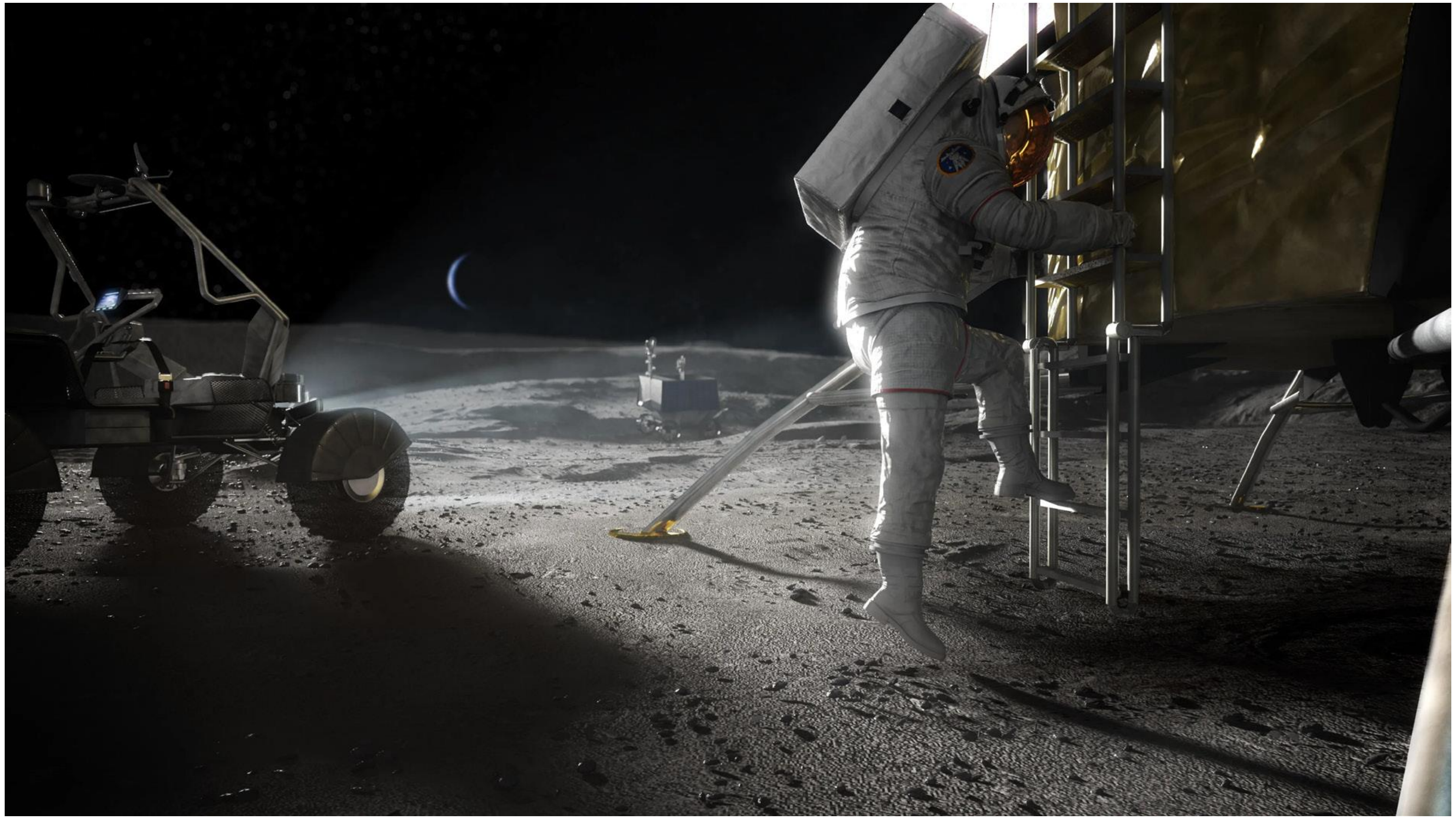
National Aeronautics and
Space Administration

Surface EVA Architectural Drivers

Microgravity to Partial Gravity EVAs



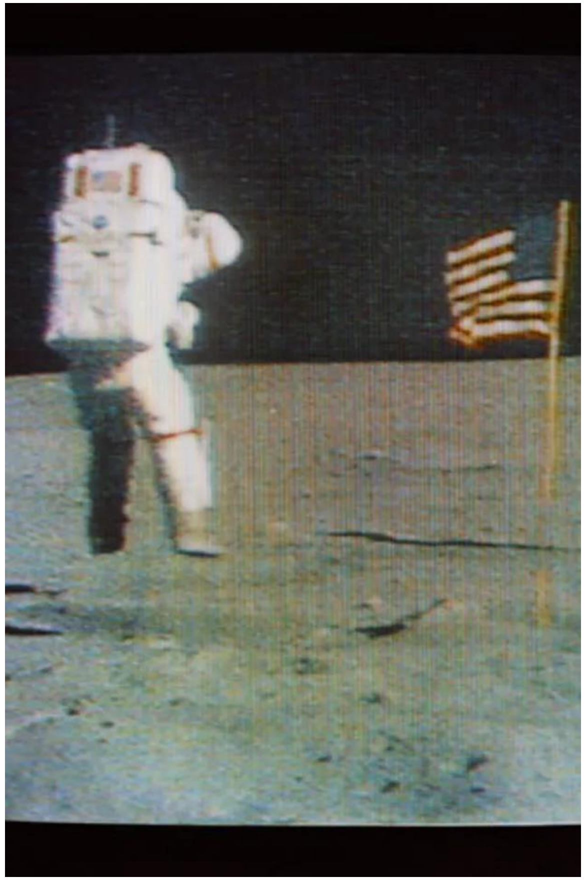
Extensive micro-gravity experience across heritage programs, Shuttle, and the International Space Station
(260+ EVAs on the space station alone)

Six total Apollo partial-gravity lunar surface missions
(14 EVAs totaling ~159 hours)

Environmental differences are a critical driver to extension of EVA expertise for Artemis and beyond

Key Considerations

Dust (Regolith) Mitigation



Partial Gravity

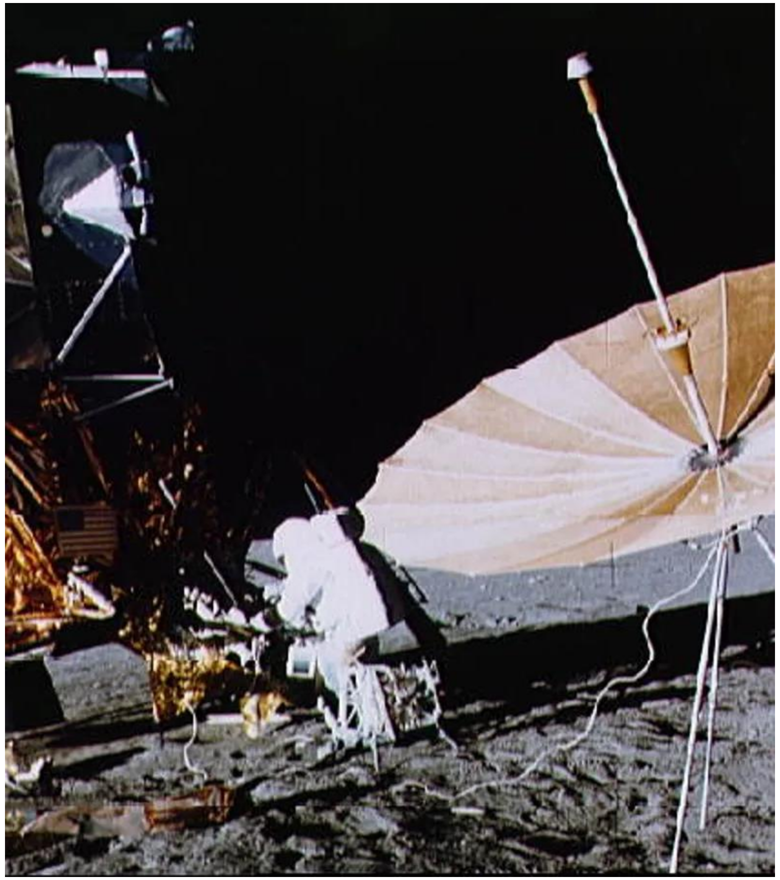
Atmospheric Pressure

Habitation and Pressurized Volumes

Key Considerations

Commodities and Logistics

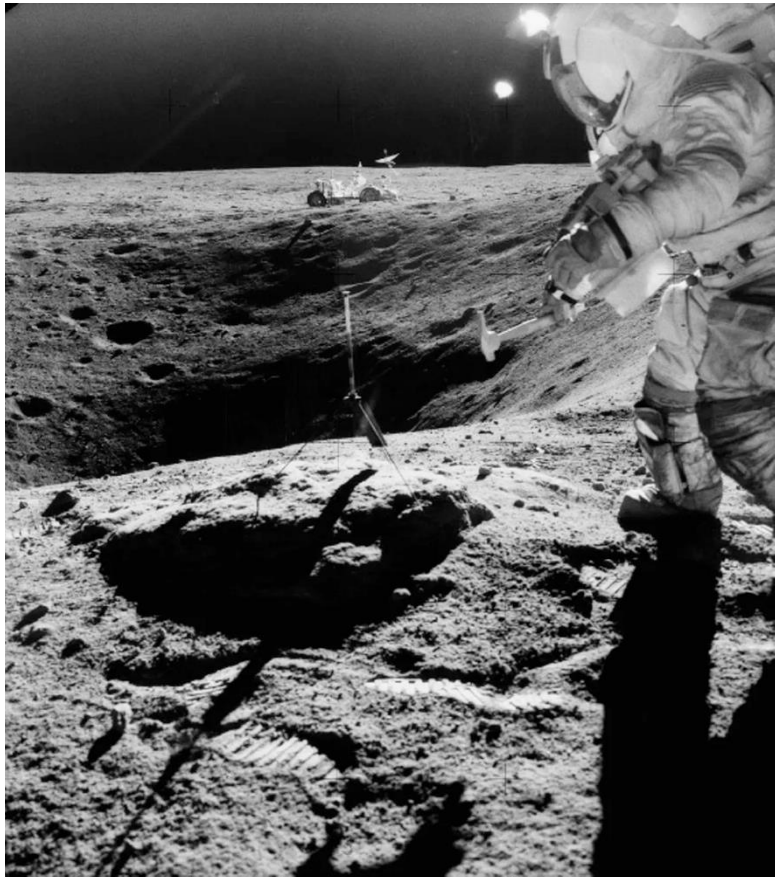
Ingress and Egress



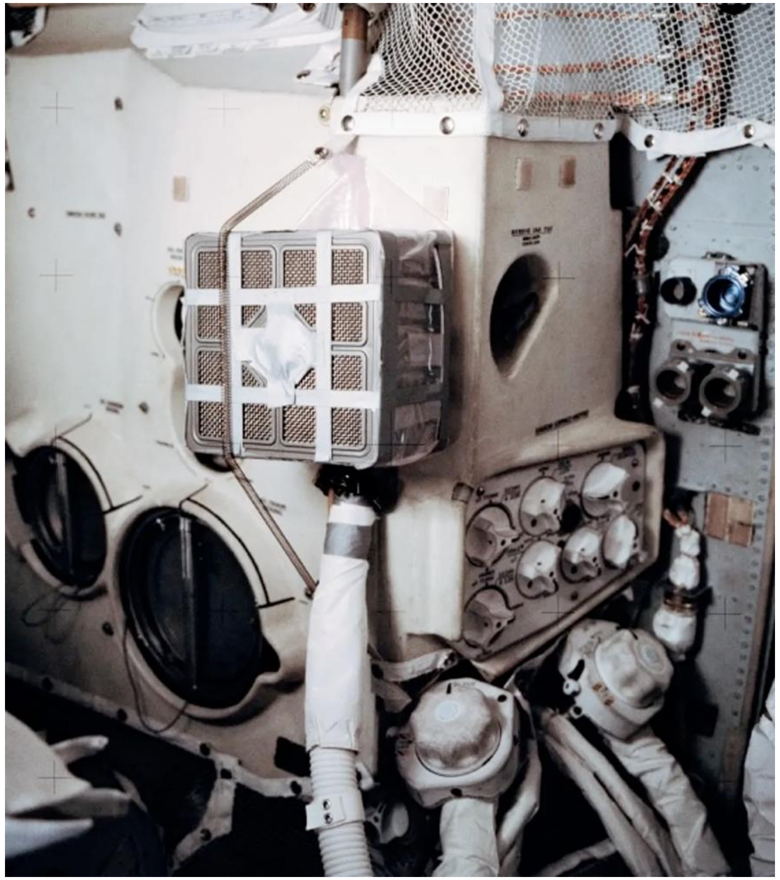
Communications, Lighting, and Navigation

Key Considerations

Enabling Suited Crew Decision Making



Site Planning



Contingencies and Operations

Summary

Moon to Mars will leverage lessons learned from microgravity EVAs

Surface EVAs
have significant number of environmental and mission drivers different from microgravity

These drivers will influence several facets of the lunar surface architecture

White Paper

National Aeronautics and
Space Administration

Surface EVA Architectural Drivers

2023 Moon to Mars Architecture | white paper

I. Introduction

Key elements of NASA's Moon to Mars Objectives for expanding humanity's presence beyond low-Earth orbit will require surface-based, partial-gravity extravehicular activities (EVAs). Surface EVA needs affect many aspects of the exploration architecture, including EVA suit subsystems, such as suit or pressure garment mobility, the portable life support system, and the informatics system; and external systems, such as habitation modules and surface mobility platforms.

Lunar surface missions take place in harsh environments with additional challenges, including limited resources/consumables resupply, communications delays, navigation, and lighting, depending on landing location and terrain. Suited activity on the Moon introduces multiple factors that drive the broader architecture, including dust intrusion, partial gravity, atmospheric pressures, logistics, pressurized volumes, site planning, contingencies, and human access to and from the lunar surface from various habitable elements. This paper highlights several key considerations related to lunar surface exploration EVAs that will be addressed in the Moon to Mars Architecture.

2. Dust (Regolith) Mitigation

An integrated strategy for lunar dust mitigation should include testing on Earth using simulants and the use of lunar experiments to characterize dust properties and build an understanding of polar regolith behavior. Dust in the polar region will be impacted by the unique natural environment: electrostatic charging can cause dust to adhere to surfaces, dust particles take longer to settle than on the Earth, and stirring/movement can remobilize dust particles.

Ground testing faces environmental limits. Convective flows typically dominate non-vacuum ground testing, making it difficult to replicate expected polar region electrostatic behaviors. Ground testing also typically requires multiple simulants, since no one simulant captures all the properties of lunar soil or the variety of soil compositions that astronauts might encounter.

Figure 1. *Conceptual Rendering 1*

2023 Moon to Mars Architecture Concept Review 1

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t poses a danger to system hardware will also not be visible to the naked

ion strategy will both minimize dust ol dust at the interface with critical uman dust exposure).[1] While human sensitive organs to dust exposure, ocular and skin effects. NASA used derive a permissible exposure limit able lunar dust exposures and size gical concern. Lunar dust adherence the habitable environment by EVA ment, and payloads is difficult to ts vary depending on the method of mitigation methods/tools available to

nents of environmental control and s, including vents, fans, intakes, and esigned with dust intrusion in mind. and EVA systems adversely affected d preparation, medical implements, cuum cleaners, seals, crew time, lights, quick disconnects/connecters, s, and more.

rogram, the Lunar Module had direct intermediate airlock volume. Apollo f dust intrusion into the Lunar Module missions, and in some cases, dust was e Command Module after on-orbit is missions will develop operations sion, develop mitigation methods to nce and clean up/filter intruded dust, ementation of this development, and ns progress.

ith differently sized crewmembers fluences the design of the suits and itectures (especially sizing, mobility, and logistics payloads that must be nembers, and tools for performing nce activities.[2] Some tasks will avigate up and down slopes, traverse ters, and deploy surface payloads. Tasks beyond collecting geological samples could include vehicle maintenance, cargo/logistics transfer, and other physically demanding activities. Tasks to be performed by the EVA crew — such as riding in a rover, hammering, or climbing — drive specific interfaces and suit mobility features.

The suit architecture and interfaces with surface elements must accommodate a wide range of crewmember sizes. These requirements drive the design of the suit and attached hardware, vehicle interfaces, the types of crew actions and motions during EVAs, direct physical interactions with the lunar surface, and the total number of EVAs. Finally, systems will have to accommodate different prebreathe protocols than Apollo or microgravity prebreathe.[3]

4. Atmospheric Pressures

A fundamental limitation of human physiology when preparing for and conducting EVAs is the potential for acute and chronic injury from decompression sickness caused by pressure transitions. It is necessary to control the transition from the habitable volume's saturation atmosphere to the EVA suit's pressure, which is set lower to improve the crewmember's ability to operate and maneuver in the suit. This transition is managed in part by an oxygen prebreathe using a combination of the vehicle's atmosphere and the suit's pressure.

The amount of time necessary for this prebreathe is directly proportional to the difference between vehicle saturation and EVA pressures. While physiologically necessary, crew time spent engaged in prebreathe affects EVA operations and the risk of decompression sickness and can affect the duration of the EVA itself. Prebreathe studies help minimize prebreathe durations, allowing for increased utilization and completion of objectives performed by the crew during EVAs.

This choice of alternative atmospheric parameters in the vehicle (as opposed to relying on the suit and implementations thereof) may pose significant issues, including vehicle design challenges, such as reduced effectiveness for atmosphere-based avionics cooling, increased flammability, and more.[4] The suit and supporting architectures will also have the capability to perform decompression sickness treatment functions during the EVA if they are required for crew safety.

5. Commodities and Logistics

Elements that provide EVA capability include the architecture to recharge suit consumables (e.g., power, oxygen, water, CO2 removal) and the ability to reserve suit consumables while connected to the vehicle via umbilical during activities such as prebreathe, suit checkouts, and pre- and post-EVA. The interfaces between the suits and the vehicles/elements must use common hardware to ensure compatibility and reduce astronaut training time and vehicle reconfiguration time.

Given the constraints for landed surface mass, different exploration architecture solutions will have varied impacts on commodity usage (such as the amount of air required to repressurize the habitable volume, depending on the ingress/egress method), in addition to the quantities used in the EVAs themselves. Suit maintenance must take place in a habitable pressurized environment.

Transferring logistics and consumables from logistics landers to habitable elements also presents a major challenge. The presence or absence of existing lunar

2023 Moon to Mars Architecture Concept Review 2

Figure 2. *Conceptual Rendering 2*

re, such as hardware for logistics architecture driver since the EVA o make up for any shortcomings in goal is to minimize logistics transfer maintain utilization objectives during

d Pressurized Volumes

nd permanently emplaced surface nd volume are important factors in f the cabin interior. Crewmembers ate internal size, in terms of both area, to perform mission tasks safely includes sufficient space to allow n/doff the suits in parallel, perform ne for spares/logistics, and gather rform the EVA objectives.

ntry suits require volume above the wmembers to climb into their suits. able volume will be needed for EVA wing open and closed, creating keep- nobile and permanently emplaced be designed for EVA compatibility. to any worksites, hatch sizes, sharp h temperatures, and other factors.

rchitectural ress/Egress

ovide a separate volume from the main cabin to facilitate surface access. As such, airlocks provide a significant opportunity to control or propagate backward and forward contamination.[4,5] While other ingress/egress architecture solutions could help with dust intrusion, consumables, and other drivers listed in this paper, they also pose significant challenges to vehicles and suit architectures such as mass and volume.[6]

8. Enabling Suited Crew Decision-Making

Distributing work functions among Earth-based assets and mission assets, enabling an Earth-independent architecture, will be a profound architectural driver. Earth independence starts by giving crew members, particularly during EVA, the capacity to make informed decisions by interacting with and acting upon locally sourced information. Achieving this feat will not only be a technological accomplishment that advances suit capabilities but would also establish a fundamentally new medium of communication and information exchange between mission assets and Earth-based support.[7,8,9]

Earth-independent crew decision-making currently faces multiple challenges, such as establishing a highly integrated network of data-sharing among mission assets (from different vendors); rendering a variety of data in meaningful and contextually useful ways for crew consumption, interaction, and understanding; and aligning the broader flight operations structure (across NASA and service vendors) with the appropriate function allocation.[10,11]

Architecture Concept Review 3

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ons, Navigation, and Lighting

etween EVA crewmembers may be and/or line of sight to each other ssets during certain periods of initial because of architecture constraints r contingencies/walk-back scenarios. ssets and other surface elements nications capabilities will allow the ther from the landing site, increasing n options.

ll mainly utilize orienteering for e and navigation systems, displayed d mobility assets, will help crew stinations and back, guiding them to designated by the science team.

ience persistent long shadows near e, while also having the Sun directly w. To traverse safely and effectively n and slopes and into shadowed will use lighting sources (e.g., helmet pped/mounted to a crewmember or rksite), which can drive power needs. rformance in dark shadows will also

e lunar South Pole are being planned, issions also include the capability to lobally. Performing multiple missions d different regions of interest within will require strategic site planning. as ability to navigate difficult terrain uit, interactions required between nd safety will affect the integrated onfiguration of surface elements to objectives. Mission designs will also environmental factors (e.g., terrain, ce, plume) in concert with surface g., rovers, habitats, landers, driving d EVA capabilities (e.g., walk-back while protecting the EVA crew.

tion of the site location of the surface f course, accommodate EVAs to d utilization, maintenance, logistics, observations, and traversing during short-term missions, long-term stays, and sustained operations. This requires monitoring surface operations effects and management of habitation.

EVA ranges must be considered when planning distances between stationary elements to provide the crew access to a pressurized safe haven within the limits of emergency consumables in the event of a suit failure or medical event. Along with other considerations (i.e., landing accuracy, plume/surface interaction), distances the mobility elements can be driven or teleoperated before requiring charging affects the mission's mass requirements and must be balanced with operational needs such as EVA preparation, EVA duration, crew time, and crew sleep.

11. Contingencies and Operations

Ensuring crew safety is the most important aspect of planning human space missions. Risks such as complexity, suit exposure, dust intrusion, EV times, vehicle failures, distance from a sa more can factor into the possible loss of and must be considered in capabilit vehicle/suit failure could result in sce must walk back to a safe haven.

Hardware and human failures can le or incapacitation on the lunar requiring assistance during EVA. Inca continuous full assistance is a ris additional loading, transport, and lif which affect suit design.

12. Conclusions

Surface EVA exploration has a sig architectural drivers that differ from differences include dust, the chall in partial gravity, mobility and habi site planning, and contingency scen challenges for surface EVAs result mass, power, volume, the environ operations that occur on the Moon a extent, on Mars.

2023 Moon to Mars Architecture Concept Review 4

Figure 3. *Conceptual Rendering 3*

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Lunar Surface

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