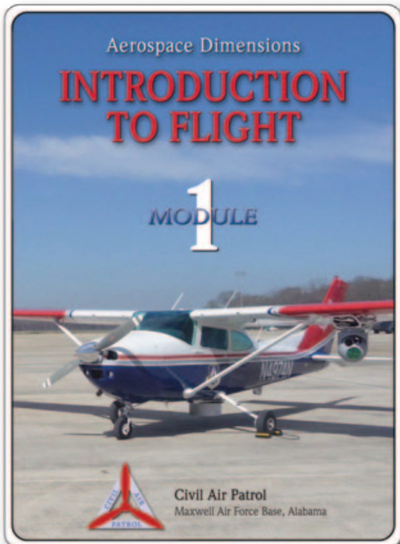
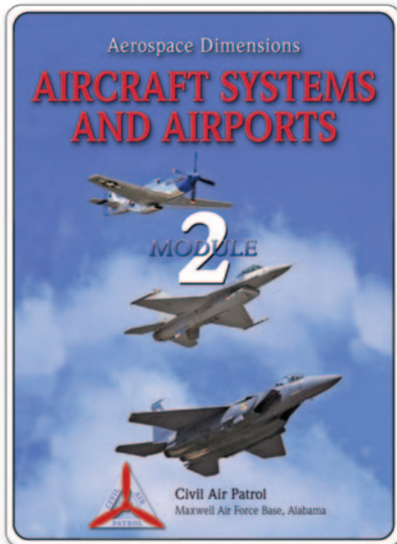
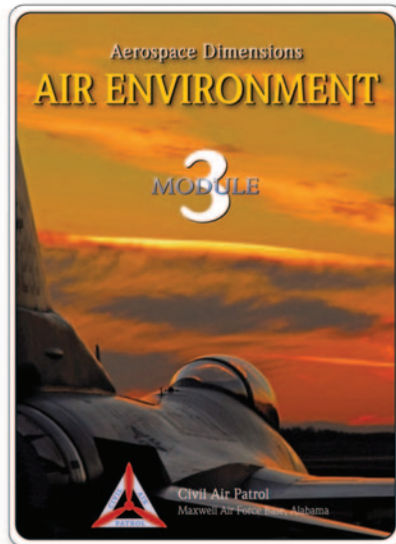
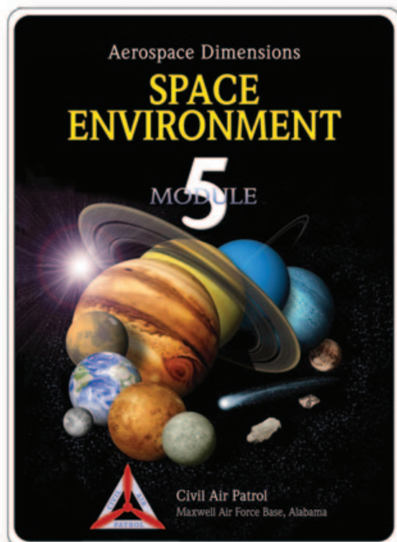
Leader Guide









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for
Aerospace Dimensions
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LEADER GUIDES
for
AEROSPACE DIMENSIONS

INTRODUCTION

A Leader Guide has been provided for every lesson in each of the Aerospace Dimensions' modules. These guides suggest possible ways of presenting the aerospace material and are for the leader's use. Whether you are a classroom teacher or an Aerospace Education Officer leading the CAP squadron, how you use these guides is up to you. You may know of different and better methods for presenting the Aerospace Dimensions' lessons, so please don't hesitate to teach the lesson in a manner that works best for you. However, please consider covering the lesson outcomes since they represent important knowledge we would like the students and cadets to possess after they have finished the lesson.

Aerospace Dimensions encourages hands-on participation, and we have included several hands-on activities with each of the modules. We hope you will consider allowing your students or cadets to participate in some of these educational activities. These activities will reinforce your lessons and help you accomplish your lesson outcomes. Additionally, the activities are fun and will encourage teamwork and participation among the students and cadets.

Many of the hands-on activities are inexpensive to use and the materials are easy to acquire. The length of time needed to perform the activities varies from 15 minutes to 60 minutes or more. Depending on how much time you have for an activity, you should be able to find an activity that fits your schedule.

If you are a classroom teacher, these guides should be very easy to use. Even if you are not a teacher, these guides should comfort you as you prepare for presenting these lessons. Please remember that these lessons will increase the aerospace knowledge of your students and cadets, as well as their knowledge of science, technology, engineering and math (STEM) subjects. STEM subjects are a major emphasis in education today and these lessons will definitely expand the students' understanding of these subjects. Additionally, these lessons help us accomplish our mission of educating and promoting aerospace education to our CAP members and the general public.

On behalf of the CAP National Headquarters Aerospace Education team, we wish you much success with these lessons.

CONTENTS

LEADER GUIDE
for
MODULE ONE

INTRODUCTION TO FLIGHT

Chapter One – Flight

LEARNING OUTCOMES – Upon completion of this chapter, the student should know:
- The relationship between Bernoulli's Principle and Newton's Laws of Motion and how they were used to develop a machine that could fly.
- The coefficient of lift and the parameters involved.
- The parts of an airplane and an airfoil.
- The four forces affecting an airplane in flight.
- The three axes, movement around those axes, and the control surfaces that create the motion.

IMPORTANT TERMS
aero - pertaining to air
aerodynamics - relating to the forces of air in motion
aeronautics - the science of flight within the atmosphere
aerospace - a combination of aeronautics and space
air - a mixture of gases that contains approximately 78% nitrogen, 21% oxygen, and 1% other gases
aircraft - any machine that is capable of flying through the air; included are ultralights, airplanes, gliders, balloons, helicopters, hangliders, and parasails
airplane - an aircraft that is kept aloft by the aerodynamic forces upon its wings and is thrust forward by a means of propulsion
airfoil - a component, such as a wing, that is specifically designed to produce lift, thrust, or directional stability
airport - a place on either land or water where aircraft can land and take off for flight
altitude - height above sea level or ground level expressed in units
aviation - the art, science, and technology of flight within the atmosphere
aviator - a person who operates an aircraft in flight
camber - the curved part of an airfoil from its leading to trailing edge
chord - a line drawn through an airfoil from its leading to trailing edge
downwash - the downward movement of air behind a wing in flight
drag - a force which slows the forward movement of an aircraft in flight
dynamic - forces in motion
gravity - the natural force pulling everything to Earth
leading edge - the front part of a wing or airfoil
lift - the upward force that opposes gravity and supports the weight of an aircraft
relative wind - the flow of air which moves opposite the flight path of an airplane
upwash - the upward movement of air ahead of the wing in flight
vortex - a spinning column of air that is created behind the wingtip as a result of air moving from an area of high pressure on the bottom to an area of low pressure on top
wind - air in motion

PRESENTATION

Attention:

- What does it mean to fly? (Ask students to give you one word that comes to mind when you say “fly” - keeping in mind the definition of fly in aviation terms.)
- Why did early dreamers fail when they tried to emulate the birds? (Wings made of feathers or light weight wood were attached to arms to test their ability to fly. The results were often disastrous as the muscles of the human arms are not like a bird’s and can not move with the strength of a bird.)
- Make a connection between Bernoulli’s principle and actual flight. (Bernoulli’s principle is involved in the theory of flight because in the air above the wings, some centrifugal potential energy will have converted into kinetic energy resulting in a faster flow of air above the wings. This faster flow of air above the wings, in line with Bernoulli’s principle, is not, however, the cause of the reduction of the air pressure, but rather a consequence of it. Bernoulli’s principle is not, therefore, the actual root cause behind the theory of flight.)
- Make a connection between Newton’s three laws of motion and actual flight. (Some facts to keep in mind regarding Newton's first law when flying at a constant altitude are: if thrust and drag are equal, aircraft holds constant airspeed; if thrust is increased, aircraft accelerates - airspeed increases; drag depends on airspeed - drag increases.When drag is again equal to thrust, aircraft no longer accelerates but holds a new, higher constant air speed. Newton’s second law explains how the velocity will change. The third law can be used to explain the generation of lift by a wing and the production of thrust by a jet engine.)
- Explain the word *force* in terms other than flight. (A force can do many things. It can make an object move. It can slow down or stop a moving object. It can also change the direction of moving objects. There are different types of forces. Two types of forces affect us all the time. These forces are gravity and friction.)
- What are the four forces acting upon an airplane in flight? (The four forces are: drag, thrust, gravity caused by weight, and lift.)
- Discuss the forces acting upon vehicles other than an airplane; like a roller coaster, or an automobile, and then compare those to an airplane. (An automobile experiences drag as the force of air resistance [friction] pushing against the front of the car while it is moving. In the airplane, the air resists the motion of the aircraft and the resistance force is called drag. In an automobile, thrust is the force that moves the car forward and comes from the engine turning the wheels. Tires on the wheels push backwards against the road as they turn, causing an equal and opposite [Newton’s third law] force which pushes the car forward. The airplane moves forward due to thrust caused by the propulsion system, and direction and speed are determined by the placement, type and number of engines, as well as the throttle setting. The automobile is affected by gravity pulling down on the automobile while Newton’s equal and opposite law applies to the opposition to gravity. An airplane is also affected by gravity and the opposite lifting force created by the wings in most instances.)
- Give an example of an axis other than those used in the study of airplanes. (In terms of astronomy, it is the imaginary line running through a planet around which it rotates.)

Motivation:
The best way to motivate students to study this module is by giving them hands-on experiences with airplanes such as starting with paper airplanes and doing the activities associated with this module. Next, have them work with simulators and finally, getting an orientation flight in an airplane. Once the student understands the vocabulary and principles of flight, the material will be more meaningful and the learning will be more permanent.

Overview:
The Wright brothers were successful because they developed an understanding of how a machine can harness the energy of the environment. They used a scientific method of testing their theories and this led to controlling the machine during a sustained, gliding flight. By adding power, the brothers then refined their machine so they could repeat their findings again and again. This was putting science to work and that is known as technology.

By weaving together the historical and the technical aspects of flying machines, the instructor can give students a clear understanding of what a flying machine is and how it works. By studying the history of flight, students will gain an appreciation for the rich heritage and incredible scientific significance of controlled, sustained powered flight.

Lesson Outline:
1. Begin by reviewing the ***Important Terms*** in the lesson and use the KWL chart to find out where the knowledge and interest levels of the group lie by completing the first two columns as a group.

What I **K**now	What I **W**ant to Know	What I **L**earned

2. Discuss the history of man's quest to fly.
   a. Introduce Icarus and his fatal effort to fly to freedom.
   b. Introduce man's first powered flight in a balloon.
3. Discuss nature and how bird's fly.
4. Introduce Bernoulli and Newton as great scientists and how their principles and laws laid the groundwork for the science of flight.
5. Upon completion of the chapter (including activities), have students fill out the last column of the KWL chart above.

6. Covered in the chapter are:
   I. Flight
      A. Gods, Angels, Prisoners, and Balloons
         a. Daedalus and Icarus
         b. Marco Polo and Chinese
         c. Montgolfier brothers
      B. Nature's Flying Machine
         a. *The Fantasy and Mechanics of Flight*, by Paul Fortin
         b. Flight of a bird
      C. Two Great Scientists Never Flew, But...
         a. Daniel Bernoulli
         b. Sir Isaac Newton
      D. A New Look At Lift
         a. Newton versus Bernoulli
         b. The theory of equal transit time
      E. The Components of a Standard Airfoil
         a. Leading edge
         b. Downwash
      F. The Wing Creates A Huge Amount Of Down Force On The Surrounding Air
         a. Coanda effect
         b. Vortex
      G. The Importance Of Angle Of Attack
         a. Increase in the angle of attack
         b. Changing the angle of attack
      H. The Four Forces Acting Upon An Airplane In Flight
         a. The two natural forces of drag and gravity
         b. The two artificial forces of thrust and lift
      I. The Three Axes
         a. Vertical, longitudinal, and lateral axes
         b. Airplanes can only move in three directions
         c. The elevator is hinged to the horizontal stabilizer
         d. The stabilator
         e. Nose right, nose left
         f. Wingtip up, wingtip down
         g. Flaps and what they are used for
      J. The Aerodynamics Of A Propeller
         a. The hub and the blade changes in angle, chord, and area
         b. Parts of the propeller blade and the aerodynamics of each
      K. UAV - Unmanned Aerial Vehicles
         a. About unmanned vehicles
         b. Other terms used to describe this new technology
      L. The Big Bird - Global Hawk
         a. Purpose
         b. Specifications

Chapter 1 activities

Activity 1 – The Soda Straw Three Axis Demonstrator

National Science Standards:
Content Standard A: Science as Inquiry
- Understanding about scientific inquiry

Content Standard B: Physical Science
- Motions and forces

Content Standard E: Science and Technology
- Understanding about science and technology

National Technology Standards:
9. Understanding of engineering design.

Background Information:
Since an aircraft operates in a three dimensional environment, aircraft movement takes place around one or more of three axes of rotation. They are called the longitudinal, lateral, and vertical axes of flight. The common reference point for the three axes is the airplane's center of gravity (CG) , which is the theoretical point where the entire weight of the airplane is considered to be concentrated. Since all three axes pass through this point, you can say that the airplane always moves about its CG, regardless of which axis is involved. The ailerons, elevator, and rudder create aerodynamic forces which cause the airplane to rotate about the three axes. The simplest way to understand the axes is to think of them as long rods passing through the aircraft where each will intersect the other two. They intersect at the center of gravity. Each of these axes is also perpendicular to the other two.

The axis that extends lengthwise through the nose and tail is called the longitudinal axis. Rotation about this axis is called roll. Drag is the force that acts along this axis, but in the opposite direction of the flight path.

The axis that extends crosswise from wingtip to wingtip is called the lateral axis. Rotation about this axis is called pitch. Side force acts along this axis.

The axis that passes vertically through the center of gravity when the aircraft is in level flight is called the vertical axis. Rotation about this axis is called yaw. Lift acts along this axis.

Movement of the ailerons produces changes in roll. Movements of the rudder produce changes in yaw. Movements of the elevator cause changes in pitch.

Resources:
1. Information on axes of an airplane and animations can be found at **http://www.allstar.fiu.edu/aero/axes31.htm**.

2. Aircraft control discussed using 1902 Wright Glider as example - **http://wright.nasa.gov/airplane/control.html**.

Activity 2 – Folding, Flying, and Controlling the Flight of a Paper Airplane

National Science Standards:

Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science

- Motions and forces

Unifying Concepts and Processes

- Evidence, models and explanation

Background Information:

The paper airplane has components just like a real airplane. The wings of the activity model have a "delta" shape. In other words, they come to a point at the nose like an arrowhead. At the back of the delta wing are control surfaces known as "elevons." This is a combination of conventional elevators and ailerons. Since the elevator makes the airplane's nose go up and down, both of the paper airplane's elevons in the up position will make the nose pitch up when it is thrown. If one elevon is down and the other is up, the actions of the ailerons are enacted and the aircraft will spiral through the air when thrown. This motion is called roll.

Additional information for questions on page 22 of the module:

1. Measuring in two different scales will help students recognize the correlation between the English and Metric systems.
2. “Wing span is the thing that really improves gliding distance (this is why sailplanes have long wings, but they have very narrow wings to try to reduce their wing area)” - Paper Airplane Tips from Ken Blackburn who holds the World’s Record for the Longest Time Aloft of a paper airplane - 27.6 seconds! Go to Ken Blackburn’s website at http://www.paperairplane.org/.
3. The distance from wing tip to wing tip is called wing span, and the distance from the front to the back of the wing is called the chord.
4. Measuring in two different scales will help students recognize the correlation between the English and Metric systems as well as the different sized units within the Metric System.
5. To locate the center of gravity for the paper airplane, students can get a piece of thread and some household tape and see if they can get the paper airplane to hang perfectly level in all directions.
6. This can be done in a group of 4-5 students. Let each fly their paper airplanes and then take the distance of the one that flew the greatest distance as your answer.
7. A stall is a condition in aerodynamics and aviation where the angle of attack increases beyond a certain point such that the lift begins to decrease. In the case of a paper airplane, it is when the nose of the airplane stops rising.
8. This answer takes experimentation and adjustments to the student’s paper airplane.
9. “Calling Your Shot” can be a fun, competitive activity to use in the classroom or as part of an Aerospace Day event.
10. Students can write the steps they would use to create a program for test flying paper airplanes.

Additional Resources:

- A great web page for different paper airplane resources is **http://www.airplane-collectible-best-net-resource.com/paper-airplane.html#Topic2**.
- A free paper airplane simulator to try distance can be found at: **http://fullscreengames.com/view/932/Paper-Airplane-Simulator.htm**.
- Folding instructions for 10 different airplanes with animated directions found at **http://www.10paperairplanes.com/**.
- Ken Blackburn (who competes in the Guinness World Book of Records for time aloft of a paper airplane) has a great website that has many science connections to building and flying paper airplanes at **http://www.paperplane.org/paero.htm**.

Activity Three – MQ-1 Predator

National Science Standards:

Content Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science
- Motions and forces

Content Standard E: Science and Technology
- Abilities of technological design

Unifying Concepts and Processes
- Evidence, models, and explanation

Background Information:

The General Atomics Aeronautical Systems MQ-1 Predator is an unmanned aerial vehicle (UAV) used primarily by the United States Air Force for reconnaissance, combat, and support roles in the most dangerous situations. These high-tech, medium altitude, long-endurance aircraft are controlled by a crew miles away from the dangers of combat. The "M" stands for multi-role, the "Q" refers to an unmanned aircraft system, and the "1" describes it as being the first in a series of aircraft systems built for unmanned reconnaissance. The remote pilot can change the behavior of the aircraft by changing certain aspects of the Predator, such as altering the pitch of the blades to increase or decrease the altitude of the plane and reach speeds of up to 135 mph. Additional lift is provided by the aircraft's 48.7 ft wingspan, allowing the Predator to reach altitudes of up to 25,000 feet. The slender fuselage and inverted-V tails help the aircraft with stability, and a single rudder housed beneath the propeller steers the craft.

Activity Four – Northrop Grumman RQ-4 Global Hawk

National Science Standards:

Content Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science
- Motions and forces

Content Standard E: Science and Technology
- Abilities of technological design

Unifying Concepts and Processes
- Evidence, models, and explanation

Background Information:
The Northrop Grumman RQ-4 Global Hawk is an Unmanned Aerial Vehicle (UAV) used in the United States Air Force and Navy as a surveillance aircraft. The Global Hawk is a high altitude endurance reconnaissance system that has been used for surveillance in missions in Afghanistan and in the Iraq war, as well as to provide persistent maritime situational awareness, contact tracking, and imagery support of various operations in the Navy's Rim of the Pacific (RIMPAC) exercise in 2006. The Global Hawk has also been used by NASA for high-altitude, long-duration Earth science missions.

The wingspan of the Global Hawk is 116 ft. 2 in., it has a service ceiling of 65,000 ft., and can attain a maximum speed of 497.1 mph. The Global Hawk is the first UAV to be approved by the FAA to file its own flight plans and use civilian air corridors in the United States with no advance notice. This potentially paves the way for a revolution in unmanned flight, including that of remotely piloted cargo or passenger airlines.

The achievements of the Global Hawk to date are: the fastest UAV flying today and it made the first trans-pacific UAV flight.

Activity Five – The Race to the Top!

National Science Standards:
Content Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science
- Motions and forces

Content Standard E: Science and Technology
- Abilities of technological design

Unifying Concepts and Processes
- Evidence, models, and explanation

Background Information:
The saying, "Tell me and I forget, show me and I remember, involve me and I understand," may be the best reason for inquiry-based learning. This activity asks students to apply the knowledge they have gained from previous experimentation (in activities 3 and 4) to successfully compete and win using the given parameters. Being able to use the scientific method to test and refine their models, students will learn the value of models and experimentation prior to the actual process. Aerospace companies use testing and models to help them with a prototype before resources are put to use to actually build the product. Students need to apply real-world applications to their learning and this activity could give students the context of functioning like a company to perfect a product for a particular use.

Contest Form for ______________________ Company
Company President: ____
Company Members: ____

____

Participant's name	Type of aircraft	Distance	Accuracy	Degrees of a circle flown	How stall was accomplished	Total points
Record averages in this row →						

Find the average for each category of competition except the Stall column and record on the bottom row.

Activity Six – Build the SR-71 Blackbird

National Science Standards:
Content Standard E: Science and Technology
- Abilities of technological design

Unifying Concepts and Processes
- Evidence, models, and explanation

Background Information:
According to Lockheed Martin, for 24 years, from 1966 through the 1980s, American leaders from field commanders to the President of the United States relied on data gathered by SR-71 Blackbird reconnaissance aircraft. Flying missions around the globe at speeds above Mach 3 and altitudes of 85,000 feet (26,000 m) or more, Blackbirds became a vital tool of international decision-making as their advanced photographic and electronic sensor systems collected intelligence for the Air Force and other federal agencies.

A congressional appropriation approved in late 1994 provided funds to return two or more SR-71s to reconnaissance flying. Subsequently, Lockheed Martin Skunk Works was awarded an Air Force contract to refurbish Blackbirds that had been kept in storage since 1990. On 15 December 2003, SR-71 #972 was put on display at the Steven F. Udvar-Hazy Center in Chantilly, Virginia.

Additional Resources:

- For videos (You Tube) of the flights of the Blackbird, go to **http://wn.com/The_last_official_flight_of_the_SR-71_Blackbird**.
- For gallery pictures of the Blackbird from NASA, go to **http://www.dfrc.nasa.gov/gallery/photo/SR-71/index.html**.

Chapter Two – To Fly By The Lifting Power Of Rising Air

LEARNING OUTCOMES – Upon completion of this chapter, the student should be able to:
- Describe how gliders use the environment to obtain altitude.
- Describe why gliders look different than powered airplanes.
- Discuss how gliders can achieve great distances without power.

IMPORTANT TERMS

altitude - the height or distance above a reference plane (The most common planes of reference used in aviation are heights above sea level and ground level. If it's above average sea level, it's referred to "MSL," or Mean Sea Level, and if it's above ground level, it's referred to as "AGL.")

convection - fluid motion between regions of unequal heating

density - mass in a given volume (example: 12 eggs in a basket)

glide ratio - a mathematical relationship between the distance an aircraft will glide forward to the altitude loss (If an aircraft has a glide ratio of twenty to one, and it is one mile above the Earth, it should glide 20 miles before landing.)

lapse rate - the average rate at which temperature decreases with an increase in altitude (The average lapse rate is 3½° F per 1000 feet increase in altitude.)

soaring - the art of staying aloft by exploiting the energy of the atmosphere

stability - the atmosphere's resistance to vertical motion

thermal - a column of air that moves upward

tow plane - usually a single-engined airplane that will pull a glider from the ground to an altitude where it can be released

wave - a waving action with strong up and down motions started as air moves across mountain ranges (Sailplane pilots can use the motion of this wave to gain altitude.)

PRESENTATION

Attention:
- How does the Sun affect the soaring conditions within the environment? (During daylight hours, the Sun heats the Earth's surface. Some areas absorb this energy while others tend to reflect it back into the atmosphere. This reflected energy heats the surrounding atmosphere and causes rising columns, or even bubbles of air, called thermals. It's these thermals that provide lift for sailplanes.)
- What is the difference between a glider and a sailplane? (A glider is an aircraft that is towed to a certain altitude and then it glides back to Earth due to the pull of gravity. A sailplane actually soars on the energy of the environment.)
- How do sailplanes differ from powered airplanes in appearance? (Use the two diagrams from pages 2 and 33 in Module 1.)
- What happens to the air above the Earth when it is heated? (The air above the Earth rises as it is heated at the surface.This air also expands and the pressure drops.)

Motivation:
Cadets or students are motivated to learn if they can connect learning to an interest or real-life experience such as a ride in an airplane. CAP offers powered orientation flights in CAP aircraft for cadets. In some areas there are even glider flights and encampments. Student pilots can solo a glider as early as age 14. Building a glider would also be a great learning experience and make the information "real" to the student.

Overview:
Soaring is motorless flight that uses a sailplane and natural atmospheric "lift" to stay aloft for periods of time. The lift needed to stay aloft can be gained by thermals, ridge lift, mountain wave, and sometimes by cloud flying, flying the edge of a cold front, or using sea breezes.

Sailplanes were used extensively in World War II to transport troops and supplies silently behind enemy lines. Sailplanes (gliders) are also used by the Air Force Academy as a first flight opportunity for their cadets. Civilian uses include recreational soaring and competition.

Lesson Outline:
1. Discuss the Important Terms and show the pictures of the powered airplane and the glider side by side to discuss how they are different.
2. Ask students what they know about the Wright brothers and their experimentation with gliders. (For more information on the Wright brothers and gliders, go to **http://www.centennialofflight.gov/essay/Wright_Bros/1900_Gliding/WR2.htm**.)
3. Explain the mathematics of glide ratio. (You may use a paper glider such as the one in Activity Seven or the CAP Paper Airplane. Have students practice and learn to throw their plane at the exact right speed and angle so that it will smoothly fly to the ground. Stretch a string, horizontally, just below chin height. Measure the height, H, of this string above the floor, perhaps H = 1.5 m. Launch your plane over this string. Note the point where the plane hits the floor. Measure the horizontal distance from the string to where the plane hit the floor, D. Compute the glide ratio, D/H. The glide ratio is the distance the glider travels through the air divided by the altitude lost. It is a measure of the glider's performance. Gliders usually have a ratio of less than 20 : 1, which means that for every foot it goes down, it goes 20 feet forward.)
4. Covered in this chapter are:
   - I. To Fly By The Lifting Power Of Rising Air
     - A. Rising air can make things fly
       - a. Factors involved in creating lift for soaring flight
       - b. How the Sun's energy effects the air
     - B. Gliders And Sailplanes - Aircraft designed to ride the rising air
       - a. The United States Air Force Academy sailplane
       - b. Parts of a sailplane
     - C. The Civil Air Patrol Cadet Glider Program
       - a. Flight Academies
       - b. Instructors

Extra Resources:
- The FAA has a glider handbook online at **http://www.faa.gov/library/manuals/aircraft/glider_handbook/media/faa-h-8083-13.pdf**.
- View a CAP cadet in glider on Youtube at **http://www.youtube.com/watch?v=a8wf**.
- CAP Soaring information is at **https://ntc.cap.af.mil/ops/dot/Glider/**.
- Read about how gliders work at **http://science.howstuffworks.com/transport/flight/modern/glider.htm**.

Activity Seven – Zia Glider

National Science Standards:
Content Standard E: Science and Technology
- Abilities of technological design

Unifying Concepts and Processes
- Evidence, models, and explanation
- Form and function

Background Information:
The glider in this activity is a high-wing design with no dihedral (the upward angle of a fixed-wing aircraft's wings) and tends to go unstable if the trim (the cuts and folds for movable parts) is not set exactly. How does the dihedral affect the flight of the airplane? Dihedral angles improve lateral stability. If a disturbance causes one wing to drop, the unbalanced force produces a sideslip in the direction of the downgoing wing. This causes a flow of air in the opposite direction to the slip. This flow of air will strike the lower wing at a greater angle of attack than it strikes the upper wing. The lower wing will thus receive more lift and the airplane will roll back into its proper position.

(A short video on You Tube that shows the dihedral angle in several model aircraft is at **http://www.youtube.com/watch?v=KvxSoPflaB0&feature=player_detailpage**.)

Resources:
- Watch an origami expert fold a double-flap glider (watch for dihedral angle) at: **http://www.wonderhowto.com/how-to-fold-double-flap-glider-paper-airplane-258029/view/**. The directions for the step-by-step process to fold this glider can be found at: **http://www.activitytv.com/paper-airplanes-for-kids**.
- NASA has a paper glider kit that was modeled after the first supersonic aircraft, the X-1. The educational brief that goes with it is entitled, The X-1 Paper Glider Kit: Investigating the Basics of Flight with a Model of the First Supersonic Aircraft. You can download it at: **http://er.jsc.nasa.gov/seh/X1_Paper_Glider_Kit.pdf**.
- There are also some great resources on the CAP AE web site. The page on gliders can be found at: **http://www.capmembers.com/aerospace_education/general/ae_lessonactivity_links/gliders.cfm**.

Chapter Three - Balloons, They Create Their Own Thermals

LEARNING OUTCOMES – Upon completion of this chapter, students should know:
• The principle of buoyancy and how this relates to the flight of a balloon.
• The components of a balloon and how each works in the flight profile.
• The history of the balloon and why it is recognized as the first powered manned flight.

IMPORTANT TERMS
altimeter - instrument to provide the height of the balloon above sea level
balloon - an aircraft that uses lighter-than-air gas for its lift, with no built-in means of horizontal control
burner - the heat source for filling the envelope with hot air
buoyancy - to rise or float on the surface of water or within the atmosphere
crown - the top of the hot air balloon's envelope
envelope - the main body of the balloon, usually made of nylon, that is filled with lighter-than-air gas
gondola - a wicker basket, hanging below the envelope, used to transport passengers and propane tanks
gore - one of several vertical panels that make up the envelope
Montgolfier - the name of the two French brothers who created the first successful, manned, hot air balloon in 1783
parachute panel - located in the top of the balloon's envelope that allows it to be deflated (When a larger area of deflation is needed, some balloons are equipped with a rip panel.)
propane - a lightweight, low carbon fuel used in hot air balloon burners
thermistor - an instrument which measures the temperature within the envelope
variometer - an instrument to determine the rate of climb or descent; sometimes referred to as vertical velocity indicator

PRESENTATION
Attention:
• Discuss the statement, "a hot air balloon creates its own thermal."(A hot air balloon uses hot air from burners to keep it aloft instead of depending on the environment to provide the warm air for lift as in the case of sailplanes.)
• Discuss the shape of a balloon and why it looks so much different from other aircraft. (The best shape for a hot air balloon is spherical. This shape holds the most air with the least amount of material and stress. Even though there are other shapes for hot air balloons, these shapes negatively affect buoyancy so they are not as efficient. The shape of most other aircraft works well because they are designed to move along at high speed therefore the aerodynamics or streamlining is important.)
• Explain the reason why propane is used as opposed to natural gas, kerosene, or even gasoline as a fuel for the burner. (Propane has the advantage of being readily available and quite inexpensive. Propane is a stable and predictable fuel, but highly volatile [burns easily]. This gas makes for a powerful flame and efficient fuel consumption. Gasoline would require on-board pressurization or a huge fuel pump [too complicated]. Compressed natural gas would need very large and heavy tanks so it can't practically be stored in its liquid state for transportation in a balloon. Kerosene is jet fuel and very explosive.)

- Discuss the various means that a balloon pilot has to control the direction of the flight of a balloon. (The pilot can control the up and down flight of the balloon by opening the propane valve to cause the balloon to rise and opening the parachute valve, by pulling on the cord, to descend. Pilots can maneuver horizontally by changing their vertical position because wind blows in different directions at different altitudes. To move in a particular direction, a pilot ascends and descends to the appropriate level and rides with the wind. Since wind speed generally increases as one gets higher in the atmosphere, pilots can also control horizontal speed by changing altitude.)

Motivation:
Showing students pictures of unusual hot air balloons or those that appear at events, such as the Balloon Festival in Albuquerque, New Mexico, are great motivators. The history and traditions involved with ballooning through time provide the stimulus for questioning and good story telling. Share the Montgolfier balloon story along with why the tradition of champagne is stilled observed after a balloon flight. Look for helpful websites in the Resources section of this chapter.

Overview:
The Wrights weren't the only famous "brothers" in the heritage of aerospace. Two French brothers, the Montgolfiers, built the first powered, manned aircraft in the 18th century. The hot air balloon is a spectacular sight and it is not only a marvel to see in flight, but also proves that "old" can be as exciting as "new" technology.

Ballooning is not only a sport, but can also be used in advertising and other commercial ventures, as well as competitions. Starting at age 14, a person can get involved in ballooning with a license, but to operate a balloon solo, the FAA requires a person to be at least 16. For the true enthusiast, there is nothing to compare with a balloon flight. Drifting over the countryside and seeing the earth below from a different perspective can be a very moving experience. Balloonists seek adventure, solitude, and a great comradeship with other balloonists. Ballooning can inspire and educate people about the air above them.

Lesson Outline:
1. Discuss the Important Terms and then have students point to and name the parts of a balloon from a picture and tell the purpose of each part.
2. Discuss the Montgolfier brothers and their contributions to aerospace.
3. Introduce buoyancy and have students describe how a balloon ascends and descends.
   A balloon buoyancy activity that is more involved can be found at
   http://space.weber.edu/harbor/Classroom/pdf/BalloonLift.pdf.
   An explanation of Archimedes Principle and buoyancy of air can be found at
   http://www.grc.nasa.gov/WWW/k-12/WindTunnel/Activities/buoy_Archimedes.html.
4. Discuss how the balloon's construction has changed over time.
5. Introduce the mathematics of the lifting power of lighter-than-air gases.
6. Discuss the instrumentation used in the cockpit of a hot air balloon.
7. Covered in this chapter are:
   - I. Balloons - They Create Their Own Thermals
     - A. Balloons were first
       - a. Early experiments
       - b. How they fly
       - c. The mathematics of a balloon's lifting power
       - d. Construction of a balloon's envelope
       - e. The basket - a balloon pilot's cockpit
     - B. Cockpit Instrumentation
     - C. Flying in a hot air balloon

Resources:

- To find out more about how hot air balloons work, go to Howstuffworks at **http://science.howstuffworks.com/transport/flight/modern/hot-air-balloon.htm**.
- View photo galleries from the Balloon Festival in Albuquerque, New Mexico, at **http://www.balloonfiesta.com/event-info/photo-galleries**.
- For the history of the Montgolfier brothers and their feats with the hot air balloon, go to Fiddler's Green (a paper model site) at **http://www.fiddlersgreen.net/models/aircraft/MontgolfierBalloon.html**.
- For the history of ballooning, go to the National Balloon Museum site at **http://www.nationalballoonmuseum.com/exhibits.cfm?exhibitid=18**.
- Find out more ballooning history, as well as some of the traditions associated with ballooning, at **http://en.wikipedia.org/wiki/Hot_air_ballooning**.
- The FAA Ballooning Flying Handbook can be found at **http://www.faa.gov/library/manuals/aircraft/media/FAA-H-8083-11.pdf**.
- The CAP AE website also contains some ideas and activities for hot air balloons. Visit **http://www.camembers.com/aerospace_education/general/ae_lessonactivity_links/hot_air_balloons.cfm**.

LEADER GUIDE
for
MODULE TWO

AIRCRAFT SYSTEMS & AIRPORTS

Chapter One – Airplane Systems

LEARNING OUTCOMES – Upon completion of this chapter, the students should be able to:
- Explain how a reciprocating engine operates.
- Identify parts of the airplane engine when viewed externally.
- Describe how a jet engine operates.
- Identify basic cockpit-mounted powerplant controls.
- Identify basic flight instruments.

IMPORTANT TERMS

combustion - the chemical process of burning
combustion chamber - an enclosed container in which fuel and air are burned for the production of energy
cycle - a recurring series of events; the airplane engine has four cycles: intake, compression, power, and exhaust
fuel - a chemical substance which is used as a source of energy; aircraft fuels include gasoline, kerosene, and propane
lean mixture - a mixture of gasoline and air in which there is less fuel and more air
magneto - an electrical generator that produces power when rotated
meter/metering - in terms of fuel for an engine, this is the process of allowing a precise amount of fuel to pass (An example would be a passageway that allows only so many molecules of gasoline to pass in a given unit of time.)
powerplant - a term which applies to the airplane engine and accessories
reciprocating - a type of engine that processes air and fuel by a back and forth movement of its internal parts
rich mixture - a mixture of gasoline and air in which there is more gasoline and less air than needed for normal combustion
stoichiometric - a ratio of fuel to air in which, upon combustion, all of the fuel is burned (In energy terms, it is 15 parts air to 1 part gasoline.)
stroke - in the example of an airplane engine, it is the movement of the piston to its limits within the combustion chamber

PRESENTATION

Attention:
- Where did the energy come from to power reciprocal and jet engines? The Sun's energy was first stored in ancient plants and animals long ago. Over millions of years, their remains were converted to fossil fuels. That stored energy is now being converted to mechanical energy by both reciprocal and jet engines.
- What are the latest developments when it comes to the energy used to power airplanes? Bio-fuels, in particular algae-based bio-fuels, are being tested and continue to be a possibility for the future. Solar power is also a direction to explore with aviation power.

Motivation:
The Wright brothers depended on the early experimenters, such as Chanute and Lilienthal, to achieve the first controlled, **powered,** and sustained flight of an airplane. Using the scientific method of questioning, researching, hypothesizing, testing, analyzing, recording results, and communicating the conclusion, the Wright brothers were able to accomplish this historic feat.

From the time of the Wright brothers to today, airplane engines and instruments have been improved using the technological advances that engineers and scientists know about from their predecessors. We have some conveniences in our everyday lives that have come as a result of this experimentation, such as GPS technology.

NOTE: If the instructor has any of the items discussed in this chapter for a display (such as old airplane engine parts, any of the engine or flight instruments, or an emergency locater transmitter), students will immediately start wondering what they are and what they might be used to do. Posters and charts showing the engine and instruments in the airplane will also be a motivator. A speaker who works on airplane maintenance could be used to speak more expertly on the items in this chapter.

Overview:
This chapter covers the airplane engine and how it operates. Comparing the types of engines and the energy conversion that takes place inside the engine are topics that help explain the "how does it work?" question. For those students who are mechanically inclined, the information in this chapter will be invaluable. For those students who may not be interested in mechanical systems, the information will be useful when learning other aspects of aviation.

Of overall interest will be the aircraft instrumentation. Students will learn about the engine and flight instruments and what they do. This chapter also covers the "glass cockpit" and future of cockpit instrumentation. Finally the new technology that made its debut for military aerospace navigation, the Global Positioning System (GPS), is discussed as becoming the primary means of navigation worldwide.

Lesson Outline:
1. Review the vocabulary words and go over the aircraft engine components. Show students how each component is related to converting energy into thrust.
2. Discuss the instrumentation in the cockpit of an airplane and if possible, show students the cockpit of a CAP Cessna to get the feel for the location and purpose of each instrument.
3. Discuss the Global Positioning System (GPS); its history, how it works, and uses (military, scientific, civil, and commercial).
4. Covered in this chapter are:
   - I. Airplane Systems
     - A. The Airplane Engine
       - a. Cylinder Arrangements
       - b. Modern Aircraft Powerplant Operation
       - c. Converting Chemical Energy to Mechanical Energy
       - d. Comparing the Reciprocating, Jet, and Rocket Engines
       - e. The Chemistry of Power
       - f. Gravity-Feed Fuel System
       - g. Fuel-Metering Carburetors
       - h. Powerplant Controls
       - i. Electrical Power to the Spark Plugs
       - j. The Electrical System
       - k. That Awesome Jet Engine

B. Engine Instruments
    a. Oil Pressure Gauge
    b. Tachometer
C. Flight Instruments
    a. The Altimeter
    b. The Vertical Velocity Indicator
    c. The Airspeed Indicator
    d. Flight Instruments - Gyro Power
D. The Glass Cockpit - A New Generation of Aircraft Instrumentation
    a. What is a “Glass Cockpit?”
    b. Future Developments
E. GPS - A New Technology For Aerospace Navigation
    a. GPS - Where Did It Start?
    b. How Does It Work?

Chapter 1 Activities

Activity 1: Gyroscope: Earthly Spinning

National Science Standards:
Content Standard B: Physical Science
- Motions and forces

Content Standard E: Science and Technology
- Understanding about science and technology

Background Information:
The gyroscope was invented in 1852 by the French experimental physicist Leon Foucault (1819-1868) as part of a two-pronged investigation of the rotation of the earth. The better-known demonstration of the Foucault pendulum showed that the plane of rotation of a freely-swinging pendulum rotated with a period that depends on the latitude of its location. His gyroscope was a rapidly rotating disk with a heavy rim, mounted in low-friction gimbals. As the earth rotated beneath the gyroscope, it would maintain its orientation in space. This proved to be hard to do in practice because the frictional forces bring the spinning system to rest before the effect could be observed.

But how does a gyroscope work? The simple answer is angular momentum. Once a gyroscope is spinning, it has angular momentum, which is a vector with both direction and magnitude.The direction of the angular momentum vector will not change unless a net torque is applied to the system. An isolated gyroscope has no choice but to "stand up," if it wants to exist in our universe. Of course in the real world of real physical gyroscopes there are always things like friction in the bearings that will slow down the rate of spin and therefore change its angular momentum.

Resources:
1. YouTube has a video of a demonstration of a gyroscope using a bicycle wheel attached to a rope found at **http://www.youtube.com/watch?v=8H98BgRzpOM**.
2. Another YouTube video gives a demonstration of the toy gyroscope and talks about the physics involved and the aerospace uses of gyroscopes at **http://www.youtube.com/watch?v=cquvA_IpEsA**.
3. A website containing all you need to know about gyroscopes can be found at **http://www.gyroscopes.org/index.asp**.

Activity 2: Geocaching

National Science Standards:
Content Standard E: Science and Technology
- Abilities of technological design

Content Standard G: History and Nature of Science
- Science as a human endeavor

Background Information:
Geocaching is a high-tech treasure hunting game played throughout the world by adventure seekers equipped with GPS devices. The basic idea is to locate outdoor hidden containers, called geocaches, and then share your experiences online. Geocaching is enjoyed by people from all age groups, with a strong sense of community and support for the environment.

Extra Resources:
1. The find it with GPS! lesson plan from TryEngineering.com is found at **http://www.tryengineering.org/lesson_detail.php?lesson=57**.
2. The official Geocaching website is at **http://www.geocaching.com/**.
3. Updated map of caches in the United States can be found at **http://www.brillig.com/geocaching/united_states.shtml**.

Chapter Two - Airports

LEARNING OUTCOMES – Upon completion of this chapter, the students should be able to:
- Explain the basic layout of a general aviation airport.
- Identify taxiway and runway signs and markings.
- Explain the role of the Federal Aviation Administration in controlling air traffic.
- Identify the different phases of the flight profile.
- List the phonetic alphabet.

IMPORTANT TERMS

ATC - air traffic control

beacon - a tower-mounted, large, rotating light located at an airport that gives pilots a guide to the type of airport and the airport's location

controlled airport - an airport with an operating control tower

control tower - a structure that houses air traffic controllers

course - the intended path of flight, which is measured in angular degrees from true or magnetic north on a compass

FAA - Federal Aviation Administration, which is the regulatory authority for all aviation

flight profile - a standardized series of steps the pilot takes from take-off to landing

FSS - Flight Service Station - a FAA facility that provides pilots with weather briefings and flight planning (opening and closure)

heading - the direction that an airplane points with respect to true, or magnetic, north including any wind displacement; based on its longitudinal axis

noise abatement - a policy set forth by a governing body that controls the noise impact upon a community surrounding an airport

ramp - the airport's "parking lot"

runway - a dedicated pathway for taking off and landing airplanes

runway heading - a number labeling a runway, which is based on corresponding degrees from true, or magnetic, north

segmented circle - a set of indicators, usually surrounding an airport's wind sock, that provide traffic pattern information to a pilot in the air

taxi - ground movement of an airplane

taxiway - a passageway between the parking area and the runways of an airport

tetrahedron - a device that gives an indication of the landing direction of an airport

traffic pattern - a rectangular virtual path above an airport that facilitates the coordination of the flow of aircraft in the air

uncontrolled airport - an airport without an operating control tower

wind direction indicators - several types of devices that give a pilot an indication of wind direction

wind sock - a fabric tube that shows which direction the wind is from

PRESENTATION
Attention:

- Ask students what an air traffic controller must know and be able to do in order to do his/her job. (Perhaps invite an air traffic controller to speak and answer questions or visit a small airport and have someone that works at the airport give them a tour of the airfield. Another option would be to show FAA videos from YouTube that discusses the job of the Air Traffic Controller - **http://videos.howstuffworks.com/faa/2103-how-air-traffic-control-works-from-the-faa-video.htm**.)
- Ask students why rules and regulations are important to aviation. (Refer to scenarios that may cause the students to think about the consequences if there were no rules and if communication becomes a problem. Since safety and regulations usually go hand-in-hand, there is a YouTube video that is humorous and demonstrates that miscommunication is sometimes the problem with radio operator and pilot - **http://www.youtube.com/watch?v=SmSAGAuvH6Y**.)
- Ask students what they think the future of FAA regulation might involve. (Such issues as the privatization of space travel, the use of unmanned aerial vehicles, and even remote controlled aircraft for hobbyists as well as model rocket launches that are becoming more and more prevalent.)

Motivation:
CAP offers orientation rides to its cadets as well as its teacher members. Senior Members are also allowed to ride in CAP aircraft in accordance with CAPR 60-1 (Civil Air Patrol Regulation 60-1). Knowing about the airport and airplane are important to the successful orientation ride. Such items as: (1) local airport layout; (2) signs; (3) traffic regulations both on the ground and in the air; (4) the flight profile; (5) safety; (6) how the airplane operates and the pre-flight experience, will make the flight both enjoyable and informational.

Overview:
This chapter covers the airport, flight profile, runway markings and lights, as well as other safety features of an airport. Airplanes are expensive and fast. The FAA and local airports know what rules should apply to keep the people safe and the aircraft in good repair and operating correctly.

Note for the Instructor: A very good resource for CAP members instructing this chapter of the Dimensions Modules is a DVD called CAP-TERS (Civil Air Patrol - Teachers Educational Remote Sensing) program. It uses satellite imagery to study airports and geography. It can be ordered by going to CAP's e-services and clicking on the AE Downloads and Resources link.)

Lesson Outline:

1. Review vocabulary words and discuss the Federal Aviation Administration - its history, purpose, and future role in air traffic management. (For background information, go to **http://www.faa.gov/about/**.)
2. Discuss the phonetic alphabet (found on page 37.) Students will work with the alphabet more in Activity Four - Hey You, Bravo-Oscar-Bravo! found on page 37.

3. Covered in this chapter are:
    I. Airports
        A. The Flight Profile
            a. Flight profile from takeoff to touchdown
            b. Federal Aviation Administration
            c. Parts of airfield
        B. Runway Markings
            a. Non precision Instrument Runways
            b. All the bells and whistles - Precision Instrument Runways
        C. Airport Signs
            a. Mandatory signs
            b. Location signs
            c. Information signs
            d. Direction signs
            e. Destination signs
            f. Runway distance remaining signs
        D. Airport Lighting
            a. Who controls airport lighting?
        E. Airport Lights
            a. Runway edge lights
            b. Threshold lights
            c. End of runway lighting
            d. Runway End Identifier Lights (REIL)
            e. In-runway lighting
            f. Approach Lighting System (ALS)
            g. Visual Approach Slope Indicator (VASI)
            h. Tri-color VASI
            i. Pulse Light Approach Slope Indicator (PLASI) and Precision Approach Path Indicator (PAPI)
            j. Taxiway lights
            k. Beacons
        F. Wind Direction Indicators
            a. Wind indicators
            b. Airport communication

Chapter 2 Activities

Activity Three – Look Down; What Are You Seeing?

National Science Standards:
Unifying Concepts and Processes
- Systems, order, and organization

Background Information:
Even though airports are varied as far as style and location, there are many features that all airports have in common - mainly due to Federal Aviation Administration rules and specifications. Another activity that can go along with this chapter is to have students build a model of an airport or do a shadowbox airport and label all of the parts. There is a NASA lesson at **http://www1.nasa.gov/pdf/205706main_Lets_Build_Table_Top.pdf** for this activity. Let students use their imaginations to choose materials to represent the different parts. Someone might even want to make an edible airport!

Resources:
1. A good resource to show students how Distance-Rate-Time figure into Air Traffic Control can be found at: **http://smartskies.nasa.gov/**. The math involved is real-world application.
2. To see aerial views of many different airports, go to **http://www.airliners.net/search/photo.search?album=7890**. Try to identify what they have in common and how they are different.

Activity Four: Hey You, Bravo-Oscar-Bravo!

National Science Standards:
Content Standard G: History and Nature of Science
- Science as a human endeavor

Background Information:
The first internationally recognized phonetic alphabet was adopted by the International Telecommunication Union (ITU) in 1927. In 1932 the ITU made some changes to the existing alphabet and was then adopted by the International Commission for Air Navigation, the predecessor of the ICAO to be used in civil aviation until World War II. It continued to be used by the International Maritime Organization (IMO) until about 1965. The alphabet has undergone a number of revisions since 1965 that were primarily aimed at making the language as universal for all countries as possible. The most recent revision was in 1993, updated again in 1996.

Verbal communications are possibly more prone to confusion and misunderstanding than those that are written. Whether the person is a controller or pilot, what the sender (or speaker) transmits is not always what the receiver (or listener) receives or hears. When a controller transmits a clearance, the clearance is "read back" by the crewmember receiving the message. The "read-back" is used to confirm that the message received was indeed the message sent. Shorter words are more often misunderstood than longer words. It seems talkers start talking before listeners start listening. Over.

Resources:

1. NASA has a website called Virtual Skies that gives information on aviation communication at **http://virtualskies.arc.nasa.gov/communication/1.html**.
2. You may choose to use walkie talkies to transmit messages to a student from another student. Make this into a treasure hunt with directions to the treasure given in the phonetic alphabet.
3. Have students do a search and find puzzle with the alphabet hidden in it. The alphabet is listed in the activity on page 37. Words can be horizontal, vertical, diagonal, and backwards. Sample below:

a	b	t	o	r	t	x	o	f	z	w	x	t	a	n	g	o	j	j
b	l	r	z	e	r	t	v	p	a	p	a	p	x	r	a	y	u	u
x	r	f	x	u	q	u	e	b	e	c	e	r	k	e	y	l	g	l
l	z	r	a	o	s	o	s	c	v	i	c	t	o	r	i	m	n	i
z	u	z	u	f	f	t	c	o	h	o	t	e	l	e	k	a	r	e
b	r	a	v	o	o	c	v	i	c	a	a	l	t	h	m	p	x	r
x	o	r	t	r	l	s	y	a	n	i	r	a	c	i	i	h	r	a
u	m	r	l	i	g	e	c	d	k	v	i	l	l	e	k	l	a	t
n	e	c	h	l	o	o	b	a	r	i	a	v	i	n	d	e	s	u
i	o	u	y	a	l	o	h	n	r	z	u	l	i	e	f	o	r	n
f	t	f	y	k	f	l	a	c	n	k	r	d	e	l	u	e	e	i
o	a	d	o	o	o	i	m	r	e	b	m	e	v	o	n	m	j	f
r	n	j	u	x	x	k	l	i	c	y	a	l	m	l	i	k	e	o
m	i	n	d	i	t	m	i	r	h	a	z	t	i	z	f	o	x	e
z	g	v	i	n	r	v	e	l	o	n	m	a	k	u	o	z	u	l
u	o	k	i	d	e	i	i	l	a	k	i	l	e	l	r	u	u	t
w	h	i	s	i	a	c	s	i	e	e	b	c	r	u	m	l	z	l
h	i	s	o	a	w	h	i	s	k	e	y	s	i	e	r	r	a	m

Answer Key for Search and Find Phonetic Alphabet Puzzle:

a	b	t	o	r	t	x	o	f	z	w	x	t	a	n	g	o	j	j
b	l	r	z	e	r	t	v	p	a	p	a	p	x	r	a	y	u	u
x	r	f	x	u	q	u	e	b	e	c	e	r	k	e	y	l	g	l
l	z	r	a	o	s	o	s	c	v	i	c	t	o	r	i	m	n	i
z	u	z	u	f	f	t	c	o	h	o	t	e	l	e	k	a	r	e
b	r	a	v	o	o	c	v	i	c	a	a	l	t	h	m	p	x	r
x	o	r	t	r	l	s	y	a	n	i	r	a	c	i	i	h	r	a
u	m	r	l	i	g	e	c	d	k	v	i	l	l	e	k	l	a	t
n	e	c	h	l	o	o	b	a	r	i	a	v	i	n	d	e	s	u
i	o	u	y	a	l	o	h	n	r	z	u	l	i	e	f	o	r	n
f	t	f	y	k	f	l	a	c	n	k	r	d	e	l	u	e	e	i
o	a	d	o	o	o	i	m	r	e	b	m	e	v	o	n	m	j	f
r	n	j	u	x	x	k	l	i	c	y	a	l	m	l	i	k	e	o
m	i	n	d	i	t	m	i	r	h	a	z	t	i	z	f	o	x	e
z	g	v	i	n	r	v	e	l	o	n	m	a	k	u	o	z	u	l
u	o	k	i	d	e	i	i	l	a	k	i	l	e	l	r	u	u	t
w	h	i	s	i	a	c	s	i	e	e	b	c	r	u	m	l	z	l
h	i	s	o	a	w	h	i	s	k	e	y	s	i	e	r	r	a	m

Chapter Three - Airport To Airport - Aeronautical Charts

LEARNING OUTCOMES – Upon completion of this chapter, the students should be able to:
- Describe the basic layout of a sectional chart.
- Explain the sectional chart legend.
- Identify latitude and longitude lines.
- Identify features such as railroads, pipelines, obstructions, and highways.
- Identify all of the information given about an airport.

IMPORTANT TERMS

cartography - the art and science of creating charts and maps
chart - a projection, usually on paper, showing a body of land and other features, such as water, that gives information, usually in the form of symbols, graphs, or illustrations
latitude - a system of lines that run parallel to the equator, also known as parallels
legend - an illustration showing the symbols that are used on charts
longitude - a system of lines, known as meridians, between the north and south poles
map - a representation of the surface of the Earth (or of the sky/space above it)
nautical mile - a unit of length that is approximately 6076 feet
projection - a method of transferring a portion of the Earth's surface onto a flat chart; the most widely used in aeronautical charts being the Lambert Conformal Conic Projection
relief - a term used to describe elevations, which is depicted by color tints, contour lines, and shading on maps
sectional - a chart specifically designed for aviation use and Visual Flight Rules, with the scale being 1 : 500,000 or approximately 8 statute miles to one inch
scale - the size of an item, or area, on a chart, compared to it in actuality
statute mile - a unit of length that is 5,280 feet
tick - a small, or abbreviated mark on a line
WAC - The World Aeronautical Chart, which covers a much larger area than the sectional chart; the scale of the WAC being 1 : 1,000,000 or approximately 16 statute miles per one inch

PRESENTATION

Attention:
- What do you need to know to read a map? In order to learn cartography or map reading, you need to know what the symbols mean and in what scale the map is written. Depending on what you are using the map for will determine what other features you should know.
- How are sectional maps used and what is important to know before reading a sectional map? These charts emphasize only landmarks and features that would be important to a pilot for navigation during flight. It is important to know when the sectional map was printed to know how current the landmarks and features are.

Motivation:
Learning to identify features and landmarks that you see from the air during an orientation flight on a sectional map makes it easier to learn the symbols and markings on these maps.

Overview:
This chapter instructs the student on mapping in general and sectional charts in particular. The sectional charts apply to pilots and aviation. The frequency of revision and details on these maps make flying safer and helps the pilot know his/her location at all times. The legend and symbols take some time to learn but if the student takes one part of the sectional at a time and concentrates on the symbols in that section only, he/she will soon be reading and understanding the sectional map and finding airports easily.

Lesson Outline:

1. Have students read and ask questions about or share prior knowledge of the vocabulary words.
2. Have some samples of local sectional charts to allow students to get some hands-on experience with the symbols and markings.
3. Have students work in small groups to take a sectional map and identify as many of the symbols that are listed on page 41 as possible.
4. Covered in this chapter are:
   I. Airport To Airport - Aeronautical Charts
      A. A System Of Global Organization
         a. Lines of longitude and latitude
         b. Ticks on sectional represents minutes
      B. Sectional Aeronautical Charts
         a. Sectional chart name, scale, north and south directions, and elevation
      C. The Legend And Its Symbols
         a. Airports
         b. Remember - uncontrolled airports are magenta, controlled airports are blue
         c. Once you've mastered cherokee, try all of the airports on the sectional
         d. Airports - time to visit one

Resources:

- NASA has an informational site for aviation navigation called "Virtual Skies" at **http://virtualskies.arc.nasa.gov/index.html**.
- List of simulator-style software resources that can be used to teach sectional charts and other maps - **http://www.flyanything.com/software_overview.htm**.
- Website that has free sectionals to print and has an airport lookup for airports in each state in the United States - **http://skyvector.com/**.
- Introduction to VFR chart symbols from the Federal Aviation Administration - **http://aeronav.faa.gov/index.asp?xml=aeronav/applications/digital/aero_guide**.

Chapter 3 Activities

Activity Five - The Final Approach!

National Science Standards:
Content Standard E: Science and Technology
- Understanding about science and technology

Content Standard G: History and Nature of Science
- Science as a human endeavor

Unifying Concepts and Processes
- Evidence, models, and explanation

Background Information:
In a real-life approach and landing of an airplane, you would need to watch the angle of approach. If the airspeed is too fast, you would bring the nose up with the elevator to slow down. If the approach is too slow, you would lower the nose. If your altitude is too high, slow down. If you altitude is too low, add power.

Runway considerations are also important. If you are landing too short or too long or you don't have a clue, try using a spot on the aircraft that you can see as you are looking at your touchdown point on the runway. Watch this spot in reference to your touchdown point on the runway. If your spot is moving away from the touchdown point, down the runway away from you, then you will land beyond your touchdown point. If your spot is moving towards you from the touchdown point then you will land short. In order for this system to work, you must be maintaining a constant airspeed on the approach.

Landing airplanes is like riding a bicycle. No one can really "teach" you how to do it, even if you are in an airplane with an instructor at your side. The instructor can give you all kinds of advice and input, but the "feel" is an acquired thing. It boils down to practice, practice, practice.

When trying to land the aircraft in this activity, you also need to practice. Get the feel for the control of the joystick and how different movements effect the landing of the airplane. If the target is moved closer or farther away from the pilot with the joystick, you can get the feeling of shorter or longer landings.

Extensions:
This activity simulates the final approach and landing of an airplane. The conditions may be adjusted for more skill problems like using Impaired Vision goggles to simulate a pilot that has less than ideal landing vision. Consider giving the students scenarios that would make them problem solve the approach and landing in that situation (such as windshear or thunderstorms or coming in too fast, etc.)

Resources:
1. Video on YouTube that shows final approach and landing procedure - **http://www.youtube.com/watch?v=S1fCohTldGY**.

LEADER GUIDE
for
MODULE THREE

AIR ENVIRONMENT

Chapter One - The Atmosphere

LEARNING OUTCOMES – Upon completion of this chapter, the students should be able to:
- Describe the composition of the atmosphere.
- Describe the standard temperature lapse rate.
- Identify the four layers of the atmosphere.

IMPORTANT TERMS

ionosphere - a region of the atmosphere where electrons are gained or lost
lapse rate - the rate of decrease with an increase in height for pressure and temperature
mesosphere - a layer of the atmosphere extending from about 30 to 50 miles
ozonosphere - a region of the atmosphere where ozone is created
stratosphere - a layer of the atmosphere extending from the tropopause to about 30 miles
thermosphere - a layer of the atmosphere extending from 50 to about 300 miles
tropopause - boundary between the tropopause and the stratosphere
troposphere - first layer of the atmosphere where most of the Earth's weather occurs

PRESENTATION

Attention:
- What are the regions of the atmosphere and what distinguishes each?
  (Answer: Troposphere - most of the atmosphere is contained in this region as well as the vast majority of weather, clouds, storms, and temperature differences; stratosphere - little weather exists in this region and the air remains stable although certain types of clouds occasionally exist in it; mesosphere - at first, the temperature increases but then it decreases at the top of the region; thermosphere - the temperature increases again depending on solar activity.)

Motivation:
Understanding the layers of the Earth's atmosphere and how they are related helps students learn why they are important and how to protect and preserve them. Also, if you look at what happens or picture in your mind what is going on in each layer, your comprehension will be more complete. Such pictures as weather occurring and commercial and general aviation airplanes flying in the troposphere; jet aircraft and high-altitude balloons in the stratosphere; meteors burning up in the mesosphere; and the Space Shuttle orbiting in the thermosphere.

Overview:
In this chapter, you will examine the Earth's blanket or buffer between the surface of the Earth and Space. How each layer plays a part in the Earth's ability to sustain life is the reason we study about the atmosphere.

Lesson Outline:
1. Students should become familiar with the Important Terms in the beginning of this chapter.
2. Have students research what is happening in the news concerning any of the four regions of the Earth's atmosphere and share with the class.
3. Have students find pictures for a display of what happens in each region of the atmosphere.
4. Covered in this chapter are:
   I. The Atmosphere
      A. Composition Of The Atmosphere
         a. Oxygen
         b. Nitrogen
         c. Argon and other gases
      B. Atmospheric Layers
         a. Troposphere
            1. Lapse rate
            2. Tropopause
         b. Stratosphere
         c. Mesosphere
         d. Thermosphere

Resources:
1. Additional activities on Atmosphere and Weather provided by National Earth Science Teachers Association's "Windows to the Universe" website at **http://www.windows2universe.org/php/teacher_resources/activity.php#3**.
2. Information and quizzes about the atmosphere at: **http://www.geography4kids.com/files/atm_intro.html**.
3. View incredible photos of earth, earth's atmosphere and weather at **http://science.nationalgeographic.com/science/earth/earths-atmosphere**.
4. Site with information, powerpoints, and games about the atmosphere and weather at (disregard the ads) **http://science.pppst.com/weather/atmosphere.html**.

Chapter Two – Air Circulation

Learning Outcomes - Upon completion of this chapter, the students should be able to:
- Describe how the Sun heats the Earth.
- Describe the Earth's rotation and revolution, and its effect on the Earth's seasons.
- Explain the various theories of circulation.
- Describe Coriolis Force.
- Define the jet stream.

IMPORTANT TERMS

autumnal (fall) equinox - the time when the Sun's direct rays strike the equator resulting in day and night of equal length, usually on September 22nd or 23rd

Coriolis Force - winds associated with the Earth's rotation that deflect a freely-moving object to the right in the Northern Hemisphere

doldrums - a global area of calm winds

global winds - the world-wide system of winds that transfers heat between tropical and polar regions

jet stream - a strong wind that develops at 30,000-35,000 feet and moves as a winding road across the U.S. generally from the west to the east

polar easterlies - global winds that flow from the poles and move to the west

prevailing westerlies - global winds that move toward the poles and appear to curve to the east

radiation - the method by which the Sun heats the Earth

revolution - the movement of the Earth revolving around the Sun; full revolution about 365 days

rotation - how the Earth turns (rotates) on its axis at an angle of 23.5° while it revolves around the Sun; full rotation 24 hours

summer solstice - the longest day when the Sun is at its northernmost point from the equator in the Northern Hemisphere, usually on June 21st or 22nd

trade winds - a warm steady wind that blows toward the equator

vernal (spring) equinox - the time when the Sun's direct rays strike the equator resulting in day and night of equal length, usually on March 21st or 22nd

winter solstice - the shortest day when the Sun is the farthest south of the equator and the Northern Hemisphere, usually on December 21st or 22nd

PRESENTATION

Attention:

- How does the Earth rotating in space effect air circulation over the surface? (Answer: The movement of a body tends to cause movement of the air around it. Depending on the location on Earth, this movement can be different at the equator compared to the poles)
- How does the difference of materials on Earth effect air circulation? (Answer: The fact that the Earth is made of land and water changes the heating and cooling of the air above them. Elevation also contributes to the difference of the movement of air over the surface of the Earth and pressure zones.)

Motivation:

Give students this statement and ask them if it is true or false and how they know: ***The water in a sink (or toilet) rotates one way as it drains in the northern hemisphere and the other way in the southern hemisphere. Called the Coriolis Effect, it is caused by the rotation of the Earth.***

(Answer:The direction of rotation in draining sinks and toilets is **NOT** determined by the rotation of the Earth, but by rotation that was introduced earlier when it was being filled or subsequently being disturbed (say by washing). The rotation of the Earth does influence the direction of rotation of large weather systems and large vortices in the oceans, for these are very long-lived phenomena and so allow the very weak Coriolis force to produce a significant effect, with time.)

An activity you might use to explain the Coriolis effect is:

- Use a sheet of 18" by 24" poster board along with a different color marker for each side (example: red on one side and blue on the other) for each group of students (4 to a group).
- You would need wall space for them to work.
- Ask students to predict in which direction a straight line will turn when drawn from top to bottom on a page spinning clockwise. Then ask them to predict which direction the line will turn when drawn in the same direction if the paper is rotating in a counterclockwise direction.
- Have students get in groups of 4 and gather the supplies from above.

- Each group should move to an empty wall space or blackboard / whiteboard space.
- One student in each group should hold the paper at the center using either a finger or capped ink pen firmly enough so that it does not drop but loose enough so that another student can spin the paper around the center point on the paper.
- Have another student in the group practice turning the paper clockwise at a steady rate.
- While the paper is being turned, another student should practice drawing a line from top to bottom on the paper with the non writing end of the marker.
- After the students have synchronized their movement and are comfortable, have the student with the marker turn the marker to the writing position and while the paper is spinning, draw a line downwards from the top to the bottom of the paper.
- The last student in the group should label the sheet with the direction of travel and the start and end points of the line. Also, names of the students in the group can be added.
- Now, have the students turn their paper over on the other side and go through the same procedure but this time the direction of the spin should be counterclockwise.
- When this activity is completed, ask the students if their predictions agreed with their results.
- Ask the students to describe the lesson and write a paragraph or two describing how the procedure modeled the effect of the spin of the Earth on the ocean and air masses.
- Ask the students which of the two directions represented movement related to the Coriolis effect in the Northern Hemisphere. (Answer: The Coriolis effect causes an object to be deflected to the east or right in the Northern Hemisphere and to the west or left in the Southern Hemisphere. The paper turning counterclockwise represented the Northern Hemispheric direction.)

Overview:
This chapter discusses how the Sun heating the Earth is the beginning for our various weather conditions. The differences in the surfaces of the Earth and how fast they are heated and cooled, causes temperature and pressure differences. The movement of the Earth causes the air to move over the surface of the Earth. All of these conditions help create and move weather systems.

Lesson Outline:
1. Discuss the vocabulary words.
2. Have students read each section and give a short summary of what they read.
3. Ask students how the factors for weather discussed in this chapter are evident where they live.
4. Covered in this chapter are:
    - I. Air Circulation
        - A. Radiation
            - a. Heat from the Sun
            - b. Warm air versus cool air
        - B. Rotation and Revolution
            - a. Solstice (Winter and Summer)
            - b. Equinox (Fall and Spring)
            - c. Coriolis Force or effect
        - C. Circulation and Global Winds
            - a. Trade winds
            - b. Doldrums
            - c. Prevailing westerlies and polar easterlies
        - D. Jet Stream
            - a. What it is and where it is for the United States
            - b. Importance to pilots

Chapter 2 Activities

Activity One - Absorbing Heat

National Science Standards:
Content Standard A: Science as Inquiry
- Understanding about scientific inquiry

Content Standard B: Physical Science
- Properties and changes of properties in matter
- Transfer of energy

Unifying Concepts and Processes
- Constancy, change, and measurement

Background Information:
Water is a slow conductor of heat, thus it needs to gain more energy than the soil in order for its temperature to increase. On the other hand, soil loses its heat much faster. Earth's oceans are far more important than the land as a source of the heat energy which drives the weather. Not only do the oceans cover more than 2/3 of the Earth's surface, they also absorb more sunlight and store more heat. Additionally the oceans retain heat longer. The Sun's rays also penetrate the oceans to a depth of many meters, but only heat up the top layer soil. Water has to lose more energy than the soil in order for the temperature to decrease.

Extra Resources:
1. Another activity that focuses on radiation. Students can investigate how different surfaces absorb heat and apply their experience with the surfaces to interpret real-world situations. Activity can be found at **http://www.ucar.edu/learn/1_1_2_5t.htm**.

Activity Two - Warm Air Rising

National Science Standards:
Content Standard B: Physical Science
- Properties and changes of properties in matter
- Transfer of energy

Background Information:
Hot air rising and cold air sinking is what drives earth's energy. These air currents also create storms, including hurricanes and tornadoes. Hot air rising and colliding with cold air is what creates thunderstorms. Strong up-drafts of warm air create cumulus clouds.

Extra Resources:
1. Video that shows an experiment that forms a cloud in a bottle at **http://vimeo.com/13582249**. Clouds form when water vapor cools down. Warm moist air in the atmosphere rises and the pressure reduces as it goes higher. As pressure reduces it gets colder. Eventually the water vapor cools enough to form clouds.

Activity Three - Coriolis Force

National Science Standards:
Content Standard B: Physical Science
- Motions and forces

Unifying Concepts and Processes
- Evidence, models, and explanation

Background Information:
The effect of the Coriolis force is an apparent deflection of the path of an object that moves within a rotating coordinate system. The object does not actually deviate from its path, but it appears to do so because of the motion of the coordinate system. In a system such as Earth with the object being the winds or air surrounding the Earth, the amount of deflection the air makes is directly related to both the speed at which the air is moving and its latitude. Therefore, slowly blowing winds will be deflected only a small amount, while stronger winds will be deflected more. Likewise, winds blowing closer to the poles will be deflected more than winds at the same speed closer to the equator. The Coriolis force is zero right at the equator. This activity demonstrates the Coriolis force on a spinning globe.

Resources:
1. A website with information and a video demonstrating the Coriolis force by rolling a ball across a merry-go-round is at **http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/fw/crls.rxml**.

Activity Four - Wing Currents

National Science Standards:
Content Standard D: Earth and Space Science
- Structure of the earth system

Content Standard G: History and Nature of Science
- Science as a human endeavor

Unifying Concepts and Processes
- Evidence, models, and explanation

Background Information:
Air flowing across a mountain range usually rises relatively smoothly up the slope of the range, but, once over the top, it pours down the other side with considerable force, bouncing up and down, creating eddies and turbulence and also creating powerful vertical waves that may extend for great distances downwind of the mountain range. This phenomenon is known as a mountain wave. Problems that pilots face with mountain waves and air currents over mountains are: vertical currents of air that could force the airplane to the ground; wind shear where the wind speeds vary dramatically; altimeter error where the increase in wind speed results in a decrease in pressure that affects the accuracy of the altimeter; and icing where the temperature varies from crest to trough of the mountain wave.

Extra Resources:
1. Video with background music “Flying High” shows take-off, flying over mountains, and landing at **http://vimeo.com/14758217**.
2. “The Top Ten Practical Considerations for Mountain Flying” from AV Web (World’s Premier Independent Aviation News Resource) is at **http://www.avweb.com/news/airman/184273-1.html**.

Chapter Three - Weather Elements

LEARNING OUTCOMES – Upon completion of this chapter, the students should be able to:
- Define wind.
- Describe the Beaufort Scale.
- Define heat.
- Explain what temperature is and how it can be expressed on scales.
- Describe what wind chill is and what it does.
- Describe how a microburst can affect a plane's flight.

IMPORTANT TERMS:
advection - lateral transfer of heat
atmospheric pressure - the weight of all of the atmosphere's gases and molecules on the Earth's surface
Beaufort Scale - a scale for estimating wind speed on land or sea
conduction - heating by direct contact
convection - heat transfer by vertical motion
heat - the total energy of all molecules within a substance
microburst - a downdraft or down burst phenomenon that creates unstable air and thunderstorm turbulence
radiation - heat transferred by the Sun
temperature - a measure of molecular motion expressed on a man-made scale
wind - a body of air in motion
wind chill - temperature and wind speed used to explain how cold it feels

PRESENTATION
Attention:
- What is wind and how can we tell its strength? (Answer: Wind is a body of air in motion and we can tell how strong it is by using a scale called the Beaufort Scale and an instrument called an anemometer.)
- How does wind affect flying? (Answer: Airplanes take off into the wind because the wind gives the plane more lift. If crosswinds are too high, planes can't takeoff or land safely. A strong tailwind will increase a plane's air speed without using any more fuel. Microbursts, which are downdrafts or updrafts, can be very dangerous to flying an airplane.)
- What units do we use to measure temperature and how is it important to flying? (Answer: Temperature is measured in units called Fahrenheit or Celsius. Warmer temperatures result in longer acceleration times to attain proper takeoff speeds. The pilot's health can also be affected by extreme temperatures.
- What instrument is used to measure atmospheric pressure and how does air pressure and temperature affect the flight of an airplane? (Answer: A barometer is used to measure air pressure. Air pressure and temperature are used to find the air's density. When the air's density is low, airplanes need longer runways to take off and land and they don't climb as quickly as when the air's density is high.

Motivation:
Ask students how weather elements such as wind, temperature, and pressure affect a pilot and his airplane. These and other weather elements affect aircraft in three ways (according to the Federal Aviation Administration or FAA): reducing visibility, creating turbulence, and reducing aircraft performance. Ask students to share any experiences, as an airplane passenger (commercial or other), that made the flight uncomfortable. Such conditions as turbulence or bumpiness, ear problems, unexpected bad weather, and hard landings can be discussed as having a weather connection.

Overview:
In this chapter, students will learn about the main weather elements that can affect the flight of an airplane: wind, temperature, and pressure.

Lesson Outline:
1. Review the vocabulary words with students.
2. Ask students to tell something they know about the following words as relates to weather: wind, temperature, and pressure.
3. Read the chapter or have students read ahead of time to discuss.
4. Covered in this chapter are:
    - I. Weather Elements
        - A. Wind
            - a. Knots
            - b. Beaufort Scale
            - c. Wind chill index
            - d. Microburst
        - B. Temperature
            - a. Convection and conduction
            - b. Temperature scales
            - c. Effects on aircraft
        - C. Pressure
            - a. Air pressure measurement
            - b. Instruments to measure air pressure

Extra Resources:
1. Wind chill calculator at **http://broadcast-weather.net/wind-chill-calculator.html**.
2. Federal Aviation Administration (FAA) - "General Aviation Pilot's Guide to Preflight Weather Planning, Weather Self-Briefings, and Weather Decision Making" at **http://www.faa.gov/pilots/safety/media/ga_weather_decision_making.pdf**.

Chapter 3 Activities

Activity 5: Wind Gauge

National Science Standards:
Content Standard B: Physical Science
- Motions and forces

Content Standard E: Science and Technology
- Abilities of technological design

Content Standard F: Science in Personal and Social Perspectives
- Science and technology in society

Unifying Concepts and Processes
- Evidence, models, and explanation
- Constancy, change, and measurement

Background Information:
A device used to measure the speed of the wind is called an anemometer, or wind gauge. In its most basic form, it is a cup anemometer, consisting of four hemispherical shafts mounted horizontally on a vertical shaft. Wind gauges can be separated into two broad groups: hand-held and fixed. A hand-held anemometer will typically only display the current wind strength. A fixed wind gauge measures the wind speed at a given location in addition to providing historical measurements, such as maximum gust and average wind speed. This activity shows students how to make a simple wind gauge.

Extra Resources:
1. Lesson about wind shear and turbulence at **http://www.aos.wisc.edu/~aos152/lesson11/content.html**.
2. Lesson and activities on wind at **http://www.weatherwizkids.com/weather-wind.htm**.
3. Wind gauge activity at **http://www.grc.nasa.gov/WWW/k-12/problems/Lorri/wind_gauge_act.htm#RETURN**.

Activity 6: Convert Temperatures

National Science Standards:
Unifying Concepts and Processes
- Constancy, change, and measurement

Background Information:
The two temperature scales used to measure the amount of heat in the air are Fahrenheit and Celsius. The degree Celsius (°C) scale was devised by dividing the range of temperature between the freezing and boiling temperatures of pure water at standard atmospheric conditions (sea level pressure) into 100 equal parts - 0°C is the freezing point of water and 100°C is the boiling point of water. The degree Fahrenheit (°F) non-metric temperature scale was devised and evolved over time so that the freezing and boiling temperatures of water are whole numbers, but not round numbers as in the Celsius temperature scale - 32°F is the freezing point and 312°F is the boiling point. The U.S. is the only nation that continues to use Fahrenheit temperatures for shelter-level (surface) weather observations. However, as of July 1996 all surface temperature observations in National Weather Service METAR/TAF (known as Meteorological Terminal Aviation Routine Weather Report or Meteorological Aviation Report) reports are now transmitted in degrees Celsius.

Extra Resources:

1. Website with information from the U.S. Metric Association (USMA) at **http://lamar.colostate.edu/~hillger/temps.htm**.
   A memory aid that helps students remember what our idea of cold, warm and hot are currently in the Fahrenheit when converted to Celsius would be:

   When it's zero it's freezing,
   when it's 10 it's not,
   when it's 20 it's warm,
   when it's 30 it's hot!
2. More about temperature scales and math from PBS at **http://www.pbs.org/teachers/mathline/concepts/weather/activity1.shtm**.

Activity Seven - Homemade Thermometer

National Science Standards:

Content Standard B: Physical Science

- Structure and properties of matter

Unifying Concepts and Processes

- Evidence, models, and explanation
- Constancy, change, and measurement

Background Information:

The activity shows students how to build a simple homemade thermometer to determine heat or cold. Thermometers are used by weather stations to determine the outside temperature. Thermometers are basic weather instruments used to measure air temperature. It also measures atmosphere heat. Temperature is measured by gauging movement of molecules that make up the atmosphere. The faster they move, the more the temperature increases.

Extra Resources:

1. Information and activities on temperature at **http://www.weatherwizkids.com/weather-temperature.htm**.
2. How Does A Thermometer Work? website with information and links at **http://www.energyquest.ca.gov/how_it_works/thermometer.html**.

Activity Eight - Cricket Thermometer

National Science Standards:

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard C: Life Science

- Regulation and behavior

Background Information:
Nature provides other clues to the liklihood of certain weather:
- Wandering or Grazing Cows = Weather will be fair.
- Huddled Cows = Storming is likely. Cows huddle on the ground to protect each other in a storm.
- In the summer, swallows will fly close to the ground before a rain. Swallows eat bugs, and the bugs fly lower in the lighter air that precedes a storm.

Remember, all these forecasting signs are just nature reacting to subtle atmospheric changes that take place before the arrival of the not-so-subtle changes that we call weather.

Extra Resources:
1. Measure the humidity in the air with a pine cone at **http://www.museumoftheearth.org/files/Outreach/tciyb/Pinecones**.

Chapter Four - Moisture and Clouds

LEARNING OUTCOMES – Upon completion of this chapter, the students should be able to:
• Describe the condensation process.
• Describe how saturation occurs.
• Define dew point.
• Define what precipitation is and give some examples.
• Define fog.
• Define turbulence.

IMPORTANT TERMS
condensation - the process of converting water vapor to liquid
dew point - the temperature at which the air becomes saturated with water vapor
fog - tiny droplets of liquid water at or near the surface of the land or water
humidity - amount of water vapor in the air
precipitation - general term given to various types of condensed water vapor
relative humidity - amount of water vapor in the air compared to its water vapor capacity at a given temperature
saturation - the condition of a parcel of air holding as much water vapor as it can at the air temperature at that time
water cycle - continuous movement of water as it circulates between the Earth and its atmosphere

PRESENTATION
Attention:
• How are clouds formed? (Answer: Three ingredients are necessary for clouds to form:
  1. Moisture - There must be sufficient water vapor in the air to build a cloud.
  2. Cooling air - The air temperature must decrease enough for water vapor to condense.
  3. Condensation nuclei - Tiny particles, invisible to the human eye, such as dust, dirt, and pollutants, provide surfaces on which water molecules can gather and condense into water droplets.)
• What types of clouds are dangerous for pilots and airplanes? (Answer: To pilots, the cumulonimbus cloud is perhaps the most dangerous cloud type. It appears individually or in groups and is known as either an air mass or thunderstorm.

Motivation:
Relate clouds and weather to flying:
1. Ask students what kind of clouds jet aircraft leave behind in the air when flying. The answer to that is: Contrails form when hot humid air from jet exhaust mixes with environmental air of low vapor pressure and low temperature. The mixing is a result of turbulence generated by the engine exhaust. 2.Ask students “What do you think of the idea of flying around in clouds? I mean, it's just water vapor, right?” According to statistics, weather accounts for a quarter of airplane accidents and 40 percent of fatalities. Clouds are indicators of weather and to stay safe, pilots watch for indicators such as clouds as well as receive current weather conditions from the weather service.

Overview:
This chapter will help students understand the water cycle, how clouds form, and explain the different types of clouds.

Lesson Outline:

1. Have students relate the vocabulary words in this chapter to a weather report. Have them use as many of the words as possible in a ficticious weather report.
2. Have students explain the water cycle and how moisture in the air affects weather.
3. Give each student a slip of paper with a cloud formation written on it and have them research what the cloud formation indicates about the weather and how it might be important for a pilot to know this information.
4. Covered in this chapter are:
   - I. Moisture and Clouds
     - A. Moisture
       - a. Saturation
       - b. Humidity and relative humidity
     - B. Fog
     - C. Precipitation
       - a. Rain
       - b. Snow and ice
     - D. Water cycle
       - a. Movement of water between the Earth and the atmosphere
       - b. Three basic cloud forms
       - c. Ten basic cloud types
     - E. Cloud Classification
       - a. High-level clouds
       - b. Mid-level clouds
       - c. Low-level clouds
     - F. The Lenticular Clouds - Forming On One Side - Going Away On The Other Side!
       - a. Altocumulus
       - b. "Wave lift"

Extra Resources:

1. More information about clouds - **http://www.weatherwizkids.com/weather-clouds.htm**
2. The types of clouds are explored in this interactive and visually stimulating activity. Low, middle, and high level clouds are presented by NASA and S'COOL (Student Cloud Observations Online) giving a complete guide to cloud identification: **http://asd-www.larc.nasa.gov/SCOOL/tutorial/clouds/cloudtypes.swf**
3. Animated water cycle diagram: **http://earthguide.ucsd.edu/earthguide/diagrams/watercycle/**

Chapter 4 Activities

Activity 9: Dew Point

National Science Standards:
Content Standard B: Physical Science
- Properties and changes of properties in matter

Content Standard G: History and Nature of Science
- Nature of science

Unifying Concepts and Processes
- Constancy, change, and measurement

Background Information:
The dew point is defined as the temperature at which water vapor begins to condense. Condensation is the change of water from its gaseous form (water vapor) into liquid water. Condensation happens when air cools to the dew point temperature, and the water vapor in the air changes to liquid. Usually the air high up in the sky is cooler than on the ground, so that is where condensation happens. Condensation up in the sky makes clouds.

Dew points indicate the amount of moisture in the air. The higher the dew points, the more moisture there is in the air at a given temperature.

When the dew point temperature and air temperature are equal, the air is said to be saturated (meaning holding as much water vapor as it can). Dew point temperature is NEVER GREATER than the air temperature. Therefore, if the air cools, moisture must be removed from the air and this is accomplished through condensation. This process results in the formation of tiny water droplets that can lead to the development of fog, frost, clouds, or even precipitation.

Resources:
1. Various meteorology experiments at **http://www.theweatherprediction.com/experiments/**.
2. Ground School information about weather at **http://airplanegroundschools.com/Weather/Theory**/.

Activity 10: Comfort and Humidity

National Science Standards:
Content Standard B: Physical Science
- Properties and changes of properties in matter

Unifying Concepts and Processes
- Evidence, models, and explanation

Background Information:
So how does humidity affect the way an airplane flies? Humidity affects the way an airplane flies because of the change in pressure that accompanies changes in humidity. As the humidity goes up, the air pressure for a given volume of air goes down. This means the wings have fewer air molecules to affect as they are pushed through the airmass. Fewer molecules = less lift.

The other problem is that jet engines do not like humidity either. Jet engines are built for cold, dry air, and humid air has fewer oxygen molecules to burn per unit volume. Therefore the engine combusts a little bit less and puts out slightly less thrust. There are four factors that decrease the performance of a jet airplane - heavy, hot, high, and humid. Notice that three of those factors all have the net effect of lowering the density of the air.

Extra Resources:

1. A high school weather lesson plan with interactive applets - "Atmospheric Moisture as a Tool for Locating the Jet Stream" at **http://weather.about.com/od/lessonplanshighschool/a/jetstreamlesson.htm**.
2. A review science game on dew point and relative humidity using basketball at- **http://www.sciencereviewgames.com/srg/games/hs.php?id=13**.

Activity 11: Making Fog

National Science Standards:

Content Standard B: Physical Science
- Properties and changes of properties in matter

Content Standard D: Earth and Space Science
- Structure of the earth system

Unifying Concepts and Processes
- Evidence, models, and explanation

Background Information:

Fog is a cloud on or near the ground comprised of either water droplets or ice crystals. Fog forms when there is additional moisture in the air near the ground or when air cools to its dew point. Fog affects both visibility and ceiling height when flying an airplane.

Extra Resources:

1. Fog facts and trivia from the Farmer's Almanac at **http://www.farmersalmanac.com/weather/2006/11/10/fog-facts/**.
2. Fog science fair project at **http://www.sciencebuddies.org/science-fair-projects/project_ideas/Weather_p028.shtml**.

Activity 12: Measuring Precipitation

National Science Standards:

Content Standard B: Physical Science

Properties and changes of properties in matter

Content Standard D: Earth and Space Science

Structure of the earth system

Unifying Concepts and Processes

Constancy, change, and measurement

Background Information:

When cloud particles become too heavy to remain suspended in the air, they fall to the earth as precipitation. Precipitation occurs in a variety of forms; hail, rain, freezing rain, sleet or snow.

Some statistics concerning rain are: The world's record for average-annual rainfall belongs to Mt. Waialeale, Hawaii, where it averages about 450 inches (1,140 cm) per year. A remarkable 642 inches (1,630 cm) was reported there during one twelve-month period (that's almost 2 inches (5 cm) every day!). The world record for the most rain in a year was recorded at Cherrapunji, India, where it rained 905 inches (2,300 cm) in 1861. On the other hand, in Arica, Chile, no rain fell for 14 years, and in Bagdad, California, precipitation was absent for 767 consecutive days from October 1912 to November 1914.

Extra Resources:

1. Article on the water cycle and precipitation from the Georgia office of the US Geological Survey at **http://ga.water.usgs.gov/edu/watercycleprecipitation.html**.
2. Information on precipitation from Windows to the Universe website sponsored by the National Earth Science Teachers Association at **http://www.windows2universe.org/earth/Atmosphere/precipitation.html**.
3. U.S. snowfall records at **http://www.currentresults.com/Weather-Extremes/US/snowiest.php**.

Activity 13: Cloud in a Bottle

National Science Standards:

Content Standard B: Physical Science

- Properties and changes of properties in matter

Content Standard D: Earth and Space Science

- Structure of the earth system

Unifying Concepts and Processes

- Evidence, models, and explanation

Background Information:

Clouds are visible collections of small particles of water or ice, or both, suspended in the atmosphere. They are one of the most obvious and influential features of Earth's climate system.Clouds form when water evaporates from rivers, ponds, oceans, and lakes.

Extra Resources:

1. Information and interactive games associated with clouds at **http://eo.ucar.edu/webweather/cloud3.html**.
2. Weather forecasting cloud chart at **http://web2.airmail.net/danb1/clouds.htm**.

Chapter Five - Weather Systems and Changes

LEARNING OUTCOMES – Upon completion of this chapter, the students should be able to:
• Define an air mass and identify air mass characteristics.
• Define a front and describe the types of fronts.
• Describe hurricanes, thunderstorms, and tornadoes.
• Identify the stages of a thunderstorm.
• Outline safety precautions for thunderstorms and tornadoes.

IMPORTANT TERMS

air mass - huge body of air with the same temperature and moisture characteristics
front - a boundary between two air masses
hurricane - a tropical cyclone of low pressure and very strong winds; usually with heavy rain and possible thunderstorms and tornadoes
thunderstorm - cumulonimbus cloud possessing thunder and lightning; usually accompanied by strong winds, rain, and sometimes hail
tornado - whirling funnel of air of very low pressure and very strong winds; may be powerful enough to suck up anything in its path; must touch the ground to be called a tornado

PRESENTATION

Attention:

• Do you know what a tornado is and how to be prepared to seek safety when you know one is possible? (Answer: Tornadoes may be a by-product of strong thunderstorms. Thunderstorms develop in warm, moist air in advance of eastward-moving cold fronts. These thunderstorms often produce large hail, strong winds, and tornadoes. Tornadoes in the winter and early spring are often associated with strong, frontal systems that form in the Central States and move east.

Before the storm:
› Develop a plan for you and your family for home, work, school, and when outdoors.
› Have frequent drills.
› Have a NOAA Weather Radio with a warning alarm tone and battery back-up to receive warnings.
› Listen to radio and television for information.

When you know a tornado is possible:
› In a home or building, move to a pre-designated shelter, such as a basement.
› If an underground shelter is not available, move to an interior room or hallway on the lowest floor and get under a sturdy piece of furniture.
› Stay away from windows.
› Get out of automobiles. Do not try to outrun a tornado in your car; instead, leave it immediately.
› If caught outside or in a vehicle, lie flat in a nearby ditch or depression.
› Mobile homes, even if tied down, offer little protection from tornadoes and should be abandoned.
› Occasionally, tornadoes develop so rapidly that advance warning is not possible. Remain alert for signs of an approaching tornado.)

• Do you know how a hurricane, tornado, and thunderstorm are related? (Answer: Tornadoes develop from powerful thunderstorms. Hurricanes are severe tropical storms that develop over the oceans with strong sustained winds (at least 74 miles per hour) and heavy rain. When hurricanes make landfall, the heavy rain and strong winds will damage or destroy buildings, trees, bridges, cars, etc. The heavy rains cause severe flooding many miles inland and sometimes even tornadoes.)

Motivation:
Everyone should know what to look for and listen for in identifying a storm system that could produce strong winds, lightning and even tornadoes. Most people live in areas of the U.S. where this is a distinct possibility. Knowing what to do and how to respond could save lives.

As well as the immediate need to know about storms, the pilot has to know about storms to avoid dangerous situations. Planning ahead and listening to the weather forecast can provide a safe flight.

Overview:
This chapter discusses how storms form and what the proper response should be to bad weather. Air masses and fronts are important to understand because they lead to the disturbances
called storms.

Lesson Outline:
1. Discuss the vocabulary words and if possible, show pictures of them and show how they are represented on a weather map.
2. Give students scenarios in which they are in a storm situation (thunderstorm involving lightning strikes, tornado, hurricane, or other) and ask them what they would do to remain safe.
3. Covered in this chapter are:
    - I. Weather Systems and Changes
        - A. Air Masses
            - a. Maritime or continental
            - b. Polar, arctic, tropical, and equatorial
        - B. Fronts
            - a. Warm, cold, stationary, and occluded
        - C. Severe Weather
            - a. Thunderstorms
            - b. Tornadoes
            - c. Hurricanes

Extra Resources:
1. National Oceanic and Atmospheric Administration (NOAA) has a website that give information and teacher lesson plans on weather at **http://www.oar.noaa.gov/k12/index.html**.
2. NASA's Earth Observatory website at **http://earthobservatory.nasa.gov/**.

Activity Fourteen: Air Masses

National Science Standards:
Content Standard D: Earth and Space Science
- Structure of the earth system

Unifying Concepts and Processes
- Evidence, models, and explanation

Background Information:
An air mass is a large body of air with generally uniform temperature and humidity. The area from which an air mass originates is called a "source region."

Air mass source regions range from extensive snow covered polar areas to deserts to tropical oceans. The United States is not a favorable source region because of the relatively frequent passage of weather disturbances that disrupt any opportunity for an air mass to stagnate and take on the properties of the underlying region. The longer the air mass stays over its source region, the more likely it will acquire the properties of the surface below.

The four principal air mass classifications that influence the continental United States according to their source region are:
• Polar latitudes - Located poleward of 60° north and south.
• Continental - Located over large land masses between 25°N/S and 60°N/S.
• Maritime - Located over the oceans between 25°N/S and 60°N/S
• Tropical latitudes - Located within about 25° of the equator.

As these air masses move around the earth they can begin to acquire additional attributes. For example, in winter an arctic air mass (very cold and dry air) can move over the ocean, picking up some warmth and moisture from the warmer ocean and becoming a maritime polar air mass (mP) - one that is still fairly cold but contains moisture. If that same polar air mass moves south from Canada into the southern U.S. it will pick up some of the warmth of the ground, but due to lack of moisture it remains very dry. This is called a continental polar air mass (cP).

The Gulf Coast states and the eastern third of the country commonly experience the tropical air mass in the summer. Continental tropical (cT) air is dry air pumped north, off of the Mexican Plateau. If it becomes stagnant over the Midwest, a drought may result. Maritime tropical (mT) air is air from the tropics which has moved north over cooler water.

Air masses can control the weather for a relatively long time period: from a period of days, to months. Most weather occurs along the periphery of these air masses at boundaries called fronts.

Extra Resources:
1. More information and activities on air masses and fronts at **http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/af/home.rxml**.
2. Information and maps showing air masses and fronts at **http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/weather_systems/air_masses.html**.
3. Video on air masses at **http://www.youtube.com/watch?v=Kmhizd4De2E**.

Activity Fifteen: Identifying Fronts

National Science Standards
Content Standard D: Earth and Space Science
- Structure of the earth system

Unifying Concepts and Processes
- Evidence, models, and explanation

Background Information:
Boundaries between air masses are called fronts. Near fronts the weather can be very unsettled, with rain and clouds. Some fronts cause lines of violent storms. The types of fronts are: cold, warm, stationary, and occluded.

Extra Resources:
1. More information on fronts at **http://okfirst.mesonet.org/train/meteorology/Fronts.html**.
2. Information on surface fronts and boundaries from the National Weather Service at **http://www.hpc.ncep.noaa.gov/html/fntcodes2.shtml**.
3. Information on fronts from the National Earth Science Teachers Association at **http://www.windows2universe.org/earth/Atmosphere/front.html**.

Activity Sixteen: Fronts on Maps

National Science Standards:
Content Standard D: Earth and Space Science
- Structure of the earth system

Unifying Concepts and Processes
- Evidence, models, and explanation

Background Information:
- Cold front - a front where cold air replaces warm air - represented on a weather map with a blue line with blue triangles pointing in the direction of the cold air flow
- Warm front - a front where warm air replaces cold air - represented on a weather map with a red line with red half moons pointing in the direction of warm air flow
- Stationary front - a front with little lateral movement - represented on a weather map with A line with alternating red warm front symbols and blue cold front symbols, pointing in opposite directions to symbolize little frontal movement.
- Occluded front - A front where the cold front has overtaken and merged with the warm front - represented on a weather map with purple (combined red and blue) half moons and barbs on the same side, pointing toward the direction of frontal motion

Extra Information:
1. Youtube video explaining air masses, fronts, and weather at **http://www.youtube.com/watch?v=rQbqujJGJRg&feature=related**.

Activity Seventeen: Distance to a Thunderstorm

National Science Standards:
Content Standard F: Science in Personal and Social Perspectives
- Natural hazards

Content Standard G: History and Nature of Science
- Science as a human endeavor
- Nature of science

Unifying Concepts and Processes
- Constancy, change, and measurement

Background Information:
The following observations can be made to help predict the weather similar to the observation of lightning followed by thunder to determine the distance to a thunderstorm that this activity explained. • One of the simplest and most well known ways of predicting bad weather is by the saying 'red sky in the morning, sailor's warning; red sky at night, sailors delight'. However, this may only be useful in the Northern Hemisphere where bad weather generally moves from west to east. A red sky at night occurs because the setting sun is only able to shine on clouds in the east if there are no clouds in the west to block its rays. A red morning indicates that there are clouds in the west to shine on, which will pass overhead on their way east.

- Another well known saying is 'mackerel sky, mackerel sky; not long wet, not long dry.' A 'mackerel sky' is a sky dotted with cirrocumulus clouds, which look like scales. They can indicate that a low pressure system is on its way, bringing rain and faster winds.
- Halos are another warning sign that bad weather is on the way. A halo around the sun or the moon is caused by light reflecting off ice crystals, generally found in cirrostratus clouds. This type of cloud can indicate a warm front is coming, and that rain or snow might be expected in 12 to 24 hours. The brighter the halo, the more likely it will rain.
- If there seem to be fewer stars out, it might also be a sign of a storm coming. As the air in the atmosphere grows more turbulent it is more difficult to see dimmer stars. Contrails (the long, thin clouds left by airplanes) can also predict the weather. A contrail that disappears quickly is an indication that dry weather will continue. The longer it stays visible, the more likely it is that rain is on its way.
- Smoke can be another predictor of bad weather. If smoke from a chimney is flowing down, or sitting low, it is probably due to a cold front moving in, or due to the smoke particles absorbing water from high humidity and becoming heavier. Both of these are signs of possible rain or storms. If the smoke is also curling, it might be a sign of changing winds.
- Human hair can indicate the amount of humidity in the air. When there is high humidity, which might indicate a storm is on the way, curly hair will droop a little, and naturally straight hair might curl a little.
- Taking a look at a cup of coffee can predict foul weather. When there is low air pressure, which is an indication that rain might form, the surface of the liquid becomes slightly convex, and bubbles will move to the edge of the cup.

Extra Information:
1. Historical perspective on weather predicting with activities from Scholastic at **http://www2.scholastic.com/browse/article.jsp?id=5176**.
2. How to predict the weather without instruments video at **http://www.howcast.com/videos/421399-How-to-Forecast-Weather-Without-Any-Instruments**.

Activity Eighteen: Matching Severe Weather

This activity is simply a review of the information on severe weather in this chapter. Matching answers are at the bottom of page 40.

Extra Information:
1. Online interactive severe weather games from the Weather Channel at **http://www.theweatherchannelkids.com/flash/games/severe-weather-challenge/**.

LEADER GUIDE
for
MODULE FOUR

ROCKETS

Chapter One – History of Rockets

LEARNING OUTCOMES – Upon completion of this chapter, the student should be able to:
- Identify historical facts about the Greeks, Chinese, and British, and their roles in the development of rockets.
- Describe America's early contributions to the development of rockets.
- List the early artificial and manned rocket launches and their missions.

IMPORTANT TERMS

Neil Armstrong - first man to walk on moon
Roger Bacon - increased the range of rockets
Wernher von Braun - director of the V-2 rocket project
William Congreve - designed rockets for military use
Jean Froissart - improved the accuracy of rockets by launching them through tubes
Yuri Gagarin - a Russian; the first man in space and the first man to orbit the Earth
John Glenn - first American to orbit the Earth
Robert Goddard - experimented with solid and liquid propellant rockets; is called the "Father of Modern Rocketry"
William Hale - developed the technique of spin stabilization
Hero - developed first rocket engine
Sergei Korolev - the leading Soviet rocket scientist; known as the "Father of the Soviet Space Program"
Sir Isaac Newton - laid scientific foundation for modern rocketry with his laws of motion
Hermann Oberth - space pioneer; wrote a book about rocket travel into outer space
Alan Shepard - first American in space
Skylab - first US space station
Space Shuttle - a space transportation system for traveling to space and back to Earth
Spin Stabilization - a technique developed by Englishman, William Hale, wherein escaping gases in a rocket hit small vanes that made the rocket spin, and stabilize, much like a bullet in flight
***Sputnik* I** - first artificial satellite; Russian
Konstantin Tsiolkovsky - proposed the use of rockets for space exploration and became known as the "Father of Modern Astronautics"

PRESENTATION

Attention:

State, "It is difficult to say what is impossible, for the dream of yesterday is the hope of today and the reality of tomorrow." Ask students what the statement means to them and if they know who said this. Either confirm or reveal that a scientist by the name Dr. Robert Goddard (1882-1945) stated this. Ask students if they know what may have prompted this statement.

Motivation:
Explain that Goddard was a physicist and rocket pioneer. His vision that a rocket could be used to send man to the moon was criticized by many. Keep in mind that Goddard experimented with rockets at a time well before anything had ever been launched into space. In fact, many people had never imagined such a thing. Goddard's vision not only became a reality, but he is part of a long history of rocketry and visionaries who believed rockets could propel man into space. Explain to students that they can learn from these early rocketry experiments and visionaries. We learn such lessons that imagination, problem solving, creative thinking, and determination can take us a long way, even to the Moon. As potential future scientists, there may be a student who continues in this rocketry and space exploration legacy by developing or improving current rocket technology that leads to other helpful inventions, or may even take us to Mars or beyond.

Overview:
Tell students that Module 4 covers rocket history, the science of rocketry, and how rocketry is being used in private space travel. In chapter one, students will begin learning about rocket history and pioneers such as Dr. Robert Goddard, who is known as the Father of Modern Rocketry.

Lesson Outline:
Tell students that a Greek named Hero is credited as having developed the first rocket engine in 100 B.C. Explain that his engine used steam to cause a sphere on top of a boiling pot of water to spin. The steam from the heated water traveled through pipes into the sphere. Two L-shaped tubes on opposite sides of the sphere allowed the gas to escape. This created a thrust that caused the sphere to rotate, and the device became known as a Hero Engine. Conduct Activity One - The Hero Engine on page 9 in Module 6.

Next, make front and back copies of the timeline worksheet that follows the Chapter 1 Activities section. Distribute a copy to each student. Ask students to read chapter one and complete the timeline.

While students complete the outline, set up Activity Three - Rocket Staging.

Once students have completed the timeline, review the timeline with the students. Discuss any questions students may have.

Closure:
Close by conducting Activity Three - Rocket Staging. Tell students that rockets may be one-stage, two-stage, or three-stage rockets. Blow up a single balloon and let it go. Explain that this demonstrates a one-stage rocket with no guidance. It is considered one-stage because there was only one fuel (air) source. Once all of the fuel (air) was expended, the rocket (balloon) had no more energy and fell to the ground. A rocket that has more than one stage has more than one part that contains fuel and an engine. The additional fuel and engine that are part of a second stage of the rocket does not ignite until the preceding stage has burned its fuel and fallen away from the body of the rocket. Multi-stage rockets have parts that fall off after the part's fuel has been used. Then, the next part "fires up." This is an example of serial staging. Conduct Activity - Three Rocket Staging to demonstrate this concept. (Be patient as this experiment may take a couple of tries to work as designed.) Explain that chapter two will focus more on how a rocket works.

CHAPTER 1 ACTIVITIES

The complete directions for each activity are provided in chapter one of Module 6 along with an explanation/summary for each activity. Whether students conduct activities together or individually at home, conducting chapter one hands-on activities helps clarify and re-emphasize specific content in chapter one.

Activity 1 – The Hero Engine

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Background Information:
This activity demonstrates Hero's engine using a soda can that spins as water streams out of holes that were placed at the bottom, outside edge of the can. This activity is also used to demonstrate Newton's third law of motion. For additional information about Hero and his engine, visit **http://www.worldwideinvention.com/articles/details/282/Greek-Hero-of-Alexandria-Ancient-Greek-inventors.html**. For information on Newton's laws, visit **http://quest.arc.nasa.gov/space/teachers/rockets/principles.html**.

Activity 2 – Making a Paper Rocket

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Background Information:
In this activity, students create a paper rocket that is launched via air forced through a drinking straw. Students may experiment by launching a different angles and using different fin configurations. Additionally, this activity can be used to teach/demonstrate Newton's laws of motion. The site **http://quest.arc.nasa.gov/space/teachers/rockets/principles.html** explains Newton's laws in relation to rockets.

Activity 3 – Rocket Staging

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

National Math Standards:
Standard 3: Measurement
- Apply appropriate techniques, tools, and formulas to determine measurements

Standard 5: Data Analysis and Probability
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them

Background Information:
This activity demonstrates the concept of multi-stage rockets using two temporarily attached balloons that are attached to straws. The straws are threaded through string that stretches across the room. The first balloon to release its air will stop, but the second balloon will continue onward until all of its air is expelled.
For information about rocket staging, including serial and parallel staging, visit **http://exploration.grc.nasa.gov/education/rocket/rktstage.html**.

HISTORY OF ROCKETS: A TIMELINE
Module 4 – Chapter One

400 BC: Archytas (Greek) built flying wooden pigeon (suspended on wire & propelled w/ steam)

100 BC: Hero (Greek) developed first ____________________________

1st century AD: _________________ developed first form of ___________________ Early rockets had arrows

attached to ____________________ filled w/ gunpowder.

______ - first time known that early rockets were used in war (Chinese used against Mongols)

13th – 15th centuries:

Roger ________ (in _________) improved forms of gunpowder (increased ______ of rocket)

Jean _____________ (in _________) launched rockets through ________ (better accuracy) and forerunner to bazooka)

17th century: _________________ laid scientific foundations for modern rocketry (laws of motion)

18th century (end): _________________ (British) set out to design rockets for ____________ use

His rockets increased rocket's range from 200 to _________________. Many could be fired at once.

These became known as __________________ rockets.

19th century:

_______________ rockets were seen at the battle at Fort McHenry in 1812. This is when

________________________ wrote our national anthem,

"____."

______________ (Englishman) developed a technique called ______________________. This helped improve the accuracy of rockets.

1898: __________________ (_____________) proposed idea of space exploration by a rocket

1903: Tsiolkovsky published report suggesting use of ____________ propellants for rockets in order to achieve greater _____________; He stated that only the __________ velocity of escaping gases limited the

____________ and ___________ of a rocket.

Tsiolkovsky is known as the "Father of ______________________________________."

1923: ________________ (German) published book about rocket travel into outer space, and then, many rocket societies started around the world.

1926: ________________ (American) first successful rocket flight using ______________ fuel

It was fueled by ________________________ and __________________.

Dr. Goddard became known as the "Father of _______________________________" for his many accomplishments including development of a ___________________ system, a __________________ compartment, and a _____________________ recovery system.

1945: von ___________ (German) and 120 of his scientists were brought to the U.S. after WWII. They signed contracts to work with the US ________________.

(WWII took place from 1939-1945. While in Germany during WWII, von Braun directed the

building of the __-____ rocket. Germany used this weapon against ________________

during WWII, but fortunately, it occurred too late in the war to change the outcome.)

Aug. 1957: __________________ (Russian) organized and led the development of the first successful _______________ ______________________ ballistic missile. Korolev is considered to be the "Father of ____."

Oct. 4, 1957: first artificial satellite, _________________, launched (Russia)

Oct 4, 1957: The _______________________ between the US and USSR began.

Jan. 31, 1958: US launch of ______________________ (America's first artificial satellite)

Oct. 1958: ____ created

This was the ______________ agency with the goal of peaceful exploration of space.

The ________ became responsible for research & dev for military aerospace activities

April 1961: ____

May 1961: ____

The rocket used to launch Shepard was the _______________________, but it was not powerful enough to place him in orbit. So, the flight lasted just about _______ minutes.

May 25, 1961: President ____________ announced this objective - ________________________

____

Feb. 1962: _______________ - 1st American to orbit Earth; launched on ____________ rocket;
flight lasted almost ____ hrs

1965-1966: The __________________ rocket was used to launch _________________ missions

1967-1975: The __________________ Program used the ______________ launch vehicles.

The Saturn I and IB were large ___-stage liquid-propellant launch vehicles.
The Saturn V was a ___-stage rocket.

October 1968: ____________________ was used to launch __________________

July 16, 1969: ____________________ was used to launch *Apollo* 11

July 20, 1969: _____________________ became first man to walk on moon

1973: *Skylab* was launched into space by a Saturn V rocket (last launch of a Saturn V rocket)

1973-1974: Saturn IB - used to launch crews to *Skylab* (longest mission was ______ days)

After space station: reusable launch system called _____________________________________ with solid rocket boosters and three main engines to launch the shuttle orbiter. The solid rocket boosters would fall off about _____ minutes after flight and parachute into the ocean where ships recovered them. 1st space shuttle launch was the year ________

Chapter Two – Rocket Principles, Systems, and Engines

LEARNING OUTCOMES – Upon completion of this chapter, the student should be able to:
- Define acceleration.
- Define inertia.
- Define thrust.
- Describe Newton's First Law of Motion.
- Describe Newton's Second Law of Motion.
- Describe Newton's Third Law of Motion.
- Identify the four major systems of a rocket.
- Describe the purpose of each of the four major systems of a rocket.
- Define payload.
- Describe how the world land speed record applies to rockets.

IMPORTANT TERMS
acceleration - the rate of change in velocity with respect to time
airframe - provides the shape of the rocket, within which all of the other systems are contained
control system - steers the rocket and keeps it stable
guidance system - gets the rocket to its destination; the brain of the rocket
inertia - the tendency of an object at rest to stay at rest and an object in motion to stay in motion
Newton's First Law of Motion - a body at rest remains at rest and a body in motion tends to stay in motion at a constant velocity unless acted on by an outside force; inertia
Newton's Second Law of Motion - the rate of change in the momentum of a body is proportional to the force acting upon the body and is in the direction of the force
Newton's Third Law of Motion - for every action there is an equal and opposite reaction
payload - what the rocket is carrying
propulsion - everything associated with propelling the rocket
thrust - to force or push; the amount of push used to get a rocket traveling upwards

PRESENTATION
Attention:
Demonstrate Activity Five 3-2-1- POP. (Place garbage bag liners on the floor under the canister before launching for easier clean up.) Tell students step by step what you are doing. After the film canister launches, ask students if they can explain what happened and why. (If the correct type of film canisters isn't readily available, consider ordering them from one of the following suppliers:
http://www.teachersource.com/Energy/EnergyConversion/RocketFilmCanisters.aspx
http://www.sciencebobstore.com/products.php?product=Bulk-Film-Canisters-for-Rockets
http://www.stevespanglerscience.com/product/flying-film-canisters

Motivation:
Explain that understanding scientific principles can help one understand visible and sometimes invisible phenomena around them. By understanding information in chapter two, not only will they learn about scientific concepts, but they will be able to understand the application of those scientific concepts in rocketry, which will ultimately help them understand how a rocket works.

Overview:
Tell students that in this chapter, they will study Newton's three laws of motion, the major systems of rockets, and how rockets can be used on land vehicles.

Lesson Outline:
Read and discuss chapter two together. When reading Newton's laws of motion, relate back to the fizzy rocket that launched at the beginning of the class. Conduct chapter two activities as time allows. An outline of chapter two content follows.

Although rockets have been around for over 2,000 years, it has only been in the last 300 years that rocket experimenters have had a scientific basis for understanding how they work.

I. Newton's Laws of Motion
- A. First law of motion – (see terms and definitions)
- B. Second law of motion – (see terms and definitions)
  - 1. Mathematical equation: Force=Mass x Acceleration (F=M x A)
  - 2. Acceleration (see terms and definition)
  - 3. Mass and acceleration have inverse relationship (one decreases, other increases)
- C. Third law of motion (see terms and definitions)

II. Four Rocket Systems (help deliver payload)
- A. Airframe (see terms and definitions)
  - 1. Lightweight, structurally strong; must withstand heat, stress, and many vibrations
  - 2. Primary design and construction objective: withstand all anticipated stresses while using the least possible weight
    - a. Atlas rocket example (skin so thin requires pressurization when not fueled) airframe serves as skin or rocket and wall of propellant tanks – so no separate, internal tanks needed, which saves weight
- B. Guidance System (see terms and definitions)
  - 1. Small compared to rest of rocket; self-contained electronic unit w/ computer
  - 2. Has a radio link between rocket's mission controllers and its guidance system
- C. Control System (see terms and definitions)
  - 1. Takes information from guidance system to steer rocket
  - 2. Several controls (vanes, movable fins, gimbaled nozzles, and attitude control rockets) work to stabilize and steer rocket
    - a. vanes – small fins inside the exhaust of rocket engine; tilting the vanes deflects exhaust and changes direction of rocket
    - b. gimbaled nozzle – sways while exhaust passes through it
    - c.moveable fins – can be tilted to change rocket's direction
    - d. attitude-control rockets – small clusters of engines mounted around vehicle; firing right combination can change direction
- D. Propulsion (see terms and definitions)
  - 1. Includes fuel, oxidizer (no air in space), containers for propellant, engine
  - 2. Solid Propellants
    - a. carried in combustion chamber
    - b. usu. mix of hydrogen compounds and carbon; oxidizer – oxygen compounds
  - 3. Liquid Propellants (more complicated)
    - a. Carried in compartments separate from combustion chamber
    - b. Usu. Kerosene or liquid hydrogen; oxidizer – usu. Liquid oxygen
    - c. Heavier, but easier to control than solid propellant & commonly used today

III. Rocket Engines and Land Vehicles
- A. Rocket engines
  - 1. Produces more power for its size than any other kind of engine
  - 2. Can make cars go faster
- B. Blue Flame
  - 1. Car that set a land speed record (622.407 mph) on Oct. 28, 1970
  - 2. Driver: Gary Gabelich
  - 3. Fuel and oxidizer: pressure red methane and hydrogen peroxide, respectively
  - 4. Thurst power: close to 50,000 pounds

IV. Jet Engines and Land Vehicles
   A. Thrust SSC (Super Sonic Car)
      1. Car that first broke the sound barrier (traveling at 763 mph) on land on Oct. 15, 1997 on the Black Rock Desert in Nevada
      2. British-designed and built (Richard Noble directed team)
      3. Driver: Andy Green (Royal Air Force pilot who files the Tornado aircraft)
      4. Engines: 2 Rolls Royce Spey Turbofans from an American McDonnell F-4 Phantom; burned 4.8 gallons of fuel per second
      5. Thurst: 2 engines together created 50,000 pounds (appr 110,000 horsepower)
   B. North American Eagle Land Speed Program
      1. Challenged to make transition from subsonic to supersonic speed and break current land speed record of 763 mph
      2. American and Canadian team working together
      3. Using modified F-104 Starfighter
      4. Hope to learn "what phenomenon occurs as a vehicle transitions past speed of sound and what happens beyond that speed" (could lead to advanced technologies)

V. Bloodhound SSC (Super Sonic Car)
   A. Has EJ200 Eurofighter Typhoon jet engine
   B. Hybrid rocket
      (Not in book: A hybrid rocket is one which uses solid and liquid propellant. It uses a hybrid motor that combines a solid fuel with a liquid oxidizer. For more information, visit **http://www.ukrocketman.com/rocketry/hybridscience.shtml**.)
   C. Leader of engineering team: John Piper
   D. Jet engine positioned over the rocket
   E. Will feature largest hybrid rocket ever designed in the United Kingdom
   F. Same length as Formula One car
   G. Designed to produce 47,500 pounds of thrust (27,500 from rocket; 20,000 from jet engine), equivalent of 135,000 HP (or power of 180 Formula One cars)
   H. Driver: Andy Green
   I. Project sponsors: currently 166
      (Visit **http://www.bloodhoundssc.com/** to stay updated on Bloodhound SSC news.)

Closure:
After reading and discussing chapter two, and after conducting hands-on activities for chapter two, consider one or more of the following suggestions to review chapter two:

- Place vocabulary words individually in a container. (Ensure that the students cannot see the words when looking through the container.) Divide the students into two teams and draw a tic-tac-toe game on the board. Take turns having a representative from each team come forward to draw a vocabulary word from the container. If the student can adequately define the word, he/she is allowed to mark an "X" or an "O" on the board for his/her team. Once a team wins tic-tac-toe, a new tic-tac-toe board may be drawn, and play may continue as desired.
- Have students record important information that they wish to remember from chapter two.
- Have students create a chapter two review worksheet. Select the best one to provide to the class to complete.
- Create a crossword puzzle or word find for chapter one. Free resources are available at **http://www.discoveryeducation.com/free-puzzlemaker/?CFID=11104874&CFTOKEN=79374463** and **http://www.theteacherscorner.net/printable-worksheets/make-your-own/crossword/**.

CHAPTER 2 ACTIVITIES

The complete directions for each activity are provided in chapter two of Module 4 along with an explanation/summary for each activity. Whether students conduct activities together or individually at home, conducting chapter one hands-on activities helps clarify and re-emphasize specific content in chapter two.

Activity 4 – Law of Inertia

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Background Information:
This activity demonstrates Newton's first law of motion. The student (or demonstrator) will slide (with force) a checker across a smooth table surface so that it hits the bottom of a stack of checkers, resulting in the bottom checker going from a state of rest to a state of movement in the direction the original checker was traveling. The second demonstration shows that a ball held in someone's hand is prevented from falling to the floor. Removing one's hand from underneath the ball allows the force of gravity to cause it to move towards the ground. For information on Newton's laws, visit **http://quest.arc.nasa.gov/space/teachers/rockets/principles.html**.

Activity 5 – 3-2-1 POP

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Content Standard G: History and Nature of Science
- Science as a human endeavor

Background Information:
In this activity, students create a rocket using a film canister, effervescent tablet, and water. This activity helps explain why a rocket launches in accordance with Newton's laws. (The site **http://quest.arc.nasa.gov/space/teachers/rockets/principles.html** explains Newton's laws in relation to rockets.)

Additionally, the fizzy rocket activity can be used to explain chemical reactions and hypergolic fuels. (Hypergolic refers to a situation in which two things ignite spontaneously when they come into contact with one another. No external source, such as heat or a flame is needed to ignite them.) The orbiter's Orbital Maneuvering System (OMS) engines used hypergolic propellants. The fuel was monomethyl hydrazine and the oxidizer was nitrogen tetroxide. Once these two propellants meet, they ignite instantly. This is similar to the water and effervescent tablet. Once the two meet, there is an instant reaction, which ultimately results in the film canister popping its lid as the pressure that was building in the film canister is released.

If you cannot find the correct type of film canisters in your local area, see the online links for optional suppliers listed in the Attention section of this leader's guide for this chapter.

Activity 6 – Two Balloons

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Background Information:
This activity demonstrates Newton's third law by showing that if you press and hold two balloons together, when you release them, they move in opposite directions and an equal distance apart (compared to the point where they were originally being pushed together.) Visit **http://science.howstuffworks.com/science-vs-myth/everyday-myths/newton-law-of-motion4.htm** for more information on Newton's third law of motion.

Activity 7 – Roller Skates and Jug

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Background Information:
This is another activity demonstrating Newton's third law of motion. When a person wearing skates is standing still (or on stopped skateboard) throws a jug (action), it results in the person in the person moving in the opposite direction (reaction) of the thrown jug. Visit **http://science.howstuffworks.com/science-vs-myth/everyday-myths/newton-law-of-motion4.htm** for more information on Newton's third law of motion.

Activity 8 – Antacid Tablet Race

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Content Standard G: History and Nature of Science
- Science as a human endeavor

National Math Standards:
Standard 3: Measurement
- Apply appropriate techniques, tools, and formulas to determine measurements

Standard 5: Data Analysis and Probability
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them

Background Information:
In this activity, students use scientific investigation skills to compare the reaction rates of effervescent antacid tablets under different conditions, in alignment with the discussion of liquid propellants. This activity relates to increasing the power of rocket fuels by manipulating surface area and temperature. For additional background information for this activity, visit **http://quest.nasa.gov/space/teachers/rockets/act4.html**. For more information about propellants, visit **http://www.braeunig.us/space/propel.htm**.

Activity 9 – Rocket Racer

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology
- Content Standard G: History and Nature of Science
- Science as a human endeavor

National Math Standards:
Standard 3: Measurement
- Apply appropriate techniques, tools, and formulas to determine measurements

Standard 5: Data Analysis and Probability
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them

Background Information:
Newton's three laws of motion are demonstrated with this activity wherein students make a Styrofoam car racer propelled by a balloon. The activity stresses technology education and provides students with the opportunity to modify their racer designs to increase performance. Data sheets may be self designed, or you may use the data sheets available at **http://www.nasa.gov/pdf/153417main_Rockets_Rocket_Races.pdf**. Visit **http://www.k8science.org/resources/files/Rocket_Racer_s.pdf** for more information on Newton's laws in accordance with this activity, visit.

Activity10 – Newton Car

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Content Standard G: History and Nature of Science
- Science as a human endeavor

National Math Standards:
Standard 4: Measurement
- Apply appropriate techniques, tools, and formulas to determine measurements

Standard 5: Data Analysis and Probability
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them

Standard 6: Problem Solving
- Solve problems that arise in mathematics and other contexts

Standard 10: Representation
- Select, apply, and translate among mathematical representations to solve problems

Background Information:
Besides demonstrating Newton's first and third laws of motion, this activity is an excellent tool for investigating Newton's second law of motion, which states that force equals mass times acceleration. The purpose of this activity allows the individual to investigate how increasing the mass of an object thrown from a "Newton Car" affects the car's acceleration over a rolling track (Newton's second law of motion). In this activity, students create a slingshot-like device using a wooden black, screws, and rubber bands. The device will be used to propel a film canister filled with various objects (affecting weight). The slingshot device will also move because it is located on top of round pencils (or similar objects). For more information and full-sized data sheets, visit **http://er.jsc.nasa.gov/SEH/Newton_Car.pdf**.

Chapter Three – Rockets and Private Space Travel

LEARNING OUTCOMES:
- Upon completion of this chapter, the student should be able to:
- Describe the requirements for achieving the X-Prize.
- Describe *SpaceShipOne's* achievements.
- Describe the future flight sequence of *SpaceShipTwo*.

IMPORTANT TERMS:
SpaceShipOne – aircraft with suborbital capability
SpaceShipTwo – *SpacShipOne's* successor that could possibly offer the general public space travel

PRESENTATION
Attention:
(Build a "Goddard rocket" prior to class. See Activity 13 for instructions.) Using a Goddard rocket, launch it upward. Ask students if they know how high an object must travel to reach space. Either reveal or confirm that the Air Force and NASA define space as beginning at an altitude of 50 miles (80.5 km), and anyone who reaches this height is awarded astronaut wings. Ask students if any civilian or private pilot has ever traveled at least 50 miles above Earth's surface to receive astronaut wings. If students answer "yes," ask them if they know the first private pilot to accomplish this. Either reveal or confirm that the answer is Mike Melvill. He was the pilot of a ship called *SpaceShipOne*.

Motivation:
Explain to students that private space travel is a growing business. Even if students do not train to become an astronaut or engineer, there is a chance that they could take a trip into space as a passenger aboard a spaceship, just like airline passengers fly aboard commercial aircraft.

Overview:
Tell students that in this chapter, they will learn about the Ansari X-Prize that encouraged private space flight and the spaceships *SpaceShipOne* and *SpaceShipTwo*.

Lesson Outline:
Read and discuss chapter three (or allow students to read independently and complete the crossword puzzle that follows the Activity information). Main points are identified below.

- 1995-Dr. Peter H. Diamandis conceived the Ansari X-Prize award
- Requirements for X-Prize: non-government-supported aerospace craft would fly to an altitude of 62 miles (or 100km) above the surface of Earth and return safely, and within a 2-week period, the same flight would be repeated; vehicle required to carry weight of 3 adult humans
- X-Prize Reward: 10 million dollars
- June 21, 2004: Mike Melvill became 1st first private pilot to earn astronaut wings while test piloting *SpaceShipOne* for Scaled Composites
- Melvill flew first official flight for X-Prize on Sept. 29, 2004; Brian Binnie flew second flight requirement on October 4 to win the $10,000,000 prize for Scaled Composites.
- 1st airline to space being offered by Virgin Galactic (owned by Sir Richard Branson); builders are Scaled Composites
- *SpaceShipTwo* is the vehicle that will carry passengers to space. Virgin Galactic expects to have a fleet of five *SpaceShipTwo* vehicles.) The approximate flight time is 2.5 hrs with approximately 6 minutes of weightlessness. Initial ticket price was $200,000.
- The "mother ship" for SpaceShipTwo is White Knight Two (as the mother ship for SpaceShipOne was White Knight).

Closure:
Ask students some review questions based on the main points above (or go over answers to the crossword puzzle). Ask students why they think commercial space travel is or is not a good idea.

Answers to crossword puzzle:
Across
2. Branson; 4. Scaled Composites; 5. passengers; 7. five; 9. White Knight; 11. Mike Melvill; 12. three

Down
1. SpaceShipOne; 3. SpaceShipTwo; 6. government; 8. million; 10. six

CHAPTER 3 ACTIVITIES

The complete directions for each activity are provided in chapter three of Module 4 along with an explanation/summary for each activity. Students may conduct activities together or individually at home.

Activity 11 – Bottle Rocket and Bottle Rocket Launcher

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Content Standard G: History and Nature of Science
- Science as a human endeavor

Background Information:
This activity allows students to construct a rocket out of a 2-liter bottle (or smaller plastic drinking bottle). The rocket is propelled using air and water pressure. Directions are included for building a rocket launcher for these type of plastic bottle rockets. You may do an online search for directions for other homemade rocket launching devices. If you do not wish to build a rocket launcher, consider purchasing one that requires little or no assembly. Prices can range from fairly reasonable, such as the Aquapod Bottle Launcher available for about $25 at **http://theaquapod.com/**, to more expensive models like the Aqua Port Launcher for about $140 at **http://shop.pitsco.com/store/detail.aspx?ID=1179&bhcp=1**. For a complete lesson plan that provides a more real-world experience in designing and launching rockets, as well as one that can be scored, go to **http://www.nasa.gov/pdf/153416main_Rockets_Project_X51.pdf**.

Activity 12 – Altitude Tracking

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Content Standard G: History and Nature of Science
- Science as a human endeavor

National Math Standards:
Standard 4: Measurement
- Apply appropriate techniques, tools, and formulas to determine measurements

Standard 5: Data Analysis and Probability
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them

Standard 6: Problem Solving
- Solve problems that arise in mathematics and other contexts

Standard 10: Representation
- Select, apply, and translate among mathematical representations to solve problems

Background Information:
Students construct an altitude tracker using a pattern and file folders. Using the altitude tracker will allow students to get a good estimate of how high their rocket flew. For detailed instructions including using a tangent table and mathematical formula to calculate rocket altitude, go to **http://er.jsc.nasa.gov/seh/Altitude_Tracking.pdf**. For additional information about tracking rocket altitude, go to
http://www.nasa.gov/pdf/153401main_Rockets_Add_Resources.pdf.

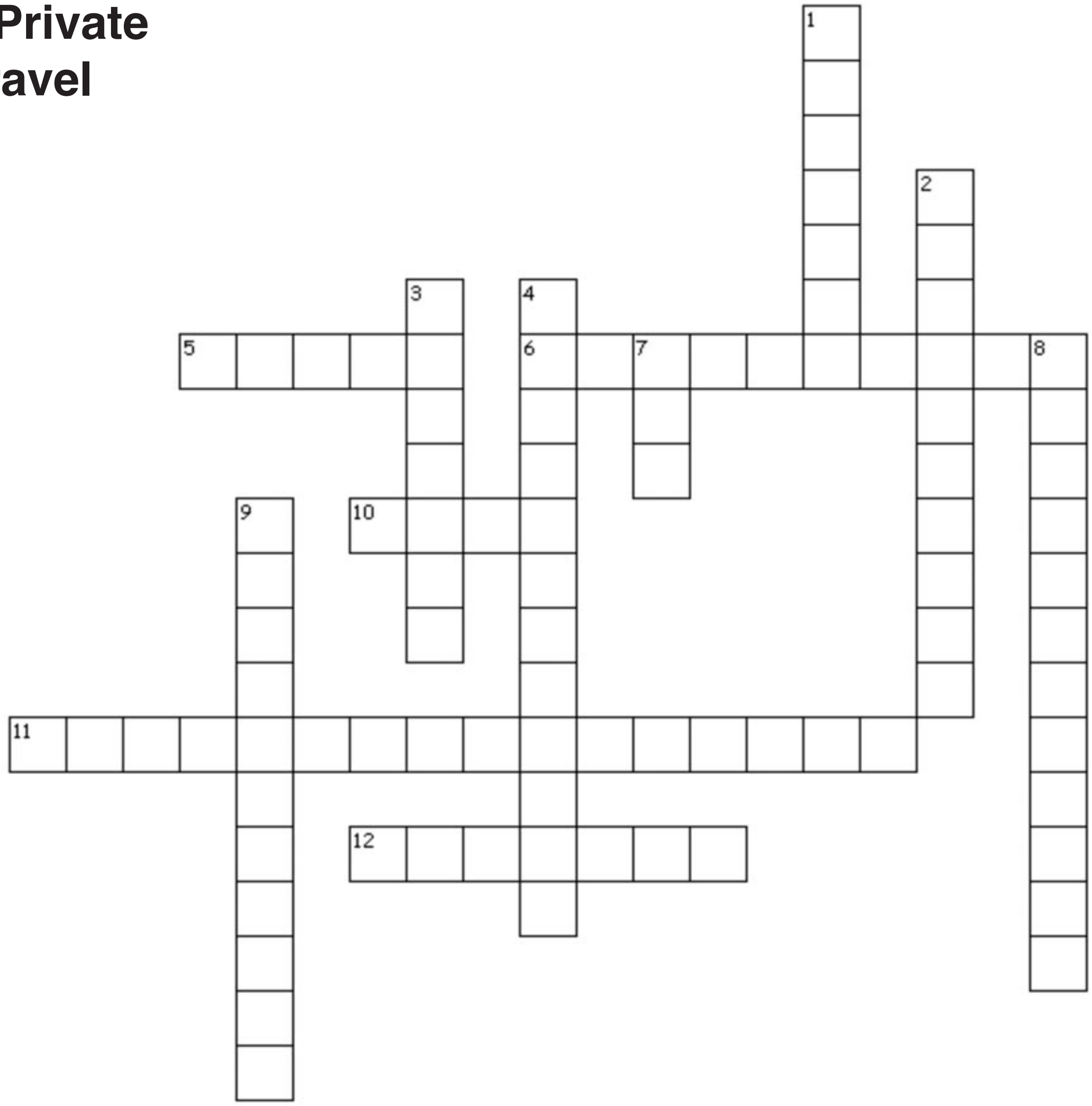
Activity13 – Goddard Rocket

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Background Information:
Using pipe foam insulation, a rubber band, and a few other items, students will create a foam rocket. The rocket is launched by stretching the rubber band that is attached to the foam pipe insulation, and then releasing the releasing the rocket. The rocket may be launched horizontally or vertically. For a lesson plan with an additional explanation for how the foam rocket works and data sheets for experiments, go to
http://www.nasa.gov/pdf/295787main_Rockets_Foam_Rocket.pdf.

Rockets & Private Space Travel



Across

5. Ansari X-Prize competition required that the vehicles entered into the competition carry the weight of how many adult humans?
6. *SpaceShipTwo* vehicles will carry 2 crewmembers and 6 ____.
10. Virgin Galactic expects to have 2 White Knight IIs and a fleet of ___ *SpaceShipTwo* vehicles.
11. Name of company that won the Ansari X-Prize and is the builder of *SpaceShipOne* and *SpaceShipTwo*
12. Sir Richard _____ owns Virgin Galactic.

Down

1. X-Prize award was 10 _____ dollars
2. The X-Prize competition required a non-______ supported aerospace craft fly to space and return twice within 2 weeks.
3. Mike _____ was the first private pilot to earn astronaut wings in 2004
4. Aerospace craft that was used to win the X-Prize
7. Virgin Galactic's commercial spaceflights will offer passengers ___ minutes of weightlessness.
8. Aerospace craft that will carry passengers to space
9. Name of mother ship for *SpaceShipOne*

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LEADER GUIDE
for
MODULE FIVE

SPACE ENVIRONMENT

Chapter One – Space

LEARNING OUTCOMES – Upon completion of this chapter, the student should be able to:
- Describe the location of space.
- Describe characteristics of space in terms of temperature, pressure, and gravity.
- Define microgravity.
- Define cislunar space.
- Distinguish between interplanetary and interstellar space.
- Define galaxy.
- Identify three types of galaxies.
- Define universe.

IMPORTANT TERMS

absolute zero - the point at which all molecules no longer move or have the least amount of energy; theoretically the absolute coldest temperature
cislunar space - the space between the Earth and the Moon
galaxy - an enormous collection of stars arranged in a particular shape
interplanetary space - space located within a solar system; measured from the center of the Sun to the orbit of its outermost planet
interstellar space - the region in space from one solar system to another
Kelvin - unit of measurement based on absolute zero and commonly used by scientists to measure temperature
microgravity - small gravity levels or low gravity; floating condition
space - region beyond the Earth's atmosphere where there is very little molecular activity
universe - all encompassing term that includes everything; planets, galaxies, animals, plants, and humans
vacuum - space that is empty or void of molecules
Van Allen belts - radiation belts around the Earth filled with charged particles

PRESENTATION

Attention:

Ask the students to take out a piece of paper and pencil. Instruct each person to write his/her name on the back of their paper. Tell the students that you are going to give them 30 seconds to draw our universe on the front of their paper. (Instead of drawing our universe, you may wish for the students to draw our galaxy. Select either the term universe or galaxy, but not both.) Tell the students to label the objects included in their pictures. Don't provide any additional details or answer any questions. They should follow the directions you provided. Once the 30 seconds has expired, allow students to look at the pictures their peers drew. Discuss which pictures or aspects of the pictures they think are correct or incorrect and why. After the short discussion, discuss what types of objects should be included in the picture of the universe (or galaxy). Determine the pictures that best depicted the definition of universe (or galaxy).

It is likely that some students drew a picture of our solar system when asked to draw a picture of our universe (or our galaxy). They may have labeled the Sun and the planets Mercury through Neptune orbiting the Sun. Briefly explain to students that a picture of the universe would include every star and planet in existence, not just those in our solar system or other stars and/or planets that may be visible to us with the help of powerful instruments, such telescopes or probes that have been launched into space. A picture of the universe would have multiple stars and planets, but the arrangement of these stars and planets would form areas that look like spirals shapes, elliptical shapes, or even not well-defined shapes. (A picture of our galaxy would include not only our solar system, but other stars and planets that collectively for the shape of a ball-like center with curved "arms" spiraling out from the center as in the picture shown of the Milky Way Galaxy on page 6 of Module 5.)

Motivation:

Inform the students that many people, even well-educated people, are not able to explain space-related or astronomy-related phenomena. They may not be able to adequately describe the world outside of what they are able to physically see. Additionally, they may not be able to explain causes of things that they observe on a regular basis. For example, in the making of a 1988 film called *A Private Universe*, many Harvard graduates could not correctly explain what causes seasons here on Earth. Additionally, at a nearby school, many ninth-graders provided the same incorrect answers as to why Earth has seasons.

Tell the students that by studying this module, they will better understand not only the planet on which they live, but they will be able to understand the universe in which they live. Additionally, they will be able to provide the correct answer to a question such as, "Why does the Earth have seasons?" Additionally, they will be able to draw a correct representation of the universe (or galaxy). Tell the students that once you get to the topic of Earth's seasons in chapter four of Module 5, you will discuss the incorrect answer that Harvard graduates gave regarding the seasons, as well as the correct answer.

Remind students that we are no longer bound to just staying on the Earth. Space travel, along with working and living in space for extended periods of time, is possible. It is important for us to understand our universe in order to make better decisions that directly impact our own planet. Additionally, continued exploration and understanding of the universe around us may lead to opportunities to live beyond our planet.

Overview:

Tell the students that chapter one of Module 5 provides a broad overview of the universe. Everything is part of the universe, including multiple galaxies. In addition to learning about galaxies, they will learn about the area between Earth and the moon, as well as the environment directly surrounding Earth's visible sky.

Lesson Outline:

Either together or individually, read chapter one and discuss it. An outline for chapter one follows below. Either in conjunction with reading and discussing the chapter or after reading the chapter, conduct at least two of the four activities included in chapter one. (See Chapter One Activities.)

1. Space Described
    A. Space definition (see terms and definitions)
        1. Space begins at an altitude of 50 mi (80.5 km) - according to NASA and the Air Force (Astronaut wings awarded for reaching this altitude.)
        2. Most widely accepted altitude where space begins - 62 mi (100 km)
    3. To maintain orbit Earth - altitude of at least 80-90 mi (129-145 km)
    B. Characteristics of Space
        1. Oxygen - none
        2. Pressure – none (Effect on unprotected human body: air rush out from lungs; skin expand like balloon; bubbles form in bloodstream; swelling; tissue damage; unconsciousness in less than 15 seconds)
        3. Temperature - closest to absolute zero (see terms and definitions)
        4. Microgravity (see terms and definitions)
    C. Regions of Space
        1. Cislunar (see terms and definitions)
        2. Interplanetary space (see terms and definitions)
        3. Interstellar space (see terms and definitions)

II.Galaxies
    A. Galaxy definition (see terms and definitions)
    B. Types of galaxies
        1. Spiral (like our Milky Way Galaxy – see image page 6 in Module 5)
        2. Elliptical (see image page 6 in Module 5)
        3. Irregular (see image page 6 in Module 5)

III. Earth's Space Environment
    A. Surrounded by radiation belt
        1. Belts known as Van Allen Radiation Belts
        2. Appear to be donut-shaped clouds with Earth at its center
        3. Importance – helps protect Earth; acts like a bottle, trapping fast-moving charged particles
        4. Radiation – has to do with energy or matter moving through space
        5. Daily dosage of radiation on ISS equivalent to about 8 chest X-rays/day
    2. Magnetosphere
        1. Begins at 215 miles above Earth's surface and extends into interplanetary space
        2. Magnetic force – strongest at the poles and weakest at equator
        3. Is affected by solar winds
    C. Ionosphere
        1. Filled with ions (atoms that carry a positive or negative charge as a result of losing or gaining one or more electrons)
        2. Caused by powerful ultraviolet radiation from Sun and the ultra high frequency cosmic rays from stars

NOTE (information not in book):
The ionosphere begins at about 50 miles above Earth's surface and extends upwards for several hundred miles. Learn more about the ionosphere at **http://www.srh.noaa.gov/jetstream/atmos/ionosphere_max.htm** and **http://www.enchantedlearning.com/subjects/astronomy/planets/earth/Atmosphere.shtml**.

Closure:
After reading and discussing chapter one, and after conducting hands-on activities for chapter one, consider one or more of the following suggestions to review chapter one:

Divide the students into two teams and draw a tic-tac-toe game on the board. Take turns having a representative from each team come forward to answer teacher generated questions from the chapter. (Include generating questions that are associated with vocabulary words.) If the student can adequately answer the question, he/she is allowed to mark an "X" or an "O" on the board for his/her team. Once a team wins, a new board may be drawn, and play may continue as desired.
Have students record important information that they wish to remember from chapter one.
Have students create a chapter one review worksheet. Select the best one to provide to the class to complete.

Create a crossword puzzle or word find for chapter one. Free resources are available at
http://www.discoveryeducation.com/free-puzzlemaker/?CFID=11104874&CFTOKEN=79374463 and
http://www.theteacherscorner.net/printable-worksheets/make-your-own/crossword/.

CHAPTER 1 ACTIVITIES

The complete directions for each activity are provided in chapter one of Module 5 along with an explanation/summary for each activity. Whether students conduct activities together or individually at home, conducting chapter one hands-on activities helps clarify and re-emphasize specific content in chapter one.

Activity 1 – Creating the Microgravity of Space

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science

- Motion and forces
- Transfer of energy

Background Information:
In this activity, students place a cup of water upside down on a cookie sheet, hold the cookie sheet in the air, and quickly slide the cookie sheet out from under the cup. Students will observe that the water and cup fall at the same time. Not only does this demonstrate microgravity and freefall, you may use this activity to discuss Newton's first law of motion: An object in motion remains in motion unless acted upon by an outside force. An object at rest remains at rest unless acted upon by an outside force. For more information on freefalling objects, including discussion regarding Newton's 2nd law of motion (F=mass x acceleration), visit **http://www.grc.nasa.gov/WWW/K-12/airplane/ffall.html**.

Activity 2 – The Can Throw

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science

- Motion and forces
- Transfer of energy

Background Information:
This activity instructs the student to poke a small hole in the end of an empty aluminum soft drink can. After filling the can with water (while covering the hole), students observe that water does not come out of the hole when the can is tossed through the air. This activity demonstrates microgravity and objects in a state of freefall. You may also use this activity to discuss Newton's laws of motion. For more information on freefalling objects, including discussion regarding Newton's 2nd law of motion (F=mass x acceleration), visit **http://www.grc.nasa.gov/WWW/K-12/airplane/ffall.html**.

Activity 3 – Surface Tension and Microgravity

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science

- Motion and forces
- Transfer of energy

Background Information:
This activity requires students to use observation skills as they observe water droplets falling through the air and record their shape once the droplets are resting on a solid, flat surface. This emphasizes the concepts of surface tension and microgravity. For addition information about surface tension, including an additional experiment, visit **http://quest.nasa.gov/space/teachers/microgravity/6surf.html**. Consider showing students some experiments conducted with spheres of water in space at **http://www.freesciencelectures.com/video/waves-bubbles-and-reactions-in-a-free-sphere-of-water/**. (3-minute video)

Activity 4 – Shoot a Cannonball into Orbit

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Background Information:
Students use a NASA webpage at **http://spaceplace.jpl.nasa.gov/en/kids/orbits1.shtml** to simulate firing a cannon that is located at the top of the Earth's atmosphere. Students realize the if there is not enough force, the cannonball returns to Earth; too much force, and the cannonball flies out into space instead of orbiting Earth (which is the goal). This activity reinforces microgravity, freefall, and orbit. For more information about microgravity and freefall, visit **http://www.nasa.gov/centers/glenn/shuttlestation/station/microgex.html** and **http://www.nasa.gov/audience/forstudents/5-8/features/what-is-microgravity-58.html**.

Activity 5 – The Expanding Universe

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Background Information:
This activity using dots placed on a balloon is used to demonstrate the concept of the expanding universe. To learn more about the expanding universe, visit
http://cosmictimes.gsfc.nasa.gov/teachers/guide/1929/guide/universe_expanding.html and **http://curious.astro.cornell.edu/question.php?number=274**.

SPACE ENVIRONMENT
Chapter Two – Stars

LEARNING OUTCOMES – Upon completion of this chapter, the student should be able to:
- Define star.
- Define nebula.
- Describe the life cycle of a star.
- Interpret a Hertzsprung Russell diagram.

IMPORTANT TERMS
black hole - a region in space where no radiation is emitted
constellation - a grouping of stars, named after mythical figures and animals
light year - the distance light travels in one Earth year
magnitude - measure of the brightness of a star
nebula – giant cloud of gas and dust
parsec – distance equal to 3.26 light years
pulsar - pulsating star that flashes electromagnetic emissions in a set pattern
star - a body of hot gases

PRESENTATION
Attention:
Put students in small groups of up to 4 students per group. Ask each group to take out a piece of paper and list as many songs as they can think of that mention the word "star." Give the students one to two minutes to complete the task. Possible answers may include: "Star-Spangled Banner", "Twinkle, Twinkle Little Star"; "When You Wish Upon a Star" (from Disney's Pinocchio); "We Three Kings of Orient Are" ("Star of Wonder"); "Hey Now, You're a Rock Star" (by Smash Mouth); "Superstar" (by Taylor Swift); "Lucky Star" (by Madonna); and "Rock Star" (by Miley Cyrus). Determine who had the most legitimate answers. (If no one has heard of the song, have the student sing it.)

Motivation:
If time permits, ask students to analyze the songs on their list (or the class list) and determine the characteristics of stars based on the songs. Ask how many groups listed the tune "Twinkle, Twinkle Little Star" as their first entry. Ask if there was any group that did not have that tune listed. Tell students that particular song makes a statement about stars which many people young and old think, "How I wonder what you are." Many people do not have a good understanding of what stars are. Additionally many people do not realize that our solar system has only has one star. Ask students if they know the name of the one star that is in our solar system. (the Sun) Remind students that it is important to understand our world and the space beyond Earth. We are no longer bound to exploration within Earth's atmosphere. Additionally, if someone were to ask you if you wanted to travel to a star, you might make a mistake in answering "yes" if you don't understand what a star is. One thing is for sure, if you traveled to visit a star, you'd be "hot stuff."

Overview:
Tell the students that in chapter two, they will be learning about stars, including the life cycle of stars. Tell students that upon completion of the chapter, they will be able to answer questions such as the following: How far away is closest star to our solar system? How bright are stars? How long do stars live? What is a black hole?

Lesson Outline:

Either together or individually, read chapter two and discuss it. An outline for chapter two follows below. Either in conjunction with reading and discussing the chapter or after reading the chapter, conduct at least 2 of the activities included in chapter two. (See Chapter Two Activities.)

I. Star Introduction
- A. Star definition (see terms and definitions)
- B. Difference between planets and stars

II. Measuring Star Distances
- A. Light year (see terms and definitions)
  - 1. Distance equals a little less than 6 trillion miles
  - 2. Approximately 32,000 round trips from the Earth to the Sun equals distance of 1 light year
- B. Parsec (see terms and definitions)

III. Measuring Star Brightness
- A. Magnitude (see terms and definitions)
  - 1. Apparent magnitude – brightness as seen from Earth
  - 2. Absolute magnitude – brightness as viewed from a distance of 10 parsecs from Earth, regardless of actually how far away it is (measure of true brightness)
  - 3. Lower magnitude number equals brighter star; higher number equals dimmer star
- B. Hertzsprung-Russell Diagram
  - 1. Graphic organizer for stars
  - 2. Properties
    - a. star magnitude
    - b. star temperature
    - c. spectral class
      - i. O stars are hottest (blue in color)
      - ii. M stars are the coolest (red in color)

IV. Life Cycle of Stars
- A. Nebula (see terms and definitions)
- B. Burn hydrogen
- C. Majority of life spent in main sequence phase
- D. Medium Mass Stars (like the Sun)
  - 1. Have 0.5 – 8 times the mass of the Sun
  - 2. Live for billions of years
  - 3. Expands to be a red giant star
  - 4. Toward end of life – outer layers of red giant blow and become a nebula; star becomes white dwarf (glowing hot star with no more fuel that cools very slowly with mass about 1.4 times that of the Sun)
- E. High Mass Stars
  - 1. Have at least 8 times the mass of the Sun
  - 2. May only spend a few million years in main sequence phase (shortest life compared to medium and low mass stars)
  - 3. Able to fuse together heavier elements
  - 4. Expands to be a red supergiant
  - 5. Explodes (supernova)
    - a. neutron star – results if remaining core of supernova has less than 3 times the mass of the Sun (1 tsp of neutron star weighs about 1 billion tons on Earth – very dense)
    - b. black hole – results if remaining core of supernova has 3 or more times the mass of the Sun

F. Low Mass Stars
  1. Have 0.08 to 0.5 the mass of the Sun
  2. Live for hundreds of billions, perhaps trillions, of years (longest lives)
  3. Red dwarfs
    a. most common type of star in universe
    b. nearest star to our solar system (Proximus Centauri) is red dwarf
    c. become white dwarfs and eventually black dwarfs

G. Multiple Stars
  1. Binary – pair of stars sharing the same gravitational center
  2. Constellation (see terms and definitions)

Closure:
After reading and discussing chapter two, and after conducting hands-on activities for chapter two, consider one or more of the following suggestions to review chapter one:
• Play a tic-tac-toe review game. (See suggestion in chapter one "closure" section.)
• Have students act out the life of a star.
• Have students record important information that they wish to remember from chapter two.
• Have students create a chapter two review worksheet. Select the best one to provide to the class to complete.
• Create a crossword puzzle or word find for chapter two. Free resources are available at **http://www.discoveryeducation.com/free-puzzlemaker/?CFID=11104874&CFTOKEN=79374463** and **http://www.theteacherscorner.net/printable-worksheets/make-your-own/crossword/**.

CHAPTER 2 ACTIVITIES

The complete directions for each activity are provided in chapter two of Module 5 along with an explanation/summary for each activity. Whether students conduct activities together or individually at home, conducting chapter two hands-on activities helps introduce, clarify, and/or re-emphasize specific content in chapter two.

Activity 6 – Analyzing Starlight

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Background Information:
In this activity, students make a simple spectroscope to see the different wavelengths of various light sources. The connection to stars is that stars give off light, and as such, they have different light patterns. For more information on this topic, visit **http://cas.sdss.org/dr7/en/proj/basic/color/fromstars.asp**. Additionally, engage students in further studying stars and light by having them complete the interactive learning opportunities at **http://amazing-space.stsci.edu/resources/explorations/light/index.html**.

Activity 7 – Measuring the Brightness of the Stars

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Background Information:
Using a homemade magnitude strip made of cellophane and cardboard (or file folders), students can determine the apparent magnitude of stars in the night sky. To learn more about magnitude and to see a list of apparent and absolute magnitudes for 26 stars, visit **http://www.astro.wisc.edu/~dolan/constellations/extra/brightest.html**.

Activity 8 – Astronomy in a Tube

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Background Information:
The purpose of this activity is to familiarize students with star patters of popular constellations such as Cassiopeia, Orion, and Bootes. Students use a narrow container to simulate looking through the night sky. At the end of the container, there is a covering with holes. Light is visible through the small holes which are arranged to show a specific constellation. For additional constellation patterns and flashcards, visit **http://www.science-teachers.com/constellation_flashcards.htm**. To make a sky wheel that shows the constellations and allows one to locate stars in the night sky, visit **http://www.lawrencehallofscience.org/starclock/skywheel.html**.

SPACE ENVIRONMENT
Chapter Three – Our Solar System: Sun, Moon, and More

LEARNING OUTCOMES – Upon completion of this chapter, the student should be able to:
- Define astronomical unit (AU).
- Distinguish between solar flares, solar prominences, and sunspots.
- Describe the Moon in terms of temperature, atmosphere, gravity, and terrain.
- Identify the phases of the Moon.
- Explain what causes a solar and lunar eclipse.
- Define comet.
- Explain the differences between an asteroid, meteoroid, meteor, and meteorite.

IMPORTANT TERMS
asteroid - a small rocky body orbiting the Sun; usually found in the asteroid belt
astronomical unit (AU) - unit of measurement used to measure distances in our solar system
comet - a small, icy body orbiting the Sun
meteor - a small streak of light; when a meteoroid enters the Earth's atmosphere it becomes a meteor
meteorite - a meteor that enters Earth's atmosphere and actually hits Earth's surface
meteoroid - clump of dust or rock orbiting the Sun
micrometeorite - very small dust-sized bits of matter
photosphere - thin shell of the Sun's outer layer
solar flares - short-lived high energy discharges from the Sun
solar prominences - larger energy discharges from the Sun that can be thousands of miles high and last for months
solar system - the Sun and the bodies that orbit around it
sunspots - darker, cooler areas of the Sun

PRESENTATION
Attention:
For this chapter, have the students complete Activity 12 on page 35 in Module 5. (In the event you do not wish to conduct Activity 12 as the "attention" step in the lesson presentation, you may conduct it as part of the "closure" step.) Ask the students to clear their desks of everything except a pencil. Divide the students into small groups of 3-4 students per group. Distribute a Lost on the Moon page to each student (or have students use their books, ensuring that no one turns the page). Read the background information aloud, and then allow each student in the group about 3 minutes to rank their items in terms of importance under the heading "YOUR RANKING." Next, have the groups work together to create a "GROUP RANKING" of the items. After all groups have ranked their items, ask the students to look at the answers on page 36 in their Module 5 book. Allow groups to tabulate their group error points (last column) by calculating the difference between NASA's ranking and the group's ranking of each individual item. Then, add all of the error points to determine scoring.

Motivation:
Explain to the students that it is important to understand environments outside Earth's atmosphere, such as the Moon, as those may potentially be environments in which humans may one day live and work. There are also celestial bodies beyond Earth that can affect us right here on Earth. Take the Sun, for example. It is responsible for our very existence. Although it is 93 million miles away, it can also be harmful by causing sunburns or even severe skin damage that can result in death.

Overview:
Tell the students that in chapter three, they will learn about the Sun, the Moon, and other celestial bodies to include asteroids, comets, and meteoroids.

Lesson Outline:
Make copies of the Chapter 3 Hunt and distribute a copy to each student. (The Chapter 3 Hunt is located following the Lost on the Moon page in this leader's guide.) Students may work individually or in pairs to complete the worksheet. As students finish, reward them with a snack bag of "moon rocks" (trail mix) or other suitable snack. Once all of the students have completed the worksheet, discuss the answers. When discussing the answers to #s 11 and 14, consider demonstrating Activity 10 - Earth-Moon Distance. For #17, consider conducting Activity 11 - Seeing the Moon.

Closure:
After discussing chapter three via the answers to the Chapter 3 Hunt, either conduct Activity 12 (if not conducted as the "attention" step in this lesson) or answer any remaining questions the students may have regarding content in chapter three.

CHAPTER 3 ACTIVITIES

The complete directions for each activity are provided in chapter three of Module 5 along with an explanation/summary for each activity.

Activity 9 – Build a Solar Cooker

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Background Information:
In this activity, students use a shoe box lined with aluminum foil to cook a hot dog. A discussion about solar energy may follow the activity. For more information about solar energy, visit
http://www.eia.doe.gov/kids/energy.cfm?page=solar_home-basics.

Activity 10 – Earth-Moon Distance

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Content Standard D: Earth and Space Science
- Earth in the solar system

Background Information:
Students will use math skills and two balls to accurately represent a scaled distance between Earth and the Moon. For an extension of this activity, visit
http://ares.jsc.nasa.gov/Education/activities/ExpMoon/DistanceMoon.pdf.

Activity 11 – Seeing the Moon

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Content Standard D: Earth and Space Science
- Earth in the solar system

Background Information:
This demonstration simulates the phases of the moon using a lamp, a ball, and a person slowly turning while holding the ball in front of himself/herself. When a student's back is to the light source (representing the Sun), remind the student to hold the ball (representing the Moon) a little below or above his/her head in order to avoid a lunar eclipse. The reason the moon would appear as a full moon (as opposed to being an eclipse) is because the Moon is tilted about 5° in its orbital path around Earth compared to the orbital path of the Earth around the Sun. Because of this, the Moon usually passes a little above or below the Earth.
Go to **http://www.schoolsobservatory.org.uk/astro/esm/moonphase** to show a computer animation of the phases of the moon. Remember to explain why the Moon is a full moon instead of a lunar eclipse when the Earth is between the Moon and Sun during the animation. Another terrific animation is located at **http://highered.mcgraw-hill.com/olcweb/cgi/pluginpop.cgi?it=swf::800::600::/sites/dl/free/0072482621/78778/Lunar_Nav.swf::Lunar%20Phases%20Interactive**.

Activity 12 – Lost on the Moon - Survival

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Content Standard C: Life Science
- Structure and function in living systems

Content Standard E: Science in Personal and Social Perspectives
- Populations, resources, and environments

Background Information:
Students engage in a team discussion to rank 15 items in order of importance as it relates to a survival scenario on the Moon. The Lost on the Moon page is located on page 35 of Module 5, and another copy is available in this leader's guide following Activity 13. The answers and scoring interpretation are located on page 36 of Module 5.

Activity 13 – Meteoroids and Space Debris

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Content Standard D: Earth and Space Science
- Earth in the solar system
- Science and Technology
- Abilities of technological design

Background Information:
Students jab a straw into a potato in order to show that even a small mass can penetrate things if its velocity is high enough. Micrometeoroids, not to mention meteoroids and other space debris, traveling at high speeds pose significant hazards to spacecraft and perhaps even a greater threat to astronauts conducting space walks. Consider showing a 5-minute video clip at **http://videos.howstuffworks.com/nasa/2183-how-spacesuits-work-video.htm** explaining how astronaut spacesuits work. For information about astronaut spacesuits, visit **http://www.nasa.gov/pdf/188963main_Extravehicular_Mobility_Unit.pdf**. For related activities, visit **http://quest.arc.nasa.gov/space/teachers/suited/9d2micro.html**.

LOST ON THE MOON – SURVIVAL
Activity 12 from Module 5, Chapter 3

Background:
Your spaceship has just crash-landed on the dark side of the Moon. You were scheduled to rendezvous with your mother ship 200 miles away, on the lighted surface of the Moon, but the rough landing has destroyed your ship and ruined all but the 15 items listed below. Since your crew's survival depends upon reaching the mother ship, you must choose the most critical items available for the 200-mile trek across the Moon's surface. NASA would have given you their priority list, but no contact can be made with NASA at this time. Rank your items in order of importance, with 1 being most important and 15 being least important. Then, compare your answers with NASA's.

ITEMS	NASA RANKING	YOUR RANKING	ERROR POINTS (you)	GROUP RANKING	ERROR POINTS (group)
Box of matches					
Food concentrate					
50' of nylon rope					
Parachute silk					
Solar powered heating unit					
Two 45 caliber pistols					
One case of Pet milk					
Stellar map					
Two 100-pound oxygen tanks					
Self-inflating life rafts					
Magnetic compass					
Five gallons of water					
Signal Flares					
First aid kit containing injection needles					
Solar powered FM transceiver					
***SCORE**					

*Scoring: For each item, record the difference between your rank number and NASA's rank number (shown on page 36 in Aerospace Dimensions Module 5) under "Error Points." Then, do the same for your group's answers. Add the differences listed in each "Error Points" column.)

0-26=Excellent 33-45=Average 46-55=Fair 56-112=Still lost on the Moon

CHAPTER 3 HUNT
Module 5, Chapter 3 (Sun, Moon, & More)

1. What is the most important element of our solar system? ___________________________________

2. What is the name of the only star in our solar system? ___________________________________

3. What is the distance of 1 AU? ___________________________________

4. What is the distance between the Sun and the Earth? ___________________________________

5. If the Sun were hollow, about how many Earths would fit inside it? ___________________________________

6. What is the temperature of the Sun in its coolest regions? ___________________________________

7. The very thin shell of the Sun's outer layer that gives off light and is the visible surface of the Sun that we see is called the ______________________________.

8. What term is used to describe darker, cooler areas of the Sun?___________________________________

9. What are solar flares, and why are they dangerous? ___________________________________
____

10 .Why are solar eclipses rare, and why do we not experience a lunar eclipse each month since the moon makes a complete orbit around Earth in about 28 days? ___________________________________
____
____

11. What is the average distance from the Earth to the Moon? ___________________________________

12. About how many Moons would fit across the diameter of the Earth?______________

13. How much does a 54-pound object on Earth weigh on the Moon?______________

14. About how many Earths would fit between Earth and the Moon?______________

15. Describe the Moon. ___________________________________
____
____

16. There is conclusive evidence of water on the Moon thanks to data obtained from what NASA mission? ___

17. What is the correct name for this moon phase?  ___________________________________

18. The first asteroid was discovered by an Italian astronomer in what year? __________

19. The asteroid belt is located between ____________________ and _____________________.

20. Halley's Comet reappears every ________ years.

21. If a meteoroid enters Earth's atmosphere, it is called a ________________.

CHAPTER 3 HUNT – ANSWER KEY

1. What is the most important element of our solar system? ***the Sun***

2. What is the name of the only star in our solar system? ***the Sun***

3. What is the distance of 1 AU? ***93 million miles***

4. What is the distance between the Sun and the Earth? ***1 AU (93 million miles)***

5. If the Sun were hollow, about how many Earths would fit inside it? ***1 million***

6. What is the temperature of the Sun in its coolest regions? ***7592° F***

7. The very thin shell of the Sun's outer layer that gives off light and is the visible surface of the Sun that we see is called the ***photosphere***.

8. What term is used to describe darker, cooler areas of the Sun? ***sunspots***

9. What are solar flares, and why are they dangerous? ***They are short-lived, high-energy discharges from the Sun. They can harm satellite, ground systems, spacecraft, and astronauts.***

10. Why are solar eclipses rare, and why do we not experience a lunar eclipse each month since the moon makes a complete orbit around Earth in about 28 days? ***This is due to the orbital path of the Moon around the Earth, which is tilted at about 5° compared to the orbital path of the Earth around the Sun.***

11. What is the average distance from the Earth to the Moon? ***240,000 miles***

12. About how many Moons would fit across the diameter of the Earth? ***4***

13. About how many Earths would fit between Earth and the Moon? ***30***

14. How much does a 54-pound object on Earth weigh on the Moon? ***9 pounds***

15. Describe the Moon. ***no atmosphere; therefore, no air and no sounds; 1/6 Earth's gravity; 250° day, -250° night (extreme temps); 2 types of terrain: highlands, lowlands***

16. There is conclusive evidence of water on the Moon thanks to data obtained from what NASA mission? ***LCROSS (Lunar Crater Observation and Sensing Satellite) – took place in 2009***

17. What is the correct name for this moon phase? ***waning gibbous***

18. The first asteroid was discovered by an Italian astronomer in what year? ***1801***

19. The asteroid belt is located between ***Mars*** and ***Jupiter***.

20. Halley's Comet reappears every ***76*** years.

21. If a meteoroid enters Earth's atmosphere, it is called a ***meteor***.

SPACE ENVIRONMENT
Chapter Four – Our Solar System: The Planets

LEARNING OUTCOMES – Upon completion of this chapter, the student should be able to:
• Define planet.
• State basic facts about the planets in our solar system.
• Define and identify dwarf planets.

IMPORTANT TERMS
Students should already be familiar with vocabulary in this chapter.

PRESENTATION

Attention:
Ask students to take out a piece of paper and either draw or explain why the Earth experiences seasons. While students are working on this task, walk by the students to observe their explanations and/or drawings. Once most students are finished, ask for a couple of volunteers who are uncertain of the exact answer to share their best guess at an explanation. Ask if any students feel certain they can correctly explain why the Earth experiences seasons. Allow some students to share their written explanations and/or drawings.

Motivation:
Explain to the students that while the question may seem very simple, there are many people who cannot answer the question correctly. Explain that in the making of a 1988 film called *A Private Universe*, there were Harvard graduates could not correctly explain what causes seasons here on Earth. Additionally, at a nearby school, many ninth-graders provided the same incorrect answers as to why Earth has seasons. Tell students that the most common incorrect answer to the question was that the Earth experiences summer when the Earth is closest to the Sun, and Earth experiences winter because that is when the Earth is farthest away from the Sun during its orbit around the Sun. Spring and fall occur as the Earth is moving closer to our farther away from the Sun. While these explanations may sound logical, they are incorrect.

Overview:
Tell the students that along with being able to correctly explain why the Earth has seasons, they will learn other interesting facts about the 8 planets in our solar system in chapter 4. Additionally, they will learn the difference between a planet and a dwarf planet like Pluto.

Lesson Outline:
Make copies of the Planet Chart Notes located in this leader's guide after the Chapter 4 Activities. Distribute a planet chart page to each student. Place the students in groups with 9 members per group. Assign each of 8 students within the group **just one** of the following planets for which to record information for the chart: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, or Neptune. Assign the ninth student in each group to be responsible for gathering information about the dwarf planet, Pluto, as well as explaining information about dwarf planets in general. If a group has less than nine students, divide the tasks equally among the number of students in the group.

Provide time for each student to gather information about his/her assigned planet or dwarf planet. Once each group member has finished researching and recording information for his/her topic, have each member present his/her information to the group starting with Mercury and progressing through Pluto/dwarf planets. Allow other members in the group to record the presenter's notes on their own Planet Chart.

NOTE: The answers provided for the instructor for the planet worksheet most likely contains more information than that which will be documented by students. Some answers may vary, such as those listed for interesting facts.

Closure:
As a class, call on one volunteer to explain why the Earth experiences 4 seasons. It is because the Earth is tilted on its axis. (See page 40 in Module 5.) Allow students to share information they found to be interesting in the chapter. Ask the following planet review questions:
• Which planet is the windiest in our solar system? *Neptune*
• Which planet in our solar system is the hottest and why? *Venus* (see page 39 in Module 5)
• Which planet is often referred to as Earth's sister planet due to similar size and distance from the Sun? *Venus*
• Which planets have rings? *Jupiter, Saturn, Uranus, and Neptune*
• Who discovered the 4 largest moons of Jupiter? *Galileo*
• Which planet has the most known moons? Saturn (53 of 62 have been named)
If time allows, either conduct Activity 14 - How Old Are You or Activity Fifteen - Creating a Clay Model of the Solar System together. If time does not allow, encourage the students to conduct one or both of these activities at home.

CHAPTER 4 ACTIVITIES

The complete directions for each activity are provided in chapter three of Module 5 along with an explanation/summary for each activity.

Activity 14 – How Old Are You?

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces

Content Standard D: Earth and Space Science
- Earth in the solar system

National Math Standards:
Standard 1: Numbers and Operations
Standard 2: Algebra Standard
Standard 4: Measurement Standard
- Apply appropriate techniques, tools, and formulas to determine measurements

Standard 9: Connections
- Recognize and apply mathematics in contexts outside of mathematics

Background Information:
In this activity, students use math skills to determine their age on other planets. They may check their calculations at **http://www.exploratorium.edu/ronh/age/index.html**.

Activity 15 – Creating a Clay Model of the Solar System

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard D: Earth and Space Science
- Earth in the solar system

National Math Standards:
Standard 1: Numbers and Operations
Standard 4: Measurement Standard
- Apply appropriate techniques, tools, and formulas to determine measurements

Standard 10: Representation
- Create representations to organize and communicate math ideas

Standard 9: Connections
- Recognize and apply mathematics in contexts outside of mathematics

Background Information:
In this activity, students use math skills and clay to create a visual scale model of the size of the planets in our Solar System. For a lesson regarding scaled distances of planets in our solar system, visit
http://nightsky.jpl.nasa.gov/download-view.cfm?Doc_ID=392.

Mod. 5, Ch. 4
Plant Charts Notes

1AU=93 million miles

MERCURY Distance from Sun: ____ AU Temperature: Surface: Interesting facts:	**VENUS** Distance from Sun: ____ AU Temperature: Surface: Atmosphere: Interesting facts:
EARTH Distance from Sun: ____ AU Atmosphere: Why does Earth experience 4 seasons? Interesting facts:	**MARS** Distance from Sun: ____ AU Bigger or smaller than Earth? Temperature: Atmosphere: Why the rusty-colored surface? Gravity: Geological features: Interesting facts:
JUPITER Distance from Sun: ____ AU Temperature: Gravity: Weather: Most prominent gas: Moons: Interesting facts:(include # of Jupiters that fit inside Sun)	**SATURN** Distance from Sun: ____ AU Temperature: Rings made of: Moons: Interesting facts:
URANUS Distance from Sun: ____ AU Temperature: Why bluish greenish color? Interesting facts: (include how it spins)	**NEPTUNE** Distance from Sun: ____ AU Describe daylight: Atmosphere: Interesting facts: (include wind)

On the back of this paper, explain what dwarf planets are, list characteristics of Pluto, and define plutoids.

PLANT CHARTS NOTES: Some answers may vary.

MERCURY Distance from Sun: ***0.39*** AU

Temperature: ***800°F day (hot); -300° F night (cold)***

Surface: ***rocky w/ craters, lava flows, quake faults***

Interesting facts: ***smallest planet (slightly larger than Earth's moon); trace amounts of helium & hydrogen; Mariner spacecraft indicated ice at poles; Dec2009-1st global map of Mercury; MESSENGER spacecraft orbited planet in 2011***

EARTH Distance from Sun: ***1*** AU

Atmosphere: ***78% N, 21% O***

Why does Earth experience 4 seasons? ***Earth is tilted 23.5° on its axis; therefore, different parts of Earth receive different amounts of direct sunlight at different times of the year. (See page 40.)***

Interesting facts: ***2 solstices (when Sun is at highest or lowest pt in sky) – about June 21 (highest) & Dec 21 (lowest) for Northern Hemisphere; 2 equinoxes (amt of daylight and darkness are about the same) – March 21 & September 21 for Northern Hemisphere; 70% surface is water***

JUPITER Distance from Sun: ***5.2*** AU

Temperature: ***appr 60,000°F at its center to -220°F at its upper cloud layers***

Gravity: ***approximately 2.5 times that of Earth's***

Weather: ***high winds and giant storms***

Most prominent gas: ***90% hydrogen***

Moons: ***49 officially recognized; 4 largest are Ganymede, Callisto, Io, & Europa (Galilean moons)***

Interesting facts: ***largest planet in solar system (All other planets would fit in it.); 915 Jupiters fit inside Sun; Giant Red Spot (storm); emits 70% more heat than absorbs due to compressed hydrogen at its center; rings are dark & difficult to see.***

URANUS Distance from Sun: ***19.18*** AU

Temperature: **averages about *-350°F***

Why bluish greenish color? ***methane gas in upper atmosphere***

Interesting facts: **(include how it spins)** – ***hardly any solar radiation reaches planet; spins on its side; daylight lasts 42 yrs followed by 42 yrs of night***

VENUS Distance from Sun: ***0.7*** AU

Temperature: ***can be excess 850°F (hottest planet)***
Thick layer clouds & CO_2 -traps heat

Surface: ***relatively smooth, hot desert***

Atmosphere: ***cloudy, water vapor, sulfuric acid, 96% CO_2, 4% N***

Interesting facts: ***Earth's sister (size, distance from Sun); "Evening Star" (brightest planet seen from Earth); most visited by spacecraft***

MARS Distance from Sun: ***1.5*** AU

Bigger or smaller than Earth? ***Smaller (1/2 Earth size)***

Temperature: ***overall cold*-ave. *temp -80°F, can get as high as 70°F***

Atmosphere: ***95% CO_2, 3% N***

Why the rusty-colored surface? ***high iron content***

Gravity: ***1/3 that of Earth's***

Geological features: ***mountains, valleys, deserts, volcanoes, polar ice caps***

Interesting facts: ***has 4 seasons; day=24hrs,37m; Olympus Mons (inactive volcano)-largest mountain in solar system; Valles Marineras-largest canyon; 2 moons; Phoenix Mars Lander (2008) confirmed water on Mars - subsurface***

SATURN Distance from Sun: ***9.5*** AU

Temperature: ***does not vary as much as other planets; day=up to 130°F; night=down to -330°F; surface temp= -298°F***

Rings made of: ***ice chunks, dust, & rocks in various sizes***

Moons: ***62 identified; 53 named***

Interesting facts: ***Cassini Huygens (international mission) responsible for many details about planet; Cassini orbiter landed on Titan (1st time probe landed on celestial body in outer solar sys); seasons – all cold – last about 7 years each***

NEPTUNE Distance from Sun: **30** AU

Describe daylight: ***about 900 times less bright on Earth because Neptune is so far from Sun; High noon seems like dim twilight.***

Atmosphere: **hydrogen, helium, and methane**

Interesting facts: *windiest planet in solar system-1,500mph, Great Dark Spot gone; 165 yrs to orbit*

Dwarf planets: celestial body that a) is in orbit around Sun, b) has sufficient mass to assume nearly round shape, c) has not cleared the neighborhood around its orbit, d) is not a satellite (moon)

Pluto: cold, 3 moons; sometimes closer to Sun than Neptune; 1yr=248 Earth yrs

Plutoids are dwarf planets located beyond Neptune.

LEADER GUIDE
for
MODULE SIX

SPACECRAFT

Chapter One – Unmanned Spacecraft

LEARNING OUTCOMES – Upon completion of this chapter, the student should be able to:
- Define satellite.
- Describe an orbit.
- Define apogee and perigee.
- Identify Sputnik.
- Define a space probe.
- Describe the related parts that make up a satellite system.
- Describe the global positioning system.
- Describe the X-37's potential uses.

IMPORTANT TERMS
apogee - the highest point of an orbit
COMSAT - communications satellite
GNSS - Global Navigation Satellite Systems, the term used for navigational satellites
GOES - Geostationary Operational Environmental Satellite
GPS - Global Positioning System, a navigational system used by all areas of society
ITSO - International Telecommunications Satellite Organization, the world's largest commercial satellite communications provider; now called INTELSAT
LANDSAT - satellite that locates natural resources and monitors conditions on the Earth's surface
NAVSTAR GPS - as of 2010, the only fully-operational GNSS
orbit - the path a satellite takes around a celestial body
perigee - the lowest point of an orbit
satellite - natural or artificial object in space that orbits the Earth
space probe - satellites that either fly by, orbit, or land on a celestial body, other than Earth
Sputnik - the first artificial satellite (from Russia)

PRESENTATION
Attention:
Ask for two volunteers to help with a visual demonstration. Quietly tell one of the students that he/she will represent the Earth. This student should spin in place (slowly for safety) to represent the Earth spinning on its axis. Whisper to the other student to walk around the Earth and make beeping noises while acting like they are taking temperatures of the air. As this student is acting this out, he/she may act like he/she is cold and hot to aid in the demonstration. Tell the students who are watching that you want to know what this role play is simulating. Then, have the two volunteers perform their roles as assigned. Listen to audience responses and guesses.

Motivation:
You may begin to provide hints if no one is close to recognizing what is being simulated. (Hints include: The student in the middle is the Earth. This happened a long time ago. The student walking around the Earth is a satellite. The satellite was launched by the Soviet Union, know known as Russia. This happened in 1957.) If the students still cannot guess the simulation, allow them to use their books. Confirm that the role play is depicting the world's first artificial satellite, Sputnik I, that was launched in 1957 by the Soviet Union. It beeped for tracking purposes, and it took atmospheric temperatures. Explain the difference between natural and artificial satellites.

Overview:
Tell the students that Module 6 covers a variety of interesting topics from unmanned spacecraft and early manned space missions to how astronauts live and work in space. Explain that they will begin with chapter one wherein they will learn about different kinds of satellites and satellite "firsts."

Lesson Outline:
Conduct Activities 1 and 2 (page 15) in Module 6. Then, provide each student with a copy of the outline for chapter one of Module 6. Have students work independently or in small groups using their books to complete the outline.

MODULE 6 – CHAPTER ONE OUTLINE

I. Satellites - General Information
   A. Satellite definition:

   B. Example of natural satellite:

   C. Artificial satellite
      1. Definition:
      2. First artificial satellite launched in 1957 by the Russians:
   D. # of countries who have launched satellites since 1957:
   E. What happens to satellites orbiting the Earth?

II. Categories of Satellites
   A. Communication
      1. Abbreviation for communication satellite:

      2. Year of first communication satellite:

      3. First commercial satellite (1962):

      4. World's largest commercial satellite communications provider:

      5. Abbreviation for Tracking and Data Relay Satellite System:

         a. # of active satellites:

         b. What do they do?

      6. Deep Space Network (DSN) established by NASA supports ______________________ spacecraft missions and _________________ observations for exploration of the _____________________.
   B. Navigation
      1. Name of 1st navigational satellite and purpose:

      2. Term now used for navigational satellites:

   C. Natural Resources
      1. Purpose:

      2. Some missions of Landsats:

   D. Weather
      1. Geostationary Operational Environmental Satellites (GOES) give us –

      2. Name of first weather satellite:
         a. year it went into space:
         b. first image it sent back:
   E. Satellites for understanding space
      1. Explorer series
         a. 1958 –
         b. Explorer I discovered:
         c. Explorer 6 –

2. Satellites or spacecraft that either fly by, orbit, or land on a celestial body, other than Earth, are called _______________.

    a. first probes to take pictures of Moon in preparation for human lunar landings-

    b. flybys provided pictures of Venus & Mercury -

    c. ________________ probes – provided pictures of _____________ & Saturn

    d. 1975 - _______________ series explored environment of Mars

    e. Late 1970's - ____________________ provided improved pictures and data of Jupiter & Saturn

III. Satellites as a System

A. Refers to –

B. People

1. Refers to –

2. Define the overall _________________ and requirements for the satellites

C. Space Environment – Potential Dangers/Problems

1. atmosphere (atmospheric drag, gravity)
2. radiation – (heat _____________ emitted from sun) gives energy to solar-powered satellites, but can bring harm to satellite's protective coatings over __________ .
3. solar ________ - can harm satellite's protective shields and damage _____________ equipment
4. _____________________ & space debris
5. Manmade debris (over a __________ pieces of junk estimated to be orbiting Earth)

D. Subsystems

1. Refers to:
2. 6 subsystems are:
3. What ties the subsystems together?
4. _____________ - has frame, windows, and is insulated to help control temp
5. _____________ system – provides boost to get satellite into orbit
6. _____________ control system – steers and controls where the satellite is pointed
7. Main source of electricity while satellite is in orbit:
8. _______________ and ______________ - used to control satellite temperature (part of thermal control subsystem)
9. Command and control function

    a. _____________ system

    b. Command portion – signal from _____________ station to satellite

    c. __________________ - information sent from satellite to ground station (tells controller how satellite is functioning)

IV. Orbits and Trajectories

A. The movement or path a satellite takes around a celestial body – _______________

B. Theories of motion of celestial bodies

1. Geocentric theory (1st theory of motion of celestial bodies) –

2. Heliocentric theory (by Copernicus in the 1400's) –

3. Kepler's laws (by Kepler in 1600's) –

a. 1st law –

b. highest point reached by an orbiting object is called __________________ (represents point where object is farthest away from body being orbited)

c. lowest point reached by an orbiting object is called ___________________ (represents point where object is closest to object being orbited)

4. Newton's laws of motion (by Sir Isaac Newton) – helpful for understanding movement of satellites

a. 1st law:

b. Law that explains the gravitational attraction or pull between bodies in the universe:

C. ____________ - gives an orbit its shape

V. The Spacecraft as a Vehicle

A. "Form follows function" meaning –

B. Reason spacecraft may be very unusual shape –

VI. NASA's X-37

A. Is an ___________________ ____________________ flight demonstrator

B. Purposes:

C. Most significant mission for which it is designed –

D. Operational speed –

E. Technologies demonstrated –

F. X-OTV-1 mission on April 22, 2010 marked beginning of ______________ operations in space

For additional information about orbits and trajectories, including the difference between the two terms, visit **http://history.nasa.gov/conghand/traject.htm**.

Closure:

(If students need more time to finish they outline, they may take it home. It may then be discussed at the next class meeting.) After students have completed the outline, ask for volunteers to take turns sharing information from each of the Roman numeral sections of the outline. Discuss any questions the students may have.

CHAPTER 1 ACTIVITIES

The complete directions for each activity are provided in chapter one of Module 6 along with an explanation/summary for each activity. Whether students conduct activities together or individually at home, conducting chapter one hands-on activities helps clarify content in chapter one.

Activity One – Escape Velocity

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Content Standard D: Earth and Space Science
- Earth in the solar system

Content Standard E: Science and Technology
- Abilities of technological design

Background Information:
In this activity, students will set up a demonstration according to instructions that uses a steel ball and bar magnets to demonstrate escape velocity. Escape velocity is the speed at which an object must travel to break free of a planet or moon's gravitational force and enter orbit. A spacecraft leaving the surface of Earth, for example, needs to be going about 11 kilometers (7 miles) per second, or over 40,000 kilometers per hour (25,000 miles per hour), to enter orbit. For more information about escape velocity, visit **http://www.nasa.gov/audience/foreducators/k-4/features/F_Escape_Velocity.html**.

Activity 2 – Why Do Satellites Stay in Orbit

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Content Standard D: Earth and Space Science
- Earth in the solar system

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Background Information:
This activity uses a can, string, and ball (among a few other items) in order to demonstrate why satellites stay in orbit around Earth. This lesson can also be used to discuss Newton's laws of motion. For additional information on Newton's laws of motion, visit **http://www.astronomynotes.com/gravappl/s2.htm**.

For an additional satellite lesson/activity in terms of remote sensing, go to **http://landsat.gsfc.nasa.gov/education/ocean_color/Lessons.html**.
This lesson will help students understand how Earth-sensing satellites "see" the Earth. Earth-sensing satellites do not have cameras, but rather they use electronic instruments (sensors) to measure reflected light (radiances).

SPACECRAFT
Chapter Two – Manned Spacecraft

LEARNING OUTCOMES – Upon completion of this chapter, the student should be able to:
- Identify various manned space flight projects and their missions.
- Identify the American and Russian joint manned spacecraft mission.
- Describe the accomplishments of Alan Shepard and Neil Armstrong.
- State specific facts about the Hubble Space Telescope.
- Discuss the overall mission of the International Space Station.
- Identify various space shuttle launches and their missions.
- Describe China's effort in space.

IMPORTANT TERMS
Apollo - US manned spaceflight project that put man on the Moon
Apollo-Soyuz - manned spaceflight project linking American and Soviet spacecraft in space
Gemini - US manned spaceflight project that achieved the first walk in space, and the first two-man capsule
Mercury - US first manned spaceflight project
Skylab - US manned spaceflight project that put a laboratory into space
Space Shuttle - US Space Transportation System (STS) for transporting into space and returning to Earth

PRESENTATION
Attention:
Explain that America's manned space programs each had detailed goals which ultimately led to two Americans landing on the Moon for the first time on July 20, 1969. After three lunar landings, the last three lunar landings allowed astronauts not only to walk on the moon, but drive around on the Moon. Ask students what they imagine a lunar vehicle to look like. (Allow students to describe their idea of a lunar rover or draw one on the classroom board.) Show students a couple of video clips about the lunar rover used during the last three manned visits to the moon that occurred in the 1970's.
http://www.nasa.gov/multimedia/videogallery/index.html?media_id=22004911 (about 6 min.)
http://video.google.com/videoplay?docid=1502962445208997168# (about 1 min.)

Motivation:
Tell students that prior to landing on the Moon, many steps had to be taken. First, artificial satellites were launched into space, as discussed in chapter one. Then, we had to learn how man would react in a space environment. Then, we devised a plan to have man exit the spacecraft while in space wearing a spacesuit. We devised a plan for and practiced docking (connecting) and undocking (disconnecting) two orbiting spacecraft. A rocket had to be designed that would be powerful enough to get to the Moon. Equipment had to be developed. Many technological advances were made in our quest to get humans into space and to the Moon. Some of the products of today can be traced back to the space program. It is important to know this space history in order to understand the relationships we have with other countries helping us now with the International Space Station and other international space projects. Additionally, understanding the past helps us prepare for tomorrow, and someone's future may involve a trip to space, the Moon, the Mars, or beyond.

Overview:
Chapter two provides a number of important manned space history highlights from the first man ever launched in space to America's three early manned space programs of Mercury, Gemini, and Apollo, to lunar landings, and on to the America's Space Transportation System program, referred to as the shuttle program. It starts as a story of a great race to space and results in international space cooperation.

Lesson Outline:
Distribute the following chart to each student. Have students use the facts listed and their books to complete it.

Write the letter of the facts in the correct box below. If a specific name, date, or mission number is not provided for the fact, write it beside the letter once it is placed in the correct box below. The first one has been done for you.

Russian Firsts	Mercury Program	Gemini Program	Apollo Program
A. Valentine Tereshkova,1963			

Skylab	Apollo-Soyuz	STS (Space Shuttle Program)	Other

FACTS:

A. first woman in space
B. first American woman in space
C. first man in space
D. first American man in space
E. first man to orbit the Earth
F. first American man to orbit the Earth
G. first person to walk in space
H. first American man to walk in space
I. First American female commander
J. first human to walk on Moon
K. first space station
L. First American space station
M. first flight in 1981
N. first flight lasted about 15 minutes
O. first joint international mission
P. first teacher to teach from space
Q. five orbiters in the fleet
R. consisted of 6 manned flights
S. consisted of 5 human lunar landings
T. goal – put man on Moon
U. 2 superpowers engaged in space race for about 15 years
V. goal – determine if man could man survive space travel & learn effects of space on human body
W. goal – study effects of long-duration spaceflight (1-3 months)
X. goal – practice rendezvous & docking
Y. goal – put US laboratory into space
Z. 1986 – crew lost due to explosion
AA. first human landing on Moon
BB. China's first manned spacecraft launch
CC. 2003 – lost crew during re-entry
DD. second American to walk on the moon
EE. deployed Hubble Telescope
FF. had same amount of room as 3-bedroom house
GG. final crew spent 84 days here
HH. first two-man capsule used
II. 10 flights between 1965 and 1966
JJ. mission aborted lunar goal due to oxygen tank explosion
KK. major advantage – reusable
LL. first US docking with Mir space station
MM. mission carried 77-year old man to space
NN. first ISS construction flight

ANSWER KEY

Russian Firsts	**Project Mercury**	**Gemini**	**Project Project Apollo**
A. Valentine Tereshkova,1963 C. Yuri Gagarin, April 1961 E. Yuri Gagarin, 1 orbit April 1961 G. Alexei Leonov, 20-min, 1965 K. Salyut, 1971	D. Alan Shepard, May 1963 (**Not in book:** Mercury 3) F. John Glenn,3 orbits (Not in book: 1962 during *Mercury* 6) N. Alan Shepard, May 1963 (suborbital) R. V.	H. Ed White, Gemini IV (**Not in book:** 1965) X. HH. II.	J. Neil Armstrong, 1969, *Apollo* 11 S. (**Not in book:** *Apollo* 11, 12, 14, 15, & 16 resulted in lunar landings; Apollo 1 resulted in losing the crew during a launch rehearsal on the ground in Florida. A spark in the 100% oxygen environment of the Apollo capsule caused a fire that resulted in asphyxiation of the 3 astronauts in a matter of seconds. Due to the design of the capsule's door, they couldn't get out. Apollo 2-6 were unmanned. Apollo 7, 8, 9, and 10 were not tasked with lunar landings.) T. AA. *Apollo* 11, 1969 DD. Edwin "Buzz" Aldrin; 1969; *Apollo* 11 JJ. *Apollo* 13 (**Not in book**: 1970)

Skylab	**Apollo-Soyuz**	**Space Shuttle**	**Other**
L. 1973 W. Y. FF. GG. (**Not in book**: *Skylab* 4; Nov.16 1973 – Feb.8, 1974)	O. 1975, between Russia and the U.S.	B. Sally Ride, 1983, STS-7 I. Eileen Collins, 1999, STS-93 M. Columbia, 1981 P. Barbara Morgan, 2009, STS-118 Q. Columbia, Challenger, Discovery, Atlantis, Endeavour Z. Challenger, STS-51L CC. Columbia, 2003, STS 107 EE. Discovery; 1990 (**Not in book**: STS-31) KK. LL. 1995, STS-71 (100th US human space launch) MM. John Glenn, 1998, STS-95 NN. 1998, STS-88	U. Russia & US BB. ShenZhou 5, 2003

NOTE:
For additional U.S. manned space history information, visit the following sites:
http://www.thespaceplace.com/history/space.html and **http://spaceflight.nasa.gov/history/**
For additional information regarding Russian space history, visit
http://www.guidetorussia.com/russian-space-program.asp.

Closure:
After students have completed the worksheet, ask for volunteers to take turns sharing information for each heading. Discuss any questions students may have.

CHAPTER 2 ACTIVITIES

The complete directions for each activity are provided in chapter two of Module 6 along with an explanation/summary for each activity. Whether students conduct activities together or individually at home, conducting chapter two hands-on activities helps clarify and/or reinforce content in chapter two.

Activity Three – The Space Shuttle Glider

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Content Standard D: Earth and Space Science
- Earth in the solar system

Content Standard E: Science and Technology
- Abilities of technological design

Background Information:
Students will create a model of the Space Shuttle's orbiter using file folders. Once they have assembled the orbiter, they will experiment with its gliding capabilities.
Visit **http://www.nasa.gov/returntoflight/system/system_Orbiter.html** for specific details about the orbiter.
Visit **http://www.nasa.gov/returntoflight/system/index.html** for links to specific details about other parts of the shuttle.

Activity Four – See How the Earth Looks to an Astronaut

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard D: Earth and Space Science
- Structure of the Earth system
- Earth in the solar system

National Math Standards:
Standard 1: Numbers and Operations
Standard 2: Algebra Standard
Standard 3: Geometry
- Use visualization, spatial reasoning, and geometric modeling to solve problems

Standard 4: Measurement Standard
- Apply appropriate techniques, tools, and formulas to determine measurements

Standard 9: Connections
- Recognize and apply mathematics in contexts outside of mathematics

Background Information:
Students will visually display a scaled relationship of the Earth and Moon in terms of size and distance. Please note that the Earth is 9.5 Earth circumferences (not diameters as may be indicated in the book) away from the Earth and 30 Earth diameters away from the Moon. For the first picture of Earth taken from the vicinity of the Moon (transmitted to Earth by the Lunar Orbiter I in 1966), visit
http://www.nasa.gov/multimedia/imagegallery/image_feature_623.html. For a picture taken by the first humans on the Moon on July 20, 1969, visit
http://nssdc.gsfc.nasa.gov/planetary/lunar/apollo_11_30th.html.

Chapter Three – Living and Working in Space

LEARNING OUTCOMES – Upon completion of this chapter, the student should be able to:
- Describe *Space Station Alpha*.
- Explain the differences between *Mir* and *Skylab*.
- Define *Spacelab*.
- Describe the significance of *Salyut* 1.
- Describe the living and working conditions in space.
- Describe the different space suits.
- Define and give examples of spinoffs from the space program.
- Describe possible future space endeavors.

IMPORTANT TERMS
Mir - Russia's space station of the 1980's and 1990's
Salyut - Russia's first space station
Skylab - first space station of the US
Spacelab - European Space Agency's first space station

PRESENTATION
Attention:
Ask students what factors would they need to consider if planning a trip into space? (amount of time in space, size of spacecraft, weight – in terms of launching the spacecraft, provisions for food, provisions for personal hygiene) Ask students what they would need to take with them if going on a trip to space for an extended period of time based on answers to the previous question. (amount of food, clothing, games/books, etc.)

Motivation:
Explain to students that while considering answers to such questions may seem fanciful, with the growing privatization of the space industry, more and more people may find a need for legitimate answers. Additionally, with hopes of one day going to Mars, much thought and planning would go into making such a trip successful. Because of our vast knowledge already gained through human space missions which began in 1961 and extended stays in space on stations such as Skylab, Mir, and the ISS, we already know a great deal about how to live and work in space.

Overview:
Tell the students that in this last chapter of module 6, they will learn more about space stations. Additionally, they will learn how astronauts live and work in space, including information about wearing a space suit. Finally, they will learn about a number of common, everyday items that got their start in the aerospace industry.

Lesson Outline:
Either before or after reading about space suits on pages 31 – 37, conduct either Activity 7 - Keeping Cool or Activity 8 - Bending Under Pressure. Read together pages 31 – 37 and discuss the information. Then, read and discuss the next heading, "the Future in Space," pages 37-38. Finally, explain to students that NASA calls the technology that is originally developed for aeronautics and space but eventually is used to benefit others a "spinoff." NASA has been responsible for thousands of spinoffs. Ask students to count how many of the spinoffs listed on pages 39-41 they have used. Select a few to read in class.

An outline of chapter three follows and includes additional information not located in Module 6.

I. Space Stations
- A. Salyut series – Russian stations
  1. Salyut 1 launched 1971 – astronauts stayed 3 weeks
  2. Salyut 7 astronauts - stayed in space for 234 days
  3. Stations burned up when reentered Earth's atmosphere
- B. Mir – Russian station
  1. Launched Feb. 1986
  2. 1998 – had several malfunctions; worked to help fix
  3. De-orbited in 2001
- C. Skylab – 1st US space station
  1. Launched 1973
  2. Last of three crews – longest stay aboard station at 84 days
  3. Remained in space for 6 years before falling back to earth; most pieces disintegrated; some pieces landed in Indian Ocean
  4. **Additional information not in book:** Some debris landed in a sparsely populated area of Western Australia. In jest, an official in the area where parts of the debris fell issued a $400 fine to NASA for littering, which NASA declined to pay, and after several months, was written off. In 2009, a radio show host at a radio station in California challenged his listeners to donate money to pay the fine, and they did just that! The radio host sent a $400 check to the Shire of Esperance in Australia on behalf of his listeners. For more information, visit **http://news.discovery.com/space/celebrating-july-13-skylab-esperance-day.html**.
- D. Spacelab (which was actually a science laboratory that fit into the cargo bay of the orbiter; short-term space station since it had to be launched with and return with the orbiter used during a specific mission)
  1. Developed by the European Space Agency (ESA)

     Additional information NOT in the book is provided below in numbers 2-5:
  2. The first mission to use Spacelab was in 1983 on STS-9 aboard Columbia. Every orbiter was part of a Spacelab mission at one time or another. The last Spacelab mission was STS-90 in 1998. For a list of Spacelab missions, visit **http://www.nasa.gov/mission_pages/shuttle/launch/spacelab_shuttle.html**.
  3. Spacelab was developed on a modular basis. Spacelab was a set of components which could be arranged in different combinations or "configurations" to form a laboratory and observatory tailor-made to the needs of each flight's research objectives. Whatever the configuration, Spacelab remained solidly attached to the orbiter for the duration of its mission.
  4. Spacelab's four principal components were: 1) the pressurized module, which contained a laboratory with a shirt-sleeve working environment; 2) one or more open pallets that expose materials and equipment to space; 3) a tunnel connecting the middeck area (where astronauts eat, sleep, and do some experiments) of the orbiter to the pressurized Spacelab module; and an instrument pointing subsystem (IPS). The IPS was necessary because some research to be accomplished on Spacelab missions required that instruments be pointed with very high accuracy and stability at stars, the sun, the Earth or other targets of observation). Find additional information at **http://science.ksc.nasa.gov/shuttle/technology/sts-newsref/spacelab.html#spacelab-ips**.
  5. Some Spacelab flights were "dedicated missions" on which the orbiter's cargo bay was completely devoted to Spacelab-no other loads were carried. Other flights were ''mixed cargo missions" in which Spacelab occupied only part of the cargo bay. For more information, visit **http://history.nasa.gov/EP-165/ch1.htm**.

NOTE: The Long Duration Exposure Facility (LDEF) was not part of a Spacelab mission. LDEF was deployed in 1984 aboard Challenger as part of the STS-41 C mission. It was a school-bus sized cylindrical space experiment rack with 57 experiments that exposed materials to space for about 5.7 years. It was retrieved in 1990 as part of Columbia's STS-32 mission. (**http://setas-www.larc.nasa.gov/LDEF/index.html**)

- E. International Space Station (ISS)

NOTE: 1st ISS module launched was Zarya in Nov. 1998 by a Russian proton rocket; 1st construction mission occurred with STS-88 in Dec. 1998 wherein Unity (U.S. piece) was launched aboard Endeavour and connected to Zarya

1. Largest international scientific project in history with 16 contributing countries
2. Purpose: to achieve long-term exploration of space and to provide benefits to the people of Earth
3. Primary fields of study (to name a few): human research, microgravity, life sciences, physical sciences, and astronomy
4. Largest satellite in space; can be seen from Earth with naked eye
5. Orbits between 173 miles and 286 miles at speed of 17,227 miles per hour
6. Completes 15.7 orbits in a 24-hour period

II. Living and Working on Space Stations

A. Skylab – had dining room, toilet area, bedrooms; had hot and cold food
(Not in book: Skylab had a specially designed shower.)

B. ISS

1. Eating: Astronauts select menus months ahead of arriving at ISS; ISS has microwave and refrigerator; drink liquids through specially designed straws; have food trays with magnets to prevent floating
2. Working: Generally, astronauts work 10 hrs during weekdays and 5 hrs on Saturdays.
3. Exercising: Very important due to loss of bone and muscle mass due to microgravity environment; exercise daily; have 2 treadmills and stationary bike
4. Sleeping: wall-mounted sleeping bags
5. Hygiene: sponge baths (no shower) or wet washcloths; Each astronaut has his/her own personal hygiene kit.

III. Extravehicular Activities (EVA)

A. Definition: general term meaning going outside of the spacecraft

B. First EVA: March 1965 by Alexei Leonov (appr. 20-minute space walk)

C. First U.S. EVA: June 1965 by Ed White (appr. 22-minute space walk)

D. EVA used to make repairs to Hubble Space Telescope (Not in book: Five shuttle missions engaged in EVAs for Hubble service repairs: STS-61 in 1993, STS-82 in 1997, STS-103 in 1999, STS-109 in 2002, and STS-125 in 2009. The last repair should extend Hubble's life through 2014. Learn more at **http://hubble.nasa.gov/missions/intro.php** and **http://hubblesite.org/the_telescope/team_hubble/servicing_missions.php**.)

E. Longest EVA to date: 8 hrs. and 56 min. in 2001 by Jim Voss and Susan Helms

IV. Space Suits

NOTE: NASA refers to space suits as EMUs (extravehicular mobility units).

A. Began in 1930's with high altitude flyers (really pressure suits)

B. Gemini Program – lightweight, easily-removable space suit developed (Gemini 7 – 1st time space suit taken off while inside spacecraft)

C. Apollo moon suit – carried oxygen on backs; had supply of drinking water in suit

D. Shuttle Program – no longer custom-fitted suits; reusable; expected to last 15 years

E. Additional Information NOT in book: The Manned Maneuvering Unit (MMU) was last used on STS-51-A in 1984. It was officially discontinued in 1986 after the Challenger disaster. NASA discontinued the use of the unit due to safety concerns. A new device called SAFER (simplified aid for extravehicular activity rescue) replaced the MMU. It is a smaller, more simplified, and safer version of the MMU. It was first tested on STS-64 in 1994. Every ISS spacewalker wears a SAFER device that is connected to his/her EMU. It is only to be used to propel the astronaut back to the ISS in the event he/she becomes untethered.

V. Future in Space
   A. International Space Station
      1. Last U.S. space shuttle flight scheduled in 2011
      2. **Additional Information not in book:** In 2011, NASA agreed to pay Russia $753 million to provide 12 round-trip flights to the ISS between 2014 and 2015. The deal “should provide a one-year overlap between astronaut flights on Soyuz craft and the anticipated commercial vehicle trips.”
      3. ISS expected to be operational at least until 2020
   B. X-37 Orbital Test Vehicle
      1. Began in 1999 at NASA, developed by Boeing
      2. 2004: transferred to US Department of Defense
      3. Potential to be America’s first operational military space plane
      4. Is reusable and can stay in space for months
      5. **Additional information not in book:** In 2006, the Air Force assumed responsibility for the X-37B (designed after the X-37A). The Air Force as two X-37Bs. The X-37B’s first orbital mission (designated as USA-212) was launched in April 2010, and it returned in December. A second X-37B mission was launched in March 2011 using the other X-37 vehicle. Payloads, flight plans, and other details about the X-37B missions have not been disclosed. Its research is classified. For additional information, visit **http://www.space.com/11031-secret-x37b-space-plane-launch.html**.
   C. SpaceShipTwo
      1. Provide commercial space travel
      2. Built by Virgin Galactic and Scaled Composites
      3. Will seat 6 passengers and 2 pilots
      4. Initial cost of ticket: $200,000
      5. 2.5 hr flight with several minutes of near weightlessness
      6. Flights expected to begin in 2011 or 2012

VI. Spinoffs
   A. Definition (not in book): technology that is originally developed for aeronautics and space but eventually is used to benefit others
   B. Items that are NOT NASA spinoffs (See **http://www.sti.nasa.gov/tto/spinfaq.htm#spinfaq12**.)
      1. ang (not a spinoff)
      2. Velcro (not a spinoff)
   C. Examples of NASA spinoffs (See additional examples on pages 39-41 in Module 6)
      1. Ear Thermometer
      2. Cordless Tools
         Additional information not in book: Black & Decker created several spinoffs, including cordless lightweight battery powered precision medical instruments and a cordless miniature vacuum cleaner called the Dustbuster, but cordless power tools predate the Space Agency’s involvement with the company. For more information, visit **http://www.sti.nasa.gov/tto/spinfaq.htm#spinfaq10**.
      3. Temper Foam (used in various products such as some football helmets)
      4. Invisible Braces

   NOTE: NASA did not invent the smoke detector. NASA’s connection to the modern smoke detector is that it made one with adjustable sensitivity as part of the Skylab project. The device was made commercially available by Honeywell. The consumer could use it to avoid “nuisance” alarms while cooking. This device is no longer available. (**http://www.sti.nasa.gov/tto/spinfaq.htm#spinfaq11**.)

CHAPTER 3 ACTIVITIES

The complete directions for each activity are provided in chapter three of Module 6 along with an explanation/summary for each activity. Activities 7 and/or 8 should be conducted either before or after reading about space suits. Allow students to conduct the other activities if time, or encourage them to do the experiments at home.

Activity Five – Investigating Near Weightlessness

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Background Information:
Students will conduct a freefall demonstration by dropping various items and observing. Near weightlessness occurs when two objects are free-falling in gravity. The Space Shuttle is able to travel fast enough to prevent it from free-falling back to Earth. For more information on free-falling and microgravity, visit **http://www.nasa.gov/centers/glenn/shuttlestation/station/microgex.html** and **http://www.nasa.gov/audience/forstudents/5-8/features/what-is-microgravity-58.html**.

Activity Six – How Does Motion Cause Disorientation?

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Content Standard C: Life Science
- Structure and function in living systems
- Diversity and adaptations of organisms

Background Information:
In this activity, students will use the motion of a swivel chair experienced by a blindfolded person to demonstrate how our senses help orient us and how motion can cause disorientation. The mismatches between what our eyes see and what our body feels can cause disorientation that leads to motion sickness. The vestibular system is a fluid-filled network of canals and chambers deep within the human ear that help us keep our balance and sense which way is up. Without artificial gravity, however, the designers of the real-life International Space Station and the Space Shuttle must rely on different tricks to establish a common sense of “up”. For example, all of the modules on the ISS will have a consistent “up” orientation. And the writing on the walls points in the same direction, too.
Visit **http://science.nasa.gov/science-news/science-at-nasa/2001/ast07aug_1/** for more information and **http://www.nasa.gov/audience/forstudents/9-12/features/F_Human_Vestibular_System_in_Space.html**.

Activity Seven – Keeping Cool

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Content Standard C: Life Science
- Structure and function in living systems
- Diversity and adaptations of organisms

Content Standard E: Science and Technology
- Abilities of technological design

Background Information:
This experiment demonstrates that cool water being circulated through a tube that directly touches an object can help keep it cool. The experiment demonstrates the liquid cooling and ventilation garment (LCVG), a one-piece mesh suit made of spandex, zippered for front entry, and weighing 6.5 pounds dry, which is worn underneath a spacesuit. Tubes are woven into this tight-fitting piece of clothing that covers the entire body except for the head, hands and feet. Water flows through these tubes to keep the astronaut cool during the spacewalk. For more space suit and LCVG information, go to **http://www.nasa.gov/pdf/188963main_Extravehicular_Mobility_Unit.pdf**.

Activity Eight – Bending Under Pressure

National Science Standards:
Content Standard A: Science as Inquiry
Content Standard B: Physical Science
- Motion and forces
- Transfer of energy

Content Standard E: Science and Technology
- Abilities of technological design

Background Information:
In this activity, students use a balloon to simulate body movement of arms and legs (or other body parts involving joints) within a space suit. Trying to bend the hot-dog shaped balloon is difficult once it is inflated. By placing bracelets or rubber bands over parts of the balloon, it becomes easier to bend where the bracelets or rubber bands are located. This demonstrates the bladders that are built into space suits to make bending movements easier. For more information about space suits, visit **http://www.nasa.gov/pdf/188963main_Extravehicular_Mobility_Unit.pdf**.