Girls Go To Mars Overview
A Tale of Two Planets: Earth and Mars *[Adult]*

1. Introduction

"Girls Go to Mars" (GGTM) is a short series of investigative activities for Cadette Girl Scouts that begins with an overview of our inner Solar System; emphasizes the planetary histories of Venus, Earth, and Mars; and concludes with evidence for the greenhouse effect on Earth. The activities reflect the scientific goals of NASA's Mars Atmosphere and Volatile Evolution Mission (MAVEN), and were developed by the SETI Institute in collaboration with Girl Scouts of Northern California. The investigations engage the Cadettes' senses as they conduct collaborative hands-on experiments that utilize online NASA resources and integrate NASA's MAVEN discoveries about the atmosphere of Mars.

Cadettes simultaneously learn about new technologies and gain new knowledge as they explore career pathways and develop potential service projects linked to the Cadette leadership journey *Breathe: It's Your Planet — Love It!* Air Care Team Take Action Plan. Upon completion, the Girls Go To Mars event patch (as shown in upper right corner) is available through Girl Scouts of Northern California.

2. General Description of the MAVEN Project

On November 18, 2013, an Atlas V vehicle lifted off at Cape Canaveral Air Force Station in Florida and sent the MAVEN spacecraft on its way to study Mars' upper atmosphere. Scientists expect that data gathered during the MAVEN mission will help explain how Mars' climate changed long ago due to the loss of atmospheric gases. The spacecraft arrived at Mars on September 21, 2014, and is gathering information until the mission ends in April 2016. MAVEN can be found on social media via MAVEN2Mars on Facebook and Twitter. The mission websites provide mission details, status updates and multimedia files. View the mission page: http://tinyurl.com/cfzbfxo and the NASA MAVEN page: http://tinyurl.com/chucl8r. (Adapted from *MAVEN Mission Facts and Stats*: http://tinyurl.com/mnmwurz)

3. Overarching Science Questions and Background Information for Leaders

3.1. Why is Mars so cold and dry and Earth, warm and wet?

Around 3.8 billion years ago, Mars likely had a similar climate to Earth's. Today, Mars is a cold and barren desert world. However, when Mars was young, it appears to have had a thick atmosphere, warm enough to support oceans of liquid water. NASA has prepared a new video to illustrate the MAVEN mission's investigation of dramatic climate change on Mars. This video is an artist's concept that shows the transition from an ancient, habitable Mars capable of supporting liquid water on its surface to the cold desert world of today. View video *Maven Mars Evolution* (NASA): http://www.seti.org/ggtm

3.2. Why is Mars' size important? There are several reasons.

3.2.1. Loss of heat:

Planets change throughout time. Like all planets, Mars and Earth were heated as they formed from the radioactive decay of elements and from the constant pummeling by impacts from space during formation.

Soon after the planets formed, they began a process of reorganizing. Their interiors either melted or partially melted. Denser elements like iron and iron-rich compounds sank to the interior and the least dense materials formed the crust.

However, Mars and Earth did not change at the same rate; large rocky planets cool more slowly than small planets. While heat is held in the volume of a planet, it is lost through its surface area. Smaller planets — for example Mars — have a larger surface area-to-volume ratio, which means that Mars

would cool more quickly than Earth. Think about leaving a small cup of hot tea on the counter versus a one-gallon bucket of water, both at the same initial temperature. When you return 10 minutes later, which container will have the warmest water?

View the image below for a comparison of the volume to surface areas of Earth, Mars, and our Moon.

3.2.2. Core cooling changes the surface landscape and ultimately impacts the atmosphere:

As long as the iron core remained fluid, and the mantle remained extremely hot, Mars probably had a magnetic field as Earth does today. For the most part, Earth's mantle stays in solid form because the pressure deep inside the planet is so great that the material can't melt. In certain circumstances, however, the mantle material does melt, forming magma that makes its way through the outer crust.

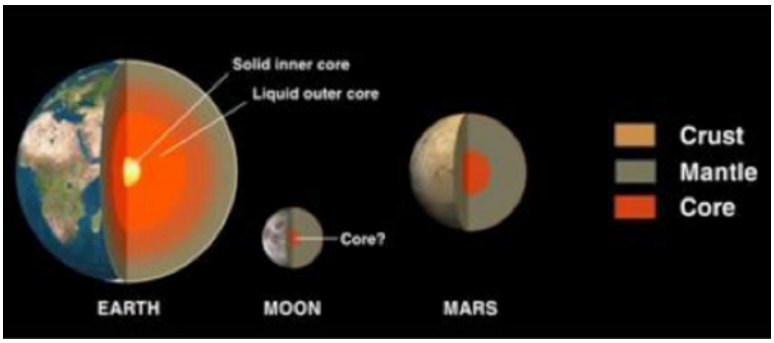

Image credit: Lunar and Planetary Institute

However, millions of years ago on Mars — *which is smaller than Earth* — both the mantle and core cooled enough so that its global magnetic field and volcanic activity disappeared.

Today Mars has only a disorganized magnetic field detected in rocks, and has no active volcanoes — important differences between Mars and Earth.

The release of gases due to volcanic activity is vital to the atmosphere.

To understand the comparison between Mars and Earth, and the impact of Mars' cooler core, watch the *Olympus Mons on Mars* (BBC) video at http://www.seti.org/ggtm

3.3. Why is an atmosphere important to a planet? Sustaining liquid water is one reason.

To have liquid water on its surface, Mars must have had a thick atmosphere with a lot of greenhouse gases that kept it warm (the greenhouse effect), such as carbon dioxide, water, and molecular hydrogen. On Earth, greenhouse gases (carbon dioxide and water vapor, to name two) in our atmosphere keep us at a reasonable temperature. What happened to Mars' atmosphere and its greenhouse gases? Where did the surface water go? Scientists aren't sure, but they do have some ideas.

This split panel image compares a section of Arizona's Grand Canyon (left) to a section of Mars' Nanedi Valles (right). The northern part of the Nanedi Valles image shows that a river once cut through it, similar to the one flowing through the Grand Canyon.

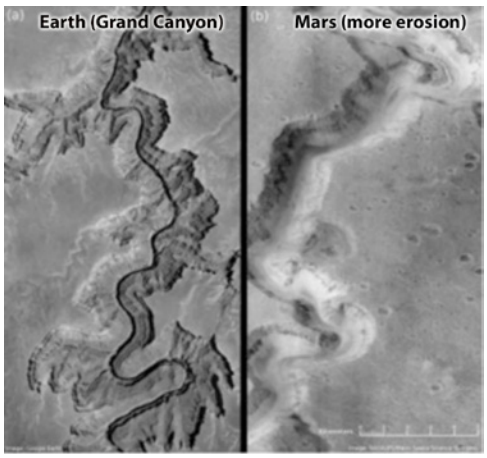

Image credit: Pennsylvania State University

The average width of the Grand Canyon is 16 km (10 mi). Although this section of Nanedi Valles is nearly 2.5 km (1.55 mi) in width, other portions are at least twice as wide. Slight differences in shape between the two canyons are attributable to the great age differences between the regions and the correspondingly higher degree of erosion on Mars.

Somewhere around 3.8 billion years ago, Mars' atmosphere started to change. To search for clues, scientists often compare what ancient Earth and Mars looked like to give them ideas as to what might have happened on Mars.

3.4. Exploring these differences is linked to understanding planetary atmospheres and the greenhouse effect on Earth, and guides the science and content of the activities in *Girls Go To Mars*:

3.4.1. Distance from the Sun: **Mars** is farther from the Sun than **Earth**. The farther a planet is from the Sun, the less energy it will receive. The Sun's solar wind, composed of super-hot gases streaming from its surface, also attacks a planet's atmosphere. The closer a planet is to the Sun, the more vulnerable it becomes to the solar wind.

3.4.2. Magnetic Field: The flow of a liquid iron core generates electric currents, which in turn produces magnetic fields. **Earth** has a magnetic field produced by a molten iron core. It's as though there is a giant magnet inside of the **Earth**, and the reason we can use a compass is because the dial in your compass lines up with **Earth**'s magnetic field. **Earth**'s magnetic field protects our planet's surface and atmosphere from the Sun's solar wind. Watch the video *Death of a Planet* (BBC): http://www.seti.org/ggtm

Mars had a magnetic field about 4.1 billion years ago, but something happened that made the magnetic field shut off. While **Mars** probably had molten iron in its core, it likely stopped flowing as **Mars** cooled down. Now **Mars** does not have a global magnetic field like Earth's.

One of the goals of MAVEN is to explore the role of the solar wind and its likely impact on **Mars'** once more-robust atmosphere.

3.4.3. Gravity: Gravity is a force of attraction that acts between all objects with mass, including atmospheric gases and planets. If a planet has less mass, there is less gravity, and it's harder for that planet to hold on to its atmosphere.

While **Mars** once had a lot more atmosphere, **Mars** doesn't have as much gravity as **Earth. Earth** has about 9 times the mass of **Mars.** When a comet or meteorite hits a planet, it splashes into the atmosphere like a rock dropped into water. If you had a big splash from a big meteorite, some atmosphere could have escaped **Mars'** low gravity. Low gravity also makes it easier for the solar wind to carry away smaller, lighter particles and atmospheric gases, including important greenhouse gases.

3.5. What are some questions the MAVEN Mission attempts to address?

- What happened to Mars' atmosphere?
- How did the solar wind affect the atmosphere?
- What is the history of liquid water on ancient Mars?

4. How will Girls Go To Mars connect with the MAVEN Mission?

4.1. Girls GoTo Mars will:

- build on existing Girl Scout science, technology, engineering, and math (STEM) by focusing on the theme of Mars exploration and the MAVEN Mission;
- enhance Girl Scout programs designed to increase Cadettes' and adults' understanding of and interest in Solar System exploration in general, and of Mars specifically; and
- expose girls to space science careers.

4.2. Links between the planetary history of Mars and Earth, and MAVEN.
In a series of interrelated activities, girls will explore the following questions:

- What are the present atmospheric properties of Venus, Earth, and Mars?
- What makes Earth so heavenly, Mars so cold, and Venus so hot?
- When we can't go "there," what types of evidence do scientists study to learn about a planet's atmosphere?

- What evidence indicates that the atmospheres of Mars and Earth were different in the past?
- What forces contribute to change in atmospheric composition and pressure?

4.3. The Cadettes will learn by hands-on experiments about the nature of scientific processes and examine evidence that scientists use to compare and contrast Mars' and Earth's atmospheres. During guided investigations, the girls will explore planetary atmospheric properties such as pressure and composition, magnetic fields, surface physical features, size, and location in our Solar System. Furthermore, scientists in videos who serve as role models and experts will guide the girls in interpreting these physical properties that are linked to the history of a planet's evolution.

4.4. In the final investigation, the Cadettes will demonstrate their growing knowledge about Earth's atmosphere and the nature of scientific investigation. They will conduct an investigation on the greenhouse effect, then in a connected activity collaborate on a project aligned with *Breathe. It's Your Planet — Love It!* leadership journey.

5. Girls Go To Mars: A Series of Investigations for Cadettes

Overview of Activities:

Overarching goal for GGTM: Think like a scientist. Be a scientist!

5.1. Activity #1. *The Goldilocks Question: Just Right, Too Cold, or Too Hot?*

Solar System Orientation and Scale: This whole-group activity provides a general introduction to all the planets in the inner solar system with a focus on interpreting the importance of the mass and location of Venus, Earth, and Mars relative to the Sun. A planet's features and temperature are significantly influenced by a variety of interrelated factors: distance from the Sun, amount of solar radiation reaching the surface, mass, and the presence of an atmosphere.

Big Picture Objectives: Cadettes will learn how some planetary features such as surface temperature can be determined by size, location in space, and atmospheric properties by comparing Venus, Earth, and Mars.

In this activity, Cadettes are introduced to a recurring theme: scientists investigate processes that cannot be directly observed through the use of models. Models can be built to scale out of common materials with evidence gathered from spacecraft images and tested to see how well that model explains a phenomenon. This process leads to discussions about the limitations of models, their usefulness when dealing with objects very far away, and at the same time, reflects one aspect of how science goes forward.

5.2. Activity #2. *It's All About the Atmosphere*

This small-group activity introduces an additional planetary feature — atmospheric pressure — by comparing density of the atmospheres. The planets' surface temperatures, atmospheric pressure, and their relative abilities to retain smaller, lighter molecules such as water on the surface are discussed.

Big Picture Objectives: Using a visual model, Cadettes will discover that Venus, Earth, and Mars have different atmospheric pressures. In the case of low pressure, Cadettes will speculate that small molecules will be able to more easily escape the atmosphere, and that fact combined with reduced sunlight to the surface will most likely produce a colder planetary environment.

This activity sets the stage for understanding one of the key factors of this program: the development of a planet's atmosphere and the forces that might cause an atmosphere to change. Evidence for these ongoing forces is currently being studied by the MAVEN mission and will be explored by Cadettes in Activities #3 and #4. Other forces for atmospheric change on Earth will be investigated in an experiment in Activity #5 *The Greenhouse Effect*.

Again, in this activity, Cadettes visit the recurring theme that scientists investigate processes though the use of models that cannot be directly observed. Models can be built to scale out of common materials with evidence gathered from spacecraft images and tested to see how well that model explains a phenomenon. This leads to discussions about the limitations of models, their usefulness when dealing with objects very far away and at the same time, reflects one aspect of how science goes forward.

Big Picture Objective: Cadettes will construct models to test ideas about objects or processes that cannot be directly studied.

Activity #2.Extension. ***Women in STEM***

Small groups of girls explore NASA careers and role models via the internet. This activity may be completed at any time. Since Activity #2 takes the least amount of time, Women in STEM can be completed in a single meeting.

Big Picture Objectives: Cadettes will explore their own perceptions of scientists and successful career pathways of women in STEM.

5.3. Activity #3. ***How Do Atmospheres Change Over Time? The Role of Magnetosphere and Solar Wind***

This small-group activity introduces one of several ways that an atmosphere can lose gases, and links directly to the goals and objectives of the MAVEN mission. Girls observe the properties of magnets and magnetic fields as they build a model of Mars and Earth to demonstrate that Mars cannot effectively protect its atmosphere from the Sun's hot solar wind.

Big Picture Objectives: Using skills they previously learned about with the use of models, Cadettes compare the planetary size and add new information about the magnetic fields of Mars and Earth to ask questions about the force of the solar wind to change a planet's atmosphere over time.

5.4. Activity #4. ***Evidence for Atmosphere on Mars Over Time: Water Surface Features***

Spacecraft images from several regions of Mars show evidence of ancient water flows. This small-group activity directs girls to compare select images of Mars and Earth water erosion surface features and then to construct, test, and observe a model of flowing water for similar erosion patterns. Evidence for once-flowing water on ancient Mars means that Mars also had a thicker atmosphere and a warmer climate reminiscent of Earth's, providing evidence for a change in Mars' atmosphere over a very long period of time. What happened to Mars' atmosphere? The MAVEN Mission is looking for some of the answers.

Big Picture Objectives: Science is about asking questions, collecting data and using evidence to answer questions. Cadettes will rely on laboratory experiments and modeling to better understand and test their ideas about whether ancient Mars had flowing water and an atmosphere.

5.5. Activity #5. ***How Do Atmospheres Change Over Time? The Greenhouse Effect***

This small-group activity demonstrates how the atmospheric temperature increases with the build-up of one greenhouse gas and directly links to Activity #6 Steps Along the Journey: Global Warming. Cadettes construct a physical model of the atmosphere using familiar materials. They discover that when exposed to infrared light, heat builds up more in a closed than in an open container containing moist soil. The information gathered from this experiment is concretely linked to global warming in the final activity. Global warming is the rise in the average temperature of Earth's atmosphere and oceans over time.

Big Picture Objectives: Cadettes construct models to test ideas about processes that cannot be directly studied on Earth or Mars. Cadettes use skills they have learned about atmospheric composition and apply that knowledge to new situations.

5.6. Activity #6. ***Summative Activity — Steps Along the Journey: Global Warming***

This activity focuses on atmospheric change over time, linking the scientific understanding of forces that lead

to change and the evidence supporting such changes that have occurred in the Earth's atmosphere due to the introduction of greenhouse gases, with a focus on carbon dioxide rather than water vapor.

Completion of this activity meets some of the steps along the leadership journey of *Breathe. It's Your Planet — Love It!*, "How to Guide Girl Scout Cadettes on *Breathe: It's Your Planet — Love It!* A Leadership Journey": http://tinyurl.com/oznhwyh

Big Picture Objectives: Cadettes use skills they have learned and apply them to new situations. Cadettes decide what topic(s) they want to explore and how they want to go about doing them.