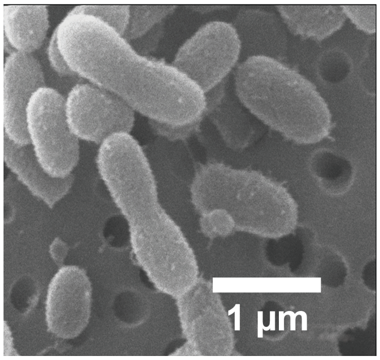
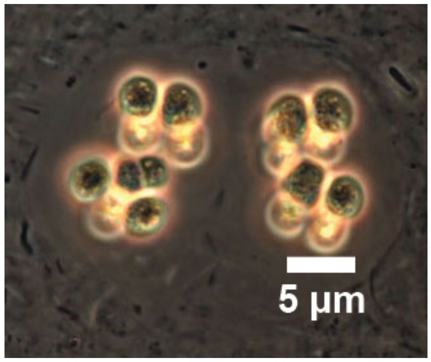
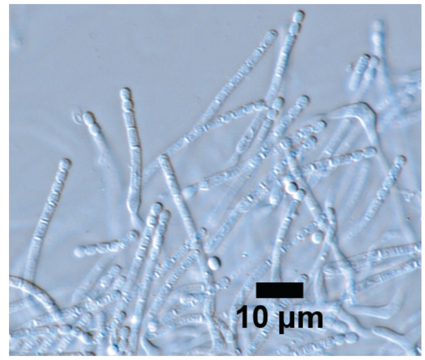
National Aeronautics and Space Administration

Astrobiobound! The Search for Life in the Solar System

High School Grade Next Generation Science Standards, Common Core State Standards, and 21st Century Skills Alignment Document







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 ARE WAVES USED TO TRANSFER ENERGY AND INFORMATION?

NGSS Core Question: PS4: Waves and Their Applications in Technologies for Information Transfer

INSTRUCTIONAL OBJECTIVES (IO)

Students will be able to

IO1: Create an engineering model of an astrobiology mission choosing instruments for research 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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How are instruments that transmit and detect waves used to extend human senses?

NGSS PS4.C: Information Technologies and Instrumentation

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

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

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 AND WHY DO ORGANISMS INTERACT WITH THEIR ENVIRONMENT AND WHAT ARE THE EFFECTS OF THESE INTERACTIONS?

NGSS Core Question: LS2: Ecosystems: Interactions, Energy, and Dynamics

How do matter and energy move through an ecosystem?

NGSS Core Question: LS2B: Cycles of Matter and Energy Transfer in Ecosystems

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1.0 About This Activity

This Astrobiology lesson leverages *A Taxonomy for Learning, Teaching, and Assessing* by Anderson and Krathwohl (2001) (referenced at end of this document). This taxonomy provides a framework to help organize and align learning objectives, activities, and assessments. The taxonomy has two dimensions. The first dimension, cognitive process, provides categories for classifying lesson objectives along a continuum, at increasingly higher levels of thinking; these verbs allow educators to align their instructional objectives and assessments of learning outcomes to an appropriate level in the framework in order to build and support student cognitive processes. The second dimension, knowledge, allows educators to place objectives along a scale from concrete to abstract. By employing Anderson and Krathwohl's (2001) taxonomy, educators can better understand the construction of instructional objectives and learning outcomes in terms of the types of student knowledge and cognitive processes they intend to support. All activities provide a mapping to this taxonomy in the Teacher Guide (at the end of this lesson), which carries additional educator resources. Combined with the aforementioned taxonomy, the lesson design also draws upon Miller, Linn, and Gronlund's (2009) methods for (a) constructing a general, overarching, instructional objective with specific, supporting, and measurable learning outcomes that help assure the instructional objective is met, and (b) appropriately assessing student performance in the intended learning-outcome areas through rubrics and other measures

How Students Learn: Science in the Classroom (Donovan & Bransford, 2005) advocates the use of a research-based instructional model for improving students' grasp of central science concepts. Based on conceptual-change theory in science education, the 5E Instructional Model (BSCS, 2006) includes five steps for teaching and learning: Engage, Explore, Explain, Elaborate, and Evaluate. The Engage stage is used like a traditional warm-up to pique student curiosity, interest, and other motivation-related behaviors and to assess students' prior knowledge. The Explore step allows students to deepen their understanding and challenges existing preconceptions and misconceptions, offering alternative explanations that help them form new schemata. In Explain, students communicate what they have learned, illustrating initial conceptual change. The Elaborate phase gives students the opportunity to apply their newfound knowledge to novel situations and supports the reinforcement of new schemata or its transfer. Finally, the Evaluate stage serves as a time for students' own formative assessment, as well as for educators' diagnosis of areas of confusion and differentiation of further instruction. This five-part sequence is the organizing tool for the Mars instructional series. The 5E stages can be cyclical and iterative.

The format for developing a question was guided by statements made by Bybee in "Scientific and engineering practices in K-12 classrooms: Understanding a framework for K-12 science education" publish by NSTA. Here Bybee explained that the term "practices" was a much more accurate explanation of scientific inquiry. These practices "involve doing and learning in such a way that cannot be really separated." The process for reaching a scientific research question in this lesson has been discussed and vetted through planetary scientists actively involved in research.

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2.0 Instructional Objectives, Learning Outcomes, Standards, & Rubrics

Instructional objectives and learning outcomes are aligned with

- Achieve Inc.'s, *Next Generation Science Standards (NGSS)*
- National Research Council's, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*
- National Governors Association Center for Best Practices (NGA Center) and Council of Chief State School Officers (CCSSO)'s, *Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and* Technical Subjects
- Partnership for 21st Century Skills, *A Framework for 21st Century Learning*

The following chart provides details on alignment among the core and component NGSS questions, instructional objectives, learning outcomes, and educational standards.

- Your **instructional objectives (IO)** for this lesson align with the NRC Framework and NGSS.
- You will know that you have achieved these instructional objectives if students demonstrate the related **learning outcomes (LO),** also aligned with NGSS Framework and NGSS.
- You will know the level to which your students have achieved the learning outcomes by using the suggested **rubrics**.

Important Note: This lesson is color-coded to help teachers identify each of the three dimensions of NGSS. The following identifying colors are used: Practices are blue, Cross-Cutting Concepts are green, and Disciplinary Core Ideas are orange.

This color-coding is consistent with the NGSS Performance Expectations and Foundation Boxes.

Quick View of Standards Alignment:

This alignment document provides full details of standards alignment, rubrics, and the way in which instructional objectives, learning outcomes, 5E activity procedures, and assessments were derived through, and align with, Anderson and Krathwohl's (2001) taxonomy of knowledge and cognitive process types. For convenience, a quick view follows:

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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 ARE WAVES USED TO TRANSFER ENERGY AND INFORMATION?

NGSS Core Question: PS4: Waves and Their Applications in Technologies for Information Transfer

How are instruments that transmit and detect waves used to extend human senses?

NGSS PS4.C: Information Technologies and Instrumentation

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

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

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 AND WHY DO ORGANISMS INTERACT WITH THEIR ENVIRONMENT AND WHAT ARE THE EFFECTS OF THESE INTERACTIONS?

NGSS Core Question: LS2: Ecosystems: Interactions, Energy, and Dynamics

How do matter and energy move through an ecosystem?

NGSS Core Question: LS2B: Cycles of Matter and Energy Transfer in Ecosystems

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Instructional Objective *Students will be able to*	**Learning Outcomes** *Students will demonstrate the measurable abilities*	**Standards** *Students will address*	
IO1: **Create an engineering model of an astrobiology mission choosing instruments for research limited by criteria and constraints and designed to achieve the task of looking for past or present life in the Solar System.**	**LO1a: to define an appropriate mission to search for life requiring initial goals for an engineering design solution** **LO1b: to analyze criteria and constraints in an engineering design task and collect data to generate and refine an appropriate solution using tools (instruments) to achieve the mission goal** **LO1c: to identify and explain the specific components of the engineering design cycle for the designed model** **LO1d: to identify and explain the complex relationship between science and engineering design**	**DISCIPLINARY CORE IDEA:** **EST1.A: Defining and Delimiting Engineering Problems** **EST1.B: Developing Possible Solutions** **EST1.C: Optimizing the Design Solution** **LS1.C: Organization for Matter and Energy Flow in Organisms** **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** **PS4.C: Information Technologies and Instrumentation** **PRACTICES:** **1. Asking Questions and Defining Problems** **2. Developing and Using Models** **3. Planning and Carrying Out Investigations** **4. Analyzing and Interpreting Data** **5. Constructing Explanations and Designing Solutions** **6. Engaging in Argument from Evidence** **7. Obtaining, Evaluating, and Communicating Information** **CROSSCUTTING CONCEPTS:** **1. Patterns** **2. Systems and System Models** **3. Structure and Function** **Science is a Human Endeavor**	***Rubrics in Teacher Guide***

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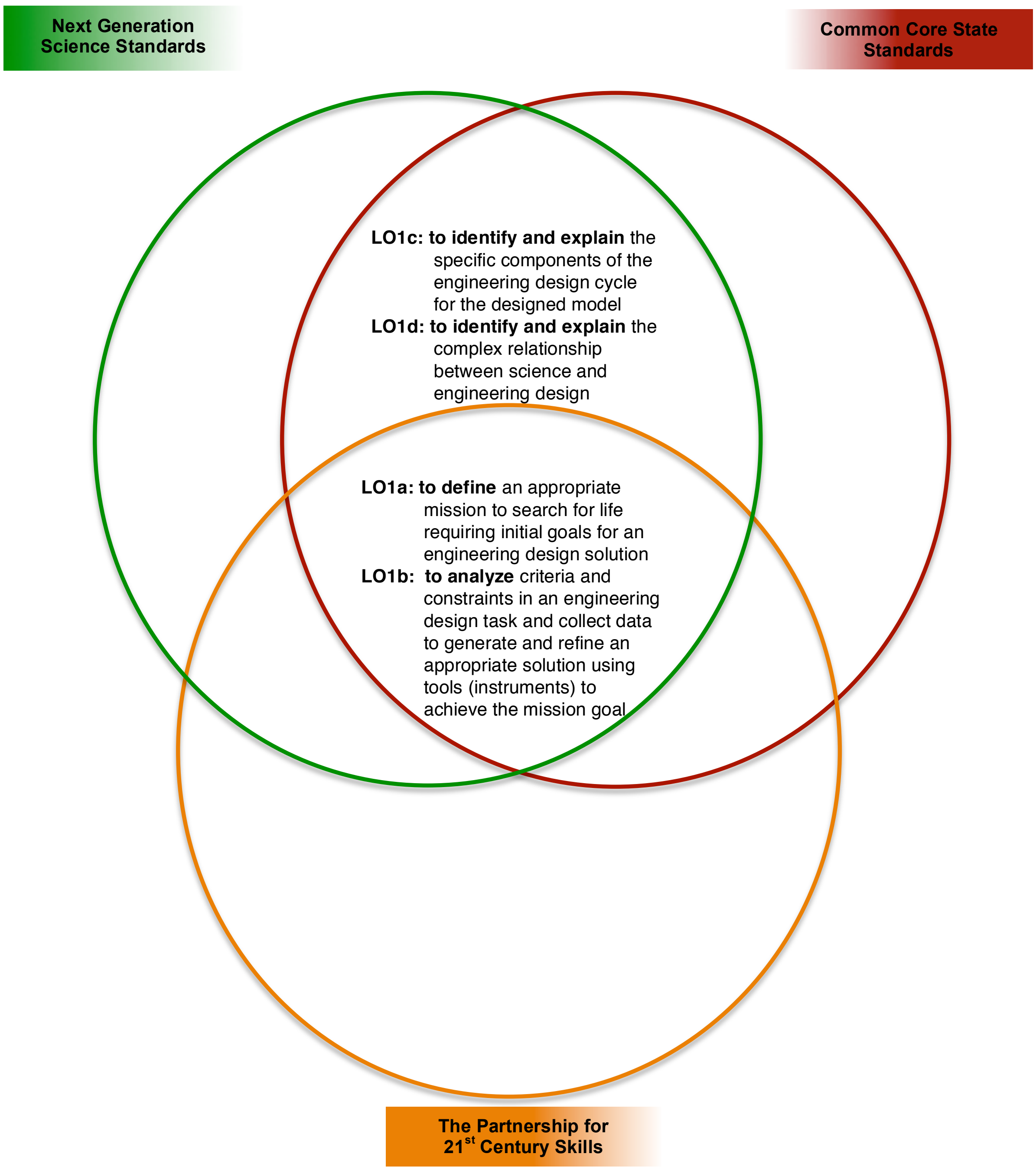
3.0 Learning Outcomes, NGSS, Common Core, & 21st Century Skills Connections

The connections diagram is used to organize the learning outcomes addressed in the lesson to establish where each will meet the Next Generation Science Standards, ELA Common Core Standards, and the 21st Century Skills and visually determine where there are overlaps in these documents.



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4.0 Evaluation/Assessment

Use the *(N) Astrobiobound! The Search for Life in the Solar System 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, Common Core State Standards, and 21st Century Skills.

5.0 References

Achieve, Inc. (2013). *Next generation science standards*. Achieve, Inc. on behalf of the twenty-six states and partners that collaborated on the NGSS.

Anderson, L.W., & Krathwohl (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives.* New York: Longman.

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Donovan, S. & Bransford, J. D. (2005). *How Students Learn: History, Mathematics, and Science in the Classroom.* Washington, DC: The National Academies Press.

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National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

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(M) Teacher Resource. Astrobiobound NGSS Alignment (1 of 3)

You will know the level to which your students have achieved the **Learning Outcomes**, and thus the **Instructional Objective(s)**, by using the suggested **Rubrics** below.

Related Standard(s)

This lesson supports the preparation of students toward achieving Performance Expectations using the Practices, Cross-Cutting Concepts and Disciplinary Core Ideas defined below:

(HS-ETS1-1), (HS-ETS1-2), (HS-ETS1-3);
(HS-LS1-6), (HS-LS2-5);
(HS-PS4-5)

Next Generation Science Standards Alignment (NGSS)

Instructional Objective	Science and Engineering Practices	Disciplinary Core Idea	Crosscutting Concepts
IO1: **Create an engineering model of an astrobiology mission choosing instruments for research limited by criteria and constraints and designed to achieve the task of looking for past or present life in the Solar System.**	**Developing and Using Models:** Design a test of a model to ascertain its reliability. **Planning and Carrying Out Investigations:** Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. **Analyzing and Interpreting Data:** Analyze data using tools,	**PS4.C: Information Technologies and Instrumentation:** Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. (HS-PS4-5) **LS1.C: Organization for Matter and Energy Flow in Organisms:** The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. (HS-LS1-6) **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems:** Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. (HS-LS2-5)	**Patterns:** Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. **Systems and System Models**: Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. **Structure and Function:** Investigating or designing new

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	technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success. **Constructing Explanations and Designing Solutions:** Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. **Engaging in Argument from Evidence:** Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.	**ETS1.A: Defining and Delimiting Engineering Problems:** Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1) **ETS1.B: Developing Possible Solutions:** When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3) **ETS1.C: Optimizing the Design Solution:** Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2)	systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

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(M) Teacher Resource. Astrobiobound NGSS Alignment (2 of 3)

Next Generation Science Standards Alignment (NGSS)

Learning Outcomes	Science and Engineering Practices	Disciplinary Core Idea	Crosscutting Concepts
LO1a: **to define an appropriate mission to search for life requiring initial goals for an engineering design solution**	**Asking Questions and Defining Problems:** Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical and/or environmental considerations.	**LS1.C: Organization for Matter and Energy Flow in Organisms:** The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. (HS-LS1-6) **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems:** Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. (HS-LS2-5) **ETS1.A: Defining and Delimiting Engineering Problems:** Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1)	**Systems and System Models:** When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.
LO1b: **to analyze criteria and constraints in an engineering design task and collect data to generate and refine an appropriate solution using tools (instruments) to achieve the mission goal**	**Asking Questions and Defining Problems:** Ask questions to clarify and/or refine a model, an explanation, or an engineering problem. Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. **Planning and Carrying Out**	**PS4.C: Information Technologies and Instrumentation:** Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. (HS-PS4-5) **ETS1.A: Defining and Delimiting Engineering Problems:** Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1) **ETS1.B: Developing Possible Solutions:** When evaluating solutions, it is important to take into account a range of	**Patterns:** Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system.

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	Investigations: Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions. **Analyzing and Interpreting Data:** Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success. **Constructing Explanations and Designing Solutions:** Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints. Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing.	constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3) **ETS1.C: Optimizing the Design Solution:** Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2)	
LO1c: **to identify and explain the specific components of the engineering design cycle for the designed model**	**Developing and Using Models:** Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria. **Engaging in Argument from Evidence:** Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.	**ETS1.C: Optimizing the Design Solution:** Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2)	**Patterns:** Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. **Systems and System Models:** Systems can be designed to do specific tasks. When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

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	Obtaining, Evaluating, and Communicating Information: Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).		
LO1d: to **identify and explain** the **complex relationship between science and engineering design**	**Analyzing and Interpreting: Data:** Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success. **Constructing Explanations and Designing Solutions:** Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. **Engaging in Argument from Evidence:** Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence.	**Interdependence of Science, Engineering, and Technology:** Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise.	**Science is a Human Endeavor:** Individuals and teams from many nations and cultures have contributed to science and to advances in engineering. Technological advances have influenced the progress of science and science has influenced advances in technology. Science and engineering are influenced by society and society is influenced by science and engineering.

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(M) Teacher Resource. Astrobiobound NGSS Individual Activity Alignment (3 of 3)

Next Generation Science Standards Activity Alignments (NGSS)

Activity	Phases of 5E Instructional Model	Science and Engineering Practices	Disciplinary Core Idea	Crosscutting Concepts
(C) Characteristics of Life	**Engage** **Explain**	**Constructing Explanations and Designing Solutions:** Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support	**LS1.A: Structure and Function** All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). (MS-LS1-1)	**Scientific Knowledge Assumes an Order and Consistency in Natural Systems:** Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. Science assumes the universe is a vast single system in which basic laws are consistent.
(G) Mission Goals	**Explore** **Explain**	**Asking Questions and Defining Problems:** Ask questions to clarify and/or refine a model, an explanation, or an engineering problem. Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical and/or environmental considerations.	**ETS1.A: Defining and Delimiting Engineering Problems:** Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1)	**Systems and System Models:** Systems can be designed to do specific tasks. When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.
(I) Spacecraft Design Log	**Explore** **Explain**	**Developing and Using Models:** Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria. **Planning and Carrying Out Investigations:** Plan an investigation or test a design	**ETS1.B: Developing Possible Solutions:** When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3) **ETS1.C: Optimizing the Design Solution:** Criteria may need to be broken down into simpler ones that can be approached systematically, and	**Cause and Effect:** Systems can be designed to cause a desired effect. **Systems and System Models:** Systems can be designed to do specific tasks. When investigating or describing a system, the boundaries and initial

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		individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. **Engaging in Argument from Evidence:** Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments.	decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2)	conditions of the system need to be defined and their inputs and outputs analyzed and described using models. **Structure and Function:** Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.
(J) Engineering Constraints	**Explain**	**Constructing Explanations and Designing Solutions:** Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**ETS1.B: Developing Possible Solutions:** When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3) **ETS1.C: Optimizing the Design Solution:** Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2)	**Structure and Function:** Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.
(K) Engineering Design Cycle	**Evaluate**	**Constructing Explanations and Designing Solutions:** Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**ETS1.A: Defining and Delimiting Engineering Problems:** Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1) **ETS1.B: Developing Possible Solutions:** When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider	**Patterns:** Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. **Cause and Effect:** Systems can be designed to cause a desired effect. **Structure and Function:** Investigating or designing new systems or structures requires a detailed

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			social, cultural, and environmental impacts. (HS-ETS1-3) **ETS1.C: Optimizing the Design Solution:** Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2)	examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.
(L) Post-Ideas	**Evaluate**	**Constructing Explanations and Designing Solutions:** Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.	**ETS1.A: Defining and Delimiting Engineering Problems:** Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1) **ETS1.B: Developing Possible Solutions:** When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3) **ETS1.C: Optimizing the Design Solution:** Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2)	**Science is a Human Endeavor:** Individuals and teams from many nations and cultures have contributed to science and to advances in engineering. Technological advances have influenced the progress of science and science has influenced advances in technology. Science and engineering are influenced by society and society is influenced by science and engineering.

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(M) Teacher Resource. Astrobiobound CCSS Alignment (1 of 3)

Common Core State Standards

Instructional Objective	Reading Standards for Literacy in Science and Technical Subjects (9-12)	Writing Standards for Literacy in Science and Technical Subjects (9-12)	Speaking and Listening Standards (9-12)
IO1: **Create an engineering model of an astrobiology mission choosing instruments for research limited by criteria and constraints and designed to achieve the task of looking for past or present life in the Solar System.**	**Key Ideas and Details:** **Grade 9-10:** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text. **Grade 11-12:** Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. **Craft and Structure:** **Grade 9-10:** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9–10 texts and topics. Analyze the structure of the relationships among concepts in a text, including	**Text Types and Purposes:** **Grade 9-10:** Write arguments focused on discipline-specific content. • Introduce precise claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that establishes clear relationships among the claim(s), counter-claims, reasons, and evidence. • Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form and in a manner that anticipates the audience's knowledge level and concerns. • Use words, phrases, and clauses to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims. • Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing. • Provide a concluding statement or section that follows from or supports the argument presented. Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. • Introduce a topic and organize ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings),	**Comprehension and Collaboration:** **Grade 9-10:** Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively. • Come to discussions prepared, having read and researched material under study; explicitly draw on that preparation by referring to evidence from texts and other research on the topic or issue to stimulate a thoughtful, well-reasoned exchange of ideas. • Work with peers to set rules for collegial discussions and decision-making (e.g., informal consensus, taking votes on key issues, presentation of alternate views), clear goals and deadlines, and individual roles as needed. • Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions. • Respond thoughtfully to diverse perspectives, summarize points of agreement and disagreement, and, when warranted, qualify or justify their own

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	relationships among key terms (e.g., force, friction, reaction force, energy). **Grade 11-12:** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11–12 texts and topics. **Integration of Knowledge and Ideas:** **Grade 9-10:** Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. **Grade 11-12:** Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.	graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension. • Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic. • Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among ideas and concepts. • Use precise language and domain-specific vocabulary to manage the complexity of the topic and convey a style appropriate to the discipline and context as well as to the expertise of likely readers. • Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing. • Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic). **Grade 11-12:** Write arguments focused on discipline-specific content. • Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence. • Develop claim(s) and counterclaims fairly and thoroughly, supplying the most relevant data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form that anticipates the audience's knowledge level, concerns, values, and possible biases. • Use words, phrases, and clauses as well as varied syntax to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims. • Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.	views and understanding and make new connections in light of the evidence and reasoning presented. Evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric, identifying any fallacious reasoning or exaggerated or distorted evidence. **Grade 11-12:** Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 11–12 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively. • Come to discussions prepared, having read and researched material under study; explicitly draw on that preparation by referring to evidence from texts and other research on the topic or issue to stimulate a thoughtful, well-reasoned exchange of ideas. • Work with peers to promote civil, democratic discussions and decision-making, set clear goals and deadlines, and establish individual roles as needed. • Propel conversations by posing and responding to questions that probe reasoning and evidence; ensure a hearing for a full range of positions on a topic or issue; clarify, verify, or challenge ideas and conclusions; and promote divergent and creative perspectives. • Respond thoughtfully to diverse perspectives; synthesize comments, claims, and evidence made on all sides of an issue; resolve contradictions when possible; and determine what additional information or research is required to deepen the investigation or complete the task. Evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric, assessing

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		• Provide a concluding statement or section that follows from or supports the argument presented. Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. • Introduce a topic and organize complex ideas, concepts, and information so that each new element builds on that which precedes it to create a unified whole; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension. • Develop the topic thoroughly by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic. • Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among complex ideas and concepts. • Use precise language, domain-specific vocabulary and techniques such as metaphor, simile, and analogy to manage the complexity of the topic; convey a knowledgeable stance in a style that responds to the discipline and context as well as to the expertise of likely readers. • Provide a concluding statement or section that follows from and supports the information or explanation provided (e.g., articulating implications or the significance of the topic). **Research to Build and Present Knowledge:** **Grades 9-12:** Draw evidence from informational texts to support analysis, reflection, and research	the stance, premises, links among ideas, word choice, points of emphasis, and tone used.

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(M) Teacher Resource. Astrobiobound CCSS Alignment (2 of 3)

Common Core State Standards

Learning Outcome	Reading Standards for Literacy in Science and Technical Subjects (9-12)	Writing Standards for Literacy in Science and Technical Subjects (9-12)	Speaking and Listening Standards (9-12)
LO1a: to define an appropriate mission to search for life requiring initial goals for an engineering design solution **LO1b:** to analyze criteria and constraints in an engineering design task and collect data to generate and refine an appropriate solution using tools (instruments) to achieve the mission goal	**Key Ideas and Details:** **Grade 9-10:** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text. **Grade 11-12:** Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. **Craft and Structure:** **Grade 9-10:** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9–10 texts and topics. Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy). **Grade 11-12:** Determine the meaning of symbols, key terms,		**Comprehension and Collaboration:** **Grade 9-10:** Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively. • Come to discussions prepared, having read and researched material under study; explicitly draw on that preparation by referring to evidence from texts and other research on the topic or issue to stimulate a thoughtful, well-reasoned exchange of ideas. • Work with peers to set rules for collegial discussions and decision-making (e.g., informal consensus, taking votes on key issues, presentation of alternate views), clear goals and deadlines, and individual roles as needed. • Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions. • Respond thoughtfully to diverse perspectives, summarize points of agreement and disagreement, and, when warranted, qualify or justify their own views and understanding and make new connections in light of the evidence and

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	and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11–12 texts and topics. **Integration of Knowledge and Ideas:** **Grade 9-10:** Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. **Grade 11-12:** Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.		reasoning presented. Evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric, identifying any fallacious reasoning or exaggerated or distorted evidence. **Grade 11-12:** Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 11–12 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively. • Come to discussions prepared, having read and researched material under study; explicitly draw on that preparation by referring to evidence from texts and other research on the topic or issue to stimulate a thoughtful, well-reasoned exchange of ideas. • Work with peers to promote civil, democratic discussions and decision-making, set clear goals and deadlines, and establish individual roles as needed. • Propel conversations by posing and responding to questions that probe reasoning and evidence; ensure a hearing for a full range of positions on a topic or issue; clarify, verify, or challenge ideas and conclusions; and promote divergent and creative perspectives. • Respond thoughtfully to diverse perspectives; synthesize comments, claims, and evidence made on all sides of an issue; resolve contradictions when possible; and determine what additional information or research is required to deepen the investigation or complete the task. Evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric, assessing the stance, premises, links among ideas, word choice, points of emphasis, and tone used.

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Common Core State Standards			
Learning Outcome	**Reading Standards for Literacy in Science and Technical Subjects (9-12)**	**Writing Standards for Literacy in Science and Technical Subjects (9-12)**	**Speaking and Listening Standards (9-12)**
LO1c: **to identify and explain the specific components of the engineering design cycle for the designed model** **LO1d:** **to identify and explain the complex relationship between science and engineering design**		**Text Types and Purposes:** **Grade 9-10:** Write arguments focused on discipline-specific content. • Introduce precise claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that establishes clear relationships among the claim(s), counter-claims, reasons, and evidence. • Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form and in a manner that anticipates the audience's knowledge level and concerns. • Use words, phrases, and clauses to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims. • Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing. • Provide a concluding statement or section that follows from or supports the argument presented. Write informative/explanatory texts, including the narration of historical events, scientific	

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		procedures/experiments, or technical processes. • Introduce a topic and organize ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension. • Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic. • Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among ideas and concepts. • Use precise language and domain-specific vocabulary to manage the complexity of the topic and convey a style appropriate to the discipline and context as well as to the expertise of likely readers. • Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing. • Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic). **Grade 11-12:** Write arguments focused on discipline-specific content. • Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence. • Develop claim(s) and counterclaims fairly and thoroughly, supplying the most relevant data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form that anticipates the audience's knowledge level,	

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		concerns, values, and possible biases. • Use words, phrases, and clauses as well as varied syntax to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims. • Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing. • Provide a concluding statement or section that follows from or supports the argument presented. Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. • Introduce a topic and organize complex ideas, concepts, and information so that each new element builds on that which precedes it to create a unified whole; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension. • Develop the topic thoroughly by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic. • Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among complex ideas and concepts. • Use precise language, domain-specific vocabulary and techniques such as metaphor, simile, and analogy to manage the complexity of the topic; convey a knowledgeable stance in a style that responds to the discipline and context as well as to the expertise of likely readers. • Provide a concluding statement or section that follows from and supports the information or explanation provided (e.g., articulating implications or the significance of the topic).	

		Research to Build and Present Knowledge: **Grades 9-12:** Draw evidence from informational texts to support analysis, reflection, and research	

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(M) Teacher Resource. Astrobiobound 21st Century Skill Alignment (1 of 1)

21st Century Skills

Learning Outcomes	21st Century Skill	Grade 12 Benchmark
LO1a: to define an appropriate mission to search for life requiring initial goals for an engineering design solution	**Collaboration**	Students collaborate with peers and experts during scientific discourse and appropriately defend arguments using scientific reasoning, logic, and modeling.
	Media Literacy	Students are able to critique claims that people make when they select only data that support the claim, and ignore data that may contradict it.
	Flexibility and Adaptability	Students are able to revise their own scientific ideas and hypotheses based on new evidence or information.
LO1b: to analyze criteria and constraints in an engineering design task and collect data to generate and refine an appropriate solution using tools (instruments) to achieve the mission goal	**Collaboration**	Students collaborate with peers and experts during scientific discourse and appropriately defend arguments using scientific reasoning, logic, and modeling.
	Media Literacy	Students are able to critique claims that people make when they select only data that support the claim, and ignore data that may contradict it.
	Flexibility and Adaptability	Students are able to revise their own scientific ideas and hypotheses based on new evidence or information.
LO1c: to identify and explain the specific components of the engineering design cycle for the designed model		
LO1d: to identify and explain the complex relationship between science and engineering design		

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(N) Teacher Resource. Astrobiobound NGSS Rubrics

Related Rubrics for the Assessment of Learning Outcomes Associated with the Above Standard(s):

Next Generation Science Standards Alignment (NGSS)

Learning Outcome	Expert	Proficient	Intermediate	Beginner
LO1a: to define an appropriate mission to search for life requiring initial goals for an engineering design solution	Goals take into account the complexity of choosing a landing site, the search for biosignatures, and choosing an appropriate spacecraft. Modifies design significantly using these pre-established science goals during the simulation.	Goals take into account choosing a landing site, the search for biosignatures, and choosing an appropriate spacecraft. Moderately modifies design using these pre-established science goals during the simulation.	Chooses a landing site, a biosignature, and a spacecraft. Modifies design using these pre-established science goals during the simulation.	Designs a mission during the simulation that reflects personal interest.
LO1b: to analyze criteria and constraints in an engineering design task and collect data to generate and refine an appropriate solution using tools (instruments) to achieve the mission goal	Design takes into account complexity of balancing budget, mass, power and science return. Modifies design significantly using pre-established science goals during the simulation.	Design accounts for complexity of balance between budget, mass, power and science return. Modifies the design during the simulation.	Design takes into account the balance between budget, mass, and power and therefore modifies the design during the simulation.	Design tends to focus only on Spacecraft components that are of interest to the builder, and is over budget, mass, and or power.
LO1c: to identify and explain the specific components of the engineering design cycle for the designed model	Justifications are based on experiences in the simulation and are relevant to engineering constraints within the design cycle. Demonstrates complexity of these constraints and iterations.	Justifications are based on experiences in the simulation and selects examples that partially describe the complexity in engineering constraints and the iterations.	Justifications are based on experiences in the simulation. Student identifies examples from the simulation.	Justifications are based on misconceptions or previous understanding / beliefs. Uses personal preferences for justification.
LO1d: to identify and explain the complex relationship between science and engineering design	Post-survey responses demonstrate the student has connected to the complexity of mission planning and recognizes their new understanding of mission planning.	Post-survey demonstrates the student has connected to the complexity of mission planning using a variety of examples and explanations.	Post-Survey responses indicate an understanding of the connection between engineering constraints and a good mission.	Post-Survey responses tend to focus on one engineering constraints or are very similar to Pre-Survey responses.

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(N) Teacher Resource. Astrobiobound CCSS Rubric

Common Core State Standards

	Expert	Proficient	Intermediate	Beginner
Research to Build and Present Knowledge	Recalls relevant information from experience; summarizes information in finished work; draws evidence from informational texts to support analysis, reflection, and research.	Recalls relevant information from experience; draws evidence from informational texts to support analysis, reflection, and research.	Recalls information from experience; draws evidence from informational texts to support analysis, reflection, and research.	Recalls information from experience.
Effective Demonstration of Comprehension and Collaboration	Clearly articulates ideas in collaborative discussion while following agreed upon class rules for discussion. Extremely prepared drawing from experiences. Asks clarifying questions to ensure full understanding of content. Articulates own ideas related to the discussion and connects others ideas to own.	Articulates ideas in collaborative discussion while following agreed upon class rules for discussion. Prepared for discussion by drawing from experiences. Asks questions. Articulates own ideas related to the discussion.	Interested in collaborative discussion. Asks questions. Articulates own ideas related to the discussion.	Interested in collaboration with peers.
Text Types and Purpose	Introduces topic clearly, provides a general observation and focus, and groups related information logically; Develops the topic with facts, definitions, concrete details, or other examples related to the topic; Links ideas using words, phrases, and clauses; Use domain-specific vocabulary to explain the topic; Provides a concluding statement related to the explanation.	Introduces topic clearly, provides a general observation, or groups related information logically; Develops the topic with concrete details, or other examples related to the topic; Links ideas using words or phrases; Uses domain-specific vocabulary to explain the topic; Provides a concluding statement related to the explanation.	Introduces topic, provides a general observation; Develops the topic with details, or other examples related to the topic; Links ideas using words or phrases; Uses domain-specific vocabulary to explain the topic; May or may not provide a concluding statement.	Introduces topic; Develops the topic with details, or other examples, potentially unrelated; Uses specific vocabulary to explain the topic; May or may not provide a concluding statement.
Key Ideas and Details	Uses specific evidence from text to support ideas. Develops an accurate and in depth summary, extending prior understanding and opinions.	Uses specific evidence from text to support ideas. Develops an in depth summary, extending prior understanding and opinions.	Uses information from text to support ideas. Develops a summary, extending prior understanding and opinions.	Supports ideas with details, relying on prior understanding and opinions.
Craft and Structure	Develops strong, accurate vocabulary through mission planning.	Develops strong, vocabulary through mission planning.	Develops vocabulary through mission planning.	Vocabulary is rudimentary and based on prior understanding.

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Integration of Knowledge	Successfully combines information from lesson with resources to develop a deep understanding of the topic.	Successfully combines information from lesson with resources to develop an understanding of a topic.	Combines information from lesson with resources to develop a summary of a topic.	References text from resources to develop a summary of a topic.

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(N) Teacher Resource. Astrobiobound 21st Century Skill Rubric

Partnership for 21st Century Skills

	Expert	Proficient	Intermediate	Beginner
Effectiveness of collaboration with team members and class.	Extremely interested in collaborating in the simulation. Actively provides solutions to problems, listens to suggestions from others, attempts to refine them, monitors group progress, and attempts to ensure everyone has a contribution.	Extremely interested in collaborating in the simulation. Actively provides suggestions and occasionally listens to suggestions from others. Refines suggestions from others.	Interested in collaborating in the simulation. Listens to suggestions from peers and attempts to use them. Occasionally provides suggestions in group discussion.	Interested in collaborating in the simulation.
Effectiveness of Media Literacy	Actively listens to suggestions and ideas from others while asking clarifying questions to ensure claims are consistent with the evidence provided.	Listens to suggestions and ideas from others while asking clarifying questions to ensure claims are consistent with the evidence provided.	Listens to suggestions and ideas from others and asking clarifying questions while following their direction.	Listens to the suggestions provided by others and follows their direction.
Effectiveness of Creativity, Innovation and Flexibility	Model is an excellent representation of a wide variety of generating and testing of ideas to achieve equilibrium while acquiring high science return.	Model is an excellent representation of a wide variety of generating and testing of ideas to achieve equilibrium while acquiring moderate science return.	Model is a representation of a variety of generating and testing of ideas to achieve equilibrium while acquiring moderate science return.	Model is a representation of generating and testing of ideas to achieve equilibrium while acquiring at least one science return.

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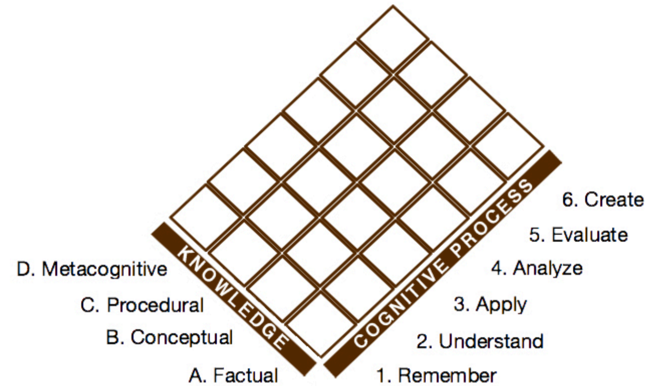
(O) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (1 of 3)

This lesson adapts Anderson and Krathwohl's (2001) taxonomy, which has two domains: Knowledge and Cognitive Process, each with types and subtypes (listed below). Verbs for objectives and outcomes in this lesson align with the suggested knowledge and cognitive process area and are mapped on the next page(s). Activity procedures and assessments are designed to support the target knowledge/cognitive process.



Knowledge	Cognitive Process
A. Factual	**1. Remember**
Aa: Knowledge of Terminology	**1.1** Recognizing (Identifying)
Ab: Knowledge of Specific Details & Elements	**1.2** Recalling (Retrieving)
B. Conceptual	**2. Understand**
Ba: Knowledge of classifications and categories	**2.1** Interpreting (Clarifying, Paraphrasing, Representing, Translating)
Bb: Knowledge of principles and generalizations	**2.2** Exemplifying (Illustrating, Instantiating)
Bc: Knowledge of theories, models, and structures	**2.3** Classifying (Categorizing, Subsuming)
C. Procedural	**2.4** Summarizing (Abstracting, Generalizing)
Ca: Knowledge of subject-specific skills and algorithms	**2.5** Inferring (Concluding, Extrapolating, Interpolating, Predicting)
Cb: Knowledge of subject-specific techniques and methods	**2.6** Comparing (Contrasting, Mapping, Matching)
Cc: Knowledge of criteria for determining when to use appropriate procedures	**2.7** Explaining (Constructing models)
	3. Apply
D. Metacognitive	**3.1** Executing (Carrying out)
Da: Strategic Knowledge	**3.2** Implementing (Using)
Db: Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge	**4. Analyze**
	4.1 Differentiating (Discriminating, distinguishing, focusing, selecting)
Dc: Self-knowledge	**4.2** Organizing (Finding coherence, integrating, outlining, parsing, structuring)
	4.3 Attributing (Deconstructing)
	5. Evaluate
	5.1 Checking (Coordinating, Detecting, Monitoring, Testing)
	5.2 Critiquing (Judging)
	6. Create
	6.1 Generating (Hypothesizing)
	6.2 Planning (Designing)
	6.3 Producing (Constructing)

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(O) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (2 of 3)

The design of this activity leverages Anderson & Krathwohl's (2001) taxonomy as a framework. Pedagogically, it is important to ensure that objectives and outcomes are written to match the knowledge and cognitive process students are intended to acquire.

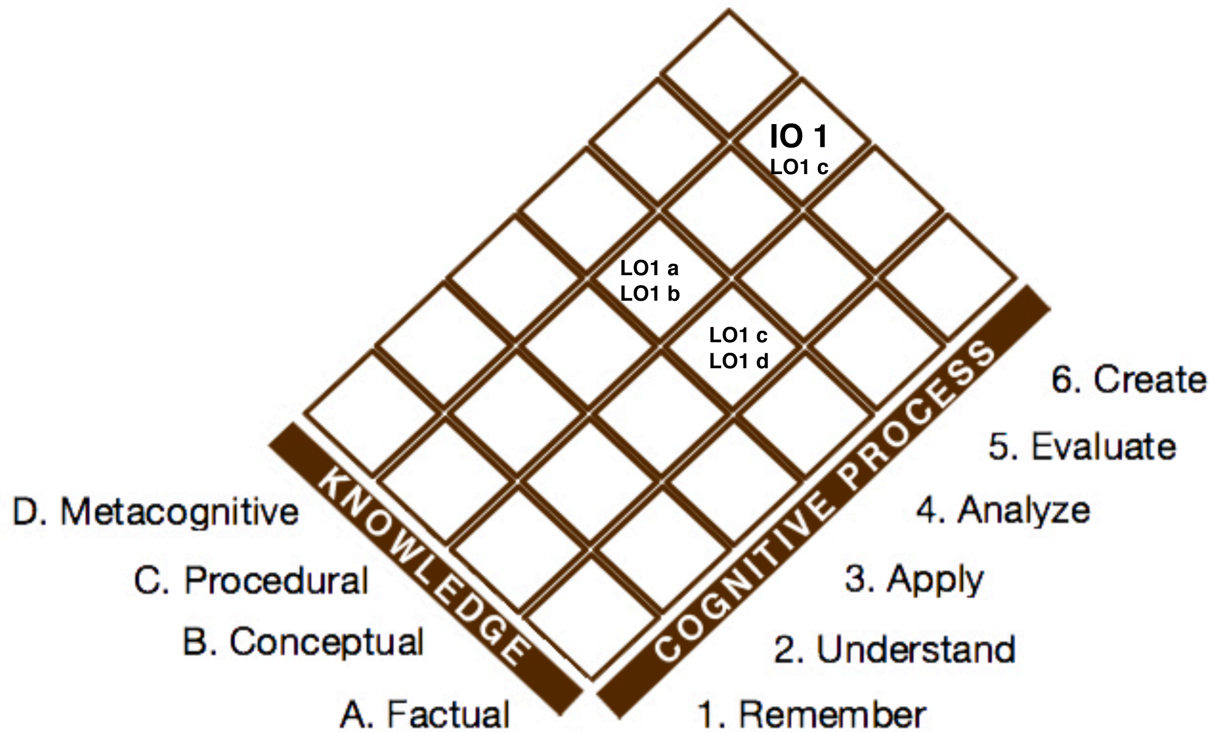
IO1: Create an engineering model of an astrobiology mission choosing instruments for research limited by criteria and constraints and designed to achieve the task of looking for past or present life in the Solar System**.** (6.1; Cb)

LO1a. to define an appropriate mission to search for life requiring initial goals for an engineering design solution (4.2; Cb)

LO1b. to analyze criteria and constraints in an engineering design task and collect data to generate and refine an appropriate solution using tools (instruments) to achieve the mission goal (4.2; Cb)

LO1c. to identify and explain the specific components of the engineering design cycle for the designed model (4.3; Ba)

LO1d. to identify and explain the complex relationship between science and engineering design (4.3; Ba)



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(O) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (3 of 3)

The design of this activity leverages Anderson & Krathwohl's (2001) taxonomy as a framework. Below are the knowledge and cognitive process types students are intended to acquire per the instructional objective(s) and learning outcomes written for this lesson. The specific, scaffolded 5E steps in this lesson (see Procedures) and the formative assessments (worksheets in the Student Guide and rubrics in the Teacher Guide) are written to support those objective(s) and learning outcomes. Refer to previous pages for the full list of categories in the taxonomy from which the following were selected. The prior page provides a visual description of the placement of learning outcomes that enable the overall instructional objective(s) to be met.

At the end of the lesson, students will be able to

IO1: Create an engineering model

6.1: to generate

Cb: Knowledge of subject-specific techniques and methods

To meet that instructional objective, students will demonstrate the abilities:

LO1a: to define an appropriate mission

4.2: to structure

Cb: Knowledge of subject-specific techniques and methods

LO1b: to analyze criteria and constraints in an engineering design

4.2: to find coherence

Cb: Knowledge of subject-specific techniques and methods

LO1c: to identify and explain the specific components of the engineering design cycle

4.3: to deconstruct

Ba: Knowledge of classifications and categories

LO1d: to identify and explain the complex relationship between science and engineering design

4.3: to deconstruct

Ba: Knowledge of classifications and categories

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