



FIRST® Robotics Competition

Bumper Guide

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Introduction

This guide is intended to serve as a supplement and companion document to the bumper section (Section 8.4) in the [Game Manual](#). The purpose of this guide is to aid teams in the fabrication of compliant bumpers by providing some historical best practices. There are many ways to fabricate compliant bumpers, so this document is not all encompassing, but rather illustrates many common practices that teams have implemented previously and found to work well. For teams building the KitBot, more specific instructions can be found in the [KitBot Instructions](#).

This guide was originally created by Kelsey Draus and revised by *FIRST*. Thank you to Kelsey for putting this guide together and allowing *FIRST* to edit and update the guide.

Kelsey started with *FIRST* back in 2009 in high school as a founding member of *FIRST* Robotics Competition Team Pwnage #2451, which inspired her to pursue a degree in Materials Engineering. In college at Iowa State University, she helped start and then mentored *FIRST* Robotics Competition Team Neutrino #3928 for a few years. She later moved back to Illinois where she mentored Pwnage #2451 and volunteers at events.

The intent of bumpers and the rules in Section 8.4 establish a common set of construction materials and methods that:

- 1) provide consistent well-defined protection for robots during match play,
- 2) identify alliance, and
- 3) identify the team.

The bumper rules define the requirements that bumpers must meet prior to passing inspection and playing in competition matches. The rules are meant to establish criteria that allows for adequate cushioning in a bumper-to-bumper contact area defined by the bumper zone while simultaneously allowing for flexibility to allow teams to be able to construct bumpers that integrate within their robot perimeter constraints and team capabilities.

Fabrication Checklist

Steps

Design

- Ensure robot has adequate support for bumpers
- Check that you will be able to accommodate access to a fastening system at the appropriate height
- Choose a bumper style
- Select materials and attachment system
- Determine measurements (lengths, hardware locations, etc.) using robot

Purchase Materials

- Backing
- Padding
- Fabric
- Hardware
- Repair supplies

Initial Preparation

- Backing - Cut to Size
- Padding - Cut and Tape (depending on method)
- Fabric - Cut to Size
- Numbers – Prepare Numbers
- Numbers – Apply to fabric (depending on method)

Assembly

- Dry fit backing pieces to robot to assure they are right size
- Fasten backing together (depending on bumper style)
- Secure padding to backing
- 2nd dry fit to robot to assure they are right size
- Secure attachment hardware to bumpers (depending on method)
- Attach fabric to bumpers
- Apply numbers (depending on method)

Tools

- Good Scissors (such as sharp sewing scissors)
- Duct Tape / Cling-wrap or similar for securing padding to backing
- Sharpie Marker
- Staple Gun and Lots of Staples
- Ruler and Tape Measure (to help with spacing)
- Tools Needed to Attach Hardware (drill, screwdriver, hammer, etc.)
- Hand Saw or Serrated Knife (for cutting padding)
- Wood Saw

Bumper Design

One of the biggest keys to having legal, robust bumpers is to make sure they are considered from the beginning of the robot design. Designing the proper backing and attachment points into the robot frame will save a lot of headaches later trying to come up with quick fixes to make everything legal and secure.

Bumper Coverage

Per R401, bumpers must protect most of the robot perimeter. Make sure your robot design accommodates this by not requiring any gaps in the bumper greater than permitted by R401.

Bumper Height

Per R405, bumpers must be located within a specified height. Make sure your bumper design and attachment system results in your bumpers filling this zone completely.

Bumper Support

While the rules do not require specific support for the bumpers, poorly supported bumpers are at much higher risk of failure, potentially resulting in missing matches while repairs are made.

Make sure that your planned robot design supports each bumper segment near each end and that any gap in support in the middle is either shallow (within the reasonable flex of your chosen backing) or narrow (to minimize the unsupported material).

Types of Bumpers

The bumper coverage requirements can be met with many different bumper architectures. A few of the most common for rectangular robots are summarized below along with pros and cons. Note that some of these can be mixed and matched together on the same robot.

L-Shaped Bumpers

Figure 1 : L-Shaped Bumpers



- **Description:** A backing segment on one side of a corner fastened together with a larger segment on the other side of a corner.
- **Pros:** Less pieces and more secure than the small segment being its own piece.

- **Cons:** Puts some constraints on attachment system and/or the single piece is “floating”.

C or U-Shaped Bumpers

Figure 2: C-Shaped Bumpers



- **Description:** Small backing segments are attached on either end of a larger segment. The small pieces may be symmetric or asymmetric.
- **Pros:** Only 2 bumper assemblies to manage per set. More secure than small segments being their own pieces.
- **Cons:** Puts some constraints on attachment system.

Full Wrap Bumpers

Figure 3: Full wrap Bumpers



- **Description:** Backing segments for each face of the robot are fastened together to form a single bumper unit that is installed on the robot from above or below.
- **Pros:** Only a single bumper assembly to manage per set. Most structural/secure.
- **Cons:** Puts the most constraints on attachment system. Bumper assembly can be a bit unwieldy to transport (e.g. fit on a robot cart, etc.)

Individual Segments

Figure 4: Individual Segments



- **Description:** One or more backing segments for each face of the robot are independent and wrapped as their own unit.
- **Pros:** Most flexibility on attachment system. Significant damage to one bumper (fabric or backing) can be repaired more easily.
- **Cons:** Many separate pieces to manage. Small segments may be difficult to attach securely to robot. Corners may not look quite as clean.

Types of Corners and Ends

Bumpers are required to protect all outside corners of the robot (see the [Game Manual](#) for details). There are a number of ways to construct corners (if adjacent bumpers are attached) and ends (if bumpers are independent) of bumper segments.

Corner: 45 Degree Angle Cut

Figure 5: Angled corner



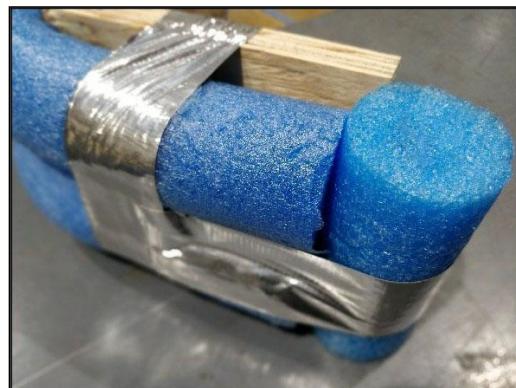
- **Description:** Ends of padding are cut at an angle so they fit together at the corner. Note that this method is not allowed for individual segments as noted in R406.
- **Pros:** Easy to cover and has a clean look.
- **Cons:** Corner does not have as much strength as other types since it is just the tips of the padding. Can be difficult to cut the angles properly.
- **Tips:** Cutting the angle of the padding just slightly sharper than 45 will help ensure the outside of the joint fit snugly so that the fabric looks clean with no indent in the corner. Avoid going too much over 45 as that will result in a significant void behind the outside edge which will reduce performance and, if significant enough, may not pass inspection.

End/Corner: Separate padding

Figure 6: Full vertical noodle corner



Figure 7: Full vertical noodle end



- **Description:** Padding along on the sides are cut flush to the end of the backing. A separate piece of padding such as a small vertical noodle is placed to fill in the corner.
- **Pros:** Slightly rounded and easy to cover.
- **Cons:** Can be slightly harder to cover with fabric and make it look nice (aka it will take more tweaking and a tighter fold).
- **Tips:** Make sure the height of the extra padding is correct.

End/Corner: Padding Extending Over the Edge

Figure 8: Overhanging noodle corner



Figure 9: Overhanging noodle end



- **Description:** The padding extends over the edge of the backing ~2.5"-~3.25" (depending on how bumper segments meet) in order to butt up to the other sides.
- **Pros:** Easy to do and easy to keep them uniform.
- **Cons:** Sometimes they do not fit together as well if some are hanging off the end more than others.
- **Tips:** Make sure they fit together well and there are no gaps before covering them with fabric. If the corner is being made as one unit, you may consider having some padding from each side extend into the corner (resembling a "lap joint").

Material Selection

Backing

Backers must be at least 4 1/2" tall and support the padding. In past seasons, plywood or solid wood has been required and below are a few options that teams have had success with.

Tip: Many big box stores or hardwood dealers will make cuts for free or very low cost. Consider having them rip the material into 5" strips for you, this will make the material easier to move and will take care of the more difficult long rip cut. The shorter 5" crosscut can be made with a much larger variety of tools.

Baltic Birch Plywood/Aircraft Plywood/Eucalyptus Plywood:

- This section refers to high quality, void free plywood. This type of material is generally not available at big-box stores or other construction-oriented lumber yards, you will typically need to locate a hardwood lumber dealer.
- **Pros:** Strongest and most stable option. Holds screws better than standard plywood.
- **Cons:** Expensive (can be 2x or more compared to standard plywood). Limited availability (requires hardwood dealer). A little heavier than standard plywood.
- **Tip:** The important part is “void-free”. Talk to the folks at your lumber dealer and let them know that all you care about is strength/stability and that appearance is not important.

Standard Plywood:

- **Pros:** More dimensionally stable than solid wood. Easier to work than OSB. Readily available.
- **Cons:** Can have voids which can reduce strength or cause issues with screw retention.
- **Tip:** The type and quality of the outside face (veneer) is not strongly correlated with the strength of the plywood. Don't pay extra for a higher grade, all you're getting is a pretty face that you're going to hide anyway!

OSB:

- **Pros:** Cheapest option. Similar overall strength to standard plywood. Consistent, but lower overall, screw retention. Readily available.
- **Cons:** Can contain formaldehyde. More difficult to work than plywood due to splintering when drilling or cutting. Edge splintering in use is a possibility. Grows irreversibly if exposed to significant moisture. Heavier than plywood.

Solid Wood:

- **Pros:** Can be purchased with 2 of the dimensions already suitable for bumpers (a 1x6 is .75 in. x 5.5 in.). Holds screws very well. Generally lightest. Moderate availability (often, but not always available at big box stores or construction lumber yards)
- **Cons:** Moderately weak to forces trying to split along the width (e.g. into two long 2.5" wide boards). Can grow, shrink, or warp as moisture content changes. Can be weakened by natural defects (e.g. knots).

Other:

If considering using other materials, make sure to plan ahead for how you will attach the fabric cover. Some plastics may accommodate staples, but harder plastics or metals may require more creative solutions for fabric attachment.

Attachment Hardware

Remember to read the rules on bumper hardware in the [Game Manual](#). Typically, hardware cannot protrude more than a certain amount, and often there is a weight limit. Here are some commonly used types (see the Appendix for pictures of hardware application):

Pull Pins:

- **Pros:** Quick and easy to make and maintain, also does not usually take up a lot of space within the robot. Pins are easily replaceable if bent and are relatively cheap.
- **Cons:** If the holes are not drilled properly for the pins, the bumpers can wiggle and feel loose. Don't provide much resistance to vertical movement on their own.

Tip: Remember to pack extra pins in case some are lost or bent.



Latches:

- **Pros:** Quick and easy to switch the bumpers and there is no need to worry about losing or missing parts. Often very secure when installed properly.
- **Cons:** Can be more expensive and harder to install. If one breaks it takes more effort to replace it.



Bolts/Nuts

- **Pros:** Inexpensive and uses things that are commonly found in a typical shop. Easy to do and easy to fix.
- **Cons:** Often takes more time to change bumpers. Need to be able to get fingers in to install bolts/nuts.



Padding

Note: Remember to read the rules on padding types in the [Game Manual](#). The 2025 Game Manual allows a greater variety of padding than in the past. This section contains examples of commonly available padding material that teams have had success with in the past.

2.5 in. Round Solid Foam Noodles (or Backer Rod):

- **Pros:** Does not compress as easily and will hold shape better than other types of foam noodle. With less compression, the fabric does not move as much and often numbers will stay on better. This type of noodle is also great for angled corners since when cut on an angle there is more material to support the corner.
- **Cons:** A little bit softer than some other alternatives. Round profile creates “voids” in the middle of the bumper.



Designed Bumper Foam:

- FIRST Robotics Competition vendors such as [AndyMark](#) and [The Thrifty Bot](#) have foam extrusions specifically intended for bumpers.
- **Pros:** Durable material pre-sized for use in robot bumpers.
- **Cons:** May be less flexible in sizing/thickness than raw materials like floor tiles or foam sheets. Must be ordered online.



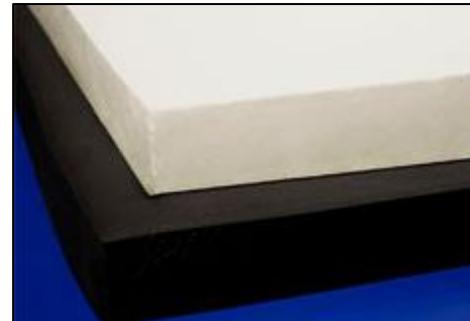
Foam Floor Tiles

- **Pros:** Typically fairly stiff which will absorb large impacts well. Often readily available at big box stores.
- **Cons:** Requires a bit of work to get into bumper shape (either alone or as part of padding system). May be a bit too stiff to absorb smaller impacts or broad side impacts. Construction (and therefore stiffness and durability) may vary.



Foam Sheets

- Raw sheets of the various materials permitted by R402 can be acquired and cut and/or laminated into the appropriate shape
- **Pros:** Most flexible in sizing, thickness and construction. Can laminate multiple different materials to optimize for multiple types of collisions.
- **Cons:** Requires a bit of work to get into bumper shape (either alone or as part of padding system). Generally not available locally.



Fabric

The ideal bumper fabric may depend on a variety of factors including what type of bumpers you are constructing, how you want them to look, and how much friction you want on the surface. Some examples of good material choices, and their pros and cons, are described below.

Ideally, the shades of red and blue are more or less uniform and are clearly “red” or clearly “blue”. Obviously, there is a very wide variety of shades of red and blue so there is no expectation that every bumper color be exactly the same. However, colors that are obviously “pink”, “purple”, “lavender”, etc. are not acceptable. Very dark reds, for example “maroons” or “burgundies”, or very dark blues, for example “dark navy blue”, are technically legal, however for consistency and uniformity teams have traditionally used shades of red and blue similar to the shades of red and blue in the *FIRST* logo.

Material: Sports Twill

- Where to Buy:
 - US Twill: <https://twillusa.com/tackle-twill/>
 - Type is “Sports Twill”
 - Colors are “Red” and “Royal”
 - Non-adhesive backing or Adhesive Backing
 - Non-Adhesive: Easier to cover and get the fabric tight, also can do complex shapes
 - Adhesive: Helps prevent saggy bumpers, but is best for straight shapes
 - Local fabric stores (look for “sports twill”)
- **Pros:** Works on all types of bumpers. Low coefficient of friction. Wears well and resists tearing. Easy to work with when covering. Easy to adhere numbers to.
- **Cons:** Adhesive backing is difficult to work with for complex shapes and the material has to be ordered in advance due to shipping time.

Material: Dacron Sail Cloth

- Where to Buy: <https://www.sailmakerssupply.com/product/colored-dacron-sailcloth/sailcloth>
 - Type is “COLORED DACRON SAILCLOTH SKU 1010-P”
 - Color is “10102 - Red” and “10106 - Dark Blue”
- **Pros:** Slick surface and low coefficient of friction. Lightweight and has a very smooth appearance. Great for making sharp corners. Smooth surface makes number application easy.
- **Cons:** Not easy to work with for complex shapes and can tear easily. Over time wear is visible. Since the material does not have any stretch to it, it is difficult to pull material tight. Wrinkles easily on rounded corners.

Material: CORDURA® or Slick Nylon

- Where to Buy: <http://www.rockywoods.com/Fabrics-Kits/1000D-Cordura-Nylon/1000-Denier-Coated-Cordura-Nylon-Fabric>

- Type is “1000 Denier Coated CORDURA® Nylon Fabric”
- Color is “Red” and “Royal Blue”
- Where to Buy:
 - AndyMark
 - <http://www.andymark.com/product-p/am-2955.htm>
 - <http://www.andymark.com/product-p/am-2956.htm>
 - RoboPromo
 - https://www.robopromo.com/product_p/rp-2023.htm
- **Pros:** Inexpensive and easy to work with. Does not tear easily and has good wear resistance.
- **Cons:** Thinner than other fabrics. Any dark tape or different colored padding may show slightly in certain lighting.

Material: Heavy Duty Nylon

- Where to Buy:
 - AndyMark
 - <http://www.andymark.com/product-p/am-2675.htm>
 - <http://www.andymark.com/product-p/am-2676.htm>
 - RoboPromo
 - https://www.robopromo.com/product_p/rp-2002.htm
 - Local fabric stores (look for “ripstop nylon”)
- **Pros:** Inexpensive and easy to work with. Does not tear easily and has good wear resistance. Great for iron on numbers and easy to sew.
- **Cons:** Surface is not as slick and has a higher coefficient of friction.

Figure 10: Sample Heavy Duty Nylon Fabric



Numbers

The best way to apply numbers to your bumpers depends on factors such as how many matches you play in a season, what resources your team has access to, and how much time or money your team is looking to put into bumper numbers. The following chart summarizes many common ways to apply bumper numbers with more detail about each in the section below. See the Appendix for additional images of different types of numbering applied to bumpers.

Note: Remember to read the rules on number sizes in the [Game Manual](#). Typically, numbers are 4 in. in height and must have at least 1/2 in. stroke (line thickness) and are usually required to be on all four sides of the robot. Team Logos and Icons may not be substituted for numbers.

Tip: Arial font, bolded, at 400pt produces numbers that are approximately the correct size

Type	Best to Put on Before Bumpers are Covered	Cost	Wear and Bond to Fabric	Level of Difficulty
Glue On		**	***	*
Sew On	X	**	*****	****
Heat Transfer Vinyl	X	****	*****	***
Embroidery	X	*****	*****	*****
Iron On	X	***	**	*
Paint		*	*	*

Glue On Numbers

- **Pros:** Glue on numbers can be done easily and in the shop. It's also a cheap way to do numbers that also look nice. Can be done in a short amount of time with little preparation.
- **Cons:** If glue is not properly spread to corners or not enough glue is used then ends may come loose.
- Material Types:

- **Vinyl:** Inexpensive and easy to find at a local fabric store. Easy to keep clean. Important to make sure layers (if any) of the fabric adhere well to each other.
- **Oil Cloth:** Inexpensive and easy to find at a local fabric store. Easy to cut out and glue on. Edges may fray if not well glued and they can get dirty easily.

Method:

1. Print and cut out stencil for numbers.
 - a. Choose a font which meets the [Game Manual](#) requirements
 - b. Print out the numbers on a piece of paper.
 - c. Check the requirements using a ruler.
 - d. Tape the back side of the paper to stiffen the paper (masking tape works well)
 - e. Cut out the numbers.
2. Trace stencil onto the fabric
 - a. Make sure it is being traced in mirror on the back side so that none of the tracing pen/marker/pencil shows on the final numbers.

Note: It is sometimes helpful to mark on the back side a reminder that when tracing number onto the fabric, you should be tracing the mirror image of the number onto the back of the fabric.

3. Cut the numbers out.
 - a. Use sharp scissors.
 - b. Take your time to ensure edges are clean with no fraying or small tears.
4. Glue the Numbers on
 - a. Use a tape measure or paper to help space the numbers evenly on the center or side of the bumper.
 - b. Cover the back of the number in glue, clear e-6000 works well, making sure there is plenty of glue especially on the edges and corners.

Figure 11: Team #5934 with glue on numbers



Sewn On Numbers

- **Pros:** Very secure. Wear well. Can look very professional.
- **Cons:** Numbers must be applied before the fabric is put on the bumpers. Edges outside seams can fray. Requires sewing knowledge and equipment.

Heat Transfer Vinyl

- **Pros:** These numbers look very professional and often adhere really well to the material. Can be done by anyone with a vinyl cutter and iron.
- **Cons:** A greater amount of planning is required. Numbers must be applied before the fabric is put on the bumpers. If sending out, the turnaround time may depend on the vendor so often these cannot be done at the last minute.
- **Tip:** A heat press can provide more even, consistent heat and pressure for better adherence of HTV to fabric.

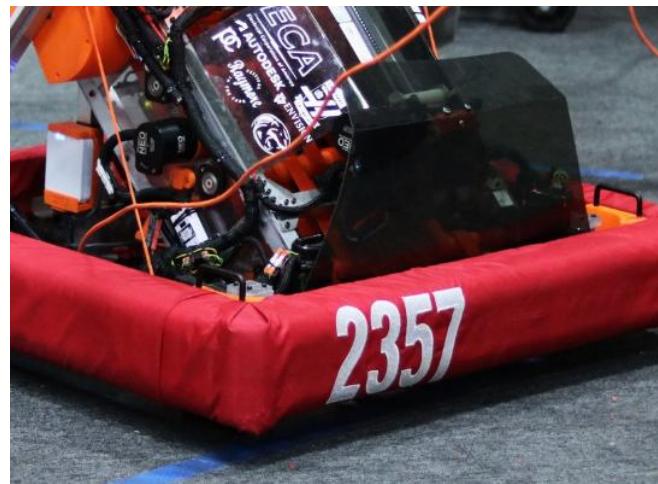
Figure 12: Team #1625 with hot press vinyl numbers



Embroidery

- **Pros:** These numbers look very professional and there is no risk of them coming off the fabric.
- **Cons:** A greater amount of planning is required. Numbers must be applied before the fabric is put on the bumpers. The turnaround time may depend on the vendor so often these cannot be done at the last minute. The font and numbering size may be limited depending on the vendor and machine. This method can also be expensive.

Figure 13: Team #2357 with embroidered numbers



Iron On

- “Iron-on” can be used to describe a number of different products. Some are Heat Transfer Vinyl (see section above), some transfer ink from a paper substrate and some are a heat sensitive adhesive pre-applied to a fabric. This section is mostly discussing the fabric style, the ink transfer likely has some blend of pros and cons from this section and the paint section that follows.
- **Pros:** These numbers look very professional and are easy to apply. They can be done in a short time frame and materials to do this can be found at a fabric store.
- **Cons:** Numbers must be applied before the fabric is put on the bumpers due to the heat needed (potential to melt the padding). If they are not applied properly, they can come off and the corners may peel. They often do not wear as well as other methods.

Figure 14: Team #135 with iron on numbers



Paint

- **Pros:** These numbers are quick and easy to apply. The type of paint that is often used is acrylic, which is inexpensive and easy to find. The numbers can be applied after the bumpers have already been assembled.

- **Cons:** Painted numbers often do not look professional. The paint can seep into the fabric or may have a hard time adhering to the fabric depending on the paint/fabric combination. A test run is encouraged to make sure the paint and fabric are compatible before painting the final bumpers. Depending on the type of paint, it can also flake off and wear poorly throughout the season.

Figure 15: Team #6490 with painted numbers



Bumper Construction

General Tips

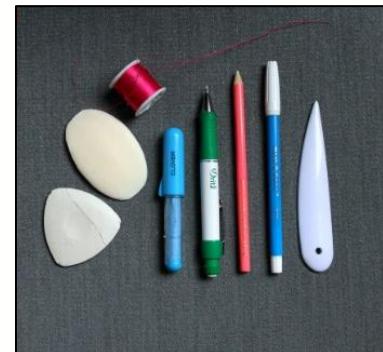
Cutting Padding

- The most effective way to trim padding is often with a hand saw or a large, serrated knife. Typically, it is good to avoid cutting the padding until it is absolutely necessary.



Spacing and Number Placement

- A piece of paper and your letter template can be used in conjunction with a tape measure to help with number spacing. Sometimes fabric chalk is also helpful in marking where numbers go and can easily be washed off later.



Attaching Hardware

- If hardware needs to be put in specific locations, it is sometimes easier to mark both on the backing and fabric while you are covering to keep track of the desired locations.

Taping Padding

- All of the instructions below recommend taping the padding to the backing before covering it with fabric. This is not required and is used only as an assembly aid. When taping the padding to the backing, make sure the tape is just barely snug or even slightly slack. If the padding is significantly dimpling in towards the tape, that is a sign that the tape is too tight!

Figure 16: Padding taped correctly



Figure 17: Padding taped too tight



Fastening wood segments together

If using wood for your backing material and constructing bumpers that wrap around one or more corners, you'll have to attach the segments together. Screwing into the side of plywood or end-grain of solid wood is not recommended, it can split the wood and/or cause bulging or separation of the plies. If you choose to do so, be sure to supplement the joint with wood glue between the two pieces and pre-drill holes for the screws (including a countersink if using countersink wood screws) to avoid splitting the wood.

Instead, recommended methods include:

- **Metal L-brackets:** A metal L-bracket helps reinforce the corner and allows screws to be applied into the face of the boards rather than the end. Pre-made brackets can be purchased off the shelf or they can be fabricated from aluminum angle stock or similar material.
- **Pocket hole screws:** Pocket hole screws are another option that can form a strong joint. For maximum strength, drill and drive your screws from the outside of the corner (padding side) so the screws end up farther from the edge of the board.
- **Joinery:** Mitters, rabbets, or other woodworking joinery techniques can also be used either alone or in combination with other techniques to increase glue surface and improve the strength of the joint.

Using a Metal Frame

- When making bumpers which secure into a metal frame as the attachment system it is important to remember to leave a little extra wiggle room for the fabric when cutting the backing.

Figure 18: Team #148 with metal frame bumpers.



Bumper Weight

While there is no explicit weight limit for bumpers, there is a 20 lb. difference between the allowable robot weight with and without bumpers. If your bumpers are heavier than this difference, your robot will need to be lighter! Some items that can contribute to bumpers that may come close to or exceed this weight limit include:

- Heavier wood such as OSB, Baltic birch plywood or high-density solid wood
- Heavy attachment systems such as full metal frame attachment or other attachment with heavy brackets or hardware.
- Utilizing the optional metal angle along the bumper edges to clamp the fabric.
- Higher weight fabrics, particularly if making a set of reversible bumpers that contain substantially more fabric.
- Denser padding materials such as floor tiles or 6lb/ft³ EVA foam.

If your bumper design meets more than one of these bullets, you may wish to weigh the raw components before assembly to ensure that your completed robot will meet the weight requirement. It's a lot easier to alter your plan before you start, than after you've put everything together!

Folding Fabric

No matter which type of bumper you are building, at some point you will need to fold fabric around a corner or end. A few techniques are documented here, however there are many other approaches that will work.

Folding Ends

While the lengths of various parts of the fabric may change based on what type of bumper end you have (flush, 45 degrees, filled corner, etc.), these same two options should generally still work.

- An easy way to fold ends is similar to the most common way to fold presents. First fold the outermost corners of the rectangular overhanging fabric down and in to form a triangle or trapezoid. Then take the point or edge farthest from the bumper and pull it around the end of the bumper. This method typically forms crisp outside corners of the bumpers but may look a little awkward when viewed from the end.

Figure 19: Triangle end fold



- An alternative method involves taking the rectangular end and folding it back over towards the backing directly. As you pull it over, take the extra fabric from above and below and poke it underneath the flap you are folding, to form 2 small pockets. This method creates a nice-looking profile looking at the end of the bumpers but may take some finesse to avoid the outside corners looking “puffy”.

Figure 20: Rectangle end fold



Folding Corners

If you are making bumpers with multiple segments wrapped together, you will also need to fold fabric over the corner. The idea is generally to have the outside surface remain smooth and continuous and have a single overlap line along the corner. Depending on how you do this fold, this overlap may be perpendicular to either segment or may be diagonal across the corner. The method shown creates a diagonal line across the corner.

- Pick which segment that you would like to be underneath the overlap and lay the fabric from this segment up and over the adjoining segment.
- Grabbing the fabric from the outside face of the opposite segment, pull the outside face taught and begin folding this fabric up and over the fabric you laid down in the previous step. Poke excess fabric in to form a pocket. You may wish to make 1 or more relief cuts to remove excess fabric from the corner.

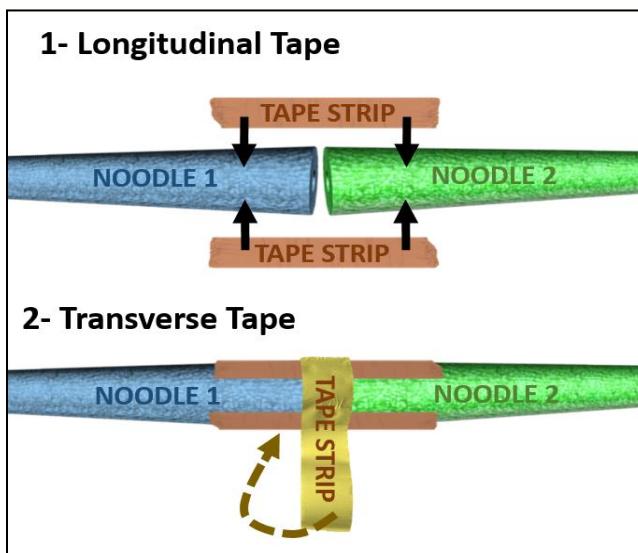
Figure 21: Corner fabric fold



Step-By-Step Instructions

1. Cut the backing for the bumpers (check the [Game Manual](#) for backing requirements)
2. (If appropriate) Fasten the backing together at corners.
3. Hold the backing up against the robot to ensure it fits as expected before proceeding.
4. (If needed) If total length is longer than a single piece of padding and you are using a wrap-around corner, you may want to fasten the padding together first. Try to make sure joints land somewhere along a side and not at a corner. To do this with foam noodles:
 - a. Press the foam noodle ends together so that there is a small amount of compression then place two strips of tape in the longitudinal direction and then one strip wrapped around the joint.
 - b. Then take the two very long noodles and tape them together with a piece of tape every 1 to 2 feet.

Figure 22: Taping foam noodles together



5. Measure the length needed for each piece of padding by measuring the length of the backing segment and adding any extra length needed to accommodate your chosen end or corner type.
6. Trim the ends of the padding using a hand saw or serrated knife.
7. Tape the padding onto the backing.
 - a. There should be one to two pieces of tape in the middle and one at each end of each piece of backing.
 - b. This also helps to prevent sagging of bumpers.
8. Once the padding is secured, hold the bumpers up to the robot or frame and check the fit. Adjust the backing location if necessary.
 - a. A little extra room between the backing pieces is often ideal since the fabric will cause the bumpers to fit slightly tighter.
 - b. You may also want to mark locations for hardware on the backing at this point.

9. Cut the fabric to the correct width so that it will wrap around the backing and padding with some overlapping fabric on the back. Do not worry about trimming the ends to length, leave them long in order to have enough material to properly wrap the ends.

Note: If you are gluing on numbers, this can be done once the bumpers are constructed before the hardware and/or frame is put on. Other number methods may require number application before the fabric wrapping process. Also consider whether your hardware requires access to the inside of the bumper and install now if it does.

10. Lay the cut fabric out on a flat surface, such as a table or the floor, with the fabric side you want on the outside of the bumper facing downwards. Place the backing/padding structure onto the fabric with the padding touching the fabric and the backing side facing up. Make sure that the backing/padding structure is centered properly.
11. When it is in place, temporarily insert a few straight pins through the padding and fabric to hold the fabric in place.
12. Starting in the center, staple one side of the fabric onto the backing, then pull tight and staple the other side. Work from the middle outwards, continuing to staple one side, pull the fabric tight, and then staple the other side, until you reach a corner or end.
13. Once you get to a corner or end, fold the fabric then pull it tight and staple as described in the Folding Fabric section above. At the ends, it's best to leave extra fabric on the ends which can be trimmed off later after the staples are in place. This step is often easier with two people.
14. Repeat steps 12 and 13 for any additional attached segments.
15. Trim any excess fabric off the back of the bumper. Make sure not to trim too close to the staples so that the fabric doesn't tear out.
16. Install hardware. Make sure you install the hardware, so the bumper installs with the numbers right-side up.
17. If installing numbers using glue, paint, or other similar techniques, you can measure and apply the numbers now.

Swappable Bumper Covers

Instead of making two sets of bumpers, some teams choose to make it so that different colors can be displayed using the same set of padding and backing by using a cover that can be flipped or changed to switch the bumper color.

- **Pros:** These covers can be made to work with any type of bumper. They are often a good way to save space and use less construction materials (less padding and backing). The attachment method to the robot is not quite as important since the bumpers will be coming on and off less.
- **Cons:** These typically take more sewing and fabric experience as well as planning to be done correctly. It is often a lot more difficult than having two sets and if done incorrectly, it does not look as professional.

Folding Cover

These are covers which fold up/down (securing the edges to the top or bottom) or side-to-side to switch between blue and red. Hook and loop or snaps are often used to secure the fabric. Using elastic or a draw string to tighten the fabric can also work but depends heavily on what kind of fabric is being used. The type of number and fabric selection is something to consider when making these since both will be tugged on and folded frequently.

- **Examples:**
 - <https://www.youtube.com/watch?v=BUDMB-aiBpo>
 - <https://youtu.be/NOTjEn1QINo>
 - <https://www.chiefdelphi.com/uploads/short-url/e3H4WFyAQ9xTqycyu48NFljwh5o.pdf>

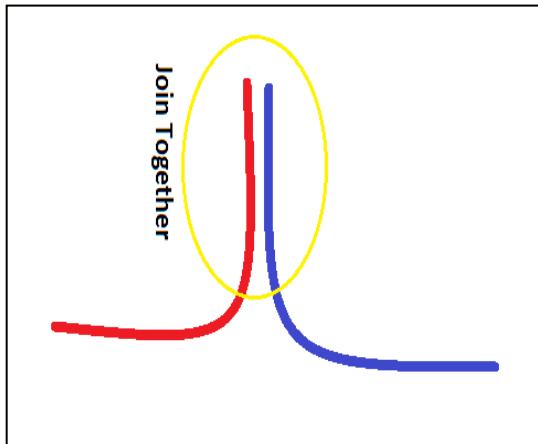
Figure 23: Folding reversible bumper.



General Construction

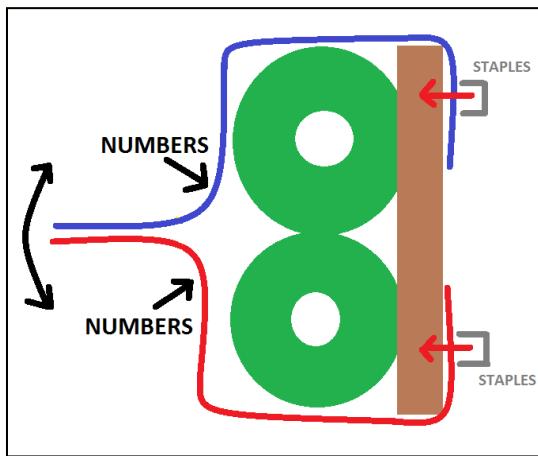
- Cut the backing and padding and tape them according to the desired method.
- Join the back half of the blue and red fabrics together using a sewing machine or iron on double sided adhesive.

Figure 24: Folding cover fabric joint



- Cover the bumpers. Tape can be used to hold fabric in place to test out the folding before the fabric is stapled to the back.

Figure 25: Folding cover installation

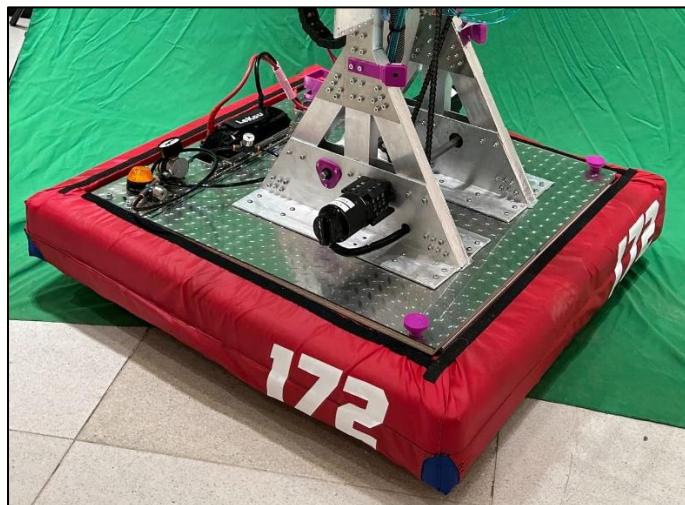


- Figure out what kind of hardware and numbers work best and install them. Make sure the fabric is tight when secured on both the top and bottom so that the numbers are easy to read. Numbers may need to be applied before or after the covering process depending on the method.

Detachable Cover:

This is where you make a red or blue bumper and make a fabric cover for the second color. You can also make an alternate bumper cover, such as something that is your team colors that would look nice for demonstrations. Then make a red and blue cover for the competition. Having full covers are nice since they do not take up a lot of space and can easily be replaced or fixed. The main downside is selecting a secure attachment method while having the fabric remain tight. In addition to the attachment methods available for folding covers (hook and loop or snaps), detachable covers can also be made using elastic to secure over the bumper. It's important to make sure the fabric is tight so that the numbers are easily readable. It's also important to make sure that the covers will not fall off regardless of what happens in the competition. Multiple types of attachment methods can be used if one type is not enough.

Figure 26: Bumpers with hook and loop attaching cover (Note: numbers must now be solid white)



Quick Fixes for Competition

Fabric

- **Sewing** - Having some blue and red thread and a sewing needle is really great for a quick fix. Thread the needle so that the thread is doubled, then hand stitch the bumpers and pull tight to make sure fabric joins together well. This works well for most fabrics, but if you are using a fabric that tears easily it could create more issues due to the small holes from the sewing needle.
- **Tape** - This is probably one of the most common temporary fixes. Duct tape and Gaffers tape both work well and are quick and easy to apply. Please check with your Lead Robot Inspector for advice. Often if there is a small rip it's better to tape all the way around so that the ends of the tape are on the back of the bumper. It may seem like too much, but it's less likely to fall off when the ends are on the back.
- **Patches** - Iron on patches can be used with low heat. It's important to not melt the padding when applying them. Stick on patches can also work similar to tape. Stick on patches can even be made with a piece of fabric and glue. E6000 glue works well but takes 24 hours to dry.
- **Fabric Section Recover** - This involves taking a piece of fabric, preferably the same type used on the bumper, cutting a section, wrapping it around the bumper, and stapling it onto the back. The bumper hardware may have to be removed depending on the attachment method. It's important to wrap it tight so that the edges stay down. Sometimes a little glue on the edges can also be helpful.

Figure 27: Bumper with tape covering ripped areas



Numbers

- **Paint** - This is often a great fix but can take a while to dry. Acrylic paint and a white paint marker will both work. A few layers may be needed if the paint soaks into the fabric.
- **Tape** - White electrical, duct, and gaffers' tapes work well for this. Cut the tape using scissors and apply it. Try to not let the adhesive touch anything other than where it is being placed on the bumper so that it does not lose any stickiness. Tape may need to be replaced multiple times during a competition and is often not a great long-term solution.
- **Glue** - If the numbers are intact but falling off, glue (such as e6000 or any clear glue) can be used to stick the corners back on. It's sometimes good to use this solution at the end of the day so the glue has time to dry. Tape such as masking tape can be used to hold the number down while the glue dries.

Figure 28: Bumper with white electrical tape over some numbers



Appendix - Bumper Gallery

Numbers

Figure 29: Iron on



Figure 30: Hot press vinyl



Figure 31: Sewn on



Figure 32: Sewn on



Figure 33: Embroidered



Hardware

Figure 34: Latch

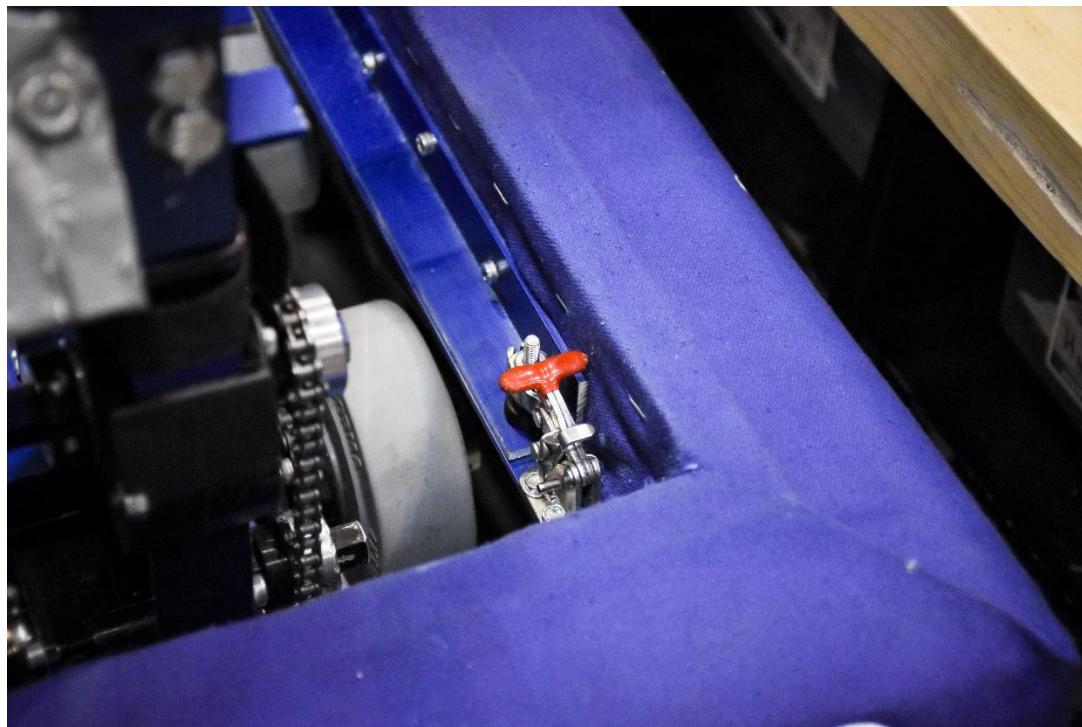


Figure 35: AndyMark bumper brackets

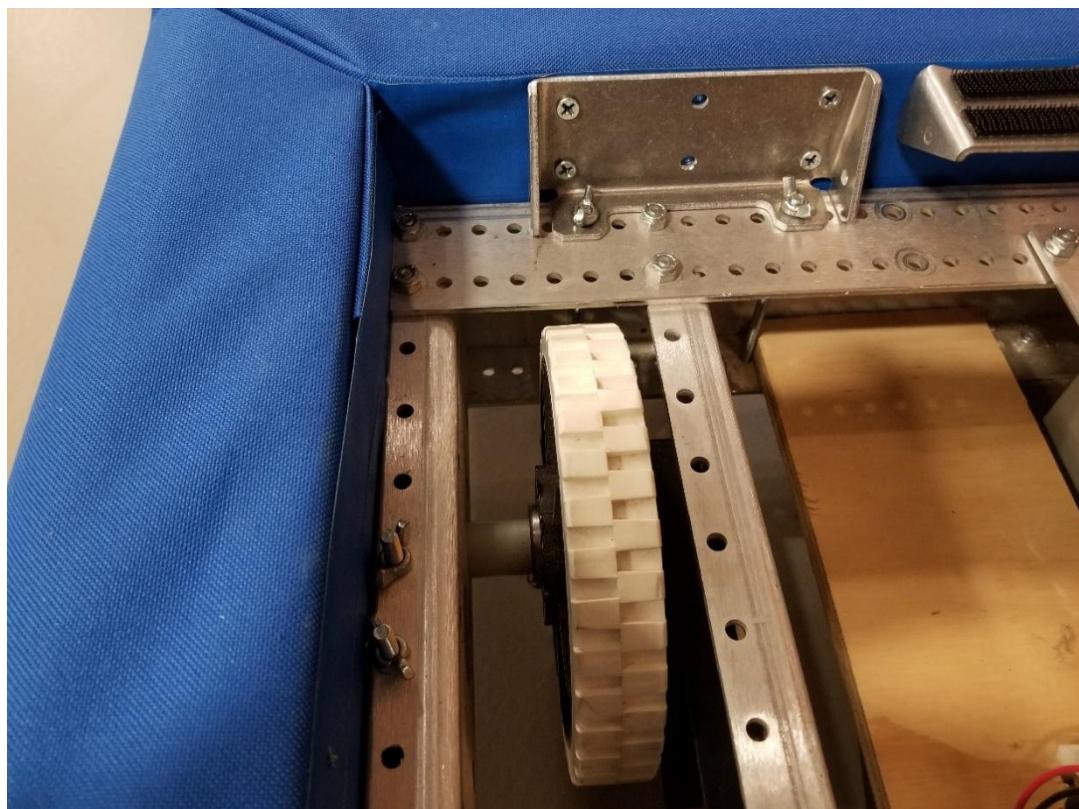


Figure 36: Door hinge and pull pin



Figure 37: Quick release pin

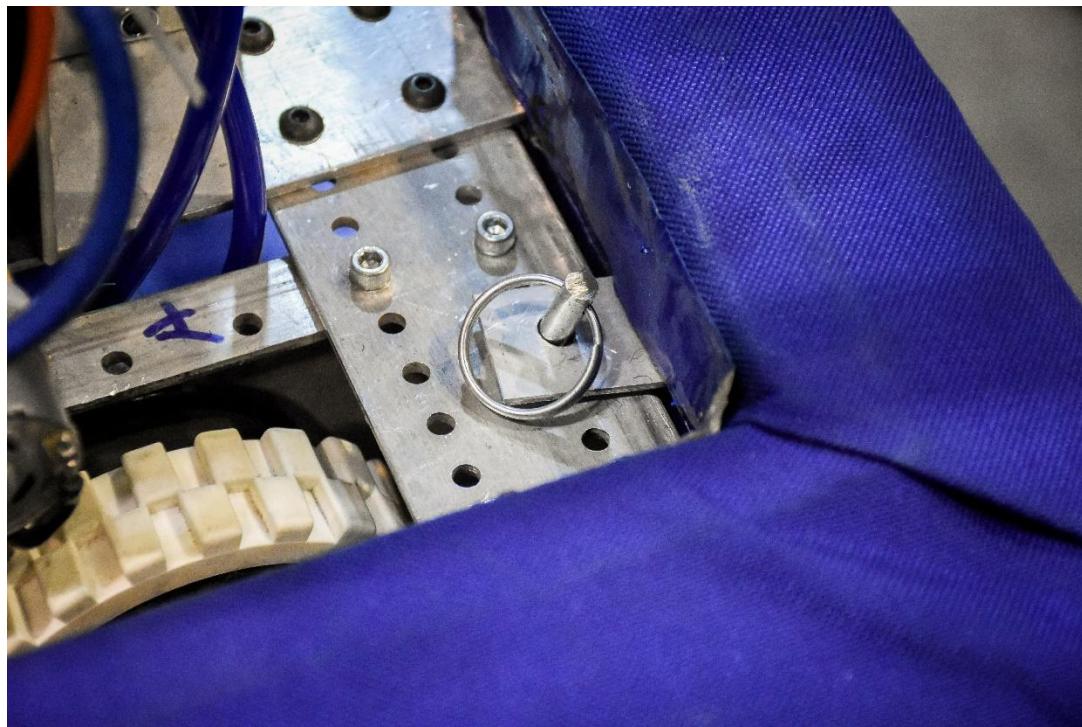


Figure 38: Pin through bolt

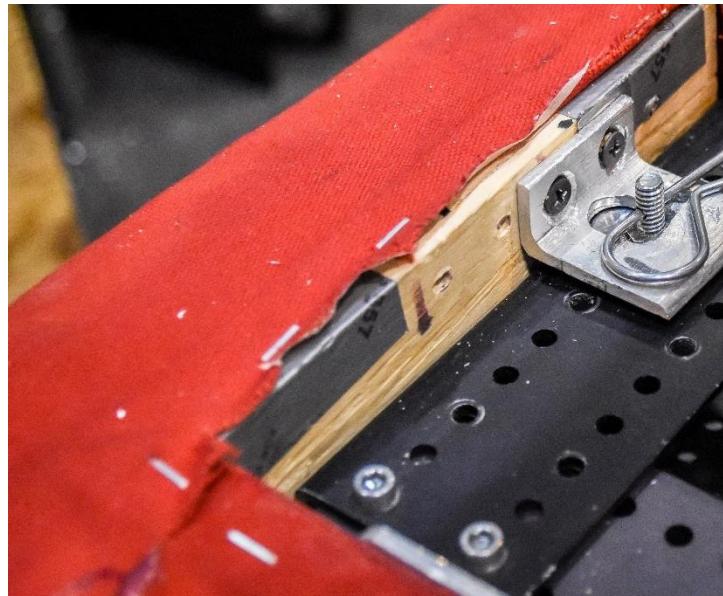


Figure 39: Bolt and wing nut

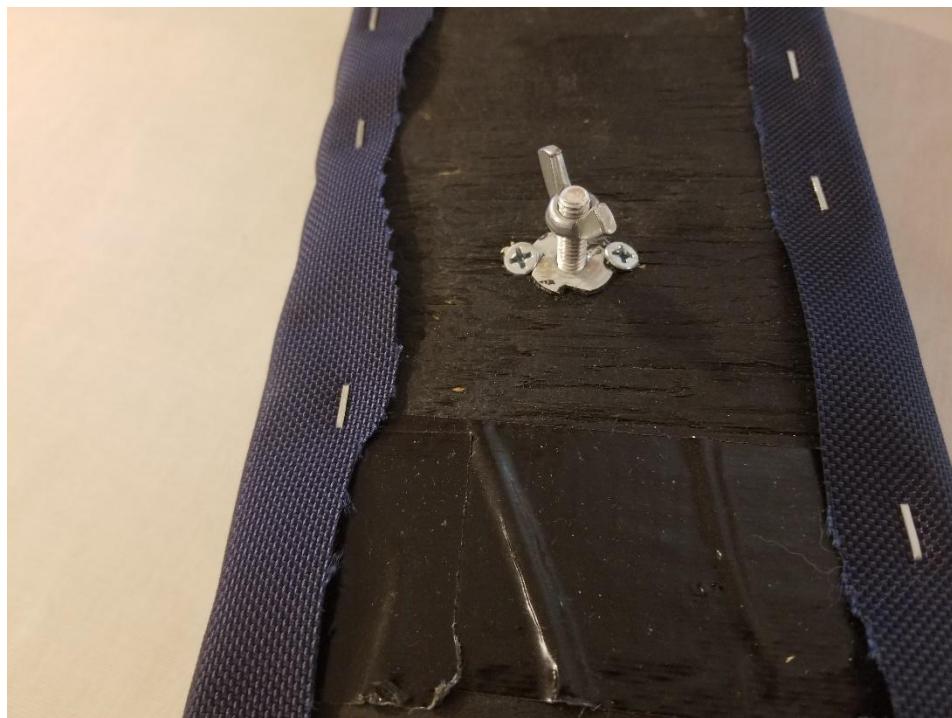


Figure 40: Latch



Other

Figure 41: Snap folding reversible

