Aseptic Assembly Procedures from Mars 2020 as a Reference for Space Suit Protocols to Prevent Forward and Backward Contamination on Human Mars Missions

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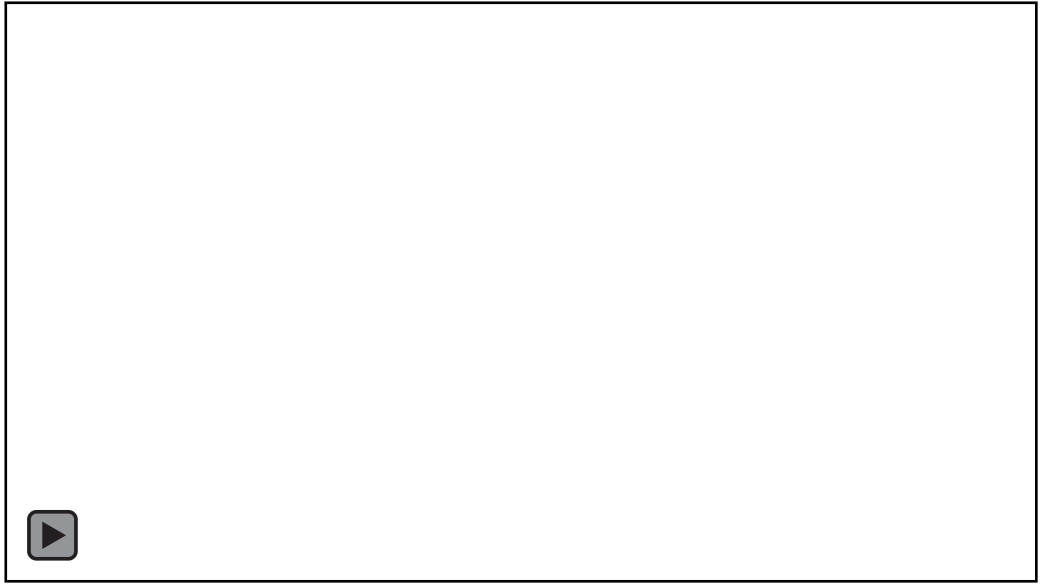
Mars 2020 Aseptic Assembly Facility Background

- Goal: <1 viable Earth-sourced organism per sample tube, 99.9% probability of each sample being free of any viable Earth-sourced organisms
- Cleanliness zones were defined considering all direct and transported contamination vectors during the Mars sample acquisition process.
- The most stringent zone includes hardware with direct contact or proximity to the Martian sample: Sample Tube Assembly, Hermetic Seals Assembly, Seal Dispenser Assembly, Volume Probe Assembly, and Bits.
- Hardware in these zones was assembled in an ISO-5 cleanroom under strict monitoring to ensure biological cleanliness.



Prevent

Contamination Prevention	Setting contamination requirements for manufacturing processes
	Material and chemical qualification before use
	Custom tooling or support equipment for hardware handling
	Surrounding hardware limits contamination exposure

Clean

Rigorous Cleaning	Contaminants known for ease of removal
	Custom precision cleaning methods
	Bake outs (outgassing and microbial reduction)

Maintain

Environmental and Handling Controls	ISO 5 cleanroom and flow benches
	Strict hardware handling protocols
	Personnel training to ensure high standards

Monitor

Hardware and Environment Verification	Cleanrooms monitored through air and settling plates
	Flight hardware sampling
	Constant validation of process effectiveness

By the Numbers:

Hundreds of materials tested!

Over 102,000 tools and parts cleaned and verified!

Average PCL150 and A/10 on all cleanroom settling plates!

Hundreds of samples collected

This image was generated using Gemini by Google AI

Connection to Human Mars Missions

- The Mars 2020 Mission's approach to contamination control [1, 2] offers valuable insights that can be adapted to the design and operation of Mars space suits for future humans to Mars endeavors.
- Space suits intended for Mars missions must consider:

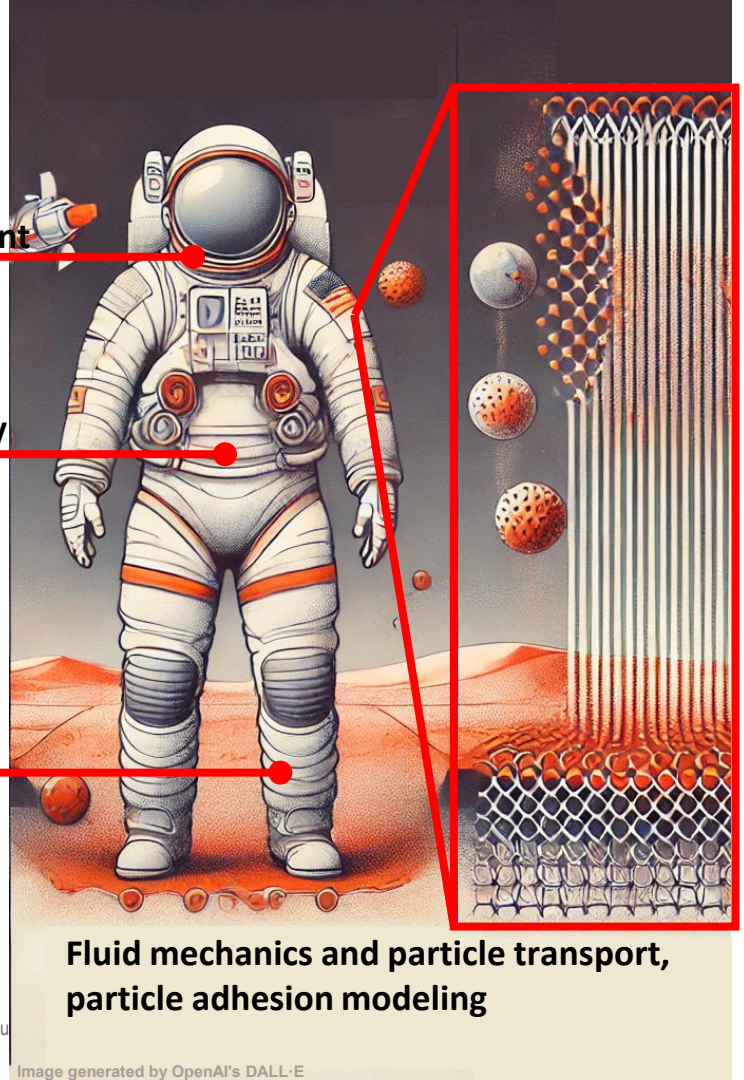
1. Preventing the forward contamination of Mars, ensuring that terrestrial microorganisms do not compromise Martian environments for science or future sample return missions and
2. Preventing the backward contamination of the earth by way of the habitat and returned astronauts or the return vehicle.

- The Mars 2020 mission successfully employed hardware design [3], transport modeling [4], cleaning [1, 2], and aseptic assembly procedures [1] to achieve and maintain unprecedented levels of cleanliness.
- These practices can be translated into space suit protocols that emphasizes biological contamination control at every stage—from design to operational use on Mars.

[1] Chen, F. et al. (2023) ASTROBIOLOGY Volume 23, Number 8.
[2] Maltais, T., et al. (2023). Astrobiology Volume 23, Number 8.

Design Considerations

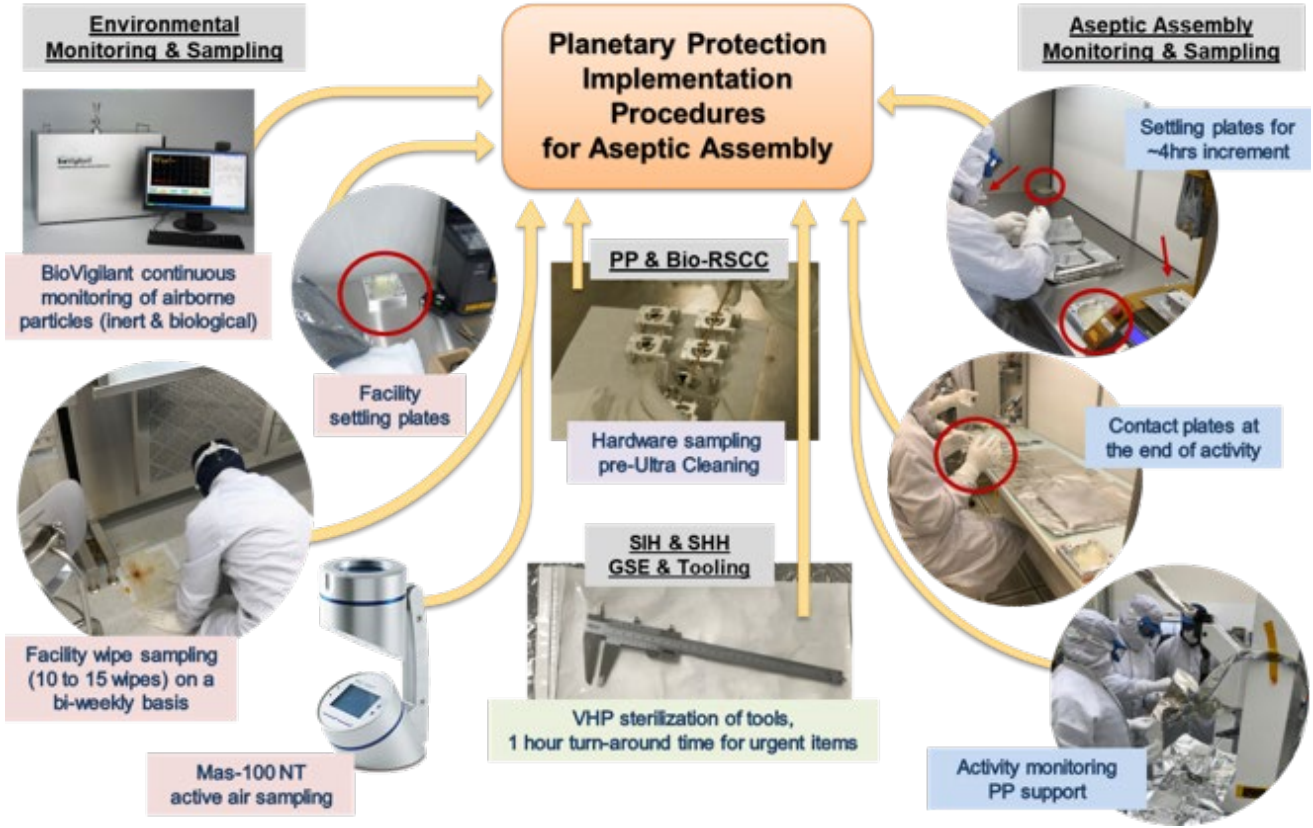
- In designing space suits, the principles of Mars 2020's hardware can be directly applied.
- Design varies by cleaning modality, whether IPA, VHP, UV, Gamma, or high temp.
- This allows for a sustainable approach to particle control and repeated cleaning of space suits/habitats that may have been recontaminated due to proximity to humans/Mars.



Monitoring Considerations from Mars 2020

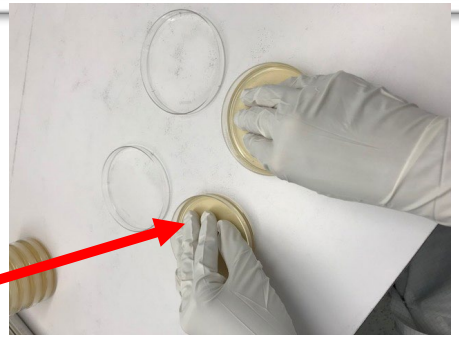
- Together, rapid assessments (e.g., ATP testing) and detailed analysis (e.g., MALDI-TOF) provided a full contamination profile.
- Mars 2020 assembly: 7,619 witness plates used across 688 activities, incubated to monitor microbial growth.

These measures can be used from spacesuit design through habitat operations to minimize contamination risks.



Operational Protocols

- Operational protocols for space suit use on Mars can mirror the contamination control strategies employed during Mars 2020's sample intimate hardware assembly phases.
  - E.g. ingress of samples/tools into a habitat for large and small-scale cargo/tools:
    - Bagging protocols
    - Airlock cleaning – clean/dirty side of the airlock, sterilization of the entire airlock
    - Aseptic handling of clean tools/suits



Post-EVA Procedures

- Additionally, just as Mars 2020 relied on constant monitoring of bioburden levels, Mars missions should employ real-time monitoring systems within the habitat and the space suits to detect and mitigate any contamination events.
  - These systems could alert astronauts to potential breaches, allowing for immediate corrective actions.
- Drawing from the Mars 2020 protocol of using settling and contact plates to monitor contamination, space suits could be swabbed and tested to confirm their cleanliness before they are reused.
- This would involve a containment area within the habitat, where cleaned suits are protected from recontamination.

Conclusions

- The Mars 2020 mission's aseptic assembly procedures provide a framework for developing protocols aimed at preventing forward and backward contamination.
- By integrating advanced sterilization techniques, real-time monitoring, and strict contamination control measures at every stage, Mars space suits can meet the high planetary protection standards required for human exploration.
- These protocols will not only protect the Martian environment but also ensure the integrity of scientific research conducted on the Red Planet and the returned sample.
- Continuous refinement and adaptation of these protocols are crucial as missions advance and our understanding of Mars evolves.