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National Aeronautics and Space Administration

MARS EXPLORATION PROGRAM

Update to the MEPAG; Crystal City

April 3, 2018

Jim Watzin
Director – Mars Exploration Program

MEP News & Status

- All Operating Missions are doing well
- All Development Missions and systems are progressing
  - Successful M2020 SIR; proceeding to Agency KDP-D
  - MOMA instrument for ESA ExoMars Rover in environmental test campaign
- MAVEN orbit adjustment to facilitate comm relay for M2020
  - Plan to reduce apoapsis for improved relay performance in 2019
    - Apoapsis change from 6200 km to 4000/4500 km
    - Incorporating approaches to preserve fuel
- Progressing in our technology maturation program for key MSR technologies
- Preparing for the next Decadal; considering studies and roadmap activities, and exploring how to leverage nontraditional opportunities for Mars investigations

MEP Budget News

- FY18 Budget Appropriation was favorable for the MEP, receiving ~$75M increase over President's request
  - Maintain the high pace of development on M2020, preserving maximum schedule reserves for ATLO
  - Continue all our operating missions
  - Continue our technology maturation activities
  - Fully fund R&A
- Obtained additional funding to explore the feasibility and potential of diverse mission technologies for future applications
  - MMO "CubeSat"
  - Mars Helicopter

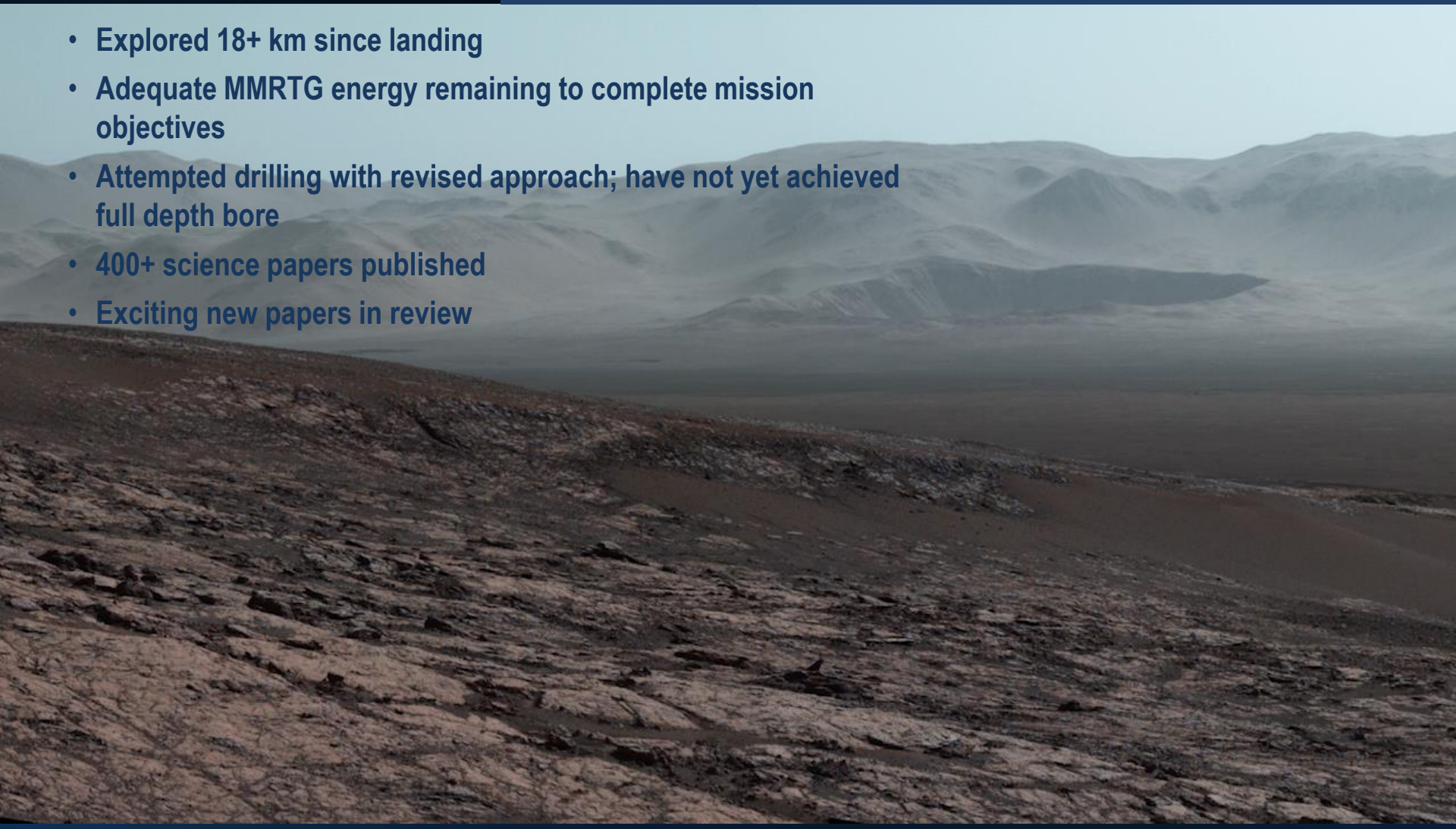
More Mars News & Status

- InSight proceeding to launch at VAFB
  - LV wet dress rehearsal complete
- TGO reached its operational mission orbit
  - Aero-braking is complete; settling into final 400 km orbit
- NASA providing payloads for JAXA MMX mission
  - MEGANE (JHUAPL) neutron and gamma-ray spectrograph
  - Pneumatic sampler

Ongoing Program Highlights

MSL Exploration of GALE Crater

- Explored 18+ km since landing
- Adequate MMRTG energy remaining to complete mission objectives
- Attempted drilling with revised approach; have not yet achieved full depth bore
- 400+ science papers published
- Exciting new papers in review

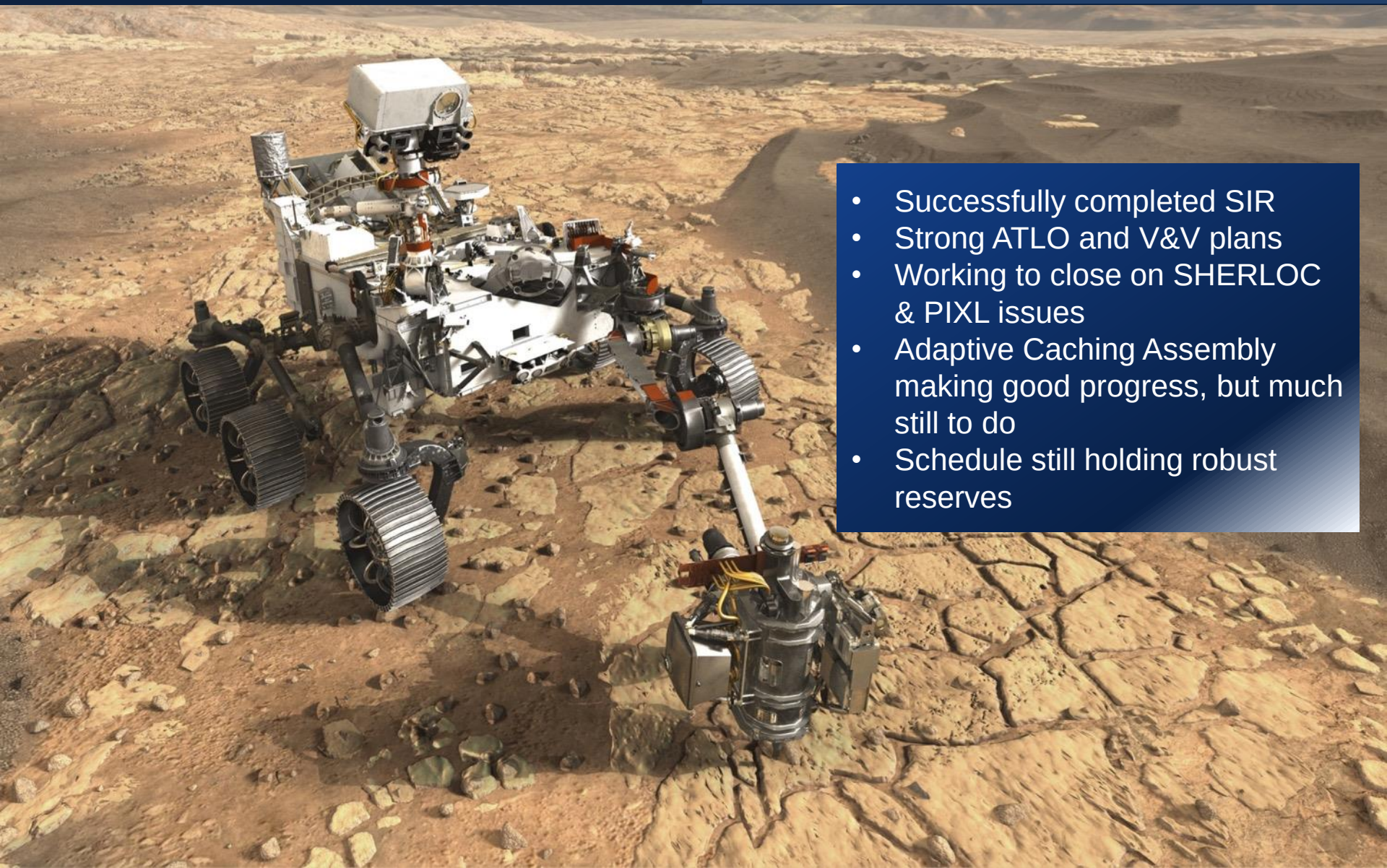


Curiosity at Martian Scenic Overlook

MRO – MISSION STATUS

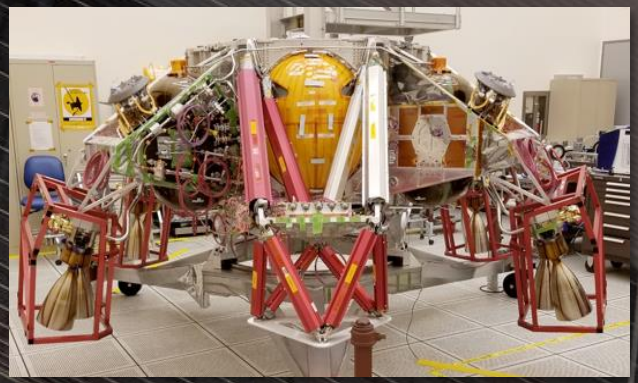
- Launched in August 2005, achieved MOI March 2006
- Continued success with both scientific and comm relay objectives
  - Over 309 Tb of science data returned
  - Spectacular new imagery
- Healthy spacecraft with large fuel reserves (> 20 years)
  - Single string telecomm since 2006
  - All-stellar capability developed to preserve IMU life
  - Improved battery charge management, increasing capacity

M2020 MISSION STATUS



- Successfully completed SIR
- Strong ATLO and V&V plans
- Working to close on SHERLOC & PIXL issues
- Adaptive Caching Assembly making good progress, but much still to do
- Schedule still holding robust reserves

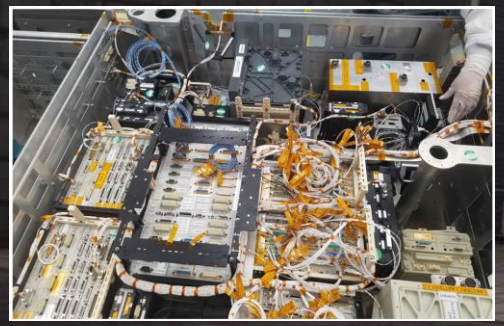
M2020 H/W and Testing Underway



Flight Descent Stage

Flight Cruise Stage

Rover harness

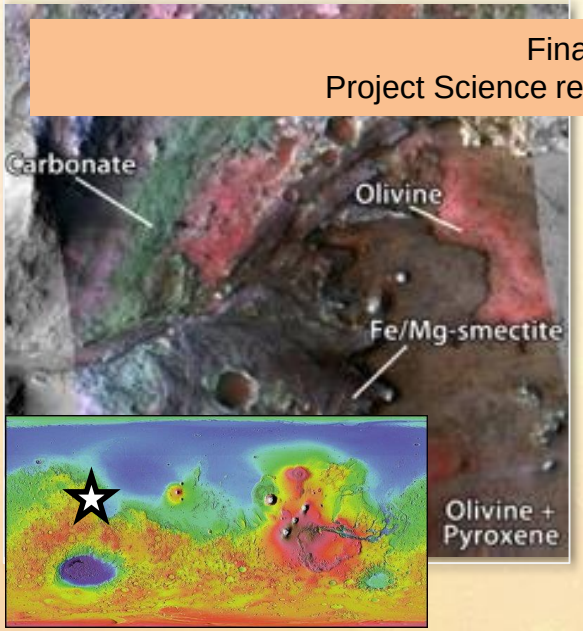


Parachute Testing

Flight Aeroshell

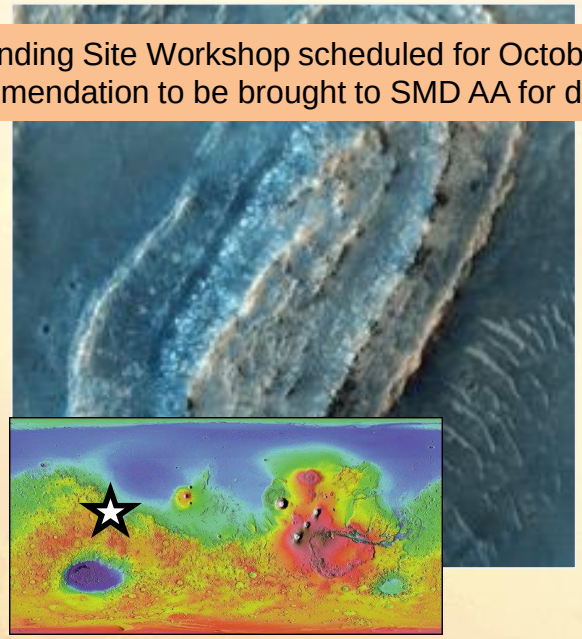
Candidate M2020 Landing Sites

Final Landing Site Workshop scheduled for October 2018.
Project Science recommendation to be brought to SMD AA for decision NET late 2018.



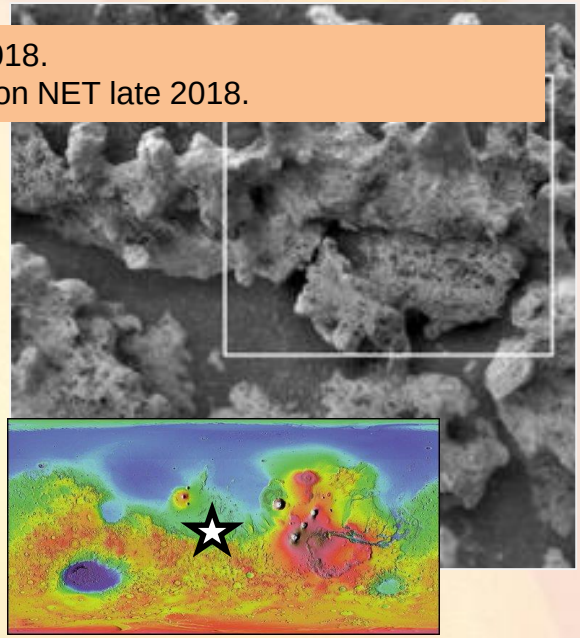
JEZERO

- Deltaic/lacustrine deposition with Hesperian lava flow and hydrous alteration
- Mineralogic diversity including clays and carbonates
- Evidence for hydrous minerals from CRISM, *including carbonates*



NE SYRTIS

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



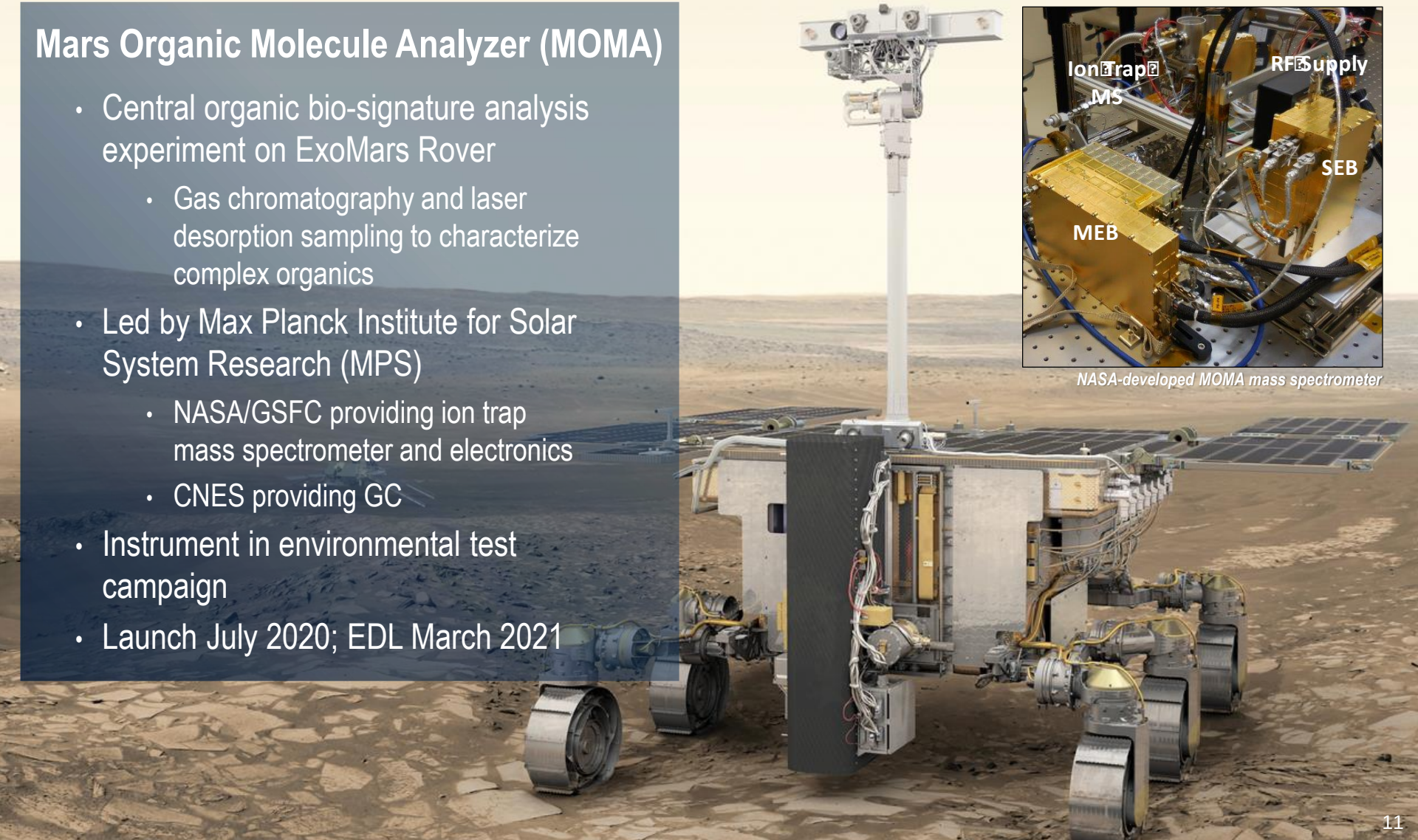
COLUMBIA HILLS

- Carbonate, sulfate, and silica-rich outcrops of possible hydrothermal origin and Hesperian lava flow
- Potential bio-signatures identified
- Previously explored by MER

NASA CONTRIBUTION TO ESA EXOMARS

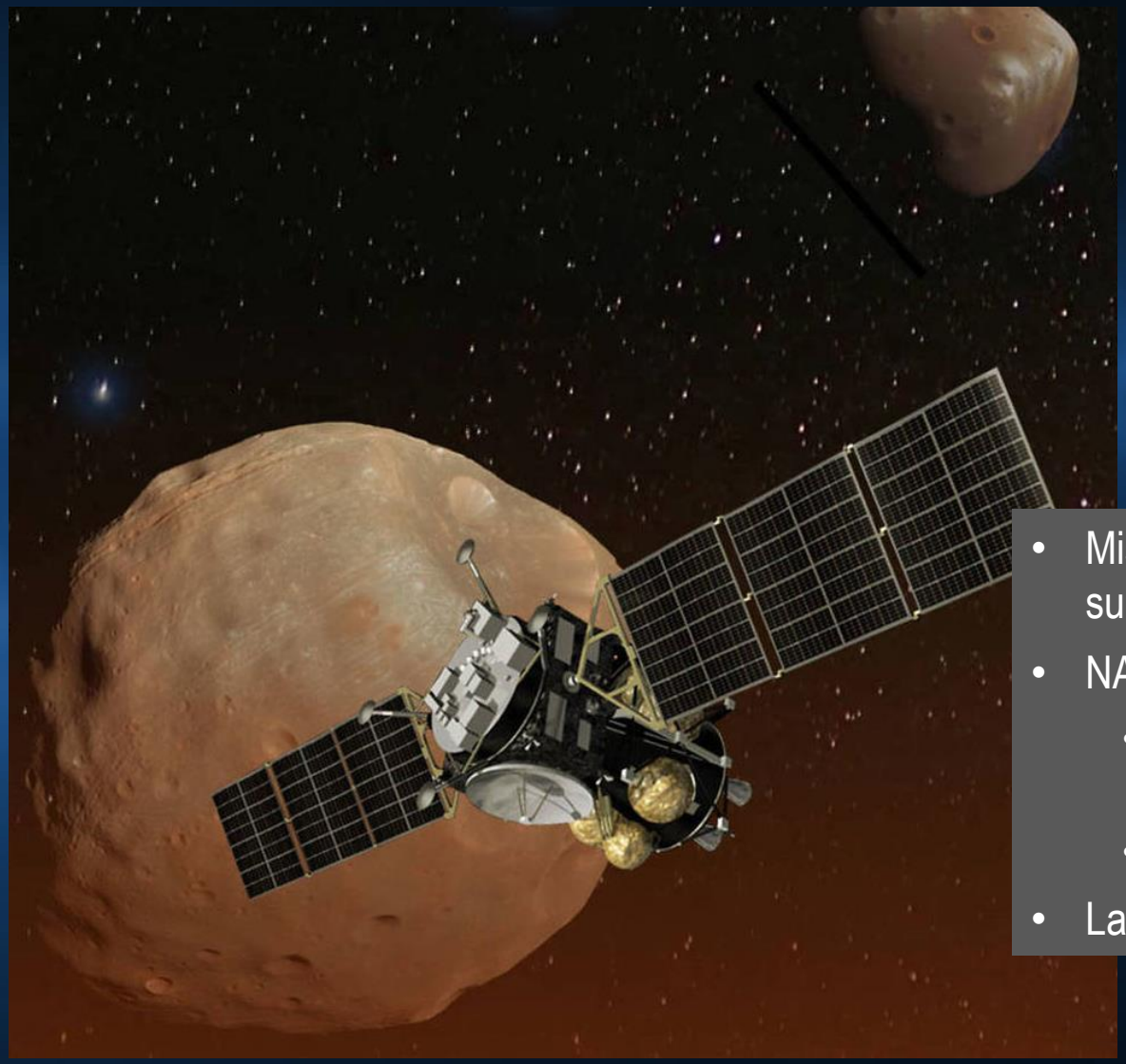
Mars Organic Molecule Analyzer (MOMA)

- Central organic bio-signature analysis experiment on ExoMars Rover
  - Gas chromatography and laser desorption sampling to characterize complex organics
- Led by Max Planck Institute for Solar System Research (MPS)
  - NASA/GSFC providing ion trap mass spectrometer and electronics
  - CNES providing GC
- Instrument in environmental test campaign
- Launch July 2020; EDL March 2021



NASA-developed MOMA mass spectrometer

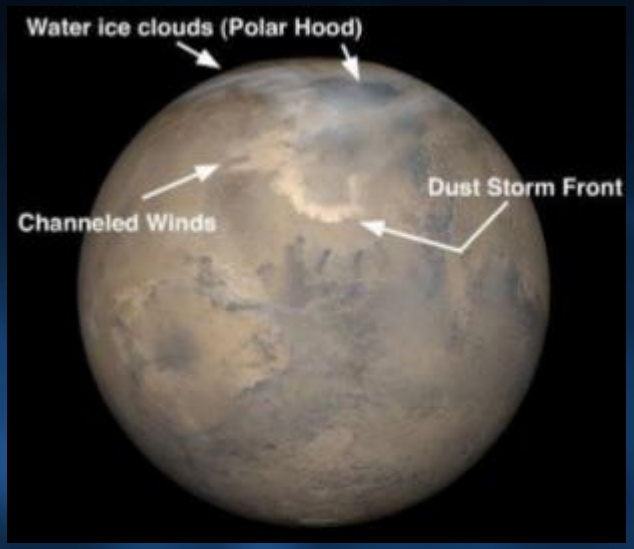
JAXA Mars Moons eXploration - MMX

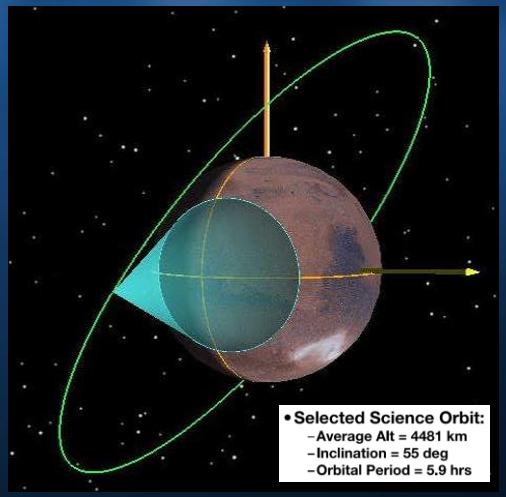


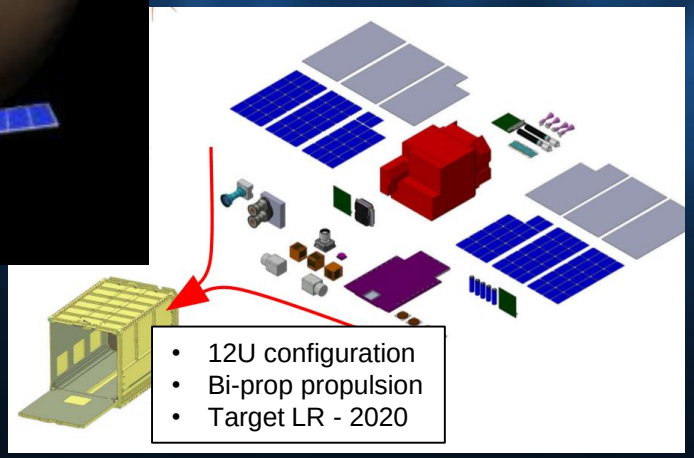
- Mission to study Mars moons & return surface samples from Phobos
- NASA providing:
  - MEGANE (JHUAPL) neutron and gamma-ray spectrograph
  - Pneumatic sampler (HBR)
- Launch 2024

Mars Micro Orbiter (MMO)

- **Highly Ranked SIMPLEx-2014:** proposal selected for risk reduction funding. After first risk reduction study was completed, a second grant was issued for technical development
  - PDR – March 28-30, 2018
- **PI: Michael Malin, MSSS**
- **Science Objective:** Global environmental monitoring of Mars



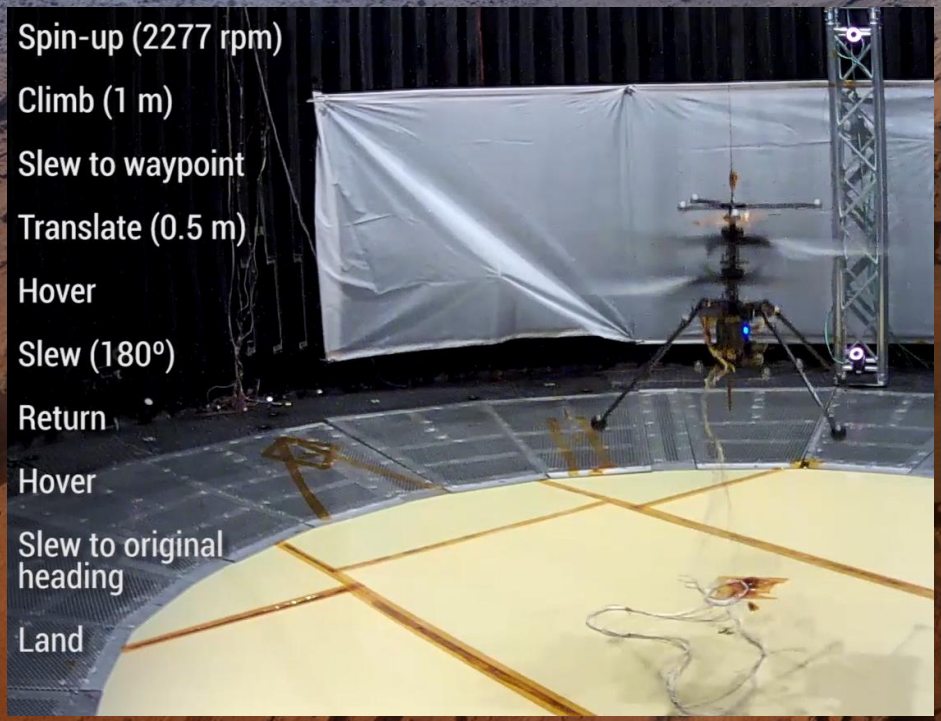




MARS HELICOPTER - TECHNOLOGY DEVELOPMENT

Objective - Explore utility of Mars aerial mobility

- Regional-scale high-resolution reconnaissance to facilitate surface operations of future robotic missions
- Access to extreme terrains, Rover scouting
- Mass < 2 kg, solar powered,300 m range on one charge, autonomous, dual cameras



Full-scale free flight testing in JPL Space Simulator

Technology Maturation Progress

- ✓ Controlled-flight feasibility demonstration – June 2016
- ✓ Engineering Model build & test complete – Feb 2018
  - ✓ 86 mins accumulated flight time in Mars environment
- ○ Decision on flight opportunity pending

S/C mate to LV April 23, 2018

Launch Window Opens May 5, 2018
- VAFB -

InSight

Future Program Highlights

Program Highlights

FY 2019 Budget

Program Highlights

Planetary Science

Exploration program supports commercial partnerships and innovative approaches to achieving human & science exploration goals

- New Planetary Defense program includes DART development
- Europa Clipper launch as early as FY25
- Plan a potential Mars Sample Return mission

Astrophysics

launch

- Given its significant cost within a proposed lower budget for Astrophysics and competing priorities within NASA, WFIRST terminated with remaining WFIRST funding redirected towards competed astrophysics missions and research

Heliophysics

strengthen cross-agency collaboration on Research-to-Operations/Operations-to-Research

- Provides for a balanced Heliophysics portfolio, including enhanced emphasis on small missions, technology development and expanded opportunities for R&A

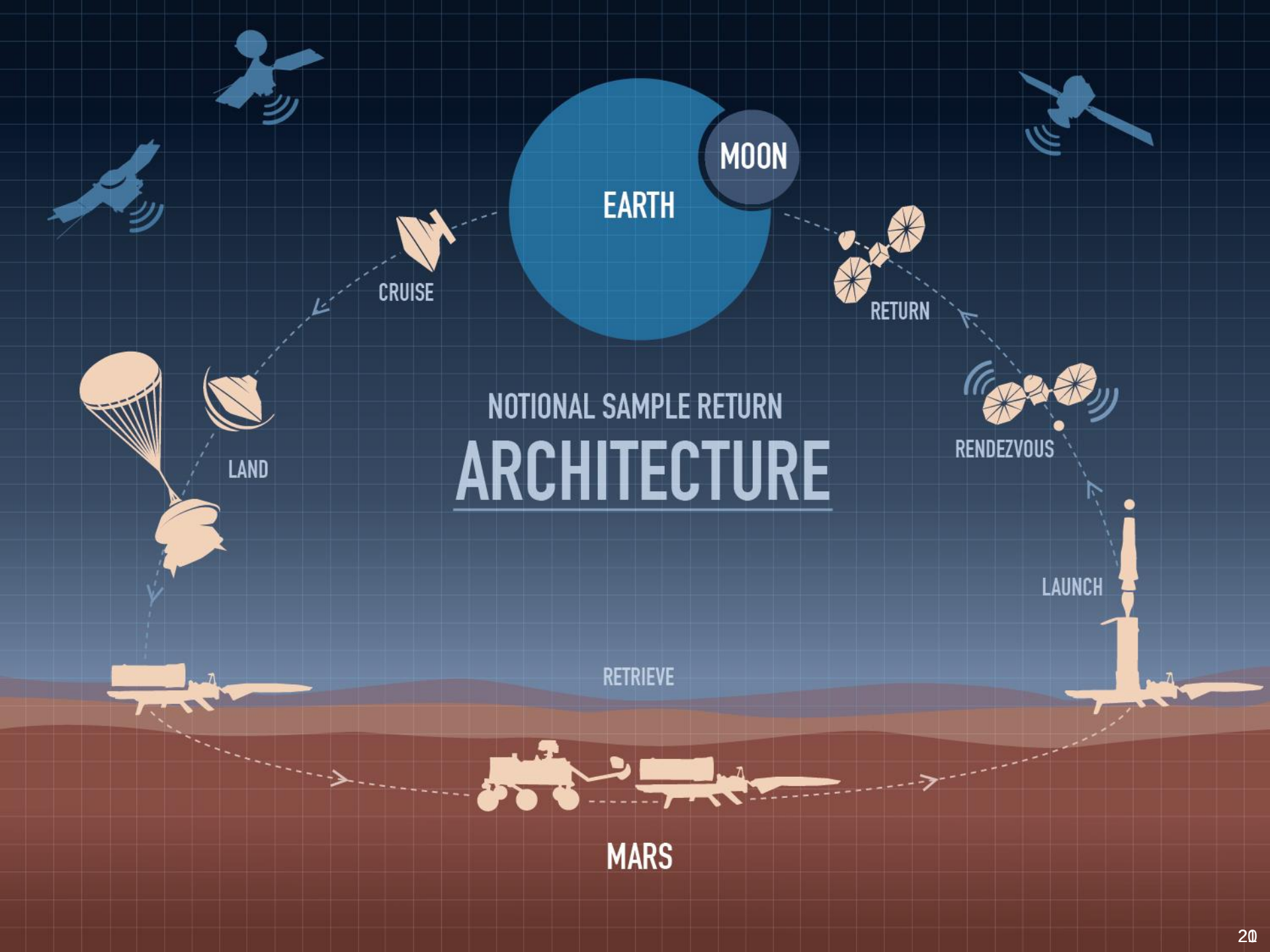
Earth Science

- Maintains regular cadence of Venture Class missions and instruments solicitations
- Healthy research and applied science programs, and SmallSat/CubeSat investments

- ➢ Continue all ongoing **MEP Missions**
- ➢ Continue **M2020 Development**
- ➢ Plan a potential **Mars Sample Return** mission, a decadal survey priority, leveraging international and commercial partnerships

MSR - Why now?

- Are now operationally and scientifically mature enough to select compelling samples
- Science has evolved to an informed recognition of the need to bring modern diagnostic tools to the table to explore at granular scales and below to interrogate chemistries and textures not possible at Mars
- Forsee that interrogating these samples using state-of-the-art instrumentation will move the science from characterizing the environment to being able to explain what was and is happening at Mars today, and into the future
- Critical technology is understood and ready
  - M2020 entering ATLO
  - MAV and PP containment approaches in prototype phase


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

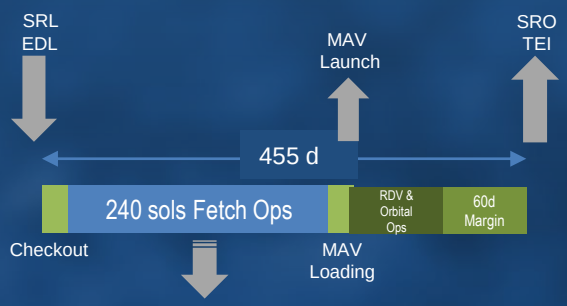
SAMPLE RETURN: KEY REQUIREMENTS

LAND in the right place

Land in small landing error ellipse (≤10 km) to access M2020 sites

COLLECT samples fast

Long traverse with tight timeline

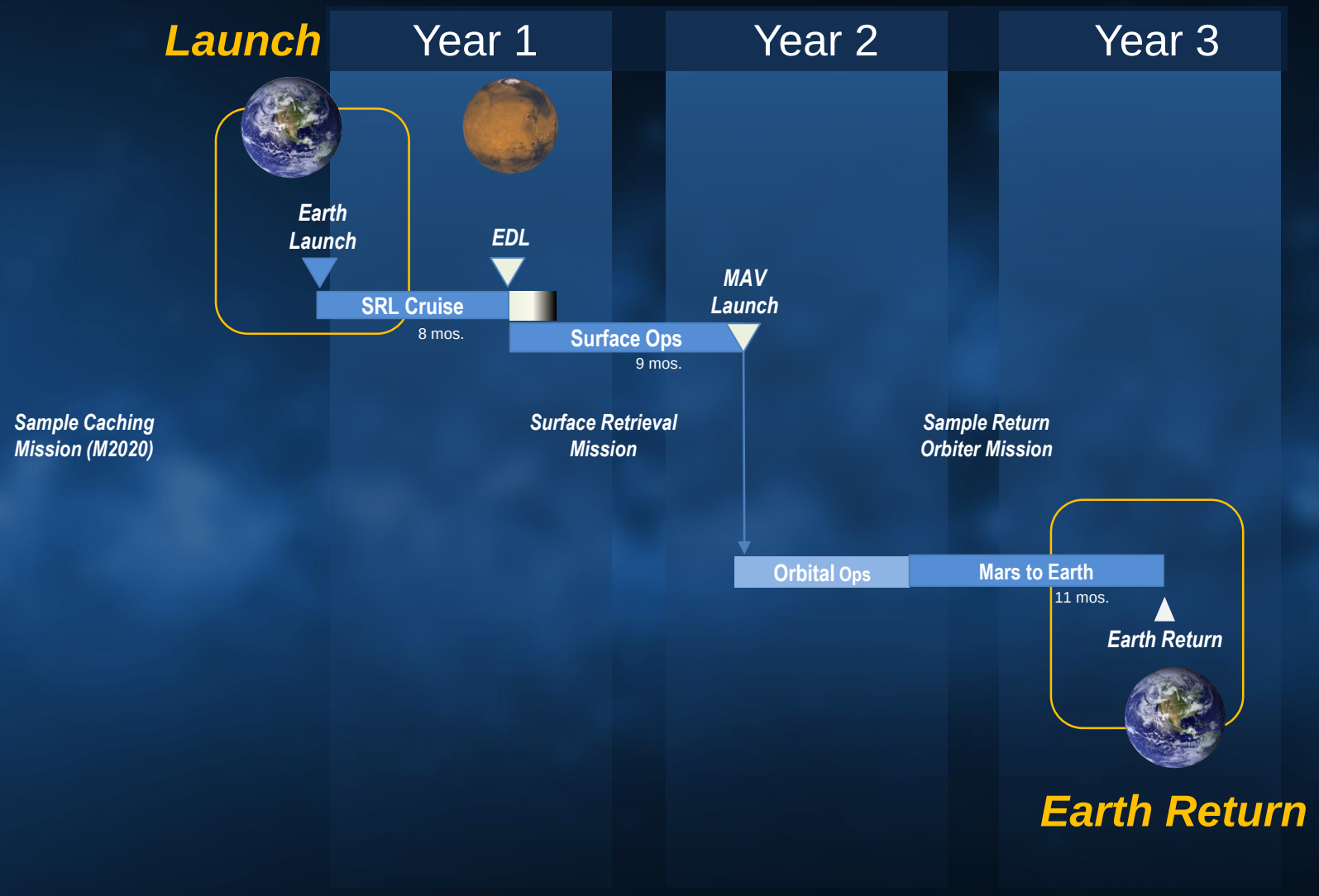


- 130 sols for driving km (rover odometry)
- 20 sols for tube pickup (1 tube/sol)
- 90 sols for faults/anomalies/engineering activities

Get it BACK

Launch, rendezvous and return

NOTIONAL MSR TIMELINE

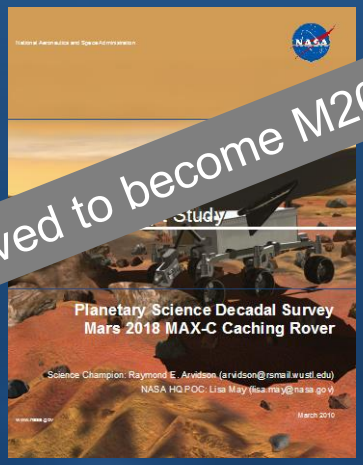


STRATEGIC APPROACH FOR MSR IMPLEMENTATION

- *"Lean Sample Return"*
  - Retain flexibility on requirements; cost & risk are part of the essential trade-space; returning good samples is the L1
  - Take calculated risk
  - Focused scope; no ornaments
  - Capitalize on experience base; Limit new development
  - Continue early technology investments to mature readiness and minimize cost risks
  - Leverage partnerships
  - Strong programmatic discipline in execution

DECADAL SURVEY MSR CONCEPTS

Sample Caching Rover



Evolved to become M2020

- MSL-heritage Skycrane EDL
- MAX-C Rover (solar powered)
  - Sample Caching System
  - Instrument suite for sample selection/context
  - 2 integrated caches, each w/ 19 sample tubes

Key Technologies

✓ Sample Caching System

✓ Terrain Relative Navigation

Sample Return Lander

Evolving to "Lean Sample Return" concept

- MSL-heritage Skycrane EDL
- Pallet Lander
  - Fetch Rover (157 kg)
  - Mars Ascent Vehicle (2-stage Solid-Solid)
  - 17-cm OS

Key Technologies

- Mars Ascent Vehicle
- Fast Fetch Rover

Sample Return Orbiter

- Round-trip Orbiter (ChemicalPropulsion)
  - MOI, Aerobrake
  - OS Rendezvous & Capture
  - Earth Return
  - Earth Entry Vehicle
- Mars Returned Sample Handling

Key Technologies

- OS Rendezvous and Capture
- Back Planetary Protection

➢ Electric Propulsion

Risk Reductions and Partnership Interests have Reduced the Cost of MSR

- Successful MSL launch, landing, and mission operations
- Mars Rover 2020 on-track for launch; confirmed at ~2/3 of Decadal cost estimate
  - With both *"key technologies"*, Sample Caching and TRN, included
  - MSL reuse strategy has been extremely effective, realizing substantial savings on heritage systems
- MEP Technology investments are maturing key MSR technologies
  - Mars Ascent Vehicle (MAV)
  - Assured Planetary Protection Containment
- Commercial sector has matured electric propulsion capabilities
- Longevity of current communications infrastructure defers need for a new orbiter
- Enduring ESA interest and Emerging commercial interest in Mars opens potential partnership opportunities

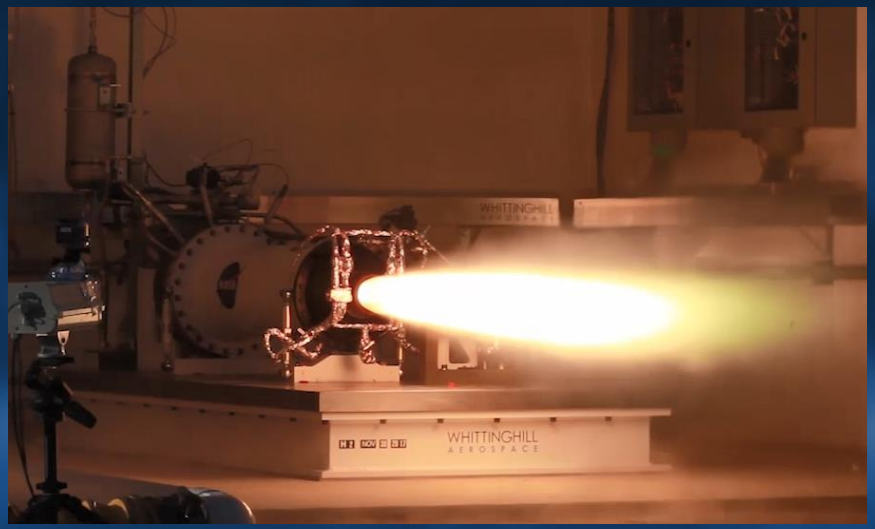
MAV - TECHNOLOGY MATURATION

Objective

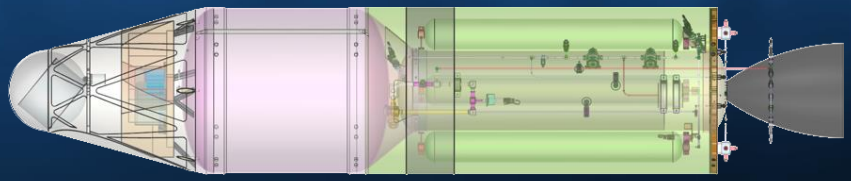
- Achieve stable orbit @ 18 deg, 350 km circular
- Minimize thermal survival power
- Constrain mass/volume

Technology Maturation Progress

- Pursuing hybrid propulsion SSTO approach
  - Paraffin based fuel has superior cold temperature properties (-90 C)
  - Inert fuel grain and low temp MON3 oxidizer
- Full scale motor test firings in-work



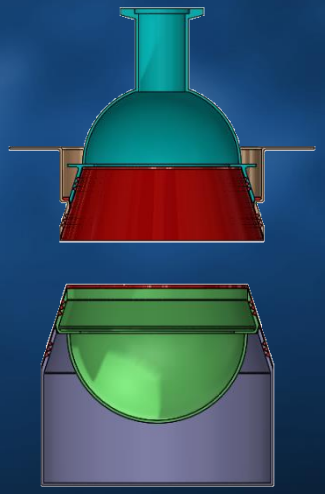
Full-scale hybrid motor test at Whittinghill Aerospace – Nov 2017



Mars Ascent Vehicle (MAV)
~2.4m length/~ 300 kg mass

BIO-CONTAINMENT TECHNOLOGY MATURATION

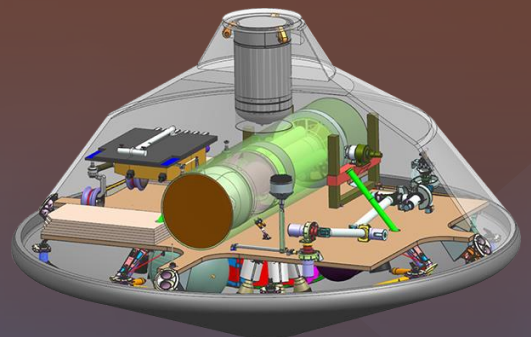
- Simultaneous Sealing and Sterilization via Brazing
- Cone-within-cone design serves both structural and sealing functions
  - Approach has been validated using 4” bench test induction heater
  - Multiple test items successfully brazed
  - Sealed and separated containers were tested with spectrometer/vacuum/Helium



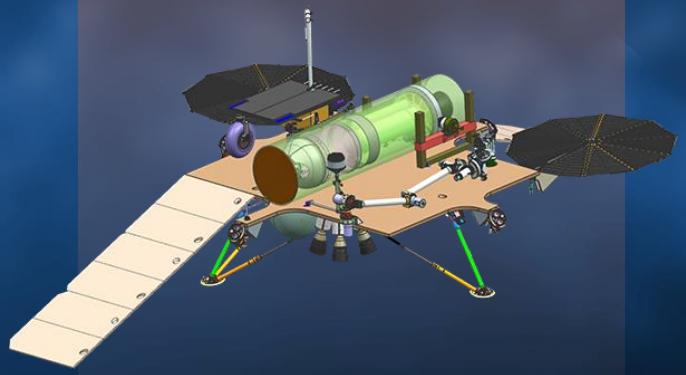
He leak test

TWO LANDER CONCEPTS

2017 Highly Integrated Concept



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

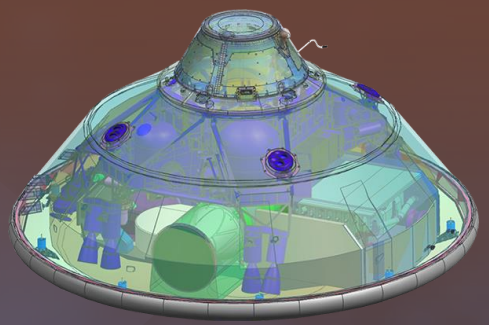


Propulsive Platform Lander
Concept Deployed

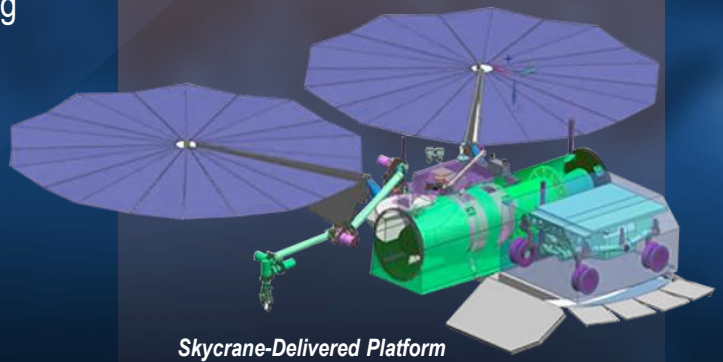
Common Attributes

- 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



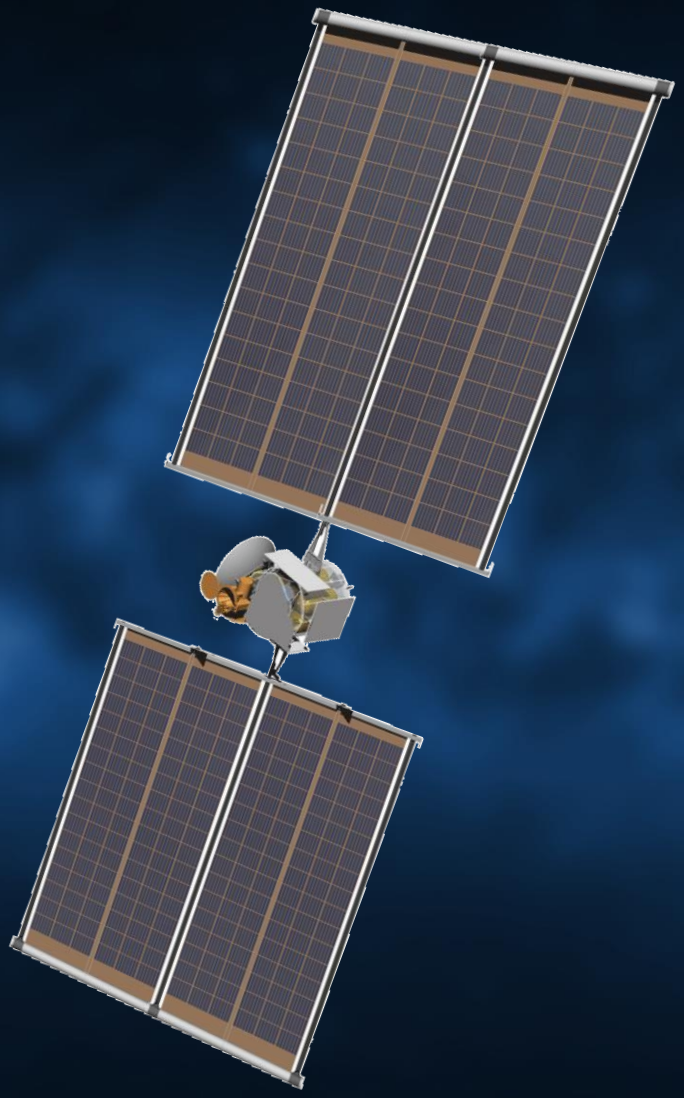
Skycrane-Delivered Platform
Concept Deployed

Two concepts that leverage Mars program legacy system capabilities

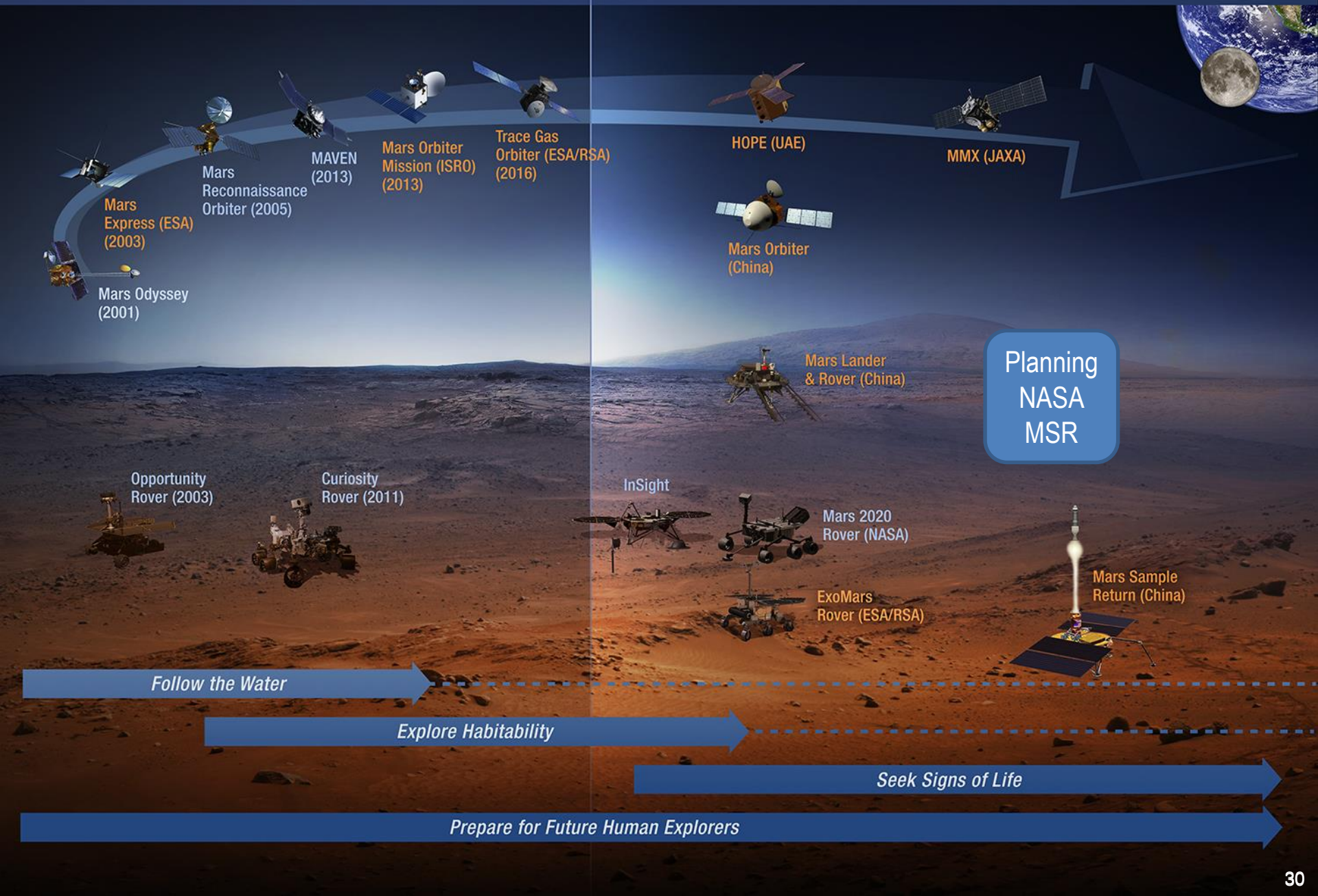
EARTH RETURN ORBITER CONCEPT

Orbital Rendezvous & Fast Sample Return

- Mars Orbit Sample Rendezvous & Capture
- Bio-Containment and Earth Planetary Protection
- Communication Relay Support for Surface Ops
- Return to Earth, either via
  - Direct return to Earth in EEV
  - Deliver to cis-lunar space for human-assisted return



MARS MISSIONS



MARS EXPLORATION PROGRAM – SUMMARY

- MEP is a healthy program
  - Current missions still productive
  - Development missions/systems doing well
  - Beginning early-stage work on a potential lower cost MSR mission, long a Decadal priority, leveraging international and commercial partnerships
  - Beginning preparations for 2019 next Decadal activities
- Upcoming meetings of interest
  - IMEWG – April 23-24, 2018
  - 2nd International MSR Conference – April 25-27, 2018