National Aeronautics and Space Administration

NASA: Moving Cargo

Human Exploration Project II
Transportation

A Standards-Based High School Unit Guide




Engineering byDesign™

Advancing Technological Literacy

A Standards-Based Program Series

This unit coordinates with the ITEA EbD™ Course: ***Foundations of Technology.***

HS-9

International Technology Education Association

Center to Advance the Teaching of Technology and Science

Educational Product

Educators Grade 9

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Teacher Notes

This unit is intended to serve as part of a high school experience for students who are interested in exploring Technology Education and/or Pre-Engineering. In terms of Science, Technology, Engineering, and Mathematics (STEM) education, this unit primarily focuses upon the "T" and "E" of STEM, with strong linkages to the "S" and "M." The intended audience includes students in Grade 9. While there are no prerequisites, prior experience in technological literacy through Technology Education is helpful.

Preface

NASA: Moving Cargo
A Standards-Based High School Unit

Acknowledgments

Many individuals committed to developing high school technological literacy made this publication possible. Their strong commitment to developing standards-based technology resources is reflected in this guide. Special thanks are expressed to the following:

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The ITEA-CATTS Human Exploration Project (HEP)
People, Education, and Technology

In May 2005, ITEA was funded by the National Aeronautics and Space Administration (NASA) to develop curricular units for Grades K–12 on Space Exploration. The units focus on aspects of the themes that NASA Engineers and Scientists—as well as future generations of explorers—must consider, such as Energy and Power, Transportation, and Lunar Plant Growth Chambers (the STS-118 Design Challenges). Moreover, the units are embedded within a larger Model Program for technology education known as Engineering byDesign™.

The Human Exploration Project (HEP) units have several common characteristics. All units:

- Are based upon the Technological Literacy standards (ITEA, 2000/2007).
- Coordinate with Science (AAAS, 1993) and Mathematics standards (NCTM, 2000).
- Utilize a standards-based development approach (ITEA, 2005).
- Stand alone and coordinate with ITEA-CATTS Engineering byDesign™ curricular offerings.
- Reflect a unique partnership between NASA scientists and engineers and education professionals.

These unit guides are designed to be practical and user-friendly. ITEA welcomes feedback from users in the field as we continually refine these curricular products, ensuring that the content remains as dynamic as the technological world in which we live. Please e-mail <ebd@iteaconnect.org> or call 703-860-2100.

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Unit Overview

Big Idea

Space exploration employs an integrated intermodal system of transportation to move people and equipment on Earth, between Earth and other planets, and on other planets.

Teacher's Note: Big ideas should be made explicit to students by writing them on the board and/or reading them aloud.

Standards and Benchmarks

Technology: **Standards for Technological Literacy (STL)** ***(ITEA, 2000/2002/2007)***

- Students will develop an understanding of the characteristics and scope of technology. (ITEA/STL 1)
  - Creative thinking and economic and cultural influences shape technological development. (1E)
  - The development of technology is a human activity and is the result of individual or collective needs and the ability to be creative. (1G)
- Students will develop an understanding of the core concepts of technology. (ITEA/STL 2)
  - Systems, which are the building blocks of technology, are embedded within larger technological, social, and environmental systems. (2X)
  - The stability of a technological system is influenced by all of the components in the system, especially those in the feedback loop. (2Y)
  - Selecting resources involves tradeoffs between competing values, such as availability, cost, desirability, and waste. (2Z)
  - New technologies create new processes. (2CC)
  - Management is the process of planning, organizing, and controlling work. (2EE)
- Students will develop abilities to apply the design process. (ITEA/STL 11)
  - Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed. (11P)
  - Develop and produce a product or system using a design process. (11Q)
  - Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models. (11R)
- Students will develop the abilities to use and maintain technological products and systems. (ITEA/STL 12)
  - Operate systems so that they function in the way they were designed. (12O)
- Students will develop an understanding of and be able to select and use transportation technologies. (ITEA/STL 18)
  - Transportation plays a vital role in the operation of other technologies, such as manufacturing, construction, communication, health and safety, and agriculture. (18J)
  - Intermodalism is the use of different modes of transportation, such as highways, railways, and waterways as part of an interconnected system that can move people and goods easily from one mode to another. (18K)

Mathematics:* Principles and Standards for School Mathematics *(NCTM, 2000)*

- Understand numbers, ways of representing numbers, relationships among numbers, and number systems. (NCTM, Number and Operations, Grades 6–8)
  - Develop an understanding of large numbers and recognize and appropriately use exponential, scientific, and calculator notation.
- Use visualization, spatial reasoning, and geometric modeling to solve problems. (NCTM, Geometry, Grades 9–12)
  - Draw and construct representations of two- and three-dimensional geometric objects using a variety of tools.
- Understand measurable attributes of objects and the units, systems, and processes of measurement. (NCTM, Measurement, Grades 9–12)
  - Make decisions about units and scales that are appropriate for problem situations involving measurement.
- Apply appropriate techniques, tools, and formulas to determine measurements. (NCTM, Measurement, Grades 9–12)
  - Analyze precision, accuracy, and approximate error in measurement situations.
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them. (NCTM, Data Analysis and Probability, Grades 9–12)
  - Understand the differences among various kinds of studies and which types of inferences can legitimately be drawn from each.
- Solve problems that arise in mathematics and in other contexts. (NCTM, Problem Solving, Grades 9–12)
- Apply and adapt a variety of appropriate strategies to solve problems. (NCTM, Problem Solving, Grades 9–12)
- Recognize and apply mathematics in contexts outside of mathematics. (NCTM, Connections, Grades 9–12)

Science:* Benchmarks for Science Literacy *(AAAS, 1993)**

- Mathematics, Science, and Technology (AAAS, 2B, Grades 9–12)
  - Mathematical modeling aids in technological design by simulating how a proposed system would theoretically behave.
- Technology and Science (AAAS, 3A, Grades 9–12)
  - Technological problems often create a demand for new scientific knowledge, and new technologies make it possible for scientists to extend their research in new ways or to undertake entirely new lines of research. The very availability of new technology itself often sparks scientific advances.
  - Mathematics, creativity, logic, and originality are all needed to improve technology.
- Issues in Technology (AAAS, 3C, Grades 9–12)
  - Social and economic forces strongly influence which technologies will be developed and used. Which will prevail is affected by many factors, such as personal values, consumer acceptance, patent laws, the availability of risk capital, the federal budget, local and national regulations, media attention, economic competition, and tax incentives.

** Standards are listed with the permission of the National Council of Teachers of Mathematics (NCTM). NCTM does not endorse the content or validity of these alignments.*

*** Material reprinted from* Benchmarks for Science Literacy *(AAAS, 1993) with permission from Project 2061, on behalf of the American Association for the Advancement of Science, Washington, D.C.*

- In designing a device or process, thought should be given to how it will be manufactured, operated, maintained, replaced, and disposed of and who will sell, operate, and take care of it. The costs associated with these functions may introduce yet more constraints on the design.
- Complex systems have layers of controls. Some controls operate particular parts of the system and some control other controls. Even fully automatic systems require human control at some point.
- To reduce the chance of system failure, performance testing is often conducted using analogous systems, or just the parts of the systems thought to be least reliable.

- Uncertainty (AAAS, 9D, Grades 9–12)
  - A physical or mathematical model can be used to estimate the probability of real-world events.
- Systems (AAAS, 11A, Grades 9–12)
  - The successful operation of a designed system usually involves feedback. The feedback of output from some parts of a system to input for other parts can be used to encourage what is going on in a system, discourage it, or reduce its discrepancy from some desired value. The stability of a system can be greater when it includes appropriate feedback mechanisms.
- Manipulation and Observation (AAAS 12C, Grades 9–12)
  - Use power tools safely to shape, smooth, and join wood, plastic, and soft metal.
- Communication Skills (AAAS, 12D, Grades 9–12)
  - Make and interpret scale drawings.

Purpose of Unit

This unit familiarizes students with the NASA Constellation project and the need for exploration, intermodal means of transportation to move goods and people, how NASA incorporates intermodal means of transportation to ensure mission success, the basic operating system behind the Ares I and Ares V launch vehicles and the testing procedures used by NASA to help ensure the vehicles will operate as designed; and NASA's model for decision making to manage the proper operation of systems.

Unit Objectives

Lesson 1: NASA Exploration

Students will learn to:

- Describe how creative thinking and economic and cultural influences shape technological development at NASA.
- Explain how the exploration of new lands, particularly the Moon and other planets, is based on human needs and the ability to be creative.
- Describe the spinoff technologies that are a direct result of the NASA space program.

Lesson 2: Intermodalism

Students will learn to:

- Describe that intermodalism is the use of various modes of transportation as parts of an interconnected system to move people and goods.
- Explain that transportation plays a vital role in the operation of other technologies, such as manufacturing, construction, communications, health, and safety.
- Describe examples for each mode of transportation, such as highways, waterways, railways, and space, which are integrated to move people and goods.
- Describe that the selection of the appropriate means of transportation involves tradeoffs between competing values.

Lesson 3: NASA Transportation Cycle

Students will learn to:

- Describe the specific intermodal forms of transportation NASA uses to move goods and people.
- Describe how one component within the NASA transportation system can impact a NASA mission.
- Explain how the NASA transportation cycle contributes to NASA achieving the mission.

Lesson 4: Ares I and Ares V: Transporting Cargo and Crew

Students will learn to:

- Describe the basic operating principles behind the Ares V in transporting cargo to the lunar surface.
- Describe the basic operating principles behind the Ares I in transporting crew members to the lunar surface and back to Earth.
- Describe testing procedures that NASA completes to ensure that the Ares I and Ares V operate successfully.
- Explain how NASA has developed new transportation processes based on new vehicle designs.
- Apply the engineering design process to solve a problem.
- Work safely and accurately with a variety of tools, machines, and materials.
- Fabricate a prototype or model of a design solution.
- Evaluate a design by using conceptual, physical, and mathematical models.

Lesson 5: Ares I and Ares V: Transporting Cargo and Crew

Students will learn to:

- Explain that the management of transportation systems includes the process of planning, organizing, and controlling the transportation cycle.
- Apply the engineering design process to solve a problem.
- Work safely and accurately with a variety of tools, machines, and materials.
- Apply systems-thinking principles to the engineering design process.
- Identify criteria and constraints and determine how these will affect the design process.
- Make two-dimensional and three-dimensional representations of a design solution.
- Fabricate a prototype or model of a design solution.
- Evaluate a design by using conceptual, physical, and mathematical models.

Student Assessment Tools and/or Methods

(See assessment instruments at end of each lesson.)

- Selected Response Items
- Brief Constructed Response Items
- Performance Rubric

Lesson 1: NASA Exploration

Lesson Snapshot

Overview

Big Idea: Cultural and economic influences affect the development of the new technology needed for the NASA Constellation project, which focuses on space exploration.

Teacher's Note: Big ideas should be made explicit to students by writing them on the board and/or reading them aloud.

Purpose of Lesson: This lesson familiarizes students with the NASA Constellation project and the need for space exploration.

Lesson Duration: Four hours.

Activity Highlights

Engagement: Students learn about different modes of transportation used in exploration throughout history.

Exploration: Working in small groups, students brainstorm social, political, environmental, and economic impacts of space exploration.

Explanation: The teacher introduces NASA's vision for space exploration and the Constellation program.

Extension: Students create a one-page handout on a specific explorer.

Evaluation: Student knowledge, skills, and attitudes are assessed using true/false items, rubrics, and brief and extended constructed responses.

Enrichment: Students may research a past NASA mission, the human needs the mission was designed to solve, and the economic and cultural influences involved in designing the mission. Students may also research a technological system and how creative thinking influenced development of the technology.

Lesson 1: Overview

Lesson Duration
- Four hours.

Standards/Benchmarks
Technology: **Standards for Technological Literacy (STL)** ***(ITEA, 2000/2002/2007)***
- Students will develop an understanding of the characteristics and scope of technology. (ITEA/STL 1)
  - Creative thinking and economic and cultural influences shape technological development. (1E)
- Students will develop an understanding of the core concepts of technology. (ITEA/STL 2)
  - New technologies create new processes. (2CC)

Science: **Benchmarks for Science Literacy** ***(AAAS, 1993)*****
- Technology and Science (AAAS, 3A, Grades 9–12)
  - Technological problems often create a demand for new scientific knowledge, and new technologies make it possible for scientists to extend their research in new ways or to undertake entirely new lines of research. The very availability of new technology itself often sparks scientific advances.
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Mathematics: **Principles and Standards for School Mathematics** ***(NCTM, 2000)****
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them. (NCTM, Data Analysis and Probability, Grades 9–12)
  - Understand the differences among various kinds of studies and which types of inferences can legitimately be drawn from each.
- Apply and adapt a variety of appropriate strategies to solve problems. (NCTM, Problem Solving, Grades 9–12)
- Recognize and apply mathematics in contexts outside of mathematics. (NCTM, Connections, Grades 9–12)

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Learning Objectives
Students will learn to:
1. Describe how creative thinking, economic, and cultural influences shape technological development at NASA.
2. Explain how the exploration of new lands, particularly the Moon and other planets, is based on human needs and the ability to be creative.
3. Describe the spinoff technologies that are a direct result of the NASA space program.

Student Assessment Tools and/or Methods

1. True/False

True 1. Economic and cultural influences shape the development of technology.

True 2. The development of technology is based on human needs and technical know-how.

True 3. The development of technology is a result of human creativity and an identified human need.

True 4. Creativity helps shape technological development.

Teacher Note: This is a brief formative assessment to evaluate student understanding. Teachers may wish to use this prior to engaging in the lesson.

2. Brief Constructed Response
   a. Describe the economic and cultural influences that shape the development of technology within the NASA Constellation program.
   b. Describe how creative thinking shapes technological development within the Constellation program.

Category	Below Target	At Target	Above Target
Understanding	Response demonstrates an implied, partial, or superficial understanding of the text and/or the question.	Response demonstrates an understanding of the text.	Was always willing to do more. Routinely offered useful ideas.
Focus	Lacks transitional information to show the relationship of the support to the question.	Addresses the demands of the question.	Went beyond what was expected of him/her.
Use of Related Information	Uses minimal information from the text to clarify or extend meaning.	Uses some expressed or implied information from the text to clarify or extend meaning.	Exceeds the demands of the question. Effectively uses expressed or implied information from the text to clarify or extend meaning.

3. Extended Constructed Response

   Describe how the development of NASA technology resulted from a human need and the ability to be creative.

Category	Below Target	At Target	Above Target
Context and Argument	Context inappropriate. Argument unsatisfactory.	Context appropriate. Argument satisfactory.	Context appropriate. Argument satisfactory. Clearly stated thesis included.
Evidence	Evidence is largely missing or generalized.	Ample and appropriate evidence provided (at least two examples).	Abundant, relevant specifics (names, events, legislation, court decisions, etc.) provided. Includes obscure, but important evidence. Thorough chronology.
Analysis	Minimal analysis or fallacious reasoning.	Organizes argument and uses data to support conclusions. Recognizes causation, change, and continuity.	Well-reasoned cause-and-effect arguments. Fully explained conclusions. Refers to views of others.
Historical Accuracy	Many errors.	May have some errors. Mistakes may slightly hinder argument but do not detract from the overall accuracy.	Virtually error-free; minor mistakes do not compromise argument.
Thoroughness	Covers question superficially.	Covers entire question, but not in proportion to their importance.	Covers all areas of question in approximate proportion to their importance.
Presentation	Inconsistent organization. Grammatical errors cloud argument to a major degree.	Uses clear language. Well organized. Contains few grammatical errors.	Uses clear, appropriate, and precise language. Cohesive organization. Very few grammatical errors.

4. Exploration Impacts Assessment Rubric

Category	Below Target	At Target	Above Target
Explorer Identification	Information is missing or difficult to locate.	Information is properly located and sized on the paper.	Information is properly located and sized on the paper, and formatting is adapted to accommodate information.
Human Need	Identification of human need is inaccurate, and no supporting information is included.	Identification of human need is accurate. Information provided gives somewhat clear evidence to support the statement of human need.	Identification of human need is accurate. Information provided gives clear evidence to support statement of human need.
Cultural Influences	There are some inaccuracies with the positive and negative cultural influences. There are less than two positive and negative influences represented.	Cultural influences that both positively and negatively affect are represented with some accuracy. At least two positive and negative cultural influences are represented.	Cultural influences that both positively and negatively affect are accurately represented. At least three positive and negative cultural influences are represented.
Economic Influences	There are some inaccuracies with the positive and negative economic influences. There are less than two positive and negative influences represented.	Economic influences that both positively and negatively affect are represented with some accuracy. At least two positive and negative economic influences are represented.	Economic influences that both positively and negatively affect are accurately represented. At least three positive and negative economic influences are represented.
Creative Thinking	Identification of creative thinking is inaccurate, and no supporting information is included.	Identification of creative thinking is accurate. Information provided gives somewhat clear evidence to support the statement of creative thinking.	Identification of creative thinking is accurate. Information provided gives clear evidence to support statement of creative thinking.
Resources	Less than two properly documented sources located on the front of handout.	Two properly documented sources located on the front of handout.	More than two properly documented and placed sources.

Resource Materials

Books, periodicals, pamphlets, and web sites may provide teachers and students with background information and extensions. Inclusion of a resource does not constitute an endorsement, either expressed or implied, by the National Aeronautics and Space Administration.

Print Materials

Collins, M.J., & the National Air and Space Museum. (1999). *Space race: The U.S.-U.S.S.R. competition to reach the Moon*. Pomegranate Communications.

Shayler, D.J., Salmon, A., & Shayler, M.D. (Eds.). (2005). *Marswalk one: First steps on a new planet.* Springer Praxis Books.

Audiovisual Materials

Biega, C. (Director). (2000). *National Geographic's the explorers: A century of discovery* [VHS]. United States: National Geographic.

Quality Information Publishers, Inc. (n.d.) *Space Race Films Collection with Cold War US/Soviet History & JFK Kennedy Footage* [DVD]. Quality Information Publishers, Inc.

Internet Sites

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Bush, G.W. (2004). President Bush Announces New Vision for Space Exploration Program. Retrieved January 16, 2009, from <http://www.whitehouse.gov/news/releases/2004/01/20040114-1.html>.

Cheek, J.S. (2005). *Explorers*. Retrieved January 16, 2009, from <http://edtech.kennesaw.edu/web/explorer.html>.

Gander Academy (n.d.). *Ferdinand Magellan*. Retrieved January 16, 2009, from <http://www.cdli.ca/CITE/exmagellan.htm>.

NASA. (2004). *The vision for space exploration*: Retrieved January 16, 2009, from <http://www.nasa.gov/pdf/55583main_vision_space_exploration2.pdf>.

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Newfoundland Labrador. (n.d.). *Christopher Columbus*. Retrieved January 16, 2009, from <http://www.cdli.ca/CITE/excolumbus.htm>.

Newfoundland Labrador. (n.d.). *Marco Polo*. Retrieved January 16, 2009, from <http://www.cdli.ca/CITE/expolo.htm>.

Oregon Post Magazine Online. (n.d.). *Ponce de León*. Retrieved January 16, 2009, from <http://www.u-s-history.com/pages/h1007.html>.

The Oregon Trail. (n.d.). *Discoverers & explorers: Who really found the Oregon Trail?* Retrieved January 16, 2009, from <http://www.isu.edu/~trinmich/Discoverers.html>.

Required Knowledge and Skills

Students should have some basic understanding of the functioning and applications of core technology systems, their common components, basic system design, safety considerations, and simple controls. Students should also have some understanding of how subsystems affect the overall performance of technology systems. They should have some basic graphic and research skills. In the engagement and exploratory phases of instruction, the teacher identifies student misunderstandings and/or misconceptions about the economic, social, political, and environmental impacts on technology systems.

Lesson 1: 5-E Lesson Plan

Engagement

1. The teacher shows a set of pictures representing different transportation used for exploration throughout history. Examples include the following:
   a. Christopher Columbus' ships
   b. Space shuttle
   c. Covered wagon
2. The teacher asks the students to create a list of common characteristics of the various exploration vehicles.
3. The students generate a list of commonalities between the various exploration vehicles and share their commonalities with the class.
4. The teacher asks students:
   a. Why do people explore new lands?
   b. What resources are needed for the exploration of new lands?
5. Students share the answers to the teacher-directed questions as a class discussion.
6. The teacher explains that the development of new technology that enables humans to explore new lands is a result of creativity and a desire to fulfill human needs.
7. The teacher assesses prior knowledge and misconceptions related to the NASA space program.

Exploration

1. Working in small groups, students brainstorm social, political, environmental, and economic impacts of space exploration.
2. Students create a brainstorm web, which represents the connections among the impacts from their brainstorm list.
3. Students share their brainstorm webs with the class.

Explanation

1. The teacher explains the following:
   a. The NASA Constellation program is based on the goal set by President Bush in 2004:

   "... this vision… is a sustainable and affordable long-term human and robotic program to explore space. We will explore space to improve our lives and lift our national spirit. Space exploration is also likely to produce scientific discoveries in fields from biology to physics, and to advance aerospace and a host of other industries. This will help create more highly skilled jobs, inspire students and teachers in math and science, and ensure that we continue to benefit from space technology, which has already brought us important improvements in areas as diverse as hurricane forecasting, satellite communications, and medical devices."

   (Bush, 2004)

   b. Based on the President's goal, the NASA Authorization Act of 2005 states that NASA shall establish a program to develop a sustained human presence on the Moon, including a robust precursor program to promote exploration, science, commerce, and U.S. preeminence in space, and as a stepping stone to future exploration of Mars and other destinations.
   c. In order to achieve their goal and meet the need for exploration, engineers and designers created two new launch vehicles: Ares I and Ares V, which contain the Orion, a crew exploration vehicle and a lunar lander, an exploration vehicle made to land on the lunar surface.

2. The teacher explains that the Constellation project mission includes the following:
   a. Using the Moon to prepare for future human and robotic missions to Mars and other destinations.
   b. Pursuing scientific activities to address fundamental questions about the solar system, the universe, and our place in them.
   c. Extending sustained human presence on the Moon to enable eventual settlement.
   d. Expanding Earth's economic sphere to encompass the Moon and pursue lunar activities with direct benefits to life on Earth (Connelly 2006).
3. New technological development is a result of creativity and economic and cultural influences.
   a. Some economic factors that influenced the Constellation project are as follows:
      i) To reduce the cost of each vehicle.
      ii) To focus on building a vehicle that is not reusable, versus the space shuttle, which was designed to be reusable. Originally it was believed that to save costs, the parts should be reusable. Because of the frequency of flights, this was not the case.
      iii) To encourage the participation of private and commercial industries to develop their own technologies to service the International Space Station.
   b. Some cultural factors that influenced the Constellation project are as follows:
      i) Concern for the safety and health of astronauts.
      ii) Public interest in the project.
      iii) Exploration and the advancement of science would create more highly skilled jobs.
      iv) Exploration and scientific discoveries will create new technologies for use on Earth, such as medical and communication devices.
   c. Spinoffs of the space program include the following:
      i) Cordless power tools.
      ii) Smoke detector.
      iii) Home insulation.
      iv) Laser heart surgery.
      v) CAT Scans.
      vi) Football helmet padding.
      vii) Crop management from satellites.
      viii) Telecommunications using satellites.
4. Students clarify their understanding of the concepts through questioning.

Extension

1. The teacher passes out ***Lesson Resource 1.1*** and reviews the requirements for the "Exploration Impacts" activity.
2. Students select an explorer from the list on the handout and create a one-page handout that describes the following:
      i) The human need the explorer was trying to solve through exploration.
      ii) Economic impacts that contributed to or negatively impacted the success of the exploration.
      iii) Cultural impacts that contributed to or negatively impacted the success of the exploration.
      iv) Examples of how the explorer used creative thinking during the exploration of the new land.
3. Students share their one-page handouts with the class during a three-minute presentation.

Evaluation

Student knowledge, skills, and attitudes are assessed using true/false items, brief constructed response items, extended constructed response items, and a rubric for the "Exploration Impacts" activity. The rubrics should be presented in advance of the activities to familiarize students with the expectations and performance criteria. They should also be reviewed during the activities to guide students in the completion of assignments. The teacher may wish to develop a collection of annotated exemplars of student work based on the rubrics. The exemplars will serve as benchmarks for future assessments and may be used to familiarize students with the criteria for assessment.

Enrichment

1. Students may research a past NASA mission, the human needs the mission was designed to solve, and the economic and cultural influences involved in designing the mission.
2. Students may research a technological system and how creative thinking influenced development of the technology.

Lesson 1: Lesson Preparation

Teacher Planning

The laboratory-classroom should provide a flexible, resource-rich learning environment that includes areas for lectures and demonstrations, small-group meetings, design processes, research activities, production and fabrication, product/prototype testing, and analysis. The teacher adapts the learning environment based on the requirements of the unit or lesson. For this lesson, areas for lectures and demonstration, small-group meetings, and fabrication activities should be readied.

Tools/Materials/Equipment

- Computers
- Library resources
- Graphic tools, materials, and equipment

Classroom Safety and Conduct

1. Students use tools and equipment in a safe manner and assume responsibility for their safety as well as the safety of others.
2. Students demonstrate respect and courtesy for the ideas expressed by others in the class.
3. Students show respect and appreciation for the efforts of others.

Lesson 2: Intermodalism

Lesson Snapshot

Overview

Big Idea: Intermodal transportation systems are logistically linked systems using two or more transport modes that allow goods and people to transfer easily between their origin location and their point of destination

Teacher's Note: Big ideas should be made explicit to students by writing them on the board and/or reading them aloud.

Purpose of Lesson: This lesson familiarizes students with intermodal means of transportation to move goods and people.

Lesson Duration: Three hours.

Activity Highlights

Engagement: Students consider how people and goods are transported in general. They create a list and categorize transportation vehicles into four categories: land, water, air, space.

Exploration: Students consider how products are transported to arrive at their homes and create a list to share with the class.

Explanation: The teacher provides information on transportation tradeoffs, such as availability, desirability, and cost, within the four categories: land, water, air, space. The teacher defines intermodal transportation. Students clarify their understanding through questioning.

Extension: Students complete a "Life Cycle Transportation" activity.

Evaluation: Student knowledge, skills, and attitudes are assessed using multiple-choice items, brief constructed response items, extended constructed response items, and a rubric for the "Exploration Impacts" activity. The rubrics should be presented in advance of the activities to familiarize students with the expectations and performance criteria. They should also be reviewed during the activities to guide students in the completion of assignments. The teacher may wish to develop a collection of annotated exemplars of student work based on the rubrics. The exemplars will serve as benchmarks for future assessments and may be used to familiarize students with the criteria for assessment.

Enrichment: Students could create their own life cycle diagram by researching a technology product and identifying the modes of transportation. Students could identify the economic and political impact for each means of transportation and present their information to the class.

Lesson 2: Overview

Lesson Duration

- Three hours.

Standards/Benchmarks

Technology:* Standards for Technological Literacy (STL) *(ITEA, 2000/2002/2007)

- Students will develop an understanding of the core concepts of technology. (ITEA/STL 2)
  - Selecting resources involves tradeoffs between competing values, such as availability, cost, desirability, and waste. (2Z)
- Students will develop an understanding of and be able to select and use transportation technologies. (ITEA/STL 18)
  - Transportation plays a vital role in the operation of other technologies, such as manufacturing, construction, communication, health and safety, and agriculture. (18J)
  - Intermodalism is the use of different modes of transportation, such as highways, railways, and waterways as part of an interconnected

Mathematics:* Principles and Standards for School Mathematics *(NCTM, 2000)*

- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them. (NCTM, Data Analysis and Probability, Grades 9–12)
  - Understand the differences among various kinds of studies and which types of inferences can legitimately be drawn from each.

Science:* Benchmarks for Science Literacy *(AAAS, 1993)**

- Issues in Technology (AAAS, 3C, Grades 9–12)
  - In designing a device or process, thought should be given to how it will be manufactured, operated, maintained, replaced, and disposed of and who will sell, operate, and take care of it. The costs associated with these functions may introduce yet more constraints on the design.
- Uncertainty (AAAS, 9D, Grades 9–12)
  - A physical or mathematical model can be used to estimate the probability of real-world events.

** Standards are listed with the permission of the National Council of Teachers of Mathematics (NCTM). NCTM does not endorse the content or validity of these alignments.*

*** Material reprinted from* Benchmarks for Science Literacy *(AAAS, 1993) with permission from Project 2061, on behalf of the American Association for the Advancement of Science, Washington, D.C.*

Learning Objectives

Students will learn to:

1. Describe that intermodalism is the use of various modes of transportation as parts of an interconnected system to move people and goods.
2. Explain that transportation plays a vital role in the operation of other technologies, such as manufacturing, construction, communications, health, and safety.
3. Describe examples for each mode of transportation, such as highways, waterways, railways, and space, which are integrated to move people and goods.
4. Describe that the selection of the appropriate means of transportation involves tradeoffs between competing values.

Student Assessment Tools and/or Methods

1. Multiple Choice. (See ***Lesson Resource 2.1***).

Teacher's Note: This is a brief formative assessment to evaluate student understanding. Teachers may wish to use this prior to engaging in the lesson.

2. Brief Constructed Response Items
   a. Describe how transportation plays a vital role in the operation of other technologies, such as construction, communication, health, and safety.
   b. Describe examples for each means of transportation and examples of how the particular means of transportation safely transports people and goods.

Category	Below Target	At Target	Above Target
Understanding	Response demonstrates an implied, partial, or superficial understanding of the text and/or the question.	Response demonstrates an understanding of the text.	Response demonstrates an understanding of the complexities of the text.
Focus	Response lacks transitional information to show the relationship of the support to the question.	Response addresses the demands of the question.	Response exceeds the demands of the question.
Use of Related Information	Response includes minimal information from the text to clarify or extend meaning.	Response includes some expressed or implied information from the text to clarify or extend meaning.	Response effectively uses expressed or implied information from the text to clarify or extend meaning.

3. Extended Constructed Response Item

   Describe why intermodalism is needed by NASA to move people and goods.

Category	Below Target	At Target	Above Target
Context and Argument	Context inappropriate. Argument unsatisfactory.	Context appropriate. Argument satisfactory.	Context appropriate. Argument satisfactory. Clearly stated thesis included.
Evidence	Evidence is largely missing or generalized.	Ample and appropriate evidence provided.	Abundant, relevant specifics (names, events, legislation, court decisions, etc.) provided. Includes obscure, but important evidence. Thorough chronology.
Analysis	Minimal analysis or fallacious reasoning.	Organizes argument and uses data to support conclusions. Recognizes causation, change, and continuity.	Well-reasoned cause-and-effect arguments. Fully explained conclusions. Refers to views of others.
Historical Accuracy	Many errors.	May have a few errors. Mistakes may slightly hinder argument, but do not detract from the overall accuracy.	Virtually error-free; minor mistakes do not compromise argument.
Thoroughness	Covers question superficially. May not complete all tasks.	Covers entire question, but may be slightly imbalanced.	Covers all areas of question in approximate proportion to their importance.
Presentation	Inconsistent organization. Grammatical errors cloud argument to a major degree.	Uses clear language. Well organized. Contains few grammatical errors.	Uses clear, appropriate, and precise language. Cohesive organization. Very few grammatical errors.

Resource Materials

Books, periodicals, pamphlets, and web sites may provide teachers and students with background information and extensions. Inclusion of a resource does not constitute an endorsement, either expressed or implied, by the National Aeronautics and Space Administration.

Print Materials

Stroh, M.B. (2006). *A practical guide to transportation and logistics* (3rd Ed.). Logistics Network Inc.

Myer, K. (2003). *Handbook of transportation engineering*. McGraw-Hill.

Audiovisual Materials

The History Channel. (2006). *Modern Marvels-International Airports* [DVD]. United States: A&E Home Video.

The History Channel. (2006). *Modern Marvels-Mail Delivery: Erasing the Miles* [DVD]. United States: A&E Home Video.

Internet Sites

Slack, B., Rodrigue, J., & Comtois, C. (1998-2009). *Transportation modes: An overview*. Retrieved January 16, 2009, from <http://people.hofstra.edu/geotrans/eng/ch3en/conc3en/ch3c1en.html>.

Bureau of Transportation Statistics. (n.d.). Retrieved January 16, 2009, from <http://www.bts.gov/>.

Required Knowledge and Skills

Students should have some understanding of the functioning and applications of core technology systems, their common components, basic system design, safety consideration, and simple controls. Students should also have some understanding of how subsystems affect the overall performance of technology systems. They should have some basic graphic and research skills. In the engagement and exploratory phases of instruction, the teacher identifies student misunderstandings and/or misconceptions about the influence of technology on history.

Lesson 2: 5-E Lesson Plan

Engagement

1. The teacher assesses the misconceptions of students regarding the various means of transporting people and goods.
2. The teacher asks students to brainstorm a list of ways that goods and people are transported.
3. Students, working individually, create a brainstorm list of ways that goods and people are transported.
4. The teacher asks students to think-pair-share their responses.
5. Students share their individual lists with a partner and add any new ways that were not on their original list.
6. The teacher states that all transportation vehicles can be divided into four categories:
    a. Land
    b. Water
    c. Air
    d. Space
7. The teacher asks students to categorize their responses.
8. Students categorize their responses under land, water, air, or space.

Exploration

1. The teacher states that goods and people use multiple means of transportation to travel from one place to another.
2. The teacher presents pictures of several products students would find in their homes and ask students to identify all the transportation vehicles that could have been used to transport the product from the original location to their home.
3. Students create a list of vehicles that would be necessary to transport the product to their home from its original location.

Explanation

1. Students share their vehicle lists with the class.
2. The teacher explains that there are four categories of transportation that transport people and goods. Each means of transportation incorporates an infrastructure to assist in the operation of the transportation system. When selecting a means of transportation, it is important to consider tradeoffs such as availability, desirability, and cost.
    a. Land
        i) Land modes of transportation include railways, roadways, and pipelines.
        ii) Railways allow the largest cargo capacity of all the land forms of transportation.
        iii) Due to the physical infrastructure of roadways, railways, and pipeline locations, there is limited flexibility in transporting goods and people using land transportation.
        iv) The infrastructure of land transportation also has a larger impact on the environment, through land use and emissions, than the other forms of transportation.
    b. Water
        i) Water modes of transportation include ships and boats.
        ii) Water means of transportation allow the largest cargo capacity of the transportation modes.
        iii) Some limitations of water transportation are the routes a vehicle must take based on depth and width of passages.

   - iv) The infrastructure necessary to maintain water transportation systems is costly when compared with land transportation.
 - c. Air
   - i) Air modes of transportation include airplanes, jets, and hot air balloons.
   - ii) Air modes of transportation are primarily concerned with the movement of people and smaller amounts of cargo.
   - iii) Air travel allows for more flexibility than land or water means of transportation.
 - d. Space
   - i) Space modes of transportation include rockets, space shuttle, and launch vehicles.
   - ii) Space travel is more costly than the other forms of transportation.
   - iii) A new focus to separate the travel of goods and people in space is reflected in the new NASA launch vehicles.

3. The teacher explains that in order to successfully transport people and goods from one location to another, an intermodal transportation system is necessary.
4. The teacher explains that an intermodal transportation system is a logistically linked system using two or more transport modes that allow goods and people to transfer easily between their origin location and their point of destination.
   - a. Tracking and communication systems are an integral part of coordinating intermodal transportation systems.
     - i) Due to the increase in the amount of goods passing through ports and across borders, new technologies are being investigated to ensure that at all times the contents and originator of containers are identified.
   - b. Infrastructures must sometimes be built to assist in the transfer of goods and people from one means of transportation to anther.
     - i) Ports are designed so that cargo can easily be moved from ocean-going ships onto trucks for delivery to manufacturing plants or stores.
5. Students clarify their understanding of the concepts through questioning.

Extension

1. The teacher passes out ***Lesson Resource 2.2***, "Life Cycle Transportation."
2. The teacher explains what a life cycle diagram represents and asks students to identify transportation vehicles within the life cycle diagram and what means of transportation the vehicle represents.
3. Students identify the various means of transportation on a life cycle diagram.

Evaluation

Student knowledge, skills, and attitudes are assessed using multiple-choice items, brief constructed response items, extended constructed response items, and a rubric for the "Exploration Impacts" activity. The rubrics should be presented in advance of the activities to familiarize students with the expectations and performance criteria. They should also be reviewed during the activities to guide students in the completion of assignments. The teacher may wish to develop a collection of annotated exemplars of student work based on the rubrics. The exemplars will serve as benchmarks for future assessments and may be used to familiarize students with the criteria for assessment.

Enrichment

1. Students could create their own life cycle diagram by researching a technology product and identifying the modes of transportation on the life cycle.
2. Students could identify the economic and political impact for each means of transportation and present their information to the class.

Lesson 2: Lesson Preparation

Teacher Planning

The laboratory-classroom should provide a flexible, resource-rich learning environment that includes areas for lectures and demonstrations, small-group meetings, design processes, and research activities. The teacher adapts the learning environment based on the requirements of the unit or lesson.

Tools/Materials/Equipment

- Computers
- Library resources
- Graphic tools, materials, and equipment

Classroom Safety and Conduct

1. Students use tools and equipment in a safe manner and assume responsibility for their safety, as well as the safety of others.
2. Students demonstrate respect and courtesy for the ideas expressed by others in the class.
3. Students show respect and appreciation for the efforts of others.

Lesson 3: NASA Transportation Cycle

Lesson Snapshot

Overview

Big Idea: NASA employs an intermodal means of transportation in order to successfully complete each mission within the Constellation program.

Teacher's Note: Big ideas should be made explicit to students by writing them on the board and/or reading them aloud.

Purpose of Lesson: This lesson familiarizes students with how NASA incorporates intermodal means of transportation to ensure mission success.

Lesson Duration: Six hours.

Activity Highlights

Engagement: Students theorize and draw a diagram/picture on how the Orion capsule gets to the Moon and back to Earth's surface. Students share diagram/picture and theory.

Exploration: Students refine the diagram/picture based upon information provided by the teacher on NASA assembly and transport (Ares I and Ares V).

Explanation: The teacher explains NASA's intermodal system for getting cargo and crew to the Moon and back to Earth.

Extension: Students record a video based on ***Lesson Resource 3.1***, "NASA Transportation Video."

Evaluation: Student knowledge, skills, and attitudes are assessed using sequencing, brief constructed response items, extended constructed response items, and a rubric for the "NASA Transportation Video" activity. The rubrics should be presented in advance of the activities to familiarize students with the expectations and performance criteria. They should also be reviewed during the activities to guide students in the completion of assignments. The teacher may wish to develop a collection of annotated exemplars of student work based on the rubrics. The exemplars will serve as benchmarks for future assessments and may be used to familiarize students with the criteria for assessment.

Enrichment: Students may target a specific audience for the ***Lesson Resource 3.1*** activity and potentially show the video to that audience (e.g., parents at open house, elementary students, middle school students). Students may research a past NASA mission that was unsuccessful and determine what part of the transportation system did not function as designed and how the problem could be avoided in the future.

Lesson 3: Overview

Lesson Duration
- Six hours.

Standards/Benchmarks
Technology:* Standards for Technological Literacy (STL) *(ITEA, 2000/2002/2007)
- Students will develop an understanding of the core concepts of technology. (ITEA/STL 2)
  - Systems, which are the building blocks of technology, are embedded within larger technological, social, and environmental systems. (2X)
  - The stability of a technological system is influenced by all of the components in the system, especially those in the feedback loop. (2Y)
- Students will develop an understanding of and be able to select and use transportation technologies. (ITEA/STL 18)
  - Intermodalism is the use of different modes of transportation, such as highways, railways, and waterways as part of an interconnected system that can move people and goods easily from one mode to another. (18K)

Mathematics:* Principles and Standards for School Mathematics *(NCTM, 2000)*
- Use visualization, spatial reasoning, and geometric modeling to solve problems. (NCTM, Geometry, Grades 9–12)
  - Draw and construct representations of two- and three-dimensional geometric objects using a variety of tools.
- Recognize and apply mathematics in contexts outside of mathematics. (NCTM, Connections, Grades 9–12)

Science:* Benchmarks for Science Literacy *(AAAS, 1993)**
- Mathematics, Science, and Technology (AAAS, 2B, Grades 9–12)
  - Mathematical modeling aids in technological design by simulating how a proposed system would theoretically behave.
- Issues in Technology (AAAS, 3C, Grades 9–12)
  - Complex systems have layers of controls. Some controls operate particular parts of the system and some control other controls. Even fully automatic systems require human control at some point.
- Uncertainty (AAAS, 9D, Grades 9–12)
  - A physical or mathematical model can be used to estimate the probability of real-world events.
- Systems (AAAS, 11A, Grades 9–12)
  - The successful operation of a designed system usually involves feedback. The feedback of output from some parts of a system to input for other parts can be used to encourage what is going on in a system discourage it, or reduce its discrepancy from some desired value. The stability of a system can be greater when it includes appropriate feedback mechanisms.

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Learning Objectives

Students will learn to accomplish the following:

1. Describe the specific intermodal forms of transportation NASA uses to move goods and people.
2. Describe how one component within the NASA transportation system can impact a NASA mission.
3. Explain how the NASA transportation cycle contributes to NASA achieving the mission.

Student Assessment Tools and/or Methods

1. Sequencing.

Directions: Place the following sequence of events in the correct order by numbering them in the right hand column:

Steps in Transportation Cycle	Sequence of Events
A. The mission crew travels to the Moon's surface using the lunar lander.	**5**
B. The Ares I and Ares V vehicles launch from Kennedy Space Center.	**2**
C. The crawlers transport the launch vehicles to the launch pad at Kennedy Space Center.	**1**
D. The lunar lander propels the crew back into lunar orbit.	**6**
E. Orion returns to Earth's orbit.	**7**
F. The Ares I and Ares V rendezvous.	**3**
G. The Orion capsule and lunar lander travel to the Moon's orbit.	**4**

2. Brief Constructed Response Items
   a. Explain how NASA ensures the stability of the subsystems within the NASQA transportation cycle.
   b. Explain how NASA uses intermodal means of transportation within the Constellation project.

Category	Below Target	At Target	Above Target
Understanding	Response demonstrates an implied, partial, or superficial understanding of the text and/or the question.	Response demonstrates an understanding of the complexities of the text.	Presentation was extremely creative, showing that a good deal of thought went into preparation.
Focus	Response lacks transitional information to show the relationship of the support to the question.	Response addresses the demands of the question.	Response exceeds the demands of the question.
Use of Related Information	Response includes minimal information from the text to clarify or extend meaning.	Response includes some expressed or implied information from the text to clarify or extend meaning.	Response effectively uses expressed or implied information from the text to clarify or extend meaning.

3. Extended Constructed Response Item

Explain how the NASA transportation cycle impacts the overall success of a NASA mission.

Category	Below Target	At Target	Above Target
Context and Argument	Context inappropriate. Argument unsatisfactory.	Context appropriate. Argument satisfactory.	Context appropriate. Argument satisfactory. Clearly stated thesis included.
Evidence	Evidence is largely missing or generalized.	Ample and appropriate evidence provided.	Abundant, relevant specifics (names, events, legislation, court decisions, etc.) provided. Includes obscure, but important, evidence. Thorough chronology.
Analysis	Minimal analysis or fallacious reasoning.	Organizes argument and uses data to support conclusions. Recognizes causation, change, and continuity.	Well-reasoned cause-and-effect arguments. Fully explained conclusions. Refers to views of others.
Historical Accuracy	Many errors.	May have a few errors. Mistakes may slightly hinder argument, but do not detract from the overall accuracy.	Virtually error-free; minor mistakes do not compromise argument.
Thoroughness	Covers question superficially. May not complete all tasks.	Covers entire question, but may be slightly imbalanced.	Covers all areas of question in approximate proportions to their importance.
Presentation	Inconsistent organization. Grammatical errors cloud argument to a major degree.	Uses clear language. Well organized. Contains few grammatical errors.	Uses clear, appropriate, and precise language. Cohesive organization. Very few grammatical errors.

4. NASA Transportation Video Assessment Rubric

Category	Below Target	At Target	Above Target
Video Length	The video is shorter than two minutes and 30 seconds or longer than three minutes and 30 seconds in length.	The video is between two minutes and 30 seconds to three minutes and 30 seconds in length.	The video is exactly three minutes in length.
Content	Some steps of the NASA transportation system are incorrect or missing.	All steps of the NASA transportation system are accurately represented.	All steps of the NASA transportation system are clearly and accurately represented and include additional detail beyond class work/discussions.
Quality	Some information and/or images included are not significant to the content and/or distracts from the content.	All information and images in the video are significant to the content.	All information and images included in the video are significant and are positive contributions to the content.
Originality	Uses other people's ideas (giving them credit), but there is little evidence of original thinking.	Product shows some original thought. Work shows new ideas and insights.	Product shows a large amount of original thought. Ideas are creative and inventive.

Resource Materials

Books, periodicals, pamphlets, and web sites may provide teachers and students with background information and extensions. Inclusion of a resource does not constitute an endorsement, either expressed or implied, by the National Aeronautics and Space Administration.

Print Materials

World Spaceflight News. (2000). *America's Space Shuttle : NASA Countdown Procedures*. Progressive Management.

World Spaceflight News. (2002). *21st Century and Beyond - Future Space Rockets and Breakthrough Propulsion*. Progressive Management.

Audiovisual Materials

The History Channel. (n.d.). *World's Biggest Machines 3, Modern Marvels* [DVD]. United States: A&E Home Video.

Internet Sites

NASA. (2003). *Crawler – Transporter.* Retrieved January 16, 2009, from <http://science.ksc.nasa.gov/facilities/crawler.html>.

NASA. (2000). *Landing, postlanding, and SRB retrievaloperations.* Retrieved January 16, 2009, from <http://science.ksc.nasa.gov/shuttle/technology/sts-newsref/stsover-landing.html>.

Required Knowledge and Skills

Students should have some understanding of the functioning and applications of core technology systems, their common components, basic system design, safety consideration, and simple controls. Students should also have some understanding of how subsystems affect the overall performance of technology systems. They should have some basic graphic and research skills. In the engagement and exploratory phases of instruction, the teacher identifies student misunderstandings and/or misconceptions about the influence of technology on history.

Lesson 3: 5-E Lesson Plan

Engagement

1. The teacher assesses student misconceptions regarding NASA's transportation system to transport goods and people to the Moon.
2. The teacher shows students a picture of the Orion human capsule.
3. The teacher asks the students:
   a. How does this crew vehicle get to the Moon and back?
   b. What means of transportation do you think are necessary to complete a mission to the Moon and back?
4. Students draw a diagram/picture depicting their theory on how the capsule gets to the Moon and back to Earth's surface. On the diagram they will label the various means of transportation such as land, water, air, or space.
5. Students share their diagrams with the class.

Exploration

1. The teacher explains the following:
   a. The launch vehicles are not assembled on the launch pad and, therefore, need to be moved from the assembly location to the launch pad.
   b. The Ares I is used to transport crew members into space, and the Ares V is used to transport large cargo, including the vehicle that lands on the Moon's surface, into space.
2. The teacher asks students to redefine their diagrams based on the new information.
3. The students redefine their diagrams based on the information given by the teacher.

Explanation

1. The teacher explains that NASA employs an intermodal transportation system in order to transport cargo and crew members to the Moon and return the crew back to Earth.
   a. Once the launch vehicle has been assembled, the vehicle must be transported to the launch pad at Kennedy Space Center in Florida.
      i) Large machines called crawlers move the vehicle to the launch pad.
         1. The crawlers "are 131 feet long and 113 feet wide, with a flat upper deck measuring 90 feet square—about the size of a baseball diamond—that serves as the carrying surface. They move on four double-tracked tread belts, similar to those on a military tank. Each contains 57 'shoes' weighing more than a ton apiece. The crawler's surface is kept level at all times by using 16 jacking, equalizing, and leveling hydraulic cylinders.
      ii) Once in place, the vehicle is ready for launch. Upon lift-off the vehicle is lifted out of the Earth's atmosphere and into Earth's orbit.
      iii) Once in Earth's orbit, the Ares I and Ares V will rendezvous and will perform a translunar injection burn, which will push the vehicle into Moon's orbit.
      iv) Once in Moon's orbit, the crew will travel to the Moon's surface using the lunar lander vehicle.
      v) The lunar lander will then propel the crew back to the Moon's orbit to dock with the crew capsule.
      vi) The Orion capsule will return to Earth's orbit and land back on Earth.
      vii) Similar to the shuttle, Kennedy Space Center coordinates the recovery of the crew and crew capsule using various vehicles such as an orbiter tow vehicle and astronaut transporter van.

2. The teacher explains that if one part of the transportation cycle is held up, the entire success of the mission could be at risk.
   a. Checklists are created to be sure that systems are stabilized before the next stage in the transportation cycle.
3. The teacher explains that without the completion of each step in the transportation cycle, NASA would not be capable of successfully completing the mission to land on the Moon and return the crew back to Earth safely.
4. Checklists are used by mission control and the crew to give feedback in order to assure successful decision making.
5. The students clear any misunderstandings using questioning.

Extension

1. The teacher hands out ***Lesson Resource 3.1***, "NASA Transportation Video" worksheet.
2. Students record a video simulating the NASA transportation cycle. The students present their videos to the class.

Evaluation

Student knowledge, skills, and attitudes are assessed using sequencing, brief constructed response items, extended constructed response items, and a rubric for the "NASA Transportation Video" activity. The rubrics should be presented in advance of the activities to familiarize students with the expectations and performance criteria. They should also be reviewed during the activities to guide students in the completion of assignments. The teacher may wish to develop a collection of annotated exemplars of student work based on the rubrics. The exemplars will serve as benchmarks for future assessments and may be used to familiarize students with the criteria for assessment.

Enrichment

1. Students may target a specific audience for the ***Lesson Resource 3.1*** activity and potentially show the video to that audience (e.g., parents at open house, elementary students, middle school students).
2. Students may research a past NASA mission that was unsuccessful and determine what part of the transportation system did not function as designed and how the problem could be avoided in the future.
3. Students create a diagram depicting the NASA transportation cycle. They compare and contrast the new diagram to their diagrams created during the exploration stage.

Lesson 3: Lesson Preparation

Teacher Planning

The laboratory-classroom should provide a flexible, resource-rich learning environment that includes areas for lectures and demonstrations, small-group meetings, design processes, and research activities. The teacher adapts the learning environment based on the requirements of the unit or lesson.

Tools/Materials/Equipment

- Computers
- Library resources
- Graphic tools, materials, and equipment
- Video camera and recording devices
- Camera tripod
- Videotapes for recording

Classroom Safety and Conduct

1. Students use tools and equipment in a safe manner and assume responsibility for their safety as well as the safety of others.
2. Students demonstrate respect and courtesy for the ideas expressed by others in the class.
3. Students show respect and appreciation for the efforts of others.

Lesson 4: Ares I and Ares V: Transporting Cargo and Crew

Lesson Snapshot

Overview

Big Idea: NASA utilizes various testing procedures and methods to ensure the proper operation of the Ares I and Ares V vehicles.

Teacher's Note: Big ideas should be made explicit to students by writing them on the board and/or reading them aloud.

Purpose of Lesson: This lesson familiarizes students with the basic operating system behind the Ares I and Ares V launch vehicles and the testing procedures used by NASA to help ensure the vehicles will operate as designed.

Lesson Duration: Seven hours.

Activity Highlights

Engagement: Students complete a Venn diagram comparing and contrasting the Ares I and Ares V and share it with the class.

Exploration: Students refine the diagram/picture based upon information provided by the teacher on NASA assembly and transport (Ares I and Ares V).

Explanation: The teacher provides information about Ares I and Ares V stages of operation and the reliability and aerodynamic testing that NASA conducts to ensure they operate correctly.

Extension: Students complete Lesson ***Resource 4.1***, a design challenge entitled, "Moving Cargo."

Evaluation: Student knowledge, skills, and attitudes are assessed using identification, brief constructed response items, extended constructed response items, and a rubric for the "Moving Cargo" activity. The rubrics should be presented in advance of the activities to familiarize students with the expectations and performance criteria. They should also be reviewed during the activities to guide students in the completion of assignments. The teacher may wish to develop a collection of annotated exemplars of student work based on the rubrics. The exemplars will serve as benchmarks for future assessments and may be used to familiarize students with the criteria for assessment.

Enrichment: Students may incorporate a cost analysis as part of the design process for ***Lesson Resource 4.1***. Students may conduct various aerodynamic testing, on a scale model, in a wind tunnel and compare results with data from NASA. Students may also look at reliability data for parts of a technology system and calculate the overall reliability of the system.

Lesson 4: Overview

Lesson Duration

- Seven hours.

Standards/Benchmarks

Technology:* Standards for Technological Literacy (STL) *(ITEA, 2000/2002/2007)

- Students will develop an understanding of the core concepts of technology. (ITEA/STL 2)
  - New technologies create new processes. (2CC)
- Students will develop abilities to apply the design process. (ITEA/STL 11)
  - Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed. (11P)
  - Develop and produce a product or system using a design process. (11Q)
  - Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models. (11R)
- Students will develop the abilities to use and maintain technological products and systems. (ITEA/STL 12)
  - Operate systems so that they function in the way they were designed. (12O)

Mathematics:* Principles and Standards for School Mathematics *(NCTM, 2000)*

- Understand numbers, ways of representing numbers, relationships among numbers, and number systems. (NCTM, Number and Operations, Grades 6–8)
  - Develop an understanding of large numbers and recognize and appropriately use exponential, scientific, and calculator notation.
- Use visualization, spatial reasoning, and geometric modeling to solve problems. (NCTM, Geometry, Grades 9–12)
  - Draw and construct representations of two- and three-dimensional geometric objects using a variety of tools.
- Understand measurable attributes of objects and the units, systems, and processes of measurement. (NCTM, Measurement, Grades 9–12)
  - Make decisions about units and scales that are appropriate for problem situations involving measurement.
- Apply appropriate techniques, tools, and formulas to determine measurements. (NCTM, Measurement, Grades 9–12)
  - Analyze precision, accuracy, and approximate error in measurement situations.
- Solve problems that arise in mathematics and in other contexts. (NCTM, Problem Solving, Grades 9–12)
- Apply and adapt a variety of appropriate strategies to solve problems. (NCTM, Problem Solving, Grades 9–12)
- Recognize and apply mathematics in contexts outside of mathematics. (NCTM, Connections, Grades 9–12)

** Standards are listed with the permission of the National Council of Teachers of Mathematics (NCTM). NCTM does not endorse the content or validity of these alignments.*

Science:* Benchmarks for Science Literacy *(AAAS, 1993)**

- Mathematics, Science, and Technology (AAAS, 2B, Grades 9–12)
  - Mathematical modeling aids in technological design by simulating how a proposed system would theoretically behave.
- Issues in Technology (AAAS, 3C, Grades 9–12)
  - In designing a device or process, thought should be given to how it will be manufactured, operated, maintained, replaced, and disposed of and who will sell, operate, and take care of it. The costs associated with these functions may introduce yet more constraints on the design.
  - To reduce the chance of system failure, performance testing is often conducted using analogous systems or just the parts of the systems thought to be least reliable.
- Manipulation and Observation (AAAS 12C, Grades 9–12)
  - Use power tools safely to shape, smooth, and join wood, plastic, and soft metal.
- Communication Skills (AAAS, 12D, Grades 9–12)
  - Make and interpret scale drawings.

*** Material reprinted from* Benchmarks for Science Literacy *(AAAS, 1993) with permission from Project 2061, on behalf of the American Association for the Advancement of Science, Washington, D.C.*

Learning Objectives

Students will learn to:

1. Describe the basic operating principles behind the Ares V in transporting cargo to the lunar surface.
2. Describe the basic operating principles behind the Ares I in transporting crew members to the lunar surface and back to Earth.
3. Describe testing procedures that NASA completes to ensure that the Ares I and Ares V operate successfully.
4. Explain how NASA has developed new transportation processes based on new vehicle designs.
5. Apply the engineering design process to solve a problem.
6. Work safely and accurately with a variety of tools, machines, and materials.
7. Fabricate a prototype or model of a design solution.
8. Evaluate a design by using conceptual, physical, and mathematical models.

Student Assessment Tools and/or Methods

1. Identification.

Directions: Identify the following vehicle specifications as the Ares I or Ares V. Circle the vehicle that matches the description.

Upper stage is powered by J-2X main engine.	Ares I	or	Ares V
Earth departure stage is powered by J-2X main engine and separates from the core stage in midflight.	Ares I	or	Ares V
Carries crew for the mission.	Ares I	or	Ares V
Capable of lifting more than 286,000 pounds.	Ares I	or	Ares V
Not safe for human travel.	Ares I	or	Ares V
Uses a single solid rocket booster during Stage 1.	Ares I	or	Ares V

2. Brief Constructed Response Items
   a. Describe the basic operating principles behind the Ares I vehicle.
   b. Describe the basic operating principles behind the Ares V vehicle.

Category	Below Target	At Target	Above Target
Understanding	Response demonstrates an implied, partial, or superficial understanding of the text and/or the question.	Response demonstrates an understanding of the complexities of the text.	Presentation was extremely creative, showing that a good deal of thought went into preparation.
Focus	Response lacks transitional information to show the relationship of the support to the question.	Response addresses the demands of the question.	Response exceeds the demands of the question.
Use of Related Information	Response includes minimal information from the text to clarify or extend meaning.	Response includes some expressed or implied information from the text to clarify or extend meaning.	Response effectively uses expressed or implied information from the text to clarify or extend meaning.

3. Extended Constructed Response Item
   a. Compare and contrast the Ares I and Ares V vehicle.
   b. Explain how NASA uses testing procedures to ensure mission success.

Category	Below Target	At Target	Above Target
Context and Argument	Context inappropriate. Argument unsatisfactory.	Context appropriate. Argument satisfactory.	Context appropriate. Argument satisfactory. Clearly stated thesis included.
Evidence	Evidence is largely missing or generalized.	Ample and appropriate evidence provided.	Abundant, relevant specifics (names, events, legislation, court decisions, etc.) provided. Includes obscure, but important, evidence. Thorough chronology.
Analysis	Minimal analysis or fallacious reasoning.	Organizes argument and uses data to support conclusions. Recognizes causation, change, and continuity.	Well-reasoned cause-and-effect arguments. Fully explained conclusions. Refers to views of others.
Historical Accuracy	Many errors.	May have a few errors. Mistakes may slightly hinder argument, but do not detract from the overall accuracy.	Virtually error-free; minor mistakes do not compromise argument.
Thoroughness	Covers question superficially. May not complete all tasks.	Covers entire question, but may be slightly imbalanced.	Covers all areas of question in approximate proportions to their importance.
Presentation	Inconsistent organization. Grammatical errors cloud argument to a major degree.	Uses clear language. Well organized. Contains few grammatical errors.	Uses clear, appropriate, and precise language. Cohesive organization. Very few grammatical errors.

4. Moving Cargo Evaluation Rubric

Category	Below Target	At Target	Above Target
Defining the Problem	Rephrases the problem with limited clarity.	Rephrases the problem clearly.	Rephrases the problem clearly and precisely.
Brainstorming	Contributes few or implausible ideas.	Contributes a plausible idea.	Contributes multiple plausible ideas.
Researching and Generating Ideas	Contributes ideas, but without documented research. Produces incomplete sketches. Does not present a concept.	Contributes one plausible idea based on documented research. Produces marginally accurate pictorial and orthographic sketches of design concepts.	Contributes multiple plausible ideas based on documented research. Produces accurate pictorial and orthographic sketches of design concepts.
Identifying Criteria and Specifying Constraints	Does not restate the criteria clearly and fails to identify constraints.	Restates the criteria clearly and identifies at least three constraints.	Restates the criteria clearly and precisely identifies at least five constraints.
Exploring Possibilities	Inadequately analyzes the pluses and minuses of a variety of possible solutions.	Satisfactorily analyzes the pluses and minuses of a variety of possible solutions.	Thoroughly analyzes the pluses and minuses of a variety of possible solutions.
Selecting an Approach	Selection of solution is not based on consideration of criteria and constraints.	Selects a promising solution based on criteria and constraints.	Selects a promising solution baed on a thorough analysis of criteria and constraints.
Developing a Design Proposal	Design proposal is inadequate, lacking pertinent information.	Design proposal is adequate, containing all pertinent elements.	Design proposal is accurate and comprehensive.
Making a Model or Prototype	Prototype meets the task criteria to a limited event.	Prototype meets the task criteria.	Prototype meets the task criteria in insightful ways.
Testing and Evaluating the Design Using Specifications	Testing and evaluation processes are inadequate.	Testing and evaluation processes are adequate for refining the problem solution.	Testing processes are innovative.
Refining the Design	Refinement based on testing and evaluation is not evident.	Refinements made, based on testing and evaluation results.	Significant improvement in the design is made, based on prototype testing and evaluation.
Creating or Making the Design	Finished solution (product) fails to meet specifications.	Finished solution (product) meets specifications.	Finished solution (product) exceeds specifications.
Communicating Processes and Results	Solution presented with limited accuracy. Limited supporting evidence on how the solution meets the task criteria.	Solution presented accurately. Some supporting evidence on how the solution meets the task criteria.	Solution presented concisely with clarity and accuracy. Extensive supporting evidence on how the solution meets the task criteria.

Resource Materials

Books, periodicals, pamphlets, and web sites may provide teachers and students with background information and extensions. Inclusion of a resource does not constitute an endorsement, either expressed or implied, by the National Aeronautics and Space Administration.

Print Materials

Anton, P.S. (2004). *Wind tunnel and propulsion test facilities: An assessment of NASA's capabilities to serve National needs.* RAND Corporation.

O'Connor, P.D.T. (2002). *Practical reliability engineering*. John Wiley & Sons.

Audiovisual Materials

NASA. (n.d.) Video gallery. Retrieved January 16, 2009, from <http://www.nasa.gov/multimedia/videogallery/>.

Internet Sites

NASA. (2008). Constellation. Retrieved January 16, 2009, from <http://www.nasa.gov/mission_pages/constellation/ares/aresI.html>.

NASA. (2008). Constellation. Retrieved January 16, 2009, from <http://www.nasa.gov/mission_pages/constellation/ares/rocket_science.html>.

Required Knowledge and Skills

Students should have some understanding of the functioning and applications of core technology systems, their common components, basic system design, safety consideration, and simple controls. Students should also have some understanding of how subsystems affect the overall performance of technology systems. They should have some basic graphic and research skills. In the engagement and exploratory phases of instruction, the teacher identifies student misunderstandings and/or misconceptions about the influence of technology on history.

Lesson 4: 5-E Lesson Plan

Engagement

1. The teacher assesses any misconceptions regarding the purpose and operation of the Ares I and Ares V vehicles.
2. The teacher shows students pictures of both the Ares I and Ares V vehicles.
3. The teacher asks students, in groups of two, to complete a Venn diagram comparing and contrasting the two vehicles.
4. Students, with a partner, compare and contrast pictures of the Ares I and Ares V vehicles using a Venn diagram.
5. Students share their Venn diagrams with the class.

Exploration

1. The teacher explains that in order to ensure that the vehicles will work and therefore complete the mission, various tests must be conducted.
2. The teacher gives students pictures of various appliances and asks them to brainstorm a list of tests that could be completed for each appliance to be sure it will operate correctly.
3. Students brainstorm a list of tests that could be used to ensure that the appliance will operate correctly.

Explanation

1. The teacher explains that the Ares I and Ares V are the new launch vehicles being developed by the NASA Constellation project to transport crew members and cargo to the Moon and beyond. New technologies allow NASA to design vehicles that may be capable of transporting people and goods to planets beyond the Moon.
2. The teacher explains:
    a. Ares V
        i) Operation
            1. The Ares V, 27 feet in diameter, is a heavy lift launch vehicle. It will use five RS-68 liquid oxygen/liquid hydrogen engines mounted below a larger version of the space shuttle's external tank, and two five-segment solid propellant rocket boosters for the first stage. The upper stage will use a J-2X engine. The Ares V can lift more than 286,000 pounds to low Earth orbit and stands approximately 360 feet tall.
            2. This versatile system will be used to carry cargo and the components needed into orbit to go to the Moon and later to Mars. At this time the Ares V is not rated to be safe for human travel. The Ares V is essential to the success of the mission to land on the Moon. Without the lunar lander, the crew would not have the capability of landing on the Moon. In addition, the crew would not have the equipment necessary to construct a lunar outpost on the Moon.
            3. Ares V First Stage: The first stage of the Ares V vehicle relies on two, five-segment reusable solid rocket boosters for lift-off.
            4. Ares V Core Stage/Core Stage Engine: The twin solid rocket boosters of the first stage flank a single, liquid-fueled central booster element. Derived from the space shuttle external tank, the central booster tank delivers liquid oxygen/liquid hydrogen fuel to five RS-68 rocket engines.

5. Ares V Earth Departure Stage/Engine: The Earth Departure Stage is propelled by a J-2X main engine fueled with liquid oxygen and liquid hydrogen. The Earth Departure Stage separates from the core stage and its J-2X engine ignites mid-flight. The Earth Departure Stage is then jettisoned, leaving the crew module and Lunar Surface Access Module mated.
6. Lunar Surface Access: Once the four astronauts arrive in lunar orbit, they transfer to the lunar module and descend to the Moon's surface. The crew module remains in lunar orbit until the astronauts depart from the Moon in the lunar vessel, rendezvous with the crew module in orbit, and return to Earth.

g. Ares I
   i) Operation
      1. The Ares I, 18 feet in diameter, is the launch vehicle for the two-to-six member crew. It uses a single five-segment solid rocket booster for the first stage. A liquid oxygen/liquid hydrogen J-2X engine will power the crew exploration vehicle's second stage. The Ares I can lift more than 55,000 pounds to low Earth orbit.
      2. The Ares I is capable of completing unmanned missions in addition to manned. Unmanned missions will allow scientists to further investigate the lunar surface before exposing humans to possible health hazards.
      3. Ares I First Stage: The Ares I first stage is a single, five-segment reusable solid rocket booster derived from the Space Shuttle Program's reusable solid rocket motor, which burns a specially formulated and shaped solid propellant.
      4. Ares I Upper Stage/Upper Stage Engine: The Ares I second, or upper, stage is propelled by a J-2X main engine fueled with liquid oxygen and liquid hydrogen.

3. The teacher explains that NASA conducts tests and research to ensure that the vehicles will perform correctly during operation. Testing procedures that are used to ensure proper operation of the systems include:
   a. Reliability testing for individual parts
      i) If the part has been used in the past for the exact same application, additional testing is not necessary. If the same part is going to be used for an application that varies in the slightest to the original application, then additional testing is necessary.
   b. Aerodynamic Testing
      i) Center of gravity of the vehicle versus the center of pressure
      ii) Axial forces
      iii) Sectional loading: tests with cross sections along the length of the vehicle
      iv) Aeroelastic effects: tests the amount or existence of wake behind the airflow around the vehicle
      v) Heating: tests the amount of heat generated based on speed of vehicle
      vi) Flow patterns: tests the flow of air over the shape of the vehicle
      vii) Wind tunnels
      viii) Computer simulated
4. The teacher asks students to look back at their testing brainstorming lists from the exploration stage and check off any tests that are also used by NASA for the launch vehicles.
5. Students indicate on their brainstorm lists similar tests that were discussed by the teacher.
6. Students clear any misunderstandings through questioning.

Extension

Students complete ***Lesson Resource 4.1***, a design challenge entitled, "Moving Cargo."

Evaluation

Student knowledge, skills, and attitudes are assessed using identification, brief constructed response items, extended constructed response items, and a rubric for the "Moving Cargo" activity. The rubrics should be presented in advance of the activities to familiarize students with the expectations and performance criteria. They should also be reviewed during the activities to guide students in the completion of assignments. The teacher may wish to develop a collection of annotated exemplars of student work based on the rubrics. The exemplars will serve as benchmarks for future assessments and may be used to familiarize students with the criteria for assessment.

Enrichment

1. Students may incorporate a cost analysis as part of the design process for ***Lesson Resource 4.1***. If materials are too expensive, students may be required to do a redesign.
2. Students may conduct various aerodynamic testing, on a scale model, in a wind tunnel and compare results with data from NASA.
3. Students may look at reliability data for parts of a technology system and calculate the overall reliability of the system.

Lesson 4: Lesson Preparation

Teacher Planning

The laboratory-classroom should provide a flexible, resource-rich learning environment that includes areas for lectures and demonstrations, small-group meetings, design processes, and research activities. The teacher adapts the learning environment based on the requirements of the unit or lesson.

Tools/Materials/Equipment

- Computers
- Library resources
- Graphic tools, materials, and equipment
- Fabrication tools and equipment
- Testing apparatus

Classroom Safety and Conduct

1. Students use tools and equipment in a safe manner and assume responsibility for their safety as well as the safety of others.
2. Students demonstrate respect and courtesy for the ideas expressed by others in the class.
3. Students show respect and appreciation for the efforts of others.

Lesson 5: Decision Making and Management

Lesson Snapshot

Overview

Big Idea: By managing operations and decision making, using a board and panel methodology and operation manuals, NASA can organize and control each subsystem, including transportation, to ensure that each subsystem operates in the way that it was designed.

Teacher's Note: Big ideas should be made explicit to students by writing them on the board and/or reading them aloud.

Purpose of Lesson: This lesson familiarizes students with NASA's model for decision making to manage the proper operation of systems.

Lesson Duration: Seven hours.

Activity Highlights

Engagement: : Students speculate about:

- How NASA coordinates various means of transportation.
- Whether one person or a group of people make the decisions.
- Who makes the decisions.

Exploration: Students create a brainstorm list of ways NASA might plan, organize, and control the Constellation program and share their lists with the class.

Explanation: The teacher provides information about NASA operations manuals and the board and panel decision-making process.

Extension: Students complete ***Lesson Resource 5.1***, a challenge problem entitled, "Integrating Transportation Systems."

Evaluation: Student knowledge, skills, and attitudes are assessed using brief constructed response items, extended constructed response items, and a rubric for the "Integrating Transportation Systems" activity. The rubrics should be presented in advance of the activities to familiarize students with the expectations and performance criteria. They should also be reviewed during the activities to guide students in the completion of assignments. The teacher may wish to develop a collection of annotated exemplars of student work based on the rubrics. The exemplars will serve as benchmarks for future assessments and may be used to familiarize students with the criteria for assessment.

Enrichment: Students may propose a change in school policy and complete steps included in the NASA decision-making process to present their information to the Student Government Association. Students may also create an operation manual, including functional flow block diagrams for a technology system.

Lesson 5: Overview

Lesson Duration

- Seven hours.

Standards/Benchmarks

Technology: **Standards for Technological Literacy (STL)** ***(ITEA, 2000/2002/2007)***

- Students will develop an understanding of the core concepts of technology. (ITEA/STL 2)
  - Management is the process of planning, organizing, and controlling work. (2EE)
- Students will develop abilities to apply the design process. (ITEA/STL 11)
  - Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed. (11P)
  - Develop and produce a product or system using a design process. (11Q)
  - Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models. (11R)
- Students will develop the abilities to use and maintain technological products and systems. (ITEA/STL 12)
  - Operate systems so that they function in the way they were designed. (12O)

Mathematics: **Principles and Standards for School Mathematics** ***(NCTM, 2000)******

- Understand numbers, ways of representing numbers, relationships among numbers, and number systems. (NCTM, Number and Operations, Grades 6–8)
  - Develop an understanding of large numbers and recognize and appropriately use exponential, scientific, and calculator notation.
- Use visualization, spatial reasoning, and geometric modeling to solve problems. (NCTM, Geometry, Grades 9–12)
  - Draw and construct representations of two- and three-dimensional geometric objects using a variety of tools.
- Understand measurable attributes of objects and the units, systems, and processes of measurement. (NCTM, Measurement, Grades 9–12)
  - Make decisions about units and scales that are appropriate for problem situations involving measurement.
- Apply appropriate techniques, tools, and formulas to determine measurements. (NCTM, Measurement, Grades 9–12)
  - Analyze precision, accuracy, and approximate error in measurement situations.
- Apply and adapt a variety of appropriate strategies to solve problems. (NCTM, Problem Solving, Grades 9–12)
  - Recognize and apply mathematics in contexts outside of mathematics. (NCTM, Connections, Grades 9–12)

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Science: **Benchmarks for Science Literacy** ***(AAAS, 1993)*******

- Mathematics, Science, and Technology (AAAS, 2B, Grades 9–12)
  - Mathematical modeling aids in technological design by simulating how a proposed system would theoretically behave.
- Issues in Technology (AAAS, 3C, Grades 9–12)
  - In designing a device or process, thought should be given to how it will be manufactured, operated, maintained, replaced, and disposed of and who will sell, operate, and take care of it. The costs associated with these functions may introduce yet more constraints on the design.
  - To reduce the chance of system failure, performance testing is often conducted using analogous systems, or just the parts of the systems thought to be least reliable.
- Uncertainty (AAAS, 9D, Grades 9–12)
  - A physical or mathematical model can be used to estimate the probability of real-world events.
- Systems (AAAS, 11A, Grades 9–12)
  - The successful operation of a designed system usually involves feedback. The feedback of output from some parts of a system to input for other parts can be used to encourage what is going on in a system, discourage it, or reduce its discrepancy from some desired value. The stability of a system can be greater when it includes appropriate feedback mechanisms.
- Manipulation and Observation (AAAS 12C, Grades 9–12)
  - Use power tools safely to shape, smooth, and join wood, plastic, and soft metal.
- Communication Skills (AAAS, 12D, Grades 9–12)
  - Make and interpret scale drawings.

*** Material reprinted from* Benchmarks for Science Literacy *(AAAS, 1993) with permission from Project 2061, on behalf of the American Association for the Advancement of Science, Washington, D.C.*

Learning Objectives

Students will learn to:

1. Explain that the management of transportation systems includes the process of planning, organizing, and controlling the transportation cycle.
2. Apply the engineering design process to solve a problem.
3. Work safely and accurately with a variety of tools, machines, and materials.
4. Apply systems-thinking principles to the engineering design process.
5. Identify criteria and constraints and determine how these will affect the design process.
6. Make two-dimensional and three-dimensional representations of a design solution.
7. Fabricate a prototype or model of a design solution.
8. Evaluate a design by using conceptual, physical, and mathematical models.

Student Assessment Tools and/or Methods

1. Brief Constructed Response Items
   a. Explain the documentation required by NASA to ensure mission success.
   b. Explain how NASA utilizes a board and panel process for decision making.

Category	Below Target	At Target	Above Target
Understanding	Response demonstrates an implied, partial, or superficial understanding of the text and/or the question.	Response demonstrates an understanding of the complexities of the text.	Presentation was extremely creative, showing that a good deal of thought went into preparation.
Focus	Response lacks transitional information to show the relationship of the support to the question.	Response addresses the demands of the question.	Response exceeds the demands of the question.
Use of Related Information	Response includes minimal information from the text to clarify or extend meaning.	Response includes some expressed or implied information from the text to clarify or extend meaning.	Response effectively uses expressed or implied information from the text to clarify or extend meaning.

2. Extended Constructed Response Item

Explain how NASA manages the Constellation project by organizing and controlling work.

Category	Below Target	At Target	Above Target
Context and Argument	Context inappropriate. Argument unsatisfactory.	Context appropriate. Argument satisfactory.	Context appropriate. Argument satisfactory. Clearly stated thesis included.
Evidence	Evidence is largely missing or generalized.	Ample and appropriate evidence provided.	Abundant, relevant specifics (names, events, legislation, court decisions, etc.) provided. Includes obscure, but important, evidence. Thorough chronology.
Analysis	Minimal analysis or fallacious reasoning.	Organizes argument and uses data to support conclusions. Recognizes causation, change, and continuity.	Well-reasoned cause-and-effect arguments. Fully explained conclusions. Refers to views of others.
Historical Accuracy	Many errors.	May have a few errors. Mistakes may slightly hinder argument, but do not detract from the overall accuracy.	Virtually error-free; minor mistakes do not compromise argument.
Thoroughness	Covers question superficially. May not complete all tasks.	Covers entire question, but may be slightly imbalanced.	Covers all areas of question in approximate proportions to their importance.
Presentation	Inconsistent organization. Grammatical errors cloud argument to a major degree.	Uses clear language. Well organized. Contains few grammatical errors.	Uses clear, appropriate, and precise language. Cohesive organization. Very few grammatical errors.

3. Integrating Transportation Systems Evaluation Rubric

Category	Below Target	At Target	Above Target
Defining the Problem	Rephrases the problem with limited clarity.	Rephrases the problem clearly.	Rephrases the problem clearly and precisely.
Brainstorming	Contributes few or implausible ideas.	Contributes a plausible idea.	Contributes multiple plausible ideas.
Researching and Generating Ideas	Contributes ideas, but without documented research. Produces incomplete sketches. Does not present a concept.	Contributes one plausible idea based on documented research. Produces marginally accurate pictorial and orthographic sketches of design concepts.	Contributes multiple plausible ideas based on documented research. Produces accurate pictorial and orthographic sketches of design concepts.
Identifying Criteria and Specifying Constraints	Does not restate the criteria clearly and fails to identify constraints.	Restates the criteria clearly and identifies at least three constraints.	Restates the criteria clearly and precisely identifies at least five constraints.
Exploring Possibilities	Inadequately analyzes the pluses and minuses of a variety of possible solutions.	Satisfactorily analyzes the pluses and minuses of a variety of possible solutions.	Thoroughly analyzes the pluses and minuses of a variety of possible solutions.
Selecting an Approach	Selection of solution is not based on consideration of criteria and constraints.	Selects a promising solution based on criteria and constraints.	Selects a promising solution based on a thorough analysis of criteria and constraints.
Developing a Design Proposal	Design proposal is inadequate, lacking pertinent information.	Design proposal is adequate, containing all pertinent elements.	Design proposal is accurate and comprehensive.
Making a Model or Prototype	Prototype meets the task criteria to a limited event.	Prototype meets the task criteria.	Prototype meets the task criteria in insightful ways.
Testing and Evaluating the Design Using Specifications	Testing and evaluation processes are inadequate.	Testing and evaluation processes are adequate for refining the problem solution.	Testing processes are innovative.
Refining the Design	Refinement based on testing and evaluation is not evident.	Refinements made, based on testing and evaluation results.	Significant improvement in the design is made, based on prototype testing and evaluation.
Creating or Making the Design	Finished solution (product) fails to meet specifications.	Finished solution (product) meets specifications.	Finished solution (product) exceeds specifications.
Communicating Processes and Results	Solution presented with limited accuracy. Limited supporting evidence on how the solution meets the task criteria.	Solution presented accurately. Some supporting evidence on how the solution meets the task criteria.	Solution presented concisely with clarity and accuracy. Extensive supporting evidence on how the solution meets the task criteria.

Resource Materials

Books, periodicals, pamphlets, and web sites may provide teachers and students with background information and extensions. Inclusion of a resource does not constitute an endorsement, either expressed or implied, by the National Aeronautics and Space Administration.

Print Materials

Elliott, S.D. & Dailey, D.J. (1995). *Wireless communications for intelligent transportation systems*. Artech House Publishers.

Bonacci, E.C. (2003). *Integrated transportation*. National Defense Transportation Association.

Audiovisual Materials

NASA. (2008). *Project based mission assurance knowledge management system*. Retrieved January 16, 2009, from <http://pbma.nasa.gov/framework_content_cid_46>.

Internet Sites

Ontario Ministry of Transportation. (2008). *Moving Forward with Intelligence - Intelligent Transportation Systems.* Retrieved January 16, 2009, from <http://www.mto.gov.on.ca/english/engineering/its/strategy3.htm>.

NASA. (2008). *Constellation*. Retrieved January 16, 2009, from <http://www.nasa.gov/mission_pages/constellation/news/ESAS_report.html>.

NASA. (n.d.). *Virtual skies: Communication you decide*. Retrieved January 16, 2009, from <http://virtualskies.arc.nasa.gov/teachers/comYDkey.html>.

Required Knowledge and Skills

Students should have some understanding of the functioning and applications of core technology systems, their common components, basic system design, safety consideration, and simple controls. Students should also have some understanding of how subsystems affect the overall performance of technology systems. They should have some basic graphic and research skills. In the engagement and exploratory phases of instruction, the teacher identifies student misunderstandings and/or misconceptions about the influence of technology on history.

Lesson 5: 5-E Lesson Plan

Engagement

1. The teacher assesses any student misconceptions regarding management and decision making within systems at NASA.
2. The teacher asks students the following questions:
    a. How does NASA coordinate their various means of transportation?
    b. Does one person or a group of people make the decisions?
    c. Who are the people who make the decisions to coordinate NASA's transportation systems? Experts? Administrators? Engineers?
3. The student, with a partner, discusses responses to the teacher's questions.
4. The teacher explains that NASA uses a board and panel process for decision making, where groups of people help make decisions regarding the operation of various systems, including transportation.

Exploration

1. The teacher explains that technological systems are made up of subsystems that must work together for the overall system to function correctly.
2. The teacher explains that management of technological systems includes planning, organizing, and controlling subsystems.
3. Students brainstorm a list of ways NASA might plan, organize, and control the Constellation program.
4. Students share lists with the class.

Explanation

1. The teacher explains that in order to successfully manage operations at NASA, a clear operations manual based on requirements for each subsystem is needed. The documentation required to ensure success includes:
    a. A statement of needs, goals, and objectives for the project.
    b. An operational concept document that explains how the overall project will function.
    c. A functional flow block diagram that includes detail on what subsystems are needed.
    d. The overall Constellation architecture requirements (the actual vehicles needed) are decided from the functional flow block diagram.
    e. Based on the architecture requirements, each subsystem project is decided upon.
    f. Each subsystem requires a separate operational concept document, a functional flow block diagram, and set of system requirements.
2. The teacher explains that once the system requirements are in place, NASA employs a board and panel decision-making process to ensure that checks and balances between offices are in place to control the decision-making process, which is sometimes needed to change system requirements throughout the project.
    a. In order to change any requirement to the design and operation of the program, NASA uses a board/panel structure for making decisions that affect the baseline, as well as for making technical implementation decisions at a program level.
        i) Example of the decisions that affect the baseline:
            1. Anything that requires a change to a program-approved document.
        ii) Examples of a technical implementation decision:
            1. Whether to approve a design modification requiring additional funding.

2. Selecting which launch pad the program will use and develop at Kennedy Space Center.

b. If someone wants to propose a change, either affecting the baseline or a technical decision, they must:
   i) Collect data to support their case by interviewing and gathering information from technical experts.
   ii) Once they have collected their information, they identify whether a decision needs to be made or not.
   iii) If a decision is needed, the person presents their information to the decision maker, who decides if he/she has enough information.
   iv) If the decision maker decides to go ahead with the change and has the authority, the change is implemented.
   v) If at any point the decision maker decides he/she needs more information, they request that the original person goes back and collects the necessary information.

3. The teacher shows the students the "NASA Decision Process Model" ***(Lesson Resource 5.2***).
4. The teacher explains that through managing operations and decision making, NASA can organize and control each subsystem, including transportation, to ensure that the subsystem operates in the way that it was designed.
5. Students clarify any misunderstandings through questioning.

Extension

Students complete ***Lesson Resource 5.1***, a design challenge entitled, "Integrating Transportation Systems."

Evaluation

Student knowledge, skills, and attitudes are assessed using brief constructed response items, extended constructed response items, and a rubric for the "Integrating Transportation Systems" activity. The rubrics should be presented in advance of the activities to familiarize students with the expectations and performance criteria. They should also be reviewed during the activities to guide students in the completion of assignments. The teacher may wish to develop a collection of annotated exemplars of student work based on the rubrics. The exemplars will serve as benchmarks for future assessments and may be used to familiarize students with the criteria for assessment.

Enrichment

1. Students may propose a change in school policy and complete steps included in the NASA decision-making process to present their information to the Student Government Association. Students should document their process.
2. Students may create an operation manual, including functional flow block diagrams, for a technology system.

Lesson 5: Lesson Preparation

Teacher Planning

The laboratory-classroom should provide a flexible, resource-rich learning environment that includes areas for lectures and demonstrations, small-group meetings, design processes, and research activities. The teacher adapts the learning environment based on the requirements of the unit or lesson.

Tools/Materials/Equipment

- Computers
- Library resources
- Graphic tools, materials, and equipment
- Fabrication tools and equipment
- Testing apparatus

Classroom Safety and Conduct

1. Students use tools and equipment in a safe manner and assume responsibility for their safety, as well as the safety of others.
2. Students demonstrate respect and courtesy for the ideas expressed by others in the class.
3. Students show respect and appreciation for the efforts of others.

References

Books, periodicals, pamphlets, and web sites may provide teachers and students with background information and extensions. Inclusion of a resource does not constitute an endorsement, either expressed or implied, by the National Aeronautics and Space Administration.

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Appendices
Resource Documents

Exploration Impacts

Big Idea: Space exploration employs an integrated intermodal system of transportation to move people and equipment on Earth and in space.

Procedure:

1. Choose an explorer from the following list:

Christopher Columbus	Ponce DeLeon
Ferdinand Magellan	Alan Shepard
Marco Polo	Neil Armstrong
Hernando de Soto	Jacques-Yves Cousteau
John Glenn	David Livingstone

2. Using the Internet and other resources, research your topic and create a one-page handout that contains the following information:
   a. The human need the explorer was trying to solve through exploration.
   b. Economic impacts that contributed to, or negatively impacted, the success of the exploration.
   c. Cultural impacts that contributed to, or negatively impacted, the success of the exploration.
   d. Examples of how the explorer used creative thinking during exploration of the new land.

Your one-page sheet must be typed and in the following format:

Explorer Name

Your Name, Period, Date

Human Need solved through exploration:

By exploring ______________________, __________________ solved a need for

_______________________.

Cultural Influences which positively or negatively contributed to exploration:

Economic Influences which positively or negatively contributed to exploration:

Examples of Creative Thinking used during Exploration:

Resources:

Lesson 2: Multiple Choice

Directions: Circle the correct answer for each question.

1. The four means of intermodal transportation include water, ________, air, and space.
   a. sea
   b. land
   c. Earth's orbit
   d. railway
2. Intermodalism is the use of different modes of transportation to move ________________ easily from one mode to another.
   a. cargo and animals
   b. natural resources
   c. people and goods
   d. luggage and mail
3. Transportation systems impact the operation of which of the following technologies?
   a. manufacturing
   b. construction
   c. communication
   d. all of the above
4. Which of the following is not a type of land transportation system?
   a. railway
   b. automobile
   c. aircraft carrier
   d. pipeline
5. Which of the following means of transportation allow for the largest cargo capability?
   a. air
   b. water
   c. land
   d. space

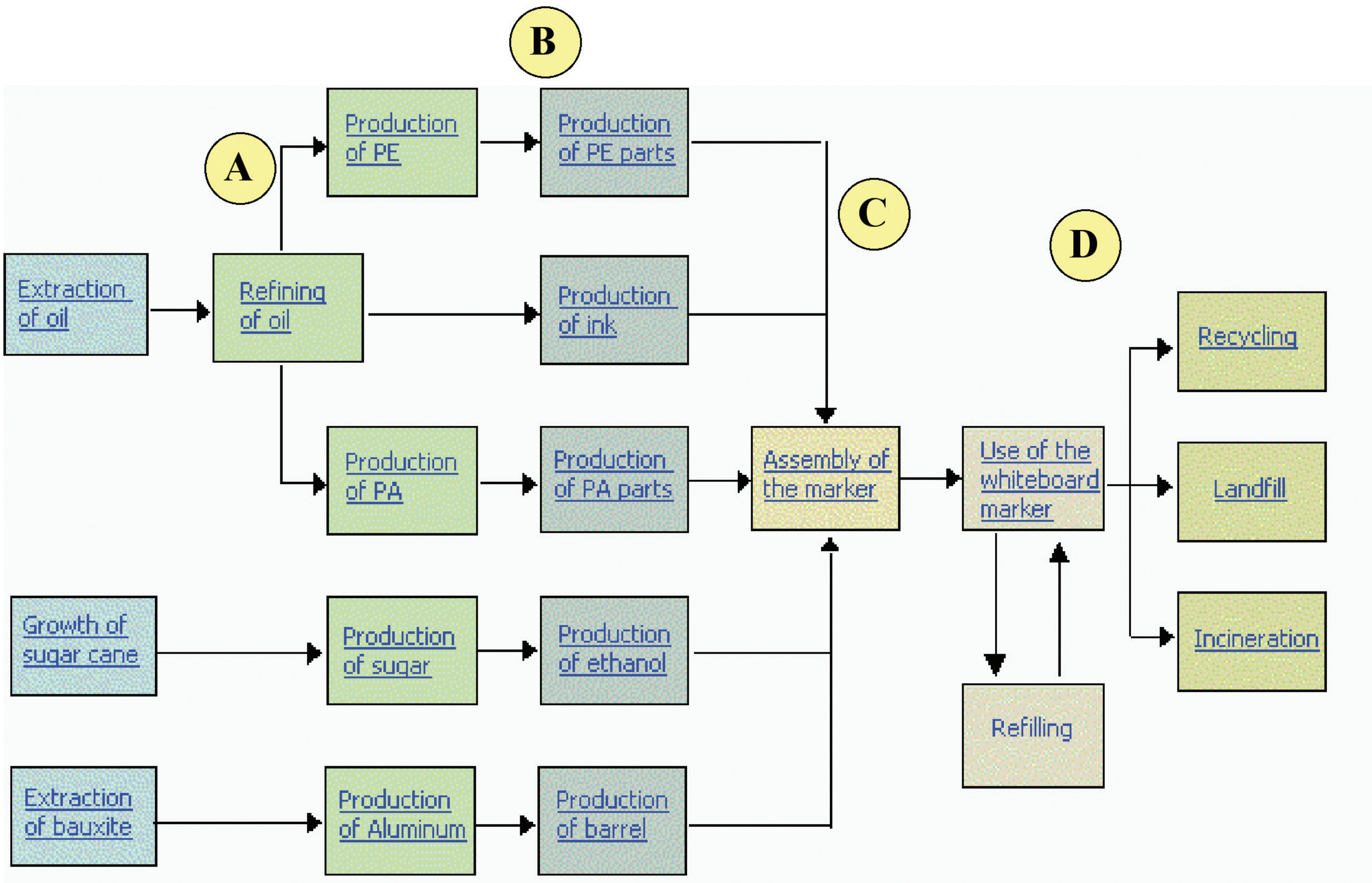
Lesson 2: Multiple Choice Answer Key

1. The four means of intermodal transportation include water, _______, air, and space.
   a. sea
   b. land
   c. Earth's orbit
   d. railway
2. Intermodalism is the use of different modes of transportation to move _______________ easily from one mode to another.
   a. cargo and animals
   b. natural resources
   c. people and goods
   d. luggage and mail
3. Transportation systems impact the operation of which of the following technologies?
   a. manufacturing
   b. construction
   c. communication
   d. all of the above
4. Which of the following is not a type of land transportation system?
   a. railway
   b. automobile
   c. aircraft carrier
   d. pipeline
5. Which of the following means of transportation allow for the largest cargo capability?
   a. air
   b. water
   c. land
   d. space

Life Cycle Transportation

The life cycle of a product is everything that is related to the product in all processes, from raw material extraction to disposal. All products pass through various stages throughout their life cycle. Life cycle stages include Raw Material Extraction, Material Production, Production of Parts, Assembly, Use, and Disposal/ Recycling (Nielsen, 2001).

Various means of transportation are required to move materials, parts, and products within the life cycle. The following life cycle diagram represents the important stages in the whiteboard markers life cycle. At the points designated on the diagram, list the type of vehicle that would be necessary and what means of transportation the vehicle falls under. An example is included.



(Nielsen, 2001)

A: A truck moves the extracted oil to a refinement plant: Land
B:
C:
D:

NASA Transportation Video

Challenge Problem

In a group of three, you must design and create a three-minute video that simulates the NASA transportation cycle.

Rules

1. Your video can be no shorter than 2 minutes and 30 seconds, and no longer than 3 minutes and 30 seconds.
2. Your simulation must include the following:
   a. Launch vehicle being moved to launch pad
   b. Ares I and Ares V: Flight in Earth's atmosphere
   c. Ares I and Ares V: Flight in Earth's orbit
   d. Rendezvous in Earth's orbit
   e. Flight to Moon's orbit
   f. Flight in Moon's orbit
   g. Landing on lunar surface
   h. Return to Moon's orbit
   i. Orion trip back to Earth through atmosphere
   j. Retrieval of crew and parts
3. The content of your video must be school appropriate.
4. Any special effects must be approved by the teacher prior to taping.
5. You will have four class periods (two for design work, two for taping) to complete your video.

Resources

People:	Teams of three students.
Information:	Facts and knowledge the individuals possess or obtain and instruction from the teacher.
Tools and Machines:	Students will use appropriate tools and equipment available in the technology laboratory.
Materials:	Any appropriate material in the technology laboratory. Any materials brought from home that are not judged by the teacher to be inappropriate or unsafe.
Time:	Determined by the teacher.
Energy:	Human muscle power.
Capital:	Provided by the school.
Evaluation:	See rubric.

Moving Cargo

Challenge Problem

With a partner, you must design and construct a transportation vehicle capable of safely carrying a container that is 4″ × 4″ × 4″ and weighs two pounds in the shortest amount of time at a distance of three feet.

Rules

1. You and your partner will be assigned a medium for your transportation vehicle: land, sea, or air.
2. Your transportation vehicle must be self propelled without human interaction when in motion.
3. Your transportation vehicle must be capable of transporting the cargo for a total distance of three feet in a straight line.
4. The cargo container may not be permanently attached to the vehicle, but must be secure at all times throughout travel.
5. The cargo container will contain a fragile item that can not be harmed during travel.
6. Your vehicle may not exceed the dimensions of 12″ long × 8″ wide × 8″ high.
7. You may not use any combustible material for your vehicle.
8. You may include a switch to turn a motor on or off.

Resources

People:	Teams of two students.
Information:	Facts and knowledge the individuals possess or obtain and instruction from the teacher.
Tools and Machines:	Students use appropriate tools and equipment available in the technology laboratory.
Materials:	Any appropriate material in the technology laboratory. Any materials brought from home that are not judged by the teacher to be inappropriate or unsafe.
Time:	Determined by the teacher.
Energy:	Human muscle power.
Capital:	Provided by the school.
Evaluation:	See rubric.

Moving Cargo
Teacher Notes (Page 1 of 2)

Objectives
Students will demonstrate knowledge of the engineering design process.

Students will demonstrate the ability to:
- Apply the engineering design process to solve a problem.
- Identify criteria and constraints and determine how these will affect the design process.
- Make two-dimensional and three-dimensional representations of a design solution.
- Fabricate a prototype or model of a design solution.
- Evaluate a design by using conceptual, physical, and mathematical models.
- Evaluate a prototype in terms of design requirements and constraints.
- Organize and present data effectively.
- Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.
- Work safely and accurately with a variety of tools, machines, and materials.

Advanced Preparations
1. Gather materials for vehicles.
   Suggested supplies include:
   - Gears
   - Pulleys
   - Toy motors
   - Dowel rods for axles
   - Wheels
   - Styrofoam
   - Propellers
   - String
   - Balsa wood
2. Construct cargo container that students will be transporting.
3. Obtain a fragile item (an uncooked egg could work nicely) to place into the cargo container.
4. Obtain an aquarium for groups who are building water vehicles.
5. Hang two sets of wire from the ceiling for groups who are building air vehicles to help guide and power the vehicles.
6. Be sure you have an equal number of groups building land, sea, and air vehicles.

Organization of Students
Students will work in groups of two.

Moving Cargo
Teacher Notes (Page 2 of 2)

Procedures

1. Teacher will:
    a. Review problem.
    b. Review rules.
2. The students will:
    a. Demonstrate materials and construction techniques.
    b. Apply the engineering design process to solve a problem.
    c. Identify criteria and constraints and determine how these will affect the design process.
    d. Make two-dimensional and three-dimensional representations of a design solution.
    e. Fabricate a prototype or model of a design solution.
    f. Evaluate a design by using conceptual, physical, and mathematical models.
    g. Evaluate a prototype in terms of design requirements and constraints.
    h. Organize and present data effectively.
    i. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

Science and Mathematics Concepts Related to Problem

- Propulsion systems
- Buoyancy
- Fluid dynamics
- Force
- Motion
- Electricity
- Structures

Testing the Problem Solutions

1. Place cargo container with fragile item on the vehicle.
2. Allow the students to start the vehicle.
3. Record the amount of time to arrive at the three-feet mark.
4. Check the fragile item for any damage during travel.

Evaluation of Students

- Students will be evaluated on their ability to:
- Apply the engineering design process to solve a problem.
- Identify criteria and constraints and determine how these will affect the design process.
- Make two-dimensional and three-dimensional representations of a design solution.
- Fabricate a prototype or model of a design solution.
- Evaluate a design by using conceptual, physical, and mathematical models.
- Evaluate a prototype in terms of design requirements and constraints.
- Organize and present data effectively.
- Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.
- Work safely and accurately with a variety of tools, machines, and materials.

Integrating Transportation Systems

Challenge Problem
Your group must plan, organize, and control the integration of three means of transportation vehicles used in the "Moving Cargo" (***Lesson Resource 4.1***) exercise to successfully move the cargo container through water, land, and air within the shortest amount of time.

Rules
1. You will work with two other teams of students from the "Moving Cargo" activity.
2. Three students will work on the integration of the water-to-land transfer, and the other three students will work on the integration of the land-to-air transfer.
3. You must modify the vehicles or design an infrastructure system that allows the cargo container to easily transfer from the water vehicle to the land vehicle to the air vehicle.
4. The cargo must travel three feet, in a straight line, for all three means of transportation.
5. There may be minimal human contact, as determined by the teacher, to transfer the cargo from one means of transportation to another.
6. You must use the original vehicles from the moving cargo activity; however you may make modifications.
7. Create documentation that includes the following:
   a. Statement of purpose
   b. Explanation of how project will function
   c. Functional flow block diagram of subsystems
   d. Architectural requirements (vehicle/infrastructure needed)

Resources

People:	Teams of six students.
Information:	Facts and knowledge the individuals possess or obtain and instruction from the teacher.
Tools and Machines:	Students use appropriate tools and equipment available in the technology laboratory.
Materials:	• Motor, propeller, pulleys, gears. • Any appropriate material in the technology laboratory. • Any materials brought from home that are not judged by the teacher to be inappropriate or unsafe.
Time:	Determined by the teacher.
Energy:	Human muscle power.
Capital:	Provided by the school.
Evaluation:	See rubric.

Integrating Transportation Systems
Teacher Notes (Page 1 of 2)

Objectives
Students will demonstrate knowledge of the engineering design process and manage the integration of inter-modal transportation.

Students will demonstrate the ability to:

a. Apply the engineering design process to solve a problem.
b. Identify criteria and constraints and determine how these will affect the design process.
c. Make two-dimensional and three-dimensional representations of a design solution.
d. Fabricate a prototype or model of a design solution.
e. Evaluate a design by using conceptual, physical, and mathematical models.
f. Evaluate a prototype in terms of design requirements and constraints.
g. Organize and present data effectively.
h. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.
i. Work safely and accurately with a variety of tools, machines, and materials.

Advanced Preparations
1. Gather materials for vehicles.
   Suggested supplies include:
   - Gears
   - Pulleys
   - Toy motors
   - Dowel rods for axles
   - Wheels
   - Styrofoam
   - Propellers
   - String
   - Balsa wood
   - Glue
   - Magnets
   - Suction Cups
2. Construct cargo container that students will be transporting.
3. Obtain a fragile item (an uncooked egg could work nicely) to place into the cargo container.
4. Obtain an aquarium for groups who are building water vehicles.
5. Hang two sets of wire from the ceiling for groups who are building air vehicles to help guide and power the vehicles.
6. Be sure you have an equal number of groups building land, sea, and air vehicles.

Organization of Students
Students will work in groups of six. Three students will work on the integration of the water and land vehicle, and three students will work on the integration of the land and air vehicles.

Procedures
1. Teacher will:
   a. Review problem.
   b. Review rules.
   (*Note:* The teacher may determine that students can move the cargo container themselves from one means of transportation to another as long as the system allows easy integration, or for more challenge, decide that no human interaction is allowed to transfer the cargo.)

Integrating Transportation Systems
Teacher Notes (Page 2 of 2)

2. The students will:
   a. Demonstrate materials and construction techniques.
   b. Apply the engineering design process to solve a problem.
   c. Identify criteria and constraints and determine how these will affect the design process.
   d. Make two-dimensional and three-dimensional representations of a design solution.
   e. Fabricate a prototype or model of a design solution.
   f. Evaluate a design by using conceptual, physical, and mathematical models.
   g. Evaluate a prototype in terms of design requirements and constraints.
   h. Organize and present data effectively.
   i. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

Science and Mathematics Concepts Related to Problem

- Propulsion systems
- Buoyancy
- Fluid dynamics
- Force
- Motion
- Electricity
- Structures

Testing the Problem Solutions

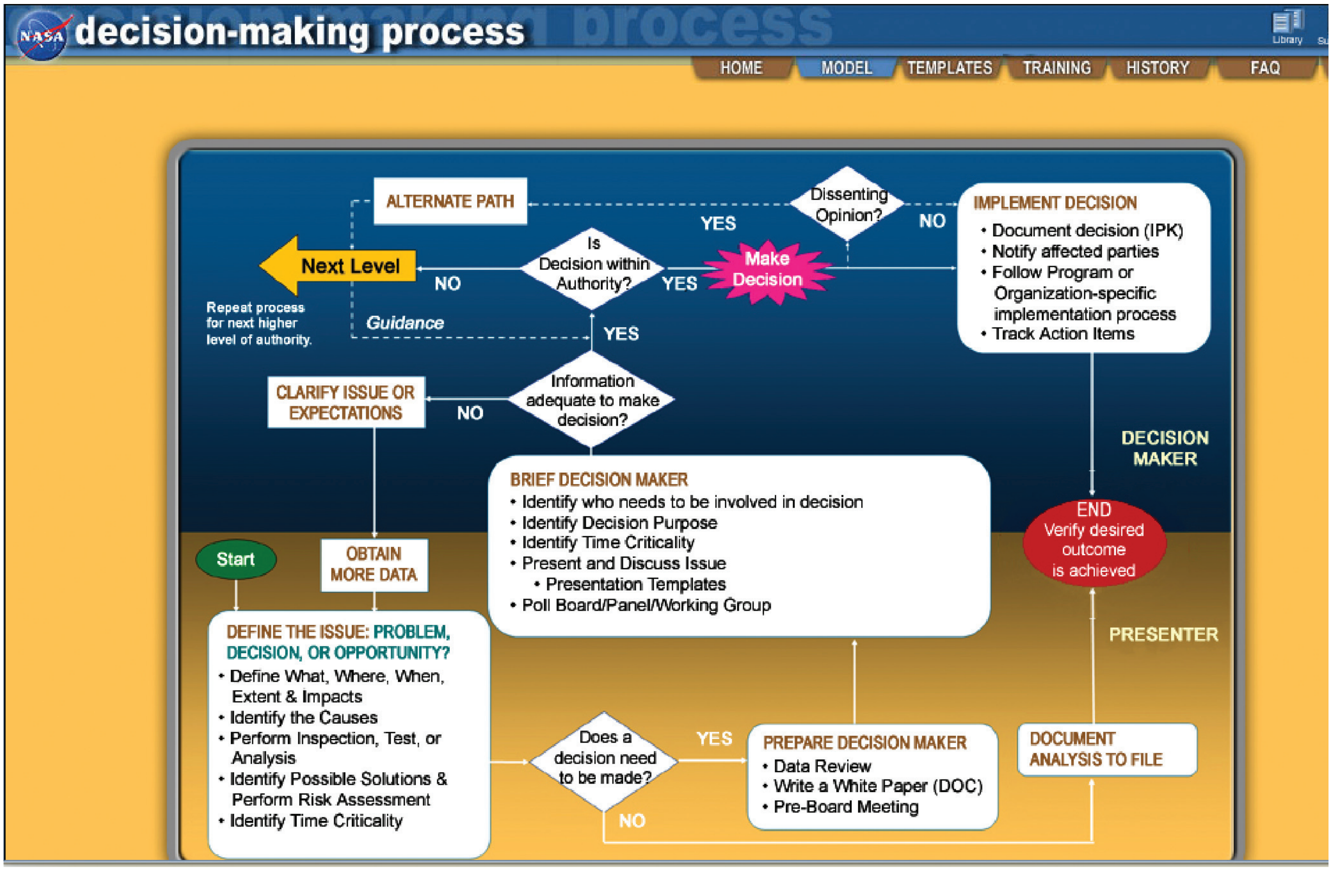
1. Place cargo container in the water vehicle.
2. Transport the cargo three feet in water.
3. Transfer the cargo to the land vehicle.
4. Transport the cargo three feet on land.
5. Transfer the cargo to the air vehicle.
6. Transport the cargo three feet in the air.
7. Record the time for the entire trip.

Evaluation of Students

Students will be evaluated on their ability to:

- Apply the engineering design process to solve a problem.
- Identify criteria and constraints and determine how these will affect the design process.
- Make two-dimensional and three-dimensional representations of a design solution.
- Fabricate a prototype or model of a design solution.
- Evaluate a design by using conceptual, physical, and mathematical models.
- Evaluate a prototype in terms of design requirements and constraints.
- Organize and present data effectively.
- Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.
- Work safely and accurately with a variety of tools, machines, and materials.

NASA Decision Process Model



(Hackfield, 2006, Slide 8.)

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