Marsbound! Mission to the Red Planet

Grades: 3rd – 5th Grade Prep Time: ~1 hour Lesson Time: 3 45-minute sessions

WHAT STUDENTS DO: Design a Mission to Mars.

Curious about how engineers design a Mars mission? In this fun, interactive card simulation, students experience the fundamentals of the engineering design process, with a hands-on, critical-thinking, authentic approach. Using collaboration and problem-solving skills, they develop a mission that meets constraints (budget, mass, power) and criteria (significant science return). This activity can introduce many activities in technology education, including robotics and rocketry.

NGSS CORE & COMPONENT QUESTIONS

HOW DO ENGINEERS SOLVE PROBLEMS?

NGSS Core Question: ETS1: Engineering Design

What Is a Design for? What are the criteria and constraints of a successful solution?

NGSS ETS1.A: Defining & Delimiting an Engineering Problem

What Is the Process for Developing Potential Design Solutions?

NGSS ETS1.B: Developing Possible Solutions

How can the various proposed design solutions be compared and improved?

NGSS ETS1.C: Optimizing the Design Solution

INSTRUCTIONAL OBJECTIVES

Students will be able to

IO1: **Generate and compare an analogous model of an engineering mission, limited by specified criteria and constraints and choosing appropriate interacting instruments in the "looking for signs of life" strategy on Mars.**

Last edited: April 24, 2014

2.0 Materials

Required Materials

Please supply:

- Equipment **Cards** – 1 per team
- Design **Mat** – 1 per team
    - These can be downloaded from http://marsed.asu.edu/lesson_plans/marsbound

Please Print:

From Student Guide

(A)	Student Instruction Sheet	– 1 per student
(B)	Student Pre-Ideas Worksheet	– 1 per student
(C)	Activity 1 Fact Sheet: Mars Exploration Science Goals	– 1 per student
(D)	Activity 1 Science Objectives Worksheets	– 1 per team
(E)	Activity 2 Identify Your Mission Goals Worksheets	– 1 per team
(F)	Activity 3 Building Your Spacecraft Fact Sheet	– 1 per team
(G)	Activity 4 Spacecraft Design Log	– 1 per team
(H)	Activity 4 Engineering Constraints	– 1 per student
(I)	Activity 5: Engineering Design Cycle	– 1 per student
(J)	Student Post-Ideas Worksheet	– 1 per student
(K)	Comparing Rover Missions Fact Sheet (optional)	– 1 per team

Optional Materials

From Teacher Guide

(L) "Marsbound" NGSS Alignment
(M) "Marsbound" CCSS Alignment
(N) "Marsbound" 21st Century Skill Alignment
(O) "Marsbound" NGSS Rubric
(P) "Marsbound" CCSS Rubric
(Q) "Marsbound" 21st Century Skill Rubric
(R) Placement of Instructional Objective and Learning Outcomes in Taxonomy

3.0 Vocabulary

Criteria	a standard list of "rules" established so judgment or decisions are based on objective and defined ideas rather than subjective ones.
Data	facts, statistics, or information.
Empirical Evidence	knowledge gained through direct or indirect observation.
Engineering	a field in which humans solve problems that arise from a human need or desire by relying on their knowledge of science, technology, engineering design, and mathematics (derived from NRC Framework, 2012).
Engineering Constraints	limits placed on your mission by the hardware you use to accomplish the mission.
Explanations	logical descriptions applying scientific information
Fly by	a spacecraft designed to go by a planet and study it on its way past.
Lander	a spacecraft designed to explore on the surface of a planet from a stationary position.
Mission	a spacecraft designed to explore space, seeking to answer scientific questions.
Models	a simulation that helps explain natural and human-made systems and shows possible flaws
Observations	specific details recorded to describe an object or phenomenon.
Orbiter	a spacecraft designed to explore space, seeking to answer scientific questions.
Planet	a sphere moving in orbit around a star (e.g., Earth moving around our Sun).
Predict	a declaration about what will happen based on reason and knowledge
Relationship	a connection between two objects
Rocketry	a branch of science that deals with rockets and rocket propulsion.
Rover	a robot designed to travel on the surface of a planet.
Scale	a comparative relation between objects such as size or distance.

4.0 Procedure

PREPARATION (~10 minutes)

A. PRINT THE FOLLOWING:

- Equipment **Cards** – 1 per team
- Design **Mat** – 1 per team
- Student **Worksheets (A-K)** – 1 per student

Teacher Tip: If you have printed the design mat and equipment cards from the website in black and white, ask your students to color the cards for you using a marker or colored pencil prior to laminating.

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

STEP 1: ENGAGE

Set up the Scenario of Mission Planning

A. Read the following:

Imagine that today, your school principal announces that you will be working on a new, very complex school project, a project that no one has ever done before. This project will be the single most important task you have ever been asked to complete thus far in your life. This project will be a group project, and you will be working with some people you know and others you don't know. Everyone in your entire group will need to complete the group project successfully or no one will pass. In fact, the project is so important, you will be working on it in every one of your classes, during an afterschool program, and as homework. You will probably be working on it at least 12+ hours a day and during many weeks; you will work through the weekend, too! You will have just 2 years to complete the project. The project is so complex and difficult, that you will have to revise and rewrite the plans for the project constantly. When the project deadline arrives, the group will have to show the completed project to the school, principal and, oh yes, all the news stations in the world will be there as well. You will have no extensions on the deadline. No pressure, but everyone is counting on you!

NASA mission planners, engineers, and scientists go through much the same process when designing and building space missions to Mars and other destinations. Many times, they are faced with tasks that have never been tried before. Imagine that they have spent 2 years of their lives, 12+ hours a day, planning, building, planning, testing, retesting, re-planning, re-building, re-testing, packaging, shipping, unpacking, testing, and re-testing, all in an attempt to do everything in their power to ensure their mission makes it to the surface of Mars.

B. Explain they will be participating in a simulation to design a mission to Mars. As part of "qualifying" for the mission planning, ask students to complete the Pre-Ideas.

This survey will help to establish their current understandings of mission planning and engineering constraints. Students will use this information during the Post-Ideas as part of their individual assessments.

C. Hand Out:

- **Marsbound! Student Guide (Worksheets A-K)** – 1 per student
- Equipment **Cards** – 1 per team
- Design **Mat** – 1 per team

Curiosity Connection Tip: For making a connection to NASA's Mars Rover "Curiosity," please show your students additional video and slideshow resources at:

http://mars.jpl.nasa.gov/participate/marsforeducators/soi/

STEP 2: EXPLORE

Construct a Science Question Requiring a Technological Design.

A. Activity 1: The purpose of this activity is to familiarize students with national goals for the exploration of Mars, and to enable students to categorize science questions according to these goals. Discuss NASA's four Mars Exploration Program goals and strategies with students. Working with their teams, students will categorize each question under each goal.

Teacher Tip: Keep in mind that a science question (mission objective) may apply to more than one science goal. There is no one "correct" answer; it is more important that your students can justify the reasons for the categorization.

NASA's four Mars Exploration Program goals

i. **Determine if life ever arose on Mars.** All life, as we know it, requires water to survive. In fact, on Earth we have found life wherever there is water, even in places we didn't think life could exist, such as frozen deserts of Antarctica. Is the same thing true of Mars? Because of the low temperatures and thin atmosphere of Mars today, we know that there is currently no liquid water on the surface of the planet. But was that always true?

ii. **Characterize the climate of Mars.** If we can understand what the climate of Mars is like today and how it changes, we will have a better idea of what the climate of Mars was like in the past. The atmosphere of Mars is mostly carbon dioxide, but two other important components are water vapor and dust. With enough information, we can begin to create a picture of the overall climate of Mars now and what it may have once been like.

iii. **Characterize the geology of Mars.** Rocks and minerals on the surface of Mars can tell us a great deal about a planet's past. By studying surface morphology and patterns and types of features found on the surface, we can find a permanent record of the history of Mars in its rocks.

iv. **Prepare for human exploration.** Humans are naturally curious. No robot will ever have the flexibility of a human explorer, so someday we will want to travel to Mars ourselves to study the planet and its history directly. Because of the difficulty and the number of challenges, robotic spacecraft must pave the way for humans to follow. One important task is to study new techniques for entering the Martian atmosphere and landing on the surface. We will also need to understand the dangers humans will face on the surface of Mars.

Differentiate between a Scientific Question and a Technological Design/Solution.

B. Activity 2: Student teams will discuss possible science objectives among themselves. Students will also determine a technological solution by deciding whether they want to fly a lander, orbiter, or fly-by mission to Mars.

Teacher Tip: 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 constraint is intentional, as it will guide them to revise their mission plan by going all the way back to the original Mission Goals page. This iterative process happens quite often in the real world as well.

Teacher Tip: In preparing students to make choices on whether to use a lander, orbiter, or fly-by, you can use the ***Strange New Planet*** for a hands-on activity about exploring new planets.

Design a Technological Solution.

C. Activity 3: Student teams will begin to design the actual spacecraft that they will use for their mission. To facilitate this, each typical system that could be onboard a spacecraft is presented on its own "trading card." Students will need to read each card carefully, as the text provides clues about the uses and limitation for that particular piece of hardware.

i. Important! Hold the **(Green) Special Events cards** until the end of the simulation.

ii. Students will begin the simulation by choosing a **(Red) Rocket Card and Rocket Nose Cone** (required). The rocket card will determine the ***Mass Limit*** for the mission and will include the ***Cost*** in millions of dollars. The nose cone will be additional ***Weight*** and money, so students will need to record this information into their ***(G) Spacecraft Design Log***.

iii. Students will then choose a **(Orange) Power System Card**. This card will determine the Power available during the mission.

iv. From here, students will choose their **(Purple) Computer Systems, (Aqua) Communication Systems**, and **(Blue) Science Instruments** cards to achieve their science goals stated in Activity 2. These will help to increase Science Return.

v. If students have chosen a rover or lander for their mission, rovers will need to include a **(Fuchsia) Mobility System**, and both rovers and landers will require **(White) Entry, Descent, & Landing Systems**.

vi. The final decision will be optional **(Yellow) Mechanical Systems**. These can increase the Science Return, but should be considered last due to budget constraints.

vii. Remind students to keep a tally in their ***(G) Spacecraft Design Log*** to ensure they are staying within budget, power and mass.

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

viii. When students have created a mission within budget, power, and mass, they can now select a **(Green) Special Events card**. Half of these cards are Spin-offs or advances in technology that can be commercialized. These add money to the budget. The other half of the cards is failures or cuts to the budget. These take away money from the budget. Allow students time to adjust their mission to accommodate these scenarios.

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

ix. The final step will be launch day. The Budget : Science Return ratio will establish the order of launch. For each mission, calculate the $/science ratio by dividing the amount of money spent on the mission by the number of science stars earned. The first place team with the lowest Science Return ratio and falling at or below budget, mass and power. Students will roll the die to determine if their mission launched successfully. The type of rocket they chose will determine the success rate. For example, the Heavy-Lift Rocket is high risk, only lifting off successfully 3 out of 6 times. If students roll a 1, 2, or 3, they lift successfully. If they roll a 4, 5, or 6, launch fails and the mission is over.

STEP 3: EXPLAIN

Analyze Constraints within a Technological Design.

Hand Out:
• Marsbound! A Mission to the Red Planet: **Worksheets (J-K)**

A. **Activity 4:** This activity focuses on the concept of engineering constraints and getting students to identify where they participated in the engineering design cycle throughout the lesson. Encourage students to think of everything that limited what they attempted to do with their mission, how they tested ideas, and how the team solved problems. Each of these examples should be written directly onto ***(K) Engineering Design Cycle***, demonstrating the iterative engineering process they have just participated in. Examples would include the limited mass that can be lifted by the rocket booster available, the electrical power that is required by each system onboard, and staying within the pre-determined budget including all of the group discourse and problem solving required to solve those engineering problems.

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

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

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

- **Size and Mass**: Some engineering constraints are due to the strength of the rocket you use to send your spacecraft to Mars. To send every instrument to Mars would require a rocket so large that it doesn't even exist.

- **Budget**: The United States Congress 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 budget. Bigger rocket boosters can carry bigger spacecraft. Unfortunately, they cost a lot more to launch.

- **Power**: Every spacecraft needs power in order to function. The more instruments that are onboard, the more power is needed for them to operate. ***Solar panels*** must be very large, but even so, still do not produce a lot of power. They require a great deal of direct sunlight to operate, so missions with solar panels are limited to being near the Martian equator, and can only operate for about 3 months of the year. ***Fuel cells*** create power through a chemical reaction much like batteries and produce a moderate amount of power, but they will only function for a limited period of time, generally only a few days or weeks. ***Radioisotope power systems*** (RPS) produce power from the heat generated by decaying radioactive materials. They produce a lot of power and can operate at any time of year and anywhere on the surface. They are quite heavy, extremely expensive, and require more precautions.

- **Reliability**: Some rockets are more reliable than others.

- **Bottom line**: Engineering constraints often force you to make trade-offs. These constraints may keep you from being able to achieve all of your science goals, so you have to choose the equipment that will allow you to achieve as many of your science goals as possible.

STEP 4: ELABORATE

Apply technological design skills to a novel problem.

A. Choose one of the following:

i. Ask students to trade their mission plan with another team. Each group will evaluate the mission teams science goal and objectives along with identifying any engineering constraints that might have been missed. Evaluation teams will make recommendations for improvement to the mission team.

ii. Rerun the simulation, planning for a sample return mission. A sample return mission would be a Surface to Earth Sample Return Mission. Teams will need to include.

a. **Surface to Earth Sample Return**: Budget = $500 million and will be valued at a Science Return of 5. The mission must include:
   i. A rover with robotic arm for sample collection
   ii. A launch vehicle to get the sample off of the planet or moon and into orbit
   iii. An orbiter to catch the launched sample

iii. A launch vehicle to get from the orbiter to Earth

iv. Research possible landing sites to consider additional engineering constraints.

v. Give student groups a copy of the Comparing Two Mars Rover Projects and ask them to reflect on the differences in the design of these Rover missions. What are some of the differences in engineering constraints that must have been overcome for each mission?

STEP 5: EVALUATE

Evaluate change in ability to solve engineering problems.

Hand Out:
• Marsbound! Mission to the Red Planet: **Worksheets (L)**

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

5.0 Extensions

1. Choose another activity from Step 4: Elaborate.

2. Have students submit a formal written proposal (utilizing Common Core State Standards and Next Generation Science Standards Arguing from Evidence) competing for additional funding for their proposed mission. Proposal winnings will not be calculated in Budget : Science Ratio allowing the bonus budget to remain a budget. An example that could be used on how to write a formal proposal: http://www.writing.eng.vt.edu/design/proposal_guidelines.html.

(A) Student Instruction Sheet

Instructions:

For this activity, you will play a scientist and engineer. Have you ever wanted to travel to Mars? Have you wondered what goes into the planning the mission to Mars? You and your team will design a "mission" to Mars. Just like the NASA mission designers, you will have a "catalog" of mission hardware from which you can choose. Also, just like the NASA mission designers, you will have budgets for mass, power and cost that you must keep in balance.

Your mission will include the following 4 tasks:

1. Group current NASA mission goals for Mars;
2. Meet with your team to choose your goals for the mission using the NASA Mars Exploration Program Goals;
3. Design a mission that meets a balanced budget for mass, power, and cost but also has significant science return, and makes it safely to the planet; and,
4. Identify any engineering constraints that limited the goals of your mission.

Good luck planning your mission to Mars!

(B) Student Worksheet. Pre-Ideas (1 of 2)

Please answer these questions as best you can.

1. What do you think would be the hardest part of planning a mission to Mars? Explain why you think these items will be so difficult.

2. Define what you think a "good" mission to Mars would be. What would be important to do during planning?

(B) Student Worksheet. Pre-Ideas (2 of 2)

3. Do scientists and engineers get everything they need and/or want when they are planning their missions? __________

4. Explain the reasons you think they do or do not get everything they request.

(C) Activity 1 Fact Sheet: Mars Exploration Science Goals

NASA Strategies and Goals for the Exploration of Mars

Thousands of questions could be asked about Mars alone, so NASA has organized its program for Mars exploration around a common strategy. This strategy is the thread that ties together all four of NASA's main goals for Mars exploration. When designing a mission to Mars, mission planners define many science objectives related to each of the four science goals. These science objectives reflect questions about the planet that they would like the mission to answer.

Guiding Mars Exploration Program Strategies

Past:	"Follow the Water"	Found evidence of water, past and present
Current:	"Seeking Signs of Life"	Search for bio-signatures and return samples

Mars Exploration Program Goals

Mars Exploration Program Goals
DETERMINE IF LIFE EVER AROSE ON MARS
CHARACTERIZE THE PAST AND PRESENT CLIMATE OF MARS
CHARACTERIZE THE GEOLOGY OF MARS
PREPARE FOR HUMAN EXPLORATION

Key Mars Discoveries:
A Springboard to the Future

- Complex geological and climate history
- Diversity of ancient water-rich environments
- Environments that have potential to preserve bio-signatures
- Cold, dry planet today still changing
- Widespread subsurface ice provides resources for exploration and special environment for possible life today

(D) Activity 1: Sample Science Objectives (1 of 3)

Sample Science Objectives for Mars Missions

Here you will find a list of some of the science questions being studied by Mars scientists that can be selected as mission objectives—questions to be answered. For each science objective, place a checkmark in the box matching the Mars Exploration Program Goals that you think it matches. Keep in mind that each objective may apply to more than one of the four goals. Discuss with your team why you think each of these topics might be important. Write these reasons into the justification column of the table.

Science Objective	Mars Exploration Program Goals				Justification
	Determine if life ever arose	Characterize the climate	Characterize the geology	Prepare for human exploration	
Craters					
What kinds of craters are on Mars and how did they form?					
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?					

(D) Activity 1: Sample Science Objectives (2 of 3)

Science Objective	Mars Exploration Program Goals				Justification
	Determine if life ever arose	Characterize the climate	Characterize the geology	Prepare for human exploration	
Volcanoes					
What types of volcanoes are on Mars?					
Does Mars have moving continental plates?					
When/how often did the Martian volcanoes erupt?					
Have Martian volcanoes been eroded by wind or water?					
Did the lava from Martian volcanoes mix 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 is so cratered?					
Polar Caps					
What are ice caps on Mars made of?					
How do the ice caps change throughout the Martian year?					
What are the dark lands/ features seen on Martian ice caps?					

(D) Activity 1: Sample Science Objectives (3 of 3)

Science Objective	Mars Exploration Program Goals				Justification
	Determine if life ever arose	Characterize the climate	Characterize the geology	Prepare for human exploration	
Canyons					
What formed the canyon systems on Mars?					
Did water ever flow through the canyons?					
Have the canyons 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?					

Take a few minutes, and with your team, write 3 of your own science questions (science objectives). Which Mars Exploration Program Goal does your question fall under and why?

Question (Science Objectives)	Mars Exploration Program Goals			
	LIFE	CLIMATE	GEOLOGY	HUMAN

(E) Activity 2: Identify Your Mission Goals

In (D) Activity 1, you classified a number of science objectives according to NASA's Mars Exploration Program goals. Your task for this activity is to select the science objective that you hope to achieve with your mission.

Using the list in (D) Activity 1 (including the objectives you created yourself), choose five science objectives for your mission. When your team has agreed upon the science objectives for your mission, record them in the table below. Record your team's reasons for why each objective is important. Be sure to explain how your objectives fit into NASA's Mars Exploration Program goals.

After discussing them with your team, rank your five science objectives from 1 to 5 in order of importance to your team **(1 being the most important)**. Ignore the final column for now.

Our mission will be (Circle one)

FLY-BY	ORBITER	LANDER
Typically one of the first missions to a planet or set of moons	Typically a second mission type to collect global data, such as photos of the surface and general mineral make-up of the planet	Typically third in a mission type to collect information, such as up close photos and mineral composition in one particular spot on the planet

Rank Order (1-5)	Goal	Reason	Dropped

(F) Activity 3: Building Your Spacecraft Fact Sheet

It is now time to build the spacecraft you will use to meet your mission goals. Use the equipment cards and poster to complete this simulation. You will work with your team to design a spacecraft by choosing the cards that stand for each system involved in your mission. Read each card carefully to make sure you have all of the required systems on your spacecraft.

Remember, your goal in this activity is to design a spacecraft with your team that stays under budget, is launchable, and meets your science goals. Your teacher will decide the budget of your mission and guide you through the first steps of your mission design. You will need to record your design in the ***(I) Spacecraft Design Log*** on the next page. You may go back at any time to change your science goals and your design. In the end, you should have a good balance between meeting your science goals and satisfying your engineering constraints.

Example ***Spacecraft Design Log***:

Your teacher will give you your budget.

System	Spacecraft Component	Budget 250	Mass 125	Power 50
Launch	Medium-Lift Rocket A	-100	0	0
		150	125	50
	Rocket Nose Cone	-10	-7	0
		140	118	50
Power	Fuel Cell	-40	-25	0
		100	93	50

Mass is determined by the rocket system and Power is determined by the power system that you choose.

The systems' names have been filled in.

Fill in the name of the item chosen. Erasures and changes may be necessary along the way.

The white boxes contain the cost, mass, and power for each card to be subtracted from your remaining budget. The blue box is the remaining budget after subtraction.

$ Cost in millions   Mass   Power   Science Return

(G) Activity 4: Spacecraft Design Log (1 of 2)

Spacecraft Design Log					
System	**Spacecraft Component**	**Budget**	**Mass**	**Power**	**Science Return**
Launch					
Power					
Computer					
Communica-tions					
Mobility					
Entry, Descent & Landing					
Science Instruments					
Mechanical					

(G) Activity 4: Spacecraft Design Log (2 of 2)

Mission Metrics

Special Events and Launch	Budget	Mass	Power	Science Return
Final Mission Costs (Record from the last row in the Spacecraft Design Log)				
Special Event Card Selected				
Final of Totals of Mission Design Categories				

1. **How did your final "Risk" card affect your mission?**

2. **Did your mission have a successful launch? (Circle one) Yes No**

3. **What are your thoughts about what you think of mission designs after this simulation?**

(H) Activity 4: Engineering Constraints

Engineering constraints are limits placed on your mission by the hardware you use to accomplish the mission.

With your team, recall the MARSBOUND! Simulation and brainstorm at least 3 hardware constraints you ran into during your mission planning. For each of these run ins with constraints, describe how your team reworked your mission to adjust to these limitations.

Engineering Constraints and Accommodation List

	Hardware #1	Hardware #2	Hardware #3
Hardware			
Constraint			
Accommodation			

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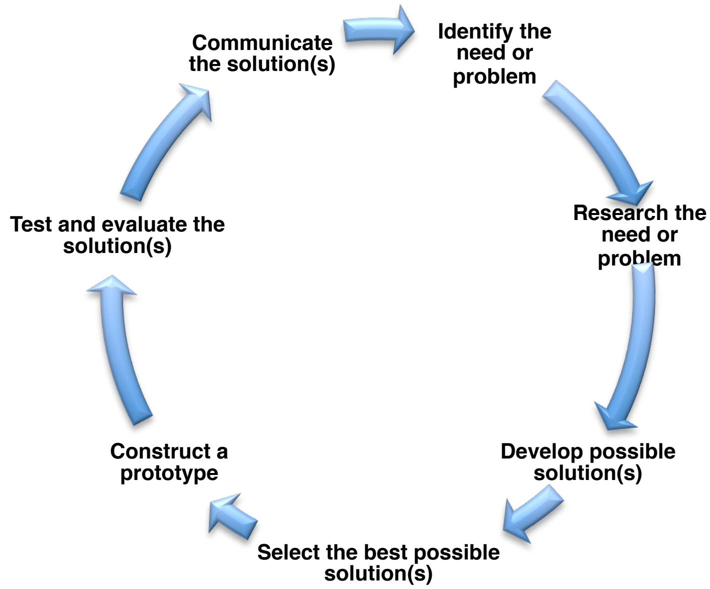
(I) Activity 4: Engineering Design Cycle (1 of 2)

This diagram of the engineering cycle is a simple version of what really happens when engineers work on a task. The process is much longer, often going from later steps in the cycle and circling back to earlier steps as new information is gathered.



Identify the need or problem
- Specify and prioritize requirements and constraints to better define the need or problem

Research the need or problem
- Examine current state of the issue and current solutions
- Explore other options through resources (Ex: Internet, interviews, periodicals, etc.)
- Identify the constraints

Develop possible solution(s)
- Brainstorm possible solutions
- Draw on mathematics and science
- Explain or describe the possible solutions on paper, computer simulation, or 3D model
- Refine the possible solutions

Select the best possible solution(s)
- Determine, using simple analysis, which solution(s) best meet(s) the original requirements

Construct a prototype
- Model the selected solution(s) on paper, computer simulation, or 3D model

Test and evaluate the solution(s)
- Does it work?
- Does it meet the original design constraints?

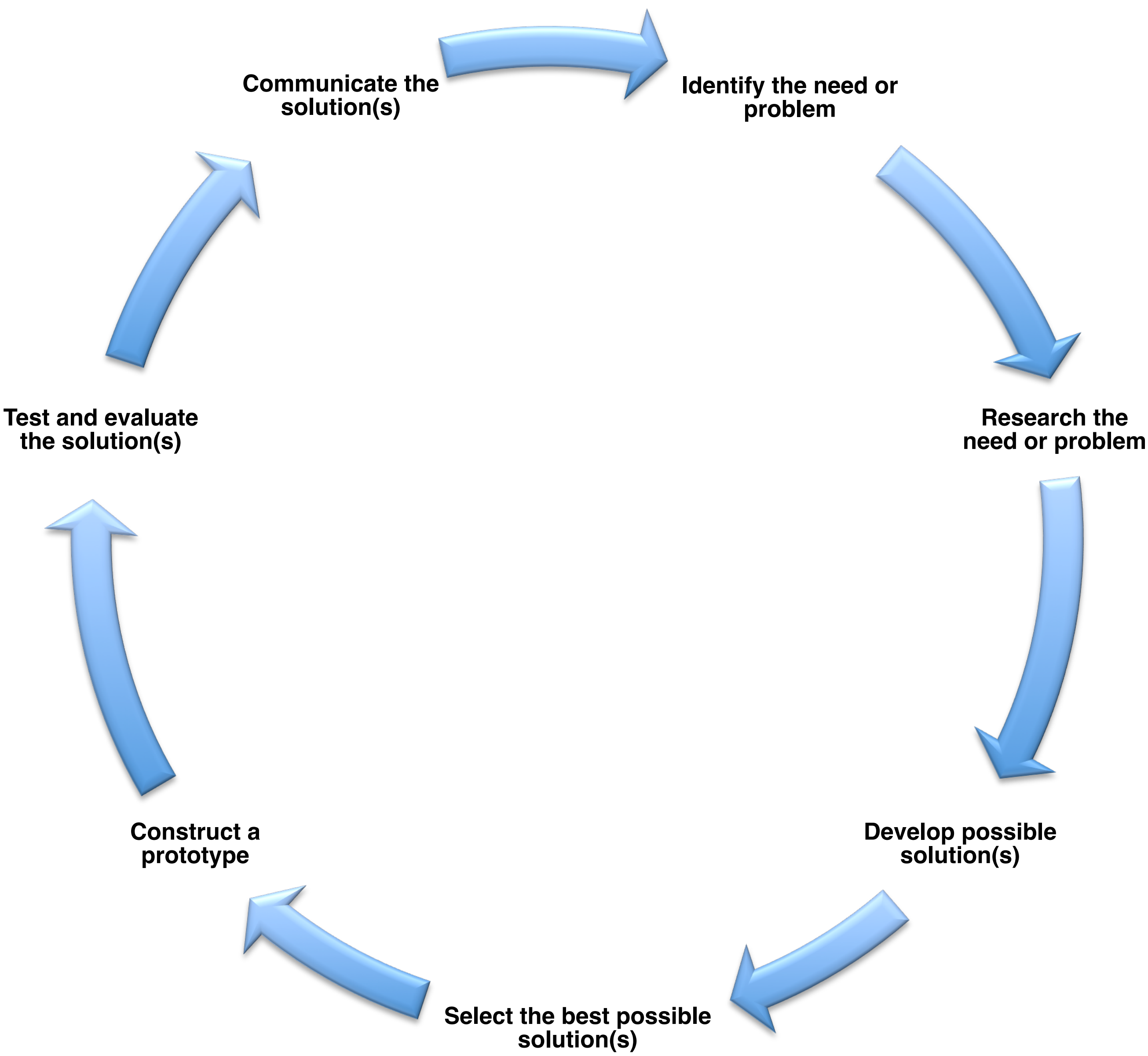
Communicate the solution(s)
- Make an engineering presentation that includes a discussion of how the solution(s) best meet(s) the needs of the initial problem, opportunity, or need
- Discuss societal impact and tradeoffs of the solution(s)

(I) Activity 4: Engineering Design Cycle (2 of 2)

Name: ________________________________

Working with your group, discuss your Marsbound mission and identify when you experience each step of the Engineering Design Cycle. Write the event, problem, need, solution, test, etc. your team ran into next to the correct section of the cycle. Add arrows between steps if your team needed to go back (iteration) during the mission planning to test a new option. There should be at least one example next to each step in the cycle.

Engineering Design Cycle



(J) Student Worksheet. Post-Ideas (1 of 2)

Based on the MARSBOUND! simulation, please answer the following questions as best you can.

1. What do you think would be the hardest part or parts of planning a mission to Mars? Explain why you think these will be so difficult.

2. Refer back to your response to #1 in the Pre-Survey. Was your prediction correct? _______ What reasons do you think allowed the prediction to be correct or incorrect?

On behalf of NASA's Mars Exploration Program, this lesson was prepared by Arizona State University's Mars Education Program, under contract to NASA's Jet Propulsion Laboratory, a division of the California Institute of Technology.

(J) Student Worksheet. Post-Ideas (2 of 2)

3. Define what you think a "good" mission to Mars would be? Why?

4. Do scientists and engineers get everything they need and/or want when they are planning their missions? __________.

5. Explain why you think they do or do not get everything they request.

(K) Comparing Two Mars Rover Projects

Comparing Two Mars Rover Projects

	Mars Science Laboratory	Mars Exploration Rovers
Rovers	1 (Curiosity)	2 (Spirit and Opportunity)
Launch vehicle	Atlas V	Delta II
Heat shield diameter	14.8 feet (4.5 meters)	8.7 feet (2.65 meters)
Design mission life on Mars	1 Mars year (98 weeks)	90 Mars sols (13 weeks)
Science Payload	10 instruments, 165 pounds (75 kilograms)	5 instruments, 11 pounds (5 kilograms)
Rover mass	1,982 pounds (899 kilograms)	374 pounds (170 kilograms)
Rover size (excluding arm)	Length 10 feet (3 meters); width 9 feet (2.7 meters); height 7 feet (2.2 meters)	Length 5.2 feet (1.6 meters); width 7.5 feet (2.3 meters); height 4.9 feet (1.5 meters)
Robotic arm	7 feet (2.1 meters) long, deploys two instruments, collects powdered samples from rocks, scoops soil, prepares and delivers samples for analytic instruments, brushes surfaces	2.5 feet (0.8 meter) long, deploys three instruments, removes surfaces of rocks, brushes surfaces
Entry, descent and landing	Guided entry, sky crane	Ballistic entry, air bags
Landing ellipse (99-percent confidence area)	15.5 miles (25 kilometers) long	50 miles (80 kilometers) long
Power supply on Mars	Multi-mission radioisotope thermoelectric generator (about 2,700 watt hours per sol)	Solar photovoltaic panels (less than 1,000 watt hours per sol)
Computer	Redundant pair, 200 megahertz, 250 MB of RAM, 2 GB of flash memory	Single, 20 megahertz, 128 MB of RAM, 256 MB of flash memory