

Building a Basic Crate 2.0

A Guide for FRC Teams



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1.1 Purpose of This Document



F.I.R.S.T. Robotics Competition teams need to ship their robot to and from competition. Strict rules surrounding shipping and complications such as reusability, assembly and weight provide a challenge to each team. However, this is a challenge that each team faces equally and, unlike the game, is nearly unchanging from year to year.

Special thanks to Richard Graft who originally designed this crate as a donation to Team 1020. However, he, Team 246, Boston University and Boston University Academy are not responsible for those using this design or any loss/damage incurred as a result of the use of the crate designed within. This design is offered in the spirit of Gracious Professionalism to aid teams, especially rookies, in building an inexpensive, easy to maintain and tool-less crate (once constructed). Support may be provided to those using this guide, but is of course not guaranteed.

That said, if you have suggestions to improve this guide, please write us at bufirst@bu.edu. Thanks, and enjoy!

2.1 Materials Needed:

	Quantity	Item
	4	3/8" Standard Plywood Sheet (4' x 8')
	1	1/2" Standard Plywood Sheet (4' x 8')
	1	4"x4"x8' Standard Lumber
	6	2"x2"x12' Standard Lumber
	~50	1/4" 20 ("Quarter Twenty") Carriage Bolts at 4" length

	~50	1/4" 20 Wing Nuts
	2	Pound box of standard deck screws (1 1/4" length)
	1	Pound box of standard deck screws (2 1/2" length)
	1	Roll of Clear Stretch Wrap (Stretch Film)

Notes about materials:

- Wing nuts are necessary to make crating/uncrating tool-less; use standard hex nuts if you intend to use power-tools instead.
- Deck screws can be of a slightly different length, but not much since they would protrude through or split the lumber.
- The thickness of the plywood is negotiable except that **if you build using all 1/2" plywood, your crate will likely be overweight.** This will usually cost you more than \$100 each time you go to a competition. This is a drayage cost, not shipping, so you cannot get around it with the free FedEx shipping.

- You will also need packaging materials to prop up, pad and strap down the robot within the crate. This is not covered by this crate design, though there is plenty of space left within the inner dimensions for packaging. We recommend using stiff foam (not Styrofoam) and cutting it to fit the corners of your robot.

2.2 Tools Needed

Table Saw/Jig Saw/Circular Saw (only one of the three)

Power Drill

1/4" Drill Bit

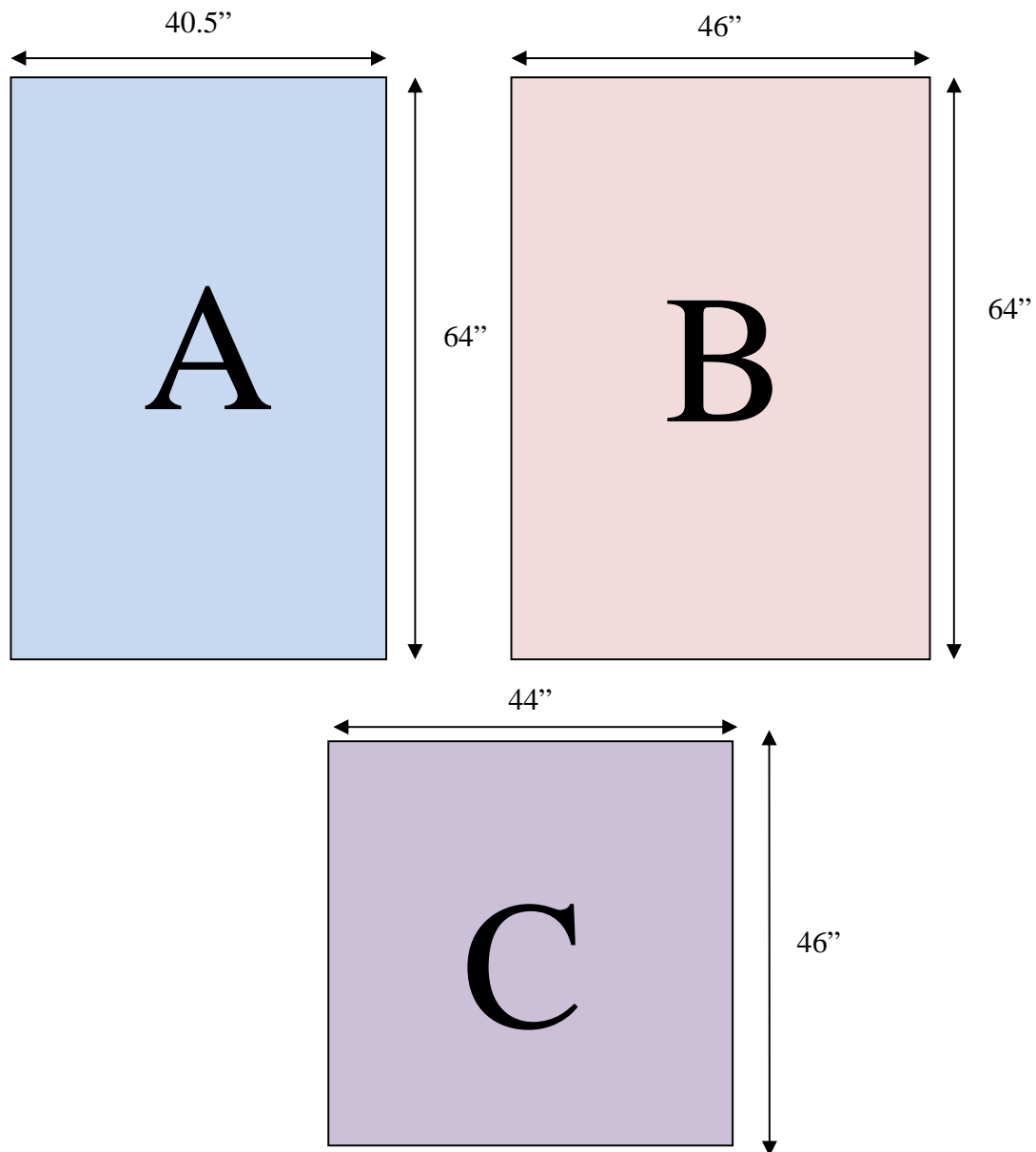
Phillips Screw Driver Bit

Hammer/Mallet

3.1 Plywood Pieces

Both piece A (called the Narrow Side) and B (called the Wide Side) are made from $\frac{3}{8}$ " plywood. Piece C (called the Base and Top) is made from $\frac{1}{2}$ " plywood. **You need to make two of each of these three pieces.** It's not important that they are flat, though you should take care to make them close to the proper dimensions with squared edges.

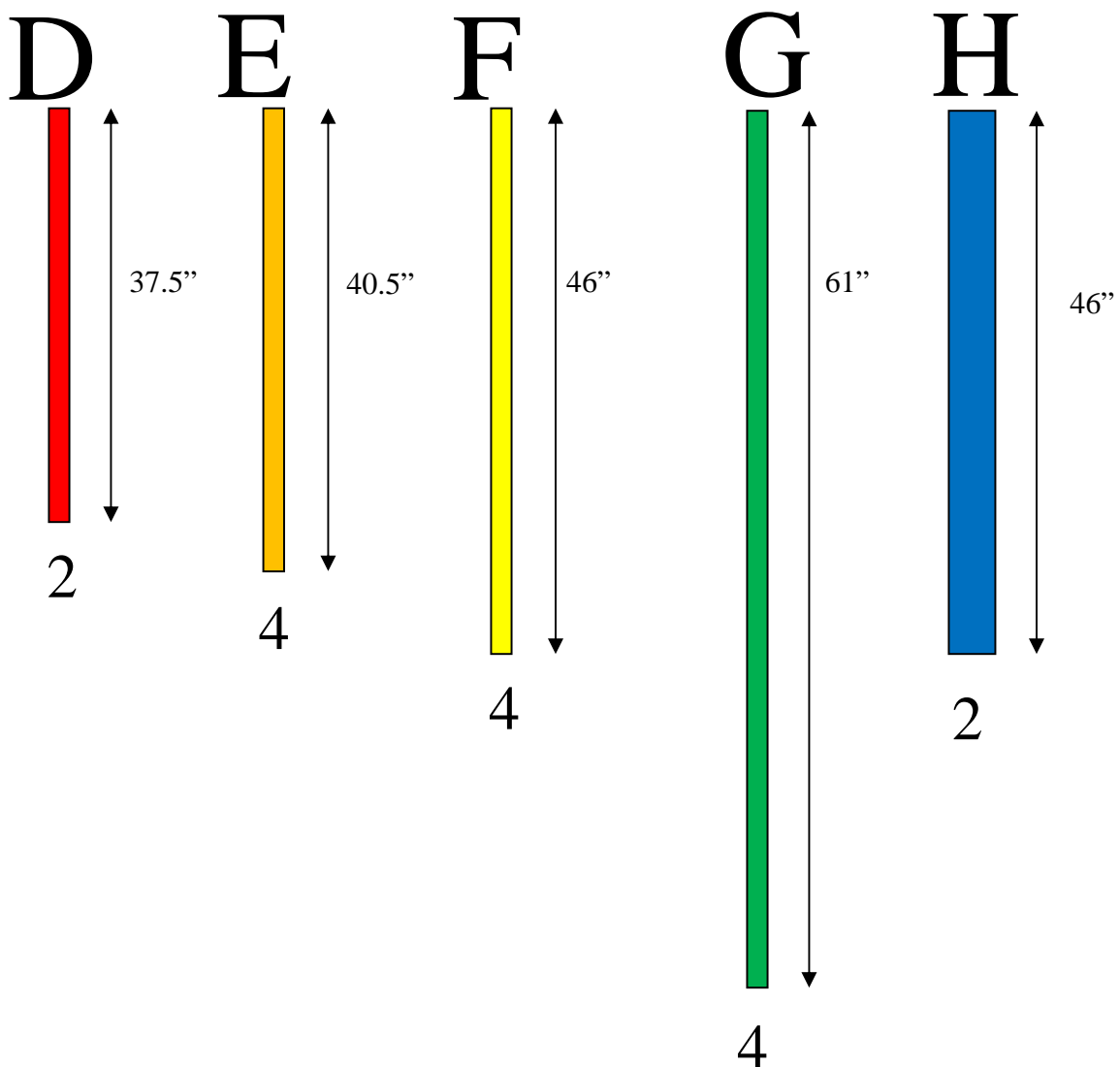
Measure and cut the pieces using the table saw/jig saw/circular saw. You won't cut the pieces perfectly, so it's best to try to make them a little smaller rather than a little bigger. The dimensions and letters for the 3 pieces are below. Again, you need two of each lettered piece.



3.2 Lumber Pieces

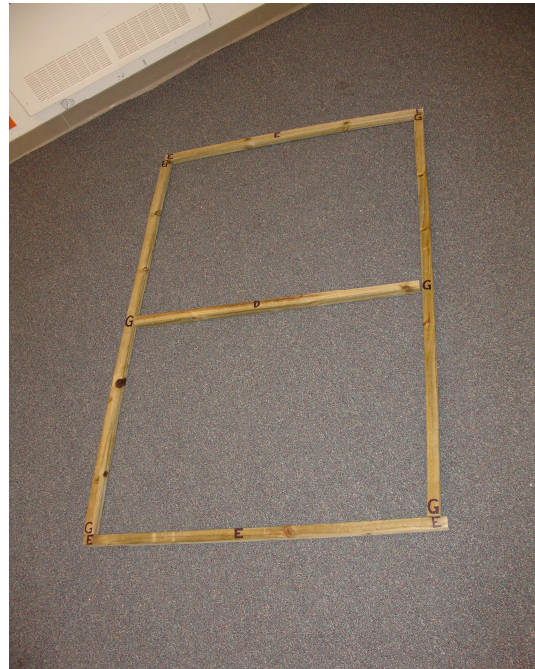
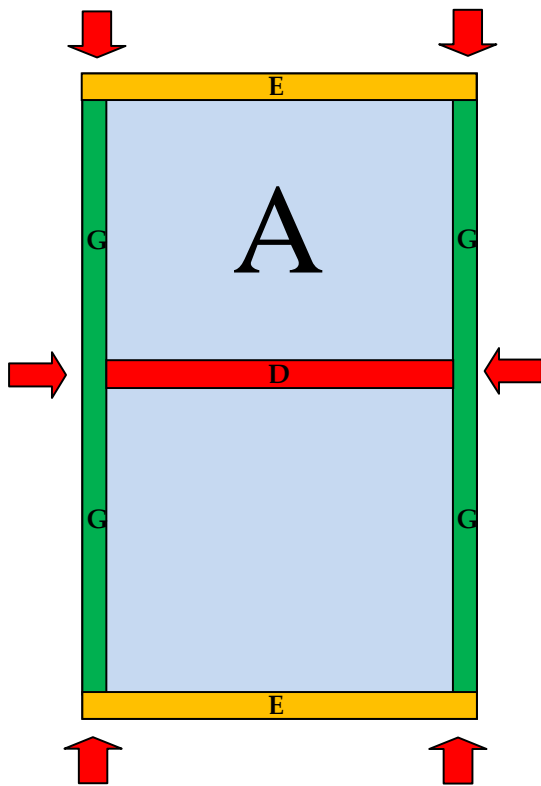
Pieces D through G are made out of the 2" x 2" lumber and H is made out of the 4" x 4" lumber. It is best if these pieces are slightly shorter than slightly longer. However, you should take your time and try making these pieces nearly perfect in length with square cuts and little or no bows in the wood.

Measure and cut the pieces using the table saw/jig saw/circular saw. You will need multiples of each piece – the quantities of each are indicated below the diagrams below.



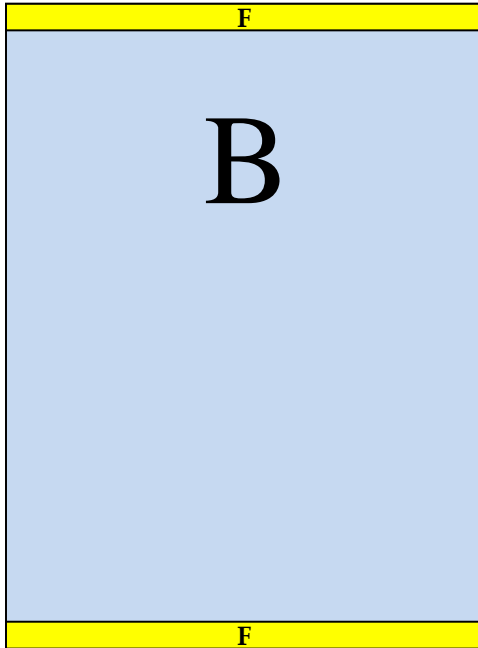
4.1 Assembly

First you will attach the 5 2x2 pieces for side A to each other (pieces D, E and G). Lay the pieces down as indicated on the diagram below (the D pieces should be centered along the length of the G pieces). At each joint you will join the two pieces with a single deck screw. To prevent splitting, you should drill a pilot hole (use a 1/8" drill bit to make a hole where the screw will go). The red arrows on the diagram below indicate the location and direction of these deck screws.

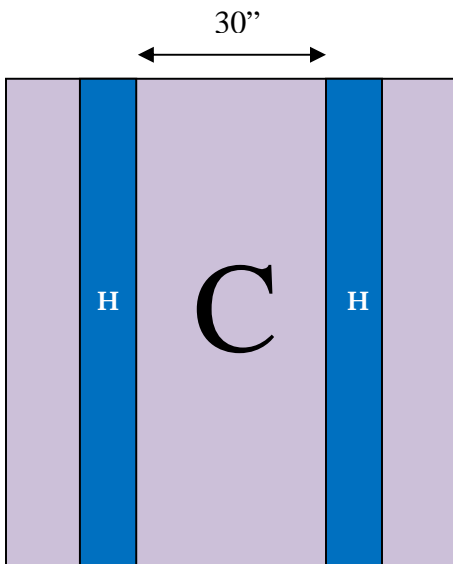


Once you have the lumber frames for the A sides assembled, lie them down and place the A plywood pieces over them. Use deck screws to attach the plywood to the 2x2 lumber frames. You should put one screw at each corner and then one about every 18" along the length of the 2x2 lumber pieces. You may need to drill pilot holes for this step as well.

For the B sides, apply the same basic steps as the last paragraph using the F 2x2 lumber pieces. As you can see, these pieces don't form a frame, so you don't need to assemble the 2x2 pieces first.



Lastly, for the base, place the two H 4x4 pieces on the floor at least 28" apart, parallel and aligned to each other. We recommend a 30" gap to ensure you don't violate the requirements of pallet lifters. Now place one of the C pieces on the 4x4's. This piece can be placed in two orientations – if it is the wrong orientation, the 4x4's will protrude around the base. Once you have the plywood centered, use several deck screws to attach each 4x4 piece. There is no need for specific placement of the screws.



4.2 First-time Assembly of the Sides

Until this point, drawings and descriptions have been enough to instruct the design. These last steps are important and tricky, so we encourage you to use the video tutorial which you can get from our website (www.burobotics.org). You should take your time finishing this part or you'll always have headaches trying to fit the box together and take it apart.

However, in case you cannot view the video, we will continue the directions:

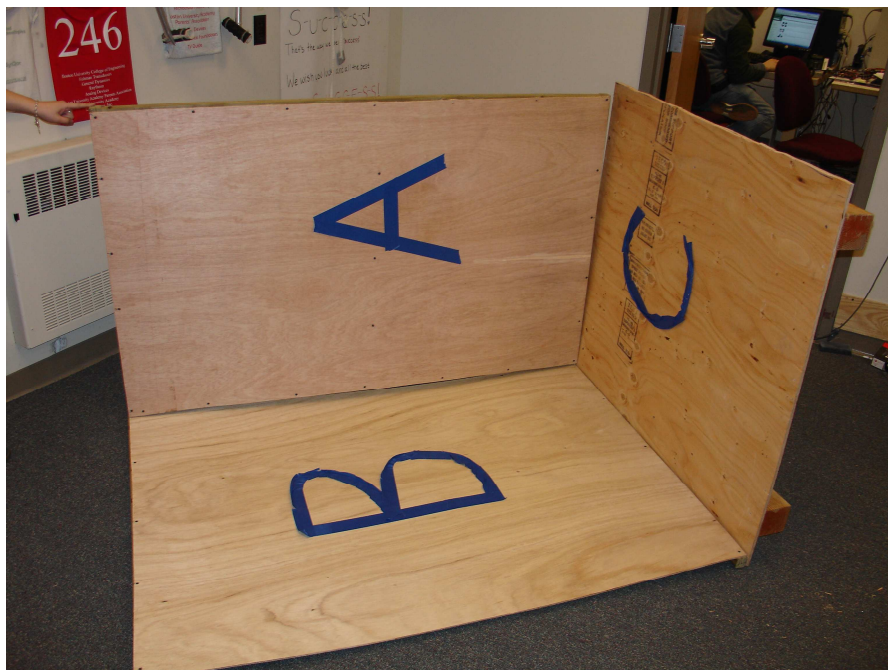
Stand the base on its edge so that the 4x4 pieces are vertical. Now stand one of B sides on its long edge and place it against the base's plywood on the side opposite of the 4x4 lumber. The 2x2 lumber of the B side should be on the outside of the crate. The edge of the 2x2 that meets with the plywood of the base should be flush with its edges. You should now drill 4 holes through the plywood of the base and then through the 2x2 lumber of the B side. Each hole will be $\frac{1}{4}$ " and they should be spaced evenly with one hole at each end of the 2x2 lumber. Once you complete a hole, place a carriage bolt in the hole and secure it with a wing nut. The head of the carriage bolt should rest upon the plywood of the base.





Now proceed with an A side in the same manner, adjacent to side B. Be sure to secure the A side with the the C piece (the base) before the side B that you already attached. For each edge between the sides and the base (piece C), you should drill 3 holes and secure with carriage bolts and wing nuts. In all cases, **continue placing carriage bolts as you go** or the wood will shift and you won't be able to put all the bolts in. The heads of the bolts will always rest against plywood. If the head rests against the 2x2 lumber, put it in from the other side of the hole. Otherwise, the tails of the bolts may be bent in shipping, preventing you from opening the crate!

Attaching the first A piece should look something like this:



It may help to stand the crate up to attach piece A to piece B, as seen below. For each of the edges between the A and B sides, you should make 6 carriage bolt holes, spaced evenly with one hole near each end.



Attach the other B side and the other A side just as you did the other two pieces, rotating and/or standing the crate each time so that the B pieces are opposite each other, as are the A pieces.

Once you have all the sides attached, tip the crate over and attach the top, the other C piece (the one without the H-pieces attached). The holes in the edges along the top should mimic the base: 4 hole per edge.



Finally, you should create unique marks on at least the edges between one A side and one B side across both the side and the base. Also, you should put one unique mark across an edge between one side and the top piece. These marks will indicate which pieces go where when you disassemble and reassemble the crate.

4.3 Tool-Less (Dis)Assembly of Completed Crate

When disassembled, the crate can be stored in sections against a wall, behind shelves, or in a corner to save space. Assembly from this state begins by placing the base of the crate on the floor with the 4x4's on the bottom. Do NOT place the robot on this platform or walk across it. Base is not strong enough without the sides attached to it.

Next, place a narrow side (side A) on the base with the 2x2 lumber facing out. The side straddle the 4"x"4 lumber that's under the plywood base. Now secure it to the base with the 1/4" carriage bolts and wing nuts. The heads of the bolts should be facing the floor. That way, when the pallet lifter picks up the crate, it won't be lifting against the tail of the bolts. The heads of the carriage bolts will always rest on plywood.

Continue placing the sides of the crate. You can proceed with either a side B or the remaining side A. Of course, once you have three sides in place, you should pack in the robot. Be sure to pad the robot from all 6 sides of the crate and secure it to the base (it is ok to make a few holes in the base). It is also a good idea to place the robot upon supports so that the drive train is not supporting the robot. If you skip this step, the robot resting on its wheels for weeks may warp the axles. Even with the robot supported on something beside the wheels, you should also tie it down to the base. Drill holes as necessary in the base, however be sure that you don't create obstructions between the 4x4's.



Once the robot is packed into crate, secure the remaining side and top. Next, you need to wrap or bind the crate to meet shipping regulations. The crate does NOT need to be sealed. Using the shrink wrap, make several circles around the crate, stretching the film, to create this binding. The finished wrap only needs to cover a few feet of the crate's height, preferably near the middle. The point of the binding is to provide a visual indication that the package has not been opened during the shipping process. It is a requirement of shipping regulations.

