## 2.1: What is Robotics?

A robot is a programmable mechanical device that can perform tasks and interact with its environment, without the aid of human interaction. Robotics is the science and technology behind the design, manufacturing and application of robots.

The word robot was coined by the Czech playwright Karel Capek in 1921. He wrote a play called “Rossum's Universal Robots” that was about a slave class of manufactured human-like servants and their struggle for freedom. The Czech word *robota* loosely means "compulsive servitude.” The word robotics was first used by the famous science fiction writer, Isaac Asimov, in 1941.


**Basic Components of a Robot**

The components of a robot are the body/frame, control system, manipulators, and drivetrain.

**Body/frame**: The body or frame can be of any shape and size. Essentially, the body/frame provides the structure of the robot. Most people are comfortable with human-sized and shaped robots that they have seen in movies, but the majority of actual robots look nothing like humans. (NASA’s Robonaut, pictured in the previous section is an exception.) They are typically designed more for function than appearance.

**Control System**: The control system of a robot is equivalent to the central nervous system of a human. It coordinates and controls all aspects of the robot. Sensors provide feedback based on the robot’s surroundings, which is then sent to the Central Processing Unit (CPU). The CPU filters this information through the robot’s programming and makes decisions based on logic. The same can be done with a variety of inputs or human commands.

**Manipulators:** To fulfill their purposes, many robots are required to interact with their environment, and the world around them. Sometimes they are required to move or reorient objects from their environments without direct contact by human operators. Unlike the Body/frame and the Control System, manipulators are not integral to a robot, i.e. a robot can exist without a manipulator. This curriculum focuses heavily on manipulators, especially in Unit 6.

**Drivetrain:** Although some robots are able to perform their tasks from one location, it is often a requirement of robots that they are able to move from location to location. For this task, they require a drivetrain. Drivetrains consist of a powered method of mobility. Humanoid style robots use legs, while most other robots will use some sort of wheeled solution.

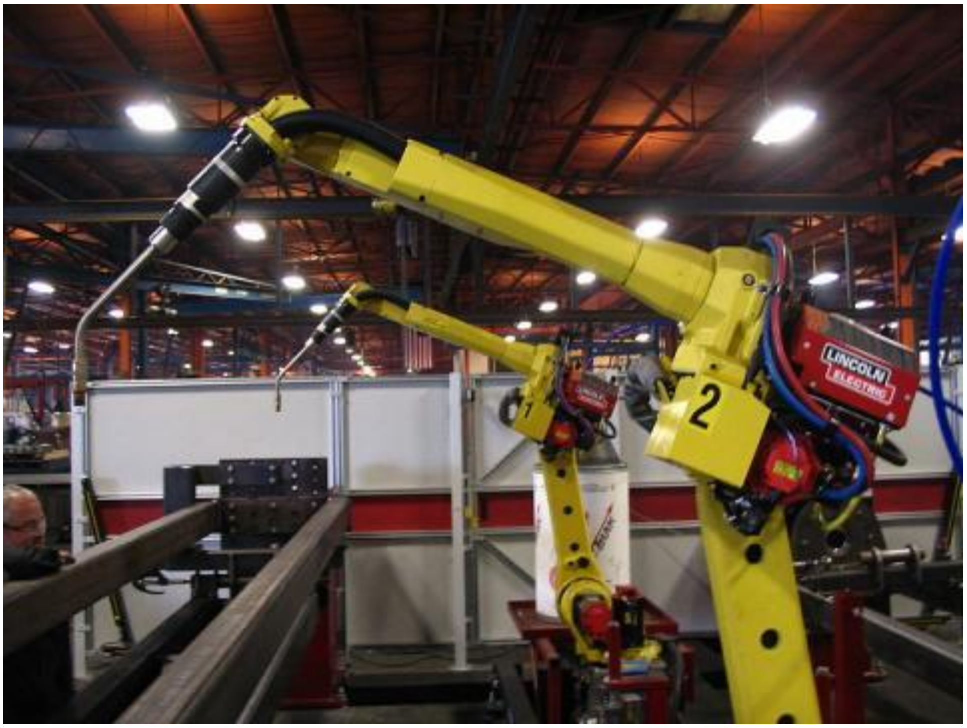
**Uses and Examples of Robots**

Robots have a variety of modern day uses. These uses can be broken down into three major categories:

- Industrial Robots
- Robots in Research
- Robots in Education

**Industrial Robots**

In industry, there are numerous jobs that require high degrees of speed and precision. For many years humans were responsible for all these jobs. With the advent of robotic technology, it became evident that many industrial processes could be sped up and performed with a higher degree of precision by the use of robots. Such jobs include packaging, assembly, painting, and palletizing. Initially robots in industry only performed very specialized and repetitive jobs that could be executed with a simple yet precise set of instructions. However as technology has improved, we now see industrial robots that are much more flexible, making decisions based on complex sensor feedback. Vision systems are now common on industrial robots. By the end of 2014, the International Federation of Robotics predicts that there will be over 1.3 million industrial robots in operation worldwide!




Robots can be designed to perform tasks that would be difficult, dangerous, or impossible for humans to do. For example, robots are now used to defuse bombs, service nuclear reactors, investigate the depths of the ocean and the far reaches of space.

**Robots in Research**

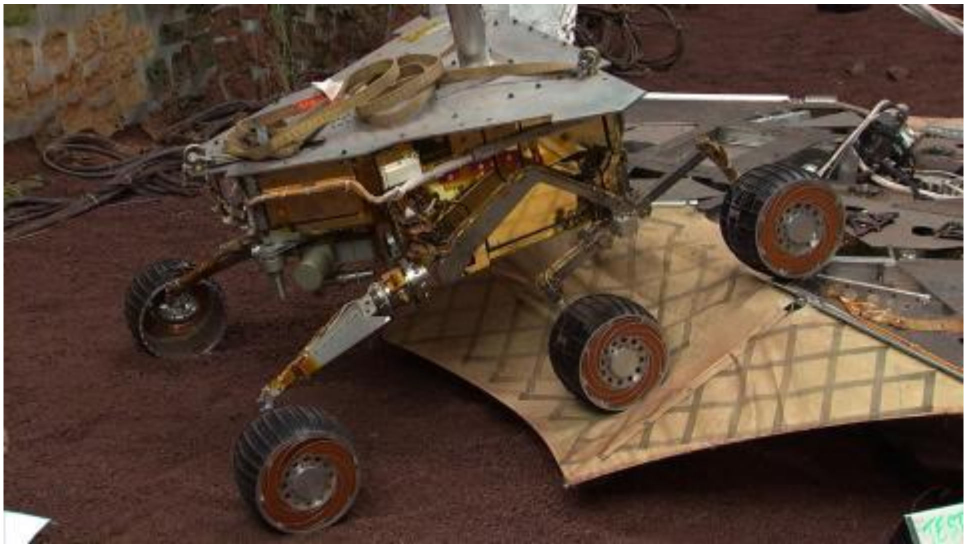
Robots come in very handy in the world of research, as they often can be used to perform tasks or reach locations that would be impossible for humans. Some of the most dangerous and challenging environments are found beyond the Earth. For decades, NASA has utilized probes, landers, and rovers with robotic characteristics to study outer space and planets in our solar system.

**Pathfinder and Sojourner**

The Mars Pathfinder mission developed a unique technology that allowed the delivery of an instrumented lander and a robotic rover, Sojourner, to the surface of Mars. It was the first robotic roving vehicle to be sent to the planet Mars. Sojourner weighs 11.0 kg (24.3 lbs.) on Earth (about 9 lbs. on Mars) and is about the size of a child's wagon. It has six wheels and could move at speeds up to 0.6 meters (1.9 feet) per minute. The mission landed on Mars on July 4$^{th}$, 1997. Pathfinder not only accomplished this goal but also returned an unprecedented amount of data and outlived its primary design life.


**Spirit and Opportunity**

The Mars Exploration Rovers (MERs), Spirit and Opportunity, were sent to Mars in the summer 2003 and landed there in January 2004. Their mission was to search for and characterize a wide range of rocks and soils that hold clues to past water activity on Mars in hopes that a manned mission may someday follow. Although initially planned for a lifespan of 90 days, the elapsed mission time surpassed six years, discovering unimaginable amounts of geological information about Mars.



**Space Shuttle Robotic Arm**

When NASA scientists first began the design for the space shuttle, they realized that there would have to be some way to get the enormous, but fortunately weightless, cargo and equipment into space safely and efficiently. The remote manipulator system (RMS), or Canadarm, made its first flight into space on November 13, 1981.

The arm has six joints, designed to simulate the joints of the human arm. Two are in the shoulder, one is at the elbow, and three are in the highly dextrous wrist.  At the end of the wrist is an end effector which can grab or grapple the desired payload. In the weightless environment of space, it can lift more than 586,000 pounds and place it with incredible accuracy. Its total weight on earth is 994 lbs.

The RMS has been used to launch and rescue satellites and has proven itself invaluable in helping astronauts repair the Hubble Space Telescope. The Canadarm's final shuttle mission took place in July of 2011, marking the 90th time it was used on a shuttle mission.


**Mobile Servicing System**

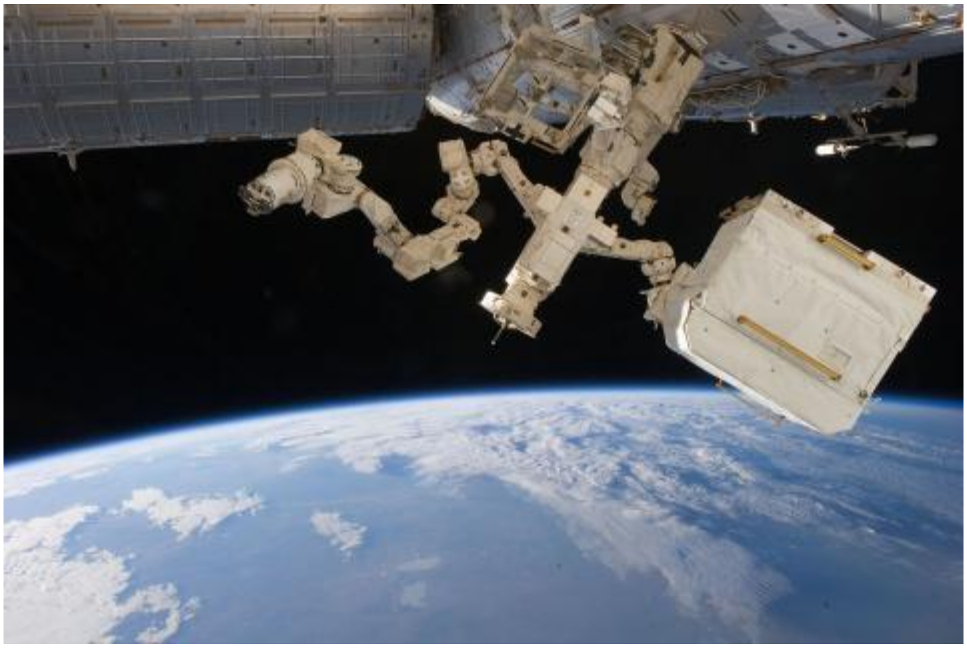
A similar device to the RMS, the Mobile Servicing System (MSS) otherwise known as Canadarm2 was designed to provide manipulation functions for the International Space Station. The MSS is responsible for servicing payloads and instruments attached to the International Space Station, while also assisting with the transport of supplies and equipment around the station.

**Dextre**

As part of the Space Shuttle mission STS-123 in 2008, the shuttle Endeavour carried the final part of the Special Purpose Dexterous Manipulator, or "Dextre."

Dextre is a robot with two smaller arms. It is capable of handling the delicate assembly tasks currently performed by astronauts during spacewalks. Dextre can transport objects, use tools, and install and remove equipment on the space station. Dextre also is equipped with lights, video equipment, a tool platform, and four tool holders. Sensors enable the robot to "feel" the objects it is dealing with and automatically react to movements or changes. Four mounted cameras enable the crew to observe what is going on.

Dextre's design somewhat resembles a person. The robot has an upper body that can turn at the waist and shoulders that support arms on either side.



**Robots in Education**

The field of robotics has become an exciting and accessible tool for teaching and supporting science, technology, engineering, mathematics (STEM), design principles, and problem solving. Robotics enables students to use their hands and minds to create like an engineer, artist, and technician does, all at once. It allows for instantaneous application of scientific and mathematical principals.

In today's education system with its budgetary constraints, middle and high schools are on a constant search for cost-effective exciting ways to deliver high-impact programs that integrate technology with multiple disciplines while preparing students for careers in the twenty-first century. Educators quickly see the advantages that robotics projects and curriculum provide by linking in a cross-curriculum method with other disciplines. Additionally, robotics can provide more affordability and reusability of equipment as compared to other prepackaged options.

Today more than ever, schools are adopting robotics in the classroom to revitalize curriculum and meet ever increasing academic standards required for students. Robotics not only has a unique and broad appeal throughout various teaching fields, but it is quite possibly the technical field that will have the largest influence upon our society throughout the next century.

**Why is Robotics Important?**

As we saw in the uses and examples of robotics section, robotics is an emerging field with applications in many facets of our lives. It is important for all members of society to have an understanding of the technology that surrounds us. However, robotics is important for more than that reason. Robotics provides a unique combination of the pillars of STEM: science, technology, engineering and math. When taught in schools, it allows students to experience a true interdisciplinary lesson while studying a cutting edge and exciting topic. Also, the aesthetics which go into the design and creation of robots allow students to experiment with an artistic side, while working through technical principals. This combination rewards participants on a plethora of different learning levels.

## 2.2: VEX Robotics Design System

The VEX Robotics Design System, which was created by Innovation First, Inc., is recognized as a leading classroom robotics platform. It has been designed to nurture creative advancement in robotics and knowledge of science, technology, engineering, and math (STEM) education. The VEX system provides teachers and students with an affordable, robust, and state-of-the-art robotics system suitable for both classroom use and for use on the competition playing field. VEX's innovative use of premade and easily formed structural metal, combined with a powerful and user-programmable microprocessor for control, leads to infinite design possibilities.

Beyond science and engineering principles, a VEX Robotics project encourages teamwork, leadership and problem solving among groups. It also allows educators to easily customize projects to meet the level of students' abilities. The affordable VEX platform is expanding rapidly and is now found in middle schools, high schools and university labs around the globe.

For more information on the VEX Robotics Design System, please visit: http://www.vexrobotics.com/

**VEX Product Subsystems**

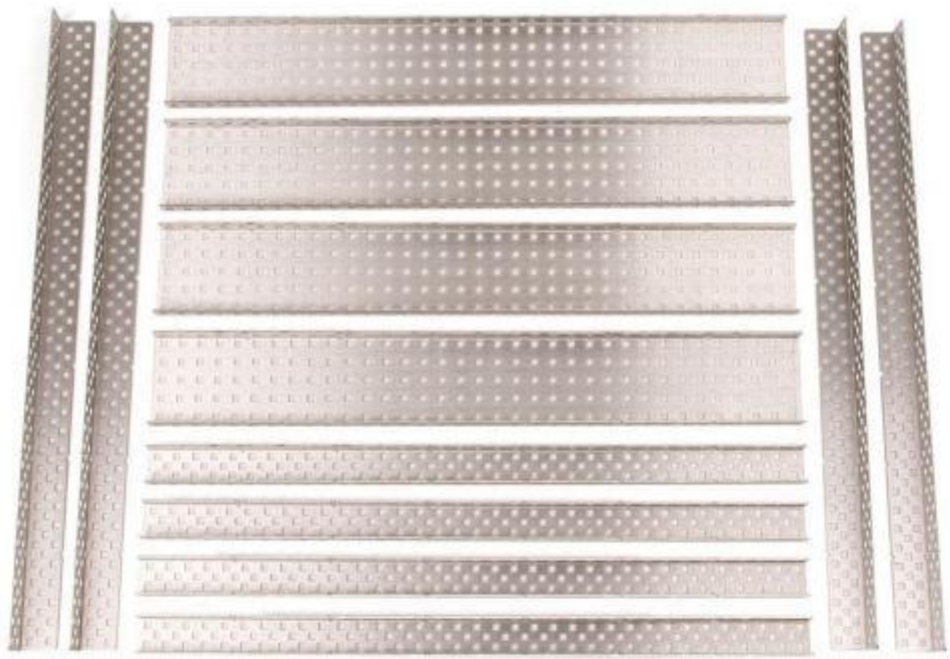
| Sub-System | Description |
|---|---|
| Structure | All metal, fasteners, and structural/mechanical plastic VEX parts |
| Motion | Motors, Servos, Gears, Chain and Sprockets, Tank Treads and Associated Items |
| Power | Batteries, Chargers and Associated Items |
| Sensors | Bumper and Limit Switch, Ultrasonic, Line Follower, Shaft Encoders, Potentiometer |
| Logic | Microcontroller, PWM Cables, Programming Kits |
| Control | Joystick, Transmitter, Receiver, Crystals, Signal Splitter, Tether Cables |

**Structure Subsystem**

The parts in the VEX Structure Subsystem form the base of every robot. These parts are the "skeleton" of the robot to which all other parts are attached. This subsystem consists of all the main structural components in the VEX Robotics Design System, including all the metal components and hardware pieces. These pieces connect together to form the "skeleton" or frame of the robot. The Structure and Motion subsystems are very tightly integrated to form the chassis of the robot.

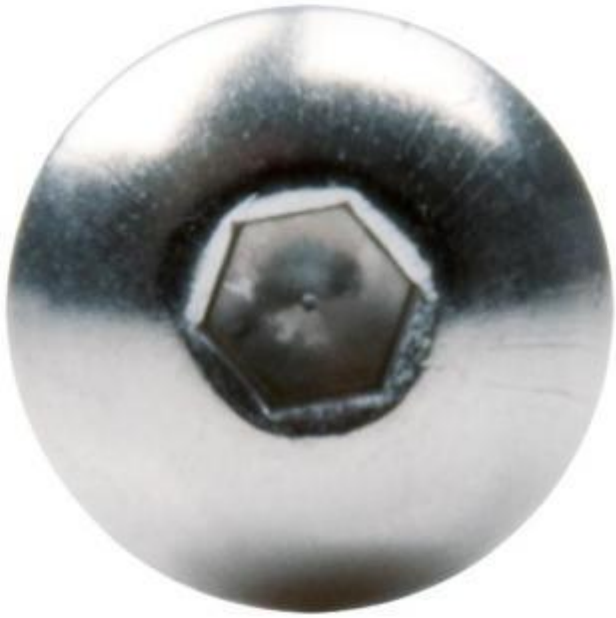
In the VEX Robotics Design System the majority of the components in the Structure Subsystem are made from bent aluminum or steel sheet metal. These pieces come in a variety of shapes and sizes and are suited to different applications on a robot.

The VEX structural pieces all contain square holes (0.182" sq) on a standardized 0.5" grid. This standardized hole-spacing allows for VEX parts to be connected in almost any configuration. The smaller diamond holes are there to help users cut pieces using tin snips or fine toothed hacksaws without leaving sharp corners.



VEX square holes are also used as an alignment feature on some components. These pieces will snap into place in these square holes. For example, when mounting a VEX Bearing Flat there are small tabs which will stick through the square hole and hold it perfectly in alignment. Note that hardware is still required to hold the Bearing Flat onto a structural piece!

Hardware is an important part of the Structure Subsystem. Metal components can be attached together using the 8-32 screws and nuts which are standard in the VEX kit. These screws come in a variety of lengths and can be used to attach multiple thicknesses of metal together, or to mount other components onto the VEX structural pieces. Allen wrenches and other tools are used to tighten or loosen the hardware. There are also smaller 6-32 screws in the VEX Robotics Design System, which are used only for the mounting of VEX Motors and Servos.



When using screws to attach things together, there are three different nuts which can be used.

- Nylock nuts have a plastic insert which will prevent the screw from loosening. These nuts are harder to install; an open-ended wrench is needed to tighten them. However, these nuts will not shake loose due to vibration or movement.
- KEPS nuts have a ring of teeth on one side of them which will grip the piece they are being installed on. An open-ended wrench is not needed to tighten them, but it is recommended. These nuts are installed with the teeth facing the structure. They can loosen up over time if not properly tightened, but they work well in most applications.
- Regular nuts that have no locking feature. These basic hex nuts require a wrench to install and may loosen up over time, especially as a result of vibration or movement. They are thin and can be used in certain applications where a Nylock or KEPS nut would not fit.

Another useful structural component are the 8-32 threaded standoffs; these standoffs come in a variety of lengths and add a great deal of versatility to the VEX kit. Standoffs are useful for mounting components as well as for creating structural beams of great strength.

One of the key features of many VEX structural parts is their “bend-able” and “cut-able” nature. Users can easily modify many of these structural parts into new configurations better suited for their current needs. These parts were designed to be modified!

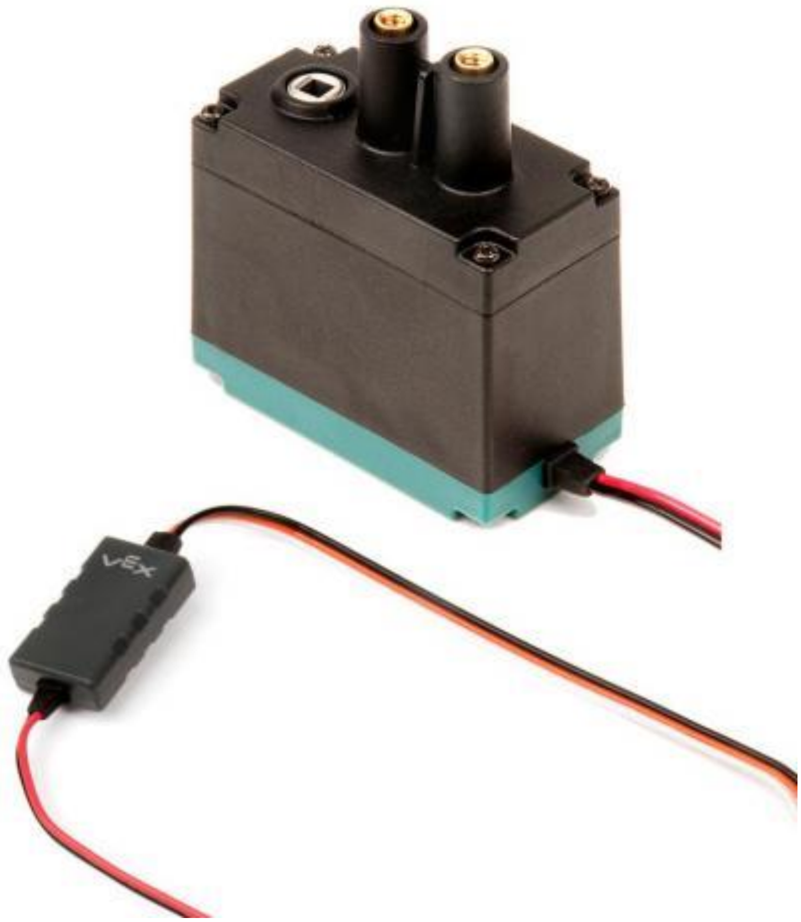
**Motion Subsystem**
The Motion Subsystem comprises all the components in the VEX Robotics Design System which make a robot move. These components are critical to every robot. The Motion Subsystem is tightly integrated with the components of the Structure Subsystem in almost all robot designs. In the VEX Robotics Design System the motion components are all easily integrated together. This makes it simple to create very complex systems using the basic motion building blocks.

The most fundamental concept of the Motion Subsystem is the use of a square shaft. Most of the VEX motion components use a square hold in their hub which fits tightly on the square VEX shafts. This square hole / square shaft system transmits torque without using cumbersome collars or clamps to grab a round shaft.

The square shaft has rounded corners which allow it to spin easily in a round hole. This allows the use of simple bearings made from Delrin. The Delrin bearing will provide a low friction piece for the shafts to turn in.

These VEX Delrin bearings come in two types, the most common of which is a Bearing Flat. The Bearing Flat mounts directly onto a piece of VEX structure and supports a shaft which runs perpendicular and directly through the structure. Another type of bearing is a Bearing Block; these are similar to the “pillow-blocks” used in industry. The Bearing Block mounts on a piece of structure and supports a shaft which is offset above, below, or to the side of the structure. Some bearings can be mounted to VEX structural components with Bearing Pop Rivets. These rivets are pressed into place for quick mounting. These Rivets are removable; pull out the center piece by pulling up on the head of the Rivet to get it to release.

The key component of any motion system is an actuator (an actuator is something which causes a mechanical system to move). In the VEX Robotics Design System there are several different actuator options. The most common types are the VEX Continuous Rotation Motors and VEX Servos. The Motors can rotate infinitely, while the range of rotation of the Servos is restricted to 150 degrees. Each VEX Motor & Servo comes with a square socket in its face, designed to connect it to the VEX square shafts. By simply inserting a shaft into this socket it is easy to transfer torque directly from a motor into the rest of the Motion Subsystem.



The Motion Subsystem also contains parts designed to keep pieces positioned on a VEX shaft. These pieces include washers, spacers, and shaft collars. VEX Shaft Collars slide onto a shaft, and can be fastened in place using a setscrew.

There are several ways to transfer motion in the VEX Robotics Design System. A number of Motion Subsystem accessory kits are available with a variety of advanced options, including spur gears, sprocket & chains, bevel gears, etc. For a full listing of what is available, please visit: http://www.vexrobotics.com/products/accessories/motion

The VEX Motion Subsystem also contains a variety of components designed to help make robots mobile. This includes a re variety of wheels, tank treads and other options. . For a full listing of what is available, please visit: http://www.vexrobotics.com/products/accessories/motion

**Power Subsystem**

Power is vital to the operation of all the electronic parts on the robot, including the controller and the motors. With the structural subsystem as the robot's skeleton, and the motion subsystem as the muscle, the power subsystem is the circulatory system that provides the rest of the robot with energy.

There are two major power considerations for a VEX robot; robot power and joystick power. The robot is powered by a rechargeable 7.2V battery pack. The VEXnet Joystick is powered by 6 AAA batteries. For more information on all the power options and accessories available, please visit: http://www.vexrobotics.com/products/accessories/power


7.2V
3000 mAh
NIMH
POWER
PACK
VEX

**Sensors Subsystem**

The sensor subsystem gives the robot the ability to detect various things in its environment. The sensors are the “eyes and ears” of the robot, and can even enable the robot to function independently of human control. A robot senses its environment and adjusts its own behaviors based on that knowledge. A sensor will generally tell the robot about one very simple thing in the robot’s environment, and the robot’s program will interpret that feedback to determine how it should react.

There are a myriad of sensor options available in the VEX Robotics Design System. Some of these include ultrasonic range finders, gyroscopes, light sensors and optical encoders. For a full list of all sensors available, please visit: http://www.vexrobotics.com/products/accessories/sensors


**Logic Subsystem**

The Logic Subsystem major component is one of the VEX Microcontrollers. A microcontroller is the most integral component of the entire VEX system, because it coordinates and controls all the other components. The Logic Subsystem is effectively the robot’s brain.


The VEX Cortex Microcontroller comes preprogrammed with a default routine which allows users to get their robots up and running as quickly as possible. With the use of jumper pins, quick adjustments can be made to this default code for greater flexibility. For more advanced programming options, the microcontroller can be fully user programmed using one of the available programming options. More information on these options can be found here:  http://www.vexrobotics.com/products/programming

**Control Subsystem**
The Control Subsystem enables a human operator to maneuver the robot. Commands are issued through joysticks and buttons on the VEXnet Joystick, and sent wirelessly to the robot. In this way, the robot can be controlled through a combination of manual and autonomous methods. The VEXnet Joystick allows a human operator to control a robot in real time using the innovative VEXnet Wireless link. The joystick has two 2-axis analog joysticks, 4 trigger buttons and two 4-button directional pads.


VEX
JOYSTICK
GAME
CONFIG
VEXnet
7
8
4
3
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