Jet Propulsion Laboratory
California Institute of Technology

Mars Exploration as a Catalyst for Technology & Innovation

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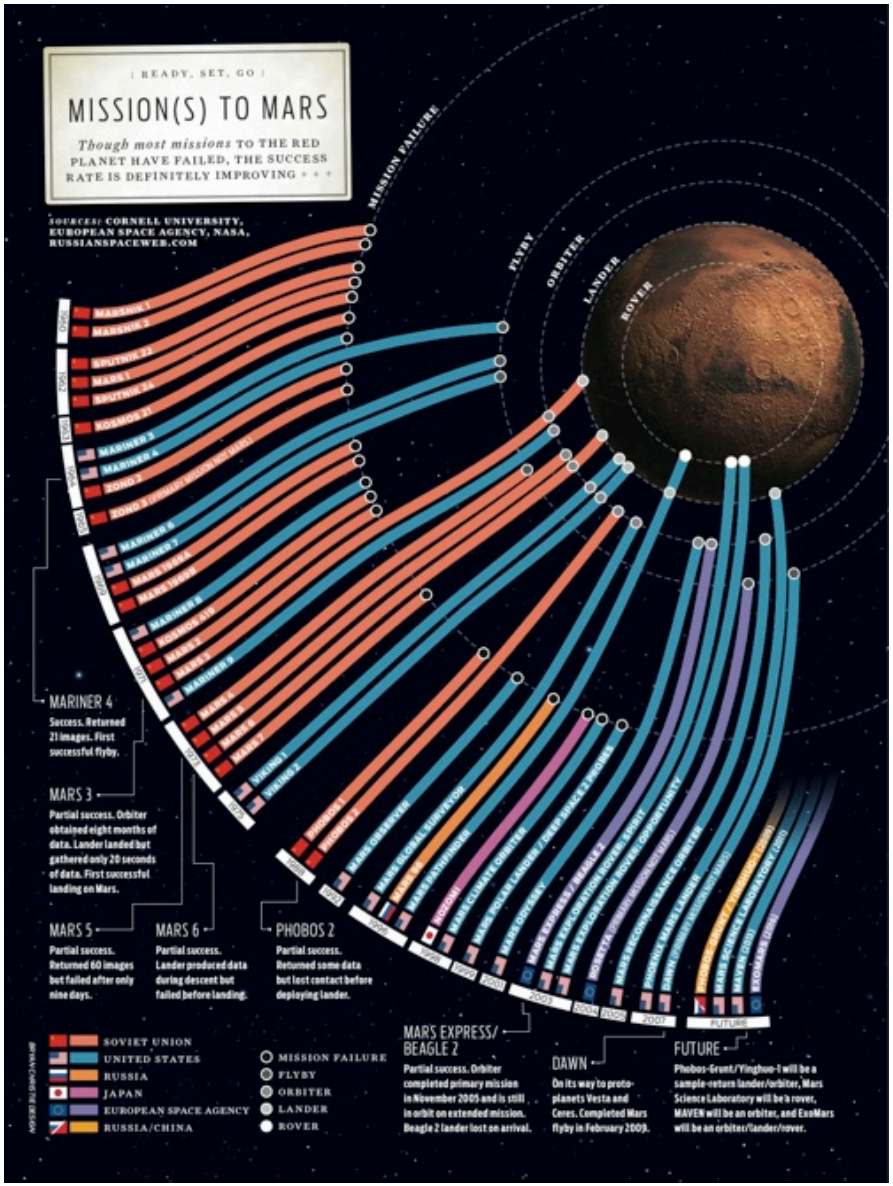
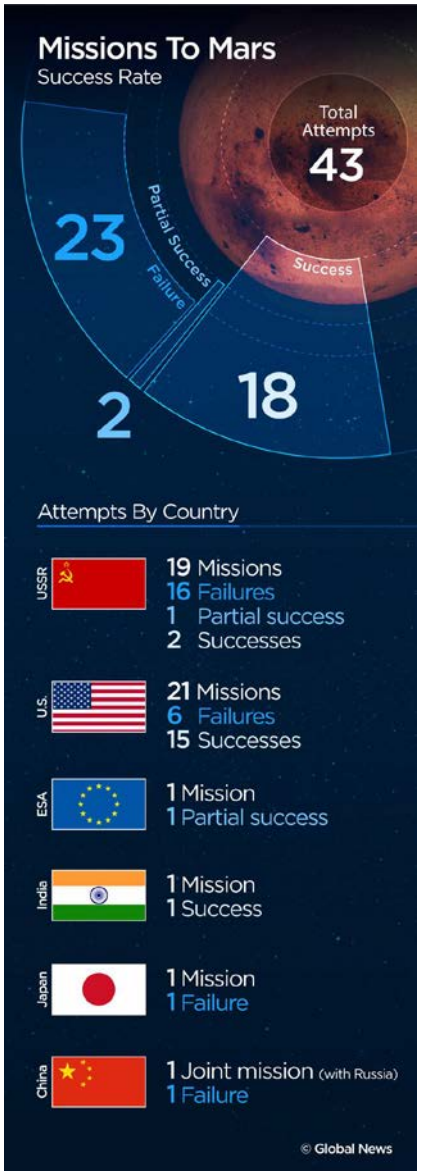
It's Not Easy Being Red

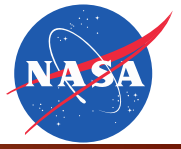




What Makes it Hard?

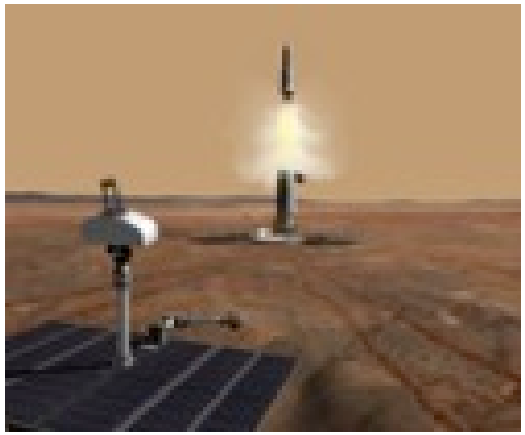
- Mars is challenging
  - Atmosphere is thick enough to hurt, but too thin to be of much help
  - Less sunlight and cold temps make solar-powered missions difficult– rover dies if it gets too cold
  - Radio signal transit time means we can't control things in real-time
- Each mission is bespoke
  - New science objectives
  - New mission objectives require new technologies (e.g., SkyCrane)
- Each opportunity is precious
  - 26-month spacing for launch opportunities
  - Still trying to get it right – must balance ambition vs. risks

Mars Sample Return Concept Animation

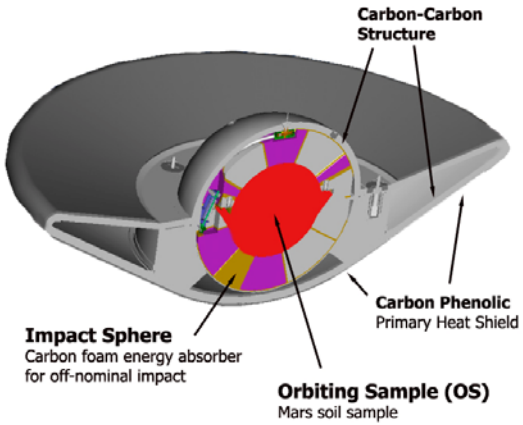


Current Technologies Under Development

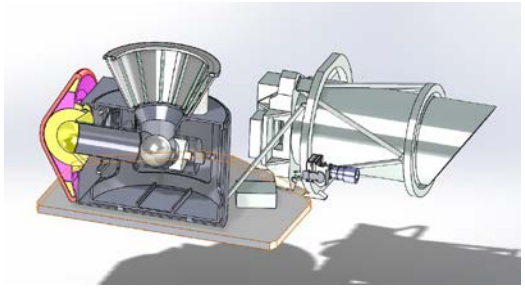
Current portfolio is focused on key technologies for potential Mars Sample Return:



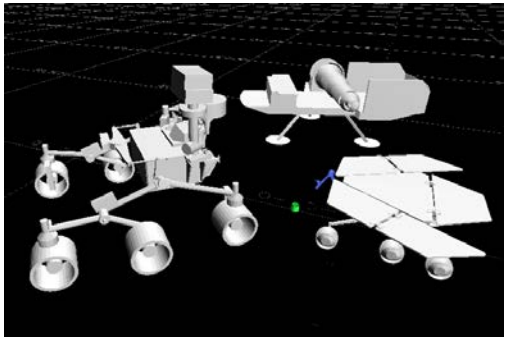
Mars Ascent Vehicle



Break-the-Chain/Containment Assurance



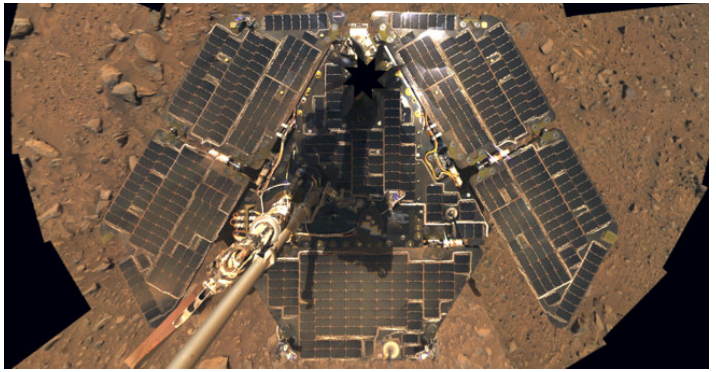
On-Orbit Sample Transfer



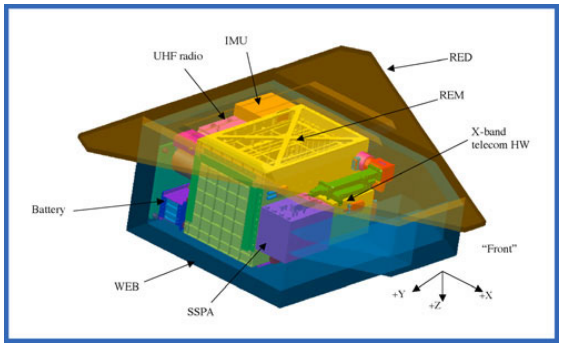
Surface Sample Transfer

Mars Technologies Trickle Back to Earth

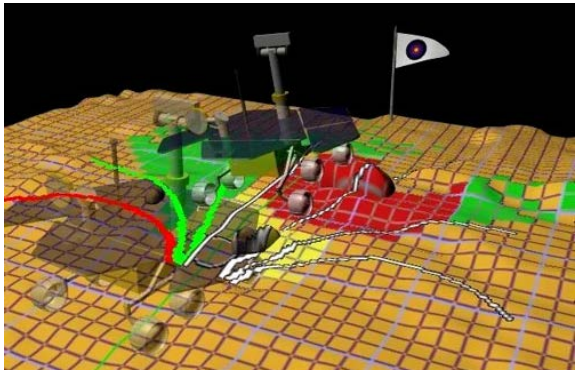
Lithium Battery for
Sojourner Rover (1997)



Selfie of Spirit Rover
Solar Array (2005)



Rover brain: 1000X increase in
computing power 1997 to 2004

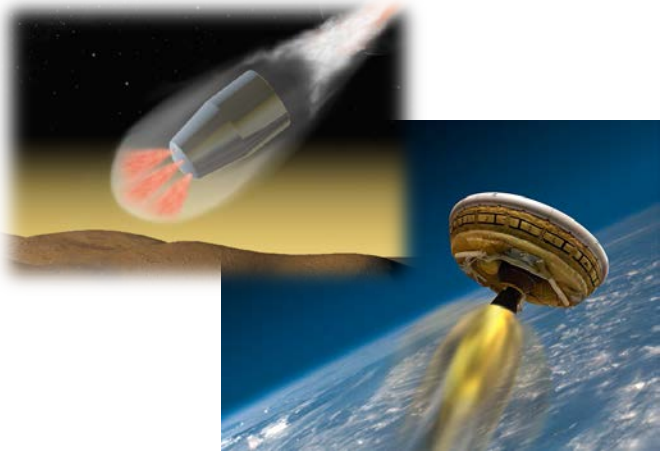


Path planning for autonomous
navigation – now in self-driving cars

New Technology Investment Directions

Longer-term investment areas:

Extreme Terrain Access



Advanced Entry, Descent & Landing

Aerial Platforms

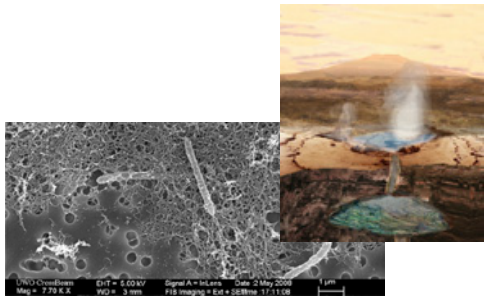
What is the Recipe for Innovation?

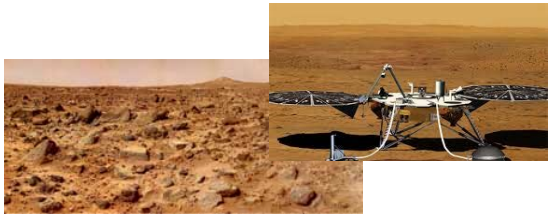
- Ingredients
  - Mission
  - Workforce
  - Environment/Culture
  - Support (Financial, Policy)
- Procedure
  1. Combine ingredients in the foothills of Southern California
  2. Mix gently – keep workforce constant, remove barriers
  3. Bake (for 26 months, in the case of Mars missions)
  4. Let cool and enjoy…

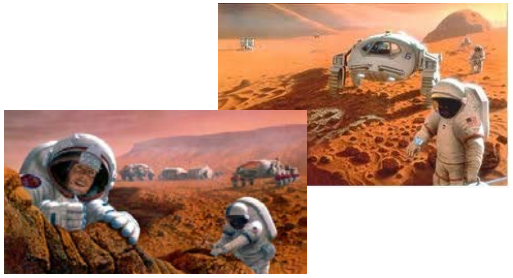
Backup

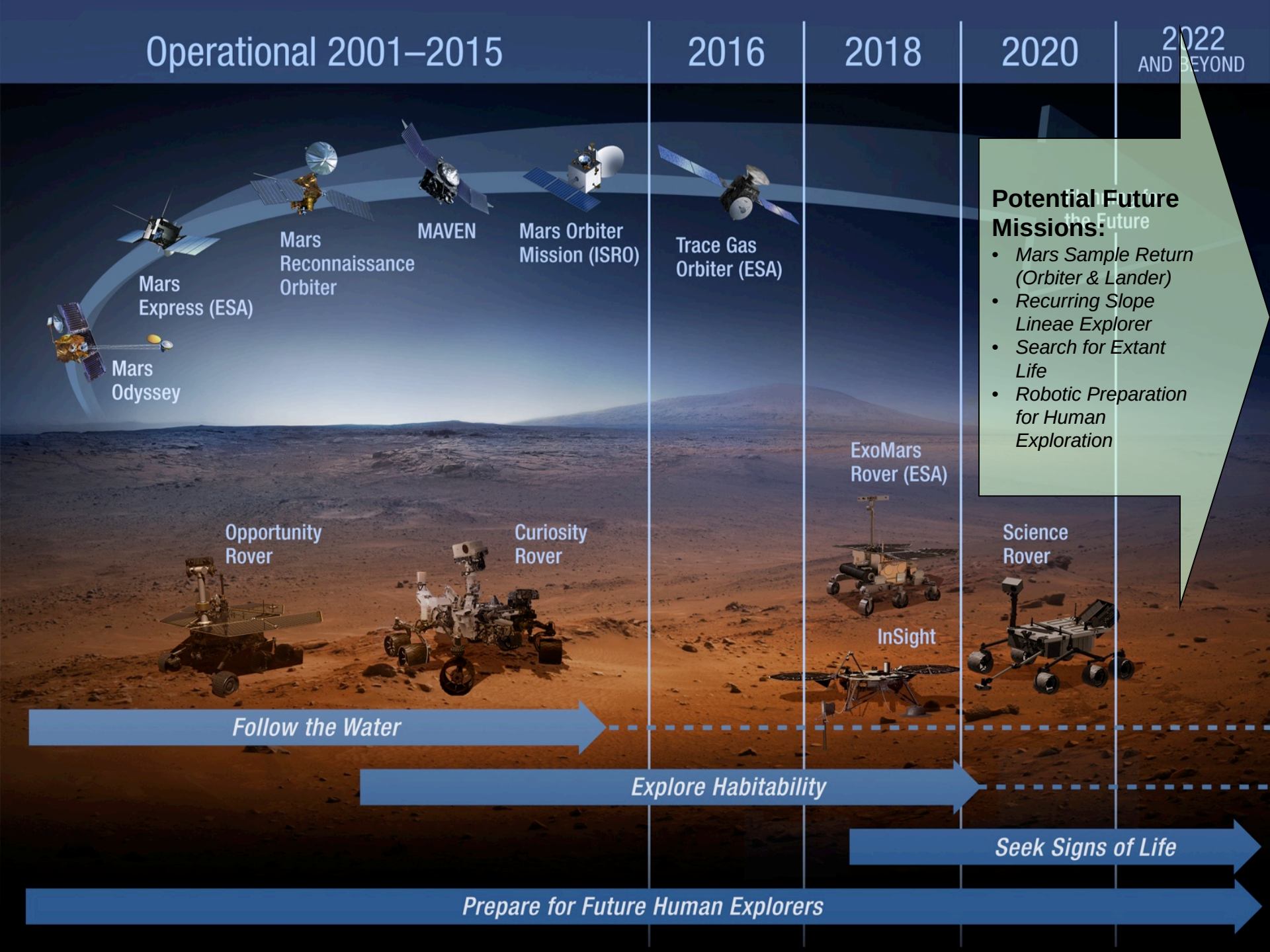
Mars Science Strategy

- **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

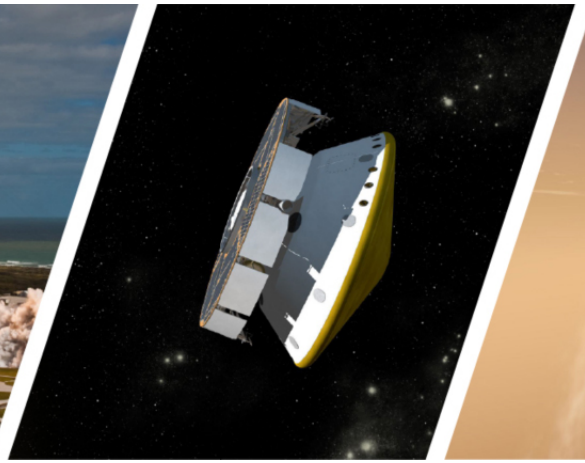


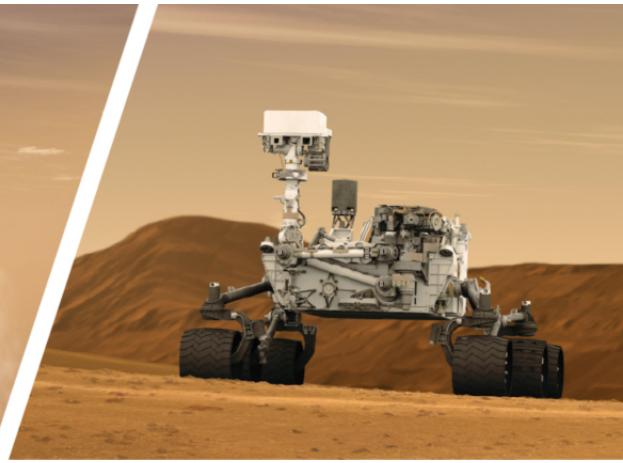





Operational 2001–2015
2016
2018
2020
2022 AND BEYOND
Mars Express (ESA)
Mars Odyssey
Mars Reconnaissance Orbiter
MAVEN
Mars Orbiter Mission (ISRO)
Trace Gas Orbiter (ESA)
Potential Future Missions:
Mars Sample Return (Orbiter & Lander)
Recurring Slope Lineae Explorer
Search for Extant Life
Robotic Preparation for Human Exploration
Opportunity Rover
Curiosity Rover
ExoMars Rover (ESA)
InSight
Science Rover
Follow the Water
Explore Habitability
Seek Signs of Life
Prepare for Future Human Explorers

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