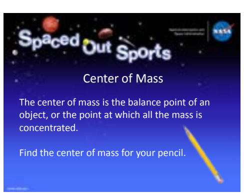
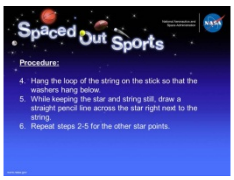
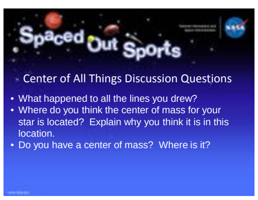
Discussion Guide

	**Slide 1**	Welcome to NASA's Spaced Out Sports Challenge. When astronauts are on the International Space Station, it is important for them to exercise and keep their bodies in shape. Whether you aspire to have a career in space or sports, you need to know how to apply science and Newton's Laws of Motion to your work….on and off the field! Knowing and applying science and the Laws of Motion are one part of being a successful astronaut, engineer, or sports figure.
	**Slide 2**	Introductory Video—Download in advance or stream the introductory video from the 21CCLC NASA STEM Challenge Web site. Play the video for students to introduce the challenge.
	**Slide 3**	For the Spaced Out Sports Design Challenge, you will design a sport that the astronauts can play in the microgravity environment of the International Space Station. Each team will make a 3-5 minute video describing or demonstrating the game. Your team will also create Game Instructions with the objective of your game, materials used, and rules for your game.
	**Slide 4**	Let's see how some sports stars and engineers use science to help them succeed! Here's Nastia Luiken, world champion gymnast telling us how she uses science to become a "supergirl".
	**Slide 5**	And here's astronaut Mike Gernhardt talking about how he relates sports and space together. Before you start designing your game or sport, it is important that you first understand Newton's Laws of Motion. There are three laws that describe the motion of physical objects. Objects behave differently in space than on Earth so each activity will help you better understand these laws.
	**Slide 6**	The center of mass is the balance point of an object, or the point at which all the mass is concentrated. Pick up a pencil and balance it on your finger. When the pencil is balanced, its center of mass will be directly above your finger. That's the only place on the pencil that will enable it to balance. Sharpen the pencil or put an eraser on the end and what will happen to the center of mass? (It will move!) Center of mass is important in sports and to astronauts for performing any kind of jump, flip, twist, or other movement. They have to know how to move their body around their center of mass, or they will lose control! Finding center of mass for people and objects is not always as easy as it was for the pencil. (Pass out the stars to each team) How can you find the center of mass for this star?

	**Slide 7**	The first activity we will do is the Center of All Things. We will determine the center of mass for these irregularly-shaped stars. (Pass out Student Pages, Pre-game Talk Show and data sheets.) First, you'll need to gather all of your materials: • Cardboard star • String with washers attached • Small stick • Pencil To begin this activity, insert your stick through one of the holes in the star points, letting the star hang freely.
	**Slide 8**	Next, hang the loop of the string on the end of the stick so that the washers hang below. This will create a plumb line. Plumb lines are strings with weights used in surveying and construction for creating a vertical line. Keep the string and star still. Have your partner draw a line across the star right next to the string. Keep going until you have drawn lines for each star point.
	**Slide 9**	Now, let's talk about what you observed. What happened to all the lines you drew? *The lines should intersect at one point on the star.* Where do you think the center of mass for your star is located? Explain why you think it is in this location. *The center of mass is located where all of the lines intersect. You should be able to balance the star on your fingertip at this exact point.* Do you have a center of mass? Where is it? *When standing straight, your center of mass will be along a perpendicular line stretching from the head, straight through your body to the floor. Because of differences in distribution of fat and muscles, the center of mass for boys tend to be higher along the line that the center of mass for girls.*
	**Slide 10**	Why is center of mass important for astronauts? *To get around the ISS, astronauts push against the walls, floor, or ceiling to create an action force. Their bodies respond with an equal reaction force in the opposite direction. Because of center of mass, it takes a little practice for new astronauts to do this right. If you don't push in a straight line with your center of mass, instead of going where you want to, you will rotate around the center with a few head bumps and feet in the faces of your fellow astronauts.* *This is also important during spacewalks. One of the first astronauts to discover this was Edward White, Jr. during the Gemini 4 mission in 1965.(Photo on slide) White carried a small gas gun on his spacewalk. He was attached to the spacecraft with a long tether and oxygen line. When he drifted away from the capsule, he had nothing to push on to get back. The gas gun had three nozzles and by pulling a trigger, jets of gas propelled him from one end of the tether line to the other. White quickly found out that his gas gun was tricky to use. If he wasn't careful, just pointing the gun and firing some gas would cause him to tumble out of balance and*

		out of control. The secret was to hold the gun in direct line with his ***center of mass.*** *Then, he could travel in the desired direction.*
	**Slide 11**	For our next activity, we will test some hovercrafts. (Pass out Student Pages, Pre-game Talk Show and data sheets.) These will show you how the action/reaction of Ed White's gas gun is another of Newton's Law's of Motion important to understand for designing your game. You should each have a CD with PVC pipe and a rubber stopper attached to it and a balloon. The first step is to blow up your balloon. Once you have blown up the balloon, twist the end of the balloon so no air escapes. Put the balloon nozzle on the rubber stopper. Put your hovercraft on the floor or your table. Make sure the surface is very smooth.
	**Slide 12**	Once you have your hovercraft in place, release the balloon. It will untwist and begin to blow air downward through the hole. This thin cushion of air will lift the CD and eliminate friction with the tabletop. Try different sizes of holes in the paper dot to see which one is the optimum size.
	**Slide 13**	Now that you know how to work your hovercraft, let's do some testing. First, let's try for distance. Using your meter stick, measure how far your craft goes once you release it. We'll measure this three times. Write down your distance in each box on your student sheet. Next, let's go for time. Using a stopwatch, time how long your craft hovers before it stops on its own. We'll do this three times also. Write down your time in each box on your student sheet.
	**Slide 14**	Lastly, we'll see how fast your hovercraft moves. This time, you'll measure both distance and time three times. Write your distance and time on your student sheet. Now, let's calculate the speed. Speed is determined by dividing your distance by your time. Calculate the speed for each run of your hovercraft and find the average.
	**Slide 15**	Now, let's discuss what we learned from this activity. What causes the hovercraft to become frictionless? *Air from the balloon escapes beneath the hovercraft. It forms a thin cushion that lifts the craft a few millimeters above the table. Without direct contact with the table-top, friction is greatly reduced.* What happens to the hovercraft's movement when the balloon runs out of air? Why? *When the balloon runs out of air, the lifting cushion stops. The full surface of the CD bottom contacts the table-top, friction is greatly increased, and the hovercraft stops.* How do different surfaces affect the hovercraft? *Smooth surfaces permit a uniform cushion of air to lift the craft. Rough*

		surfaces allow air to escape more in some directions than others and the craft is no longer level. Parts of the CD touch the surface and cause drag. How does the size of the paper dot hole affect the hovercraft? *The hole controls the flow of air from the balloon. If the paper is removed, the hole is very large and the air escapes quickly. A tiny hole greatly slows the flow of air and may not provide enough lifting force. Through experimentation, the best hole size is _______ (student answer).Explain how Isaac Newton's Laws of Motion control the movement of the hovercraft.* *1. An unbalanced force is needed to lift the craft. Another force is needed to propel the craft along the table.* *2. The lifting force is determined by how much air is released (its mass) and how fast it accelerates out of the hole.* *3. The action force of the air released from the balloon creates a reaction force lifting the hovercraft. Pushing on the hovercraft to cause it to move along the table-top is also an example of action and reaction.*
	**Slide 16**	How can hovercraft technology be used to simulate microgravity when training astronauts? *Understanding Newton's First Law of Motion is important for astronauts training for future space missions on the International Space Station (ISS). When in space, they will have to move objects and themselves from place to place.* *In space, friction is greatly reduced because of the microgravity environment. It feels like gravity has gone away. The type of friction caused by objects resting on each other is gone. To move, astronauts have to push (exert an unbalanced force) on something, and to stop themselves, they have to push on something else.* How can astronauts practice for the microgravity environment on the ISS? *NASA uses many different simulators to train astronauts. One simulator is something like a large air hockey table. It is called the Precision Air Bearing Platform (PABP) and is located at NASA Johnson Space Center in Houston, Texas.* *The PABP uses moving air to produce a powerful lifting force very much the way hovercraft work. High-pressure air rushes out of three small pad-like bearings and lifts the pads, and a platform mounted above them, a fraction of a centimeter from the floor. No longer resting directly on the floor, the device, with the astronaut on top, is virtually frictionless.* *There is one more important feature of the PABP. In order to move across the floor, the astronaut uses a hand control to release jets of air in different directions around the suit to create a push. How much of a push the astronaut gets determines how fast he or she slides across the PABP floor. This is explained by Newton's Second Law of Motion. The force of the air jets is equal to how much air shoots from the jets times how fast the air accelerates. Newton's Second Law of Motion is really an equation.* Notice all the technicians in the photo have covers over their shoes. Why do you think they are required to put those on before entering the test area? *Shoes could track in dust, dirt, and other foreign objects that would increase the friction on the floor.* *force = mass times acceleration (F=m x a)*

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<td>Slide 17</td>
<td>Our last activity is Javelin Rockets. (Pass out Student Pages, Pre-game Talk Show and data sheets.)

Javelins are sticks that are about 2.6 meters long and have a mass of about 800 grams. The center of mass for the javelin is about a meter from the tip. When the javelin flies true and doesn't wobble, air friction is reduced and the distance the javelin can travel is greater.

First, let's get your materials together. You'll need a piece of PVC pipe, the javelin rocket pattern, scissors, tape, and a piece of Velcro.</td>
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<td>Slide 18</td>
<td>To make a javelin rocket, you'll need to do the following:
1. Roll paper tube around pipe.
2. Tape seam all the way so no air escapes.
3. Add fins with tape
4. Cut a few short slits around upper end.
5. Fold the tabs inward and tape closed.
6. Tape a piece of velcro over the end. Hooks outward!</td>
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<td>Slide 19</td>
<td>Here are some ideas for fin shapes. Try to figure out which shape will be the best to make your rocket go farther.</td>
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<td>Slide 20</td>
<td>Now, we will launch our rockets toward the target! Try and use the same force each time you launch your rocket.

How did your rocket fly? Did it curve? Did it go straight?

Did you go back and try to make it better?

Remember from our first activity about the center of mass? All objects in flight tend to rotate around their centers of mass. Astronauts quickly discover this when they push off the wall of the International Space Station. A javelin with its center of mass in the very middle of the shaft will tumble or wobble when it is thrown. However, when the center of mass is moved toward the front end, it will fly true without wobbling and achieve the longest distance.</td>
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<td>Slide 21</td>
<td>Will rockets travel farther across the surface of the moon or Mars if the same launch force is used?
Yes. There are three reasons for this. First, the rockets will fall more slowly on the moon or Mars because their gravity is not as strong as on Earth. Second, both bodies are much smaller than Earth. Although each are round, the curvature for Earth is flatter than for the moon or Mars. A well-launched rocket javelin on the moon or Mars will fly over the horizon and have farther to go before hitting the surface. Third, the moon doesn't have an atmosphere and the atmosphere of Mars is about one one-hundredth the density of Earth's atmosphere at sea level. With little or no atmosphere, atmospheric drag is eliminated and greater distances are possible.

If rocket javelins were flown inside the International Space Station, how would they need to be aimed to hit the target?

The ISS and astronauts inside it are traveling together on a curved path that enables them to orbit the Earth. Because of this, a rocket javelin launched down</td>
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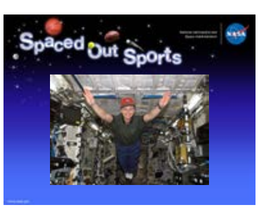
		the length of the ISS modules would appear to travel in a straight line. This requires a mental adjustment. On Earth, rocket javelins have to be aimed above the target because gravity causes the rocket to fall towards the ground. With just the right direction and speed, the rocket arcs to the target. In orbit, the illusion of traveling in a straight line means that you have aim directly at the target.
	**Slide 22**	Now that we've completed our activities, we'll talk about some scientific concepts that will help us design our games for the ISS astronauts. Each of the activities has something to do with Newton's Laws of Motion. Newton's Laws of Motion are the basis for sport movements. Newton's 1st Law of Motion states: "A body at rest tends to remain at rest. A body in motion tends to stay in motion at the same speed and direction unless acted upon by an outside force." The soccer ball will not move unless a force causes it to move. If it were rolling on a smooth surface with no friction, it would keep rolling unless met with an outside force (wall, foot, etc). Which activities used Newton's 1st Law of Motion? *Hovercraft – An unbalanced force is needed to lift the craft. Another force is needed to make it move.*
	**Slide 23**	Newton's 2nd Law of Motion states: "The rate of change of momentum of a body is proportional to the resultant force acting on the body and is in the same direction. This can be described as an equation – F=$m*a$, where F is Force, m is mass, and a is acceleration." The mass of the baseball and bowling ball are different. Because of that, when hit with the same amount of force, each ball will travel a different distance and at a different speed. Which activities used Newton's 2nd Law of Motion? *Hovercraft – The lifting force is determined by how much air is released (its mass) and how fast it accelerates out of the hole.* *Javelin Rockets – Using the mass and acceleration, you can determine the amount of force it takes to hit the target.*
	**Slide 24**	Newton's 3rd Law of Motion states: "The third law says that for every action, there is an equal and opposite reaction." When there is force by one skateboarder, there will be an equal an opposite force by the other skateboarder, and each side will move in an opposite directions. Which activities used Newton's 3rd Law of Motion? *Hovercraft – The action of the force of the air released from the balloon created a reaction force lifting the hovercraft. Pushing on the hovercraft to cause it to move along the tabletop is also an example of action and reaction.*
	**Slide 25**	Now, let's think a bit about how these laws of motion affect sports on Earth and in space. What challenges would astronauts face if they tried to play football in microgravity? *A microgravity football game would be very difficult because players would not be able to run across a grassy field like they do on Earth. They would have to find some other way of exerting force to propel them*

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<td>forward. A microgravity football game might work if the players had rocket propulsion units. A better place for a football game would be inside a domed stadium on the moon.

Optional: You may wish to show several videos of astronauts aboard the ISS demonstrating different sports. Go to http://www.nasa.gov/audience/foreducators/diypodcast/sportsdemo-index-diy.html and look for the Sports Demo Resources on the right hand side.

Now it's your turn take what you've learned about how objects move in space to imagine your own sport or game for the astronauts to play! Pass out the SOS Student Guide for review. (Divide students into teams of 3-6 and have them decide on a team name.)</td>
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<td>Slide 26</td>
<td>To refresh your memory, you will design a sport that the astronauts can play in the microgravity environment of the International Space Station.

Each team will make a 3-5 minute video describing or demonstrating the game. You can select only 5 objects from the materials list on the next slide. Your team will also create Game Instructions with the objective of your game, materials used, and rules for your game.</td>
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<td>Slide 27</td>
<td>These are the only materials available to use for your game on the ISS. You may use up to 5 objects. These include handkerchiefs, t-shirts, washcloth, towel, bungee cords, cotton swabs, string, alligator clips, Velcro, duct tape, pens & pencils, paper, markers, and flashlights.

Have students tape out a play area the size of the US Destiny Lab to give students an idea of how much room the astronauts will have to set up and play the game or sport. Follow the Student Guide.</td>
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