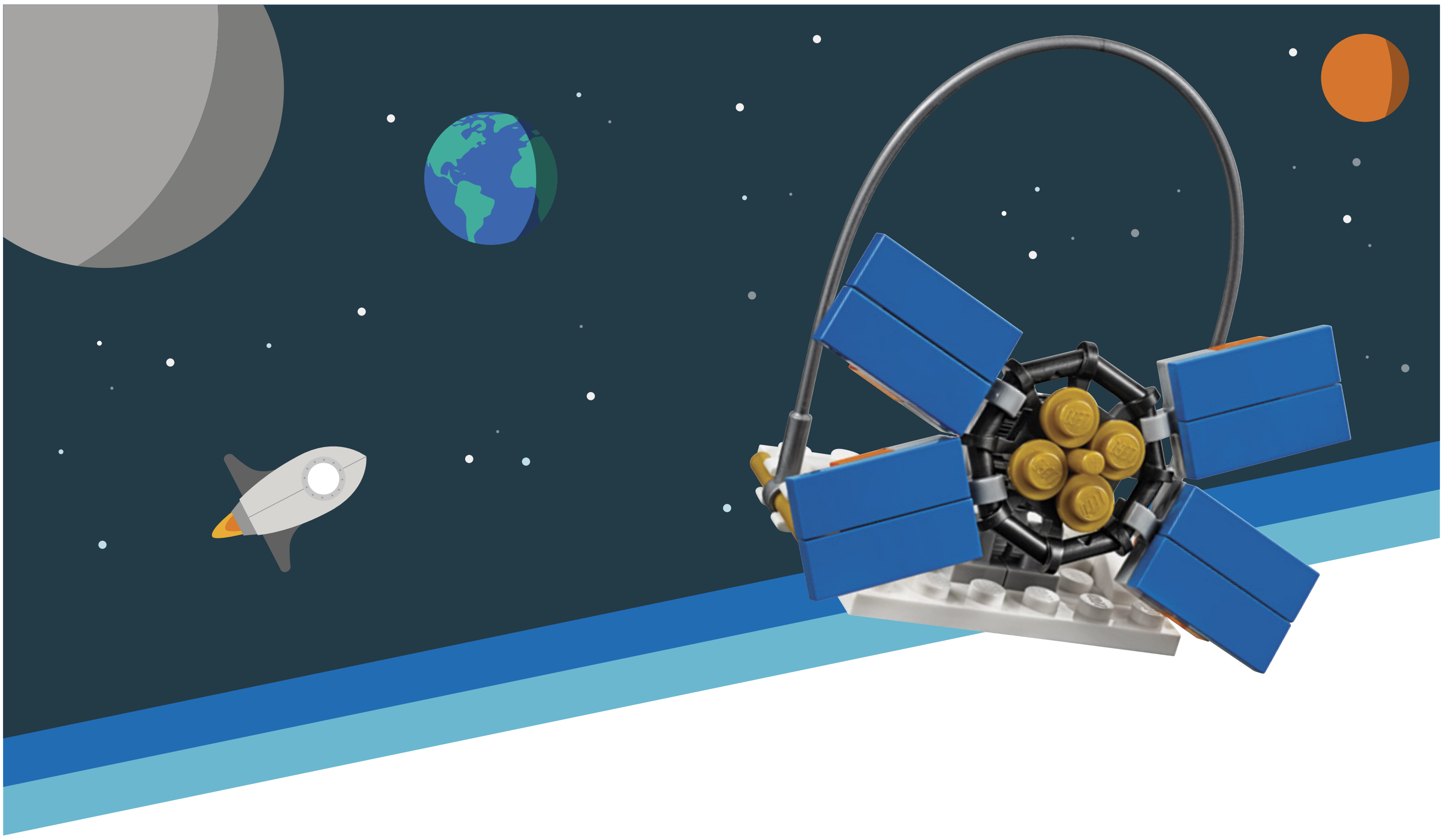
FIRST® LEGO® LEAGUE

Challenge Guide

2018/2019



INTO ORBIT℠

FIRST® LEGO® League is the result of an exciting alliance between *FIRST*® and the LEGO® Group.

The *FIRST*® Core Values

The Core Values are the heart of *FIRST.*® By embracing the Core Values, participants learn that friendly competition and mutual gain are not separate goals, and that helping one another is the foundation of teamwork. Review the **new** *FIRST*® Core Values with your team and discuss them whenever they are needed

We express the *FIRST* philosophies of *Gracious Professionalism*® and *Coopertition*® through our Core Values:

- **Discovery**: We explore new skills and ideas.
- **Innovation**: We use creativity and persistence to solve problems.
- **Impact**: We apply what we learn to improve our world.
- **Inclusion**: We respect each other and embrace our differences.
- **Teamwork**: We are stronger when we work together.
- **Fun**: We enjoy and celebrate what we do!

NOTE:
The *FIRST*® LEGO® League Core Values have been updated for the 2018 season. Please observe that there are no longer program-specific Core Values. They have been replaced by the ***FIRST*® Core Values** presented here.

The Core Values Poster

The Core Values poster is designed to help tell your team's unique story. It may be a requirement at official events. Check with your region's tournament organizer to find out if you will need to make a Core Values poster.

CORE VALUES POSTER:
This is a great tool to help your team think about how they implement the Core Values in team meetings and elsewhere. Check with your tournament organizer to see if your team is expected to bring a Core Values poster into the Core Values judging session.

Create a Core Values poster

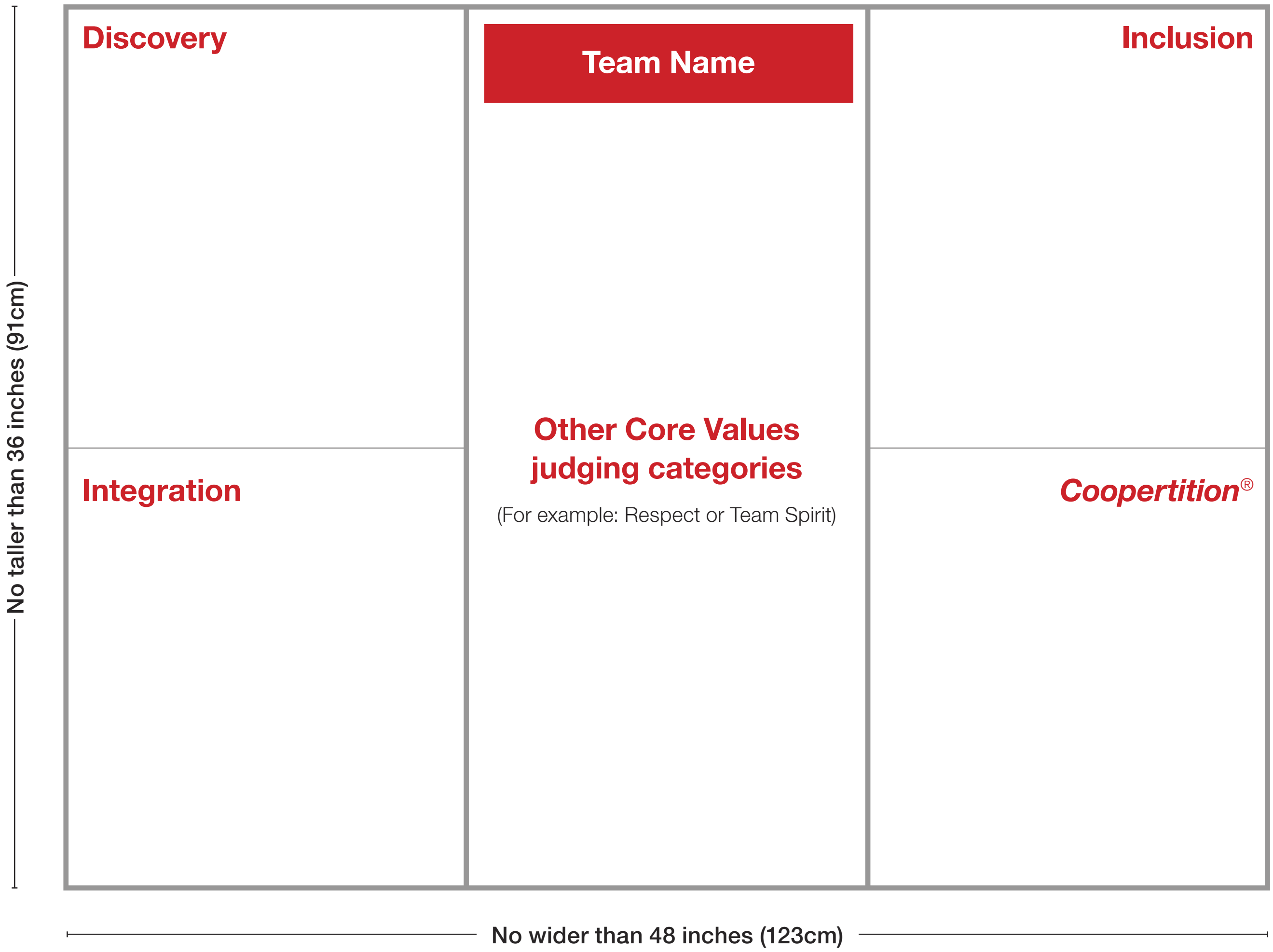
1. Discuss ways your team used the Core Values this season – both in team meetings and in other parts of life. Make a list of examples.
2. Ask your team to select examples that highlight the specific Core Values areas below. These are typically the most challenging categories for judges to explore during judging sessions. The poster can help your team present their successes in an organized format.
    c. **Discovery**: Provide examples from the season about things your team discovered that were not focused on gaining an advantage in the competition or winning an award. Tell the judges how the team balanced all three parts of *FIRST* LEGO League (Core Values, Project and Robot Game), especially if they were really excited about one part.

    d. **Integration**: Provide examples of how your team applied the Core Values and other things you learned through *FIRST* LEGO League to situations outside of team activities. Let the judges know how team members integrated new ideas, skills and abilities into their everyday life.

    e. **Inclusion**: Describe how your team listened to and considered ideas from everyone and made each team member feel like a valued part of the team. Share with the judges how they accomplished more by working together than any team member could have done alone.

    d. ***Coopertition***: Describe how your team honors the spirit of friendly competition. Include information about how your team provided assistance to and/or received assistance from other teams. Share with the judges how your team members help each other, and help other teams to prepare for a potentially stressful competition experience.

    e. **Other**: Use the middle of the poster to highlight anything else your team would like to share with the judges about the remaining Core Values criteria. Maybe consider sharing examples of team spirit, respect, or teamwork.
3. Have your team create their Core Values poster. One *possible* format is shown one page 3. The overall size of the poster should be no more than the measurements shown, and it may be smaller, especially if required for travel needs. The poster may be rolled or assembled on site.



Want to Learn More? Visit http://www.firstlegoleague.org/challenge.

- Your team will be assessed in the judging room using a standard rubric. Review the Core Values judging information and rubric.

Think About The Project

Tortillas in Space

Dr. Rodolfo Neri Vela's incredible career as an engineer and scientist reached new heights when, in 1985, he became the first Mexican to travel into space. While onboard the space shuttle Atlantis, he helped to deploy communication satellites, went on spacewalks, and conducted many other experiments. But it was his choice of a space food menu that would forever change the way astronauts eat! Dr. Neri Vela's simple request for NASA food scientists to include tortillas in the menu meant that, for the first time, this basic food of Latin American cuisine would fly in space. Why was this such a breakthrough? **Space food** is important for so many reasons: obviously it gives astronauts nourishment, but it also provides a little piece of home in an environment that can be very confined. Many astronauts say they can't taste things as well in space, so having food that is appetizing can mean that space explorers eat enough to stay fit. But taste isn't the only issue. Having food that is safe for the crew *and* the **spacecraft** is also critical. How can food hurt a spacecraft? Well think about what would happen if floating crumbs worked their way into sensitive electronics. The tortilla was a real breakthrough: Astronauts now had a type of bread that made very few crumbs and could serve to hold a variety of other foods from eggs to peanut butter and jelly. It was an immediate hit! *Having a little "slice" of home in space is important in so many ways. But every decision you make about your crew and your spacecraft can have enormous consequences.*

The Microgravity Marathon

Sunita "Suni" Williams is a US astronaut used to extreme challenges. She is a graduate of the US Naval Academy, an experienced pilot who has flown more than 30 types of aircraft, an accomplished athlete, and she's spent hundreds of days in space over several missions. So, she's done it all, right? Well in 2007, there was one record just waiting to be broken. Who could run the first marathon in space? That's right, on April 16, Suni ran the 42.2 km (26.2-mile) Boston Marathon on the International Space Station treadmill. It's vital that astronauts use their bones and muscles daily in reduced gravity and microgravity. Otherwise, their muscles lose strength and their bones become fragile. Most astronauts on the space station exercise about two hours a day to prevent muscle and bone loss. Suni's marathon took a little more than four hours, which was a pretty amazing feat considering she was strapped to the treadmill with giant rubber bands so she wouldn't float away! While runners on Earth were making the race in windy 9° C (48° F) weather, Suni was in the climate-controlled space station orbiting the Earth at more than 27,000 kph (17,000 mph). In fact, Suni went around the Earth more than twice while her sister Dina Pandya and fellow astronaut Karen Nyberg were running the earthbound Boston Marathon. *Suni's marathon wasn't just a publicity stunt: Staying fit in space is not optional, and Suni's message to all of us is that staying active is important on Earth* **and** *in space.*

The Project In-Depth

Identify a Problem

Have you ever thought about what it would be like to live on a spacecraft, the international space station, or the surface of the Moon or another planet? What if you were there for a year or more? With your team, consider all the things you would need to stay alive, healthy and happy while living and working in outer space. Remember, outer space is a *very* unforgiving place: much of space is almost a complete vacuum, meaning there is no air, and none of the moons or other planets in our solar system have an atmosphere that is suitable for humans to breathe.

Oh, and don't forget, many trips into outer space last a *very long time*: a round-trip journey to explore Mars may take humans up to three years. So, everything you design and build must work almost perfectly, or have a backup system. Your equipment must be tested and retested, and you will even need to think about what it would take to repair something if it breaks a million miles from Earth!

This sounds like a lot of work…*And it is!* It takes thousands of people on Earth, including engineers, mathematicians, scientists and technicians, to send just a few humans into space. It also takes teamwork and international cooperation because living and working in space is complex and expensive.

But the rewards are tremendous! When humans take on challenges like space travel, we learn all kinds of new things that help us live better lives here on Earth, and we can discover extraordinary scientific knowledge about our solar system.

Your Team's INTO ORBIT℠ Project Challenge:

Have your team identify a *human* physical or social problem faced during long duration space exploration within our Sun's solar system and propose a solution.

Just getting humans safely into space for a short time is enormously hard. Creating rockets, spacecraft, and basic life support systems is one of the most complex tasks that humans can do. But just imagine that your mission to explore the solar system will last *for a year or more.* How will you cope with the physical problems your crew will face?

Keeping people healthy enough to do their job in outer space can be very complicated. It can be either very cold or very hot, depending upon where you are. The human body is exposed to microgravity or reduced gravity, and solar radiation – which can harm people over time. You must take all the supplies needed to stay alive, including air, water and food, or you will need a way to make these supplies once you leave Earth. Space travelers must also be able to exercise to keep their bones and muscles strong. This means you need to have special workout equipment that can function with little or no gravity. You will also need a system to make power for your spacecraft or habitat so you will have energy to work, explore and provide life support for you and your crew. You will even need a way to dispose of or recycle trash and human waste!

Physical problems aren't the only troubles humans confront when they go to space for long periods of time. People have been traveling to space since 1961, and scientists have learned a lot about how humans react when they are in a spacecraft for weeks, months and even years. We know that people are happier and more productive in space when they feel connected to friends and family back on Earth. This may mean that they may need to bring along a favorite game or hobby, have a way to interact with people on Earth who are millions of miles away, or, in the future, they may even have a pet in space! Space explorers also need food that is tasty enough so that they will want to eat and maintain their strength.

TIP

The Robot Game provides many examples of some of the physical and social challenges humans face when exploring space.

TIP

Many of the terms used to describe space exploration are unique. The first time a glossary term appears, you can click on it to see the definition.

FOR THE *FIRST* LEGO LEAGUE INTO ORBIT℠ CHALLENGE:

The solar system of our Sun will be defined as the area of outer space, including all the bodies contained in it, extending fifty (50) astronomical units (AUs), or about 4.6 billion miles, from the Sun.

FOR THE INTO ORBIT℠ CHALLENGE:

A human physical problem is one that impacts the health or safety of a space explorer, such as the need for air, water, food or exercise. A human social problem is one that could affect the long-term ability of a human to be productive in space. This could include issues like isolation and boredom. "Long duration" space exploration means spending a year or more in outer space.

The things we learn when solving these complicated issues for space travel can also sometimes help solve problems on Earth. For example, did you know that inventions as different as cordless tools, medical CAT scans and satellite television all trace their roots back to space exploration? These "spinoff" technologies come about when someone sees an earthly use for a device developed for space exploration. Who knows, maybe your team's innovative solution can benefit the space explorers of the future and help people here on Earth! We can learn so much from overcoming the challenges of space exploration if you are willing to go INTO ORBIT and beyond with *FIRST* LEGO League.

Not sure where to start?

Try this process to help your team choose and explore a physical or social problem faced by humans during long duration space exploration:

Ask your team to draw or create a chart that shows all the things you will need to stay healthy and productive in space. You might want to use some of the Project Resources to explore just what it takes to keep humans alive and well on your solar system journey.

Consider questions like:

- Where do astronauts, cosmonauts and taikonauts get the oxygen and water they need when they are onboard a spacecraft or space station?
- How do humans eat in space? What kinds of food can we take to space?
- How is trash and human waste disposed of in space?
- What are some of the challenges humans will face as we make plans to travel to and explore Mars?
- What kinds of things do astronauts, cosmonauts and taikonauts do to stay healthy and happy in space when they are there for long periods of time?
- How do humans in space communicate with mission controllers, friends and family back on Earth?
- What does microgravity, reduced gravity and radiation do to the human body? How do humans lessen the effect of microgravity, reduced gravity and radiation on the body?
- What systems have been used in the past, are what methods are currently used, to provide power and life support on spacecraft and space stations?
- What power and life support systems are being planned for future spacecraft and human habitats on other planets?
- Humans have been going into space since 1961. How has our knowledge about living and working in space grown since then?
- What types of people study and work on human spaceflight here on Earth?
- What does it take to become an astronaut, cosmonaut or taikonaut?
- How do astronauts, cosmonauts and taikonauts, and their mission controllers, train for spaceflight?
- Why are spacewalks necessary, and is there a way to make them safer for humans?
- What are some of the unique challenges encountered when making spacecraft repairs in microgravity and reduced gravity environments?

This might be a great time for the team to interview a professional. At first this may seem like a challenge unless you live near a place that launches rockets, or trains astronauts, cosmonauts or taikonauts; but as you will see, there are many experts around the world who can help you find information about space exploration. We'll give you a head start with some of the "Ask a Professional" resources in this Challenge Guide, but you can talk to people at science museums, colleges and universities, or even speak with medical doctors and psychologists.

TIP

Your team may be able to use the scientific method or the engineering design process to tackle your problem. You can find out about the engineering design process at sites like this, conduct your own research to learn more about how these approaches to problem solving can help your team, or use your *FIRST* LEGO League Engineering Notebook. This is an optional tool.

Ask your team to select the problem they would like to investigate and solve. You might select a problem in one of these areas (or add your own):

- Exercising in space
- Growing food in space
- Recreation in space
- Generating oxygen or recycling water in space
- Protecting humans and spacecraft from radiation or micrometeoroids
- Recycling waste in space
- Finding the best place for humans to live on a moon or another planet
- Creating energy for your spacecraft or habitat
- Performing maintenance on a spacecraft or a habitat

After your team selects a problem, the next step is to find out about the current solutions. Encourage them to research their problem using resources like:

- News articles
- Documentaries or movies
- Interviews with professionals working in the field
- Libraries
- Books
- Online videos
- Websites

Ask your team questions like: Why does this problem still exist? Why aren't the current solutions good enough? What could be improved?

Design a Solution

Next, your team will design a solution to the problem. Any solution is a good start. The goal is to design an innovative solution that solves your problem **by improving something that already exists, using something that exists in a new way, or inventing something totally new.**

Ask your team to think about:

- What could be done better? What could be done in a new way?
- What is one problem we can recognize and solve that will make life better for humans in space?
- What are some ways our solution might also help people on Earth?

Ask your team to think of your problem like a puzzle. Brainstorm! Then turn the problem upside down and think about it in a completely different way. Imagine! Get silly! Even a "silly idea" might inspire the perfect solution. Encourage team members to try one idea (or more), but be prepared that each idea may need some improvements. And remember to keep track of everything you have tried, and don't worry if your first attempts don't work: sometimes your early disappointments pave the way for future success.

Make sure your team thinks about how they could make their solution a reality. Try asking them questions like:

- Why would your solution succeed when others have failed?
- What information would you need to estimate the cost?
- Do you need any special technology to make your solution?
- Who would be able to use it?

Remember, your team's solution **does not** need to be completely new. Inventors often improve an idea that already exists or use something that exists in a new way.

TIP

Field trips are a great way to learn about a new topic. Planetariums, or science museums that specialize in astronomy, are a great place to start. If you live in the United States, you can visit a NASA Center, or if you live elsewhere, there are dozens of aerospace museums around the world that might be able to help you. You could also talk to your local science center, or reach out to an aerospace engineer at a college or university or even online.

TIP

A good rule of thumb about supplies while exploring space: **You have to take it or make it!**

Share with Others

Once the team has designed a solution, the next step is to share it!

Ask your team to think about who your solution might help. Is it possible your solution could help space explorers and people here on Earth? What type of people in your community might be able to give you feedback? Be creative! Although space may seem like a giant topic, many of the problems humans will encounter in space may be similar to problems already faced on Earth. How can you share your solution with people who might have suggestions on how to make your ideas even better?

- Can you present your research and solution to scientists and engineers in person?
- Can you submit your ideas via email or Skype?
- Can you share with someone who helped you learn about your problem in the first place?
- Can you brainstorm about talking to people you might not normally ask about space, like other students, teachers or members of your community?

When your team plans their presentation, encourage them to use the talents of team members. Teams often explore creative presentation styles, but it is also important to keep the focus on your team's problem and solution. Sharing can be simple or elaborate, serious or designed to make people laugh while they learn.

No matter what presentation style your team chooses, remember to infuse fun wherever you can!

TIP

It might be helpful for your team to share with someone who could provide real-world feedback about the solution. Getting input and improving a solution are part of the design process for any inventor. It is OK to revise an idea if the team receives some helpful feedback.

The Project Presentation

Any inventor must present their idea to people who can help them make it a reality, such as engineers, investors, or manufacturers. Like adult inventors, the Project presentation is your team's chance to share their great Project work with the judges.

All regions require teams to prepare a Project presentation. If your team covers the basic Project information, they may choose any presentation style they like. Check with your tournament organizer to see if there are any size or noise restrictions in the judging rooms.

Your team's presentation may include posters, slideshows, models, multimedia clips, props, costumes, and more. Creativity in the presentation is rewarded, but covering all the essential information is even more important.

Teams will only be eligible for Project awards if they:

- Identify a problem that meets this year's criteria.
- Explain their innovative solution.
- Describe how they shared with others prior to the tournament.

Presentation requirements:

- All teams must present live. The team may use media equipment (if available) only to enhance the live presentation.
- Include all team members. Each team member must participate in the Project judging session.
- Set up and complete the presentation in **five minutes** or less with no adult help.

The teams who excel at tournaments also use the Project presentation to tell the judges about their sources of information, problem analysis, review of existing solutions, elements that make their idea innovative, and any plans or analysis related to implementation.

TIP

Attending an Official Event?
The Event Guide for Teams can help you prepare.

Glossary

INTO ORBIT Operational Definitions

TERM OR PHRASE	DEFINITION
solar system	For the INTO ORBIT Challenge: *The area of outer space, including all the bodies contained in it, extending fifty (50) astronomical units (AUs), or about 4.6 billion miles (7.5 billion km), from the Sun.* The solar system of our Sun generally describes all the objects that are under the gravitational influence of the Sun, or objects that may be influenced by the radiation of the Sun. However, there is no exact agreement as to where the solar system ends due to the lack of data about the boundaries of the heliosphere.
outer space	The area that exists between the Earth and other bodies in the universe; with respect to Earth, outer space starts at an altitude of approximately 63 miles (100 km) above sea level.

Astronomy

TERM OR PHRASE	DEFINITION
astronomy	The study of the sun, moon, stars, planets, comets, galaxies, and other non-Earthly bodies in space.
astronomical unit (AU)	A measurement of distance used in astronomy and space travel. One AU is the average distance from the Earth to the Sun, or about 93 million miles (150 million km).
orbit	The path of a celestial object – such as a planet or moon – around another celestial body. In our solar system, for example, the planets are in orbit around the Sun, and there are many moons that are in orbit around the planets. Man-made satellites and spacecraft are also placed INTO ORBIT around the Earth and other planets.
star	A celestial body composed of gas that produces light and energy through nuclear reactions. Stars are probably the most recognizable object in the night sky. Astronomers and physicists estimate there may be as many as two trillion stars in a typical galaxy.
galaxy	A galaxy is a huge collection of gas, dust, and trillions of stars and their solar systems. Scientists believe there could be as many as one hundred billion galaxies in the universe.
the Sun	The closest star to Earth, and the most massive body in our solar system. The Sun is also the most important source of energy for life on Earth.
heliosphere	The area around the Sun that is influenced by the solar wind.
heliopause	The region around the Sun that marks the end of the heliosphere and the boundary of our solar system.
electromagnetic radiation	Electromagnetic (EM) energy that travels in the form of waves or particles. The term “radiation” includes everything from x-rays, to visible light, to radio waves. Some forms of electromagnetic radiation, such as x-rays and gamma rays, can be very harmful to humans.
solar wind	A type of high-energy EM radiation that is released from the upper atmosphere of the Sun. This radiation can create hazards for humans in space, damage orbiting satellites, and even knock out power grids on Earth.
comet	A ball of frozen gases, rock and dust that orbit the Sun. Jets of gas and dust from comets form long tails that can be seen from Earth.
asteroid	A rocky object in space that is at least one meter in diameter, and up to one thousand kilometers in diameter. Most asteroids in the solar system orbit in a belt between Mars and Jupiter.
meteoroid	A rocky object in space that is less than one meter in diameter. When a meteoroid heats up in Earth’s atmosphere, it makes a bright trail, and is called a meteor. If the meteor makes it to the Earth’s surface intact as a rock, it is called a meteorite.
micrometeoroid	Micrometeoroids are very small meteoroids that can seriously damage spacecraft. They are often moving at speeds of 10 km/s (22,000 mph) or more.
planet	A planet is an astronomical body orbiting a star that is massive enough that its own gravity has shaped it into a sphere and has cleared its orbit of other large solar system objects. Planets are not massive enough to cause thermonuclear fusion and become a star.
satellite	The term “satellite” usually refers to a human-made or natural object in orbit around the Earth, the Moon or another planet. Human made satellites are used to collect information or for communication. The term can also refer to an astronomical body orbiting the earth or another planet.
moon	A natural satellite is an astronomical body that orbits a planet or minor planet.
the Moon	The Moon is the name given to Earth’s only permanent natural satellite. It is the fifth-largest natural satellite in the Solar System.

TERM OR PHRASE	DEFINITION
atmosphere	The layer of gases surrounding the Earth or other planets. The Earth's atmosphere can be described as a series of shells or layers of different characteristics.
remote sensing	Gathering information about a place or thing without being in direct contact with it. Satellites and space probes are used to gather remote sensing data about planets throughout the solar system, and planetary rovers have been using a variety of tools and sensors to obtain information about planets like Mars.
planetary rover	A semi-autonomous robot that explores the surface of another planet in our solar system.
space probe	An un-crewed spacecraft that travels through space to collect information about our solar system.
telescope	A device that allows humans to conduct a type of remote sensing by collecting electromagnetic radiation, such as visible light or radio waves, and creating images or descriptions of celestial bodies. Visible light, or optical, telescopes use mirrors or lenses to see far away planets, stars and galaxies. Radio, x-ray or gamma-ray telescopes look for the invisible electromagnetic waves given off by stars, galaxies and even black holes.
core sample	A cylindrical section of rock or soil that is obtained to examine the geologic history of an area, or to see the composition of the materials below the surface. In planetary exploration, core samples are desirable so that scientists can explore for possible signs of life, discover how various planets were formed, and search for resources that might be useful for life support or energy.
regolith	On all the terrestrial, or "Earth-like" planets in the solar system, regolith describes the layer of relatively loose soil and small rocks that covers a harder layer of solid rock called bedrock. The inner planets of the solar system – Mercury, Venus, Earth and Mars – have a layer of regolith, as well as some moons.

Physics, Forces, and Motion

TERM OR PHRASE	DEFINITION
gravity	Gravity is a force of attraction that exists between any two masses, any two bodies, any two particles. Gravity is not just the attraction between objects and the Earth. It is an attraction that exists between all objects, everywhere in the universe. The surface gravity observed on a planet depends on the planet's size, mass and density.
mass	A measure of how much matter is in an object. The mass of an object does not change relative to the object's place in the solar system or universe. The official SI ("metric") unit of mass is the kilogram (kg), and the imperial unit of mass is the slug.
weight	A measure of the force exerted by gravity on an object. The SI unit of weight is the newton (N), and the imperial unit of weight is the pound (lb.).
microgravity	Microgravity is a condition of apparent weightlessness experienced on spacecraft in orbit around the Earth or other planets. The effect of microgravity is caused by a spacecraft being in freefall while in orbit around a planet, even though the spacecraft is still under the influence of the planet's gravitational pull.
reduced gravity	The gravity observed on the surface of the Moon or Mars is less than that on Earth. When humans are on the surface of the Moon or other planets, they are in a state of reduced gravity.
speed	Speed is the rate at which an object covers distance, like "10 meters per second (m/s)."
velocity	Velocity is the speed of an object plus the direction in which it is traveling, like "10 meters per second (m/s) north."
acceleration	The rate of change of the velocity of an object. In the SI system, acceleration is usually measured in meters per second squared (m/s^2), and in the imperial system, in feet per second squared ($ft./s^2$). Acceleration can be linear, if an object simply speeds up or slows down, or non-linear, if an object changes the direction of its motion.
force	A force is a push or pull on something that is caused when one object interacts with another object. The SI measure unit of force is the newton (N), and the imperial unit is the pound (lb.)
momentum	The mass of an object multiplied by it velocity
Sir Isaac Newton	An English mathematician, astronomer, and physicist whose "Laws of Motion" explain the physical principles that describe the motion of a rocket as it leaves the Earth and travels to other parts of the solar system. Newton also developed theories about gravity when he was only 23 years old.
Newton's First Law	Everything in the universe – including people, a rocket, a soccer ball or even a rock – will stay at rest or in motion unless acted upon by an outside force. This idea is also known as "inertia."
Newton's Second Law	This scientific law describes how the force of an object, its mass and its acceleration are related. It can be written as a formula: force is equal to mass times acceleration ($F = ma$).
Newton's Third Law	Often referred to as the "rocketry law," Newton's Third Law states that for every action in the universe, there is an equal and opposite reaction.

Rocketry and Spacecraft

TERM OR PHRASE	DEFINITION
rocket	Usually, a tall, thin, round vehicle that is launched into space using a rocket engine.
spacecraft	Any vehicle that travels in outer space.
rocket engine	A device that ejects mass – usually hot gasses from a burning fuel – to create thrust that propels an object through the sky or into outer space. The work of rocket engines can be explained by Newton's Third Law of Motion: The engine pushes out exhaust gases, and the exhaust pushes back on the engine and its spacecraft. A rocket engine does not need to "push" on the ground or the atmosphere to work, so it's perfect for the vacuum of space.
thrust	Thrust is the force which moves an airplane or rocket through the air, or moves a rocket through space.
solid fueled rocket engine	A rocket engine that uses a fuel and oxidizer mixed together in a relatively stable solid state of matter.
liquid fueled rocket engine	A rocket that has separate tanks for its liquid fuel and oxidizer, which are combined at the point of combustion to produce the rocket exhaust and thrust.
fuel	A material used by a rocket engine that produces a chemical reaction that results in thrust being created by a rocket engine. Kerosene and hydrogen are common liquid fuels for rocket engines.
oxidizer	An oxidizer is a type of chemical which a rocket fuel requires to burn. Most types of combustion on Earth use oxygen, which is prevalent in the atmosphere. However, in space there is no atmosphere to provide oxygen so rockets need to carry their own oxidizers.
launch	The phase of a rocket's flight where it is leaving the surface of the Earth or another planetary body.
re-entry	The phase of a rocket or spacecraft's flight where it is returning to Earth or attempting to land on the surface of another planetary body. If a spacecraft is passing through the atmosphere of a planet, it may encounter extreme heating when it re-enters, and must have a protective heat shield if it is to survive.
space capsule	A crewed spacecraft that often has a plain shape and is attached to the top of a rocket for launch into outer space. Space capsules must contain basic life support systems for their crews, and are often intended as re-entry vehicles to return crews safely to Earth.
space station	A type of spacecraft that is assembly of habitation and science modules that orbits the Earth, or potentially other planets, and is intended for long-term space exploration and experimentation.
solar panel	A device that absorbs sunlight and converts it into electrical energy. Solar panels are often used to generate power on spacecraft that will stay near the Sun because they provide an efficient source of renewable energy.
spacewalk	When a human uses a spacesuit to leave a spacecraft for a short period to work or experiment in the vacuum of space.

Life Support and Communication

TERM OR PHRASE	DEFINITION
life support system	In space exploration, a life support system is a collection of tools and machines that allow humans to stay alive away from Earth's resources such as air, water and food.
spacesuit	A pressurized suit that allows humans to conduct a spacewalk. Spacesuits must contain robust life support systems that provide air to breath, protection from radiation and micrometers, and a way to regulate body temperature.
airlock	An airtight room that has two doors that allows a person to leave a spacecraft without letting all the air out.
space food	Food that has been prepared specially prepared for human spaceflight to make sure that it will not cause illness, that it is relatively easy to prepare, and that it will not damage the hardware of the spacecraft. Food scientists also try to ensure that the food is appetizing, because it is very important that astronauts eat while in space so that they have enough energy to carry out their work.
mission control	A mission control center is a facility on Earth that manages the flight of crewed or un-crewed spacecraft while they are in outer space. Mission control centers monitor all aspects of spaceflight, including life support, navigation and communication.
ISRU	In-Situ Resource Utilization, or ISRU, is the concept of using the raw materials from a planet or asteroid to create supplies needed for life support or further space exploration. An example might be using water found on the Moon or Mars to create rocket fuel (hydrogen) and an oxidizer (oxygen) so that further exploration could take place.
spinoff	A commercial product developed through space research that benefits life on Earth. These products result from the creation of innovative technologies that were needed for a unique aspect of space exploration.

Resources

Video

Business Insider Science: The Scale of the Universe

The Verge: Astronaut Scott Kelly on the Psychological Challenges of Going to Mars

Smithsonian Channel: Three Types of Food You Can Take to Space

Smithsonian Channel: Mining for Minerals in Space

Smithsonian Channel: Martian Living Quarters

Smithsonian Channel: How Mission Control Saved the Apollo 13 Crew

NASA eClips™

Makers Profile: Katherine G. Johnson, Mathematician, NASA

European Space Agency (ESA): International Space Station Toilet Tour

NASA-Johnson Space Center: Karen Nyberg Shows How You Wash Hair in Space

European Space Agency (ESA): Cooking in Space: Whole Red Rice and Turmeric Chicken

PBS Learning Media: Life on the International Space Station: An Astronaut's Day

PBS Learning Media: Running in Space!

Websites and Articles

National Aeronautics and Space Administration (NASA)

National Aeronautics and Space Administration (NASA) – For Educators

National Aeronautics and Space Administration (NASA) – For Students

NASA Visitor Center Locations

European Space Agency

European Space Agency – For Educators

European Space Agency – For Kids

Japanese Aerospace Exploration Agency – JAXA

ROSCOSMOS – The Russian State Space Corporation

China National Space Administration

Department of Space – Indian Space Research Organisation

Brazilian Space Agency (AEB)

International Planetarium Society, Inc.

International Planetarium Society – Directory of the World's Planetariums

List of Aerospace Museums

Association of Science –Technology Centers

NASA – Life Support Systems

NASA – What is a Spacesuit?

NASA – Space Food Fact Sheets

The American Institute of Aeronautics and Astronautics (AIAA)

Royal Aeronautical Society – Careers and Education

NASA – Spinoff

Space.com – Best Space Books for Kids

Planetary Society – Emily Lakdawalla's Recommended Kids' Space Books

Books

Chasing Space (Young Readers' Edition)
By Leland Melvin, Amistad (2017) ISBN-13: 978-0062665928

You Are the First Kid on Mars
By Patrick O'Brien, G.P. Putnam's Sons (2009) ISBN-13: 978-0399246340

Mission to Pluto: The First Visit to an Ice Dwarf and the Kuiper Belt
By Mary Kay Carson and Tom Uhlman, HMH Books (2017) ISBN-13: 978-0544416710

Chris Hadfield and the International Space Station
By Andrew Langley, Heinemann (2015) ISBN-13: 978-1484625224

Martian Outpost: The Challenges of Establishing a Human Settlement on Mars
By Erik Seedhouse, Praxis (2009) ISBN-13: 978-0387981901

Alien Volcanoes
By Rosaly M. C. Lopes, Johns Hopkins University Press (2008) ISBN-13: 978-0801886737

Welcome to Mars: Making a Home on the Red Planet
By Buzz Aldrin and Marianne Dyson, National Geographic Children's Books (2015) ISBN-13: 978-1426322068

Max Goes to the Space Station
By Jeffrey Bennett and Michael Carroll, Big Kid Science (2013) ISBN-13: 978-1937548285

Ask A Professional

Talking with professionals (people who work in the field of this year's Challenge theme) is a great way for your team to:

- Learn more about this season's theme.
- Find ideas for your INTO ORBIT℠ problem.
- Discover resources that might help with your research.
- Get feedback on your innovative solution.

Examples of Professionals

Consider contacting people who work in the following professions. See if your team can brainstorm any other jobs to add to the list. Many company, professional association, government, and university websites include contact information for professionals.

JOB	WHAT THEY DO	WHERE THEY MAY WORK
aerospace engineer	Aerospace engineers design spacecraft, rockets, aircraft and satellites. They also simulate and test the flight of these vehicles to make sure they work properly and are safe for crews.	national or international space agencies; aerospace companies; colleges and universities
aerospace education specialist	Aerospace education specialists are experts whose job is to share knowledge about space exploration and flight with students, teachers and the public.	national or international space agencies; museums and science centers
astrogeologist (and geologist)	Geologists are scientists who study the soil, rocks and liquid matter on Earth. Astrogeologists study the same things, only they focus of the Moon, other planets and their moons, comets, asteroids, and meteorites. *If your project involves investigating the geology of another world, you can still talk to a geologist who focuses on Earth.*	national or international space agencies; colleges and universities; government agencies
astronaut	An astronaut is the term used in the US and many European nations to describe a person who travels into outer space.	national or international space agencies: NASA, the European Space Agency (ESA), the Japan Aerospace Exploration Agency (JAXA), etc.
astronomer	A scientist who studies stars, moons, planets comets, galaxies and other objects in outer space.	national or international space agencies; colleges and universities; museums and science centers
cosmonaut	A cosmonaut is the term used in Russia and many nations of the former Soviet Union to describe a person who travels into outer space.	Roscosmos, or the Russian Space Agency
flight surgeon (doctor); flight nurse (nurse)	Flight surgeons oversee the healthcare of pilots and astronauts and monitor the unique impacts that flight and space travel can have on the human body. During a space mission, flight surgeons work in mission control to answer any health questions that may arise. *For the INTO ORBIT season, if you can't talk to a flight surgeon about a Project, see if you can talk to another healthcare professional who might have expertise in your area of research.*	national or international space agencies; colleges and universities; medical colleges; hospitals and clinics
life support specialist	A scientist, researcher or technician who specializes in studying the systems needed to keep humans healthy and productive in harsh environments. If the life support specialist works in the space industry, they might be involved in any number of areas, such as air or water quality, human physiology, space food production, spacesuit development or maintenance, water quality, waste management, and so forth.	national or international space agencies; colleges and universities; medical colleges
machinist	A technician who uses specialized tools to make primarily metal parts. Machinists are critical in the aerospace industry and space exploration, since so much of modern aircraft and spacecraft is made from metals like aluminum.	national or international space agencies; aerospace companies; manufacturing firms that work with metal fabrication

JOB	WHAT THEY DO	WHERE THEY MAY WORK
mathematician	A scientist who has a wide-ranging knowledge of numbers, math operations, shapes, change and data collection. Mathematicians often assist other scientist and engineers in doing their work and are especially important in aerospace engineering.	national or international space agencies; colleges and universities
mission controller	A scientist or technician who monitors crewed or un-crewed space missions from Earth to ensure that things like navigation, power systems, life support and communications are functioning properly.	national or international space agencies
physicist	A scientist who studies the how energy and matter interact. Some physicists study the building blocks of the universe, like atoms and subatomic particles, while others are concerned with cosmology, the analysis of the structure and origins of the universe, and thus stars and galaxies.	national or international space agencies; colleges and universities
psychologist	A psychologist is a scientist who studies human behavior. Since astronauts live and work in highly unusual and challenging environments, their ability to maintain a positive psychological outlook and good relationships with their crewmates is crucial. In space programs, psychologists and other professionals study ways to ensure that space explorers maintain sound mental health.	national or international space agencies; colleges and universities; school counselors and social workers; private practice therapists
taikonaut	A taikonaut is the term used in China to describe a person who travels into outer space.	China National Space Administration
welder	A technician who specializes in fusing two separate pieces of material together. Welders often heat the two metals up to connect them, but many newer materials such as carbon composites, plastics and other polymers use different techniques. Skilled welders are essential to the construction of spacecraft.	national or international space agencies; aerospace companies; manufacturing firms that work with metal joining and fabrication

Who Do You Know?

Use the list of professionals above to help you brainstorm ideas. Think about all the people who might work in the aerospace industry near you, or researchers and scientists who might be experts in areas related to the INTO ORBIT Challenge.

One of the best recruiting tools for your Project is your own team. Think about it. Who do you know? There's a good chance that someone on your team knows a professional who works in aerospace or who might be able to answer questions about human health. Ask your team members to think about family, friends, or mentors who work in any job that meets those criteria. You may also want to see if you can locate a scientist or engineer who is willing to communicate with your team via email or web conferencing. Then make a list of people your team might want to interview.

How Should You Ask?

As a team, talk about your list of professionals and choose one or more who you think could help learn about space exploration. Have the team do a little research about each professional. Find out how the person works with this year's theme and think about what questions the team might want to ask in an interview.

Next, work with team members to contact the professional you chose. Explain a little about *FIRST*® LEGO® League. Tell the professional about the team's research goals and ask if you can conduct an interview.

What Should You Ask?

Have the team prepare a list of questions for the interview. When you think about questions to ask:

- Use the research the team has already done to brainstorm questions about the professional's area of expertise. It's important to ask questions that the person can answer.
- Keep the team's Project goal in mind. Ask questions that will help the team learn more about their topic and design an innovative solution.
- Keep questions short and specific. The more direct team members can be, the more likely they are to receive a useful answer.
- Do NOT ask the professional to design an innovative solution for your team. The team's solution must be the work of team members. If they already have an innovative solution though, it is OK for the professional to provide feedback on the idea.

At the end of the interview, ask the professional if your team may contact him or her again. Your team might think of more questions later. Maybe the person would be willing to meet with your team again or give you a tour or review your solution. Don't be afraid to ask!

And finally, make sure your team shows *Gracious Professionalism®* during the interview and thanks the professional for his or her time!

Robot Game Rules

Guiding Principles

GP1 - *GRACIOUS PROFESSIONALISM*® You are "Gracious Professionals." You compete hard against **problems**, while treating **all people** with respect and kindness. If you joined *FIRST* LEGO League with a main goal of "winning a robotics competition," you're in the wrong place!

GP2 - INTERPRETATION

- **If a detail isn't mentioned, then it doesn't matter.**
- Robot Game text means exactly and only what it plainly says.
- If a word isn't given a game definition, use its common conversational meaning.

GP3 - BENEFIT OF THE DOUBT If the referee feels something is a "very tough call," and no one can point to strong text in any particular direction, you get the **Benefit Of The Doubt**. This
good-faith courtesy is not to be used as a strategy.

GP4 - VARIABILITY Our suppliers and volunteers try hard to make all Fields correct and identical, but you should always expect little defects and differences. Top teams design with these in mind. Examples include Border Wall splinters, lighting changes, and Field Mat wrinkles.

GP5 - INFORMATION SUPERIORITY If two official facts disagree, or confuse you when read together, here's the order of their authority (with #1 being the strongest):

#1 = Current Robot Game UPDATES
#2 = MISSIONS and FIELD SETUP
#3 = **RULES**
#4 = **LOCAL HEAD REFEREE** In unclear situations, local head referees may make good-faith decisions after discussion, with Rule GP3 in mind.

- Pictures and video have no authority, except when talked about in #1, #2, or #3.
- Emails and Forum comments have no authority.

Definitions

D01 - MATCH A "Match" is when two teams play opposite each other on two Fields placed north to north.

- Your Robot **LAUNCHES** one or more times from Base and tries as many Missions as possible.
- Matches last 2-1/2 minutes, and the timer never pauses.

D02 - MISSION A "Mission" is an opportunity for the Robot to earn points. Requirements are written in the form of

- **RESULTS** that must be visible to the referee at the **END OF THE MATCH**.
- **METHODS** that must be observed by the referee **AS THEY HAPPEN**.

D03 - EQUIPMENT "Equipment" is everything **YOU BRING** to a Match for Mission-related activity.

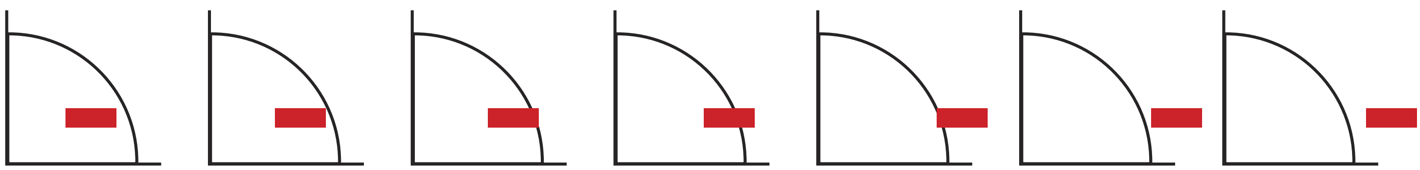
D04 - ROBOT Your "Robot" is your **LEGO® MINDSTORMS®** controller and all the Equipment you've combined with it by hand which is not intended to separate from it, except by hand.

D05 - MISSION MODEL A "Mission Model" is any LEGO® element or structure **ALREADY AT THE FIELD** when you get there.

D06 - FIELD The "Field" is the Robot's game environment, consisting of Mission Models on a Mat, surrounded by Border Walls, all on a Table. "Base" is part of the Field. For full details, see FIELD SETUP.

D07 - BASE "Base" is the space directly above the Field's quarter-circle region, in the southwest. It extends southwest from the outside of the thin curved line TO the corner walls (no farther). The thin line around any scoring area counts as part of that area. When a precise location related to a line is unclear, the outcome most favorable for the team is assumed. (See diagram below.)

D07 - BASE



Completely In | *Benefit Of The Doubt* | *Partly In* | *Partly In* | *Partly In* | *Benefit Of The Doubt* | *Out*

D08 - LAUNCH Whenever you're done handling the Robot and then you make it GO, that's a "Launch."

D09 - INTERRUPTION The next time you interact with the Robot after Launching it, that's an "Interruption."

D10 - TRANSPORTED When a thing **(anything)** is purposefully/strategically being

- taken from its place, and/or
- moved to a new place, and/or
- being released in a new place,

it is being "Transported." The process of being Transported ends when the thing being transported is no longer in contact with whatever was transporting it.

Equipment, Software, and People

R01 - ALL EQUIPMENT All Equipment must be made of LEGO-made building parts in original factory condition.

Except: *LEGO string and tubing may be cut shorter.*

Except: *Program reminders on paper are OK (off the Field).*

Except: *Marker may be used in hidden areas for identification.*

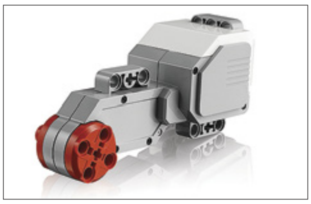
R02 - CONTROLLERS You are allowed only ONE individual controller in any particular Match.
- It must exactly match a type shown below (**Except:** Color).
- ALL other controllers must be left in the **PIT AREA** for that Match.
- All remote control or data exchange with Robots (including Bluetooth) in the competition area is illegal.
- This rule limits you to only **ONE** individual **ROBOT** in any particular Match.

EV3

NXT

RCX

R03 - MOTORS You are allowed up to **FOUR** individual motors in any particular Match.
- Each one must exactly match a type shown below.
- You may include more than one of a type, but again, your grand total may not be greater than **FOUR**.
- ALL other motors must be left in the **PIT AREA** for that Match, **NO EXCEPTIONS**.



EV3 "LARGE"

EV3 "MEDIUM"

NXT

RCX

R04 - EXTERNAL SENSORS Use as many external sensors as you like.

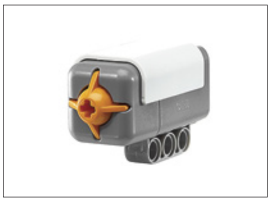
- Each one must exactly match a type shown below.
- You may include more than one of each type.


EV3 TOUCH


EV3 COLOR


EV3 ULTRASONIC


EV3 GYRO/ANGLE


NXT TOUCH

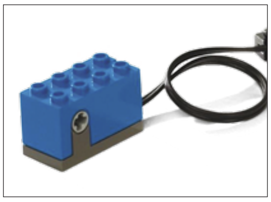

NXT LIGHT


NXT COLOR


NXT ULTRASONIC


RCX TOUCH


RCX LIGHT


RCX ROTATION

R05 - OTHER ELECTRIC/ELECTRONIC THINGS No other electric/electronic things are allowed in the competition area for Mission-related activity.

Except: *LEGO wires and converter cables are allowed as needed.*
Except: *Allowable power sources are ONE controller's power pack or SIX AA batteries.*

R06 - NON-ELECTRIC ELEMENTS Use as many non-electric LEGO-made elements as you like, from any set.

Except: *Factory-made wind-up/pull-back "motors" are not allowed.*
Except: *Additional/duplicate Mission Models are not allowed.*

R07 - SOFTWARE The Robot may only be programmed using LEGO MINDSTORMS RCX, NXT, EV3, or RoboLab software (any release). No other software is allowed. Patches, add-ons, and new versions of the allowable software from the manufacturers (LEGO and National Instruments) are allowed, but tool kits, including the LabVIEW tool kit, are not allowed.

R08 - TECHNICIANS

- Only two team members, called "Technicians," are allowed at the competition Field at once.

  Except: *Others may step in for true emergency repairs during the Match, then step away.*

- The rest of the team must stand back as directed by tournament officials, with the expectation of fresh Technicians being able to switch places with current Technicians at any time if desired.

Play

R09 - BEFORE THE MATCH TIMER STARTS After getting to the Field on time, you have at least one minute to prepare. During this special time only, you may also

- ask the referee to be sure a Mission Model or setup is correct, and/or
- calibrate light/color sensors anywhere you like.

R10 - HANDLING DURING THE MATCH

- You are not allowed to interact with any part of the Field that's not **COMPLETELY** in Base.

  Except: *You may Interrupt the Robot any time.*
  Except: *You may pick up Equipment that* **BROKE** *off the Robot* **UNINTENTIONALLY**, *anywhere, any time.*

- You are not allowed to cause anything to move or extend over the Base line, even partly.

  Except: *Of course, you may* **LAUNCH** *the Robot.*
  Except: *You may move/handle/***STORE** *things off the Field, any time.*
  Except: *If something accidentally crosses the Base line, just calmly take it back – no problem.*

- Anything the Robot affects (good or bad!) or puts completely outside Base **stays as is** unless the Robot changes it. Nothing is ever repositioned so you can "try again."

R11 - MISSION MODEL HANDLING

- You are not allowed to take Mission Models apart, even temporarily.
- If you combine a Mission Model with something (including the Robot), the combination must be loose enough that if asked to do so, you could pick the Mission Model up and nothing else would come with it.

R12 - STORAGE

- Anything completely in Base may be moved/stored off the Field, but must stay in view of the referee.
- Everything in off-Field Storage "counts" as being completely in Base and may be placed on an approved holder.

R13 - LAUNCHING A proper Launch (or re-Launch) goes like this:

- **READY SITUATION**
  - Your Robot and everything in Base it's about to move or use is arranged by hand as you like, all fitting "**COMPLETELY IN BASE**" and measuring no taller than 12 inches" (30.5 cm).
  - The referee can see that nothing on the Field is moving or being handled.
- **GO!**
  - Reach down and touch a button or signal a sensor to activate a program.

IF FIRST LAUNCH OF THE MATCH – *In this case, accurate fair timing is needed, so the exact time to Launch is the beginning of the last word/sound in the countdown, such as* "**Ready, set, GO!**" *or* **BEEEEP!**

R14 - INTERRUPTING If you **INTERRUPT** the Robot, you must stop it immediately, *then calmly pick it up for a re-Launch. Here's what happens to the Robot and anything it was Transporting, depending on where each was at the time:

- **ROBOT**
  - Completely in Base: . . . . Re-Launch
  - NOT completely in Base: . . . . Re-Launch + Penalty
- **TRANSPORTED** THING WHICH **CAME FROM BASE** DURING THE MOST RECENT LAUNCH
  - Always: . . . . Keep it
- **TRANSPORTED** THING WHICH **DID NOT COME FROM BASE** DURING THE MOST RECENT LAUNCH
  - Completely in Base: . . . . Keep it
  - NOT completely in Base: . . . . Give it to the referee

The "[PENALTY]*" is described with the Missions.*

IF YOU DON'T INTEND TO RE-LAUNCH – *In this case, you may shut the Robot down and leave it in place.*

R15 - STRANDING If the **UNINTERRUPTED** Robot loses something it was Transporting, that thing must be allowed to come to rest. Once it does, here's what happens to that thing, depending on its rest location:

- **TRANSPORTED THING**
  - Completely in Base: . . . . Keep it
  - Partly in Base: . . . . Give it to the referee
  - Completely outside Base: . . . . Leave as is

R16 - INTERFERENCE

- You are not allowed to negatively affect the other team except as described in a Mission.
- Missions the other team tries but fails because of illegal action by you or your Robot will count for them.

R17 - FIELD DAMAGE

- If the Robot separates Dual Lock or breaks a Mission Model, Missions obviously made possible or easier by this damage or the action that caused it do not score.

R18 - END OF THE MATCH As the Match ends, everything must be preserved exactly as-is.

- If your Robot is moving, stop it ASAP and leave it in place. (Changes after the end don't count.)
- After that, hands off everything until after the referee has given the OK to reset the table.

CONTINUED »

R19 - SCORING

- **SCORESHEET** The referee discusses what happened and inspects the Field with you, Mission by Mission.
  - If you agree with everything, you sign the sheet, and the scoresheet is final.
  - If you don't agree with something, the head referee makes the final decision.
- **IMPACT** Only your **BEST** score from regular Match play counts toward awards/advancement. Playoffs, if held, are just for extra fun.
- **TIES** Ties are broken using 2nd, then 3rd best scores. If still not settled, tournament officials decide what to do.

Changes for 2018

MAJOR

- *If you Interrupt the Robot while it's transporting something it took from Base during the most recent launch, you can now keep that object.*

MINOR

- *Border lines are always part of the area they define.*
- *Disputes related to the thickness of thin lines (such as the border of Base) always settle in favor of the team.*
- *You need to conform to local event standards regarding the style and size of your Storage trays and carts.*
- *It's OK to shut off the Robot and leave it in place without penalty if it's done with intended Missions.*

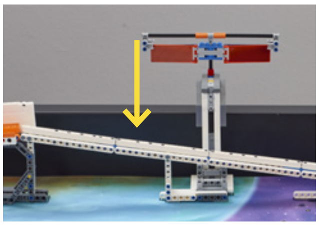
Missions

Scoring Requirement Signals

- Within the Mission descriptions, specific scoring requirements are written in GREEN.
- Methods with an asterisk "✱" must be the **ONLY** ones used, and must be **OBSERVED** by the referee .
- **Underlined RESULTS/CONDITIONS** must be visible at the END of the match.
- For each Mission, only the text following "**TECHNICALLY SPEAKING**" is used for scoring.

M01 - SPACE TRAVEL Incredible engineering accomplishments like space travel come about in steps. And many huge, progressive sub-goals need to be met before we can forever leave Earth and live to tell about it!

Simply Speaking: *The Robot needs to send Payload rockets (carts) rolling down the Space Travel Ramp. The first cart is pre-set and ready to go, but the Robot needs to load the other two from Base.*



FIRST TRACK CONNECTION

TECHNICALLY SPEAKING:

✱ **Start each Payload clearly rolling** down the Space Travel Ramp.

- For each roll, the cart must ✱ **be Independent by the time it reaches the first track connection**.
- Vehicle Payload: **22**
- Supply Payload: **14**
- Crew Payload: **10**

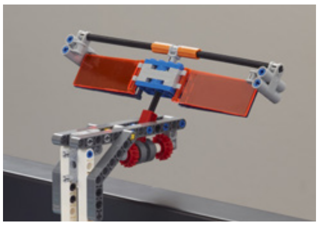
As a Mission requirement in any Mission, the word "Independent" means "not in contact with any of your Equipment."

As long as the cart clearly rolls Independently past the First Track Connection, it's OK if it doesn't roll all the way east.

Possible Scores: **0, 10, 14, 22, 24, 32, 36, 46**

M02 - SOLAR PANEL ARRAY Solar Panels in space are a great source of energy for a space station in the inner Solar System, but since things in space is always moving, aiming the Panels takes some thought.

Simply Speaking: *Solar Panels need to be Angled toward or away from you, depending on strategy and conditions.*



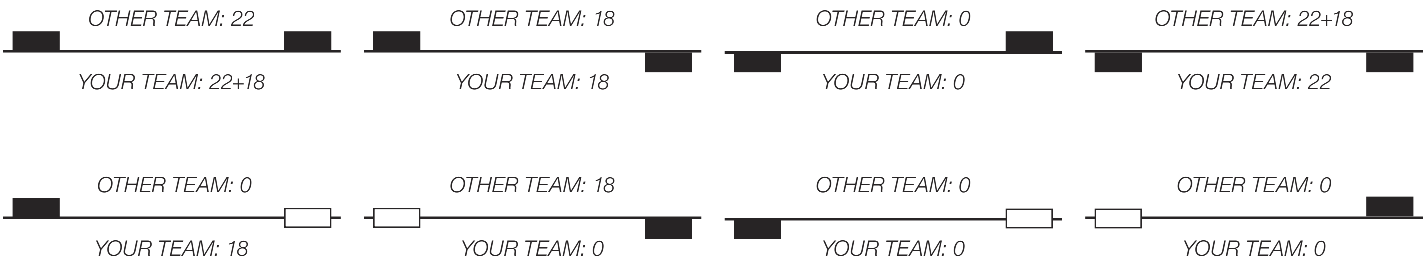
ANGLED

TECHNICALLY SPEAKING:

- **Both Solar Panels are Angled toward the same Field:** 22 For Both Teams
- **Your Solar Panel is Angled toward the other team's Field:** 18

In the diagrams below, as on your practice Field, "Your" Solar Panel is the one on your west end of the Table.

Possible scores **0, 18, 22, 40** are shown below, as seen from above your North Border, facing north.



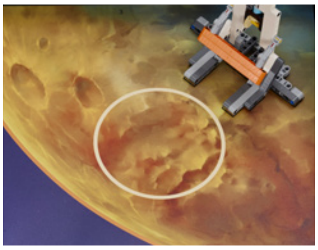
M03 - 3D PRINTING It is amazingly expensive to send heavy stuff like construction material into space, so scientists and engineers are instead learning how to print what they need in space, using available extraterrestrial elements.

Simply Speaking: *The Robot needs to get a Regolith Core Sample and place it into the 3D Printer, which will cause the 2x4 Brick to pop out. The ejected 2x4 Brick can then be delivered elsewhere for more points.*

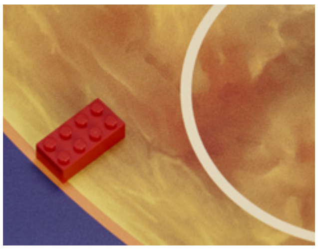
TECHNICALLY SPEAKING:

- Eject the 2x4 Brick ✱ **by placing a Regolith Core Sample into the 3D Printer**.
- The 2x4 Brick ejected and **completely in the Northeast Planet Area**: **22**
- **OR** The 2x4 Brick **ejected and not completely** in the Northeast Planet Area: **18**

Possible Scores: **0, 18, 22**



NORTHEAST PLANET AREA



22

18

M04 - CRATER CROSSING For rovers in other worlds, getting stuck is definitely not OK! Teams of rovers can help each other, but a lone rover needs to be very careful.

Simply Speaking: *The Robot or whatever agent-craft it sends out needs to cross the Craters Model completely, by driving directly over it. Not near it. Not around it.*

TECHNICALLY SPEAKING:

- All weight-bearing features of the crossing equipment must cross ✱ **completely between the towers.**
- Crossing must be **from east to west, and** ✱ **make it completely past the flattened Gate:** **20**

Possible Scores: **0, 20**

BETWEEN THE TOWERS

PAST THE GATE

M05 - EXTRACTION To live away from Earth, it would help if we were good at detecting and mining resources under the surfaces of other planets, moons, asteroids, and even comets.

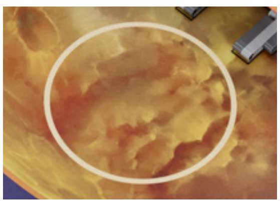
Simply Speaking: *The Robot needs to get all the Core Samples out of the Core Site Model, then it has options for what to do with them as described here, and in Mission M03.*

TECHNICALLY SPEAKING:

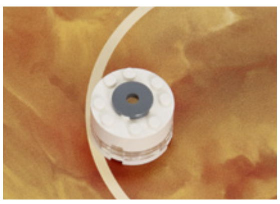
- Move all **four Core Samples so they are no longer touching the axle that held them in the Core Site Model**: **16**
- Place the Gas Core Sample so it is **touching the mat, and completely in the Lander's Target Circle**: **12**
- **OR** Place the Gas Core Sample **completely in Base**: **10**
- Place the Water Core Sample so it is **supported only by the Food Growth Chamber**: **8**

Possible Scores: **0, 16, 24, 26, 28, 34, 36**

16



LANDER'S TARGET CIRCLE



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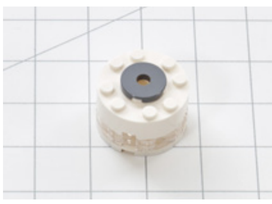


10

8

M06 - SPACE STATION MODULES Space Stations allow us to learn about and even practice living in space, but improved technology and new international partners require Modules to be easily interchangeable.

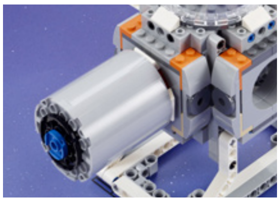
Simply Speaking: *The Robot needs to remove and insert Modules among the Habitation Hub's port holes.*

TECHNICALLY SPEAKING:

- Inserted Modules must <u>not be touching anything except the Habitation Hub</u>.
- Move the Cone Module <u>completely into Base</u>: **16**
- Insert the Tube Module <u>into the Habitation Hub port, west side</u>: **16**
- Transfer/Insert the Dock Module <u>into the Habitation Hub port, east side</u>: **14**

Possible Scores: **0, 14, 16, 30, 32, 46**

16



16

14

M07 - SPACE WALK EMERGENCY Space is quiet and beautiful, but with almost no heat, air, nor air pressure, it could freeze, suffocate, and boil you all at once! Help our spacewalking Astronaut "Gerhard" get to safety.

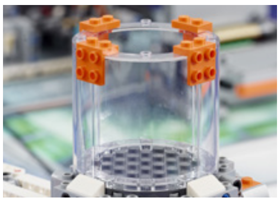
Simply Speaking: *The Robot needs to get Gerhard's body into the Airlock Chamber.*

TECHNICALLY SPEAKING:

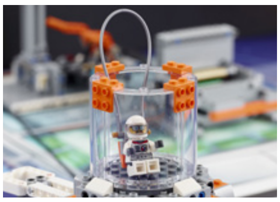
- Move Gerhard so his body is inserted <u>at least partly into the Habitation Hub's Airlock Chamber</u>.
- Completely In: **22**
- <u>OR</u> Partly In: **18**

For this Mission, the word "Body" includes all parts except the loop.

Possible Scores: **0, 18, 22**



AIRLOCK CHAMBER



22

18

M08 - AEROBIC EXERCISE Though spacecraft travel crazy-fast, even the shortest trips involve a lot of time for the traveler's body away from labor and recreation, which is bad for the heart and lungs.

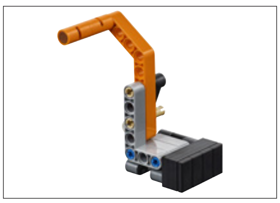
Simply Speaking: *The Robot needs to repeatedly move one or both of the Exercise Machine's Handle Assemblies to make the Pointer advance.*

TECHNICALLY SPEAKING:

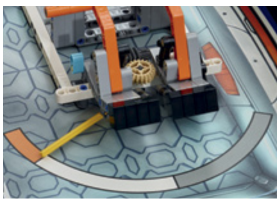
- Advance the Exercise Machine's Pointer along its Dial
  *** by moving one or both of the Handle Assemblies**.
- Get the Pointer tip <u>completely in orange, or partly covering either of orange's end-borders</u>: **22**
- <u>OR</u> Get the Pointer tip <u>completely in white</u>: **20**
- <u>OR</u> Get the Pointer tip <u>completely in gray, or partly covering either of gray's end-borders</u>: **18**

The Handle Assembly is part of the Exercise Machine, but it is shown by itself here for clarity.

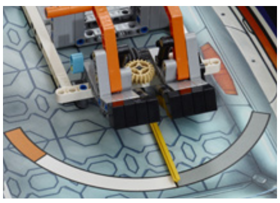
Possible Scores: **0, 18, 20, 22**



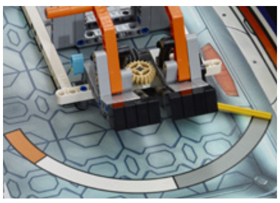
HANDLE ASSEMBLY



22 (BENEFIT OF THE DOUBT)



18



18

M09 - STRENGTH EXERCISE In zero-gravity, everything's easy to move, and you couldn't fall "down" even if you tried, so Astronauts need movement resistance - two hours a day in fact, just to keep muscle and bone density.

Simply Speaking: *The Robot needs to lift the Strength Bar to scoring height.*

TECHNICALLY SPEAKING:

- Lift the Strength Bar so the tooth-strip's 4th hole comes at least partly into view as shown: **16**

Possible Scores: **0, 16**

STRENGTH BAR

16

0

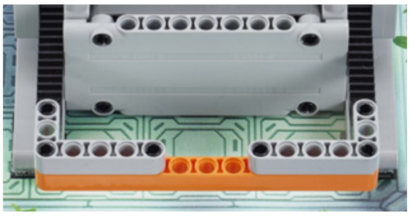
M10 - FOOD PRODUCTION Gardening is easy, right? You just need a truckload of rich soil, some rain, sun, fertilizer, helpful bugs, CO2 and a rake… but what if you were orbiting Neptune, in a room the size of a minivan?

Simply Speaking: *Move the Push Bar the right distance at the right speed, to get into the green scoring range.*

TECHNICALLY SPEAKING:

- Spin the Food Growth Chamber's colors so the gray weight is DROPPED after green, but before tan, *** by moving the Push Bar**: **16**

Possible Scores: **0, 16**



PUSH BAR

16

16

0

M11 - ESCAPE VELOCITY Soon after a launch, rocket engines often separate away from spacecraft by design, but that's long before the spacecraft leaves the pull of gravity. So why doesn't the spacecraft fall back to Earth?

Simply Speaking: *The Robot needs to impact the Strike Pad hard enough to keep the spacecraft from dropping back down.*

TECHNICALLY SPEAKING:

- Get the spacecraft to go so fast and high that it stays up, *** by pressing/hitting the Strike Pad**: **24**

Possible Scores: **0, 24**

STRIKE PAD

24

M12 - SATELLITE ORBITS If a Satellite doesn't have the correct velocity and distance from Earth, it can fall, drift away, fail to function, or get destroyed by debris. Propulsive adjustments need to be performed with precision.

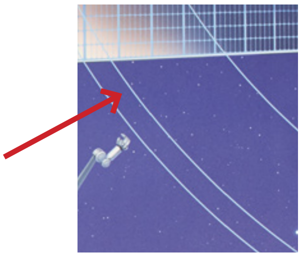
Simply Speaking: *The Robot needs to move one or more Satellites to the Outer Orbit.*

TECHNICALLY SPEAKING:

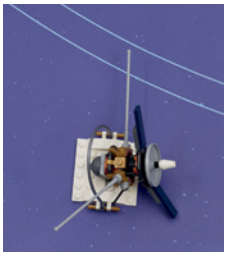
- Move any part of a Satellite on or above the area between the two lines of the Outer Orbit: **8 Each**

Possible Scores: **0, 8, 16, 24**

BETWEEN ONLY THESE TWO LINES



OUTER ORBIT



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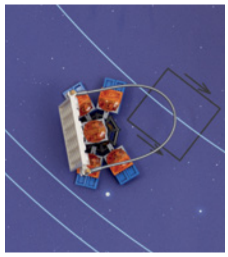
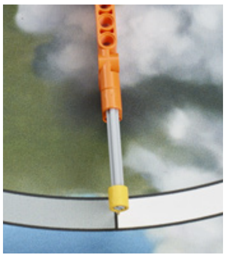


0

M13 - OBSERVATORY A space telescope is astonishing, but it can't beat the accessibility and simplicity of a college or science museum observatory - that is, if you know how and where to point it.

Simply Speaking: *Rotate the Observatory to a precise direction.*



16

16

0

TECHNICALLY SPEAKING:

- Get the pointer tip completely in orange, or partly covering either of orange's end-borders: **20**
- **OR** Get the pointer tip completely in white: **18**
- **OR** Get the pointer tip completely in gray, or partly covering either of gray's end-borders: **16**

Possible Scores: **0, 16, 18, 20**

M14 - METEOROID DEFLECTION The chance of a "serious" Meteoroid hitting Earth in our lifetime is extremely low, but it's not zero, and the devastation could truly wipe us out. How will scientists and engineers keep us safe?

Simply Speaking: *From west of the Free-Line, send one or both Meteoroids Independently to the Meteoroid catcher.*

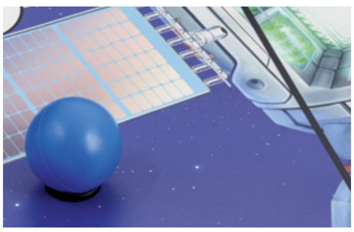
TECHNICALLY SPEAKING:

- Send Meteoroids ✱ **over the Free-Line to touch the mat in the Meteoroid Catcher**.
- The Meteoroids must be hit/released while they are ✱ **clearly and completely west of the Free-Line**.
- While between hit/release and scoring position, the Meteoroid ✱ **must be clearly Independent**.
- Meteoroids in the Center Section: **12 Each**
- Meteoroids in Either Side Section: **8 Each**

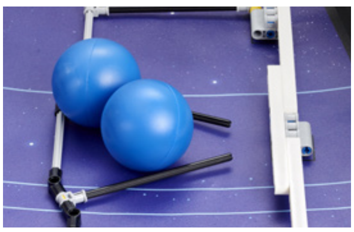
If ever the Ring-Set Meteoroid is off its Ring, you may remove the Ring from the Field by hand (this is a special exception to the Rules).

Possible Scores: **0, 8, 12, 16, 20, 24**

FREE-LINE



MUST BE INDEPENDENT WHILE EAST OF THE FREE-LINE



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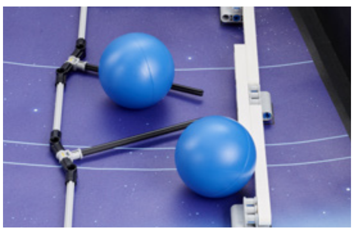


20

M15 - LANDER TOUCH-DOWN: Our Lander doesn't have working parachutes, thrusters, or cushions, but one important feature is realistic… it's very fragile.

Simply Speaking: *Get the Lander to one of its targets intact, or at least get it to Base.*

TECHNICALLY SPEAKING:

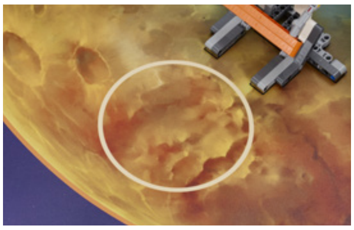
- Move the Lander to be intact, touching the Mat, and completely in its Target Circle: **22**
- OR Move the Lander to be intact, touching the Mat, and completely in the Northeast Planet Area: **20**
- OR Move both parts of the Lander completely into Base: **16**

The Lander is "Intact" if its parts are connected by at least two of its four tan location axles.

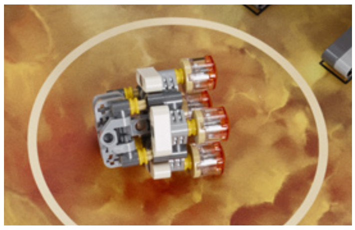
Possible Scores: **0, 16, 20, 22**

INTACT

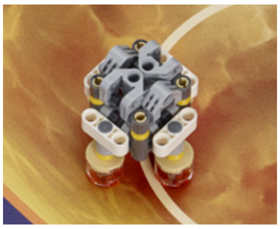
LANDER'S TARGET CIRCLE



NORTHEAST PLANET AREA



22



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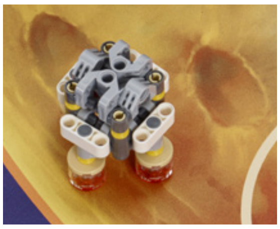

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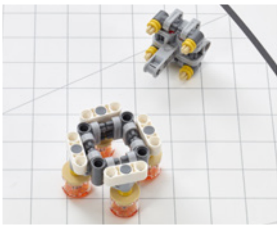
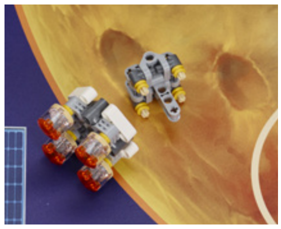


16

0



0

P01 – INTERRUPTION PENALTIES: Read the RULES carefully and often.

Simply Speaking: *FIRST* LEGO League *Mission Requirements need to be achieved by your Robot through its programs and its use of equipment. You're allowed to hand-rescue your Robot, but that does cause this Penalty. Be sure to pay extra attention to the Rules where they talk about "Interruptions."*

PENALTY DISCS

TECHNICALLY SPEAKING:

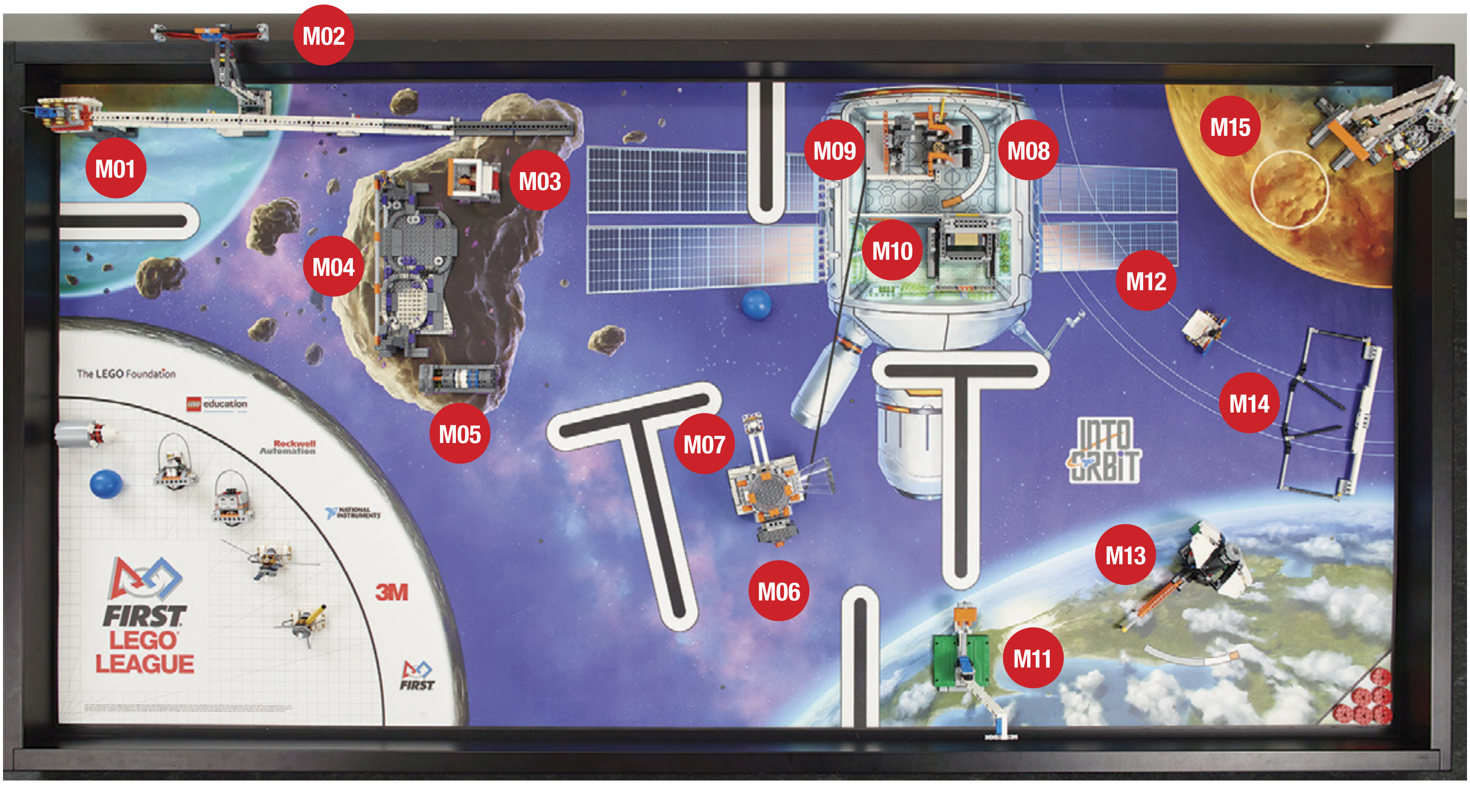
- If you ∗ **Interrupt the Robot**: **Minus 3 Each Time**

Upon Penalty, the referee will place one Penalty Disc in the southeast triangle as a permanent Interruption marker.

You can get up to six such Penalties.

If a Penalty Disc comes off the triangle, it is simply returned, with no effect on score.

Possible Penalty Totals: **-18, -15, -12, -9, -6, -3, 0**


M01
M02
M03
M04
M05
M06
M07
M08
M09
M10
M11
M12
M13
M14
M15
The LEGO Foundation
education
Rockwell Automation
3M
FIRST LEGO LEAGUE
INTO ORBIT

Robot Design Executive Summary (RDES)

An "executive summary" is often used by engineers to briefly outline the key elements of a product or project. The purpose of the Robot Design Executive Summary (RDES) is to give the Robot Design Judges a quick overview of your team's robot and all that it can do.

Unlike the Core Values Poster, teams do not need to create a poster or written material for the RDES. However, teams may share pictures of the design process and records of strategy sessions, and are strongly encouraged to bring examples of programming (either printed or on a laptop).

Have your team prepare a short presentation (no longer than four (4) minutes) covering the elements below:

1. **Robot Facts** Share a little bit about your robot, such as the number and type of sensors, drivetrain details, number of parts, and the number of attachments. The Judges also like to know what programming language your team used, the number of programs, and the Robot Game mission where your team had the most success.
2. **Design Details**
    a. **Fun:** Describe the most fun or interesting part of robot design as well as the most challenging parts. If your team has a fun story about your robot please feel free to share.
    b. **Strategy:** Explain your team's strategy and reasoning for choosing and accomplishing missions. Talk a little bit about how successful the robot was in completing the missions that were chosen.
    c. **Design Process:** Describe how your team designed their robot and what process they used to make improvements to the design over time. Briefly share how different team members contributed to the design.
    d. **Mechanical Design:** Explain the robot's basic structure. Explain to the Judges how the robot moves (drivetrain), what attachments and mechanisms it uses to operate or complete missions, and how your team makes sure it is easy to add/remove attachments.
    e. **Programming:** Describe how your team programmed the robot to ensure consistent results. Explain how the team organized and documented programs. Mention if the programs use sensors to know the location of the robot on the field.
    f. **Innovation:** Describe any features of the robot's design that the team feels are special or clever.
3. **Trial Run** Run the robot briefly to demonstrate how it completes the mission(s) of your team's choice. Please do not do an entire robot round. The Judges need time to ask questions after the RDES.

Want to Learn More?

- Explore the essential details of the Robot Game by reading the Rules and Missions in this Challenge Guide.
- Check the Robot Game Updates, often. *FIRST* LEGO League staff will clarify common questions. Updates supersede anything in this Challenge document and will be in effect at tournaments.
- Your team will be assessed in the judging room using a standard Robot Design rubric.
- Your team will also compete in at least three Robot Performance matches. Read the Event Guide for Teams to know what to expect at an Official Event.

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