Ball Clamp Foot Restraint

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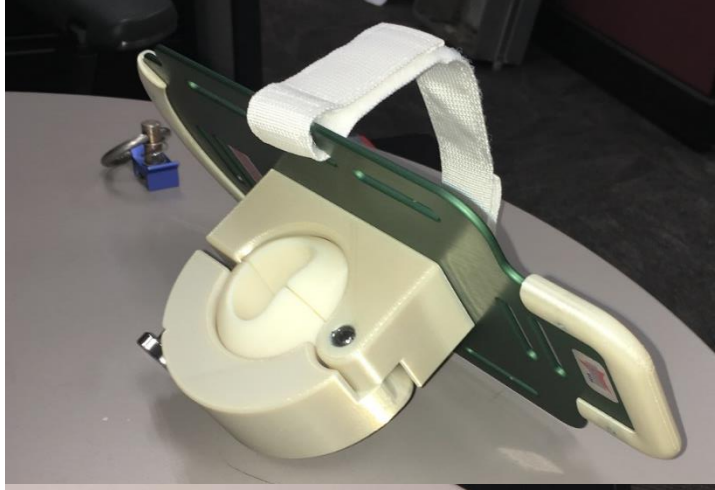
Design School: Cypress Woods H.S. Texas
Kieffer Krist, Ian Kapp, Daniel Hines, Owen Theeck, Andrew Coulson, Logan Sammons
Machining School: Austin H.S. Alabama
Jake Mitchell, Colton Sandlin
Advanced Manufacturing/3D printing Schools: Grissom H.S., Jemison H.S. Alabama
Camryn Smith, Brandon Campos, John Rodgers, Nathaniel Fenn,Nathan Eckenrode, Ashley Kimbel, Chella Rossel, Michael Sorrell, Mattthew Mayes, Jaden Smith, Niceson Ejem
Teachers: Mike Bennett, Bill Gibson, Kyle Brakke, Chris Faust
Mentors: Glenn Johnson, Alli Westover, Bob Zeek, Lee Hanson, Marcie Dickson, Roy Bellard, Carlos Valencia, George Kessler
Engineers: Bruce Blazine, Tom Marshburn



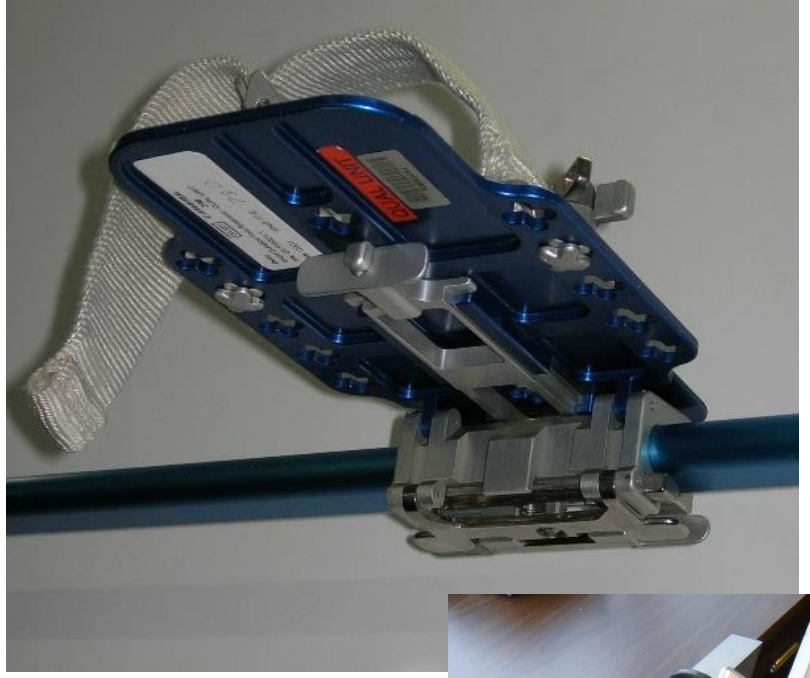
The Ball Clamp Foot Restraint is a variable, friction based restraint that attaches to a Space Station handrail and is designed to allow a crew member's foot to pivot and swivel several degrees. The clamp can be tightened to increase the friction on the ball, making the restraint more rigid or less rigid by loosening. This will be one of very few friction based restraints to fly.

Problem:

When astronauts work all day at a location on the ISS using the current Short Duration Foot Restraints, they sometimes get knee pains. The main difficulty is that the foot restraints are very rigid and don't allow for swiveling between the laptop and the experiment near by.

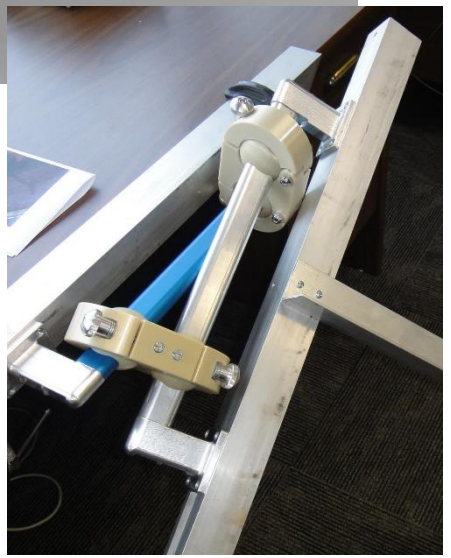
One day while working on the Double Ball Clamp for restraining the Galley Table, Astronaut Tom Marshburn asked if the Double Ball Clamp could be modified into a foot restraint that would allow for swiveling.

Students worked with NASA mentors, engineers and astronauts to come up with a new foot restraint to satisfy their needs.



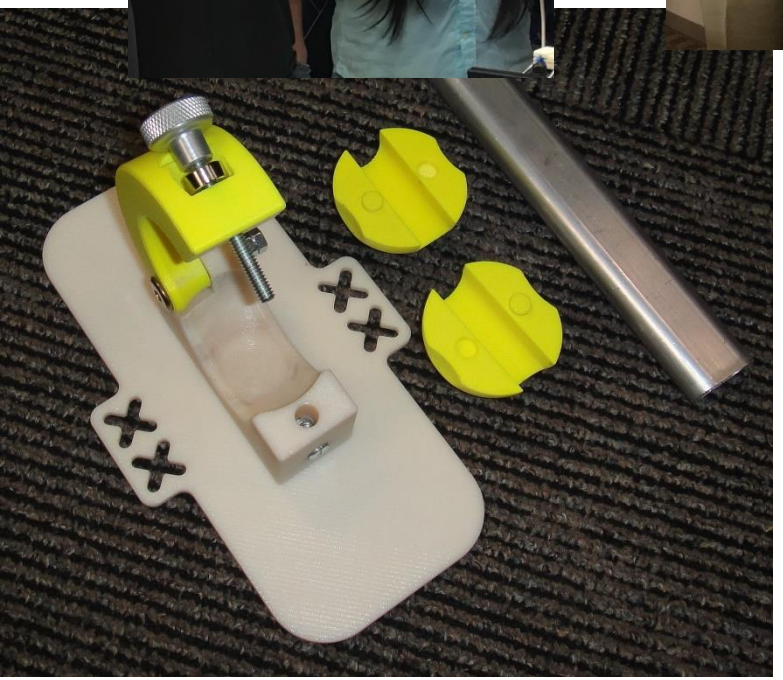
Short Duration Foot Restraint has 2 perpendicular configurations but no swiveling or pivoting capability.

Double Ball Clamp



Two Double Ball Clamps showing swivel capability between the handrail attached to something solid (table) and the second handrail that would represent the Galley Table.

Design team



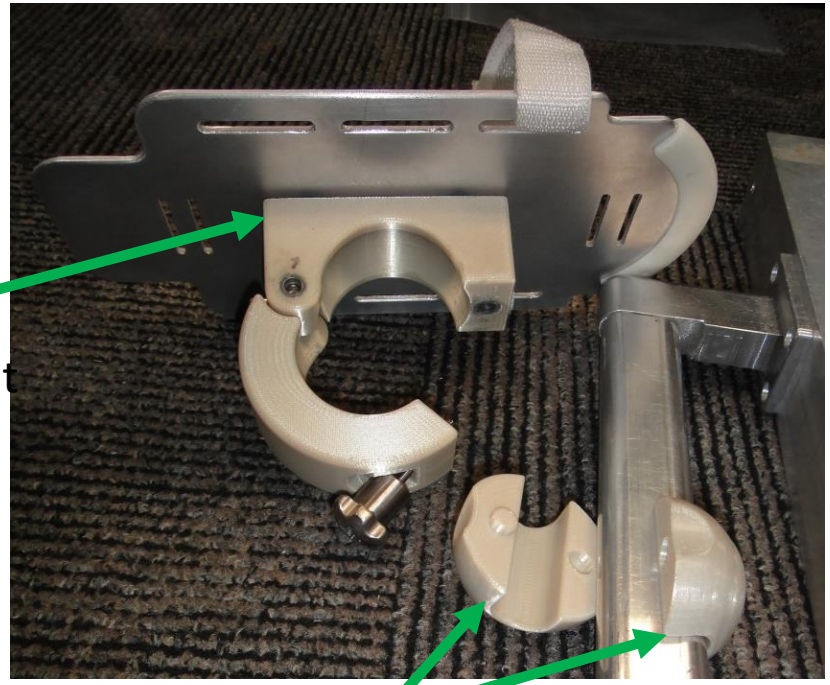
Initially the foot plate and the ball clamp were all one printed piece and the foot straps were the same as those on the original foot restraints.

- The design team started with work that was done with the Double Ball Clamp and then went through many iterations of the ball hemispheres, the ball clamps and the foot restraints before coming up with the final design. One of the many great ideas was to make the ball clamp and the foot plate separate. This allows the ball clamp to be its own component that could be placed on any other device or hardware. All of this work on the ball clamp also helped improve the design of the Double Ball Clamp.

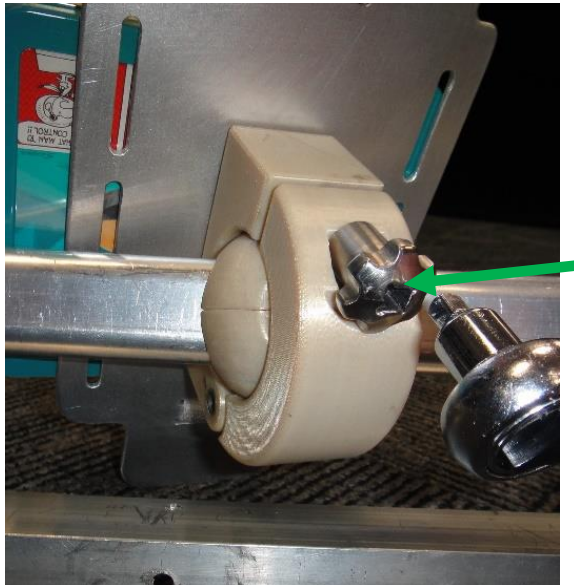
Functionality

- Ball Clamp Foot Restraints are made of certified ULTEM plastic from a 3D printer with stainless steel shoulder bolts, inserts, thumbscrew, an aluminum foot plate with a nomex and Velcro foot strap.
- Each Ball Clamp Foot Restraint is composed of 4 pieces: a Ball Clamp with attached Foot Plate bolted into place, 2 identical half spheres that are removable and a foot strap that is also removable.
- Two identical Ball Hemispheres attach around a handrail and are the bearing surface for the clamps to rotate around. (Ball Hemispheres stay together by friction fit on or off the handrail)
- The clamp can rotate about 90 degrees around an attached handrail The tightness of the thumbscrew determines the amount of friction applied to the ball. Tighter= more friction
- The thumbscrew is intended to be tightened by hand but if too tight by one person, another person can use a 1/4" wrench to loosen. (it could also be tightened by wrench if needed)
- The stainless steel Thumb screw is captive to the clamp by way of threaded inserts in the arm of the clamp

Ball Clamp Foot Restraint with balls being positioned on handrail for attachment



Friction holds ball onto handrail but can be removed easily

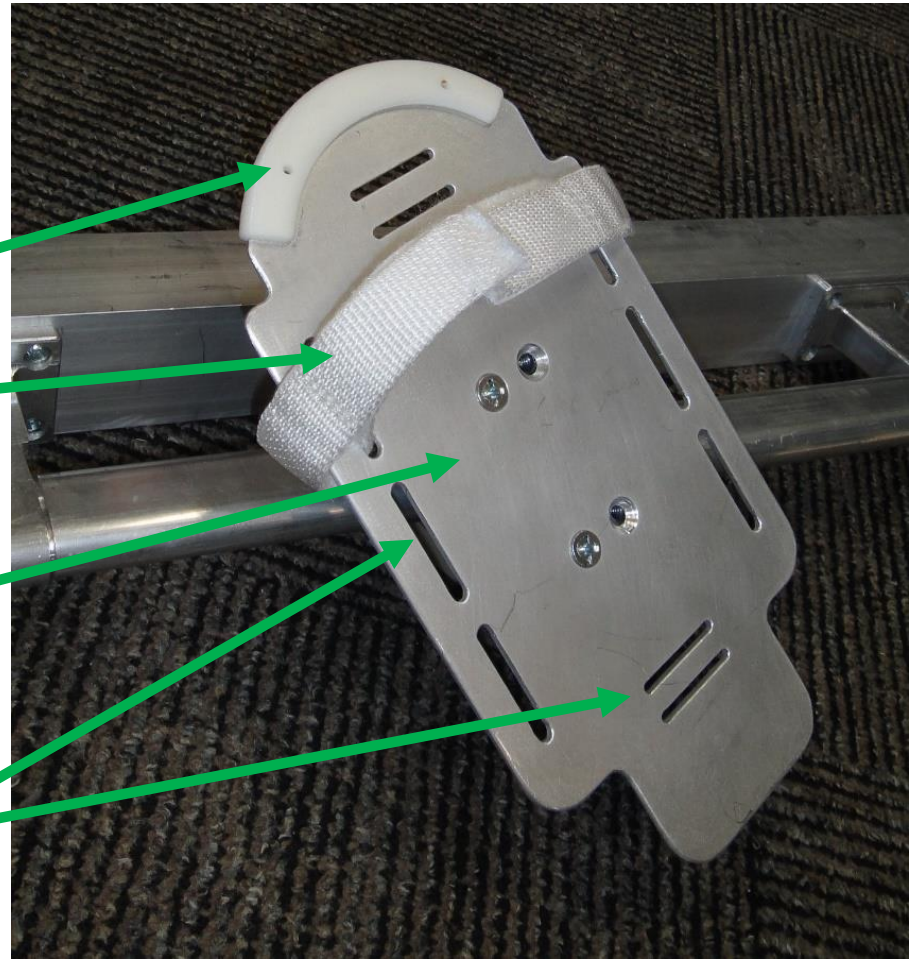


Thumbscrew includes built in socket for ¼" tool.

Features

Allows for about:

- 35 degrees of yaw
- 90 degrees of pitch
- 20 degrees of roll



Upgrades for flight unit:

- All the strap holes will be the larger size.
- Green anodized foot plate
- Add a Toe Grip on the smaller side of the plate

Multiple positions for the straps allows for variable placement of the restraint to fit the need, foot, and location. This is similar to the current Short Duration Foot Restraint but the Ball Clamp Foot Restraint allows for pivoting for comfort or improved positioning.

Repositioned Foot Strap

If used for hardware or experiments (like the ISS experiment BCAT or Snoopy lunch boxes) pivoting allows for repositioning to fit the location or getting it out of the way quickly.

Machining, polishing and checking thumb screws

After machining and electro polishing these parts, they are dipped in an acid bath to remove any foreign materials that may be left on the surface from the machining process. Event though they are made of stainless steel, the foreign particles can cause corrosion if they are not removed.

Printing Ball Clamp and toe grips

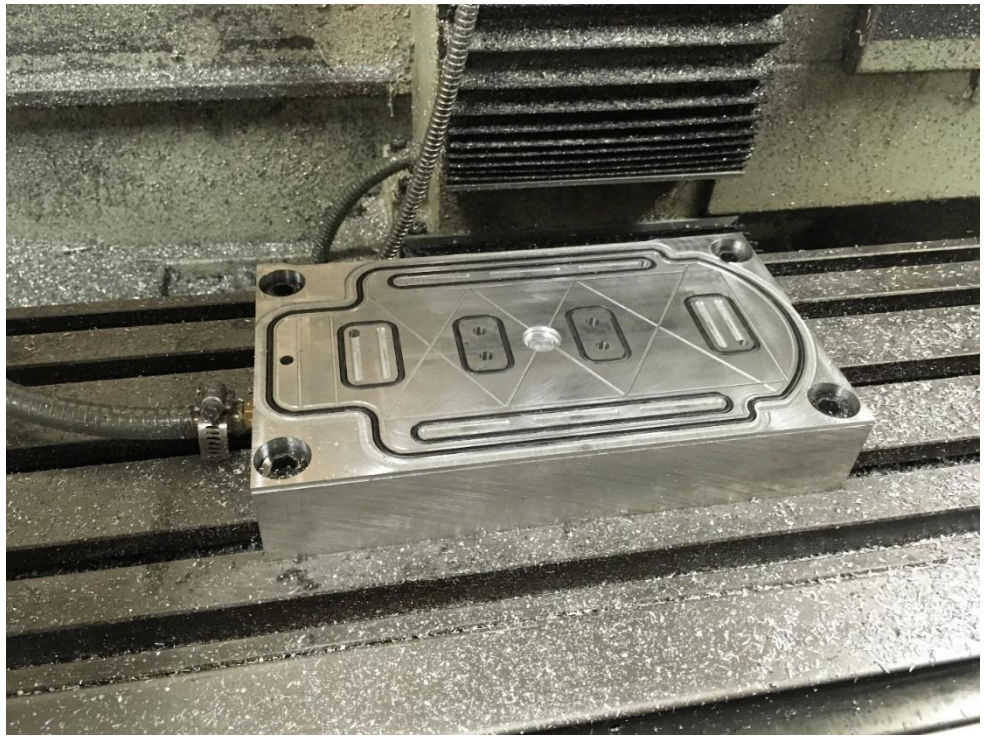
Determining the best print orientation to get the best quality.

High temperatures

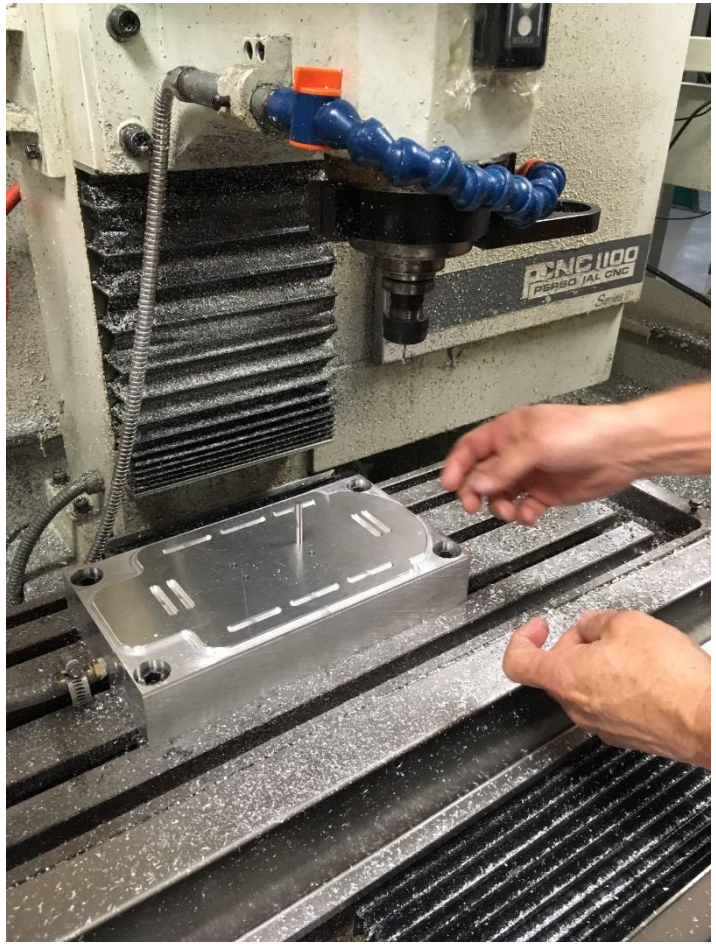
Cleaning support material off is time consuming but critical for obtaining high quality printed

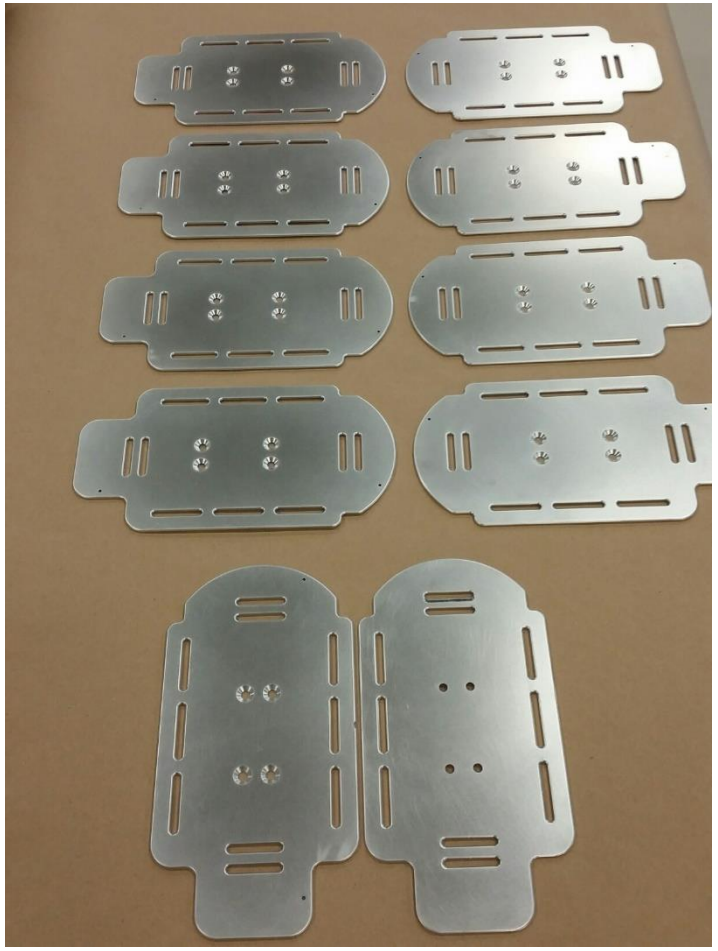
Printed ULTEM parts for flight.

Machining foot plate



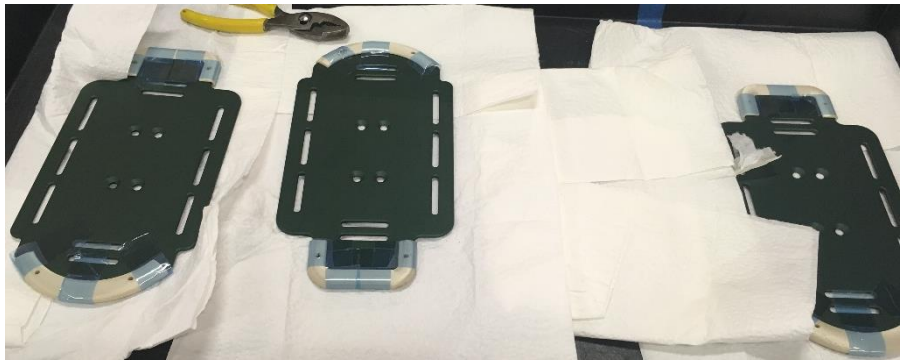
Vacuum plate that had to be built for holding foot plate while milling holes and rounding edges. Notice the gasket material used to retain the vacuum on the majority of the plate while drilling holes in the middle of the plate.





Although the foot plate seems like a simple part, all of the edges have to be machined for the proper radius. Roy Bellard is HUNCH's master machinist utilizing several techniques to hold the flat plate while machining each side.

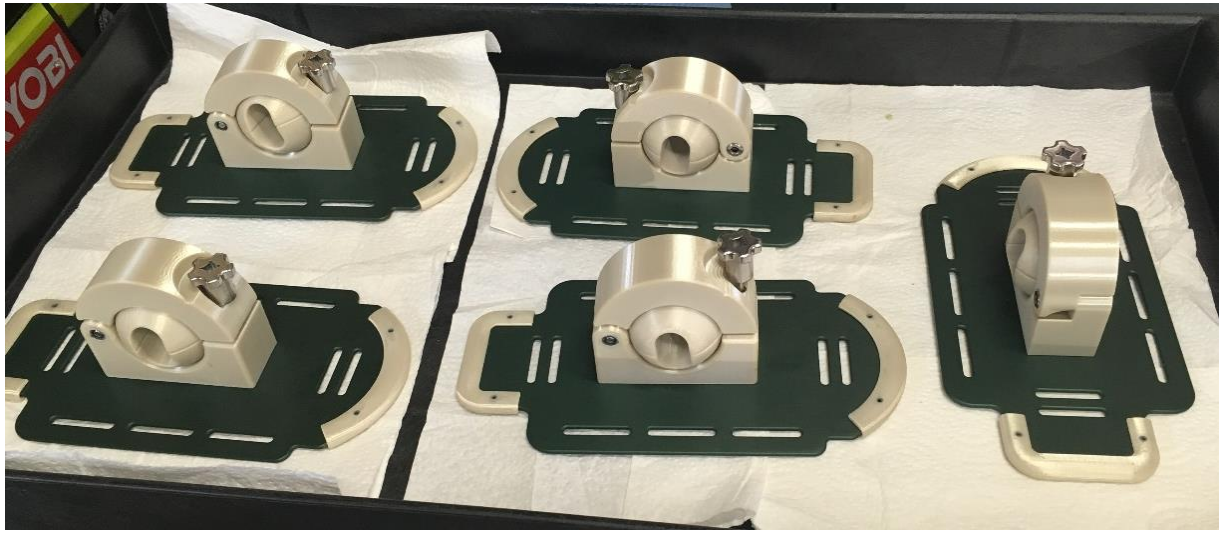
Finalizing the build



Anodizing is a surface coating to protect the aluminum from oxidation and is done by Turn Key Coatings. Anodizing can be done in many colors and adds a few thousandths of an inch thickness to metal which can be very important when dealing with high precision parts. These foot plates received a hard coat and anodized green to match the HUNCH Galley Table.

Some of the final assembly includes match drilling holes for the roll pins to hold the toe grips. Carlos Valencia is the HUNCH master assembler who is responsible for the final assembly of most of our flight hardware.

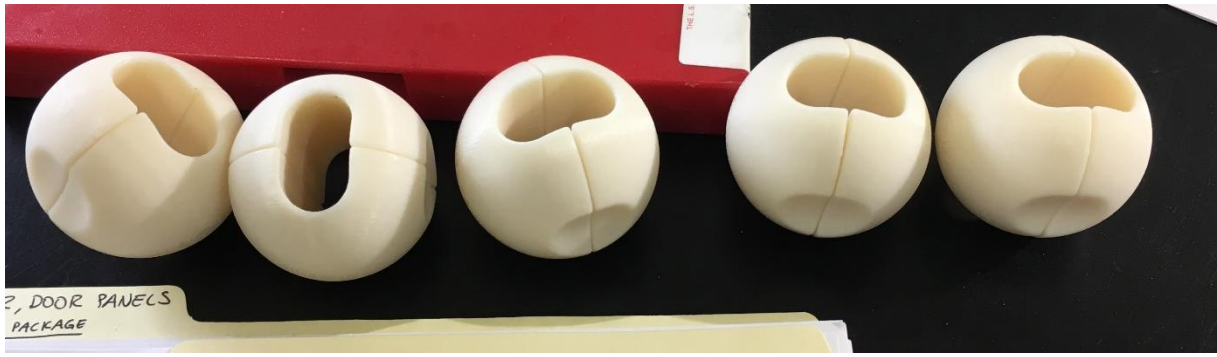
Four of these will fly to the ISS and the fifth will be used as a trainer in B9 at JSC.



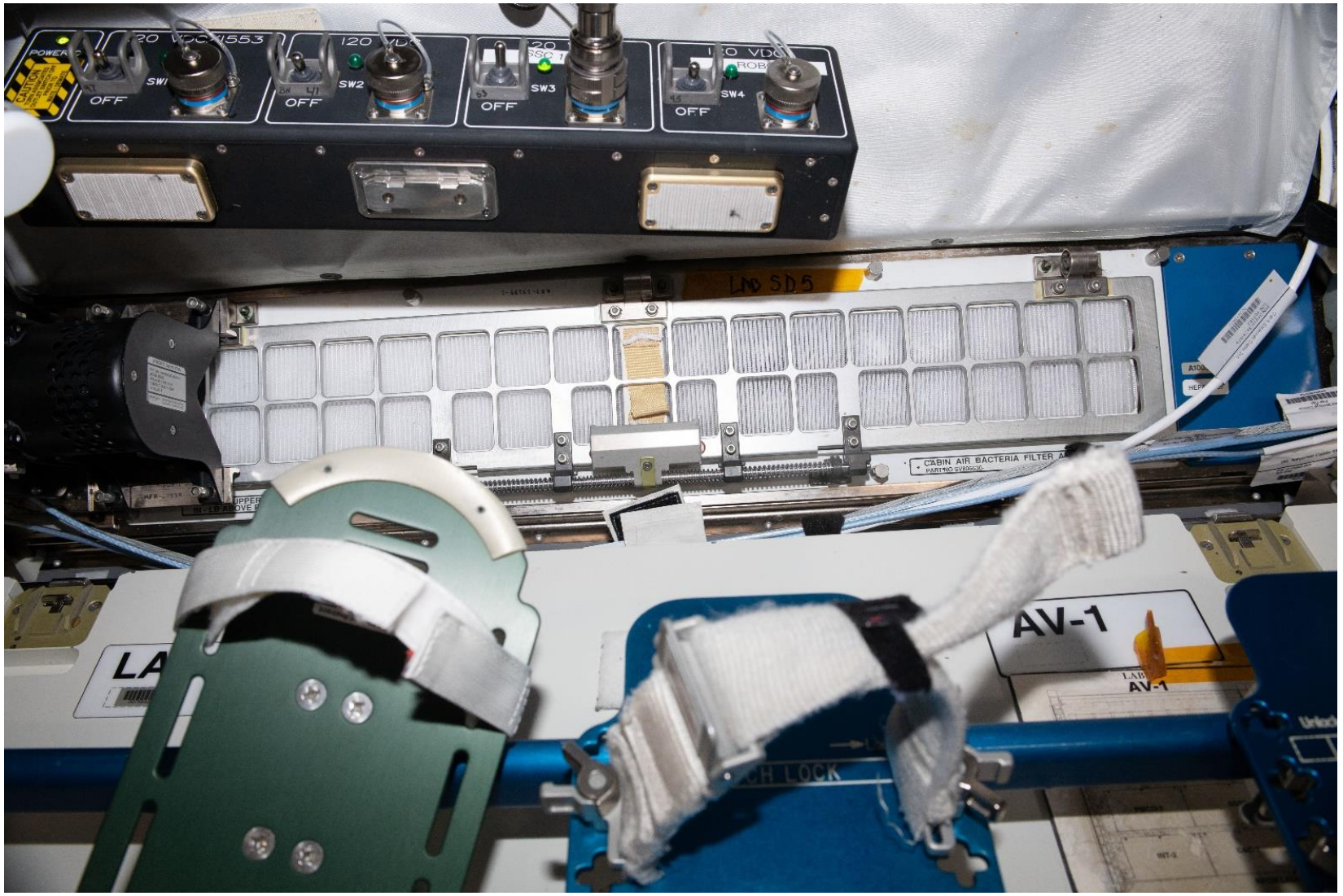
HFIT—Human Factor Integration Team

Before launching hardware it is important to make sure that astronauts won't get scraped or cut by any of the hardware. HFIT is like a final safety and quality check of the flight hardware just before delivery. Sean Shimelpfening wears a special cloth glove that snags easily on burrs or sharp edges to assist in locating potential problems. Every surface needs to be inspected to ensure good, clean parts. Notice that they now have the Nomex and Velcro foot straps. This foot restraint includes Design and prototyping, build to print machining for the foot plate and the thumbscrew, 3D printed parts both ULTEM and ABS parts, Soft goods engineering for the strap. Although this seems like a simple component for the ISS, it is composed of many different disciplines to make the final product.

Last minute change



- After assembly was nearing complete, the HUNCH team wasn't satisfied with the friction between the ball and the clamp. There was too much stick and slipping. The ULTEM balls and the ULTEM clamp are both pretty rigid—we need one to deform slightly. All of the initial prototypes were made of ABS plastic and seemed to have very good friction as the clamp was tightened but because ABS is considered flammable on the ISS we had always planned on making the whole thing out of ULTEM which is not considered flammable.
- Fortunately we had discussed the possibility of using ABS for the ball and had received a tentative approval to use it since the ULTEM clamp would encapsulate most of the ball and protect it from flame. With some phone calls, emails and paper work, HUNCH was able to get approval and new ABS hemispheres printed by Cypress Woods High School in time for launch.



Ball Clamp Foot Restraint in the ISS Lab on Deck 5 next to two Short Duration Foot Restraints. Short Duration Foot Restraints have two positions—one horizontal (as seen in photo) and one vertical. The ball clamp Foot restraint allows for variable positions and variable friction to allow motion within the restraint. The intent is that this new foot restraint is an addition to the ISS restraint mechanisms to help the crew and station be more versatile.

Ball Clamp Origin

Bruce holding the flight like trainer

Bruce Blazine was the originator of the idea that has become the Double Ball Clamp and he has been working with the HUNCH team as we continue develop the Ball Clamp technology. Thanks to comments from many NASA astronauts, engineers and HUNCH students the ball clamp concept has been refined and developed into several good options to restrain hardware but still allow for swivel and adjustment of position.

The 58S crew debrief response transcript is below.

- QUESTION 26:
- DEBRIEF: Did you have a chance to use them?
- NICK: I tried real hard to. Did you want to be able to hook your foot underneath the toe loop so that you can raise your foot up and pull yourself down but you also need to still be able to curl your toes up over the top of the foot restraint and push as well. So doing that motion allows you to keep where you want to be. If you can only pull in one direction, it doesn't really work. So the strap on the HUNCH foot restraint was too narrow to be able to do something like that effectively. I think on the ones that are in the JEM, I replaced it with another strap that I found. I doubled it up and tried to put some duct tape on it and tried to make it more effective. That worked, but the ball clamp, I can't tighten that down enough to give me something steady that just doesn't end up being super loose after a little bit of time.
- The knob on the end of that is too small. If it had a little something bigger that I could grab, I could get more torque on that ball clamp, but without pulling out a tool that's, it's pretty hard to get tight.
- DEBRIEF: So is it something we probably should bring home and redesign?
- NICK: Well, redesign. Right now I think the default for most of the crew up there is just flip them upside down and get them out of the way and never use them so they're just consuming space.