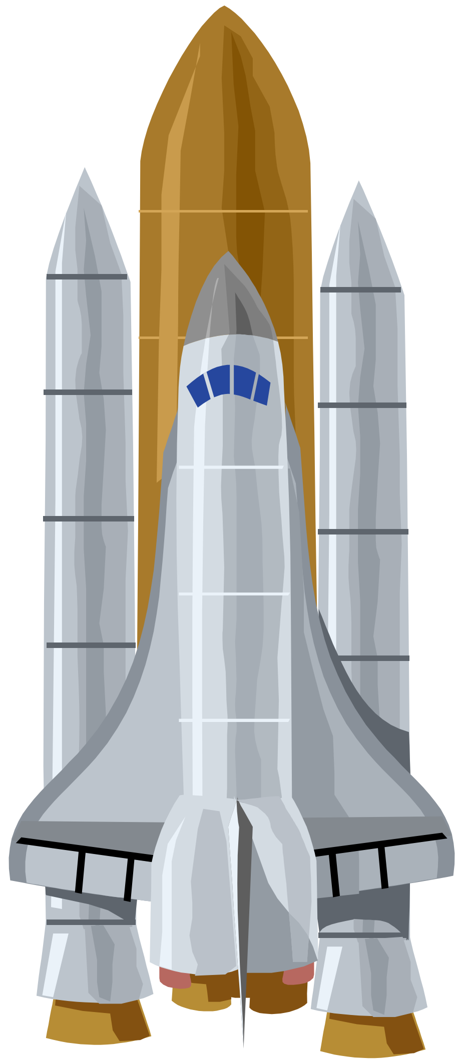

SPACE EXPLORERS

Space Explorers
A Space Exploration Program for Middle School Youth
A School Enrichment Project

Space Explorers is an interdisciplinary space exploration education curriculum designed for middle school youth funded by the Texas Space Grant Consortium. The curriculum includes lessons for use in mathematics, language arts, social studies, science, computer, theater, physical education, and art classes.

Goal: Students will broaden their knowledge and comprehension of space exploration through interactive, hands-on learning activities.

Objectives:
1. Space Exploration activities will meet suggested TEKS and SCANS objectives identified by grade level.
2. Students will learn ten vocabulary words related to space exploration.
3. Students will increase knowledge in life science, remote sensing, orbital mechanics, and space exploration in general.

Audience: Fifth to eighth grade middle school students.

Delivery Methods:
The curriculum is divided into four content areas: Overall Introduction to Space Exploration, Life Sciences, Remote Sensing, and Orbital Mechanics. Activities are designed to be part of an interdisciplinary program. Possible classroom organization methods include whole classroom instruction, cooperative groups, individual tasks, and learning centers. Teachers in grade level teams may choose to work cooperatively for a grade level thematic unit.

Materials: Descriptions for materials needed to implement each experiment are listed at the beginning of each teaching plan.

Agent Education/Support: Training is available upon request from the Texas Space Grant Consortium or your local County Extension Service.

Evaluation: Evaluation methods are included in the appendix.

Developed by:

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Activities Overview

I. Introduction

II. Introduction to Space Exploration

Grade Level	*Page Number*	*Activity*	*Subject Areas*							
			S	**M**	**SS**	**L**	**C**	**FA**	**PE**	**H**
5 – 8	8 – 9	Creating a Time Capsule			✔	✔	✔	✔		
5 – 8	10 – 12	International Cooperation			✔	✔	✔			
5 – 8	13 – 15	Stellar Theory	✔	✔		✔	✔	✔		
5 – 8	16 – 21	Abort, Launch, It's A Go!	✔	✔				✔		
5 – 8	22 – 28	Spinoffs			✔					

III. Life Sciences

Grade Level	*Page Number*	*Activity*	*Subject Areas*							
			S	**M**	**SS**	**L**	**C**	**FA**	**PE**	**H**
5	29 – 32	Nutrition in Space	✔	✔						
5	32 – 38	Lunchtime	✔			✔				
6	39 – 43	Is It Soup Yet?	✔			✔	✔	✔		✔
6	44 – 46	Lung Model	✔	✔			✔			
5 – 6	47 – 51	Recycling on the Moon	✔	✔		✔	✔	✔		
7	52 – 54	Exercise & Other Recreation					✔		✔	✔
7	55 – 56	Sleeping in Space	✔	✔						
7	57 – 58	Weightlessness . . .					✔			✔
7 – 8	59 – 62	History of Int'l Cooperation			✔	✔				
8	63 – 68	Shuttle Spacesuits		✔			✔			
8	69 – 73	Mission Design – Personnel	✔			✔				
8	74 – 77	Aging				✔	✔			

IV. Remote Sensing

Grade Level	*Page Number*	*Activity*	*Subject Areas*							
			S	**M**	**SS**	**L**	**C**	**FA**	**PE**	**H**
5	78 – 83	Light Energy	✔							
5	84 – 89	Light Telescopes	✔							
6	90 – 91	Venus Sky Box	✔	✔						
7	92 – 96	Satellite Orbits	✔			✔				
8	97 – 99	Mapping	✔			✔	✔			

V. Orbital Mechanics

Grade Level	*Page Number*	*Activity*	*Subject Areas*							
			S	**M**	**SS**	**L**	**C**	**FA**	**PE**	**H**
5	100 – 114	Toys in Space	✔			✔				
5	115 – 117	Creating a Space Journey	✔			✔		✔		
6	118 – 120	Experimenting with Gravity	✔	✔						
6	121 – 125	It's A Blastoff!	✔	✔						
6	126 – 129	Glider, Flying Saucer, Plane	✔	✔						
6	130 – 131	Making Space Stations	✔	✔						
7	132 – 134	Orbits	✔					✔		
7	135 – 137	Circumference		✔						
7	138 – 141	Orbit Crossword				✔				
7	142 – 144	Orbit Word Search				✔				
8	145 – 147	Mission Design – Shuttle	✔							
8	148 – 163	Bottle Rocket	✔	✔						
8	164 – 166	Asteroid Impact	✔			✔	✔			

VI. Evaluation

Page Number	*Description*
167	K - W - L Strategy Evaluation
168 – 169	Retrospective Pretest
170	Rubric

VII. Appendix

Page Number	*Description*
171 – 176	Space Glossary
177	Texas Essential Knowledge and Skills Info Sheet
178 – 184	National Education Standards
186	NASA Articles

K - W - L Strategy
Introduction

Tell students that our topic is ***Space Exploration***. Ask them to discuss what they know about exploration in space. Display a K-W-L chart on the overhead, and explain the three parts: **K** – What I **K**now, **W** – **W**hat I Want to Know, and **L** – What I Need to **L**earn. Mention that we will complete this form at the beginning of the Space Exploration unit and again upon completion.

Space Exploration

What I Know	What I Want to Know	What I Need to Learn

This strategy may be used for any topic within this broad unit. Also, it may be used as an information individual assessment, in which each student writes his/her own responses for each of the three columns. For ***Evaluation***, see form located in the Appendix.

Cooperative Activity
Jobs in Space Exploration Curriculum

Teachers may wish to use this activity for career exploration when completing any classroom activity in this curriculum. It may be used as an ***Introduction*** *to the activity,* ***Requirement*** *for group activities, or as an* ***Organizing*** *guide for an activity.*

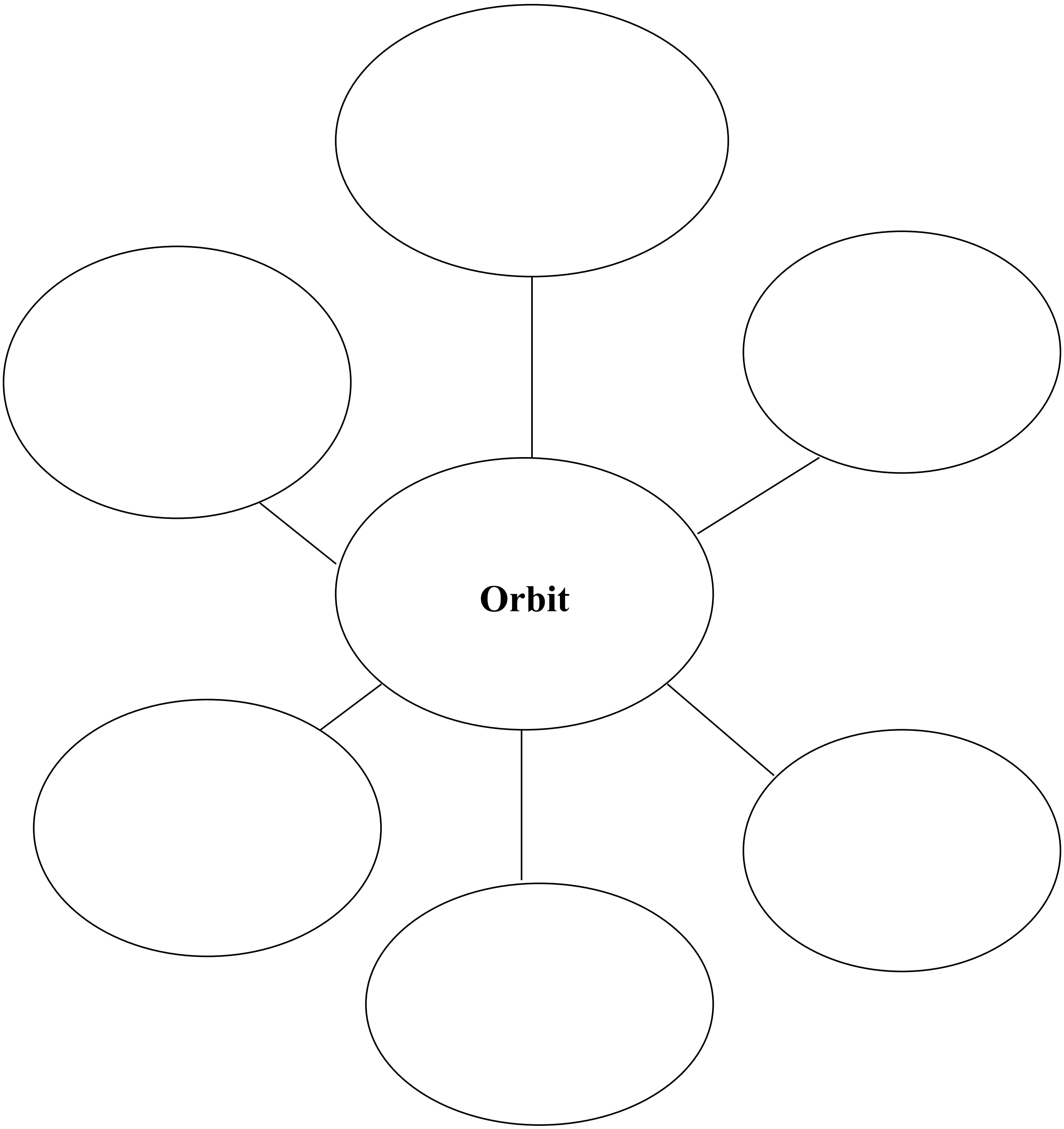
1. Mission Controller (Teacher)
2. Pilot (Facilitator/Leader)
3. Copilot (Recorder)
4. Crew Chief (Organizer/Liaison with Mission Controller)
5. Flight Engineer (Materials Manager)

Flight Checklist

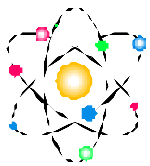
1. Everyone should actively participate in the activity.
2. Be considerate of each group member.
3. Ask others in your group to explain their thinking and work.
4. Help any group member who asks a question.
5. Recognize that it's acceptable to disagree with others in the group.
6. In the final analysis, everyone in the group should agree on the process/solution/product.
7. Ask the Mission Controller for assistance only when everyone in the group has the same question.

Creating A Web:
Introducing an Activity

In an oral discussion initiated by the teacher, students talk about what they know about orbits, for example. The teacher lists all phrases/facts in the circles and adds his/her own concepts. This serves as a springboard for the unit or topic.

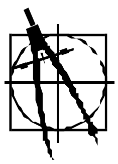


Subject Icons



Science (S)

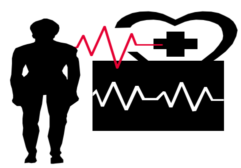
Physical Education (PE)



Math (M)

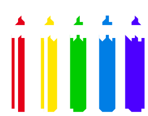
Theater Arts (TA)

Social Studies (SS)



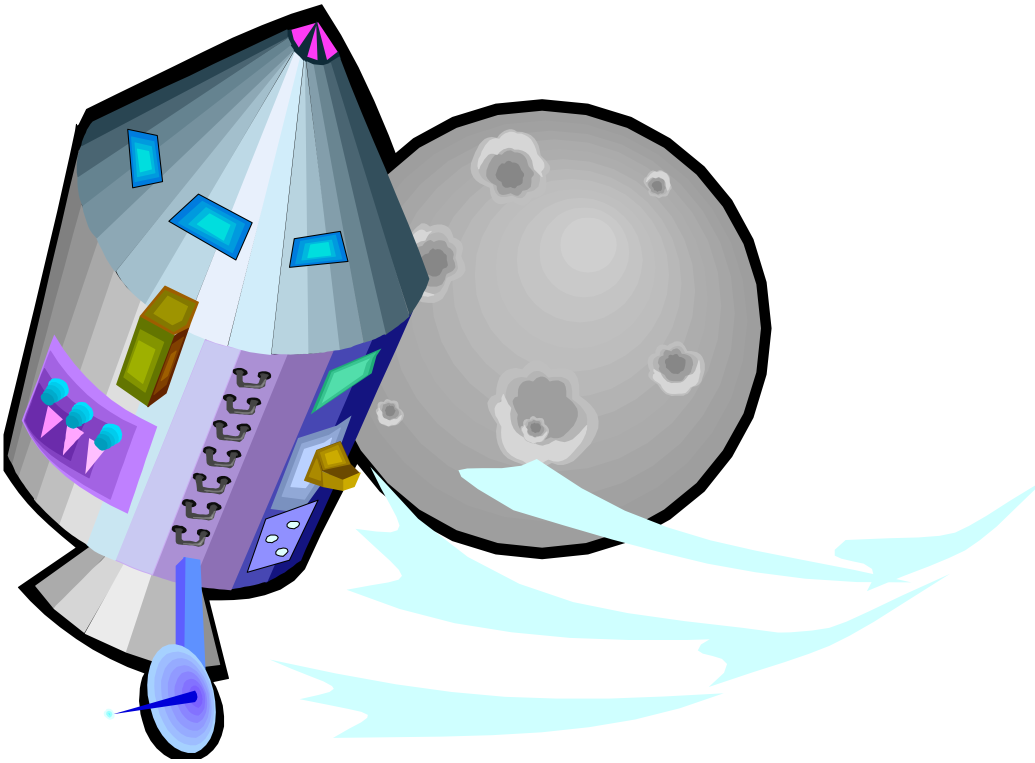
Health (H)

Language Arts (LA)



Fine Arts (FA)

Computer Technology (C)



INTRODUCTION TO SPACE EXPLORATION

Creating a Time Capsule

Grade Level: 5 - 8

Time Required: 30 - 45 minutes

Countdown: Writing paper
Pencils

Suggested TEKS

Language Arts -	5.15	6.15	7.15	8.15
Social Studies -	5.18	6.20	7.20	8.20
Art -	5.2	6.2	7.2	8.2
Computer -	5.2	6.2	7.2	8.2

Suggested SCANS

Interpersonal. Interprets and Communicates Information

National Science and Math Standards

Science as Inquiry, Physical Science, Earth & Space Science, Science & Technology, History & Nature of Science, Measurement, Observing, Communicating

Ignition:

For decades, space colonies have been the creation of science fiction writers. However, with world population growing at an alarming rate, the concept of a second home in space could very likely become a stark reality.

Already, a number of visionary scientists have drawn up plans for off-earth habitats. Biosphere II near Tucson, Arizona is an example. Additionally, NASA has future plans for a mission to Mars in the next 20 years. It certainly appears that earth will not always be our home. With this in mind, ask the students to consider the scenario suggested next in "Liftoff."

Liftoff:

You will have the opportunity to bury a time capsule, a sealed and durable box, which will be opened after one hundred years. Future discoverers of the box will be able to guess from the contents what your life was like 100 years before their time.

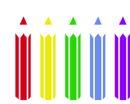
Below are six different categories. For each category, choose an object that would best represent it. Keep in mind that you may choose items like photographs, scrapbooks, films or videos, books, newspapers, miniature models, and other favorite mementos.

Describe your object in detail, and tell why you think it would be a good choice for a time capsule.

The categories are ***yourself, your school, your city, your country, transportation,*** and ***communication.***

Once students have completed their lists, ask them to share their favorite items. Discuss the categories of transportation and communication. Compare and contrast today's means of transportation and communication with what could be possible in the future.

Time Capsule



Countdown:
Photos, Newspaper, Miniature Models, Etc.
Coffee Can or Box

Have students make their own "time capsules" with the items they collected to represent each category. Students may use additional items collected to "collage" the outside of the box or can. When completed, place on display. See if students can identify the owner of each time capsule.

Word Processing and Internet or Library Research

Students will research Biosphere II, Mission to Mars, or the International Space Station. Students will choose one of the following projects:
- write a three page report describing the project
- design a travel brochure to the chosen destination
- using computer graphics, draw the layout of the project selected
- write a persuasive paper about the project and whether it is feasible

More Ideas…

1. Extend the list of categories to include the following:
   - famous person
   - important past event
   - best movie
   - favorite television program
   - most widely read book
   - funny comic strip
   - favorite music
   - most delicious food
   - important invention
   - most useful appliance
   - favorite electronic equipment
   - best-liked game or sport
   - most interesting clothes or hair fashion
2. Discuss the variations and similarities in responses.
3. Talk about how the responses from this geographic area would vary from another geographic area and even another country.
4. E-mail someone from another state or country to get responses to the above categories.
5. Have each student contact their grandparents for responses to the above categories.
6. Discuss variations and similarities.
7. Research whether a time capsule has ever been found in your community? If so, how old was it? What was in it?

International Cooperation

Grade Level: 5 - 8

Time Required: 2 or 3 classes

Countdown: Internet
Reference Material

Suggested TEKS				
Language Arts -	5.13	6.13	7.13	8.13
Social Studies -		6.20	7.20	8.20
Computer -		6.15	7.15	8.15

Suggested SCANS

Interprets and Communicates Information
Uses Computers to Process Information

National Science and Math Standards

Science as Inquiry, Science in Personal and Social Perspectives, Physical Science, Science and Technology, History & Nature of Science

Ignition:

Many invaluable discoveries and contributions have been made by international figures in the exploration of Mars. They are described in the following brief history:

1) Humans have known of Mars since before recorded history. As long as 3,600 years ago, Babylonians wrote about Mars' looping motion across the sky and its changing brightness.
2) In ancient India, Mars appeared like a fire in the sky and, in ancient Greece, the “red wanderer” Mars symbolized the god of war “Ares”. After the Romans conquered Greece, they adopted this symbolism and named the planet for their god of war, “Mars”.
3) During the Middle Ages, astrologers studied Mars' motions to help them predict the future. If Mars moved unfavorably, then wars would be lost. They attempted to predict Mars' motion accurately by using the theory of Polish astronomer Nicolaus Copernicus (1543) stating that the planets orbit in circles around the sun. Finally, German Johannes Kepler discovered in 1609 that Mars orbits the sun in an ellipse, rather than a circle.
4) Meanwhile, Italian Galileo Galilei gave the world its first viewing of Mars. In 1609, he viewed Mars through his newly invented telescope. It revealed that Mars was a large sphere, a world like the Earth. More advanced telescopes showed polar icecaps, color patterns on the surface of Mars, clouds, and hazes. Speculations arose that Mars could actually be a habitable planet.
5) The idea of living Martians continued to flourish when Italian astronomer Giovanni Schiaparelli, in 1877, observed thin dark lines crossing Mars' bright “continents” and called them “canali” (channels in Italian). In the United States, Percival Lowell mistakenly seized upon the idea of “canals” as being proof of a Martian civilization, with water and other resources necessary to sustain life.
6) Beginning in 1965, the United States launched several missions to Mars, as detailed in the table below.

U.S. MARS MISSIONS - SUCCESSFUL			
MISSION	**LAUNCH**	**ARRIVAL**	**HIGHLIGHTS**
Mariner 4 Flyby	Nov. 28, 1964	July 14, 1965	22 black and white images of desolate, cratered southern hemisphere. No canals or signs of life. Water front seas. Proof that Mars' atnisogere us very thin
Mariner 6 and 7 Flybys	Feb, 24 and Mar. 27, 1969	July 31 and Aug. 5, 1969	75 and 126 black and white images of equatorial regions, southern hemisphere, and south polar ice. Measured Mars' mass and density.
Mariner 9 Orbiter	May 30, 1971	Orbit: Nov. 14, 1971	7329 images, many in color. Global maps of elevation, temperature. First views of large volcanos of Tharsis, chasms of Valles Marimera, water-cut channels, Mars' moons.
Viking 1 Orbiter Lander	Aug. 20, 1975	Orbit: June 19, 1976 Landing: July 20, 1976	Orbiter gives > 30,000 images of surface, many in color. Global maps of temperature, atmosphere water content, surface properties. Lander gives first images from Mars' surface dark rocks, red dust, pink sky. Tests soil for life and finds some. Records Mars weather.
Viking 2 Orbiter Lander	Sept. 9, 1975	Orbit: Aug. 7, 1976 Landing:Sept. 3, 1976	Like Viking 1, Orbiter gives >20,000 images of surface. Lander finds no life, again dark rocks, red dust, pink sky. Records Mars weather.
Mars Global Surveyor Orbiter	Nov. 7, 1996	Sept. 1997	Global weather imagery, surface topography and temperatures.
Mars Pathfinder Lander	Dec. 4, 1996	July 4, 1997	Landing in area valleys: engineering tests, imaging and chemical investigations.
Mars Surveyor Orbiter 1998	Dec. 11, 1998		Global imagery, atmospheric temperature profiles.
Mars Surveyor Lander 1998	Jan. 3, 1999		First landing near Martian poles.

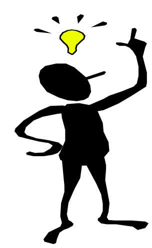
7) In January 1989, the Russian spacecraft Phobos 2 entered Mars' orbit and took images of Mars and its moon in infrared light. However, in March, Phobos 2 lost contact with the Earth.
8) Launched in 1990, the Hubble Space Telescope, with its Near-Infrared Camera, Multi-Object Spectrometer, and Imaging Spectograph, provides invaluable information about the global temperatures, weather, seasons, and color changes of Mars.

Students should conclude that our knowledge of Mars can be attributed not to just one individual or nation, but rather to a host of individuals and nations -- thus, the concept of international cooperation.

Liftoff:

Students will research another long-term international mission,the MIR Space Station. Although launched by Russia, cosmonauts and astronauts from dozens of nations have lived on the station, conducted many experiments cooperatively, and made many important contributions. (http://www.maximov.com/Mir/index.html). Additionally, the film Mission to Mir would provide students with a visual opportunity to experience life aboard MIR. Questions to be answered include the history of MIR, the current status, the importance of MIR, and who cooperated on this venture.

More Ideas. . .



1. Research the International Space Station (ISS).
2. Find the latest information about the Hubble Space Telescope.
3. Locate myths about Mars, and summarize them.
4. List the chronological happenings on the MIR during its existence.
5. Draw the flags of each country participating in the International Space Station.

Stellar Theory

Grade Level: 5-8

Time Required: Four class periods

Countdown:

English - Writing Paper
Pens

Suggested Teks

Math -		5.13	6.13	7.13	8.13
English -	5.19	6.13	7.13	8.13	
Science -	5.3	6.13	7.13	8.13	
Art -		5.2	6.2	7.2	8.2
Computer -		5.2	6.2	7.2	8.2

Suggested SCANS

Information. Acquire and evaluates information.

National Science and Math Standards

Science in Inquiry, Life Science, Physical Science, Earth and Space Science, History & Nature of Science, Computation, Measurement, Reasoning, Observing, Communicating

Science - Assorted Candies
Varied Sizes:

- Nerds
- Red Hots
- Gum Balls
- Malted Milk Balls
- Mini Chocolate Chips
- M & M's
- Butterfinger Dots
- Junior Mints
- Jawbreakers
- Glue

Math - Metric Ruler
Metric Tape Measure
Graph Paper

Ignition:

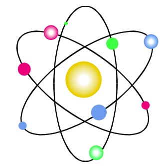
Our solar system is made up of the sun and all of the planets and other small bodies including moons, comets, and asteroids. The planets and other small bodies are influenced by the sun's gravity.

Liftoff:

Divide students into ten groups. Have each group research the following topics. We are particularly interested in size, number of moons, distance to the next planet, etc. Students will write a paper and do an oral presentation to the class about their research.

Sun	Mercury	Uranus	Mars
Earth	Neptune	Venus	
Jupiter	Pluto	Saturn	

A good web site for research is: http://seds.lpl.arizona.edu/nineplanets/nineplanets/



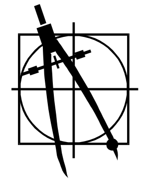
Using the knowledge gained in English, students will use candy to represent the size of various planets by gluing candy piece onto the correct planet. Which planet is the smallest? Which planet is the largest?

Mercury	
Venus	
Earth	
Mars	
Jupiter	
Saturn	
Uranus	
Neptune	
Pluto	

Have each student blow up a balloon to 15 centimeters in diameter. Have the balloon represent the Sun. Explain that the size of the actual Sun is 10,000,000,000 times larger than their model.

Learn the order of the planets my memorizing this sentence: **M**y **V**ery **E**ducated **M**other **J**ust **S**erved **U**s **N**ine **P**izzas! ***Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto***

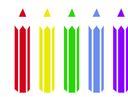
Math students will draw a graph that explains:



Differences in the size of the planets
Distances between each planet
The percentage of the planets that are large compared to those that are small in the solar system
Make a chart of the planets showing diameter, distance, and force of gravity in English units. Convert to metric measurements. Why is it important that we record units of measure?

More Ideas …

- Design a travel brochure or video to the planet they researched. This could be a Computer, Art, English, or Journalism project.



- Make a model of the solar system. Students should recall that each planet orbits the Sun on different paths and at different speeds. Some planets even orbit in different planes.
- Bring objects from home, other than candy, to model the solar system for a broader understanding of the scale concept. Example: fruit (orange, kiwi, berries, etc.) or sport balls (golf, baseball, basketball, etc.) Student should determine which item represents which planet/sun.

- Research Jupiter and its moons and develop a scale model.
- Search the Internet for the overview of space history.
- Draw a time line related to space events during the past thirty (30) years.
- Visit http://observe.ivv.nasa.gov/nasa/fun/concentrate/concentration.html and play Space Concentration

Abort, Launch, It's A Go!

Grade Level: 5 and 6

Time Required: 30 - 45 minutes

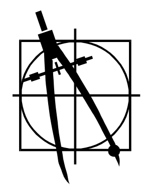
Suggested TEKS		
Math -	5.14	6.11
Science - 5.3	6.3	
Theatre Arts -	5.2	6.2
Art -	5.2	6.2
Suggested SCANS		
Interpersonal. Teaches others.		
National Science and Math Standards		
Science as Inquiry, Life Science, Physical Science, Earth and Space Science, Science & Technology, Observing, Communicating		

Countdown:

White Board (or Blackboard)
Marker
Eraser
Abort, Launch, It's A Go! Cards
Sixty second (One-Minute) Timer

Ignition:

Explain that this game is similar to Pictionary, because each person will be shown a card with a space word and will then draw a picture to illustrate it.



Liftoff:

The rules are:

1. The class is to be divided into two even teams.
2. The first team member of Team #1 will be shown an index card with a space-related word.
3. Team member will then draw the picture on the board.
4. Team members from Team1 will then have 60 seconds in which to guess the correct answer.
5. If Team 1 is unable to guess correctly, Team 2 is then given 30 seconds to guess what is already drawn on the board.
6. A point is awarded for each correct answer.
7. **Reminder:** The illustrator may not speak or pantomime with his/her hands. Written words or numbers are not allowed unless the team has guessed one of a two-word answer (example: space station). The correct part of the two-word response may be written on the board.
8. **To break a tie:** Choose a more challenging card or show cards with illustrations and ask the teams to identify them.

More Ideas:

1. Create your own ***Abort, Launch, It's A Go!*** Cards.
2. "Invent" a game with a space theme.

Theatre Arts

Countdown:

Movie, Book, or Thing Cards
Timer

Ignition:

Students play *Charades*. An individual draws a card from the stack. The individual gives a movie, book, or thing symbol.

Liftoff:

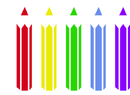
The individual then acts out (pantomimes) each word in the name within a five-minute time limit. The individual that guesses the correct answer then has to draw and make others guess their Charade. Example categories and titles include:

Movie	Book	Thing
Contact	The Martian Chronicles	Perfect Landing
Apollo 13	Star Trek	Jet Expulsion
Mission Impossible	Journey to the Moon	Flotation Device
Lost in Space	Mission to Mars	Rescue Team
Deep Impact	Goodnight Moon	Space Suit
The Jetsons	Journey to the Center of the Earth	Global Warming
Mars Attacks	Space Flight	Moonlight Madness
Star Wars	Blue Skies	Lunar Rover
Space Cowboys	Roaring Rockets	Astronaut

More Ideas:

1. Brainstorm in student groups to think of additional movies, books, and things.
2. Act out (pantomime) for the other groups to see if they can guess the names.
3. Keep points for each group.

Art



Countdown:

Box
Materials
Paint

Ignition:
Student will select a movie, book, or thing from the index cards.

Liftoff:
Students will make a diorama depicting a scene or the title of the card drawn.

More Ideas:

- Make a salt sculpture depicting a space-related theme.
- Visit the web site: Arty the Part-time Astronaut and take the solar system tour at http://www.artyastro.com/artyastro.htm

Abort, Launch, It's A Go!

Abort, Launch, It's A Go!

Sun Star that is the central celestial body in the solar system	**Moon** Natural satellite of the earth	**Earth** Planet inhabited by humans; the third planet from the sun, water planet	**Planet** Any of the nine primary celestial objects that orbit the sun
Mars Fourth planet from the sun, reddish in color	**Orbit** The path followed by celestial objects moving under gravity	**Universe** The system that encompasses all known space, matter, and energy	**Telescope** Instrument that produces a distinct, generally magnified image of a distant object
Stars Enormous ball of glowing gases	**Gravity** Force of attraction between all mass in the universe	**Biosphere** Part of Earth and its atmosphere capable of supporting life	**Astronaut** A person that pilots or conducts experiments on a spacecraft
Spacesuit Suit worn by astronauts while in outer space	**Rocket** A device used to propel vehicle designed to travel through space.	**Space shuttle** Reusable spacecraft for travel to space	**Space probe** A spacecraft designed to study physical properties of outer space

Abort, Launch, It's A Go!

Satellite A small body or human made object orbiting a celestial body	**Space station** Flying laboratory in space	**Ocean** Body of salt water covering 70% of earth	**Black holes** An object in space so dense that no light or radiation can pass through
Constellation Star patterns in the sky	**Robot** Mechanical device that can be programmed to perform tasks	**Comet** A small solar system body made primarily of ices and gases	**Meteorite** A solid mass of rock matter that fell to earth from outer space
Volcano A vent or fissure where magma escapes	**Sunspot** Cool and dark area on the sun's photosphere with strong magnetic field	**Light-year** Unit of measure for how long it takes for light to travel in one year – 5.88 trillion miles	**Galaxy** A gravitational bound collection of stars, dust, and gas
Countdown Backward counting of hours, minutes, and seconds leading up to the launch of a vehicle.	**Capsule** Small pressurized module	**Control panel** The console which houses the major switches and controls	**Air lock** Intermediate chamber between places of unequal pressure

Space Spinoffs

Grade Level: 5 - 8

Time Required: 30 - 45 minutes

Countdown:

Space Spinoffs Bingo Cards
Space Spinoffs Descriptions
Small Paper Clips/Beans/Pennies
(to cover Bingo cards)

Suggested TEKS

Social Studies -	5.24	6.20	7.21	8.28
Science -	5.3	6.3	7.3	8.3

Suggested SCANS

Interpersonal. Interprets and Communicates Information

National Science and Math Standards

Science as Inquiry, Science in Personal and Social Perspectives, Physical Science, Science & Technology, History & Nature of Science, Observing, Communicating

Ignition:

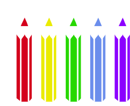
One of the important aspects of the space program has been the technological advance we experience every day as a result of space exploration. A 'spin-off" is something that has resulted from experiments, inventions, or technology in space.

Liftoff:

1) Pass out one Bingo card per person and one sheet of words. Have students write a Spinoff word answer in each Bingo square.
2) Distribute chips to cover correct answers on Bingo cards.
3) Announce which "Bingo" game you will play – blackout (entire card covered), straight line (can be across, down or diagonal), four corners, etc.
4) Read the description of the spinoff and explain the history. If the student has the correct answer on his/her bingo card for what you are describing, he/she would cover the answer.
5) The student to get a "Bingo" calls out. Verify the answers.
6) Reward students with a space sticker, "Mars" or "Milky Way" candy bar, etc.

Conclusion:

After the first "Bingo, you may want to play again. It is important that all Spinoffs are discussed. Ask the students to think of something used every day that is a result of the space program. Have the students do research on Space Spinoffs to find out if their prediction is correct.



Space Spinoffs Collage

Countdown:

Photos, Magazines, Advertisements, Etc.
Poster or Tag Paper

Working in teams, have students make a Space Spinoffs collage. Students must choose a theme for their collage: Examples include: Safety, Environmental Concerns, Medical, Technology, etc. Students will use the magazines and photos to make a "collage" of Space Spinoffs that represent that theme.

More Ideas…

1. Connect to the Internet to find more Spinoffs.
   http://www.sti.nasa.gov/tto/spinoff.html
2. Research articles in the library about space technology.
3. Bring something from home (either the actual item or a picture of the item) that is a space spinoff.

Space Spinoff Bingo

		FREE		

Spinoff Bingo Words – Select words and fill in Spinoff Bingo Card.

Home Buying	**Milk Bottle Blankets**	**Fighting Hunger in Africa**	**Air Quality Monitoring**	**Treating Brain Cancer**
Scratch Resistant Lens Coating	**Cordless Products**	**ICEMAT**	**Riblets**	**Corrosion Resistant Coating**
Improved Airport Operations	**Whale Studies**	**Tire Recycling**	**Improved Vacuum Cleaners**	**Superfund Site Clean up**
Memory Golf Clubs	**Toy Gliders**	**Ergonomic Chairs**	**Sporting Goods Lubricants**	**Invisible Flame Imaging**
Automotive Insulation	**Satellite Antenna Systems**	**Vision Enhancement**	**Weather Prediction**	**Porpoise Safety**
Breast Cancer Detection	**Chair Lift**	**Microbe Eaters**	**Computer Graphics**	**Fertilizer**
Tang	**Velcro**	**Controller**	**Heart Monitor**	**Thermometer**

Space Spinoffs

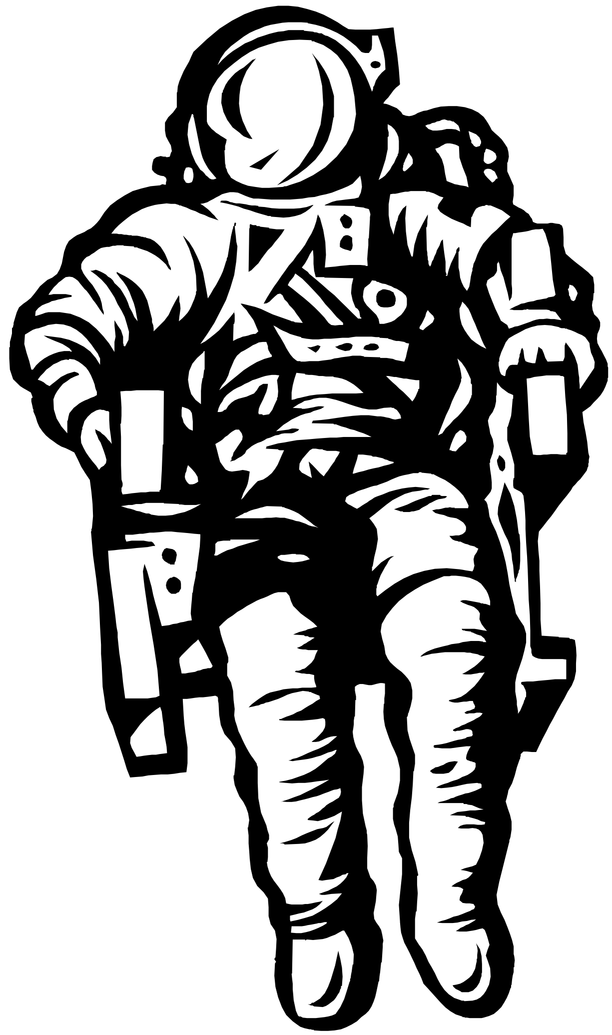
Remote Sensing for Home Buying Without leaving the office, prospective buyers can view property characteristics such as percent shade of the lot, setback distances between the street and the house, visibility from the house, sites of interest, other houses, and stores in the area. *History:* NASA/Stennis teamed with Diamondhead realtor to adapt a detailed airborne remote sensing program to help homebuyers.	**Recycled Milk Bottle Blankets** These are recycled into lightweight blankets used for rescues and emergencies. They are non-allergenic, dry five times faster than wool, and are four times warmer than wool in cold/damp climates. *History:* S.D. Miler & Assoc., in conjunction with NASA/Ames, originally developed the honeycomb concept, used in plastic insulation for future spacecraft.
Help in the Solution to Hunger in Africa Solar Cookers International uses NASA's Surface Solar Energy data set to pinpoint locations where solar cooking would be useful. They then go teach the community how to set up and use solar cooking. This is important because many of the communities do not have fuel options, such as firewood. *History:* The Surface Solar Energy data set was generated for scientific solar energy research.	**Air Quality Monitoring** U.S. Industries can better monitor and reduce their smokestack emissions using a NASA-developed remote gas-sensing instrument. It is more reliable than past instruments. *History:* The instrument was originally developed at NASA/Langley to measure gases in the Earth's atmosphere from aircraft and spacecraft.
Treating Cancerous Brain Tumors in Children Using a pinhead sized LED's (Light Emitting Diodes) to activate light-sensitive tumor treating drugs, more tumors can be destroyed than with conventional surgery. The LED probe costs less than laser, can be used for hours, and remains cool to the touch. *History:* Quantum Devices, Inc. developed LED's as a light source for plant research in space.	**Scratch Resistant Lens Coating** This is used on sunglasses to prolong the life of plastic lenses. *History:* Foster & Grant recognized the applicability of the coating originally designed at NASA/Ames Research Center to protect plastic surfaces on equipment exposed to harsh environments.
Cordless Products Consumers use a whole range of these devices – from tools to vacuum cleaners. *History:* Black and Decker designed a cordless drill for Apollo astronauts to obtain lunar samples away from their command modules.	**ICEMAT Ice Making System** This system is used to create temporary ice rinks in amusement parks, sports arenas, dinner theaters, etc. for traveling ice shows. *History:* Adapted by Calmac Manufacturing Corporation from a solar heating system developed under contact with NASA/Marshall.
Riblets Used by the yacht crew of Stars and Stripes to help win the America's Cup in 1987. 3M developed this film with adhesive backing to retrofit existing aircraft. Tiny, v-shaped grooves on the surface in the direction of the air or water flow reduces skin friction, reduces drag, and cuts fuel consumption. *History:* Concept originated at NASA/Langley to improve aircraft fuel efficiency.	**Corrosion Resistant Coating (IC 531)** This was used to coat the iron skeleton of the State of Liberty during its renovation and on many other structures/landmarks worldwide. *History:* NASA/Goddard started the research program to protect the NASA/Kennedy Space Center launch structures from salt corrosion, rocket exhaust, and thermal shock. Once developed it reduced maintenance costs.

Space Spinoffs

Improving Airport Operations	**Superfund Site Clean Up**
This surface movement advisor, developed by NASA, is used to reduce ground operations and bottlenecks, allowing planes to be serviced and dispatched faster. The system reduced airplane taxi times by one minute per flight, equaling 1,000 minutes per day and $50,000 in airport operating costs. *History:* The Surface Movement Advisor was developed at NASA/Ames with the FAA.	The U.S. Geological Survey produced maps which allow the Bureau of Reclamation and the EPA to identify and evaluate possible contamination sources as small as individual mine dumps using data from NASA Airborne Visible and Infra-Red Imaging Spectrometer. *History:* The AVIRIS instrument does non-traditional remote sensing by measuring how light is absorbed or reflected by various materials on the Earth.
Whale Studies	**Tire Recycling**
Marine biologists use TOPEX/Poseidon data and measurements from the European Space Agency's ERS-2 satellite to generate circulation feature maps of the ocean. Research ships are then directed to those areas most likely to be feeding areas for this mammal. *History:* TOPEX/Poseidon is a joint NASA/French Space Agency satellite that produces ocean topographic maps every ten days to calculate speed and direction of worldwide ocean currents.	Due to NASA's expertise in fuel handling due to launch vehicle and spacecraft operation requirements, Cryopolymers, Inc. is using NASA's expertise to make a more efficient and cost-effective method for this recycling process. *History:* NASA/Stennis used its expertise in cryogenic fuel handling for this study.
Improving Vacuum Cleaners	**Safeguarding Porpoises**
Using NASA's holography equipment and advanced computer software, an improved fan blade design was developed making the machine quieter and more efficient. *History:* The NASA/Lewis holography equipment is usually used to analyze the vibration modes of jet engine fans. The Kirby Company used it to improve vacuum cleaners.	A low-cost, easy to use acoustic pinger broadcasts a signal within the hearing range for these mammals warning them about the location of sink gill nets, to help avoid becoming tangled in the nets used by commercial fisheries. *History:* NASA/Langley developed an underwater location aid in the 1960's to help in the retrieval of NASA payloads following watery touchdowns to Earth. The Dukane Corporation modified this for commercial fishing.
Memory Golf Clubs	**Sporting Goods Lubricants**
Shape memory metal inserts put more spin on the ball without sacrificing distance and give the sports enthusiast greater control and a solid feel. *History:* Memry Corporation's investigation and commercialization of shape memory alloys stems from its NASA/Marshall contract to study materials for the space station.	Two types were developed that are environmentally safe, non-hazardous, and non-flammable. One is designed for fishing rods and one for gun cleaning. *History:* Sun Coast Chemicals originally developed environmentally safe lubricants, under sub-contract with Lockheed Martin, for use on Kennedy Space Center's Mobile Launch Platform, which transports the Space Shuttle from the Vehicle Assembly Building to the launch pad.
Toy Gliders	**Ergonomic Chairs**
Changes were made to the design of this toy to improve performance. Some of the changes were: wing location on the toy's fuselage and correct tail surface angles. *History: Hasbro, Inc. worked with* NASA/Langley because of its decades of experience in scale-model, low-speed aircraft design research and wind tunnel testing.	These are used in offices to help reduce back pain and muscle fatigue in office workers. *History:* BodyBilt created this chair based on NASA research on the effects of microgravity on the human body. The NASA Antropometric Source Book is a compilation of NASA's findings on the effects of microgravity on the human body and came from research conducted by astronauts on Skylab and other space flights.

Space Spinoffs

Invisible Flame Imaging Fire fighters use this device to see invisible flames of hydrogen and alcohol fires during the day. The device works like a pair of binoculars. Previously, fire departments probed areas of suspected hydrogen fires with brooms to find flames. *History:* SafetySCAN used NASA/Stennis technology to visually detect presence, location, and extent of hydrogen fires. NASA's technology was developed due to hydrogen use in rocket engine test programs.	**Automotive Insulation** This thermal protection system is like a blanket for use on NASCAR equipment where temperatures in the cockpit can climb to 140 to 160 degrees. Tests have shown that TPS can lower the temperature by as much as 50 degrees. *History:* The TPS materials adapted by BPS Products, Inc. are used to insulate Space Shuttle equipment and other orbiting satellites.
Satellite Antenna Systems Telecommunications equipment used by television news crews and any other organization that needs reliable mobile satellite antennae systems has been developed by converting NASA/JPL equipment. The product is an improved mobile satellite antenna that is designed to be able to smoothly lock onto a specific satellite signal without fluctuations. *History:* NASA/JPL developed the prototype antenna as part of the ACTS program.	**Vision Enhancement** LVES is a portable image processing system that enhances and alters images to compensate for a patient's impaired eyesight. Scientists at NASA/Stennis and the John Hopkins Wilmer Eye Institute developed the LVES (often called Elvis by its users), to improve the visual capability of people with severely impaired eyesight. *History:* The LVES uses NASA technology developed for computer processing satellite images.
Weather Prediction Analysis of data from the TOPEX/Poseidon and Upper Atmosphere Research (UARS) satellites give meteorologists advanced warning of the occurrence and severity of the El Nino phenomenon. *History:* TOPEX/Poseidon studies worldwide ocean currents. The UARS Microwave Limb Sounder instrument was originally designed to study atmospheric ozone depletion but can also be adapted to study atmospheric water vapor.	**Breast Cancer Detection** Is an advanced method for screening breast cancer detection by detecting blood flow differences in early development. The BioScan System is used to locate and confirm the location of cancerous breast lesion by detecting the cancer's ability to detect a new blood supply. Mammograms detect calcification associated with cancer cells after they are well into development. *History*: OmniCorder Inc. used technology developed by NASA JPL.
Chair Lift Using technology developed to allow workers to get off the launch platform in the event of an emergency, a retired NASA KSC engineer developed a way to lift people from a seated position. The eZ uP device was developed for his wife who has arthritis. *History:* This NASA engineer used technology developed at NASA Kennedy Space Center for this device to help those who need a helping hand.	**Microbe Eater** Biological products for a cleaner and safe environment is the business of Micro-Bac. Partnering with NASA, they developed a phototropic cell for water purification. It is used on the space station and for future missions to the Moon and Mars. The material is presently used on earth in septic systems, ponds, etc. for degrading fat, oil, and fecal matter. *History:* Micro-Bac partnered with NASA Marshall for product development.
Computer Graphics A 3-D graphics tool created for the International Space Station serves double duty by helping Hollywood with special effects, animation, and colorization of old back-and-white television shows and movies. By graphically constructing models, kinematic and dynamic analysis tests can be performed specifying forces, torque, and other conditions. *History:* Dycom partnered with NASA to further enhance the TREETOPS software.	**Fertilizer** Although zeolite sounds like a space term, it is actually minerals used in a fertilizer. NASA has long been interested in ways to sustain plant growth in space exploration to support astronauts with oxygen, food, water, and to help recycle waste products. A highly productive synthetic soil was created to support plant growth. *History:* Boulder Innovative Technologies worked with NASA to develop superior plant growth media for spaceflight.



LIFE SCIENCE

Nutrition in Space

Grade Level: 5

Time Required: 6 - 10 days
(using sun as energy source)
two 45 minute class periods
(using oven as energy source)

Suggested TEKS:		
Math -	5.11	5.14
Science -	5.2	

Suggested SCANS:
Information. Acquires and evaluates information.

National Science and Math Standards
Science as Inquiry, Life Science, Science In Personal and Social Perspectives, Science and Technology, Physical Science, Measurement, Reasoning, Observing, Communicating

Countdown:
- Fruits (i.e. apples, bananas, grapes)
- Vegetables (i.e. celery, carrots, tomatoes)
- Knife
- Cheese Cloth
- Drying Trays (i.e. cookie sheet or aluminum foil pieces)
- Gram scale and masses

Ignition:

In 1959, NASA started planning for manned space travel and was challenged by the problem of how and what to feed astronauts. Two basic concerns arose:
(1) preventing food crumbs from contaminating the spacecraft's atmosphere and
(2) preventing the formation of potentially catastrophic disease-producing bacteria, viruses, and toxins.

To solve these problems, NASA hired the Pillsbury Company. The first solution was to coat bite-size food like sandwich cubes, thereby preventing crumbling. Also, as in Apollo, food like ham salad was packaged into toothpaste-type tubes and squeezed out. The second solution was more difficult. Pillsbury developed the HACCP (Hazard Analysis and Critical Control Point) concept. This procedure involves a systematic study of the food product to be produced and packaged, along with the processing conditions, handling, storage, packaging, distribution, and package directions for consumer use. The stages in the chain from raw materials to finished product are constantly monitored.

Due to lack of storage space and refrigerators on most manned spacecrafts, NASA has found that the method of dehydration and freeze-dried foods is an effective answer to feeding astronauts. The ancient method of dehydration serves two purposes: (1) to dry food, thereby reducing its moisture to between 5% and 25% and eliminating bacteria which cause decay and (2) to preserve food for future use without concern for an expiration date.

Liftoff:

According to time and resources available, choose between using sun energy (which could require 10 days) and using the oven.

1. Make sure that your fruit is fully ripe.
2. Have students weigh each fruit and vegetable before drying and record weights in the table provided.
3. To use the sun method:

- Cut the food into medium chunks (except the grapes, which should be left whole, either in a bunch or separated).
- Place fruits and vegetables on drying trays outside and cover with cheesecloth. Dry on one side, then turn and dry on the other side. This should take 6 - 10 days.

4. To use the oven method:

- Slice the fruit and vegetables one-eighth inch think; put in a single layer on the drying trays. (Do not try the grapes in the oven because of their skin.)
- Place in a 120 F oven for 8 - 12 hours.

5. Ask the students to weigh the dried fruit and vegetables. Record new weights in the table, and determine the mass/water weight loss.

Conclusion:

1. Compare and contrast the process of dehydration with the processes of freezing and canning. Suggest that in other environments refrigerators may not be readily available. Ask for suggestions of other possible food storage.
2. Discuss the types of energy used. Predict energy sources that may be accessible in the future in different environments such s the moon and planets, most notably Mars.

More Ideas:

- Extend the measurements in the table to include the ratio of loss of mass to beginning mass and the percentage of water in a variety of different fruits and vegetables (pear, pineapple, potato, squash, mushroom).
- Preserve meats (i.e., ham, beef, chicken, lamb) by sun or oven drying. Use extra care when drying meats due to the possibility of spoilage. The drying time for meat is about 3 days if done outdoors (although this method is not recommended) and several hours in the oven.
- Make jerky, using the following recipe.

Jerky

1 1/2 lbs. Lean, boneless meat (beef flank, brisket, top round stead, venison, turkey)
1/4 cup soy sauce
1 T. pepper
1/4 t. garlic powder
1/2 t. onion powder
1 t. liquid hickory smoke
Flavored salt
Hot sauce/Tabasco (optional)

Partially freeze the meat to be used so that slicing will be easier. Trim and discard all fat from the meat. Cut the meat into 1/8 to 1/4-inch thick slices. In a bowl, combine sauces and seasonings until dissolved. Add the meat strips and coat thoroughly. Cover tightly; let stand overnight in the refrigerator. Shake off the excess liquid; sprinkle coarse black pepper on both sides. Arrange the meat strips close together, single layer, directly on the oven racks with shallow rimmed pans underneath. Dry the meat at 150 - 200 degrees F until it turns brown, feels hard, and is dry to the touch. Cooking time for chicken and turkey is about 5- 6 hours, 4 - 7 hours for beef and venison. Pat off any beads of oil. Cook and store in airtight plastic bags or jars with tight fitting-lids.

The Effects of Dehydration on Fruits and Vegetables

Food Sample	Mass (before drying) (g)	Mass (after drying) (g)	Loss of Mass (g)

Lunch Time

Grade Level: 5 - 6

Time Required: 30 - 45 minutes

Countdown:
Food Word Search
Menu Selection Sheet
Pencils

Suggested TEKS	
Science -	5.2
English -	5.9

Suggested SCANS
Interpersonal. Teaches others.
National Science and Math Standards
Science and Inquiry, Life Science, Science in Personal and Social Perspectives,

Ignition:

Eating is essential to survival. Now that we have the International Space Station, astronauts are from many different countries. The food astronauts take into space must:

- be lightweight
- require little storage space
- be nutritious
- be convenient to use
- need no refrigeration
- be foods they like

Some foods are dehydrated to help meet weight and storage restrictions for the space shuttle liftoff. Dehydration means all the water is removed from the item. Can you think of a food you ate during the last week that was dehydrated? (Example: cup of soup, raisins, instant pudding, etc.)

The food is later rehydrated in orbit when it is ready to be eaten. Water used for rehydration comes from the space shuttle's fuel cells. The fuel cells produce electricity by combining hydrogen and oxygen, resulting in water. Since water is an available byproduct from the shuttle's fuel cells, it is possible to send food in a dried form for later rehydration.

What did each student eat for lunch? Write down all responses on the chalkboard or on a transparency on the overhead projector. Discuss whether each item could be taken on the space shuttle. Why or why not?

More than 100 different food items such as cereals, spaghetti, scrambled eggs, and strawberries, go through this dehydration/rehydration process.

Some 20 varieties of drinks, including tea and coffee, are also dehydrated for use in space travel. But pure orange juice or whole milk cannot be used for dehydration. Do you know why? If water is added to dehydrated orange crystals, the crystals just become orange rocks in water. During the 1960's, General Foods developed a synthetic orange juice product called Tang, which could be used in place of orange juice. If whole milk is rehydrated, the dried milk does not dissolve properly. Instead, it floats around in lumps and has a disagreeable taste. Instead, skim milk is used to avoid problems.

Liftoff:

Shuttle foods are brought aboard in several different forms.

❖ Divide students into four groups. Each group will be given one of the four ways that foods are brought aboard the space shuttle which are listed below. Each group will then come up with a list of examples of foods in each category. Have each group share with the class these examples.

Natural Form - examples are graham crackers, pecan cookies, peanut butter, hard candy and gum.

Thermostabilized - cooked at moderate temperatures and sealed in cans. Examples are tuna fish and canned fruit in heavy syrup.

Irradiated - preserved by exposure to ionizing radiation. Examples are meat and bread.

Intermediate Moisture Process - removing part of the water. Examples are dried apricots, peaches, and pears.

Salt and pepper are packaged in liquid form because crystals would float around the cabin.

❖ The variety of food carried into orbit is so broad that crewmembers enjoy a several-day menu cycle. A typical dinner might consist of a shrimp cocktail, steak, broccoli, rice, fruit cocktail, chocolate pudding, and grape drink. Have each group plan a meal based on the example food list and then tell how it would prepare the meal. Each group will then share the results with the class.

To prepare the example typical meal, a crewmember takes a big plastic overwrap out of the food locker. The package is then attached to a worktable; inside the over-wrap are four smaller plastic overwraps, each holding a complete meal of separate containers. Using a hollow needle attached to the hot water outlet, the crewmember injects a prescribed amount of water into the plastic bowls of dehydrated broccoli and rice through a narrow passageway.

The crewmember then kneads the packages through their flexible plastic tops and secures them in the oven along with the four precooked steaks. The steaks are packaged in flexible aluminum-backed plastic bags, called flex-pouches. The heat in the oven can reach 82 degrees C (1880 degrees F), which does not harm the plastic containers. A fan circulates air so that the food is heated evenly.

While these items are heated in the oven, the crewmember takes four trays from the galley and attaches them by magnets or clamps to a portable dining table hooked to the lockers. The crewmember then adds cold water through the hollow needle to rehydrate the bowls of shrimp, chocolate pudding, and grape drink. A plastic straw with a clamp on it is inserted into the passageway of the grape drink. These cold items, along with the cans of fruit cocktail, the silverware, and a can opener, are assembled on the trays and held by magnets or Velcro tape. When the heated foods are ready, it's dinnertime.

English Students will:

- ❖ Write a paper on mealtime in space.
- ❖ Learn new vocabulary words by unscrambling words in the ***Shuttle Food Scramble***.
- ❖ How many space foods can you make from the words: ***Shuttle Food Selection Menu?***

More Ideas …

- Complete "Foreign Bread" Word Search.
- Make a list of food items we use today that started because of the Space Program.
- Design a meal tray for the shuttle launch using a Styrofoam meat tray.
- Plan menus for a seven-day launch.
- Research the nationality or heritage of an international astronaut in the U.S. Astronaut Program http://spaceflight.nasa.gov/spacenews/factsheets/pdfs/astro.pdf
- Research foods that are eaten in each country. Identify foods that could be taken into space that would make this astronaut "feel at home."

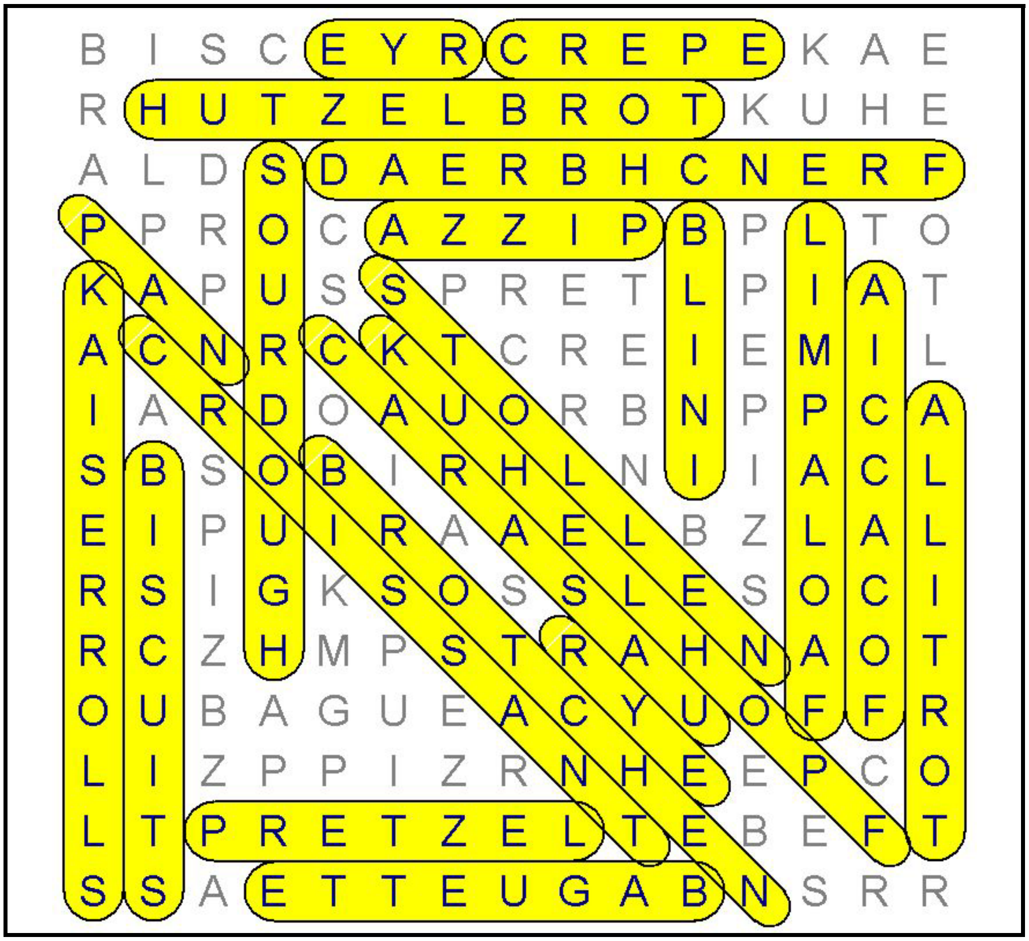
Foreign Breads

B	I	S	C	E	Y	R	C	R	E	P	E	K	A	E
R	H	U	T	Z	E	L	B	R	O	T	K	U	H	E
A	L	D	S	D	A	E	R	B	H	C	N	E	R	F
P	P	R	O	C	A	Z	Z	I	P	B	P	L	T	O
K	A	P	U	S	S	P	R	E	T	L	P	I	A	T
A	C	N	R	C	K	T	C	R	E	I	E	M	I	L
I	A	R	D	O	A	U	O	R	B	N	P	P	C	A
S	B	S	O	B	I	R	H	L	N	I	I	A	C	L
E	I	P	U	I	R	A	A	E	L	B	Z	L	A	L
R	S	I	G	K	S	O	S	S	L	E	S	O	C	I
R	C	Z	H	M	P	S	T	R	A	H	N	A	O	T
O	U	B	A	G	U	E	A	C	Y	U	O	F	F	R
L	I	Z	P	P	I	Z	R	N	H	E	E	P	C	O
L	T	P	R	E	T	Z	E	L	T	E	B	E	F	T
S	S	A	E	T	T	E	U	G	A	B	N	S	R	R

Kaiser Rolls	**Hutzelbrot**	**Stollen**	**Kuhelhopf**	**Limpa Loaf**
Sourdough	**Pizza**	**Biscuits**	**Rye**	**Blini**
Pretzel	**Tortilla**	**Croissant**	**French Bread**	**Crepe**
Baguette	**Carasau**	**Brotchen**	**Focaccia**	**Pan**

Bonus: The Japanese eat these more often than bread.
This crisp bread product is flat and crispy.
Which bread can you find more than once?
Name the countries that the breads and Astronauts represent.
Kulich, Crepe, Blini, Lefse, Tortilla, are names for what American breakfast product?

Foreign Breads *Answer Sheet*



Kaiser Rolls	**Hutzelbrot**	**Stollen**	**Kuhelhopf**	**Limpa Loaf**
Sourdough	**Pizza**	**Biscuits**	**Rye**	**Blini**
Pretzel	**Tortilla**	**Croissant**	**French Bread**	**Crepe**
Baguette	**Carasau**	**Brotchen**	**Focaccia**	**Pan**

Bonus: The Japanese eat these more often than bread. Rice

This crisp bread product is flat and crispy. Crackers

What word is shown more than once? Rye

Countries of breads and astronauts: Canada, France, Germany, Italy, Japan, Spain, Sweden, Switzerland, and United States

These are names for what popular American breakfast product? Pancake

Answers to Shuttle Food Scramble

Natural Form	Tang
Thermostabilized	Dehydrated
Irradiated	Rehydrated
Intermediate Moisture Process	Nutritious

Shuttle Food Scramble

AURTANL OMRF - ______________________________

OMREHDTSBAIIZE - ______________________________

ITERIDARAD - ______________________________

TNIMREIDEETA IOMUTSER ORPSECS -

____

ANTG - ______________________________

HEDRDYETAD - ______________________________

ERHYTDARDE - ______________________________

IIUNTTSUOR - ______________________________

Example Shuttle Food Selection Menu

Almonds (NF)
Applesauce (T)
Apricots, dried (IM)

Barbecue beef with sauce (R)
Beef almondine (R)
Beef w/sauce (T)
Beef ground w/spice sauce (T)
Beef patty (R)
Beef steak (T)
Beef stroganoff w/noodles (R)
Bran flakes (R)
Bread (NF)
Breakfast roll (NF)
Butter cookies (NF)
Butterscotch pudding (T)

Candy coated chocolates (NF)
Candy coated peanuts (NF)
Cashews (NF)
Cauliflower w/cheese (R)
Cheese spread (T)
Chicken a la king (T)
Chicken consommé (R)
Chicken and rice (R)
Chicken salad spread (T)
Chili mac w/beef (R)
Chocolate mints (NF)
Chocolate pudding (T)
Corn, green beans and paste (R)
Corn flakes (R)
Dried beef (IM)

Eggs, scrambled (R)
Eggs, seasoned scrambled (R)
Eggs, Mexican scrambled (R)
Frankfurters (T)
Fruit bars (IM)
Fruitcake (T)
Fruit cocktail (T)

Graham crackers (NF)
Granola cereal (R)
Granola cereal w/blueberries (R)
Granola cereal w/raisins (R)
Granola bar (NF)
Green beans and broccoli (R)
Green beans w/mushrooms (R)

Ham (T)
Ham salad sandwich spread (T)

Italian vegetables (R)

Jam/jelly (IM)

Lemon pudding (T)
Life savers (NF)

Macadamia nuts (NF)
Macaroni and cheese (R)
Meatballs w/BBQ sauce (T)
Mushroom soup (R)

Oatmeal w/raisins and spice (R)

Peach ambrosia (R)
Peaches, diced (T)
Peaches, dried (IM)
Peanut butter (T)
Peanuts (NF)
Pears, diced (T)
Pears, dried (IM)
Pecan cookies (NF)
Pineapple (T)
Potatoes au gratin (R)
Potato patty (R)

Rice krispies (R)
Rice pilaf (R)

Salmon (T)
Sausage patty (R)
Shortbread patty (NF)
Shrimp cocktail (R)
Shrimp creole (R)
Soda crackers (NF)
Spaghetti, w/meat sauce (R)
Spinach, creamed (R)
Strawberries (R)
Sweet 'n sour Chicken (R)

Teriyaki Chicken (R)
Trail mix (NF)
Tuna (T)
Tuna salad spread (T)
Turkey and gravy (T)
Turkey salad spread (T)
Turkey tetrazzini (R)

Vanilla pudding (T)

Beverages:
Apple drink
Cherry drink w/artificial sweetener
Citrus drink
Cocoa
Coffee, black
Coffee w/artificial sweetener
Grapefruit drink
Instant breakfast, chocolate
Instant breakfast, strawberry
Instant breakfast, vanilla
Lemonade
Lemonade w/artificial sweetener
Lemon-lime drink

Orange drink
Orange drink w/artificial sweetener
Orange juice mix
Orange-grapefruitdrink
Peach drink
Pineapple drink
Strawberry drink
Tea
Tea w/artificial sweetener
Tea w/cream
Tea, w/lemon
Tea w/lemon and sugar
Tea w/sugar
Tropical punch
Tropical punch w/artificial sweetener

Condiments:
Catsup
Mustard
Pepper
Salt
Hot pepper sauce
Mayonnaise
Taco sauce

Abbreviations:
T Thermostabilized
IM Intermediate Moisture
R Rehydrated
FD Freeze Dried
NF Natural Form

Is It Soup Yet?

Grade Level: 6

Time Required: 2 to 3 class periods

Countdown:

Baseline Shuttle Food List
Colored Paper
Paper for Menus
Colored Pens, Pencils and Markers
Food Guide Pyramid

Suggested TEKS

Science -	6.4
Health -	6.11
Language Arts -	6.19
Art -	6.1
Computer -	123.13 (2)

Suggested SCANS

Interpersonal. Teaches others.

National Science and Math Standards

Science as Inquiry, Life Science, Science in Personal and Social Perspectives, Computation, Measurement, Communication.

Ignition:

Astronauts on shuttle missions have many of the same physical and social needs as we have here on Earth. It is essential for the healthy crewmember to eat and drink correctly -- according to space nutrition requirements -- to sleep, to exercise, and to relax. And, due to the size limitation of the spacecraft and the nature of the mission, it is vital that each of the crew functions well as a team member, showing leadership skills and following directions as dictated by the specific task and situation.

Liftoff:

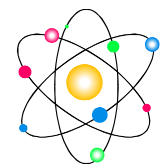
A. Discussion

Tell students that a typical meal in space can be compared to an Earth meal, with some variations.

1. Foods are precooked or processed here on Earth and are individually packaged and stowed for easy handling in the microgravity environment. Weight allowed for food is 3.8 pounds per person daily.
2. Foods are either ready to eat or can easily be prepared by adding water or heating. Beverages are packaged in a foil laminate, similar to the Capri-Sun type juice bags. The drinks are usually dehydrated, so the crew adds water. A straw with a clip is inserted into the bag for easy drinking.
3. Fresh fruit and vegetables, i.e., apples, bananas, oranges, and carrot and celery sticks are stored in the fresh food locker along with tortillas, fresh bread, and breakfast rolls. The carrots and celery must be eaten within the first few days of flight to avoid spoilage. Refrigeration, except on Skylab, has not been available on space missions.
4. Astronauts use conventional eating utensils in space -- knives, forks, and spoons. In addition, they use scissors for cutting open the food and beverage packages.
5. A meal tray is used to hold the food and beverage containers. The tray can be attached to an astronaut's lap by a strap or attached to a wall. The meal tray becomes the astronaut's dinner plate and enables him/her to choose from several foods at once, just like a meal at

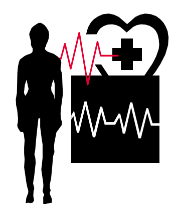
home. Without the tray, the contents of one container must be completely eaten before other containers are opened, so that they do not float away in the microgravity of space.

6. Meals are prepared in the galley located on the orbiter's mid deck. The galley contains a water dispenser for rehydrating foods and a forced air convection oven for warming foods to the proper serving temperature.
7. A supplementary food supply is stowed in the pantry on each flight. This provides about 2100 kilocalories per person for two extra days in case the flight is extended due to bad weather at the landing site or some other unforeseen reason. Also included are extra beverages and snacks.



B. Shuttle Menu Selection

1. Tell students that food evaluations are conducted about 8 to 9 months before the flight. At that time, the astronauts are given the opportunity to sample a variety of foods and beverages available for the flight. A pack of information is given to the astronauts to use in planning their personal preference menus. Included in the packet is a standard menu, training menu, past flight menu, and the baseline shuttle food and beverage list. Astronauts select their menus approximately five months before flight. The menus are analyzed by the shuttle dietitian, and recommendations are made to correct any nutrient deficiencies based on the Recommended Dietary Allowances. The menus are then finalized and sent to Houston three months before launch. The flight Equipment Processing Contractor (FEPC) processes, packages, and stows the food in the shuttle lockers.



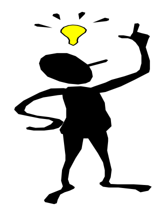
2. Ask students to design and decorate a menu that includes breakfast, lunch, and supper for one day. They may use the Baseline Shuttle Food List that is given at the end of this activity. Remind them to include the necessary condiments for each meal. The astronauts' sense of taste and smell are reduced in-flight, so astronauts tend to enjoy more highly seasoned foods. Review the Food Pyramid and basic nutritional requirements.
3. Have the class select the winning student menu and, if possible, ask the school nutritionist to review it and make recommendations. You may also submit it to FSEF online.
4. Have students weigh all food eaten in one day. This may be done as a homework assignment. How does this compare to the 3.8 pounds of food astronaut’s are allowed? What percentage needs to be reduced?

Research

Possible reference:

http://www.jsc.nasa.gov.pao/factsheets/nasapubs/food.html

1. Missions beyond ten days are called Extended Duration Orbiter (EDO) Missions. How do the astronauts handle the weight and volume of trash on EDO missions?
2. Dehydrated food on a space mission means that all of the water has been extracted from the foods to help meet the weight and storage restrictions for space shuttle liftoff. In order to rehydrate foods before eating, astronauts use water from the galley water dispenser. Where does the water come from?
3. Why are some foods completely dehydrated while others are only partially dehydrated with 15 to 30% moisture retained (Intermediate Moisture Foods)?
4. Foods flown on space missions are researched and developed at the Food Systems Engineering Facility (FSEF) at the NASA Johnson Space Center. How are foods analyzed? Also, how are foods tested to see how they will **react** in microgravity?



More Ideas …

- Record everything eaten the previous day. Beside each food item, the student will record if it can be taken on a space mission as is, or if changes need to occur. If so, what changes?
- Research how astronauts ate during the first space missions.
- Plan foods for one astronaut during a shuttle mission which will last five days.
- Interview a nutritionist about *Why Food Variety is Important*.

Baseline Shuttle Food List

Beef, Dried (IM)
Beef Goulash (T)
Beef Pattie (R)
Beef Steak (I)
Beef Stroganoff w/Noodles (R)
Beef Tips w/Mushrooms (T)
Bread (FF)
Breakfast Roll (FF)
Brownies (NF)
Candy,
- Coated Chocolates (NF)
- Coated Peanuts (NF)
- Gum (NF)
- Life Savers (NF)

Cereal
- Bran Chex (R)
- Cornflakes (R)
- Granola (R)
- Granola w/Blueberries (R)
- Granola w/Raisins (R)
- Grits w/Butter (R)
- Oatmeal w/Brown Sugar (R)
- Oatmeal w/Raisins (R)
- Rice Krispies (R)

Cheddar Cheese Spread (T)
Chicken
- Chicken ala King (T)
- Chicken Cacciatore (T)
- Chicken Pattie (R)
- Chicken Salad Spread (T)
- Chicken, Sweet n Sour (T
- Chicken, Sweet n Sour (R)
- Chicken Teriyaki (R)
- Chunky Chicken Stew (T)

Cookies
- Butter (NF)
- Chocolate Covered (NF)
- Shortbread (NF)

Crackers
- Butter (NF)
- Graham (NF)

Eggs
- Scrambled (R)
- Mexican Scrambled (R)
- Seasoned Scrambled (R)

Frankfurters (T)
Fruit
- Apple, Granny Smith (FF)
- Apple, Red Delicious (FF)
- Applesauce (T)
- Apricots, Dried (IM)
- Banana (FF)
- Cocktail (T)
- Orange (FF)
- Peach Ambrosia (R)
- Peaches, Diced (T)
- Peaches, Dried (IM)
- Pears, Diced (T)
- Pears, Dried (IM)
- Pineapple (T)
- Strawberries (R)
- Trail Mix (IM)

Granola Bar (NF)
Ham (T)
Ham Salad Spread (T)
Jelly
- Apple (T)
- Grade (T)

Macaroni & Cheese (R)
Meatballs in Spicy Tomato (T)
Noodles and Chicken (R)
Nuts
- Almonds (NF)
- Cashews (NF)
- Macadamia (NF)
- Peanuts (NF)
- Trail Mix (IM)

Peanut Butter (T)
Potatoes au Gratin (R)
Puddings
- Banana (T)
- Butterscotch (T)
- Chocolate (T)
- Tapioca (T)
- Vanilla (T)

Rice and Chicken (R)
Rice Pilaf (R)
Salmon (T)
Sausage Pattie (R)
Shrimp Cocktail (R)
Soups
- Chicken Consomme (R)
- Mushroom (R)
- Rice & Chicken (R)

Spaghetti w/Meat (R)
Tortillas (FF)
Tuna
- Tuna (T)
- Tuna Creole (T)
- Tuna Salad Spread (T)

Turkey
- Turkey Salad Spread(T)
- Turkey Tetrazini (R)

Vegetables
- Asparagus (R)
- Broccoli au Gratin (R)
- Carrot Sticks (FF)
- Cauliflower /cheese (R)
- Celery Sticks (FF)
- Gr. Beans/Broccoli (R)
- Gr.Beans/Mushroom(R)
- Italian (R)
- Spinach, Creamed (R)
- Tomatoes/Eggplant(T)

Yogurt
- Blueberry (T)
- Peach (T)
- Raspberry (T)
- Strawberry (T)

Condiments
- Catsup (T)
- Mayonnaise (T)
- Mustard (T)
- Pepper (Liquid)
- Salt (Liquid)
- Tabasco Sauce (T)
- Taco Sauce (T)

Abbreviations
FF Fresh Food
IM Intermediate Moisture
I Irradiated
NF Natural Form
R Rehydrated
T Thermostabilized

Beverages

Apple Cider
Cherry Drink w/A/S
Cocoa
Coffee
- Black
- w/A/S
- w/Cream
- w/Cream & A/S
- w/Cream & Sugar
- w/Sugar

Coffee (Decaffeinated)
- Black
- w/A/S
- w/Cream
- w/Cream & A/S
- w/Cream & Sugar
- w/Sugar

Coffee (Kona)
- Black
- w/A/S
- w/Cream
- w/Cream & A/S
- w/Cream & Sugar
- w/Sugar

Grape Drink
Grape Drink w/A/S
Grapefruit Drink
Instant Breakfast
- Chocolate
- Strawberry
- Vanilla

Lemonade
Lemonade w/A/S
Lemon-Lime Drink
Orange Drink
Orange Drink w/A/S
Orange Juice (Tang)
Orange-Grapefruit Drink
Orange-Mango Drink
Orange-Pineapple Drink
Peach-Apricot Drink
Pineapple Drink
Strawberry Drink
Tea
- Plain
- w/A/S
- w/Cream
- w/Lemon
- w/Lemon & A/S
- w/Lemon & Sugar
- w/Sugar

Tropical Punch

Abbreviations

A/S - Artificial Sweetener
R - Rehydratable
T - Thermostabilized

Definitions

Irradiated (packaging is flexible, foil, laminated pouch)
Natural Form (packaged in flexible pouches)
Rehydratable (packaging in rehydratable containers)
Thermostabilized (packaging is cans, plastic cups, flexible pouch)

Lung Model

Suggested TEKS:	
Science -	6.13
Math -	6.13
Computer -	6.2

Suggested SCANS:
Technology. Apply technology to task.

National Science and Math Standards
Science as Inquiry, Life Science, Science in Personal and Social Perspective, Observing, Communicating

Grade Level: 6

Time Required: 1 class period

Countdown:
- Flexible Straws
- Clear Plastic Cups (7, 8 or 9 oz.)
- Small Balloons
- Large Balloons
- Scissors
- Transparent Tape
- Rubber Bands

Ignition:

The respiratory system consists of lungs and air passages and is part of the cardiopulmonary system that supplies your body with oxygen and nutrients and removes carbon dioxide and other waste products produced within your cells.

Each breath begins with a contraction of the diaphragm, a dome-shaped sheet of muscle that lies just below the lungs. When you inhale, your diaphragm contracts, or flattens downward. This contraction creates a lower pressure in the chest cavity. Normal outside air pressure forces air through the nose and mouth, down the trachea and into the lungs. When you exhale, your diaphragm relaxes, increasing pressure on the lungs and forcing air, containing carbon dioxide, out of the body.

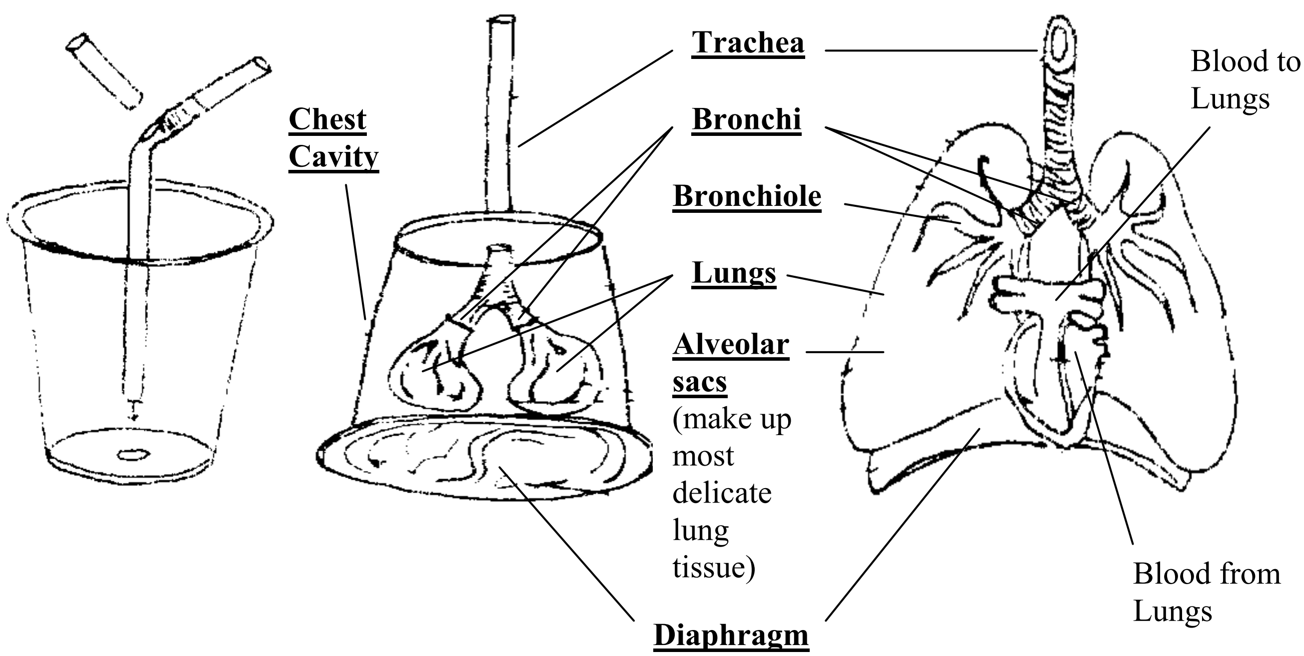
What causes your diaphragm to contract and relax? Your brain controls everything you do. The small area within the brain stem known as the medulla regulates your breathing. It senses the amount of carbon dioxide present, the faster you breathe.

Computer:

Scientists believe the condition of apparent weightlessness to which astronauts are subjected during spaceflight may affect the respiratory system. See if you can find tests that have been conducted during space flight on astronauts or when the astronaut returns to earth and the cardiopulmonary system must readjust to gravity. What did these tests show?

Liftoff:

1. Divide the students into pairs. Each team should have a cup, a straw, scissors, tape, two small balloons, one large balloon, and a rubber band.
2. Make a hole in the bottom of the plastic cup with scissors.
3. Cut a 5-cm, inflexible section of a straw.
4. Make a small slight in the elbow of another straw.
5. Insert the 5-cm piece of straw into the slit to form a "Y". Tape this joint to make it airtight.
6. Tape the small balloons to each end of the diagonal segments of the "Y". These connections must be airtight.
7. Thread the vertical leg of the "Y" through the hole in the cup and seal with tape.
8. Cut the neck off the large balloon and discard. Cover the open end of the cup with the remainder of the balloon.



Have each student describe the function of the respiratory system and identify its parts. This lung model demonstrates the movement of the diaphragm which regulates the pressure in the chest cavity and that air flows into the lungs when air pressure in the chest cavity is lowered.

More Ideas:

◊ Research the cause of lung disease.
◊ Identify ways to prevent lung disease.
◊ Make a list showing examples of lung disease.
◊ Give examples of how astronauts might keep their lungs in shape during space flight.
◊ Measure Lung Capacity of an Average Student with the experiment: http://lifesci3.arc.nasa.gov/SpaceSettlement/teacher/course/lung_capacity.html
◊ Play Circulatory System Relay. Obtain directions from: http://quest.nasa.gov/smore/teachers/act9.html

Recycling on the Moon

Suggested TEKS

Science -	5.13	6.13	
Computer -		5.15	6.15
Art -		5.2	6.2
Language Arts -		5.17	6.17
Math -		5.11	6.8

Suggested SCANS

Information. Acquires and evaluates information.

National Science and Math Standards

Science as Inquiry, Science in Personal and Social Perspectives, Earth and Space Science, Science and Technology, Physical Science, Observing, Communicating

Grade Level: 5 - 6

Time Required: 3 - 4 class periods

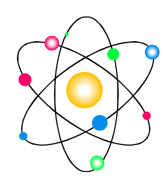
Countdown:

Hot Plate	1 Candle	Seeds (alfalfa, radish, soybeans, etc.)
Small Pot	3 Jars (different sizes)	1 Jar per student
Cookie Sheet		Masking Tape
Ice Cubes		Plastic wrap/foil
		Strainers

Ignition:

The moon, according to our most recent information, is a "dead world". There is no air to breathe, no vegetation, no life of any kind. The temperatures are extreme – 266 degrees F during the day and -200 degrees F during the two week lunar night. Nevertheless, human beings have already visited the moon briefly, NASA's Lunar Prospector orbited the moon collecting data, and many scientists have begun making ambitious plans for possible permanent human bases on the moon.

At first, people who are traveling and planning to visit the moon will be required to bring all of their food, water, and air with them from Earth. Eventually, though, these necessities will need to be generated and recycled on the moon by means of life-support Systems designed for long-duration space missions.



Liftoff:

Experiments with Water

1. Emphasize that water in a life-support system needs to be reused or recycled.
2. Demonstrate the recycling of water as follows:
   - Fill the small pot with water, and heat the water until it boils.

- Put the ice cubes on the cookie sheet, and hold the sheet carefully over the pot of boiling water.
- Have the students describe what happens.
- Compare the results with the Earth water cycle. Define the terms condensation, precipitation, and evaporation.

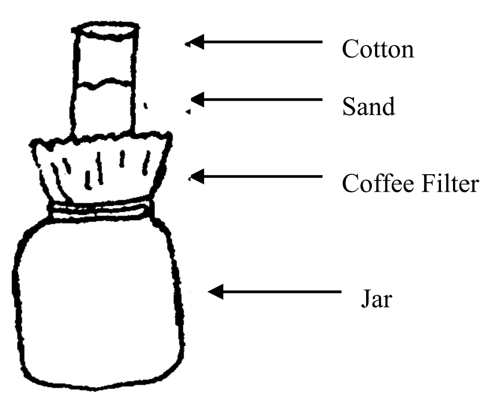
3. Emphasize that water, when recycled continuously in a life-support system, needs to be cleaned. Elicit from the students different methods of purifying the water.
4. Ask the students to design their own water-purification devices. This could possibly be a home assignment or group classroom assignment. The experiments should meet the following criteria:
   - The device will be designed to remove 10 grams of dirt from 250 ml of water in a time period of 5 minutes.
   - At least half of the water will be returned to the collecting jar.
   - A water clarity scale will be used to assess the device's ability to cleanse the water.

0	=	no difference noted
1	=	very dirty
2	=	somewhat dirty
3	=	slightly dirty
4	=	mostly clear
5	=	clear

- Student record keeping should include the following:
  - Written plan of design
  - Sketch of design
  - List of materials used (inexpensive materials – recycled, if possible)
  - Step-by-step instructions for constructing the device
  - Data observed and recorded in a table or chart
  - After the students present and test their devices for the class, elicit ideas about which materials achieved the best results and why. Discuss also which designs were the most effective.

One example of a possible device is shown below:

Drawing of filtration system

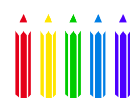


More ideas:

- Visit a water purification plant.
- Invite a guest speaker. Possibilities include:
  - City Water Department on conservation
  - Health Department on water contamination and possible diseases
- Observe your home practices. What methods are used to reduce water consumption? How can this effect your family? Your environment? (Examples: low flow toilet and shower devices, take shower instead of bath, use bath water to wash cars, etc.)
- Design a media campaign (mailout, article, story, TV advertisement, radio PSA, etc.) on water conservation.

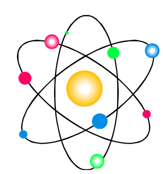
Computer:

Research and write a paper on where your city gets its water. Check city water rates. How can you reduce your home water bill?



Art:

⇒ Prepare a salt map on the route your water takes to get to your city.
⇒ Design a poster on the importance of water conservation.



Experiments With Air

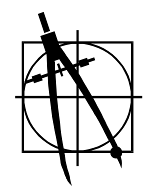
1. Discuss that the air in a life-support system has to be recirculated. Ask why people in such a system don't breathe up all the air.
2. Conduct the following experiment:
   - Carefully set the candle in a safe place, and light it.

- Set the smallest jar upside down over the candle.
- Record the time it takes the candle to go out.
- Predict what will happen with the other 2 jars. Follow the same procedure with both.
- Why did the candle go out? Ask the students to predict how long the candle would burn in a domed moon base.

Experiments With Food

Explain that in NASA's Advanced Life Support System (ALSS), green plants will be used to convert carbon dioxide to oxygen through photosynthesis, provide potable water through evapotranspiration, recycle organic wastes, and produce food. Synthetic soil containing plant-growth nutrients plus water will be used to grow these plants.

1. Ask students if it is possible to grow food without soil.
2. Perform the following experiment:
   - Give each student a jar and several seeds (one type).
   - Have jars labeled with student names and seed type.
   - Put seeds in the jar and add 100 ml of water.
   - Cover with foil/plastic wrap. Leave overnight.
   - Discuss with students the data to be observed, i.e., water absorption, rate of growth, weight, and length.
   - On the second and succeeding days, drain the seeds, rinse them twice, and cover lightly. Store the jars in a dark place.
   - After the first leaves begin to appear on the sprouts, set the jars outside in the sun for a few hours daily to develop the chlorophyll.



Students will measure plant growth daily in cm.
Students will chart their findings.

Computer

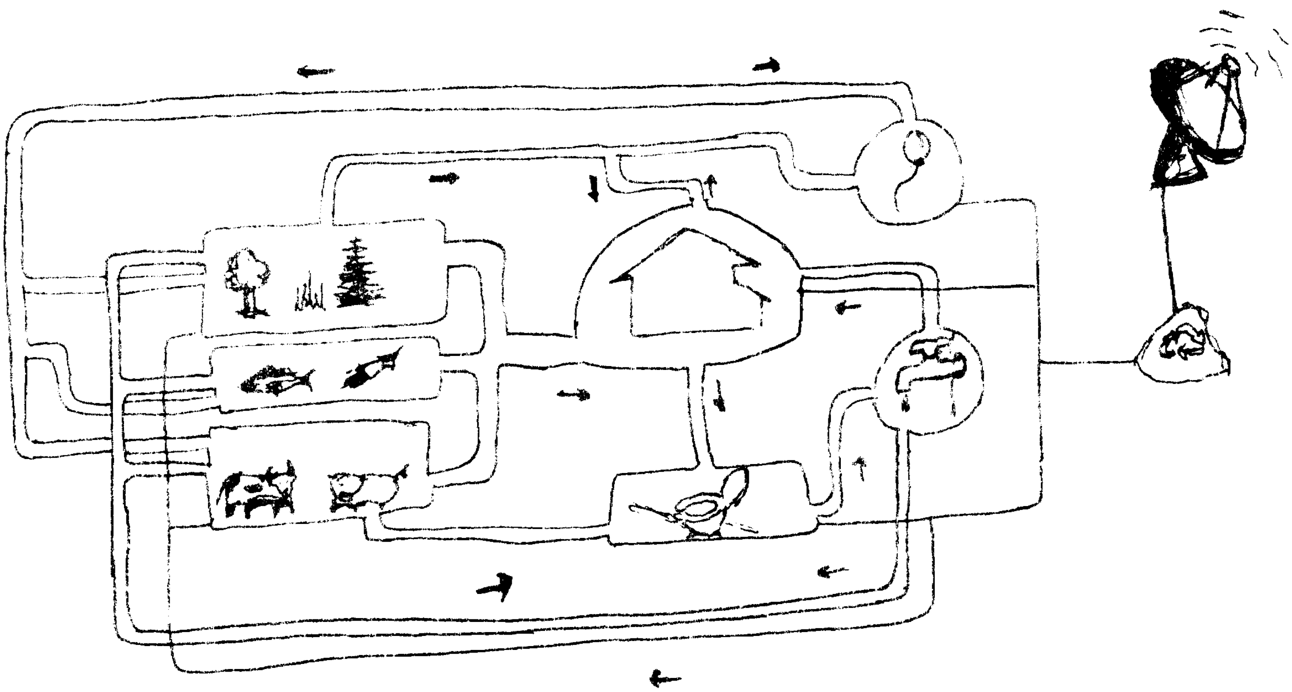
Have students research the seed that they sprouted. What is the nutritive value of these sprouts as a food source? Determine if they are low in fat, high in minerals, vitamin content, etc. Find or create a recipe using this sprout.

- At the conclusion of the experiment, discuss the value of sprouts as a food source.

English

Discuss the life support systems in the diagram below. Write a paper that will compare and contrast these life support systems with our own way of living at the present time on Earth.

Diagram of life support system



Exercise and Other Recreation

Grade Level: 7

Time Required: 2 class periods

Suggested TEKS		
Physical Education -	7.3	7.4
Health -		7.4
Computer -		7.2
Suggested SCANS		
Interpersonal. Teaches others.		
National Science and Math Standards		
Science as Inquiry, Life Science, Science in Social and Personal Perspectives, Measurement, Observing, Communicating		

Countdown:

Weekly Activity Chart/student
Pencils

Ignition:

On Earth, some people like to exercise more than others do. Aboard the space shuttle, however, astronauts have little choice. On earlier missions, scientists discovered that astronauts suffer some bone and muscle deterioration because their bodies were not getting the resistance they were accustomed to receiving in gravity.

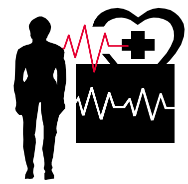
Today, astronauts participate in a planned exercise program to counteract the effects of microgravity. Flight doctors recommend 15 minutes of exercise daily on 7 to 14-day missions and 30 minutes of exercise daily on 30-day missions.

As for other recreation, astronauts can do whatever they prefer. They take their own preference kits along on the missions. Examples of extra-time activities are: reading, e-mails home on laptops, listening to music, playing games, chatting with people on the ground via ham radio, hanging around the windows looking at Earth roll by underneath (during the first part of the flight).

Liftoff:

A. Discussion
Describe to students the types of shuttle exercises listed below:
1. Treadmill - astronauts exercise their arms by pushing upward on the bar while walking; moving air from a nearby duct dries off the perspiration.
2. Rowing machine
3. Exercise bicycle

B. Research
Ask students to research other types of exercise equipment, i.e., in school/gym weight rooms and make recommendations for additional shuttle exercise equipment. They should focus on resistance exercises.



C. Weekly Activity Chart
Tell students that they have been chosen to serve as Youth Representatives aboard a 7-day shuttle mission. What will they do during that time? Ask them to plan their week in space by completing the Weekly Activity Chart. Remind them to include time for "survival basics": (eating, sleeping, exercising) as well as conducting experiments, observing the stars, and daily writing (shuttle jog, journal, letters home). Student compares their Weekly Activity Chart to a actual Astronaut schedule from a recent mission.

More Ideas …

1) Record an exercise video.
2) Plan a 30 minute exercise class.
3) Review and critique an exercise video.
4) Interview an athlete. Record their daily exercise and recreation regime.

Weekly Activity Chart

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
6 am							
7 am							
8 am							
9 am							
10 am							
11 am							
12 am							
1 pm							
2 pm							
3 pm							
4 pm							
5 pm							
6 pm							
7 pm							
8 pm							
9 pm							

Sleeping In Space

Grade Level: 7

Time Required: 2 class periods

Suggested TEKS
Science - 7.3 7.6
Math - 7.11
Suggested SCANS
Information. Acquires and evaluates information.
National Science and Math Standards
Science as Inquiry, Life Science, Science in Personal and Social Perspectives, Computation, Measurement

Countdown:
- Graph Paper
- Scale
- Pencils
- Paper

Ignition:

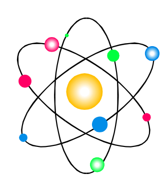
As can be expected, sleeping and sleeping accommodations on Earth vary greatly from those in microgravity. On Earth, our sleeping position is horizontal, whereas in microgravity where there is no "up", astronauts can sleep as comfortably in the vertical position as the horizontal.

In Earth's gravity, our bodies sink into a mattress. But, because of the near weightlessness of space, the hard bed board that is used in bunks feels soft.

Liftoff:

A. Discussion

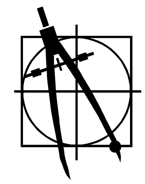
Tell students that sleeping accommodations aboard the shuttle vary depending on the requirements of the particular mission. For single crew missions in which everyone in the crew shares the same sleep cycle or flight day, sleep compartments are not normally aboard the shuttle. However, on dual crew missions during which half the crew sleeps while the other half works, the sleep compartments are on-board to screen out the distractions of the working crew.



The different sleeping accommodations are as follows:

1. Sleep compartments - are two level; the bunks measure more than 1.8 meters (6 ft.) long and .75 meters (30 in.) wide and are padded boards with fireproof sleeping bags attached. They can sleep four people.
   a. The first person sleeps on the top bunk, the second on the lower bunk.
   b. The third person sleeps on the underside of the bottom bunk facing the floor.
   c. The fourth person sleeps vertically in another bunk that stands against one end of the two level bed.
   d. Each astronaut has their own private compartment.
2. Seats -- crew can sleep in their seats, when necessary.

3. Walls - crewmembers can tether themselves to the orbiter walls with Velcro.
4. Sleeping bags - are cocoon-like restraints attached to the crew provision lockers; astronauts zip themselves inside the bags -- leaving their arms outside -- and snap together straps that circle the waist; other amenities include:
   - Lights that are provided for reading
   - Side panels that can be shut for privacy
   - Eye shades and earmuffs that are provided to reduce cabin light and noise.
   - Communications headgear that are provided for two of the crew, when all seven crewmembers are sleeping at the same time.



On the International Space Station, each crewmember has a private room, or “galley.” With no gravity, they’ll need to be anchored down in their beds so they don’t float away! That might sound like a strange way to catch some z’s, but astronauts from past space missions report that sleeping in space is actually pretty great!

B. Research

Ask students to determine the specific inside dimensions of the basic shuttle.

1. Using graph paper and a scale, students can then draw a cut-away view of the inside of the shuttle. Next, ask them to draw in the sleeping arrangements for all 7 astronauts, i.e., 2 could be sleeping in their chairs while 5 are tethered to the walls.
2. Ask students to design and create new sleeping accommodations, keeping in mind the weight and space restrictions of the shuttle.

Weightlessness and the Human Body

Grade Level: 7

Time Required: 4 - 5 class periods

Countdown:
Electronic Text
Printed Resources
(suggestions listed)

Suggested TEKS	
Computer -	7.2
Health -	7.2
Suggested SCANS	
Technology. Apply technology to task.	
National Science and Math Standards	
Science as Inquiry, Life Science, Science in Personal and Social Perspectives, Physical Science, Computation, Measurement, Reasoning, Observing, Communicating	

Ignition:

If we are ever to venture beyond Earth orbit and visit, perhaps even colonize planets and the moon, we must know the risk that our space explorers face.

As we leave the Earth's surface and escape its gravitational pull, our bodies rapidly adjust to the new weightless environment. Many of the changes seen are similar to the process of Earth-based diseases i.e. anemia, osteoporosis, muscular atrophy, and immune system dysfunction -- but in space these changes occur much faster than on Earth. Although we have observed and documented these changes, we have not yet answered these questions:

- How are they happening?
- Can we stop or prevent them?
- Do we need to?
- What risks are we asking our crews to accept?

Liftoff:

A. Discussion

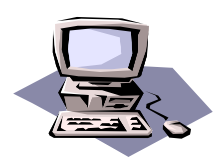
Explain to the students that microgravity affects our bodies in many ways. Listed below are several that have been compiled from "Nutrition in Space", Vol. 21, #1, Nutrition Today (Jan./Feb/ 97).

1. **Loss of bone tissue** (in weight-bearing bones) - the lack of weight on the skeleton causes minerals to be released from the bones.
2. **Loss of muscle mass -** this is probably related to a stress-induced increase in protein turnover and changes in muscle nitrogen and pyridoxine metabolism.
3. **Loss of red blood cell mass** - the release and retention of new red cells seems to be halted upon entry into weightlessness; amnesia has, therefore, been observed for a short period of time after space flights.
4. **Decline in plasma volume** - fluids are shifted within the first 21 hours of flight from the extracellular to the intracellular space rather than being lost from the body.
5. **High iron intake** - when the red blood cells are destroyed, iron is released and processed for storage in the body; also, space foods tend to be high in iron.
6. **Endocrine influences on energy metabolism** - decreased sympathetic nervous system activity and increased cortisol secretion have been recorded.

7. **Calcium metabolism and Vitamin D** - calcium intake needs to be regulated daily (about 880 mg./day for each crewmember); Vitamin D also needs to be regulated to ensure calcium absorption.
8. **Space motion sickness** - about 70% of crewmembers experience some degree of motion sickness during the first few days of flight.
9. **Risk of forming kidney stones** - this is attributed to inadequate fluid intake and increases in urinary calcium.

.B. Research

1. Most of these consequences of space flight affect the nutrition requirements for the space crews. Ask students to research the nutrient requirements that act as countermeasures to the effects of microgravity on the body. Possible printed resources include:
   - Lane HW, Smith SM, Rice BL, Bourland CT.
     Nutrition in Space: Lessons from the past applied to the future. Am J Clin Nutr 1994; 60:S801-5.
   - Lane HW, Schulz LO. *Nutritional questions relevant to space flight*. Ann Rev Nutr 1992: 12: 257-78.
2. Nutritional intake has not been considered a high priority during the relatively brief programs of the Space Shuttle program (less than 21 days). However, on extended-duration missions of 30 days or more, nutrition becomes extremely critical. Ask students to research and analyze the differences between short duration and long duration mission nutrient requirements.
3. The Spacelab Life Sciences-1 mission (STS-40) in June 1991 was the first space mission dedicated to biomedical research, experiments in cardiovascular, cardiopulmonary, regulatory, neurovestibular, and muscle and bone physiology in both human and rodent subjects. Ask students to research this mission and its specific experiments and results.
4. More recently, on April 17, 1998, the shuttle Columbia undertook a two-week mission to study how the brain and nervous system adapt and develop in weightlessness. Other experiments included insomnia, vertigo, imbalance, reduced blood pressure, and weakened immunity. Have students research this mission.



C. Activity

See Stellar link listed below for a Neutral Buoyancy and Simulated Weightlessness Activity -- using a Cardiovascular module.
http://stellar.arc.nasa.gov/stellar/Activities/cardiovascular

History of International Cooperation

Grade Level: 7 - 8

Time Required: 3 to 4 class periods

Countdown:
- Paper
- Pencils

Suggested TEKS:
Language Arts - 8.15 8.16 8.17 8.21
Social Studies - 8.12 8.13

Suggested SCANS
Interpersonal. Participates as a member of a team.

National Science and Math Standards
Science as Inquiry, Life Science, Physical Science, History &

Ignition:

The concept of international cooperation in space was initiated more than 30 years ago. Three basic beliefs underlie this idea:

1) Space does not belong only to the mightiest.
2) No one country or people can realize its full potential without the cooperation of others.
3) Benefits derived from the exploration of space belong to all humankind.

Ironically, the Cold War between the United States and the former Soviet Union, characterized by unprecedented technological growth in the development of machines for mass destruction, brought about scientific advances that spilled over into the development of materials, processes, and a body of aeronautical knowledge that has made real the dream of long-term space habitation. The seeds of peaceful interdependence now inherent in space research around the world were sowed in strife.

On the grounds of the United Nations stands a bronze statue with the saying “Let Us Beat Swords in Plowshares”, a gift from the Soviet Union in 1959. It symbolizes the noble human desire to put an end to war and convert the means of destruction into creative tools for the welfare of all of human life.

Another significant landmark toward international cooperation was the Outer Space Treaty, the first international space treaty that was signed simultaneously in London, Moscow, and Washington, D.C. on January 27, 1967. The ultimate document governing space activities, it asserts the philosophy that space exploration should “contribute to broad international cooperation and the development of mutual understanding between States and peoples”.

Using the Outer Space Treaty and other agreements, the U. S., Russia, Japan, Canada, and the 14 member states of the European Space Agency (E.S.A.) began to develop the International Space Station (ISS). The first segment of ISS was launched from Russia in November 1998.

Liftoff:

A. Ask the students to envision that a moon colony has been recently established and that the inhabitants represent many different cultures. A vital part of colonization is to establish an International Space Treaty that will have a variety of purposes.

1. Define a "treaty" as an agreement between groups of people or nations. A treaty may be negotiated to:
   a. end wars
   b. settle boundary disputes
   c. form agreements on taxes, navigation, and fisheries
   d. set up international organizations, i.e. a Universal Postal Union
   e. deal with the extradition of criminals
   f. protect a country's trademarks, copyrights, and patents
   g. deal with religious rights of individuals

2. Group students according to the countries or organizations that they wish to represent, i.e. United States, Canada, Japan, China, Russian, and E. S. A.

3. Ask each group to discuss general questions such as:
   a. Who will have the power to negotiate a treaty? (king, chief executive, etc.)
   b. How will the treaty be approved – by a majority vote or a unanimous vote?
   c. What will be the official language for negotiation?
   d. What might happen if a nation chooses not to sign the treaty? Will its people be banned from the moon colony?

   Discuss the answers to these questions as a class.

4. Then, tell each group that it will compose a bill for the treaty. The bill, once presented to all countries, will then be approved or dismissed by vote, majority or unanimous (whichever has been previously decided.)

5. The bill should specifically address the following questions:
   a. Who will make the laws, and how will they be enforced? Will poor nations have the same rights as rich nations?
   b. How will land rights be determined? On a first come, first-serve basis?
   c. Can a nation own the mineral and water rights on the moon?
   d. Should a nation be allowed to copyright its remote sensing imagery photographs and its space experiments?
   e. Should technological advances be shared by the international community? Or copyrighted and protected?

f. Should a system of public education be developed for all nations? Or should each nation develop its own education system?
g. Should an international religion and language be selected? Or should each nation retain its own language and religions?
h. How will trading rights be established, and what type of bartering or money system will be used?

6. When each "nation" has completed its discussion, pairs of nations may choose to work together in negotiation.

7. Then, using parliamentary procedure, the "floor" should be open for the discussion of each group's bill. After each presentation, the entire class will vote on whether to accept or dismiss the bill. The vote should be unanimous for a bill to become part of the treaty. Additional negotiation among nations may be necessary.

8. Once the bill(s) have been accepted, the treaty will then be read aloud in its entirety and given a final vote. It will then be typed up and signed by each individual nation. All students should receive a copy.

B. The "Mission to Mir" Imax film is another resource that emphasizes international cooperation. According to Michael Kernan in The Smithsonian, it is "a magnificent, stirring tribute to Russian-American cooperation at space station Mir (peace), with cosmonauts and astronauts working together and signing "Moscow Nights" together to guitar accompaniment and all of the cheering for Shannon Lucid after her record 188 days in space.

C. The National Air and Space Museum has an excellent exhibit entitled "Space Race". On display are the following:

1. a Russian spacesuit with a small dagger for fighting off bears and wolves since the cosmonauts had decided on U.S.S.R. rural landings, not ocean landings

2. a mannequin named Ivan Ivanovich (or John Doe) sent up to test the resistance of Vostok life-support systems to the 10-G impact of landing

3. Yuri Gagarin's ID card as Cosmonaut No. 01 and his training suit—beside John Glenn's actual spacesuit

4. the training air lock and spacesuit that Aleksei Leonov used in preparation for the first space walk in 1965

5. a Soviet moon suit with a built-in life support backpack

6. a doll autographed by an early cosmonaut—dated the day he expected to return from space; however, his capsule accidentally depressurized and he was killed

7. our Corona satellite – a secret space camera that was declassified recently

8. a video depicting Oklahoman Thomas Stafford and Leonov reminiscing about the first joint American-Soviet spaceflight, Apollo-Suyuz, in 1975.

More Ideas …

- Research Apollo-Suyuz.
- Record ways we are presently cooperating internationally in the space program.
- Draw a picture or layout of the proposed space station.

Shuttle Spacesuits

Suggested TEKS:	
Math:-	8.11
Computer -	8.2
Suggested SCANS	
Interpersonal. Teaches others.	
National Science and Math Standards	
Science as Inquiry, Science in Personal and Social Perspectives, Observing, Communicating	

Grade Level: 8

Time Required: 45 - 60 minutes

Countdown:

Several metric measuring tapes
Metric rulers
Cardboard calipers
Brass paper fasteners
Pencil and paper
Large, round balloons
Paper maché paste and newspaper
String
Graph Paper
Field-of-view measuring device: (plywood board 60 x 30 cm), white poster board, thumbtacks, marking pen, protractor)

Ignition:

Like the shuttle itself, the new shuttle spacesuit Extravehicular Mobility Unit (EMU) is reusable. Spacesuits used in previous manned space flight programs were not; they were custom made to each astronaut's body size. For example, in the Apollo program, each astronaut had three suits – one for flight, one for training, and one for flight backup. Shuttle suits, however are tailored from a stock of standard-size parts to fit male and female astronauts with a wide range of measurements.

Earlier suits had to serve multiple functions. In the Gemini mission, they had to provide backup pressure in case of cabin pressure failure and protection if ejection became necessary during launch. In the Apollo missions, they had to provide an environment for EVA in microgravity and walking on the moon. Suits were worn during liftoff and reentry and had to be comfortable under the high-g forces experienced during acceleration and deceleration.

Shuttle suits are designed to serve one function – going EVA (spacewalking). They are worn in their entirety only when it is time to venture outside the orbiter cabin. Otherwise, the crew wears comfortable shirts and slacks, or coveralls.

The suit is a pressure retention structure that, coupled with a life support system, provides a life-sustaining environment that protects the astronauts against the hazards of space. These hazards include the following:

1) temperature extremes of -300 degrees F
2) a vacuum environment, where low pressure would allow blood to boil
3) the impact of micrometeroids, which could rip through the spacesuit.

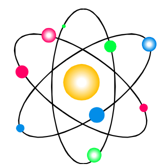
Twelve garment layers serve to protect astronauts from these hazards. The two inner layers, made of spandex fabric and plastic tubing, comprise the liquid-cooling and ventilation garment. Next comes the pressure bladder layer of urethane-coated nylon and a fabric layer of pressure-restraining Dacron. This is followed by a seven-layer micrometeroid garment of aluminized Mylar, laminated with Dacron scrim topped with a single-layer fabric combination of

Gortex, Kevlar, and Nomex materials.

Computer or Library Research

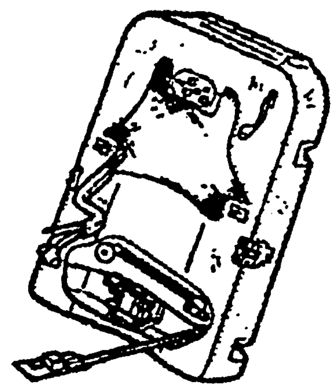
- Students will look up the characteristics of the following fabrics and their uses.
  Dacron, Mylar, Gortex, Keylar, Nomex
- Visit the following web site for additional information

http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Suited.For.Spacewalking/



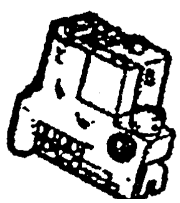
Liftoff:

Spacesuit Parts

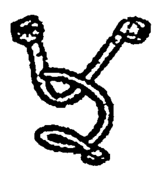


A. Discuss with students the 19 separate parts of an EVA shuttle spacesuit.

1. Primary Life-Support System (PLSS) -
   a self-contained backpack unit with an oxygen supply, carbon-dioxide removal equipment, caution and warning system, electrical power, water cooling equipment, ventilating fan. machinery, and radio

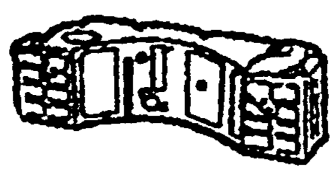


2. Displays and Control Module (DCM) -
   a chest-mounted control module with all controls, a digital display, and the external liquid, gas, and electrical interfaces; has the primary purge valve for use with the SOO

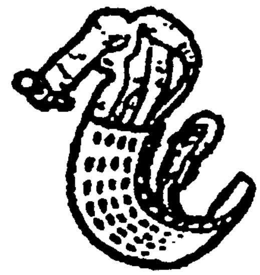


3. EMU Electrical Harness (EEH) -
   a harness worn inside the suit to provide bioinstrumentation and communications connections to the PLSS

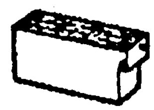
4. Secondary Oxygen Pack (SOP) -
   2 oxygen tanks with a 30-minute emergency supply, valve, and regulators; it is attached to the base of the PLSS



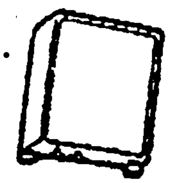
5. Service and Cooling Umbilical (SCU) -
connects the orbiter airlock support system to the EMU to support the astronaut before EVA and to provide in-orbit recharge capability for the PLSS; contains lines for power, communications, oxygen and water recharge, and water drainage



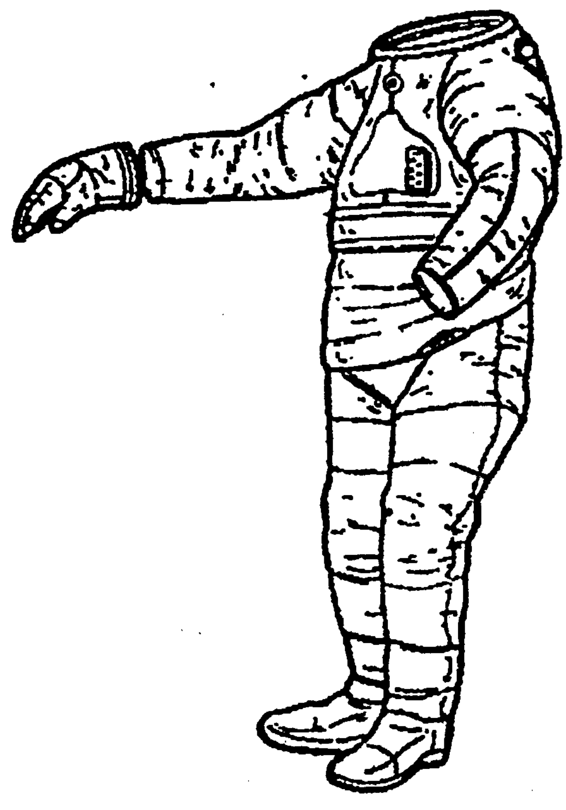
6. Battery -
supplies electrical power for the EMU during EVA; is rechargeable in orbit



7. Contaminant Control Cartridge (CCC) -
cleanses suit atmosphere of contaminants; is replaceable in orbit



8. Hard Upper Torso (HUT) -
composed of a hard fiberglass shell; provides a structural support for mounting the PLSS, DCM, arms In-Suit Drink Bag, EEH and the upper half of the waist closure; can mount a mini-workstation tool carrier



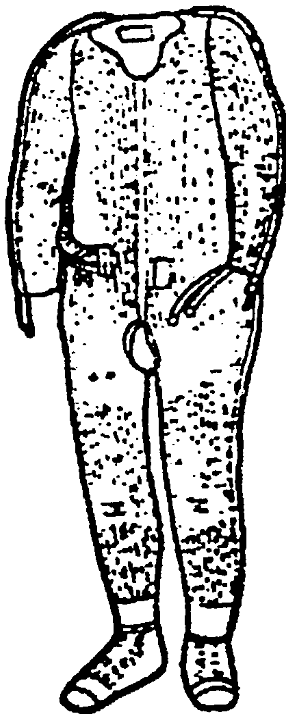
9. Lower Torso -
spacesuit pants, boots, and the lower half of the closure at the waist; has a waist bearing for body rotation and mobility, and brackets for attaching a tether

10. Arms (left and right) -
shoulder joint and armscye (shoulder) joint and armscye (shoulder) bearing, upp arm bearings, elbow joint, and glove-attaching closure

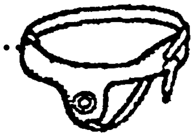
11. EVA Gloves (left and right) -
wrist bearing and disconnect, wrist joint, and fingers; one glove has a wrist-watch sewn onto the outer layer; both have tethers for restraining small tools and equipment; thin fabric comfort gloves with knitted wristlets are also worn underneath

12. Helmet -
plastic pressure bubble with neck disconnected ring and ventilation pad; has a backup purge valve for use with the secondary oxygen pack to remove expired carbon dioxide

13. Liquid Cooling and Ventilation Garment (LCVG) -
long underwear-like garment worn inside the pressure layer; has liquid cooling tubes, gas ventilation ducting, and multiple water and gas connectors for attachment to the PLSS through the HUT

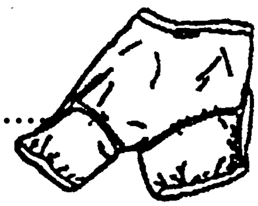


14. Urine Collection Device (UCD) -
for male crewmembers consisting of a roll-on cuff and storage bag; discarded after use



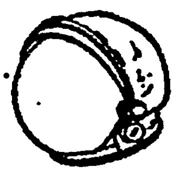
Men's

15. Disposable Absorption and Containment Trunk (DACT) -
for female crewmembers consisting of a pair of shorts made from 5 layers of chemically treated absorbent nonwoven fibrous materials; discarded after use



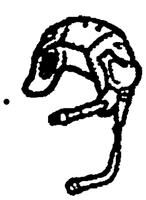
Women's

16. Extravehicular Visor Assembly (EVA) -
contains a metallic-gold covered sun-filtering visor, a clear-thermal impact-protective visor, a clear thermal impact-protective visor, and adjustable blinders that attach over the helmet; also, 4 small "head lamps" are used and a TV camera-transmitter may be added

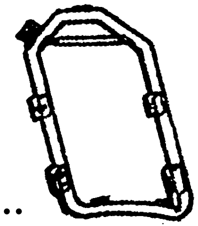


17. In-Suit Drink Bag (IDB) -
plastic water-filled pouch mounted inside the HUT; a tube projecting into the helmet works like a straw

18. Communications Carrier Assembly (CCA) -
fabric cap with built-in earphones and a microphone for use with the EMU radio



19. Airlock Adapter Plate (AAP) -
fixture for mounting and storing the EMU inside the airlock; also used to help put on the suit



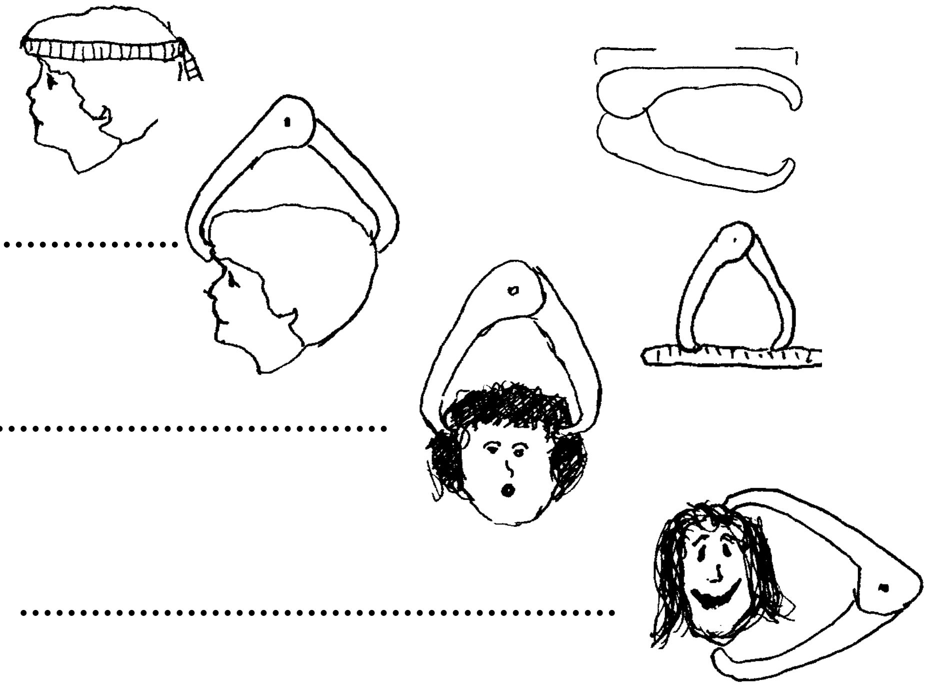
When fully assembled, the shuttle EMU is a nearly complete short-term spacecraft for one person. It provides pressure, thermal and micrometeroid protection, oxygen, cooling water, drinking water, food, waste collection (including carbon dioxide removal), electrical power, and communications. The only thing that the EMU lacks is maneuvering capability, but this can be added by fitting a gas jet propelled Manned Maneuvering Unit (MMU) over the EMU's primary life-support system.

On Earth, the suit fully assembled with all its parts (except the MMU) weighs about 113 kilograms. Orbiting above Earth, it has no weight at all. It does, however, keep its mass in space, which is felt as resistance to a change in motion.

Getting the Right Fit

1. Working in teams of 3 to 5, ask the students to design and build space helmets that can be used by anyone in the class.
2. Working in teams, the students should take four separate measurements of each member's head in centimeters, and record the data. Measure the following:

- Head Circumferenc
- Head Breadth
- Head Depth
- Chin to Top of Head



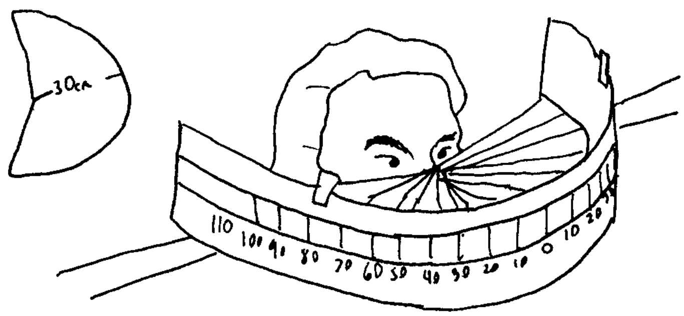
Use calipers and a cloth tape measure for the actual measuring. Be sure the students check their work and record all data.

3. After the measurements are taken, the teams should calculate the average measurements for all members of the team.
4. Each group will report the average for each measurement to the class. The class will then calculate the classroom average for each measurement.

Field of View Measure

1. Construct a field-of-view measurement device out of wood and poster board. Cut a partial circle (220 degrees) with a radius of at least 30-cm out of plywood. Refer to the pattern on the next page for details. Tack or glue a strip of white poster board to the arc. Using a protractor and a marking pen, measure and mark the degrees around the arc as shown in the illustration.

2. Place the device on the edge of a table so that it extends over the edge slightly. Begin measuring the field of view by having a student touch his or her nose to the center of the arc and look straight ahead. Have a second student slide a marker, such as a small strip of folded paper around the arc. Begin on the right side of the 110-degree mark. The student being tested should say, “Now”, when he or she sees the marker out of the corner of the eye. Record the angle of the marker on a data tale for the right eye. Repeat for the left eye.
3. Take the same measurements for the other students. When all the data have been collected, calculate the average field of view for all students.



Designing A Space Helmet

1. Working in the same teams as before, have the students draw sketches on graph paper of their ideas for a space helmet that could be worn by anyone in class. The students should determine a scale on the graph paper that will translate into a full-size helmet. In designing the helmet, three considerations must be met. First, it must fit anyone in the class. Second, it must provide adequate visibility. Finally, it must be made as small as possible to reduce its launch weight and make it as comfortable to wear as possible.
2. Students may wish to add special features to their helmet designs such as mounting points for helmet lights and radios.

Building a Space Helmet

1. Have each team inflate a large round balloon to serve as a form for making a space helmet. Tie the balloon with a string.
2. Using strips of newspaper and paper maché paste, cover the balloon except for the nozzle. Put on a thin layer of newspaper and hang the balloon by the string to dry.
3. After the first layer of paper maché is dry, add more layers until a rigid shell is formed around the balloon. Lights, antennas, and other appendages can be attached to the helmet as the layers are built up.
4. Using a pin, pop the balloon inside the paper maché shell. According to the design prepared in the earlier activity, cut out a hole for slipping the helmet over the head and a second hole for the eyes.
5. Paint the helmet, and add any designs desired.
6. When all helmets are completed, evaluate each one for comfort and utility. Have students try on the helmets and rate them on a scale that the students design. (Example: on a scale of 1 to 5, with 1 being the best, how easy is it to put the helmet on?)

Mission Design - Personnel

Grade Level: 8

Time Required: 2 class periods

Suggested TEKS:		
Language Arts -	8.13	8.21
Science -	8.3	
SCANS		
Information. Interprets and Communicates		
National Science and Math Standards		
Science as Inquiry, Life Science, Observing, Communicating		

Countdown:

Items for teacher:
Basic Form for a Resumé (sample attached)
Basic form/questions for conducting an interview (sample attached)

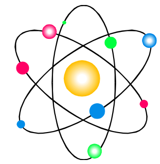
Ignition:

One of the most important aspects in planning for a NASA shuttle mission is the team selected – both on the shuttle and on the ground. The shuttle team, with a minimum crew of 5, consists of the following crew positions.

⇒ Commander - pilot astronaut has on-board responsibility for the vehicle, crew, mission success, and safety of flight.
⇒ Pilot - assists the commander in controlling and operating the vehicle; keeps track of the shuttle location by plotting the longitude and latitude on a world map; maintains communication with mission control.
⇒ Mission Specialist - is responsible for crew activity planning, consumables usage, and experiment/payload operations; performs extravehicular activities (EVAs) or spacewalks; gives information to the crew about specific experiment operations
⇒ Video Specialist - records all shuttle experiments and special events on a video
⇒ Medical Technician - takes blood pressure and pulse readings before and after liftoff and during exercise and at rest; times reactions for certain activities; gives basic first aid; conducts medical experiments.
⇒ Payload Specialist - person other than a NASA astronaut who has specialized on-board duties; monitors equipment, i.e., the remote manipulator arm

The ground team consists of many trained specialists working in mission control. These people keep continuous contact with the shuttle crew throughout the mission, by using voice contact, computers, and security cameras with monitors.

The United States, in cooperation with Japan, Canada, and the European Space Agency, is presently developing the International Space Station. Future spacecraft missions to the Moon and Mars are additionally being planned, so the need for qualified space flight professionals is vital.



Liftoff:

A. Discussion of Qualifications

Discuss with students that NASA accepts applications for the Astronaut Candidate Program on a continuous basis. Candidates are selected as needed, normally every two years, for pilot and mission specialist positions. Both civilians and military personnel may apply. Civilians may apply at any time; military personnel must be nominated through their particular branch in the service.

Mission specialist and pilot astronaut candidates must have at least a bachelor's degree from an accredited institution in engineering, biological science, physical science, or mathematics. An advanced degree is desirable; this may be substituted for part of the specific educational requirement (Master's = 1 year of work experience, Doctoral = 3 years of work experience).

Specific requirements for pilot astronaut applicants are:

* at least 1,000 hours pilot-in-command time in jet aircraft; flight test experience highly desirable
* ability to pass NASA Class I space physical (similar to military or civilian class I physical)
* height between 64 and 75 inches

Specific requirements for mission specialist applicants are similar to those listed for the pilot astronaut, with one major exception: the qualifying physical is a NASA Class II space physical (similar to military or civilian Class II flight physical). ***Have students research actual qualifications before writing job description and resume.***

B. Writing a Resumé

1. Divide the class into the following groups:

    one panel of 6 interviewers
    one group of student interviewees, interested in the shuttle crew positions
    one group of student interviewees interested in the mission control positions

2. Announce that all 6 shuttle crew positions are open and the 5 mission specialist positions are available.

3. Specify the tasks for each group. The interview panel should cooperatively write specific job descriptions for each positions. Special emphasis should be placed on the job skills for effective teamwork, leadership, communication, and the ability to follow directions. This team should develop a set of questions to ask at the interview. The two groups of job seekers should collectively decide on a brief format for a resumé. Then, individually, each person will write his/her resumé and prepare to be interviewed.

C. Interviews

Discuss the interview procedure with the entire class. Suggest to the panel that each interviewer should make notes regarding applicants' particular strengths and possible weaknesses. Set a time limit for each interview. Have interviews conducted individually, in a separate space in the classroom.

When the interview process has been completed, give the panel an opportunity to confer and make final decisions. Interviewers should then thank all of the applicants for their interest, and offer the available positions to the persons most qualified. They should, additionally, make one or two positive comments on what impressed them most in each interview.

John G. Jobhunter

777 Forest Road
Apartment AA-1
Some Town, XX 55555

Phone: (999) 999-9999
Fax: (999) 999-9991
Email: csmart@please.com

Overview

A high-energy and peak-performing Senior Media Buyer with 7 years of progressively responsible experience. Recognized for:

> Commitment and reliability
> Strong communication and negotiation skills
> Exceptional organizational and analytical skills
> Client relations and account maintenance abilities
> Willingness to go the "extra mile"
> Friendly and outgoing personality
> Creative problem solving abilities
> Proven leadership aptitude

HIGHLIGHTS OF EXPERIENCE

Media Buying: Negotiate and maintain media buys from network, cable, and syndication channels. Expertise in prime-time and sports programming. Prescreen programs, maintain familiarity with Nielson Ratings, allocate inventory, analyze proposals, conduct post-analyses of buys, and negotiate for additional units.

Management and Supervision: Interview and hire job candidates. Supervise assistant media buyer and interns; assure quality performance on projects. Maintain detailed records and track purchasing budgets. Involved in up-front budget planning and negotiations.

Relationship Building: Develop rapport and cooperation, maintain excellent relations with networks. Successfully serve as an intermediary between networks and clients; conduct negotiations assertively and effectively. Design customized proposals and deliver presentations; skilled at listening to client needs and developing effective solutions.

Strategy and Planning: Successfully launched 3 new brands. Designed and implemented launch strategies; developed unique sponsorships and innovative techniques for marketing products, researched target audience, hand-picked media buys, and coordinated strategically timed product launched.

PROFESSIONAL HISTORY

Some Advertising Agency, Somewhere, TX 1990 - Present
Senior Media Buyer (1996 - Present)
Media Buyer (1993 - 1996)
Assistant Media Buyer (1990-1993)

EDUCATION

Bachelor of Science The University of Texas, Austin, Texas (1990)
Major: Business Administration - concentration in Marketing

Computer Literate - Proficient with Lotus, WordPerfect, Word, Excel, JDS Netline, Internet

References furnished upon request.

Sample Interview Questions

QUESTIONS DESIGNED TO DISCOVER CANDIDATE'S TRAITS

Considering your current employment status, what attracts you to this position?
If I were to contact your current (previous supervisor), what would s/he tell me about your dependability and reliability?
Did you ever have a disagreement with your present (or previous) supervisor?
If yes, briefly explain the issue, its relative importance and the pro or con consequences.
Give me two reasons why I should not hire you? Why I should hire you?
What do you consider to be the best characteristic a supervisor could have? The worst?
Tell me a bit of what you know about our company (organization, department, etc.), in terms of our mission, goals, objects; or products and services?
If selected for this position, where do you see yourself two, four or six years from now?
What are your career goals, both short- and long-term?
What are you doing to achieve your goals?
What are your strengths/weaknesses?
How would you describe yourself?
Why did you choose this career?
What does success mean to you?
How can you contribute to this organization?
What achievements have given you the most satisfaction? Why?
Do you work well under pressure?

Aging: Space Pioneer John Glenn

Grade Level: 8

Time Required: 2 - 4 class periods

Suggested TEKS		
Language Arts -	8.5	
Computer -	8.2	8.3
Suggested SCANS		
Technology . Apply technology to task.		
National Science and Math Standards		
Science as Inquiry, Life Science, Science in Personal and Social Perspectives, Observing, Communicating		

Countdown:

Electronic Text
http://www.senate.gov/~glenn/main.html
http://www.lerc.nasa.gov/WWW/PAO/html/jglenbio.htm
http://www.senate.gov/~glenn/17.html
http://www.senate.gov/~glenn/discovery.html

Ignition:

The recent revolution in our ideas about aging has been remarkable. Many Americans are enjoying tremendous vitality at a time of life that would have been unimaginable to their grandparents.

In Prevention's March 1998 issue, "Super Immunity" states that scientists have also learned that age is not just measured by the calendar. Rather, it depends more on biology than on chronology. And two things shape biology: **our genetic makeup** (over which we have no control) and **our lifestyle** (which we can control).

The overall message that we are currently receiving is that exercise and a healthy diet can empower our old age profoundly. Numerous studies have been conducted during this decade at the USDA Human Nutrition Research Center on Aging (HNRCA) at Tufts University in Boston that validate and emphasize this message.

Liftoff:

A. Discussion

1. Give background information about John Glenn. Tell students that on January 16, 1998, 76 year-old Glenn persuaded NASA of the importance of studying the effects of aging and space. Part of his "argument" was that perhaps space can explain some of the aging processes on the human body because weightlessness often induces similar, if temporary, conditions in younger astronauts. He also emphasized that "the study of aging becomes even more critical as we enter the 21st century. By 2030, the number of Americans over the age of 65 is estimated to exceed 69 million, more than double the current figure. This increase will have a profound effect on our economy, culture, and healthcare". (John Glenn's Flight on STS interview)

2. Talk about Glenn's personal comments about the October 29, 1998, flight. Also, go over the facts about STS, its crew and its mission.

3. Discuss Friendship 7 statistics and Glenn's comments on this 1962 mission.

Research

Ask students to contact the National Institute on Aging (NIA) and/or USDA Human Nutrition Research Center on Aging (HNRCA) and request information about specific experiments on aging. Have them list and discuss the findings about the aging process. This research can be done on the computer or letters written.

B. Mission Update

Suggest to students that they retrieve current information on the Discovery through the NASA Homepage or NASA's Spacelinks. They may also refer to local newspapers and newsmagazines.

C. Analysis

1. Ask students to compare and contrast the two missions.

Friendship 7	**STS**

2. John Glenn has been referred to as a Space Pioneer. Ask students to explain why he was considered a pioneer on the Friendship 7 flight and why he is considered a pioneer on STS.

D. Research
1. Ask students to research the different types of experiments conducted on past NASA missions.
2. Students define the difference between a Payload Specialist and a Mission Specialist. Which was Glenn categorized as?
   - Have students design and complete an application to NASA to be a payload specialist in a future shuttle mission.
   - Ask students to design an experiment to be conducted in space.

E. Documentary
Explain to students that a documentary is a program that presents facts in an interesting manner. Ask them to determine what viewers would like to know about John Glenn's background, education and training, and experiences as an astronaut. Have them write their ideas in documentary form, and then present the documentary to the class.

F. Tasks
1. Have student's design and complete an application to NASA for the Payload Specialist position opening on a future shuttle mission.
2. Ask students to design an experiment to be conducted in space.

G. Vertical Verse
In his Friendship Seven interview, John Glenn describes the sensations he felt during lift-off and in flight (weightlessness). Ask students to write a poem whose lines begin with the letters *liftoff* and *weightless*. Remind them to include vivid descriptive words and onomatopoeia (sound words). They may wish to display their poem in the shape of a spacecraft ready for launch.

Vertical Verse

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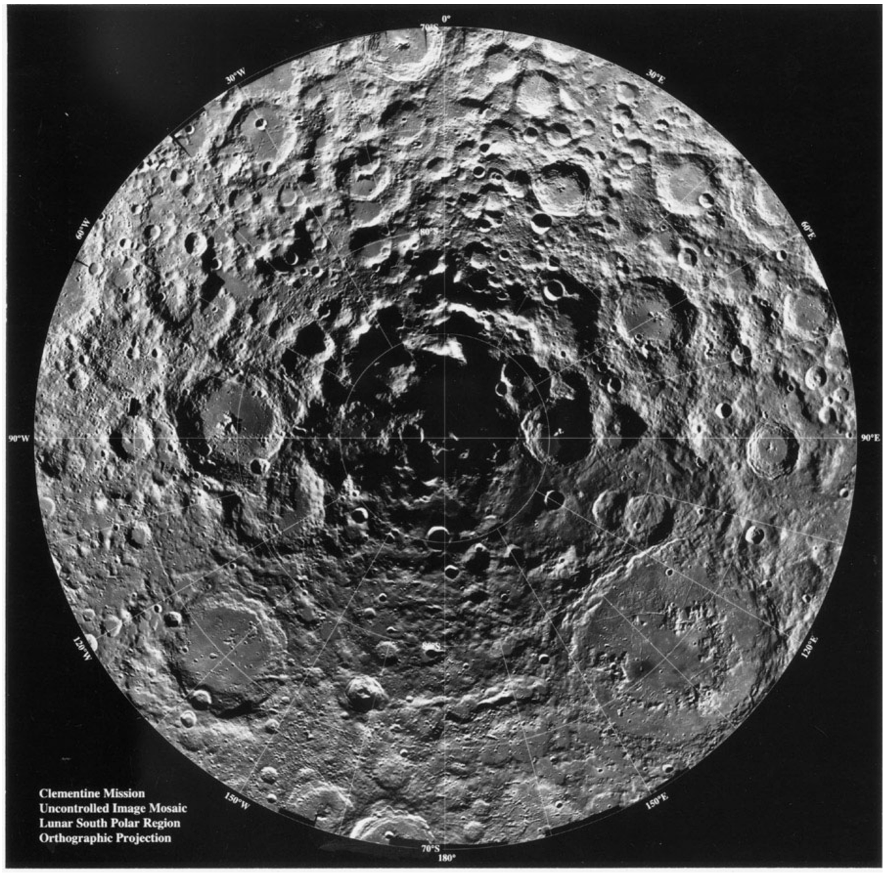


REMOTE SENSING

Light Energy

Grade Level: 5

Time Required: 1 - 2 class periods

Suggested TEKS:
Science - 5.8
Suggested SCANS:
Information. Acquires and evaluates information.
National Science and Math Standards
Science as Inquiry, Life Science, Earth & Space Science, Physical Science, Measurement, Reasoning, Observing, Communicating

Countdown:

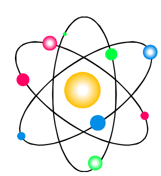
Experiment 1:
1 tomato paste can (without top or bottom)
white poster board, 7" x 9"
wax paper (small piece)
aluminum foil (small piece)
straight pin
table lamp
pencil
scissors
2 rubber bands

Experiment 2:
flashlight
small flat mirror
1 white poster board 3" x 5"
various materials (i.e., fabric, aluminum foil, wax paper, different color poster board, etc. to test for light reflection)

Experiment 3:
pencil
glass of water

Experiment 4:
8 toothpicks
1 bowl of soapy solution
8 raisins
1 short piece of string

Activity:
1 (3" x 5") index card
stapler
1 pencil



Ignition:

Two basic forms of energy through which we experience our world are light and sound. Both have their own special qualities.

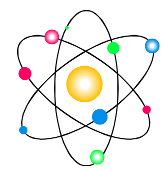
Light is energy that we can see. Light travels as waves, like ripples on a pond. But not all the waves are the same size. Some waves are short, while others are long. When we observe colors, we are seeing light of different wavelengths. The light of the sun appears to be colorless, as it is called white light. It is, however, a mixture of many colors of light. When a rainbow appears in the sky after rain, you can see some of these colors. As sunlight is reflected through raindrops, it is bent, or **refracted**. Light with long wavelengths like red is bent more than light with shorter wavelengths, like violet. For this reason, the colors fan out into a rainbow as they reemerge from a raindrop.

Also, light waves travel in straight lines. If they hit an object in their path, three things might happen:

1) Some of the light waves pass through the object and are **transmitted** (as with a transparent glass window).
2) Some of the light waves bounce off the object and are **reflected** (as with a mirror).
3) Some of the light waves are trapped by the object and are **absorbed** (as with the opaque green leaves of a plant).

Light travels much faster than other kinds of waves, at a speed of about 300,000 kilometers per second. In one second, a wave of light can travel around the earth 7 times.

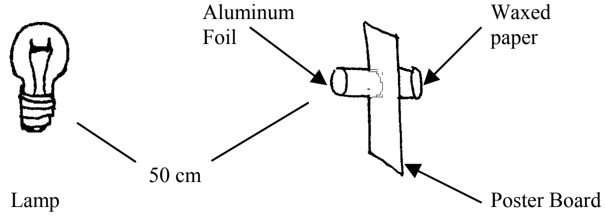
Additionally, light can move through a vacuum. This means that astronauts on the moon's surface can see and photograph each other, even though there is no air on the moon. This does not hold true, however, for sound. Astronauts must depend on radio waves – rather than sound waves – to communicate on the moon.



Liftoff:

A. Experiment 1 - Do light waves travel in straight lines?

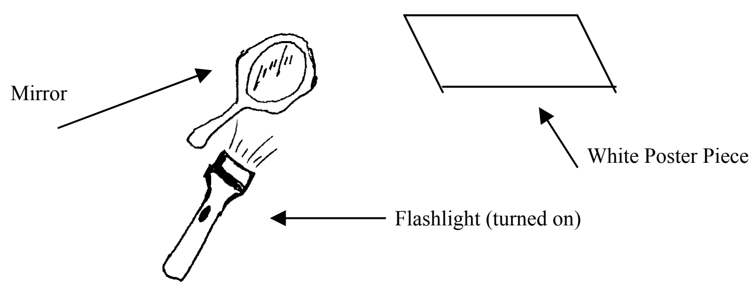
1. Stand the tomato can in the center of the poster board and trace it. Cut out the circle that you've traced.
2. Place the wax paper over 1 end of the can, and secure it firmly with a rubber band. Place the aluminum foil over the other end of the can; secure it with a rubber band.
3. Use the straight pin to carefully make a small hole in the center of the aluminum foil.
4. Push the can through the hole in the poster board.
5. Make the room as dark as possible. Facing the lighted lamp, hold the poster with the can in it, as shown below.



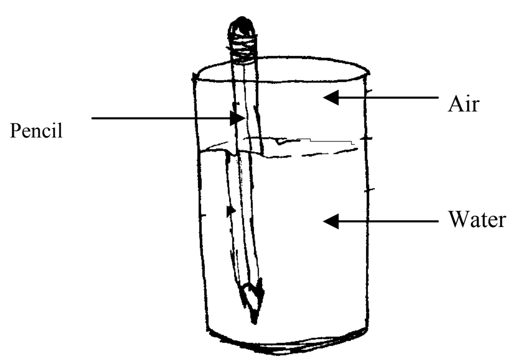
6. Move the poster board closer to or farther away from the lamp until you can see the bulb image clearly on the wax paper.
7. Answer the following questions:
    a. How is the image on the paper different from the light bulb?

b. What are the paths of the light waves from the top and bottom of the bulb to the top and bottom of the image?
c. Do light waves travel in straight lines?

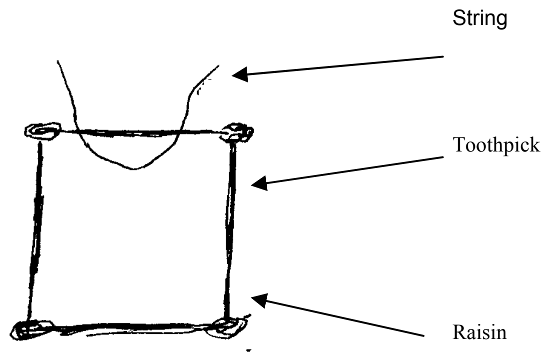
B. Experiment 2 - How do different surfaces reflect light?
1. Test how well a mirror reflects light. Set up the experiment, according to the diagram below. Shine the light on the mirror in a dark room. The light that is reflected upon the white poster should be almost as bright as the flashlight beam itself.
2. Test how well different kinds of materials reflect light. Do the same experiment as for #1, except put the new material in the place of the mirror.
(You may prefer to drape the material over the mirror, and then shine the light on it.) Observe the differences of reflection for each.



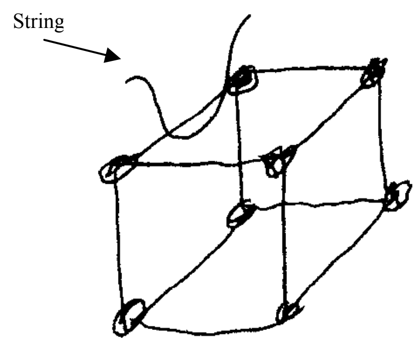
C. Experiment 3 - Can the direction of a light wave change?
1. Place a pencil in a glass of water. Notice that the pencil appears bent, or refracted. See diagram below. The speed of light changes slightly as it moves from one material (water) to another (air). Therefore, the light waves change direction, causing the illusion of a bent pencil.



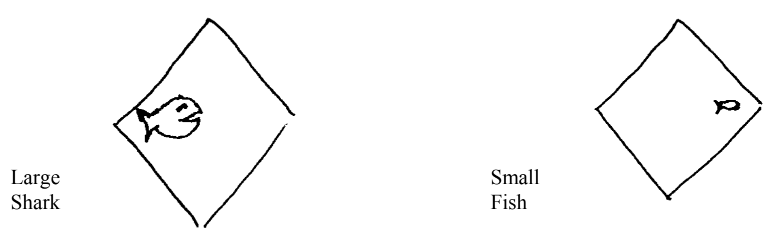
D. Experiment 4 - Can you make colored bubbles?
1. Make a square by using 4 toothpicks as sides and 4 raisins as vertices.
2. Loop the string through a toothpick side, and dip the square into soapy water. Gently pull it out – notice the 2-D bubble that's been formed.



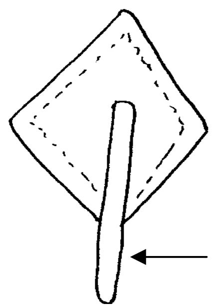
3. Make a cube by using 8 toothpicks as sides and 8 raisins as vertices.
4. Carefully, loop the string through a toothpick side, and dip the cube into soapy water. Pull it out, notice the 3-D colored soap bubble that formed. Light rays reflect from both the outer and the inner surfaces of the bubble. A ray that is reflected from the inside must travel slightly farther than one that is reflected from the outside, so – when the waves meet – they are slightly out of step. Some colors cancel out and disappear, others combine to make bands of color on the surface.



E. Activity - Making a Thaumatrope Movie
   1. Get one 3” x 5” index card, and cut it in half horizontally. Draw a big shark on the left side of the first card. Then, draw a small fish on the right side of the 2nd card.



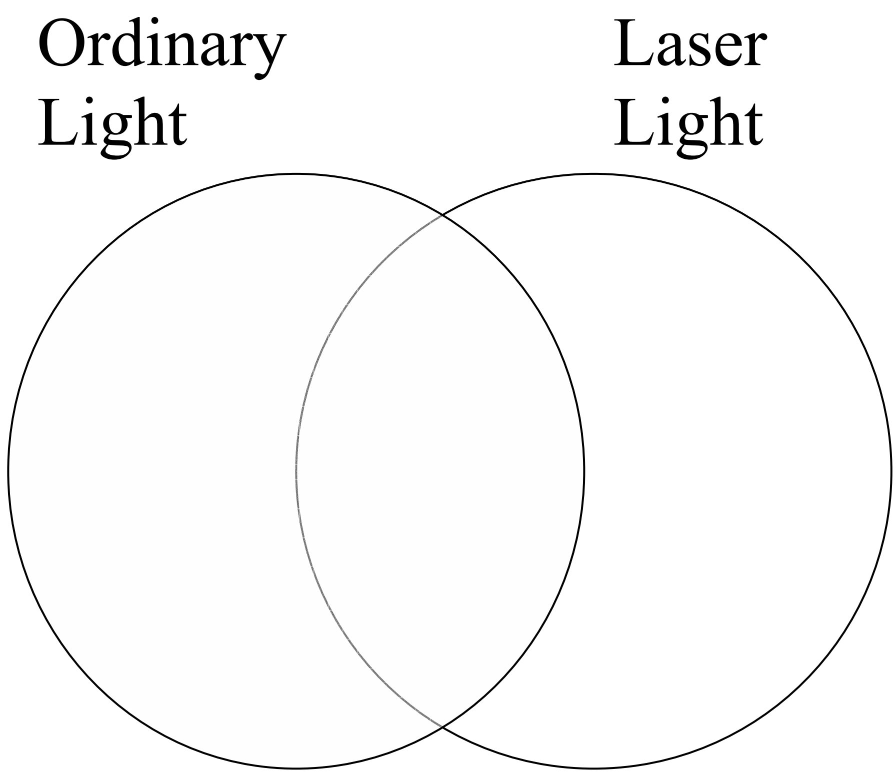
2. Put the 2 cards together, with pictures facing toward the outside. Slide a pencil, eraser first between the cards and staple in place. See diagram below.



3. Hold the pencil between your palms. Roll it back and forth quickly. Notice that the shark is eating the little fish.
4. Make different "movies" with different stories, i.e., a cat sitting in a wastebasket and a speeding gorilla chasing a car.
5. Explain to the students that our eyes "remember" things. For a split second, they hold onto the last image that they've seen. If we quickly replace the object with another, we will see both images together. It is eye/brain memory that makes movies and cartoons work.

F. Activity - Comparing Ordinary Light to Laser Light

1. Ask students to research laser light to answer the following questions:
    a. What is laser light?
    b. How is laser light different from ordinary light?
    c. How is laser light generated?
    d. What are the applications of laser light in modern day technology?
2. Using the information located, students should then organize it into a Venn Diagram, as below:


Ordinary Light
Laser Light

Light – Telescopes

Grade Level: 5

Suggested TEKS:
Science - 5.4
Suggested SCANS
Information. Acquires and evaluates information.
National Science and Math Standards
Science as Inquiry, Earth and Space Science, Science and Technology, Physical Science, Measurement, Observing, Communicating

Time Required: 2 - 3 class periods (more if in-depth research occurs)

Countdown:

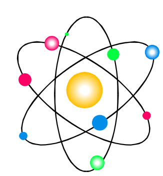
2 cardboard tubes (i.e., toilet paper, paper towel if cut down to less than toilet paper tube)
2 convex lenses, 1 thick and 1 thin

Ignition:

Early astronomers depended on the human eye to study the visible stars and the patterns they made. They discovered five planets and the patterns they made. But, the true nature of celestial objects awaited the invention of the telescope in 1609.

A telescope is defined as an instrument that makes distant objects nearer and larger. A simple kind of telescope is made of two tubes and three lenses. One of the tubes fits inside the other. A large glass lens, called the objective, is at one end of the tubes. It points at the object to be viewed. The eyepiece, located at the other end, is held to the eye, magnifying the image.

All objects give off light. Light travels in “light waves” in straight lines. Therefore, light waves travel from the object being observed to the telescope. The light waves pass through the objective and into the tube of the telescope. Depending on the type of telescope used, the image appears upside down. Halfway down the tube is the middle lens, which bends the light waves to turn the image right side up. The observer views the image through the eyepiece, right side up.



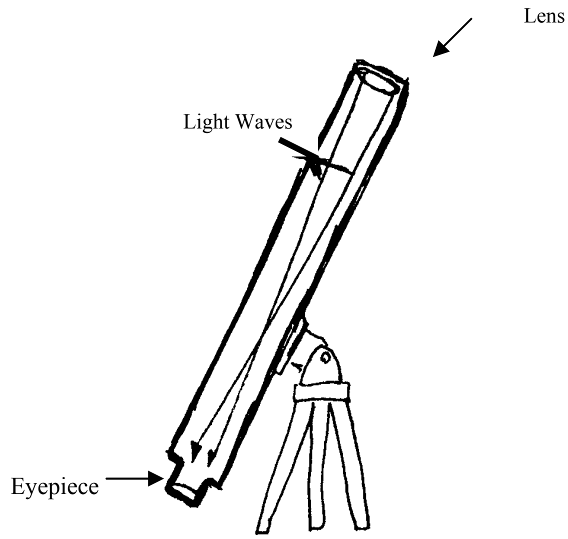
Liftoff:

A. Discussion

1. **The refracting telescope**

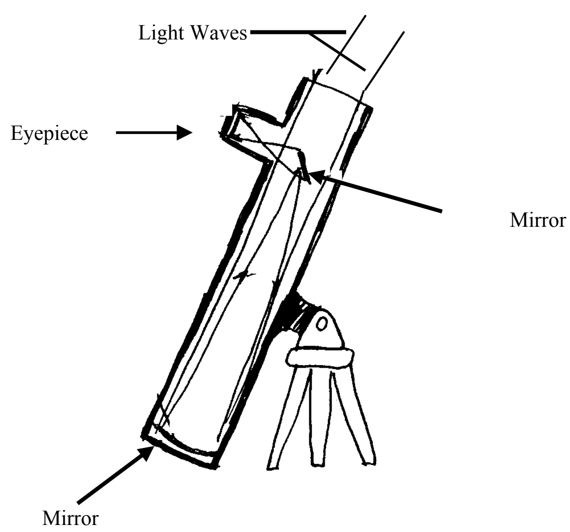
   Discuss with the students that one kind of optical telescope is the refracting telescope. This telescope uses glass lenses to focus light directly into the eyepiece. Note the diagram below. The largest refracting telescope is located at the Yerkes Observatory in Wisconsin. Unfortunately, the lenses had to be restricted to a width size of 40 inches because greater sizes caused them to sag.

Refracting Telescope



2. **The reflecting telescope**
   Discuss that another kind of optical telescope is the reflecting telescope. These telescope uses curved mirrors which bounce off light to each other, then send it to the eyepiece. See diagram below. Big telescopes, like the Hubble with its 94.5 inch mirror and the Hale telescope with its 200-inch mirror, are reflecting telescopes that can gather a tremendous amount of light. When coupled with an electronic camera, they can see galaxies billions of miles away.

Reflecting Telescope

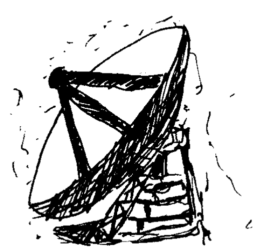


3. **The solar telescope**
   A solar telescope is specifically designed to observe the details of our blazing Sun. It has an extremely long focal length in order to focus on areas just 100 miles wide. The McMath telescope, located in Arizona, is the size of a 50-story building laid on its side. The 11-story tower, built above ground, allows sunlight to enter undisturbed by air turbulence near the ground. The light strikes a movable flat mirror that follows the Sun; then it is beamed to a concave mirror at the bottom of the shaft. From there, it is reflected to another mirror and then into the observation room.

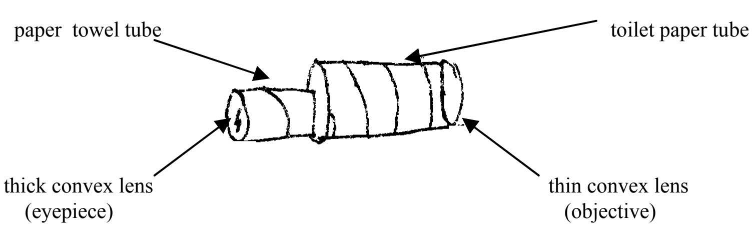
4. **The coronagraph**
   A coronagraph is a special type of optical telescope that helps astronomers to see the corona, the Sun's thin upper atmosphere. Because the corona can only be seen when the brilliant light from the Sun's surface is blocked out, the coronagraph has a disk in its tube that creates an artificial eclipse. Skylab in 1973 photographed the corona. In this photograph, the corona extends twice the Sun's diameter.

5. **The radio telescope**
   Discuss that a radio telescope "sees" the long wavelength waves, emitted by celestial bodies that make up the radio end of a spectrum. The mirror of a radio telescope is a huge saucer-shaped reflector. See diagram below. The National Radio Astronomy Observatory, located in Socorro, New Mexico, utilizes several radio telescopes.

The Radio Telescope



B. Activities
   1. Make a simple refracting telescope
      a. Slide the smaller paper towel tube inside the slightly larger toilet paper tube. The tubes need to fit snugly.
      b. To the outside of the smaller tube, attach the thick convex lens. To the outside of the larger tube, attach the thin convex lens. See diagram below.



c. Look through the eyepiece lens, and slide the tubes in and out until the object being viewed comes into focus.

2. Categorize the different kind of telescopes. Have students complete the attached table (sample below) according to information given in Part A.

Kind of Telescope	What is used to focus Light	Identifying Feature	When Used

3. Divide the students into groups. Each group will work on one of the following activities and give an oral presentation.
   a. Research the Hubble Space Telescope. Students will record findings, write a research paper, drawings, and report back to the class. According to the February 1998 issue of Discover, the space shuttle will pay its fourth and final maintenance visit to the Hubble Space Telescope in March 2002. Thereafter, its famed work will soon be completed. As is true with modern computer technology, the amazing Hubble's capabilities are actually beginning to seem a little limited:

      1) its mirror is too small
      2) its focus is too narrow
      3) its heat is too obscuring
      4) its earth orbit is too crowded
      5) its "blindness" extends to half the light of the sky (i.e. gamma rays, ultraviolet, and radio waves)

      NASA-sponsored lab plans for the future are not to replace the Hubble, but rather to improve it. New technologies will overcome the obstacles and limitations of the Hubble, as well as answer far-reaching questions such as whether life exists elsewhere in the universe.

   b. Research NASA's future plans for space telescopes and missions
      If all goes according to schedule, NASA will introduce **Space Infrared Telescope Facility (SIRTF)** in 2001. Some of the features are as follows:
      1) it will contain enough liquid helium to keep its temperature at 450 degrees below zero Fahrenheit (this will allow it to "view" infrared light)
      2) it will orbit the Sun, rather than the Earth
      3) it will have a 33-inch mirror and infrared-sensitive detectors
      4) it will be able to spot "superplanets" and brown dwarfs
      5) it will be able to examine the birthplaces and cemeteries of stars and provide information about how galaxies are formed
      6) it may be able to pick up signs of carbon and water vapor in the disks of dust around the stars, thereby suggesting other life-supporting planets
      NASA has plans to launch three other space telescopes:

Space Interferometry Mission (SIM) in March 2005
NASA Generation Space Telescope (NGST) around 2007
Terrestrial Planet Finder (TPF) around 2013

As part of its Origins program, NASA is also planning four pre-cursor missions by 2001. They are as follows:

Wide-Field Infrared Explorer (WIRE)
Far Ultraviolet Spectroscopic Explorer (FUSE)
Stratospheric Observatory for Infrared Astronomy (SOFIA)
New Millennium Interferometer (NMI)

c. Locate the Southwest Observatories and Observe the Night Sky
Suggestions for information include: StarDate Productions (800-STARDATE)
Or write to StarDATE, 2609 University Avenue, #3,118, Austin, TX 78712
Web Site: http://stardate.utexas.edu
World Wide Web listing in Appendix

Telescopes

Kind of Telescope	What is used to focus Light	Identifying Feature	When Used

Venus Sky Box

Grade Level:	6
Time Required:	2 class periods

Suggested TEKS:
Science - 6.4
Math - 6.10

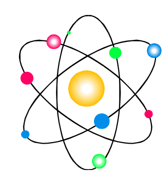
Suggested SCANS:
Technology. Apply technology to task.
National Science and Math Standards
Science as Inquiry, Earth and Space Science, Physical Science, Computation, Measurement, Reasoning, Observing, Communicating

Countdown:

Empty standard shoe boxes (1 for each 2 students)
Coffee stirring straws
Centimeter scale graph paper (5 squares per inch is easily adapted)
Color pencils
Miscellaneous objects of various shaped and sizes to go inside box
(examples: Styrofoam shapes, lids, etc.)
Tape
Metric ruler
Ice Pick

Ignition:

Satellites and aircraft use radar to obtain an elevation map of a surface that cannot be seen visually. To prepare for this activity, prepare the shoeboxes yourself prior to class, or have the students prepare the boxes and then switch with another group.



Liftoff:

1. Prepare the shoeboxes to be the hidden terrain.

- Tape/glue objects to the bottom of the inside of the shoebox.
- Tape/glue a piece of graph paper to the top of the shoebox lid. Punch a hole through the lid every one-centimeter over the entire surface. The holes should be just large enough for the stirring straws to fit through.
- Tape the lid on the shoebox.

2. Have the students create low-resolution maps of the “hidden surface”. To get a reading, place a stirring straw into one of the lid holes, measure the length of the straw that is left above the lid (in centimeters), find the color for that measurement on the Color Scale (listed below), and fill in the appropriate squares on the graph paper in that color. For a low-resolution map, use every other hole across the lid surface. For a high-resolution map, use every hole.

   Note: Each hole measured represents an area half the distance to the next hole measured on all sides. For example, on a high-resolution map, the area colored is based on one hole measurement that would extend 0.5 centimeters around the hole since the holes are 1 centimeter apart.

3. Have the students compare and contrast the level of detail obtained from low and high-resolution maps. What do they reveal about the terrain?

4. Have the students provide oral and written descriptions of their terrain based on their maps.

5. Show maps of the Venutian surface (Video available from ERCs or check the Web) and discuss how NASA scientists used the same basic techniques to get those maps using satellite radar.

6. Have the students remove the lids to the shoeboxes and compare their “radar” maps to the actual terrain. Can we do the same with Venus? Why or why not?

Color Code:

0-2	cm	Violet	7-8	cm	Red/Orange
2-3	cm	Brown	8-9	cm	Orange
3-4	cm	Light Brown	9-10	cm	Green
4-5	cm	Blue	10-11	cm	Yellow-Green
5-6	cm	Sky Blue	11-12	cm	Yellow
6-7	cm	Red			

Satellite Orbits From Planet Earth

Suggested TEKS:	
Science -	7.8
English -	7.20
Suggested SCANS:	
Interpersonal. Teaches others.	
National Science and Math Standards	
Science as Inquiry, Earth and Space Science, Science and Technology, Physical Science, Computation, Measurement, Reasoning, Observing, Communicating	

Grade Level: 7

Time Required: Several class periods, depending on research

Countdown:

1 copy of table for each student
1 copy of Elliptical Orbits worksheet for each student
Electronic texts, if available
Printed resources

Ignition:

Satellites are man-made objects or vehicles intended to orbit the Earth, the moon, or another celestial body. Probes are satellites that move outward and skim by other worlds, sometimes actually landing on them. Since the Soviet Union launched Sputnik in 1957, hundreds of artificial satellites have been sent into orbit.

Satellites and probes can be classified into three groups, as follows:

1. those that observe the Earth
2. those that peer into space
3. the spacecraft that travel to other planets
4.

Additionally, there are many types of satellites. Several are listed below, according to their purpose:

1. communications satellite - provides fast radio, telephone and TV communications
2. weather satellite - takes photographs of Earth, sending them down in the form of radio waves; forecasters show satellite pictures on nightly weather reports
3. remote sensing satellite - studies the Earth's surface and send back vital data about global environments
4. mapping satellite - takes pictures of the Earth and make exact maps (in the absence of clouds)
5. surveillance satellite - takes pictures of the Earth from 100 miles and higher (22,300 miles); recorders and cameras can listen in on walkie-talkie radio conversations, make out peoples' faces and buildings, and even figure out the building composition
6. astronomical observatories - studies distant stars and galaxies, cosmic rays, and high-frequency radiation from deep space; learn about super-novas, black holes, and neutron stars

Liftoff:

A. Initiate a discussion about the main orbit types. A satellite's orbit depends on its speed and distance from Earth. Below, the main orbit types are listed and defined.
   1. LEO (Low Earth Orbit) - When a satellite circles close to Earth, it's in Low Earth Orbit. Satellites in LEO are just 200-300 miles high. Because they orbit so close to the Earth, they must travel very fast (17,000 mph) so the gravity can't pull them back into the Earth's atmosphere.
      a. Polar orbit - A satellite in polar orbit travels a north-south direction. This makes polar orbits particularly useful for viewing the entire Earth's surface, since the Earth spins in an east-west direction.
      b. Retrograde - A satellite, which goes against the Earth's rotation in an east-west orbit, is called retrograde.
      c. Posigrade - A satellite, which goes in the same direction as the Earth's rotation, is called posigrade.
   2. GEO (Geosynchronous equatorial orbit) - A satellite in geosynchronous orbit (GEO) is located directly above the equator, exactly 22,300 miles out in space. At that distance, it takes the satellite 24 hours to circle the planet. Since it also takes Earth 24 hours to spin on its axis, the satellite and earth move together.
   3. Elliptical Orbit - A satellite in elliptical orbit follows an oval-shaped path. One part of the orbit is closest to the center of the Earth (perigee) and the other part is farthest away (apogee).

B. Ask students to determine which types of orbits would best fit the different kinds of satellites, and complete the table. (Student table attached.)

Satellite	**Type of Orbit(s)**
Communications	______________________
Weather	______________________
Remote Sensing	______________________
Mapping	______________________
Surveillance	______________________

C. Using the information given on elliptical orbits, ask students to complete the Elliptical Orbit worksheet. (Attached)

D. Ask students to formulate questions about satellites and then research specific satellites and probes.

Examples include:

Hubble Space Telescope
International Ultraviolet Explorer (IUE)
Infrared Astronomical Satellite
Viking I & Viking II
Voyager 2
the Mariner Series
Tenma (Japanese)
Sputnik (Russian)

More Ideas …

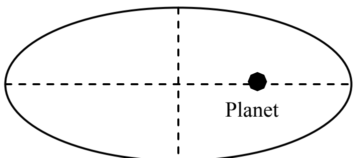
- Research the anatomy of a satellite. One resource might be "The Satellite Site" located at: (http://www.thetech.org.hyper/satellite/).
- Make a satellite through an interactive program, "Satellite Construction Set". Use the same link as listed above.

Student Satellite Worksheet

Satellite	Type of Orbit(s)
Communications	______________________________
Weather	______________________________
Remote Sensing	______________________________
Mapping	______________________________
Surveillance	______________________________

Elliptical Orbits

Many satellites have orbits that look like ellipses, or ovals. Using the definitions given below, label the parts of an elliptical orbit on the diagram.



Definitions

semi-major axis (a): the distance between the center of the ellipse and the outer edge in the long direction

semi-minor axis (b): the distance between the center of the ellipse and the outer edge in the short direction

radius of perigee (r_p): the distance from the center of the planet to the point of closest approach for the satellite

radius of apogee (r_{ap}): the distance from the center of the planet to the point in the orbit farthest from the planet

eccentricity (e): the measure of how "squashed" an ellipse is; i.e. the distance between the center of the planet and the center of the ellipse

If you know an orbit has an eccentricity of 9.1 and a semi-major axis of 40,000 km, use the equations below to calculate these quantities:

1. $r_p =$ ___________
2. $r_{ap} =$ ___________
3. e = ___________
4. a = ___________
5. b = ___________

$$a = \frac{(r_{ap} + r_p)}{2}$$

$$e = \frac{(r_{ap} - r_p)}{(r_{ap} + r_p)}$$

$$r_p = a(1 - e)$$

$$r_{ap} = a(1 + e)$$

$$b = \sqrt{r_{ap}\, r_p}$$

Fun Facts

- A satellite can either be natural like the Moon or artificial like the Hubble Space Telescope.
- A circle is actually an ellipse with zero eccentricity (e = 0).
- For a circular orbit, the semi-major axis, the semi-minor axis, the radius of perigee, and the radius of apogee are all equal ($a=b=r_p=r_{ap}$).
- People who plan satellite orbits study **orbital mechanics.**
- If you are interested in the motions of satellites, planets, or exploratory spacecraft (like Voyager), you should plan on being an aerospace engineering major in college.

Mapping Terrestrial and Ocean Areas

Suggested TEKS:	
English -	8.13
Science -	8.2
Computer -	8.2

Suggested SCANS:
Information. Acquires and evaluates information.

National Science and Math Standards
Science as Inquiry, Life Science, Earth and Space Science, Science & Technology, Physical Science, Observing, Communicating

Grade Level: 8

Time Required: 3 to 4 class periods

Countdown:

Electronic text, if available
A copy of TOPEX/Poseidon: Revealing our Ocean Planet publication

Ignition:

The year 1972 was a turning point in applying remote sensing from space to mapping, or cartography. That was when NASA initiated the LANDSAT program for surveying Earth with Multispectral Scanners (MSS).

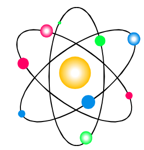
Multispectral Scanners can distinguish several visible colors and invisible infrared radiation from Earth's surface. Researchers have learned to interpret these spectral images to do several things:

1) chart the variety and health of trees and crops,
2) chart water and airborne pollutants,
3) track rainfall and seasonal changes in vegetation,
4) study the earth's chemical composition,
5) determine earthquake fault lines,
6) track forest fires, flooding, and volcanic activity,
7) locate potential mineral deposits and surface water, and
8) study changes in the earth's surface (both natural and man-made) i.e., the desertification in parts of West Africa and the deforestation in the South American rainforest.

In the area of oceanography, researchers have been able to accomplish the following:

1) chart the pollution in streams and the spread of plankton in the sea;
2) determine the ocean's salinity, surface height, wind speed, and eddy and ocean current circulation;
3) provide ice cover analysis;
4) observe year-to-year changes in the ocean;
5) calculate heat storage in the ocean to better understand how currents move heat energy around the globe;
6) improve climate forecasting as in El Niño events;
7) conduct survey and research missions, also search and rescue; and
8) conduct biological studies.

The data and images collected by the remote sensing satellite are transmitted in digital form. That means they can be readily stored in computers, then processed and converted to maps.



Liftoff:

A. Discussion - Talk about the importance of phytoplankton in the ocean.
   1. Explain that phytoplankton (from phyto=plant + planktos=wandering) are minute, single-celled ocean plants that float freely in the lighted surface. These plants convert nutrients into plant material by using sunlight and the green pigment chlorophyll in a process called photosynthesis. Different types of phytoplankton have different concentrations of chlorophyll.
   2. Emphasize that the reason why phytoplanktons are so important is because they are the basis of the marine food chain. They are the primary food and energy source for the ocean ecosystem. As phytoplankton grow and multiply, small fish and other animals eat them as food. Larger animals then eat these smaller ones.

B. Discuss ocean color when viewed from space.
   1. Remind students that the color of the ocean is not a consistent blue; rather, the ocean reflects the color of the sky, and several other factors also alter its color. One major factor is the phytoplankton. Areas in the ocean where a great number of these organisms are concentrated – called "bloom" – show a distinct color change. The more chlorophyll "a" that is present at the surface, the "greener" the reflected light will be, and blue-violet and red light is absorbed. When more chlorophyll "b" is present at the surface, the reflection will be yellow-green, and blue and orange light are absorbed.
   2. Discuss that, from space, satellite instruments measure the amount of reflected light of different wavelengths. The amount is viewed as a false color image. False color means a color scale with number values depicting the milligrams of phytoplankton per cubic meter of sea water. Red and yellow areas contain the most life, green and blues indicate less, dark blue and purple indicate very low concentrations of phytoplankton in very clear ocean water. It should be noted that areas of high productivity where more oxygen is produced and carbon dioxide consumed support more life than less productive areas.

C. View ocean color from satellite images.
   Resources include:
   1) Internet site - http://athena.wednet.edu/curric/oceans/indexhtml

2) Internet site –
http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/OCDST/classic_scenes/01_classics_tasmania.html
3) TOPEX/Poseidon: Revealing Our Ocean Planet
obtain from: Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA 81109

D. Research
Ask students to research ocean productivity, looking for factors that are influential in productivity in different regions. Students may select one region and prepare a poster showing the ocean productivity in that region and present it to the class.

F. Research
The TOPEX/Poseidon satellite, launched in 1992, represents a major leap forward in oceanography. It has achieved its original goal: “to lay the foundation for a continuing program to provide long-term observation of ocean circulation”. Ask students to research this satellite, determine its global measurements and orbit, its construction, and its equipment.

G. Research
Ask students to research El Niño on the news, magazines, newspapers, or electronic text to answer the following questions:
1) What is the derivation of the term “El Niño”?
2) What might cause El Niño?
3) How has El Niño affected our national weather during this school year?
4) How can the TOPEX/Poseidon predict the coming of an El Niño?
5) What has been the frequency of El Niño in this century?

ORBITAL MECHANICS

Toys in Space

Grade Level: 5

Time Required: 30 minutes per toy

Suggested TEKS:		
Science - 5.2	5.3	
Language Arts -	5.10	5.13

Suggested SCANS:
Technology. Apply technology to task.

National Science and Math Standards
Science as Inquiry, Earth & Space Science, Science & Technology, Physical Science, Reasoning, Observing, Communicating

Countdown:

"Rat Stuff" pop-over mouse by Tomy Corp., Carson, CA 90745
Yo-Yo flight model is a yellow Duncan Imperial by Duncan Toy Co., Barbaoo, WI 53913
Wheelo flight model by Jak Pak, Inc. Milwaukee, WI 53201
"Snoopy" Top flight model by Ohio Art, Bryan, OH 43506
Slinky model #100 by James Industries, Inc., Hollidaysburg, PA 16648
Gyroscope flight model by Chandler Gyroscope Mfg., Co., Hagerstown, NJ 47346
Magnetic Marbles by Magnetic Marbles, Inc., Woodinville, WA
Wind up Car by Darda Toy Company, East Brunswick, NJ
Jacks flight set made by Wells Mfg. Cl., New Vienna, OH 45159
Paddleball flight model by Chemtoy, a division of Strombecker Corp, Chicago, IL 60624

Note: Special Toys in Space Collections are available from various distributors including Museum Products, the Air & Space Museum in Washington, DC, and many are on loan from your local Texas Agricultural Extension Agent

Ignition:

Gravity's downward pull dominates the behavior of toys on earth. It is hard to imagine how a familiar toy would behave in weightless conditions. Discover gravity by playing with the toys that flew in space. Try the experiments described in the Toys in Space guidebook. Decide how gravity affects each toy's performance. Then make predictions about toy space behaviors. If possible, watch the Toys in Space videotape or study a Toys in Space poster (video available through your local Texas Agricultural Extension Agent). To check predictions, read the results section of the guidebook.

Toys in Space developer: Dr. Carolyn Sumners, Director of Astronomy & Physics, Houston Museum of Natural Science

Guidebook layout and design: Gary Young, Vela Productions

Poster & Guidebook illustration: Chris Meister, Vela Productions

Toys in Space videotape production: Pat Schwab, KPRC Television, Channel 2

On April 12, 1985, at 7:59 a.m., CST, the Space Shuttle Discovery transported eleven familiar motion toys into the weightless environment of space. In turn, each toy carried along the questions of all the curious children, teachers, and parents who had suggested toy experiments and predicted possible results. Twenty dollars worth of toys and several hours of free time donated by five enthusiastic astronauts and one space-bound senator could bring the experience of weightlessness and an understanding of gravity's pull to students of all ages.

This toy cargo gave the Space Shuttle one more role in extending human access to the space environment. With the addition of a few pounds of toys, the Shuttle mid-deck became a space classroom where astronauts could teach the nation's children about life in space.

The following physics basics were tested with the toys:

Gravity : On the earth's surface, all objects experience a downward force caused by the gravitational attraction between the object and the earth. Any toy on earth is affected to some extent by the pull of gravity.

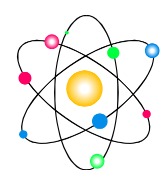
Microgravity : The earth's gravity keeps satellites and their contents in orbit. The satellites travel so quickly that they do not fall toward the earth. Astronauts feel as if they are falling freely like a diver jumping off a diving board. This experience is also called "weightlessness" or "zero gravity". Microgravity is the official term because there are small forces still felt in the Space Shuttle when the spacecraft maneuvers in orbit. The toys on the shuttle float through the cabin without experiencing any downward force relative to the spacecraft.

Energy Conservation: When an object moves, it has Kinetic Energy. An astronaut trying to move a toy in space must find a source for the energy needed by the toy.

Momentum Conservation: Objects in motion have momentum. More massive faster moving objects have more momentum. In a collision, momentum is conserved. When one object loses momentum, another object must gain momentum. This momentum conservation is also described as a *reaction force* produced by an object for every *action force* acting on the object. This conservation law determines the results of many toy collisions.

Inertia: Objects in motion tend to stay in motion. Objects at rest tend to stay at rest. An astronaut must exert a force to cause a toy to change its motion. It requires more force to move an object with more mass. If an astronaut tries to make a toy turn or move in a circle, the inward action force exerted on the toy is called *centripetal force*. The outward reaction force produced by the toy is called the *centrifugal force.* Gravity provides the centripetal force that keeps the space shuttle in space.

Angular Momentum Conservation: Spinning objects have angular momentum. More massive, more spread-out, and more rapidly spinning objects have more angular momentum. Angular momentum must be conserved. A spinning toy will continue spinning with the same axis tilt until it transfers some of its angular momentum to another object – such as a supporting table.

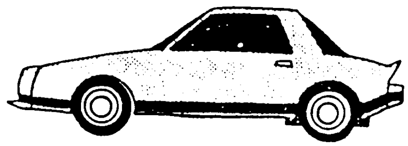


Liftoff:

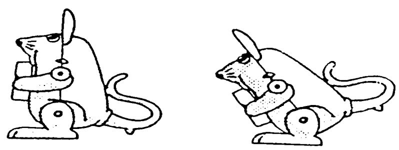
> Have the students complete the **Making Toy Predictions Worksheet** (attached) and then begin playing with the toys. After playing with the toy, you may wish to watch that segments of the video and do the teacher explanation, or you may wish to have them play with all the toys and then watch the complete video.

A. Experiment 1: Moving Along

Three motion toys went into space: a wind-up car, a paper airplane, and a flipping mouse. Push the car along a table to wind it up. Release it. Try different surfaces. On what surface does it go faster? Tilt the surface upward. How is the speed affected? Would the car move in space?



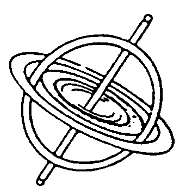
Make a standard airplane. Fly it forward. Fly it backward. Is there a difference? Make a runway for your plane. Is it hard to land the plane accurately? Try to make a plane that spins and one that does loops. Discover how wing flaps make a plane turn.



Wind up Rat Stuff, the flipping mouse. Set him on a smooth surface. Watch him flip. Tilt the surface. What happens? Make the surface soft. What happens? How does Rat Stuff use the bump on his tail? Put marshmallows on Rat Stuff's ears. Does it change his flip? Will this work in microgravity on the space shuttle?

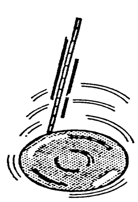
B. Experiment 2: Spin Stability

Start a gyroscope or top spinning. Try to tilt its spin axis. What happens? Push a spinning gyroscope or top with a string. How does it move? Try balancing a gyroscope on your finger, on a string, or on another spinning gyroscope. What happens to the spin axis?

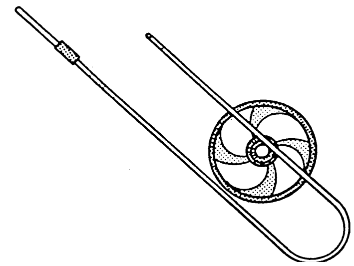


C. Experiment 3: Spin Ene

Watch a yo-yo in action – moving down and up the string. Unwind a yo-yo string. Hang the yo-yo at the bottom of the string. Try to make it climb the string. What determines whether or not a yo-yo will climb upward? Where does the yo-yo get the energy needed to climb upwards? Give a yo-yo a lot of spin as you throw it downward. Relax your hand as it reaches the end of the string. See if the spinning yo-yo will stay there until you jerk your hand to bring it up. This is "sleeping" the yo-yo.

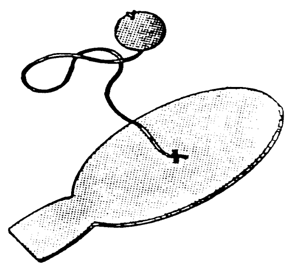


Tilt the wheel-o up and down as the wheel rolls. You are using gravity to start the wheel spinning. You can start the wheel without gravity. Experiment to find out how. Remember, you must not tilt the track. Get the wheel spinning and then stop moving the tracks. Where does the wheel get the energy needed to keep moving? What keeps the wheel on the track as it moves through the bend? See how fast you can move the wheel. Where on the track does the wheel finally fly off?

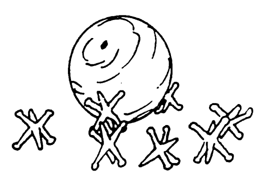


D. Experiment 4: The Bouncing Ball

Play paddleball downward, upward, and sideways. Which is easiest? Why? Hit the ball softly. Hit the ball hard. Which works better? Why? Shorten the elastic string. Is it harder or easier to paddle? Why? When is the paddleball ball going fastest?

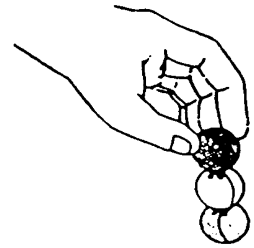


When playing jacks, you must bounce the ball, pick up a jack, and catch the ball. After picking up all the jacks in this manner, try to pick up two jacks at a time while the ball is bouncing. Then try for three jacks, four jacks, etc. What is the best toss and catch strategy? Would it be easier to play with a very bouncy ball or a flat ball?



E. Experiment 5: Magnetic Motions

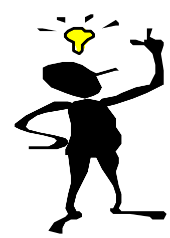
See how many marbles you can pick up with just one marble. The more marbles you pick up, the stronger the magnetic force. Toss up groups of marbles arranged in lines and circles. Which arrangements are stable? Move two circles of 6 marbles together. What happens when they touch? Turn one of the circles over. Push the circles together again. Does the same thing happen? Roll two marbles into each other. See if you can make them spin. Arrange three marbles in a triangle. Put a fourth marble on top to make a pyramid. Be careful. It can be done. Can you push one marble across the table with another one by not touching it?



F. Experiment 6: Slinky Waves

Stretch out a slinky. Move one hand back and forth – pushing in and pulling out on the slinky. Watch the waves travel along the slinky. Does the wave stop when it reaches your other hand? Does the whole slinky move from one hand to the other? These compression waves are like sound waves traveling through the air. Your ear can detect the changes in air pressure as the sound wave strikes your eardrum. Your mind interprets the vibration as sound.

Stretch out a slinky. Move it from side to side with one hand. Watch these waves move along the slinky. This is a transverse wave. Light waves and water waves are transverse waves. What happens to this wave when it reaches your other hand? Move the slinky back and forth faster and faster. See if you can get the wave moving at just the right speed so that at least one place on the slinky stays still as the wave moves up and down around it. This is a standing wave.



More Ideas …

- Complete the ***Twenty Toy Questions*** Worksheet
- Search the Internet for additional Toys in Space programs.

Access the following web site for a Toys in Space wordsearch.
http://observe.arc.nasa.gov/nasa/fun/wordsearch/toys_search/toys_search.html

To find out how the Car and Track works here on earth, visit:

http://observe.arc.nasa.gov/nasa/exhibits/toys_space/fact_car_2.html

To find out how the Car and Track works in orbit, visit:

http://observe.arc.nasa.gov/nasa/exhibits/toys_space/fact_car_3.html

To find out how the Submarine works on earth, visit:

http://observe.arc.nasa.gov/nasa/exhibits/toys_space/fact_sub_2.html

To find out how the Submarine works in orbit, visit:

http://observe.arc.nasa.gov/nasa/exhibits/toys_space/fact_sub_3.html

To find out how other items worked on earth and in space, visit:

http://observe.arc.nasa.gov/nasa/exhibits/toys_space/quickies.html

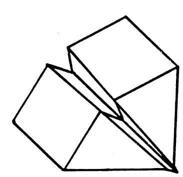
Toys in Space Activity Kits I and II are available through the CORE catalog

You can download the NASA curriculum for Toys in Space II, at:

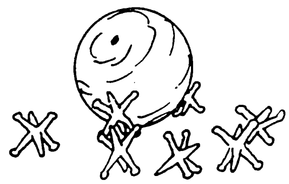
http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Toys.In.Space.II/Toys.In.Space.II.pdf

Teacher Explanations to Toys in Space

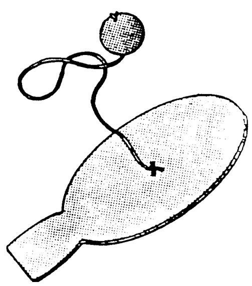
The Space Plane: In space a paper airplane will soar farther than on earth. The airplane's shape is important. It must be aerodynamic. It will fly forward, but will NOT fly backward. When the airplane is released with no push, the airplane will drift on air currents. When an airplane hits the wall, it will bounce off and float backward. In space, an astronaut can blow on a paper airplane to make it fly. A paper airplane should loop in space although no looping airplane was tried on Mission 51D. If a standard paper airplane is released with a sideways push, the airplane will twist to the right or left as it soars forward.



The Space Jacks: Playing jacks is a very different game in space. When the jacks player opens her hand, the jacks stick a bit to her fingers. As they leave her hand, they have some of the momentum from her opening fingers. This momentum makes the jacks drift apart. The jacks player must act quickly before the jacks move beyond her reach. If a more massive ball hits a lighter jack it will cause the jack to fly away at a much faster speed. In a space jacks game, a dropped ball will not fall. The astronaut must throw the ball toward a wall and wait for the bounce and return. Any wall or the ceiling or floor can be used as a bouncing surface. The ball can also be tossed at any speed. Some minimum speed must be set so that the game is still challenging. If a tiny jack is given a spin, it will behave like a tiny gyroscope – keeping its spin orientation as it drifts through the air. Once while collecting jacks, Astronaut Seddon lost her footing. As she grabbed for the jack, her momentum carried her forward. She tucked her body and caused a rolling motion and a flip as she conserved angular momentum.

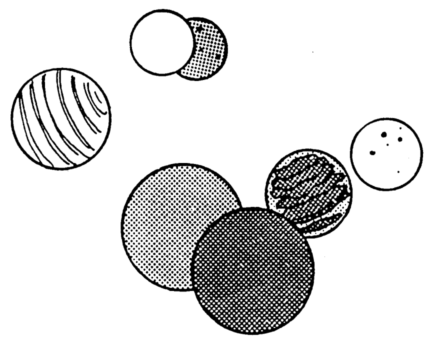


The Space Paddleball: In space paddling a paddleball is much easier. The activity can be done in any direction. The ball will float outward as it gently stretches its string. Afterward it will return to the paddle. The whole activity appears to be in slow motion. To get the ball to return to the paddle instead of falling toward earth, the paddleball player must hit the ball much harder on earth than in space. The paddleball player's space style is more deliberate and graceful. If the ball and paddle are stretched apart and released, they will come back together. The paddle will twist because the string is not connected to the paddle's center of mass. As a result, when the ball reaches the paddle, the paddle is turned so that the ball passes by without any collision. If the paddle is released after the ball is hit, the ball will reach the end of its stretch and return toward the paddle. Meanwhile the paddle will be pulled forward by the elastic string. Astronaut Don Williams was able to get the ball to return and bounce off the paddle once after he released the paddle.

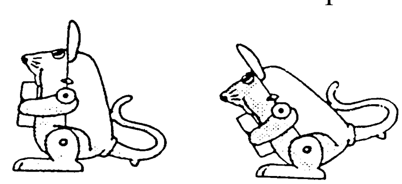


The Space Slinky: In space, the slinky will not walk. Instead it always returns to the hand holding onto it. The slinky coils can be pushed from hand to hand much as is done on earth. The space slinky can perform a yo-yo like behavior. The astronaut pushes the yo-yo forward. The slinky moves outward until the coils are stretched. The spring action pulls the coils back toward the astronaut and outward behind him as the slinky's behavior repeats. If the slinky is stretched apart and released, it will come together and then turn slowly. Astronauts Jeff Hollman and Rhea Seddon discovered that the slinky will carry compression waves and transverse waves. When the coils on one end of the slinky are squeezed together and released, a compression wave travels along the slinky. When one end of the slinky is swung sideways, the slinky will carry a left to right transverse wave. When a wave reaches the end of the slinky, it will bounce back along the slinky. If the compression wave or transverse wave is continually sent along the slinky, a place or places on the slinky may stand still as the wave moves around them. This is called a standing wave, and the non-moving spots are called nodes.

a) **The Space Marbles:** When two marbles are pushed together in space, they stick and begin to spin around their joining point. Tossed and floating marbles will stick together. As other marbles are pushed into the chain they will attach to one end and cause the whole chain to oscillate. If enough marbles are added to the chain, the chain will move about so wildly that the two ends will come close enough for their magnetic attraction to close the chain into a circle. When the marble chain is swung around, inertial forces of the marbles trying to move in a straight line cause the chain to break. The chain always breaks between the first and second marbles – the ones closest to the center. Astronaut Hoffman discovered that three things can happen when two six-marble circles are pushed together.
   1) The circles can repel.
   2) The circles can attach to form a figure eight.
   3) The circles can attach to form a large circle.

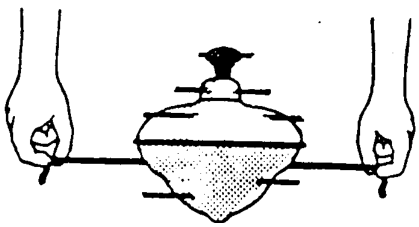


Rat Stuff, The Flipping Mouse: In space Rat Stuff could not stay on the wall long enough to flip. The astronauts used hand cream to make the mouse's feet sticky enough to adhere to the wall. By the mission's end, the mouse also had a small strip of Velcro to hold him to the Velcro patches on the cabin wall. Astronaut Don Williams deployed Rat Stuff by winding him up and sticking him to the wall with a blob of hand cream as big as a pencil eraser. When Rat Stuff leaned forward and then jerked backward, his feet pushed against the wall. The wall reacted by pushing the mouse away in a straight out motion. The mouse continued to flip as he sailed quickly across the cabin.

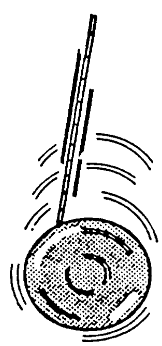


The Gyroscope and Top in Space: In space a spinning gyroscope can reach about the same spinning speed as it does on earth. Its spinning will cause its support cage to spin. Because there is no friction with a support surface, the gyroscope will spin much longer. Only air resistance gradually slows down the spinning space gyroscope. Gravity causes the wobble in a gyroscope or top. This wobble (officially called Precession) increases as the gyroscope slows down on earth. In space there is no force to cause a wobbling motion. When touched by a string, a spinning space gyroscope reacts by floating away. When attached to a string and swung around in circles, a spinning gyroscope will orient its axis to be perpendicular to the string.

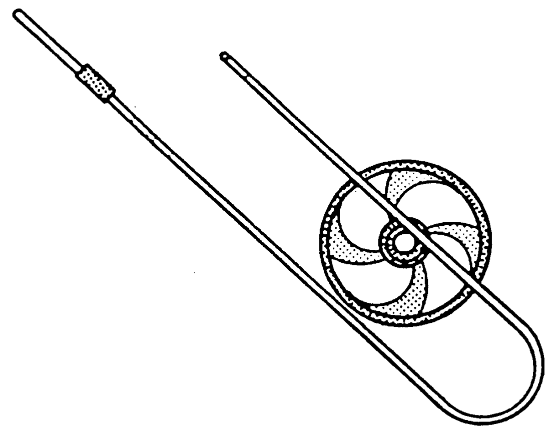
In space a push-top comes back up when the astronaut pulls on the knob. To start the top, one hand must push downward on the top while the other pumps the knob up and down. For this reason, the top cannot reach the same spinning rate in space. Commander Bobko demonstrated the value of gyroscopes by starting his gyroscope spinning and then circling around it. As he moved around, the gyroscope kept its orientation. There are gyroscopes inside the Shuttle's computer instrumentation that tell the Commander about the orientation of the Shuttle as it circles the earth.



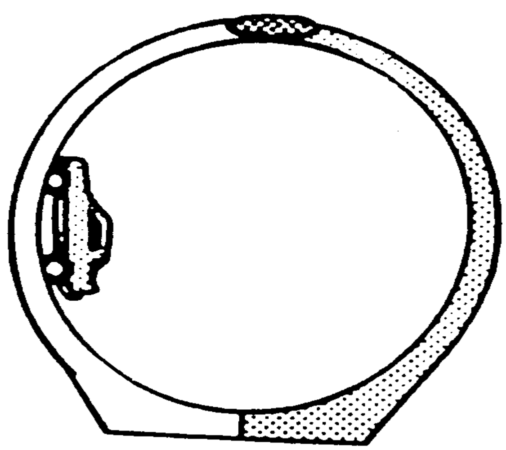
The Space Yo-Yo: In space a yo-yo performs well at any speed. It will gracefully move down the string without tangling and bounce backward along the string when it reaches the loop at the end. The yo-yo will not sleep in space because there is no force to keep the yo-yo from moving back up the string. If the astronaut releases the yo-yo when it is coming back along the string, the yo-yo will continue to wind up its string as it moves past the astronaut. If the string is released on the way out, the yo-yo will wind up its string while moving forward. Yo-yo tricks involving sleeping the yo-yo (like "walking-the-dog" and "rocking the baby") cannot be performed in space. "Around the world" requires a sleeping yo-yo and too much room for an effective demonstration in the cabin. Dynamic yo-yo tricks work beautifully in space. Astronaut Dave Griggs can send the yo-yo out, bring it back, and send it upward with little effort. On earth, this trick is called "shooting the moon".



The Space Wheelo: Magnetism is the same in space as on earth, so the wheel does stick to the track. By slinging the wheel sideways in a circular arc, Astronaut Hoffman could start the wheelo using a combination of inertia and centripetal force. In conserving momentum, the wheel will continue moving along the track after the track is released. It will continue spinning to conserve angular momentum. It transfers some of its angular momentum to the track as the track also begins to turn. If the wheelo is released as the wheel is moving away, the wheel will pull the track away with it – especially when the wheel turns the curve in the track.



Space Car on a Circular Track: The car carried into space had an engine that could be wound up by turning the wheels. On earth, when the engine is wound-up and released, it turns the wheel to make the car go forward on a surface. The car can also be pushed to make it go forward. In space there is no force to hold the car to a surface and, therefore, no friction. When the wound-up car is released, its wheels spin uselessly as the car floats in the air. When the car is pushed forward, it floats across the cabin – but its wheels do not turn. When a wound-up car is placed in a circular track, it begins to move forward. The track pushes in on the car to make it turn. The car reacts to this inward push by pushing outward. Once these two forces are produced, the car sticks to the track and friction occurs. With friction, the car's wheels have traction, and their turning motion makes the car move. The car's motion on the circular track slows down as the car transfers its kinetic energy of motion to the heating up of the wheels and track.



Making Toy Predictions

Gyroscope and top in space:
1) Will a spinning gyroscope or top spin faster or longer?
2) Will a spinning object wobble as it slows down?
3) Will a spinning object move along a string?
4) If a spinning gyroscope is swung around in circles by an attached string, how will its axis orient?
5) Will it be possible to start a push knob top?

Yo-Yo in space:
1) Can a yo-yo be yo-yoed at any speed?
2) Will a yo-yo return when it reaches the end of its string?
3) Will a yo-yo sleep?
4) What will a yo-yo do when the astronaut releases the string?
5) Which yo-yo tricks will be possible in zero gravity?

Wheelo in space:

1) Will the magnetic wheel still stick to the track?
2) Can the wheel's motion be started and maintained?
3) Will the wheel continue to move on the track when the track is released?
4) Will the wheel continue to spin?
5) How will the wheelo system move when released?

Marbles in space:
1) If a marble chain is swung in circles, where will it break?
2) What will happen to two marbles that are tossed together?
3) What will happen when two rings of 6 marbles collide?
4) Will floating or tossed marbles stay together?
5) What will happen when a marble attaches to a marble chain?

Slinky in space:
1) Will a slinky walk?
2) What will happen when the slinky is stretched apart and released?
3) Can a slinky be rocked from hand to hand?
4) Will a slinky carry transverse or compression waves?
5) Can standing waves be formed in a slinky?

Paddleball in space:
1) Will a paddleball's speed be faster or slower?
2) Will it be as easy to paddle in any direction?
3) Will a ball on a stretched string return to the paddle?
4) Will a paddleball player change his style?
5) If a paddleball is released after the ball is hit, will the paddleball paddle itself?

Paper Airplane in space:

1) Will a standard paper airplane soar as well as it does on earth?
2) Can a paper airplane be flown as well backward as forward?
3) How will a paper airplane behave when released with no push?
4) What will happen to a paper airplane when it reaches a wall?
5) Can a paper airplane be thrown so that it makes a loop?

Cars on a Circular Track in space:

1) Will turning wheels make the car move on a table?
2) Will a pushed car move forward?
3) Will there be friction between the car's wheels and the table?
4) Will a wound-up car move along a circular track at a constant speed?
5) Will the wheels of a friction car turn as the car moves along a circular track?

Jacks in space:

1) Will the ball bounce?
2) Will a moving ball slow down and speed up like it does on earth?
3) What will happen to the jacks when they are released?
4) How must the rules be changed for a game of jacks?
5) How will a spinning jack behave?

Flipping Mouse ("Rat Stuff") in space:

1) Will Rat Stuff flip over?
2) Will Rat Stuff be able to flip off a wall?
3) Will Rat Stuff return to the table after a flip?
4) At what angle will Rat Stuff leave a wall?
5) After Rat Stuff leaves a wall, will he continue to flip?

Twenty Toy Questions

1. In space, paddling a paddleball upwards is
   ___as easy as paddling downward.
   ___impossible.
   ___very difficult.
   ___much faster than paddling downward.

2. In space, the paddleball ball has its greatest speed when it is
   ___farthest from the paddle.
   ___closest to the floor.
   ___hitting the paddle.
   ___stretched away from the paddle.

3. When a wound-up toy car is released in space, its wheels:
   ___spin rapidly in place.
   ___move the car forward.
   ___rub against the table as the car moves.
   ___cause the car to turn flips.

4. In space, a toy car moving on the inside of a circular track will
   ___keep its speed.
   ___slow down.
   ___have non-turning wheels.
   ___increase its speed.

5. When a paper airplane is thrown backward in space, it
   ___makes a loop.
   ___does a banked curve.
   ___flies as well as it does going forward.
   ___tumbles.

6. When compared with earth flight, a space plane
   ___flies faster.
   ___dives more easily.
   ___flies a straighter path.
   ___is more difficult to fly.

7. When you release a ball in space, it
   ___falls.
   ___floats.
   ___spins.
   ___sticks to the cabin wall.

8. Why is it difficult to play space jacks?
   ___The jacks move apart.
   ___The ball does not bounce.
   ___The jacks stick together.
   ___The ball moves too fast.

9. What is Rat Stuff's problem as he tries to flip off a wall?
   ___His spring will not wind in space.
   ___He floats off the wall.
   ___His head will not bend forward.
   ___His legs kick forward.

10. What is the direction of Rat Stuff's motion as he leaves the wall?
   ___toward the ceiling
   ___in a backward arc
   ___in a forward arc
   ___straight out

11. To start a top with a push knob in space, you must remember to
   ___start the top upside down.
   ___hold the top down.
   ___push down harder on the knob.
   ___pull up more quickly on the knob.

12. A gyroscope's spin causes it to resist any force that would
   ___retilt its spin axis.
   ___keep it floating in space.
   ___move it through the cabin.
   ___prevent its wobbling.

13. In space an astronaut can yo-yo
   ___at slow speeds only.
   ___at fast speeds only.
   ___at any speed.
   ___when the loop around the yo-yo shaft is tight.

14. It is impossible for astronauts in space to do yo-yo tricks where the yo-yo must
   ___change direction.
   ___be thrown side arm.
   ___move slowly.
   ___stay at the end of the string.

15. In space a wheelo can be started by
   ___slinging the track sideways.
   ___tilting the track down.
   ___tilting the track up.
   ___placing the wheel at the loop in the track.

16. The wheel stays on the wheelo track in space because of its
   ___spin.
   ___inertia.
   ___magnetism.
   ___mass.

17. When two magnetic marbles come together in space, they
   ___spin around each other.
   ___repel.
   ___bounce apart.
   ___orbit at a distance.

18. When two rings of six marbles collide in space, they
   ___always repel.
   ___can form one large ring.
   ___must form a figure eight.
   ___can break into a long chain.

19. In space a slinky will NOT
   ___walk.
   ___carry waves.
   ___come together when stretched.
   ___vibrate when shaken.

20. When a slinky is stretched apart in space,
   ___it sags.
   ___it stays stretched out.
   ___it coils spread apart evenly.
   ___its coils collect at the ends.

Creating a Space Journey to the Moon

Grade Level: 5

Time Required: several class periods

Suggested TEKS:

Language Arts -		5.21	
Music -		5.1	
Science -	5.2	5.3	5.9

Suggested SCANS:
Interpersonal. Teaches Others.

National Science and Math Standards
Science as Inquiry, Earth & Space Science, Science & Technology, Observing, Communicating

Countdown:

reference books/Internet
writing paper
pencils
recordings from music, i.e. E. T., Star Trek , and Horst's Symphony of the Planets

Ignition:

The moon has always intrigued humans. For centuries, we have tracked the passage of time by watching the moon change shape – from new moon to crescent to full moon and back again.

During the 1950's and 60's, the United States and the Soviet Union raced to get to the moon. Soviet rockets got there first. However, it was the U. S. Apollo program that landed the first human there –Neil Armstrong in 1969.

Americans were excited by the discoveries. By 1972, 12 astronauts had walked on the moon and had brought back 850 pounds of rocks. However, due to budget cuts, the United States was forced to discontinue its moon landings. For the next two decades, our only glimpses of the moon were from telescopes and fly-by spacecraft.

In January of 1998, NASA launched the Lunar Prospector mission to the moon. A light spacecraft, Lunar Prospector carries no computer or camera, but it was well equipped for its mission. Its objectives included the following:

1) to determine the elements of the moon
2) to look for hydrogen (a component of water) at the moon's polar areas
3) to look for gas released from the moon's interior, thereby giving scientists clues about the moon's history
4) to measure gravity at different points around the surface
5) to look for minerals and signs of water
6) to study the moon's magnetic field
7) to map the deeply cratered surface

Among its findings are strong evidence that water exists in certain sunless areas of the Moon's Polar Regions.

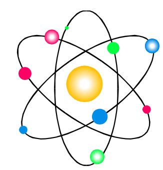
Looking into the future, a number of visionary scientists have begun to draw up plans for off-Earth habitats. Our world population on Earth is growing at an alarming rate, and it may become necessary to find a second home in space.

Based on the findings of Lunar Prospector and the potential discoveries on future moon missions, it is possible that humans could live on the moon someday.

Liftoff:

A. Divide the class into four groups according to topic. Topics include:

1. Space Suits
2. The Moon
3. Space Transportation
4. Space Music



Initiate the groups' research by asking the following questions:

Space Suits

1) How does a space suit protect an astronaut in space?
2) What are the different parts of the space suit? What is the purpose for each?
3) How do astronauts communicate with each other?
4) How does an astronaut move around in space with no gravity? On the moon that has an estimated surface gravity of .16? On the earth?
5) How does an astronaut breathe and drink water?

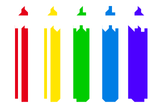
Moon

1) When was the moon formed?
2) How does the moon compare in size to the earth?
3) What temperature ranges can be found on the moon, and how can people handle the extremes?
4) What is the moon's shape?
5) What caused the huge craters on the moon?
6) Do active volcanoes exist? Do "moonquakes" occur?

Space Transportation

1) How long would it take to travel from earth to the moon?
2) Where should blast-off be, and where should the landing on the moon be? Since it takes rockets launched from the earth so much fuel to escape the gravity, should the spacecraft be launched from a platform orbiting the earth?
3) What kind of spacecraft should be used? One powered by fuel engines? Or one powered by ion engines?
4) What would the spacecraft look like, and how would it be designed? What would its power source be?

5) How should the return to Earth be planned? Will the astronauts land on the ground or in the ocean? Why?



Space Music

1) Consider the music from popular "space movies" like E.T., Apollo 13, Close Encounters of the Third Kind, Star Wars, and Sphere. Also, think about the television series Star Trek music and Horst's Symphony of the Planets. If music is to be created for the space journey, what would be most appropriate for:
   >blast off music?
   >travel music?
   >moon landing music?
   >exploration music?
   >earth landing music?

2) Is there any evidence or theories regarding sounds coming from outer space?

B. When the research has been completed, ask a speaker from each group to report to the class.

More Ideas …

- Write and perform a play about a space journey taken by the class. The play could be divided into acts and could center on the journey as told by the narrator(s). Props, costumes, and music would be utilized.
- Design a travel brochure to the moon.
- Students keep a daily journal of their daily activities on the space journey.
- Write a letter home from the moon describing what you see, what you are doing, and what you are learning on this journey.
- Create a mural which visualizes this space journey.

Experimenting With Gravity

Grade Level: 6

Time Required: 1 to 2 class periods

Suggested TEKS:
Math - 6.11
Science - 6.12
Suggested SCANS:
Interpersonal. Participates as a team member.
National Science and Math Standards
Science as Inquiry, Earth & Space Science, Physical Science, Computation, Measurement, Observing, Communicating

Countdown:

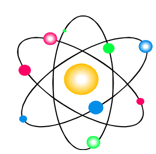
Low wooden chair or stool	3 types of balls (ping pong, tennis, golf)
Paper	Ruler
Textbook	Pencil
Table	Small water balloons
String	Tape
Shoe Box	Small lingerie bag/stocking
Newspaper/Styrofoam peanuts	Various kinds of packing materials

Ignition:

Gravity is the natural force that causes objects to move toward each other. The strongest pull of gravity in our world is from the middle of the earth.

When you throw a ball into the air, gravity pulls it down. When you sit on the sofa, gravity holds you down. Also, when you walk and run, gravity keeps your feet near the ground. Without gravity, we would have no "staying force" and would float off into outer space.

Moons, satellites, and spacecraft orbit planets, like earth, due to their strong gravitational fields. The planets, in turn, orbit the sun because of its massive gravitational pull.



Liftoff:

A. Since you cannot see gravity, how can you prove that it's around you?

Using one low durable chair or stool,

1) Place the chair in front of you. From the floor, jump up onto the seat of the chair. Next, jump back down. Notice the difference: which action required you to exert more energy?
2) Repeat the procedure, this time closing your eyes. How do you feel?

Conclusion: It is a lot harder to jump up onto the chair rather than to jump down. The reason is that when you jump up, you're jumping against the force of gravity. When you jump down, you're jumping toward the force of gravity. The gravity itself is doing all of the work; all you need to do is to step off the seat.

B. Do heavier objects fall faster than lighter objects?

Using a ping pong ball, a golf ball, a tennis ball, and a wooden chair:
1) Stand on the chair, holding the ping pong ball in one hand and the golf ball in the other. Hold them out in front of you as high as you can and drop them simultaneously. Observe when both balls hit the floor.
2) Follow the same procedure, using the golf ball and the tennis ball. Finally, use the ping pong ball and the tennis ball.

Conclusion: Each pair of balls hits the floor at the same time. This is due to the fact that gravity acts upon all forces equally. Objects accelerate at the rate of 32.14 feet per second^2, every second. This is called the "acceleration of free fall". (9.8 m/s^2)

C. Does an object's shape affect its speed?

Using a ball of crumpled paper, an unfolded sheet of paper, and a wooden chair:
1) Stand on the chair, holding the crumpled paper in one hand and the unfolded paper in the other. Hold both as high as possible; release them at the same time.

Conclusion: The crumpled paper hits the floor first. The air that hit the under-surface of the unfolded paper slowed its rate of fall.

D. How do you find an object's center of gravity?

Using a ruler, pencil, textbook, and a table or counter top:
1) Place the ruler on the end of the table. Slowly begin to push it toward the table's edge. Keep pushing, until it eventually falls to the floor.
2) Repeat the same procedure with the pencil and the textbook.

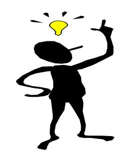
Conclusion: Each object eventually reaches the point where all of its weight is concentrated at its "center of gravity". When it passes this point, it is no longer balanced and falls to the floor.

E. Can the impact of a falling object be cushioned from impact by certain insulating materials?

Using small water balloons, string, tape shoe box, newspaper, Styrofoam peanuts, small lingerie washing bag, insulating materials:
1) One or two weeks prior to the beginning of this experiment, ask students to collect different types of packaging materials and bring them to school.
2) Emphasize to students that the objective of this activity is to design a package that will cushion the water balloon – a fragile object – and thereby absorb some of the force of the landing. If they are successful, the balloon will not break.
3) Have students work in pairs or small groups and experiment with different types and shapes of boxes, as well as insulating materials. A few suggestions might be to plan to completely

surround the water balloon with "absorbing materials". Another is to suspend the water balloon in the middle of the box, inside a lingerie bag or stocking, and to tie the bag securely to both ends of the box with string.

4) Assign a group leader to write up the experiment, using the following format:
   Problem: Which material is the best insulator?
   Hypothesis: We think . . .
   Procedure:
   Data Analysis: Table showing materials used
   Conclusion:
5) On the day of the experiment, make sure that the balloons are fully filled. Use the football bleachers (or outside steps) as your site. Determine 3 - 5 different heights from which to drop the balloon packages. Insure that each group drops its package as uniformly as possible.
6) Record in a table/chart the type of package used by each group and the results from different heights.
7) Conclusion: Elicit a discussion comparing the water balloon results with the landing of the space shuttle on earth. Also, ask for predictions as to how future spacecraft will land on Mars, which has an estimated surface gravity of .38 that of the earth.



More ideas …

- Find the center of gravity for several objects. To start, make a cardboard model of a simple boat. Then, using an unsharpened pencil, form a pivot from which the boat can hang. Hang a length of weighted thread from the same pivot. Trace the line of the thread on the cardboard. Repeat the same procedure with 2 other pivot points. The center of gravity is the intersection of the 3 lines. This same process can be done with a cardboard model of an airplane, space shuttle, and other spacecraft.
- Design an experiment. Plants respond to the earth's gravity. Plant stems grow in the opposite direction to the pull of gravity. Plant roots, however, grow downward in the direction of gravity. Use each of the experiment components listed below:
  Purpose
  List of materials
  Step-by-step procedure (which uses both a control and a variable)
  Observations Record
  Conclusion based on data

It's A Blastoff!

Suggested TEKS:

Science -	6.6
Math -	6.9

Suggested SCANS:
Technology. Applies technology to task.

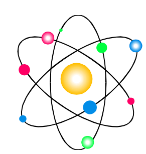
National Science and Math Standards
Science & Technology, Physical Science, Measurement, Observing, Communicating,

Grade Level: 6

Time Required: one class period

Countdown:

2 Index Cards per student
35 mm film canister Those with inside snapping lids that are transparent such as Fuji film work best. Ones with outside snapping lids that are opaque such as Kodak will not work. Canisters are usually available from camera shops or where photographic processing takes place. This is a great recycling project.
Scotch tape
Scissors
Markers, crayons or colored pencils
Effervescing antacid tablet (like Alka-Seltzer)
Aluminum pie plate or piece of aluminum foil
Tape Measure or meter sticks
Paper towels
Tablespoon Measuring Spoon
Water
Eye protection
Student Worksheets



Ignition:

Newton's First Law of Motion states that unless something exerts a force onto an object, the object will stay at rest. Newton's Second Law states that an object will move with constant velocity until a force is exerted on the object. Newton's Third Law states that for every action there is an equal and opposite reaction. The rocket lifts off because an unbalanced force (First Law) acts upon it. This is the force produced when the lid blows off by the gas formed in the canister. The rocket travels upward with a force that is equal and opposite to the downward force propelling the water, gas, and lid (Third Law). The amount of force is directly proportional to the mass of water and gas expelled from the canister and how fast it accelerates (Second Law).

Students will construct a rocket powered by the pressure generated from an effervescing antacid tablet reacting to water. Rockets that use excessive paper and tape are likely to be less effective fliers because they carry additional weight.

Liftoff: Students may work in pairs or individually. It can take up to 45 minutes to complete this activity. Make sample rockets in various stages of completion if you have students who may need help visualizing the construction steps.

Distribute the materials to each student, along with the instruction sheet and worksheet.

Using index cards, students should plan how they are going to construct their rocket. Students will decide whether to cut the paper in the short or long direction to make the body tube of the rocket. This will allow for rockets of different lengths for flight comparison during liftoff.

Remind students to:

1) Decorate one of the index cards. This will form the body of the rocket.
2) Roll the index card into a tube. Slide an empty film canister into the tube so that the canister opens at one end of tube. The lid needs to be far enough from the paper tube to allow for ease in snapping the lid. Tape the tube to the canister securely.
3) Tape along the tube seam.
4) Cut the other index card in half. Use half the index card to make the rocket nose cone. Use the other half of the index card to make fins. Secure to the rocket tube.
5) Have the student record predictions of what will happen when the rocket launches:
    1) How high do you think your rocket will go?
    2) How much water will you use for launch (record in Tablespoons)?
    3) Does the amount of water matter?
    4) When launching, place the rocket on the pie plate or a piece of aluminum foil. Predict what will happen to this launch "pad".
    5) When performing the countdown from the number 15, on what number will your rocket launch?
6) After making predictions, have all students proceed outside. Launch on a concrete surface next to a wall if available. Tape a tape measure or meter stick to the wall to see how high the rocket flies. Each student will come forward, turn rocket upside down, remove canister lid, measure the number of Tablespoons of water into canister, add 1/2 effervescing tablet, snap lid, turn rocket upside down, and place on the launch pad. Student quickly backs away from the rocket. Countdown begins. 15 – 14- 13…Have the student record when their rocket launched and how high it went.

When the students return to the classroom, compare their predictions to what actually happened. Were the predictions accurate? Why or why not?

Have the class make a simple graph of height vs. amount of water. Such a graph gives a clear visual record of the observations and can be used as evidence to support interpretations of different "fuel" mixtures.

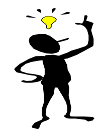
Add variables to the experiment and have the students try it again.

1) Does the amount of water placed in the cylinder affect how high the rocket will fly?
2) Does the temperature of the water affect how high the rocket will fly?

3) Does the amount of the tablet used affect how high the rocket will fly?
4) Does the length or empty weight of the rocket affect how high the rocket will fly?
5) How would it be possible to create a two-stage rocket?

Evaluation:

- Ask students to explain how Newton's Laws of Motion apply to this rocket.
- Compare the rockets for skill in construction (i.e., those with reinforced fins work better and those with excessive paper and tape are likely to be less efficient because of the additional weight).



- More ideas …
  - Remake the rocket. What geometric shapes are present in the rocket?
  - Conduct an altitude contest to see which rockets fly the highest.
  - Design another experiment with the rocket.
  - Experiment to see how the weight of the rocket affects the height it travels keeping the amount of water and alka seltzer constant each time.
  - Design a rocket powered by two, three, or more film canisters.
  - Design a rocket that launches in two stages.

Rocketeer Name______________________

Predictions:

How high do you think your rocket will go?

____

How much water will you use for launch
(record in Tablespoons)?

____

Does the amount of water matter? Why?

____

When launching, place the rocket on the pie plate or a piece of aluminum foil. Predict what will happen to this launch "pad".

____

When performing the countdown from the number 15, on what number will your rocket launch?

____

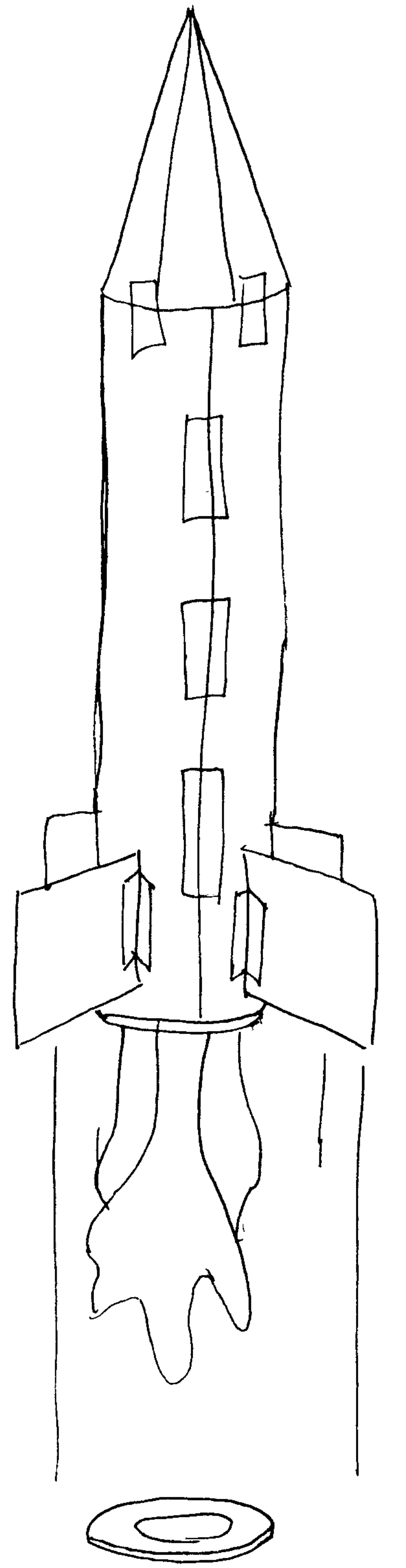
List three ways you can improve your rocket performance.

1. _____________________________

2. _____________________________

3. _____________________________

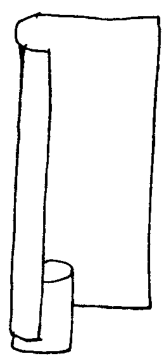
Test your theory!



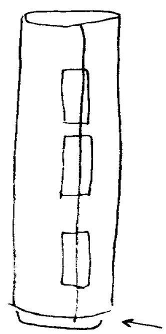
IT'S A BLASTOFF

1

Wrap and tape a tube of paper around the film canister. The lid end of the canister goes down

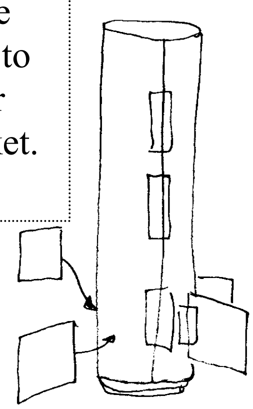


2



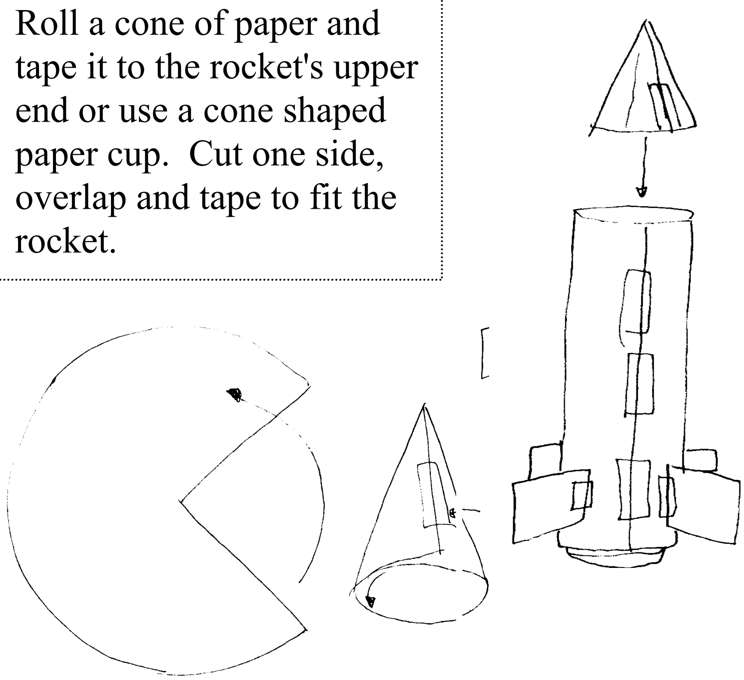
3

Tape fins to your rocket.



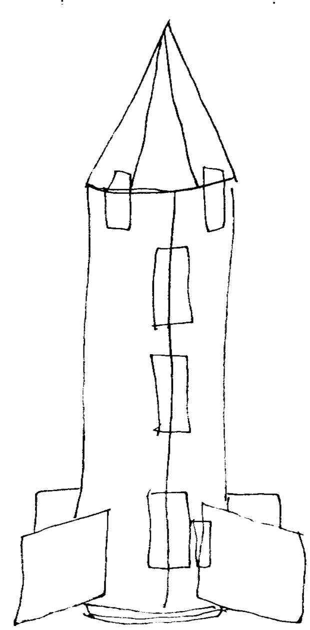
4

Roll a cone of paper and tape it to the rocket's upper end or use a cone shaped paper cup. Cut one side, overlap and tape to fit the rocket.



5

Ready for flight



Glider, Flying Saucer, It's A Plane!

Grade Level: 6

Time Required: 2 class periods

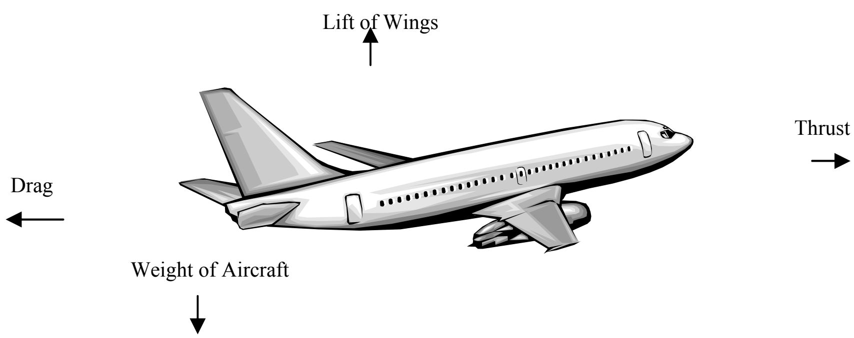
Suggested TEKS:
Science - 6.6
Math - 6.9
Suggested SCANS:
Technology. Applies technology to task.
National Science and Math Standards
Science and Technology, Physical Science, Observing, Communicating

Countdown:

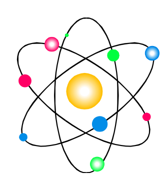
White Paper
Tape
String (3 1/4" piece per student)
Pencils
Paper Clips (7 per student)
Cardboard of Poster Board
Paper Fastener (1 per student)
Scissors
Glue

Ignition:

The four forces acting on an aircraft in flight are: weight, lift, thrust, and drag. The design of an aircraft accounts for these forces.



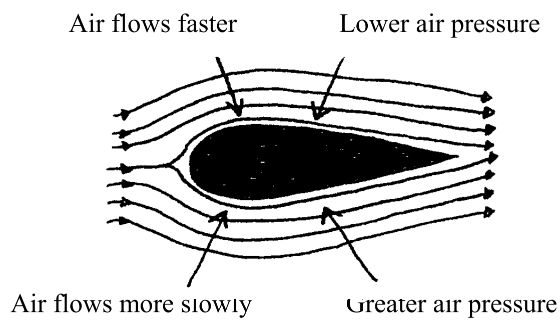
Weight, or gravity, is the force which pulls objects towards the earth. The pull of the earth's gravity accelerates everything downward at the same rate – no matter how much they weigh.



Lift is the opposite force of weight. It occurs when the air pressure below an object is greater than the air pressure above the object. Known as the Bernoulli effect, lift can be demonstrated as follows:

1) Hold a sheet of thin paper at eye level, parallel to the floor.
2) Blow hard over the top.
3) Instead of hanging limply, the far end begins to lift into the air.

The harder you blow, the higher the lift. See diagram below. Wings are able to lift gliders as well as jumbo jets into the air. Lift is created in flying saucers by the raised circles.

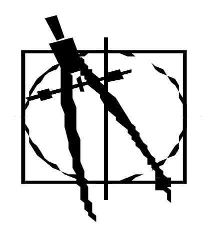


Wing of a plane

Thrust is the force that makes an object airborne and then causes it to continue to move. Isaac Newton's Third Law of Motion states that for every action, there is an equal and opposite reaction. For example, each time you walk, your feet push down on the ground (action) and the ground pushes up with equal force (reaction).

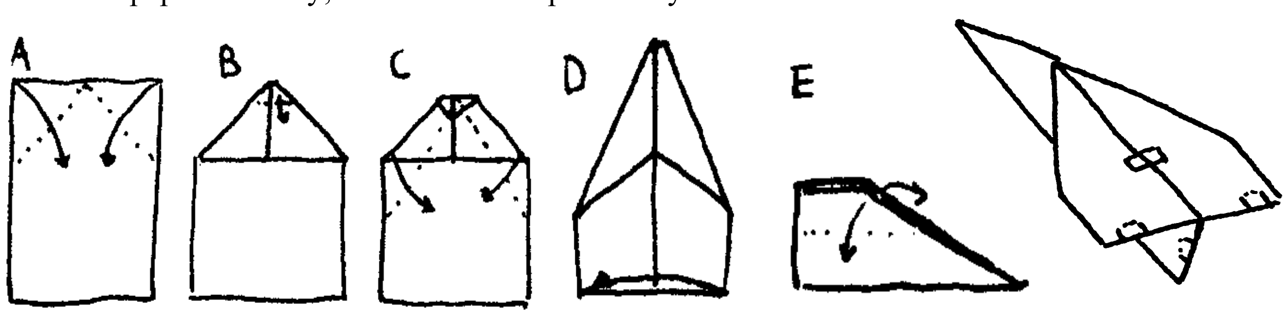
For a gasoline-powered plane, the propellers provide thrust. In rockets, the blast of hot gases from the tails pushing on the air provide the thrust for take-off. Once in the air, the reaction is between the rocket and the gases rushing from the engine, which thrust the rocket forward and the gases back. Students will provide thrust when they launch their paper airplanes (gliders) and flying saucers.

Drag is the force that opposes thrust. It is friction (or resistance) of the air to an object moving through it. Students will feel drag on the airplane and the saucer when their hands whip through the air for launching. To keep drag to a minimum, aircraft are especially shaped or "streamlined". The purpose is to get air to flow around them as smoothly as possible. One of the best-streamlined shapes is a slim teardrop.



Liftoff:

A. Make an airplane (glider)
   1. Have each student fold a sheet of white typing paper according to the 5 steps shown in the figure that follows. Emphasize the importance of folding and creasing the paper carefully; each side of the plane is symmetrical.

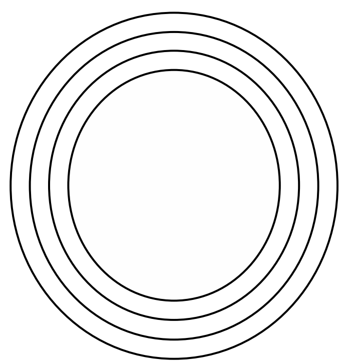


2. Launch planes in a large field or other clear area (like the gym). Compare and contrast flight times, distances, and ability of aircraft to soar.
3. After all planes have flown, ask students to experiment with another piece of paper to make the aircraft more streamlined. They may also choose to add weight by attaching a paper clip to the nose of their planes.

B. Make a flying saucer

Tell your students they will make a flying saucer with four cardboard circles.

1. Discuss how to make a circle by using a piece of string and a pencil. Tell the students to hold the nearest edge of the string steady, in one place. Loop the farthest edge of the string once around the pencil; secure it. Hold the pencil tautly and draw a full circle around the enter point. This is the pattern that will be traced on the cardboard to make the largest circle (6 inches in diameter).
2. Students will then cut the string one-half inch to make a small circle. They will follow the same procedure as above to make a 5-inch diameter circle from the cardboard.
3. For the third circle, cut the string one-half inch once again and make a 4-inch cardboard circle.
4. Repeat the same procedure to make the 3-inch circle.
5. The largest circle will be the base. The second circle is glued to the base. The third and fourth circles are to be glued in the same manner, similar to the picture below.



6. Fit a paper fastener (brad) into the middle point of the smallest circle, and spread the blades on the bottom side. Tape them securely.
7. Ask students to launch their saucers with a flip of the wrist, similar to how they would throw a Frisbee. The saucer will fly until the combined forces of gravity and drag overcome the forces of lift and thrust. The currents of air will also react with the design of the saucer, affecting how it flies. Its circular design and rotation should allow it to slice through the air with less resistance than the plane. The length of airtime will vary. Make comparisons and contrasts with a Frisbee and with the paper airplane.
8. Finally, to experiment with the effect of "weights" and balance of the craft, students may wish to add 6 large paper clips – evenly placed around the circle. They should be taped down on both sides of the saucer.

More Ideas …

- Discuss the three main parts of a glider: wings, body, and tail assembly. Each part has a streamlined design that creates minimum drag. When a glider flies through the air, it has certain glide ratio. This ratio is forward motion to backward motion. Or it may be called ground distance covered to kilometers of altitude lost. For teaching strategies with ratio see the following link:
  (http://trc.dfrc.nasa.gov/shape/TCU/radio.htm)
- Research gliders in conjunction with lessons on transversal lines and slope. See the following links: (http://trc.dfrc.nasa.gov/shape/TCU/trans.htm)and (http://trc.dfrc.nasa.gov/shape/TCU/jdslopes.htm).

Making Space Stations

Grade Level: 6

Time Required: 1 class period

Suggested TEKS:	
Math -	6.11
Science:	6.2
Suggested SCANS:	
Interpersonal. Teaches others.	
National Scien ce and Math Standards	
Science and Technology, Physical Science, Measurement, Observing, Communicating	

Countdown: http://voyager.cet.edu/iss/

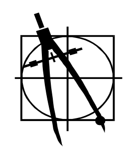
Newspaper	Aluminum Foil
Box of Straws	Cardboard/Construction Paper
Tape	Scissors

Ignition:

Discuss the background of the space station in both the United States and Russia. (See NASA articles International Space Station: Russian Space Stations and International Space Station: U.S. Space Station History in the Appendix.)

Distribute books with illustrations of the Mir Space Station and sketches of the International Space Station. Point out the construction techniques. Mention that the stations use very light materials; ask the students "why?". Elicit the following information: the heavier the material, the more fuel needed to get the station into outer space. Once in space, it is then weightless. Note also that the struts in the photos are arranged into triangular shapes.

Liftoff:



1. Students will construct a space station of their own design. Model how to construct the individual struts:
   a. Unfold one sheet of newspaper and tape a straw at a slant to one corner.
   b. Roll the newspaper onto the straw very tightly.
   c. When the newspaper has been completely rolled, tape the tag end to hold the roll.
   d. Students should make at least 8 struts before they begin planning their design and building it.
2. Using the struts, students will fold one strut over another at the ends and tape the two to make a corner.
3. Discuss the importance of their designs and emphasize durability. For instance, if students choose to make cubes, they may wish to reinforce their structures with extra struts.
4. Students share their ideas with the class.
5. Compare and contrast the different designs.

More ideas. . .

- Add "shuttles" paper airplanes, telescopes, satellite dishes, solar panels, etc. to the constructions. Compare and contrast the additions.
- Choose one astronaut that has been a part of the Mir Space Station. Research and write a paper on this astronaut. Emphasize the international cooperation of this project, as well as the many contributions made.
- Share the "astronaut" with the class. Students evaluate: What contributions did this astronaut make? What type of college degree does this astronaut have? What skills does this astronaut have that makes him/her valuable? What job do you think this astronaut might hold on the Space Station?
- Build an International Space Station model from one of the patterns found at:
  http://www.marscenter.it/iss/download_iss.htm
  http://spaceflight.nasa.gov/station/assembly/models/index.html
  http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/
  International.Space.Station.Bookmark/International.Space.Station.Bookmark.pdf
- Where is the International Space Station now?
  http://spaceflight.nasa.gov/realdata/tracking/index.html
- Can you see the International Space Station from your back yard?
  http://spaceflight.nasa.gov/realdata/sightings/index.html
- Take the International Space Station challenge:
  http://voyager.cet.edu/iss/

Orbits

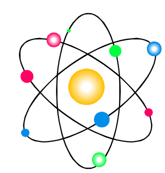
Suggested TEKS:
Science - 7.13
Art - 7.2
Suggested SCANS:
Information. Acquires and evaluation information.
National Science and Math Standards
Science as Inquiry, Earth & Space Science, Physical Science, Observing, Communicating

Grade Level: 7

Time Required: 2 class periods

Countdown:

1 large fruit can (29 oz. size)	Hammer
Medium Nail	Scissors
String/Twine	Light Sand (from store)
Red or Blue Sand	Meter Stick
2 Chairs	Freezer Tape (or other sticky tape)
1 White Poster Board	
1 medium Apple	5 ft. sturdy string
Duct Tape	Spool with hole wider than string thickness
1 Fork	

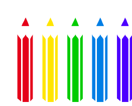


Ignition:

An orbit is defined as the path of any object in space whose motion is controlled by the gravitational pull of a heavier object. The heavier object is called the primary and the lighter object is the secondary. As an example, the moon is a secondary that revolves in an orbit around the Earth, a primary.

The sun, a primary, has such an immense gravitational pull that it holds together the nine planets of our solar system. The planets hurtle through space at speeds that just balance the sun's gravitational pull; therefore, they are locked into a perpetual orbit around the sun.

The orbit shape of the planets is generally elliptical – sometimes, the planets are closer to the sun and sometimes farther away.

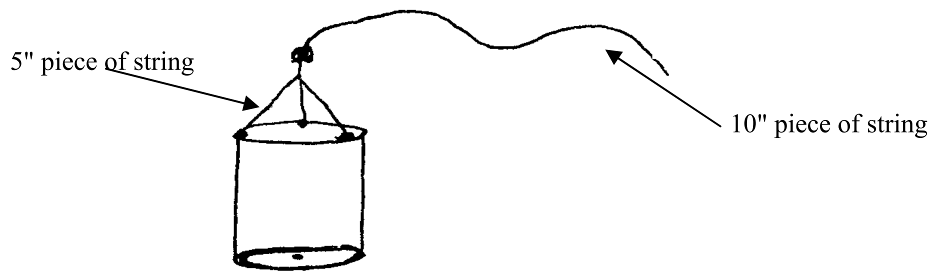


Liftoff:

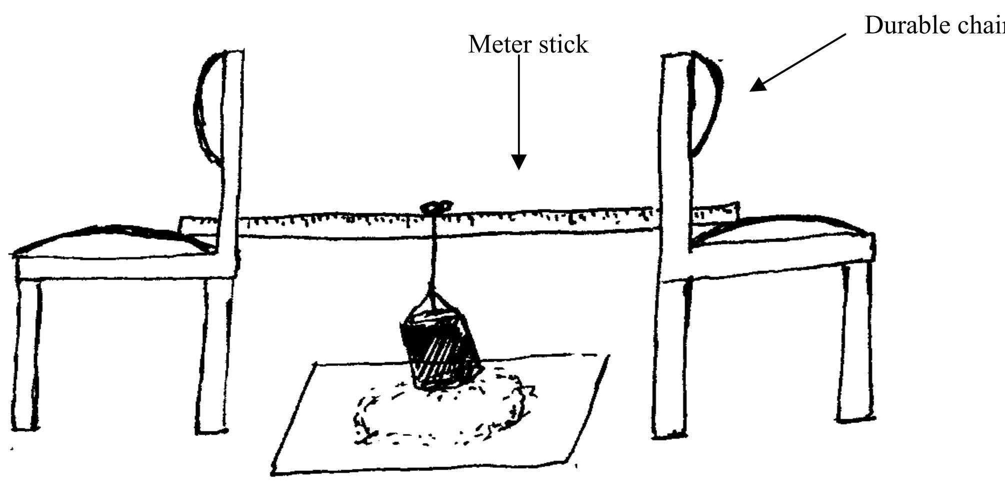
A. Elliptical orbits through sand painting.

This experiment will utilize the swinging motion of a pendulum to make a pattern of ellipses. Because sand is used, it is recommended that this activity be conducted on a flat concrete surface outside.

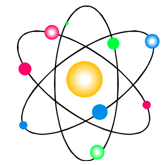
1. Carefully using the hammer and nail, punch a hole in the bottom of the fruit can. Then, punch 3 holes in the top edge of can, equally spaced.
2. Cut 3 short pieces of string (about 5 inches long). Tie and knot each one through the holes in the can's rim. Pull together the 3 loose ends and tie into a knot. Then, tie a 10-inch piece of string, and loop it around this knot. See diagram below.



3. Set 2 sturdy chairs opposite each other, back to back, about ¾ m apart. Place the meter stick between the chairs, on the chair seats, and secure with a weight, if needed. See Diagram B.
4. Tape the bottom hole of the can with freezer tape, and fill the can with dry colored sand. Tie in the middle of the suspended meter stick.
5. Put the poster board on the floor between the 2 chairs, and sprinkle it lightly with white sand. Tilt the can slightly to one side, remove the tape on the bottom to release the sand, and gently push the can.
6. You may need to give the string near the can additional pushes, back and forth and to the sides, until all the sand has drained out.



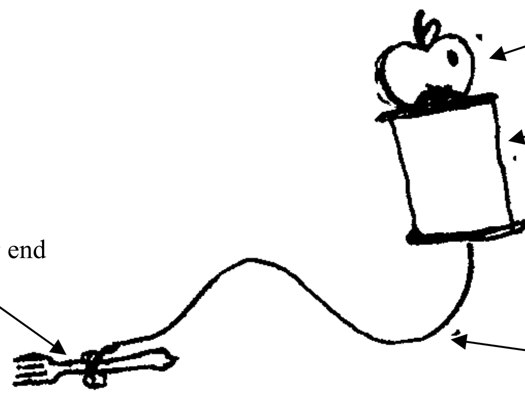
Conclusion: The sand being released from the can makes a series of arcs and ellipses on the poster board.



B. Experiment with planet orbit

This experiment is initiated by the question "Why do planets stay in orbit around the sun? Why don't they just spin off into space?"

1. Tie one end of the string around the apple, and knot it tightly. Use the tape to secure the string tautly around the apple.
2. Push the unattached end of the string through the spool hole and, then, tie it around the fork. Tape the string securely.



3. In an open area, hold the spool with the apple directly on top of it. The remaining string with the fork is hanging out of the spool, pointing toward the floor. Then, twist your wrist, sending the apple into orbit.

Results: The apple remains "in orbit" around you, rather than hurtling off into space.

Conclusion: Elicit from the students what part of the experiment acted like gravity. Also, ask what would have happened if the string were not tied to the fork. Compare this experiment with the nine planets and their continuous orbit around the sun.

Circumference of the Sun and the Planets

Suggested TEKS:	
Math -	7.9
Suggested SCANS:	
Technology. Apply technology to task.	
National Science and Math Standards	
Earth & Space Science, Physical Science, Computation, Reasoning	

Grade Level: 7

Time Required: 1 class period

Countdown:

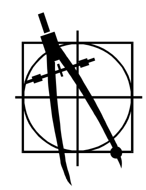
Calculators
1 Planet Table per Student

Ignition:

Archimedes, a Greek mathematician of the 3rd century, found a way to determine a more exact value of **pi**, the ratio of a circle's circumference to its diameter. He showed that the value of pi is between 3 1/7 and 3 10/71. This discovery made it possible to solve many problems involving the area of circles and the volume of cylinders.

Additionally, using a numeration system that he invented, Archimedes calculated the number of grains of sand it would take to fill the universe.

Liftoff:



A. Circumference

1. Discuss with students that "circumference" means the distance around a circle or a circular object. Using tape measures, students should measure the circumference of different body parts (head, arm, wrist, leg, waist, ankle, etc.).
2. Measure the circumference of the globe with the tape measure. Then, tell students that it is possible to determine circumference of all circular objects accurately and scientifically by using formulas. The two circumference formulas are as follows:

$$c = \pi \times d$$
$$c = 2 \times \pi \times r$$

(Circumference = C; π = 3.14; d=diameter; r=radius)

3. Demonstrate how to find the Earth's circumference, knowing the Earth's radius.

C	=	$2\ \pi\ \ r$
C	=	(2 x 3.14) x 6,375.5 km
C	=	6.28 x 6,375.5 km
C	=	40,038.14 km

4. Ask the students to complete the table attached, using calculators. You may wish to vary the information given, by supplying the diameter, thereby requiring the students to use the first formula.

(See table attached.)

5. Have students rearrange the planets according to circumference: greatest to least, least to greatest.

More ideas …

- Extend the table by finding the volume and the surface of each planet. Formulas to be used are as follows:
  Volume (V) = $4/3\ \pi\ \ r^3$ r
  Surface Area (S) = $4\ \pi$ r

  Scientific calculators would be useful in this experiment, if available.
- Compare the method of using the volume formula with Archimedes' method of calculating grains in the universe.

Circumference of the Sun and Planets

Planet	(km) radius	(km) diameter	(km) circumference
Earth	6,375.5		
Mercury	2,427		
Venus	6,056		
Mars	3,394		
Jupiter	71,500		
Saturn	60,500		
Uranus	23,500		
Neptune	23,264.5		
Pluto	1,200		
Sun	675,000		
Moon	1,738		

Orbit Crossword

Grade Level: 7

Time Required: 30 - 45 minutes

Suggested TEKS:
Language Arts: 7.24
Suggested SCANS:
Interpersonal. Interprets and Communicates Information
National Science and Math Standards
Earth & Space Science, Physical Science, Communicating

Countdown:

1 copy of Orbit Crossword per student
Dictionary

Ignition:

An orbit is defined as the path of any object in space whose motion is controlled by the gravitational pull of a heavier object.

Liftoff:

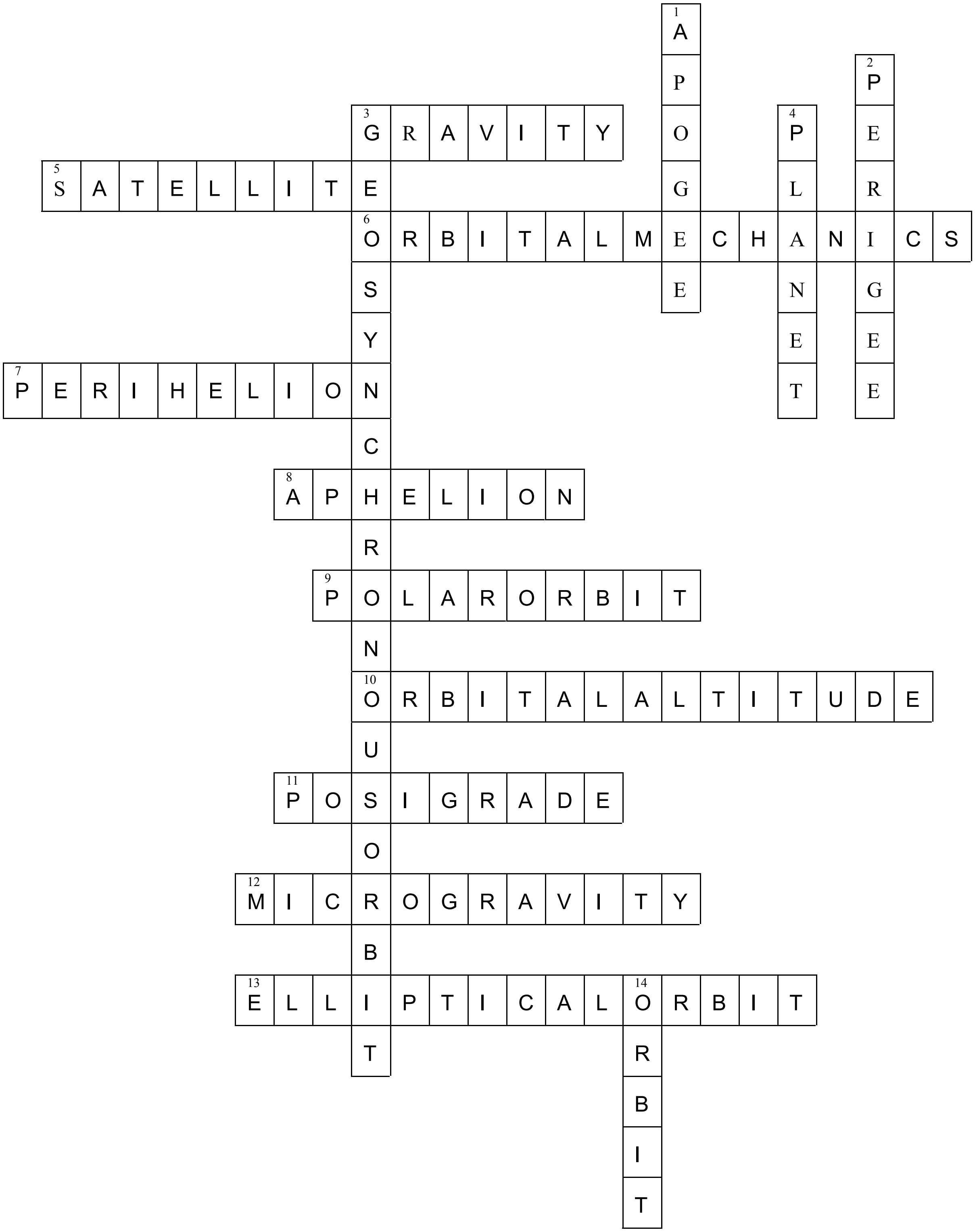
Students will increase their vocabulary by identifying words and their definition in the Orbit Crossword puzzle.

More Ideas …

- ❖ Spell the vocabulary words on the Orbit Crossword.
- ❖ Write a story using 50% of the words in the Orbit Crossword.
- ❖ Choose one word from the Orbit Crossword and complete a three-page report.

Orbit Crossword

ANSWER KEY



Name: ________________________________ **Orbit Crossword**

Across

3. the force that attracts all bodies toward the center of Earth; the force of attraction between all objects

5. a man-made object or vehicle intended to orbit the earth, the moon, or another celestial body

6. the science of determining how objects can escape the force of gravity and be placed in orbit at different altitudes

7. the closest point of bodies orbiting the sun

8. the farthest point of bodies orbiting the sun

9. a path over the north and south poles of a planet

10. the distance a satellite is positioned above its primary

11. a west-to-east orbit that goes in the same direction as the earth's spin

12. more accurate term, used instead of "zero G", to describe weightlessness

13. oval or egg-shaped orbit path for a satellite

Down

1. the farthest point on a spacecraft's orbit around the Earth

2. the closest point of a spacecraft's orbit around the Earth

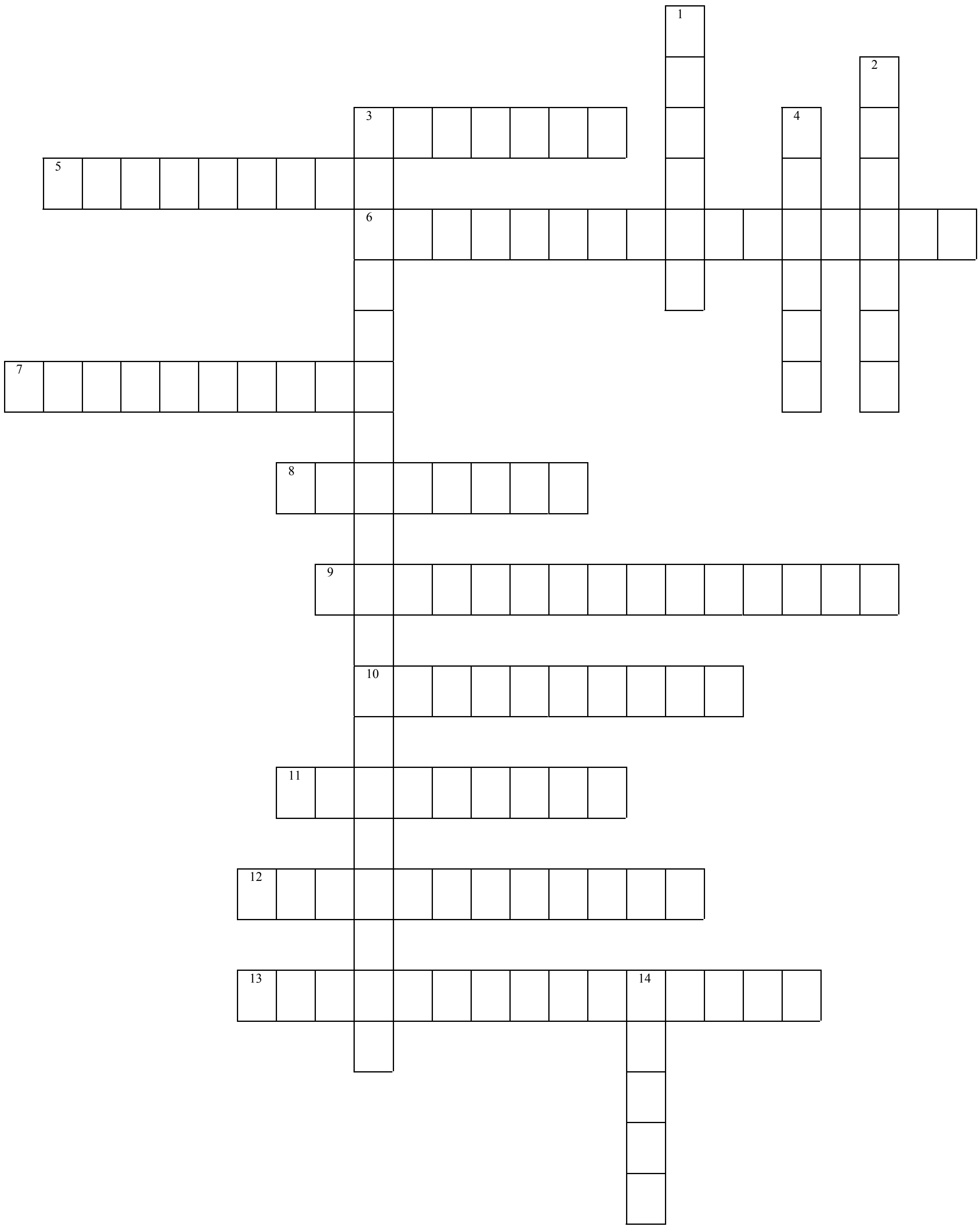
3. a circular orbit achieved at exactly 22,300 miles up at a speed of about 6,800 mi./hr.

4. a celestial body that moves around the sun in a nearly circular path

14. the path in space along which an object moves around a primary body

Orbit Crossword

Name: ________________________________



Orbit Word Search

Grade Level: 7

Time Required: 30 - 45 minutes

Suggested TEKS
Language Arts: 7.6
Suggested SCANS:
Information. Acquires and evaluates information.
National Science and Math Standards
Earth & Space Science, Physical Science

Countdown:

1 copy of Orbit Wordsearch per student

Ignition:

An orbit is defined as the path of any object in space whose motion is controlled by the gravitational pull of a heavier object.

Liftoff:

Students will increase their vocabulary by identifying words and their definition in the Orbit Wordsearch puzzle.

More Ideas …

- Learn to spell the vocabulary words on the Orbit Wordsearch puzzle.
- Write a story using 50% of the words in the Orbit Wordsearch puzzle.
- Choose one word from the Orbit Wordsearch and complete a three-page report.

ORBIT WORDSEARCH

E	D	U	T	I	T	L	A	L	A	T	I	B	R	O	M	T	E	A
O	I	I	M	I	C	R	O	G	R	A	V	I	T	Y	I	I	T	V
S	R	C	A	P	O	G	O	P	E	P	E	R	I	G	C	B	I	A
A	A	B	P	L	O	R	B	R	E	P	O	L	A	R	R	R	B	P
T	P	P	I	E	O	P	O	P	P	R	E	L	L	I	O	O	R	H
E	H	O	A	T	R	R	R	L	E	I	I	P	E	R	G	S	O	E
T	E	L	P	A	A	I	B	A	R	R	O	G	L	P	R	U	L	L
E	L	A	H	U	M	L	H	N	I	P	A	H	E	R	A	O	A	I
N	I	R	E	A	P	O	M	E	P	O	L	A	P	E	C	N	C	O
A	O	E	L	T	E	P	O	E	L	P	O	S	I	G	G	O	I	R
L	N	A	I	I	E	E	E	N	C	I	E	S	A	T	R	R	T	B
P	O	R	O	B	G	R	L	E	E	H	O	E	O	O	A	H	P	I
S	R	T	N	R	O	I	A	P	O	G	A	N	T	R	V	C	I	T
A	B	H	Y	O	P	G	P	E	R	I	G	N	I	B	I	N	L	A
T	I	O	T	N	A	S	R	V	P	E	R	I	I	T	T	Y	L	L
E	T	R	P	O	S	P	E	R	I	H	E	L	I	C	Y	S	E	A
L	I	B	B	P	O	S	I	G	R	A	D	E	O	V	S	O	T	T
E	T	I	L	L	E	T	A	S	R	A	P	O	G	P	R	E	R	B
O	I	T	L	A	P	O	G	M	I	C	R	O	G	R	A	G	E	I

aphelion orbit
apogee
elliptical orbit
orbital mechanics
perigee
planet
geosynchronous orbit
gravity
microgravity
orbit
orbital altitude
perihelion
polar earth orbit
posigrade
satellite

ORBIT WORDSEARCH
Answer Key

E	D	U	T	I	T	L	A	L	A	T	I	B	R	O	M	T	E	A
O	I	I	M	I	C	R	O	G	R	A	V	I	T	Y	I	I	T	V
S	R	C	A	P	O	G	O	P	E	P	E	R	I	G	C	B	I	A
A	A	B	P	L	O	R	B	R	E	P	O	L	A	R	R	R	B	P
T	P	P	I	E	O	P	O	P	P	R	E	L	L	I	O	O	R	H
E	H	O	A	T	R	R	R	L	E	I	I	P	E	R	G	S	O	E
T	E	L	P	A	A	I	B	A	R	R	O	G	L	P	R	U	L	L
E	L	A	H	U	M	L	H	N	I	P	A	H	E	R	A	O	A	I
N	I	R	E	A	P	O	M	E	P	O	L	A	P	E	C	N	C	O
A	O	E	L	T	E	P	O	E	L	P	O	S	I	G	G	O	I	R
L	N	A	I	I	E	E	E	N	C	I	E	S	A	T	R	R	T	B
P	O	R	O	B	G	R	L	E	E	H	O	E	O	O	A	H	P	I
S	R	T	N	R	O	I	A	P	O	G	A	N	T	R	V	C	I	T
A	B	H	Y	O	P	G	P	E	R	I	G	N	I	B	I	N	L	A
T	I	O	T	N	A	S	R	V	P	E	R	I	I	T	T	Y	L	L
E	T	R	P	O	S	P	E	R	I	H	E	L	I	C	Y	S	E	A
L	I	B	B	P	O	S	I	G	R	A	D	E	O	V	S	O	T	T
E	T	I	L	L	E	T	A	S	R	A	P	O	G	P	R	E	R	B
O	I	T	L	A	P	O	G	M	I	C	R	O	G	R	A	G	E	I

aphelion orbit
apogee
elliptical orbit
orbital mechanics
perigee
planet
geosynchronous orbit
gravity
microgravity
orbit
orbital altitude
perihelion
polar earth orbit
posigrade
satellite

Mission Design – Shuttle

Grade Level: 8

Time Required: 4 - 5 class periods

Suggested TEKS:	
Science -	8.3
Suggested SCANS	
Interpersonal. Teaches others.	
National Science and Math Standards	
Science and Technology, Computation, Measurement, Communicating	

Countdown:

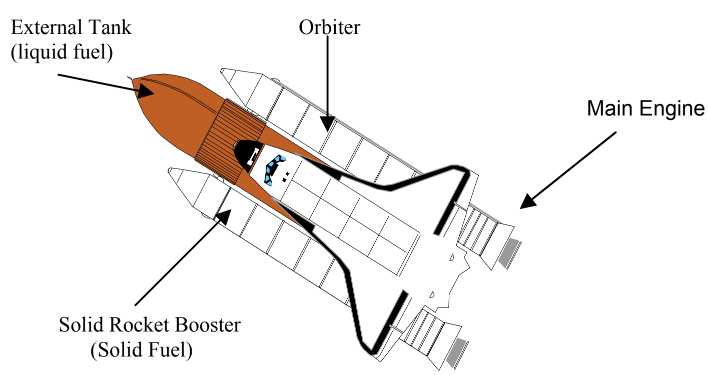
Inexpensive materials to build a model shuttle -- student choice
Suggestions: Pringles cans, Oatmeal cartons, plastic soda bottles in various sizes
1 Venn Diagram per student

Ignition:

The space shuttle is a spacecraft that can be used for many flights into space. It has four major parts:

1) orbiter
2) 3 main engines - burn a mix of supercooled liquid oxygen and hydrogen
3) external tank
4) 2 solid rocket boosters - each carry about 500 tons of fuel which create 6.6 million pounds of thrust.

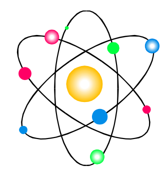
Only the orbiter and the main engines go into orbit around the Earth. The other two parts, the rocket boosters, and the external fuel tank, are only for liftoff and powered flight. See diagram below.



The space shuttle has three distinct modes of flight. Following is a brief flight description.

1. At liftoff, weighing about 2,200 tons, the shuttle soars **vertically** into the sky. About two minutes later, the reusable boosters burn out, are jettisoned, and fall to the ocean below. Nine minutes into the flight, the external fuel tank runs dry and is released. It burns up as it falls back through the atmosphere.

2. In orbit 175 miles above the Earth, the craft flies **upside down**, with its cargo doors opened toward Earth, unless it is launching a satellite. This also allows the heat inside the crew's living quarters to radiate away.
3. To prepare for landing, the shuttle -- now weighing about 94 tons -- is turned so that its engines face **in the direction of its flight**. The engines are fired in short bursts, slowing the craft from 17,000 to 8,000 miles per hour. The craft is then turned again so that **its bottom is toward the ground**, and it enters the atmosphere. Cruising earthward as a glider, it touches down at about 200 miles per hour.



Liftoff:

A. Shuttle Construction

Explain to the students that they will plan, design, and build a model of a shuttle. Their shuttle will consist of three areas:

1. cockpit - on the top level, with built-in storage underneath
2. shuttle bay - contains the experimental stations and the living areas
3. cargo area - houses the bathrooms and storage

Approximate measurements should be 8 feet by 16 inches for the cargo and cockpit area, 8 feet by 11 inches for the shuttle bay.

B. Written plans

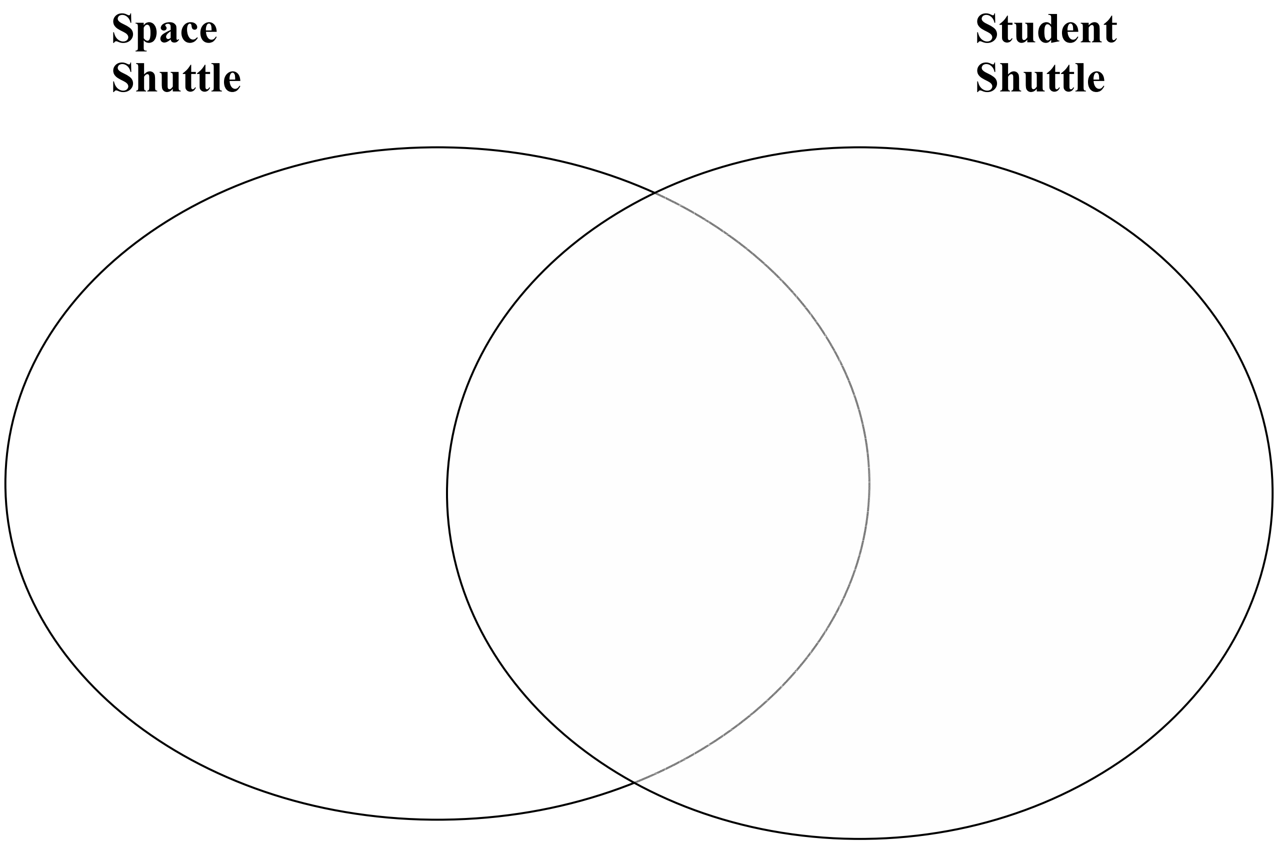
Ask a recorder to write down the following, as the initial part of the procedure. Students should brainstorm their ideas together, and provide the writer with the necessary information.

1. Detailed sketch or blueprint of the model (a 3D small model could be made).
2. List of materials (inexpensive) to be used.
3. Step-by-step instructions for construction of the model.
4. Descriptions of equipment, i.e., cameras and velcro (attached to the walls) to be added to the basic model.

C. Analysis

Ask students to make a Venn diagram to compare and contrast the inside of a real space shuttle with the student shuttle model. Ask students to analyze their model, and determine how they might change it to make it more efficient and more realistic.

Venn Diagram



More Ideas …

- Make a display for the school or public library.
- Donate a space shuttle to a pre-school class.
- Develop an information sheet from notes on how to build a Space Shuttle.
- Make a shuttle with NASA: http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Space.Shuttle.Glider/Space.Shuttle.Glider.pdf

Bottle Rocket

Suggested TEKS:			
Science -	8.3	8.4	8.7
Math -		8.6	8.14
Suggested SCANS:			
Interpersonal. Teaches others.			
National Science and Math Standards			
Science as Inquiry, Science and Technology, Computation, Observing, Communicating			

Grade Level: 8

Time Required: two weeks

Countdown:

The following supplies should be available for each group of 3 students:
2 liter soda bottles
1 liter soda bottles
Film Canisters
Aluminum Cans
Scrap cardboard and poster board
Large cardboard panels
Duct tape
Electrical tape
Glue sticks
Low-temperature glue gun
Water
Clay
Plastic garbage bags
Crepe paper
String
Paint
Safety glasses
Bottle rocket launcher
Altitude Calculator
Copies of budget/order forms
Copies of check forms
This lesson adapted from NASA Project X-35 Teachers Guide.

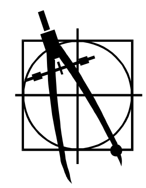
Ignition:

A rocket that flies straight through the air is said to be a stable rocket. A rocket that veers off course or tumbles wildly is said to be an unstable rocket. The difference between the flights of these two rockets is in the design. All rockets have two "centers." The first is the *center of mass*. This is where the rocket balances. If you placed a ruler under the rocket, it would balance horizontally like a seesaw. What this means is that half of the mass of the rocket is on one side of the ruler and half is on the other side.

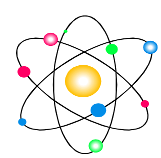
The other center in a rocket is the *center of pressure.* This is a point where half of the surface area of a rocket is on one side and half is on the other. This is just a point based on the surface of the rocket, not on what is inside. During flight, the pressure of air rushing past the rocket will balance half on one side of this point and half on the other. You can determine the center of pressure by cutting out the silhouette of the rocket from cardboard and balancing it on ruler.

The positioning of the center of mass and center of pressure is critical to the rocket stability. The center of mass should be towards the rocket's nose and the center of pressure should be towards the rocket's tail for the rocket to fly straight. This is because the lower end of the rocket has more surface area than the upper end. When the rocket flies, more air pressure exists on the lower end of the rocket than the upper end. Air pressure will keep the lower end down and the upper end up. If the center of mass and the center of pressure are in the same place, neither end of the rocket will point upward. The rocket will be unstable and tumble.

This project provides students with the opportunity to discover practical demonstrations of force and motion in actual experiments while dealing with budgetary restraints and deadlines in real life situations. Students should review Newton's Laws of Motion before beginning this project. All building materials and handouts should be reproduced before beginning this activity. Make several copies of the budget forms and checks for each group. The first day should be spent reviewing all materials, assignments and development of a project plan. Describe the student score sheet to insure the student has a clear understanding of expectations of this project.



Students will:
a. Design and draw a bottle rocket plan to scale (1 square = 2 cm).
b. Develop a budget for the project and stay within the budget allowed.
c. Build a test rocket on the budget and plans developed by the team.
d. Identify rocket specifications and evaluate the rocket stability by determining center of mass and center of pressure and conducting a swing test.
e. Display fully illustrated rocket design in class. Include: dimensions, center of mass, center of pressure, and flight information.
f. Successfully test the launch rocket.
g. Complete the rocket journal.
h. Develop a cost analysis and demonstrate the most economically efficient launch.



Liftoff:
1. Design a project plan for the two week assignment. (show sample attached)
2. Review Project Checklist
3. Assign job responsibilities.
4. Review business information and portfolio requirements.
5. Review Budget Preparation and Order forms.

6. Design and build rocket.
7. Complete the rocket journal/portfolio.

More Ideas …

- Research the reasons why so many different rockets have been used in space exploration.
- Construct models of rockets from the past.
- Compare rockets from science fiction movies with actual rockets.

Bottle Rocket
Project Plan

Sample

<table>
<tr>
<td>Day 1
▪ Form rocket companies
▪ Brainstorm ideas for rocket and budget
▪ Sketch preliminary design for rocket</td>
<td>Day 2
▪ Develop materials list
▪ Prepare budget list
▪ Develop scale drawing</td>
<td>Day 3
▪ Demonstrate nose cone
▪ Gather materials</td>
<td>Day 4
▪ Construct rocket</td>
<td>Day 5
▪ Construct rocket</td>
</tr>
<tr>
<td></td>
<td>Day 7
▪ Demonstrate finding mass and center of pressure
▪ Prepare rocket silhouette and analysis</td>
<td>Day 8
▪ Complete silhouette and hang
▪ Perform swing test</td>
<td>Day 9
▪ Launch!</td>
<td>Day 10
▪ Complete launch results
▪ Silhouette demonstration
▪ Complete journal and
▪ Documentation</td>
</tr>
</table>

Bottle Rocket Check List

Tasks of group members:

Budget Director
- Keeps accurate accounting of money and expenses and pays the bills. Must sign all checks.
- Arranges all canceled checks in order and staple four to a sheet of paper.
- Checks over budget projection sheet. Be sure to show total project cost estimates.
- Checks over the balance sheet. Be sure the columns are complete and show if you have a positive or negative balance.
- Complete part 3 of the score sheet.
- Assist other team members as needed.

Design and Launch Director
- Supervises the design and construction of the rocket.
- Directs others during launch.
- Makes a neat copy of the Launch Day Log. Uses labels if necessary.
- Arranges to have a creative cover made for the portfolio/journal.
- Assists other team members as needed.

Project Manager
- Oversees the project.
- Keeps others on task.
- Communicates with the teacher.
- Makes a neat copy of the team's journal/portfolio. Uses labels when necessary.
- Checks over the balance sheet. List all materials used in rocket construction.
- Completes silhouette information and display properly in room.
- Assists other team members when needed.

Suggested Project Grade:

50% Documentation. Should be complete, neat, accurate and on time.

25% Proper display and documentation of rocket silhouette.

25% Launch data: Measurements, accuracy, and completeness

Project Journal/Portfolio: Check off as you complete each item.

- ❑ Creative cover with names of the members of your team, date, project number and company name
- ❑ Certificate of Assumed Name (Name of your business)
- ❑ Scale drawing of rocket plans. Indicate scale size. Label: Top, Side, and End View
- ❑ Budget
- ❑ Balance Sheet
- ❑ Canceled Checks. Staple or tape checks in ascending numerical order, four to a sheet of paper
- ❑ Pre-Launch Analysis
- ❑ Rocket Launch Day Log
- ❑ Score Sheet

State of _______
Certificate of Assumed Name

All information on this form is public information.
Please type or print legibly in black ink.

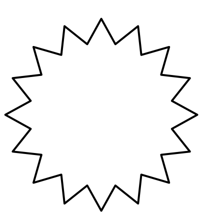
Project Number ______________

1. State the exact assumed name under which the business is or will be conducted:
____

2. List the name and title of all persons conducting business under the above assumed name:
____
____
____
____
____

Today's Date ______________________, 19_______ Class Hour _____________________

Filing Fee: A $25 fee must accompany this form.



____
Signature/title

____
Signature/title

____
Signature/title

Bottle Rocket Budget

Each team has a budget of $1,000,000. Use money wisely and keep accurate records of all expenditures. Once your money runs out, you will operate in the "red" and this will count against your team score. If you are broke at the time of launch, you will be unable to purchase rocket fuel. You will then be forced to launch only with compressed air. You may purchase as much rocket fuel as you can afford at the time of launch.

All materials not purchased from the list of subcontractors will be assessed an import duty tax of 20% of the market value. Materials not from the subcontractors list will be assessed an Originality Tax of $5,000 per item.

A project delay penalty fee will be assessed for not working, lacking materials, etc. This penalty fee could be assessed as high as $300,000 per day.

Approved Subcontractor List

Subcontractor		Market Price
Bottle Engine Corporation		
	2 L bottle	$200,000
	1 L bottle	$150,000
Aluminum Cans Unlimited		
	Can	$ 50,000
International Paper Corporation		
	Cardboard - 1 sheet	$ 25,000
	Tagboard - 1 sheet	$ 30,000
	Manila Paper - 1 sheet	$ 40,000
	Silhouette Panel - 1 sheet	$100,000
International Tape and Glue Company		
	Duct Tape - 50 cm segments	$ 50,000
	Electrical Tape - 100 cm segments	$ 50,000
	Glue Stick	$ 20,000
Blast Off Rocket Fuel Service		
	1 ml	$ 300
String, Inc.		
	1 m	$ 5,000
Plastic Sheet Goods		
	1 bag	$ 5,000
Earth Works		
	Modeling Clay - 100 g	$ 5,000
NASA Launch Port	Launch Rental	$100,000
NASA Consultation	Question	$ 1,000

Bottle Rocket **Order Form**

Company Name: ____

Check No. __________ Budget Director's Signature ______________________________

Date: _______________ Supply Company Name ______________________________

Item Ordered	Quantity	Unit Cost	Total Cost

Bottle Rocket **Order Form**

Company Name: ____

Check No. __________ Budget Director's Signature ______________________________

Date: _______________Supply Company Name ______________________________

Item Ordered	Quantity	Unit Cost	Total Cost

Bottle Rocket **Order Form**

Company Name: ____

Check No. __________ Budget Director's Signature ______________________________

Date: _______________ Supply Company Name ______________________________

Item Ordered	Quantity	Unit Cost	Total Cost

Bottle Rocket **Order Form**

Company Name: ____

Check No. __________ Budget Director's Signature ______________________________

Date: _______________ Supply Company Name ______________________________

Item Ordered	Quantity	Unit Cost	Total Cost

Bottle Rocket Budget Proposal

Company Name________________

Record below all expenses your company expects to incur in the design, construction, and launch of your rocket.

Item	Supplier	Quantity	Unit Cost	Total Cost

Projected Total Cost

Company Checks

Keep Stub For Your Records
Check No. ___________
Date _________, 19 ___
To _________________
____
For _________________
____
Amount $ [ ]

Company Name ______________________________ Check No. __________
Date _______________, 19_____
Pay to the
order of ____ $ [ ]
____Dollars _______________
For _______________________Authorized Signature______________________________
_______________________Budget Director's
Signature ______________________________

Keep Stub For Your Records
Check No. ___________
Date _________, 19 ___
To _________________
____
For _________________
____
Amount $ [ ]

Company Name ______________________________ Check No. __________
Date _______________, 19_____
Pay to the
order of ____ $ [ ]
____Dollars _______________
For _______________________Authorized Signature______________________________
_______________________Budget Director's
Signature ______________________________

Keep Stub For Your Records
Check No. ___________
Date _________, 19 ___
To _________________
____
For _________________
____
Amount $ [ ]

Company Name ______________________________ Check No. __________
Date _______________, 19_____
Pay to the
order of ____ $ [ ]
____Dollars _______________
For _______________________Authorized Signature______________________________
_______________________Budget Director's
Signature ______________________________

Keep Stub For Your Records
Check No. ___________
Date _________, 19 ___
To _________________
____
For _________________
____
Amount $ [ ]

Company Name ______________________________ Check No. __________
Date _______________, 19_____
Pay to the
order of ____ $ [ ]
____Dollars _______________
For _______________________Authorized Signature______________________________
_______________________Budget Director's
Signature ______________________________

Bottle Rocket Balance Sheet

Company Name ____________________

Check No.	Date	To	Amount	Balance

Rocket Measurements For Scale Drawing

Project No. ___________
Date ________________

Company Name____

Use metric measurements to measure and record the data in the blanks below. Be sure to accurately measure all objects that are constant (such as the bottles) and those you will control (like the size and design of fins). If additional data lines are needed, use the back of this sheet.

Object	Length	Width	Diameter	Circumference

Use graph paper to draw a side, top, and bottom view of your rocket, to scale (1 square = 2 cm), based on the measurements recorded above. Attach your drawings to this paper.

Pre-Launch Analysis

Company Name: ______________________________ Project Number: [ ]

Employee Name: ______________________________

Job Title: ______________________________

Employee Name: ______________________________

Job Title: ______________________________

Employee Name: ______________________________

Job Title: ______________________________

Rocket Specifications

Total Mass: ____________g

Total length: ___________cm

Width (widest part) ____________cm

Circumference: _______________cm

Number of Fins: ____________

Length of Nose Cone: _________cm

Volume of Rocket Fuel to be used on Launch Day:
_____________mL, ___________L

Rocket Stability

Center of Mass (CM)

Distance from Nose: ____________cm

Distance from Tail: _____________cm

Center of Pressure (CP)

Distance from Nose: _________cm

Distance from Tail: __________cm

Distance of CM from CP: ____________cm

Did your rocket pass the swing test?

- ❑ Yes
- ❑ No

Flight Day Log

Date: ___________

Time: ___________

Project No. ☐

Company Name: ____

Launch Director: ____

Weather Conditions: ____

____

Wind Speed: _______________________Wind Direction: ______________

Air Temperature: ________________C

Launch Location: ____

Launch Angle (degrees): _______________Launch Direction: ___________

Fuel (water) volume: _______________mL______________________L

Flight Altitude: ____________________M

Evaluate your rocket's performance:

Recommendations for future flights:

Bottle Rocket Score Sheet

Total Score: [ ]

Project No. ___________________

Date: ________________________

Company Name: ____

Part I: Documentation: 50% of project grade

Neatness	__________	Completeness	__________
Accuracy	__________	Order	__________
On Time	__________		

SCORE: [ ]

Part II: Silhouette: 25% of project grade

Neatness	__________	Completeness	__________
Accuracy	__________	Proper balance	__________
Correct labels	__________		

SCORE: [ ]

Part III: Launch Results: 25% of project grade (teams complete this section)

a. Rocket Altitude ______________________ Rank ________________________

b. Expenditures and Penalty Fees ____
(Check total from Balance Sheet)

c. Investment and Penalty Fees ____
(Total check amount column on Balance Sheet)

d. Final Balance____
(New Balance on Balance Sheet)

e. Efficiency (Cost/Meter) ____
(Divide Investment (b) by Rocket Altitude (a))

f. Contract Award ____

g. Profit ____
(Contract Award (f) minus Investment (c))

SCORE: [ ]

Asteroid Impact

Suggested TEKS		
Science -	8.7	8.13
Language Arts -		8.13
Computer -		8.2

Suggested SCANS
Information. Interprets and communicates information.
National Science and Math Standards
Science as Inquiry, Earth and Space Science, Physical Science

Grade Level: 8

Time Required: 2 or 3 class periods

Countdown:
Printed Resources
Electronic Text, if available

Ignition:

Asteroids are small, usually rocky bodies about 10 to 1000 km in diameter. Many asteroids are made of silicate rocks and minerals with a little metal; some, however, are mostly composed of metal. They are ancient, primitive bodies, which represent the building blocks of the inner planets and are the sources of most meteorites.

Most asteroids orbit the sun between Mars and Jupiter in an area called the asteroid belt. However, some asteroids travel in highly elliptical orbits that cause them to cross the orbits of Mars or Earth.

Liftoff:

A. Discussion
Discuss the following article information with the students. "*Never Mind*" from Mar. 23, 1998, Newsweek.

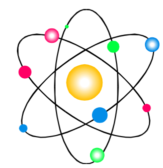
In December 1997, University of Arizona astronomers discovered a new asteroid, which they named 1997 XF11, that was zipping around in an orbit that would bring it toward Earth in a "miss distance of zero." Soon after, two Japanese amateurs found that its trajectory is to swing around the sun once every 21 months and, in 2028, it will come within 500,000 miles of Earth. Finally, McDonald Observatory Peter Shelus in early March 1998 presented astronomers with an 88-day arc of the asteroid's path. His new itinerary had XF11, at 1:30 PM Eastern daylight time, on October 26, 2028, within 26,000 miles of Earth's surface -- or closer. It was designated as the 108th PHA, or "potentially hazardous asteroid".

The immediate consequence was that for 24 hours television stations ran terrifying simulations of an asteroid slamming into Earth. Hollywood studies, soon releasing two asteroid and comet movies -- "Armageddon" and "Deep Impact", speculated that reality would actually whip up interest in these two productions. Newspapers indicated that "the end was near". Our world was threatened.

Astronomer Eleanor Helin, working for NASA's Near Earth Asteroid Tracking Team (NEAT), had run an asteroid survey at the Palomar Observatory from 1973-1995 and was fortunately able to locate a photographic plate from 1990, when XF had swung by Earth. By computer, she calculated the exact position of XF in the 1990 shot; then, using the information provided about XF's orbit, it was determined that the new "miss distance" is 600,000 miles. Immediate threat over …

But, astronomer Clark Chapman of the Southwest Research Institute reminds us that the cratering of the planets and the mood **do** show that worlds collide. Earth itself has been slammed at least 139 times. And, it is possible that XF-11 could still be nudged onto a deadly path, if it passes close enough to another asteroid, whose gravity would alter its orbit.

NASA estimates that 1,000 to 4,000 asteroids cross Earth's orbit, and they are larger than half a mile across. Of those, only about 150 have been identified. Our challenge is, then, that we take the possibility of future asteroid impact seriously and realistically. Also, we should be aware of and be prepared to intercept hazardous asteroids, as necessary.



B. Comparisons

Ask students to compare and contrast asteroids with comets.

Asteroids	***Comets***

C. Research

Have each student research one of the following topics:

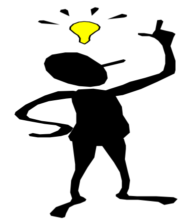
- ❖ Asteroid Gaspra that was imaged by Galileo spacecraft in 1991.
- ❖ Comet Shoemaker-Levy 9 which, in July 1994, impacted Jupiter.
- ❖ The impact craters on the moon, Mercury, and Mars.
- ❖ Meteor Crater on Earth.

Students will team with a classmate who did research on the same topic.
Each team will present an oral presentation to the class on its findings.

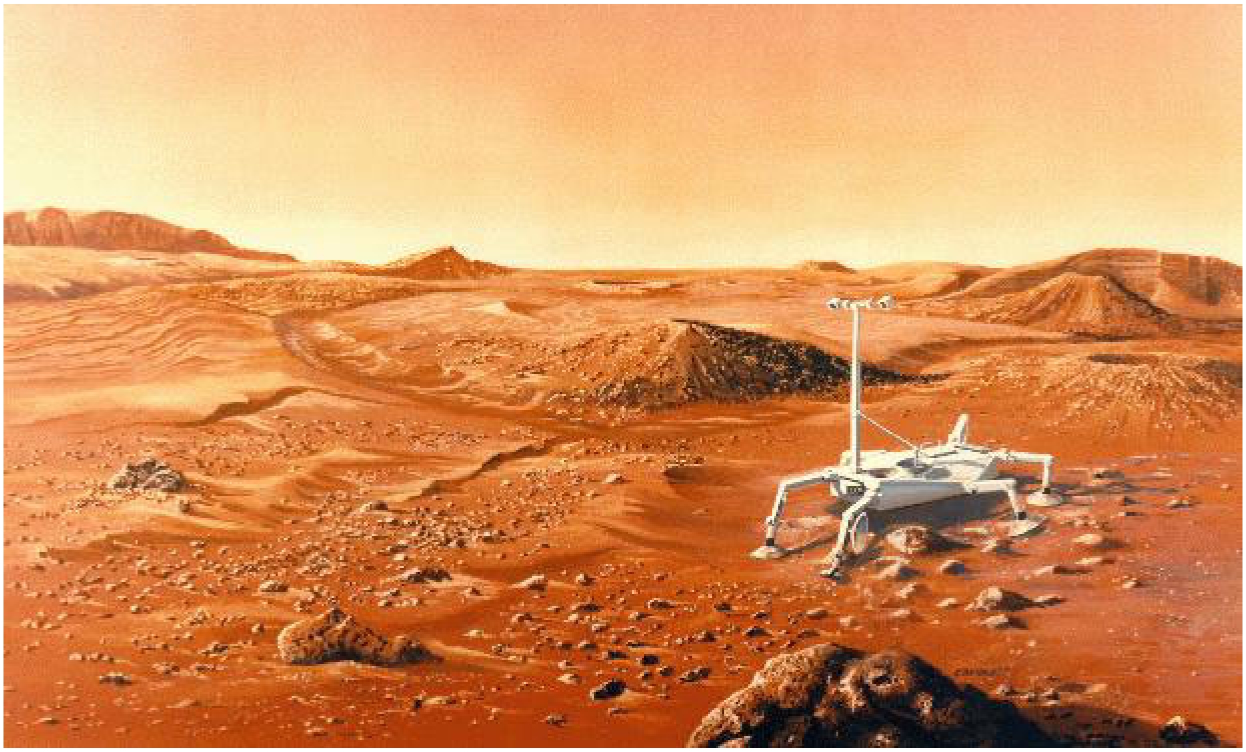
Science Fiction Story

Each student will write a science fiction story about XF11 and "our close encounter".

More Ideas …



- Write a poem titled "Asteroid Close Encounter".
- Watch a movie about space close encounters. Compare and contrast the movie to the Newsweek article about XF11.
- Divide into groups. Each group will brainstorm ways to avoid asteroids hitting the earth. Each group will develop a minimum of 5 ideas.



EVALUATION

K - W - L Strategy
Evaluation

Tell students that our topic is ***Space Exploration***. Ask them to discuss what they know about exploration in space. Display a K-W-L chart on the overhead, and explain the three parts: **K** -- What I **K**now, **W** -- **W**hat I Want to Know, and **L** -- What I Need to **L**earn. Mention this form was completed at the beginning of the Space Exploration unit and students should now complete column 3 titled "***What I Learned"***. Students may compare this to the Introduction to this unit completed earlier or teacher may use for evaluation.

Space Exploration

What I Know	What I Want to Know	What I Learned

This strategy may be used for any topic within this broad unit. Also, it may be used as an information individual assessment, in which each student writes his/her own responses for each of the three columns. See form in ***Introduction*** for the form to use as an introductory step to evaluation and goal setting.

Space Explorers
Evaluation
Retrospective Pretest or sometimes called Post-then Evaluation

This evaluation is designed to measure students' attitudes regarding what they have learned. The evaluation is given after the unit or activities are conducted. The theory behind the test is that often we give a pre-test and the student thinks they actually know a lot about a subject and would, therefore, rank themselves high in knowledge in a specific area. After the unit, the student finds they may not know as much as they thought they knew and subsequently the evaluation results may show a decrease in knowledge. By asking after the unit is completed, you are asking students to evaluation how much they know **NOW** (after the unit is complete) about a specific subject and then asking them to reflect back and evaluate how much they knew **THEN** (before the unit started). The test is designed to measure the attitude about learning, not knowledge gained. (We don't actually know if they know more or not unless we test on a specific knowledge based test.)

Space Explorers
Evaluation Form

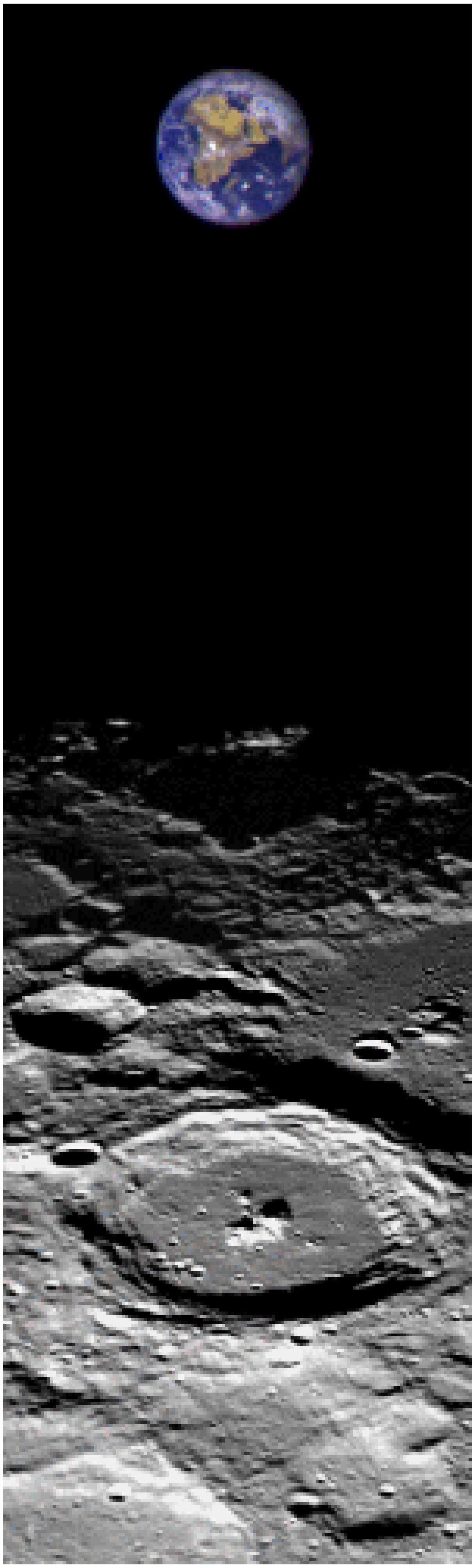
Rank the following on a scale of 0 - 5, 0=learned nothing and 5=learned a lot.
Put an X in the box with the appropriate number.

BEFORE 0	1	2	3	4	5		AFTER 0	1	2	3	4	5
						International Cooperation						
						Space Spinoffs						
						Nutrition in Space						
						Recycling on the Moon						
						Lung Functions						
						Exercise in Space						
						Sleeping in Space						
						Weightlessness and the Human Body						
						Shuttle Spacesuits						
						Mission Design - Personnel						
						Aging in Space						
						Light Energy						
						Telescopes						
						Satellite Orbits						
						Mapping Terrestrial and Ocean Areas						
						Physics of Toys						
						Gravity						
						Space Stations						
						Circumference of the Sun & Planets						
						Rocket Launch						
						Space Shuttle						
						Asteroids						
						Life Science (in general) regarding space						
						Remote Sensing (in general) regarding space						
						Orbital Mechanics (in general) regarding space						

Activity Response Rubric, A Form of Assessment (Student)

	0	1	2	3	4	5	SCORE
CREATIVE THINKING	No Response given	• Does not connect activity with personal experience • Sees no relevance	• Begins to connect self minimally with activity • Sees relevance of activity in everyday life	• Connects with activity in several ways though: 1. Prior knowledge 2. Ability to infer	• Predicts future outcomes in space events • Poses significant questions about the global implications of space exploration	• Designs and builds space experiments based on knowledge gained and individual perception (I.e. build plan to carry out a specific task) • Shows substantial personal involvement	
CRITICAL THINKING	No Response given	• Does not analyze activity	• Minimum analysis of activity • Can respond to some basic comprehension questions	• Begins to apply activity concepts to "real world" • Recognizes the importance of space exploration to society and to their own life	• Explains alternate solutions • Compares and contrasts space exploration in the past with that of the future	• Analyzes critically and is able to create a space colony bill of rights and constitution • Analyzes completely thought-provoking questions	
TASK COMMITMENT	Fails to respond appropriately to 1. Expectations of teacher and group 2. Expectations of task	• Activity started but incomplete • Instructions only partially followed • Little thought and effort exhibited	• Task is completed but not thought/ effort devoted to extension activities • Some interaction in group	• Follows directions completely and accurately • Seeks to be a productive member in group	• Shows enthusiasm and commitment to activity • Exhibits a positive attitude in interactions	• Takes initiative in group work • Exceeds task expectations • Exhibits pride in work well done	

Use this rubric to assess a specific activity or unit of activities. Score the individual student in each of the 3 areas
Outstanding performance in all 3 areas will result in a total score of 15. Most students, however, will vary in each of the areas



APPENDIX

Space Glossary

Aft	The rear area of any spacecraft.
Air Lock	An intermediate chamber between places of unequal pressure.
Altitude	The vertical elevation from the surface of the Earth.
Apogee	The farthest or highest point of an orbit farthest from the Earth.
Apollo	The third American manned space program, developed to land Astronauts on the Moon's surface and explore the lunar environment.
Apollo-Soyuz	An international mission designed to test docking spacecraft. It involved the American Apollo and the Soviet Union Soyuz.
Astronaut	A person who operates a space vehicle, conducts experiments and gathers information during a space flight.
Atmosphere	A mass of air-gases that surrounds the Earth and other planets. Gravity holds the masses to the surface.
Attitude	The position of a spacecraft determined by the inclination of its axis to a reference point.
Booster	A rocket that assists the main propulsive system of a spacecraft.
Cape Canaveral	Located on the east coast of Florida. It is the site of Kennedy Space Center (KSC), NASA's primary launch facility.
Capsule	A small pressurized module for a person or animal to occupy at a high-altitude or in orbit.
Cargo Bay	The mid section of the orbiter fuselage. It measures 15 feet in diameter and is 60 feet long. It is used to carry payloads and the laboratory modules.
Command Module	A section of the Apollo spacecraft which contained the crew and the main controls. It was the only component to reenter the Earth's atmosphere with astronauts.
Commander	The crew member of a space flight with ultimate responsibility for the flight and crew.
Control Panel	The console which houses the major switches and controls for the pilot and commander to fly the spacecraft.
Countdown	A backward counting of hours, minutes, and seconds leading up to the launch of a vehicle.

Deorbit Burn	A firing of the OMS engine in the direction of flight to slow the shuttle down for reentry.
Deploy	To remove a payload from the cargo bay and release it to travel to its correct orbit or destination.
Dock	To attach or join to another spacecraft while in flight.
Drag	Opposite of thrust; limits the speed of an object.
Engine	The part of the aircraft which provides power to propel the aircraft through the air.
Escape Velocity	The speed that spacecraft or particle needs to attain to escape from the gravitational field of a planet or star. In the case of Earth, the velocity needed is 11.2 km (36,700 feet) per second.
Extravehicular Activity	Spacewalk.
Flight Deck	The part of the crew module where the commander and pilot fly the Shuttle.
Flight Path	Imaginary line that an object follows when traveling through the air in relation to the ground.
Fuel	The chemical that combines with an oxidizer to burn and produce thrust.
Free Fall	The condition of an object falling freely in a gravitational field.
g	A unit of force equal to the standard gravitational acceleration on Earth.
g-Force	Force produced on the body by changes in velocity; measured in increments of Earth's gravity
Galley	The area on the Shuttle's middeck where food is prepared.
Geosynchronous earth orbit	Path in which a spacecraft orbits 35,680 kilometers (22,300 miles) above the equator in a circular orbit. From Earth, the spacecraft seems to remain fixed in the sky because the spacecraft goes around Earth in the same amount of time as Earth turns on its axis.
Glider	An aircraft without an engine.
Ground Support Crew	A person or group of people who perform services for crew and passengers.
Hubble Space Telescope	The largest astronomical observatory ever to be placed in orbit, able to make high-quality interplanetary and interstellar observations.
Jet aircraft	An aircraft that travels very fast and is powered by a jet engine.
Jet engine	An engine which turns air and fuel into a hot gas which is forced out the back of the engine and pushes the airplane through the air.
Launch	To take off.

Launching System	Devices used to send off a rocket vehicle under its own rocket power.
Lift	Opposite of weight; upward force created by airflow as it passes over the wing.
Liquid Propellant	Rocket propellants in liquid form.
Lunar Landing Vehicle	The Apollo spacecraft that took astronauts from the command module to the surface of the Moon.
Lunar Rover	A special vehicle designed to travel on the Moon's surface.
Mach	The speed of sound.
Manned/Unmanned	Space flights that have people on board. Space flights that do not carry humans are unmanned flights.
Manned Maneuvering Unit	A manned unit designed to fly away from the orbiter by using small **MMU** thrusters.
Max Q	The period of maximum dynamic pressure the shuttle encounters during a launch.
Main Engine Cut Off	When the main engines are shut down because the orbiter has reached **MECO**its desired altitude.
Mercury Program	The first manned American space program testing if humans could survive and function in space.
Middeck	Portion of the crew module that serves as the shuttle crew's home in space. It is on the middeck that they prepare meals, use the bathroom, clean up and sleep.
Microgravity	Term used to describe the apparent weightlessness and fractional g-forces produced in orbit. Little gravity. In orbit, you essentially fall around the earth, producing a floating condition. This is the accurate and preferred reference for zero-g and weightlessness.
Mission Control Center	Operational headquarters where the various functions of the shuttle are controlled and monitored during flight. Addressed as "Houston" by the astronauts, it is located at the Johnson Space Center.
Module	A unit that is separate from a spacecraft or space station that is usually pressurized and has all life support systems.
NASA	National Aeronautics and Space Administration. This organization was founded in 1958 to manage all space activities for the United States.
Nautical Mile	One length of one minute of arc on the Earth's surface; used to measure the distance traveled by air or sea. Equal to 1.15 statute miles.
Neutral Buoyancy	A balance (neither rising or sinking) when in fluids.
Newton's Laws	Three basic principles of physics: 1) If an object is at rest, it takes an unbalanced force to move it, and if it is in motion, it takes an unbalanced force to stop it or change its direction or speed. 2) Force equals mass times acceleration. 3)

Every action has an equal and opposite reaction. Putting Newton's Laws of Motion together results in a successful launch of a vehicle/rocket.

Nose Cone The cone-shaped front end of a rocket.

Orbit A 360 degree path around a planet or sun.

Orbital Maneuvering System Located at the rear of the shuttle, these are two engines that are used to **(OMS)** raise or lower the orbiter in orbit. They also slow the shuttle down for reentry.

Orbital Radius The distance from the center axis of the earth to the circular path of the spacecraft.

Orbiter The Space Shuttle.

Parachute Fabric attached to objects or persons to reduce the speed of descent which in the air.

Payload On a space flight, a collection of instruments and software for performing scientific or applications investigations, or commercial production.

Payload specialist Crew member, not a career astronaut, that is responsible for managing assigned experiments or other payload elements. The payload specialist is an expert in experiment design and operation.

Perigee The lowest point of an orbit.

Pilot A person who operates an aircraft.

Pitch Changed angle of movement of aircraft fuselage in relation to the horizon (nose up or nose down of aircraft.) The up/down motion of an object.

Probe A craft that travels to inner and outer planets and sends back data to Earth. Probes do not return to Earth and are never recovered.

Propellant A mixture of fuel and oxidizer that burns to produce rocket thrust.

Recovery System Device incorporated into a rocket for the purpose of returning it to the ground safely by creating drag or lift to oppose force of gravity.

Reentry The point in which the orbiter returns to the atmosphere after a space flight. Because of the friction, temperatures reach up to 2,750 degrees Fahrenheit and communication between the orbiter and Mission Control is lost.

Rendezvous When two objects meet at a predetermined place and time.

Rocket A projectile propelled by liquid or solid fueled engines. As gases are released through the bottom of the rocket, it is propelled in the opposite direction.

Rocket Stages Two or more rockets stacked on top of one another in order to go up higher in the air, or to carry more weight.

Roll Side-to-side movement along the horizontal axis of an object. Rotation around the axis from front to back.

Satellite	A relatively small body (e.g. moon) orbiting a planet, or a human made object intended to orbit a celestial body.
Scrub	To postpone until a later date because of a problem.
Shuttle	A space vehicle designed to be reusable. It launches like a rocket and lands like an airplane. Its technical term is "orbiter."
Simulator	A model "cockpit" or control panel that allows pilots to practice operating aircraft instruments in computerized situations that are very much like the real thing. A piece of flight hardware that imitates computer programmed scenarios.
Skylab	America's first space station. There were three missions (three men each) that traveled to Skylab to conduct experiments.
Solid Propellant	Rocket fuel and oxidizer in solid form.
Solid Rocket Booster	A large solid-propellant rocket that is attached to the external tank. The **(SRB)** space shuttle uses two SRBs that provide most of the thrust during lift-off. They burn for two minutes and are then detached. They fall into the ocean to use again.
Space Station	A permanent space facility used to carry out scientific and technological studies, earth-oriented applications, and astronomical observations and to service other vehicles and their crews in space
Space Transportation System	The manned program in operation today. Its primary purpose is to **(STS)** carry payloads into space, repair satellites, bring payloads back to Earth, and conduct scientific investigations.
Space	Atmosphere and beyond. Sky, universe.
Spacecraft	A space vehicle that is either manned or unmanned.
Spacelab	The Space Shuttle's first flying laboratory.
Spacewalk	Extravehicular activity.
S-Turn	Wide turns taken by the orbiter to help slow it down after reentering the atmosphere.
Stability	Property of a glider, aircraft or rocket to maintain its attitude or resist displacement and if displaced to develop forces to return to the original position.
Stow/Unstow	To put up/take out.
Take off	The part of the flight during which the aircraft gains speed.
Thrust	Opposite of drag; force that moves an object through the air.
Trajectory	The spacecraft's path during all phases of flight.
Trainer	An object identical to one used during a mission, but intended for training purposes only.

Trans-Atlantic Landing An abort process when the orbiter cannot make it to orbit but has **(TAL)** enough altitude and speed to land in Africa or Europe.

Weight Opposite of lift; causes an object to be pulled downward. The pull of gravity on a certain mass.

Weightlessness A term used to describe microgravity. The astronauts "feel" weightlessness while they are in orbit…and constant free fall around the Earth…aboard the shuttle or other spacecraft.

Yaw Rotation of the nose to the left or right about the vertical axis of an object.

Zero-G A term used to describe microgravity. It is a common misconception that there is no gravity in space, when in fact it is gravity that keeps the shuttle in orbit. The weightless feeling is a result of free falling around the Earth.

Texas Essential Knowledge and Skills
TEKS

The state of Texas educational standards are found at:

http://www.tea.state.tx.us/teks/

The correlation table for the National Standards to TEKS is located at:

http://www.tenet.edu.teks/science/stacks/teks/ns_middle.html

National Science and Math Education Standards
Activity Matrix

Introduction to Space Exploration

	Creating a Time Capsule	International Cooperation	Stellar Theory	Abort, Launch, It's a Go!	Spinoffs
Science as Inquiry Abilities necessary to do scientific inquiry	☆	☆	☆	☆	☆
Life Science Matter, energy, and organization in living systems			☆	☆	
Science in Personal and Social Perspectives Personal Health		☆			☆
Earth and Space Science	☆		☆	☆	
Science and Technology	☆	☆		☆	☆
Physical Science Properties of objects and materials Position and motion of objects	☆	☆	☆	☆	☆
History & Nature of Science	☆	☆	☆		☆
Computation			☆		
Measurement	☆		☆		
Reasoning			☆		
Observing	☆		☆	☆	☆
Communicating	☆		☆	☆	☆

Life Sciences

	Nutrition in Space	Lunch Time	Is It Soup Yet?	Lung Model	Recycling on the Moon	Exercise & Other Recreation
Science as Inquiry Abilities necessary to do scientific inquiry	☆	☆	☆	☆	☆	☆
Life Science Matter, energy, and organization in living systems		☆	☆	☆		☆
Science in Personal and Social Perspectives Personal Health	☆	☆	☆	☆	☆	☆
Earth and Space Science					☆	
Science and Technology		☆			☆	
Physical Science Properties of objects and materials Position and motion of objects		☆			☆	
History & Nature of Science						
Computation			☆			
Measurement	☆		☆			☆
Reasoning						
Observing	☆			☆	☆	☆
Communicating	☆		☆	☆	☆	☆

Life Sciences

	Sleeping in Space	Weightlessness	History of Int'l Cooperation	Shuttle Spacesuits	Mission Design Personnel	Aging
Science as Inquiry Abilities necessary to do scientific inquiry	☆	☆	☆	☆	☆	☆
Life Science Matter, energy, and organization in living systems	☆	☆	☆			
Science in Personal and Social Perspectives Personal Health	☆			☆		☆
Earth and Space Science					☆	☆
Science and Technology						
Physical Science Properties of objects and materials Position and motion of objects		☆	☆		☆	
History & Nature of Science			☆			
Computation	☆	☆			☆	
Measurement	☆	☆			☆	
Reasoning		☆				
Observing		☆	☆	☆		
Communicating		☆	☆	☆		

Remote Sensing

	Light Energy	Light Telescopes	Venus Sky Box	Satellite Orbits From Planet Earth	Mapping Terrestrial & Ocean Areas
Science as Inquiry Abilities necessary to do scientific inquiry	☆	☆	☆	☆	☆
Life Science Matter, energy, and organization in living systems					☆
Science in Personal and Social Perspectives Personal Health					
Earth and Space Science	☆	☆	☆	☆	☆
Science and Technology		☆		☆	☆
Physical Science Properties of objects and materials Position and motion of objects	☆	☆	☆	☆	☆
History & Nature of Science					
Computation			☆	☆	
Measurement	☆	☆	☆	☆	
Reasoning	☆		☆	☆	
Observing	☆	☆	☆	☆	☆
Communicating	☆	☆	☆	☆	☆

Orbital Mechanics

	Toys in Space	Creating a Space Journey	Experiment with Gravity	It's a Blastoff	Glider, Flying Saucer, Plane
Science as Inquiry Abilities necessary to do scientific inquiry	☆	☆	☆		
Life Science Matter, energy, and organization in living systems					
Science in Personal and Social Perspectives Personal Health					
Earth and Space Science	☆	☆	☆		
Science and Technology	☆			☆	☆
Physical Science Properties of objects and materials Position and motion of objects	☆		☆	☆	☆
History & Nature of Science					
Computation			☆		
Measurement			☆	☆	
Reasoning	☆		☆		
Observing	☆	☆	☆	☆	☆
Communicating	☆	☆	☆	☆	☆

Orbital Mechanics

	Making Space Stations	Orbits	Circumference Sun/Planets	Orbit Crossword	Orbit Word Search	Mission Design Shuttle	Bottle Rocket	Asteroid Impact
Science as Inquiry Abilities necessary to do scientific inquiry		☆					☆	☆
Life Science Matter, energy, and organization in living systems								
Science in Personal and Social Perspectives Personal Health								
Earth and Space Science		☆	☆	☆	☆			☆
Science and Technology	☆					☆	☆	
Physical Science Properties of objects and materials Position and motion of objects	☆	☆	☆	☆	☆			☆
History & Nature of Science								
Computation			☆			☆	☆	
Measurement	☆					☆		
Reasoning			☆					
Observing	☆	☆					☆	
Communicating	☆	☆		☆		☆	☆	

NASA Facts

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas 77058

IS-1997-06-ISS009JSC

International Space Station 1998

June 1997

A History of U.S. Space Stations

Introduction

Space stations have long been seen as a laboratories for learning about the effects of space conditions and as a springboard to the Moon and Mars. In the United States, the Apollo lunar program preempted early station efforts in the early 1960s, and changing priorities in the U.S. deferred post-Apollo station efforts to the 1980s. Since 1984, space station design has evolved in response to budgetary, programmatic, and political pressures, becoming increasingly international in the process. This evolution has culminated in the International Space Station, orbital assembly of which will begin in 1998.

The Beginning (1869-1957)

The concept of a staffed outpost in Earth orbit dates from just after the Civil War. In 1869, American writer Edward Everett Hale published a science fiction tale called "The Brick Moon" in the *Atlantic Monthly*. Hale's manned satellite was a navigational aid for ships at sea. Hale proved prophetic. The fictional designers of the Brick Moon encountered many of the same problems with redesigns and funding that NASA would with its station more than a century later.

In 1923, Hermann Oberth, a Romanian, coined the term "space station." Oberth's station was the starting point for flights to the Moon and Mars. Herman Noordung, an Austrian, published the first space station blueprint in 1928. Like today's International Space Station, it had modules with different functions. Both men wrote that space station parts would be launched into space by rockets.

In 1926, American Robert Goddard made a major breakthrough by launching the first liquid-fueled rocket, setting the stage for the large, powerful rockets needed to

The first U.S. space station, Skylab, seen as its final mission approached in 1974

launch space station parts into orbit. Rocketry advanced rapidly during World War II, especially in Germany, where the ideas of Oberth and Noordung had great influence. The German V-2 rocket, a missile with a range of about 300 miles, became a prototype for both U.S. and Russian rockets after the war.

In 1945, renowned German rocket engineer Wernher von Braun came to the U.S. to build rockets for the U.S. Army. In the 1950s, he worked with *Collier's* magazine and Walt Disney Studios to produce articles and documentaries on spaceflight. In them, he described a wheel-shaped space station reached by reusable winged spacecraft. Von Braun saw the station as an Earth-observation post, a laboratory, an observatory, and a springboard for Moon and Mars flights.

On October 4, 1957, the Soviets launched Sputnik 1. This triggered the Cold War competition between the U.S. and Soviet Union in space which characterized the early years of the Space Age—competition replaced today by cooperation in the International Space Station Program. In response to Sputnik, the U.S. established the National Aeronautics and Space Administration in 1958 and started its first man-in-space program, Project Mercury, in 1959.

Apollo and Space Stations (1958-1973)

Project Mercury had hardly begun when NASA and the Congress looked beyond it, to space stations and a permanent human presence in space. Space stations were seen as the next step after humans reached orbit. In 1959, A NASA committee recommended that a space station be established before a trip to the Moon, and the U.S. House of Representatives Space Committee declared a space station a logical follow-on to Project Mercury.

In April 1961, the Soviet Union launched the first human, Yuri Gagarin, into space in the Vostok 1 spacecraft. President John F. Kennedy reviewed many options for a response to prove that the U.S. would not yield space to the Soviet Union, including a space station, but a man on the Moon won out. Getting to the Moon required so much work that the U.S. and Soviet Union were starting the race about even. In addition, the Moon landing was an unequivocal achievement, while a space station could take many different forms.

Space station studies continued within NASA and the aerospace industry, aided by the heightened interest in spaceflight attending Apollo. In 1964, seeds were planted for Skylab, a post-Apollo first-generation space station. Wernher von Braun, who became the first director of NASA's Marshall Space Flight Center, was instrumental in Skylab's development.

By 1968, a space station was NASA's leading candidate for a post-Apollo goal. In 1969, the year Apollo 11 landed on the Moon, the agency proposed a 100-person permanent space station, with assembly completion scheduled for 1975. The station, called Space Base, was to be a laboratory for scientific and industrial experiments. Space Base was envisioned as home port for nuclear-powered tugs designed to carry people and supplies to an outpost on the Moon.

NASA realized that the cost of shipping supplies to a space station using expendable rockets would quickly exceed the station's construction cost. The agency also foresaw the need to be able to return things from a space station. A reusable spacecraft was the obvious solution. In 1968, NASA first called such a spacecraft a space shuttle.

Skylab (1973-1974)

In May 1973, the U.S. launched the Skylab space station atop a Saturn V rocket similar to those that took astronauts to the Moon. The rocket's third stage was modified to become an orbital workshop and living quarters for three-person crews. Non-reusable Apollo spacecraft originally designed for Moon missions ferried astronauts to and from the station. Skylab hosted three different crews for stays of 28, 56, and 84 days. Skylab astronauts conducted medical tests and studied microgravity's influence on fluid and material properties. The crews also made astronomical, solar, and Earth observations. Long-duration microgravity research begun on Skylab will continue and be refined on the International Space Station.

Skylab proved that humans could live and work in space for extended periods. The station also demonstrated the importance of human involvement in construction and upkeep of orbital assets–the first Skylab crew performed emergency spacewalks to free a solar array jammed during the station's launch.

Skylab was not designed for resupply, refueling, or independent reboost. When the last Skylab crew headed home in February 1974, NASA proposed sending the Space Shuttle to boost Skylab to a higher orbit or even to refurbish and reuse the station. But greater than expected solar activity expanded Earth's atmosphere, hastening Skylab's fall from orbit, and shuttle development fell behind schedule. Skylab reentered Earth's atmosphere in 1979.

NASA Responds to Changing Priorities (1974-1979)

The Space Shuttle was originally conceived as a vehicle for hauling people and things back and forth between Earth and a space station. People and the supplies they needed for a long stay in space would go up, and people and the industrial products and experiment samples they made on the station would come down. But economic, political, social, and cultural priorities in the U.S. shifted during the Apollo era. Despite Apollo's success, NASA's annual budgets suffered dramatic cuts beginning in the mid-1960s. Because of this, NASA deferred plans for a permanent space station until after the space shuttle was flying, and explored international cooperative space projects as a means of filling in for a permanent station.

The U.S. invited Europe to participate in its post-Apollo programs in 1969. In August 1973, Europe formally agreed to supply NASA with Spacelab modules, mini-laboratories that ride in the space shuttle's payload bay. Spacelab provides experiment facilities to researchers from many countries for nearly three weeks at a time–an interim space station capability. Spacelab 1 reached orbit in 1983, on the ninth space shuttle flight (STS-9). The main European contributions to International Space Station, a laboratory module and a supply module, are based on Spacelab experience and technology.

U.S. and Soviet negotiators discussed the possibility of a U.S. Space Shuttle docking with a Soviet Salyut space station. This was an outgrowth of the last major U.S.-Russian joint space project, Apollo-Soyuz, the first international spacecraft docking in 1975. The Space Shuttle's ability to haul things down from space complimented Salyut's ability to produce experiment samples and industrial products–things one would want to return to Earth. NASA offered the Space Shuttle for carrying crews and cargo to and from Salyut stations and in return hoped to conduct long-term research on the Salyuts until it could build its own station, but these efforts ended with the collapse of U.S.-Soviet detente in 1979.

Defining the Goal and Building Support (1979-1984)

By 1979, development of the Space Shuttle was well advanced. NASA and contractor engineers began conceptual studies of a space station that could be carried into orbit in pieces by the Space Shuttle. The Space Operations Center was designed to serve as a laboratory, a satellite servicing center, and a construction site for large space structures. The Space Operations Center studies helped define NASA expectations for a space station.

The Space Shuttle flew for the first time in April 1981, and once again a space station was heralded as the next logical step for the U.S. in space. NASA founded the Space Station Task Force in May 1982, which proposed international participation in the station's development, construction, and operations. In 1983, NASA held the first workshop for potential space station users.

NASA Gets the Go-Ahead (1984-92)

These efforts culminated in January 1984, when President Ronald Reagan called for a space station in his State of the Union address. He said that the space station program was to include participation by U.S. allies.

With the presidential mandate in place, NASA set up the Space Station Program Office in April 1984, and issued a Request for Proposal to U.S. industry in September 1984. In April 1985, NASA let contracts on four work packages, each involving a different mix of contractors and managed by a separate NASA field center. (This was consolidated into three work packages in 1991.)

This marked the start of Space Station Phase B development, which aimed at defining the station's shape. By March 1986, the baseline design was the dual keel, a rectangular framework with a truss across the middle for holding the station's living and working modules and solar arrays.

By the spring of 1985, Japan, Canada, and the European Space Agency each signed a bilateral memorandum of understanding with the U.S. for participation in the space station project. In May 1985, NASA held the first space station international user workshop in Copenhagen, Denmark. By mid-1986, the partners reached agreement on their respective hardware contributions. Canada would build a remote manipulator system similar to the one it had built for the space shuttle, while Japan and Europe would each contribute laboratory modules. Formal agreements were signed in September 1988. These partners' contributions remain generally unchanged for the International Space Station.

In 1987, the dual keel configuration was revised to take into account a reduced space shuttle flight rate in the wake of the Challenger accident. The revised baseline had a single truss with the built-in option to upgrade to the dual keel design. The need for a space station lifeboat–called the assured crew return vehicle–was also identified.

In 1988, Reagan gave the station a name–Freedom. Space Station Freedom's design underwent modifications with each annual budget cycle as Congress called for its cost to be reduced. The truss was shortened and the U.S. Habitation and Laboratory modules reduced in size. The truss was to be launched in sections with subsystems already in place. Despite the redesigns, NASA and contractors produced a substantial amount of hardware. In 1992, in moves presaging the current increased cooperation between the U.S. and Russia, the U.S. agreed to buy Russian Soyuz vehicles to serve as Freedom's lifeboats (these are now known as Soyuz crew transfer vehicles) and the Shuttle-Mir Program got its start.

International Space Station (1993-2012)

In 1993, President William Clinton called for the station to be redesigned once again to reduce costs and include more international involvement. To stimulate innovation, teams from different NASA centers competed to develop three distinct station redesign options. The White House selected the option dubbed Alpha.

In its new form, the station uses 75 percent of the hardware designs originally intended for the Freedom program. After the Russians agreed to supply major hardware elements, many originally intended for their Mir 2 space station program, the station became known as the International Space Station. Russian participation reduces the station's cost to the U.S. while permitting expansion to basic operational capability much earlier than Freedom. This provides new opportunities to all the station partners by permitting early scientific research.

The program's management was also redesigned. Johnson Space Center became lead center for the space station program, and Boeing became prime contractor. NASA and Boeing teams are housed together at JSC to increase efficiency through improved communications.

The first phase of the International Space Station Program, the Shuttle-Mir Program, kicked off in February 1994 with STS-60, when Sergei Krikalev became the first Russian astronaut to fly on a shuttle. The Shuttle-Mir Program is giving U.S. astronauts their first long-duration space experience since Skylab. The Shuttle-Mir Program also gives U.S. and Russian engineers and astronauts experience in working together. Space station hardware is being tested and improved. For example, difficulties with Mir's cooling system led to modifications in the International Space Station design.

The Shuttle-Mir Program continued in February 1995, when Discovery rendezvoused with Mir during the STS-63 mission with cosmonaut Vladimir Titov aboard. In March 1995, U.S. astronaut Dr. Norman Thagard lifted off in the Russian Soyuz-TM 21 spacecraft with two Russian cosmonauts for a three-month stay on Mir. In June 1995, on the STS-71 mission, the Shuttle Atlantis docked with the Mir station for the first time and picked up Thagard and his colleagues, plus experiment samples and other items from the station, for return to Earth.

In November 1995, on mission STS-74, Atlantis delivered the Russian-built Docking Module to Mir - the first time a shuttle added a module to a space station, a task which will be commonplace during assembly of the International Space Station.

On STS-76 in March 1996, Atlantis dropped off U.S. astronaut Shannon Lucid for 6 months of scientific research on Mir, the first time a shuttle delivered a long-duration crew member to a space station. Astronauts Linda Godwin and Richard Clifford performed a spacewalk outside Mir, the first time American astronauts performed a spacewalk outside a space station since the Skylab missions.

In August 1996, on the STS-79 mission, Atlantis docked with Mir and exchanged Lucid for John Blaha. Crew exchange will also be commonplace during operations on the International Space Station. All shuttle missions to Mir deliver supplies, equipment, and water, and return to Earth experiment results and equipment no longer needed. Blaha returned to Earth aboard Atlantis on STS-81, which left behind Jerry Linenger. He returned to Earth on STS-84, which left behind Michael Foale.

Assembly of the International Space Station begins in June 1998 with launch of the FGB propulsion module. The first International Space Station crew–William Shepherd, Sergei Krikalev, and Yuri Gidzenko–will arrive in January 1999, starting a permanent human presence aboard the new station. The station's first laboratory module, supplied by the U.S., will reach the International Space Station in May 1999. After the Lab is in place, assembly flights will be interspersed with flights dedicated to research. International Space Station operations are planned to continue until at least 2013.

The International Space Station is shown here with assembly completed in early 2003. The new station is the largest and most complex peacetime international collaboration ever undertaken. It also will be the largest spacecraft ever built.

International Space Station

National Aeronautics and Space Administration

International Space Station
The International Space Station Program is Underway

Introduction

The International Space Station has three phases, each designed to maximize joint space experience and permit early utilization and return on our investment. In Phase I, Americans and Russians will work together in laboratories on Mir and the shuttle. They will conduct joint spacewalks and practice space station assembly by adding new modules to Mir. American astronauts .will live and work on Mir for months beside their .Russian counterparts, amassing the first U.S. long-duration space experience since Skylab (1973- 1974).

International Space Station Phase I began with Russian cosmonaut Sergei Krikalev's flight aboard the Space Shuttle Discovery in February 1994 on STS-60. In February 1995, on the STS-63 mission. Discovery flew around the Russian Mir space station with Vladimir Titov on board as a mission specialist. During the fly around. Discovery stopped 37 feet from Mir-a rehearsal for the first docking between Space Shuttle Atlantis and Mir in May or June 1995. In March 1995, U.S. astronaut Dr. Norman Thagard flew to Mir for a three-month stay with two Russian cosmonauts.

Phase I Impact on Phases II and III

The goal of Phase I is to lay the groundwork for International Space Station Phases II and III. Phase n will place in orbit a core space station with a U.S. Laboratory module, the first dedicated laboratory on the station. The U.S. Laboratory will be put to work during utilization flights in Phase in, while assembly continues. Phase in ends when assembly is complete (scheduled for mid-2002) and astronauts and cosmonauts from many countries commence a planned 15 years of research on the International Space Station.

Phase I is contributing to the success of Phases II and III in four major areas:

- Operations-learning to work together on the ground and in space
- Risk reduction-mitigation of potential surprises in hardware exchange, working methods, spacecraft environment, and spacewalks
- Long-duration stays on a space station-amassing experience
- Science-early initiation of science and technology research

Space Station Mir-Shuttle's Partner in Phase I

Mir represents a unique capability-an operational long- term space station which can be permanently staffed by two or three cosmonauts. Visiting crews have raised Mir's population to six for up to a month.

Mir is the first space station designed for expansion. The 20.4-ton core module, Mir's first building block, was launched in February 1986. The core module provides basic services (living quarters, life support, power) and scientific research capabilities. Soyuz-TM manned transports and automated Progress-M supply ships dock at two axial docking ports, fore and aft.

Expansion modules dock first at the forward port then transfer to one of four radial berthing ports using a robot arm (except for the expansion module, Kvant-see below).

Up to 1990, the Russians added three expansion modules to the Mir core:

- Kvant. Berthed at the core module's aft axial port in 1987, the module weighs 11 tons and carries telescopes and equipment for attitude control and life support. Kvant blocked the core module's aft port, but had its own aft port which took over as the station's aft port.
- Kvant 2. Berthed at a radial port in 1989, the module weighs 19.6 tons and carries an EVA airlock, two solar arrays, and science and life support equipment.
- Kristall. Berthed opposite Kvant 2 in 1990, Kristall weighs 19.6 tons and carries two stowable solar arrays, science and technology equipment, and a docking port equipped with a special androgynous docking mechanism designed to receive heavy (up to about 100 tons) spacecraft equipped with the same kind of docking unit. The androgynous unit was originally developed for the Russian Buran shuttle program. The Russians will move Kristall to a different radial Mir port to make room for the new Spektr module in May 1995. Atlantis will use the androgynous docking unit on Kristall for the first shuttle-Mir docking in June 1995.

Three more modules, all carrying U.S. equipment, will be added to Mir in 1995 for International Space Station Phase I:

- Spektr. Launch on a Russian Proton rocket from the Baikonur launch center in central Asia is currently set for May 1995. The module will be berthed at the radial port opposite Kvant 2 after Kristall is moved out of the way. Spektr will transport four solar arrays and scientific equipment (including more than 1600 Ibs of U.S. equipment).
- Docking Module. The module will be launched in the payload bay of Atlantis and berthed at Kristall's androgynous docking port during STS-74 in October 1995. The docking module makes shuttle dockings with Mir easier and will carry two solar arrays-one Russian and one jointly developed by the U.S. and Russia—to augment Mir's power supply.
- Priroda. Launch on a Russian Proton rocket is scheduled for November 1995. Priroda will berth at the radial port opposite Kristall and will carry microgravity research and Earth observation equipment (including 2200 Ib of U.S. equipment).

In late 1995, after Priroda is added, Mir will mass more than 100 tons. The station will be made up of seven modules launched separately and brought together in space over ten years. Experience gained by Russia during Mir assembly provides valuable experience for International Space Station assembly in Phases II and III. Phase I Shuttle Mission Summaries

STS-60 (February 3-11. 1994)

This mission inaugurated International Space Station Phase I. Veteran Russian cosmonaut Sergei Krikalev served as a mission specialist aboard Discovery. He conducted experiments beside his American colleagues in a Spacehab laboratory module carried in Discovery's payload bay.

STS-63 (February 3-11. 1995)

Discovery maneuvered around Mir and stopped 37 feet from the Kristall module's special androgynous docking unit, which Atlantis will use to dock with Mir on the STS-71 mission. Cosmonauts on Mir and Discovery's crew-which included veteran Russian cosmonaut Vladimir Titov- beamed TV images of each other's craft to Earth. For a time it appeared that minor thruster leaks on Discovery might keep the two craft at a preplanned contingency rendezvous distance of 400 feet. However, mission control teams and management in Kaliningrad and Houston worked together to determine that the leaks posed no threat to Mir, so the close rendezvous went ahead. The minor problem became a major builder of confidence and joint problem- solving experience for later International Space Station phases. Titov served on board Discovery as a mission specialist, performing experiments beside his American colleagues in a Spacehab module in the orbiter's payload bay.

STS-71 (May-June 1995)

Atlantis will be launched carrying five astronauts, two Russian cosmonauts, and, in its payload bay, a Spacelab module and an orbiter docking system for docking with Mir. The STS-71 orbiter docking system is designed for use on this mission only-subsequent shuttle-Aft'r docking missions will use a Muldmir orbiter docking system. The STS-71 and Multimir orbiter docking systems are outwardly identical-they consist of a cylindrical airlock with a Russian-built androgynous docking mechanism on top. For ST^-71, Atlantis will dock with an identical androgynous unit on Mir's Kristall module. The shuttle will be used for the first time to change a space station crew, a task which will become a routine part of its duties in later International Space Station phases. Atlantis will .drop off cosmonauts Anatoli Solovyev and Nikolai Budarin, and pick up Vladimir Dezhurov, Gennadi Strekalov, and U.S. astronaut Norman Thagard for return to Earth. They were launched from Russia in the Soyuz-TM 21 spacecraft on March 14. Thagard and his Russian colleagues will be completing a three-month stay on Mir, the first long-duration space mission involving an American since the last U.S. Sky lab mission in 1974. The joint crew will carry out experiments similar to those planned for International Space Station Phases n and III. Atlantis will remain docked to Mir for five days.

STS-74 (October-November 1995)

Atlantis will carry the Russian-built docking module, which has androgynous docking mechanisms at top and bottom. During flight to Mir, the crew will use the orbiter's remote manipulator system robot arm to hoist the docking module from the payload bay and position its bottom androgynous unit atop Atlantis' orbiter docking system. Atlantis will then dock to Kristall using the docking module's top androgynous unit. After three days, Atlantis will undock from the docking module's bottom androgynous unit and leave the docking module permanently docked to Kristall, where it will improve clearance between the shuttle and Mir's solar arrays during subsequent dockings. The docking module also carries two solar arrays, one Russian and one U.S.-Russian, which will increase power available on Mir for experiments. No crew exchange is scheduled, but on board Mir will be an astronaut from the European Space Agency (ESA), halfway through a four-month stay on the station, and on board Atlantis will be a Canadian astronaut. The European long- duration mission is part of the Euromir space research program, which included a month-long stay on Mir by ESA astronaut Ulf Merbold in 1994. Canada built the shuttle's robot arm and will provide robotics systems for the International Space Station in Phase II, while Europe will provide a laboratory module for the station in Phase III. On this and subsequent flights Atlantis will deliver water, supplies, and equipment to Mir and will return to Earth experiment samples, dysfunctional equipment for analysis, and products manufactured on the station.

STS-76 (March-April 1996)

Atlantis will deliver astronaut Shannon Lucid to Mir for a five-month stay. The orbiter will carry a single Spacehab module in its payload bay, and will remain docked to the Russian station for five days. While docked, astronauts Linda Godwin and Michael R. "Rich" Clifford will perform a spacewalk to transfer three experiments from Atlantis to Mir's exterior and evaluate International Space Station hardware.

STS-79 (August 1996)

Astronaut Shannon Lucid, delivered to Mir on STS-76, will be picked up and astronaut Jerry Linenger will be dropped off for a planned four-month stay on the Russian station. U.S. astronauts will perform a spacewalk during the five-day docked phase. Atlantis will carry a Spacehab double module.

STS-81 (December 1996)

Astronaut Jerry Linenger, delivered on STS-79, will be returned to Earth and astronaut John Blaha will take up residence on Mir for four months. Atlantis will also deliver U.S. and Russian equipment for spacewalks to take place on this and subsequent missions. Two Russians or an American and a Russian will perform U.S. experiments as part of a spacewalk during or after the five-day docked phase. Atlantis will carry a Spacehab double module.

STS-84 (May 1997)

Astronaut John Blaha, delivered on STS-81, will be picked up and astronaut Scott Parazynski dropped off for a four-month stay on Mir. Atlantis will carry a Spacehab double module, and will remain docked to Mir for five days.

STS-86 (September 1997)

Atlantis will pick up astronaut Scott Parazynski, dropped off on STS-84, and will deliver a joint U.S.-Russian solar dynamic energy module. As many as two spacewalks by U.S. astronauts and Russian cosmonauts will be needed to deploy the energy module outside Mir. The solar dynamic system will heat a working fluid which will drive a turbine, generating more electricity than current photovoltaic solar arrays. The Mir solar dynamic energy module will test the system for possible use on the International Space Station. In addition, developing the solar dynamic energy module will provide joint engineering experience. The astronauts and cosmonauts will also retrieve and deploy experiments outside Mir.

International Space Station

National Aeronautics and Space Administration

International Space Station
Phase I-III Overview

Introduction

The International Space Station program has three phases. Each builds from the last, and each is made up of milestones representing new capabilities. Phase I (1994-1997) uses existing assets-primarily U.S. shuttle orbiters and the Russian space station Mir-to build joint space experience and start joint scientific research. In Phase II (1997-1999), the core International Space Station will be assembled from U.S. and Russian parts and early scientific research on the station will begin. Phase III (1999-2002) includes utilization flights, during which crews of docked shuttle orbiters will conduct research inside the station's U.S. Laboratory module. Also during this phase European, Japanese, Russian, Canadian, and U.S. components will be added to expand the station's capabilities. Phase III ends in June 2002, when International Space Station assembly is completed and a planned 10 years of operations by international crews commence.

International Space Station Phase I: Shuttle and Mir (1994-1997)

PhaseI Shuttle Missions

STS-60	February 3-11,1994	Discovery	First Phase I flight
STS-63	February 3-11.1995	Discovery	Mir rendezvous
STS-71	June 1995	Atlantis	First Mir docking; pick up U.S. astronaut and 2 cosmonauts
STS-74	November 1995	Atlantis	Docking module added to Mir
STS-76	April 1996	Atlantis	Shuttle drops off U.S. astronaut at Mir
STS-79	August 1996	Atlantis	U.S. astronaut picked up; leave replacement
STS-81	December 1996	Atlantis	U.S. astronaut picked up; leave replacement
STS-84	May 1997	Atlantis	U.S. astronaut picked up; leave replacement
STS-86	September 1997	Atlantis	U.S. astronaut picked up; solar dynamic turbine energy module added to Mir

International Space Station Phase I serves as a 3-year prologue to station assembly in Phases n and ni. Phase I began on February 3,1994, when veteran cosmonaut Sergei Krikalev became the first Russian to fly on a U.S. spacecraft. On the STS-60 mission, Krikalev worked beside his U.S. crewmates in a Spacehab module in Discovery's payload bay, helping pave the way for future joint research.

The STS-63 mission built on STS-60 experience. On February 6,1995, Discovery rendezvoused with the Mir space station in rehearsal for shuttle-Mir dockings. For a time it seemed that minor leaks in Discovery's thrusters would keep shuttle and station at a preplanned contingency rendezvous distance of 400 feet. Mission control teams in Houston and Kaliningrad worked together to determine that the leaks posed no threat to Mir. The minor problem became a major builder of confidence and joint problem- solving experience for later International Space Station phases. The planned close rendezvous went ahead, with Discovery stopping 37 feet from the station. On board Discovery, cosmonaut Vladimir Titov conducted scientific research in a Spacehab module with his U.S. crewmates.

On STS-71 (June 1995) Space Shuttle Atlantis will dock with Mir for the first time. Atlantis and Mir will be linked on this and all subsequent docking missions by the orbiter docking system, which comprises a Russian docking mechanism atop a U.S. pressurized tunnel mounted in the orbiter's payload bay. The crews will conduct joint research on Mir and in a Spacelab module on Atlantis. In addition, for the first time the orbiter will be used to change a space station crew, a task which will become a routine part of its astronauts will work in the U.S. laboratory module for more than two weeks at a time while a docked shuttle orbiter provides assured Earth return capability. Utilization flights are designed to start U.S. research on the International Space Station as early as possible.

The first assembly milestone takes place on the next U.S. flight, STS-97. Endeavour's crew will berth an airlock module on Resource Node 1. The airlock will permit U.S. astronauts and Russian cosmonauts to perform routine spacewalks when the shuttle orbiter is not present (contingency spacewalks are possible as early as three- person permanent human presence capability-April 1998- by using hatches on the Russian service module). Addition of the airlock makes easier the limited number of spacewalks required to assemble the International Space Station.

Addition of new international laboratories constitutes most of the rest of the Phase III assembly milestones. The first Russian research module, similar to the science modules on the Mir space station, will be added in August 1999. Russian research modules will also be added in June 2000 and May 2001. The Japanese experiment module (JEM) and Europe's attached pressurized module will be added over the course of five assembly flights in 2000-2001. Robotic equipment inside the European laboratory will aid human experimenters, lessening demands on their time. The JEM laboratory has a special "front porch" for exposing experiments and equipment to space conditions. Europe plans to launch the attached pressurized module on its Ariane 5 rocket, while Japan is considering using its H-n rocket to launch portions of the JEM.

The U.S. will add the centrifuge module on STS-116 in October 2001. The centrifuge will for the first time permit studying the effects of sustained partial gravity on living things. For example, the centrifuge will be able to simulate a stay on the surface of Mars, where the gravitational pull is only one-third as strong as on Earth.

The largest single element of the International Space Station, the truss, grows segment by segment during Phase III, with the tenth and last segment added during the 15th U.S. assembly flight, STS-117, in January 2002. The completed truss, measuring more than 350 feet in length, will hold systems requiring exposure to space, such as communications antennas; external cameras; mounts for external payloads; and equipment for temperature control, transport around the station's exterior during spacewalks, robotic servicing, and stabilization and attitude control.

The truss will also support eight Sun-tracking solar array pairs. Combined with the arrays on the Russian segment, they will provide the station with 110 kilowatts of electrical power-twice as much power for experiments as the old Freedom design and more than 10 times as much as Sky lab or Mir.

In February 2002, a second Soyuz crew transfer vehicle will dock, enabling six people to return to Earth when the shuttle orbiter is absent and signaling achievement of six- person permanent human presence capability. Later in the month, on the STS-119 mission, Atlantis will deliver the U.S. habitation module. Once outfitted, the habitation module will provide a crew of four with dining, personal hygiene, sleep, conference, and recreation facilities during their long stays in space.

Completion of U.S. habitation module outfitting in 2002 on Shuttle mission STS-121, the 16th U.S. assembly flight, signals the end of Phase m. International Space Station will be complete in 2002 and ready to provide unprecedented space research capability in the new millennium.

NASA Facts

National Aeronautics and
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International Space Station **January 1997**

International Space Station
Russian Space Stations

Introduction

The International Space Station, which will be assembled between mid-1998 and 2003, will contain many Russian hardware elements developed in the nearly 30 years of the Russian space station program. The history of Russian space stations is one of gradual development marked by upgrades of existing equipment, reapplication to new goals of hardware designed for other purposes, rapid recovery from failures, and constant experimentation. The earliest Salyut stations were single modules, designed for only temporary operations. *Mir*, the most recent station, is a permanent facility in orbit since 1986 with a base made up of four separately-launched modules. Additional modules have been added to now total six laboratory modules and one docking module, added to allow the Space Shuttle to more easily dock with the station. U.S. Space Shuttles have been periodically docking with the Mir since July 1995. U.S. astronauts have maintained a permanent presence onboard Mir since March 1996 and that presence is expected to continue through 1998.

Prelude to Space Stations (1903-1964)

In 1903, Russian schoolteacher Konstantin Tsiolkovsky wrote *Beyond the Planet Earth*, a work of fiction based on sound science. In it, he described orbiting space stations where humans would learn to live in space. Tsiolkovsky believed these would lead to self-contained space settlements and expeditions to the Moon, Mars, and the asteroids. Tsiolkovsky wrote about rocketry and space travel until his death in 1935, inspiring generations of Russian space engineers.

Soviet engineers began work on large rockets in the 1930s. In May 1955, work began on the Baikonur launch site in central Asia. In August 1957, the world's first intercontinental ballistic missile lifted off from Baikonur on a test flight, followed by the launch of *Sputnik 1*, world's first artificial satellite, on October 4, 1957. On April 12, 1961, Yuri Gagarin lifted off from Baikonur in the *Vostok 1* capsule, becoming the first human in space.

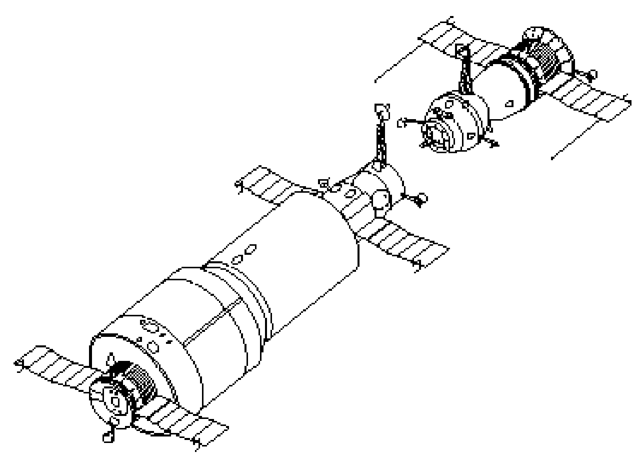
A year later, Soviet engineers described a space station comprised of modules launched separately and brought together in orbit. A quarter-century later, in 1987, this concept became reality when the *Kvant* module was added to the *Mir* core station.

First-Generation Stations (1964-1977)

First-Generation Stations

Salyut 1	civilian	1971	First space station
Unnamed	civilian	1972	Failure
Salyut 2	military	1973	First *Almaz* station; failure
Cosmos 557	civilian	1973	Failure
Salyut 3	military	1974-75	*Almaz* station
Salyut 4	civilian	1974-77	
Salyut 5	military	1976-77	Last *Almaz* station

First-generation space stations had one docking port and could not be resupplied or refueled. The stations were launched unmanned and later occupied by crews. There were two types: *Almaz* military stations and *Salyut* civilian stations. To confuse Western observers the Soviets called both kinds *Salyut*.



Salyut 1 station with Soyuz about to dock

The *Almaz* military station program was the first approved. When proposed in 1964, it had three parts: the *Almaz* military surveillance space station, Transport Logistics Spacecraft for delivering soldier-cosmonauts and cargo, and Proton rockets for launching both. All of these spacecraft were built, but none was used as originally planned.

Soviet engineers completed several *Almaz* station hulls by 1970. The Soviet leadership ordered *Almaz* hulls transferred to a crash program to launch a civilian space station. Work on the Transport Logistics Spacecraft was deferred, and the *Soyuz* spacecraft originally built for the Soviet manned Moon program was reapplied to ferry crews to space stations. *Salyut 1*, the first space station in history, reached orbit unmanned atop a Proton rocket on April 19, 1971.

The early first-generation stations were plagued by failures. The crew of *Soyuz 10*, the first spacecraft sent to *Salyut 1*, was unable to enter the station because of a docking mechanism problem. The *Soyuz 11* crew lived aboard *Salyut 1* for three weeks, but died during return to Earth because the air escaped from their *Soyuz* spacecraft. Then, three first-generation stations failed to reach orbit or broke up in orbit before crews could reach them. The second failed station was *Salyut 2*, the first *Almaz* military station to fly.

The Soviets recovered rapidly from these failures. *Salyut 3*, *Salyut 4*, and *Salyut 5* supported a total of five crews. In addition to military surveillance and scientific and industrial experiments, the cosmonauts performed engineering tests to help develop the second-generation space stations.

Second-Generation Stations (1977-1985)

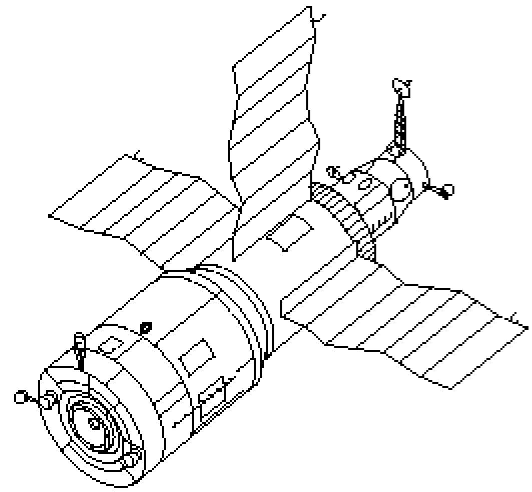
Second-Generation Stations

Salyut 6	civilian	1977-82	
Salyut 7	civilian	1982-91	Last staffed in 1986

With the second-generation stations, the Soviet space station program evolved from short-duration to long-duration stays. Like the first-generation stations, they were launched unmanned and their crews arrived later in *Soyuz* spacecraft. Second-generation stations had two docking ports. This permitted refueling and resupply by automated *Progress* freighters derived from *Soyuz*. *Progress* docked automatically at the aft port, and was then opened and unloaded by cosmonauts on the station. Transfer of fuel to the station took place automatically under supervision from the ground.

A second docking port also meant long-duration resident crews could receive visitors. Visiting crews often included cosmonaut-researchers from Soviet bloc countries or countries sympathetic to the Soviet Union. Vladimir Remek of Czechoslovakia, the first space traveler not from the U.S. or the Soviet Union, visited Salyut 6 in 1978.

Visiting crews relieved the monotony of a long stay in space. They often traded their *Soyuz* spacecraft for the one already docked at the station because *Soyuz* had only a limited lifetime in orbit. Lifetime was gradually extended from 60-90 days for the *Soyuz Ferry* to more than 180 days for the *Soyuz-TM*.



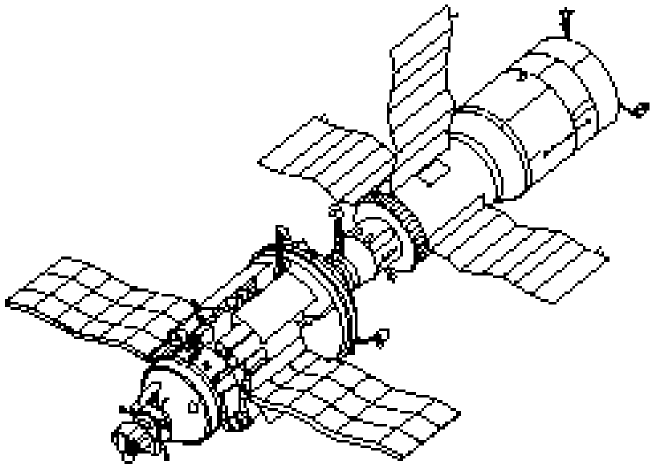
Salyut 6: 1977-1982

Salyut 6 Key Facts

- The station received 16 cosmonaut crews, including six long-duration crews. The longest stay time for a *Salyut 6* crew was 185 days. The first *Salyut 6* long-duration crew stayed in orbit for 96 days, beating the 84-day world record for space endurance established in 1974 by the last *Skylab* crew.
- The station hosted cosmonauts from Hungary, Poland, Romania, Cuba, Mongolia, Vietnam, and East Germany.
- Twelve *Progress* freighters delivered more than 20 tons of equipment, supplies, and fuel.
- An experimental transport logistics spacecraft called *Cosmos 1267* docked with *Salyut 6* in 1982. The transport logistics spacecraft was originally designed for the *Almaz* program. *Cosmos 1267* proved that large modules could dock automatically with space stations, a major step toward the multimodular *Mir* station and the International Space Station.

Salyut 7 Key Facts

- *Salyut 7*, a near twin of *Salyut 6*, was home to 10 cosmonaut crews, including six long-duration crews. The longest stay time was 237 days.
- Cosmonauts from France and India worked aboard the station, as did the first female space traveler since 1963.
- Thirteen *Progress* freighters delivered more than 25 tons of equipment, supplies, and fuel to *Salyut 7*.
- Two experimental transport logistics spacecraft, *Cosmos 1443* and *Cosmos 1686*, docked with *Salyut 7*. *Cosmos 1686* was a transitional vehicle, a transport



Salyut 7 with Cosmos 1686 attached

logistics spacecraft redesigned to serve as an experimental space station module.

- *Salyut 7* was abandoned in 1986 and reentered Earth's atmosphere over Argentina in 1991.

Third-Generation Station: *Mir* (1986-present)

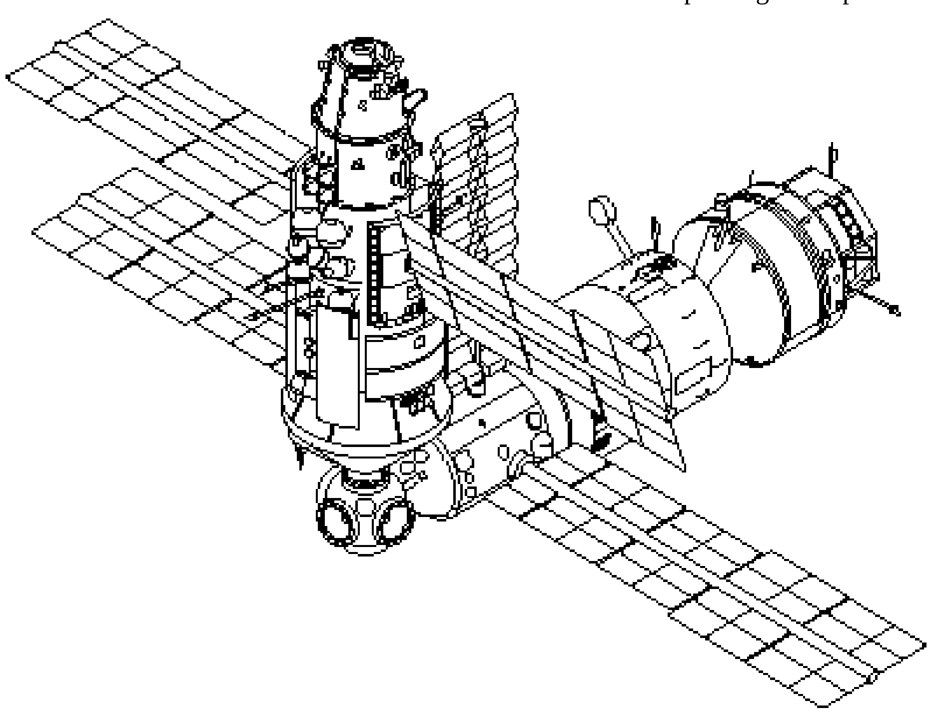
Third-Generation Station

Mir	civilian	1986-present	First permanent station

Mir is the first permanent space station. The station has been in orbit for 11 years, and staffed continuously for the past 7 years. The complex presently weighs more than 100 tons, and consists of the *Mir* core, *Kvant, Kvant 2, Kristall, Spektr, Priroda and Docking* modules. *Mir* measures more than 107 feet long with docked *Progress-M* and *Soyuz-TM* spacecraft, and is about 90 feet wide across its modules.

Mir Module Descriptions

- The *Mir* core resembles *Salyut 7,* but has six ports instead of two. Fore and aft ports are used primarily for docking. Four radial ports in a node at the station's front are for berthing large modules. The core weighed 20.4 tons at launch in 1986.
- *Kvant* was added to the *Mir* core's aft port in 1987. This small, 11-ton module contains astrophysics instruments and life support and attitude control equipment.
- *Kvant 2*, added in 1989, carries an EVA airlock, solar arrays, and life support equipment. The 19.6-ton module is based on the transport logistics spacecraft originally intended for the *Almaz* military space station program of the early 1970s.
- *Kristall*, added in 1990, carries scientific equipment, retractable solar arrays, and a docking node equipped with a special androgynous docking mechanism designed to receive spacecraft weighing up to 100 tons. Originally, the Russian *Buran* shuttle, which made one unmanned orbital test flight in 1988, would have docked with *Mir* using the androgynous unit. Space Shuttle *Atlantis* used the androgynous unit to dock with *Mir* for the first time on the STS-71 mission in July 1995. On STS-74, in November 1995, *Atlantis* permanently attached a *Docking Module* to *Kristall*'s androgynous docking unit. The *Docking Module* improved clearance between *Atlantis* and *Mir's* solar arrays on subsequent docking flights. The 19.6-ton *Kristall* module is based on the transport logistics spacecraft originally designed



Mir Space Station, 1989, with Base Block, center; Kvant module, right; and Kvant-2 module, top

to carry
Soviet soldier-cosmonauts to the *Almaz* military space stations.

- *Spektr* was launched on a Russian Proton rocket from the Baikonur launch center in central Asia on May 20, 1995. The module was berthed at the radial port opposite *Kvant 2* after *Kristall* was moved out of the way. *Spektr* carries four solar arrays and scientific equipment, including more than 1600 pounds of U.S. equipment. The focus of scientific study for this module is Earth observation, specifically natural resources and atmosphere. The equipment onboard is supplied by both Russia and the United States.
- *Priroda* was the last science module to be added to the Mir, launched from Baikonur on April 23, 1996, it docked to the space station as scheduled on April 26. Its primary purpose is to add Earth remote sensing capability to Mir. It also contains the hardware and supplies for several joint U.S.-Russian science experiments.
- The *Docking Module* was delivered and installed by shuttle mission STS-74 in November 1995, making it possible for the space shuttle to more easily dock with Mir. On STS-71 in June 1995, the shuttle docked with the *Kristall* module on Mir. However, to make that docking possible, the *Kristall* configuration had to be changed to give the shuttle enough clearance to dock. Russian cosmonauts performed a spacewalk to movethe *Kristall* module from a radial axis to a longitudinal axis, relative to Mir. After the shuttle departed, *Kristall* was moved back to its original location.

Modules for *Mir's* radial berthing ports first dock at the front port. Each module carries a manipulator arm which locks into a socket on *Mir*. The arm pivots the module into place at the proper radial port

Mir Key Facts

- An important goal of the *Mir* program has been to maintain a permanent human space presence. Except or two brief periods (July 1986-February 1987; April-September 1989), Russian cosmonauts have lived aboard *Mir* continuously for the past 9 years, demonstrating proven experience in space station operations.
- Dr. Valeri Polyakov arrived on *Mir* on *Soyuz-TM 18* in January 1994 and returned to Earth on *Soyuz-TM 20* on March 21, 1995. He lived in orbit for more than 438 days, a new world record.
- Through 1994, 16 long-duration crews lived and worked on *Mir*. In all, 19 piloted craft have docked with the station.
- Cosmonaut-researchers from Afghanistan, Austria, Britain, Bulgaria, the European Space Agency, France, Germany, Japan, Kazakhstan, and Syria have visited *Mir*. European and French cosmonauts lived on *Mir* for as long as a month. U.S. astronauts typically spend four months on the station, although U.S. astronaut Shannon Lucid has had the longest tour onboard, six months in 1996.
- More than 40 *Progress* and *Progress-M* freighters have delivered more than 100 tons of supplies and fuel to *Mir*. The improved *Progress-M* occasionally carries a capsule for returning to Earth a small quantity of experiment results and industrial products from the station. Occasionally cargo comes back to Earth with cosmonauts in *Soyuz-TM* capsules. Beginning with STS-71, the shuttle has returned to Earth more industrial products and experiment samples than is possible using the *Progress-M* capsules or *Soyuz-TM*. In addition, the shuttle can be used to return components from *Mir*'s exterior, such as solar arrays, for studying the effects of long exposure to space conditions–a capability not available with *Progress-M* and *Soyuz-TM*. Important lessons from Mir operations and Shuttle-Mir operations and research are being incorporated into the International Space Station design and planning.