National Aeronautics and
Space Administration

Educational Product	
Educators	Grades 5–12

Educational Brief

Connecting in Space: Docking With the International Space Station

Objectives
Students will demonstrate and identify procedures, selecting the best method to complete the docking activity.

Students will identify Newton's Laws of Motion.

Science Standards
Science as Inquiry
Physical Science
Motions and forces
Position and motion of objects

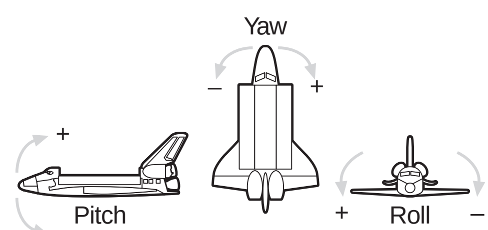
Math Standards
Problem Solving
Communication

Materials *(for each group of two)*
String, 4.6 meters
Pencil, sharpened
Tape
Space Shuttle template
Stand-off cross and docking ring template
2 small plastic cups
Straw
Clay

Background Information
The International Space Station will provide a long-term orbital laboratory in which research in biology, chemistry, physics, and other sciences will be conducted. With an approximate mass of 456,620 kilograms when it is complete, the International Space Station will be the largest object humans have built in orbit. Forty-five space flights are required to assemble this orbiting laboratory. These flights will occur over a 5-year period.

There are three phases to the development of the International Space Station. Phase One encompasses U.S. participation in the Russian *Mir* space station project. Having astronauts live aboard *Mir* with the Russian cosmonauts enables the United States to study the long-term effects of space on the human body and to practice procedures that will be used on the International Space Station. Phase Two of production for the International Space Station consists of the first portion of assembly, while Phase Three is the second portion of assembly.

In order for the components, crews, and supplies to be delivered to the International Space Station, a system needs to be in place that allows the Space Shuttle to dock, or attach, to the structure. One procedure practiced on *Mir* includes the docking techniques. After the Space Shuttle is launched and once inserted into an initial orbit, the Commander uses the Orbital Maneuvering System to thrust the Space Shuttle from one orbit to another. Using the Orbital Maneuvering System and Reaction Control System, the Space Shuttle is positioned approximately 110 meters below *Mir*. The Reaction Control System is used to complete the approach of the Space Shuttle toward *Mir*. The Reaction Control System is used to change speed, orbit, and attitude (pitch, roll, and yaw.) The pitch is an angular rotation about an axis parallel to the widthwise axis of a vehicle. The roll is the angular rotation movement about the lengthwise axis of the vehicle. The yaw is the angular rotation movement about the heightwise axis of the vehicle. The Reaction Control Systems are located in the nose and tail sections of the Space Shuttle. When the systems are activated, they are fired in a direction opposite to that which the Commander wishes to move. If the Commander wants to move to the left, he or she fires the Reaction Control System on the right, and if the desired movement is to the right, the system is fired on the left. The Space Shuttle travels toward *Mir* with a force that is equal and opposite to the Reaction Control System firings (Newton's Third Law).



The Space Shuttle stops within 50 meters of *Mir*, which is approximately one-half the length of a football field. From that position the Space Shuttle waits for clearance from Mission Control to continue. When the command is given to continue, the Reaction Control System is activated again and the Space Shuttle closes in on *Mir* at a speed of about 0.05 meters per second until it reaches a distance of about 9 meters. There, the Space Shuttle stops again and waits for approximately 5 minutes. The Commander and Pilot make sure they can see the docking target clearly and fine-tune the alignment of the Space Shuttle with the docking target. A large black cross called the Stand-off-Cross is mounted 30 centimeters (cm) above the back plate in the center of the target. When the Commander has the Stand-off Cross squarely in line with the docking target, he or she maneuvers the Space Shuttle and makes contact with the docking ring. Once a series of hooks is engaged, the Space Shuttle is then successfully docked with *Mir*. It takes about 2 hours for the passage between the Space Shuttle and *Mir* to pressurize. After the passage is pressurized, the hatch is opened and the crews exchange greetings and supplies.

These procedures, which have been learned during Phase One of the International Space Station, have been invaluable to astronauts and supporting ground crews. With the knowledge gained through cooperation, these procedures will secure the future success of the International Space Station for years to come.

Astronauts must understand the three important scientific principles that govern the motion of all objects whether on Earth or in space. These were described by English scientist Sir Isaac Newton in 1687 and are now called Newton's Laws of Motion. In simple form, they are:

1. Objects at rest will stay at rest and objects in motion will stay in motion in a straight line unless acted upon by an unbalanced force.
Newton's First Law of Motion is demonstrated by the Space Shuttle using the Reaction Control System to align itself with *Mir*. If the system were not used, the Space Shuttle would continue to move in its orbit instead of changing position to encounter *Mir*.

2. Force is equal to mass times acceleration.
This equation is used to determine how much force is needed to move the Space Shuttle from one position to another.

3. For every action there is always an opposite and equal reaction.
A good example of this law is the use of the Reaction Control System. When the Commander wants to move the Space Shuttle to the left, he or she fires the system on the right, and if the movement needs to be to the right, the system fires on the left.

Docking Activity
Invite two students to demonstrate the activity for the class. Introduce the Space Shuttle on a string apparatus. Help the students tie the loose end of the string around their waists as illustrated in the drawing. Place an empty, small plastic cup on the floor between the two students. Tell the students the cup represents the docking ring on the *Mir* space station. Explain that their task or mission is to get the orbiter inside the cup without tipping the cup over. The students may not use their hands. Allow them to demonstrate for the class. They will find teamwork is very important as they decide how to maneuver. Different techniques are to move back and forth, move closer together, and bend at the knees. Students should experiment to find the best and quickest way to dock the orbiter.

After demonstrating the activity, show the illustration and have the students estimate how long a string they will need to tie between them. Make sure each team has a copy of the Shuttle template and instruct them to tape the cut-out Space Shuttle orbiter onto a sharpened pencil. The sharpened end of the pencil needs to be at the nose or front of the orbiter. Have the students estimate the length of string that will be needed to tie the orbiter to the string that connects the students. Allow students time to practice the docking maneuver. When the students have practiced docking, bring the class together and discuss what problems may have occurred and how those problems were solved. Discuss Newton's Laws of Motion, and have the students give examples of those laws in their docking procedure.

For older students:
Copy the docking target, and enlarge the Stand-off Cross to 150 percent on heavy paper. Have the students cut out the docking target. Construct a docking apparatus by placing a piece of clay at one end of a straw. Affix this to the bottom of a small cup. Put a small hole through the docking target, and slide it over the straw. The straw should be tall enough to protrude 2–3 cm above the docking target (i.e., above the bottom of the cup). Identify the center of the Stand-off Cross. Mount the center of the cross on top of the straw over the center of the docking target. The cross should be 2–3 cm above the target. It needs to be below the top of the cup. The top of the cup simulates the actual docking ring, which is the surface that is contacted by the Space Shuttle docking system capture ring.

Have the students dock the orbiter using the same techniques as stated for younger students. When dockings have been practiced with two students, a third student might be added. This student would stand directly over the docking target and Stand-off Cross and control the string with the orbiter attached. This student would communicate to the other students what they need to do in order to line up to dock. This student would communicate to the two students attached to the string which way to move to line up with the Stand-off Cross. The center student would use his or her hands on the string to control the orbiter movement in an up-and-down motion and thus control the docking. These three students simulate the x, y, and z axes (roll, pitch, and yaw) used in docking the Space Shuttle in orbit.

Assessment:
Each group will prepare a demonstration to show which techniques they found to be the best procedure. In this demonstration, they should state the reasons they chose this procedure. The students should discuss which of Newton's Laws of Motion pertain to the activity.

Extensions:
1. Restrict students' view of the docking ring by using glasses or a headband that has blinders affixed to the sides, such as those used for horses. Then they should practice the activity with their vision impaired.

2. Use a shorter string for the docking string.

3. Use a different size cup: taller, smaller, larger, different shape.

4. Use two-way radio and/or video camera to simulate actual communication with Mission Control.

For more information about the International Space Station, please visit: **http://station.nasa.gov**

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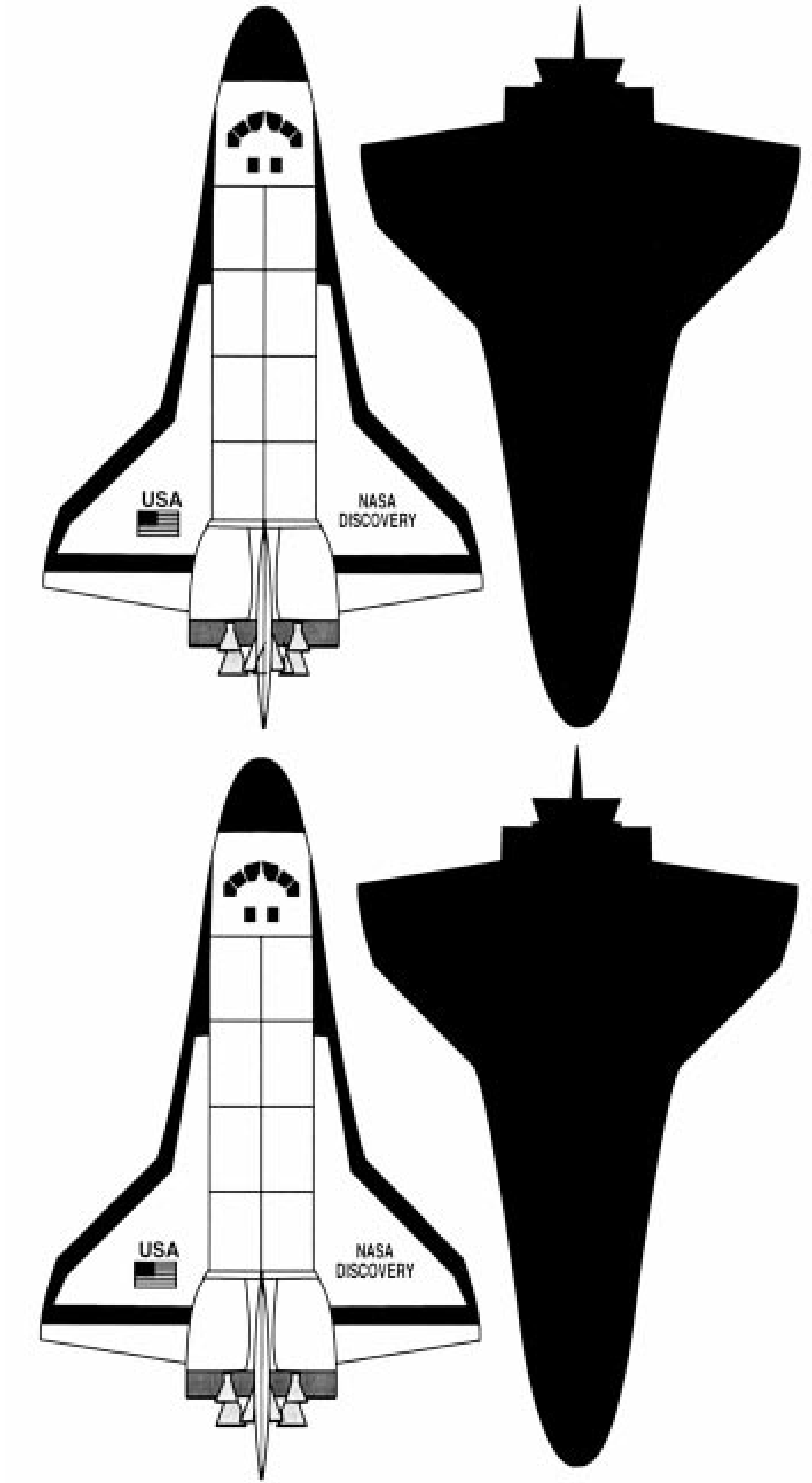
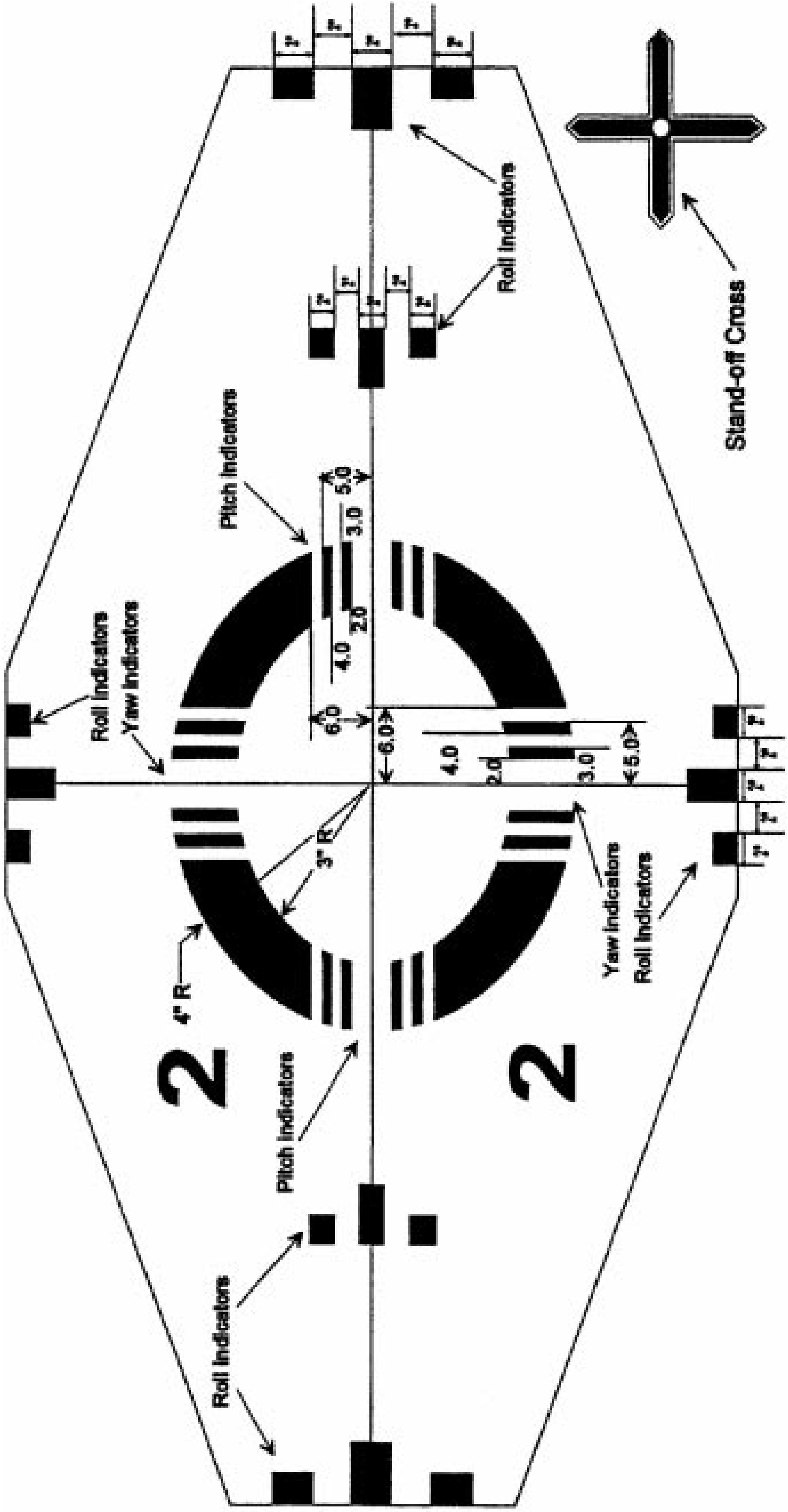
http://ehb2.gsfc.nasa.gov/edcats/educational_brief
Your evaluation and suggestions are vital to continually improving NASA educational materials. Thank you.



Note: Two copies of the Shuttle orbiter are provided for ease in duplication.


Roll Indicators
Roll Indicators
Stand-off Cross
Pitch Indicators
Roll Indicators
Yaw Indicators
6.0
5.0
3.0
2.0
4.0
4" R
3" R
Yaw Indicators
Roll Indicators
2
2
Pitch Indicators
Roll Indicators