National Aeronautics and Space Administration

Transportation and Space: Reuse and Recycle

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: ***Technological Issues and Impacts.***

HS-10-12

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

Educational Product	
Educators	Grades 10–12

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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 Grades 10–12. While there are no prerequisites, prior experience in technological literacy through Technology Education is helpful.

Preface

Transportation and Space: Reuse and Recycle
A Standards-Based High School Unit

Acknowledgments

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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 email <ebd@iteaconnect.org> or call 703–860–2100.

Transportation and Space: Reuse and Recycle

Table of Contents

Transportation and Space: Reuse and Recycle

Transportation and Space: Reuse and Recycle A Standards-Based High School Unit

Unit Overview

Big Idea

When humans colonize space, they will need to adapt the technologies and processes of disposing and using waste and natural resources to overcome the challenges of this new environment.

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)
  - Inventions and innovations are the results of specific, goal-directed research. (1L)
  - Most development of technologies these days is driven by the profit motive and the market. (1M)
- Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study. (ITEA/*STL* 3)
  - Technological ideas are sometimes protected through the process of patenting. (3I)
- Students will develop an understanding of the cultural, social, economic, and political effects of technology. (ITEA/*STL* 4)
  - Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects. (4I)
  - Ethical considerations are important in the development, selection, and use of technologies. (4J)
- Students will develop an understanding of effects of technology on the environment. (ITEA/*STL* 5)
  - Humans can devise technologies to conserve water, soil, and energy through such techniques as reusing, reducing and recycling. (5G)
  - Decisions regarding the implementation of technologies involve the weighing of trade-offs between predicted positive and negative effects on the environment. (5L)
- Students will develop an understanding of the role of society in the development and use of technology. (ITEA/*STL* 6)
  - The decision whether to develop a technology is influenced by societal opinions and demands, in addition to corporate cultures. (6I)
- Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving. (ITEA/*STL* 10)
  - Technological problems must be researched before they can be solved. (10J)
- Students will develop an understanding of and be able to select and use information and communication technologies. (ITEA/*STL* 17)
  - Information and communication systems can be used to inform, persuade, entertain, control, manage, and educate. (17N)

  - There are many ways to communicate information, such as graphic and electronic means. (17P)
- Students will develop an understanding of and be able to select and use transportation technologies. (ITEA/*STL* 18)
  - 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)**

- Compute fluently and make reasonable estimates. (NCTM, Number and Operations, Grades 9–12)
  - Judge the reasonableness of numerical computations and their results.
- Use mathematical models to represent and understand quantitative relationships. (NCTM, Algebra, Grades 9–12)
  - Draw reasonable conclusions about a situation being modeled.
- 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)
  - Understand and use formulas for the area, surface area, and volume of geometric figures, including cones, spheres, and cylinders.
- 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)***

- The Scientific Enterprise (AAAS, 1 C, Grades 9–12)
  - Progress in science and invention depends heavily on what else is happening in society, and history often depends on scientific and technological developments.
- The Nature of Technology and Science (AAAS, 3 A, 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.
- Human Identity (AAAS, 6 A, Grades 9–12)
  - Written records and photographic and electronic devices enable human beings to share, compile, use, and misuse great amounts of information and misinformation. No other species uses such technologies.

** 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.*

Language Arts:* Standards for the English Language Arts *(NCTE, 1996)

- Students read a wide range of print and nonprint texts to build an understanding of texts, of themselves, and of the cultures of the United States and the world; to acquire new information; to respond to the needs and demands of society and the workplace; and for personal fulfillment. Among these texts are fiction and nonfiction, classic and contemporary works. (NCTE, Standard 1)
- Students apply a wide range of strategies to comprehend, interpret, evaluate, and appreciate texts. They draw on their prior experience, their interactions with other readers and writers, their knowledge of word meaning and of other texts, their word identification strategies, and their understanding of textual features (e.g., sound-letter correspondence, sentence structure, context, graphics). (NCTE, Standard 3)
- Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and nonprint texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience. (NCTE, Standard 7)
- Students use a variety of technological and information resources (e.g., libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge. (NCTE, Standard 8)
- Students use spoken, written, and visual language to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information). (NCTE, Standard 12)

Purpose of Unit

This unit encourages students to think about space exploration as an activity that will require humans to "live off the land" and use any resources available, whether natural or man-made.

Unit Objectives

Lesson 1: Introduction to Space Resources

Students will learn to:

- Explain that most development of technologies these days is driven by the profit motive and the market.
- Explain that technological problems must be researched before they can be solved.
- Describe how governmental regulations often influence the design and operation of transportation systems.
- Explain how making decisions about units and scales that are appropriate for problem situations involve measurement.
- Describe how to judge the reasonableness of numerical computations and their results. (NCTM Number and Operations)
- Contribute to a group endeavor by offering useful ideas, supporting the efforts of others, and focusing on the task.
- Actively participate in group discussions, ideation exercises, and debates.

Lesson 2: Commercialization of Space

Students will learn to:

- Describe how inventions and innovations are the results of specific, goal-directed research.
- Explain that most development of technologies these days is driven by the profit motive and the market.
- Explain that technological ideas are sometimes protected through the process of patenting.
- Provide examples of how making decisions about the use of technology involves weighing the trade-offs between positive and negative effects.
- Explain that the decision whether to develop a technology is influenced by societal opin-

ions and demands, in addition to corporate cultures.
- Describe how governmental regulations often influence the design and operation of transportation systems.
- Explain that 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.
- Describe how to judge the reasonableness of numerical computations and their results.
- Explain the differences among various kinds of studies and which types of inferences can legitimately be drawn from each.
- Contribute to a group endeavor by offering useful ideas, supporting the efforts of others, and focusing on the task.
- Actively participate in group discussions, ideation exercises, and debates.

Lesson 3: Reuse and Recycle Man-Made Resources

Students will learn to:

- Explain that ethical considerations are important in the development, selection, and use of technology.
- Provide examples of how humans can devise technologies to conserve water, soil, and energy through such techniques as reusing, reducing, and recycling.
- Describe how decisions regarding the implementation of technologies involve the weighing of trade-offs between predicted positive and negative effects on the environment.
- Describe how information and communication systems can be used to inform, persuade, entertain, control, manage, and educate.
- Describe the many ways to communicate information, such as graphic and electronic means.
- Explain how transportation plays a vital role in the operation of other technologies, such as manufacturing, construction, communication, health, safety, and agriculture.
- Explain that 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.
- Explain that written records and photographic and electronic devices enable human beings to share, compile, use, and misuse great amounts of information and misinformation. No other species uses such technologies.
- Explain how making decisions about units and scales that are appropriate for problem situations involve measurement.
- Describe how to use formulas for the volume of geometric figures, such as spheres and cylinders.
- Describe how to judge the reasonableness of numerical computations and their results.
- Explain how to draw reasonable conclusions about a situation being modeled.
- 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.
- Actively participate in group discussions, ideation exercises, and debates.

Student Assessment Tools and/or Methods

- A ***Unit Pre/Post Test*** is provided that includes questions from each lesson. It represents the knowledge assessment component for each lesson, but it may be used as a preassessment tool.
- The ***Pre/Post Test Answer Key*** can be used to verify correct answers.
- Assessment for each lesson includes a quiz, and rubrics will be used for group work and/or the research, analysis, and presentation.

Teacher Preparation and Resources

Teacher preparation for this unit includes the following:

- Review the three lessons, and then review the optional extension activity at the end of the unit. This activity requires students to know advanced mathematics applications and can be added if time permits. It is not meant to replace any of the lessons.
- View the Launch Vehicle Comparisons (***Lesson Resource 1.2***) and the Ares Launch Vehicle Elements (***Lesson Resource 1.3***) to become familiar with NASA's future space transportation architecture. Several resources are listed with each lesson that may be reviewed as well.
- Gather references and compile a list of suggested Internet sites to visit. As students discover good references, Internet sites, films/documentaries, etc., the teacher should add these to the list to develop a database.
- Research space debris on the Internet. Visit the NASA Orbital Debris Program Office and the Center for Orbital and Reentry Debris Studies.
- Discuss with other teachers what students are studying in their classes, including history, economics, social studies, science, mathematics, and other technology classes, and consider how those concepts are related to technological issues.
- Gather examples of technological issues related to space transportation that are current from news articles or media presentations.
- Review the 5E Lesson Plan for Lessons 1–3.
- Make copies of the assignments and the worksheets for each student or group (one page, double-sided if need be).

Lesson 1: Introduction to Space Resources

Lesson Snapshot

Overview

Big Idea: The most successful human exploration efforts on Earth have always required that explorers "live off the land."

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 identify the natural and man-made resources existing in space.

Lesson Duration: Two hours.

Activity Highlights

Engagement: Students become familiar with NASA's future space exploration plans. The teacher addresses the idea of technology transfer and asks the students what a human crew would need to take with them for a two-week trip to the Moon.

Exploration: Students begin with the statement, "In the past, explorers found it easier to 'live off the land.' This allowed them to travel in smaller, lighter vehicles." Working with a partner, students research the natural and man-made resources that may be available on the lunar surface.

Explanation: The teacher explains that technological problems must be researched, using the Constellation Program as an example. The teacher explains that most technological development these days is driven by the profit motive and the market. Future entrepreneurs will discover ways to use the natural and man-made resources. The teacher helps students determine the chemical makeup of lunar rocks and regolith. The teacher explains that governmental regulations often influence the design and operation of transportation systems. The teacher explains that progress in science and invention depends heavily on what else is happening in society, and history often depends on scientific and technological developments.

Extension: Working with a partner, students list the natural and man-made resources they discovered and determine whether there is just enough for survival or if there would be a surplus.

Evaluation: Student knowledge, skills, and attitudes are assessed using selected response items, rubrics for class participation, and rubrics for research/analysis to determine their success at completing the ***Available Resources Survey.***

Enrichment:

1. Research the 20+ missions to land on the Moon, listing all experiments and hardware left behind.
2. Brainstorm various businesses that could be started on the Moon to help meet the needs of future colonists.
3. Read Jules Verne's *From the Earth to the Moon* and *Round the Moon*, then report to the class how Verne pictured a trip to the Moon.
4. Search for information that would be helpful in determining the safety of tanks and other materials exposed to long-term hard radiation.
5. Research the Lewis and Clark expedition to identify what resources the explorers brought with them and what resources they found along the trail.

Lesson 1: Overview

Lesson Duration

- Two 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)
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- Students use spoken, written, and visual language to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information). (NCTE, Standard 12)

Learning Objectives

Students will learn to:

1. Explain that most development of technologies these days is driven by the profit motive and the market.
2. Explain that technological problems must be researched before they can be solved.
3. Describe how governmental regulations often influence the design and operation of transportation systems.
4. Explain how making decisions about units and scales that are appropriate for problem situations involve measurement.
5. Describe how to judge the reasonableness of numerical computations and their results.
6. Contribute to a group endeavor by offering useful ideas, supporting the efforts of others, and focusing on the task.
7. Actively participate in group discussions, ideation exercises, and debates.

Student Assessment Tools and/or Methods

1. Quiz (***Unit Pre/Post Test***)

2. Rubric for Group Work
   Teacher's Note: Teachers may choose to use this rubric as a way to assess students, with or without making it a basis for student grades.

Category	Below Target	At Target	Above Target
Participation	Seldom participated. Did very little work.	Cooperative. Did his/her part of the work. Often offered useful ideas.	Was always willing to do more. Routinely offered useful ideas.
Reliability	Did not have work done on time. Did not show up when the group met.	Group members could count on him/her.	Went beyond what was expected of him/her.
Attitude	Did not support group members. Did not share information. Had little interest in success of the group.	Supported efforts of others. Served to facilitate rather than disrupt the group work.	Listened to and shared ideas with others. Was very self-directed.

3. Rubric for Research/Analysis
   Teacher's Note: Teachers may choose to use this rubric as a way to assess students, with or without making it a basis for student grades.

Category	Below Target	At Target	Above Target
Variety of Sources	Used very few or insufficiently varied sources.	Used multiple sources with multiple perspectives.	Used many sources with a variety of viewpoints.
Documentation	Offered little or inadequate documentation.	All sources were documented properly.	Documentation was well developed and referenced.
Reflection	Analysis showed little effort.	Analysis was thorough and well thought out.	Analysis was exceptionally well thought out and showed keen insight.

4. Assessment Totals

Element	Criteria	Points Possible	Earned Assessment Self / Teacher
Quiz	As per above		
Group Work	As per above		
Research/ Analysis	As per above		

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.

Audiovisual Materials or Packets

The Futures Channel. (2008). *Living and working in space. Spaceports; Space architecture; The Orion space capsule; Revisiting the Moon*. Retrieved April 2, 2008, from <http://www.thefutureschannel.com/living_working_space.php>.

NASA. (n.d.) *Launching to the Moon and beyond* [Presentation]. Retrieved November 19, 2008 from <http://www.nasa.gov/pdf/221420main_Amb_Briefing_STD_noMovie.pdf>.

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Center for Orbital and Reentry Debris Studies. (2005, February 16). Retrieved April 2, 2008, from <http://www.aero.org/capabilities/cords/debris-basics.html>.

NASA Orbitial Debris Office. (2005, April 29). Retrived April 2, 2008, from <http://orbital debris.jsc.nasa.gov/>.

Technovelgy.com (2007, May 16). *Used spacecraft lot needed on Moon*. Retrieved April 2, 2008, from <http://www.technovelgy.com/ct/Science-Fiction-News.asp?NewsNum_1031>.

Wikipedia.org (2008, March 25). *List of artificial objects on the Moon*. Retrieved April 2, 2008, from <http://en.wikipedia.org/wiki/List_of_artivial_objects_on_the_Moon>.

Required Knowledge and Skills

Students should have the ability to research topics related to space and orbital debris on the Internet.

Lesson 1: 5-E Lesson Plan

Engagement

1. The teacher distributes a packet or gives a multimedia presentation to the class entitled *Launching to the Moon and Beyond*, to provide students with an introduction to the space transportation unit and a place to begin discussions.

NASA. (n.d.) *Launching to the Moon and beyond* [Presentation]. Retrieved November 19, 2008 from <http://www.nasa.gov/pdf/221420main_Amb_Briefing_STD_noMovie.pdf>.

The teacher informs students that:

   a. The space architecture they are looking at was designed to incorporate as many recommendations from the Columbia Accident Investigation Board as possible to ensure crew safety.
   b. The best characteristics of spacecraft and launch vehicles from NASA's past 50 years of research and development have been incorporated into the design.
   c. The Shuttle system is being retired due to safety concerns and to allow the private sector the opportunity to develop vehicles for space station resupply. It is also inadequate for future needs. The Shuttle is incapable of traveling beyond low Earth orbit.

2. The teacher addresses the idea of technology transfer, explaining how many technologies designed for space exploration are now used here on Earth.
3. The teacher asks the students what a human crew would need to take with them for a two-week trip to the Moon. Working with a partner, students identify those items that are necessary for human survival.

Exploration

1. Students begin with the statement: "In the past, explorers found it easier to 'live off the land.' This allowed them to travel in smaller, lighter vehicles."
2. Working with a partner, students research the natural and man-made resources that may be available on the lunar surface and determine whether human necessities for survival are contained in these resources. (***Lesson Resource 1.1***, Part 1)

Explanation

1. The teacher explains that technological problems must be researched before they can be solved. Using the Constellation Program as an example, the teacher describes the vehicles being designed to travel to the Moon, Mars, and beyond. The teacher shows students the Launch Vehicle Comparisons (***Lesson Resource 1.2***) and the Ares Launch Vehicle Elements (***Lesson Resource 1.3***). The teacher explains how the vehicles will travel to the Moon and beyond.
2. The teacher explains that most development of technologies these days is driven by the profit motive and the market. Future entrepreneurs will discover ways to use the natural and man-made resources that exist in space as well as on other planetary bodies and will need to judge the reasonableness of numerical computations and their results. Space resources include rocket/satellite parts; lack of pressure/vacuum; temperature extremes; magnetic fields; gravitational fields; microgravity environment; radiation; asteroids; rocks, minerals, and soils on planetary surfaces; planetary atmospheres; and planetary volatiles (such as liquids and gases), as well as other debris. (These resources will need to be addressed again and in greater depth in the Extension activity.)

3. The teacher helps students determine the chemical makeup of lunar rocks and regolith (soil) and describes the variety of man-made debris that is on the lunar surface. (Elements found on the Moon include aluminum, calcium, iron, magnesium, oxygen, silicon, and titanium.) (Man-made debris includes the Soviet Luna landers, U.S. Surveyor landers, Apollo descent stages and equipment, Soviet Lunakhod robotic rovers, and crashed spacecraft.) The teacher and students make decisions about units and scales that are appropriate for problem situations involving measurement and quantities of available elements.
4. The teacher explains that governmental regulations often influence the design and operation of transportation systems, particularly when the safety of the crew is involved. 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.
5. The teacher explains that progress in science and invention depends heavily on what else is happening in society, and history often depends on scientific and technological developments.

Extension

Working with a partner, students list the natural and man-made resources they discovered and determine whether there is just enough for survival or if there would be a surplus (which could be marketed) (***Lesson Resource 1.1***, Part 2). Students then research man-made debris that is on the lunar surface (***Lesson Resource 1.4***).

Evaluation

Student knowledge, skills, and attitudes are assessed using selected response items, rubrics for class participation, and rubrics for research/analysis to determine their success at completing the Available Resources Survey (***Lesson Resource 1.4***). 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. Research the 20+ missions to land on the Moon, listing all experiments and hardware left behind.
2. Brainstorm various businesses that could be started on the Moon to help meet the needs of future colonists.
3. Read Jules Verne's *From the Earth to the Moon* and *Round the Moon*, then report to the class how Verne pictured a trip to the Moon.
4. Search for information that would be helpful in determining the safety of tanks and other materials exposed to long-term hard radiation.
5. Research the Lewis and Clark expedition to identify what resources the explorers brought with them and what resources they found along the trail.

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, and research activities. The teacher adapts the learning environment based on the requirements of the unit or lesson. For this lesson, access to information gathering and research equipment as well as room for small-group and whole-class discussion should be readied.

Tools/Materials/Equipment

- Computers with Internet access
- Other reference materials
- Printers
- Presentation software/equipment

Classroom Safety and Conduct

1. Students use tools and equipment safely, maintaining a safety level for themselves and others in the laboratory-classroom.
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: Commercialization of Space

Lesson Snapshot

Overview

Big Idea: As humans traverse out into space, businesses will be formed to satisfy the explorers' needs, as long as those businesses can realize a return on their investments.

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 list available space resources and analyze their potential to generate a profit.

Lesson Duration: Three hours.

Activity Highlights

Engagement: Students search for the video or information about SpaceShipOne on the Internet and watch the clip or read the information.

Exploration: With their partners, students critically examine their lists of available resources from Lesson 1 (***Lesson Resource 1.1*** and ***Lesson Resource 1.4***).

Explanation: The teacher leads a discussion on how a business needs a plan in order to succeed. The teachers explains:

- Parts of the plan will include many trade-offs.
- There are differences among various kinds of studies concerning the success or failure of a business venture.
- Inventions and innovations are the result of specific, goal-oriented research, but some products and services will have negative as well as positive effects.
- Technological problems often create a demand for new scientific knowledge.
- Government regulations might also influence how a business operates.

Extension: Working with their partners, students analyze the list of resources to determine which ones have the greatest need, the greatest potential for profit, and the need for new inventions or innovations to make those resources useable.

Evaluation: Student knowledge, skills, and attitudes are assessed using selected response items, rubrics for class participation, and the research/analysis rubric to determine their success at completing the ***Resource Utilization Chart (Lesson Resource 2.3)***.

Enrichment: Research one of the space entrepreneurial companies, such as Rocketplane Kistler, LTD, Inc., Space Exploration Technologies, Virgin Galactic, Scaled Composites, LLC, and Begelow Aerospace, Inc. Report to the class, explaining how the company plans to use space to make a profit.

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 characteristics and scope of technology. (ITEA/*STL* 1)
  - Inventions and innovations are the results of specific, goal-directed research. (1L)
  - Most development of technologies these days is driven by the profit motive and the market. (1M)
- Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study. (ITEA/*STL* 3)
  - Technological ideas are sometimes protected through the process of patenting. (3I)
- Students will develop an understanding of the cultural, social, economic, and political effects of technology. (ITEA/*STL* 4)
  - Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects. (4I)
- Students will develop an understanding of the role of society in the development and use of technology. (ITEA/*STL* 6)
  - The decision whether to develop a technology is influenced by societal opinions and demands, in addition to corporate cultures. (6I)
- Students will develop an understanding of and be able to select and use transportation technologies. (ITEA/*STL* 18)
  - Governmental regulations often influence the design and operation of transportation systems. (18H)

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

- Compute fluently and make reasonable estimates. (NCTM, Number and Operations, Grades 9–12)
  - Judge the reasonableness of numerical computations and their results.
- 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)***

- The Nature of Technology and Science (AAAS, 3 A, 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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Language Arts:* Standards for the English Language Arts *(NCTE, 1996)

- Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and nonprint texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience. (NCTE, Standard 7)
- Students use a variety of technological and information resources (e.g., libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge. (NCTE, Standard 8)
- Students use spoken, written, and visual language to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information). (NCTE, Standard 12)

Learning Objectives

Students will learn to:

1. Describe how inventions and innovations are the results of specific, goal-directed research.
2. Explain that most development of technologies these days is driven by the profit motive and the market.
3. Explain that technological ideas are sometimes protected through the process of patenting.
4. Provide examples of how making decisions about the use of technology involves weighing the trade-offs between positive and negative effects.
5. Explain that the decision whether to develop a technology is influenced by societal opinions and demands, in addition to corporate cultures.
6. Describe how governmental regulations often influence the design and operation of transportation systems.
7. Explain that 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.
8. Describe how to judge the reasonableness of numerical computations and their results.
9. Explain the differences among various kinds of studies and which types of inferences can legitimately be drawn from each.
10. Contribute to a group endeavor by offering useful ideas, supporting the efforts of others, and focusing on the task.
11. Actively participate in group discussions, ideation exercises, and debates.

Student Assessment Tools and/or Methods

1. Quiz (***Unit Pre/Post Test***)

2. Rubric for Group Work
   Teacher's Note: Teachers may choose to use this rubric as a way to assess students, with or without making it a basis for student grades.

Category	Below Target	At Target	Above Target
Participation	Seldom participated. Did very little work.	Cooperative. Did his/her part of the work. Often offered useful ideas.	Was always willing to do more. Routinely offered useful ideas.
Reliability	Did not have work done on time. Did not show up when the group met.	Group members could count on him/her.	Went beyond what was expected of him/her.
Attitude	Did not support group members. Did not share information. Had little interest in success of the group.	Supported efforts of others. Served to facilitate rather than disrupt the group work.	Listened to and shared ideas with others. Was very self-directed.

3. Rubric for Research/Analysis

   Teacher's Note: Teachers may choose to use this rubric as a way to assess students, with or without making it a basis for student grades.

Category	Below Target	At Target	Above Target
Variety of Sources	Used very few or insufficiently varied sources.	Used multiple sources with multiple perspectives.	Used many sources with a variety of viewpoints.
Documentation	Offered little or inadequate documentation.	All sources were documented properly.	Documentation was well developed and referenced.
Reflection	Analysis showed little effort.	Analysis was thorough and well thought out.	Analysis was exceptionally well thought out and showed keen insight.

4. Assessment Tools

Element	Criteria	Points Possible	Earned Assessment Self / Teacher
Quiz	As per above		
Group Work	As per above		
Research/Analysis	As per above		

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.

Internet Sites

Bigelow Aerospace, LLC. (2008). Retrieved April 2, 2008 from <http://bigelowaerospace.com/>.

Center for Orbital and Reentry Debris Studies. (2005, February 16). Retrieved April 2, 2008, from <http://www.aero.org/capabilities/cords/debris-basics.html>.

NASA Orbital Debris Program Office. (2005, April 29). Retrieved April 2, 2008, from <http://orbitaldebris.jsc.nasa.gov/>.

Rocketplane Kistler, LTD, Inc. (2005). Retrieved April 2, 2008 from <http://www.rocketplanekistler.com/>.

Scaled Composites, LLC. (2008). Retrieved April 2, 2008 from <http://www.scaled.com/>.

Space Exploration Technologies. (2008). Retrieved April 2, 2008 from <http://www.spacex.com/>.

Technovelgy.com. (2007, May 16). *Used spacecraft lot needed on Moon*. Retrieved April 2, 2008, from <http://www.technovelgy.com/ct/Science-Fiction-News.asp?NewsNum=1031>.

X Prize Foundation. (2008). *X Prize Foundation Space Initiatives*. Retrieved November 20,2008, from <http://space.xprize.org/>.

Virgin Galactic. (2008). Retrieved April 2, 2008 from <http://www.virgingalactic.com/>.

Vulcan Productions/Discovery Channel. (2006, July 27). *Spaceship one X-prize flight.* Retrieved April 2, 2008 from <http://video.google.com/videoplay?docid=-7774278636534133371&q=spaceship+1&total=702&start=0&num=10&so=0&type=search&plindex=0>.

Wikipedia.org. (2008, March 25). *List of artificial objects on the Moon*. Retrieved April 2, 2008 from <http://en.wikipedia.org/wiki/List_of_artivial_objects_on_the_Moon>.

Required Knowledge and Skills

Students should have the ability to research topics related to space and orbital debris on the Internet. They should be able to identify and list various resources that are available in space and on other planetary bodies.

Lesson 2: 5-E Lesson Plan

Engagement

Students search for the video or information about SpaceShipOne on the Internet or read the information (the video is suggested, if available). As a group, students discuss why Bert Rutan and his company, Scaled Composites, flew SpaceShipOne on its suborbital flight. The teacher explains the X Prize Competition to the class, including the goal (suborbital flight and incentive of $10 million).

Exploration

With their partners, students critically examine their lists of available resources from Lesson 1 (***Lesson Resource 1.1*** and ***Lesson Resource 1.4***) and explore the various inventions and innovations that will be needed to utilize resources available on the Moon and on other planetary bodies.

Explanation

The teacher leads a discussion on how a business needs a plan in order to succeed. Teachers explain:

1. Some of the plan's trade-offs include: a quick, short-term profit as opposed to a slow long-term profit; a desirable product or service as opposed to a necessary product or service; a product that requires a lot of processing or no processing at all; a product or service that is location-specific (just the Moon), or a product or service that could be moved to other locations (Mars, asteroids, etc.).
2. The differences among various kinds of studies concerning the success or failure of a business venture (cost comparisons of materials, consumer surveys, and break-even point charts). The teacher asks which types of inferences can legitimately be drawn from the various studies. The teacher describes how to judge the reasonableness of numerical computations and their results. (Include information concerning investors, investment in capital, profit motive, and the use of patents to protect inventions and innovations.)
3. Inventions and innovations are the result of specific, goal-oriented research, but some products and services will have negative as well as positive effects to the colony/community, culture, and the environment. Some decisions about the use of technology involve weighing the trade-offs between positive and negative effects. Sometimes a business' ideals might not mesh well with the ideals of the colony/community. The decision whether to develop a technology is influenced by societal opinions and demands, in addition to corporate cultures.
4. 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.
5. Government regulations might also influence how a business operates. Examples include: issues dealing with crew safety and the fact that space debris is not considered abandoned, but is still the responsibility of the country that launched it.

Extension

Working with their partners, students analyze the list of resources to determine which ones have the greatest need, the greatest potential for profit, and the need for new inventions or innovations to make those resources useable. They should include natural and man-made resources on the lunar surface now and in the future (Constellation Project components) and determine what modifications would need to be made to them. The NASA Johnson Space Center Decision-Making Process Chart (***Lesson Resource 2.2***) might be of assistance. The students and teacher might discuss the chart and agree to some modification(s) to facilitate the process.

Evaluation

Student knowledge, skills, and attitudes are assessed using selected response items, rubrics for class participation, and the research/analysis rubric to determine their success at completing the Resource Utilization Chart (***Lesson Resource 2.3***). 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 some of the private companies that are developing technology for future commercialization of space. These include transportation to space (e.g., Rocketplane Kistler, Space X, Virgin Galactic, Scaled Composites) and destinations in space (e.g., Bigelow Aerospace.)
2. Students may search the Internet for "space junk," "rocket stages," and "old satellites" and compile a database of articles about these topics.

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, access to information gathering and research equipment, as well as room for small-group and whole-class discussion, should be readied.

Tools/Materials/Equipment

- Computers with Internet access
- Other reference materials
- Printers
- Presentation software/equipment

Classroom Safety and Conduct

1. Students use tools and equipment safely, maintaining a safety level for themselves and others in the laboratory-classroom.
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: Reuse and Recycle Man-Made Resources

Lesson Snapshot

Overview

Big Idea: Man-made objects, abandoned in space, can become valuable resources.

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 and communicate a business plan that reuses discarded man-made resources.

Lesson Duration: Eight hours.

Activity Highlights

Engagement: Students list as many uses as they can for an empty two-liter soda bottle. They then compare the two-liter soda bottle to the empty fuel tanks on the Altair lunar lander descent stage on the lunar surface.

Exploration: Students disassemble (on paper) the various man-made resources (tanks, engines, fuel pumps, etc.) on the lunar surface and determine which pieces could be used now and which could be used later.

Explanation: The teacher explains:

1. Some man-made resources may be used "as is," some may need to be disassembled so parts could be reused, and some may need to be broken down to their basic components and remade into new devices.
2. Ethical considerations are important in the development, selection, and use of technology. Decisions regarding the implementation of technologies involve the weighing of trade-offs. Humans can devise technologies to conserve by reducing, reusing, and recycling.
3. That information and communication systems can be used to inform, persuade, entertain, control, manage, and educate. There are many ways to communicate information, such as graphic and electronic means.
4. Transportation plays a vital role in the operation of other technologies.
5. Technological problems often create a demand for new scientific knowledge.
6. How to make decisions about units and scales that are appropriate for problem situations involving measurement.
7. How to use formulas for the volume of geometric figures, how to judge the reasonableness of numerical computations, and how to draw reasonable conclusions about a situation being modeled.

Extension: Working with their partners, students develop a plan to reuse man-made resources on the lunar surface.

Evaluation: Student knowledge, skills, and attitudes are assessed using selected response items, rubrics for group work, and rubrics for presentation.

Enrichment:

1. Technology students could discuss their plan with the business students to solicit ideas and improve the plan's chance of success.
2. Students could present their plans to other groups to simulate the search for investors.
3. Students could try a Lunar Lander Simulation on the Internet to experience the difficulty of landing a spacecraft on the Moon, if available.
4. Students could complete the Orbital Debris Activity (***Lesson Resource 3.3***).
5. Students could collect a variety of different sized and shaped containers and calculate their volumes. Containers should be spherical, cylindrical, square, and rectangular.

Lesson 3: Overview

Lesson Duration

- Eight 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)
  - Ethical considerations are important in the development, selection, and use of technologies. (4J)
- Students will develop an understanding of effects of technology on the environment. (ITEA/*STL* 5)
  - Humans can devise technologies to conserve water, soil, and energy through such techniques as reusing, reducing, and recycling. (5G)
  - Decisions regarding the implementation of technologies involve the weighing of trade-offs between predicted positive and negative effects on the environment. (5L)
- Students will develop an understanding of and be able to select and use information and communication technologies. (ITEA/*STL* 17)
  - Information and communication systems can be used to inform, persuade, entertain, control, manage, and educate. (17N)
  - There are many ways to communicate information, such as graphic and electronic means. (17P)
- 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)

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

- Compute fluently and make reasonable estimates. (NCTM, Number and Operations, Grades 9–12)
- Use mathematical models to represent and understand quantitative relationships. (NCTM, Algebra, Grades 9–12)
  - Draw reasonable conclusions about a situation being modeled.
- 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)
  - Understand and use formulas for the area, surface area, and volume of geometric figures.

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

The Nature of Technology and Science (AAAS, 3 A, 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

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undertake entirely new lines of research. The very availability of new technology itself often sparks scientific advances.

- Human Identity (AAAS, 6 A, Grades 9–12)
  - Written records and photographic and electronic devices enable human beings to share, compile, use, and misuse great amounts of information and misinformation. No other species uses such technologies.

Language Arts: Standards for the English Language Arts *(NCTE, 1996)*

- Students apply a wide range of strategies to comprehend, interpret, evaluate, and appreciate texts. They draw on their prior experience, their interactions with other readers and writers, their knowledge of word meaning and of other texts, their word identification strategies, and their understanding of textual features (e.g., sound-letter correspondence, sentence structure, context, graphics). (NCTE, Standard 3)
- Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and nonprint texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience. (NCTE, Standard 7)
- Students use a variety of technological and information resources (e.g., libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge. (NCTE, Standard 8)
- Students use spoken, written, and visual language to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information). (NCTE, Standard 12)

Learning Objectives

Students will learn to:

1. Explain that ethical considerations are important in the development, selection, and use of technology.
2. Provide examples of how humans can devise technologies to conserve water, soil, and energy through such techniques as reusing, reducing, and recycling.
3. Describe how decisions regarding the implementation of technologies involve the weighing of trade-offs between predicted positive and negative effects on the environment.
4. Describe how information and communication systems can be used to inform, persuade, entertain, control, manage, and educate.
5. Describe the many ways to communicate information, such as graphic and electronic means.
6. Explain how transportation plays a vital role in the operation of other technologies, such as manufacturing, construction, communication, health, safety, and agriculture.
7. Explain that 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.
8. Explain that written records and photographic and electronic devices enable human beings to share, compile, use, and misuse great amounts of information and misinformation. No other species uses such technologies.
9. Explain how making decisions about units and scales that are appropriate for problem situations involve measurement.
10. Describe how to use formulas for the volume of geometric figures, such as spheres and cylinders.
11. Describe how to judge the reasonableness of numerical computations and their results.
12. Explain how to draw reasonable conclusions about a situation being modeled.

13. Contribute to a group endeavor by offering useful ideas, supporting the efforts of others, and focusing on the task.
14. Work safely and accurately with a variety of tools, machines, and materials.
15. Actively participate in group discussions, ideation exercises, and debates.

Student Assessment Tools and/or Methods

1. Quiz (***Unit Pre/Post Test***)

2. Rubric for Group Work
   Teacher's Note: Teachers may choose to use this rubric as a way to assess students, with or without making it a basis for student grades.

Category	Below Target	At Target	Above Target
Participation	Seldom participated. Did very little work.	Cooperative. Did his/her part of the work. Often offered useful ideas.	Was always willing to do more. Routinely offered useful ideas.
Reliability	Did not have work done on time. Did not show up when the group met.	Group members could count on him/her.	Went beyond what was expected of him/her.
Attitude	Did not support group members. Did not share information. Had little interest in success of the group.	Supported efforts of others. Served to facilitate rather than disrupt the group work.	Listened to and shared ideas with others. Was very self-directed.

3. Rubric for Presentation

Category	Below Target	At Target	Above Target
Organization	Presentation was not well-organized and was hard to follow.	Presentation was well-organized and easy to follow.	Presentation was exceptionally well-organized and flowed very well.
Creativity	Presentation was not very creative and was somewhat boring.	Presentation was creative, showing a good deal of planning.	Presentation was extremely creative, showing that a good deal of thought went into preparation.
Feedback	Audience did not participate in the presentation.	Audience was attentive to the presentation and participated when asked.	Audience was extremely interested and asked many questions.
Presentation Requirements	Students stated the type of business to be started but had a small list of resources to be used. Some inventions, innovations, and other needs were listed. Some visuals were used in the presentation, and an incomplete, poorly designed model was available for viewing.	Students stated the type of business to be started and listed all resources to be used. All inventions, innovations, and other needs were listed. Visuals were used in the presentation, and a scale model was available for viewing.	Students stated the type of business to be started and completely listed all resources used. All inventions, innovations, and other needs were listed with an explanation of their purpose. Many visuals were used in the presentation, and a scale model was available for viewing.

4. Assessment Tools

Element	Criteria	Points Possible	Earned Assessment Self / Teacher
Quiz	As per above		
Group Work	As per above		
Presentation	As per above		

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

Sellers, J.J. (2000). *Understanding space: An introduction to Astronautics*. New York: The McGraw-Hill Companies, Inc.

Internet Sites

Bigelow Aerospace, LLC. (2008). Retrieved April 2, 2008, from <http://bigelowaerospace.com/>.
Com Dev International. (2008). Retrieved April 2, 2008 from <http://www.comdev.ca/>.
Rocketplane Kistler, LTD, Inc. (2005). Retrieved April 2, 2008, from <http://www.rocketplanekistler.com/>.
Scaled Composites, LLC. (2008). Retrieved April 2, 2008, from <http://www.scaled.com/>.
Space Exploration Technologies. (2008). Retrieved April 2, 2008, from <http://www.spacex.com/>.
Virgin Galactic. (2008). Retrieved April 2, 2008, from <http://www.virgingalactic.com/>.
Wikipedia.org. (2008, March 12). Commercial Orbital Transportation Services. Retrieved April 2, 2008, from <http://en.wikipedia.org/wiki/Commercial_orbital_transportation_services>.
X-Prize Foundation. (2008). Retrieved April 2, 2008, from <http://space.xprize.org/x-prize-cup/>.

Required Knowledge and Skills

Students should have the ability to research topics related to space/lunar man-made debris on the Internet. They should be able to describe a simple business plan and the various factors that could affect that plan. Students should be able to describe the Constellation Program and its major elements.

Lesson 3: 5-E Lesson Plan

Engagement

Students list as many uses as they can for an empty two-liter soda bottle. They then compare the two-liter soda bottle to the empty fuel tanks on the Altair lunar lander descent stage on the lunar surface. Using conceptual images of the Altair lunar lander (***Lesson Resource 3.1***), students estimate the length and diameter of the tanks and calculate the volume of one tank. Students assume the tanks have flat ends as opposed to spherical ends. The teacher may need to review mathematical formulae for volume.

Exploration

Students disassemble (on paper) the various man-made resources (tanks, engines, fuel pumps, etc.) on the lunar surface and determine which pieces could be used now and which could be used later. Students may need to design an infrastructure to allow transportation, storage, disassembly, and remanufacture of parts.

Explanation

The teacher explains:

1. Some man-made resources may be used "as is," some may need to be disassembled so parts could be reused, and some may need to be broken down to their basic components and remade into new devices. The teacher should review ***Lesson Resource 1.2*** and ***Lesson Resource 1.3*** about the Constellation Program to refresh student memory concerning the various components.
2. Ethical considerations are important in the development, selection, and use of technology. Decisions regarding the implementation of technologies involves the weighing of trade-offs. Humans can devise technologies to conserve by reducing, reusing, and recycling.
3. That information and communication systems can be used to inform, persuade, entertain, control, manage, and educate. There are many ways to communicate information, such as graphic and electronic means. Written records and photographic and electronic devices enable human beings to share, compile, use, and misuse great amounts of information and misinformation.
4. Transportation plays a vital role in the operation of other technologies.
5. 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.
6. How to make decisions about units and scales that are appropriate for problem situations involving measurement.
7. How to use formulas for the volume of geometric figures, such as spheres and cylinders, how to judge the reasonableness of numerical computations and their results, and how to draw reasonable conclusions about a situation being modeled.

Extension

Working with their partners, students develop a plan to reuse man-made resources on the lunar surface (***Lesson Resource 3.2***). The plan may include charts, graphs, drawings, 3-D models, presentation slides, and a plan to realize a profit. Students present their plans to the class. (It is generally accepted that all man-made debris on the lunar surface belongs to the country that launched it. In order to use it, an entrepreneur colonist must ask permission from the owner. Students play the role of various officials from the country that owns the debris in question.)

Evaluation

Student knowledge, skills, and attitudes are assessed using selected response items, rubrics for group work, and rubrics for 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.

Enrichment

1. Technology students could discuss their plan with the business students to solicit ideas and improve the plan's chance of success.
2. Students could present their plans to other groups to simulate the search for investors.
3. Students could try a Lunar Lander Simulation on the Internet web site to experience the difficulty of landing a spacecraft on the Moon, if available.
4. Students could complete the Orbital Debris Activity (***Lesson Resource 3.3***).
5. Students could collect a variety of different sized and shaped containers and calculate their volumes. Containers should be spherical, cylindrical, square, and rectangular.

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, students should have access to information gathering and research materials, and room for small-group and whole-class discussions.

Tools/Materials/Equipment

- Computers with Internet access
- Other reference and research materials
- Printers
- Presentation software/equipment
- Poster board and markers
- Scrap materials to construct 3-D models (e.g. metal, wood, styrofoam, etc.)
- Tools to shape scrap materials (e.g., saws, hammers, knives, etc.)

Classroom Safety and Conduct

1. Students use tools and equipment safely, maintaining a safety level for themselves and others in the laboratory-classroom.
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

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Appendices
Resource Documents

Unit Pre/Post Test Knowledge Questions

The following questions are taken from each set of unit lessons. They represent the knowledge assessment component for each lesson, but may be used as a pre-assessment tool.

Lesson 1: Introduction to Space Transportation and Space Resources

Directions: Select the response that best answers the question or statement.

_____ 1A. The development of most technologies today is driven by
A. Pure research
B. Profit motive and the market
C. Human curiosity
D. Humanitarian needs

_____ 1B. Prior to solving any technological problem, that problem must be thoroughly
A. Reviewed
B. Observed
C. Researched
D. Defined

_____ 1C. The design and operation of transportation systems is often influenced by
A. Governmental regulations
B. Individual wants
C. Educational needs
D. Corporate regulations

_____ 1D. Making decisions about units and scales that are appropriate for problem situations often involves
A. Calculation
B. Analysis
C. Research
D. Measurement

_____ 1E. When traveling in space, aspects of the space environment may be used to assist with human processes and could be considered resources. These include
A. Magnetic and gravitational fields
B. Space debris and extreme temperatures
C. Vacuum of space and radiation
D. All the above

Directions: Provide answers to the following questions:

1F. Explain how to calculate the volume of a cylinder that could be used to store oxygen gas extracted from the lunar regolith. Assume the cylinder has flat ends as opposed to spherical ends.

1G. Describe how to estimate the answer to a simple math equation prior to completing the calculation. Provide an example.

1H. Gravity is a resource that exists in space and on all planets/moons. What can be inferred about the force of gravity on the spacecraft or on the surface of the planet/moon? (Hint: Newton's Law of Universal Gravitation)

1I. Describe the Constellation Program and the vehicles being designed to travel to the Moon, Mars, and beyond.

1J. List three elements that are found in abundance on the lunar surface.

Directions: Select the response that best answers the question or statement.

_____ 2A. Most inventions and innovations are the result of
A. Human wants
B. Profit potential
C. Goal-oriented research
D. Serendipity

_____ 2B. Technological ideas are sometimes protected through the process of
A. Analyzing
B. Patenting
C. Researching
D. Categorizing

_____ 2C. Decisions whether to develop a technology are influenced by
A. Governmental regulations
B. Individual wants
C. Human needs
D. Societal opinions and demands

_____ 2D. Making decisions about the use of technology involves weighing the trade-offs between
A. Positive and negative effects
B. Profit and loss
C. Research and Development
D. Human wants and human needs

_____ 2E. A new technology will disappear if perceived by the general public as
A. A threat to the environment
B. Waste of time and not needed
C. Time consuming and requiring more work
D. All the above

Directions: Provide answers to the following questions:

2F. Mining materials from lunar rock and regolith has the potential to be a great source of income. Name an element found on the Moon in large quantities that is rarely found on Earth, and explain its use.

2G. Describe the infrastructure needed to begin a mining operation on the lunar surface.

2H. Describe businesses that may arrive after a lunar colony has been established.

2I. Assume that space will be explored by international crews. Develop a rationale to determine which country's laws will apply to commerce, worker safety, patent protection, investment, taxes, etc.

2J. The discovery of water on the Moon would mean O_2 for life support and/or O_2 and H for rocket fuel. This could present many commercial opportunities. What considerations are involved to determine how this resource should be used?

Directions: Select the response that best answers the question or statement.

_____ 3A. There is a considerable amount of man-made debris on the lunar surface that includes
A. Soviet Soyuz landers
B. American Viking landers
C. Apollo descent modules and equipment
D. The Hubble Space Telescope

_____ 3B. The technological problem of man-made debris on the Moon could lead to
A. A transportation industry to return it all to Earth
B. Large lunar landfills
C. New uses for old technology
D. Many memorials and lunar parks

_____ 3C. Although there are no specific laws stating this, it is generally accepted that lunar man-made debris belongs to
A. The person who gets to it first
B. The country of the person who gets to it first
C. All people on Earth
D. The country that launched it

_____ 3D. Large empty fuel tanks found on the lunar surface could be used as is for
A. Living space
B. A vehicle garage
C. Storage tanks for lunar extracted gases
D. Water storage

_____ 3E. Some of the elements found in the lunar regolith are so plentiful on Earth that the expense would not justify shipping them back to Earth. One exception would be
A. Oxygen
B. Aluminum
C. Helium 3
D. Silicon

Directions: Provide answers to the following questions:

3F. There is a considerable amount of hardware on the Moon from various American and Soviet missions. Which ones deserve to be preserved as historic sites and why?

3G. Explain how transportation on the lunar surface will play a vital role in the operation of other technologies, such as manufacturing and construction.

3H. If water ice is found at the lunar poles, describe how it could be processed and used.

3I. If water could be stored in empty fuel tanks, how would the colonists calculate the volume that could be stored in each tank? What mathematical formula would be used?

3J. Aside from old fuel tanks, what other parts could be salvaged from abandoned spacecraft for reuse by lunar colonists?

Unit Pre/Post Test Answer Key

Teacher Note: The answers to the written questions will vary. They are designed to make the students think creatively and critically about the situations presented.

1A. B

1B. C

1C. A

1D. D

1E. D

1F. $V = \frac{PI \times d^2 \times h}{4}$

1G. Answers may vary. The student might say that multiple digit numbers should be rounded to numbers that the student could calculate in his/her head. For example: The area of a rectangle 1.2 ft x 2.2 ft could be rounded down to 1 ft x 2 ft and equal an area of just over 2 ft^2.

1H. The force of gravity will keep a spacecraft orbiting around the body if the spacecraft has a high enough velocity. The force of gravity will cause a spacecraft of less velocity to be pulled toward the center of the planet/moon and will result in a collision with the surface. Gravity will keep the spacecraft or its parts (in the case of a collision) on the surface of the planet or moon.

1I. The Constellation Program consists of two rockets, a spacecraft, and a lunar lander. The larger rocket, Ares V, will be launched into Earth orbit carrying the lunar lander, Altair, and other supplies. The smaller rocket, Ares 1, will be launched carrying the crew in the spacecraft, Orion. Orion will dock with Altair, and the two will depart for the Moon. The crew will leave the Orion to orbit unattended and land on the Moon in the Altair. The crew will leave the lunar surface in the upper portion of the lunar lander and dock with the Orion in lunar orbit. The crew will depart lunar orbit and return to Earth. The crew will return to the Earth surface in the Orion capsule.

1J. Aluminum, Silicon

2B. B

2C. D

2D. A

2E. D

2F. Helium 3 is being studied as a source of energy for fusion nuclear reactors to generate electricity.

2G. Equipment and facilities needed for a mining operation on the Moon could include: mining machines, storage facilities, equipment to refine the mined minerals/elements, transportation on the lunar surface and/or off the surface.

2H. Aluminum and iron could be mined for building materials. Oxygen could be mined for oxidizer (for engines) and life support. Silicon could be mined for computer chips and photovoltaic cells. Helium-3 could be mined for research as a potential energy source.

2I. Possible answers include: The laws of the country with the most citizens will apply. Colonists will meet to determine what rules and laws will apply. The United Nations will decide. NASA, the European Space Agency (ESA), and the Russian Federal Space Agency (Roskosmos) will decide.

2J. Who will make the decision: entrepreneurs, colonists, or Earth-based governments? How much water is available? How much will be used for fuel, and how much will be used for life support?

3A. C

3B. C

3C. D

3D. C

3E. C

3F. Students may be able to justify many sites. The first landing sites could easily be deemed to have historical significance, including the first site for each country that has landed on the Moon, the Apollo 11 landing site, and the first landing site of the new lunar lander, Altair. Students may be able to justify other sites, as well.

3G. Possible answers include: Vehicles will be needed to transport manufactured goods and construct facilities. Short distances may be traversed using open buggies similar to those used during the Apollo program. Long distances may be traversed using pressurized vehicles that would double as short-term living spaces.

3H. Water ice on the lunar surface could be mined into blocks and processed by melting the water and boiling the water to remove impurities. The water could be used as is or further processed to separate it for use as rocket fuel.

3I. Most fuel tanks are cylindrical, spherical, or cylindrical with spherical ends. Volume formulas include:

- Volume of a Rectangle = l x w x h.
- Volume of a Sphere = (4/3) x PI x r^3 where r is the radius of the sphere.
- Volume of a Cylinder = PI x r^2 x h where h is the height of the cylinder, and r is the radius of the cross section.

3J. Spacecraft parts left on the Moon that could be reused include: engines, turbo pumps, hoses, various instruments, and solar panels.

Available Resources Survey 1

Name: _____
Name: _____
Date: _____

Part 1

List as many resources as you and your partner can think of that exist in space.

_____
_____
_____
_____
_____
_____

List as many resources as you and your partner can think of that exist on the Moon.

_____
_____
_____
_____
_____
_____

List as many resources as you and your partner can think of that exist on other bodies in the solar system.

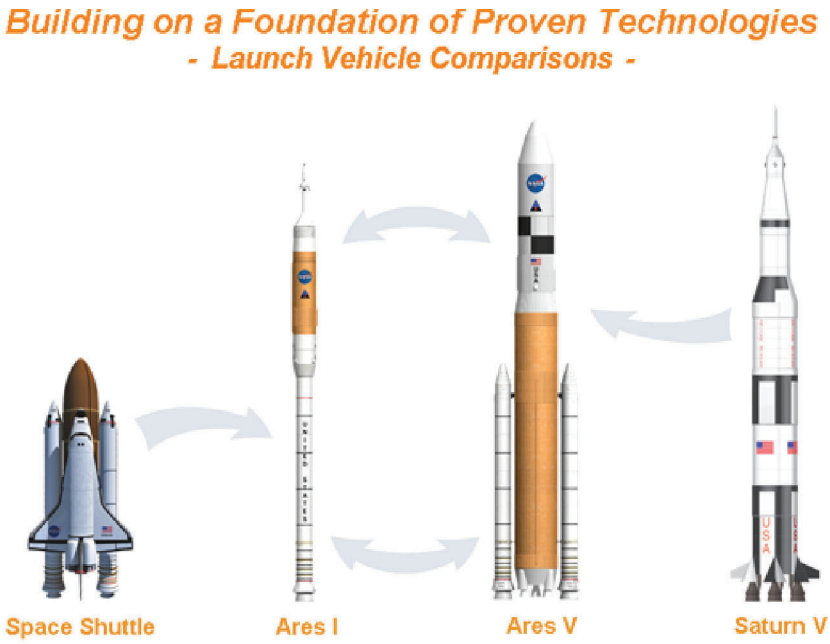
_____
_____
_____
_____
_____
_____

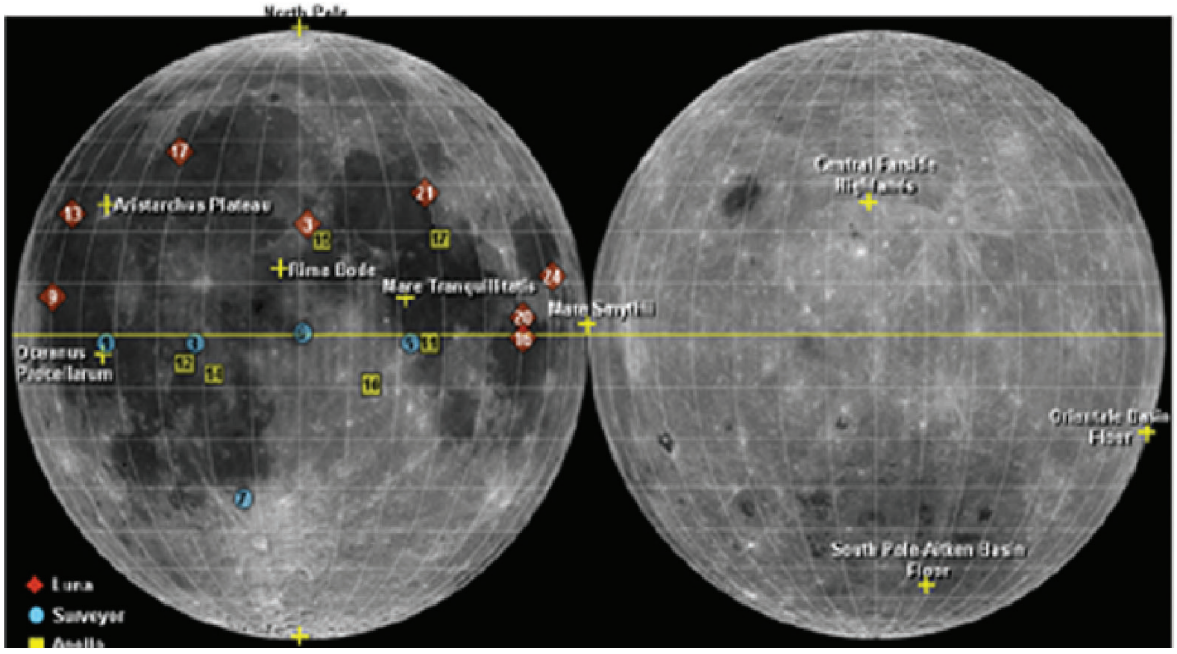
Part 2

List those items you believe are the most plentiful on the Moon. Indicate whether you believe there is just enough for a colony to survive or if there is enough to support a business.

Resource	Survival	Support a Business
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

Launch Vehicle Comparisons





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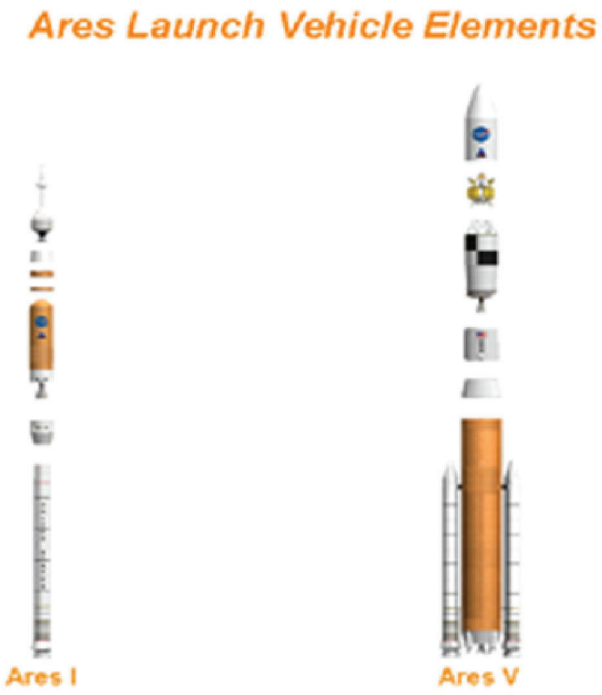
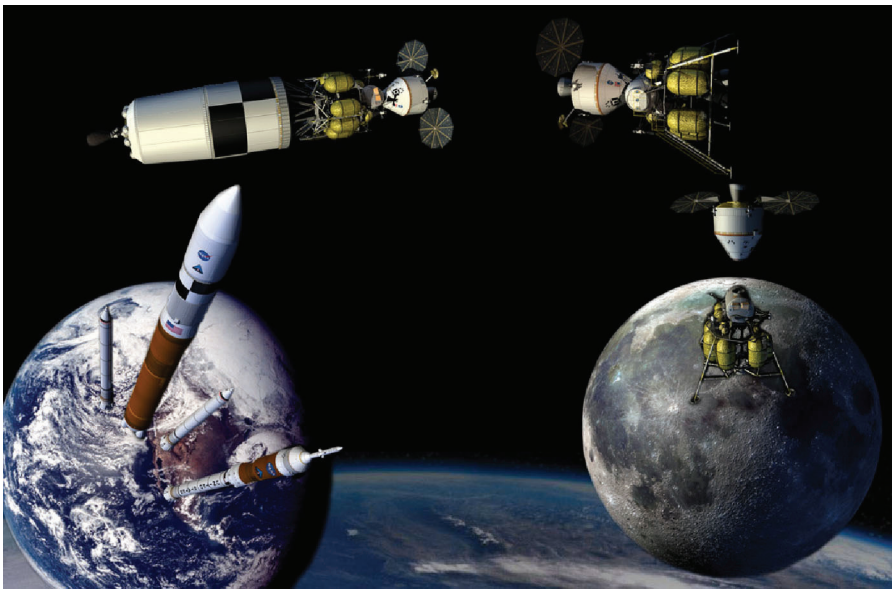
Launch Vehicle Comparisons





Connolly, J.F. (2006, October). *Constellation program overview* (Presentation to ITEA Human Exploration Project Authors November 2007). Huntsville, AL.

Available Resources Survey 2

Name: _____
Name: _____
Date: _____

Locate pictures of the Russian Luna spacecraft that landed on the Moon in the 1960s. List the parts that could be salvaged by lunar colonists.

Locate pictures of the American Ranger spacecraft that landed on the Moon in the 1960s. List the parts that could be salvaged by lunar colonists.

Locate pictures of the Apollo landing sites, spacecraft, and experiment packages that landed on the Moon in the 1960s and 1970s. List the parts that could be salvaged by lunar colonists.

Locate pictures of the other spacecraft that landed on the Moon since the 1960s. List the parts that could be salvaged by lunar colonists.

One Potential Resource

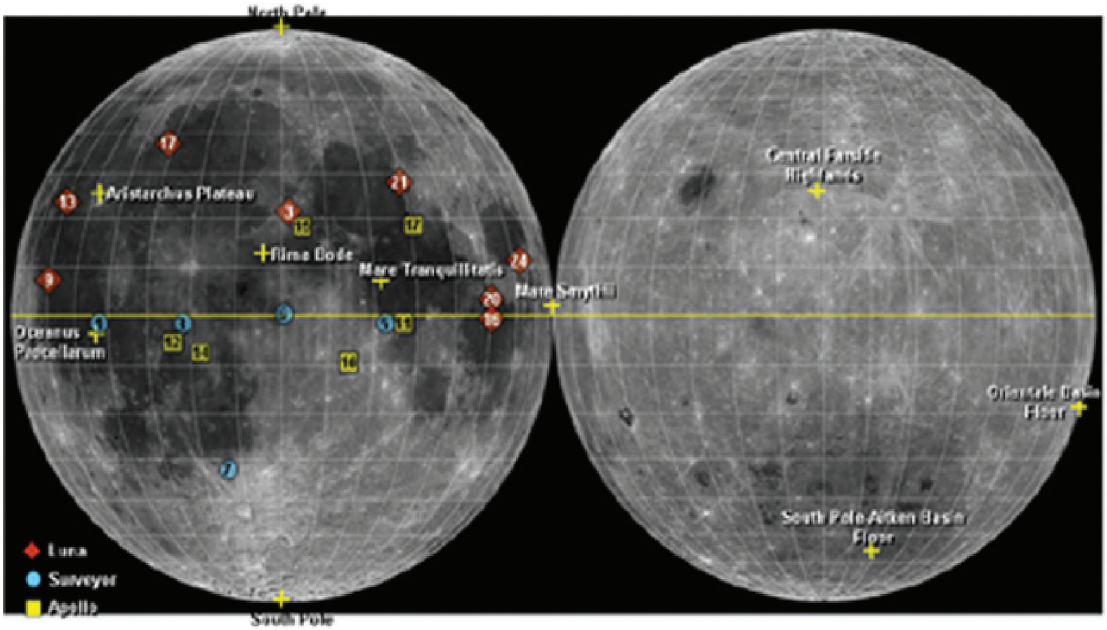
Books, periodicals, pamphlets, and web sites may provide teachers and students with background information and extensions. Inclusion of a resource does not constitute an endorsement, either expressed or implied, by the National Aeronautics and Space Administration.

Encyclopedia Astronautica. (n.d.) *Today in Space history.* Retrieved November 20, 2008 from <http://www.astronautix.com/>.

Scenario

Picture your company operating from the Tranquility Shores Industrial Park.

After a hard day at work, you head home to your family at the new lunar colony.



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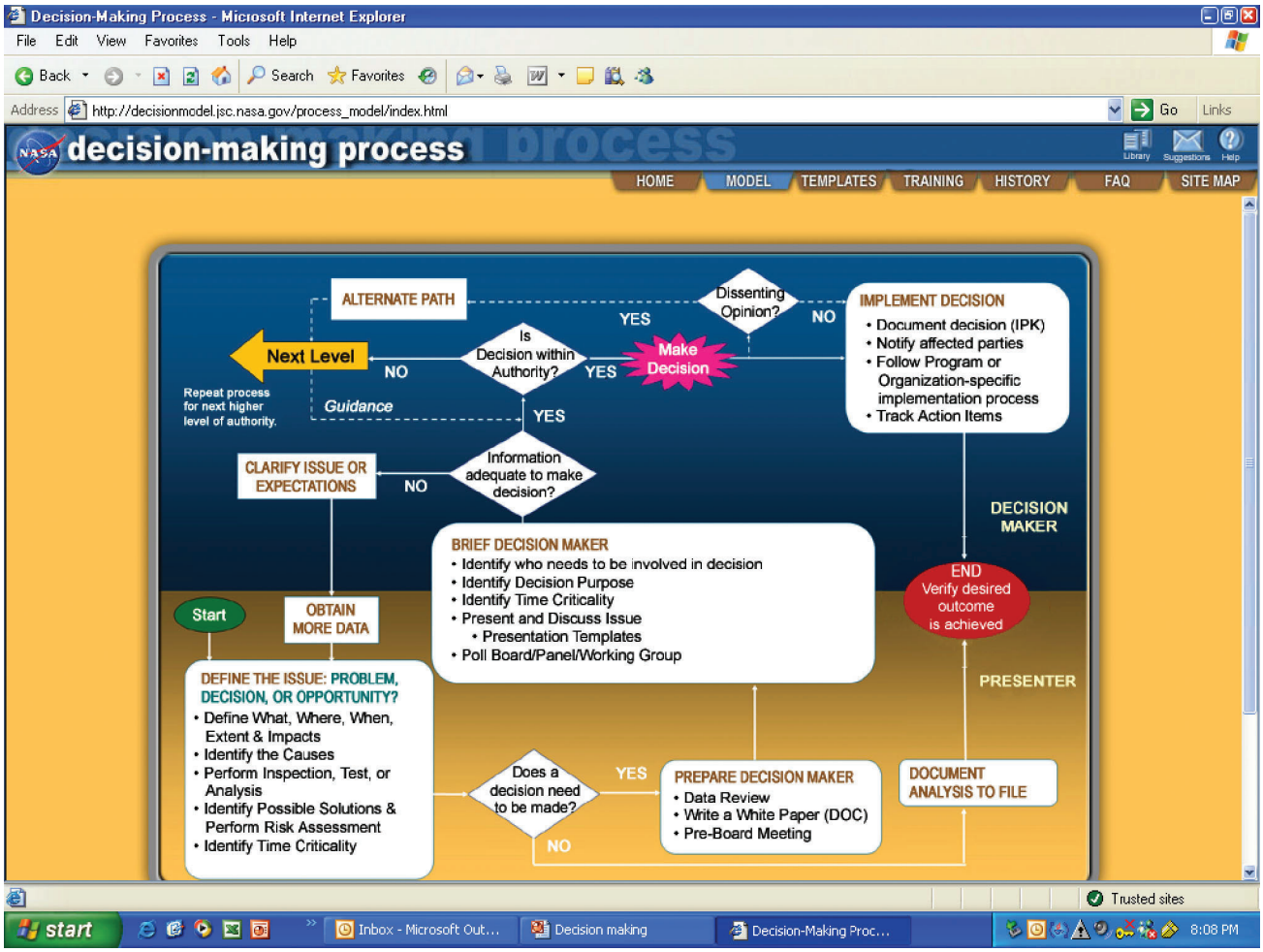
NASA Johnson Space Center Decision-Making Process Chart



Deana Hackfeld, D. (2006, November 17). Powerpoint® Presentation at Johnson Space Center, Houston, Texas.

Note: The teacher and student may want to modify this chart somewhat to speed the decision-making process.

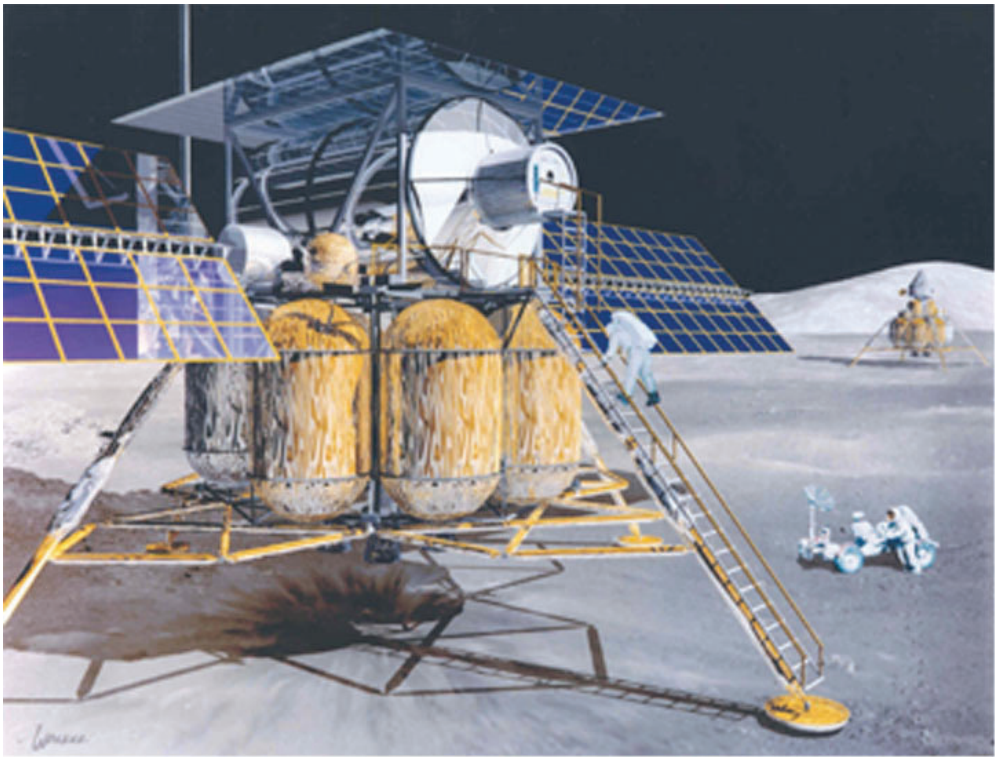
Resource Utilization Chart

Name: _____
Name: _____
Date: _____

List the resources you and your partner identified in the last activity. Number them according to their importance for survival. Indicate (yes or no) whether you and your partner believe there could be a profit to be made by developing that resource. Finally, list the invention and/or innovation that may need to be developed in order to extract that resource.

Resources	Potential Need	for Profit	New Invention or Innovation Required

Lunar Lander (Altair) Conceptual Images



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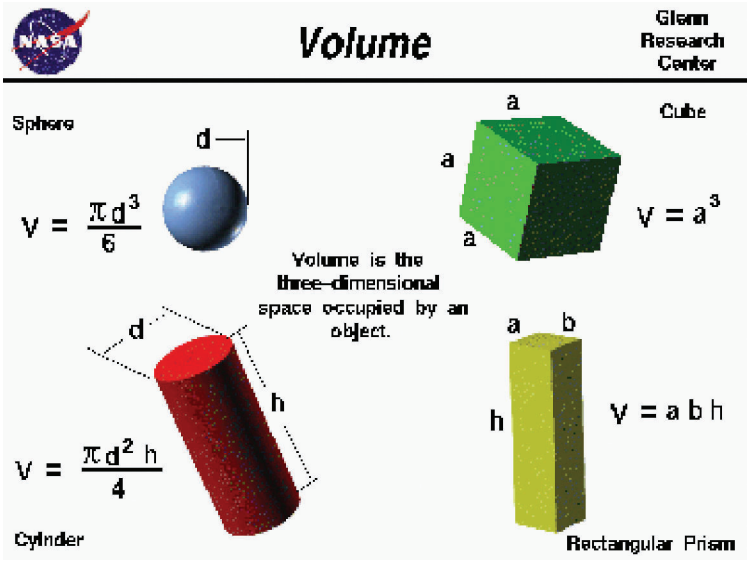

NASA, Glenn Research Center. (2006, March 16). *Volume*. Retrieved April 2, 2008, from <http://www.grc.nasa.gov/WWW/K-12/airplane/volume.html>.

In Situ Resource Utilization
Design Challenge

Situation:
You will soon be moving to the new Lunar Colony. The colony only lets people move there if they have a business plan to support themselves and their families.

Challenge:
Working with your business partner, you develop a plan to use the Moon's natural resources and reuse man-made resources on the Moon to help lower costs.

Criteria and Constraints
- It is generally accepted that all man-made debris on the lunar surface belongs to the country that launched it. In order to use it, an entrepreneur colonist must ask permission from the owner.
- Your plan must include visuals, such as charts, graphs, drawings, 3-D models, and PowerPoint® slides.
- Your plan must realize a profit.
- A preliminary proposal must be completed in five days.

Materials
- Computer with Internet access
- Pencil, paper, worksheets
- Tools and materials typically found in a technology education lab, including modeling materials such as wood, acrylic, metal, cardboard, glue, mechanical fasteners, electrical components, plastic tubing, spray paint, etc.

Procedure:
- Research different lunar resources, natural and man-made.
- Decide what type of business you will start.
- Research required inventions and innovations.
- Determine what will be needed for your business. (Write your request to the owner of the hardware you wish to use.)
- Develop charts, graphs, drawings, PowerPoint® slides, etc.
- Design and build a scale model of your business (at the lunar colony).
- Present your plan to the class.

Teachers and students may wish to revisit the ***Design Process.***

Orbital Debris Resource Utilization (Page 1 of 3)

Activity Snapshot/Overview

This activity may be included if time permits. It is similar to the activity in Lesson 3, except that the man-made resources to be used are NOT on another planet/moon; they are orbiting the planet/moon on which the student is living. To complete this activity, students must be comfortable with the J Track web site at <http://science.nasa.gov/realtime/jtrack/Spacecraft.html> (see p. 3 of this Lesson Resource). This activity requires one to two hours of work prior to beginning the activity.

Overview

Big Idea: Orbiting objects are constantly changing their positions in 3-D space.

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

Purpose of Activity: This lesson enables students to predict the location of objects in 3-D space.

Activity Duration: Five hours.

Activity Highlights

Engagement: Students visit the J Track 3-D web site to view the orbits of various spacecraft around Earth. Some of the better-known satellites are shown on the map.

Exploration: Students explore the web site to learn about low Earth orbits (LEO), middle Earth orbits (MEO), geosynchronous and geostationary orbits (GEO), sun synchronous orbits, and highly elliptical orbits.

Orbit Type	Example Spacecraft
LEO satellites	HST, UARS, Cobe
MEO satellites	GPS
GEO satellites	Direct TV, Galaxy, Intelsat, Brazilsat, GE
Sun Synchronous satellites	TRACE
Highly Elliptical Orbiting satellites	AO10, AO40, Cluster, Sirius, Chandra

Explanation: The teacher demonstrates/explains:

- Orbital mechanics and how the orbital elements are used to characterize the orbits.
- That all orbits are elliptical.
- The time for one complete orbit is called its period.
- In order to rendezvous, a spacecraft must launch in the same orbit as the target spacecraft.
- A spacecraft can "speed up" by maneuvering to a lower orbit than the target, and it can "slow down" by maneuvering into a higher orbit than the target.

Extension: Working alone or with a partner, students follow the worksheet to familiarize themselves with the use of J Track, J Pass, and J Track 3D. They should now be ready to continue with the Orbital Debris Design Challenge.

Evaluation: Student knowledge, skills, and attitudes are assessed using selected response items, rubrics for group work, and rubrics for presentation (found in Lesson 3).

Orbital Debris Resource Utilization (Page 2 of 3)

Design Challenge

Situation:

During the last century of spaceflight, the orbital space around Earth has become cluttered with thousands of obsolete spacecraft. The most dangerous part of any space trip to the other planets is navigating through the debris field that circles Earth.

Challenge:

Working with your business partner, you develop a plan to deorbit man-made debris orbiting Earth. Your first client is NASA. They wish to deorbit the UARS satellite.

Criteria and Constraints

- You must learn to track debris so you can launch into the same orbit and rendezvous with the target satellite.
- You design a device to deorbit the target satellite so it will burn up in Earth's atmosphere.
- Your plan must include visuals, such as charts, graphs, drawings, 3-D models, and PowerPoint® slides.
- Your plan must realize a profit.
- A preliminary proposal must be completed in five days.

Materials

Computer with Internet access, pencil, paper, and worksheets

Procedure:

- Research the use of J Track, J Pass, and J Track 3D.
- Research required inventions and innovations that will be required to rendezvous and deorbit the target spacecraft.
- Develop charts, graphs, drawings, PowerPoint® slides, etc.
- Present your plan to the class.

Orbital Debris Resource Utilization (Page 3 of 3)

Using J Track

Name: _____
Name: _____
Date: _____

Find J Track on NASA's Satellite Tracking web page at the following URL:
<http://science.nasa.gov/realtime/jtrack/Spacecraft.html>.
The following menu will appear on the left, with a map of the world on the right (see Figure 1).

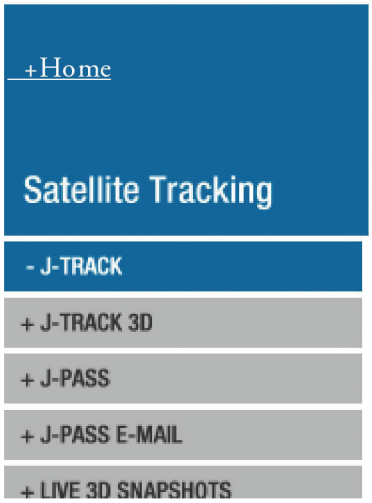

Fig. 1 Menu from NASA's Satellite Tracking Webpage.

Find UARS on the map.
To activate the ground trace on the UARS satellite, hold down the "Ctrl" key and "click" on the UARS satellite. To deactivate a ground trace, do the same, and the ground trace will disappear. Two complete orbits will be shown on the map. Notice how the orbit shifts as Earth spins underneath.

Predict the next pass.
Because Earth spins beneath an orbiting spacecraft, you will need to predict when that spacecraft will be over your location. To predict the next pass of the satellite over your location, "click" on the *J Pass* link on the left of the screen. You will be directed to type in your zip code and "click" the *GO* button.

A compass will appear on the bottom right and a display of commands to the left of that. "Click" the *Options* button and "click" the *Control* tab.

To select the UARS satellite, on the *Satellites* menu select "Custom" and on the *Search Criteria* menu select "All passes."

"Click" the *Satellite* tab and on the *Select method Menu* choose "manual select."
A menu of satellites will appear on the left. Scroll down to UARS and "Click" the *Add* button to add it to the column on the right. "Click" the *Okay* button.

"Click" the *Next Pass* button to determine when it will orbit over your location. Notice the date and time in the upper left corner and the trace across the sky.

Find UARS on the 3-D globe.
To see UARS' orbit on a 3-D map, "click" J *track 3D* on the original menu. On the top left, "click" the Satellite pull-down menu. "Click" on the *Select* button and scroll down to the UARS satellite. Close the pull-down menu. The UARS satellite will appear on the red circle around the globe. "Click" on Earth and drag until you see your location on the globe.

National Aeronautics and Space Administration

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www.nasa.gov

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