

FIRST[®] ROBOTICS COMPETITION

Tool & Fabrication Expectations

Introduction

This guide is intended for teams that are new to *FIRST* Robotics Competition (0-2 years old). This often means your team only has a few mentors who may have limited experience with tools and manufacturing. The recommendations in this guide provide a solid foundation for building fabrication capabilities for your team.

While there is no set of minimum requirements for tools or capabilities to be able to participate in *FIRST* Robotics Competition, it is important to recognize that the robot-building process is technically complex and will be very difficult without the proper tools.

FIRST will use this guide as a baseline assumption for the capabilities that all teams possess. This is particularly important for teams building designs provided by *FIRST*, such as KitBot or Team Test Elements (wood versions of game-specific field elements). *FIRST* may provide more advanced designs that require additional capabilities, but those will be accompanied by a note to make the distinction clear.

The recommendations in this guide are inspired by work done by *FIRST* Robotics Competition Team 3847, Spectrum. We would like to thank them for their contributions.

Tool Sources

Common sources to purchase tools:

- **Harbor Freight**: A dedicated tool store offering very affordable tools. If there is one in your area this is one of the most inexpensive places to purchase tools.
- **Home Improvement Stores**: Lowes, Home Depot, Ace Hardware, etc. Compare prices and check for sales. Black Friday weekend sales are often a great opportunity to purchase tools at these stores at lower prices.
- **Amazon**: You can purchase many tools from Amazon. Be sure to read some of the reviews as you aren't always sure how the quality of the tools compares to other brands or stores.
- **Walmart**: They offer a range of tools that can be useful for robot building.
- **AndyMark.com**: AndyMark is a common *FIRST* supplier, and they also sell tools; it may be convenient to purchase tools from them when ordering other items or with some restricted grant funds.

Tool Suggestions

The following list of tools is the easiest way to get your team started. For many of these tools, particularly the most expensive power tools, your team may not need to own the tool outright and can save money by borrowing tools from supporters or members of your team. The price ranges are only provided for convenience and will vary significantly between sources and overtime.

Assembly Tools

Tool	Price Range	Notes
Screwdriver Set	\$1-\$20	Get a set with a wide range of phillips and slotted screwdrivers. These are mostly useful around the shop rather than on specific robot components.
Precision Screwdriver Set	\$1-\$20	Used for very small screws, usually on electronic devices.
Combination Wrench Set	\$21-\$50	Imperial and metric. Most important sizes are 3/8in, 7/16in, and 1/2in. Various styles and options available including ratcheting types.
Socket Set	\$21-\$50	Many low-cost options available. Used for the same applications as the combination wrenches. Sockets are also very useful as spacers for when assembling or disassembling press-fit components.
Hex Key Set	\$1-\$20	Need both imperial and metric. Typical hex key or "allen" wrenches for turning hex drive socket screws (may also be called hex L keys). Some come with a ball end that is useful in tight spaces but more likely to strip out screws. You can't have too many of these, buy multiple sets if you can.
Adjustable Wrench Set	\$1-\$20	Important for turning odd-sized fittings or parts. Having 2-3 different sizes is often useful but 1 will do if needed.
Screwdriver Bit Set	\$1-\$20	Screwdriver bit set for a cordless drill. Most important is to have bits that can drive wood screws. Torx are the best option but Phillips is also common. Most sets also have bits that work with other common fasteners or a few common drill bits.

Tool	Price Range	Notes
Hook & Pick Set	\$1-\$20	Typically used for installing or removing o-rings, these are useful in tight places. Can be used as metal scribes if needed.
Mallet/Dead Blow Hammer	\$1-\$20	Important for hammering parts that are easily damaged.
Hammer	\$1-\$20	A metal hammer such as used for driving nails or a "ball peen" hammer. Shouldn't need it often, but there will always be times when you do.
Rivet Gun	\$21-\$50	Manual rivet guns are cheap and widely available, however the number of rivets on a typical robot can quickly overwhelm the capabilities of a manual rivet gun. The Milwaukee M12 Rivet Tool is a highly recommended option by many teams if you are able to make the investment.
Staple gun	\$21-\$50	A variety of options are available, including manual, corded, pneumatic, and cordless. You'll mostly use this for attaching bumper fabric to the backer (plywood)
Hot Glue Gun	\$1-\$20	Used for securing electrical connections and can also be used for certain robot assemblies.
#25 Chain Break	\$21-\$50	Most major robot part suppliers carry a chain breaker tool. Some chain tools are only capable of breaking the chain and not reattaching it (called "riveting", not to be confused with the rivet tool mentioned above). Make sure the tool you select has both capabilities.

Measuring & Marking

Tool	Price Range	Notes
Tape Measure	\$1-\$20	Most tape measures will do. Tape measures with both imperial and metric markings are practical. 30ft tape measures are ideal for measuring out portions of the field.
Fabric Tape Measure	\$1-\$20	Flexible tape measure for sewing. Used for measuring your robot's perimeter and ensuring you meet the rules.

Tool	Price Range	Notes
Digital Calipers	\$1-\$20	A good pair is much more expensive, but a cheaper set will suffice for most purposes.
Combination Square	\$1-\$20	Used for measuring and layout tasks. Most include a scribe for marking metal.
Adjustable Protractor	\$1-\$20	Used for measuring/setting angles. "Adjustable" is critical, a typical fixed classroom protractor will not work for many tasks. Digital and analog versions are available. Some combination squares have an adjustable protractor head.
Metal Scribe	\$1-\$20	Scribes lines on metal. Most combination squares include a small scribe that is sufficient so purchasing a dedicated tool may not be needed.
Automatic Center Punch	\$1-\$20	Quickly and easily mark a hole to drill so the bit won't walk.
Ball Point Pens	\$1-\$20	For marking, labelling, and general notetaking.
Pencils	\$1-\$20	For marking, labelling, and general notetaking. Pencils are good at making precise marks on wood.
Sharpies	\$1-\$20	Black at a minimum. Having a variety of colors is helpful for labelling. Metallic Silver sharpies are very helpful for marking black-colored parts like hex shaft stock.
Digital Scale	\$51-\$100	Used to weigh your robot, bumpers, components, etc. This ensures you don't show up to your event over the weight limit. Get a scale that can support up to 150lbs. Bathroom scales can work in a pinch but a more professional scale for shipping is recommended for accuracy.

Workholding

Tool	Price Range	Notes
Bench Vise	\$51-\$100	Clamps parts for cutting, drilling, tapping, etc. Can also be used as a press for bearing, etc, when needed. Ideally avoid clamp-on styles and find one you can bolt to a work bench.

Tool	Price Range	Notes
Bar Clamps	\$1-\$20	Used for securing material to cut or drill. Usually having 2-4 or a variety of sizes on hand is helpful.
Locking Pliers	\$1-\$20	Countless uses as regular pliers or clamps. They can also be used as a wrench if you don't have the right size or a tap handle, etc
Pliers Set	\$1-\$20	All the uses of pliers, gripping, holding, grabbing, etc. Depending on what you get, this set may include other tools on this list.
Precision Pliers Set	\$1-\$20	Usually comes in a set of 6 and includes variations of needle nose pliers and snips that are useful in tight places.

Cutting & Drilling

Tool	Price Range	Notes
Circular/Track Saw	>\$100	Used for making straight cuts in large wood or plastic sheets. Can also cut aluminum sheets with the right metal-cutting blade.
Cordless Drill	\$51-\$100	A typical battery-powered drill. Should have a 1/2in capacity chuck. The biggest consideration with this tool is what brand to buy into for the purposes of standardizing batteries. Once you have a small number of cordless tools that use the same batteries, it's often advantageous to keep future tool purchases within the same battery system to avoid multiple
Jigsaw	\$21-\$50	A jigsaw is great for cutting sheet material such as wood, plastic and aluminum. Allows you to make interior cutouts for field elements or complex shapes that are harder to produce with the track saw and bandsaw.
Drill Bit Set	>\$100	Used for drilling holes of precise sizes. Recommend investing in a large (typically 115pc) set known as a "drill index". Cheap drill bit sets are typically only meant for wood

Tool	Price Range	Notes
		and will wear out very quickly or break when used in metal. Cheap sets also don't usually include the most common drill sizes that you will use on your robots.
Step Drill Bit Set	\$1-\$20	Used for drilling various-sized holes in thin material.
Countersink Bits	\$1-\$20	Used for making countersinking holes to allow flathead bolts to fit flat. There are 2 common angles: Imperial flat head screws are usually 82° and metric are typically 90°.
Tap & Die Set	\$21-\$50	For cutting threads in metal or cleaning up damaged threads. Most cheap sets are only really meant for cleaning up threads but will typically work fine on aluminum. Buying an expensive tap and die set usually isn't worth it, but your team may want to consider buying higher quality taps in the 1-2 sizes that you use most often.
External Deburring Bit	\$1-\$20	Used to chamfer the ends of shafts so they more easily go into bearings. Works with 1/2" and 3/8" hex shafts.
Aviation Snips	\$1-\$20	Used for cutting thin plastic and metal. Also called "tin snips".
Flush Cutters	\$1-\$20	Useful for wiring and cutting cable ties. Recommend keeping a lot of these on hand, they typically come in a pack of multiple.
Swivel Deburring Tool	\$1-\$20	Used for cleaning up drilled or cut parts and removing sharp edges.
1in Belt Sander	\$51-\$100	Used for smoothing edges or cutting tubes, shafts, and other materials. You can also make things a more precise length if you cut parts to a longer length and sand them down to size.
Metal File Set	\$1-\$20	For cleaning up edges after a cut or removing small amounts of material. Typically comes in a set with flat as well as other profiles of files.
Precision File Set	\$1-\$20	A set of very small files good for small parts or internal geometry.
Hacksaw	\$1-\$20	Most of the cutting should be done with one of the power tools but having a hack saw on hand is still useful.

Tool	Price Range	Notes
EMT Shears	\$1-\$20	Great work scissors for cutting fabrics and thin material.
Scissors	\$1-\$20	Any cheap pair that can cut paper.
Utility Knife/Box Cutter	\$1-\$20	General purpose cutting. You can pick these up nearly anywhere, and they can be used for stripping large-gauge wire (6 AWG/4 AWG) if needed.
Screw Extractor Set	\$1-\$20	Used for removing screws with stripped or broken heads. Many sets come with drill bits, but these are usually not suitable for the very high strength screws used on robots. Buying high quality cobalt steel drill bits to go along with the extractors is advised.

Electrical Tools

Tool	Price Range	Notes
Wire Stripper/Cutter	\$1-\$20	Used for cutting and stripping small (non-battery) wires.
Hydraulic Wire Crimper	\$51-\$100	For crimping large-gauge wire lugs for battery and robot power supply cables. There are hydraulic and non-hydraulic variations of this tool (both are still hand-operated) but the hydraulic versions yield significantly better results.
Battery Beak	\$51-\$100	Used for checking your robot batteries, this measures internal resistance, which is a better measure of battery health than just voltage.
Heat Gun	\$21-\$50	Used for various purposes, such as heat shrink tubing or removing Loctite-secured hardware. Many different brands, corded or cordless works for this.
Multimeter	\$1-\$20	Most multimeters will be good enough for new teams. You can check battery voltage if you don't have your battery beak. You can check continuity on wires, etc.

Miscellaneous Tools

Tool	Price Range	Notes
3D Printer	>\$100	A high-quality 3D printer (such as a Bambu Labs A1) can produce a wide range of parts for <i>FIRST</i> Robotics Competition robots. Use PLA+, PETG, or some engineering filaments (PA, etc.). A 3D printer is one of the most affordable and user-friendly CNC machines, making it an excellent way to start creating custom parts for your team. A hardened nozzle, available for \$10, will enable you to print carbon fiber-filled materials, such as NylonCF and PETG-CF.
Wet/Dry Shop Vacuum	\$21-\$50	Used for general purpose shop cleaning as well as vacuuming out tight spaces in the robot to avoid debris ending up in electronics or moving parts.

There is overlap in the uses for some of these tools and a lot of flexibility in specific tool choices. If you have some tool expertise and would like to make different selections for your team, just ensure that your tools provide the same range of capabilities as the tools listed above.

Tools to Have Spares Of

FIRST Robotics Competition teams usually have a number of team members working in parallel on different tasks. Having multiple sets of tools is always beneficial for this, but there are a few tools that are particularly important to have spares or multiple sets of:

- Hex key sizes: 1/8in, 5/32in, 3/16in.
- Combination wrench sizes: 3/8in, 7/16in, 1/2in.
- Flat metal files.
- Tap sizes: #10-32, 1/4-20
- Drill bit sizes: #21, 3/16in, #9, #7, H

Safety Equipment

Have enough PPE (personal protective equipment) on hand for all team members as well as enough spares to handle lost or damaged items. The appropriate PPE depends on the

work being done, the tools being used, and materials being worked with. Here are some common items that all teams should have on hand:

- **Safety glasses/goggles**: It's important to have safety glasses that fit over eyeglasses available, in addition to standard safety glasses.
- **Cut-resistant gloves**: Take care to understand the circumstances where gloves are appropriate to use and educate your team: There are many situations where gloves create an entanglement risk (e.g. around power tools) and should not be used.
- **Nitrile gloves**: Used for working with chemicals or just messy materials. Nitrile is a suitable material for many applications but be sure to check a chemical compatibility chart in case another type of glove is needed.
- **Hearing protection**: Can be disposable in-ear plugs or ear muffs.

Storage & Organization

Good organization and storage are nearly as important as the tools you own. After all, a tool or robot part that is hard to find when you need it isn't very helpful. There are two areas to consider when planning your team's storage & organization:

1. **Shop space**: Permanent or semi-permanent space where you build your robots. Depending on the space available, your shop may not need to be particularly compact or portable. This allows you to prioritize other things when organizing.
2. **Travel/pit space**: This is the set of items that travels to and from events and gets set up in your teams' pit space at the event. When planning for travel, consider the following:
 - At most, you will have a 10ft x 10ft space to set up, and many events have less space than that.
 - How are the items being transported (truck, trailer, bus, van, etc.)? How much space is available and how will items be loaded and unloaded?
 - Some events have restrictions on the number of team members that are allowed to load in before the event. This may affect the size or weight of items that you are able to move during load-in.
 - How will your travel methods change if your team qualifies for a District Championship or Championship?

Portable stacking toolboxes are very convenient for taking your tools to events. Harbor Freight's "US General" brand of toolboxes are robust yet inexpensive compared to other quality brands.

Having storage solutions for both tools and robot parts is ideal. Portable "small parts cases" are a popular choice for organizing small robot parts. These cases are good for

travelling to competitions, but their portability is also often useful in a shop environment as well.

Working surfaces are also very important. At minimum, find a workbench that you can bolt your bench vise to. Having a robust table or workbench with enough space to set a fully assembled robot on and work on multiple sides is ideal.

Additional Tool Suggestions

Once your team is established, making continual additions to your tool collection is a good way to improve your performance as a team and expand your knowledge base. Many teams explore different styles or brands of tools to replace the basic tools they start out with. This allows them to build a collection that suits their needs and preferences.

The following list is a few suggestions of further expansions that your team may want to consider investing in. These options are in no particular order and include a range from low-cost additions to the basic tool list to high end equipment that will help you take your robots to the next level with proper planning and investment.

Tool	Price Range	Notes
Battery Rivet Tool	\$250-\$300	If you started out with a manual rivet tool, upgrading to a battery-powered version is a big quality of life improvement. A large number of teams use the Milwaukee M12 Rivet Tool with good results. Many alternative options are unreliable and not worth spending money on.
Soldering Iron	\$21-\$50	Used for making electrical connections to circuit boards or splices with small wires. Either buy a complete kit or make sure to purchase all of the needed accessories. Getting a good solder connection often relies more on the workholding, cleanliness of the joint, flux, type of solder, etc. than the soldering iron itself.
Drivers for Cordless Drills	\$20-\$50	Adding high quality power-tool nut drivers and hex drivers in the most common sizes for robot building can speed up the assembly process considerably. It is easy to over-tighten screws using these tools, so these are best left to team members who have had some training and practice.

Tool	Price Range	Notes
Arbor Press	\$60-\$400	This is the proper way to press in bearings, pinions, and many other robot tasks. You may not know what else you will use this for until you get one. We recommend the 1-ton version at a minimum, but a 3-ton arbor press can be paired with a 1/2in hex broach to add hex bores to custom parts.
1/2in Hex Broach	~\$250	When paired with a 3-ton arbor press, this tool turns a 1/2in round hole into a 1/2in hexagonal hole which is a common standard for rotating shafts on robots.
Carpet Vacuum	\$50-\$200	Practice areas get dirty quickly when driving a robot around. Cleaning these areas with a wet/dry shop vacuum is slow and not very ergonomic. Use a vacuum meant for normal floor cleaning. Using a cheap vacuum is advised because the debris from robots tend to wear these out faster than normal and the investment into an expensive vacuum is not worth it.
Clecos & Cleco Pliers	\$20-\$50	These are fixturing tools that act like temporary rivets to hold structural robot parts in place before riveting or bolting. Once you use them you won't want to go without them again. You will need "Cleco Pliers" along with a bunch of Clecos of the appropriate size for the holes on your robot (3/16in is the most common size and works for 3/16in rivets and #10 screws).
Table Saw	\$400-\$1.5k	Mostly used for cutting down larger sheets of plywood or plastic. Sometimes useful for ripping lumber. Mostly useful when building wood versions of field elements.
Oscillating Multi-Tool	\$50-\$100	Very versatile tool for cutting wood, plastic, or metal. Good in tight spaces and with straight or curved cuts. This tool can replace a jigsaw and rotary (dremel-style) tool.

Tool	Price Range	Notes
Metal Lathe & Tooling	\$1k-\$5k	Create cylindrical parts, such as spacers and shafts. Cut snap ring grooves. Drill center holes in round stock and many other tasks. A mini lathe (7in) is often a good way to get started, while a 10in lathe is enough for most <i>FIRST</i> Robotics Competition tasks. A DRO (Digital Read-Out) will increase the ease of use of a lathe. Some commonly recommended brands include Precision Matthews, Grizzly, and Harbor Freight.
CNC Router	\$3k-\$20k	A CNC router is one of the most useful tools a <i>FIRST</i> Robotics Competition team can acquire. It allows you to cut parts from flat materials such as aluminum, polycarbonate, and wood. Commonly recommended options include: Omio X8 (\$3k-\$4k) and ShopSabre (\$10k-\$20k). A smaller machine is usually suitable for robot parts, however a larger machine may be able to cut parts out of a raw sheet without cutting the material down. Additionally, a larger machine can cut larger parts for wood versions of field elements.
Laser Cutter	\$6k-\$10k	A laser cutter is great for cutting wood and plastic. They cut parts very fast and require very little training to use. An 80-watt to 130-watt CO2 laser is the ideal range for cutting robot parts. Thunder Laser is a common brand used by <i>FIRST</i> Robotics Competition teams.
Manual or CNC Mill	>\$3k	Used for creating precision parts, usually out of metal. Manual mills are useful for creating a few oddly shaped precise parts and are relatively affordable. CNC mills are capable of producing high precision parts with a high throughput but are typically very expensive. These machines take a lot of expertise to use and usually need someone with prior training or experience operating them to be useful to a team.

Tool	Price Range	Notes
Sheet Metal Brake	\$500-\$10k	A sheet metal brake is used for bending flat material such as aluminum or polycarbonate. There are many styles of brakes that have different strengths and use cases. "Box brakes" are very common and inexpensive, however aren't well suited for bending robot parts. Very skilled operators can achieve precise bends with them, but that isn't achievable for the vast majority of teams. "Press brakes" are much better suited for bending robot parts but are quite a bit more expensive and hard to find. There are a range of options for press brakes from simple jigs that fit into bench vises to CNC-controlled production-quality machines. The "Titan 25T" from Langmuir Systems is a small CNC press brake that is new to the market that a few teams have begun exploring.