Battery Pack

Battery Pack New Members Start Here

The following is a collection of links covering many key responsibilities of a battery pack team member. While this list is far from complete, it serves as a solid starting point for new members and a resource to deepen the knowledge of current team members. If you come across a helpful resource that isn't listed here, reach out to the battery pack lead to have it added. The goal is to make this a living reference that grows with the team.

Batteries & Module Design:

Cell Selection:

https://youtu.be/YCh88Ryad_Q?si=Yw_wG6LsN5r4Ornj

Series and parallel:

https://youtu.be/L-UfAeyTI9g?si=yir0FnnBiHhU1srt

https://youtu.be/q46Ev9KVNLI?si=YsqTRm5le1euUbf8

Voltage Taps:

https://youtu.be/fyjDGSPHmYI?si=5Kp8fsCbrSVWaXMv

Thermistors:

https://youtu.be/SaQBD0NMT04?si=l00LCxrSBgjsRT3N

C Rating:

https://youtu.be/cxkVxi9P0EA?si=YKWbFfsxErOex3jR

Other Electrical Components:

Contactors:

https://youtu.be/tMIg24cHqwE?si=GoEc4lXgQr_8lMpy

Fuse:

https://youtu.be/ot-_PJEja7c?si=KV7p-s2u39I-sIpb

BMS:

https://youtu.be/GXYJ1xC10j4?si=qpv4zLVIUbQx35To

SOC/SOH:

https://youtu.be/rOwcxFErcvQ?si=OZlE5tshIGgikb_1

https://youtu.be/imjbyeS1caI?si=EPW2c0dFBSrEwk_O

Pack Cooling:

https://www.dober.com/electric-vehicle-cooling-systems

Box Construction:

https://youtu.be/tiS8ArzEA58?si=LryIuSmVO1Bgp0T1

https://youtu.be/3Pc-Sd_J26E?si=4FIgSPMbBmwdX29j

Battery University:

This is one of the most comprehensive websites there is about batteries.

https://batteryuniversity.com/articles

Good Overall EV videos:

https://youtu.be/hBbhevHZZ5E?si=Yja3qvNngAX7KERJ

https://youtu.be/2aDyjJ5wj64?si=grT37s0xccLxDWOC

Car 3 & 4 Battery Pack Design Reports

Car 3 (2022):

https://uflorida.sharepoint.com/:w:/r/teams/SolarGators/_layouts/15/Doc.aspx?sourcedoc=%7B18E3B502-5AFA-4EAE-A952-36471527760F%7D&file=2022%20Batt%20Pack%20Design%20Report.docx&action=default&mobileredirect=true

Car 4 (2025):

https://uflorida.sharepoint.com/:w:/r/teams/SolarGators/_layouts/15/Doc2.aspx?action=edit&sourcedoc=%7B636fbaf0-1348-482f-8d67-d8e72c52167c%7D&wdOrigin=TEAMS-MAGLEV.teamsSdk_ns.rwc&wdExp=TEAMS-TREATMENT&wdhostclicktime=1746400125729&web=1

Car 4 Battery Pack Manufacturing & Considerations for Car 5

This serves as a comprehensive journal of our manufacturing processes for Car 4 and what could have been improved, as well as remarks on what can generally be done better for Car 5.

Box

- DXFs were created for the sides and bottom of the box to get an idea of how big we needed to make the sandwich panels and if we had core (divinycell was chosen because of availability) that could fit the parts we wanted to cut out.
- 0.25" thick core was chosen over the 0.125" to be on the safer side.
- After measuring out what could theoretically fit on the core available, 2 slightly oversized sheets of fiberglass weave were cut out.

Prepping the work surface

- A large sheet of polycarbonate was cleaned with alcohol and wiped down.
- Then waxed smooth and let dry (this is to not allow the glass to cure and stick onto the polycarb

Layup

- One layer of glass placed down onto the polycarb and wetted out with the mix of resin and hardener.
- Squeegees were used to evenly spread the resin all over and into the fiberglass.
- The next layer was put on top and then wetted out similarly.

Curing

- We had two methods for this next step:
  1. Peel ply then some large plate (could be wood even) to distribute the weight

2. Another clean waxed piece of polycarb

- Either way, a large weight was placed over it, making sure to get any air bubble out before.
  - This is not the best method for this, that would be vacuum bagging with peel ply and breather (ask aero or structures)
- Then it was left for 24-48 hours to fully cure.

Other Side

- The steps above were repeated for the other laminate
- Then one laminate was covered in a thin film of [ea 9430] using squeegees and the core was placed onto it and pushed down for full contact and to remove any air bubbles. Then the next laminate was similarly coated and placed, adhesive side down, onto the core and any air bubbles were pushed out.
- Then it was weighed down in a similar manner to when the laminate were curing.

Water Jet (WJ)

- After the panel was fully cured we water jet at MAE C and let the cut out parts and let fully dry at the lowest temperature a home oven could go for 15 minutes.

Assembly

- After all the sides and bottom were WJ they were assembled at their box joints (after being sanded — for roughness — and cleaned) with ea 9430 and filler (to make the adhesive easier to work with).
  - We did not take into account the radius of the water jet to there were small fillets that did not allow the box joints to fully join. Take that into account next time.
- After the joints were all joined together, a thicker mixture of the ea and filler was used to fillet the edges inside.
- This was repeated for the lips and we had been running low on ea so we used regular epoxy.
- The lid was manufactured the same exact way just out of thinner core.
- 3D printed alignment guides were glued onto the lips to help in placement and securing of the lid. No latch design was needed since chassis would constrain the pack sufficiently in that vertical direction.
- For the straps, we used epoxy to stick them to the bottom of the pack.

Integration with Chassis

- The box was sanded and scraped down for any extra glue or adhesive and chamfers were sanded on all the edges to allow for easy insertion into chassis.
- The box was then placed inside chassis and cutouts on either side were made with an angle grinder.
- One side for battery pack to be slid in, the other side not large enough to let battery box slid out but enough to let someone push the box or pull the straps to make it easier to

place within the car.
- Pin and grommet fasteners mounted on brackets will prevent battpack from sliding out the way it came in, and the other side is constrained by chassis itself.
- Same with the other 2 degrees of freedom, there are other chassis panels that prevent battpack from translating in those directions.

Modules

- The modules has 3 main aspects to manufacture/assemble:
  1. Cell assembly
  2. Waterjet (copper/HDPE)
  3. Module 3D printing
- The 3D printing proved to be the most time consuming considering it was not in our control.

Cells

- We originally wanted to test all the cells, but after realizing we started way too late to realistically finish and finding that our variation was barely 50 mAh over the error of the cell testers, we decided to just spotweld the cells.
- Spotwelding took no more than 15 hours in total.

Waterjet

- The copper was one of the first things to be manufactured.
- Waterjet at MAE C then bent at the SDC
- Next was the cell spacers from HDPE (much longer process because of all the holes)
  - Used 2 different HDPE sheets, the thicker (0.25") was much stiffer and nicer to hold the cells in.
- For the spacers, we tested different diameters around the nominal diameter of the cell to see which fit the way we wanted before fully WJ an actual spacer. More testing to see how the federate affected the tolerancing might have been beneficial.

3D Printing

- We sent the prints to Rapid Proto (because they have a large enough printer for what we needed to print) and it took significantly longer than expected (especially in between the spring and summer semesters).
- The prototypes we did receive bent more easily than we would have liked which could have introduced failure points where the copper was not in contact with he nickel at some points because of the bending.
- We implemented 2 solutions:
  - Struts WJ from HDPE that distributed the load of 2 screws along the width of the modules

    - 3D printed rods to prevent the flanges from flexing downwards.
- This added a couple extra layers of protection to a very critical part of the assembly
    - But it would definitely be worth considering stiffer materials (Delrin?) and possibly manufacturing using other methods than 3d printing to allow us to dictate our own timelines.

Electrical Components & Assembly

Car 5 Considerations

- The biggest obstacle when manufacturing was the time it took to 3D print the modules and rails with rapid proto, we even sent it to Jeff's lab as well but in the future, it might be worth finding other manufacturing methods. Considering the size and the importance of the modules to the functionality of the pack, manufacturing using a non-prototyping method and material. One idea is to CNC the modules out of Delrin or some other hard plastic to avoid issues of bending we had with the 3D printed ASA. This would also introduce another manufacturing technique that members would greatly benefit from gaining experience in.
- Another manufacturing consideration is the time it took to make the fiberglass sandwich panels for the box. Vacuum bagging seemed to be more time upfront but it may have allowed us to do multiple panels side by side.
- Tolerancing should have been more of a priority and thought out fully. Including tolerancing within chassis, holes for the flanges in the modules as well as the voltage tap holes. Also the radius of the WJ wasn't accounted for in the box joints. Things like that have to be double checked.
- Overall, timeline should have been sped up. It would have been nice to give electrical months to test on an actual pack instead of weeks. Design, barring any unforeseen design overhauls, should be finished by the spring of the first year in the cycle. Summer should be for finalizing any small design features. And fall should be all out manufacturing. By winter break ideally, module prototypes should be printed and enough cells spotwelded to check functionality of the design. Box manufacturing should have at least begun if not finished entirely. Then in spring, ideally within a month or two, battery pack should be fully assembled, giving electrical 3+ months to fully test their architecture. *Do not underestimate how long things actually take.* If you can do something, do it. Don't wait around.

Post Comp 25' Considerations

This is a short summary of some issues we found needed addressing after Comp 2025 and how we plan on fixing them next year.

Cells

- Cells might have gotten too hot — could be bad thermistors, but either way the thermistor data shows a clear upward trend, meaning we ran hotter than we'd like
- Tim pointed out we're drawing a much higher percentage of the discharge rating than before
- Might be worth switching to cells with higher continuous discharge ratings

Conclusion:

- 8p36s configuration with molicel p50b best for longevity of future packs. This way there is no need to change s,p configuration considering extremely high discharge current and max voltage of MC.
- Re-test thermistors to confirm accuracy or buy new ones

Second Story

- Some boards have odd bases and inconsistent enclosures
- We should work with electrical to design one proper enclosure that fits everything
- This would let us move the battery pack contactors up to the second story
- Would also free up more space for better cell layout, leaving only fuse with the cells
- Cleaner wire harnessing becomes easier with one shared structure

Conclusion:

- Make the electrical assembly plate/box easily removable
- Ask electrical for a full wiring schematic of the assembly to plan out wiring harnessing

Module Design

- Module compression needs to be more reliable — more screws or better retention
- Thermistors need defined placement, possibly inside the cell holders
- Make voltage taps more accessible
- Improve general wiring management
- Maybe include wire clips in railing design
- Use Amphenol connectors to avoid relying on direct busbar connections
- Machine modules from Delrin for higher flexural modulus

Testing

- Plan timeline to include testing for next year. We don't want to be assembling the modules for the first time during June
- Get full discharge/charge curves to better estimate SOC starting on current pack and ideally on next pack before ASC 2026
- Get a better cell tester to fully characterize next cells

Spotwelding Instructions

The following document serves as a guide to using the U.S. Solid USS-BSW00005 Battery Spot Welder to spot weld nickel strips to cells. Although this SOP is written for this specific model, the information can also apply as general spot-welding guidelines for many small spot welder models.

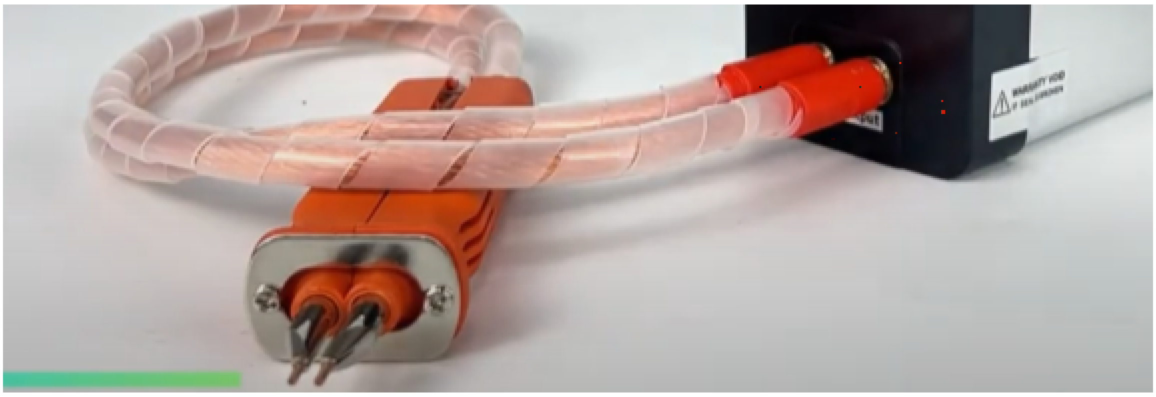
Setup

Remove the welding machine, the power supply adapter, the welding pen, and the foot pedal from the box. Plug in the power adapter and the foot pedal on the back right side of the machine and plug the power supply into an outlet. Place the foot pedal on a comfortable spot for your foot to press down on the floor.

In order to activate the machine into manual welding mode (MT), ensure the machine is off (if not press both the up and down arrows on the front simultaneously) and press and hold down the foot pedal. While holding it down, press the up and down arrow buttons on the front of the machine to turn it on, and once the screen turns on, step off of the pedal. Ensure that MT appears at the [illegible] ide of the screen, indicating that the machine is in manual

The manual welding mode with the foot pedal is recommended, although if you wish to use the automatic welding mode, please read the manual.

With the machine now on, plug in the two welding pen connectors into the circular ports on the front of the device marked “Pulse Output”. You may have to make sure the connectors are properly aligned with the ports and push them in quite hard, as the fit is tight. It does not matter which connector is inserted into each port.



Spot Welding

When spot welding, there are three main factors to take into consideration to produce a good weld:

- Power
- Time
- Pressure

Material	Thickness	Surface	Power Grade
pure nickel	0.05 mm	stainless steel	15-20 t
pure nickel	0.1 mm	stainless steel	30-35 t
pure nickel	0.15 mm	stainless steel	60-65 t
pure nickel	0.2 mm	stainless steel	85-90 t
nickel-plated steel	0.05 mm	stainless steel	5-10 t
nickel-plated steel	0.1 mm	stainless steel	20-25 t
nickel-plated steel	0.15 mm	stainless steel	50-55 t
nickel-plated steel	0.2 mm	stainless steel	75-80 t

- (We found that raising the weld time about 10 t more than the provided table values works well to create a stronger weld with minimal sparks and damage.)

When ready to spot weld, refer to the following steps:

1. Before Spotwelding, measure the voltage of the cells and make sure they are the same to the tenths place. Putting cells that have wildly different voltages in parallel could be catastrophic.

2. Align cells within spacer in the configuration that you wish for them to be welded in, ensuring that the terminal ends of all cells are parallel and flush to each other.

3. Take a nickel strip and cut it to a length that is slightly shorter than the total length of the row of cells you wish to weld together, ensuring that nickel is not hanging off the edges of the end cells.

4. Properly align the nickel strip on top of the row of cells so that each cell is making even and symmetrical contact with the strip.

5. Ensure that the “CH” indicator (charging) is not present on the machine screen and that the voltage is reading at least 5.4 V.

6. Grab the welding pen and hold down the nickel strip in the set position while placing the two welding pins on the strip at a spot on the center of the first cell you wish to weld.

    - If you are welding a long strip that contacts more than two cells in a row, it is recommended that the first cell that you weld is one at the center of the strip, making it easier to align the strip with the rest of the cells.

7. With a spot chosen and contact made, ensure that the two pins of the pen are making le vel and even contact, and that the pen is aligned as perpendicular as possible to the strip.

8. While keeping the pen as level as possible, push down and apply pressure onto the strip with the pen until a click is heard and felt within the pen. Apply a small amount of extra pressure after.

    - Generally, the more pressure that is used, the better the weld, but ensure to not apply so much pressure that the material is completely pierced through, which could damage the cell.

- 

9. When ready, press down on the foot pedal to weld.

10. During the welding, pay attention to any sparks that fly out and what direction they fly in.

    - If there is an exaggerated volume of sparks, you may have set the pulse time too high, or you may not be applying enough pressure.

    - If there is a small amount of sparks, the pressure you applied may have been slightly unlevel or uneven between the two pins. The direction in which the sparks flew generally indicates the direction you want to lean the pen slightly towards to account for this and reduce sparks.

    - Less sparks generally indicates a higher quality weld.

11. After the welding is done, continue to hold down the pen and apply pressure for about 1-2 seconds, which allows the weld to remain compressed as it begins to cool.

12. Ensure that the voltage has recharged to at least 5.4 V and repeat steps 6-10 for the same cell but with the pins of the pen aligned to be perpendicular with the weld just done on the same cell, creating a “cross” weld pattern.

13. Ensure that pins are clean (if not, clean with abrasive pad) and that voltage is recharged to at least 5.4V before repeating these steps on the other cells.

14. When finished spotwelding, make sure to store cells in a place where their terminals cannot touch any metal or other cells as this could cause a short and lead to fire.

Water-Jet Instructions (MAE C)

The following document is for setting up a file for Water jetting (WJ) at MAE C.

Jeff's Lab

To send a file to be WJ you could also go through Jeff Bielling (the HWLEE Lab) by following these instructions: Waterjet Software Instructions.docx.

All HWLEE Prototype Shop Requests

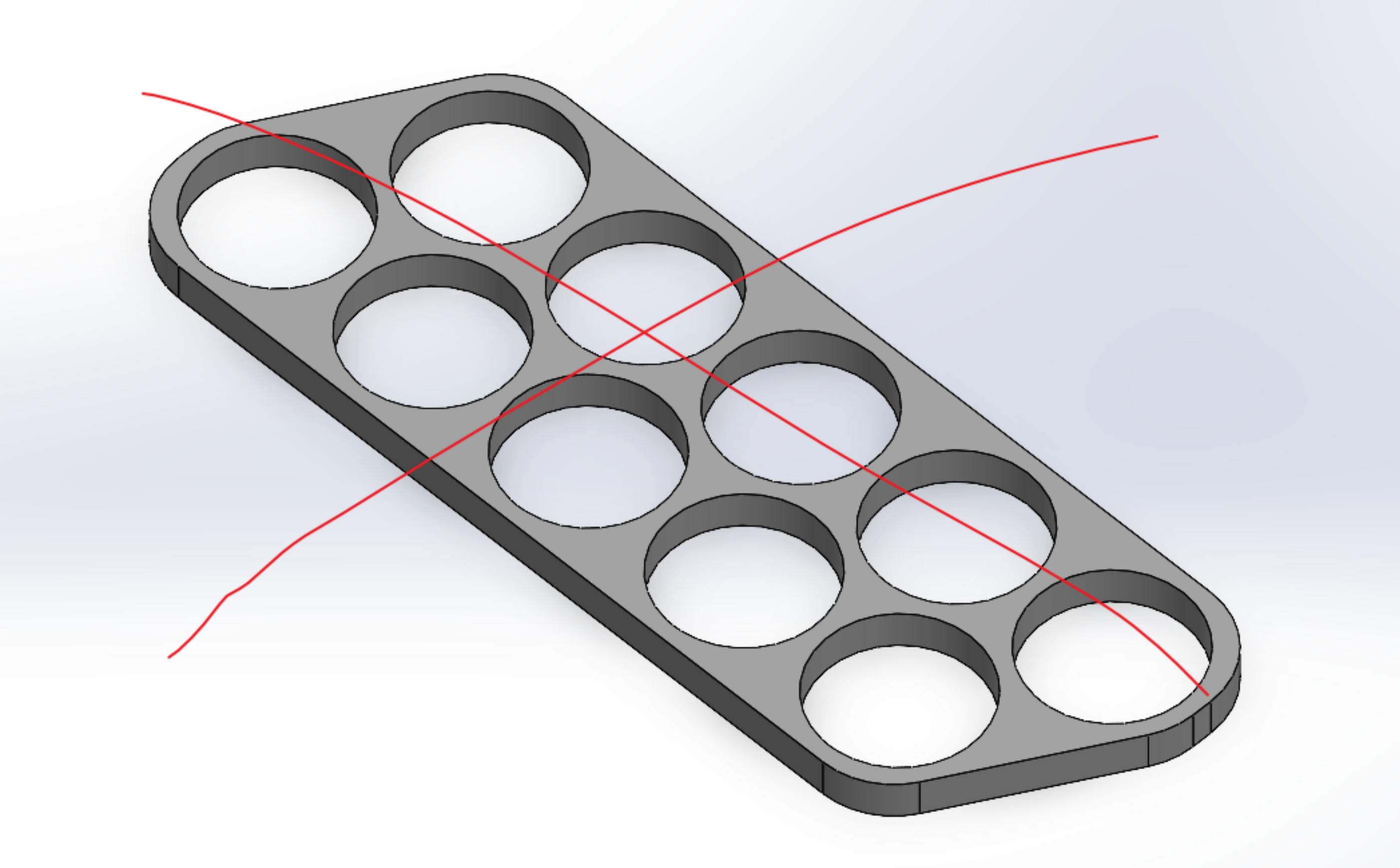
- https://uflorida.sharepoint.com/teams/ENGHWLEELab/Lists/Shop%20Usage%20Requests/Default.aspx?env=WebViewList
- Hours of Operation: Monday-Friday 7:30am – 4:00pm closed 12-1 for lunch
- HWLEE Prototype labs are dedicated to HWCOE students and faculty for research or class assignments only, no private projects are accepted
- Requests need at least 3 days prior notice for approval on a first come first served basis
- All Machine Shop Equipment requests must have attached a screenshot of requesters Official UF transcript with name & UFID verifying successful completion of EML2322L (no exceptions) before approval
- No sandals, shorts, jewelry, long sleeves or long hair of a length that could potentially be caught in machinery must be securely tied back as to not fall forward to avoid being caught in machinery moving parts
- All Waterjet requests must have DXF (top view/pane) attached to the request for review, raw material margins need to be at minimum ½" for clamping
- Material dimensions (LxWxT) need to be included in the notes section of the request for the waterjet. Operating Software recognizes in inches if mm is desired, please specify for conversion factoring
- All Waterjet requests other than metal, wood and polycarbonate material must have MSDS attached to verify potential safety hazards
- Metal 3D (Additive Manufacturing) print requests require funding chartfield information from your department AD to cover material costs only
- FDM print requests will be capped at $150 total per student or $300 student team organization per calendar year
- No food or drink are allowed in any of the PT labs

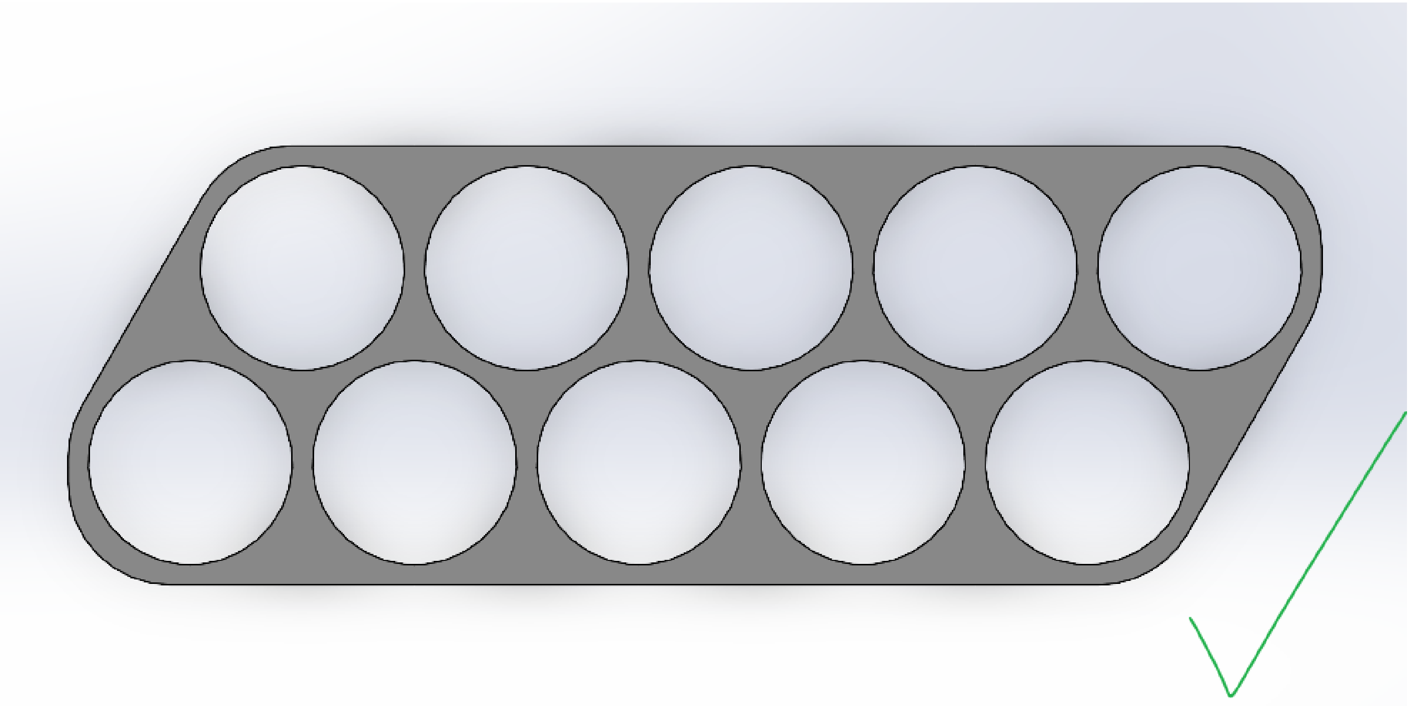
MAE C

The main difference between this document and the one linked above is that you do most of the work at the machine in MAE C. Shown below is how to set up the .dxf.

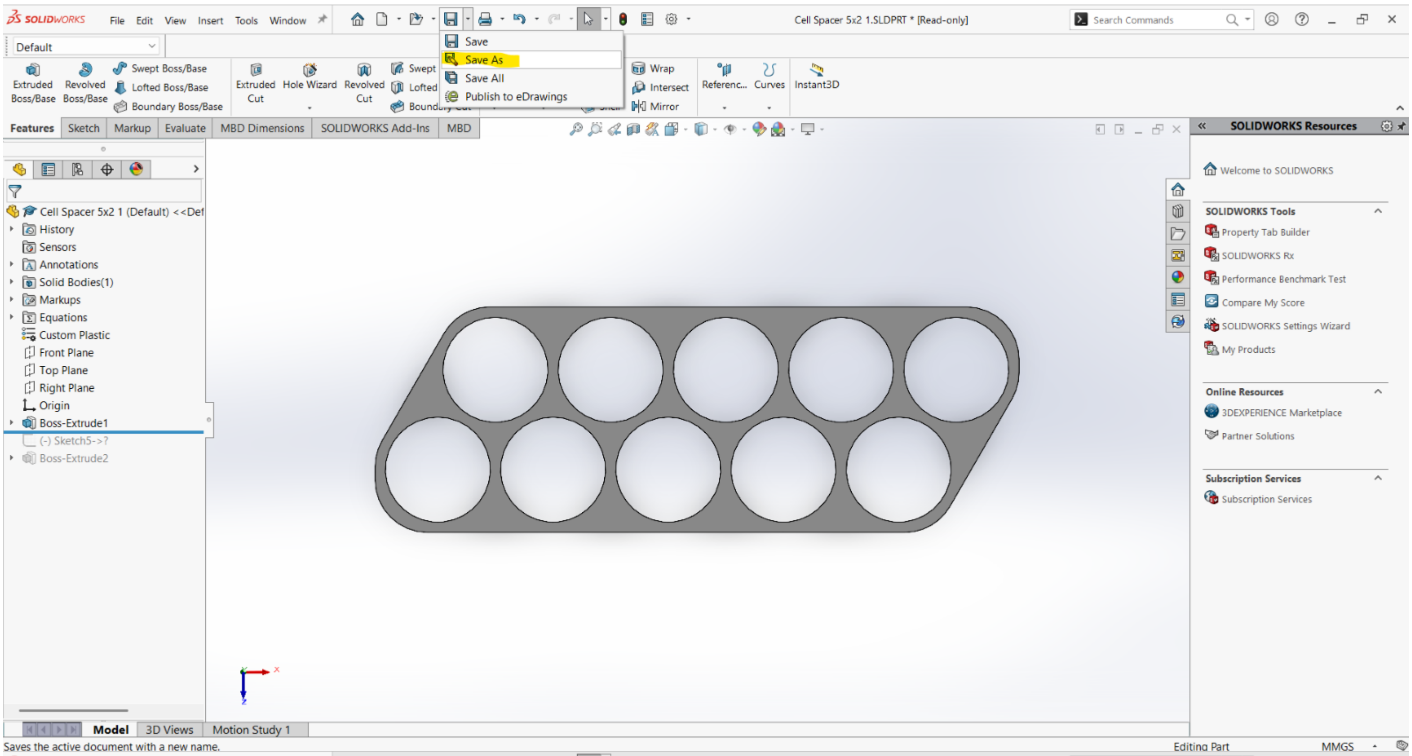
Step by Step

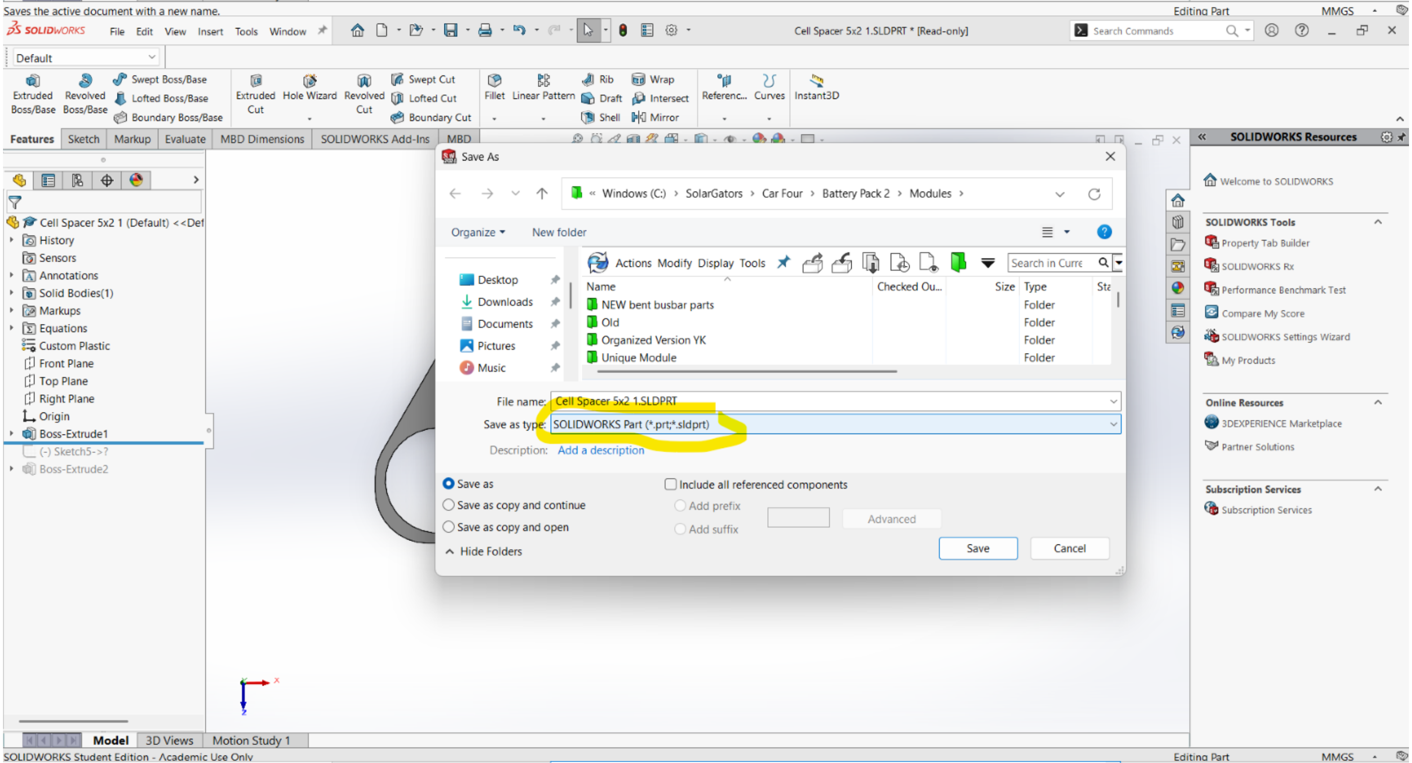
First open the file you want to WJ in SolidWorks and look normal to the face you would like to WJ. Remember the WJ can only cut out 2D contours.

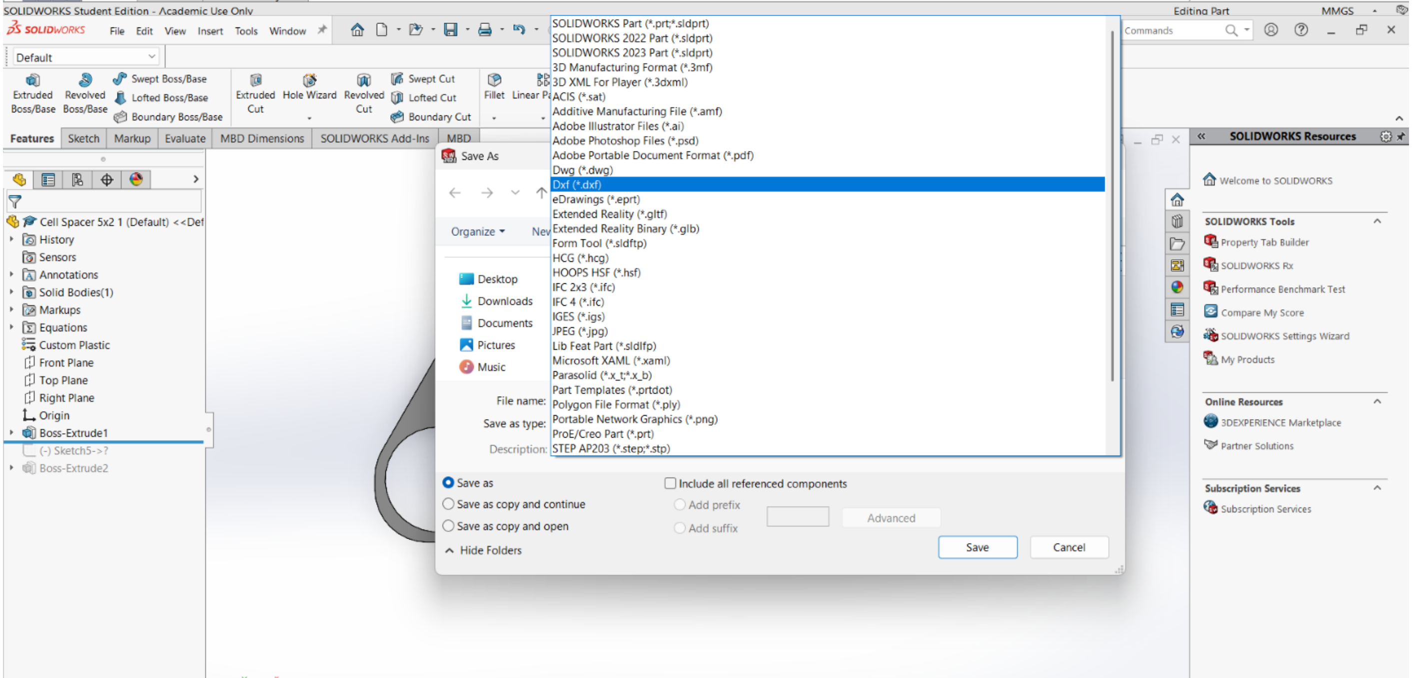




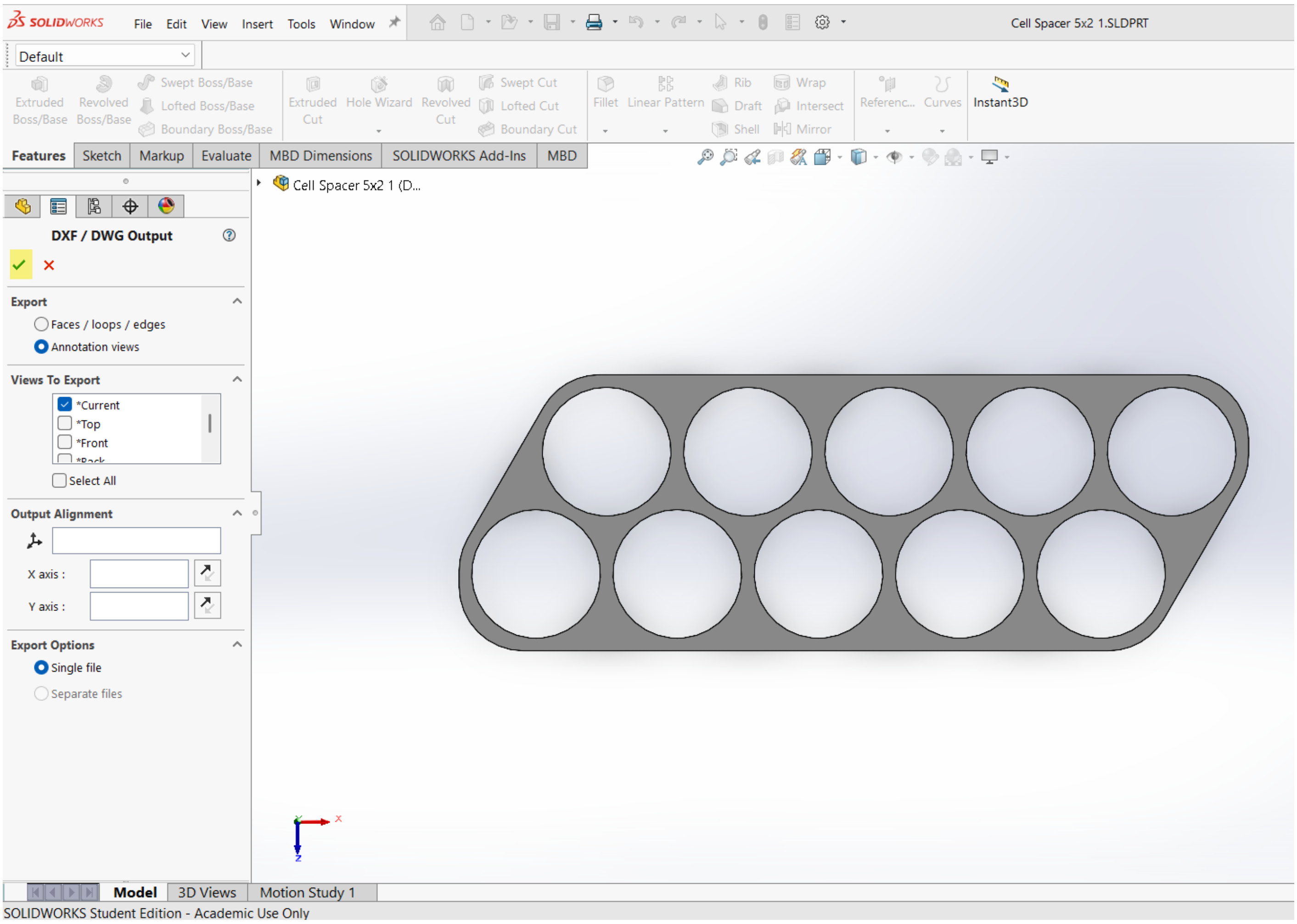
Then go to “Save As”


Cell Spacer 5x2 1.SLDPRT * [Read-only]
Save
Save As
Save All
Publish to eDrawings
Cell Spacer 5x2 1 (Default) <<Def
History
Sensors
Annotations
Solid Bodies(1)
Markups
Equations
Custom Plastic
Front Plane
Top Plane
Right Plane
Origin
Boss-Extrude1
Boss-Extrude2
SOLIDWORKS Resources
Saves the active document with a new name.
Editing Part
MMGS

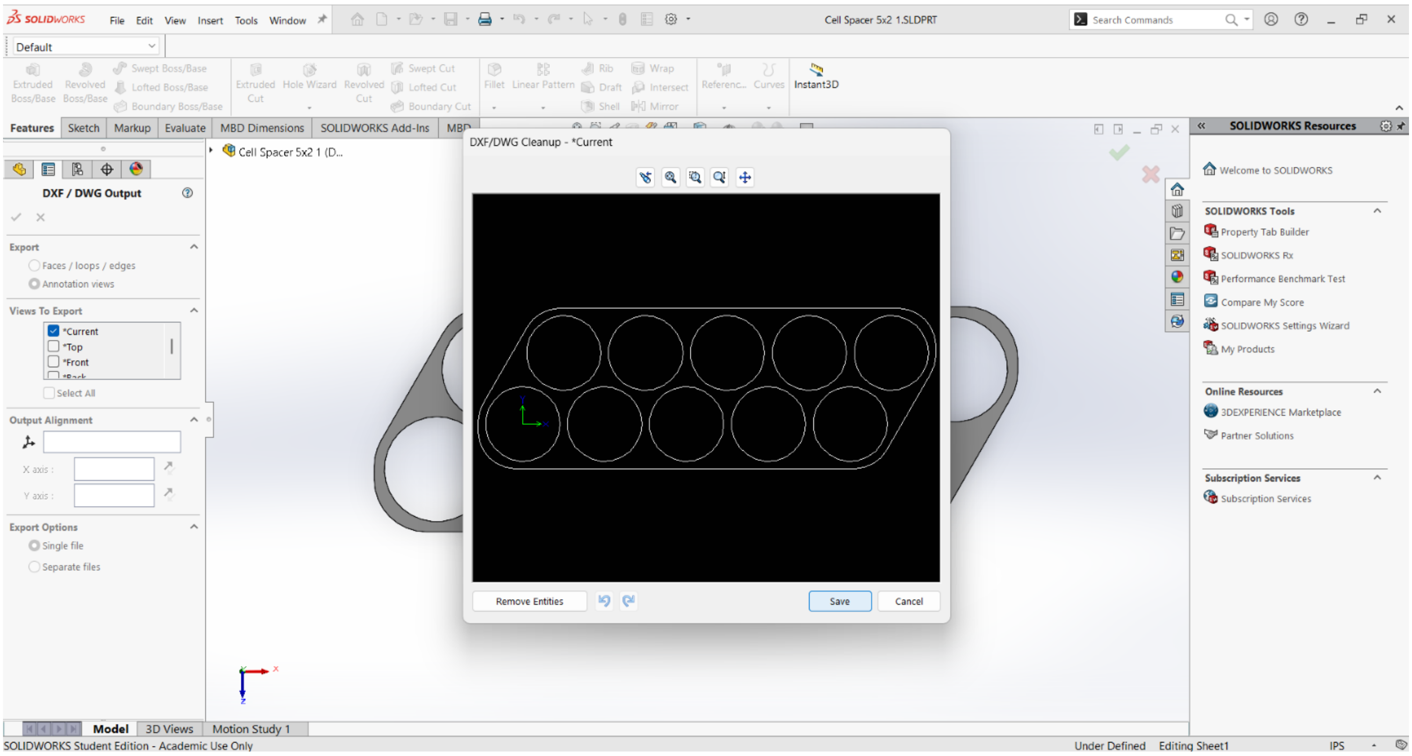

Save As
Windows (C:) › SolarGators › Car Four › Battery Pack 2 › Modules ›
Organize
New folder
Name
NEW bent busbar parts
Old
Organized Version YK
Unique Module
File name: Cell Spacer 5x2 1.SLDPRT
Save as type: SOLIDWORKS Part (*.prt;*.sldprt)
Description: Add a description
Save as
Save as copy and continue
Save as copy and open
Include all referenced components
Add prefix
Add suffix
Advanced
Save
Cancel
Hide Folders
SOLIDWORKS Student Edition - Academic Use Only


SOLIDWORKS Part (*.prt;*.sldprt)
SOLIDWORKS 2022 Part (*.sldprt)
SOLIDWORKS 2023 Part (*.sldprt)
3D Manufacturing Format (*.3mf)
3D XML For Player (*.3dxml)
ACIS (*.sat)
Additive Manufacturing File (*.amf)
Adobe Illustrator Files (*.ai)
Adobe Photoshop Files (*.psd)
Adobe Portable Document Format (*.pdf)
Dwg (*.dwg)
Dxf (*.dxf)
eDrawings (*.eprt)
Extended Reality (*.gltf)
Extended Reality Binary (*.glb)
Form Tool (*.sldftp)
HCG (*.hcg)
HOOPS HSF (*.hsf)
IFC 2x3 (*.ifc)
IFC 4 (*.ifc)
IGES (*.igs)
JPEG (*.jpg)
Lib Feat Part (*.sldlfp)
Microsoft XAML (*.xaml)
Parasolid (*.x_t;*.x_b)
Part Templates (*.prtdot)
Polygon File Format (*.ply)
Portable Network Graphics (*.png)
ProE/Creo Part (*.prt)
STEP AP203 (*.step;*.stp)

Save as a .dxf



Click the checkmark. Here you can also change your orientation, but you should not need to if you were already looking normal to the face you want to WJ.



Now click ”Save”. Here you can ”remove entities” if there is any text or lines you do not wish to cut. The origin does not need to be removed. To double check that the dxf looks how you intended, use the Omax software (download link in the WJ software instructions) to do so.

Now that you have saved the dxf, it is ready to be placed onto a USB drive and taken to MAE C to WJ. Follow the linked guide at the very top to see how.

Unique Sheets or Multiple Parts with Protomax

You can also use the software to place multiple parts onto a unique sheet to save space instead of using the FlowNest software at MAE C. Although the FlowNEST at the WJ is good for many parts, its programming for optimizing the space does not always seem the most efficient. So, shown below is how you can do the same process but on your own before going to MAE C.