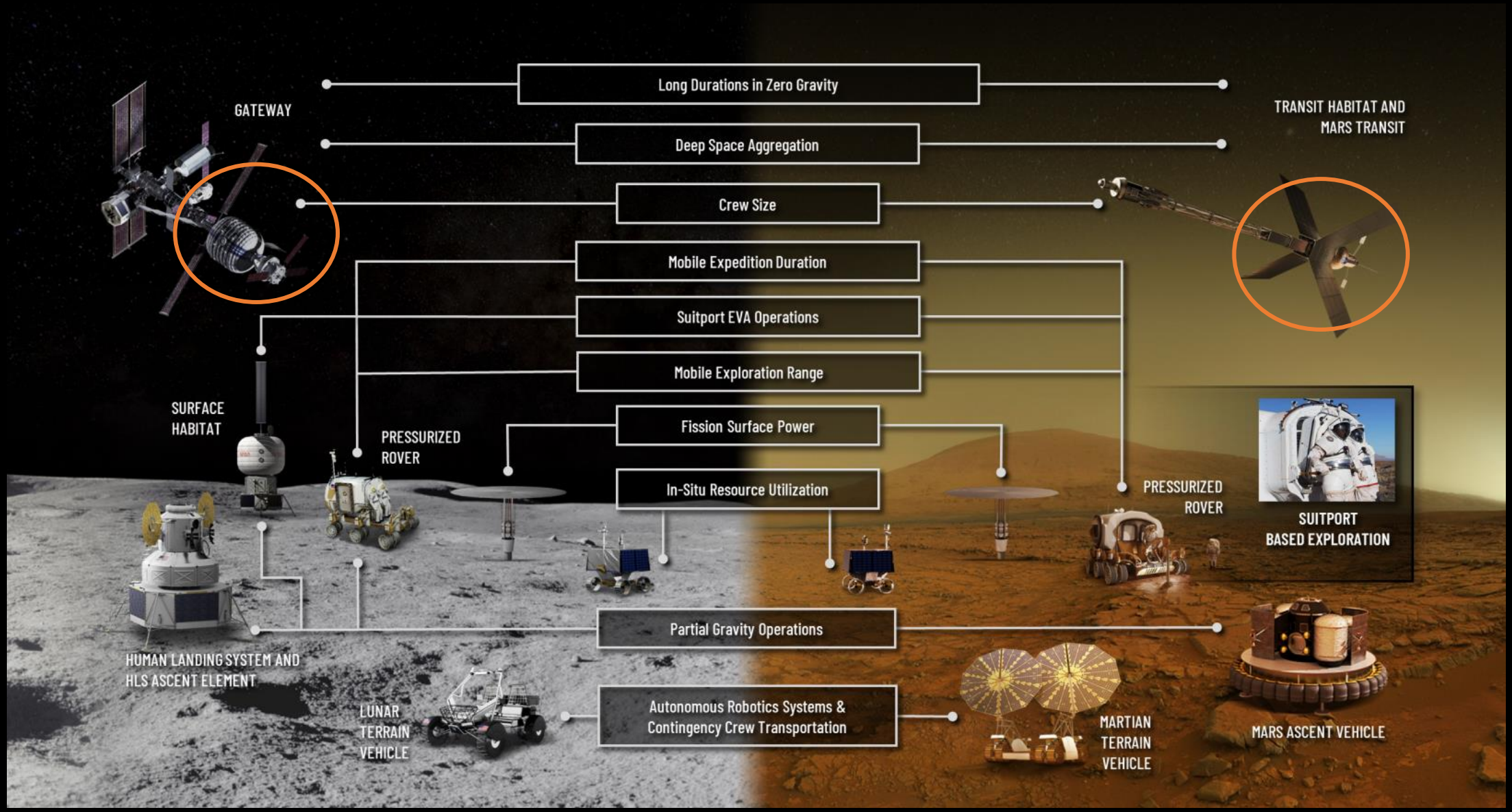
Moon2Mars Integration & CONOPS Phases



Notional CONOPS



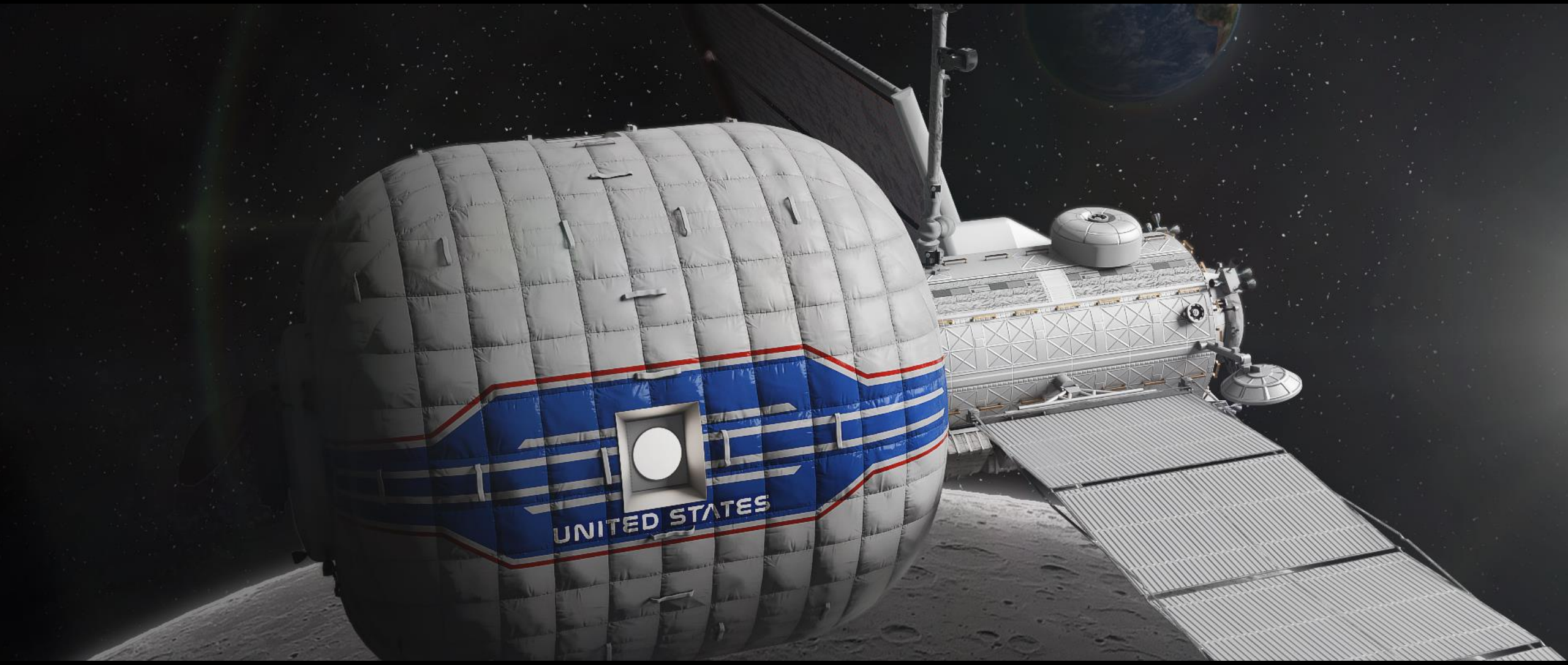
Moon2Mars Exploration Element Concepts



TH Overview

- Hybrid inflatable-metallic habitat with dry mass (26.4 metric tons) capable of being launched commercially and supplied with logistics in cis-lunar orbit
- Support 4-crew during Lunar-Mars Analog missions leading up to a 700-1110-day Mars mission
- Dock w/ an interim propulsion bus or Gateway for first ~5 years until Mars Propulsion System (MPS) elements available
- Extends Gateway operations beyond 60 days
- 10.2 psia (26.5% O_2) atmosphere for Gateway ops
- 14.7 psia (21% O_2) atmosphere for transit and analog missions
- Contingency Airlock and EVA capability
- Planned reuse for multiple missions over 15-year lifetime
- Builds on ISS and commercial investment in deep space habitation
- Mid-2030s launch with late 2030s Mars Departure

Notional Mars TH

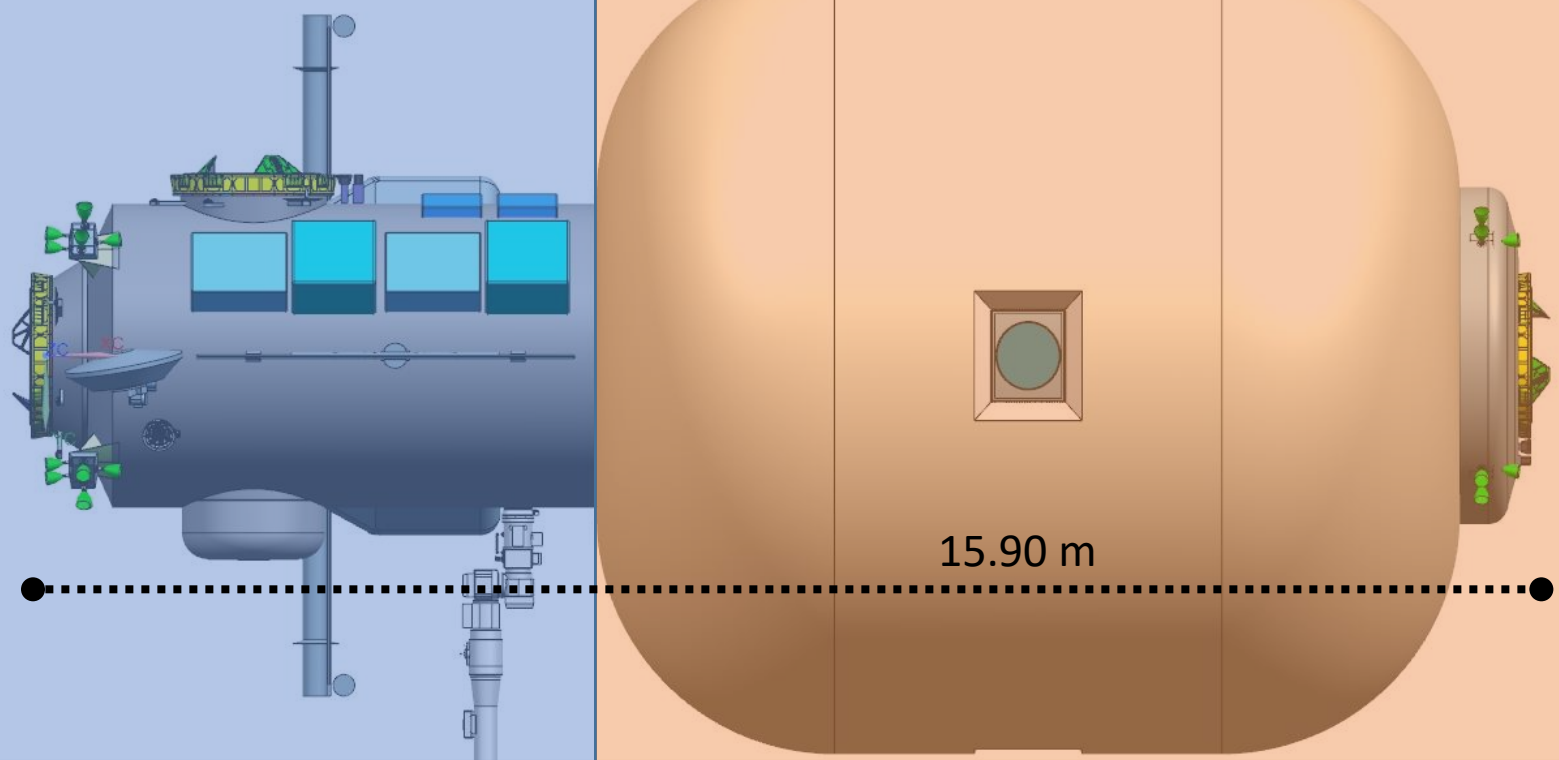


TH Concept Pressurized Volume

TH Overall Pressurized Volume: ~400 m^3

Metallic Volume (~35m^3)

Soft Goods Volume (~365m^3)



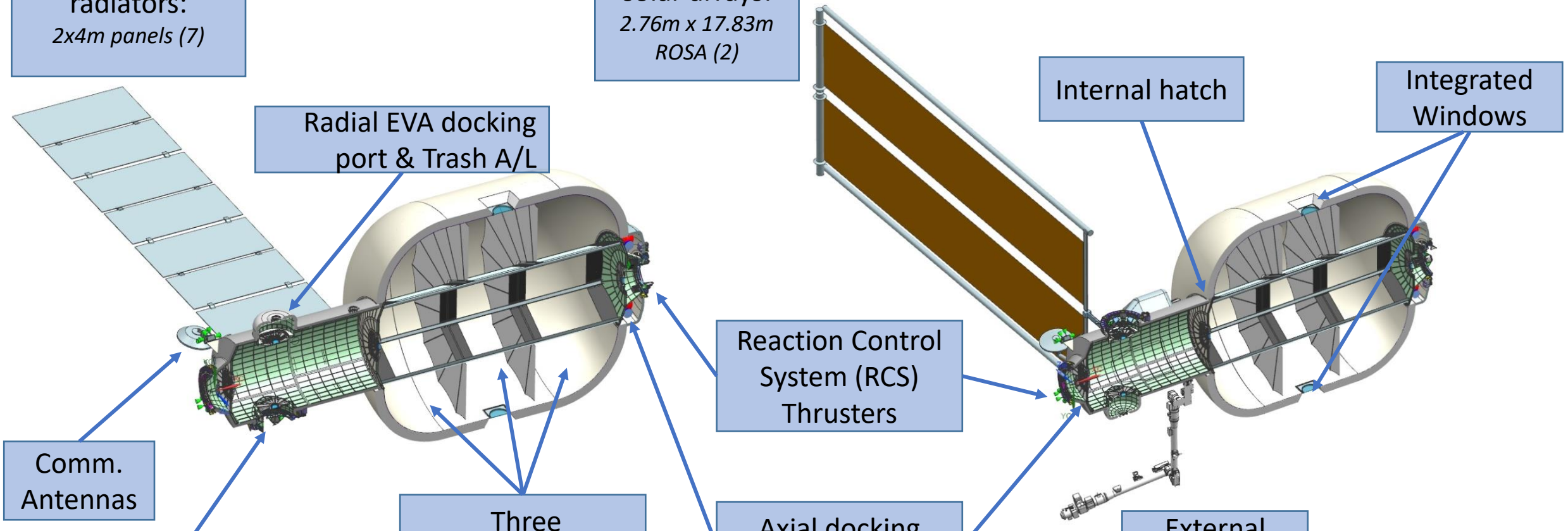
Similar to: 1700 ft^2 home
ISS Pressurized Volume: ~1000 m^3 (~390 m^3 habitable)

TH Concept OML Features

Deployable radiators:
2x4m panels (7)

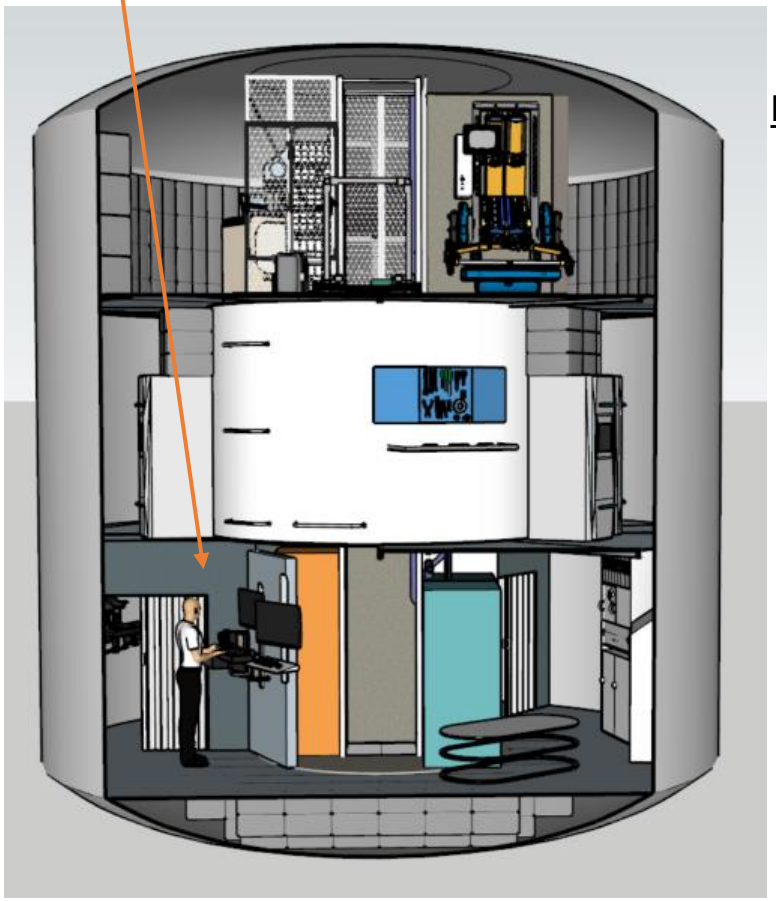
Deployable solar arrays:
2.76m x 17.83m ROSA (2)

TH Overall Pressurized Volume: ~400 m^3
Inflatable: ~365 m^3, Metallic: ~35 m^3

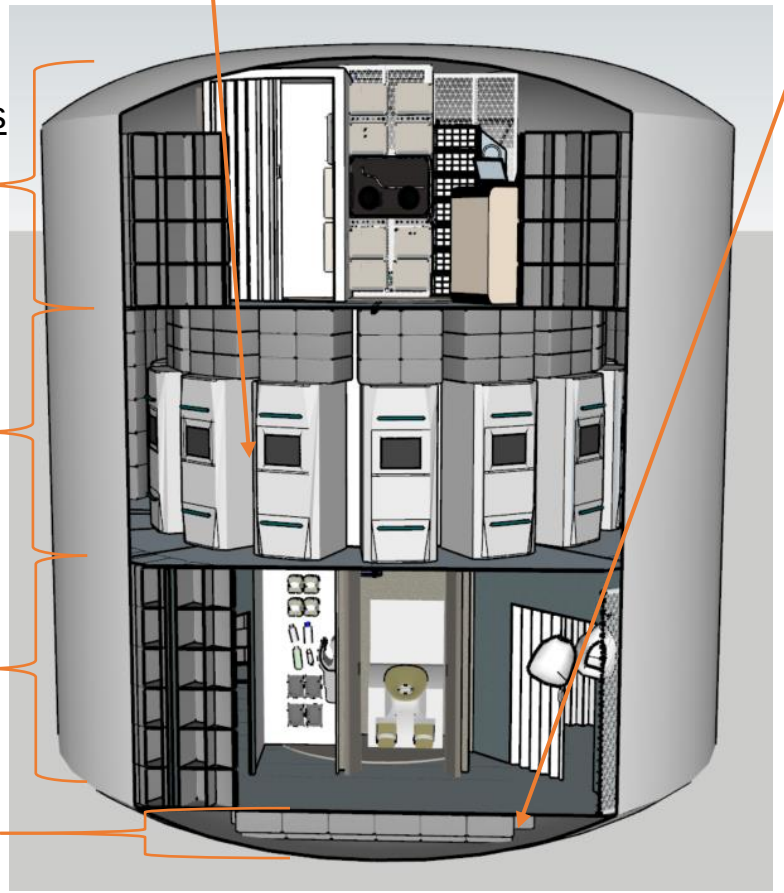


TH Concept Interior Features

Level 1 – Galley, Command & Control, Medical, Hand Washing Station, Toilet (1 of 2), Logistics Management, Trash Management

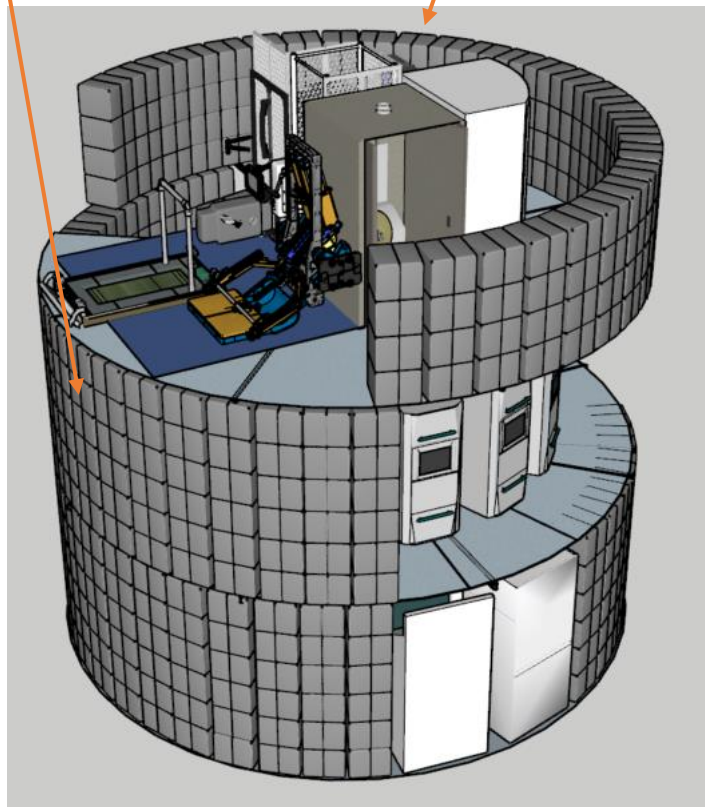


Level 2 – Crew Quarters, Sub-Systems, Maintenance Stations



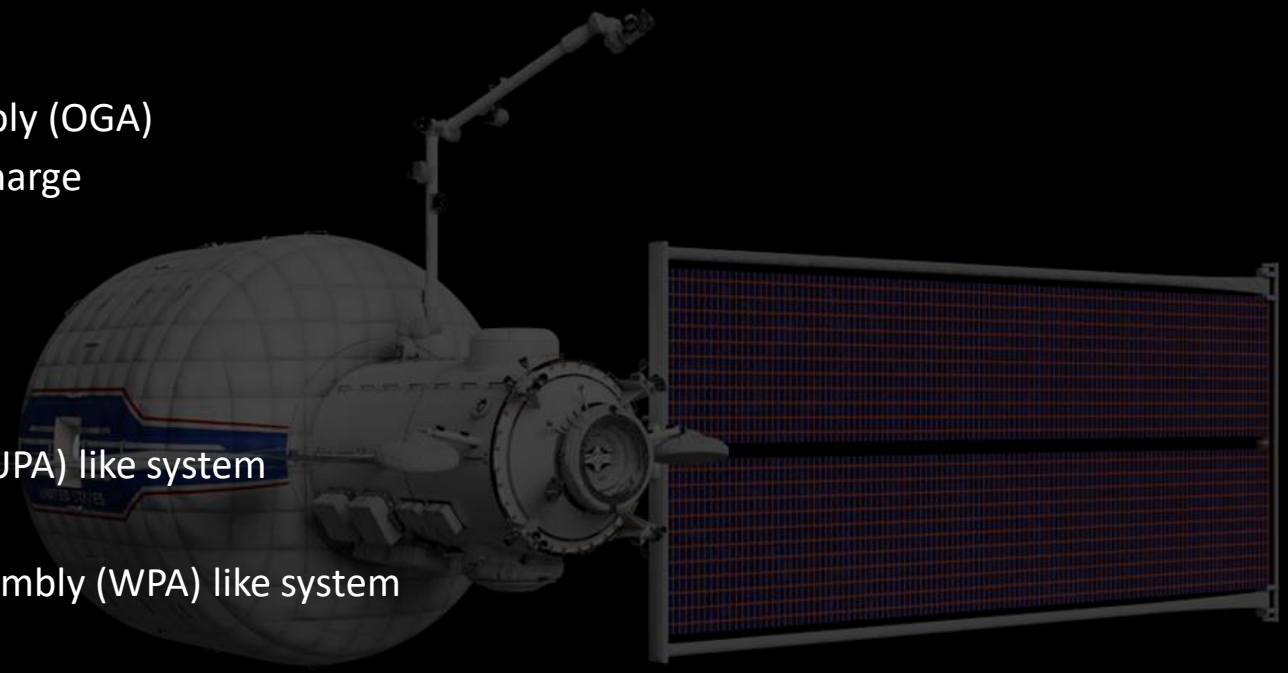
Storage – Cargo Transfer Bags (CTB) lining the outer wall, additional storage below Level 1

Level 3 – Exercise, Utilization, Toilet (2 of 2), Hygiene Station



Notional Mars TH ECLS

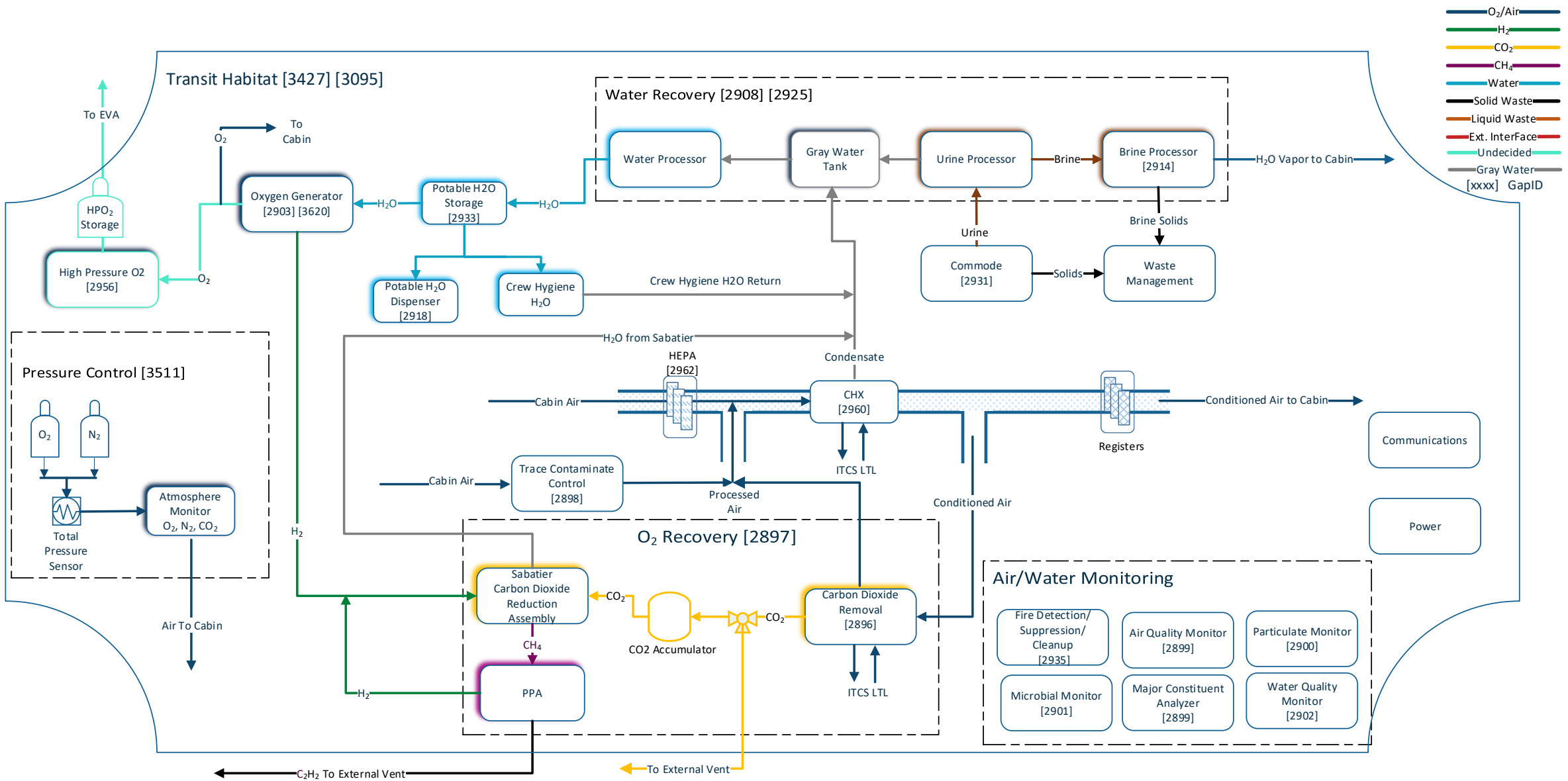
- Closed loop system based on an evolution/upgrade of legacy ISS systems
- O_2 generation
  - H_2O electrolysis system like Oxygen Generation Assembly (OGA)
  - High pressure O_2 (> 3,600 psi) to allow for EVA suit recharge
- CO_2 removal
  - Four Bed CO_2 scrubber like system
- H_2O recycling/recovery
  - Crew urine recovery via a Urine Processing Assembly (UPA) like system
  - Water from brine via a brine processing system
  - Potable water processing using a Water Processor Assembly (WPA) like system
- H_2O generation
  - Utilize captured CO_2 and waste H_2 in a SABATIER like system
  - Possibility for further generation through SABATIER post processing
  - Additional H_2O generation may not be necessary depending on amount of water content in food supply



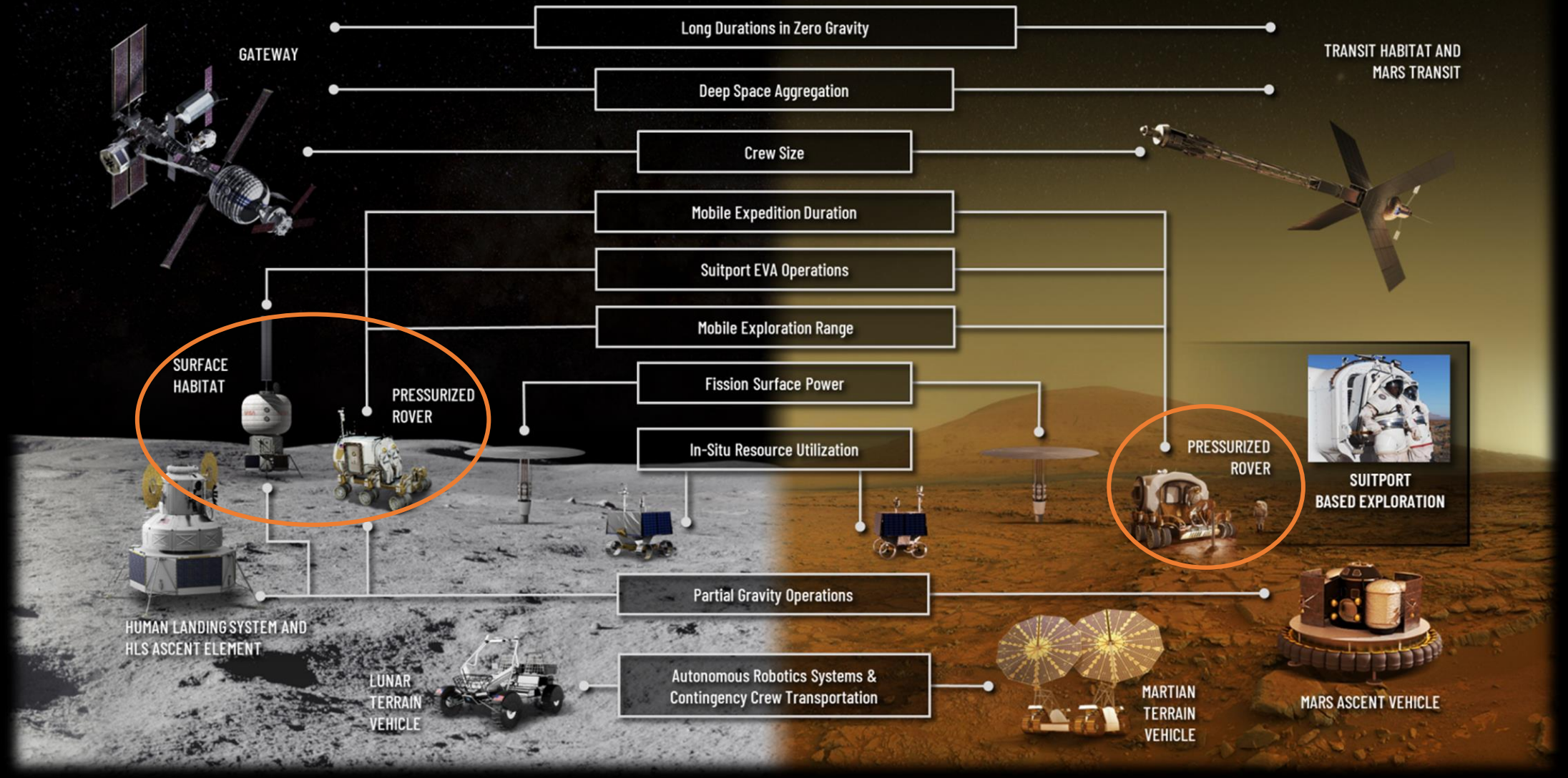
Notional Mars TH ECLS

- Atmosphere control
  - Tanked supply of O_2 and N_2 will help to control atmosphere needs beyond OGA
    - Trash jettisons, vehicle dockings, science/utilization, etc.
  - Tanked O_2 will support contingency EVAs
  - Cabin pressure changes for various mission phases (nominal flight, docked to Gateway, etc.)
- Temperature and humidity control
  - Use of a condensing heat exchanger for temperature control
  - Allows for humidity control and water recovery
  - Air movement/ventilation
  - Air scrubbing (dust, FOD, trace gasses)
- Emergency equipment
  - Fire suppression/recovery
  - Breathing masks

Notional Mars TH ECLS

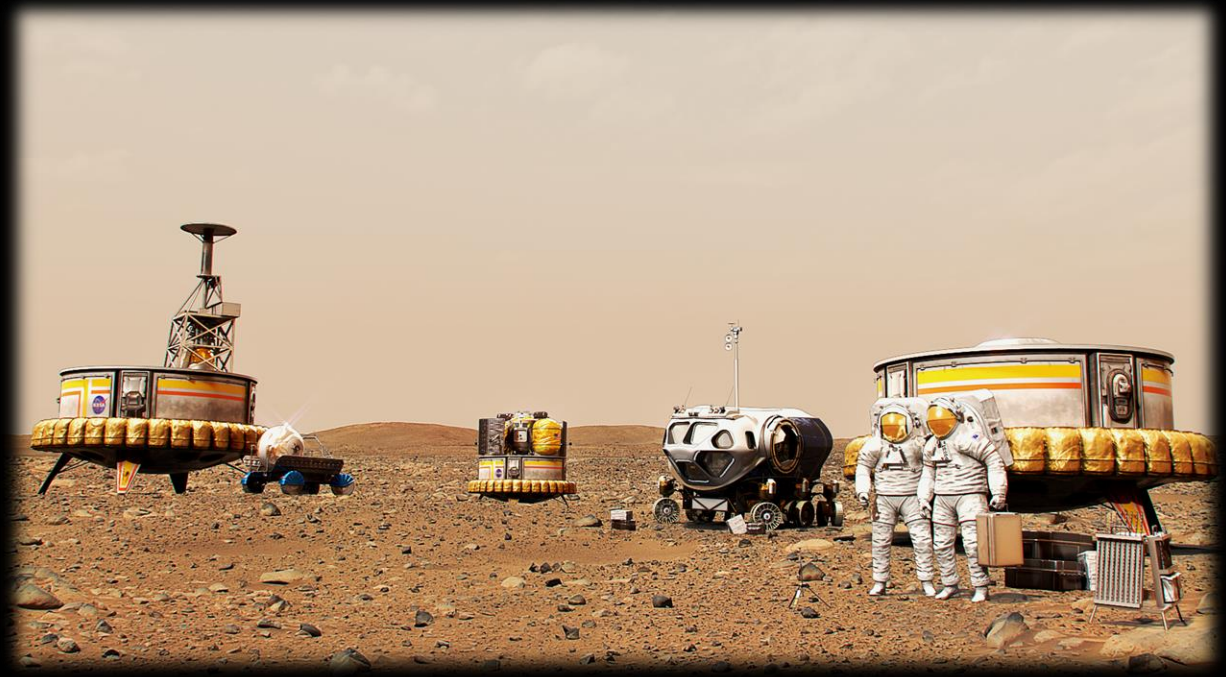


Moon2Mars Exploration Element Concepts



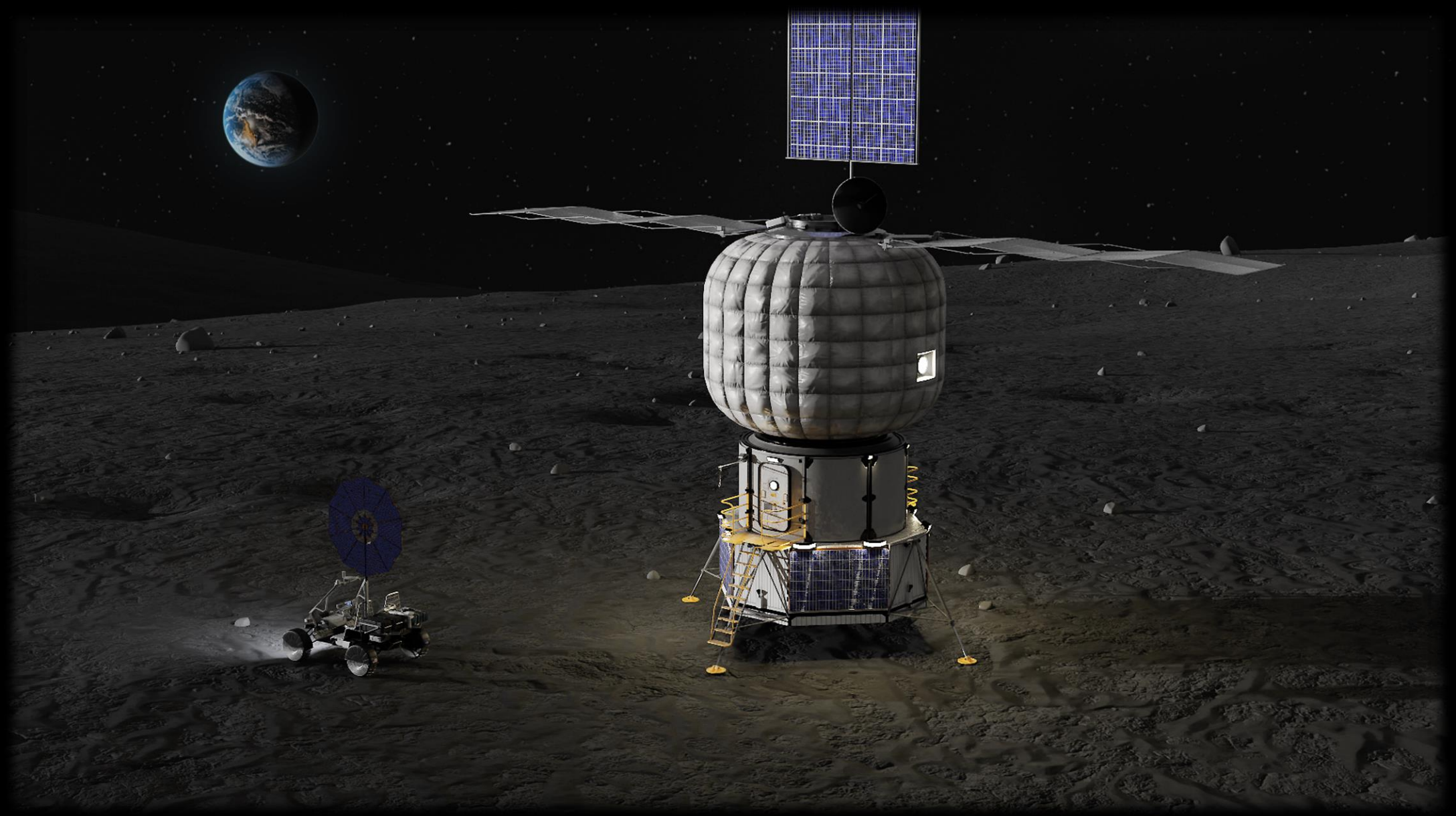
Overview of Mars Surface Habitats

- Habitation elements will reflect surface mission objective and architecture
- *Proposed* Initial Missions:
  - Mobile habitation (via Pres. Rover)
    - Small, power limited, little space
    - 8.2 psia atmosphere
  - Short term stay
    - Up to 30 sols
- Subsequent Missions
  - Larger more permanent type habitat
    - Similar to lunar surface habitats
    - 8.2 psia atmosphere
  - Longer stays
    - 30+ sols



Notional Mars Descent Vehicle and Pressurized Rover

Notional Lunar Surface Habitat



Notional Mars Surface Habitats ECLS

- Initial Missions
  - Open loop
  - Tanked O_2 and N_2
    - >3,600 psi for EVA suit recharge
    - Ability to support multiple EVAs (depress/repress events)
  - Tanked water
    - Used water will most likely be stored for planetary protection
  - Urine storage
  - Small CO_2 scrubber
    - Amine type system similar to the Orion capsule
  - Filtration/ventilation/humidity control
    - Effectively remove toxic Martian dust
    - Humidity control through membrane system or in conjunction with CO2 scrubbing amine system

Notional Mars Surface Habitats ECLS

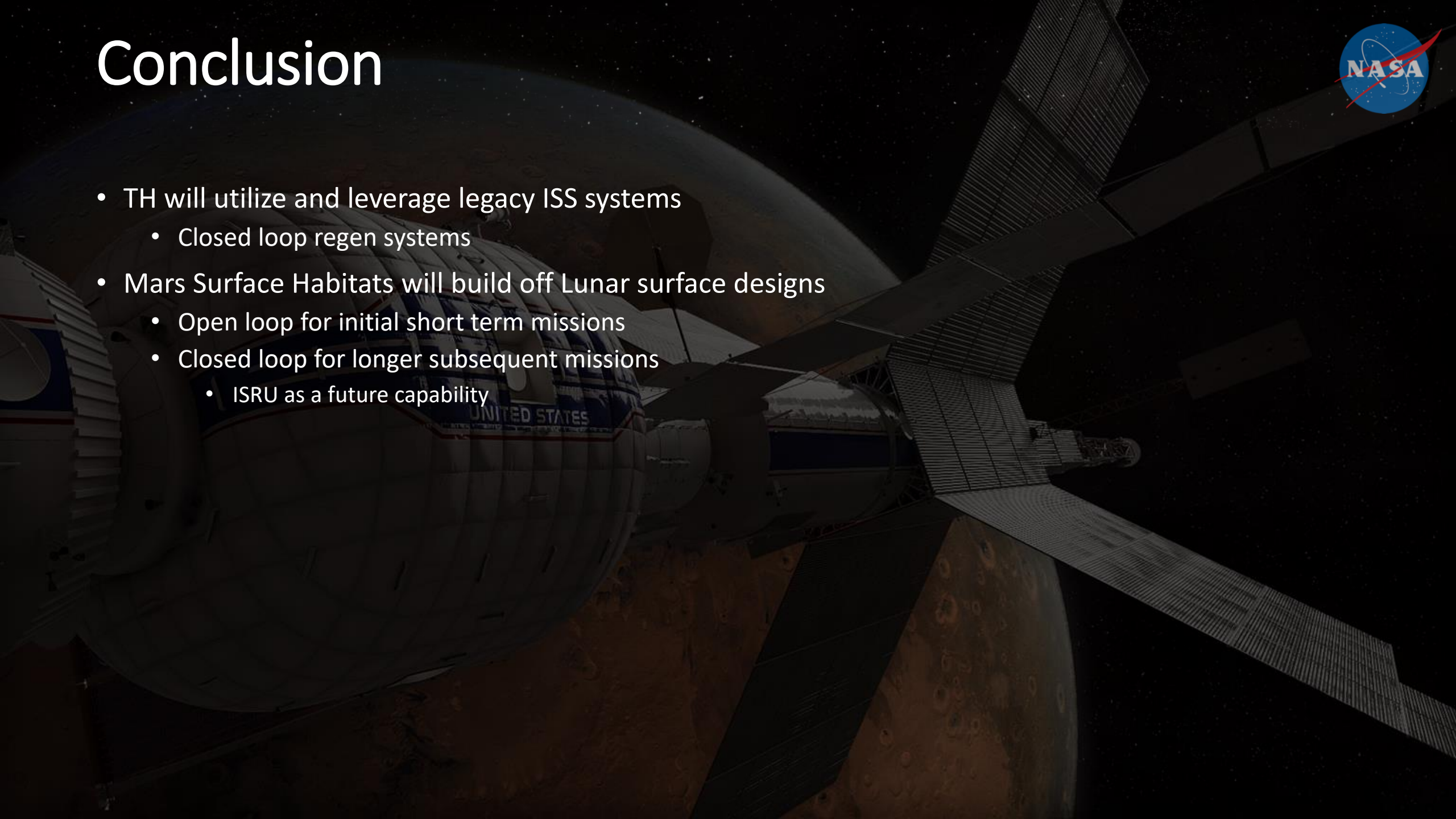
- Subsequent Missions
  - Closed loop
  - Regen systems
    - Similar to systems from the Transit Hab
    - Minimize Martian dust in the condensate
  - High pressure O_2 generation
    - >3,600 psi for EVA suit recharge
  - 3/8g compatibility
  - Martian atmosphere at ~5 torr
    - Could cause longer vent/bakeout times if vacuum access required

Notional Mars Surface Habitats ECLS

- In-Situ Resource Utilization (ISRU)
  - No immediate plans
    - Could be utilized on longer term missions
  - Water from ice deposits that can be processed through the regen system
  - Martian atmosphere is 95% CO_2
    - Recover O_2 as proven by NASA MOXIE hardware on the Mars Perseverance rover
- Dormancy
  - Hardware will experience significant dormancy periods
  - No set time between missions, optimal Mars departures every ~2 years
  - Systems will need to be able to be brought online out of dormancy with goal to minimize crew time/interaction required
  - Wetted systems will be difficult

Conclusion

- TH will utilize and leverage legacy ISS systems
  - Closed loop regen systems
- Mars Surface Habitats will build off Lunar surface designs
  - Open loop for initial short term missions
  - Closed loop for longer subsequent missions
    - ISRU as a future capability



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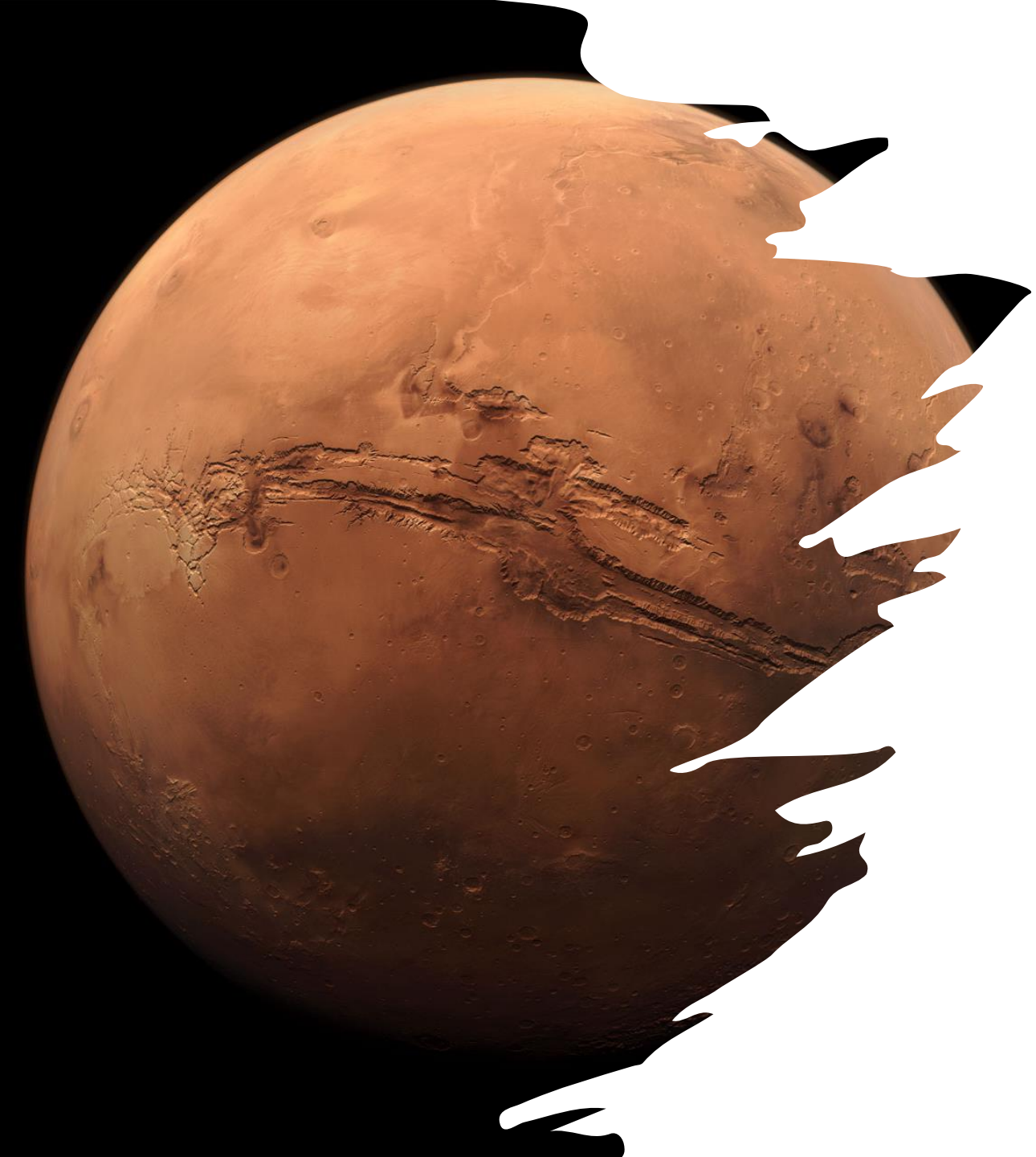
Habitation ECLS

Special Thanks!

Paul Kessler, James Johnson

Questions

Backup



Key Mission & Functional Challenges

- No spares resupply chain during transit
- Impact on propulsion element size
- Waste and trash management in transit/loiter orbits
- Logistics storage capacity for mission
- Human health and performance for long duration missions
- Long duration shakedown
- Radiation & Micrometeoroid/Orbital Debris (MMOD) protection
- Communication delays/blackouts
- Ability to recover from major habitation failures

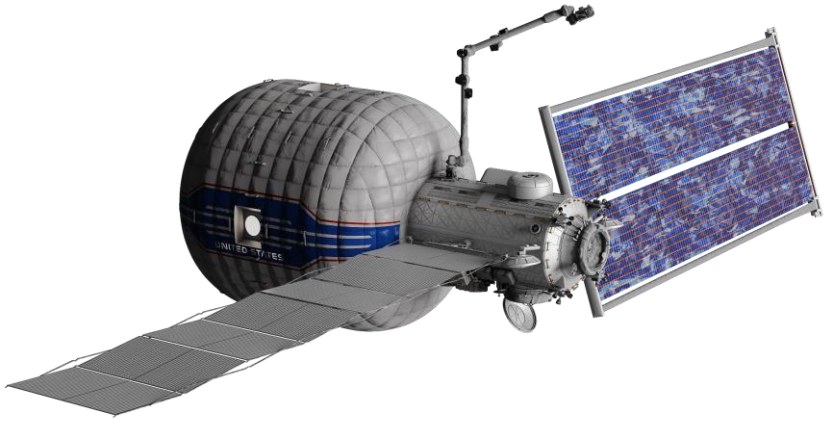
Ground Rules & Assumptions

Significant GRs:

- 4 crew for up to 1,200-day Mars Transit mission duration
- 26.4 mt target dry mass (including mass growth allowance (MGA) and margin)
- Autonomous operation when uncrewed
- Max uncrewed dormancy of up to 3 years
- Minimum of 2 axial and 1 radial docking ports
- Performs a series of up to ~180d Mars Analog missions while docked at Gateway
- Self-sufficient habitat once fully deployed at orbits up to 1.0 Astronomical Unit (AU), capable of receiving power from Mars propulsion system beyond 1.6 AU
- 14.7 psia 21% O2 atmosphere nominal, capable of 10.2 psia 26.5% O2 during Gateway docked open-hatch ops
- Safe Haven and Solar Proton Event (SPE) Shelter
- 15-year life with multiple missions of increasing duration
- TH Sparing and Maintenance - Manifested to achieve 99% system availability

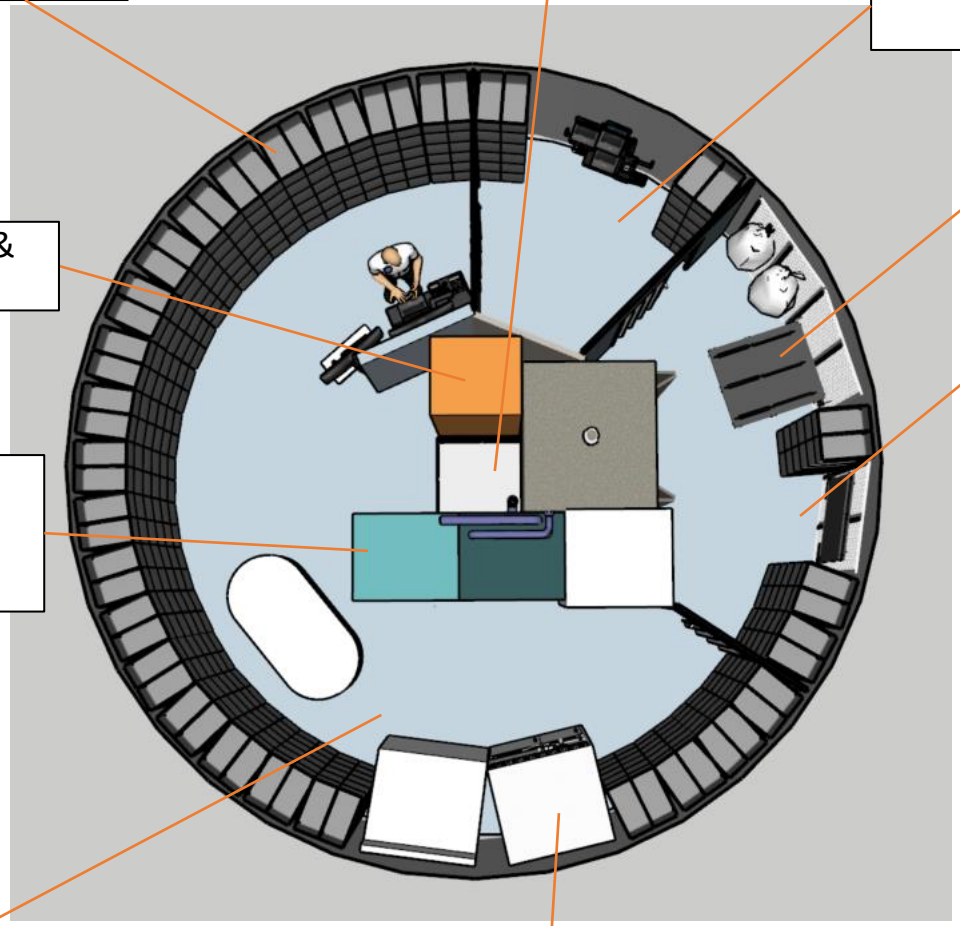
Significant Assumptions:

- Near-Rectilinear Halo Orbit (NRHO) via Commercial Launch Vehicle(s)(CLV). Options for SLS cargo delivery are possible but should feed cost assessments.
- Early 2030's launch with Mars mission in late 2030's
- Replenishable Reaction Control System (RCS) through docking or Gateway interface between mission phases (analogs, Mars Propulsion System (MPS) shakedown, Mars transit)
- Contingency EVA airlock
- Trash/waste removal (11.6 kg/day avg)
- Accommodate 1000 kg of science and utilization payloads



M2M Habitation Considerations Technical Memo.pdf

TH Concept Interior Features



Logistics Stowage

Vertical Access (above & below)

Private Medical Area

Computer & Avionics

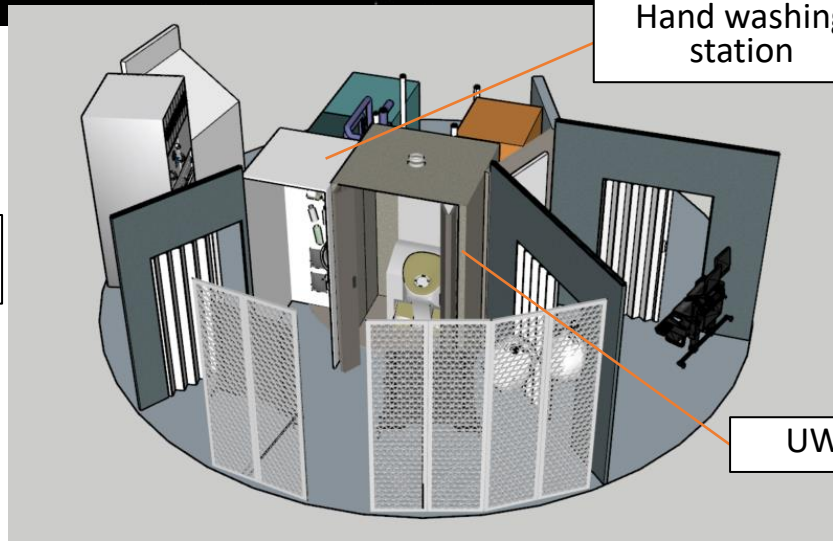
Waste Management

Logistics Management

2 ISPRs (Thermal & Additional Systems)

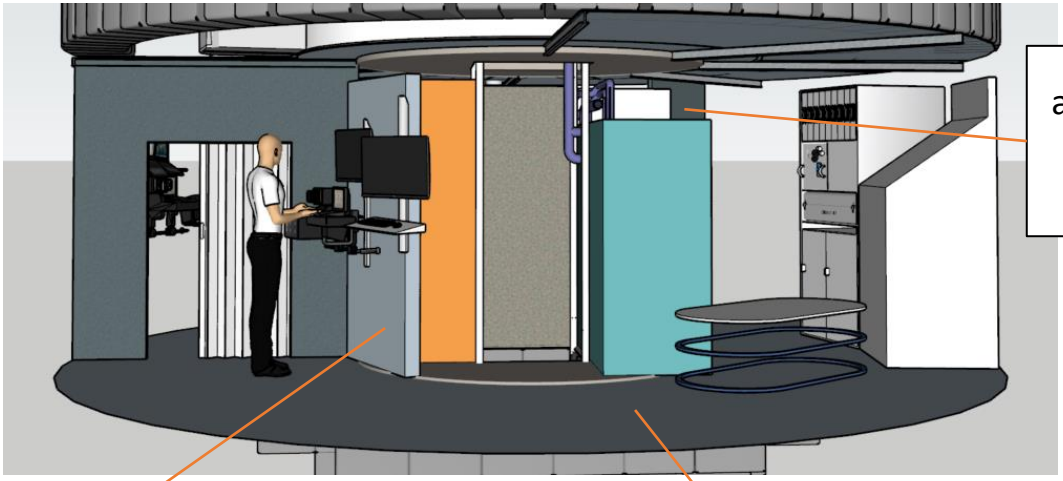
Galley & Meals

Food Processing



Hand washing station

UWMS

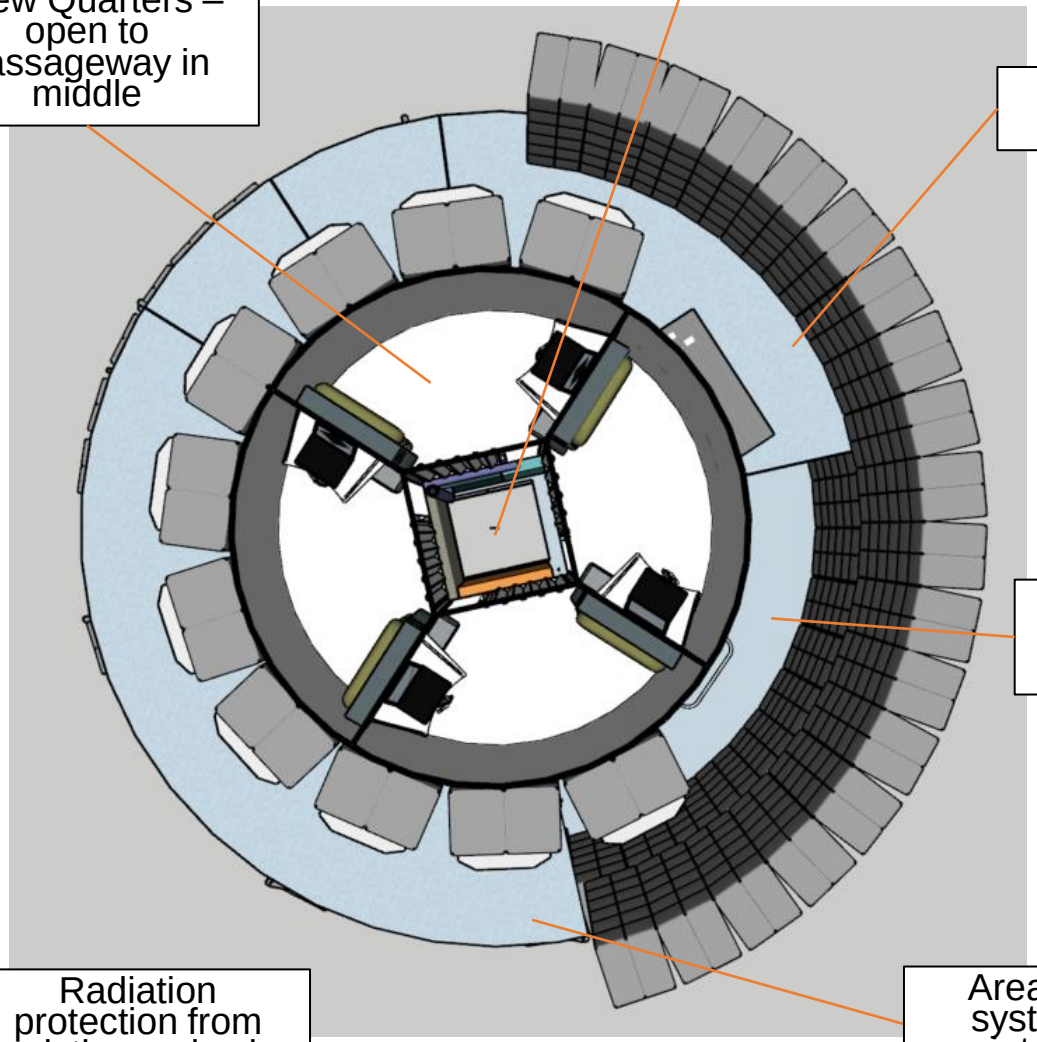


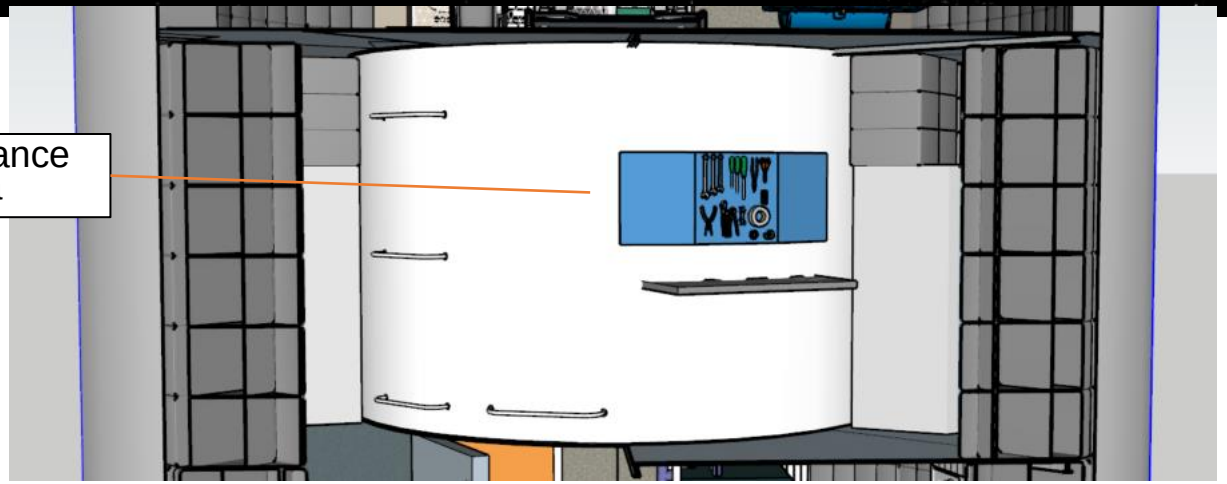
Open space above Systems & UWMS/ Hygiene for Pipes

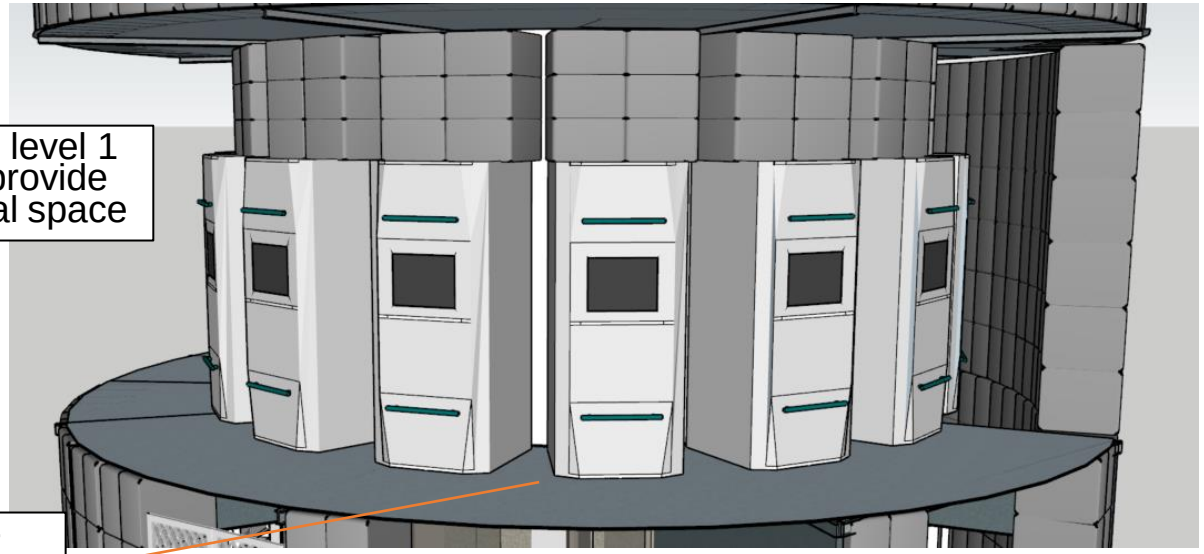
Computer Station: Command & Control

Open Area (open to second level above) for Group Recreation, etc.

TH Concept Interior Features







TH Concept Interior Features