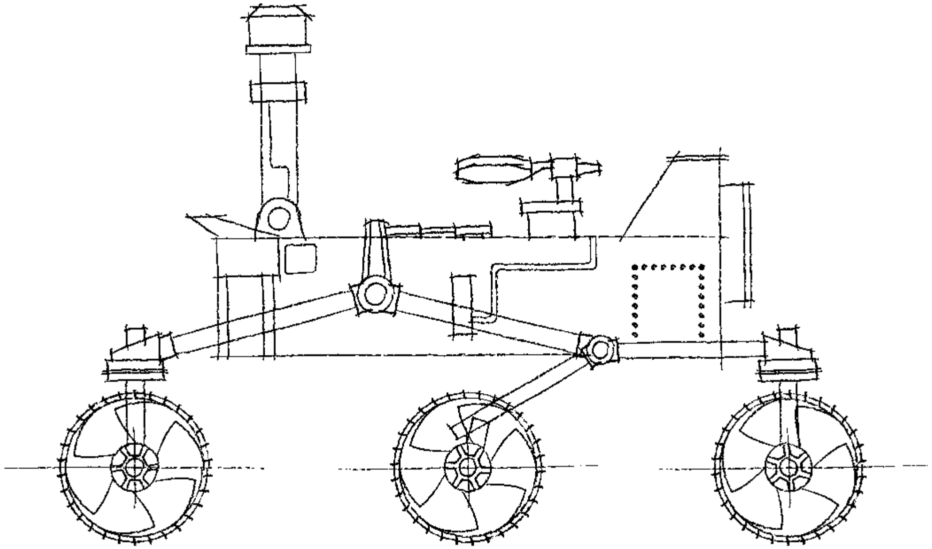
Jet Propulsion Laboratory
California Institute of Technology

Mars 2020 Mission

Ken Farley

Project Scientist (Caltech)

July 13, 2017



Mars 2020 Project

Outline

- 1. Mission Objectives and Requirements
- 2. Mission Overview
- 3. Key Challenges
- 4. Landing Sites

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 its entry and descent to the Mars surface.

Key Level 1 Project Requirements

- Prime Mission of at least 1 Mars year (669 sols, 689 Earth days)
- Develop, integrate, test the science payload
- Capability of acquiring at least 31 samples of rock or regolith (with blanks) and caching them on the surface. Size 8 cm^3 (~15 g) each.
- Meet stringent requirements for organic and biologic contamination of samples
- During the prime mission, must be capable of performing the following in a minimum of two scientifically diverse Regions of Interest:
  a) conduct the investigations required to achieve objectives A and B, and
  b) acquire/cache on the surface of Mars a minimum of 20 samples of rock, regolith, and/or procedural "blank" samples

Mars 2020 vs Decadal Recommendation

	Decadal Recommendation	Mars 2020
Rover	Solar-Powered MER-Class (350 kg)	RTG-Curisoity Class (~1000 kg)
Lifetime (sols)	500	>669
Sample Caching System (kg)	35	120
Science Instruments (kg)	25	40
Cache	2 (primary, contingency)	Adaptive Caching
Samples	10 grams each	15 grams each
	20 primary samples 20 contingency samples	43 sample tubes (6 are witness blanks)
	prevent cross-contamination prevent exposure to Mars atmosphere	<1% cross contamination hermetic seal
	keep samples within temperature experienced prior to collection	<20 C (landing site dependent)
sample survival time (y)	10	30-50

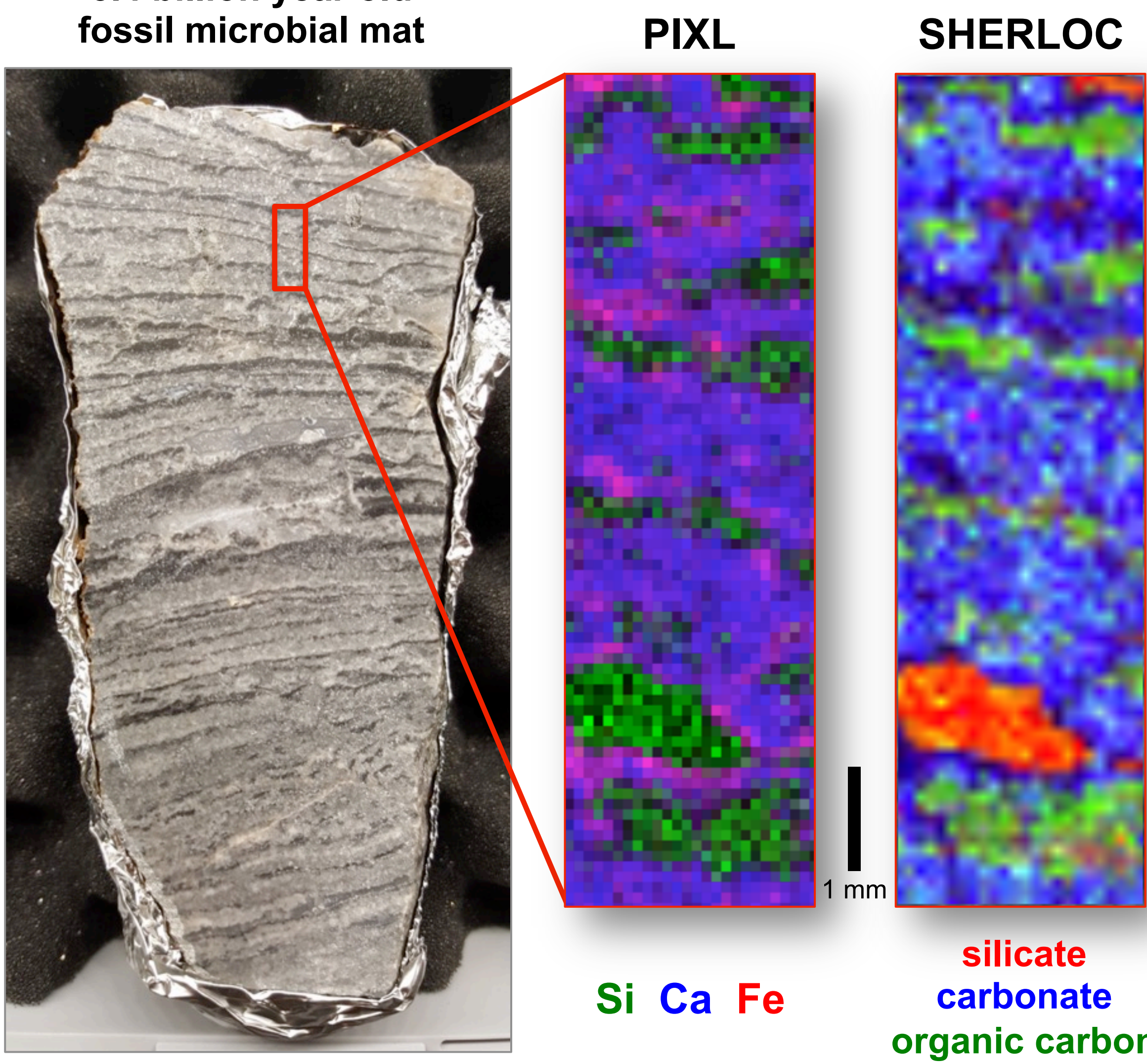
What Mars 2020 science is not…

MSL exploration + *Mars Sample Return with the same rover and a lower budget

*possible

Example – seeking signs of ancient life with in-situ instruments

3.4 billion year old fossil microbial mat



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**.

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

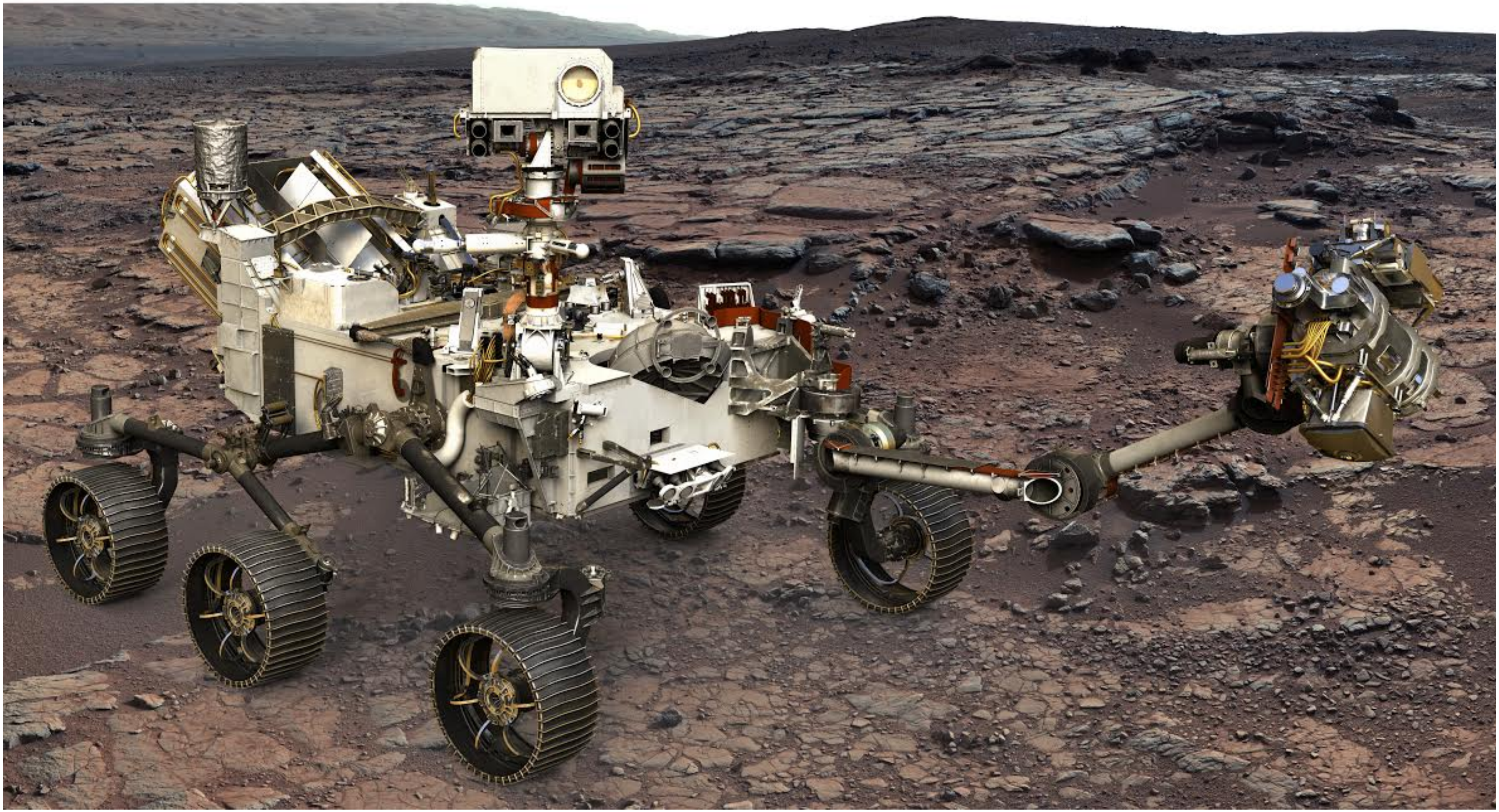
ENTRY, DESCENT & LANDING

- 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

Mars 2020 Looks like Curiosity



Similar, but different…

Mars 2020 Project Science Group (PSG)

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

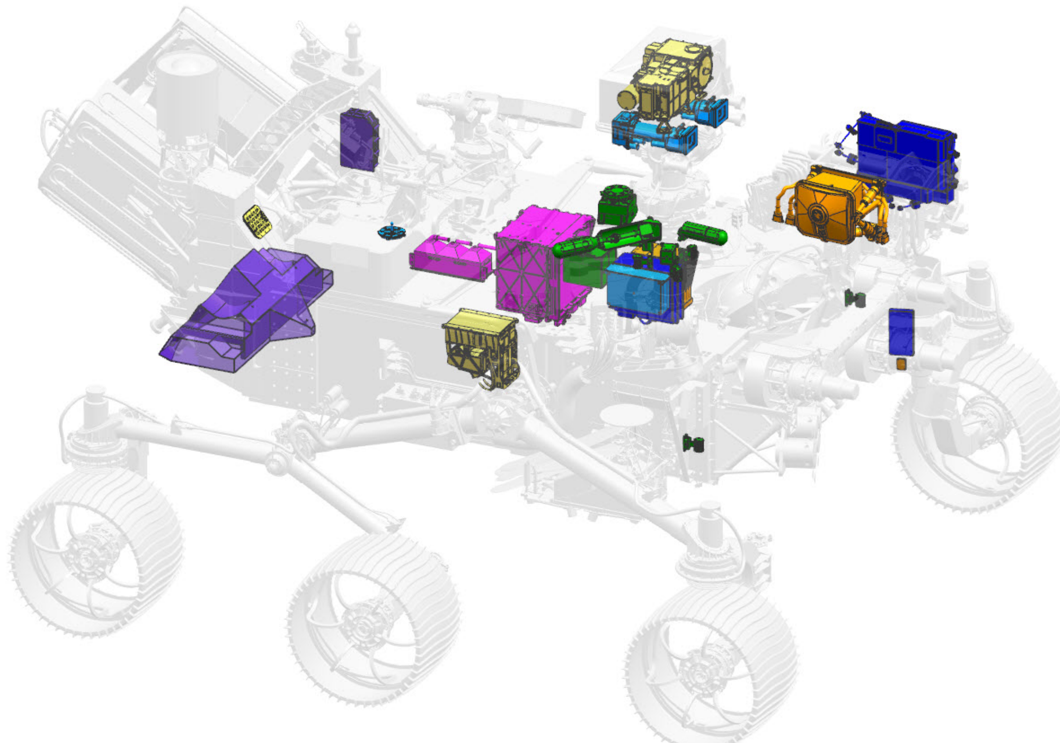
Svein-Erik Hamran, RIMFAX Principal Investigator
David Paige, RIMFAX Deputy Principal Investigator

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

New 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

ALSO:
- 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)

Mars 2020 vs Decadal Recommendation

Science Instruments

1. *Pancam high resolution stereo imager (on mast)*
2. *Alpha particle X-ray spectrometer*
3. *Microscopic Imager*
4. *Dual Wavelength Raman/Fluorescence Instrument*
5. *Near-Infrared Point Spectrometer*

Instrument Key
Mastcam-Z Stereo Imager
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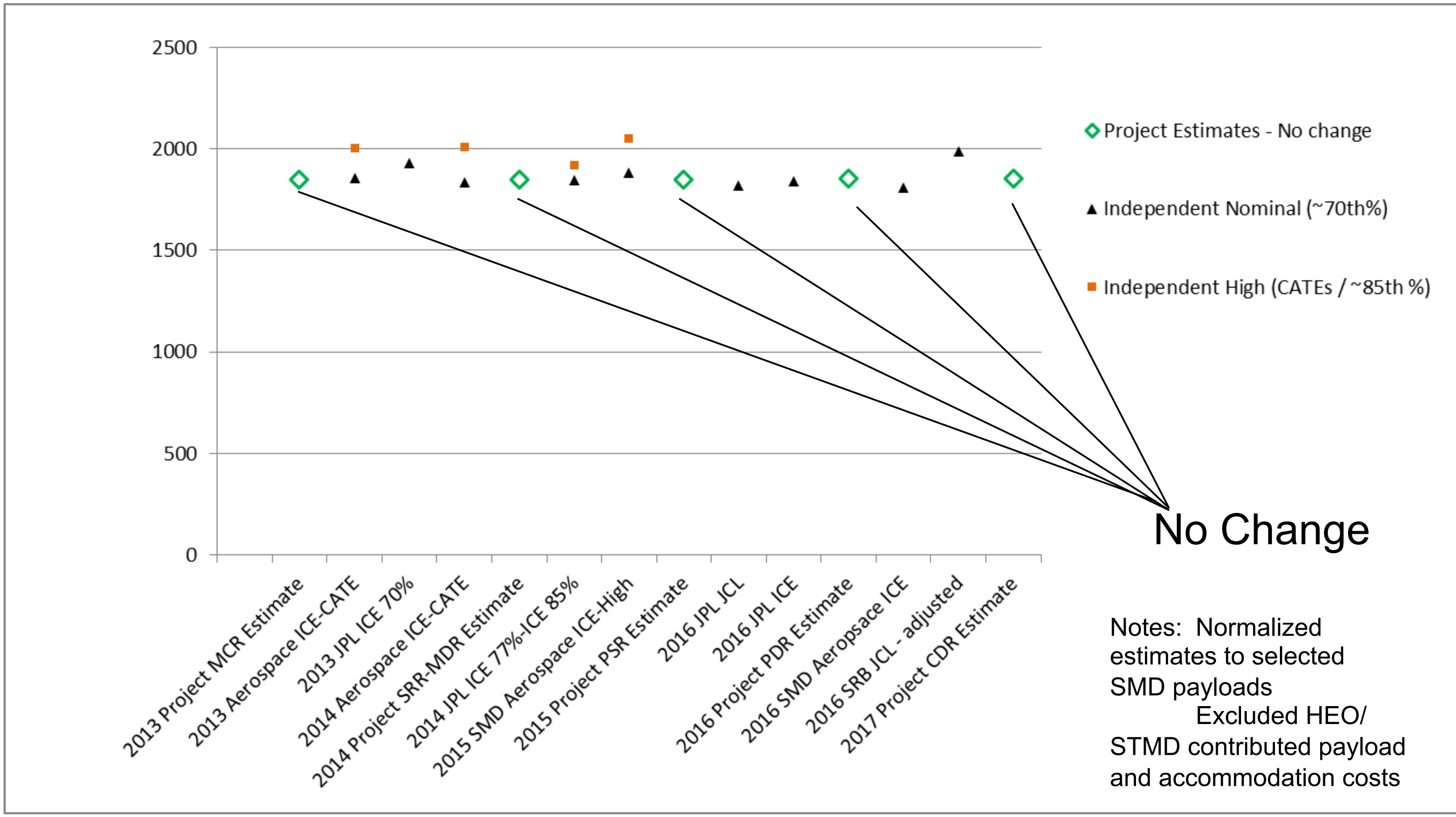
RIMFAX Ground Penetrating Radar
SHERLOC Fluorescence and Raman spectrometer and Visible context imaging
SuperCam LIBS ,VISIR, and Raman

Very Steady Cost Estimate

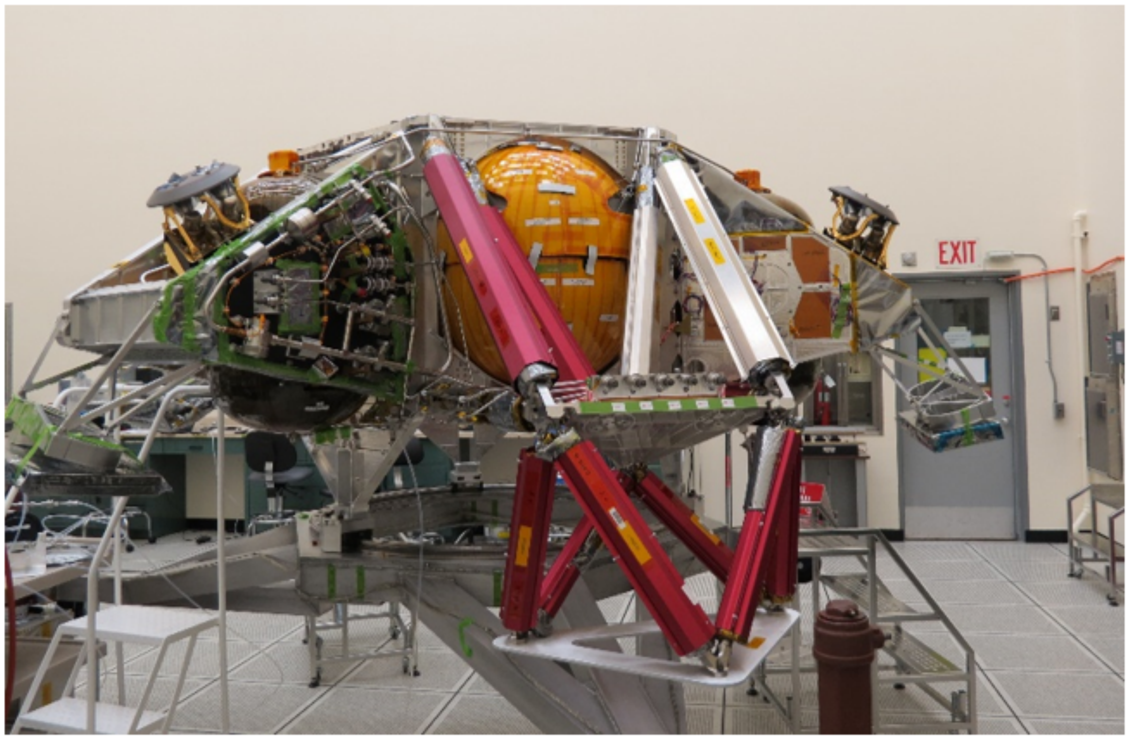
SMD Phase A-D, Including Launch Vehicle

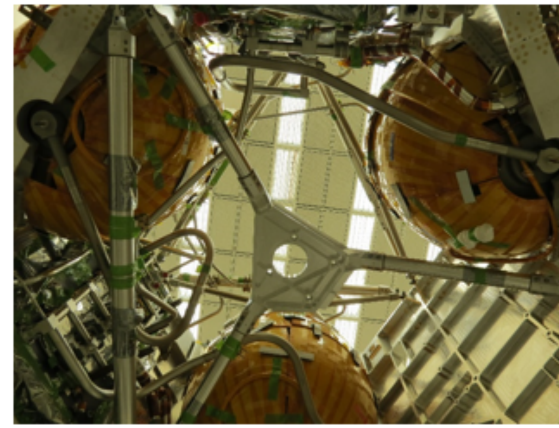


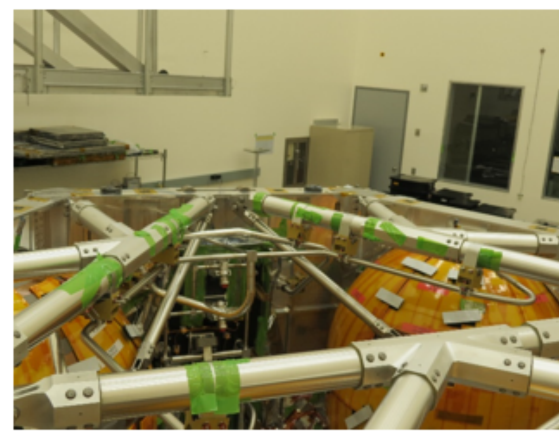
- Within cost, greatly aided by MSL heritage design and fabrication procedures
- Responsive to the Decadal Survey's admonition to get the cost ≤ $2.5B

Just past CDR:
Hardware already well along

Flight Descent Stage







Key Challenges

- **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. MRO-MAVEN-TGO availability.

- **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.

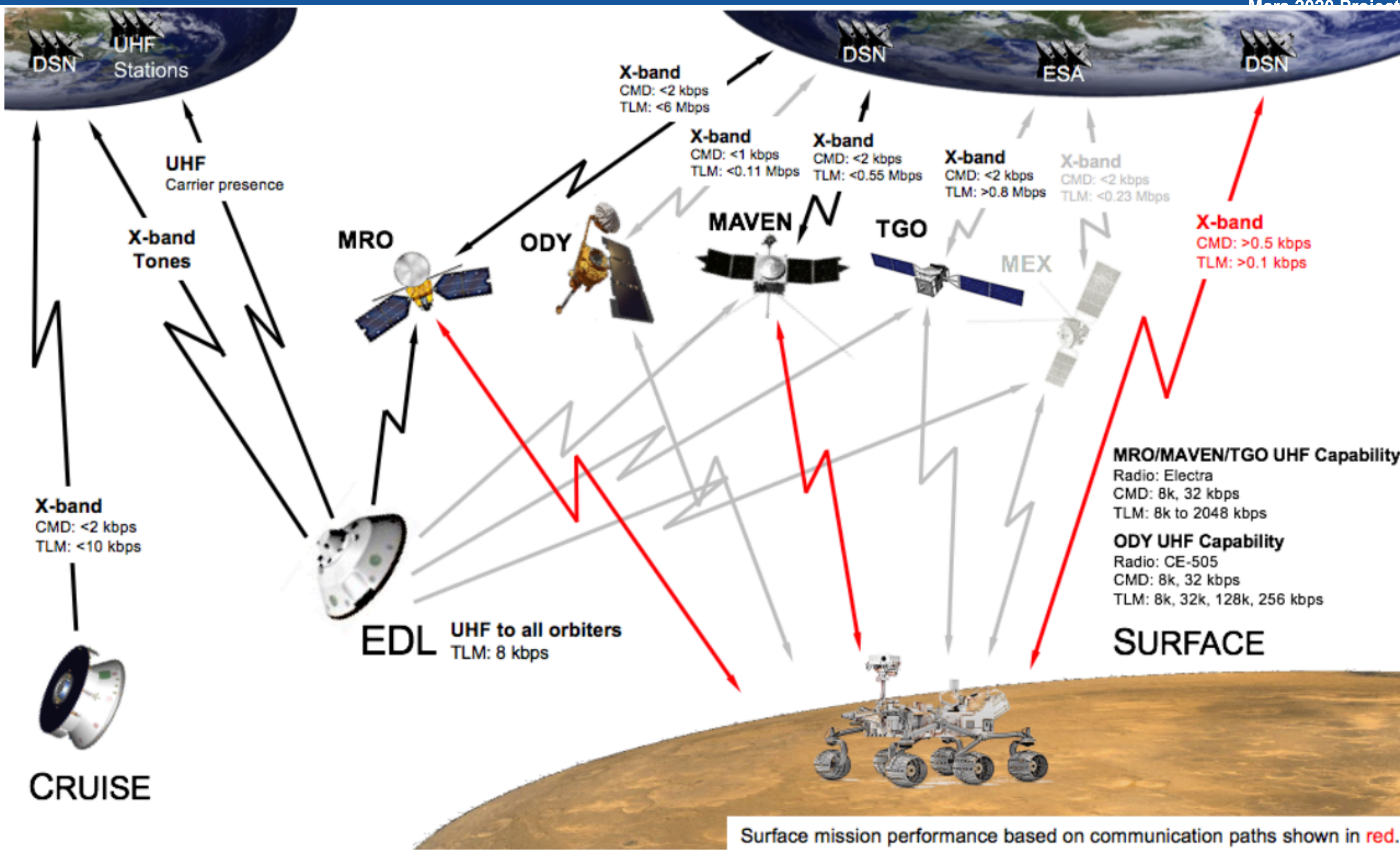
Improved Operational Efficiency

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

M2020 Communication Links



Key Mars 2020 PP and Sample Cleanliness Requirements at L1

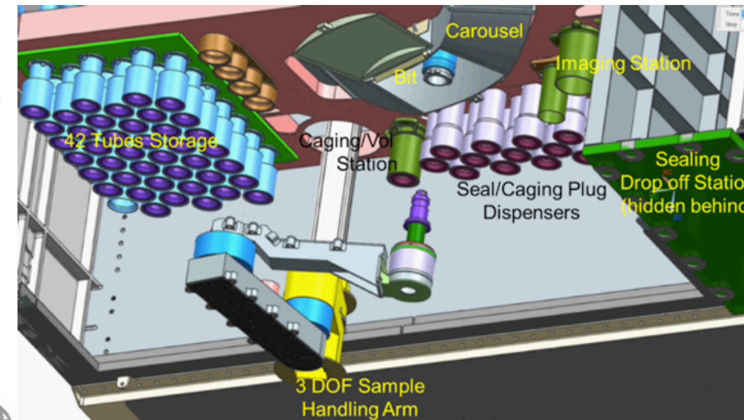
#	Topic	Text	Maps to
L1-14	NPR 8020.12D	The Mars 2020 Project shall comply with requirements for the outbound portion of a Planetary Protection Category V Restricted Earth Return mission as defined in **NPR 8020.12D** and as clarified in Section 6.8 of this PLRA.	PP L2 requirements
L1-15	Organic Carbon (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)

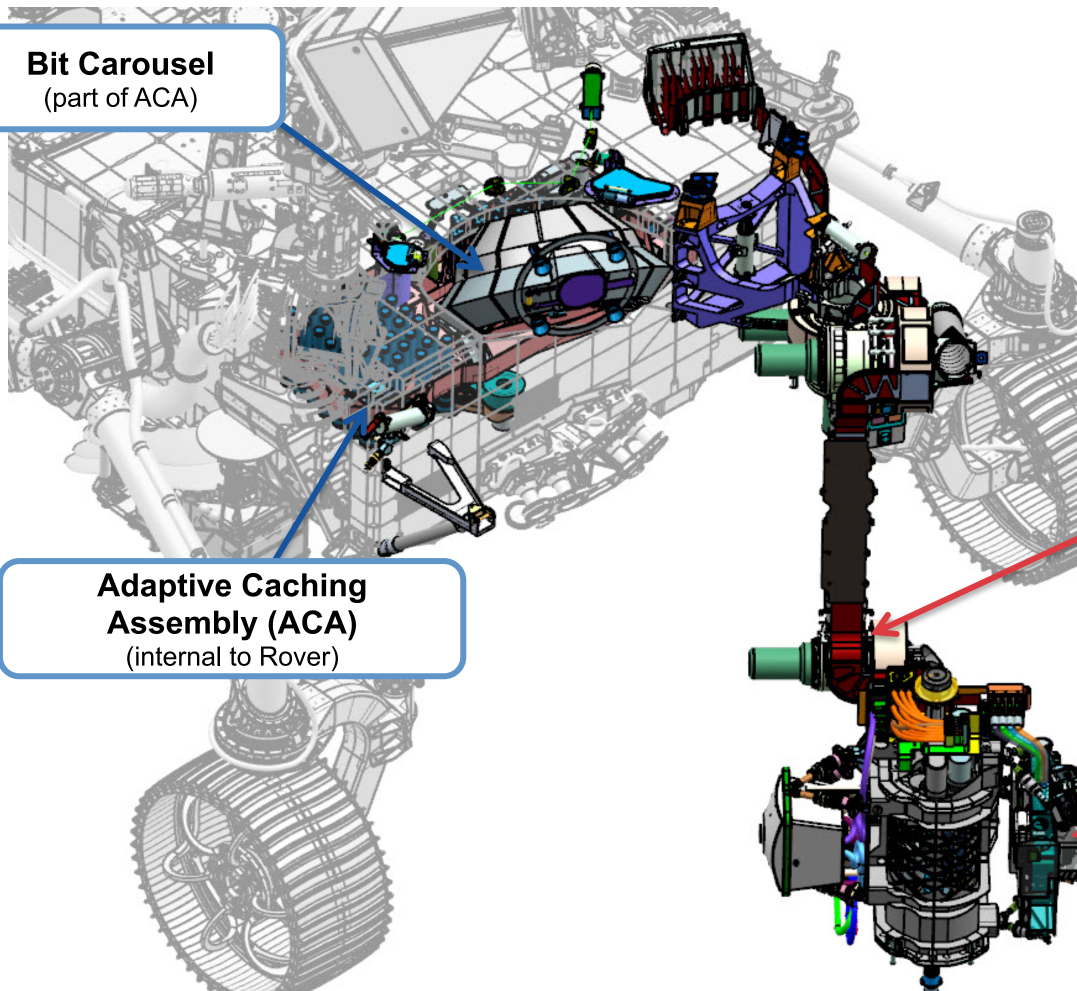
Sampling & Caching Subsystem (SCS)

Jet Propulsion Laboratory
California Institute of Technology

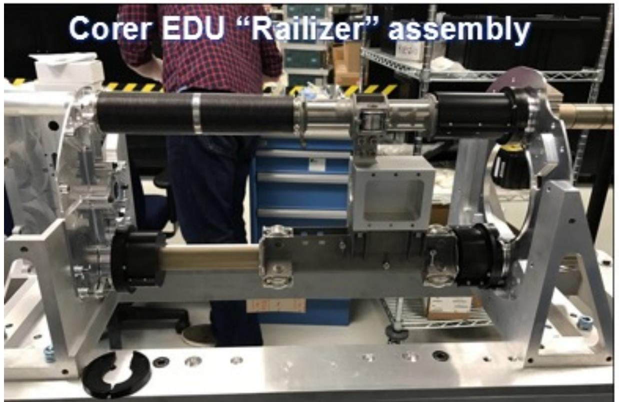
~ 42 sample tubes

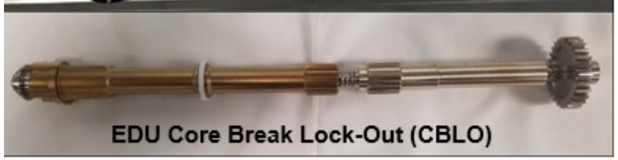


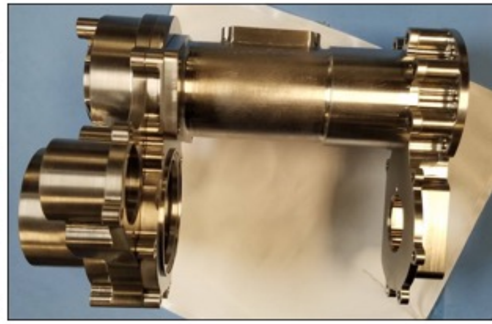
Caching Assembly



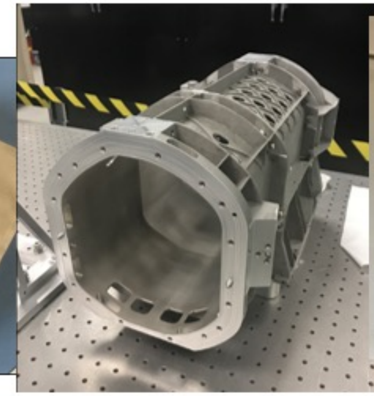
SCS



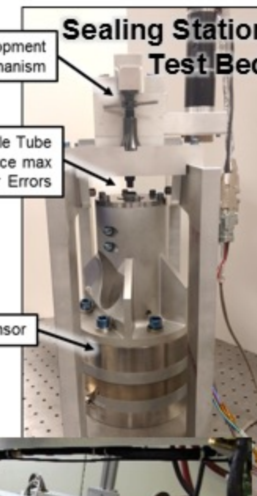


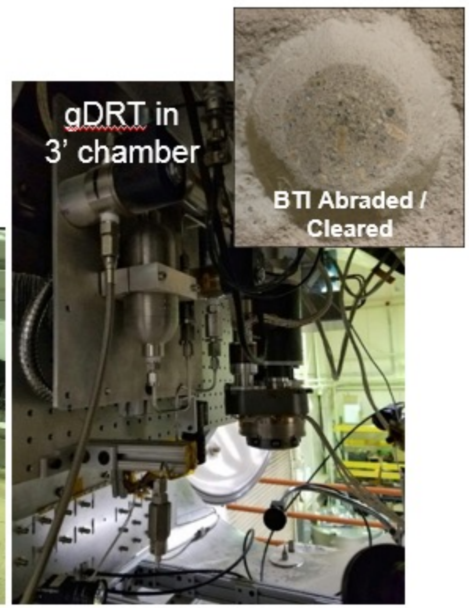


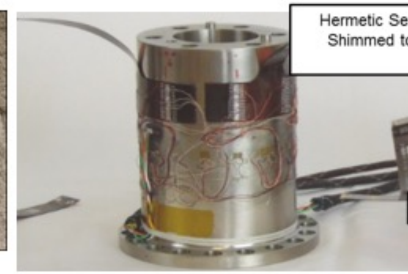
Corer EDU Spindle Twin-Input Gear (STIG) housing



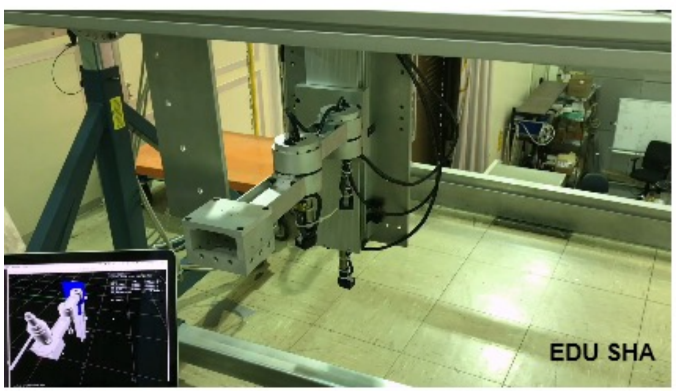
Corer EDU Feed Structure

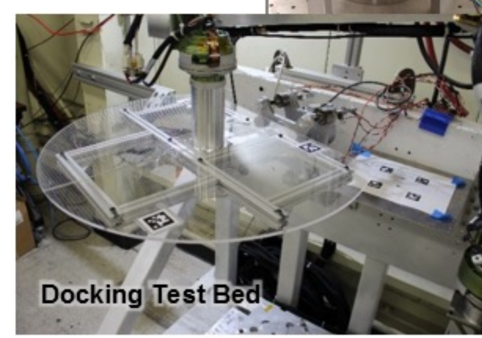






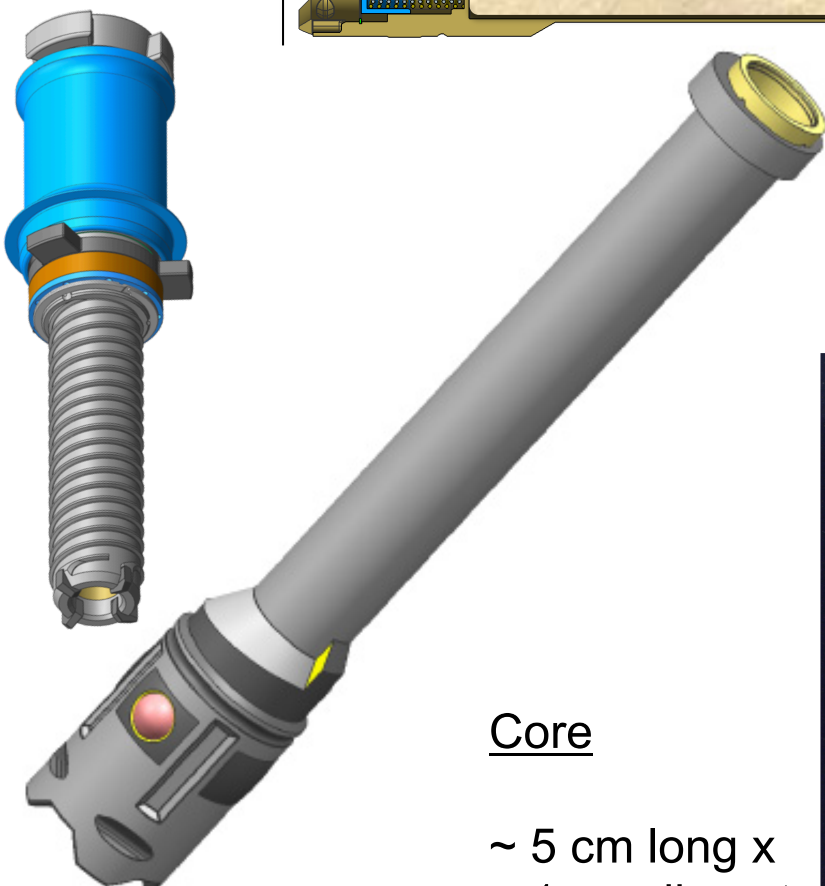
RA Development
6 DOF Force
Torque
Sensor



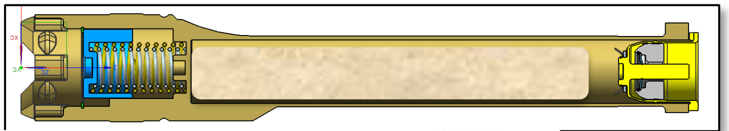


Coring and Sample Tube

Coring Bit

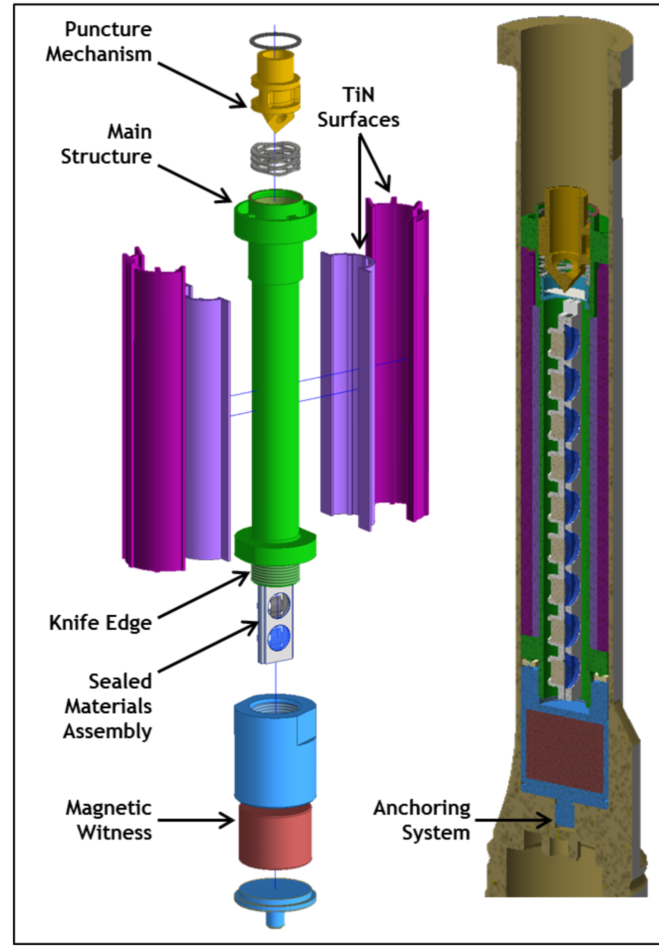


Hermetically sealed sample tube



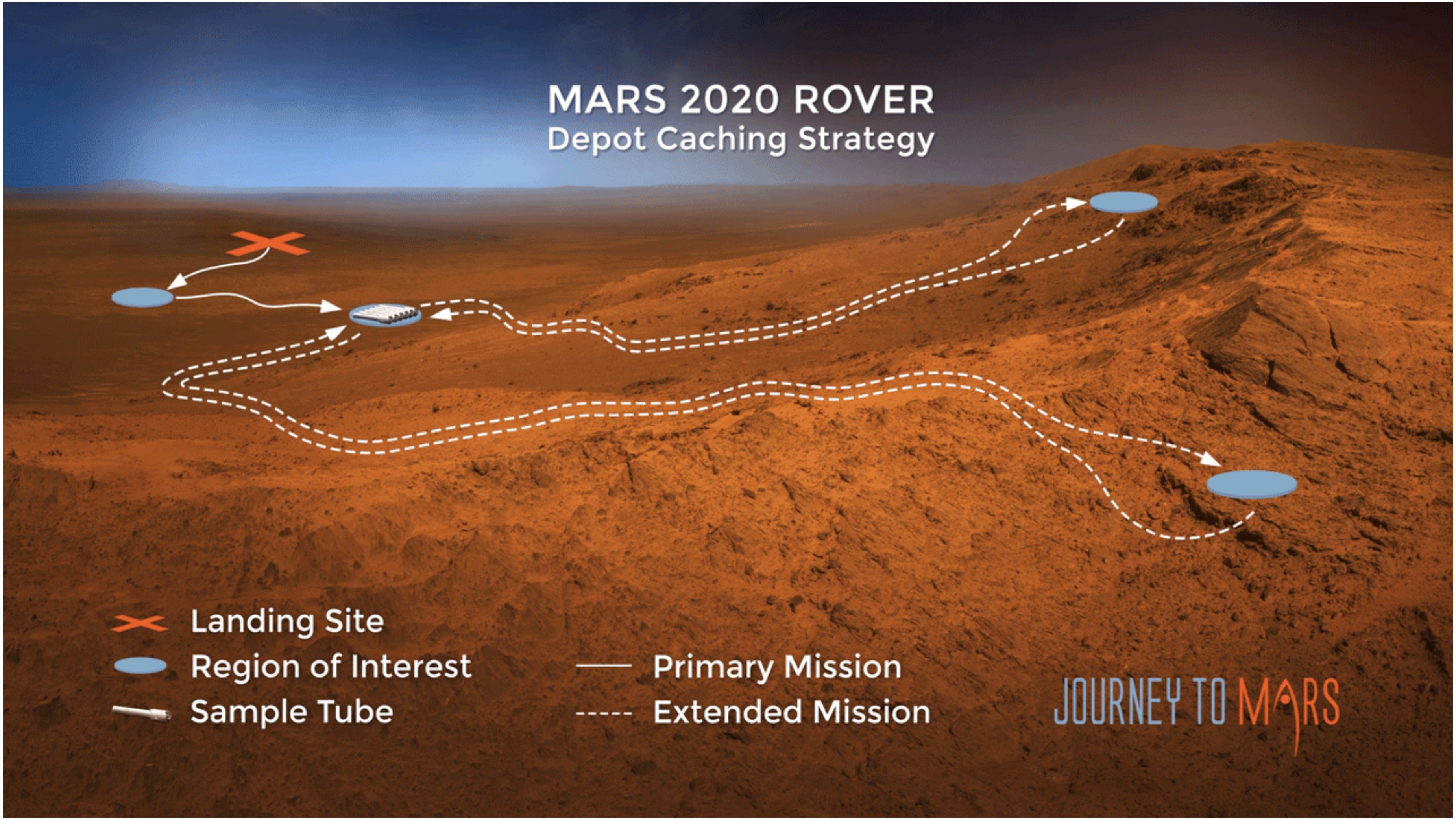
<u>Core</u>

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

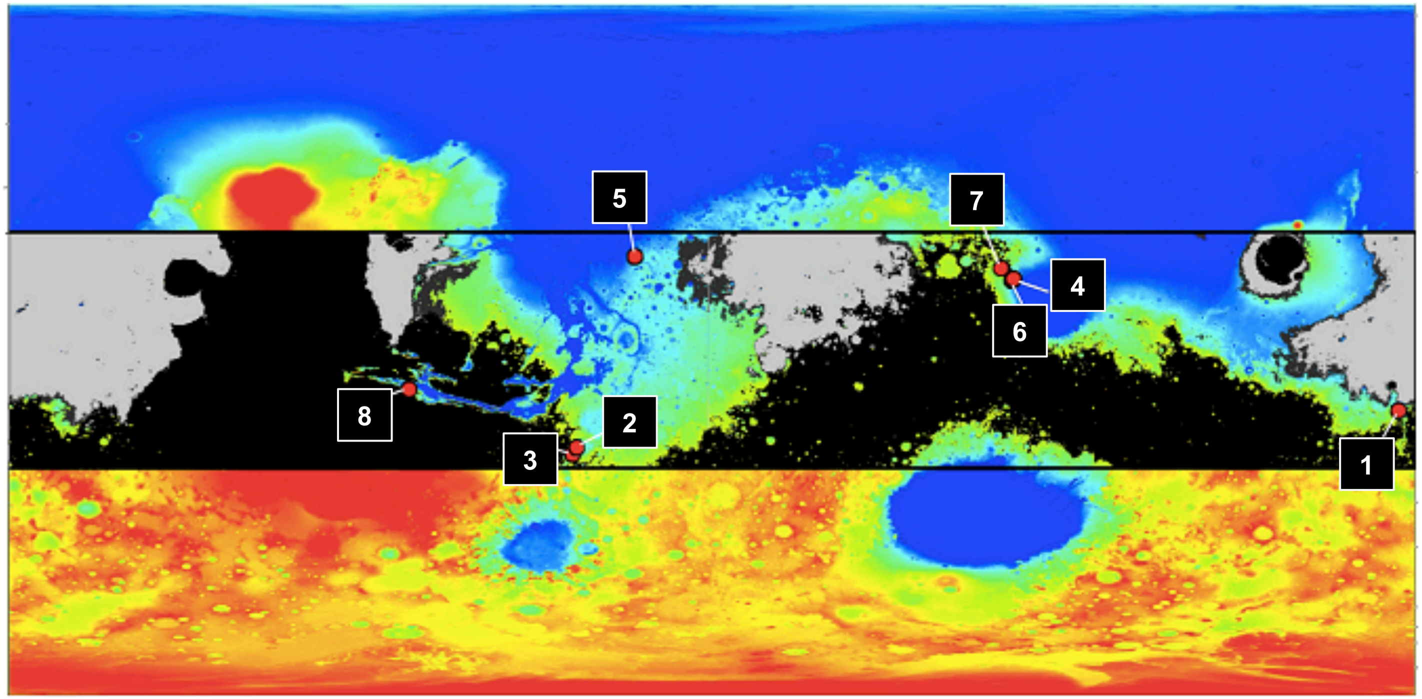


Witness tube assembly for round trip contamination characterization

Depot Caching



Where is Mars 2020 Landing?



Candidate landing sites
in alphabetical order

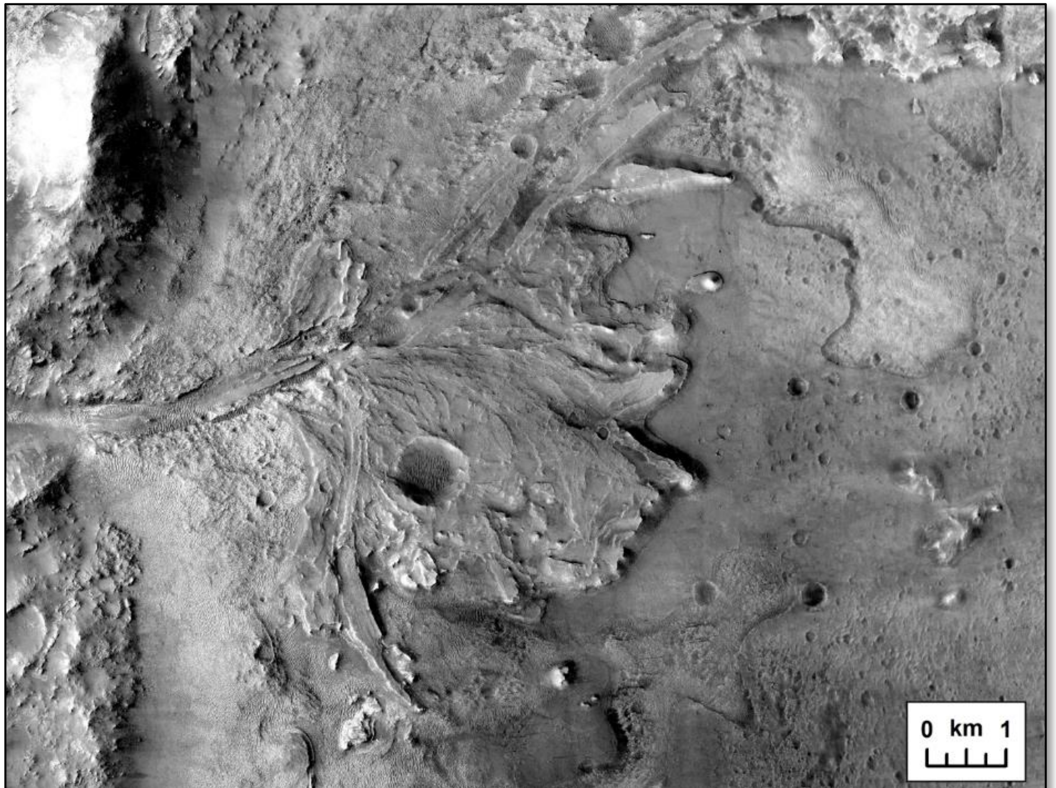
1. **Columbia Hills+**
2. Eberswalde*
3. Holden+
4. **Jezero***
5. Mawrth+
6. **NE Syrtis***
7. Nili Fossae+
8. SW Melas*

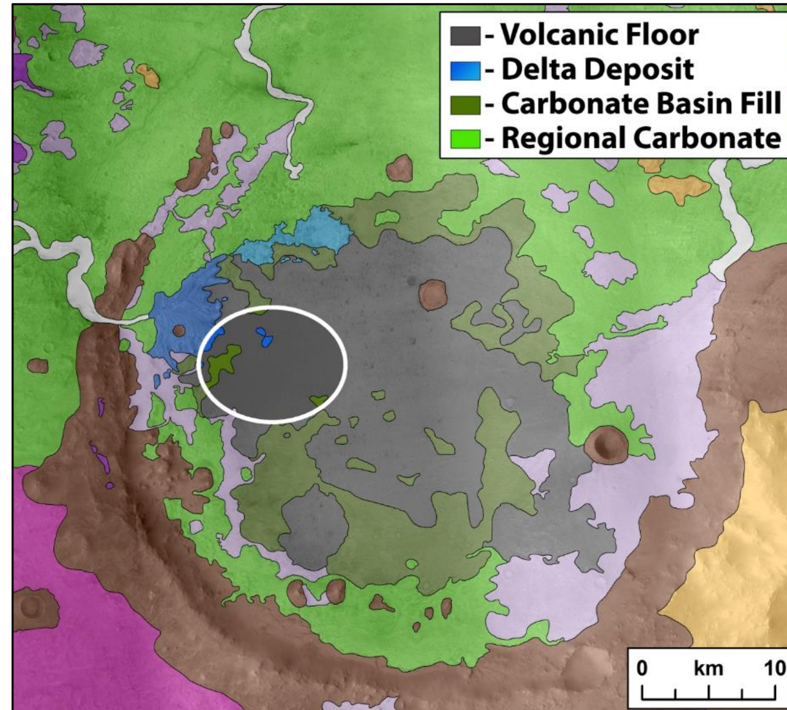
* TRN enables access
\+ TRN improves science

- 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” are not under consideration for exploration.

Landing Site Candidates

1. Jezero Crater

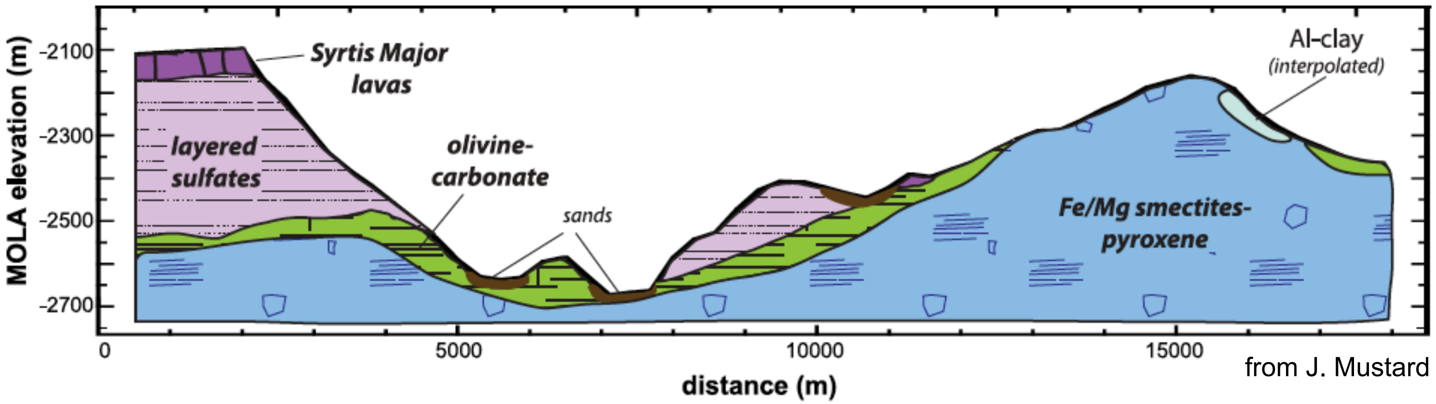




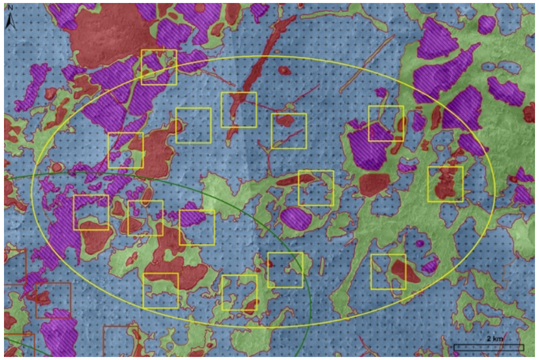
from T. Goudge presentation at LSW3

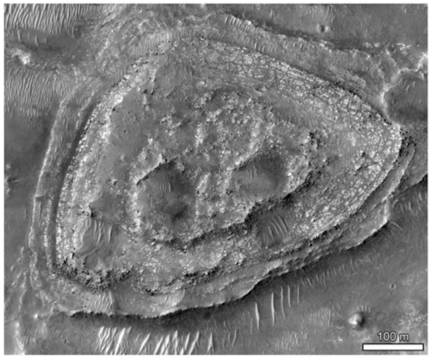
Possible habitable environment - An ancient crater lake

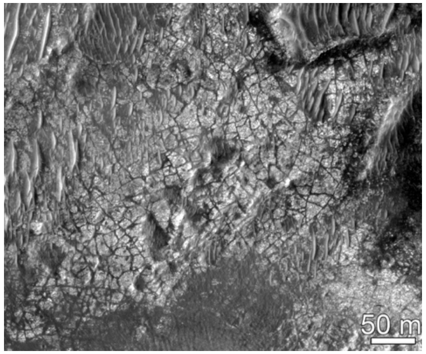
Landing Site Candidates
2. Northeast Syrtis



from J. Mustard and M. Bramble at LSW3

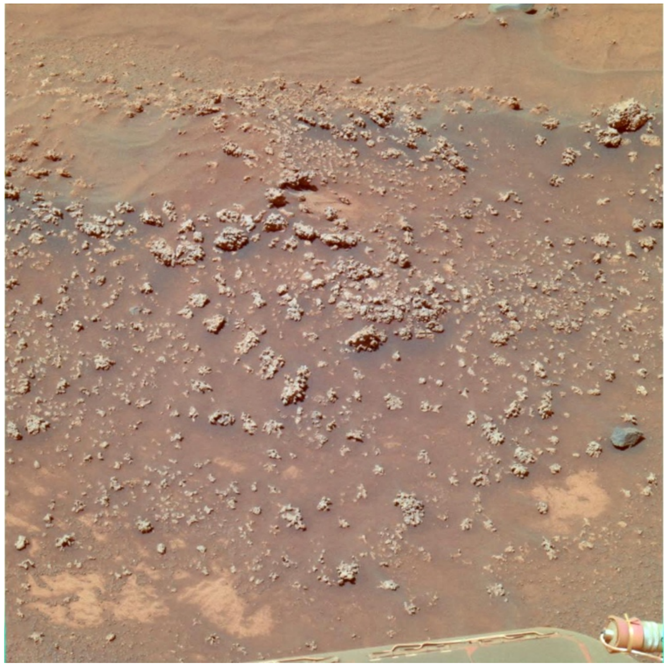






Possible habitable environment - groundwater circulating through warm or hot rock

Landing Site Candidates
3. Columbia Hills (Gusev)



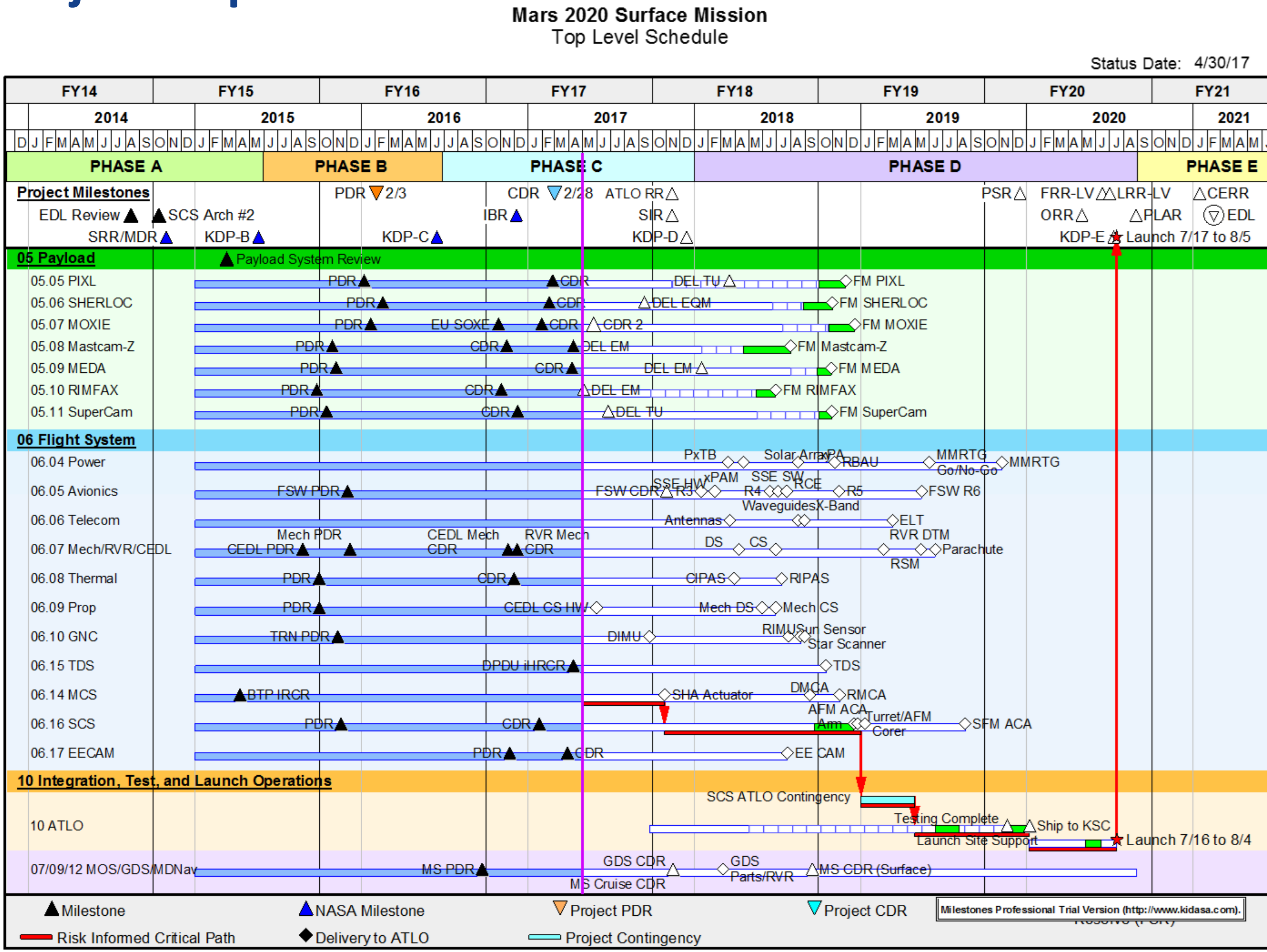
from presentations by S. Ruff and R. Arvidson at LSW3

Possible habitable environment - An ancient hot spring

Backup Material

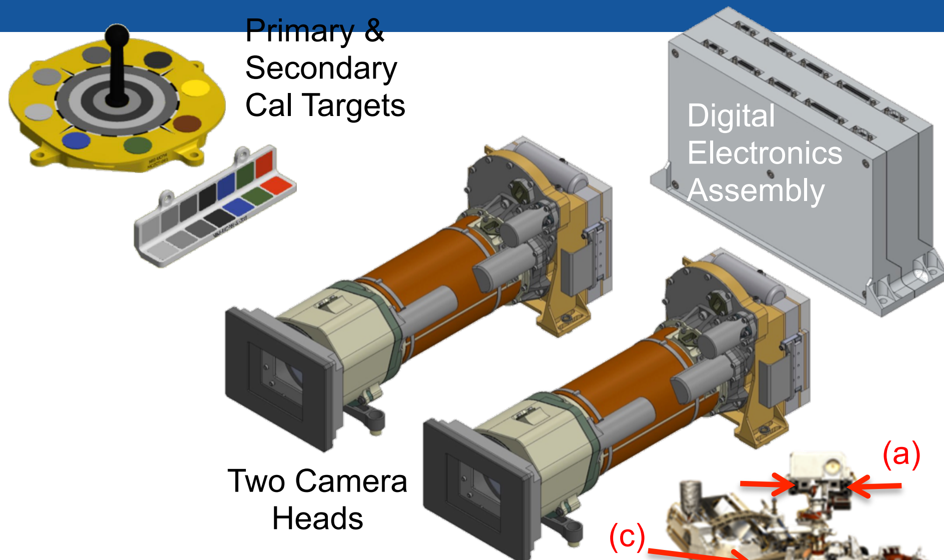
Project Top-Level Schedule

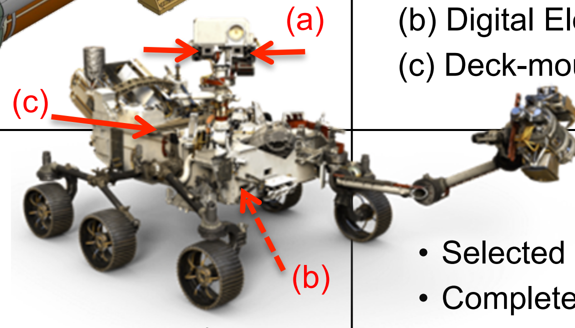
Jet Propulsion Laboratory
California Institute of Technology



Mastcam-Z Overview

https://mars.nasa.gov/mars2020/mission/instruments/mastcam-z/





INSTRUMENT DESCRIPTION:

(a) RSM-mounted zoom stereo camera pair:

- New optics, but electronics based on MSL Mastcam
- Focal length: 34-100 mm
- IFOV: 266 μrad/pixel to 74 μrad/pixel from 34-100 mm
- Wavelength range: 420-1000 nm, 11 narrowband filters, 2 ND filters for solar imaging, RGB Bayer-pattern filter
- Stereoscopic: 0.5 mm range accuracy @ 2.1m
- Detector: Kodak KAI-2020CM CCD with 1648x1200 pixels

(b) Digital Electronics Assembly box housed inside the rover

(c) Deck-mounted primary and secondary calibration targets

INVESTIGATION TEAM:

- PI: **Jim Bell** (ASU)
- DPI: **Justin Maki** (JPL)
- Inv. PM: **Greg Mehall** (ASU)
- Industry Partner: MSSS (**Mike Ravine**, Inst. PM)
- Science Team: 21 Co-Is, 6 Working Groups
- E/PO collaboration with The Planetary Society

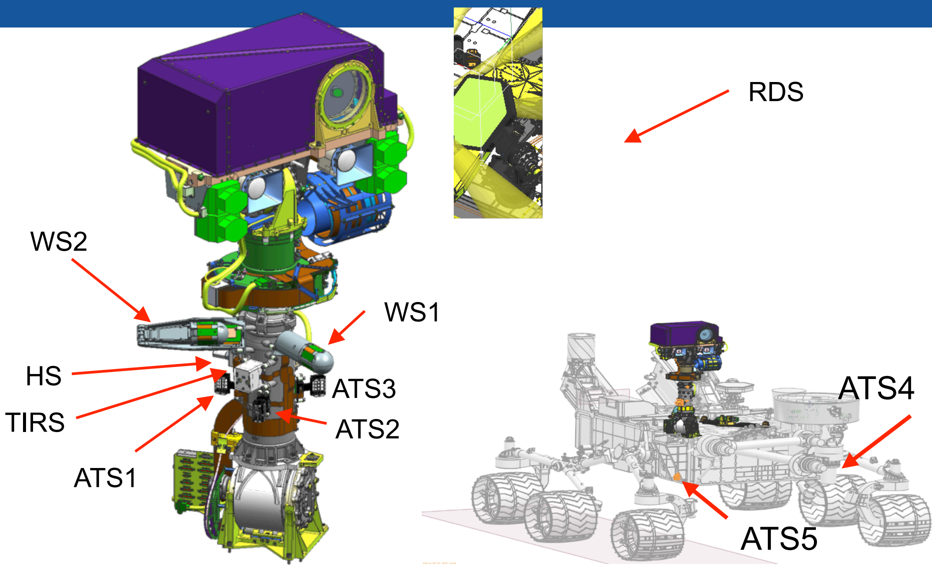
SCIENCE DISCRIPTIONS:

1. Characterize geomorphology and processes
2. Assess current atmospheric and astronomical conditions & events
3. Provide operational support and scientific context

STATUS

- Selected in July 2014
- Completed IPDR on 29 Oct. 2015
- Completed ICDR on 15 Nov. 2016
- Final opto-mechanical design is completed and fabrication is now under way!
- Short motor procurement delay due to gear issues
- Testbed Units delivered to JPL: mid-April 2017
- EQM build underway; testing will begin in Aug. 2017
- Science calibration scheduled for mid-2018
- FM delivery to JPL scheduled for July 2018

MEDA Overview



INSTRUMENT DESCRIPTION:

- Upgraded sensor package and electronics unit serve as follow-on to REMS
  - ICU and PS on RAMP
  - Wind sensor booms at 120º from each other, 170 mm and 220 mm (deploys to ~400 mm) in length on RSM
  - Five ATSs (3 on RSM, 2 on rover body)
  - Thermal IR Sensor (TIRS) on RSM
  - Humidity Sensor (HS)
  - Radiation and Dust Sensor, including a SkyCam to image the sky to infer the dust properties, on rover deck
  - , on rover deck
- Various power states can meet needs of all sol types

INVESTIGATION TEAM:

- PI – Jose Rodriguez-Manfredi (CAB, Spain)
- DPI – Manuel de la Torre (JPL)
- IPM – Roser Urqui (CAB)
- Industry Partners: CRISA, INTA, Finnish Meteorological Institute (FMI), AVS

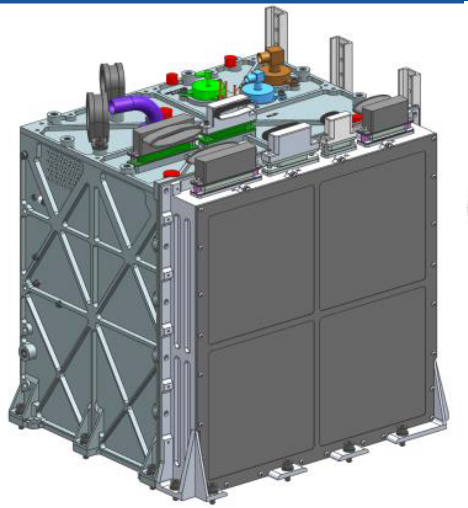
SCIENCE DESCRIPTION

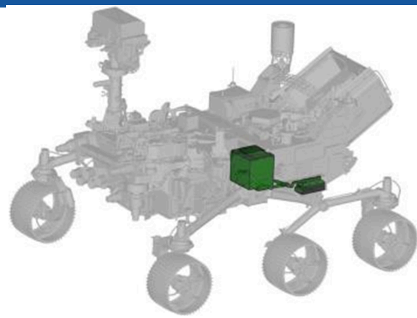
- Characterization of pressure, humidity, wind speed and direction, and the thermal and solar radiation cycles.
- Characterization of dust size and morphology, including dust scattering and absorption properties
  - Can monitor changes in optical depth, particle size distribution, and interaction with the solar radiation.

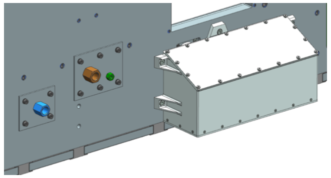
STATUS

- Signed MOU between NASA HQ and MINECO + MINETUR + CDTI + INTA: Funding resolutions and resources in Europe provisioned for the next 2 years.
- Passed Interface Risk Assessment (IRA) in Feb and CDR in April with no major issues raised.
- Tight schedule is the main concern.
- EM ICU/ASIC/WS, QM RDS & HS development & FM ATS, SkyCam optics & PS manufacturing have started
- Validation and PQV testing proceeding as planned for ATS, TIRS, HS, RDS, and WS2
- Vibe & Shock tests run on most sensors.

MOXIE Overview







INSTRUMENT DESCRIPTION:

- Solid Oxide Electrolysis (SOXE) Stack
  - CO_2 decomposed to CO and $O^=$ in cathode
  - $O^=$ ions transported through solid electrolyte
  - Operates at 800°C
- SOXE Assembly
  - SOXE Packaging, thermal control, compression
- CO_2 Acquisition and Compression (CAC)
  - Scroll Compressor – Mars atmosphere @ 1 bar
- Mechanical & Flow Control
  - Filters, lines, fittings, pressure regulation
- Process Monitor and Control
  - Sensors for experiment analysis and process control
- Electronics – Power, Command, Control & Telemetry

INVESTIGATION TEAM:

- PI – Michael Hecht (MIT)
- DPI – Jeffrey Hoffman (MIT)
- IPM – Jeff Mellstrom (JPL)
- Industry Partners:
  - Ceramatec (SOXE)
  - Air Squared (Compressor)

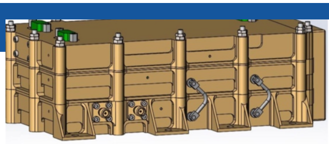
SCIENCE DESCRIPTION:

- Demonstration of In-Situ Resource Utilization (ISRU) technologies to enable propellant and consumable oxygen production from the Martian atmosphere for future exploration missions.

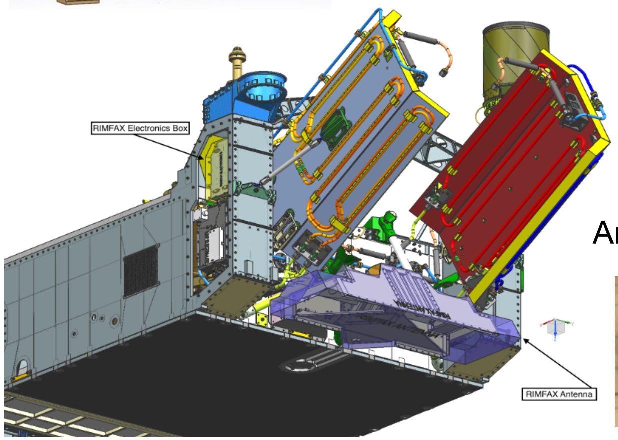
STATUS

- Increased mass allocation (17.8 kg), due to scope transfer
- Excellent SOXE performance, throughput and reliability
- Scroll Compressor prototype in test & meeting requirements
- COTS Sensor suite selected & in qualification process.
- Technical Resource margins meet Design Principles
- Key technical issues:
  - Electronics development underestimated and significantly behind schedule
  - SOXE Assembly – Insulation & heater mechanical, making good progress, initial tests with flight-like packaging has commenced.
- Programmatics: Additional funds required [$5–7M]

RIMFAX Overview



Electronics Unit



Antenna

INSTRUMENT DESCRIPTION:

- Ground-penetrating gated FMCW radar, operating from 150 MHz to 1.2 GHz
- Bow-Tie Slot Antenna underneath MMRTG
- Electronics box in aft tower, above ElectraLites (UHF radio)
- 3 modes collected simultaneously every 10 cm:
  - Surface Mode (700 MHz center frequency)
  - Shallow Mode (700 MHz center frequency)
  - Deep Mode (400 MHz center frequency)

INVESTIGATION TEAM:

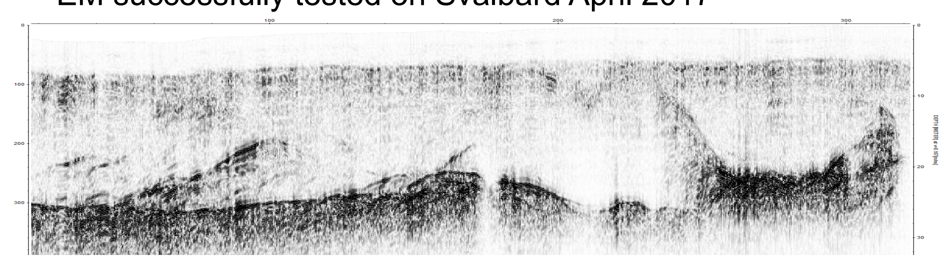
- PI – Svein-Erik Hamran (FFI, Norway)
- DPI – David Paige (UCLA)
- IPM – Leif Damsgård (FFI)
- Science Team: 7 CO-Is and 3 Collaborators
- Major Partners: Norspace (Norway), Comrod (Norway)

SCIENCE DESCRIPTION:

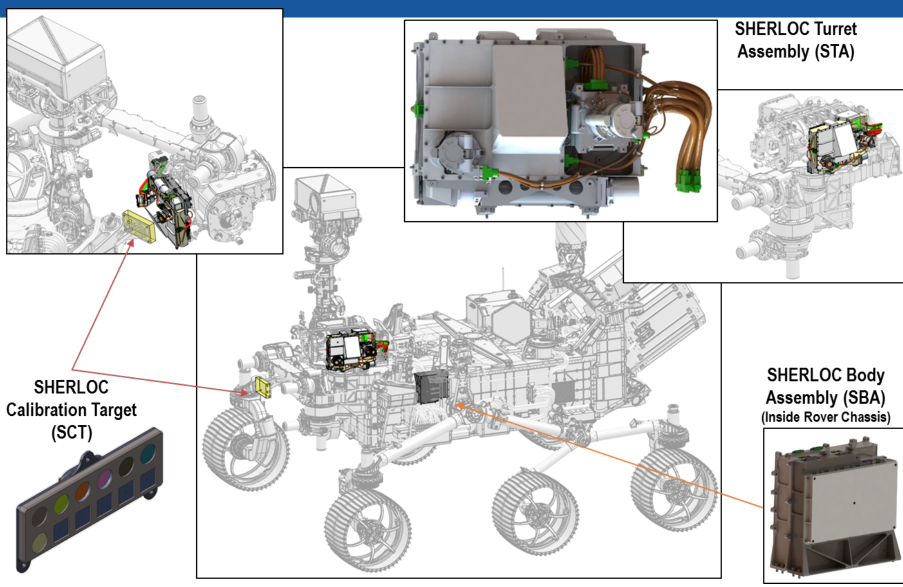
- Transmits radar signal and determines layering in subsurface from the echo.
- Can distinguish layers to at least 10 m deep with 30 cm resolution in Mars analog soil

STATUS

- Completed CDR and majority of RFAs completed
- Mechanical, electrical, FSW interfaces agreed to with Flight System
- TU delivered to Testbed in May 2017
- Completed one PQV tests successfully of Antenna Matching Network PCB and is working on E. Box Board to Board Connectors
- EM successfully tested on Svalbard April 2017



SHERLOC Overview



INSTRUMENT DESCRIPTION:

On Turret:

- Laser Raman and Fluorescence spectrometer
  - Deep UV 248.6 nm laser
  - Asphere-Sphere Spectrometer (252-373 nm range)
  - e2v CCD with 512 x 2048 pixels
- Internal Fast Steering Mirror
- Autofocus and Context Imager
  - Monochromatic imager
  - Kodak KAI 2020 1200x1600 pixel CCD
- Phase Change Material Heat Sink for CCD
- Microscopic Color imager
  - Full MAHLI heritage

In WEB and on Rover Body:

- C&DH (WEB)
- Calibration target (Rover Body)

INVESTIGATION TEAM:

- PI – Luther Beegle (JPL)
- DPI – Rohit Bhartia (JPL)
- IPM – Ed Miller (JPL)
- Industry Partners: Malian Space Science (Imaging and ACI), LANL (C&DH), Photon Systems (Laser) and Left Hand Design (Scanner mirror)

SCIENCE DESCRIPTION:

- *Detects* and *classifies* organics and astrobiologically relevant minerals on the surface and near subsurface of Mars.
- Microscopic scientific imaging for textures, color and context for the other measurements.

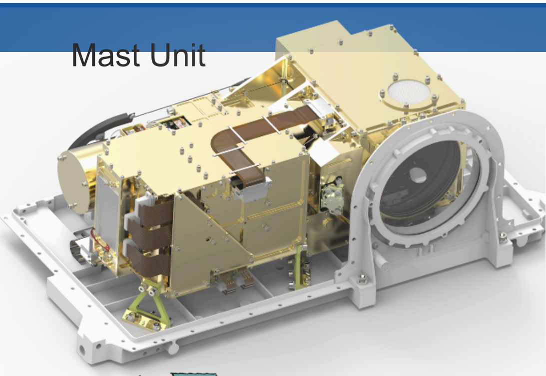
STATUS

- Flight like laser has been tested and demonstrated.
  - Expecting first flight lasers middle of July.
- Testing of LANL designed and built C&DH has occurred
  - Demonstrated interface between the Rover computer and the MSSS built DEA.
- Key technical issues:
  - Development of the Laser Power Supply has lagged system development and is now the critical path.
  - Getting the scanning mirror on contract has been an issue.
  - Continue vigilance of contamination control issues.
- Uncertain calibration target dimensions due to addition of drillable blank.

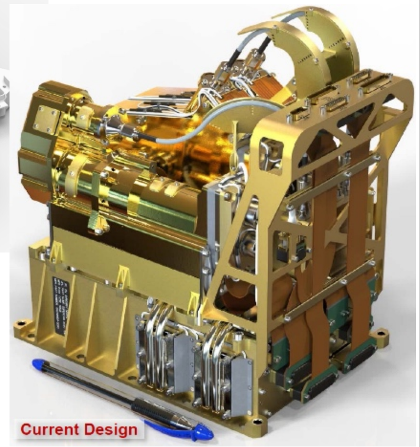
SuperCam Overview

Jet Propulsion Laboratory
California Institute of Technology

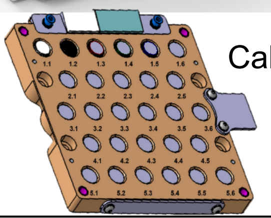
Mast Unit



Body Unit



Cal Target



INSTRUMENT DESCRIPTION:

Mast-mounted telescope, laser, IR spec., micro. and color imager.

Body-mounted Raman and visible/NIR band spectrometers

- LIBS (1.5 m – 7 m range)
  - < 550 µm spot size, 15 mJ max on target, 1064 nm, 3 Hz laser
  245 – 853 nm band, 0.15 – 0.65 nm resolution, >100 SNR @ 7 m
- Raman – Fluorescence (1.5 m – 12 m range)
  - 532 nm, 3-11 mJ on target, 1k shot burst @ 10 Hz laser
  - 150 – 4400 cm^{-1} band, < 12 cm^{-1} resolution >64 SNR on olivine
- VISIR Reflectance Spectrometry (1.4 m – 10 km range)
  - 400 – 853 nm band, 0.6 nm resolution, ~10 ms / acq, > 60 SNR @ 800 nm
  - 1.3 – 2.6 µm band, 30 cm^{-1} resolution, ~80 sec / acq, > 60 SNR @ 2.6 µm
- Color Imaging (> 1.4 m)
  - 19 mrad FOV, standard RGB color filtering
- Microphone
  - 100 Hz – 10 kHz. Standalone (3.5 min rec. max) and LIBS modes

INVESTIGATION TEAM:

- PI: Roger Wiens (LANL)
- DPI: Sylvestre Maurice (IRAP)
- Inv. PM: Scott Robinson (LANL); Philippe Caïs (IRAP)
- Science Team Co-Is: 9 US, 8 French, 2 Spanish

SCIENCE INVESTIGATION:

- Rapid, synergistic, fine-scale mineralogy, chemistry, and color imaging at remote distances after removing obscuring surface dust.
- Co-aligned Raman-fluorescence, visible/infrared reflectance, laser-induced breakdown spectroscopy (LIBS), and microphone, with color imaging for context.

STATUS:

- EDU end-to-end tests from May 2016 to May 2017
- Demonstrated microphone audio signal by testing in a Martian-environment chamber (Jan 2017)
- EQM : Design, layout completed. Parts ordered and most received. Full integration by Nov. 2017
- Cal. targets fabricated. Being chemically characterized. Passed vibe and shocks.
- FM : some hardware already manufactured and received. EEE ordered, should arrive in June 2017.