



Mars Sample Return Planetary Protection Update

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MSR Program Planetary Protection Team

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Clearance CL#25-1368

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MSR Planetary Protection Update Summary



MARS SAMPLE RETURN (FORMULATION/PHASE B)

- **Forward PP: based on prior Mars missions, largely unchanged from the previous architecture**
- **Backward PP: new MSR architecture would Break the Chain (BTC) *at Mars***
 - BTC is the point in the mission when all Mars material has been contained inside hardware that is externally clean or sterilized
 - The Sample Retrieval Lander (SRL) packages the samples in an externally clean, primary container
 - The primary container is kept clean during launch and ascent, then deployed in Mars orbit
- **Enhanced planetary protection is enabled by a new lander design**
 - Radioisotope-powered lander that allows for a smaller ascent vehicle and makes way for a cleanroom-like sample-handling enclosure
 - The Perseverance robotic arm is utilized for all external sample transfer tasks, reducing functionality required of robotics carried by SRL and allowing the use of heritage robotics inside the enclosure
- **BTC at Mars eliminates the need for sterilization in flight while enhancing safety assurance**
 - Both Mars lander options under consideration are compatible with BTC at Mars
 - The new approach eliminates the need to manage uncontained particles after leaving Mars
 - Utilizing multi-layered, physics-based approach to particle management exceeds the containment assurance provided by sterilization treatments planned for prior architectures



MSR BPP approach addresses key NASA PP policies with improved safety assurance



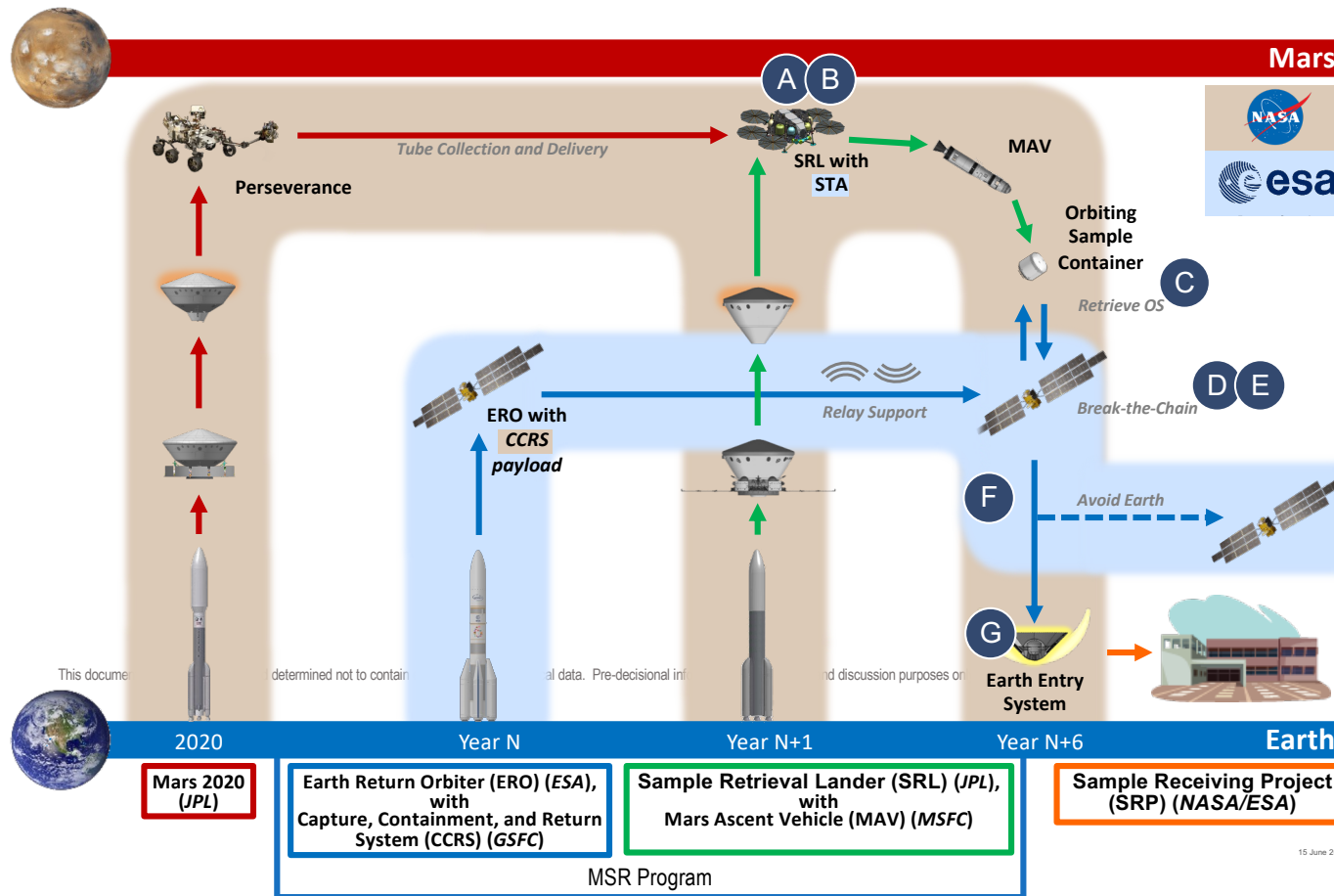
MARS SAMPLE RETURN (FORMULATION/PHASE B)

MSR is a Category V(r) – Restricted Earth Return

- External studies called for MSR to implement restricted Earth return measures
 - “Samples returned from Mars by spacecraft should be contained and treated as though potentially hazardous until proven otherwise.”
NRC (1997) Mars Sample Return: Issues and Recommendations
 - “No uncontained martian materials, including spacecraft surfaces that have been exposed to the martian environment, should be returned to Earth unless sterilized.”
NRC (2009) Assessment of Planetary Protection Requirements for Mars Sample Return Missions.
- NASA Policies reflect this guidance and underpin our BPP strategy
 - NPR 8715.24 §3.4.1: For missions conducting restricted sample return preventing harmful biological contamination of Earth’s biosphere is the highest priority.
 - NASA Tech. Standard 8719.27 §5.4.2: “Category V(r) missions shall demonstrate avoidance of harmful contamination of the Earth-Moon System by release of one or more unsterilized particles into the Earth-Moon system of extraterrestrial material during all mission phases
- **The updated MSR architecture would be built around BPP and deliver enhanced safety assurance by *preventing* Mars particle contamination of the primary containment vessel instead of sterilizing uncontained contaminants**



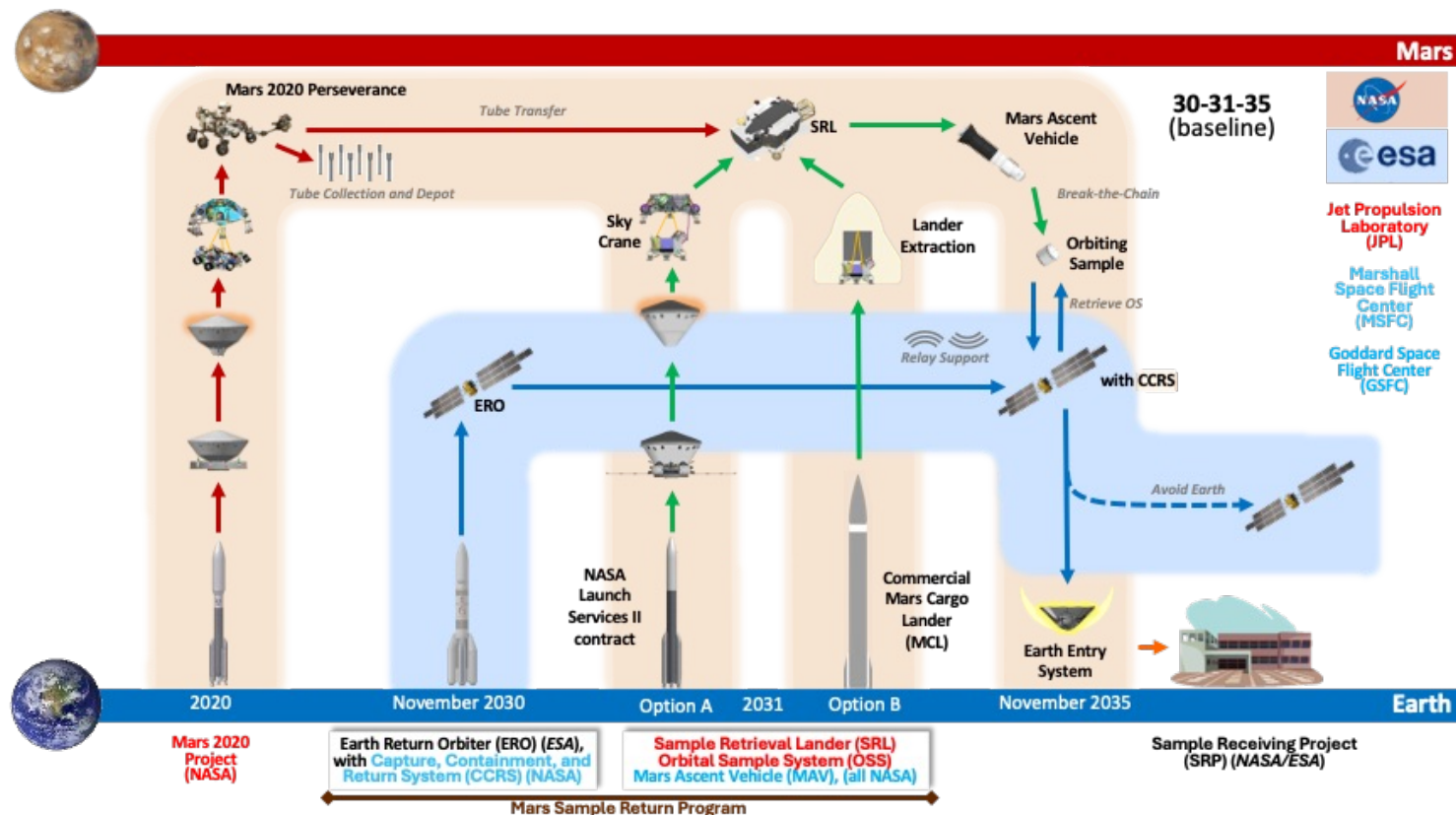
MSR BPP in the 2023 Campaign Planning Architecture



- A. Limit Mars particle accumulation during open-door sample transfer activities
- B. Implement primary containment
- C. Track all Mars particle transfer paths from OS exterior to ERO/CCRS
- D. Sterilize OS exterior with UV light
- E. Implement secondary containment
- F. Track all Mars particle transfer paths from ERO/CCRS to Earth
- G. Ensure containment through entry, descent and landing



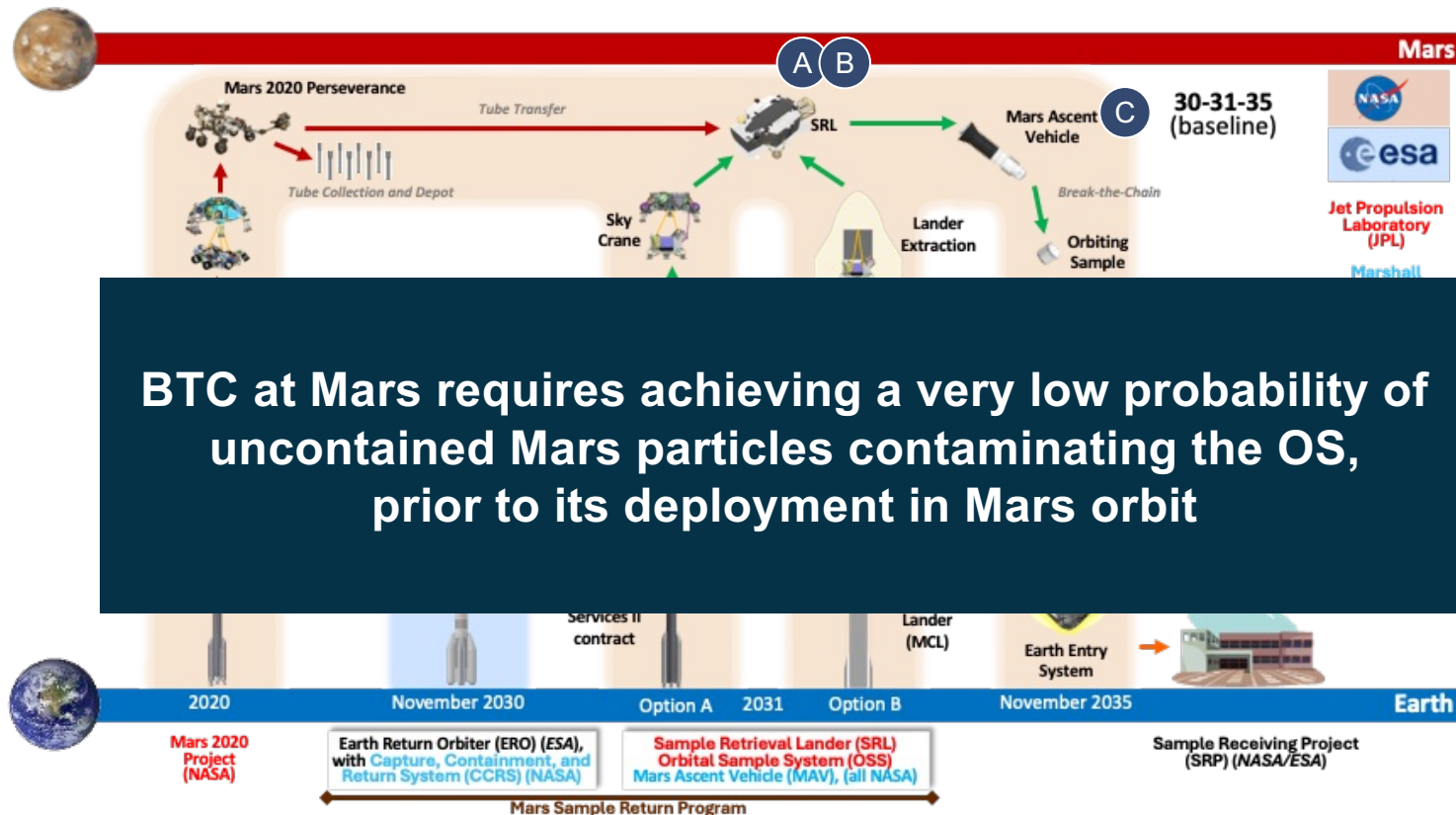
Updated MSR Campaign Architecture Planning Options



- Based on an independent review, NASA paused some MSR work in late 2023 to evaluate alternative architectures
- NASA evaluated 12 rapid response studies on alternative MSR architectures and initiated planning around two possible architectures through MSR Program PDR
- **Backwards Planetary Protection is functionally identical in both architectures**



Updated MSR Campaign BPP Approach: Break the Chain at Mars



- A. Exclude Mars particles from the OS exterior during sample transfer
- B. Implement primary containment
- C. Exclude Mars particles from the OS exterior during ascent
- D. Implement secondary containment
- E. Ensure containment through entry, descent and landing



BTC at Mars: New Benefits, Continued Approaches

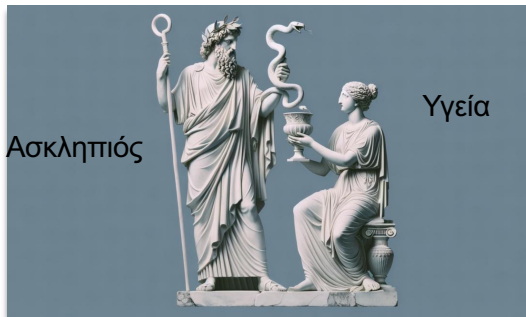


MARS SAMPLE RETURN (FORMULATION/PHASE B)

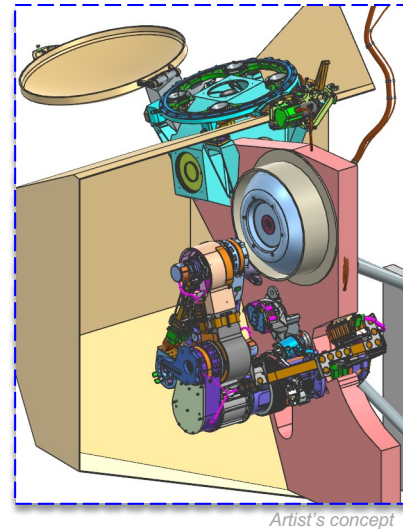
- **A BTC at Mars approach offers enhanced certainty over sterilization: *prevention* >> *cure***
 - Eliminates fundamental sterilization limits: uncertain biological response and assurance level $\leq 10^{-6}$
 - Particle management can be informed by the fundamental physics of particle behavior and achieve particle contamination probabilities $\ll 10^{-6}$ with a multi-layered approach
- **Decouples MSR BPP success from sterilization development and implementation risks**
 - In-flight sterilization is novel and posed development risks, even with well-accepted modalities
 - Biological discoveries made during the mission might challenge a process designed ~10 years before
- **Simplifies the BPP tasks required after leaving Mars**
 - The MSR Program, CCRS, and ERO no longer need to analyze in-flight particle release and transport vectors for the nominal mission
 - CCRS no longer needs to address sterilization and uncontained particle management requirements
- **Maintains the existing approaches to containment through Earth entry and landing**
 - MSR can leverage prior work for other BPP-critical components such as the OS, Earth Entry System (EES) and Micrometeoroid Protection System



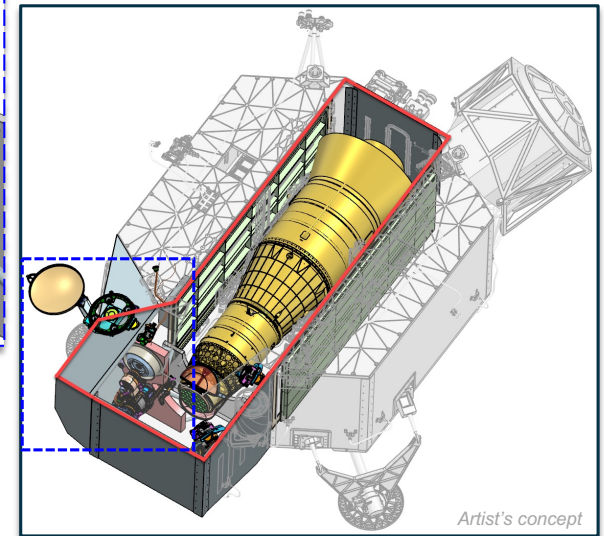
The Hygienically Encapsulated Assembly (HygEA) breaks the chain of contact *before* the OS reaches Mars orbit



Υγεία (modern Greek), Hygēa or Hygīa (Latin), Hygieia or Hygiea or Hygeia (English) was the goddess of health, cleanliness and hygiene in Greek mythology. Her name is the source for the word "hygiene". She was the daughter of Asclepius, the god of medicine.



Artist's concept

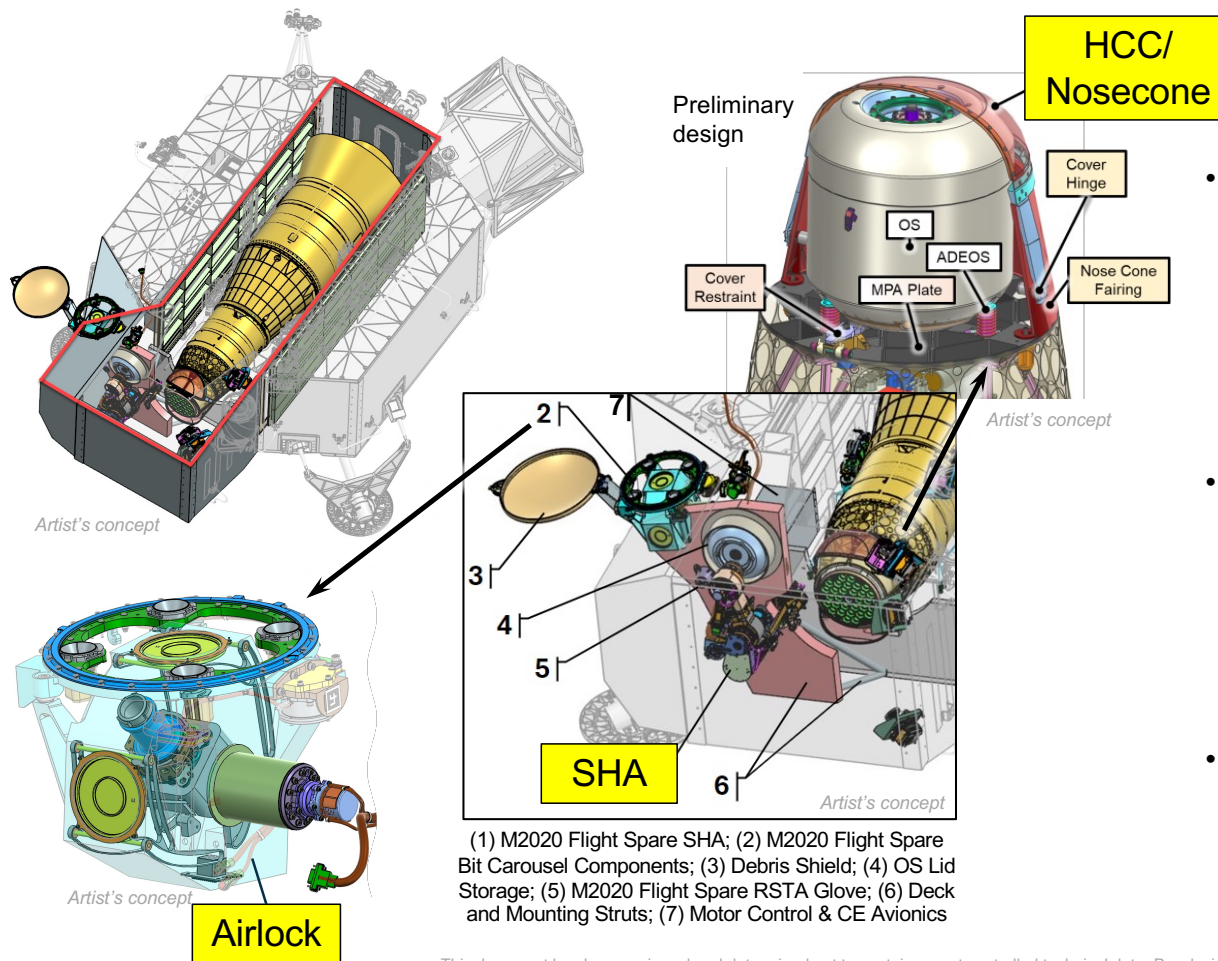


Artist's concept

HygEA is the Hygienically Encapsulated Assembly on the MSR Sample Return Lander (SRL) - comprised of an airlocked compartment, dust-tight enclosure around the OS/MAV and a closeout cover - the combination of which is designed to keep the OS exterior clean from Mars material.



Key components of HygEA that would keep the OS exterior clean and Break The Chain on Mars



HygEA (red outline) is clean enclosure around the OS/MAV

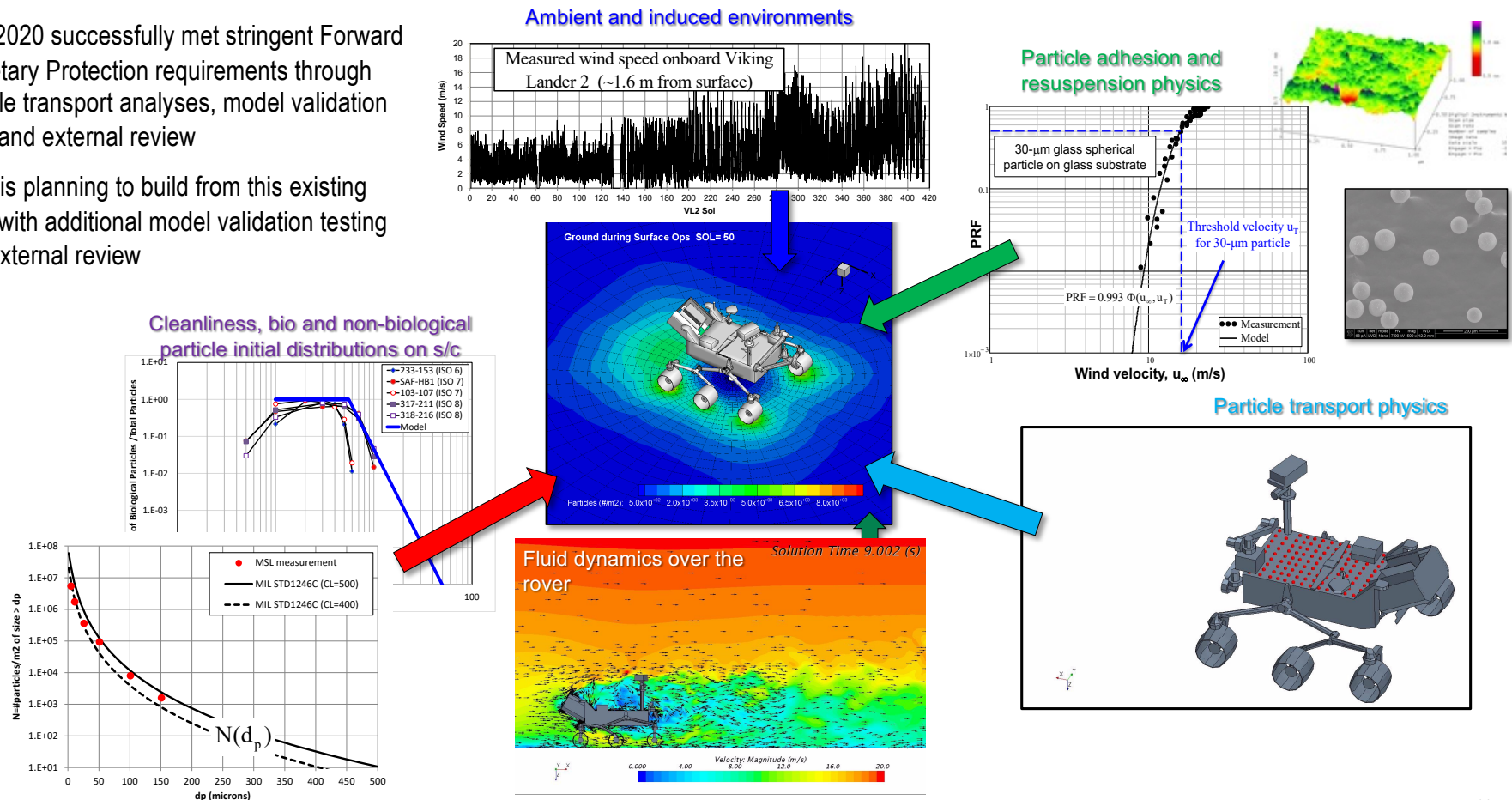
- Tubes are received from Perseverance through an **Airlock**
 - Prevents air flow and transfer of free particles to the lander interior
 - Allows for settling of particles from Mars atmosphere
 - Positions tubes for transfer to the OS
- A Sample Handling Arm (**SHA**) completes key steps in sample transfer and containment
 - Moves tubes from the Airlock to the OS under conditions that control particle release
 - installs a particle tight lid on the OS
- The HygEA Closeout Cover (**HCC, or nosecone**) protects the OS from Mars dust during Mars launch and ascent



HygEA requires particle transport analyses very similar to those successfully used by Mars 2020 for Planetary Protection

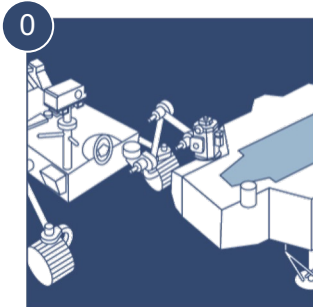


- Mars2020 successfully met stringent Forward Planetary Protection requirements through particle transport analyses, model validation tests and external review
- MSR is planning to build from this existing work with additional model validation testing and external review

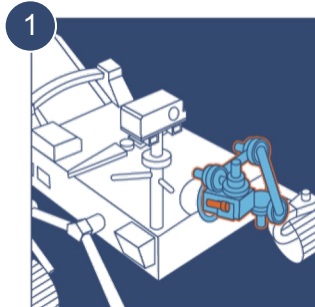




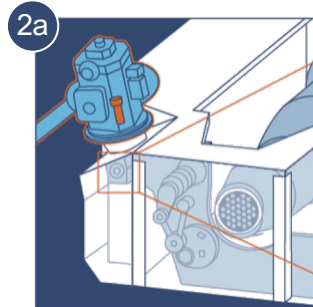
How HygEA protects the OS from the sample tubes, the most contaminated and closest source of Mars particles



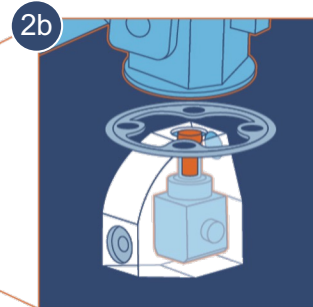
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Perseverance parks near the lander and acquires the tube carrier



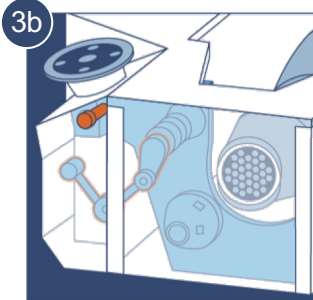
1
Perseverance RA picks up a tube from its Bit Carousel and **performs percussive cleaning**



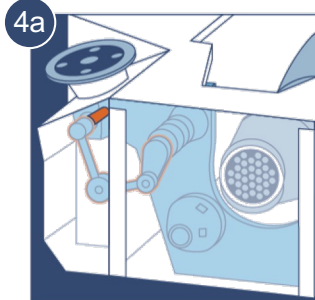
2a
Perseverance RA **docks** to SRL lander Bit Carousel and **transfers** tube to SRL Airlock



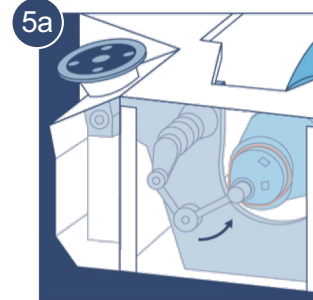
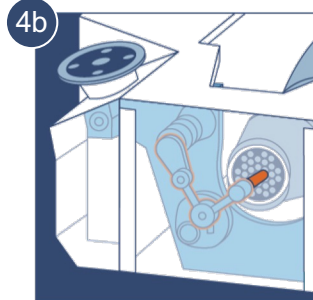
3a
Bit Carousel **pivots**, the Airlock door is **closed** and, then **motion is paused** to settle any dust.



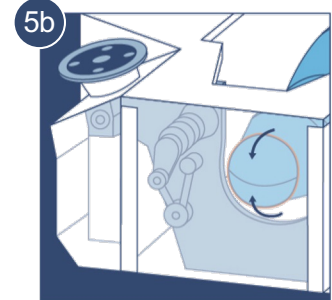
3b
Bit Carousel **moves** tube to lower Airlock door and the door is **opened**



4a
SHA **extracts** the tube from the Airlock, then **positions** and **inserts** the tube into OS

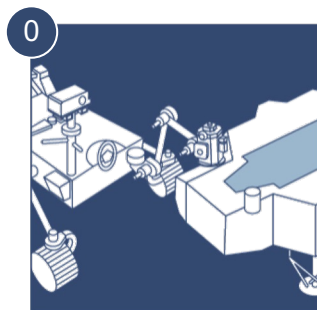


5a
After sample transfers, SHA installs the OS lid, creating a primary containment vessel. The HygEA Closeout Cover nosecone is then closed to keep OS clean during ascent

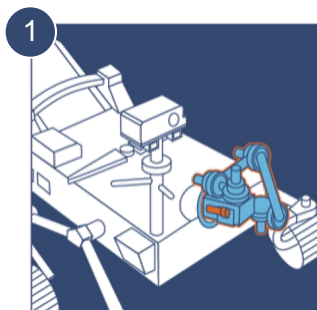




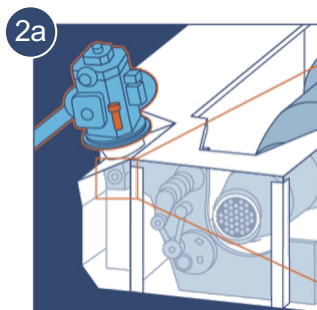
HygEA protects the OS through careful application of acceleration loads to the sample tubes during transfer



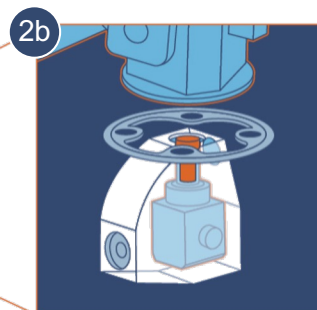
Perseverance parks near the lander and acquires the tube carrier



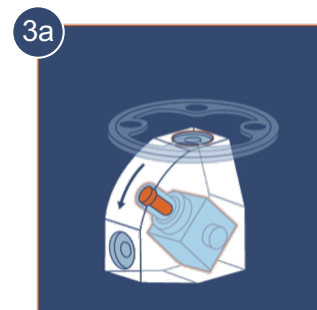
Perseverance RA picks up a tube from its Bit Carousel and performs percussive cleaning
 $\geq 1000 \times g$



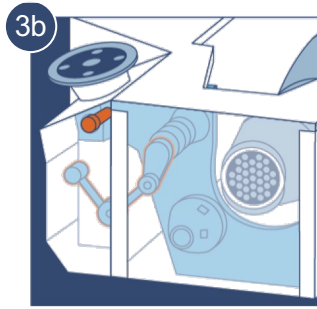
Perseverance RA docks to SRL lander Bit Carousel and transfers tube to SRL Airlock



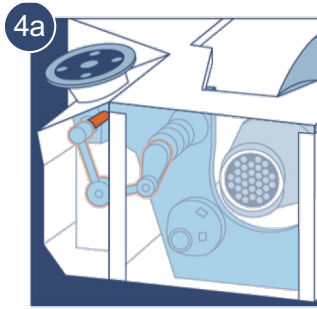
$\leq 10 \times g$



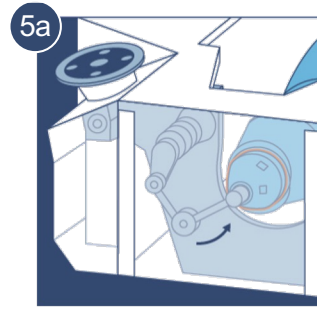
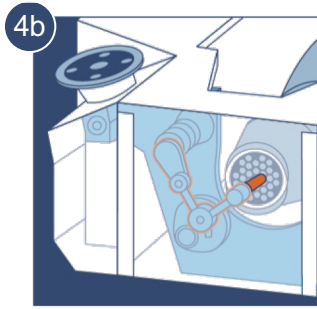
Bit Carousel pivots, the Airlock door is closed and, then motion is paused to settle any dust.
 $\leq 1 \times g$



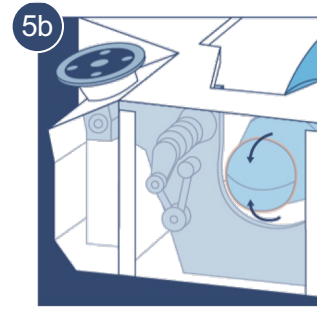
Bit Carousel moves tube to lower Airlock door and the door is opened
 $\leq 1 \times g$



SHA extracts the tube from the Airlock, then positions and inserts the tube into OS
 $\leq 1 \times g$

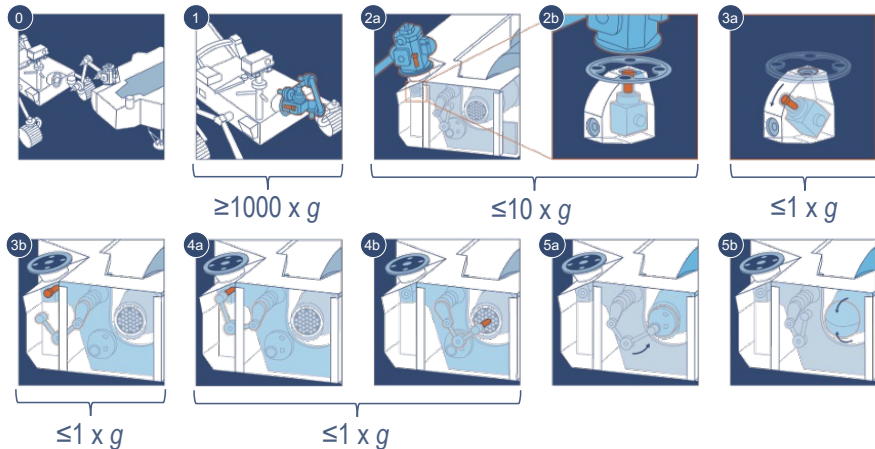


After sample transfers, SHA installs the OS lid, creating a primary containment vessel. The HygEA Closeout Cover nosecone is then closed to keep OS clean during ascent.
 $g = \text{Earth gravity} = 9.8\text{m/s}^2$

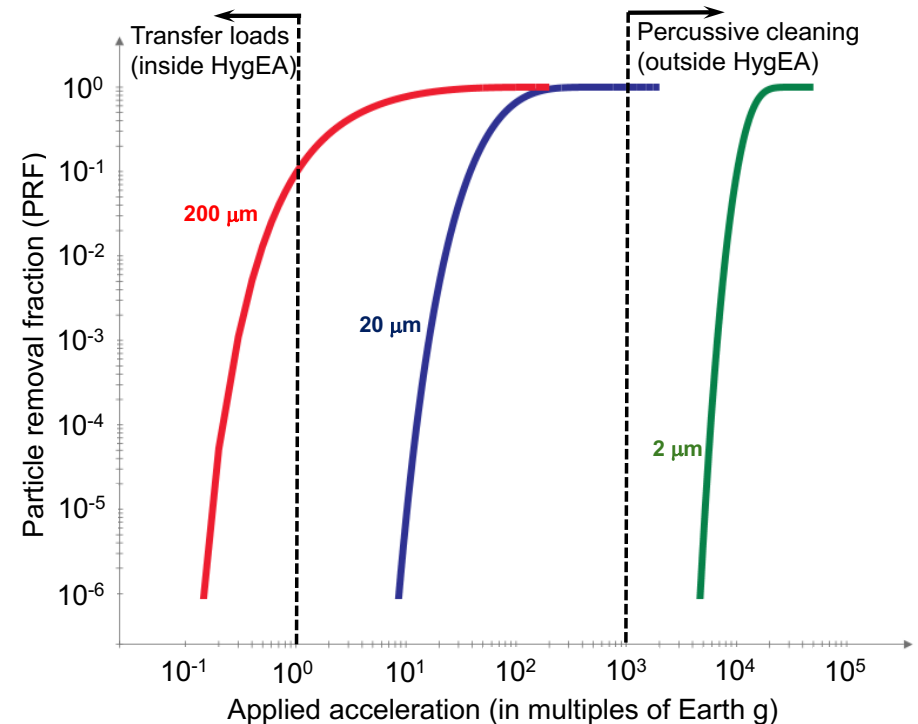




High acceleration before and low acceleration during transfer makes particle release inside HygEA highly unlikely

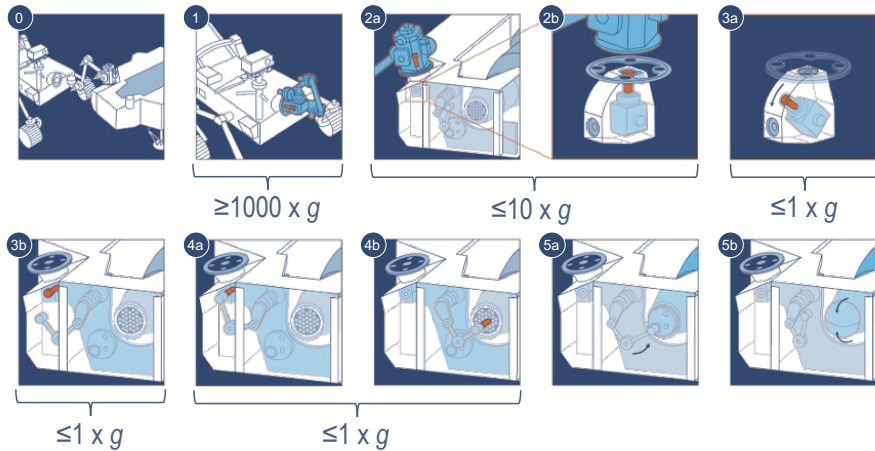


- Percussive cleaning (≥ 1000 Earth-g acceleration) removes most large particles (~ 100 s microns) and a large fraction of medium particles (~ 10 s microns)
- Every subsequent handling operation applies accelerations at least 100x smaller than the percussive cleaning, reducing the probability of particle dislodgment in later steps by several orders of magnitude
- **Particle release inside HygEA is highly unlikely**

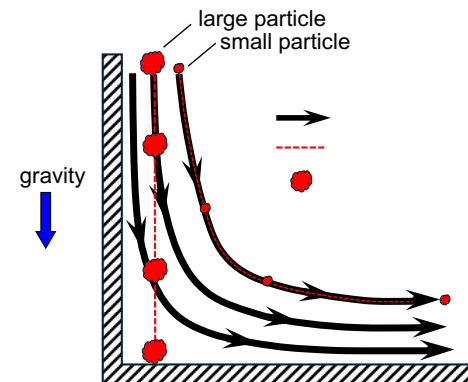
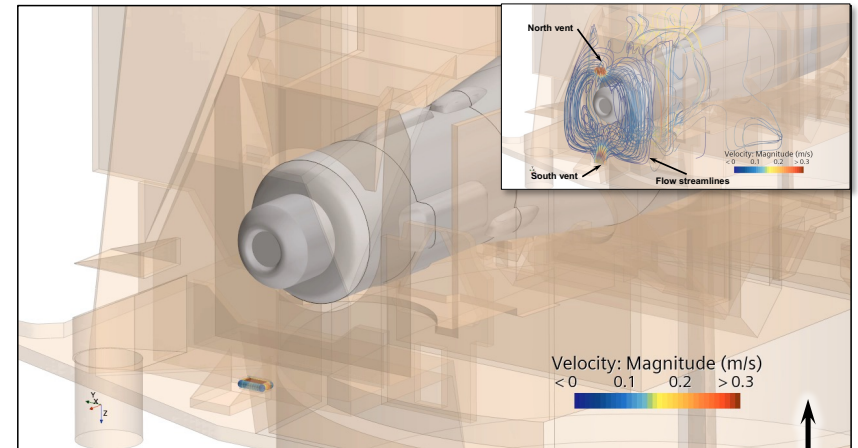




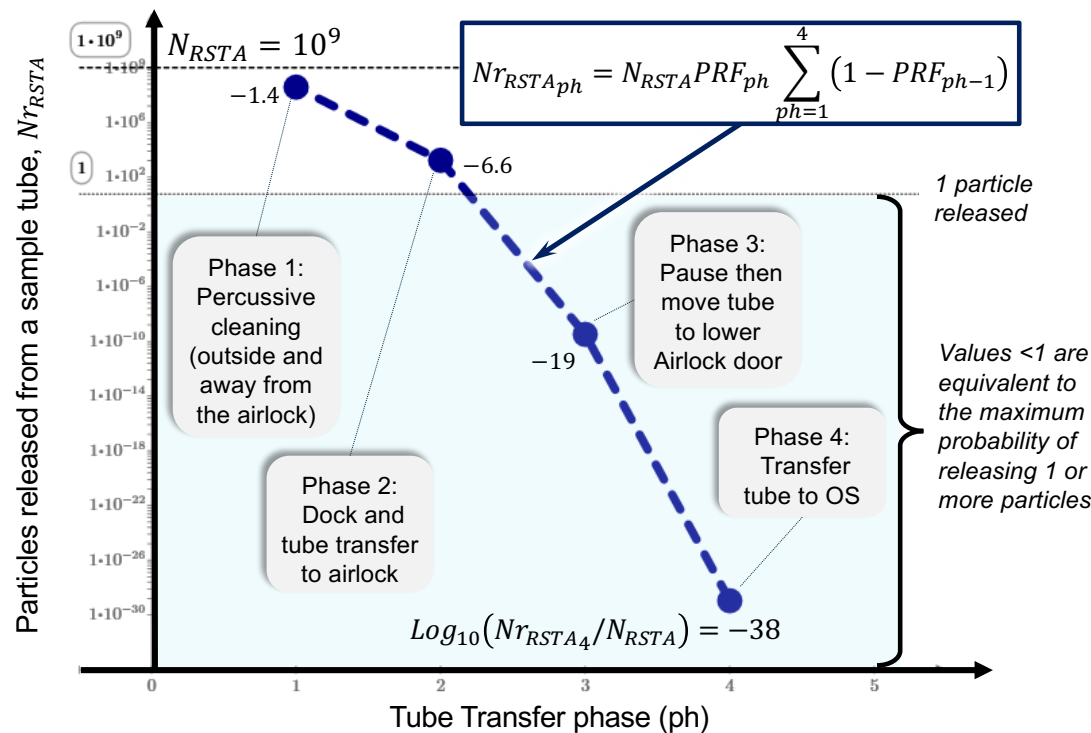
Should particle release occur, transport controls mitigate the probability of OS contamination



- Even in the very unlikely event of particle release in the enclosure, particles are kept away from the OS
 - Larger particles will settle onto the HygEA floor where they cannot be remobilized
 - Smaller particles will be managed by weak interior thermal convection
- Thermal convection will be directed, by design, away from the OS into HEPA-controlled vents
- **Managed convective flow is a fail-safe, protecting the OS exterior from any released small particles**



Animation shows evolution of flow streamlines around the OS and towards the north vent. Dots at the end of each streamline are not particles – they are massless tracers to used here to illustrate the directionality of each streamline. Result of the simulation: When 41,000 light (0.8-micron) particles were introduced in the simulations, none reached the OS.



Example plot of particles released from a sample tube by transfer phase assuming 10^9 particles on the tube. Particles released in phases 1 and 2 are physically blocked from reaching the OS. The probability of released particles reaching the OS is currently estimated at $<10^{-4}$ which means the net probability of one or more particles contaminating the OS during sample transfer, i.e., the probability of release multiplied by the probability of reaching the OS, is significantly less than the values shown here.

Takeaways

- Prevention is better than a cure: compared to sterilization, particle transport management can achieve much greater safety assurance
- Current analyses indicate HygEA performance would effectively eliminate sample tube transfer as a *driving* contamination threat for MSR
 - MSR is working to identify and mitigate other OS contamination vectors in mission phases from Mars entry to Mars orbit
- MSR Program is developing a robust plan for model validation and scientific review of its particle transport and control approach
 - MSR is leveraging experience gained in developing and implementing physics-based particle management for Mars2020

Thank You

