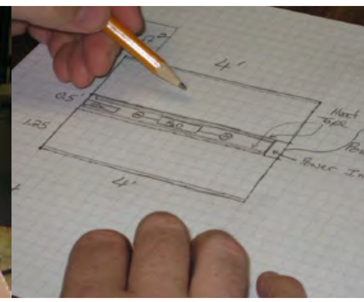
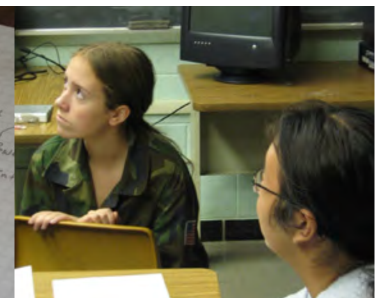
National Aeronautics and Space Administration

Creating a Space Exploration Infrastructure

Human Exploration Project II Transportation

A Standards-Based Middle School Unit Guide



Engineering byDesign™

Advancing Technological Literacy

A Standards-Based Program Series

This unit coordinates with the ITEA EbD™ Course: *Invention and Innovation*.

MS-7

International Technology Education Association
Center to Advance the Teaching of Technology and Science

Educational Product	
Educators	Grade 7

EP–2009–03–45–MSFC

Teacher Notes

This unit is intended to serve as part of a middle 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 middle school, particularly Grade 7. While there are no prerequisites, prior experience in technological literacy through Technology Education is helpful.

Preface

Creating a Space Exploration Infrastructure
A Standards-Based Middle 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, 2000/2002/2007).
- 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 email <ebd@iteaconnect.org> or call 703–860–2100.

Space Exploration Infrastructure

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Creating a Space Exploration Infrastructure A Standards-Based Middle School Unit

Unit Overview

Big Idea

Constellation, NASA's latest space program, is a combination of large and small technology systems that will enable humans to travel to and explore the solar system.

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

The Moon is not a hostile, barren rock in space. It is humanity's stepping stone into the solar system. Outposts on the surface of the Moon could act as "oases" for humans in the desert of near-Earth space. To live there and at destinations beyond, we must identify resources that will support human life and enable the creation of a new space exploration infrastructure.

Standards and Benchmarks

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

- Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study. (ITEA/*STL* 3)
  - Knowledge gained from other fields of study has a direct effect on the development of technological products and systems. (3F)
- Students will develop an understanding of the cultural, social, economic, and political effects of technology. (ITEA/*STL* 4)
  - The use of technology affects humans in various ways, including their safety, choices, and attitudes about technology's development and use. (4D)
  - Technology, by itself, is neither good nor bad, but decisions about the use of products and systems can result in desirable or undesirable consequences. (4E)
  - The development and use of technology poses ethical issues. (4F)
  - Economic, political, and cultural issues are influenced by the development and use of technology (4G)
- Students will develop an understanding of effects of technology on the environment. (ITEA/*STL* 5)
  - The management of waste produced by technological systems is an important societal issue. (5D)
  - Technologies can be used to repair damage caused by natural disasters and to break down waste from the use of various products and systems. (5E)
  - Decisions to develop and use technologies often put environmental and economic concerns in direct competition with one another. (5F)
- Students will develop an understanding of the role of society in the development and use of technology. (ITEA/*STL* 6)
  - Throughout history, new technologies have resulted from the demands, values, and interests of individuals, industries, and societies. (6D)
  - Social and cultural priorities and values are reflected in technological devices. (6F)
- Students will develop the abilities to use and maintain technological products and systems. (ITEA/*STL* 12)
  - Use computers and calculators in various applications. (12J)

- Students will develop the abilities to assess the impact of products and systems. (ITEA/*STL* 13)
  - Use data collected to analyze and interpret trends in order to identify the positive and negative effects of a technology. (13G)
  - Interpret and evaluate the accuracy of the information obtained and determine if it is useful. (13I)
- Students will develop an understanding of and be able to select and use transportation technologies. (ITEA/*STL* 18)
  - Transporting people and goods involves a combination of individuals and vehicles. (18F)
  - Transportation vehicles are made up of subsystems, such as structural, propulsion, suspension, guidance, control, and support, that must function together for a system to work effectively. (18G)
  - Governmental regulations often influence the design and operation of transportation systems. (18H)
  - Transportation plays a vital role in the operation of other technologies, such as manufacturing, construction, communication, health and safety, and agriculture. (18J)

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

- Use mathematical models to represent and understand quantitative relationships. (NCTM, Algebra, Grades 6–8)
  - Model and solve contextualized problems using various representations, such as graphs, tables, and equations.
- Apply appropriate techniques, tools, and formulae to determine measurements. (NCTM, Measurement, Grades 6–8)
  - Select and apply techniques and tools to accurately find volume to appropriate levels of precision.
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them. (NCTM, Data Analysis and Probability, Grades 6–8)
  - Select, create, and use appropriate graphical representations of data.
- Select and use appropriate statistical methods to analyze data. (NCTM, Data Analysis and Probability, Grades 6–8)
  - Discuss and understand the correspondence between data sets and their graphical representations, especially histograms, stem-and-leaf plots, box plots, and scatterplots.
- Develop and evaluate inferences and predictions that are based on data. (NCTM, Data Analysis and Probability, Grades 6–8)
  - Make conjectures about possible relationships between two characteristics of a sample on the basis of scatterplots of the data and approximate lines of fit.

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

- Design and Systems (AAAS, 3B, Grades 6–8)
  - All technologies have effects other than those intended by the design, some of which may have been predictable and some not. In either case, these side effects may turn out to be unacceptable to some of the population, and therefore, lead to conflict between groups.
  - Systems fail because they have faulty or poorly matched parts, are used in ways that exceed what was intended by the design, or were poorly designed to begin with. The most common ways to prevent failure are pretesting parts and procedures, overdesign, and redundancy.

- Issues in Technology (AAAS, 3C, Grades 6–8)
  - New technologies increase some risks and decrease others. Some of the same technologies that have improved the length and quality of life for many people have also brought new risks.
- Energy Transformations (AAAS, 4E, Grades 6–8)
  - Energy cannot be created or destroyed, but only changed from one form into another.
- Physical Health (AAAS, 6E, Grades 6–8)
  - The environment may contain dangerous levels of substances that are harmful to human beings. Therefore, the good health of individuals requires monitoring the soil, air, and water and taking steps to keep them safe.
- Global Interdependence (AAAS, 7G, Grades 6–8)
  - The global environment is affected by national policies and practices relating to energy use, waste disposal, ecological management, manufacturing, and population.
- Scale (AAAS, 11D, Grades 6–8)
  - Properties of systems that depend on volume, such as capacity and weight, change out of proportion to properties that depend on area, such as strength or surface processes.

** 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, DC.*

Purpose of Unit

From the Apollo landings on the Moon, to robotic surveys of the Sun and the planets, to the compelling images captured by advanced space telescopes, U.S. achievements in space have revolutionized humanity's view of the universe and have inspired people around the world. The purpose of this unit is to familiarize students with current space exploration initiatives.

Unit Objectives

Lesson 1: Establishing a Lunar Outpost

Students will learn to:

- Identify, explain, and evaluate what explorers will do on the Moon and the scientific and economic reasons for establishing a lunar outpost.
- Explain that technology, by itself, is neither good nor bad, but decisions about the use of products and systems can result in desirable or undesirable consequences.
- Identify and describe examples of how technology affects humans.
- Explain that all technologies have effects other than those intended by the design, some of which may have been predictable and some not.
- Describe, analyze, and evaluate the impacts that inventions and innovations have had on humans.
- Explain that the development and use of technology poses ethical issues.
- Explain that systems fail because they have faulty or poorly matched parts, are used in ways that exceed what was intended by the design, or were poorly designed to begin with.
- Use computers and calculators in order to achieve a given purpose.
- Actively participate in group discussions, ideation exercises, and debates.

Lesson 2: Launch Vehicles and Early Departure Stages

Students will learn to:

- Describe the functioning and applications of the Constellation Program's Crew Launch Vehicle (CLV).
- Describe the functioning and applications of the Constellation Program's Crew Exploration Vehicle (CEV).
- Describe the functioning and applications of the Constellation Program's Cargo Launch Vehicle (CaLV).
- Explain that knowledge gained from other fields of study directly affects the development of technological products and systems.
- Describe how economic, political, and cultural issues are influenced by the development and use of technology.
- Describe, analyze, and evaluate the impacts that inventions and innovations have had on the environment.
- Describe how decisions to develop and use technologies often put environmental and economic concerns in direct competition with one another.
- Use data collected to analyze and interpret trends in order to identify positive or negative effects of a technology.
- Explain that energy cannot be created or destroyed, but only changed from one form into another.
- Explain that properties of systems that depend on volume, such as capacity and weight, change out of proportion to properties that depend on area, such as strength or surface processes.
- Interpret and evaluate the accuracy of the information obtained and determine if it is useful.
- Explain that transporting people and goods involves a combination of individuals and vehicles.
- Explain that transportation vehicles are made up of subsystems, such as structural, propulsion, suspension, guidance, control, and support, that must function together for a system to work effectively.

Lesson 3: Designing a Spacecraft Subsystem

Students will learn to:

- Explain that to live on the Moon and destinations beyond, we must identify resources that will support human life and enable the creation of a new space exploration infrastructure.
- Explain the functioning and application of sample acquisition and retrieval systems.
- Identify and describe the reasons for further exploration of the Moon.
- Describe the physical characteristics of the lunar surface.
- Design and fabricate a model depicting one of the lunar mission components, and describe how that component contributes to sample selection, collection, protection, and retrieval, as well as for placement of instruments on or below the surface.
- Contribute to a group endeavor by offering useful ideas, supporting the efforts of others and focusing on the task.
- Work safely and accurately with a variety of tools, machines, and materials.

Student Assessment Tools and/or Methods

(See assessment instruments at end of each lesson.)

- Selected Response Items
- Brief Constructed Response Items
- Performance Rubrics

Student Assessment Criteria

Student Assessment Criteria - Transportation and Space: NASA Human Exploration Project (HEP)			
Category	**Below Target**	**At Target**	**Above Target**
Understanding	Response demonstrates an implied, partial, or superficial understanding of the graphics and/or the question.	Response demonstrates an understanding of the graphics.	Response demonstrates understanding of the complexities of the graphics.
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 uses minimal information from the graphics to clarify or extend meaning.	Response uses some expressed or implied information from the graphics to clarify or extend meaning.	Response uses effectively expressed or implied information from the graphics to clarify or extend meaning.

Lesson 1: Establish a Lunar Outpost

Lesson Snapshot

Overview

Big Idea: Constellation, NASA's latest space program, is a combination of large and small technology systems that will enable humans to travel to and explore the solar system.

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 reasons for establishing a lunar outpost and with what explorers will do on the Moon.

Lesson Duration: Three hours.

Activity Highlights

Engagement: The teacher asks students to make an educated guess about how the size of the Moon compares to Earth.

Exploration: Students use calculators to determine the ratio of Earth's mass, volume, equatorial radius, mean density, and surface gravity with that of the Moon.

Explanation: The teacher facilitates a discussion on the reasons for establishing a lunar outpost and what explorers will do on the Moon.

Extension: Students, working in groups of three or four, research and report on one of the nine systems required for maintaining a lunar outpost.

1. Air supply system
2. Communications system
3. Electricity system
4. Food supply system
5. Recreation system
6. Temperature control system
7. Transportation system
8. Waste management system
9. Water supply system

Evaluation: Student knowledge, skills, and attitudes are assessed using selected response items, rubrics, and brief constructed responses.

Lesson 1: Overview

Lesson Duration
- Three hours.

Standards/Benchmarks
***Technology:* Standards for Technological Literacy (STL) (ITEA, 2000/2002/2007)**
- Students will develop an understanding of the cultural, social, economic, and political effects of technology. (ITEA/*STL* 4)
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  - Systems fail because they have faulty or poorly matched parts, are used in ways that exceed what was intended by the design, or were poorly designed to begin with. The most common ways to prevent failure are pretesting parts and procedures, overdesign, and redundancy.

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Learning Objectives

Students will learn to:

1. Identify, explain, and evaluate what explorers will do on the Moon and the scientific and economic reasons for establishing a lunar outpost.
2. Explain that technology, by itself, is neither good nor bad, but decisions about the use of products and systems can result in desirable or undesirable consequences.
3. Identify and describe examples of how technology affects humans.
4. Explain that all technologies have effects other than those intended by the design, some of which may have been predictable and some not.
5. Describe, analyze, and evaluate the impacts that inventions and innovations have had on humans.
6. Explain that the development and use of technology poses ethical issues.
7. Explain that systems fail because they have faulty or poorly matched parts, are used in ways that exceed what was intended by the design, or were poorly designed to begin with.
8. Use computers and calculators in order to achieve a given purpose.
9. Actively participate in group discussions, ideation exercises, and debates.

Student Assessment Tools and/or Methods

1. True/False

True	1.	Technology, by itself, is neither good nor bad, but decisions about the use of products and systems can result in desirable or undesirable consequences.
False	2.	The development and use of technology does not pose ethical issues.
True	3.	Systems fail because they have faulty or poorly matched parts, are used in ways that exceed what was intended by the design, or were poorly designed to begin with.
True	4.	All technologies have effects other than those intended by the design, some of which may have been predictable and some not.
False	5.	The Moon is about the same size as Earth.
True	6.	We always see the same side of the Moon from Earth.
False	7.	The Moon has an atmosphere.
False	8.	Mean density can be expressed as: The highest density of an object equals its total mass divided by its total volume.
True	9.	Every day, we use products and services that originated from space technologies.
True	10.	We can use our time on the Moon to develop and test new approaches and technologies and systems that will allow us to function in other, more challenging environments.

2. Brief Constructed Response

Describe the scientific and economic benefits of establishing a lunar outpost. Write a one-paragraph answer. Include a strong topic sentence with good details to support your answer.

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 question.	Response demonstrates an understanding of the complexities of the text and/or the question.
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 uses minimal information from the lectures, discussions, or texts to clarify or extend meaning.	Response uses some expressed or implied information from lectures, discussions, or texts to clarify or extend meaning.	Response effectively uses expressed or implied information from lectures, discussions, or texts to clarify or extend meaning.

3. Oral Presentation Rubric

Category	Below Target	At Target	Above Target
Organization	Audience has difficulty following presentation because student jumps around.	Student presents information in a logical sequence that audience can follow.	Student presents information in a logical, interesting sequence that audience can follow.
Subject Knowledge	Student is uncomfortable with the information and is able to answer only rudimentary questions.	Student is at ease with the expected answers to all questions but fails to elaborate.	Student demonstrates full knowledge (more than required) by answering all class questions with explanations and elaboration.
Graphics	Student occasionally uses graphics that rarely support text and presentation.	Student graphics relate to text and presentation.	Student graphics explain and reinforce screen text and presentation.
Eye Contact	Student occasionally uses eye contact but still reads most of report.	Student maintains eye contact most of the time but frequently returns to notes.	Student maintains eye contact with audience, seldom returning to notes.
Elocution	Student's voice is low. Student incorrectly pronounces terms. Audience members have difficulty hearing presentation.	Student's voice is clear. Student pronounces most words correctly. Most audience members can hear presentation.	Student uses a clear voice and correct, precise pronunciation of terms so that all audience members can hear presentation.

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

Lacroux, J., Legrand, C., & Sutcliffe, C. (2004). *Discover the Moon.* New York: Cambridge University Press.

Schmitt, H.H. (2006). *Return to the Moon: Exploration, enterprise, and energy in the human settlement of space.* New York: Springer.

Ulivi P. & Harland, D. (2004). *Lunar exploration: Human pioneers and robotic surveyor*s. New York: Springer Praxis Books.

Audiovisual Materials

Carson, D., & Frankel, D. (Directors). (1998). *From Earth to the Moon: The signature edition* [Motion picture]. United States: HBO Home Video

NASA. (2000). *Apollo Moon landings: Out of this world* [Motion picture]. United States: Finely-Holiday Film Corp.

Spacecraft Films. (2002). *Apollo II: Men on the Moon* [Motion picture]. United States: 20th Century Fox.

Internet Sites

NASA. (2008). *Constellation.* Retrieved April 20, 2008, from <http://www.nasa.gov/mission_pages/constellation/main/index.html>.

NASA. (2008). *Exploring the Moon: A teacher's guide with activities for Earth and space sciences.* Retrieved April 20, 2008, from <http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Exploring.the.Moon.html>.

NASA. (2008). *Space flight systems @ GRC.* Retrieved April 20, 2008, from <http://exploration.grc.nasa.gov>.

NASA. (n.d.). *Photojournal*. Retrieved November 18, 2008, from <http://photojournal.jpl.nasa.gov/index.html>.

Required Knowledge and Skills

Students should have some basic graphic and research skills. In the engagement and exploratory phases of instruction, the teacher will identify student misunderstandings and/or misconceptions about the influence of technology on history.

Lesson 1: 5-E Lesson Plan

Engagement

1. The teacher shows a picture of the Moon's surface (see **Resource Materials**).
2. The teacher asks students to identify what they are seeing.
3. The teacher asks students the following questions:
   - Is the Moon smaller than Earth, the same size as Earth or larger than Earth? (The Moon is smaller than Earth.)
   - Do we always see the same side of the Moon from Earth? (The same side of the Moon always faces Earth.)
   - Does the Moon have an atmosphere? (The Moon has no atmosphere.)
   - Who was the first person to walk on the Moon? (Neil Armstrong was the first person to set foot on the Moon.)
   - In what year did this first Moonwalk occur? (July 20, 1969)
4. The teacher asks students when they think the next human will walk on the Moon.
5. The teacher asks students to make an educated guess about how the size of the Moon compares to Earth.

Exploration

1. In groups, students compare the bulk parameters of the Moon and Earth.
2. The teacher explains the bulk parameters:
   a. Mass is the amount of matter in an object.
   b. Volume is the quantification of how much space an object occupies.
   c. Equatorial radius is the distance from its center to a point on its surface at mean sea level.
   d. Mean density is the average density of an object equals its total mass divided by its total volume.
   e. The surface gravity of an astronomical object (planet, star, etc.) is the gravitational acceleration experienced at its surface. The surface gravity depends on the mass of the object and its radius. It is often expressed as a ratio to the value for Earth.
3. Students use calculators to determine the ratio of the Moon's mass, volume, equatorial radius, mean density, and surface gravity, with that of Earth (see ***Lesson Resource 1.1***).

Bulk Parameter	Moon	Earth	Ratio (Moon/Earth)	% (Moon/Earth)
Mass (1024 kg)	0.07349	5.9736	0.0123: 1	1.23 %
Volume (1010 km^3)	2.1958	108.321	0.0203: 1	2 %
Equatorial Radius (km)	1738.1	6378.1	0.2725: 1	27 %
Mean density (kg/m^3)	3350	5515	0.607: 1	6 %
Surface gravity (m/s^2)	1.62	9.80	0.165: 1	16.5 %

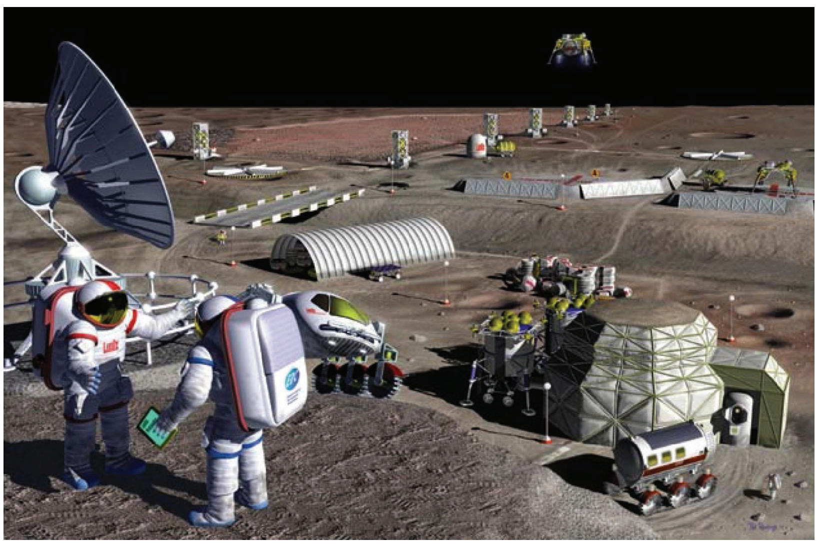
4. The teacher assists students in calculating ratios and percentages.
   a. $\text{Ratio}_{\text{(Moon/Earth)}}$ = Mass (Moon) divided by Mass (Earth)
   b. $\text{Ratio}_{\text{(Moon/Earth)}}$ = 0.07349 divided by 5.9736
   c. $\text{Ratio}_{\text{(Moon/Earth)}}$ = 0.0123

1. The teacher reminds student how to convert ratios to percentages by multiplying the ratio by 100. (0.0123 x 100 = 1.23 %)
2. The teacher reminds students that ratios are stated in three formats.
   a. 0.0123/1
   b. 0.0123 to 1
   c. 0.0123 : 1
3. The student groups present their comparison in a table format (***Lesson Resource 1.1***).

Explanation

1. Students share their comparisons from the ***Exploration*** activity.
2. The teacher asks students to describe what it is like to walk on the Moon.
3. Students speculate on the question.
4. The teacher asks students why we would want to establish a lunar outpost.
5. The teacher explains that:
   a. The far-reaching, big-picture goal of returning humans to the Moon's surface is to prepare for missions beyond the Moon.
   b. With the Moon viewed as home for abundant resources, the lunar soil contains raw materials that might be harvested and processed into rocket fuel or breathable air, construction materials, and other useful products.
   c. We can use our time on the Moon to develop and test new approaches and technologies and systems that will allow us to function in other, more challenging environments.
   d. We will use the Moon as a proving ground for subsequent missions to Mars. Just three days away, the Moon is a nearby place where astronauts can learn to live and work in a hostile environment before heading off to more distant destinations.
6. The teacher explains that the upcoming space initiatives reflect some of the core concepts of technology that apply in space as well as on Earth. Some of these concepts are:
   a. That technology, by itself, is neither good nor bad, but decisions about the use of products and systems can result in desirable or undesirable consequences.
   b. That the development and use of technology poses ethical issues.
   c. Systems fail because they have faulty or poorly matched parts, are used in ways that exceed what was intended by the design, or were poorly designed to begin with.
7. The teacher explains that there are scientific and economic reasons for establishing a lunar outpost including:
   a. From the time of our birth, humans have felt a primordial urge to explore—to blaze new trails, map new lands, and answer profound questions about our universe and us.
   b. The Moon also offers many clues about the time when the planets were formed.
   c. Every day, we use products and services that originated from space technologies.
   d. We have better means of detecting and treating cancer and cardiovascular disease because of our space programs.
   e. Space programs also taught us about the large ozone hole in our atmosphere, the hazards of solar radiation, the path of killer hurricanes, and how to more effectively manage crops and our national forests.
   f. NASA-developed technologies have contributed to significantly improve the quality of human life.
   g. If not for America's continued investment in space exploration, we would not have wireless telephones, satellite television, or Global Positioning Systems.
   h. Technology has even been used to help law enforcement put criminals behind bars and to protect firefighters.
   i. The technologies that led to the computer bar codes in retail stores, quartz watches, and household smoke detectors were originally developed for NASA.

   j. Through exploring space, we improve our lives, boost our economy, inspire future generations, and lift our national spirit.
   k. We could achieve better understanding of the impact flux throughout time of the Earth-Moon system and the inner solar system and how it relates to life on Earth (e.g., impact-derived extinctions).
   l. We could achieve better understanding of the evolution of the Moon and terrestrial planets in the inner solar system (e.g., planetary differentiation between crust-mantle-core).
   m. Using the Moon as a natural laboratory, we could better understand basic geologic processes (e.g., volcanism and impact).
   n. The Moon may help us better understand the sun's evolution and output throughout time.
   o. The Moon may serve as a platform to observe Earth and the universe.
8. The teacher asks students to speculate on what a lunar outpost might look like.
9. The teacher shows students a NASA picture of a conceptualized lunar outpost (***Lesson Resource 1.2***).



NASA. (2008) *Entering a lunar outpost.* Retrieved April 20, 2008, from <http://www.nasa.gov/mission pages/exploration/multimedia/jfa18833 prt>.

10. Students speculate about the purpose of each of the objects.
11. The teacher leads a discussion on the nine systems that are required for sustaining life on the Moon and the systems required to carry out the mission's scientific and economic goals.
   a. Air supply system (Oxygen can be obtained by chemically processing the lunar soil.)
   b. Communications/navigation system
   c. Electricity system
   d. Food supply system
   e. Recreation system
   f. Temperature control system
   g. Transportation system
   h. Waste management system
   i. Water supply system (Water can be obtained, hopefully, from ice at the poles and/or permanently shadowed craters or from oxygen [chemically bound in soil] and hydrogen [implanted in soil by solar wind] obtained from processing lunar soil.)
12. Students clarify their understanding of concepts by asking questions.

Extension

1. Students, working in groups of three or four, research and report on one of the nine systems required for maintaining a lunar outpost.
2. Student groups develop a five-minute presentation that includes pictures, diagrams, or other images that describe the system.
3. Student groups present information on their assigned system.

Evaluation

Student knowledge, skills, and attitudes are assessed using selected response items, rubrics for class participation, and brief constructed responses. 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.

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
- Printers
- Presentation software
- Poster printer/sign maker
- Computer projector
- Calculators

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: Launch Vehicles and Earth Departure Stages

Lesson Snapshot

Overview

Big Idea: Constellation, NASA's latest space program, is a combination of large and small technology systems that will enable humans to travel to and explore the solar system.

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 functioning and applications of the new vehicles NASA has designed for space exploration.

Lesson Duration: Three hours.

Activity Highlights

Engagement: The teacher assists students in identifying the major goals for space exploration discussed in the video: *A Renewed Spirit of Discovery*.

Exploration: Students create a one-page fact sheet on one of the projects (Mercury, Gemini, or Apollo) that conveys the most important information about the project in a brief and easily understood format.

Explanation: The teacher leads a discussion on the functions and applications of the new vehicles NASA is designing for space exploration.

Extension: Students conduct research and create a display and presentation that explains the functioning of one of the Constellation Program vehicles or modules.

Evaluation: Student knowledge, skills, and attitudes are assessed using selected response items, rubrics for class participation, and brief constructed responses.

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 relationships among technologies and the connections between technology and other fields of study. (ITEA/*STL* 3)
  - Knowledge gained from other fields of study has a direct effect on the development of technological products and systems. (3F)
- Students will develop an understanding of the cultural, social, economic, and political effects of technology. (ITEA/*STL* 4)
  - The development and use of technology poses ethical issues. (4F)
  - Economic, political, and cultural issues are influenced by the development and use of technology (4G)
- Students will develop an understanding of effects of technology on the environment. (ITEA/*STL* 5)
  - The management of waste produced by technological systems is an important societal issue. (5D)
  - Technologies can be used to repair damage caused by natural disasters and to break down waste from the use of various products and systems. (5E)
  - Decisions to develop and use technologies often put environmental and economic concerns in direct competition with one another. (5F)
- Students will develop the abilities to assess the impact of products and systems. (ITEA/*STL* 13)
  - Use data collected to analyze and interpret trends in order to identify the positive and negative effects of a technology. (13G)
  - Interpret and evaluate the accuracy of the information obtained and determine if it is useful. (13I)
- Students will develop an understanding of and be able to select and use transportation technologies. (ITEA/*STL* 18)
  - Transporting people and goods involves a combination of individuals and vehicles. (18F)
  - Transportation vehicles are made up of subsystems, such as structural, propulsion, suspension, guidance, control, and support, that must function together for a system to work effectively. (18G)

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

- Apply appropriate techniques, tools, and formulas to determine measurements. (NCTM, Measurement, Grades 6–8)
  - Select and apply techniques and tools to accurately find volume to appropriate levels of precision.
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them. (NCTM, Data Analysis and Probability, Grades 6–8)
  - Select, create, and use appropriate graphical representations of data.
- Select and use appropriate statistical methods to analyze data. (NCTM, Data Analysis and Probability, Grades 6–8)
  - Discuss and understand the correspondence between data sets and their graphical representations, especially histograms, stem-and-leaf plots, box plots, and scatterplots.

- Develop and evaluate inferences and predictions that are based on data. (NCTM, Data Analysis and Probability, Grades 6–8)
  - Make conjectures about possible relationships between two characteristics of a sample on the basis of scatterplots of the data and approximate lines of fit.

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

- Issues in Technology (AAAS, 3C, Grades 6–8)
  - New technologies increase some risks and decrease others. Some of the same technologies that have improved the length and quality of life for many people have also brought new risks.
- Energy Transformations (AAAS, 4E, Grades 6–8)
  - Energy cannot be created or destroyed, but only changed from one form into another.
- Physical Health (AAAS, 6E, Grades 6–8)
  - The environment may contain dangerous levels of substances that are harmful to human beings. Therefore, the good health of individuals requires monitoring the soil, air, and water and taking steps to keep them safe.
- Global Interdependence (AAAS, 7G, Grades 6–8)
  - The global environment is affected by national policies and practices relating to energy use, waste disposal, ecological management, manufacturing, and population.
- Scale (AAAS, 11D, Grades 6–8)
  - Properties of systems that depend on volume, such as capacity and weight, change out of proportion to properties that depend on area, such as strength or surface processes.

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Learning Objectives

Students will learn to:

1. Describe the functioning and applications of the Constellation Program's Crew Exploration Vehicle (CEV).
2. Describe the functioning and applications of the Constellation Program's Crew Launch Vehicle (CLV).
3. Describe the functioning and applications of the Constellation Program's Cargo Launch Vehicle (CaLV).
4. Explain that knowledge gained from other fields of study directly affects the development of technological products and systems.
5. Describe how economic, political, and cultural issues are influenced by the development and use of technology.
6. Describe, analyze, and evaluate the impacts that inventions and innovations have had on the environment.
7. Describe how decisions to develop and use technologies often put environmental and economic concerns in direct competition with one another.
8. Use data collected to analyze and interpret trends in order to identify positive or negative effects of a technology.
9. Explain that energy cannot be created or destroyed, but only changed from one form into another.
10. Explain that properties of systems that depend on volume, such as capacity and weight, change out of proportion to properties that depend on area, such as strength or surface processes.

11. Interpret and evaluate the accuracy of the information obtained, and determine if it is useful.
12. Explain that transporting people and goods involves a combination of individuals and vehicles.
13. Explain that transportation vehicles are made up of subsystems, such as structural, propulsion, suspension, guidance, control, and support, that must function together for a system to work effectively.

Student Assessment Tools and/or Methods

1. True/False

False 1. The Ares I Crew Launch Vehicle will carry cargo to the Moon and later to Mars.

True 2. NASA's next flight to the Moon is planned for no later than 2020.

False 3. Knowledge gained from other fields of study has little effect on the development of technological products and systems.

True 4. Economic, political, and cultural issues are influenced by the development and use of technology.

True 5. In the event of a launch emergency, the Ares I Launch Abort System will separate the crew module from the rocket and return the crew safely back to Earth.

False 6. Energy can be created and destroyed.

False 7. Properties of systems that depend on volume, such as capacity and weight, change in proportion to properties that depend on area, such as strength or surface processes.

True 8. Transporting people and goods involves a combination of individuals and vehicles.

True 9. Transportation vehicles are made up of subsystems, such as structural, propulsion, suspension, guidance, control, and support, that must function together for a system to work effectively.

2. Optional Class Participation Rubric

Category	Below Target	At Target	Above Target
Preparation	Rarely prepared. Minimal effort to participate.	Prepared for class. Attempts to answer teacher-generated questions.	Well prepared for class. Attempts to answer teacher-generated questions and adds additional information to class when relevant.
Curiosity	Rarely demonstrates curiosity.	Usually demonstrates curiosity.	Consistently demonstrates curiosity.
Motivation for Learning	Rarely demonstrates motivation for learning.	Usually demonstrates motivation for learning.	Consistently demonstrates motivation for learning.
Use of Time	Gives up easily. Is not engaged. Has difficulty remaining on task.	Makes good use of class time to work on assignments and projects.	Makes excellent use of class time to work on assignments and projects.

3. Brief Constructed Response

Write a one-paragraph answer. Include a strong topic sentence and good supporting details. Describe the functioning and applications of the new vehicles NASA has designed for space exploration.

Category	Below Target	At Target	Above Target
Understanding	Response demonstrates an implied, partial, or superficial understanding of the graphics and/or the question.	Response demonstrates an understanding of the graphics.	Response demonstrates an understanding of the complexities of the graphics.
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 uses minimal information from the graphics to clarify or extend meaning.	Response uses some expressed or implied information from the graphics to clarify or extend meaning.	Response effectively uses expressed or implied information from the graphics to clarify or extend meaning.

4. One-Page Information Sheet Rubric

Category	Below Target	At Target	Above Target
Title	Title missing or difficult to locate.	Timeline has an effective title that accurately describes the material and is easy to locate.	Timeline has a creative title that accurately describes the material and is easy to locate.
Content Facts	Facts are often inaccurate for events reported on the timeline.	Facts are accurate for almost all events reported on the timeline.	Facts are accurate for all events reported on the timeline.
Graphics or Pictures	Several graphics are not effective.	All graphics are effective.	All graphics are effective and balanced with text use.
Use of Class Time	Does not make good use of class time to work on assignments and projects.	Makes good use of class time to work on assignments and projects.	Makes excellent use of class time to work on assignments and projects.
Style and Organization	Yearly divisions are not uniform.	Timeline is set up to cover the relevant time period. Timeline contains yearly gradations but not at set intervals.	Timeline is set up to cover the relevant time period. Timeline contains appropriate yearly gradations of set intervals.
Documentation	Sources are not properly documented, too few, or inappropriate.	There are two properly documented sources.	There are more than two properly documented sources.
Subject Knowledge	Student is uncomfortable with information and is able to answer only rudimentary questions.	Student is at ease with expected answers to all questions but fails to elaborate.	Student demonstrates full knowledge (more than required) by answering all class questions with explanations and elaboration.

5. Display and Presentation Rubric

Category	Below Target	At Target	Above Target
Overall Display	The display is not organized OR the items are not securely attached to the display. Display is not professional.	The display is somewhat organized. The items are securely attached to the display. Display is partly clean and professional.	The display is attractive and well organized. The items are neatly and securely attached to the display. Display is clean and professional.
Number of Items/Colors	The display has less than three items OR the items are all the same OR are in poor condition.	The display has at least four different but related items. At least three of these are in good condition.	The display has ten or more different but related items in good condition.
Labels	One or more items are not labeled. There are more than two errors in capitalization or punctuation, and/or there are more than two grammatical mistakes on the poster.	Each item has a label, but some lack required information. There are two errors in capitalization or punctuation, and/or there are two grammatical mistakes on the poster.	Each item has a small, neat label describing the item. Capitalization and punctuation are correct throughout the poster. There are no grammatical mistakes on the poster.
Participation	Student often loses focus or becomes frustrated and distracts others.	Student works but loses focus or becomes frustrated. Does not distract others.	Student shows great enthusiasm and focuses on the task. Student is helpful to others if asked.
Knowledge Gained	Student has trouble answering questions about the topic without using the labels in the display.	Student is able to accurately answer at least three questions about the topic accurately without reading the labels.	Student is able to accurately answer at least five questions about the topic without reading the labels.

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

Fisher, D.K. (2003). The biggest rocket ever. *Technology and Children 7(3), 21.*

Spangenburg, R., & Moser, K. (2001). *The history of NASA*. London: Franklin Watts.

Audiovisual Materials

NASA. (2008). *A renewed spirt of discovery*. Retrieved November 18, 2008, from <http://www.nasa.gov/mission_pages/exploration/main/vision_video.html>.

NASA. (2008). *Exploration: NASA's plans to explore the Moon, Mars and beyond*. Retrieved April 20, 2008, from <http://www.nasa.gov/mission_pages/exploration/main/vision_video.html>.

NASA. (2008). *Return to the Moon: The journey begins*. Video. Retrieved April 20, 2008, from <http://www.nasa.gov/mission_pages/constellation/main/index.html>.

NASA. (2006). *The nation's vision for exploration – an update.* Retrieved April 20, 2008, from <http://acquisition.jpl.nasa.gov/boo/2006Hightechpresentations/The%20Nations%20Vision%20for%20Exploration.pdf>.

Internet Sites

NASA. (2008). *Apollo: One giant leap for mankind.* Retrieved April 20, 2008, from <http://www.nasa.gov/mission_pages/apollo/index.html>.

NASA. (2008). *Constellation: NASA's new spacecraft*. Retrieved April 20, 2008, from <http://www.nasa.gov/mission_pages/constellation/main/index.html>.

NASA. (2008). *Gemini: Bridge to the Moon*. Retrieved April 20, 2008, from <http://www.nasa.gov/mission_pages/gemini/index.html>.

NASA. (2008). *Mercury: America's first astronauts*. Retrieved April 20, 2008 from <http://www.nasa.gov/mission_pages/mercury/index.html>.

NASA. (2006). *Project Orion overview.* Retrieved April 20, 2008, from <http://www.nasa.gov/pdf/156297main_orion_tv_slides.pdf>.

Required Knowledge and Skills

Students should have some understanding of the scientific and economic reasons for establishing a lunar outpost. 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 shows the video, *A Renewed Spirit of Discovery*, to students.
   NASA. (2008). *A renewed spirt of discovery*. Retrieved November 18, 2008, from http://www.nasa.gov/mission_pages/exploration/main/vision_video.html.
2. The teacher assists students in identifying the major goals for space exploration discussed in the video. These goals may include:
   a. Advancing U.S. scientific, security, and economic interests through a robust space exploration program.
   b. Implementing a sustained and affordable human and robotic program to explore the solar system and beyond.
   c. Extending a human presence across the solar system, starting with a return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations.
   d. Promoting international and commercial participation in exploration.
3. Students, working in pairs, discuss the goals and rank them in importance.
4. Students record their rankings of the goals and become prepared to defend their rankings.

Exploration

1. Student groups present and defend their rankings of the goals for space exploration.
2. Students read the vignette, "A Renewed Spirit of Discovery." (***Lesson Resource 2.1***)
3. The teacher asks students to do a quick Internet search for information on three earlier space projects (Mercury, Gemini, and Apollo).
4. Students create a one-page fact sheet on one of the projects that conveys the most important information about the project in a brief and easily understood format.
5. The teacher identifies resources for information and images on the projects (See *Resource Materials* for Lesson 2).

Explanation

1. The student pairs present their fact sheets on one of the projects.
2. The teacher explains that:
   a. Transporting people and goods involves a combination of individuals and vehicles.
   b. Transportation vehicles are made up of subsystems, such as structural, propulsion, suspension, guidance, control, and support, that must function together for a system to work effectively.
3. The teacher states that:
   a. NASA has decided on the next generation of vehicles for space exploration.
   b. The Crew Exploration Vehicle (CEV) will be NASA's next human spacecraft after the Space Shuttle retires. The CEV is being designed to carry astronauts back to the Moon and to be used during missions to Mars. It will first be used to deliver crew and small amounts of cargo to the International Space Station (ISS). The CEV consists of a crew module, a service module, and a launch abort system. In the event of a launch emergency, the rocket motors on the launch abort system are designed to ignite and quickly separate the CEV from the Ares I rocket. (The teacher shows ***Lesson Resource 2.2: Ares I and Ares V.***)
   c. The Ares I Crew Launch Vehicle (CLV) will carry the CEV into orbit around the Earth and consists of a first stage based on the Space Shuttle solid rocket booster and an upper stage.

   d. The Ares V CLV will serve as the primary rocket for safe, reliable delivery of large amounts of cargo to space. (The teacher shows ***Lesson Resource 2.3: Ares I and Ares V***.)
   e. The Earth Departure Stage (EDS) is the rocket stage that will propel the CEV and the lunar lander from Earth orbit to the Moon. The EDS will be carried into space on the Ares V.
   f. The lunar lander will be used to carry crew and cargo from lunar orbit to the lunar surface. The lunar lander is carried into space, along with the EDS, on the Ares V. (The teacher shows ***Lesson Resource 2.4: Lunar Lander***.)
   g. The first flight of the CEV with astronauts aboard is planned for 2015.
   h. The first flight with humans returning to the Moon is currently planned for 2020.
4. The teacher leads a discussion on the relative size of NASA's past, present, and future launch vehicles. (The teacher shows ***Lesson Resource 2.5: NASA's Past, Present, and Future Launch Vehicles***.)
5. The teacher leads a discussion on the current plan for going to the Moon. (The teacher shows ***Lesson Resource 2.6: Going to the Moon: Current Approach.***)
6. The teacher explains how the following concepts are related to NASA's Constellation Program.
   a. Knowledge gained from other fields of study has direct effect on the development of technological products and systems.
   b. Economic, political, and cultural issues are influenced by the development and use of technology.
   c. Energy cannot be created or destroyed but only changed from one form into another.
   d. Properties of systems that depend on volume, such as capacity and weight, change out of proportion to properties that depend on area, such as strength or surface processes.
7. Students clarify their understanding of concepts by asking questions.

Extension

1. Students select one of the Constellation vehicles or modules.
2. Students conduct research and create a display and presentation that explains the functioning of the vehicle or module they chose.
3. The teacher reviews the rubric to be used for assessment of the graphic.

Evaluation

Student knowledge, skills, and attitudes are assessed using true/false questions, brief constructed response, and rubrics for participation, the one-page data sheet, and the display questions and presentation. 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.

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, and research activities. The teacher adapts the learning environment based on the requirements of the unit or lesson. For this lesson, areas for lectures and demonstrations, design, small-group meetings, and fabrication activities should be readied.

Tools/Materials/Equipment

- Computers with Internet access
- Presentation software
- Printers
- Computer projector
- Poster printer/sign maker

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: Sample Acquisition and Retrieval Systems

Lesson Snapshot

Overview

Big Idea: Constellation, NASA's latest space program, is a combination of large and small technological systems that will enable humans to travel to and explore the solar system.

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 enables students to develop an understanding of the functioning and application of sample acquisition and retrieval systems.

Lesson Duration: Ten hours.

Activity Highlights

Engagement: The teacher asks students, "What would you find on the Moon's surface?"

Exploration: Student groups make a simulated regolith and observe its properties.

Explanation: The teacher leads a discussion of the functioning and application of sample acquisition and retrieval systems.

Extension: Students design and fabricate a three-dimensional model of one of the Constellation system components along with a one-page explanation of how the component contributes to the overall mission goal of sample acquisition and retrieval.

a. Earth-to-Orbit Transportation Systems
b. In-Space Transportation Systems
c. Surface Transportation Systems
d. Surface- and Space-Based Habitats
e. Power Generation Systems
f. Communications Systems
g. Maintenance and Science Instrumentation
h. Robotic Investigators and Assistant

Evaluation: Student knowledge, skills, and attitudes are assessed using selected response items and rubrics for class participation, group work, brief constructed responses and for the three-dimensional model of one of the system components, along with a one-page explanation.

Lesson 3: Overview

Lesson Duration

- Ten hours.

Standards/Benchmarks

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

- Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study. (ITEA/*STL* 3)
  - Knowledge gained from other fields of study has a direct effect on the development of technological products and systems. (3F)
- Students will develop an understanding of the cultural, social, economic, and political effects of technology. (ITEA/*STL* 4)
  - The development and use of technology poses ethical issues. (ITEA/*STL* 4F)
  - Economic, political, and cultural issues are influenced by the development and use of technology. (ITEA/*STL* 4G)
- Students will develop an understanding of the role of society in the development and use of technology. (ITEA/*STL* 6)
  - Throughout history, new technologies have resulted from the demands, values, and interests of individuals, industries, and societies. (6D)
- Students will develop the abilities to assess the impact of products and systems. (ITEA/*STL* 13)
  - Interpret and evaluate the accuracy of the information obtained and determine if it is useful. (13I)

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

- Use mathematical models to represent and understand quantitative relationships. (NCTM, Algebra, Grades 6–8)
  - Model and solve contextualized problems using various representations, such as graphs, tables, and equations.

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Learning Objectives

Students will learn to:

1. Explain that to live on the Moon and destinations beyond, we must identify resources that will support human life and enable the creation of a new space exploration infrastructure.
2. Explain the functioning and application of sample acquisition and retrieval systems.
3. Identify and describe the reasons for further exploration of the Moon.
4. Describe the physical characteristics of the lunar surface.
5. Design and fabricate a model depicting one of the lunar mission components, and describe how that component contributes to sample selection, collection, protection, and retrieval, as well as for placement of instruments on or below the surface.
6. Contribute to a group endeavor by offering useful ideas, supporting the efforts of others and focusing on the task.
7. Work safely and accurately with a variety of tools, machines, and materials.

Student Assessment Tools and/or Methods

1. True/False

True 1. To live on the Moon and at destinations beyond, we must identify resources that will support human life and enable the creation of a new space exploration infrastructure.

True 2. On Earth, soil is part of the regolith, and lunar regolith is consequently often called "soil."

False 3. We've known for many years that the Moon has surface water.

True 4. Knowledge gained from other fields of study has a direct effect on the development of technological products and systems.

False 5. The loose stuff that overlies the solid rock on the Moon is called the topsoil.

True 6. Earth itself is protected from the solar wind by its magnetic field, which deflects charged particles.

False 7. On lunar missions with people, we can bring back about 100 tons of materials.

True 8. Solar-wind-implanted elements act as a "tape recorder" of the Sun's output for the past 4.5 billion years.

False 9. Meteorites are streams of charged particles that are ejected from the upper atmosphere of a star.

True 10. Throughout history, new technologies have resulted from the demands, values, and interests of individuals, industries, and societies.

2. Optional Class Participation Rubric

Category	Below Target	At Target	Above Target
Preparation	Rarely prepared. Minimal effort to participate.	Prepared for class. Attempts to answer teacher-generated questions.	Well prepared for class. Attempts to answer teacher-generated questions and adds additional information to class when relevant.
Curiosity	Rarely demonstrates curiosity.	Usually demonstrates curiosity.	Consistently demonstrates curiosity.
Motivation for Learning	Rarely demonstrates motivation for learning.	Usually demonstrates motivation for learning.	Consistently demonstrates motivation for learning.
Use of Time	Gives up easily. Is not engaged. Has difficulty remaining on task.	Makes good use of class time to work on assignments and projects.	Makes excellent use of class time to work on assignments and projects.

3. Group Work Rubric

Category	Below Target	At Target	Above Target
Contributions	Seldom cooperative. Does little work and rarely offers useful ideas.	Cooperative. Works at assignments. Usually offers useful ideas.	Always willing to help and do more. Does more than required. Routinely offers useful ideas.
Cooperation	Rarely listens to, shares with, or supports the efforts of others. Often is not a good team member.	Usually listens to, shares with, and supports the efforts of others. Does not cause problems in the group.	Always listens to, shares with, and supports the efforts of others. Tries to keep people working together.
Focus on the Task	Does not focus on the task and what needs to be done. Lets others do the work.	Focuses on the task and what needs to be done most of the time.	Almost always focused on the task and what needs to be done. Self-directed.

4. Brief Constructed Response
   Write a one-paragraph answer. Include a strong topic sentence and good supporting details. Describe the physical characteristics of the lunar surface.

   Possible Answer: The lunar surface has some interesting characteristics when compared to Earth's soil. The particles in Moon soil are mostly very small (usually less than 0.1 millimeters across). These tiny particles become electrostatically charged, meaning that they can "stick" to objects like space suits and equipment. Lunar dust is almost like tiny fragments of glass or coral—odd shapes that are very sharp and lock together. The dust can easily become airborne inside a spacecraft, irritating the space explorers' lungs and eyes. The darker dust particles can even absorb sunlight and heat up whatever they coat.

Category	Below Target	At Target	Above Target
Understanding	Response demonstrates an implied, partial, or superficial understanding of the graphics and/or the question.	Response demonstrates an understanding of the graphics.	Response demonstrates an understanding of the complexities of the graphics.
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 uses minimal information from the graphics to clarify or extend meaning.	Response uses some expressed or implied information from the graphics to clarify or extend meaning.	Response effectively uses expressed or implied information from the graphics to clarify or extend meaning.

5. Lunar Sample Acquisition and Retrieval Project Rubric

Category	Below Target	At Target	Above Target
Research on Mission Component	Gathered relevant information from only one source.	Gathered relevant information from three sources.	Gathered relevant information from five sources.
Model of Mission Component	Does not accurately depict actual device and/or is not neatly constructed.	Accurately depicts actual device and is neatly constructed.	Accurately depicts actual device and is neatly constructed and built to scale.
One-Page Explanation of Mission Component	Fails to explain how the component contributes to the overall mission goal of sample acquisition and retrieval. Addresses one of the three categories of natural resources: regolith materials, solar-wind-implanted volatiles, and possible polar ice deposits.	Accurately explains how the component contributes to the overall mission goal of sample acquisition and retrieval. Addresses at least two of the three categories of natural resources: regolith materials, solar-wind-implanted volatiles, and possible polar ice deposits.	Accurately explains how the component contributes to the overall mission goal of sample acquisition and retrieval and describes how the component interacts with other system components. Addresses all three categories of natural resources: regolith materials, solar-wind-implanted volatiles, and possible polar ice deposits.
Invention/ Innovation Component	Depicts and describes a new or modified version of a mission component but fails to explain how it enhances the sample acquisition and retrieval process.	Depicts and describes a new or modified version of a mission component and explains how it enhances the sample acquisition and retrieval process.	Demonstrates exceptional ingenuity in the design of a new or modified version of a mission component and explains how it enhances the sample acquisition and retrieval process.
Integration of Mission Component Model With the Class Display	Inaccurately depicts how the mission component contributes to overall lunar sample acquisition and retrieval process.	Accurately depicts how the mission component contributes to overall lunar sample acquisition and retrieval process.	Accurately depicts how the mission component contributes to overall lunar sample acquisition and retrieval process and describes links to other mission components.

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

Beattie, D.A. (2003). *Taking science to the Moon: Lunar experiments and the Apollo program*. Baltimore, MD: The Johns Hopkins University Press.

Clark, C. (2002). *Mining the Moon*. Hightstown, NJ: McGraw Hill.

LaFontaine, B. (2001). *Moon exploration fact and fantasy*. Mineola, NY: Dover Publications.

Audiovisual Materials

Spaceshots. (2008) *The Moon poster*. Retrieved April 20, 2008, from http://www.spaceshots.com/Merchant2/merchant.mvc?Screen=PROD&Product_Code=1360&Category_Code=220.

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NASA. (2008). *What would you find on the Moon?* Retrieved April 20, 2008, from http://ksnn.larc.nasa.gov/21Century/p10.html.

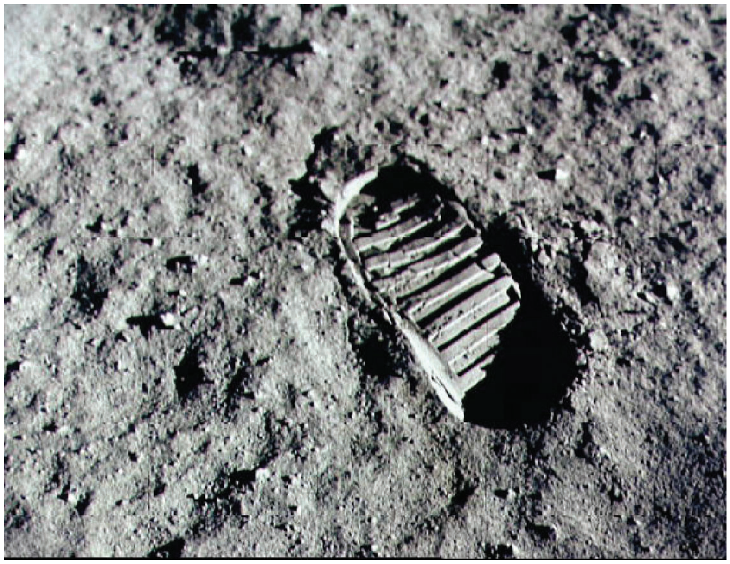
Required Knowledge and Skills

Students should have some understanding of what explorers will do on the Moon and the scientific and economic reasons for establishing a lunar outpost. They should also be familiar with the functioning and applications of the new vehicles NASA has designed for space exploration. They should have some basic graphic and research skills. In the engagement and exploratory phases of instruction, the teacher will identify student misunderstandings and/or misconceptions about the influence of technology on history.

Lesson 3: 5-E Lesson Plan

Engagement

1. The teacher asks students, "What would you find on the Moon's surface?"
2. Students share their ideas.
3. The teacher shows the class a picture of the Moon's surface.



The lunar regolith. This picture was taken on July 20, 1969 by Apollo 11 astronaut Buzz Aldrin (courtesy NASA: AS11-40-5878).

4. Students share their ideas about what the picture shows.
5. The teacher explains that, although the Moon appears to be a hostile, barren rock in space—it is actually our "stepping-stone" into the solar system.

Exploration

1. The teacher explains that a fine dust covers the top 10 cm of the Moon's surface and that this dust is the result of the bombardment of micrometeoroids that broke the Moon's rocks into very tiny pieces. There are various sized rocks mixed with the dust.
2. The teacher states that:
   a. The lunar surface is covered with a layer, or mantle, of fragmental, unconsolidated, and weathered rock and soil materials called the lunar regolith. The regolith can be tens of meters deep and overlies solid bedrock.
   b. Lunar regolith is about 20% metals, 20% silicon, and about 45% oxygen that is chemically bonded in the crystalline structure of various minerals.
   c. Oxygen as a gas could one day support a human base on the Moon and fuel vehicles designed to land on and launch from the Moon.
   d. Most of the particles in lunar regolith are very small (usually less than 0.1 millimeter across).
3. Students, working in groups, make a simulated regolith and observe its properties. See NASA Activity *Making Regolith*. NASA. (2008). *Making regolith*. Retrieved April 20, 2008, from <http://www.nasa.gov/pdf/146860main_Making_Regolith_Educator.pdf>.
4. Students develop a conclusion by making inferences about the properties of the regolith based on their observations.

Explanation

1. The student groups present their ideas from the ***Exploration*** activity to the class and respond to questions.
2. The teacher leads a discussion of the functioning and application of sample acquisition and retrieval systems.
3. The teacher explains that to live on the Moon and at destinations beyond, we must identify resources that will support human life and enable the creation of a new space exploration infrastructure.
4. The teacher describes how advances and innovations in medical technologies are used to maintain the health of space travelers.
5. The teacher explains that there are a number of reasons for further exploration of the Moon, such as:
   a. Future settlement and habitation of the Moon.
   b. Scientific inquiry.
   c. Resource utilization.
   d. Cultivation of international partnerships.
   e. Development of commerce.
   f. Public engagement with the space program.
6. The teacher discusses a few examples of scientific inquiry.
   a. Study of the chemical and physical nature of the Moon's regolith, the name given to the layer of unconsolidated material at the surface of a planet—the loose stuff that overlies the solid rock.
   b. The regolith contains solar-wind-implanted elements (i.e., H, He, C, O, N, and S) that act as a "tape recorder" of the Sun's output for the past 4.5 billion years.
   c. The collection and study of impact melt rocks to age-date craters and get information about the history of the Moon.
7. The teacher discusses resource utilization. These natural resources fall into three categories: regolith materials, solar-wind-implanted, volatiles, and possible solar ice deposits.
   a. Regolith materials (Moon rocks and dust).
      i. On Earth, soil is part of the regolith, and lunar regolith is consequently often called "soil."
      ii. Lunar regolith is composed in part of rock and mineral fragments that were broken apart from underlying bedrock by the impact of meteorites.
      iii. Since the regolith is already crushed into fine particles (by impact processes), it would be easier to mine and process the rocks.
      iv. By mining and processing the Moon's regolith, we could get oxygen to breathe, water to drink, and rocket propellant.
      v. Areas of the regolith are rich in iron and aluminum (in feldspars) that could be used for future construction projects on the Moon, eliminating the need to transport materials from the Earth.
      vi. Lunar dust is almost like tiny fragments of glass or coral—odd shapes that are very sharp and lock together.
      vii. A process called carbothermal reduction may enable the manufacture of oxygen from lunar materials at the Moon's polar regions where solar energy is plentiful.
   b. The teacher discusses solar-wind-implanted volatiles.
      i. Solar wind is a stream of charged particles (i.e., a plasma) that are ejected from the upper atmosphere of a star.
      ii. Volatiles are substances that are gases at ordinary temperatures. In astronomy, they include hydrogen, helium, water, ammonia, carbon dioxide, and methane.

        iii. Earth itself is protected from the solar wind by its magnetic field, which deflects charged particles.
        iv. Because the Moon has no global magnetic field, and the solar wind ions are moving fast, they are imbedded or implanted into the surface material of the Moon.
        v. They do not penetrate very deep into a rock or mineral grain, only a few hundredths of a micrometer, so all the solar-wind-implanted atoms are at the very surface of lunar regolith grains.
        vi. Meteorite impacts stir the surface regolith so that the upper few meters of regolith are rich in implanted ions of hydrogen and helium.
        vii. The amount of solar-wind implanted ions is greater in the very finest material because the fine material has more surface area than the coarser material.
        viii. Studies of the volatile elements (i.e., H, He, C, O, N, and S), abundances, and isotopic compositions in extraterrestrial materials help us understand the evolution of volatiles on other bodies in our solar system.
    c. Possible Lunar Polar Ice
        i. We have known for many years that the Moon has no atmosphere and hence, no stable surface water.
        ii. Some evidence suggests that water ice exists in permanently dark areas near the poles.
        iii. Crater floors near the poles of the Moon are permanently dark and very cold, receiving heat only from space and the interior of the Moon (a cold, geologically dead object.). Craters are permanently shadowed only at the poles. This is because the Moon's axis of rotation is almost perpendicular to the ecliptic plane, and the Moon is not tilted enough to let sunshine into the bottom of polar craters (unlike our Earth's axis of rotation with a tilt of 23.5 degrees).
        iv. Such a combination makes a "cold trap," where ice remains stable for geological time spans.
        v. As water-bearing comets and meteorites were known to strike the Moon, the slow addition of water—molecule by molecule—could result in large quantities of ice over the multibillion-year history of the Solar System.
        vi. Water ice on the Moon would make living there easier, cheaper, and thus, more likely.
        vii. Because there is no atmosphere to scatter light at the poles, high elevation areas that are always sunlit are prime sites for solar energy applications.
        viii. Most of the Moon has days of darkness followed by 14 days of light, so solar energy is most likely to be effective in the polar areas.

8. The teacher explains that now that we have some understanding of the scientific and resource utilization possibilities, it is time to consider how we might collect, protect, and transport samples of lunar materials.
9. The teacher explains that:
    a. On missions with people, we can bring back about 100 kilograms of materials.
    b. Samples must be placed in airtight containers to seal in the vacuum of the lunar environment. (For example, our warm, moist air would cause iron to rust.)
    c. Samples must be kept separate from each other to prevent contamination; for example, they may be placed in individual sample bags inside airtight containers.
10. Students clarify their understanding of concepts by asking questions.

Extension

Students are assigned to project teams that are assigned the job of developing a subsystem for a Moon-bound manned spacecraft. Students use the engineering design process to develop their system while working with other design teams to negotiate trade-offs. Scale models and written descriptions of each system are produced and evaluated.

Evaluation

Student knowledge, skills, and attitudes are assessed using brief constructed responses and rubrics for class participation, group work, and the three-dimensional model of one of the system components, along with a one-page explanation of how the component works. 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.

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, and research activities. The teacher adapts the learning environment based on the requirements of the unit or lesson. For this lesson, areas for lectures and demonstrations, design, small-group meetings, and fabrication activities should be readied.

Tools/Materials/Equipment

- Computers with Internet access
- Microscopes or magnifiers
- Shoe boxes
- Copy paper boxes
- Cinnamon-sugar graham crackers
- White powdered sugar cake minidonuts
- Clear packing tape
- Design tools
- Fabrication tools 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.

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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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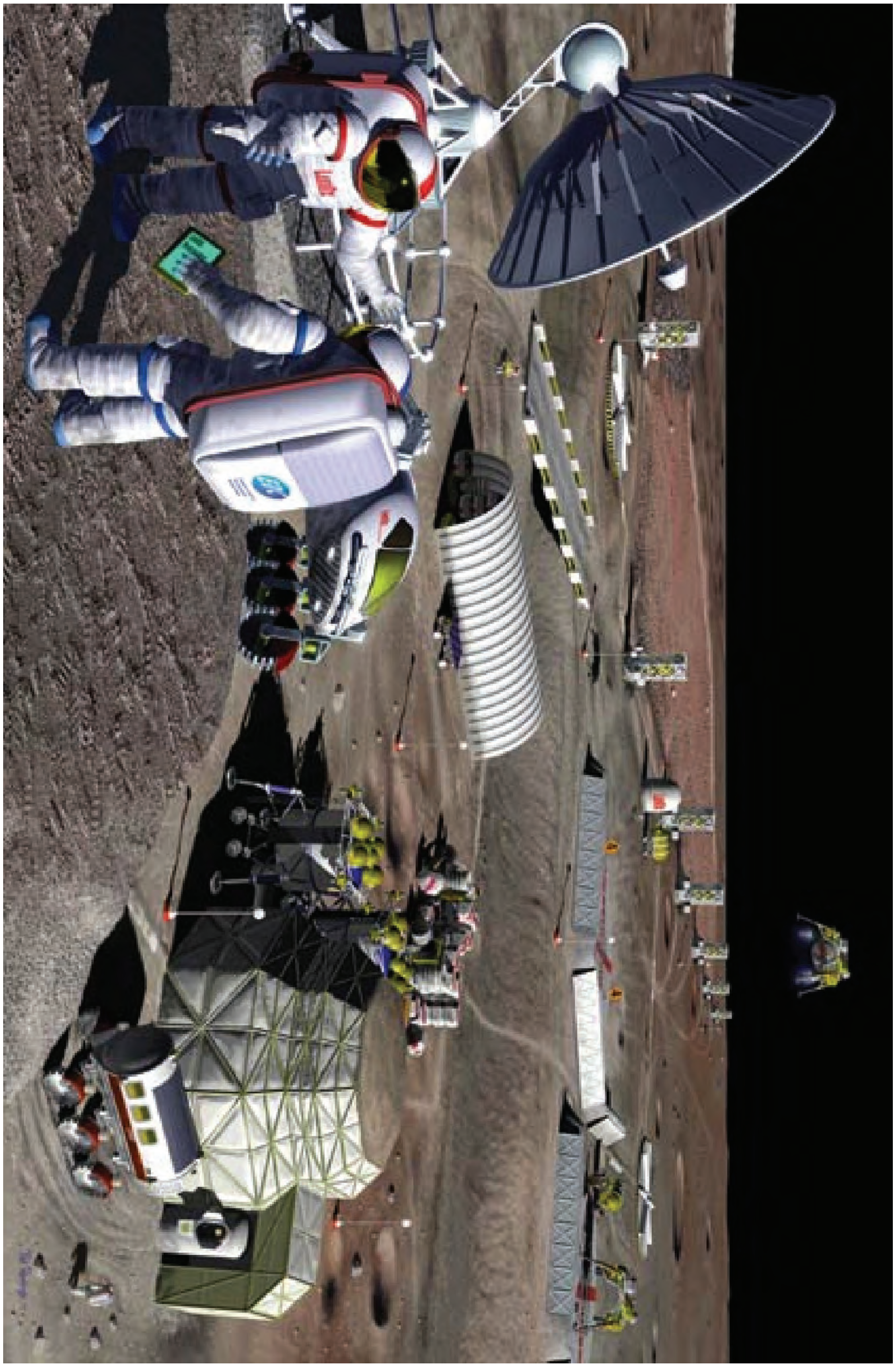
Appendices
Resource Documents

Moon/Earth Comparison Sheet

Bulk Parameter	Moon	Earth	Ratio (Moon/ Earth)	% (Moon/ Earth)	Mass (1024 kg)
Volume (10^{10} km^3)					
Equatorial Radius (km)					
Mean density (kg/m^3)					
Surface gravity (m/s^2)					

National Space Science Data Center (NSSDC). (2008). *Moon fact sheet.* Retrieved April 20, 2008, from <http://nssdc.gsfc.nasa.gov/planetary/factsheet/moonfact.html>.

NASA Conceptualized Lunar Outpost



NASA. (2008) *Entering a lunar outpost*. Retrieved April 20, 2008, from <http://www.nasa.gov/mission_pages/exploration/multimedia/jfa18833_prt>.

Vignette
A Renewed Spirit of Discovery

Today, humanity has the potential to seek answers to the most fundamental questions posed about the existence of life beyond Earth. Telescopes have found planets around other stars. Robotic probes have identified potential resources on the Moon, and evidence of water—a key ingredient for life—has been found on Mars and the moons of Jupiter.

Direct human experience in space has fundamentally altered our perspective of humanity and our place in the universe. Humans have the ability to respond to the unexpected developments inherent in space travel and possess unique skills that enhance discoveries. Just as Mercury, Gemini, and Apollo challenged a generation of Americans, a renewed U.S. space exploration program with a significant human component can inspire us—and our youth—to greater achievements on Earth and in space.

The loss of Space Shuttles Challenger and Columbia and their crews are a stark reminder of the inherent risks of space flight and the severity of the challenges posed by space exploration. In preparation for future human exploration, we must advance our ability to live and work safely in space and, at the same time, develop the technologies to extend humanity's reach to the Moon, Mars, and beyond. The new technologies required for further space exploration also will improve the Nation's other space activities and may provide applications that could be used to address problems on Earth.

Like the explorers of the past and the pioneers of flight in the last century, we cannot today identify all that we will gain from space exploration; we are confident, nonetheless, that the eventual return will be great. Like their efforts, the success of future U.S. space exploration will unfold over generations.

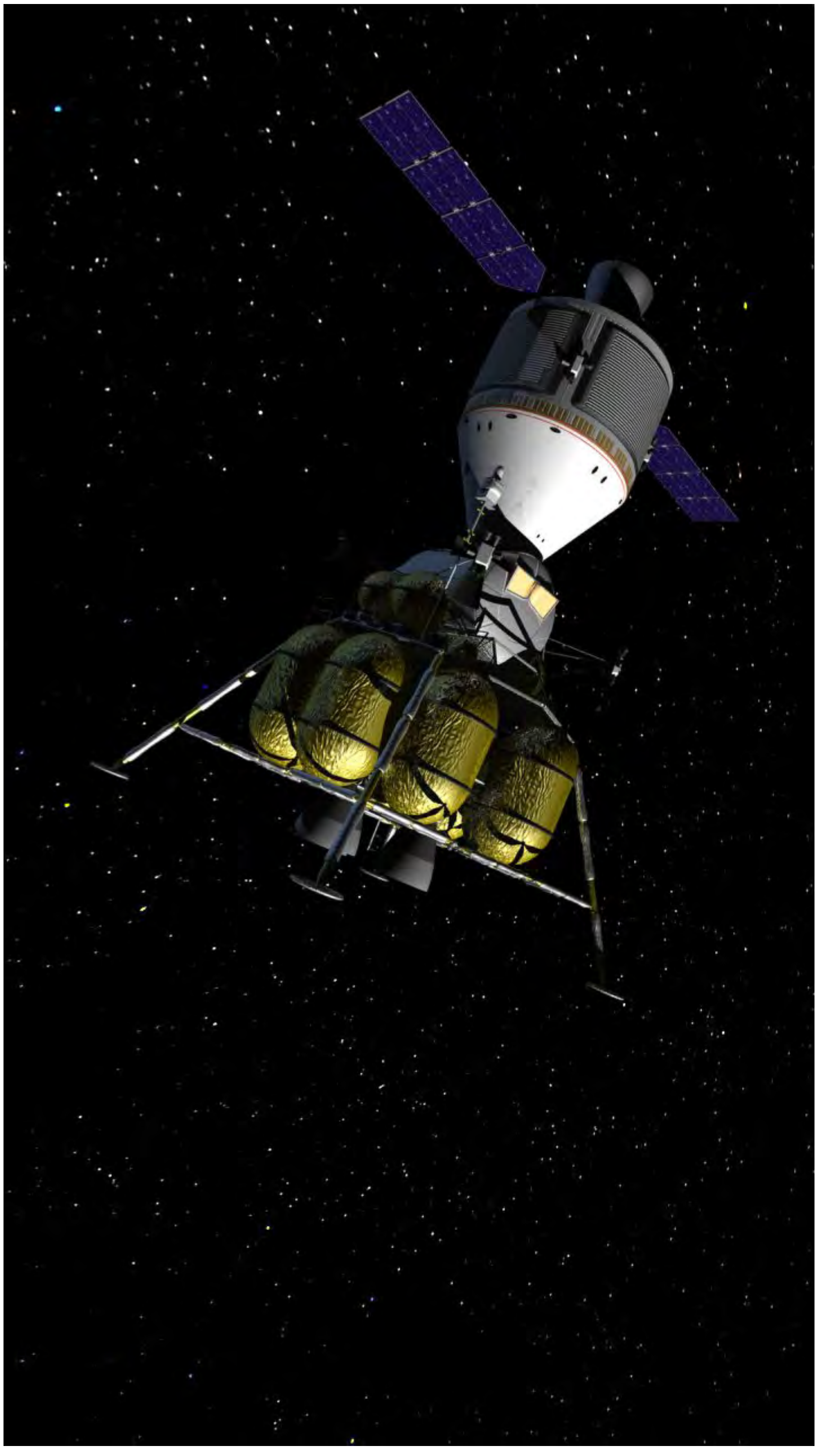
Goals and Objectives

The fundamental goal of this vision is to advance U.S. scientific, security, and economic interests through a robust space exploration program. In support of this goal, the United States will do the following:

- Implement a sustained and affordable human and robotic program to explore the solar system and beyond;
- Extend human presence across the solar system, starting with a human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations;
- Develop the innovative technologies, knowledge, and infrastructures both to explore and to support decisions about the destinations for human exploration; and
- Promote international and commercial participation in exploration to further U.S. scientific, security, and economic interests.

The White House. (14 January 2004). *A renewed spirit of discovery.* From a speech by George W. Bush. Retrieved April 20, 2008, from <http://www.whitehouse.gov/space/renewed_spirit.html>.

Image
Ares I CEV



NASA. (2008). *NASA's new Crew Exploration Vehicle and lander head for orbit*. Retrieved October 9, 2008, from <http://www.nasa.gov/images/content/123121main_docked_full.jpg>.

Image
Ares I and Ares V

NASA. (2008). *Ares I Crew Launch Vehicle and Ares V Cargo Launch Vehicle.* LG-2008-11-152-MSFC (5-389268).

NASA's Ares Projects — Ares I Crew Launch Vehicle and Ares V Cargo Launch Vehicle

Launchers for the Next Phase of American Space Exploration

The Ares I crew launch vehicle and Ares V cargo launch vehicle will transport explorers to the Moon, and then onward to Mars and other destinations in the solar system. These systems are being designed for safer, more reliable, and more cost-effective operations.

Building on Powerful, Proven Hardware

The Ares I and the Ares V launch vehicles feature common hardware derived from the Apollo Saturn, Space Shuttle, and other programs. The Ares I will loft the Orion crew exploration vehicle into orbit early next decade. It comprises a Shuttle-legacy 5.5-segment Reusable Solid Rocket Booster (RSRB) first stage and a new upper stage powered by the J-2X liquid oxygen/liquid hydrogen (LOX/LH_2) engine with heritage from the Saturn rocket's J-2 engine. The Ares I/Orion in-line configuration includes a launch abort system to move the crew swiftly away from the rocket in the event of an emergency, significantly improving astronaut safety.

The Ares V will lift the Altair lunar lander into orbit late next decade. The Ares V first stage comprises two 5.5-segment RSRBs, which are similar to the Ares I first stage, and a core stage propulsion system consisting of a Saturn-class 33-foot-diameter tank delivering LOX/LH_2 to a cluster of six commercially available RS-68 main engines. The Ares V second stage, known as the Earth departure stage (EDS), transports the Altair lunar lander to low-Earth orbit. The EDS is powered by the same J-2X engine powering the Ares I upper stage.

Expanding Horizons

For lunar missions, the Ares I and Ares V will work in concert to send people to the Moon. The Ares V heavy-lift system will loft Altair, equipment, and supplies needed to work on the Moon.

The Ares I will launch the crew into space. After the first stage is jettisoned, the Ares I upper stage will ignite its J-2X engine to place Orion into orbit. Once Orion reaches orbit, it will rendezvous and dock with Altair and the Earth departure stage. After checking out all systems, the Earth departure stage's J-2X engine will perform a translunar injection burn, and then Orion and the lander are off to the Moon.

With its roots in the Saturn V and the Space Shuttle, and its future in traveling to the Moon and Mars, the Ares I and Ares V will help America achieve the next step toward expanding knowledge through space exploration.

A Nationwide Team

The Ares development effort is a government and industry partnership, led by Ares Projects at NASA's Marshall Space Flight Center in Huntsville, AL, under the direction of the Constellation Program at NASA's Johnson Space Center in Houston, TX, and the Exploration Systems Mission Directorate at NASA's Headquarters in Washington, DC.

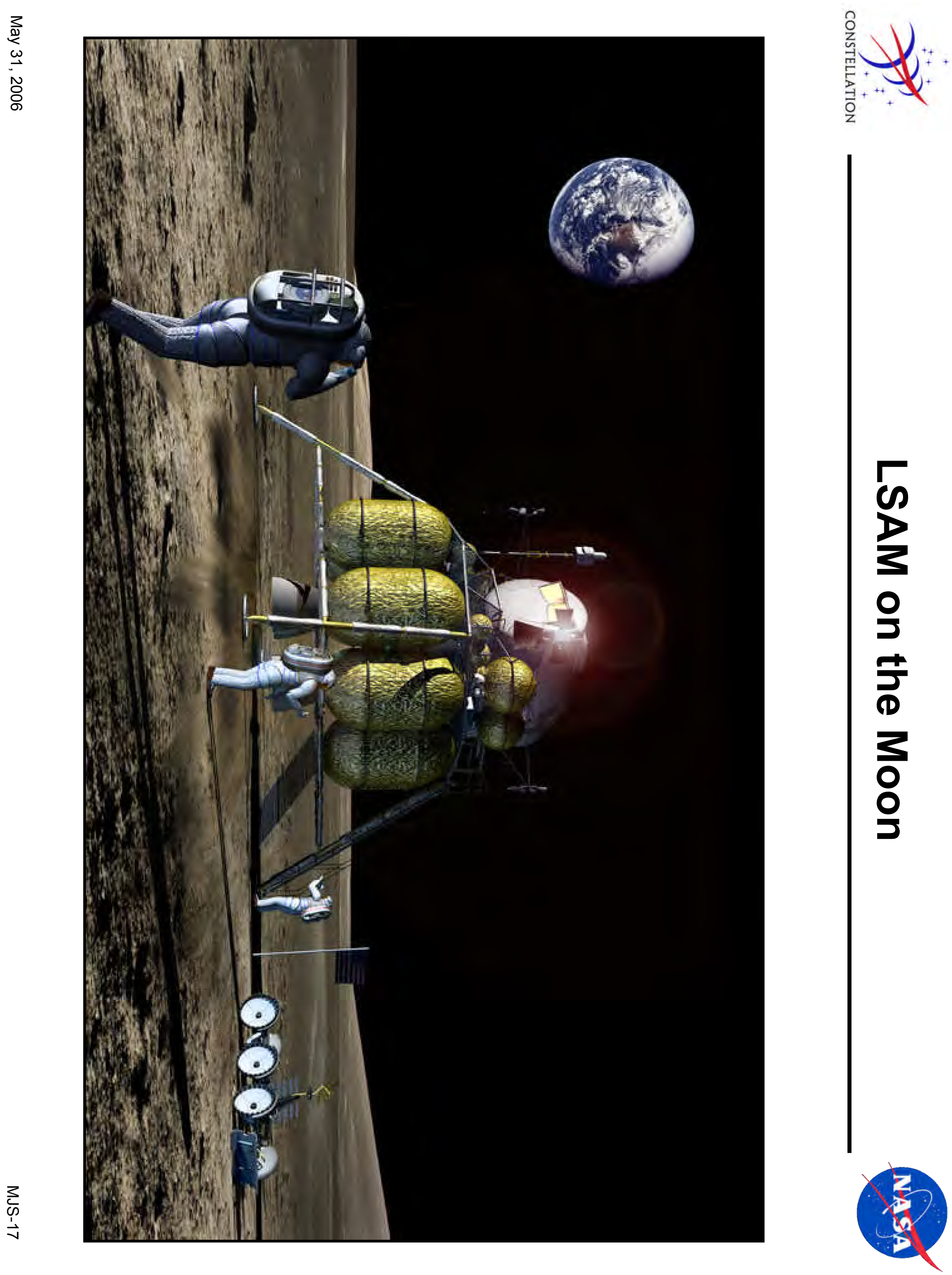
For more information see: **www.nasa.gov/ares**

LG-2008-11-152-MSFC (5-389268)
November 2008

NASA. (2008). *Ares I Crew Launch Vehicle and Ares V Cargo Launch Vehicle.* LG-2008-11-152-MSFC (5-389268).

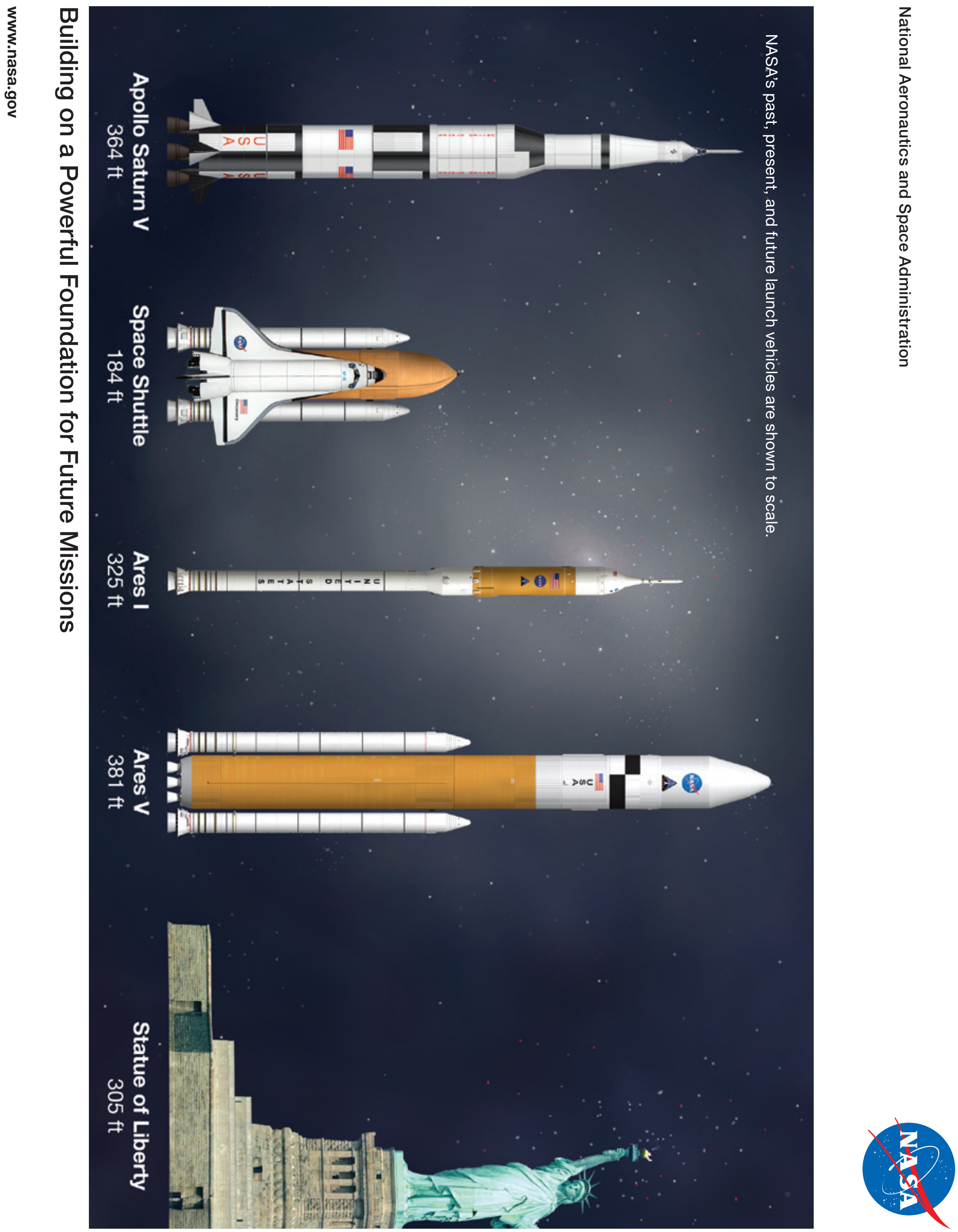
Image

Lunar Lander



Sander, M. (2006). *The Nation's Vision for exploration—an update.* Retrieved October 9, 2008, from <http://acquisition.jpl.nasa.gov/boo/2006Hightechpresentations/The%20Nations%20Vision%20for%20Exploration.pdf>, p.17.

Image
NASA's Past, Present, and Future Launch Vehicles



NASA. (2008). *NASA's past, present, and future launch vehicles are shown to scale.* LG-2008-11-131-MSFC (5-337440).

NASA's Ares Projects—Building on a Powerful Foundation for Future Missions

NASA is building a new generation of launch vehicles based on a foundation of hard-won experience and proven, reliable hardware to increase the probability of mission success.

NASA's know-how will enable America to build a permanent outpost on the Moon to prepare for the first human footprint on Mars. NASA's crew launch vehicle — the Ares I — and cargo launch vehicle — the Ares V — will transport astronauts and heavy equipment to orbit for journeys to the Moon, Mars, and beyond.

On Solid Footing

To make these new launch systems safer and simpler, NASA is using proven technologies from the Apollo Saturn V, Space Shuttle and other launch vehicles. Common propulsion elements between the two systems will reduce operations costs to promote the long-term investigation of Earth's cosmic neighborhood and worlds beyond.

The Ares I includes a five-segment first stage evolved from the Shuttle's reusable solid rocket booster and an upper stage powered by a J-2X engine, with heritage from the Saturn V. The Ares I will carry the Orion crew exploration vehicle to Earth orbit.

The Ares V propulsion includes two five-and-a-half-segment solid rocket boosters, much like the booster used in the Ares I's first stage. It also uses six commercial RS-68 engines fueled by a 33-foot-diameter tank that will be longer than the Saturn V first stage. The Earth departure stage, which transports the Altair lunar lander and Orion toward the Moon, is powered by a J-2X engine, the same engine used for the Ares I's upper stage.

In this artist's concept, an astronaut gathers samples on the surface of Mars, while a robotic explorer stands by to help. The Global Exploration Strategy calls for human and robotic missions that will return to the Moon and eventually explore Mars and beyond.

Learning From Space

The Ares I will loft astronauts in the Orion to the *International Space Station* by 2015. Late next decade, the Ares I and Ares V combination will empower a new age of exploration, beginning with America's establishment of an outpost on the Moon to prepare for longer trips to Mars.

Safe, reliable, affordable launch vehicle systems will help NASA focus its resources on the cutting-edge science that space transportation makes possible.

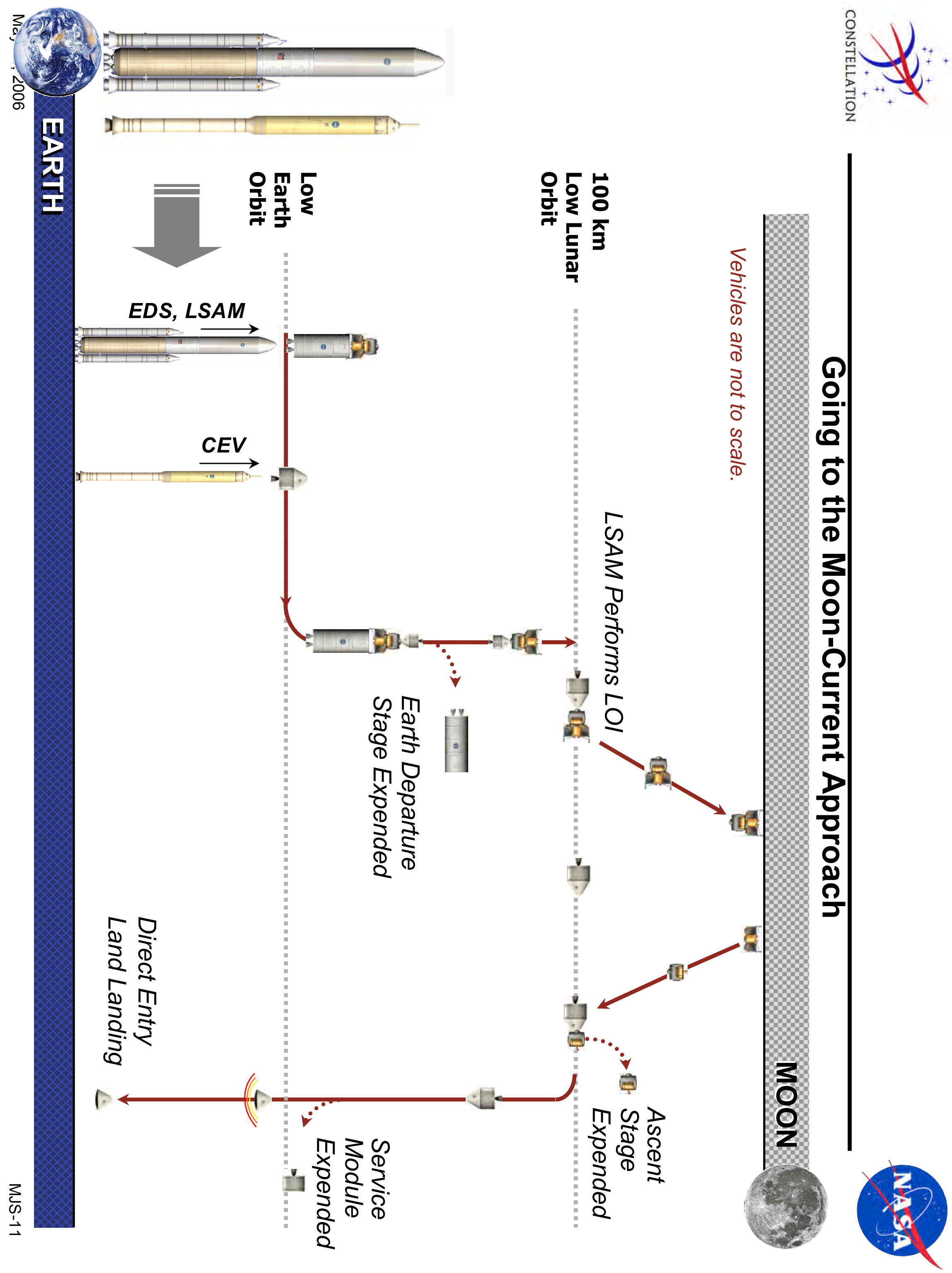
For more information see: **www.nasa.gov/ares**

LG-2008-11-131-MSFC (5-337440)
November 2008

NASA. (2008). *NASA's past, present, and future launch vehicles are shown to scale.* LG-2008-11-131-MSFC (5-337440).

Image

Going to the Moon: Current Approach



Sander, M. (2006). *The Nation's Vision for exploration—an update.* Retrieved October 9, 2008, from <http://acquisition.jpl.nasa.gov/boo/2006Hightechpresentations/The%20Nations%20Vision%20for%20Exploration.pdf>, p.11.

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