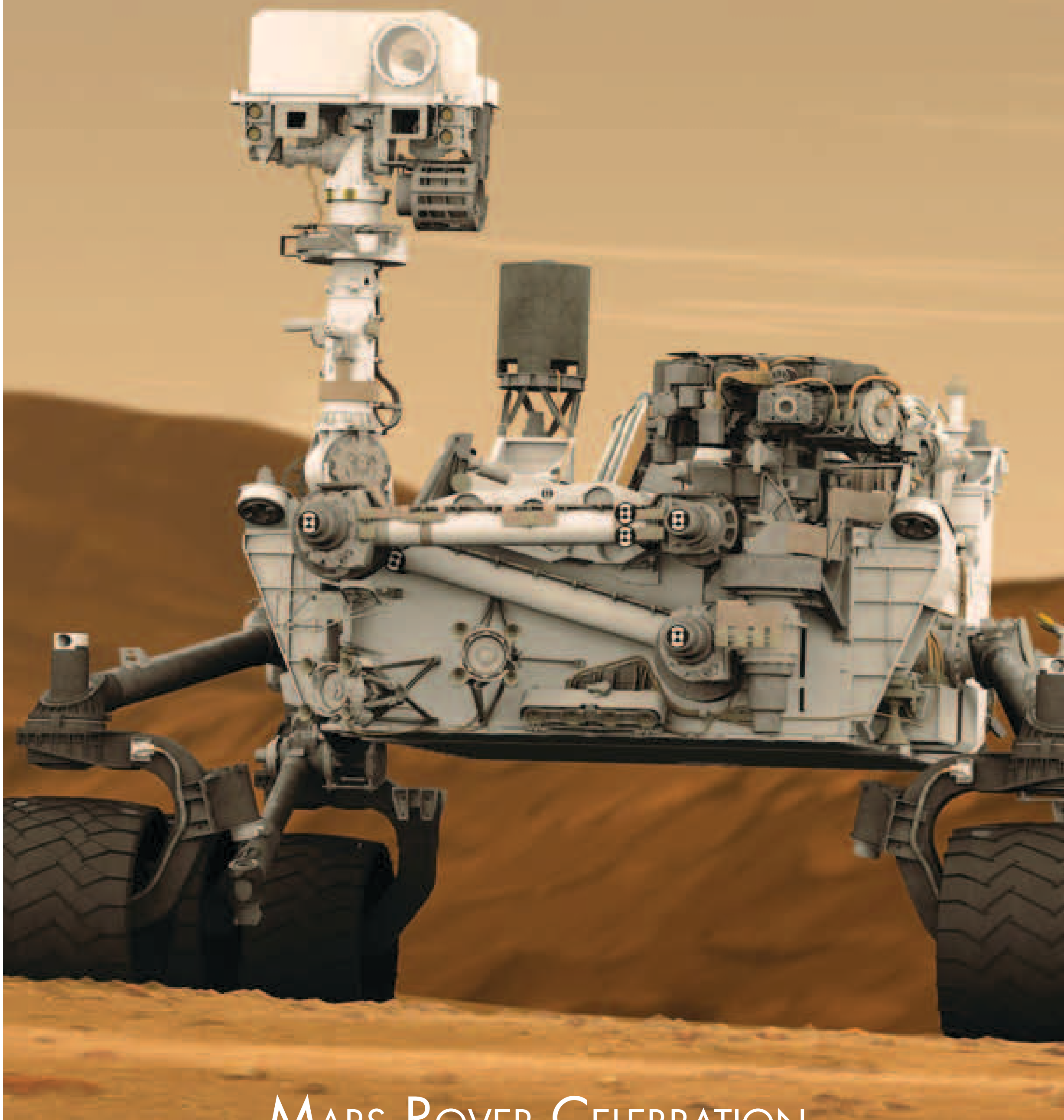
AIAA

educator academy



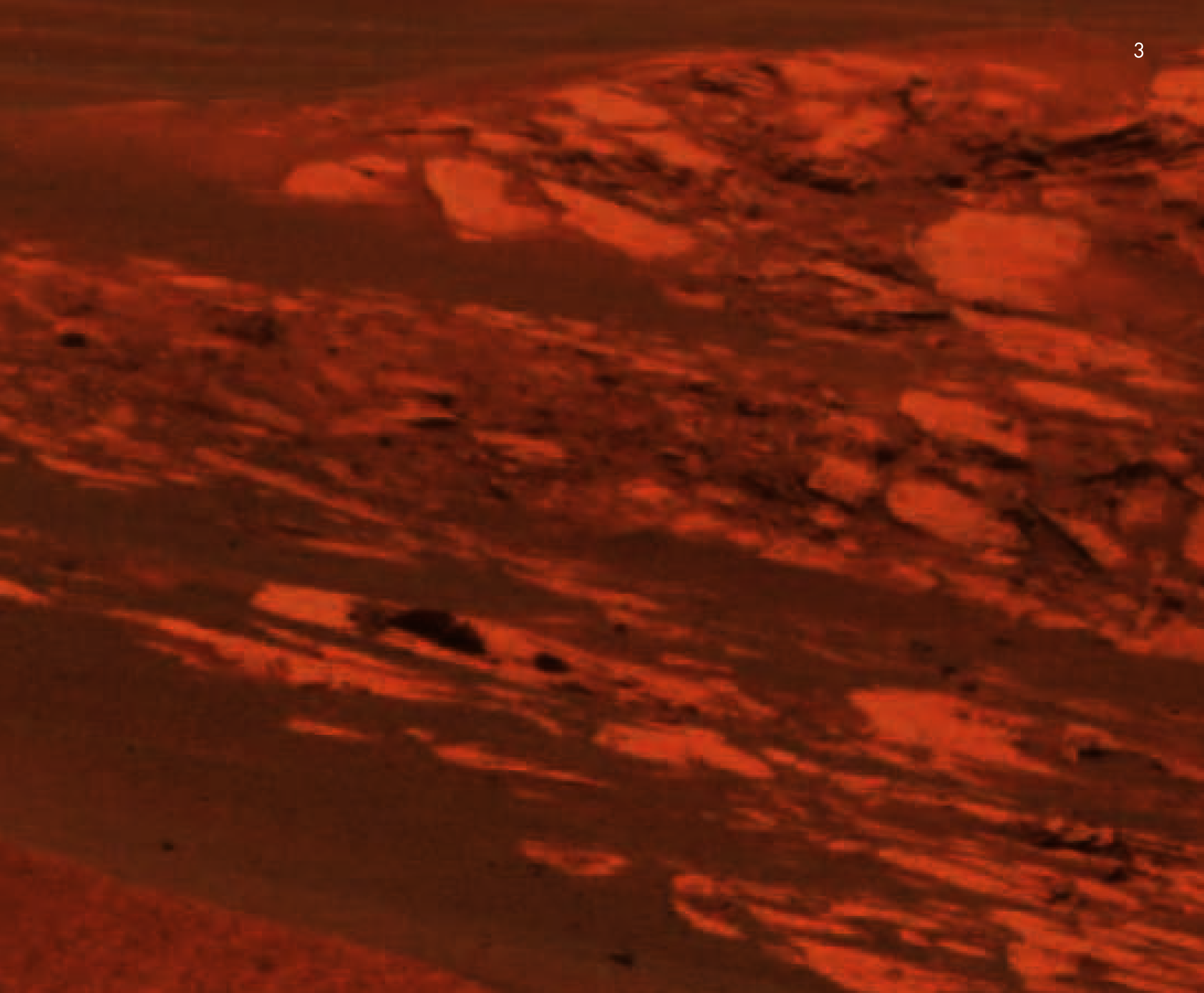
Mars Rover Celebration Curriculum Module

AIAA

The World's Forum for Aerospace Leadership

Table of Contents

Photo Credit NASA/JPL-Caltech/Cornell University



Acknowledgments

The American Institute of Aeronautics and Astronautics STEM K–12 Outreach Committee would like to thank the following individuals and organizations for their dedication to STEM education and their contributions to the AIAA Educator Academy.

AIAA STEM K–12 Curriculum Development Team:
Ben Longmier
Elizabeth Henriquez
Tom Milnes
Paul Wiedorn
Edgar Bering
Elana Slagle

AIAA STEM K–12 Partners and Supporters:
The AIAA Mid-Atlantic Section
The AIAA Houston Section
The University of Houston
The AdAstra Rocket Company
Colonel Neal Barlow

About the American Institute of Aeronautics and Astronautics

Our History: Two Pioneering Traditions United

For more than 70 years, AIAA has been the principal society of the aerospace engineer and scientist. But we haven't always been AIAA, or even one organization.

In 1963, the two great aerospace societies of the day merged. The American Rocket Society and the Institute of the Aerospace Sciences joined to become AIAA. Both brought long and eventful histories to the relationship – histories that stretched back to 1930 and 1932 respectively, a time when rocketry was the stuff of science fiction and the aviation business was still in its infancy.

Each society left its distinct mark on AIAA. The merger combined the imaginative, risk-taking, shoot-for-the-moon outlook of Project Mercury-era rocket, missile, and space professionals with the more established, well-recognized, industry-building achievers of the aviation community. The resulting synergy has benefited aerospace ever since.

Today, with more than 35,000 members, AIAA is the world's largest professional society dedicated to the progress of engineering and science in aviation, space, and defense. The Institute continues to be the principal voice, information resource, and publisher for aerospace engineers, scientists, managers, policymakers, students, and educators. AIAA is also the go-to resource for stimulating professional accomplishment and standards-driven excellence in all areas of aerospace for prominent corporations and government organizations worldwide.

AIAA STEM K–12 Outreach

AIAA offers a wide range of learning, career enhancement, and employment opportunities for the aerospace community.

Our programs engage each generation of aerospace engineers. Beginning with STEM learning opportunities for K–12 students, AIAA provides the tools and resources necessary for educators and students to take their understanding of aerospace to the next level. Our growing community of university students is invited to take part in design competitions, scholarships, and internships, and receives discounts on textbooks and conferences. Additionally, aerospace professionals can participate in our many conferences and continuing education courses, and use our career development services, promoting career enhancement and professional growth.

AIAA is committed to supporting STEM education and provides complimentary lifetime memberships to K–12 educators. For more information on joining AIAA as an Educator Associate, please visit **www.aiaa.org/join.**

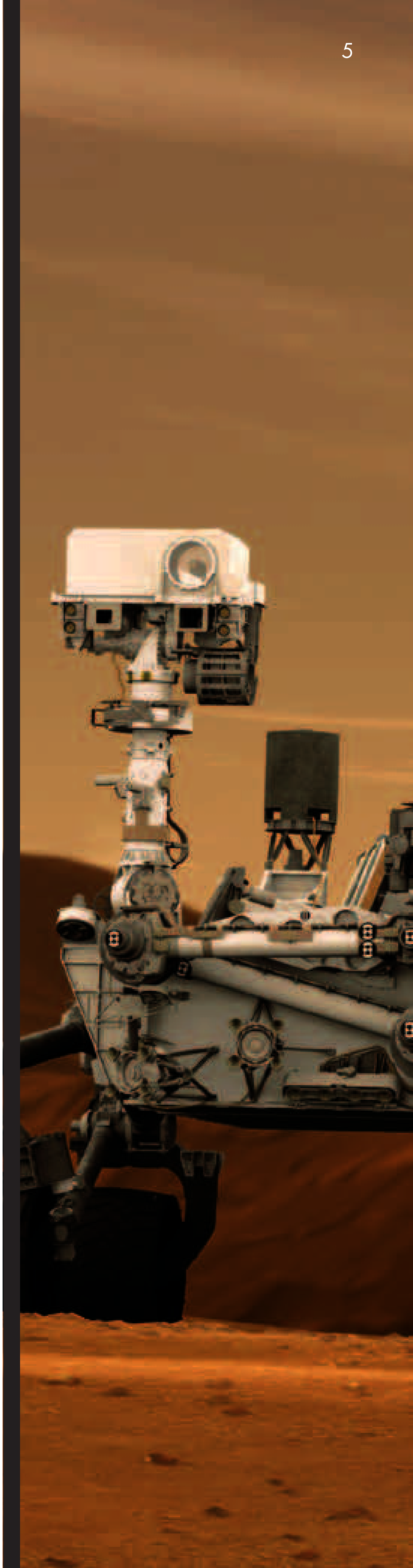
AIAA Educator Academy Curriculum Module Overview

This interdisciplinary module encompasses Martian geology, vulcanology, atmospheric science, biogeophysics, and space physics, as well as the engineering disciplines of aerospace engineering, electrical engineering, power systems engineering, thermal management, robotics, mechanical engineering, and systems design. In language arts, reading comprehension, technical writing, and oral communication skills are developed. Student study skills are also addressed through the development of organizational, interpersonal, and project management skills. The underpinning of students learning through this program is the implementation of a curriculum using instructional strategies that promote comprehension, knowledge retention, and student interest and motivation.

The Mars Rover Celebration module (Bering et al., 2005) integrates interdisciplinary science content with applied engineering principles in an inquiry-focused but outcomes-based mission project. Targeted at students in grades 3–8, it can be implemented as a six-week fall semester classroom-learning or homework project on Mars, or as the basis for an after-school informal education project, and may be used as part of a unit in classes studying general science, Earth science, solar system astronomy, or robotics, or as a multidisciplinary unit that spans courses. The heart of the Mars Rover Celebration module is an inquiry-based collaborative learning process. The program begins with students learning about the mission design process, the design criteria for a rover, and conducting basic research on Mars. The students do the research using NASA Mars mission curriculum enrichment materials and the main NASA Mars mission websites. Students apply this knowledge to design their own Mars mission.

The required outputs of the Mars Rover Celebration module for each team (2–6 students) are:

1. A written statement of their mission that provides justification and explains its goal and operational objectives;
2. A detailed budget narrative for the rover;
3. An organized and coherent Rover Guide booklet that illustrates their knowledge about Mars science, the design of the mission, and how the model sho uld function on Mars;
4. A mock-up model of a Mars rover, designed and built by each team to carry out their selected science mission on Mars; models are constructed for less than \$10 to \$25 of found objects and simple art supplies; if desired, teachers may supply students with a low cost (\$10) solar-powered car kit or a low-cost remote-control car to serve as the chassis; and
5. A presentation about their rover that describes, explains, and demonstrates their mission and model, illustrates their understanding of Mars and Mars rover technology, and includes a question and answer session at the closing.



Continued

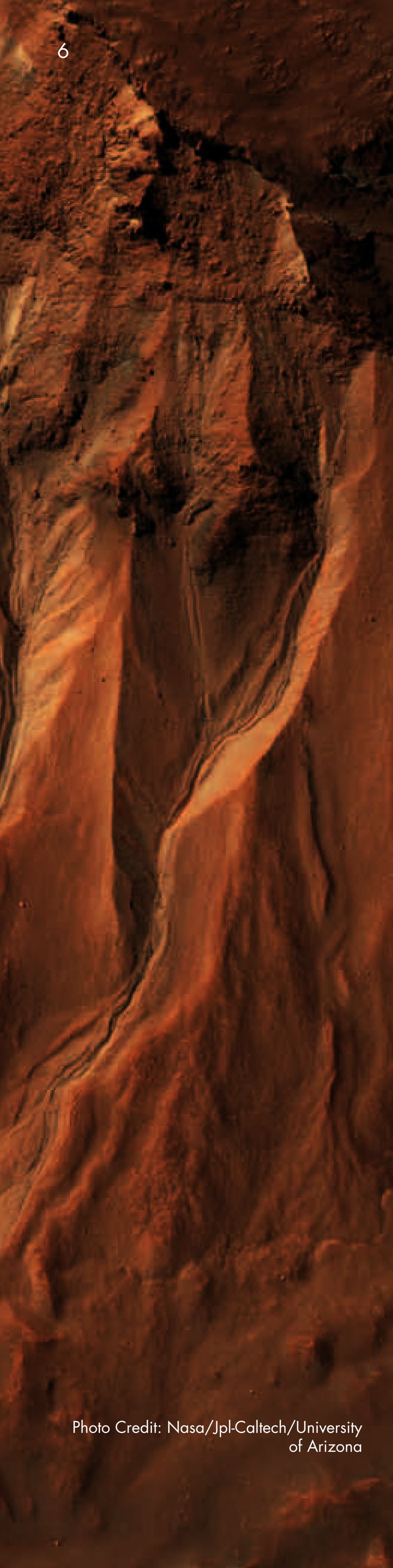


Photo Credit: Nasa/Jpl-Caltech/University of Arizona

The Mars Rover Celebration module was designed to introduce a new basic paradigm into the arsenal of teachers and youth leaders looking for vehicles to promote STEM education. It changes the character of the traditional extracurricular science activity (i.e., science fair) from prescriptive to innovative, from monolithic to interdisciplinary, from competitive to elaborative, from individual to collaborative and team-based, from institutional to cross-institutional, from the extrinsic to the intrinsic. The Mars Rover Celebration module is carefully designed to set students' imagination and creativity free in a way that science fairs do not and to encourage them to discover for themselves how much fun a STEM career can be.

At the end of the project, each school may have the option to select teams to participate in a capstone event where they showcase their projects to invited volunteer professionals in STEM fields and to the public, and receive feedback in the form of an evaluation. The teams present what they have learned, the skills they have developed, and their excitement about a STEM project through their models and their oral and written presentations. This culminating event brings together teachers, informal educators, parents, and students with scientists and engineers, designed to foster close interactions. In a situation where student, teacher, and parents have never known any working adult engineers, professors, or graduate students, one cannot overestimate the value and power of such relationships. Usually, a nearby college campus will be the venue for this event, allowing for the arrangement of tours of participating research labs and facilities, further reinforcing exposure to professionals and careers in a STEM field. The kids learn first-hand that real space scientists also have kids, pets, and a sense of humor.

For additional AIAA Educator Academy Curriculum Modules or to download additional resources for the Mars Rover Curriculum Module, please visit:
www.AIAASTEMeducation.org
www.marsrover.org

Glossary of Terms

aphelion, perihelion: Aphelion is the point on a planet's orbit when it is furthest from the Sun. Perihelion is the point on a planet's orbit when it is closest to the Sun. Earth's perihelion occurs about January 2nd–5th.

atmospheric pressure: Pressure is the force per unit area exerted by a fluid. Atmospheric pressure is the pressure of the ambient atmosphere of a planet. All planetary atmospheres have pressure. The term atmospheric pressure refers to a local variable whose value will depend on the planet, altitude, location and time. On Earth, we measure the atmospheric pressure with barometers. Formally, the SI unit for pressure is the Pascal, which is defined as 1 N/m^2. Other units of convenience for pressure include the bar, mm (and inches) of mercury, and torr.

bar, millibar: The bar is a unit of pressure that is defined to be 100,000 N/m^2 (100 kiloPascal). It is about a percent less than the mean atmospheric pressure at sea level on the Earth, which is 1.013 bar. A millibar is 1/1000 of a bar.

conjunction: This term refers to the geometry of a planet's visible position in the sky relative to the Sun. A planet is at conjunction when it is closest to the Sun in the sky. For the inner planets, Mercury and Venus, there are two types of conjunction: inferior conjunction means the planet is between the Sun and the Earth and superior conjunction means the planet is on the far side of the Sun from the Earth. The outer planets only exhibit superior conjunction.

opposition: This term refers to the geometry of a planet's visible position in the sky relative to the Sun. A planet is at opposition when it is directly opposite from the Sun in the sky, which means it is highest in the sky at midnight.

Valles Marinares: The largest canyon on the surface of Mars. It is longer than the United States is wide and is wider than the north-south extent of Arizona.

Standards Correlation Matrices

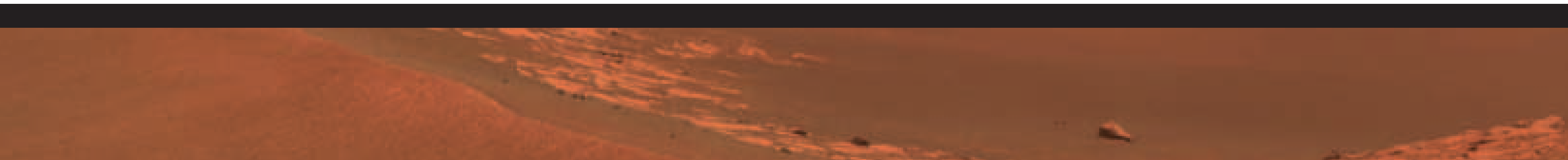
As different educators take different approaches to teaching each segment of the content, this section indicates the national standards that correlate to the Mars Rover Curriculum Module as a whole.

The Mars Rover Curriculum Module steps can be found in detail in the paper "Mars Rover Models - - A Program to Enrich Teaching Space Science, Planetary Exploration and Robotics in Elementary and Middle School" by Edgar A. Bering III, John Ramsey, Brenda Boyko, Holly Smith, Sandy Peck, and William H. Arceneaux.– *Proceedings of the AIAA 43rd Aerospace Sciences Meeting*, Paper AIAA-2005-0285, Reno, NV, January 10–13, 2005.

National Education Technology Standards for Students (NETS·S)

Creativity and Innovation	
Apply existing knowledge to generate new ideas, products, or processes	●
Create original works as a means of personal or group expression	●
Use models and simulations to explore complex systems and issues	●
Identify trends and forecast possibilities	
Communication and Collaboration	
Interact, collaborate, and publish with peers, experts, or others employing a variety of digital environments and media	●
Communicate information and ideas effectively to multiple audiences using a variety of media and formats	●
Develop cultural understanding and global awareness by engaging with learners of other cultures	
Contribute to project teams to produce original works or solve problems	●
Research and Information Fluency	
Plan strategies to guide inquiry	●
Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media	●
Evaluate and select information sources and digital tools based on the appropriateness to specific tasks	●
Process data and report results	●

Critical Thinking, Problem Solving, and Decision Making	
Identify and define authentic problems and significant questions for investigation	●
Plan and manage activities to develop a solution or complete a project	●
Collect and analyze data to identify solutions and/or make informed decisions	●
Use multiple processes and diverse perspectives to explore alternative solutions	●
Digital Citizenship	
Advocate and practice safe, legal, and responsible use of information and technology	
Exhibit a positive attitude toward using technology that supports collaboration, learning, and productivity	●
Demonstrate personal responsibility for lifelong learning	
Exhibit leadership for digital citizenship	
Technology Operations and Concepts	
Understand and use technology systems	●
Select and use applications effectively and productively	
Troubleshoot systems and applications	
Transfer current knowledge to learning of new technologies	



National Science Standards K–4; 5–8

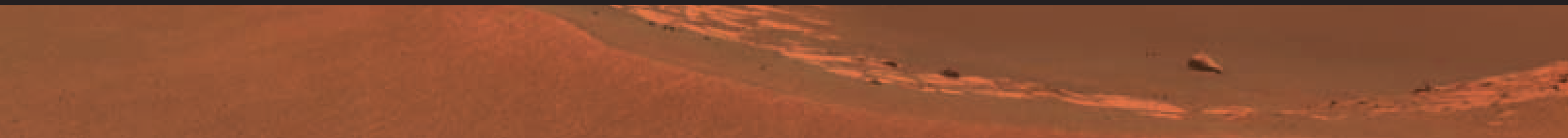
Unifying Concepts and Processes, K–4	
Systems, order and organization	●
Evidence, models and explanation	●
Change, constancy and measurement	●
Evolution and equilibrium	
Form and function	●
Science as Inquiry	
Abilities necessary to do scientific inquiry	●
Understanding about scientific inquiry	●
Physical Science	
Properties of objects and materials	
Position and motion of objects	●
Light, heat, electricity and magnetism	
Life Science	
The characteristics of organisms	
Life cycles of organisms	
Organisms and environments	
Earth and Space Science	
Properties of earth materials	●
Objects in the sky	●
Changes in earth and sky	●
Science and Technology	
Abilities of technological design	●
Understanding about science and technology	●
Abilities to distinguish between natural objects and objects made by humans	●
Personal and Social Perspectives	
Personal health	
Characteristics and changes in populations	
Types of resources	
Changes in environments	
Science and technology in local challenges	
History of Nature and Science	
Science as a human endeavor	●

Unifying Concepts and Processes, 5–8	
Systems, order and organization	●
Evidence, models and explanation	●
Change, constancy and measurement	●
Evolution and equilibrium	
Form and function	●
Science as Inquiry	
Abilities necessary to do scientific inquiry	●
Understanding about scientific inquiry	●
Physical Science	
Properties and changes of properties in matter	
Motions and forces	●
Transfer of energy	
Life Science	
Structure and function in living systems	
Reproduction and heredity	
Regulation and behavior	
Populations and ecosystems	
Diversity and adaptations of organisms	
Earth and Space Science	
Structure of the Earth system	●
Earth's history	●
Earth in the solar system	●
Science and Technology	
Abilities of technological design	●
Understanding about science and technology	●
Personal and Social Perspectives	
Personal health	
Populations, resources, and environments	
Natural hazards	
Risks and benefits	
Science and technology in society	●
History and Nature of Science	
Science as human endeavor	●
Nature of science	●
History of science	●

National Math Standards K–12

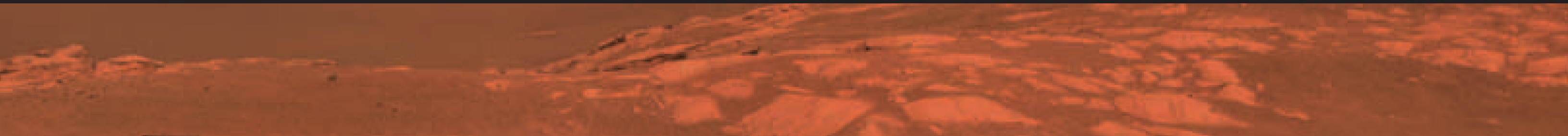
Number and Operations	
Understand numbers, ways of representing numbers, relationships among numbers, and number systems	
Understand meanings of operations and how they relate to one another	●
Compute fluency and make reasonable estimates	●
Algebra	
Understand patterns, relations, and functions	
Represent and analyze mathematical situations and structures using algebraic symbols	
Use mathematical models to represent and understand quantitative relationships	
Analyze change in various contexts	
Geometry	
Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships	
Specify locations and describe spatial relationships using coordinate geometry and other representational systems	
Apply transformations and use symmetry to analyze mathematical situations	
Use visualization, spatial reasoning, and geometric modeling to solve problems	●
Measurement	
Understand measurable attributes of objects and the units, systems, and processes of measurement	●
Apply appropriate techniques, tools, and formulas to determine measurements.	●
Data Analysis and Probability	
Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them	
Select and use appropriate statistical methods to analyze data	
Develop and evaluate inferences and predictions that are based on data	
Understand and apply basic concepts of probability	

Problem Solving	
Build new mathematical knowledge through problem solving	●
Solve problems that arise in mathematics and in other contexts	●
Apply and adapt a variety of appropriate strategies to solve problems	●
Monitor and reflect on the process of mathematical problem solving	
Reasoning and Proof	
Recognize reasoning and proof as fundamental aspects of mathematics	
Make and investigate mathematical conjectures	
Develop and evaluate mathematical arguments and proofs	
Select and use various types of reasoning and methods of proof	
Communication	
Organize and consolidate their mathematical thinking through communication	
Communicate their mathematical thinking coherently and clearly to peers, teachers, and others	●
Analyze and evaluate the mathematical thinking and strategies of others	
Use the language of mathematics to express mathematical ideas precisely.	
Connections	
Recognize and use connections among mathematical ideas	●
Understand how mathematical ideas interconnect and build on one another to produce a coherent whole	
Recognize and apply mathematics in contexts outside of mathematics	
Representation	
Create and use representations to organize, record, and communicate mathematical ideas	●
Select, apply, and translate among mathematical representations to solve problems	
Use representations to model and interpret physical, social, and mathematical phenomena	



National Language Arts Standards K–12

Standard	Description	
Reading for Perspective	Students read a wide range of print and non-print texts to build an understanding of texts, of themselves, and of the cultures of the United States and the world; to acquire new information; to respond to the needs and demands of society and the workplace; and for personal fulfillment. Among these texts are fiction and nonfiction, classic and contemporary works.	●
Understanding the Human Experience	Students read a wide range of literature from many periods in many genres to build an understanding of the many dimensions (e.g., philosophical, ethical, aesthetic) of human experience.	
Evaluation Strategies	Students apply a wide range of strategies to comprehend, interpret, evaluate, and appreciate texts. They draw on their prior experience, their interactions with other readers and writers, their knowledge of word meaning and of other texts, their word identification strategies, and their understanding of textual features (e.g., sound-letter correspondence, sentence structure, context, graphics).	●
Communication Skills	Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.	●
Communication Strategies	Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences for a variety of purposes.	
Applying Knowledge	Students apply knowledge of language structure, language conventions (e.g., spelling and punctuation), media techniques, figurative language, and genre to create, critique, and discuss print and non-print texts.	
Evaluating Data	Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and non-print texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience.	●
Developing Research Skills	Students use a variety of technological and information resources (e.g., libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.	●
Multicultural Understanding	Students develop an understanding of and respect for diversity in language use, patterns, and dialects across cultures, ethnic groups, geographic regions, and social roles.	
Applying Non-English Perspectives	Students whose first language is not English make use of their first language to develop competency in the English language arts and to develop understanding of content across the curriculum.	
Participating in Society	Students participate as knowledgeable, reflective, creative, and critical members of a variety of literacy communities.	
Applying Language Skills	Students use spoken, written, and visual language to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).	●



Background Information for Educators

Pedagogy

Module Review

The program begins with students forming into teams. Working in these teams, the students will learn the properties and characteristics of a planet, information about Mars, and quite a lot about the skills needed to conduct basic research concerning Mars. The students do the research using NASA Mars mission curriculum enrichment materials and the main NASA Mars mission websites. Students apply this knowledge to identify a Mars science question that is of burning interest to them. Using the scientific method, the students will then be guided in developing a list of the measurements needed to address their science question. They will study the mission design process, the design criteria for a rover, and then design their own Mars mission to make these measurements.

Pedagogical Rationale

The study of planetary motion and of the nature of the solar system was one of the major parts of the effort that led to the development of physics as a science. Unfortunately, today's children do not actually get to see the night sky often enough to understand what planets are or why they were considered so important. One of the major objectives of this program is to provide students with some motivation for getting back in touch with the sky around us.

One of the key structural concepts behind the whole enterprise of science is that scientific knowledge is not a matter of belief; it is a matter of fact. Science must be derived from a sound basis of data and observation. Good science is based on multiple examples and repeated observations. Science is best evaluated if we understand the process used to make the measurements. Planetary science is an essential part of any Earth science course because planetary studies provide additional, sometimes contrasting examples of the fundamental physics and chemistry of planetary interiors, surfaces and atmospheres. Many standard Earth Science curriculum objectives can be equally well addressed by learning about the same phenomena on a planet such as Mars. Furthermore, the Mars Rover Celebration module includes a detailed study of the methods used in planetary exploration. Learning about methodology will empower students to think critically about the validity of any scientific results that they may encounter later in life.

Current Science Questions

The Mars Rover Celebration team has identified a few mission choices that you can suggest to your students as starting points for their mission development activity. Emphasize that these are general starting points that can and should be refined and made more specific during the course of their work.

Design and build a model rover that will accomplish one or more of the following missions:

1. Explore the craters on Mars. Your vehicle will try to find a crater suitable for use as a domed settlement site. It should make measurements, test the soil, and take photographs.
2. Explore the polar ice caps of Mars. Mars has carbon dioxide ice and water ice. Your vehicle should determine how much of each type of ice there is and map the distribution and depth. Samples of the ice should be analyzed for impurities and its potential to be purified for future manned missions.
3. Explore the valleys of Mars. Rift valleys will provide information about the geologic history of the planet, while river valleys might provide clues as to the sources of past water or evidence of ancient forms of life. Devise a method to collect samples and analyze them.
4. Analyze the weather at several sites that have been identified as possible areas for future settlement. Instruments will need to make careful measurements of temperature, wind, and the composition of the atmosphere (gases and water vapor).
5. Identify the elements and compounds found in the rocks and soil of Mars. Determine how much oxygen is present, and whether the soil could be used for planting or if metal ores are present for future mining.
6. Search for forms of water on Mars possibly found in a layer of frozen soil, called permafrost. Your vehicle will be exploring the areas near the poles, drilling tens to hundreds of meters below the surface, providing data for future Mars colonies.
7. Explore for fossils of ancient life forms in the riverbeds and the canyons of Mars. Samples that are collected will need to be mapped, analyzed, and photographed.
8. Search for present life on Mars in the polar regions. Microbes have been found in the permafrost and glaciers on Earth; some remain dormant until they are warmed up. Design a system to gently warm and analyze polar and permafrost samples, looking for similar occurrences on Mars.
9. Develop your own concept based on recent scientific developments.

Teachers should keep in mind that mission 9 is the most empowering and fun for the students. This choice initiates a process that is investigative learning in its purest form. Also keep in mind that all of the other eight are actually too broad to form the basis of a successful effort without choosing a more specific question. The students should be encouraged to refine the mission concept based on Mars research prior to initiating the rover design phase of the module. For example, Mission 3 involves exploring an area larger than the United States. The students will have to make decisions that focus this mission on a specific canyon and specific strata. These decisions should be question driven and based on the outcome of their library and internet research. Teachers will be required to help them start the investigation and to guide it toward meaningful conclusions without doing it for them.

Spacecraft Development

The Mars Rover Model Celebration emulates the entire spacecraft mission development process. During the science portion of the module that was just discussed, the students have selected and fleshed out an investigation of their choice. By this point, they should have begun to develop a list of the measurements required to address their question. This list of measurements is the initial set of requirements that the spacecraft designer will use to begin the process of developing the required rover. In this way, the celebration requires the students to learn about the engineering design process and the interplay between science and engineering in carrying out complex scientific investigations.

Distances and their Consequences

Education research has shown that the distance scale of the solar system is one of the hardest concepts for young children to grasp. For example, many younger students, if asked, will tell you that the Sun is closer than a neighboring state. Since the distances involved dictate some of the engineering choices that must be made in designing their rover, interactive activities aimed at building better mental models of the solar system will be important in the middle of the project. Two major issues tend to crop up, the supply chain and command and control. Since most kids have some familiarity with radio-controlled toys, use of teleoperation, or operation from a distance, is a frequent design choice made during rover brainstorming. However, this is not a useful "real-Mars" approach, since Mars is 4 light minutes away at closest approach and 20 light minutes away at its farthest. Eight minutes round trip interaction time is much too long of a delay time for teleoperation to work. Another related concern is refueling on the one hand and sample return on the other. Many teams assume that they can easily shuttle stuff back and forth to their rover. Working with them to get them to understand for themselves why this is impractical will be a significant challenge. Solving it will address one of the most fundamental and pervasive misconceptions elementary students have in solar system astronomy.

Surface Environment

Mars has an extremely challenging surface environment. The surface is rugged. Even at its flattest, the surface is boulder strewn. There are also sand pits and crusty weak soil to trap the unwary. The temperatures are usually very cold, corresponding to polar conditions on the Earth. The air is very tenuous and does not support combustion. However, there is enough air and high enough wind to allow large scale dust storms. Erosion and abrasion by wind-blown and wheel-churned dust are major design challenges. Finally, the amount of sunlight available for solar power is less than half that at the Earth.

Rover Design

The team will need to develop a rover design that delivers the required instruments to appropriate sites to make their measurements. These requirements impose design choices on the landing and mobility systems. It will then need to store, organize and transmit the data back to Earth. The required computer and telemetry system will impose another set of major design constraints. The rover will require a power system rugged enough to withstand the expected temperature range and abrasion from the dust.

Mars

Description

Mars is the fourth planet from the Sun. It is about 1.5 times as far away from the Sun as the Earth. The Mars year is roughly twice an Earth year, but the Mars day is about the same as the Earth's. It has a diameter about half that of the Earth and a surface gravity about 38% of the Earth's. Mars has a tenuous atmosphere composed largely of carbon dioxide. The average surface pressure of 7 millibars is slightly less than 1% the surface pressure on the Earth. Since the temperature at the South Pole in winter is colder than the freezing point of carbon dioxide, the total atmospheric pressure has an annual variation of about 25%. Temperatures on Mars range from 140˚K (–133˚C, –207˚F) at the South Pole in winter to almost 300˚K (27˚C, 80˚F) in the deep equatorial canyons at noon on a summer day.

Mars has no bodies of liquid water on the surface, no lakes or oceans. The surface area of Mars is about equal to the surface area of the dry land on Earth, which means that there is as much surface for geology studies as there is on Earth. Most Earth science surface morphology learning objectives can be met by studying Martian surface features. Mars also has examples of geological processes not typically seen on the Earth that are instructive compare and contrast cases. The big shield volcanoes and Valles Marinares are examples of terrain types found on the Earth, but taken to extremes. The surface age of Mars is intermediate between the Earth (where most of the surface is less than a few million years old) and the Moon (where most of the surface is more than 3.8 billion years old).

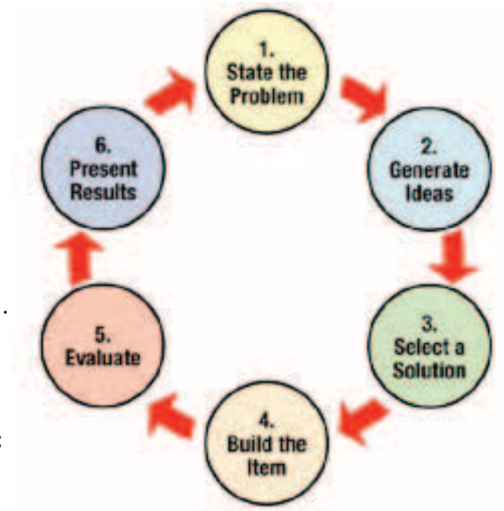
Since the Earth is the third planet from the Sun, Mars comes second closest to the Earth of any of the planets. At perihelic opposition, Mars can be closer than 56 million km. For comparison, Venus can be as close as 40 million km at inferior conjunction. The fascination of many people with Mars stems from the fact that planetary observations are a lot easier to make during opposition, when Mars is highest in the sky at midnight, than they are during conjunction, when Venus appears at dusk or dawn. The observations that can be made from the Earth's surface show a planet that is enough like Earth to raise fascinating possibilities about the presence of life.

Properties of Mars

	Earth	**Mars**
Distance from the Sun (km)	149,598,262	227,936,824
Mean Radius (km)	6,371.0	3,389.5
Volume (km^3)	1.08321 x 1012	1.63116 x 1011
Mass (kg)	5.9722 x 1024	6.4169 x 1023
Surface Gravity (m/s^2)	9.81	3.7
Rotation Period (Earth Days)	0.99727	1.02596
Orbit Period (Earth Years)	1.00000	1.8808
Inclination of Equator to orbit	23.45°	25.19°
Min/Max Surface Temperature	-88/58 C	-143/17 C
Atmospheric Constituents	Nitrogen, Oxygen	Carbon Dioxide, Nitrogen
Moons	1	2

Engineering Design Process for Elementary Students

Engineers and scientists create new products and systems every day. In order to create a new product that solves a common problem or a system for making something better, engineers follow a process. Similar to the Scientific Method, the Engineering Design process is a series of steps used to guide an engineer through solving a problem.



State the Problem

What is the problem that you are trying to solve? Try to be as specific as possible. Tell what the problem is and explain why it needs to be solved.

Generate Ideas

How will you solve the problem? Brainstorm ideas to solve your problem. You can write a list, draw a picture, or create an idea web.

Select a Solution

Which idea is best? Examine your ideas and decide which one is the best. To decide, think about which idea does the best job of solving your problem and which one makes the most sense.

Build the Item

What will it look like? Draw or build your solution. Use common materials to show that your idea will work.

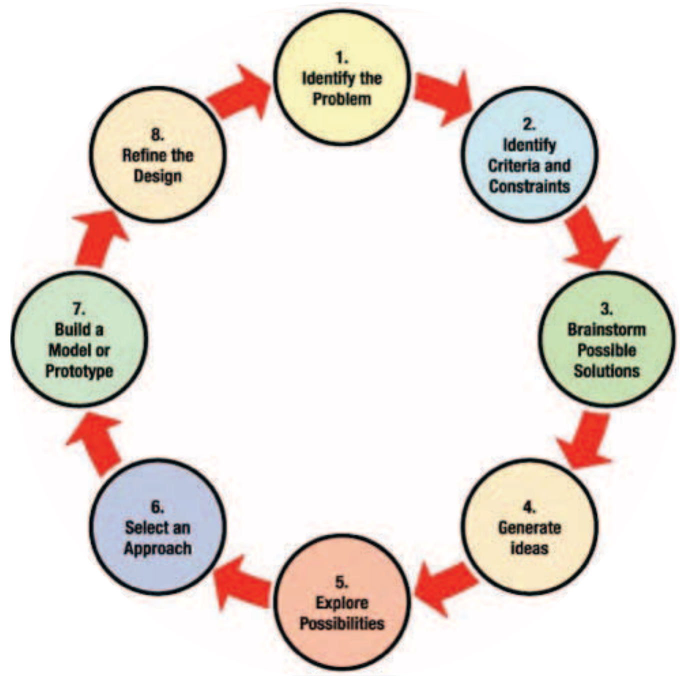
Evaluate

Did it work? Examine your prototype to see if it works the way you wanted it to. If it does, work to make it better or easier. If it does not work, try building it differently.

Present Results

How did it turn out? Share your results and ask others what they think. Use their suggestions to make your solution better

Engineering Design Process for Secondary Students



Engineers and scientists create new products and systems every day. In order to create a new product that solves a common problem or a system for making something better, engineers follow a process. Similar to the Scientific Method, the Engineering Design process is a series of steps used to guide an engineer through solving a problem.

Identify the Problem

State the problem that you will solve. Be sure to identify what the problem is, why it needs to be solved, and who will benefit from the solution. Describe how existing solutions fail to address the problem.

Identify the Criteria and Constraints

Specify any criteria and constraints that your solution must encompass to be successful. Write a design brief containing all of the key information to help focus on the solution.

Brainstorm Possible Solutions

Sketch or list as many ideas as you can, focusing on the details in your design brief. List all ideas you think of even if they may seem impractical.

Generate Ideas

Select a few of your brainstormed solutions to develop further. Create isometric drawings and/or orthographic diagrams, being sure to accurately label all measurements.

Explore Possibilities

Share and discuss your developed ideas to determine which one to pursue. Create a pro/con chart or a matrix for your design brief to determine which idea best fits to solve the problem and meet your criteria and constraints.

Select an Approach

Examine your pro/con chart or your matrix to decide which idea is the best approach. Add a statement to this effect to your design brief. Explain why you have selected this approach and how it will succeed where other solutions have failed.

Build a Model or Prototype

Construct a full-sized or scale-model based on your isometric and/or orthographic drawings. Your model should be made from easily found and low cost materials, but should an operating version of your chosen solution.

Refine the Design

Test your solution, making changes when necessary, to refine your design. Continue to record your findings in your design brief until you have designed and tested your final product.

Mars Rover Unit Plan

Week 1

Students will begin the project by learning and researching about Mars. Specifically, students should know and be able to research features and planetary data about Mars such as:
- Basic facts, gravity, temperature, etc.
- Atmosphere, weather
- Current and previous land features
- Signs of previous life, fossil evidence
- Moons and how they compare to the Earth's Moon

Students will also need to gather information critical for a Mars space probe by learning:
- How space probes communicate and conduct experiments
- Why language plays such an important role in communication
- How space probes are designed to survive in harsh/hostile conditions
- How rovers are designed and tested

During this week, students will need the abilities to identify research objectives, collect and organize data from multiple sources, and collectively decide how to best use the information gathered. Students should be reminded to keep track of all resources for use in a bibliography at the end of the project.

If the class plans on participating in the Mars Rover Celebration Capstone event, teachers will need to review competition rules and register for the event.

Week 2

Students will continue to investigate Mars and will:
- Investigate features of NASA's probes and available power sources
- Understand the harsh conditions of Mars
- Begin to think about possible design their own Mars Rovers*
- Think about needed equipment/features of their rovers

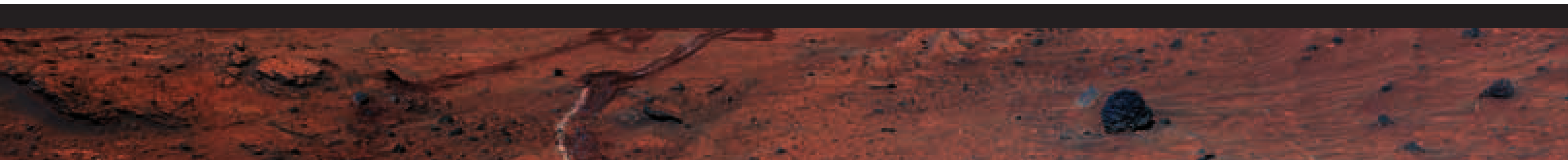
*Students should be reminded that if they choose to purchase a kit to use as the chassis of their rover, their total costs must not exceed $25.

During this week, students will need the ability to decide how to best use the information gathered, analyze their findings, and determine what components will be needed on their rovers. Students should be reminded that next week they will be put into groups to begin designing and building their rovers.

Week 3

Students will begin to work in design teams and will:
- Be divided into teams of 3 or 4
- Determine their Mars Rover challenge (download Mars Rover Mission Choices)
- Brainstorm technology and features needed to accomplish the mission
- Obtain consensus from their teams to determine 2–3 mission objectives
- Examine a map to determine an appropriate landing site
- Begin collecting group data in the Mars Rover Guides
- Create initial rover design

During this week, students will need the ability to solve problems, work together to make decisions, and continue to collect and analyze data in their Mars Rover Guides. Students should be reminded that they are responsible for creating an initial design or draft that incorporates their team's ideas.



Week 4

Students will continue to work in their design teams and will:
- Begin building their rover models using found/craft materials*
- Continue to collect data in their Mars Rover Guides
- Review conditions on Mars and ensure the design will carry out those specific functions
- Review features of NASA's probes and power sources
- If participating in the Mars Rover Celebration capstone event, review competition criteria

*Review safety guidelines for using any materials and tools available in the classroom.

During this week, students will need the ability to work cooperatively, make team decisions, and ensure that their rover will carry out the missions they selected. Students should be reminded to continue to keep track of expenditures as no rover can cost more than $25.

Week 5

Students will work cooperatively in their design teams and will focus on:
- Planning their mission and presentation
- Continuing to update their Mars Rover Guide
- Identifying critical information such as Mars landing coordinates
- Describing how the rover will handle/overcome conditions on Mars and how it will communicate with Earth
- Begin a bibliography of resources used

During this week, students will need the ability to explain their rover's key features and capabilities, write a script for their group presentation, and collect their research in to a bibliography. Students should be reminded that use of props, and costumes during their skits are encouraged.

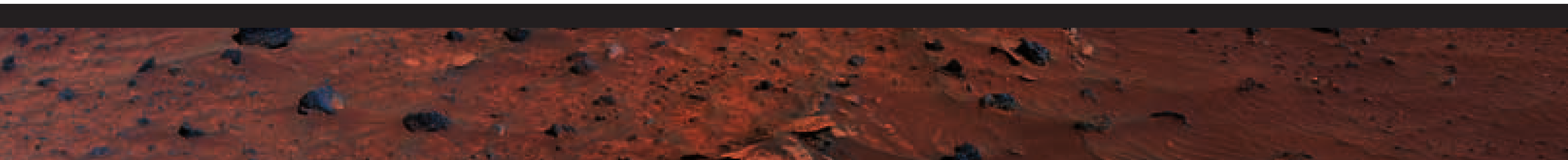
Week 6

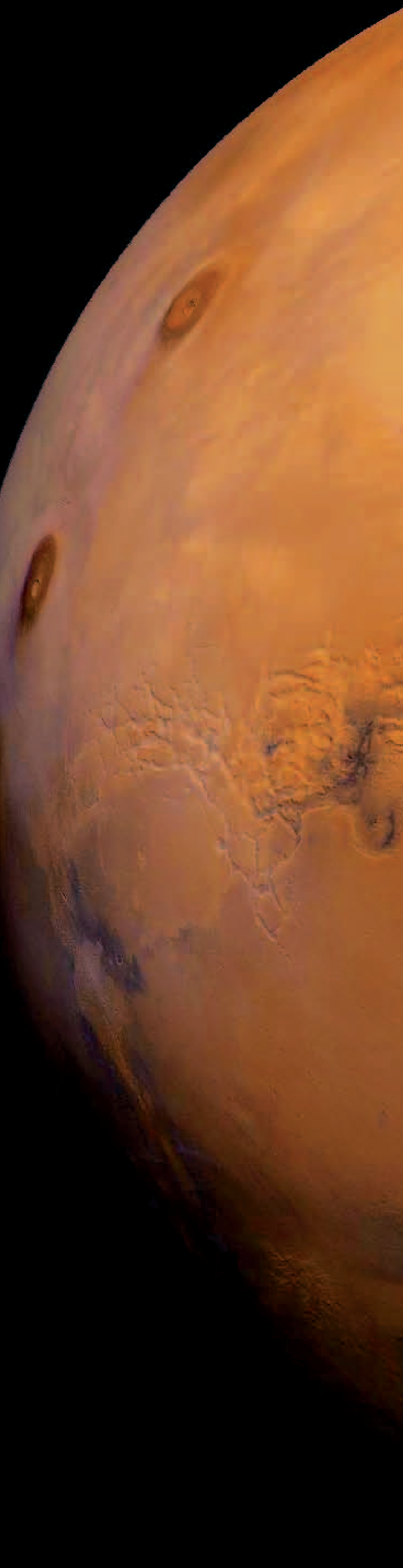
Students will continue to work in their design teams to:
- Polish their presentations/skits
- Work out last minute details of rover capabilities and functions
- Complete their Mars Rover Guide
- Collect and document any expenses
- Document each team member's contribution to the project

During this final week, students will need the ability to work together as a team to assemble the necessary requirements to finish the project. Students should be encouraged to collect and arrange their materials on a display board or poster.

For the Teacher

For additional AIAA Educator Academy Curriculum Modules or to download additional resources and lessons for the Mars Rover Curriculum Module, please visit:
www.AIAASTEMeducation.org
www.marsrover.org





APPENDIX

Mars Rover Mission
Guide Forms
Elementary Version

MARS ROVER CELEBRATION

Rover Guide

Group/Rover Name:

School/Organization:

Marathon Oil Corporation

UNIVERSITY of HOUSTON
YOU ARE THE PRIDE

AIAA

Rover Design Team Members:

Mars Landing Coordinates:

Latitude: ______ Longitude: ______

Purpose/Goals of the Rover Mission:

Important Facts/Notes:

Describe how the rover will overcome the conditions on Mars.

Explain how the rover will be powered and controlled.

Describe how the rover will communicate with Earth to send and receive data.

Bibliography and Resources Used:

Budget (Maximum $25 plus cost of Kelvin Solar Racer Kit). Please attach receipts.

Explain the jobs done by each member of the project team:

Mars Rover Mission
Guide Forms
Middle School Version

Mars Rover Celebration

Mission to Mars

Rover Components

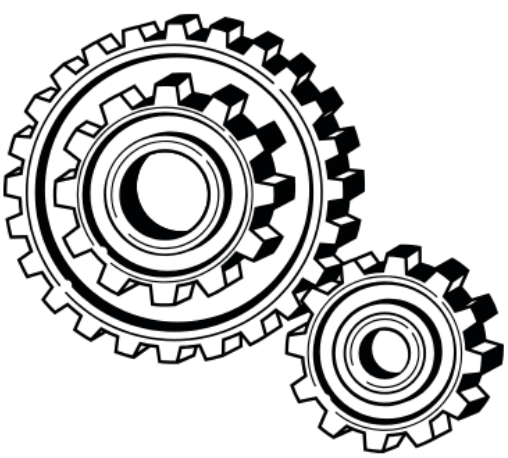
Draw and label parts, take a picture of each part, or describe it in writing

POWER SOURCE
Solar panels, battery, etc.

TRACTION COMPONENTS
Wheels, worm wheels, robotic feet, hover craft, etc.

PROPULSION COMPONENTS
Gears, propellers, etc.

MISSION COMPONENTS
Cameras, soil collectors, drills, etc.



Marathon Oil Corporation

UNIVERSITY of HOUSTON
YOU ARE THE PRIDE

AIAA
The World's Forum for Aerospace Leadership

Rover Mission

ROVER TRANSPORT

MISSION

LANDING PROCEDURES
AND LANDING COORDINATES

LANDING SITE VALIDATION
(Why was this site chosen?)

MISSION PROCEDURES
(How will the mission be accomplished?)

Rover Telecommunications Capabilities

Diagram/Photo/Drawing of Telecommunications Devices (Satellites, radio, digital camera, etc.)	Telecommunication Device Functions How will this device send data from Mars? How will this device receive data from Earth?

Mars Atmospheric and Terrain Obstacles

ATMOSPHERIC CONDITIONS How will the atmospheric conditions affect entry, landing, survival?	MARS TERRAIN CONDITIONS What type of surface/soil materials will the rover have to move over to complete its mission?

ROVER GROUND GEAR AND PROCEDURES How will the rover overcome the harsh terrain of Mars?

Rover Financial Report

Rover Part	Quantity	Price
Total Cost Of Project	>>>>>	

Attach all receipts to this page

Mars Rover and Planetary Research

INTERNET RESEARCH SITES
(http://www address, title of web page, author, website date)

STANDARD BIBLIOGRAPHY RESOURCES (BOOKS, MAGAZINES, etc....)
Author name, Article Title, Book or Magazine Name, Date of Publishing

ADDITIONAL COOL FACTS ABOUT YOUR ROVER AND THE MISSION

Planetary Information:
http://mars.jpl.nasa.gov
http://mars.jpl.nasa.gov/participate/marsforeducators/
http://marsoweb.nas.nasa.gov/landingsites/index.html
http://nssdc.gsfc.nasa.gov/planetary/factsheet/marsfact.html
http://pds.nasa.gov/planets/special/mars.htm
http://science.nationalgeographic.com/science/space/solar-system/mars-article/
http://solarsystem.nasa.gov/planets/profile.cfm?Object=Mars
http://www.factmonster.com/dk/science/encyclopedia/mars.html
http://www.factmonster.com/science/astronomy/planet-mars.html
http://www.kidsastronomy.com/mars.htm
http://www.marsonearth.org
http://www.nineplanets.org/mars.html
http://www.planetfacts.net/Mars-Facts.html
http://www.sciencekids.co.nz/sciencefacts/planets/mars.html
http://www.solarviews.com/eng/mars3d.htm

Mars Missions:
http://mars.jpl.nasa.gov/
http://mars.jpl.nasa.gov/mer/
http://mars.jpl.nasa.gov/MPF/index1.html
http://mars.jpl.nasa.gov/msl/
http://mars.jpl.nasa.gov/msp98/lander
http://mars.jpl.nasa.gov/programmissions/
http://marsrovers.jpl.nasa.gov/home/index.html
http://www.planetary.org/explore/space-topics/space-missions/missions-to-mars.html

Photo Galleries:
http://science.nationalgeographic.com/science/photos/mars/
http://photojournal.jpl.nasa.gov/targetFamily/mars
http://science.howstuffworks.com/mars-landing-pictures.htm

Mars/Space Resources:
http://www.aiaa.org
http://airandspace.si.edu/etp/mars/MARSresources.html
http://ares.jsc.nasa.gov/ares/education/program/destinationmars.cfm
http://mars.jpl.nasa.gov/classroom/pdfs/MSIP-MarsActivities.pdf
http://mars.jpl.nasa.gov/participate/marsforeducators/
http://teachspacescience.stsci.edu/cgi-bin/ssrtop.plex
http://www.educationworld.com/a_lesson/lesson/lesson003.shtml
http://www.mars2030.net/
http://www.nasa.gov/audience/foreducators/index.html
http://www.nasa.gov/mission_pages/mars/images/index.html

Educational Materials:
http://www.nasa.gov/offices/education/about/index.html
Is there Water on Mars?
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Is.There.Water.on.Mars.html

Posters:
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Mars_The_Red_Planet_Poster.html

Lithographs:
Mars Pathfinder Lithograph Set
http://er.jsc.nasa.gov/seh/Mars_Pathfinder_Lithograph_Set.pdf
Mars Lithographs
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Our_Solar_System_Lithograph_Set.html
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Mars_Lithograph.html

Videos / CD-ROMS / Slide Sets:
CORE – Central Operation of Resources for Educators list of Multimedia on Mars –
http://corecatalog.nasa.gov/searchform.cfm?query=mars

Mars – Past, Present, Future VHS Video & CD-ROM– Finley-Holiday Film Corp.
http://www.finley-holiday.com

Pathfinder and Best of Mars Picture CD – Finley-Holiday Film Corp.
http://www.finley-holiday.com

Online Tools:
http://www.google.com/mars Does not provide latitude and longitude.
http://www.google.com/earth/index.html Mars in Google Earth does.
http://www.worldwidetelescope.org/Home.aspx
http://www.worldwidetelescope.org/whatis/whatIsWWT.aspx?Page=Mars

Books:
Moons and Planets, William K. Hartmann, 5th Edition, Brooks Cole, 2004. ISBN-13: 978-0534493936

The New Solar System, J. Kelly Beatty, Carolyn Collins Petersen, Andrew Chaikin, 4th Edition, Cambridge University Press, 1999. ISBN-13: 978-0521645874

Destination Mars: New Explorations of the Red Planet, Rod Pyle, Prometheus Books, 2012. ISBN-13: 978-1616145897

http://www.uapress.arizona.edu/onlinebks/MARS/CONTENTS.HTM