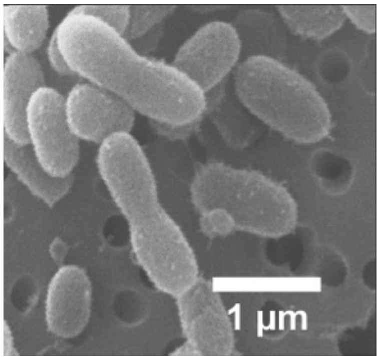
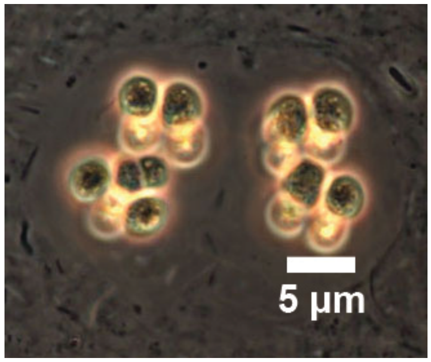
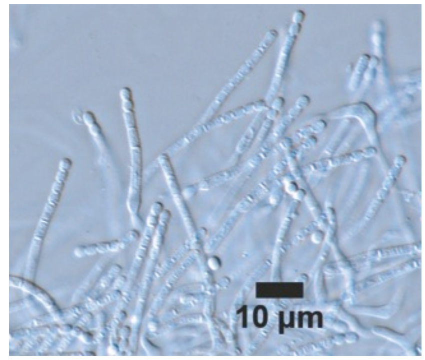
Astrobiobound! The Search for Life in the Solar System

Grades: 6-8 Prep Time: ~1 hour Lesson Time: ~135 minutes







WHAT STUDENTS DO: Design a Mission to Search for Life in the Solar System.

Curious about how scientists and engineers design a mission to search for life? 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 to search for life in the Solar System that meets constraints (budget, mass, power) and criteria (significant science return).

NRC FRAMEWORK/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

HOW DO ORGANISMS LIVE, GROW, RESPOND TO THEIR ENVIRONMENT, AND REPRODUCE?

NGSS Core Question: LS1: From Molecules to Organisms: Structures and

INSTRUCTIONAL OBJECTIVES (IO)

Students will be able to

IO1: Create an engineering model of an astrobiology mission limited by criteria and constraints and designed to achieve the task of looking for past or present life in the Solar System.

With support from the NASA Astrobiology Institute (NAI), this lesson was prepared by Arizona State University's Mars Education Program. This lesson was adapted from Marsbound!, a lesson funded by NASA's Jet Propulsion Laboratory, a division of the California Institute of Technology.

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Processes

How do the structures of organisms enable life's functions?

NGSS LS1.A: Structure and Function

How do organisms obtain and use the matter and energy they need to live and grow?

NGSS LS1.C: Organization for Matter and Energy Flow in Organisms

HOW IS ENERGY TRANSFERRED AND CONSERVED?

NGSS Core Question: PS3: Energy

How do food and fuel provide energy? If energy is conserved, why do people say it is produced or used?

NGSS PS3.D: Energy in Chemical Process and Everyday Life

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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/astrobiobound

Please Print:

From Student Guide

(A) Student Instruction Sheet – 1 per student
(B) Student Pre-Ideas Worksheet – 1 per student
(C) Characteristics of Life – 1 per team
(D) What is Astrobiology and Its Goals? – 1 per team
(E) What are Extremophiles? – 1 per team
(F) What are Biosignatures? – 1 per team
(G) Student Worksheet: Identify Mission Goals – 1 per team
(H) Building Your Spacecraft Fact Sheet – 1 per team
(I) Student Worksheet: Spacecraft Design Log – 1 per team
(J) Student Worksheet: Engineering Constraints – 1 per student
(K) Student Worksheet: Engineering Design Cycle – 1 per student
(L) Student Worksheet: Post-Ideas Worksheet – 1 per student
(M) Reflections – 1 per student

Optional Materials:

From Alignment Document

(N) "Astrobiobound: The Search for Life in the Solar System" Alignment
(O) "Astrobiobound: The Search for Life in the Solar System" Assessment Rubrics
(P) Placement of Instructional Objective and Learning Outcomes in Taxonomy

NGSS Materials:

"A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas" (NRC, 2012), also known as the Framework, articulates a vision of exemplary science instruction based upon current research. This vision centers on 3-dimensional learning in which Disciplinary Core Ideas, Science and Engineering Practices, and Crosscutting Concepts in science and engineering are coherently integrated in instructional design. It isn't enough, however, that students engage in the Practices as they develop a deep understanding of the Core Ideas. Students must also be cognitively aware of what they are doing and what the Practices are. The reflection assignment will engage students in thinking about the Practices, about what those Practices are, and how the Practices relate to doing science.

This lesson will assist you in integrating this activity and will suggest resources.

Please Print:

NGSS Practices Poster
NGSS Crosscutting Concepts Poster
NGSS Understanding about the Nature of Science Poster

Please Read:
Appendix F – Science and Engineering Practices in NGSS
Appendix G – Crosscutting Concepts
Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

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3.0 Lesson Timeline

Astrobiobound! **Lesson Timeline**:

Time:

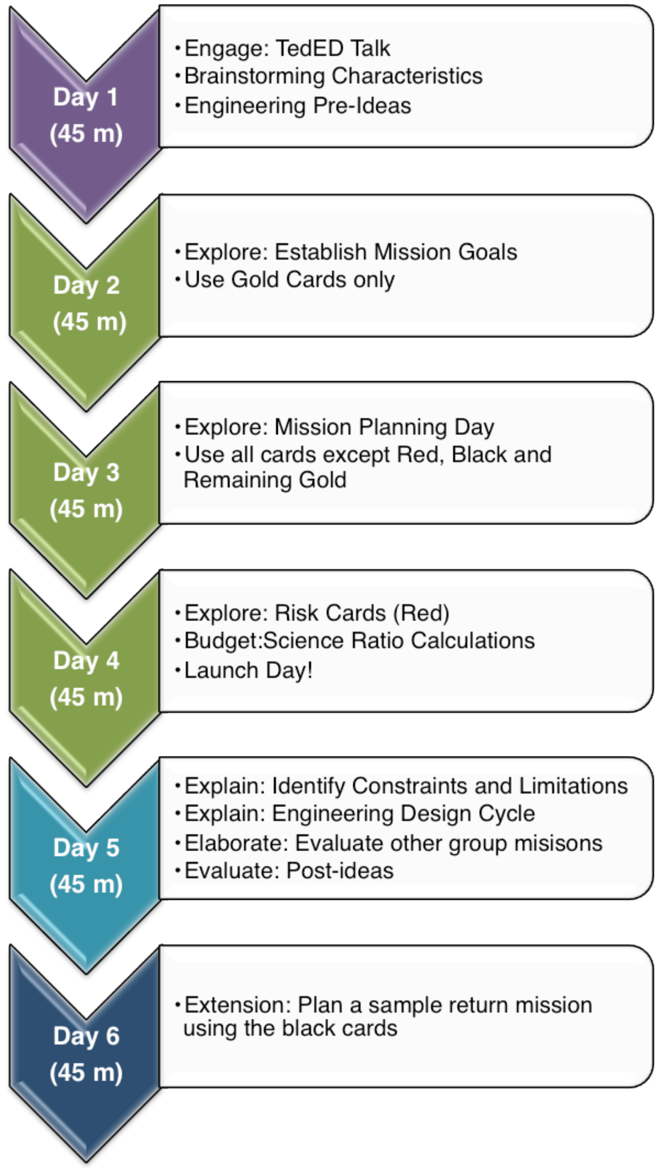
- Five (45 minute) segments

Materials:

- Student Guide pages
- Card colors to use where appropriate

5-E Inquiry Process:

- The arrow color represents the 5-E step students will be primarily engaging in for that class session



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4.0 Vocabulary

Aerogel	the world's lightest, synthetic, solid material, composed of up to 99.98% air by volume. Often called "frozen smoke."
Astrobiology	study of the origin, evolution, distribution, and future of life in the universe.
Analyze	consider data and results to look for patterns and to compare possible solutions.
Biosciences	any natural science dealing with the structure and behavior of living organisms.
Biosignatures	elements, isotopes, molecules or phenomena that result from past or present life.
Biota	the animal and plant life of a particular region, habitat, or geological period.
Characteristics	distinguishing traits, qualities, or properties of an object or phenomenon.
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.
Extremophile	organisms that thrive in extreme environments.
Fly by	a spacecraft designed to go by a planet and study it on its way past.
Geochemistry	science that uses chemistry to explain the geological systems such as the Earth's crust and its oceans.
Geosciences	the sciences, such as geology, geophysics, and geochemistry dealing with the study of earth.
Geomicrobiologists	The study of microbes and their processes in the field of geology and geochemistry.

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Lander	a spacecraft designed to explore on the surface of a planet from a stationary position.
Life	a state defined by the capacity for metabolism, growth, reaction to stimuli, and reproduction**.**
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.
Molecules	a group of atoms bonded together, representing a chemical compound, like H_2O, that can take part in a chemical reaction.
Observations	specific details recorded to describe an object or phenomenon.
Orbiter	a spacecraft designed to explore space, seeking to answer scientific questions.
Organism	an individual able to carry out the activities of life.
pH	represents how acidic or alkaline a solution is with 7 being neutral, 1 being acidic and 14 being alkaline.
Planet	a sphere moving in orbit around a star (e.g., Earth moving around our Sun).
Prebiotic	existing or occurring before the emergence of life.
Predict	a declaration about what will happen based on reason and knowledge.
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.

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5.0 Procedure

PREPARATION (With cards and board prepared ~ 10 minutes; to prepare 8 sets ~ 4-6 hours)

A. PRINT THE FOLLOWING:

- Equipment **Cards** – 1 per team
- Design **Mat** – 1 per team
- Student **Worksheets (C-I)** – 1 per team
- Student **Worksheets (A-B, J-L)** – 1 per student

Teacher Tip: If you have printed the simulation board and 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		
Simulation Board System	**Color**	**Coordinating Card #s**
Launch System	Yellow	1-6
Power System	Green	7-12
Computer System	Bright Pink	13-15
Communications System	Tan	16-18
Mobility System	Sky Blue	19-24
Mechanical System	Dark Blue	25-29
Entry, Descent, & Landing System	Purple	30-33
Science Instruments	Orange	34-47
Special Events	Red	48-53
Mission Goals	Gold	54-74
Sample Return	Black	75-78

STEP 1: ENGAGE (~ 20 minutes)
Set up the Scenario of Mission Planning

A. At the beginning of the lesson very briefly tell students that scientists and engineers engage in certain practices when they are doing science or engineering and certain fundamental ideas are applicable to all science and engineering, called crosscutting concepts.

B. Provide either wall posters (11 x 17 format) or individual handouts (8.5 by 11 format) briefly describing the Practices and Crosscutting Concepts (be sure to include the Nature of Science also).

C. Tell students that they will be asked to identify if they do any of these practices at the end of the activities.

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 NGSS Teacher Tip: The descriptions of the Practices and Crosscutting Concepts on the poster or handout are brief; therefore, you may wish to become more familiar with the Crosscutting Concepts and the Understandings about the Nature of Science. You can get very good information from the Next Generation Science Standards (NGSS) web site. Recommended are *Appendix F – Science and Engineering Practices in NGSS, Appendix G – Crosscutting Concepts*, and *Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards*. These resources will help you to assist your students if they say that they don't understand the Practices, Crosscutting Concepts, or the Nature of Science. Also, in the Alignment document provided for this lesson the instructional designers have indicated the Crosscutting Concepts they have determined to be most appropriate.

D. 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 destination.

E. Ask the students: "What are we looking for in space? What is the big question we are trying to answer by exploring other planets and moons in our solar system and through identifying other planets in other solar systems outside of our own?"

a. Facilitate the discussion to lead the students to **LIFE**. We are looking for signs of present or past life on other planets/moons. This is one of the guiding principles in the study of Astrobiology. Astrobiology is the study of the origin, evolution, distribution, and future of life in the universe.
b. Show students the TedED video "A needle in countless haystacks: Finding habitable worlds by Dr. Ariel Anbar" to learn more about what we are looking

for out there. http://ed.ted.com/lessons/a-needle-in-countless-haystacks-finding-habitable-planets-ariel-anbar#watch

F. Discuss with students how we classify something as "alive." What are the characteristics of living things? (Hand Out ***(C) Characteristics of Life***)

 Curriculum Connection: If students are not familiar or need a refresher with the characteristics of life, they can complete the "***Is It Alive?***" lesson that walks students through an inquiry investigation to discover these characteristics. For more on this lesson, visit http://marsed.asu.edu/content/it-alive.

G. Explain that the students will be playing a card simulation to design a mission looking for life, or evidence of life, in our solar system. As part of "qualifying" for the mission planning, ask students to complete the ***(B) Student Pre-Ideas Worksheet***.

This Pre-Ideas 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.

H. Hand Out:

- Astrobiobound! The Search for Life in the Solar System: **Worksheets (A, D-I)**
- Equipment **Cards** – 1 per team
- Design **Mat** – 1 per team

STEP 2: EXPLORE (~ three 45 minute class periods)
Identify a Goal Requiring a Technological Design.

A. Activity 1: The purpose is to familiarize and discuss the NASA Astrobiology Institute Goals and focus on Goal #2 and #7 as it relates to biosignatures used for the exploration of life and our understanding of extremophile life found on Earth in our search for life in our solar system. Possible narrative for discussion below:

"The NAI Goals for Exploration provide guidance for research and technology development across NASA in an attempt to address three basic questions:

1. *How does life begin and evolve?*
2. *Does life exist elsewhere in the Universe?*
3. *What is the future of life on Earth and beyond?*

Here is a list of those seven goals. We will focus on two of them for this simulation, #2 and #7."

Discuss some of these key word with students and what they might mean:

- *Past or present habitable*
- *Chemistry*

- *Water*
- *Energy*
- *Biosignatures*
- *In situ (on planet)*
- *or Returned (sample return)*

Curriculum Connection: If students are not familiar or need a refresher with the extremophiles, they can complete the "***Xtreme-o-philes***" lesson that walks them through an inquiry investigation to discover these types of organisms and where they are could potentially be found. For more on this lesson, visit http://marsed.asu.edu/content/xtreme-o-philes.

NASA Astrobiology Institute (NAI) Goals

GOAL 1. Understand the nature and distribution of habitable environments in the universe. Determine the potential for habitable planets beyond the Solar System, and characterize those that are observable.

GOAL 2. Determine any past or present habitable environments, prebiotic chemistry, and signs of life elsewhere in our Solar System. Determine the history of any environments having liquid water, chemical ingredients, and energy sources that might have sustained living systems. Explore crustal materials and planetary atmospheres for any evidence of past and/or present life.

GOAL 3. Understand how life emerges from cosmic and planetary precursors. Perform observational, experimental, and theoretical investigations to understand the general physical and chemical principles underlying the origins of life.

GOAL 4. Understand how life on Earth and its planetary environment have co-evolved through geological time. Investigate the evolving relationships between Earth and its biota by integrating evidence from the geosciences and biosciences that shows how life evolved, responded to environmental change, and modified environmental conditions on a planetary scale.

GOAL 5. Understand the evolutionary mechanisms and environmental limits of life. Determine the molecular, genetic, and biochemical mechanisms that control and limit evolution, metabolic diversity, and acclimatization of life.

GOAL 6. Understand the principles that will shape the future of life, both on Earth and beyond. Elucidate the drivers and effects of microbial ecosystem change as a basis for forecasting future changes on time scales ranging from decades to millions of years, and explore the potential for microbial life to survive and evolve in environments beyond Earth, especially regarding aspects relevant to US Space Policy.

GOAL 7. Determine how to recognize signatures of life on other worlds and on early Earth. Identify biosignatures that can reveal and characterize past or present life in ancient samples from Earth, extraterrestrial samples measured in situ or returned to

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Earth, and remotely measured planetary atmospheres and surfaces. Identify biosignatures of distant technologies.

Differentiate between a Mission Science Goal and a Technological Design/Solution.

A. Activity 2: Scientists often choose the science goal for a mission, so for this activity, students will first act as scientists and determine mission goals using the **(Gold) Mission Goal Cards**. Student teams will discuss their possible science mission goal and decide on an appropriate Mission Target (using the ***Potential Mission Target*** cards), what biosignature or biosignatures they will investigate for (using the ***(F) What are Biosignatures?*** sheet), and whether they want to fly a stationary lander, mobile lander, orbiter, or fly-by mission to search for life. Students will complete ***(G) Student Worksheet: Identify Mission Goals***.

Teacher Tip: In preparing students to make choices on whether to use a stationary lander, mobile lander, orbiter, or fly-by, you can use the "***Strange New Planet***" lesson for a hands-on activity about exploring new planets. For more on this lesson, visit: http://marsed.asu.edu/strange-new-planet

Design a Technological Solution.

B. 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.

Teacher Tip: Students will be hard-pressed to design a spacecraft (under or at budget) that can meet all of their mission goals and objectives. This constraint is intentional, as it will guide the students to revise their mission plan by going back to their goals and possibly changing them. This is the iterative process that happens quite often between scientist and engineers in the real world as well.

i. Important! Hold the **(Red) Special Events cards** and **(Black) Sample Return Cards** until the end of the simulation.

ii. Students will begin the simulation by choosing a **(Yellow) 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 ***(I) Spacecraft Design Log***.

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

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

v. If students have chosen either type of lander for their mission, mobile landers will need to include a **(Sky Blue) Mobility System**, and both will require **(Purple) Entry, Descent, & Landing Systems**.

vi. The final decision will be optional **(Dark Blue) 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 ***(I) 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 $300 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 **(Red) 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 ***(I)* 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.

Teacher Tip: If there is a tie between teams for a “winning” proposal, each team will then need to evaluate the level of risk for their mission. Teams will review all of their mission cards and count up the total number of instruments that indicate they are “risky.” The lowest number of “risky” cards wins the proposal. This is the same process that occurs in the NASA proposal selection process. Higher risk missions are considered less favorable options.

STEP 3: EXPLAIN (~ 60 minutes)
Analyze Constraints within a Technological Design.

Hand Out:
• Astrobiobound! The Search for Life in the Solar System: **Worksheets (J-K, M)**

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 stationary 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 space. To send every instrument to a planet or moon 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, but 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 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 surface missions with solar panels are limited to being near a planets equator and can only operate for about 6 months of the year, or cannot even be used for outer planet/moon mission for lack of sunlight. ***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.

C. Organize students into groups of size and composition you know to be most effective.

D. Hand out *(M) Reflections*.

E. Allow discussion for 10 – 15 minutes.

F. Ask each group to share its best thinking about which Practices and Understanding of Nature of Science were done, when it was done, and what the group's reasoning was for this. Record the results from each group in columns on the board.

 Teacher Tip: The most important part of these activities is to engage students' thinking about the Practices, Crosscutting Concepts and the Nature of Science. The emphasis is on the rationale the students provide rather than what Practices or Crosscutting Concepts were identified in the Alignment document. Be prepared to ask questions to elicit more complete reasoning for the group's decision. Allow discussion if groups do not initially agree. The discussions will help to develop deeper understandings.

STEP 4: ELABORATE (~ 20 minutes – two 45 minute class periods)
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 can either be a Surface to Earth Sample Return Mission or an Orbit to Earth Sample Return Mission. Teams will need to choose which they will complete.

a. **Surface to Earth Sample Return**: Budget = $650 million and will be valued at a Science Return of 5. The mission must include:

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i. **A Rover** with Robotic Arm (#25) for sample collection, the Sample Cache card (#29), and science instruments required to identify attractive samples for collection. All other requirements listed on the Astrobiobound board must be followed during this mission plan.
ii. **A Lander** vehicle that includes the Surface to Orbit card (#77) to get the sample off of the planet or moon and into orbit. Follow all requirements on the Astrobiobound board to design the lander portion of the mission.
iii. **An Orbiter** to catch the launched sample and return it to Earth using the Orbit to Earth Spacecraft card (#78) and all requirements on the Astrobiobound board. (EDL will require a parachute and heat shield ONLY).

b. **Orbit to Earth Sample Return**: Budget = $300 million and will be valued at a Science Return of 5. The mission must include:

i. **An Orbiter** with aerogel sample collector on a robotic arm that will return to Earth using the Orbit to Earth Spacecraft card (#78) and all requirements on the Astrobiobound board. (EDL will require a parachute and heat shield ONLY).

Teacher Tip: These sample return missions will be very large projects. It is recommended that the class is broken into groups of 4. 3 groups will be on the Surface Sample Return Team, the other 1 will be on the Orbital Sample Return Team. From there, each sub-team will plan one segment for their Sample Return Mission. For example:

Surface Sample Return Team:
Rover Team
Surface to Orbit Team
Orbiter to Earth

Orbit to Earth Sample Return Team:
Orbiter to Earth

STEP 5: EVALUATE (~ 15 minutes)

Evaluate change in ability to solve engineering problems.

Hand Out:
• Astrobiobound! The Search for Life in the Solar System: **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.

6.0 Evaluation/Assessment

Use the *(N) Astobiobound! Rubric* as a formative and summative assessment, allowing students to improve their work and learn from mistakes during class. The rubric evaluates the activities using the Next Generation Science Standards.

7.0 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 be placed in the role of scientist and engineer. Have you ever wanted to travel to other planets or moons in our Solar System. Or maybe you have wondered what goes into planning the mission to these places? You and your team will design a mission to a planet or moon in our solar system. 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 (mass, power and cost) that you must keep balanced.

Your mission will include the following 4 tasks:

1. Work with your team in deciding your goals for the mission. These goals should reflect the NASA Astrobiology Institute goals. You will be choosing between the search for organics, chemistry, and/or structures;

2. Work with your team and choose a planet or moon to explore with your mission;

3. Design a mission that meets the requirements for balancing budget, mass, and power, reaches significant science return, and makes it safely to the planet or moon; and,

4. Identify any engineering constraints that limited the capability of your mission.

Good luck planning your mission to search for life!

With support from the NASA Astrobiology Institute (NAI), this lesson was prepared by Arizona State University's Mars Education Program. This lesson was adapted from Marsbound!, a lesson funded by NASA's Jet Propulsion Laboratory, a division of the California Institute of Technology.

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

Name: ________________________________

Please answer the following questions as completely as you can.

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

2. Define what you think a "good" mission to search for life would be? What are the important parts you need for the mission during planning?

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(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.

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(C) Characteristics of Life

Use this table to determine if something is living or non-living. To be classified as living things, ***ALL*** the characteristics must be exhibited.

✔	Characteristic	Description and Examples
	Made of Cells	Bacteria, viruses, plants, fungi, and animals are all made of cells. Either single or multiple.
	Obtain and use Energy	Plants and some bacteria use the Sun to make energy. Many animals collect their food through hunting or straining the water/air for food. Many bacteria and viruses will get energy from cells they have entered. Even rock can provide food for a hungry bacteria or fungus. Sometimes this is referred to as metabolism.
	Grow and Develop	Plants grow from seeds. Animals grow from infant. Fungi grow from spore. This means they grow from a single cell multiplying and dividing to create an entire organism. For bacteria and viruses, this refers to cell division and copying.
	Reproduce	Plants, animals, and fungi will create offspring. Bacteria and viruses will create clones or copies of themselves.
	Respond to Environment	Plants, animals, fungi, bacteria, and viruses, will react to changes and try to stay stable. Sometimes this is referred to as metabolism. For example: A negative reaction to a freezing environment could be blood flow moving to internal organs to keep the animal alive. A positive response would be healthy bodies from good foods and fluids consumed by the human body.
	Adapt to Environment	Plants, animals, fungi, bacteria, and viruses will change how they live or their body to be better for an environment. An example is our pupils getting smaller in bright light, goose bumps when cold, or even tummy grumbles when hungry.

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(D) What is Astrobiology and It's Goals?

Astrobiology is the study of the origin, evolution, distribution, and future of life in the Universe. It involves a many types of scientists to put together the puzzle of "Is there life out there?" Many biologists, geomicrobiologists, and geochemists are studying life on Earth in many places to learn more about where life can live. At the same time, geochemists and geologists are studying other planets and moons in our solar system. They are trying to identify places these same types of life might be able to live in space and possibly already are! These scientists work together to try to answer the question of life.

One group doing this kind of research is the ***NASA Astrobiology Institute (NAI)***. NAI has a set of goals for the understanding of life in our Universe. For this activity, we are very interested in goal #2 and #7. These two goals are about finding ***biosignatures*** (elements, isotopes, molecules or events that result from past or present life) and our understanding of life found on Earth in our search for life in our Solar System, such as ***extremophiles.*** Extremophiles are organisms that live happily in very extreme environments. life found on Earth in our search for life in our Solar System.

NASA Astrobiology Institute (NAI) Goals

GOAL 1. Understand the nature and distribution of habitable environments in the universe. Determine the potential for habitable planets beyond the Solar System, and characterize those that are observable.

GOAL 2*. Determine any past or present habitable environments, prebiotic chemistry, and signs of life elsewhere in our Solar System. Determine the history of any environments having liquid water, chemical ingredients, and energy sources that might have sustained living systems. Explore crustal materials and planetary atmospheres for any evidence of past and/or present life.*

GOAL 3. Understand how life emerges from cosmic and planetary precursors. Perform observational, experimental, and theoretical investigations to understand the general physical and chemical principles underlying the origins of life.

GOAL 4. Understand how life on Earth and its planetary environment have co-evolved through geological time. Investigate the evolving relationships between Earth and its biota by integrating evidence from the geosciences and biosciences that shows how life evolved, responded to environmental change, and modified environmental conditions on a planetary scale.

GOAL 5. Understand the evolutionary mechanisms and environmental limits of life. Determine the molecular, genetic, and biochemical mechanisms that control and limit evolution, metabolic diversity, and acclimatization of life.

GOAL 6. Understand the principles that will shape the future of life, both on Earth and beyond. Elucidate the drivers and effects of microbial ecosystem change as a basis for

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forecasting future changes on time scales ranging from decades to millions of years, and explore the potential for microbial life to survive and evolve in environments beyond Earth, especially regarding aspects relevant to US Space Policy.

GOAL 7. *Determine how to recognize signatures of life on other worlds and on early Earth. Identify biosignatures that can reveal and characterize past or present life in ancient samples from Earth, extraterrestrial samples measured in situ or returned to Earth, and remotely measured planetary atmospheres and surfaces. Identify biosignatures of distant technologies.*

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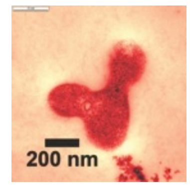
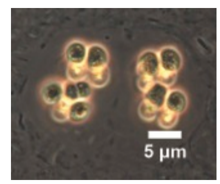
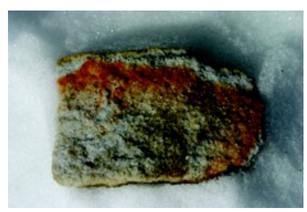
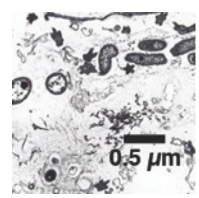
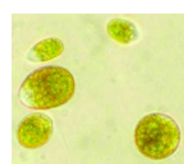
(E) What are Extremophiles? (1 of 2)

Extremophiles are living things that happily live in extreme environments. This is a table with the eight common types of extremophiles. There is also an explanation of what they are, an example of a location they have been found, and a photo example. Reminder; these are all examples. There are many more types of extremophiles and places to find them.

Common Extremophiles	Definition	Example Location	Example Microbe
Acidophiles [uh-sid-uh-fahyl]	Acid-loving microbes pH levels 3 or below	 Rio Tinto, Spain	 *Ferroplasma acidiphilium*
Alkaliphiles [al-kuh-luh-fahyl]	Alkali-loving microbes pH levels 9 or above	 Mono Lake, CA	 *Microcystis*
Endoliths [en-doh-lith]	Rock-loving Makes food using dissolved minerals from water or dissolving rock and absorbing minerals	 Trans-Antarctic Mountains	 *Microbial biofilm*
Halophiles [hal-uh-fahyl]	Salt-loving microbes 0.2M concentration of NaCl (salt)	 Bonneville Salt Flats, UT	 *Dunaliella salina*

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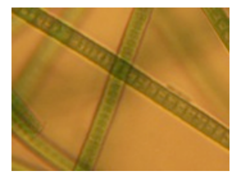
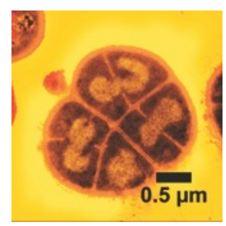
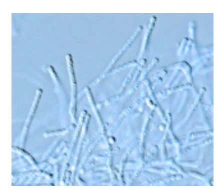
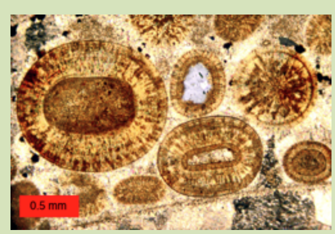
(E) What are Extremophiles? (2 of 2)

Common Extremophiles	Definition	Example Location	Example Microbe
Psychrophiles [sahy-kru-fahyl]	Cold-loving microbes Temperatures -15°C and lower	 Peritio Moreno Glacier, Patagonia, Argentina	 *Chryseobacterium greenlandensis*
Thermophiles or Hyperthermophiles [thur-muh-fahyl]	Heat-loving microbes Temperatures between 45-122°C	 Grand Prismatic Springs, Yellowstone National Park	 *Phormidium*
Radioresistant [rey-dee-oh-ri-zis-tuhnt]	Radiation resistant microbes Commonly UV radiation or even nuclear	 Nuclear and Solar Radiation	 *Deinococcus radiodurans*
Xerophile [zeer-uh-fahyl]	Dry loving microbes In drying conditions	 Atacama Desert, Chile	 *Wallemia sebi*

(F) What are Biosignatures? (1 of 2)

Biosignature	Description	Examples and/or Images
Organic Material	Specific carbon molecules usually found when life is or was present. If found on a planet or moon, carbon doesn't necessarily mean life existed. In order to be connected to living things, these examples would have to show chirality. Chirality is where molecules show "handedness;" similar to right and left hands. Life prefers to build molecules with a "left-hand" structure. This means if something like amino acids were found on another planet or moon with left-handed molecular structure, it would be considered a biosignature of life.	**13C (Carbon 13)** **Amino acids** **Lipids** **Proteins** **Nucleic acids** **Fatty acids**
Chemistry	Minerals, chemicals and other materials that are found when life may be or is present. These are called isotopes. Isotopes are elements that have lost or gained a neutron while keeping the same number of protons and electrons.	**Isotope Ratios in Compounds of:** **Carbon** **Hydrogen** **Nitrogen** **Oxygen** **Phosphorus** **Sulfer**
Structures	**Microfossils** – tiny fossils only seen by microscope and preserved in rock. Examples would be endoliths, ooids and diatoms.	**Microfossil** –  Ooids  Ooids under microscope

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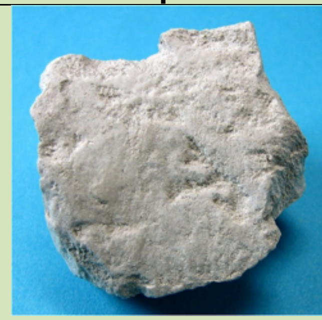
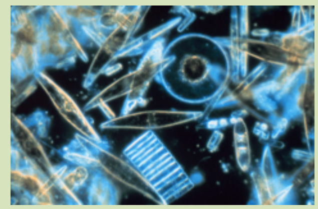
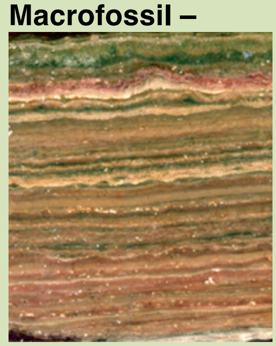
Biosignature	Description	Examples and/or Images
Structures	**Macrofossils** – larger fossils that can look like a rock, but looking closer will show shapes that look like living things. Examples are microbial mats, stromatolites, and coral reefs.	 Diatoms  Diatoms under the microscope **Macrofossil –**  Microbial mat  Stromatolites  Coral reefs

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(G) Student Worksheet: Identify Mission Goals

So far, your team has found that life can live in extreme environments and that life will leave behind any of 3 types of biosignatures. Now, your team will talk about where you want to explore, what biosignatures you will look for, and the general type of mission you will use to look for these biosignatures.

For this section you will need the ***(Gold) Potential Mission Target*** cards and the ***(F) What are Biosignatures?*** sheet. As a group, decide which mission target you would like to design for, which type or types of biosignatures you will look for at your target and then the type of mission you will build. Mission types include Fly-by, Orbiter, Stationary Lander, and Mobile Lander.

Fly-by: Typically one of the first missions to a planet or set of moons
Orbiter: Typically a second mission type to collect data from all over the planet, like taking photos of the surface and general minerals found on the planet
Stationary Lander: Typically the third mission type to collect information, like taking up close photos and mineral measurements in one particular spot on the planet
Mobile Lander: Typically third or fourth in a mission type to collect information, like taking up close photos and mineral measurements, but also mobile to explore larger areas of the planet.

Fill in your choices and explanations in the table below:

Mission Target:				
Explain why you have chosen this target:				
Circle the biosignature or biosignatures you will look for:		**Organic Carbon**	**Chemistry**	**Structures**
Explain why you have chosen this/these biosignatures (hint: look at your mission target card):				
Circle the type of mission you will design:	**Fly-by**	**Orbiter**	**Stationary Lander**	**Mobile Lander**
Explain why you have chosen this type of mission design:				
Mental Check: Use the mission type descriptions above to answer the following question. Is this type of mission appropriate for the mission target? If not, choose a more appropriate mission type.				

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(H) Student Worksheet: Building Your Spacecraft Fact Sheet

It is now time to build the spacecraft. Use the cards and poster your teacher gave you to complete this simulation. You will work with your team to create a spacecraft by assembling the cards for each system needed 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 is under budget and meets your science goals (Gold cards). Your teacher will decide the budget of your mission and guide you to get started in your mission design. You will need to keep track of your budget, mass and power 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 science goals and your budget, mass, and power.

Example ***Spacecraft Design Log***:

Your teacher will give you your budget.

System	Spacecraft Component	Budget	Mass	Power
		300	125	50
Launch	Medium-Lift Rocket A	-100	0	0
		200	125	50
	Rocket Nose Cone	-10	-7	0
		190	118	50
Power	Fuel Cell	-40	-25	0
		150	93	50

Mass is decided 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 you choose. You will need a pencil in case you change your mind and need to erase.

The white box is the cost, mass, and power for each card. This is subtracted from the gray box above. The gray box below is the remaining budget, mass, and power after subtraction.

Cost in millions

Mass

Power

Science Return

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(I) Student Worksheet: Spacecraft Design Log (1 of 2)

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

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(I) Student Worksheet: 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 did you realize about mission designs after this simulation?

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(J) Student Worksheet: Engineering Constraints

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

With your team, recall the ***Astrobiobound!*** simulation and brainstorm at least 3 hardware limitations you encountered along the way. For each of these constraints, describe how your team had to rework your mission to fix these limitations.

Engineering Constraints and Accommodation List

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

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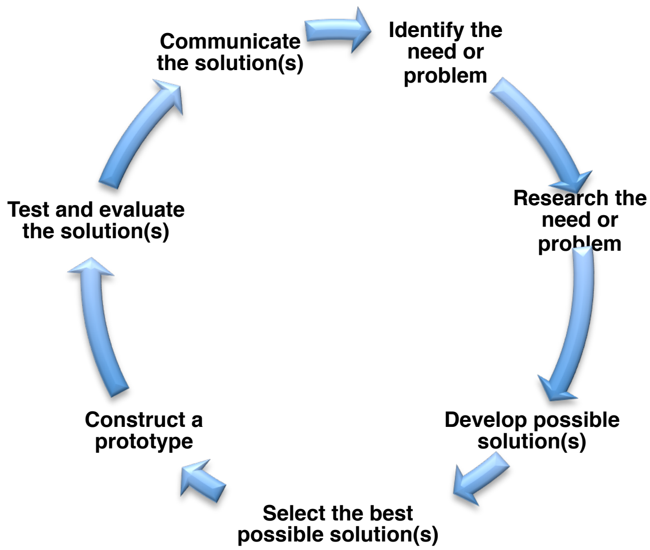
(K) Student Worksheet: Engineering Design Cycle (1 of 2)

This diagram of the engineering cycle is a simple version of what happens in an engineering task. The actual process is much more iterative, meaning the engineer will move from later steps in the cycle (like testing a prototype) and back to earlier steps with new information.



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)

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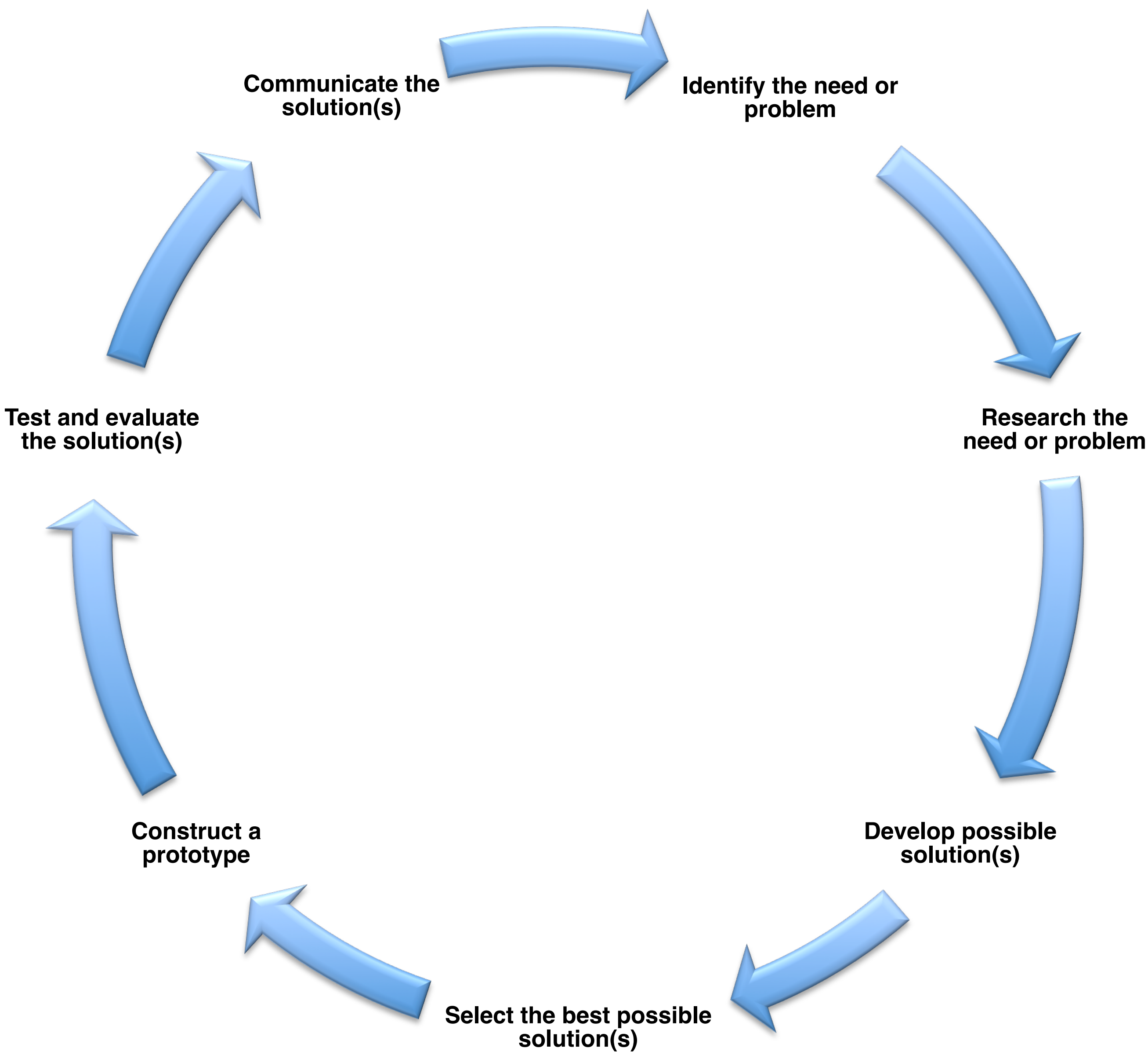
(K) Student Worksheet: Engineering Design Cycle (2 of 2)

Name: ___________________________________

Working with your group, talk about your Astrobiobound! mission. When did you experience each section of the Engineering Design Cycle? Write the event, problem, need, solution, test, etc. your team did in next to that part of the cycle. Draw arrows between steps if your team needed to go back (iteration) while mission planning to try something new. There should be at least one example next to each step in the cycle.

Engineering Design Cycle



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(L) Student Worksheet: Post-Ideas (1 of 2)

Name: ________________________________

Based on the *Astrobiobound* simulation, please respond to the following questions as accurately and completely as you can.

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

2. Refer back to your response to #1 in the Pre-Survey. Was your prediction accurate? ______ What reasons do you think caused allowed the prediction to be accurate or inaccurate?

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(L) Student Worksheet: Post-Ideas (2 of 2)

3. Define what you think a "good" mission to search for life would be and what are the important elements of the mission during planning.

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.

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(M) Reflection – Science and Engineering Practices (1 of 6)

When scientists study phenomena to better understand how the natural world works or when engineers design solutions to a problem, they engage in certain processes called practices. These practices are, essentially, how science or engineering is done.

These Practices are:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Furthermore, there are 4 understandings about the Nature of Science that scientists have that are a foundation for the practices.

These Understandings about the Nature of Science are:

1. Scientific investigations use a variety of methods.
2. Scientific knowledge is based on empirical evidence (knowledge obtained by observation and experimentation).
3. Scientific knowledge is open to revision in light of new evidence.

Science models, laws, mechanisms, and theories explain natural phenomena.

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(M) Reflection – Crosscutting Concepts (2 of 6)

Some concepts are important to all studies in science and engineering. Seven of these ***Crosscutting Concepts*** – ideas that are important to any science (biology, physics, chemistry, ecology, astronomy, geology, etc.) and to all engineering – have been identified.

1. ***Patterns.*** Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

2. ***Cause and effect:*** *Mechanism and explanation*. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

3. ***Scale, proportion, and quantity.*** In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.

4. ***Systems and system models.*** Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.

5. ***Energy and matter: Flows, cycles, and conservation.*** Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.

6. ***Structure and function.*** The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

7. ***Stability and change.*** For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

Furthermore, there are 4 understandings about the Nature of Science that are closely related to the Crosscutting Concepts.

These Understandings about the Nature of Science are:

1. Science is a way of knowing.
2. Scientific knowledge assumes an order and consistency in natural systems.
3. Science is a human endeavor.
4. Science addresses questions about the natural and material world.

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(M) Reflection – Science and Engineering Practices (3 of 6)

Name: ______________________________

In your group, reflect carefully on the activities you have just completed and answer the following questions using the table on the next page.

a. What Science and/or Engineering Practices did you do and which of the understandings about the Nature of Science were important to what you did? (There is probably more than one.)
b. When? During which activities?
c. Explain your reasoning.
d. Be prepared to explain your best thinking about what Practices you used and when you were doing them in a full class discussion.

Nature of Science	When?	What is your reasoning?
Scientific investigations use a variety of methods.		
Scientific knowledge is based on empirical evidence (knowledge obtained by observation and experimentation).		
Scientific knowledge is open to revision in light of new evidence.		
Science models, laws, mechanisms, and theories explain natural phenomena.		

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(M) Reflection – Science and Engineering Practices (4 of 6)

Practice	When?	What is your reasoning?
Asking questions (for science) and defining problems (for engineering)		
Developing and using models		
Planning and carrying out investigations		
Analyzing and interpreting data		
Using mathematics and computational thinking		
Constructing explanations (for science) and designing solutions (for engineering)		
Engaging in argument from evidence		
Obtaining, evaluating, and communicating information		

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(M) Reflection – Crosscutting Concepts (5 of 6)

Name: ______________________________

In your group, reflect carefully on the activities you have just completed and answer the following questions using the table on the next page.

a. What Crosscutting Concepts did you do and which of the understandings about the Nature of Science were important to what you did? (There is probably more than one.)
b. When? During which activities?
c. Explain your reasoning.
d. Be prepared to explain your best thinking about what Crosscutting Concepts you used and when you were doing them in a full class discussion.

Nature of Science	When?	What is your reasoning?
Science is a way of knowing.		
Scientific knowledge assumes an order and consistency in natural systems.		
Science is a human endeavor.		
Science addresses questions about the natural and material world.		

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(M) Reflection – Crosscutting Concepts (6 of 6)

Crosscutting Concepts	When?	What is your reasoning?
Patterns		
Cause and effect: Mechanism and explanation		
Scale, proportion, and quantity		
Systems and system models		
Energy and matter: Flows, cycles, and conservation		
Structure and function		
Stability and change		

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