



NASA'S JOURNEY TO

# MARS

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MEP Status and Future Planning – Presentation to  
Committee on Astrobiology and Planetary Science

Mars 28, 2017

# Operational 2001–2017

# 2018

# 2020 and Beyond



*MAVEN, MSL, MRO, MEX, MER-B, ODY were all approved for extended missions in FY2017-2018*



Follow the Water

Explore Habitability

Seek Signs of Life

Prepare for Future Human Explorers

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# OPERATING MISSIONS

# Status of Landed Missions: MSL (*Curiosity*)

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- Continuing to characterize environments in Gale Crater
  - Diverse habitable environments with fluctuating water activity
  - Investigated active dunes, revealing new phenomena
  - Exiting Murray Formation and approaching higher elevation hematite, clay and sulfate strata (see diagram)
    - Murray Formation has revealed a complex and evolving environment
    - Contains clays & hematite minerals more widespread than detected from orbit
- Risk to long-lived science objectives being mitigated
  - RTG power will enable full science capability for the current and following two-year extended missions
    - Subsequent power limitations will still permit significant science activity, but mobility will be increasingly limited
  - Present difficulties with the drill are being explored. This remains a challenge for the team.
    - Samples can be scooped for CHEMIN & SAM (will be done as drill is being investigated)
    - Other instruments are expected to continue with current capabilities: MastCam, ChemCam, APXS, REMS (not winds), MAHLI, DAN

# Status of Landed Missions: MER, InSight

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- InSight
  - On pace to launch in 2018 and arrive November 2018
  - MEP orbital assets will be prepared to support EDL & relay
- MER-B (*Opportunity*)
  - Continuing to characterize Noachian-age environments in Endeavour Crater
    - Will drive down Perseverance Valley (an ancient gully-like feature) to determine if it formed via debris flow or fluvial processes
    - Characterization of rocks during transit into the crater will provide cross section of crater rim and its sedimentary strata
      - Also provides ground truth for orbital measurements (by ODY THEMIS, MRO CRISM and MEX OMEGA)
  - Risks to long life being mitigated
    - Solar power still adequate thanks to episodic dust removal by winds
      - MRO MARCI monitors regional weather and provides dust storm alerts
    - Successful work-arounds for overnight memory loss
      - e.g., additional MRO passes during winter when rover cannot stay up for an ODY pass

# Status of Orbital Missions: MAVEN

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- Continuing to characterize atmospheric loss processes
  - Observations in 2<sup>nd</sup> Mars year to characterize interannual variability
  - Observing different parts (approaching minimum) of the solar cycle
  - Characterizing effects of new solar events (e.g., CMEs)
  - High-resolution mapping of cold-ion outflow
  - High-resolution mapping of ion outflow near remanent magnetic fields
  - Directly measure neutral winds in the upper atmosphere
  - New radio occultations to map ionosphere electron density peak
- Programmatic: Relay
  - Demonstrated relay capability with MER and MSL
  - Ongoing assessment of aerobraking options:
    - Can enable move to a more relay-friendly orbit, but will impact MAVEN science
- Risks to long life being being mitigated
  - No degradation observed in spacecraft capabilities
  - Looking for ways to conserve fuel to extend life for 2020 missions
    - e.g., Gravity-gradient attitude may reduce fuel needed for momentum management

# Status of Orbital Missions: Mars Reconnaissance Orbiter

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- Continuing to characterize changes on a dynamic Mars
  - Diversity of possibly habitable environments on early Mars
  - Polar ice cap internal layering and mid-latitude subsurface ice distribution; large south polar deposits of buried CO<sub>2</sub> ice
  - Active changes today: New impacts, Recurring Slope Lineae, subliming CO<sub>2</sub> as an erosive agent, dust storm tracks and seasonal patterns
- Programmatic: Relay & Reconnaissance
  - MSL: ~227 Mbits per pass twice a day
  - Preparing for critical event coverage (i.e., EDL telecom) of InSight in Nov 2018 and relay during its commissioning phase
  - Landing site characterization/certification for InSight lander, 2020 NASA and ExoMars rovers, Human Exploration Zones
- Risks to long life being mitigated; lifetime goal  $\geq 2023$ 
  - Eclipse power management being implemented to extend battery life
  - Development of all-stellar mode to complement inertial (IMU) control
  - Remarkably, *all* instrument modes are available 11 years after launch, including measured use of CRISM IR spectrometer cooler
  - 200 kg of fuel still available for use

# Status of Orbital Missions: Odyssey

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- Science
  - Continues to operate after 15+ years in Mars orbit
  - Observing Mars systematically in its new near-terminator orbit (~ 6 a.m., 6 p.m.)
    - Observing atmospheric clouds and surface frosts at different times of day
  - Completing polar coverage of visual imaging using spacecraft rolls
  - Continuing to add to climate records of atmospheric dust and temperature
- Programmatic: Relay & Reconnaissance
  - Primary relay for MER-B (*Opportunity*)
  - Two contacts for day for MSL (*Curiosity*), providing a third of its data return
- Risk to long life being mitigated
  - All-thruster control mode mitigates loss of a second reaction wheel (mission would run out of fuel in about 1 year if that loss occurs)
  - Migration to serve as backup relay for Mars 2020 EDL would exhaust remaining fuel



# Status of Orbital Missions: ESA Mars Express and Trace Gas Orbiter

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- Mars Express
  - Continues to operate after 13+ years in Mars orbit
  - Science instruments continue to operate except during periods of long eclipse when they are powered off to conserve battery
  - Mars observations, including NASA-ASI radar observations of the polar caps, continue; NASA supporting US co-investigators
  - New Phobos observation campaign with close approaches
  - Coordinated observations with MAVEN (ASPERA, MARSIS instruments)
  - Back-up relay periodically tested for use with Curiosity
  - Amount of remaining fuel uncertain; unlikely to be available after 2020
- Trace Gas Orbiter
  - Began aerobraking March 15; will pause for Solar Conjunction
  - Final science orbit will be achieved by March 2018
  - Carries dual Electra relay units, which have been tested with Curiosity
    - Prime for 2020 ExoMars rover
    - Can work with 2020 NASA rover and other NASA assets

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# DEVELOPMENT MISSIONS

# 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
- **Three sites under assessment**
  - **Jezero Crater**
  - **NE Syrtis**
  - **Columbia Hills**
- Curiosity-class Rover

## SURFACE MISSION

- 20 km traverse distance capability
- **Enhanced surface productivity/efficiency**
- **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 Status – Key Areas

- Instruments

- Substantial progress on all fronts
- PIXL x-ray tube challenges resolved, awaiting test results on new configuration
- SHERLOC Laser alignment and mirror changes in-work. Power supply corona testing underway – alternate implementation approach for electronics being pursued



- Sampling System and Actuators

- Major contracts in place. Completed PDRs and most DDRs/CDRs
- Return sample cleanliness budgets look good. Approach appears stable and sufficient. Added (MSL) T-zero purge for robustness.

- Parachute

- Sounding rocket test program added. Key technical challenge and concern
- Test definition and logistics proceeding. Anticipate ~3 tests in calendar 2017
- Dual Heritage, strengthened) parachute flight builds underway

- Heritage Systems

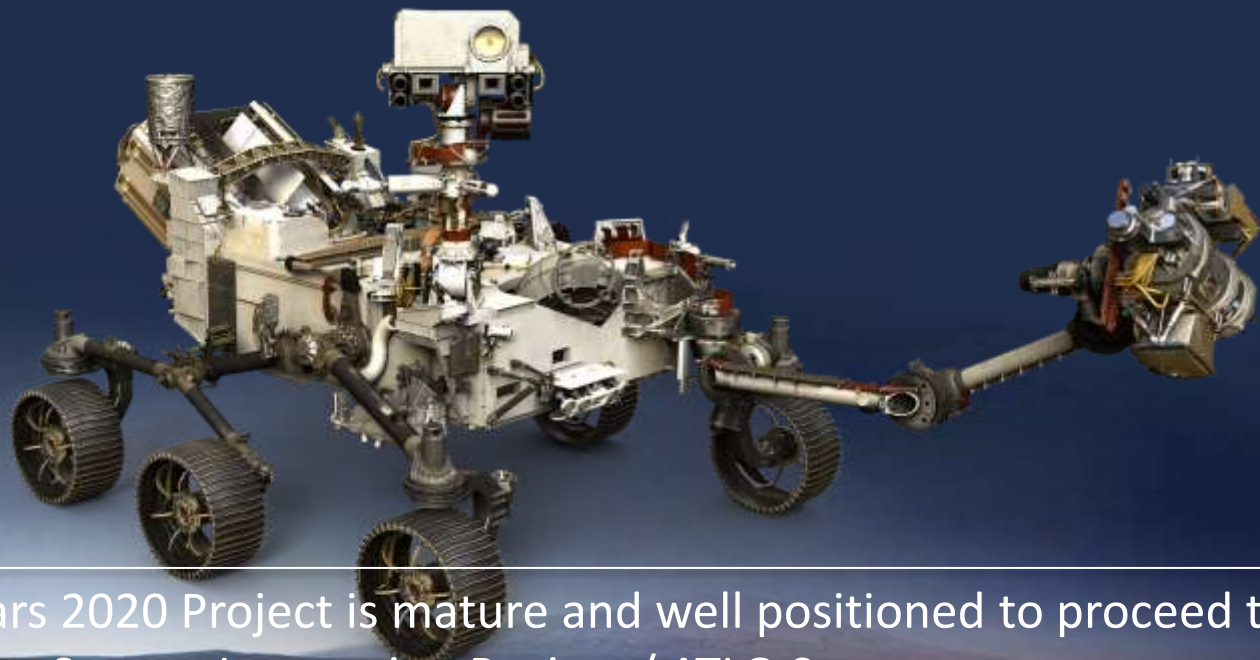
- MSL residual risks have been largely retired
- Heritage elements beginning integration



# Mars 2020 Programmatic Summary

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- CDR successfully completed.
- All significant known post-PDR cost risks have been baselined or mitigated.
- Project focus shifted to execution and maintaining schedule.
- Project budget has remained stable for close to 4 years. Adequate reserves are budgeted.



The Mars 2020 Project is mature and well positioned to proceed to System Integration Review / ATLO Start

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# FUTURE MISSION PLANNING

# The World Looks to NASA for Mars Leadership

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- Essential Infrastructure – comm relay, critical operations
  - Mars Orbit Insertion (MOI)
  - Aerobraking
  - Entry, Descent & Landing (EDL)
  - Surface operations
  - Orbital conjunction surveillance
  - Enabling MSR
- Remote Sensing
  - Landing sites
  - Strategic/tactical maps
  - Resource identification
- Potential future opportunities for returning samples to Earth

# Mars 2021 Arrival Season: Loading Analysis

- Multiple missions are planned for launch to Mars in the 2020 Mars launch opportunity, potentially creating deep space and relay telecommunications support challenges during the 2021 arrival period
- In addition, a number of other missions may be in continuing operations at this time
- MEP is working with DSN to study of deep space communications loading
  - Particular emphasis on final approach, and initial surface and/or post-MOI phases with periods of high tracking requests and potential need for anomaly response
- MEP is independently assessing Mars Relay Network loading in this period
  - Very difficult to meet EDL coverage requirements for M2020, ExoMars/RSP, and 1-2 Red Dragon landings over a 1-2 month period
  - Surface relay support will also be challenging, given number of potential simultaneous surface users
  - Assessing contingency scenarios corresponding to loss of one or more relay orbiters

## Arriving Missions:

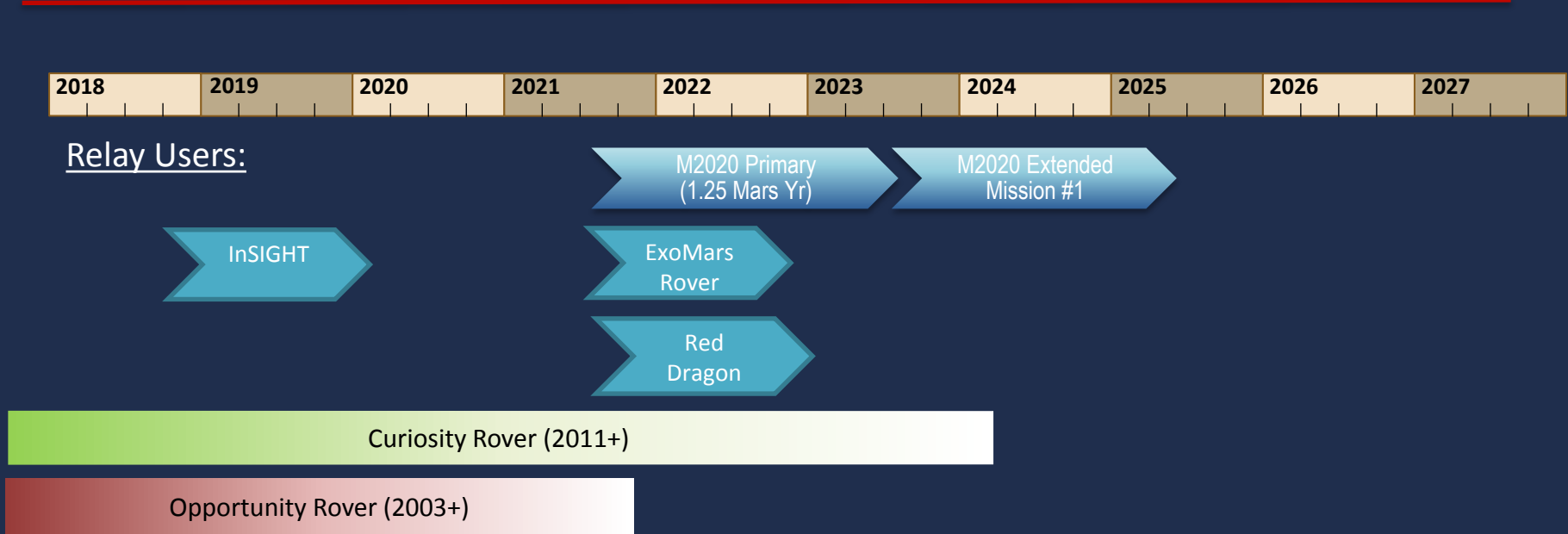
- NASA Mars 2020 Rover
- ESA ExoMars/Rover and Surface Platform (RSP)
- Space X Red Dragon Lander(s)
- UAE Emirates Mars Mission (Hope Orbiter)
- China NSSC 2020 Mars Mission (Orbiter, Lander/Rover)

## Potential Continuing Missions:

- ODY, MEX, MER, MRO, MSL, MAVEN, InSight

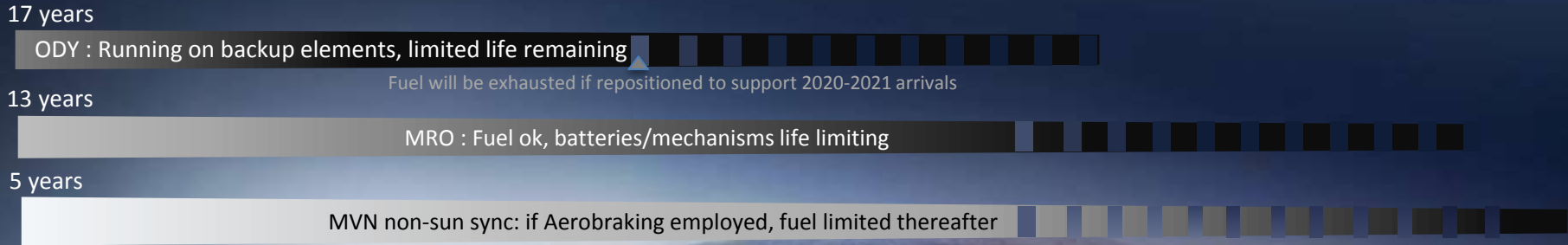


# MEP Infrastructure



Years Since  
Launch (2018):

## Heritage Relay Providers:



# NASA Recognizes the Importance of Mars Sample Return expressed by the Decadal Survey

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Return of scientifically selected samples from Mars to address key objectives across the field on Planetary Science has been and remains the highest scientifically endorsed priority by both of last two decadal surveys

- *“Because of its potential to address essential questions regarding planetary habitability and life, Mars sample return has been a primary goal for Mars exploration for many years. It directly addresses all three of the crosscutting themes ..., and it is central to the committee's Planetary Habitability theme “ (Chapter 9)*
- *“The highest priority Flagship mission for the decade 2013-2022 is MAX-C [now, Mars 2020], which will begin the...Mars Sample Return campaign ... ”(Chapter 9)*
- *“MAX-C [now, Mars 2020] is the critical first element of Mars sample return and should be viewed primarily in the context of sample return,”... (Chapter 6)*
- *“The [Decadal Survey] committee has therefore taken the unusual step of recommending a plan for the coming decade that also has significant budget implications for one or even two decades beyond. The committee does this intentionally and explicitly, with the realization that important multi-decade efforts like Mars Sample Return can only come about if such recommendations are made and followed”... (Chapter 9)*

# Mars Sample Return Affordability

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- Perceived cost & cost risk are significant impediments
- Affordability challenges are well understood
  - Robust comm & recon
    - Both mission operability & critical events
    - Orbit flexibility
  - Minimal fetch traverse
    - Enables fixed lander and simplified conops
    - Requires improved landing accuracy
  - Ascent propulsion tolerant of extreme Martian cold
    - Allow for a solar power solution
  - Secure sample containment – break the chain, BSL-4 Curation facility
    - Important planetary protection functions

Architecture and early tech maturation can reduce risk and cost for MSR

# Future Orbiter Studies

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- Exploring approaches that lower cost and risk, and provide mission flexibility
  - Conducted Industry studies in 2016 which indicate multiple viable commercial providers available
  - Assessed Safe Sample Containment Technologies for Return Planetary Protection
  - Evaluated Solar Electric Propulsion and associated new trajectory design approaches (including round-trip planning)
  - Found the utility of the existing MSR infrastructure to meet new program objectives, based on the Decadal Survey high-priority objectives and new discoveries, throughout the 2020's to be inadequate
  - Worked with MEPAG to identify remote sensing and teaming strategies via NEX-SAG and MIC-SAG activities

# Minimizing Fetch Traverse

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- Precision landing
  - Terrain Relative Navigation (flying on Mars 2020) provides precision navigation “fix” during descent
  - Precision landing for future missions can be achieved by simply adding more fuel, and “flying out” any remaining errors
- Versatile fetch technologies
  - Fast rover – focus on speed vs. exploration, returning to previously visited site
    - Power is the limiting resource
  - Exploring the feasibility of using future versions of Mars helicopter for sample retrieval
    - Evaluating ability to carry one or more tubes per sortie
    - For longer distances (e.g. extended mission sites) may trade well against longer rover traverses

# Ascent Propulsion Tolerance to Extreme Martian Cold

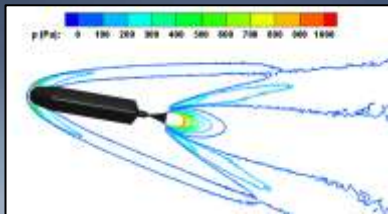
- Historical studies focused solid propellant motors, which require significant heating power to remain within allowable thermal limits
- MAV Motor Technology Maturation for Paraffin-based Hybrid Propulsion emerging as strong candidate technology
  - Enables colder storage temperature and lower survival heater power required from lander
  - Enables simpler single-stage-to-orbit (compared with 2-stage solid)
  - Hot-fire testing of flight-scale motors will validate propulsion technology



*Sub-scale test firings in 2015/2016*



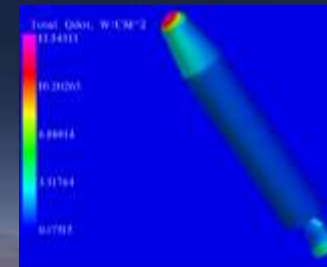
*Testing auto-restart additives*



*Aero forces & torques*



*Paraffin Motor "Grain" Casting*



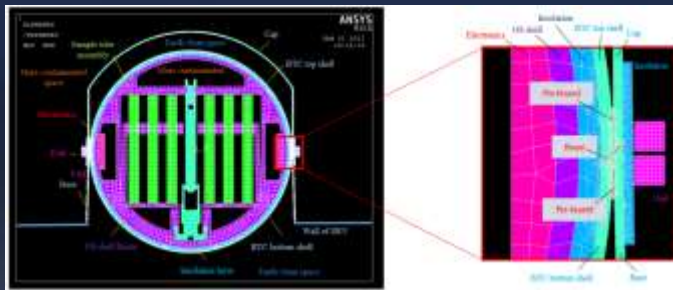
*Aero-heating / TPS sizing*

# Secure Sample Containment

Broad range of alternatives, including ongoing work sponsored by ESA



Sealing via in-flight brazing  
(Simultaneous heat sterilization)



Protection of Samples from Heat / Shock  
During Sealing Operations



Plasma Sterilization  
Ring Concept



Impact testing for Sample and  
Seal Integrity

# MSR - Progress since *Vision & Voyages 2011*

## *In Development*

### **Mars 2020**

- Breakthrough *In Situ* Science
- Affordable inheritance from MSL
- Select & Acquire Samples
- International participation



*Current Mars 2020 Budget: ~\$2.1B  
Decadal CATE cost for Caching  
Mission: \$3.5B, with \$2.4B GOAL*

## *Studies & Tech Maturation for Earth Return*

### **Orbiter**

- Comm/recon Infrastructure
- Sample Rendezvous
- Sample Containment
- Support return to Earth



*Cost estimates for current  
concepts below estimates  
developed for Decadal CATE  
(\$2.1B including ~\$0.5B for  
Terrestrial Handling Facility)*

### **Sample Retrieval/Launch into Mars orbit**

- Fetch samples
- Support MAV
- Launch samples from Mars surface to 500km orbit



*Cost estimates for current concepts  
remain below Decadal CATE  
estimate of \$4.0B  
– Risk reduction investments  
ongoing*



# Summary

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- Ongoing rover and orbiter missions continue to produce valuable and exciting science, although many missions are showing signs of aging
- Mars 2020 development continuing on schedule for planned launch date
- MEP continues to fund mission studies and make technology investments consistent with the last Decadal Survey guidance for potential future missions
  - Emphasis has been on looking for ways to decrease cost and technical risk
  - Exploring opportunities to leverage commercial and other partnerships
  - Recent investments are improving confidence in affordability and risk control