# 7.0 The Robot

## 7.1 Overview

A *FIRST* Tech Challenge *Robot* is a remotely operated vehicle designed and built by a registered *FIRST* Tech Challenge *Team* to perform specific tasks when competing in the annual game challenge. This section provides rules and requirements for the design and construction of a *Robot*. *Teams* should be familiar with the *Robot* and game rules before beginning *Robot* design.

## 7.2 Robot Control System

A *FIRST* Tech Challenge *Robot* is controlled by an Android-based platform powered by Snapdragon processors. *Teams* will use two (2) Android devices to control their *Robot* and compete in a "*Sports Start*" model of competition. One Android device is mounted directly onto the *Robot* and acts as a *Robot Controller*. The other Android device is connected to a pair of gamepads and acts as the *Driver Station*.

For more information, tutorials, and to access our Android Technology forum, please visit: https://www.firstinspires.org/resource-library/ftc/robot-building-resources

### 7.2.1 Robot Technology Definitions

*Core Device Interface Module* – A USB-enabled device that can be used to provide input/output ports for the *Robot Controller*. The *Core Device Interface Module* has 8 digital I/O ports, 8 analog input ports, 2 analog output ports, 2 PWM output ports and 6 high speed (100kHz) $I^2C$ ports.

*Core Motor Controller* – A USB-enabled DC motor controller with two (2) motor control channels.

*Core Power Distribution Module* – The electronic device that connects the *Robot Controller* Android device to one or more USB-enabled modules such as the *Core Motor Controller*, *Core Servo Controller*, and the *Core Device Interface Module*. The *Core Power Distribution Module* draws power from an approved 12V battery to power an internal USB Hub, DC motor controllers and servo controllers, and certain specified electronics.

*Core Servo Controller* – A USB-enabled servo controller with six (6) servo control channels.

*Driver Station* – Hardware and software used by a *Drive Team* to control their *Robot* during a *Match*. The *Driver Station* consists of an Android device; *FIRST* Tech Challenge supplied Android App; adapter cable(s); optional USB Hub; an optional, commercial, off the shelf, USB external battery connected to the USB Hub to charge the Android device; and up to two controllers to drive the *Robot*. *Teams* may use either of the two models of controller device(s) in any combination– either the Logitech F310 Gamepad Controllers or the Xbox 360 Controller for Windows (Part #: 52A-00004). The *Driver Station* also includes any components used to hold the above listed legal devices.

*Java* – The recommended programming language for the *Robot Controller*.

*Logic Level Converter* – An electronic device that allows an encoder or sensor, that operates using 5V logic levels, to work with the *REV Expansion Hub*, which operates using 3.3V logic levels. This device may contain a step-up voltage converter (from 3.3V to 5V) and a dual channel, bidirectional logic level converter. This device may be used directly with a 5V digital sensor or with an *$I^2C$ Sensor Adaptor Cable* to a 5V $I^2C$ sensor.

*$I^2C$ Sensor Adapter Cable* – An adapter to change the pin orientation of the REV Robotics *Logic Level Converter* to match a Modern Robotics compatible $I^2C$ sensor*.*

*Mini USB to OTG (On-The-Go) Micro Cable* – The connection between the *Robot Controller* and the *Core Power Distribution Module* or *REV Expansion Hub*.

*Modern Robotics Core Control Modules* – The *Core Motor Controller*, the *Core Servo Controller*, the *Core*

*Power Distribution Module*, and the *Core Device Interface Module* are all considered to be *Core Control Modules*.

*Modern Robotics Sensors* – Sensors designed by Modern Robotics that connect to the *Core Device Interface Module*.

*Op Mode* – An *Op Mode* (short for "operational mode") is software that is used to customize the behavior of a competition *Robot*. The *Robot Controller* can execute a selected *Op Mode* to perform certain tasks during a *Match*.

*OTG Micro Adapter* – Connects a USB hub to Micro USB OTG (On-The-Go) port on the *Driver Station* Android device.

*REV Expansion Hub* – An integrated electronic device with four (4) DC motor channels, six (6) servo channels, eight (8) digital I/O channels, four (4) analog input channels, and four (4) independent I$^2$C buses. The *REV Expansion Hub* draws power from an approved 12V battery to power these input/output channels.

*REV SPARK Mini Motor Controller* - An electronic device that accepts a PWM control signal (from a servo controller) and supplies 12V power to a DC motor.

*REV Robotics Sensors* – Sensors designed by REV Robotics that connect to the *REV Expansion Hub*.

*REV Servo Power Module* – An electronic device that boosts the power supplied to 3-wire servos. A *REV Servo Power Module* has 6 input servo ports and 6 matching output ports. It draws power from a 12V source and provides 6V power to each output servo port. A *REV Servo Power Module* can provide up to 15A of current across all output servo ports for a total of 90 Watts of power per module.

*Robot Controller* – An Android device located on the *Robot* that processes *Team* written software, reads on-board sensors, and receives commands from the *Drive Team* by way of the *Driver Station*. The *Robot Controller* sends instructions to the motor and servo controllers to make the *Robot* move.

*USB Mini Type B Cable* – These cables are used to connect the USB-enabled modules (*Core DC Motor Controller, Core Servo Controller* and *Core Device Interface*) to the *Core Power Distribution Module*.  The cables provide 5V DC power to the modules and send information to/from the modules.

*UVC Compatible Camera* – A USB Video Class *(UVC) Compatible Camera* is a digital camera that conforms to the USB Video Class specification.

## 7.3 Robot Rules
Anyone that has attended a *FIRST* Tech Challenge tournament knows that *Teams* think outside the kit-of-parts to create unique and creative *Robot*s. The intent of the *Robot* construction rules is to create a level playing field and a framework for *Teams* to build *Robot*s that safely play the annual game challenge. *Teams* should read all the *Robot* rules before building. *Teams* can also reference our Legal and Illegal Parts List on our website for common legal and illegal *Robot* parts. Some suppliers' websites may claim that a part is *FIRST* Tech Challenge approved. The only official references for the legality of parts and materials are the Game Manual Part 1, the Legal and Illegal Parts List, and the Official Game Q&A Forum.

### 7.3.1 General Robot Rules
It is the intent of *FIRST* to encourage creativity in design as long as it does not present a safety hazard or unfairly affect the opportunities of any opposing-*Alliance Teams* to compete. Although there is significant creative freedom allowed in the *Robot* design rules, *Teams* should consider the adverse effects of any design decisions that they make. When considering your *Robot* design and your game strategy, ask yourself the following questions. If the answer to any of these questions is yes, the design part is not allowed:

- Could it damage or disable another *Robot*?
- Could it damage the *Playing Field*?
- Could it injure a participant or volunteer?
- Is there already a rule that restricts this?
- If everybody did this, would the game play be impossible?

**<RG01> Illegal Parts** - The following types of mechanisms and parts are not allowed:

a. Those used in a *Robot* drive system that could potentially damage the *Playing Field* and/or Scoring Elements such as high traction wheels (for example, AM-2256) and high grip tread (for example, Rough top).

b. Those that could potentially damage or flip other competing *Robot*s.

c. Those that contain hazardous materials such as mercury switches, lead, or lead containing compounds, or lithium polymer batteries (except for the Android devices' internal batteries).

d. Those that pose an unnecessary risk of entanglement.

e. Those that contain sharp edges or corners.

f. Those that contain animal-based materials (because of health and safety concerns).

g. Those that contain liquid or gel materials.

h. Those that contain materials that would cause a delay of game if released (for example, loose ball bearings, coffee beans, etc.).

i. Those that are designed to electrically ground the *Robot* frame to the *Playing Field*.

j. Closed gas devices (for example, gas storage vessel, gas spring, compressors, etc.).

k. Hydraulic devices.

**<RG02> Maximum Starting Size** - The maximum size of the *Robot* for starting a *Match* is 18 inches (45.72 cm) wide by 18 inches (45.72 cm) long by 18 inches (45.72 cm) high. A *Robot Sizing Tool* will be used as the official gauge to make sure *Robots* comply with this rule. To pass inspection a *Robot* must fit within the sizing tool while in its *Match* start configuration without exerting force on the sides or top of the sizing tool. *Robots* may expand beyond the starting size constraint after the start of the *Match*. Preloaded game elements may extend outside the starting volume constraint.

The *Robot* must be self-supporting while in the *Robot* Sizing tool by either:

a. A mechanical means with the *Robot* in a power-OFF condition. Any restraints used to maintain starting size (that is, zip ties, rubber bands, string, etc.) must remain attached to the *Robot* for the entire *Match*.

b. A *Robot* Initialization Routine in the Autonomous *Op Mode* that may pre-position the servo motors, with the *Robot* powered on, to the desired stationary position.

    i. If the *Robot* Initialization Routine moves the servos when a program is executed, there must be an indication label on the *Robot*. A warning label placed near the *Robot*'s main power switch is required. Attach the image ("WARNING! - *Robot* moves on Initialization") to your *Robot* near the *Robot* main power switch if servos are commanded to move during the initialization routine. To be easily seen by field personnel the label should be at least 1 in x 2.63 in (2.54 cm x 6.68 cm, Avery Label # 5160) and placed on a flat surface (not wrapped around corners or cylinders).:

**⚠ WARNING**

**Robot Moves on Initialization.**

**<RG03>** *Robot Controller* **Mount** – It is recommended the *Robot Controller* be accessible and visible by field personnel. If a *Team's Robot Controller* is not accessible or visible to field personnel, the *Team* may not receive adequate support from the field personnel.

The *Robot Controller* should be mounted so the display screen is protected from contact with the *Playing Field* elements and other *Robot*s. This and other electrical parts (for example, batteries, motor and servo controllers, switches, sensors, wires) make poor bumpers and are unlikely to survive *Robot*-to-*Robot* contact during game play.

**Important Note:** The *Robot Controller* contains a built-in wireless radio that communicates with the Android device in the *Driver Station*. The *Robot Controller* should not be obscured by metal or other material that could block or absorb the radio signals from the *Robot Controller*.

**<RG04> Maximum** *Robot* **Weight** – *Robots* must not weigh more than 42 pounds (19.05 kg) including battery. To account for variances between scales, there will be a .5 pound (.23kg) overage allowance on top of the 42 pound weight limit. This weight constraint includes one set of *Team* supplied *Alliance Marker* (either red or blue) and it does not include the *Team Scoring Element*. If a *Team* is using multiple mechanisms that will be swapped out between *Matches*, all parts and the *Robot* must be weighed together during weight inspection. The *Robot* and all mechanisms must not weigh more than 42 pounds.

**<RG05>** *Team* **Number Display** - *Robot*s must prominently display their *Team* number (numerals only, for example "12345") on two separate signs.

   a.  The judges, referees, and announcers must be able to easily identify *Robot*s by *Team* number.

   b.  *Team* number must be visible from at least **two** opposite sides of the *Robot* (180 degrees apart).

   c.  The numerals must each be at least 2.5 inches (6.35 cm) high, at least in 0.5 inches (1.27 cm) stroke width, and in a contrasting color from their background. Minimum size requirements can be met with Arial Font, Bold, 250 point.

   d.  *Team* numbers must be robust enough to withstand the rigors of *Match* play. Example robust materials include: 1) self-adhesive numbers (mailbox or vinyl numbers) mounted on polycarbonate sheet, wood panel, metal plate, etc. or 2) Ink jet or laser printed numbers on paper and laminated.

**<RG06>** *Alliance Marker* – *Robots* must include a *Team* supplied, *Alliance* specific marker on two opposite sides of the *Robot* to easily identify which *Alliance* a *Robot* is assigned to. The *Alliance Marker* must be displayed on the same side of the *Robot* as the *Team* number, within a 3" distance of the number. The *Alliance Marker* must be visible to the Referees during a *Match*.

   a.  The Red *Alliance Marker* must be a solid red square, approximately 2.5 inches x 2.5 inches (6.35 cm x 6.35 cm) +/- 0.25 inches (0.64 cm).

   b.  The Blue *Alliance Marker* must be a solid blue circle, approximately 2.5 inches (6.35 cm) +/- 0.25 inches (0.64 cm) in diameter.

c.  Both *Alliance Markers* must be removeable in order to swap them between *Matches*.

d.  The *Alliance Marker* must be robust enough to withstand the rigors of *Match* play. Example robust materials include: 1) *Alliance Marker* template printed and laminated; mounted on polycarbonate sheet, wood panel, metal plate, etc.

The intent of this rule is to allow easy identification of the *Robot* and their *Alliance* to field personnel. *Alliance* flags will no longer be provided by Tournament Directors. A template for Teams is located on our website.

**<RG07> Allowed Energy Sources** - Energy used by *FIRST* Tech Challenge *Robot*s (that is, stored at the start of a *Match*), shall come only from the following sources:

a.  Electrical energy drawn from approved batteries.

b.  A change in the position of the *Robot* center of gravity.

c.  Storage achieved by deformation of *Robot* parts. *Teams* must be careful when incorporating spring-like mechanisms or other items to store energy on their *Robot* by means of part or material deformation.

**<RG08> Launching *Robot* Parts** - Parts of the *Robot* itself may not be launched, even if the part launched is still connected to the *Robot* by a tether (for example, wire, rope, or cable).

**<RG09> Launching Game Scoring Elements** – *Robot*s can launch scoring elements through the air unless limited by a game specific rule. *Teams* must only launch the elements with enough velocity to score. Launching elements with excessive velocity could create a safety hazard for other *Teams* and field personnel. If the referees feel that a *Robot* is launching scoring elements with excessive velocity, the *Robot* must be re-inspected. *Robot*s must then show that a launched scoring element cannot travel in the air more than a 16 ft. (4.88 m) distance or more than 6 ft. (1.83 m) in elevation.

### 7.3.2 Robot Mechanical Parts and Materials Rules

**<RM01> Allowed Materials -** *Teams* may use raw and post-processed materials to build their *Robots*, provided they are readily available to the majority of *Teams* from standard distributors (for example, McMaster-Carr, Home Depot, Grainger, AndyMark, TETRIX/PITSCO, MATRIX/Modern Robotics, REV Robotics, etc.).

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Examples of allowed raw materials are:

- Sheet goods
- Extruded shapes
- Metals, plastics, wood, rubber, etc.
- Magnets

Examples of allowed post-processed materials are:

- Perforated sheet and diamond plate
- Injection molded parts
- 3D printed parts
- Cable, string, rope, filament, etc.
- Springs of all types: compression, extension, torsion, surgical tubing, etc.

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**<RM02> Commercial Off-The-Shelf Parts** - *Teams* may use Commercial Off-The-Shelf (COTS) mechanical parts that have a single degree of freedom. A single degree of freedom is a system whose motion is defined by

a single, independent, co-ordinate (or function)[1].

It is the intent of *FIRST* to encourage *Teams* to design their own mechanisms rather than buying pre-designed and pre-manufactured solutions to achieve the game challenge. Purchased mechanism kits (for example, grippers) that violate the single degree of freedom rule, either assembled or requiring assembly, are not allowed. COTS drive chassis (for example, AndyMark TileRunner, REV Robotics Build Kit) are allowed provided none of the individual parts violate any other rules.

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Examples of allowed single degree of freedom parts:

- Linear Slide
- Single Speed (non-shifting) gearboxes
- Pulley
- Lazy Susan
- Lead screws

Examples of illegal multiple degrees of freedom parts:

- Gripper assemblies or kits
- Ratcheting wrenches

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**<RM03> Holonomic Wheels** - Holonomic wheels (omni or mechanum) are allowed.

**<RM04> Modifying Materials and COTS Parts** - Allowed materials and legal COTS parts may be modified (drilled, cut, painted, etc.), as long as no other rules are violated.

**<RM05> Allowed Assembly Methods** - Welding, brazing, soldering, and fasteners of any type are legal methods for assembling a *Robot*.

**<RM06> Lubricant** - Any COTS lubricant is allowed, if it doesn't contaminate the *Playing Field*, scoring elements or other *Robot*s.

### 7.3.3 Robot Electrical Parts and Materials Rules

There are many possible ways to build and wire a *Robot*. These rules provide specific requirements on what is and is not allowed. *Teams* must ensure that electrical and electronic devices are used consistently with manufacturer's requirements and specifications. *Teams* are encouraged to review the *FIRST* Tech Challenge Robot Wiring Guide for suggestions on how to build a *Robot* with safe and reliable wiring.

**<RE01> Main Power Switch** - The *Robot* Main Power Switch must control all power provided by the *Robot* main battery pack. *FIRST* requires *Teams* to use either the TETRIX (part # W39129), MATRIX (part # 50-0030), or REV (REV-31-1387) power switch. This is the safest method for *Teams* and field personnel to shut down a *Robot*.

The *Robot* main power switch must be mounted or positioned to be readily accessible and visible to field personnel. A Main *Robot* Power label must be placed near the Main Power Switch of the *Robot*. Attach the image ("POWER BUTTON") to your *Robot* near the Main Power Switch. To be easily seen by field personnel the label should be at least 1 in x 2.63 in (2.54 cm x 6.68 cm, Avery Label # 5160) and placed on a flat surface

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[1] See https://www.scribd.com/document/357151975/STRC201-SDOF-JMWB-pdf Accessed on 7/10/2018

(not wrapped around corners or cylinders).



The *Robot* Main Power Switch should be mounted on the *Robot* so it is protected from *Robot*-to-*Robot* contact to avoid inadvertent actuation or damage.

**<RE02> Battery Mount** - Batteries must be securely attached (for example, VELCRO, zip tie, rubber band) to the *Robot* in a location where they will not make direct contact with other *Robot*s or the *Playing Field*.

**<RE03>** *Robot* **Main Battery** – All *Robot* power is provided by a single 12V *Robot* main battery.

The only allowed *Robot* main power battery packs are:

    a. TETRIX (W39057, formally 739023) 12V DC battery pack

    b. Modern Robotics/MATRIX (14-0014) 12V DC battery pack

    c. REV Robotics (REV-31-1302) 12V DC Slim Battery pack

Note: There are similar looking batteries available from multiple sources, but the ONLY legal batteries are those listed above.

**<RE04> Fuses** - must not be replaced with fuses of higher rating than originally installed or according to manufacturer's specifications; fuses may not be shorted out. Fuses must not exceed the rating of those closer to the battery. If necessary, a fuse may be replaced with a smaller rating. Replaceable fuses must be single use only; self-resetting fuses (breakers) are not allowed.

**<RE05>** *Robot* **Power** - *Robot* power is constrained by the following:

    a. Allowed electronic devices may only be powered by power ports on the *Core Power Distribution Module* or the *REV Expansion Hub* except as follows:

        i. The *Core Power Distribution Module* or *REV Expansion Hub* is powered by the *Robot* main battery.

        ii. *REV SPARK Mini Motor Controllers* are powered by the *Robot* main battery.

        iii. Allowed sensors connected to the *Core Device Interface Module* or the *REV Expansion Hub*.

        iv. Light sources per <RE12>.

        v. Video cameras per <RE13>.

    b. The *Robot Controller* Android device must be powered by its own internal battery or by the built-in charging feature of the *REV Expansion Hub*; external power is not allowed.

**<RE06> Android Devices** - The following Android devices are allowed:

a. ZTE Speed

b. Motorola Moto G 2nd Generation

c. Motorola Moto G 3rd Generation

d. Motorola Moto G4 Play

e. Motorola Moto G5

f. Motorola Moto G5 Plus

g. Motorola Moto E4 (USA versions only, includes SKUs XT1765, XT1765PP, XT1766, and XT1767)

h. Motorola Moto E5 (includes XT1920 and XT1925)

i. Google Nexus 5*

j. Samsung Galaxy S5*

> Starting in the 2020-2021 season, the ZTE Speed, Google Nexus 5, and Samsung S5 will no longer be allowed for use at any *FIRST* Tech Challenge Tournament.

i. No other devices may be used as *Robot Controllers* or in *Driver Stations.* See Rule <RS03> for the approved list of Android Operating System versions.

ii. Exactly one (1) Android device must be used as the *Robot Controller* and the USB interface may only connect to the *Core Power Distribution Module*, a *REV Expansion Hub*, or a USB hub.

*Does not support Wi-Fi Direct channel changing through the *Robot Controller* app. Having the ability to switch to a different channel during an event is important if there is any wireless interference or bandwidth issues on a specific channel.

**<RE07> Control Module Quantities** - *Robot* control module quantities are constrained as follows:

a. Exactly one (1) *Core Power Distribution Module* is required for *Teams* using any *Modern Robotics Core Control Modules*.

b. No more than two (2) *Core Device Interface Modules* are allowed.

c. Any quantity of *Core Motor, or Core Servo Controllers* are allowed.

d. Any quantity of *REV Servo Power Modules* is allowed.

e. No more than two (2) *REV Expansion Hubs* are allowed.

f. Any quantity of *REV SPARK Mini Motor Controllers* are allowed.

g. The REV Control Hub is not allowed.

h. The Core Legacy Module is not allowed.

**<RE08> Motor and Servo Controllers** - Motor and Servo Controllers are allowed in the following configuration: *Core Motor Controllers, Core Servo Controllers*, *REV Expansion Hub*, *REV Servo Power Module*, and *REV SPARK Mini Motor Controllers* in any combination.

**<RE09> DC Motors** – A maximum of eight (8) DC motors are allowed in any combination. The only allowed motors are:

  a.  TETRIX 12V DC Motor

  b.  AndyMark NeveRest series 12V DC Motors

  c.  Modern Robotics/MATRIX 12V DC Motors

  d.  REV Robotics HD Hex 12V DC Motor

  e.  REV Robotics Core Hex 12V DC Motor

No other DC motors are allowed.

**<RE10> Servos** – A maximum of twelve (12) servos are allowed. Any servo that is compatible with the attached servo controller is allowed. Servos may only be controlled and powered by an allowed Servo Controller, *REV Expansion Hub* or *REV Servo Power Module* (when used with an allowed Servo Controller or *REV Expansion Hub*). Servos may be rotary or linear but are limited to 6V or less and must have the three-wire servo connector.

> *Teams* should be prepared during *Robot* inspection to show documentation confirming that the servos individually and together on the same servo controller do not exceed the manufacturer specifications for the controller.

The VEX EDR 393 motor is considered a servo and it is subject to the maximum, an overall total of twelve (12) servos. *Core Servo Controllers* may control up to two (2) VEX EDR 393 Motors per module. A VEX Motor Controller 29 must be used between a servo module and each VEX EDR 393 motor. *REV Expansion Hubs* must use a *REV Servo Power Module* between the *REV Expansion Hub* and the VEX Motor Controller 29. A maximum of two (2) VEX EDR 393 Motors may be controlled/powered per *REV Servo Power Module*.

**<RE11> Sensors -** Sensors are subject to the following constraints:

  a.  Compatible sensors from any manufacturer may be connected to the *Core Device Interface Module* or *REV Expansion Hub*.

  b.  Compatible sensors from any manufacturer may be connected to the *Logic Level Converter and/or the I²C Sensor Adapter Cable.* Refer to Rule <RE14.k> for details on the use of *Logic Level Converter* and the *I²C Sensor Adapter Cable.*

  c.  Passive electronics may be used as recommended by sensor manufacturers at the interfaces to the sensors.

  d.  Voltage sensors are allowed; except on an output port of a motor or servo controller.

  e.  Current sensors are allowed; except on an output port of a motor or servo controller.

  f.  Simple I²C multiplexers are allowed and they may only be connected to and powered from the I²C connections available on the *Core Device Interface Module* or the *REV Expansion Hub*.

  g.  Voltage and/or current sensors are also allowed to connect between the battery pack and the *REV Expansion Hub* or *Core Power Distribution Module*.

**<RE12> Light Sources** - Functional and/or decorative light sources (including LEDs) are allowed with the

following constraints:

    a. Focused or directed light sources (for example: lasers and mirrors) are not allowed except for the REV Robotics 2m Distance sensor (REV-31-1505).

    b. Light-source control by compatible ports on the *REV Expansion Hub* and *Modern Robotics Core Control Modules* is allowed.

    c. Commercial Off the Shelf (COTS) interface modules (without user programmable microprocessors) are allowed between the light source and the components listed in <RE12>b.

    d. The only approved power sources for lights are as follows:

        i. Internal (as supplied by the Commercial Off the Shelf manufacturer) battery pack or battery holder.

        ii. Power ports on the *Core Power Distribution Module.*

        iii. Motor-control ports on the *Core Motor Controller Module.*

        iv. *REV Expansion Hub* Motor-control ports, spare XT30 ports, 5V auxiliary power ports, and I2C sensor ports.

**<RE13> Video Cameras**
    a. Self-contained video recording devices (GoPro or similar) are allowed providing they are used only for non-functional post- *Match* viewing and the wireless capability is turned off. Approved self-contained video cameras must be powered by an internal battery (as supplied by the manufacturer).

    b. *UVC Compatible Cameras* are allowed for computer vision-related tasks. It is recommended that *UVC Compatible Cameras* be connected to the *Robot Controller* through a powered USB hub that is in turn connected to the *Robot Controller* through an OTG adapter.

**<RE14> *Robot* Wiring** - *Robot* wiring is constrained as follows:

    a. USB Surge Protectors connected to USB cables are allowed.

    b. Ferrite chokes (beads) on wires and cables are allowed.

    c. A *Mini USB to OTG (On-The-Go) Micro Cable or any combination of* a *Mini USB cable, a USB hub,* and an *OTG Micro Adapter may be* used to connect the *Robot Controller* Android device to the *Robot* electronics. Note that the *OTG Micro Adapter* may be integrated into the USB hub. These devices may connect to the *Robot* electronics in the following ways:

        i. Built-in USB input port of the *Core Power Distribution Module, or*

        ii. Built-in USB input port of the *REV Expansion Hub, or*

        iii. A USB hub that connects to the built-in USB input port of the *REV Expansion Hub.* If a powered hub is used, it must draw its energy from either

            i. A commercial USB battery pack, or

            ii. A 5V auxiliary power port on a *REV Expansion Hub.*

    d. Non-powered USB hubs connected to the *Core Power Distribution Module* are allowed.

e.  Anderson Powerpole, and similar crimp or quick-connect style connectors are required to connect downstream electronics with the *Core Power Distribution Module* and are recommended for joining electrical wires throughout the *Robot*. Power distribution splitters are recommended where appropriate to reduce wiring congestion. All connectors and distribution splitters should be appropriately insulated.

f.  Installed connectors (such as battery-pack connectors, battery charger connectors, and *Core Power Distribution Module* power input connectors) may be replaced with Anderson Powerpole or any compatible connector.

g.  Power and motor control wires must use consistent color-coding with different colors used for the positive (red, white, brown, or black with a stripe) and negative/common (black or blue) wires.

h.  Wire and cable management products of any type are permitted (for example, cable ties, cord clips, sleeving, etc.).

i.  Wire insulation materials of any type are permitted when used to insulate electrical wires or secure motor control wires to motors (for example, electrical tape, heat shrink, etc.).

j.  Power, motor control, servo, encoder, and sensor wires and their connectors may be extended, modified, custom made, or COTS subject to the following constraints:

　　i.  Power wires are 18 AWG or larger.

　　ii.  Motor control wires as follows:

　　　　ii 22 AWG or larger for TETRIX Max 12V DC motors and REV Robotics Core Hex (REV-41-1300) 12V DC motors

　　　　ii 18 AWG or larger for all other 12V DC motors

　　iii.  PWM (servo) wires are 20 AWG or 22 AWG.

　　iv.  Sensor wires should be the same size or larger than the original wiring.

> *Teams* should be prepared during *Robot* inspection to show documentation confirming the wire gauges used; particularly for multi-conductor cables.

k.  *Logic Level Converters – Logic Level Converters* that are used to connect a *REV Expansion Hub* to a 5V-compatible $I^2C$ sensor or a 5V-compatible digital sensor are allowed. Exactly one *Logic Level Converter* per $I^2C$ device and one *Logic Level Converter* per digital sensor are allowed. A *Logic Level Converter* should only draw power from the *REV Expansion Hub*.

l.  Electrically grounding the Control System electronics to the frame of the *Robot* is only permitted using a *FIRST*-approved, commercially manufactured Resistive Grounding Strap. The only Resistive Grounding Strap approved for use is the REV Robotics Resistive Grounding Strap (REV-31-1269). *Teams* that have electronics with Powerpole-style connectors may also use the REV Robotics Anderson Powerpole to XT30 Adapter (REV-31-1385) in conjunction with the REV Robotics Resistive Grounding Strap. No other grounding straps or adapters are permitted. For additional details on installation of the grounding strap or adapter, please see the Robot Wiring Guide.

**<RE15> Modifying Electronics** - Approved electrical and electronic devices may be modified to make them more usable; they may not be modified internally or in any way that affects their safety.

Examples of modifications that are allowed:

- Shortening or extending wires
- Replacing or adding connectors on wires
- Shortening motor shafts
- Replacing gearboxes and/or changing gears

Examples of modifications that are **not** allowed:

- Replacing an H-Bridge in a motor controller
- Rewinding a motor
- Replacing a fuse with a higher value than specified by the manufacturer
- Shorting out a fuse

**<RE16>** *Driver Station* **Constraints** – *Teams* provide their own *Driver Station* and it must comply with the following constraints:

a. The *Driver's Station* must consist only of:

    i. One (1) Android device

    ii. One (1) OTG Cable

    iii. No more than one (1) USB hub

    iv. No more than one (1) COTS USB external battery

    v. No more than two (2) gamepads

    vi. Any components used to hold the above listed legal devices.

b. The *Driver Station* Android device USB interface may only connect to either:

    i. A Mini *USB to OTG* (On-The-Go) cable or combination of cables connected to a USB Hub, or

    ii. One (1) gamepad and an *OTG Micro Adapter*.

c. One optional COTS USB external battery connected to the USB Hub to charge the Android device is allowed.

d. The only allowed gamepads are listed below. They may be used in any combination.

    i. Logitech F310 gamepad (Part# 940-00010)

    ii. Xbox 360 Controller for Windows (Part# 52A-00004)

e. The touch display screen of the *Driver Station* must be accessible and visible by field personnel.

**Important Note:** The *Driver Station* is a wireless device with a built-in wireless radio. During a *Match*, the *Driver Station* should not be obscured by metal or other material that could block or absorb the radio signals from the *Driver Station*.

**<RE17> Additional Electronics** – Electronic devices that are not specifically addressed in the preceding rules

are not allowed. A partial list of electronics that are not allowed includes: Arduino boards, Raspberry Pi, relays, and custom circuits.

### 7.3.4 Robot Software Rules

**<RS01> Android Device Names** - Each *Team* MUST "name" their *Robot Controller* with their official *FIRST* Tech Challenge *Team* number and –RC (for example, "12345-RC"). Each *Team* MUST "name" their *Driver Station* with their official *Team* number and –DS (for example, 12345-DS). Teams with more than one Driver Station or Robot Controller Android device must name these devices with the Team number followed by a hyphen then a letter designation beginning with "A" (for example, "12345-A-RC", "12345-B-RC").

**<RS02> Recommended Programming Language** - *Java* and the Blocks Development Tool are the recommended programming languages for the *FIRST* Tech Challenge. The minimum allowed app version number is 5.2. Programming must be done using one of the following applications:

a. FTC Blocks Development tool – a visual, blocks-based programming tool hosted by the *Robot Controller*.

b. Android Studio – a text-based integrated development environment.

c. Java Native Interface (JNI) & Android Native Development Kit (NDK) – *Teams* can incorporate native code libraries into their apps using the JNI framework and the Android NDK.

d. FTC OnBot Java Programming tool – a text-based integrated development environment hosted by the *Robot Controller*.

If mandatory updates are announced by *FIRST* later in the season, *Teams* must install them before the time of competition. Additionally, beta versions of the software are allowed at official tournaments.

**<RS03> Allowed Android Operating Systems** - The only allowed operating systems for the *Robot Controller* and *Driver Station* Android devices are:

a. ZTE Speed: 4.4 or higher (Kit Kat)

b. Motorola Moto E4, Motorola Moto E5, Motorola Moto G4 Play, Motorola Moto G5, Motorola Moto G5 Plus,: 7.0 or higher (Nougat)

c. Motorola Moto G 2nd Generation, Motorola Moto G 3rd Generation, Google Nexus 5, Samsung Galaxy S5: 6.0 or higher (Marshmallow)

> **IMPORTANT:** Rules <RS02> or <RS03> do not require that *Teams* upgrade to the latest version of the software. A mandatory upgrade would only be required if *FIRST* determined there was a critical software fix that must be adopted by *Teams*. Mandatory upgrades will be communicated in the following ways:
>
> - Via *Team* Blast – The mandatory upgrade and version number will be communicated to *Teams* on the *Team* Blast, which will also show the date the required upgrade must be made.
> - Online – the minimally required software will be listed on our Technology Resources page, with the date *Teams* are required to make the mandatory software upgrade.
> - Forum – The minimally required software will be listed in the Technology Forum page, with the date *Teams* are required to make the mandatory software upgrade.
>
> Templates for all programming choices are available through the links located at http://www.firstinspires.org/node/5181.

**<RS04> Autonomous to Driver-Controlled Transition** - *Teams* that expect to operate their *Robot* during the Autonomous period must demonstrate during Field Inspection the *Driver Station* switches the *Robot Controller* between Autonomous mode and Driver-Controlled mode.

**<RS05> *Robot Controller* App -** The *Robot Controller* must have a designated "FTC *Robot Controller*" app that is the default application for the *Core Robot modules (Servo, Motor, and Device Interface)* or the *REV Expansion Hub.* The *Robot Controller* App must not be installed on the *Driver Station Android Device*.

**<RS06> *Driver Station* App –** *Teams* must install the official "FTC *Driver Station*" app onto their *Driver Station* Android Device and use this app to control their *Robot* during a *Match*. The *Driver Station* software version number must match the version number of the *Robot Controller* app. The *Driver Station* App must not be installed on the *Robot Controller Android Device*.

**<RS07> Android Device Operating System Settings** - The *Robot Controller* and *Driver Station* must be set to:

   a) Airplane mode must be turned on

   b) Bluetooth must be turned off

   c) Wi-Fi must be turned on.

**<RS08> Wi-Fi Direct Channel Changing App -** The *Robot* Controller must have the *FIRST* Tech Challenge "Wi-Fi Direct Channel Changing" App installed (ZTE Speed ONLY).

**<RS09> Software Modification -** *Teams* are not allowed to modify the *FIRST* Tech Challenge *Driver Station* App in any fashion. When using the *Robot Controller* SDK, *Teams* are not allowed to replace or modify the portions of the SDK which are distributed as binary .AAR files.

**<RS10> *Driver Station* Communication** - Communication between the *Robot* and *Driver Station* is only allowed via the *Robot Controller* and *Driver Station* applications.

Communication between the *Robot Controller* and the *Driver Station* is limited to the unmodified mechanisms provided by the official *FIRST* Tech Challenge (FTC) software, which consists of the official FTC Software Development Kit (SDK), the FTC *Robot Controller* app, and the FTC *Driver Station* app. *Teams* are not permitted to stream audio, video or other data using third-party software or modified versions of the FTC software. *Teams* may only use the unmodified telemetry feature included with the FTC software to transfer additional data between the *Robot Controller* and the *Driver Station*. Software that is preinstalled by an approved phone's manufacturer and cannot be disabled is exempt from this constraint.

During a *Match*, a *Team's Robot Controller* and a *Team's Driver Station* are not allowed to be connected wirelessly to any other device besides each other.

### 7.4 Team Scoring Element
The *Team Scoring Element* is an object that *Teams* create and bring to a competition to be used in the current season's game. The *Team Scoring Element* must pass *Inspection* before it can be used in a *Match*.

For the 2019-2020 SKYSTONE℠ game, the *Team Scoring Element* is called the *Capstone*.

**<TE01> Material Constraints** - The *Team Scoring Element* is subject to the *Robot* Mechanical Parts and Materials Rules in section 7.3.2.

**<TE02> Size Constraints** - The maximum size of the *Team Scoring Element* is 4 inches (10.16 cm) by 4 inches (10.16 cm) by 8 inches (20.32 cm). The minimum size of the *TSE* is 3 inches (7.62 cm) by 3 inches (7.62 cm) by 4 inches (10.16cm).

**<TE03> *Team* Number** - The *Team Scoring Element* must be labeled with their *Team* number (numerals only, for example "12345") The letters must be legible when viewed from 12 inches away. The *Team* number needs to appear only once on the *Team Scoring Element*.

**<TE04> Illegal Parts** - The following types of mechanisms and parts are not allowed:

      a.  Electronics.

      b.  Any other part or material that violates *Robot* construction rules outlined in section 7.3.

**<TE05>** Current season's *Scoring Elements* may not be used as the *Team Scoring Element*.