Exploring Mars: Past, Present, and Future Robotic Missions

Bruce Jakosky
LASP / University of Colorado
The Public’s Fascination With Mars
Overarching Question: Did Mars Ever Have Life?

Mars appears to meet or have met all of the environmental requirements for the occurrence of life:

- Liquid water
- Access to the biogenic elements
- Source of energy to drive metabolism

**Did Mars ever have life?**

If it does, is it related to life on Earth?

How did any life interact with its planetary environment?

How has the habitability of Mars changed over time?
**Operational 2001 – 2014**

- Odyssey
- MRO
- Mars Express Collaboration
- MAVEN
- ISRO – MOM Mangalyaan
- Opportunity
- Curiosity – Mars Science Laboratory
- InSIGHT (Discovery Program)

**2016**

- ESA Trace Gas Orbiter (Electra)
- ISRO – MOM Mangalyaan
- MAVEN

**2018**

- ESA ExoMars Rover (MOMA)
- InSIGHT (Discovery Program)
- Opportunity

**2020**

- 2020 Mars Rover

**2022**

- Future Planning
Minerals in Watersheds Around Gale Crater

- **Mission/instrument:** MRO/CRISM

- **Finding:** Gale and surrounding craters host similar bedrock mineralogy and altered clay deposits on their floors, but vary in evaporate salt content.

- **Importance:** Fluvial processes emplaced detrital clay minerals. As Mars dried out, the three craters became hydrologically isolated and salts were left behind nonuniformly. Curiosity will explore this geologic history.

Summit Cape Tribulation

Pancam Sol 3902 Looking South to Marathon Valley
Evidence for Surface Water on Ancient Mars
Where Did the Water Go? Where Did the CO$_2$ Go?

Abundant evidence for ancient water

Volatile can go into the crust

Volatiles can be lost to space

Volatile deposits in a Martian meteorite

Escaping ions detected from Mars Express
MAVEN Will Allow Us to Understand Escape of Atmospheric Gases to Space

- Measure energetic drivers from the Sun, response of upper atmosphere and ionosphere, and resulting escape to space
- Understand the key processes involved, allowing extrapolation over Mars history
MAVEN Mission

Launched on 18 Nov. 2013, first day of its 20-day launch period

Ten-month cruise to Mars; Orbit insertion took place on 21 Sept. 2014

Spacecraft Designed For This Mission

One Year of Science Operations

Orbit shown to scale
Close Encounter With Comet Siding Spring

- MAVEN IUVS imaged CSS in scattered solar Lyman-alpha two days before closest approach to Mars
- H detected to distance of ~150,000 km (comparable to Mars miss distance of comet)
- Suggested significant potential risk to spacecraft

- Comet Siding Spring had close approach (~140,000 km) to Mars on 19 Oct. 2014
- Spacecraft took protective measures to ensure safety
- Strong desire to observe comet and its effects on Mars’ atmosphere

Breckland Skies Observatory
Detection of Metal-Ion Layer Following Encounter With Comet Siding Spring

- Cometary dust entering Mars’ atmosphere is vaporized and ionized
- IUVS saw very bright UV emissions due to metal ions (left)
- Emission observed at tangent altitude of ~120-150km

- NGIMS detected 11 different metal ions (right); detected in situ as low as periapsis altitude of ~185 km
- Metals not detected prior to CSS encounter
- Ions lasted hours to days, consistent with model predictions
- No previous detection of metal-ion layer at Mars; electron layers had been detected
IUVS Observations of Atomic Components of H$_2$O and CO$_2$ on Their Way to Escaping
Pre-Escape Energization in Polar Plume (1 of 4)

$O_2^+$

$O^+$

$He^+$

$H_2^+$

$H^+$

$Z = 250$ km

MAVEN c9 32e64 m eflux
2014-10-18/16:11:30-16:11:42
Pre-Escape Energization in Polar Plume (2 of 4)

$O_2^+$

$O^+$

$He^+$

$H_2^+$

$H^+$

$Z = 300 \text{ km}$
Pre-Escape Energization in Polar Plume (3 of 4)

$O_2^+$

$O^+$

$He^+$

$H_2^+$

$H^+$
Pre-Escape Energization in Polar Plume (4 of 4)

\[ \text{O}_2^+ \quad \text{O}^+ \quad \text{He}^+ \quad \text{H}_2^+ \quad \text{H}^+ \]

\[ Z = 500 \text{ km} \]
Coming Next:

Mars 2020 Rover

- Mastcam-Z Calibration Target
- SuperCam Calibration Target
- MEDA Electronics & Pressure Sensor RIMFAX Electronics
- Mastcam-Z Electronics
- SuperCam Mast Unit
- 2 x Mastcam-Z
- PIXL Electronics Unit 1
-PIXL Sensor
-SHERLOC Sensor
-SHERLOC Cal Target
-PIXL Cal Target
-MEDA Mast
-3x Wind Sensors
-1 x RH Sensor
-3 x Temp. Sensors

RIMFAX Antenna
SuperCam Body Unit
MOXIE
PIXL Electronics Unit 2
MEDA Mast
MRO (Odyssey) 2001 - 2014

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2020
- ESA ExoMars Rover (MOMA)
- Mars Rover

2022
- Future Planning

Future Planning

Follow the Water
Explore Habitability
Seek Signs of Life
Prepare for Future Human Explorers

EVOLVING MARS SCIENCE THEMES