

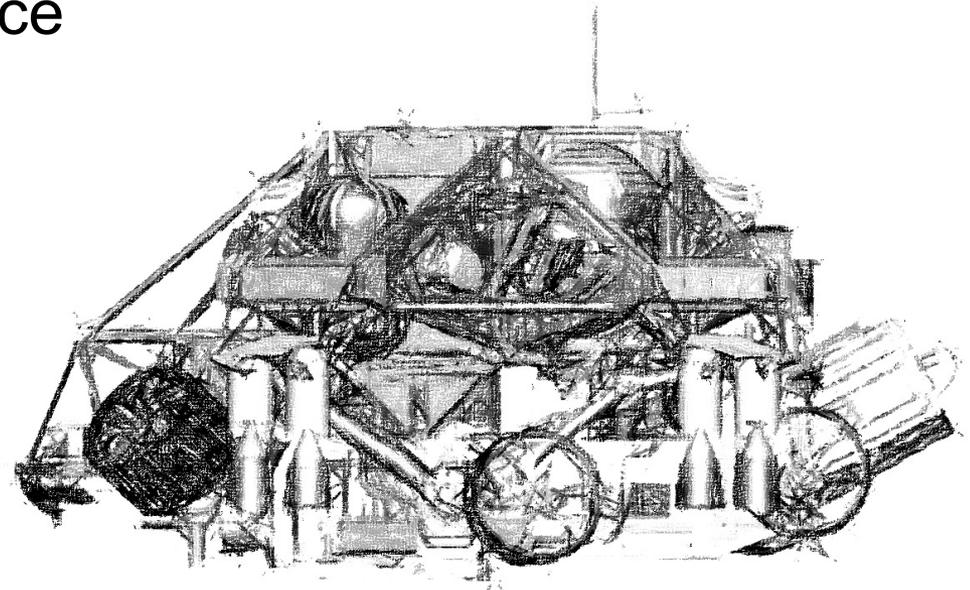


# Mars 2020 Entry, Descent, and Landing System Overview

## 2019 Aerospace Conference

Big Sky, MT  
March 4, 2019

Adam Nelessen, Chloe Sackier, Ian Clark, Paul Brugarolas, Gregorio Villar, Allen Chen, Aaron Stehura, Richard Otero, Erisa Stilley, David Way, Karl Edquist, Swati Mohan, Cj Giovingo, Mallory Lefland





# Mars 2020 Mission Overview

2019 • IEEE Aerospace Conference



## 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**: 7.1 x 6.5 km landing ellipse
- Augmented by **TRN**: enables safe landing at a greater number of scientifically valuable sites
- Access to landing sites  $\pm 30^\circ$  latitude,  $\leq -0.5$  km elevation
- Deliver a ~1050 kg rover safely

## SURFACE MISSION

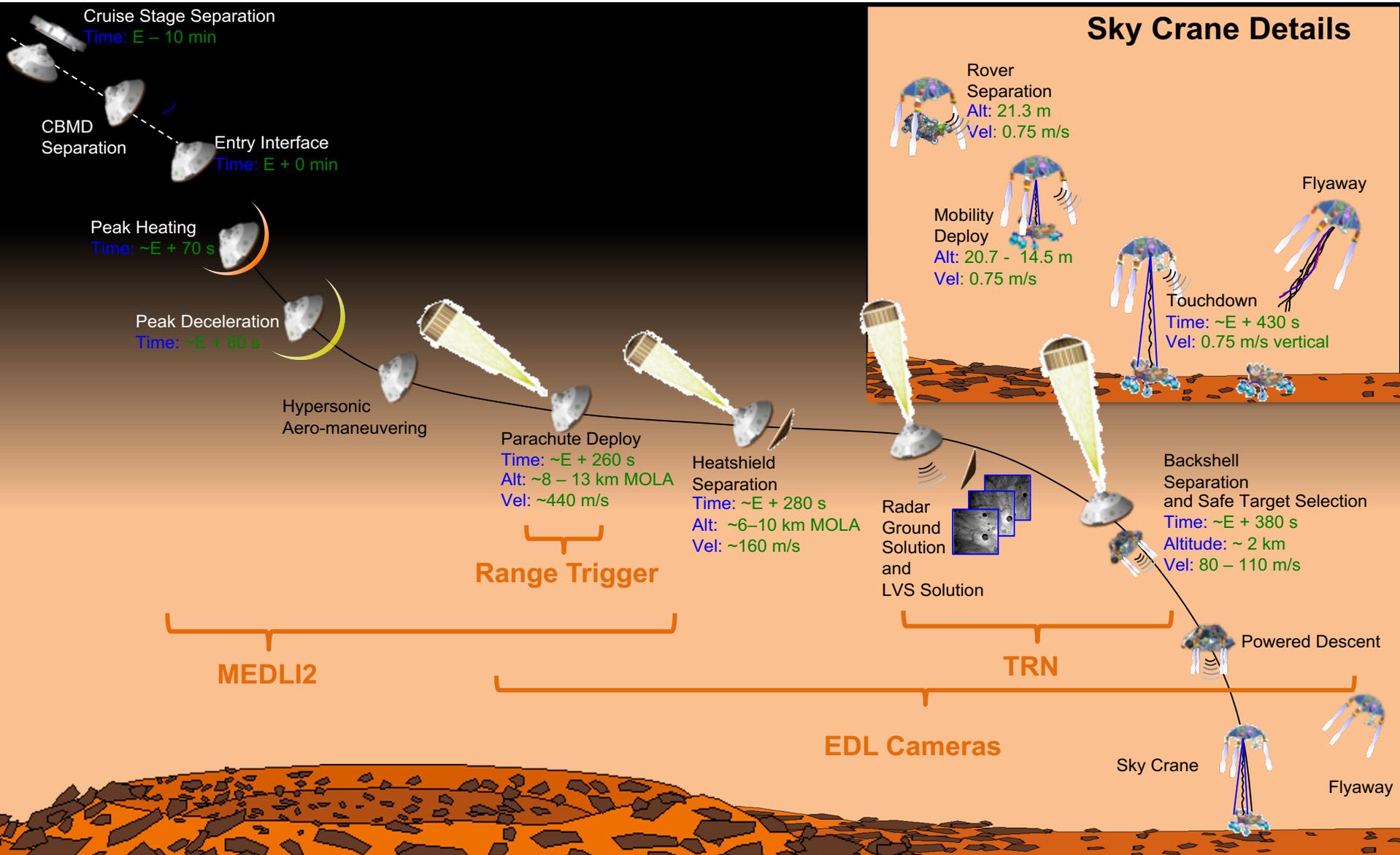
- Prime mission of 1.5 Mars years
- 20 km traverse distance capability
- Seeking signs of past life
- Returnable cache of samples
- Prepare for human exploration of Mars

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

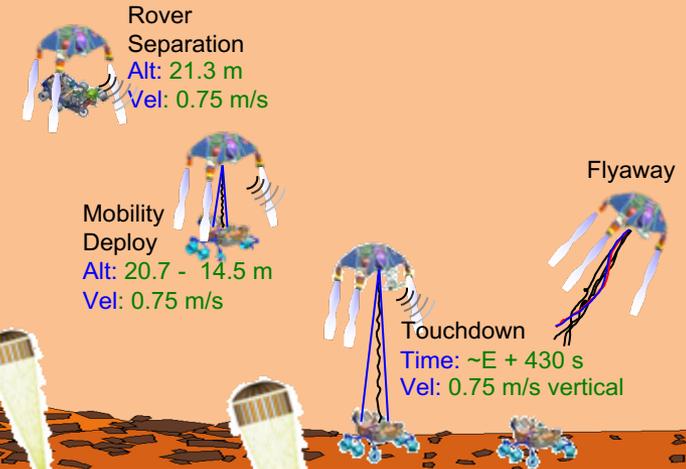


# EDL Timeline

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## Sky Crane Details

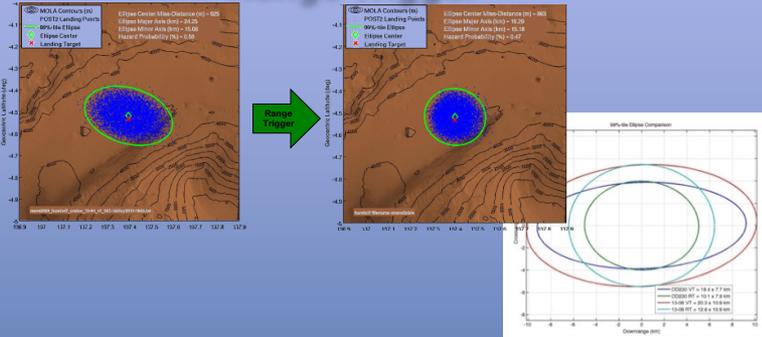


# New Capabilities for Mars 2020

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Enables access to high priority landing sites

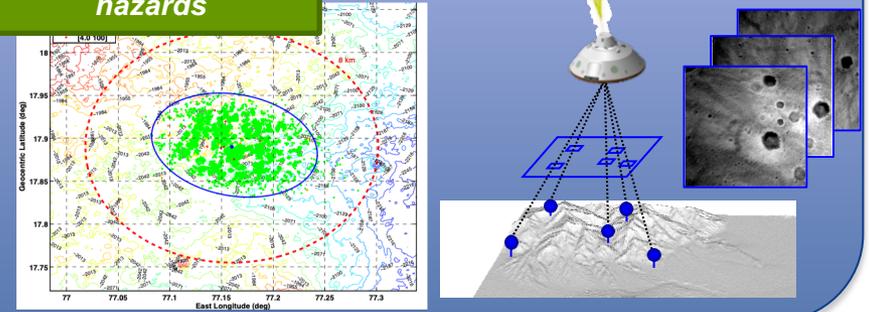
## Range Trigger



Range trigger shrinks the landing ellipse area by 40%

## Terrain Relative Navigation

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



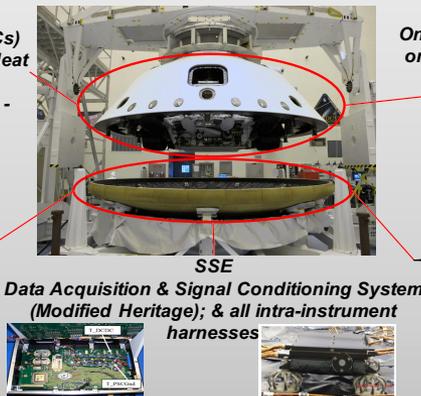
Collect data to see the EDL system in action

## MEDLI2

MISP (BS)  
6 Sensor Plugs (7 T/Cs)  
(SLA – Heritage) & 3 Heat Flux Sensors  
(2 total & 1 radiative - New)



MISP (HS)  
11 Sensor Plugs  
(17 T/Cs)  
(PICA – Heritage)



MEADS (BS)  
One Pressure Transducer on the Backshell (COTS)



MEADS (HS)  
1 PT for Hypersonic regime (MEDLI Spare)

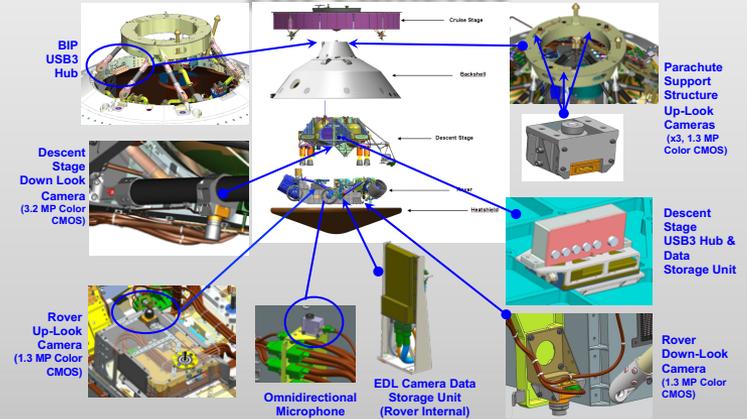


6 PTs for Supersonic Regime (New)



Builds upon MEDLI with new backshell observations and supersonic pressure measurements

## EDL Cameras



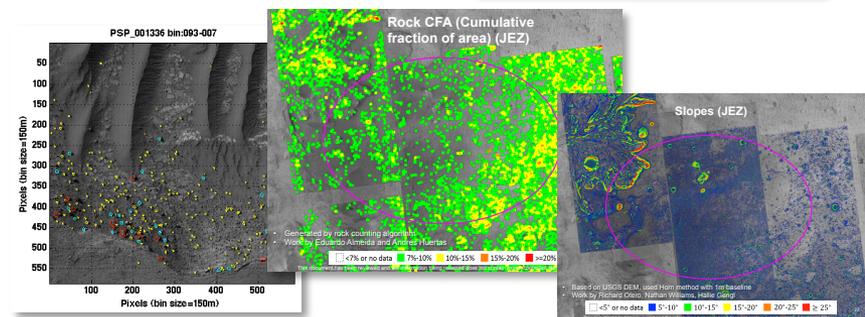
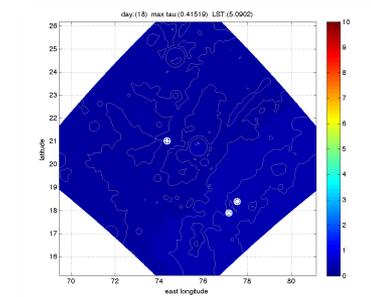
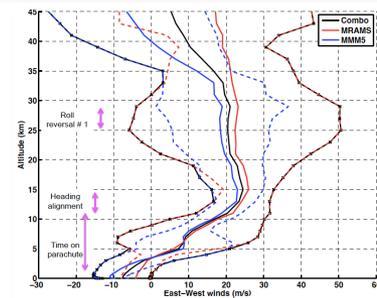
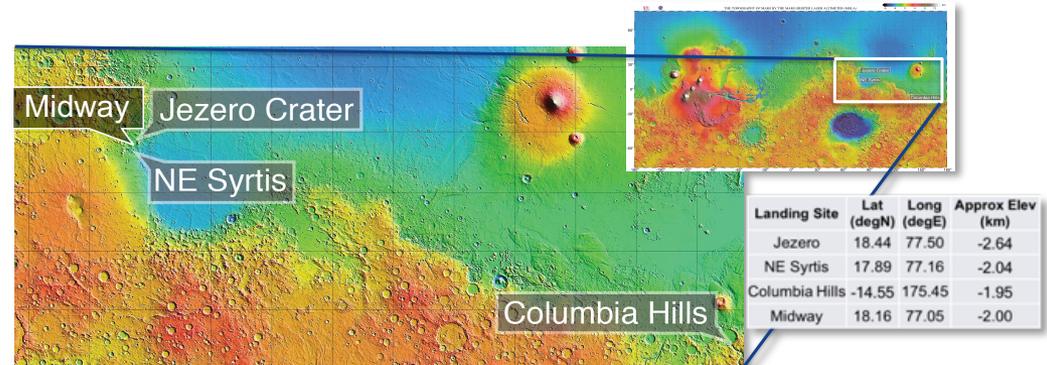
High resolution, high frame rate parachute, descent stage downlook, and rover up and downlook cameras



# Challenging Landing Sites

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- Three of the final four candidate 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
- Supported final site selection in Fall 2018 - Jezero Crater



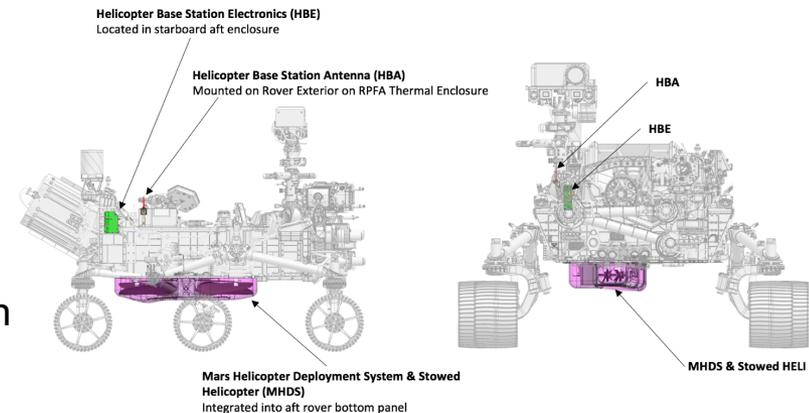
EDL enhancements enable Mars 2020's science objectives

# Mars Helicopter

- Mars Helicopter is now officially part of the Mars 2020 Mission

- Overview:

- Mass: ~1.8kg
- Dual counter-rotating blades
- 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 30-90 sec each

- EDL Impact: due to its location, the helicopter increases the risk due to a rock strike by ~0.5-1%



# Current Development Status Highlights

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- Hardware deliveries flowing in throughout this year
- Residual heatshield from MSL failed static test
  - Differed from heatshield flown by MSL
  - Building a replacement heatshield for flight
  - No resulting schedule impact
- Integration and test is well underway
  - Descent stage and cruise stage nearly complete
  - Vast majority of avionics delivered or near delivery
  - Two successful system-level EDL tests on flight hardware have been completed





# Summary

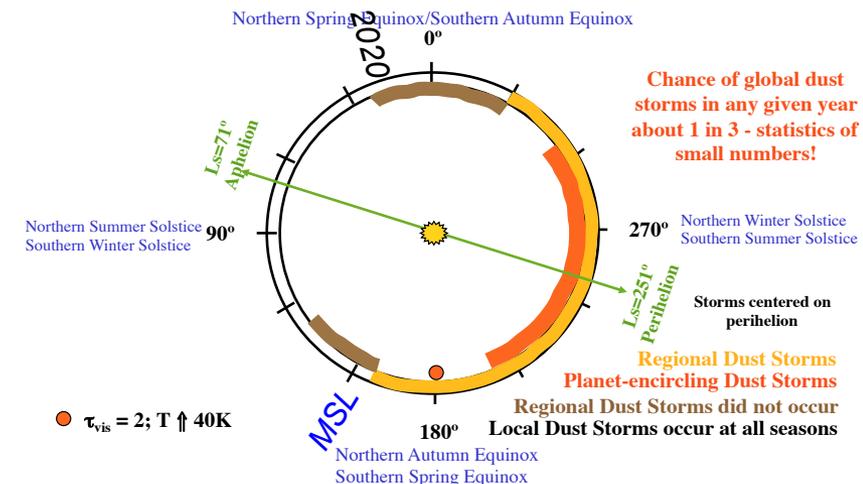
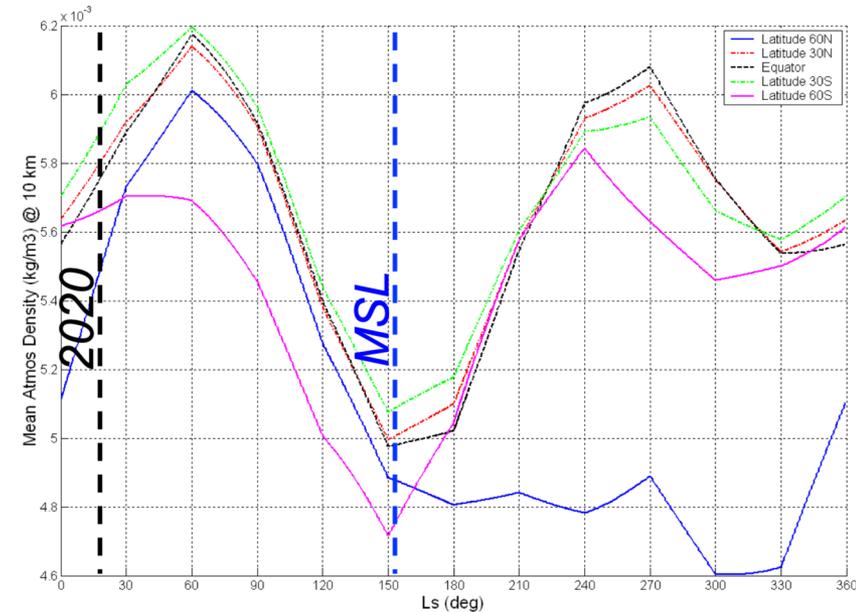
- Mars 2020's EDL system builds upon MSL's successful EDL system
  - Given the opportunity to improve upon things we learned about MSL
  - Extended our landing capability with key additions to the system
  
- Mars 2020 EDL development remains on track
  - Jezero Crater selected for landing site
  - Hardware is being delivered for integration
  - Deep into our verification and validation campaign and system testing
  - Parachute risk reduction efforts successfully completed
  
- 717 days until landing!

# Backup

# 2020: A Great Time to Go to Mars



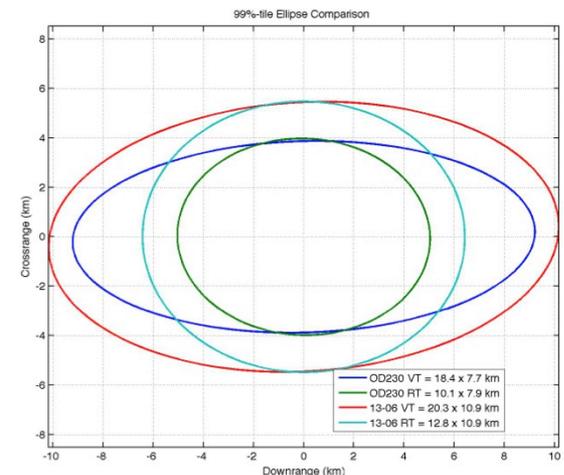
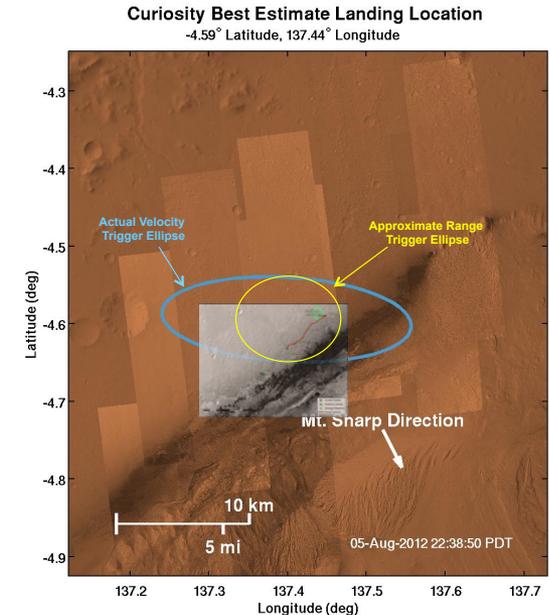
- Pressure cycle very favorable for 2020 arrival season
  - Mars orbit eccentricity transfers CO<sub>2</sub> from polar caps to atmosphere
  - Atmosphere significantly more dense compared to MSL opportunity
  - Low risk of dust events
  
- More atmospheric density = more stopping power
  
- 2020 atmosphere provides significant “no cost” improvements to landing elevation for same landed mass
  
- Alternatively, can trade landing elevation improvement for increase in delivered mass



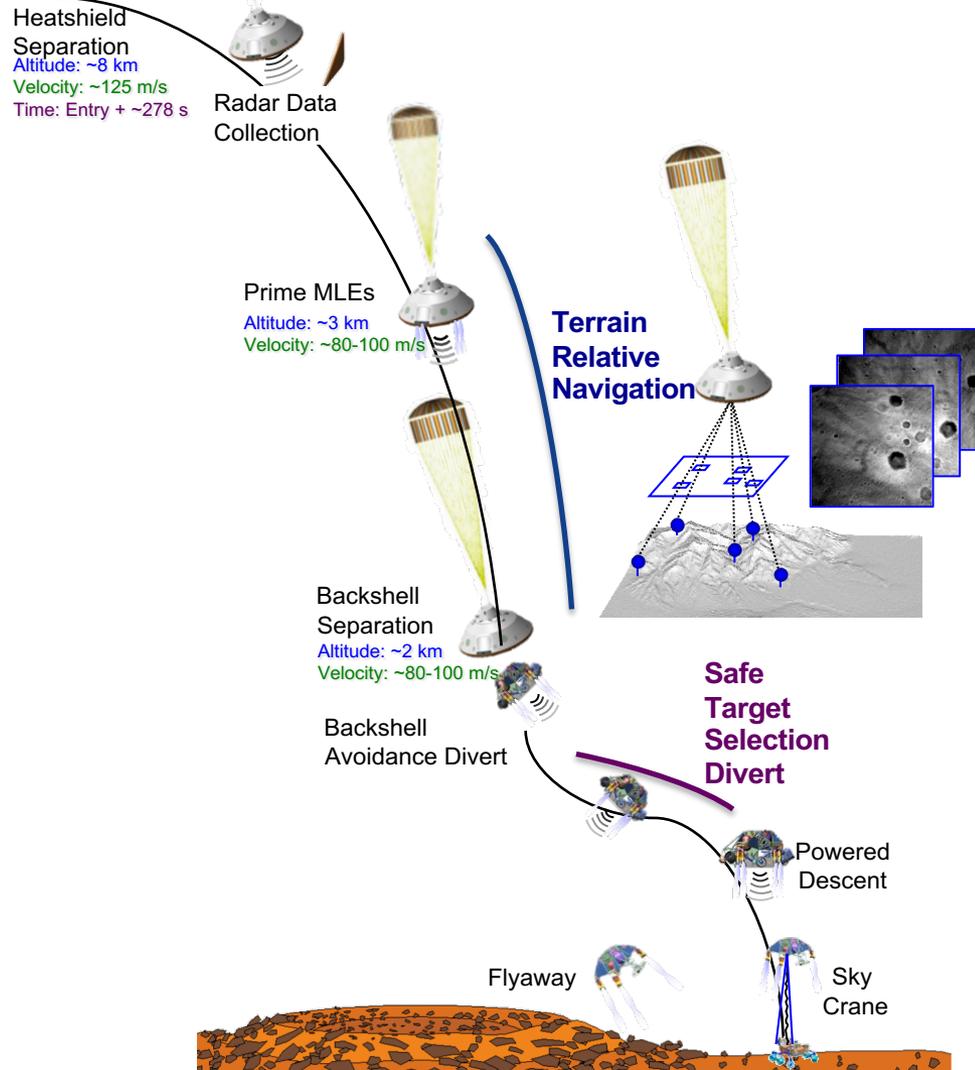
# Range Trigger Increases Landing Precision



- 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
  - See Dave Way's IEEE paper of the year from 2011 for more details



# 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**

# TRN Development Status

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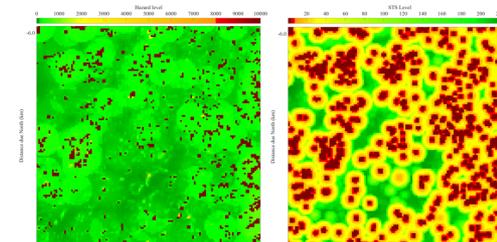
- Terrain Relative Navigation (TRN), Vision Compute Element (VCE), and VCE SW design reviews are complete
- Design has matured and hardware and software deliveries are in progress
  - VCE engineering dev units (EDU) delivered; EM and FM builds are in progress; LVS Camera (LCAM) EM1 delivered
  - Box-level software design is ongoing and expected to be part of 2019 field test
  - System-level software design is finalized and being tested
- Monte Carlo simulations have exercised the TRN capability using a Safe Targets Map (STM) and generated successful landing metrics based on the hazard map
- Delivered to ATLO December 2018
- ATLO functional testing occurred Jan 2019
- Field testing occurred Feb 2019



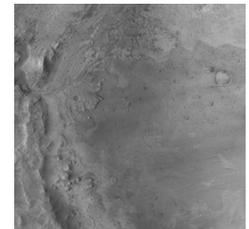
LCAM EM1 calibration image



VCE EDU4 FPGA Card



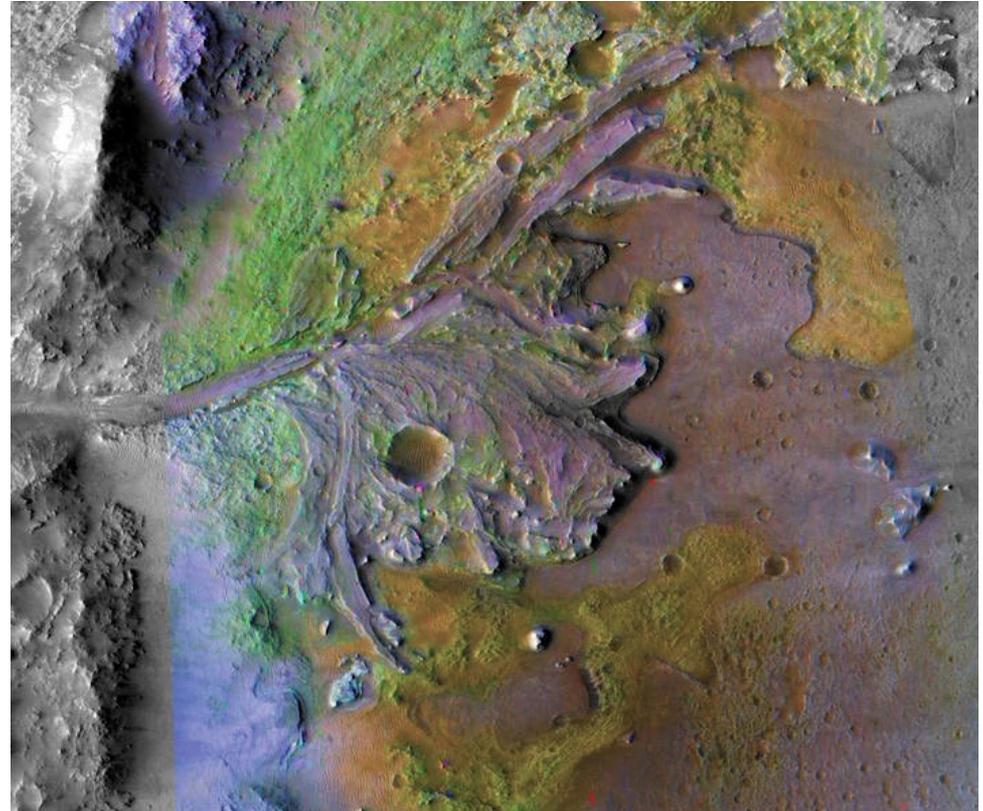
Jezero site: hazard map vs. STM



Jezero Mosaic, example of onboard appearance map for TRN

# Selected Landing Site: Jezero Crater

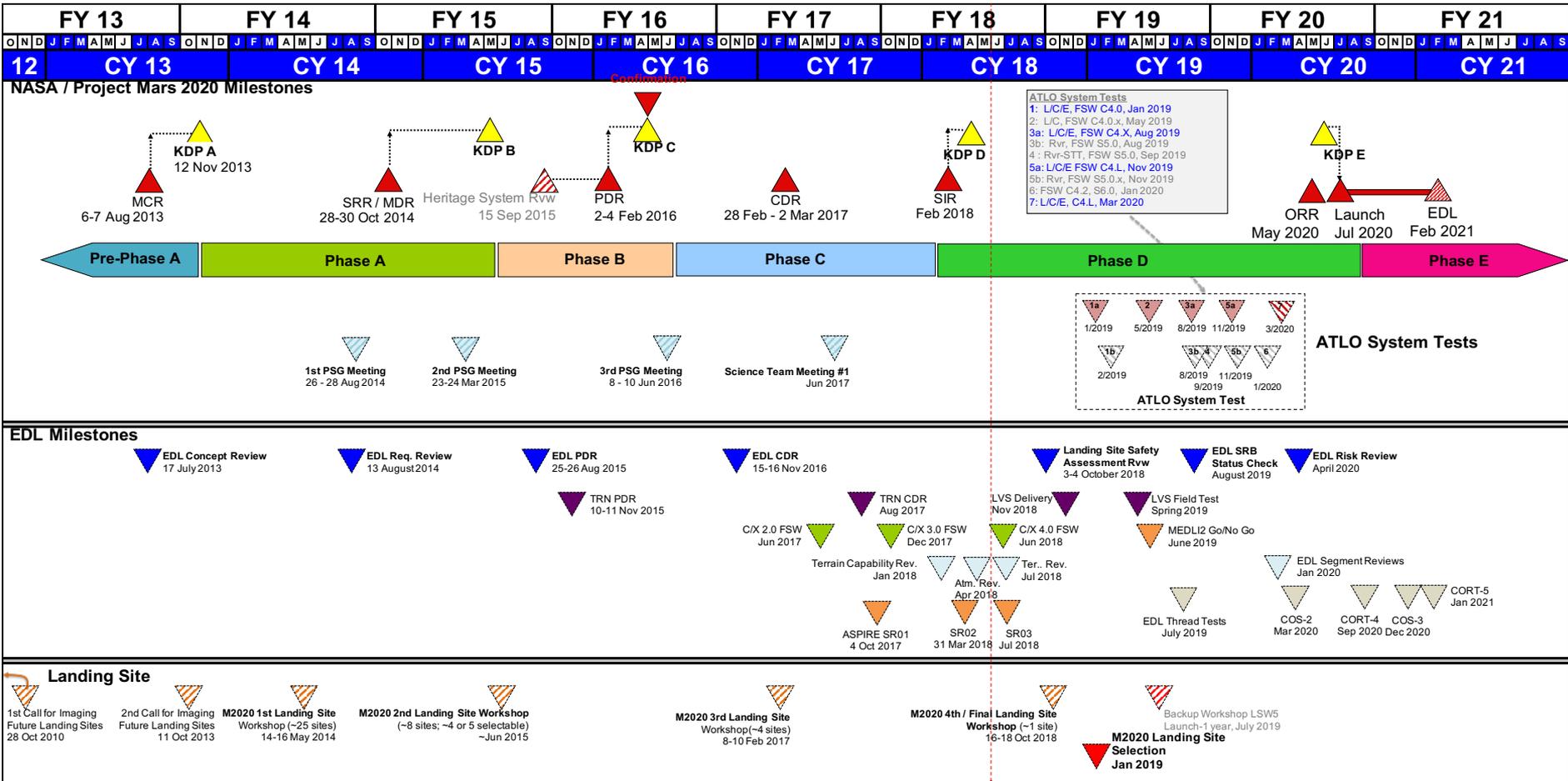
- In November 2018, Jezero Crater was selected as the Mars 2020 landing site
- An ancient river delta, Jezero offers diverse geologic features with high biosignature preservation potential
- Due to the numerous hazards, this site selection was enabled by new Mars 2020 capabilities such as TRN and range trigger





# High Level Schedule

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## Key activities

☐ 2018:

- EDL FSW V&V
- Landing site selection
- Parachute risk reduction

☐ 2019:

- Systems tests
- EDL functional certification V&V
- Operations planning

☐ 2020:

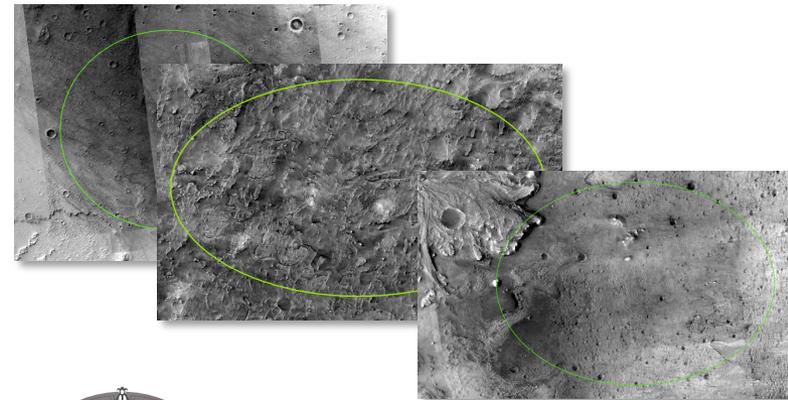
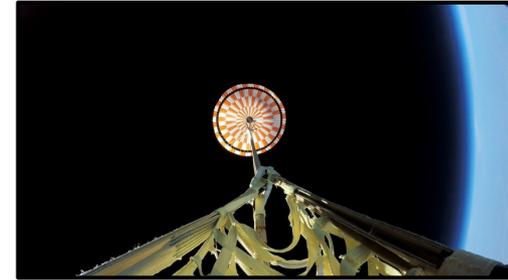
- Stress testing
- Operations V&V
- Risk review

# Key EDL Work to Go

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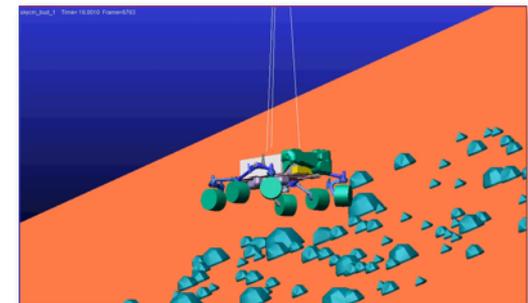
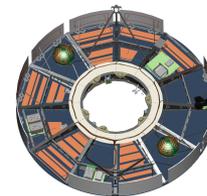
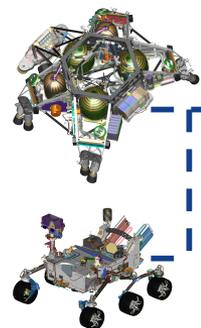
## 2019

- EDL system tests on the flight vehicle
- Verification and validation of the flight dynamics
- Operations preparation



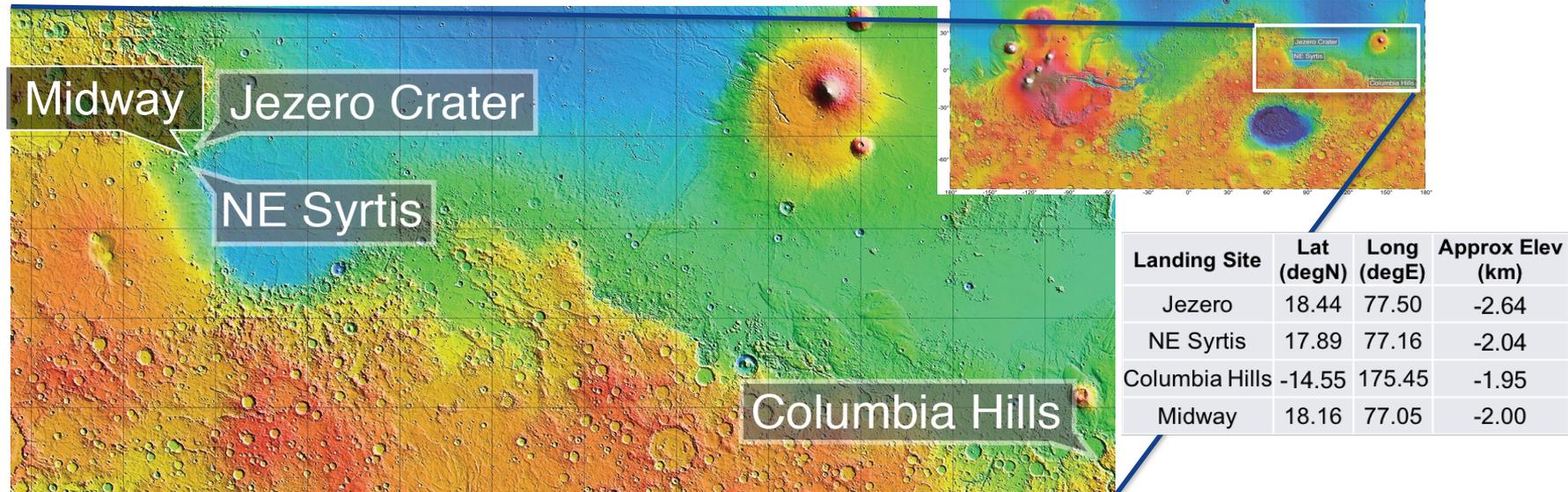
## 2020

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



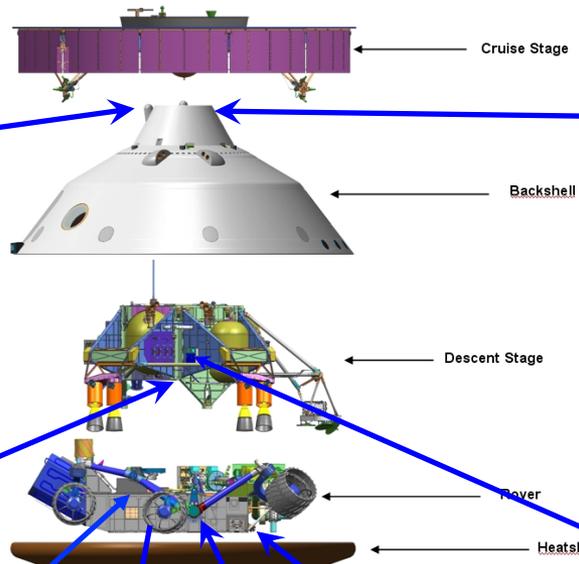
# Landing Site Selection

- A fourth candidate site, Midway, has been added for evaluation by the engineering and science teams
- Terrain and Atmosphere reviews completed in the past year; several improvements to rock identification have been incorporated
- EDL is currently evaluating landing site safety in support of the 4th landing site workshop this Fall, with final site selection expected in early 2019 by NASA HQ
- All sites are expected to have acceptable risk

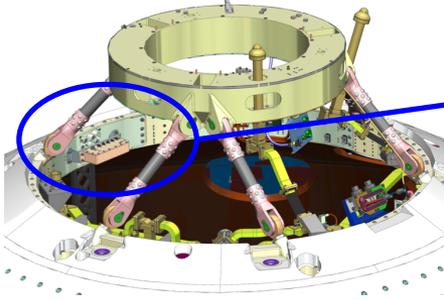




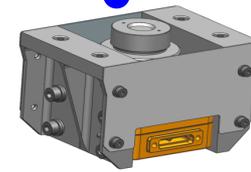
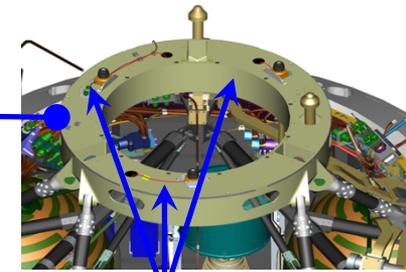
# EDL Camera Overview



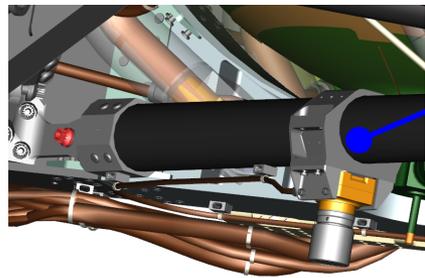
**BIP  
USB3  
Hub**



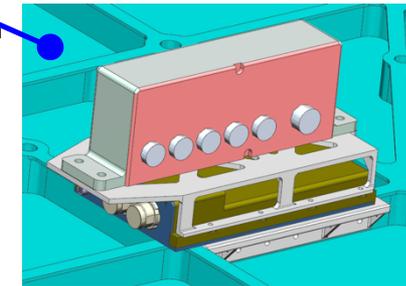
**Parachute  
Support  
Structure  
Up-Look  
Cameras  
(x3, 1.3 MP  
Color CMOS)**



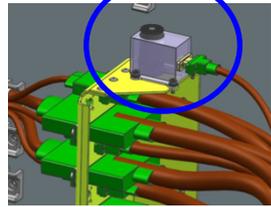
**Descent  
Stage  
Down Look  
Camera  
(3.2 MP Color  
CMOS)**



**Descent  
Stage  
USB3 Hub &  
Data  
Storage Unit**

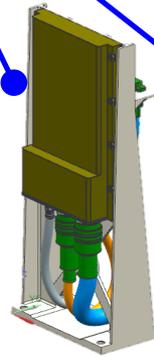


**Rover  
Up-Look  
Camera  
(1.3 MP Color  
CMOS)**



**Omnidirectional  
Microphone  
Capsule**

**EDL Camera Data  
Storage Unit  
(Rover Internal)**



**Rover  
Down-Look  
Camera  
(1.3 MP Color  
CMOS)**

