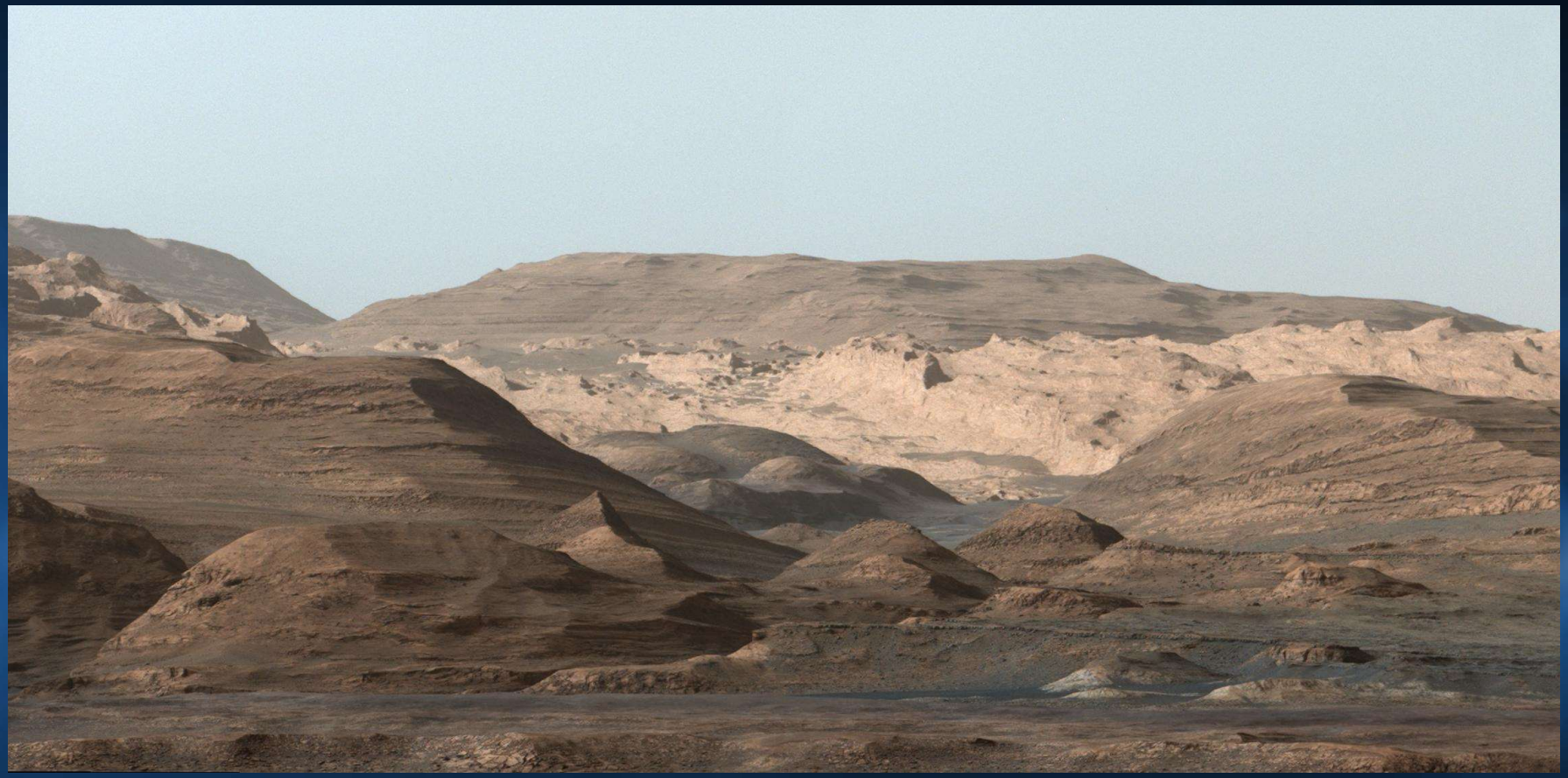
MARS EXPLORATION PROGRAM (MEP)

Update to the PAC



Jim Watzin
Director - Mars Exploration Program

September 23, 2019

MEP News & Status

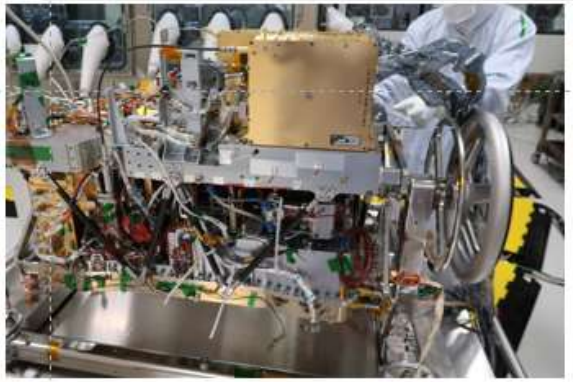
- All Operating Missions are doing well
  - MRO, MSL, Odyssey, and MAVEN continue to be healthy and scientifically productive
  - MAVEN orbit adjustment completed (improved comm relay)
  - TGO providing excellent and substantial relay support for NASA surface missions
  - Opportunity lost in 2018 dust storm
- All Development activities are doing well
  - MOMA instrument integrated into ExoMars rover
  - Mars 2020 ATLO in environmental test phase
    - On schedule for July 2020 LRD
- Planning and preparation for Mars Sample Return proceeding very well
  - Successful Agency Acquisition Strategy Meeting (ASM)
  - Beginning to staff pre-projects
- Beginning preparations for the next Decadal

MEP Budget Status

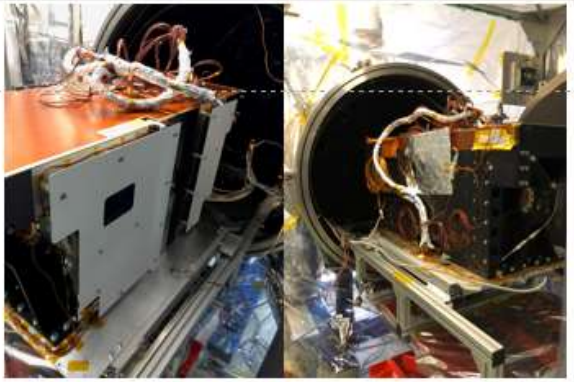
- FY19 Budget Appropriation, though favorably marked, was significantly over-stressed supporting problem resolution in multiple areas on M2020
  - Required cutbacks across the entire portfolio, except R&A, plus additional support from PSD
  - As of end of FY19, M2020 cost has stabilized and mission is on-track for July 17, 2020 LRD
- FY20 President's Budget Request is favorable for the MEP, including request for continued planning with ESA for MSR

MOMA

ExoMars Rover – MOMA Instrument Status



ALD I&T - January 2019



ALD TVAC – March 2019

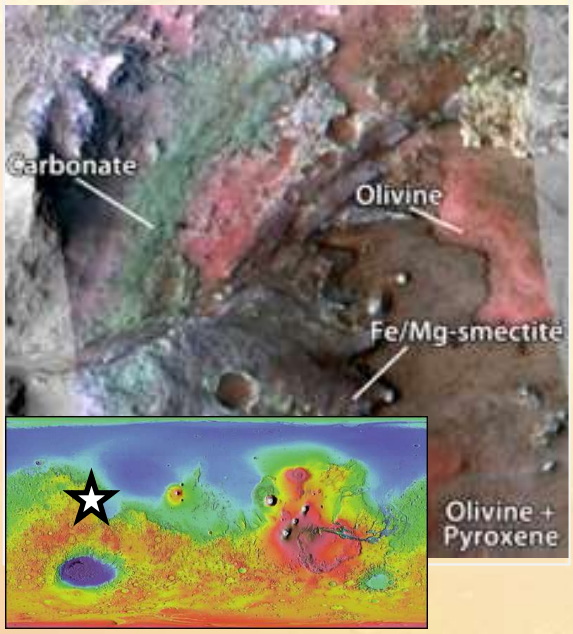
FM Descent Module

- MOMA flight model (FM) delivered to TAS-I, integrated with Analytical Lab Drawer (ALD)
- Full end-to-end functional checks of sample analysis system completed, including first use of tapping station, oven, and sample carousel
- FM Descent Module (DM), FM Rover Module completed integration in August 2019
- SpaceCraft Composite Flight Model (SCC FM) assembled, to be shipped to environmental test facility in September 2019

Pancam Integration in Rover FM

M2020

Mars 2020 Landing Site Selected



JEZERO

- Deltaic/lacustrine deposition with Hesperian lava flow and hydrous alteration
- Mineralogic diversity including clays and carbonates
- Evidence for hydrous minerals from CRISM, *including carbonates*

NE SYRTIS

- Extremely ancient igneous, hydrothermal, and sedimentary environments
- High mineralogic diversity with phyllosilicates, sulfates, carbonates, olivine
- Serpentinization and subsurface habitability?

COLUMBIA HILLS

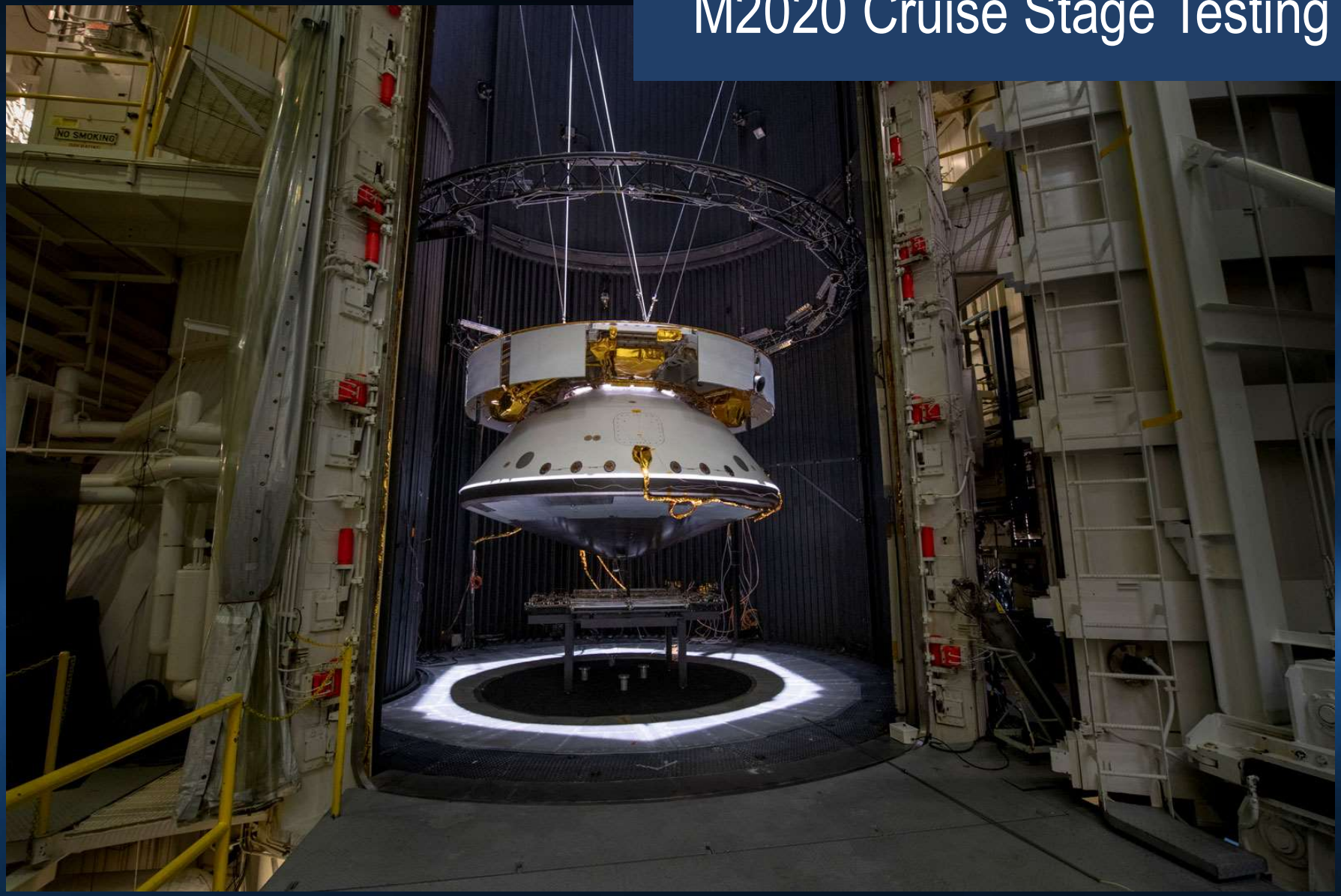
- Carbonate, sulfate, and silica-rich outcrops of possible hydrothermal origin and Hesperian lava flow
- Potential bio-signatures identified
- Previously explored by MER

M2020 Rover in ATLO

Helicopter Integration on the M2020 Rover

M2020 New-Heatshield Fit Check

M2020 Cruise Stage Testing



M2020 Status

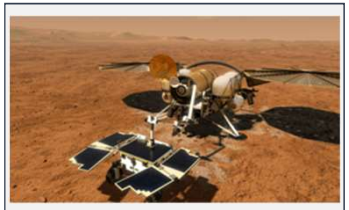
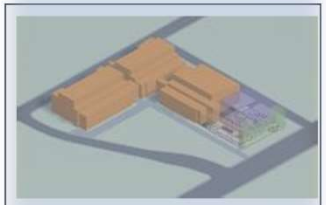
- Flight system integrated and preparing for “Surface Systems” environmental testing
  - Cruise stage environmental already completed
  - Vibration testing in-work
- Sample Caching System integrated “dirty” test program underway; Testbed functionally complete
  - Drilling/caching real rocks
  - At Mars pressure and atmosphere
  - At Mars thermal conditions
- New heatshield fabrication complete
- Healthy schedule reserves of 48 work days (10 calendar weeks)
  - 3 months to first shipment to KSC
  - M2020, the first step in Mars Sample Return, launches July 17, 2020

MSR

MSR Preparation Status

- Throughout 2018/2019: NASA/ESA have been converging campaign requirements, completing mission trade studies, refining mission concept designs, and maturing plans for jointly implementing MSR, potentially launching as early as 2026
- On April 26, 2018: NASA and ESA signed Joint SOI at the Berlin Airshow to jointly develop plans for MSR by the end of 2019
  - Within NASA - conducted multiple studies leveraging Agency competencies across Centers
  - Within ESA - completed four industry phase B1 studies: 2 ERO and 2 SFR
- On July 12, 2019: NASA conducted an Acquisition Strategy Meeting for MSR
  - HQ approved the proposed roles & responsibilities developed by the joint NASA/ESA team
- On July 23, 2019: ESA released an Invitation to Tender (ITT) for an Earth Return Orbiter (ERO)
- On November 26-28, 2019: ESA Ministerial Council will meet and consider approval of MSR
- In February 2020: President will submit his FY2021 Budget Request to Congress
  - Both FY19 Appropriation and FY20 President's Budget Request support preparation for MSR
- Studies have prepared NASA and ESA to make an informed decision on MSR in late 2019 / early 2020

MSR Campaign Architecture (3+1)

1	2	3	+ 1
			
Sample Caching Rover (Mars 2020) Operations • *Sample acquisition/caching* • *Sample (subset) delivery*	**Sample Retrieval Lander** • *Fetch Rover* • *Orbiting Sample (OS) container* • *Mars Ascent Vehicle*	**Earth Return Orbiter** • *Capture/Containment System* • *Earth Return Vehicle*	**Mars Returned Sample Handling** • *Sample Receiving Facility* • *Curation* • *Sample science investigations*
"Initiates the campaign"	*"new element"*	*"new element"*	*"new element"*

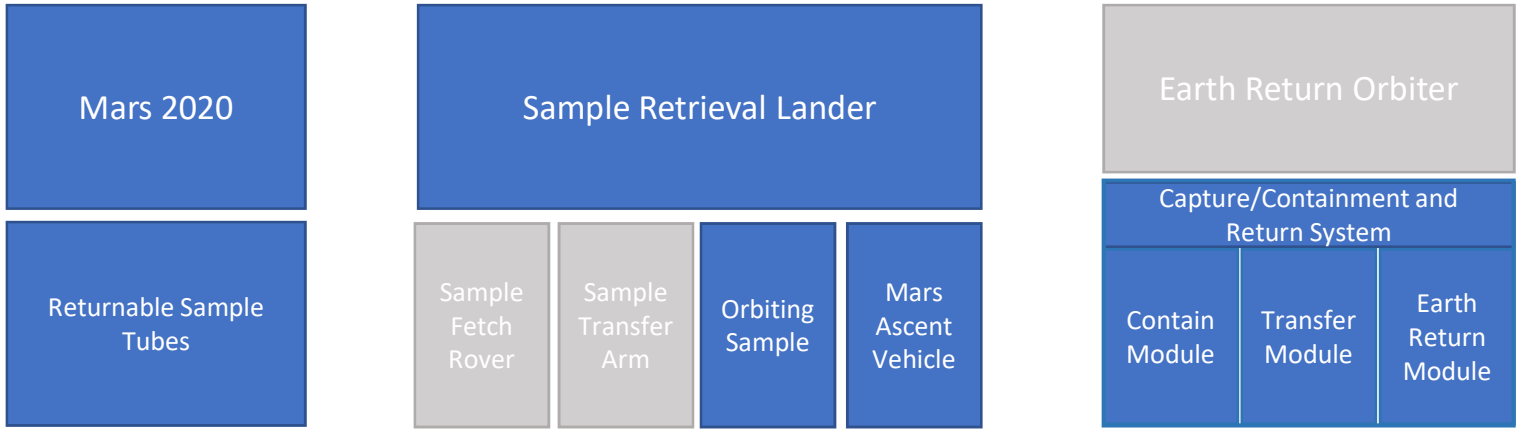
MSR Flight Elements

Ground Element

to be defined at a future date

MSR Campaign Video

MSR Campaign Architecture Elements: Agency Roles



Agency roles chosen to be **strategically aligned with capabilities and experience,** and to minimize and balance campaign technical and programmatic risks within anticipated resources

ESA MSR Investment ~$1.7B (~20% of ESA Human and Robotic Exploration portfolio)

Legend:

NASA | ESA

Leveraging the Full Capability of NASA for MSR

Organization	Role
JPL	M2020 operations, **MSR Systems Management, Lead for SRL project**, provider of Containment module, and lead for MSR operations
MSFC	**Lead on MAV**
LaRC	**Lead on EEV** (specifically aero-thermal structure), UTTR coordination/planning, supports SRL EDL
ARC	**Lead on TPS** for EEV and SRL, supports SRL EDL
GSFC	**Lead for CCRS project**, provider of the Transfer module, consultation to ESA on rendezvous & proximity operations
GRC	**Provider of SFR "tires" to ESA**, provider of SRL solar array procurement
KSC	**LV provider**
JSC	**Lead on Sample Curation**

Summary

MEP is a healthy and productive program

making good progress on current obligations and actively working towards humanity's first roundtrip to another planet, the Mars Sample Return Campaign

Back-up

Early Investments to Reduce Program Risks

- NASA has invested in MSR architecture studies and key technology maturation throughout FY16-19
  - MSR architecture studies (~$25M)
  - MAV technology development: (~$20M)
  - Containment assurance technology development (~$10M)
  - Earth Entry Vehicle (EEV) technology development (~$15M)

- ESA has made significant investments in MSR mission studies and technologies (since 2017)
  - Mission Studies (~ €9M): Phase A/B1 Industrial system studies on ESA MSR contributions
  - MSR Technologies (~ €19M):
    - Earth Return Orbiter (~ €4M)
      - Propulsion, Rendezvous GNC & Sensors
    - Sample Transfer Arm (~ €2M)
      - Robotic Arm Breadboard
    - Sample Fetch Rover (~ €13M)

Technology	TRL	Path to TRL 6 by PDR
MAV propulsion		**Planning hot fire testing of propulsion systems over next two years to establish TRL**
Hybrid	4	Establish ignition, stable burn and restart with needed performance and thrust vector control, at operating temp of -20C
Solid	5	Establish performance at operating temp of -20C after cold storage at -50C
Break-the-Chain Sterilization and Containment		**Performing subscale and full scale testing to verify performance and establish TRL**
High temperature brazing	4	Establish full scale inductive brazing with flight-like electronics
Mid-temperature brazing	4	Establish resistive heating braze and strength
Earth Entry Vehicle Thermal Protection System		**Conducting high velocity impact, arc jet testing and manufacturing studies to make baseline choice and establish TRL**
PICA	9	Establish acceptable level of MMOD safety during 4 day free-flight from ERO separation to entry
HEEET	4	Establish MMOD tolerance for single or dual layer and demonstrate manufacturability within schedule

MSR Science Planning Group (MSPG)

MSPG established by NASA and ESA to help develop a stable foundation for international scientific assessment and study of MSR samples

- Addressing key questions to inform the approach for sample analysis
  - To what extent does MSR science need to be done in containment?
  - How do the science objectives affect SRF contamination control requirements?
  - What are the science-related attributes of a Sample Receiving Facility (SRF) that can be used as the basis for estimation of cost, schedule, and outfitting?
  - What are the mechanisms whereby sponsor-affiliated scientists will be given fair access to the returned samples?
- Accomplished via open, collaborative mechanisms
  - A series of workshops and workshop reports
  - Town hall presentations and community fora
  - Collection of feedback via MSPG website
- Status
  - Two workshops completed
  - MSPG report by October 2019 (https://mspg.jpl.nasa.gov)

MSPG Major Findings to Date

FINDING: Maximize Opportunity

A sizeable fraction (~75%) of the MSR-related science investigations, as identified by iMOST (2019), could be acceptably performed on sterilized samples, thus potentially enabling the analysis of MSR samples in uncontained laboratories without a dependency on the results from PP testing.

- Containment and security of unsterilized samples must still be addressed

FINDING: Science Maximization and Sample Preservation

Even though the Mars 2020 Sample CC Requirements have very low values, the workshop participants were collectively not aware of reasons why these requirements could not also be implemented in isolation cabinets on Earth. This should therefore be the starting point for CC planning in the SRF and/or sample curation facilities.

FINDING: One Return Canister : One Collection

The returned sample collection will have been selected and optimized for its geologic and geochemical diversity. The similarities and differences between samples (as part of the design of the sample suites) will be as important or more than the absolute composition of individual samples. As such, to optimize the value of the returned samples, they need to be **managed as one collection**.