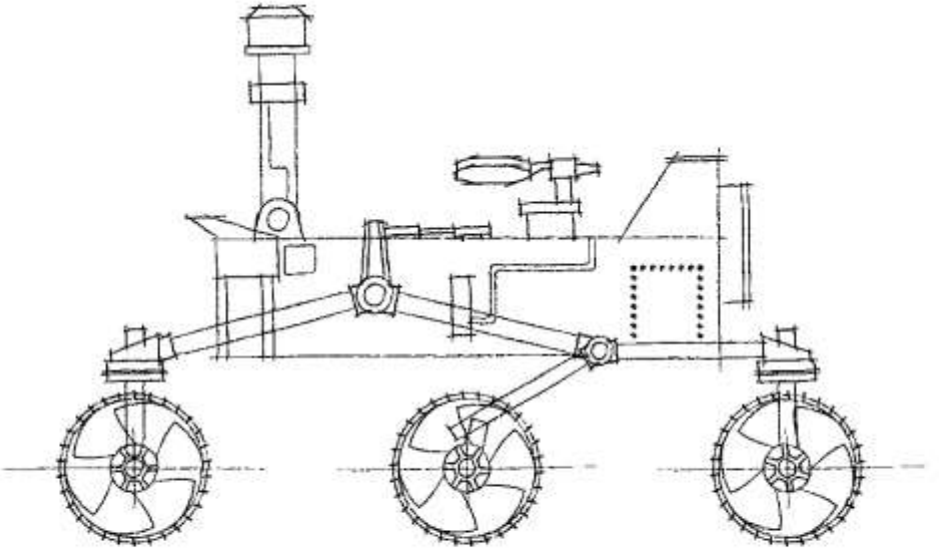
Jet Propulsion Laboratory
California Institute of Technology

Mars 2020 Mission

Ken Farley

Project Scientist (Caltech)

September 13, 2017



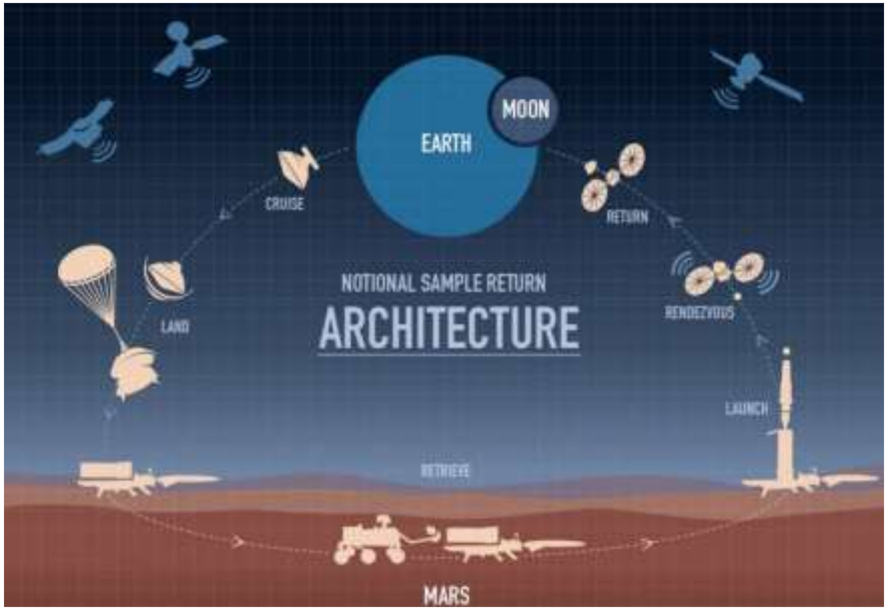
Mars 2020 Project

Outline

- 1. Mission Context, Objectives, and Overview
- 2. Status and Key Challenges
- 3. Landing Sites

Mars 2020 Context: MSR Campaign

- Recently, SMD AA Thomas Zurbuchen discussed architecture for a Mars Sample Return Campaign



from TZ presentation to PS Decadal Survey Midterm Review

- launch date uncertain, but expedited SRL launch (notional date in 2026) could be advantageous in that currently existing telecommunications relay assets (MRO, MAVEN, TGO) should be available.

- general concept he described is consistent with Mars 2020 Project expectations. If launch occurs in 2026, then it is not unreasonable to imagine extended mission Mars 2020 and SRL mission directly interacting.

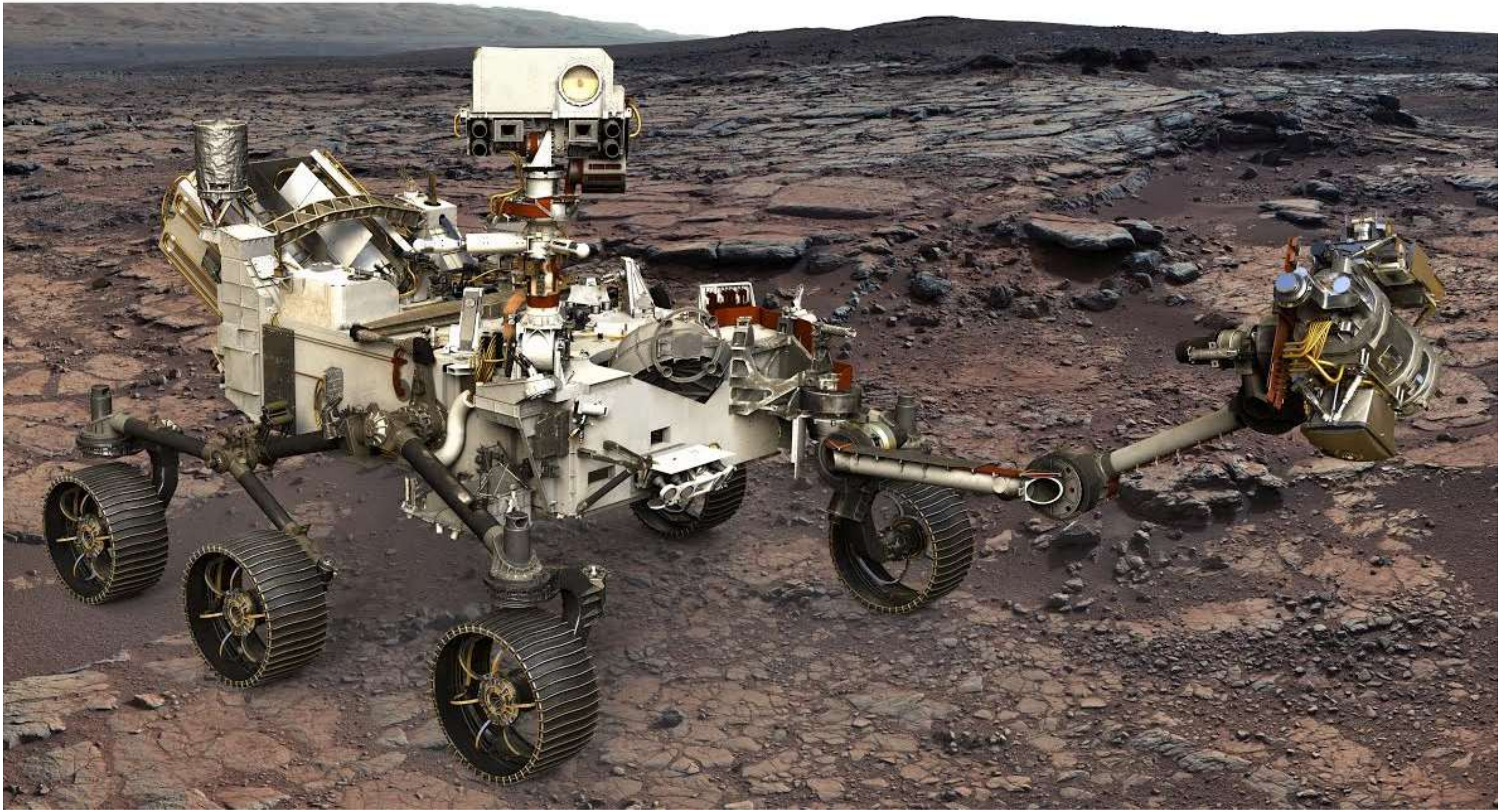
Mars 2020 Mission Objectives

- **Conduct Rigorous *In Situ* Science**
  - **Geologic Context and History** Characterize the processes that formed and modified the geologic record within a field exploration area on Mars selected *for evidence of an astrobiologically-relevant ancient environment and geologic diversity*
  - **In Situ Astrobiology** Perform the following astrobiologically relevant investigations on the geologic materials at the landing site:
    1. Determine the habitability of an ancient environment.
    2. For ancient environments interpreted to have been habitable, search for materials with high biosignature preservation potential.
    3. Search for potential evidence of past life using the observations regarding habitability and preservation as a guide.
- **Enable the Future: Sample Return**
  - Assemble rigorously documented and returnable cached samples for possible future return to Earth.
    1. Obtain samples that are scientifically selected, for which the field context is documented, that contain the most promising samples identified in Objective B and that represent the geologic diversity of the field site.
    2. Ensure compliance with future needs in the areas of planetary protection and engineering so that the cached samples could be returned in the future if NASA chooses to do so.

Mars 2020 Mission Objectives

- **Enable the Future: Human Exploration**
  - Contribute to the preparation for human exploration of Mars by making significant progress towards filling at least one major Strategic Knowledge Gap (SKG). The highest priority SKG measurements that are synergistic with Mars 2020 science objectives and compatible with the mission concept are:
    1. Demonstration of In-Situ Resource Utilization (ISRU) technologies to enable propellant and consumable oxygen production from the Martian atmosphere for future exploration missions.
    2. Characterization of atmospheric dust size and morphology to understands its effects on the operation of surface systems and human health.
    3. Surface weather measurements to validate global atmospheric models.
    4. A set of engineering sensors embedded in the Mars 2020 heat shield and backshell to gather data on the aerothermal conditions, thermal protection system, and aerodynamic performance characteristics of the Mars 2020 entry vehicle during EDL.

Mars 2020 Looks like Curiosity



Similar, but different…

Mars 2020 Project Science Group (PSG)

New instruments,
New science team leadership

Ken Farley, Project Scientist
Mitch Schulte, Program Scientist

Ken Williford, Deputy Project Scientist
Katie Stack Morgan, Deputy Project Scientist
Adrian Brown, Deputy Program Scientist
George Tahu, Program Executive

Jim Bell, Mastcam-Z Principal Investigator
Justin Maki, Mastcam-Z Deputy Principal Investigator

Jose Antonio Rodriguez-Manfredi, MEDA Principal Investigator
Manuel de la Torre Juarez, MEDA Deputy Principal Investigator

Michael Hecht, MOXIE Principal Investigator
Jeff Hoffman, MOXIE Deputy Principal Investigator

Abby Allwood, PIXL Principal Investigator
Joel Hurowitz, PIXL Deputy Principal Investigator

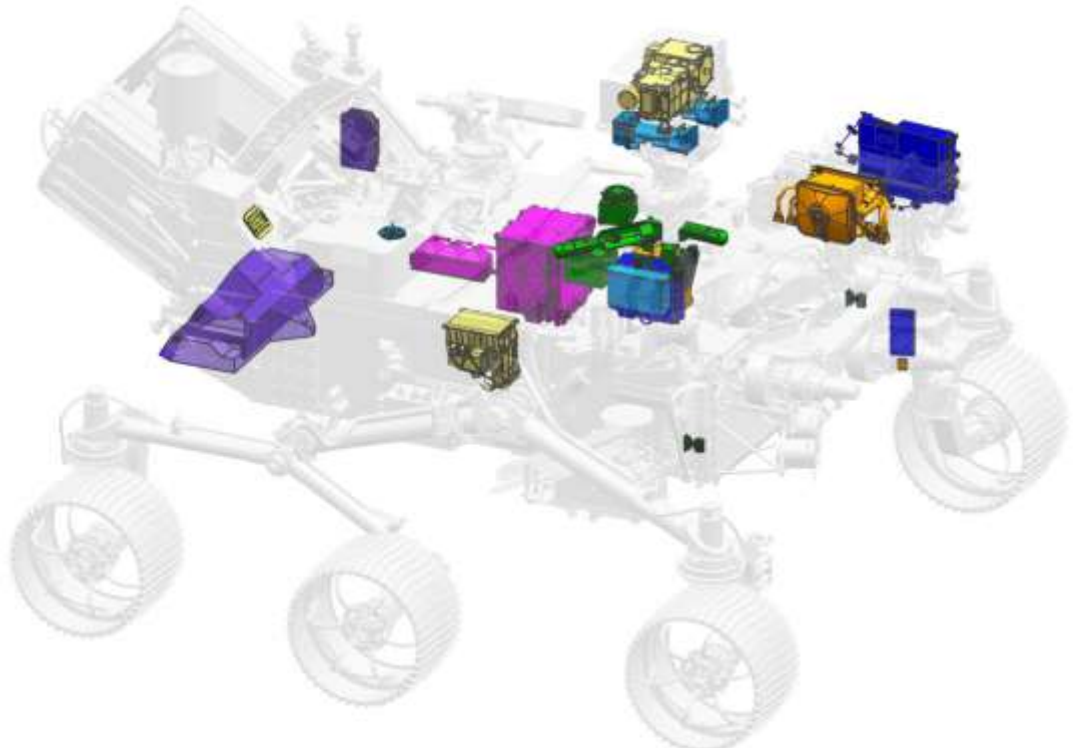
Svein-Erik Hamran, RIMFAX Principal Investigator
David Paige, RIMFAX Deputy Principal Investigator

Luther Beegle, SHERLOC Principal Investigator
Rohit Bhartia, SHERLOC Deputy Principal Investigator

Roger Wiens, SuperCam Principal Investigator
Sylvestre Maurice, SuperCam Deputy Principal Investigator

Hap McSween, Returned Sample Science Board Co-Chair
Dave Beaty, Returned Sample Science Board Co-Chair

Science and technology instruments



Instrument Key
Mastcam-Z Stereo Imager
MEDA Mars Environmental Measurement
MOXIE In-Situ Oxygen Production
PIXL Microfocus X-ray fluorescence spectrometer
RIMFAX Ground Penetrating Radar
SHERLOC Fluorescence and Raman spectrometer and Visible context imaging
SuperCam LIBS ,VISIR, and Raman

- new wheels
- Terrain Relative Navigation and Range Trigger for EDL
- new engineering cameras
- enhanced autonomy capabilities
- 5 hour ops timeline
- enhanced EDL cameras, and microphone. Strengthened parachute.
- helicopter (still being assessed)

Mission Overview

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

Mission Status

- Project Critical Design Review (CDR) completed in March 2017. All instrument CDRs fully completed by Spring 2017.

- Currently in Phase C (implementation).

- Next milestones: System Integration Review (SIR) and KDP-D in early 2018.

Seven months post-CDR: hardware is well-along

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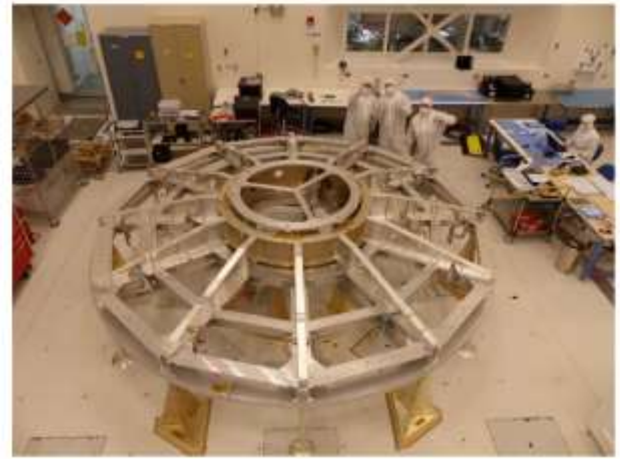
Cruise Stage LVA Assembly, Rib Installation



Flight Descent Stage

GNC Sensors & TRN Electronics

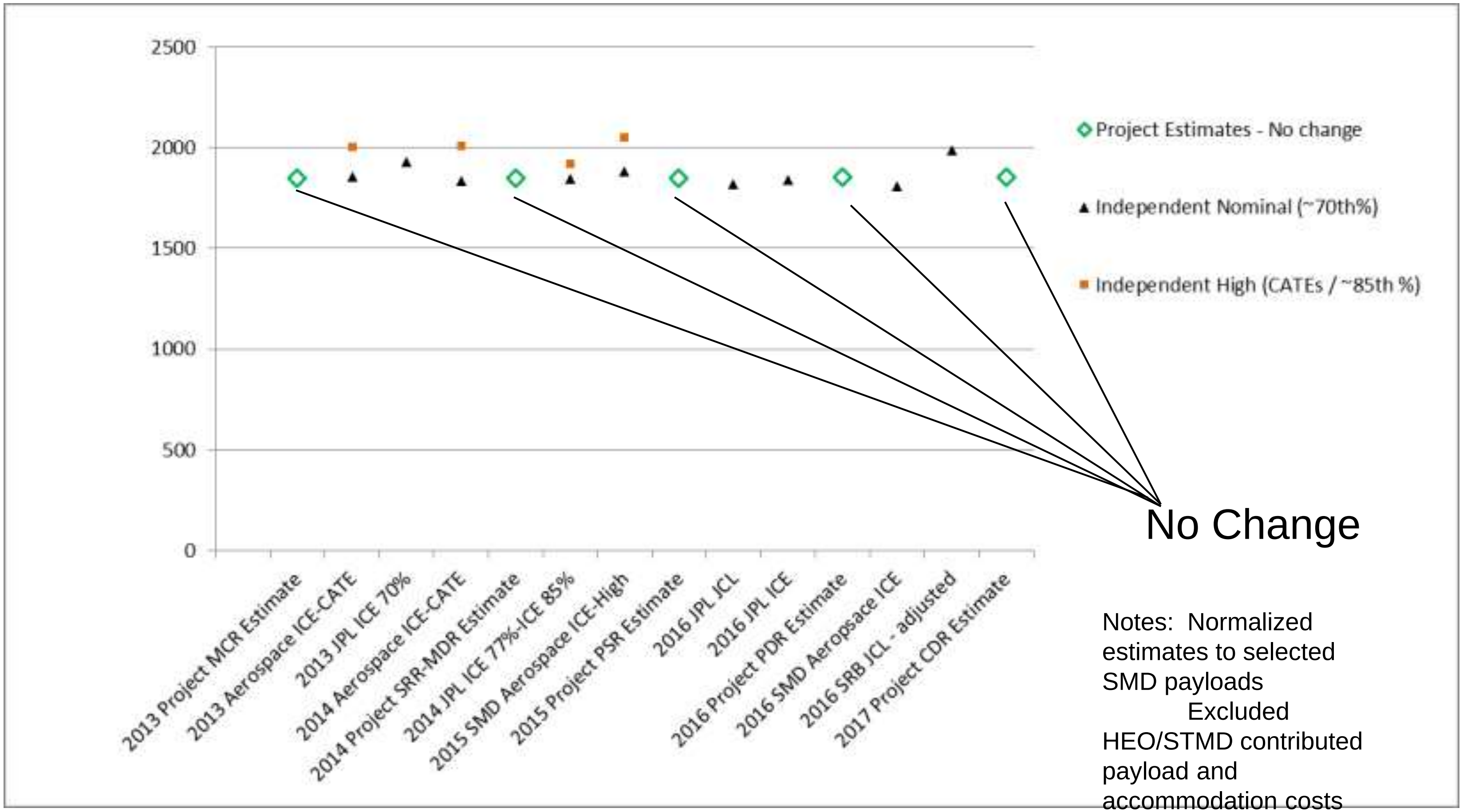
RTG Heat Exchanger Hot Plate Tube Bending

Cruise Solar Array Substrate

RIPA Accumulator
(with pre-weld tooling)

Very Steady Cost Estimate

SMD Phase A-D, Including Launch Vehicle



- Within cost, greatly aided by MSL heritage design and fabrication procedures
- Responsive to the Decadal Survey's admonition to get the cost ≤ $2.5B

Key Challenges

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- **New Science Instruments:** Key to both in-situ exploration and sample selection/documentation (especially SHERLOC and PIXL, with high spatial resolution co-registered imagery and spectroscopy).

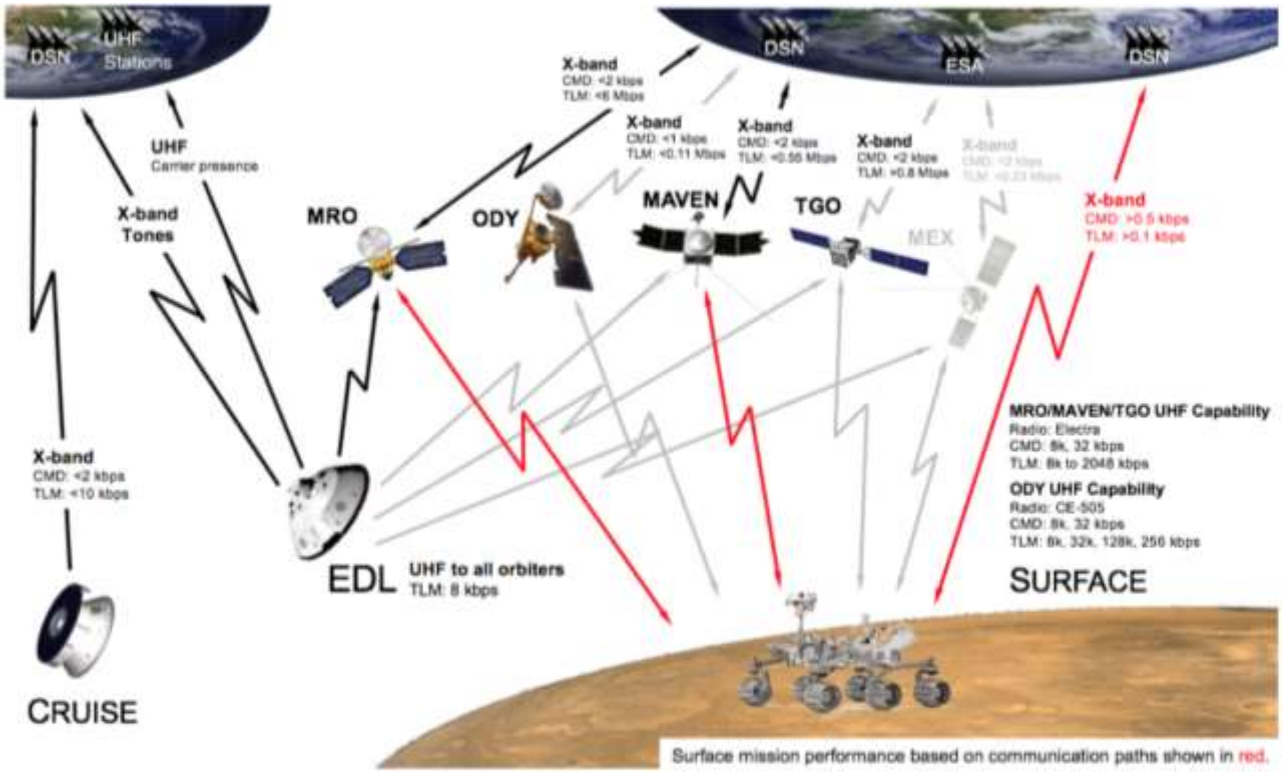
- **High Science Data Volume:** multiple new imaging instruments with high data downlink demands.

- **Efficiency of Operation:** Need to meet both in-situ science and sample collection requirements in prime mission.

- **Sampling System:** core, verify, hermetically seal, and cache rock and regolith samples.

- **Sample Cleanliness**: extraordinarily low biological and organic contamination limits on cached samples.

M2020 Communication Links



Mars 2020 requires substantially more data downlink volume than MSL. Planning use of both MRO and MAVEN for relay. Possible augmentation from EXOMARS-TGO.

Improved Operational Efficiency

1. Enhanced autonomy – navigation and driving, sample approach and targeting, on-board science observation scheduling.

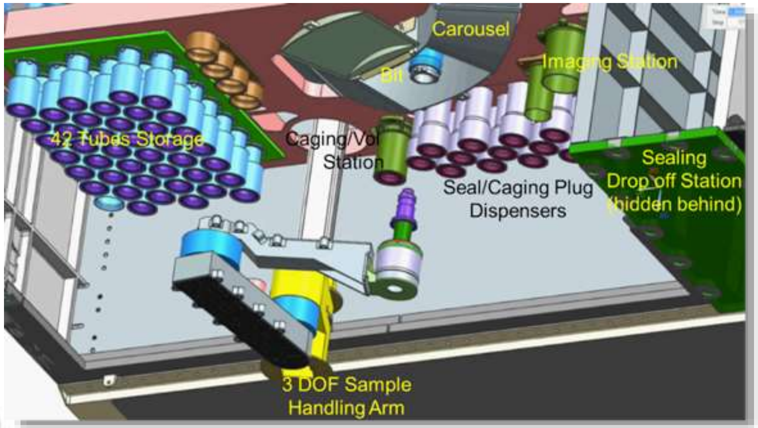
2. Five-hour daily timeline – greatly reduces sols partially or completely lost due to communications relay over-flight schedule.

3. Modified operations model – greater focus on higher level "strategic" and "campaign" science and science planning, de-emphasis on tactical level

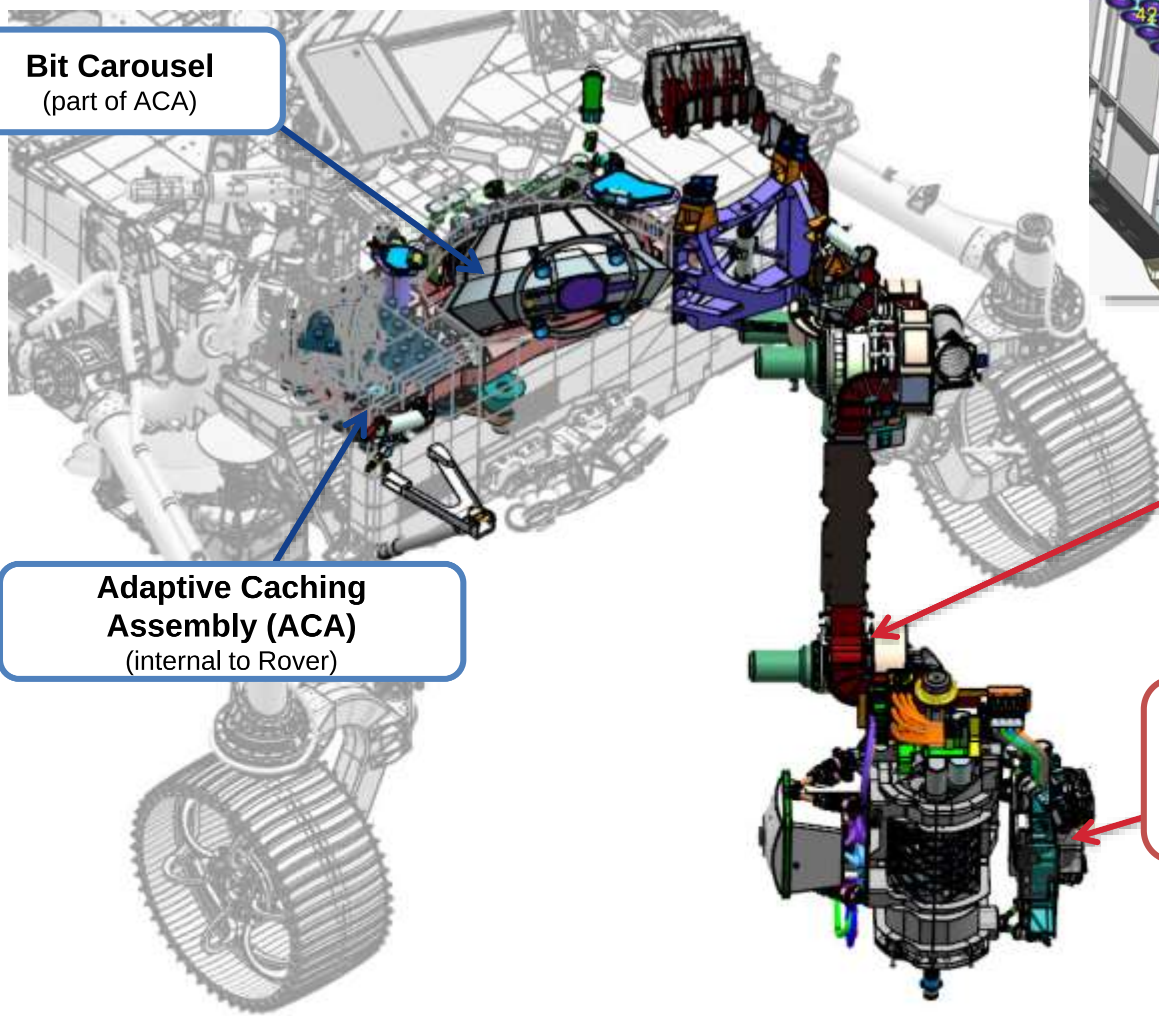
Lots of process and software development, lots of science team training.

Sampling & Caching Subsystem (SCS)

~ 42 sample tubes



Caching Assembly



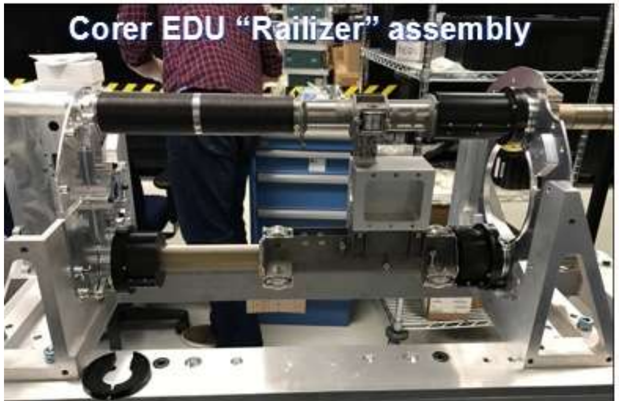
Bit Carousel
(part of ACA)

Adaptive Caching Assembly (ACA)
(internal to Rover)

Robotic Arm

Turret
- Coring drill
- SHERLOC / WATSON Instrument
- PIXL Instrument

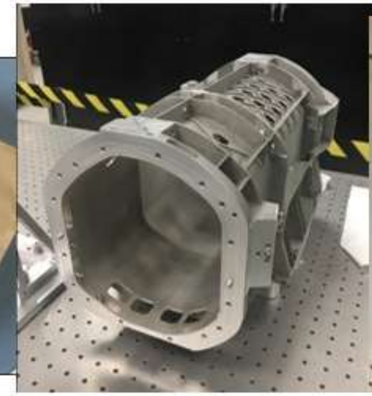
SCS



Corer EDU “Railizer” assembly

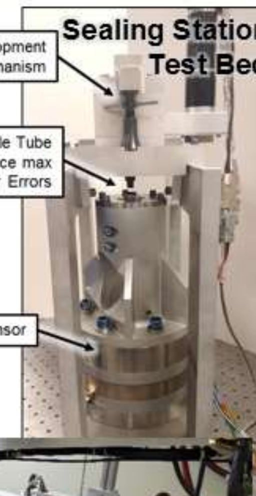
EDU Core Break Lock-Out (CBLO)

Corer EDU Spindle Twin-Input Gear (STIG) housing



Corer EDU Feed Structure

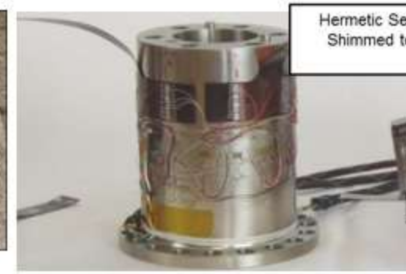
EDU isolator strut canisters



Sealing Station Test Bed

BTI Abraded / Cleared

gDRT in 3’ chamber



RA Development 6 DOF Force Torque Sensor

EDU SHA

Docking Test Bed

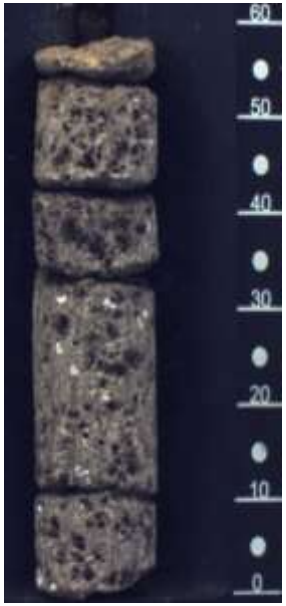
Coring and Sample Tube

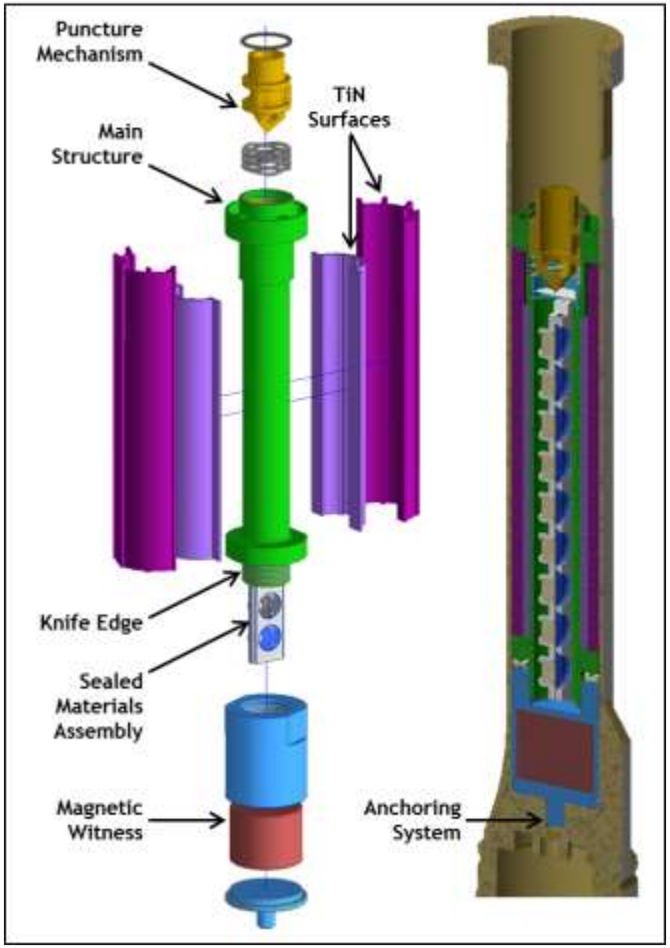
Coring Bit

Hermetically sealed sample tube

<u>Core</u>

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





Witness tube assembly for round trip contamination characterization

Key Mars 2020 PP and Sample Cleanliness Requirements at L1

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#	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)

Organic Carbon Budget

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%**

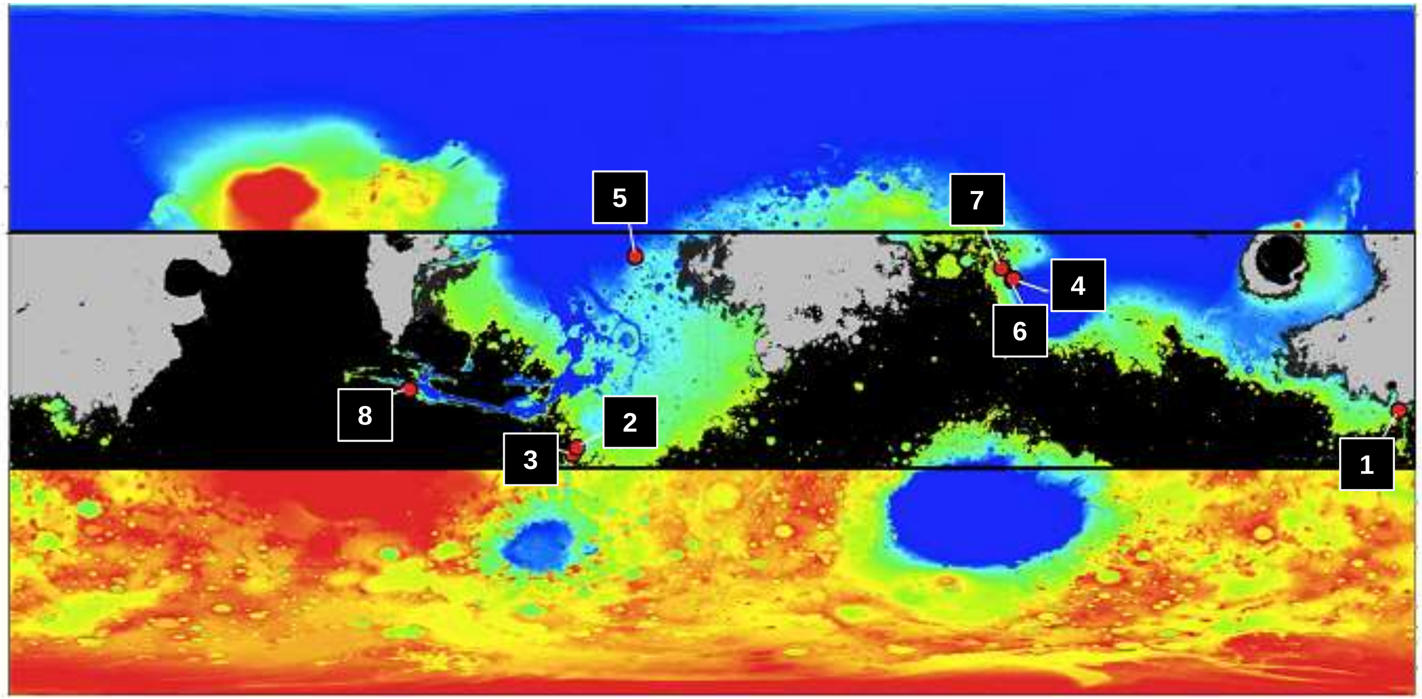
Viable Organism Budget

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)	**4 E-6**	**1 E-6**
	L1 Requirement	**<1**	**<1**
	Margin (as factor)	**300,000**	**900,000**

Other

- Drillable Blank
- Science Team Meeting and Team Training Plan

Where is Mars 2020 Landing?



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” have never been under consideration for exploration.

Landing Site Candidates

1. Jezero Crater

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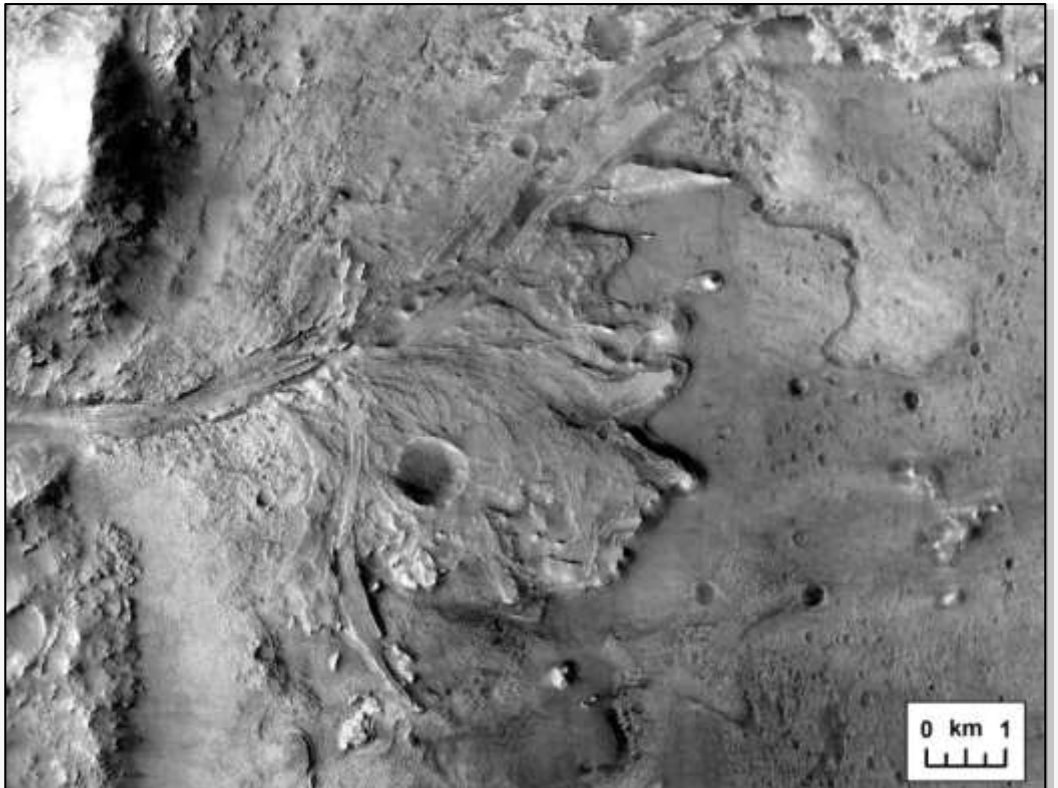

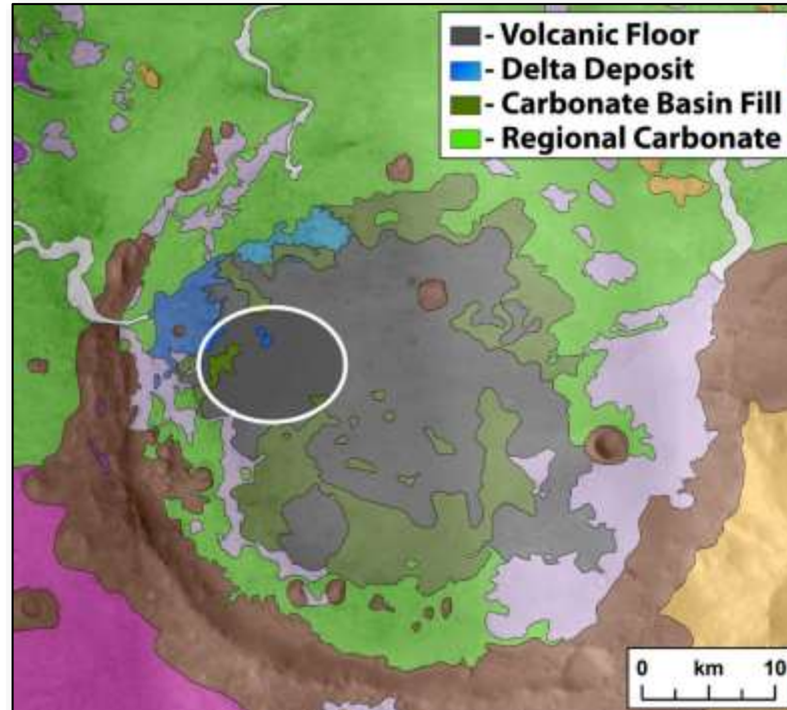

from T. Goudge presentation at LSW3

Possible habitable environment - An ancient crater lake

Landing Site Candidates

2. Northeast Syrtis

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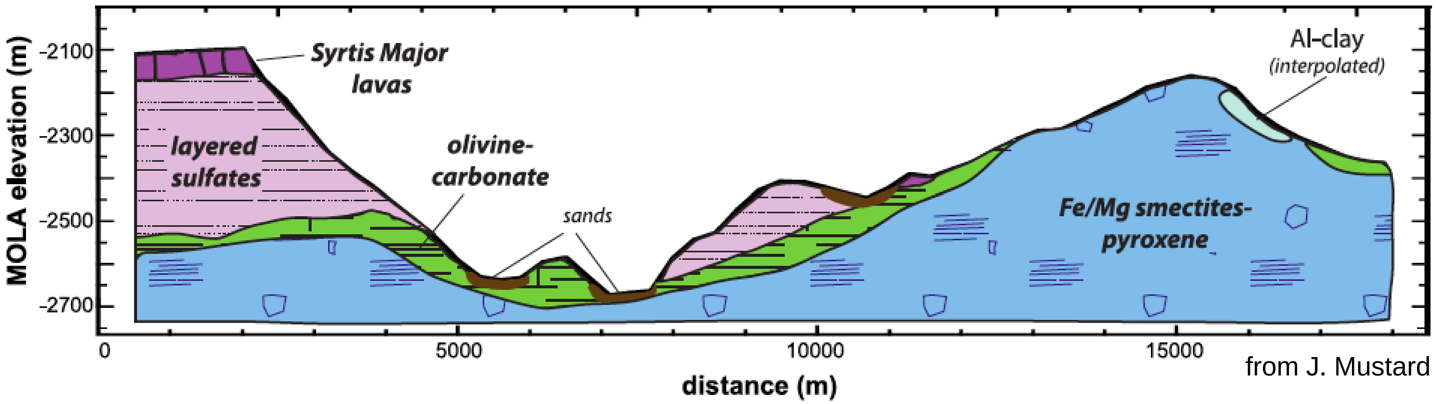
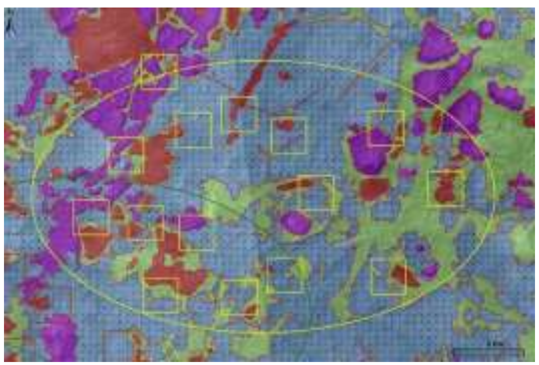
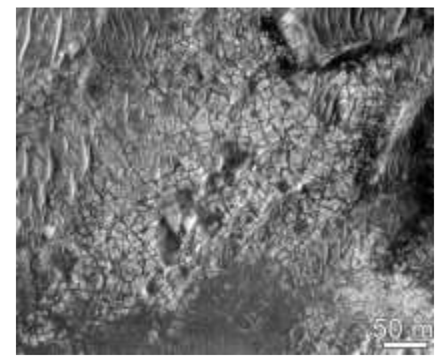


from J. Mustard and M. Bramble at LSW3





Possible habitable environment - groundwater circulating through warm or hot rock (serpentinite?).

Landing Site Candidates
3. Columbia Hills (Gusev)

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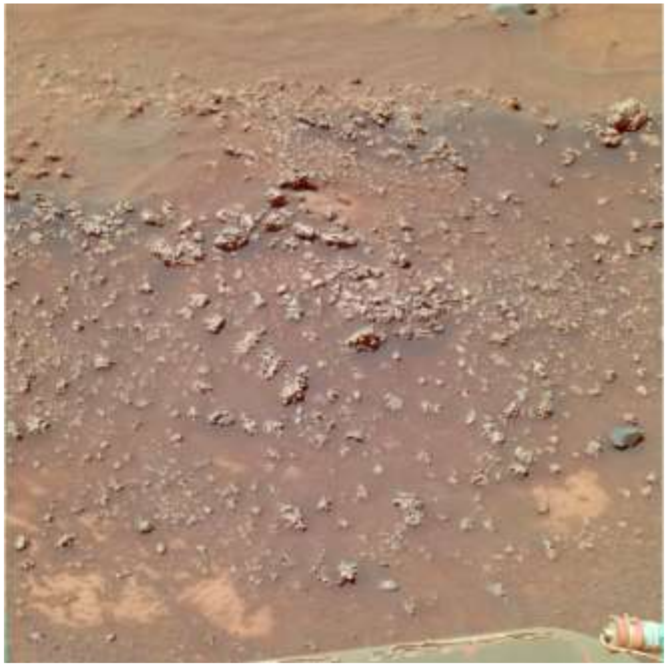

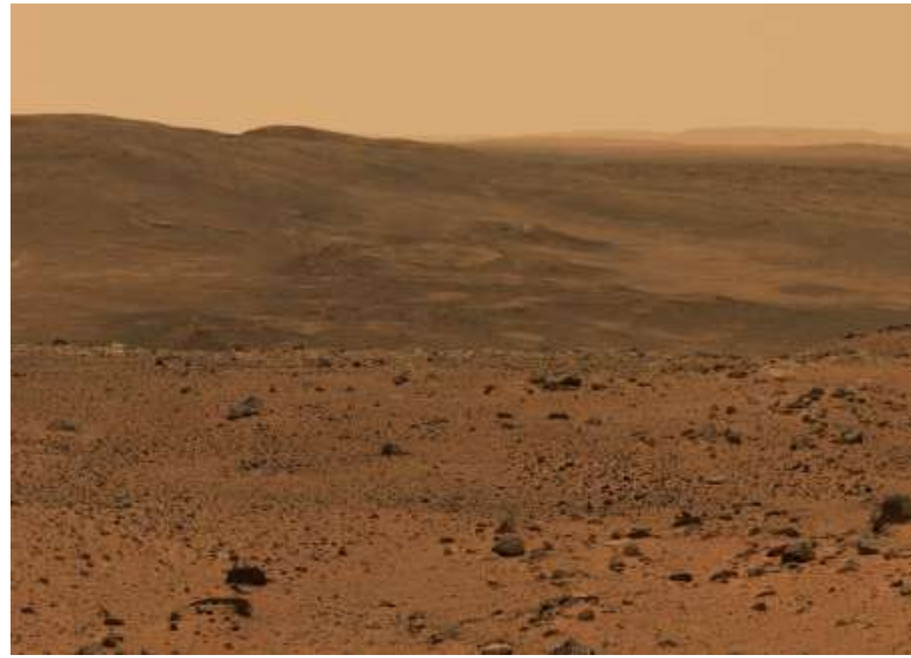

from presentations by S. Ruff and R. Arvidson at LSW3

Possible habitable environment - An ancient hot spring

Landing Site Process

Down-Select Path:

1. Mars 2020 Science Team is currently engaged in a very deep analysis of data (and published interpretations) of the landing sites. The goal is a critical assessment of the geologic setting and the science value of each site, and a clear understanding of uncertainties, challenges, and opportunities at each.

2. Community workshop likely summer 2018.

3. Recommendation of prioritized site(s) to SMD AA likely by early Fall 2018.

Backup Material

Project Top-Level Schedule

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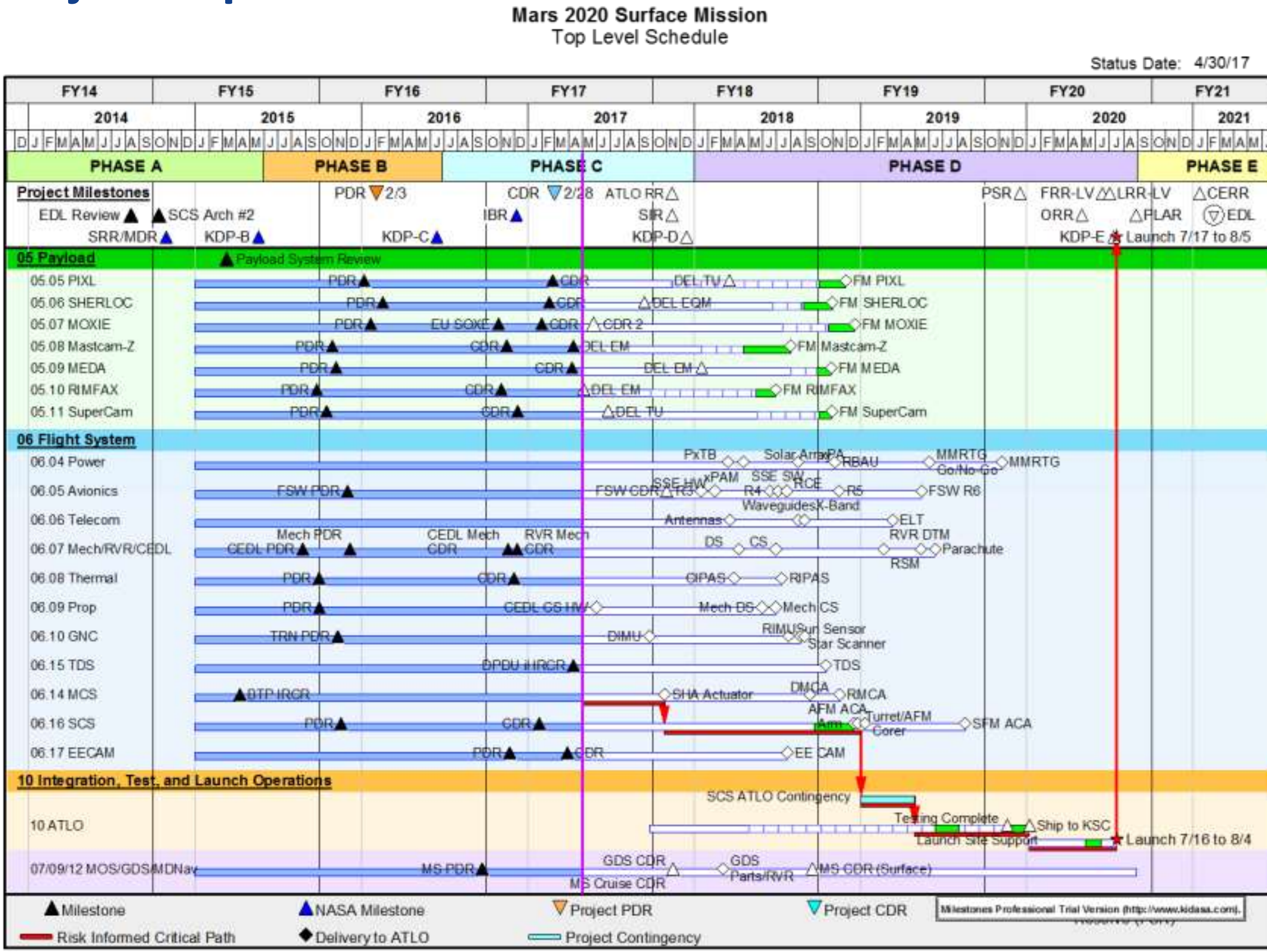

Key Elements of Lowering Risk to Viable Organisms Requirement

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Mars 2020 Project

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

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