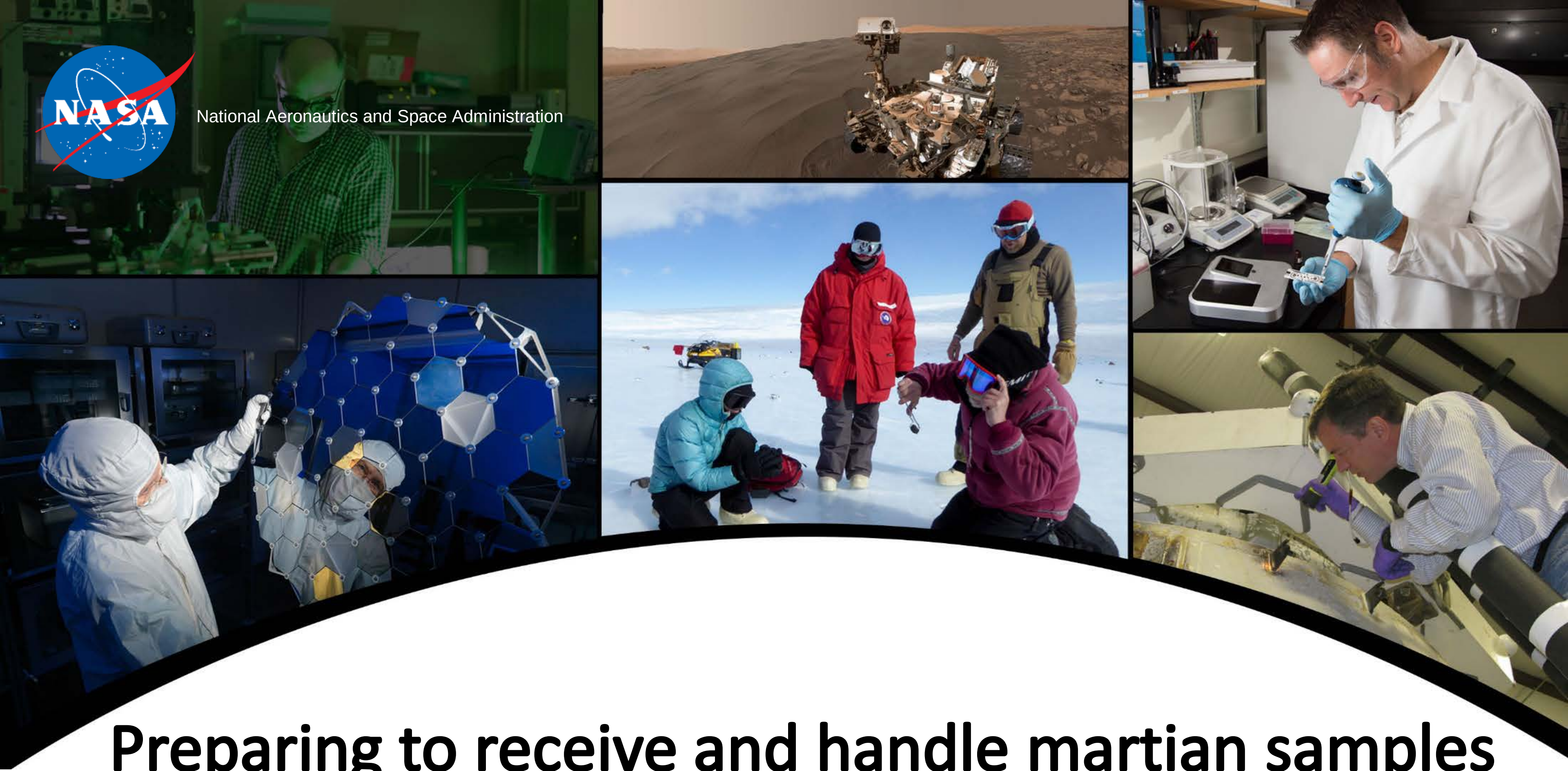
National Aeronautics and Space Administration



Preparing to receive and handle martian samples when they arrive on Earth

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eisd
EXPLORATION INTEGRATION AND SCIENCE DIRECTORATE

NASA Astromaterials Acquisition & Curation Office

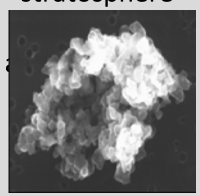
The Astromaterials Acquisition and Curation Office at NASA Johnson Space Center (JSC) is responsible for curating all of NASA's extraterrestrial samples. Under the governing document, NASA Policy Directive (NPD) 7100.10F + derivative NPR "Curation of Extraterrestrial Materials", JSC is charged with "The curation of all extraterrestrial material under NASA control, including future NASA missions." The Directive goes on to define Curation as including "…documentation, preservation, preparation, and distribution of samples for research, education, and public outreach."

NASA Astromaterials Acquisition & Curation Office

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

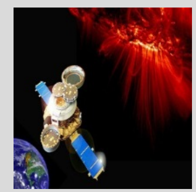
Meteorite
(1977)
Antarctic Search for Meteorites (ANSMET) program

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

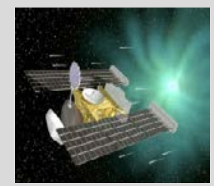


Space Hardware
(1985)
Space exposed hardware from spacecraft

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
(2021)
Subset of samples collected from JAXA asteroid mission to (162173) 1999

OSIRIS-REx
(2024)
Asteroid sample return from 101955 Bennu

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

Current New Frontiers Call

Comet
(2030s)
Cold curated surface sample return from a comet

Current New Frontiers Call

Mars
(2030s)

Jezero, NE Syrtis, or Columbia Hills

Mars 2020 may be first leg in MSR campaign

The importance of contamination knowledge (CK) samples during ATLO

- The curation of samples should not begin when they arrive at JSC (though this is important).
- The curation of samples should not begin when they arrive on Earth (though this is important).
- The curation of samples should not begin while you are building the spacecraft (though this is important).
- The curation of samples should begin with the initial planning and design of the mission, and be carried through every aspect of the mission.
  - This is the only way to ensure that you maximize the science return of your samples, particularly if something unexpected happens
  - CK samples, including blanks, witness plates, and hardware coupons help to establish the baseline contamination for scientific investigations

The collection of CK samples during ATLO

CK Strategy for OSIRIS-REx

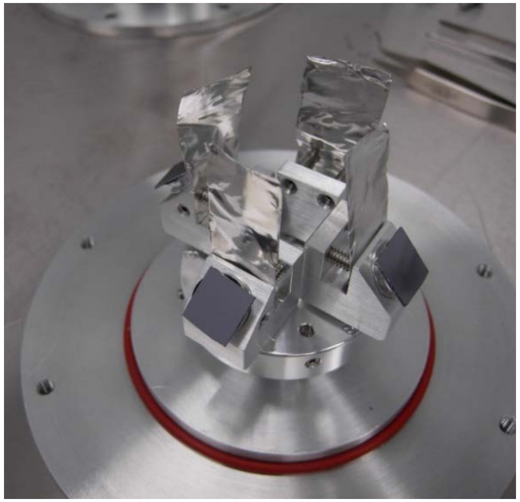
Materials either in direct contact with sample, or line of sight

Component	Al	epoxy	foil	honeyc omb	lubricant	misc	NVR	paint	polymer	sapphire	steel	Ti	Total
KSC	2	4	1		1	6	7		4				25
OCAMS		3			2	2		2	1				10
OLA		15	1										16
OTES					1								1
OVIRS		2			1			1					4
REXIS		1			1	2			1			1	6
spacecraft		4		3		8			1				16
SRC	30	51	1	1	3	18	6		3	3	45	1	161
support	1		1		1	19	2		11				35
TAGSAM	28	11			1	9	4			6	57	4	120
Total	61	90	4	4	11	64	19	3	21	9	102	6	395

Witness Plates – High purity materials continuously exposed during spacecraft ATLO

Ultrapure Al-foil and Si-wafers are exposed during spacecraft assembly.

They are analyzed by SEM each month (while others are archived) for near real-time feedback on the contamination environment that the spacecraft is exposed to.

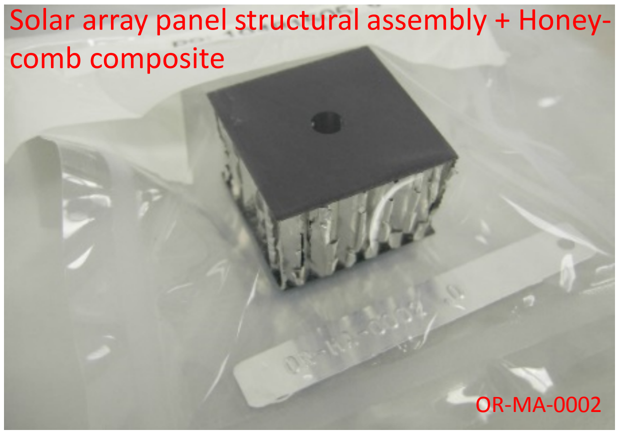


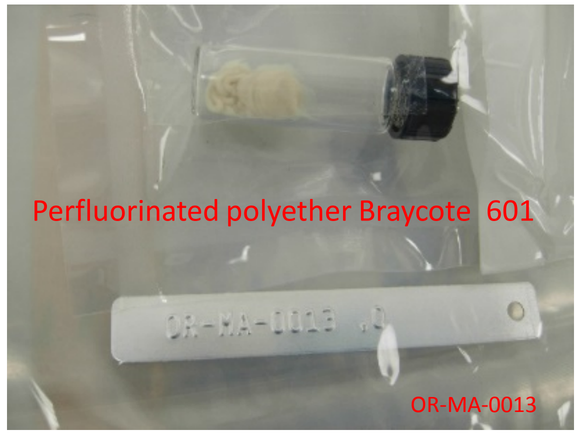
- Prepared at JSC
- Hand carried to Denver or KSC
- Deployed for one month
- Hand carried back to JSC

The collection of CK samples during ATLO

CK Strategy for OSIRIS-REx

Materials either in direct contact with sample, or line of sight





OSIRIS-REx coupon storage cabinet at JSC

Materials Coupons – Examples of materials used in the spacecraft that are possible sources of contamination.

Several hundred materials in total.

Some analyzed now, most archived for posterity in a dedicated cabinet in an ISO 7 cleanroom.

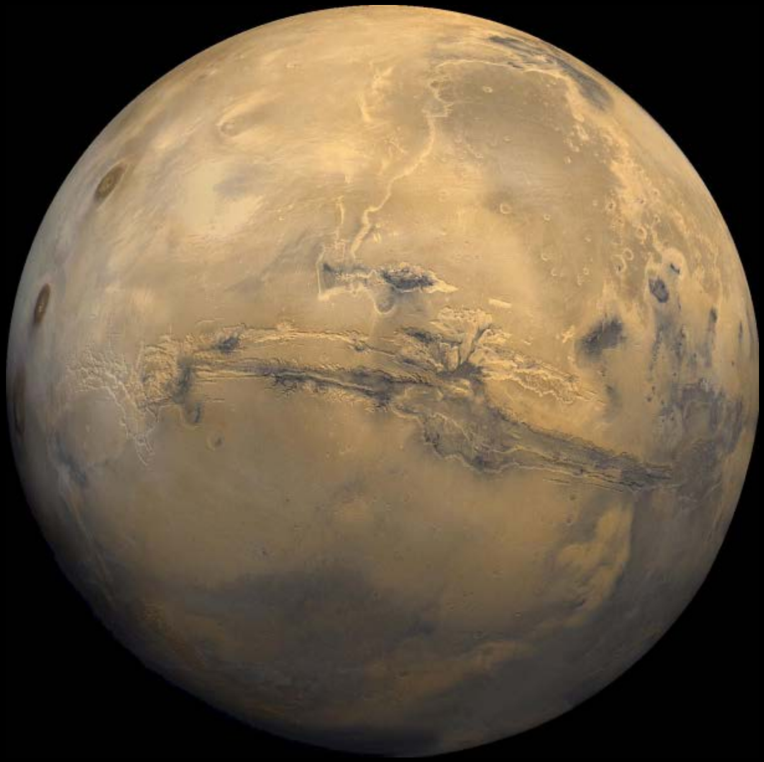
The collection of CK samples during ATLO

CK Strategy for Mars 2020

- Will follow closely with the strategies implemented for OSIRIS-REx
- CK samples will include witness plates and hardware coupons for any spacecraft components that might come into contact with samples, including any lubricants or machining fluids used during the fabrication of the spacecraft
- The CK collection will be stored in the JSC Microparticle Impact Lab (formerly Space Exposed Hardware Lab) within nitrogen flow cabinets

Cabinets identical to the one that houses OSIRIS-REx CK samples have been acquired for Mars 2020 CK samples

Mars sample return will present unique challenges



Mars (along with Europa and Enceladus) is designated as Planetary Protection Class V restricted Earth-return. This designation is for sample-return missions from bodies deemed by scientific opinion to be of significant interest to the process of chemical evolution and/or the origin of life.

- MSR could represent our first restricted Earth-Return mission

- This has important implications for the delivery of samples to Earth, and the subsequent handling, processing, and curation of samples once they are returned

Planetary Protection requirements for class V Restricted Earth-Return

NASA Interim Directive
NID 8020.109A
Planetary Protection Provisions for Robotic Extraterrestrial Missions
Effective Date: March 30, 2017

Category V, Restricted Earth Return (Noted Summary Requirements): "Impact avoidance and contamination control including: clean room assembly, microbial containment of sample, breaking chain of contact with target planet, sample containment and biohazard testing in receiving laboratory (continuing monitoring of project activities, preproject advanced studies and research, as needed)."

"2.3.3 For PP Category V missions designated as "Restricted Earth Return," an extensive set of additional documentation, detailed in section 2.7, shall be required. The associated activities and reviews are intended to ensure that the Earth's biosphere is not adversely affected by the introduction of material from returned samples.

2.3.3a The highest degree of concern is expressed by the prohibition of destructive impact upon return, the need for containment throughout the return phase of all returned hardware which directly contacted the target body and/or any unsterilized material from the body, and the need for containment of any unsterilized sample collected and returned to Earth.

2.3.3b After the flight mission there is a need to conduct, under strict containment and using approved techniques, timely analyses of the unsterilized sample collected and returned to Earth. If any sign of a non-terrestrial replicating entity is found, the returned sample must remain contained unless treated by an effective sterilizing procedure."

How do we meet PP requirements?

Biosafety Level 4 (BSL-4) Laboratory

Biosafety Level 4 (BSL-4) is required for work with dangerous and exotic agents that pose a high individual risk of aerosol-transmitted laboratory infections and life-threatening disease that is frequently fatal, for which there are no vaccines or treatments, or a related agent with unknown risk of transmission (*e.g.*, unknown viable life on extraterrestrial geologic material or flight hardware).

Agents with a close or identical antigenic relationship to agents requiring BSL-4 containment must be handled at this level until sufficient data are obtained either to confirm continued work at this level, or re-designate the level to less than BSL-4.

There are two models for BSL-4 laboratories:

- Cabinet Laboratory — Manipulation of agents must be performed in a Class III Biosafety Cabinet (BSC); *i.e.,* glovebox
- Suit Laboratory — Personnel must wear a positive pressure supplied air protective suit.

Negative Pressure BSL-4 cabinet and suit laboratories have special engineering and design features to prevent microorganisms from being disseminated into the environment.

Laboratory staff must have specific and thorough training in handling extremely hazardous infectious agents and must understand the primary and secondary containment functions of standard and special practices, containment equipment, and laboratory design characteristics. All laboratory staff and supervisors must be competent in handling agents and procedures requiring BSL-4 containment in accordance with institutional policies controls access to the laboratory.

USAMRIID – Fort Detrick
BSL-4 Pressurized Suit Laboratory

USAMRIID – Fort Detrick
ABSL-4 BSC Class III (Glovebox) Laboratory

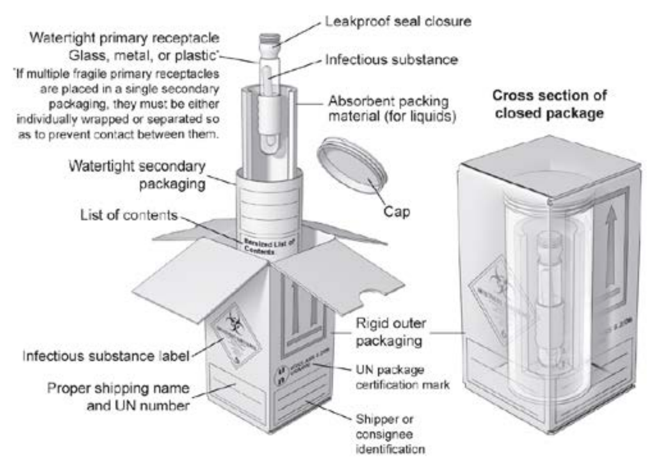
How do we meet PP requirements?

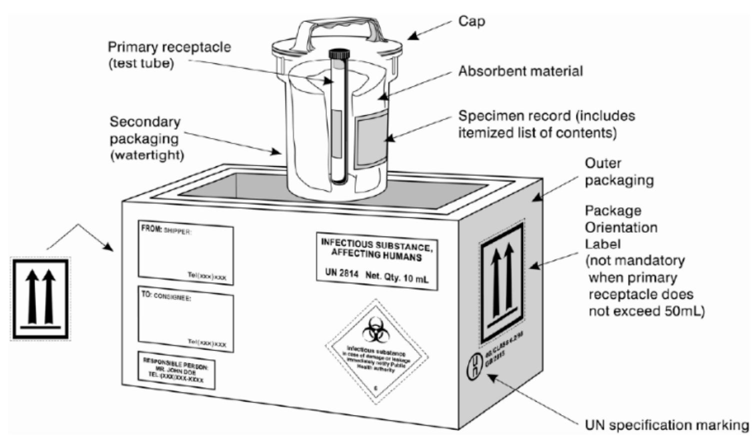
DOT Packaging Requirements for Transport of infectious substances from BSL-4 Facilities (from BMBL 2009)

The DOT packaging for transporting infectious substances by aircraft are required by domestic and international aircraft carriers, and are the basis for infectious substance packaging for motor vehicle, railcar, and vessel transport.

Category A Infectious Substance (UN 2814 and UN 2900): A Category A material is an infectious substance that is transported in a form that is capable of causing permanent disability or life-threatening or fatal disease to otherwise healthy humans or animals when exposure to it occurs. An exposure occurs when an infectious substance is released outside of its protective packaging, resulting in physical contact with humans or animals

Figure 1. *A Category A UN Standard Triple Packaging*





Examples of the UN standard triple packaging system for materials known or suspected of being a Category A infectious substance. The package consists of a watertight primary receptacle or receptacles; a watertight secondary packaging; for liquid materials, the secondary packaging must contain absorbent material in sufficient quantities to absorb the entire contents of all primary receptacles; and a rigid outer packaging of adequate strength for its capacity, mass, and intended use. Each surface of the external dimension of the packaging must be 100 mm (3.9 inches) or more. The completed package must pass specific performance tests, including a drop test and a water-spray test, and must be capable of withstanding, without leakage, an internal pressure producing a pressure differential of not less than 95 kPa (0.95 bar, 14 psi). The completed package must also be capable of withstanding, without leakage, temperatures in the range of -40ºC to +55ºC (-40ºF to 131ºF).

How do we meet PP requirements?

Conceptual BSL-4 Labs: Containers and Trucks – Air-Transportable









How do we meet PP requirements?

Conceptual BSL-4 Labs: Modular BSL-4 lab at JSC

Life detection testing and Preliminary Examination

NASA Interim Directive
NID 8020.109A
Planetary Protection Provisions for Robotic Extraterrestrial Missions
Effective Date: March 30, 2017

2.7.4.5 Sample Pre-Release Report
Before an extraterrestrial sample is released to the general scientific community for investigation, a "Sample Pre-Release Report“ shall be prepared certifying that, if released, the sample will not harm the Earth's biosphere. This report verifies that biohazard and life detection protocols have been executed and that samples are free of hazard to the Earth's biosphere and are, therefore, safe for release.

2.3.3b
After the flight mission there is a need to conduct, under strict containment and using approved techniques, timely analyses of the unsterilized sample collected and returned to Earth. If any sign of a non-terrestrial replicating entity is found, the returned sample must remain contained unless treated by an effective sterilizing procedure.

Life detection testing and Preliminary Examination

Martian Samples

Preliminary Examination

Under BSL-4

In tandem?

Sterilized sample

Life detection

Samples for initial scientific examination (CAPTEM)

Curated sample for future studies

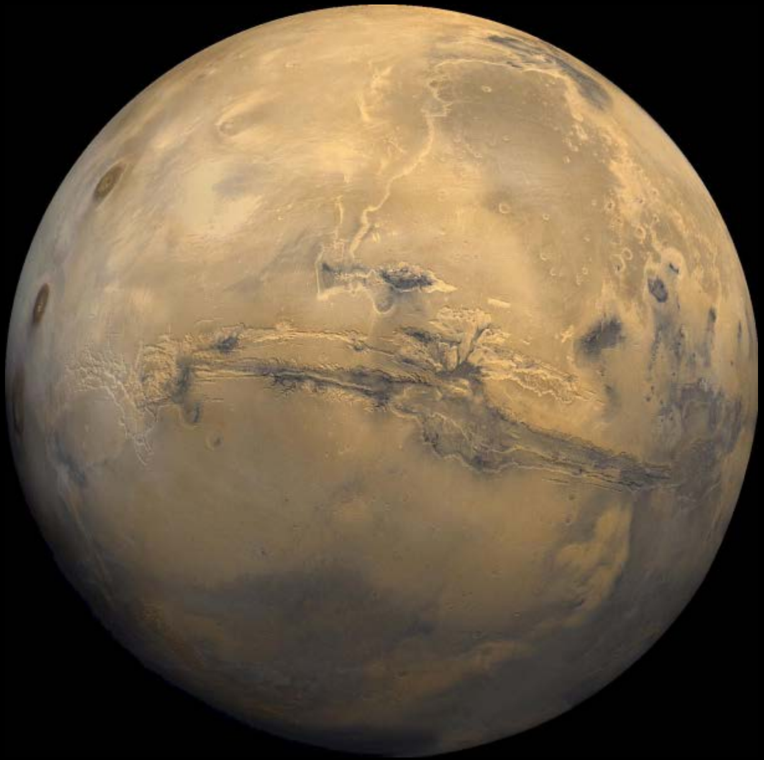
Determining the work flow for this process will require substantial community input and integration of multiple NASA policy documents

Determining the work flow for this process will require substantial community input

Some Outstanding Questions

- What percentage of sample will be allocated for PE, LD, and preserved for future studies?
    - Typically 50-75% is preserved in a pristine state. Is this reasonable for MSR?
- What instruments will be used for PE and LD?
- Should a subset of samples be sterilized to facilitate immediate release prior to the completion of life detection studies?
    - What high priority science questions can be answered with sterilized samples?
    - What high priority science questions can be answered only with pristine samples?
- If extant life is detected, we will need to conduct research and answer high priority science questions under BSL-4 conditions that are also organically and inorganically clean
    - Positive pressure clean labs in negative pressure BSL-4 facility

Mars sample return will present unique challenges….



But I think the community is ready for Mars Sample Return!