Grade 9–12
Earth Science
Item Specifications

Missouri
DEPARTMENT OF ELEMENTARY & SECONDARY
EDUCATION

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Introduction

In 2014 Missouri legislators passed House Bill 1490, mandating the development of the Missouri Learning Expectations. In April of 2016, these Missouri Learning Expectations were adopted by the State Board of Education. Groups of Missouri educators from across the state collaborated to create the documents necessary to support the implementation of these expectations.

One of the documents developed is the item specification document, which includes all Missouri grade level/course expectations arranged by domains/strands. It defines what could be measured on a variety of assessments. The document serves as the foundation of the assessment development process.

Although teachers may use this document to provide clarity to the expectations, these specifications are intended for summative, benchmark, and large-scale assessment purposes.

Components of the item specifications include:

Expectation Unwrapped breaks down a list of clearly delineated content and skills the students are expected to know and be able to do upon mastery of the Expectation.

Depth of Knowledge (DOK) Ceiling indicates the highest level of cognitive complexity that would typically be assessed on a large scale assessment. The DOK ceiling is not intended to limit the complexity one might reach in classroom instruction.

Item Format indicates the types of test questions used in large scale assessment. For each expectation, the item format specifies the type best suited for that particular expectation.

Content Limits/Assessment Boundaries are parameters that item writers should consider when developing a large scale assessment. For example, some expectations should not be assessed on a large scale assessment but are better suited for local assessment.

Sample stems are examples that address the specific elements of each expectation and address varying DOK levels. The sample stems provided in this document are in no way intended to limit the depth and breadth of possible item stems. The expectation should be assessed in a variety of ways.

Possible Evidence indicates observable methods in which a student can show understanding of the expectations.

Stimulus Materials defines types of stimulus materials that can be used in the item stems.

Grades 9-12 EARTH AND SPACE SCIENCE

<table>
<tr><th colspan="2">Engineering, Technology, and Applications of Science</th><th>9-12.ETS1.A.1</th></tr>
<tr><td>Core Idea
Component
MLS</td><td colspan="2">Engineering Design
Defining and Delimiting Engineering Problems
Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.</td></tr>
<tr><td colspan="2"><u>Expectation Unwrapped</u>

<u>SCIENCE AND ENGINEERING PRACTICES</u>
Asking Questions and Defining Problems
● Analyze complex real-world problems by specifying criteria and constraints for successful solutions.

<u>DISCIPLINARY CORE IDEAS</u>
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.
● Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.

<u>CROSSCUTTING CONCEPTS</u>
Influence of Science, Engineering, and Technology on Society and the Natural World
● New technologies can have deep impacts on society and the environment, including some that were not anticipated.
● Analysis of costs and benefits is a critical aspect of decisions about technology.</td><td><u>DOK Ceiling</u>
3

<u>Item Format</u>
Selected Response
Constructed Response
Technology Enhanced</td></tr>
<tr><td colspan="2"><u>Content Limits/Assessment Boundaries</u>

● Tasks should focus on drawing conclusions from graphs, data tables, or text.
● Tasks should include contexts that are familiar to students.
● Tasks should not require students to differentiate between credible and non-credible sources.</td><td><u>Sample Stems</u></td></tr>
</table>

Possible Evidence	
• Students identify and analyze the problem to be solved. ○ Describe the challenge with a rationale for why it is a major global challenge. ○ Describe qualitatively and quantitatively, the extent and depth of the problem and its major consequences to society and/or the natural world on both global and local scales if it remains unsolved. ○ Document background research on the problem from two or more sources, including research journals. • Students define the boundaries in which this problem is embedded and the components of that system. ○ In their analysis, students identify the physical system in which the problem is embedded, including the major elements and relationships in the system and boundaries so as to clarify what is and is not part of the problem. ○ In their analysis, students describe societal needs and wants that are relative to the problem (e.g., for controlling CO_2 emissions, societal needs include the need for cheap energy). • Students specify qualitative and quantitative criteria and limitations (constraints) for acceptable solutions to the problem.	
Stimulus Materials Graphic organizers, diagrams, graphs, data tables, drawings	

Grades 9-12 EARTH AND SPACE SCIENCE

<table>
<tr><th colspan="2">Engineering, Technology, and Application of Science</th><th>9-12.ETS1.A.2</th></tr>
<tr><td>Core Idea</td><td colspan="2">Engineering Design</td></tr>
<tr><td>Component</td><td colspan="2">Defining and Delimiting Engineering Problems</td></tr>
<tr><td>MLS</td><td colspan="2">Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.</td></tr>
<tr><td colspan="2" rowspan="2"><u>Expectation Unwrapped</u>

<u>SCIENCE AND ENGINEERING PRACTICES</u>
Constructing Explanations and Designing Solutions
● Design a solution to a complex real-world problem based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.

<u>DISCIPLINARY CORE IDEAS</u>
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.
● Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.

Organizing 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.

<u>CROSSCUTTING CONCEPTS</u>
Stability and Change
● Much of science deals with constructing explanations of how things change and how they remain stable.</td><td><u>DOK Ceiling</u>
3</td></tr>
<tr><td><u>Item Format</u>
Selected Response
Constructed Response
Technology Enhanced</td></tr>
<tr><td colspan="2"><u>Content Limits/Assessment Boundaries</u>

● Tasks should include complex real-world problems with more than one possible solution. Adequate background information is needed for any problem not potentially relevant to students.
● Students are not required to generate complex real-world problems.
● Tasks should not require students generate more than one solution for each real-world problem.</td><td><u>Sample Stems</u></td></tr>
</table>

Possible Evidence	

• Students formulate a claim to potentially solve a complex real-world problem, using a multistep solution based on scientific knowledge.
  ○ Students restate the original complex problem as a set of two or more subproblems (possibilities include in writing or as a diagram or flow chart).
  ○ For each of the subproblems, students propose at least one solution that is based on student-generated data and/or scientific information from other sources.
  ○ Students describe how solutions to the subproblems are interconnected to solve all or part of the larger problem.
• Students describe the criteria and limitations (constraints) for the selected subproblem.
• Students describe the rationale for the sequence of how subproblems are to be solved and which criteria should be given highest priority if trade-offs must be made.	

Stimulus Materials	
Graphic organizers, diagrams, graphs, data tables, drawings	

Grades 9-12 EARTH AND SPACE SCIENCE

Engineering, Technology, and Application of Science		9-12.ETS1.B.1
Core Idea	**Engineering Design**	
Component	**Developing Possible Solutions**	
MLS	Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.	

Expectation Unwrapped	DOK Ceiling
SCIENCE AND ENGINEERING PRACTICES **Constructing Explanations and Designing Solutions** ● Evaluate a solution to a complex real-world problem based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations. **DISCIPLINARY CORE IDEAS** **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. **Crosscutting Concepts** **Influence of Science, Engineering, and Technology on Society and the Natural World** ● New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.	3 **Item Format** Selected Response Constructed Response Technology Enhanced

Content Limits/Assessment Boundaries	Sample Stems
● Tasks should require students to evaluate solutions based on at least two of the following: cost safety, reliability, and aesthetics. ● Tasks should not require students to generate their own solutions.	
Possible Evidence	
● Students provide an evidence-based decision of which solution is optimum, based on prioritized criteria, analysis of the strengths and weaknesses of each solution, and barriers to be overcome. ● In their evaluation, students describe which parts of the complex real-world problem may remain even if the proposed solution is implemented.	

Grades 9-12 EARTH AND SPACE SCIENCE

<u>Stimulus Materials</u> Graphic organizers, diagrams, graphs, data tables, drawings	

Grades 9-12 EARTH AND SPACE SCIENCE

<table>
<tr><th colspan="2">Engineering, Technology, and Application of Science</th><th>9-12.ETS1.B.2</th></tr>
<tr><td>Core Idea</td><td colspan="2">Engineering Design</td></tr>
<tr><td>Component</td><td colspan="2">Developing Possible Solutions</td></tr>
<tr><td>MLS</td><td colspan="2">Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between System relevant to the problem.</td></tr>
<tr><td colspan="2" rowspan="2"><u>Expectation Unwrapped</u>

<u>SCIENCE AND ENGINEERING PRACTICES</u>
Using Mathematics and Computational Thinking
● Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems.

<u>DISCIPLINARY CORE IDEAS</u>
Developing Possible Solutions
● Both physical models and computers can be used in various ways to aid in the engineering design process.
● Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical and in making a persuasive presentation to a client about how a given design will meet his or her needs.

<u>CROSSCUTTING CONCEPTS</u>
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.</td><td><u>DOK Ceiling</u>
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<tr><td><u>Item Format</u>
Selected Response
Constructed Response
Technology Enhanced</td></tr>
<tr><td colspan="2"><u>Content Limits/Assessment Boundaries</u>

● Tasks should include real-world problems that are relevant to students. Adequate background information is needed for any problem not potentially relevant to students.
● Tasks should not require students to generate their own complex real-world problem.</td><td><u>Sample Stems</u></td></tr>
</table>

Possible Evidence	
● Students define what each part of the simulation represents. ○ Identify the complex real-world problem, with numerous criteria and limitations (constraints). ▪ Identify the system that is being modeled by the computational simulation, including the boundaries and individual components of the systems. ▪ Identify what variables can be changed by the user to evaluate the proposed solutions, trade-offs, or other decisions. ▪ Identify the scientific principles and or relationships being used by the model. ● Students use the given computer simulation to model the proposed solutions by selecting logical and realistic inputs and using the model to simulate the effects of different solutions, trade-offs, or other decisions. ● Analyze how the criteria and limitations (constraints) impact the problem. ○ Students will be able to analyze the simulated results as compared to the expected results. ○ Students interpret the results of the simulation and predict the effects of the proposed solutions within and between systems relevant to the problem based on the interpretation. ○ Students identify the possible negative consequences of solutions that outweigh their benefits. ○ Students identify the simulation's limitations (constraints).	
Stimulus Materials	
Graphic organizers, diagrams, graphs, data tables, drawings	

Grades 9-12 EARTH AND SPACE SCIENCE

<table>
<tr><th colspan="2">Earth and Space Sciences</th><th>9-12.ESS1.A.1</th></tr>
<tr><td>Core Idea</td><td colspan="2">Earth’s Place in the Universe</td></tr>
<tr><td>Component</td><td colspan="2">The Universe and Its Stars</td></tr>
<tr><td>MLS</td><td colspan="2">Develop a model based on evidence to illustrate the life span of the Sun and the role of nuclear fusion in the Sun’s core to release energy in the form of radiation.</td></tr>
<tr><td colspan="2" rowspan="2"><u>Expectation Unwrapped</u>

[Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the Sun’s core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the Sun’s radiation varies due to sudden solar flares (“space weather”).]

<u>SCIENCE AND ENGINEERING PRACTICES</u>
Developing and Using Models
• Develop a model based on evidence to illustrate the relationships between systems or between components of a system.

<u>DISCIPLINARY CORE IDEAS</u>
The Universe and Its Stars
● The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years.

Energy in Chemical Processes and Everyday Life
● Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation.

<u>CROSSCUTTING CONCEPTS</u>
● The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.</td><td><u>DOK Ceiling</u>
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<tr><td><u>Item Format</u>
Selected Response
Constructed Response
Technology Enhanced</td></tr>
<tr><td colspan="2"><u>Content Limits/Assessment Boundaries</u>

● Tasks should not include specific details of the atomic and sub-atomic processes involved in nuclear fusion.</td><td><u>Sample Stems</u></td></tr>
</table>

Grades 9-12 EARTH AND SPACE SCIENCE

Possible Evidence	
• Students use evidence to develop a model in which they identify and describe the relevant components, including that ○ hydrogen is the sun's fuel. ○ helium and energy are the products of fusion processes in the sun. ○ the sun, like all stars, has a lifespan based primarily on its initial mass and that the sun's lifespan is about 10 billion years. • In the model, students describe relationships between the components, including descriptions of the process of radiation and how energy released by the sun reaches Earth's system. • Students use the model to predict how the relative proportions of hydrogen to helium change as the sun ages. • Students use the model to qualitatively describe the scale of the energy released by the fusion process as being much larger than the scale of the energy released by chemical processes. • Students use the model to explicitly identify that chemical processes are unable to produce the amount of energy flowing out of the sun over long periods of time, thus requiring fusion processes as the mechanism for energy release in the sun.	
Stimulus Materials Graphic organizers, diagrams, graphs, data tables, drawings	

Grades 9-12 EARTH AND SPACE SCIENCE

Earth and Space Sciences		9-12.ESS1.A.2
Core Idea	**Earth's Place in the Universe**	
Component	**The Universe and Its Stars**	
MLS	Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.	

<table>
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Expectation Unwrapped

[Clarification Statement: Emphasis is on the astronomical evidence of the redshift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).]

SCIENCE AND ENGINEERING PRACTICES
Constructing Explanations and Designing Solutions
- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena
- A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.

DISCIPLINARY CORE IDEAS
The Universe and Its Stars
- The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.
- The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe.
- Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.

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DOK Ceiling
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Item Format
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Constructed Response
Technology Enhanced

</td></tr>
</table>

Electromagnetic Radiation ● Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities. **<u>CROSSCUTTING CONCEPTS</u>** **Energy and Matter** ● Energy cannot be created or destroyed—only moved between one place and another place, between objects and/or fields, or between systems. **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. **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.	
<u>Content Limits/Assessment Boundaries</u> ● Tasks should include all necessary astronomical evidence. ● Tasks should not require students to complete any calculations.	**<u>Sample Stems</u>**

<u>Possible Evidence</u>
 	
● Students construct an explanation that includes a description of how astronomical evidence from numerous sources is used collectively to support the Big Bang theory, which states that the universe is expanding and thus, it was hotter and denser in the past and that the entire visible universe emerged from a very tiny region and expanded.
● Students identify and describe the evidence to construct the explanation, including
  ○ the composition (hydrogen, helium and heavier elements) of stars.
  ○ the hydrogen-helium ratio of stars and interstellar gases.
  ○ the redshift of the majority of galaxies and the redshift vs. distance relationship.
  ○ the existence of cosmic background radiation.
● Students use a variety of valid and reliable sources for the evidence, which may include students' own investigations, theories, simulations, and peer review.
● Students describe the source of the evidence and the technology used to obtain that evidence.	

• Students use reasoning to connect evidence, along with the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future, to construct the explanation for the early universe (the Big Bang theory). Students describe the following chain of reasoning for their explanation: ○ Redshifts indicate that an object is moving away from the observer, thus the observed redshift for most galaxies and the redshift vs. distance relationship is evidence that the universe is expanding. ○ The observed background cosmic radiation and the ratio of hydrogen to helium have been shown to be consistent with a universe that was very dense and hot a long time ago and evolved through different stages as it expanded and cooled (e.g., the formation of nuclei from colliding protons and neutrons predicts the hydrogen-helium ratio [numbers not expected from students], later formation of atoms from nuclei plus electrons, background radiation was a relic from that time). ○ An expanding universe must have been smaller in the past and can be extrapolated back in time to a tiny size from which it expanded.	
Stimulus Materials Graphic organizers, diagrams, graphs, data tables, drawings	

Grades 9-12 EARTH AND SPACE SCIENCE

Earth and Space Sciences		9-12.ESS1.A.3
Core Idea	**Earth's Place in the Universe**	
Component	**The Universe and Its Stars**	
MLS	Communicate scientific ideas about the way stars, over their life cycle, produce elements.	

Expectation Unwrapped	DOK Ceiling
[Clarification Statement: Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.] **SCIENCE AND ENGINEERING PRACTICES** **Obtaining, Evaluating, and Communicating Information** ● Communicate scientific ideas (e.g., about phenomena, the process of development, the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). **DISCIPLINARY CORE IDEAS** **The Universe and Its Stars** ● The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. ● Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. **CROSSCUTTING CONCEPTS** **Energy and Matter** ● In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.	3 **Item Format** Selected Response Constructed Response Technology Enhanced

Content Limits/Assessment Boundaries	Sample Stems
● Tasks should avoid the different nucleosynthesis pathways for stars of differing masses.	

Possible Evidence	
 ● Students use at least two different formats (e.g., oral, graphical, textual, and mathematical) to communicate scientific information and cite the origin of the information as appropriate. ● Students identify and communicate the relationships between the life cycle of the stars, the production of elements, and the conservation of the number of protons plus neutrons in stars. Students identify that atoms are not conserved in nuclear fusion, but the total number of protons plus neutrons is conserved. ● Students describe that ○ helium and a small amount of other light nuclei (i.e., up to lithium) were formed from high-energy collisions starting from protons and neutrons in the early universe before any stars existed. ○ more massive elements, up to iron, are produced in the cores of stars by a chain of processes of nuclear fusion, which also releases energy. ○ supernova explosions of massive stars are the mechanism by which elements more massive than iron are produced. ○ there is a correlation between a star's mass and stage of development and the types of elements it can create during its lifetime. ○ electromagnetic emission and absorption spectra are used to determine a star's composition, motion, and distance to Earth.	
Stimulus Materials Graphic organizers, diagrams, graphs, data tables, drawings	

Grades 9-12 EARTH AND SPACE SCIENCE

Earth and Space Sciences		9-12.ESS1.B.1
Core Idea	**Earth's Place in the Universe**	
Component	**Earth and the Solar System**	
MLS	Use Kepler's Law to predict the motion of orbiting objects in the solar system.	

Expectation Unwrapped	**DOK Ceiling**
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[Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.] **SCIENCE AND ENGINEERING PRACTICES** ● Use mathematical or computational representations of phenomena to describe explanations. **DISCIPLINARY CORE IDEAS** **Earth and the Solar System** ● Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. **CROSSCUTTING CONCEPTS** **Scale, Proportion, and Quantity** ● Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). **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.	**Item Format** Selected Response Constructed Response Technology Enhanced
Content Limits/Assessment Boundaries	**Sample Stems**
● Tasks focused on Kepler's laws of orbital motion should be limited to no more than two bodies. ● Tasks should not involve calculus or any memorization of formulas.	

Possible Evidence	
• Students identify and describe the following relevant components in the given mathematical or computational representations of orbital motion: the trajectories of orbiting bodies, including planets, moons, or human-made spacecraft, each of which depicts a revolving body's eccentricity e = f/d, where f is the distance between foci of an ellipse and d is the ellipse's major axis length (Kepler's first law of planetary motion). • Students use the given mathematical or computational representations of orbital motion to depict that the square of a revolving body's period of revolution is proportional to the cube of its distance to a gravitational center (Kepler's third law of planetary motion). • Students use the given mathematical or computational representation of Kepler's second law of planetary motion (an orbiting body sweeps out equal areas in equal time) to predict the relationship between the distance between an orbiting body and its star and the object's orbital velocity (i.e., that the closer an orbiting body is to a star, the larger its orbital velocity will be). • Students use the given mathematical or computational representation of Kepler's third law of planetary motion to predict how either the orbital distance or orbital period changes given a change in the other variable. • Students use Newton's law of gravitation plus his third law of motion to predict how the acceleration of a planet toward the sun varies with its distance from the sun and to argue qualitatively about how this relates to the observed orbits.	
Stimulus Materials	
Graphic organizers, diagrams, graphs, data tables, drawings.	

Grades 9-12 EARTH AND SPACE SCIENCE

Earth and Space Sciences		9-12.ESS1.C.1
Core Idea	**Earth's Place in the Universe**	
Component	**The History of Planet Earth**	
MLS	Evaluate evidence of the past and current movements of continental and oceanic crust, the theory of plate tectonics, and relative densities of oceanic and continental rocks to explain why continental rocks are generally much older than rocks of the ocean floor.	

Expectation Unwrapped	DOK Ceiling
[Clarification Statement: Examples include the ages of oceanic crust increasing with distance from mid-ocean ridges (a result of plate spreading) and the ages of North American continental crust increasing with distance away from a central ancient core (a result of past plate interactions).] **SCIENCE AND ENGINEERING PRACTICES** **Engaging in Argument from Evidence** ● Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments. **DISCIPLINARY CORE IDEAS** **The History of Planet Earth** ● Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old. **Plate Tectonics and Large-Scale System Interactions** ● Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. (ESS2.B Grade 8 GBE) **Nuclear Processes** ● Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. **CROSSCUTTING CONCEPTS** **Patterns** ● Empirical evidence is needed to identify patterns. Refer to Engineering, Technology, and Application of Science 9-12.ETS.B.1.	3 **Item Format** Selected Response Constructed Response Technology Enhanced
Content Limits/Assessment Boundaries	**Sample Stems**
● Tasks should provide students with all needed evidence, explanations, models, and data.	

Possible Evidence	

• Students identify the given explanation, which includes the following idea: that crustal materials of different ages are arranged on Earth's surface in a pattern that can be attributed to plate tectonic activity and formation of new rocks from magma rising where plates are moving apart.
• Students identify the given evidence to be evaluated.
• Students identify and describe additional relevant evidence (in the form of data, information, models, or other appropriate forms) that was not provided but is relevant to the explanation and to evaluating the given evidence, including the
  ○ measurement of the ratio of parent to daughter atoms produced during radioactive decay as a means for determining the ages of rocks.
  ○ ages and locations of continental rocks.
  ○ ages and locations of rocks found on opposite sides of mid-ocean ridges.
  ○ type and location of plate boundaries relative to the type, age, and location of crustal rocks.
• Students use their evidence to assess and evaluate the validity of the given evidence.
• Students evaluate the reliability, strengths, and weaknesses of the given evidence along with its ability to support logical and reasonable arguments about the motion of crustal plates.
• Students describe how the following patterns observed from the evidence support the explanation about the ages of crustal rocks:
  ○ The pattern of the continental crust being older than the oceanic crust
  ○ The pattern that the oldest continental rocks are located at the center of continents, with the ages decreasing from their centers to their margin.
  ○ The pattern that the ages of oceanic crust are greatest nearest the continents and decrease in age with proximity to the mid-ocean ridges.
• Students synthesize the relevant evidence to describe the relationship between the motion of continental plates and the patterns in the ages of crustal rocks, including that
  ○ at boundaries where plates are moving apart, such as mid-ocean ridges, material from the interior of Earth must be emerging and forming new rocks with the youngest ages.
  ○ the regions furthest from the plate boundaries (continental centers) will have the oldest rocks because new crust is added to the edge of continents at places where plates are coming together, such as subduction zones.
  ○ the oldest crustal rocks are found on the continents because oceanic crust is constantly being destroyed at places where plates are coming together, such as subduction zones.	

Stimulus Materials	
Graphic organizers, diagrams, graphs, data tables, drawings	

Grades 9-12 EARTH AND SPACE SCIENCE

Earth and Space Sciences		9-12.ESS1.C.2
Core Idea	**Earth's Place in the Universe**	
Component	**The History of Planet Earth**	
MLS	Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.	

Expectation Unwrapped

[Clarification Statement: Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. Examples of evidence include the absolute ages of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest minerals), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.]

SCIENCE AND ENGINEERING PRACTICES

Constructing Explanations and Designing Solutions

- Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

- A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that has been repeatedly confirmed through observation and experiment, and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.
- Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory.

DISCIPLINARY CORE IDEAS

The History of Planet Earth

- Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history.

Nuclear Processes

- Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials.

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Item Format

Selected Response
Constructed Response
Technology Enhanced

Grades 9-12 EARTH AND SPACE SCIENCE

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CROSSCUTTING CONCEPTS
Stability and Change
● Much of science deals with constructing explanations of how things change and how they remain stable.

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Content Limits/Assessment Boundaries

● N/A

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Sample Stems

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Possible Evidence

● Students construct an account of Earth's formation and early history that includes that
○ Earth formed with the rest of the solar system 4.6 billion years ago.
○ the early Earth was bombarded by impacts just as other objects in the solar system were bombarded.
○ erosion and plate tectonics on Earth have destroyed much of the evidence of this bombardment, explaining the relative scarcity of impact craters on Earth.
● Students include and describe the following evidence in their explanatory account:
○ The age and composition of Earth's oldest rocks, lunar rocks, and meteorites as determined by radiometric dating
○ The composition of solar system objects
○ Observations of the size and distribution of impact craters on the surface of Earth and on the surfaces of solar system objects (e.g., the moon, Mercury, and Mars)
○ The activity of plate tectonic processes, such as volcanism, and surface processes, such as erosion, operating on Earth
● Students use reasoning to connect the evidence to construct the explanation of Earth's formation and early history, including that
○ radiometric ages of lunar rocks, meteorites and the oldest Earth rocks point to an origin of the solar system 4.6 billion years ago, with the creation of a solid Earth crust about 4.4 billion years ago.
○ other planetary surfaces and their patterns of impact cratering can be used to infer that Earth had many impact craters early in its history.
○ the relative lack of impact craters and the age of most rocks on Earth compared to other bodies in the solar system can be attributed to processes such as volcanism, plate tectonics, and erosion that have reshaped Earth's surface, and that this is why most of Earth's rocks are much younger than Earth itself.

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Stimulus Materials

Graphic organizers, diagrams, graphs, data tables, drawings

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Grades 9-12 EARTH AND SPACE SCIENCE

<table>
<tr><th colspan="2">Earth and Space Sciences</th><th>9-12.ESS2.A.1</th></tr>
<tr><td>Core Idea</td><td colspan="2">Earth's Systems</td></tr>
<tr><td>Component</td><td colspan="2">Earth Materials and Systems</td></tr>
<tr><td>MLS</td><td colspan="2">Develop a model to illustrate how Earth's interior and surface processes (constructive and destructive) operate at different spatial and temporal scales to form continental and ocean-floor features.</td></tr>
<tr><td colspan="2" rowspan="2"><u>Expectation Unwrapped</u>

[Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and seafloor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass wasting, and coastal erosion).]

<u>SCIENCE AND ENGINEERING PRACTICES</u>
Developing and Using Models
● Develop a model based on evidence to illustrate the relationships between systems or between components of a system.

<u>DISCIPLINARY CORE IDEAS</u>
Earth Materials and Systems
● Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.

Plate Tectonics and Large-Scale System Interactions
● Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust.

<u>CROSSCUTTING CONCEPTS</u>
Stability and Change
● Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.</td><td><u>DOK Ceiling</u>
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<tr><td><u>Item Format</u>
Selected Response
Constructed Response
Technology Enhanced</td></tr>
<tr><td colspan="2"><u>Content Limits/Assessment Boundaries</u>

• Tasks should not require students to have memorized the of geologic history of specific geographic areas.</td><td><u>Sample Stems</u></td></tr>
</table>

Possible Evidence	
● Students use evidence to develop a model in which they identify and describe the following components: ○ descriptions and locations of specific continental features and specific ocean-floor features ○ a geographic scale, showing the relative sizes/extents of continental and/or ocean floor features ○ internal processes (such as volcanism and tectonic uplift) and surface processes (such as weathering and erosion) ○ a temporal scale showing the relative times over which processes act to produce continental and/or ocean-floor features ● In the model, students describe the relationships between components, including that ○ specific internal processes, mainly volcanism, mountain building, or tectonic uplift, are identified as causal agents in building up Earth's surface over time. ○ specific surface processes, mainly weathering and erosion, are identified as causal agents in wearing down Earth's surface over time. ○ interactions and feedbacks between processes are identified (e.g., mountain-building changes weather patterns that then change the rate of erosion of mountains). ○ the rate at which the features change is related to the time scale on which the processes operate. Features that form or change slowly due to processes that act on long time scales (e.g., continental positions due to plate drift) and features that form or change rapidly due to processes that act on short time scales (e.g., volcanic eruptions) are identified. ● Students use the model to illustrate the relationship between 1) the formation of continental and ocean floor features and 2) Earth's internal and surface processes operating on different temporal or spatial scales.	
Stimulus Materials	
Graphic organizers, diagrams, graphs, data tables, drawings	

Grades 9-12 EARTH AND SPACE SCIENCE

<table>
<tr><th colspan="2">Earth and Space Sciences</th><th>9-12.ESS2.A.2</th></tr>
<tr><td>Core Idea</td><td colspan="2">Earth’s Systems</td></tr>
<tr><td>Component</td><td colspan="2">Earth Materials and Systems</td></tr>
<tr><td>MLS</td><td colspan="2">Analyze geoscientific data to make the claim that one change to Earth’s surface can create changes to other Earth Systems.</td></tr>
<tr><td colspan="2" rowspan="2"><u>Expectation Unwrapped</u>

[Clarification Statement: Examples should include climate feedback, such as how an increase in greenhouse gases causes a rise in global temperatures that melt glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.]

<u>SCIENCE AND ENGINEERING PRACTICES</u>
Analyzing and Interpreting Data
● Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.

<u>DISCIPLINARY CORE IDEAS</u>
Earth Materials and Systems
● Earth’s systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.

Weather and Climate
● The foundation for Earth’s global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy’s re-radiation into space.

<u>CROSSCUTTING CONCEPTS</u>
Stability and Change
● Feedback (negative or positive) can stabilize or destabilize a system.</td><td><u>DOK Ceiling</u>
3</td></tr>
<tr><td><u>Item Format</u>
Selected Response
Constructed Response
Technology Enhanced</td></tr>
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Influence of Engineering, Technology, and Science on Society and the Natural World
● New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

Refer to Engineering, Technology, and Application of Science 9-12.ETS1.A.1.
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<td>
<u>Content Limits/Assessment Boundaries</u>

● Tasks should not assess the interdependence of all systems simultaneously
● Tasks should provide students with all needed data.
</td>
<td rowspan="3"><u>Sample Stems</u></td>
</tr>
<tr>
<td>
<u>Possible Evidence</u>

● Students organize data that represent measurements of changes in hydrosphere, cryosphere, atmosphere, biosphere, or geosphere in response to a change in Earth’s surface.
● Students describe what each data set represents.
● Students use tools, technologies, and/or models to analyze the data and identify and describe relationships in the data sets, including
  ○ the relationships between the changes in one system and changes in another (or within the same) Earth system.
  ○ possible feedback, including one example of feedback to the climate.
● Students analyze data to identify effects of human activity and specific technologies on Earth’s systems if present.
● Students use the analyzed data to describe a mechanism for the feedback between two of Earth’s systems and whether the feedback is positive or negative, increasing (destabilizing) or decreasing (stabilizing) the original changes.
● Students use the analyzed data to describe a particular unanticipated or unintended effect of a selected technology on Earth’s systems if present.
● Students include a statement regarding how variation or uncertainty in the data (e.g., limitations, accuracy, any bias in the data resulting from choice of sample, scale, instrumentation) may affect the interpretation of the data.
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<td>
<u>Stimulus Materials</u>

Graphic organizers, diagrams, graphs, data tables, drawings
</td>
</tr>
</table>

Grades 9-12 EARTH AND SPACE SCIENCE

Earth and Space Sciences		9-12.ESS2.A.3
Core Idea	**Earth's Systems**	
Component	**Earth Materials and System**	
MLS	Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.	

Expectation Unwrapped

[Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.]

DISCIPLINARY CORE IDEAS

Developing and Using Models

- Develop a model based on evidence to illustrate the relationships between systems or between components of a system

Scientific Knowledge is Based on Empirical Evidence

- Science knowledge is based on empirical evidence.
- Science disciplines share common rules of evidence used to evaluate explanations about natural systems.
- Science includes the process of coordinating patterns of evidence with current theory.

SCIENCE AND ENGINEERING PRACTICES

Earth Materials and Systems

- Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, and a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior.

Plate Tectonics and Large-Scale System Interactions

- The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection.

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Technology Enhanced

CROSSCUTTING CONCEPTS **Energy and Matter** ● Energy drives the cycling of matter within and between systems. **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.	
Content Limits/Assessment Boundaries • N/A	**Sample Stems**
Possible Evidence ● Students develop a model (i.e., graphical, verbal, or mathematical) in which they identify and describe the components based on both seismic and magnetic evidence (e.g., the pattern of the geothermal gradient or heat flow measurements) from Earth's interior, including ○ Earth's interior in cross section and radial layers (i.e., crust, mantle, liquid outer core, solid inner core) determined by density. ○ the plate activity in the outer part of the geosphere. ○ radioactive decay and residual thermal energy from the formation of Earth as a source of energy. ○ the loss of heat at the surface of Earth as an output of energy. ○ the process of convection that causes hot matter to rise (move away from the center) and cool matter to fall (move toward the center). ● Students describe the relationships between components in the model, including that ○ energy released by radioactive decay in Earth's crust and mantle and residual thermal energy from the formation of Earth provide energy that drives the flow of matter in the mantle. ○ thermal energy is released at the surface of the Earth as new crust is formed and cooled. The flow of matter by convection in the solid mantle and the sinking of cold, dense crust back into the mantle exert forces on crustal plates that then move, producing tectonic activity. ○ the flow of matter by convection in the liquid outer core generates Earth's magnetic field. ○ matter is cycled between the crust and the mantle at plate boundaries. Where plates are pushed together, cold crustal material sinks back into the mantle, and where plates are pulled apart, mantle material can be integrated into the crust, forming new rock.	

• Students use the model to describe the cycling of matter by thermal convection in Earth's interior, including ○ the flow of matter in the mantle that causes crustal plates to move. ○ the flow of matter in the liquid outer core that generates the Earth's magnetic field, including evidence of polar reversals (e.g., seafloor exploration of changes in the direction of Earth's magnetic field). ○ the radial layers determined by density in the interior of Earth. ○ the addition of a significant amount of thermal energy released by radioactive decay in Earth's crust and mantle.	
Stimulus Materials Graphic organizers, diagrams, graphs, data tables, drawings	

Grades 9-12 EARTH AND SPACE SCIENCE

<table>
<tr><th colspan="2">Earth and Space Sciences</th><th>9-12.ESS2.A.4</th></tr>
<tr><td>Core Idea</td><td colspan="2">Earth’s Systems</td></tr>
<tr><td>Component</td><td colspan="2">Earth Materials and System</td></tr>
<tr><td>MLS</td><td colspan="2">Use a model to describe how variations in the flow of energy into and out of Earth’s System result in changes in climate.</td></tr>
<tr><td colspan="2" rowspan="2"><u>Expectation Unwrapped</u>

[Clarification Statement: Examples of the causes of climate change differ by timescale: over 1–10 years—large volcanic eruption, ocean circulation; 10–100s of years—changes in human activity, ocean circulation, solar output; 10–100s of thousands of years—changes to Earth’s orbit and the orientation of its axis; 10–100s of millions of years—long-term changes in atmospheric composition.]

<u>SCIENCE AND ENGINEERING PRACTICES</u>
Developing and Using Models
● Use a model to provide mechanistic accounts of phenomena.

Scientific Knowledge is Based on Empirical Evidence
● Science arguments are strengthened by multiple lines of evidence supporting a single explanation.

<u>DISCIPLINARY CORE IDEAS</u>
Earth and the Solar System
● Cyclical changes in the shape of Earth’s orbit around the sun, together with changes in the tilt of the planet’s axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on Earth. These phenomena cause a cycle of ice ages and other gradual climate changes.

Earth Materials and Systems
● The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun’s energy output or Earth’s orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.

Weather and Climate
● The foundation for Earth’s global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems and this energy’s re-radiation into space.</td><td><u>DOK Ceiling</u>
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<tr><td><u>Item Format</u>
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Constructed Response
Technology Enhanced</td></tr>
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Grades 9-12 EARTH AND SPACE SCIENCE

CROSSCUTTING CONCEPTS **Cause and Effect** ● Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.	
Content Limits/Assessment Boundaries ● Tasks should not require students to generate their own model. ● Tasks should limit the results of changes in climate to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution. **Possible Evidence** ● From the given model, students identify and describe the components of the model relevant for their mechanistic descriptions. Given models include at least one factor that affects the input of energy, at least one factor that affects the output of energy, and at least one factor that affects the storage and redistribution of energy. Factors are derived from the following list: ○ Changes in Earth's orbit and the orientation of its axis ○ Changes in the sun's energy output ○ Configuration of continents resulting from tectonic activity ○ Ocean circulation ○ Atmospheric composition (including amount of water vapor and CO_2) ○ Atmospheric circulation ○ Volcanic activity ○ Glaciation ○ Changes in extent or type of vegetation cover ○ Human activities From the given model, students identify the relevant different time scales on which the factors operate. ● Students identify and describe the relationships between components of the given model, and organize the factors from the given model into three groups: ○ those that affect the input of energy ○ those that affect the output of energy ○ those that affect the storage and redistribution of energy ● Students describe the relationships between components of the model as either casual or correlational.	**Sample Stems**

• Students use the given model to provide a mechanistic account of the relationship between energy flow in Earth's systems and changes in climate, including
  ○ the specific cause and effect relationships between the factors and the effect on energy flow into and out of Earth's systems.
  ○ the net effect of all of the competing factors in changing the climate.	

Stimulus Materials Graphic organizers, diagrams, graphs, data tables, drawings	

Grades 9-12 EARTH AND SPACE SCIENCE

Earth and Space Sciences		9-12.ESS2.C.1
Core Idea	**Earth's Systems**	
Component	**The Role of Water in Earth's Surface Processes**	
MLS	Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.	

Expectation Unwrapped

[Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or ice wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).]

SCIENCE AND ENGINEERING PRACTICES

Planning and Carrying Out Investigations

- Plan and conduct an investigation, individually and collaboratively, to produce data to serve as the basis for evidence, and in the design, decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

DISCIPLINARY CORE IDEAS

The Roles of Water in Earth's Surface Processes

- The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.

CROSSCUTTING CONCEPTS

Structure and Function

- The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of their various materials.

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Content Limits/Assessment Boundaries	Sample Stems
• Tasks should avoid calculating specific heat.	

Possible Evidence
 	
• Students describe the phenomenon under investigation, which includes the following idea: a connection between the properties of water and its effects on Earth materials and surface processes.
• Students develop an investigation plan and describe the data that will be collected and the evidence to be derived from the data, including the
  ○ properties of water, including
    ▪ the heat capacity of water.
    ▪ the density of water in its solid and liquid states.
    ▪ the polar nature of the water molecule due to its molecular structure.
  ○ effect of the properties of water on energy transfer that causes the patterns of temperature, the movement of air, and the movement and availability of water at Earth's surface.
  ○ mechanical effects of water on Earth materials that can be used to infer the effect of water on Earth's surface processes. Examples can include
    ▪ stream transportation and deposition using a stream table, which can be used to infer the ability of water to transport and deposit materials.
    ▪ erosion using variations in soil moisture content, which can be used to infer the ability of water to prevent or facilitate movement of Earth materials.
    ▪ the expansion of water as it freezes, which can be used to infer the ability of water to break rocks into smaller pieces.
  ○ chemical effects of water on Earth materials that can be used to infer the effect of water on Earth's surface processes. Examples can include
    ▪ the solubility of different materials in water, which can be used to infer chemical weathering and recrystallization.
    ▪ the reaction of iron to rust in water, which can be used to infer the role of water in chemical weathering.
    ▪ data illustrating that water lowers the melting temperature of most solids, which can be used to infer melt generation.
    ▪ data illustrating that water decreases the viscosity of melted rock, affecting the movement of magma and volcanic eruptions.
• In their investigation plan, students describe how the data collected will be relevant to determining the effect of water on Earth materials and surface processes.	

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- In their investigation plan, students include a means to indicate or measure the predicted effect of water on Earth's materials or surface processes. Examples include
  - the role of the heat capacity of water to affect the temperature, movement of air and movement of water at the Earth's surface.
  - the role of flowing water to pick up, move and deposit sediment.
  - the role of the polarity of water (through cohesion) to prevent or facilitate erosion.
  - the role of the changing density of water (depending on physical state) to facilitate the breakdown of rock.
  - the role of the polarity of water in facilitating the dissolution of Earth materials.
  - water as a component in chemical reactions that change Earth materials.
  - the role of the polarity of water in changing the melting temperature and viscosity of rocks.
- Students collect and record measurements or indications of the predicted effect of a property of water on Earth's materials or surface.
- Students evaluate the accuracy and precision of the collected data.
- Students evaluate whether the data can be used to infer the effect of water on processes in the natural world.
- If necessary, students refine the plan to produce more accurate and precise data.

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<u>Stimulus Materials</u>

Graphic organizers, diagrams, graphs, data tables, drawings

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</table>

Grades 9-12 EARTH AND SPACE SCIENCE

Earth and Space Sciences		9-12.ESS2.D.1
Core Idea	**Earth's Systems**	
Component	**Weather and Climate**	
MLS	Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.	

Expectation Unwrapped	**DOK Ceiling**
[Clarification Statement: Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.] **SCIENCE AND ENGINEERING PRACTICES** **Developing and Using Models** ● Develop a model based on evidence to illustrate the relationships between systems or between components of a system. **DISCIPLINARY CORE IDEAS** **Weather and Climate** ● Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. ● Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. **CROSSCUTTING CONCEPTS** **Energy and Matter** ● The total amount of energy and matter in closed systems is conserved.	3 **Item Format** Selected Response Constructed Response Technology Enhanced
Content Limits/Assessment Boundaries	**Sample Stems**
● Tasks should provide students will all evidence needed to develop a model. ● Tasks should not require students to generate their own data.	

Possible Evidence	
● Students use evidence to develop a model in which they ○ identify the relative concentrations of carbon present in the hydrosphere, atmosphere, geosphere, and biosphere. ○ represent carbon cycling from one sphere to another. ● In the model, students represent and describe the following relationships between components of the system: ○ The biogeochemical cycles that occur as carbon flows from one sphere to another ○ The relative amount of and the rate at which carbon is transferred between sphere ○ The capture of carbon dioxide by plants ○ The increase in carbon dioxide concentration in the atmosphere due to human activity and its effect on climate ● Students use the model to explicitly identify the conservation of matter as carbon cycles through various components of Earth's systems. ● Students identify the limitations of the model in accounting for all of Earth's carbon.	
Stimulus Materials	
Graphic organizers, diagrams, graphs, data tables, drawings	

Grades 9-12 EARTH AND SPACE SCIENCE

Earth and Space Sciences		9-12.ESS2.E.1
Core Idea	**Earth's Systems**	
Component	**Biogeology**	
MLS	Construct an argument based on evidence about the simultaneous coevolution of Earth's Systems and life on Earth.	

Expectation Unwrapped	DOK Ceiling
[Clarification Statement: Emphasis is on the dynamic causes, effects, and feedbacks between the biosphere and Earth's other Systems, whereby geoscience factors control the evolution of life, which in turn continuously alters Earth's surface. Examples of coevolution include how photosynthetic life altered the atmosphere through the production of oxygen, which in turn increased weathering rates and allowed for the evolution of animal life; how microbial life on land increased the formation of soil, which in turn allowed for the evolution of land plants; or how the evolution of corals created reefs that altered patterns of erosion and deposition along coastlines and provided habitats for new life.] **SCIENCE AND ENGINEERING PRACTICES** **Engaging in Argument from Evidence** ● Construct an oral and a written argument or counter-arguments based on data and evidence. **DISCIPLINARY CORE IDEAS** **Weather and Climate** ● Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen. **Biogeology** ● The many dynamic and delicate feedback between the biosphere and other Earth systems cause a continual coevolution of Earth's surface and the life that exists on it. **CROSSCUTTING CONCEPTS** **Stability and Change** ● Much of science deals with constructing explanations for how things change and how they remain stable.	3 **Item Format** Selected Response Constructed Response Technology Enhanced

Grades 9-12 EARTH AND SPACE SCIENCE

Content Limits/Assessment Boundaries	Sample Stems
• Tasks should provide students with all needed evidence. • Tasks should avoid the mechanisms of how the biosphere interacts with all of Earth's other systems.	

Possible Evidence
 	
• Students develop a claim, which includes the following idea: there is simultaneous coevolution of Earth's systems and life on Earth. This claim is supported by generalizing from multiple sources of evidence.
• Students identify and describe evidence supporting the claim, including
  ○ scientific explanations about the composition of Earth's atmosphere shortly after its formation;
  ○ current atmospheric composition.
  ○ evidence for the emergence of photosynthetic organisms.
  ○ evidence for the effect of the presence of free oxygen on evolution and processes in other Earth systems.
  ○ in the context of the selected example(s), other evidence that changes in the biosphere affect other Earth systems.
• Students evaluate the evidence and include the following in their evaluation:
  ○ A statement regarding how variation or uncertainty in the data (e.g., limitations, low signal-to-noise ratio, collection bias) may affect the usefulness of the data as sources of evidence
  ○ The ability of the data to be used to determine causal or correlational effects between changes in the biosphere and changes in Earth's other systems
• Students use at least two examples to construct oral and written logical arguments. The examples
  ○ include that the evolution of photosynthetic organisms led to a drastic change in Earth's atmosphere and oceans in which the free oxygen produced caused worldwide deposition of iron oxide formations, increased weathering due to an oxidizing atmosphere and the evolution of animal life that depends on oxygen for respiration.
  ○ identify causal links and feedback mechanisms between changes in the biosphere and changes in Earth's other systems.	

Stimulus Materials Graphic organizers, diagrams, graphs, data tables, drawings	

Grades 9-12 EARTH AND SPACE SCIENCE

<table>
<tr><th colspan="2">Earth and Space Sciences</th><th>9-12.ESS3.A.1</th></tr>
<tr><td>Core Idea</td><td colspan="2">Earth and Human Activity</td></tr>
<tr><td>Component</td><td colspan="2">Natural Resources</td></tr>
<tr><td>MLS</td><td colspan="2">Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.</td></tr>
<tr><td colspan="2"><u>Expectation Unwrapped</u>

[Clarification Statement: Examples of key natural resources include access to freshwater, regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting, and soil erosion), and severe weather. Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.]

<u>SCIENCE AND ENGINEERING PRACTICES</u>
Constructing Explanations and Designing Solutions
● Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations, peer reviews) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

<u>DISCIPLINARY CORE IDEAS</u>
Natural Resources
● Resource availability has guided the development of human society.

Natural Hazards
● Natural hazards and other geologic events have shaped the course of human history; [they] have significantly altered the sizes of human populations and have driven human migrations.

<u>CROSSCUTTING CONCEPTS</u>
Cause and Effect
● Empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects.
Influence of Science, Engineering, and Technology on Society and the Natural World
● Modern civilization depends on major technological systems</td><td><u>DOK Ceiling</u>
3

<u>Item Format</u>
Selected Response
Constructed Response
Technology Enhanced</td></tr>
</table>

Content Limits/Assessment Boundaries

- Tasks should provide students with all needed evidence.
- Tasks should avoid any mathematical population analyses.
- Tasks should avoid any scenarios that involve a loss of human life.

Possible Evidence

- Students construct an explanation that includes
  - specific cause and effect relationships between environmental factors (natural hazards, changes in climate, and the availability of natural resources) and features of human societies including population size and migration patterns.
  - that technology in modern civilization has mitigated some of the effects of natural hazards, climate, and the availability of natural resources on human activity.
- Students identify and describe the evidence to construct their explanation, including
  - natural hazard occurrences that can affect human activity and have significantly altered the sizes and distributions of human populations in particular regions.
  - changes in climate that affect human activity (e.g., agriculture) and human populations, and that can drive mass migrations.
  - features of human societies that have been affected by the availability of natural resources.
  - evidence of the dependence of human populations on technological systems to acquire natural resources and to modify physical settings.
- Students use a variety of valid and reliable sources for the evidence, potentially including theories, simulations, peer reviews, or students' own investigations.
- Students use reasoning that connects the evidence, along with the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future, to describe
  - the effect of natural hazards, changes in climate, and the availability of natural resources on features of human societies, including population size and migration patterns.
  - how technology has changed the cause and effect relationship between the development of human society and natural hazards, climate, and natural resources.
- Students describe reasoning for how the evidence allows for the distinction between causal and correlational relationships between environmental factors and human activity.

Stimulus Materials

Graphic organizers, diagrams, graphs, data tables, drawings

Sample Stems

Grades 9-12 EARTH AND SPACE SCIENCE

Earth and Space Sciences		9-12.ESS3.A.2
Core Idea	**Earth and Human Activity**	
Component	**Natural Resources**	
MLS	Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on economic, social, and environmental cost-benefit ratios.	

Expectation Unwrapped

[Clarification Statement: Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shale), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.]

SCIENCE AND ENGINEERING PRACTICES

Engaging in Argument from Evidence

- Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations).

DISCIPLINARY CORE IDEAS

Natural Resources

- All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors.

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.

CROSSCUTTING CONCEPTS

Influence of Science, Engineering, and Technology on Society and the Natural World

- Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.
- Analysis of costs and benefits is a critical aspect of decisions about technology.

DOK Ceiling

3

Item Format

Selected Response
Constructed Response
Technology Enhanced

Grades 9-12 EARTH AND SPACE SCIENCE

Science Addresses Questions About the Natural and Material World

- Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions.
- Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge.
- Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues.

<u>Content Limits/Assessment Boundaries</u>

- Tasks should provide students with at least two possible solutions to evaluate.

<u>Possible Evidence</u>

- Students describe the nature of the problem each design solution addresses.
- Students identify the solution that has the most preferred cost-benefit ratios.
- Students identify evidence for the design solutions, including
  - societal needs for that energy or mineral resource.
  - the cost of extracting or developing the energy reserve or mineral resource.
  - the costs and benefits of the given design solutions; and iv.
  - The feasibility, costs, and benefits of recycling or reusing the mineral resource, if applicable.
- Students evaluate the given design solutions, including
  - the relative strengths of the given design solutions, based on associated economic, environmental, and geopolitical costs, risks, and benefits.
  - the reliability and validity of the evidence used to evaluate the design solutions.
  - the constraints, including cost, safety, reliability, aesthetics, cultural effects environmental effects.
- Students use logical arguments based on their evaluation of the design solutions, costs and benefits, empirical evidence, and scientific ideas to support one design over the other(s) in their evaluation.
- Students describe that a decision on the "best" solution may change over time as engineers and scientists work to increase the benefits of design solutions while decreasing costs and risks.

<u>Stimulus Materials</u>

Graphic organizers, diagrams, graphs, data tables, drawings

<u>Sample Stems</u>

Grades 9-12 EARTH AND SPACE SCIENCE

<table>
<tr><th colspan="2">Earth and Space Sciences</th><th>9-12.ESS3.C.1</th></tr>
<tr><td>Core Idea</td><td colspan="2">Earth and Human Activity</td></tr>
<tr><td>Component</td><td colspan="2">Human Impacts on Earth’s Systems</td></tr>
<tr><td>MLS</td><td colspan="2">Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.</td></tr>
<tr><td colspan="2"><u>Expectation Unwrapped</u>

[Clarification Statement: Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.]

<u>SCIENCE AND ENGINEERING PRACTICES</u>
Using Mathematics and Computational Thinking
● Create a computational model or simulation of a phenomenon, designed device, process, or system.

<u>DISCIPLINARY CORE IDEAS</u>
Human Impacts on Earth Systems
● The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.

<u>CROSSCUTTING CONCEPTS</u>
Stability and Change
● Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Influence of Science, Engineering, and Technology on Society and the Natural World
● Modern civilization depends on major technological systems.
● New technologies can have deep impacts on society and the environment, including some that were not anticipated.

Science is a Human Endeavor
● Science is a result of human endeavors, imagination, and creativity.</td><td><u>DOK Ceiling</u>
3

<u>Item Format</u>
Selected Response
Constructed Response
Technology Enhanced</td></tr>
<tr><td colspan="2"><u>Content Limits/Assessment Boundaries</u>

● Tasks should focus on relationships rather than data calculations.</td><td><u>Sample Stems</u></td></tr>
</table>

Possible Evidence

- Students create a computational simulation (using a spreadsheet or a provided multi-parameter program) that contains representations of the relevant components, including
  - a natural resource in a given ecosystem; ii. The sustainability of human populations in a given ecosystem.
  - biodiversity in a given ecosystem.
  - the effect of a technology on a given ecosystem.
- Students describe simplified realistic (corresponding to real-world data) relationships between simulation variables to indicate an understanding of the factors (e.g., costs, availability of technologies) that affect the management of natural resources, human sustainability, and biodiversity. (For example, a relationship could be described that the amount of a natural resource does not affect the sustainability of human populations in a given ecosystem without appropriate technology that makes use of the resource or a relationship could be described that if a given ecosystem is not able to sustain biodiversity, its ability to sustain a human population is also small.)
- Students create a simulation using a spreadsheet or provided multiparameter program that models each component and its simplified mathematical relationship to other components. Examples could include
  - $S=C \times B \times R \times T$, where S is sustainability of human populations, C is a constant, B is biodiversity, R is the natural resource, and T is a technology used to extract the resource so that if there is zero natural resource, zero technology to extract the resource, or zero biodiversity, the sustainability of human populations is also zero.
  - $B=B_1 + C \times T$, where B is biodiversity, B_1 is a constant baseline biodiversity, C is a constant that expresses the effect of technology, and T is a given technology so that a given technology could either increase or decrease biodiversity depending on the value chosen for C.
    - The simulation contains user-controlled variables that can illustrate relationships among the components (e.g., technology having either a positive or negative effect on biodiversity).
- Students use the results of the simulation to
  - illustrate the effect on one component by altering other components in the system or the relationships between components.
  - identify the effects of technology on the interactions between human populations, natural resources, and biodiversity.
  - identify feedback between the components and whether the feedback stabilizes or destabilizes the system.
- Students compare the simulation results to a real-world example(s) and determine whether the simulation can be viewed as realistic.
- Students identify the simulation’s limitations relative to the phenomenon at hand.

Stimulus Materials	
Graphic organizers, diagrams, graphs, data tables, drawings	

Grades 9-12 EARTH AND SPACE SCIENCE

Earth and Space Sciences		9-12.ESS3.C.2
Core Idea	**Earth and Human Activity**	
Component	**Human Impacts on Earth's Systems**	
MLS	Evaluate or refine a technological solution that reduces impacts of human activities on natural systems in order to restore stability and or biodiversity of the ecosystem as well as prevent their recurrences.	

Expectation Unwrapped	**DOK Ceiling**
	3
[Clarification Statement: Examples of human activities could include forest fires, acid rain, flooding, urban development, pollution, deforestation, and introduction of an invasive species.] **SCIENCE AND ENGINEERING PRACTICES** **Constructing Explanations and Designing Solutions** ● Design or refine a solution to a complex real-world problem based on scientific knowledge, student generated sources of evidence, prioritized criteria, and tradeoff considerations. **DISCIPLINARY CORE IDEAS** **Human Impacts on Earth Systems** ● Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. **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. (secondary) **CROSSCUTTING CONCEPTS** **Stability and Change** ● Feedback (negative or positive) can stabilize or destabilize a system. **Influence of Science, Engineering, and Technology on Society and the Natural World** ● Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.	**Item Format** Selected Response Constructed Response Technology Enhanced

Grades 9-12 EARTH AND SPACE SCIENCE

Content Limits/Assessment Boundaries

- Tasks should provide students with technological solutions.
- Tasks should focus the restoration of biodiversity and/or the stability of an ecosystem.
- Tasks should avoid any scenarios that involve a loss of human life.

Possible Evidence

- Students use scientific information to generate a number of possible refinements to a given technological solution.
- Students describe the system being impacted and how the human activity is affecting that system. Students
  - identify the scientific knowledge and reasoning on which the solution is based.
  - describe how the technological solution functions and may be stabilizing or destabilizing the natural system.
  - refine a given technological solution that reduces human impacts on natural systems.
  - describe that the solution being refined comes from scientists and engineers in the real world who develop technologies to solve problems of environmental degradation.
- Students describe and quantify (when appropriate)
  - criteria and constraints for the solution to the problem.
  - the tradeoffs in the solution, considering priorities and other kinds of research-driven tradeoffs in explaining why this particular solution is or is not needed.
- In their evaluation, students describe how the refinement will improve the solution to increase benefits and/or decrease costs or risks to people and the environment.
- Students evaluate the proposed refinements for
  - their effects on the overall stability of and changes in natural systems.
  - cost, safety, aesthetics, and reliability, as well as cultural and environmental impacts.

Stimulus Materials

Graphic organizers, diagrams, graphs, data tables, drawings

Sample Stems

Grades 9-12 EARTH AND SPACE SCIENCE

<table>
<tr><th colspan="2">Earth and Space Sciences</th><th>9-12.ESS3.D.1</th></tr>
<tr><td>Core Idea</td><td colspan="2">Earth and Human Activity</td></tr>
<tr><td>Component</td><td colspan="2">Global Climate Change</td></tr>
<tr><td>MLS</td><td colspan="2">Analyze geoscientific data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.</td></tr>
<tr><td colspan="2" rowspan="2"><u>Expectation Unwrapped</u>

[Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).]

<u>SCIENCE AND ENGINEERING PRACTICES</u>
Analyzing and Interpreting Data
● Analyze data using computational models in order to make valid and reliable scientific claims.

Scientific Investigations Use a Variety of Methods
● Science investigations use diverse methods and do not always use the same set of procedures to obtain data.
● New technologies advance scientific knowledge.
● Science arguments are strengthened by multiple lines of evidence supporting a single explanation.

<u>DISCIPLINARY CORE IDEAS</u>
Global Climate Change
● Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts.

<u>CROSSCUTTING CONCEPTS</u>
Stability and Change
● Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.</td><td><u>DOK Ceiling</u>
3</td></tr>
<tr><td><u>Item Format</u>
Selected Response
Constructed Response
Technology Enhanced</td></tr>
<tr><td colspan="2"><u>Content Limits/Assessment Boundaries</u>

● Tasks should provide students with a model and all needed data.
● Tasks should be limited to one example of a climate change and its associated impacts.</td><td><u>Sample Stems</u></td></tr>
</table>

Grades 9-12 EARTH AND SPACE SCIENCE

<table>
<tr><td>

<u>Possible Evidence</u>

- Students organize data (e.g., with graphs) from global climate models (e.g., computational simulations) and climate observations over time that relate to the effect of climate change on the physical parameters or chemical composition of the atmosphere, geosphere, hydrosphere, or cryosphere.
- Students describe what each data set represents.
- Students analyze the data and identify and describe relationships within the data sets, including
  - changes over time on multiple scales.
  - relationships between quantities in the given data.
- Students use their analysis of the data to describe a selected aspect of present or past climate and the associated physical parameters (e.g., temperature, precipitation, sea level) or chemical composition (e.g., ocean pH) of the atmosphere, geosphere, hydrosphere or cryosphere.
- Students use their analysis of the data to predict the future effect of a selected aspect of climate change on the physical parameters (e.g., temperature, precipitation, sea level) or chemical composition (e.g., ocean pH) of the atmosphere, geosphere, hydrosphere or cryosphere.
- Students describe whether the predicted effect on the system is reversible or irreversible.
- Students identify one source of uncertainty in the prediction of the effect in the future of a selected aspect of climate change.
- In their interpretation of the data, students
  - make a statement regarding how variation or uncertainty in the data (e.g., limitations, accuracy, any bias in the data resulting from choice of sample, scale, instrumentation) may affect the interpretation of the data.
  - identify the limitations of the models that provided the simulation data and ranges for their predictions.

</td><td rowspan="2"></td></tr>
<tr><td>

<u>Stimulus Materials</u>

Graphic organizers, diagrams, graphs, data tables, drawings

</td></tr>
</table>

Grades 9-12 EARTH AND SPACE SCIENCE

Earth and Space Sciences		9-12.ESS3.D.2
Core Idea	**Earth and Human Activity**	
Component	**Global Climate Change**	
MLS	Predict how human activity affects the relationships between Earth Systems in both positive and negative ways.	

Expectation Unwrapped	DOK Ceiling
[Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere.] **SCIENCE AND ENGINEERING PRACTICES** **Using Mathematics and Computational Thinking** ● Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations. **DISCIPLINARY CORE IDEAS** **Weather and Climate** ● Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere. ● Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities. **CROSSCUTTING CONCEPTS** **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.	3 **Item Format** Selected Response Constructed Response Technology Enhanced

Content Limits/Assessment Boundaries	Sample Stems
● Tasks should provide students with all needed background information on human activity. ● Tasks should define the terms biosphere, atmosphere, hydrosphere, geosphere, and cryosphere if used. ● Tasks should not include rote memorization or definitions of vocabulary.	

Grades 9-12 EARTH AND SPACE SCIENCE

Possible Evidence	
• Students identify and describe the relevant components of a model of Earth's systems, including system boundaries, initial conditions, inputs and outputs, and relationships that determine the interaction (e.g., the relationship between atmospheric CO_2 and production of photosynthetic biomass and ocean acidification). • Students describe relationships between at least two of Earth's systems, including how the relevant components in each individual Earth system can drive changes in another, interacting Earth system. • Students use evidence to describe how human activity could affect the relationships between Earth's systems under consideration.	
Stimulus Materials	
Graphic organizers, diagrams, graphs, data tables, drawings	