SCIENCE BACKGROUND KNOWLEDGE

Planetary Science and the Study of Mars

If youth completed the Engineering Everywhere unit, Worlds Apart: Engineering Remote Sensing Devices, they learned about three types of remote sensing technologies: telescopes, filters, and LiDAR. The PLANETS Science Series Activities explore similar instruments that help scientists learn more about the minerals and topography of Mars so they can choose a landing site. In these activities, youth learn more about remote sensing tools and techniques that planetary scientists use to understand habitable environments on Mars, and how the planet has changed over geologic time.

Planetary scientists try to answer big questions such as the following:

- How have the planets in our solar system changed over time?
- Did life evolve only on Earth, or is there evidence that life evolved on other planets, too?

This unit focuses on the exploration of Mars. Scientific evidence indicates that Mars may have once had a more Earth-like climate, but now it is a dry and cold desert. Scientists want to know how the climate on Mars changed and whether life could have evolved there. Mars is also closer to Earth than many other planets, making it easier to send future missions there.

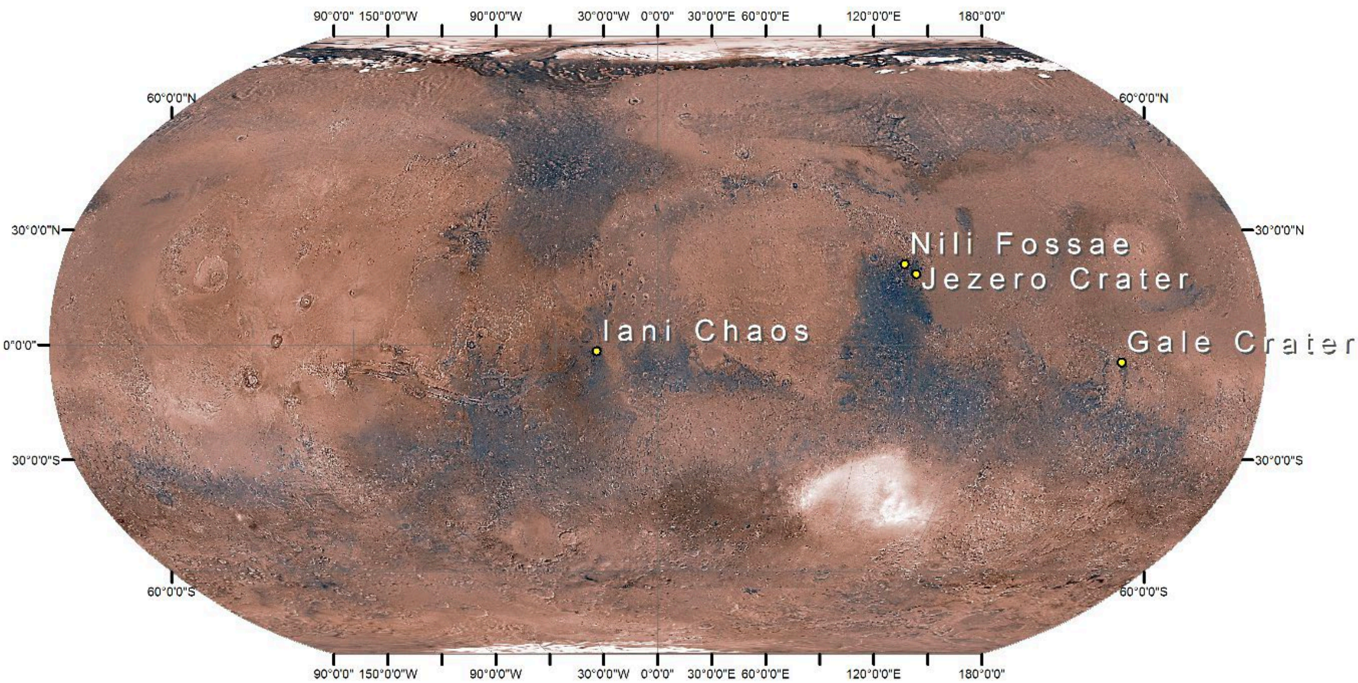
One reason to land on Mars is to collect samples that can be returned to Earth for detailed analysis in a laboratory. For example, volcanic rocks contain minerals that can be analyzed to find out how old the rock is, allowing scientists to get a much better understanding of how Mars changed over time. Some types of sedimentary rocks may contain organic (carbon-based) materials that give clues to whether life could ever have evolved on Mars. Even without returning samples to Earth, landing robotic rovers on Mars allows scientists to explore new areas and understand the processes that shaped the surface of the planet. Some of the most scientifically interesting locations to visit are places like impact crater walls or canyons where different rock layers are exposed in the walls. Layers of rocks are like the pages in a book that tell the story of the geologic history of an area.

But steep canyons and crater walls are dangerous places to try to land a spacecraft. There is a tradeoff between sites of interest to scientists and sites that are safe to land on. The ideal site has a broad, flat area to land on, as well as interesting minerals and landforms nearby, so scientists can learn more about the planet's past. In the following activities, youth will learn how they can use remote sensing to identify such a site.

Landing Sites on Mars

To help youth work through the activities, it is helpful for educators to have some background knowledge about each of the locations that youth will be studying. All of the following locations are actual Mars rover landing sites or have been considered as landing site candidates.

Note: These descriptions are intended for educators, and include the "answers" for each of the sites. Youth-oriented descriptions of the sites are included in the activities.



Global map of Mars using Viking color data.
The four sites used in these activities are indicated.

Site 1: Gale Crater

The Mars Science Laboratory rover Curiosity landed in Gale Crater in 2012 and continues to explore. Gale is a large impact crater. This site is interesting because the middle of the crater contains a mountain that is 3.4 miles (5.5 km) tall and is made of layered sedimentary rocks. The layered rocks have spectral signatures of clay minerals and sulfates, indicating multiple different environments involving water. The crater floor is also made of layers of sediment washed down from the crater rim. The floor is flat and safe for landing. Near the base of the mountain there are black sand dunes containing olivine and pyroxene.

In the HiRISE insets provided to the youth, location A shows layered rocks and a channel carved into the rocks by water and filled with sediment. Location B shows the black sand dunes.

Site 2: Jezero Crater (Yez-er-oh or Jez-er-oh)

NASA chose the Jezero Crater as the landing site for the Perseverance rover which landed in February of 2021. It is a large impact crater. It is interesting because the northwestern rim of the crater is breached by an ancient river channel which ends in a fan-shaped deposit of layered sedimentary rocks (possibly an ancient river delta). River deltas form when flowing water carrying sediment empties into a standing body of water like a lake. The Jezero delta contains clay minerals, and some of the crater floor deposits contain carbonate minerals. Much of the crater floor is covered by an old lava flow, which forms a flat surface with many small impact craters.

In the HiRISE insets provided to the youth, location A shows complex layers deposited in the delta. Location B shows the edge of the heavily cratered lava flow unit, with many small dunes at its base.

Site 3: Nili Fossae Trough (Nee-lee Foss-eye)

The Nili Fossae Trough was originally considered as a landing site in the Mars 2020 mission. However, Jezero Crater was selected as the landing site for Perseverance rover. Nili Fossae is located in a large, long valley, called a graben, or trough. The floor of the valley contains a lava flow and some clay minerals. The eroding walls also expose clay minerals, possibly formed by circulating hot water. Olivine (a mineral that comes from volcanoes) is also exposed in the walls. The higher ground outside the valley is very rugged and resistant to erosion because of a lava flow.

In the HiRISE insets provided to the youth, location A shows some large sand dunes.
Location B shows the edge of the cratered lava flow unit.

Site 4: Iani Chaos (ee-Ah-nee Kay-oss)

This area is one of several “chaos” terrains on Mars, which are areas where a huge amount of underground water was released, resulting in giant floods and the collapse of the area where the water was stored. Within Iani Chaos, there are layered deposits of sulfate minerals. The location in the Student Data Packets was chosen as an example of a scientifically interesting location that would not make a good landing site because it is too rough and not safe to land there.

In the HiRISE insets provided to the youth, location A shows an outcrop of sulfate-bearing fractured rock. In the CTX data, layers can be seen in the rocks at this site, but at this higher resolution we can see that there aren’t obvious finer-scale layers. Location B shows the edge of a cratered lava flow unit, partially covered by small dunes.

Types of Remote Sensing Data

The chart below is intended for the educator’s background knowledge, but youth may also benefit from summarizing the data types in this way.

Data Type	What the Data Tell Us	Nasa Remote Sensing Tools
Visible Images	what the planet’s surface would look like to our eyes	• Viking—Low spatial resolution color • Context Camera (CTX)—High spatial resolution black and white • HiRISE—Extremely high spatial resolution black and white
Topographic Maps	how high or low the surface of the planet is	Mars Orbital Laser Altimeter (MOLA)
Spectroscopic Data	what minerals are present, which can tell us about the planet like in the past	Compact Reconnaissance Imaging Spectrometer for Mars (CRISM)

The Data Packets contain remote sensing data for the different Martian sites described above. Each data type provides a different “piece of the puzzle” when using them to answer questions about Mars’ geologic history. Youth will study the data types to become familiar with the concepts, and then use them all together to choose a landing site for a sample return mission.

Visible Light

Images collected using visible light can be displayed as either black-and-white images or color images that show what the surface would look like to a human observer. For example, the reddish colors are the actual colors of Martian rocks. In the 1970s, the Viking orbiter acquired visible-light images covering the entire planet. These images are useful to get an overview of large areas and for comparison to more recent remote sensing data.

Because Viking was a 1970's era spacecraft, the images are not as high in quality as images from modern spacecraft. Visible-light images covering the entire planet have also been acquired with the Context Camera (CTX) onboard a satellite called the Mars Reconnaissance Orbiter, which started orbiting Mars in 2006. This camera acquires only black-and-white images, but they are better quality images, with more details about surface features, than older Viking images.

The Student Data Packets include annotated versions of the CTX images, with key geologic features labeled. A small portion of the surface of Mars has been observed at extremely high resolution using the High-Resolution Imaging Science Experiment (HiRISE). This camera also acquires mostly black-and-white images, but they have a resolution of 25 cm per pixel, as compared to 6 meters per pixel with CTX.

Laser Light (LiDAR)

Laser light can be bounced off an object and used to determine how far away it is (because we know how fast light travels). This is called Light Detection and Ranging (LiDAR) technology. If you are flying over a planet's surface with a LiDAR instrument, you can bounce laser light off its surface and determine the elevation and the shapes of objects on the surface, which are called landforms. A map that shows the elevations in an area is called a topographic map. The Mars Orbiter Laser Altimeter (MOLA) is a LiDAR instrument that was on the Mars Global Surveyor (MGS) satellite, which operated in orbit around Mars from 1997 to 2007. MOLA mapped the topography of the entire planet.

In the Student Data Packet, MOLA topographic maps are shown for each of the potential landing sites. The colors on the MOLA maps correspond to different elevations, and contour trace lines of equal elevation. Areas in the images that have the same color and widely spaced contour lines are at the same elevation. Areas where the color changes and the contour lines are close together are steep slopes.

Infrared Light

The Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) is an instrument that can acquire images in the visible and infrared parts of the electromagnetic spectrum. By taking hundreds of images of the same location at different wavelengths of light and stacking them, this instrument creates a data set in which each pixel contains a spectrum that provides clues about what minerals are located there. This data can be used to make maps that show the location of volcanic minerals and water-related minerals that indicate the past presence of liquid water, hot springs, or lakes on the surface of Mars.

In the Science Activity 3 Data Packet, the patterned areas on the mineral maps correspond to locations where specific minerals are detected with the CRISM instrument. For each pattern, there is a graph of the laboratory spectrum of the important mineral. Youth can compare these spectra to those on the Mineral Fingerprints Handout to identify the minerals.