



# **MARSBOUND!**

## **Mission to the Red Planet**

### **Teacher Guide**

#### **Grade Level:**

6-12

#### **Estimated Time Required:**

One to Three 45-minute sessions

#### **Brief Lesson Overview:**

Marsbound! is a simulation that invites students to experience the fundamentals of the engineering design process in a fun, interactive simulation. Your students will go through the steps of developing a spacecraft mission to Mars. This activity can serve as an introduction for a number of other activities in technology education - including robotics and rocketry.

In this lesson, students will use a hands-on, critical-thinking, collaborative, and authentically simulated approach for planning a mission to Mars. Using collaboration and problem-solving skills, the students will develop a mission that meets the constraints of budget, mass, power and has a significant science return. Students will:

- Identify science goals as they are related to Mars and the “Follow the Water” strategy;
- Develop a mission that is under budget, mass, power, and a significant science return;
- Collaborate with their peers to develop their mission;
- Explain that missions are a compromise between scientists, engineers, and funding;
- Identify engineering constraints that must be met for any successful mission; and
- Communicate with and question peers regarding the compromises made in their own mission due to constraints.

#### **Essential Questions and Endpoints\*:**

##### **CORE QUESTION:**

ETS1: ENGINEERING DESIGN

**How do engineers solve problems?**

##### **COMPONENT QUESTION:**

ETS1.A: Defining and Delimiting an Engineering Problem

**What is a design for? What are the criteria and constraints of a successful solution?**

Grade 8 Framework Endpoint: The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful.

Specifications of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions (e.g., familiarity with the local climate may



rule out certain plants for the school garden.)

Grade 12 Framework Endpoint: Design criteria and constraints, which typically reflect the needs of the end-user of a technology or process, address such things as the product's or system's function (what job it will perform and how), its durability, and limits on its size and cost. Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and state in such a way that one can tell if a given design meets them.

\*NRC Framework for K-12 Science Education, 2011

**Learning Objectives – In alignment with relevant standards and skills (below), at the end of this lesson, students will be able to:**

- Differentiate between scientific inquiry and technological design and their purposes
- Construct an appropriate science question (problem) requiring a technological design
- Design a technological solution (mission) by making tradeoffs within constraints

**Relevant Standards and Skills:**

**1. National Science Education Standards (NSES)**

a. Content Standard E: Science and Technology

i. Abilities of Technological Design:

1. Guides: Identify appropriate problems for technological design; Design a solution or product; Evaluate completed technological designs or products; Communicate the process of technological design

ii. Understandings about Science and Technology

1. Guides: Scientific inquiry and technological design have similarities and differences. Scientists propose explanations for questions about the natural world, and engineers propose solutions relating to human problems, needs, and aspirations

Science and technology are reciprocal. Science helps drive technology, as it addresses questions that demand more sophisticated instruments and provides principles for better instrumentation and technique. Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable due to factors such as quantity, distance, location, size, and speed. Technology also provides tools for investigations, and inquiry.



Perfectly designed solutions do not exist. All technological solutions have tradeoffs, such as safety, cost, efficiency, and appearance. Engineers often build in back-up systems to provide safety. Risk is part of living in a highly technological world. Reducing risk often results in new technology.

Technological designs have constraints. Some constraints are unavoidable, for example, properties of materials, or effects of weather and friction; other constraints limit choices in the design, for example, environmental protection, human safety, and aesthetics.

## 2. 21<sup>st</sup> Century Skills

- a. Creativity and Innovation
- b. Collaboration
- c. Social and Cross-Cultural Skills
- d. Productivity and Accountability

## 3. National Education Technology Standards (NETS-S)

- a. Creativity and Innovation
- b. Communication and Collaboration
- c. Critical Thinking, Problem Solving, and Decision Making
- d. Digital Citizenship

### Additional Disciplines:

Reading, Writing, Math

**Teacher Tip:** If you have printed the game board and cards from the website and they are black and white, ask your students to color the cards for you using marker or colored pencil prior to laminating. You can find the key for colors below:

Game Board System	Color	Coordinating Card #'s
Launch System	Red	1-6
Power System	Orange	7-12
Science Instruments	Blue	13-25
Mobility System	Fuchsia	26-27
Mechanical System	Yellow	28-30
Entry, Descent, and Landing	White	31-35
Computer System	Purple	36-38
Communications System	Aqua	39-41
Special Events	Green	42-47

**Materials/Equipment (per group of 4 students):**

1. **MARSBOUND! Mission to the Red Planet Student Guide** – 1 per student
2. **Equipment Cards** – 1 per team
3. **Design Mat** – 1 per team

**Vocabulary:**

Engineering      Technology      Constraints      Simulation      STEM

**Procedure (5E Application):****1. Engage:**

Set up the imaginary scenario by reading the following:

Imagine that today, your school principal announces that you will be working on a new, very complex school project, a project that no one has ever done before. This will be the single most important project you have ever been asked to complete thus far in your life. This project will be a group project and you will be working with some people you know and others you don't know. Everyone in your entire group will need to complete the group project successfully or no one will pass. In fact, the project is so important, you will be working on it in every one of your classes, during an afterschool program, and as homework. You will probably be working on it at least 12+ hours a day and during many weeks, you will work through the weekend, too! You will have just 2 years to complete the project. The project is so complex and difficult, that you will have to revise and rewrite the plans for the project constantly. When the project deadline arrives, the group will have to show the completed project to the school, principal and, oh yes, all the news stations in the world will be there as well. You will have no extensions on the deadline. No pressure, but everyone is counting on you! Mission planners, engineers, and scientists go through much the same process when designing and building space missions. Many times, they are faced with tasks that have never been tried before. Imagine that they have spent 2 years of their lives, 12+ hours a day, planning, building, planning, testing, retesting, re-planning, re-building, re-testing, packaging, shipping, unpacking, testing, and re-testing, all in an attempt to do everything in their power to ensure their mission makes it to the surface of Mars.

**2. Explore:**

(**MARSBOUND! Mission to the Red Planet Student Guide** – 1 per student, **Equipment Cards** – 1 per team, **Design Mat** – 1 per team)

**A.** Ask student's to complete the Pre-Ideas. This survey will help to establish what the current understandings of mission planning and engineering constraints. Students will use this information during the Post-Ideas as part of the individual assessment.

**B. Activity 1:** Students will be familiarized with NASA's Mars Exploration Program Goals and "Follow the Water" Strategy. Students will be given the current science goals for missions to Mars and working with their team categorize each topic under each goal. The purpose of this activity is to familiarize students and establish the



relevance of Mars exploration. Discuss the 4 Mars mission goals and program strategies with the students:

- i. **Determine if life ever arose on Mars.** All life, as we know it, requires water to survive. In fact, on Earth we have found life wherever there is water, even in places we didn't think life could exist, such as frozen deserts of Antarctica. Is the same thing true of Mars? Because of the low temperatures and thin atmosphere of Mars today, we know that there is currently no liquid water on the surface of the planet. But was that always true?
- ii. **Characterize the climate of Mars.** If we can understand what the climate of Mars is like today and how it changes, we will have a better idea of what the climate of Mars was like in the past. The atmosphere of Mars is mostly carbon dioxide, but two other important components are water vapor and dust. With enough information, we can begin to create a picture of the overall climate of Mars now and what it may have once been like.
- iii. **Characterize the geology of Mars.** Rocks and minerals on the surface of Mars can tell us a great deal about a planet's past. By studying surface morphology and patterns and types of features found on the surface, we can find a permanent record of the history of Mars in its rocks.
- iv. **Prepare for human exploration.** Humans are naturally curious. No robot will ever have the flexibility of a human explorer, so someday we will want to travel to Mars ourselves to study the planet and its history directly. Because of the difficulty and the number of challenges, robotic spacecraft must pave the way for humans to follow. One important task is to study new techniques for entering the martian atmosphere and landing on the surface. We will also need to understand the dangers humans will face on the surface of Mars.

**C. Activity 2:** Student teams will discuss possible science goals among themselves and using NASA's Mars Exploration Program Goals and "Follow the Water" Strategy.

**Teacher Tip:** Keep in mind that many of these science goals may fit under more than one mission goal. There is no one "correct" answer; it is more important that your students can justify the reasons for the categorization.

- i. Students will also decide whether they want to fly a lander, orbiter, or fly-by mission to Mars.



**Teacher Tip:** Space is provided for 5 science goals, but your students will be hard-pressed to design a spacecraft (under budget) that can meet all five goals. This is intentional, as it will guide them to revise their mission plan by going all the way back to the original Mission Goals page. This happens quite often in the real world as well.

In preparation of choosing whether they are using a lander, orbiter, or fly-by, you can use the ***Strange New Planet*** activity for a hands-on activity about exploring new planets. This activity can be found on the <http://marsed.asu.edu> website under the **Resources** tab in the ***Mars Activities*** document.

- D. Activity 3:** Student teams will begin to design the actual spacecraft that they will use for their mission. To facilitate this, each typical system that could be onboard a spacecraft is presented on its own “trading card.” Students will need to read each card carefully, as the text provides clues to the uses and limitation for that particular piece of hardware.
- i. To begin, hold the **(Green) Special Events cards** until the end of the simulation.
  - ii. Students will begin the simulation by choosing a **(Red) Rocket Card and Rocket Nose Cone** (required). The rocket card will determine the ***Mass Limit*** for the mission and will include the ***Cost*** in millions of dollars. The nose cone will be additional ***Weight*** and money, so students will need to record this into their ***Spacecraft Design Log***.
  - iii. Students will then choose a **(Orange) Power System Card**. This will determine the Power available during the mission.
  - iv. From here, students will then choose their **(Purple) Computer Systems**, **(Aqua) Communication Systems**, and **(Blue) Science Instruments** to achieve their science goals stated in Activity 2. These will help to increase Science Return.
  - v. If students have chosen a rover or lander for their mission, Rovers will need to include a **(Fuchsia) Mobility System**, and both rovers and landers will require **(White) Entry, Descent, & Landing Systems**.
  - vi. The final decision will be optional **(Yellow) Mechanical Systems**. These can increase the Science Return, but should be considered last due to budget constraints.
  - vii. Remind students to keep a tally in their Spacecraft Design Log to ensure they are staying within budget, power and mass.

**Differentiation Alert!!** The teacher will need to define the budget. Lower amounts make for a more challenging activity, while higher amounts make it less challenging. It is recommended to start with \$250 million as a good “average” level of difficulty for any of the missions.

- viii. When students have created a mission within budget, power, and mass, they can now select a **(Green) Special Events card**. Half of these cards



are Spin-offs or advances in technology that can be commercialized. These add money to the budget. The other half of the cards is failures or cuts to the budget. These take away money from the budget. Allow students time to adjust their mission to accommodate these scenarios.

**Teacher Tip:** Ask students to use a pencil on their Spacecraft Design Log so that they can easily erase when necessary.

- ix. The final step will be launch day. **Science Return** will establish the order of launch. Start with the highest **Science Return** and falling under budget, mass and power. Students will roll the die to determine if their launch was successful. The type of rocket they have chosen will determine the success rate. For example, the Heavy-Lift Rocket is high risk only lifting of successfully 3 out of 6 times. If students roll a 1,2 or 3, they lift successfully. If they roll a 4,5 or 6, launch fails and the mission is over.

### 3. Explain:

(**MARSBOUND! Mission to the Red Planet Student Guide** – 1 per student)

**A. Activity 4:** This introduces the concept of engineering constraints. Encourage students to think of everything that limited what they attempted to do with their mission. Examples would include the limited mass that can be lifted by the rocket booster available, the electrical power that is required by each system onboard, and they needed to stay within their pre-determined budget.

**Differentiation Alert!!** Ask students to consider other constraints that might limit a mission beyond what they discussed here. For example, a lander mission needs to be able to land safely in the terrain chosen to meet the science goals. After a little research, your students may realize that it is impossible to land safely in some kinds of terrain (such as mountains or the slopes of a volcano).

**B.** Ask students to share their constraints and accommodations with the class. The goal of this sharing process is to have the kids listen critically to their peer's explanation, explain their own solutions, and question others explanations.

**C. After class sharing, take a few minutes to discuss and reaffirm some of the items they may have mentioned and highlight those missed (see bulleted list below.)**

- **Size and Mass:** Some engineering constraints are due to the strength of the rocket you use to send your spacecraft to Mars. To send every instrument to Mars would require a rocket so large that it doesn't even exist.
- **Budget:** The United States Congress set the budget, the total amount of money available to spend for each NASA mission. NASA must therefore, design mission to achieve as many science goals as possible while still staying within the mission's budget. Bigger rocket booster can carry bigger spacecraft. Unfortunately, they cost a lot more to launch.



- **Power:** Every spacecraft needs power in order to function. The more instruments that are onboard, the more power will be needed for them to operate. **Solar panels** must be very large, but even so, still do not produce a lot of power. They require a great deal of direct sunlight to operate, so missions with solar panels are limited to being near the equator and can only operate for about 3 months of the year. **Fuel cells** create power through a chemical reaction much like batteries and produce a moderate amount of power, but they will only function for a limited period of time, generally only a few days or weeks. **Radioisotope power systems** (RPS) produce power from the heat generated by decaying radioactive materials. RPS's produce a lot of power and can operate at any time of year and anywhere on the surface. They are quite heavy, extremely expensive, and require more precautions.
- **Reliability:** Some rockets are more reliable than others.
- **Bottom line:** Engineering constraints often force you to make trade-offs. These constraints may keep you from being able to achieve all of your science goals, so you have to choose the hardware that will allow you to achieve as many of your science goals as possible.

#### 4. **Elaborate:**

**MARSBOUND! Mission to the Red Planet Student Guide** – 1 per student – (<http://marsbound.asu.edu>)

**A. Activity 5:** Ask students to identify at least 2 engineering constraints from the video and follow up with an explanation of how NASA may have overcome these constraints in the mission. This should be in individual assignment to determine if students are able to apply the knowledge to a new scenario.

#### 5. **Evaluate:**

(**MARSBOUND! Mission to the Red Planet Student Guide** – 1 per student)

**A. Post-Ideas:** Ask students to complete the post-ideas. Students will need to refer back to the pre-survey and simulation to successfully respond to these questions.

**B. Rubric:** A rubric has been provided to assess student understanding of the simulation and to assess meta-cognition. A copy has been provided in the Student Guide for students to reference prior to the simulation. This will allow them to understand the expectations set before them.

#### **Extensions:**

1. Rerun the simulation, but decrease the budget.
2. Research possible landing sites to consider additional engineering constraints.