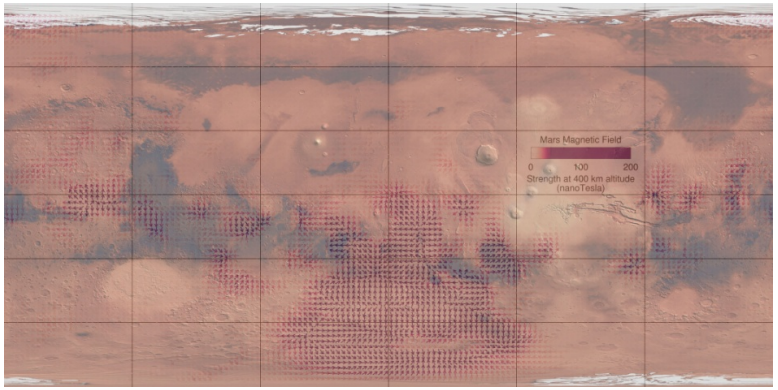
Invisible Mars

MAVEN
Mars Atmosphere and Volatile Evolution Mission



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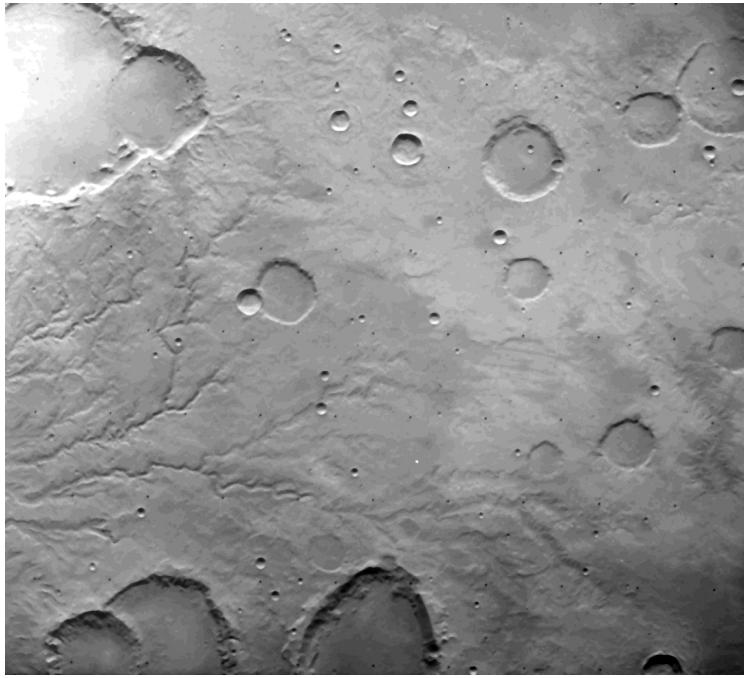
Background for Facilitator: Water on Mars

Introduction

Earth is unique in the Solar System because of the amount of water on its surface and because all three phases of water (solid, liquid, and gas) are stable on its 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 more and more evidence of a world shaped under the influence of water, 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.

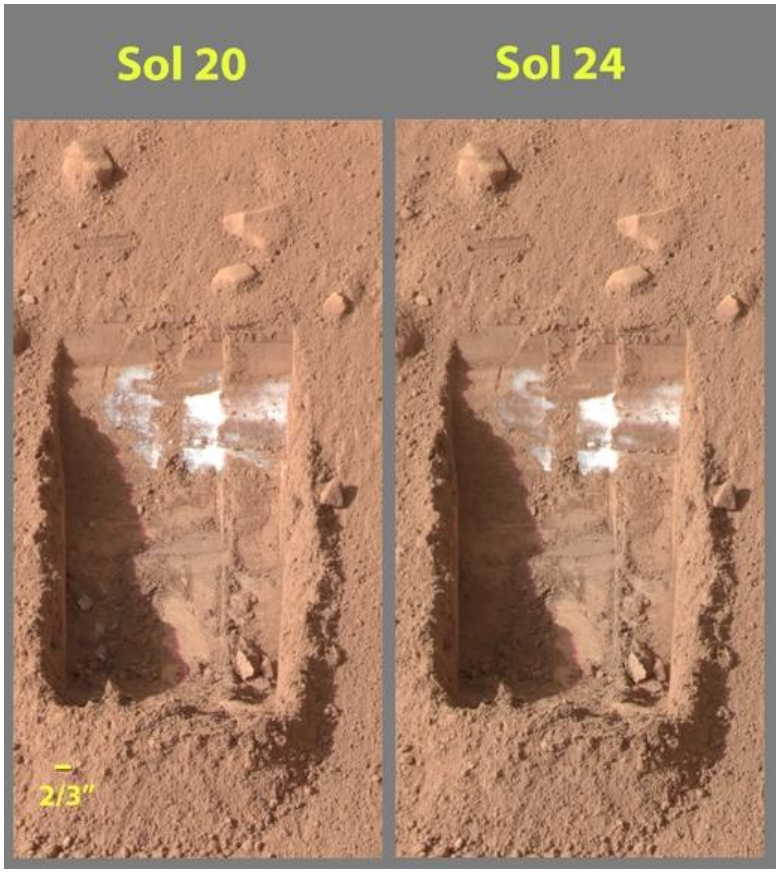


Water-Related Features on Mars

Mars has intricate networks of drainage channels, some which may have been carved by rain that fell on our rusty-red neighbor (see Figure 1). Thick layers of dusty carbon dioxide and water ice deposits cap the poles, there is evidence of martian glaciers, and recent impacts at lower latitudes have exposed water ice hiding just below the rocky surface. Some martian gullies that appear to have been carved by flowing water have shown recent activity. Mars also shows evidence of floods from long ago 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, and some of these lakes had deltas in them. Deltas (see Earth-Mars comparison images in *Invisible Mars* script) are exciting features to find on Mars because they form over fairly long periods of time, meaning water had to be stable on the

Figure 1: 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 credit: NASA.

surface for sustained periods of time to form these features. 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 the high northern latitudes, imaged ice disappearing as it sublimated (Figure 2) and provided chemical evidence that water ice exists on Mars. Minerals and sedimentary structures apparently formed or influenced by water are found on the martian surface (such as those found by the Opportunity rover, shown in Figure 3), and the Mars Science Laboratory Curiosity rover 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 2: This pair of images of a trench dug by the Phoenix lander was captured by Phoenix on June 15 and June 19, 2008 (the 20th and 24th martian days or “sols” that Phoenix was operating on Mars). They show that ice (that appears white) is present just beneath the Mars surface where Phoenix landed, and that it disappeared (by sublimating) when exposed. Image credit: NASA/JPL-Caltech/University of Arizona/Texas A&M University.

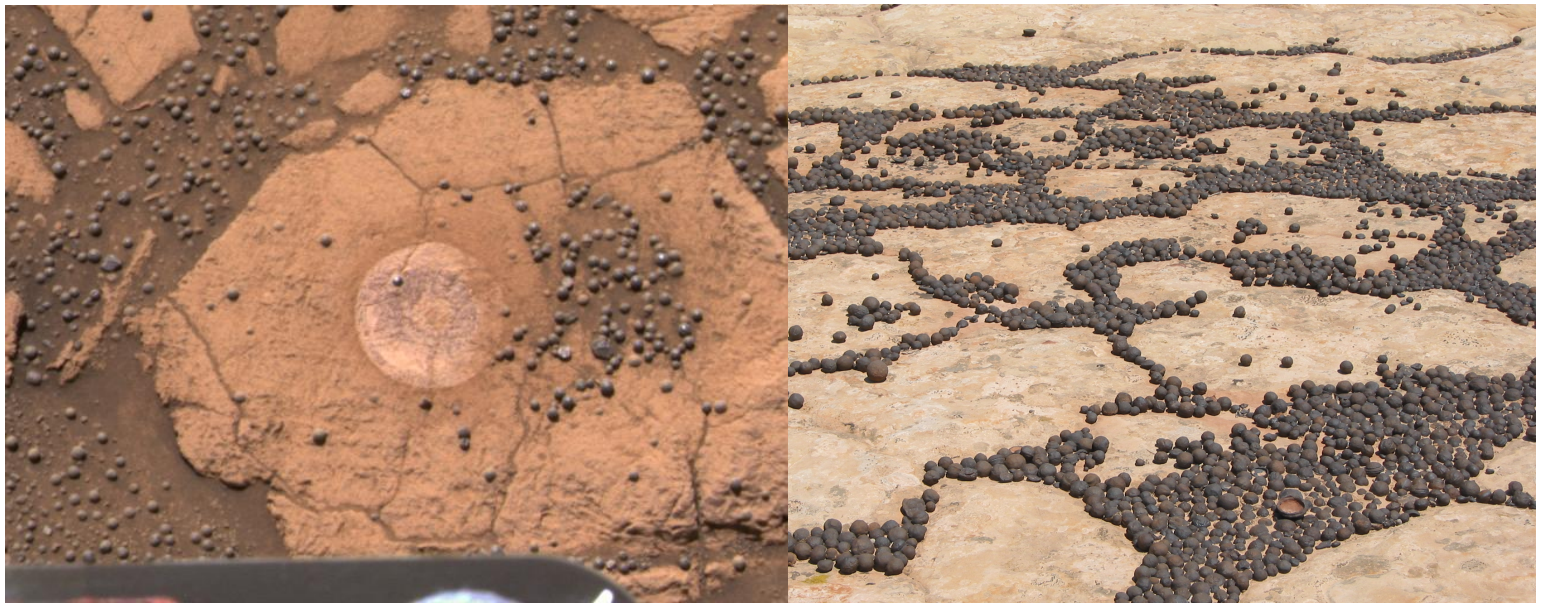


Figure 3: The image on the left shows the “Berry Bowl” rock captured by the Mars Exploration Rover Opportunity in the Eagle Crater outcrop on Mars. This sandstone rock is full of spherical grains (~4mm in diameter, on average) known as “blueberries” that contain a high concentration of the iron-bearing element hematite. Scientists think that groundwater carrying dissolved iron percolated through the sandstone and formed the “blueberries.” The circular feature in the center of the image was cleared of dust by Opportunity’s rock abrasion tool’s brush so that Opportunity could separately analyze the mineralogy of the dust, the rock, and the blueberries, and confirm that the chemical composition of the rock was significantly different than the chemical composition of the blueberries. Image credit: NASA/JPL/Cornell. The image on the right shows hematite concretions very similar to the martian “blueberries” found on the surface of the Navajo sandstone at Grand Staircase-Escalante National Monument in southern Utah. Photo credit: Brenda Beitler

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 (something that is not true today), and that there was once quite a bit more water on the surface than we see today.

What happened to all of the water? Where did it go? 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, ice or rocks that trapped water in the crust to explain the water-related features, so many scientists have shifted their search for the lost water from the ground to the sky. 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.

Along with their hunt for missing water, scientists are also hunting for missing carbon dioxide (CO_2). Greater abundances of carbon dioxide than we see in the polar ice caps and atmosphere today are expected to have been present with the water, producing greenhouse warming that would have allowed liquid water to be present. This means the other half of the question is: where did the carbon dioxide go? Again, we don't see evidence for it in the crust (and we would expect to see it if it were there), so we look to loss to space.

MAVEN
MAVEN will study the martian atmosphere, from close to the planet's surface to high up in the outer reaches, to find out the rate of loss of water and other gases from the atmosphere today and to determine what the loss rate might have been in the past. Data from MAVEN will help scientists as they try to solve the mystery: what happened to the water on Mars?

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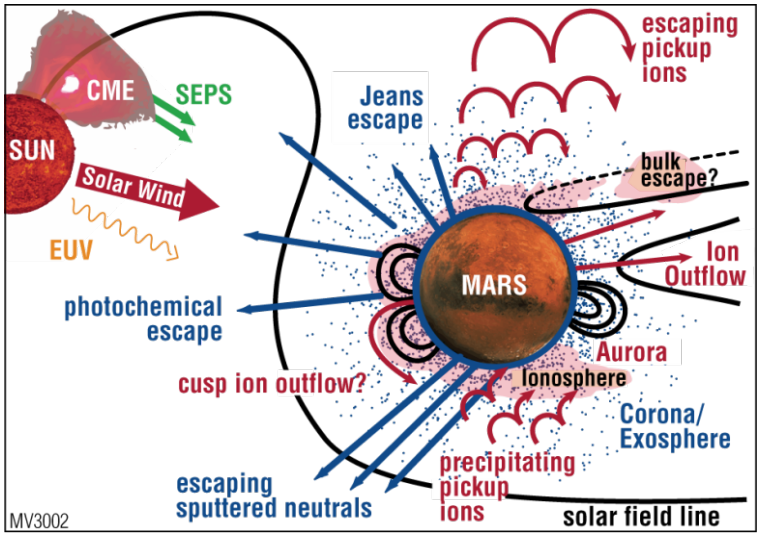
Background for Facilitator: MAVEN

What is MAVEN?

Previous missions to Mars have shown us that the atmosphere and climate have changed over time and have found evidence of abundant liquid water on the surface billions of years ago, though not today. Scientists wish to understand the processes that led to the instability of liquid water on the surface of Mars. A leading theory is that the martian atmosphere was lost to space. The Mars Atmosphere and Volatile EvolutioN, or MAVEN, mission will orbit Mars to explore how the Sun may have stripped Mars of most of its atmosphere, turning a once possibly habitable planet into a cold and barren desert world. MAVEN will address 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 will MAVEN answer the science questions?

The processes that control the loss of the martian atmosphere are complex; different processes occur at different times and geographical scales on the planet. Figure 4 illustrates the processes occurring at Mars today. The role these processes have played in the loss of the martian atmosphere over time is not well constrained.

Figure 4: MAVEN measurements will help us to understand the escape of neutral (blue) and charged (red) atmospheric particles from Mars. The measurements will constrain the atmospheric reservoirs for loss, the escaping particles, and the drivers from the Sun that control escape. By understanding the entire system today, MAVEN data can be used to understand how these processes contributed to atmospheric loss in the past. This diagram is not to scale.

MAVEN Takes Measurements

In order to answer the main science questions, MAVEN will carry three instrument suites - the Particles and Fields Package (PFP), the Remote Sensing Package, and the Neutral Gas and Ion Mass Spectrometer (NGIMS). Together, these instrument suites will measure the reservoirs of particles in the upper atmosphere (including their distribution, composition, variability, and temperature), the particles escaping from the atmosphere, and the sunlight and particles from the Sun (the solar wind) reaching the martian atmosphere. Each of the measurements fit together like a piece of a puzzle, allowing MAVEN scientists to understand how atmospheric loss works 'from start to finish'. This, in turn, will allow the scientists to reconstruct how these same processes worked billions of years ago at Mars.

MAVEN Changes its Orbit

MAVEN's job is complicated by the fact that measurements must be 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. Further, the MAVEN team expects the measurements to vary with location. For example, the measurements MAVEN collects on the side of Mars facing the Sun will likely be different than the measurements it collects on the side of Mars facing away from the Sun. Thus, it was important to design a spacecraft orbit that was elliptical, and that moved with respect to the planet (precessed) over time (see Figure 4). MAVEN will pass through the entire upper atmosphere in each orbit. It will also make special maneuvers to dip down into the well-mixed lower atmosphere. MAVEN will sample all of the different atmospheric regions directly, in an orbit designed to ensure that measurements are taken at as many possible combinations of time of day, location, and altitude as possible. MAVEN is designed to operate for one Earth year. By the end of that year, scientists will have a better understanding of the state of martian atmospheric loss than ever before.

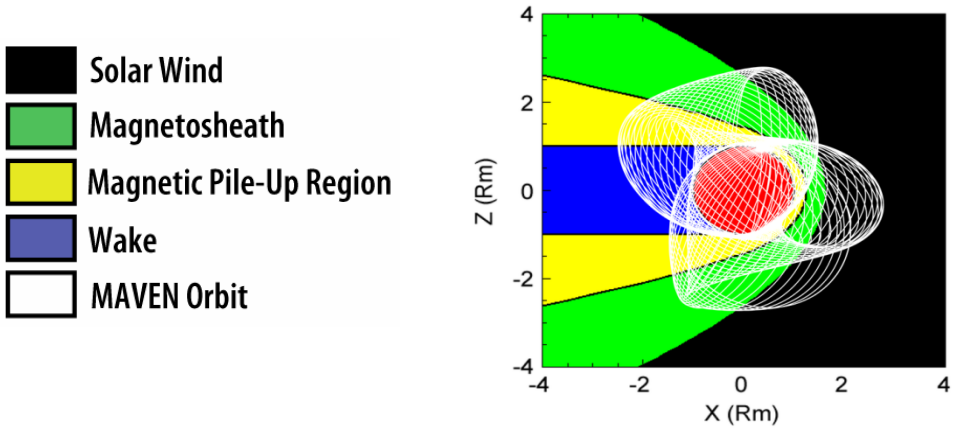


Figure 5: A bird's eye view of the MAVEN mission orbit showing the relationship of the mission orbit (white) to Mars (red), and interactions of the solar wind and the martian atmosphere (black through blue). In this view, the Sun is off to the right. Relationships between the orbit, scale of the planet, and scale of solar/atmospheric interaction (Magnetosheath, magnetic pile up region, wake) are not to scale.

Optional Materials

Laser pointer, for drawing attention to specific features within datasets (such as in Earth and Mars comparison images)

NOTE: Materials and notes about optional atmospheric loss dry ice activity are included in the Notes About Dry Ice Activity on page 32.

Tips for Facilitator

In the script, there is an optional section where you may talk about recent discoveries from the Curiosity rover. If you would like to include this information, mission updates may be found on the Curiosity website (listed on next page).

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.

The MAVEN Education and Public Outreach Team will offer professional development webinars about the *Invisible Mars* script and related Mars and MAVEN science topics. These webinars will be advertised through messages to members of the NOAA Science On a Sphere Yahoo group (to join, visit website, listed on next page) and on the MAVEN Invisible Mars Science On a Sphere webpage.

Additional Resources for Facilitator

MAVEN mission website: http://lasp.colorado.edu/home/maven/

MAVEN Invisible Mars Science On a Sphere website:
http://lasp.colorado.edu/home/maven/education-outreach/afterschoolsummer-programs/invisible-mars/

Curiosity mission website: http://mars.jpl.nasa.gov/msl/

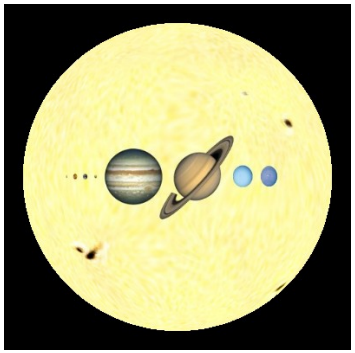
Mars Exploration Program website: http://mars.jpl.nasa.gov

NOAA Science On a Sphere Yahoo group: http://groups.yahoo.com/neo/groups/noaasos/info

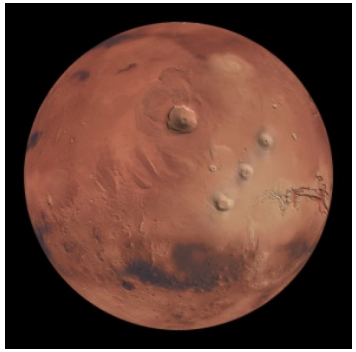
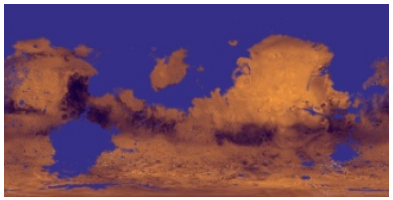
For more information about the magnetic field of Earth and the solar wind: http://image.gsfc.nasa.gov/poetry/

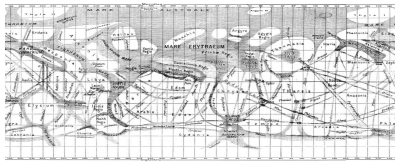
For more information about the magnetic field of Mars: http://mgs-mager.gsfc.nasa.gov/Kids/magfield.html

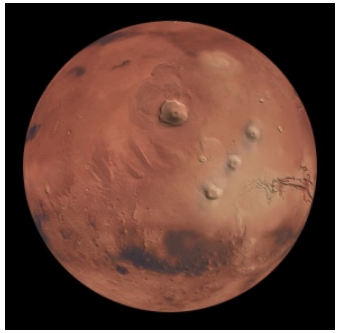
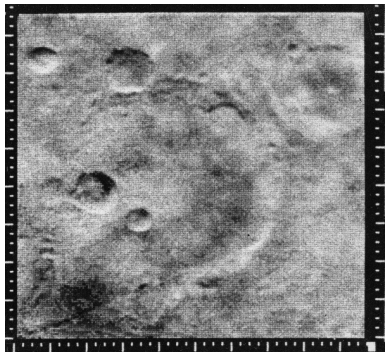
MAVEN *Invisible Mars* SOS Script & Playlist

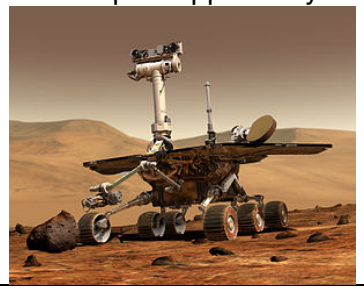
SCRIPT	PLAYLIST
Circling our Sun are eight planets, from Mercury on out to Neptune, each beautiful in its own way. **Saturn has its lovely rings,** [Use a laser pointer to point to Saturn in PIP.] **and Jupiter is banded with colorful clouds.** [Use a laser pointer to point to Jupiter in PIP.] **But none is more beautiful than our own planet Earth.**	• SOS: Planet diagram 

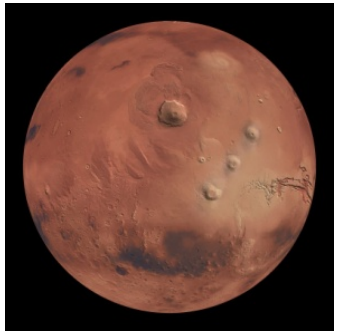
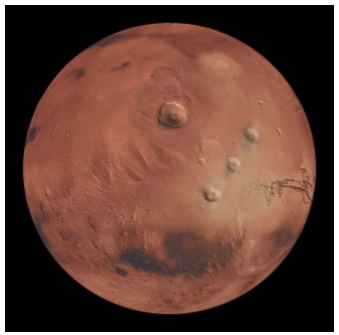
Now, maybe I'm just saying that because I live here and I'm a little biased, but let's have a look: **A dazzling blue marble, painted with green and brown, and all wrapped up in swirling white clouds…** **The Earth—as far as we know—is the only planet in our Solar System that supports life.** **In general, the inner planets (Mercury and Venus) are too hot and the outer planets (Mars, Jupiter, Saturn, Uranus, and Neptune) are too cold, but, just like in the story of Goldilocks, Earth is just right.** **What do we mean by "just right"? Well, for one thing, scientists believe that you can't have life without liquid water. And Earth is the only planet we know of that has stable liquid water at its surface. At least today.** **But do you think it's possible that a planet that is dry today may have had liquid water in the past? Can conditions on a planet change over time? Yes, they can.** **And there's one planet, in particular, that we think once had liquid water on its surface. Do you know which one?**	• SOS: Blue marble 

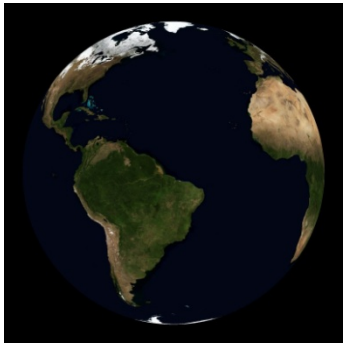
That's right: Mars. **This is what Mars looks like today. Dry.**	• SOS: Mars Red Planet 
But, millions of years ago, we think it was wetter, with flowing water, maybe even lakes or oceans. Even if there weren't oceans, most scientists agree that Mars was wetter in the past. **How can we know that?** **Well, scientists are really detectives—they solve mysteries by searching for clues.**	• SOS: Watery Mars 

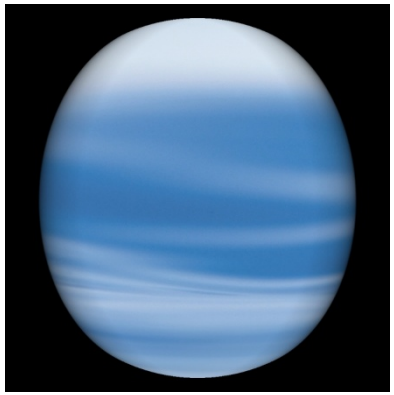
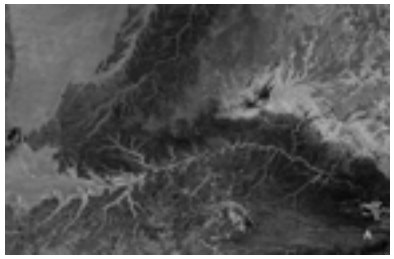
We've been observing Mars for thousands of years, but, for the longest time, it was just a small reddish dot in the sky, which couldn't tell us very much. **… until 400 years ago, when a powerful new tool was invented for studying the planets and stars. Do you know what it was?** [Take answers from audience.] **That's right: the *telescope* allowed us to see Mars more clearly.**	• SOS: Blurry Mars 
As astronomers, like Schiaparelli, began to map Mars, they saw details like polar ice caps, and lines that looked like canals—some people imagined they were built by a martian civilization. **Our telescopes got better, and we eventually developed a space program in order to send spacecraft into space.**	• SOS: Pause Blurry Mars and overlay map of Schiaparelli's canals, then fade out canals and bring Mars into focus 

Over the past 50 years, we've sent spacecraft to all the planets of the Solar System, which has let us extend our senses—so to speak—out into the Solar System, to get an even closer look at 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.	• SOS: Mars Red Planet 
The first successful NASA mission to Mars was called Mariner 4, launched in 1964. This spacecraft flew past Mars, collecting the first close-up photographs of another planet, and we could observe more features than before with the telescope. **Other missions followed, and now, nearly 40 years later, the next upcoming mission to Mars is MAVEN, which launched in 2013.** **MAVEN will fly close to Mars to provide information about the Red Planet's atmosphere, climate history and its potential for supporting life greater detail than ever before.**	• Mariner PIP 

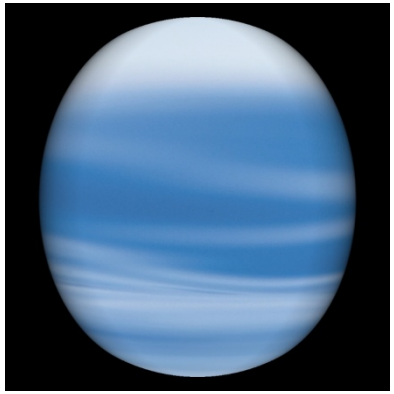
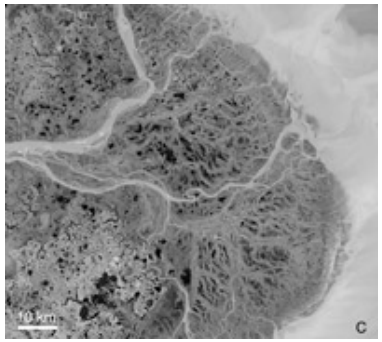
There have also been spacecraft that have actually landed on Mars. How many of you remember the rovers *Spirit* and *Opportunity*? These exploring rovers landed on Mars in 2004. The primary mission for these rovers was only supposed to last for 90 days, but nearly ten years later, *Opportunity* is still going!	• PIP of Spirit/Opportunity 
More recently, NASA landed another rover, called Curiosity, on Mars in August, 2012. **And do you know what we've found? (some really cool stuff)** **These spacecraft have found impact craters made by things like comets and asteroids, a volcano that's three times taller than Mt. Everest, and we've even confirmed that there's ice on Mars.** [Optional: Talk about most recent Curiosity discoveries.] **But you know what we *haven't* found? Lots of liquid water or canals. We haven't found any signs of life yet.**	• PIP: Photo of Curiosity 

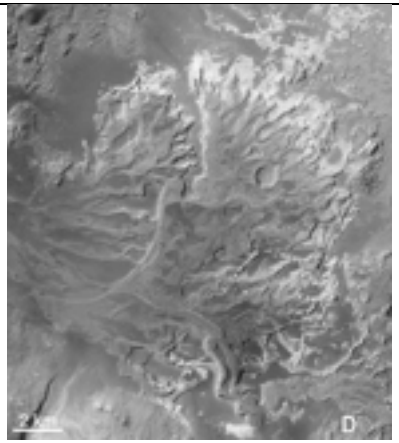
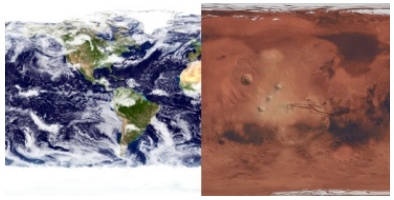
This is one of the newest images from the Curiosity rover, and you can see that—today—Mars is desolate and dry. **But… there are some interesting features that tell us Mars once had liquid water on the surface.** **Does anyone know how we came to that conclusion? How could we know that? If there's not liquid water now, what could make us think there once was?**	• SOS: Mars Red Planet  • PIP: Overlay panorama image from Curiosity  • SOS: Mars Red Planet 

Well, what if we use Earth as an example? **Geologists have had a long time to study the surface of the Earth, up close and hands-on. And we have a very good understanding of how things work here: how the forces of nature, like wind, water and volcanoes, can shape the land.** **Each process leaves behind different clues that tell us what happened in the past. When scientists do their detective work, they study these clues. The clues can reveal the difference, for example, between land features that were carved by wind, and ones that were made by flowing water.**	• SOS: Blue Marble No Clouds 

Let's compare some black and white images taken from space of features on Earth and Mars that were formed by flowing water. Audience Participation Activity [Two options: Docent 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, and ask guiding questions that focus the audience's attention on similarities in features. **Now that we've talked about some of our observations of these images, let's talk about what they show. Does anyone know what the features in these images are?** [Take answers from the audience.] **That's right, 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**	• SOS: Watery background  • PIP (For Option 2): Fade in photos of features on Earth and Mars that were carved by water 

This image shows river and stream channels in 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 is a desert. It receives only 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 likely carved by liquid water flowing over the surface of Mars. The direction of flow in these channels would have been from image right to image left.**	

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 images of deltas. A delta is a landform that is formed at the mouth of a river, where the river flows into an ocean, sea, estuary, lake, or reservoir. Deltas are formed when sediment (like sand or mud or pebbles) carried from the river settles out 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.] **Image C: Earth** **This is a black and white image of the Yukon Delta in southwestern Alaska. 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.** **Image D: Mars** **The Eberswalde Delta on Mars is a "fossil delta"—a delta that no longer has water flowing through its channels. This delta is a very important feature on Mars because it provides evidence that water flowed over the surface for a long period of time.** **What we have learned here on Earth, we can apply to Mars. The same processes**	• SOS: Watery background  • PIP (For Option 2): Fade in photos of features on Earth and Mars that were carved by water 

that happen here on Earth can happen on other planets, too. So, when we look at Mars and we see certain kinds of minerals and certain kinds of formations—like stream channels and deltas—scientists can figure out that there was once water flowing on the surface of Mars. **But not anymore. Why?** **Something must have changed.**	
Let's compare Earth and Mars again. And just for fun, let's split the sphere in two: half Earth, half Mars. Is there something about the Earth that might explain why WE still have water and Mars doesn't? [Take guesses from the audience. Sample responses might include Earth is bigger and has more gravity. The audience may also notice that the Earth has visible clouds in this dataset, while Mars does not.] **There are few clouds on Mars because it is so cold and dry. Water and clouds are connected.** **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 

That's right, Mars has a very thin atmosphere—less than 1% of Earth's. And the Mars atmosphere would be toxic for humans. **In order to keep liquid water, a planet must have temperatures that are above freezing. On Earth, we have natural "greenhouse warming" because of the carbon dioxide and water in our atmosphere, which raises the temperatures here above freezing. If Mars—a planet that is farther from the Sun than Earth—used to have liquid water, it must also have had warmer temperatures. And, in order to have warmer temperatures, it must also have had a thicker atmosphere early in its history.** **So, maybe we can figure out what happened to the water on Mars by asking a different question:** **What happened to Mars's atmosphere?** **Let's put on our detective caps.** **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?** [Optional: Possible lighthearted suggested wording could include the following] **Could it go…. to Disneyland? No. Could it go… to the grocery store? To…the bathroom? No.** **Where could an atmosphere go?** [Docent starts slowly looking up, up… maybe a shrugging gesture that leads to hands rising slowly up, too.] **Up! That's right. Or…**	

[gesturing, if necessary] **… down! Those are two possibilities.** **DOWN means that maybe the atmosphere went down into the rocks and below the surface. We have found evidence that this happened but we don't know how *much* of it happened. There are still some missing pieces to the puzzle. Another possibility is that Mars's atmosphere escaped UP, into space.** **You might not realize what a complicated thing an atmosphere is. I know it seems like it's just the air we breathe, but it's actually a very complicated system that stretches from the ground all the way up to space. And it interacts with a lot of things.**	
For instance, if Mars's atmosphere is escaping UPwards, can you think of anything up there that might affect it and help it escape? Maybe a familiar object that affects all the planets? I'll give you a hint: it's the biggest object in the Solar System, and it's very bright. [Take guesses from the audience. Identify "the Sun" as correct.] **That's right—the Sun.**	• SOS: Sun (white light image with sunspots) 

In addition to light and heat, the Sun gives off a stream of charged particles called the solar wind. Over time, perhaps, the solar wind could have stripped away most of Mars's atmosphere.

On the sphere right now, you see an animation of the solar wind stripping away Mars's atmosphere. The white particles represent the solar wind. See those blue lines around Mars? Those represent Mars's magnetic field. Mars used to have a strong magnetic field which protected it from the solar wind. But something happened to the magnetic field and without it, the solar wind stripped away Mars's atmosphere, turning the planet into the dry, cold planet it is today.

It may have happened kind of like this…

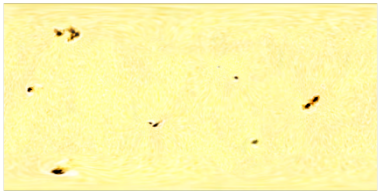
<u>Atmosphere Loss Demonstration</u>
[Have audience volunteer hold fan with docent holding dry ice on a plate.]
Can I have a volunteer come up and hold this fan?
I'm going to hold a chunk of dry ice.
The fan represents the solar wind. The dry ice represents Mars's atmosphere.

Notice how the wind from the fan blows away the gases from the dry ice. This is similar to how the solar wind can blow away a planet's atmosphere.

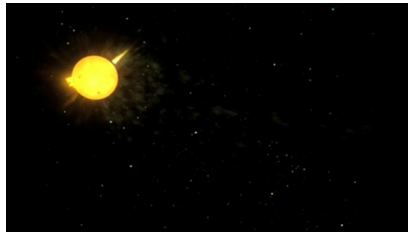
Think about Earth for a minute—we know Earth has an atmosphere. Why doesn't the solar wind strip away Earth's atmosphere?

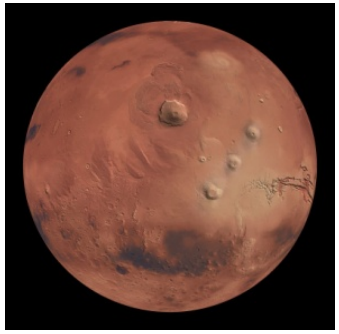
[Take different answers, guiding audience to the idea of Earth having some kind of protection.]

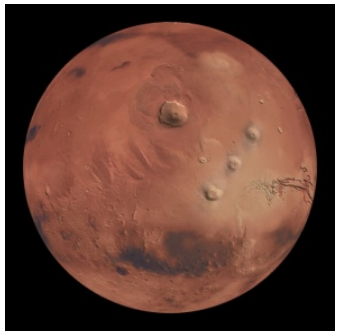
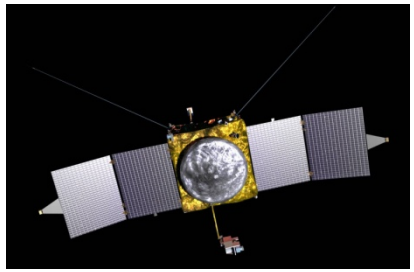
- SOS: Sun (white light image with sunspots)



- PIP: Mars Atmosphere Loss video running continuously

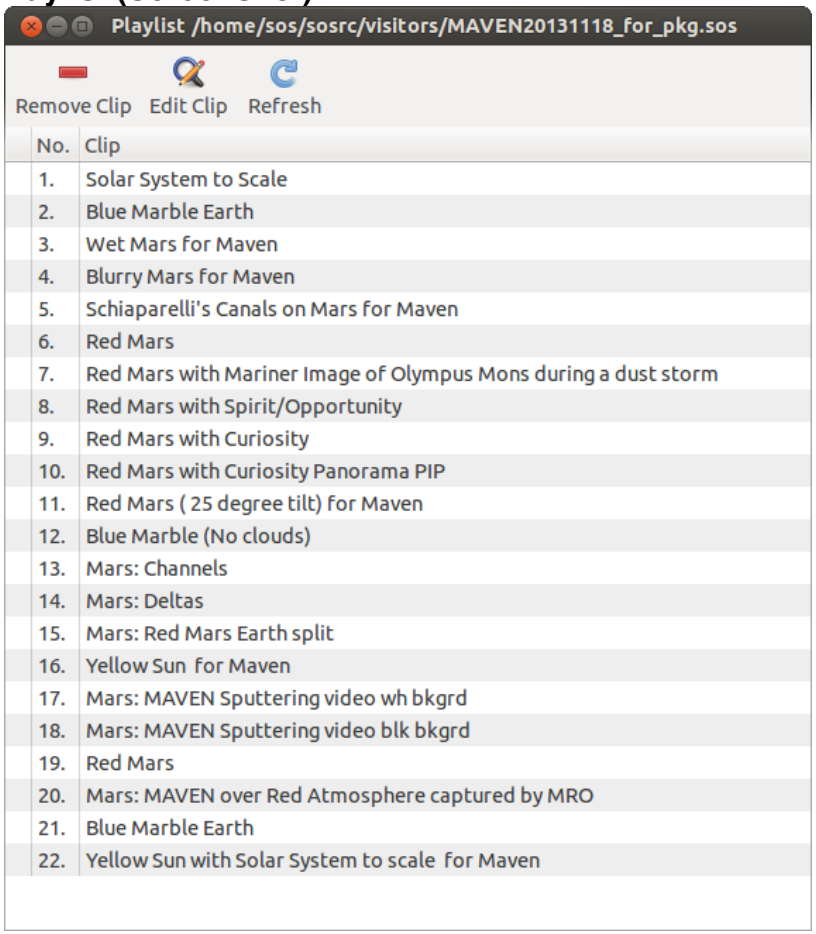


Now I'm going to put a clear dome on top of the ice. [Put dome over top of dry ice on plate.] **Look at how the dry ice—representing the atmosphere—doesn't blow away. The dome represents the Earth's protective magnetic field. The Earth's magnetic field is so strong that it deflects the solar wind. Aren't you glad we have such a great an invisible force field protecting us?**	
Without a strong magnetic field, Mars doesn't have the same protection from the solar wind that Earth has. The solar wind may have stripped away the martian atmosphere. **So, you can see there are important connections between a planet's atmosphere, its magnetic field, its water, and even the faraway Sun. It's a complicated system. And, if one part changes, it can have serious effects on the other parts.**	• SOS: Red Planet Mars 

NASA wants to study all of these dimensions of the martian atmosphere, as well as the way it interacts with its surroundings. To do this, NASA is preparing a new mission called the Mars Atmosphere and Volatile Evolution MissioN. **We'll just call it MAVEN, for short.** **MAVEN is an amazing spacecraft that will orbit Mars and study its atmosphere. MAVEN will help us learn more about how Mars has changed through time, its water and even how the surface has evolved.** **With eight different scientific instruments onboard, MAVEN will make a variety of measurements of light, magnetic fields, the solar wind, and more.** **We hope MAVEN will help us solve the mystery of the missing atmosphere… like a detective using a toolkit to solve a crime.** **MAVEN launched in the fall of 2013 and will travel for almost a year to get to Mars. NASA will let you know as MAVEN starts sending information back to us.**	• SOS: Red Planet Mars  • PIP: MAVEN spacecraft 

Sometimes people wonder why we study things so far away. Why do you think? What are some reasons? Do you think maybe it can tell us something that would be useful back here on Earth? [Take responses from the audience.] **Yes. We believe the laws of nature are the same everywhere in the universe. We use what we know about Earth to help us understand what we find on Mars. And, then we use what we learn on Mars to help us better understand Earth and other planets.** **It's a big, beautiful, complicated, intertwining system.** **And science is really about learning as much as we can about the world we live in—our home.** [Note: the location in the script and within the zoom-out PIP can be customized by individual SOS institutions.] **You may live in Boulder, but if you do, you also live in Colorado, and the United States, and we all live on Earth. And we live in the Solar System, and in the Milky Way Galaxy. And, if you take the biggest view, we live in the Universe. All of this is our home. And we always want to know more about it.** **We hope MAVEN will give us insight into what happened to the martian atmosphere. But it may also raise some new questions—which is great! Scientists love having a new mystery to solve!** **So stay tuned…**	• SOS: Blue Marble  • PIP: Zoom out from city location to Solar System 

Playlist (Screenshot):



No.	Clip
1.	Solar System to Scale
2.	Blue Marble Earth
3.	Wet Mars for Maven
4.	Blurry Mars for Maven
5.	Schiaparelli's Canals on Mars for Maven
6.	Red Mars
7.	Red Mars with Mariner Image of Olympus Mons during a dust storm
8.	Red Mars with Spirit/Opportunity
9.	Red Mars with Curiosity
10.	Red Mars with Curiosity Panorama PIP
11.	Red Mars (25 degree tilt) for Maven
12.	Blue Marble (No clouds)
13.	Mars: Channels
14.	Mars: Deltas
15.	Mars: Red Mars Earth split
16.	Yellow Sun for Maven
17.	Mars: MAVEN Sputtering video wh bkgrd
18.	Mars: MAVEN Sputtering video blk bkgrd
19.	Red Mars
20.	Mars: MAVEN over Red Atmosphere captured by MRO
21.	Blue Marble Earth
22.	Yellow Sun with Solar System to scale for Maven

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/

NOTES ABOUT DRY ICE ACTIVITY (The Atmospheric Loss Demonstration):

The dry ice activity requires the following supplies:

- Pizza pan or plate
- Clear plastic dome (can be purchased online at http://www.themedecor.com/product.jsp?prodId=3874&catId=703.)
- Pair of gloves or oven mitts
- Fan or hair-dryer
- Block of dry ice

Dry ice can be purchased at many supermarkets. It is usually sold by the pound. The following information about how to handle dry ice safely is taken from http://www.dryiceinfo.com.

HANDLING
Dry ice temperature is extremely cold at -109.3°F or -78.5°C. Always handle dry ice with care and wear protective cloth or leather gloves whenever touching it. An oven mitt or towel will work. If touched briefly it is harmless, but prolonged contact with the skin will freeze cells and cause injury similar to a burn.

STORAGE
Store dry ice in an insulated container. The thicker the insulation, the slower it will sublimate. Do not store dry ice in a completely airtight container. The sublimation of dry ice to carbon dioxide gas will cause any airtight container to expand or possibly explode. Keep proper air ventilation wherever dry ice is stored. Do not store dry ice in unventilated rooms, cellars, autos or boat holds. The sublimated carbon dioxide gas will sink to low areas and replace oxygenated air. This could cause suffocation if breathed exclusively. Do not store dry ice in a refrigerator freezer. The extremely cold temperature will cause your thermostat to turn off the freezer. It will keep everything frozen in the freezer but it will be used up at a faster rate. It is the perfect thing if your refrigerator breaks down in an emergency. There are also commercial storage containers available.

VENTILATION
Normal air is 78% nitrogen, 21% oxygen and only 0.035% carbon dioxide. If the concentration of carbon dioxide in the air rises above 0.5%, carbon dioxide can become dangerous. Smaller concentrations can cause quicker breathing and

headaches but is otherwise not harmful. If dry ice has been in a closed auto, van, room, or walk-in, for more than 10 minutes, open doors and allow adequate ventilation before entering. Leave area containing dry ice if you start to pant and breath quickly develop a headache or your fingernails or lips start to turn blue. This is the sign that you have breathed in too much CO_2 and not enough oxygen. Dry ice CO_2 is heavier than air and will accumulate in low spaces. Do not enter closed storage areas that have or have had stored dry ice before airing out completely.

PICK-UP TIME AND TRANSPORTING

Plan to pick up the dry ice as close to the time it is needed as possible. It sublimates at 10%, or 5 to 10 pounds every 24 hours, whichever is greater. Carry it in a well-insulated container such as an ice chest. If it is transported inside a car or van for more than 15 minutes make sure there is fresh air.

BURN TREATMENT

Treat dry ice burns the same as a regular heat burns. See a doctor if the skin blisters or comes off. Otherwise if only red it will heal in time as any other burn. Apply antibiotic ointment to prevent infection and bandage only if the burned skin area needs to be protected. Two Material Safety Data Sheets available online can be accessed through the following links:

http://stores.biochem.uiowa.edu/Pages/dryicemsds.html
http://www.airgas.com/documents/pdf/001091.pdf

COUNTERTOPS

Do not leave dry ice on a tiled or solid surface countertop as the surface could crack due to the extreme cold.

DISPOSAL

Unwrap and leave dry ice at room temperature in a well-ventilated area. It will sublimate from a solid to a gas.

DO NOT leave dry ice unattended around children.