



MARS SAMPLE RETURN PLANNING - STRATEGIES FOR MEETING PLANETARY PROTECTION REQUIREMENTS

Andrea D. Harrington

Mars Sample Curation Lead

Astromaterials Acquisition and Curation Office

NASA Johnson Space Center

National Academy of Sciences – Committee on Planetary Protection Fall Meeting

November 2022



ASTROMATERIALS RESEARCH AND EXPLORATION SCIENCE
JOHNSON SPACE CENTER

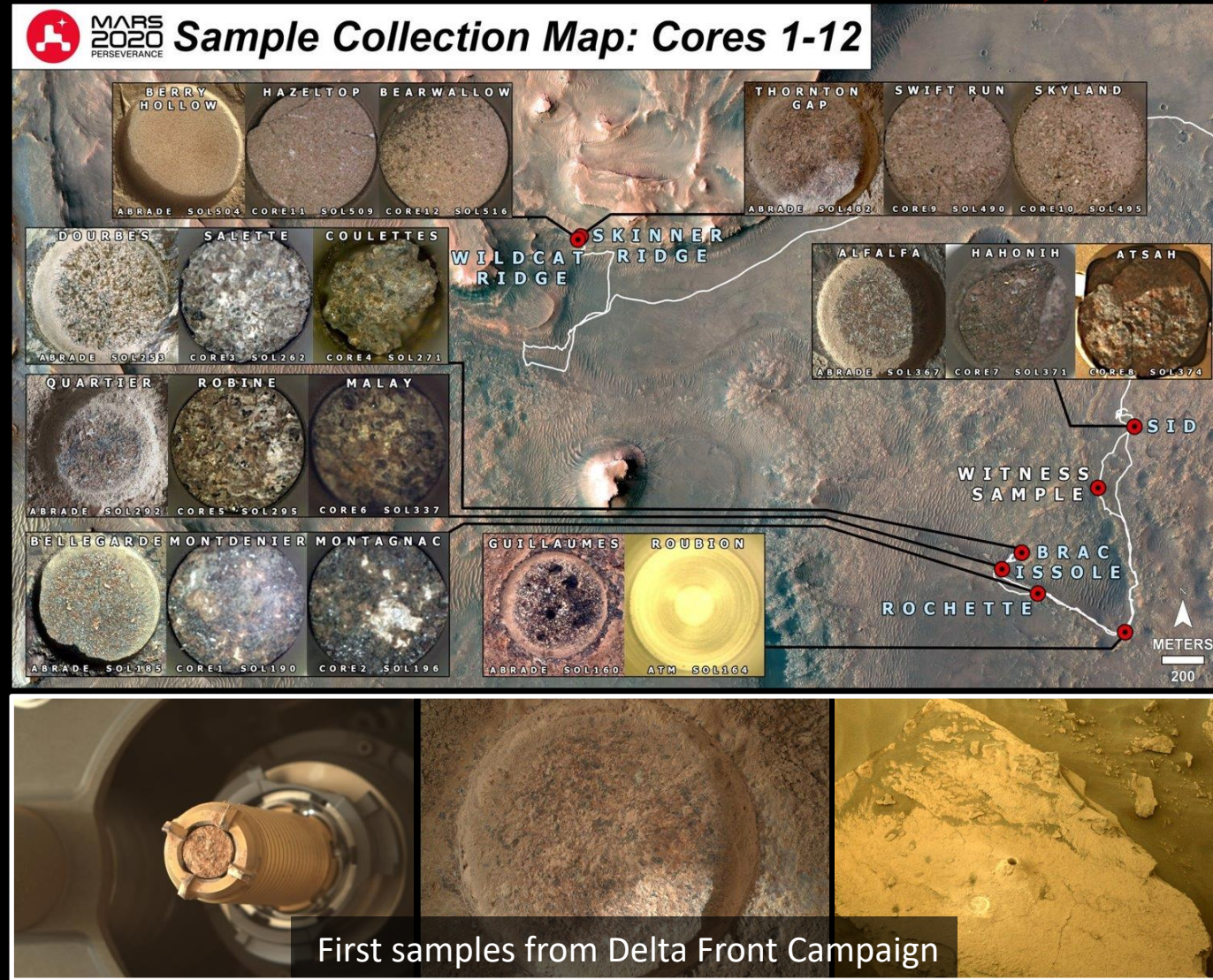
The decision to implement Mars Sample Return will not be finalized until NASA's completion of the National Environmental Policy Act (NEPA) process. This document is being made available for information purposes only.



INTRODUCTION



- Mars Sample Return (MSR) is a strategic partnership venture between NASA and ESA.
- The Campaign would notionally return between 10-26 geologically diverse samples (plus witness tubes) able to answer an array of science objectives,
- One of the high priority science objectives is to “assess and interpret the potential biological history of Jezero Crater, including assessing returned samples for the evidence of life.” (iMOST Report)



First samples from Delta Front Campaign



PLANETARY PROTECTION GUIDELINES



- In compliance with the UN Space Treaty, the COSPAR Policy on Planetary Protection has designated Mars Sample Return (MSR) as a Planetary Protection Category V, restricted Earth return due to the scientific opinion that Mars is of significant interest to the process of chemical evolution and/or the origin of life.
- Article IX of the UN Treaty on Principles Governing the Activities of States in the exploration and Use of Outer Space [...] states: “parties to the Treaty shall pursue studies of outer space, including the moon and other celestial bodies, and conduct exploration of them so as to **avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter** and, where necessary, shall adopt appropriate measures for this purpose.”
- NASA Planetary Protection Requirements (NPR 8724.15, September 2021)
 - §3.4.1 For missions conducting restricted sample return **preventing harmful biological contamination of Earth’s biosphere is the highest priority**. [Backwards PP (BPP)]
 - §3.4.2 For each restricted sample return mission, the MDAA shall establish and implement a strategy and design concepts to **break the chain of contact with the target body, isolate, and robustly contain restricted samples**... [Forward PP (FPP)]
 - §3.4.3 The process to assure the safety and containment of Earth-return samples should address:
 - Consideration of PD/NSC-25 and the Procedures for Implementing the National Environmental Policy Act (NEPA), 14 CFR § 1216.3.
 - Definition of an appropriate risk posture, comparative or otherwise, to inform decisions regarding the biological containment of returned samples. (BPP)
 - Development, reporting, independent review, and acceptance by relevant authorities of an assurance case substantiating sufficient biological contamination control... (BPP)



DRIVING BPP CONCERN: MARS MATERIAL HAZARD POTENTIAL



- Mars has very low likelihood of hosting active biology or biomolecules
 - High radiation, low water environment damages biomolecules
 - Temperature and water activity are below levels required for active metabolism at depths from which M2020 will sample
 - Absent active metabolism, biomolecules will be degraded significantly
- The biological potential of a putative “Mars biosphere” is low
 - Cellular abundance estimates used by NASEM for the JAXA MMX mission are <10% of mean Earth abundance
 - Estimates based on available energy for metabolism indicate Mars could only host 0.01-0.001% of Earth's biomass (Sholes et al., <https://doi.org/10.1089/ast.2018.1835>)
- The potential hazards are also very low likelihood
 - Host-pathogen relationships are evolutionary in nature and Mars-Earth exchange is infrequent – any pathogens are likely be non-specific to Earth species (including humans)
 - Invasive (Mars) species would encounter a largely inhospitable environment
 - Meteoritic inputs have delivered Mars material throughout Earth’s history – some on fast paths that do not experience sterilization (e.g., [Gladman, 1997](#))

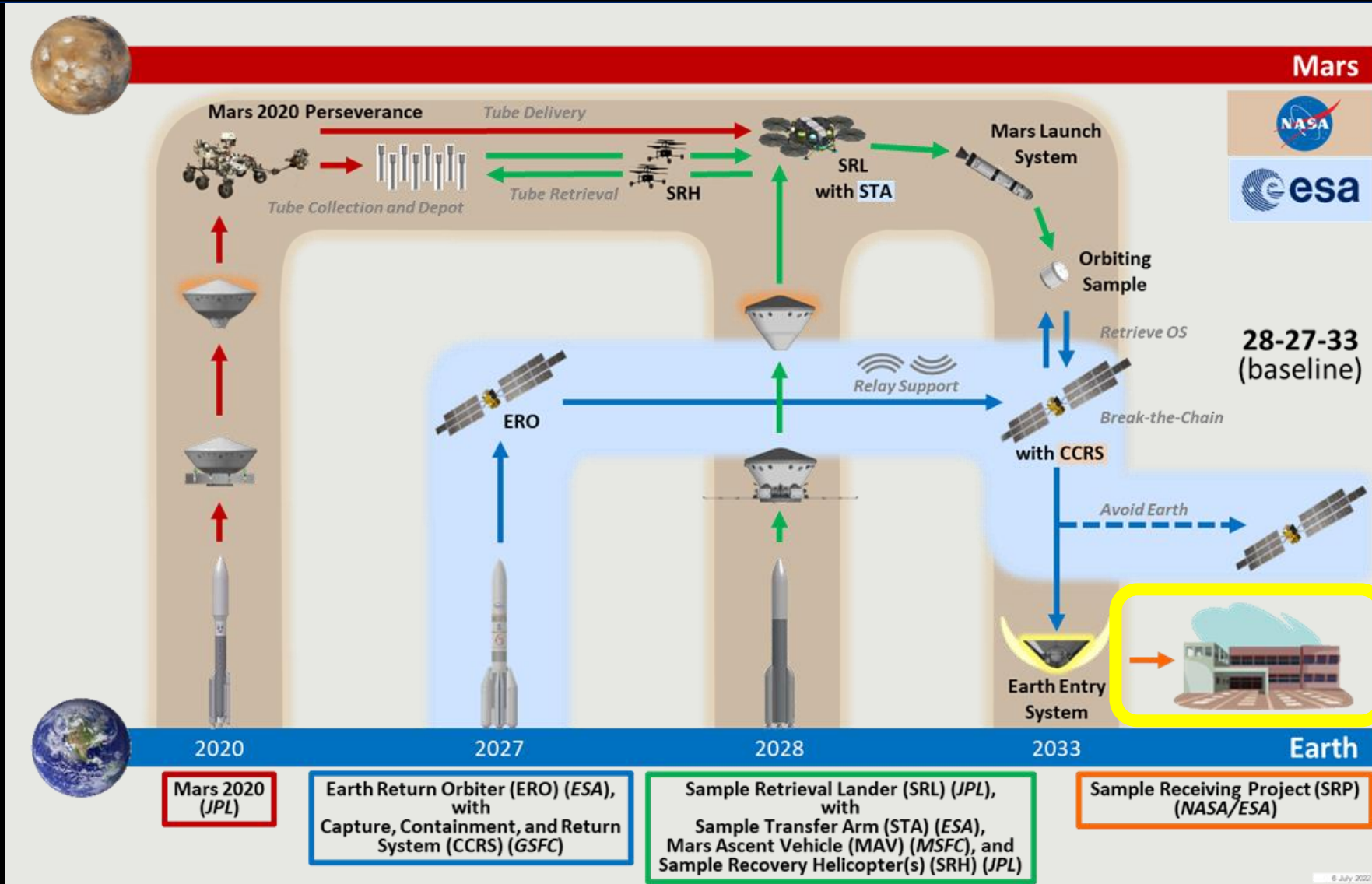
Still, due to our lack of data, we cannot exclude the potential for adverse effects

—and—

Current best practice is a “safety first” approach to contain unsterilized Mars material



MSR CAMPAIGN PLANNING OVERVIEW





ACTIVITIES IMPLEMENTING PLANETARY PROTECTION REQUIREMENTS

- **Ground Recovery Activities**
 - Safe capture and containment and sample transportation from UTTR to SRF
 - NEPA MSR PEIS Tier I: Site-Specific Analysis of Flight Elements (includes the site-specific proposal to land the vehicle containing the samples at UTTR);
 - Draft PEIS release 11/4 (<https://www.nasa.gov/feature/nepa-mars-sample-return-campaign/>)
- **Sample Receiving Facility (SRF)**
 - Investigate infrastructural options and requirements to accommodate the curation and science instruments needed to generate a sample catalogue, perform the biohazard assessment, and select early science.
 - NASA Mars Sample Receiving Facility (SRF) Assessment Study (MSAS) - Assess the feasibility of utilizing different infrastructural modality options as well as assess the accommodation options for the curation and science instruments needed to generate a sample catalogue, perform the biohazard assessment, and select early science.
 - ESA's European Extraterrestrial Sample Infrastructure (EETSI) System Study - Part of the study delivers a preliminary design, cost and schedule for an SRF, following the same assumptions as MSAS, but considering only a traditional new-built facility.
 - NEPA MSR PEIS Tier II: Site-Specific Analysis of Ground Elements (sample transportation from UTTR and SRF)
- **Research and Development**
 - Support SRF studies, enable pristine and contained sample processing/storage, and sterilization verification for samples and equipment

Today's Focus

- **Contamination Knowledge Samples**
 - Witness and reference items collected during ATLO to be utilized as scientific baselines

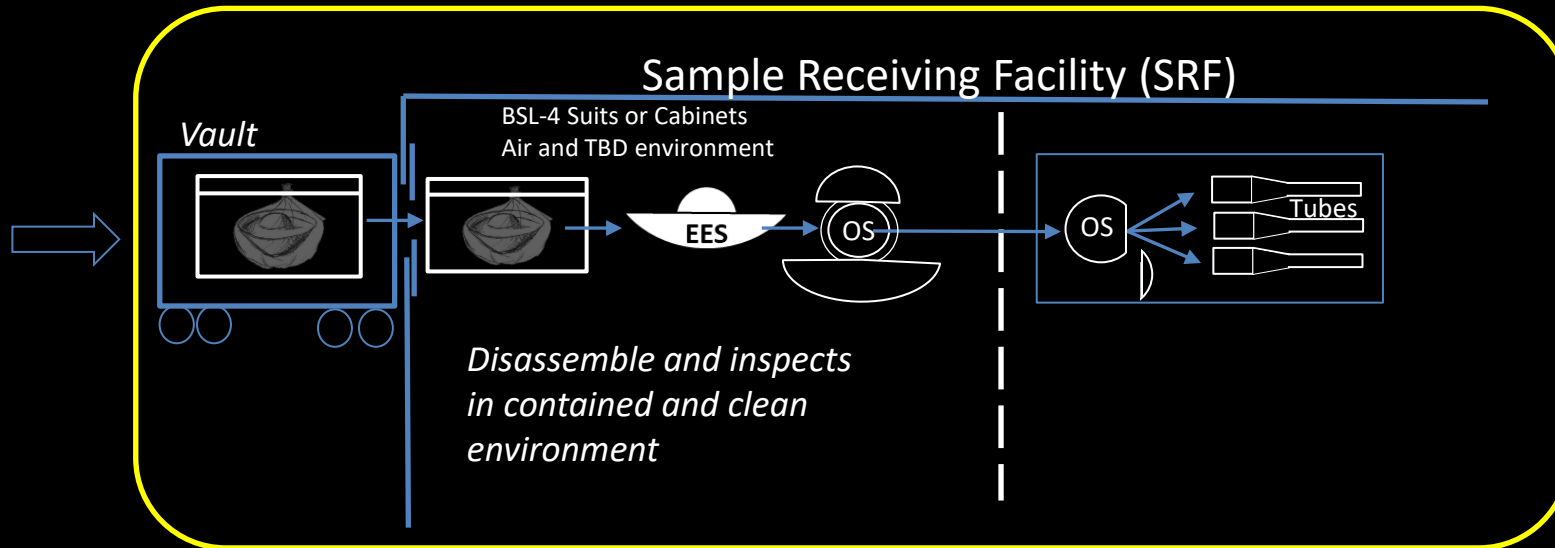
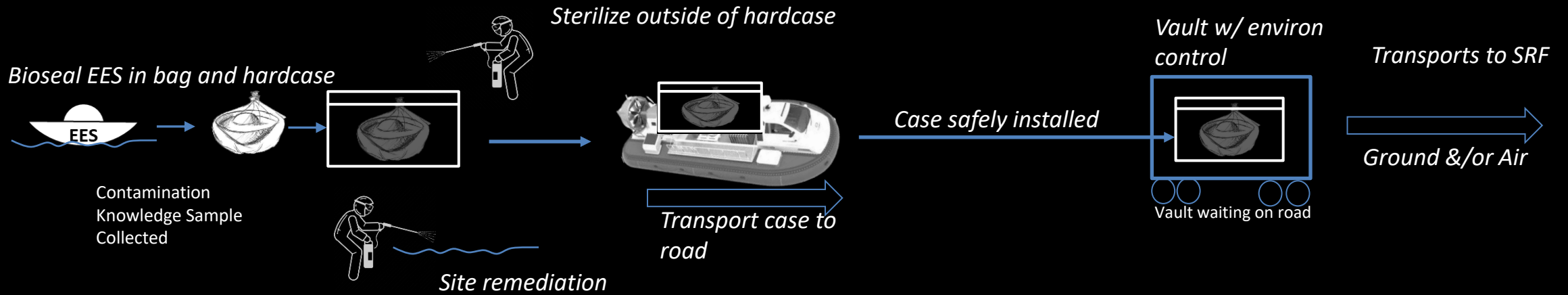
Curation Leading or Significantly Involved

- **Biohazard Testing**
 - COSPAR Sample Safety Assessment Framework - Evaluates whether there is Martian life present in the samples that could be released into Earth's systems (e.g., environment, biosphere, geochemical cycles). (Kminek et al 2022; <https://doi.org/10.1089/ast.2022.0017>)
 - Sample Safety Assessment Protocol is not yet defined
- **Assurance Case Approach for BPP**
 - Utilize quantitative data from requirements verification and validation (V&V) and qualitative arguments to demonstrate a safe return capability (analogous to nuclear and aviation safety approaches), includes 1) Biological Safety Case, 2) Containment Assurance Case, and 3) Role of MSR Backwards PP Risk Elements and Requirements Structure
 - Potential Standards for Defining Sufficient Containment

Curation Supporting and Implementing



NOTIONAL GROUND RECOVERY ACTIVITY



In-line with Genesis and Stardust Recovery at UTTR



MSR SRF CAPABILITIES AND PRIORITIES



Receive Spacecraft



Hardware Disassembly



Sample Tube
Pre-Basic Characterization



Samples Opened and
Basic Characterization



Samples Picked
and/or subdivided

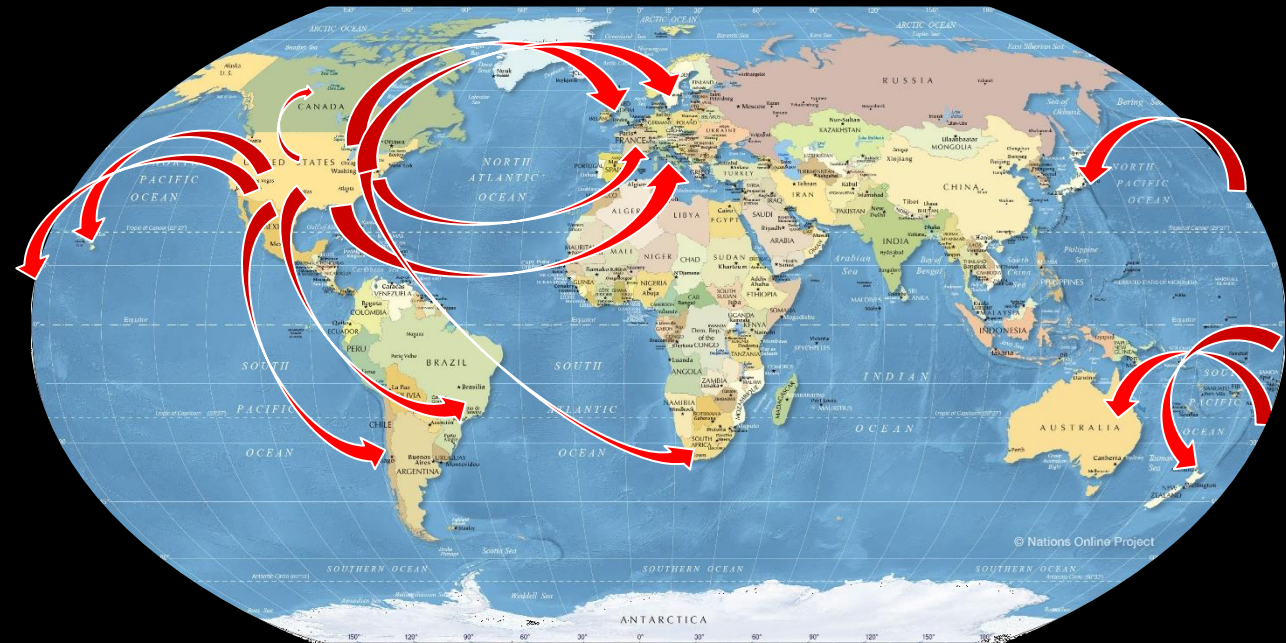


Allocated Sample
Sterilization Process
(Irradiation or Heat)

~72% of science investigations concerning geological phenomena that include past interactions with the hydrosphere and atmosphere can be performed on sterilized samples. (see MSPG-2)

~14% of science investigations concerning the presence of (mostly molecular) biosignatures can be performed on sterilized samples. (see MSPG-2)

Biohazard Assessment,
Preliminary
Examination, and/or
Select Early Science



Global Safe Sample Distribution for
Earth-based Science Investigations

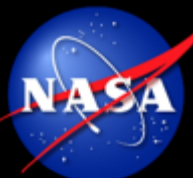


MSR SRP HIGH-LEVEL NOTIONAL SCHEDULE



FISCAL YEAR	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	COMMENTS
Sample Receiving Facility																
Sample Receiving Project Formulation		Project Formulation														
Pre-Study Prep	Pre-Study Prep															
Assessment Study Phase 1 - Modality Down-Selection		Modality Feasibility Study --> Gate 1														
Assessment Study Phase 2 - High-Level Conceptual Design			Conceptual Design --> Gate 2													
Detailed (Site Specific) Design				Detailed (Site Specific) Design												
Construction						Construction (includes installation of major equipment)										
Commission										Commission						
Outfit/Test/Training											Outfit/Test/Training in Operational Facility					
Operations													Operations			
SRF Required Inputs																
Establish Science, Contamination Control & Infrastructural			Establish Requirements (Isolators, Cleanroom, Science Instrumentation)													
Planetary Protection & Regulatory			Facility containment & sample isolation requirements													
NEPA Inputs/EIS		Launch Approval Engineering														
R&D - Major Infrastructural Impacts		Prototypes for major equipment necessary for SRF sizing/design (Double Walled Isolator; Sample Handling; Science Instrumentation)														
MSR Campaign Science Group(s)			Define science priorities (Inform facility requirements, science instrumentation, R&D tasks)													
Ground Recovery Activity			Scope of activities at landing site, SRF Integration Requirements													

- Sample Receiving Facility (SRF) readiness is driving schedule
- Outputs from International MSR Working Groups (e.g., MSPG2, SSAF) are foundational for planning
- Refinement of guidelines into requirements is a priority to inform site-specific design
- PP considerations are a priority and span from major infrastructure to instruments and workflows



Inform Site-Specific Design
Major infrastructural impacts

Refine Workflows
Minor infrastructural impacts

Finalize Instrumentation
No infrastructural changes possible without schedule slip (programmatic risk)

NASA ASTROMATERIALS ACQUISITION & CURATION OFFICE



- The Astromaterials Acquisition and Curation Office at NASA Johnson Space Center (JSC) is charged with “the curation of all extraterrestrial materials under NASA control, including future NASA missions” as per NASA Policy Directive (NPD) 7100.10F + derivative NPR “Curation of Extraterrestrial Materials.”
- The Directive goes on to define Curation as including “...documentation, preservation, preparation, and distribution of samples for research, education, and public outreach.”
- As a part of documentation and preservation, the Curation Office also coordinates sample capture, containment, and transportation to the curation facility.
- A major part of the Curation Office’s charge is to integrate requirements, develop implementation strategies, and deliver a facility capable of meeting Mission goals while satisfying requirements levied by the Project, Planetary Protection, the Agency, and Regulatory Authorities.
- The Curation Office does NOT generate Planetary Protection requirements.



CURATION OF ASTROMATERIALS IS MORE THAN STORAGE



- Curation begins with the initial planning and design of the sample return mission, and is carried through every aspect of the mission due to:
 - Heritage Knowledge – By carrying over information from past missions, lessons learned can be put in place to try to ensure a more successful mission. Two prime examples:
 - Material Compatibility with Contamination Control Requirements
 - Proper budgeting (time and financial) for manufacturing of scientific blanks
 - Sufficient Contingencies and Contamination Knowledge (CK) Samples – This is the only way to ensure that the science return on samples, particularly if something unexpected happens.
 - Enable Objective-Driven & Opportunity Science – Characterize and allocate samples in order to accomplish Project science goals and early science.
 - Enable Future Science – Conserve a representative quantity of pristine samples for future generations of scientists with innovative ideas and more advanced analytical equipment.

Proper curation ensures short and long-term science objectives are achieved.



JSC's ASTROMATERIALS ACQUISITION & CURATION OFFICE



Lunar
(1969)
Apollo program lunar rocks and soils; Luna samples

Meteorite
(1977)
Antarctic Search for Meteorites (ANSMET) program

Cosmic Dust
(1981)
Cosmic dust grains from Earth's stratosphere

Microparticle Impact Col.
(1985)
Space exposed hardware from spacecraft

Genesis
(2004)
Genesis solar wind samples at Earth-Sun L1 point

Stardust
(2006)
Cometary and interstellar samples from Comet Wild 2

Hayabusa
(2012)
Samples collected from JAXA asteroid mission to Itokawa

Hayabusa II
(2020)
Subset of samples collected from JAXA asteroid mission to (162173) 1999

Our Near Future . . .

OSIRIS-REx
(2023)
Asteroid sample return from 101955 Benu

Artemis
(~2026)
Lunar polar region; Lunar rocks, soils, and volatiles

Authority from NPD 7100.10F + derivative NPR

Our More Distant Future . . .

Moon
(2020s)
Non-volatile-rich farside/polar sample return

Next New Frontiers Call

Comet
(2020s)
Cold curated (?) surface sample return from a comet

Next New Frontiers Call

Phobos
(late 2020s)
10% of a JAXA mission to bring back Phobos material

JAXA sample return mission
MMX

Mars
(~2030+)
Various Mars Sample Return

Over 50 years in the planning (est. 1964)



LUNAR RECEIVING LAB FOR APOLLO RESTRICTED MISSIONS



1967 Site Aerial Photo

The 84,326 ft² (7,834 m²) LRL facility was designed to the following functional requirements:

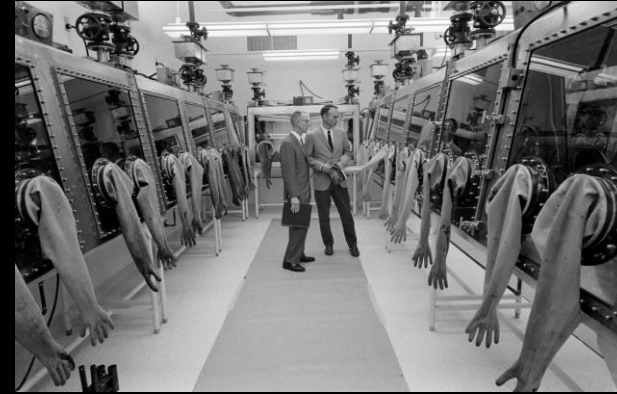
- Biological quarantine of astronauts, spacecraft, equipment, and samples
- Biohazard clearance testing
- Preparation of sample return containers and astronaut geologic hand tools before flight
- Receiving sample return containers and conducting preliminary sample characterization
- Time-sensitive primary scientific analyses
- Sample curation: cataloging, sample storage, re-packaging and distribution of lunar samples to the scientific community for analysis



LUNAR RECEIVING LAB FOR APOLLO RESTRICTED MISSIONS



1967 Site Aerial Photo



Thermal Analyzer/Mass Spec.



Single-Crystal X-Ray Diffractometer



Ion Microprobe Mass Analyzer



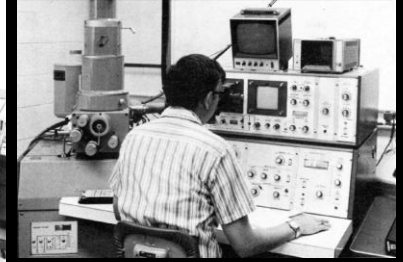
Electron Microprobe



Mass Spectrometer



Scanning Electron Microprobe



Routes into biologically isolated sectors of the Lunar Receiving Lab are shown here by red lines. At upper left, lunar samples arrive and are taken to vacuum system and radiation lab by elevator. Other entrances indicated are for astronauts, for the command module, for food and laundry. Lines at far right show where lab personnel come and go through ultraviolet airlocks (purple).

Lunar Sample Laboratory

More than 100 scientists and technicians will perform tests with lunar materials in the lab area, shaded green.

- 1 Vacuum system where lunar material is received and processed
- 2 Carousels for storage and transfer of lunar material
- 3 Controls for vacuum system
- 4 Equipment for preflight tool sterilization
- 5 Gas analysis laboratory
- 6 Special air conditioning system to sterilize air entering and leaving building
- 7 Elevator
- 8 Viewing room for participating scientists
- 9 Pump room and electrical support equipment for vacuum system
- 10 Transfer tubes for moving samples directly from vacuum system to labs
- 11 Physical-chemical test lab—mineralogy, petrology, geochemistry
- 12 Bio-preparation lab where lunar material is prepared, weighed and packaged for distribution
- 13 Bio-analysis lab for blood tests and other tests on mice
- 14 Holding lab for germ-free mice
- 15 Holding lab for conventional mice
- 16 Lunar microbiology lab to isolate, identify and possibly grow lunar microorganisms
- 17 Spectrographic lab and darkroom (connects to 11)

Anatomy of a Lunar Receiving Lab

Astronaut Reception Area

Quarantine area where astronauts will live and be examined is shaded yellow. In an emergency, lunar lab workers could also be quartered there.

- 18 Bird, fish and invertebrate lab where shrimp, quail, cockroaches, oysters and other creatures are exposed to lunar material
- 19 Microbiology lab for test cultures of lunar and astronaut material
- 20 Egg and tissue culture lab (support and additional facilities for 21)
- 21 Crew virology lab for postflight virological analysis of astronauts
- 22 Plant lab where germ-free algae, spores, seeds and seedlings will be exposed to lunar material
- 23 Entrance to lunar sample operations area. Showers and facilities for all personnel passing in and out to change clothing
- 24 Autoclave for sterilizing all material entering or leaving area
- 25 Bio-safety lab to monitor all systems
- 26 Support offices
- 27 Entrance to radiation counting lab

Radiation Laboratory

Chips from the first lunar samples will be sent to a radiation lab (blue in drawing) built 50 feet underground. There, their radioactivity will be measured and results may help indicate the age of the rocks and whether they ever existed in molten form.

Support and Administration

Beyond the two biologically secure portions of the lab, offices and support facilities are shown at left above. In the light green area, test animals and plants are raised and readied for studies. When quarantine is lifted, other areas in the section will be used to prepare lunar samples for shipment to universities around the world.

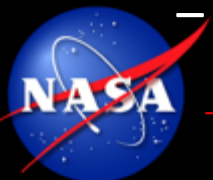


Life Magazine
July 4, 1969

MARS SAMPLE RECEIVING FACILITY (SRF) INITIAL ASSUMPTIONS



- The SRF is a short-term facility or facilities (2-5 year nominally) that should be fully operational by sample arrival and able to accommodate the highest priority instrumentation for curation, biohazard assessment, and select early/competed science.
- The SRF should also provide **high-containment** for all Martian material and keep the samples **pristine**.
 - **Containment** is assumed to be at Biological Safety Level (BSL)-4, the highest level available.
 - Appropriate for the most dangerous terrestrial pathogens
 - **Pristine** assumes, at minimum, contamination control (CC) levels met by M2020 for sample-intimate hardware.
 - This is **subject to future trades analysis**.
 - Historically, curated samples are required to be in pristine condition for a minimum of 50 years, which in-turn could lead to more stringent CC requirements.



BSL-4 CONTAINMENT FACILITY OPTIONS

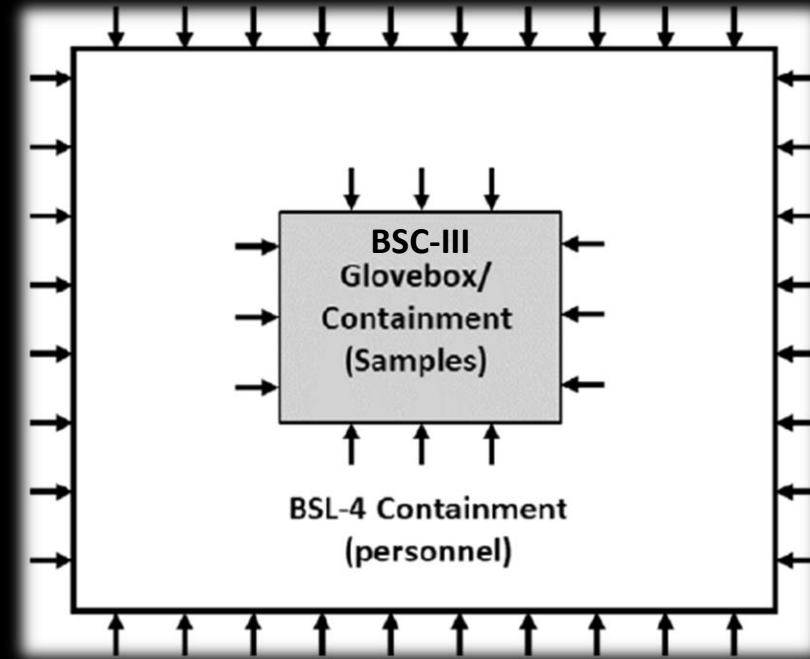


Personnel in Pressure Suits



Shope (USA)

Traditional high-containment facilities are designed to protect scientists and the community from exposure to known hazard(s).



Biosafety Cabinet (BSC)-III Cabinet Line



Porton Down (UK)

Negative Pressure Environment(s)



BSL-4 CONTAINMENT FACILITY

Personnel in Pressure Suits



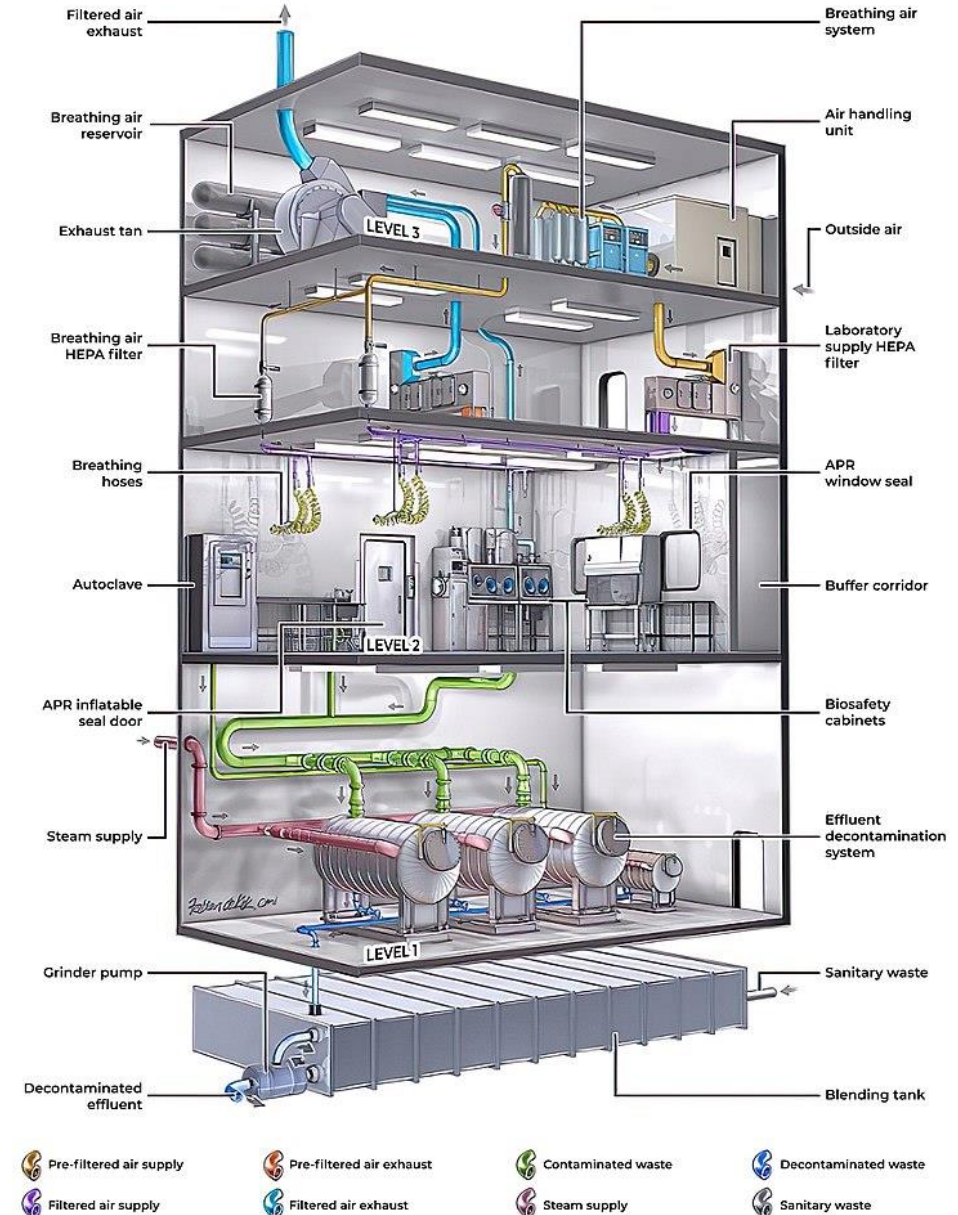
Shope (USA)

Biosafety Cabinet (BSC)-III Cabinet Line



Porton Down (UK)

SCHEME OF THE MOST ISOLATED BIOLOGICAL LABORATORY FOR WORKING WITH MICROORGANISMS OF PATHOGENICITY GROUPS I-II



PRISTINE FACILITY OPTIONS



Cleanroom in Full Bunny Suits



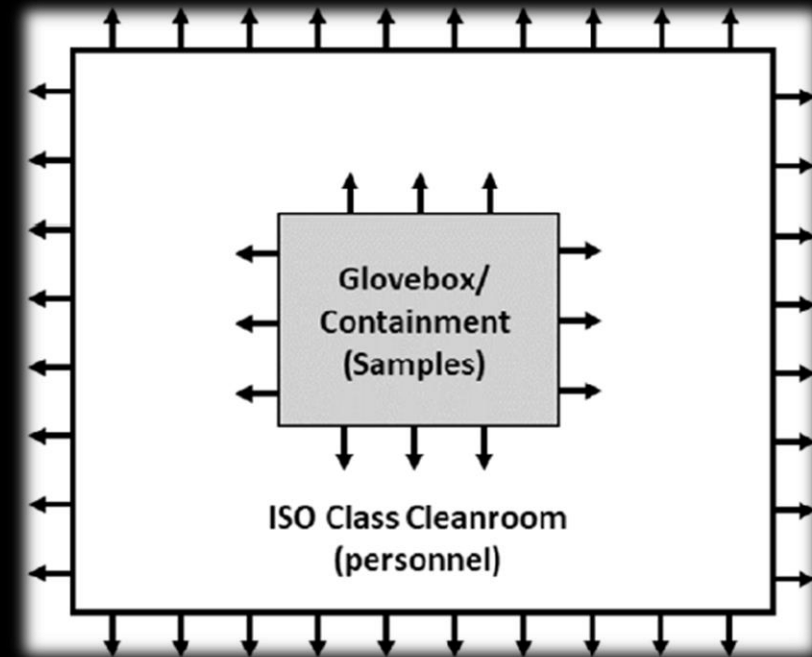
Cosmic Dust Laboratory JSC

Properly handling, examining, and curating Martian samples also requires that the samples be protected from terrestrial contamination so Planetary Protection (PP) and Science investigations are not impeded.

Gloveboxes



Apollo Laboratory JSC



Positive Pressure Environment(s)



PRISTINE FACILITY OPTIONS



Cleanroom in Full Bunny Suits

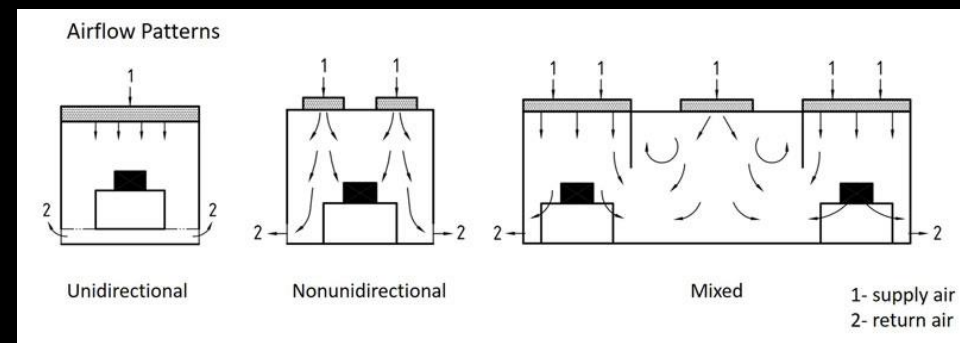
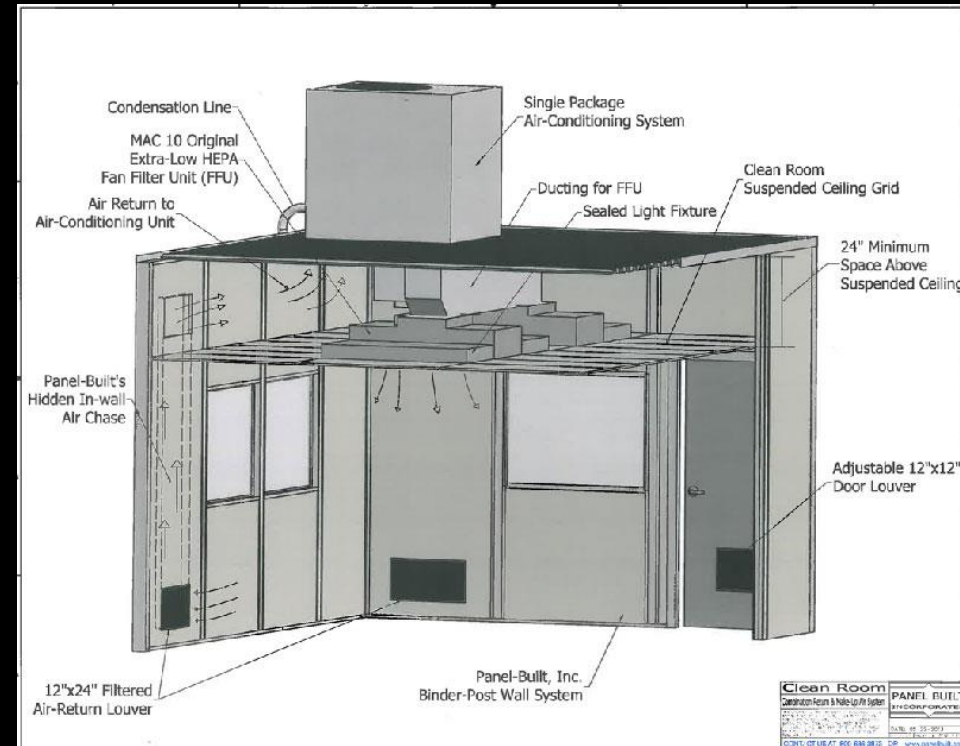


Cosmic Dust Laboratory JSC

Gloveboxes



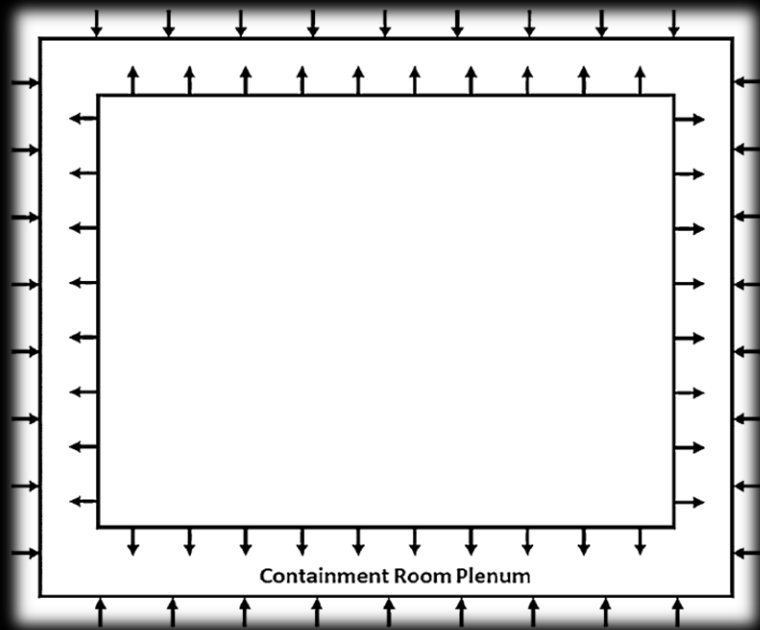
Apollo Laboratory JSC





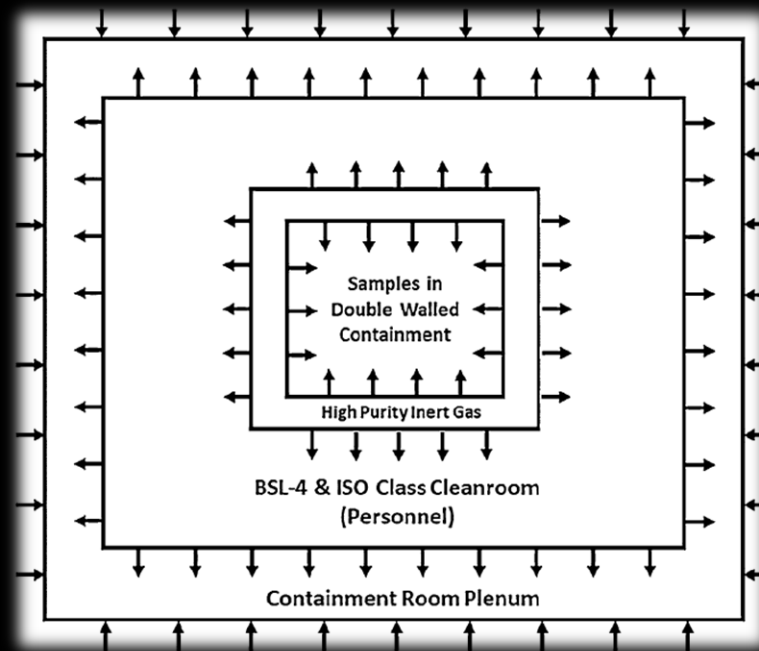
This combined effort requires the integration of both negative and positive pressure environments to meet the needs of PP and contamination control (CC).

Pristine Cleanroom Facilities within High Biological BSL-4 Containment



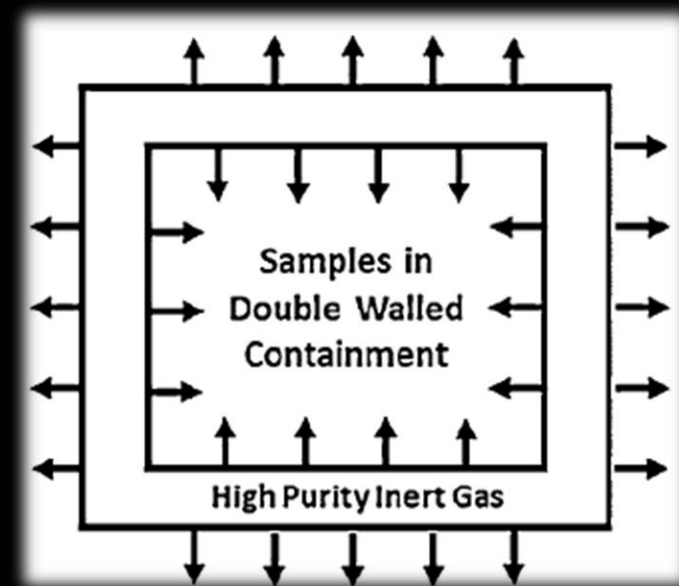
Outermost layer is negative pressure/containment to offer the greatest protection.

Combined facility and specialized isolator approach

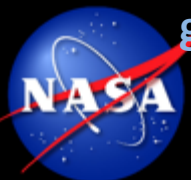


This measure may be necessary to ensure sample pristinity is not lost to sterilization in an off-nominal event.

BSC-III Cabinet within a Pristine Glovebox



Innermost layer is negative pressure/containment to offer the greatest protection.



SRF MODALITY OPTIONS



Traditional Fixed – Brick and Mortar



Dept. of Homeland Security
New USDA NBAF BSL-4 Facility

Utilize Existing BSL-4 Facility or Facilities



USAMRIID at Fort Detrick, MD

Modular Construction



Germfree BSL-3+ Modular Facilities



Hybrid of Multiple Facility Modalities



modular + *constructed annex (shell)* @ *existing BSL-4*



NEW BRICK-AND-MORTAR FACILITY APPROACH



Benefits

- Tailored to MSR's needs
- Method used by all U.S. BSL-4 laboratories constructed to date



Considerations

- Could be the most expensive modality
- Take the longest to implement
- Significant programmatic risk of delay



EXISTING BSL-4 FACILITY APPROACH



Benefits

- Leveraging existing infrastructure
- Built-in high-containment expertise
- Existing community buy-in
- Possible cost and schedule savings (with caveats)



Considerations

- Possible **capacity issues** providing enough lab space
- Accepting **large equipment** (e.g., EEV, DWIs, analytical instrumentation, etc.)
- **Possible cross-contamination vectors** and difficulties keeping an MSR lab clean; complications integrating cleanroom technology
- **Limits on modifications to facility** structure for tailored SRF needs
- Assuring **adequate isolation** from other labs so that unsterilized samples could be shared (pending biohazard assessment)
- **Programmatic risks** with sharing a facility (competing interest)



CONTEMPORARY MODULAR FACILITY APPROACH



Benefits

- Significant cost savings
- Shorter design/construction/commissioning schedule
- Flexibility for easier retrofits and future expansion
- Tailored to MSR's needs

Considerations

- Never been done before. While this approach has only been used for BSL-3/3Ag facilities, it appears feasible.*

The modular elements could be installed in a traditional building (existing or new) or shell structure.





HYBRID CONSTRUCTION APPROACHES:

- Utilize a combination of the three main modality options (e.g., Annex (Modular and/or Brick-and-Mortar) AND Existing BSL-4 Facilities)

Benefits

- Shorter design/construction/commissioning schedule
- Flexibility for easier retrofits and future expansion
- Tailored to MSR's needs
- Leveraging existing infrastructure
- Built-in high-containment expertise
- Existing community buy-in
- Possible cost and schedule savings

Considerations

- **Modular has never been done before.** While this approach has only been used for BSL-3/3Ag facilities, it appears feasible.
- Multiple simultaneous construction projects

The advantage of a hybrid approach is that the facility could leverage the strengths of each other's approaches



Contemporary Modular Facility in Conjunction with an Existing BSL-4 space



HIGHLIGHT OF OVERARCHING CONSIDERATIONS



Structural Constraints
Personnel Safety
PP Requirements
CC Requirements
Preliminary Examination Requirements
Science Requirements
Construction Timeline
Cost Effectiveness (short and long-term)
Adaptability to Changing Needs
Facility Fair Use/Access to Samples
Partnership/Reutilization Opportunities

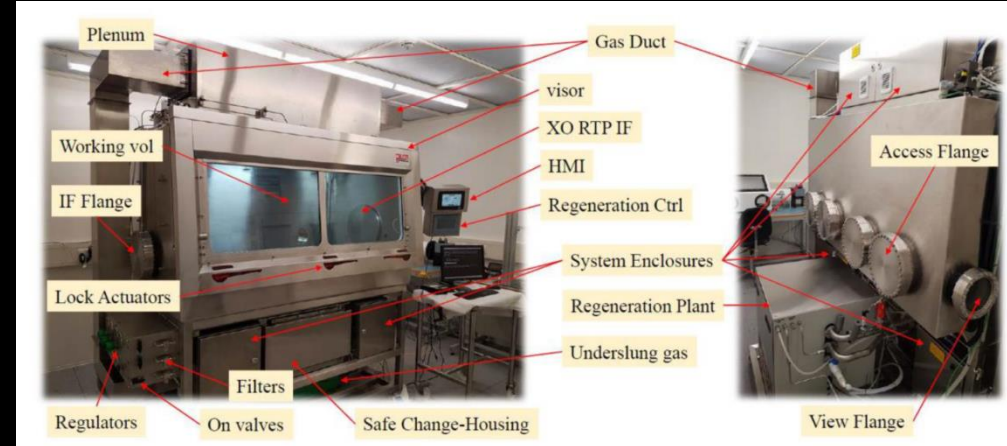
Upon completion of the assessment studies, the preferred modality and refined requirements would be utilized for site-specific design but will not be finalized until NASA's completion of the National Environmental Policy Act (NEPA) process.



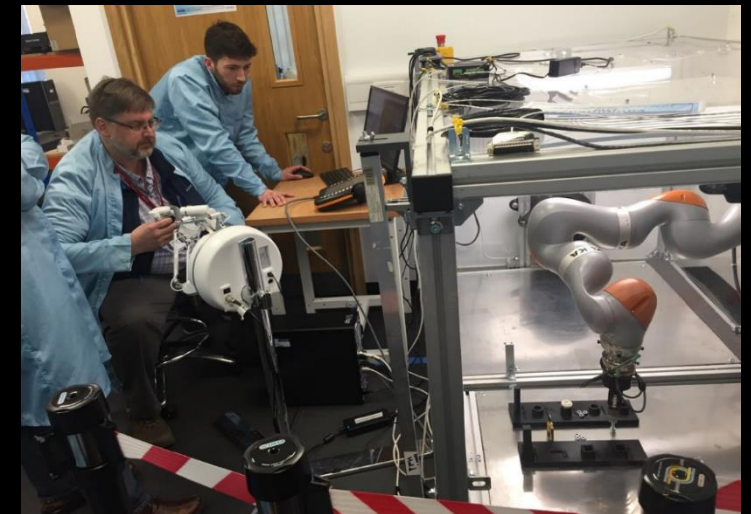
RESEARCH & DEVELOPMENT IN SUPPORT OF SRF DESIGN & OPS



- Double Walled Isolator (DWI) Design
- Sample handling - Robotic and/or Remote Manipulation
- Sample Tube and Subsample Isolation Containers for Analyses Outside SRF
- High-Containment suit and infrastructural material contamination control testing
- Quantify contamination loads of existing BSL-4 facilities
- Instrument accommodations
- Sample sterilization
- Infrastructural cleaning and sterilization procedures



DWI Breadboard at U. Leicester



Robotic Manipulation Breadboard at Thales Alenia UK

Close collaboration between Curation, Science, and PP Teams



CLOSING HIGHLIGHTS

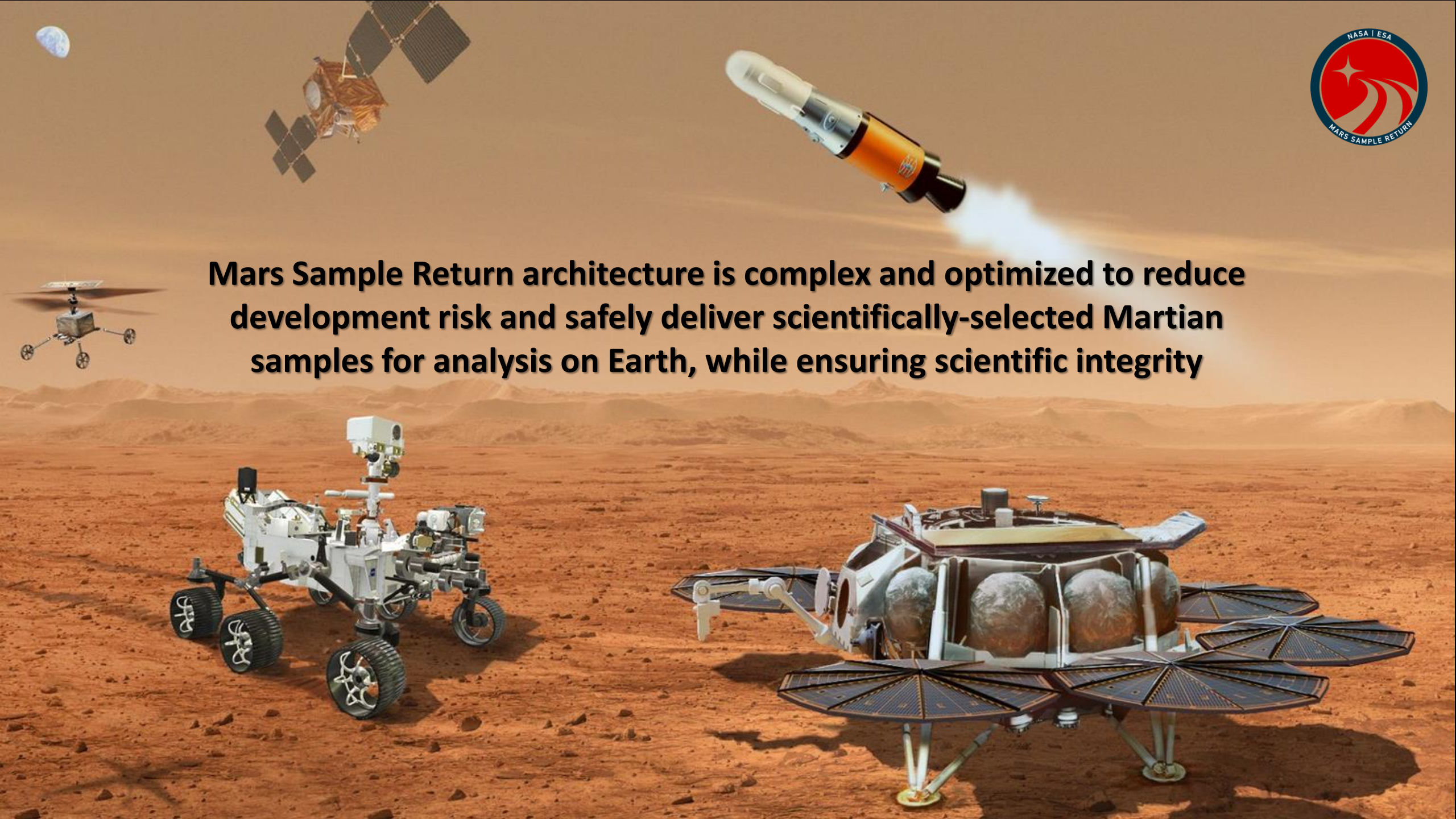


- The Curation Office implements Planetary Protection requirements, it does not make them.
- Complementary NASA/ESA SRF studies will inform site-specific design
- Array of R&D with Planetary Protection implications are prioritized
- The nature of MSR ground operations planning requires effective communication across agencies (national and international), centers, scientists, and the general public





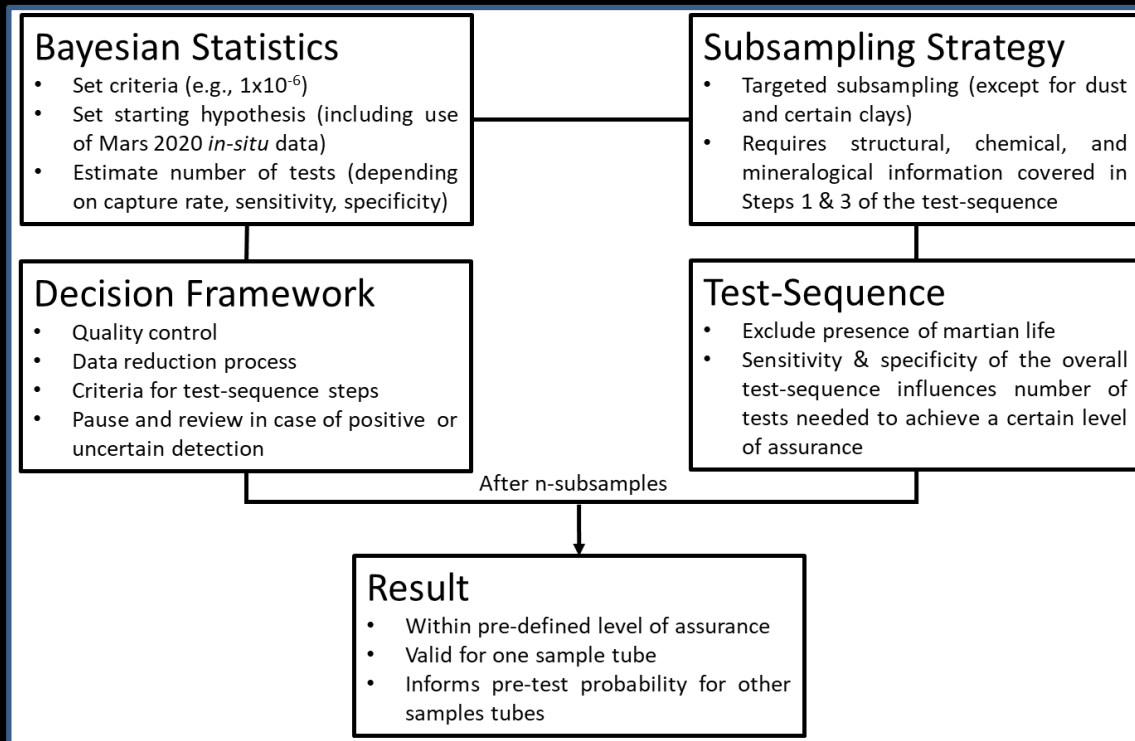
Mars Sample Return architecture is complex and optimized to reduce development risk and safely deliver scientifically-selected Martian samples for analysis on Earth, while ensuring scientific integrity



THE SAMPLE SAFETY ASSESSMENT FRAMEWORK



- Framework to “evaluate only whether the presence of martian life can be excluded in samples returned from Mars.”
- Considers only carbon-based life
- It is a Framework – detailed Protocol still tbd



ASTROBIOLOGY
Volume 22, Supplement 1, 2022
Mary Ann Liebert, Inc.
DOI: 10.1089/ast.2022.0017

Open camera or QR reader and scan code to access this article and other resources online.



COSPAR Sample Safety Assessment Framework (SSAF)

Gerhard Kminek,¹ James N. Bonardini,² Frank E. Brenker,³ Timothy Brooks,⁴ Aaron S. Burton,⁵ Suresh Dhanipala,⁶ Jason P. Dworkin,⁷ Jeffrey L. Fortman,⁸ Mihaela Glamoclija,⁹ Monica M. Grady,¹⁰ Heather V. Graham,¹¹ Junichi Haruyama,¹² Thomas L. Kieft,¹³ Marion Koopmans,¹⁴ Francis M. McCubbin,⁵ Michael A. Meyer,¹⁵ Christian Mustin,¹⁶ Tullis C. Onstott,¹⁷ Neil Pearce,¹⁸ Lisa M. Pratt,¹⁹ Mark A. Sephton,²⁰ Sandra Siljeström,²¹ Haruna Sugahara,²² Shino Suzuki,²³ Yohey Suzuki,²⁴ Mark van Zuilen,^{24,25} and Michel Viso²⁶

Abstract

The Committee on Space Research (COSPAR) Sample Safety Assessment Framework (SSAF) has been developed by a COSPAR appointed Working Group. The objective of the sample safety assessment would be to evaluate whether samples returned from Mars could be harmful for Earth's systems (e.g., environment, biosphere, geochemical cycles). During the Working Group's deliberations, it became clear that a comprehensive assessment to predict the effects of introducing life in new environments or ecologies is difficult and practically impossible, even for terrestrial life and certainly more so for unknown extraterrestrial life. To manage expectations, the scope of the SSAF was adjusted to evaluate only whether the presence of martian life can be excluded in samples returned from Mars. If the presence of martian life cannot be excluded, a Hold & Critical Review must be established to evaluate the risk management measures and decide on the next steps. The SSAF

¹European Space Agency, Mars Exploration Group, Noordwijk, The Netherlands.

²NASA Headquarters, Office of Planetary Protection, Washington, DC, USA.

³Goethe University, Department of Geoscience, Frankfurt, Germany.

⁴UK Health Security Agency, Rare & Imported Pathogens Laboratory, Salisbury, UK.

⁵NASA Johnson Space Center, Astronautics Research and Exploration Science Division, Houston, Texas, USA.

⁶Clarkson University, Department of Mechanical and Aeronautical Engineering, Potsdam, New York, USA.

⁷NASA Goddard Space Flight Center, Solar System Exploration Division, Greenbelt, Maryland, USA.

⁸Security Programs, Engineering Biology Research Consortium, Emeryville, USA.

⁹Rutgers University, Department of Earth and Environmental Sciences, Newark, New Jersey, USA.

¹⁰The Open University, Faculty of Science, Technology, Engineering & Mathematics, Milton Keynes, UK.

¹¹NASA Goddard Space Flight Center, Astrochemistry Laboratory, Greenbelt, Maryland, USA.

¹²Japan Aerospace Exploration Agency (JAXA), Institute of Space and Astronautical Science (ISAS), Chofu, Tokyo, Japan.

¹³New Mexico Institute of Mining and Technology, Biology Department, Socorro, New Mexico, USA.

¹⁴Erasmus University Medical Centre, Department of Viroscience, Rotterdam, The Netherlands.

¹⁵NASA Headquarters, Planetary Science Division, Washington, DC, USA.

¹⁶Centre National d'Etudes Spatiales (CNES), Nancy, France.

¹⁷Princeton University, Department of Geosciences, Princeton, New Jersey, USA.

¹⁸London School of Hygiene & Tropical Medicine, Department of Medical Statistics, London, UK.

¹⁹Indiana University Bloomington, Earth and Atmospheric Sciences, Encris, Bloomington, Indiana, USA.

²⁰Imperial College London, Department of Earth Science & Engineering, London, UK.

²¹RISE, Research Institutes of Sweden, Department of Methodology, Textiles and Medical Technology, Stockholm, Sweden.

²²Japan Aerospace Exploration Agency (JAXA), Institute of Space and Astronautical Science, Sagamibara Kanagawa, Japan.

²³University of Tokyo, Graduate School of Science, Tokyo, Japan.

²⁴Université de Paris, Institut de Physique du Globe de Paris, Paris, France.

²⁵European Institute for Marine Studies (IUEM), CNRS-UMR6538 Laboratoire Geo-Océan, Plouzané, France.

²⁶Conselleria Científica, Innovaxiom, France.

© Gerhard Kminek *et al.*, 2022; Published by Mary Ann Liebert, Inc. This Open Access article is distributed under the terms of the Creative Commons License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

S-186



SAMPLES COLLECTED DURING ATLO



Witness Items
→

Contamination Control

Spacecraft & Sample Integrity

Contamination Control manages molecular, particulate, and biological contamination that can degrade or compromise: 1) the performance of the spacecraft and 2) the scientific investigations on returned samples.

Governed by the Mission

Planetary Protection

Forward & Backward Contamination

Planetary Protection involves protecting the planet we are visiting and protecting the Earth from harmful organic or biological elements when we return samples, contaminated spacecraft, or astronauts.

Governed by the Planetary Protection Office

Witness Items
→
Reference Materials

Contamination Knowledge

Scientific Baselines

Contamination Knowledge is the information gained from studying the collected/curated reference materials and witness plates in conjunction with returned sample analysis.

Governed by the Astromaterials Acquisition and Curation Office

Reference Materials
→

Engineering Knowledge

Troubleshooting

Information gained from engineering models after launch.

Governed by the Mission

Each sample type of sample is for distinct objectives

CC and PP data can be complementary to CK



MARS SAMPLE RETURN CK COLLECTION (GENETIC & CC DATA)



- Biological CK
 - Swabs
 - Wipes
- Flight Vacuum Bake-Out Witness Plates
- Flight Replicates
 - Sample Tubes
 - Drill Bit
 - Coring Bit
 - Abrading Bit
 - Drillable Blank
- Environmental Witness Plates & Foils
 - SIH Flow Benches
 - Assembly Rooms
 - Organic
 - Inorganic
- SIH Witness Items
 - Gloves
 - Wipes
- Flight Replicates
 - SHERLOC Cal Target
 - 7 Sample Tube Assemblies
 - 7 Glove Assemblies
 - 7 Sample Tube Storage
 - Volume Station Assembly
 - Seal Dispenser Assembly
 - 7 Hermetic Seal Assemblies
 - 2 Cover Assemblies
 - 2 Witness Tube Assemblies
- Material Samples
- Final Solvent Rinses
 - Hexane
 - Isopropanol
 - Acetone
 - Ethanol
 - DI Water

