This assignment builds off of materials developed by Dr. Tracy Gregg.

PLANETARY GEOLOGY, Fall 2003

Geology 20B, Grosfils

LAB 10: Comparative Planetology—Selecting a Mars Landing Site

In this tenth lab you will explore first hand what sorts of processes occur when scientists and engineers try to identify a landing site for a mission to Mars. This will mimic the process used to select the coming MER rover landing sites, and what will be used for future missions

1. Briefly become a planetary geologist, engineer or astrobiologist (should have done this on Halloween!)
2. From the point of view you feel is appropriate for your new position, and using the same constraints employed by the scientific teams preparing for forthcoming Mars missions, you will identify your top list of candidate landing sites and submit a short report describing them to me **by Friday's class period**.
3. On Friday in class, all three groups of experts will work together to narrow down the site selection to a top candidate. Where would you send the next lander if the choice was up to you?

If at any point you have questions, don't hesitate to ask!

1. Pick Your Perspective (Job)

At the start of the lab period we will pick a set of **six** planetary geologists, **five** astrobiologists and **five** engineers. This will be done randomly, and each group will work on its own (i.e., out of earshot from the remaining groups) for the remainder of the lab period. Each group is charged with using its own constraints and interests to select what it considers to be the top five (six for the geologists) landing site candidates for the next Mars mission.

2. Available Resources

At the front of the classroom I will have a suite of different Mars materials, including maps, books with Mars-related data in them, etc. Use (and share) these freely during the course of the lab, but at the end of the lab period please make sure that all the materials are placed neatly at the front of the room again, and that each map has been carefully folded and returned to the proper envelope.

In addition to the materials provided in "hard copy" there are a wide variety of web sites which may prove useful, but I'd like you to restrict yourselves to the sites below unless further instructions are explicitly provided for your group. ***Please note*** *– web pages with current landing site selection choices exist, but you are forbidden to use these until after Friday when we wrap up the exercise… it'll be a lot more fun to make the decisions yourselves, and besides, who's to say that their choices are good ones!*

- HIGH RESOLUTION MARS GLOBAL SURVEYOR IMAGES
    - Web page: http://www.msss.com/mars_images/index.html
    - This site will allow you to access over 134,000 Mars images, "image of the day" archives, as well as selected images organized by target type. If you want the raw Mars images, select which date range you wish to examine (up to February 2003), and you will see a global map of Mars. Click on the map location in which you're interested and it will be shown at

higher resolution, covered with lots of little blue rectangles. Clicking on a rectangle will bring up a copy of the high resolution image covering this area, and the list of data below the images will tell you the resolution of the image, etc.

- LOWER RESOLUTION VIKING IMAGES
    - Web page: http://pdsmaps.wr.usgs.gov/
    - This site will allow you to examine Viking resolution coverage of any map area you designate; it is the same tool you used for the seismic station placement lab, but if you have questions about how to use it be sure to ask!
- PRESS RELEASE IMAGES
    - Web Page: http://photojournal.jpl.nasa.gov/
    - Select Mars, then on the new page which pops up indicate the mission from which you wish to review the public release images. These are organized sequentially, and there is no fast way to access them except for paging through.
- GENERAL MARS EXPLORATION STRATEGY INFORMATION
    - Web Page: http://mars.jpl.nasa.gov/
    - This is the front page of the Mars exploration web page. It'll lead you all sorts of places eventually, but to stick to the spirit of this exercise please restrict yourselves to the pages directly accessible from the main menu bar at the top ("Overview," etc.). If you have an additional page you'd like to access, please check with me first.

3. Procedure During the Lab Period

Recalling that I'd like to have essentially zero interaction between the three groups for the duration of the lab period, you have a choice to make. Either you need to decide how to divvy up the time spent in the computer lab by group (i.e., each group gets to be in the lab for a specific period of time that everyone agrees to), or you need to agree that while multiple people can work in the lab, discussion must be quiet, and probably no more than two representatives of a given group should be in the lab at a given time. Your call – but we'll decide this before proceeding.

On Friday before class each **group** will submit a typewritten report, either in hard copy or by email. This is what will be graded for Lab 10, so it is important to do a good job! See below for more details.

4. Lab Assignment (to be completed by Friday's class period) 80 points out of 100

By the start of class on Friday each group should submit a typed report which contains your top five (six for the geologists) landing sites. The report should begin with an overview of the constraints you employed, and for each specific site you should provide the following information:

The site location – provide latitude and longitude for the center of the landing ellipse, and a Viking (or other) image showing the region, with the landing ellipse **axes** drawn on at the correct scale and approximate orientation. The landing site is defined as a "landing ellipse" 100 km x 20 km, with its long axis oriented at N80°E degrees.

Your detailed justification for selecting this site – provide any ancillary documentation you feel is necessary, and be sure to indicate why, with all of Mars to choose from, this site made it onto your top two list. As part of this explanation, please indicate how well the site meets the job-specific criteria with which you were presented at the start of the lab – these are “rules” and as such should be taken seriously, but with sufficient justification they can perhaps be bent a little.

Each person in the group should write up one of the landing site choices, and there should be no overlap within the group. Each person will be graded solely on the basis of what they have written, so this part must be an individual effort and it is important that the group members work together to ensure that each person has a site to write up with which they are comfortable. This should be easy if everyone participates actively in the group discussion and selection process, but if there are any questions or concerns please let me know! Make sure that your name is at the top of what you write, and as a general guideline I’m expecting your write up (not including figures) will be on the order of 2 pages or so, carefully organized and written properly, i.e. adhering to proper grammatical and spelling rules with writing and flow that is clear, direct and concise – I’ll be grading these aspects of the report as well as its technical components!

5. Landing Site Selection — 20 points out of 100

At the start of class each group will select one person, who will change roles for the class period to become a NASA program officer. As in the real NASA, the program officers associated with mission selection bring a wide variety of backgrounds to the job. They are no longer dedicated solely to their previous role but are instead charged with facilitating discussion amongst the various parties which will allow selection of the most suitable landing site to occur. Ideally, they will promote discussion which is lively, open, balanced and which leads to a consensus among the groups, but in the absence of a consensus they will also be responsible in the final few minutes of the class period for selecting a single site to recommend to **the** NASA Administrator. Each group should thus choose the person they wish to release with care.

The remaining members from all three groups will form an advisory panel charged with helping the program officers identify a landing site which is safe and yet which holds great promise as a location for scientific exploration. This panel is “headed” by the three program officers, and they are responsible for running the discussion.

Collectively, your job during class is to hold a productive discussion which cleanly and analytically narrows NASA’s choice for a landing site down to one, possibly with a runner up. The class as a whole will receive a single grade for this discussion, which will be awarded on the basis of criteria such as:

- Did you use the information at your disposal properly, effectively, and convincingly?
- Did you all work together to resolve any conflicts of criteria which occur?
- Did you argue your position effectively yet keep an open mind?
- Did you come up with a well supported argument as a group for the final landing site you selected?
- Did everyone participate and contribute in a meaningful fashion?

Have fun, and good luck!!

Engineering Constraints

Of all the groups, your constraints are the most "straightforward." The landing ellipse defined accounts for possible error in our navigation. You may want to cut out a piece of paper with roughly those dimensions to help you when you're looking over the various maps.

The engineering constraints upon landing site selection can be found in some detail at the following web site (***http://mars.jpl.nasa.gov/2001/landingsite/EngConstr.html***) and a summary is provided below. The various datasets available for your use can be found online at

http://mars.jpl.nasa.gov/2001/landingsite/Data.html**.**

Please note: on this web page, you should not use the Landing Site link at the top of the page.

SUMMARY OF ENGINEERING CRITERIA

- It must be located between 3°N and 12°S.
    - This gives the rover the greatest amount of solar energy (the rover is driven by solar power) during the day.

- It must be located in a region that is below 2.5 km "mean planetary radius", or MRP. (There is no "sea level" on Mars, so we use MRP instead.)
    - This is a requirement for the lander, which is designed to slow its descent using a parachute. If there isn't enough atmosphere, the parachute won't do any good.

- Surface slopes must be <10°.
    - Shallow slopes minimize the danger of mass wasting (landslides burying the rover) and of the rover getting caught in a big shadow and losing its solar power. Furthermore, the rover itself can't function on slopes >16°.

- The total rock abundance must be 5 - 10%.
    - The lander's legs are only 31 cm high, so we need to send it to a place where the chances of it crash-landing on a big rock are minimal. But we want to make sure there's more than just dust—we don't want the lander ending up being swallowed because it touched down on a surface that is nothing but meters and meters of dust.

- The site must appear "hazard free" on all available Viking Orbiter (VO) and Mars Orbiter Camera (MOC) images. Hazards would be things like deep, small canyons, boulder fields, or lots of small, deep impact craters.
    - This cannot be effectively assessed without appropriate image coverage. Therefore, the landing site must be covered by VO images that have resolutions of 50 meters per pixel or better. In addition, there must be one high-resolution MOC image within the landing ellipse. If 50 m/pixel VO images are not available, the site can still be considered IF:
        - there is 100 m/pixel VO coverage AND
        - there is at least 1 MOC image with 6 m/pixel resolution and another at 1.5 m/pixel within the landing ellipse or nearby on identical terrain.

Astrobiology Constraints

The astrobiology community wants to find either evidence of past life (that is, fossils) or extant (living) life on Mars, or demonstrate conclusively that life does not and has not existed there. Where you go to look for life depends on your hypotheses of how it evolves. So let's consider some possibilities. They are listed below in order of presumed importance.

WATER

- Most astrobiologists agree that water (preferably in liquid form) is required for the origination of life (although not necessarily for its continuance once it has already appeared). There is nowhere on Mars today that liquid water is stable on the surface. However, evidence of liquid water on the surface in the past includes dried-up river channels, smooth, flat-floored craters, layered sediments and river deltas. It's generally believed that Valles Marinaris was once filled with water. The book "Water on Mars" by Carr contains maps of channels and the like on Mars if you want to figure out quickly where they are located.
- There is no unequivocal evidence for liquid water on Mars today: the atmospheric temperatures and pressures mean that liquid water would be unstable on the surface. If it appeared, it would (in theory) immediately freeze and then sublime (like dry ice does here on Earth). However, recent images taken by the Mars Obiter Camera (MOC) show very small, fresh gullies on the walls of some craters. See http://www.msss.com/mars_images/moc/june2000/ for some examples and discussion, and be sure to check the Planetary Photojournal for additional examples. Some scientists believe that these little gullies may be the work of liquid water, and therefore would be a great place to go and look for life on Mars. Other scientists believe that these gullies may be the result of brines (water that is really, really salty—100 times saltier than ocean water) or of some sort of CO_2 "flow".
- Places where water could collect (impact craters or other closed basins) which also contain evidence for layered sediments (such as are found in lake deposits – though of course other processes can generate layered sediment) and/or water (inlet channels, etc.) might be good places to consider too.

HEAT

- From what we think we know about the origin of life on Earth, heat is the other likely requirement for life to be created. All of the molecular compounds that are required for life may be present on Mars, but some additional energy is thought to be necessary to bring these compounds to the next, much more complicated, step. Thermal energy (heat) is a likely candidate. On Earth, the most ancient type of life was thermophilic (heat-loving). We think those old life forms loved temperatures that would kill most familiar life forms today. Relatives of these old bacteria are found today living in hot springs associated with volcanoes, and at mid-ocean ridges.
- At mid-ocean ridges on Earth, there is a LOT of water available (the whole darn ocean!) and a LOT of heat in the form of magma below the surface. This combination is thought to be particularly favorable for the origin of life. So, one of the more favorable places to look for life on Mars would be to find a volcano that shows evidence of nearby water, and one that's been active for a long time to supply heat over a long period of time. Obvious evidence for water would be channels. Less obvious evidence might be pyroclastic deposits. In other words, an explosive volcano (rather than one that produces quiet lava flows) may have been explosive because it either contained a lot of water dissolved in the magma, or because the magma ran into a lot of water in the ground.

AGE

- The oldest fossils we have on Earth are 3.9 billion years old. By that time, life was already pretty well established. Chemical evidence suggests that life may have originated around 4.2 billion years ago. We believe that if life originated on Mars, it may also have appeared early on.
- The Viking Landers and Sojourner (Pathfinder) were equipped to search for evidence of life on Mars. The Viking Lander data suggest that no life exists at the landing site surface currently, although some bizarre chemistry was encountered; Sojourner didn't find anything either.
- It may be that life appeared on Mars, but then became extinct. Or that it only appeared in a very few, hard-to-reach places and never became ubiquitous as it has on Earth. Perhaps by looking in some of the oldest rocks on Mars, we can at least find evidence for fossil life, if not anything actually living now. Alternatively, we have learned that microscopic life survives very harsh environments underground; it is estimated that on Earth there is 10x as much biomass beneath the surface as there is above it, which is pretty astonishing. Could it be that recent excavations by craters somehow exposed organism-rich depths even if the modern surface proves to be sterile?

Geologic Constraints

Where you want to send a rover depends on your individual goals as a planetary geologist. If you're interested in volcanism, for example, you may want to push hard for visiting a volcano. If you're more concerned about finding evidence for a past ocean on Mars, however, you might want to look near the North Pole. Please feel free to take on an egotistical persona common among planetary geologists to push for your own individual interests, but remember that you need to contribute to the group as a whole in a productive fashion while doing so.

That said, below are the general points of view for geologists trying to determine where to send the next rover on Mars.

THE "GRAB-BAG" SITE.

- The idea here it to go to a spot that has the widest possible diversity of rocks in the smallest area. Even though we wouldn't know where each rock originated, the potential for examining a large diversity of Martian rocks in a small area could reveal a lot about Mars overall. Geologic processes that can concentrate a wide variety of rocks on earth include the formation of river deltas, impact crater formation, and tallus slopes (piles of rubble) that form at the foot of steep cliffs.

"LARGE UNIFORM SITE" (AT VIKING ORBITER RESOLUTION) OF UNKNOWN ROCK TYPE

- The site appears uniform at Viking resolution, but the interpretation of rock type or composition of the unit is uncertain. Landing at the site would allow determination of the rock type that makes up the unit. This could be especially significant if the unit is very old, or heavily channeled, very large, or in some way important/unique for our understanding of Mars evolution.

"LARGE UNIFORM SITE" OF SUSPECTED COMPOSITION

- An example of this would be something that we're pretty darn sure is a lava flow based on VO and/or MOC images. Landing at such a site would confirm the rock type and measure something about it that was important (e.g., iron and magnesium content; potassium and uranium content). This would be important to confirm what we think we know from the VO and MOC images.
    - One of the strongest contenders for a landing site these days is a region known as the "hematite region" (0-3°S, 2-7°W). This is a region identified using the orbiting Thermal Emission Spectrometer (TES) as one which contains an abundance of almost pure hematite (Fe_2O_3). On Earth, this type of hematite can only form in the presence of LOTS of water, so some believe this would be a good location to find old, oceanic sedimentary deposits on Mars.

Working together, the geologists should brainstorm about things they think might prove interesting, discuss the relative scientific merits, and try to pick an array of targets both spatially and topically in case it turns out that there are restrictions imposed by the constrains known at present only to the other groups. Put yourself in their shoes – you know the engineers will be concerned with mission safety and operation, while the astrobiology group's objectives are probably pretty obvious too!