The Mars 2020 Entry, Descent, and Landing System

AIAA Aviation Conference

Allen Chen

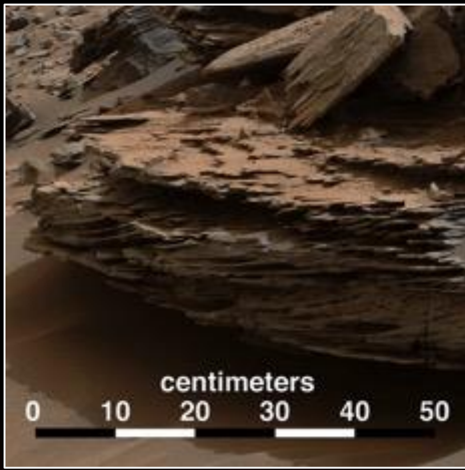
Jet Propulsion Laboratory, California Institute of Technology

June 25, 2018

Jet Propulsion Laboratory
California Institute of Technology

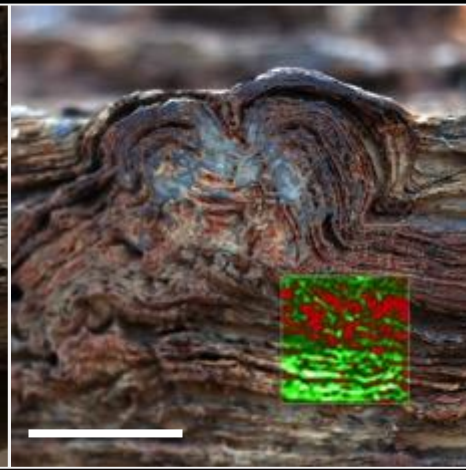
Mars Exploration in This Decade

Mars 2020 Mission Objectives



GEOLOGIC EXPLORATION

- Explore an ancient environment on Mars
- Understand processes of formation and alteration



HABITABILITY AND BIOSIGNATURES

- Assess habitability of ancient environment
- Seek evidence of past life
- Select sampling locations with high biosignature preservation potential

PREPARE A RETURNABLE CACHE

- Capability to collect ~40 samples and blanks, 20 in prime mission
- Include geologic diversity
- Deposit samples on the surface for possible return

PREPARE FOR HUMAN EXPLORATION

- Measure temperature, humidity, wind, and dust environment
- Demonstrate In Situ Resource Utilization by converting atmospheric CO_2 to O_2

Mars 2020 Scientific Payload

A. GEOLOGIC EXPLORATION
B. HABITABILITY & BIOSIGNATURES
C. PREPARE A RETURNABLE CACHE
D. PREPARE FOR HUMAN EXPLORATION

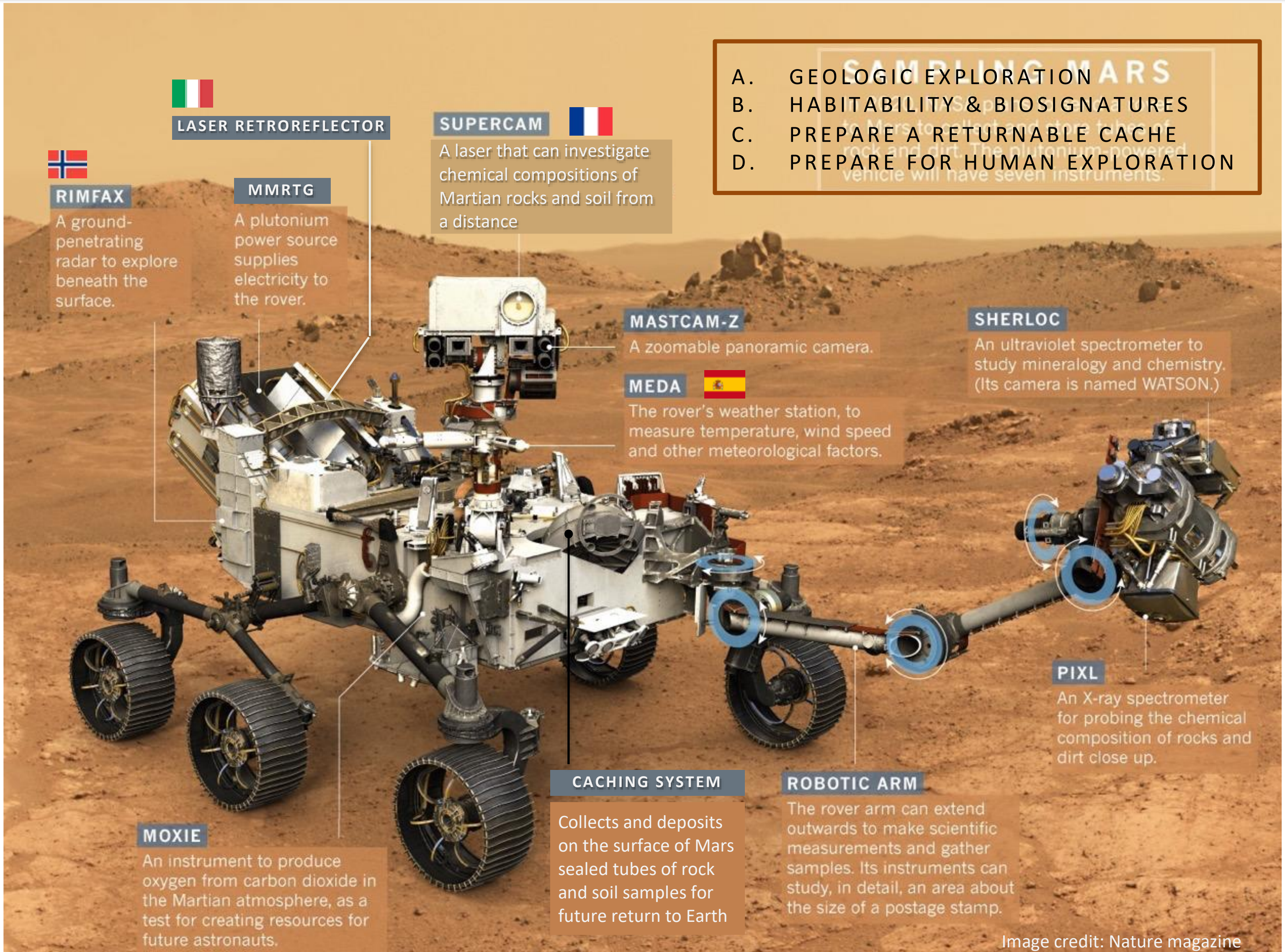
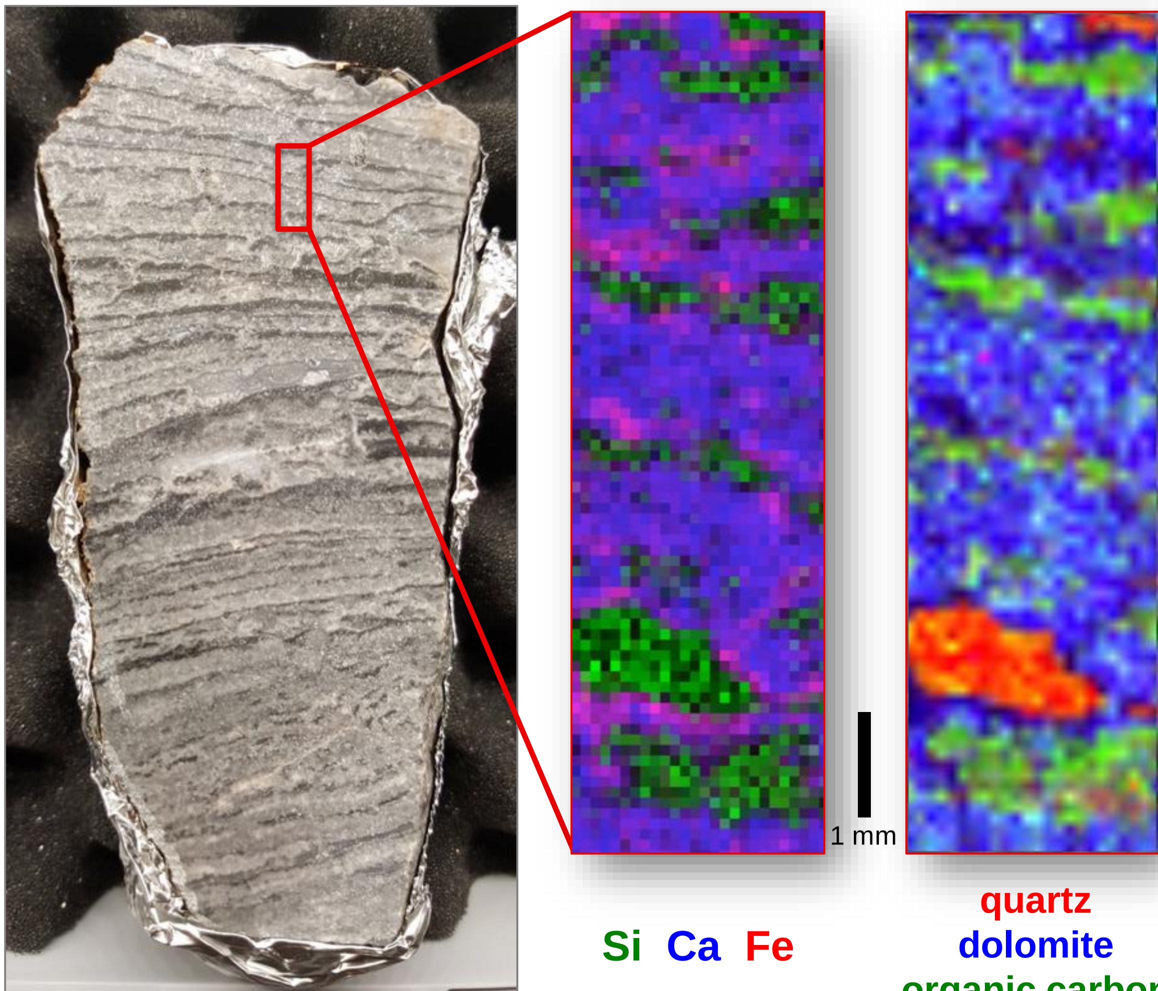


Image credit: Nature magazine

Seeking Signs of Ancient Life

3.4 billion year old fossil microbial mat

PIXL **SHERLOC**



Si Ca Fe

quartz
dolomite
organic carbon

Mars 2020 can recognize **potential biosignatures** as *life-like patterns in the exploration environment*

1. Concentrations of biologically important elements, minerals and/or molecules

Particularly when they are

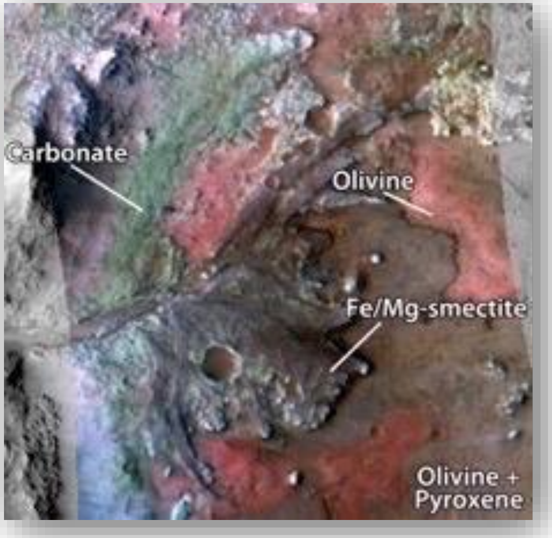
2. Spatially associated with biologically suggestive morphologies

Confirmation of a biosignature likely requires analysis of returned samples

5

Jet Propulsion Laboratory
California Institute of Technology

Where Are We Going?



JEZERO CRATER

- Deltaic/lacustrine deposition with possible igneous unit and hydrous alteration
- Mineralogic diversity including clays and carbonates
- Shallow water carbonates?

NORTH EAST SYRTIS and MIDWAY

- Extremely ancient igneous, hydrothermal, and sedimentary environments
- High mineralogic diversity with phyllosilicates, sulfates, carbonates, olivine
- Possible serpentinization and subsurface habitability

COLUMBIA HILLS

- Carbonate, sulfate, and silica-rich outcrops of possible hydrothermal origin and Hesperian volcanics
- Potential biosignatures identified
- Previously explored by MER

Final Landing Site Workshop scheduled for October 2018

Jet Propulsion Laboratory
California Institute of Technology

Mars 2020 Mission Overview

LAUNCH

- Atlas V 541 Rocket
- Period: Jul-Aug 2020

CRUISE/APPROACH

- ~7 month cruise
- Arrive Feb 2021

ENTRY, DESCENT & LANDING

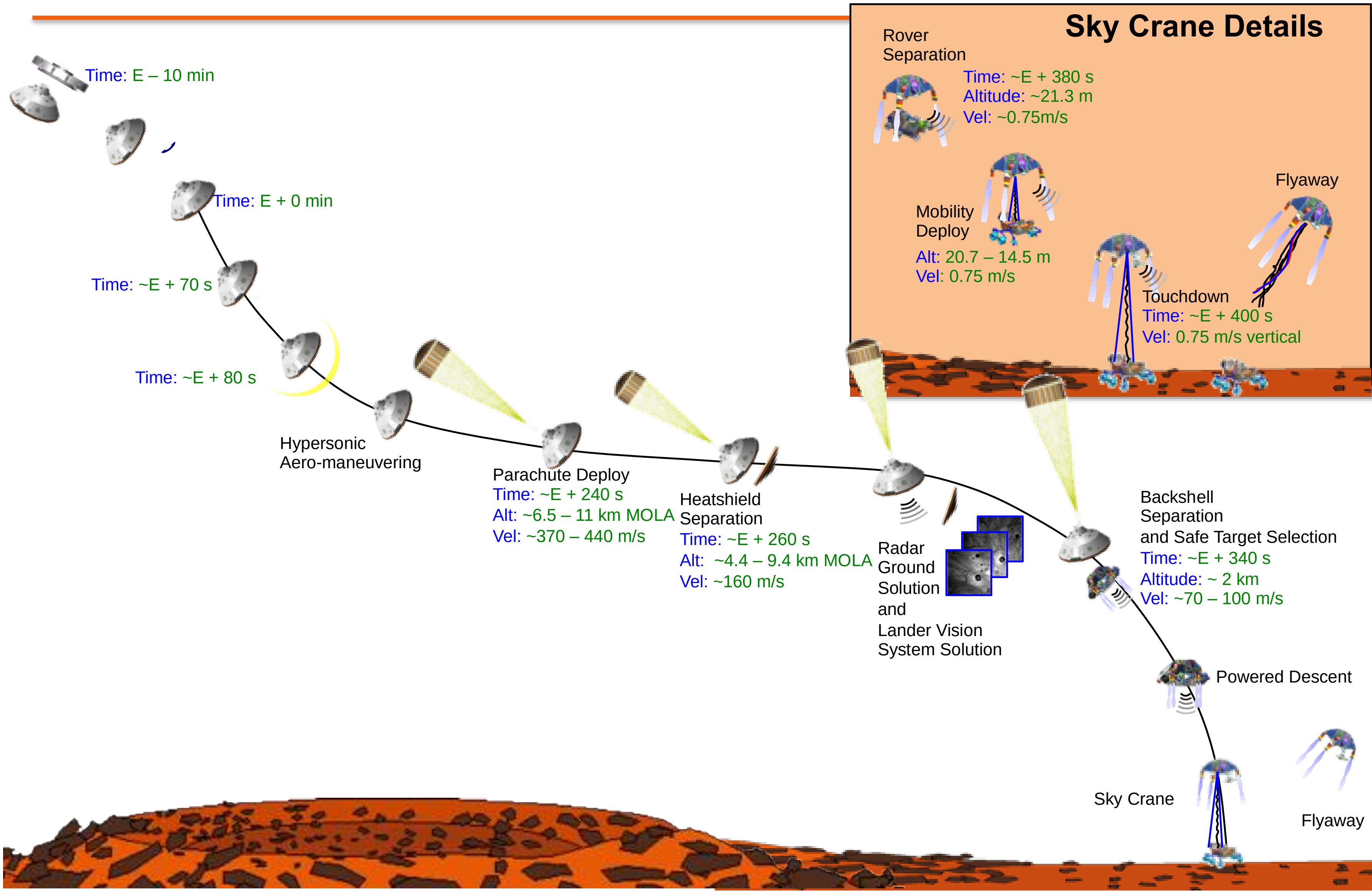
- MSL EDL System: guided entry, powered descent, and sky crane
- Augmented by ***range trigger***: 16 x 14 km landing ellipse
- Augmented by ***TRN***: enables safe landing at a greater number of scientifically valuable sites
- Access to landing sites ±30° latitude, ≤ - 0.5 km elevation
- Delivered a ~1050 kg rover safely

SURFACE MISSION

- Prime mission of 1.5 Mars years
- 20 km traverse distance capability
- Seeking signs of past life
- Returnable cache of samples
- Prepare for human exploration of Mars

Mars 2020 leverages the MSL design, residual hardware, and experienced team to reduce cost and risk; particularly in the EDL system

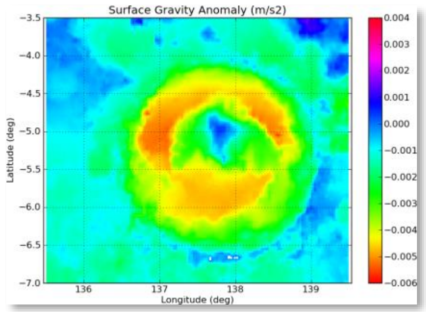
Mars 2020 EDL



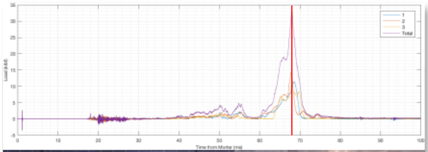
Reducing Risks from MSL

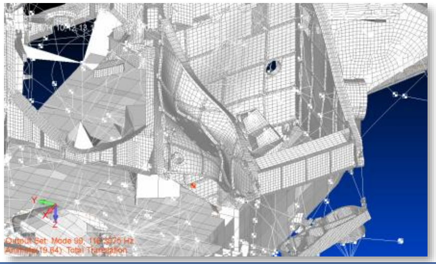
Site-Specific Gravity Modeling

- Inaccurate local gravity modeling caused a softer than expected touchdown for MSL
- Developed high fidelity terrain-implied gravity model
- Incorporate necessary software updates to utilize model



Parachute Deployment Induced Navigation Error

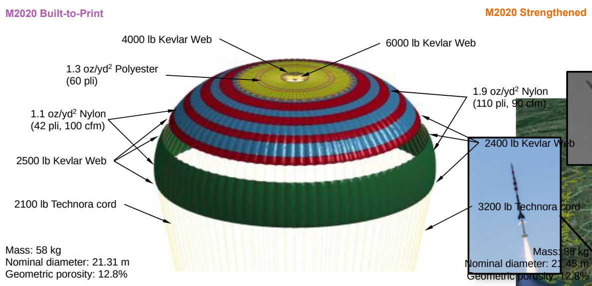


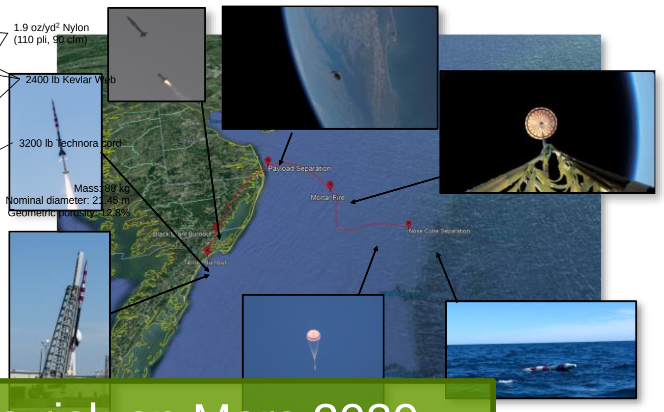


- Sabot and confluence fitting snatch induced a disturbance that caused the IMU to detect non-body rotational rates and accelerations
- Concerned about potential saturation and/or navigation errors
- Implementing mechanical mitigation options to reduce the disturbance input
- Developing GNC filtering option to mitigate the impact

Parachute Inflation Stress Risk Reduction

- The LDSD program revealed shortcomings in our understanding of supersonic inflations
- Key risk reduction activities:
  - Developed strengthened parachute
  - Supersonic test campaign in progress



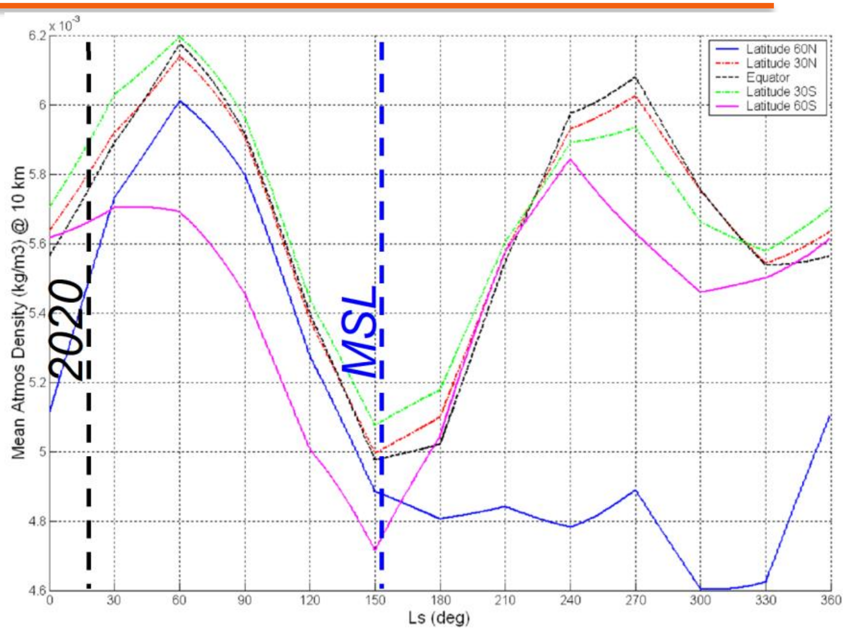


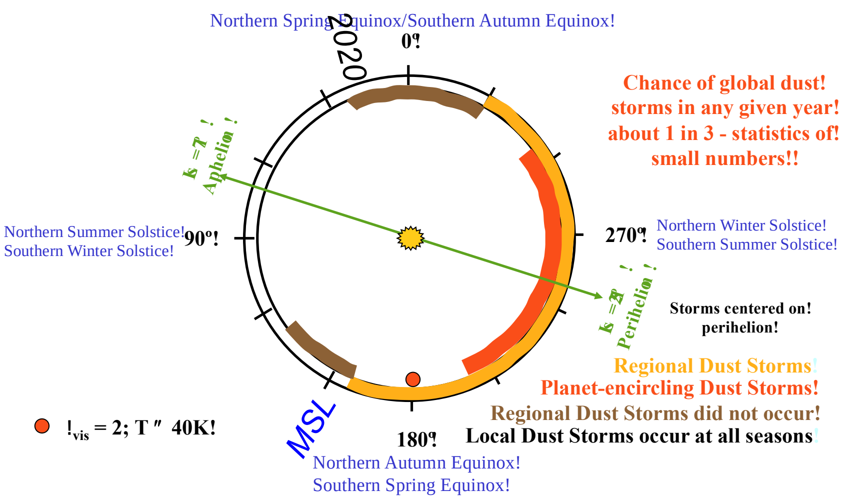
Applying lessons learned from MSL to reduce risk on Mars 2020

Successful Supersonic Parachute Test

2020: A Great Time to Go to Mars

- Pressure cycle very favorable for 2020 arrival season
  - Mars orbit eccentricity transfers CO_2 from polar caps to atmosphere
  - Atmosphere significantly more dense compared to MSL opportunity
  - Low risk of dust events
- More atmospheric density = more stopping power
- 2020 atmosphere provides significant "no cost" improvements to landing elevation for same landed mass
- Alternatively, can trade landing elevation improvement for increase in delivered mass



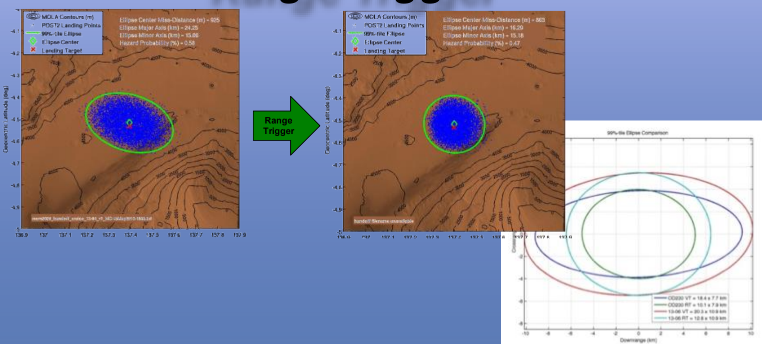


Jet Propulsion Laboratory
California Institute of Technology

New Capabilities for Mars 2020

Enables access to high priority landing sites

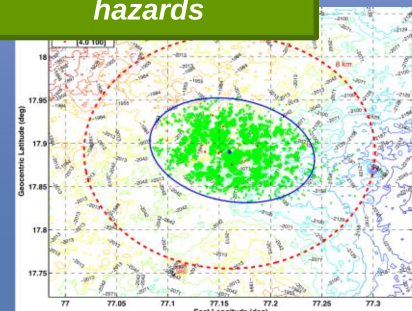
Range Trigger

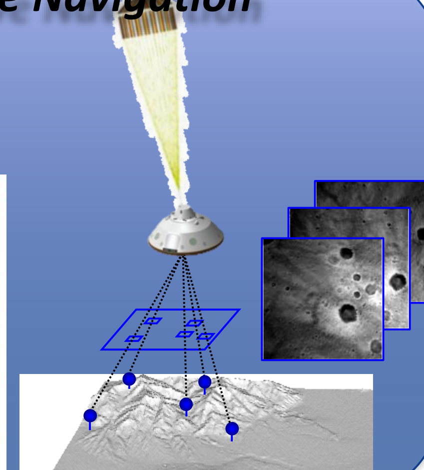


Range trigger shrinks the landing ellipse area by 40%

Terrain Relative Navigation

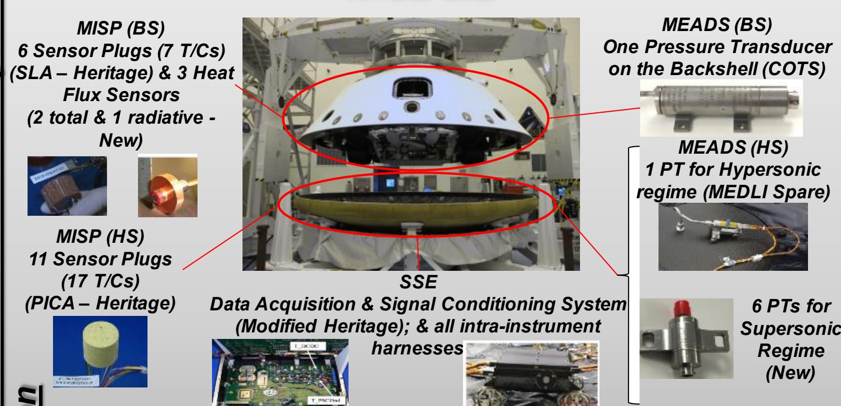
TRN gives Mars 2020 "eyes" to avoid identified landing hazards





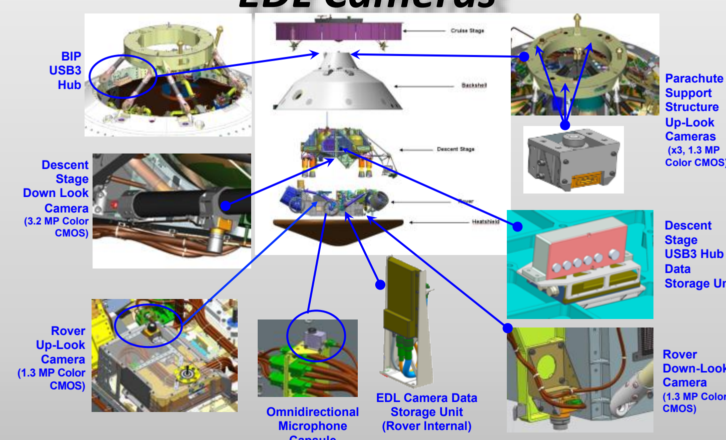
Collect data to see the EDL system in action

MEDLI2



Builds upon MEDLI with new backshell observations and supersonic pressure measurements

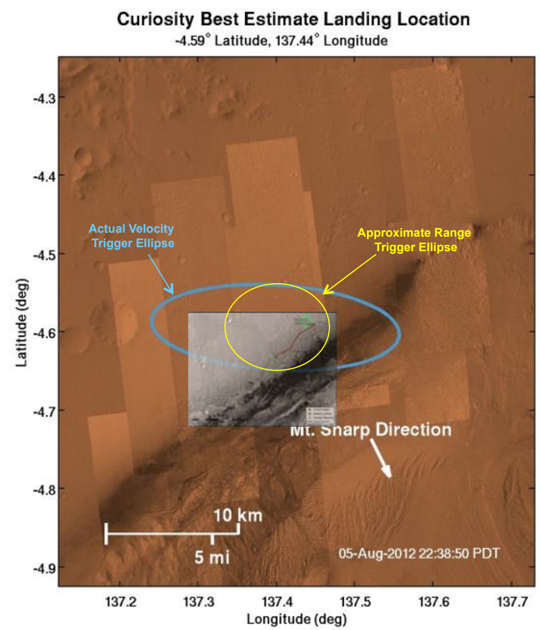
EDL Cameras

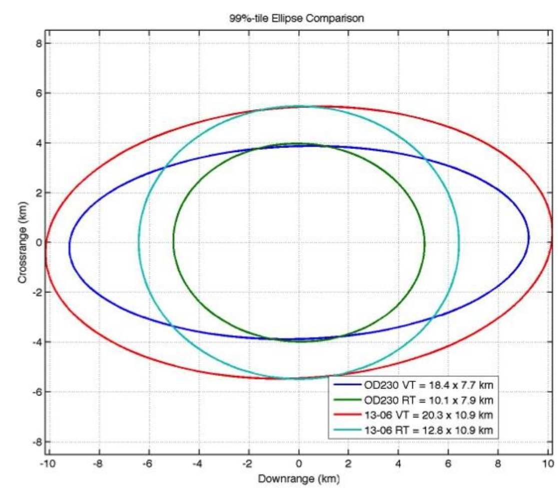


High resolution, high frame rate parachute, descent stage downlook, and rover up and downlook cameras

Range Trigger Increases Landing Precision

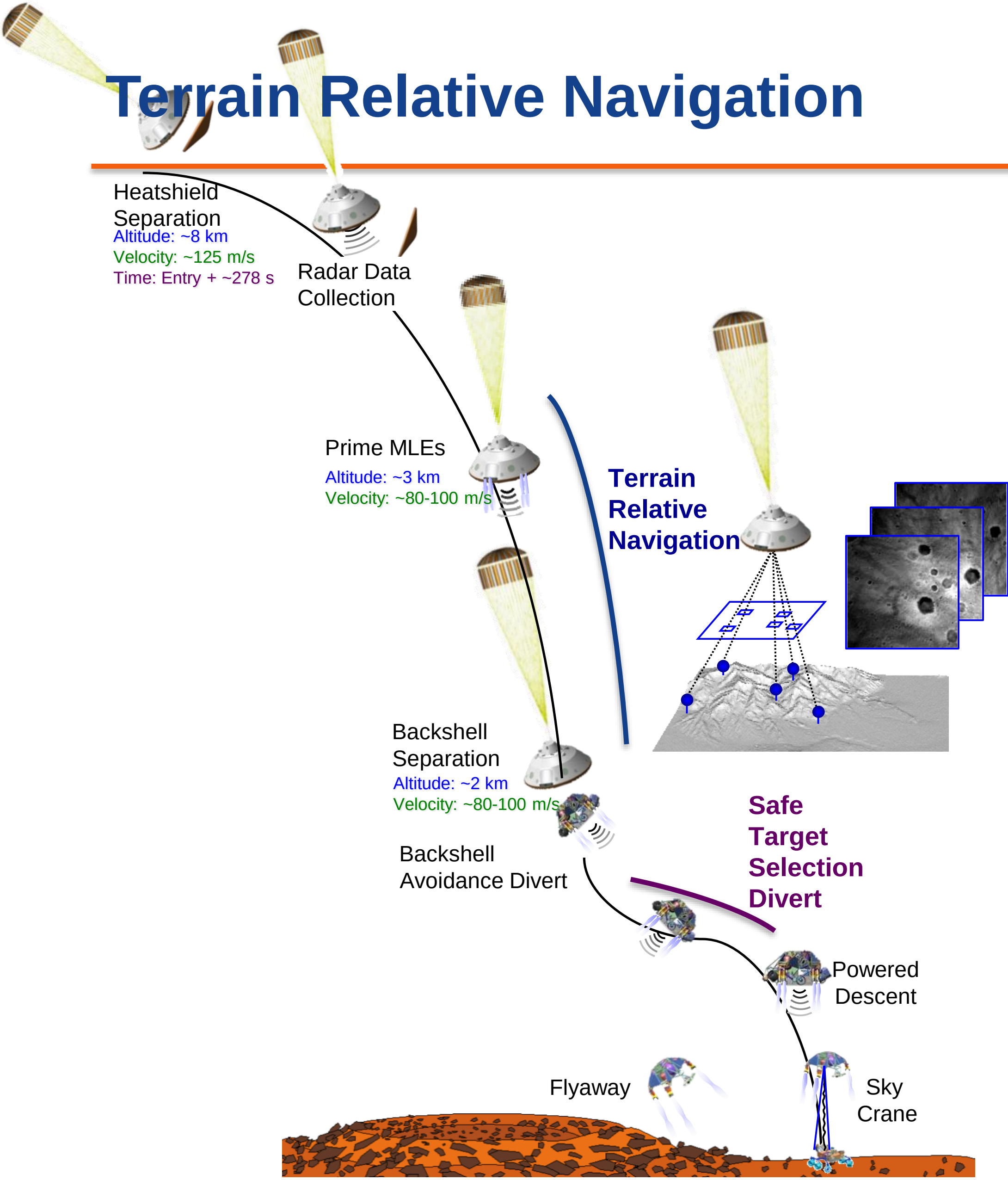
- **Range trigger deploys the parachute based on navigated range instead of navigated velocity**
- **Using range trigger significantly shrinks the landing ellipse**
- **Key benefits:**
  - Makes previously inaccessible landing sites accessible
  - Could save ~1 Earth year of driving
- **Range trigger is not a new idea**
  - Originally considered for MSL
  - After MSL landing, more comfortable with guided entry performance





Jet Propulsion Laboratory
California Institute of Technology

Terrain Relative Navigation



Terrain Relative Navigation

- Takes images during parachute descent and matches them to an onboard map
  - Uses a dedicated computer and camera
  - Yields a position solution
- Performs terrain relative navigation while the spacecraft is priming the descent engines
- Executed by the Lander Vision System (LVS)

Safe Target Selection

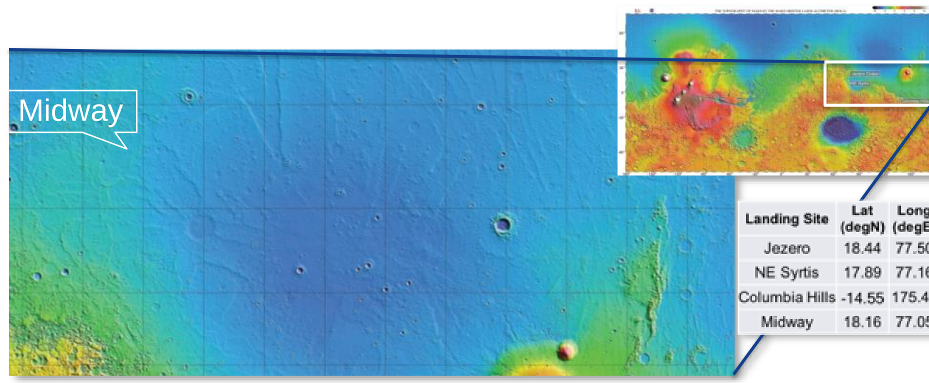
- Uses position solution and list of safe landing locations to select a safe landing target
- Augments original MSL backshell avoidance divert
- Lives within MSL fuel and control constraints
- Not “pinpoint” landing

TRN gives Mars 2020 “eyes” to avoid identified landing hazards

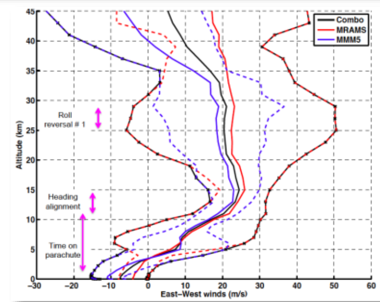
Jet Propulsion Laboratory
California Institute of Technology

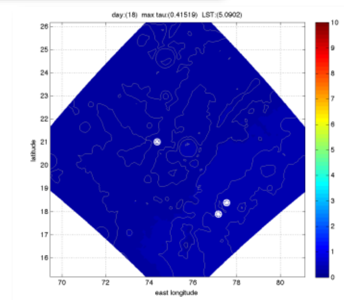
Challenging Landing Sites

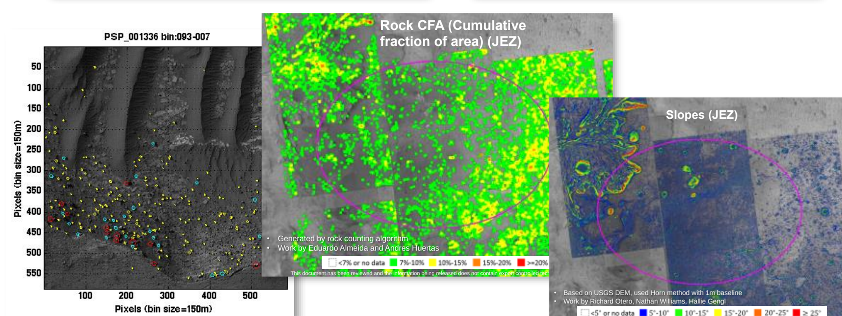
- Three of the final four Mars 2020 landing sites were deemed unsafe for MSL
- The addition of range trigger and TRN enable safe landing at these sites
  - Can now avoid dangerous rock fields, slopes, and inescapable hazards
  - Science targets can now be located within the landing ellipse, significantly expediting the landed mission
- Terrain and atmosphere characterization efforts nearing completion
- Ready to support final site selection in the fall



Landing Site	Lat (degN)	Long (degE)	Approx Elev (km)
Jezero	18.44	77.50	-2.64
NE Syrtis	17.89	77.16	-2.04
Columbia Hills	-14.55	175.45	-1.95
Midway	18.16	77.05	-2.00







EDL enhancements enable Mars 2020's science objectives

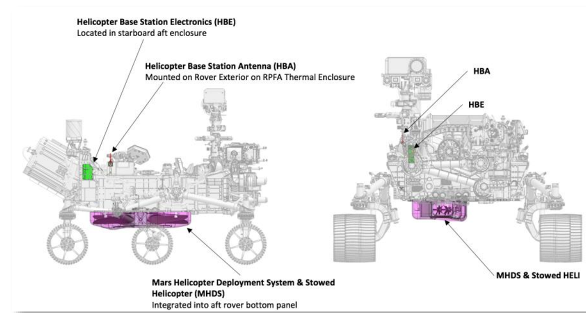
Current Development Status Highlights

- Hardware deliveries flowing in throughout this year

- Residual heatshield from MSL failed static test
  - Differed from heatshield flown by MSL
  - Failure root cause under investigation
  - No damage to the backshell
  - Building a replacement heatshield for flight
  - No resulting schedule impact

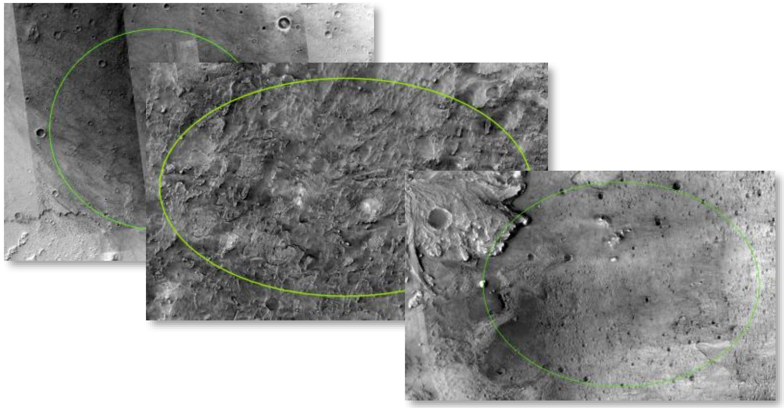
- Helicopter now part of the project baseline
  - Increases chance of belly pan strike at landing due to reduced ground clearance
  - Decision to include the helicopter informed by EDL risk analysis

- Integration and test has begun
  - Descent stage and cruise stage nearly complete
  - Vast majority of avionics delivered or near delivery



Jet Propulsion Laboratory
California Institute of Technology

Key EDL Challenges Remaining



2018

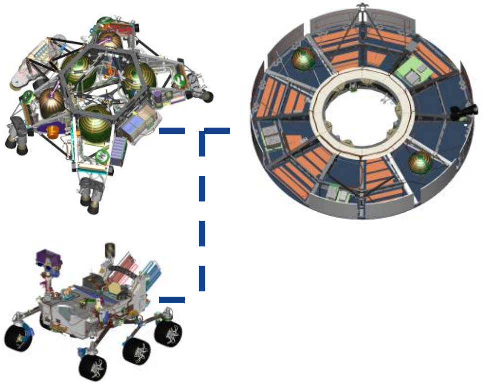
- Landing site safety assessment in support of final landing site selection
- Completion of parachute inflation stress supersonic risk reduction testing
- Resolution of parachute induced IMU disturbance issue
- Verification and validation of the EDL FSW behavior

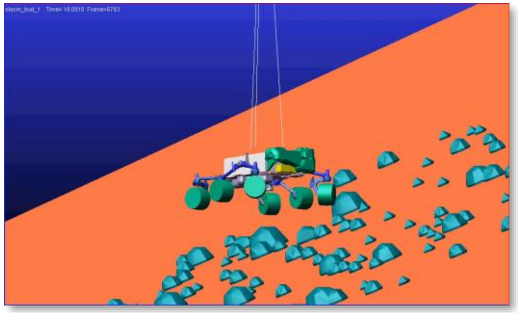
2019

- EDL system tests on the flight vehicle
- Verification and validation of the spacecraft interactions with the Martian environment
- Operations preparation

2020

- Stress testing
- Operations verification and validation
- Risk review and launch





Summary

- Mars 2020's EDL system builds upon MSL's successful EDL system
  - Given the opportunity to fix things we learned about on MSL
  - Extended our landing capability with key additions to the system

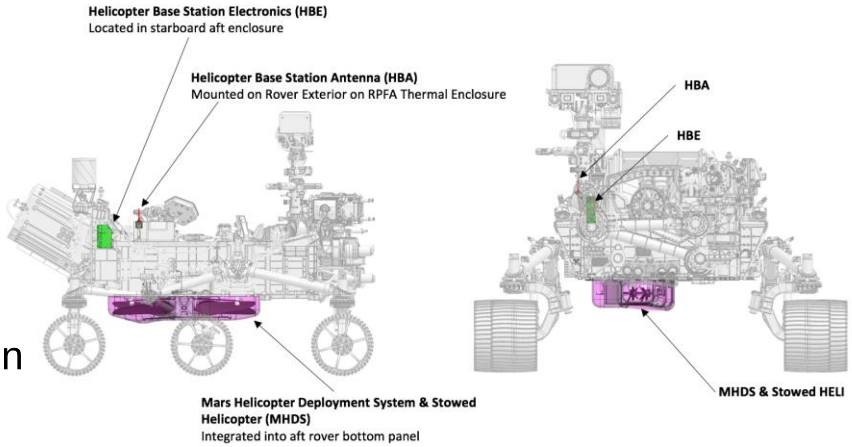
- Mars 2020 EDL development remains on track
  - Landing site safety assessment process nearing completion
  - Hardware is being delivered for integration
  - Deep into our verification and validation campaign and system test preparation
  - Parachute risk reduction efforts in progress; so far so good

- 969 days until landing!

Backup

Mars Helicopter

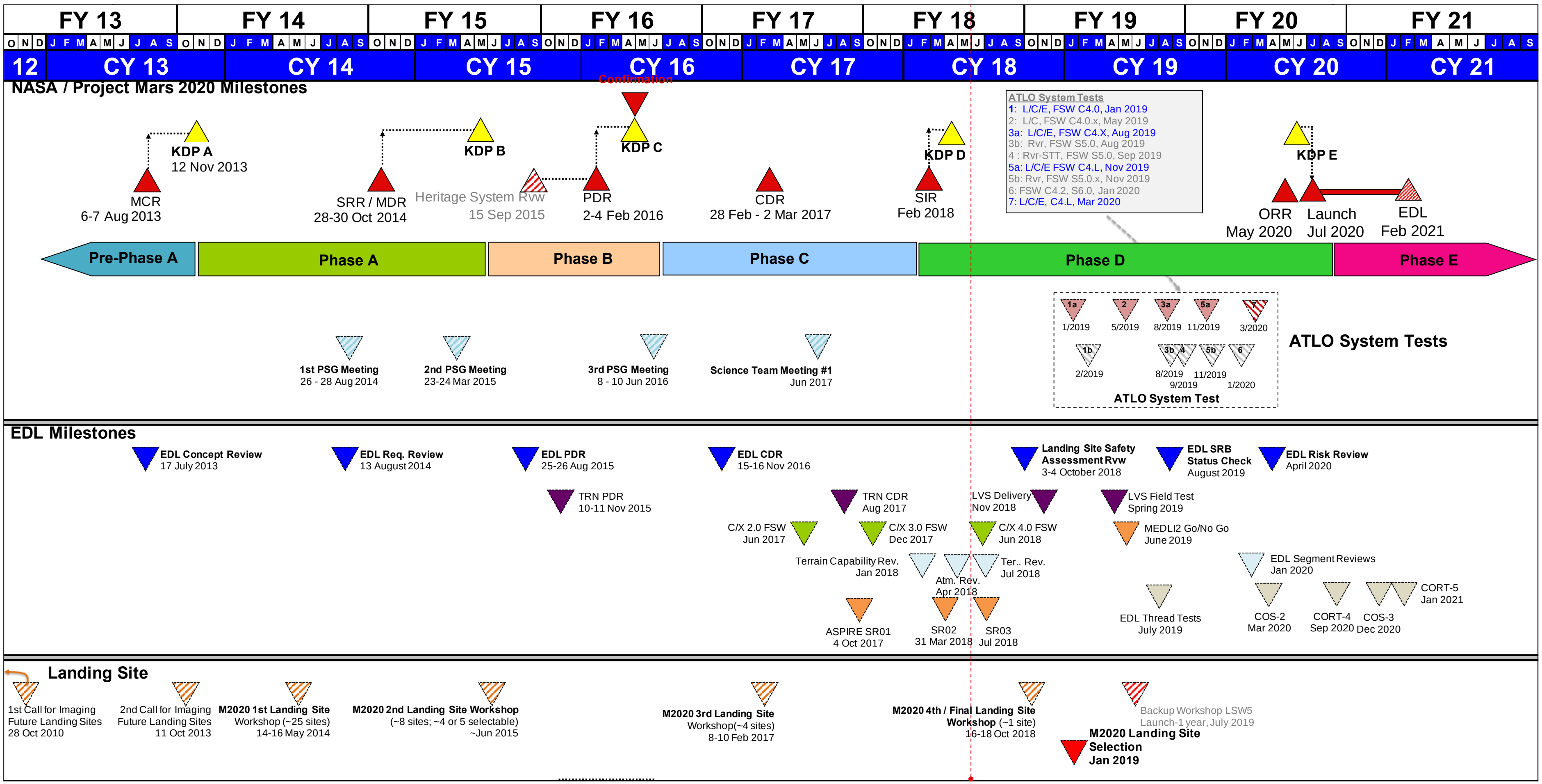
- Mars Helicopter is now officially part of the Mars 2020 Mission
- Overview:
  - Mass: ~1.8kg
  - Approx. 1.1m x 0.25m x 0.02m
  - Dual counter-rotating blades (L = 1.21m)
  - Solar powered with lithium-ion battery
  - B&W camera for nav; color camera for terrain



- Concept of Operations
  - The helicopter will be “dropped off” at a relatively flat location.
  - 5 tech demo flights in 30-sol period of 30-120 sec each
- EDL Impact: due to its location, the helicopter increases the risk due to a rock strike by ~0.5-1%

Credits: NASA/JPL-Caltech

High Level Schedule



Key activities

- 2018:
  - EDL FSW V&V
  - Landing site selection
  - Parachute risk reduction
- 2019:
  - Systems tests
  - EDL functional certification V&V
  - Operations planning
- 2020:
  - Stress testing
  - Operations V&V
  - Risk review