Mars Landing Site Selection Activity

by David V. Black

This is an introductory lesson on Mars exploration and Mars geology and geography. Teams of students use maps of Mars and Google Earth's Mars resources to select potential sites for furture Mars landers and rovers, then defend their choices.

Overview:

Each time a lander or rover is sent to Mars, a landing site has to be selected that meets the criteria or objectives of the mission. When the Viking I and II landers were sent to Mars in 1976, their landing sites were selected primarily for their safety – a nice, flat surface without obstacles that might endanger the landers. Since this was the United States' first attempt to land on the surface of Mars, and since previous Soviet attempts had failed, the mission planners at NASA considered safety to be the highest priority and science second. Viking I landed on the flat outwash plain of Kasei Valles, in Chryse Planitia. Viking II waited in orbit until Viking I was safely down before it landed in the even flatter Utopia Planitia.

For the Pathfinder mission, safety was still important but science took top priority since the landing system of airbags was less prone to failure in case of landing on an uneven surface. The outwash plain of Ares Valles was selected, and the scenery was a bit more interesting. Pathfinder showed that rocks of various origins had all been deposited in the landing site by running water.

Spirit and Opportunity landed in safe territory but within a short drive from interesting features. Each of the landing sites was carefully evaluated from a long list to pick the one that had the maximum potential of reaching the rovers' mission of "following the water." Opportunity landed in a small crater and immediately proved running water had existed there from the thin layers of sedimentary rock exposed in the crater wall and from the small "blueberries" of hematite everywhere that could only have formed in liquid water. Spirit landed in Gusev Crater, with its river valleys and delta from Ma'adim Vallis. Despite landing in an area that seemed to have been a lake, all it found at first were basalts, until it climbed into the Husband Hills and found sulfates and other evidences of water deposits.

None of these scientific discoveies could have been made without careful selection of the landing sites. Now the Mars Science Laboratory, Curiosity, is going to land on Mars in 2012. The Mars Landing Site Selection Committee has been meeting regularly to hear the recommendations of Mars scientists. Given the suite of instruments and the capabilities of the rover, mission planners have decided to move beyond merely following the water and to now look for the chemicals and rock types that could give rise to life, such as carbonates, phosphates, sulfates, and clays. From a field of hundreds of attractive sites, four top candidates have been chosen where water probably existed long enough for such deposits to form.

At the same time, all missions have their constraints. Spirit and Opportunity depended on solar power to provide electricity and heat, and so they could not land beyond ten degrees north or south of the equator. Curiosity will use a Radioisotope Thermoelectric Generator (RTG) – a kind of nuclear battery – to produce power and will not be dependent on the sun. It can land anywhere between 60 degrees north and south of the equator. All three missions need sufficient atmosphere to slow down the descent, so they must land at elevations lower than two kilometers above the Martian mean level. That eliminates any landings on the Tharsis Plateau or other high plateaus on Mars.

For each mission a landing ellipse is designed depending on the speed and angle with which the lander will enter Mars' atmosphere. For Curiosity, the ellipse is 20 km wide and 25 kilometers long, much smaller than previous landings. Because of this pinpoint landing accuracy, we can visit areas that are potentially more dangerous (and interesting) but still have an acceptable margin for safety. Overall, over 50 potential landing sites have been analyzed and discussed at a series of landing site selection workshops, where members of the engineering and scientific teams have voted on the best candidate sites (http://marsoweb.nas.nasa.gov/landingsites). That list was narrowed down to four sites in early 2009, with final site selection scheduled for early 2011 (more on which ones made the cut at the end of the activity).

The purpose of this activity is for student teams to analyze maps of Mars from online sources and pick a potential landing site for Curiosity based on the criteria discussed above. They will then use Google Mars to investigate their site thoroughly and write a proposal why this is a good site from science, scenery, variety, and safety perspectives. They will present this proposal to their peers in class.

The hidden objective is for the students to become familiar with Mars' terrains, features, and geography as they analyze and investigate the surface for possible landing sites. They will also learn to use Google Earth's Mars data and other online Mars resources.

Teacher Instructions

Objectives:

By the end of this activity, students will be able to:
1. Identify the names and locations (including latitude and longitude) of prominent features on Mars,
2. Select areas on Mars that show the past effects of water erosion and sediment deposition,
3. Evaluate possible landing sites using the constraints and objectives of the Mars Science Laboratory.

National Science Standards:

This lesson is appropriate for Earth Science, Geology, or Astronomy classes. It fits into the following national science standards:

Abilities Necessary to do Scientific Inquiry (f): Communicate and defend a scientific argument.

Geochemical Cycles (b): Movement and changes of matter in geochemical systems.

Abilities of Technological Design (a): Identify a problem or design an opportunity, and (b) Propose designs and choose between alternative solutions.

Materials:

Each group of students will need a printed or online version (with labeled place names and latitude and longitude markings) of the surface of Mars, preferably showing both true color and Mars MOLA altitude data. They will also need a computer with Google Earth installed and Internet access.

Preparation:

Write on the board or print out as a handout:

Mars Science Laboratory Landing Site Criteria:

1. Between 60° North and South of the equator.
2. Lower than +2 km altitude (so parachutes can deploy).
3. Mostly flat landing zone 25 km by 25 km without large rocks or deep canyons.
4. Near interesting geological features that show a wide variety of rock types and terrains.
5. Near areas that show evidence of standing water and sedimentary layers that could be associated with life (such as salts, phosphates, sulfates, carbonates, and phyllosilicates [clays]). These could include lakebeds or long-standing, well-developed river systems.
6. Room enough to explore for over 20 km beyond the landing zone.

More information: http://marsoweb.nas.nasa.gov/landingsites

And at: http://webgis.wr.usgs.gov/msl

You can also write examples of Mars geographical terms (such as mensa and chasma) and their definitions, and show the following links where they can find Mars maps:

http://pubs.usgs.gov/imap/i2782/ (Mars MOLA map with labels in PDF format)

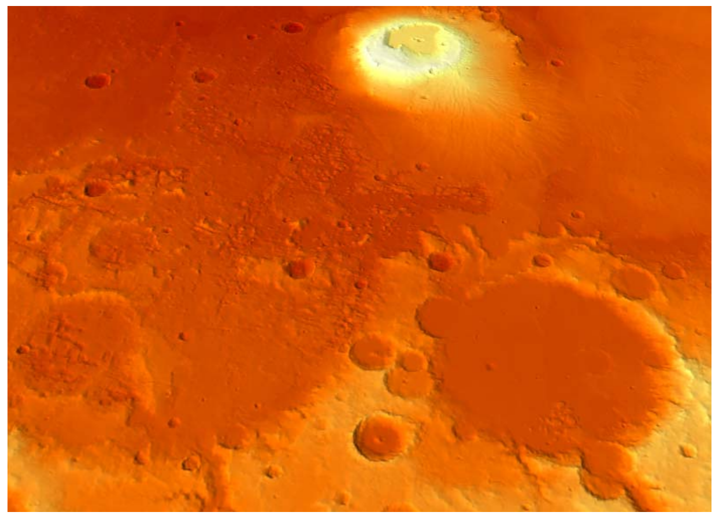
http://www.solarviews.com/cap/mgs/mgstopo7.htm (can download an 11 MB TIFF image)

http://jmars.mars.asu.edu/maps (detailed interactive map at ASU based on Mars 2001 Odyssey THEMIS images)

http://marsoweb.nas.nasa.gov/globalData/ (Zoomable interactive map and image downloads)

http://www.msss.com/mars_images/moc/moc_atlas/ (Uses MOC data from the Mars Global Surveyor probe)

http://crism-map.jhuapl.edu/ (Zooms into detailed map to locate CRISM images from Mars Reconnaissance Orbiter)



Procedure:

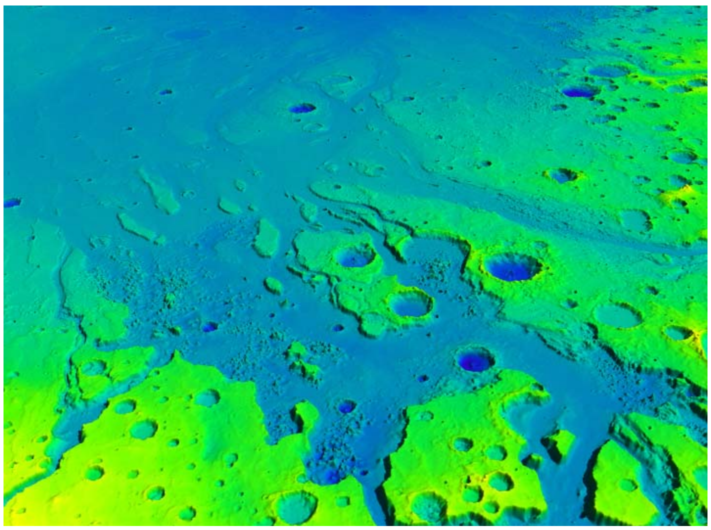
Divide the students into teams of four and assign them the following roles:
1. Entry, Descent, and Landing Lead (EDL)
2. Principle Investigator/Science Team Lead (PI)
3. Power, Mobility, and Communications Subsystems Lead (PMC)
4. Project Manager (PM)

The EDL student is in charge of the safe landing of the space craft, from entry into Mars' atmosphere through descent and finally landing. Although this phase only takes six minutes (of terror), it is the most critical phase of the mission and the most prone to errors. This person will argue for the safest place possible to land, without steep slopes, high altitude, or two many rocks or craters.

The PI is in charge of the science instruments and for selecting a landing site that has good scientific value, based on the objectives of the mission. For Curiosity, those objectives are to go beyond "following the water" to look at the deposits that were left by the water to check for signs of the elements found in living organisms on Earth, which we think would also be in life elsewhere. In addition, the rover needs to be near the largest variety of geological features and rock layers possible to maximize the science return.

The PMC is in charge of the continuing health of the rover once it lands. This student would make certain the restraints of the mission are met in terms of distance from the equator, the overall smoothness of the terrain and its suitability for roving around the surface. Landing on a mesa, for example, wouldn't be good for extended mobility. This person plans the routes that the rover will follow. This person is also in charge of ensuring that the rover can stay in communication with Earth so that data can be relayed both directions.

The Project Manager is the final boss of the mission and makes the final decision on which site to land at, based on input from the other three. All of the objectives and constraints must be met in the final choice. The PM also represents the group as its spokesperson.



Once the teams are set up and assigned and the members know their responsibilities, have the students visit the websites listed above and analyze the maps of Mars to find suitable locations, where water has existed for some time, and where there is a smooth area about 25 km by 20 km to land in. They can use Google Earth to look at the location and see if there are any images or other data on the site acquired by the Mars Global Surveyor, the Mars 2001 Odyssey, or the Mars Reconnaissance Orbiter. These can be found partially in Google Earth, but also can be looked up online at NASA's Planetary Photojournal site:
http://photojournal.jpl.nasa.gov/

Once the teams have selected a site and have researched its features, the team will prepare a quick outline detailing the latitude and longitude of the site, why they have chosen it, how it fulfills the mission objectives while keeping the rover reasonably safe for landing and continued operations, and the locations around the landing zone that offer especially good scientific targets (with their latitudes and longitudes) and the paths the rover will take to reach those locations. Once the proposals are ready, have the team Project Managers take turns presenting their sites and their rationale and what places they plan to visit and why.

Once the Project Managers are done, have a panel of three students that have been reserved as the final judges discuss the sites presented, then make the final decision. This panel represents the final Mars Site Selection Committee, headed by Matt Golombek, as well as the NASA leadership who make the final choices.

Once this is all done, show them the sites that have actually been selected (as of January, 2011) as the final four candidates: Holden Crater, Eberswalde Crater, Gale Crater, and Mawrth Vallis. They can visit the actual websites of the selection committee and science community and follow along as the final site is chosen later this year, prior to the launch in November. The websites are:

http://msl.gps.caltech.edu/MSL%20Targets/Welcome.html

http://marsoweb.nas.nasa.gov/landingsites/index.html

Based on what the students can observe about Mars' geological processes, they should be able to choose some outstanding sites, perhaps even as good as the scientific community can do. An interesting follow up would be to contact a Mars scientist, perhaps Matt Golombek himself, and propose the site for either Curiosity or future missions. With Mars at our fingertips now, students can be part of the process just as my students were part of the Mars Exploration Student Data Team program in 2003-2004.