The MAVEN Mission: Exploring Mars’ Climate History

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The Science
Earth

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?
How did any life interact with its planetary environment?
How has the habitability of Mars changed over time?
Evidence for Surface Water on Ancient Mars
Where Did the Water Go? Where Did the CO$_2$ Go?

Abundant evidence for ancient water

Volatiles can go into the crust

Volatiles can be lost to space

Carbonate deposits in a Martian meteorite
MAVEN Will Allow Us to Understand Escape of Atmospheric Gases to Space
The Solar Wind is Able to Strip Off Gas from the Top of the Atmosphere
The Mission
The MAVEN Spacecraft

- Launch (Wet) Mass: 2455 kg at launch
- Spacecraft Dry Mass: 810 kg at launch
- Power: 1135 W at Mars Aphelion
The MAVEN Science Instruments:

Sun, Solar Wind, Solar Storms
- SWEA
- SEP
- EUV
- SWIA

Ion-Related Properties and Processes
- STATIC
- MAG
- LPW

Neutrals and Ions Plus Evolution
- IUVS
- NGIMS
The Spacecraft Undergoes Final Testing
MAVEN Mission Architecture

Launched on 18 Nov. 2013, first day of its 20-day launch period
Launch Vehicle: Atlas – V 401

Ten-Month Type-II Ballistic Cruise to Mars

Orbit Insertion: 22 Sept 02:00, 2014 UTC. 33 minute rocket burn

One Year of Science Operations

Orbit Insertion:
Northern Approach ~1246 m/s ΔV

Capture Orbit:
35 hour period
370 km, 2nd Periapsis Alt
75° inclination

Orbit shown to scale
MAVEN’s Path To Mars

19 Nov 2013 06:30:00.000
Days to Mars Arrival (MSElap): -306/14:00:00.000

MAVEN Range and Velocity (units of Kilometers)
Earth.Range (km): 192233
Velocity_wrt_Earth (km/sec): 4.045
Mars.Range (km): 264525423
Velocity_wrt_Mars (km/sec): 33.724
Sun.Range (km): 147718010
Velocity_wrt_Sun (km/sec): 33.019

MAVEN Range and Velocity (units of Miles)
Earth.Range (mi): 119485
Velocity_wrt_Earth (mi/sec): 2.513
Mars.Range (mi): 164368478
Velocity_wrt_Mars (mi/sec): 20.955
Sun.Range (mi): 917877716
Velocity_wrt_Sun (mi/sec): 20.517
Mars Orbit Insertion Preparations

- MOI occurred on 9/21/14 (EDT)
- Sequence activated 3 days out
- Emergency TCM 5a and 5b opportunities at MOI-24 hours and MOI-6 hours
- Configured for GoFast Recovery (MOI-1 hour)
- In contact with Earth during the entire burn sequence (at 40 bps)
- Primary operations at LM-Denver, backup operations at Goddard
The MAVEN Team that Got Us Here
The Comet
Cosmic Serendipity
The Problem
What you see in this image is dust.
An image of comet Halley taken by the camera on ESA’s Giotto spacecraft. Giotto was hit by a large dust particle and took 30 minutes to recover.
Interplanetary Dust Particle
Actually, Not So Bad
IUVS Imaging of Comet Siding Spring

- IUVS imaged CSS in scattered solar Lyman-alpha two days before closest approach to Mars
- Reflects distribution of atomic H surrounding comet
- H detected to distance of ~150,000 km (comparable to Mars miss distance of comet)
- Gas cloud behaves differently from dust; dust comprises bulk of tail and is what is seen in visible images, so LyA images looks different from most telescopic images
The Opportunity
Comet Siding Spring Plans for Mars Orbiters:

Duck and Cover!
Complications
An Embarrassment of Riches
Drama In The Control Room
A Peak at Results: Dust After All

MAVEN/IUVS Spectrum of Mars Atmosphere After Comet Siding Spring

Meteor Shower Metal Emissions

Intensity

Wavelength

200nm 240nm 280nm
IUVS False-Color Image of Mg$^{+2}$ Distribution

- Observed throughout periapsis pass of each orbit following comet passage
- Intensity of emissions decayed in hours to days, likely due to conversion of Mg and Fe to other forms
A Peak at Results: Dust After All

Eight different metal ions from comet Siding Spring were detected by NGIMS

- Sodium (Na)
- Magnesium (Mg)
- Potassium (K)
- Chromium (Cr)
- Manganese (Mn)
- Iron (Fe)
- Nickel (Ni)
- Zinc (Zn)
The Planet
SEP Observes a Coronal Mass Ejection (CME) Arriving at Mars

First SEP Event Observed at Mars by MAVEN
Magnetometer Measures Interactions With Solar Wind

- Field draped over conducting ionosphere
- Lots of wave activity evident in sheath and associated with bow shock
Martian Dayglow: Determining the Upper Atmospheric Composition

![Image of atmospheric composition analysis with peaks at 108 nm, 190 nm, and 330 nm wavelengths for H, O, and CO₂⁺ respectively.]
IUVS Maps Changing Mars Ozone

Ozone column

$L_e = 202$

Orbits 00001-00003
2014 09 22 10h 42mn 03s
2014 09 25 06h 28mn 37s

Orbits 00107-00109
2014 10 18 08h 40mn 26s
2014 10 18 19h 18mn 12s

Ozone column

$L_e = 217$

µm-atm

8
7
6
5
4
3
2
1
0
Atmospheric Density at Orbital Altitudes Shows Seasonal Trend
IUUVS Observations of Components of $\text{H}_2\text{O}$ and CO$_2$ on Their Way to Escaping
## NASA’s Mars Exploration Program

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MAVEN Impacts All Ages

MAVEN “Send your artwork to Mars” contest, 2013

LASP Clean Room Tour, 2012

Little Miss MAVEN, Halloween, 2014
MAVEN launched on schedule and under budget!
It arrived at Mars in September and began its science mission in November!
Just beginning to get science results – stay tuned!

Go MAVEN!

[Continue to follow us on Facebook and Twitter: MAVEN2MARS]

[Join MAVEN and Exploration Station – 1-5 p.m. today for hands-on exploration for the family.]