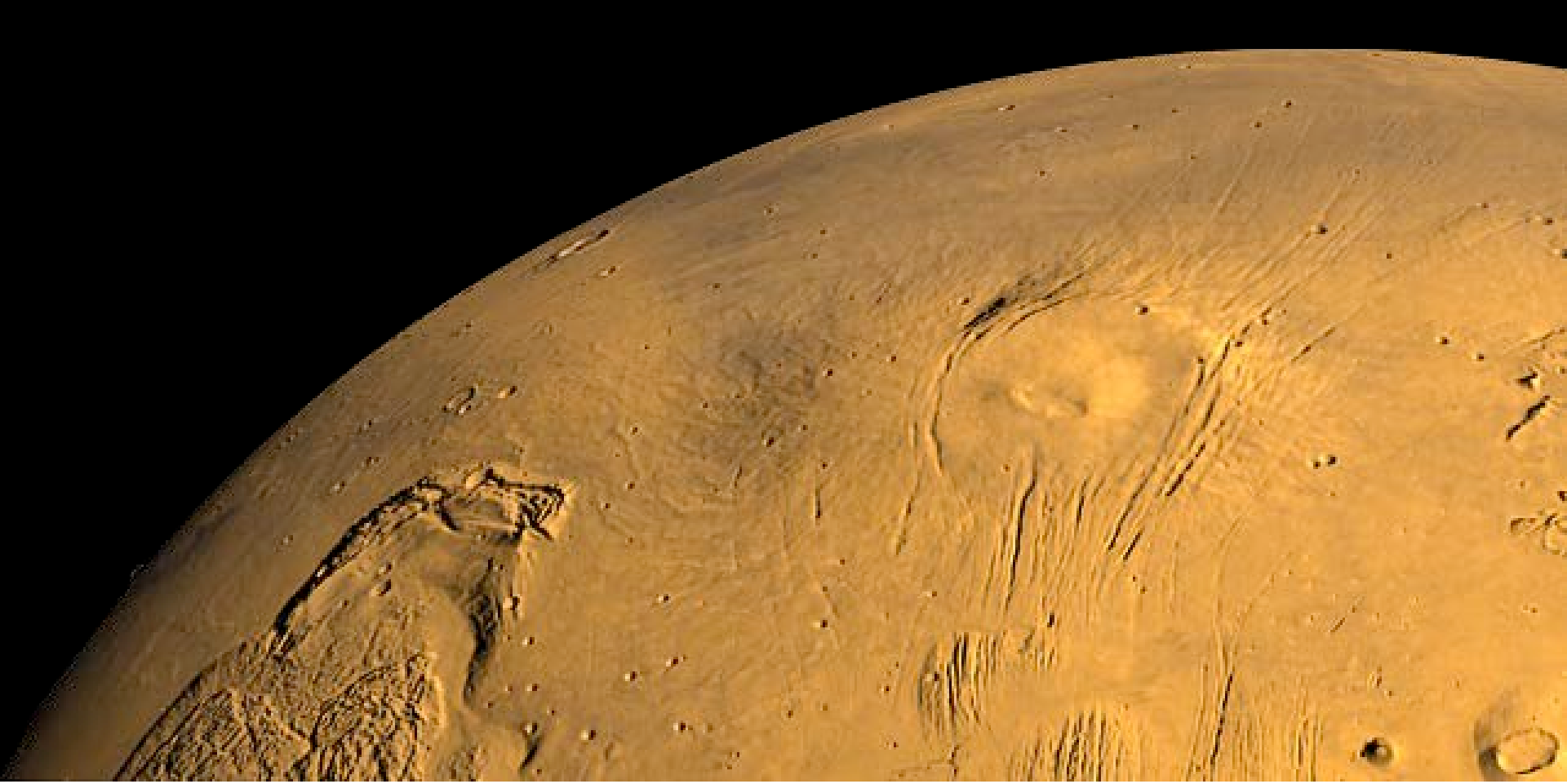

To Mars and Back:
The Road to Potential Mars Sample Return

Joseph Parrish
Deputy Manager, Mars Program Formulation Office
Manager, Mars Technology Development
5 December 2016

Jet Propulsion Laboratory
California Institute of Technology

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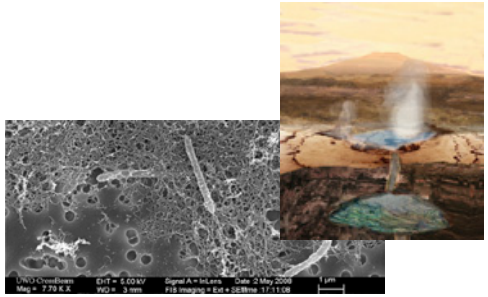
Overview

- Mars Science and Mission Context
- Potential Mars Sample Return Mission Elements
  - Next Mars Orbiter (NeMO) Concept
  - Sample Retrieval & Launch (SRL) Concept
  - Mars Returned Sample Handing (MRSH) Concept
- Longer-Term Mars Exploration Needs
- Summary

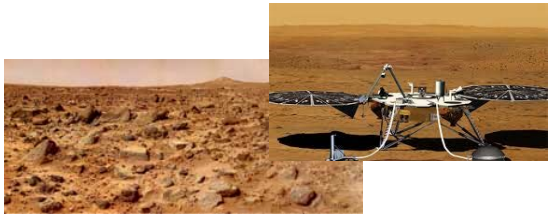
Mars Science Strategy

- **Goal I: Determine If Life Ever Arose On Mars**
  - Objective A: Characterize past habitability and search for evidence of ancient life
  - Objective B: Characterize present habitability and search for evidence of extant life
  - Objective C: Determine how the long-term evolution of Mars affected the physical and chemical environment critical to habitability and the possible emergence of life

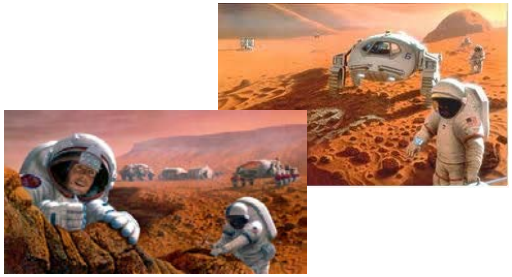


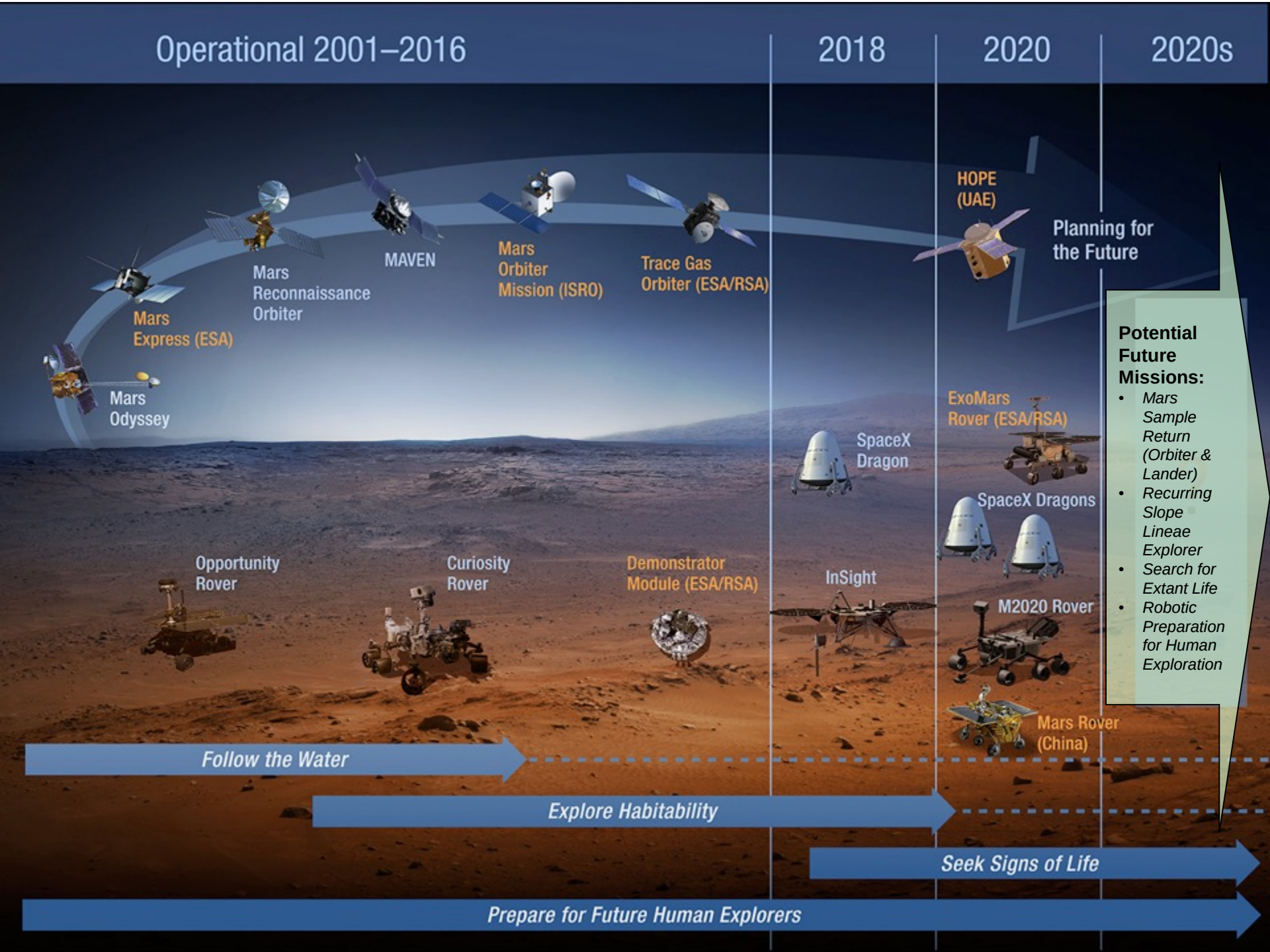
- **Goal II: Understanding The Processes And History Of Climate On Mars**
  - Objective A.: Characterize Mars' Atmosphere, Present Climate, and Climate Processes Under Current Orbital Configuration
  - Objective B.: Characterize Mars' Recent Climate and Climate Processes Under Different Orbital Configurations
  - Objective C.: Characterize Mars' Ancient Climate and Climate Processes

- **Goal III: Determine The Evolution Of The Surface And Interior Of Mars**
  - Objective A.: Determine the nature and evolution of the geologic processes that have created and modified the Martian crust
  - Objective B.: Characterize the structure, composition, dynamics, and evolution of Mars' interior
  - Objective C.: Understand the origin, evolution, composition and structure of Phobos and Deimos.

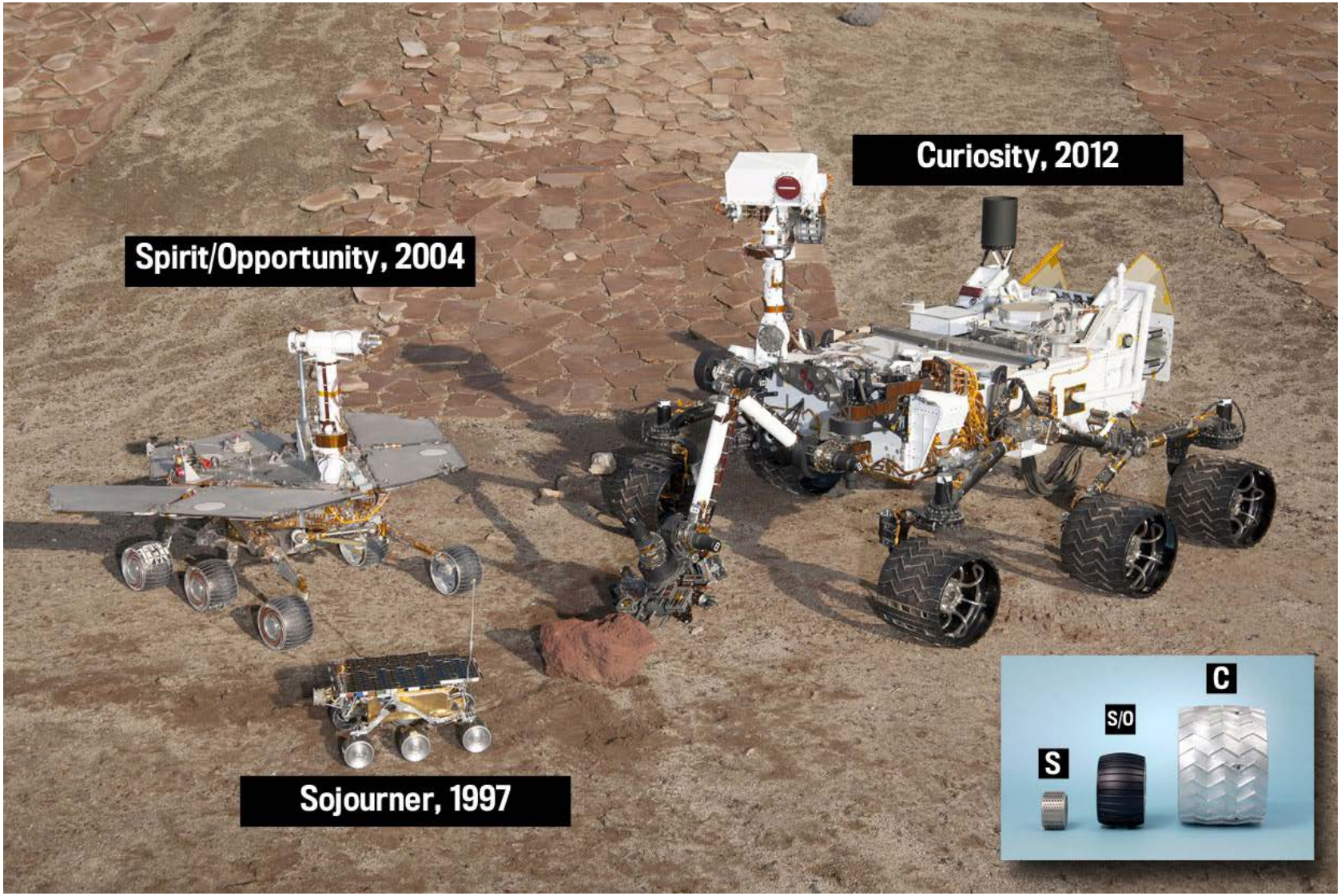


- **Goal IV: Prepare For Human Exploration**
  - Objective A: Obtain knowledge of Mars sufficient to design and implement a human mission with acceptable cost, risk and performance




Operational 2001–2016
2018
2020
2020s
Mars Odyssey
Mars Express (ESA)
Mars Reconnaissance Orbiter
MAVEN
Mars Orbiter Mission (ISRO)
Trace Gas Orbiter (ESA/RSA)
HOPE (UAE)
Planning for the Future
Opportunity Rover
Curiosity Rover
Demonstrator Module (ESA/RSA)
SpaceX Dragon
InSight
ExoMars Rover (ESA/RSA)
SpaceX Dragons
M2020 Rover
Mars Rover (China)
Potential Future Missions:
• Mars Sample Return (Orbiter & Lander)
• Recurring Slope Lineae Explorer
• Search for Extant Life
• Robotic Preparation for Human Exploration
Follow the Water
Explore Habitability
Seek Signs of Life
Prepare for Future Human Explorers

NASA's Mars Rovers



NASA's Mars Rovers

Current Status

- Last decade of Mars exploration has answered many questions and points to the most promising places on Mars to look for answers to the remaining questions
- Scientific community consensus is that key remaining questions are most effectively addressed by returning samples from Mars to earth and investigating them with the best laboratory instruments available
  - The key questions which can be answered with orbital or in situ data have been answered – the next steps require analysis of returned samples

Vision for 2020s and Beyond

Now through 2020	Decade of 2020's	Beyond

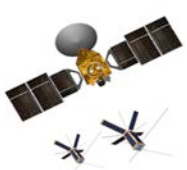
Mars 2020

*

MSR Orbiter
(MSR, Comm, Complementary Science)

*

Sample Retrieval
(Landing, Retrieval Rover, Ascent Vehicle)



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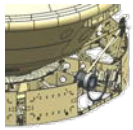

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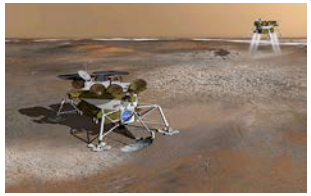
Secondary Vehicles
(CubeSat, Aerocapture)



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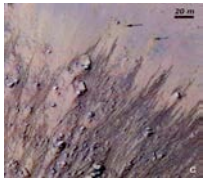
Robotic Precursor Missions

*

Human-Robotic Missions

*



Other Scientific Priorities

*Artist concepts

Why MSR, and not *in situ*?

There are <u>three primary reasons</u> why MSR is of such high value compared to in situ alternatives.

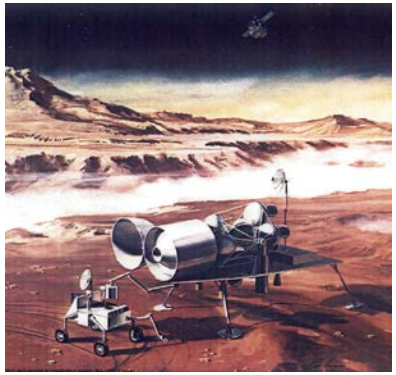
1. Complex sample preparation, including sample-related decision-making

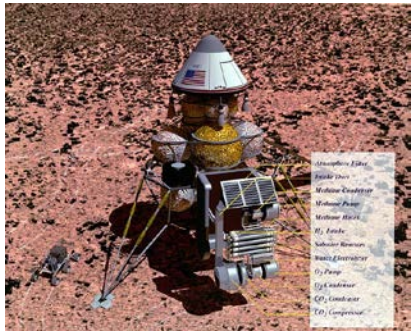
2. Many critical lab-based instruments are large/complex

3. Instrument diversity. Investigation pathways are not hypothesis-constrained

Image courtesy Dimitri Papanastassiou

History of Mars Sample Return Concepts





- First era of concepts considered and studied in the 1970's and 1980's, with a wide variety of approaches and goals
- Second era of concepts gained momentum late '90's after claims of bio-signatures discovered in meteorite ALH84001
  - Strong international interest: Initially CNES (1999-2003), then multilateral iMEWG (2007-2009), and eventually bilateral NASA-ESA (2009-2011)
- Multi-project "Campaign" Approach adopted during 2010 Planetary Science Decadal Survey development
- Remains the basis for current planning approach described in following slides

Essential Elements of a Sample Return

Acquire Samples on Mars

- Launch from Earth/Land on Mars
- Select Samples
- Acquire/Cache Samples

Get Samples off Mars

- Retrieve/Package Samples on Mars
- Launch Samples from Mars

Return Samples

- Capture and Isolate Sample Container
- Return to Earth
- Land on Earth

Earth Ops w Samples

- Retrieve, Quarantine, and Store Samples on Earth
- Assess Hazards/Sample Science
- Preserve for Future Investigations

Under Study

Notional Mars Sample Return Architecture

Sample Caching Rover (Mars 2020)

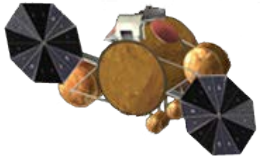
Launch from Earth/Land on Mars → Select Samples → Acquire/Cache Samples

Sample Tubes on Mars Surface (artist concept)

Mars Sample Return Lander Concept

Retrieve/Package Samples on Mars → Launch Samples to Mars Orbit *

Orbiting Sample (OS) in Mars Orbit (artist concept)



Mars Sample Return Orbiter Concept

Capture and Isolate Sample Container → Return to Earth → Land on Earth *

Orbiting Sample (OS) Prototype on Earth

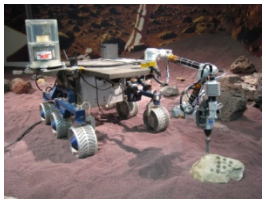
Mars Returned Sample Handling (MRSH) Facility Concept

Retrieve/Quarantine and Preserve Samples on Earth → Assess Hazards → Sample Science

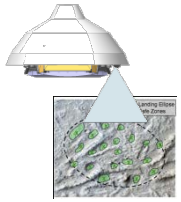
Sample Science

* Launching orders of MSR orbiter and lander can be reversed

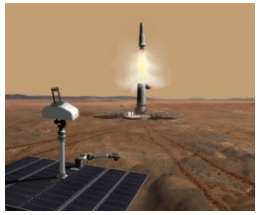
Potential MSR Campaign: Key Technologies



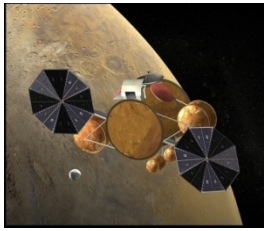
Sample Acquisition & Caching



Terrain Relative Navigation/ Hazard Detection & Avoidance



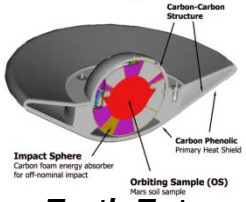
Mars Ascent Vehicle



OS Rendezvous & Capture

Caching Rover → **MSR Lander** → **MSR Orbiter** → **MRSH Sample Receiving Facility**

Enhanced Mobility



Earth Entry Vehicle

Sample Science Instruments

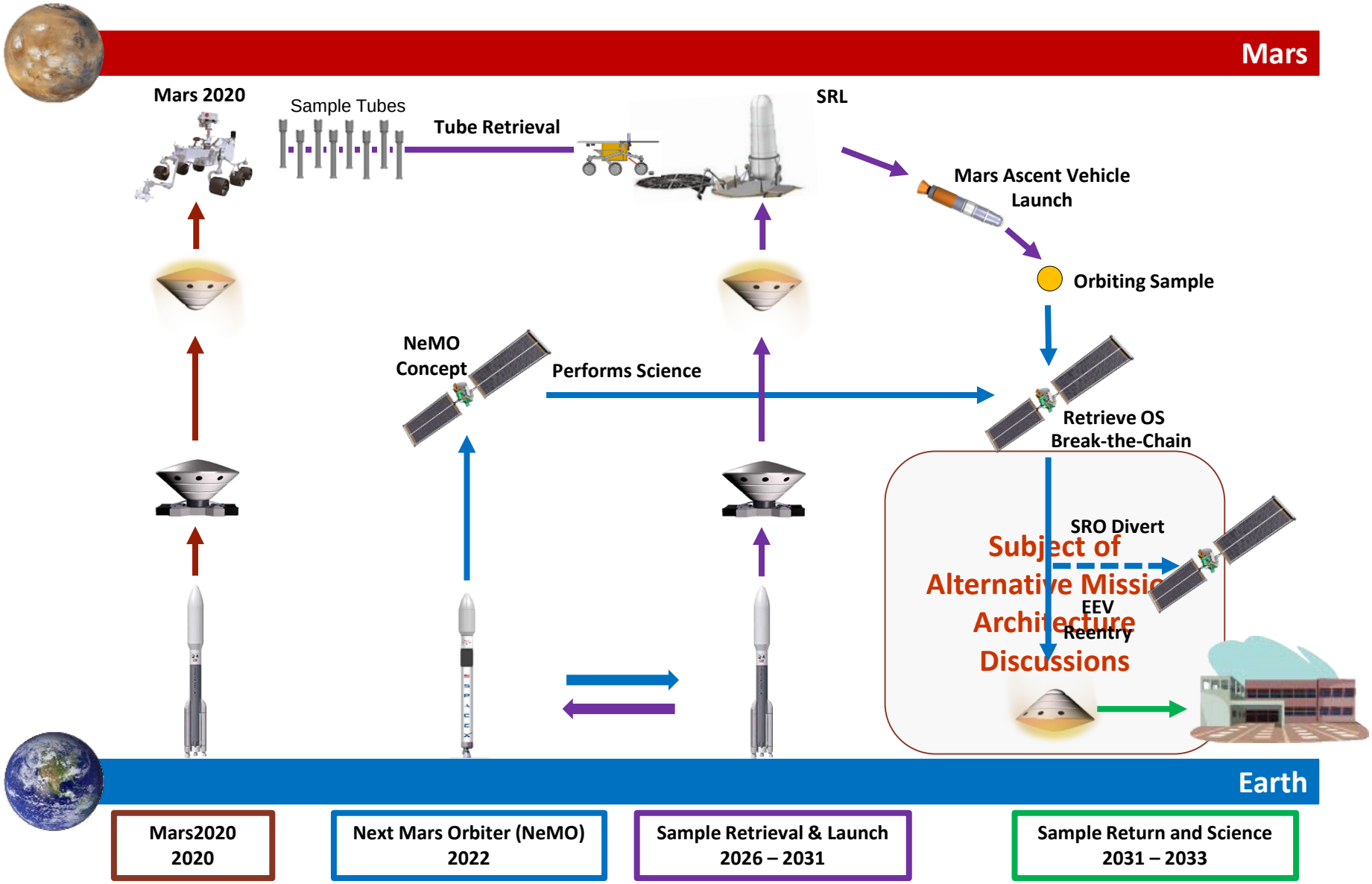
Planetary Protection to Minimize Round-trip Contaminants

Assured Containment for Safe Earth Entry and Landing

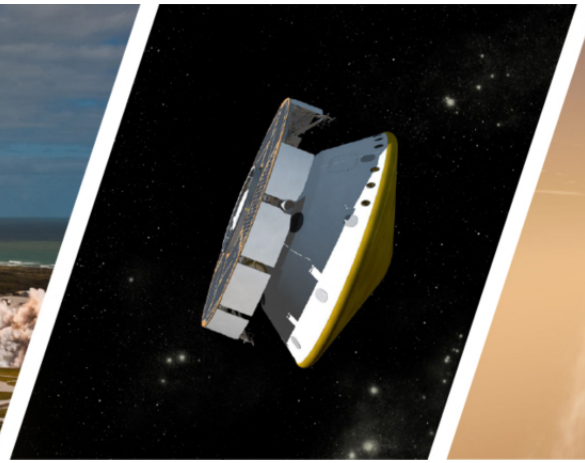
Mars Sample Return Concept Animation

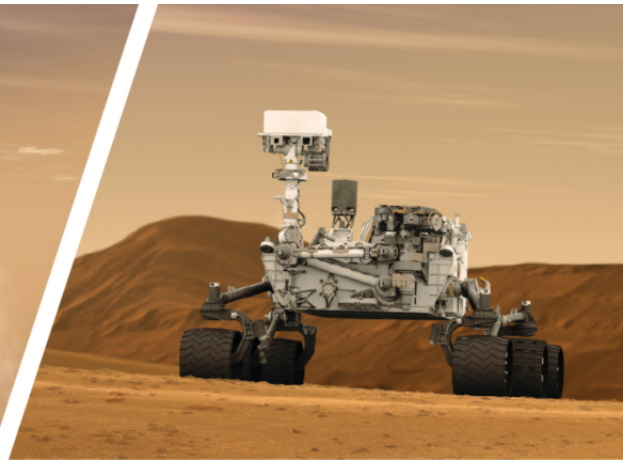
I'll LFT the video file to Lea

Potential Mars Sample Return Architecture



Mars 2020 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 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

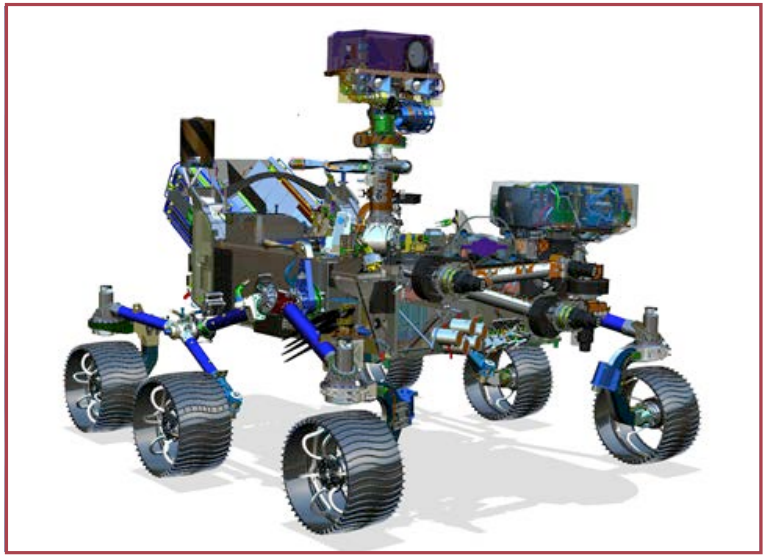
SURFACE MISSION

- 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

Mars 2020 Project Overview

Salient Features

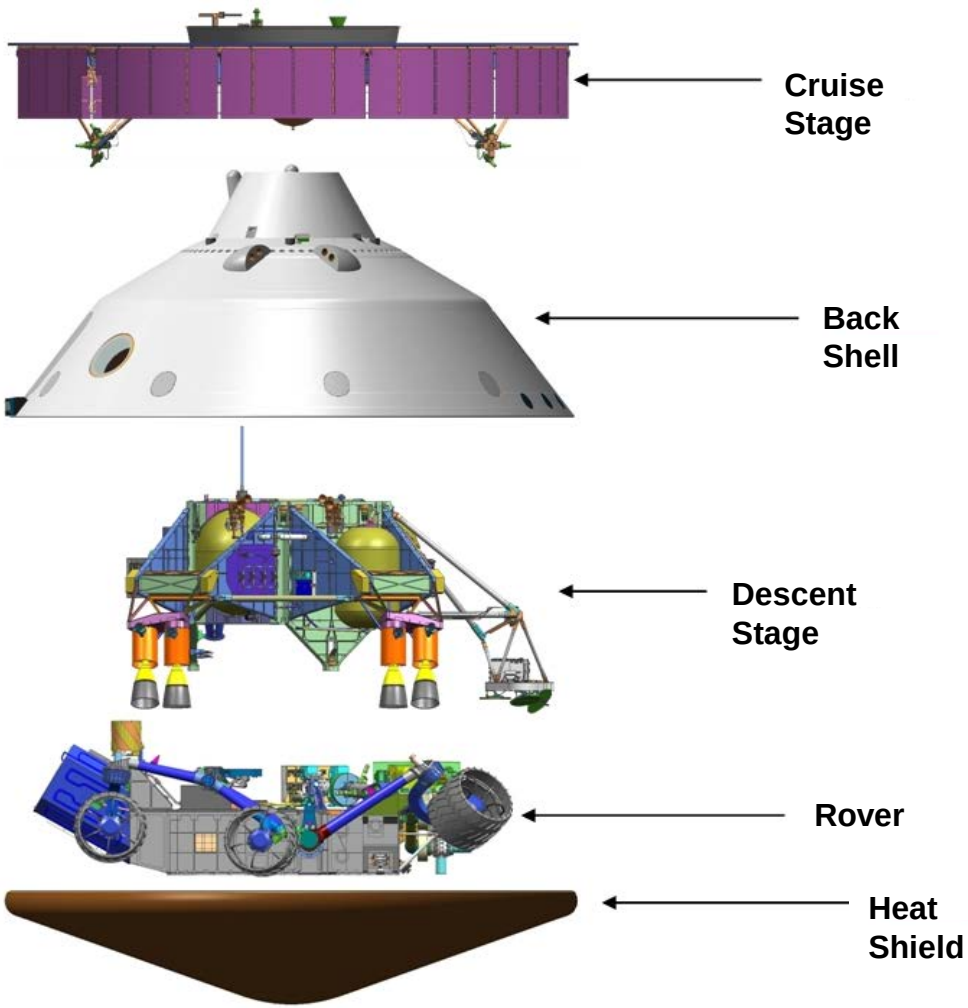
- *High heritage MSL design*
- *Modifications only as necessary to accommodate new payload and Sampling / Caching System (SCS)*



Science

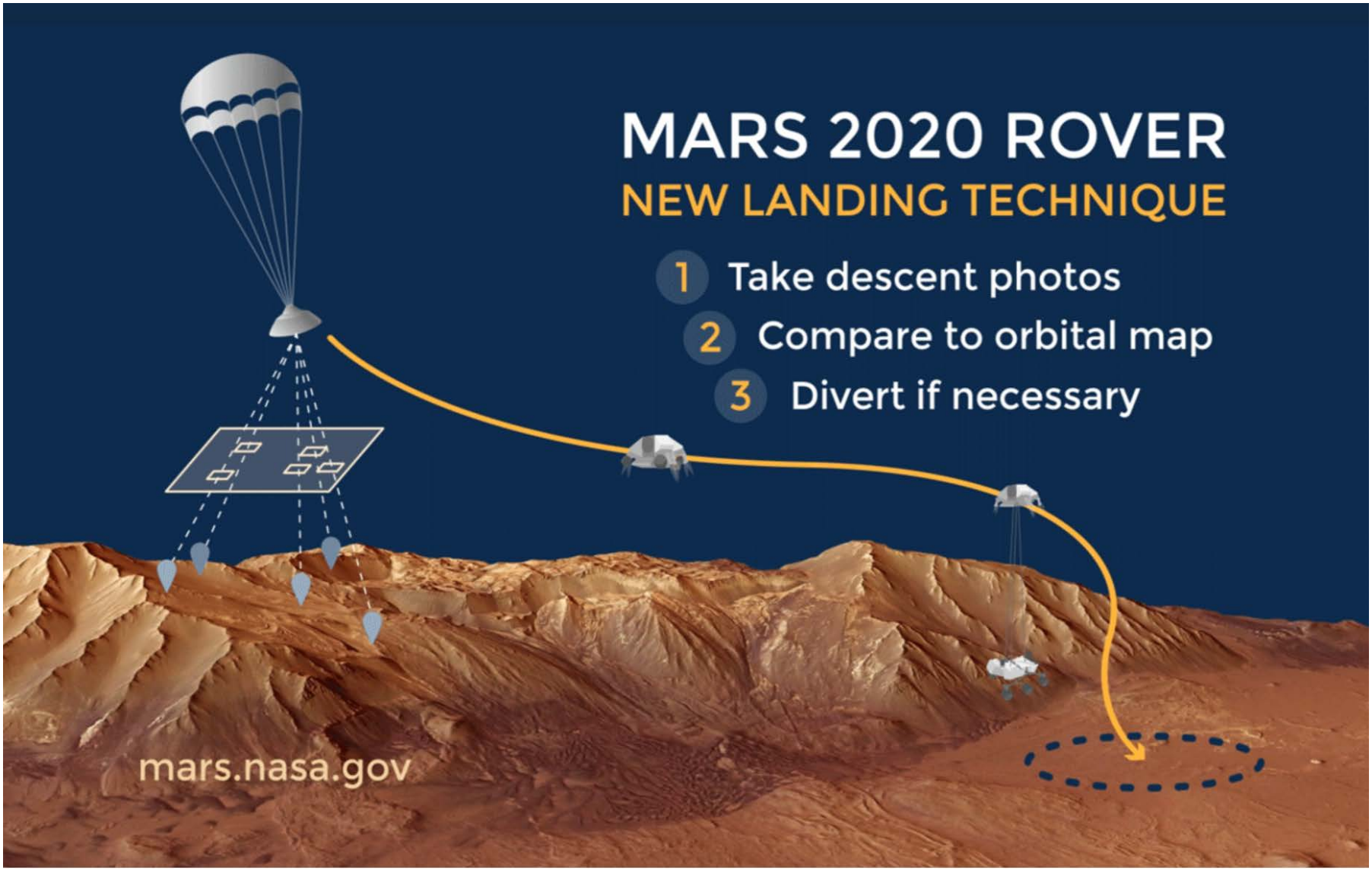
- *Assess past habitability of an astrobiologically relevant ancient environment on Mars*
- *Assess biosignature preservation potential with the environment and search for biosignatures*
- *Assemble cached samples for possible future return to Earth*
- *Provide an opportunity for contributed HEO/STMD participation to advance technologies with potential applications to future human exploration objectives*

MSL/M2020 Cruise and EDL System



MSL/M2020 Cruise and EDL System (Packaged)

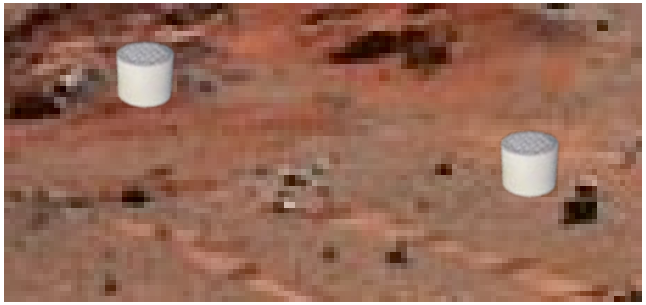
Terrain Relative Navigation for Rover Landing



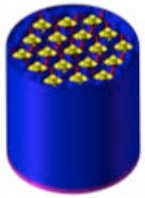
Sample Caching – Then vs. Now

Decadal Survey: MAX-C

300 kg, solar power (15S-25N), MER-class instruments for sample triage



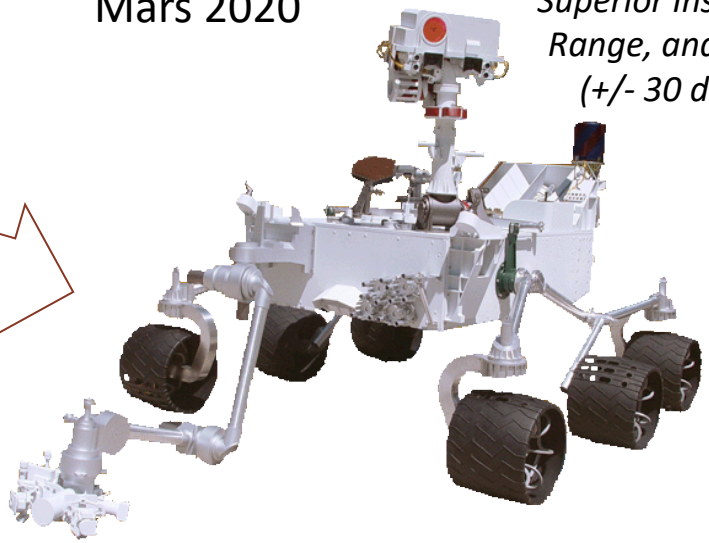
Two Caches (redundant)

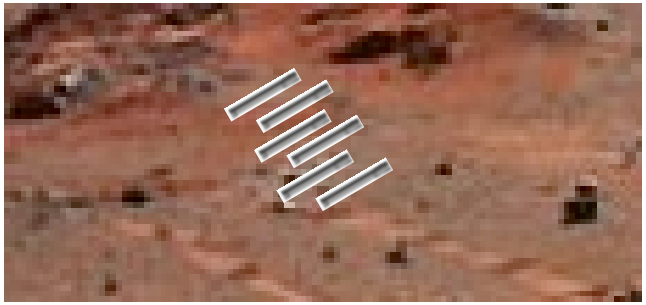


~20 samples
(each)

Mars 2020

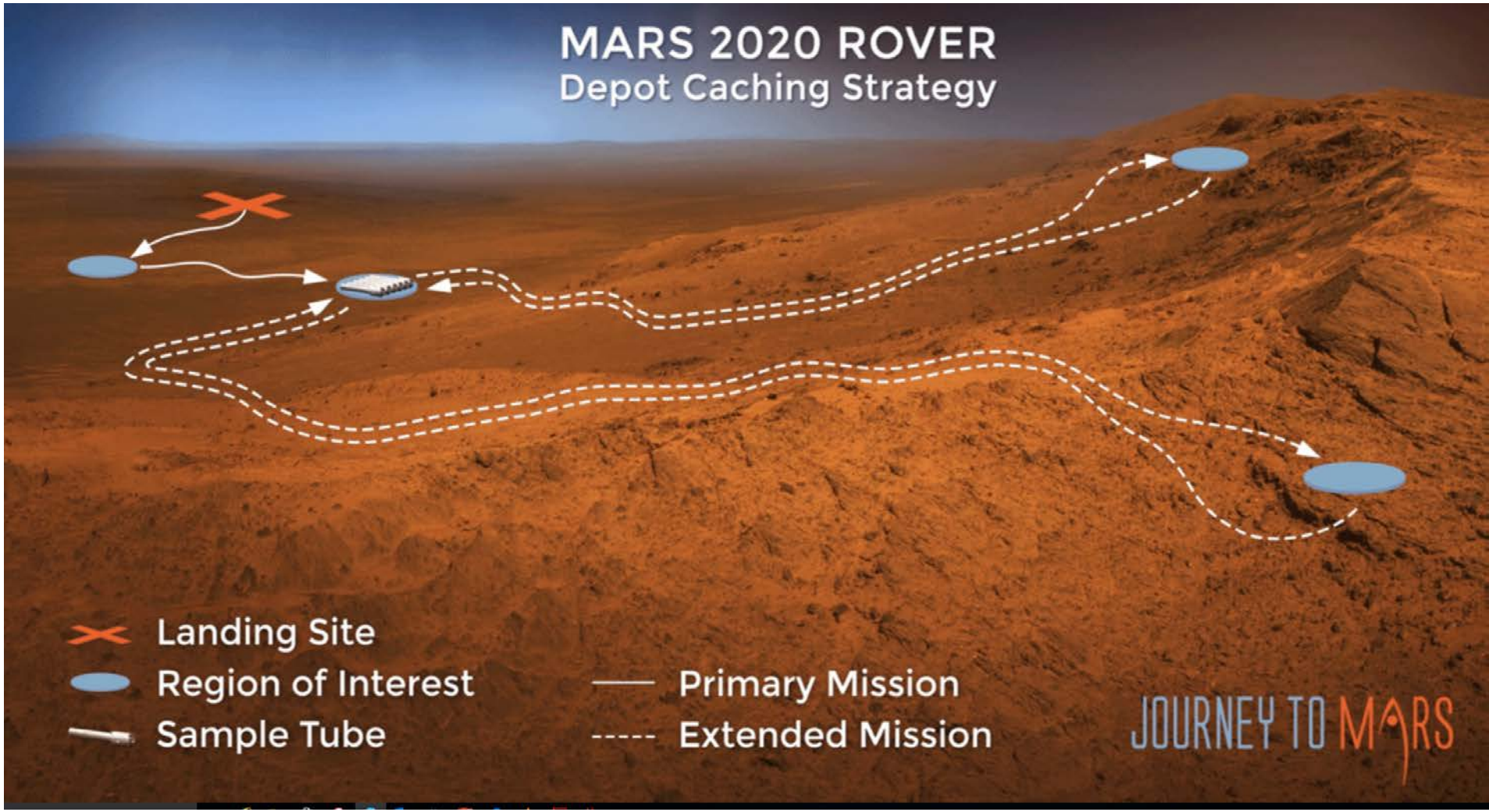
Superior Instruments, Range, and Latitude (+/- 30 degrees)





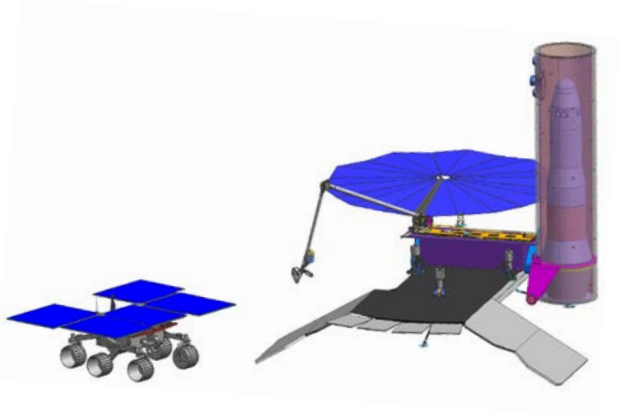
31 Individual Samples @ one or more pickup locations

Sample Tube Caching Strategy



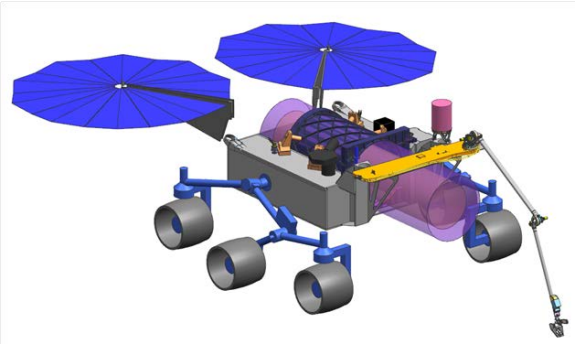
Potential Sample Return Lander Concepts

2011 Decadal Study Concept –
MER-class rover + Fixed platform

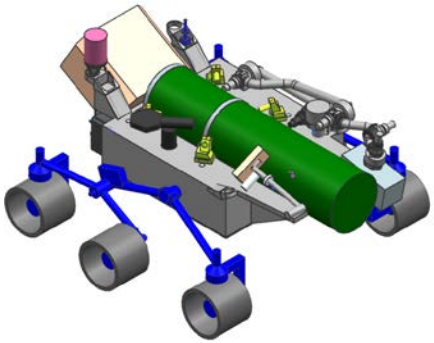


Mobile MAV Concepts –
MSL-class rover

Solar Mobile MAV



RTG Mobile MAV



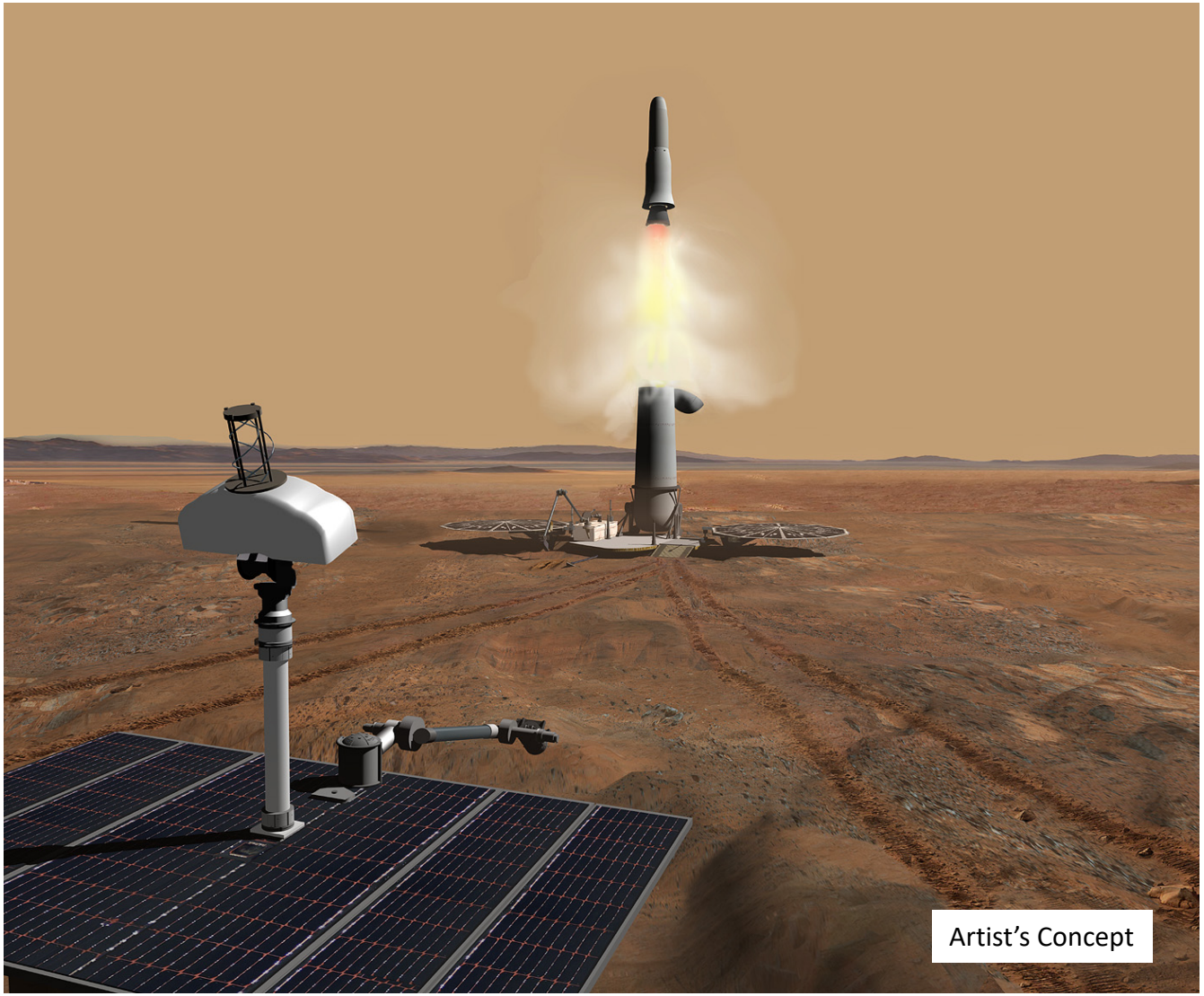
Example MAV (SSTO Hybrid)
Approx 2.8 m length; 280 kg mass

Other propellant options (solid, liquid) also under consideration

Design considerations and Drivers:

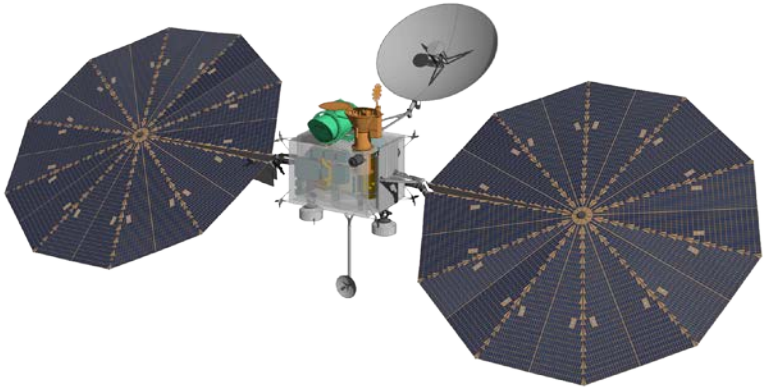
- Traverse distance
- Landing ellipse and hazard avoidance
- Sample Handling and Transfer
- MAV Launch
- Ancillary Objectives

MAV Launch



Pre-Decisional: For Planning and Discussion Purposes Only

Next Mars Orbiter (NeMO) Concept Overview



Objectives

- Renew and Update Aging Communications Infrastructure
- Provide Continuity of High Resolution Imaging
- Potential additional objectives for:
  - Orbital Support for Sample Return
  - Remote Sensing

Payload Overview

- High Resolution Imager (30 cm/pixel)
- Rendezvous and Capture payload
- Potential for additional observational instruments to be contributed by international partners

Falcon-9 or Atlas V-411

Key Capabilities

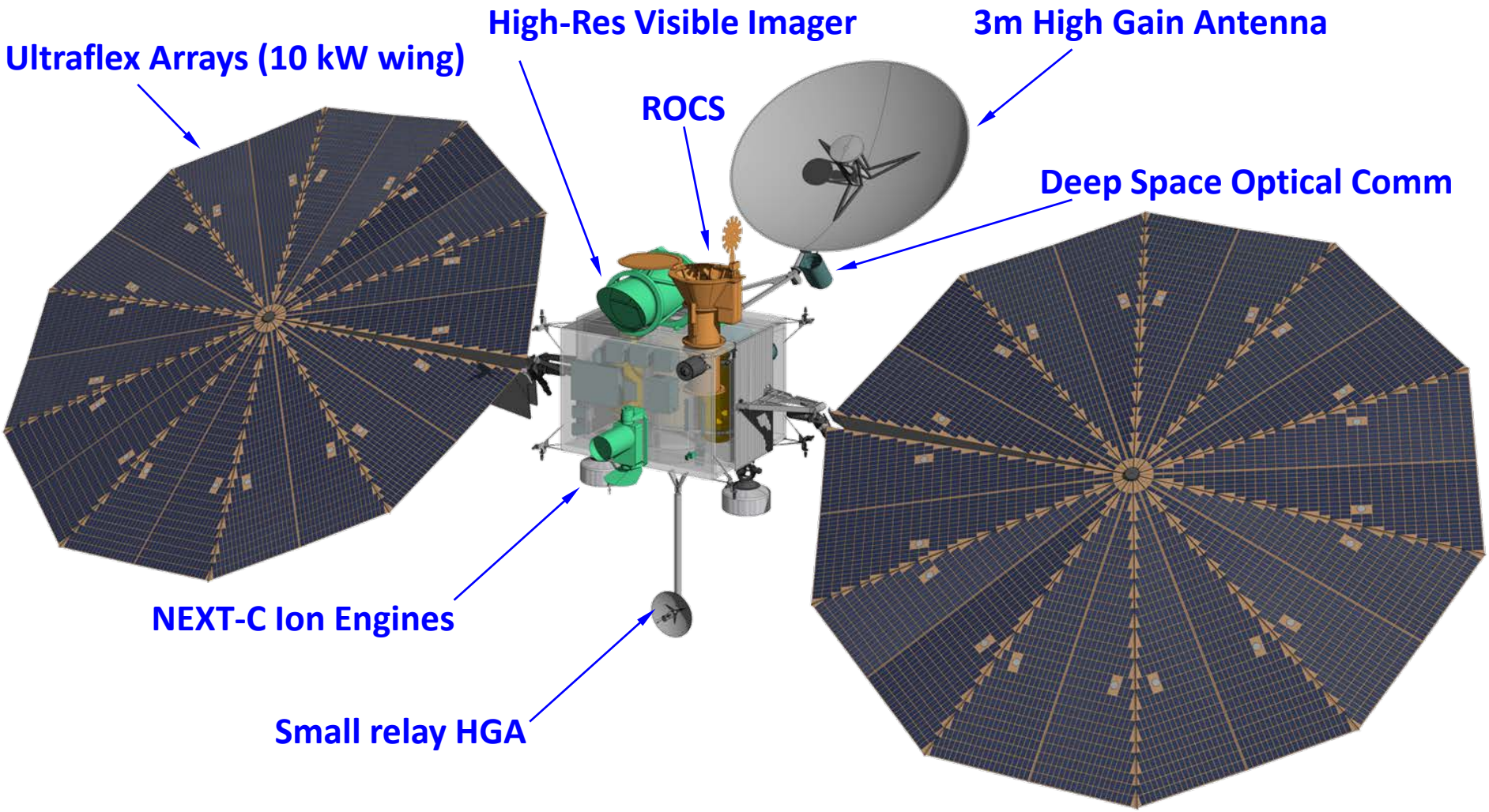
- High-rate RF direct-to-earth telecom system
- X-band/UHF relay telecom system
- Advanced solar electric ion propulsion system
- Significant orbital flexibility for long term support of future missions

Flight System Characteristics

- Moderate Size Spacecraft (6.5 yr life)
- 1250 kg Bus
- 50 kg Payload (High Resolution Imager)
- 600 kg Propellants (~14 km/sec)
- Launch C3 = 15 km^2/s^2
- 20 kW Solar Arrays
- NEXT-C Ion Engines (1 active, 1 spare)

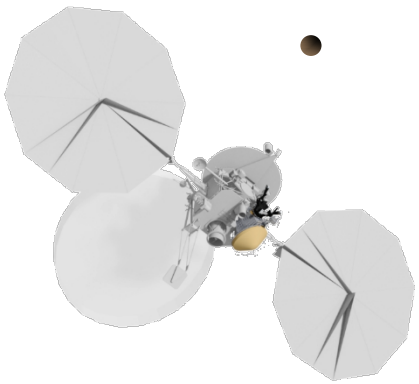
Mission Phase	Start Date
Launch	Jul 2022
Mars Capture Spiral	Sep 2023
Low Orbit Science	Jul 2024
Extended Mission Start	Apr 2028

NeMO Concept Deployed Configuration



MSR Rendezvous & OS Capture System (ROCS) Concept Functions

1) Rendezvous

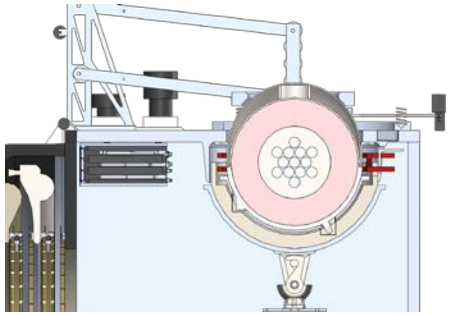


- Acquire OS from 4000km (optical or RF)
- Match orbits using SEP
- Ground-commanded until terminal phase
- Autonomous terminal rendezvous from 100 m

2) Capture

- SC approaches OS at 0-10 cm/sec rate, 0-10 cm accuracy
- OS enters capture volume, trips sensor
- Capture mechanism also orients OS for subsequent operations

3) Break-the-Chain



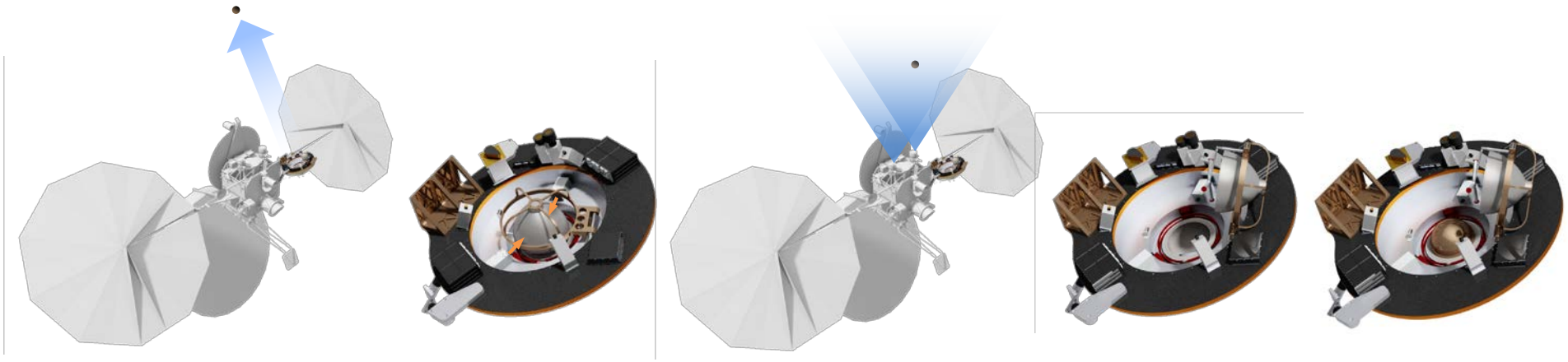
- Outside of OS is assumed contaminated with Martian material
- Clean/sterilize/ encapsulate to meet PP requirements
- Install clean OS into ruggedized container for return

4) Encapsulated OS Release

- Encapsulated OS may be: (1) released into Mars orbit (courier return), (2) returned to Earth-Moon system, or (3) placed in EEV for direct Earth entry
- Spacecraft releases OS after PP approval

Configuration B - Steps

Spacecraft View

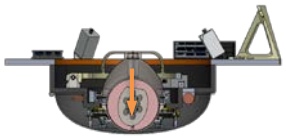


1. Sensing and rendezvous
   1. Long Distance
   2. Med Distance
   3. Short Distance

2. OS Capturing
   1. Check position of lid / training OS arm
   2. Turn on cryo-cooler and go to transition temperature for training flux pinning superconductor
   3. SEP Blow-Off
   4. Turn off training OS
   5. Open Lid/move training OS out of the way
   6. Final Approach
   7. OS Capture (flux-pinning)
   8. Check OS is in position (camera)

Configuration B - Steps

Spacecraft View



3. Break The Chain
   1. Jettison Training OS and Arm
   2. Closing lid with cover + crimping (metal bag)
   3. Brazing (secondary container) +
   4. Frangibolt
   5. Latching into delivery
   6. Cool down temperature (check time to get to 100C)

5. Return Cruise

6. Delivery and Release
   1. Open hangar door
   2. Release (light band)

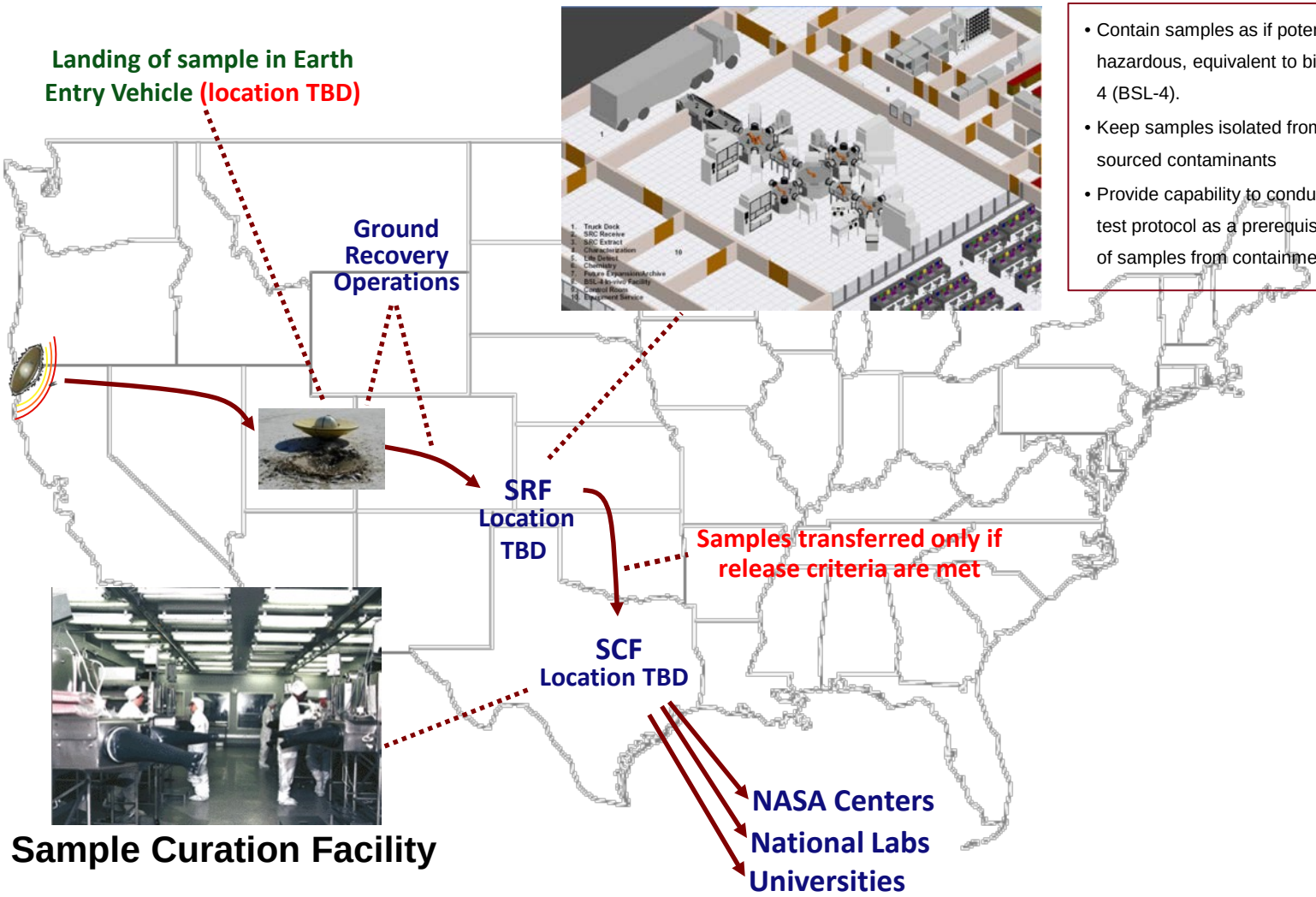
Configuration B

Video - EEV Options

I'll LFT the video file to Lea

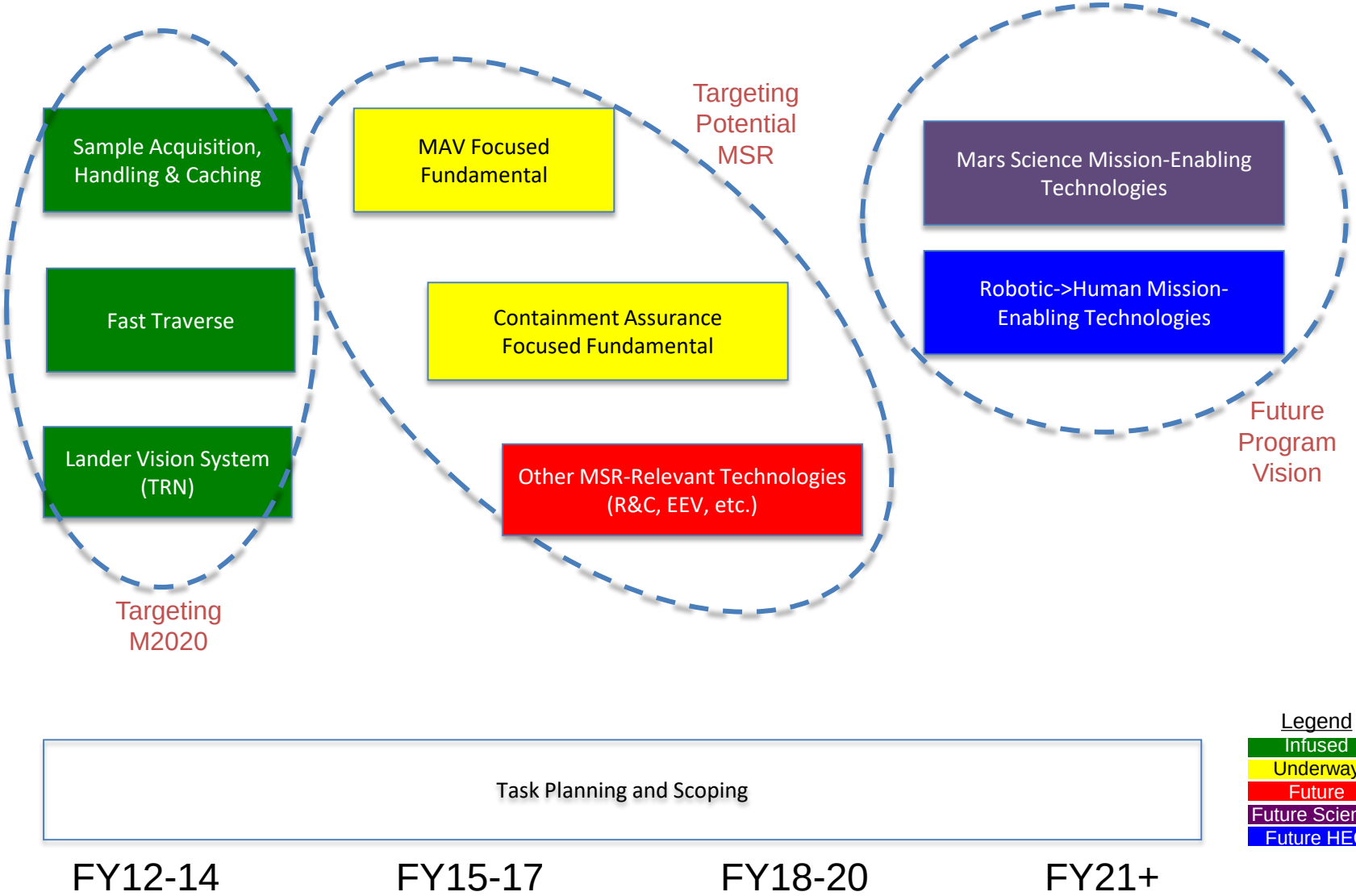
Returned Sample Handling and Science Analysis Functions (example case)

Notional Sample Receiving Facility (SRF)



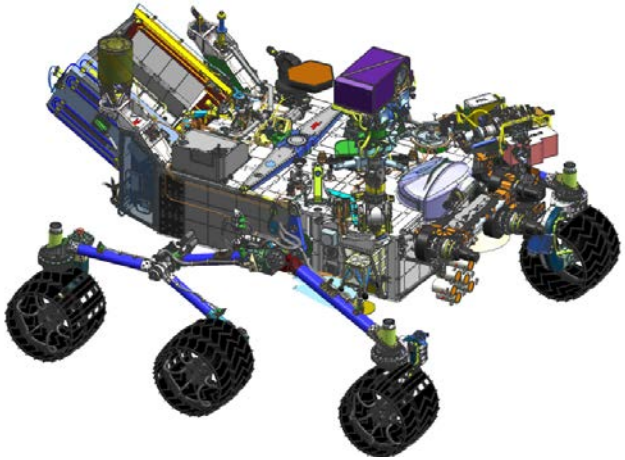
- Contain samples as if potentially hazardous, equivalent to bio-safety level-4 (BSL-4).
- Keep samples isolated from Earth-sourced contaminants
- Provide capability to conduct biohazard test protocol as a prerequisite to release of samples from containment.

Mars Technology Development (MTD) Architecture



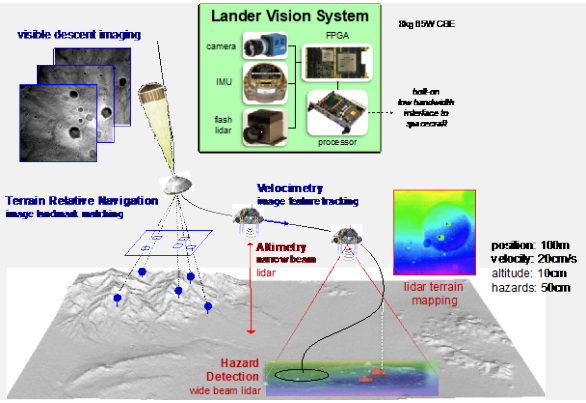
Recent MTD Infusion Successes

Several key technologies have successfully infused to the Mars 2020 Rover mission



Sample Acquisition & Caching

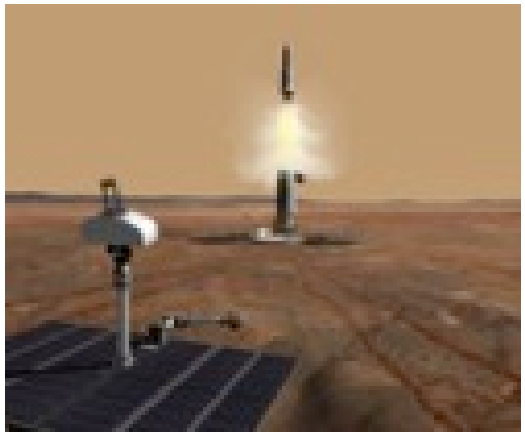
Safe & Fast Traverse



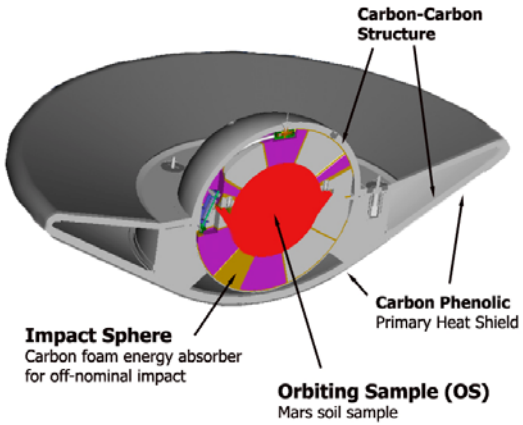
Terrain Relative Navigation

Current Mars Technologies Under Development

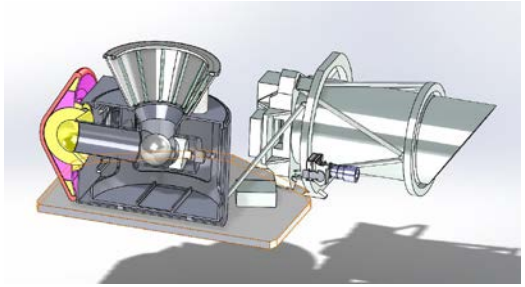
Current portfolio is focused on key technologies for potential Mars Sample Return:



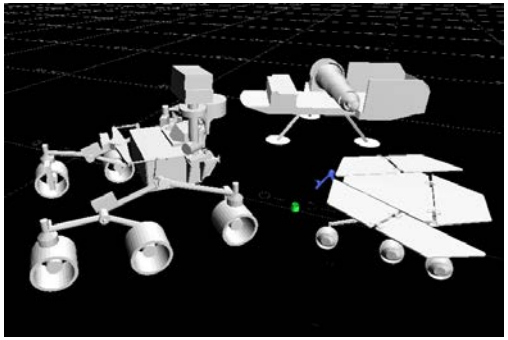
Mars Ascent Vehicle



Break-the-Chain/Containment Assurance



On-Orbit Sample Transfer

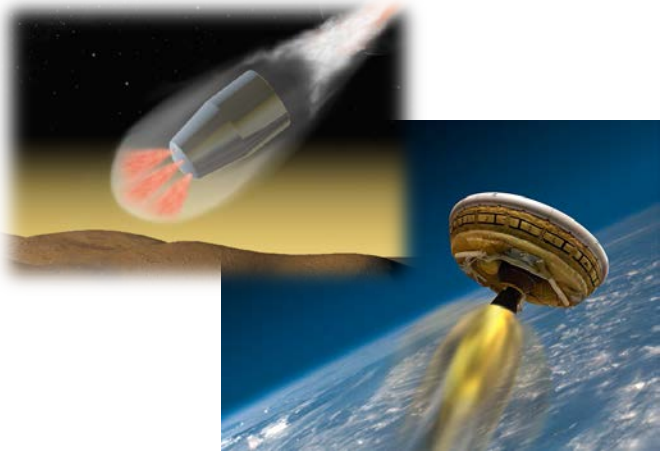


Surface Sample Transfer

New Technology Investment Directions

Longer-term investment areas:

Extreme Terrain Access/ Special Regions Explorer Concept



Advanced EDL

Proposed Aerial Platforms

Thank you!

My contact info:
Joe Parrish
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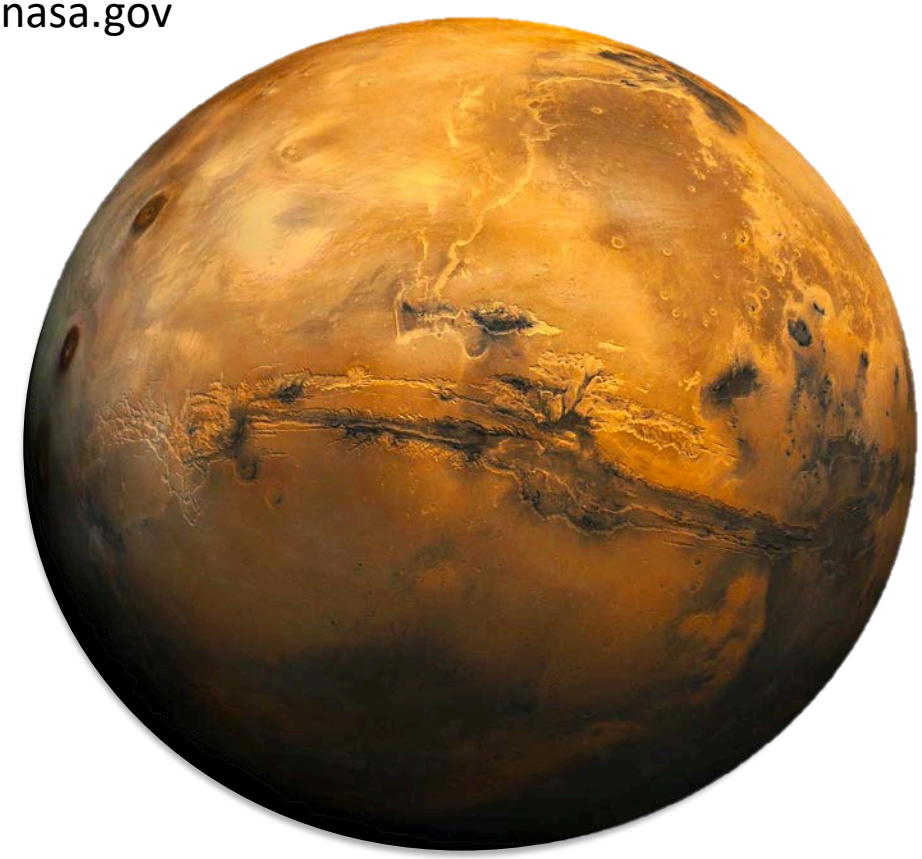
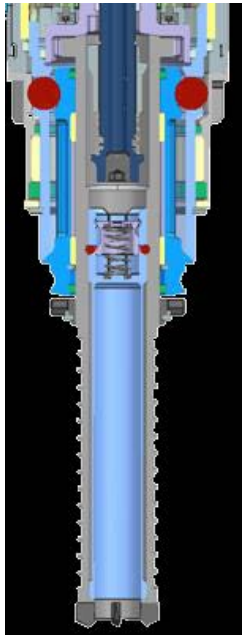
(818) 354-1077
JPL Bldg. 321-632



Questions?

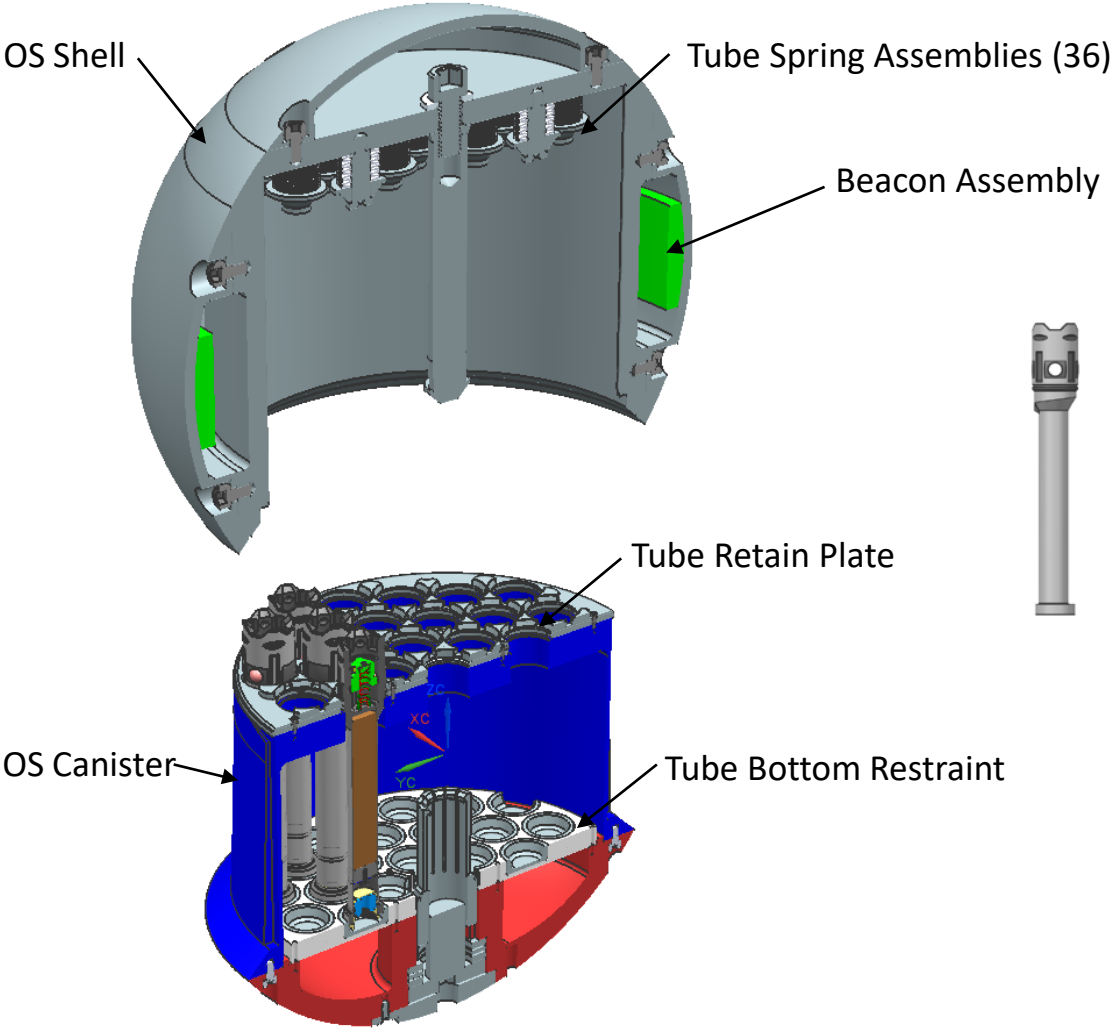
Backup

Sample Packaging Tube Concept

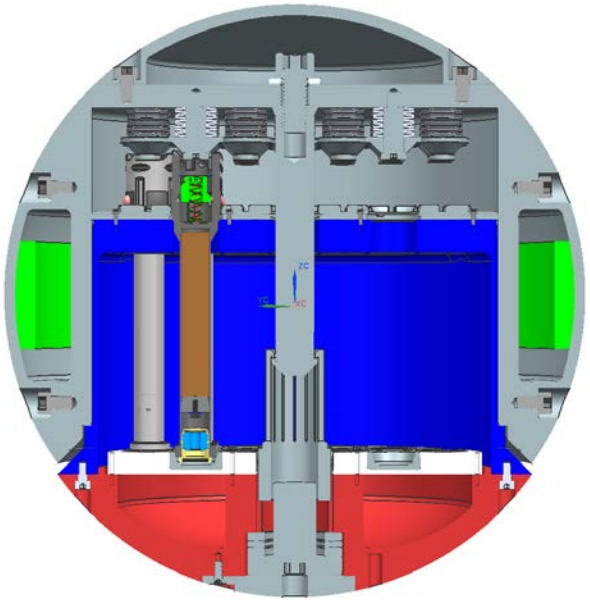


Extraordinary steps taken on rover for contamination control.

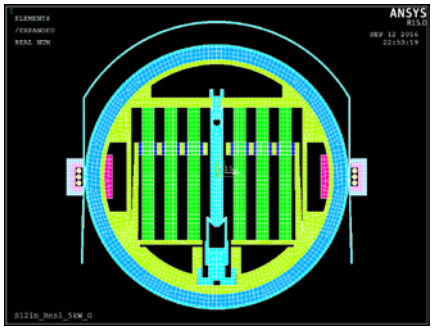
Current OS Design Concept



- 27 cm OD Sphere
- Less than 12 kg
- Accommodates 31 sample tubes
- Capable of accommodating:
  - Air Samples
  - Tracking Beacon

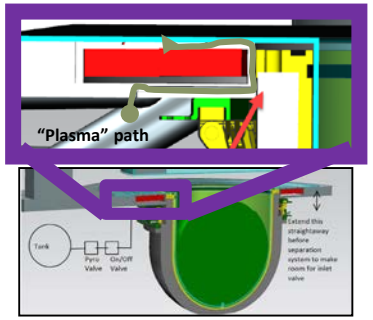


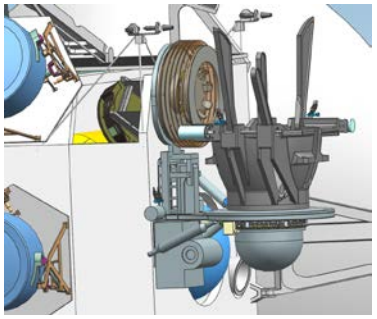
Break-the-Chain Technologies



Brazing

Explosive Welding

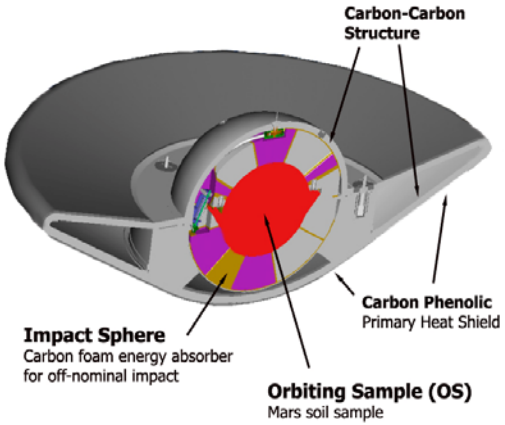


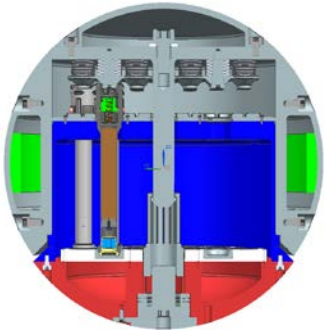


Bagging w/ Plasma Sterilization

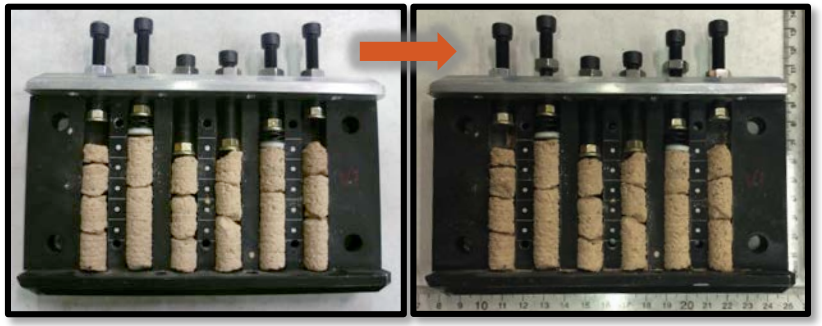
Focusing effort on maturing technologies to enable downselect in late CY16 → Enables transition to flight implementation in second half on FY17

Earth Return -- Concept for Direct EEV Option



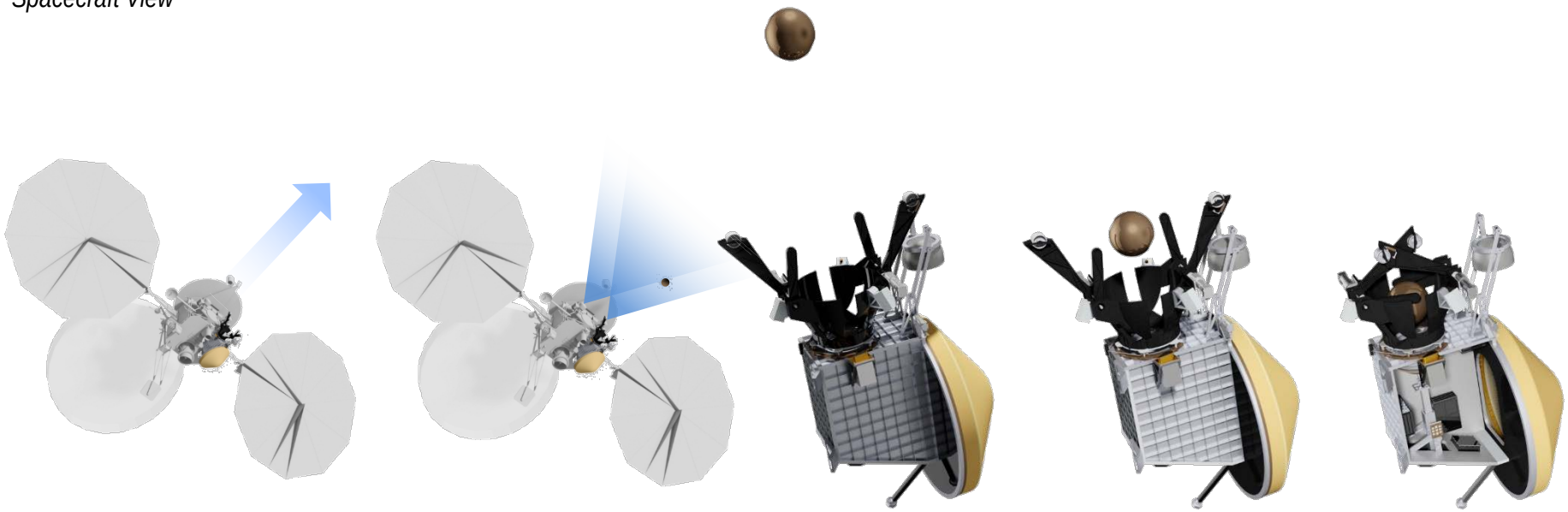


Drop #1, Vertical Orientation, 3000 g's, Before + After



Configuration A - Steps

Spacecraft View



1. Sensing and rendezvous
   1. Long Distance
   2. Med Distance
   3. Short Distance

2. OS Capturing
   1. Arm Opening
   2. SEP Blow-Off
   3. Final Approach
   4. Closing Arms
   5. Arms closed, OS captured

Configuration A - Steps

Spacecraft View

3. Break The Chain
   1. Release Cone
   2. Close Lid with cover
   3. Brazing
   4. Detachment
   5. Cool down temperature (check time to get to 100C)

4. Containment Assurance and Stowage
   1. Translation
   2. Rotation
   3. Translation (inside delivery)
   4. Knife edge and latching (containment assurance)

5. Return Cruise

Configuration A - Steps

Spacecraft View

I'll LFT the video file to Lea