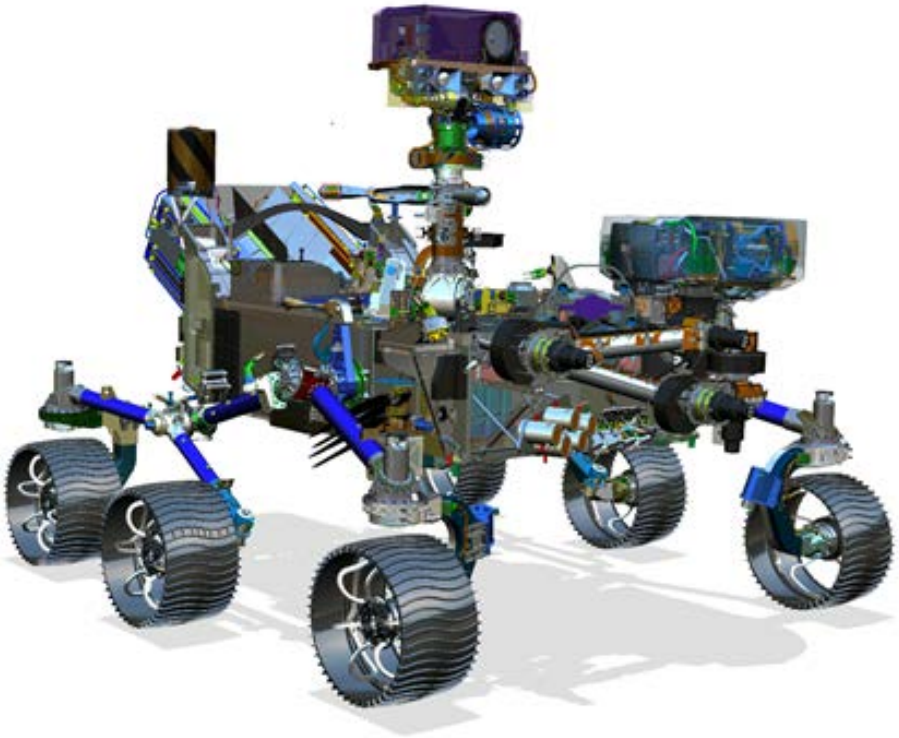
Jet Propulsion Laboratory
California Institute of Technology

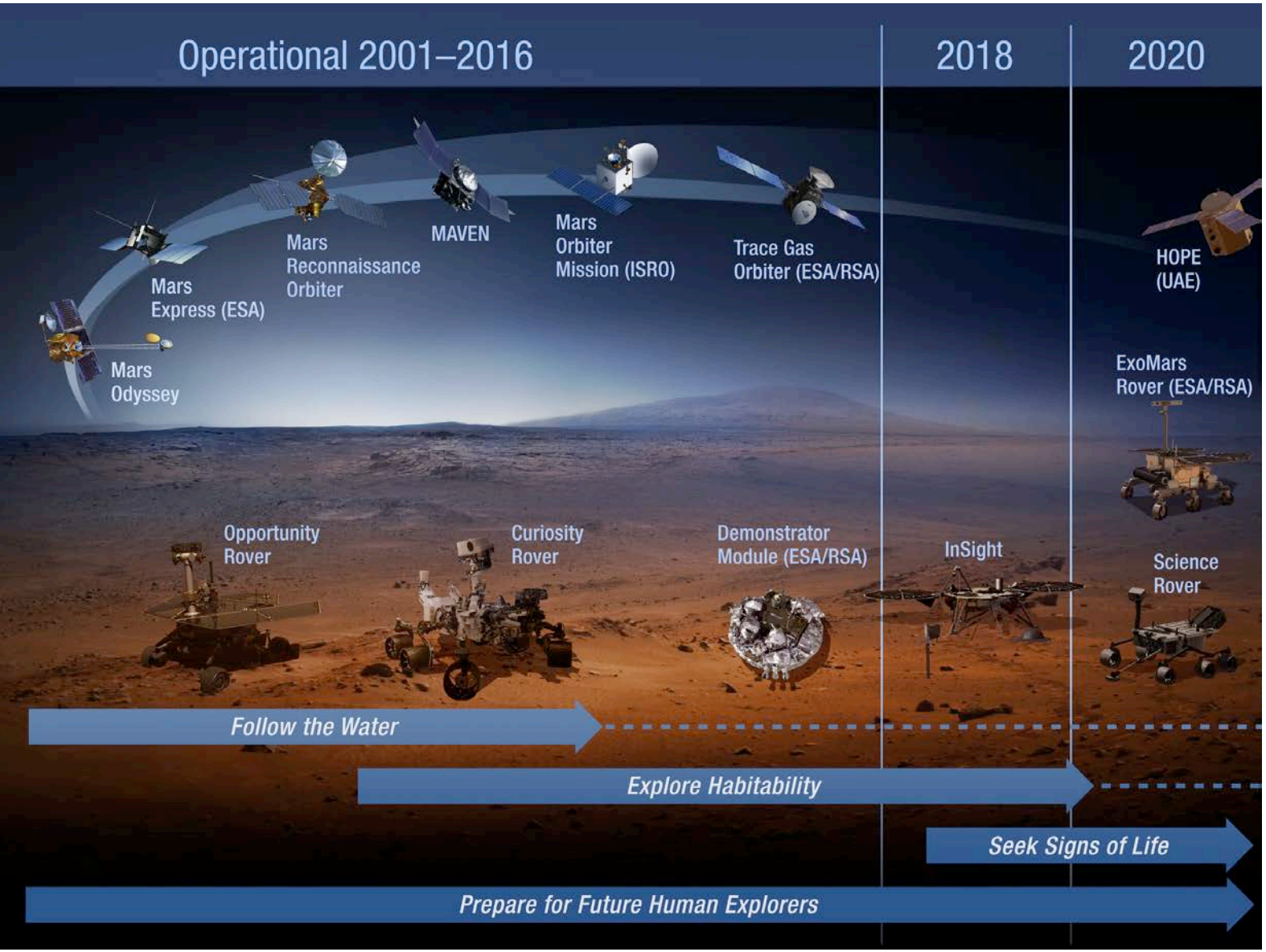
Mars 2020 Interagency Nuclear Safety Review Panel



John McNamee
Mars 2020 Project Manager

September 7, 2016

Mars Exploration in This Decade

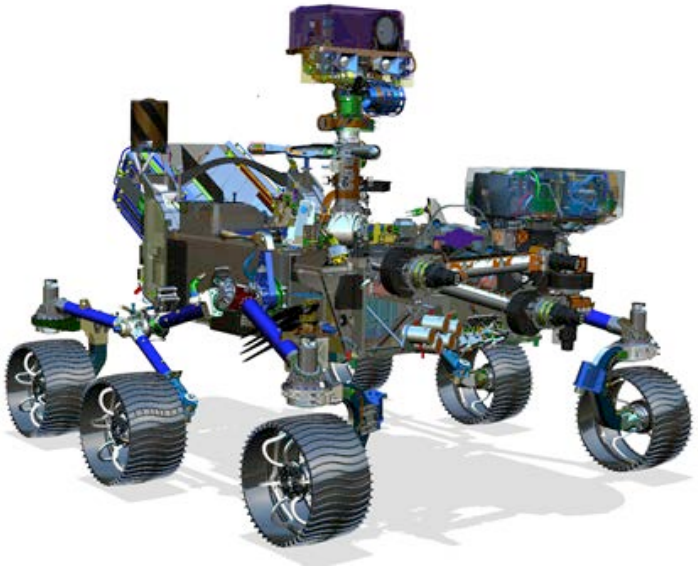


Mars 2020 mission builds on the legacy of NASA's Mars Exploration Program, addressing the highest priority science of preparing samples for possible return to Earth

Project Overview

Salient Features

- *Category: 1*
- *Risk Class: A-tailored*
- *Directed, JPL in-house implementation*
- *High heritage MSL design*
- *Modifications only as necessary to accommodate new payload and Sampling / Caching System (SCS)*
- *Planetary Protection Category V Restricted Earth Return per Level 1 Requirements*



Science

- *Assess past habitability of an astrobiologically relevant ancient environment on Mars*
- *Assess biosignature preservation potential with the environment and search for biosignatures*
- *Assemble cached samples for possible future return to Earth*

Technology

- *Advance technologies with applications to future human and robotic explorations objectives*

Mars 2020 Organization

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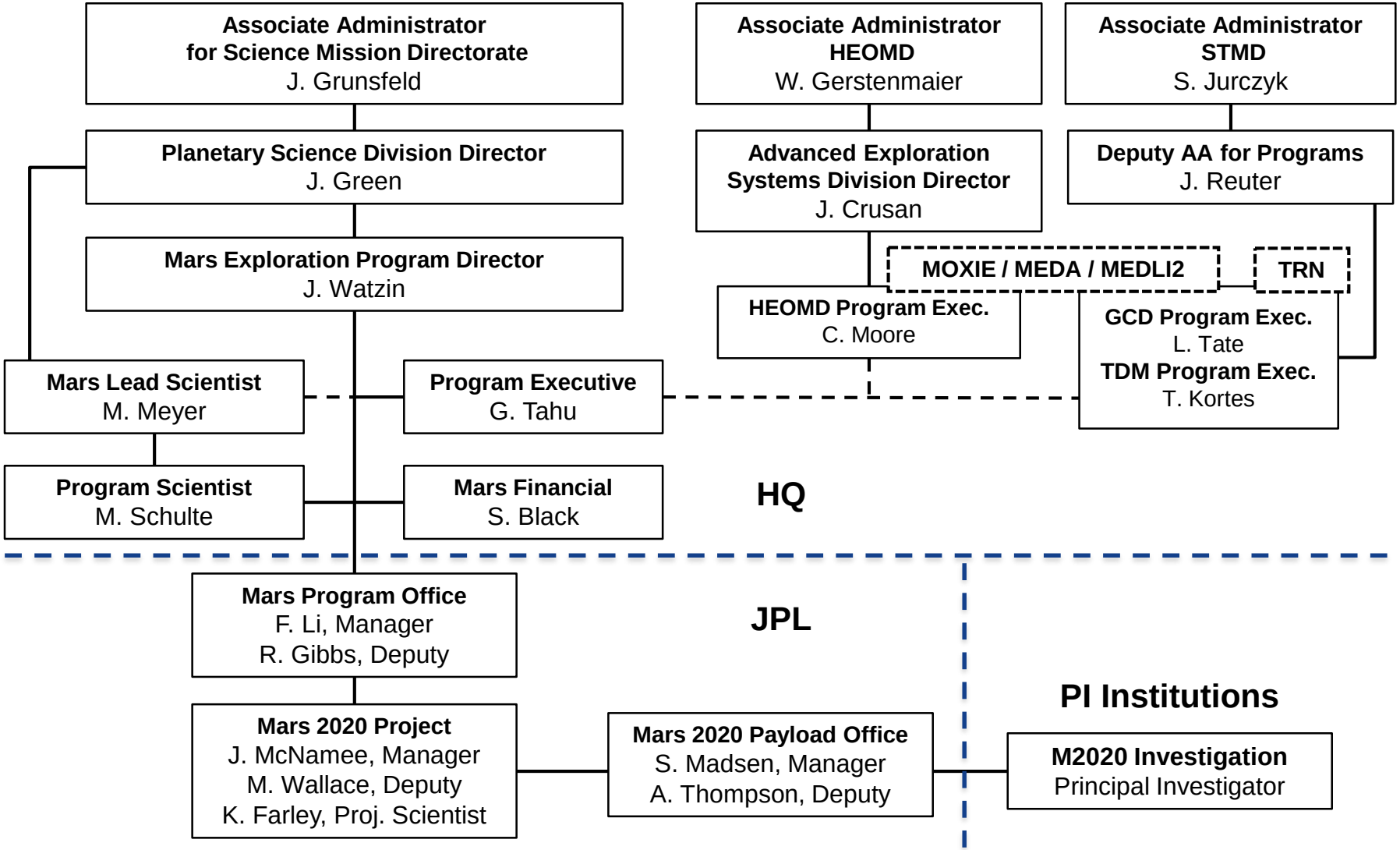
California Institute of Technology
Mars 2020 Project



Major Accomplishments Since KDP-B

- Completed Heritage Flight System review in September 2015. Early acquisition and builds of heritage elements and items with low risk of change are proceeding at a fast pace.
- Completed Sampling & Caching System architecture, preliminary design, and baselined adaptive caching approach
- MOXIE team developed new implementation plan in response to Tiger Team effort
- Concluded international agreements with France for SuperCam mast unit, Spain for high gain antenna and SuperCam calibration target, and Norway for RIMFAX instrument Phase B-F
- Formalized agreement with HEOMD/STMD for contribution of MEDLI-2. Established partnership with STMD to infuse Terrain Relative Navigation (TRN) capability into the mission.
- Conducted 2nd Landing Site Workshop in August 2015; ongoing imaging and analysis for top sites
- Established Returned Sample Science Board
- Preliminary Design Review completed 4 February 2016
- Pre KDP-C JPL Center Management Council completed 24 February 2016
- Pre KDP-C Science Mission Directorate Program Management Council completed 30 March 2016

Mars 2020 Science

Mars 2020 Mission Objectives

- **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

Scientific Overview

Although we rely on a heritage approach to the vehicle,
Mars 2020 is a new and distinct type of planetary mission.

We will use our payload to explore a new region of Mars,
and to support the selection of samples that, *if successfully returned to Earth,*
would provide material for generations of planetary scientists.

For previous Mars rover mission (e.g. Curiosity), *sampling results support the scientific exploration objectives*.

For Mars 2020, the first step towards a possible Mars sample return,
scientific exploration results support sample caching.

Mars 2020 Payload Family Picture

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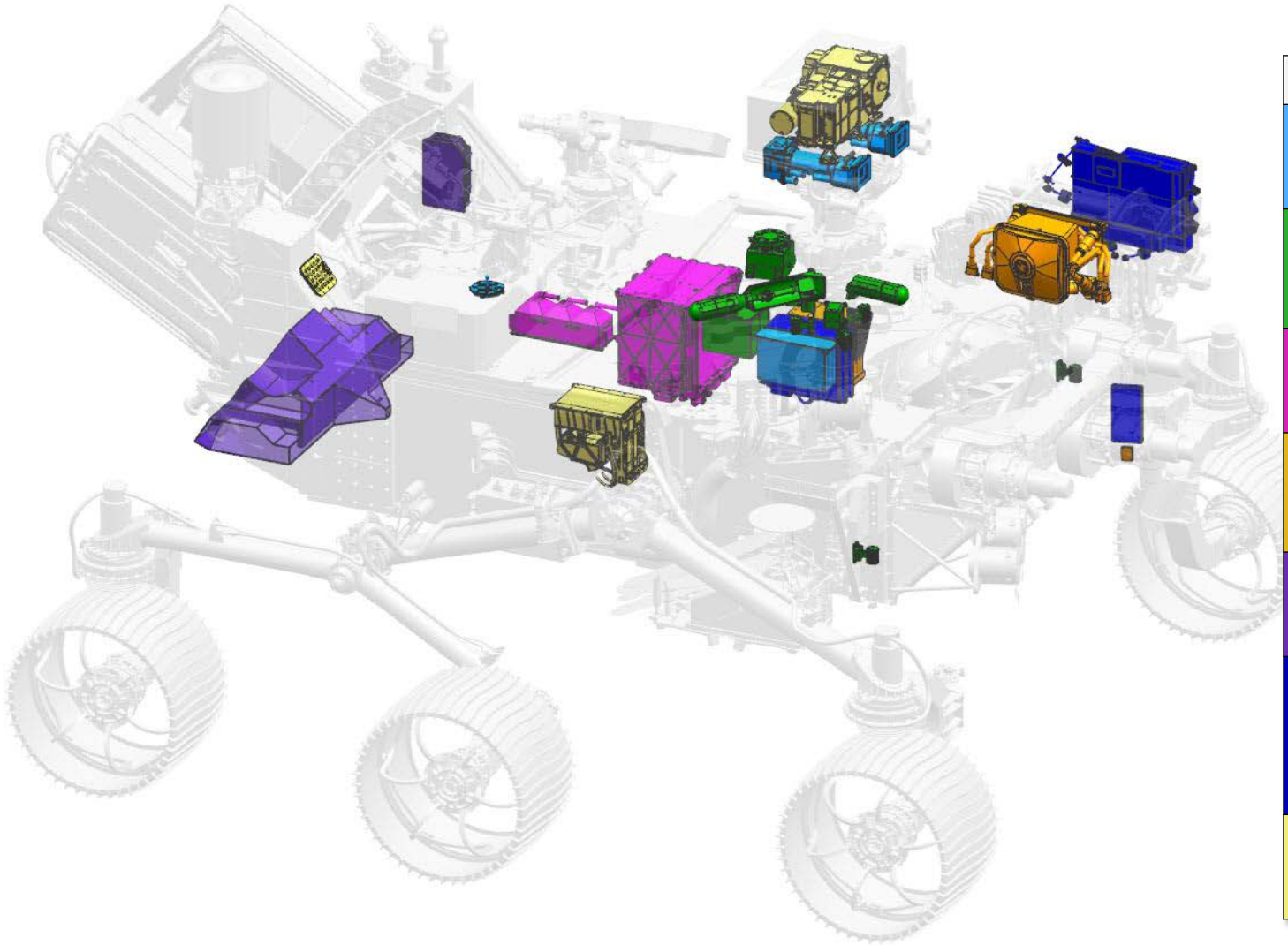
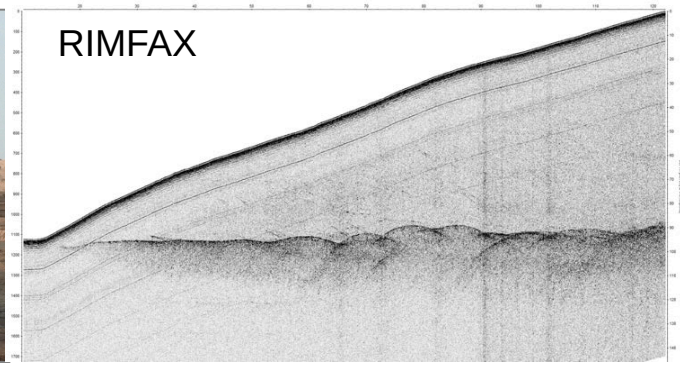
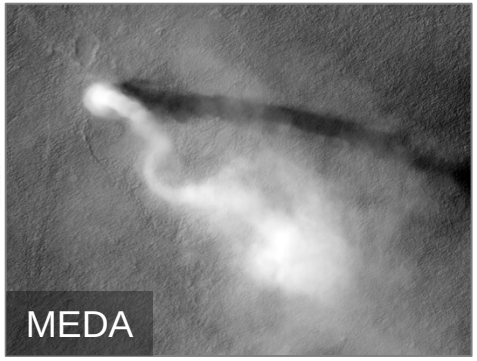


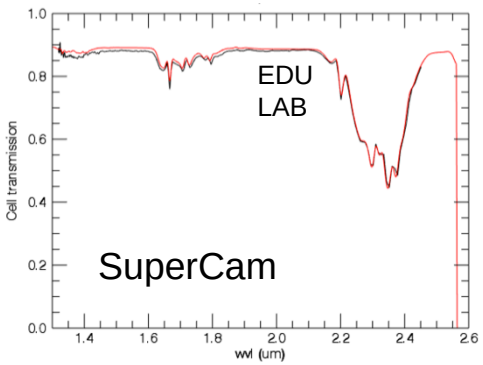
Instrument Key
Mastcam-Z Stereo Imager
MEDA Mars Environmental Measurement
MOXIE In-Situ Oxygen Production
PIXL Microfocus X-ray fluorescence spectrometer
RIMFAX Ground Penetrating Radar
SHERLOC Fluorescence and Raman spectrometer and Visible context imaging
SuperCam LIBS and Raman

Scientific Exploration Model

Develop the geologic and astrobiologic context of an ancient martian environment using observations made at a range of spatial scales, culminating in a search for potential biosignatures. Use the emerging model of deposition and alteration to guide the collection of samples that maximize opportunities to understand Mars as a planetary system and determine whether it was once inhabited.

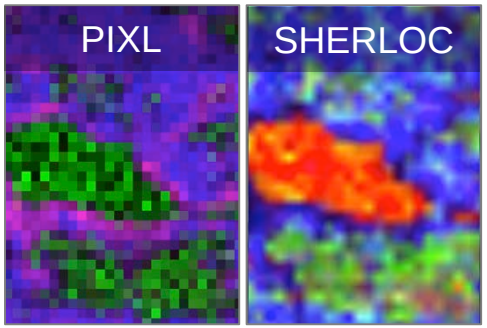






remote chemistry / mineralogy

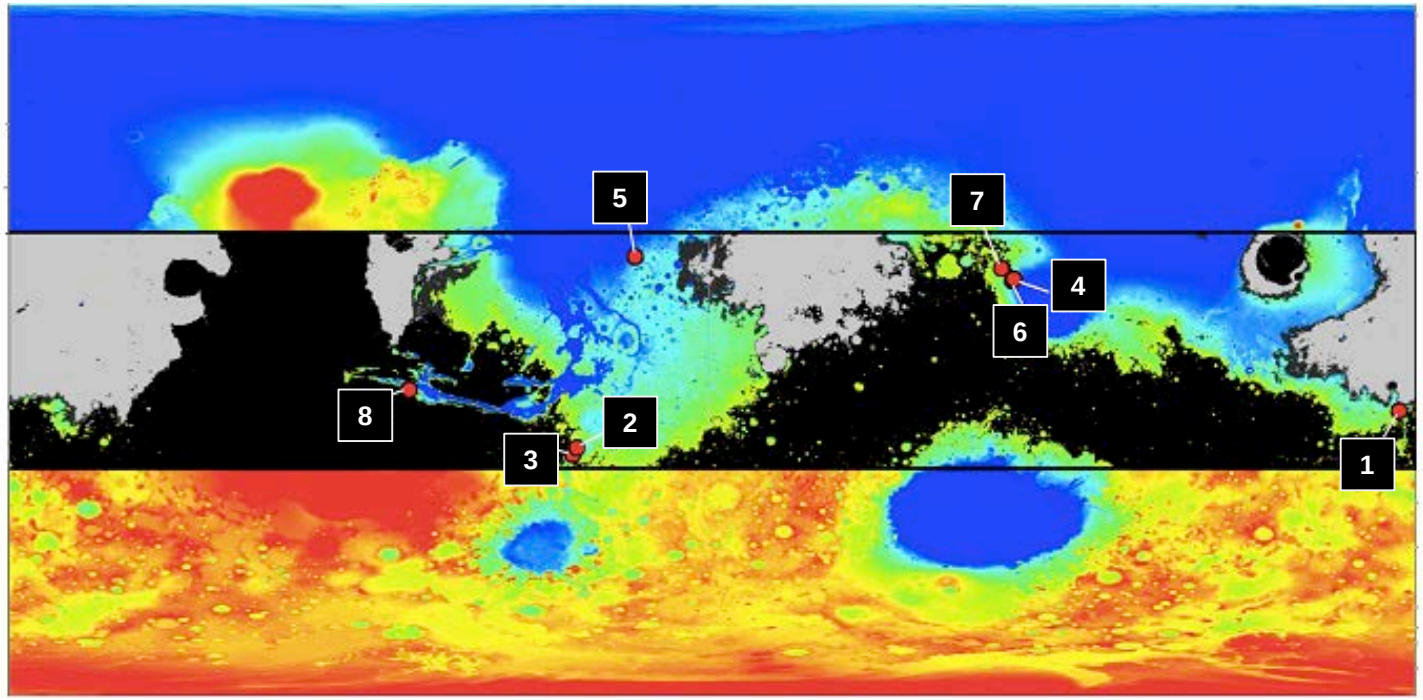
proximity imaging



proximity chemical / mineral mapping

sampling and borehole science

Where Are We Going?



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

- Eight landing sites are currently under consideration; depositional models range from deltaic/lacustrine to hydrothermal. 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.

Project Overview

Mission Overview

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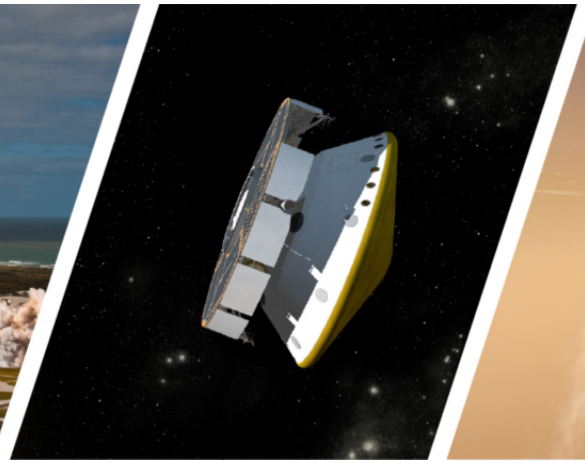

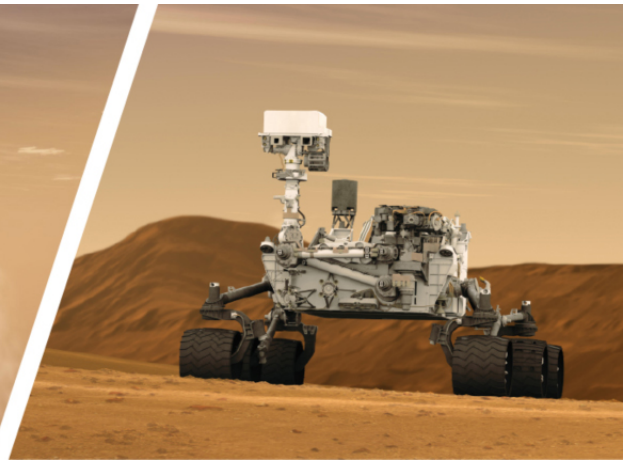

LAUNCH

- MSL Class / Capability LV
- Period: July / August 2020

CRUISE/APPROACH

- 7.5 month cruise
- Arrive Feb 2021

ENTRY, DESCENT & LANDING

- MSL EDL system (Range Trigger and TRN baselined): 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

Project Top Level Schedule

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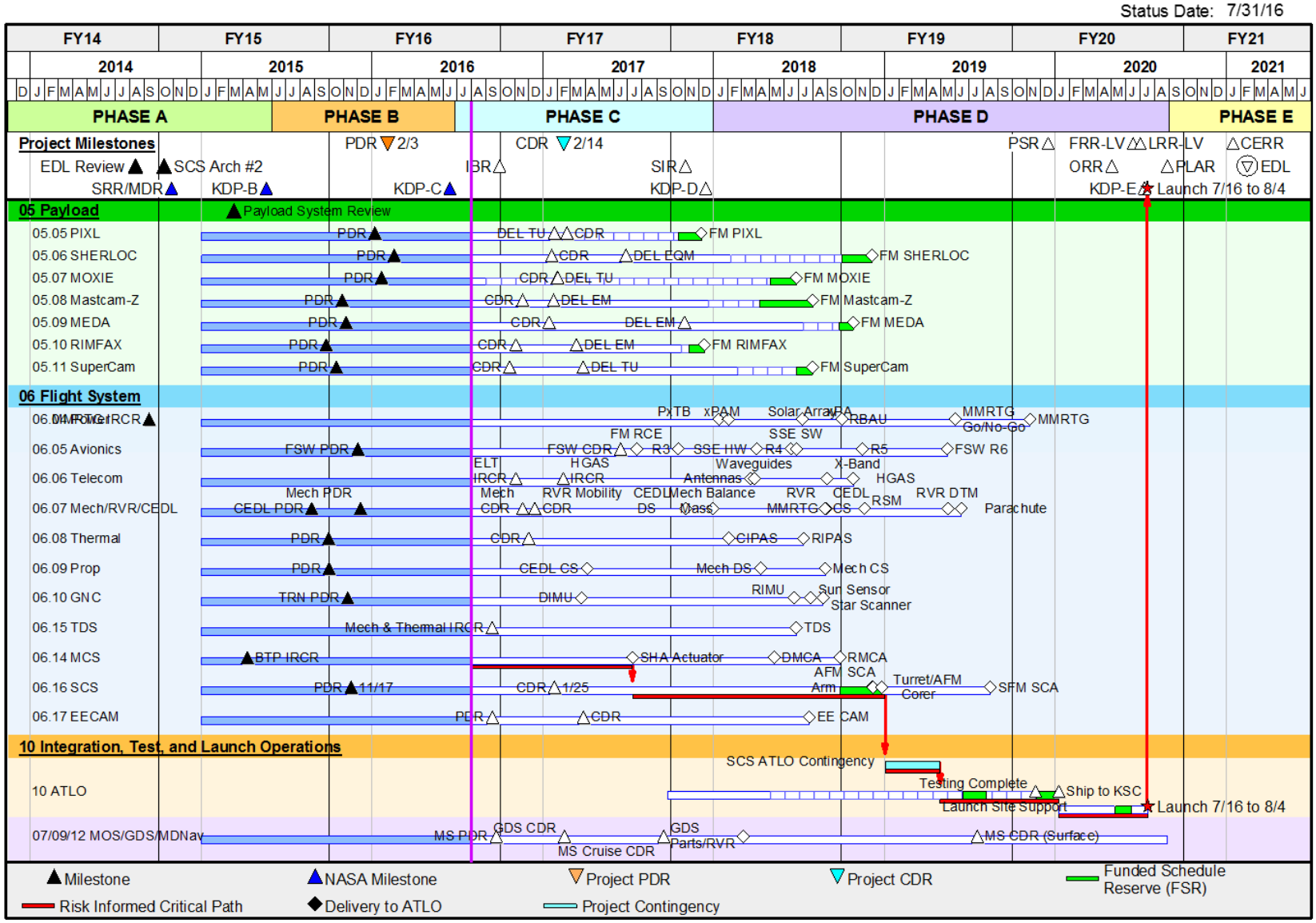
Mars 2020 Project

2016 • Interagency Nuclear Safety Review Panel

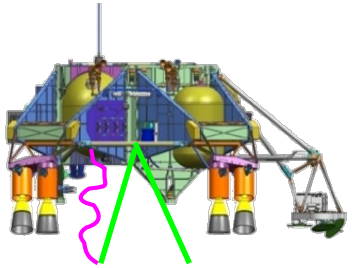


Spacecraft Build Approach

Launch Vehicle
- KSC/Launch Services Program procurement

- Built in-house at JPL
- Lowest cost and risk per make-buy study and industry RFIs

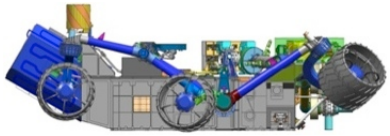
- Built by Lockheed-Martin/Denver
- Procure as sole source—most cost effective



- Built in-house at JPL
- Major industry subcontracts/components
- Rebuild in-house due to criticality of EDL and rover interface

MMRTG
- DoE procurement to industry

Science & Exploration Technology Investigations
- Source per proposals via AO selection

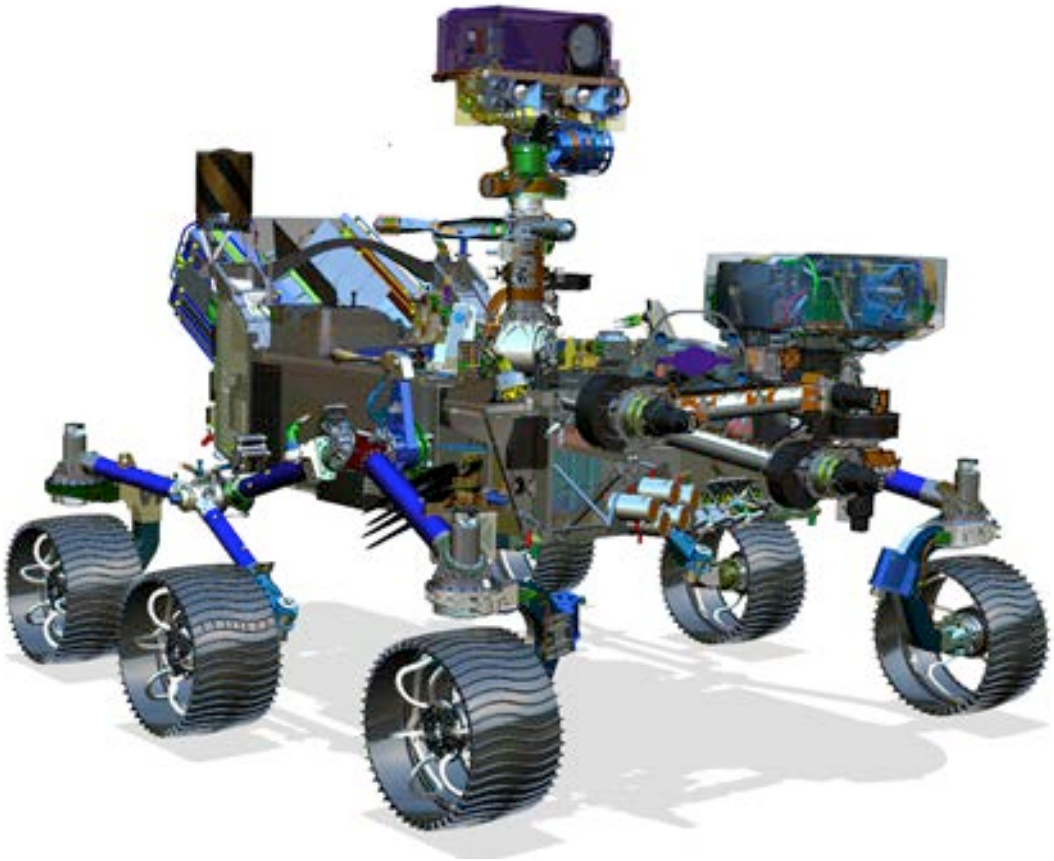


- Built in-house at JPL
- Major industry subcontracts/components
- Spanish contributed High Gain Antenna
- Rebuild in-house due to complexity of vehicle, residual hardware, criticality of EDL and rover interface, operations experience

MEDLI2
- NASA Centers (LaRC, ARC, and JPL)

- Built by Lockheed-Martin/Denver
- Procure as sole source—most cost effective

Mars 2020 Rover Concept



Stays the Same as MSL

- Avionics
- Power
- GN&C
- Telecom
- Thermal
- Mobility

Changed

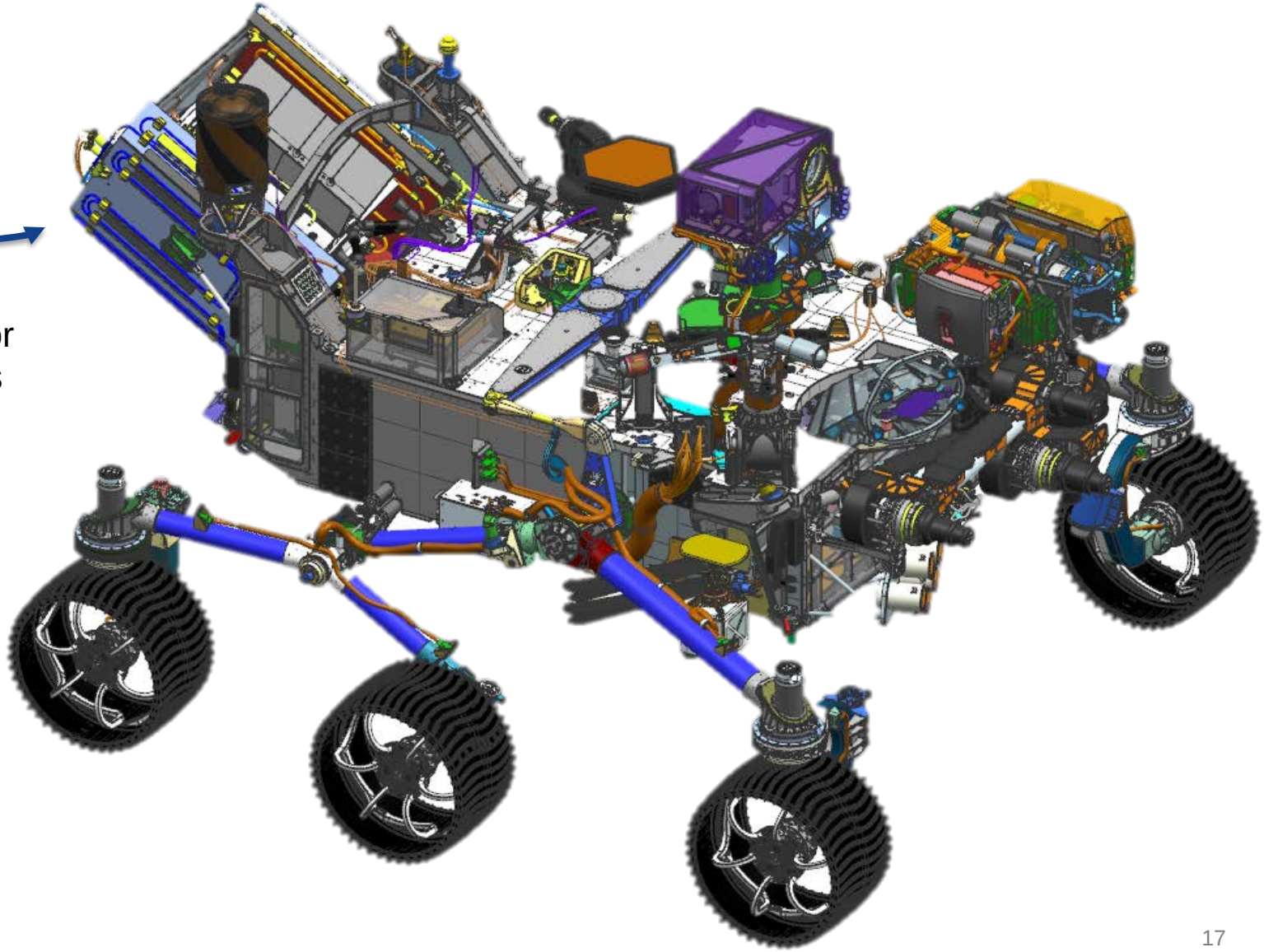
- New Science Instrument Suite
- New Sampling Caching System
- Modified Chassis
- Modified Rover Harness
- Modified Surface FSW
- Modified Rover Motor Controller
- Modified Wheels

Expected to Change

- Some Mobility components (to support wheel and/or Rover mass)

Mars 2020 Rover Concept

Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) provides heat and electricity for rover operations



Multi-Mission Radioisotope Thermoelectric Generator (MMRTG)

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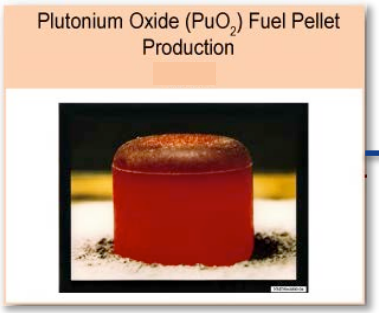
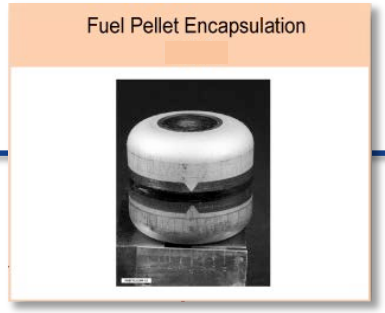
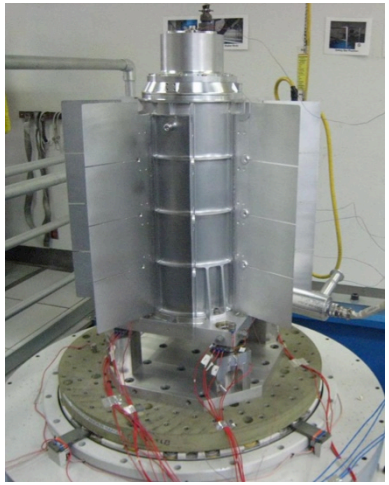
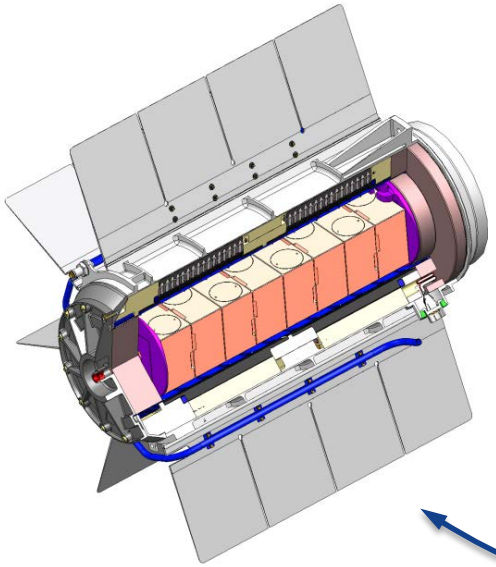
- Produces 2000 W thermal of heat; 110 W electricity at beginning of mission
- Fueled by 10.6 lbs. (4.8 kg) PuO_2 protected within 8 GPHS modules

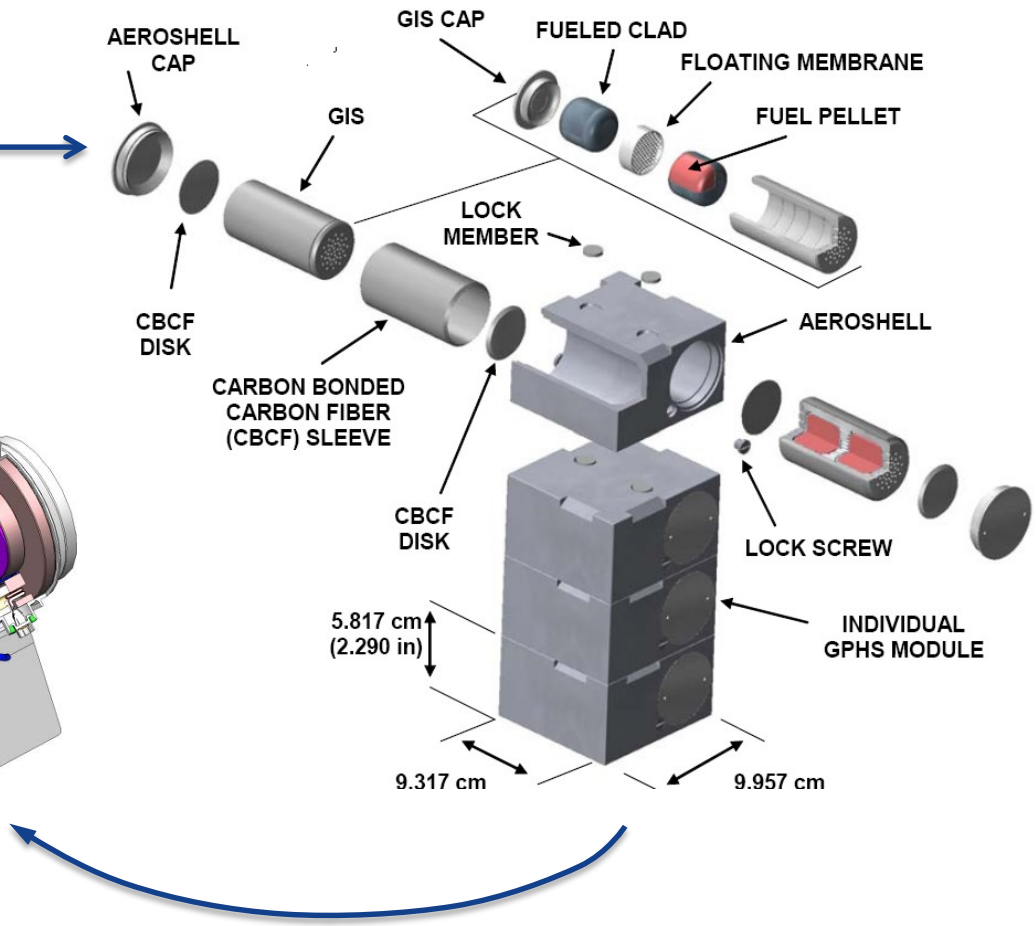






Flight Units 2 & 3 in storage for Mars 2020 (F2 shown)



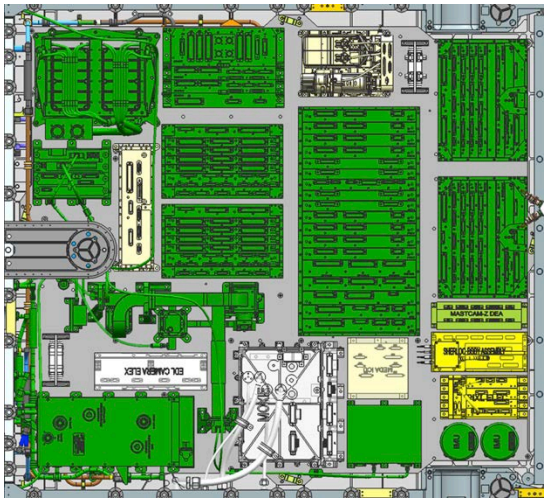


Heritage Policy / Implementation

- The Project took an early strategic approach to heritage management based on institutional, agency, and industry lessons learned.
- Established pre-Phase A Heritage Policy
  - Designated the MSL “as-flown” vehicle as the baseline and instituted formal change control with elevated change control authority and visibility
  - Strengthened Inheritance Review requirements and criteria to include deeper and broader penetration into all aspects of heritage (design, process, documentation, interfaces, environments, facility, organizational, etc…)
  - Requires reclassification of heritage elements when changed, and recirculates element back through full PDR/CDR cycle
  - Established full MSL V&V program as the (minimum) baseline, independent of the level of heritage. Deviations are explicitly approved at specific gates with concurrence from subject matter experts.

Technical Resources

- Project is closely watching Rover mass and turret mass
- Current design fits within available power, energy, volume, power switch, pyro circuits, analog, thermal, sensor, and cmd/data interfaces, <u>but with no additional scope capacity in many cases</u>



Key Resources	CBE	Allocation (power system capability)	Margin (%) = (Allocation-CBE) / Allocation	Required Margin (%) at PDR
Launch Energy (Nominal Launch, max %DOD)	31	70	56%	13%
Late Cruise Power (W)	983	1158	15%	13%
EDL Energy (Rover Battery, max %DOD)	2.9	20	86%	13%
Surface Energy Balance – 500WH day (Wh)	1777	2509	29%	17%
Surface High Energy – 1500WH day(Wh)	1777	4116	57%	17%

		Allocation (kg)	CBE (kg)	Uncertainty of CBE (%)	CBE + Unc. (kg)
	1.C.3 Landed Mass	**1050**	**914**	**11%**	**1013**
	1. Heritage Rover Guts	208	203	2%	208
"Mod"	2. Rover Chassis	204	180	14%	204
"Mod"	3. Rover Mobility	259	248	4%	259
"Mod"	4. RSM Mechanical	37	34	8%	37
"Mod"	5. Rover System Harness	55	46	20%	55
"New"	6. Navcam & Hazcam	8	6.0	25%	7.5
"New"	7. SCS/Caching	68	51	33%	68
"New"	8. SCS/Robotic Arm	78	67	16%	78
"New"	9. SCS/Turret+Corer, etc.	28	24	16%	28
"New"	10. Payload (on Turret)	12	9.2	24%	11
"New"	11. Payload (on RSM)	10	9.2	10%	10
"New"	12. Payload (not on Turret)	37	30	23%	37
"New"	13. TRN (VCE/LCAM)	6	5.4	8%	5.8
	14. Balance Mass	10			3
	PM unencumbered allocation	29			

	Allocation (kg)	CBE (kg)	Uncertainty of CBE (%)	PBE = CBE + Unc. (kg)
1 Launch Mass (wet)	**4050**	**3866**	**4%**	**4009**
1.A Cruise Stage Prop	72	72	-	72
1.B EDL System Prop	401	401	-	401
1.C Launch Mass (dry)	3577	3393	4%	3536
1.C.1 Heritage Cruise Stage (dry)	472	466	1%	472
1.C.2 EDL System (dry)	**2055**	**2014**	**2%**	**2052**
1. Heritage EDL System	1689	1673	1%	1690
Heritage a. Descent Stage	676	670	1%	676
Heritage b. Parachute + Lid	61	60	1%	61
Heritage c. Heatshield	433	428	1%	432
Heritage d. Backshell	520	515	1%	520
"New" 2. MEDLI2	30	22	24%	27
"New" 3. EDLCameras - DS/BS	7	5	20%	6
4. CBM	154	146	5%	154
5. EBM	175	168	4%	175
1.C.3 Landed Rover Mass	**1050**	**914**	**11%**	**1013**

Sampling & Caching Subsystem

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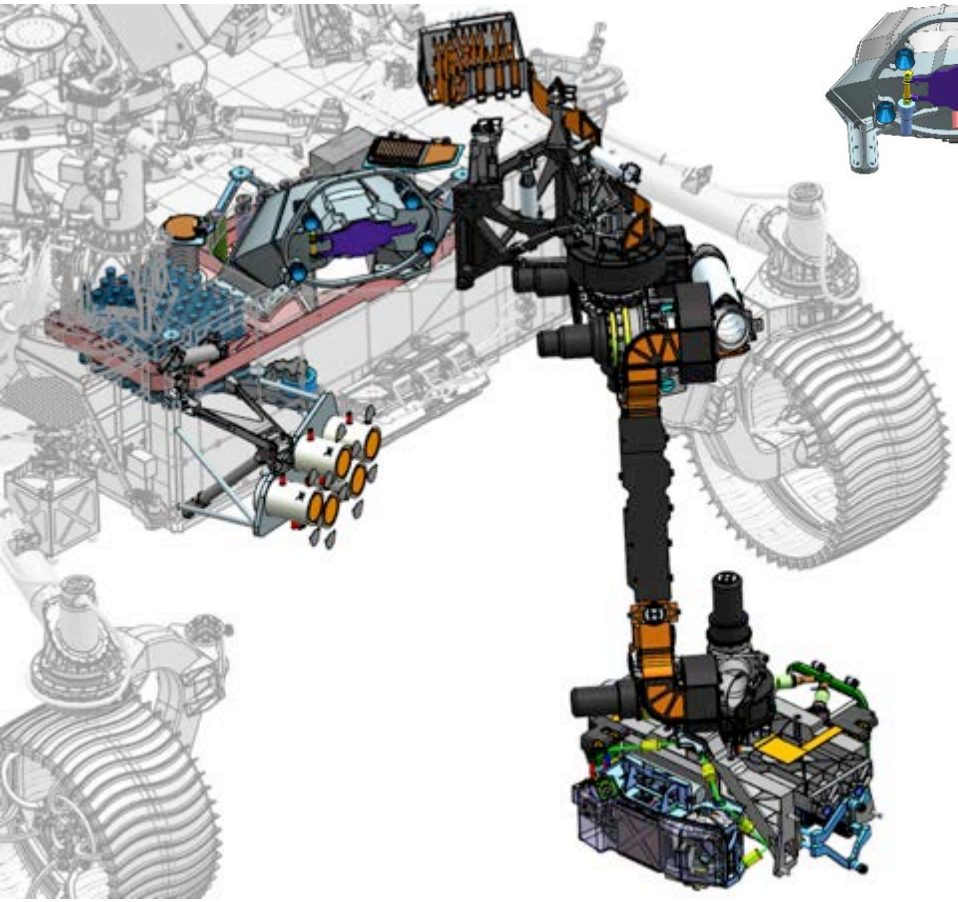
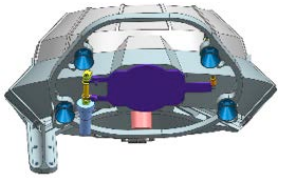
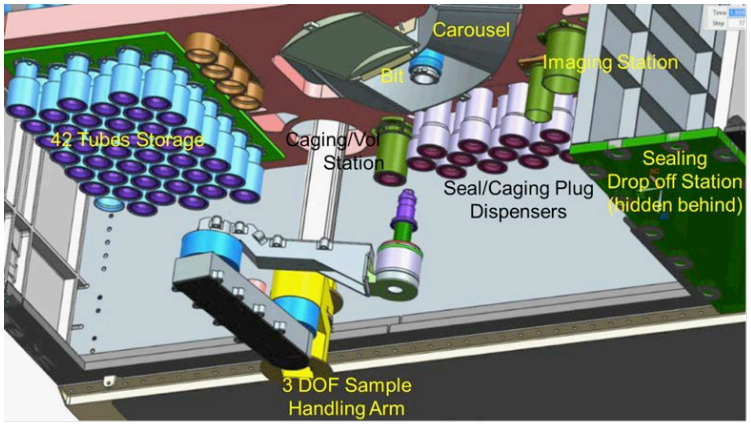
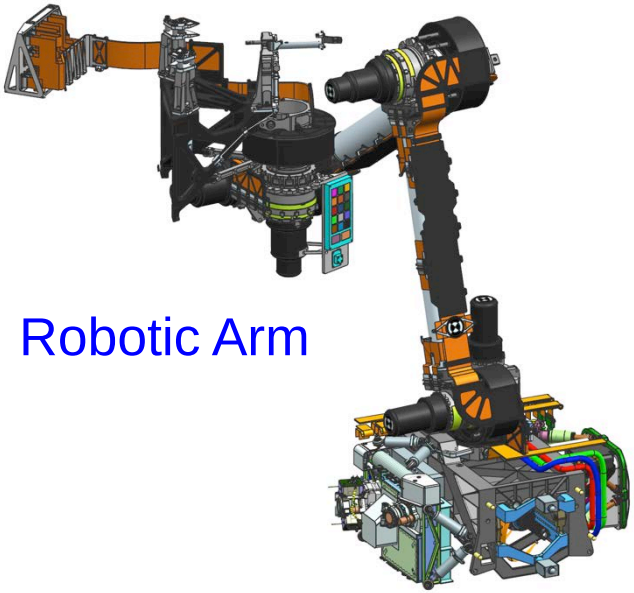


Bit Carousel



Caching Assembly





Robotic Arm

Turret w/corer

Surface Productivity Improvements

#	Productivity Improvement Name	Description	Dev Impacts		
			FS	MS	PS
1	1.5 Mars Year HW Qual Lifetime	• Perform additional testing during development to extend verify extension of hardware lifetime from 1.0 Mars Year	X		X
2	5 Hour Tactical Timeline	• Improved from MSL 11 hour timeline • Emphasis on strategic and campaign planning • Higher level planning capability; automated command and sequence generation from plan.		X	
3	Faster Traverse	• Uses TRN avionics for image processing and navigation • Re-factor FSW to 'think while driving'	X		
4	On-Board Simple Planner	• On-board state autonomy to optimize resources and utilize opportunistic activity windows.	X	X	
5	Remote Science Productivity	• Closed loop autonomous pointing using resolvers , on-board backlash model, and camera images	X		
Under Evaluation: Proximity Science (arm placement autonomy); FSW Load and Transition (EDL to surface transition; FSW patching); Low-Density Parity-Check Coding (enhance orbiter data return volume)					

Note: Addition of Terrain Relative Navigation may minimize driving time by allowing access to landing sites with Regions of Interest in close proximity

Key: FS = Flight System Development
MS = Mission System Development
PS = Payload System Development

Additional Technology Objectives

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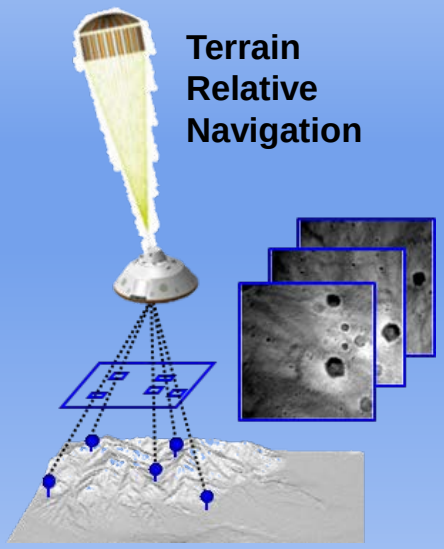
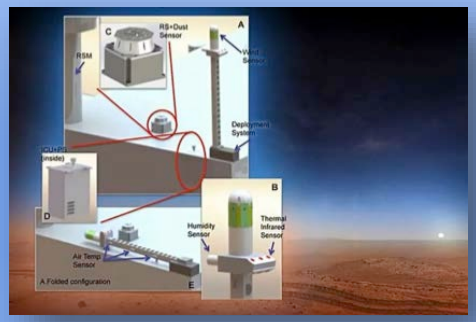
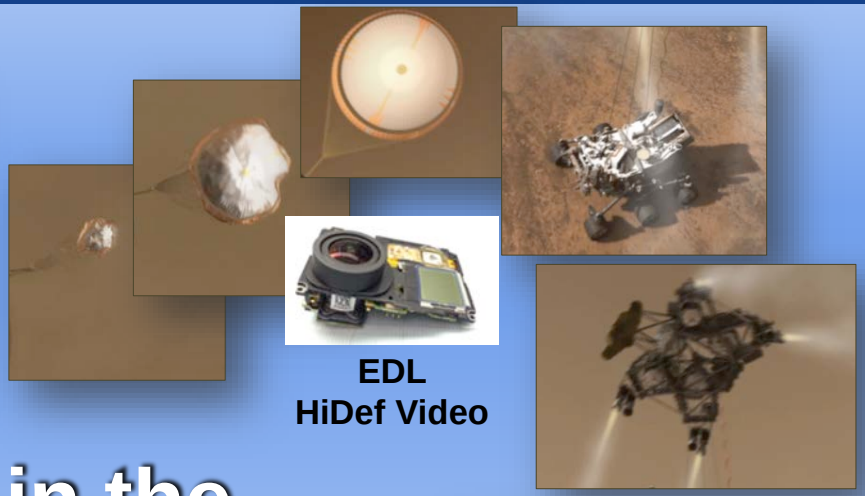
Terrain Relative Navigation



Weather & Dust - MEDA

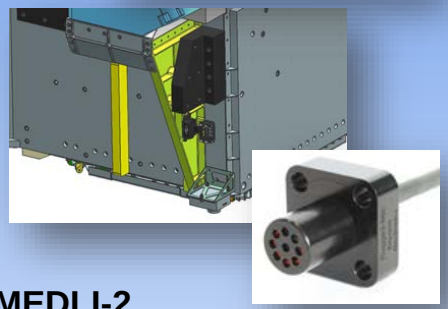




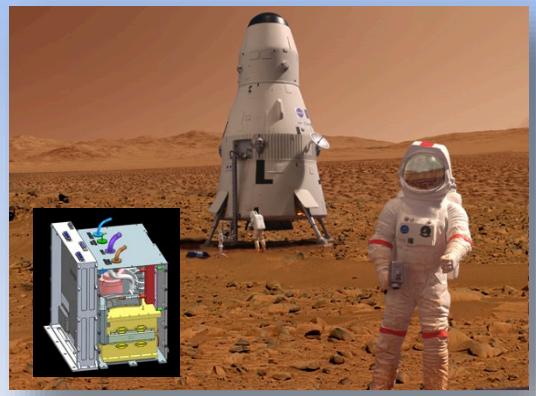
EDL HiDef Video

Investing in the Future

First Recorded Sounds from Mars



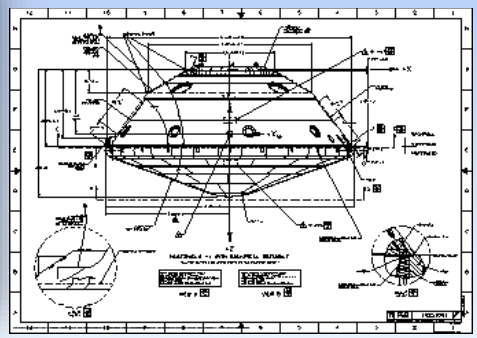
Oxygen Generation - MOXIE

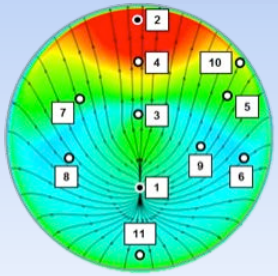


Aerial Reconnaissance

Artist's Concept

Aeroshell Instrumentation – MEDLI-2





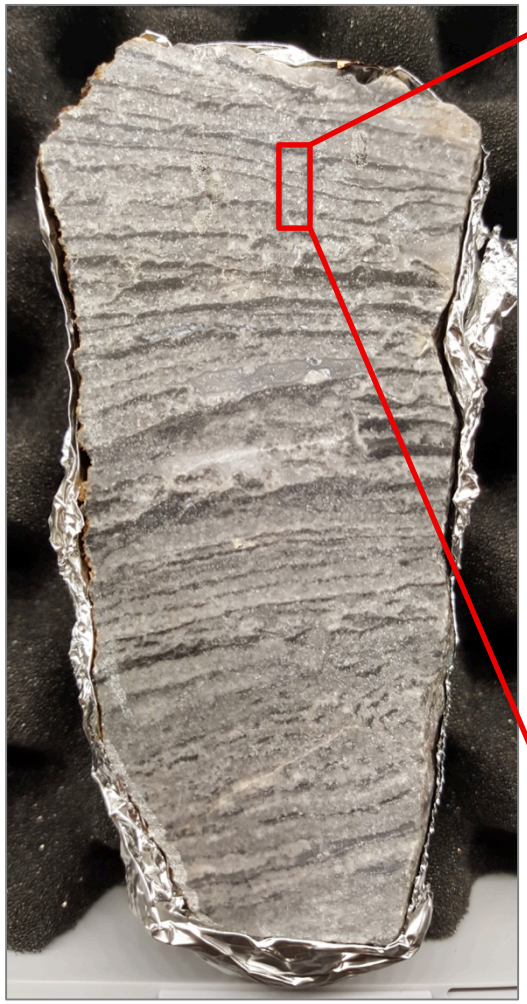
Project Summary and Conclusions

- The mission design and implementation approach is fully responsive to meeting the Level 1 requirements
- The Mars 2020 Project can be executed on schedule for a 2020 launch at acceptable risk for a flagship mission within the current total life cycle cost and within the current funding profile
- Costs performance on heritage hardware continues to be on or under plan
- Cost estimates for new developments (i.e., the instrument payload and Sample Caching System) incorporated known cost growth into the baseline and provide acceptable cost and schedule margins - - payload and Sample Caching System remain critical path developments
- Successfully conducted an extensive and intensive set of instrument, subsystem, Office level PDR's, and the Project PDR
- Pre KDP-C JPL Center Management Council completed 24 February 2016
- Pre KDP-C Science Mission Directorate Program Management Council completed 30 March 2016
- The KDP-C Agency Program Management Council completed April 27, 2016
- **The Mars 2020 Project was approved and entered Phase C June 27, 2016**

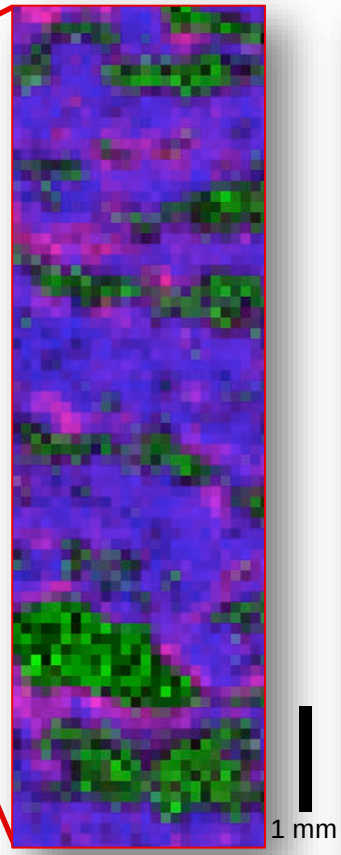
Back-ups

Seeking Signs of Ancient Life

3.4 billion year old fossil microbial mat

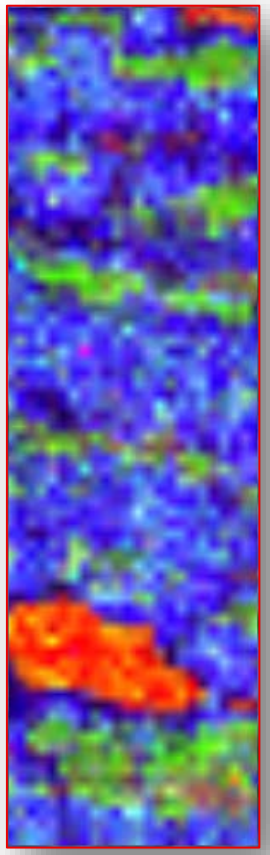


PIXL



Si Ca Fe

SHERLOC



silicate
carbonate
organic carbon

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**.

Sample Integrity Requirements

1. Physical characteristics of samples and environments
   - Sample mass, number of samples, fracture limits, environmental requirements
2. Inorganic contaminants
   - Limitations on levels of ~30 elements critical for scientific study of samples
3. Organic contaminants
   - Total organic carbon + critical “Tier 1” list + limit on any single compound
4. Biologic contamination
   a) tightly limit the number of cells per sample
   b) collect thorough genetic inventory and contaminant archive to facilitate recognition of any terrestrial hitchhikers
5. Thorough characterization and archiving of materials which may add inorganic, organic, or biologic contamination to samples
   - Critical information and archive supports future missions, and is necessary for the full diversity of investigations likely to be undertaken on returned samples.

Sample Integrity Requirements

6. Procedural blank program to characterize inorganic, organic, and biologic contamination occurring at and after ATLO (round-trip contamination).
7. Thorough documentation of geology of landing site and drilled sample context
   - critical linkage to the in-situ investigation
   - context-rich samples are of far greater value than “grab” samples

Sample integrity requirements derived through an extensive interaction with the relevant community including the Organic Contamination Panel, the Returned Sample Science Board, and JSC Astromaterial Curation Lab