Mars Exploration Program Discussions

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11/6-7/17

Mars Exploration Program Science Goals

Life

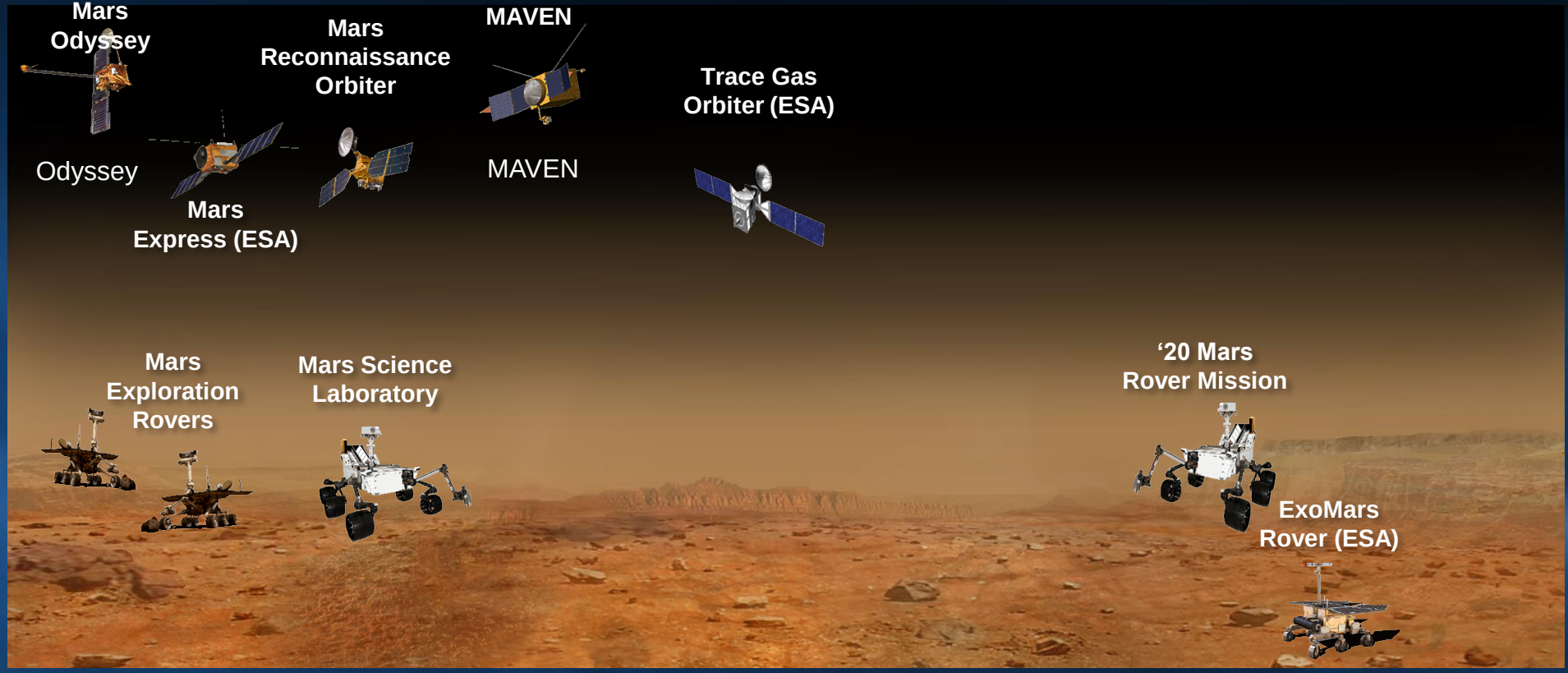
Climate

Geology & Geophysics

Prepare for Human Exploration

Mars Exploration Program Missions

2001 - 2015 | 2016 | 2018 | 2020 | Future Mars Missions



Summary of ~2 decades of Program achievements

Key science findings

- Presence of liquid water on ancient Mars
- Evidence of habitable environment on ancient Mars
- Subsurface ice and validation
- Measurement of atmospheric loss points to much thicker ancient atmosphere
- Long-lived missions show climate trends and changing phenomena on Mars today

Engineering and science capabilities

- Rover evolved from Sojourner (~ 11 kg) to Curiosity (~900 kg)
- Ability to land safely with improving landing accuracy
- Orbital and surface operation know-how enabled driving a Marathon distance on Mars
- Global mapping @ 6m/pixel; even higher resolution local mapping @ 0.3 m/pixel resolution
- High data volume returned via telecom network from orbit, with orbital relay 10-100 times better than direct-to-earth
- Capability for sample acquisition and *in situ* sample analysis

Inspiration of people worldwide

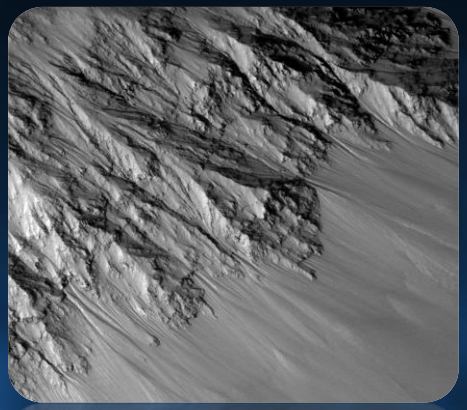
- Mars rover landings followed worldwide
  - “Seven minutes of terror” video transformed an engineering operation into a human message
- Strong following on social media
- Public fascination with missions, rover operations and science findings

Mars Exploration Program Highlights

Opportunity: Journey to Perseverance Valley

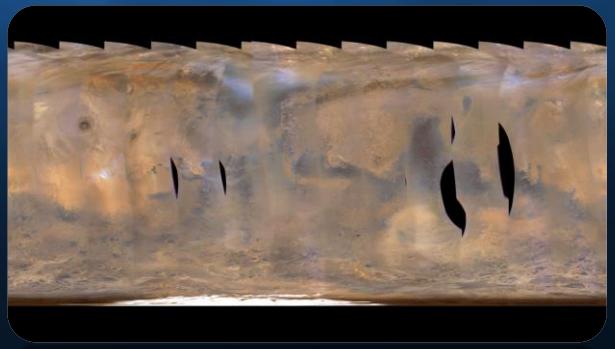
MRO: >50,000 orbits Completed Global 6m Resolution Imagery

MRO: Continuing Observations of Recurring Slope Lineae



Curiosity: >5 years since landing

MAVEN Tracks Back-to-back Regional Storms



Mars 2020 Landing Site Finalists

MEP Operation Mission Status

ODY

- S/C in good health
  - >70,000 orbits around Mars
  - Currently in 645 am/pm orbit
  - Fuel supports ~10 years of nominal S/C operation
  - Lost one reaction wheel in June 2012
    - If an additional wheel fails, will operate <1-2 yrs
- Continue meeting both scientific and programmatic objectives
  - Observations of Martian atmosphere in dawn/dusk conditions and early morning cloud search images
  - UHF relay for MER and MSL and planned support for InSight; Mars 2020; ESA ExoMars rover

MER

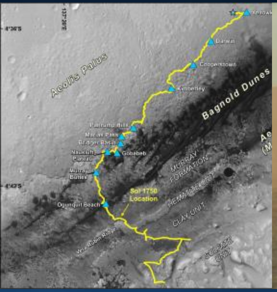
- Roved >45 km in >4800 sols since Jan'04 landing
- Currently conducting winter exploration of Perseverance Valley on the west rim of Endeavour Crater
- Imaging and APXS capabilities continue to be applied, collecting digital elevation model of Perseverance Valley and in situ measurements at each waypoint down the valley to explore hypotheses of its origin

MRO

- S/C in excellent health
  - Large fuel reserve (>20 yrs)
  - Single string telecomm since 2006
  - Recent event indicated that battery life may be a concern
    - Assessing approaches to lengthen battery operation life
- Continue meeting both scientific and programmatic objectives
  - Over 309 Tb of science data returned
  - UHF relay for MER and MSL and planned support for InSight; Mars 2020; ESA ExoMars rover

MEP Operation Mission Status

MSL



- Roved >17.7 km since 8/5/12 landing
- Currently exploring the Vera Rubin hematite ridge

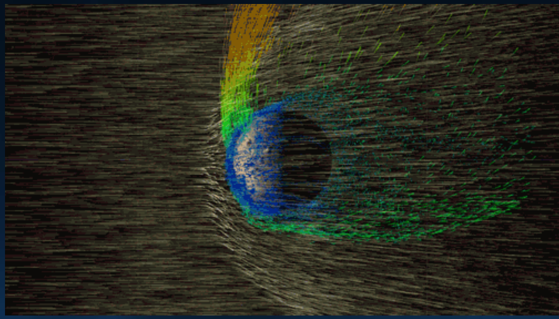
Drill Feed Status

- Drill feed, used to extend and retract drill bit, exhibiting motion problems since 12/1/16
- Successfully fully extended drill bit on 8/12/17
- Techniques to drill with feed extended (i.e. arm-only without stabilizers) in development; testbed results promising; additional testing on-going

Wheel Status

- Wheels accumulating cracks and punctures more rapidly than expected
- Mitigating through strategic terrain assessment and careful selection of local drive paths
- Extensive ground testing suggests >29 km total life

MAVEN



- Launched November 2013, achieved MOI September 2014
- Completed primary mission in November 2015
  - Provided strong evidence for solar wind driven atmospheric loss history
- Currently in second extended mission (EM-2) through September 2018
- Spacecraft is in excellent health, with all instruments operating
- Carries Electra UHF transceiver and UHF antenna
- Assessing orbit options for improved relay performance
  - Change apoapsis from 6200 km to 4500 km

Mars 2020 Status

Mars 2020: 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 Mission Objectives

A. Characterize the… geologic record… of an astrobiologically-relevant ancient environment.

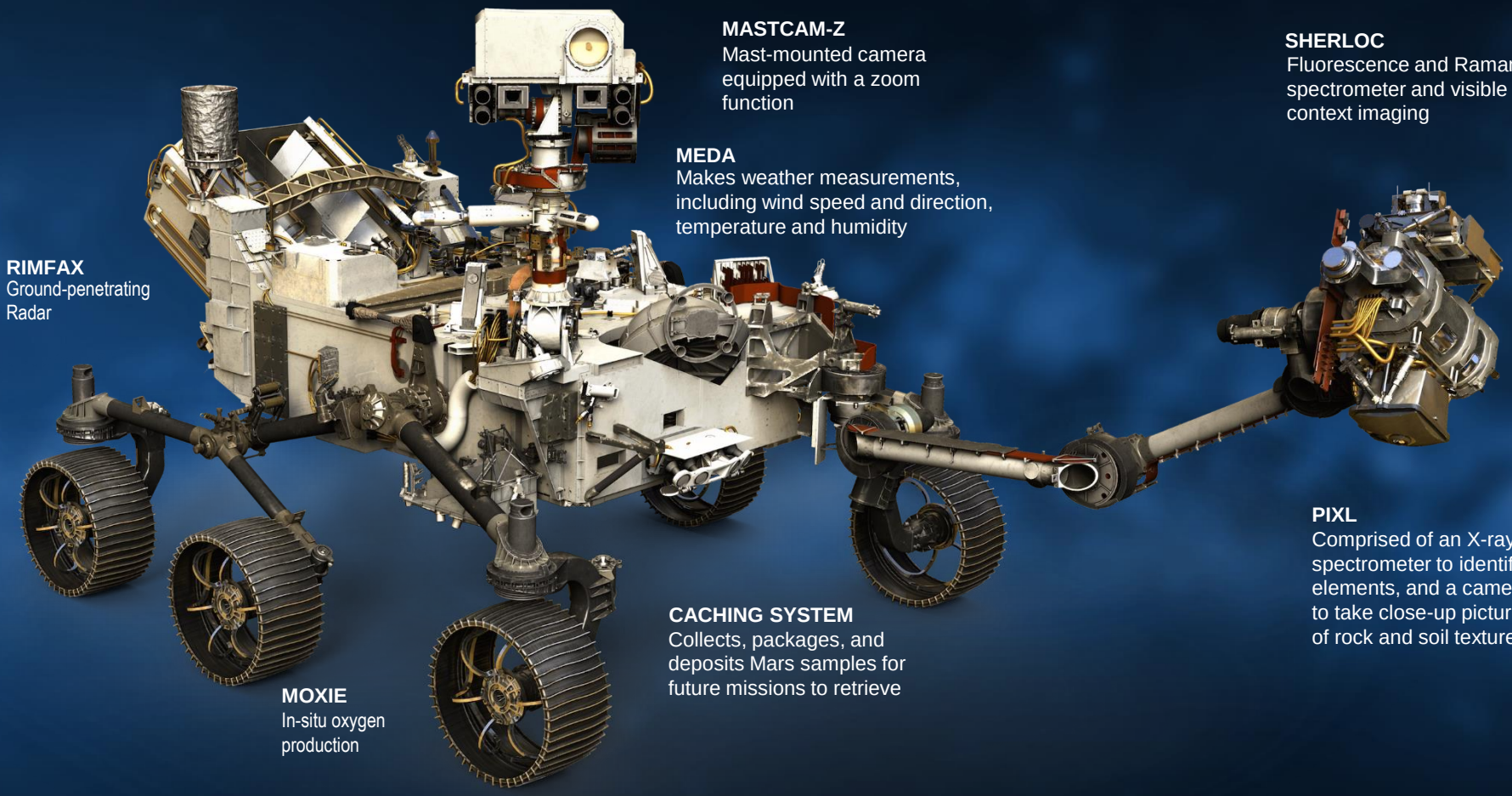
B. Perform… astrobiologically-relevant investigations.

C. Assemble rigorously documented and returnable cache…

D. Contribute to the preparation for human exploration of Mars…

The Mars 2020 mission fully responds to the high priority Planetary Decadal Survey recommendation for a Mars science rover to perform in situ science and collect and cache a set of scientifically documented martian samples for potential future return to Earth

Mars 2020 Rover Instruments



SUPERCAM
Examines rocks and soils with a camera, laser and spectrometers to seek organic compounds

MASTCAM-Z
Mast-mounted camera equipped with a zoom function

MEDA
Makes weather measurements, including wind speed and direction, temperature and humidity

SHERLOC
Fluorescence and Raman spectrometer and visible context imaging

RIMFAX
Ground-penetrating Radar

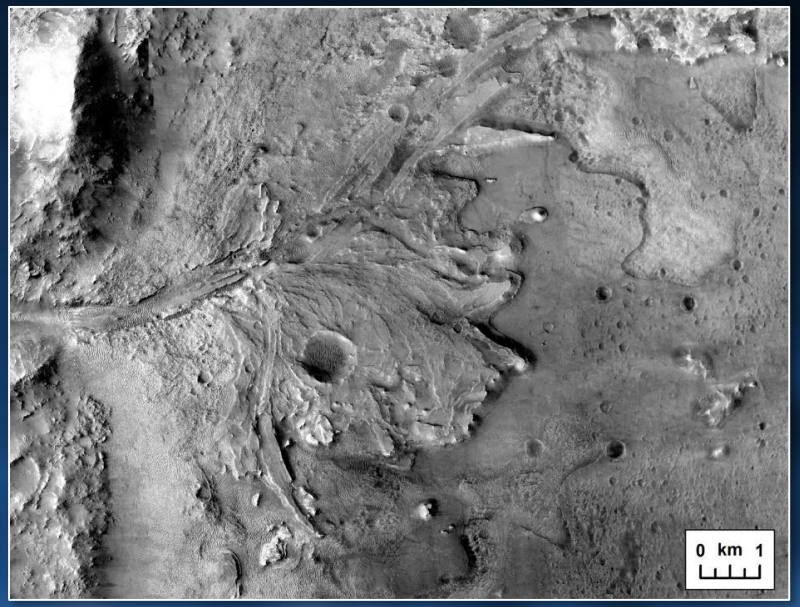
PIXL
Comprised of an X-ray spectrometer to identify elements, and a camera to take close-up pictures of rock and soil textures

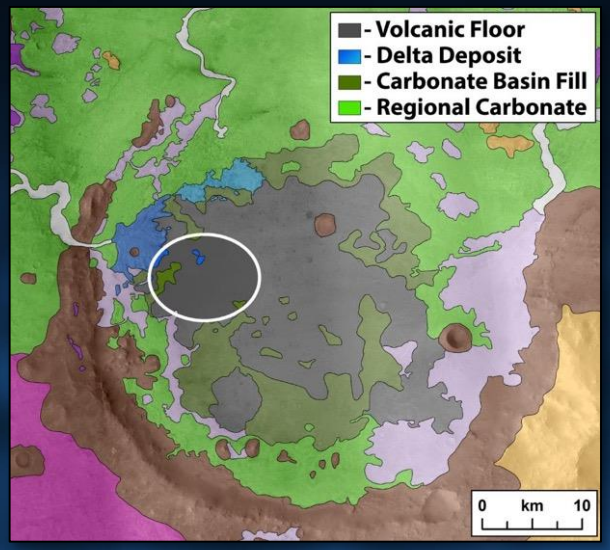
CACHING SYSTEM
Collects, packages, and deposits Mars samples for future missions to retrieve

MOXIE
In-situ oxygen production

Landing Site Candidates

1. Jezero Crater



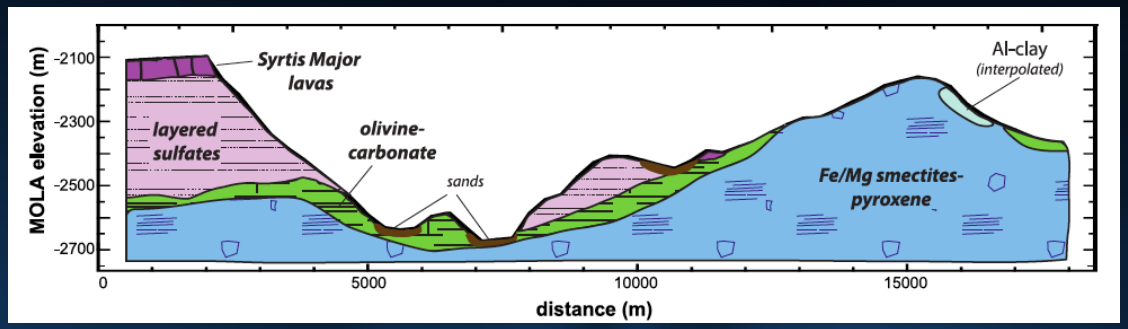


from T. Goudge presentation at LSW3

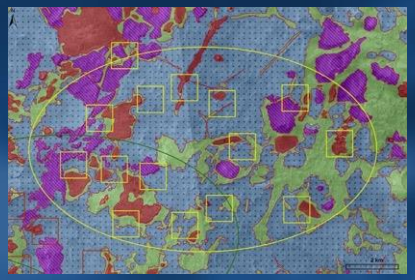
Possible habitable environment - An ancient crater lake

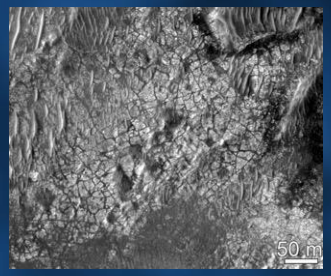
Landing Site Candidates

2. Northeast Syrtis



from J. Mustard and M. Bramble at LSW3

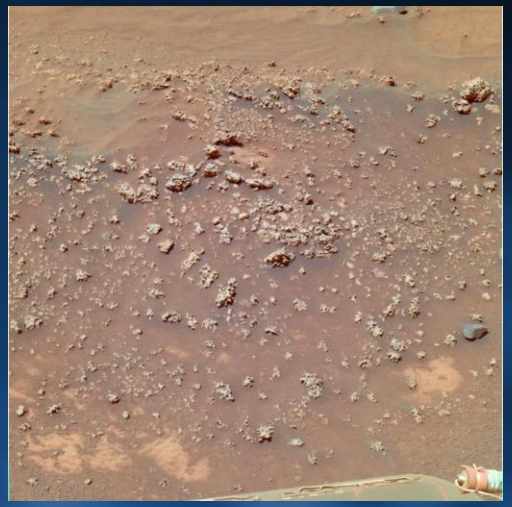




Possible habitable environment - groundwater circulating through warm or hot rock

Landing Site Candidates

3. Columbia Hills (Gusev)

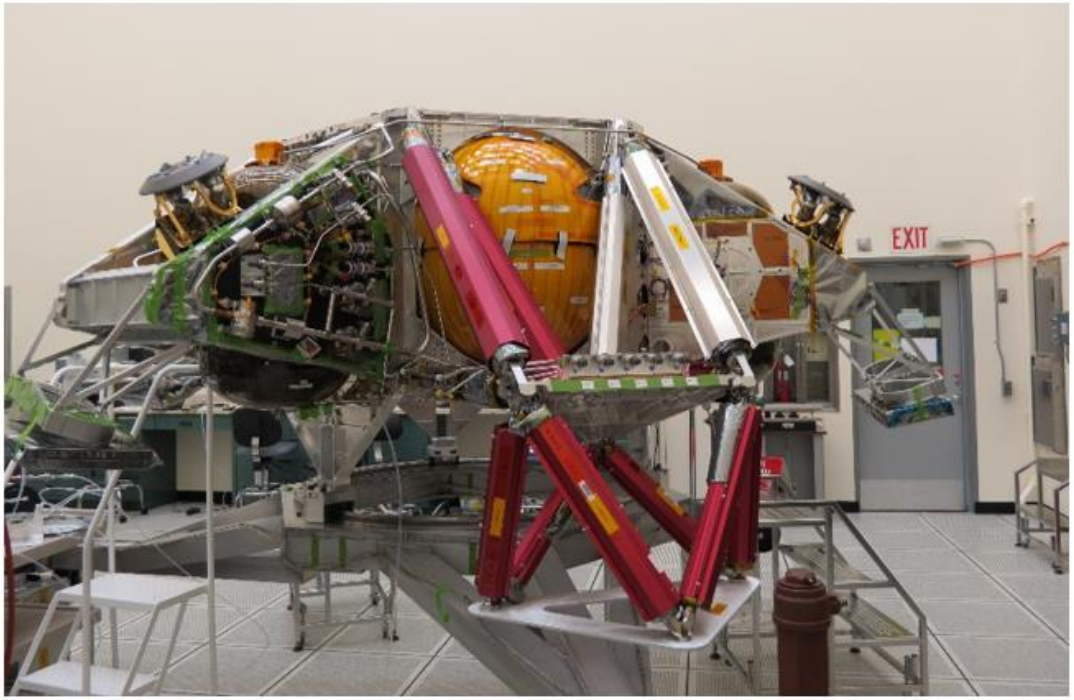


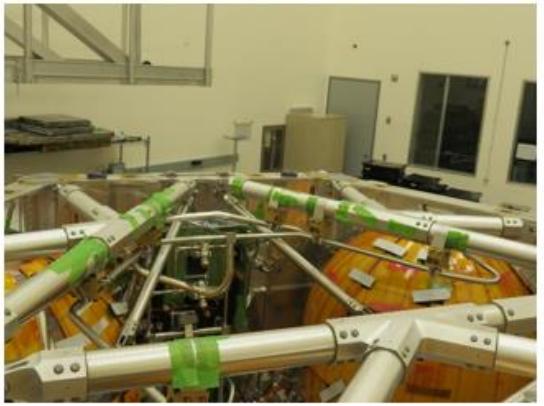
from presentations by S. Ruff and R. Arvidson at LSW3

Possible habitable environment - An ancient hot spring

Descent stage near completion: Moved to SAF

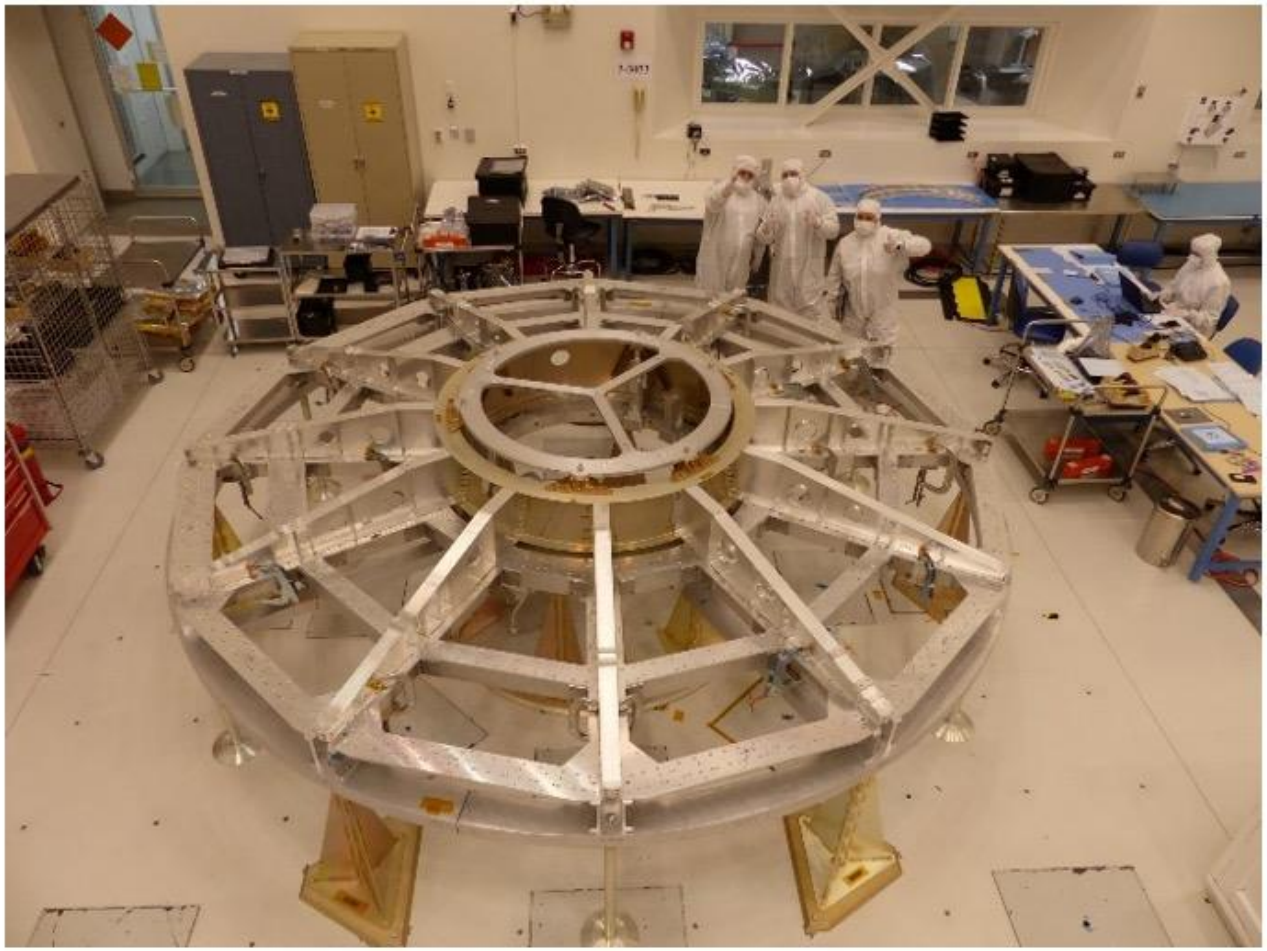
Flight Descent Stage



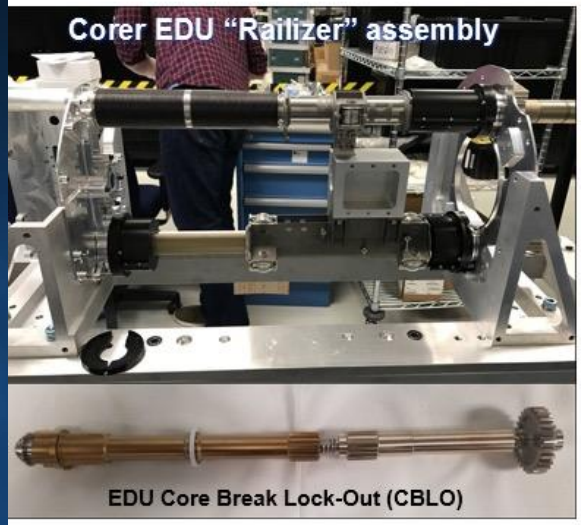


Cruise stage in SAF

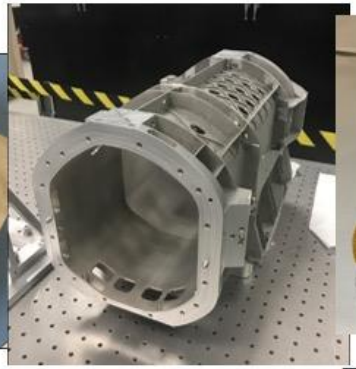
Cruise Stage LVA Assembly, Rib Installation

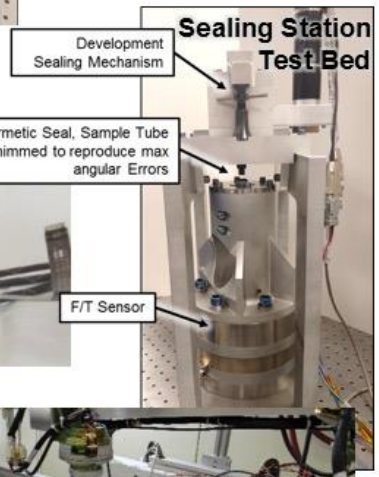


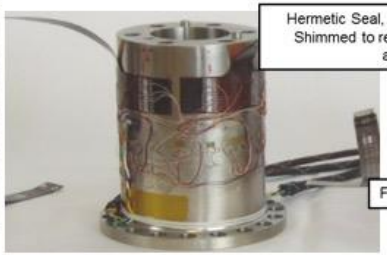
Sample caching system elements

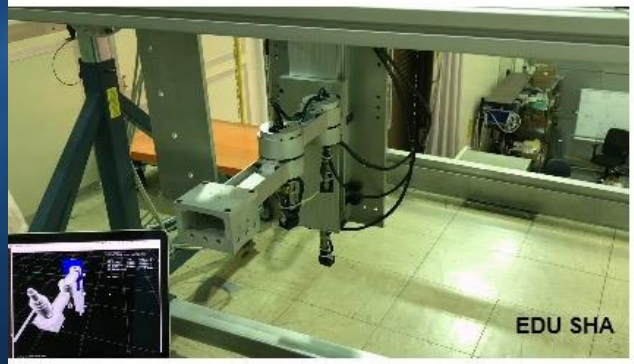


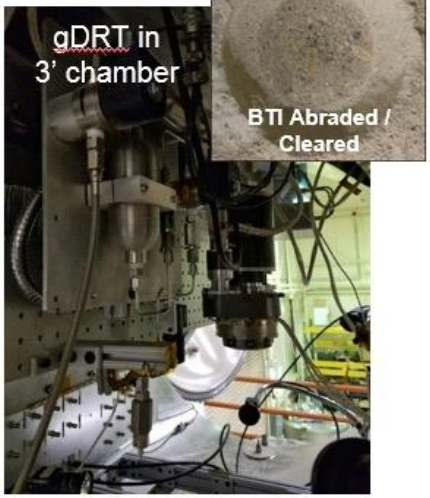

Corer EDU Spindle Twin-Input Gear (STIG) housing

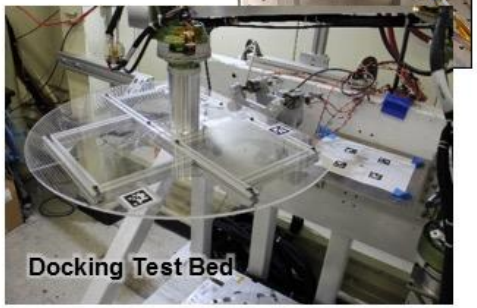

Corer EDU Feed Structure




RA Development
6 DOF Force
Torque
Sensor

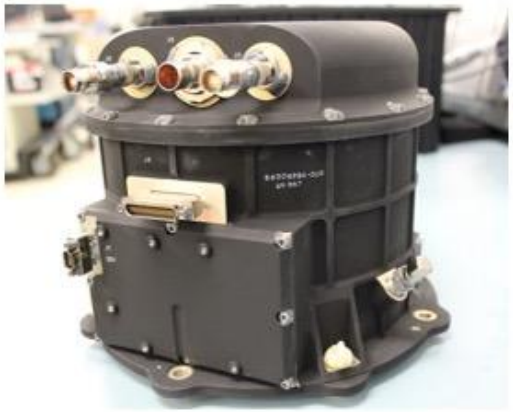


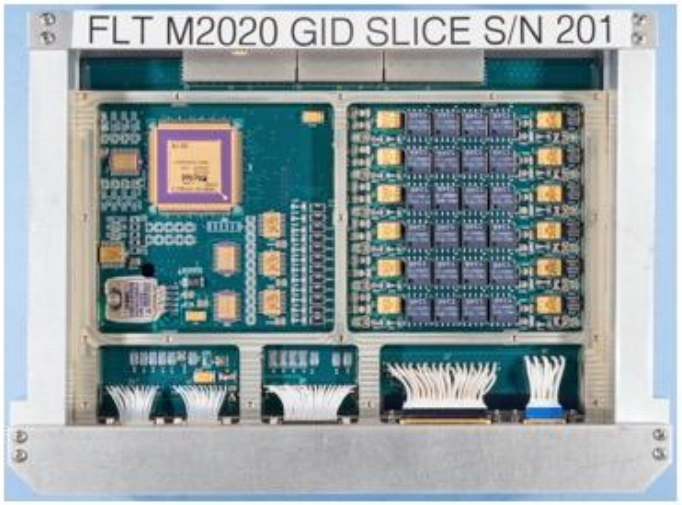




GNC Sensors and TRN Electronics

GNC Sensors & TRN Electronics

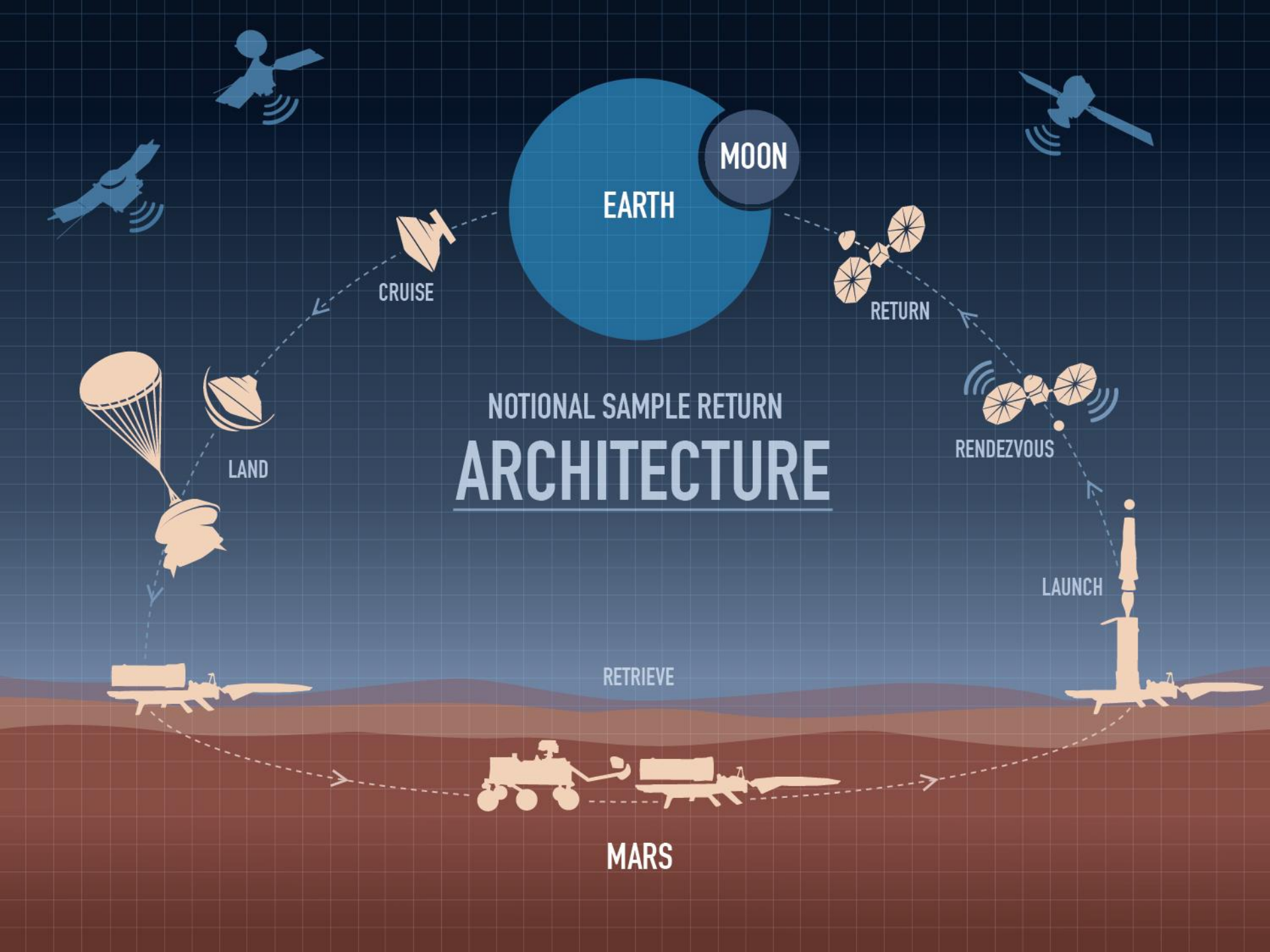




Mars 2020 Status Summary

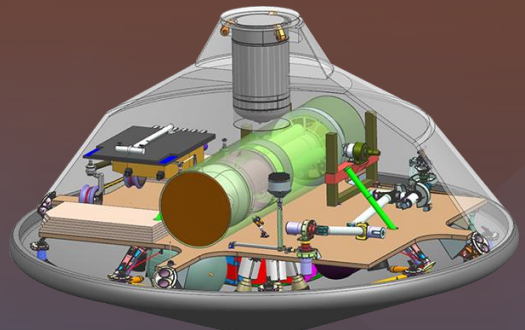
- Completed Project CDR Feb ’17
- Technical Status/Key challenges
  - Good mass, power, and other technical margins
  - Key challenges
    - Sample caching system: Complex mechanical system
    - Science instruments: SHERLOC and PIXL
    - Compliance with sample cleanliness: Stringent biological and organic cleanliness requirements
    - Mission conops for achieving 20 samples in prime mission
- Programmatic Status
  - Good schedule margins to launch
  - Stable life-cycle costs since inception
  - Requesting re-phasing of reserve from FY19/20 into FY18
  - Decision to accommodate Helicopter and drillable blank before end of CY17
- System Integration Review scheduled for February ’18
  - Spacecraft assembly on target to begin in March’18

Mars Sample Return Planning

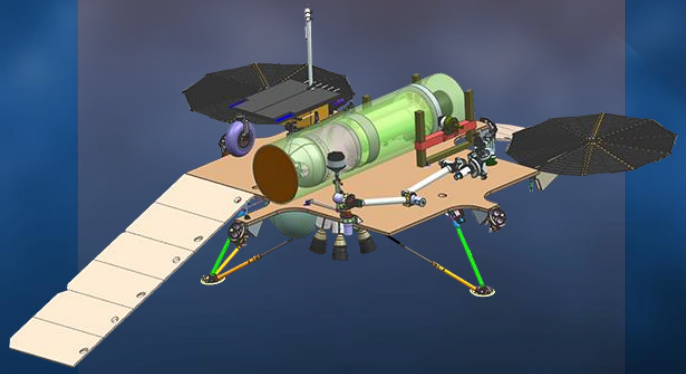

MOON
EARTH
CRUISE
RETURN
NOTIONAL SAMPLE RETURN
ARCHITECTURE
LAND
RENDEZVOUS
LAUNCH
RETRIEVE
MARS

TWO LANDER CONCEPTS

2017 Highly Integrated Concept



Propulsive Platform Lander (PPL) *Concept Packaged in MSL 4.5m Aeroshell*

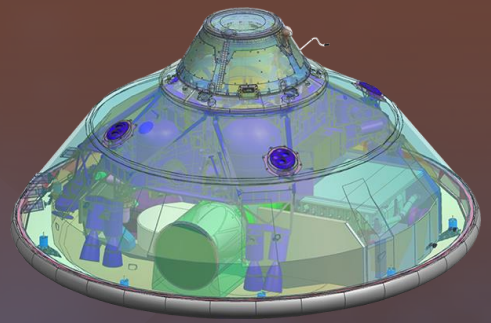


Propulsive Platform Lander
Concept Deployed

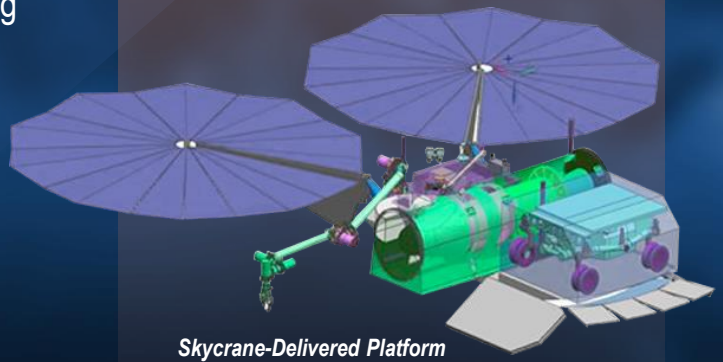
Common Attributes

- Identical cruise and entry architecture
- ~ 10 km landing ellipse
- ~ 900-1000 kg landed useful mass
- Accommodates ~ 600 kg MAV and Fetch Rover

Evolved 2011 Decadal Concept



Skycrane-Delivered Platform Concept Packaged in MSL 4.5m Aeroshell



Skycrane-Delivered Platform
Concept Deployed

Two concepts that leverage Mars program legacy system capabilities

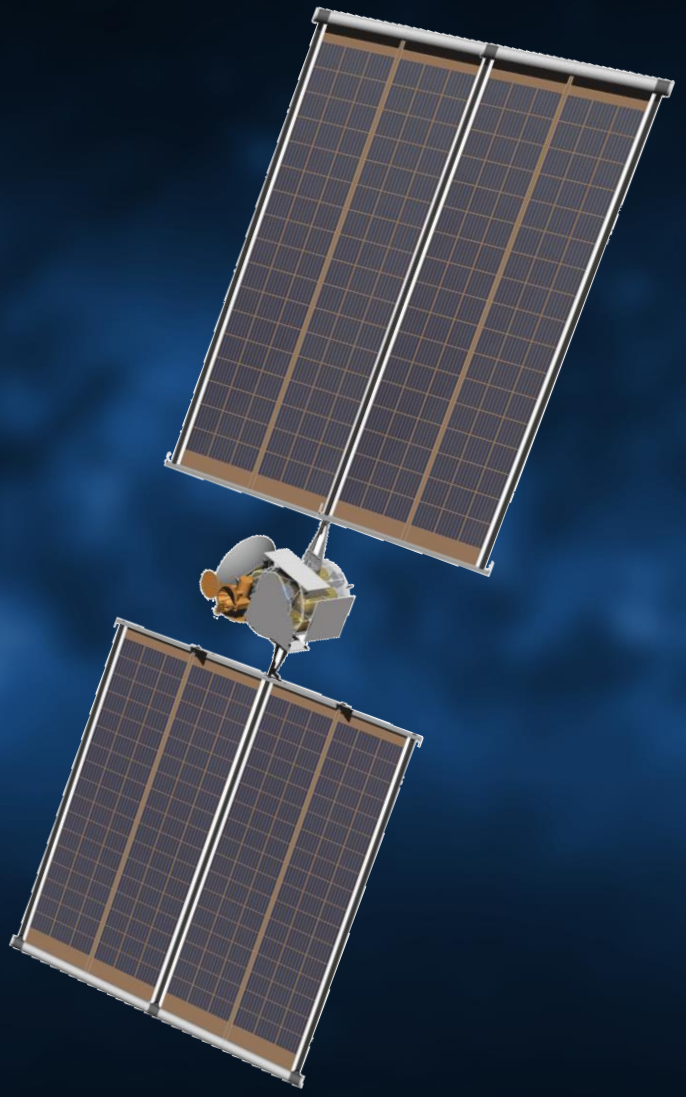
NOTIONAL SAMPLE RETURN ORBITER

Design for Orbital Rendezvous & Fast Sample Return

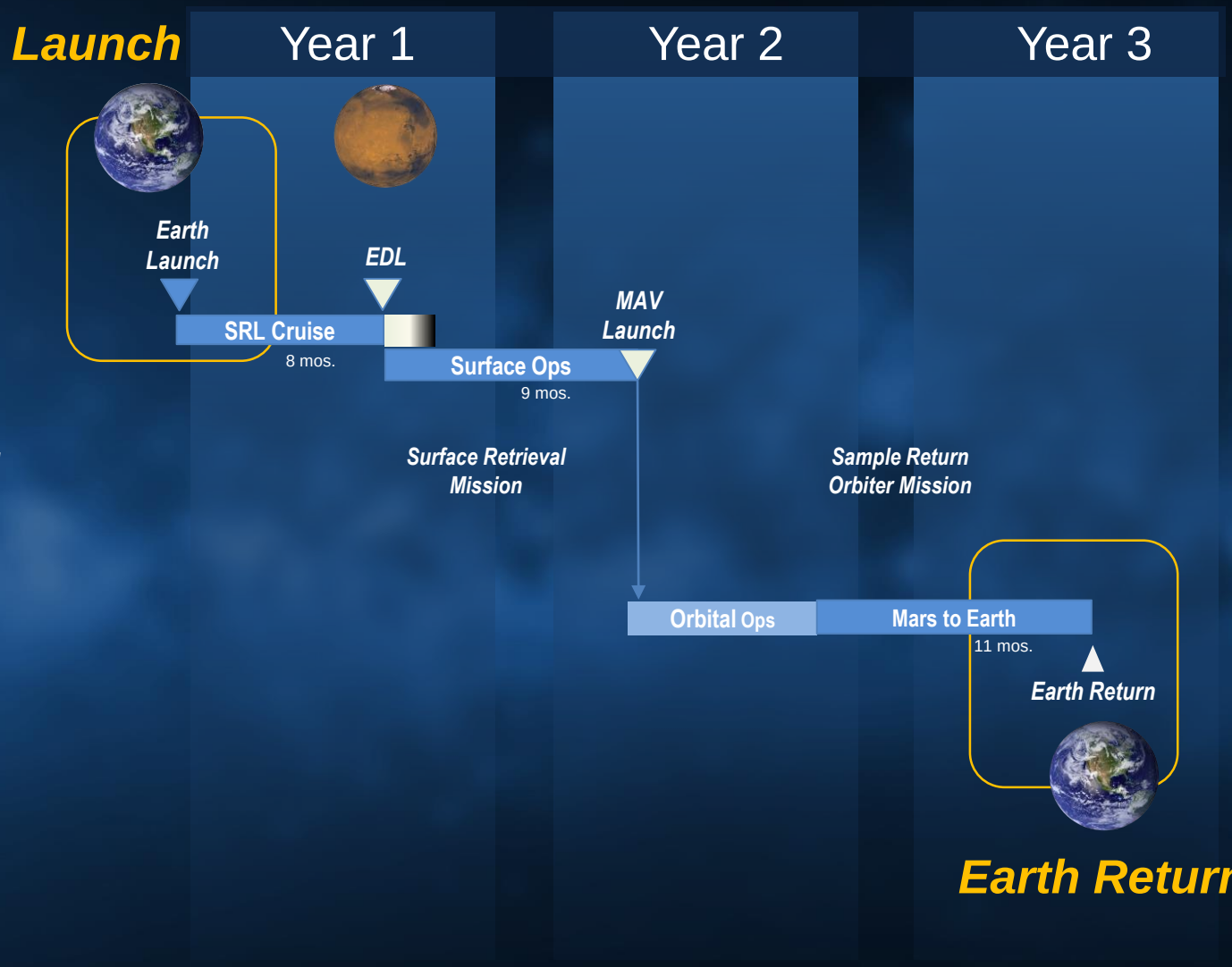
- Rendezvous & Capture
- Containment and Earth Planetary Protection
- Communication Relay Support for Surface Ops and Critical Events
- Return to Earth, either via
  - Direct return to Earth
  - Deliver to cis-lunar space for human-assisted returns

Implementation Options

- NASA provided
- Partner provided



NOTIONAL MSR TIMELINE



PARTNERSHIP OPPORTUNITIES

- **International**
  - Enduring scientific/technical and programmatic interests
  - Multiple space agencies headed to Mars
- **Growing commercial interest in Mars**
  - Potential to leverage commercial offerings of capability
- **Exploration benefits from MSR**
  - Feed-forward into preparation, planning and development
  - First round trip demonstration
  - Samples inform environmental uncertainties [biological, physical, toxicity]
  - Potential opportunity for early leverage of cis-lunar capabilities


MARS MISSIONS
OPERATIONAL 2001–2017
FUTURE 2018–2030
Mars Express (ESA) (2003)
Mars Reconnaissance Orbiter (2005)
MAVEN (2013)
Mars Orbiter Mission (ISRO) (2013)
Trace Gas Orbiter (ESA/RSA) (2016)
Mars Odyssey (2001)
HOPE (UAE)
MMX (JAXA)
Mars Orbiter (China)
Mars Lander & Rover (China)
Opportunity Rover (2003)
Curiosity Rover (2011)
InSight
Mars 2020 Rover (NASA)
ExoMars Rover (ESA/RSA)
Mars Sample Return (China)
Follow the Water
Explore Habitability
Seek Signs of Life
Prepare for Future Human Explorers