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Mars 2020 Mission

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Mars 2020 Project Scientist

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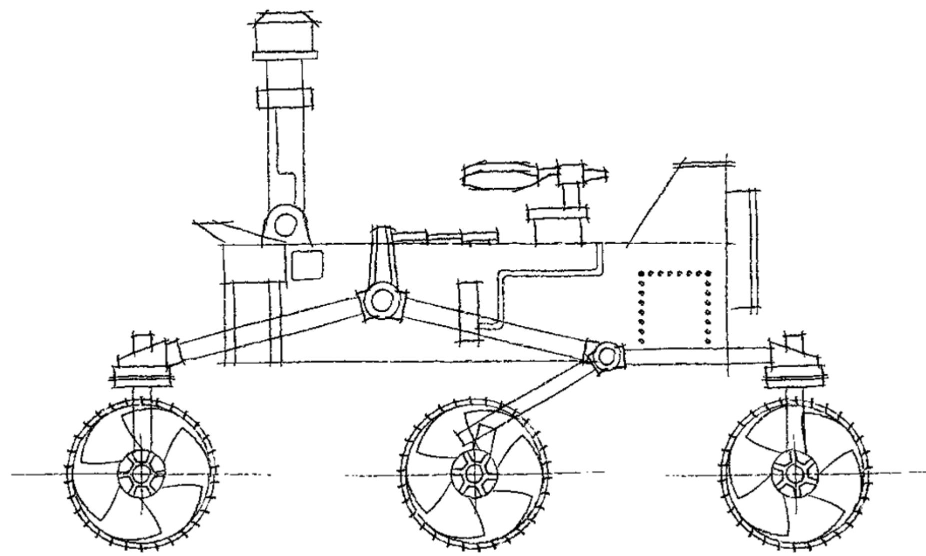

Mars 2020 Project

Outline

- What is the Mars 2020 Mission?
- Planetary Protection on Mars 2020
  - Requirements
  - Challenges
  - “Science Integrity”
- How Mars 2020 is Implementing/Verifying Sample Science Integrity

Mars 2020 Mission Objectives

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- **Conduct Rigorous *In Situ* Science**
  - **A. Geologic Context and History** Carry out an integrated set of context, contact, and spatially-coordinated measurements to characterize the geology of the landing site
  - **B. In Situ Astrobiology** Using the geologic context as a foundation, find and characterize **ancient** habitable environments, identify rocks with the highest chance of preserving **signs** of **ancient** Martian life if it were present, and within those environments, seek the signs of life
- **Enable the Future**
  - **C. Sample Return** Assemble rigorously documented and returnable cached samples for possible return to Earth
  - **D. Human Exploration** Facilitate future human exploration by making significant progress towards filling major strategic knowledge gaps and…

    Technology …demonstrate technology required for future Mars exploration
- **Execute Within Current Financial Realities**
  - Utilize MSL-heritage design and a moderate instrument suite to stay within the resource constraints specified by NASA

These are a thoroughly integrated set of objectives to support Agency's Journey to Mars

Responsive to 2011 Decadal Survey

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"The highest priority Flagship mission for the decade 2013-2022 is MAX-C, which will begin the NASA-ESA Mars Sample Return campaign.

The Mars community, in their inputs to the decadal survey, was emphatic in their view that a sample return mission is the logical next step in Mars exploration… MAX-C will explore a new site and significantly advance our understanding of the geologic history and evolution of Mars, even before the cached samples are returned to Earth. Because of its potential to address essential questions regarding planetary habitability and life, Mars sample return has been a primary goal for Mars exploration for many years." *Visions and Voyages*, 2011

Note: Mars 2020 is the NASA implementation of MAX-C, a mission originally envisioned as a collaboration between NASA and ESA.

Mars 2020 Looks like Curiosity

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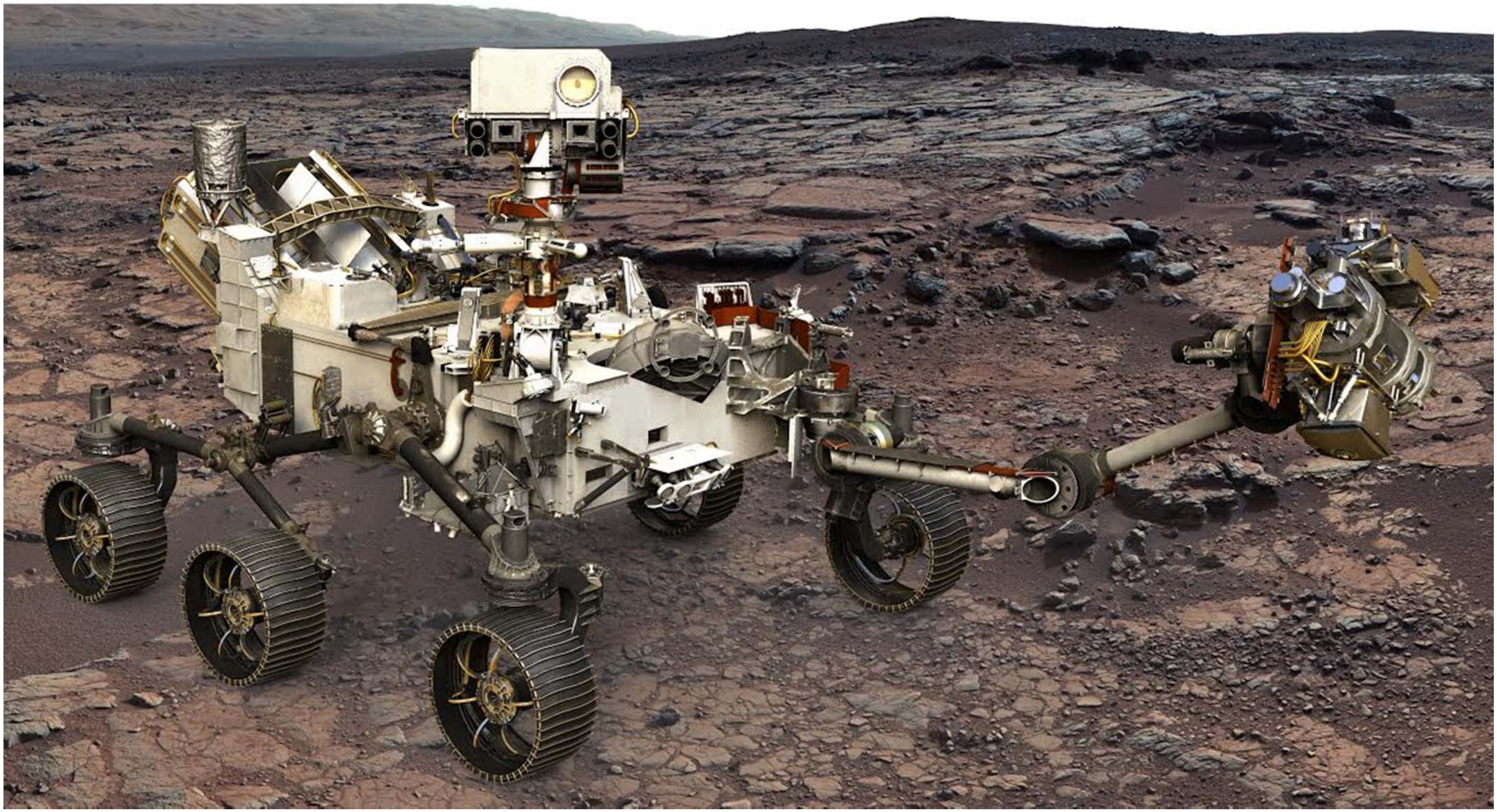

Very high heritage design

Mars 2020 Payload

- Mastcam-Z, an advanced camera system with panoramic and stereoscopic imaging capability with the ability to zoom. The instrument also will determine mineralogy of the Martian surface and assist with rover operations. The principal investigator is James Bell, Arizona State University in Tempe.
- **SuperCam**, an instrument that can provide imaging, chemical composition analysis, and mineralogy. The instrument will also be ***able to detect the presence of organic compounds*** in rocks and regolith from a distance. The principal investigator is Roger Wiens, Los Alamos National Laboratory, Los Alamos, New Mexico. This instrument also has a significant contribution from the Centre National d'Etudes Spatiales,Institut de Recherche en Astrophysique et Plane'tologie (CNES/IRAP) France.
- **Planetary Instrument for X-ray Lithochemistry (PIXL)**, an X-ray fluorescence spectrometer that will also contain an imager with high resolution to determine ***the fine scale elemental composition of Martian surface materials***. PIXL will provide capabilities that permit more detailed detection and analysis of chemical elements than ever before. The principal investigator is Abigail Allwood, NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California.
- Scanning Habitable Environments with Raman & Luminescence for Organics and Chemicals (SHERLOC), a spectrometer that will provide fine-scale imaging and uses an ultraviolet (UV) laser to determine ***fine-scale mineralogy and detect organic compounds***. SHERLOC will be the first UV Raman spectrometer to fly to the surface of Mars and will provide complementary measurements with other instruments in the payload. The principal investigator is Luther Beegle, JPL.
- The Mars Oxygen ISRU Experiment (MOXIE), an exploration technology investigation that will produce oxygen from Martian atmospheric carbon dioxide. The principal investigator is Michael Hecht, Massachusetts Institute of Technology, Cambridge, Massachusetts.
- Mars Environmental Dynamics Analyzer (MEDA), a set of sensors that will provide measurements of temperature, wind speed and direction, pressure, relative humidity and dust size and shape. The principal investigator is Jose Rodriguez-Manfredi, Centro de Astrobiologia, Instituto Nacional de Tecnica Aeroespacial, Spain.
- The Radar Imager for Mars' Subsurface Exploration (RIMFAX), a ground-penetrating radar that will provide centimeter-scale resolution of the geologic structure of the subsurface. The principal investigator is Svein-Erik Hamran, Forsvarets Forskning Institute, Norway.

Seeking Signs of Ancient Life

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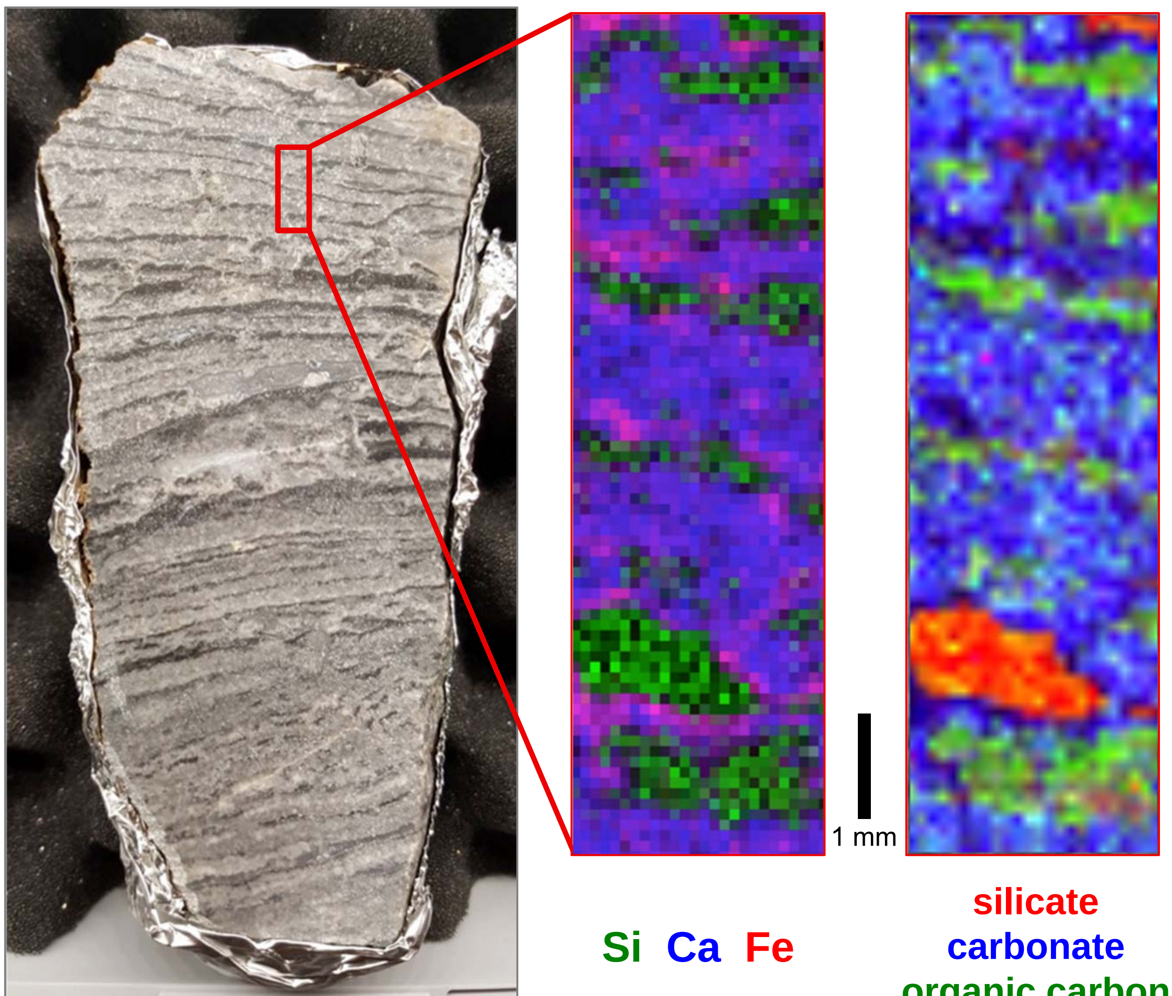


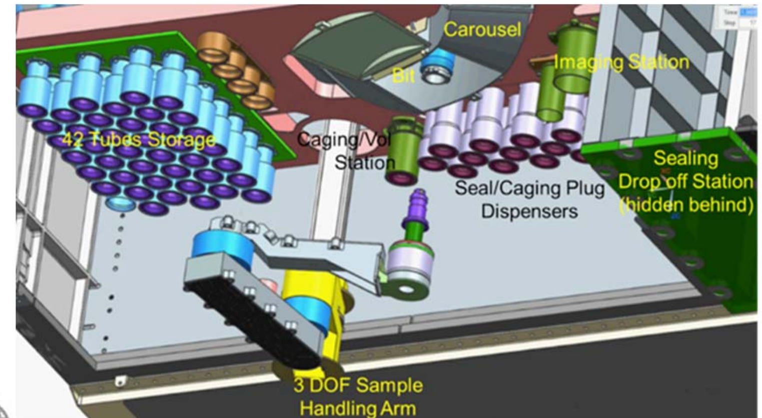
Strelley Pool stromatolites are among the oldest evidence for life on Earth, *equivalent in age to rocks at candidate Mars 2020 landing sites*. Coordinated PIXL and SHERLOC laboratory observations reveal:

- **sub-mm scale chemistry** following visible rock textures
- alternating **silicate** and **carbonate** layers with variable Fe
- **organic carbon** associated with silicate layers

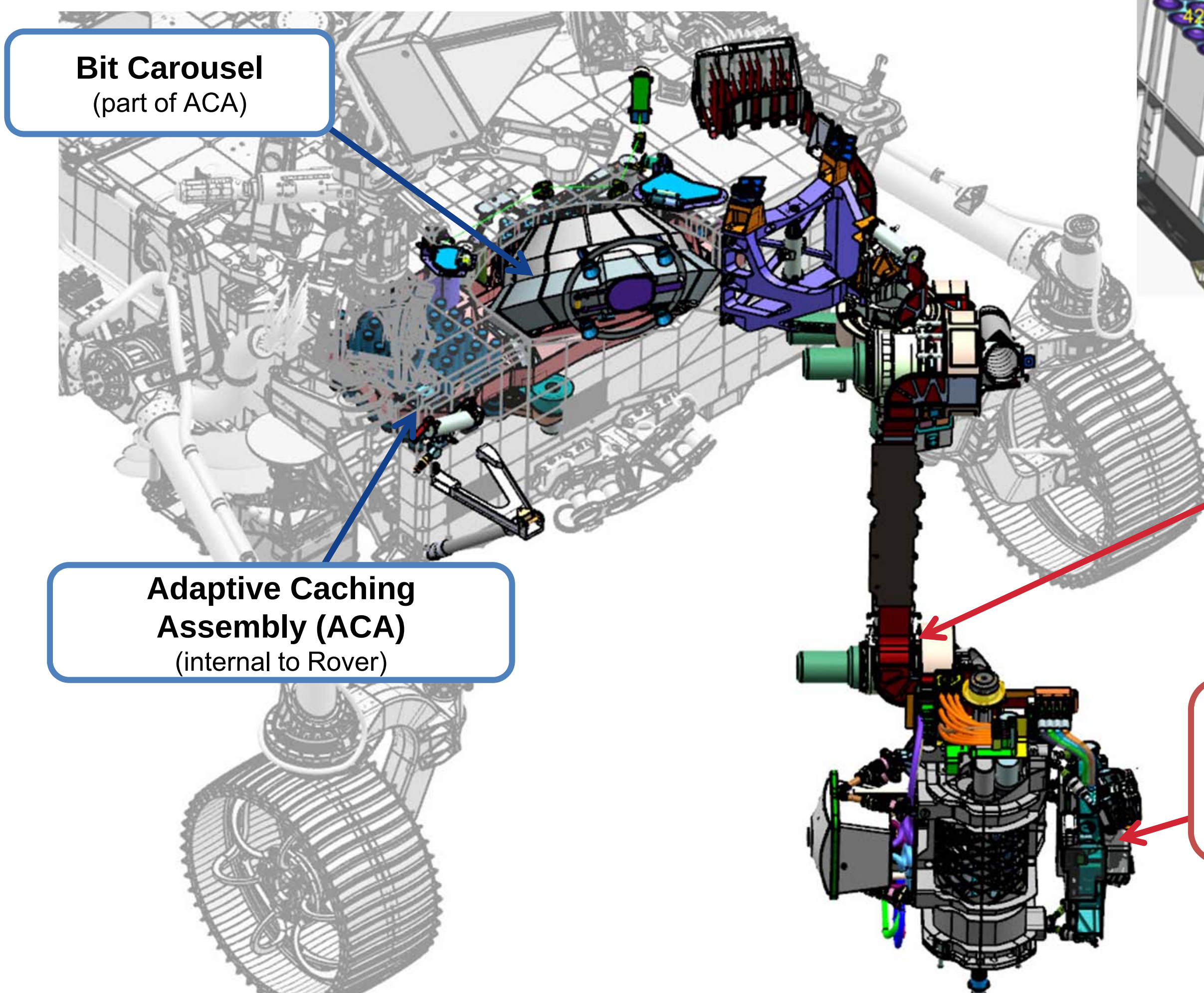
When observed *in a geologic context indicating habitability*, this type of morphologically correlated chemical and mineralogic variation is a **powerful potential biosignature***.*

Sampling & Caching Subsystem

~ 42 sample tubes



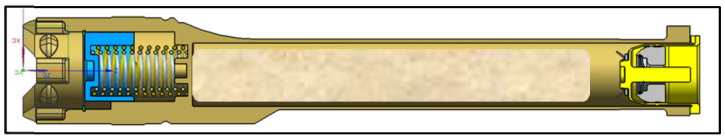
Caching Assembly



Coring and Sample Tube

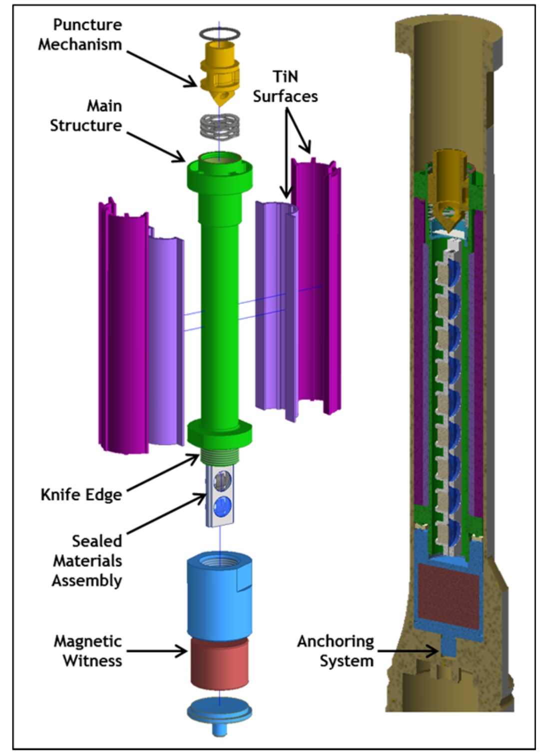
Coring Bit

Sealed sample tube



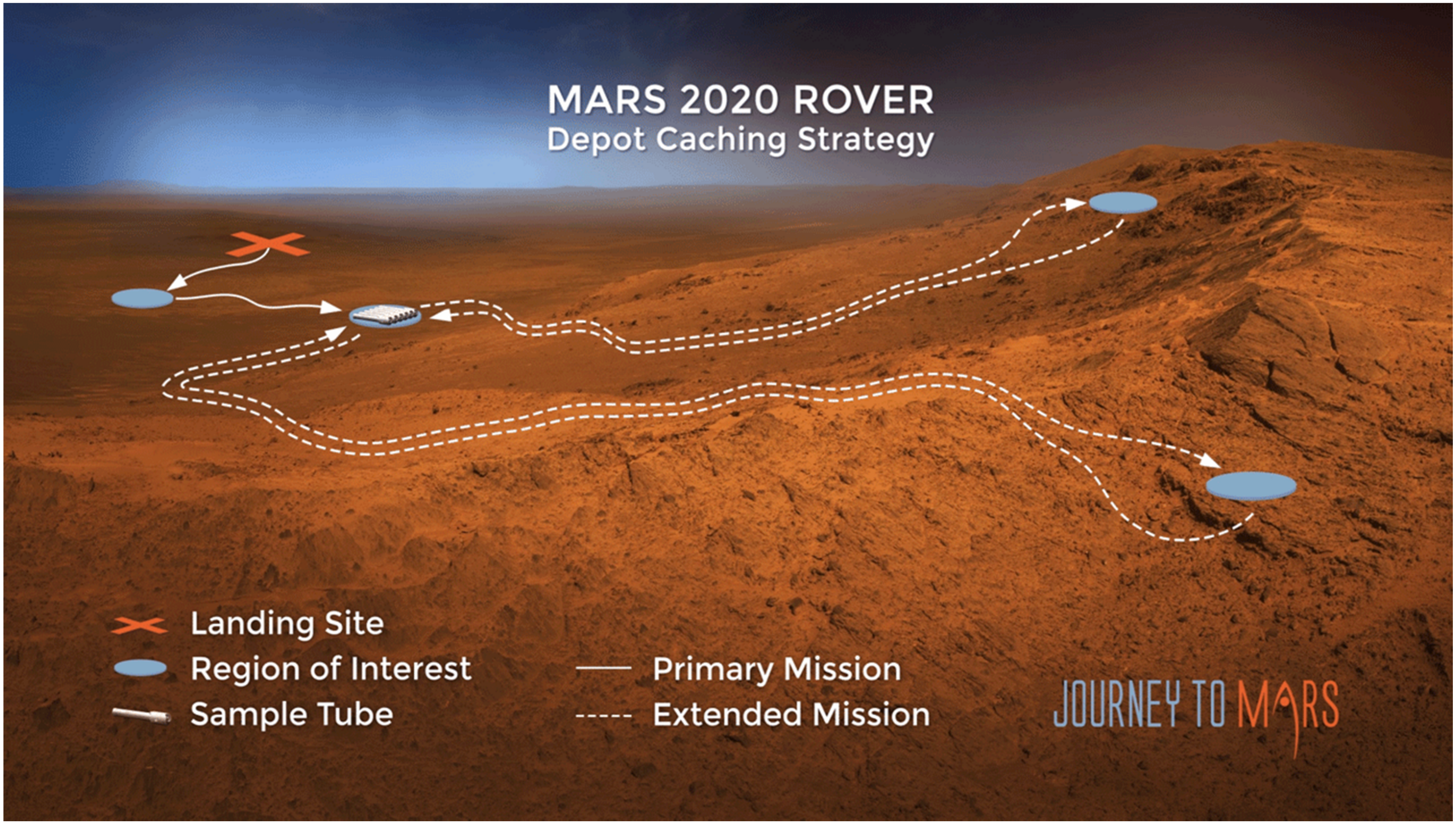
<u>Core</u>

~ 5 cm long x
~ 1 cm diameter
~ 15 grams



Witness tube assembly for round trip contaminant characterization

Depot Caching



Where is Mars 2020 Landing?

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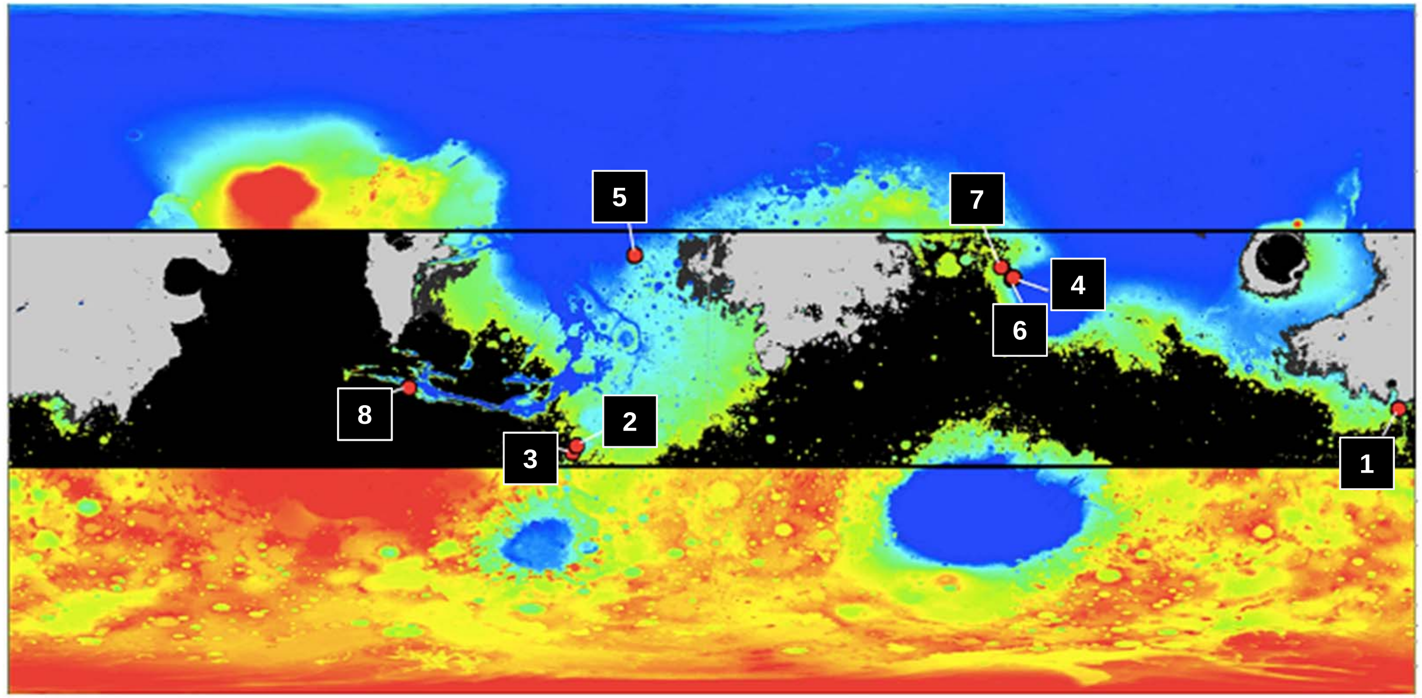
Mars 2020 Project



Candidate landing sites
in alphabetical order

1. **Columbia Hills⁺**
2. Eberswalde*
3. Holden⁺
4. **Jezero***
5. Mawrth⁺
6. **NE Syrtis***
7. Nili Fossae⁺
8. SW Melas*

* TRN enables access
⁺ TRN improves science

- The selected site must provide *clear opportunities to safely and efficiently explore and sample geologically diverse regions with high potential to preserve signs of* **ancient** *life and planetary evolution*.
- With no mission objective or capability to investigate **extant** life, “special regions” are not under consideration for exploration.

Mission Overview

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LAUNCH

- Atlas V 541 vehicle
- Launch Readiness Date: July 2020
- Launch window: July/August 2020

CRUISE/APPROACH

- ~7 month cruise
- Arrive Feb 2021

ENTRY, DESCENT & LANDING

- MSL EDL system (+ Range Trigger and Terrain Relative Navigation): guided entry and powered descent/Sky Crane
- 16 x 14 km landing ellipse (range trigger baselined)
- Access to landing sites ±30° latitude, ≤ -0.5 km elevation
- Curiosity-class Rover

SURFACE MISSION

- 20 km traverse distance capability
- Enhanced surface productivity
- Qualified to 1.5 Martian year lifetime
- Seeking signs of past life
- Returnable cache of samples
- Prepare for human exploration of Mars

Mars 2020 Planetary Protection

1. **Forward Contamination**

   (prevent contamination of Mars by terrestrial viable organisms)

   - Mars 2020 has a high heritage strategy based on successful MSL cleaning approach and will not target a known Special Region

   This is not controversial nor problematic

2. **Backward Contamination**

   (prevent contamination of Earth by possible Martian organisms)

   - Mars 2020 has a limited role in this aspect of planetary protection
   - Backward contamination control ("break the chain") will primarily be the responsibility of future possible missions

   This is not controversial nor problematic

3. Science Integrity

Ensure that life-related investigations in-situ on Mars and on possible returned samples on Earth can be successfully conducted *(my interpretation)*

This <u>is</u> problematic and controversial if considered a PP responsibility

- Detection of life (past or present) and assessment of biohazards are undoubtedly scientific undertakings, why treat them as if they are not?
- maintaining scientific integrity of *in-situ* investigations and of possible returned samples is of paramount importance to the Mars 2020 project. <u>It is the reason for doing the mission.</u>
- broadly speaking, responsibility for the the scientific success of a mission rests with the science community, the mission science team, the project science group, and the project scientist.
- science integrity requirements mandated by "Planetary Protection" are at best redundant to those developed <u>by and for</u> the science community. The science community is in the best position to optimize the science yield of a mission, especially in a field evolving as rapidly as is astrobiology.

PP vs Science Ownership

Project Science can best define and maintain science integrity of samples because:

- It has access to up-to-date relevant knowledge within the science team (for Mars 2020, currently 260 scientists) to inform requirements and decisions
- If information is lacking on the science team, the team knows well the broader science community and can identify and recruit expertise as necessary
- It has resources (time, money)
- It has extremely deep knowledge of the entirety of the mission, from science goals to architecture, to implementation
- It has daily interaction with the engineering team implementing the mission, allowing a clear and deep mutual understanding of goals and emerging challenges
- and our reputations are defined by how well we do…

Experience shows that having dual PP and Project Science ownership is not tenable

Key Mars 2020 PP and Sample Cleanliness Requirements at L1

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Mars 2020 Project

#	Topic	Text	Maps to
L1-14	NPR 8020.12D	The Mars 2020 Project shall comply with requirements for the outbound portion of a Planetary Protection Category V Restricted Earth Return mission as defined in **NPR 8020.12D** and as clarified in Section 6.8 of this PLRA.	PP L2 requirements
L1-15	Organic Carbon (OC)	The Mars 2020 landed system shall be capable of encapsulating samples for return such that the organic contamination levels in each sample in the returned sample set are less than*: • Any Tier 1 compound (organic compounds deemed as essential analytes for mission success): 1 ppb • Any Tier 2 compound (organic compounds not categorized as Tier 1): 10 ppb • Total Organic Carbon: 10 ppb Baseline, 40 ppb Threshold	Sample Science L2 requirements
L1-17	Viable Organisms (VO)	The Mars 2020 landed system shall be capable of encapsulating samples for return such that each sample in the returned sample set has less than 1 viable Earth-sourced organism.	Sample Science L2 requirements

* based on Summons et al., 2014 (Organic Contamination Panel report)

Viable Organisms at L1 and L2

#	Topic	Text
L1-17	Viable Organisms	The Mars 2020 landed system shall be capable of encapsulating samples for return such that each sample in the returned sample set has less than 1 viable Earth-sourced organism.
L2PS - 72265	Probability of viable Earth organism in returned sample	The Mars 2020 Project shall be capable of encapsulating samples for return such that each sample in the returned sample set has more than a 99.9% probability of being free of any viable Earth-sourced organisms.

- Note that the level 2 requirement is tighter than the Level 1 requirement by a factor of 1000

- **Additional L2: The PS shall allow no more than 10 microorganisms (living <u>or dead</u>) in each sample**

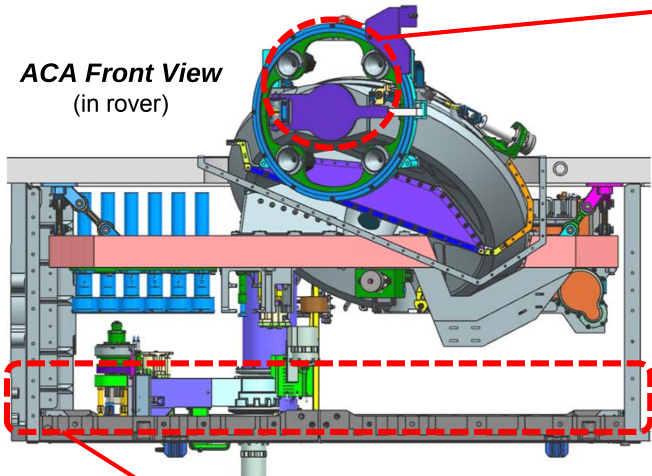
Organic Carbon L1 and L2

#	Topic	Text
L1-15	Organic Carbon	The Mars 2020 landed system shall be capable of encapsulating samples for return such that the organic contamination levels in each sample in the returned sample set are less than: • Any Tier 1 compound (organic compounds deemed as essential analytes for mission success): 1 ppb • Any Tier 2 compound (organic compounds not categorized as Tier 1): 10 ppb • Total Organic Carbon: 10 ppb Baseline, 40 ppb Threshold
L2PS - 44380	Organic Carbon	Same as L1 Baseline

Note : 10 ppb is an extraordinarily low level of total organic carbon

Engineering Solutions to Meet VO and OC Requirements

ACA Front View
(in rover)



Bit Carousel Doors

- *Outer and inner doors sealed from final cleaning in ATLO through landing on Mars surface (one-time release doors)*
- *Prevents particle transport into bit carousel*

ACA T-0 purge

- *Purge in place from installation of belly panel through launch to limit buildup of OC in ACA*

ACA Outgassing

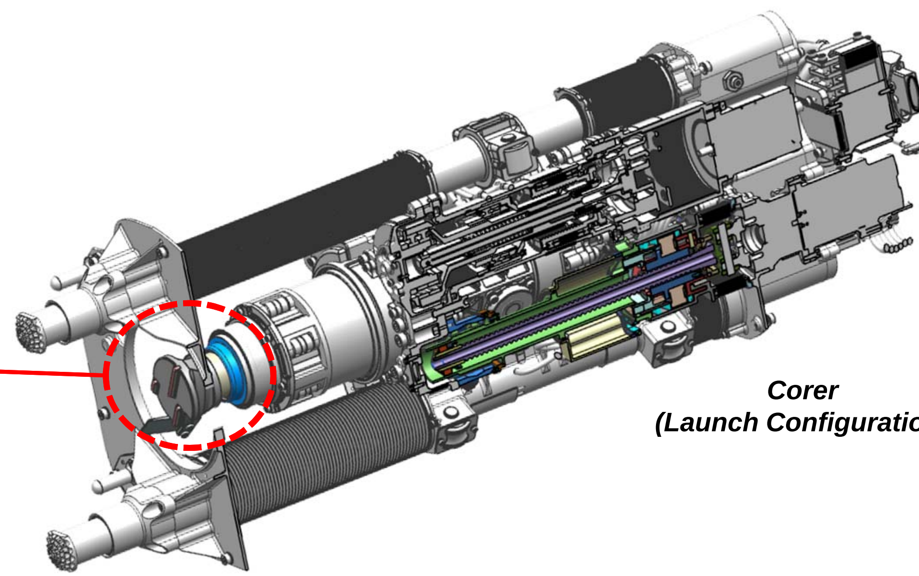
- *Stringent requirement on allowable outgassing of all ACA components*
- *Material selections that limit outgassing*

Ejectable Belly Panel

- *ACA close out to limit particle transport into ACA through Mars landing; dropped within first 30 sols on Mars*
- *Tenax molecular getter panels for OC control from ATLO through Mars landing*
- *Open belly panel on Mars allows for air circulation that limits concentration of OC in ACA*

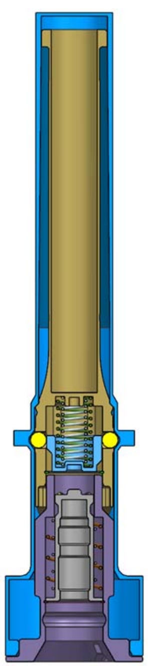
Corer Launch Cover

- *“Launch cover” (modified abrading bit) installed from final cleaning through landing on Mars*
- *Creates seal to prevent particle into interior of corer*

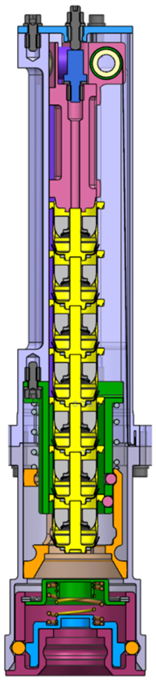


Corer (Launch Configuration)

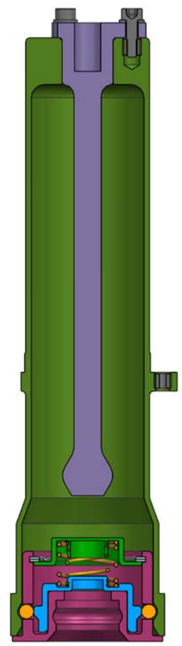
SCS Features for Sample Cleanliness: ACA Details



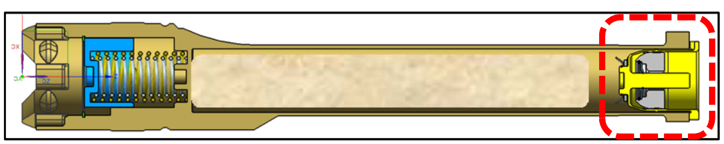
Sample Tube Storage



Seal Dispenser



Volume Probe



Hermetic Seal

- *Additional requirements and features to prevent transport of particles and OC into sample post-sealing*

Low Energy Surfaces

Surface finish/coatings used to limit accumulation of OC on critical surfaces:

- *Sample tube interior – Ti Nitride*
- *Sample tube storage interior walls – Ti Nitride*
- *Hermetic seals – Ti Nitride, Gold*
- *Volume probe – Ti Nitride*
- *Coring bits – Ti Nitride*

High-temperature bakeouts

350C bakeout (1 hr) for critical hardware – removes surface OC and achieves 6-log biological reduction

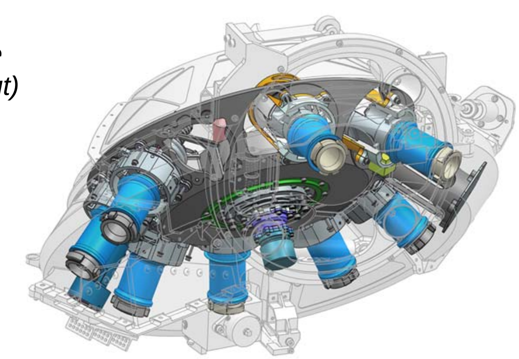
- *Sample tube assemblies (tube in storage w/ FMPB)*
- *Seal dispensers (seals in dispenser w/ FMPB)*
- *Volume probe assembly (w/ FMPB)*

Sterile Flight Models

For critical hardware, "Sterile Flight Models" are installed late in ATLO ("ATLO Flight Models" are used for a majority of ATLO testing and checkout)

- *Sample tubes in storage*
- *Seal dispensers*
- *Volume probe*
- *Bits (single bit carousel that is removed, cleaned, and reinstalled with remaining SFM hardware)*

Coring Bit



Viable Organism Budget

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Index	Name	Conservative Estimate	Best Estimate
VO1-1	Sample tube prior to removal from FMPB	1 E-7	4 E-14
VO1-2	Sealing Plug prior to removal from FMPB	2 E-8	5 E-15
VO2-1	Viable Organisms (VO) on Mars surface due to EDL dispersal	1 E-12	1 E-12
VO2-2	VO due to winds during commissioning or science phases	1 E-8	3 E-9
VO3-1	VO added to coring bit due to wind from Bit Carousel	3 E-8	2 E-9
VO3-2	Initial VO on coring bit	2 E-6	6 E-7
VO3-3	VO from corer to tube on surface, during drilling operations	2 E-6	6 E-7
VO4-1	VO transported into open tube due to wind inside ACA	2 E-13	1 E-13
VO4-2	VO transmitted into open tube due to vibration inside ACA	negligible	negligible
VO4-4	VO transferred from volume probe during volume assessment	4 E-9	1 E-15
	Total (Sum) for modeled processes	**4 E-6**	**1 E-6**
	L1 Requirement	**<1**	**<1**
	Margin (as factor) for modeled processes	**300,000**	**900,000**
VO2-3	Un-modeled process causes resuspension from rover prior to sampling	5 E-5	2 E-6
VO4-3	VO transferred into the tube interior due to un-modeled process	1 E-5	2 E-7
	Total (Sum) including unmodeled processes	**6 E-5**	**3 E-6**
	L1 Requirement	**<1**	**<1**
	Margin (as factor) including unmodeled processes	**16,000**	**300,000**

Organic Carbon Budget

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Mars 2020 Project

Index	Name	Description	TOC (ng)	TOC (ppb)	Max Tier 1 (ppb)	Max Tier 2 (ppb)
OC1	ATLO Phase	Tube and sealing plug – direct	6	0.4	0.00	0.0
OC2	Cruise Phase	Tube and sealing plug – direct	3	0.2	0.00	0.0
OC3	Commissioning Phase	Tube and sealing plug – direct (bellypan closed)	7	0.5	0.00	0.0
OC4	Surface Science Phase	Tube and sealing plug – direct (bellypan open)	29	1.9	0.02	0.2
OC5	Open	Accumulation when tube and sealing plug are open on Mars	5	0.4	0.00	0.0
OC6	Mars Surface	Accumulation on Mars surface prior to coring (rover outgas)	5	0.3	0.00	0.0
OC7	Coring	Transfer to sample during coring (bits + tubes)	35	2.3	0.02	0.2
OC8	Volume Probe	Contact transfer from volume probe	1	0.0	0.00	0.0
OC9	Post sealing: M2020	Leak rate through seal while carried by M2020	1	0.1	0.00	0.0
OC10	Post sealing: future missions	Future missions leak rate	3	0.2	0.00	0.0
Total Estimate			**95**	**6**	**0.1**	**0.6**
Baseline L1 Requirement			**150**	**10**	**1**	**10**
Threshold L1 Requirement			**600**	**40**	**1**	**10**
Margin (as % of L1 Baseline)			**37%**	**37%**	**94%**	**94%**
Margin (as % of L1 Threshold)			**84%**	**84%**	**94%**	**94%**

Key Elements of Lowering Risk to Viable Organisms Requirement

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Group	Item (Key items in bold)	✔	Date	Confidence
Phase A/B	Architecture definition prior to Planetary Protection Assessment Review	✔	3/15	Medium
	Analysis of past experimental results for Particle Resuspension & Transport Review Part 2	✔	6/15	Medium
	Updated particle resuspension estimates using JPL BioVigilant VO to particle test results	✔	8/15	Medium
	Independent bounding "Meta Analysis" shows excellent margin	✔	12/15	Medium
	Analysis and test establishing FMPB effectiveness	✔	1/16	Med-High
	Baseline cleanliness approach documented in CC Plan	✔	2/16	Med-High
	PDR		**2/16**	
Pre-CDR Phase C	**Tests & Higher-fidelity Analyses for Particle Resuspension & Transport Review Part 3**	✔	11/16	High
	Tests and Analyses leading to Return Sample Biological Contamination Review	✔	12/16	High
	End to End RSCC Review	✔	1/17	High
	CDR		**2/17**	
Post-CDR Phase C	Document key VO vectors analysis summary		4/17	High
	Clean room surface experiments leading to updated VO to particle distribution		7/17	High
	Completion of Spore to VO JPL clean room study		7/17	High
	VO resuspension test results		8/17	Complete
	Return Sample Biological Contamination Review 2		9/17	V&V
	SIR		**11/17**	
Phase D	Completion of Spore to VO KSC clean room study		7/18	V&V
	Completion of V&V for Corer delivery certification		9/18	V&V
	Completion of V&V for Sterile Flight Model ACA delivery certification		1/19	V&V
	Rover stack/destack/system test 2 spore assays		6/19	V&V
	Rover post environmental test spore assays		12/19	V&V
	Rover pre-ship spore assays		1/20	V&V

✔ Indicates completed activity

Key Elements of Lowering Risk to Organic Carbon Requirements

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Group	Item (Key items in bold)	✔	Date	Confidence		
				Tier 1 < 1 ppb, Tier 2 < 10 ppb	TOC < 40 ppb Threshold	TOC < 10 ppb Baseline
Phase A/B	Architecture definition prior to PP Assessment Review	✔	3/15	Low	Low	Low
	Approach and early test description for external consultation	✔	5/15	Low	Low	Low
	Test results: characterization of MSL Tier 1 fraction of TOC	✔	9/15	Medium	Low	Low
	Test Results: OC accumulation on Titanium Nitride	✔	12/15	Medium	Medium	Low-Med
	Baseline OC approach documented in CC Plan	✔	2/16	Medium	Medium	Low-Med
	PDR		**2/16**			
Pre-CDR Phase C	**Molecular Absorber Review following characterization tests**	✔	10/16	Med-High	Medium	Low-Med
	Baseline T-0 Purge for ACA	✔	11/16	High	Med-High	Medium
	Document key OC vectors analysis summary	✔	11/16	High	Med-High	Medium
	Analyses and Tests leading to Molecular Contamination and Transport Modeling Review	✔	12/16	Complete	Med-High	Medium
	End to End RSCC Review	✔	1/17	V&V	Med-High	Medium
	Refine outgassing onto Mars surface analysis	✔	2/17	V&V	High	Med-High
	CDR		**2/17**			
Post-CDR Phase C	Verify tube OC cleanliness levels after firing		6/17	V&V	High	Med-High
	Key additional ACA component outgassing tests		7/17	V&V	High	Med-High
	Mitigation Option: dilution cleaning or higher contam. on 1st sample?		8/17	V&V	Complete	High
	Molecular Contamination and Transport Modeling Review 2		9/17	V&V	V&V	High
	Mitigation Option: coring operations/core temperature control		11/17	V&V	V&V	Complete
	SIR		**11/17**			
Phase D	Completion of V&V for to Corer delivery certification		9/18	V&V	V&V	V&V
	Completion of V& for Sterile Flight Model ACA delivery certification		1/19	V&V	V&V	V&V

This work is frequently externally reviewed

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- **Particle Re-suspension & Transport Review 11/22/16**
  - Chair: Dr. Suresh Dhaniyala, Professor and Co-Director of CARES, Clarkson University
  - Dr. Richard Flagan, Professor, Caltech
  - Dr. William Hinds, Professor Ret, UCLA
  - Dr. Oleg Kim, Research Faculty, Notre Dame/UCR
- **Molecular Contamination and Transport Modeling Review 12/5/16**
  - Chair: Dr. Michael Stanley Woronowicz, SGT, Inc. (NASA/GSFC)
  - Dr. Francisco Zaera, Professor, UCR
  - Dr. John Alred, Deputy Branch Chief, M and P, NASA JSC
  - Dr. David Brinza, Principal Engineer, JPL
  - Dr. Geneviève (Jenny) Devaud, Principal Scientist, Ball Aerospace
  - Dr. Alvin Huang, Senior Materials, Process & Physics/Systems Engr, Boeing
- **Sample Tube Cleaning and Analysis Review 12/5/16**
  - Co-Chair: Dr. Chip Cody, JOEL, Inc.
  - Co-Chair: Dr. Brent Ekstrand, Astropak, Inc.
  - Dr. Francisco Zaera, Professor, UCR
  - Dr. David Brinza, Principal Engineer, JPL
  - Dr. Amy J. G. Jurewicz, Asst. Research Professor, ASU – Temple

- **Return Sample Biological CC Review 12/16/16**
  - Chair: Dr. Melissa Jones, Asst Section Mgr., Spacecraft Mechanical Engineering, JPL
  - Jason Kastner; Europa Clipper Deputy Flight System Engineer, JPL
  - Laura Newlin; Biotechnology and Planetary Protection Engineer, JPL
  - Wayne Nicholson; Professor, U of Florida, Microbiology & Cell Science
  - Kai Purohit; Sterilization Consultant, Process Tek
  - Ken Frey; Navy Medical Research Center Biological Defense Research Directorate
  - John Lindsay; Aseptic Consultant, Aseptic Solutions, Inc.
  - Yulia Goreva; Mars 2020 Project, JPL/RSSB Member
  - Jason Willis; InSight Project Systems Engineer, JPL
- **Return Sample Contamination Control (RSCC) End-to-End Review 1/31/17**
  - Chair: Hoppy Price (JPL), Chief Engineer, JPL Mars Program
  - Rob Manning, (JPL) ESD Chief Engineer
  - G. Mark Brown (JPL), Systems Engineering Division Manager
  - Kevin Hand, PhD (JPL) Deputy Project Scientist, Europa Science Office
  - Suresh Dhaniyala, Ph.D. (Clarkson University) – Particle Resuspension and Transport review board chair
  - Chip Cody, Ph.D. (JEOL) – Sample Tube Cleaning & Analysis review board co-chair
  - Melissa Jones, Ph.D. (JPL) Asst. Mgr., S/C Mechanical Engineering– Return Sample Biological Contamination Control board chair
  - Geneviève (Jenny) Devaud, Ph.D., Principal Scientist, Ball Aerospace, Inc. - Molecular Modeling and Transport board
  - Woodward W. (Woody) Fischer, Ph.D. – Professor of Geobiology, Caltech
  - Aaron S. Burton, Ph.D. – JSC, Laboratory Manager for Soluble Organics in Astromaterials