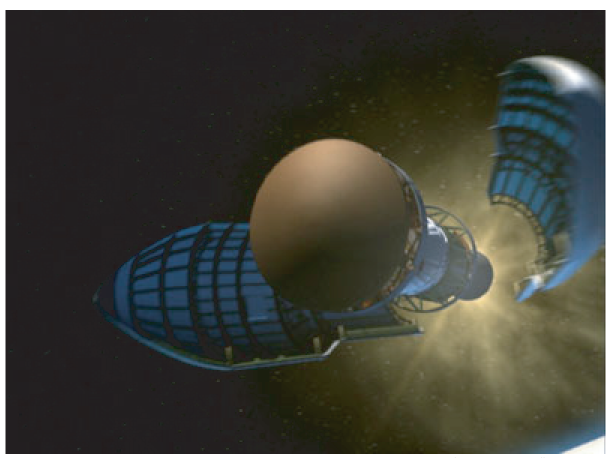
Marsbound!

Mission to the Red Planet

Student Handbook and Activity Guide



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Mars Education Program
Jet Propulsion Laboratory
Arizona State University

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Marsbound!
Mission to the Red Planet

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Introduction

Have you ever wanted to travel to Mars? Have you wondered what goes into the planning of a mission to Mars? In this set of activities, you are going to find out! You and your team have been selected to help NASA design a potential mission to the martian surface. You must make your recommendation carefully, keeping in mind all the science and engineering considerations that go into planning a successful mission. Just like NASA mission designers, you will have a "catalog" of mission hardware you can choose from. Also, just like NASA mission designers, you will have a budget that you must keep your costs under! Good luck planning your mission to the Red Planet!

Overview

The activities included in this book are divided into five general sections. The first two sections will teach you how to choose your **science goals** for a mission to Mars. The science goals clearly lay out what you hope to achieve by performing this mission. Your team will work together to decide on these goals and will develop the justification for them. When your design is complete, your team will send these goals and the reasons for them to NASA as part of your recommendations.

The third section will give you information about restrictions on your mission due to the hardware – the spacecraft, rocket boosters, instruments, and other systems – that you are going to send to Mars. These restrictions or limitations on your mission design are called **engineering constraints**. You will need to keep these constraints in mind as you design your spacecraft.

In the fourth section you will actually "build" your spacecraft using a set of "equipment cards". Each of these cards contains a picture of each spacecraft or instrument system and a description of what it does.

Along the right side of each card are three numbers in circles. The number with the "weight" represents the **mass** of the system. The more mass your spacecraft has, the bigger your rocket booster will have to be to get it to Mars. The number with the lightening bolt represents how much **power** the system needs to function. You will have to make sure that your spacecraft provides enough power to run everything onboard! Finally, the number with the dollar sign represents the **cost** of the system in millions of dollars. You must stay within your budget!

In the final section, you will bring all of your team’s work together into a report that you will submit to NASA's *Marsbound!* website as your recommendations for NASA’s next mission to Mars.

Science Goals

There are many reasons to explore the planets in our Solar System. One of the main reasons we explore is because humans are, as a species, curious beings. We have always had the desire to know what is over the next hill or the next horizon. It was the curiosity of the early explorers that directly led to the discovery of the lands where we make our homes today. The exploration of space does not just satisify our curiosity, however. Many of the **"spin-offs"**, products that have been developed as a result of space exploration, become a part of our daily lives. Cellular phones, rechargeable batteries, portable computers, Velcro, live television, weather satellites, pacemakers, and in-the-ear thermometers are just a few of these spin-offs.

When designing a mission to a planet, mission scientists are not usually thinking about what spin-offs may be produced from the mission. Instead, mission planners have definite **science goals**, questions about the planet that they would like to have answered by the mission. For instance, there are literally thousands of questions that could be asked about Mars alone, so NASA has organized its program of Mars exploration around a common strategy: **"Follow the Water"**. Water is the thread that ties together all four of NASA's main themes for the study of Mars. These themes are:

1. 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 the 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? Some evidence from missions to Mars has indicated that Mars was once warmer and wetter than it is today. Further evidence is needed to settle this question.

2. 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. By studying the clouds and dust storms in the martian atmosphere and the patterns of wind-blown dust on its surface, we can begin to understand how the weather changes on Mars during its different seasons. With enough information of this type, we can begin to create a picture of the overall climate of Mars now and what it may have once been like.

Science Goals (cont.)

3. Characterize the geology of Mars. Rocks and minerals on the surface of Mars can tell us a great deal about the planet's past. By studying the **surface morphology**, the patterns and types of features found on the surface, we can find a permanent record of the history of Mars in its rocks. Also, by studying the patterns of ancient channels we can identify where water may have flowed on the surface in the past. Certain minerals only form in liquid water. Even though any water on Mars seems to be gone now, finding these minerals can give us clues as to how much water may have been on Mars in the past and where it might have gone. Craters on Mars can also help us determine the relative ages of different areas on the surface, helping to establish a "timeline" of geological events on Mars. Finally, Mars is home to geological features that dwarf anything found on Earth: It has both the largest volcano and the largest canyon system in the entire Solar System! All of these geological features provide clues we can use to uncover the Red Planet's past.

4. Prepare for human exploration of Mars. As said before, 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 so that we can study the planet and its history directly. Because of the difficulty of the journey and the large number of challenges that must be faced in order to undertake it, robotic spacecraft must pave the way for their human counterparts to follow later. One important task is to study new techniques for entering the martian atmosphere and landing on the surface. It is also important that we understand the dangers humans will face on the surface of Mars and how they can protect themselves from these dangers. How will the basic needs of water, food, and shelter be met? Mars has no planet-wide magnetic field to shield humans from the dangerous radiation emitted by the Sun. How can humans on Mars protect themselves from this radiation? What kind of landing site is suitable for a spacecraft – robotic or human-piloted – to land upon? All of these questions and more must be answered before human beings can satisfy their urge to explore and actually safely travel to Mars themselves.

In the activity that follows, your team will be asked to choose the science goals that you hope to achieve during your mission. Choose wisely, and keep thinking about how your goals will fit into NASA's overall plan for the exploration of Mars. Your team must be prepared to justify its decisions when you defend your mission plan to your classmates!

Activity 1: Sample Science Goals

Here is a list of some of the science goals being studied by Mars scientists. For each science goal, write the numbers of NASA's "Follow the Water" strategy that you think these will fall under. Keep in mind that each goal may apply to more than one part of NASA's strategy! Discuss with your team why you think each of these topics might be important and how it would help answer the questions raised in NASA's Mars Exploration Program.

NASA's "Follow the Water" Strategy for Mars Exploration

1. **Determine if life ever arose on Mars**
2. **Characterize the climate of Mars**
3. **Characterize the geology of Mars**
4. **Prepare for human exploration of Mars**

Craters

___ What kinds of craters are on Mars and how were they formed?
___ How old are the craters on Mars?
___ How are martian craters different from craters on the Moon?
___ Have martian craters been eroded by wind or water?
___ Were some of the craters on Mars ever flooded?
___ What kinds of rocks make up the ejecta from martian craters?
___ Has the amount of cratering on Mars changed over time?

Volcanoes

___ What types of volcanoes are on Mars?
___ Does Mars have moving continental plates?
___ When and how often did the martian volcanoes erupt?
___ Have martian volcanoes been eroded by wind or water?
___ Has the lava from martian volcanoes been mixed with water?

Plains

___ Were the northern plains on Mars once a huge ocean?
___ Why is the northern hemisphere of Mars so smooth and flat, while the southern hemisphere is so cratered and rugged?

Polar Ice Caps

___ What are the ice caps on Mars made of?
___ How do the ice caps change throughout the martian year?
___ What are the dark lanes and other features seen on the martian ice caps?

Activity 1: Sample Science Goals (cont.)

Canyons
- ___ What formed the canyon systems on Mars?
- ___ Did water ever flow through the canyons?
- ___ Have the canyons been eroded by wind or water?

Channels and Gullies
- ___ What formed the channels we see on Mars?
- ___ What evidence is there of water flowing through the channels?
- ___ What is the source of any water that flowed through the channels?
- ___ Where did the water go?
- ___ How long ago did water flow on Mars and for how long did it flow?
- ___ Have the channels been eroded by wind or water?

Atmosphere
- ___ Why do the clouds we see in the atmosphere of Mars form?
- ___ What are the clouds in the atmosphere of Mars made of?
- ___ What do the cloud patterns tell us about the winds on Mars?
- ___ What do the patterns of sand dunes tell us about the winds on Mars?
- ___ How are global dust storms created?
- ___ How often do global dust storms occur and how long do they last?
- ___ What affect do dust storms have on the surface of Mars?

Dust and Sand
- ___ What is the dust on Mars made of?
- ___ How does the dust move around the planet throughout the martian year?
- ___ Where is it dusty and where is it rocky on Mars?
- ___ Are there microscopic lifeforms living in the soil on Mars?

Radiation and Magnetic Field
- ___ Did Mars ever have a planetary magnetic field? If so, what happened to it?
- ___ Are there any rocks on Mars that still have a magnetic field?
- ___ How much radiation reaches the surface of Mars?
- ___ Do the landforms on Mars provide any protection from radiation?

Your Own Questions

- ___ ____
- ___ ____
- ___ ____
- ___ ____
- ___ ____

Activity 2: Science Goals

In Activity 1 you classified a number of science goals according to NASA's "Follow the Water" strategy for the exploration of Mars. Your task for this activity is to select the science goals that you hope to achieve with your mission!

Using the list in Activity 1 (including the goals you created yourself), choose five science goals for your mission. After discussing them with your team, rank your five science goals from 1 to 5 in order of importance to your team (1 being the most important).

When your team has agreed upon the science goals for your mission, record your five science goals, in order of importance, in the space below. On the lines below each science goal, record your team's reasons for why each goal is important. Be sure to explain how your goals fit into NASA's "Follow the Water" strategy!

1) Goal: ____

Reason: ____

____

2) Goal: ____

Reason: ____

____

3) Goal: ____

Reason: ____

____

4) Goal: ____

Reason: ____

____

5) Goal: ____

Reason: ____

____

Our mission will be a ________________ (fly-by/orbiter/lander) mission.

Engineering Constraints

As mentioned earlier, engineering constraints are limits that are placed on your mission by the **hardware** – the rockets, the spacecraft, the science instruments, and other systems – you use to accomplish that mission. In this section you will look at some of these constraints.

A. Size and Mass: Some engineering constraints are due to the strength of the rocket booster you use to send your spacecraft to Mars. NASA would very much like to send every scientific instrument imaginable to Mars! Unfortunately the spacecraft would have to be so big that no rocket in existence could launch it into space. 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.

B. Budget: The United States Congress sets the **budget**, the total amount of money available to spend, for each NASA mission. NASA must, therefore, design missions to achieve as many science goals as possible while still staying within the mission's budget. Bigger rocket boosters can carry bigger spacecraft, but unfortunately, they cost a lot more to launch.

C. Power: Every spacecraft needs power in order to function. The more instruments that are onboard, the more power is needed for them to operate. **Solar panels** produce electricity through a special material that interacts with sunlight. Solar panels must be very large, but even so, still do not produce a lot of power. Solar panels 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 three 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** (usually called an **"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, anywhere on the surface. They are, however, quite heavy, extremely expensive, and require more precautions to use.

D. Reliability: The last constraint you will have to consider is the reliability of the spacecraft and its booster. Some boosters are more reliable than others – are you willing to accept a greater risk to save money? You should think about how you would revise your mission if you were to lose some of your hardware in flight. Having backup systems on-board just may save your mission!

Activity 3: Engineering Contraints

In the previous activity you worked out the science goals you want to be met by your mission. In this activity you will begin to think about the limits that will be placed on your mission design: engineering constraints. Answer each question as completely as possible, discussing each with your teammates. Your list of engineering constraints, along with your list of science goals, make up your **design specifications document**. Your final mission design will be compared to your design specifications document to see how well it accomplishes your goals with the limitations that have been established. For this activity you will use a set of "equipment cards" which describes each piece of equipment, and lists its mass, power requirements, cost, and any special capabilities or restrictions it may have.

1. Booster Capabilities

Look through the equipment cards and find all of the rocket boosters (red-bordered cards) that you have available. Notice that they have no mass or power cost listed. That is because they generate their own power through their engines and are able to lift their own mass in addition to the mass of the spacecraft they carry. The description for each booster tells how much mass it can lift in addition to its own mass. Record this mass, the reliability rating, and the cost of each booster in the space below.

Booster Name	Mass Lifted	Reliability Rating	Cost
______________________________	________	______________	_____
______________________________	________	______________	_____
______________________________	________	______________	_____
______________________________	________	______________	_____
______________________________	________	______________	_____

2. Budget

As you have learned, NASA's budget for each space mission is set by the United States Congress. In this case, your budget will be set by your teacher or facilitator. Record that maximum budget amount here (NOTE: The number next to the dollar sign on each card is the cost of that system in millions of dollars.):

Maximum Budget: $______________________________

Activity 3: Engineering Constraints (cont.)

3. Power

The power required by your spacecraft is the total power required by all its components combined. Each power source (orange-bordered cards) your spacecraft carries generates a certain amount of power that can be used by your other systems. The power sources themselves do not use power (except for the on-board battery, which stores power). The description of each power source lists how many units of power it generates, along with any special advantages or disavantages. Keep in mind that you do not have to limit yourself to only one kind of power source! Also, many power sources require a battery to store power. In the spaces below, list each power source, the amount of power it generates, its mass, and its cost.

Power Source	Power Generated	Mass	Cost
______________________________	____________	_____	____
______________________________	____________	_____	____
______________________________	____________	_____	____
______________________________	____________	_____	____
______________________________	____________	_____	____
______________________________	____________	_____	____

4. Safety

When designing your mission, you may have limitations placed on you by a landing site or by hazardous materials that might be on board during launch. You also need to plan for possible hardware failures during the mission. Work out a plan with your teammates for dealing with these issues and record it in the space below.

____

____

____

____

Activity 4: Building Your Spacecraft

Your team has decided on its science goals and has also looked at the engineering constraints that will limit your mission. It's now time to build the spacecraft you will use to accomplish your mission. Use the "equipment cards" included with this activity to help design your spacecraft. You are to work with your team to design your spacecraft by assembling the cards that represent each system involved in your mission. Read each card carefully to make sure you have all the required systems on board your spacecraft. Remember, your objective in this activity is to design a spacecraft that will stay under budget, be launchable with existing rocket boosters, and meet all of your science goals within the engineering constraints you have identified. Here are some things to keep in mind:

- Make certain that your booster can lift the mass of the spacecraft!
- Make sure you have enough power to run all of the systems onboard.
- Do you have the instruments you need to fulfill your science goals?
- How safe is your spacecraft? Will you need special care during launch?
- Do you have backups for your most critical systems – you may lose them in flight!
- Make certain you stay within your budget!

Keep in mind that the design process is a loop: You may have to go back and change your science goals, look at your constraints again, and change your design. This is all part of the process. In the end, you should have a mission design that is a good balance between meeting your science goals and satisfying your engineering constraints.

When you have completed your design, record it on the Spacecraft Design Log on the next page. Your teacher or facilitator may have other instructions for you to follow as well. Take careful notes during your discussions while designing your spacecraft – they will help you when the time comes to submit your final report to NASA!

Activity 4: Building Your Spacecraft (cont.)

Spacecraft Design Log

Spacecraft Component	Mass	Power	Cost

Totals ________ ________ ________

Activity 5: The Design Specifications Document

Now that you have developed your mission to the Red Planet, the only task remaining for you to do is to write up your mission design and send it to NASA! You have already done everything you need to write your design specifications document, you just need to tie it all together into one, organized paper. Your report should follow the outline shown below:

I. Introduction
Include your team name, where your team is from, the name of your school or organization, your grade or age, and your teacher or adult facilitator's name. Write a couple of sentences explaining why your mission is important for NASA to consider.

II. Science Goals
Write a brief paragraph explaining each of your science goals, why you chose them, how they fit into NASA's overall plan for Mars exploration, and how they fit together for your mission. Can you think of any spin-offs that might come from your mission?

III. Engineering Constraints
What engineering constraints does your mission face? How will your mission handle safety issues, hardware failures, or other problems?

IV. Spacecraft Design
Describe each of the components and instruments that make up your spacecraft. Why did you choose each component? How will they help you achieve your science goals? Were you under budget? If so, by how much?

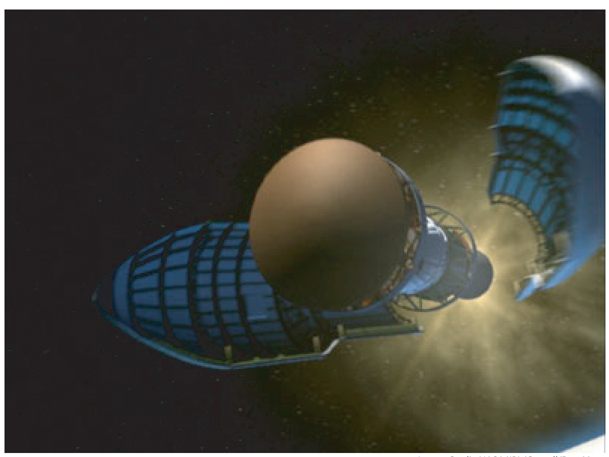
V. Conclusion
Summarize the most important points about your mission and why you feel NASA should consider it for flight.

Remember, you should write an original organized paper, not just submit the activity worksheets you used to design your mission. When you are ready to submit your design, go to the Marsbound! website at http://marsbound.asu.edu and cut-and-paste your report into our online form. If accepted, your team will appear in our roster of Certified Student Mission Planners!

Marsbound!

Mission to the Red Planet

Teacher's Guide



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MARSBOUND! TEACHER GUIDE

Welcome to *Marsbound! Mission to the Red Planet*, a self-contained activity in which your students will use realistic techniques to plan a mission to Mars. The goal of this activity is to use the excitement of Mars exploration as the "hook" for getting your students interested in the process of design, engineering, and technology. The activity is intended for students in grades 4-12 and can be adapted for a wide range of abilities and interests.

Technology Education

Currently in the United States, there is a great deal of confusion regarding technology education. In many schools, "technology education" means "computer education." While learning how to use a computer is an important and valuable skill, it is not technology education. Technology education is the study of how humans create and use tools to solve problems. It is about the design process, balancing constraints, and realizing that there is no one perfect solution to a problem.

We live in an increasingly technological world, yet how many of our students can explain how a cell phone, television, or even the plumbing in their houses work? This knowledge is becoming more and more concentrated in a "techological elite," while the technology literacy of the average American is decreasing rapidly. If we consider that the main goal of education is to prepare our students to function in society at large, we have the responsiblity to ensure that our students are technologically literate. Technological literacy concerns everything from learning to be an intelligent consumer to understanding the environmental and ethical issues involved in emerging technology. At its core, technological literacy is about understanding and applying the process of design for solving real-world problems.

Technology for All Americans

In order to provide direction for the emerging field of technology education, the National Science Foundation (NSF) and NASA have provided funding to the International Technology Education Association (ITEA) to develop a set of national education standards for technology education. Called *Technology for All Americans: Standards for Technological Literacy*, the standards lay out the specific tasks that a technologically literate student should understand and be able to perform. The complete set of technology standards is given in Appendix 1.

Marsbound! Mission to the Red Planet was written specifically to address these standards. The specific alignment of *Marsbound!* to the standards is also given in Appendix 1. In this *Teacher's Guide*, you will learn about the emerging educational field of Design, Engineering, and Technology (DET) and how you can implement this exciting and motivating area of study into your classroom.

The Design Process

Like the scientific process, the design process is not a simple, linear progression from one step to the next, resulting in a finished product. Although there *are* steps, the design process is an iterative one: designing, modifying, testing, and designing again until a finished product is made. While *Marsbound!* serves as just an introduction to DET, it is important that you, as the students' teacher, understand the larger picture.

A central tenet of engineering, however, is that there is no such thing as a "perfect" design. Each design solution has constraints, limitiations that are placed on the solution. For example, cost is a common constraint, as is the reliability or the strength of the materials being used. It will almost always turn out, however, that a design that excels in one aspect of the problem to be solved will be poor in another aspect. Making and justifying these trade-offs is a major part of the design process.

Keeping in mind that the design process is not as linear as it may appear, here are the steps that are normally identified as being part of the design process:

1. Clearly identify the problem, identifying all aspects of the issue. It's not enough to identify the problem in broad terms, for example, "There is too much traffic near our school." The specific aspects of the problem need to be identified. For example, is the traffic moving too fast, are there too many cars on the road, or is there simply poor traffic management and routing? Usually it is the "end consumer" who will specify the problem to be solved, so this is a good opportunity to explore the sociological implications of the technology that result from the design as well! In *Marsbound!*, NASA is the "end consumer" and sets the overall goals for the "problem": the exploration of Mars.

2. Identify the functional requirements the solution must meet. If, in our previous example, the problem is poor traffic management near the school grounds, your functional requirements might include, "Traffic must enter and exit the school area within one minute," and, "It must be easy to pick up and drop off students." The functional requirements should be written so that if they are satisfied, the problem itself will also be satisfied. In *Marsbound!*, the students identify their functional requirements by choosing specific science goals that their mission must fulfill.

3. Identify the constraints to the solution. Again using our school traffic example, the possible constraints might be, "All traffic must remain below 15 MPH," or, "Vehicles must not pass closer than 10 meters from the school building." In *Marsbound!*, mass, power, and cost are the primary constraints that the students must deal with.

4. Design a prototype. This is the step that most people think of as "design" or "engineering", but actually this is just one step in the overall process. The prototype could be a simple concept model (perhaps a drawing on a piece of paper for our school traffic example) or a complete working model (temporary lines painted on the pavement near the school). The goal is to develop something that can be tested to see if it satisfies the functional requirements and constraints. Note that the prototype does not have to satisfy *all* of the functional requirements. It is perfectly acceptable (and common) to test only one aspect of a complex problem at a time. In *Marsbound!*, the students use the "equipment cards" to develop their prototype.

5. Evaluate the prototype. In this step, the designer must test and evaluate his or her proposed solution. Note that this is more than simply asking, "Does it work?" In this step the designer must instead ask, "How *well* does it work?" Graphs and charts are a common way to display the results of this test and evaluation process. Continuing with our example, the designers in this case might collect data on how many cars pass near the school, how fast they travel, or how long it takes to load and unload passengers. In *Marsbound!*, the students evaluate the mass, power, and cost of their spacecraft versus the science return obtained.

6. Revise and retest as needed. Based on the data collected in the previous step, the designer can see where the proposed design can be improved or what new trade-offs will have to be made. The engineer then goes back to step four (and sometimes back to step one!) and repeats the process until the design satisfies, as near as possible, all of the functional requirements and constraints.

If you think about the classic "egg drop experiment" (in which students build a "carrier" for an egg that will allow it to survive being dropped from heights), essentially all of the students' effort is devoted to step four (design a prototype) alone. As a result, they often come away feeling that this step represents all of engineering, but in actuality this is one step among many. Students who have experienced this type of experiment may have trouble understanding why it takes so long to design a new cellular telephone or a new street intersection. How long can it take to put things together? But most of the effort in the design process is spent testing and evaluating so that the designers get the finished product "right the first time."

Getting it "right the first time" is another failing of the classic egg drop. As typically presented, students build their egg carriers, drop it from a great height, and hope it works. Engineers do not have the luxury of building a bridge and "hoping it works"! The design and modeling process for even a fairly straightforward design such as a construction project can take as long to complete as the actual building itself. As your students design their mission to Mars, you should find out how they can ensure that their mission will "get it right the first time." In *Marsbound!*, the students will likely adjust their design several times before arriving at a final design.

7. Present the final product. Once the design is finished, it must be demonstrated to the "end consumer" who identified the problem in the first place. Ultimately, it is the consumer, the user of the technological solution, who decides if the problem has really been solved. If the consumer is not satisfied, usually the problem has not been well-specified or the consumer may not understand the constraints that must be placed on the solution. In *Marsbound!*, the students will submit their final design, along with its justification to NASA via an online form.

Using *Marsbound!*

Marsbound! is an exciting and engaging activity that allows your students to experience the fundamentals of the design process in a fun game environment. Your students will, in a simplified way, go through the steps described previously in the context of developing a spacecraft mission to Mars. In this section you will learn how each activity included with *Marsbound!* relates to the design process.

The *Marsbound!* activity pack includes this *Teacher's Guide*, a *Student Activity Guide*, and a set of 48 "equipment cards" that your students will use to actually "build" their spacecraft. You can also print out an optional "design mat" that graphically shows how all the systems fit together in an actual spacecraft. The *Student Activity Guide* is divided into five activities. Activities One and Two introduce the concept of "science goals," which form the basis of any exploration mission. Science goals serve the dual purpose of defining both the problem and laying out the functional requirements for the solution. NASA's Mars Exploration Program website (http://mars.jpl.nasa.gov) has a wealth of information on the types of missions NASA has flown to Mars, as well as details of the spacecraft and instruments we have sent there.

Activity One is designed to familiarize students with NASA's "Follow the Water" strategy for the exploration of the Mars. "Following the Water" also provides an excellent tie-in to a variety of Earth science topics, if you are interested in expanding the impact of *Marsbound!* beyond design, engineering, and technology. Keep in mind that many of these science goals could fit under more than one part of the "Follow the Water" strategy. There is no "correct" answer; it is more important that your students can *justify* their answer!

Activity Two involves having your student teams discuss possible science goals among themselves and, based on NASA's overall strategy, choose the specific goals for their mission. The science goals are the equivalent of the functional requirements we discussed previously. Space is provided for five 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 problem statement. This happens quite often in the real world as well! In addition, it is here that your students should decide whether they want to fly a lander, orbiter, or fly-by mission to Mars. You may find the activity "Strange New Planet" in ASU Mars Education's *Mars Activities* book to be helpful if you would like your students to have more hands-on practice with the process of exploring new planets. You can obtain this activity online by following the "Curriculum" link at the ASU Mars Student Imaging Project website (http://msip.asu.edu). If they have participated in the "Strange New Planet" activity, they will be familiar with each of these possibilities. If not, you may want to take a moment to explain how each option works.

Activity Three introduces the concept of engineering constraints. For younger students, this may very well be a new word and even a new concept for them, so you will likely want to spend some time making sure your students understand what the term means. Encourage your students to think of everything that could possibly limit what they can do with their mission. 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 on mountains or the slopes of a volcano). Nevertheless, encourage your students to list the constraints they find and try to come up with a solution. You may be surprised how creative your students can be!

Other kinds of constraints involve the limited mass that can be lifted by the rocket boosters that are available, the electrical power that is required by each system onboard, and of course, the need to stay within their pre-determined budget! You will need to define their budget for them. Lower amounts make for a more challenging activity. We recommend $200 million as a good "average" level of difficulty for a rover mission. Feel free to adjust this value to whatever is approriate for your students!

In Activity Four, the students 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." Make certain that your student teams read the text of each card carefully, as the text provides clues to the uses and limitations for that particular piece of hardware. The cards also make it easy for students to experiment with various selections of equipment for their mission. This is where the process of revision comes in. *Marsbound!* works best as a collaborative activity; ideally, your students should be in teams of 3-4 students. You may find it helpful to laminate the cards so that they can survive the wear and tear of student use. Once the students have designed their spacecraft using the cards, they should record their design on the Spacecraft Design Log. Have them total up the mass, power, and cost of their mission and ensure they have satisfied all their science goals/functional requirements and engineering constraints.

Activtiy Five allows the students to submit their finished product to NASA, the "end consumer" in this case. The *Marsbound!* website, located at http://marsbound.asu.edu, features a submission form where your students can submit their designs. You can submit a class design or have each team submit their own designs. Once you have completely filled out the form, the system will generate a personalized "Certified Mission Planner" certificate that you can print out. Note that the system is completely automated. You can submit individual reports or a single report for the entire team, but one certificate will be created per submission. It is up to you to print them from your computer.

There are a number of modifications you can make to this activity. In addition to adjusting the budget, you can introduce your students to the concept of risk by having them roll a die at "launch" -- if they roll over the reliability of the booster, it is destroyed in a launch accident! Finally, you can also require students to research and write a formal proposal for their mission, including choosing a target site for their observations.

Using the *Marsbound!* Cards as a Stand-Alone Activity

As a shortened version of the *Marsbound!*, you can do only Activity Four and hold a "design challenge" competition to see which team can achieve the most science return and/or be the most under budget. Certain cards have printed "SCIENCE RETURN: +1" on them. By totalling up the "science return" on their cards, your students can get an abstract rating of the science value of their mission. We have also included a special set of six green cards. These cards represent random events that can occur during the development and execution of a mission. Half the cards represent "spin-offs", commerical applications of the students' mission, that are in effect "free money" for the students' budgets. The other half of the green cards are "problem" cards and represent difficulties that can arise during a mission. If the students have planned for these contingencies as part of their constraints, these cards will have little or no effect on their mission, but if they have not, they will be serious issues to be dealt with!

Conclusion

Marsbound! is a fun and flexible activity that introduces your students to the engineering design process. The activity can serve as a "jumping off" point for a number of other activities in technology education, including robotics, rocketry, and other types of project-based learning. *Marsbound!* is designed to work seamlessly with other ASU Mars Education products such as *Mapping the Surface of a Planet* and the *Mars Student Imaging Project* (available at http://msip.asu.edu). We encourage you to investigate all of the opportunities the exploration of Mars has for bringing authentic science into your classroom!

Appendix 1: Standards for Technological Literacy

"*" = standards addressed by *Marsbound! Mission to the Red Planet*

The Nature of Technology

***Standard 1:** Students will develop an understanding of the characteristics and scope of technology.
***Standard 2:** Students will develop an understanding of the core concepts of technology.
***Standard 3:** Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology and Society

***Standard 4:** Students will develop an understanding of the cultural, social, economic, and political effects of technology.
Standard 5: Students will develop an understanding of the effects of tech nology on the environment.
***Standard 6:** Students will develop an understanding of the role of society in the development and use of technology.
Standard 7: Students will develop an understanding of the influence of technology on history.

Design

***Standard 8:** Students will develop an understanding of the attributes of design.
***Standard 9:** Students will develop an understanding of engineering design.
***Standard 10:** Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Appendix 1: Standards for Technological Literacy (cont.)

Abilities for a Technological World

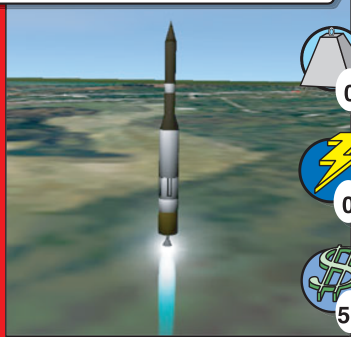
***Standard 11:** Students will develop abilities to apply the design process.
Standard 12: Students will develop abilities to use and maintain techno logical products and systems.
Standard 13: Students will develop abilities to assess the impact of prod ucts and systems.

The Designed World

Standard 14: Students will develop an understanding of and be able to se lect and use medical technologies.
Standard 15: Students will develop an understanding of and be able to se lect and use agricultural and related biotechnologies.
***Standard 16:** Students will develop an understanding of and be able to select and use energy and power technologies.
***Standard 17:** Students will develop an understanding of and be able to select and use information and communication technologies.
***Standard 18:** Students will develop an understanding of and be able to select and use transportation technologies.
Standard 19: Students will develop an understanding of and be able to se lect and use manufacturing technologies.
Standard 20: Students will develop an understanding of and be able to se lect and use construction technologies.

Source: *Technology for All Americans Project*, International Technology Education Association, 2003.

Light-Lift Booster



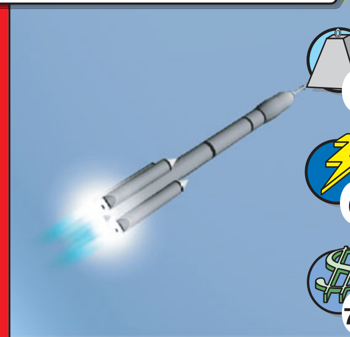
Model by: David Sundstrom

This booster can send only small spacecraft to the Solar System, but it is inexpensive and reliable.

RELIABILITY: 5/6
MASS LIMIT : 45 Mass Units

1

Uprated Light-Lift Booster



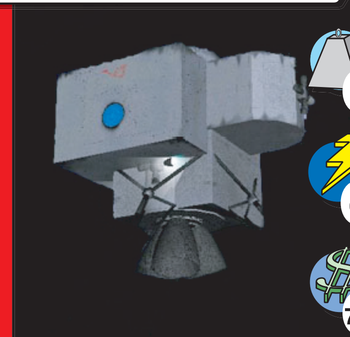
Model by: Jeffrey Simpson

By adding strap-on rockets to the Light-Lift Booster, the booster can carry larger spacecraft into space, but is more expensive and less reliable than the standard version.

RELIABILITY: 4/6
MASS LIMIT : 90 Mass Units

2

Space-Launched Booster



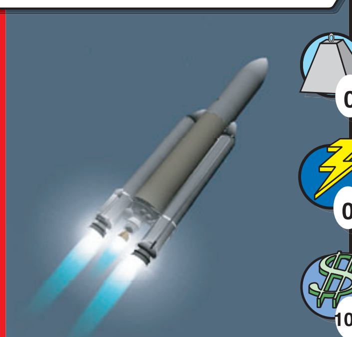
Model by: Justin Haupt

This booster is launched in space from a carrier (such as the Shuttle Orbiter). With this card, you may launch additional spacecraft for only $40 miillion each.

RELIABILITY: 5/6
MASS LIMIT : 60 Mass Units

3

Medium-Lift Booster



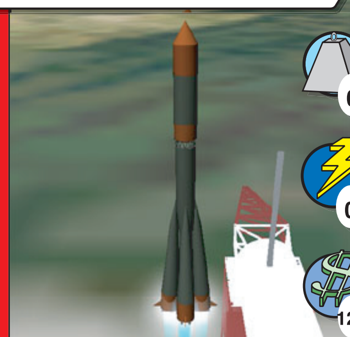
Model by: Vinka

This booster can carry a much larger spacecraft than the Light-Lift Boosters, but is much more expensive.

RELIABILITY: 4/6
MASS LIMIT : 125 Mass Units

4

Medium-Lift Booster



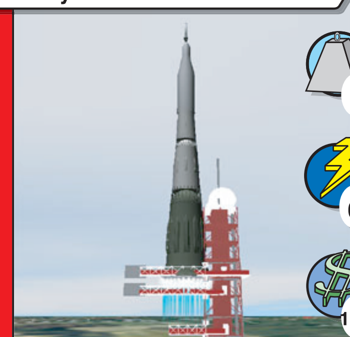
Model by: Manuel Amorim, Richard Croy

This is another version of the Medium-Lift Booster. This booster can carry the same mass into space, but is more reliable and more expensive.

RELIABILITY: 5/6
MASS LIMIT : 125 Mass Units

5

Heavy-Lift Booster



Model by: Manuel Amorim, Richard Croy

This is the most powerful booster on Earth. It can carry very large payloads, but is not very reliable.

RELIABILITY: 3/6
MASS LIMIT : 200 Mass Units

6

Low-Resolution Visual Camera

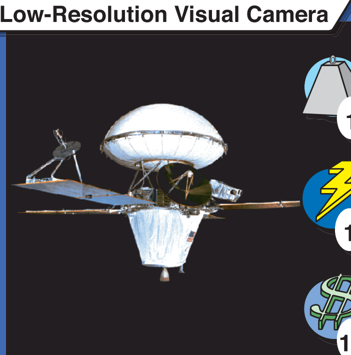


Photo credit: NASA/JPL

This camera can photograph a very wide area in each image, but it is not able to make out small details on the surface.

SCIENCE RETURN: +1

7

Med.-Resolution Visual Camera

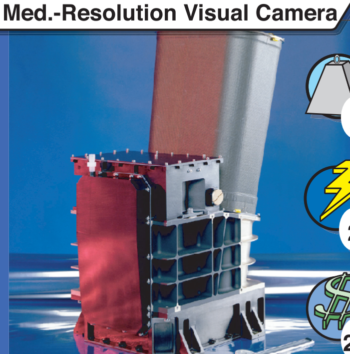


Photo credit: Arizona State University

This camera can see objects from orbit that are about the size of a small house, but the area covered by each image is fairly small.

SCIENCE RETURN: +1

8

High-Resolution Visual Camera

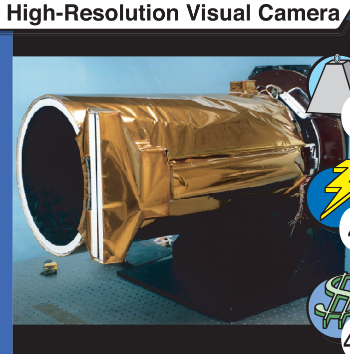


Photo credit: Malin Space Science Systems

This camera is able to see objects from orbit that are just a few meters in size, but can only see a very small part of the surface in each image.

SCIENCE RETURN: +1

9

Medium-Res. Infrared Camera

2

2

25

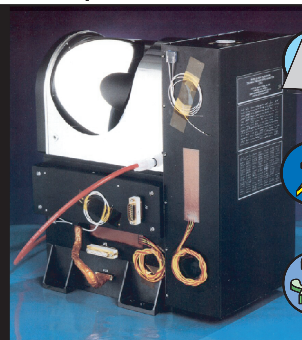
Photo credit: Arizona State University

This camera has the capability of taking temperature images on both the day and night side of a planet. It also provides information about soil grain size and basic mineral composition.

SCIENCE RETURN: +1

10

Infrared Spectrometer



3

2

30

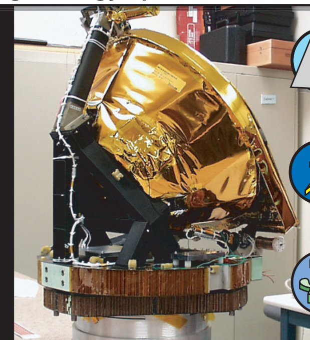
Photo credit: Arizona State University

This instrument detects the infrared "fingerprint" of minerals on the planet's surface. Using an instrument like this provides very detailed information about the geology of the planet.

SCIENCE RETURN: +1

11

High-Energy Spectrometer



4

5

30

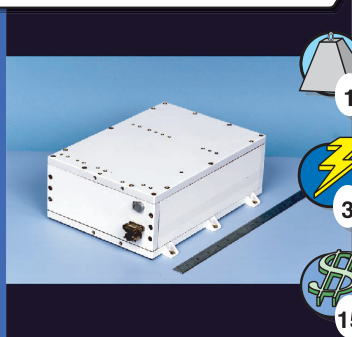
Photo credit: University of Arizona

This instrument is able to detect neutrons, gamma rays, and other high-energy radiation. With this information scientists can detect hydrogen, which may mean water is present.

SCIENCE RETURN: +1

12

Radiation Sensor



1

3

15

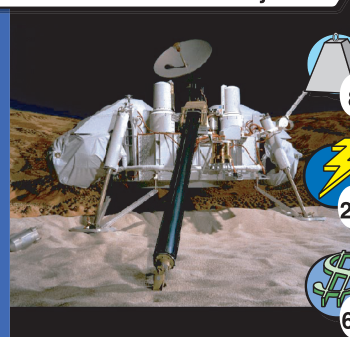
Photo credit: NASA/JSC

This instrument measures the amount of radiation in the area of the spacecraft. This information is important when preparing for human exploration of the planet, since radiation can be dangerous to humans.

SCIENCE RETURN: +1

13

Life Sciences Laboratory



8

25

60

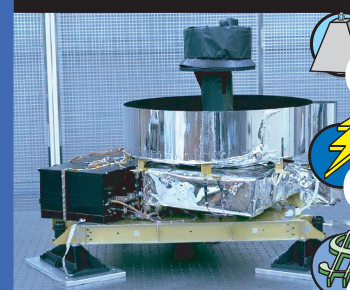
Photo credit: NASA/JPL

This laboratory is a collection of instruments that has the possibility of detecting life on the planet's surface. It can ONLY be installed on a lander and also requires the soil sample collection scoop (card #28).

SCIENCE RETURN: +2

14

Laser Topography Mapper



3

2

30

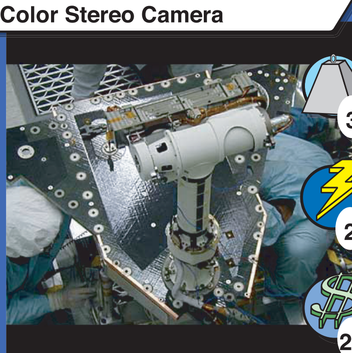
Photo credit: NASA/GSFC

This instrument beams a laser down from orbit and can make very accurate measurements of the heights and depths of features of the planet. With this instrument you can make a 3D map of the surface.

SCIENCE RETURN: +1

15

Color Stereo Camera



3

2

20

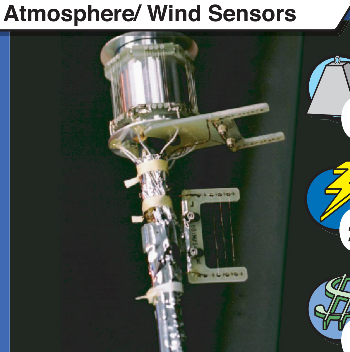
Photo credit: NASA/JPL/Cornell

This camera takes two color images, slightly apart from one another. When viewed through special glasses, the two images can combine into a single image that appears 3D.

SCIENCE RETURN: +1

16

Atmosphere/ Wind Sensors



2

2

5

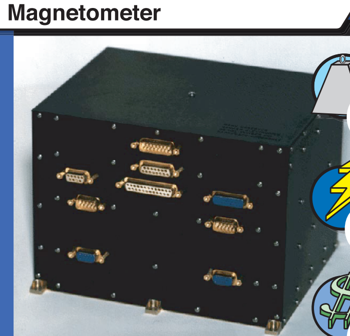
Photo credit: NASA/JPL

This sensor package will take detailed data about the planet's surface winds and atmosphere composition.

SCIENCE RETURN: +1

17

Magnetometer



1

2

5

Photo credit: NASA

This instrument measures the magnetic field of the planet. The planet's magnetic field is important because it helps protect crews from radiation.

SCIENCE RETURN: +1

18

Rover Mobility - Wheels

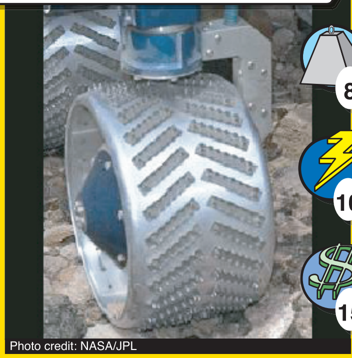


Photo credit: NASA/JPL

This system is needed to give a rover basic maneuverability on the surface of a planet.

SPEED: MEDIUM
TERRAIN: SMOOTH
NOTE: CARD #19 OR #20 IS REQUIRED FOR ALL ROVER MISSIONS

19

Rover Mobility - Tracks

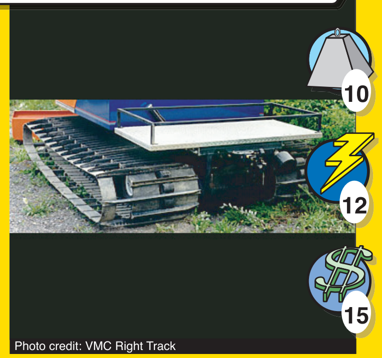


Photo credit: VMC Right Track

A track system (similar to tank treads) allows the rover to travel across rugged terrain.

SPEED: SLOW
TERRAIN: ROUGH
NOTE: CARD #19 OR #20 IS REQUIRED FOR ALL ROVER MISSIONS

20

Remote Manipulator Arm

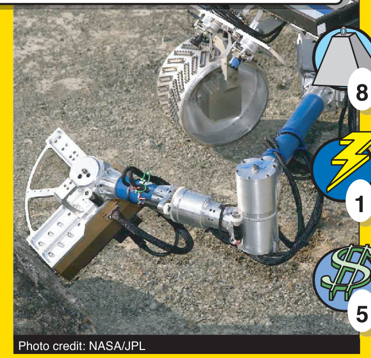


Photo credit: NASA/JPL

This is a standard "robot arm" that can be used either to pick up samples for analysis directly or can have a number of experiment tools attached to it.

SCIENCE RETURN: +1

21

Geological Studies Drill

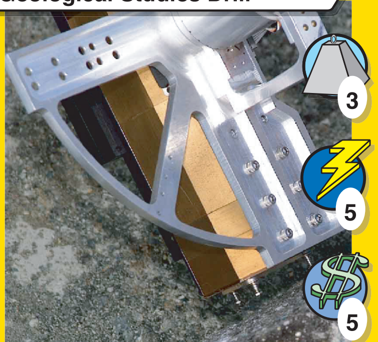


Photo credit: NASA/JPL

The surface of many rocks have been changed by their environment. To perform detailed geological studies, we must drill into the rock and take samples from below its surface.

SCIENCE RETURN: +1

22

Atmospheric Entry Shield

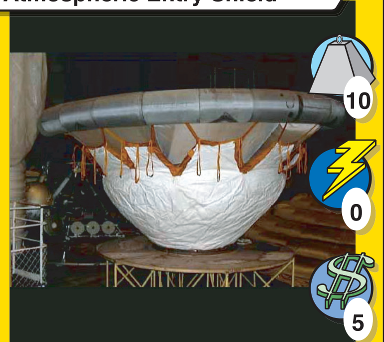


Photo credit: ESA

This system is needed for all missions that travel into the atmosphere of a planet. Without this system the spacecraft will burn up as it enters the planet's atmosphere.

NOTE: CARD #23 IS REQUIRED FOR ALL LANDER & ROVER MISSIONS

23

Airbag Landing System

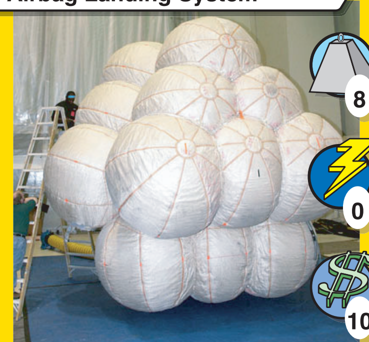


Photo credit: NASA/JPL

This system can be used with a parachute to provide a safe landing for a spacecraft without using retro-rockets. The spacecraft will bounce and roll many times, so precise landings are very difficult.

NOTE: CARD #24 OR #25 IS REQUIRED FOR ALL LANDER & ROVER MISSIONS

24

Retro-Rocket Landing System

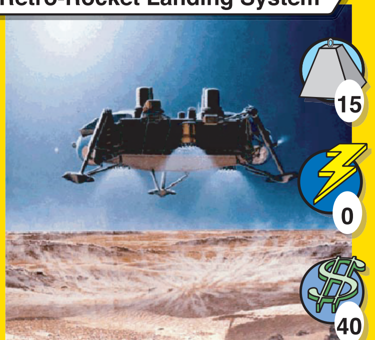


Photo credit: NASA

This retro-rocket can slow the spacecraft down to a very safe, controlled, pinpoint landing, enabling landings in areas not reachable with an airbag system.

NOTE: CARD #24 OR #25 IS REQUIRED FOR ALL LANDER & ROVER MISSIONS

25

Impact Probe

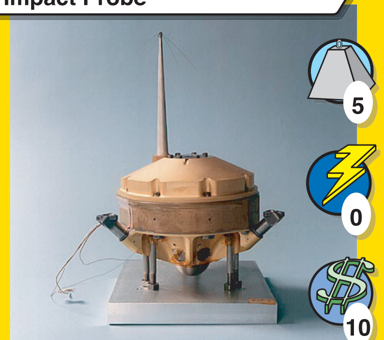


Photo credit: NASA/JPL

This is a small, self-contained spacecraft that is dropped from the main spacecraft. The probe hits the surface at high speeds, allowing it to take readings from below the surface.

SCIENCE RETURN: +1

26

Rotating Instrument Mount

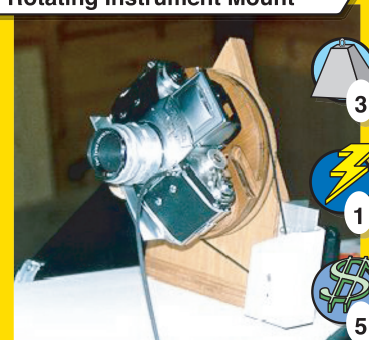


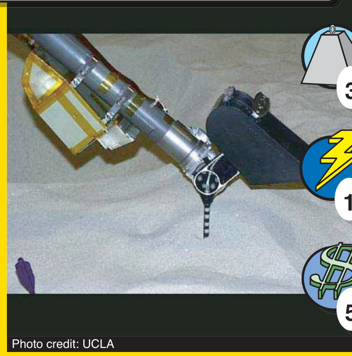
Photo credit: Berthold Hamburger

This system can be used to hold scientific instruments or cameras so that they can get a 360-degree view of their surroundings without having to move the spacecraft.

SCIENCE RETURN: +1

27

Soil Sample Collection Scoop



3

1

5

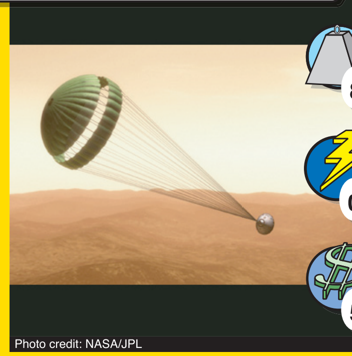
Photo credit: UCLA

This instrument can be used with a remote manipulator arm (card #21) to allow soil samples to be brought into the spacecraft for analysis. This system is required for the life science laboratory instrument (card#14).

SCIENCE RETURN: +1

28

Parachute Landing System



8

0

5

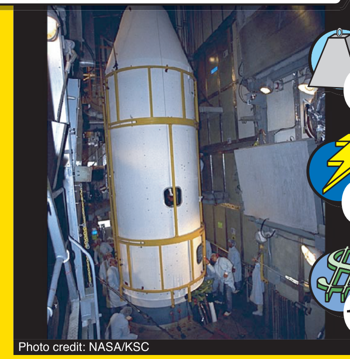
Photo credit: NASA/JPL

This system will slow the spacecraft so that a rocket or airbag landing system can take over in the final stages of descent.

NOTE: CARD #29 IS REQUIRED FOR ALL LANDER & ROVER MISSIONS TO PLANETS WITH AN ATMOSPHERE

29

Payload Shroud



7

0

10

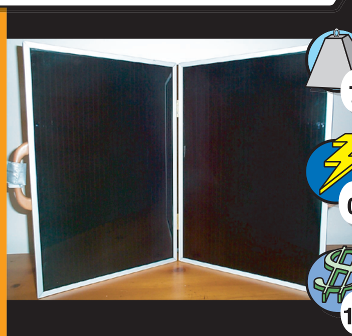
Photo credit: NASA/KSC

The payload shroud protects the spacecraft as it travels through the Earth's atmosphere during launch. The shroud is thrown off when the spacecraft leaves the atmosphere.

NOTE: CARD #30 IS REQUIRED FOR ALL MISSIONS EXCEPT SPACE-LAUNCHED MISSIONS

30

10-Watt Solar Panel



7

0

10

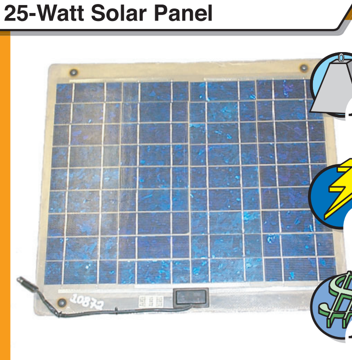
Photo credit: Connecticut Solar LLC

Solar panels provide energy for as long as they are exposed to the Sun. You must also have an on-board battery (card #34).

POWER GENERATED: 10 Power Units
MISSION LENGTH: 3 Months
LANDING SITES: Equator Only

31

25-Watt Solar Panel



15

0

15

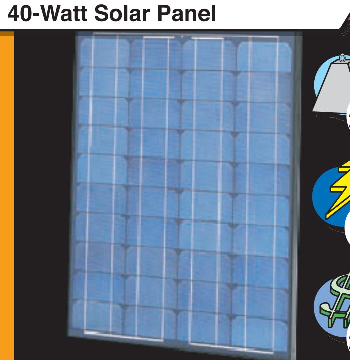
Photo credit: UCAR UNAVCO Facility, Boulder, Colorado

Solar panels provide energy for as long as they are exposed to the Sun. You must also have an on-board battery (card #34).

POWER GENERATED: 25 Power Units
MISSION LENGTH: 3 Months
LANDING SITES: Equator Only

32

40-Watt Solar Panel



20

0

25

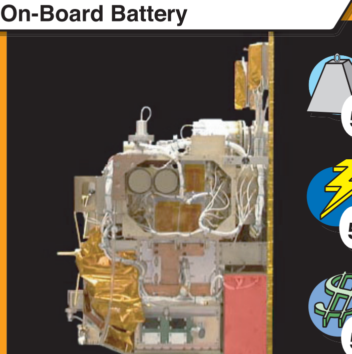
Photo credit: MTM LLC.

Solar panels provide energy for as long as they are exposed to the Sun. You must also have an on-board battery (card #34).

POWER GENERATED: 40 Power Units
MISSION LENGTH: 3 Months
LANDING SITES: Equator Only

33

On-Board Battery



5

5

5

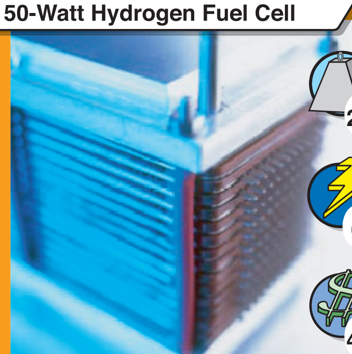
Photo credit: Boston University

This battery is used to store power produced by solar panels so that the spacecraft will have power when the Sun is not visible. It does not produce power itself.

POWER GENERATED: 0 Power Units

34

50-Watt Hydrogen Fuel Cell



25

0

40

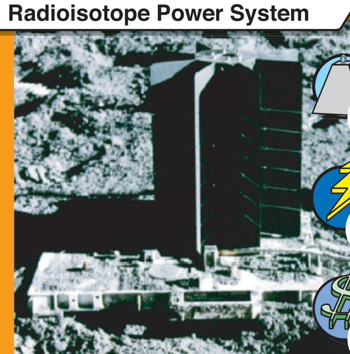
Photo credit: Intelligent Energy Limited

This power source combines hydrogen and oxygen to produce electrical power. It does not need sunlight or an on-board battery.

POWER GENERATED: 50 Power Units
MISSION LENGTH: 2 Weeks
LANDING SITES: Anywhere

35

Radioisotope Power System



30

0

75

Photo credit: NASA/LPRI

An RPS uses heat from the decay of radioactive elements to produce electricity. It does not need sunlight or a battery.

POWER GENERATED: 75 Power Units
MISSION LENGTH: 3 Years
LANDING SITES: Anywhere

36

Standard Central Microprocessor

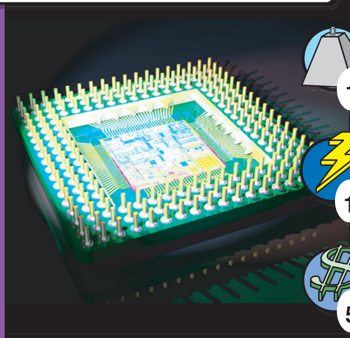


Photo credit: nanoelectronics.jp

This is the "brain" for your spacecraft. This model provides only the basic functions required to operate the spacecraft and return the data to Earth.

NOTE: CARD #37 OR #38 IS REQUIRED FOR ALL MISSIONS

37

Adv. Central Microprocessor

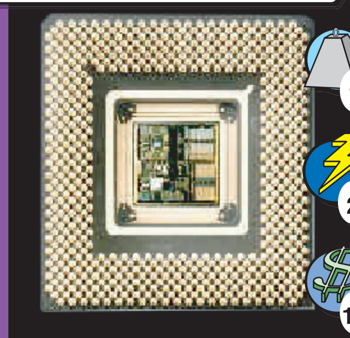


Photo credit: Digital

This is an advanced "brain" which can accomplish all of the basic mission tasks and has enough intelligence to make simple decisions of its own.

SCIENCE RETURN: +1

NOTE: CARD #37 OR #38 IS REQUIRED FOR ALL MISSIONS

38

High-Gain Antenna

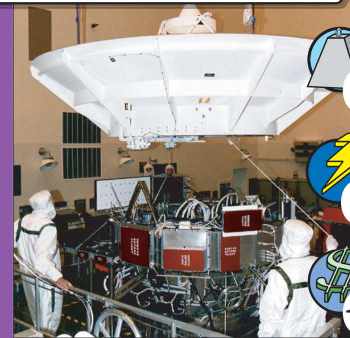


Photo credit: NASA/KSC

This is the primary means of sending data and commands between the spacecraft and the Deep Space Network on Earth. It can send large amounts of data at one time.

SCIENCE RETURN: +1

NOTE: CARD #39 OR #40 IS REQUIRED FOR ALL MISSIONS

39

Low-Gain Antenna

Photo credit: Space-technology.com

The low-gain antenna can serve as a back-up system for communicating data and commands between the spacecraft and the Deep Space Network on Earth, but cannot send much information at one time.

NOTE: CARD #39 OR #40 IS REQUIRED FOR ALL MISSIONS

40

Main Memory Card

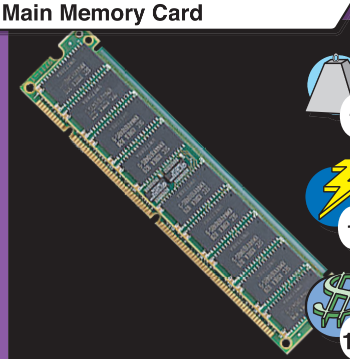


Photo credit: Viking Interworks

Because the spacecraft does not have a continuous link with controllers on Earth, the main memory card must store all the data taken by the spacecraft until it can be transmitted back to Earth.

NOTE: CARD #41 IS REQUIRED FOR ALL MISSIONS

41

Main Bus

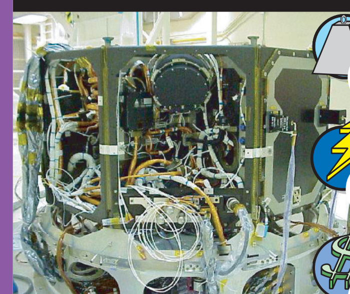


Photo credit: California Institute of Technology

The main bus serves as the electronic "backbone" for the spacecraft. All power, instruments and computers will connect to this bus in order to be able to communicate with each other on board the spacecraft.

NOTE: CARD #42 IS REQUIRED FOR ALL MISSIONS

42

Spin-Off: Automobile Sensors

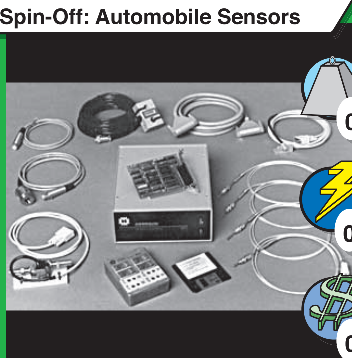


Photo credit: Dyno Data Acquisition Systems

The sensors you developed for your mission have an application to automobile monitoring. Thanks to your research, automobiles can be made more energy efficient and easier to maintain.

ADD $25,000,000 TO YOUR BUDGET

43

Spin-Off: Communications

Photo credit: Sony Ericsson

The new communications radios developed for your spacecraft can also be used to improve wireless telephone networks. Thanks to your research, people all over the world can now stay in touch more easily.

ADD $35,000,000 TO YOUR BUDGET

44

Spin-Off: Weather Prediction

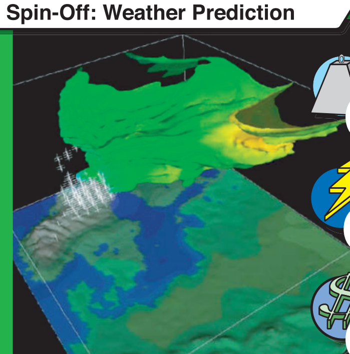


Photo credit: Interdisciplinary Centre for Mathematical and Computational Modeling

The observations made and techniques you developed have led to a better understanding of Earth's atmosphere. Scientists can now better predict severe weather, saving money as well as lives.

ADD $15,000,000 TO YOUR BUDGET

45

Budget Cut!

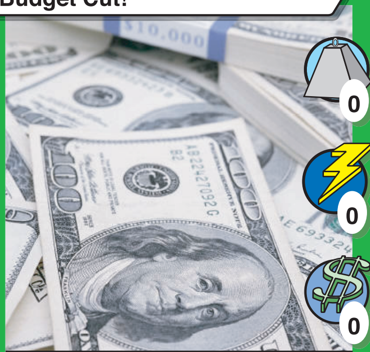


Photo credit: Microsoft Office ClipArt gallery

Congress has reduced NASA's overall budget for space missions. As a result your budget has been reduced as well.

SUBTRACT $25,000,000 FROM YOUR BUDGET

46

Booster Failure!

Photo credit: NASA/DSN

There was a problem during the testing of your booster. Roll a die (or draw one card from card numbers 1-6). If the number that comes up is greater than the reliability of your booster, your booster has failed and you must buy a new one!

47

Hardware Failure!

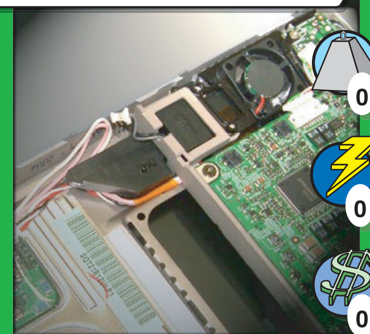


Photo credit: Medical Macintosh

One piece of your mission hardware has failed! Take all of your cards (except booster cards) and draw one at random. That system has failed— remove the card. If you have a backup system installed, there is no penalty. If you no longer have all the required cards, your mission fails!

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MARSBOUND: MISSION TO THE RED PLANET
SPACECRAFT DESIGN MAT

MARS EXPLORATION PROGRAM

This Certifies That

has successful completed

Marsbound!
Mission to the Red Planet

and is now a Certified Mission Planner