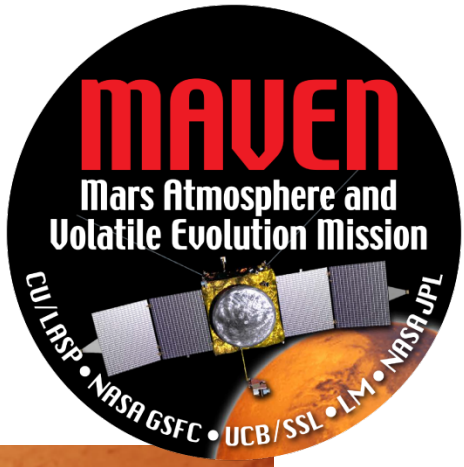
Invisible Mars

A Planetarium and Science-On-A-Sphere Show



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Background for Facilitator: Water on Mars

Introduction

Earth is unique in the solar system. Earth has a large amount of water on its surface and all three phases of water (solid, liquid, and gas) are stable on Earth's surface. However, Earth is not the only place water is found in the solar system. Other places have water too – including Mars.

Landscapes on Mars formed by water were first revealed up close by the Mariner 9 spacecraft in 1971. Since then, we have found significant evidence of past water on Mars, and water ice is still present on and just beneath the martian surface.

NASA is very interested in water because life as we know it requires water. The search for life often starts with a search for water.

Evidence for Water on Mars

- Mars has networks of drainage channels, possibly carved by rain (see Figure 1).
- Some minerals on Mars are formed in water.
- Mars' poles are covered with thick layers of frozen water coated with frozen carbon dioxide.
- The surface includes features that may have been caused by martian glaciers.
- Recent impacts closer to the equator have exposed water ice hiding just below the rocky surface.
- Some recent martian gullies appear to have been carved by flowing water.
- Mars has features from ancient floods that are a hundred times larger than the largest known floods on Earth.
- There is evidence that there were once lakes in some martian craters.
- Some of these lakes had deltas in them. Deltas form over fairly long periods of time-- water had to be stable on the surface for sustained periods of time to form these features.

Figure 1: This 1976 Viking 1 Orbiter image shows Parana Valles, a valley network. Parana Valles is 350 kilometers (about 215 miles) long. Liquid water flowing over the surface of Mars likely carved its channels. Credit: NASA

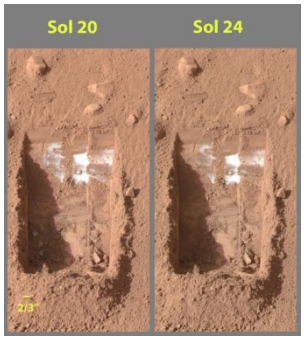

Figure 2: This trench dug by the Phoenix lander shows white ice disappeared (by sublimating) after it was uncovered. Credit: NASA/JPL-Caltech/University of Arizona/Texas A&M.

Because they occur so quickly, floods and gullies do not require a warmer, wetter climate to explain their existence. But features that take longer to form, such as deltas, do require a different climate and thus a thicker earlier atmosphere.

The Phoenix lander, a mission sent to Mars' high northern latitudes, imaged ice disappearing as it sublimated (Figure 2) and provided chemical evidence that water ice exists on Mars.

Some minerals and sedimentary structures on Mars also appear to be formed or influenced by water (such as those found by the Opportunity rover, shown in Figure 3). The Mars Science Laboratory Curiosity rover also captured images of pebbles that were rounded and had been transported in an ancient martian streambed.

Some evidence suggests that a vast ocean may have once covered much of the northern hemisphere–though not all scientists agree whether the evidence is strong enough to support this hypothesis.

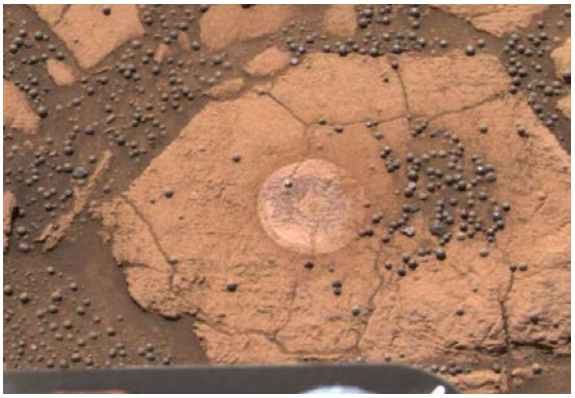

Figure 3: This shows the "Berry Bowl" rock examined by the Mars Exploration Rover Opportunity. This sandstone rock is full of round grains (about 4mm wide) known as "blueberries" with high amounts of hematite. Scientists think groundwater with dissolved iron filtered through the sandstone and formed the "blueberries." Credit: NASA/JPL/Cornell.

Earth-Mars Comparisons

We know that features on Mars were formed or influenced by water because we study similar features on Earth. Features that share similar shapes tend to share similar histories – they usually formed by similar processes. The Earth-Mars image comparisons included in *Invisible Mars* will allow you and your visitors to see how similar some water-related features on Earth are to features on Mars.

What Happened to the Water?

The water-related features suggest that liquid water was once stable on the surface of Mars for fairly long periods of time, and that there was once much more water on the surface than we see today.

The two places the water could have gone are down (into the crust) or up (into the atmosphere). We do not see large enough concentrations of water in the Mars crust to explain all of the water-related features. We also do not see large concentrations of water in the martian atmosphere, but water that was once in the atmosphere could have been lost to space, if it wasn't protected or returned to the surface. With its weaker gravity and without a global magnetic field like the Earth's, Mars' atmosphere is susceptible to erosion from the solar wind.

Climate Change on Mars

In order for liquid water to have been stable on the martian surface, it must have once had a thicker, atmosphere. Its atmosphere today primarily consists of carbon dioxide, a greenhouse gas, but it is very thin—just 1% of Earth's atmosphere. Just as increased amounts of carbon dioxide in Earth's atmosphere can increase our overall global temperatures, a significantly greater amount of carbon dioxide in Mars' atmosphere would have warmed the planet, allowing liquid water to be present. So along with their hunt for missing water, scientists are also hunting for missing carbon dioxide (CO_2). Although some of it is tied up in the crust, some has been lost to space.

Another factor in Mars' climate is its changing tilt. Earth's tilt is stabilized by our large Moon and remains steady, around 23.5 degrees. Evidence from computer models indicates Mars' tilt may wobble by tens of degrees, changing the locations of its poles. This could cause swings in the climate, melting the frozen water and carbon dioxide from some regions and depositing it in others, and temporarily increasing the air pressure and humidity in the atmosphere in the process; some sedimentary deposits on Mars support this. But this changing tilt cannot explain where all of the missing water and carbon dioxide went from Mars' warmer, wetter past.

About MAVEN

The *Mars Atmosphere and Volatile EvolutioN*, or MAVEN, mission is orbiting Mars to explore how the Sun has stripped Mars of most of its atmosphere, turning a once possibly habitable planet into a cold and barren desert world. MAVEN is addressing three questions:

- What is the current state of the upper atmosphere and what processes control it?
- What is the current escape rate and how does it relate to the controlling processes?
- What has the total loss to space been through time?

How is MAVEN answering the science questions?

The processes that control the loss of the martian atmosphere are complex. The Sun drives atmospheric escape in several different ways:

- Extreme ultraviolet light (photons) from the Sun encounters particles in Mars' upper atmosphere, heating some of them enough to escape Mars gravity and driving chemical reactions in other particles that result in escape.
- The moving solar wind and its embedded magnetic field "pick up" charged particles in the upper atmosphere, carrying them away from the planet.
- Electric fields form in Mars' upper atmosphere, causing some charged particles to flow away from the planet.
- Some charged solar particles crash into the atmosphere directly, splashing away atmospheric particles.

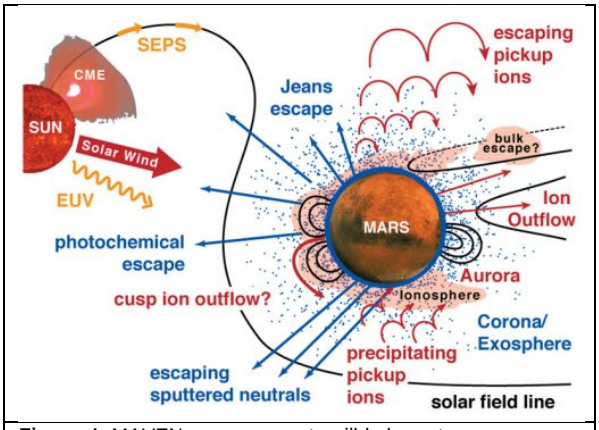

Figure 4: MAVEN measurements will help us to understand the escape of neutral (blue) and charged (red) atmospheric particles from Mars. Credit: MAVEN

Enhanced versions of each of these processes can occur during solar storms, when very energetic sunlight and particles from the Sun encounter Mars. Figure 4 illustrates the processes occurring at Mars today.

MAVEN Takes Measurements

In order to answer the main science questions, MAVEN has three instrument suites - the Particles and Fields Package, the Remote Sensing Package, and the Neutral Gas and Ion Mass Spectrometer. Together, these measure the particles in Mars' upper atmosphere, the particles escaping from the atmosphere, and the sunlight and particles from the Sun (the solar wind) reaching Mars' atmosphere. This is allowing scientists to reconstruct how the processes that erode away Mars' atmosphere today worked billions of years ago at Mars.

MAVEN Orbit

MAVEN's measurements are being made both near and far from the planet in order to characterize both the regions of the upper atmosphere from which particles escape, and the escaping particles that are leaving the planet. MAVEN is measuring how particles are escaping both on the daytime and nighttime sides of Mars.

MAVEN Results *(as of April 2015)*

MAVEN has measured the effects of the Sun's radiation and particles on Mars' atmosphere, and the rates at which particles are escaping into space. The findings include:

- the solar wind strips away gas at a rate of about 100 grams (equivalent to roughly 1/4 pound) every second.

- about 80% of Mars' atmosphere has been lost over its history as particles in the atmosphere are knocked out due to collisions with other particles (a process called "sputtering").
- the erosion of Mars' atmosphere increases by a factor of 10 or more during solar storms.
- Mars' outermost hydrogen atmosphere changes in size and over time, varying the amount of hydrogen being eroded away.
- most of the particles (75%) are lost in a "tail" behind Mars, while almost 25% are lost in a plume near the day/night boundary.

Figure 5: An artist's rendition depicts a solar storm hitting Mars and stripping ions from the upper atmosphere. Credit: NASA GSFC

- a new kind of ultra-violet aurora was discovered on Mars, where solar particles had tunneled deep into the atmosphere across the planet and interacted with the gases.
- a surprising amount of dust at very high altitudes in the upper atmosphere of Mars.
- dust storms release water in Mars' upper atmosphere where the molecules are broken down and dissipated.

Overall, the mission has determined that the erosion of Mars' atmosphere was great enough to account for a significant change in Mars' climate.

Optional Materials for *Invisible Mars*

- Laser pointer, for drawing attention to specific features within datasets (such as in Earth and Mars comparison images).
- Laminated handouts of the Earth-Mars comparison images.

Tips for Facilitator

There are a variety of topics in this presentation that may interest your audience and you might need to be prepared to delve deeper into them:

- They may want to talk more about the planets in general. Additional information about the Solar System is available at solarsystem.nasa.gov/planets/solarsystem
- They might want to know more about recent discoveries from other Mars missions, particularly the Curiosity rover. Mission updates are available at mars.jpl.nasa.gov/msl.
- They might want to talk about climate change on Earth. NASA has overviews and information at climate.nasa.gov.

The last dataset in the script zooms out from Boulder, Colorado (the city where MAVEN's Principal Investigator is based). Facilitators may customize this dataset to zoom out from the city where your institution is based.

Additional Resources for Facilitator

- MAVEN mission website: lasp.colorado.edu/home/maven
- MAVEN new results: lasp.colorado.edu/home/maven/features-news
- MAVEN Invisible Mars Science On a Sphere website: lasp.colorado.edu/home/maven/education-outreach/afterschoolsummer-programs/invisible-mars/
- Recorded presentations about MAVEN and related Mars science, at bit.ly/MAVENCoP.
- Curiosity mission website: http://mars.jpl.nasa.gov/msl/
- Mars Exploration Program website: mars.jpl.nasa.gov
- NOAA Science On a Sphere Yahoo group: groups.yahoo.com/neo/groups/noaasos/info
- Fulldome DigitalSky planetarium version of Invisible Mars: berkeley.box.com/s/pwv9810s8x8vwyoq2q0sicw7f2rcp23l
- For more information about the magnetic field of Earth and the solar wind: image.gsfc.nasa.gov/poetry/
- For more information about the magnetic field of Mars: mgs-mager.gsfc.nasa.gov/Kids/magfield.html

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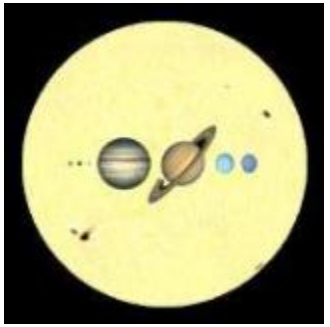
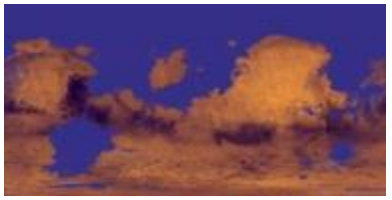
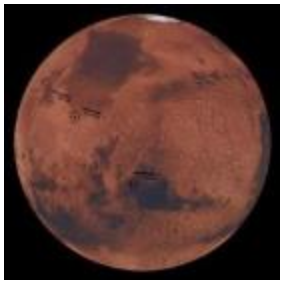
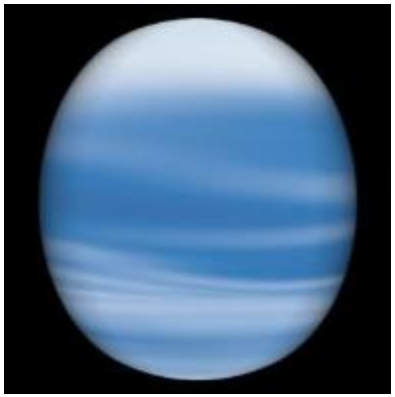
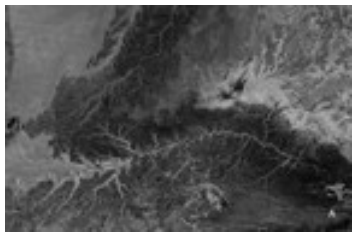
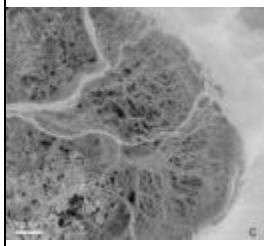
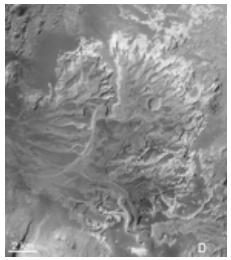
REVISED MAVEN *Invisible Mars* SOS Script & Playlist

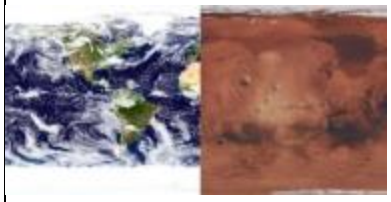
SCRIPT	PLAYLIST
Our Solar System has planets orbiting our Sun, along with their moons, asteroids, dwarf planets, and comets. **Which one is your favorite?** [Use a pointer to point to the planets that the audience identifies.] **The most special planet is the one with life—our own planet Earth.**	SOS: Planet diagram 
[looking at Earth] **Can you find us—where we are right now—on the Earth?** **Can you find where you're from?** **The Earth—as far as we know—is the only planet in our Solar System that supports life. What does Earth have that life needs?** • Possibilities could include air, water, moderate temperatures… **We've found microbes that deep at the bottom of the ocean and deep in the ground that don't need the same type of air that we do. But all of the life that we've found needs one thing. What is that?** [Water.] **How much water does the Earth have?** • Let the audience respond—could include percentage covered by the ocean, they can mention water vapor in the atmosphere, ice, etc. **Earth is the only planet we know of that constantly has liquid water on its surface.**	SOS: Blue marble 

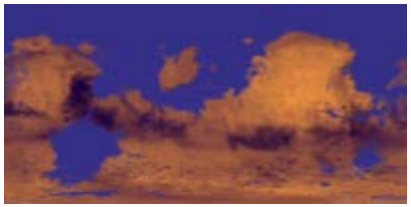
Other planets might have had liquid water in the past. There's one planet, in particular, that we think once had liquid water on its surface. Which planet do you think might have had water? [Mars] **That's right: Mars.** (crossfade from Earth to Mars) **This is what Mars looks like today. Dry.**	SOS: Mars Red Planet 
But, billions of years ago, we think it was wetter, with flowing water, maybe even with lakes or oceans. Finding out how Mars' climate has changed can help us understand more about our own Earth. So let's talk a bit about Mars. **How do we know that Mars once was wetter?** **Well, scientists are like detectives—they solve mysteries by searching for clues. Over the past 50 years, we've found lots of clues about Mars' past. How have we found these clues?** • Responses could include telescopes, missions, more. Presenters might need to respond to some common misconceptions: o Humans have not been to Mars yet o Aside from meteorites from Mars, we don't have other Mars rocks/samples yet	SOS: Watery Mars 

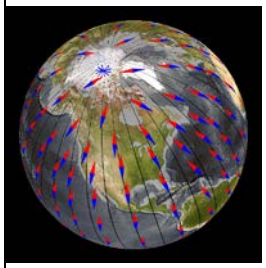
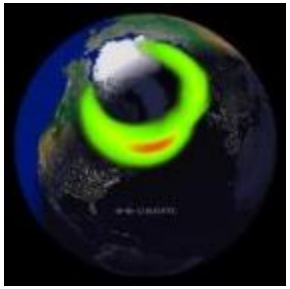
Yes! Over the past 50 years, we've sent spacecraft to all the planets of the Solar System to gather clues about the planets. Some of these spacecraft have flown right by Mars, sending back pictures like postcards. Some have gone into orbit around Mars. And some have even landed on its surface. **Can you name any of the Mars missions?** • Help them to find the landing site for the landers they can name, but don't point out each one.	SOS: Mars Landing Sites http://sos.noaa.gov/Datasets/dataset.php?id=445  Map of Mars including landing sites for Vikings, Pathfinder, Spirit, Opportunity, Phoenix, and Curiosity
This is an image from the Curiosity rover, and you can see that today Mars is dry. **But…there are some interesting features on Mars that we can compare to Earth features. These tell us Mars once had water on its surface. Do you have any ideas on what these clues or features might be?** [Take answers from the audience.]	SOS: Mars PIP: Overlay panorama image from Curiosity 
Geologists have had a long time to study the Earth. We understand how wind, water, and volcanoes can shape the land. Each process leaves different clues that tell us what happened, clues that reveal the difference between features that were carved by wind, and ones that were made by flowing water.	SOS: Blue Marble No Clouds 

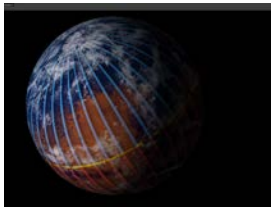
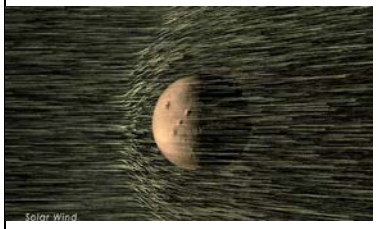
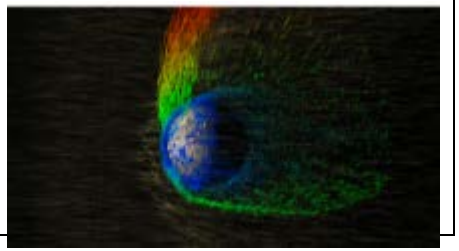
Let's compare some clues—images taken from space of features on Earth and Mars. Audience Participation Activity [Two options: Facilitator decides which to use, based on factors such as lighting in SOS area and knowledge of their particular audience.] OPTION 1: Hand out labeled images A & C of Earth's features and B & D images of Mars features. (Or have handouts pre-placed underneath/on seats before show starts.) OPTION 2: Use PIPs to compare the images (instead of handouts). For both options, have audience look at, discuss, and compare the images. Ask the audience about their observations of each of the images.	SOS: Watery background 
What do these images show—what are these features? [Take answers from the audience.] **Yes, they are river and stream channels. One image is from Earth and one is from Mars. Can you tell which picture is Earth and which is Mars?** [Take guesses from the audience.] **Image A: Earth** **This image shows river and stream channels in Yemen, a desert region in the Middle East. The light-gray features are channels that start out as small streams and flow into larger and larger rivers. Yemen only gets a little rain, but water still plays an important role in shaping the landscape.** **Image B: Mars** **This Viking 1 Orbiter image from 1976 shows channels on Mars. The biggest channel is 350 kilometers (about 215 miles) long. It was probably carved by water flowing over the surface of Mars.**	SOS: Watery background (cont) PIP (For Option 2): Fade in Image A and Image B.  

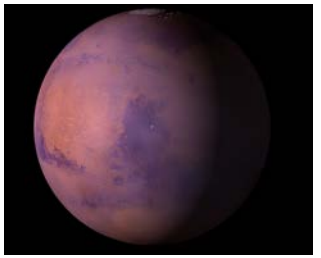
Now let's take a look at a second pair of images. Does anyone know what these images show? [Take answers from the audience.] **That's right, they are deltas. A delta is formed where a river flows into something larger, like an ocean or lake. Deltas form because sediment (like sand or mud or pebbles) carried by the river is dropped onto the lake bed or sea floor. Look at these two photos – you can see how the delta in both pictures has the same shape. How many people think the image on the left is Earth? How many people think it is Mars?** [Take answers from the audience.] **<u>Image C: Earth</u>** **This is an image of the Yukon Delta in Alaska. The squiggly light gray lines are river and stream channels bringing water and sediment from the Yukon River to the Bering Sea.** **<u>Image D: Mars</u>** **The Eberswalde Delta on Mars is a "fossil delta"—a delta that no longer has water flowing through its channels. This delta is evidence that water flowed over Mars' surface for a long period of time.**	SOS: Watery background (cont) PIP (For Option 2): Fade in Image C and Image D  

When we look at Mars and we see certain kinds of formations—like stream channels and deltas—we think that there was once water flowing on the surface of Mars. **But not anymore. Is there something about the Earth that might explain why WE still have water and Mars doesn't?** [split screen for half Mars and half Earth] Take guesses from the audience. • Mars has less atmosphere, fewer clouds • Earth has more gravity • Mars is colder, farther from the Sun • Mars doesn't have volcanic activity anymore **There aren't many clouds on Mars because it is so cold and dry. Water and air are connected; the mystery of Mars' missing water is connected to its atmosphere and climate.**	SOS: Blue Marble/Red Planet Mars 

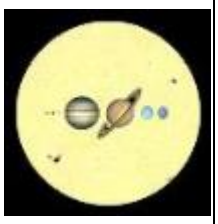
Mars has a very thin, poisonous atmosphere, less than 1% of Earth's. It is too thin and far from the Sun to hold in the heat, making Mars very cold! **In order to keep water as a liquid, a planet needs temperatures above freezing. If Mars used to have liquid water, it must also have had warmer temperatures and a different climate. In order to have warmer temperatures, Mars must have had a thicker atmosphere, to hold in the heat.** **So, maybe we can figure out what happened to the water on Mars by asking a different question: What happened to Mars's atmosphere?** **If Mars used to have a thicker atmosphere but doesn't anymore, what do you think could have happened to it? Where could it go?** [Facilitator starts slowly looking around, down, up, …] **Up! That's right. Or down! Those are two possibilities.** **DOWN means that maybe the atmosphere went down into the rocks and below the surface. We have evidence that some of the atmosphere has been trapped in the rocks but we don't know how *much* of it. There are still some missing pieces to the puzzle. Another possibility is that Mars's atmosphere escaped UP, into space.**	SOS: Rotating Mars today  SOS:, crossfaded to early Mars with water 
We're studying how much of Mars' atmosphere has escaped into space. One of the missions orbiting Mars is the Mars Atmosphere and Volatile EvolutioN mission, or MAVEN, for short. **MAVEN is telling us how Mars' climate has changed, by studying how the Mars atmosphere is being blown away by energy from the Sun.**	SOS: MAVEN over Mars' atmosphere 

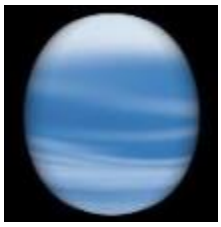
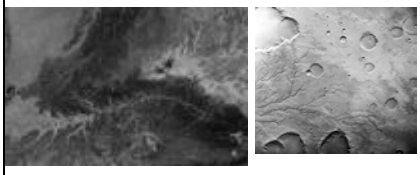
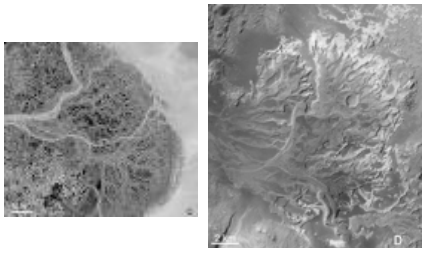
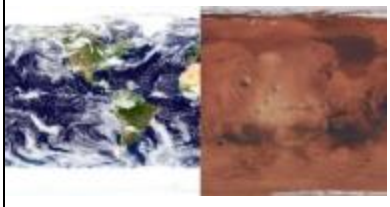
The Sun gives off light, and it also blows off charged particles called the solar wind. The white particles in this video represent the solar wind. **Sometimes the Sun burps out an enormous cloud of particles along with lots of radiation, called a solar storm. The Sun's radiation, the solar wind, and occasional solar storms can wear away Mars' atmosphere over time.**	SOS: Mars PIP sputtering video  new video or image of storm 
So why don't the solar wind and solar storms wear away Earth's atmosphere? [Take answers from the audience.] **We have a powerful protector—a strong magnetic field—that surrounds our planet.** **As charged particles from the Sun run into our magnetic field, they are caught and spiral into our atmosphere at the North and South magnetic poles, interacting with our upper atmosphere and forming beautiful auroras—the Northern and Southern Lights.** **But Mars doesn't have a strong global magnetic field anymore.**	SOS: Earth's magnetic field  Crossfade to SOS: Earth Auroras 

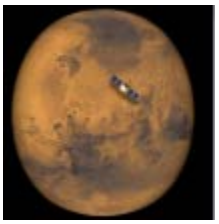
See those blue lines around Mars? Those represent ancient Mars' magnetic field. Mars used to have a strong magnetic field which protected it from the solar wind. **But Mars is too cold inside now –the hot "engine" that powered its magnetic field isn't running anymore. Without a global magnetic field, the solar wind helped strip away Mars' atmosphere.**	SOS:—new of early Mars with magnetic lines:  crossfade to PIP: 
MAVEN has measured the solar wind, crashing into Mars' remaining thin atmosphere. Just like a water hose can spray away dirt from a driveway or sidewalk, the Sun's particles are blowing away charged particles from Mars' atmosphere. MAVEN measured the speeds and directions of ionized gas particles in Mars' atmosphere, as they are being blown away. The red particles are moving the fastest as they escape into space, and the blue are the slowest.	SOS: Mars PIP: Video of Mohawk: 

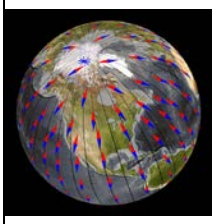
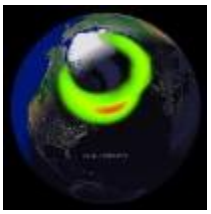
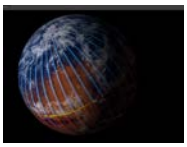
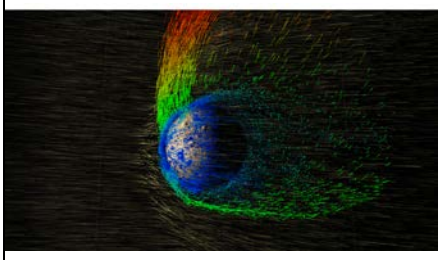
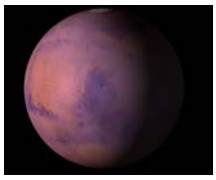
Some of the Sun's charged particles punch deep into Mars' atmosphere. These can interact with gases and create a new type of aurora on Mars—one that we don't have on Earth. This aurora can be detected all over Mars, not just at the poles. Imagine the entire sky glowing at night!	SOS: Mars new of aurora around current Mars 
Sometimes people wonder why we study things so far away. What are some reasons for studying Mars' atmosphere? [Take responses from the audience.] • It tells us more about how Earth's atmosphere is interacting with the Sun, in comparison • It tells us how planets change over time • It tells us about the relationship between Mars' climate and its atmosphere • It might be able to tell us more about climate change • Etc. **And science is really about learning as much as we can our own world—our home.**	SOS: Blue Marble  Optional PIP: Zoom out from city location to Solar System

Invisible Mars SOS OUTLINE and Playlist

SCRIPT	PLAYLIST
Solar System • Audience favorites? • Which one is most important? (Earth)	SOS: Planet diagram 
Earth supports life • **what does life need?** Water • **How much water does the Earth have?**	SOS: Blue marble 
Mars had water in the past **Today Mars is dry.**	SOS: Mars Red Planet 
Billions of years ago, Mars was wetter • **Understanding Mars' climate can help us understand Earth.** • **How do we know that Mars once was wetter?** • Responses could include telescopes, missions, more.	SOS: Watery Mars 
Spacecraft to Mars • **Which missions to Mars can you name?** Help audience find the landing sites	SOS: Mars Landing Sites 
image from the Curiosity rover • **some Mars features tell us Mars once had water**	SOS: Mars PIP: Overlay panorama image from Curiosity 

Geology leaves clues **features were made by water, wind, lava**	SOS: Blue Marble No Clouds 
Compare images of features on Earth and Mars <u>Audience Participation Activity</u> OPTION 1: Hand out labeled images OPTION 2: Use PIPs to compare the images	SOS: Watery background 
What are the features? [Take answers from the audience.] • **river and stream channels.** • **which picture is Earth and which is Mars?** **<u>Image A: Earth</u>—light grey stream channels in desert** **<u>Image B: Mars</u>—long channels (350 km/ 215 mi)**	SOS: Watery background PIP (For Option 2): Fade in photos Earth and Mars 
New pictures: what are they? [Take answers from the audience.] **Deltas: river flows into something larger (ocean/lake), dropping sediments** • **Which picture is Earth and which is Mars?** [Take answers from the audience.] **<u>Image C: Earth:</u> Yukon Delta in Alaska** **<u>Image D: Mars:</u> The Eberswalde Delta—evidence that water flowed over Mars' surface for a long period of time.**	SOS: Watery background PIP (For Option 2): Fade in photos of features on Earth and Mars 
Water was on Mars, not anymore. **Why does the Earth have water, Mars doesn't?** [Take guesses from the audience.] **Mars is cold and dry, no fewer clouds** **Water connected to Mars' air** **Do you think you would be able to breathe on Mars? No? Why not?** [Take guesses from the audience.]	SOS: Blue Marble/Red Planet Mars 

Can't breathe on Mars • **Mars's air is toxic** • **Mars has thin atmosphere, < 1% of Earth's.** • **too thin and far from the Sun to hold in the heat** **Mars must have been warmer** **Must have had thicker atmosphere** **What happened to Mars's atmosphere? Two options—it went up (into space) or it went down (into the ground)** **DOWN –into rocks (still learning about)**	SOS: Rotating Mars today  SOS: crossfade to early wet Mars 
Studying atmosphere: orbiting Mars Atmosphere and Volatile Evolution MissioN. (MAVEN) **MAVEN providing info how Mars has changed** • **studying how the Mars atmosphere is being blown away by energy and particles from the Sun** • **learning how Mars' atmosphere, and its climate, have changed!**	SOS: MAVEN over Mars' atmosphere 
Sun gives off light and blows off charged particles—solar wind (white particles in video) **Also Sun burps out clouds of particles/radiation—solar storm.** **The Sun's radiation, solar wind, and occasional solar storms wear away Mars' atmosphere.**	SOS: Mars PIP sputtering video  new video or image of storm 

Why not Earth's atmosphere? **strong magnetic field** • **charged particles from Sun caught by <u>mag field</u>** • **spiral into North and South magnetic poles** • **forms auroras—the Northern and Southern Lights.** **Mars doesn't have a strong global magnetic field anymore**	SOS: Earth's magnetic field  SOS: Earth Auroras 
Blue lines represent Mars' ancient magnetic field **Mars too cold now** • **"engine" that powered magnetic field gone** • **Without global magnetic field, the solar wind helped to strip away Mars's atmosphere.**	SOS: View of early Mars with magnetic lines:   crossfade to PIP:
MAVEN measured solar wind • **Water hose / leaf blower analogy** • **Sun's particles blowing away charged particles from Mars' atmosphere.** • **MAVEN measured speeds and directions of ionized gas** • **red particles moving fastest**	SOS: Mars PIP: Video of Mohawk: 
Sun's particles crashing deep into Mars' atmosphere • **create new type of aurora** • **can be detected <u>all over</u> Mars** • **mostly in ultraviolet light**	SOS: Mars--New animation of blue glow 

Why study Mars' atmosphere? [Take responses from the audience.] • learn how Earth's atmosphere interacts with Sun • learn how planets change over time • learn relationship between Mars' climate and atmosphere • climate change • Etc. **And science is really about learning as much as we can our own world—our home.**	SOS: Blue Marble  Optional PIP: Zoom out from city location to Solar System

MAVEN *Invisible Mars* Playlist

```
# Solar System
include = /shared/sos/media/astronomy/solar_system/playlist.sosrename = MAVEN: Planet Diagram

# Blue Marble
include = /shared/sos/media/land/blue_marble/blue_marble/playlist.sosrename = MAVEN: Blue Marble

# Current Mars
include = /shared/sos/media/extras/live_programs/maven/dry_mars/playlist.sos

# Early wet Mars
include = /shared/sos/media/extras/live_programs/maven/wet_mars/playlist.sos

# Landing sites from missions to Mars
include = /shared/sos/media/extras/live_programs/maven/mars_landingsites_2016/playlist.sos

# Panorama of Mars from Curiosity rover
include = /shared/sos/media/extras/live_programs/maven/panorama/playlist.sos

# Blue Marble: without clouds
include = /shared/sos/media/land/blue_marble/earth_vegetation/playlist.sosrename = MAVEN: Earth with
No Clouds

# PIP of water channels on Earth and Mars
include = /shared/sos/media/extras/live_programs/maven/waterfeatures/channels/playlist.sos

# PIP of deltas on Earth and Mars
include = /shared/sos/media/extras/live_programs/maven/waterfeatures/deltas/playlist.sos

# comparison of Earth and Mars with split screen
include = /shared/sos/media/extras/live_programs/maven/mars_earth/playlist.sos

# current dry Mars
include = /shared/sos/media/extras/live_programs/maven/dry_mars/playlist.sos

# an early wet Mars
include = /shared/sos/media/extras/live_programs/maven/wet_mars/playlist.sos

# MAVEN in orbit around Mars
include = /shared/sos/media/extras/live_programs/maven/maven_orbit/playlist.sos

# PIP of the solar wind causing "sputtering" on Mars
include = /shared/sos/media/extras/live_programs/maven/mars_sputtering/playlist.sos

# Earth's magnetic field
include = /shared/sos/media/land/earths_magnetism/magnetic_lines/playlist.sos

# Earth Aurorae
include = /shared/sos/media/astronomy/aurora/playlist.sos

# Early Wet Mars with global magnetic fields
include = /shared/sos/media/extras/live_programs/maven/wet_mars_magnetic_fields/playlist.sos

# PIP of the Solar Wind at Mars
include = /shared/sos/media/extras/live_programs/maven/mars_solar_wind/playlist.sos

# Current Mars with Diffuse Aurora
include = /shared/sos/media/extras/live_programs/maven/mars_diffuse_aurora/playlist.sos

# Blue Marble: Without Clouds
include = /shared/sos/media/land/blue_marble/blue_marble/playlist.sosrename = MAVEN: Blue Marble
```

MAVEN *Invisible Mars* Earth-Mars Comparison Image Captions

Note that all images are in black and white to allow easy comparison of features shown in the images, without the distraction of color. This makes it a little trickier to tell which image is of a place on Earth and which image is of a place on Mars.

Image Pair One: Channels

Image A: Earth

This black and white image shows river and stream channels near Wadi Hadramawt in eastern Yemen. The light-gray channels stand out against the darker-gray surroundings. The streams start out in very small channels and flow downhill to feed streams and rivers in larger and larger channels. This area of Yemen receives only a little rain, but water still plays an important role in shaping the landscape. The image was taken by NASA's Terra satellite in 2008.

Image B: Mars

This Viking 1 Orbiter image from 1976 shows Parana Valles, a valley network in the Margaritifer Sinus region of Mars. Parana Valles is 350 kilometers (about 215 miles) long. Liquid water flowing over the surface of Mars likely carved its channels.

Image Pair Two: Deltas

Image C: Earth

This is a black and white image of the Yukon Delta in southwestern Alaska. It was taken by NASA's Landsat 7 satellite in 2002. The squiggly light gray lines are river and stream channels that bring water and sediment (like sand and clay) from the Yukon River out towards the Bering Sea. Because the Yukon is a fairly smooth, flat area, the river channels often change course and carve new channels as they try to find the fastest route towards the sea. The light gray colors surrounding the delta show water with lots of sediment in it. Farther from the delta, the darker gray colors show sea water that holds less sediment. The Yukon Delta is an important habitat for waterfowl and migratory birds.

Image D: Mars

The Eberswalde Delta is a "fossil delta" – a delta that no longer has water flowing through its channels. The dry channel floors, which have been turned into rock, stick out above the surrounding landscape – the opposite of how you'd find them when the channels formed. The Eberswalde Delta is a very important feature on Mars because it provides evidence that a liquid (most likely water) flowed over the surface for a long period of time. It is one of the locations scientists considered sending the Mars Science Laboratory Curiosity rover. This black and white image mosaic was taken by NASA's Mars Global Surveyor and released in 2005.

For more information:
Channels in Yemen: http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=35729
Terra: http://terra.nasa.gov
Channels in Margaritifer Sinus: http://nssdc.gsfc.nasa.gov/imgcat/html/object_page/vo1_084a47.html
Viking-1: http://www.nasa.gov/mission_pages/viking/
Yukon Delta: http://earthobservatory.nasa.gov/IOTD/view.php?id=72762
Landsat-7: http://landsat.gsfc.nasa.gov/about/landsat7.html
Eberswalde Delta: http://www.msss.com/mars_images/moc/2005/09/20/eberswalde/
Mars Global Surveyor: http://mars.jpl.nasa.gov/mgs/
Mars Science Laboratory Curiosity Rover: http://mars.jpl.nasa.gov/msl/