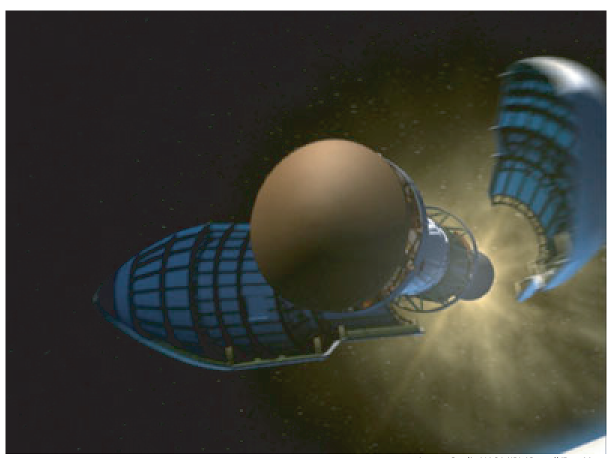
Marsbound!

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.