Role of this Document

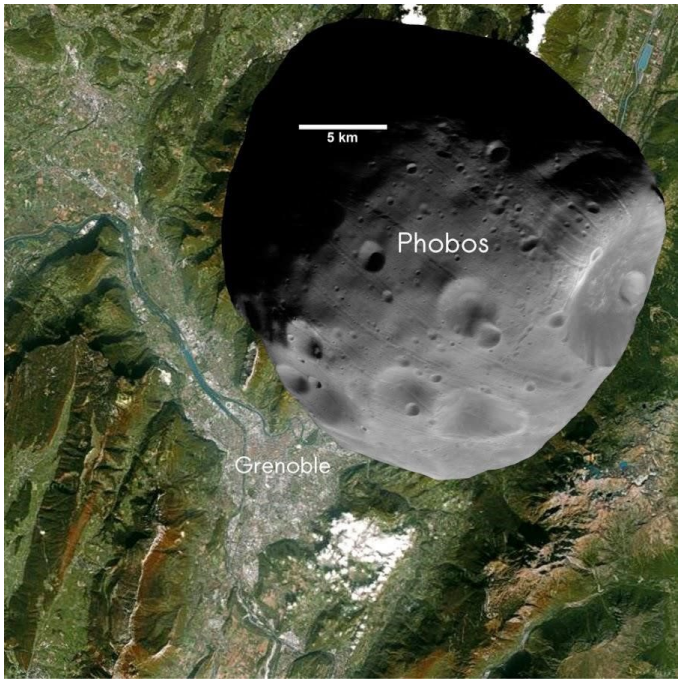
Challenger Center seeks to find the balance between engaging students in simulated learning and scientific accuracy when developing missions. This document serves as an explanation for the scientific reasoning behind the location and function of Mission Control and the Spacecraft in the Expedition Mars mission. It is intended to provide Flight Directors with important background information and help answer questions if they arise.

Mission Control (MC)

Description: Mission Control is located on the moon of Phobos.

Why Phobos?: A sustainable presence on Mars presents many logistical problems. Many proposals over the years, including one endorsed by the Planetary Society, involve using Phobos as a launching off point into the Mars system to mitigate a few of those problems.

Phobos Facts: Phobos orbits Mars at an average of 9376 km from the surface. Its orbit is nearly circular, and its inclination relative to Mars is only about 1 degree. From an orbital mechanics perspective, this makes it a very energy-efficient target to hit from an equatorial Mars Launch. The amount of Δv required to travel from the surface of Mars to the surface of Phobos is only about 5 km/s compared to the 15 km/s of Δv it takes to travel from the Earth's surface to our moon. Landing on Mars requires even less energy due to being able to use the atmosphere for some aerobraking. Phobos is a very small natural satellite compared to its parent body. That being said, it still has as much surface area as a mid-sized city as shown in this image portraying Grenoble, France in comparison to Phobos.



What scientific reason would there be to build a Mission Control on Phobos?
In planning a real Mars Mission, there are several advantages to building a habitat on Phobos. Any long-term Mars settlement would need orbital support in the form of a space station in order to survive. The space station would take on the role of science facility, shipyard, data relay point and observatory. There are several advantages to using Phobos as the location for that space station. They include:

- Its stable orbit. Anything built on Phobos would not suffer from orbital decay, decreasing maintenance costs and failure rates.
- Phobos is tidally locked to Mars. This means that a structure built pointing towards Mars would constantly point towards Mars regardless of where Phobos was in its orbital period.
- Since Phobos has an equatorial orbit, it would be an excellent data exchange point between a satellite in an Aerostationary orbit and Mars.
- Mars has no ionosphere or significant atmosphere to keep people in a space station safe from solar and cosmic radiation. Burying into Phobos would solve the radiation problem without having to reinforce the space station with expensive and heavy materials hauled up from the Martian surface or shuttled from Earth.
- Being able to use the natural structure of Phobos would reduce the amount of materials needed to build a human habitat.
- The road to Mars is a long one. It makes sense that a mission would have been sent to Phobos before a full-scale mission to Mars was launched. A Phobos mission would be much less expensive and complicated. When the Mars mission did finally happen, there would already be supportive infrastructure on Phobos.

Spacecraft (SC)

Description: The spacecraft serves the role of transportation device and mini-science lab. This vessel makes regular trips between the surface of Mars and the surface of Phobos.

SC Facts: The SC can support up to 40 or so crew at a time. When the SC launches from Mars it carries with it about 8km/s of Δv. This is enough energy to get it from the surface of Phobos to the surface of Mars and back to the surface of Phobos again without refueling.

The SC has a reusable, lightweight, and heat-dispersing heatshield with an ablative coating. This ablative coating is reapplied with every Mars descent via a spray device. In comparison to Earth, Mars has a smaller mass and thinner atmosphere. This translates to heatshields undergoing much less stress for a spacecraft entering the atmosphere from Martian orbit as compared to the Earth analog. The less stress a heatshield undergoes, the more it can be reused.

The SC is refueled on the surface of Phobos and, under normal operating conditions, is

expected to be able to perform the Phobos -> Mars -> Phobos transfer once every Martian Sol. However extra refined fuel is always available on the Martian surface in the event of an emergency take-off scenario.

What scientific reason would there be to build a Phobos to Mars shuttle?
There are several advantages to a Mars-Phobos shuttle. For all the reasons stated in the previous section, a center of operations on Phobos would be advantageous. However, that operations center would be limited unless it was easily accessible.

- The SC represents the end goal of ISRU (In Situ Resource Utilization) on Mars. On Mars, CO_2 exists in abundance in the atmosphere. Hydrogen may be found in the soil of Mars or brought there from Earth. Using the Sabatier reaction, CO_2 and hydrogen can be combined with heat to create methane and water. Methane can be used as rocket propellant. The remaining H_2O can be broken down by electrolysis into oxygen and water. The oxygen can be used to create more rocket propellant (liquid oxygen), and the hydrogen can be recycled back into the Sabatier reaction. Through this process, fuel will always be available for the SC.
- Long term exposure to low gravity environments can be hazardous to health. It would make sense to rotate the crew at Mission Control to ensure they had enough surface time in a gravity environment.
- The vehicle that transferred crew from Earth to Mars would never land on either planet. Having a shuttle capable of carrying people from the surface to that orbiting vessel would be essential.
- Having a reusable shuttle capable of getting Mars samples into orbit would be very useful. A more robust sample analysis process will be possible on Earth compared to Mars. Using the SC to transfer materials with something like an Aldrin Cycler would create an excellent pipeline of goods and crew between Mars and Earth.

Labs

Below are explanations for the scientific reasoning behind the various student labs and their real-life counterparts. In Expedition Mars, most teams have a Primary Activity which is the focus of their work during the mission. Those teams that finish early are tasked with completing a less important Secondary Activity that is not critical to the success of the mission. Throughout the document, you will see the labs referred to as such below.

BIO TEAM

Primary Activity, Soil Analysis

Scientific Foundation: The BIO team works with soil from the surface of Mars. The lab they are doing is based on the Viking Gas Exchange (GEX) experiment. In this experiment, a liquid mix of

nutrients was added to Martian soil, and a gas chromatograph is used to look for a variety of gases, including CO_2, nitrogen, hydrogen, methane, and oxygen. The hypothesis was that any organisms on the soil would release at least one of those gasses. Finding one of those gases would indicate the possibility of organic activity.

Student Interpretation: The students apply a liquid (H_2O_2) to the soil and use an oxygen sensor to determine if any oxygen is produced from the soil. The H_2O_2 is combined with Manganese Dioxide (MnO_2) to produce the reaction $MnO_2 + 2\ H_2O_2 \rightarrow 2H_2O + O_2$. The O_2 is released and triggers the oxygen. We tell students that the presence of O_2 from the soil sample indicates the potential for life, or at least the building blocks for life. However, it could also indicate the presence of inorganic compounds.

Secondary Activity, Microbe Scanner:

Scientific Foundation: The BIO team analyzes bacteria in the SC to determine if they are beneficial or harmful. The lab the students are doing is not based on a specific experiment but on the principle that not all bacteria are harmful. For example, acidophilus in the intestines are essential to digestion. In addition, it is speculated that certain bacteria could play a large role in combatting the immunocompromised state people experience during longer bouts of microgravity.

Student Interpretation: Students in the SC collect bacteria samples and send them to MC for analysis. MC uses a virtual microscope to first classify beneficial and harmful bacteria. MC then compares that list they classified with the SC samples. Should any harmful bacteria be found in the SC, MC will guide them to a solution.

BOT TEAM

Primary Activity, BOT Programming

Scientific Foundation: A remotely operated vehicle's ability to perform on Mars is based on how well it is programmed. When an ROV is trying to move from Point A to Point B on a particular route, two major factors need to be considered: the terrain along that route and the limitations of the ROV to move across that terrain. Deciding the route of the ROV is a collaborative effort between experts who study the terrain and experts who understand the limitations of the rover.

Student Interpretation: Students in MC serve as the map experts and dictate the programming path of the rover based on overhead maps, taken from orbiting satellites. Students in the SC have limitations on how much they can program the ROV to do. Only by working together in real-time can they program a path to their destination. Once the program is complete, the SC BOT student will upload their programmed "software" into an ROV module to be placed/utilized by the SC ROV team.

Secondary Activity, Plan Selection

Scientific Foundation: The planning of any scientific mission on Mars is one that involves many decisions. Where should the ROV land? What should it survey? Which experiments should it run? In the real world, universities and corporations submit proposals to have their idea or piece of hardware incorporated into the mission based on the mission's needs. Those in charge of the mission need to weigh the proposals and choose those that fit both with the needs of the mission and the various budgets that support the mission (financial, payload mass, energy, etc.).

Student Interpretation: Students in MC are given a series of plans. These plans propose different requirements for an ROV which uses a robot arm in the field. MC needs to quantify the needs of those proposals. For example, how much mass does the plan require the BOT arm to lift? Meanwhile, SC performs a series of checks on the limits of the robot arm and sends that data to MC. MC compares the limits of the robot arm against the needs of the plans and picks the plan that best fits the capability of the arm.

COM TEAM

Primary Activity, Communication

Scientific Foundation: Communication in any mission is the cornerstone of success. Centralized communication ensures that all aspects of a mission run smoothly.

Student Interpretation: Expedition Mars requires that all teams speak with their counterpart in at least one significant aspect. The COM team makes that communication possible.

ROV TEAM

Primary Activity, ROV Assembly

Scientific Foundation: Problem-solving and communication, combined with engineering, is how different unique problems in the world are solved. ROVs are often used in space exploration to gather important information, particularly in areas where it may not be safe or possible to send humans.

Student Interpretation: Expedition Mars requires that, in both arcs, the ROV team must build and design their unique ROV. Students communicate between the MC and SC using a headset to test, problem-solve, and successfully build the ROV to deploy on Mars.

GEO TEAM

Primary Activity, RAT

Scientific Foundation: The current surface of Mars is nearly geologically inert. Without tectonic plates shifting, the rocks and dirt of the surface remain unchanged. That unchanging surface geology has been exposed to solar and cosmic radiation for millions of years and is not necessarily representative of Martian Geology. By digging under the surface, a representation of Mars's past can be revealed. Recently, both the Perseverance and Curiosity landers have dug under the surface of Mars to investigate soil and bedrock in hopes of discovering evidence for signs of water, life, or leads to new questions.

Student Interpretation: Students in the SC are given a series of surface samples which include both topsoil and bedrock. By using a robot arm, they can clear away the topsoil and expose the bedrock. They will examine the bedrock and determine certain features of the rocks. What color are they? Are they porous? Do they have veins? SC will send this information to MC, who will analyze those rocks and determine what they are. MC will determine if they were formed in water or not.

Secondary Activity, Rock Identification

Scientific Foundation: Martian science has almost become synonymous with the phrase "Follow the Water." Life as we know it depends on the presence of water, so following its path may be the best way to find evidence for life. Geologically, this means searching for minerals or rock features formed through sedimentary means or in the presence of water.

Student Interpretation: Students in the SC are given a series of minerals. Using a series of identification techniques, they will determine what the mineral is and where it came from.

LS TEAM

Primary Activity, Systems Checks

Scientific Foundation: Any closed-loop environment relies on keeping a consistent pressure and temperature to ensure human survival. On the International Space Station (ISS), systems are constantly monitored by ground and crew and repaired frequently.

Student Interpretation: Students are tasked in the SC with monitoring systems and sending that data to MC. MC will analyze the conditions of the systems and send instructions on how to deal with any issues they identify.

MED TEAM

Primary Activity, Wellness Checks

Scientific Foundation: Research from previous space exploration has shown that the human body can change and experience negative reactions when leaving the Earth's atmosphere. Common issues can include vitamin deficiency, malnutrition, bone density loss, muscle loss, and anxiety/depression due to isolation. Health and safety of crew members is always the top

priority for all space missions. The crew must be monitored regularly before, during, and after any spaceflight.

Student Interpretation: The MED team in MC will be responsible for ensuring the health of the crew. Students will learn about common medical issues that occur for astronauts in space and create a treatment library that will assist those in the SC in determining if any crew members need additional treatment or assistance. The MED team in SC will conduct the wellness exams, including simulated tests to ensure that the astronaut vitamin levels are stable and there are no signs of bone density or muscle loss. They will also engage in conversations with the crew members regarding the impact of isolation during space travel. The SC team will follow up with MC to confirm that all crew members are healthy and report any concerns.

NAV TEAM

Primary Activity, Descent/Landing

Scientific Foundation: A vehicle in orbit around Mars would need to perform two major actions in order to land. The first is to perform a retrograde burn in order to remove lateral velocity, so that the spacecraft would begin falling toward the planet. The second action is to use the spacecraft engines to eliminate any remaining lateral and vertical velocity when approaching the surface. This ensures that the spacecraft touches down at a speed of around 0 m/s relative to the surface of Mars. With its thin atmosphere, Mars provides the potential to assist with the second action through the process of aerobraking. The atmosphere can absorb some of the kinetic energy from the spacecraft and release it as heat and light. Also, despite being very thin, the atmosphere allows for parachuting to be used as a braking mechanism.

Student Interpretation: Students will perform both the descent and landing sequences. MC will calculate the trajectory, and SC will physically perform the burns.

WEATHER TEAM

Primary Activity, Starfield Search

Scientific Foundation: Mars presents an excellent observation post from which to observe the universe. With virtually no atmosphere or competing radio signals, the platform there would rival the far side of the moon in some ways.

Student Interpretation: Students will use an observatory on Mars to study the sky with the intent of locating a satellite that is falling towards the Mars surface. During this process, they will discover that a large piece of space debris is also falling towards the surface of Mars.

Primary Activity, Dust Storm Tracking

Scientific Foundation: Dust storms on Mars are a regular occurrence. During the warmer spring months, it is very normal for continent-sized storms to form. Storms on Mars are weaker than their Earth counterparts. With an atmosphere 1/100th as dense as our own, the potential for destructive storms simply does not exist on Mars like it does here. However, storms can still cause major problems for equipment and visibility and need to be monitored.

Student Interpretation: Students will track several dust storms and predict whether they have the potential of intersecting any of the major human populations on the planet.

Resources

- Martian Gravity: http://www.universetoday.com/14859/gravity-on-mars/
- Martian Celestial Bodies: http://www.space.com/20413-phobos-deimos-mars-moons.html
- Mars's Electromagnetism: https://www.universetoday.com/154461/we-might-know-why-mars-lost-its-magnetic-field/
- Martian Soil: http://www.space.com/16999-mars-red-planet.html
- Martian Atmosphere: http://www.space.com/16903-mars-atmosphere-climate-weather.html
- Communicating with Mars: http://www.physlink.com/education/askexperts/ae381.cfm
- Mars Weather: http://www.space.com/30663-the-martian-dust-storms-a-breeze.html