Jet Propulsion Laboratory
California Institute of Technology

Mars 2020 Project Update

for Committee on Astrobiology and Planetary Science

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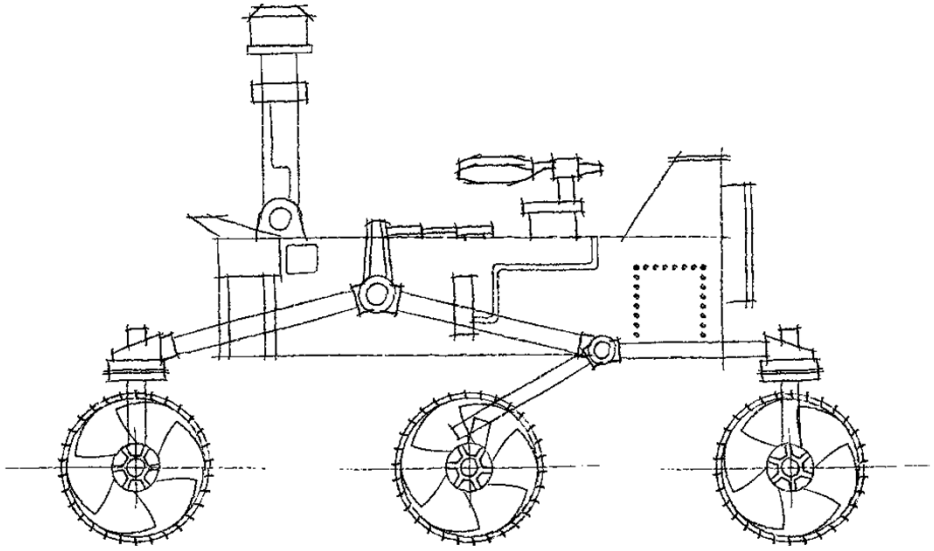
(Caltech-JPL)

September 17, 2015



Mars 2020 Project

Mars Exploration in This Decade

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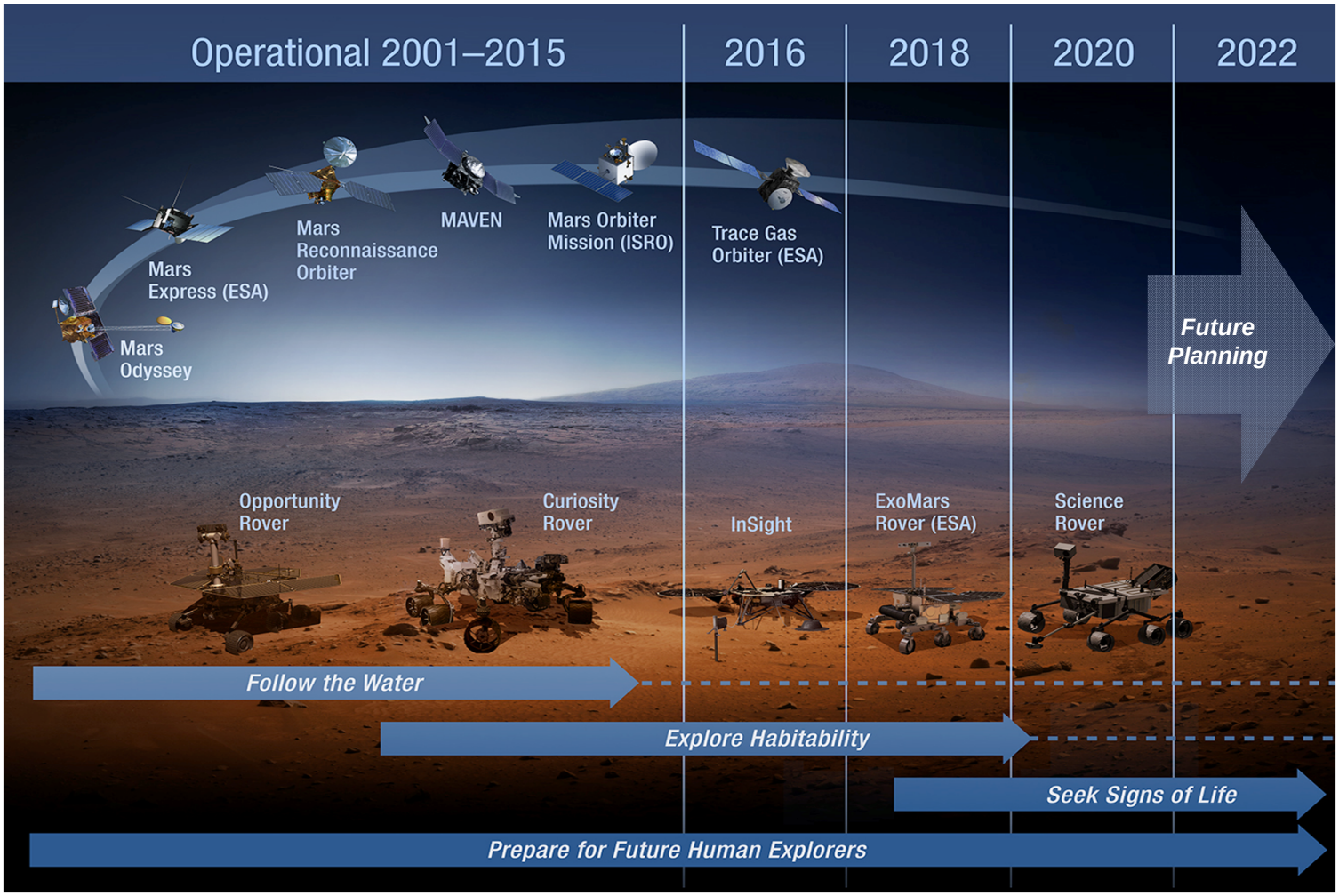
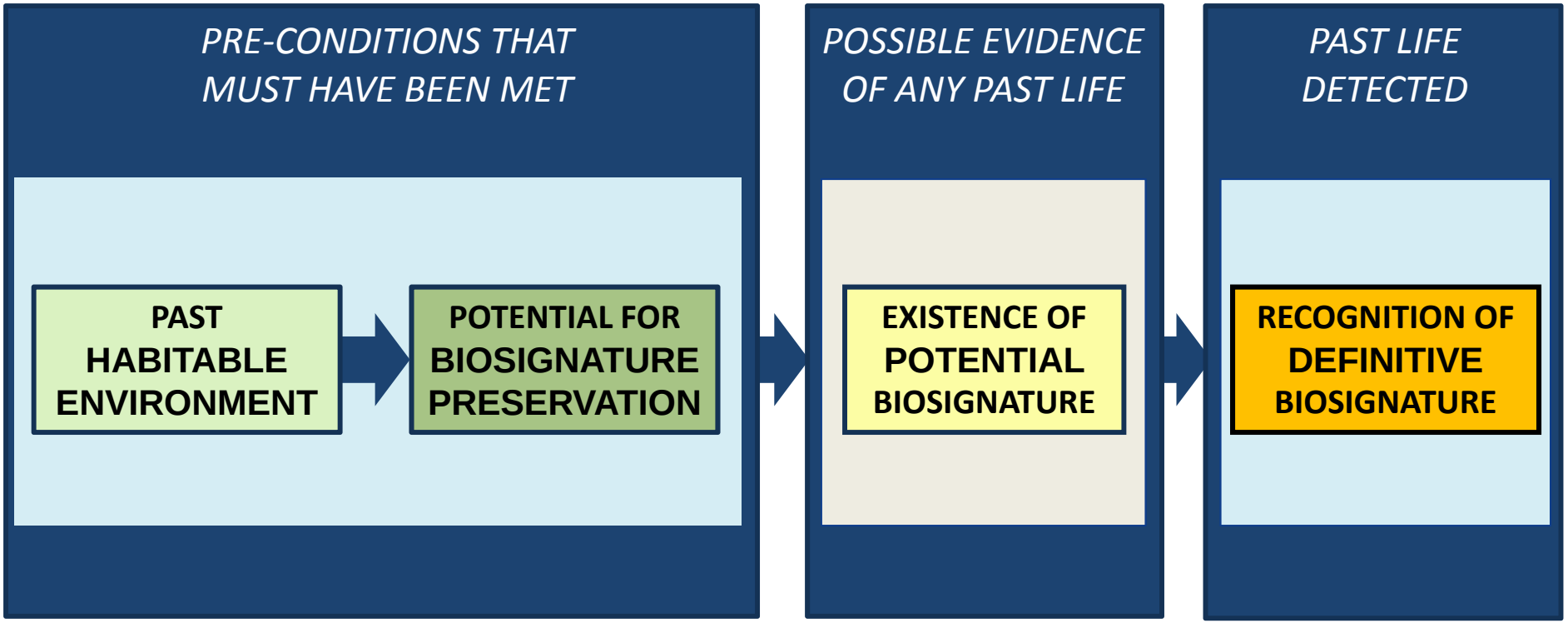
Baseline Mars 2020 mission addresses the highest priority science

- Builds on Curiosity results by investigating a landing site for possible bio-signature preservation in full geologic context
- Provides HEOMD/STMD contributions to address key Strategic Knowledge Gaps
- Provides cached samples for possible return – *highest priority of Decadal Survey*



Biosignatures: seeking the signs of ancient life



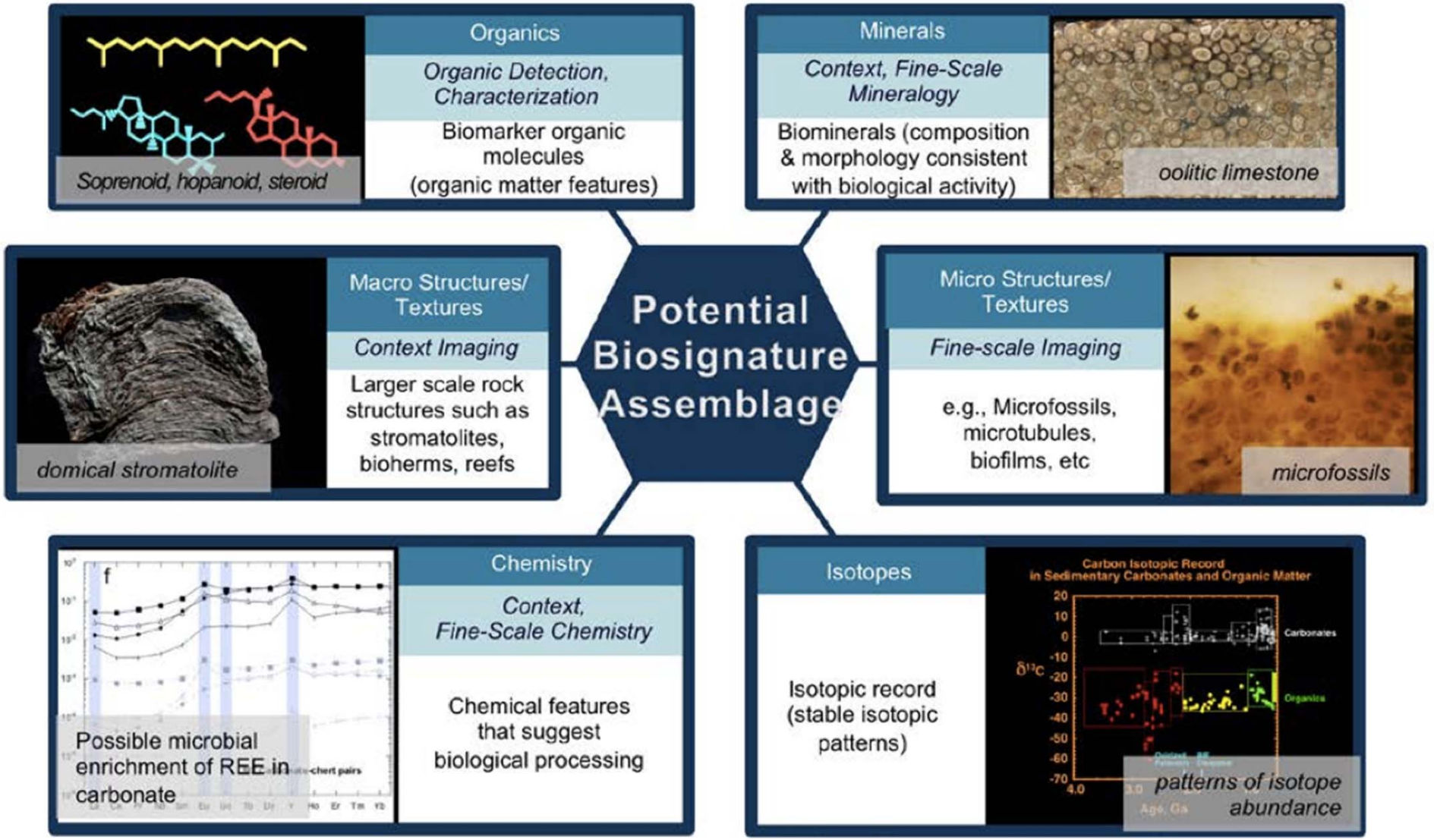
Proposed Mars 2020 Rover

Mars Sample Return

Labs on Earth

From the Mars 2020 Science Definition Team Report (Mustard et al. 2014)

Biosignatures: seeking the signs of ancient life



From the Mars 2020 Science Definition Team Report (Mustard et al. 2014)

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 future return to Earth

  D. **Human Exploration** Facilitate future human exploration by making significant progress towards filling major strategic knowledge gaps and…

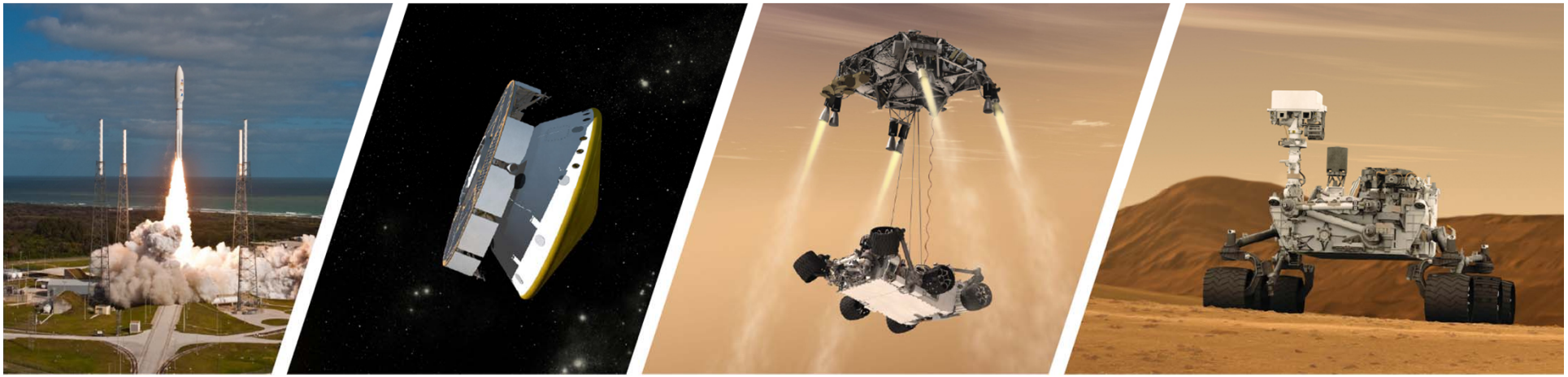
  Technology …demonstrate technology required for future Mars exploration

- **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

Mission Overview



LAUNCH

- MSL Class/Capability LV
- Period: Jul/Aug 2020

CRUISE/APPROACH

- 7.5 month cruise
- Arrive Feb 2021

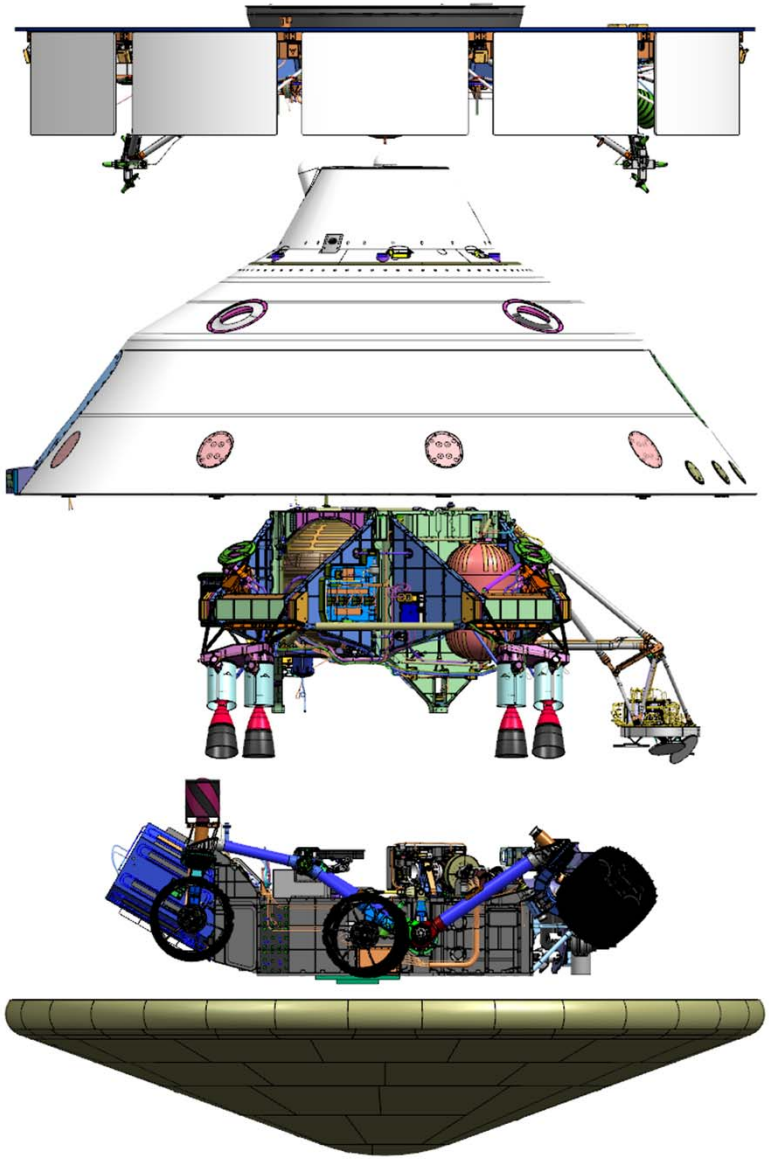
ENTRY, DESCENT & LANDING

- MSL EDL system (Range Trigger baselined, Terrain Relative Navigation funded thru PDR): 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
- Seeking signs of past life
- Returnable cache of samples
- Prepare for human exploration of Mars

Heritage Implementation - What's New?



Cruise Stage Vehicle: Build to print

Backshell/Parachute: Build to print
+ additional sensors for MEDLI2
+ EDL Camera (Parachute up-look)

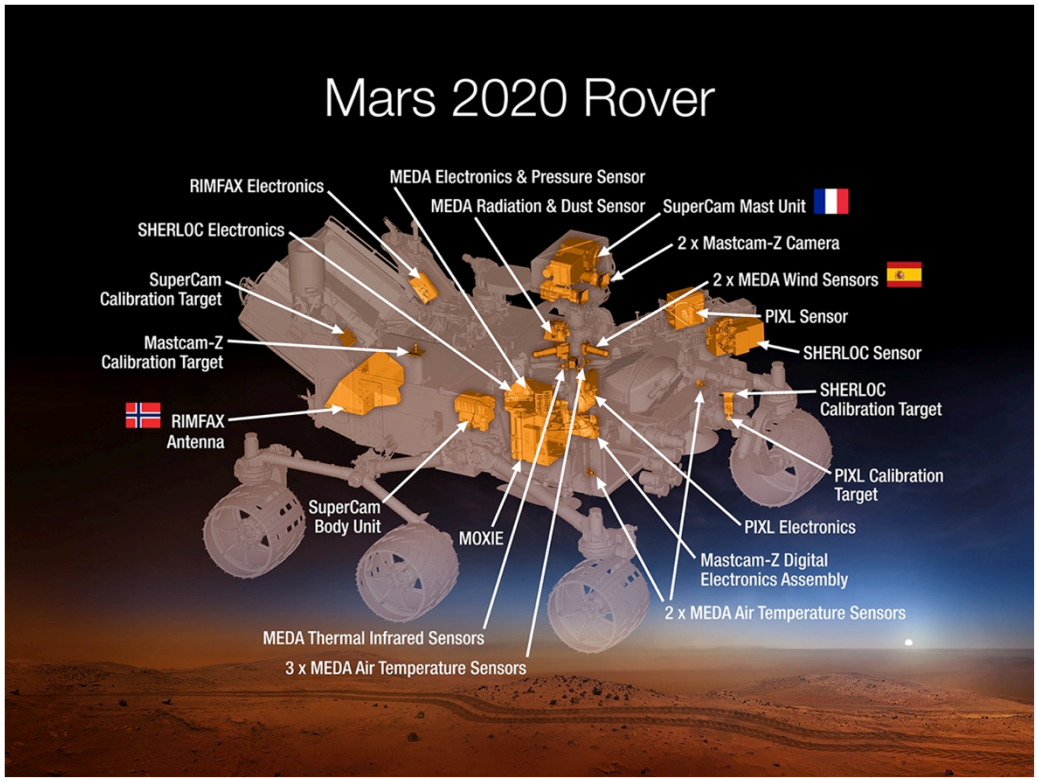
Descent Stage Vehicle: Build to print
+ EDL Camera (Rover down-look)

Rover: High heritage
+ 7 NASA-selected Instruments
+ Sampling & caching system
+ EDL Camera (DS up-look) + (new) EECAMs
+ Resources reserved for TRN (image processor and down-look camera)

Heatshield: Build to print
+ additional sensors for MEDLI2

Mars 2020 Payload

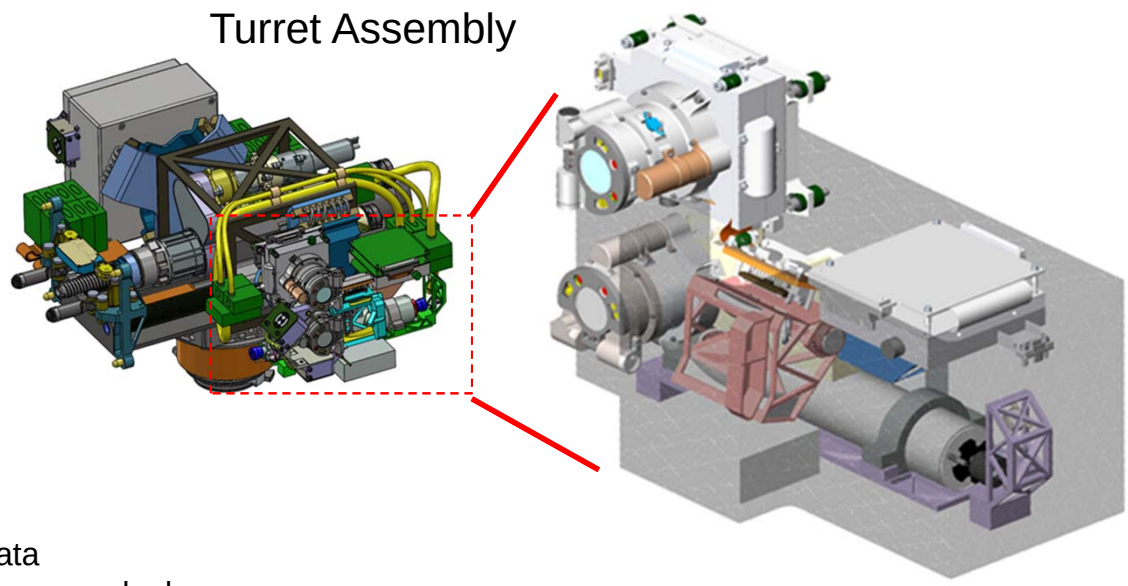
1. **Mastcam-Z** - stereo zoom camera
2. **Supercam** - remote elemental chemistry and mineralogy
3. **SHERLOC** - fine-scale organic geochemistry and mineralogy (mapping)
4. **PIXL** - fine-scale elemental chemistry (mapping)
5. **RIMFAX** - subsurface structure - ground penetrating radar (Norway)
6. **MEDA** - weather and atmospheric dust monitoring (Spain)
7. **MOXIE** - ISRU – conversion of atmospheric CO_2 to O_2



Mars 2020 Payload Update

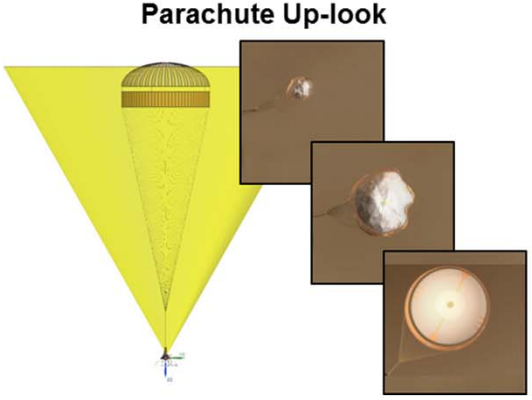
Added Wide Angle Topographic Sensor for Operations and eNgineering (WATSON)

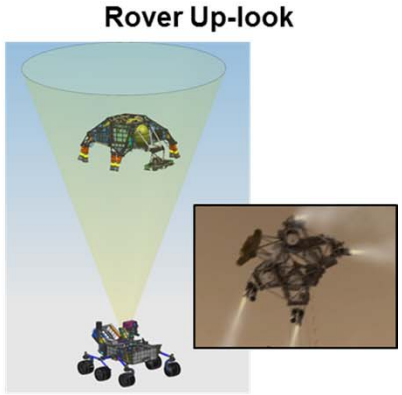
- Augmented turret fine-scale imaging capability by adding MAHLI heritage optic + mux board to SHERLOC instrument
- Provides contextual science and engineering data



Added EDL / Parachute Uplook Cameras

- Improved EDL instrumentation for engineering data
- Parachute up-look, descent stage down-look, & rover up-look cameras





Mars 2020 Returned Sample Science Board

RSS Board

- represents interests of future scientists who would analyze samples collected by Mars 2020.
- provides guidance to the project on full range of RSS-related issues.
- contributes to landing site selection.
- NASA HQ sponsored selection process.

Membership:

Hap McSween and Dave Beaty (co-chairs); Andrew Czaja; Elisabeth Hausrath; Christopher Herd; Munir Humayun; Scott McLennan; Lisa Pratt; Mark Sephton; Andrew Steele; Ben Weiss

Ex-officio: Francis McCubbin (JSC Mars curation)
Yulia Goreva (RSS investigation scientist)

Ex-officio observers: NASA HQ planetary protection; NASA HQ Mars program; MPO – MSR campaign advance planning

Mars 2020 Sampling and Caching System

Scope:

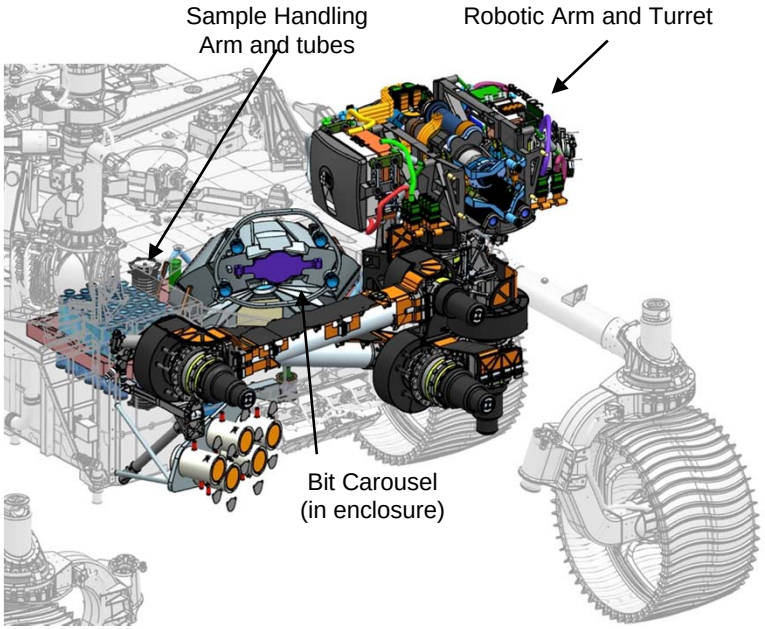
- Acquire and seal samples of Martian surface material
  - Rock cores and regolith

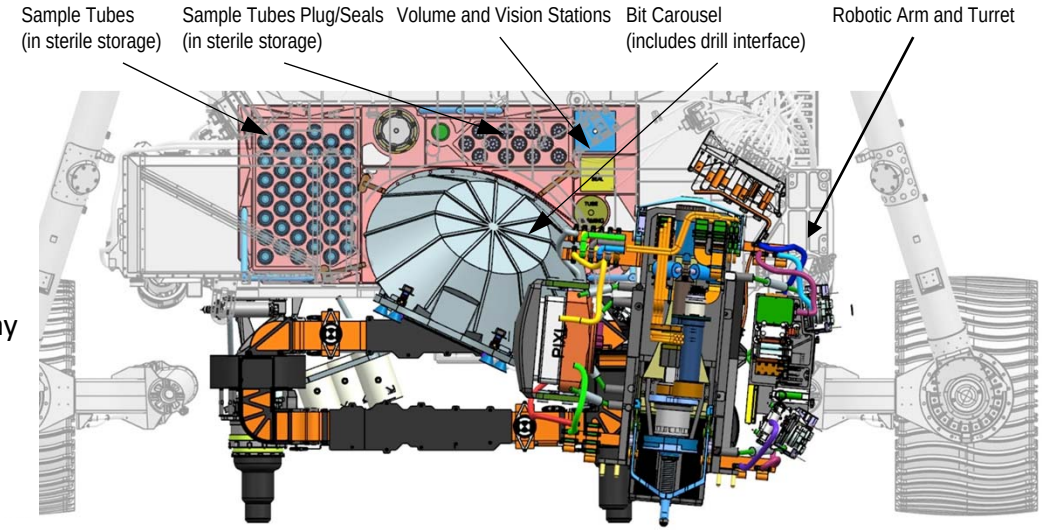
Approach:

- Use MSL-like robotic arm for sample acquisition
- Rotary Percussive coring drill
- Acquire samples directly into sample tubes
  - Reduce exposure to contamination vectors (PP and Science)
- Process filled sample tubes within controlled volume using a sample handling arm
- Hermetically seal samples in tubes
  - Prevent loss of volatiles
  - Prevent contamination of sample
- Cache samples on Mars for potential return to Earth

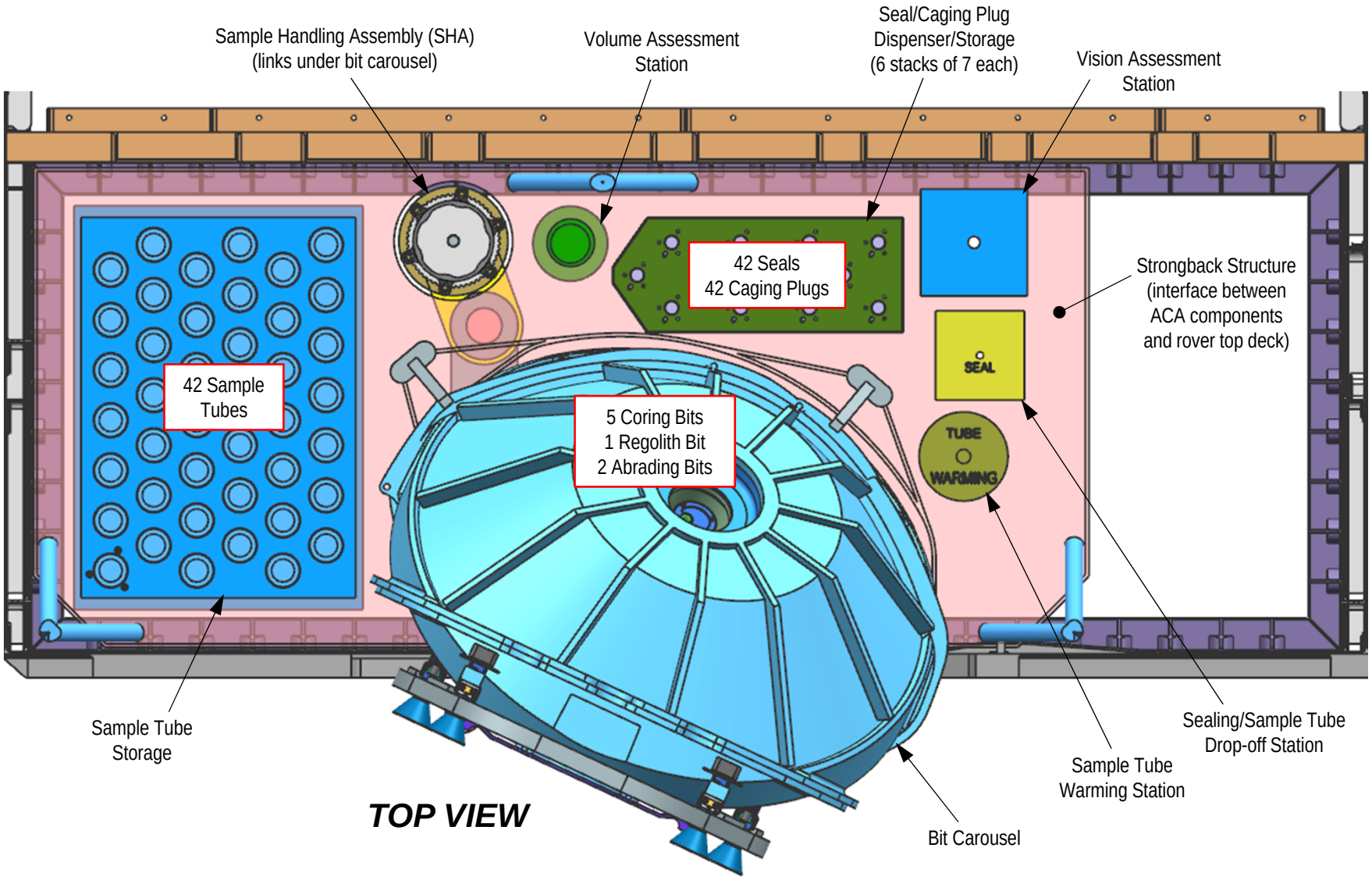
Status

- Architecting of system is complete
- Design of many elements is underway
  - Robotic (sample acquisition) arm vendor competitively selected and on contract
  - Sample handling arm RFP vendor selection underway
  - Lay-out of sampling handling elements and rover volume has closed
  - Adaptive Caching approach has been baselined





Hardware/Design Overview



TOP VIEW

Adaptive Caching Overview

Adaptive Caching is the baseline approach for Mars 2020

1. Samples are drilled into tubes, tubes are sealed, and then stored on board the rover
2. At an appropriate location, samples (and blanks) are deposited together on the surface

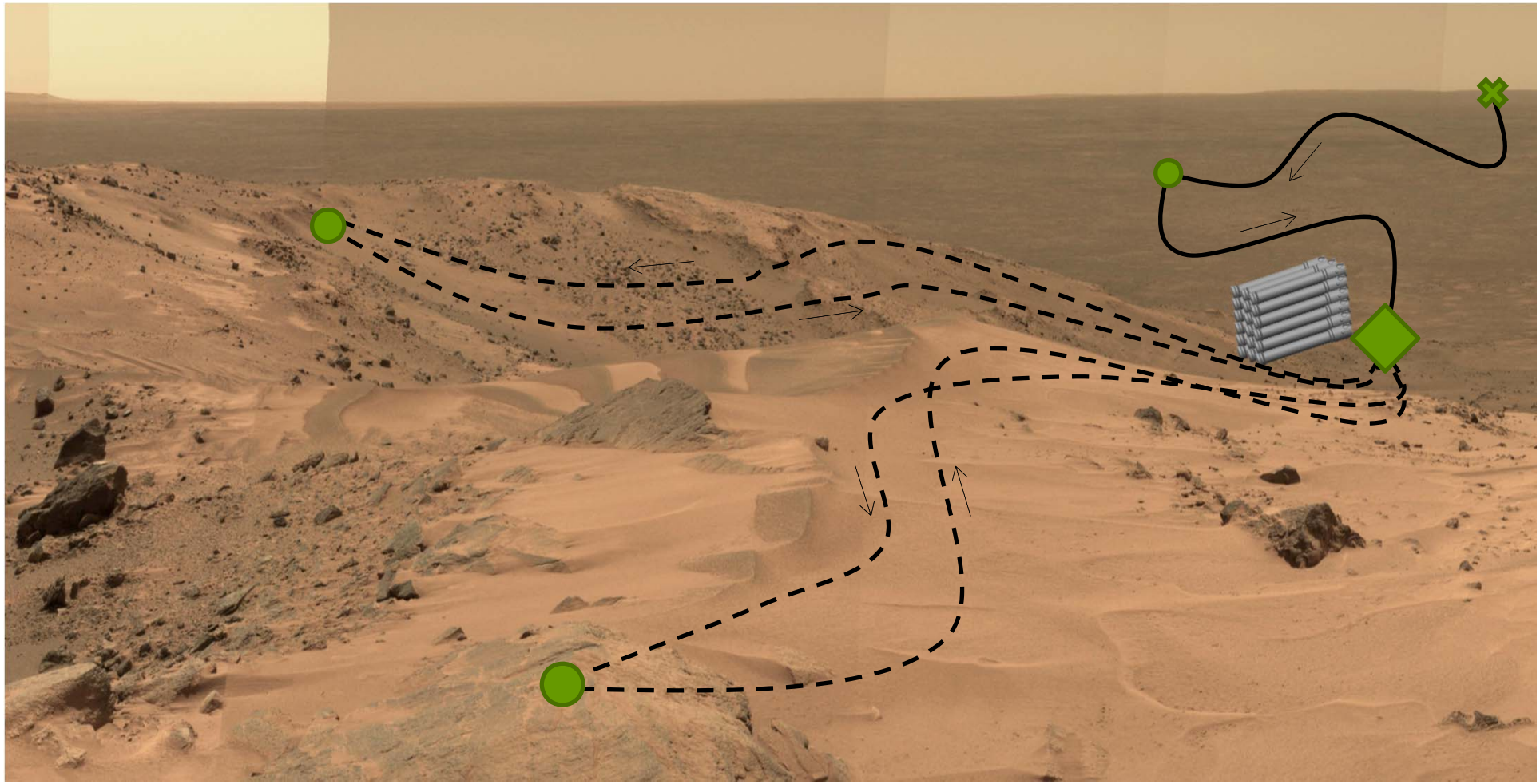
There is no "cache container" that holds the samples

Tubes and seals designed to withstand >10 years on Mars surface

Advantageous for science

- Allows for continued sampling and caching after prime mission
- offloading of samples reduces mission risk (and risk averse behavior) associated with traverse and other hazards
- samples could be down-selected individually for Earth return long after the end of the Mars 2020 mission

Adaptive Caching Overview

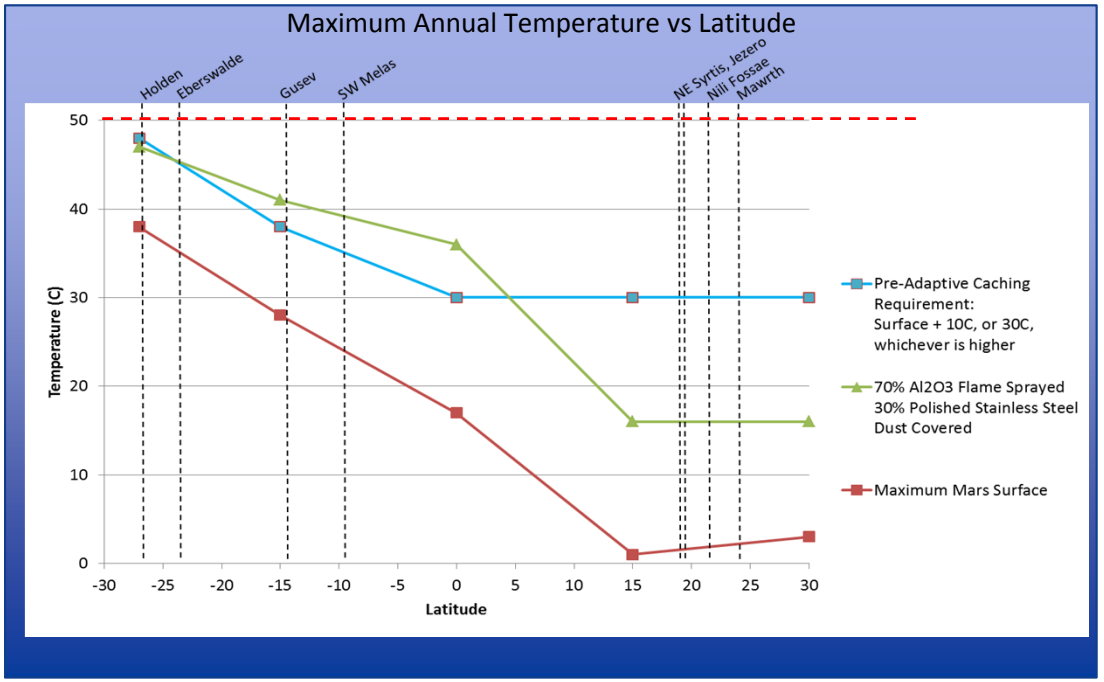


- Baseline operational assumption: *Depot Cache* operational scheme
  - All sample tubes are deposited in a single location
  - Location is determined to be accessible for a potential follow-on retrieval mission
  - Location is chosen to minimize joint mission risk across both M2020 and potential retrieving mission

Sample Tube Temperature

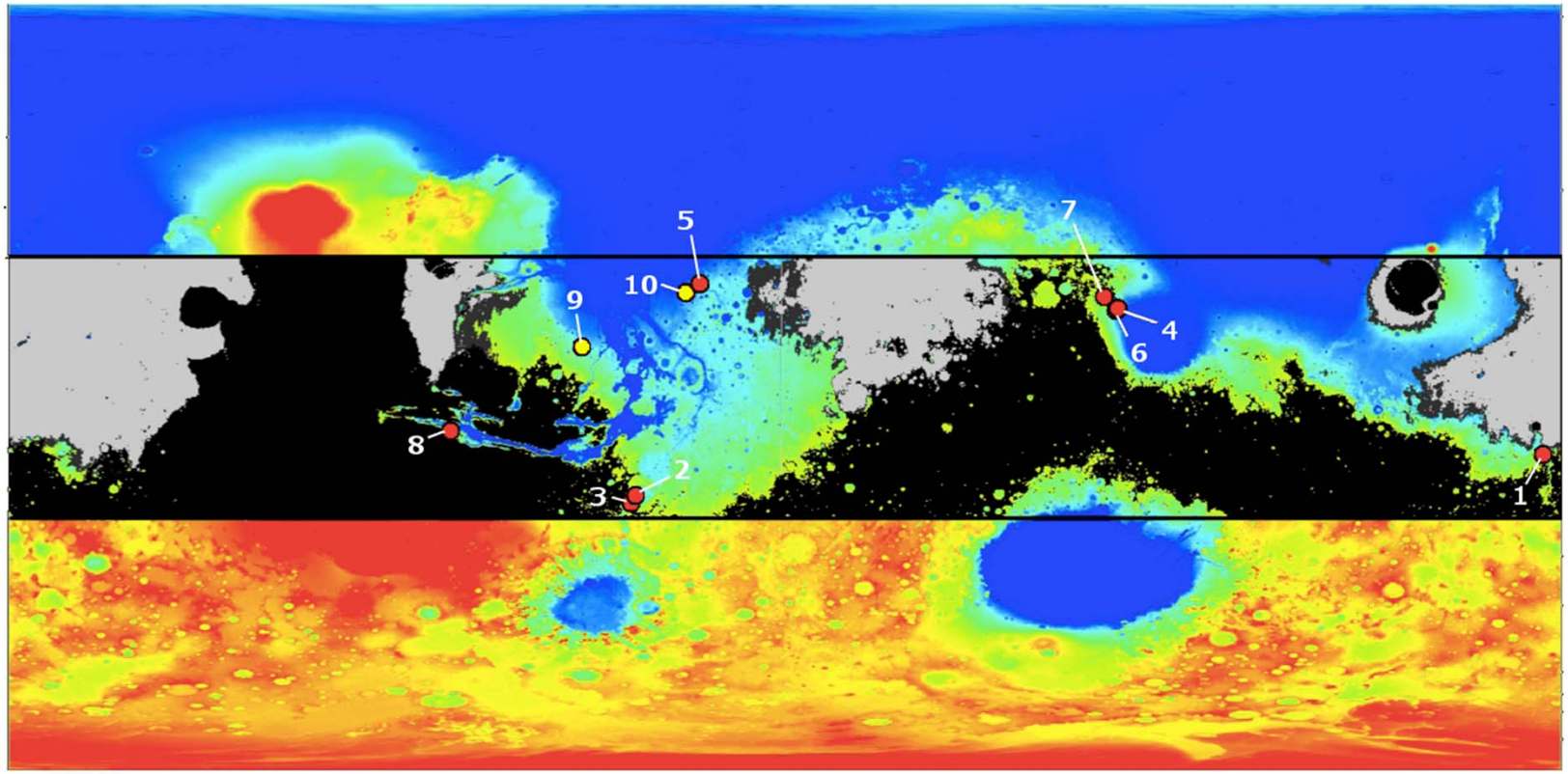
Assessment:

- Mars 2020 project is assessing the sample temperature under a set of conservative assumptions
  - Low albedo surface assumptions
  - No thermal conduction to the surface
  - Conservative dust covered state
- Project is looking to coat sample tubes for high emissivity
- On going testing underway to confirm performance assumptions
- Science concern is related to maximum ambient surface temperatures which vary with latitude
- Science concern focuses most keenly on temperatures above 50C



The latitudinal variations in temperature can be considered as a science trade in landing site selection. Priority landing sites shown with vertical lines.

Candidate Landing Sites



(alphabetical order)

1- Columbia Hills (Gusev)
2- Eberswalde
3- Holden
4- Jezero
5- Mawrth
6- NE Syrtis
7- Nili Fossae
8- SW Melas

9- Hypanis
10- McLaughlin

Elevation above MOLA Geoid (m)

High: 4000 Low: -5000

Black elevation mask > 0.5 km
Thermal Inertia masks:
< 150 = Dark Gray
< 100 = Light Gray

Candidate Sites for Science and Engineering Evaluation (in alphabetical order)

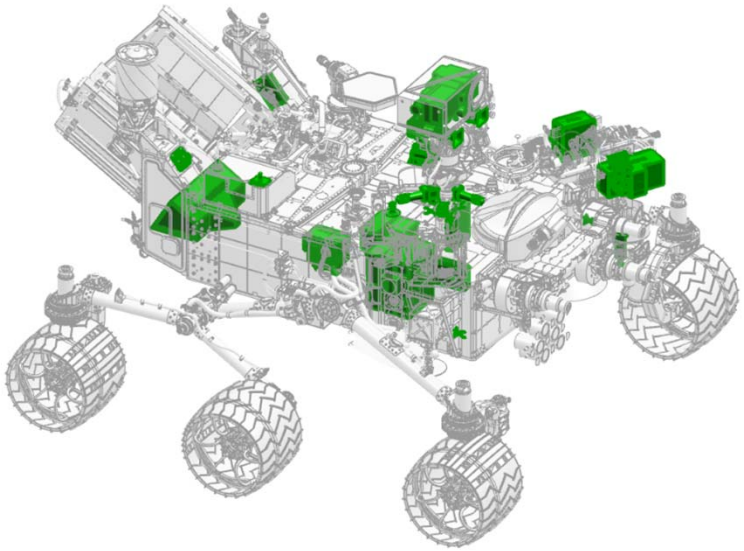
Site	Approximate Locations	Elevation	Geologic Process
Columbia Hills (Gusev)	14.4S, 175.6E	-1.9 km	Hydrothermal Crustal
Eberswalde	23S, 327E	-1.4 km	Fluvial/Deltaic
Holden (original MSL target)	26.4S, 325.1E	-2.1 km	Fluvial/Deltaic
Jezero	18.5N, 77.4E	-2.5 km	Fluvial/Deltaic
Mawrth	24N, 341.1E	-2.3 km	Pedogenic
NE Syrtis	17.8N, 77.1E	-2.2 km	Hydrothermal Crustal
Nili Fossae	21N, 74.5E	-0.6 km	Hydrothermal Crustal
SW Melas	12.2S, 290E	-1.9 km	Fluvial/Deltaic

Two sites for additional science investigation (not engineering evaluation):

- Hypanis (11.8N, 314.6E; -2.6 km)
- McLaughlin (21.9N, 337.8E; -5.0 km)

Mars 2020 Summary

- Completed Phase A and formally entered Phase B of formulation
  - Completed instrument accommodation reviews, including implementing design modifications required at selection
  - SRB reported: *"Project is more mature than most in Phase A, ready for KDP-B decision milestone and Phase B start."*
  - Approved for Phase B by Agency Program Management Council (APMC) on May 20
- High-heritage approach is providing stable foundation for Mars 2020. Heritage hardware (~90% of the flight system by mass) is essentially in Phase C/D. Parts buys and procurements for items with low risk of change are proceeding at a fast pace
- Published environmental impact statement and issued Record of Decision to baseline radioisotope power system, thus completing compliance with National Environmental Policy Act (NEPA)
- Working detailed engineering and design for cache system implementation
- Rover systems / Payload Update:
  - Agreement reached with Spain to provide high gain antenna
  - Upgraded engineering camera design with color and improved resolution compared to MSL navcam/hazcams
  - Added EDL / Parachute Uplook Cameras
  - Augmented SHERLOC with infinite focus fine-scale color imager (based on MSL MAHLI)
  - RIMFAX formally selected for flight based on accommodation
- Second landing site workshop conducted August 2015
- Continuing to evaluate Terrain Relative Navigation (TRN) capability for potential inclusion on the mission



Project has made excellent progress to date, with plenty of challenging work still ahead

Timeline to Mission Confirmation

- 20 May - KDP-B Agency Program Management Council (APMC) completed
- 2-3 June - Flight System Baseline Workshop completed
- 9 June - SCS Architecture Review completed
- 21 July - Flight Software Inheritance Review completed
- 4-6 Aug - 2nd Landing Site Workshop completed
- 15-16 Sept - Heritage Flight System update to Standing Review Board completed
- Jul-Nov - Pre-PDR Reviews (EDL, FS, SCS, Operations, Cost, etc.)
- Sept'15 – Feb'16 - Instrument PDRs
- 19-20 Oct - Sampling & Caching System (SCS) PDR
- 3 Nov - Surface Operability Review
- Feb 2016 - Project Preliminary Design Review (PDR)
- 1st Qtr 2016 - KDP-C

KDP = Key Decision Point
PDR = Preliminary Design Review
EDL = Entry, Descent, and Landing
FS = Flight System
SCS = Sampling & Caching System

Backup

Mars 2020 Major Accomplishments and Status

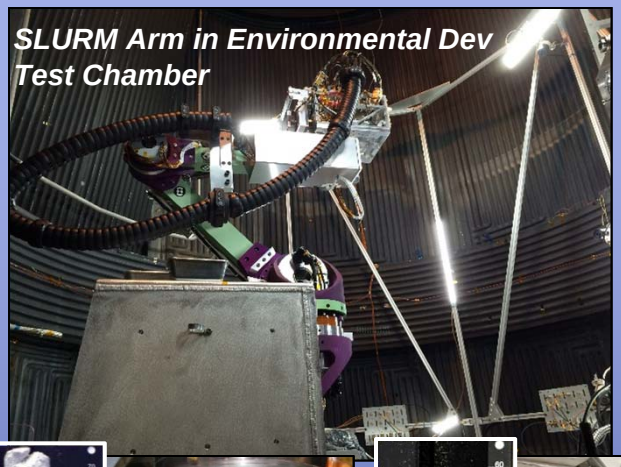
- Project formally entered Phase A of formulation in November 2013.
- Evaluated 57 proposals in response to Announcement of Opportunity (AO) for science & exploration technology investigations; announced 7 selected investigations in July 2014
- Issued Environmental Impact Statement Record of Decision in January 2015, thus completing compliance with National Environmental Policy Act (NEPA)
- Completed mission definition and accommodation activities; entered Phase B in May 2015
- Early acquisition and builds of heritage elements and items with low risk of change are proceeding at a fast pace
- Established international agreements with France, Spain, and Norway for contributions to science instruments and elements of the rover flight system
- Completed Sampling & Caching System (SCS) architecture definition
- Conducted two Landing Site Workshops in summer 2014 and 2015; ongoing imaging and analysis for top sites
- Payload instrument and flight system preliminary design reviews (PDR) will start up in the Fall, culminating in Project PDR in February 2016

The project is executing the Phase B plan on schedule and within budget, effectively balancing both significant heritage hardware procurements / builds and new developments (payload, Sampling and Caching System, planetary protection implementation)

Sampling & Caching System Testbed

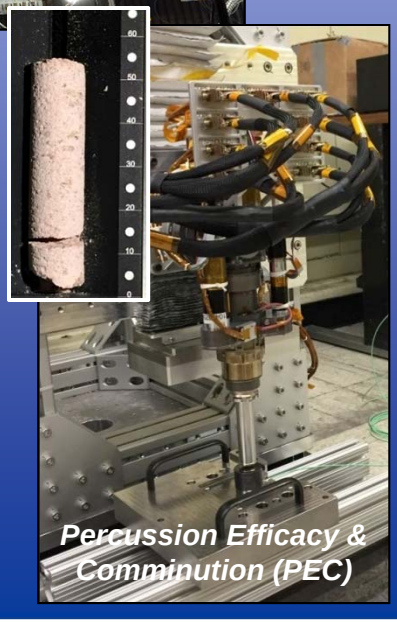
Jet Propulsion Laboratory
California Institute of Technology

Testbed / Coring Development


SLURM Arm in Environmental Dev Test Chamber

- Built 3 brassboard corers
  - Core break
  - Bit exchange
- Testbeds focused on core quality
  - Actuator sizing
  - Bit geometry
  - Run time
- Integrated software / hardware activity
- Over 200 tests run since May 2014 across 5 testbeds


Rescue Chamber Testbed (RCTB)


Percussion Efficacy & Comminution (PEC)


Ambient Robotic Coring (ARC) /Boundary Condition Testbed (BCT)

Geo-Analogs

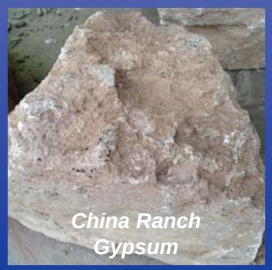
- Built inventory of samples across suite of rock types
- Care-and-feeding program supplying samples to testbeds


Bishop Tuff Intermediate


Napa Basaltic Sandstone


Kramer Massive Mudstone


Old Dutch Pumice


China Ranch Gypsum


Uniform Saddleback Basalt