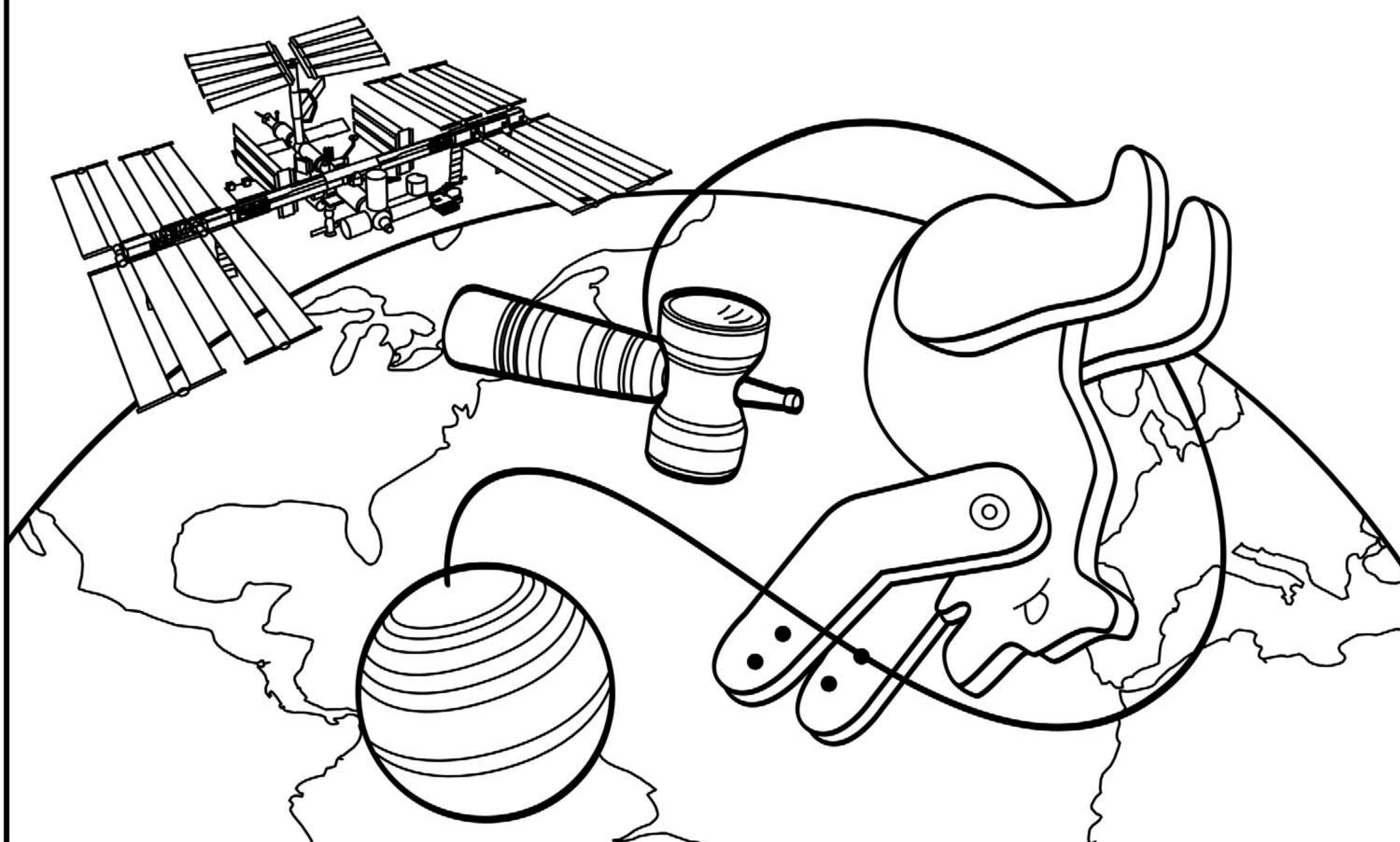
National Aeronautics and
Space Administration

Educational Product	
Educators	**Grades 5-12**

ED-2004-06-001-JSC

INTERNATIONAL TOYS in SPACE

SCIENCE ON THE STATION



VIDEO RESOURCE GUIDE

Video Synopsis

Title: *International Toys in Space: Science on the Station*

Length: 33:09

Subject: Toys in microgravity

Description:

The program demonstrates the actions of a variety of toys in microgravity for classroom comparison with the actions of similar toys on Earth.

Educational Objectives:

1. Science: To demonstrate the behaviors of toys in microgravity, thereby allowing students to determine how gravity affects the motions of familiar toys.
2. Engineering: To modify the way a toy is used so that it does function in microgravity, thereby illustrating the methods NASA uses in adapting tools to function on orbit.
3. Mathematics: To quantify, graph, and analyze the behaviors of toys in microgravity.
4. Social Studies: To investigate the origin of toys and decide which toys and sports activities might someday be used by a people living in space.

The International toys have been selected based on the following criteria:

A. Likelihood of being environmentally safe in the Space Station

B. Familiarity of students with the toy's behavior in the 1-g environment

C. Representational of the partners in the International Space Station

D. Reasonably priced or homemade with many suppliers whenever possible

E. Likelihood of a different behavior in microgravity

F. Ease in taping and documenting behavior

G. Relationship to toys that have flown – no duplication of a behavior.

Science Standards:

Physical Science

- Position and motion of objects
- Properties of objects and materials

Unifying Concepts and Processes

- Change, constancy, and measurement
- Evidence, models, and exploration

Science and Technology

- Understanding about science and technology
- Abilities of technological design

Science Process Skills:

- Observing
- Communicating
- Measuring
- Collecting Data
- Inferring
- Predicting
- Hypothesizing
- Interpreting Data
- Controlling Variables
- Defining Operationally
- Investigating

Background

On April 12, 1985, the Space Shuttle *Discovery* carried the first 11 toys into orbit. The STS-54 mission in January 1993 returned some of these toys and added 29 more to the Toys in Space program. In May 1996, the STS-77 mission crew returned 10 of the STS-54 toys that had not been tested in space. In 2002, the Expedition 5 crew tested 16 international toys and sports activities on the International Space Station where there was more room to perform these experiments. For all four missions, crew members also carried along the questions of curious children, teachers, and parents who had suggested toy experiments and predicted possible results. A few dozen toys and a few hours of the crewmembers' free time have brought the experience of free-fall and an understanding of gravity's pull to students of all ages.

Education Standards

The *National Science Education Standards* states that curricula should measure "well-structured knowledge" and "science reasoning" and should focus on progressive assessment of what students are learning rather than what they do not know. The Toys in Space program is based on this approach. Students develop concepts and structure their knowledge as they experiment with different toys. They must use their toy experiences to acquire an understanding of how toys work in order to predict what these toys will do in microgravity. These predictions require scientific reasoning and focus on student hypotheses about what will happen in space. Such predictions are open-ended and provide opportunities for positive student assessment. Many different predictions can be right for each toy's performance on orbit.

The *National Science Education Standards* encourages a focus on systems and the use of models to understand how things work. Whenever possible, toys are presented as miniature mechanical systems that may perform differently in microgravity. Science concepts are introduced to explain the behaviors of these toy systems. Many of the toys are investigated as models for behaviors of full-size mechanisms. The National Science Education Standards' emphasis on the relationship between form and function is also shared by this program. With many of the toys, especially the paper toys, the toy's function can be changed by modifying its form or shape.

Each toy investigation is structured around student abilities to do scientific inquiry as described in the National Science Education Standards:

- Students must first evaluate their toy as it compares to the toy that the crewmembers used in space. They learn to ask questions that are important to the comparison of toy performance on Earth and in space.
- Students conduct investigations about how toys perform on Earth. They describe and quantify toy behaviors whenever possible. They also explain what causes each toy's behavior.
- Students use the data collected in their experiments to predict what the toys do in space. Students must communicate their explanations of how the toys work on Earth in order to explain their predictions for space.
- Students must then evaluate their predictions based on the performance on the toys in space. They then analyze toy behaviors based on their understanding of concepts. Students must see the relationship between the toy's behavior on Earth and in space in terms of specific science concepts.

Most importantly, the Toys in Space program integrates science, engineering, and technology. The National Science Education Standards recognize that scientists and engineers often work in teams on a project. With this program, students are technicians and engineers as they construct and evaluate toys. They become scientists as they experiment with toys and predict toy behaviors in space. Finally, they return to an engineering perspective as they think about modifying toys to work in space or about designing new toys for space. Designing for space teaches students that technical designs have constraints (such as the Shuttle's packing requirements) and that perfect solutions are not realistic. Space toys, like space tools, must work within a new and unfamiliar environment.

But why take toys into space, anyway? Motion toys are well-behaved and their motions on Earth are easily observed. Without exception, these toys obey the physical laws that fill science textbooks. Regardless of their owners' wishes, toys will always play by the rules of physics. Toys are familiar, friendly, and fun – three adjectives rarely associated with physics lessons. Toys are also subject to gravity's downward pull, which often stops their most interesting behaviors. The crewmembers volunteered to perform toy experiments on orbit where gravity's tug would no longer have an effect on toy activities. Toy behaviors on Earth and in space could then be compared to show how gravity shapes the motions of toys and of all other moving objects held to the Earth's surface.

Introducing the International Toys in Space Project

When introducing the International Toys in Space program, remind students that the Earth's gravity at the location of the Space Station is nearly as strong as it is on the surface of the Earth. However, the Space Station, along with all objects on it, is actually falling toward the Earth as it orbits. From the viewpoint of objects on the Station, there appears to be virtually no gravity because objects are not pushed into the floor of the Space Station as they fall since the Space Station itself is falling. Space scientists use the term **"microgravity"** to describe this situation. The term "free-fall" can also be applied to the experience as both crewmembers and their Space Station "fall" around the Earth in their orbit.

The video segments show that several of the toys seem not to work as well in space as on the surface of the Earth. This is not surprising, since the toys were designed for use on Earth rather than in the microgravity environment of the International Space Station. However, our ability to use a toy effectively on Earth also improves as we gain practice. Try to decide which toys could perhaps have been demonstrated more effectively if the crewmembers had had more time to practice with them in space and which ones were fundamentally changed by the microgravity environment.

Teaching Strategy

The *International Toys in Space: Science on the Station* payload was conceived as an experiment in which the ISS crewmembers and the student viewers of the video program would be co-investigators. Students begin the experiment by investigating how selected toys function on Earth.

To gain the greatest benefit from this video program, students should then develop a set of experimental questions about how these toys will function in microgravity. For example, can you yo-yo in space? Will a paper boomerang return if there is no gravity? Will a flipping bear flip? Through their own experiments, students develop hypotheses to answer their questions. Students test their hypotheses by watching the video program to see what actually happened in space. While not all student questions will be addressed by the orbital experiments, enough information can be gained from watching the video program to accept, refine, or develop new hypotheses and explanations for their observations.

Many of the toys chosen for the experiment are readily available from NASA CORE.

However, other toys, such as the paper boomerang, origami flipper, and climbing bear, can be made by the students. ***Construction procedures are included in this video resource guide.***

One set of toys can adequately allow all students in the class to experience examining the toys and forming hypotheses if the teacher keeps the following strategies in mind:

- Students can be organized into cooperative study groups that specialize in one or more toy and report to the rest of the class.
- Each student can specialize in a particular toy and report to the rest of the class.
- Each student can experiment with every available toy and engage in class discussions on how the toys will operate in space.

Video Program Design

This video program is intended to be shown in segments to the students. The program is hosted by Astronaut Leland Melvin. There is also an introduction by Expedition 5 Science Officer Peggy Whitson, who provides an overview of the toy investigations and requests the participation of the students as co-investigators. The introduction of the tape is followed with toy demonstrations. Each toy segment begins with a bumper that demonstrates the toys' behavior in 1g (Earth's gravity).

Astronaut Leland Melvin

Note – Additional information on each of the toys tested in the *International Toys in Space: Science on the Station* video program begins on page 6 of this guide. Suggested activities, brief descriptions of what happened during the flight, and science and mathematics links also follow. The science/math links provide lists of relevant terms, principles, and equations. Additional information about these links begins on page 6.

Microgravity

Many people misunderstand why crewmembers appear to float in space. A common misconception is that there is no gravity in space. Another common idea is that the gravity from Earth and the Moon each pull on the crewmembers from the opposite direction and cancel out.

The real reason crewmembers appear to float is that they are in a state of free-fall around Earth. To help your students understand microgravity, show them the videotape *Space Basics* or use the *Microgravity - A Teacher's Guide with Activities*. For more information about these NASA educational products, refer to the References and Resources List on page 24.

Understanding why crewmembers appear to float in space first requires an understanding of how the crewmembers and their space vehicle stay in orbit. Rather than orbiting Earth because there is no gravity in space, the crewmembers and the International Space Station orbit Earth because there is gravity.

More than 300 years ago, the English scientist Isaac Newton discovered the Universal Law of Gravitation. He reasoned that the pull of Earth that causes an apple to fall to the ground also extends out into space to pull on the Moon as well. Newton expanded this discovery and hypothesized how an artificial satellite could be made to orbit Earth. He envisioned a very tall mountain extending above Earth's atmosphere so that friction with the air would not be a factor. He then imagined a cannon at the top of that mountain firing cannonballs parallel to the ground. As each cannonball was fired, it was acted upon by two forces. One force propelled the cannonball straight forward and gravity, the second force, pulled the cannonball down towards Earth. The two forces combined to bend the path of the cannonball into an arc ending at Earth's surface.

Newton demonstrated how additional cannonballs would travel farther from the mountain if the cannon were loaded with more gunpowder each time it was fired. Eventually, in Newton's imagination, a cannonball was fired so fast that it fell entirely around Earth and came back to its starting point. This is called an orbit of Earth. Without gravity to bend the cannonball's path, the cannonball would not orbit Earth and would instead shoot straight out into space. The same condition applies to Space Shuttles. The Space Shuttle is launched high above Earth and aimed so that it travels parallel to the ground. If it climbs to a 321-kilometer-high orbit, the Shuttle must travel at a speed of about 27,750 kilometers per hour to circle Earth. At this speed and altitude, the curvature of the Shuttle's falling path will exactly match the curvature of Earth.

Knowing that gravity is responsible for keeping the Space Station in orbit leads us to the question, why do crewmembers appear to float in space? The answer is simple: the Space Station falls in a circular path around Earth and so does everything in it. The Space Station, crewmembers, and the contents of the Space Station (food, tools, cameras, etc.) all fall together so they seem to float in relation to each other. Imagine if the cables supporting a high elevator would break, causing the car and its passengers to fall to the ground. Discounting the effects of air friction on the elevator, the car and its passengers all fall together at the same rate, so the passengers seem to float.

The floating effect of Space Shuttles and crewmembers in orbit has been called by many names, including free-fall, weightlessness, zero-g (zero-gravity), and microgravity. Weightlessness and zero-g are incorrect terms because they imply that gravity goes away in space. The term free-fall best describes the cause of the floating effect. Space scientists prefer to use the technical term microgravity because it includes the very small (micro) accelerations that are still experienced in orbit regardless of the objects falling.

International Toys in Space Experiments

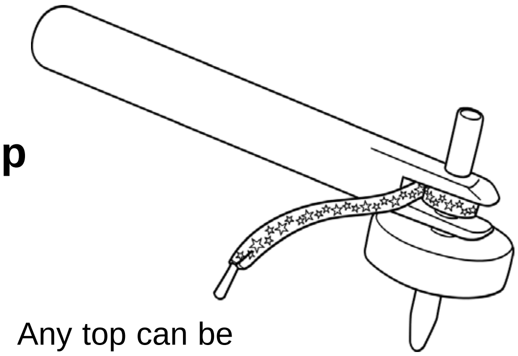
Suggested Activities

Expedition 5 Data

Science / Math Link

Questions from Video

Top



Any top can be used in classroom activities. The better the top spins, the more experiments students can do. A string top that students release (or a gyroscope) works very well for experimenting. Students should start the top spinning on a smooth, flat surface and then nudge it with a pencil. They should observe that the top keeps its axis of spin – even after pushing – until it starts to slow down. Then gravity pulls on the mass of the top and causes it to tip over. Ask students to add a small mass to the wide edge of the top and see if the unbalanced top spins as well as the balanced one does. Ask students to predict if the top will spin in space and if it will wobble as it slows down. Also ask for predictions about the effect of adding an unbalanced mass.

In space, the top spun as it does on Earth except that it floated instead of staying on a surface. This removed the friction between the top and a surface so the top could spin longer in space. The top also remained stable as long as it was spinning at all in a dramatic demonstration of gyroscopic stability.

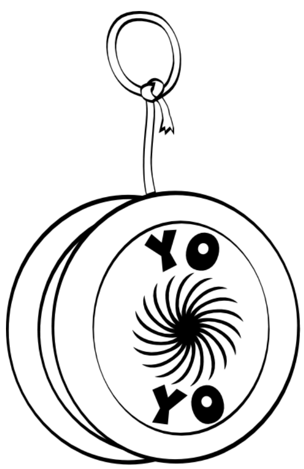
When the handle was left on the top, the top transferred some of its angular momentum or spin to the handle. When the handle and top drifted apart, they were both spinning and moving in opposite directions to conserve linear momentum. The top was also spinning more slowly than it was when the handle was pulled away.

Astronaut Peggy Whitson taped a bolt onto the rim of the top's disk to see how this would affect the top's spin. On Earth, gravity acting on the unbalanced weight of the bolt would cause the top to fall over quickly. In space, there was little effect. A second bolt also made little difference in the spin. The second bolt would have tumbled the top immediately on the Earth's surface. Astronaut Whitson also showed that pushing a top near its end caused a change in the direction of the top's spin axis. This is because an unbalanced torque produces a change in angular momentum, just as an unbalanced force produces a change in momentum.

Gravity, angular momentum, torque

The top is an ancient toy. The conservation of angular momentum gives the top its gyroscopic stability and keeps the top's axis pointed in the same direction. On the Earth's surface, friction with the surface causes the top to slow down and soon the axis of the top tips and becomes unstable. This is caused by the torque produced by the Earth's gravity acting on the tipped top.

Yo-Yo



Use a yo-yo that can sleep in your activities. To sleep there must be a loop in the string around the shaft. (The string cannot be glued to the shaft.) If possible, practice until you can sleep the yo-yo or determine that there are students in the class that can. Ask students to watch a sleeping yo-yo and decide what makes the yo-yo sleep and what causes it to climb back up the string.

Also ask students to investigate how important the yo-yo's spin is. Does the yo-yo travel faster down the string if it is spinning faster? Does the yo-yo wobble more or less if it is spinning faster? After students have made these observations, they can predict how the yo-yo will work in space.

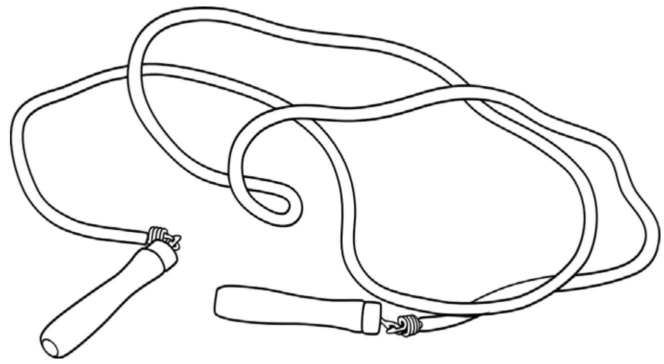
All demonstrations in space showed how the yo-yo behaved when released at a relatively slow speed by a yo-yo novice. The results may have varied had the Expedition 5 crew had more practice using the yo-yos.

Sergei Treschev's yo-yo experiments showed that the yo-yo requires a minimum spinning motion or it will wobble and float away from the string. The spin rate determined the yo-yo's speed and stability on the string. Also, once the yo-yo started back along the string, it continued to move toward Treschev even if the string was loose. In space, objects in straight line motion stay in motion.

The black yo-yo has a digital computer inside that can provide the yo-yo's speed. This yo-yo is also heavier. When spinning in space, it had more angular momentum and returned along the string more easily. The maximum turning rate was measured by the yo-yo's computer in revolutions per minute. The black yo-yo is capable of sleeping on Earth, but in space there was no downward force to hold the yo-yo in the loop when it reached the bottom of its string.

Gravity, centripetal force, angular and linear momentum, velocity, rotation rate

The yo-yo is an ancient toy, probably originating as a weapon in the Philippines. Many of the most famous yo-yo tricks (walking the dog, around the world, rocking the baby) require the yo-yo to spin freely around the loop at the end of the string. This is called a "sleeping yo-yo." Unfortunately, there is no force in space to hold the yo-yo in the loop at the bottom of the string. When the yo-yo reaches the bottom of the string, it pushes against the loop and starts back up the string. Other yo-yo tricks (loop-the-loops, flying saucer) are very elegant in space because they can be done very slowly, since there is no risk of the yo-yo not returning.



Jump Rope

The jump rope is a good toy for students trying to predict what will happen in microgravity. Students know that jumping doesn't work in space, so they must design another way to use the jump rope. Ask students to explain why the jump rope will not work in space and to describe how an crewmember might swing the rope to get exercise in space.

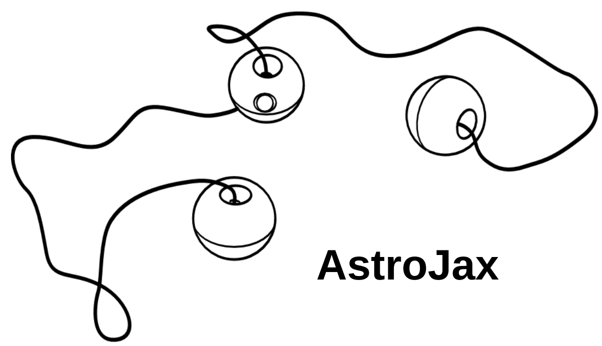
Cosmonaut Valeri Korzun decided to abandon the jumping part of the jump rope and concentrate on swinging the rope. This was not easy, either. He had to raise his legs without pushing off, and then swing the jump rope without hitting himself or the walls. When the rope was too long, it tangled. With a rope of the correct length, Korzun could swing the rope around his body several times before he floated into a wall with his body or the rope.

Gravity, centripetal force, conservation of angular momentum

The jump rope is fundamentally a gravity toy, with gravity pulling the jumper back down to the ground. A jumping crewmember travels away from the floor in a straight line and probably bumps into the ceiling. When the rope circles in one direction, the free-floating crewmember may swing around in the other direction to conserve angular momentum.

What new technique would you try?

In this video, the crew never really jumped. Encourage students to think about how the crew could have jumped – perhaps, from one wall to the opposite wall – or possibly around circular lockers, as crewmembers did in Skylab. Once crewmembers master the jumping activity, they can add the jump rope to make it more challenging.



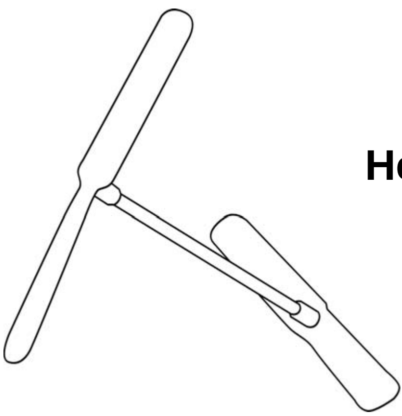
AstroJax

This toy can be purchased or constructed with three medium-sized nuts and twine. You will have to experiment to get the correct weight of the twine. Students can hold one nut and jerk the string so that the end ball makes vertical circles around the middle ball. By swinging the top nut in horizontal circles, students can cause the middle nut to swing in horizontal circles around the bottom nut. Both are stable motions. Let students play with the AstroJax until they produce a stable repeating motion. Then ask them to describe what they would do with the toy in space.

The AstroJax toy did not settle into a stable swinging pattern in space like it does on Earth, although some kind of stable motion might be achieved with much more practice. During the experiment, the middle ball continued to move chaotically unless it was next to the end ball. Cosmonaut Sergei Treschev did perform a beautiful demonstration of the conservation of angular momentum. He held the end balls and started the center ball swinging. When he released the AstroJax, the center ball moved forward with the other two balls swinging around it. The swinging balls had exactly the same motion on opposite sides of the center ball, creating a very elegant demonstration of physics in action.

Gravity, centripetal force, inertial force, circular motion

AstroJax is a modern toy invented by a U.S. physicist. AstroJax has three balls – one attached to each end of a string and the other floating loose in between. On Earth, you can hold one ball and exert a swinging motion on the other two. After a few swings, the balls will settle into a stable swing. When the balls are swinging, they conserve angular momentum. The string is also exerting a centripetal force on the balls to keep them moving in circles.



Helicopter

This is an inexpensive toy with many possible student experiments. Students can discover that the direction of the turning causes the helicopter to go up or down. Then they can experiment with adding a second propeller on the other end of the shaft, adding mass to the shaft, adding tape to one of the propeller blades or using helicopters of different sizes. After experimenting, students can describe the best helicopter on Earth and predict what would be the best helicopter in space. The crewmembers took two large helicopters and two small ones.

Sergei Treschev operated the helicopter just as he would on Earth with the same effect, except the helicopter hit the ceiling rather than falling to the ground. If the helicopter was spinning more slowly, its speed through the air was also slower and it was more likely to tumble. Adding a blade to the bottom of the helicopter definitely stabilized the helicopter due to the increased angular momentum, but also added weight so there seemed to be little, if any, gain in speed.

The small helicopter turned better than the large helicopter and was better balanced. The smaller helicopter had smaller blades, which produced less upward force, but also less mass, which made it easier to move. The double small helicopter had a large helicopter shaft between the two small copters. It also worked well.

When crewmembers combined a large blade with a small one, they discovered that it's more stable if the larger blade led the helicopter. In space the helicopter flew well with tape on one blade, but did wobble a tiny bit.

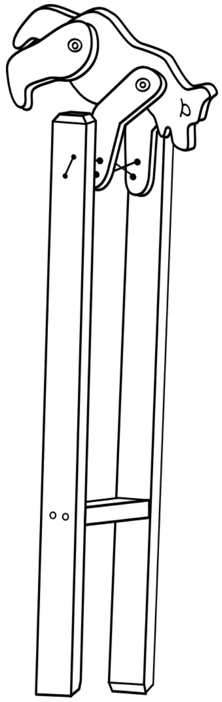
Gravity, propeller flight

The hand helicopter is a very old Victorian parlor toy. The spinning blades act like a propeller, pulling the toy through the air. The spinning motion also stabilizes the helicopter. The helicopter's speed depends on the size of the blades, the mass of the helicopter, the gravity field, and the turning rate.

Do you think that the double blades increase the helicopter's speed?

This is a good discussion question because the extra blades add more pulling force as they turn through the air in the lab. However, they also add more mass to the helicopter and it is a little harder to give the double-bladed helicopter as much spin. For these reasons, the single-bladed helicopter is faster in the video.
NOTE: although the helicopter is weightless in microgravity, its mass is still important when trying to move it through the air.

Flipping Bear



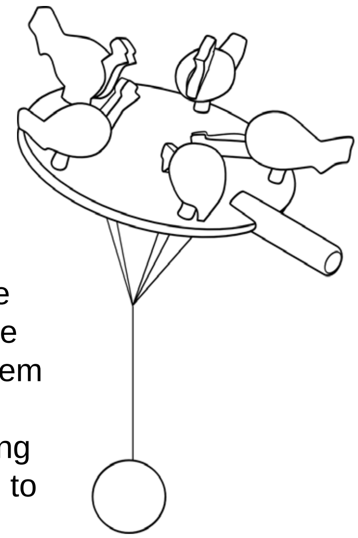
Ask students to hold the toy vertically and squeeze on the handle. Students should see the bear doing flips. Ask students to describe what happens when they squeeze on the handle and why the bear flips. Then ask students to predict if the bear will flip when they hold it sideways or downward. Also ask students to predict what will happen if they tape the bear's legs so they cannot swing. Let students try these experiments and discuss their observations. Then ask them to predict what will happen to the bear in space.

The bear flipped in space, but slowed down quickly. Cosmonaut Sergei Treschev wound up the bear to increase the turning force, but after a quick unwinding, the bear returned to its sluggish behavior. In space as well as on Earth, the operator must keep putting in energy to keep the bear swinging. Otherwise friction between the strings and the wood slows the swinging motion. The bear swung much better with its legs taped. The friction of the spinning motion of the loose arms and legs was stealing energy and momentum from the bear. With modifications and practice playing with the toy, the flipping bear might become a good space acrobat.

Gravity, circular motion, angular momentum, torque

The flipping bear is a Russian toy, still manufactured in Eastern Europe. The swinging bear works because the twisted strings connecting the bear's hands to the handle give the bear a twist (torque) as they are stretched. Gravity also pulls the bear downward. The twist of the strings gives the bear enough angular momentum to swing around the strings.

Pecking Hens



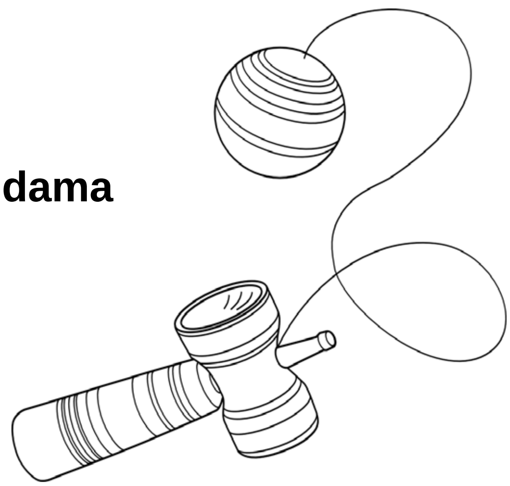
First ask students to hold onto the handle with the disk level. Then ask them to swing the handle, causing the ball to swing in circles and the hens to peck. Ask students to draw a silhouette of the hen showing where the string is attached. On the drawing ask students to show what happens when the string is pulled and what happens when the string exerts no force. Students may need to pull on one string and observe the motion of one hen carefully. Students should observe that the pulling of the string causes the head to rise and when the string is loose, gravity causes the head to fall. After making these observations, students can predict how this toy will work in space.

On Earth, the ball is always hanging downward. In space, the crewmembers could swing the ball while holding the toy sideways, and there was no downward force to pull the heads of the hens down. In some instances, shaking the hens caused the heads to move down, but the hens did not behave as smoothly as they did on Earth.

Gravity, centripetal force, angular momentum, torque

This is a traditional toy of European Russia and is still made and exported. The version that flew had five hens on a round disk with strings attached to the heads. A hen's head is raised when its string is pulled. On Earth, gravity lowers the head when tension in the string is released. The strings are connected to a ball hanging below the disk. By swinging the ball in a circle, the five sets of strings are pulled one by one. The result is the hens pecking in succession. The strings exert a centripetal force as they hold onto the swinging ball and keep it from flying away in a straight line. At the other end, each string exerts a torque on a hen's neck, causing the head to move away from the disk.

Kendama



Although this toy is available in stores, students can also make their own version with two cups taped on either side of one end of a wide craft stick and a superball on a string attached to the craft stick. The size of the cups and the ball determines how hard it is to catch the ball in the cup. A real kendama has a point between the two cups and sometimes a cup on the bottom end of the handle. Regardless of type, the challenge on Earth and in space is to get the ball into the cup. The most successful technique is to drop the cup downward as the ball enters it to keep the ball from bounding out.

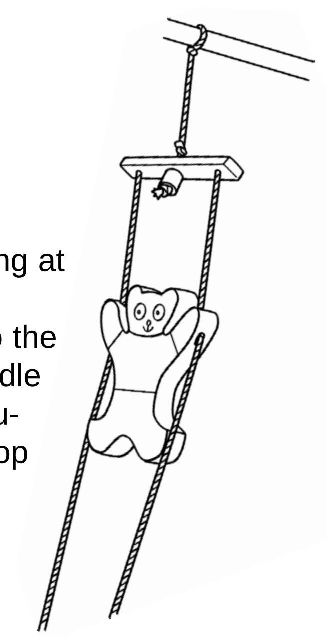
Cosmonaut Valeri Korzun tried to catch the ball in the cup and then on the spike at the end of the kendama. The ball always bounced away even when pulling the ball down into the kendama.

He then pulled the ball and kendama apart and released them. The lighter ball moved faster than the kendama to conserve linear momentum. The ball also experienced less air resistance than the handle. Cosmonaut Korzun was finally successful in catching the ball by creating a very slow impact and adding sticky tape to the bottom of the cup. This ancient Japanese toy definitely required modifications for microgravity.

Gravity, action-reaction, friction

The kendama is an ancient Japanese toy, but similar toys are found in cultures around the world. On Earth, gravity causes the ball to fall into the cup and to stay there. In space, you can either pull the ball in a straight-line motion into the cup or swing the ball around in a circular motion to reach the cup. There is no force to keep the ball from bouncing out of the cup (action-reaction).

Climbing Bear



Attach the string at the top of the wooden rod to the wall or to a handle on the wall. A second student can also hold this top string. The wooden bar must be able to move back and forth freely as the long strings are pulled. Instruct students to stretch out the strings and move the bear to the ends. As a student pulls one string and then the other, the bear climbs up the strings hand by hand. Ask students to explain what makes one hand move up the string while the other holds on. They must look at the hands carefully and see how the string goes through the hands at an angle. Younger students should be able to describe what is happening. Older students can associate the climbing with the angle of the string going through the hand and the amount of resulting friction.

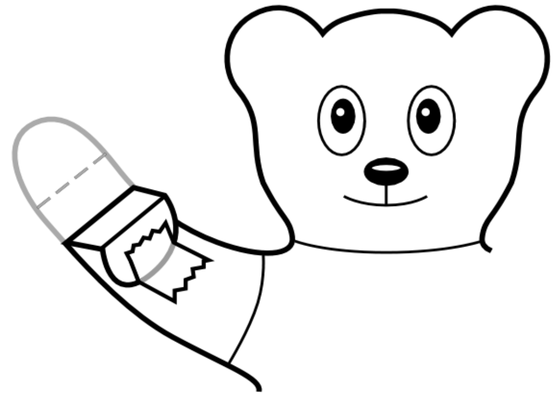
Then ask students to hold up the pivot arm, release the tension on the strings, and watch the bear slide back down. Ask students to predict how this toy will work in space. Could it be a way to move objects across the Space Station?

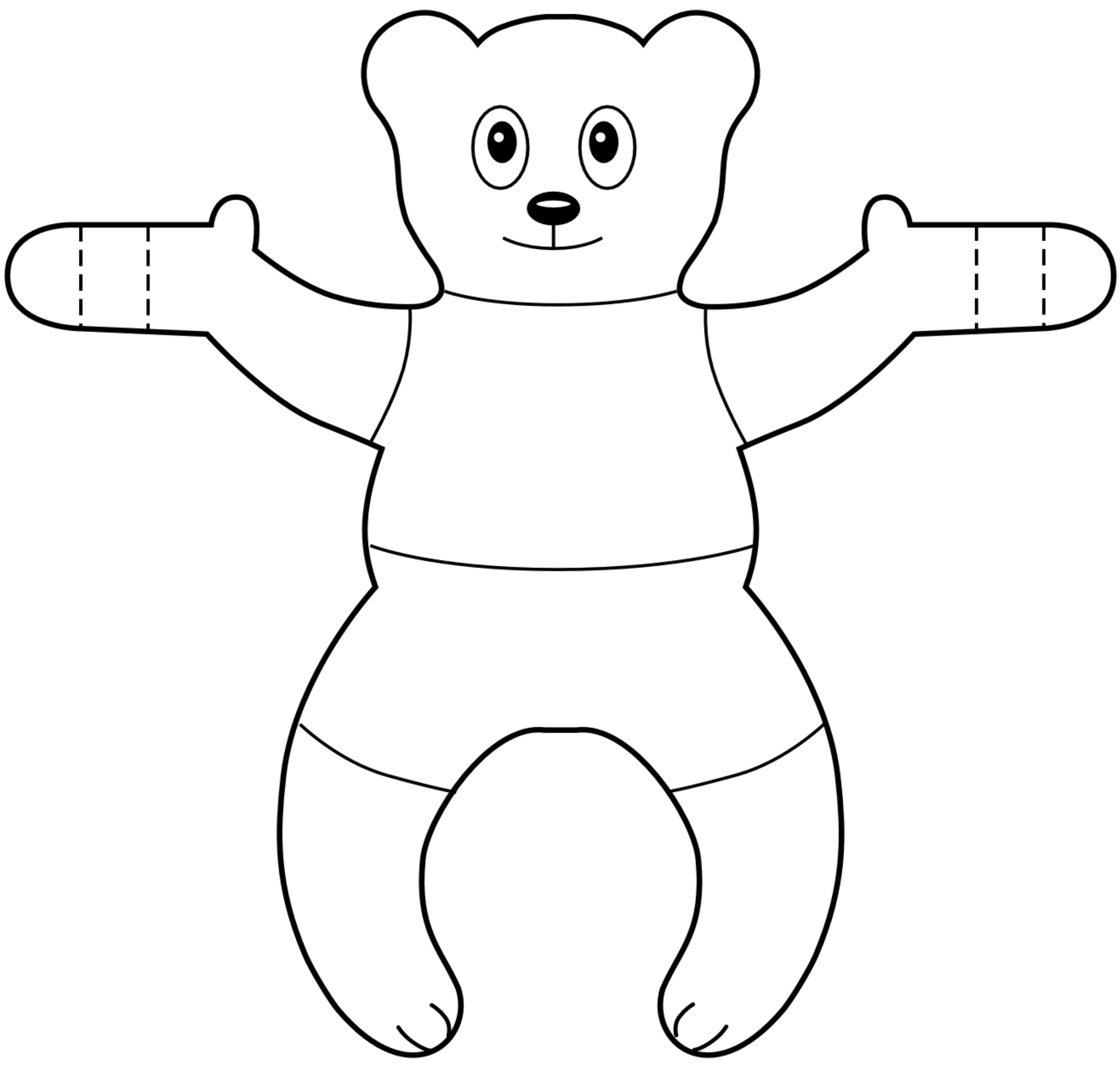
The bear climbed on the strings exactly as it does on Earth and the crewmembers performed exactly the same motions in operating the toy. As long as the strings were held tight, the bear climbed, regardless of the tilt of the strings. The only problem came in returning the bear to the starting position. The crewmembers had to pull it back down the strings since there was no downward force to make the bear slide down the strings. Because there's no way to return the bear, this would probably not be a way to move objects across the Space Station.

Gravity, friction

This is a wooden "mountain toy" sold in craft stores in the United States. The key to the toy's success is friction. When the string pulls straight through the path in the bear's hand, the friction is minimal and the bear's hand moves along the string. When the string pulls at an angle to the path through the bear's hand, the friction is so great that the hand does not move along the string. By alternating the pull, the bear climbs along the strings, hand-by-hand – with one hand held still by friction while the other moves upward. On Earth, you can raise the pivoting bar when the bear reaches it and let the strings hang free. Gravity will then pull the bear back down the strings.

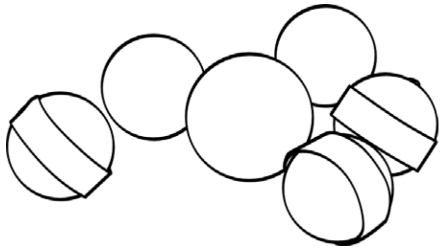
After you carefully cut out your bear, fold each hand at the dotted lines as shown and attach with tape or a staple. This will make “hands” for the bear to grip the string with.





Climbing Bear

Marbles



The marbles of different sizes and masses allow for two kinds of experiments. First students can use inexpensive glass marbles to play marbles with a shooter and a ring. After playing marbles, students can predict what will happen when crewmembers try to play marbles with the marbles floating in space.

Next students can predict what happens when a heavy marble hits a lighter marble. The experimenting can be done with a regular glass marble and the heavier shooter. Marbles can be rolled into each other on a smooth surface. Students should predict what will happen when a lighter marble (wooden) hits a heavier marble (rubber) and vice versa in space.

Peggy Whitson and Sergei Treschev tried to play three-dimensional marbles. Treschev's first problem was releasing the nine balls from his hand without losing them. They stuck to his fingers a bit and began moving apart as he pulled his hands away. Both crewmembers tried to hit floating marbles with the shooter. The game was much more difficult with the balls floating in space.

When the three different kinds of marbles were thrown to a wall, all three bounced off. The black rubber superball left the wall traveling the fastest, followed by the white wooden ball and then the second rubber ball with the red stripe (the one that did not bounce well). The speed of the ball leaving the wall depended on how much energy the ball kept in the bounce. The black rubber ball kept most of its energy and left the wall with nearly the same speed as it had on impact. The other rubber ball transferred most of its energy to the floor on the bounce and left the floor more slowly.

When a more massive ball hit the lighter ball head-on, it dominated the collision and the lighter ball changed direction and left the collision in the direction the more massive ball was originally traveling. When the lighter ball hit the heavier ball, it bounced backward, giving the more massive ball a smaller forward speed.

Gravity, conservation of momentum, elastic and inelastic collisions, game playing

Marbles are an ancient toy with different rules in different countries. All kinds of rolling spheres have been used. Normally marbles are glass, but glass is not acceptable for space so the space marbles are made of wood and rubber. The small wooden balls (30g) are somewhat lighter than the rubber balls, a fact which affects the way they move when hit. Total momentum is conserved in each collision, but kinetic energy is conserved only in perfectly elastic collisions. The plain rubber ball (36g) is polyneoprene and bounces (elastic collision). The striped rubber ball (40g) is polynorbornene and produces no bounce (inelastic collision). The elasticity of the bounce of the wood balls (coefficient of restitution) lies in between the two types of rubber balls. The elasticity will have a greater effect than the difference in mass of the two types of balls during a collision.

Why is it harder to play marbles in space?

On Earth, marbles roll on a table or floor. This surface confines their motion to one plane. The friction with the surface also slows down the rolling marbles. In space, the marbles can take off in any direction with only a tiny bit of air resistance to slow them down. So it's harder to play marbles in space because it's more difficult to control the speed and direction of their motion.

Can you figure out why the "dead marble" bounces so high in the Space Station, even though its speed is slow?

On Earth, gravity is always pulling objects downward so that if an object has a very small bounce, it will stay close to the floor. In space, the slightest bounce will send the object slowly to the surface or until another force counteracts its motion.

What conclusions can you make from observing the impacting marbles?

1. When a less massive marble hits a more massive marble, the less massive marble bounces in the opposite direction and the more massive marble moves forward slowly.
2. When a more massive marble hits a less massive marble, both marbles move forward.
3. When marbles of the same mass collide, the marble that is hit moves forward with the most of the speed of the impacting marble.

Although there are differences between interactions with the "dead rubber" marble, they are difficult to observe in the video.

Soccer

Have students watch a soccer game on video tape or describe what happens when they play soccer. Then students should describe what a soccer game with no hands would be like in space and make a list of tasks that will work and those that will not. It is very difficult and students will not think of all the possible problems.

Gravity, trajectories, action-reaction, game playing

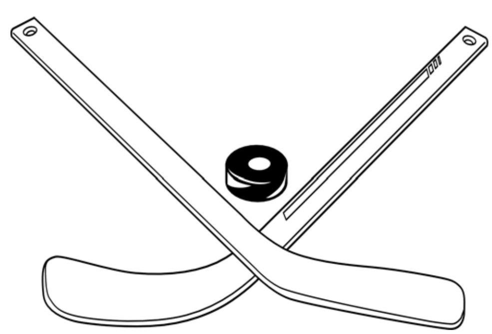
Soccer is ancient – dating back to the first ball toy. It is also played extensively around the world. Because it relies on the feet, it will be one of the most interesting toys in space.

The whole strategy for playing the game must change when there is no force to hold the soccer player's feet to the ground. Crewmembers must be certain that all loose objects are stowed and that they do not kick the ball hard against a cabin wall. It will be much more difficult to kick the ball well since there is no surface to push against with your legs.

Cosmonauts Valeri Korzun and Sergei Treschev quickly discovered that the whole strategy for playing soccer must change when there's no force to hold their feet to the ground and keep their bodies from turning.

Using feet to pass is always challenging, but even more so in space where the crewmembers can't stay on the floor. It was much harder to keep hands out of the way in space. In space crewmembers often used their arms to help position their bodies without touching anything. It is much more difficult to kick with some force and not hold onto anything.

Hockey



Games that are played on a surface, such as hockey and marbles, are much more difficult to play in space and require significant rule changes. Ask students to describe all of the behaviors required to play hockey. Behaviors should be grouped in terms of those that will work in space and those that will not. Then, after watching the video from space, students can describe how they would rewrite the rules of hockey for space.

Gravity, trajectories, impulse, game playing

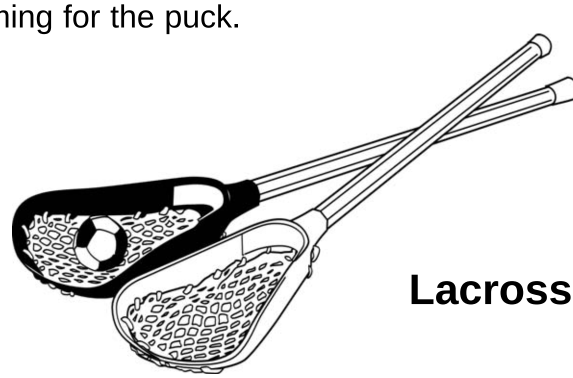
Ice hockey is a favorite Canadian sport that is played in northern climates around the world. Without a surface for the puck to slide on, the space version cannot be like the game played on Earth. On Earth, this sport relies on gravity, on the energy transferred to a puck when hit by a stick, on the puck's speed, and on what happens when the puck hits a wall. The speed of the puck depends on the speed of the swing and the amount time that the puck is in contact with the stick. The impulse given to an object is the average force exerted on it multiplied by the time over which it is exerted. The impulse is equal to the change of momentum. The speed of the puck is therefore determined, not by the force applied by the hockey stick, but by the impulse – the product of the force of the stick and the time it touches the puck.

First of all, it was hard to begin a hockey game with a face off, but Valeri Korzun and Sergei Treschev gave it a try. In space, it was easy to swing the stick, but harder to keep the stick touching the puck as the puck bounced off. Passing back and forth worked well until the puck was pushed against the floor. Then it bounced up and became hard to control. Passing the puck back and forth could be mastered, but there was no downward force to hold the puck to the floor. It was easier to check with the puck on the locker than in the air and also easier to pass when there was a surface to help control the puck's motion. Treschev discovered that the vent helped control the puck. Both the vent texture and the air pulling down through the vent slowed down the puck's motion.

To play hockey, crewmembers used the doorway as the goal with Korzun as the goalie. The mask added to the effect, but the puck is really too soft to be dangerous. First it was hard to keep the puck still long enough to take a shot at the goal. The goalie had to put his feet in straps for stability so he could stay in place as he moved to protect the goal.

What if Korzun and Treschev decide to compete for the puck?

We will need a whole new set of rules for what is "legal" in space hockey. With the puck and the crew free to go in any direction, they will have much more trouble avoiding hitting each other with their hockey sticks while aiming for the puck.



Lacrosse

You will need lacrosse sticks for students to experiment, perhaps a play set or borrowed sticks from the lacrosse team, if available. Students need to realize that the ball (in the case of the crewmembers, a hackey-sack ball) gets trapped in the mesh of the handle and does not bounce out. The player must swing the stick to release the ball from the netting. Ask students to compare lacrosse with hockey and decide which would be easier and why. Also ask students if there are other toys that might be improved with nets - like the kendama. Finally, ask students if there are other ways that crewmembers might use lacrosse sticks while living on the space station.

Gravity, trajectories, F=MA, game playing

Lacrosse is originally a Native American game played with sticks and a leather-covered ball. French settlers in Canada spread the game to the Old World.

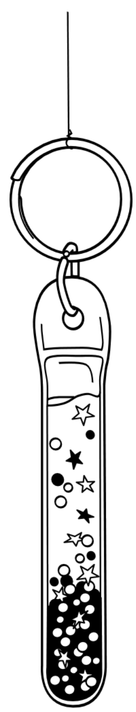
The loose nets on each stick absorb the energy of impact and keep the ball from bouncing out of the net. A hacky-sack ball was chosen for space because it would not continue bouncing after it hit a wall.

Lacrosse was the best game to play in the Space Station. The nets on the lacrosse sticks trapped the ball and made it easier to catch, aim, and return to the other player. The nets absorbed the energy of impact and kept the ball from bouncing out.

The follow-through of the stick increased the speed of the ball and determined its direction. Each ball traveled in a straight line with no dropping because of gravity.

The reach of the lacrosse stick helped in keeping track of the ball. By moving the stick in the direction the ball was traveling, the crewmembers could trap an escaping ball and the ball wouldn't bounce out of the net. Lacrosse is definitely a game that works in space.

Density Wand



This toy is a small wand with water and beads inside. The beads sink in the water. There is also an air bubble. Any wand of similar construction can be used on Earth to predict what will happen to the wand in space. Distribute the wands to students and ask them what would be different in space. Discuss how the air bubble floats on the water and how the beads sink. Ask if objects in water can sink or float in space. Ask students to play with the toy and then describe gravity's role in floating and sinking. If students are older, discuss density.

Gravity, density, centripetal force, inertial force, electrostatics

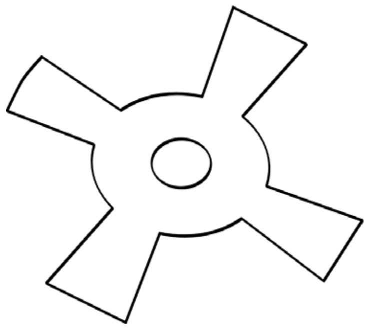
Teachers have requested this toy most because of the liquid. In microgravity, there is no force to separate the more dense beads from the water. If you jerk the wand forward, you may cause the more dense beads to move toward the end. It will probably be more effective to swing the wand and cause the beads to move to the bottom (or the outside of the swing angle). In both instances the acceleration of your hand creates an inertial force which, like gravity, causes the more dense beads and the less dense water in the wand to separate. This force also acts like a buoyant force on the small air bubble in the wand, causing it to move to the opposite end from the beads. On Earth, when the wand is turned over, the stars settle on top of the beads because their greater surface area makes them fall more slowly through the water. Rubbing the wand may put a charge in the tube, which can affect the particles inside.

In space, the air, water, beads and stars mixed together in the tube. There was no gravity force to separate the particles of different densities.

To separate them, Astronaut Peggy Whitson swung the wand in a circle. The air, water, beads, and stars all moved outward toward the end of the wand because of inertia (their tendency to continue moving in a straight line), while the plastic tube produced an inward (centripetal) force that kept the contents of the wand from flying away in a straight line. The densest particles (the beads and stars) moved to the outside end of the tube, leaving the water and the air closer to the ring that the wand was swinging around. The beads packed more tightly when they were swung than they do on Earth.

In space, shaking the wand dispersed the particles – causing the particles clustered at the back of the wand to move forward and mix with the water. The particles then remained dispersed because there was no downward force to separate them. Because of static electricity effects, some particles also stayed on the sides of the wand. Rubbing the wand caused more beads to cling to the sides of the wand and the air bubble was no longer apparent.

Boomerang

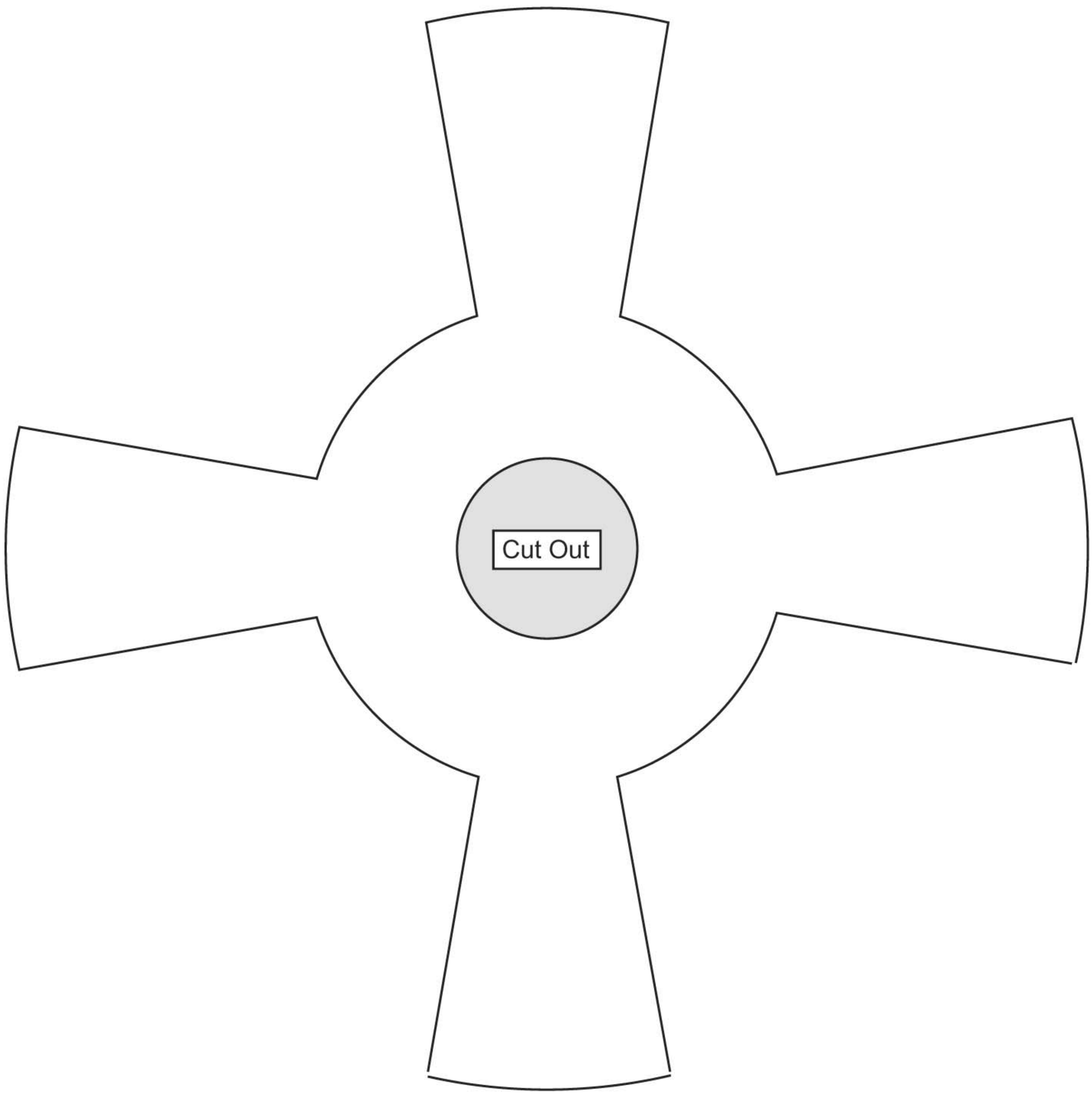


Students should first make their own boomerangs from the attached pattern copied onto cardstock or tagboard. The four blades must curve slightly upward, like the curve in a plate. Holding the boomerang vertically, students should throw it and release it with a vertical spin. When thrown correctly, the boomerang tilts from vertical to horizontal, which brings the boomerang back to the thrower. The more curved the blades, the more quickly the boomerang returns. Students need to experiment with the boomerang to discover the effects of how fast the boomerang is spinning and how much the blades are curved. After experimenting with these two variables, students can predict if the boomerang will turn in space.

Gravity, angular momentum, winged flight, air resistance

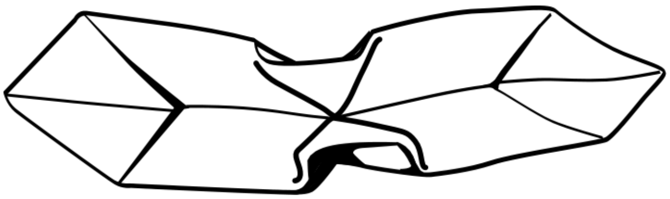
This boomerang's success in returning on Earth is due to aerodynamics, angular momentum, and gravity causing the boomerang to fall. The boomerang does not return unless it is spinning. The faster it is spinning and the more upward the curve of the blades, the more quickly it returns. The blades act as propellers pushing back against the air and propelling the boomerang forward. Because of the spin through the air, the orientation of the blades is always changing and the boomerang is always falling. As a result, the blades cause the whole boomerang to make a circle in the same orientation as the spin of the boomerang. This causes the axis of the spinning boomerang to change from vertical to horizontal so that the boomerang returns to the thrower.

Cosmonaut Sergei Treschev launched the boomerang four times: twice with a vertical throw and twice with a horizontal throw relative to the camera. In every throw in space, the boomerang continued to move forward and did not change orientation or begin curving back to Treschev. There was no downward pull to change the boomerang's angle, but air currents inside the Space Station affected the boomerang's motion.



Paper Boomerang

Origami Flipper



Origami is an ancient Japanese art. The Origami flipper is a toy that students can make for themselves. An instruction sheet is part of this package. Make a copy for each student and show students how to trim a piece of paper into a square. Once the flipper is folded, have students practice tossing the toy so that it moves forward while spinning along its wing axis. Once students are flipping their flippers, ask how the toy's behavior will change in space. The flipper used in space was made from an 8.5" by 8.5" piece of light cardstock paper.

Gravity, air resistance, angular momentum

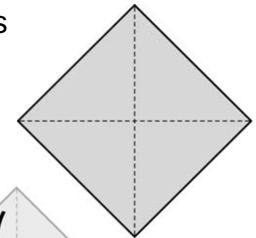
Origami objects are folded from a square of paper. This object was chosen because it is easy to fold and it has a very interesting flipping motion along its long axis when it is released. When the toy is deployed, it is given a spinning motion along its long axis. On Earth, gravity then pulls the toy downward through the air. The spinning continues until the toy hits the ground. In space, the toy can also receive linear motion as it is thrown. Besides spinning, the motion of the flipper will show whether or not the hand actually pushed on the flipper.

The flipper flipped just like it did on Earth, but it was carried upward by air currents instead of floating downward because of gravity's pull. In contrast to some of the other toys, the flipper is light enough that air currents and air resistance were sufficient to change its axis of rotation and its rotation rate quickly. On Earth, gravity helps the flipper spin and maintain its rotation longer as the toy falls through the air.

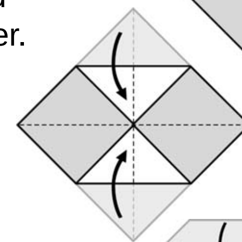
How to Make the Flipper

Materials: One square piece of paper

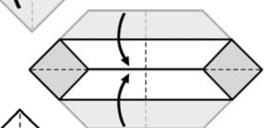
1. Make two diagonal creases in the paper by folding it diagonally each way, then open it back up. This will make an X-shaped crease in the center.



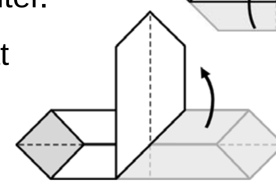
2. Fold two opposite corners in to the center marked by the two creases.



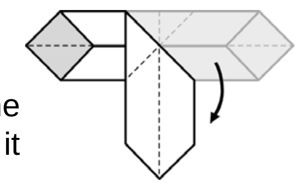
3. Bring the two folded edges to the center.



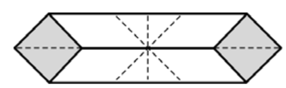
4. Fold the wings at the center to make an "L" shape, and then open it back up.



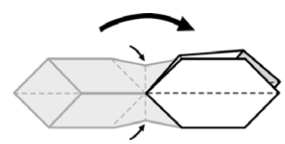
5. Fold them again to make an "L" shape the other way, then open it back up.



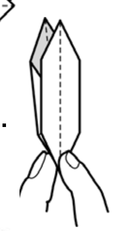
6. There should now be an X-shaped crease in the center.



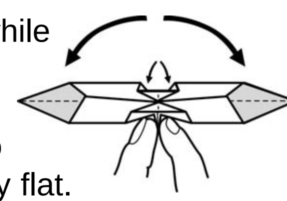
7. Fold the wings in half, tucking in the center creases.



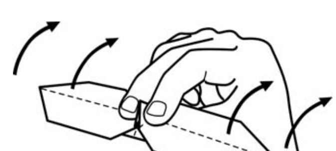
8. Grasp the flipper at the tip of the fold.



9. Open the wings while holding the fold, and then flatten the inside folds so that the wings stay flat.



10. When you turn the flipper over, there should be two flat wings with a v-shaped fin in the middle. Hold the flipper with the fin between your fingers, with your thumb underneath the flipper. Flick your hand so that the flipper flips over as it falls toward the ground. Adjust the wings to maximize the flipping.



Glossary of Science Terms, Principles and Mathematical Equations

The following terms, scientific principles, and mathematical equations are useful in describing the actions of toys on Earth and in space. It is recommended that you refer to physical science or physics textbooks for detailed explanations of terms, principles, and equations with which you are unfamiliar.

Acceleration – The rate of change in velocity.

Action Force – A force exerted on an object.

Air Resistance – The force of the air pushing against a moving object.

Amplitude – The distance that a moving wave rises or falls above or below its rest position.

Angular Momentum – A property of spinning motion that must be conserved.

The top's stability illustrates the concentration of angular momentum.

Angular momentum is the product of an object's mass, the radius of its circular path, and its velocity. The angular momentum of a spinning object is equal to its moment of inertia times its angular velocity. If the resultant external torque acting on a system is zero, the total angular momentum of the system is constant. The angular momentum is greater when the mass is farther from the rotation axis, as in the spinning disk of a gyroscope. The direction of the angular momentum of a spinning object is along the axis of rotation in a direction defined by the "right hand rule": When the curled fingers of the right hand point in the direction of the rotation, the direction of the angular momentum is that of the outstretched thumb.

Bernoulli's Principle – In a flowing fluid, increases in its velocity are accompanied by a decrease in its pressure. Bernoulli's Principle applies to all fluids, including liquids.

Buoyancy – An upward force exerted on an object in a liquid equal to the weight of the liquid which the object displaces. Microgravity is a neutral buoyancy condition.

Center of Mass – The point at which the entire mass of an object is centered.

Centrifugal Force – The apparent outward force exerted by an object moving in a circle. In reality, the object is simply trying to move in a straight line.

Centripetal Force – The inward force which causes an object to turn.

$$\textit{centripetal force} = \frac{\textit{mass x velocity}^2}{r}$$

Circular Motion – A force is required to change the direction of the velocity of an object which is moving in a circle. This inward force is called a centripetal force. Without an inward centripetal force, the object would move outward in straight line motion.

Collision: Elastic and Inelastic – For perfectly elastic collisions, the relative speed of recession after the collision equals the relative speed of approach before the collision. In a perfectly inelastic collision, there is no relative speed after the collision – the objects remain together. All other collisions lie between these two extremes.

Compression – A concentration of particles in a longitudinal wave.

Conservation of Energy – The amount of energy in a closed system remains constant over time.

Conservation of Momentum – The conservation of momentum is equivalent to **Newton's Third Law of Motion**: For two objects subject only to their mutual interactions, the sum of the momenta of the objects remains constant quantity and the momenta of objects must be added vectorally.

Crest – The high point in a wave.

Drag – The resistant force exerted by a fluid (such as the air) when an object moves through it. The drag force opposes the motion of the object.

Space Hockey produces unexpected elastic collisions.

Elastic Potential Energy – Term used to describe the energy stored in a stretched object (usually a spring).

Energy – A property of nature that is present in many forms. Energy that moves from one system to another under the action of forces is called work.

Force – A push or pull.

Free-fall – The condition of an object falling in a gravity field.

Frequency – The number of waves or pulses passing a point per unit of time.

Friction – A force which opposes sliding motion. When two bodies are in contact with each other, they exert forces on each other due to the interaction of the particles in one body with those of the other. The tangential component of the contact force exerted by one object on another is called a frictional force.

G-Force – The ratio produced when the force felt by an object is divided by the weight of that object when motionless on Earth's surface.

Gravitational Potential Energy – The energy possessed by an object by virtue of its position relative to Earth or any large mass.

Gravity – The attraction of all objects to one another due to their mass.

Gyroscopic Stability – Term used to describe the resistance of a spinning object to any torque that would change the orientation of the object's spin axis.

Heat Energy – The energy associated with the vibration of atoms and molecules.

Inertia – The property by which an object tends to resist any change in its motion.

Kinetic Energy – The energy possessed by an object because of its motion.

Law of Universal Gravitation – All particles exert a gravitational force of attraction upon each other. The magnitude of the force between two objects is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

$$Force = G\frac{m_1 m_2}{r^2}$$

(Note: G is a constant, r = distance between the center of masses for the two objects.)

Longitudinal Wave – A wave which vibrates back and forth in the direction of the wave's motion. (Also called a compression wave)

Magnetism – A property of certain objects in which there is an attraction to unlike poles of other objects. Its origin lies in the orientation of atoms within the object. The strength of the magnetic force varies inversely with the square of the distance between the magnets. The magnetic force drops off very quickly with distance.

Mass – The amount of matter an object contains.

Microgravity – An environment, produced by free-fall, that alters the local effects of gravity and makes objects seem weightless.

On Earth, the Kendama uses Earth’s gravity to keep the ball in the cup.

Moment of Inertia – The moment of inertia for a spinning body depends on the mass distribution relative to the axis of rotation. The moment of inertia equals the sum of the mass times the square of the distance from the axis of spin for each particle in the body. The moment of inertia is greater for spinning objects with their mass distributed farther from the axis of rotation. Gyroscopes and tops are designed on this principle.

Momentum – The product of an object's mass times its velocity. Momentum is a conserved quantity within a closed system.

Momentum = mass x velocity

Newton's Laws of Motion – Sir Isaac Newton first formulated these three basic laws of motion:

Newton's First Law of Motion – An object continues in its initial state of rest or motion with uniform velocity unless acted on by an unbalanced external force. This is also called the Law of Inertia or the Inertia Principle.

Newton's Second Law of Motion – The acceleration of an object is inversely proportional to its mass and directly proportional to the resultant external force acting on it.

Force = mass x acceleration

Newton's Second Law for Rotation – The torque of a spinning object is equal to the object's moment of inertia times its angular acceleration. The fact that a torque is required to change a spinning gyroscope's angular velocity is called gyroscopic stability.

Newton's Third Law of Motion – Forces always occur in pairs. If object A exerts a force on object B, an equal but opposite force is exerted by object B on object A. Application: objects move forward by pushing backward on a surface or on a fluid.

Node – A point in a standing wave where no motion occurs (zero amplitude).

Parabola – One possible path of an object falling freely in a gravity field. A tossed ball follows a parabolic arc.

Photon – A packet of radiant energy.

Potential Energy – The energy required to place an object in a position. This energy is stored in the object until the object moves. It is then converted into another form of energy, such as kinetic or thermal.

Precession – The wobbling of a spinning object.

Rarefaction – The part of a longitudinal wave where the density is lower than the surrounding medium.

Reaction Force – The force exerted by an object experiencing an action force. The reaction force is equal to the action force, but in the opposite direction.

Surface Tension – The strength of the boundary film at the surface of a liquid.

Speed – The rate of change of an object's position with time.

Toronal Wave – The wave caused by twisting a coiled spring.

Transverse Wave – The wave in which vibrations are to the left and right as the wave moves forward.

Trough – A wave valley.

Velocity – The speed and direction of an object's motion.

Wave Motion – In a longitudinal wave, the vibration of the medium is along the same direction as the motion of the wave. A longitudinal wave is also called a compression wave. In a transverse wave, the vibration of the medium is perpendicular to the motion of the wave. A vibration caused by twisting the coiled spring is called a torsional wave. A standing wave has places where the wave appears to stand still. Locations where the waves interfere to produce no motion are called nodes. The frequency of a wave is the number of vibrations per unit time. The wavelength is the distance between two wave crests. The wave's speed of propagation is equal to the frequency times the wavelength.

Wavelength – The distance between two identical points in a wave (i.e., from crest to crest).

Weight – The magnitude of a gravitational pull.

Acknowledgments

Some of the text in this video resource guide was provided by Dr. Carolyn Sumners of the Houston Museum of Natural Sciences, Houston. Dr. Sumners, working with an educator advisory panel, selected the toys shown in this videotape and planned the experiments. She has published a book on the Toys in Space experiments, “Toys in Space: Exploring Science with the Astronauts.” A technical review of physics concepts was provided by Dr. John Beam, Physics Department, University of Houston.

References

NASA Online Resources for Educators provide current educational information and instructional resource materials to teachers, faculty, and students. A wide range of information is available, including science, mathematics, engineering and technology education lesson plans, historical information related to the aeronautics and space program, current status reports on NASA projects, news releases, information on NASA educational programs, useful software and graphics files. Educators and students can also use NASA resources as learning tools to explore the Internet, access information about educational grants, interact with other schools, and participate in online interactive projects in which they can communicate with NASA scientists, engineers, and other team members to experience the excitement of real NASA projects.

Access these resources:

www.nasa.gov

Videotapes:

Lowry, Patricia, Dir., *Toys In Space II*, National Aeronautics and Space Administration, 1994.

Baker, Diedra, Dir., *Space Basics*, National Aeronautics and Space Administration, 1991.

Baker, Diedra, Dir., *Newton In Space*, National Aeronautics and Space Administration, 1991.

Curriculum Guide:

Vogt, Gregory L.; Wargo, Michael J. *Microgravity – Teaching Guide With Activities for Physical Science*, EG-103, National Aeronautics and Space Administration, 1993.

NASA Resources For Educators

NASA's Central Operation of Resources for Educators (CORE) was established for the national and international distribution of NASA-produced educational materials in multimedia format. Educators can obtain a catalogue and an order form by one of the following methods:

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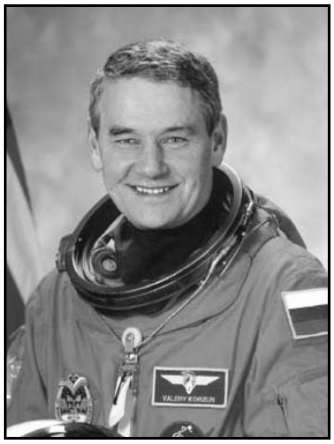

Expedition 5 ISS Commander Valery Korzun (Rosaviakosmos)

Valery Korzun, a cosmonaut and colonel in the Russian Air Force, is a veteran of 197 days on the Russian space station Mir. Korzun, 49, is a first-class military pilot and has logged 1,473 hours in four types of aircraft. He is also a parachute training instructor with 337 parachute jumps to his credit. Korzun graduated from Kachin Military Aviation College in 1974. He served as a pilot, a flight section senior pilot, and commanded an Air Force squadron. Korzun was awarded six Air Force medals.

In 1987, Korzun was selected as a cosmonaut for training at the Gagarin Cosmonaut Training Center, and was certified as a test cosmonaut in 1989. His flight aboard Mir began August 17, 1996, and continued through March 2, 1997. During that period, three NASA astronauts, a French astronaut and a German astronaut flew aboard Mir. While on Mir, Korzun performed two spacewalks totaling 12 hours and 33 minutes.

The Expedition 5 crew launched on June 5, 2002, aboard STS-111 and docked with the International Space Station on June 7, 2002. Korzun performed two Extravehicular Activities (EVAs) during his six-month stay aboard the Space Station. For his second flight, he logged 184 days, 22 hours and 14 minutes in space, including two EVAs totaling 9 hours and 46 minutes.

NASA ISS Science Officer and Flight Engineer Peggy Whitson

Astronaut Peggy Whitson, 42, is from Beaconsfield, Iowa. She holds a doctorate in biochemistry from Rice University and served in several research positions at Johnson Space Center before being selected as an astronaut in 1996. She completed two years of training and then performed technical duties in the Astronaut Office Operations Planning Branch. Whitson served as the lead for the Crew Test Support Team in Russia during 1998 and 1999. After receiving her doctorate in 1985, she remained at Rice as a postdoctoral fellow until late 1986. Whitson began her studies at JSC as a National Research Council Resident Research Associate then later served the Center in a variety of scientific positions, including project scientist for the Shuttle-Mir from 1992 to 1995. Expedition 5 was her first flight into space.

During Whitson's six-month stay aboard the Space Station, she helped install the Mobile Base System, the S1 truss segment, and the P1 truss segment using the Space Station Remote Manipulator System. She also performed a 4-hour, 25-minute EVA to install micrometeoroid shielding on the Zvezda Service Module and activated and checked the Microgravity Sciences Glovebox, a facility-class payload rack. Named the first NASA Science Officer on Expedition 5 during her stay, Whitson conducted 21 investigations in human life sciences and microgravity sciences, as well as commercial payloads. On the completion of her first flight, Dr. Whitson had logged 184 days, 22 hours and 14 minutes in space.

Flight Engineer Sergei Treschev (Rosaviakosmos)

Sergei Treschev, a cosmonaut of the RSC ENERGIA, is a graduate of the Moscow Energy Institute. He served from 1982 to 1984 as a group leader in an Air Force regiment, then joined RSC ENERGIA as a foreman and engineer. His responsibilities included analysis and planning of cosmonaut activities and their in-flight technical training. In addition, he developed technical documentation and helped set up cosmonaut training with the Yuri Gagarin Cosmonaut Training Center. He also supported training of crewmembers aboard Mir to help them maintain skills in performing descent and emergency escape operations. As a cosmonaut, Treschev trained from June 1999 to July 2000 as a flight engineer for the Soyuz-TM backup ISS contingency crew.

Expedition 5 was Treschev's first spaceflight. During Expedition 5, he and Korzun installed a frame on the outside of the Zarya Module to house components for future spacewalk assembly tasks. They installed new material samples on a pair of Japanese Space Agency materials exposure experiments housed on the outside of Zvezda and installed devices on Zvezda that will simplify the routing of tethers during future assembly spacewalks. They also improved future Station amateur radio operations by adding two ham radio antennas on Zvezda. On the completion of his first space flight, Treschev had logged 184 days, 22 hours and 14 minutes in space, including an EVA totaling 5 hours and 21 minutes.

International Toys in Space: Science on the Station

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Video Resource Guide

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