Carbon Fiber Rocket Airframe Capstone

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Mechanical Engineering
Portland State University
June 2014

PSAS 2013 MME Capstone Project

Problem Definition

Portland State Aerospace Society (PSAS) is an educational aerospace program at PSU that builds small sounding rockets. For more information, please see http://psas.pdx.edu/. PSAS is currently planning a 100 km launch vehicle that requires new airframe modules that have a larger diameter and are lighter weight than our current fiberglass/Aluminum modules. PSAS needs not only the **design of the new modules**, we also need the **tooling and a repeatable module building process** in order to build future airframes.

Requirements

- **Airframe Modules**
  - MUST
    - Be lightweight (80% weight reduction from current airframe modules)
    - Be strong enough to withstand 100km launch (1600 lbf solid rocket motor)
    - Be stiff enough to avoid resonant frequencies below 5000 Hz.
    - Have customizable end flanges for module coupling and internal structures
    - Have varying lengths, (100,450,2000mm)
    - Have a single target OD, currently (150,250,300 mm)
  - SHOULD
    - Use inexpensive materials
- **Tooling**
  - MUST
    - Be able to make variable length modules (see **Airframe** above)
    - Be portable and operational in a standard garage/workshop
    - Be able to be rebuilt or adapted to alternate module diameters
    - Have documentation in order to be replicated and modified
  - SHOULD
    - Be able to make variable wall thickness modules (.25" to .375")
    - Take into account windows and holes in modules
    - Use as much COTS equipment as possible
  - MAY
    - Be adaptable for nosecone design and construction
    - Be automated (e.g., in the style of a filament winder)
- **Process**
  - MUST
    - Deliver have a well documented Work Instruction on using tooling to make airframe modules
    - Be inexpensive to run
  - SHOULD
    - Minimize time and resources (including crew) necessary
    - Minimize training requirements

Deliverables

Students **must** deliver completed tooling and a complete process writeup with standard operating procedures, and at least one completed airframe module. Students **should** deliver an entire test airframe for launch during Summer 2014.

Design Log:

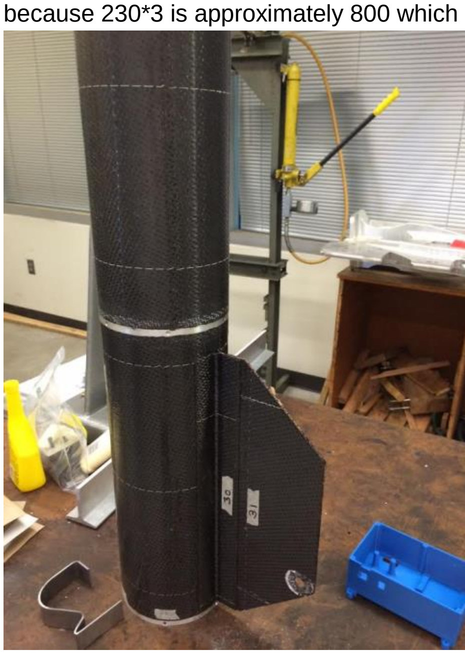
5/31/14 6:30pm Jack:

Writeup on the fins:

We glued the fins on with gorilla glue, and let them cure overnight. We held the parts down with clamps. We used pieces of tape to locate the fin brackets, and then liberally applied glue. We then glued the fin in between the two fin brackets. We used gorilla glue on the edges to fill in the edge and it worked perfectly.

Testing the fins:

The fins were tested by drilling a hole in the fin itself and hanging weights from it. When we ran out of weights, we put barett's 230 pound body on it. This still did not break the wing off. But this is certainly larger than the expected load because 230*3 is approximately 800 which it cannot possibly see.

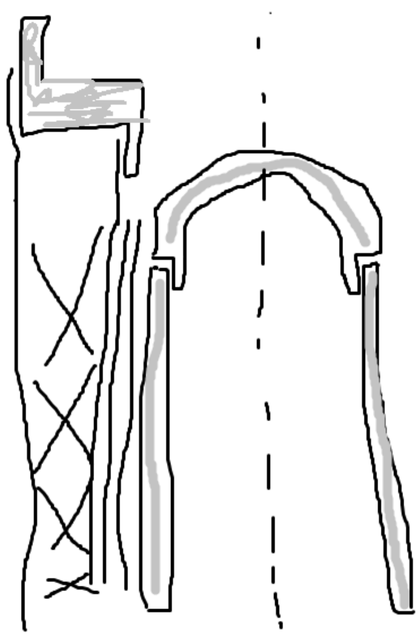



5/31/14 6:30pm Jack:
135 + 140 + 62 + 48 = 385 pages of design log documentation
37 composites parts on manufacturing log
40 page textbook for composites
16 page instruction manual for Haas
6 page layup instructions

5/31/14 3:30pm Jack:
Sam is machining the dummy rings for us to use in layup next week.

I am writing a paper on high end pressure vessels like the ones used in rocketry. I drew up a sketch of a design that I thought of while working on this. This report is a first step for any future tank design, so I will upload it to the stash folder.

The particular design I drew would be better if the ring and the aluminum bulkhead were one piece.



Interesting fact: the second design of the solid rocket boosters for the space shuttle were kevlar wrapped pressure vessels. They are also used by fire fighters and for oxygen first aid equipment. They are rarely used for scuba diving because they don't weigh enough.

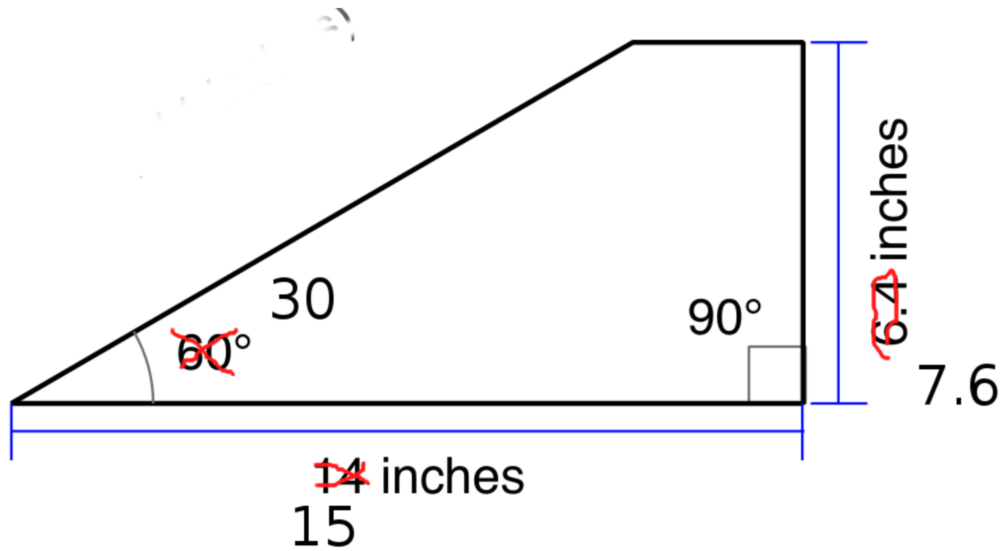
1. Kevlar Fiber Model

In order to develop the reliability model, the Kevlar vessel and strand databases were carefully analyzed. The first observation of the data was that fiber volume fraction influences apparent or 'delivered' fiber strength (even after applying the rule-of-mixtures), but the effect on stress-rupture lifetime is different. This complicated data interpretation in comparing various Kevlar/epoxy strand experiments, and the LLNL and Orbiter COPVs, among which the fiber volume fraction differed substantially.

aluminium cylinders. Kevlar wrapped composite cylinders are used in fire fighting breathing apparatus and oxygen first aid equipment, but are rarely used for diving, due to their high positive buoyancy.

This is the "magic angle" for filament wound vessels, at which the fibers are inclined just enough toward the circumferential direction to make the vessel twice as strong circumferentially as it is axially. Firefighting hoses are also braided at this same angle, since otherwise the nozzle would jump forward or backward when the valve is opened and the fibers try to align themselves along the correct direction.

5/28/14 9:30pm Sam:
Final fin dimensions x3:



5/27/14 4:30pm Barett:
FR-4700 High Temperature Tooling Board Specifications

- Things we need to buy:
  - Bonding Adhesive
    - See below (Appendix A)
  - Foam Surface Sealants
    - Airtech Tooltec CS5 adhesive release film
      - This is an all-in-one: sealant, surface finish and release agent

http://www.freemansupply.com/AirtechTooltecPres.htm

AIRTECH
ADVANCED MATERIALS GROUP

CORPORATE HEADQUARTERS
5700 Skylab Road
Huntington Beach, CA 92647
PHONE: (714) 899-8100
FAX: (714) 899-8179
Internet: www.airtechonline.com
e-mail: airtech@airtechintl.com

DATA SHEET

TOOLTEC® CS5 and CA5

Non-Reinforced PTFE Film Coated with Adhesive for Semi-Permanent Release and Mold Surface Reconditioning.

Description
Tooltec®CS5 and **CA5** are .005 inch (125μ) PTFE films coated with a high temperature pressure sensitive adhesive. **Tooltec® CS5** has a silicone adhesive and **Tooltec® CA5** has a non-silicone adhesive. Both are non-reinforced allowing conformance to complex contours. **Tooltec®CS5** and **CA5** can be used to seal masters and leaky tool surfaces while providing semi-permanent and contamination free part release.

Application
Tooltec® should be applied by carefully lifiting the edge of the backing, then applying the adhesive side to the mold surface. The remainder of backing should then be carefully removed while pressing the **Tooltec®** onto the mold surface with an airweep or other straight edge. A vacuum bag can then be applied to remove any residual air. A cure cycle under vacuum will provide the best results.

Material Characteristics	**CS5**	**CA5**
Carrier Type:	PTFE	PTFE
Adhesive Type:	Silicone	Acrylic
Total Thickness, in (μ):	.0065 (165)	.0065 (165)
Film Thickness, in (μ):	.005 (125)	.005 (125)
Adhesive Thickness, in (μ):	.0015 (38)	.0015 (38)
Adhesion oz/inch/width:	40 (4.4)	30 (3.3)
Elongation, %:	300	300
Maximum Recommended Use Temperature, °F (°C):	600 (316)	600 (316)
Color:	Light Brown	Light Brown
Standard Sizes(1):	36" x 18 yards (91cm x 16m)	36" x 18 yards (91cm x 16m)
	48" x 18 yards (122cm x 16m)	48" x 18 yards (122cm x 16m)
Shelf Life:	1 year when stored at 72°F (22°C)	

1) Other widths available.

CATALOG POSITION: **PRESSURE SENSITIVE TAPES**

- Mold Release Agents
    - Looks like the Orca stuff may work, but see Appendix A below

FR-4700 High-Temperature Tooling and Mold Recommendations

Bonding Adhesive

FR-4700 tooling board will not inhibit adhesive curing or curing of commercial prepregs. Select an adhesive appropriate for the processing temperature. **See Appendix A on page 13 for recommended adhesives.**

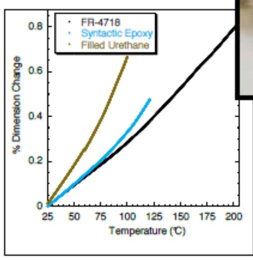
Bonding Process

Surfaces to be bonded must be clean, dust-free, flat, and square. Apply adhesive to both surfaces so they are completely coated. Apply more adhesive in the middle as squeeze-out will occur. For best results, apply even pressure such as a vacuum bag. Good results have been obtained using a 1/4" or 1/8" notched trowel to apply the adhesive.

NOTE: **It is best to use a room-temperature cure with a high-temperature adhesive. Trying to achieve an elevated temperature cure on a large mass of foam can take a very long time and can result in cracking of the foam if not cooled slowly.**

Follow the manufacturer's recommendation for curing the adhesive.

Coefficient of Thermal Expansion Table For FR-4700



It is optional to remove extra material to create an "egg-crate" structure. This will reduce cycle times and improve stability of the tool.

CNC Routing recommendations

The FR-4700 tooling board will machine well compared with traditional aluminum tools. It is recommended you do a rough cut first, leaving an extra 1-3 mm for finishing. Use caution with edges and tight corners to avoid chipping at the start of a new pathway. See Fig. 1 (page 7) for basic CNC recommendations.

Follow these additional FR-4700 guidelines:

- Use four-flute cutters or woodworking router bits
- Use high RPM and feed rates
- Use forced air on the drill bit to reduce dust and particle build-up
- Keep a load on the cutter to avoid chatter

Sealant Compounds

A sealer should be used to fill the cut foam surface cells and provide a hard, smooth finish on the tooling surface. For the FR-4700, a primer is recommended if a very smooth finish is needed. NOTE: **Best results have been obtained using Airtech ToolTec CS5 adhesive release film. This all-in-one product is a sealant, surface finish and release agent.** For curing temperatures lower than 275°F (135°C), a lower cost solvent-borne acrylic resin or a cross-linking vinyl ester resin will suffice. **See Appendix A on page 13.**

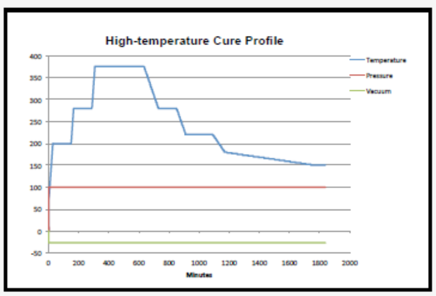
Mold Release Agents

A number of mold releases can be used. The end user needs to test compatibility with the resins and temperatures needed in the production process. **See Appendix A on page 13 for FR-4700 bonding mold release recommendations.**

TIP: High-temperature Curing

High-temp Curing

FR-4700 tooling board can be used under autoclave conditions up to 400°F (200°C) at 90 psi. NOTE: The temperature gradient between the core of the tool and the surface should not exceed 30°F (17°C). Care should be taken during the cool down cycle below 220°F (104°C). There should always be a step sufficient to ensure the tool can equilibrate before cooling to room temperature. See chart. For a recommended cool-down cycle, please contact customer service at (253) 473-5000.



Appendix A - continued

Recommended Products for LAST-A-FOAM® FR-4700

Bonding Adhesives

- Hysol EA 9396 Epoxy Paste Adhesive (ambient cure, low viscosity)
- Hysol EA 9394 Epoxy Paste Adhesive (ambient cure, high viscosity)
- Duralco 4461-SS-2 from Cotronics Corporation
- Reklein Plastics Resin Services HTR-350

Sealant Compounds / Surface Finish Sealing

- CHEMLEASE MPP117 from Chemtrend (FR-4730 or FR-4740)
- Duratec Vinylester primer
- Orca Composites Super Clear Additive/Coating
- Orca Composites Vinyl Ester White Surface Primer

For curing temperatures greater than 250°F (120°C) (Epoxy, BMI, Cyanate Ester), a resin-based filled sealer/primer can be used. It is recommended that the manufacturer's surface preparation and curing instructions be carefully followed.

- ADTECH MR #7 Mold Sealer from CASS Polymers (FR-4740)
- ADTECH ES-221 High-Temp Epoxy Surface Coat from CASS Polymers
- ADTECH ES-215 High-Temp Sealer from CASS Polymers
- ADTECH P-17 (useful for filling larger voids or repairs)
- Hawkeye Industries Duratec® Vinyl Ester Primer
- ZYVAX Sealer GP

Mold Release Agents

- Zyvax Composite Shield
- Frekote® 700-NC
- Frekote® WOLO
- Airtech® ToolTec CS5
- Adtech MR#10 High Gloss (> 300°F (148°C))

5/27/14 3:10pm Jack:
Body of email:

We would like to thank you for making a significant contribution to our academic success. Please join our capstone team in celebrating the completion of our Mechanical Engineering degrees at this year's senior capstone showcase. We will be showing off our composite fabrication tools, carbon fiber airframe, and project documentation.

- Time: 2-3pm
- Location: Atrium of the Engineering Building, 1930 SW Fourth Avenue
- Portland, Oregon 97201
- Date: June 5th, 2014

Thank you,
Rob Melchione
Jack Slocum
Sam Arnold
Barett Strecker
Tung Nguyen

People to invite:

- Andrew Greenberg
    - ADG@ece.pdx.edu
- Evan Waymire
    - Evan@ccwebster.net
- Allan Slocum
    - Allan@merkurencyclopedia.com
- Tom Bennet
    - tbennett@pdx.edu
- Mike Chuning
    - chuning@cecs.pdx.edu
- Joe at NW Rapid
    - joe@nwrapidmfg.com
- Kevin at PCC
    - kevin@pccomposites.com
- Alek at Arrow
    - alek@arrowmachineworks.com
- Paul Wheatcroft & Brian McCabe & Buck at Machine Sciences
    - paul.wheatcroft@machinesciences.com
    - brian.mccabe@machinesciences.com
    - buck.rich@machinesciences.com
- Jenner Hanni
    - jeh.wicker@gmail.com
- Eric Ward
    - ericdward@gmail.com
- Betsy Camp
    - betsy.h.camp@gmail.com

5/22/14 7:00pm Tung:
I got Jenner email that said the arduino board is at the bottom which is what I designed. However, about the vertical dimension to make a hold for COM port, sd card I think I should get the physical board. It does not take long time to fix the design but will be wasted time and material to print the box now and fix it.

Jenner email

The board stackup is an Arduino Uno on the bottom with the oven board in the middle and then the TFT LCD shield on top.

The Arduino Uno and TFT display shield dimensions info is online. The oven board is an Eagle file which you can get from the repository. I had to put out v3.1 so be sure to pull from the repo for the newest version. You know how the boards are related to each other because the pins are the same all the way up.

Total height is 1.2 inches from bottom of the Arduino including soldered pins up to the LCD display. The joystick sticks out a little more than that but you have to leave that sticking out anyway because it's how the user interacts. So I suggest leaving the LCD display and the joystick uncovered in the front of the box.

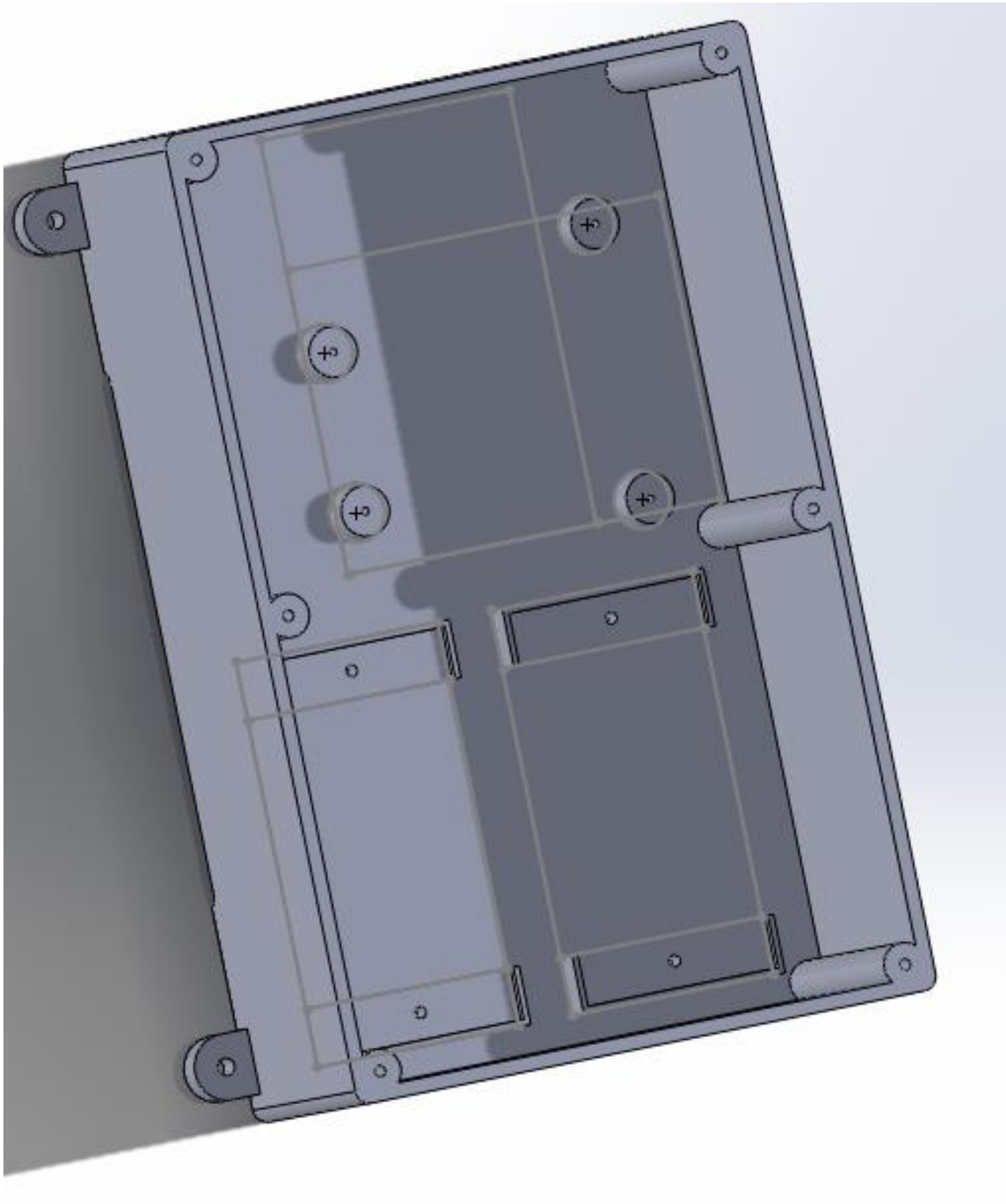
All three boards are about 0.06 inch thick. The female headers are

0.032 inch tall. The height of the feet on the TFT shield above the female headers is 0.11 inch. The feet on the middle board put the board 0.07 inch above the Arduino's female headers.

I've included top view so you can see the oven board comes out below the top shield. I've included side view so you can see how the stack-up looks.

05/21/14 4:25pm Tung: Control box

This is the box that was designed. The dimensions of the 4 hold used to attach board are based on the arduino board. The control board I use dimension of 1.8''x3'.0'' which in the version
It will be better to have the vertical dimension of the board so that I can adjust the depth of the box. Now it is fit with the relays height. The gray lines represent the position of the boards and the relays.
The file is located in : \\stash\psas_airframe\Oven Controller\Box\Oven_box.sldr



5/21/14 1:15pm Jack, Barett:
Machining the inside of the MTR almost .01”. the rocket motor. 3.879” ish and not a real circle by nearly 1.5 thou.

5/21/14 1:10pm Jack:
Calling General Plastics to get the info. User guide, adhesives contact cements, 4700 section in there for material and heat cycles. Key points to look at: especially in cool down cycles so tool doesn’t crack. Speeds and feeds for machining also. No standard bonding agents, high temp stuff.

The information he sent me is in the documentation folder of the stash. It is a PDF.

5/21/14 1:00pm Jack, Sam, Barett, Tung:
For the next three weeks: (15 days until capstone fair) Urgent Less Urgent Done/Notes

- NSR separation testing
  - Radial holes
  - Figure out post bonding

    - Get Dave on board for NSR test next week (Wednesday?)
        - Saturday 5/31 after 2 or Sunday before 2
    - Give Andrew the ring and let him figure out wiring, epoxy, etc.
        - Dave will have done by Saturday 5/31
    - Design opposing ring for post bonding
- Fix MTR and MRR
    - Put on lathe to sand. Use dummy to hold MRR
- Motor module with fins
    - Need to make another fin bracket and test ways to attach fin. Can use wrankly module.
- Electronics carrier with mock electronics mounted
    - Make new carrier and give to PSAS for electronics
    - Encourage PSAS to order carbon airframe flight test components
- Nosecone mold
    - Cut
    - Find and order glue
    - Find shop to machine
        - Ask Arrow to machine first, then try Portland Pattern and Additive Workshop
            - Positive but not certain about being able to machine nosecone mold by capstone fair, probably not sooner.
- Motor and antenna mandrels
    - Call Alek at Arrow
        - Can probably have the mandrels finished by next week. Waiting for a call back.
- Make full assembly parts
    - 3 standard module
    - 1 motor module with fins and MTR/MRR
    - 1 Antenna module
    - NSR
- Invites to Capstone fair
    - Andrew Greenberg
    - Evan Waymire
    - Allan Slocum
    - Tom Bennet
    - Mike Chuning
    - Joe at NW Rapid
    - Kevin at PCC
    - Alek at Arrow
    - Paul Wheatcroft & Brian McCabe & Buck at Machine Sciences
    - Jenner Hanni
    - Eric Ward
    - Betsy Camp
- Capstone presentation
    - Find out time slot, content, who's presenting
        - Don't know time slot yet. Two members present. 12min + 3min format. See examples for content
- Capstone report

- **Things we want to stand next to at Capstone fair**
    - Printed copy of design log
        - Make cover
        - Include mfg. log
        - Binding of some sort
        - 5 copies
    - Oven w/ UI in professional housing
        - 3D printed housing for board, relays, thermocouple wires

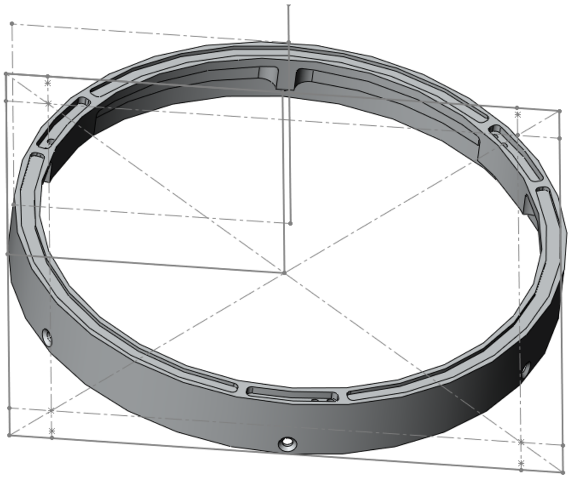
        - Need power to Arduino to demo UI
    - Poster(s)
        - Big, overview poster w/ project details, old rocket, new rocket assembly, sponsor logos and thank you
        - Individual posters w/ data, etc. for oven/table (mfg. tools), and one for carbon parts, one for alum. parts
        - Vinyl stickers -> in process (Barett)
            - Arrow
            - Machine Sciences
            - NW Rapid
            - PSAS
            - ACES
                - Need to figure out dimensions (4in tall)
    - iPad with video
        - 3 iPads, two with prototyping videos, one with slide show
    - Parts
        - Show evolution of prototyping
        - Have extra parts inside oven
    - Layup table prepared for layup
        - Mandrel holders w/ assembled mandrel
        - Tools
        - A couple chemical treatment examples ready for show
        - Printed copy of layup instructions

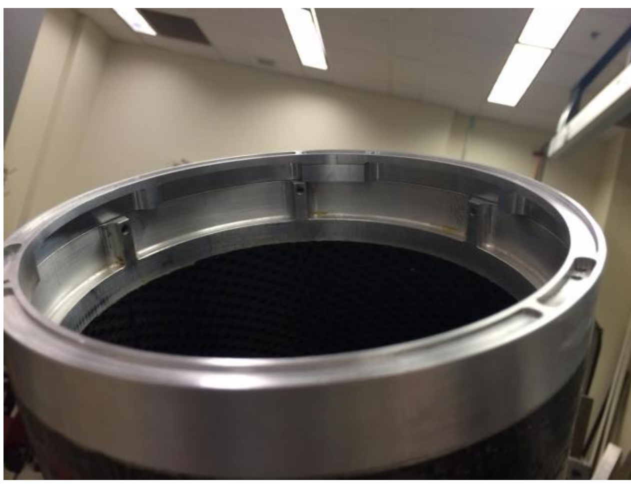
Things we accomplished in last week:

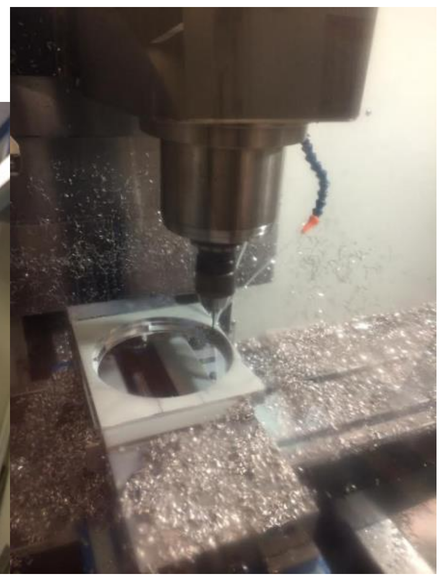
- Machined NSR
- Laid up 3 more test modules to figure out exactly why the veins happened
- Manufactured a second module
- Tested module in compression
- Tested both modules in bending
- Got approval and wrote a test plan to use a bigger compression machine (Thursday at 12)

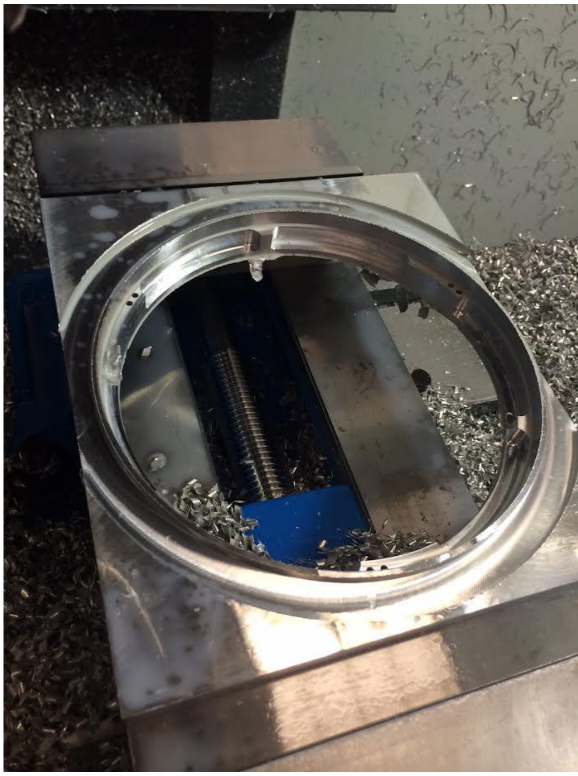
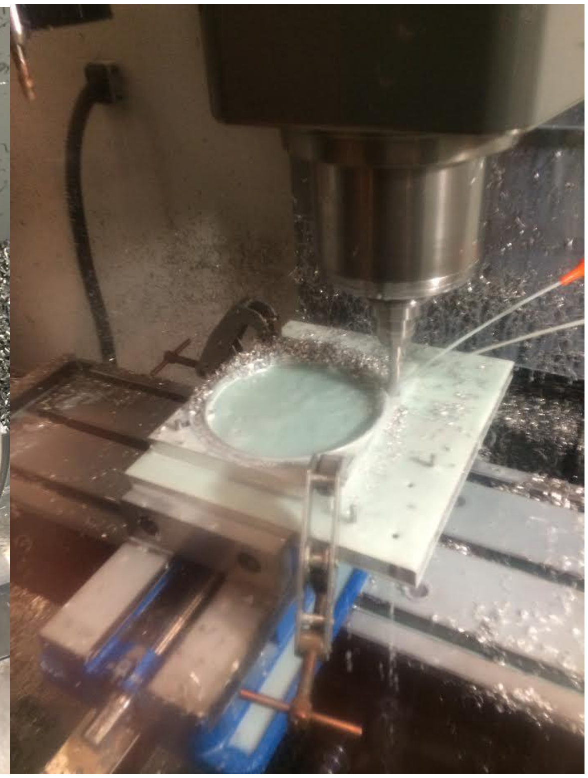
5/20/14 6:00pm Jack:

We finished machining the NSR. This was a challenge because we did not have big enough stock to machine things like we usually do. We usually hold the stock in the vice and let the inner part fall out and then stop the machine. This time there was not enough stock around the edges, and if we were going to keep machining, the part would have failed in compression under the vice load. We ended up taking it off the vice after machining some pin holes in it, and then we put it on top of another flat piece of aluminum that we put pin holes in and we clamped it to it. We used 3 tabs that were .25” tall and .5” wide to hold it in place. We realized that it might be hard to drill the radial holes, because we don’t have anywhere to locate off of. We could 3D print a part that would locate off of the pillars.







5/19/14 12:00pm Jack, Rob, Barett:
Wern said he would think about letting us use his MTS machine if we gave him a test plan. So we gave him a test plan, shown below.

MTS Machine Carbon Fiber Module Test Plan

1. Objective
Our proposed project will be used for our senior design capstone, the carbon fiber airframe for Portland State Aerospace Society (PSAS). One prototype module will be tested in a buckling analysis experiment to further understand and develop the rocket airframe structure using composites.

2. Experimental Setup and Procedure
The testing apparatus will be the 20k lbf compression tester located in the Materials Testing Lab under the direction of Dr. Wern. The experiment will test one module in compression to a maximum load of 18,000 pounds, or until laminate failure. The load rate will be .005 in/sec. The ultimate load is expected to be in the range of 6,000 pounds and 14,000 pounds.

Module Specifications

- One-core-one [0/0]
- 6061 T6 Aluminum end rings
- 6061 T6 Aluminum dummy rings
- Pre-preg 5 harness carbon fiber
- Nomex honeycomb core .25" thick
- 6" ID x 18" L dimensions

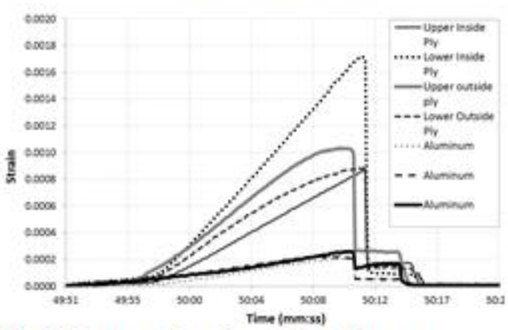


Fig 1. Expected strain vs. time for test.

Fig. 2. Similar experimental setup from previous scale module test.

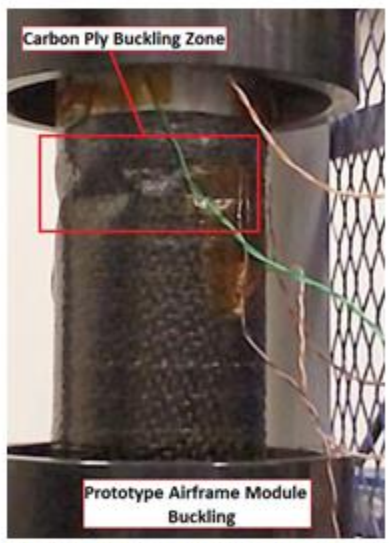
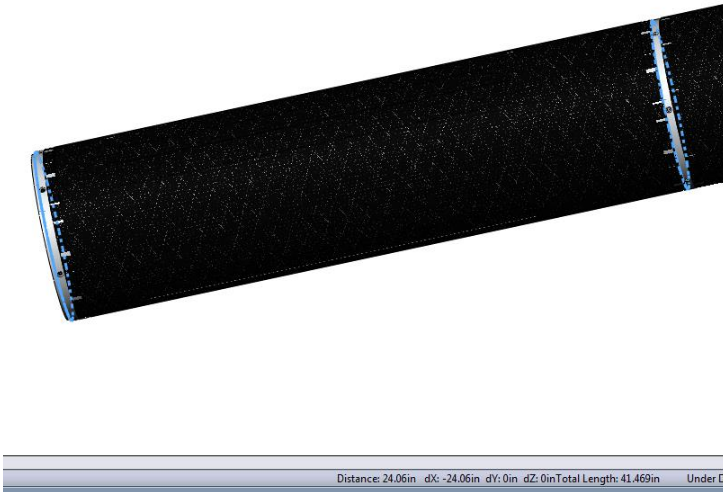


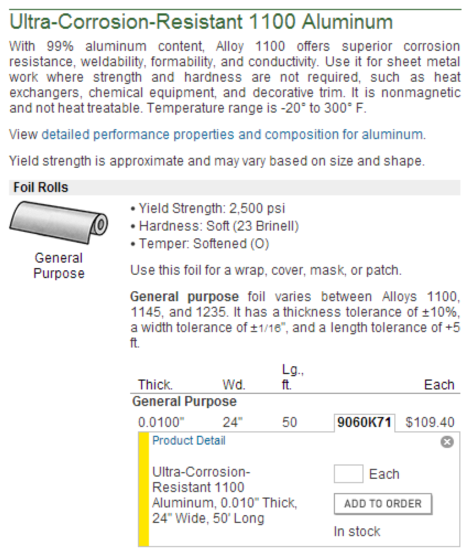
Fig. 3. Failure mode from previous test on scale modules.

5/19/14 10:00am Jack, Rob:
Motor module is 24.06" wide. 2 ft by 2 ft of sheet aluminum .01" will work for the motor module. 2 ft by 18" will work for the standard, and 2 ft by 6" for the antenna module.
Places called:

- Pacific metal, they have none, and don't know where to send me to get any
- Versatech
  - They said order from mcmastercarr
- Metal supermarkets

- no
- Ordered from mcmaster 5/19





Ultra-Corrosion-Resistant 1100 Aluminum

With 99% aluminum content, Alloy 1100 offers superior corrosion resistance, weldability, formability, and conductivity. Use it for sheet metal work where strength and hardness are not required, such as heat exchangers, chemical equipment, and decorative trim. It is nonmagnetic and not heat treatable. Temperature range is -20° to 300° F.

View detailed performance properties and composition for aluminum.

Yield strength is approximate and may vary based on size and shape.

Foil Rolls

General Purpose

- Yield Strength: 2,500 psi
- Hardness: Soft (23 Brinell)
- Temper: Softened (O)

Use this foil for a wrap, cover, mask, or patch.

General purpose foil varies between Alloys 1100, 1145, and 1235. It has a thickness tolerance of ±10%, a width tolerance of ±1/16", and a length tolerance of +5 ft.

Thick.	Wd.	Lg., ft.		Each
General Purpose				
0.0100"	24"	50	9060K71	$109.40

Product Detail

Ultra-Corrosion-Resistant 1100 Aluminum, 0.010" Thick, 24" Wide, 50' Long

Each

ADD TO ORDER

In stock

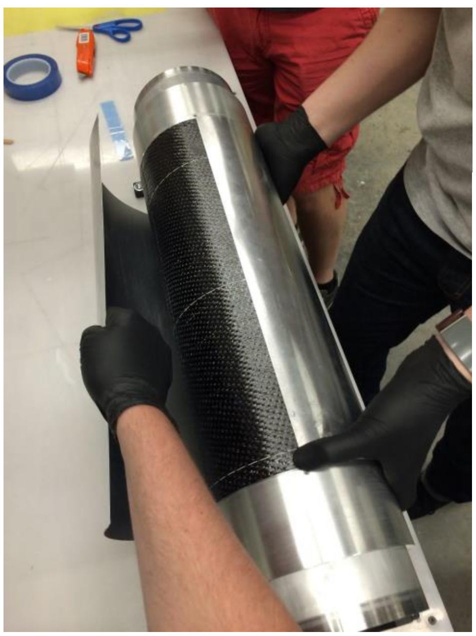
5/19/14 10:30am Jack, Rob:
Meeting with rob and jack:

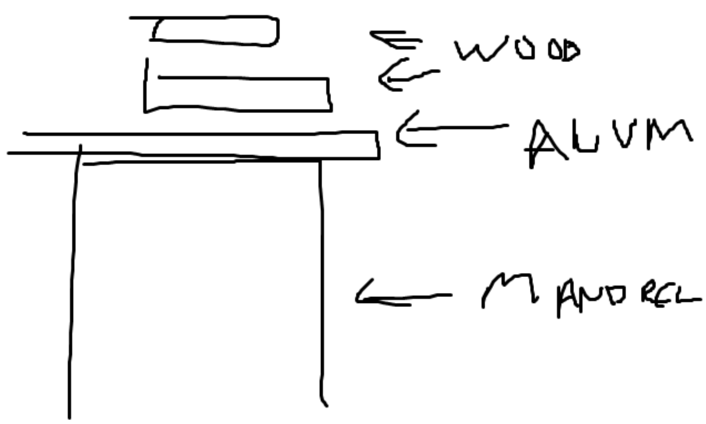
- Need to be patient with the cooling off of the modules after they come out of the oven so they come off the mandrel easier. Put in freezer
- Decide on which caul plate
  - Mylar or sheet?
  - Ordering sheet metal
- Would be nice to make the mandrel removal system more elegant
  - Maybe something fixtured that doesn't jump around, and doesn't spray pieces of wood. No stacks of crap
    - Could adjust current mandrel removal system
- 17 days until the capstone fair. This is when we have to have the oral presentation, and the display showcase
- 21 days until report due

To do:

- Tell machine sciences to make more. Order 6+2 (16 total rings) if they can keep making them for us. If they aren't going to be able to do them in the future maybe 2.5 rockets worth.
    - Need to call andrew and ask him
        - Order 16 total rings
    - Potentially ask my father for sponsorship
- Order some sort of caul plate
    - .01 aluminum sheet
- Figure out how to glue and cut foam
    - Order glue
    - Email from Sam
- Machine NSR
- Design PRR
- Design post cure process
    - Email Dave
- Design mandrel separation system
- Do NSR test with module

5/17/14 1:30pm Jack:
Making of part 35. the caul plate that is too thick is seen. This configuration with aluminum against the mandrel works very good for getting parts off. We loaded up the rings with wax and didn't wipe it off and the wax flowed into the carbon and became the whiteness seen at the top.





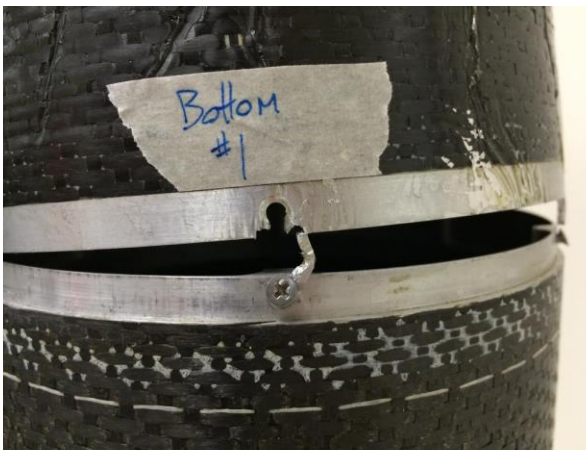
5/17/14 1:30pm Jack:
This mylar wrap is supposed to give good surface finish. It is only 11$.
http://www.acpsales.com/Mylar.html

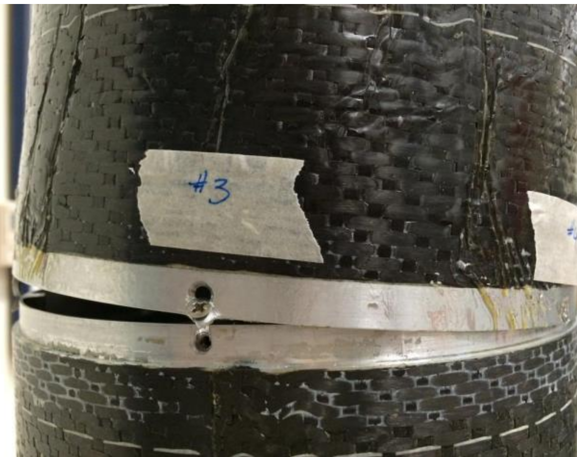
PET Polyester Film

A Mylar® carrier sheet provides a smooth glossy surface for wing s
use.

- Thickness: .014"
- Widths: 24", 48"
- Quantities over 360 feet (full roll) will be on multiple rolls.

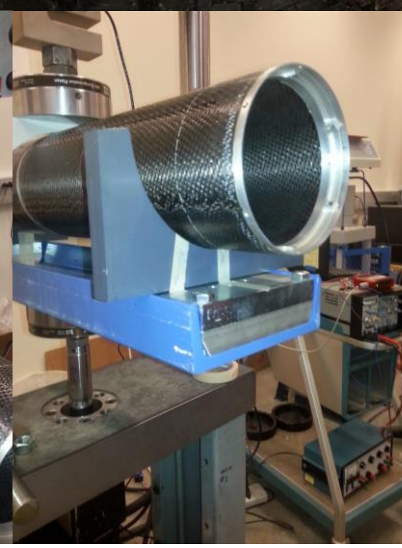
5/16/14 3:30pm Sam:
Finally got around to doing a bending test. 500 pound point loads will fail the carbon. First failure was at .69V= 1000lbf. It popped and the bolt came out. You can see this in the photo below with the small failure. We pushed past the first failure just to see the ultimate.




#3

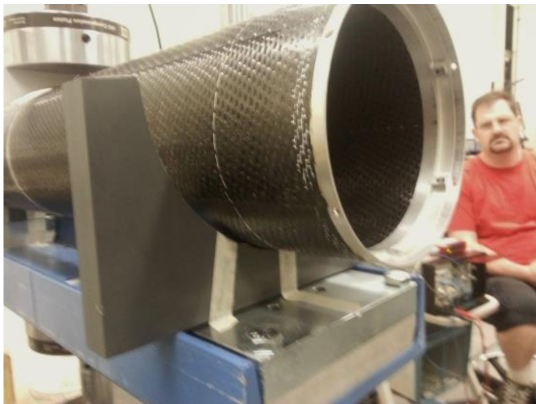
#4

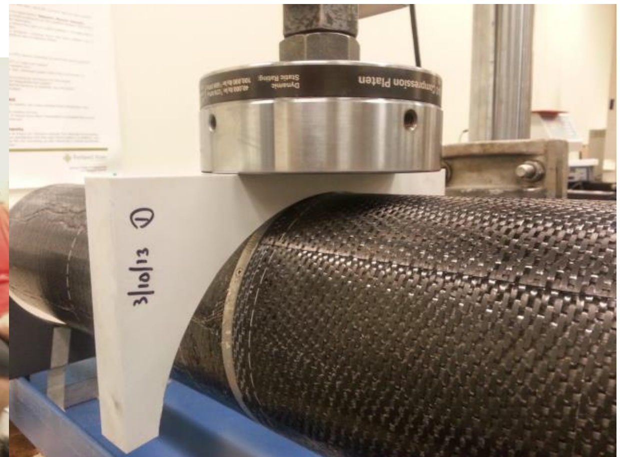
MTS
CAUTION

MTS
CAUTION


CAUTION

MTS
CAUTION

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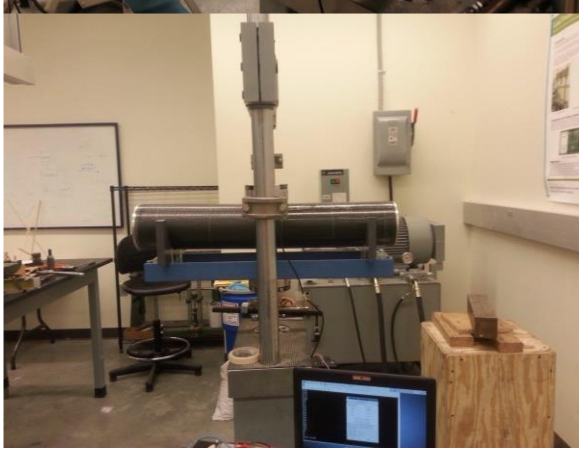
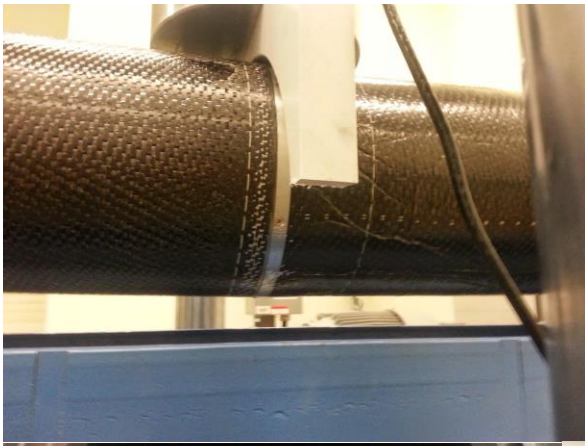
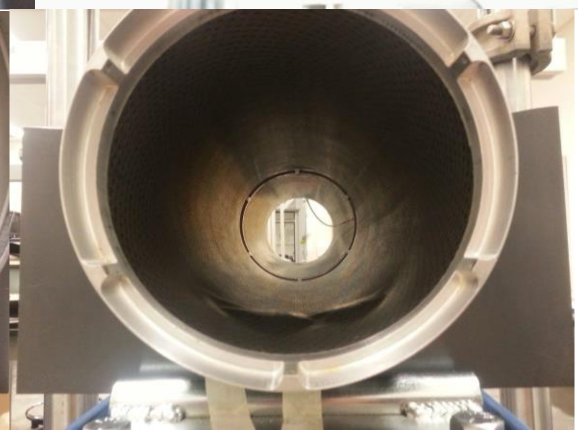




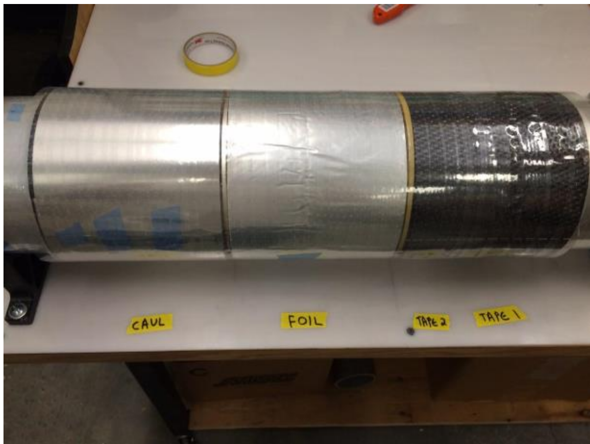
5/15/14 4:00pm Sam

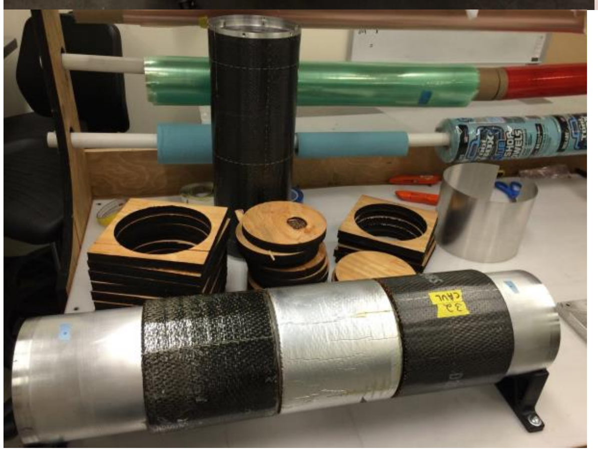
Got the MTS testing machine calibrated by taking the load cell off the machine and placing it in the concrete tester. This process was super easy and quick. We loaded the cell in increments and got 4 points for a calibration. It was difficult to control the concrete machine fine enough to get more data points.

The calibration showed that the load cell voltage is approx: 1400 lb/V

The second module came out terribly. We believe that the caul plate was too stiff and didn’t allow for uniform pressure from the shrink tape. The module is obviously delaminated in some areas.

5/15/14 11:36am Jack:
The three test pieces with different surface processes came out and very clearly showed that the foil causes wrinkling like in the first full scale module. The caul plate worked great, however all of the parts seemed somewhat delaminated. We think this is because the yellow rubberized adhesive film does not get tacky enough to stick to the core, so it remains a little loose when all is assembles, which potentially allows for some play between layers.

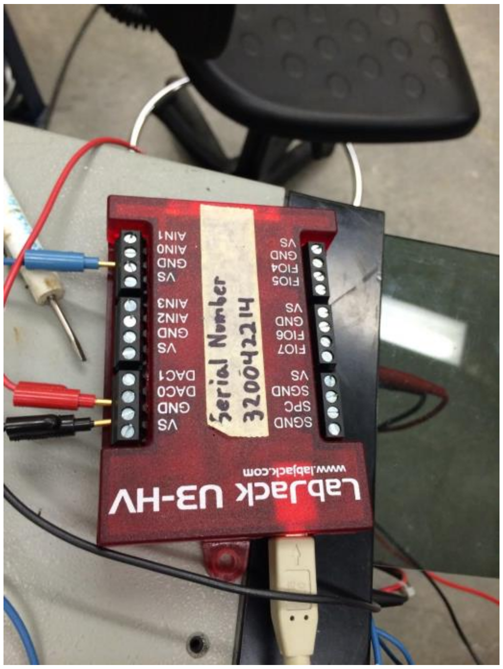




5/14/14 1:36pm Jack:
Testing the module using the MTS machine. We got the platens from wern. We are using the old 3.5” dummy rings that are already outfitted with strain gauges to do our calibration of the load cell, because we found it to be accurate last time(measurements test).

We tested out the new control system for the MTS. We use the program written to try and move the piston the smallest increment that we can, so that we can measure it using a dial indicator. This will let us be sure we can safely and slowly smash our parts. We tried to move it the smallest increments and it would not work, we clicked it 3 more times and then it would move the full 4x the increment. The output from the labjack would only change when we got to the next .02V increment. We need accuracy to .005V at least which would be about .004” per click.

Our parts will break at approximately .0016 strain. This translates to .028” delta L before it fails.



5/14/14 8:36am Jack:
We could test the motor module by putting a small hockey puck looking disk as a stand in for the motor, and put a dummy ring on top of the module. Then use the MTS to apply 800 pounds and measure strain in the MTR. This could be our way of calibrating it.

To do:

- Work with Andrew on MTS machine
  - Set up strain gauges
- Figure out wrinkles
  - In oven
- layup second module
- Machine NSR (both sides)
- Laser cut mandrel pound off tools

If all that gets done:

- Put strain gauges on MTR
- Machine/laser cut dummy motor for MTR testing
- Sand out MTR to make it fit over the motor
- Work on final paper

Reference:

For part 19:
.0532 volts for 6220 lbf for the aluminum
Stress=strain*modulus
Load/Area=strain*modulus
6220lbf/3.17in^2=Strain*10E6psi
Strain=1.962145E-4/in

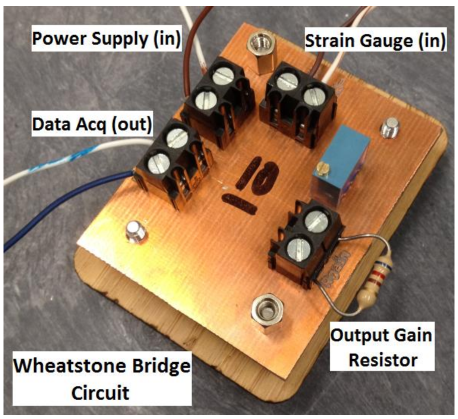
Now to relate strain and volts:
1.962145E-4 strain/.052565 volts = .00373 strain/volts

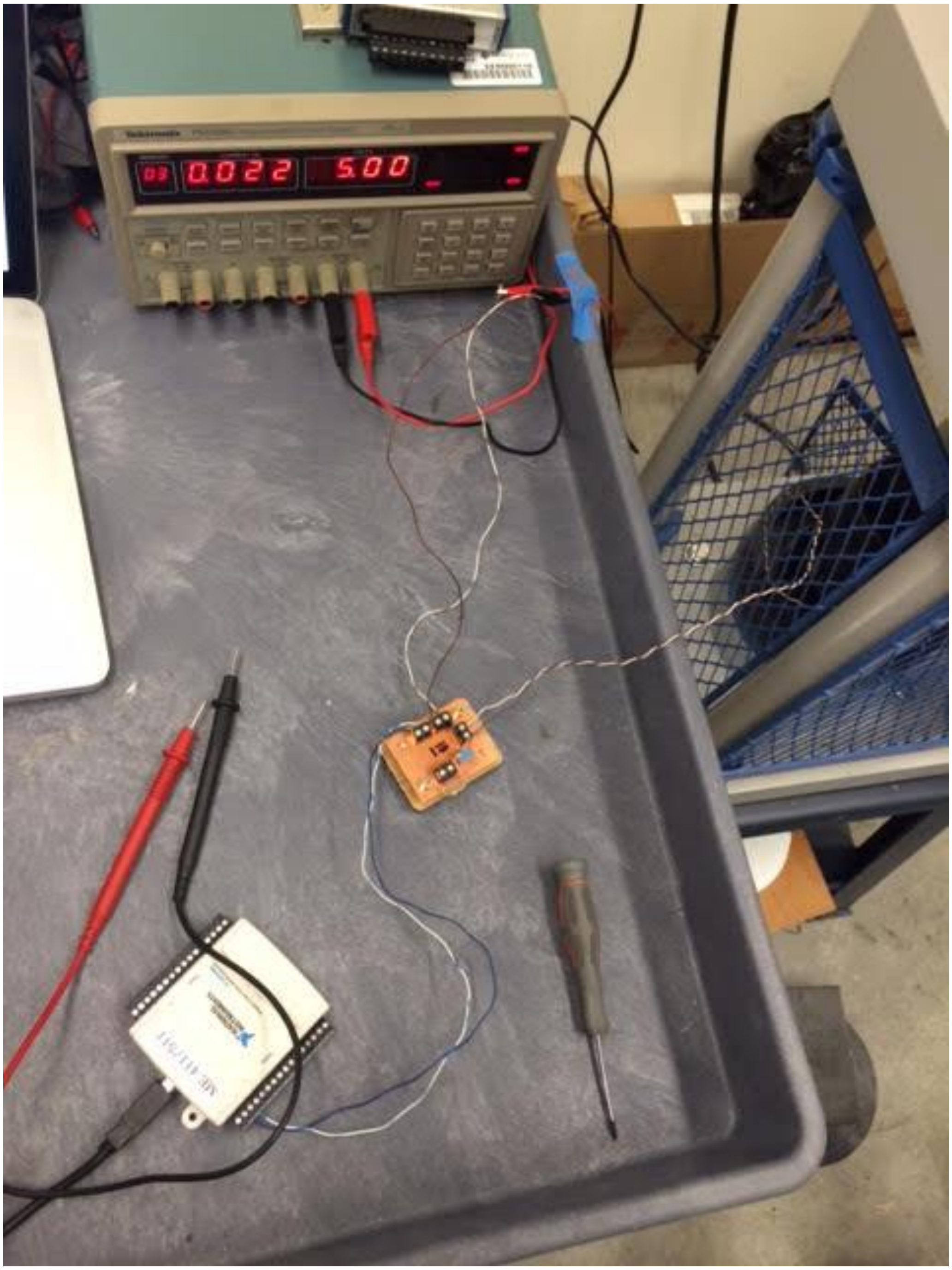
If we calculate the theoretical strain gauge strain:

Strain= 4*voltageout/(voltage excitation*Amplification*gaugefactor)
strain=(4*.052565)/(5*100.77*1.99)
Strain=.0002097
Now relating strain and volts:
.0002097/.052565= .003989 strain/volts

Trying to validate this method calculating theoretical strain for carbon at failure:
Load/area=strain*modulus
6220/(values from .32 to .42 in^2)=strain*(9e6 and 10e6)
strain = values from .0029 to .0035
These are close to the .0025 that was measured for strain at 6220lbf

.001715 strain, 7280 lbf, area between (.16 and .21), calculating modulus
7280/(strain*(range from .16 to .21))=modulus
modulus=10.1e6

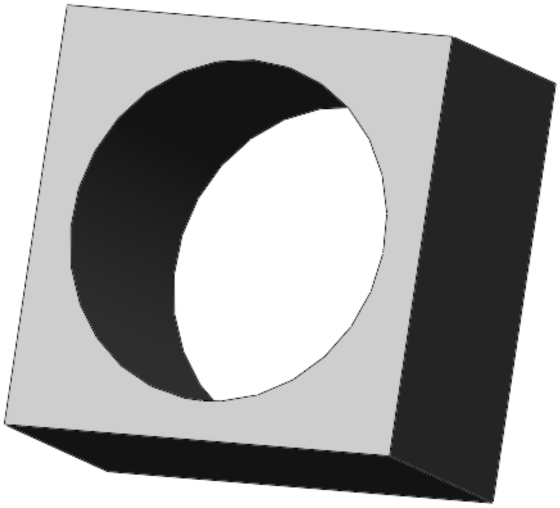


For Reference: 

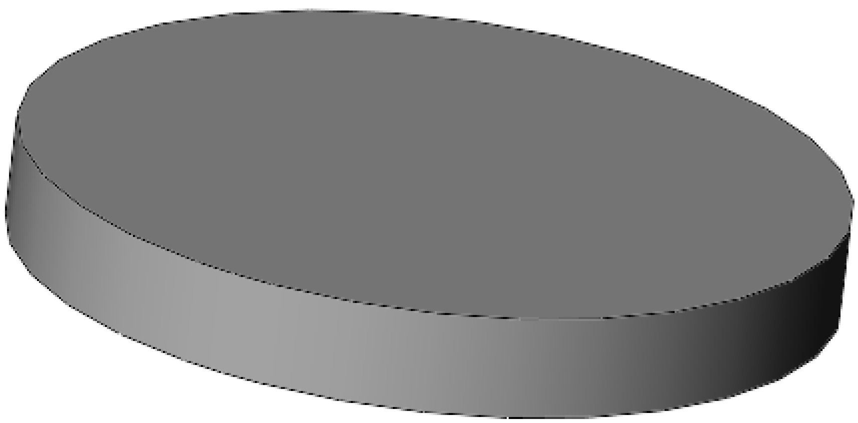
5/13/14 4:36pm Jack:
We got the module off the mandrel. It weighs 1.25 lbf. This is about 30g less than calculated.

We could make a removal tool out of laser cut plywood. We could make multiple stacks of the one with a hole to let the mandrel come out farther. We tried to cut them tonight but Drew couldn't figure out how to make it work.

Removal tool, inside PSAS/models/ideas:
15 of these:

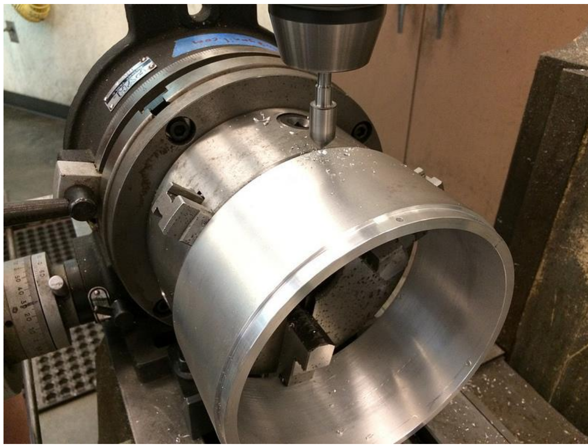


Removal tool 2, inside PSAS/models/ideas:
1 of these:



5/13/14 1:36pm Sam:
Sent an email to Kevin asking for more AF191-M. We need this to fix the big wrinkles that are caused by the yellow glue.

5/13/14 1:36pm Sam:
Finishing the dummy rings:
We set up the rotary chuck on the mill table using Mike's needle dial indicator. The dummies were held on the inside with the mating face facing outward. All holes were indexed from this surface. We did one hole at a time, all the way through center drilling, through drilling, and countersinking. This was to prevent misalignment after moving the table and the chuck around so everything was coaxial. For countersinking, we just used the 82deg tool we bought, touching the tool to the hole and locking the quill, then moving the table up 0.040". This was a sufficient depth for the 100deg screws we are using.



2535370966: Number for ACES

5/13/14 9:20am Jack:

We are making part 32. This is our first full module. **Writeup:**

> The new adhesive (yellow) is very heavy. It would be better to use the older adhesive. The new plastic layup blocks work great. We got a little confused about cutting the adhesive film. We are using both types of adhesive films, to save our good stuff (blue, old). So we are only using the yellow film on the adhesive core, and the blue film on the alumminum rings. The templates were designed to only use one film type. The first carbon layer was a tiny bit too wide to fit between the rings. The first layer of adhesive film is also slightly too wide. Overlaps are good. The overlap is too much on the core, we cut off 1.875" to make the seam correct. There is a tiny bit of a step down from the core to the ring. This is because the yellow adhesive is thicker, we want to switch back to the blue stuff to save a .15lbf per module. The surface came out very veiny with big valleys along the length of it. We think this is because of the big wrinkles in the first layer of adhesive film. The new adhesive film is hard to work with because it is so thick, brittle, and not tacky. The aluminum foil we used did not work very good. It was a pain to peel off, and did not make an amazing surface finish. The surface finish was tolerable. We put it in the freezer to help us get it off the mandrel. We need to dip the screws in liquid mold release next time, because they get epoxied pretty substantially.

Weight of layup parts:

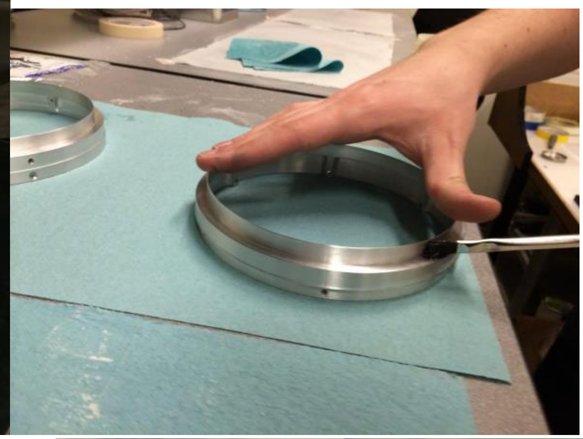
- FCR 74g
- MCR 66g
- Core 42g
- Yellow adhesive film 131g
- Blue adhesive film: 6g
- Carbon 268g

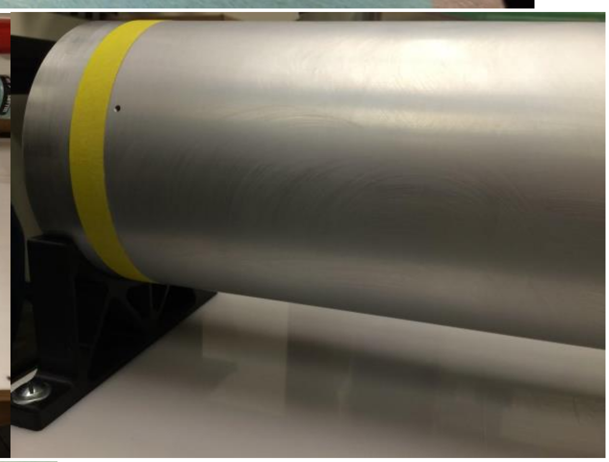
Total: 590g = 1.30pounds before cure

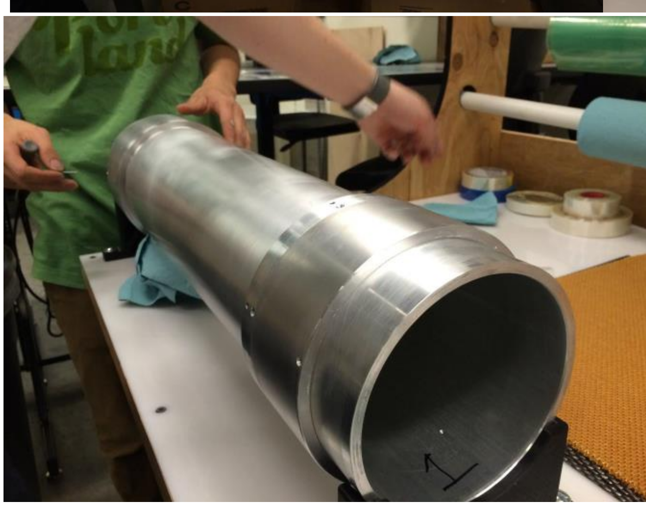
Tech sheet: AF 30 (yellow, new): 250-300g/m^2 for 10mil

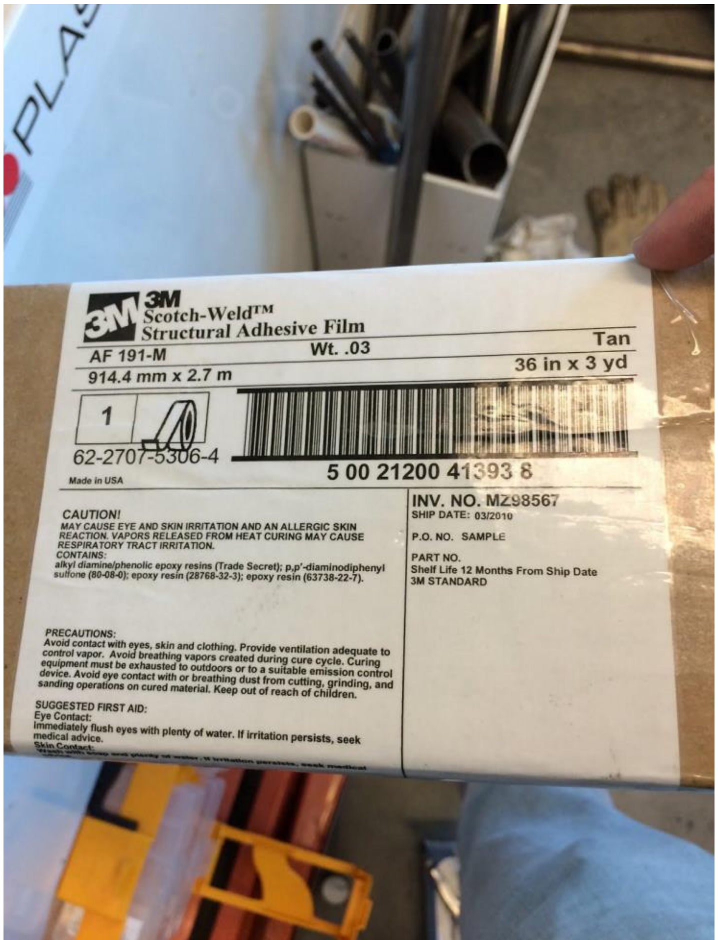
Tech sheet: AF191-m (blue, old): 146 g/m^2 for .03

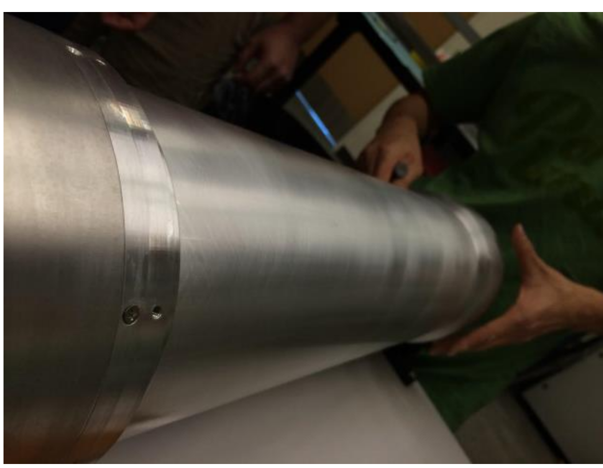
This means we can save approximately .15 pounds per module by switching back to blue. the blue is .03, and the yellow is 10 mil.





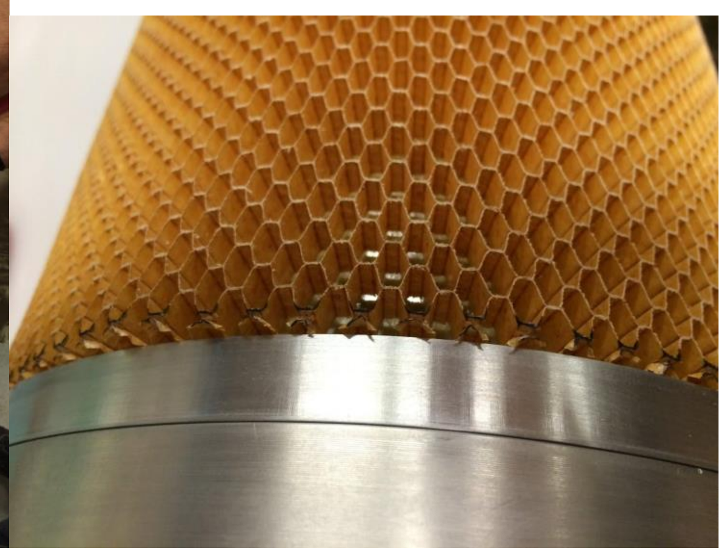


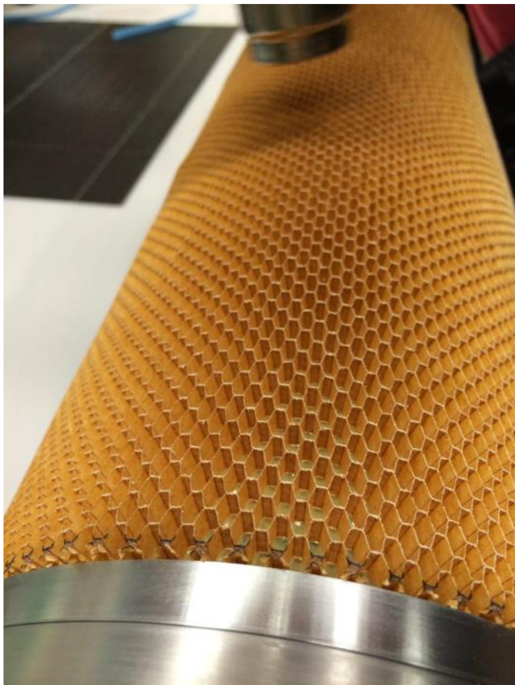

3M
Scotch-Weld™
Structural Adhesive Film
AF 191-M
Wt. .03
Tan
914.4 mm x 2.7 m
36 in x 3 yd
1
62-2707-5306-4
5 00 21200 41393 8
Made in USA
CAUTION!
MAY CAUSE EYE AND SKIN IRRITATION AND AN ALLERGIC SKIN REACTION. VAPORS RELEASED FROM HEAT CURING MAY CAUSE RESPIRATORY TRACT IRRITATION.
CONTAINS:
alkyl diamine/phenolic epoxy resins (Trade Secret); p,p'-diaminodiphenyl sulfone (80-08-0); epoxy resin (28768-32-3); epoxy resin (63738-22-7).
PRECAUTIONS:
Avoid contact with eyes, skin and clothing. Provide ventilation adequate to control vapor. Avoid breathing vapors created during cure cycle. Curing equipment must be exhausted to outdoors or to a suitable emission control device. Avoid eye contact with or breathing dust from cutting, grinding, and sanding operations on cured material. Keep out of reach of children.
SUGGESTED FIRST AID:
Eye Contact:
Immediately flush eyes with plenty of water. If irritation persists, seek medical advice.
Skin Contact:
INV. NO. MZ98567
SHIP DATE: 03/2010
P.O. NO. SAMPLE
PART NO.
Shelf Life 12 Months From Ship Date
3M STANDARD

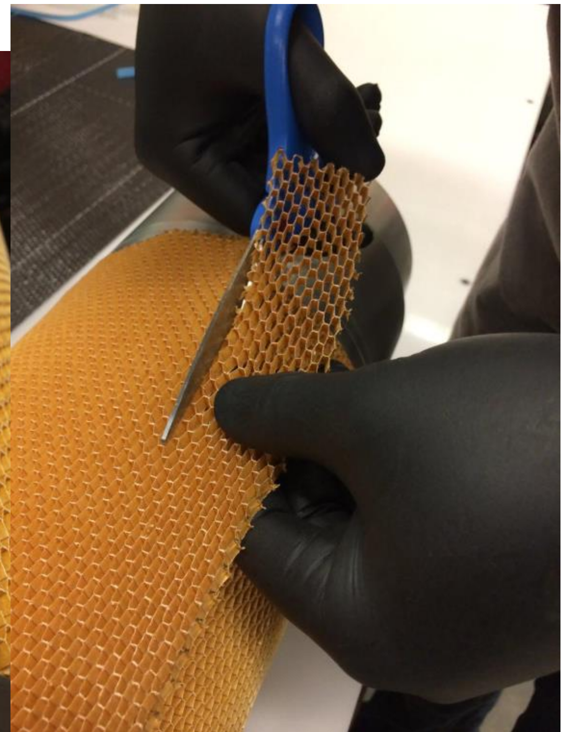


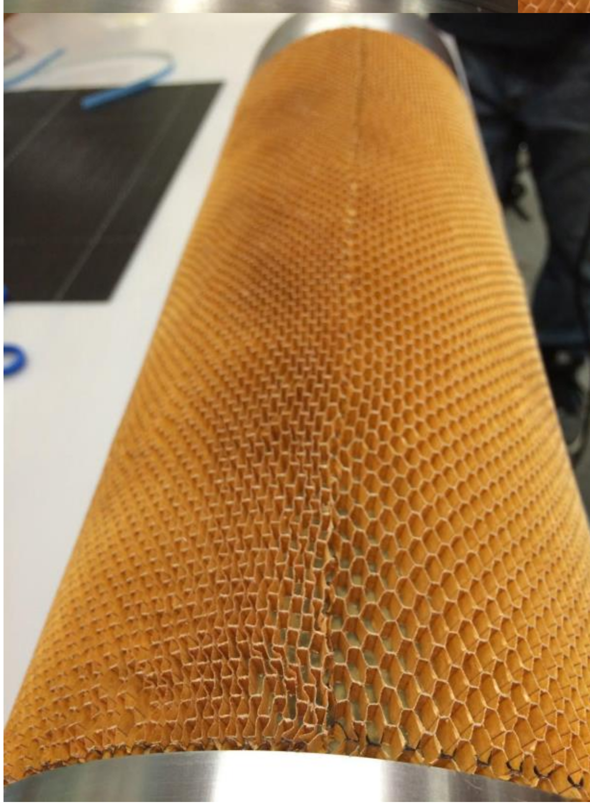


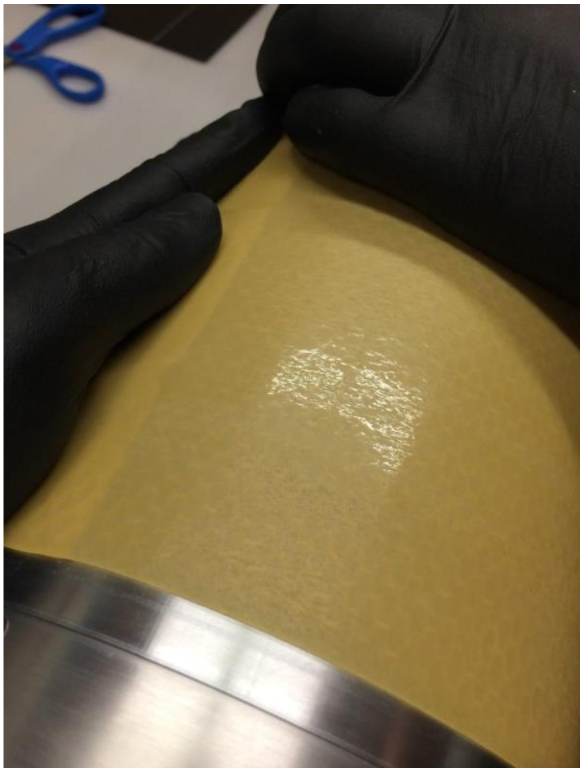


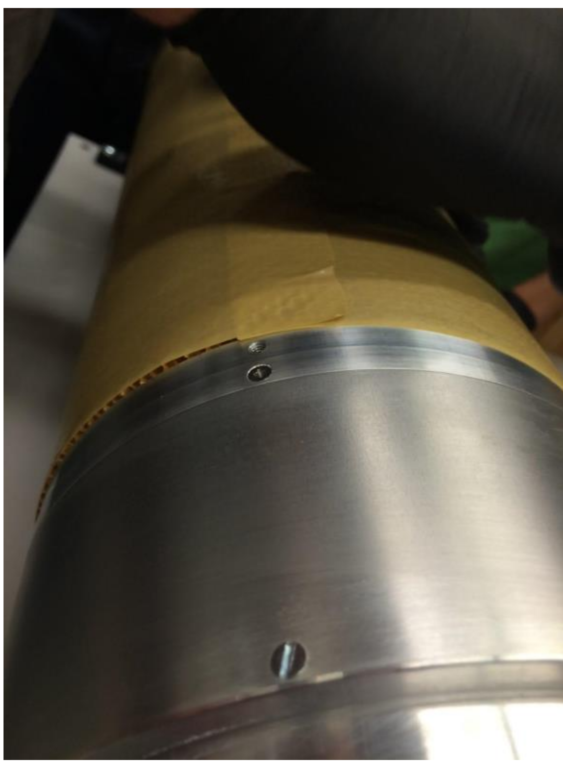
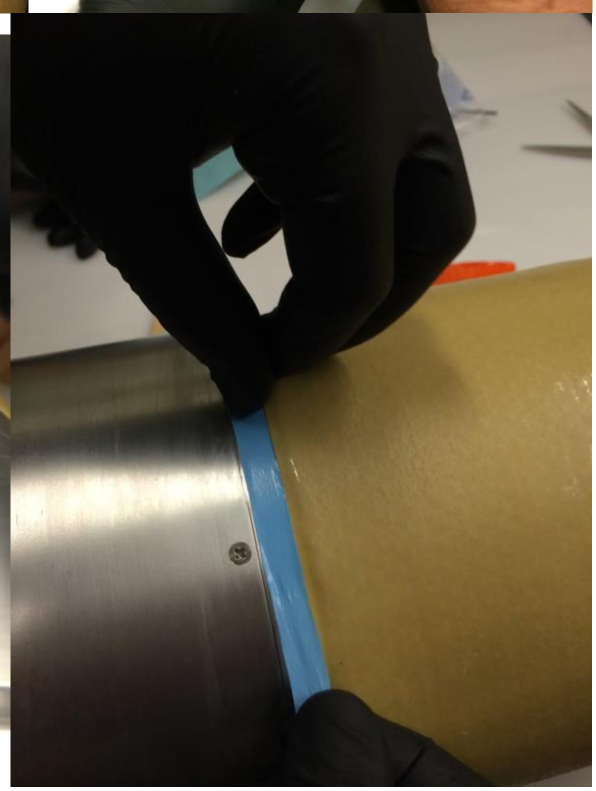



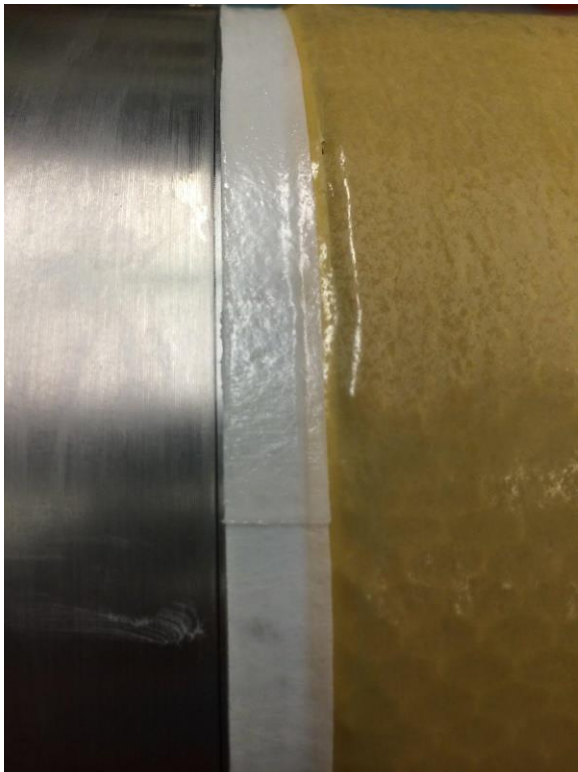


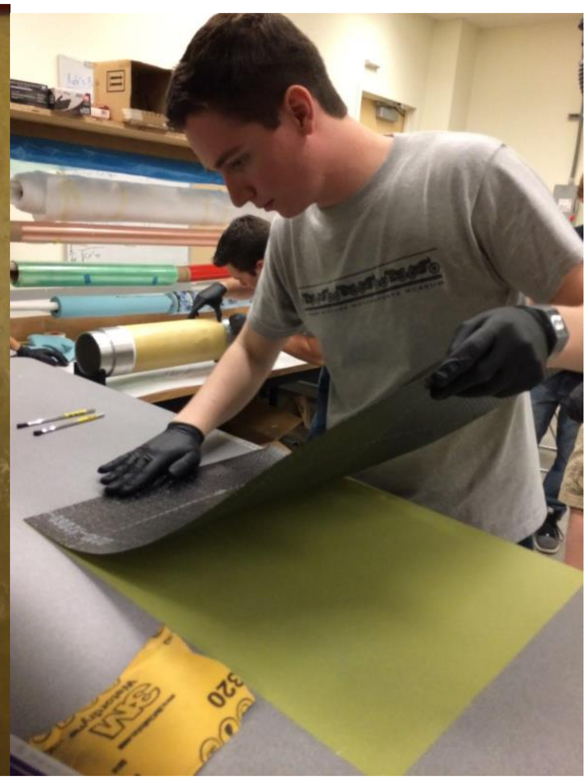


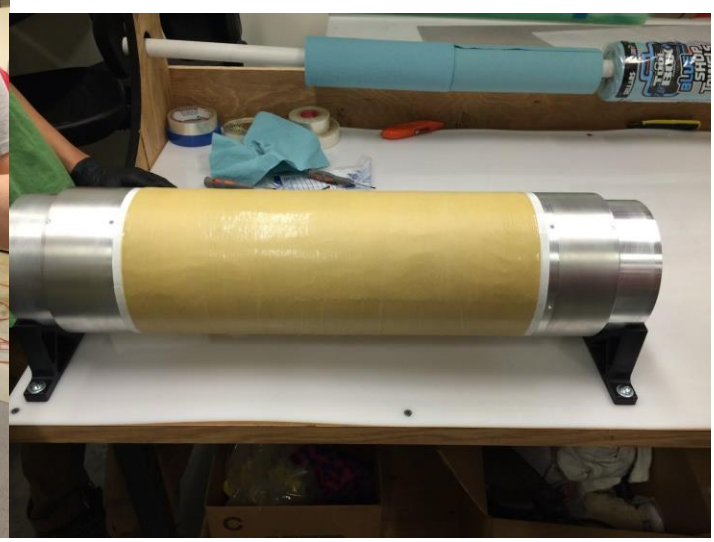




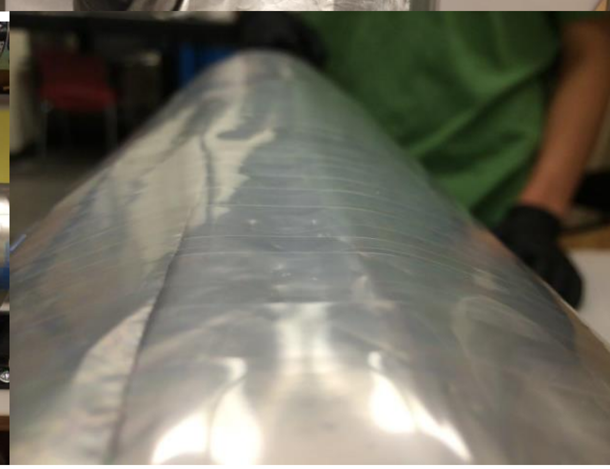











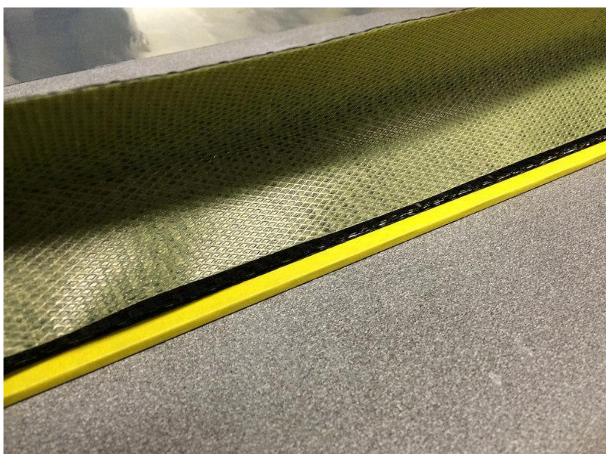
5/7/14 5:20pm Sam:
Sheet metal parts in SolidWorks:
Just go to View > Toolbars > Sheet Metal

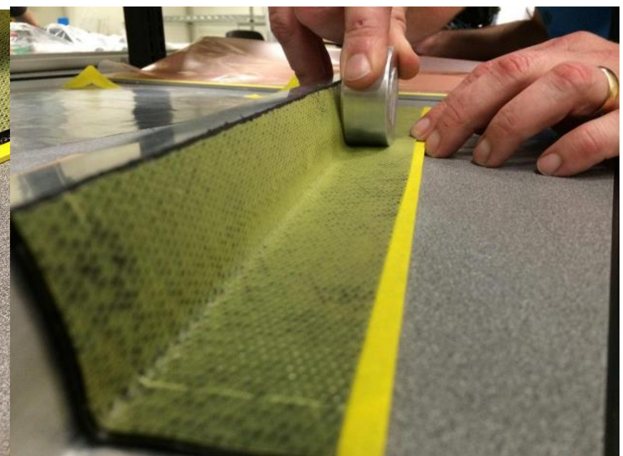
5/7/14 11:40am Jack:
We made parts 28, 29, 30. 28 is a test to see if post cure works.

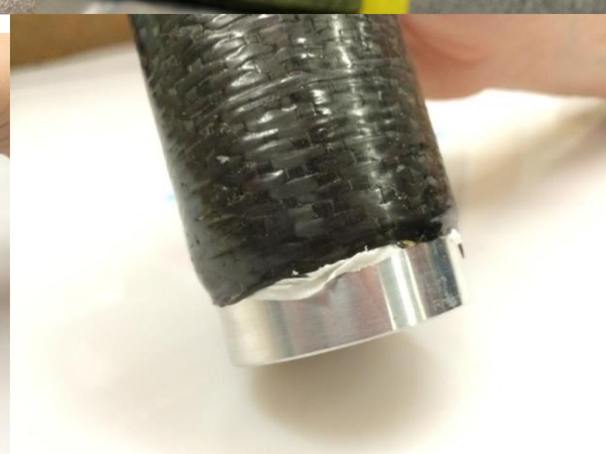
We machined aluminum plugs and then attempted to film adhesive cure them into part 5. The joint on one half didn't hold up at all, and the joint on the other half was weak.

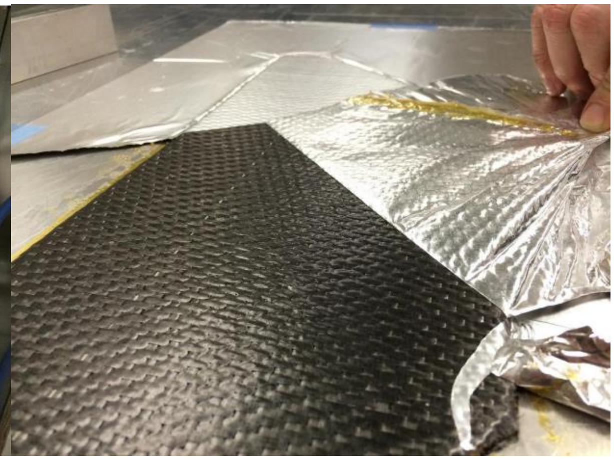
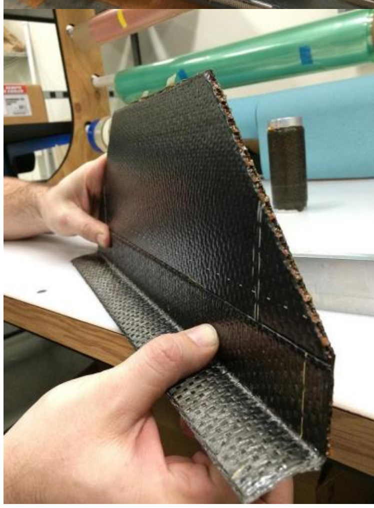
Part 30 was made using the surfaced aluminum fin mold. This part came out great. Getting the carbon into the small 1/16" radius was nearly impossible, but it came out mostly alright. The vacuum bag came undone halfway through cure.

Part 31 was a test to see how strong a ⅛” 1 core 1 part would turn out. We used aluminum foil as the caul plate, which worked fairly well. The surface finish on both sides wasn’t spectacular, but we were using a thin layer of carbon and a vacuum bag on top of core.





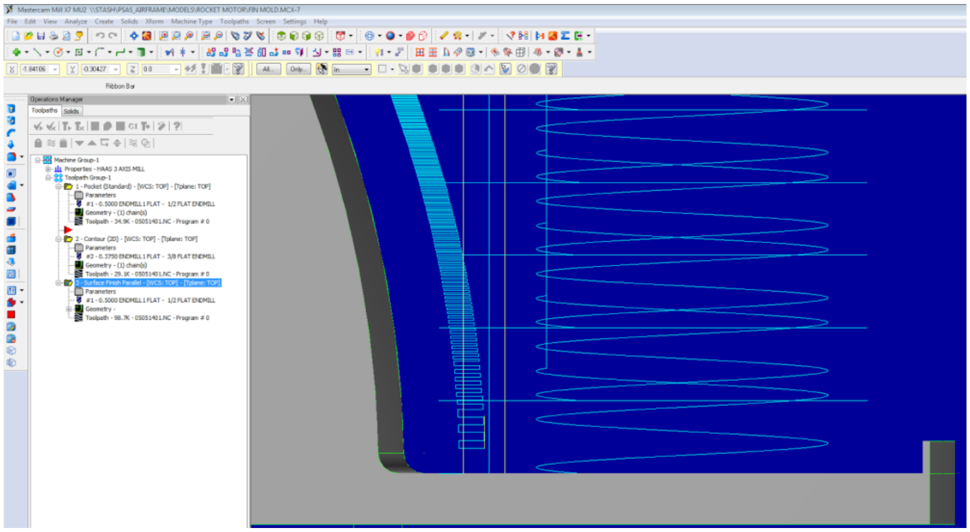


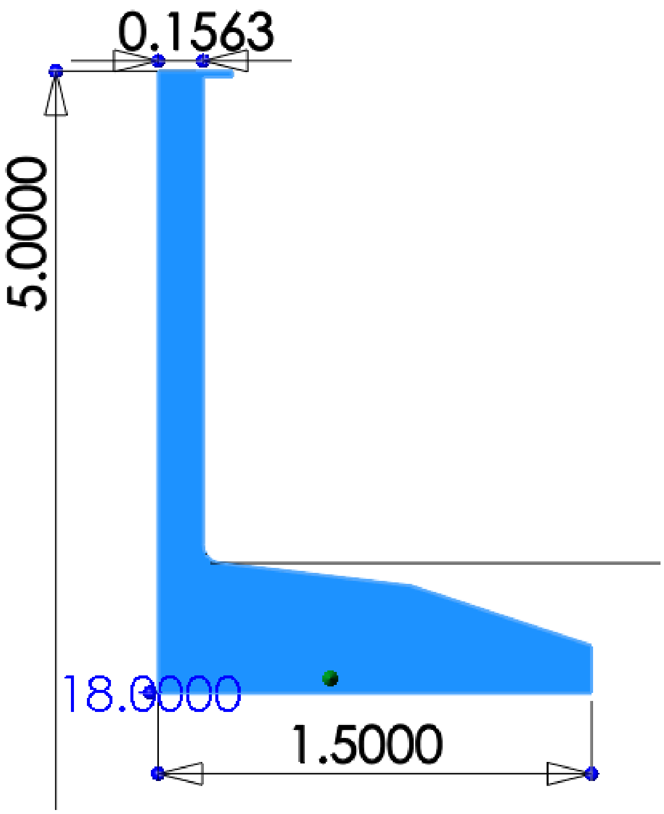




5/6/14 5:20pm Barett:
Machined two post-cure test pieces to fit into part #5, a 4-layer 2" ID carbon tube. The point of the test is to determine the tolerances for post curing a ring into a carbon tube. For the 2" ID diameter tube the aluminum rings diameter needed to be 0.015" under to allow fitment of the carbon tube with one layer of film adhesive.
Tube Dimensions: 2.010" ID
Ring Dimensions: 1.995" OD
Film Adhesive Thickness: 0.005"
In addition to the 0.015" under dimensions, the edge of the ring that goes into the carbon tube first must be chamfer at an approximate 30 degrees off axial. The film adhesive should be down on the chamfer during installation to allow the carbon tube to slide over ring and adhesive without dislodging the adhesive. The film adhesive ends must butt together, not overlap.

5/6/14 1:10pm Jack:
We are machining the fin base supports. Program 05061401. It has a lot of material to take, and has to be accurate on the curved section. using rpm 2700 and feed rate of 10.

We machined the fin support mold, dummy rings, and two aluminum pucks that we will try to post bond into carbon part 5.





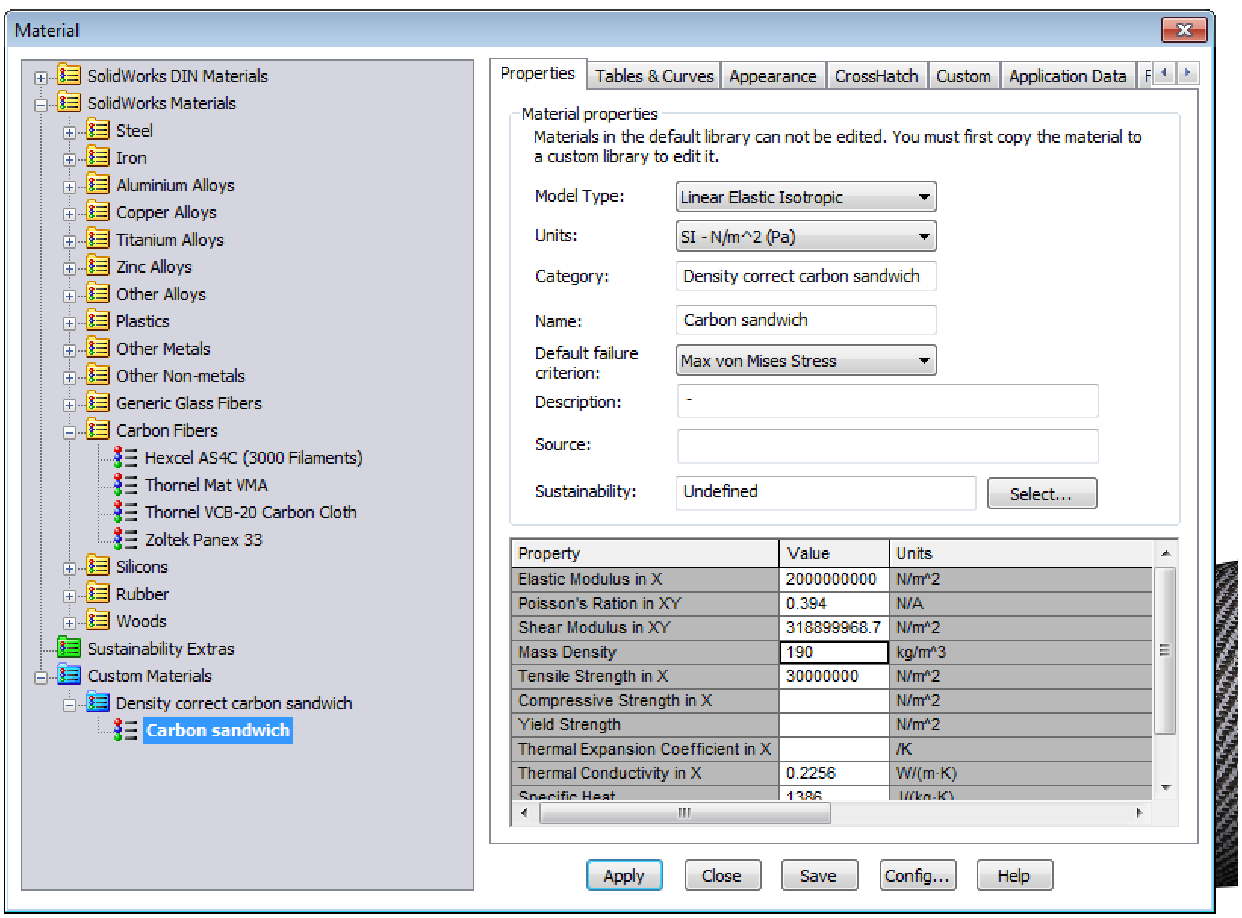
5/4/14 5:10pm Jack:
To do:

- Write final report
    - Make drawings
    - BOM
    - Schedule
- Machine Dummy rings
- Machine NSR
    - Finalize dimensions
- Machine Nosecone side NSR
    - Try post cure first

        - Machine cylinder to fit into part 5
        - Bake into part 5
- Talk about PRR
- Sheet metal shelves
- Fin brackets
- Pick up material at EMJ and deliver to Arrow
- Lay up several ideas
    - Fin edges andrew wanted aluminum edges on the fins
    - post cure in the tube 4 layer (part 5)
    - Cone shape
        - Still needs to be thought about
        - ask to use their wooden one

5/2/14 6:50pm Jack:
Part 28 weighs 3 oz (87 grams). Dimensions: 3.4” ID 4” OD 5.8” long
Density= mass/volume
Volume= 2*Pi*(4^2-3.4^2)=27.88 in^3= .0004569m^3
Density= 87 grams/ (.0004569 m^3)= 190.413 kg/m^3

Part 5 weighs 1.875 oz (53 grams) dimensions: 2” ID 2.12” OD 4.6” Long
Density= mass/volume
Volume= 2*Pi*(2.12^2-2^2)=3.1 in^3= .0000508m^3
Density= 53 grams/ (.0000508 m^3)= 1043.307kg/m^3



7075-0 [edit]

Un-heat-treated 7075 (7075-0 temper) has maximum tensile strength no more than 40,000 psi (275 MPa), and maximum yield strength no more than 21,000 psi (145 MPa). The material has an elongation (stretch before ultimate failure) of 9–10%.

7075-T6 [edit]

T6 temper 7075 has an ultimate tensile strength of 74,000–78,000 psi (510–572 MPa) and yield strength of at least 63,000–69,000 psi (434–503 MPa). It has a failure elongation of 5–11%.[3]

The T6 temper is usually achieved by homogenizing the cast 7075 at 450C for several hours, and then aging at 120C for 24 hours. This yields the peak strength of the 7075 alloy. The strength is derived mainly from finely dispersed eta and eta' precipitates both within grains and along grain boundaries.[4]

7075-T7 [edit]

T7 temper has an ultimate tensile strength of 73,200 psi (505 MPa) and a yield strength of 63,100 psi (435 MPa). It has a failure elongation of 13%.[5]

T7 temper is achieved by overageing (meaning ageing past the peak hardness) the material. This is often accomplished by ageing at 100C-120C for several hours and then at 160C-180C for 24 hours or more. The T7 temper produces a micro-structure of mostly eta precipitates. In contrast to the T6 temper, these eta particles are much larger and prefer growth along the grain boundaries. This reduces the susceptibility to stress corrosion cracking. T7 temper is equivalent to T73 temper.[6]

5/2/14 2:50pm Jack Rob:

Design of the NSR:

Adjusted half of the beams to be the correct width. The beams under the explosion area are significantly larger so that we make sure no deflection in the aluminum ruins the shock load that breaks the glue.

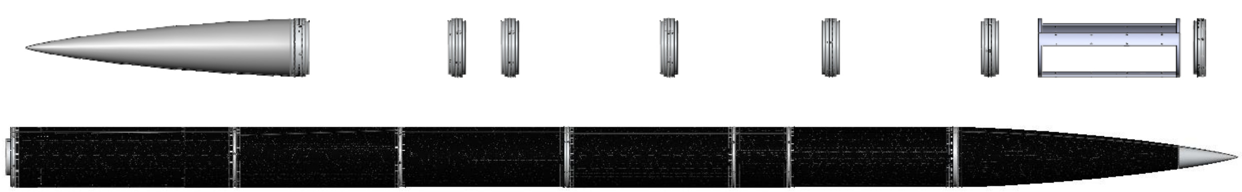
y=6.48/(3.14^.5)*(arccos(1-2*x/30))-(sin(2*(cos(1-2*x/30)/2)))^.5

=$L$2/(3.14^0.5)*((ACOS(1-2*A2/$K$2))-(SIN(2*(ACOS(1-2*A2/$K$2)))/2))^0.5)

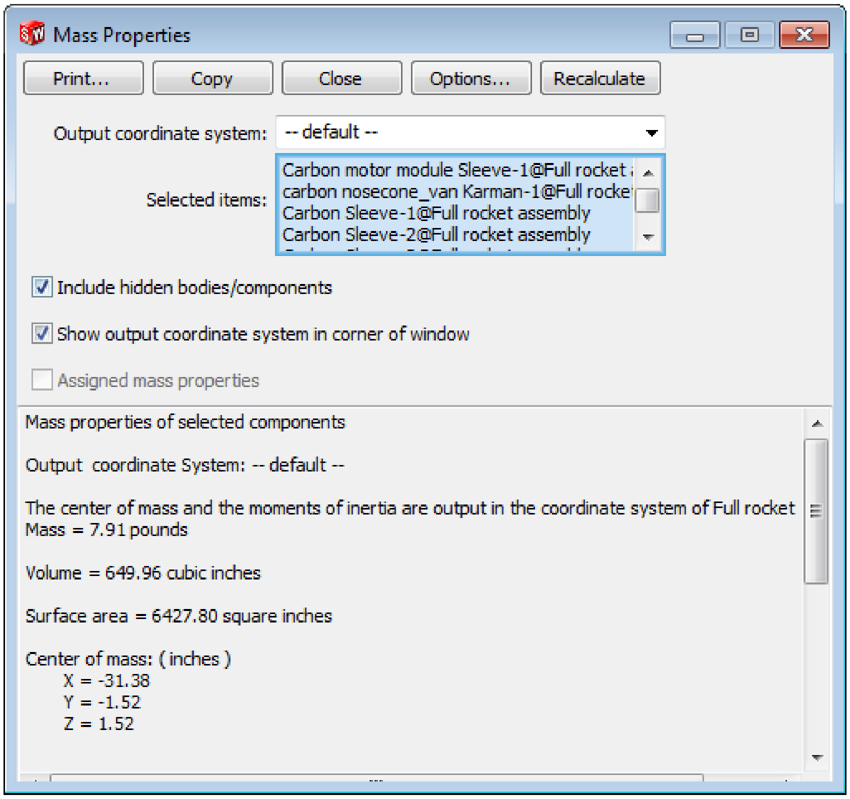
Final:

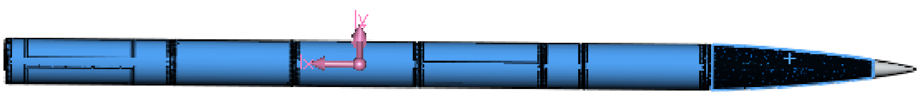
y=R/(3.14^0.5)*((arccos(1-2*x/L))-(sin(2*(arccos(1-2*x/L)))/2))^0.5

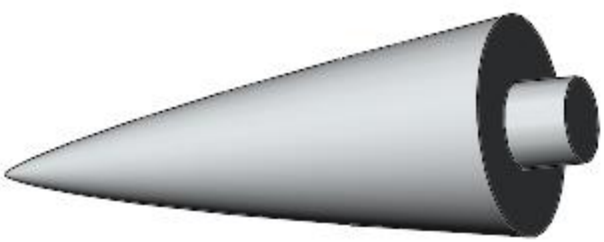
R= 3.24, L=30



Weight not including the nosecone tip: 7.91 pounds. this includes electronics carrier. The old motor module weighs 11.8 pounds. The motor without grains weighs 7.2 pounds.


Mass Properties
Print...
Copy
Close
Options...
Recalculate
Output coordinate system:
-- default --
Selected items:
Carbon motor module Sleeve-1@Full rocket
carbon nosecone_van Karman-1@Full rocke
Carbon Sleeve-1@Full rocket assembly
Carbon Sleeve-2@Full rocket assembly
Include hidden bodies/components
Show output coordinate system in corner of window
Assigned mass properties
Mass properties of selected components
Output coordinate System: -- default --
The center of mass and the moments of inertia are output in the coordinate system of Full rocket
Mass = 7.91 pounds
Volume = 649.96 cubic inches
Surface area = 6427.80 square inches
Center of mass: (inches)
X = -31.38
Y = -1.52
Z = 1.52





nose cone shapes

Haack series [edit]

Unlike all of the nose cone shapes above, the Haack Series shapes are not constructed from geometric figures. The shapes are instead mathematically derived for the purpose of minimizing drag; see also Sears–Haack body. While the series is a continuous set of shapes determined by the value of *C* in the equations below, two values of *C* have particular significance: when *C* = *0*, the notation *LD* signifies minimum drag for the given length and diameter, and when *C* = *1/3*, *LV* indicates minimum drag for a given length and volume. The Haack series nose cones are not perfectly tangent to the body at their base[citation needed] except for case where *C* = *2/3*. However, the discontinuity is usually so slight as to be imperceptible. For *C* > *2/3*, Haack nose cones bulge to a maximum diameter greater than the base diameter. Haack nose tips do not come to a sharp point, but are slightly rounded.

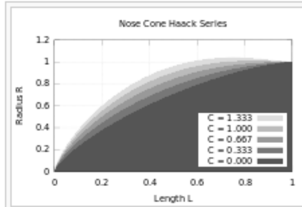
$$\theta = \arccos\left(1 - \frac{2x}{L}\right)$$

$$y = \frac{R}{\sqrt{\pi}}\sqrt{\theta - \frac{\sin(2\theta)}{2} + C\sin^3\theta}$$

Where:

C = 1/3 for LV-Haack

C = 0 for LD-Haack

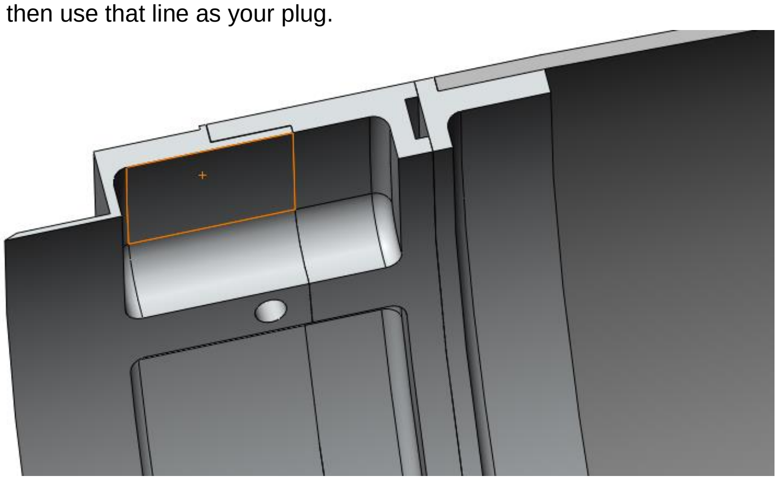


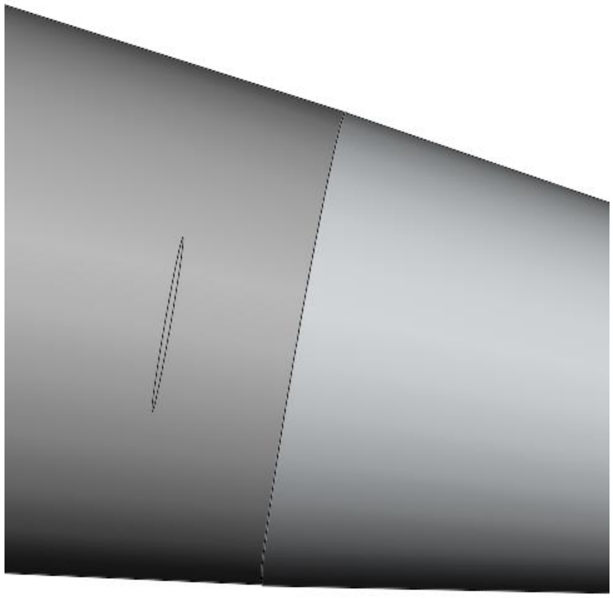
Graphs illustrating *Haack series* nose cone shapes

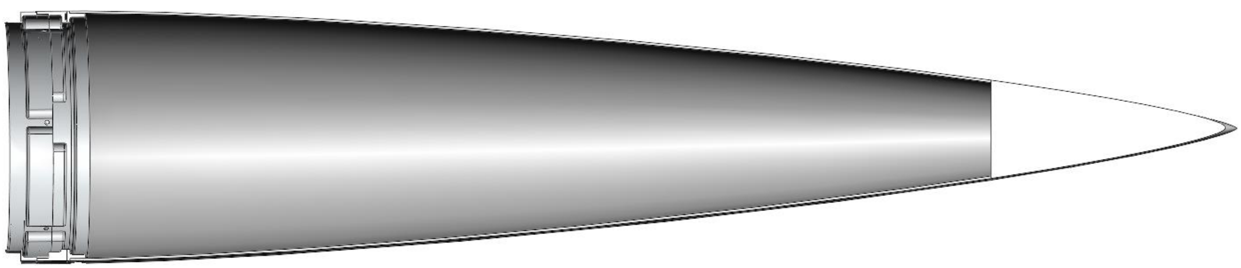
Von Kármán [edit]

The Haack series giving minimum drag for the given length and diameter, LD-Haack, is commonly referred to as the Von Kármán or the *Von Kármán Ogive*.

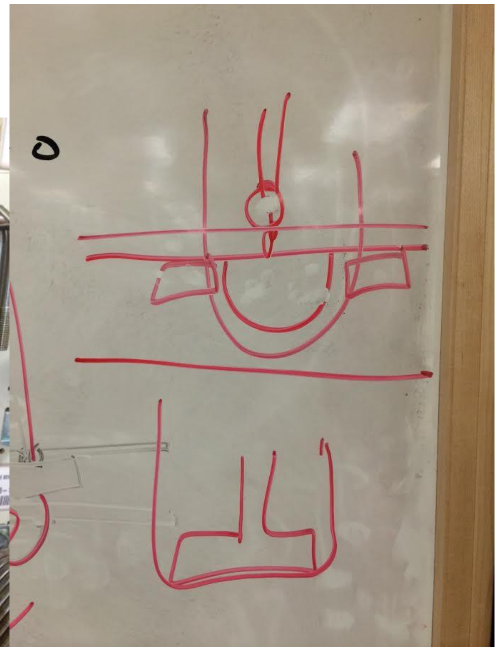
I had a lot of difficulty figuring out how to make the carbon shell. The problem is that if you make the plug the correct shape, and then offset the sketch line .06", the resulting outer curve is not the correct von karman curve. If you make two van karman curves and then revolve between them, the resulting shell is not a constant thickness. The way you have to do it is draw the von karman line as the outermost surface, and then offset inwards the thickness of the carbon, then use that line as your plug.

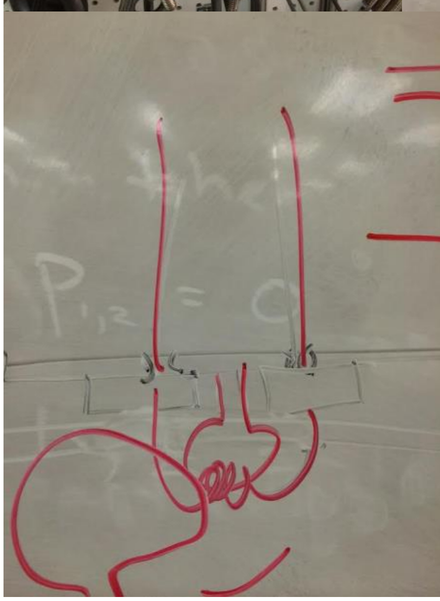


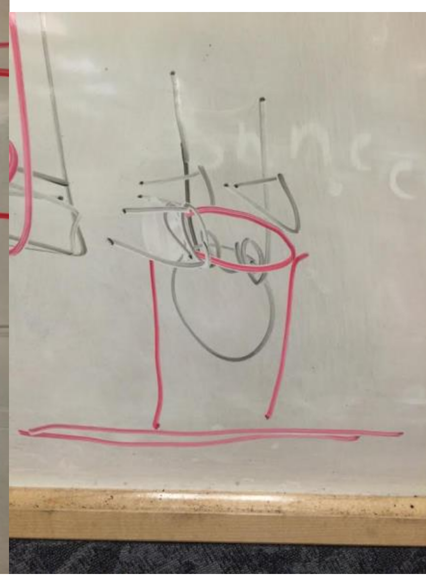


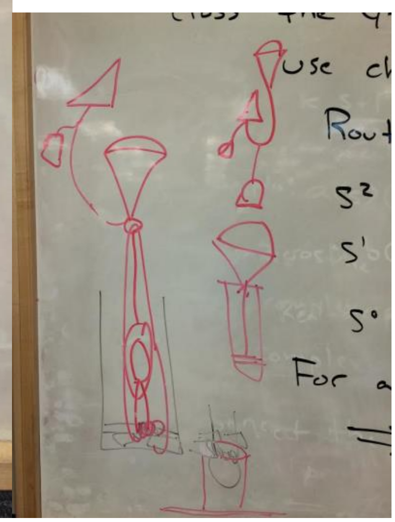


5/1/14 4:50pm Jack:







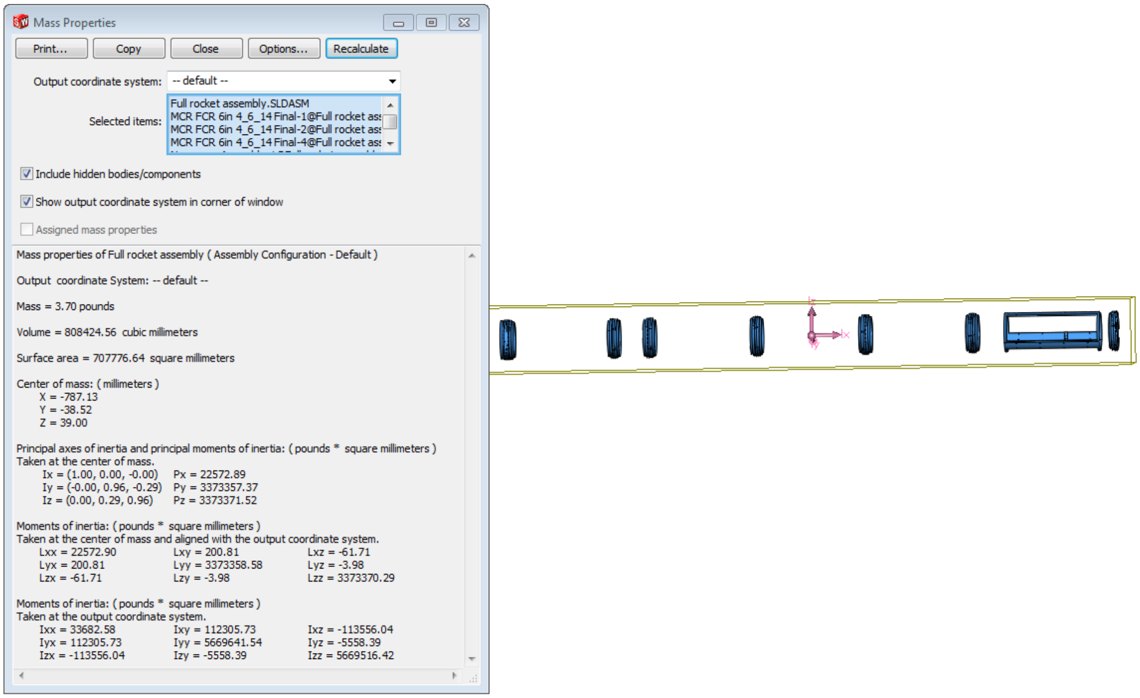


For the fin molds, we need to order stock
Aluminum bar stock 2.25" x 1.5” x 18”

We need to talk to Andrew and Dave first so they can approve our design. Then we need to get the dimensions from PSAS so we can make sure we make them the right length. I suggest we order at least 2 of these bars so we can make the 6 fin brackets in 3 bakes.

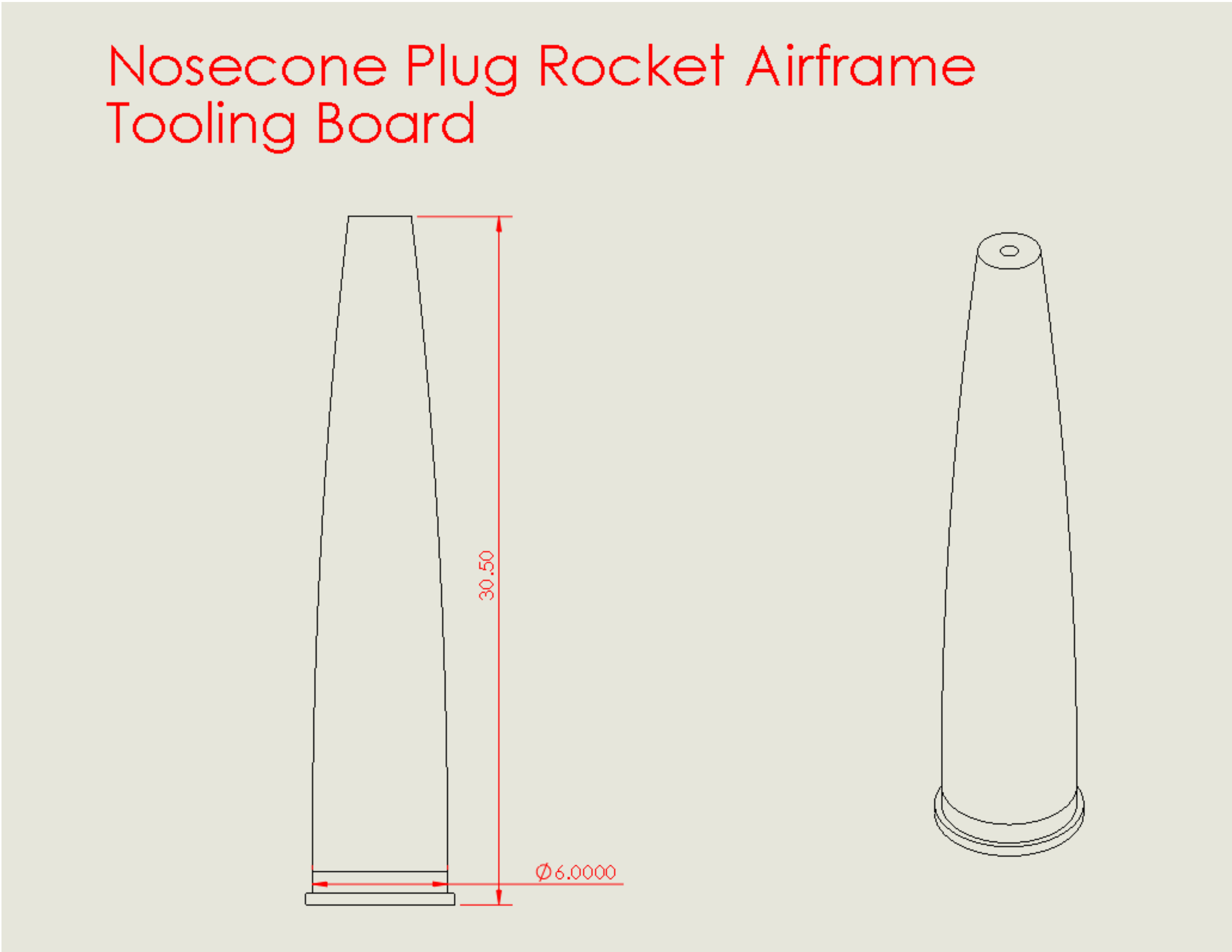
Forged steel eyebolts:
The 5/16 eyebolt is rated to 900lbf
The 3/8 eyebolt is rated to 1300lbf

The weight of the airframe so far: 3.65lbf



5/1/14 4:50pm Jack:

Made a rough drawing to give Arrow an idea of how hard this nosecone plug is to machine. This way we can have a conversation about it when we get there.

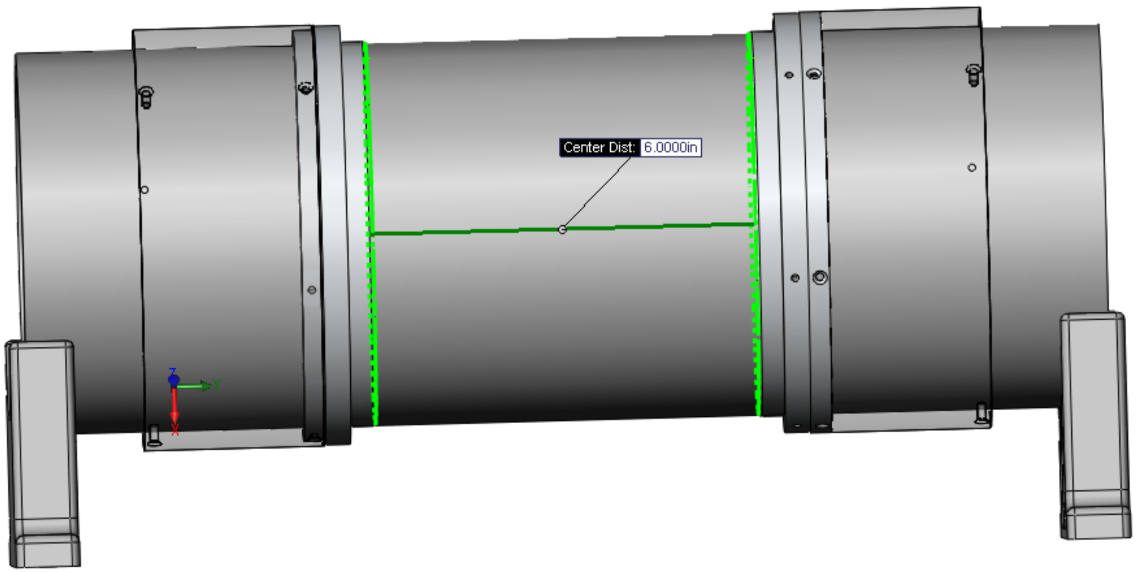


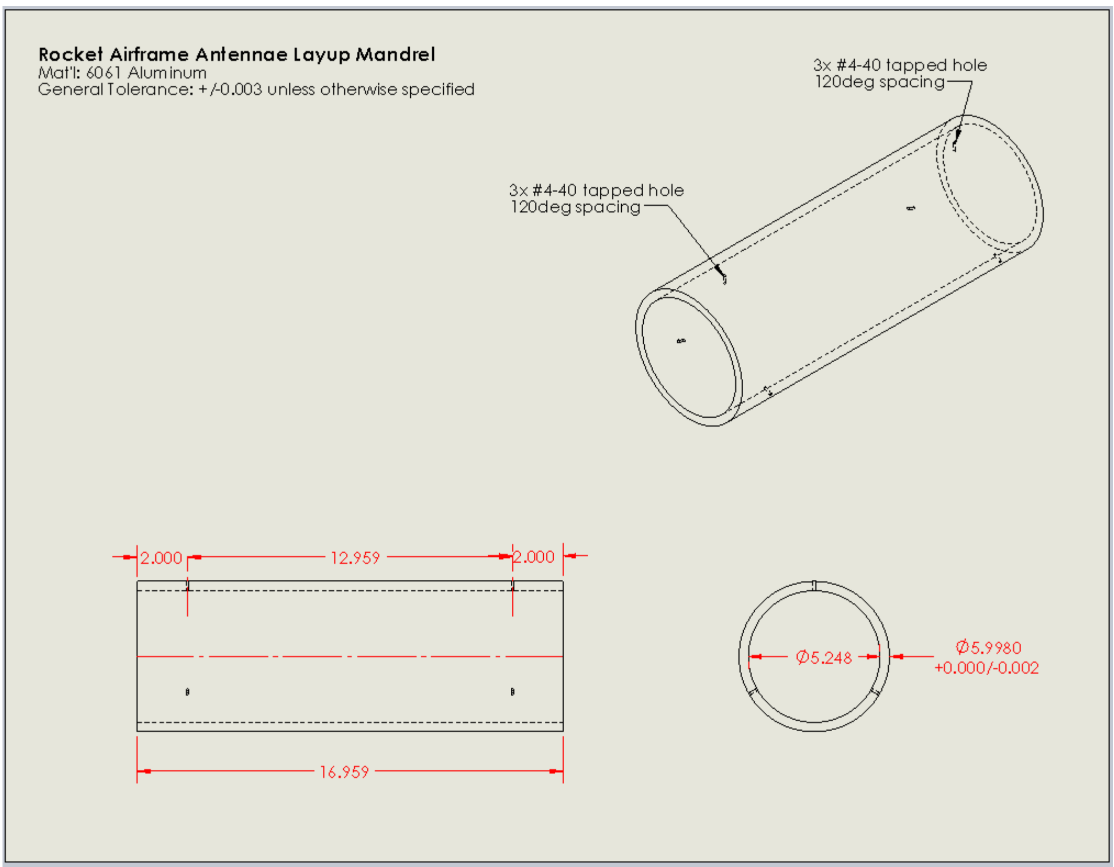
5/1/14 4:50pm Jack:
I accidentally saved the drawings backwards in names. The antenna is the motor and vice versa.

29.062 is the distance between the mandrel holes, for a module length of 24.06.
This means that we have 29.062” - 24.06”= 5.002”

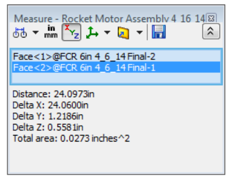
So if we want a 6” long module, we add the number above (5.002”)

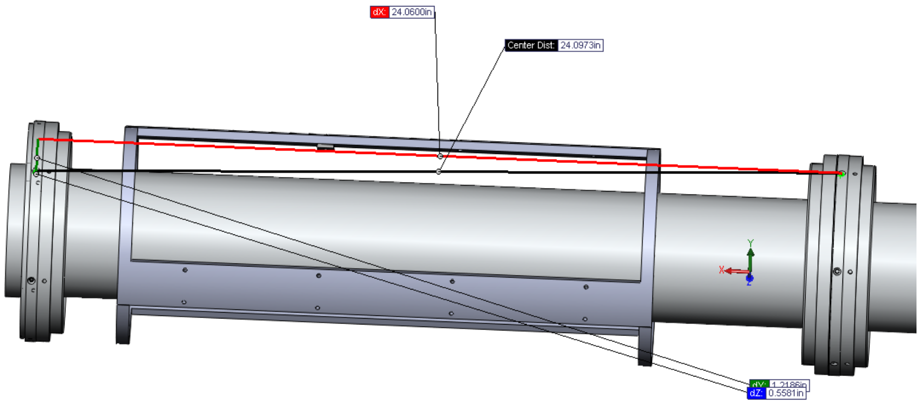
This theory didn’t work. The correct value to put in was 15.002, even though it seems like it should have been 11.002.

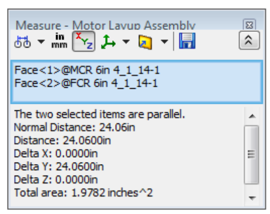


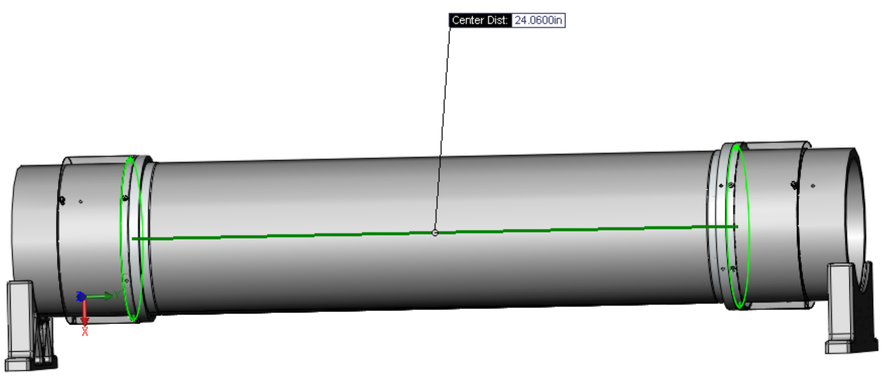


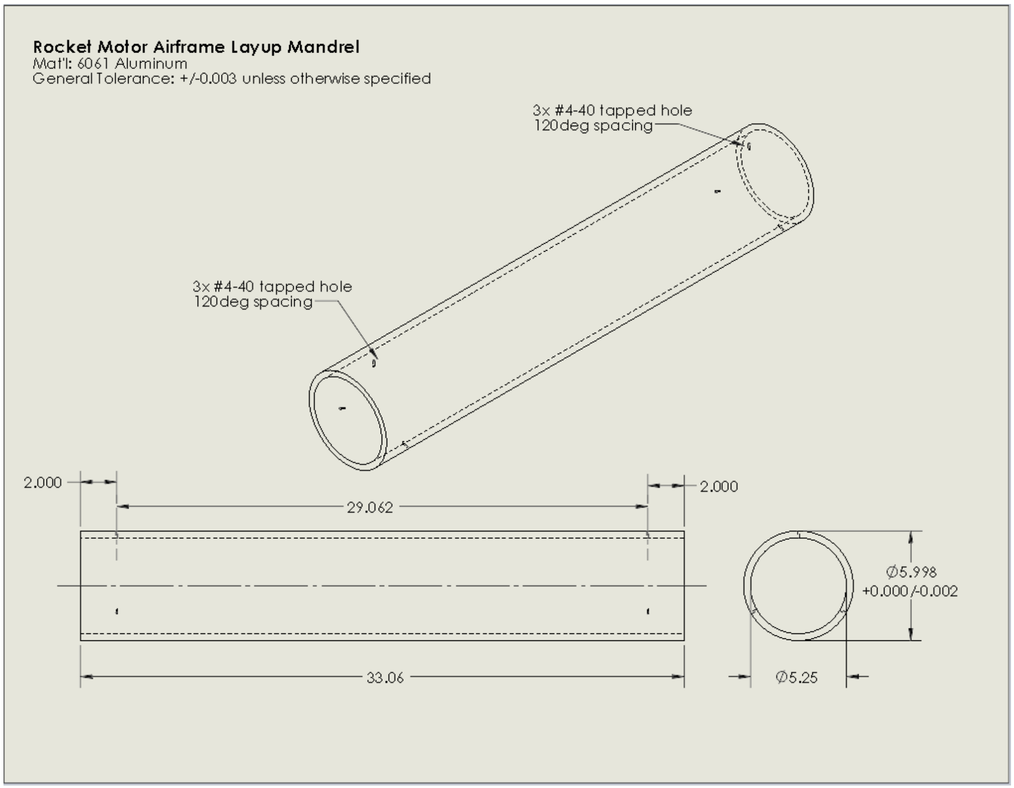
5/1/14 3:50pm Jack:
We are trying to figure out the other two mandrel dimensions so that we can bring the drawings with us if arrow wants to help us out.


Measure - Rocket Motor Assembly 4 16 14
Face<1>@FCR 6in 4_6_14 Final-2
Face<2>@FCR 6in 4_6_14 Final-1
Distance: 24.0973in
Delta X: 24.0600in
Delta Y: 1.2186in
Delta Z: 0.5581in
Total area: 0.0273 inches^2


dX: 24.0600in
Center Dist: 24.0973in
dY: 1.2186in
dZ: 0.5581in


Measure - Motor Layup Assembly
Face<1>@MCR 6in 4_1_14-1
Face<2>@FCR 6in 4_1_14-1
The two selected items are parallel.
Normal Distance: 24.06in
Distance: 24.0600in
Delta X: 0.0000in
Delta Y: 24.0600in
Delta Z: 0.0000in
Total area: 1.9782 inches^2

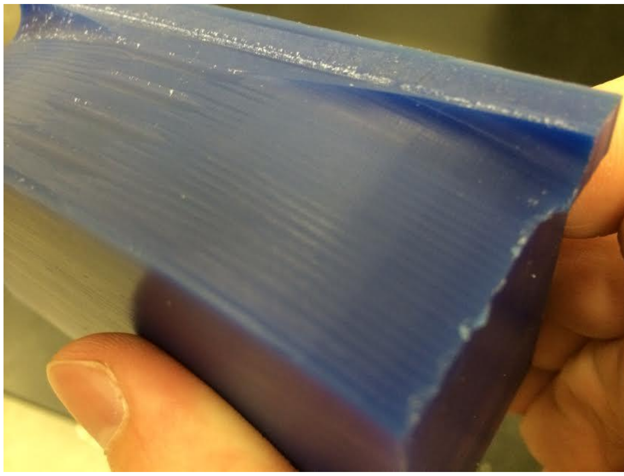

Center Dist: 24.0600in

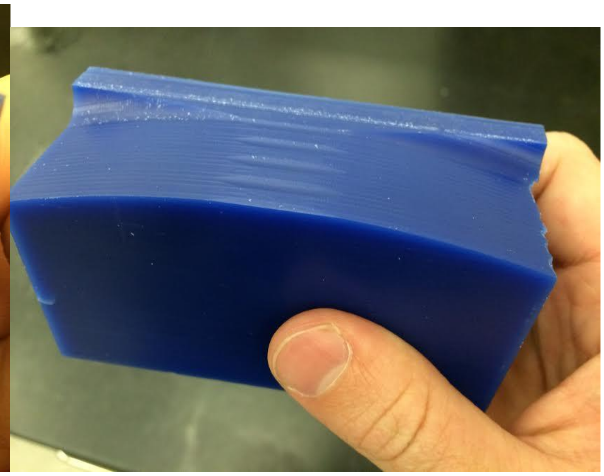


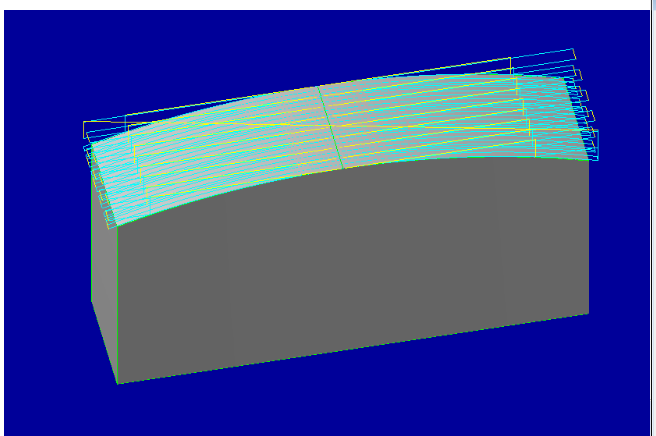
5/1/14 3:30pm Jack:
We got the tooling board donated (free) by general plastics! They are sending us a scrap piece that is slightly bigger than we need as remnants. We should ask arrow to machine it for us.
Questions answered by the guy Sam has been talking to:

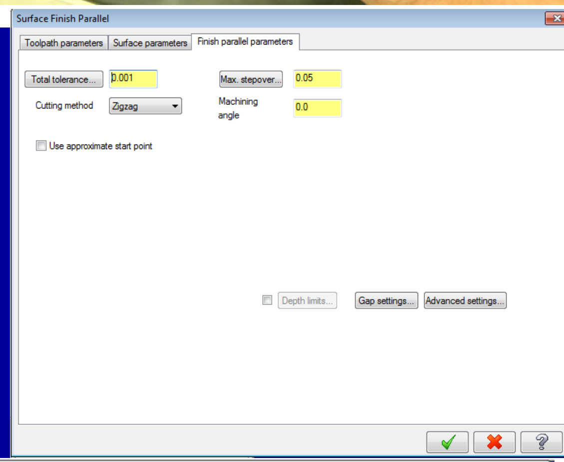
- How do we glue it?
- Can we cut it on a band saw?
- what is the surface prep process?
    - Can we just put our mold release directly on it?
    - Any sealing?
        - Going to want to seal it, otherwise get material transfer
        - Buy glue to glue it together
        - It'll look pretty smooth. In the 40 lb there is a significant difference in surface finish.He will include this information in the email

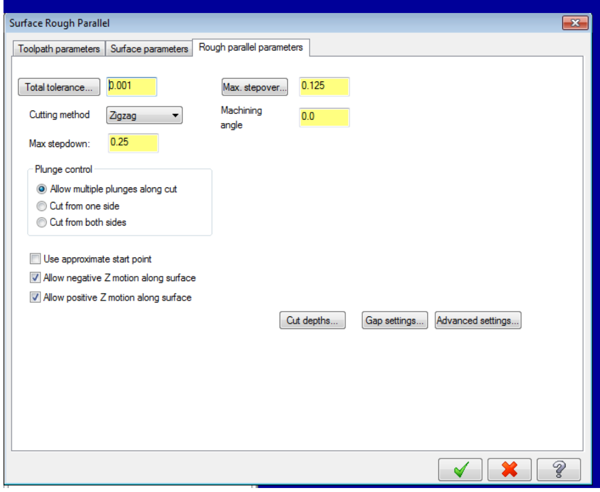
5/1/14 2:30pm Jack:
Learned how to surface parts to see if it was doable easily by us. This would allow us to make more complex molds for carbon fiber. It is very easy to do. We surfaced a piece of wax with both a rough surfacing path and a fine surfacing path. It is very easy to get going, and took us 2 hours to learn.

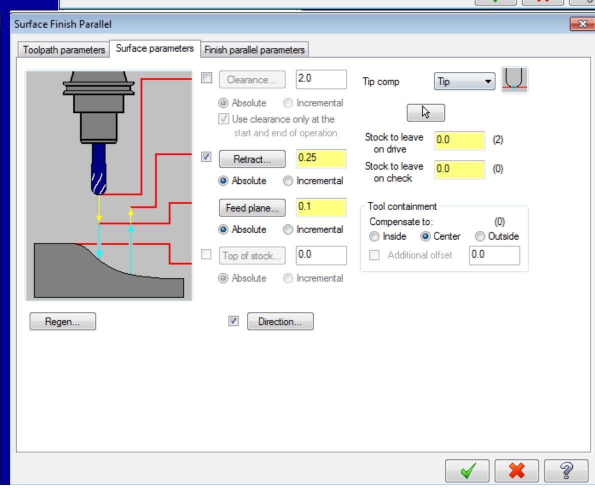


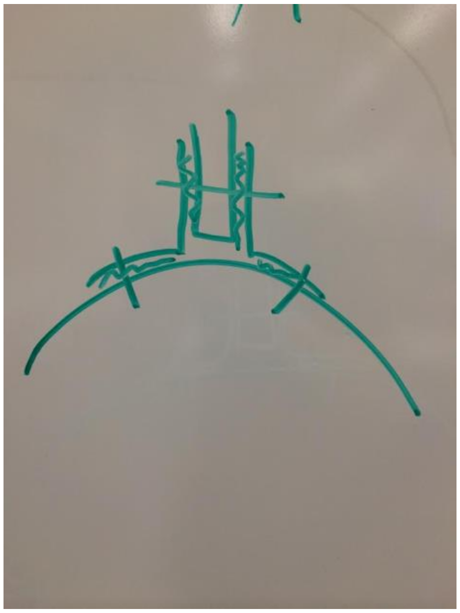





Surface Finish Parallel
Toolpath parameters
Surface parameters
Finish parallel parameters
Total tolerance...
0.001
Max. stepover...
0.05
Cutting method
Zigzag
Machining angle
0.0
Use approximate start point
Depth limits...
Gap settings...
Advanced settings...

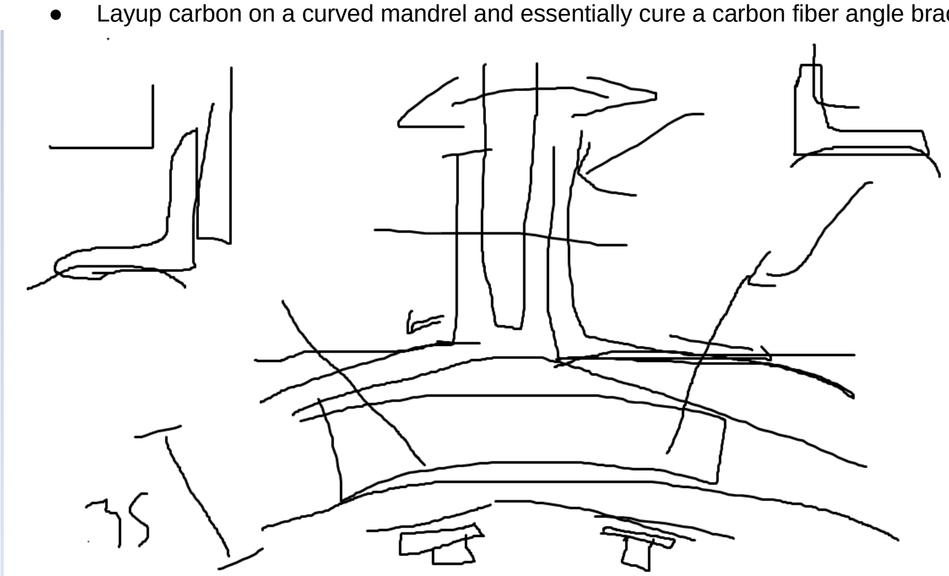

Surface Rough Parallel
Toolpath parameters
Surface parameters
Rough parallel parameters
Total tolerance...
0.001
Max. stepover...
0.125
Cutting method
Zigzag
Machining angle
0.0
Max stepdown:
0.25
Plunge control
Allow multiple plunges along cut
Cut from one side
Cut from both sides
Use approximate start point
Allow negative Z motion along surface
Allow positive Z motion along surface
Cut depths...
Gap settings...
Advanced settings...

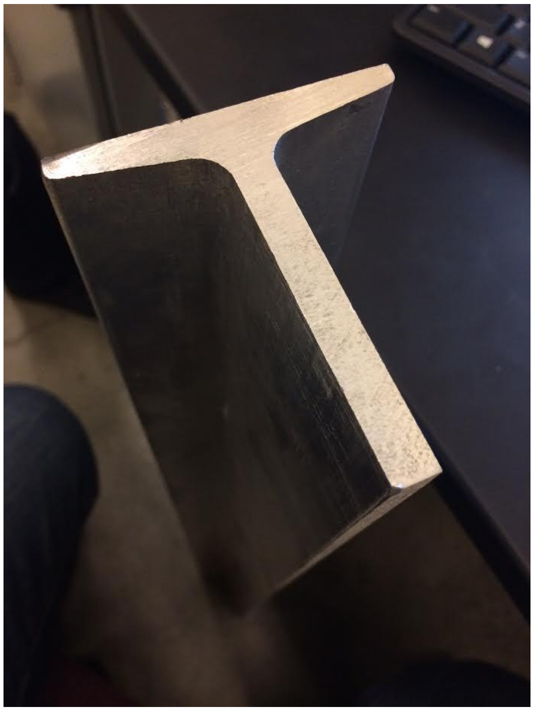

Surface Finish Parallel
Toolpath parameters
Surface parameters
Finish parallel parameters
Clearance...
2.0
Absolute
Incremental
Use clearance only at the start and end of operation
Retract...
0.25
Absolute
Incremental
Feed plane...
0.1
Absolute
Incremental
Top of stock...
0.0
Absolute
Incremental
Tip comp
Tip
Stock to leave on drive
0.0
(2)
Stock to leave on check
0.0
(0)
Tool containment
Compensate to:
(0)
Inside
Center
Outside
Additional offset
0.0
Regen...
Direction...

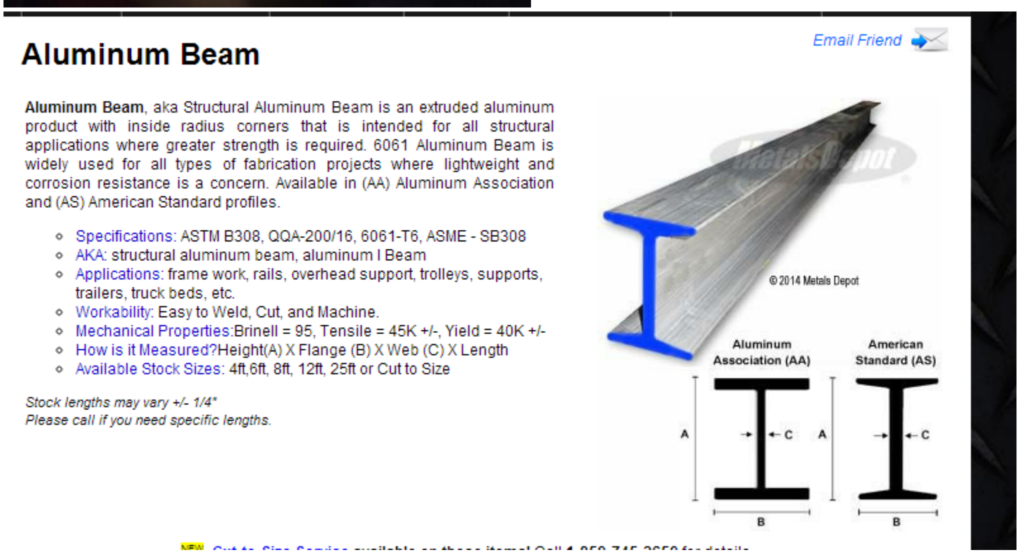


4/30/14 5:30pm Jack:
Trying to figure out how to make and design the fin brackets.
Ideas:

- Start with angle aluminum
  - pound it over, or machine the 6.6” diameter profile into one side of it
- Start with I beam
  - Machine the web to about .125” thickness
  - Cut off the rest of the I beam
  - Flip it over and machine the 6.6” diameter surface using the 3 axis
  - Cocure a .125” core carbon panel to the T-beam that is left
  - Rivet or bolt to the side of the rocket
- Bend sheet metal into angle bracket shape and pound over a steel mandrel
- Layup carbon on a curved mandrel and essentially cure a carbon fiber angle bracket







4/29/14 5:30pm Jack:
Ordering the thermocouples that Tung spec'd.

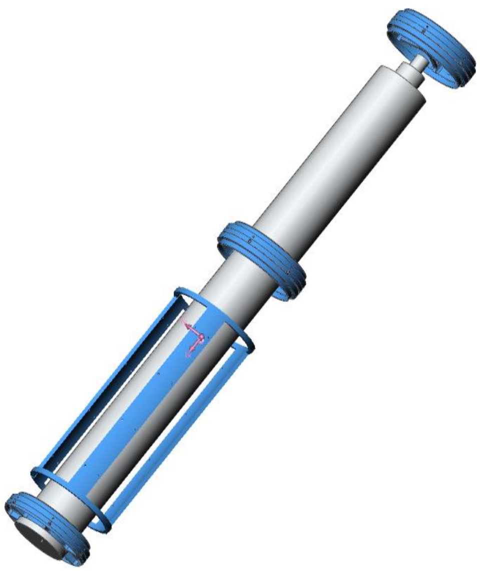
We also responded to Julie Rutherford that we will meet her at 2pm so that we can be video'd for the school's video.

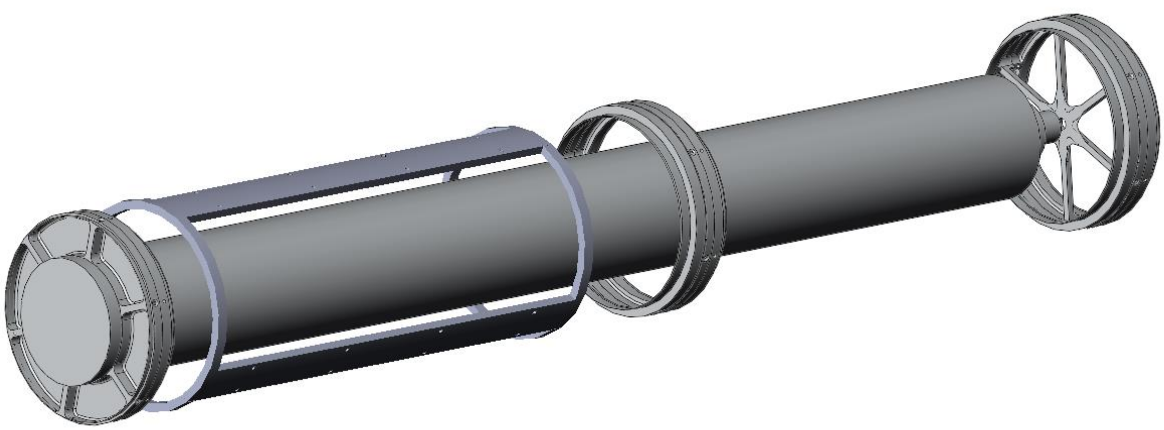
4/29/14 5:30pm Jack:
How do we know fin loads?

- Rob guesses from drag calculations approximately 30lbf per fin
- That would be approximately 5 ftlb of torque
    - PSAS did not have a better mechanism for predicting fin loads.

PSAS needs to figure out how to make the angle brackets for outer fin mounting

All of the non-carbon parts on the motor module weigh 2 pounds. This will make the motor module approximately 5 pounds including carbon. We had an idea for the fin hardpoints. These would locate and concentric themselves.

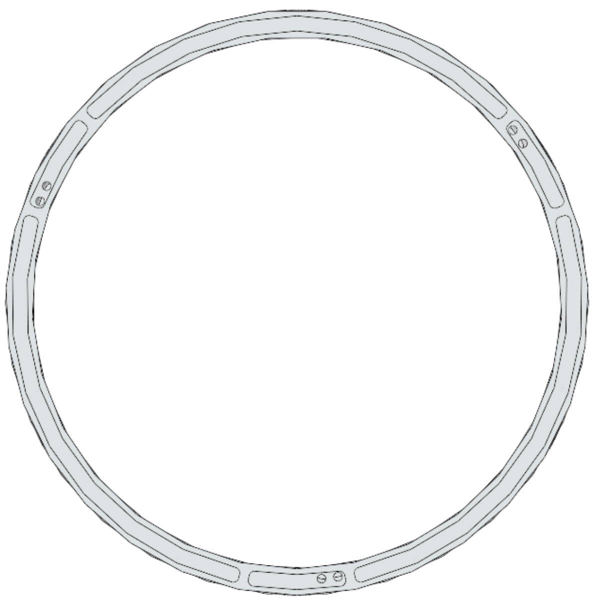


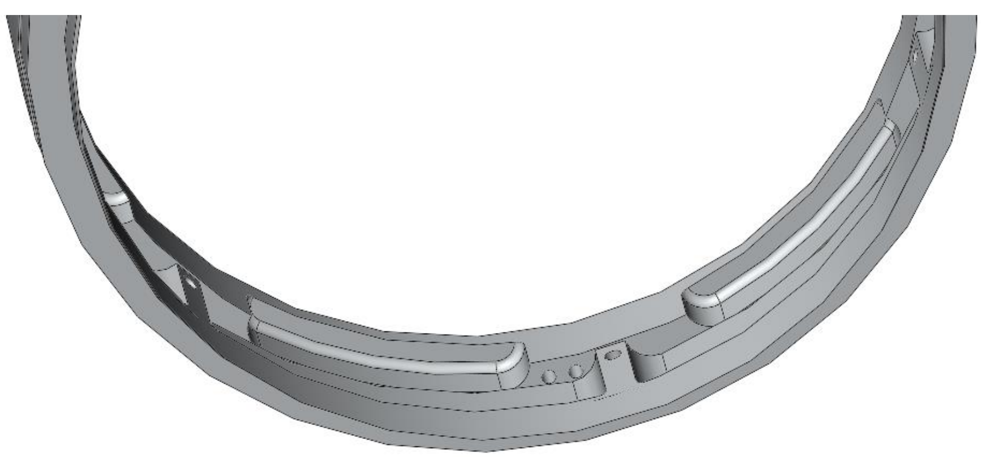


4/29/14 1:30pm Jack:
We designed the NSR. It weighs .22 lbf.

Things we need to ask andrew:

- 3 Gunpowder sections?
    - Friday discuss Andrew's wiring wishes
    - Need PSAS to spec gunpowder
    - For ematches need high temp epoxy ~750F
- What kind of superglue do you use?
    - M300M medium viscosity adhesive (3,000-3700psi strength). Would rather use Loctite or similar.
- How did you test it last time and to what load?
    - RT pull test, blew it while it was hot. Check psas website for more deets.
- PRR accessories?
    - Eye bolt for main line. Line cutters are zip tied because they need to float. Need protection barrier from explosion debris.
- When will you be finished with fin design?
    - We need it for the fin blocks and finalize the fin hardpoints
        - Need more info about center of mass, center of pressure. CG for full rocket model. Nose weight can change. Electronics ~5kg. Length, diameter, center of mass
        - PSAS needs fin material to make more fins
- When will you finish the nosecone shape?
    - Parker curve. Overkill the bonding of the tip.
    - Reconsider the bullshit spring nosecone separation mechanism





Looking at the motor assembly, the top of each module is a male.This is set by the MTR.
We have to do some calculations to see how to design this part:

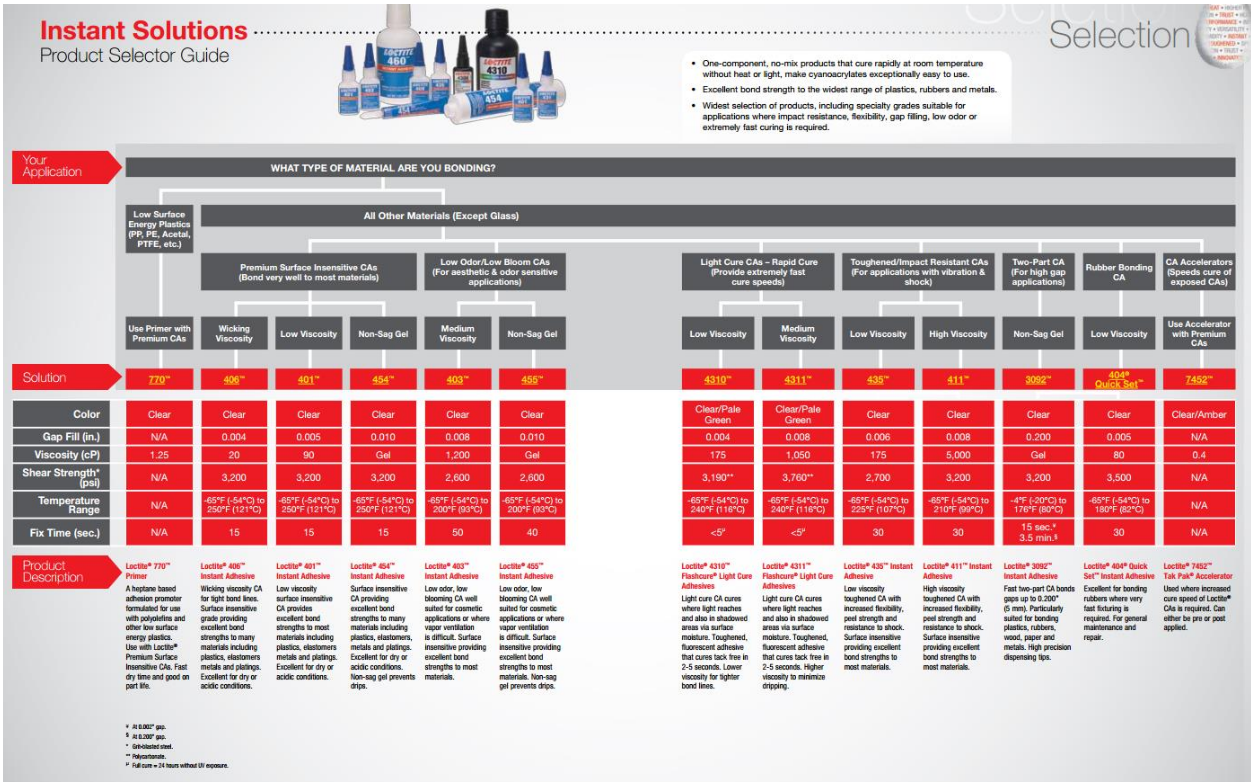
Strength of glue: 1200 lbf/in^2, 2600 lbf/in^2, 3760 lbf/in^2
Area of current joint: 2.65 in^2

Pull strength: 3180lbf

Assuming 100% of the 5g deceleration comes through the nosecone from drag, the force would be:

Optimistic:
F=ma
F= 30kg*5*9.81
F=1500 N

Pessimistic:
F=.5*Cd*A*V^2*rho
F=(.5)*(.5)*(.08255^2*3.14)*(680)^2*(1.22kg/m^3)
F=3000N = 600lbf



	Use Primer with Premium CAs	Wicking Viscosity	Low Viscosity	Non-Sag Gel	Medium Viscosity	Non-Sag Gel	Low Viscosity	Medium Viscosity	Low Viscosity	High Viscosity	Non-Sag Gel	Low Viscosity	Use Accelerator with Premium CAs
Solution	770™	406™	401™	454™	403™	455™	4310™	4311™	435™	411™	3092™	404® Quick Set™	7452™
Color	Clear	Clear	Clear	Clear	Clear	Clear	Clear/Pale Green	Clear/Pale Green	Clear	Clear	Clear	Clear	Clear/Amber
Gap Fill (in.)	N/A	0.004	0.005	0.010	0.008	0.010	0.004	0.008	0.006	0.008	0.200	0.005	N/A
Viscosity (cP)	1.25	20	90	Gel	1,200	Gel	175	1,050	175	5,000	Gel	80	0.4
Shear Strength* (psi)	N/A	3,200	3,200	3,200	2,600	2,600	3,190**	3,760**	2,700	3,200	3,200	3,500	N/A
Temperature Range	N/A	-65°F (-54°C) to 250°F (121°C)	-65°F (-54°C) to 250°F (121°C)	-65°F (-54°C) to 250°F (121°C)	-65°F (-54°C) to 200°F (93°C)	-65°F (-54°C) to 200°F (93°C)	-65°F (-54°C) to 240°F (116°C)	-65°F (-54°C) to 240°F (116°C)	-65°F (-54°C) to 225°F (107°C)	-65°F (-54°C) to 210°F (99°C)	-4°F (-20°C) to 176°F (80°C)	-65°F (-54°C) to 180°F (82°C)	N/A
Fix Time (sec.)	N/A	15	15	15	50	40	<5µ	<5µ	30	30	15 sec.¥ 3.5 min.§	30	N/A

Table #2: Bonding Characteristics of Master Bond MB Series Cyanoacrylates

TENSILE SHEAR STRENGTH (psi)
At 20°C ±2°C after aging 48 hours. Test specimens were bonded after sand blasting followed by wiping of bonding surfaces with acetone.

Bonding Identical Materials	MB300 (Ethyl)	MB302 (Ethyl)	MB297 (Ethyl)	MB325 (Methyl)	MB320 (Methyl)
Plastics					
ABS-ABS	1,300*	1,300*	1,300*	1,300*	1,300*
Bakelite-Bakelite	1,400*	1,400*	1,400*	1,400*	1,400*
Delrin-Delrin	960	1,060	1,000	640	650
Melamine-Melamine	1,490	1,630	1,560	1,630	1,520
MMA-MMA	2,120	2,140	2,100	2,120	2,100
Nylon-Nylon	920	850	910	780	690
PBT-PBT	1,800	1,840	1,810	1,650	1,620
Phenolic-Phenolic	1,400*	1,400*	1,400*	1,400*	1,400*
Polyacetal- Polyacetal	850*	850*	850*	850*	850*
Polycarbonate-Polycarbonate	1,300*	1,300*	1,300*	1,300*	1,300*
Polyester-Polyester	2,200	2,300	2,210	2,050	2,080
Polystyrene-Polystyrene	600*	600*	600*	600*	600*
PVC (rigid)-PVC (rigid)	2,800*	2,800*	2,800*	2,800*	2,800*
Rubbers					
Butyl-Butyl	290*	290*	290*	290*	290*
Chloroprene-Chloroprene	540*	540*	540*	540*	540*
Natural Rubber-Natural Rubber	450*	450*	450*	450*	450*
NBR-NBR	560*	560*	560*	560*	560*
Neoprene-Neoprene	580*	580*	580*	580*	580*
Nitrile-Nitrile	550*	550*	550*	550*	550*
SBR-SBR	480*	480*	480*	480*	480*
Metals					
Aluminum-Aluminum	1,060	1,130	1,110	1,980	1,980
Brass-Brass	2,130	2,550	2,410	2,980	2,960
Chromium- Chromium	1,060	1,350	1,280	1,840	1,910
Copper-Copper	2,410	2,620	2,500	3,400	3,260
Stainless Steel-Stainless Steel	2,340	2,620	2,480	3,050	3,100
Steel-Steel	2,200	2,720	2,440	3,200	3,800
Miscellaneous					
Glass-Glass	2,700*	2,700*	2,700*	2,700*	2,700*
Porcelain- Porcelain	2,400*	2,400*	2,400*	2,400*	2,400*
Wood (Oak)-Wood (Oak)**	2,100*	2,100*	2,100*	2,100*	2,100*

*Substrate failure—test bond held
**May require accelerator

TENSILE SHEAR STRENGTH (psi)
At 20°C ±2°C after aging 48 hours. Test specimens were bonded after sand blasting followed by wiping of bonding surfaces with acetone.

Bonding Dissimilar Materials	MB300 (Ethyl)	MB302 (Ethyl)	MB297 (Ethyl)	MB325 (Methyl)	MB320 (Methyl)
Aluminum-Stainless Steel	1,420	1,700	1,670	2,090	2,060
Delrin-Phenolic	730	820	800	680	640
Melamine-Copper	1,700*	1,700*	1,700*	1,700*	1,700*
Melamine-Steel	1,400*	1,400*	1,400*	1,400*	1,400*
NBR-Aluminum	960	1,040	1,020	990	970
Neoprene-Melamine	350	390	380	420	420
Neoprene-Steel	500	560	540	530	520
Nylon-Bakelite	850	990	980	780	780
Nylon-Copper	1,500*	1,500*	1,500*	1,500*	1,500*
Polystyrene-Bakelite	560*	560*	560*	560*	560*
PVC (rigid)-Wood (Oak)**	2,300*	2,300*	2,300*	2,300*	2,300*
Steel-Aluminum	2,270	2,410	2,400	2,410	2,390
Steel-Brass	1,700	2,700	2,540	2,980	2,960
Steel-Butyl	310*	310*	310*	310*	310*
Steel-Chloroprene	350*	350*	350*	350*	350*
Steel-Natural Rubber	340*	340*	340*	340*	340*
Steel-PVC (rigid)	2,200*	2,200*	2,200*	2,200*	2,200*
Steel-Stainless Steel	1,200	1,770	1,740	2,190	2,170

CHEMICAL RESISTANCE
Master Bond cyanoacrylates are not affected by solvents such as gasoline, propane, light oil, alcohol or kerosene. Alkaline materials, however, may somewhat reduce the bonding strength.

Steel-Steel	psi	psi	psi	psi	pdi
Acetone	1,200	1,560	1,290	2,700	3,760
Kerosene	2,270	2,620	2,410	2,960	3,330
Gasoline	2,200	2,700	2,340	3,200	3,260
10% — HCL	1,700	1,920	210	2,180	2,340
10% — NaOH	110	280	140	140	380
Motor Oil	2,200	2,700	2,270	3,200	3,410
Trichloroethylene	2,270	2,700	2,440	3,100	3,330
Water	2,130	2,410	2,410	3,100	3,120

Note: Full document in Design Folder

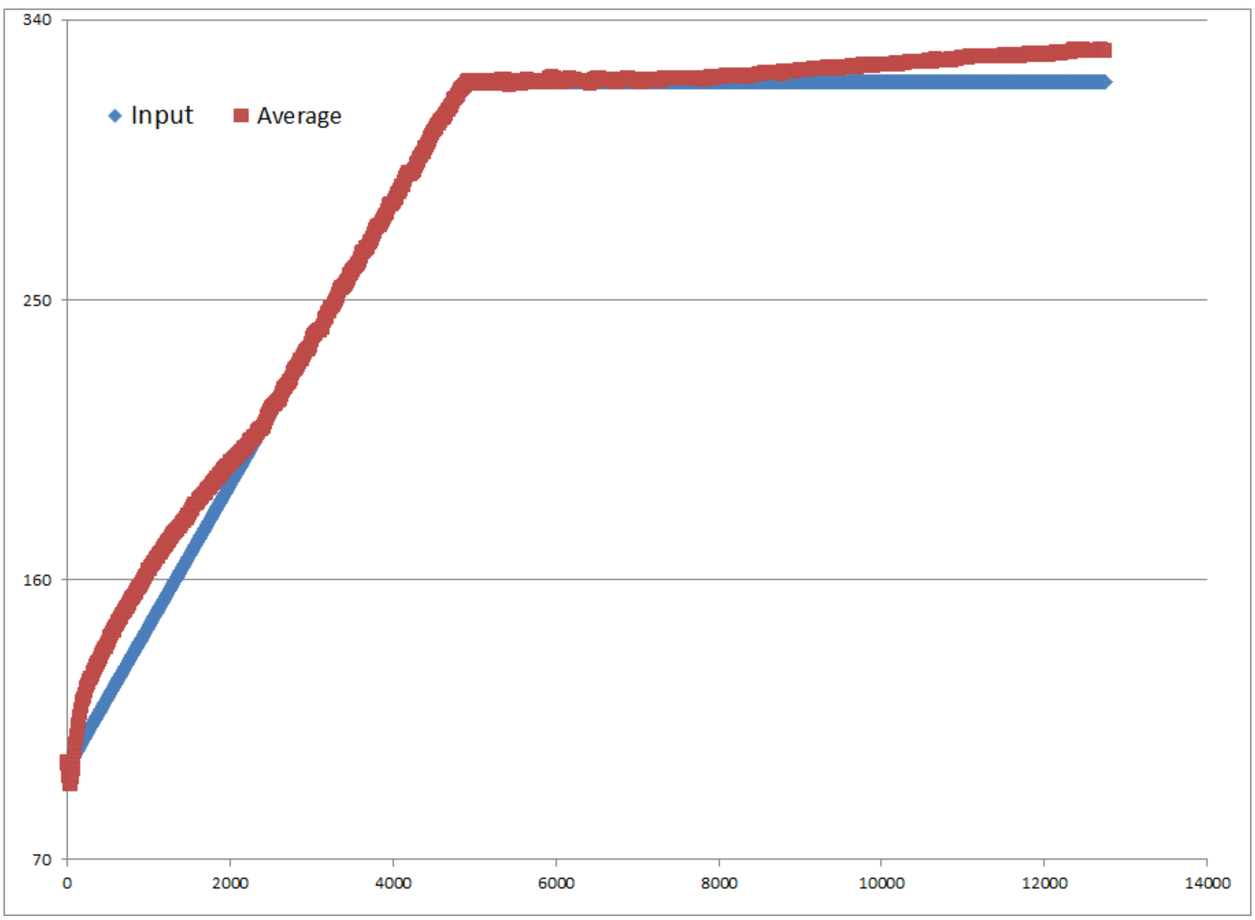
4/29/14 11:50am Jack:
Part 28: the surface finish using just the waxed caul plate is fantastic. Almost as good as tool surface. We put a coat of acrylic enamel on it. We sanded the rough line that's created when using the caul plate.

4/28/14 11:10pm Tung:
Find the Ktype thermocouples

Type	Length	Working temp	Price	Link	Note
K	6ft	<1800F	7.55$/each	**http://www.auberins.com/index.php?main_page=product_info&products_id=2**	
K	10ft	800F	9.95$	http://www.amazon.com/10ft-type-Thermocouple-pole-waterproof/dp/B004HHY0W6	Have 3ft, 6ft http://www.amazon.com/10ft-3M-K-type-Thermocouple/dp/B0043BHBVI

K	8.8ft	700F	4.67$	http://www.amazon.com/Amico-Thermocouple-Temperature-Control-Sensor/dp/B00843IKWK/ref=pd_sbs_misc_1?ie=UTF8&refRID=11RMZYKXEDB0KB8PCM2F	
K	**10**	**853F**	**4.50$**	**http://www.lightobject.com/10ft-3M-K-type-Thermocouple-P114.aspx**	If meet Jenner design then will buy this one. Order this one

4/28/14 12:50pm Tung:
The plot of temperature vs time in the oven on 04/23/14 baked. The average temperature is the result of sensor 1. The plot showed a sharp control range from [2000-7000]. The overshoot temperature compared to the input is result of 3 uncontrolled coils.

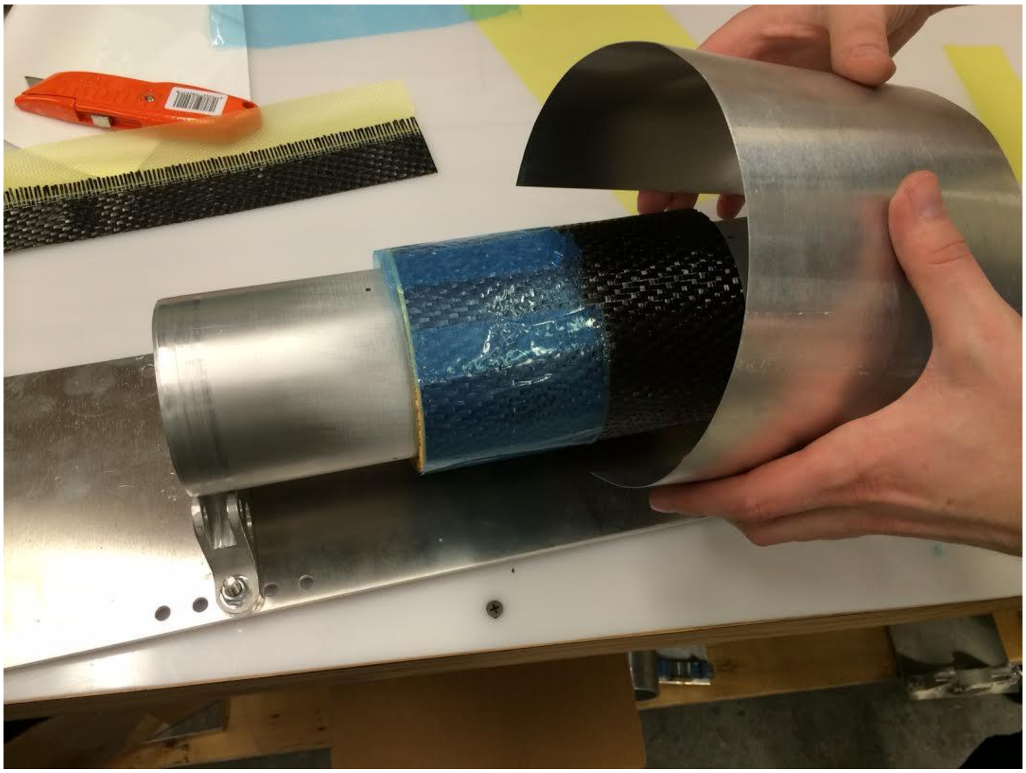


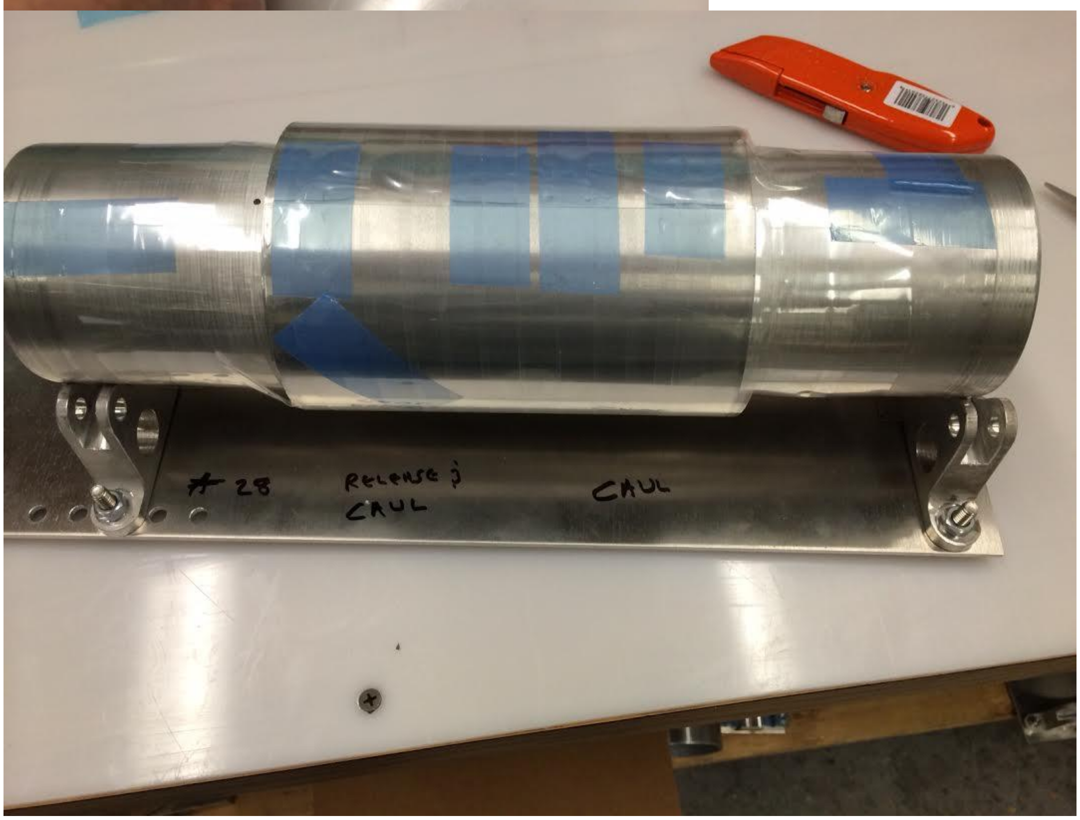
4/28/14 12:50pm Jack:
How do we move forward?

- Mandrel
  - Waiting on call back from alek
  - He said lead time of 1 week once we get him the material from EMJ.
  - EMJ said they would call back with their lead time. He gave us a purchase order
  - Material ordered by Andrew, pick up May 5 afternoon

4/28/14 12:50pm Jack:
We are baking **part 28** to see if we can improve surface finish. We are using a waxed caul plate. Under half of the plate we are using the blue perforated release film under half of the caul plate to see if we can improve the surface finish even further. We are using the non perforated shrink tape because it is not against the part.

The technique of laying the flash tape out and then cutting it on the table works best.





4/25/14 12:00pm Jack:
Figuring out the painting schedule for the carbon fiber
On part 27:
600 for 2 minutes
Damp cloth
1500 for 1
Clean damp
Clean dry
Thin coat of acrylic enamel (starting and stopping off the part
Time until dry: 35 min
1500 grit for 2

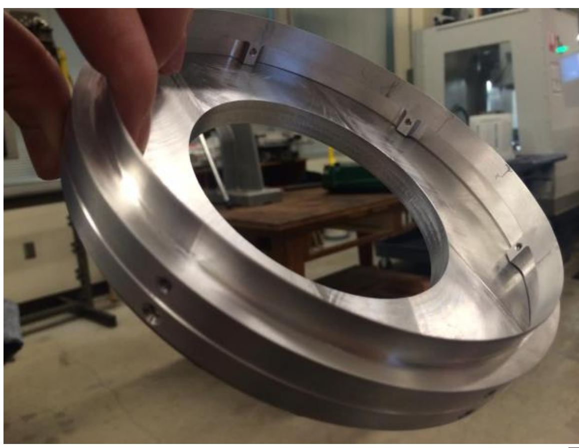
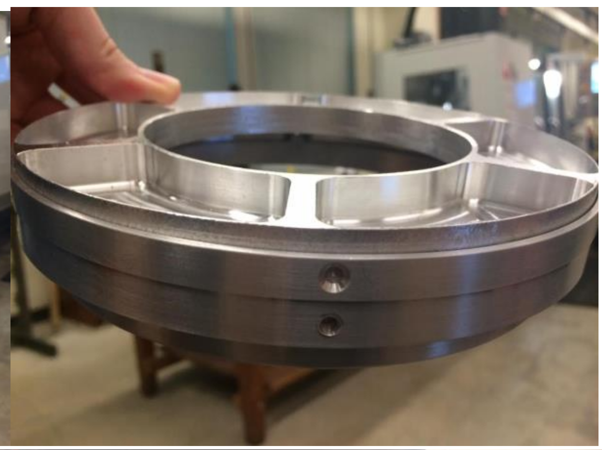
Damp cloth
Clean cloth
Thin coat
repeat using 320 grit. This has proven to be best. We are on coat 4 now, and are not sure if it is improving much between coats

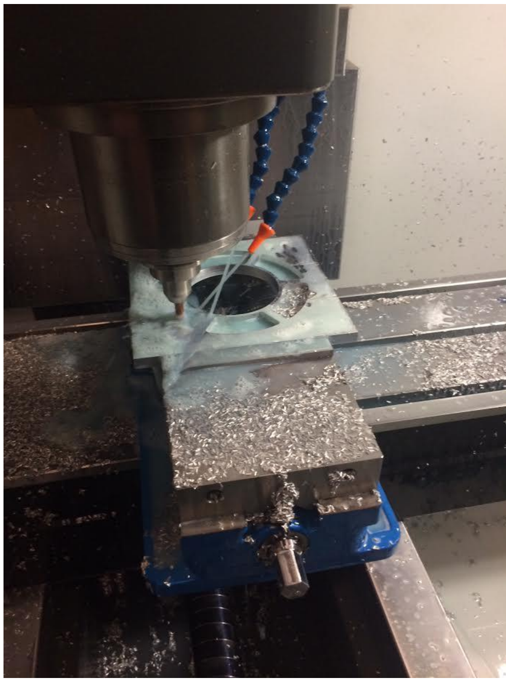
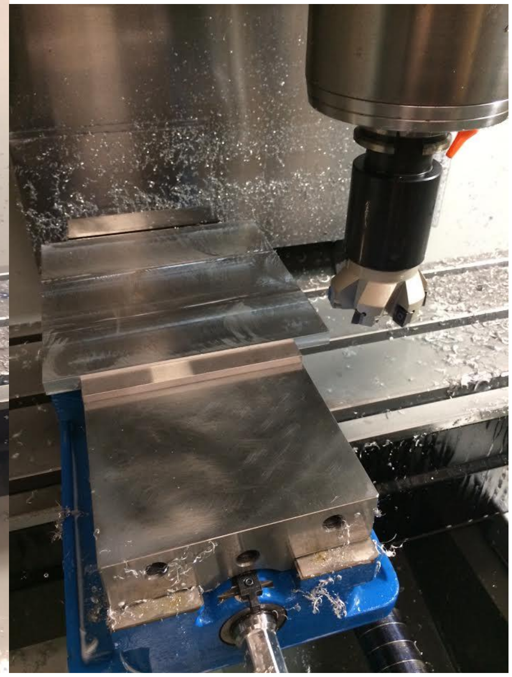
Summary: The surface finish looks really great now, but we will keep going to see how good we can get it. We are getting to the point where the fibers are the issue because they aren’t filled with epoxy. We will put more acrylic enamel on to make it smoother.

4/25/14 12:00pm Jack:
We are starting the MRR drill jig in the 3D printer. It costs 6$/ in^3 and we have to pay now. Pay to Melissa. The EPL also charges, so Andrew can’t get us that for free either.
Update: We have 10in^3 free for use on our capstone. It was free this time. We have used approximately 90% of our allotment.

We put both the MTR and MRR drill jigs in the printer. They are done by Monday.

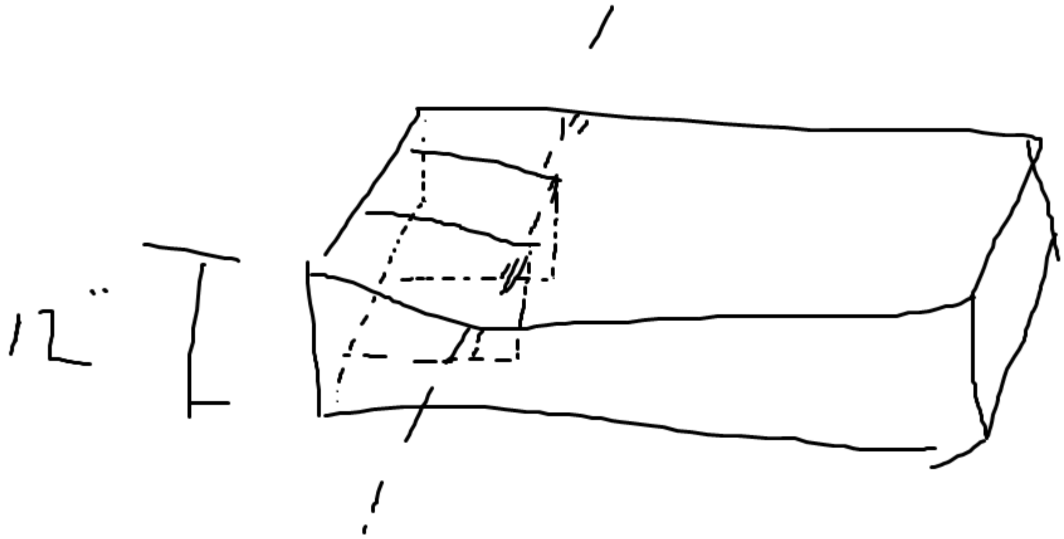
4/23/14 5:40pm Jack:
Machined the MTR and MRR. Need to get 1” stock for the PRR

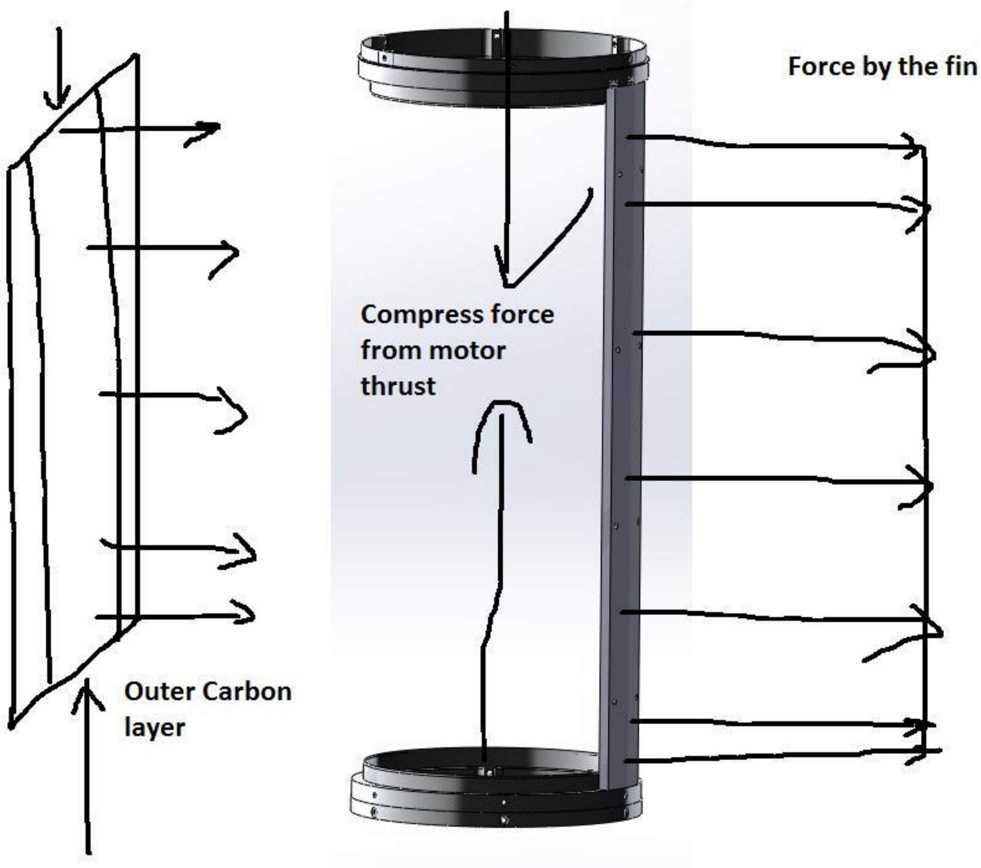


4/22/14 5:40pm Jack:
We are baking 2 parts (26, 27) in the oven at 328F. They are the 3D printed Nylon CF rings adhering to the carbon. The test pieces came out perfect. The Nylon CF will survive the oven and can be adhered to. The new glue can be used to attach carbon to honeycomb. The surface finish feels superior when you put a perforated peel ply beneath the perforated shrink tape. The amount of overlap of the shrink tape does not appear to make a difference to the surface finish, nor the quality of the fabric.

4/22/14 5:40pm Jack:
Dimensions for making the nosecone plug:
The foam comes in 12" tall. So we could get 7"x7"x12" rectangles and we would need 3 of them.
One **21" L x7" W x12" H**
https://www.generalplastics.com/fr-4700.html

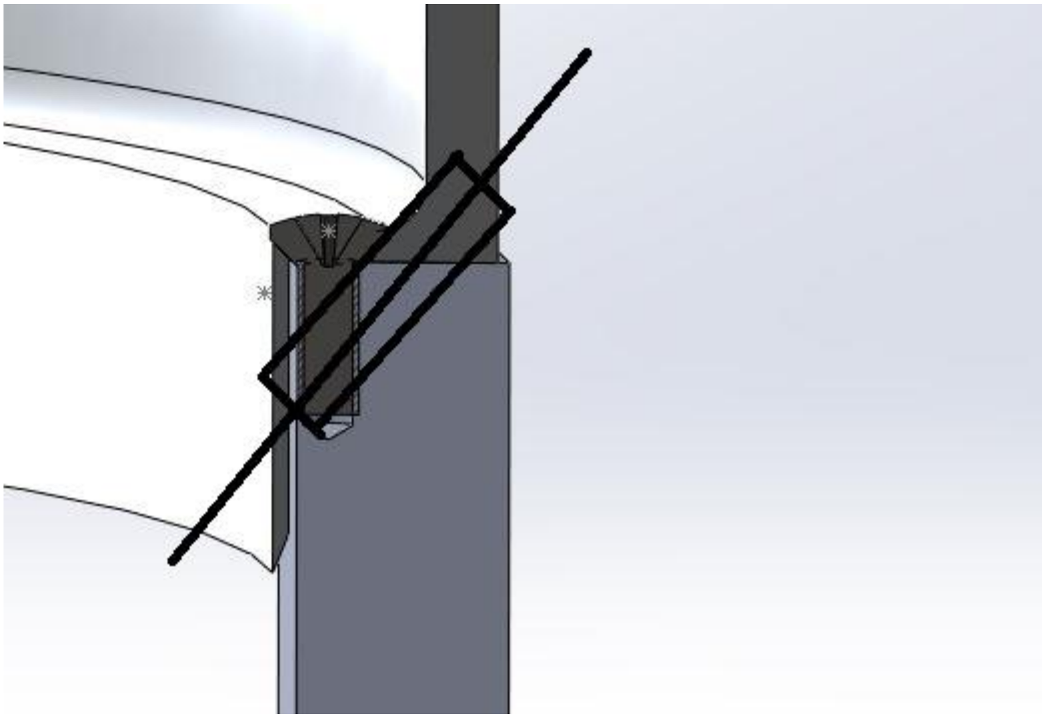


4/22/14 3:40pm Tung



The out of plane force of the fin make the outer carbon layer deflect out of the vertical plane, thus, decreasing the compression strength of carbon fiber. My thought is having2 bolts at the end of the fin hardpoint to attach it into the ring. However, the leftover material is not thick enough for an M2 screw.

Another way to attach the ring and the fin hardpoint is using the tilted bolt like the drawing below .



4/22/14 1:40pm Jack:
Solutions to the fin hardpoint problem:

Solution	**Cost**	**Effort**
Nylon plastic	free	low
aluminum	medium	high
Carbon fiber	medium	medium

4/22/14 1:40pm Jack:
Solutions to the nosecone problem:

Solution	**Cost**	**Effort**
Their old wet layup solution	Cheap	medium
Aluminum Male	$620	low, finding machine shop
Aluminum filled epoxy resin	$800	new process, medium high
Tooling board	Get Donated	medium
Styrofoam Expendable mold	Cheap, donated	low

MDF to fiberglass female to...	medium	medium
3D print	expensive	getting shop impossible
Two piece female	low	medium

4/22/14 9:40pm Sam:
Looking into the possibility of casting a plug for the nose cone mold using some sort of high temperature plastic. Found a couple leads:

Hardener Sold Separately

EC-415 ULTRA HIGH-TEMP ALUMINUM FILLED CASTING SYSTEM

E-mail this product to a colleague

EC-415 is an advanced two-component aluminum-filled ultra high-temperature epoxy casting system for use up to 220°C/425°F for the extreme temperature requirements of today's material processing. Molds and tools fabricated with EC-415 exhibit extreme wear resistance capabilities and extended production capabilities. EC-415 is a room temperature (B-stage) hardening system, however, a preliminary post cure (see schedule) of the cast is recommended prior to demolding to pre-cure the cast. EC-415 offers a low coefficient of thermal expansion and high heat deflection and excellent tool life.

Features:

- Two component epoxy, filled casting resin
- 120-180 Minute Work Life
- Aluminum

An ultra high-temp epoxy system developed for casting molds that require heat resistance greater than 177°C/350°F and intermittent use up to 220°C/425°F, with consistent strength and impact properties. Use with high-temp epoxy surface coat ES-215IHG when adding N-20 or N-50 aluminum bulk filler for casting larger masses.

Applications: Typical applications include: Autoclave (prepreg) Tooling, Plastic Injection Molds, SMC Compression Molds, High-Pressure/High-Temp RTM Molds, LP-SMC Compression Molds, High-Temp Rubber Molding. To achieve maximum casting volume or thickness it is recommended that EC-415 be used in conjunction with N-20 granular aluminum, N-50 aluminum grain or N-6 ceramic bulk filler.

Also

EPOXY CASTING SYSTEMS	
Epoxy casting resins are versatile products that can provide an excellent solution to a variety of industrial applications. They generally contain a filler of some type that is provided to produce specific handling or cured properties. These fillers can be of a metallic nature, or of a variety of non-metal fillers. The specific fillers used can provide lower shrinkage, higher compressive strengths, better metal forming properties, or other characteristics suited to a particular use. Two systems, for high temperature service applications are listed here. Both have different hardeners available to more closely match the material to the requirements of the application.	
PT4925	Gray high temperature epoxy casting resin with a very high aluminum filler content. Finished casting looks, feels and machines like an aluminum casting. Very good heat resistance and thermal conductivity, and very high compressive strength.
PT4935	Gray casting resin with excellent heat resistance and handling qualities. Lower viscosity allows easy mixing and pouring to pick up fine detail with ease. Fillers do not hard pack in transit or storage. Works well with PA0703 aluminum needles bulk filler.

Links:
ADTech system
Curbell system

Should get a quote from these guys: Last-A-Foam

LAST-A-FOAM® FR-4700 HIGH-TEMPERATURE TOOLING BOARD SERIES

Our advanced LAST-A-FOAM® FR-4700 high-temperature polyurethane foam tooling boards can withstand peak temperatures up to 400° F (200°C) and continuous-use temperatures up to 350° F (177°C) – significantly more than other products on the market. This series is non-abrasive and can be machined with standard high-speed steel (HSS) cutting tools. It can also be cut cleanly with water jets and traditional wood-carving tools. Affordable and dimensionally stable, this rigid foam board is ideal for prototype machining, high-temperature curing prepregs, vacuum forming, pattern making, and other limited-run tooling where traditional metal dies are cost-prohibitive. The FR-4700 high-temperature series of high-density foam is available in thicknesses up to 12 inches in 18-lb. densities, and up to 11 inches in 30- and 40-lb. densities. This high-performance material is an excellent choice for all of your high-temperature needs.

General plastics has an application page for donating this tooling foam board to university projects. **Info is here.**

Applied for the donation. Will call tomorrow to follow up.

Form Results	
University:	Portland State University
Department Head Name:	Dr. Gerald Recktenwald - Mechanical Engineering
Name:	Sam Arnold
Email:	samuel.k.arnold@gmail.com
Phone:	541-510-9557
Street Address:	1930 SW 4th Ave. Suite 400
State:	Oregon
Zip:	97201
Country:	[[+country]]
Comment:	My senior mechanical engineering capstone team is designing a next generation rocket airframe for the Portland State Aerospace Society (PSAS). The ultimate goal for PSAS is to reach the edge of space (100 km), which would make them the second amateur rocketry group in history to do so. To enable this, my team is designing an ultra-lightweight carbon fiber airframe. The full-size rocket will be approximately 12 feet tall and 6.5 inches in diameter, and we expect nearly an 80% reduction in weight with our redesign. We are always searching for better and more efficient ways to manufacture composite parts, and we are very interested in using the Last-A-Foam FR-4700 tooling foam to expand our capabilities. Below are two links to videos showcasing the rocket and this year's capstone work: http://youtu.be/aF3dWLS7jy0 http://youtu.be/VAnPtbYMA8o Thank you for your consideration.

4/22/14 3:40pm Jack:
Design of the Parachute retention ring (PRR).
Acceleration load according to Andrew is approximately 3g, so designing for a 10g load. The rocket airframe weighs 65lbf (30kg)

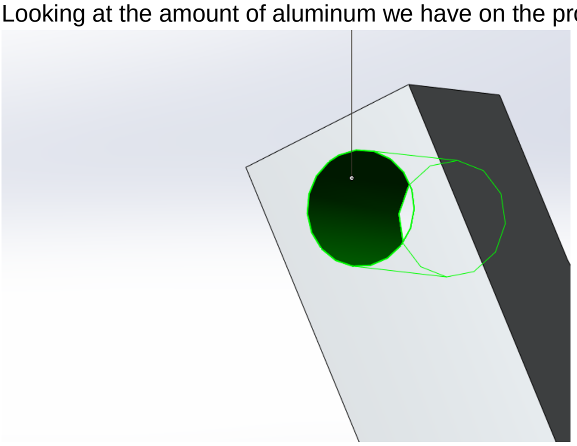
F=MA
F=30*10*9.81
F=2940 newtons = 660lbf

There are 6 bolts in shear, each a #4 40 which has a 540 lbf through threads shear rating.

6*540= 3240lbf

So we have almost a factor of safety of 5 on the screws shearing.

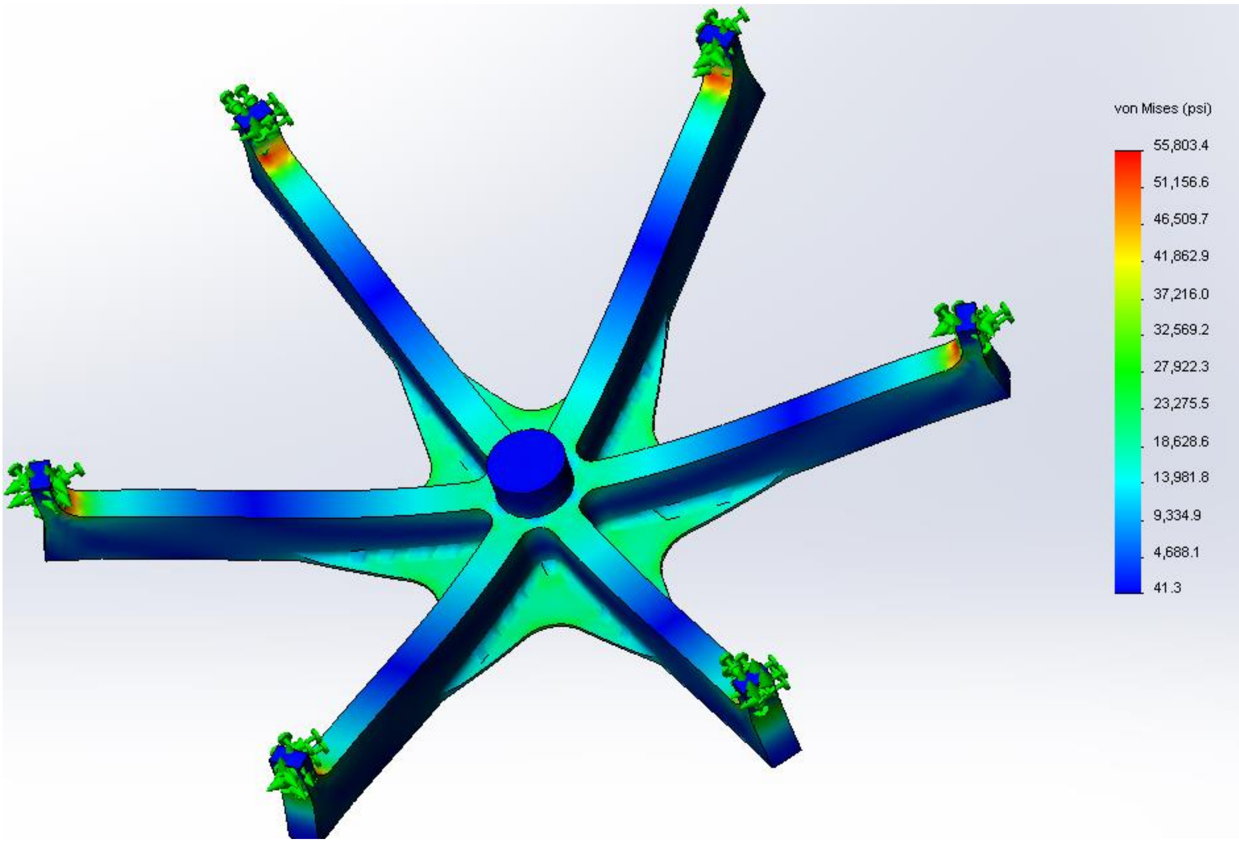
Looking at the amount of aluminum we have on the projected area of the bolt is:

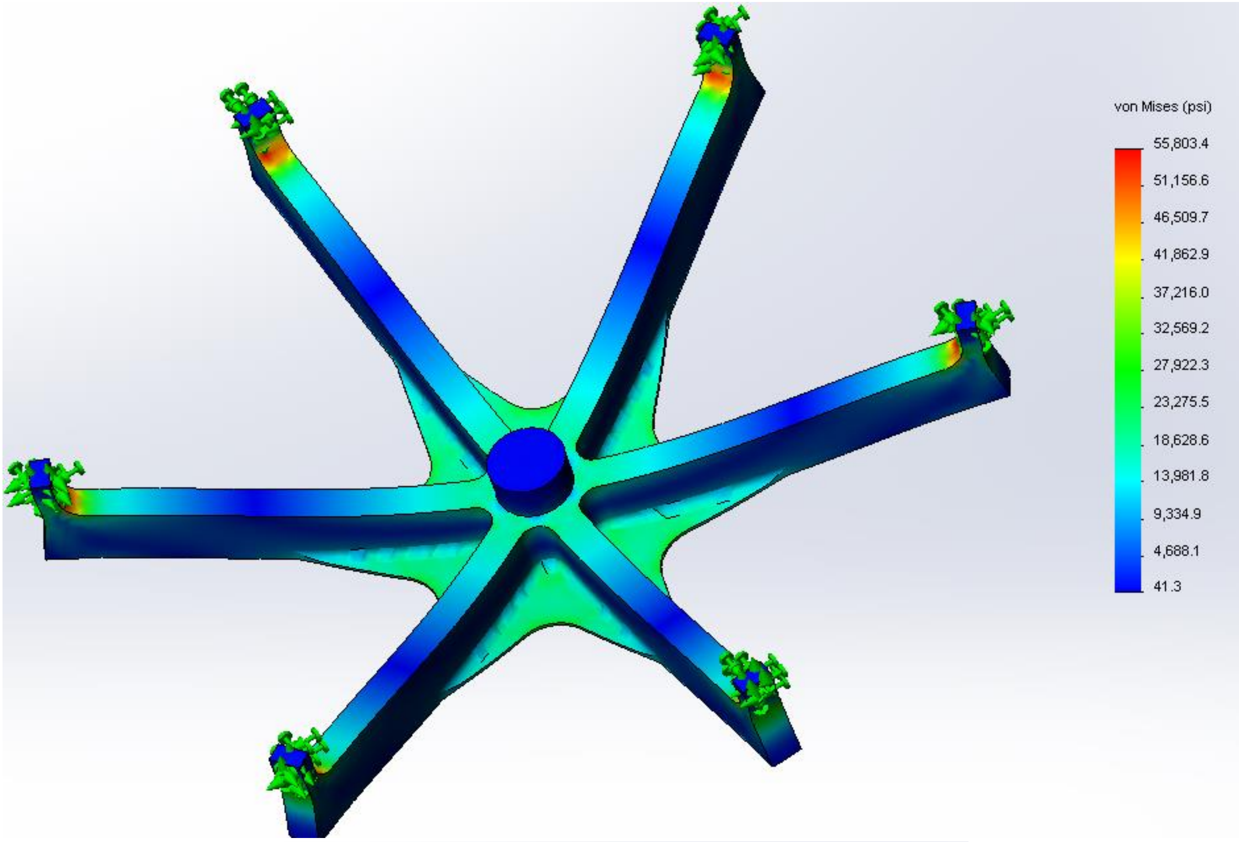


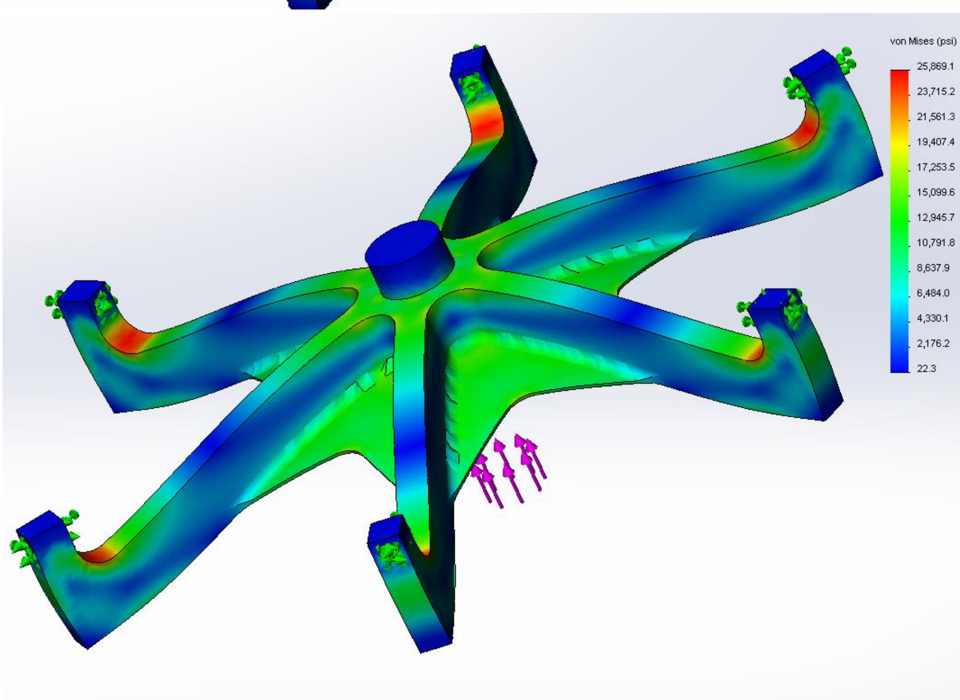
A= .112” * .25”
A=.028 in^2
Total A= 6*.028=.168

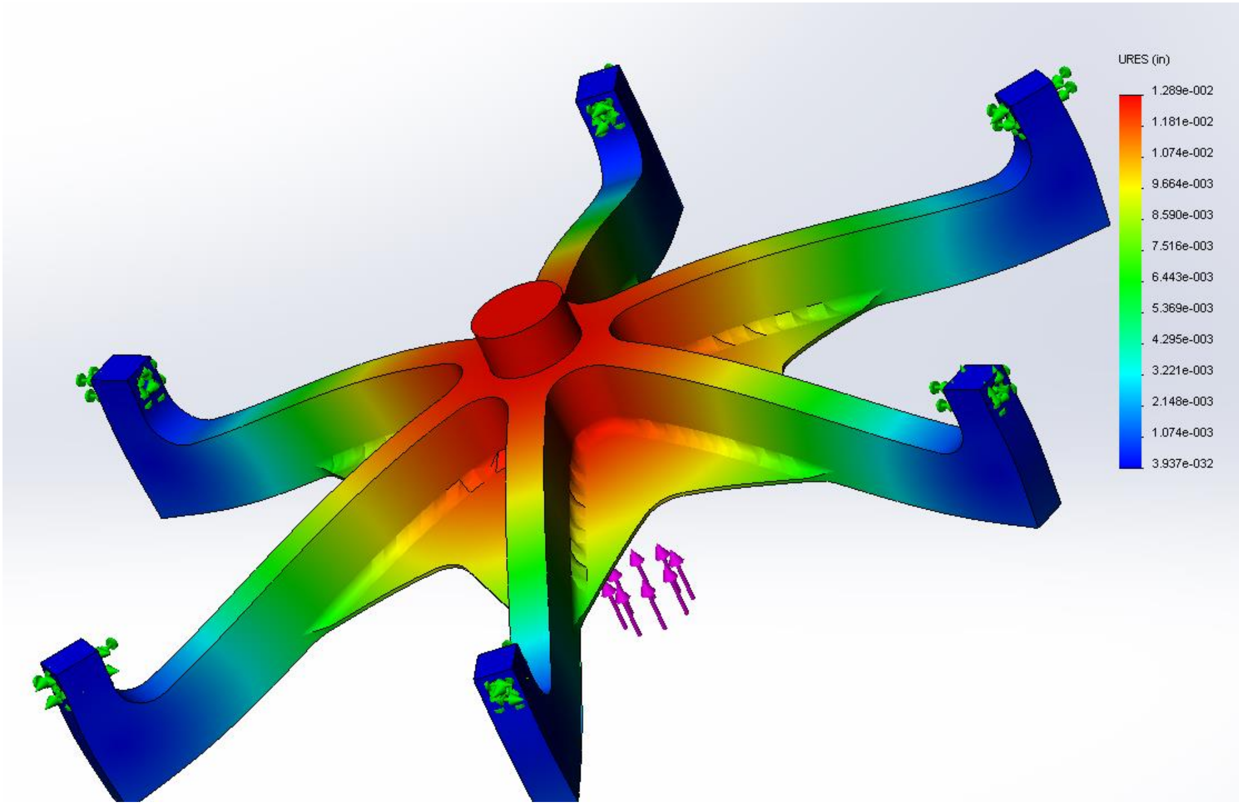
Stress= F/A
Stress= 660/.168
Stress= 3928 PSI

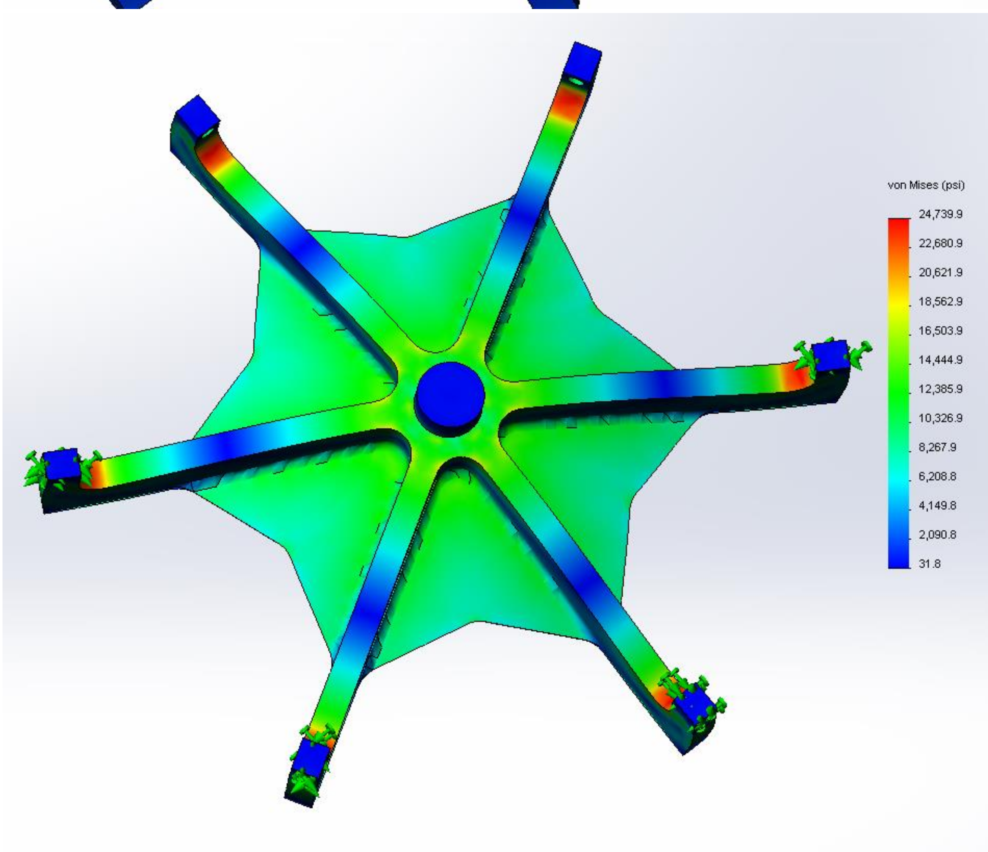
The PRR is loaded about 5 times more than the MRR, and the MRR was at the limit for design for a piece of stock .450" thick. I think we should make it out of thicker stock. .70" should be good. We could use the same shape as the MRR, just thicker.

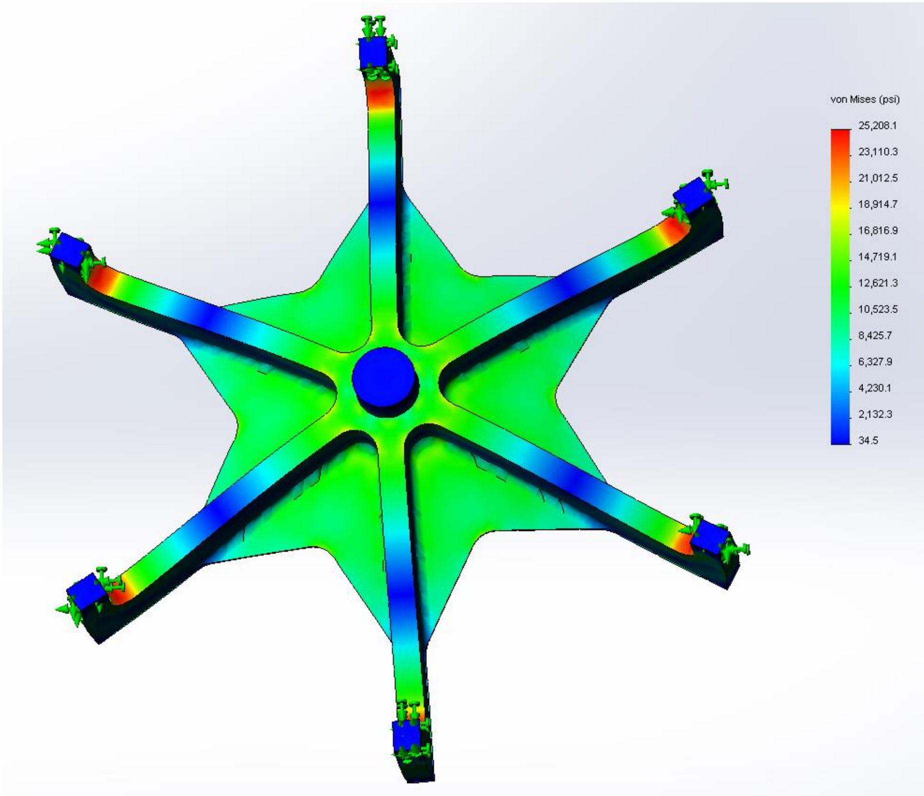



von Mises (psi)
55,803.4
51,156.6
46,509.7
41,862.9
37,216.0
32,569.2
27,922.3
23,275.5
18,628.6
13,981.8
9,334.9
4,688.1
41.3

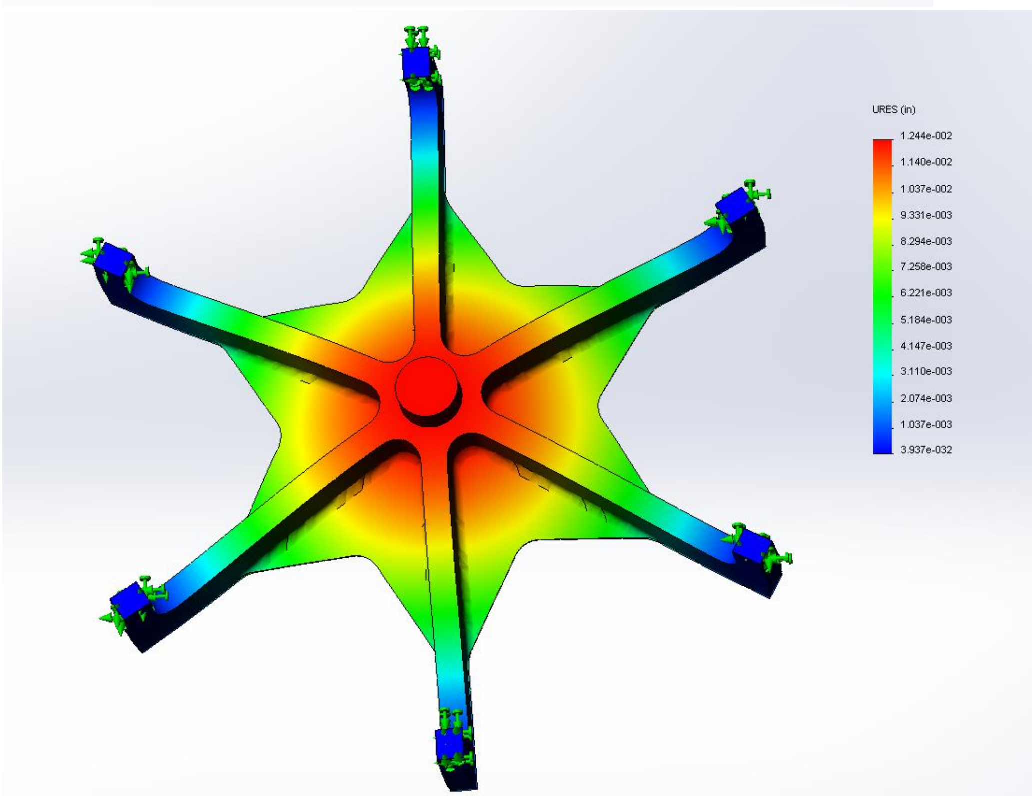

von Mises (psi)
25,869.1
23,715.2
21,561.3
19,407.4
17,253.5
15,099.6
12,945.7
10,791.8
8,637.9
6,484.0
4,330.1
2,176.2
22.3


URES (in)
1.289e-002
1.181e-002
1.074e-002
9.664e-003
8.590e-003
7.516e-003
6.443e-003
5.369e-003
4.295e-003
3.221e-003
2.148e-003
1.074e-003
3.937e-032


von Mises (psi)
24,739.9
22,680.9
20,621.9
18,562.9
16,503.9
14,444.9
12,385.9
10,326.9
8,267.9
6,208.8
4,149.8
2,090.8
31.8

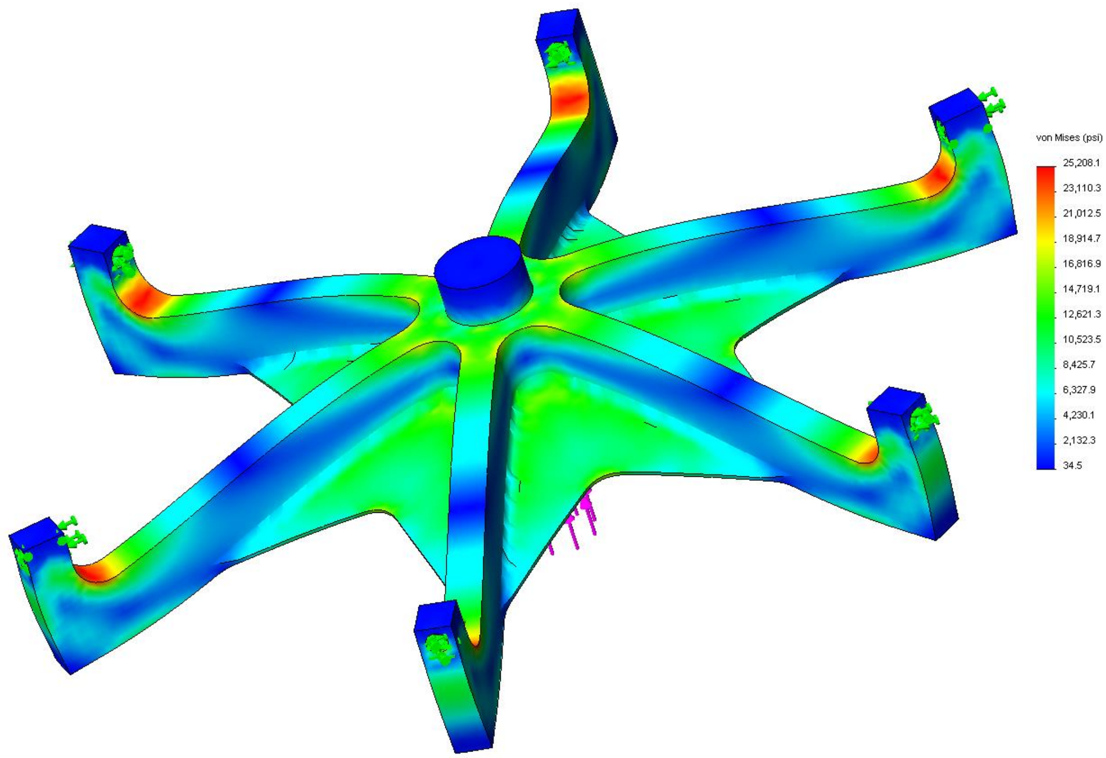


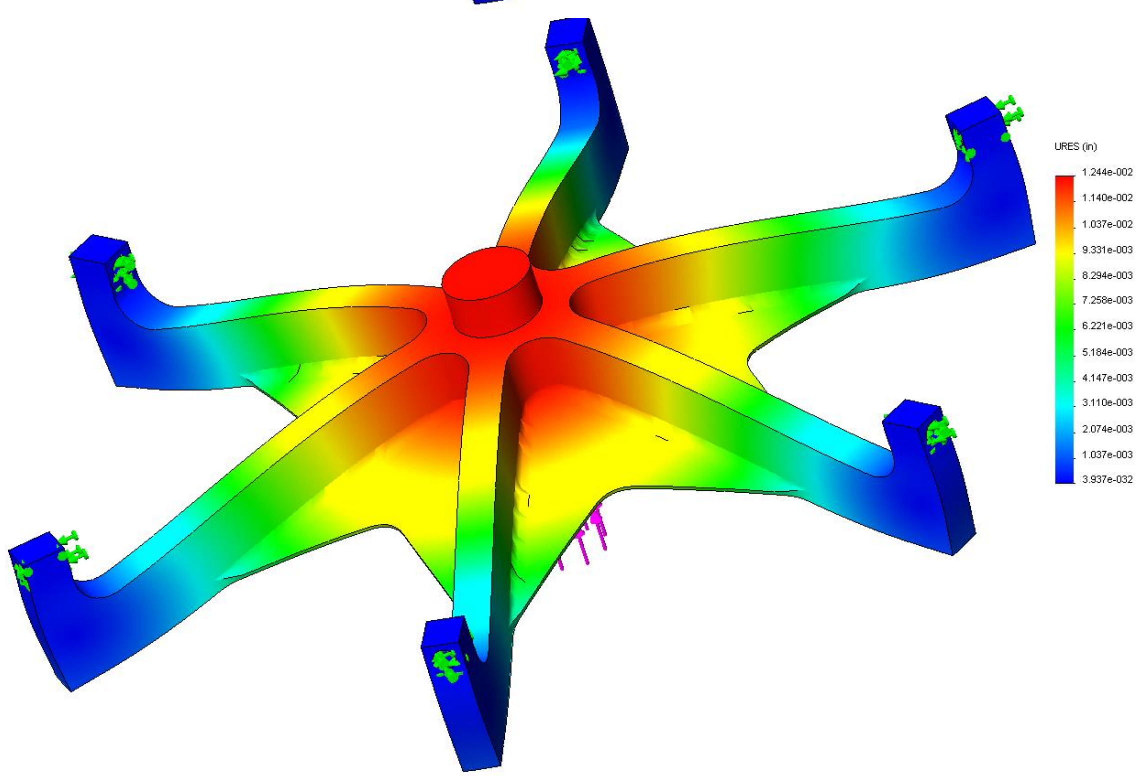
von Mises (psi)
25,208.1
23,110.3
21,012.5
18,914.7
16,816.9
14,719.1
12,621.3
10,523.5
8,425.7
6,327.9
4,230.1
2,132.3
34.5



URES (in)
1.244e-002
1.140e-002
1.037e-002
9.331e-003
8.294e-003
7.258e-003
6.221e-003
5.184e-003
4.147e-003
3.110e-003
2.074e-003
1.037e-003
3.937e-032

Final:


von Mises (psi)
25,208.1
23,110.3
21,012.5
18,914.7
16,816.9
14,719.1
12,621.3
10,523.5
8,425.7
6,327.9
4,230.1
2,132.3
34.5


URES (in)
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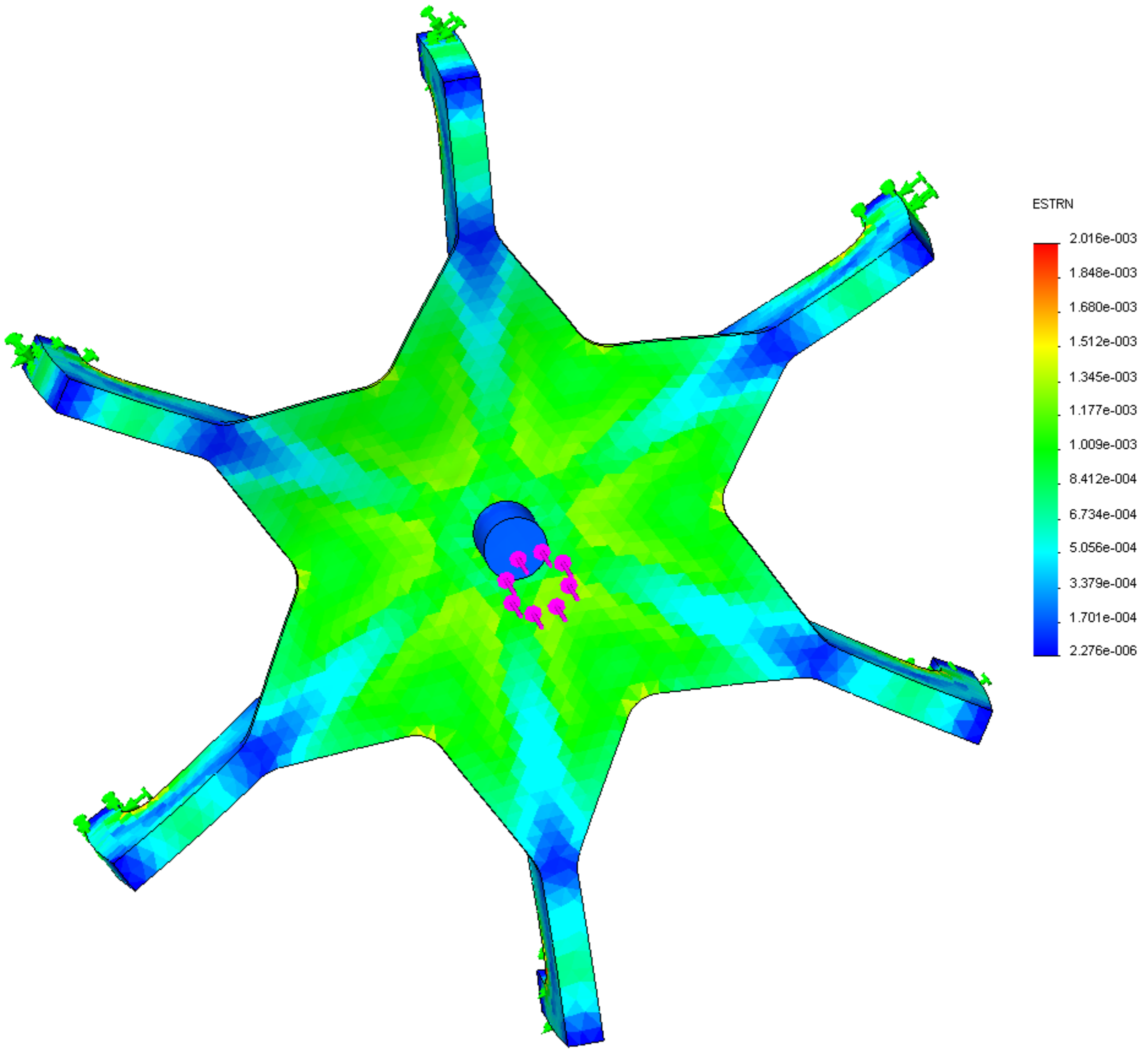
1.140e-002
1.037e-002
9.331e-003
8.294e-003
7.258e-003
6.221e-003
5.184e-003
4.147e-003
3.110e-003
2.074e-003
1.037e-003
3.937e-032

This is a picture of strain to help us decide where to put strain gauges.



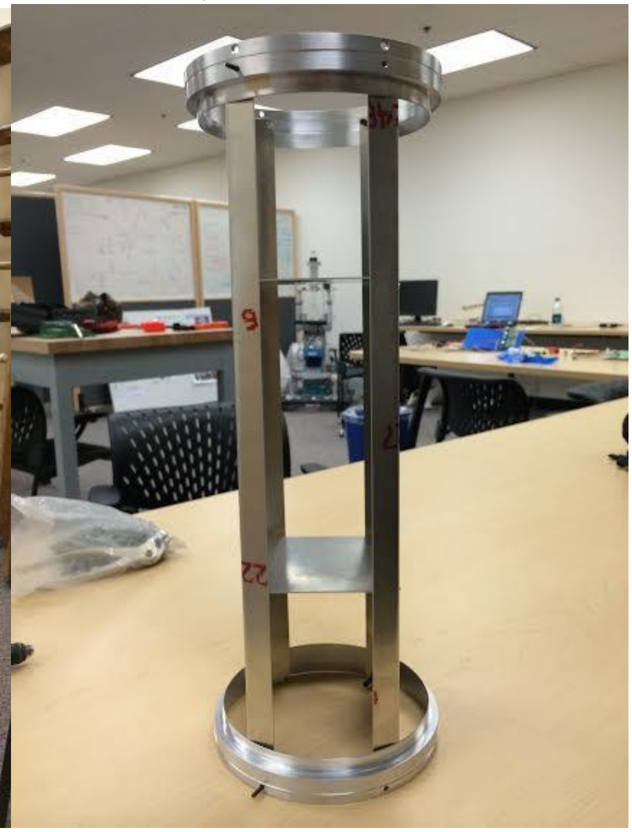
4/22/14 3:30pm Jack:
We are machining the MTR using the Haas. The program number is 04201401. Sam and I both took time lapses. The machining is going good. We are using a plunge rate of 1.5, a feed rate of 9.5, and a spindle speed of 3000 rpm using the .25” cutter

4/21/14 10:30pm Sam:
The new bend angle is 56deg, not the previous 60deg

With Drew’s help, I learned how to use the laser cutter and made a new electronics carrier prototype. It turned out great. All of the holes lined up nicely and when it’s mounted between the rings it is super stiff. Even with our rudimentary mounting, the length dimension from ring to ring came out to almost exactly 18”.

I added very small notches to the laser cut drawing to locate and align the bend line on each piece. This was very effective. However, the 90deg bends on the shelves introduced slight cracking along parts of the bend line. I also overlooked the fact that when I changed the model, the bend angle on the towers changed slightly, so I bent them too far and they don’t fit exactly right. I will try to get them closer to the correct angle and see how they fit again.

Drew and I also determined today that the width of the cut of the laser is very close to 0.008”.



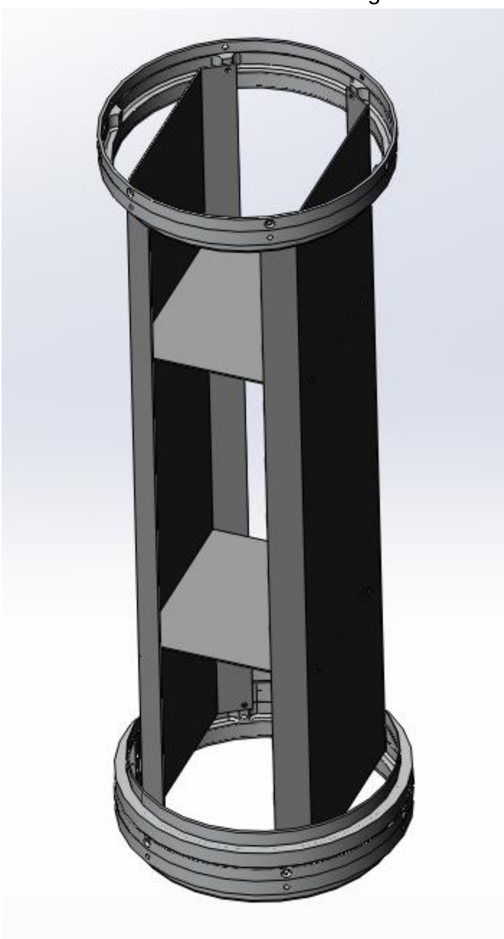
4/21/14 7:00pm Jack:

We began machining the MTR. We squared off two edges, planed and reduced the thickness to the desired .450". Used the shell mill at 2000 rpm.

We also wrote the mastercam program for the part (3axis) and wrote an instruction manual for general 3 axis machining.

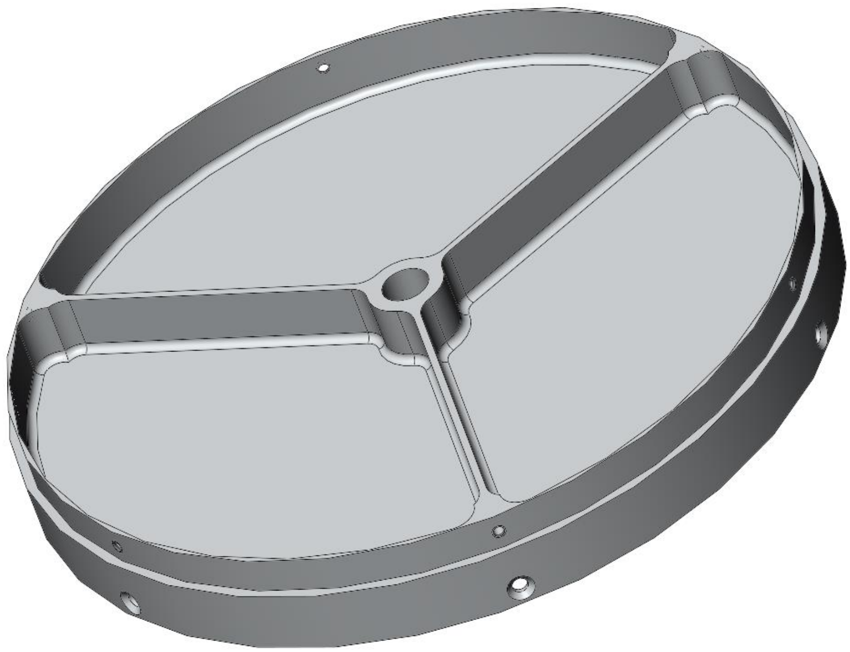
We made the redesigned electronics carrier from PSAS suggestions, laser cut and bent.

4/18/14 6:00pm Sam:
Redesigned electronics carrier based on feedback from PSAS today. Made drawings for laser cutting including shelf holes and notches for bend locating.

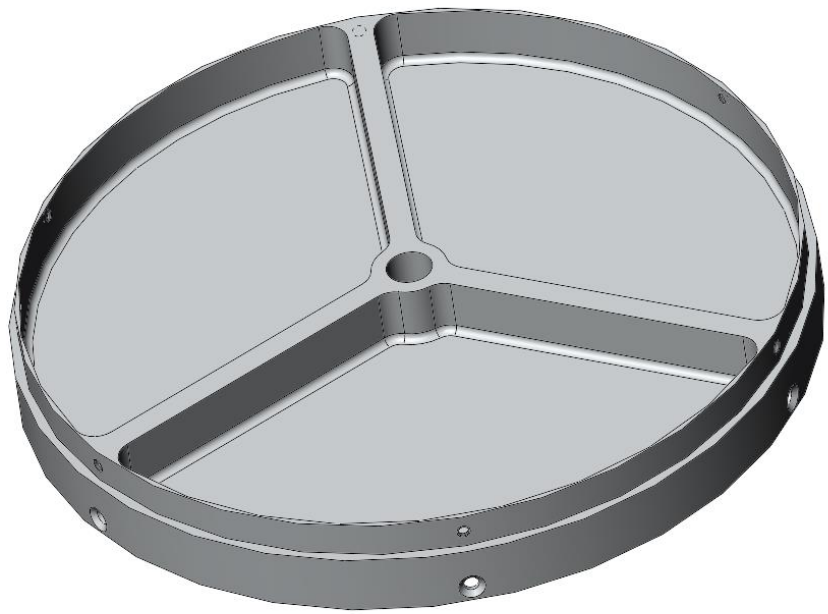


4/18/14 4:00pm Jack:
The problem I'm running into is this thing is way too heavy and it is not particularly easy to lighten. Here are some ideas. We could also move away from this idea entirely and go to something that would bolt into the main hole like the electronics carrier modules do instead.

Idea 1: weight .21lbf

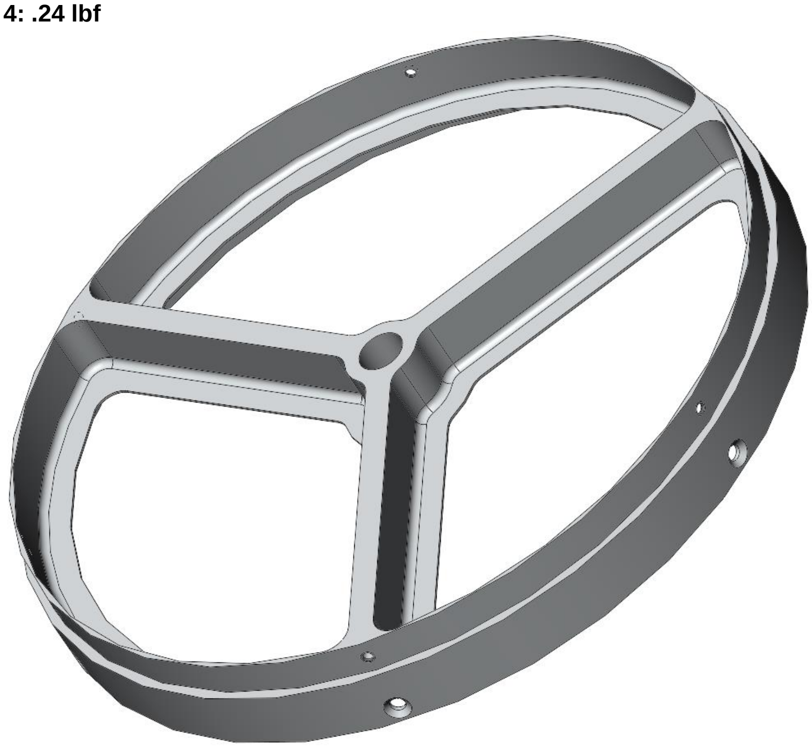


Idea 2: .28 lbf



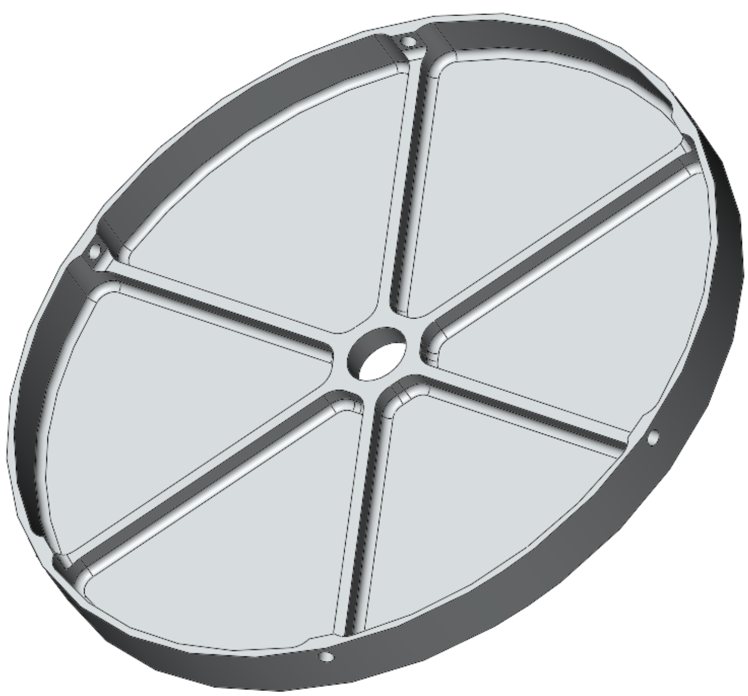
Idea 3: .22 lbf

Idea 4: .24 lbf

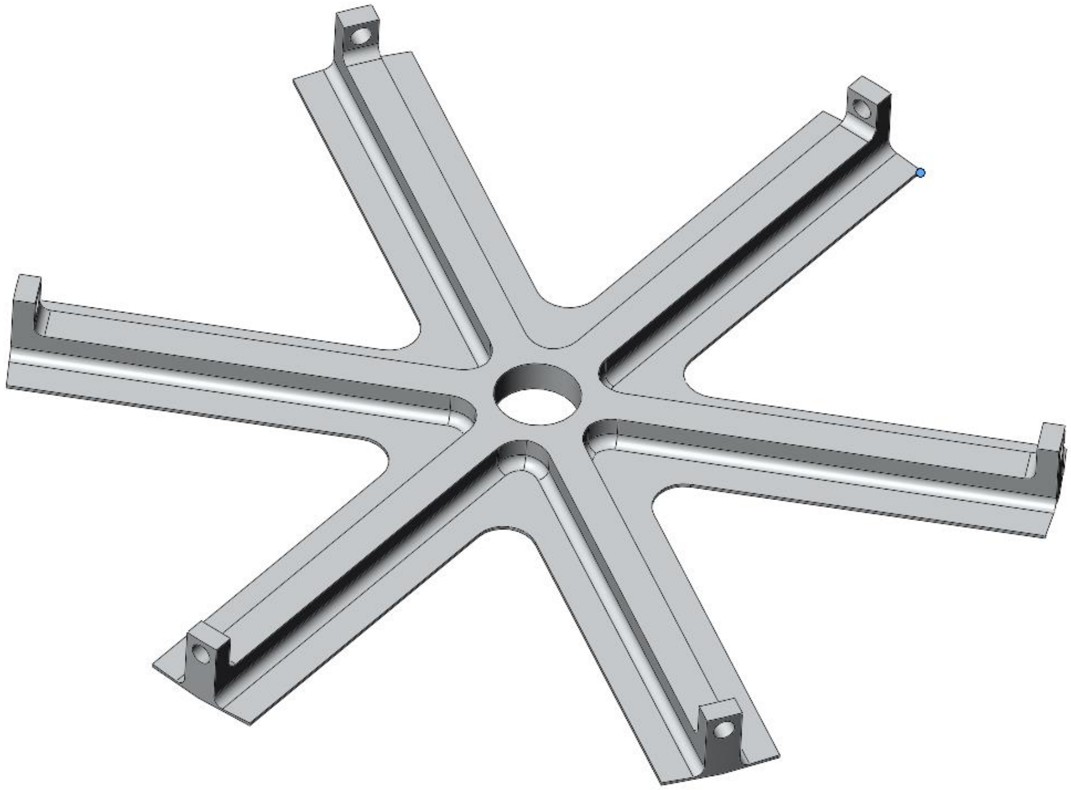


Idea 5: .18lbf

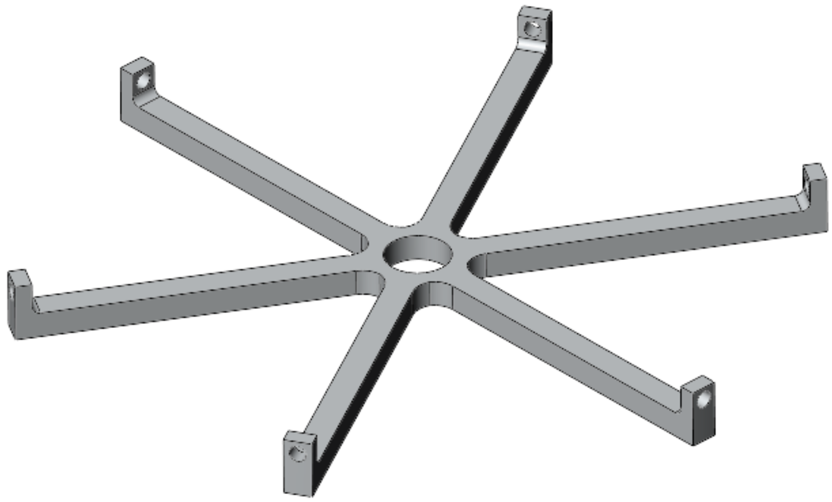
Idea 6: .14 lbf

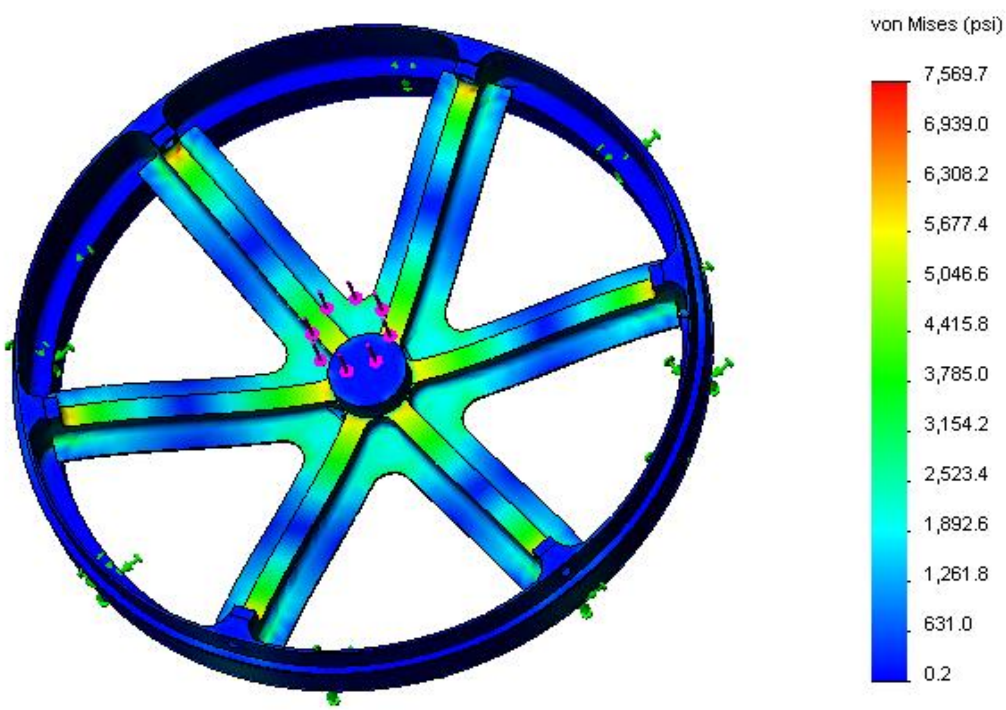


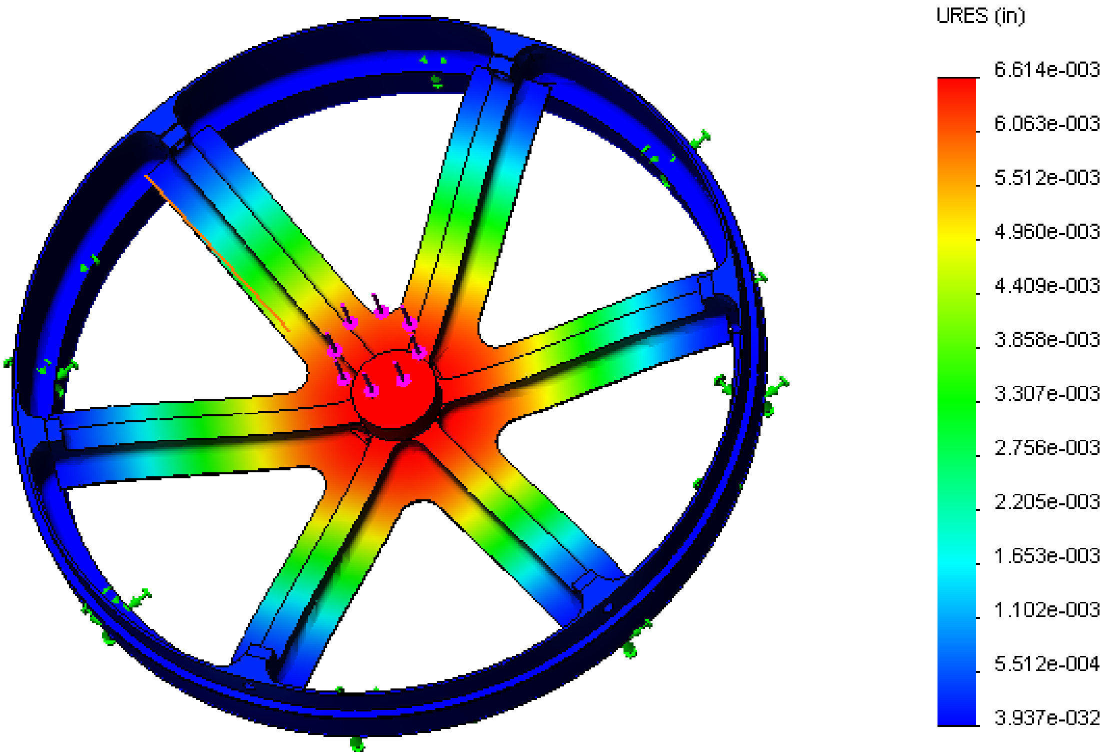
Idea 7: .09 lbf



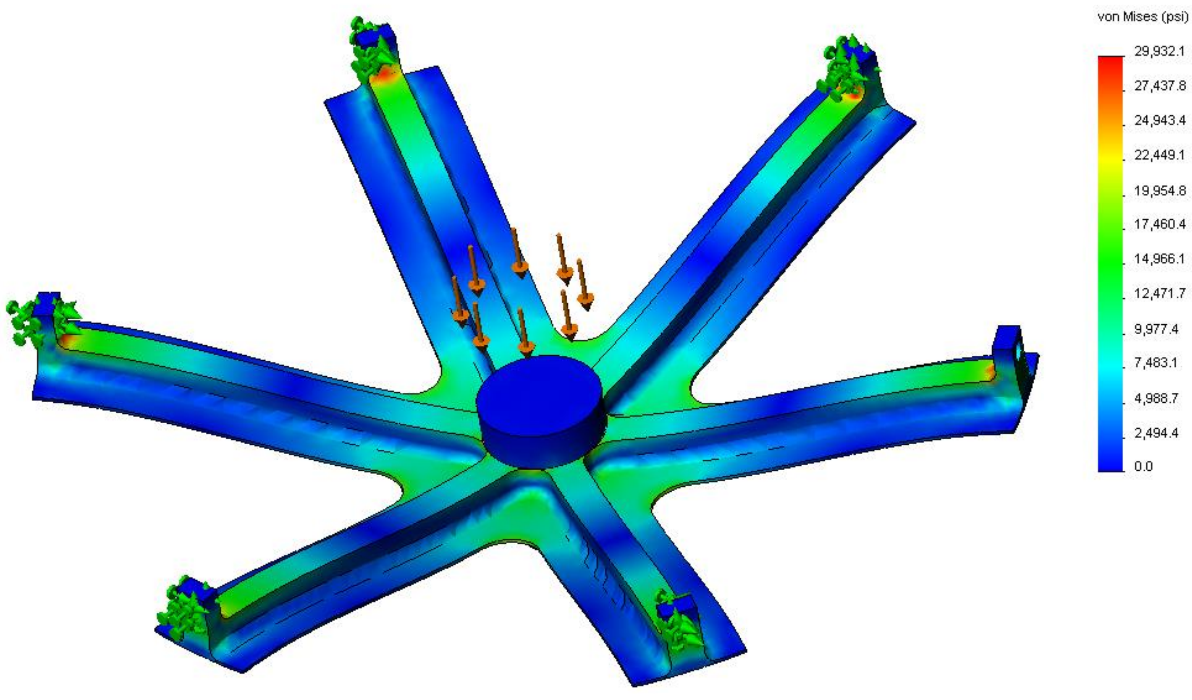
Idea 8: .08lbf

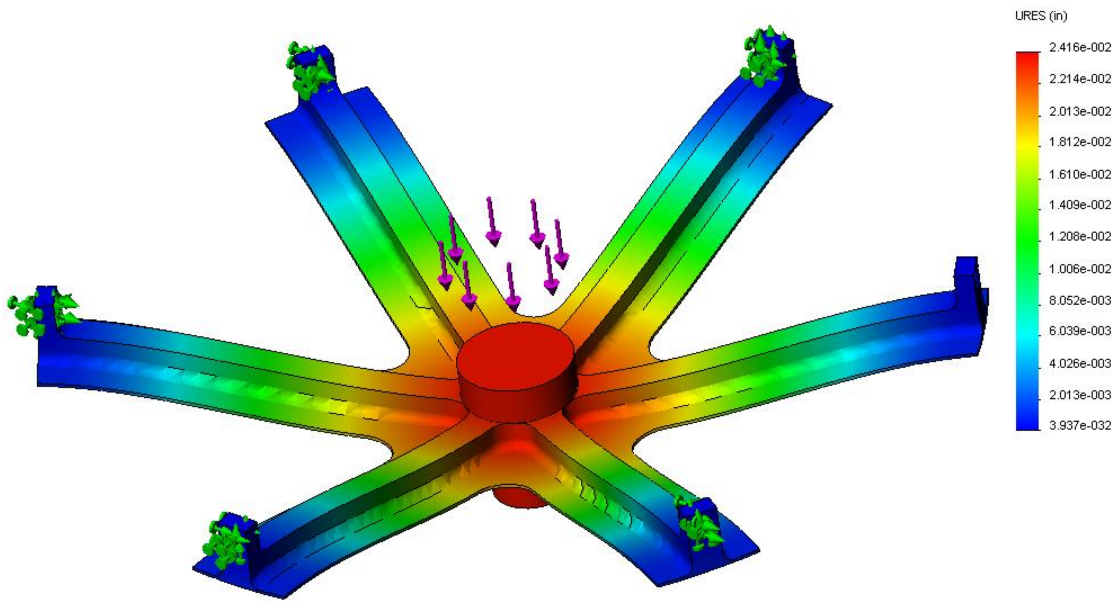


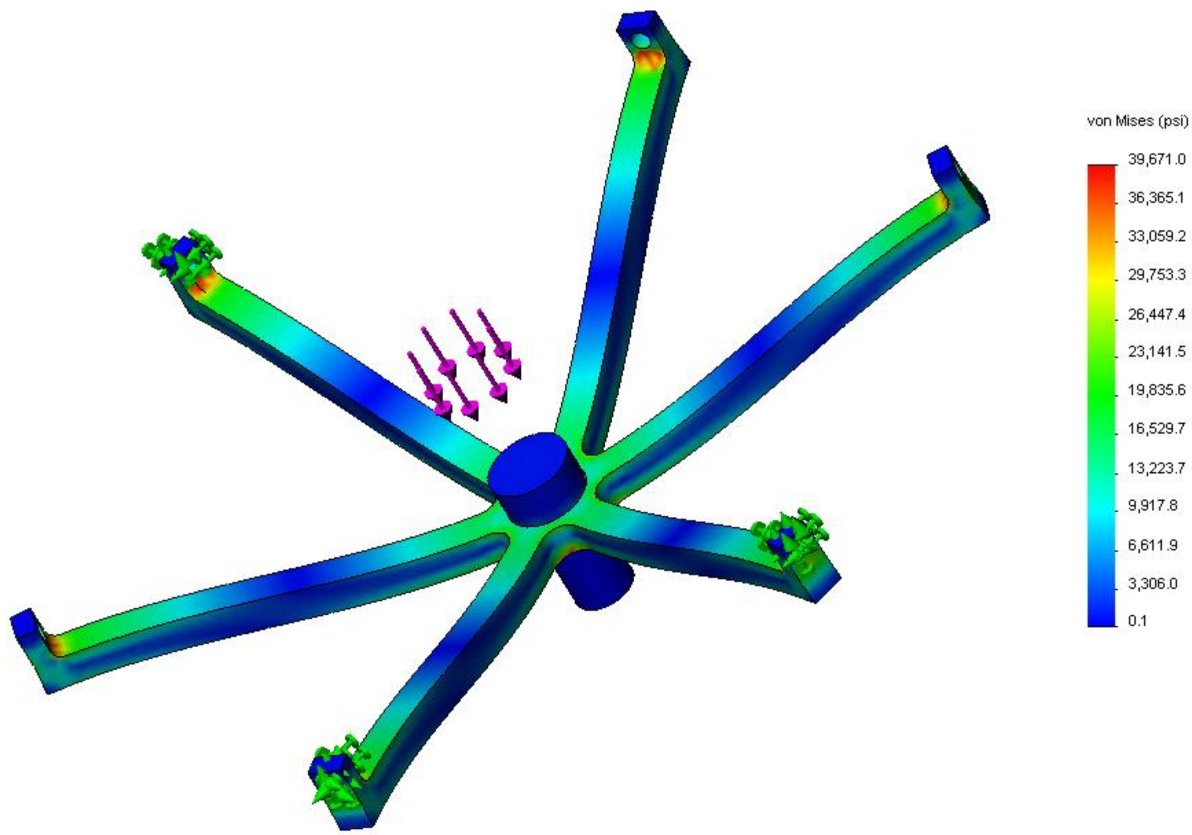

von Mises (psi)
7,569.7
6,939.0
6,308.2
5,677.4
5,046.6
4,415.8
3,785.0
3,154.2
2,523.4
1,892.6
1,261.8
631.0
0.2

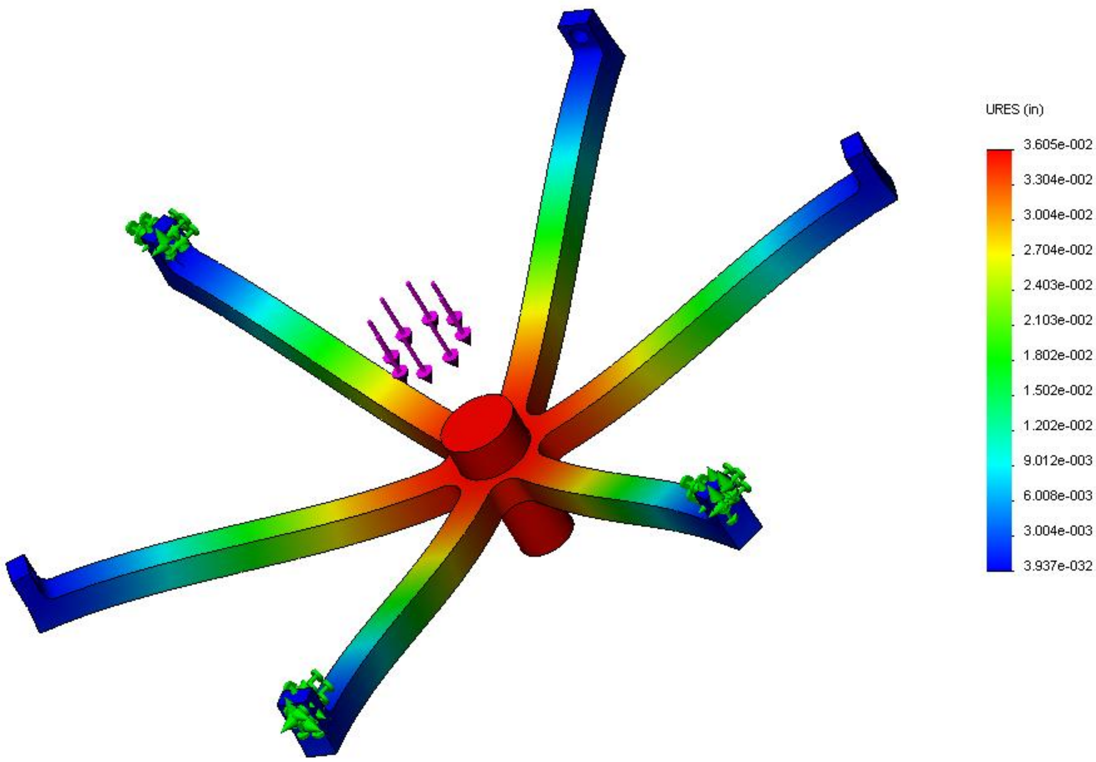


We ran FEA using 50 pounds force for the first models. The second one was using a 15 pound motor accelerating at 10 g which is a 600 newton force.

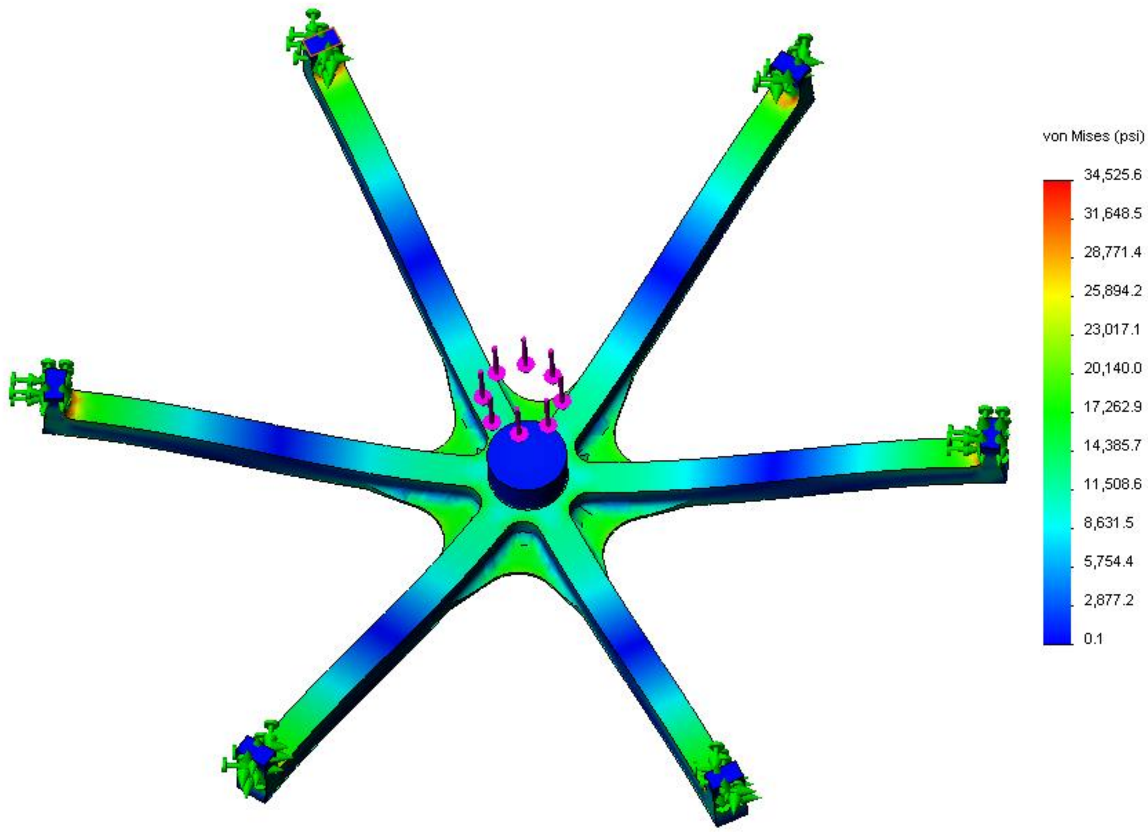


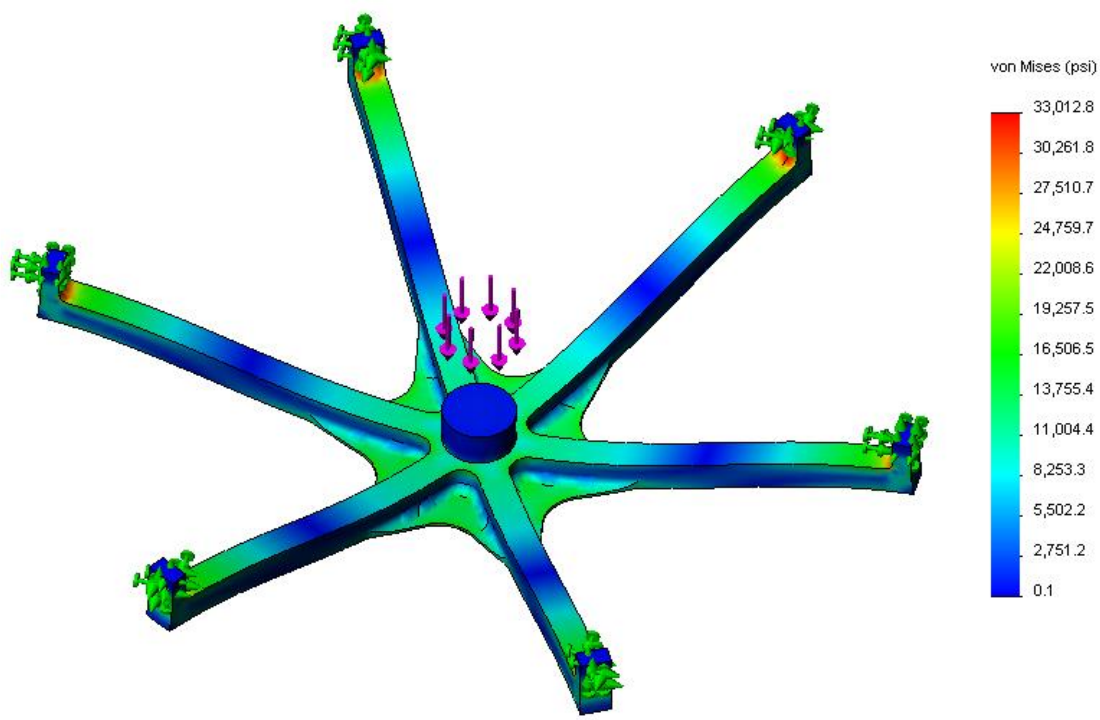

URES (in)
2.416e-002
2.214e-002
2.013e-002
1.812e-002
1.610e-002
1.409e-002
1.208e-002
1.006e-002
8.052e-003
6.039e-003
4.026e-003
2.013e-003
3.937e-032

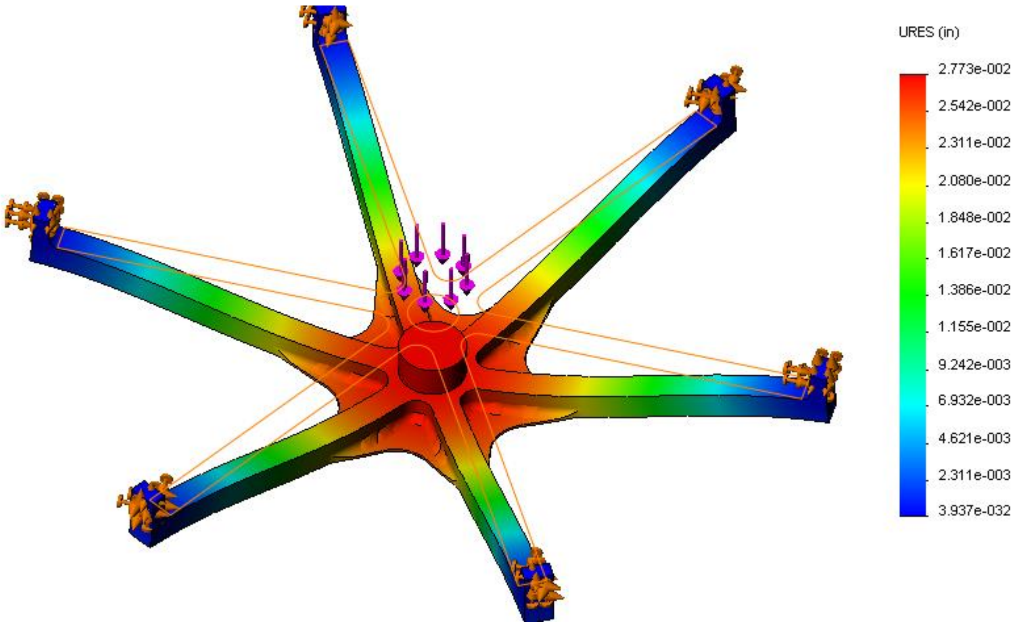

von Mises (psi)
39,671.0
36,365.1
33,059.2
29,753.3
26,447.4
23,141.5
19,835.6
16,529.7
13,223.7
9,917.8
6,611.9
3,306.0
0.1



Summary: Adding the T shape to the beams makes the weight go from .08 to .09 (11% increase). The stress in the T shape beam is around 10kpsi, and the stress in the without T beam is about 14kpsi (40% increase). The deflection with the T beams is .024" compared to without is .036" (50% increase).


von Mises (psi)
34,525.6
31,648.5
28,771.4
25,894.2
23,017.1
20,140.0
17,262.9
14,385.7
11,508.6
8,631.5
5,754.4
2,877.2
0.1


von Mises (psi)
33,012.8
30,261.8
27,510.7
24,759.7
22,008.6
19,257.5
16,506.5
13,755.4
11,004.4
8,253.3
5,502.2
2,751.2
0.1



This is with an applied 134 pounds load. 10g is a safety factor of 2.5. Weight is .08lbf

4/18/14 2:30pm Jack:
Met with Jenner, Andrew, Nathan, Eric, etc today. We scheduled a meeting with Tom Monday at 4pm to solve the MTS machine issues. We got input from Andrew on how he wants the electronics carriers to be. He wants button head screws and the plates to be spaced farther apart. He was very interested in the hole flaring operation, and is interested in owning one so that in the future they may use it. Sam has drawings of what Andrew is imagining for the carrier. Jenner got all the equipment he needed to so that he can install the oven controller in the next 3 weeks.

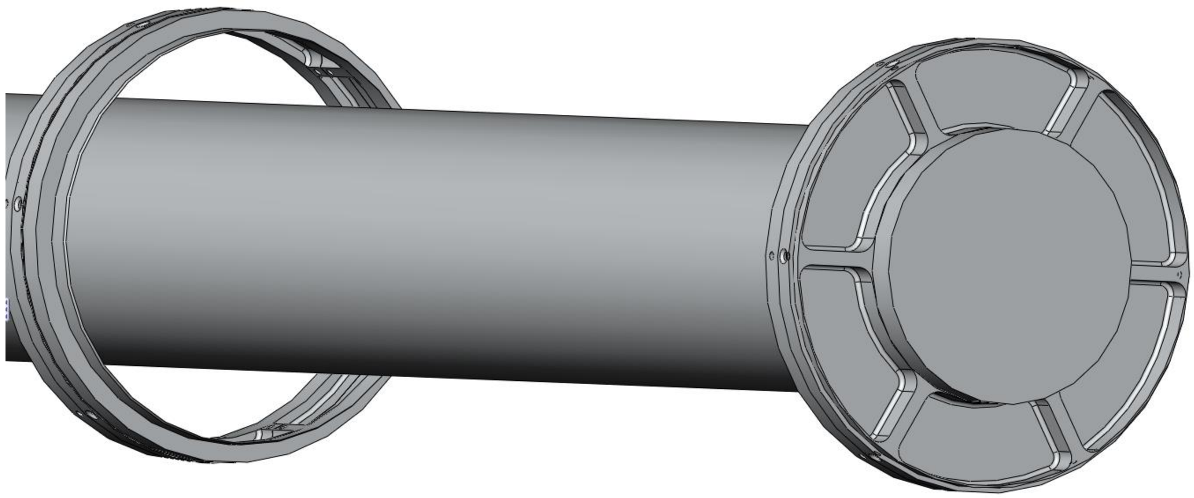
To do:

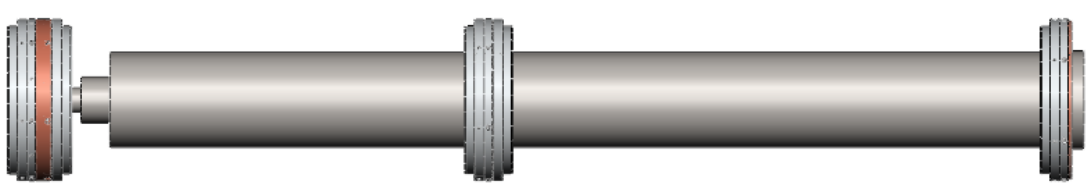
- Order dummy ring material
- machine thing for Tom
- machine MTR
- Finish designing MRR
- Machine MRR

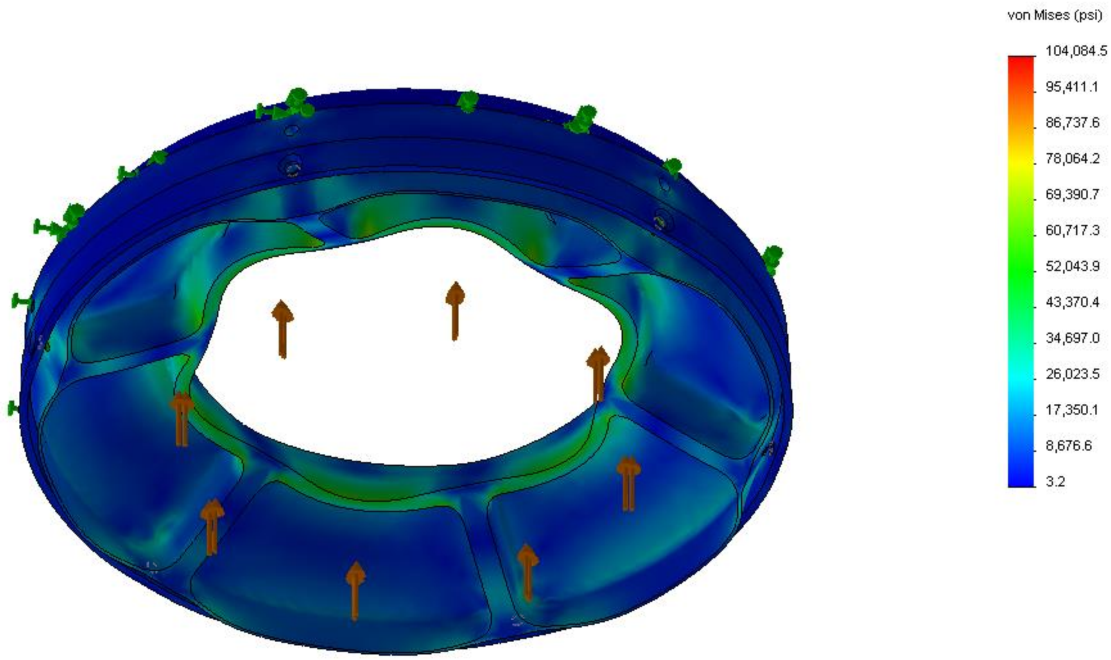
4/16/14 3:50pm Tung
Polishing Carbon Fiber : Chemical to Polish the carbon surface
How To: Polishing Carbon Fiber - Chemical Guys Rupes

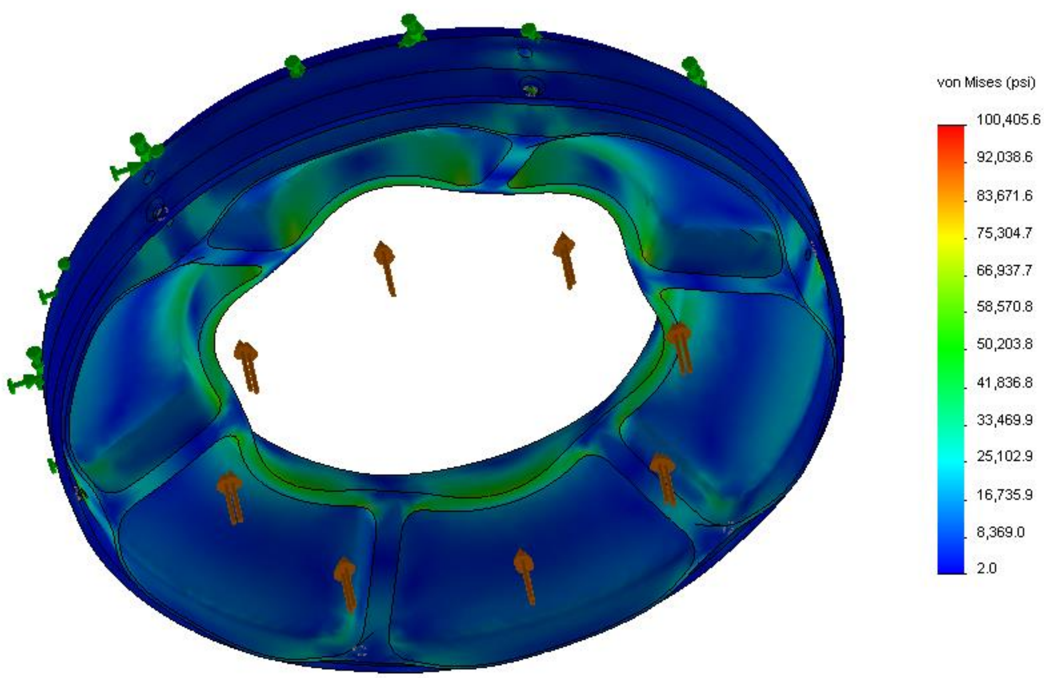
4/16/14 3:50pm Jack:
Rob and I designed the motor module. The motor module and the nosecone are the only modules that are different. The motor module will be a different length, and have the integral fin hardpoints. We are essentially taking all the differentness and putting it all in one module.

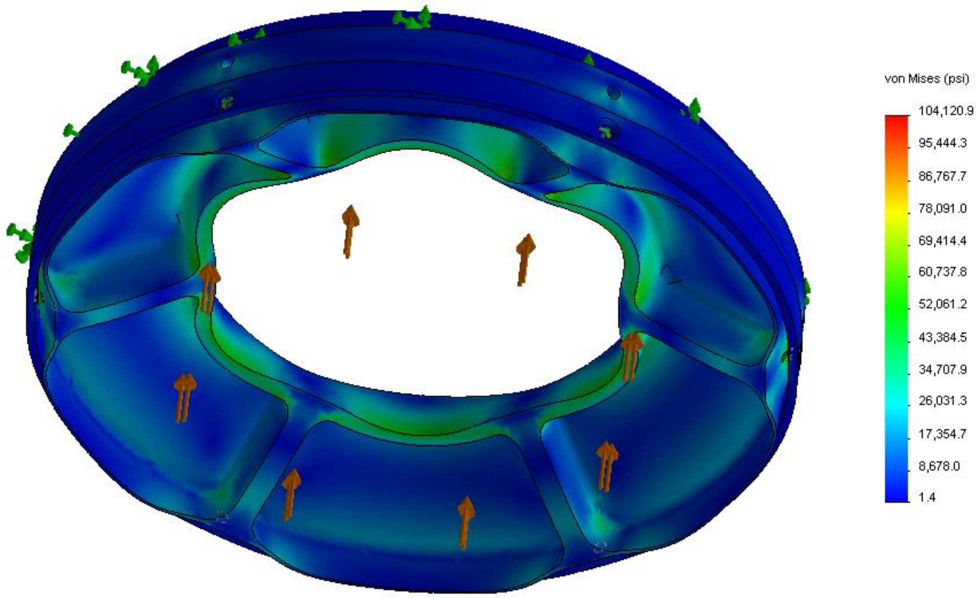
Finished the design for the MTR. It is ready for CNC from .5" 6061 T6

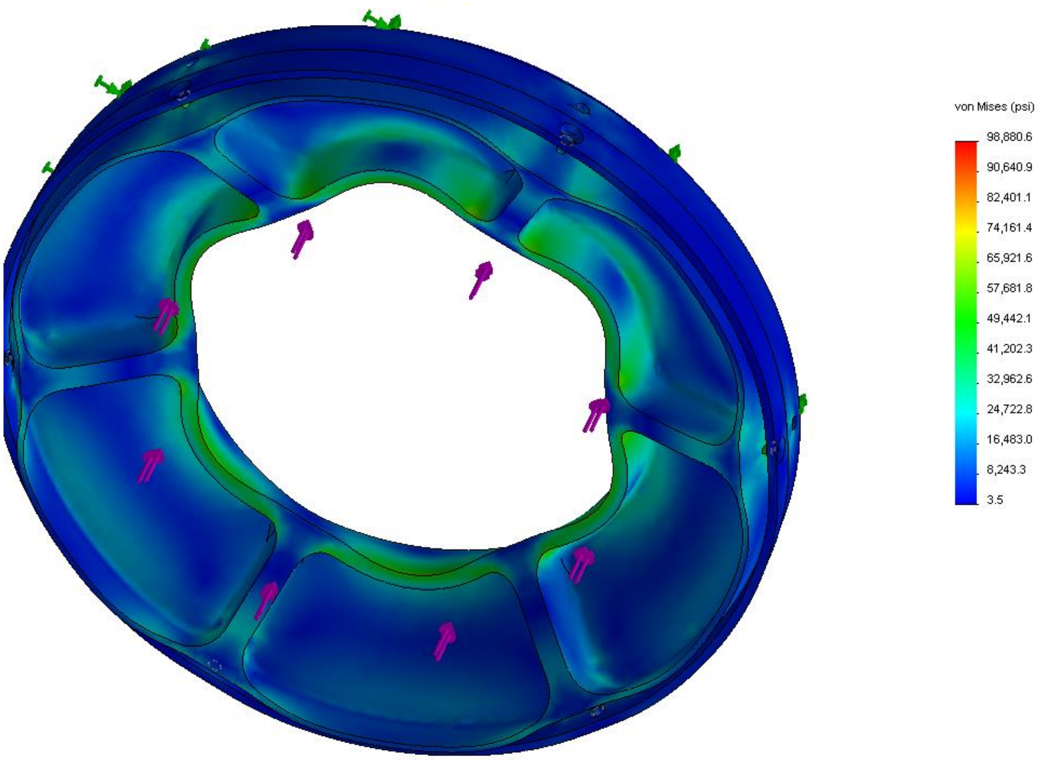




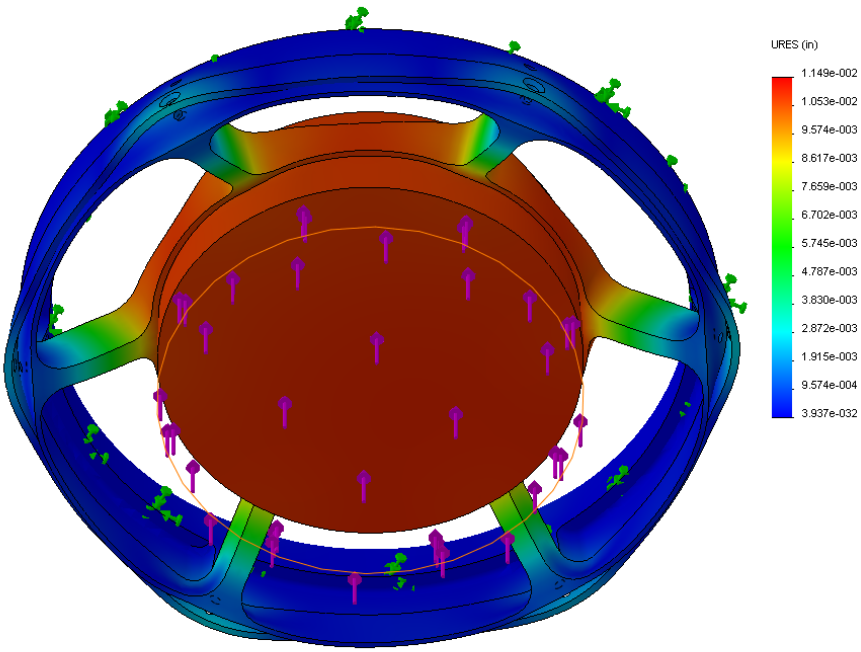

von Mises (psi)
104,084.5
95,411.1
86,737.6
78,064.2
69,390.7
60,717.3
52,043.9
43,370.4
34,697.0
26,023.5
17,350.1
8,676.6
3.2

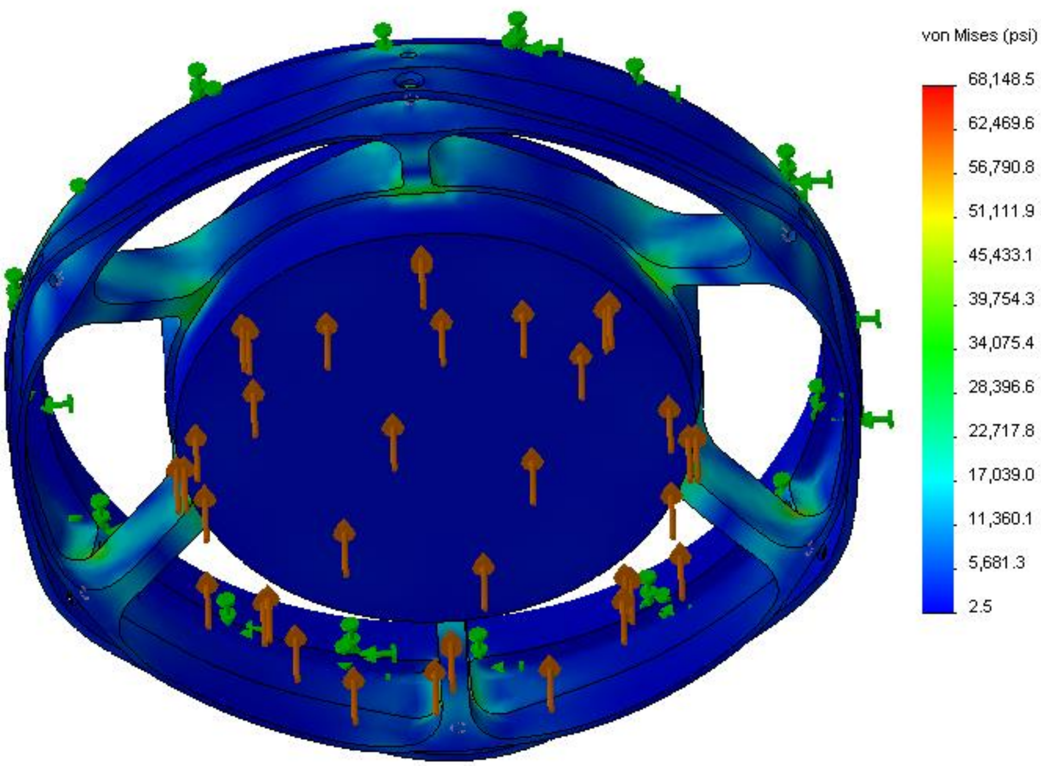

von Mises (psi)
100,405.6
92,038.6
83,671.6
75,304.7
66,937.7
58,570.8
50,203.8
41,836.8
33,469.9
25,102.9
16,735.9
8,369.0
2.0



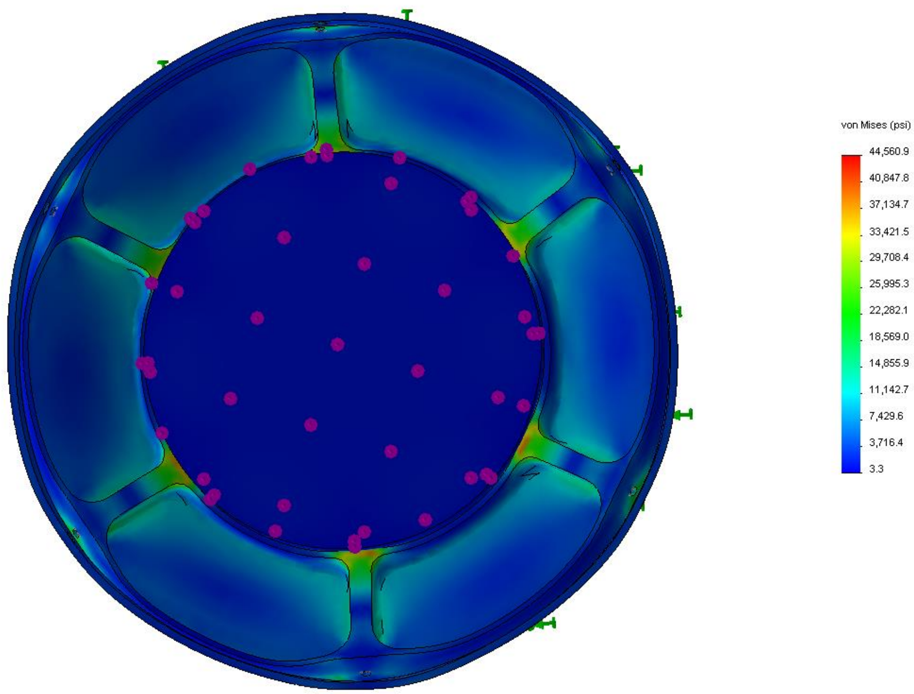


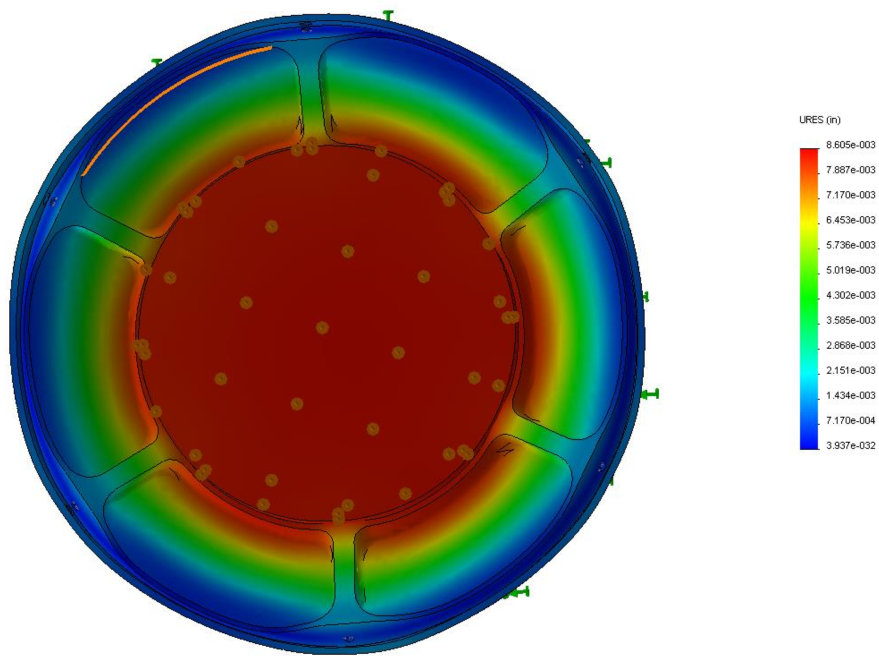
Testing with and without pocket. stresses: mid 40s along ring, mid 20s along spoke. .029" max displacement. This is with .05" pocket thickness, which weighs .28lbf.



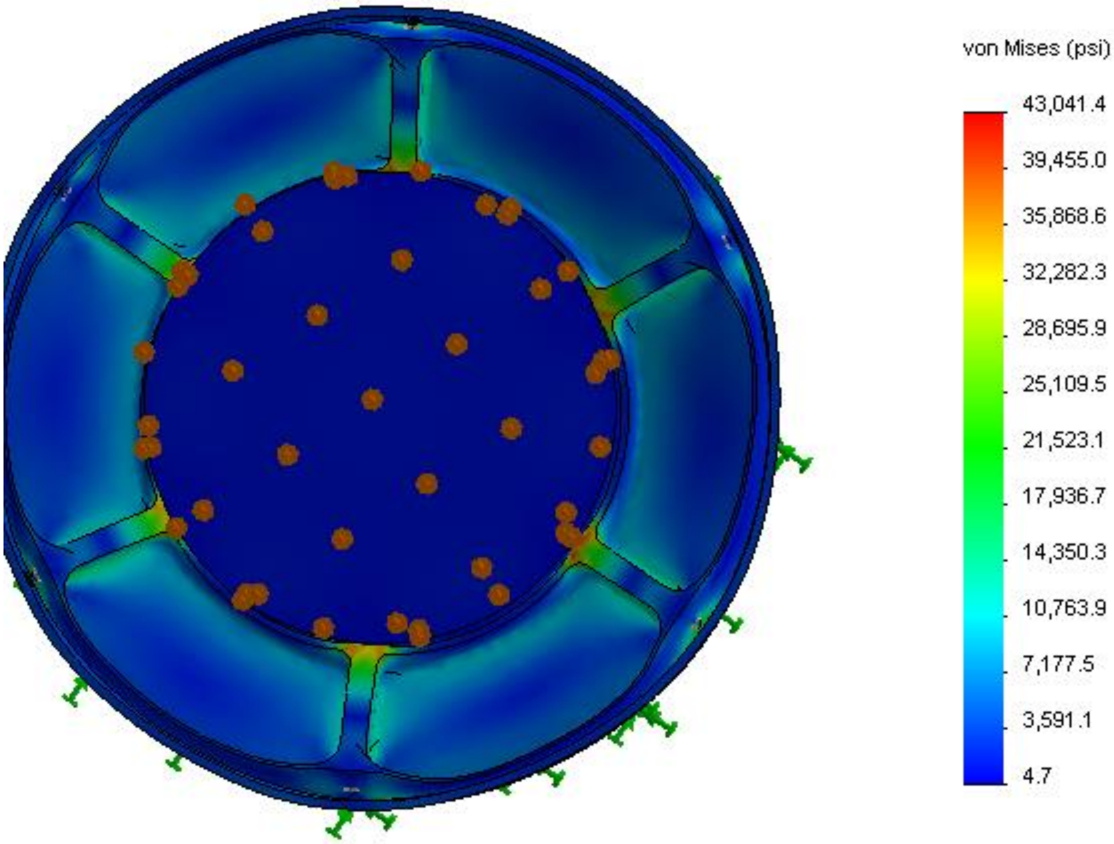


Weight: .20 lbf max stress approx 40ksi
With .04” pockets added back, weight: .27 lbf stress is now about 30ksi

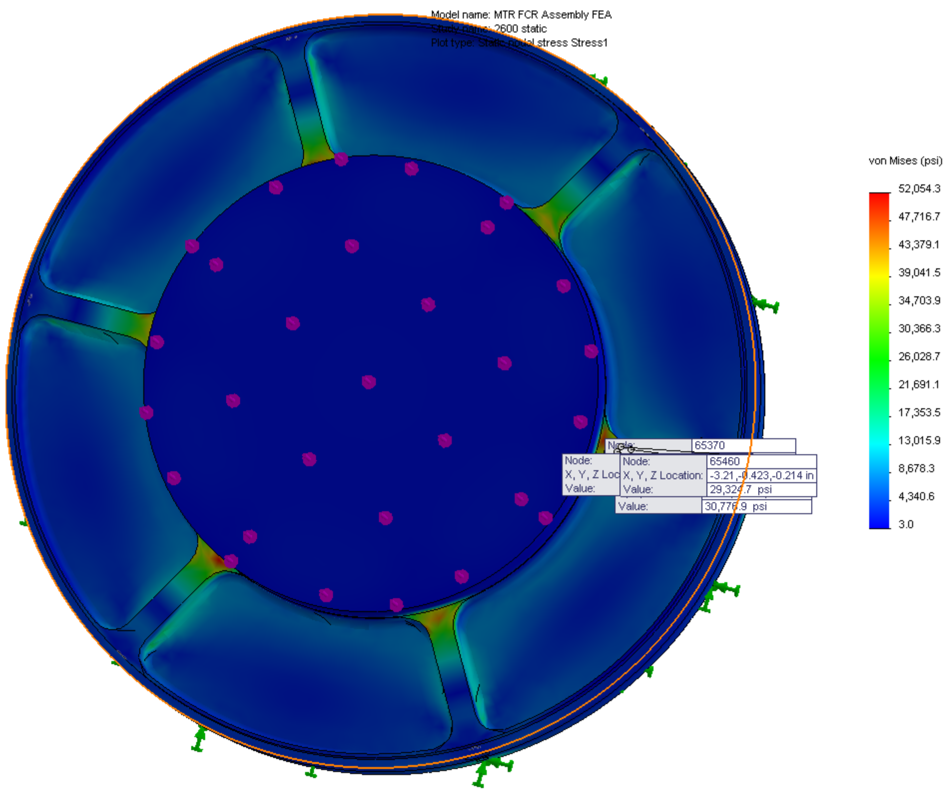




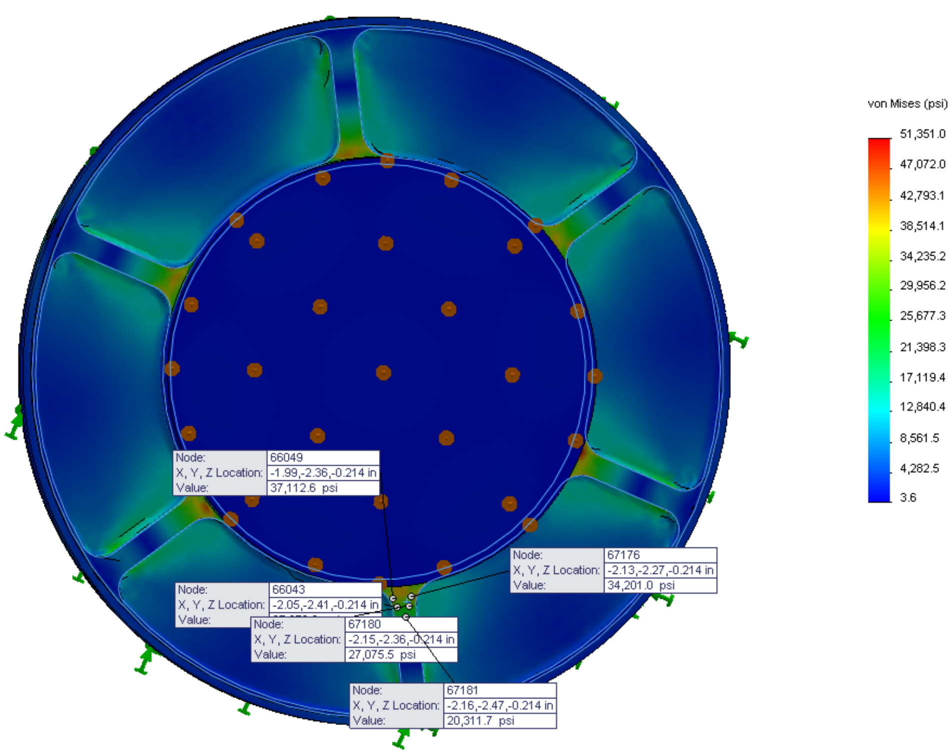
Appears to be no significant difference flipping the pocket from one side to the other.

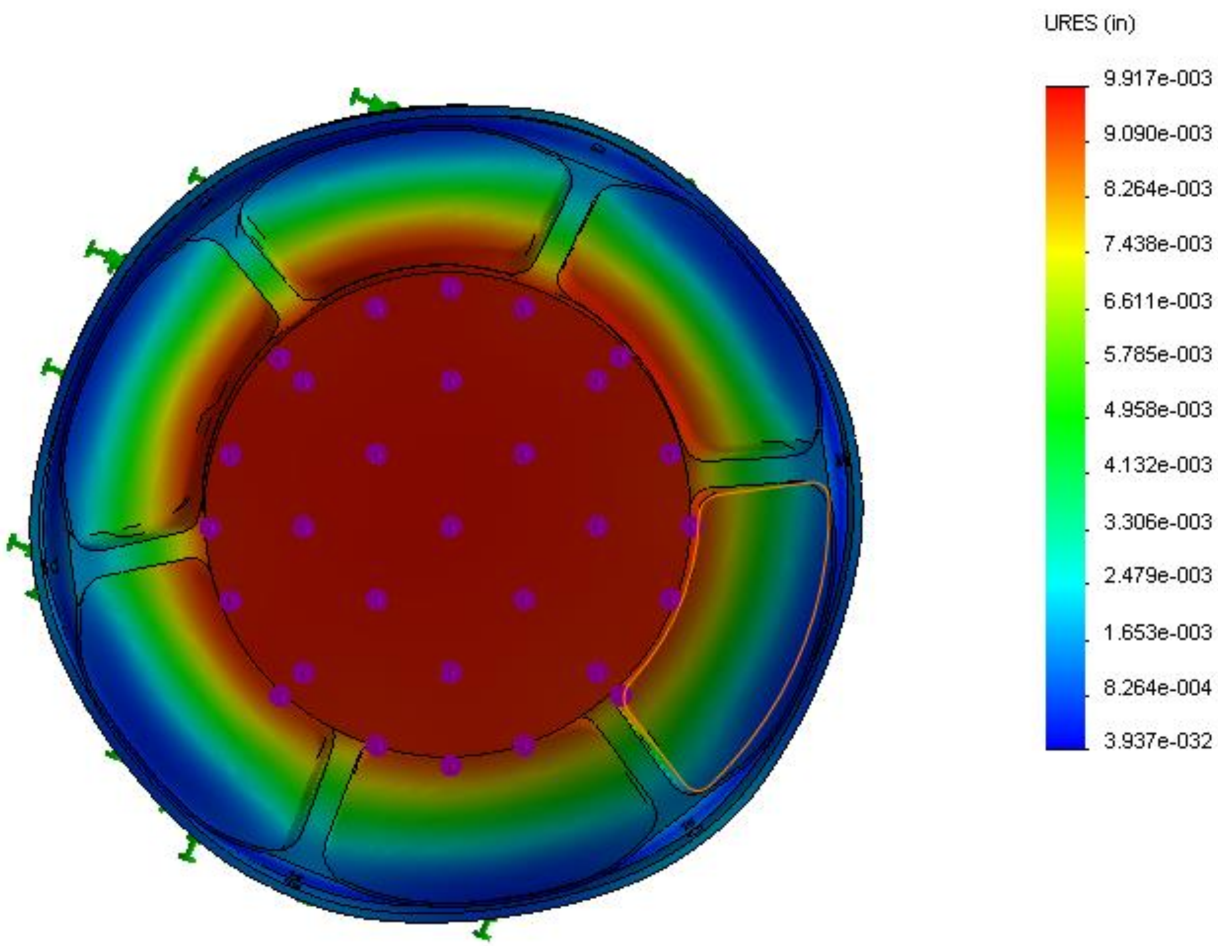


Changed the pockets so they match the FCR above. displacement .009"

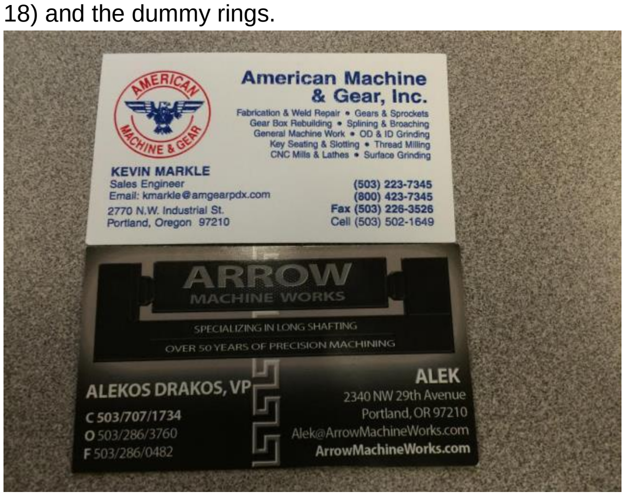


This is with a pocket down from .05" to .02" which saved .06lbf



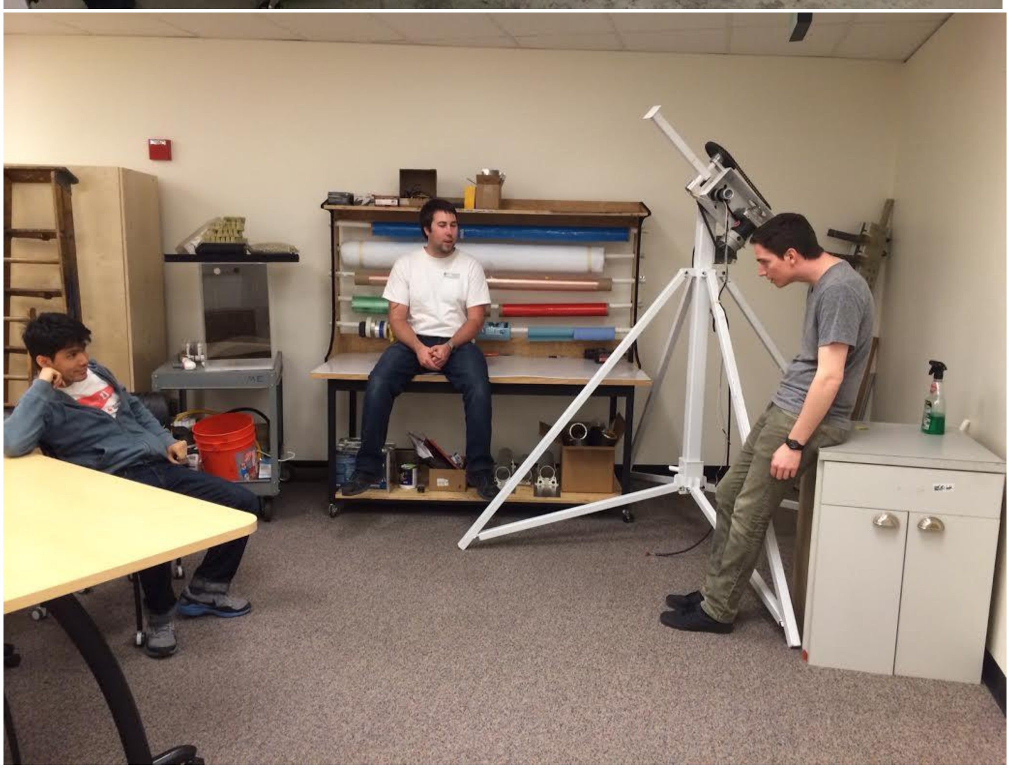


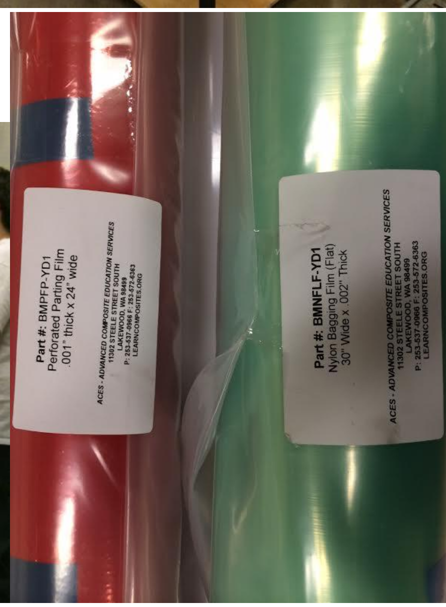
4/16/14 2:20pm Jack:
Barett, Rob, Sam and Jack went to two machine shops this morning. Arrow seemed very excited about our project, american machine was less so, but still excited. We sent them drawings of both small and large mandrels (23.5 and 18) and the dummy rings.



4/14/14 6:20pm Jack:
We finished the table today. It is in 84 now. It would be better if it had some sort of cubby or drawer/storage area.


ORCA SKIN

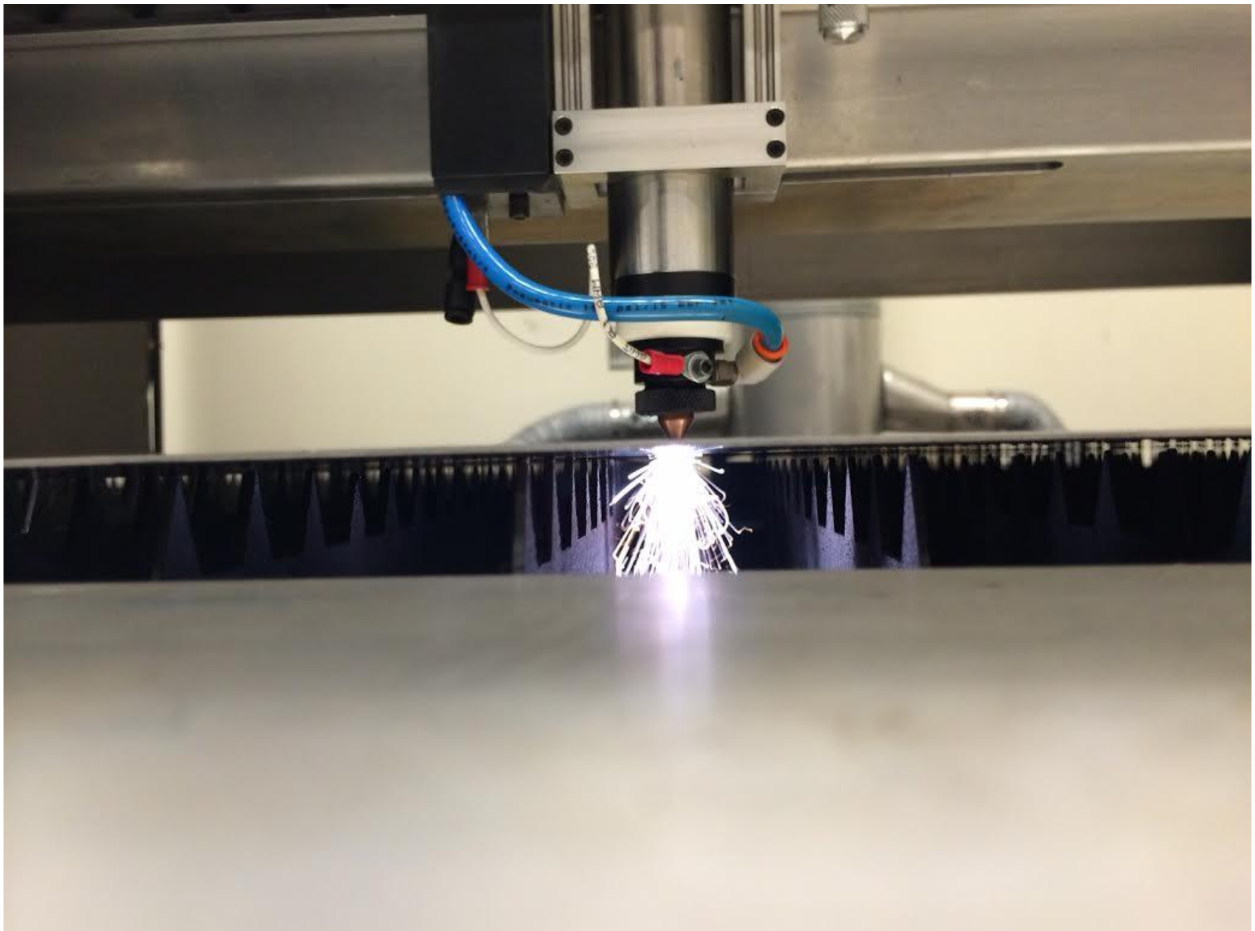


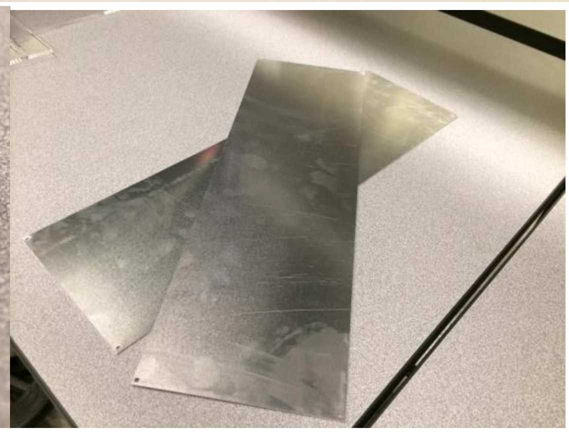


4/14/14 11:10am Jack:
Idea for stiffening up the electronics carriers if need be. It's called a punch and flare tool. Googling sheet metal flared hole brings all the information.

We made a prototype electronics carrier. The flanges on the edges are half as big as they should be, and are pretty thin. We might want to consider a more robust design. We floated up ideas about getting rid of the bend by using something similar to what they have now.

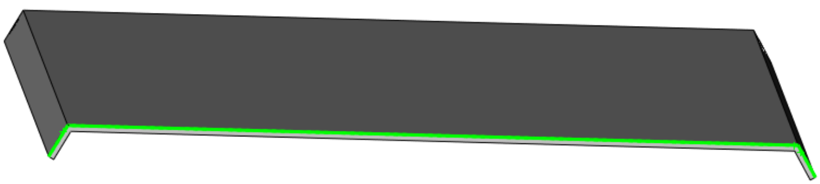
4/11/14 3:10pm Jack:
We laser cut two electronics carriers and the 4 composite cutout templates.

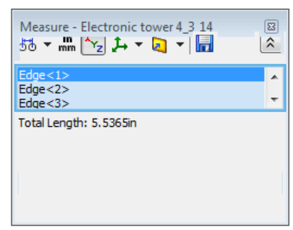


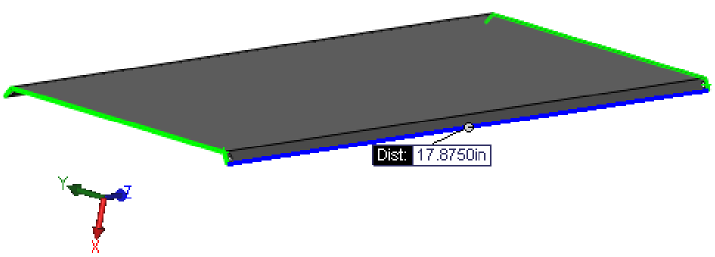


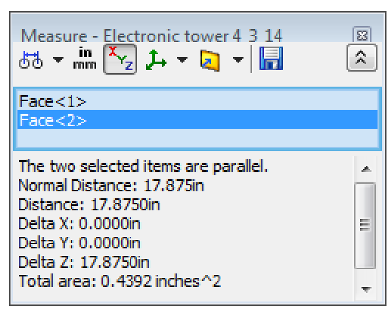
4/11/14 1:10pm Jack:
We are laser cutting the acrylic templates for the carbon layup, and the aluminum .04” electronics carrier. Acrylic templates are ready to laser cut.

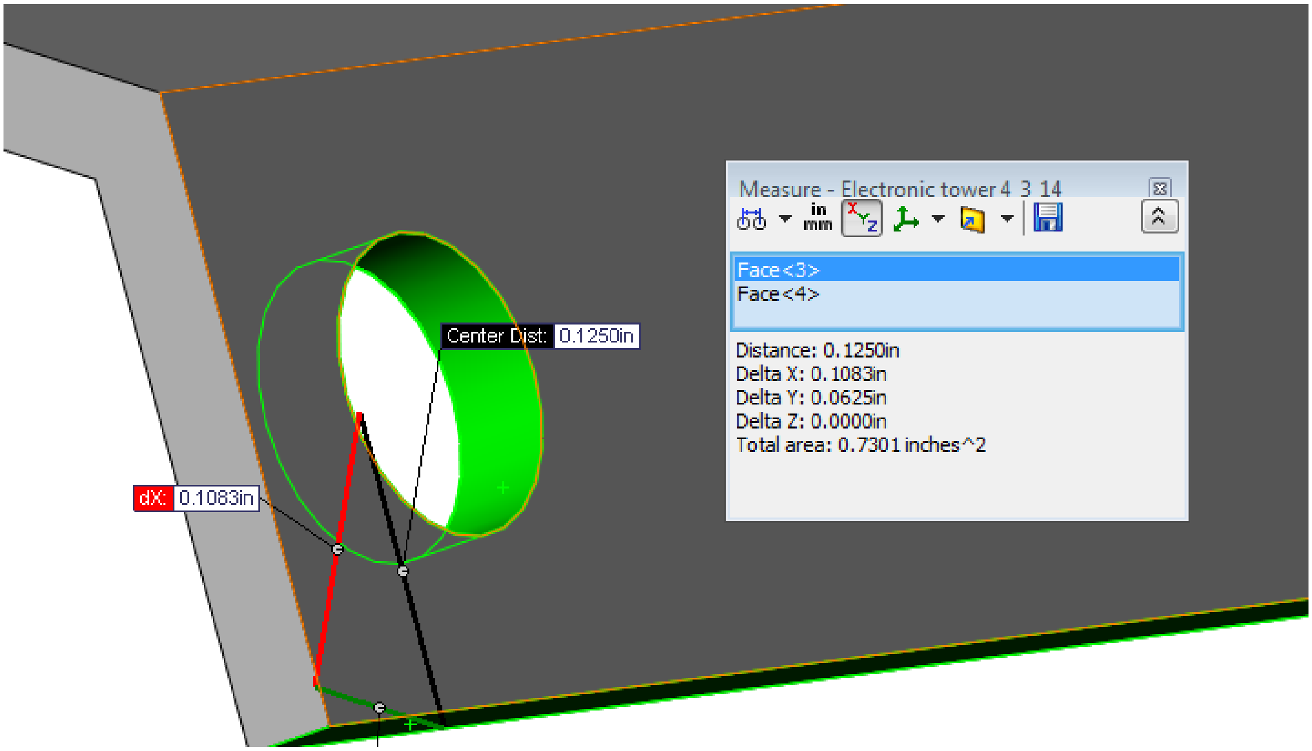
Updated the carrier so that it spans the larger gap like andrew wanted. Carrier is ready to laser cut

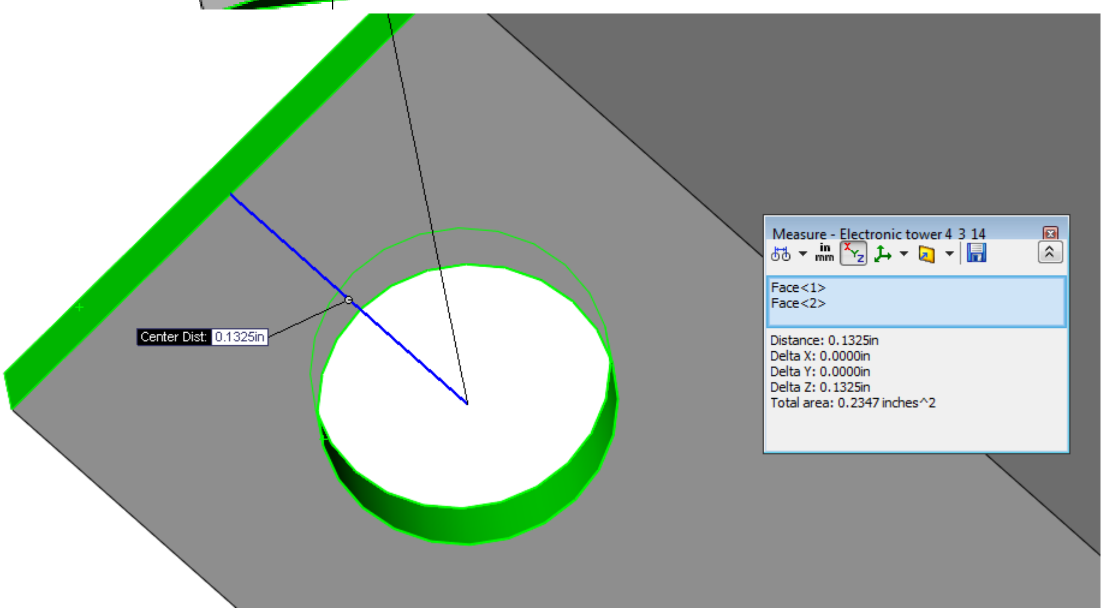




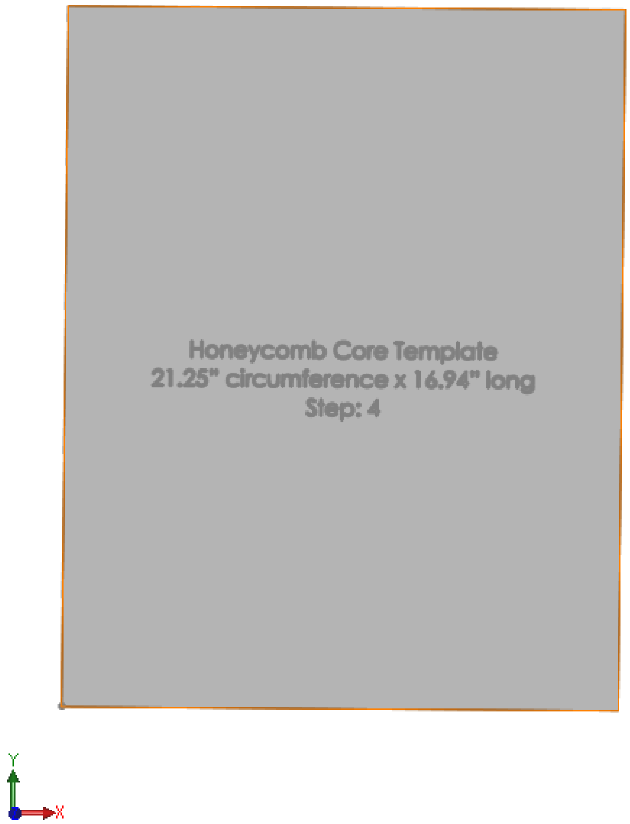


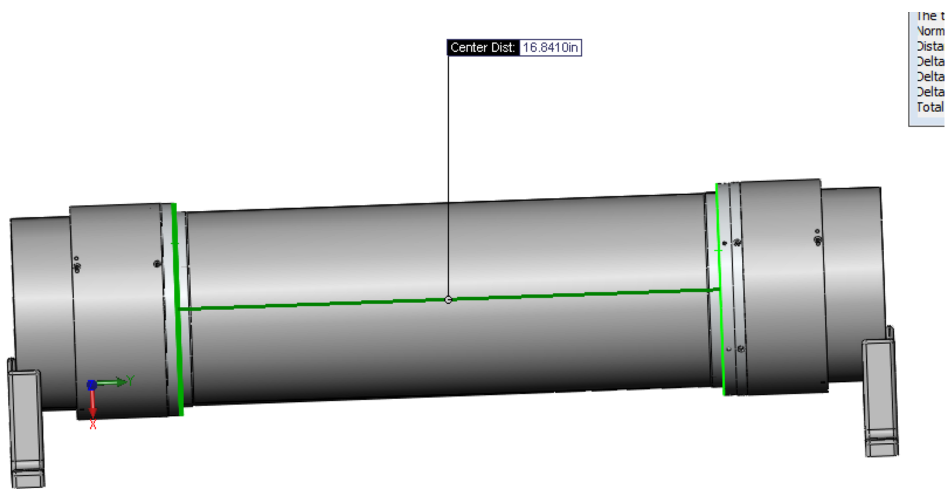


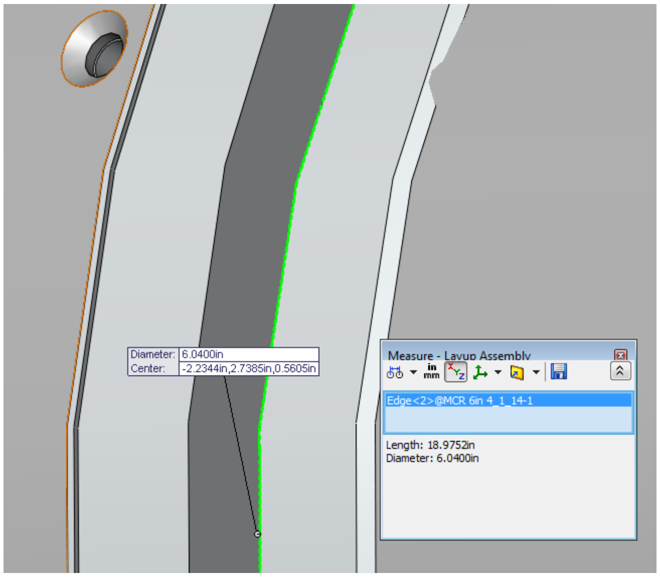


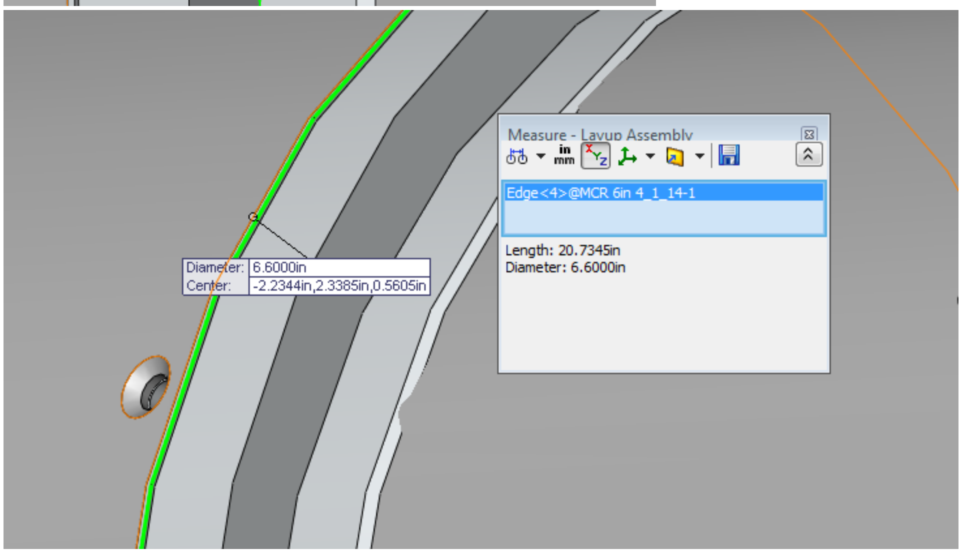


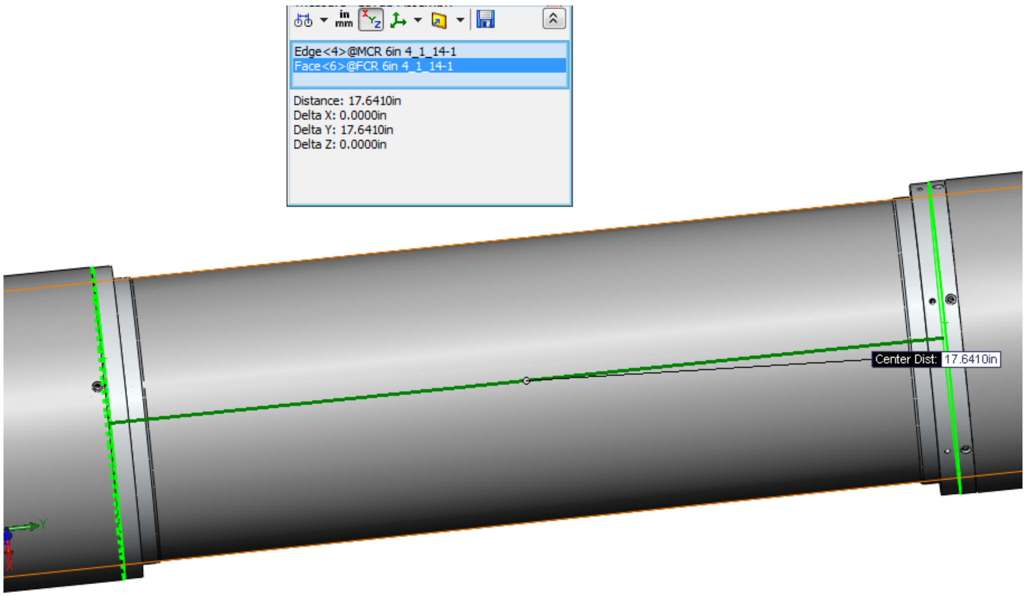
4/10/14 9:10pm Jack:
I made the drawings for the carbon/core/adhesive templates for the module layup. Each one has written on it what it is to be laser etched. Someone should go through and check my work. They are in the tooling folder.


Honeycomb Core Template
21.25" circumference x 16.94" long
Step: 4
Y
X


Center Dist: 16.8410in


Diameter: 6.0400in
Center: -2.2344in,2.7385in,0.5605in
Measure - Layup Assembly
Edge<2>@MCR 6in 4_1_14-1
Length: 18.9752in
Diameter: 6.0400in


Diameter: 6.6000in
Center: -2.2344in,2.3385in,0.5605in
Measure - Layup Assembly
Edge<4>@MCR 6in 4_1_14-1
Length: 20.7345in
Diameter: 6.6000in



Inside ply and adhesive film template base dimensions:
18.975” circumference x 16.841” long
Adjusted:
20” circumference x 16.85” long
Inscription: Inside Ply and Adhesive Film Template
6” x 18” module V1
20” circumference x 16.85” long
Steps: 2, 3

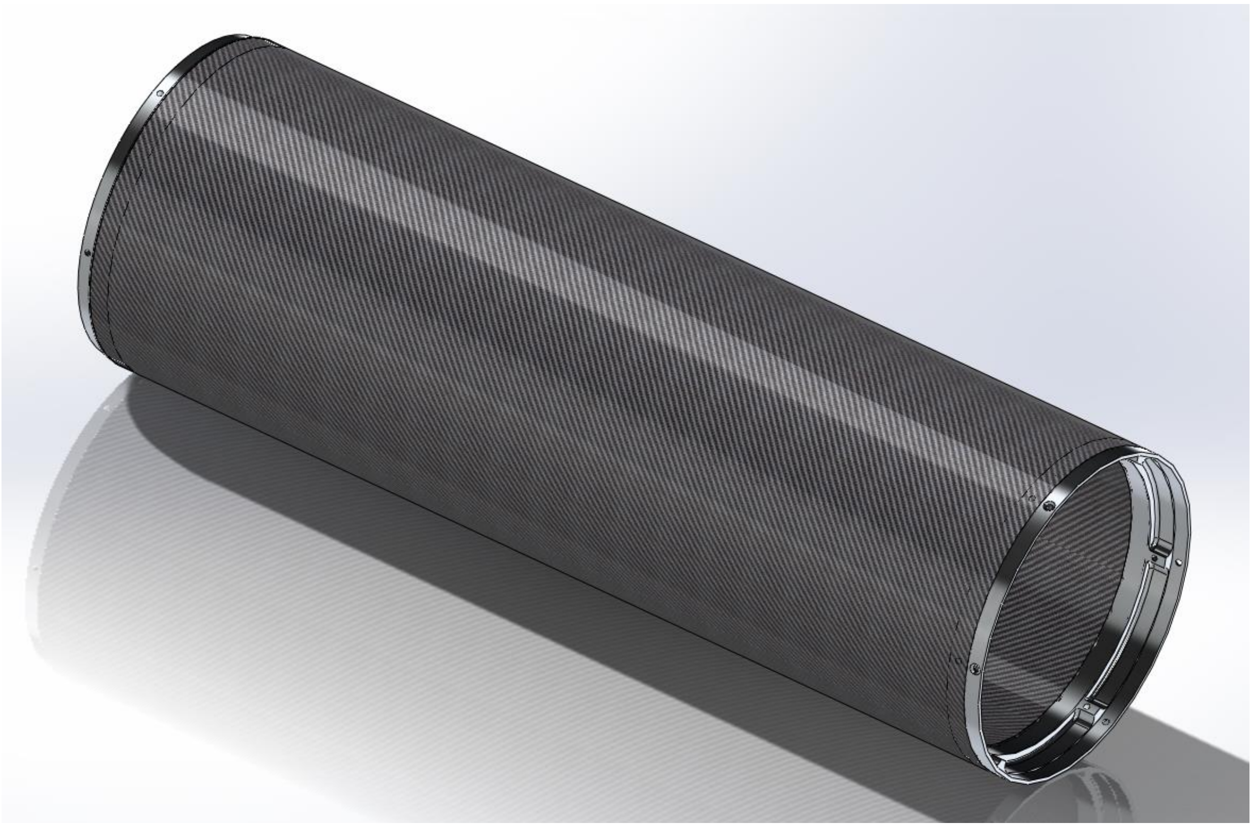
Aluminum step adhesive film strip template dimensions:
18.975” circumference x .35” long
Adjusted:
21” circumference x .35” long
Inscription:
Aluminum Step Adhesive Film Template 6” x 18” module: 21” circumference x .35” long Step: 1

Carbon Core template dimensions:
20.64” circumference x 16.841” long
Adjusted:
21.25” circumference x 16.94” long
Inscription: Honeycomb core template
6” x 18” module V1
21.25” circumference x 16.94” long
Step: 4

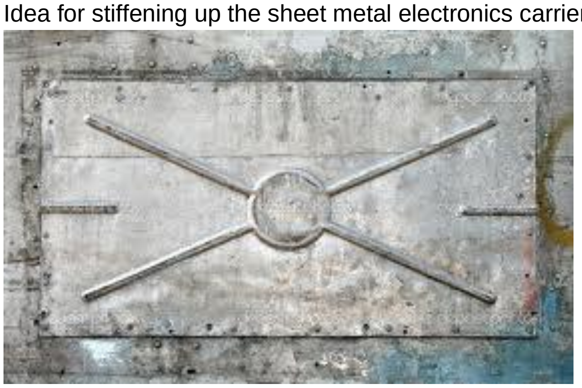
Outside ply and second adhesive film template dimensions:
20.735” circumference x 17.641” long
Adjusted:
22” circumference x 16.945” long
Inscription: Outside ply and second adhesive film template
6” x 18” module V1
22” circumference x 16.945” long

Steps: 5, 6

4/9/14 5:50pm: Tung
I plan to make the 3D drawing of the whole 6in rocket including the electrical carrier and the nose cone which will be very useful for the demonstration. It is located in the stash: Rocket ASSY folder. Everyone is welcome to add part.



4/9/14 5:20pm Jack:
Idea for stiffening up the sheet metal electronics carriers



Dimensions for purchasing sheet aluminum: 18” x 6” per side
36x 6 +some or 18 x 12 +some

4/9/14 5:20pm Jack:

Advanced-West Composite Solutions

Home
Prepreg
Hard Composite Armor Systems
Bagging Materials
Bleeders and Breathers
Pressure Sensitive Tapes
Sealant Tapes
Valves and Hoses
Peel Plies
Cutting Mats
Release Films
Thermoform Tooling and Plug Assists
Cellular Core Materials
Urethane Tooling Boards
Epoxy Tooling Boards
About Advanced West
Contact Us

Contact Us: 714.543.7824

Epoxy Tooling Boards

To meet the needs of a variety of tooling applications, epoxy tooling blocks and boards supplied by Trelleborg Emerson & Cuming exhibit a range of physical properties and performance characteristics including:

- CNC machinable with high speed steel and carbide cutters
- Excellent dimensional stability to prevent tool deformation during high-pressure molding/fabricating processes
- Exceptional smooth surface finish to virtually eliminate the need for hand-polishing of tools
- Low density
- Good compression strength
- Good high-temperature performance to accommodate exposure to temperatures as high as 400°F (204°C)
- Full range of thicknesses; boards measure 24 in. wide x 60 in. long x 2, 3 and 6 in. thick
- Color and performance-matched adhesives and repair pastes.

Product	Color	Density, lb./ft.3 (g/cm3)	Hardness, Shore D	CTE, in./in./°F (cm/cm/°C)	Heat Distortion Temperature, °F (°C)	Compression Strength, psi (MPa)	Description
TC-420	White	42 (0.67)	78	17x10-6 (31x10-6)	350 (177)	6,500 (45)	High-temperature epoxy syntactic with excellent surface finish
TC-460	Blue	46 (0.74)	78	17x10-6 (31x10-6)	450 (232)	7,400 (51)	Ultra-high temperature epoxy syntactic with excellent surface finish

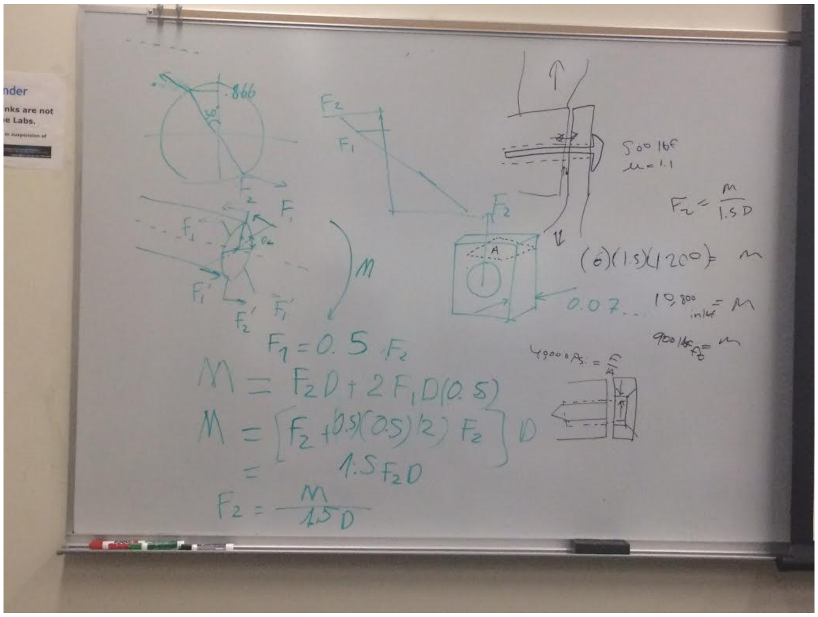
Found another potential epoxy tooling board we could get. We can call for a quote. Maybe they have cylindrical

4/9/14 4:30pm Jack:
Wrote up a rough outline for laying up a module. Wrote it in the design folder called **layup instructions**. This will be a work in progress, and we will continually add more photos, details etc as we continue.

4/9/14 1:00pm Sam, Jack,Tung:
We've looked more into the joint bending issue and have mostly just found more uncertainty. Rob found a paper online done by another rocketry group claiming a moment of 1500 ft-lb with similar geometries to what we have.

This would introduce approximately a 6000 lb force on the tension side of the cylinder at the bolt, which would cause 360kpsi bearing stress in the female aluminum flange. This is way higher than the yield strength of aluminum around 40kpsi. However, that moment was determined from a 10deg attack angle which seems highly unlikely. The paper even says that the angle of attack won't be over 4deg. At 4 deg, the moment is 1.01kN*m according to the paper. Also, the load will be spread out over multiple bolts and partially accounted for by the friction generated by the screw clamp load.The rough calculation for how much friction each bolt will introduce is 600lbf.

The other article that quoted a 20,000lbin moment is in a rocket that has 6700lbf thrust and max Q happens at mach 5.5. This is not even in the order of magnitude that we are expecting with our 800lbf and and mach 2.



We attempted to calculate the load on all 3 of the bolts in bending and we got that the maximum moment was 10,000lb in. We don't know if this is correct.

4/9/14 1:00pm Sam, Rob, Jack:
We did a quick joint bending test using the stacked 3.4" modules. We put a maximum of 200 lb of weight at the joint with no sign of deflection or failure.

4/8/14 6:00pm Sam, Barett:

Sam made a semi-comprehensive list (in the main Capstone folder) of tasks that need to be completed before we build an entire rocket and finish this project. It is a living document so please add to and update it as you please. **Note that all the red boxes are things that haven't been started.** And these are just the things I came up with today, so there are probably half again as many tasks that need to be added.

Task	Detail	Urgency	Completion	Notes
Capstone final report			In progress	Tung started a google doc, gathered some outline info
Capstone final presentation			Not started	
Electronics carrier finalized and prototyped				
	Finalize design		In progress	
	Source material		Not started	
	Manufacture prototype		Not started	
	Manufacture full set		Not started	
Mandrel machining				
	Find shop - low cost or free, ~2 week turnaround		In progress	Cold called about 5 shops. Only 3 bites. Enoch won't do a single part. Waiting to hear on quotes from BBC Steel and American Precision in Hillsboro
	In-house processing		Not started	
Layup table materials and fab				
	Source materials: plywood, pvc tubing, fasteners, casters, tool mounting hardware, plastic cutting surface (?)		In progress	Ordered: tool holding hardware, casters, plywood. Can pick up 1/4" plastic cutting surface (HDPE) from TAP for $90. PVC and fasteners, will pick up from Home Depot
	Laser cut wood		Done	
	Assemble shelf structure and cutting surface, drawers (?)		Not started	
	Cut and install PVC		Not started	
	Install casters and hardware		Not started	
	Install tool holders		Not started	
Update and make material cutout templates				
	Ring adhesive, inner carbon, inner adhesive, core (decide on optimal length), outer adhesive, outer carbon		Not started	
Motor module design				
	MTR Design		In progress	
	Threaded motor attachment		Not started	
	Fins and fin mounting		In progress	
	How to handle length, mandrel issue		Not started	
	Thrust measurement (?)		Not started	
Motor module mfg.				
	Source MTR material		Not started	
	MTR programming and machining		Not started	
	Specialized ring/attachment material sourcing and manufacturing		Not started	
	Fin layup/mfg.		Not started	
Full scale module testing				
	Compression test individual module		Not started	
	Vibration test (?)		Not started	
	Bending test (?)		Not started	
Nose cone				
	Finalize tool design		In progress	
	Source material		Not started	
	Source machining		Not started	
	Manufacture prototype		Not started	
	Design separation rings		Not started	
	Source material and machining for separation rings		Not started	
Oven				
	Solve thermocouple issues		Not started	
	Finish display and electronics packaging		Not started	
Figure out module surface finish and paint				
	Determine best post-process		In progress	Painting has not gone great so far. Sanding proves tedious. PSAS wants paint, not clear coat
	Source all necessary post-processing supplies		In progress	Already have sandpaper, polishing supplies, some (shitty) paint
Get module test machine working with Tom			Not started	
Figure out full rocket parts list			Not started	
Figure out full start-to-finish tool list			Not started	
Write full module mfg. instruction manual			Not started	
PSAS mfg. workshops			Not started	
Misc. details like fasteners, supplies go here				

Barett found some plywood for the table and laser cut the more complicated shapes. He will pick up hardware and other materials for the table at Home Depot tonight or tomorrow.

4/7/14 8:30am Jack:
Response from mark:
Your assumption here is kind of wrong...'likely and willing' depend on stuff. He is not going to print stuff for free.It has to be super-cool and promotion worthy. Not utilitarian parts. What is the compellingly novel aspect of this part you are talking about?

We want to send an email and call all the 3D printing places around to see if they have a plastic that could be laid up as core for the fins.

Email to mark:

Mark,

You mentioned before that your friend that does 3D printing would likely be willing to help us with parts for the rocket. We have a part that would be most easily done with a 3D printer.

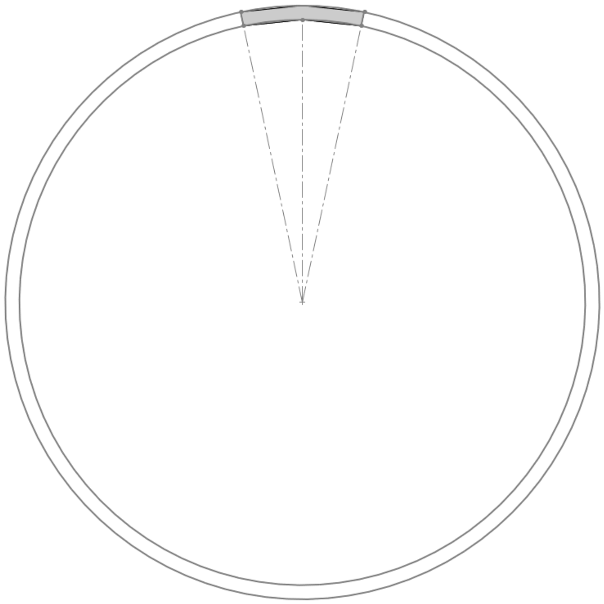
The plastic would have to be able to withstand 350F baking temperature, and we have to be able to bond it to the carbon fiber.

The part we have designed is 5 cubic inches, and we would need a total of 4 parts. I attached a sketch of the cross section of the part. It is almost a circular sector, extruded to approximately 24" long. If this is too long, we can figure out how to make it shorter.

What is the best way to proceed?

Thanks,
Jack Slocum

4/4/14 3:30pm Jack:
Rob had an idea about how to attach the fins to the propulsion skirt. If we laid up a 3D printed plastic part instead of the core, then we could drill into it and use it as a hard point. We could do 4 of these around the edges. They would be the full 18" or 24" long.

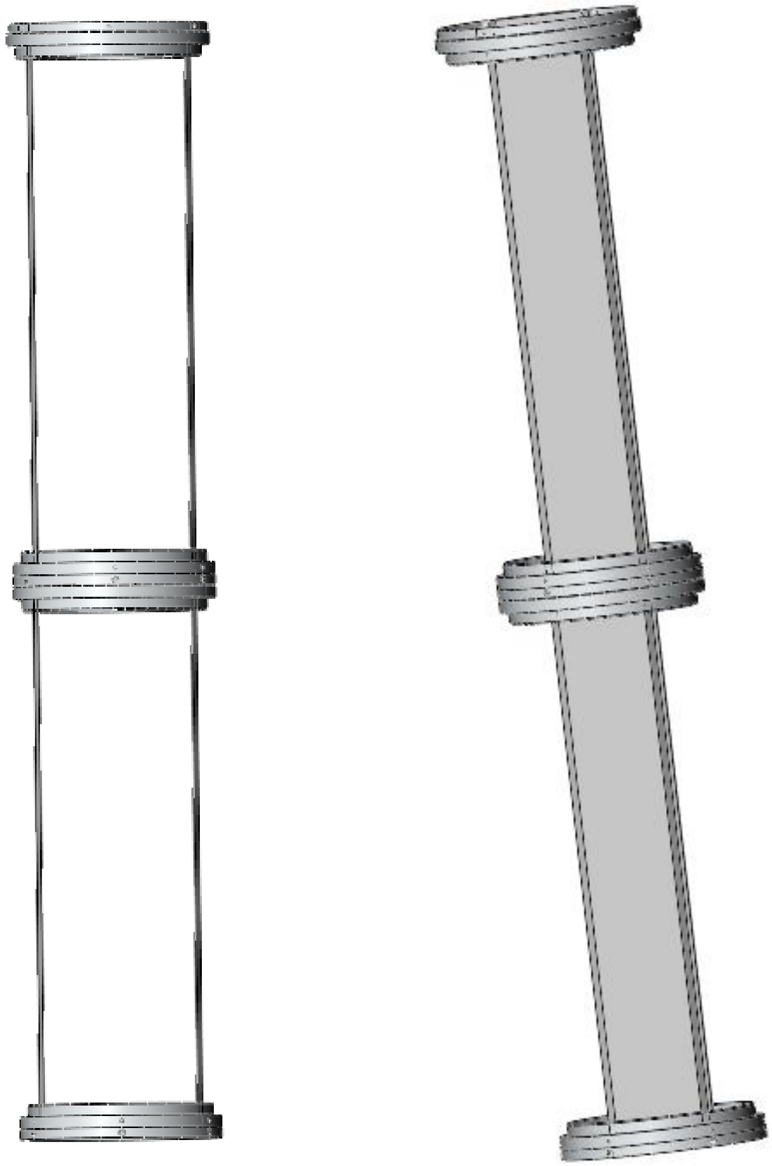


4/4/14 3:00pm Jack:
Andrew has approved all of our designs and concepts.
He ordered all the fasteners and helicoils and the casters for the table etc.

Rob suggested that instead of beginning to get super deep in making the nosecone or the propulsion skirt that we do the stuff that is required for capstone class, like writing the final report and stuff.

Andrew brought up the idea of making each module have its own set of sensors and a board attached to it. So modules would have a couple of strain gauges and an accelerometer circuit board attached to it permanently. He called making them like “smart modules”

4/3/14 5:40pm Jack:
Drew up the electronics carriers.We need to get everything okay’d by Andrew and PSAS



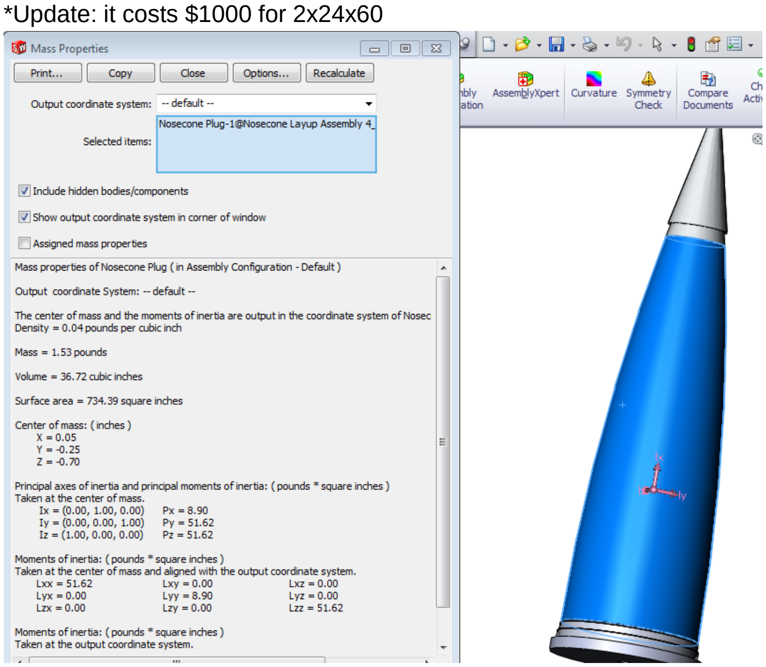
4/2/14 5:40pm Jack:

Freeman sells the perfect carbon layup machinable foam of course, we just have to figure out how much it costs, and how we will get it. We could potentially get additive manufacturing to make it, or maybe Machine Sciences would CNC lathe the shape for us.

http://www.freemansupply.com/RenShape5065HighTe.htm

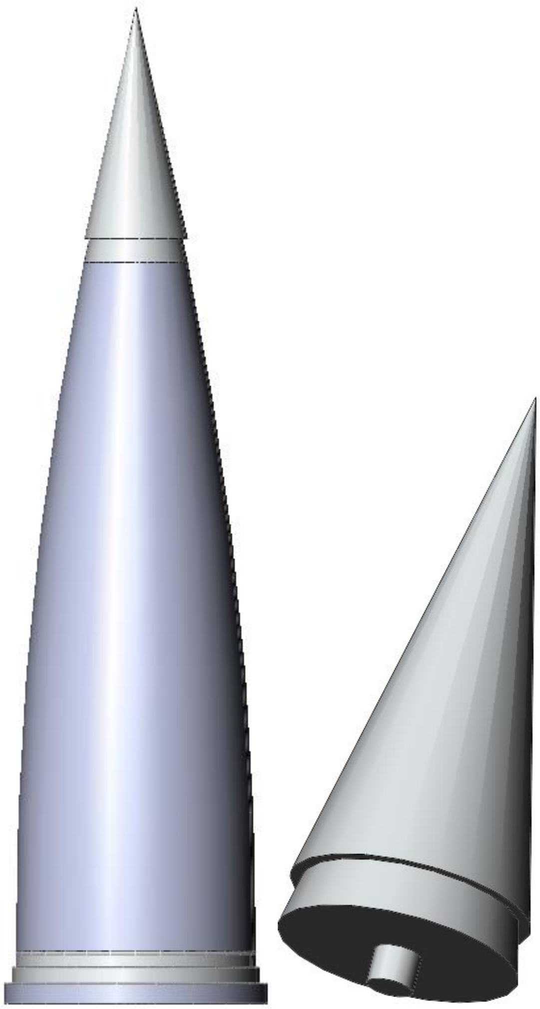
Freeman Manufacturing & Supply Co.
www.freemansupply.com 800-321-8511

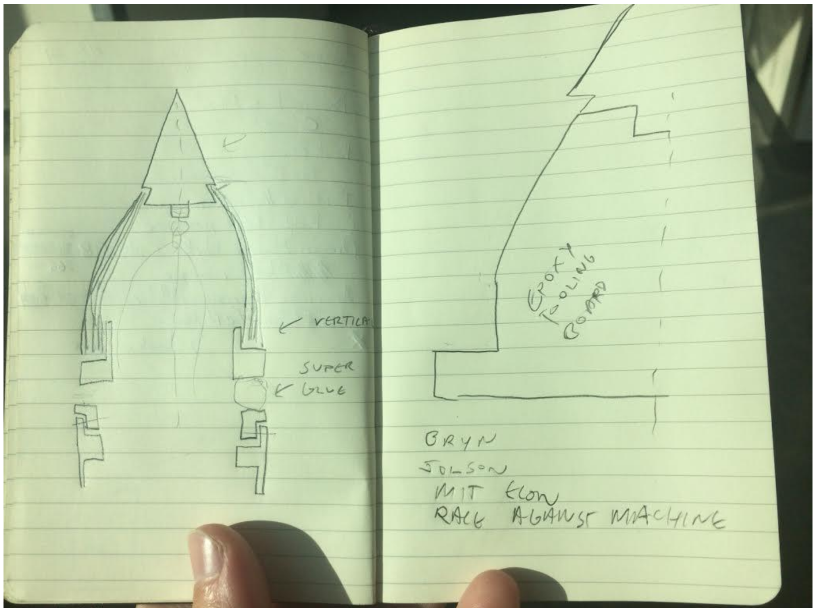
*Update: it costs $1000 for 2x24x60

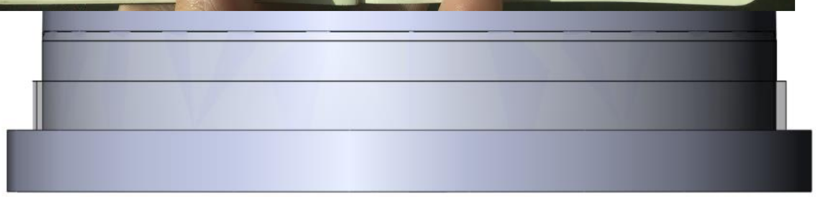


Sam and I talked about some ways to figure out how to do the nosecone and propulsion skirt. I think there are some good ideas here to make it manufacturable:

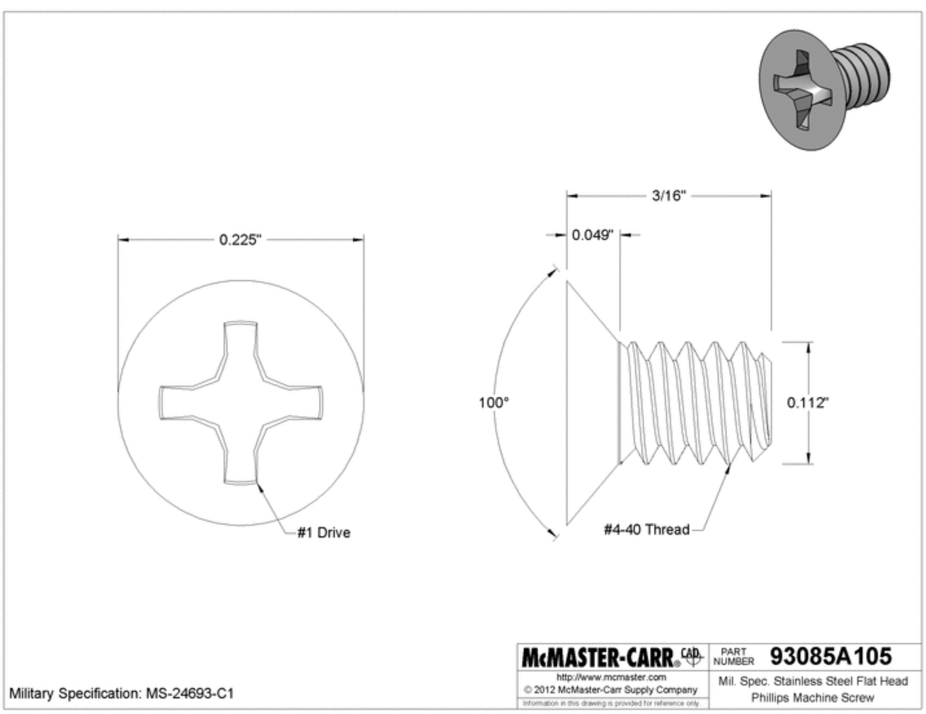
- We could make it a male plug made from epoxy tooling board, and get it machined by additive manufacturing.
- If the nosecone were straight sided instead of a curve, we could make it downstairs potentially.
- The nosecone could have a step on it where all the fibers end and adhere to, and the step thickness could be the thickness of the laminate there.
- The Nosecone separation ring could be straight and then the carbon could curve after it leaves the adhesive surface of the NSR. This is shown in the horizontal photo with the NSR transparent.
- Machined into the bottom of the nosecone tip could be a little cylinder that could be used as a locating pin in the plug. There would be the complementary hole in the plug.
- If we didn't use core, we could make it like a 5 layer and just use a vacuum bag. We would get a pretty good surface

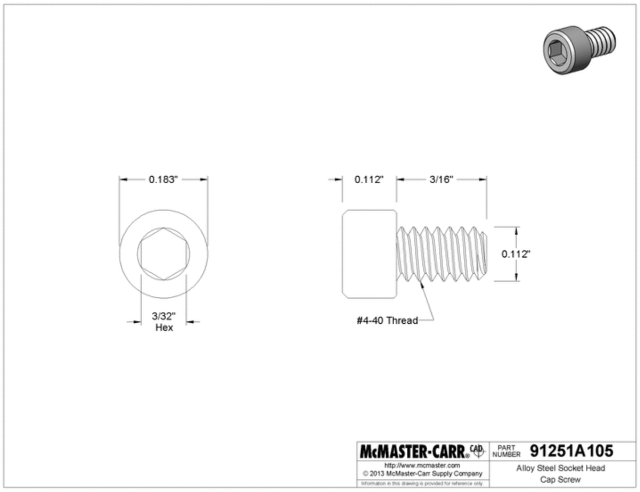






4/2/14 1:40pm Jack:





4/1/14 6:40pm Jack:

Part Number	Quantity	Description
91732A701	3	Helicoil Insert 4 40 Internal Threads
91732A901	1	Helicoil Insert Repair kit
93085A105	1	4 40 100deg screw
91251A105	1	Black oxide 4 40 thread screw
2834T33	4	Threaded stem swivel casters with brake 3/8 16

Sub Total: $141.47

Jack

Line	Quantity	Product		Ships	Unit price	Total	Delete
1	3 packs	91732A701	18-8 Stainless Steel Standard Helical Insert, 4-40 Internal Thread, 0.224" Length, MS122156, packs of 10	today	$6.06 pack	18.18	
2	1 each	91732A901	18-8 Stainless Steel Standard Helical Insert, Repair Kit, 4-40 Thread, .112",.168",.224" Long	today	71.25 each	71.25	
3	1 pack	93085A105	18-8 Stainless Steel 100°Flat Head Phillips Machine Screw, 4-40 Thread, 3/16" Length, MS24693-C1, packs of 100	today	8.01 pack	8.01	
4	1 pack	91251A105	Black-Oxide Alloy Steel Socket Head Cap Screw, 4-40 Thread, 3/16" Length, packs of 100	today	7.99 pack	7.99	
5	4 each	2834T33	Threaded-Stem Swivel Caster with Brake, 3/8"-16 Stem, 2-1/2" X15/16" Rubber Wheel, 100 lb Capacity	today	9.01 each	36.04	
6							

ADD ? Paste products and quantities

Merchandise total $141.47

Shit we would like to order:

- Helicoil kit
- Helicoil extra coils
- 4 40 screws 100deg
- 4 40 socket cap screw socket cap screws
- casters
- Threaded helicoil inserts seen below

4/1/14 4:40pm Barett:

Composite Table Design

Things to order/purchase for table:
Also need to get some 1.5”x0.065” steel tube to connect the legs and put a sheet of plywood.

B

1/4"-20	3/4"	1/16"	5/16"	5/16"	7/64"	50	90611A350	10.74
5/16"-18	7/8"	1/16"	3/8"	3/8"	7/64"	25	90611A400	7.00
3/8"-16	1"	5/64"	29/64"	7/16"	5/32"	25	90611A450	8.09
1/2"-13	1 1/4"	3/32"	19/32"	3/8"	11/64"	10	90611A500	8.51
Style B								
1/4"-20	3/4"	1/16"	5/16"	7/16"	7/64"	25	**90611A600**	7.25

Product Detail CAD

Plain Steel Weld Nut with Holes, 1/4"-20 Thread Size with Protrusions

Packs of 25

ADD TO ORDER

In stock

Line	Quantity	Product	
1	1 each	91709A101	Helical Insert Tap, 4-40 Internal Thread, Plug Style
2	2 each	2834T24	Threaded-Stem Swivel Caster, 3/8"-16 Stem, 2-1/2" x 15/16" Rubber Wheel, 100 lb Capacity
3	2 each	2834T33	Threaded-Stem Swivel Caster with Brake, 3/8"-16 Stem, 2-1/2" X15/16" Rubber Wheel, 100 lb Capacity

JM eagle 1-1/2 in. x 10 ft. PVC Sch. 40 DWV Plain End Pipe

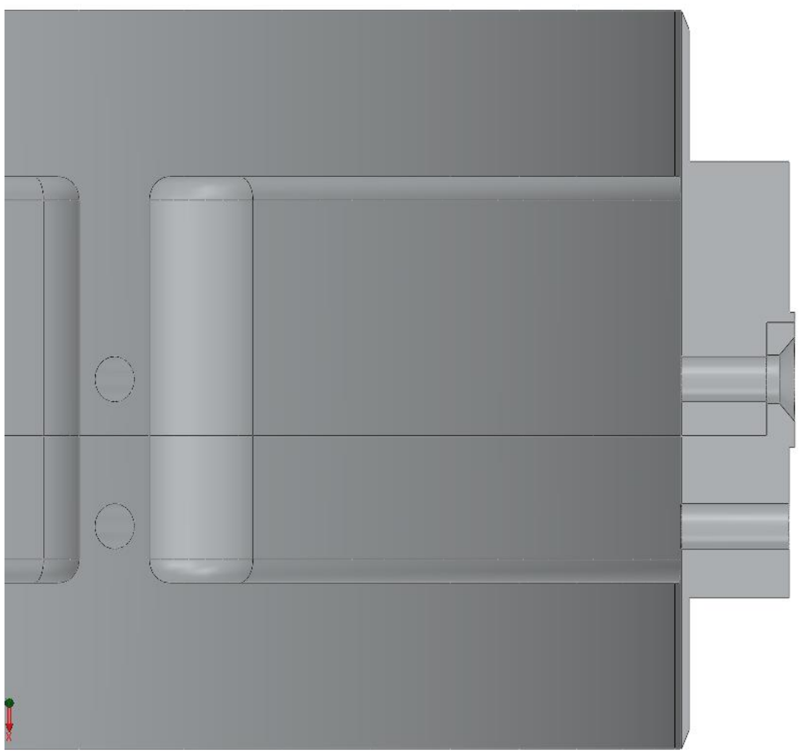
Model # 1727   Store SKU # 193844   Store SO SKU # 136293

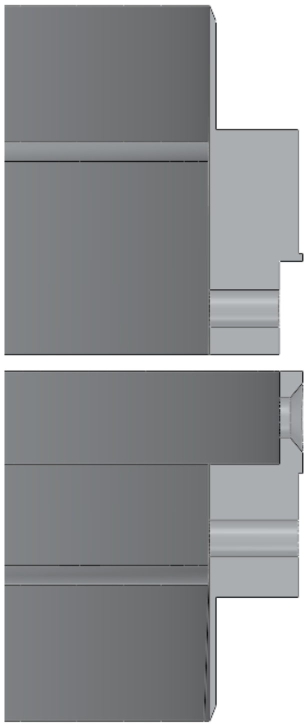
★★★★★ | Write the First Review +

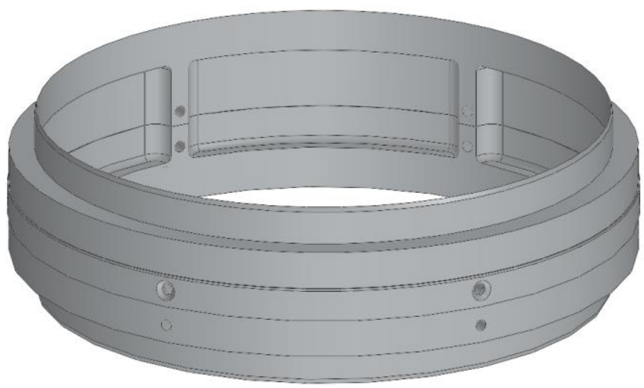
$5.26 / each

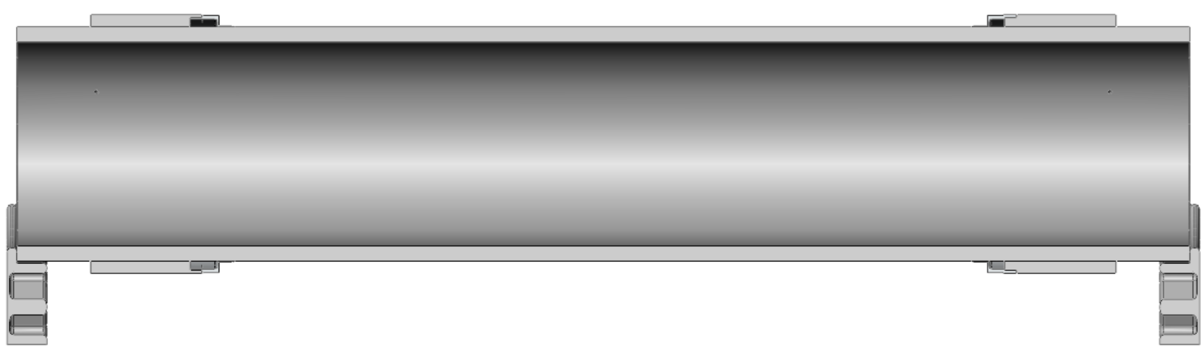
72 in Stock at Jantzen Beach #4007
Aisle 11 Bay 006
(change pick up store)

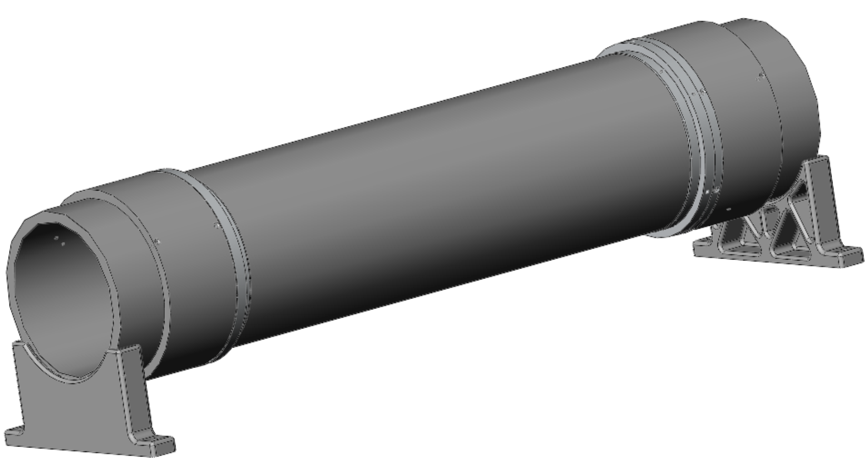
4/1/14 6:00pm Jack:











Designed more finalized rings 4/1

4/1/14 3:30pm Jack:
Trying to figure out how to do this helicoil thing:
So we are using a 4-40 screw. This means we have to drill a #31 hole, then tap using the special specific helicoil tap, then insert helicoil with the installation tool.

The kit (shown directly below) includes the installation tool, 3 different length coils (12 coils per length), and the specific plug tap necessary. We should buy the kit, and then several more of the specific helicoil size we need.

4-40	0.112"	10	91732A351	4.92	91709A101	16.07	0.112", 0.168", 0.224"	12	**91732A901**	71.25

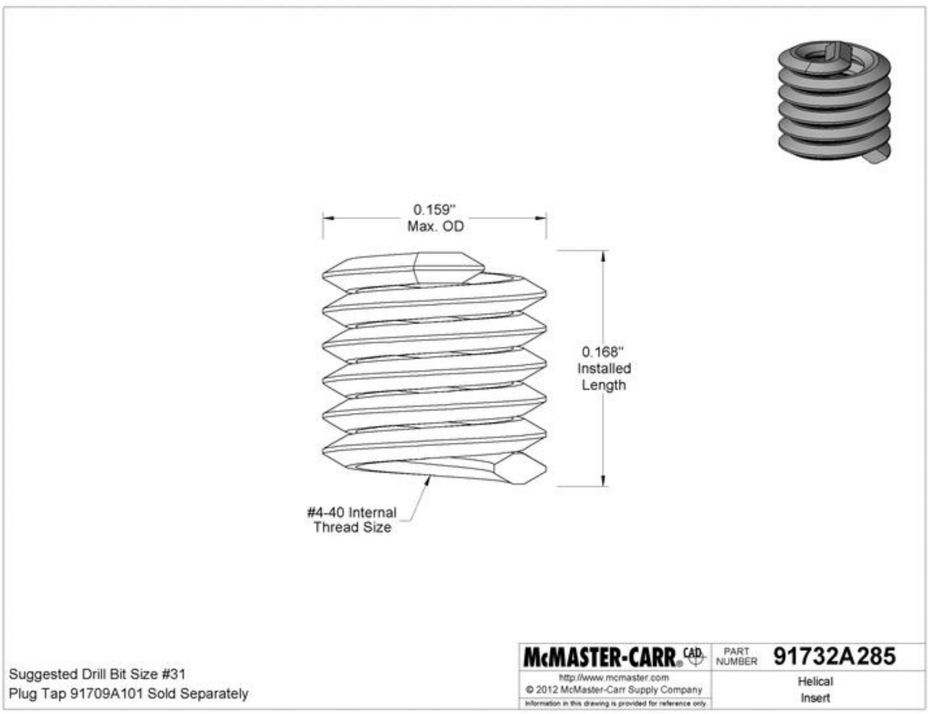
Catalog Page

18-8 Stainless Steel Standard Helical Insert, Repair Kit, 4-40 Thread, .112",.168",.224" Long

Each

ADD TO ORDER

In stock



Inch

Internal Thread	Inserts: Installed Lg.	Pkg. Qty.		Pkg.	Plug Taps	Each
1-64	0.073"	10	91732A004	$6.68	91709A090	$36.38
1-64	0.110"	10	91732A008	6.70	91709A090	36.38
1-64	0.146"	10	91732A011	6.78	91709A090	36.38
2-56	0.086"	10	91732A203	5.38	91709A098	19.24
2-56	0.129"	10	91732A204	5.18	91709A098	19.24
2-56	0.172"	10	91732A201	3.58	91709A098	19.24
2-56	0.215"	10	91732A202	3.83	91709A098	19.24
3-48	0.099"	10	91732A205	4.73	91709A099	52.63
3-48	0.148"	10	91732A207	4.05	91709A099	52.63
3-56	0.099"	10	91732A001	5.10	91709A055	49.85
3-56	0.148"	10	91732A003	4.92	91709A055	49.85
4-40	0.112"	10	91732A351	4.92	**91709A101**	16.07

Catalog Page

Helical Insert Tap, 4-40 Internal Thread, Plug Style

Each

ADD TO ORDER

1 added to your order 04/01/14.

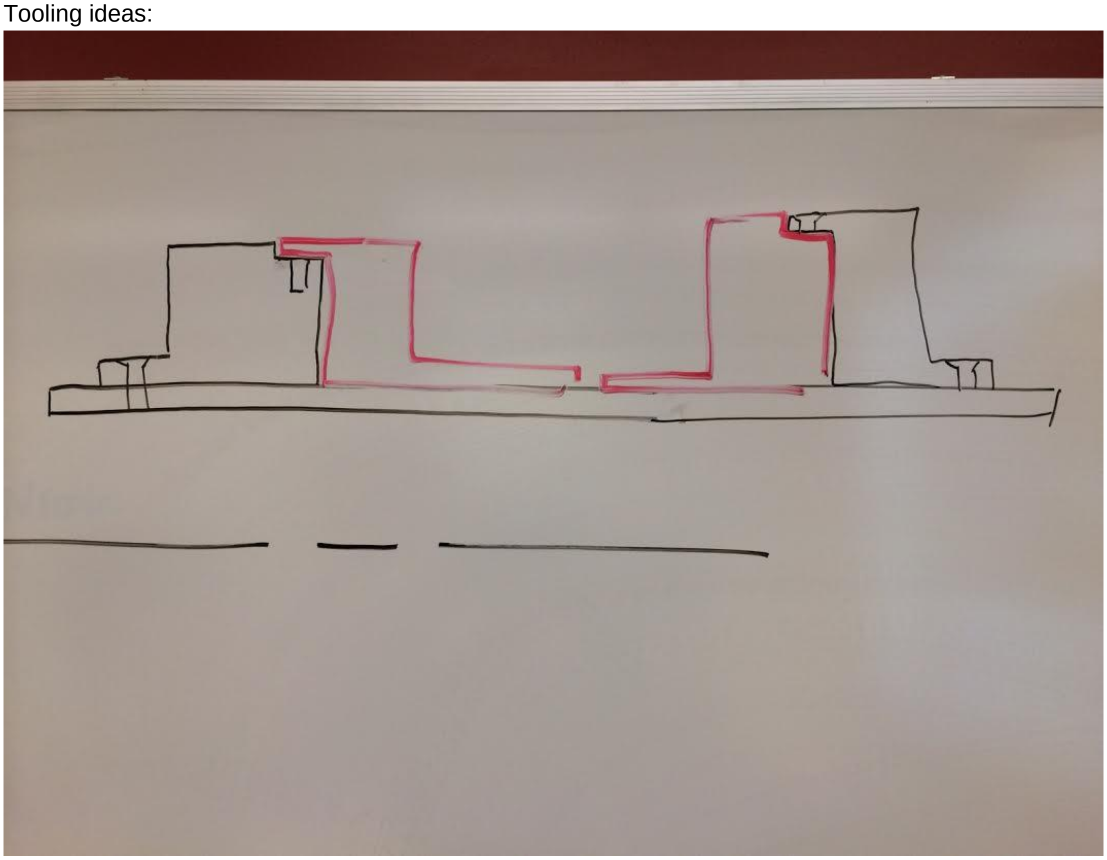
In stock

For Internal Thread	Max. Hole Dia.	Drill Bit Size
1-64	0.103"	#46
2-56	0.119"	#41
3-48	0.139"	7/64"
3-56	0.146"	#36
4-40	0.159"	#31

Fract. (in)	Decimal	Wire No. /Letter	Metric (mm)
	0.1065	36	
7/64	0.1094		
	0.1100	35	
	0.1102		2.80
	0.1110	34	
	0.1130	33	
	0.1142		2.90
	0.1160	32	
	0.1181		3.00
	0.1200	31	
1/8	0.1250		

4/1/14 1:00pm Jack:
Meetings with Mark at 1 in EB 450

3/31/14 1:45pm Jack, Sam, Rob, Barett:
Tooling ideas:



3/31/14 8:40am Jack:
Regroup meeting for spring term:
Topics for discussion:

- How was everyone's break?
- Work days/work hours
    - feel out this week schedule first. 10am to 5pm ish (not including rob). Potentially work tuesday after capstone from 2 to 7ish including dinner. Potentially adding friday 10am to 5pm. Feel this out, these are just the available times. This week we will do monday, tuesday, wednesday
- What went right and wrong in the last term? What would we like to change about our team?
    - We have been successfully dealing with issues as they come up. We need to continue working with Tung correctly. Making sure he is involved in the process.
    - Maybe could be better about being on time, leaving on time.
- What scope do we agree on as a team? We should decide and commit to something
    - Barett, Rob, Jack are wanting to do the whole rocket. We would like to see it fly. This is our goal.
- How are we going to move forward? CNC sent out prototype rings, manual machine in house, 3D print
    - Need materials
    - Barett emailed Machine Sciences, having trouble communicating via email. Solid option. Probably nothing out of our pockets, worst case reduced price. We would be working with the shop supervisor. Barett sent email schmoozing, link to PSAS website/video etc, potentially will give him a presentation.
    - Process will be: Redesign rings, design tooling, 3D print rings, order material, machine approx 6 rings downstairs +dummies, machine tooling (outsource?), break test pieces, then send drawings to machine sciences,
    - Finalize electronics carrier design, and prototype and install
    - Order more strain gauges
    - Design nosecone, fins, windows, doors, antennae module, propulsion skirt, camera module, parachute attachments, Nosecone Separation ring (NCR) etc
    - Email people and keep sponsors happy, and get Maseeh college excited about project. Sending parts to Tom, and Jerry, and Su, emailing PCC
- What questions do we have left before we make full scale parts?
    - Probably most of the work will have to be done with rocket systems, no longer subsystem design issues
    - Expecting rocket to buckle, think we will see similar strength between 3.4" and 6"
    - Maybe make sure the cubesat will actually fit with fixtures
        - Appears it will be okay for now
- What questions do we need to answer when we make full scale parts?
    - Bending across joint
        - Maybe use a different machine? How to get small loads. Using roller fixture. maybe using solid end rings that would sit on the rollers. The only detail they would have is the inner step for bonding area.
    - Full length module in buckling
    - Double length might be nice, maybe not required
    - Need masters for smashing, with installed strain gauges?
- What exactly needs to be designed for the new rings?
    - Scale
    - Increase step size so the outer ply doesn't step down
    - Bond areas all same, 400 thou was smallest before, so is plenty
    - No drilling through carbon, add extra length and flange
        - Pocket deeper in the female
    - Investigate helicoils
- What exactly needs to be designed for the new tooling
    - Fixturing mechanism
    - alignment mechanism
        - Skipping pins and toothpicks, moving to bolting rings to dummies, dummies to mandrels. We think that tolerances will be good enough.
    - variable length?
    - Enough surface area so that we don't fuck them up when we pound them off the mandrels

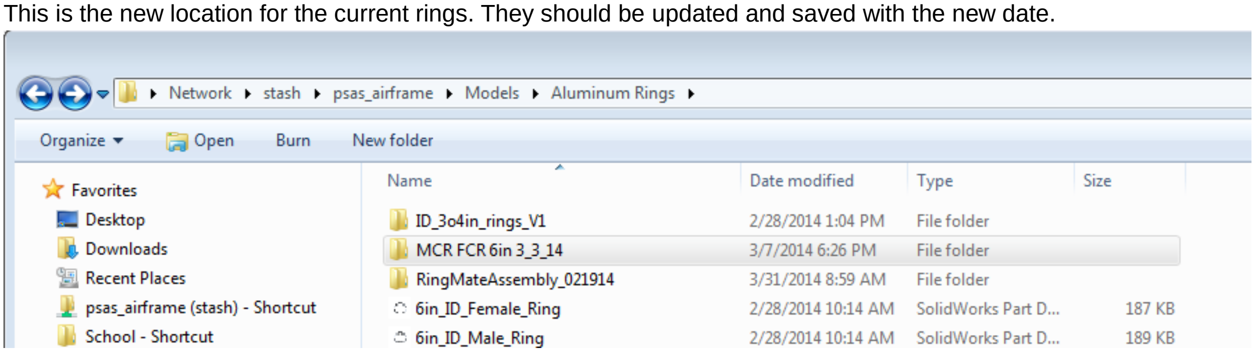
To do list:
Green= First Priority Done by PSAS meeting tomorrow
Yellow= Second Priority Done by Wednesday afternoon
Red= Third Priority Maybe never
Blue= Done

- Email Su, Gerry, Mark about video, jobs etc
    - Julie Rutherford will meet up with us to do the article. We can schedule with her.
    - Dean Su wants our resumes and us to apply to Boeing.
- Email Mark about faculty advisor meetings. Figure out if that will be during the thursday class scheduled time
    - Put this off until tomorrow after class
- Rob figure out naming convention and file structure
- Clean welding lab
    - Gerry wants us to move pile of crap behind oven
    - maybe eventually make nice rack. Put it under the table?
- Contact people about DMLS?
    - Ask about tour also
- Making rack for roll stocks, for underneath table?
- Shelf for core under table?
- Contact Machine Sciences
    - Called, but email is the best form of contact. Emailed a thursday last week and today
- Clean up 3 modules to give to Su, Gerry, Tom
    - Decided not to clean them up (Barett, Sam, Jackson)
    - Emailed andrew about mission stickers to put on the side of them
- Redesign rings
- Design tooling
- Do reimbursements
- Order stock that is significantly bigger than the part
    - Call Dave about stock place
        - http://www.speedymetals.com/c-8371-round-tube.aspx
        - http://www.speedymetals.com/pc-4660-8371-7-od-x-1-wall-tube-6061-t6-aluminum.aspx
    - Make sure the stock that we order will fit on the machines downstairs
        - Yes we can, but it will be tight. OD of 7" will fit it appears

3/31/14 8:30am Jack:
New Design log started.

Youtube video of our manufacturing progress (Winter Term Short):
https://www.youtube.com/watch?v=LpWEhKho2y0

This is the new location for the current rings. They should be updated and saved with the new date.



3/16/14 11:50pm Jack:
Write up for the analysis and results section:
Results and Discussion:

We set out to answer several questions:

how consistent is the strength of a module when the construction of the cylinders was done by different people and baking sessions?

> Our weakest cylinder (part 19) broke at 6220lbf and our strongest (part 20) broke at 7140lbf. This is a 13% difference. Both parts were cured at the same time in the same oven next to each other. Because our cylinders have a large safety factor, 13% is an acceptable difference between parts.

With our manufacturing tolerances, how evenly are the fibers being loaded around the perimeter? And, does evenly loading the fibers around the perimeter conclusively affect module strength?

> 3 out of 4 tests showed that the loading was consistent around the perimeter as seen in **Fig1**. The maximum and minimum strain of the aluminum test jig are within 20% of each other. This means that even though the layup process is not perfectly consistent, the resulting cylinder is seeing even stress around the perimeter. As for module strength being dependent on even loading, the results are not conclusive. The weakest cylinder had only 12% difference between the maximum and minimum strain readings on the aluminum, which would suggest it is not a factor. The other 3 tests followed the original hypothesis that even loading is a dominating factor for module strength. We need a larger sample size to confidently verify our hypothesis.

Were the new lightweight aluminum module connections stronger than the fiber? Do the tapped holes in the aluminum continue to work after being loaded? Will the bolts still come out easily?

> The new aluminum module connections appear to not have yielded before the carbon structure buckled. This is important for adding confidence to our Finite Element Analysis. The tapped holes were not affected by the loading, and the bolts were removable by hand.

Were we evenly loading the inside and outside plies of composite?

> Finite Element Analysis initially predicted that the inside and outside plies of carbon would see many orders of magnitude different amounts of load. The strain readings from inside and outside showed loadings within 50% of each other for each test. We also had failures on both the inside and outside plies on different tests. This means that both layers are being utilized enough with our current ring geometry.

Is the strain of the carbon predictable by traditional techniques (stress=strain*modulus)?

> Strain in composite structures is notoriously difficult to predict. We applied the traditional techniques to attempt to guess what the strain gauges should have been reading. Traditional techniques were incorrect by as much as 45%. This technique can be used to approximate in the future.

Is the ultimate force value from the concrete testing machine correct? How close is it to reality?

> The aluminum dummy was used to see if the concrete testing machine reads correct values. This was done because the machine is designed for significantly higher loads (250k lbf maximum), and reads erroneous data up to 3% of our desired values under no load conditions. The strain gauge calculation was used and compared against load/area=strain*modulus. The percent errors can be seen in **table1.** As shown, the difference was much less than 10% for most of our results, with only one test being as high as 21.7% different. The strain gauges for the highest error test show a large spread. The large error could mean that the machine was not shut off after the data stopped being collected, which caused a peak value as something different than the strain gauges read. If the average strain gauge reading can be believed, then this cylinder was actually the strongest, and not the weakest.

Is there a consistent value for strain at failure of the carbon plies?

> The strain at failure is not completely consistent between tests. Because the inside and outside plies experienced slightly different loadings, it’s difficult to actually correlate a certain strain and failure. For the most part, the inner cylinder failed when the inner ply was greater than .0015 strain. This is useful as a tool for predicting safety factor when launching a rocket and measuring its strain.

What is our strain at failure compared to the theoretical strain at failure of our carbon fiber?

> Theoretical strain at failure for our carbon fiber is around .012. Our strain at failure values are approximately 10% of what the material is capable of under ideal conditions. This is to be expected, because geometrically our cylinder is failing under buckling conditions.

What happens to the critical buckling strength when stacking multiple modules? Do the aluminum rings define the critical buckling length?

For a stack of 2 modules, the critical buckling strength was approximately the same as a single module. To extrapolate this would mean that the rocket's strength in buckling is not a function of a mass buckling of the entire structure, but of the strength of a single module. This test would say that in the future we can continue using single modules as representative examples of the rocket's buckling strength.

Analysis:

Analysis was done using two fundamental equations. The equation relating voltages across a quarter bridge circuit with an amplifier to strain, and the engineering application of Hooke's law. These two methods were compared often to have confidence in the analysis.

Future questions: Does the aluminum ring lightening reduce the overall strength of the module by imparting a bending load into the fiber?

3/16/14 11:50pm Jack:
Write up for the analysis and results section:
Results and Discussion:

We set out to answer several questions:

how consistent is the strength of a module when the construction of the cylinders was done by different people and baking sessions?

Our weakest cylinder (part 19) broke at 6220lbf and our strongest (part 20) broke at 7140lbf. This is a 13% difference. Both parts were cured at the same time in the same oven next to each other. Because our cylinders have a large safety factor, 13% is an acceptable difference between parts.

With our manufacturing tolerances, how evenly are the fibers being loaded around the perimeter? And, does evenly loading the fibers around the perimeter conclusively affect module strength?

3 out of 4 tests showed that the loading was consistent around the perimeter as seen in **Fig1**. The maximum and minimum strain of the aluminum test jig are within 20% of each other. This means that even though the layup process is not perfectly consistent, the resulting cylinder is seeing even stress around the perimeter. As for module strength being dependent on even loading, the results are not conclusive. The weakest cylinder had only 12% difference between the maximum and minimum strain readings on the aluminum, which would suggest it is not a factor. The other 3 tests followed the original hypothesis that even loading is a dominating factor for module strength. We need a larger sample size to confidently verify our hypothesis.

Were the new lightweight aluminum module connections stronger than the fiber? Do the tapped holes in the aluminum continue to work after being loaded? Will the bolts still come out easily?

The new aluminum module connections appear to not have yielded before the carbon structure buckled. This is important for adding confidence to our Finite Element Analysis. The tapped holes were not affected by the loading, and the bolts were removable by hand.

Were we evenly loading the inside and outside plies of composite?

Finite Element Analysis initially predicted that the inside and outside plies of carbon would see many orders of magnitude different amounts of load. The strain readings from inside and outside showed loadings within 50% of each other for each test. We also had failures on both the inside and outside plies on different tests. This means that both layers are being utilized enough with our current ring geometry.

Is the strain of the carbon predictable by traditional techniques (stress=strain*modulus)?

Strain in composite structures is notoriously difficult to predict. We applied the traditional techniques to attempt to guess what the strain gauges should have been reading. Traditional techniques were incorrect by as much as 45%. This technique can be used to approximate in the future.

Is the ultimate force value from the concrete testing machine correct? How close is it to reality?

The aluminum dummy was used to see if the concrete testing machine reads correct values. This was done because the machine is designed for significantly higher loads (250k lbf maximum), and reads erroneous data up to 3% of our desired values under no load conditions. The strain gauge calculation was used and compared against load/area=strain*modulus. The percent errors can be seen in **table1.** As shown, the difference was much less than 10% for most of our results, with only one test being as high as 21.7% different. The strain gauges for the highest error test show a large spread. The large error could mean that the machine was not shut off after the data stopped being collected, which caused a peak value as something different than the strain gauges read. If the average strain gauge reading can be believed, then this cylinder was actually the strongest, and not the weakest.

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Theoretical strain at failure for our carbon fiber is around .012. Our strain at failure values are approximately 10% of what the material is capable of under ideal conditions. This is to be expected, because geometrically our cylinder is failing under buckling conditions.

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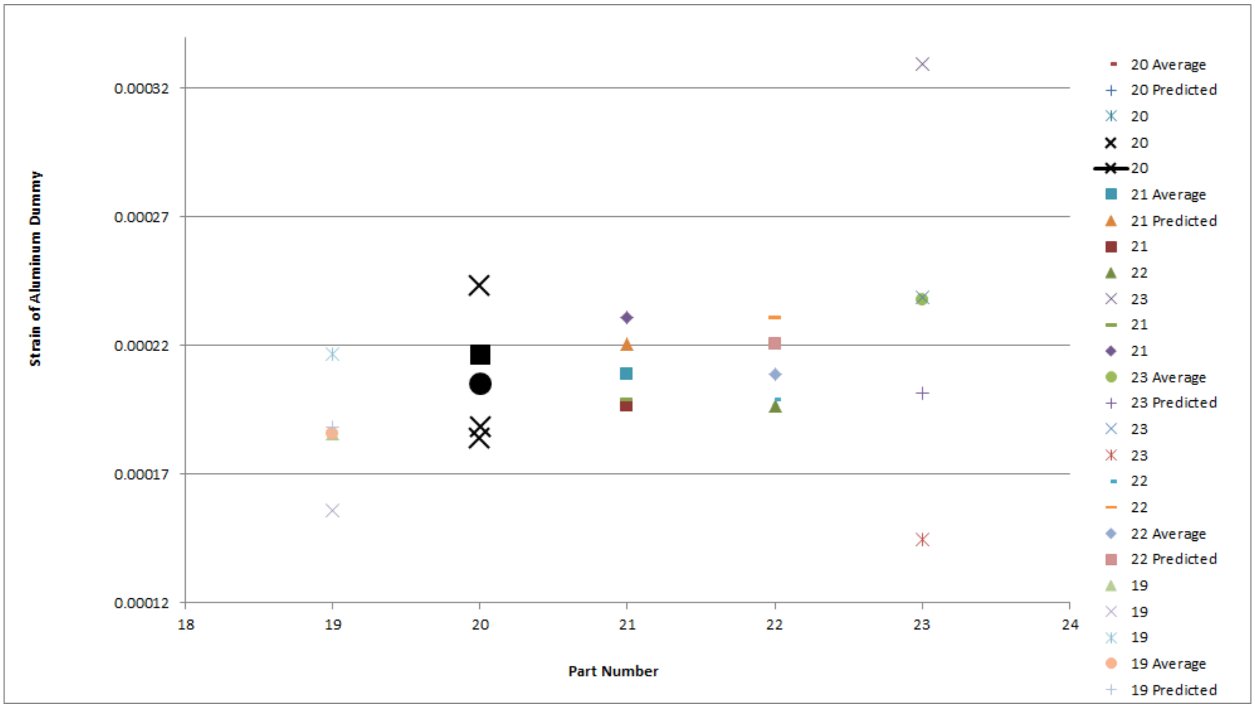
Analysis:
Analysis was done using two fundamental equations. The equation relating voltages across a quarter bridge circuit with an amplifier to strain, and the engineering application of Hooke's law. These two methods were compared often to have confidence in the analysis.

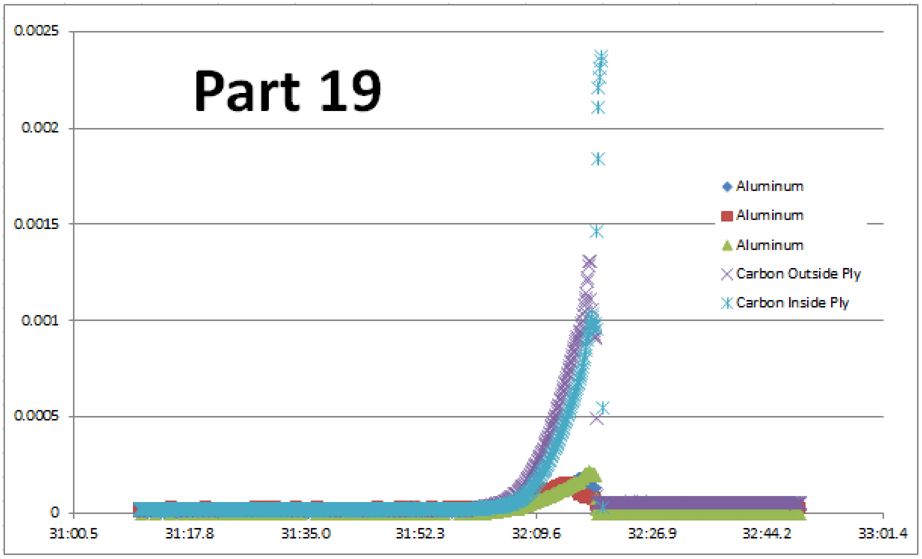
Future questions: Does the aluminum ring lightening reduce the overall strength of the module by imparting a bending load into the fiber?

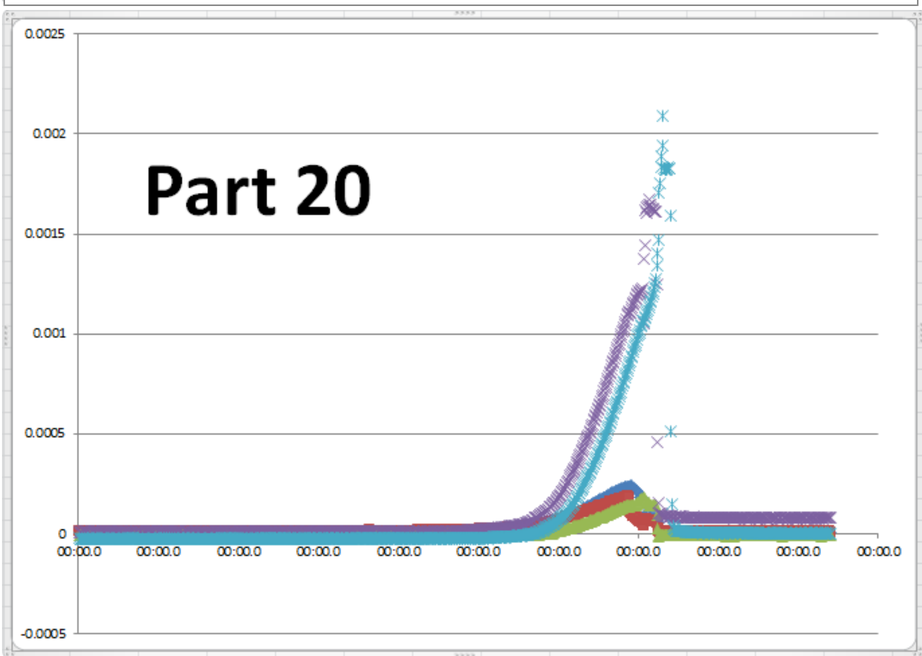
3/14/14 4:00pm Jack:
Aluminum dummy: Theoretical strain (from machine) and average measured strain (SG calculation) within 2.6%, 2.75%, 6.56% and 21.7%

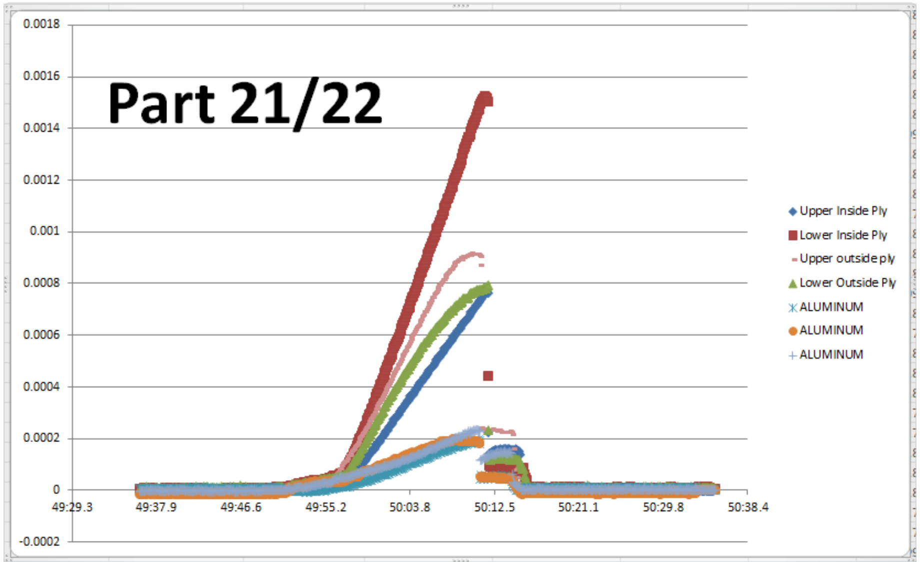
Carbon fiber: Measured Strain (SG calculation) and predicted strain (from machine) within 5%, 44%, 13.89%, 37.25%, 44.6%

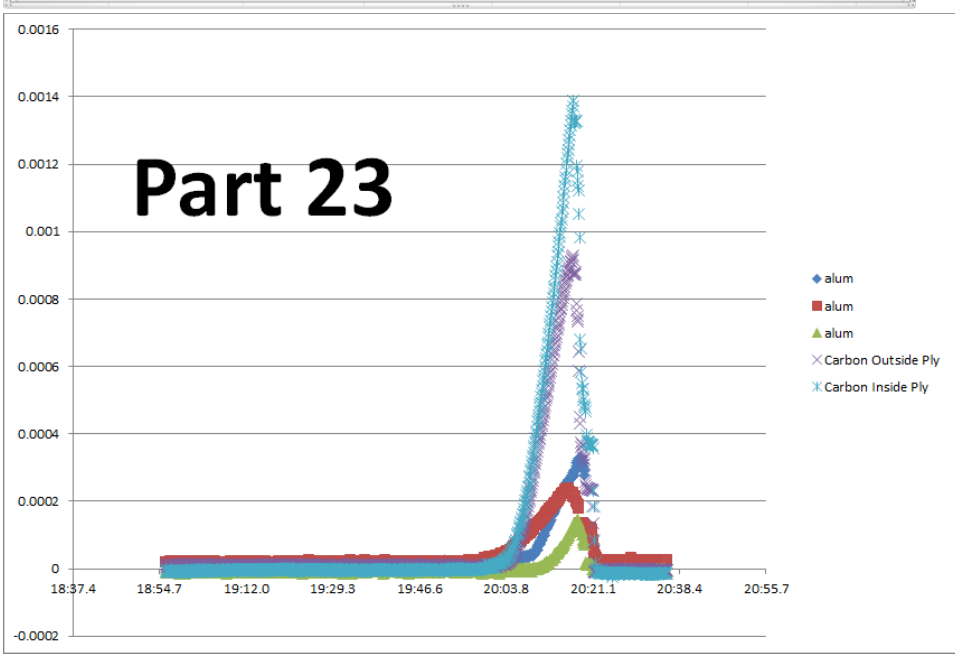
3/13/14 9:00pm Jack:
I think this graph is very important. The dummy was used on these parts when they were smashed (21,22 were at the same time). The maximum reading for each of the 3 strain gauges was collected and converted from volts to strain using the strain gauge calculation. These 3 points were put into the category of which part they came from. The average of those was calculated. Then, the theoretical strain was was calculated for the aluminum at the peak reading from the machine.This was plotted also. **What we can see is that average measured strain and theoretical strain are very close (as small as 2.2% error as big as 21.7% error). This means that we can believe the strain gauges from the aluminum and the carbon fiber. We can also believe the value given to us from the machine as maximum force.**




Part 19
0.0025
0.002
0.0015
0.001
0.0005
0
31:00.5
31:17.8
31:35.0
31:52.3
32:09.6
32:26.9
32:44.2
33:01.4
Aluminum
Aluminum
Aluminum
Carbon Outside Ply
Carbon Inside Ply


Part 20
0.0025
0.002
0.0015
0.001
0.0005
0
-0.0005
00:00.0



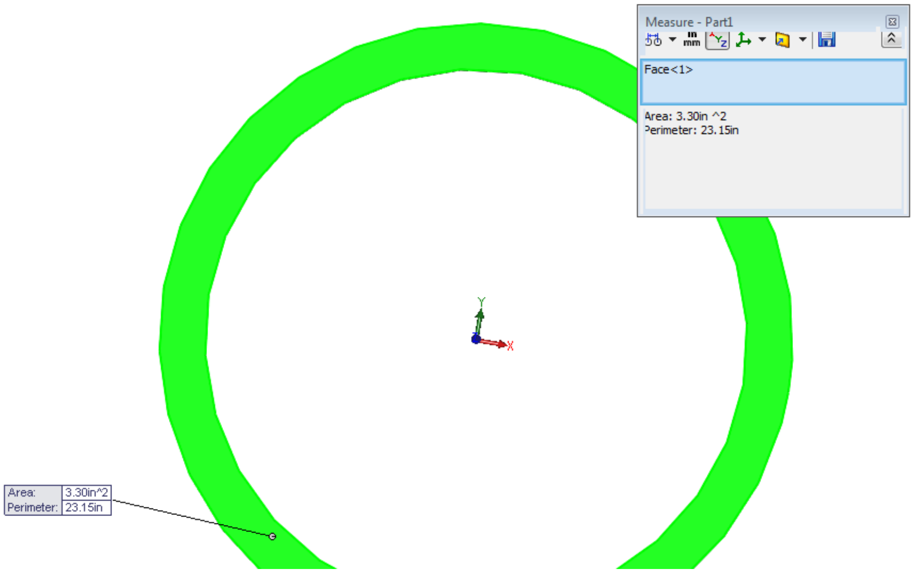


Interesting is that all the carbon plies failed very close to .0016in/in.

Calculating theoretical carbon strain at failure and comparing it to what we are failing the carbon at would tell us essentially how much strength is left in the carbon that we are not utilizing.

Theoretical Strain at failure of carbon:
stress=strain modulus
110000=strain 9e6
strain=.0122
That means we aren't using even 10% of our material strength, and that we are buckling first by a lot which is exactly what we expected.

3/13/14 3:30pm Jack:



For part 19:
.669 volts at 6220 lbf for the carbon

.0532 volts for 6220 lbf for the aluminum
Stress=strain*modulus
Load/Area=strain*modulus
6220lbf/3.17in^2=Strain*10E6psi
Strain=1.962145E-4/in

Now to relate strain and volts:
1.962145E-4 strain/.052565 volts = .00373 strain/volts

If we calculate the theoretical strain gauge strain:
Strain= 4*voltageout/(voltage excitation*Amplification*gaugefactor)
strain=(4*.052565)/(5*100.77*1.99)
Strain=.0002097
Now relating strain and volts:
.0002097/.052565= .003989 strain/volts

Trying to validate this method calculating theoretical strain for carbon at failure:
Load/area=strain*modulus
6220/(values from .32 to .42 in^2)=strain*(9e6 and 10e6)
strain = values from .0029 to .0035
These are close to the .0025 that was measured for strain at 6220lbf

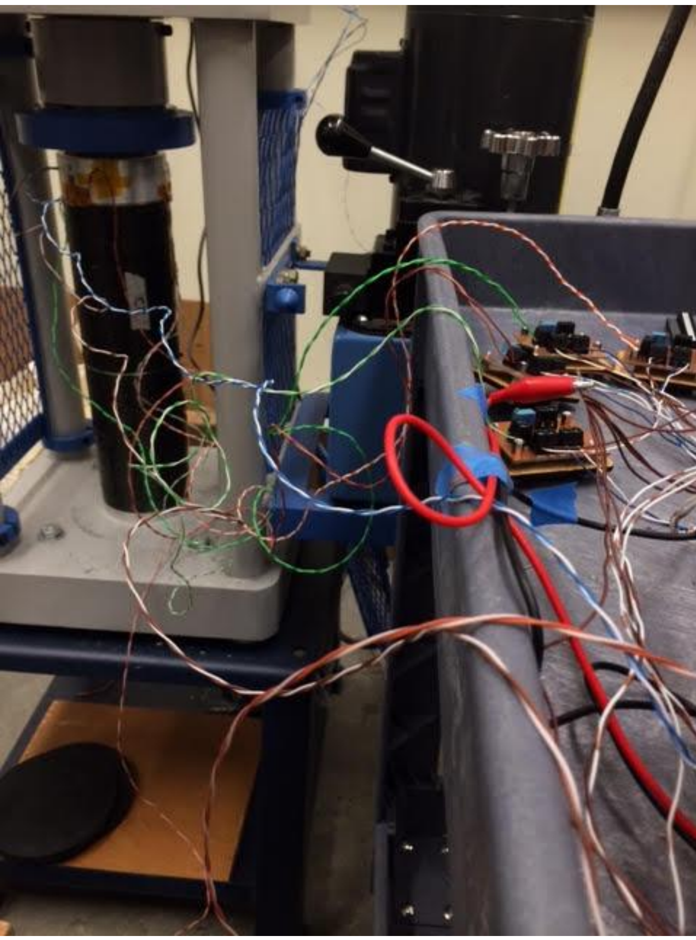
.001715 strain, 7280 lbf, area between (.16 and .21), calculating modulus
7280/(strain*(range from .16 to .21))=modulus
modulus=10.1e6

Carbon plies failed at .0016in/in but I will have to double check all of this. Appears that this isn't true. The data is updated in the stash

3/12/14 8:30pm Jack:
Things to do:

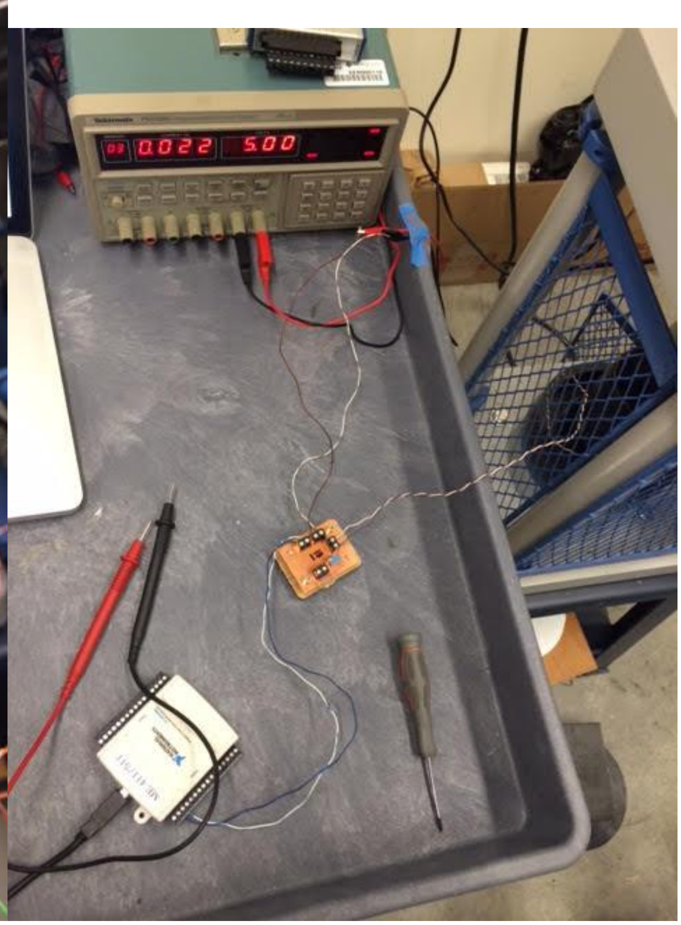
- Email Su, Joe
    - Need complete video
    - Need oven temperature vs time
- Analyze data from experiment
    - They are assembled into tests with a plot in the shared folder

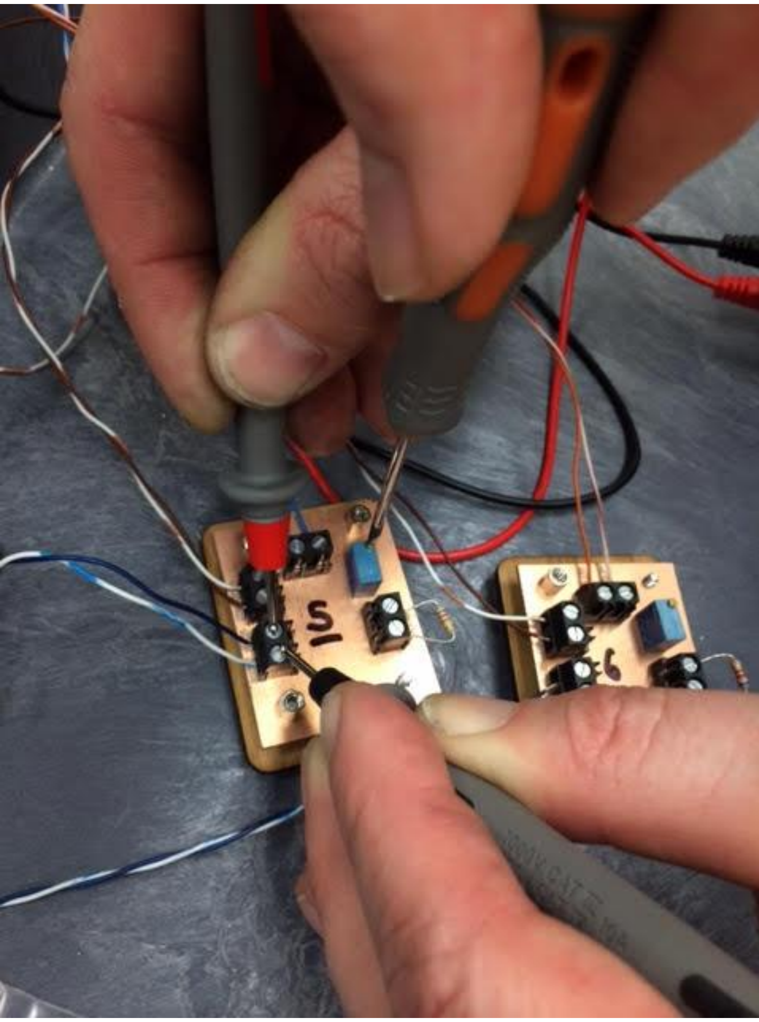
3/12/14 8:30pm Jack:

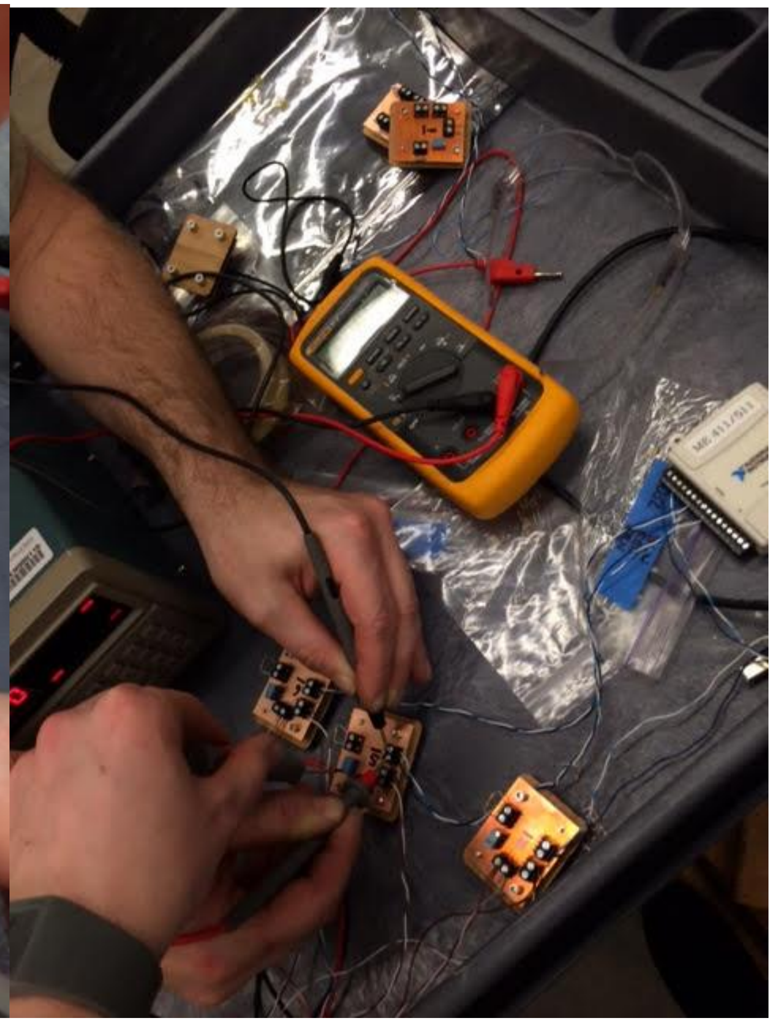




Voltage_0(Voltage)


0.022
5.00

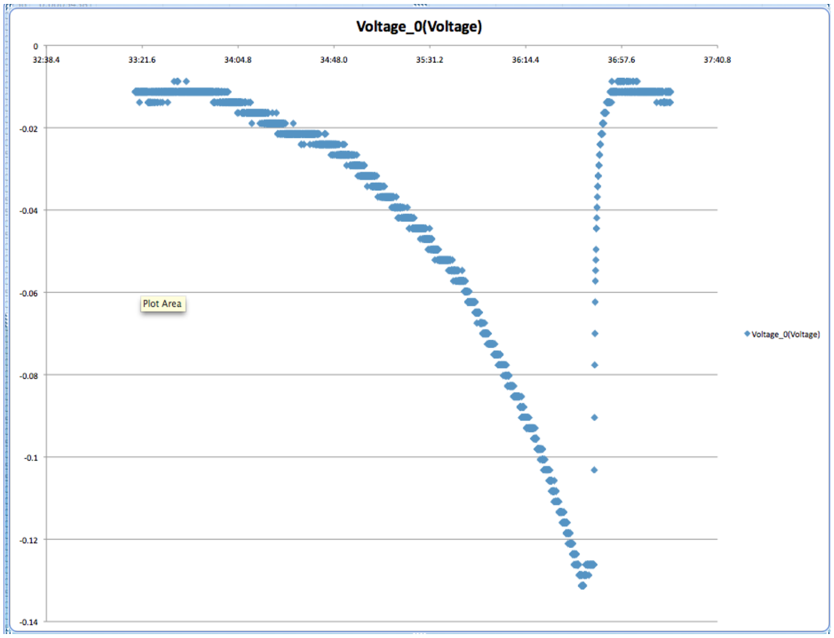




3/12/14 3:30pm Jack
All tests done at 50lbf/sec. The aluminum top is a0,a1,a2
aluminum ring is labeled on the ring 1,2,3. These numbers correspond to boards 1,2,3. Outside ply is board 4, inside ply is board 10.
We have to use 2 different computers with Tom's data logging NI software. Pink was collected with the computer that is not Tom's, it's name is "webster". Tom's computer collected the purple, called "moskowitz".

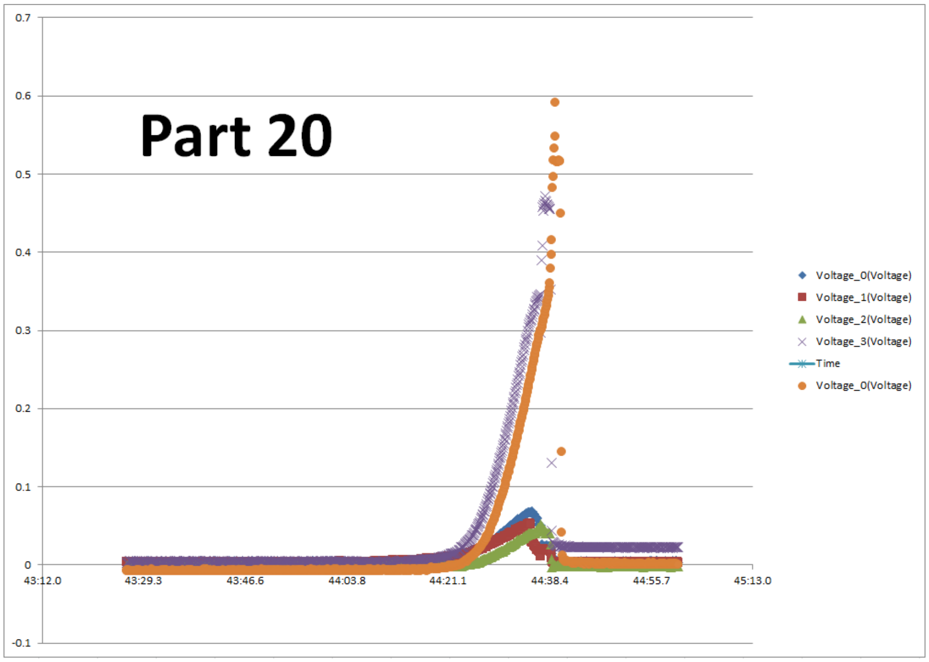
Voltage0	Board 10	Upper Inside ply
Voltage1	Board 5	Lower module inside ply
Voltage2	Board 6	Lower module outside ply
EMPTY	EMPTY	EMPTY
Voltage0	Board 1	aluminum ring 1
Voltage1	Board 2	aluminum ring 2
Voltage2	Board 3	aluminum ring 3
Voltage3	Board 4	Upper Outside ply

Part number 24: Starting to crush at 3800lbf, turned off officially at 3960lbf. First test was done with a 6.2kOhm resistor which gave us a gain of 10. We are switching back to 620Ohm. Second test only taken up to 2600lbf then stopped because Tom didn't like how we had it situated in the crushing machine because it was hurting his rubber pads. Third test was taken to 2500lbf approximately again and then backed up and started again. Stopped for the final time at 2810lbf. Typical curve shown below.

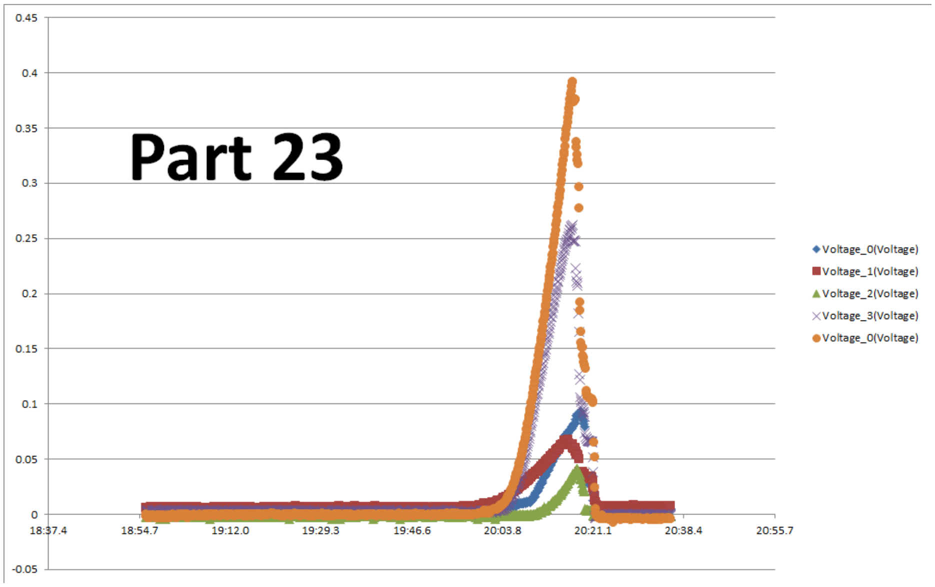


Part number 25: crushing without strain gauge. Failed at 2430lbf

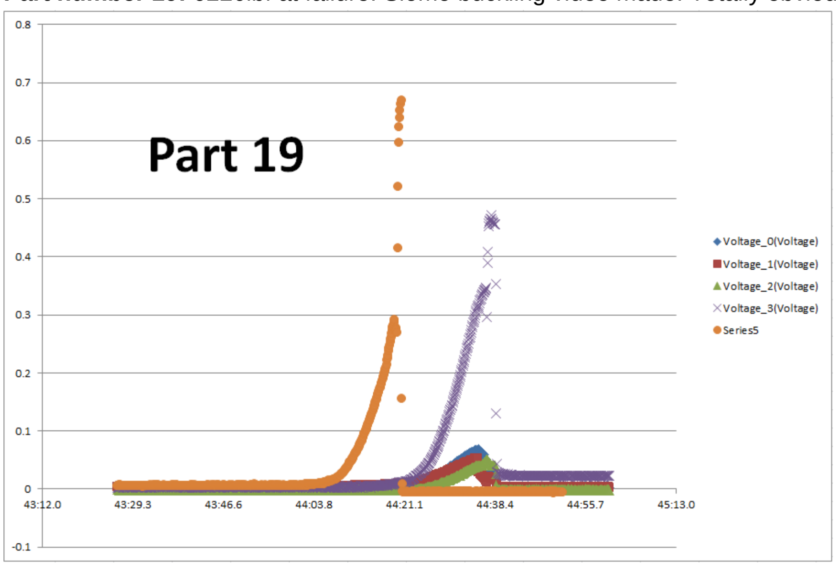
Part number 20: 7140lbf at failure. Plot seen below. Both plies failed at approximately the same! The aluminum rings did not fail!!!



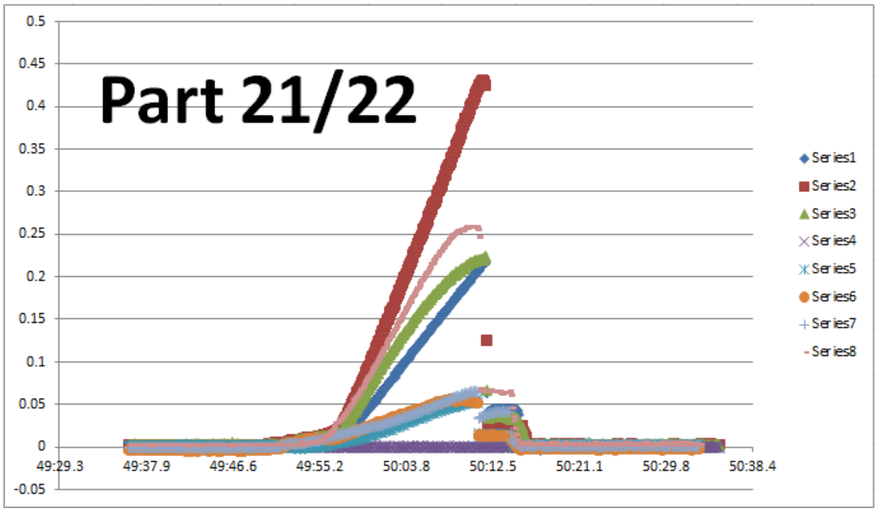
Part number 23: 6650lbf at failure. Sam says he could see the whole bottom section of the frame crinkle in by about .25"-.5". Sam says this is a buckling failure!



Part number 19: 6220lbf at failure. Slomo buckling video made. Totally obvious it buckled.

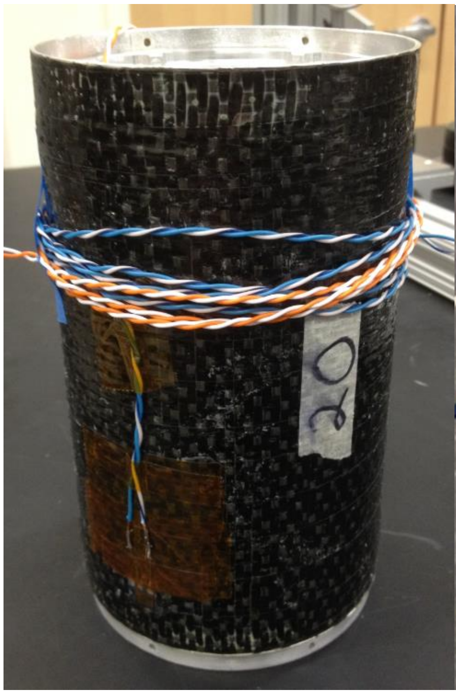


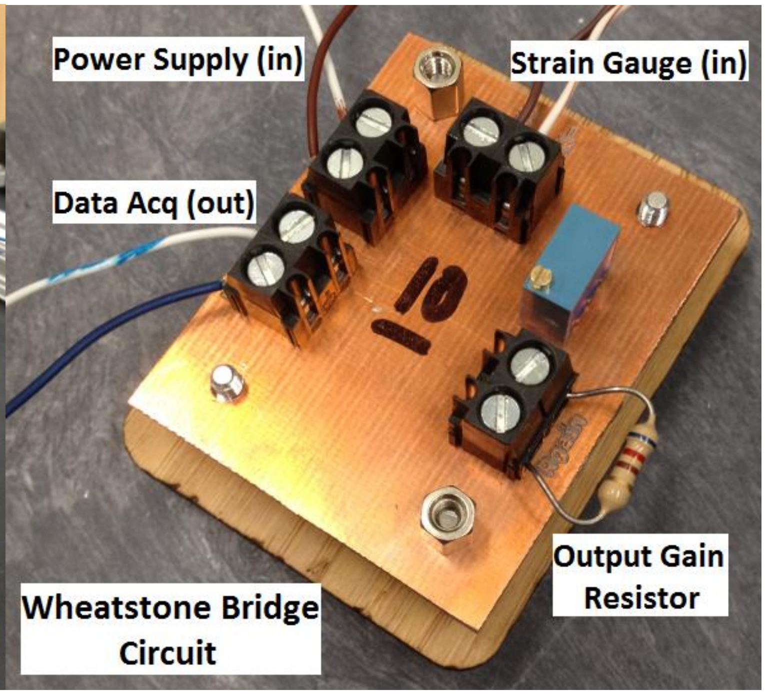
Part numbers 22 on top and 21 on bottom: buckled at 7280lbf. The strain gauges on the outside and inside plies on both are all lined up. This means that we were right about critical buckling being a function of just the length of one module. Slomo buckling video made. Obvious it failed in buckling near the center joint.

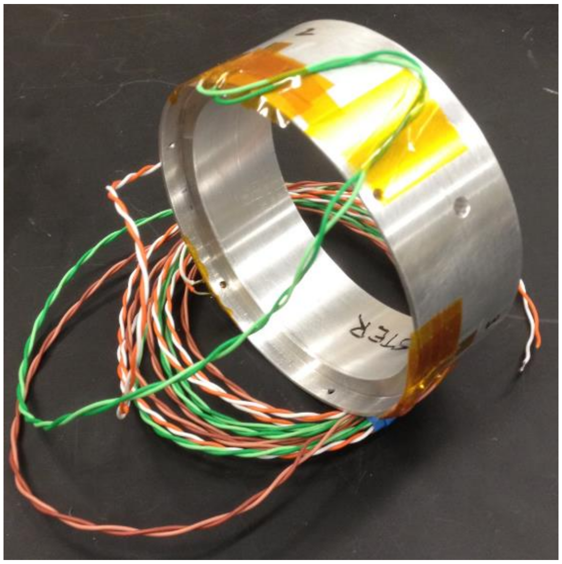


Conclusion, What did we learn from this test?: We can change critical buckling strength by adding aluminum rings more often. We finally have buckling, with the ¼" core. Strain measurements are totally doable, but the software can be a big challenge. Our modules were consistent within 12%, even with big differences in baking schedules, and completely different people laying them up. We had failure approximately the same on both inside and outside plies, and the loading around the rings is consistant. Now that we actually have buckling we know the limitation of ¼" core. We believe that we are imparting a bending load with our current ring design, but the failure was at a high enough load that we don't have to worry about it right now. The rings could be redesigned to not impart the bending load into the future. The boards worked perfectly, and the potentiometer was calibrated each time and was very easy to do with a high quality multimeter. It only took 3 hours to run through all of the testing, the slow part was setting up the software. This took all day. We started at 9:30AM, and finished at 7pm. The aluminum faces and their current design can carry more load the carbon in the current configuration. They should not be made any thinner, though. No aluminum failed at any point. The failure of the stacked modules is the same as the single modules, this means that the critical buckling length is determined by the individual module length. This means we can move on to the 6" diameter modules, because we have confidence in the design the way it is now. Next question is does it scale, which we believe it will. We cannot crush composites without a ring. The composites just fail at the surface, and aren't representative of the failure with a ring. Putting it on a thick rubber coaster helps, but is not perfect.

3/12/14 12:30pm Barett







3/12/14 8:00am Jack
Things we need:

- Wires for power each amplifier, and from the power source
- small flathead screwdriver for the terminals
- wire to go to the DAQ

Questions for Andrew:

- Is it already calibrated?
- Are these ready to go?
- Do we have more wire?
- Can we solder in the EPL?
- What's up with gain? Is it already set?
- How static sensitive are the boards?
- Where does DAQ, Power and gage go?

3/12/14 8:00am Jack
Andrew finished the PCBs. We will meet up with him at 9:30 to talk about them. He said calculating the gain will be a challenge. Our strain gauges are 120ohm (SGD-4/120-LY11). We have to look back at our equations from measurements.

> **Gage Factor:**
> The strain sensitivity k of a strain gage is the proportionality factor between the relative change in resistance ∆ R/R0 and the strain to be measured: ∆ R/R0 = k · ε The strain sensitivity yields a dimensionless number and is designated as gage factor. This gage factor is determined for each production batch by measuring and is specified on each strain gage package as a nominal value complete with tolerance. The gage factors vary between the production batches by just a few thousandths.

3/11/14/12:20pm: Tung: Strain gage measurement box
The strain gage measurement box is perfect for us. It's portable device using battery without computer needed. There are 4 strain gage channels for 1 box and we got 2 boxes in the lab. The output of this box is strain not the voltage. The data of 4 channels are recorded into a memory cards. The smallest sampling time is 1 sec in which I think it will be quite large. I think it is the suitable plan right now.
If we have all of the strain gages mounted then the experiment can be operated after that. We need to find the strain gages factor. 1.99 Gage Factor -Jack
I left the box in the measurement lab.

3/11/14 12:00pm Tung
Oven temperature:

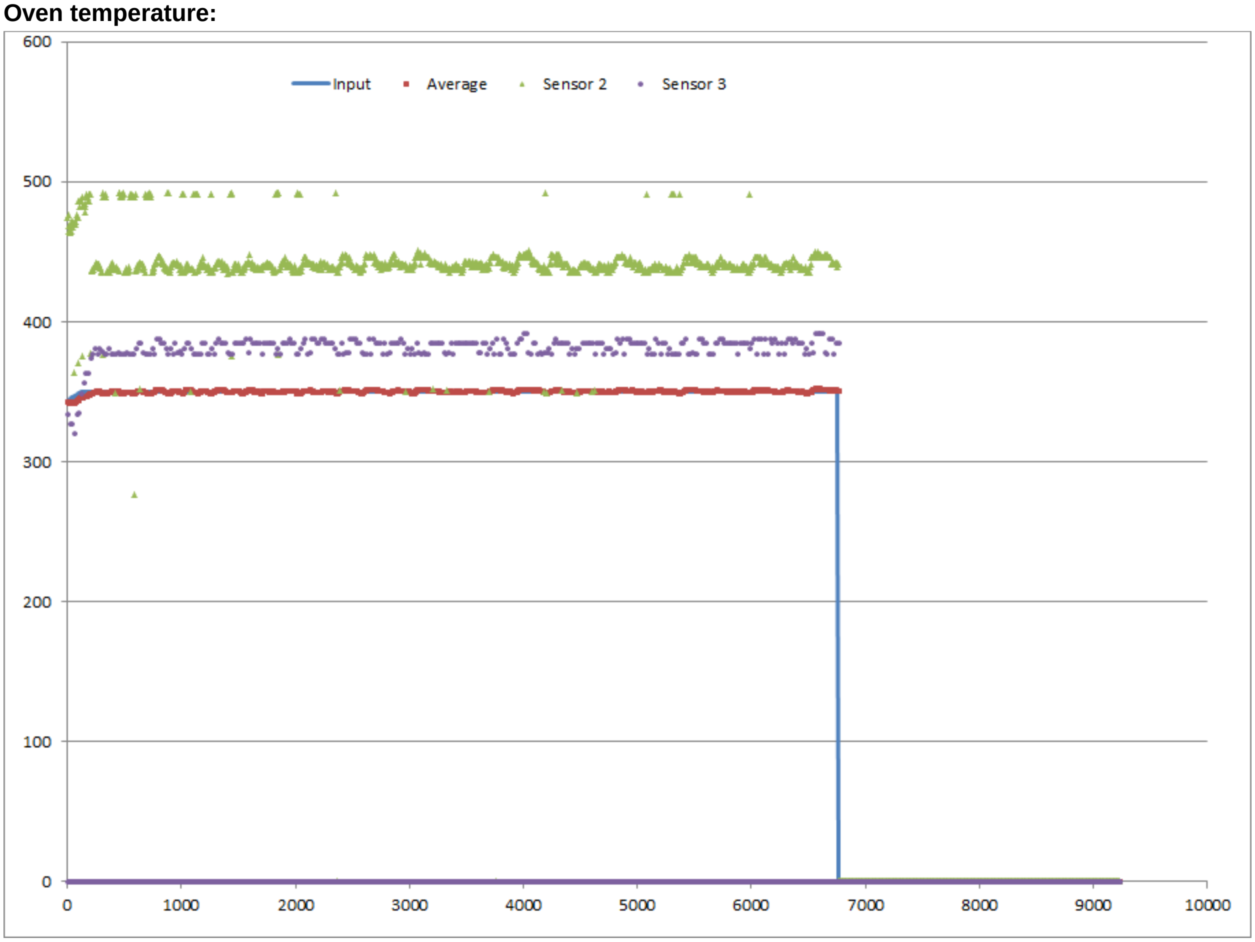


Figure 1: Plot of oven temperature: 03/10/2014/12:30

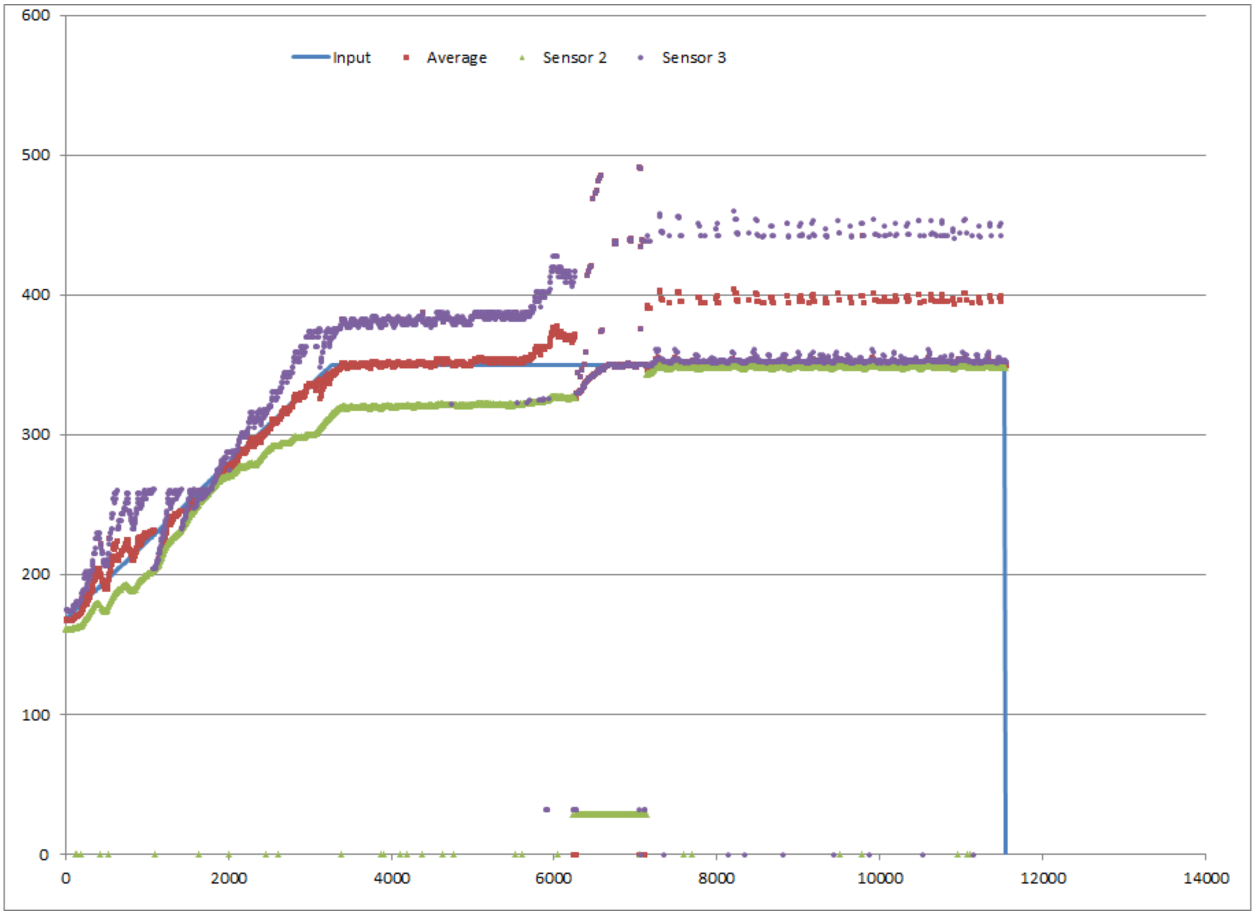


Figure 2: Plot of oven temperature: 03/07/2014/3:30

Here are the plots of the oven temperature in 03/07/2014 and 03/10/2014 runs. The excel files can be found in *\\stash\psas_airframe\Oven Controller\OvenControl* folder. The data shows in Fig.2 a good agreement of the average temperature with the input temperature during ramping up and ⅓ of holding temperature process. The data from sensor 2 is good. However, the temperature measuring from sensors 3 is unreliable. >>>Need to fix the sensors.

The new code (Oven_control_V2_2) has updated with fixing the error in different holding time because of its starting temperature. Right now, the oven will holding at 2 hours without caring about the different in its initial temperature. The code is located in: *\\stash\psas_airframe\Oven Controller\OvenControl\Oven_control_V2_2*

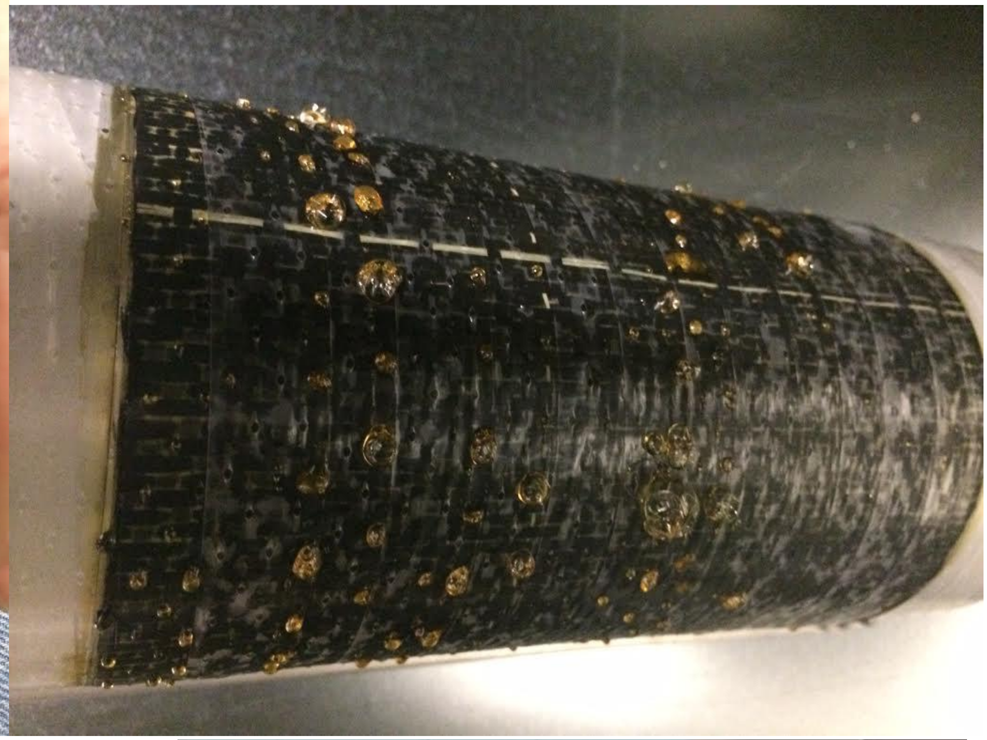
The code using temperature reading from sensor 1 which is the most reliable compared to other sensors. Fig.1 show the holding temperature process of the oven. The average value which is the data from sensor 1 is the same as the desired temperature. The last version of the code is O*ven_control_V2_3 located in*

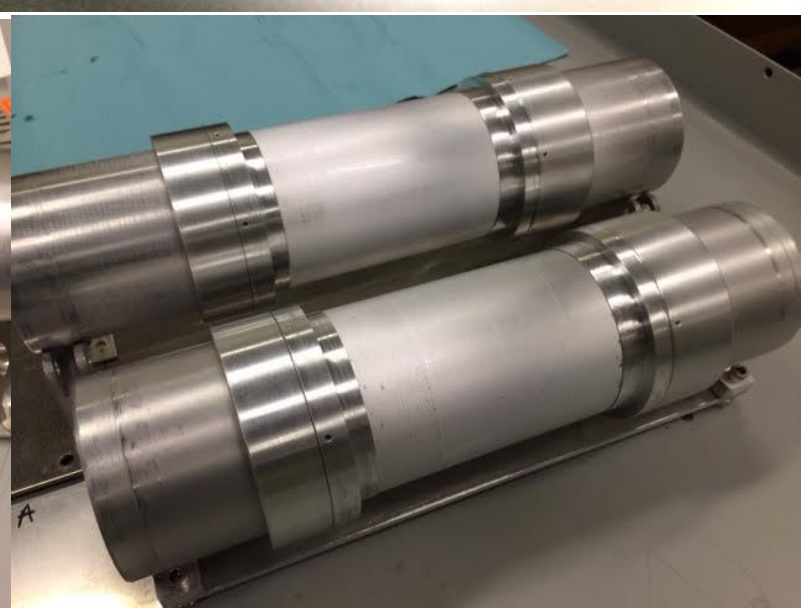
\\stash\psas_airframe\Oven Controller\OvenControl\Oven_control_V2_3

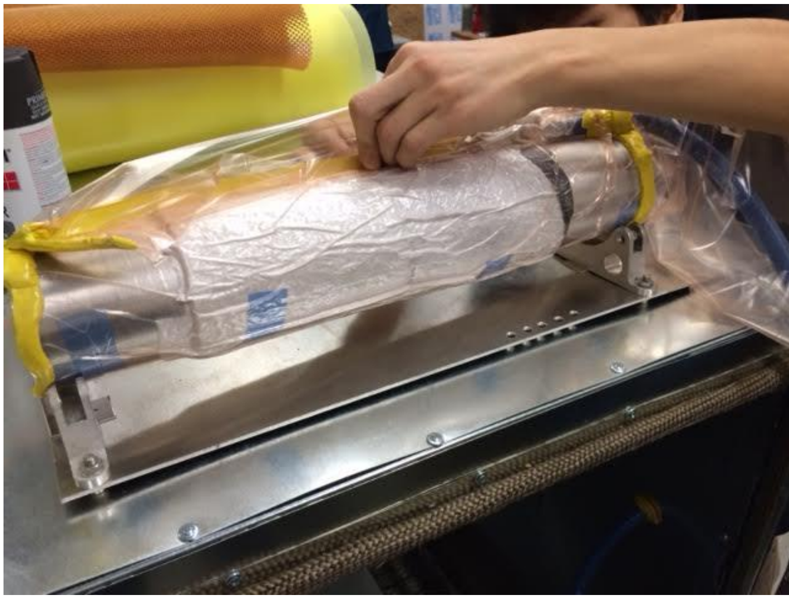
3/10/14 3:00pm Jack

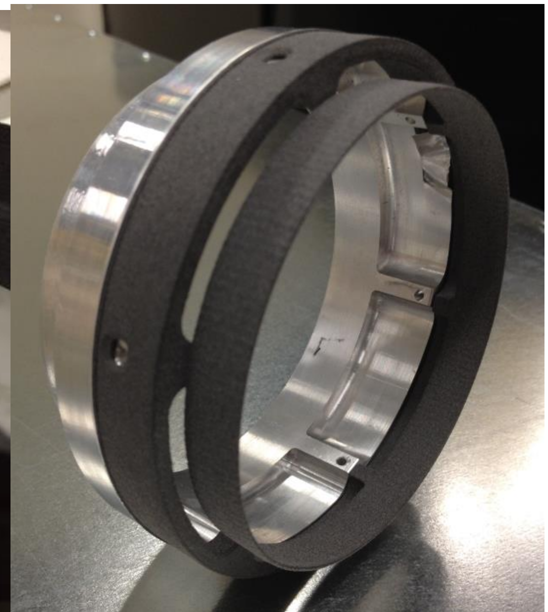
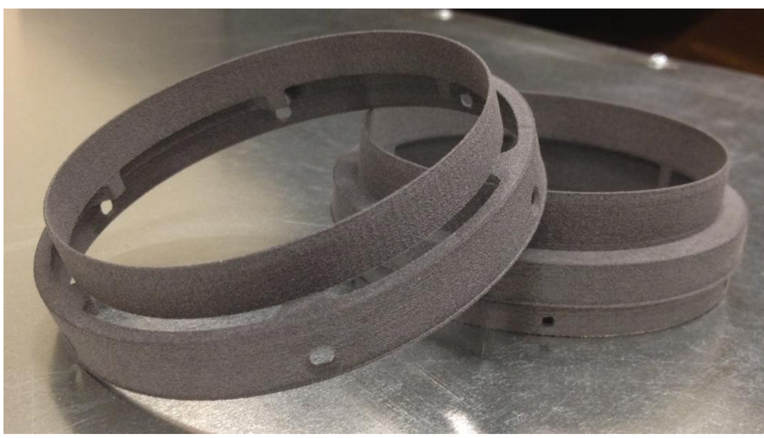
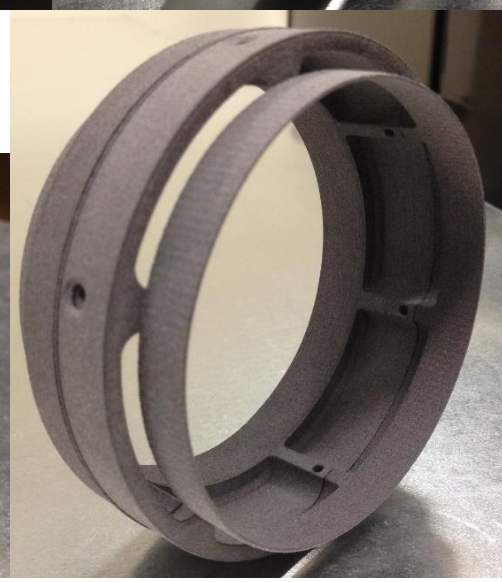
We are baking 4 more parts today. 2 of them are for our measurements project. 2 are engineering pathfinders, one is carbon the other fiberglass (23, 24). They both use the ⅛" core and have both a vacuum bag and perforated shrink tape. It was a pain in the ass to get the fiberglass part off the mold, and the shrink tape is almost completely bonded to the surface. It is transparent and looks like scales on a snake. We made this so PSAS can look at radio transparency or something like that.

We also got our nylon 12 carbon fiber impregnated 3d printed parts today. Joe said he would do more parts for us, and will give us information on SLS process and DMS(?) metal laser sintering quote for our parts. This would be in titanium, stainless and alumina. The internet made it seem like aluminum is not doable but aluminum oxide or something is. This would not be the familiar 6061 type stuff.







3/9/14 8:00pm Jack
Things to do tomorrow:

- cut out carbon adhesive etc
- Layup and bake
- install strain gauges on the top dummy
- test PCBs with strain gauges
    - Not done yet

- entertain and impress the 3d Printer guy
- figure out what computer we can use for our data logging (ask tom?)
    - Tung’s computer, he will download the software
- clean up carbon/aluminum gluey ends
- drill, tap and countersink holes
- email troy about capstone room access

3/9/14 5:00pm Jack

This is my (Jack) schedule for next term. Can everyone else post their stuff here too.

Previous Week   Week of 31-MAR-2014 (184 of 194)   N

	Monday	Tuesday	Wednesday	Thursday	Friday
9am	ME 241L-001 65642 Class 9:00-11:50 EB 145				
10am					
11am					
12pm		ME 493-001 61824 Class 12:00-13:50 EB 102		ME 493-001 61824 Class 12:00-13:50 EB 102	
1pm					
2pm	ME 241-002 61808 Class 14:00-15:50 CIN 92	ME 454-001 61822 Class 14:00-15:50 EB 565	ME 241-002 61808 Class 14:00-15:50 CIN 92	ME 454-001 61822 Class 14:00-15:50 EB 565	
3pm					
4pm					

Rob

	Monday	Tuesday	Wednesday	Thursday
9am			ME 241L-006 61810 Class 9:00-11:50 EB 145	
10am		ME 410-MEC 64921 Class 10:00-11:50 EB 360		ME 410-MEC 64921 Class 10:00-11:50 EB 360
11am				
12pm		ME 493-001 61824 Class 12:00-13:50 EB 102		ME 493-001 61824 Class 12:00-13:50 EB 102
1pm				
2pm	ME 241-002 61808 Class 14:00-15:50 CIN 92		ME 241-002 61808 Class 14:00-15:50 CIN 92	
3pm				
4pm				
5pm				
6pm				TA 101-002 65193 Class 18:00-21:35 LH 301
7pm				
8pm				
9pm				

Barett Schedule

12pm		ME 493-001 61824 Class 12:00-13:50 EB 102		ME 493-001 61824 Class 12:00-13:50 EB 102
1pm				
2pm	ME 241-002 61808 Class 14:00-15:50 CIN 92		ME 241-002 61808 Class 14:00-15:50 CIN 92	
3pm				

Sam

	Monday	Tuesday	Wednesday	Thursday	Friday
9am	ME 241L-001 65642 Class 9:00-11:50 EB 145				
10am		PER 330U-001 64501 Class 10:00-11:50 NH 391		PER 330U-001 64501 Class 10:00-11:50 NH 391	
11am					
12pm		ME 493-001 61824 Class 12:00-13:50 EB 102		ME 493-001 61824 Class 12:00-13:50 EB 102	
1pm					
2pm	ME 241-002 61808 Class 14:00-15:50 CIN 92		ME 241-002 61808 Class 14:00-15:50 CIN 92		
3pm					

Tung

Previous Week | Week of 07-APR-2014 (94 of 103) | Next Week

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
9am		PE 185-123 62911 Class 9:00-9:50 PSC 203		PE 185-123 62911 Class 9:00-9:50 PSC 203			
10am	ASL 101-001 65281 Class 10:00-11:50 CH 158		ASL 101-001 65281 Class 10:00-11:50 CH 158				
11am							
12pm		ME 493-001 61824 Class 12:00-13:50 EB 102		ME 493-001 61824 Class 12:00-13:50 EB 102			
1pm							
2pm		ME 454-001 61822 Class 14:00-15:50 EB 565		ME 454-001 61822 Class 14:00-15:50 EB 565			
3pm							

Advising appointments. Current and prospective students can schedule a 30 minute appointments with a Maseeh College advisor between 9am-5pm by calling 503-725-4631. Quick, 10-15 minute walk-in appointments are available Tuesday 9-10am and 1:30-2:30pm or Thursday 2-3pm during fall, winter and spring terms.

Spring Career Workshops

Maseeh College of Engineering

What **Industry Panel**

YOUR chance to find out what hiring managers are looking for in recent grads.

Representatives from a variety of industries will be on Campus to answer your questions. Also a great chance to network.

BOEING

CH2MHILL

BLOUNT INTERNATIONAL

UTi Supply Chain Solutions that Deliver

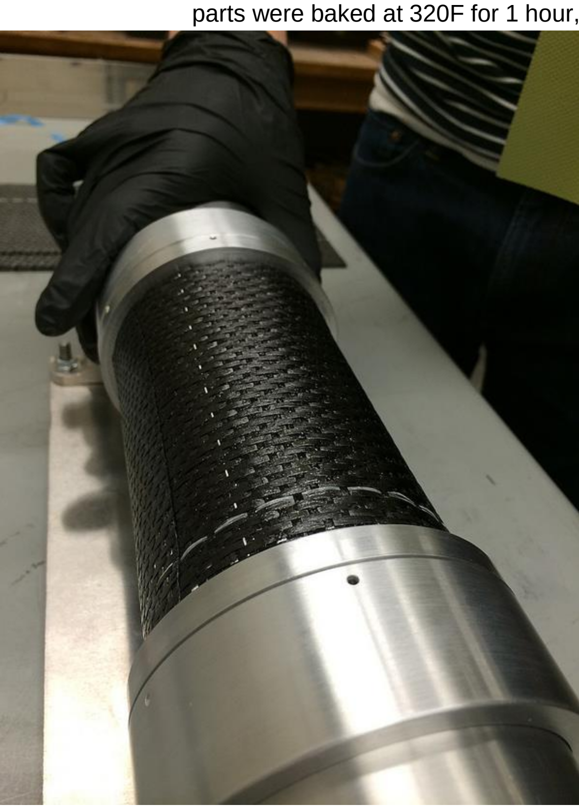
DIGITAL TRENDS

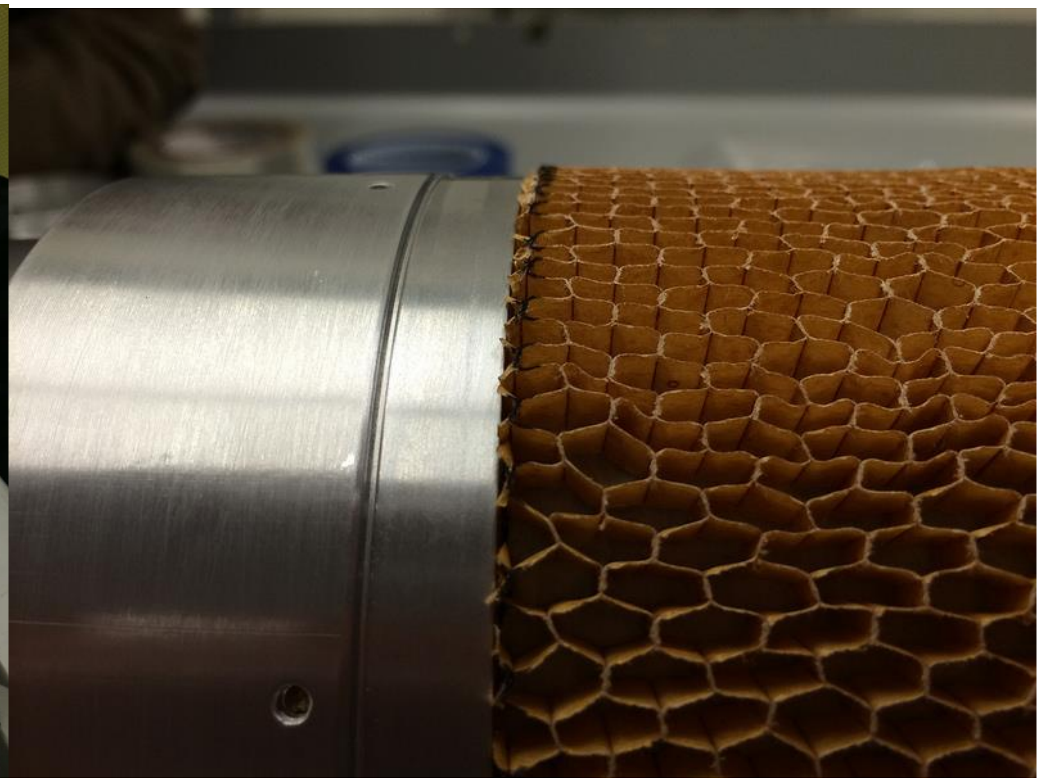
3/9/14 3pm Jenner
I hope the modules came out okay! I'm off to Seattle and will be back this weekend.

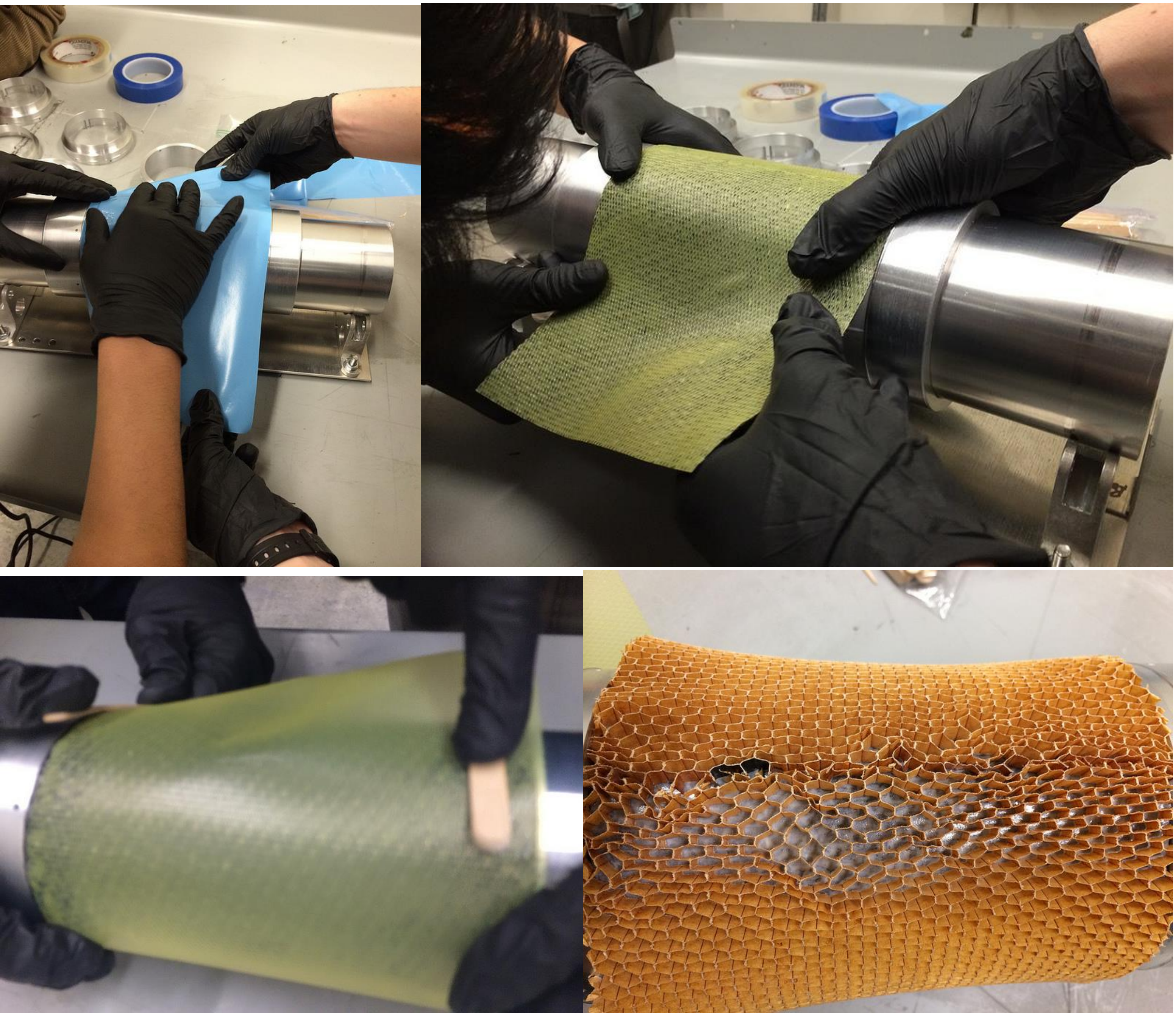
I made all the strain gauge boards, I just hope they're good enough. I left ten routed boards and ten bamboo carrier boards on the table in the EPL for Andrew, and threw in some bonus parchment stencils.

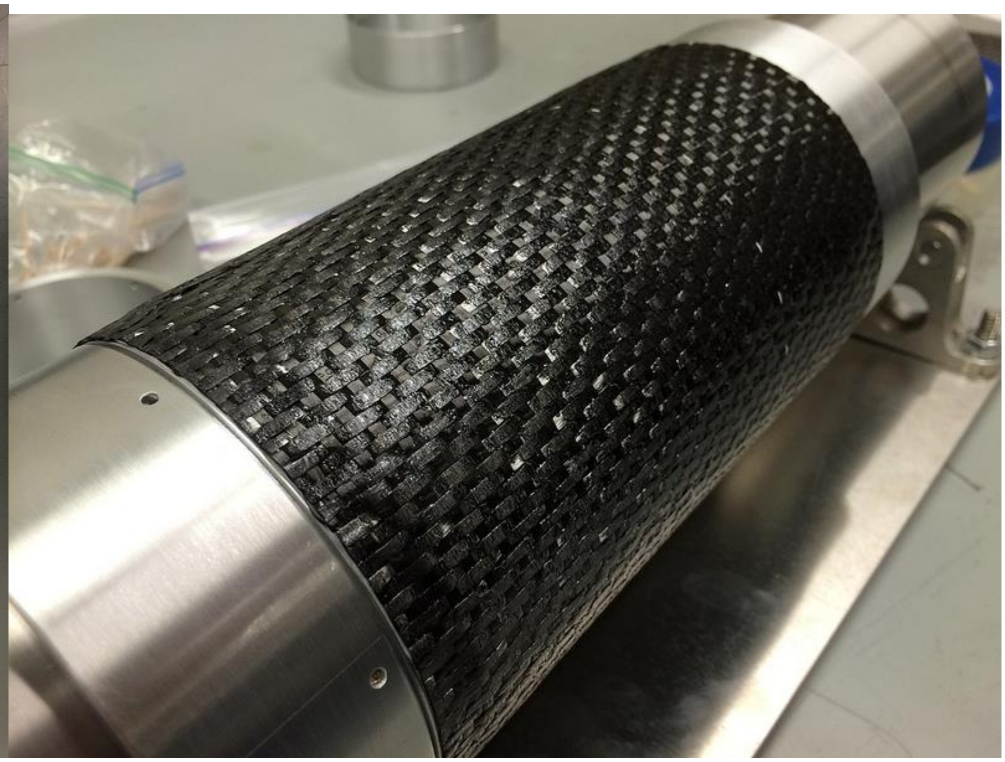
I also made two posts -- [Strain Gauge Board v1] and [Carbon Fiber Airframe Layup] -- so if you could look at them and tell me where the EE used the ME words wrong, that'd be fab. Also feel free to steal pics. Looks great Jenner. I think technically it's not wax, its liquid hybrid mold release, and I'm not sure the chemicals. Can't wait to hook up our gauges!

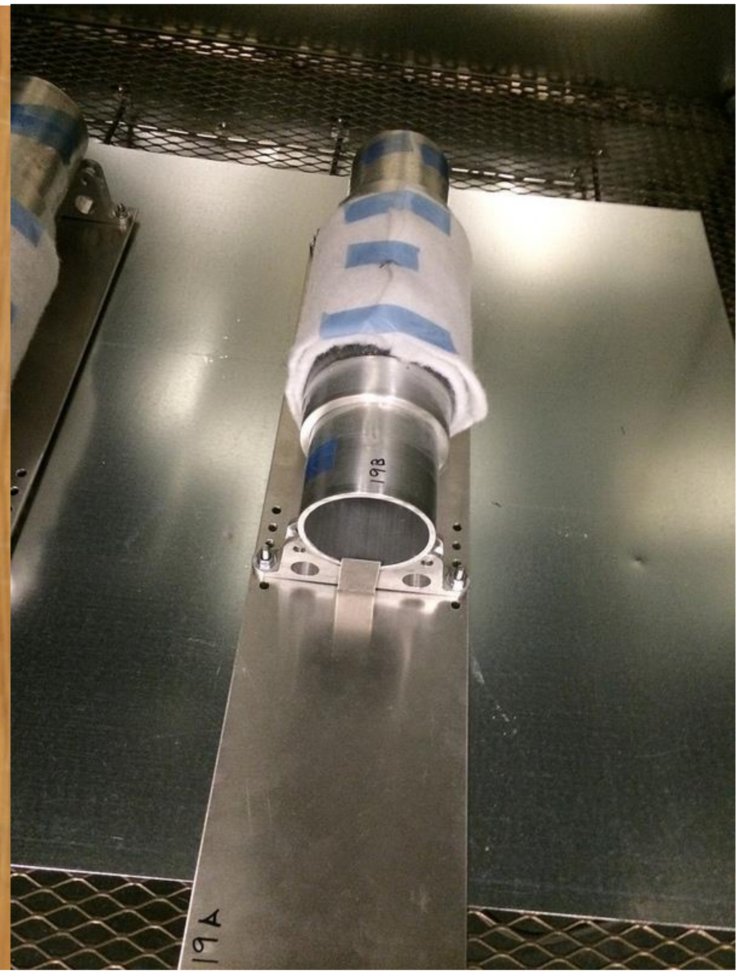
3/7/14 7:00pm Jack, Sam
Parts 19, 20, 21 are baking at 322F according to the fluke, but 350F according to the computer. God only knows what's going on. The parts were baked at 320F for 1 hour, then 350F for 2 hours. We had to pound 20 off.





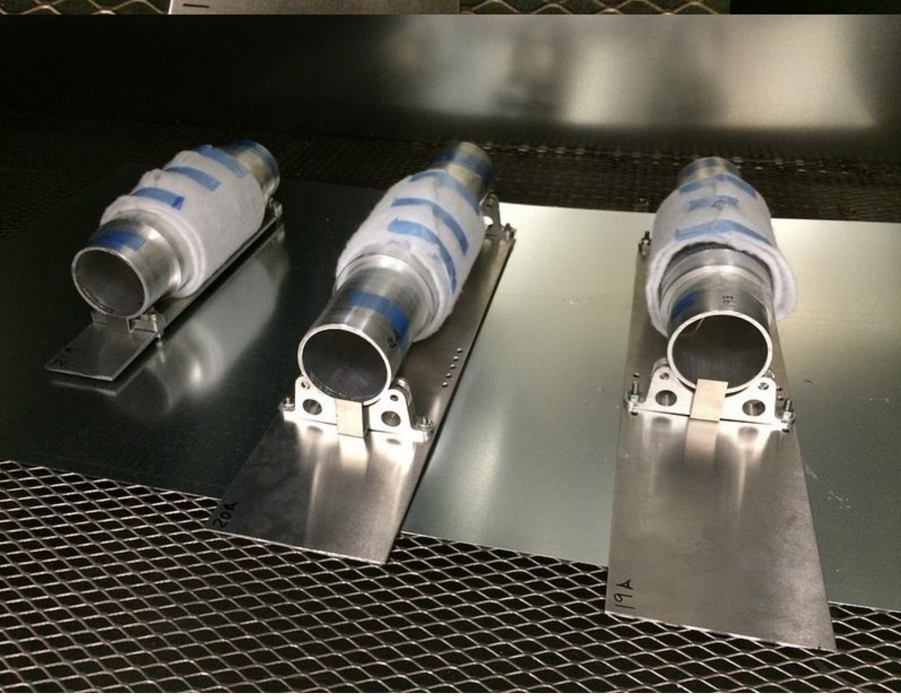



19B
19A


19B
19A


21A


19A

3/7/14 2:30pm Jack
Write up on everything that's happened over the past week:
We finished design of the rings for testing the 3.4" modules. We made 5 pairs of rings. We also made dummy rings that mate, and are flat to apply the compressive load to. They have room for the strain gauges.

We got another large shipment of materials including a lot of bleeder, and some ⅛" honeycomb core.

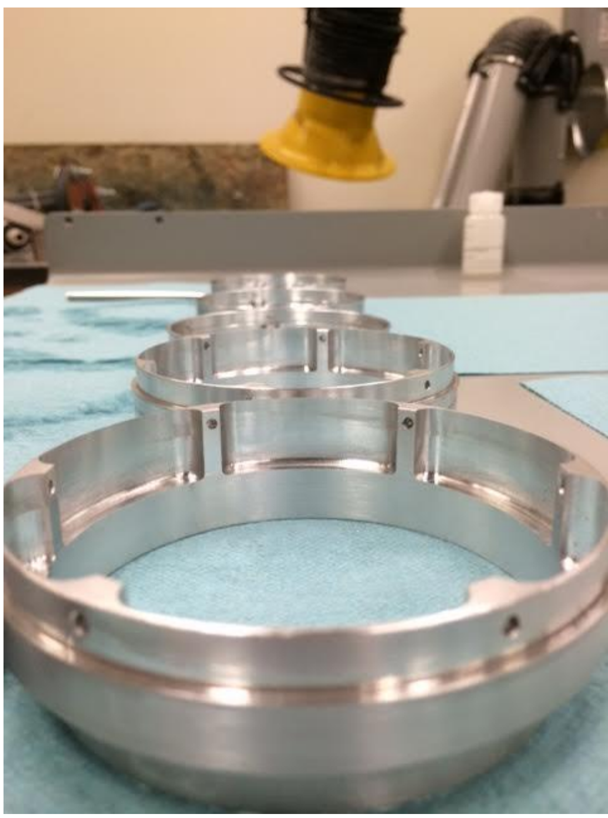
Cutting honeycomb core with scissors works great, making templates is a necessity to making parts efficiently. We cut them ahead of time and then put them back in the freezer. Total thawing time is much less this method.

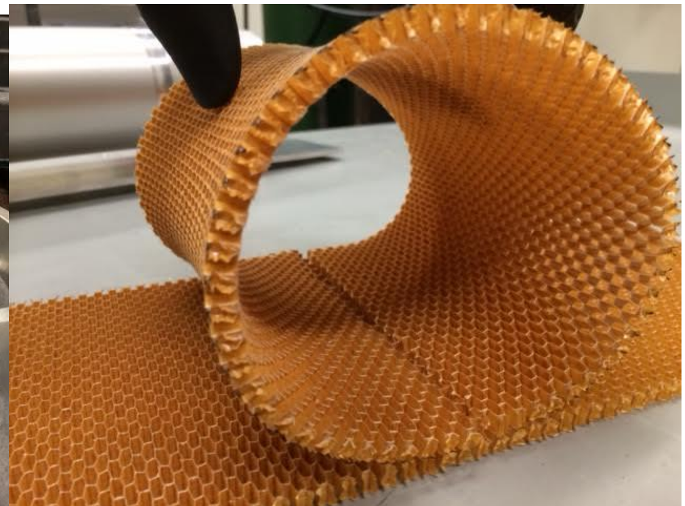
The second piece of pipe we got was seriously out of round. We need a lot more extra stock to be able to get it into the correct shape. It'd be a lot nicer to get these CNC by someone else.

Machining the length of the mandrel is a little tough. Our jig isn't super rigid, so it tapers. This makes it a challenge to get them all the same size. These would be better off machined a different way.

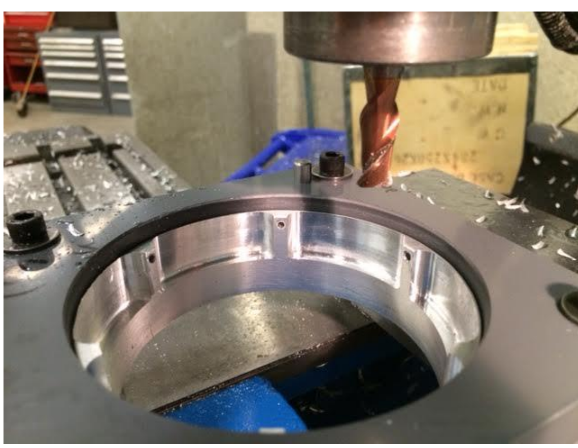
It costs about 50$ for one 2ft stick of the 3.5" piping. So it's around 10$ per part to make (our cost).

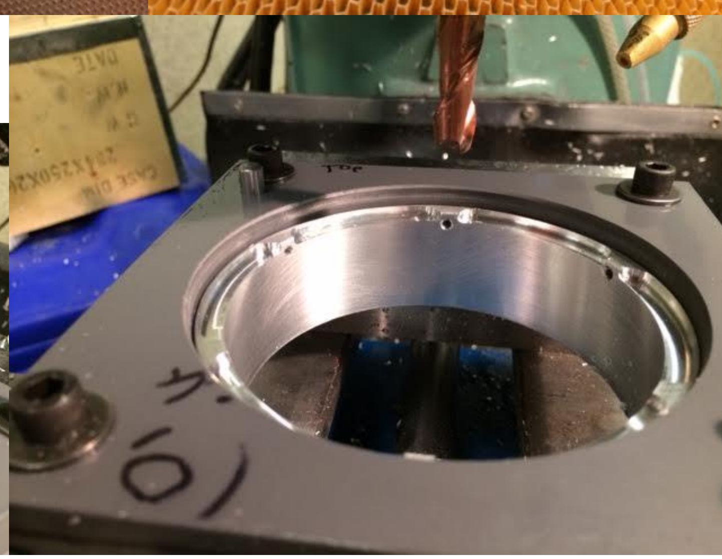
Making the PVC jig to do the machining worked great, but we might want to consider something more robust like aluminum for final jigs.

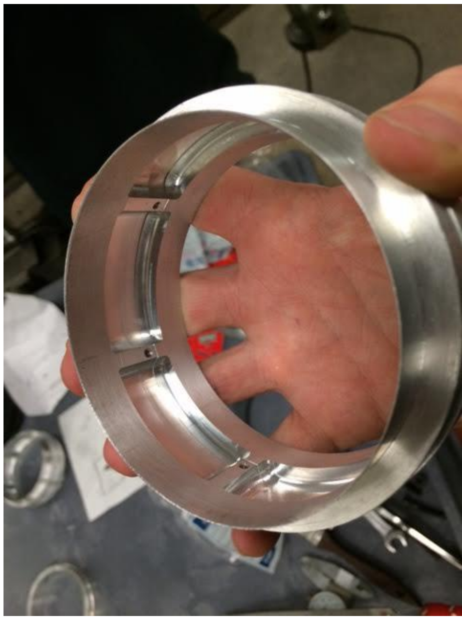


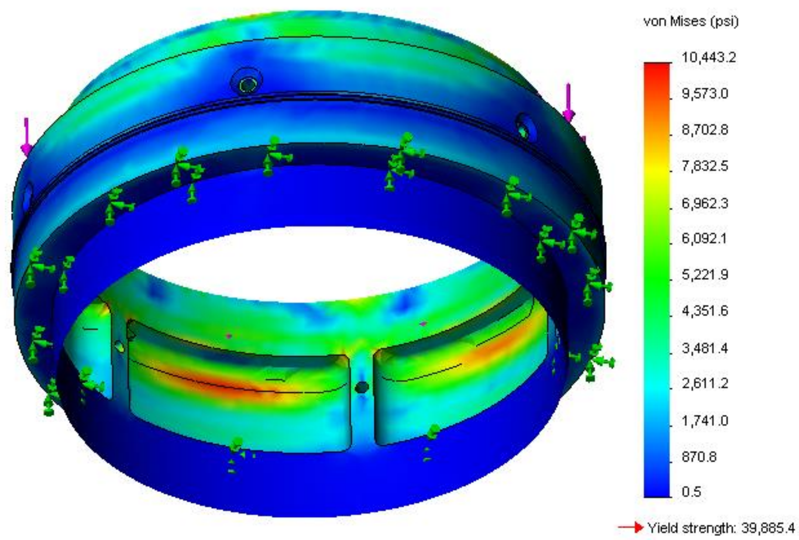



P5A5
Core
5.75X12.80





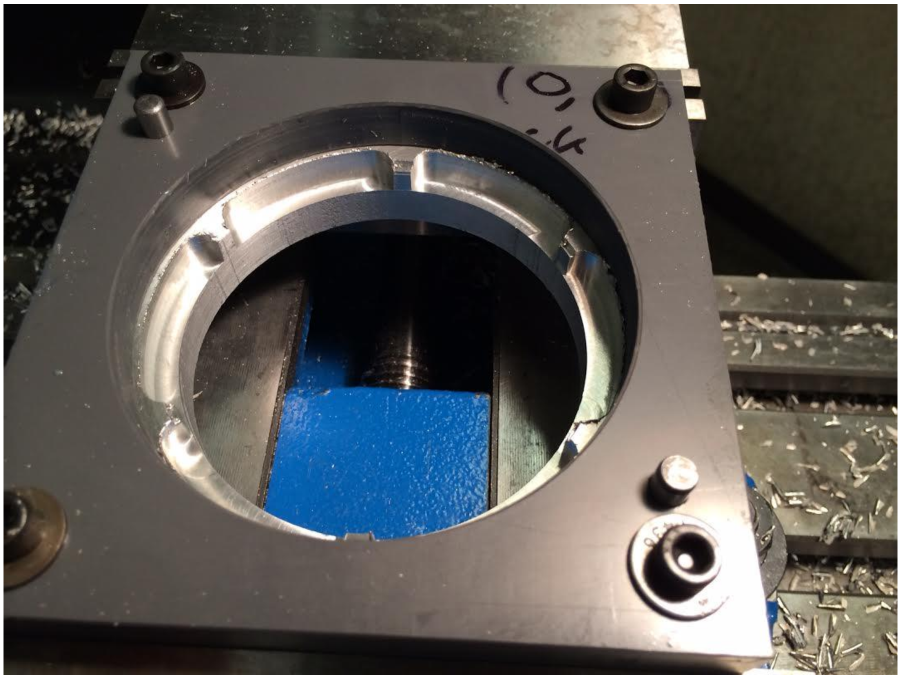


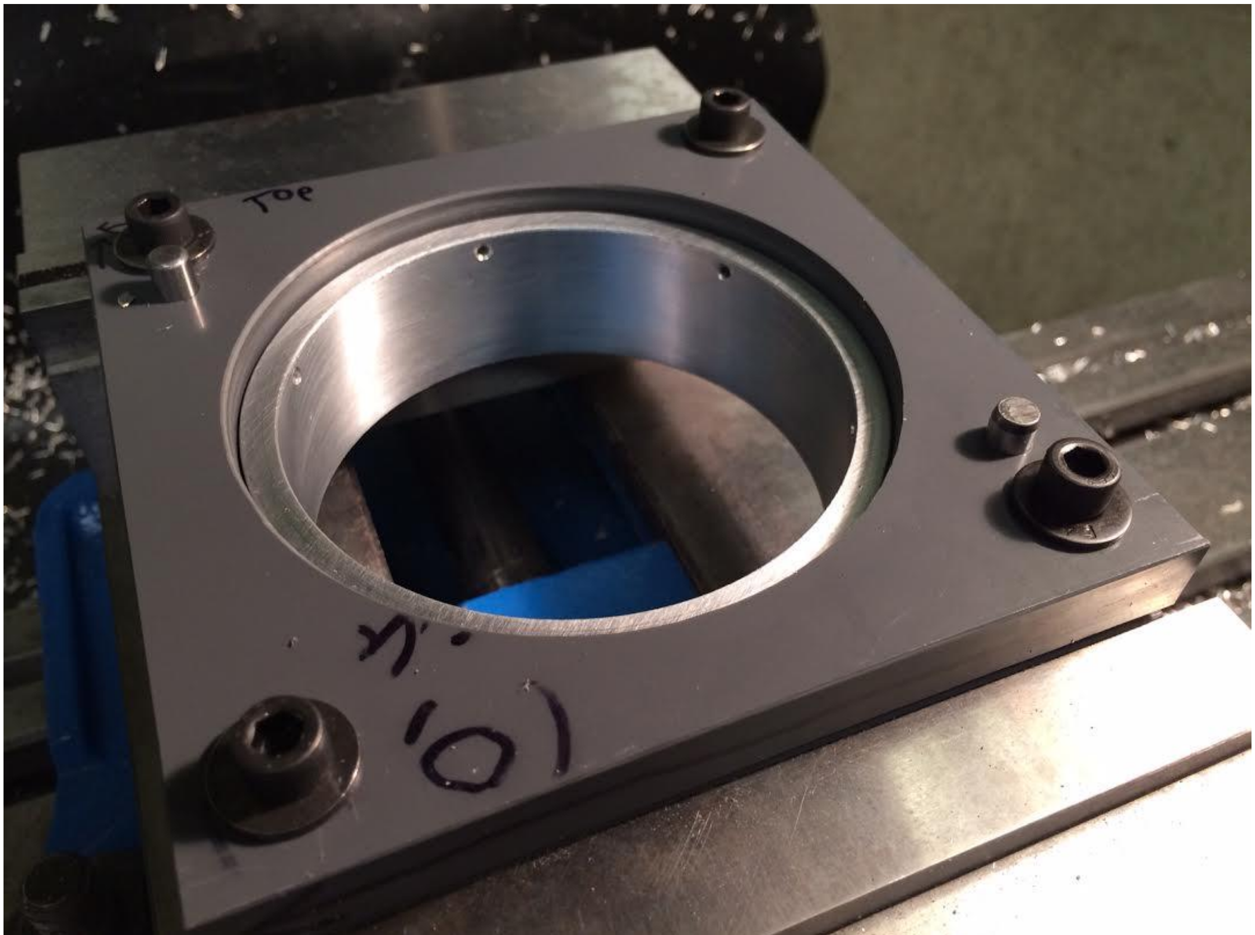
3/7/14 10:30am Jack
Things to do:

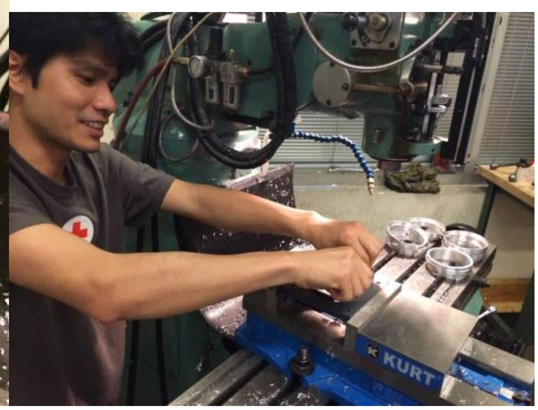
- cut core, carbon and adhesive films
- Aluminum treatment
- Wax and prep all molds
- Solve pinning issue
- Finish machining dummy parts
- Help Jenner with electronics

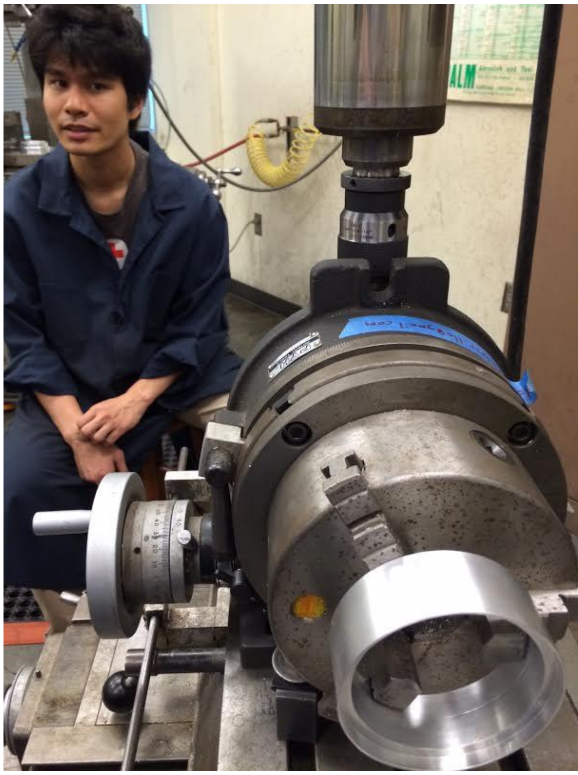
3/5/14 6:30pm Jack
We made the CNC programs and ran a test piece (03061401). It is very important to use this program, because we messed up the the The machine is ready and set up to do the rest of the pocketing. We made all the females and males today (go sam and rob), drilled all the radial holes, set up the fixtures and programs and such. We got the tail stock support, but next we need to get the tools from sam's house to run some parts. We are setting up the tailstock now.

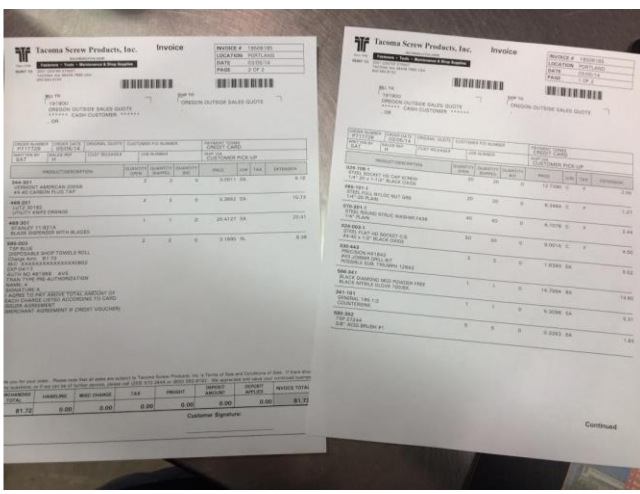



SOUTHWESTERN INDUSTRIES
PROTO TRAK EMX
GO
PROG
P/N 03051401
INCH
RETURN
LOOK
INC ABS
INC SET
X
Y
Z
MODE
+/-
HELP
RESTORE




KURT




Tacoma Screw Products, Inc.
Invoice
Tacoma Screw Products, Inc.
Invoice
Continued

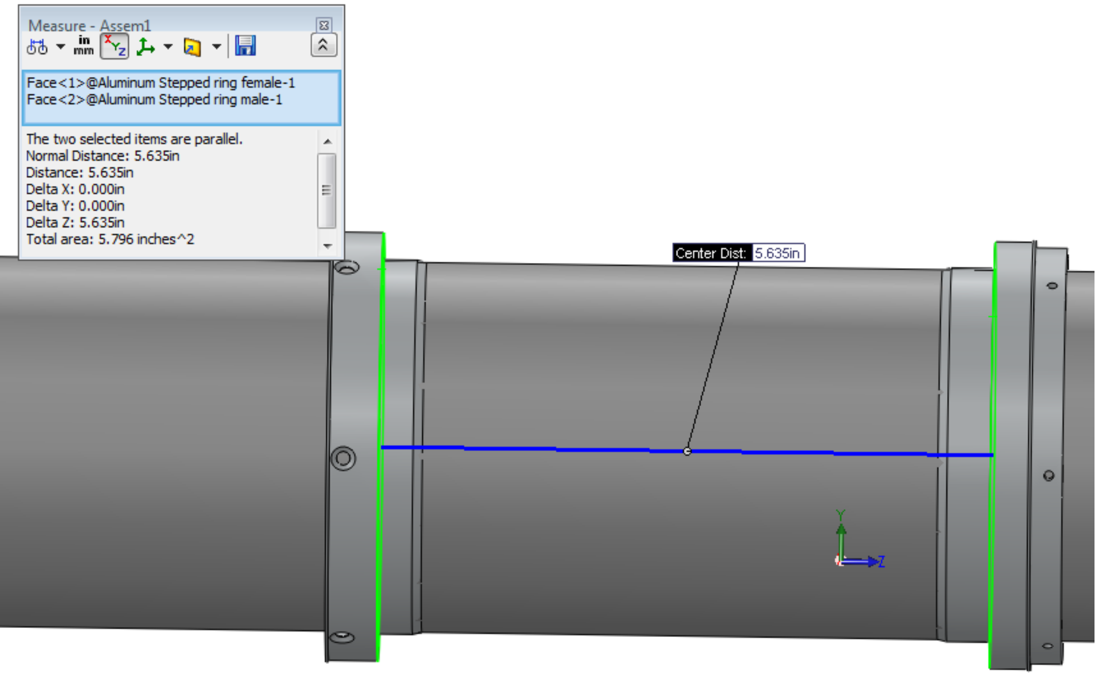
3/5/14 6:30pm Jack
The combined height of the dummys (FCR + MCR) is 2”. This means that the modules have to be 6.5” so that we can stack them.

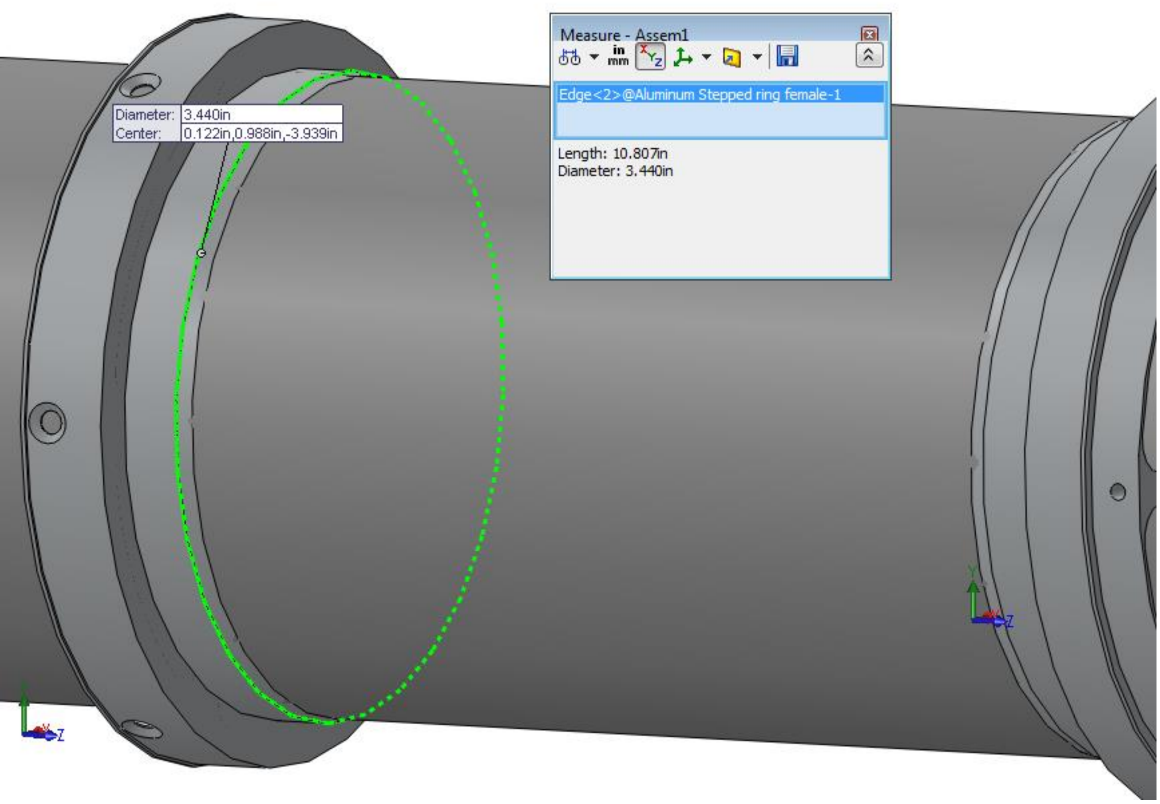
6.5”+6.5”+2”=15” which is less than the maximum 15.5”

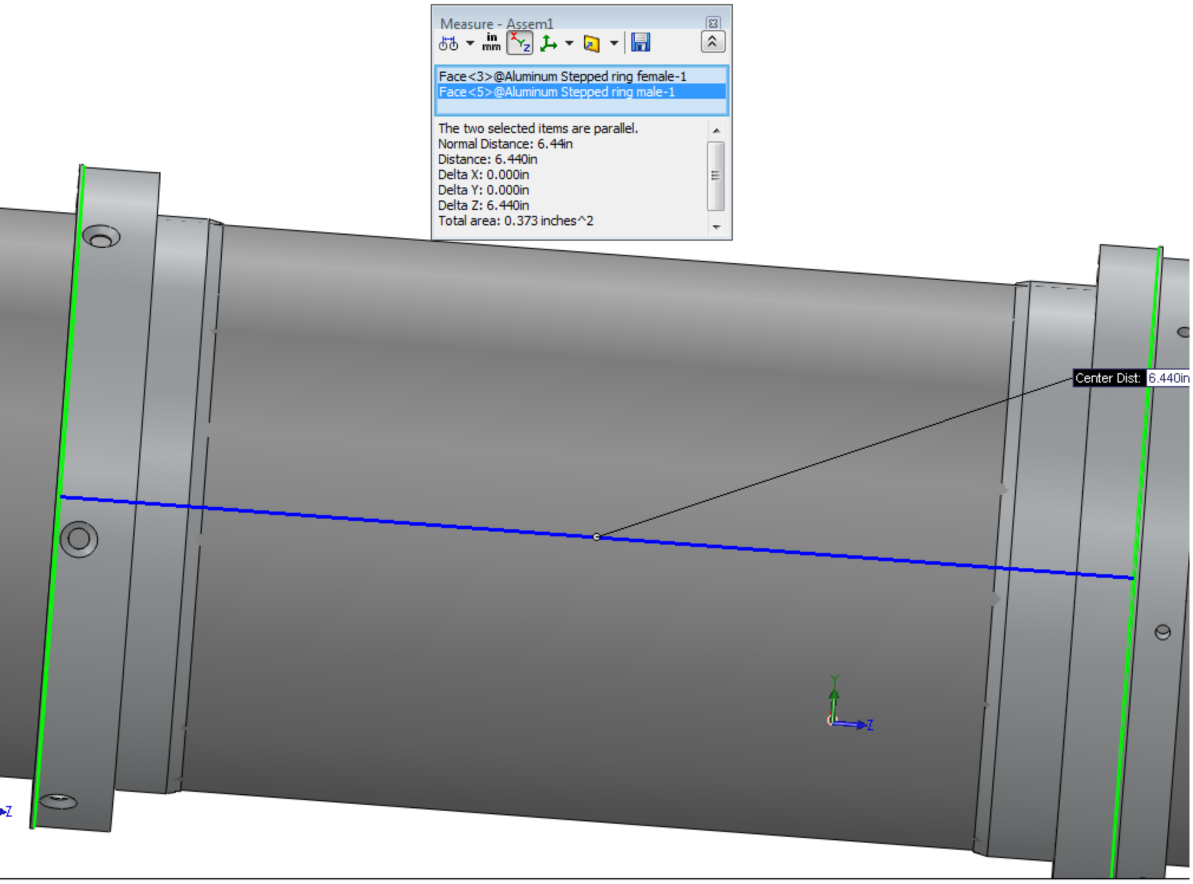
We cannot use the dummies because they are not machined nice enough on the inside. We can use the same design though and make 6 total. They are long, the shrink tape will work well with it.

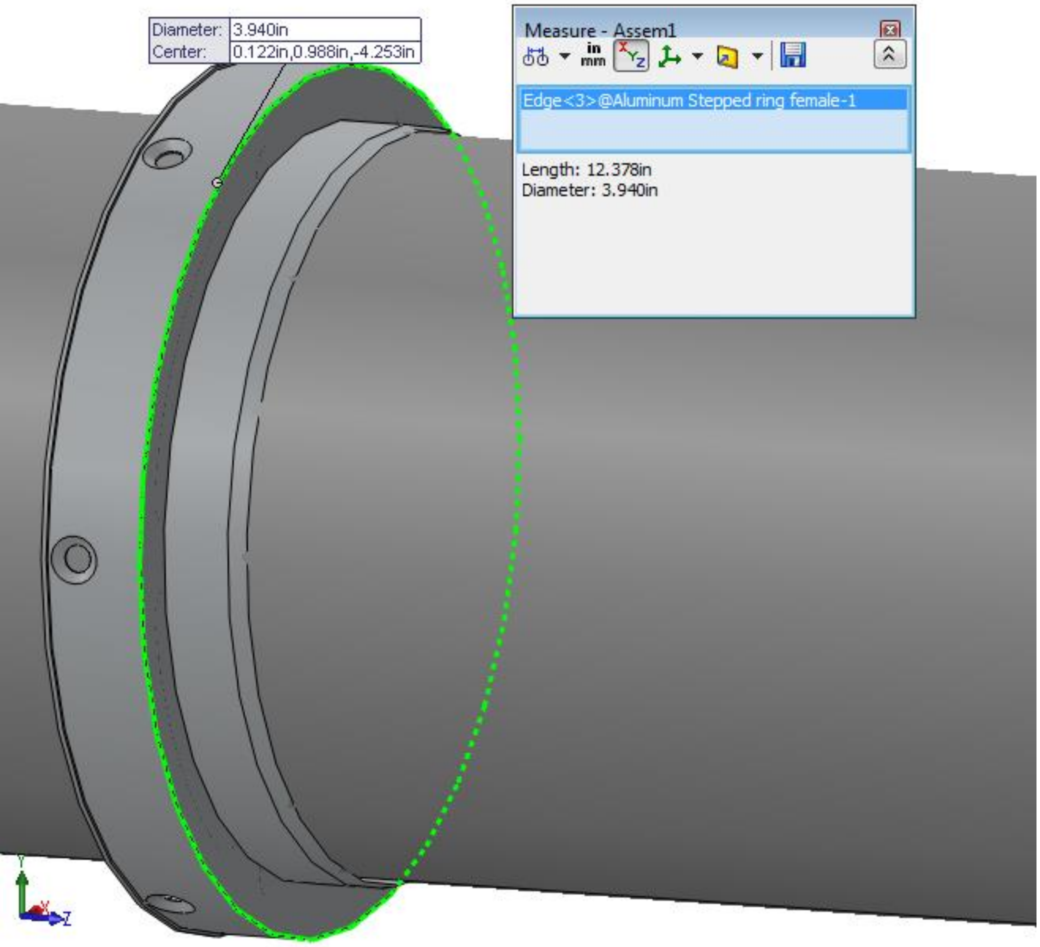
We need to make a template for the inner layer of carbon, the layer of core, and the outer layer of carbon.

Inner layer of carbon: 5.625” x 12.0”
Outer layer of carbon: 6.43” x 13.5”
Layer of core: 5.635” x 12.875”

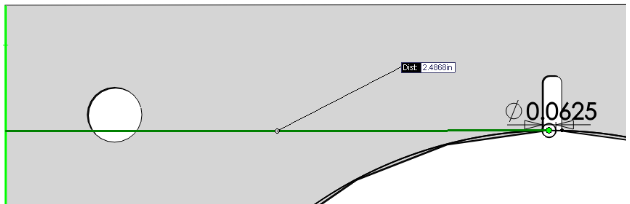

Measure - Assem1
Face<1>@Aluminum Stepped ring female-1
Face<2>@Aluminum Stepped ring male-1
The two selected items are parallel.
Normal Distance: 5.635in
Distance: 5.635in
Delta X: 0.000in
Delta Y: 0.000in
Delta Z: 5.635in
Total area: 5.796 inches^2
Center Dist: 5.635in

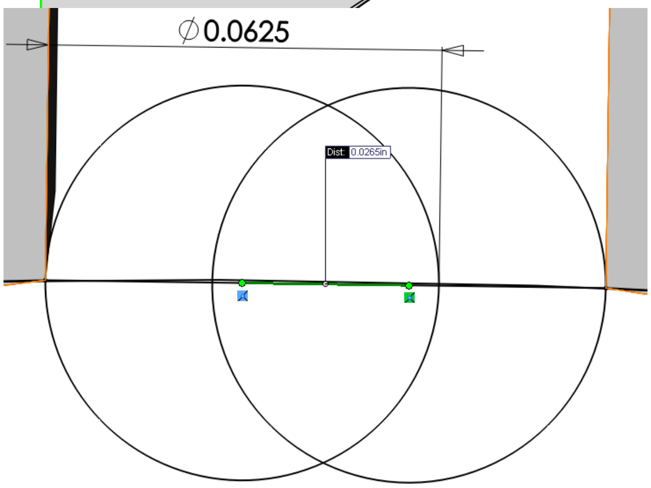

Diameter: 3.440in
Center: 0.122in,0.988in,-3.939in
Measure - Assem1
Edge<2>@Aluminum Stepped ring female-1
Length: 10.807in
Diameter: 3.440in

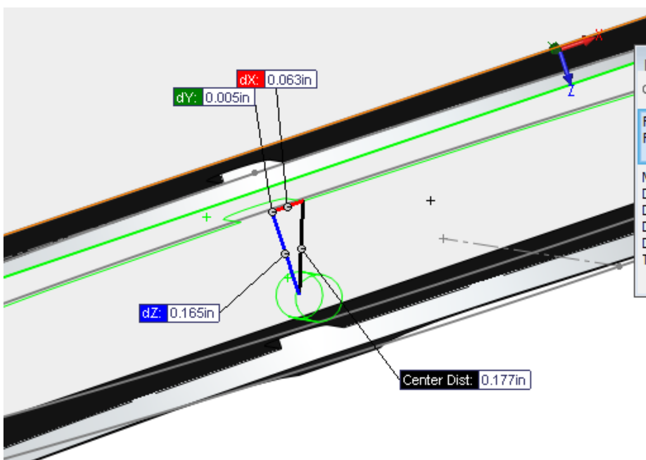

Measure - Assem1
Face<3>@Aluminum Stepped ring female-1
Face<5>@Aluminum Stepped ring male-1
The two selected items are parallel.
Normal Distance: 6.44in
Distance: 6.440in
Delta X: 0.000in
Delta Y: 0.000in
Delta Z: 6.440in
Total area: 0.373 inches^2
Center Dist: 6.440in

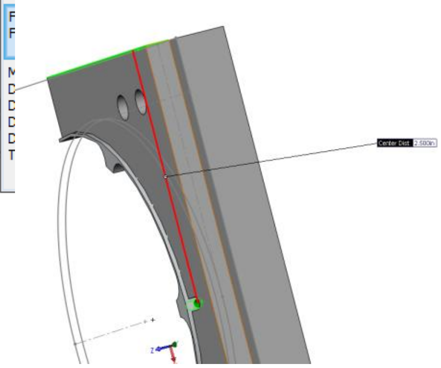


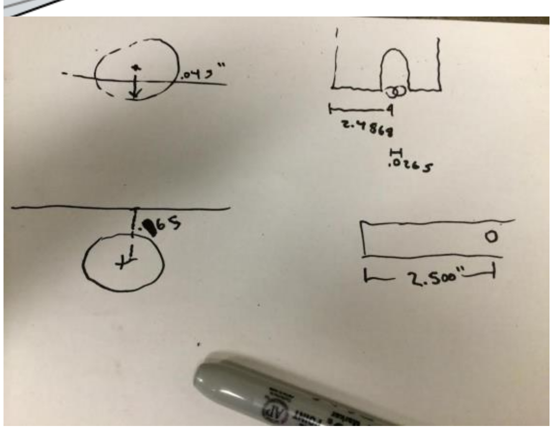
3/5/14 1:30pm Jack
Machined the last of the rings. Aligning the rotary table is a bit of a challenge. It took 30 minutes to drill 12 rings with 6 holes each. Setting up the rotary is the hard part.





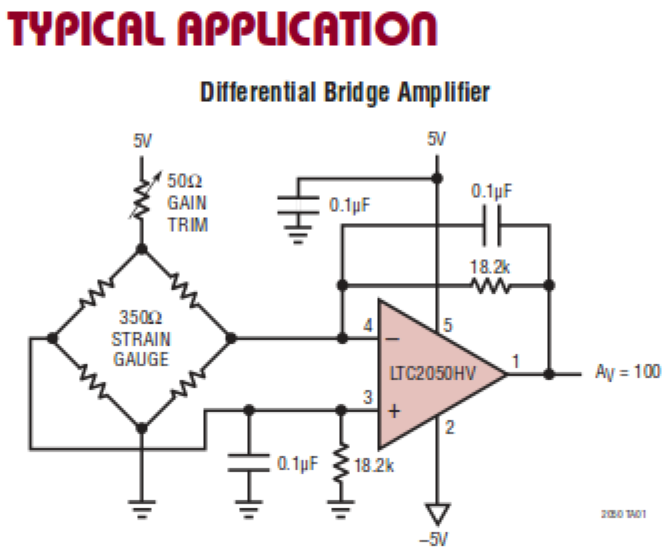






3/5/14 12pm Jenner

This is basically the data-driven design solution. I sent Andrew an email asking about what specific parts he might have laying around and what we'll have to order in. I made a folder for this thing in the Design folder and dropped the datasheet in it.

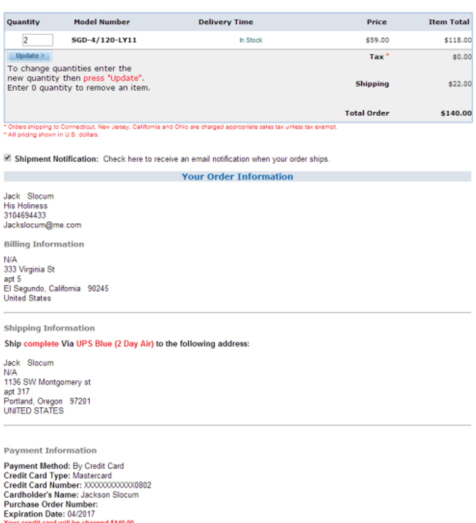


3/4/14 11:15 am Jack
Need to use the term data driven solutions

Things to order (done):
6061 T6: Schedule 80 3.5 for Rings: 2
$50.88 under Jackson Slocum for pickup

OMEGA:
SGD-4/120-LY11

We will use:
NI 634x DAQ - 16-bit resolution



Quantity	Model Number	Delivery Time	Price	Item Total
2	SGD-4/120-LY11	In Stock	$59.00	$118.00
Update >			Tax *	$0.00
To change quantities enter the new quantity then press "Update". Enter 0 quantity to remove an item.			Shipping	$22.00
			Total Order	$140.00

* Orders shipping to Connecticut, New Jersey, California and Ohio are charged appropriate sales tax unless tax exempt.
* All pricing shown in U.S. dollars.

Shipment Notification: Check here to receive an email notification when your order ships.

Your Order Information

Jack Slocum
His Holiness
3104694433
Jackslocum@me.com

Billing Information

N/A
333 Virginia St
apt 5
El Segundo, California 90245
United States

Shipping Information

Ship complete Via UPS Blue (2 Day Air) to the following address:

Jack Slocum
N/A
1136 SW Montgomery st
apt 317
Portland, Oregon 97201
UNITED STATES

Payment Information

Payment Method: By Credit Card
Credit Card Type: Mastercard
Credit Card Number: XXXXXXXXXXXX0802
Cardholder's Name: Jackson Slocum
Purchase Order Number:
Expiration Date: 04/2017
Your credit card will be charged $140.00

3/4/14 11:15 am Jack

Evan emailed back about brittle lacquer (StressKote):

Jack,

When I was a test engineer, at Freightliner, we used brittle lacquer prior to installing strain gauges if we weren't sure where the regions of high stress (actually, strain) were located on a part. we didn't always know the high strain locations for all load cases so we used the brittle lacquer to help us identify their locations. That saved us from putting 500 strain gauges on a part only to find out that 499 of them had low strain and were unnecessary. Or, worse, missing the high strain area altogether when placing the gauges.

Stresskote is the only manufacturer I know of and we always ordered the products directly from Stresskote. To my knowledge, there's nobody in Portland who routinely stocks it for sale.

Stresskote publishes documentation on how to use their products. Last time I looked, they had all of it available on their website. The documentation was pretty thorough.

The aerosol cans are perfect for small areas. At Freightliner, we used air spray equipment because we were coating large areas (frame rails & crossmembers) and it would have required several cases of the aerosol cans. The PSAS stuff is small enough that a few aerosol cans ought to be adequate, unless you're going to repeat the testing enough times to require a lot more Stresskote. Make sure you buy extra Stresskote -- there's nothing worse than getting in the middle of a project and running out of materials that: A) take days to be ordered and arrive, and B) require that the entire project be done under the same atmospheric conditions from start to finish.

There's two major tricks to getting good results from Stresskote:

1. The sensitivity of the lacquer (how repeatedly it cracks under a specified strain) is quite sensitive to the temperature of the part, the temperature of the air, and the humidity of the air. To get accurate results you need to:

- Clean the part thoroughly, get everything off the surfaces including the oils from your hands.
- Apply the lacquer in a climate controlled environment, where you can keep a constant temperature 24 hours per day. It's great if you can control the humidity too but that's usually not possible (unless the engineering building has good humidity control and you can do the entire project -- start t- finish -- inside the lab). An alternative way to control for the humidity is to make sure there are no major changes in the weather between the time you spray the lacquer and the time you apply the loads and read the crack patterns. At least the humidity conditions remain constant even if they're not fully controlled.
- Make sure you bring the parts to be lacquered into the climate controlled environment at least 24 hours prior to applying the lacquer. This will allow all the internal temperatures to equalize before you apply the lacquer.
- Stresskote sells the lacquer with different temperature ranges. To get the best sensitivity and repeatability, you need to use the Stresskote that's rated for the temperature at which you plan to paint and then load & analyze your parts.

2. If you want to use the Stresskote to actually measure the strain (rather than just using it as an indication of where the high strains are located on the part) then you will need to create a calibration bar

- The calibration bar must be made from the same material you're testing
- It should be lacquered at the same time that you lacquer your test parts, so that it undergoes the same cure cycle
- Stresskote sells a calibration fixture that the calibration bar is placed into when undergoing the calibration loading and analysis. You'll need to buy one of these if you intend to perform the calibration
- Stresskote has directions on how to load & analyze the calibration bars in their documentation
- Again, the calibration step isn't necessary if you're only using the Stresskote as an indicator to show you where to place strain gauges -- your actual strain measurements will come from the gauges. Calibration is only necessary if you are skipping the strain gauges and want high accuracy strain measurements directly from the Stresskote.

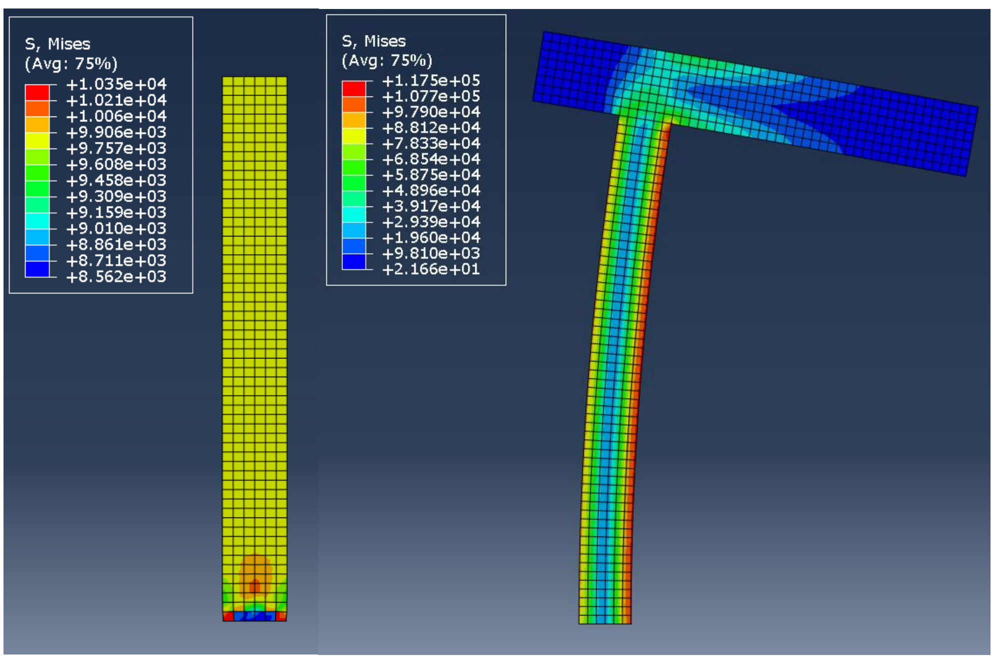
I don't have any experience with using Stresskote in purely compressive loading circumstances. Our materials all failed under tensile loading or fatigue loading (reversed stresses).

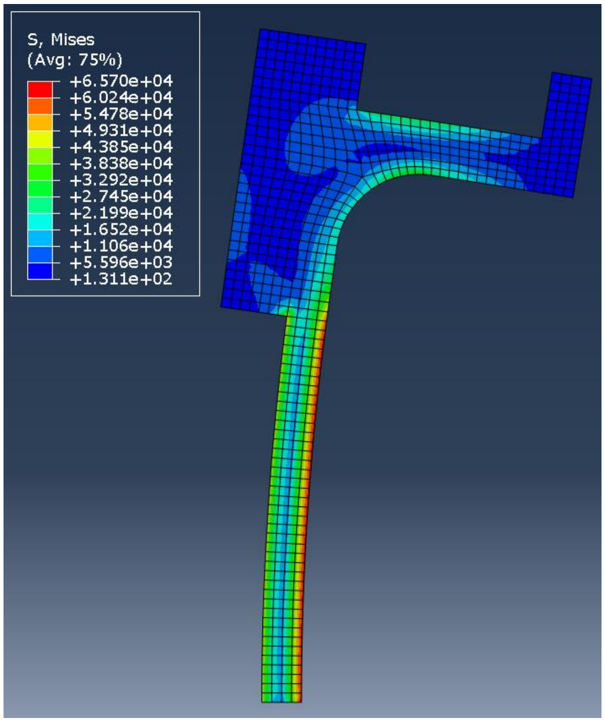
Most ductile materials don't fail by cracking under compressive loading, they buckle -- which is pretty obvious and easily detected without sensors. Compressive failure is typically a problem with brittle materials (e.g. concrete, glass, etc.). What kind of materials or application are you testing? I ask only because what you're planning to test may not be necessary and it might save you some time & money if you don't need to test.

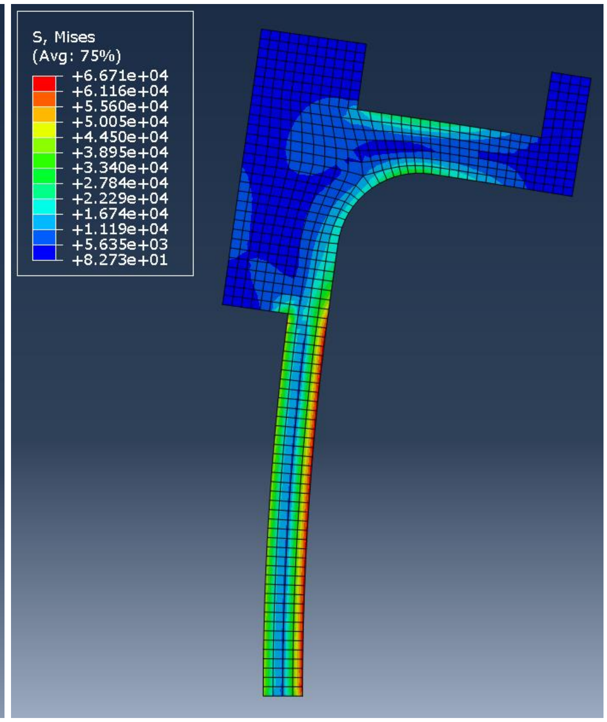
sincerely,
Evan Waymire

The guy from StressKote (Dave sales@datc.us 2625699789) gave me some information. He says for plastics we will need the plastic sealer, then the undercoat, then the stresskote. For the aluminum, we will just need the undercoat and stresskote. He says for parts in compression you need to cure the stressKote on it when it is loaded, and unload it to look at the cracks. I asked him how long this process would take and he made it seem like it would take a few hours to 24 hours at elevated temperatures. **This seems unreasonable for us in this test. Maybe on a different project.**

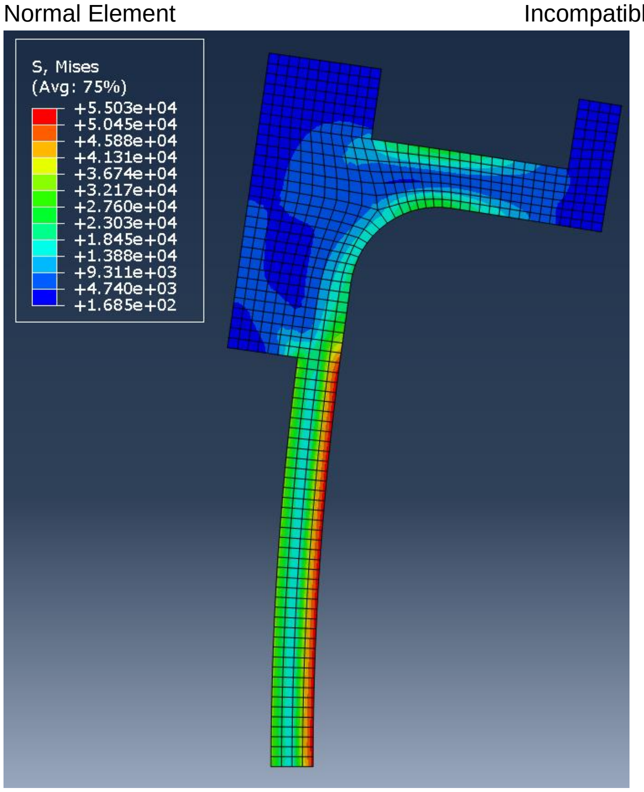
3/4/14 9:15 am Rob
Attempting to understand why the stress in small section is so high (an order of magnitude greater than simple pressure). All of the following have the equivalent of 2400 lb thrust load.







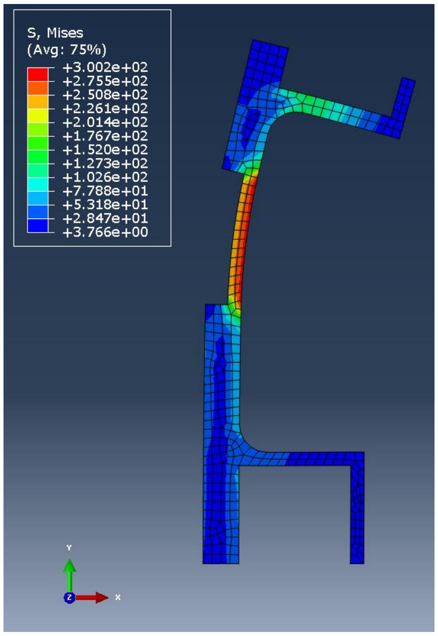
Normal Element Incompatible Element

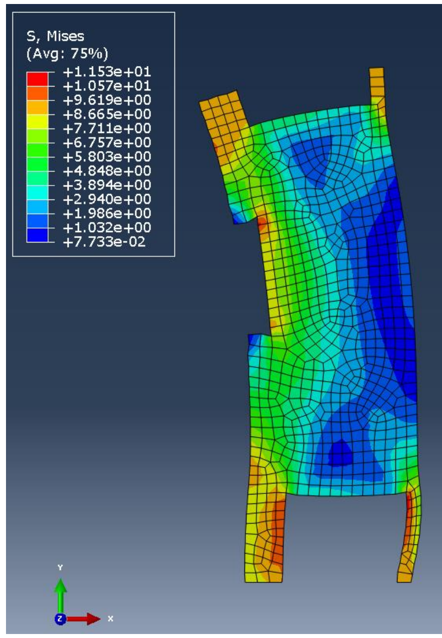


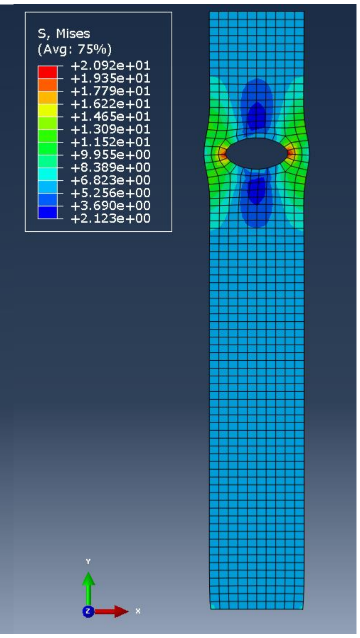
Reduced Integration Element

3/4/14 7:16 am Rob

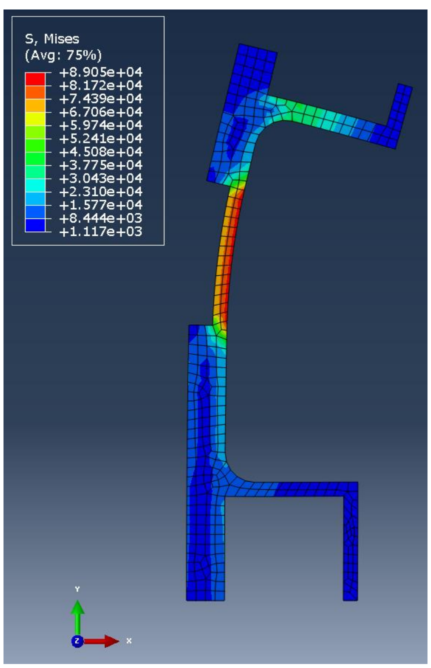
More awake and more confidence in results. One pound of force applied…

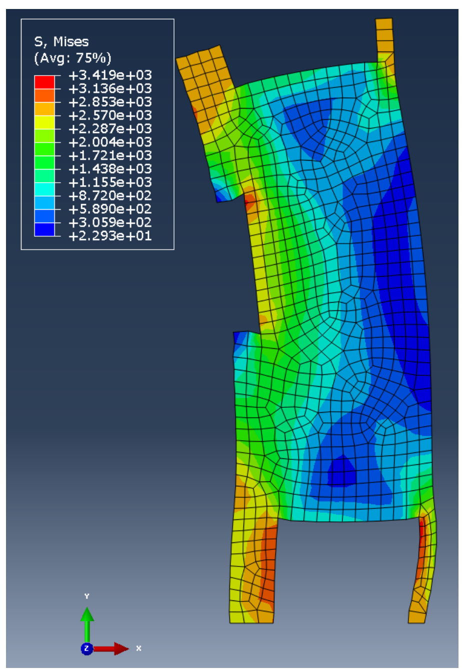


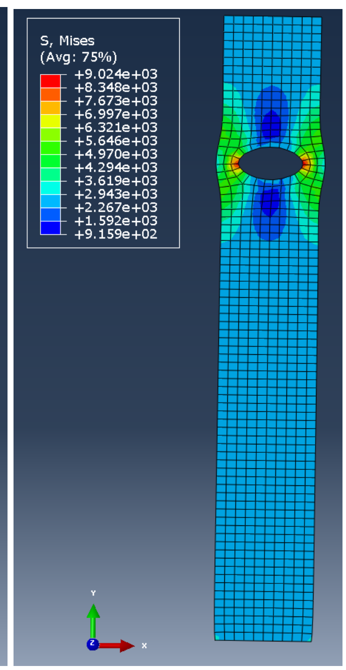




The total mating surface area of the MCR is 0.89 in^2. A 2400 lb load applied to this area is 2696 psi. The following are the results when 2696 psi is applied.







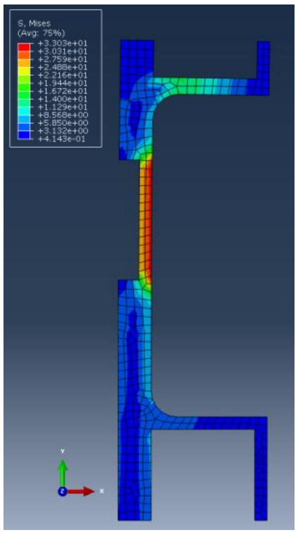
3/3/14 11:45 pm Jack

I emailed Evan Waymire asking questions about brittle lacquer (Stresskote). They sell it in an aerosol can for 75$. If it is as easy as spray painting the part, letting it dry, and then looking at the little crack patterns then I think we should do it. We could learn a ton from it, both on the rings and on the carbon shells. I'd like to somewhat validate the FEA models. That'd be so cool. Besides, I think this could be another tool in our toolbox that helps set us apart in knowledge.

If anyone doesn't know what brittle lacquer is, it is paint that is brittle so it cracks when the part is stressed. It forms strain fields, and you can measure the relative and absolute strain from it. You know the principal stress directions from that, and it looks like the pretty pictures from FEA. It's a little weird in compression, it's mostly a tension thing I believe, but I asked Evan for advice.

3/3/14 10:45 pm Rob
Quick and dirty FEA of MCR to FCR joint.

Unit pressure load on area of 0.11 square inches (0.11 lbs?), fixed at the bottom...33 psi max stress…stress concentration of 300?



3/3/14 4:23pm Jack, Sam, Rob
We machined 3 additional FCR, one of which will be the dummy FCR. This one is large enough that we can put all our strain gauges on it, and use it for multiple tests. These will be continued tomorrow morning. Still need 2 more females and 5 males, which is going to require at least another 7 inches of stock.

We borrowed 4 tools from Mike that make machining wayyy easier. We need a ⅜" radiused end mill with .0625" radiuses that is at least .65" tall. Ordered 2 of these cutters. Receipt below.

Radius endmill: http://www.mscdirect.com/product/73295719

We machined the PJ (Pocketing Jig). Machining the PVC was super easy. Program numbers (03031401, 03031402). We should consider PVC for all our future jigs. The pinned holes were hand reamed to .251 and the pins slide nicely in and out.

* First Name: jack
* Last Name: slocum
Company Name:
Phone Number: (310) 469 - 4433 Ext: 44
* Email Address: Jackslocum@me.com
* Confirm Email Address: Jackslocum@me.com

Please email me about special offers and promotions.

* Username: jgs11 Check Availability
Minimum 5 characters.
* Password: ••••••••
Password is case-sensitive, must be at least 7 characters, and must include at least 1 number and 1 letter.
* Confirm Password: ••••••••

Order Information

Customer Information
Customer Name: jack slocum
Company Name: jack slocum
Account Number:

Shipping Address
Samuel Arnold
2109 NW IRVING ST #112
Portland, OR 97210
United States
541-510-9557
Tax Exempt: No

Shipping Method
Your item(s) will be shipping from the location(s) below
1 item Standard Ground 2 days from NV

VIEW DETAILS

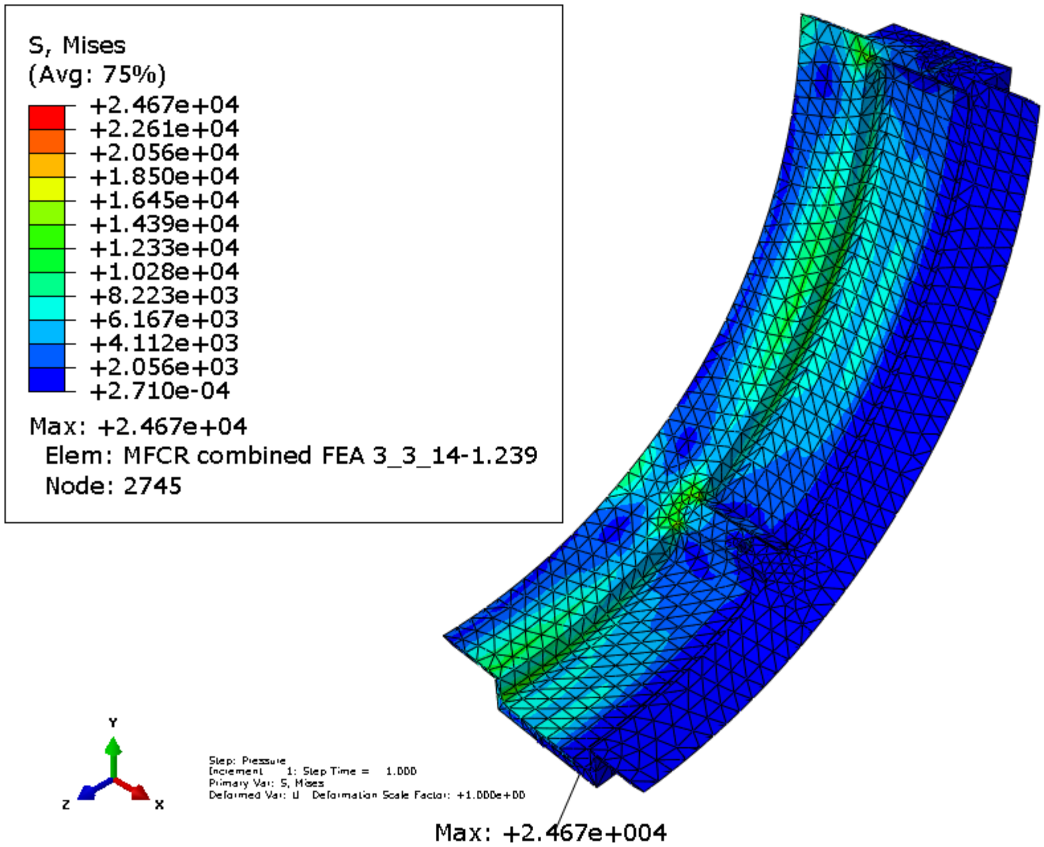
Billing Information
Card: Jacks Card
Mastercard: ************0802
Expires: 04/2017
Total:$109.26

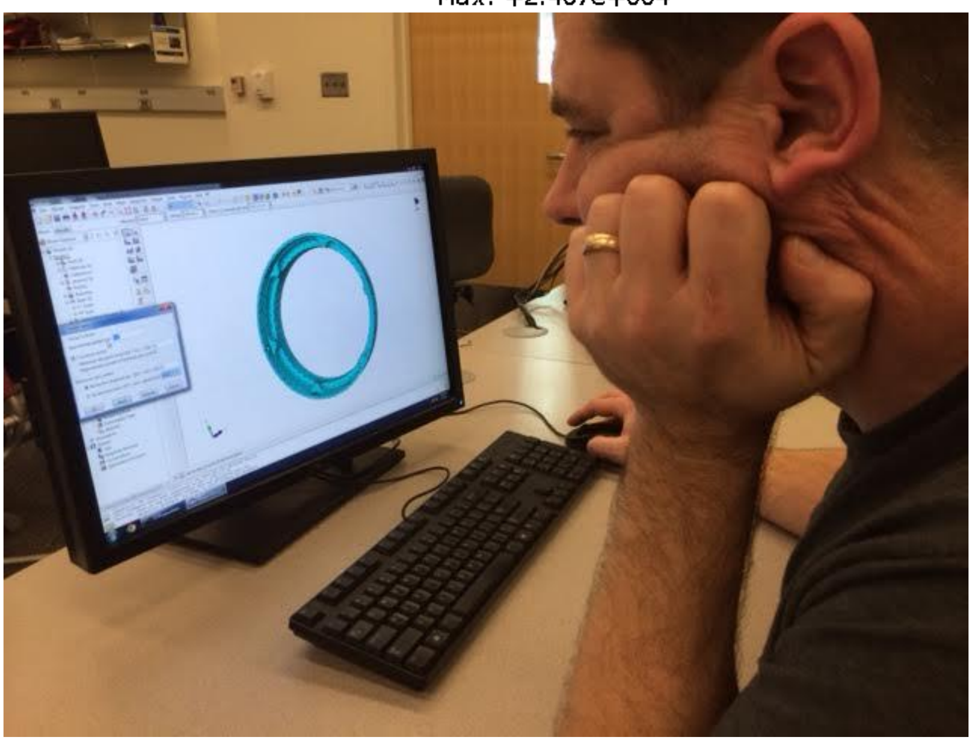
Purchase Order Number:

jack slocum
333 Virginia St
Unit 5
El Segundo, CA 90245-2967
United States
310-469-4433

3/3/14 4:23pm Jack, Barett, Rob

After "combining" the MCR & FCR into one part, we were able to conduct a static analysis study. Due to the maximum allowable number of nodes (20,000) in student FEA we had to do a quarter model. The CF adhesion surfaces on the MCR were constrained in XYZ and the CF adhesion surface on the FCR were given a Surface Traction load in Shear with a value of 156 PSI. This was calculated by dividing the estimated 2400 lbf load by the CF adhesion surface area. We believe that the values represented by the colors below orange are reasonable.

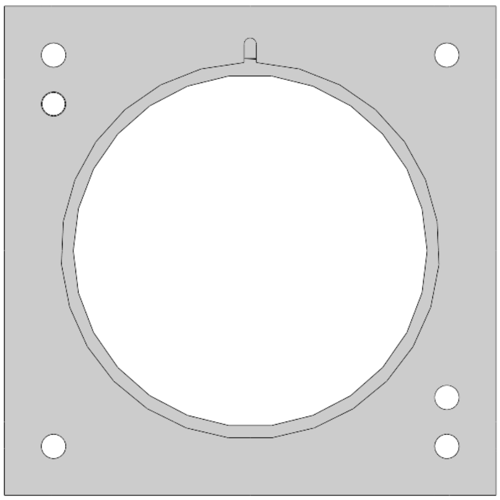


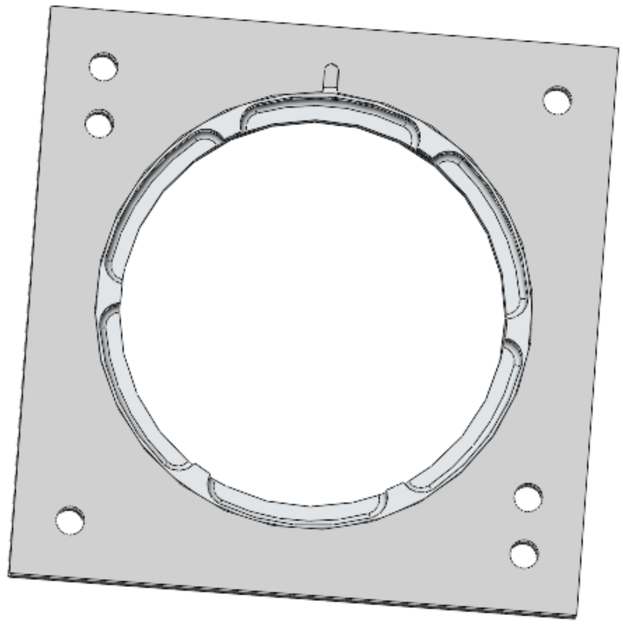


3/3/14 3:50pm Jack

We had to create a single part that was the combination of the assembled rings so we could put it into FEA. We eventually got the part to work, but the analysis of it isn't working very well. We are trying to cut it in half now. The contact model was way too hard. It was never going to work, so we switched to the one part model.

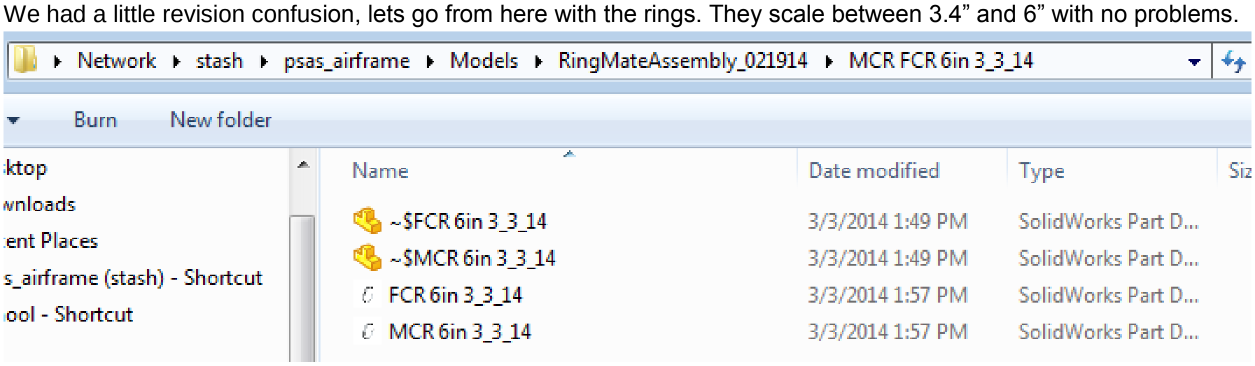
3/3/14 3:10pm Jack
Changed some aspects of the jig. We added a little pin slot so we can line up the radial holes. We also added a pin hole to align the top and bottom plates.

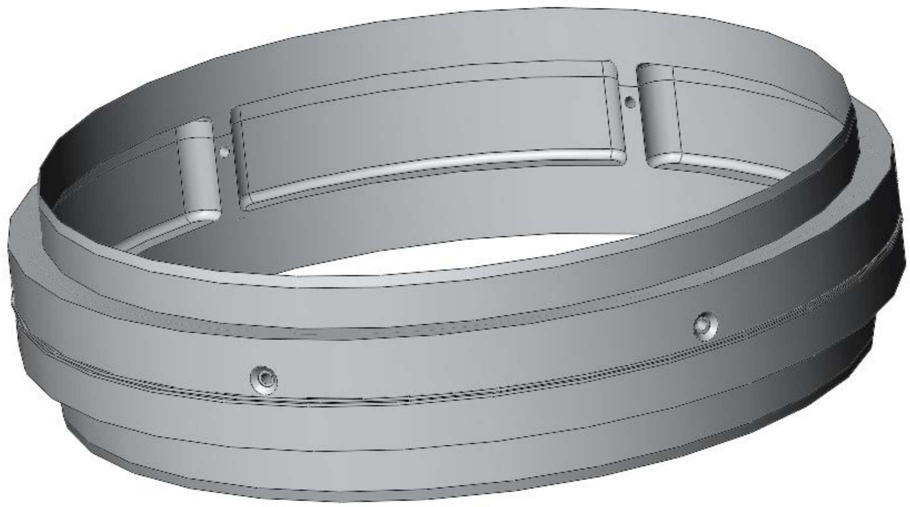




3/3/14 2:10pm Jack
Barett machined the third mandrel to the 3.4" OD +.003". We are ready to layup on the 3 mandrels.

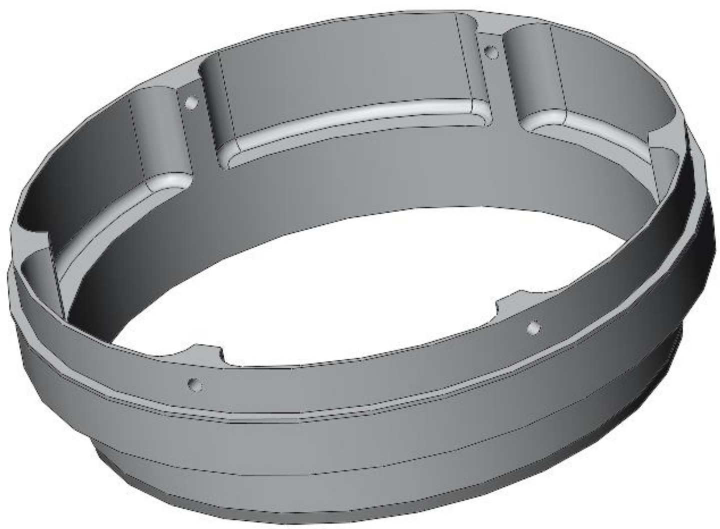
3/3/14 2:00pm Jack
The new 6" rings weigh .22lbf per module. Without the pocketing they would weigh .48lbf. **This is a 58% weight reduction in ring weight.** The screenshot below is the 6" rings in an assembly. This part is ready for manufacture. We had a little revision confusion, lets go from here with the rings. They scale between 3.4" and 6" with no problems.





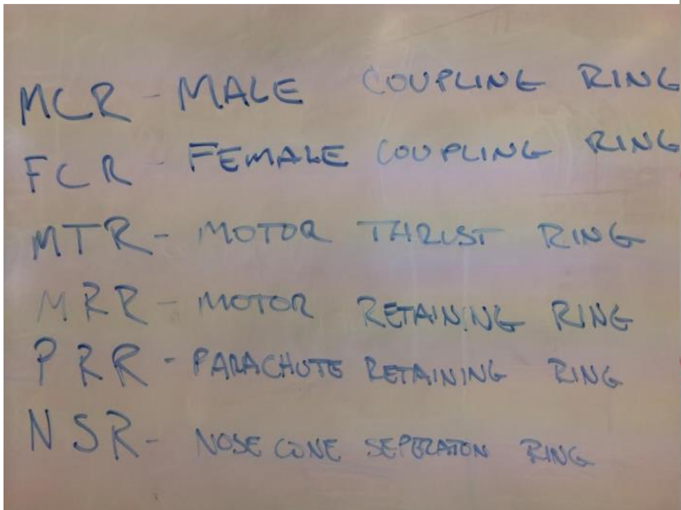
3/3/14 1:10pm Jack

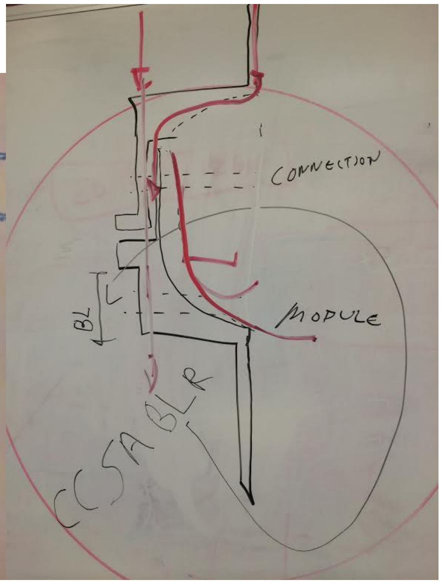
Drew up the new idea for MCR, FCR (Male coupling ring, female coupling ring) that we discussed at this mornings meeting. Both the new rings together now weigh .13lbf, less than half of what they did before.

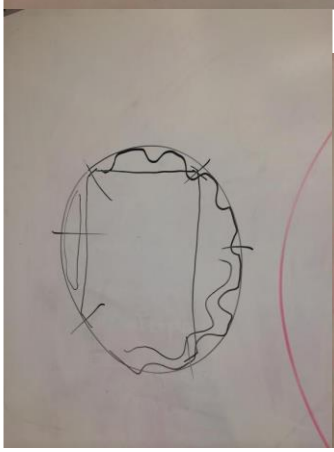
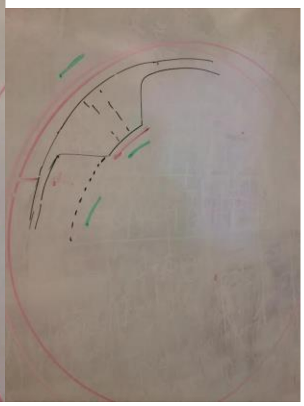


3/3/14 12:00pm Jack, Barett, Rob, Sam
After a long meeting, decided on how to move forward.
To-do:

- Draw new ring design
- Run FEA on new ring design
- Machine more rings
- Source ring material and jig material
- Machine third mandrel
- Order strain gauges

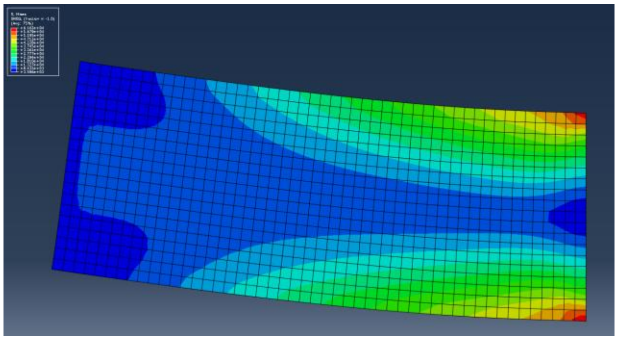


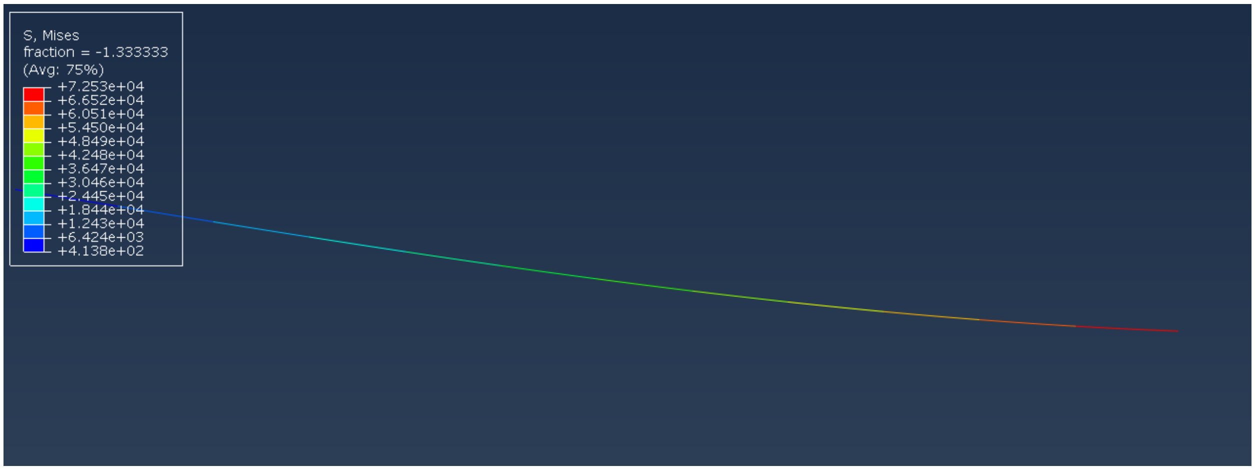


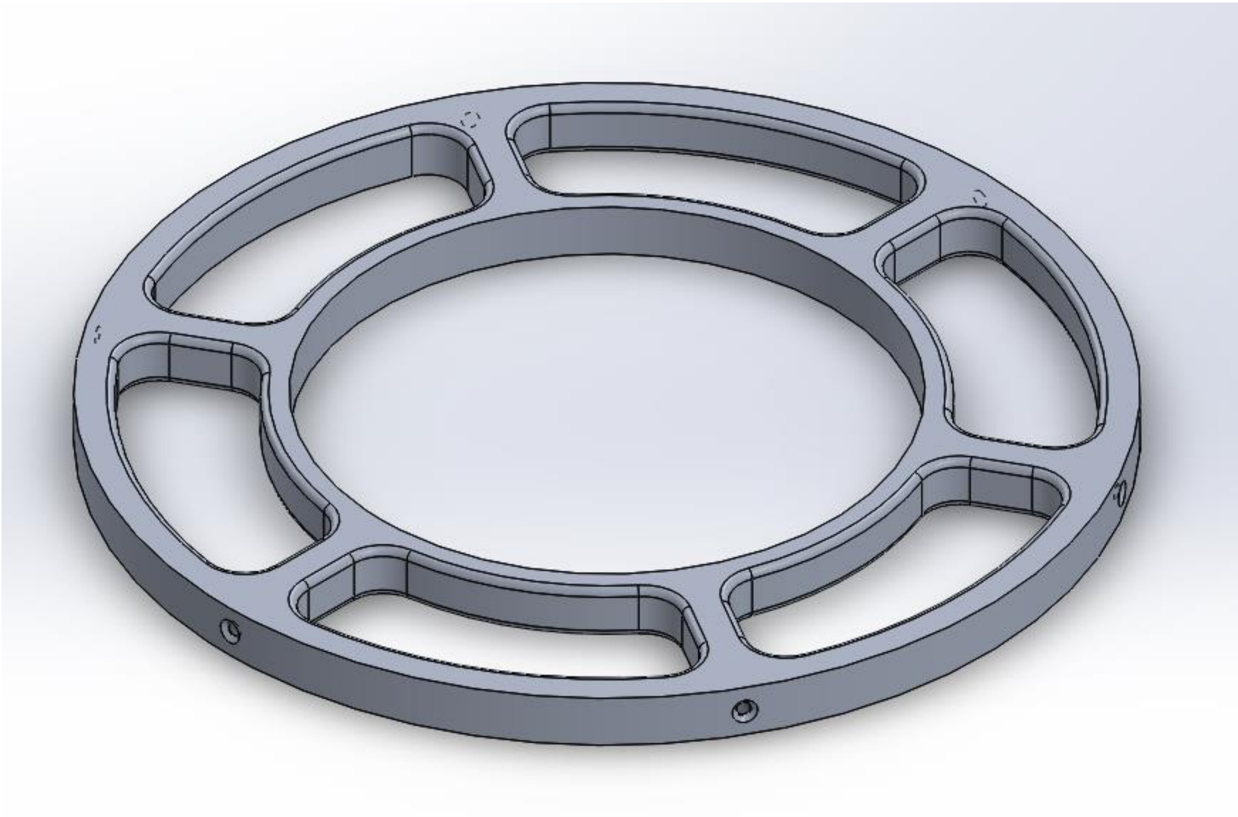
3/3/14 8:18am Rob
Summary
After doing an apples to apples comparison of an open and closed MTR made of 7075 T6; a 6" MTR with 2400 lb thrust capacity weighs 0.32 lbs for the open design and 0.36 lbs for the closed design.

I was investigating the difference between an open and closed MTR and I discovered that in my original analysis that I did not scale the load as I increased the height of the spoke. This resulted in excess load being applied to the spoke. I have re-run the analysis and the minimum spoke size for the trust mounting ring is 0.35” (tall) x 0.30” (wide) when using 7075 T6.



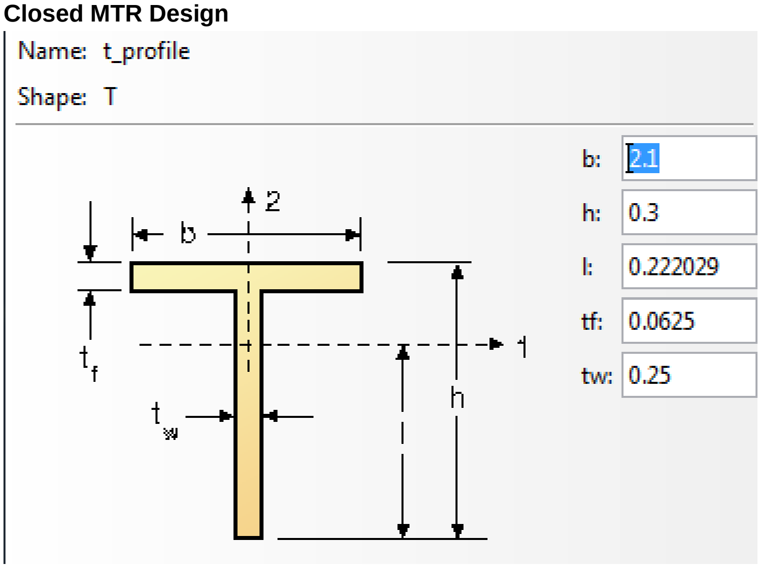


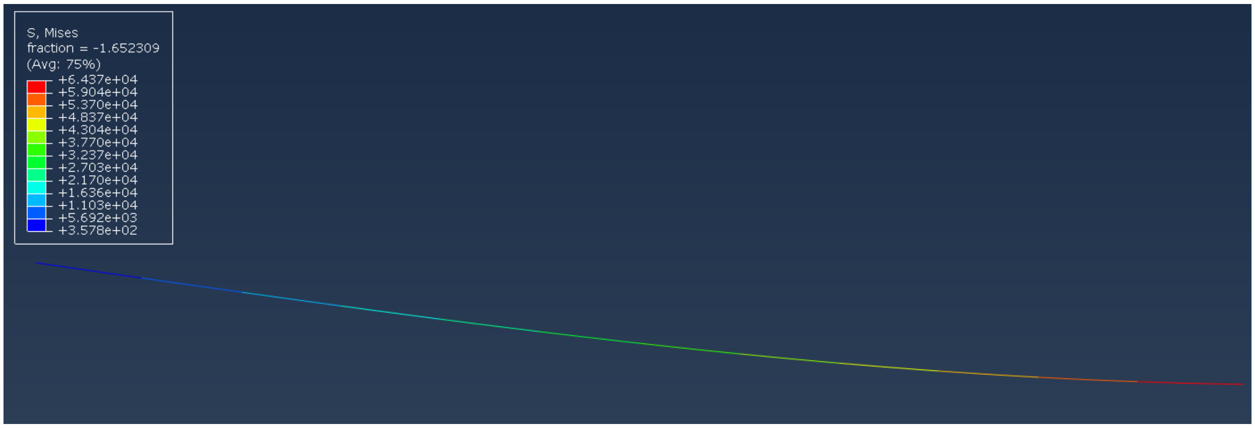
Both shell and beam analysis return similar results. Based on the above; this is the minimum open MTR design:



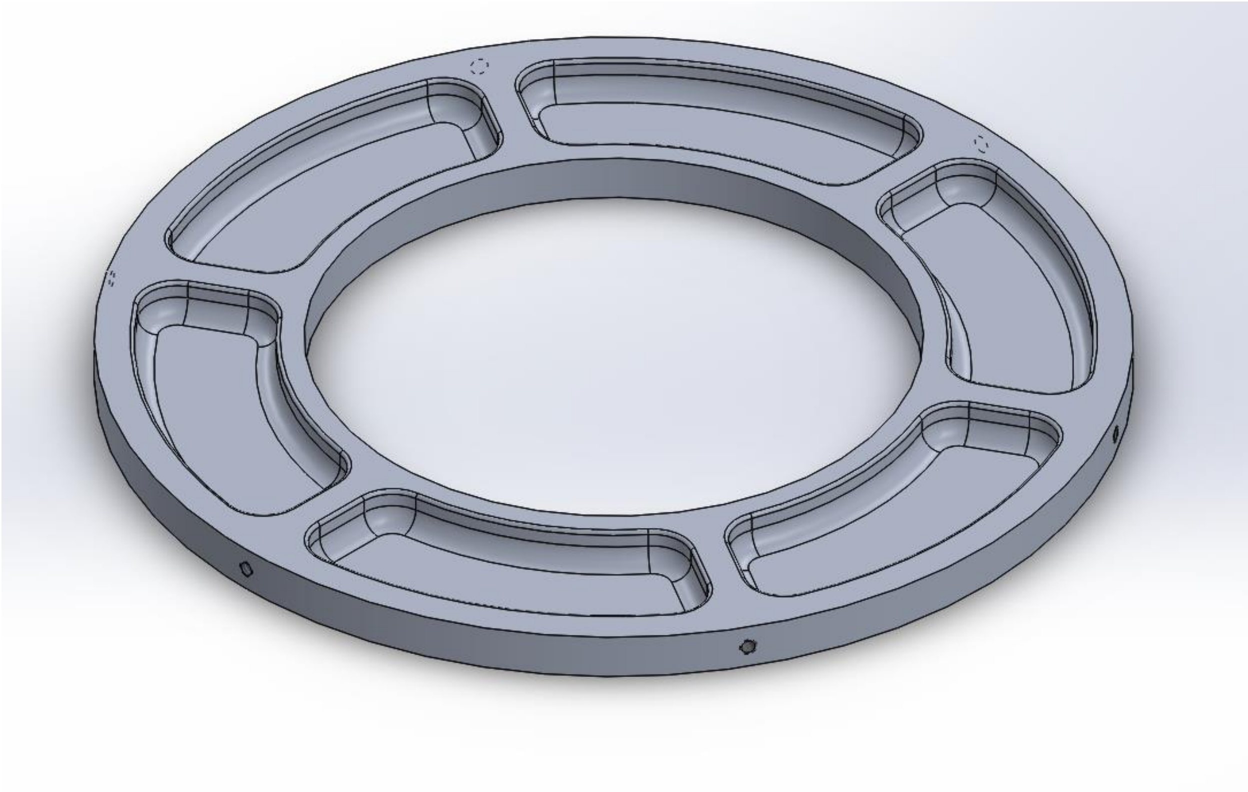
6” Open MTR 7075 T6 (0.32 lbs) 2400 lb thrust capacity

Closed MTR Design





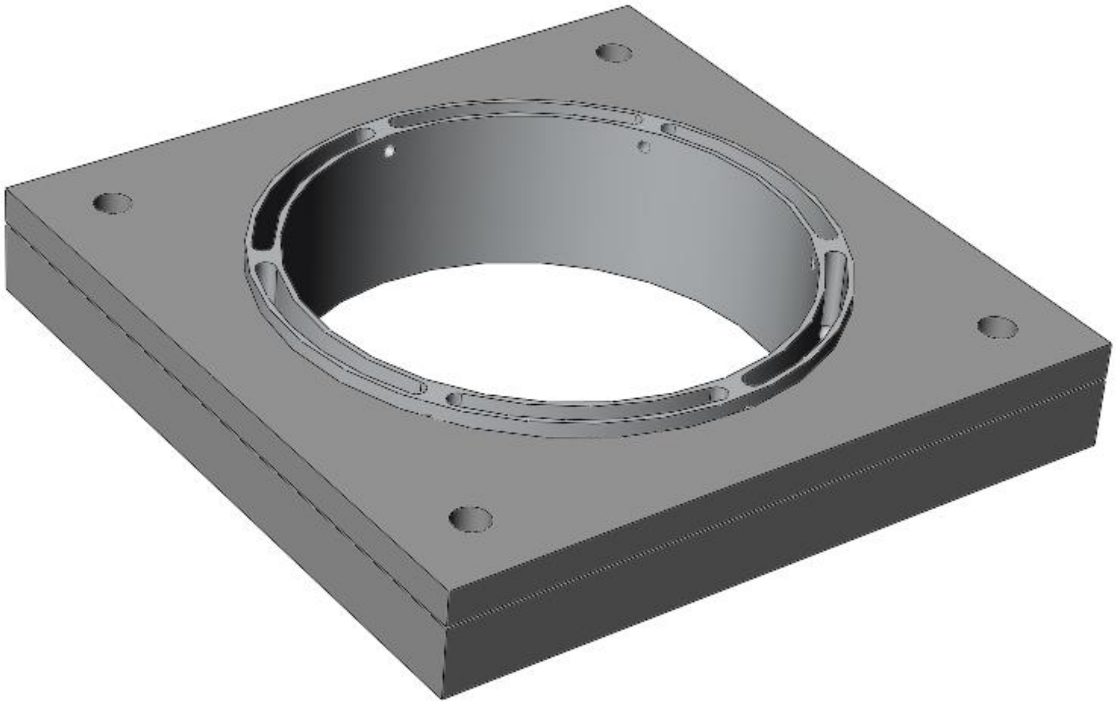
Based on the above; this is the minimum closed design

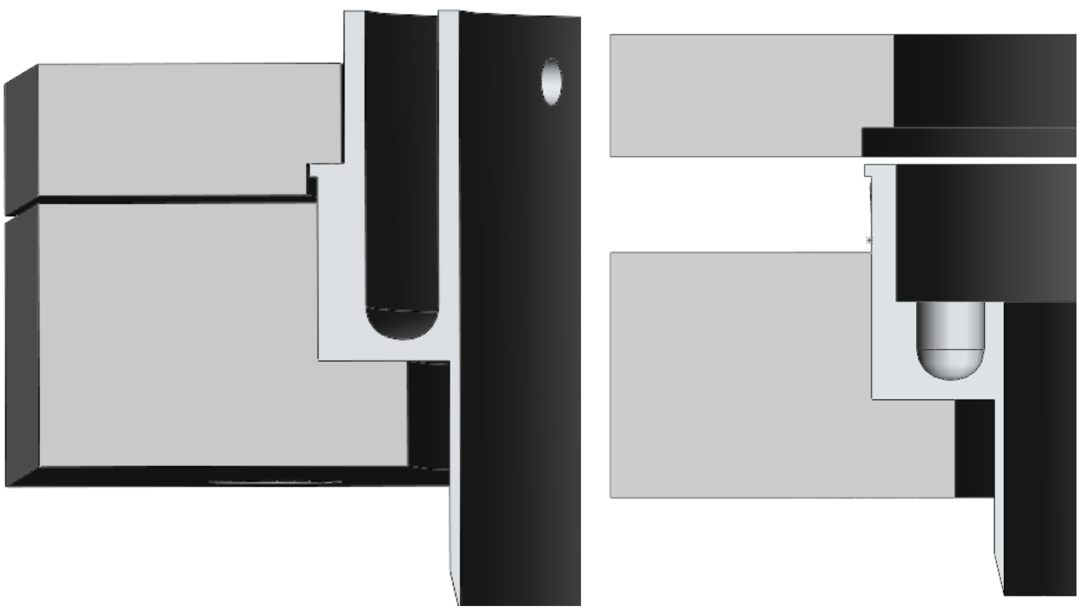


6" Closed MTR 7075 T6 (0.36 lbs) 2400 lb thrust capacity

3/2/14 6:40pm Jack

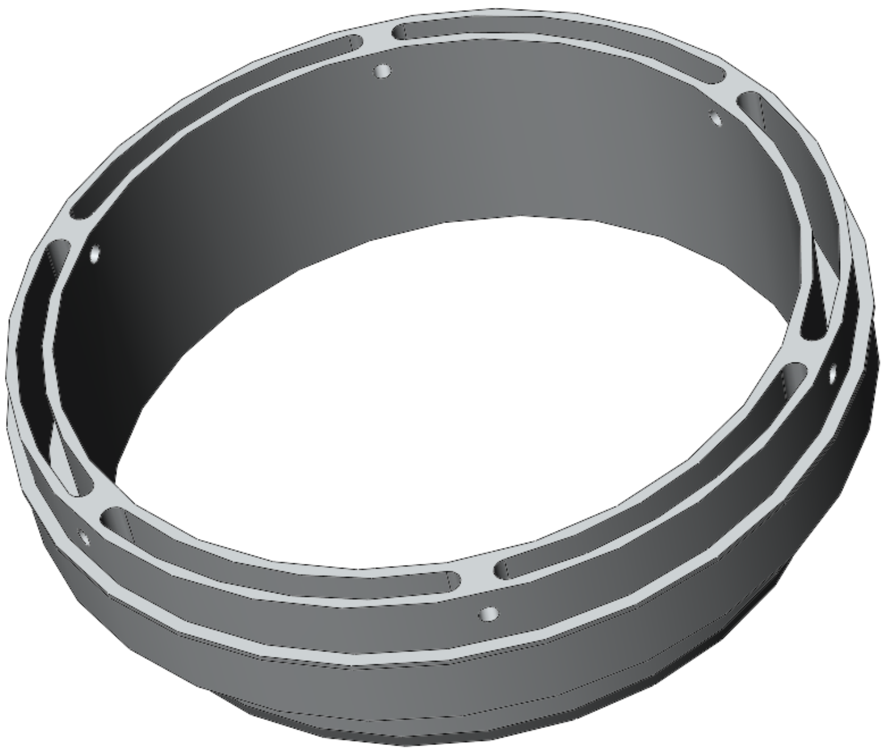
Trying to figure out a way to hold the rings in the vice so we can CNC pocket them. This one jig would work for both upper and lower rings. It should be made from some plastic like UHMW, PVC or nylon.

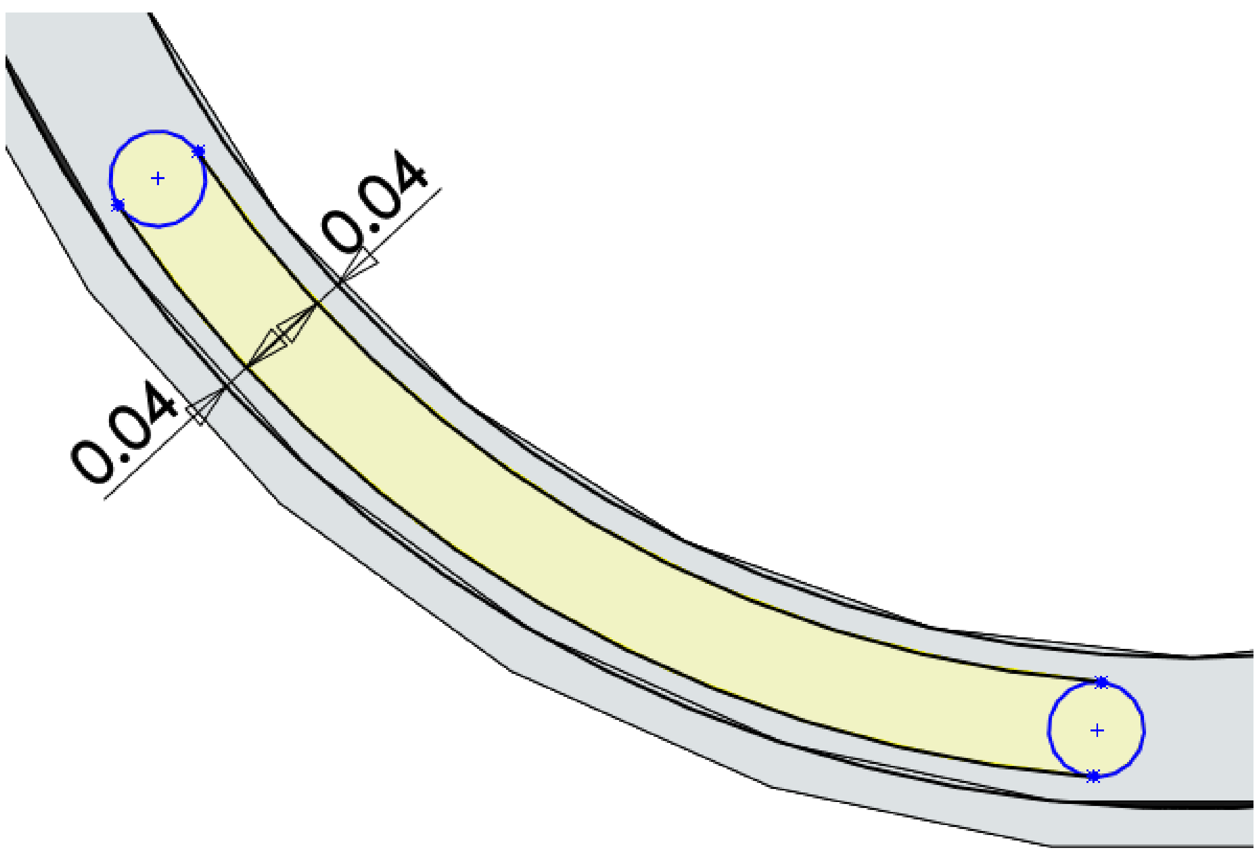




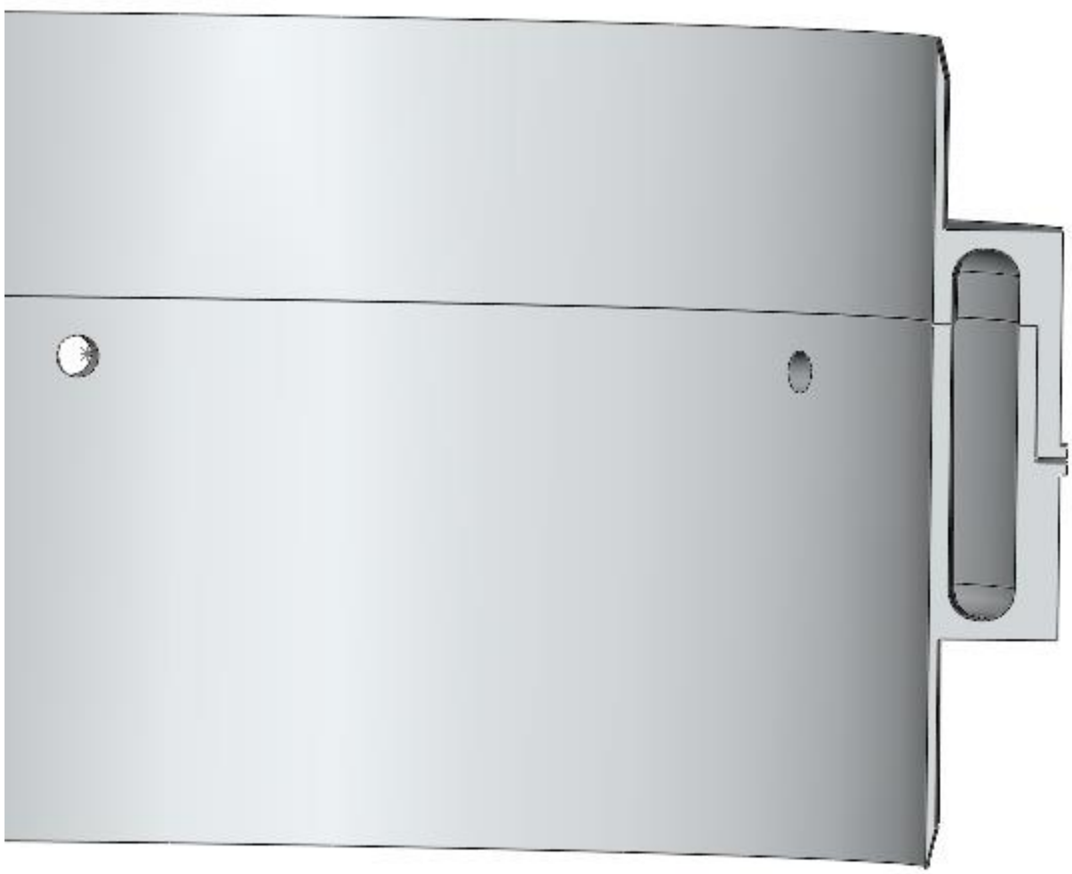
3/2/14 4:40pm Jack

This is one concept for reducing the weight. Weight of the ring is currently designed without any lightening is **.19lbf**. This geometry could easily be ported to a plastic/3D printed design, because the stress is super low. We could add extra ribs for rigidity. Assembly weighs .28lbf before, with pockets weighs .17lbf.




0.04
0.04

Pocket wall thickness (in)	Weight (lbf)	Cross sectional area (in^2)	Stress at 2400lbf (psi)
.05	.11	1.31	1800
.04	.1	1.03	2300
.03	.09	.81	3000



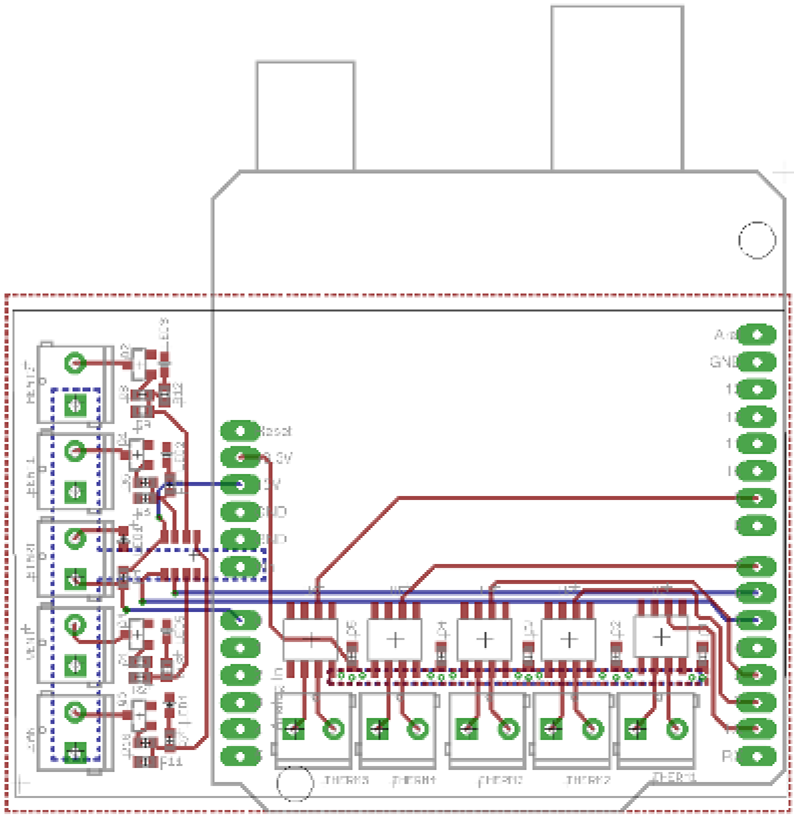
The current thinking on the electronics carrier is 8 holes, but we could change the geometry a little bit and have it be 6. this would change the aspect ratio of the electronics holder, but I think it'd be okay.

3/2/14 1pm Jenner
I've got the LCD shield working with graphics code along with our oven control code. I'll demo Tuesday. I'd like to talk user interface then too.
Cool! -Jack

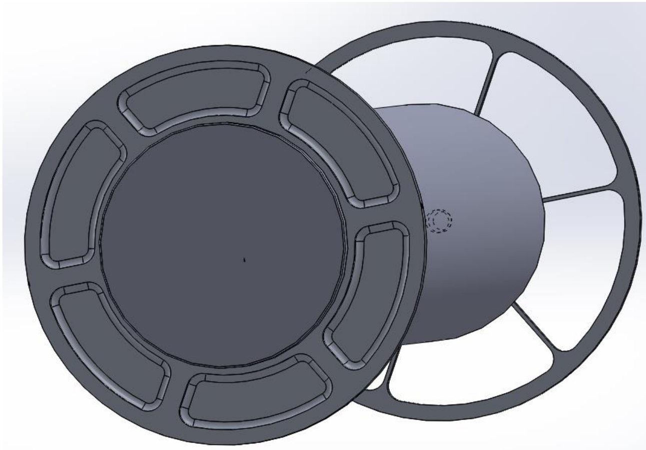
3/2/14 11:40am Jenner, Tung
Tung and I have been working on the final version of the control shield. I'm not sure about the FET yet but this is the general approach for the board. It's a middle board, remember, so access to the headers is an issue. This board size comes out to about $20 for three from OSHPark and moving them inside the Arduino in that open space only saves about a dollar so I prefer this way. Board dimensions are 2.8"x1.7".

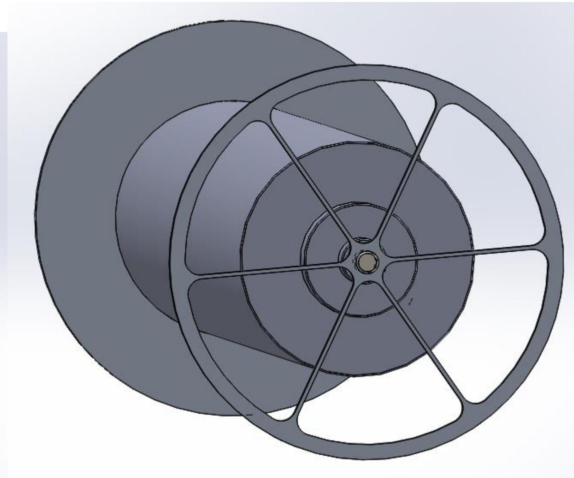
- The five connectors on the left are the relays and the start/stop header.
- ~~There's a single 2:4 8-pin multiplexer chip.~~ Ignore it. We'll just use A1 and A2 for the other relays and wire them directly, since we can use analog pins as digital I/O.
- The three-pin chips are itty bitty FETs. (this is the current question.)
- The five connectors on the bottom between headers are the thermocouple headers.
- They each have a MAX31855 chip of their own.

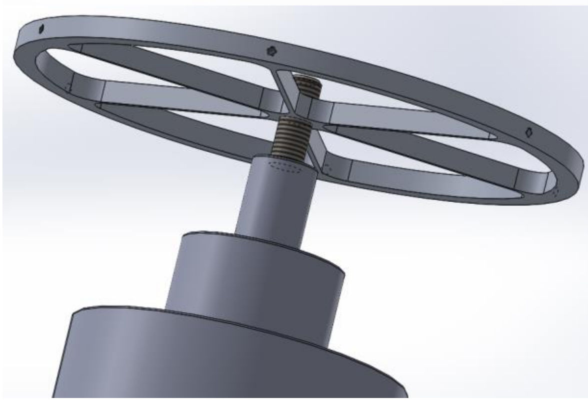
Once we do another review, I'll spin a revision of the board in the EPL to check sizes and then we'll be OK to order it. OSHPark has a 2-week turnaround time for 2-layer boards. It's totally possible to have this thing in the oven control box by the end of March.



3/2/14 7:59 am Rob
Motor Mounting Summary
This is my concept for mounting the motor casing in the rocket. It consists of two rings: Motor Thrust Ring (MTR) and the Motor Retaining Ring (MRR). The rings are made of 7075 T6 aluminum. The MTR weighs approximately 0.41 lbs and has a capacity of 2400 lbs of thrust. The MRR weighs approximately 0.15 lbs and has a capacity of approximately 150 lbs.



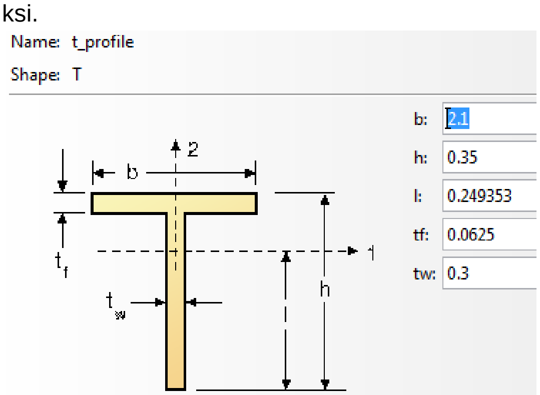


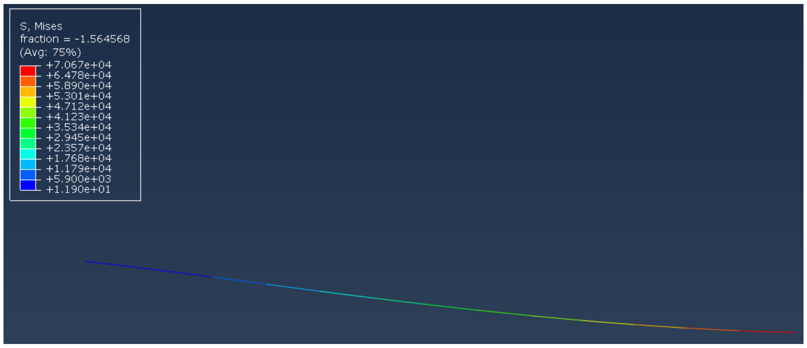


Note: For reference I modeled an open MTR with 0.5 x 0.5 inch spokes. It weighs 0.51 lbs; this quantifies the benefit to using the closed design. That is 0.51 lbs vs 0.41 lbs, 0.1 lb savings and there is a nice diaphragm to mount strain gauges as a bonus. So that is not quite apples to apples: The 0.5 x 0.5 is required for 6061 T6 and the closes design is using 7075 T6 so the difference will be smaller.

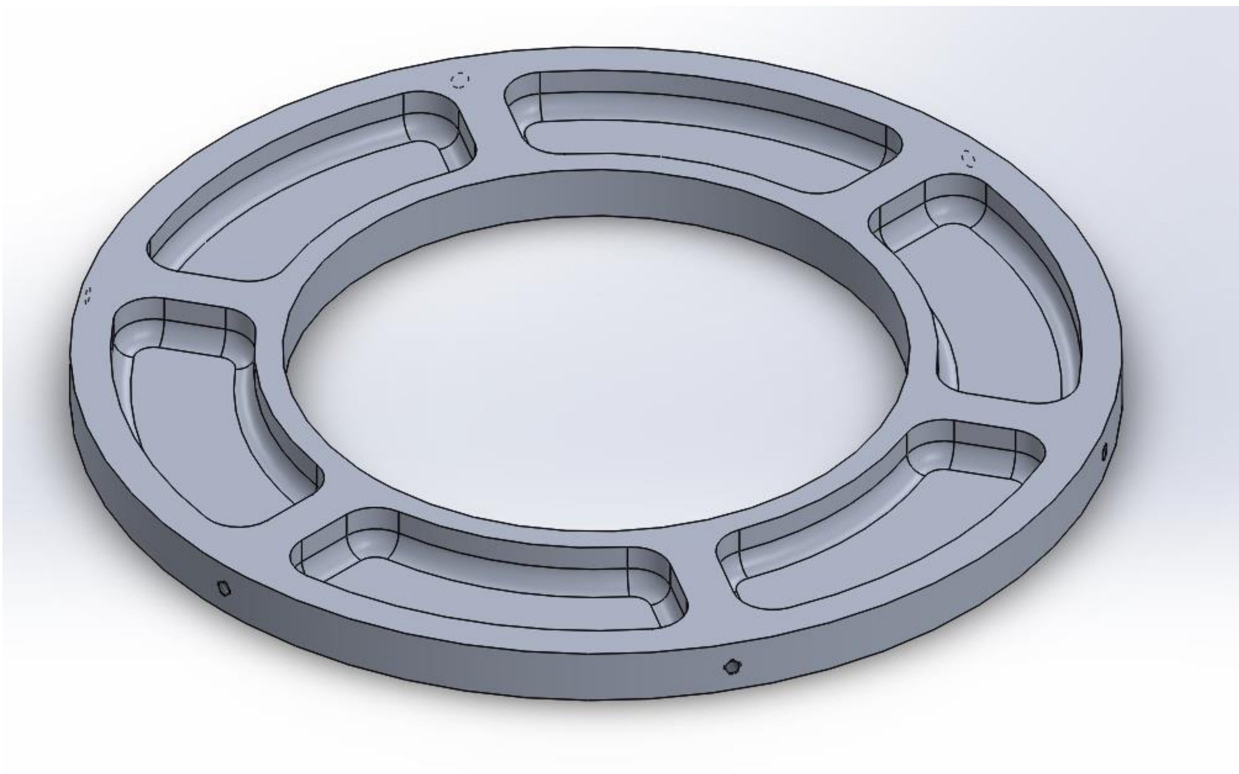
3/1/14 8:44 pm Rob

I did some shape optimization of the trust ring spoke and switched the material to 7075 T6 with a yield strength of 70 ksi.





6” Motor Trust Ring (MTR) based on optimum geometry (0.41 lbs) 2400 lb thrust capacity
Th



3/1/14 5:50pm Jack
We could start looking at engineering plastics. This seems super late in the game to try and redo all of our adhesive testing. Unless we can get a plastic alternative very soon ideally before our measurements project. That’s a quick turnaround, but maybe possible.

For a 1000 pound load on the design we have now on the 2.5in^2 area we have now, that is 400PSI. If the 1000 pound load is solely carried by the thinner inside .02” fin, the stress would be 4500PSI. These are only part of the story, but goes to show the order of magnitude we are likely dealing with. It appears engineering plastics have potential.

Peek
Density: 1320kg/m^3
Tensile strength: 14000 psi to 24000 psi when glass bead filled

Notes: Internet says it is expensive, but I haven't gotten a price yet. Will work at elevated temperatures. This theoretically could easily hold up to the

Aluminum
Density: 2700 kg/m^3
Tensile Strength: 40000psi

Magnesium
Density: 1700 kg/m^3
Tensile strength:

Beryllium
Might be toxic.

Data Sheets:
Peek
Nylon
ULTEM, Buying ULTEM in portland

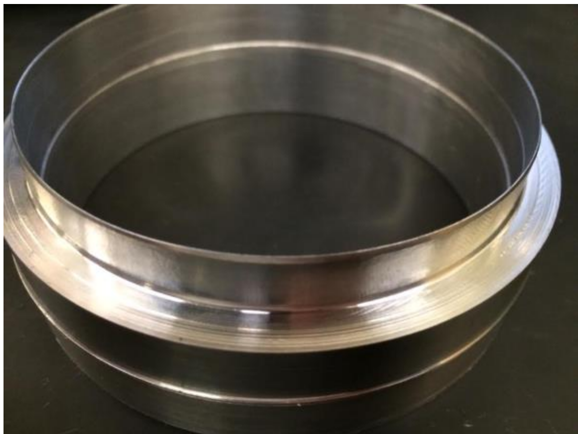
3D Printing:

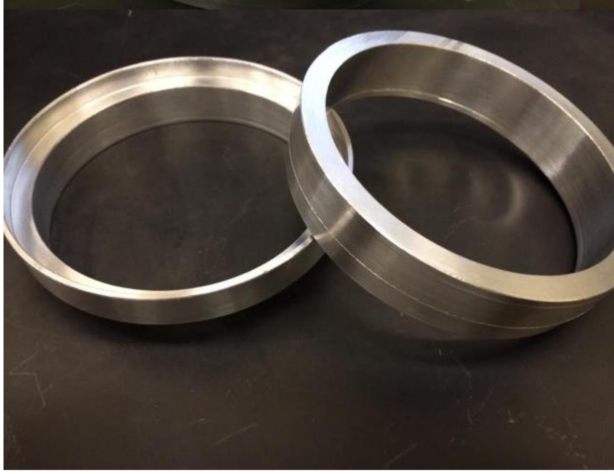
Stratasys:
Stratasys 3d printing Ultem
Ultem material specs
Stratasys machines 3D print ULTEM. This could work for us. I think we could find someone with their machine. It says its glass transition temperature is 367F, I'm not exactly sure what that means as far as we are concerned. I'd say lets test a piece of it with our glue and see what happens. http://en.wikipedia.org/wiki/Glass_transition

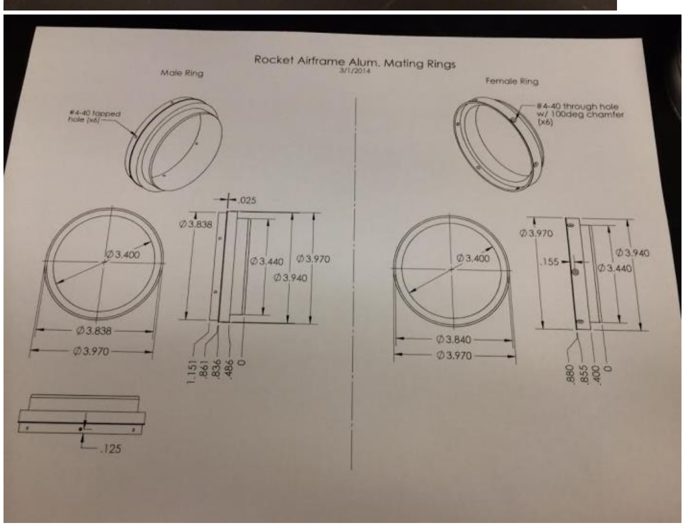
3D Systems:
The people that help Weislogel out with 3D printed parts use 3D systems machines. Looking through their suite of materials I'm finding some that are borderline okay for us. I got a "Quick Quote" for $330. I filled out the form to get an engineering sample "within 3 days" of Duraform EX. I texted Brandon, he says they probably won't have the material around right now. He is going to ask around to see if he can get these for us. I told him we are in a hurry, so we will see. It all looks not too promising. Our best bet might be NW Rapid or Weislogel.
Duraform HST Composite
Duraform EX plastic
Duraform PA

There is always still the option of buying something like ULTEM and machining it ourselves, though that doesn't seem preferable. It might still be better than aluminum.

3/1/14 5:30pm Jack
Sam and I made rings for our measurements project. We made one female ring, and one male ring that will sit at the bottom. It was going to be the strain gauge test fixture, but it is not really tall enough to fit the strain gauges. It will work fine as the same thing except on the bottom, without gauges. **The first thing that comes to mind when you pick up the male ring is holy god this is way too heavy**. The female seems like what the weight should be like. We should seriously look at an alternative solution to aluminum.







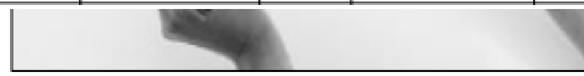
2/29/14 3:00pm Jack

I am trying to answer the question that Weislogel alerted us to which was if the large temperature swings will compressively fail our core. I believe we have something like the highlighted core here. I will use these numbers for my analysis.

HRH-10 Aramid Fiber/Phenolic Resin Honeycomb

Hexcel Honeycomb Designation Material – Cell Size – Density	Compressive					Plate Shear					
	Bare		Stabilized			L Direction			W Direction		
	Strength psi		Strength psi		Modulus ksi	Strength psi		Modulus ksi	Strength psi		Modulus ksi
OX-Core											
HRH-10/OX – 3/16 – 1.8	100	80	110	90	7	50	40	2.0	60	50	3.0
HRH-10/OX – 3/16 – 3.0	320	260	350	285	17	105	95	2.5	120	100	6.0
HRH-10/OX – 3/16 – 4.0	600	500	650	550	26	130	105	4.6	150	130	8.4
HRH-10/OX – 1/4 – 3.0	350	280	385	310	17	110	90	3.0	135	110	6.0

Coefficient of Thermal Expansion



Honeycomb will change its dimensions slightly when subject to a change in temperature. The change in dimensions as a function of temperature is determined by the substrate material. Coefficients of thermal expansion in the thickness direction for various honeycomb materials are as follows:

Honeycomb Core	Coefficient of Thermal Expansion (inch/inch – °F)
CR III, CR-PAA, 5052, 5056, ACG Aluminum	13.2×10^{-6}
HRP, HFT, HRH-327 Fiberglass	8.2×10^{-6}
HRH-10, HRH-310, HRH-78 Nomex	19.4×10^{-6}
HRH-49 Kevlar	2.7×10^{-6}
HFT-G Carbon	2.0×10^{-6}

Specifically Find:

A) What is the safety factor for core compressive failure from 70F to 250F?

B) What DeltaT will fail the core?

Summary: The more important question to answer is part B, which is what change in temperature will fail the core. Answer: 736F swing. So our part cures at 350F, so it could swing down to -360F before the core failed. Part A says that between values in the range it could see in the lower atmosphere 70F to 250F it is 4 times stronger than that stress.

The temperature of space isn't a single number, it is dependent on other things as seen here. It is most dependent on whether or not the sun is hitting you, and what values for radiation heat transfer you have. Wikipedia also offers some help (below). It appears shit gets weird when you get up to these atmospheres, saying "the gas particles are so far apart that its temperature in the usual sense is not very meaningful. The air is so rarefied that an individual molecule travels an average of 1 km between collisions with other molecules."

It continues to get weirder, when things like radio communications bounce off of things, and other electrical things happen including lightning. Reaching into the base of the ionosphere.

This analysis showed that weislogel was right about it being close to the edge of failure, especially when talking about a black part that is designed to capture solar energy.

Mesosphere

Main article: Mesosphere

The mesosphere is the third highest layer of Earth's atmosphere, occupying the region above the stratosphere and below the thermosphere. It extends from the stratopause at an altitude of about 50 km (31 mi; 160,000 ft) to the mesopause at 80–85 km (50–53 mi; 260,000–280,000 ft) above sea level.

Temperatures drop with increasing altitude to the mesopause that marks the top of this middle layer of the atmosphere. It is the coldest place on Earth and has an average temperature around −85 °C (−120 °F; 190 K).[9][10]

Thermosphere

Main article: Thermosphere

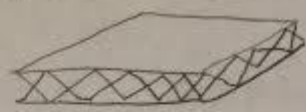
The thermosphere is the second-highest layer of Earth's atmosphere. It extends from the mesopause (which separates it from the mesosphere) at an altitude of about 80 km (50 mi; 260,000 ft) up to the thermopause at an altitude range of 500–1,000 km (310–620 mi; 1,600,000–3,300,000 ft). The height of the thermopause varies considerably due to changes in solar activity.[6] Since the thermopause lies at the lower boundary of the exosphere, it is also referred to as the exobase. The lower part of the thermosphere, from 80 to 550 km above Earth's surface, contains the ionosphere.

This atmospheric layer undergoes a gradual increase in temperature with height. Unlike the stratosphere, wherein a temperature inversion is due to the absorption of radiation by ozone, the inversion in the thermosphere occurs due to the extremely low density of its molecules. The temperature of this layer can rise as high as 1,500 °C (2,700 °F), though the gas molecules are so far apart that its temperature in the usual sense is not very meaningful. The air is so rarefied that an individual molecule (of oxygen, for example) travels an average of 1 kilometer between collisions with other molecules.[8] Even though the thermosphere has a very high proportion of molecules with immense amounts of energy, the thermosphere would still feel extremely cold to a human in direct contact because the total energy of its relatively few number of molecules is incapable of transferring an adequate amount of energy to the skin of a human. In other words, a person would not feel warm because of the thermosphere's extremely low pressure.

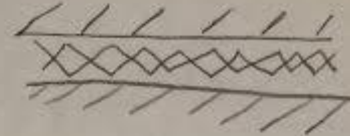
Conclusion: I think we will be okay, and if for some reason it turns out we are not okay, we can up the core density which would increase the strength 3.5x, but only increase the modulus 2.5x. Or we could switch to a different material honeycomb, which have half or 1/10 the thermal expansion coefficient.

Discussion: Part of this analysis seems impossible to do, because our core is cured at 350F, all these simulations were run with the compressive strength, as opposed to the tensile strength. The core manufacturers don't list that strength, though it is likely even higher than compressive. Because there are some questions left in our mind, it does seem wise to put a part in 350F and then put it in our freezer at 0F, and then buckle to make sure it isn't losing its strength.

CARBON - HONEYCOMB SANDWICH



SCHEMATIC FOR ANALYSIS



GIVEN

HRH-10 ARAMID - PHENOLIC OX CORE PROPERTIES:

COMPRESSIVE: 100 psi STRENGTH

7000 psi MODULUS

THERMAL: 19.4 E-6 $\frac{IN}{IN}$ °F CTE

GEOMETRY: .25" THICK

FIND

A) SAFETY FACTOR FOR CORE COMPRESSIVE FAILURE FROM 70F TO 250F

B) WHAT ΔT WILL FAIL THE CORE

SOLUTION

$\varepsilon = \alpha \Delta T$

$\alpha = 19.4E-6$ °F

$\Delta T = 250 - 70 = 180F$

$\varepsilon = (19.4E-6)(180)$

$\varepsilon = .003492$

$\sigma = E\varepsilon$

$\sigma = (7000)(.003492)$

$\sigma = 24.4$

A) $\boxed{SF = \frac{100}{24.4} = 4.1}$

$\varepsilon = \alpha \Delta T$

$\sigma = E \varepsilon$

$\sigma_{max} = E \alpha \Delta T$

$\sigma_{max} = 100$ psi

$E = 7000$ psi

$\alpha = 19.4 E{-6}$

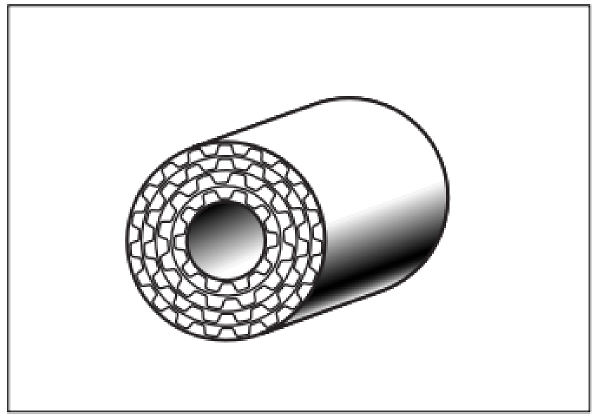
$100 = (7000)(19.4 E{-6})(\Delta T)$

(B) $\boxed{\Delta T = 736 \text{ F}}$

3/1/14 1:00pm Jack
This exists which is interesting.
http://www.hexcel.com/Resources/DataSheets/Brochure-Data-Sheets/Honeycomb_Attributes_and_Properties.pdf

Tube-Core®

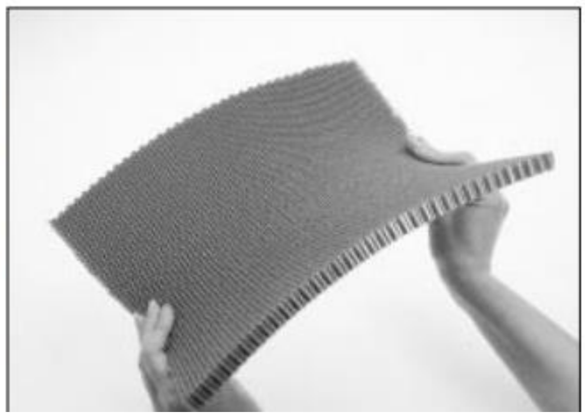
Tube-Core configuration provides a uniquely designed energy absorption system when the space envelope requires a column or small diameter cylinder. The design eliminates the loss of crush strength that occurs at the unsupported edges of conventional honeycomb. Tube-Core is constructed of alternate sheets of flat aluminum foil and corrugated aluminum foil wrapped around a mandrel and adhesively bonded. Outside diameters can range from 1/2 inch to 30 inches and lengths from 1/2 inch to 36 inches.



Bending of Honeycomb

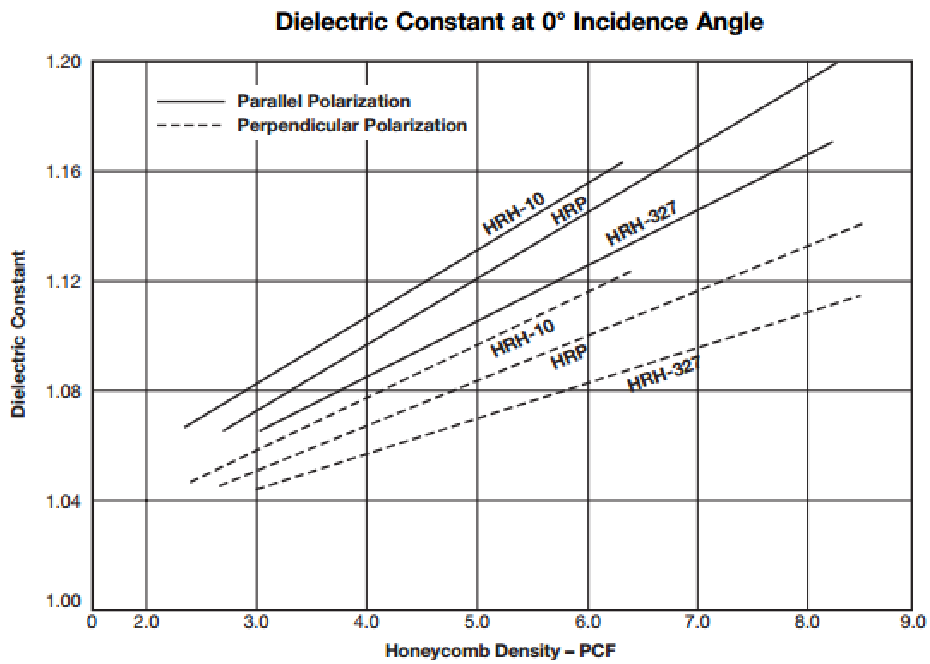
When hexagonal honeycomb is bent, it exhibits a phenomenon where the honeycomb is forcibly curved around one axis and the core reacts by bending in a reversed curvature along an axis oriented 90°. This phenomenon is called anticlastic curvature.

Poisson's ratio μ is the ratio of the lateral strain to the axial strain when the resulting strains are caused by a uniaxial stress. Poisson's ratios for different types of honeycomb have been determined to vary between 0.1 and 0.5. As would be expected, Poisson's ratio for Flex-Core cell configuration is less than Poisson's ratio for hexagonal cell configuration.



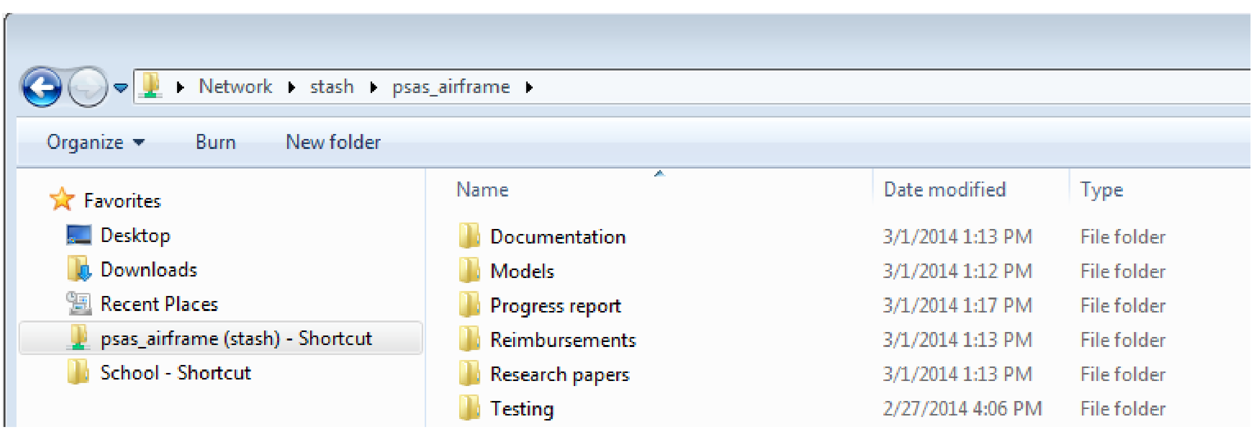
Dielectric

Nonmetallic honeycomb is used extensively in radomes, both airborne and stationary, because of its very low dielectric constant and loss tangent. Thus nonmetallic honeycomb allows the wave energy to be transmitted with only negligible reflection and absorption. The figure below shows the dielectric constant as a function of core density for several honeycomb types. The values were obtained for both polarizations and with the electric field vector E perpendicular and parallel to the ribbon direction. Testing was conducted at 9375 Megahertz. In addition to the electric field polarization, the dielectric constant is a function of the incidence angle and the thickness of the honeycomb.



3/1/14 1:00pm Jack

Everyone should merge their files with the files in the stash folder. It's important that we stop individually saving things to our local drives, and only save things to the stash folder from here on out. Inside the progress report folder, it's all ready to go with a document already started. The progress report presentation is in there.



3/1/14 12:00 pm Sam

I started looking into high temp/strength rapid prototyping materials and specifically looked at what NW Rapid can do.

They sponsored the FSAE team with rapid prototyped intakes.

They have some pretty cool materials including a nylon/CF composite:

PRODUCT DESCRIPTION

Our carbon-fiber filled Nylon CF is ideal for conditions where heat is a concern and added strength a necessity. Nylon CF is our choice for motorsports, UAV, aviation, and aerospace applications. Nylon CF provides added strength compared to our standard Nylon 12 as well as improved heat deflection properties at elevated temperatures.

MECHANICAL PROPERTIES	VALUE	UNIT	TEST STANDARD
Flexural Modulus (XY)	3447/500	MPa/kpsi	ASTM D790
Izod Impact Strength Notched	54	J/m	ASTM D256
Izod Impact Strength Unnotched	110	J/m	ASTM D256
Heat Deflection Temp @ 0.45 MPa	178	ºC	ASTM D648
Heat Deflection Temp @ 1.82 MPa	177	ºC	ASTM D648
Volume Resistivity (22C, 50%RH, 500V)	7.8x10^14	ohm-cm	ASTM D257
Surface Resistivity (22C, 50%RH, 500V)	2.9x10^14	ohm	ASTM D257

3D DATA	VALUE	UNIT	TEST STANDARD
The properties of parts manufactured using laser sintering are due to their layer-by-layer production, to some extent direction dependent. This has to be considered with designing the part and defining the build orientation.			
Tensile Modulus (X Direction)	2896/420	MPa/kpsi	ASTM D638
Tensile Modulus (Y Direction)	2896/420	MPa/kpsi	ASTM D638
Tensile Strength (X Direction) Ultimate	66/9500	MPa/psi	ASTM D638
Tensile Strength (Y Direction) Ultimate	66/9500	MPa/psi	ASTM D638
Elongation at Break (X Y Direction)	3.6	%	ASTM D638

THERMAL PROPERTIES	VALUE	UNIT	TEST STANDARD
Melting Point	184	ºC	ASTM D3418
Melting Flow Rate (3min, 5.0kg, 235C)	50/10	grams/min	ASTM D1238

OTHER PROPERTIES	VALUE	UNIT	TEST STANDARD
Density (Laser Sintered)	1.07	grams/CC	ASTM D792

CHARACTERISTIC

Processing –
Laser Sintering

Delivery Form –
Black

Chemical Resistance –
General Chemical Resistance

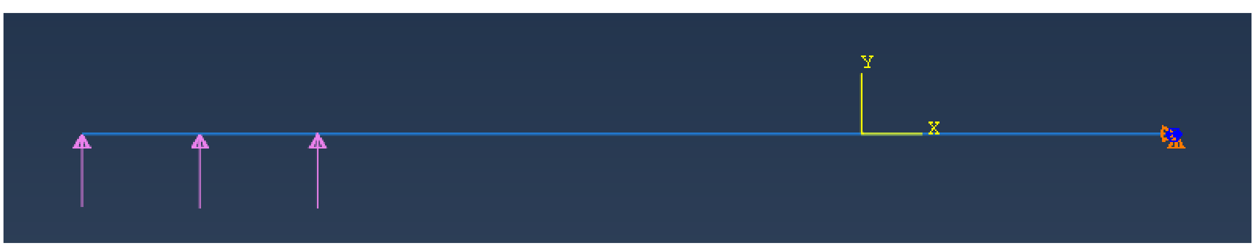
Manufacturer –
ALM (PA 601-CF)

Source: Advanced Laser Materials, LLC
Last Change: 2011-09-28

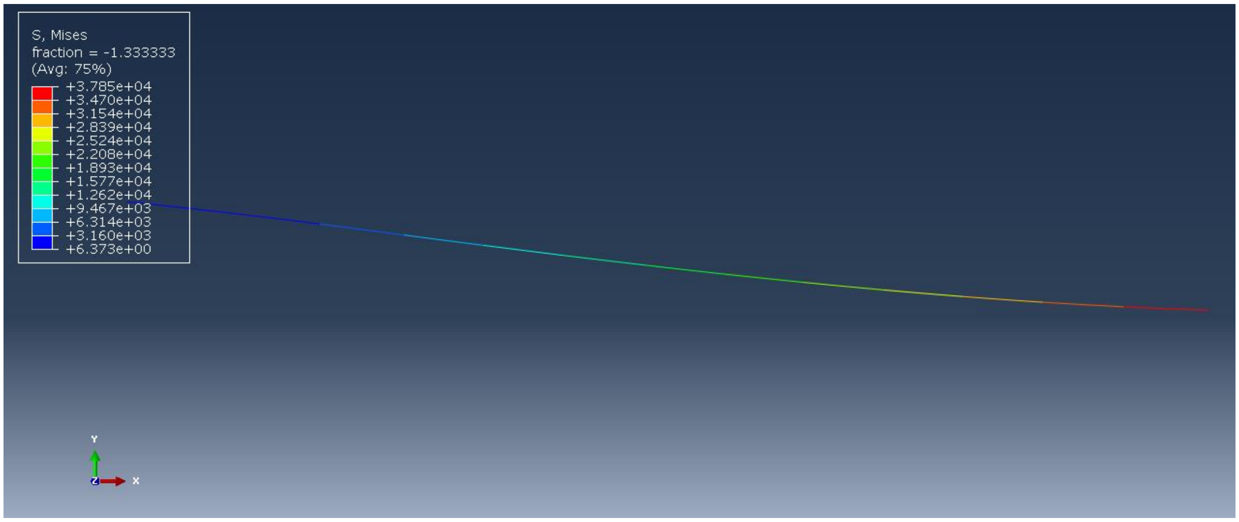
I'm going to email them and ask if they'd be willing to help us and what other capabilities they have for high strength, high temp materials. Contact info:

NW UAV		Alex Dick	503-434-6845 x117	alex@nwuav.com

3/1/14 11:36 am Rob
Beam FEA analysis of thrust ring spoke. The purpose is to evaluate the effectiveness of not pocketing the ring all the way through. Effectively creating a T shaped beam.

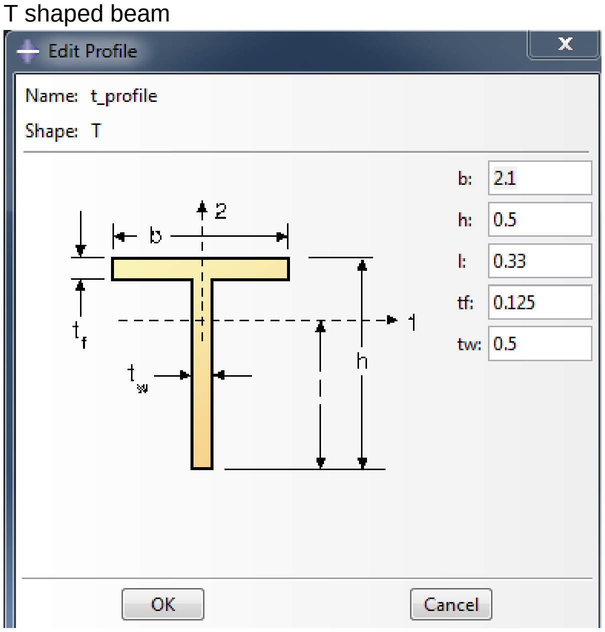


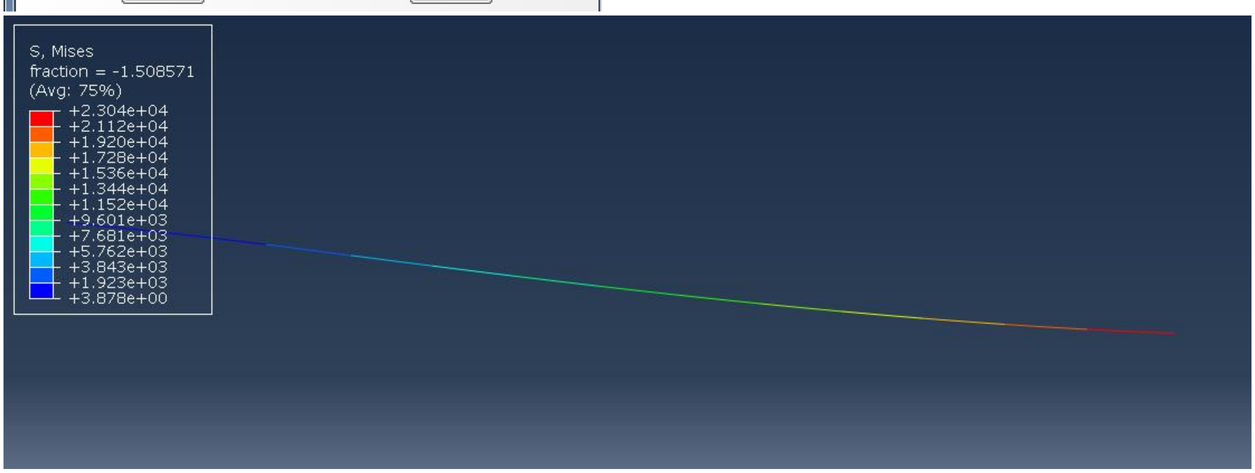
0.5" x 0.5" x 0.87" Box Beam (same as shell analysis for correlation)



Results are the same as the shell analysis; which gives a fair degree of confidence in the results for the given conditions.

T shaped beam



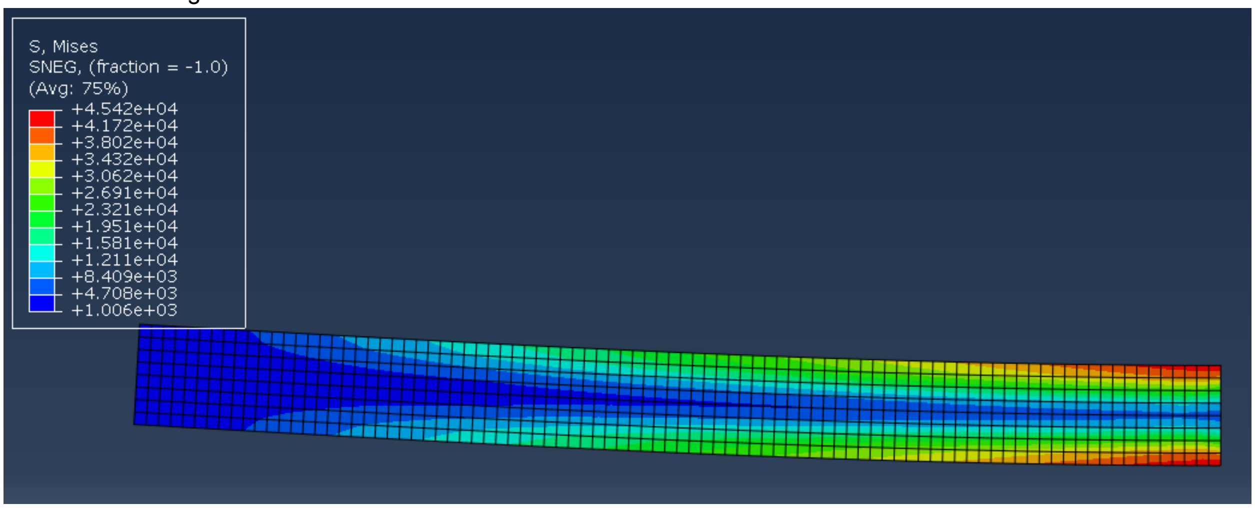


Results for the T shaped beam indicate a nearly 40% reduction in stress . It appears we can use this to reduce the spoke sized required for the thrust ring.

3/1/14 8:10in am Rob
Preliminary 3d shell FEA analysis of different spoke thicknesses (vonMises in psi). This should be followed up with 3d analysis. This gives us a good starting ballpark, however due to the boundary conditions imposed this is likely a conservative analysis.

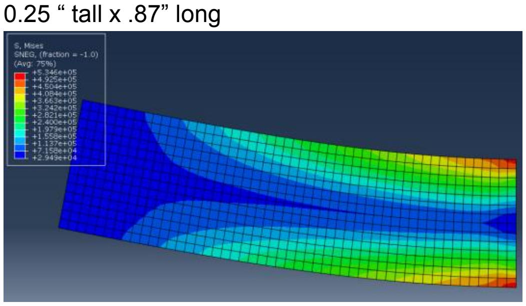
Note. 6061 T6 has a yield strength of 40000 psi.

Retaining ring spoke
.25" tall x 2.7" long

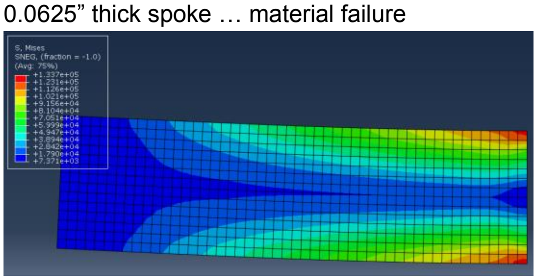


0.0625" thin spoke 12.5 lb vertical load...75 lb ring capacity
0.125" thick spoke 25.0 lb vertical load… 150 lb ring capacity
0.25" thick spoke 50.0 lb vertical load… 300 lb ring capacity

Trust ring spoke
Applied load 400 lbs for a total ring capacity of 2400 lbs
0.25 " tall x .87" long

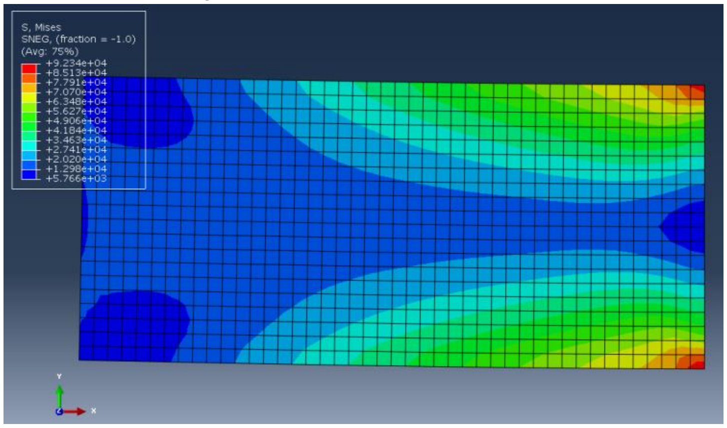


0.0625" thick spoke … material failure

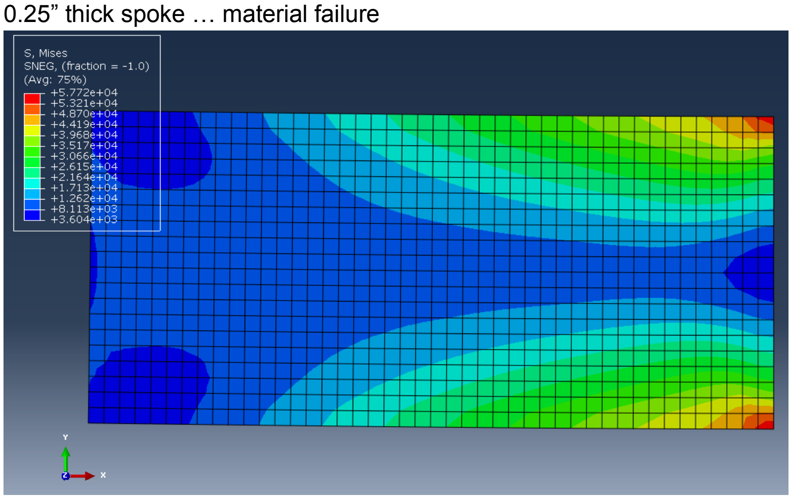


0.25" thick spoke … material failure

0.4” tall x 0.87” long

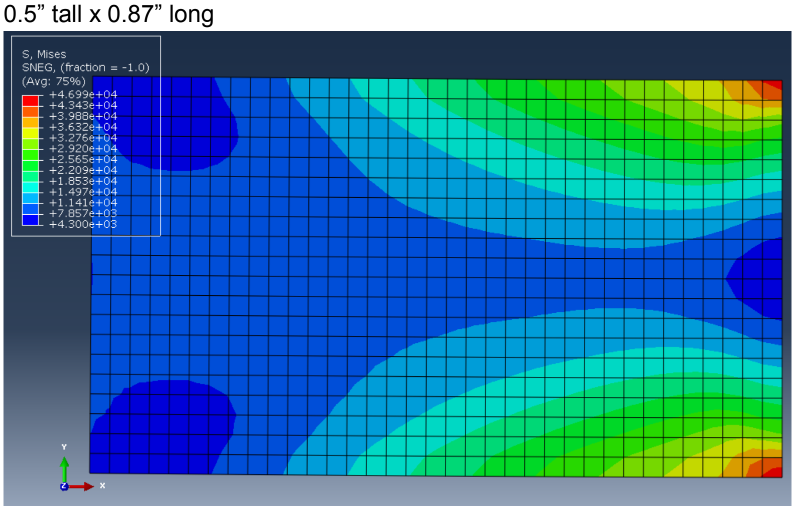


0.25” thick spoke … material failure

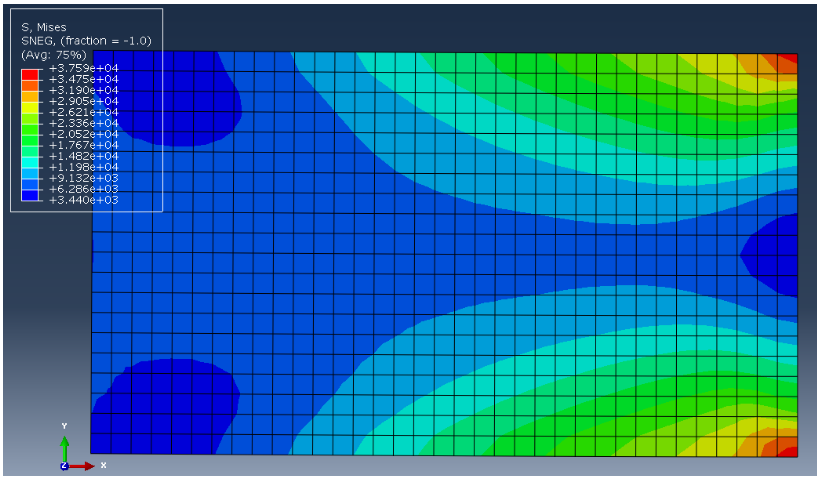


0.4” thick spoke … material failure

0.5” tall x 0.87” long



0.4” thick spoke … might survive?



0.5” thick spoke …. survives

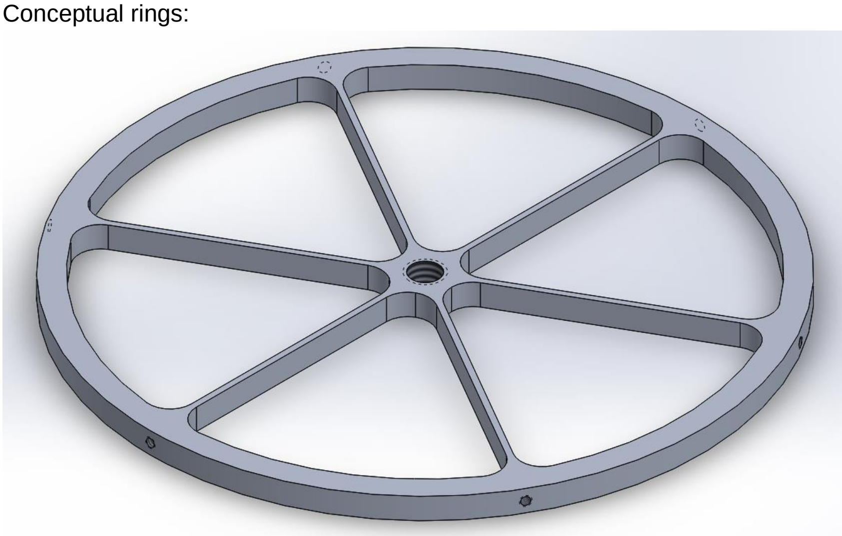
3/1/14 6:57 Rob

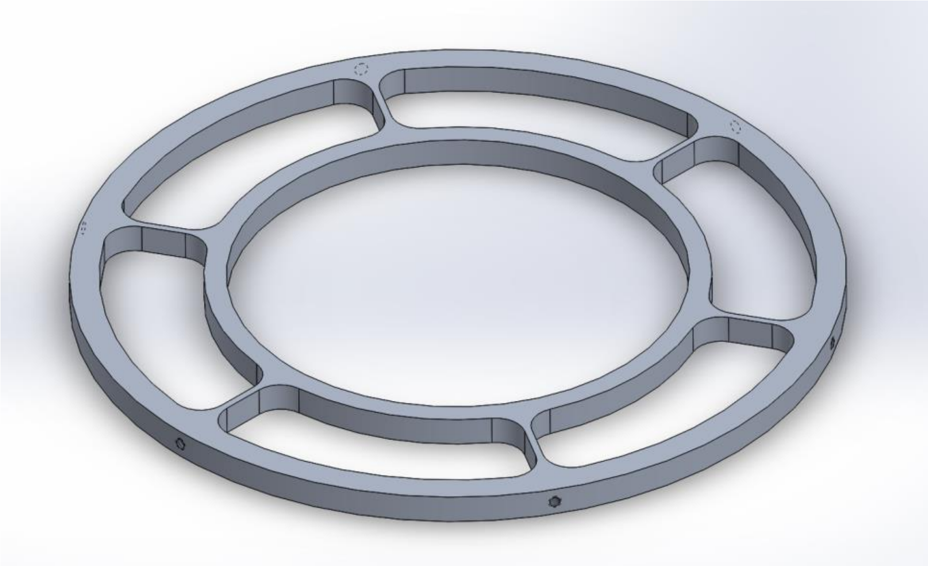
A quick list of rings we need that are not just module to module connections:

1. motor thrust ring (MTR)
2. motor retention ring (MRR)
3. parachute retention ring (PRR)
4. nosecone separation ring (NSR)

If the parachute is moved to the nosecone the PRR and NSR can be combined.

Conceptual rings:


6” retaining ring (0.15 lb)



6” thrust ring (0.19 lb)

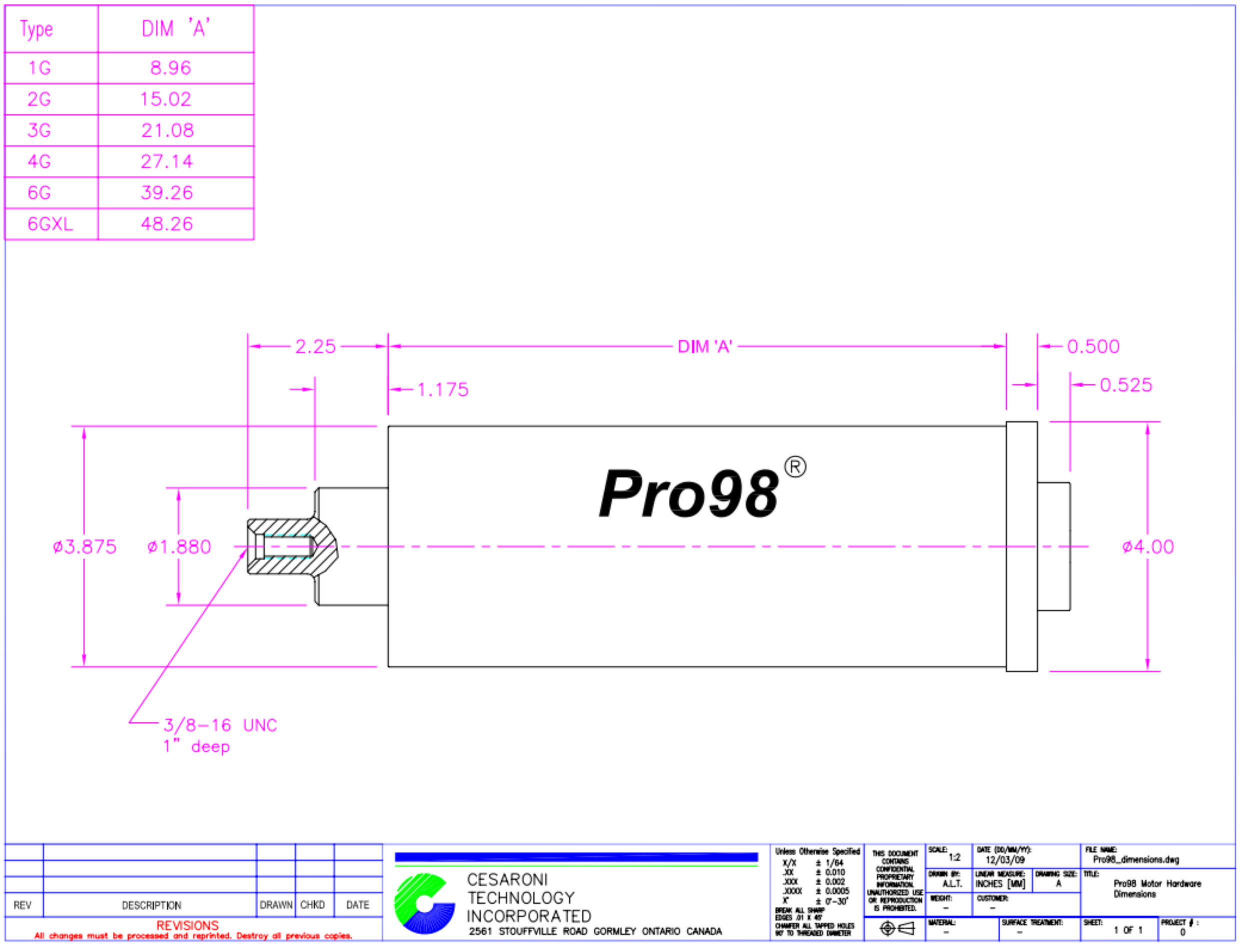
2/28/14 8:13pm Rob

Here is a link to the solid rocket motor manufacuter used by PSAS http://www.pro38.com/index.php. I have also upload all of the specs from the web site and many firing profiles. The specific motor the use is the Pro98-6G.

I believe the trust is designed to be transferred out of the casing through the bottom lip. Dave indicated this is other way to do it. The largest thrust profile I found for this motor was about 2000 lbs. A quick calculation indicates this is about 3000 psi on the lip; which is about 1/10 the yield strength of aluminum.

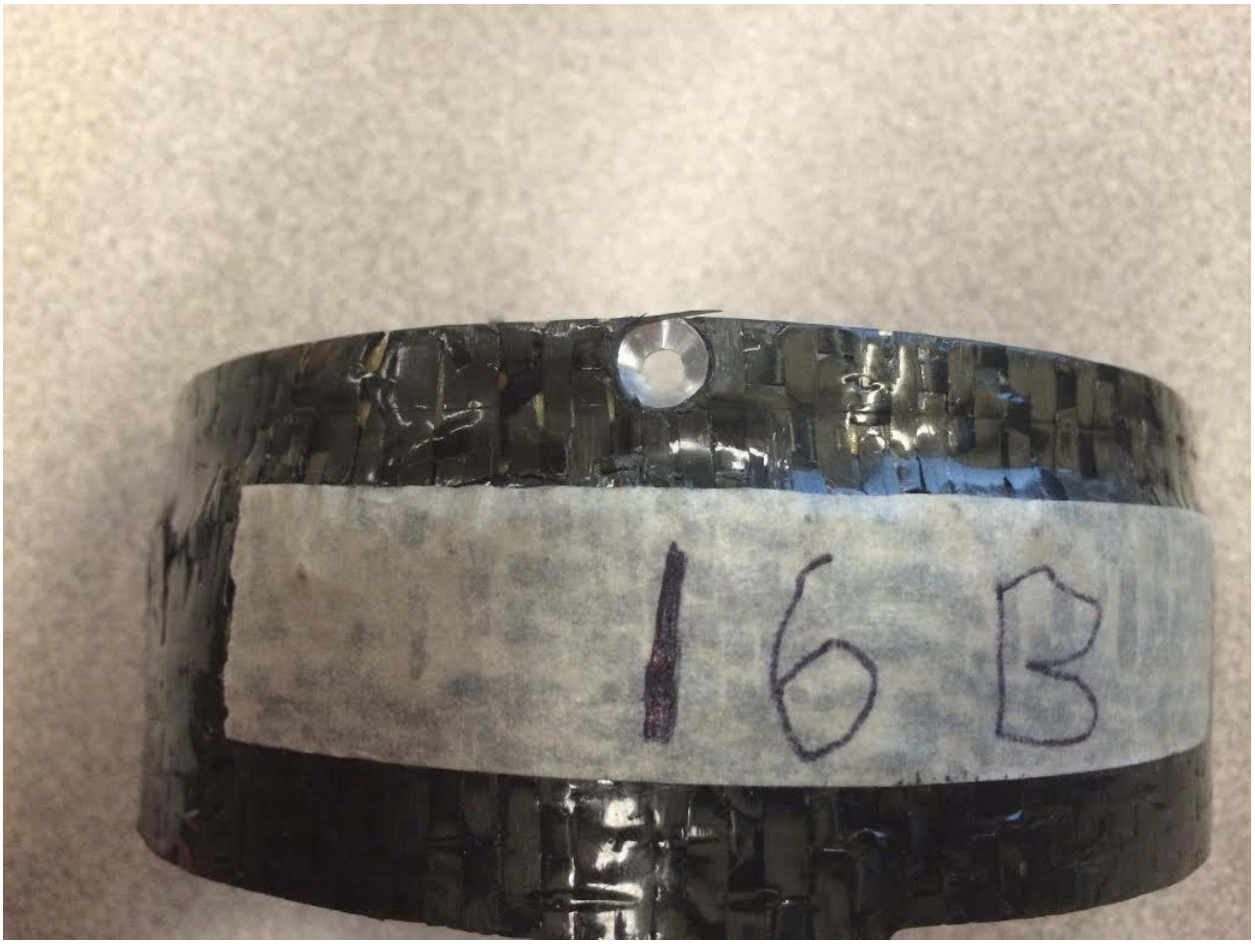
We need to contact CTI on Monday to confirm where they recommend transferring the trust force out of the motor casing.

I emailed them Friday, but we can call on Monday also. I wrote up some of this just below here inside our trip to Dave’s house. -Jack



2/28/2014 6:00pm Sam, Rob, Jack

We realized that the design of these rings would get super heavy (.24lbf) if we didn't drill through the carbon the thing had potential to get super heavy. So we went to the shop and spot drilled, .125" through drill, then 60* chamfered it to find out if we could go through a carbon aluminum layer. It worked pretty well. There was a little bit of fiber unhappiness with the chamfer, but a little bit of epoxy dabbled on it would hopefully do the trick.



2/28/2014 5:00pm Sam, Rob, Jack
http://www.pro38.com/pdfs/Pro98_Instructions.pdf
I cannot find on this how exactly you are supposed to hold the motor. There was some hesitation by Dave on how exactly it should be done. **I emailed Cesaroni and will post the response.**

2/28/2014 4:42pm Sam, Rob, Jack
We went to Dave's house today:
We saw what tools he has, and how the motor currently fits inside the rocket. There was some confusion as to how that actually works. Right now they are holding onto the outside edge, and aren't sure exactly what the correct way to do it. There is a lip at the bottom that might be another correct one. We will have to contact them to figure it out.

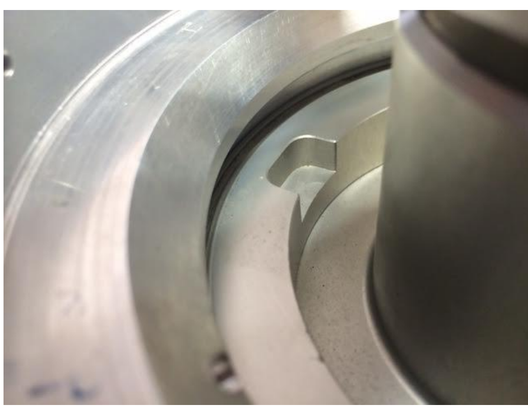
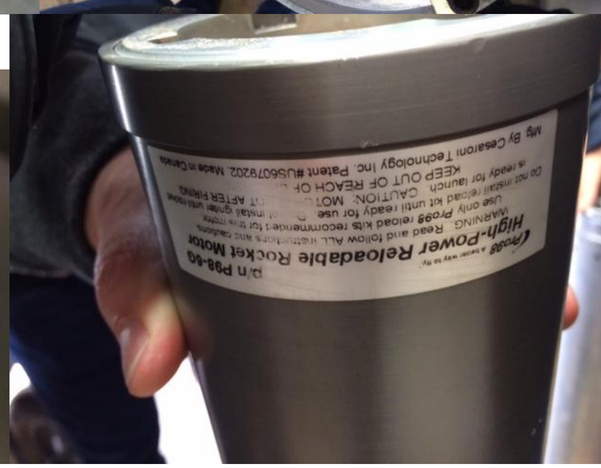
Machines: He has a 3 axis mill with a computer controlled 4th axis. He has a manual rotating table with a good angle measure on it. He also has a good tailstock support system. We can borrow either of these tools. His lathe is not the best, and ours seem superior. We need to really see if we can fit 6" ID stock on the lathe.




A better way to fly.
Pro98

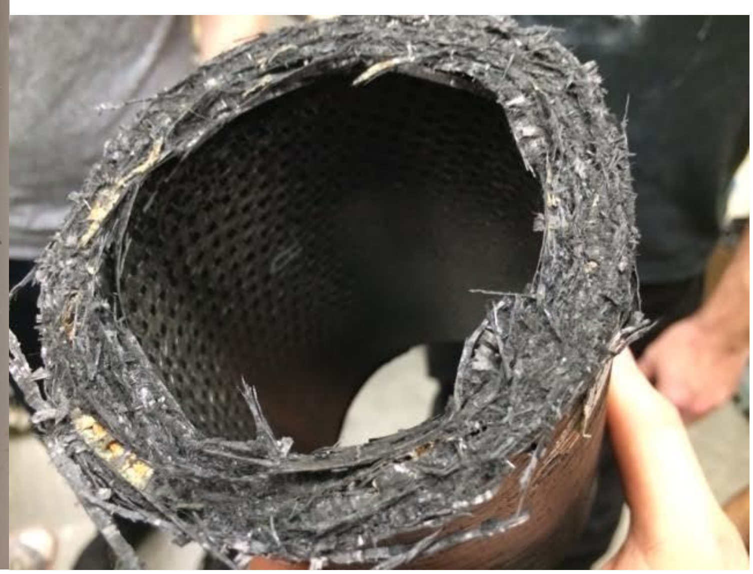




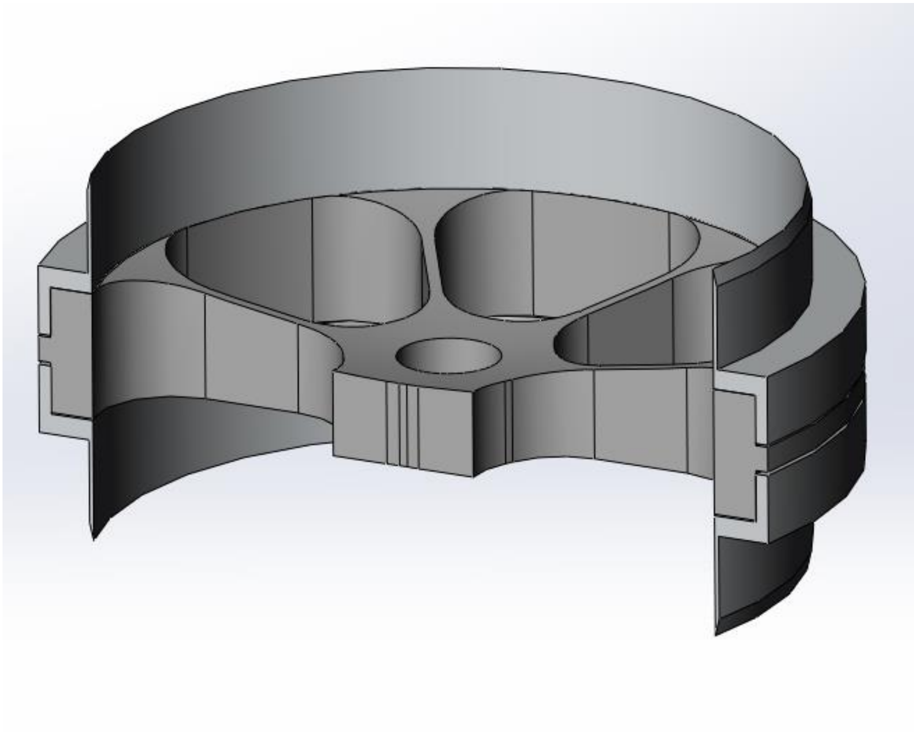



High-Power Reloadable Rocket Motor
p/n P98-6G


2/28/2014 4:40pm Sam, Rob, Jack
Broke parts 16, 17 in the concrete tester again. We cut them both to the same length using the fiber chop saw. We cut them both to 6.25” length, and had just the exposed core and carbon on the ends.
17: Initial failure at 14900lbf, then 11000 to make it continually crumble.
16: 5190, then 3500, 2600. Had failure on inside and outside plies. It was unevenly loading it at the top due to the unparallelness of the cut.

Test conclusion: Inconclusive. Part 17 broke at about what it should have, part 16 should been much stronger, it broke at 7200lbf before that and was much longer and had stress concentrations. Conclusion is continue with 1core1 and .25” core for now. Unfortunate this test didn’t work out. Tom mentioned he has rubber rings that could have potentially alleviated this problem.

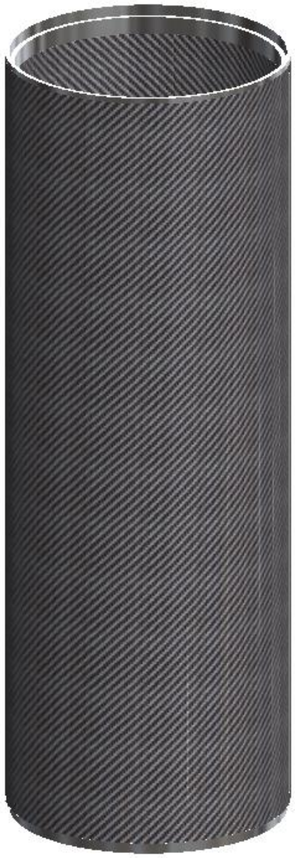



2/28/2014 10:30am Sam, Tung, Rob, Jack
Questions and topics for PSAS meeting:
- How is the motor mounted, how is the load transferred to the airframe?
    - Load transferred through two screws to lip/ring at top of motor module
- Input on measurements project electrical system
    - They've already developed a similar board. Simple to use and works with measurements daq. Should maybe use lab jack for data collection. Check on NI daq model in the lab.
- Ideas for electronics carrier, motor mount
    - They like their old idea, with two pieces of sheet metal, and they like our motor mount idea
- What size fasteners are being used between modules, at the motor?
    - m3, they love metric everything
- Field trip to Dave's
    - Dave Camarillo
    - 503.869.0579



2/24/2014 10:00pm Jack, Tung
We finished rehearsing the progress report presentation. Everyone can look at it in the progress report folder, and comment on the facebook what they think. I sent a copy to weislogel also. It is kind of a cool way to look at some of what we have done.

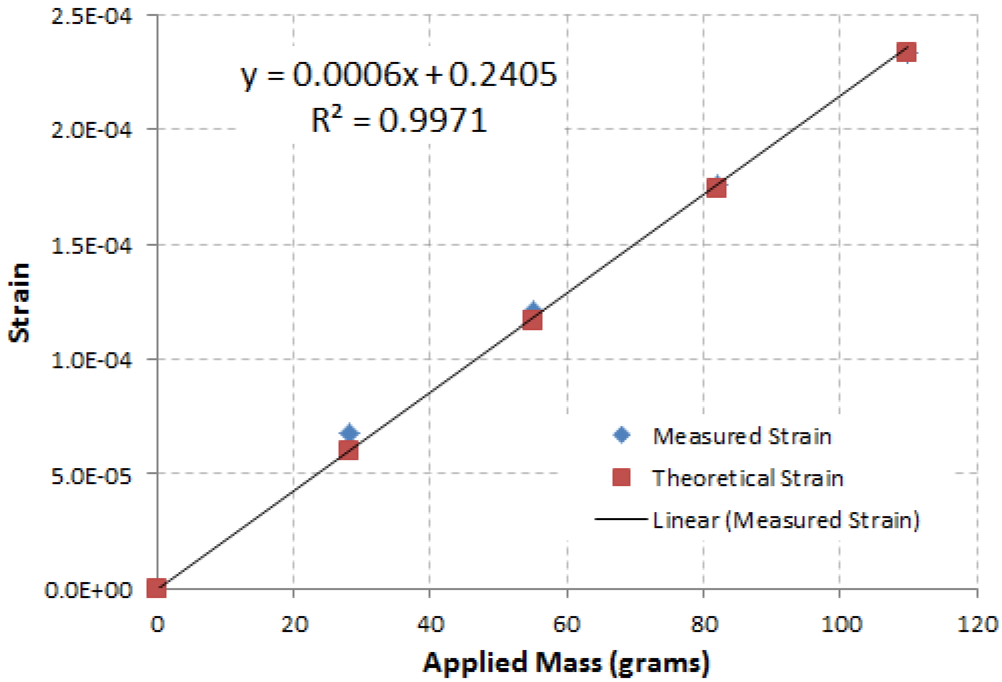
2/24/2014 5:30pm Barett



2/24/2014 2:30pm Jack

Picture of 17 in Tom's concrete test fixture from several days ago.

Strain gauges seem to work fine on carbon. We used a 4ply beam for our cantilevered beam lab for measurements class. We had a little bit of issues sticking the gauge to it, but I think that was just our inexperience. We made a calibration curve of gauge output vs bending load, and got a .997r^2 value linear fit that worked very well. We then calculated theoretical strain using linear beam theory and abaqus and got very good results. We guessed the thickness of the epoxy beneath the gauge was .15mm. The graph is below.



2/24/2014 11:30am Jack

Old Adhesive film:
Adhesive film 36" by 3 yards:
3M Scotch-weld structural film AF 191-M has flexible cure temp ~275-400degF
Data sheet:
data sheet for adhesive film

Rob posted this a while back with good vocab we should not forget. Engineering pathfinder, flight fidelity article etc…

Rob 11/18/13 8:00 am:
A few notes while watching the tour of SpaceX:

- Testing
  - Thermal cycle testing
  - Vibration testing
- Terms
  - Engineering Pathfinder
  - Flight Fidelity Article
- Components
  - Propulsion Section Skirt

2/22/2014 1:30pm Jenner

I got the LCD shield and it's awesome and super-easy to program. I think we can store the pre-programmed programs on the SD card and also support a manual mode so the user can either choose from a list of pre-set temp profiles or enter their own profile. The box containing all the electronics can be locked so those using it as an appliance just choose from the menu options using the little joystick on the LCD shield. Those with the key can then open the electronics box and access/swap out the SD card.

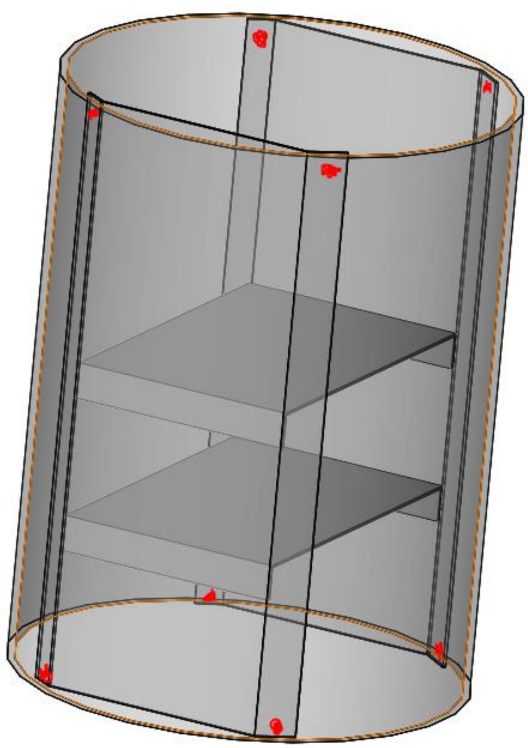
I'm exploring using the MAX31850 instead of MAX31855. I'm not convinced: the MAX31850 is twice as much at $8.18 each from Digikey but it supports 1-Wire to Arduino and Adafruit has compatible libraries so we could have more thermocouples and/more I/O in general. I'm working up both and will check with Tung to see what he thinks.

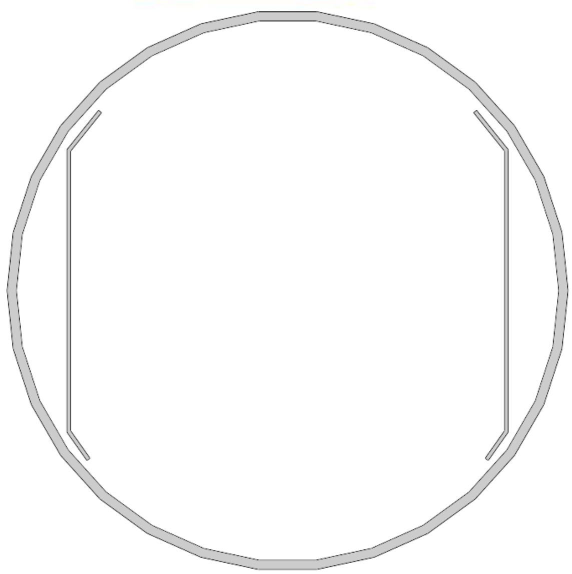
http://www.adafruit.com/products/1727
https://github.com/adafruit/MAX31850_OneWire
https://github.com/adafruit/MAX31850_DallasTemp

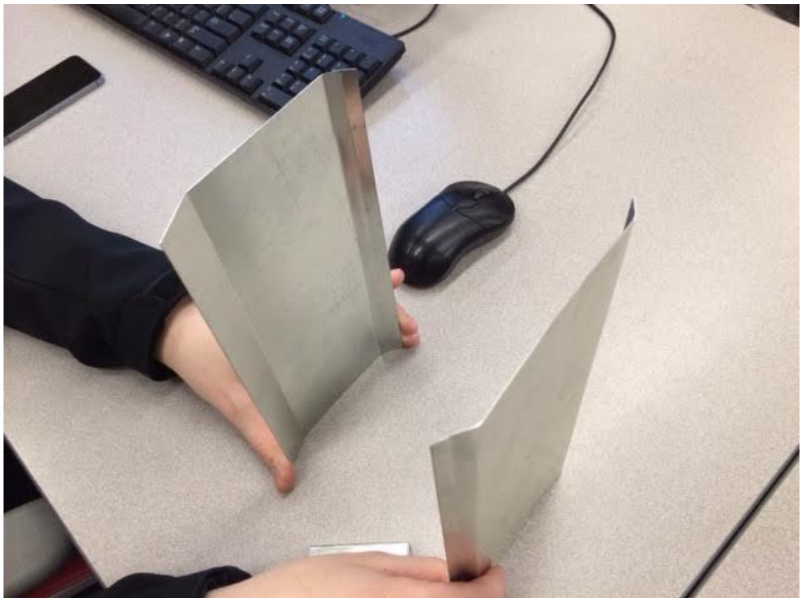
Do we already have a github organization page for the team? What's the name?
If not, I'll set one up. What name do we want? composite-rocket-capstone? pdx-composite-rockets? me-capstone-aka-team-awesome?
Tung: We got a stash drive
    On Windows:
    \\stash\psas_airframe

Anyway, as soon as you tell me, I'll totally make us a little website on github.

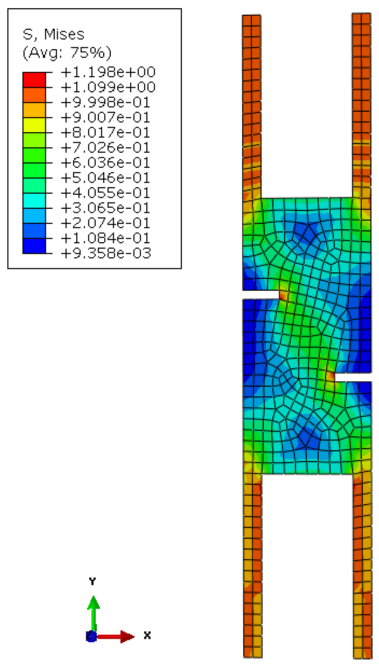
2/21/2014 4:25 pm Jack
Made up an idea for about the electronics carriers out of excess flashing. It is very easy, and we potentially don't have to make it from composite. Sheet aluminum would likely be strong and lightweight enough. Something similar to the photos below. You could even use like plastic/aluminum thumb screws as the attachment mechanism into the aluminum rings. The bolt holes are in red, and would go into the aluminum rings. Deciding to go with a design like this, especially one that is not composite, means we can move on to other bigger challenges like the nosecone and propulsion skirt.







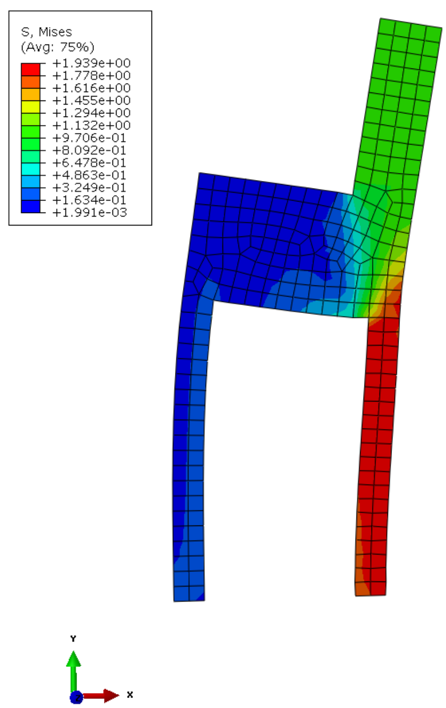
2/21/2014 8:25 am Rob
If we use clamping force between the modules we can get participation of both plies and add a addition tolerance to our machined parts.

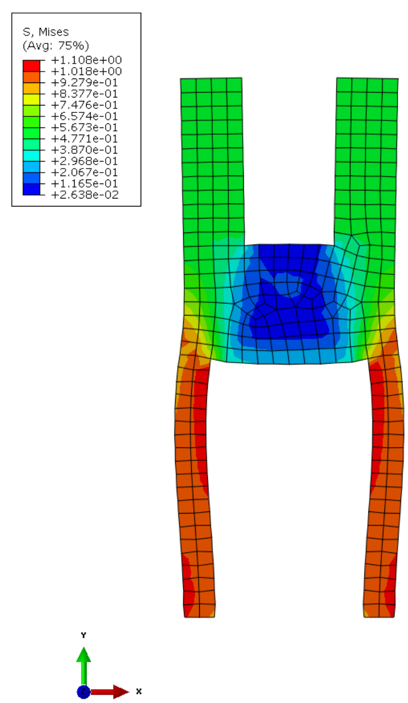


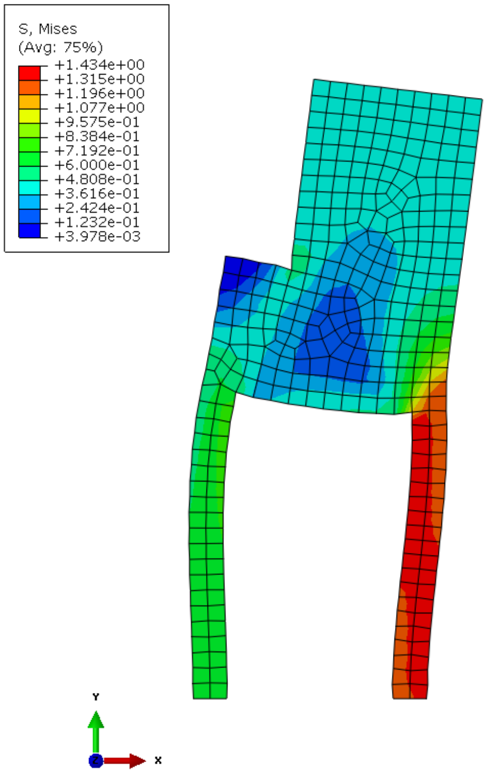
2/21/2014 5:35 am Rob

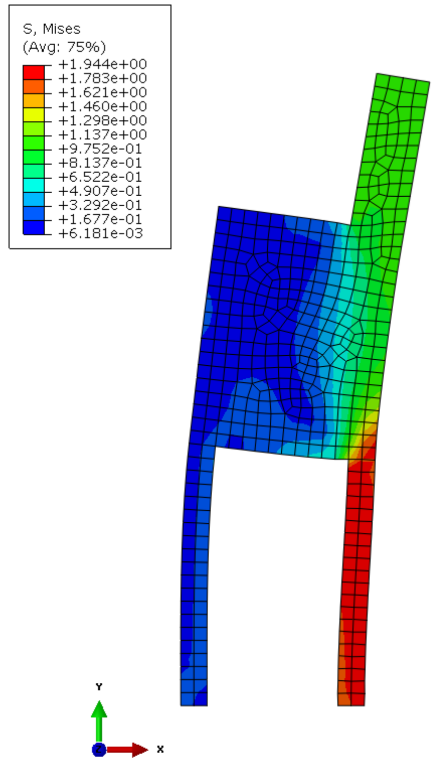
A quick list of items I would like to talk about (will add to this during discussion)

- Material Failure vs Buckling Failure
- Bending Test Of Joints/Cylinders
- Thermal Testing Of Cylinders
- Influence Of Joint Geometry On Ply Failure









- Need To Account For Stacked Tolerances In Joint/Payload Holding Design

2/20/2014 11:42pm Jack

Things to talk to Andrew about:

- Best method of communication with him
    - Communicate more with Nathan and Eric, and via email is best
- How we should go about designing the rings?
    - Dave is the guy to talk to about manufacturing on CNC lathe.
- How we should go about designing the electronics carriers?
    - Integrate the carrier with the ring. Can try to design out of carbon fiber. Carrier design should be similar to existing design for compatibility with electronics.
    - Meeting Tuesday night with Eric Nathan Andrew
- How should we deal with making the larger diameter parts? Will Dave machine for us? is there budget to get machine shops to make parts for us?
    - Dave, and yes budget
- Can we get access to a module with the same design as their current one to buckle?
    - Yes. Contact Dave about manufacturing a module specifically for that.
- Are we spending too much money? What is our spending allowance?
    - Impulse buy if necessary. ~$700 leeway
- How is best to get them in to teach them to lay things up?
    - End of term. Do interim workshop series to begin developing skills
- Who determines smooth enough surface finish?
    - Current is okay, not best. Matte finish is better than gloss. Try a thin coat of satin black paint.
- What is the realistic possibility of launching it this summer?
    - Yes, July. Get general component designs from PSAS then design composite processes. 1 week lead time on rocket nosecone and fins
- Is the mandrel used to make the nosecone available? How should we go about making the nose cone?
    - It exists made out of wood. Should try to make our own new one for cheap.
- The things holding us back from full module construction are the rings and the tools, we are about a month

away from completing the PDS requirements

2/20/2014 11:42pm Jack
We could use prepreg fiberglass to make the antennae module so that the patch antennae doesn't have to go on the outside of the rocket. This is one way how planes get away with having antennas on the inside.

- Do it. 3 independent 2in tall module

2/20/2014 5:38pm Jack
Part 16 weighs .345lbf after we cut it into parts. **It is clear that half the weight of the module was the aluminum rings.**

2/20/2014 4:38pm Jack
We tested parts 16, 17, 18. We plugged this into our empirical model.
What we learned:

- The 2core2 was only 4% stronger yet it weighs 30% more than the equivalent 1core1 **according to the model**.
- The empirical model appears to be predicting reasonable values, but more data will make it more accurate
- The difference between parts 15 and parts 16, 17 is a 30% increase in strength with no increase in weight. This is attributed to a better layup, and potentially the stepped ring style. **According to model**
- Need to increase distance from edge of tapped hole to wall, because of the bolt threads getting pressed on
- Both 16, 17 failed at the step up at the top of the module. This will hopefully go away when we get rid of the step.
- The .02" step failed in buckling, likely right where the carbon or core ended.
- The aluminum is very strong
- They were very noisy when they failed, lots of strand breaking
- This carbon tube layout is going to be very strong
- the core must be butted up against the aluminum. This is why the aluminum ring buckled on part 17

We could crush a 6" long module individually, and then crush with 2 stacked and see how the model performs. We could also make different length 3.4" modules to buckle and test the model.

We have to think about how strong the whole rocket length is going to be, not just individual modules. It would be best to test the current rocket module's buckling strength, so we can understand where we are in the spectrum.

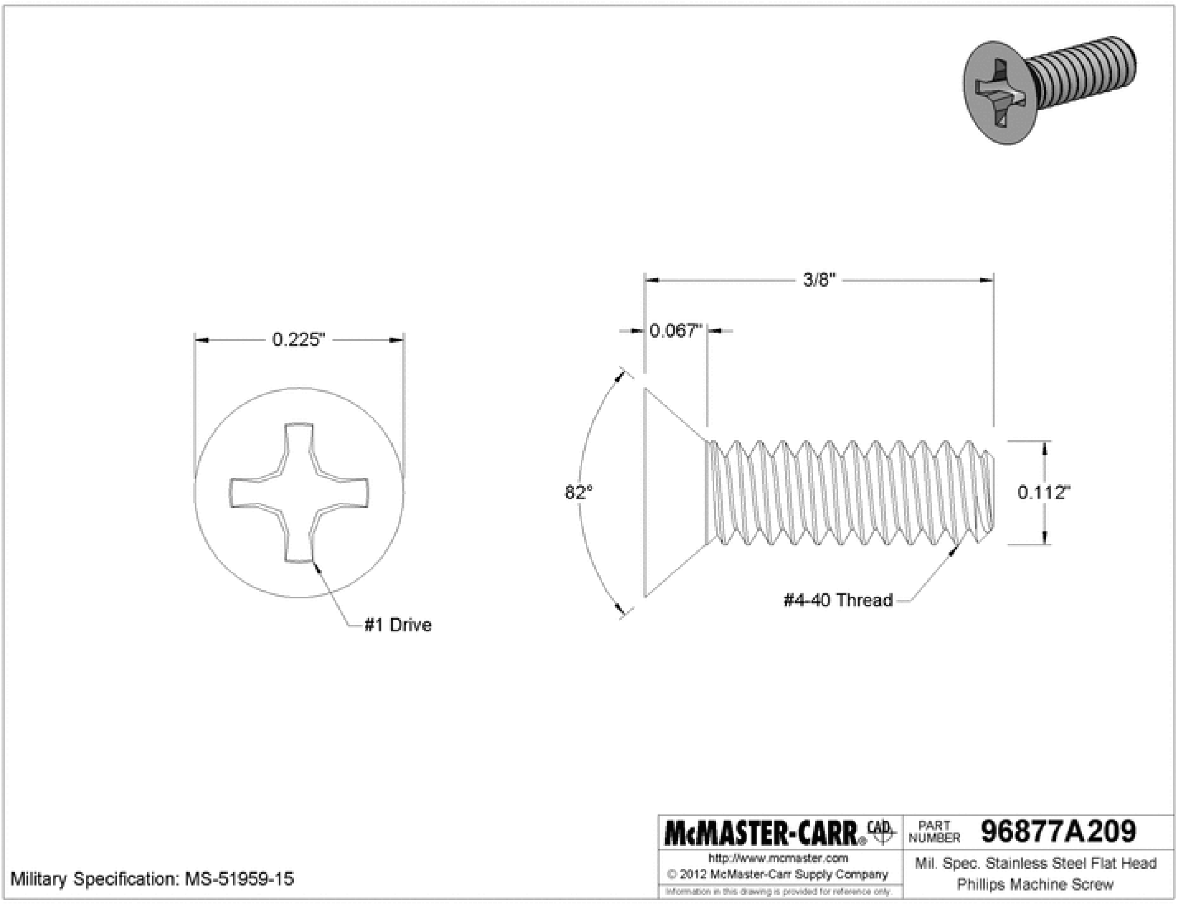
Empirical GFR	9	9.09	13.07	9	19000	3,066	3
Empirical part 15	3.5	4.0625	6.00	8.5	85000	7,060	2
Empirical part 16	3.5	4.095	6.43	9.75	110000	7,445	2
Empirical part 17	3.5	4.1925	7.80	9.25	115000	10,478	4
Theoretical cylinder	6	6.595	29.23	17	110000	11,125	
	3.4	3.995	5.94	6	110000	18,153	2
	6	6.625	30.93	16	57000	6,886	4

2/19/2014 9:38pm Rob
If it turns out the # 8 is too large a screw we can also go with additional (a larger quantity) of #6 or #4 screws and still have the required strength. We just need to balance our desire to have the minimum number of screws with the size of the required part. If we need to grow the part to fit the screw we may be heavier than if we used more smaller screws.

We may also need to consider installing Helicoils since a steel bolt in aluminum may eventually experience failure.
http://www.helicoil.in/pdf/HeliCoil%20Catalogue.pdf

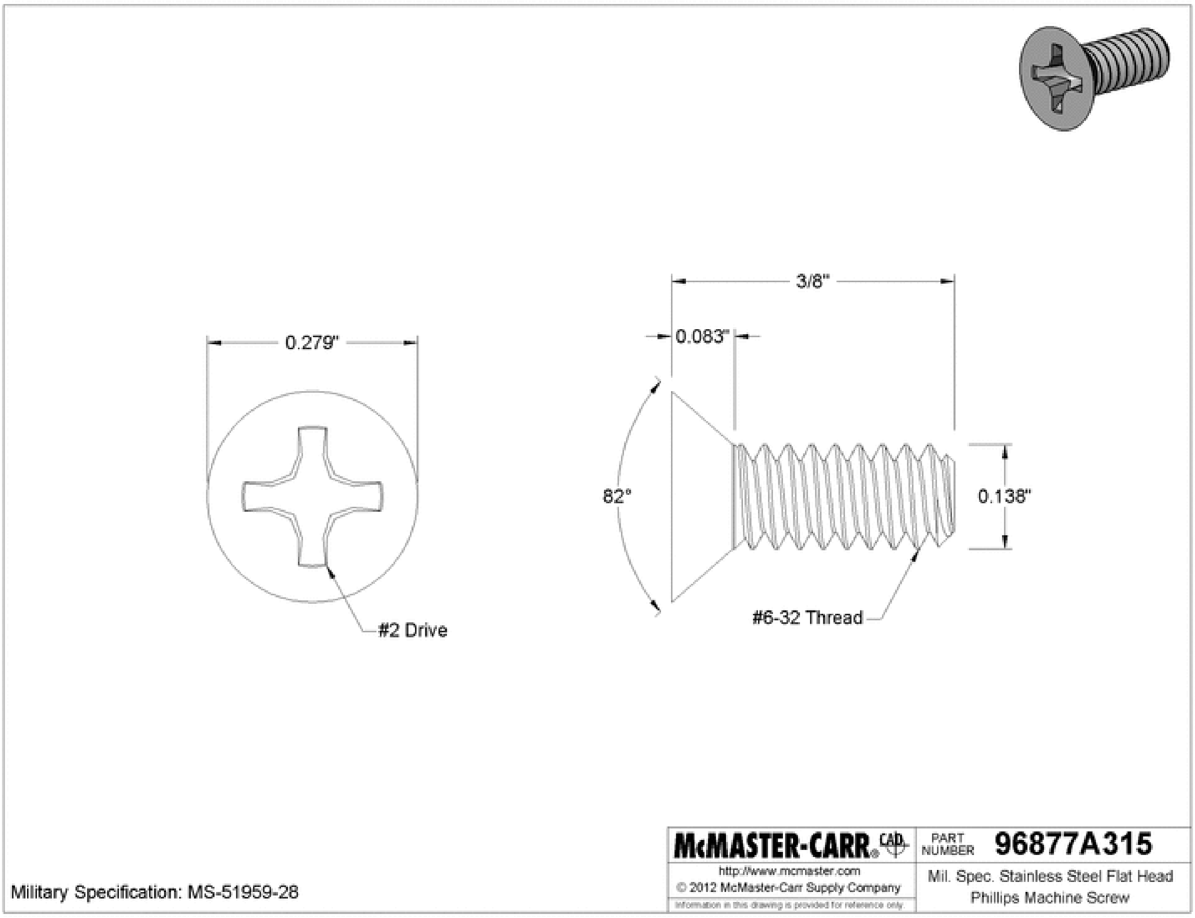
Length	3/8"
Dash No.	15
Additional Specifications	82° Screws
	4-40—#1 Drive; Meet MS-51959

Print



Length	3/8"
Dash No.	28
Additional Specifications	82° Screws
	6-32—#2 Drive; Meet MS-51959

Print



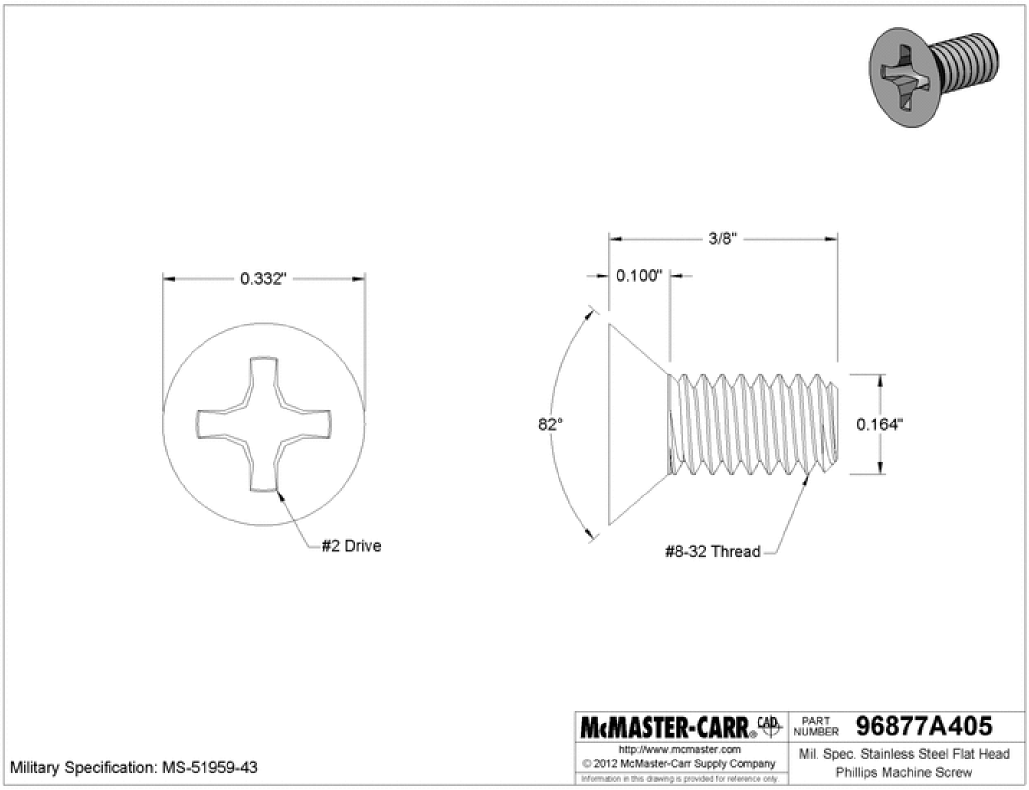
2/19/2014 8:03pm Jack

We are looking at the screws we will have to use. These are milspec stainless, which isn't what we want exactly but it is pretty close. The thickness of the outer flange has to be at least .100" to sit mostly flush. So making the outer flange about .11" should be about enough.

If you look at the area that is actually carrying the load right now it is 2.35 in^2. With a 7,000lbf load that is only 2,976 psi stress (Alum yield 37,000). This means we have plenty of area we can give up and still be well below the yield.

Length	3/8"
Dash No.	43
Additional Specifications	82° Screws
	8-32—#2 Drive; Meet MS-51959

Print



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3-D Models
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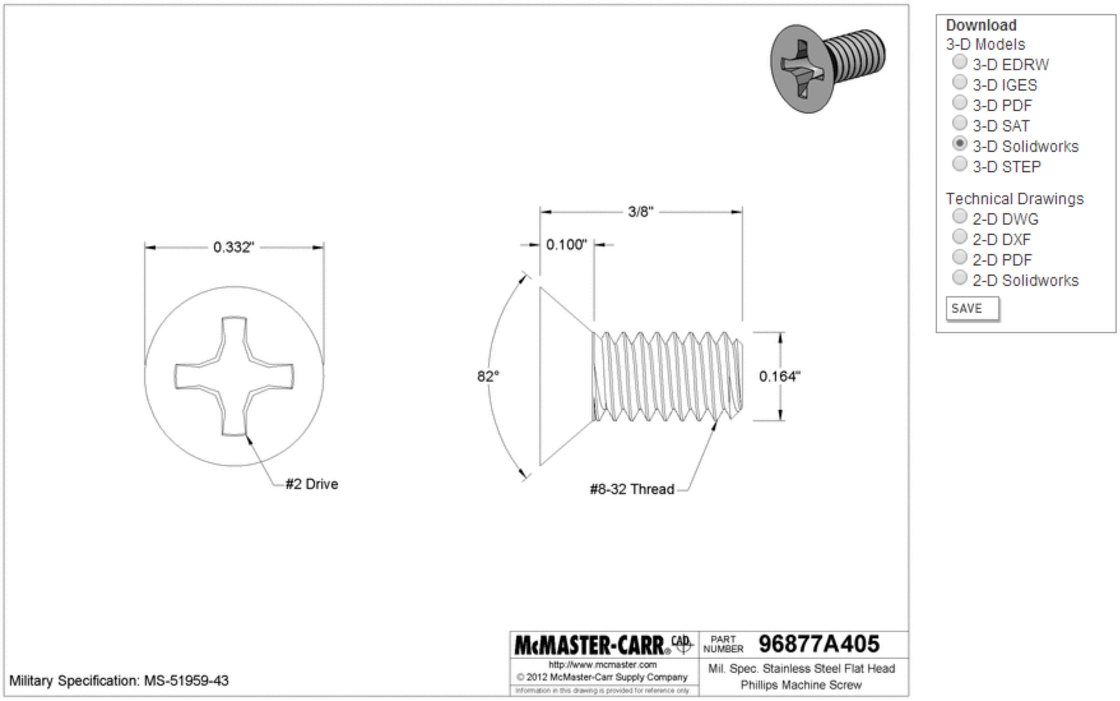
- 3-D SAT
- 3-D Solidworks
- 3-D STEP

Technical Drawings
- 2-D DWG
- 2-D DXF
- 2-D PDF
- 2-D Solidworks

SAVE

Length	3/8"
Dash No.	43
Additional Specifications	82° Screws 8-32—#2 Drive; Meet MS-51959

Print

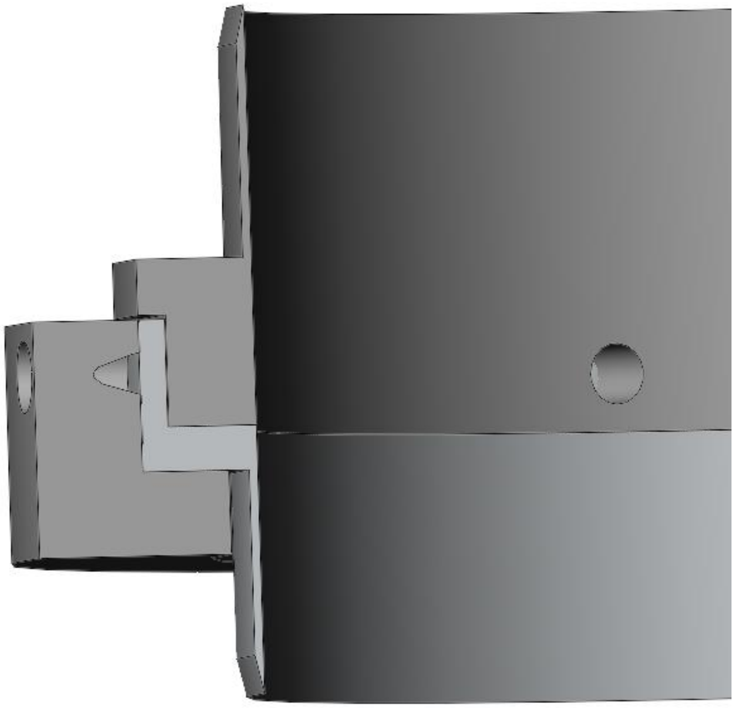


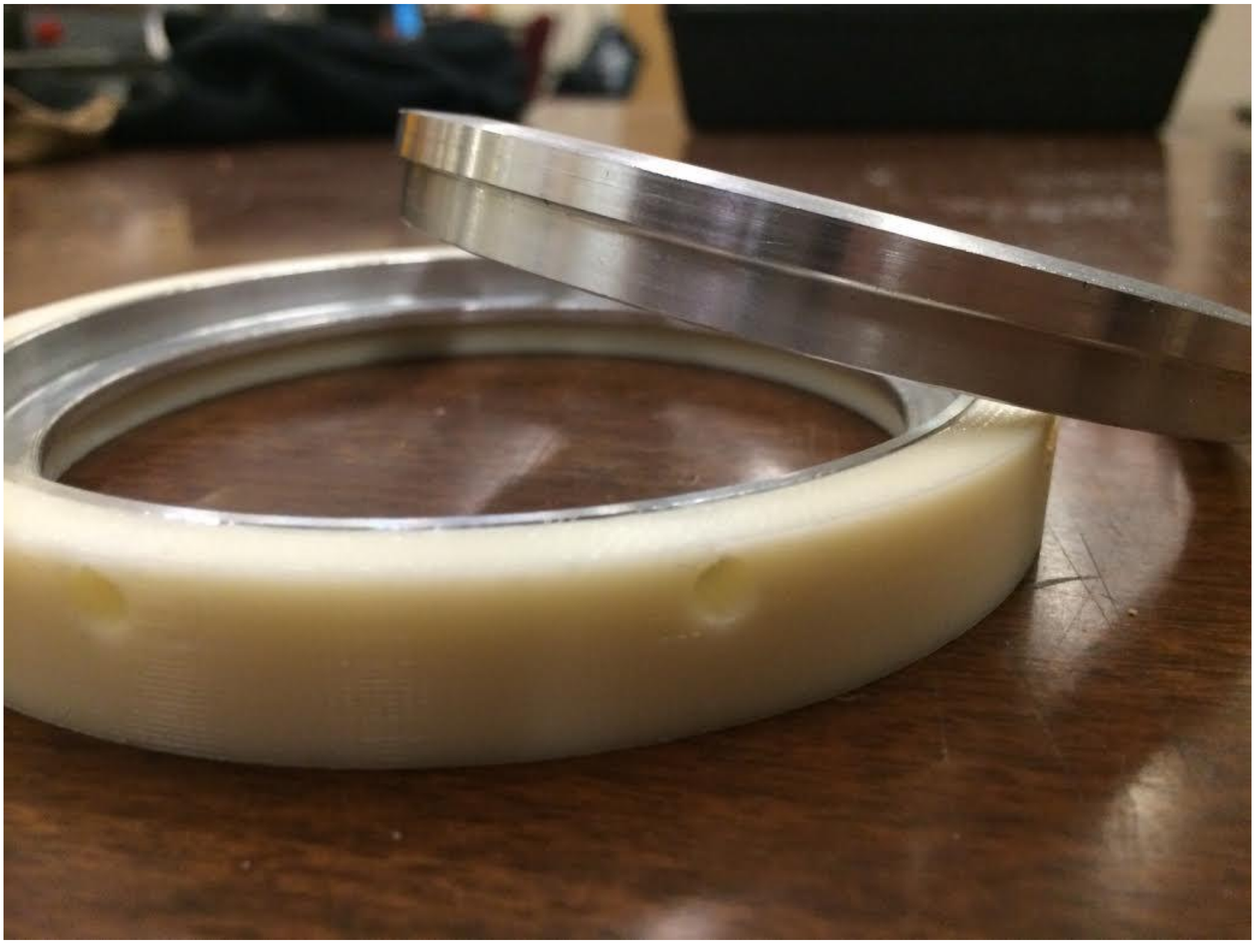
2/19/2014 5:20pm Jack

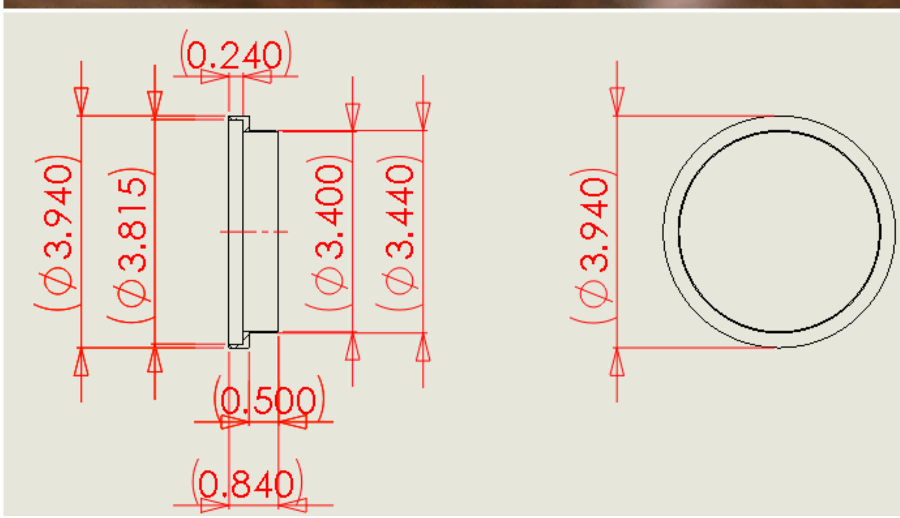
We are taking the mandrels all down to 3.4" OD. This makes it so all the rings can be the correct dimensions they actually were supposed to be. The mandrel needed to decrease in diameter so the ring could be the correct dimensions. We used a piece of plastic, double sided tape, and sandpaper to make this happen. Picture below.

We are 3d printing a drill jig so that we can accurately drill holes through the whole assembly and then tap them. All of the load is carried by the inner flange. The bolts just holds things in place. The bolt can take 2522lbf shear through threads, and 3802lbf through the shoulder. the clamp force is 1261lbf per bolt with 41.4 inlb torque. We elected to use 3 bolts for right now, and we will smash it until failure tomorrow with Tom.

The drill jig is .005" undersized so you have to press stuff in and out. It was supposed to be .005" oversized. Woops. We are trying putting it in the freezer to de-press it because it's hard to get back out



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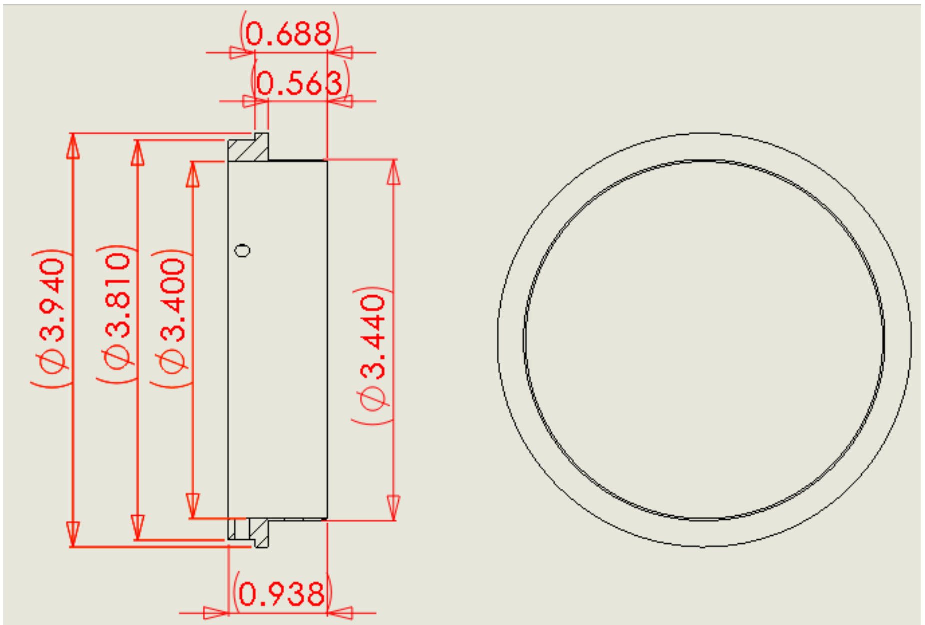
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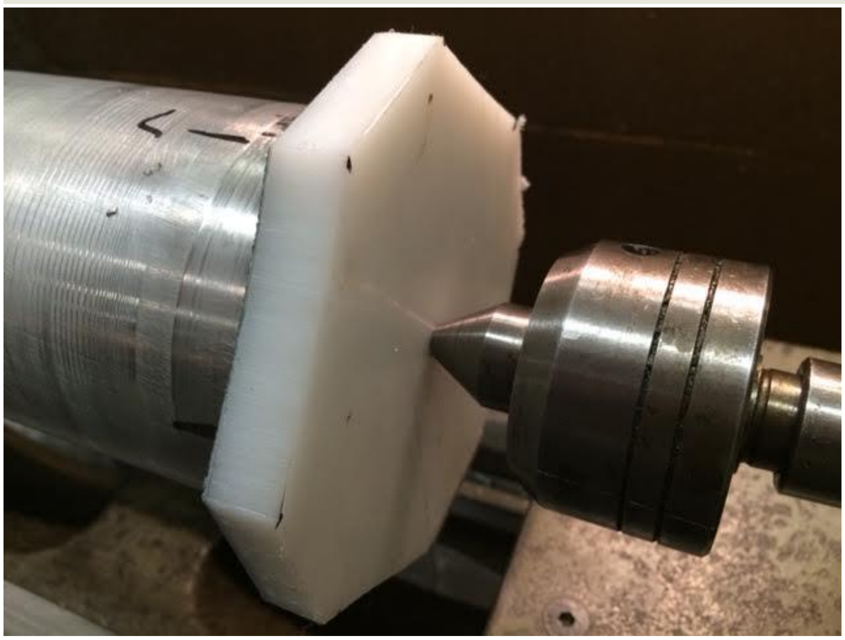
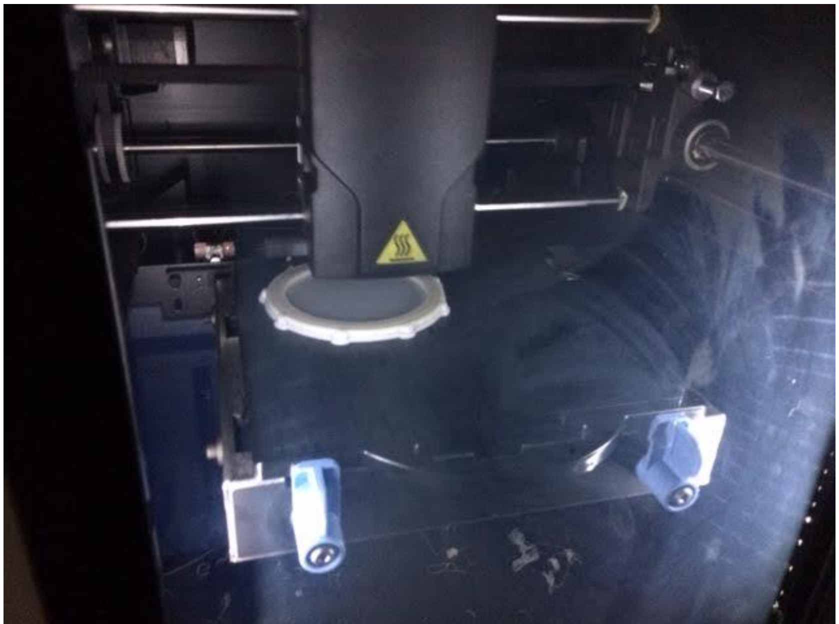
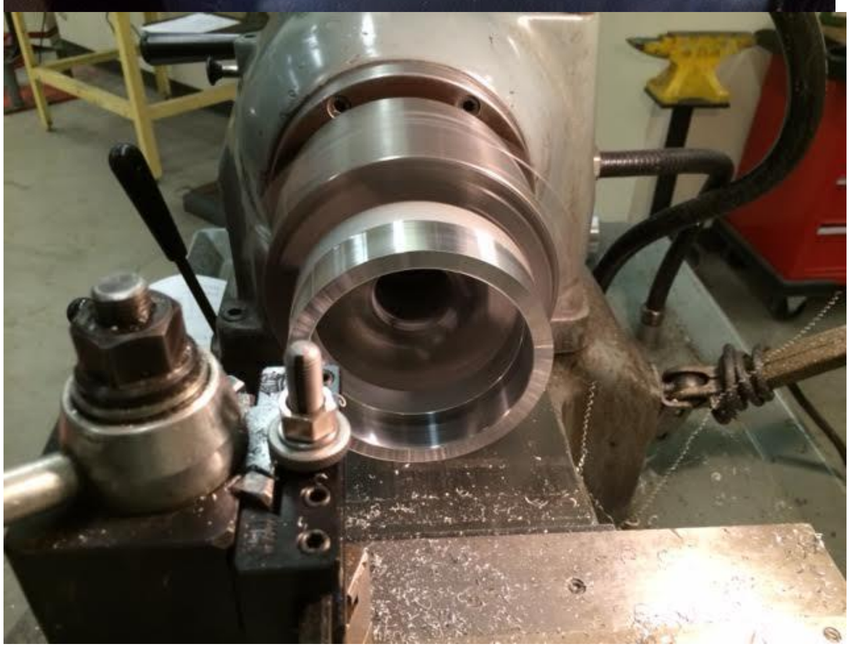






2/19/2014 5:20pm Jack
The ID of the ring material was 3.378” until run out is gone. Ring initial ID is 3.35”. **This means in the future we can get cylindrical stock into a cylinder within .04” of its nominal. So if we have stock thats 2.04” OD, we can make it a perfect 2.00”.**

We are spraying 16 again to see the weight gain. It went from .470 to .475, and with a heavy coat of acrylic enamel. The enamel dries in about 10 minutes. It appears to have better filled the little divots. It’s possible if we keep doing this the surface finish will come out very smooth.

2/17/2014 6:49pm Jack
We attempted to do some post baking surface cleanup. We sanded with 320, 800, 1500 and sprayed 16 with acrylic enamel. We did the same but did not acrylic enamel spray 17.

The surface finish when you just sand the carbon gets a little hazy. When you spray it with one coat, it appears darker and better.

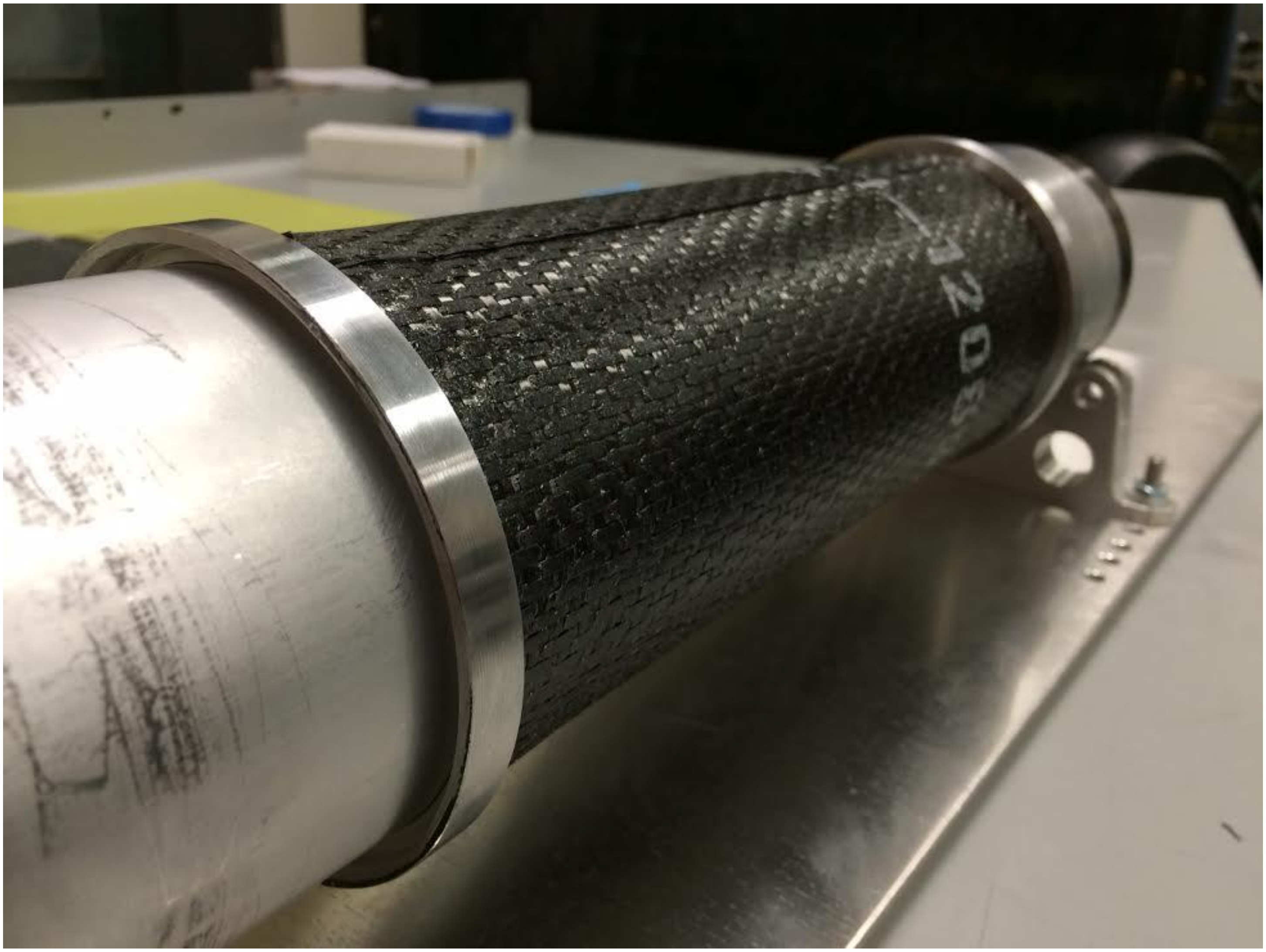
After sanding and washing and spraying, the weight of the part rose from .465 to .475 lbf. 2 days later, weighs .470. The sanding took material off, but the washing and painting added some back. There is likely water inside which is the majority of the weight added. We are letting it dry and will weigh it again in a week.

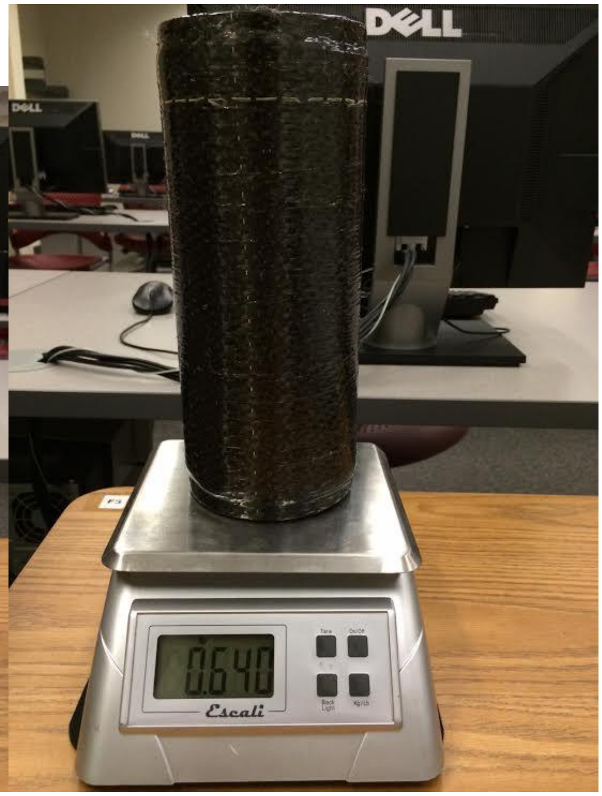
We measured the parallel-ness of the two aluminum rings (16,17). They were off by .015” and .035”. This reiterates that we need a fixture for the rings.

Aluminum 3.5” ID .125” wall, 10.5” long: 1.44lbf
Carbon 3.5” ID, .3” wall, 10.5” long: .465lbf,

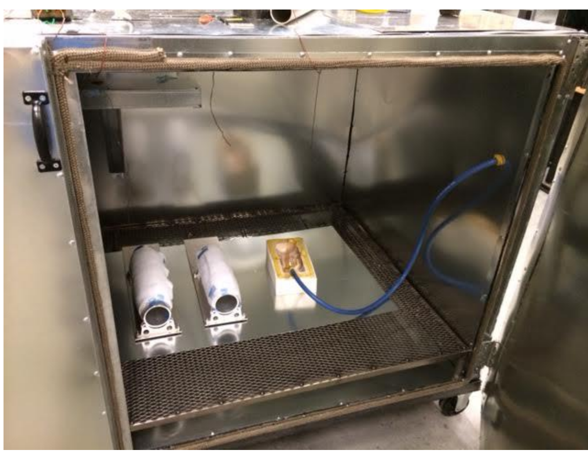
2/17/2014 6:49pm Jack
Writeup on parts 16, 17, 18:
Came off the mandrel very nicely. The 1core1 weighs .465lbf. The 2core2 weighs .64lbf. There was no dimpling, the surface finish is very good. The core splicing method worked well, but there is a slight bulge where the core splice happened. It might be good for us to tone down the amount of smooshing of the core next time. It is very minimal though, and acceptable. The carbon stepped down very nicely onto the aluminum ring. The shrink wrap did an excellent job of surface finish and not too rich. Maybe should put another layer of non perforated shrink wrap on top of the breather cloth to suck the glue out better. We have to get the carbon dimensions right before we bake it, the sharp edges are going to be impossible to clean up. Layup on the stepped rings was significantly easier than on the wedge design.

Part 18 was made in a plaster mold. The surface finish came out great against the plaster mold, and great against the vacuum. The two layer might have stopped the dimpling that happened on 15, but it might be because the vacuum was only 25inches as opposed to the 30 on the last one. The vacuum pressure went to 0 for a while when the pump broke, and god only knows what the pressure from the venturi was. The plaster mold is a one time use the way it happened here. Using it to make a composite mold is totally doable.



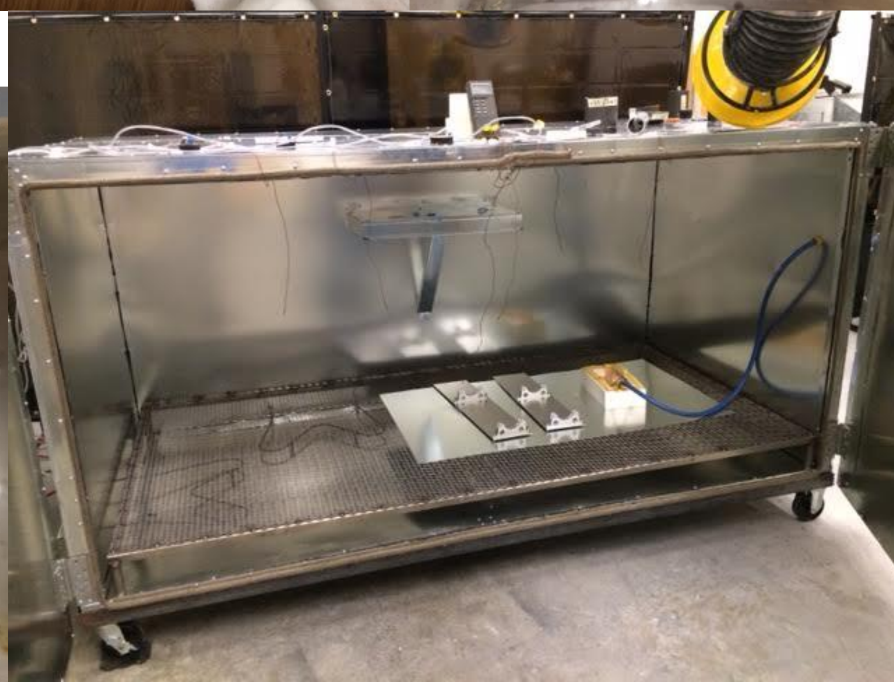

0.465
Escali

DELL
0.640
Escali


Warning: For use in well ventilated indoor areas. Read manual and wear ANSI approved goggles and respirator











The vacuum pump started ejaculating green fluid and making a horrible smell. We turned it off and replaced it with the venturi style vacuum. We don't think the vacuum pump is designed to sit there and hold a vacuum. That and maybe it isn't designed to have such a high flow rate, because it was only at 25 inches. We probably cannot use it anymore.

We are baking parts 16, 17, and 18 in the oven with the new shelf. We ran a heat cycle up to 350 and burned off most of the oil. It looks clean now, and my lungs feel a little sore.

Parts 16, 17 are cylinders with a single stepped joint. 16 has 1 core 1, and 17 has 2 core 2. They are both using perforated shrink tape wrapped approximately halfway. The purpose of these is to see if we can fix the core issues from part 15. Part 15 was built using a vacuum bag, and the carbon fell into each of the core cells. There was also a large gap in the honeycomb core.

Brain dump: We attempted to fix the core falling into cells by using perforated shrink tape. We cut the core too long and then used the heat gun and scrunched it and forced it to mate up with itself. This appears promising. We used the heat gun a lot to make the carbon slightly more pliable and sticky, and to make the adhesive film lay.

Should have bagged entire plastic female mold.

2/14/2014 6:29pm Jack

Measuring strain in lab got me thinking about how we can measure strain and look at what's happening when we buckle cylinders so we can better design them. Strain gauges have proven to be a bit of a pain, and don't give you all the info you want. Maybe DIC software could be easier for us and be a sweet secret weapon.

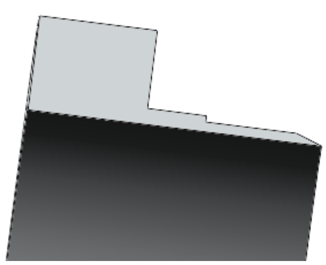
So I found a way to measure strain that uses speckle paint on your part and takes two images and displaces the strain field just like FEA. It is exactly the same thing as PIV, like Betsy does. I think it is totally within the realm of something we could do. Betsy said she potentially could help us by using her 14k$ camera to take the images for us. But, I bet that my DSLR is good enough for what we want. I found free software and am going to download it. I'll take two images and see if i can get the software to work. If this works we could potentially use it for all our strain measurements. That'd be a sweet plug and play method to get great data.

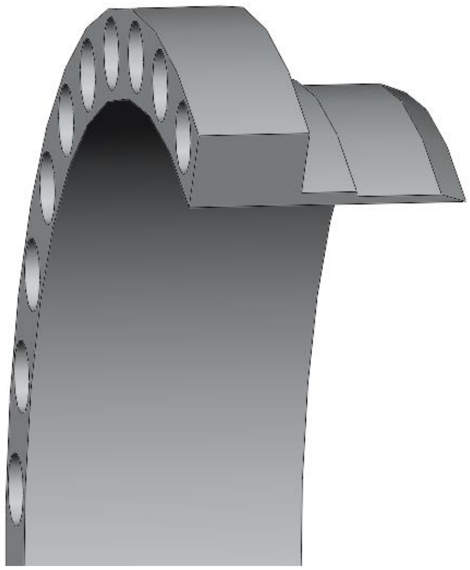
Below is a video, and the link to download the software. There were a bunch of comments from people and professors about what they were doing and where they had trouble. The general trend is that everyone thought it was great and they were doing cool stuff with it.

http://www.opticist.org/node/73
http://www.youtube.com/watch?v=PT2azeLnjgc
http://www.mecheng.osu.edu/lab/dmm/sites/default/files/smooth-round-tension-e1.avi

I emailed MatchID (http://www.matchid.org/index.php/software/what) to try and get a copy of their software for free. I sent it from my .edu email, because it's a professor that wrote it. Also emailed Correlatedsolutions.

2/14/2014 4:29pm Jack, Rob, Sam



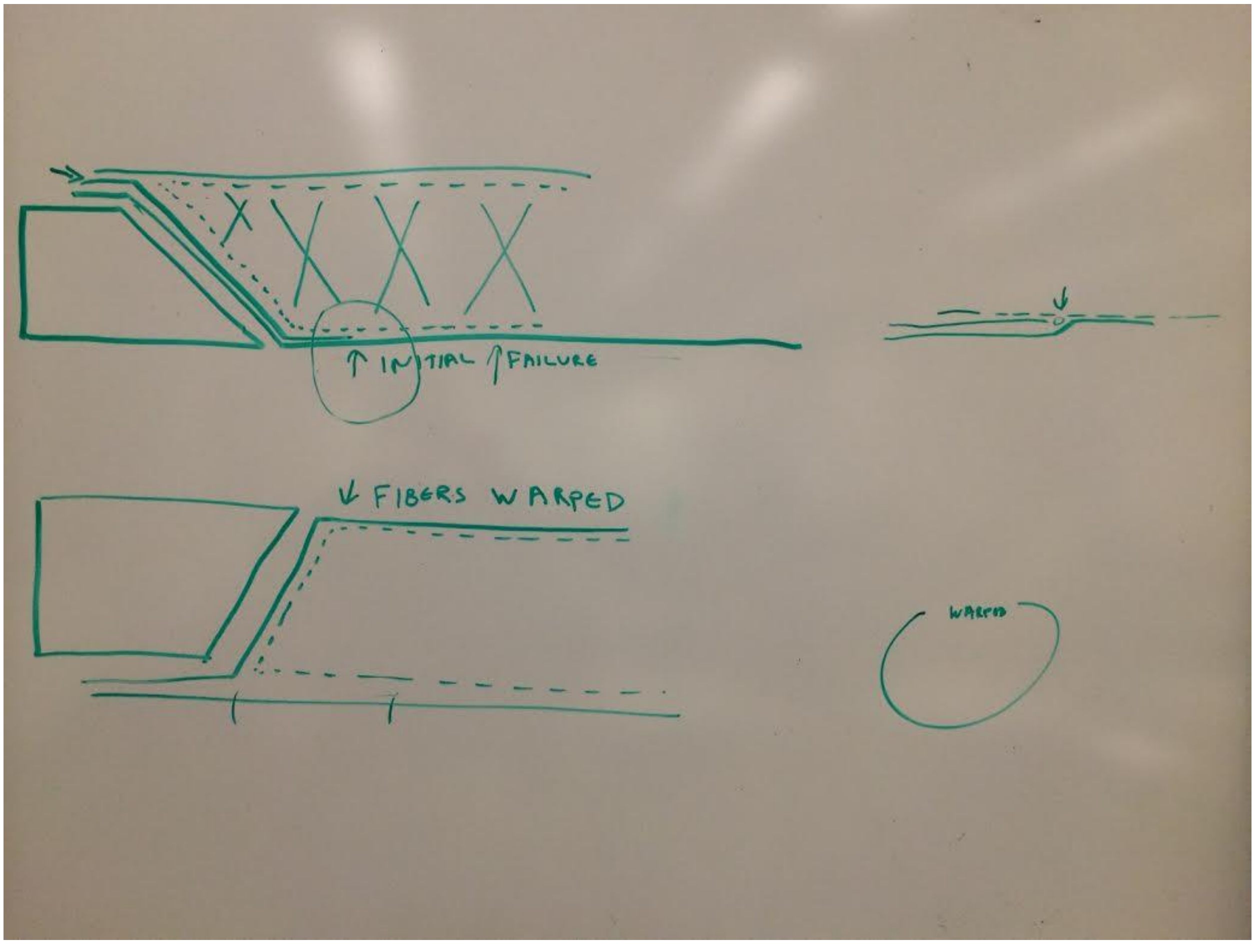


This is a sketch of a potential stepped ring. file is in the design folder

2/13/2014 4:29pm Jack
I think I figured out how and why the cylinder failed. There was an extra layer of carbon that was added to the ramp when wrapping it became impossible. This layer ended right about where the initial failure occurred. (Top drawing).

The secondary failure happened at where the fibers were warped, because there was no secondary layer. The warped fibers were then the weakest point. The extra wrap around the ramp didn't reach all the way around the cylinder as shown in the bottom right drawing.

I think the initial cause of failure was a stress concentration in the top left drawing that is circled and has a zoomed in view on the top right.



2/13/2014 4:29pm Jack
Called Alaskan Copper and Brass and they didn't have the material we need. Metal supermarkets did though, but they are a little more expensive than online metals. They can have it for us tomorrow morning. I have to order it now though, so they can get it in. It will be 120$ so I was going to ask Andrew first but he didn't pick up. I'll order it anyway.

Our Order:
6061 T6
Schedule 40 3" for mandrel: 4'
Schedule 80 3.5 for Rings: 2'

He said we could pick it up tomorrow

2/12/2014 5:29pm Rob
I cast a male mandrel and a female mold in plaster. The female mold is 3.5 in in diameter and the male mandrel is 3.0 in in diameter. This is basically the inside and outside of a 3" pvc pipe.

..

2/12/14 4:00pm Jenner

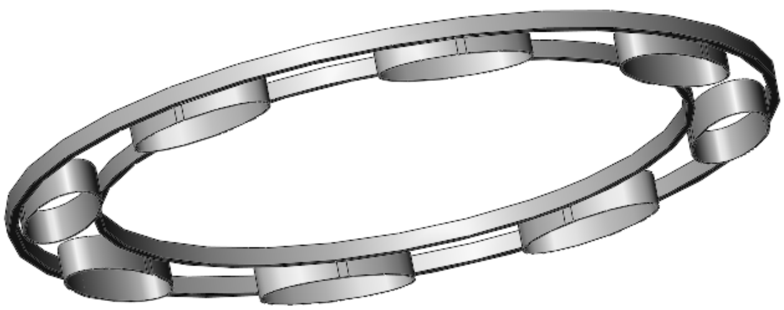
I ordered the TFT LCD shield for $35. If it ends up not being what we want, I'll just keep it and play with it myself and not get reimbursed, but I think it'll work out. That'll let us prototype a little bit with the next version of the shield.

http://www.adafruit.com/products/802

I'm gonna need to come in and take another look at the oven electronics to answer some questions about potential fan/cooling voltage and current. Not sure when I can get away during the day, though. I'll be in touch.

Cool Jenner !!! -Rob

2/12/14 4:00pm Jack, Barett
This is the aluminum ring that fits in the flower style corrugated module.



2/12/14 2:50pm Jack

Inside Diameter	Outside Diameter	I	Length	Constant*Pi^2*E/k^2	Critical Buckling	Number of Layers (Each Layer of carbon= .015)
9	9.09	13.07	9	19000	3,066	3
3.5	4.0625	6.00	6.5	50000	7,102	2
8	8.5625	62.77	16	50000	12,259	
10	10.5625	120.06	16	50000	23,449	
6	6.09	3.90	16	50000	762	
6	6.5625	27.41	16	50000	5,354	2
6	6.625	30.93	16	50000	6,041	4

$$F = \frac{\pi^2 EI}{(KL)^2}$$

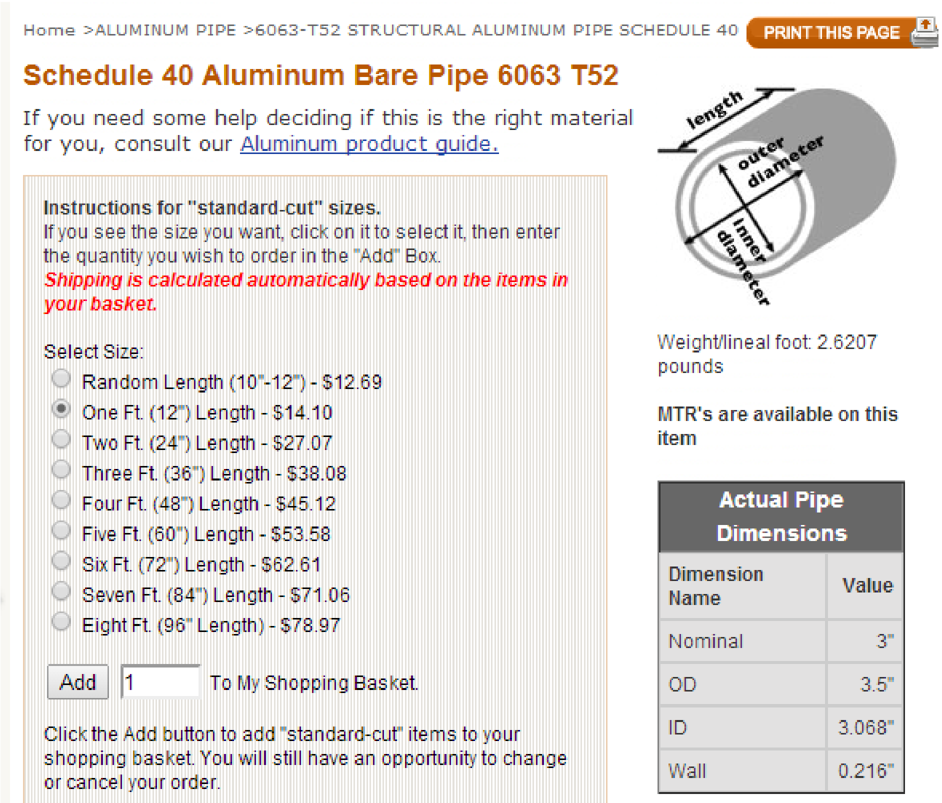
I made a buckling calculator in the stress calculators spreadsheet. The calculator is supposed to take empirical values we get from the buckling machine, and feed them into this to make predictions for future cylinders.

It works by plugging in the data about the shape of the cylinder, and then you plug in the critical buckling load and fudge the correction factor until it matches. My thought is that the fudge factors will be about the same from test to test. I tried this between GFR's buckling and ours. The fudge factor is different by a factor of 2.2, which is somewhat close. But, GFR and our buckling were pretty different. The aluminum rings in ours likely make it much stronger in buckling, and we had different number of carbon layers.

When we buckle another cylinder we should be able to get an idea of how accurate our fudge factor value is. Now we can see with the calculator that a module that is about 6 inches long, (not including the aluminum ends) is about the same strength as our future module. This means we inadvertently made about the correct size cylinder for a 1 to 1 ratio of strength with our future cylinder.

2/12/14 2:20pm Jack
This seems like good stock to make our practice mandrel on. We'd only need one foot of it for our practice pieces. It's got the thick wall we want. We could buy multiple sections of it to make multiple module tests at a time.

Beneath that is the complementary pipe to make the aluminum rings. Both of these aluminum parts give us the space to machine all surfaces.



Home >ALUMINUM PIPE >6063-T52 STRUCTURAL ALUMINUM PIPE SCHEDULE 40 PRINT THIS PAGE

Schedule 40 Aluminum Bare Pipe 6063 T52

If you need some help deciding if this is the right material for you, consult our Aluminum product guide.

Instructions for "standard-cut" sizes.
If you see the size you want, click on it to select it, then enter the quantity you wish to order in the "Add" Box.
Shipping is calculated automatically based on the items in your basket.

Select Size:
- Random Length (10"-12") - $12.69
- One Ft. (12") Length - $14.10
- Two Ft. (24") Length - $27.07
- Three Ft. (36") Length - $38.08
- Four Ft. (48") Length - $45.12
- Five Ft. (60") Length - $53.58
- Six Ft. (72") Length - $62.61
- Seven Ft. (84") Length - $71.06
- Eight Ft. (96" Length) - $78.97

Add 1 To My Shopping Basket.

Click the Add button to add "standard-cut" items to your shopping basket. You will still have an opportunity to change or cancel your order.

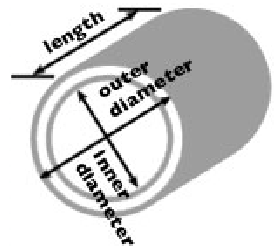
Weight/lineal foot: 2.6207 pounds

MTR's are available on this item

Actual Pipe Dimensions	
Dimension Name	**Value**
Nominal	3"
OD	3.5"
ID	3.068"
Wall	0.216"

Extruded Schedule 80 Aluminum Pipe 6101 T61

If you need some help deciding if this is the right material for you, consult our Aluminum product guide.



Instructions for "standard-cut" sizes.
If you see the size you want, click on it to select it, then enter the quantity you wish to order in the "Add" Box.
Shipping is calculated automatically based on the items in your basket.

Select Size:
- Random Length (10"-12") - $22.20
- One Ft. (12") Length - $24.70
- Two Ft. (24") Length - $47.44
- Three Ft. (36") Length - $66.71
- Four Ft. (48") Length - $79.07
- Five Ft. (60") Length - $93.89
- Six Ft. (72") Length - $109.70
- Seven Ft. (84") Length - $124.53
- Eight Ft. (96") Length - $138.37

Add 1 To My Shopping Basket.

Click the Add button to add "standard-cut" items to your shopping basket. You will still have an opportunity to change or cancel your order.

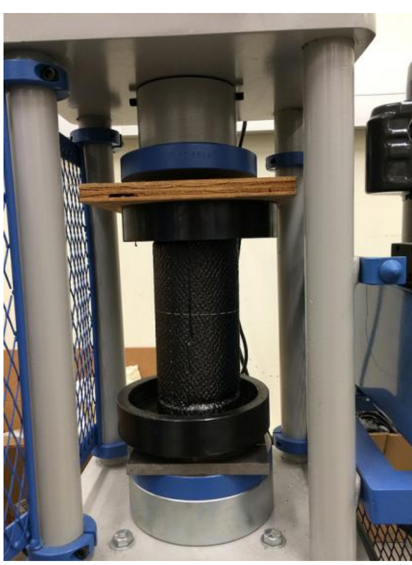
Weight/lineal foot: 4.3259 pounds

MTR's are available on this item

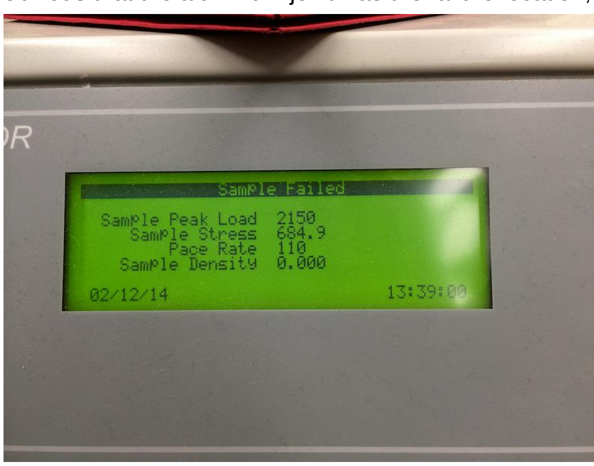
Actual Pipe Dimensions	
Dimension Name	**Value**
Nominal	3.5"
OD	4"
ID	3.364"
Wall	0.318"

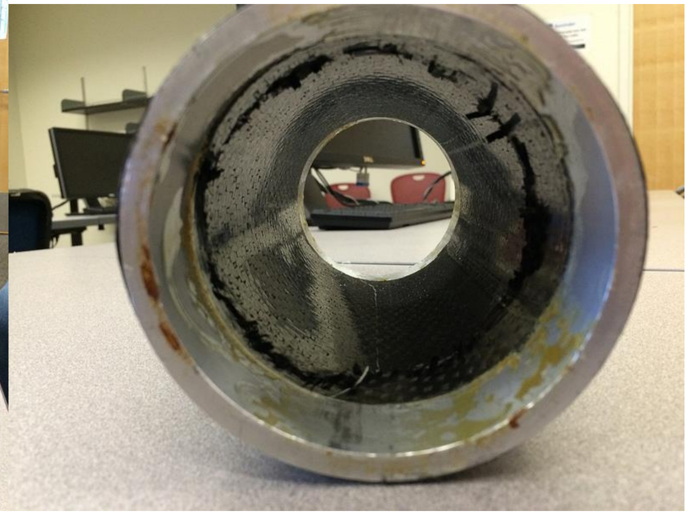
2/12/14 10:45am Sam, Rob, Barett
We crushed the cylinder in the compression machine with fantastic results. It wasn't very exciting. The machine readout only records load until the part starts to fail, so we stopped it right after it started to fail.

The machine reported a maximum load of, wait for it…. **6940 lbf**. After removing the part and inspecting it, you could see a thin line on the inside ply where the carbon layer started to buckle. See photos below. It surprisingly failed on the pristine inside layer about an inch away from the poorly made aluminum bond joint.




We put it back in the machine after the initial test and the peak load was reported as 2150 lbf. After this test it was obvious that the aluminum joint was the failure location, as it crumpled into itself. See photos.





2/11/14 6pm Jenner **Oven Control Shield v3**

(It's great watching your design log, you guys rock. Just saying.)
Thanks!

Now that you have some tests under your belt, what's the ideal number of thermocouples?
Can we get away with five?
It appears that yes we can. We will talk about this as a group and respond more fully. For right now and the foreseeable future, 5 is enough. -Jack

We could probably get away with two if we really need to. It also looks like a 100 ft roll of thermocouple wire is about $80. So there is no reason the amp/ADC need to be remote from the controller board. This would vastly improve the SPI communication.- Rob

Five works great .

What are the cooler and fan, exactly? I'd like to know the hardware just so I know where the relays are going.
Cooler might be a reference to a valve to let air out of the box during post cure, but I don't know. Fan is a way to mix up the air so we don't just get hot on top and cold on bottom. Our baking shows that at very most we have a 20 deg difference between top and bottom, which is close enough that right now we don't need to worry about it. It might not be installed for months, or maybe never. So that's kind of a tricky issue. The perfect oven would have a fan, if that helps. -Jack

Thank you! I will strive for perfect and we'll see where we fall short. -- Jenner

Perfection is not attainable. But if we chase perfection, we can catch excellence. ~Vince Lombardi

On a side note, commercial ovens have exhaust and recirculation fans to provide both even temperatures in the oven and a controlled amount of fresh air. We may or may not need this, however it should be a consideration in the overall design; even if it is never implemented. - Rob

I figured out pins for the LCD Shield with its joystick input and SD card for logging. If we use six thermocouples, the below pinout could work. All peripherals are on the SPI bus. LCD and SD card are MOSI. I've provided for two relays, fan control, and cooler control.

AN0	Start/Stop control
AN1	
AN2	
AN3	JOY_READ
AN4	
AN5	
DIG0	CS_THERM1
DIG1	CS_THERM2
DIG2	CS_THERM3
DIG3	CS_THERM4
DIG4	CS_SD
DIG5	CS_THERM5
DIG6	COOLERCONTROL
DIG7	RELAY1
DIG8	DCRS_LCD
DIG9	RELAY2
DIG10	CS_LCD
DIG11	FANCONTROL
DIG12	SPI_MOSI
DIG13	SPI_SCLK

2/10/14 10:00pm Jack, Rob, Barett, Sam
What did we learn from part 15?

- Surface is too dimply with just 1 layer and vacuum bag
    - Potential solutions: 2+ layers carbon instead of 1, caul plate, shrink tape, smaller core cell sizes
- Tool needs to be concentric, and accurate, hold and locate rings, likely needs to be the same material as rings. Mandrel needs to be properly held during layup.
- Core chamfer is super difficult to cut at all, and needs to be done accurately. Potential a jig to help with this, or a different solution.
    - Potentially using a table saw with sacrificial wood and double sided tape and a jig would be best. Rob has one of these things.
- The core splice joint didn't work at all with the wrapped adhesive film. We must solve the core joints.
    - Maybe talk to PCC about what solutions they have
- Figure out the carbon overlap seam didn't sit and cure
- The carbon went up the ramp perfectly
- Potentially look at post curing
- Potentially look at other core materials, foams
- Potentially look at other joint geometries
- Need to put mold release on inside of rings
- Need more tools, better tools, scissors, knives, paper cutters, jigs, a real table to work on, mandrel material, bolts, ring materials, real infrastructure, aluminum treatments
- research plastics and 3D printingp

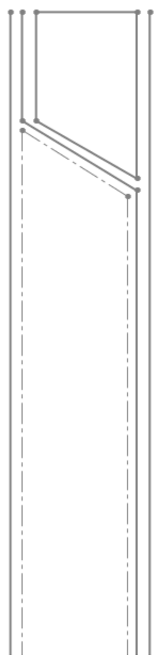
To Do:

- Send photos and writeup to PCC
- Call PCC and get information
- Buckle the cylinder, want to learn to use buckling machine
- Secure tools and materials
- Source table solution
    - Ask PSAS if the composites layup room/ storage could be in 84
        - It likely cannot
    - Ask PSAS opinion about table, what they want etc

    - Ask Don what facilities tables exists
    - Ask Tom about where to get one
- Attempt new core solutions from PCC/research
- research plastics and 3D printing
    - Call brandon about tool, rocket parts etc plastics what exists. (PEEK?)
- Bake new joint geometries
- We could try post curing aluminum back on to test things

Next monday: Perforated shrink tape cylinder to work on surface finish, layup same style cylinder

2/10/14 10:00pm Jack



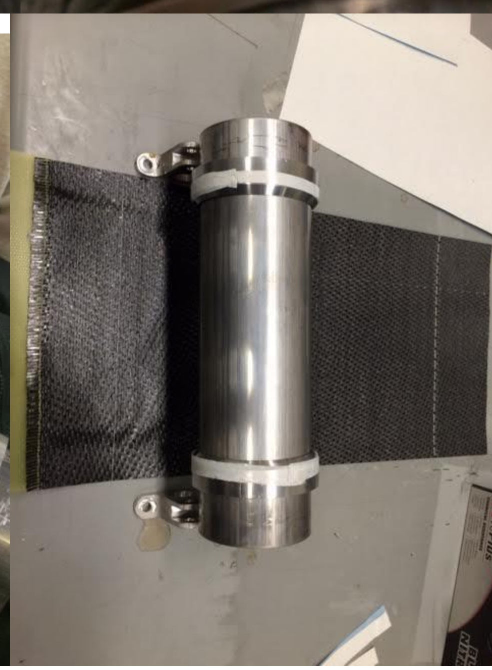
We laid up part number 15. It's a mini module concept. It has two chamfered aluminum bonded in rings and ¼ inch core. It is the drawing above. 3.5" ID. This is the first part we have used the automatic control system which worked well. It ramped perfectly and held it perfectly at 357F according to the fluke.

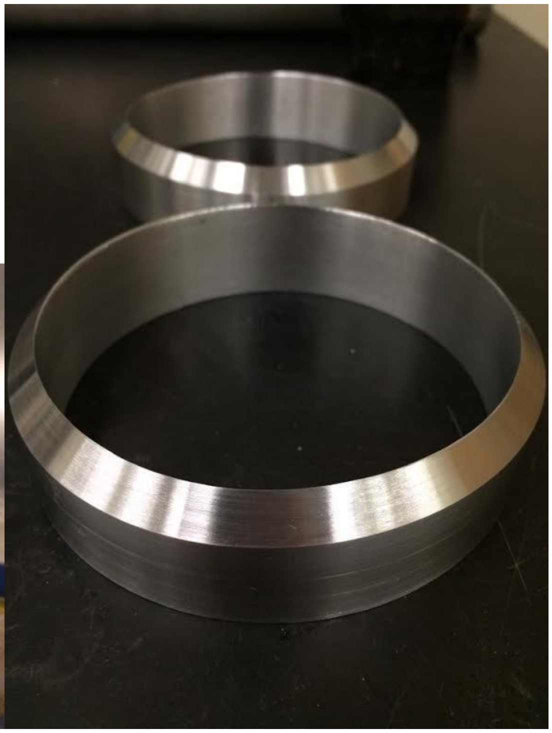
We realized today that our carbon is a 5 harness in both directions. This means it's like a plain weave but stronger.

We have been checking on the oven and control system every 10 minutes and it's doing great at keeping it at 358-360.

This is what was written in the manufacturing log:
The control system worked great. Except it held it at around 360F instead of 350F. We aren't sure if the Fluke is wrong, or if the computer is wrong. The fluke hasn't always been the most reliable, it is slow to respond and not sure the accuracy. We did a 1 core 1. [0,0]. we had a little bit of issues when we changed diameter. The carbon doesn't like to fold around corners very well. We cut slits in it and that worked very well. But, because of this, we added an extra ring of carbon with slits the other direction and this worked amazing. We think we should do this on the final part. The first layer sat pretty good flat down. We attempted to do a big bag over the entire part but when we pulled vacuum the bag pulled inside the tube and broke itself. This should have been obvious, but we didn't realize it. We instead put the tape around the edge of the tool, like usual. Pictures are in the log. We are using the older adhesive film, for the aluminum adhesive joint and the core attachments. We tried a new method of tying the core tight by using a strip of adhesive film and gluing it to itself. Pictures in the log. We first used flash tape to hold it in place and then added the strips. Everything seemed to be held down pretty good, barely any ripples. We only did one coat of hybrid

release. We machined aluminum rings with a chamfer in them. They were very eccentric, and the chamfer wasn't constant. We only sanded them with the scotchbrite. The chamfer was about 45 degrees. Making the chamfer on the core is challenging. We talked to Robert Story who advised that we use a cutoff wheel and a die grinder with carpet taping it down and using a bit of wood as a jig. We found after trying a bunch of different options that taping the core on one side and using a bit of wood to hold it down and one as sacrifice was best. Carpet tape would be superior we think, but painter's tape worked. The air tool from FSAE is broken so we had to use the milwaukee drill and a thick cut off tool. We need higher rpm, smaller thinner disk, and double sided tape for next time.





2/10/14 2:00pm Jack
Robert says they have this but don’t use it very often. They just butt it up to itself and let it be. It’s called adhesive splice film.
http://solutions.3m.com/wps/portal/3M/en_US/Aerospace/Aircraft/Prod_Info/Prod_Catalog/?PC_Z7_RJH9U5230GE3E02LECIE20SOG5000000_nid=1K8S0VTXW6be1K3HXBTMF8gl

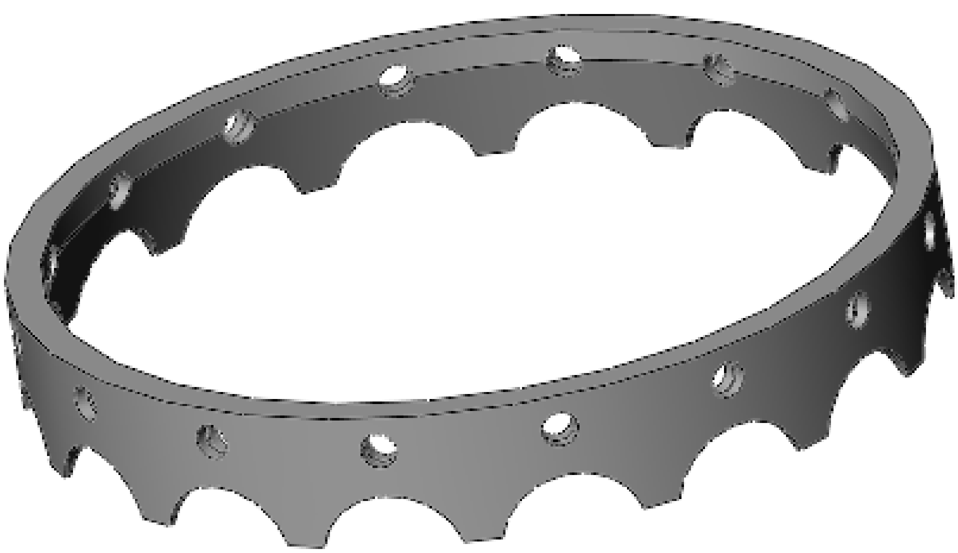
For cutting core he says they use carpet tape to hold it down and sacrificial mdf or other wood and use a die grinder with a cut off wheel for the angle. He says it works well.

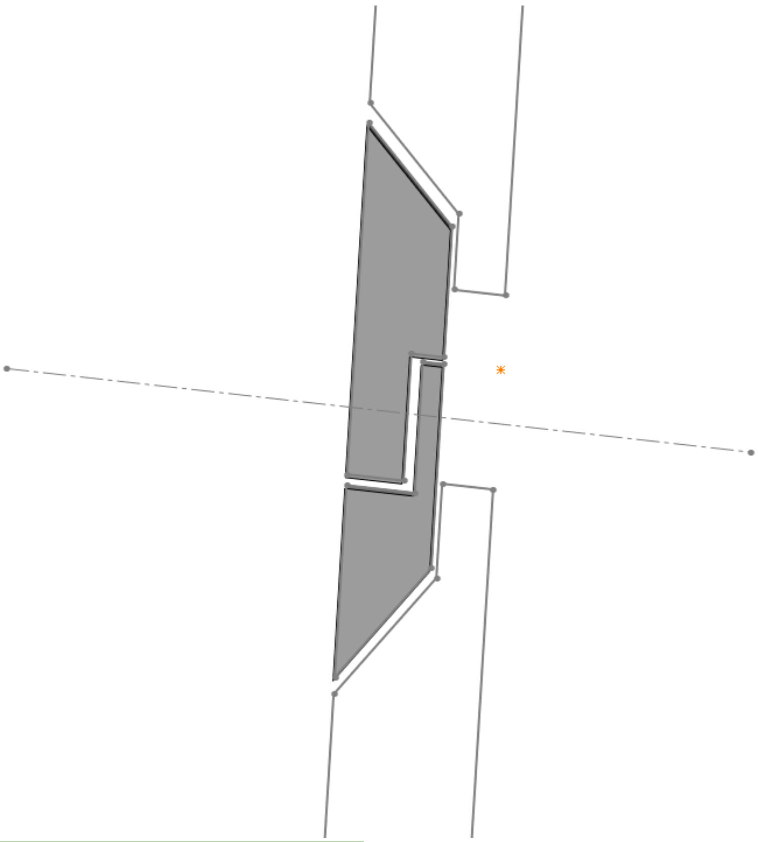
He said putting core between a sandwich of wood with carpet tape and then feeding it through a table saw would work.

2/10/14 10:00am Jack
To do:

- Prove oven control system
- research
- lay something up

2/6/14 5:30pm Jack
Had an idea for the ring shape. This would reduce the amount of aluminum, reduce the strength of the joint, yet still give it a prayer of being okay in bending. It incorporates the taper, radial bolt holes, and scalloping. This is essentially what me made on the dogbone test except all whittled away.





The carbon is about .01” per layer

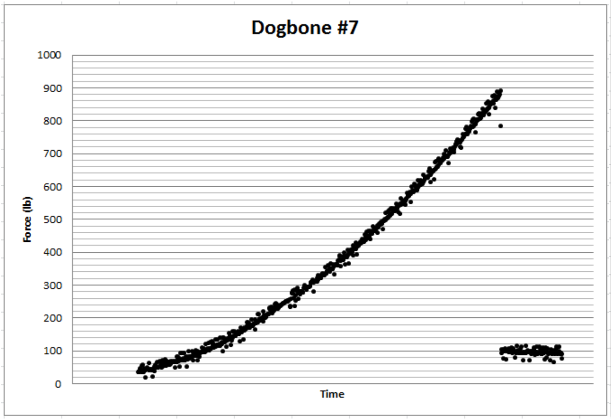
2/6/14 5:30pm Jack
Wern wasn’t really interested in being helpful with the tensile tester again. Tom seems to be the way to go for us.

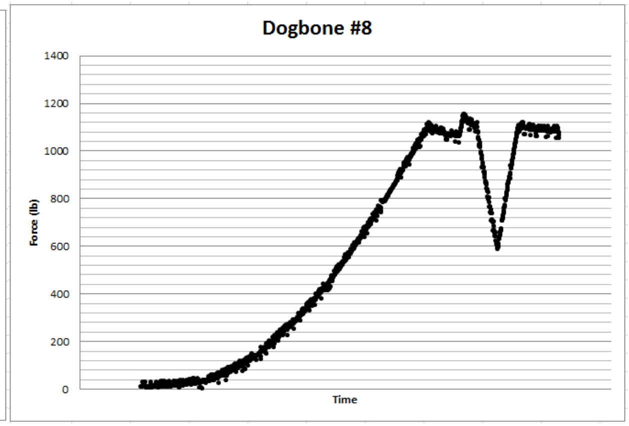
We used the tensile test machine and attempted to break our specimens. We collected data using the computer. It is located in the testing folder.

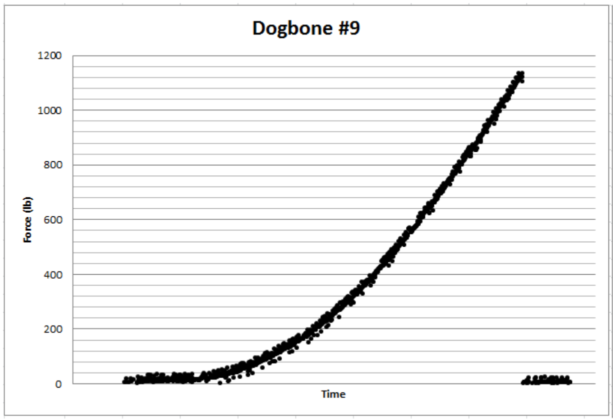
Both of the old glues were stronger than 1150lbf so we could not break them. We took them back to zero and back to 1150 for strength. They had 1.5 in^2 glued area.

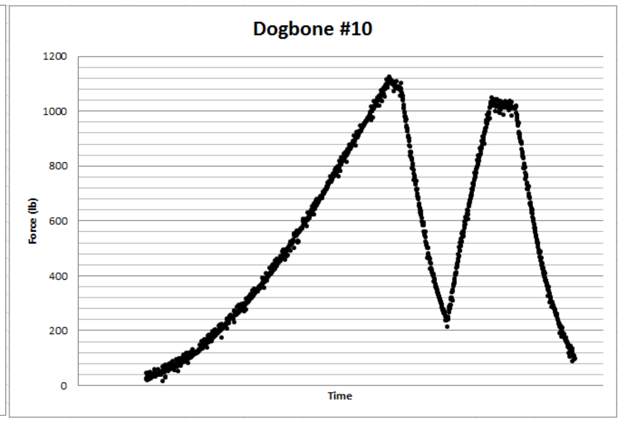
Two of the new glues failed, but at around 1000lbf. One did not, but judging by the crackling noises, it sounded close. They had 2 in^2 glued area. We think this glue was not designed for 350 cocure. It started curing at 250F.

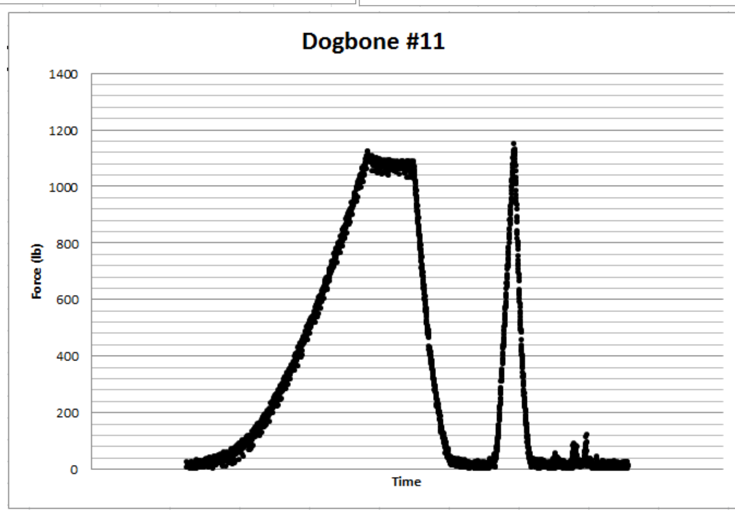
Questions we have from the test:
How close were our samples actually from failure? will they take the vibration and shock loading? could we simulate shock loading with his machine?







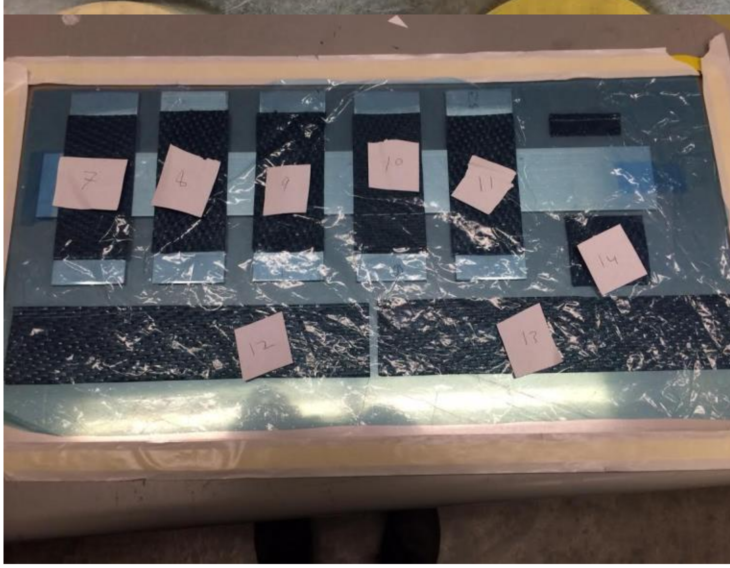




2/5/14 7:30pm Jack

We ran the oven and cured parts 7 through 13. Everything went perfectly. A little wisp of smoke happened, but we think that was left over glue residue on the inside of the door. The smell really wasn't bad in the room, significantly more benign than the plywood burning smell. We will break them on the tensile tester.


13
12
14
11
10
9
8
7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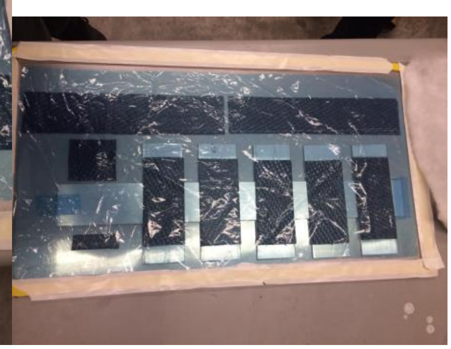
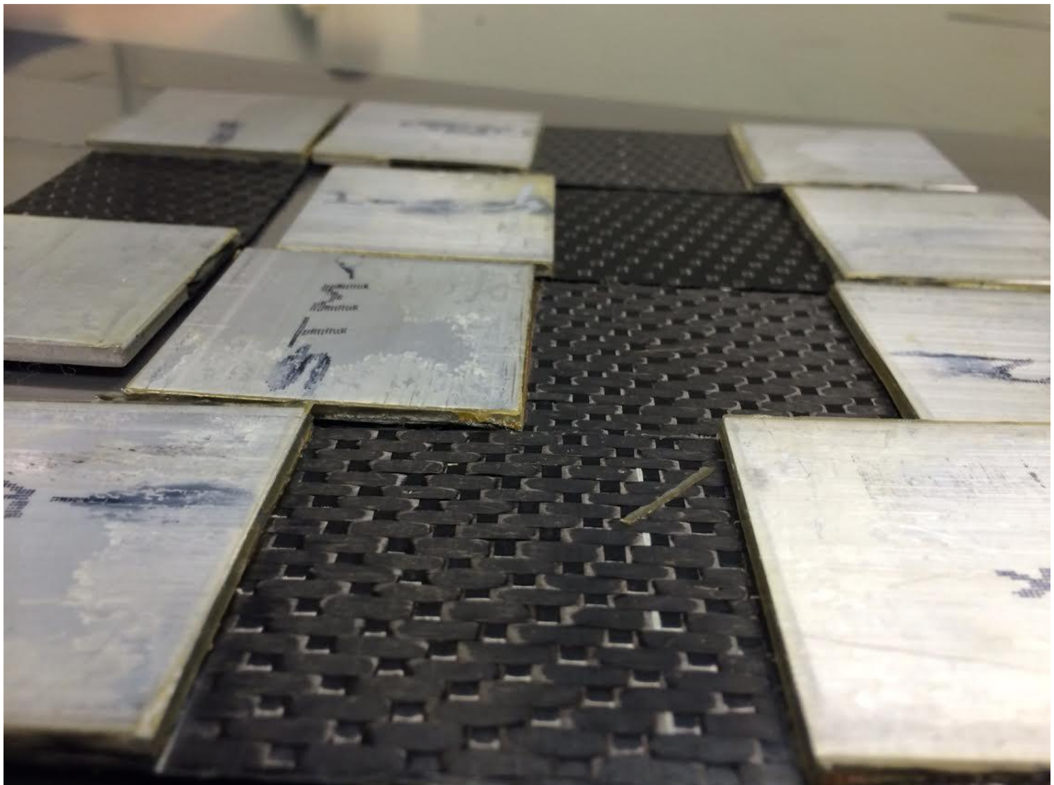
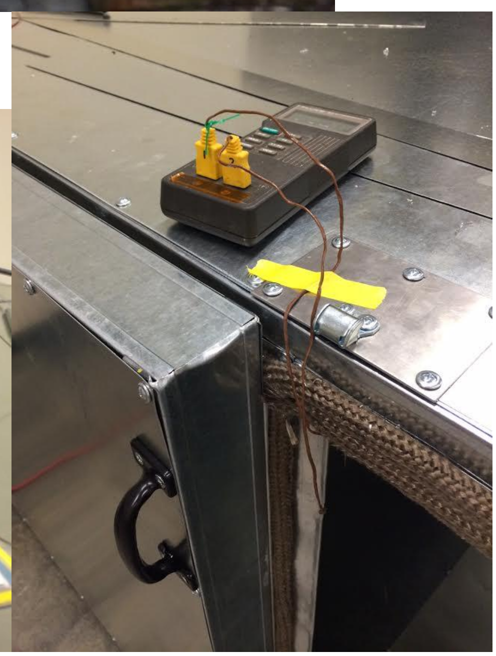
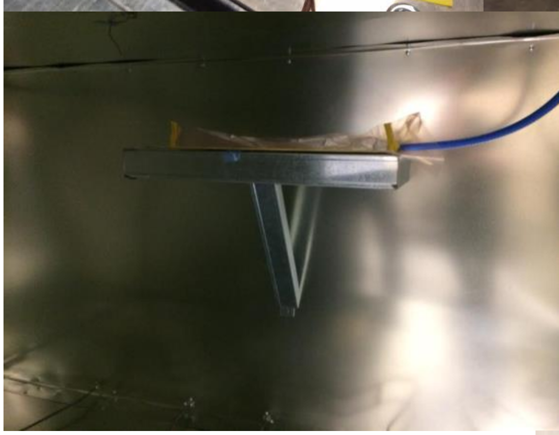
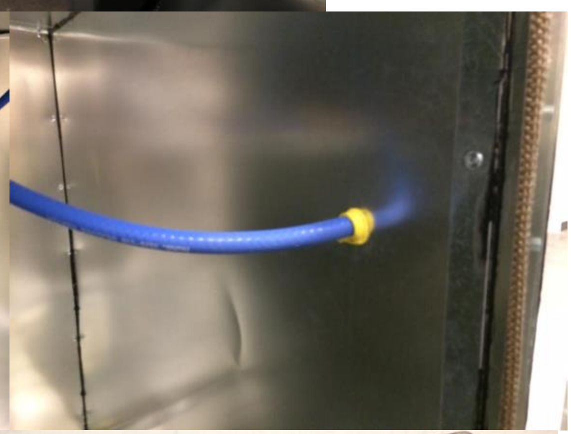
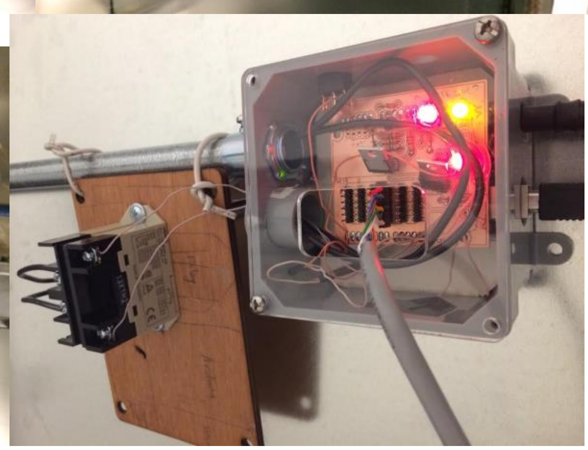







FLUKE 52
69.4
°F
ON/OFF
T1
F/C
T2
HOLD
T1-T2
RECORD
VIEW



2/5/14 6:30pm Jenner
I moved the folder to inside the design folder
I made a document in the Design folder called Oven Control Shield v3 and that's where I'm going to play around with how best to do what we want to do.

2/5/14 4:20pm Jack, Sam
Link to 2/5/14 curing of parts #7-13
https://docs.google.com/spreadsheet/ccc?key=0AiXT9hnzBhecdFhWaEppUXpvTmIzbmZ5X25IY1N4d3c#gid=0

Curing a bunch of parts

2/5/14 1:20pm Jack, Rob
Mondays we could bake parts, wednesday/friday we can test them and do analysis and figure out what to do next. Because Mondays are long days

2/5/14 10:20am Jack

List of variables we could change for the dogbone testing:

- surface finish of aluminum
  - 20 grit vs ? grit etc
    - need to look at tech sheet for adhesive film
- cross sectional profile of aluminum
  - single shear lap joint vs stepped. Sloped vs parabolic vs constant
    - Should try single shear lap joint first
- surface treatments of aluminum
  - Phosphoric vs none vs Boeing solution
    - Should try Boeing solution first
- interface length L (as drawn on cad way below)
    - Constant area across all tests for now
- cocuring vs post curing
    - Cocuring first round, but curing carbon strips for post curing at the same time
- thickness of carbon
  - Changes peel stress because of bending stiffness
    - Go with a 2 ply for now
- Autoclave pressure vs bag
  - Might be hard to do
    - Go with bag pressure for now

Design of the test:
The point of this test is to see how consistent our joint can be, and if it is strong enough as tested. If not, more research and effort will have to be put into the joint.
Not a DOE style test because we will only be changing 1 variable between tests (Overlap shape)
3 replicates per change, 6 total dog bones.

We will also cure 6 single strips of carbon for post cure testing

Dogbones will have 2" width, 1" L, and a 1" flange sticking out past the carbon. We will have shims under the portion sticking out to prevent rocking. We will measure the thickness of of the wall of the previous cured piece and make the shims about that thick. 2x1 adhesive patch.

MSDS for AF30 Adhesive Film:
http://multimedia.3m.com/mws/mediawebserver?mwsId=SSSSSuUn_zu8l00x4xtBM8m94v70k17zHvu9lxtD7SSSSSS--

It says ventilate when curing but doesn't sound horrible. Wear gloves when touching it, and don't grind it without a real mask. Irritation is the main side effect.

Technical Specs AC130 Metal Alloy Surface Preparation (Instructions):
http://multimedia.3m.com/mws/mediawebserver?mwsId=SSSSSufSevTsZxtUoYtx5Y_BevUqevTSevTSevTSeSSSSSS--&fn=TDS_AC130_AC130-2.pdf

Another link:
http://multimedia.3m.com/mws/mediawebserver?mwsId=66666UF6EVsSyXTtO8TX5XTcEVtQEVs6EVs6EVs6E666666--&fn=TDS_AC131_AppGuide.pdf

To do:

- find sheet metal to layup on
- cut, sand and clean the aluminum (6x)
- research the adhesive film
- research the Boeing solution
- set up the oven for vacuum
- install thermocouple in correct location
- treat aluminum
- treat sheet metal
-

2/5/14 10:10am Jenner

Here's an option for a display solution for the oven. We can drop it right onto the Arduino (stacking shields) and program it. I still need to check to make sure we're OK for pins but I think we are.

Adafruit 1.8" 18-bit Color TFT Shield w/microSD and Joystick

www.adafruit.com/products/802 $34.95

- microSD card slot which could possibly save bitmap images from the screen (plots!)
- 18-bit color display
- 5-way joystick nav switch with plastic knob

pin requirements:
- DIG 8, 10, 11, 13 for display
- DIG 4, 12 for microSD
- AN 3 for nav joystick

2/5/14 1:15am Tung
The control oven code including ramp up temperature function, 6 thermocouples, 2 relays is put in the Oven_control_v2 folder.It is easy to edit the control parameters (set temperature, cure time...etc) from the constants set in the code.

The idea of the code is the oven will heat up when pressing the start button. The set temperature will ramp up by time (3 deg F/mins) until reach setTemp(350F). The program will control the temperature in between (tempSetLow,tempSetHigh) by turing on/off the heaters. The range (tempSetLow,tempSetHigh) will increase by time during the ramp up duration and stay constant during 350F cure level. After a duration: timeMax (8 hours), the program will stop and indicate the job done.

I hope that we can have the relay attached and test the code. Can't wait for it

2/4/14 9:30pm Jack
Conversation with Andrew, Jenner, rob, jack:
The general idea was to keep moving forward the way we are. Make it safe and look like an appliance. Gerry is only worried about the safety of the group after us. The worry with 2 110V is the neutral. He was worried about there being a potential between the two neutrals.

Jenner is going to continue working on the user interface to make it more appliance like. He will be getting it to the point that you can select cure cycle profiles using an interface. He is essentially taking it from *our* minimum viable product to Gerry's minimum viable product.

Gerry is worried about other people using it and hurting themselves. From our perspective, the more people that use it the better. In fact, it might be worthwhile for us to give a little material to other groups and help them do stuff as long as they give us a shoutout. Nothing says we made a composites lab like 2 capstones, VMS and HPV using it to make parts.

2/4/14 4:30pm Jack
We tested the 5 coil setup with the professionally done electronics and it worked like a champ. It took like 5 minutes to get to 200F, and was easily increasing by 15-20F/minute (Required 3F/min). Great success! The box is working and looking great. The Fluke measurement gauge is a little laggy and odd. It might be doing some sort of internal filtering that makes the readings jumpy and not consistent.

Rob and Sam gave the PDS presentation today and nailed the time length and content. We created a prettier schedule that's called "copy".

2/3/14 11:30pm Jack
We installed the latches, the extra elements, the fancy electrical box, the electrical protective belt, and the small controls box today.

We came up with a design for the shelf inside that we could build Wednesday. We might need a bigger electrical controls box. Also the program switch didn't fit inside after it was all assembled, so we will deal with that later. We tested the electrical controls after using the thermocouple and it worked.

Barett made the wise point that a female mold must break in half afterwards or else you cannot get your part out because it will cure at the elevated temperature. So we cannot use that big ass tube unless we put some serious effort into prepping it.

2/2/14 1:30pm Tung
Board is done. It took me all day to figure some ground connections on the top and the failed diot.
I need help in making the sensor extension wires. It took me around 1 hour to make one wire by myself. It will be more efficiency if someone prepares the wire someone else is soldering.

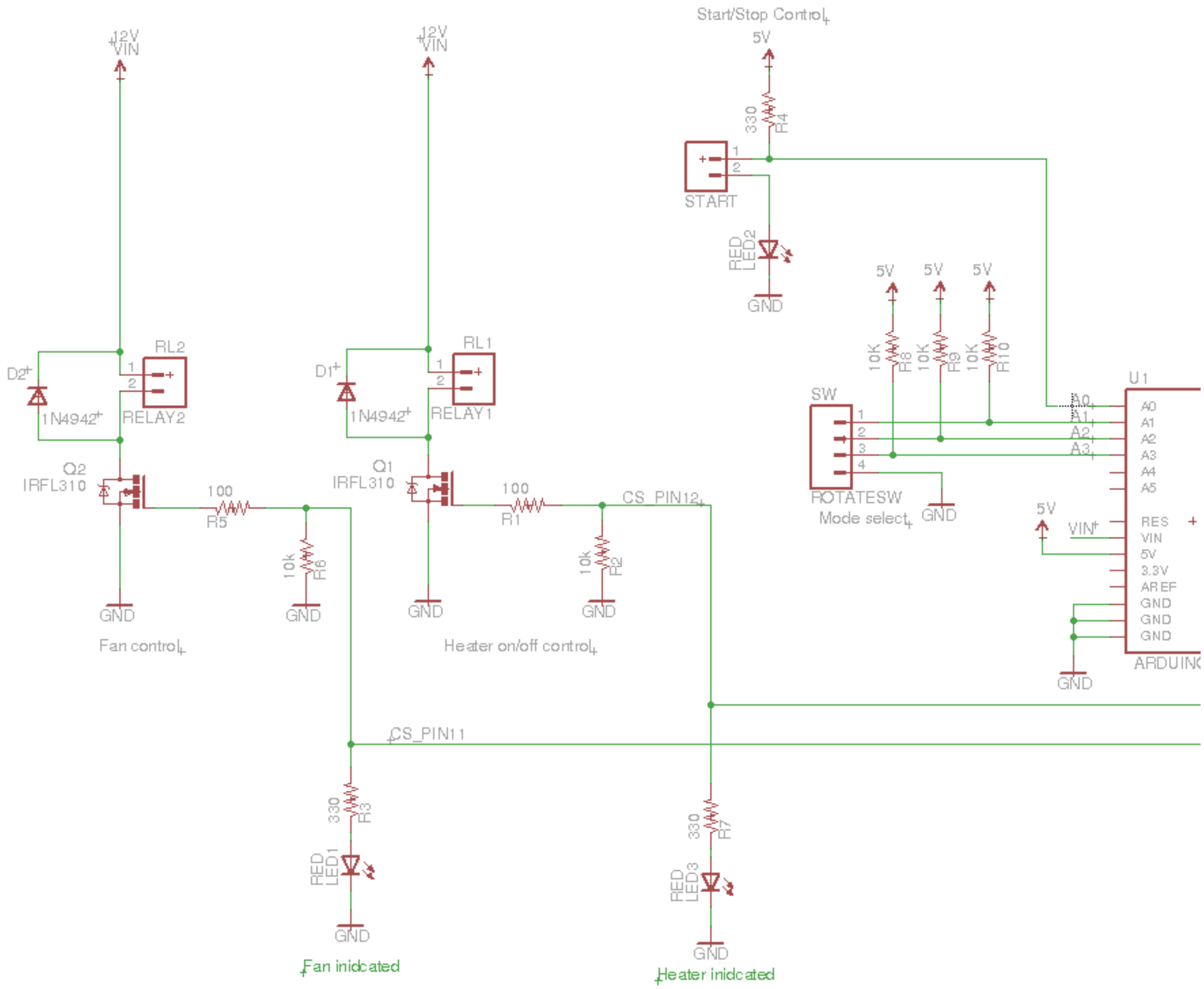
Things to buy on Monday.
- Heat shrink tube: Small: 6 colors, 1big
- 2 pins female connectors: 3
- Circuit break for 2 110V
- Angle male header: 1 row (40 pins)
- Electrical box

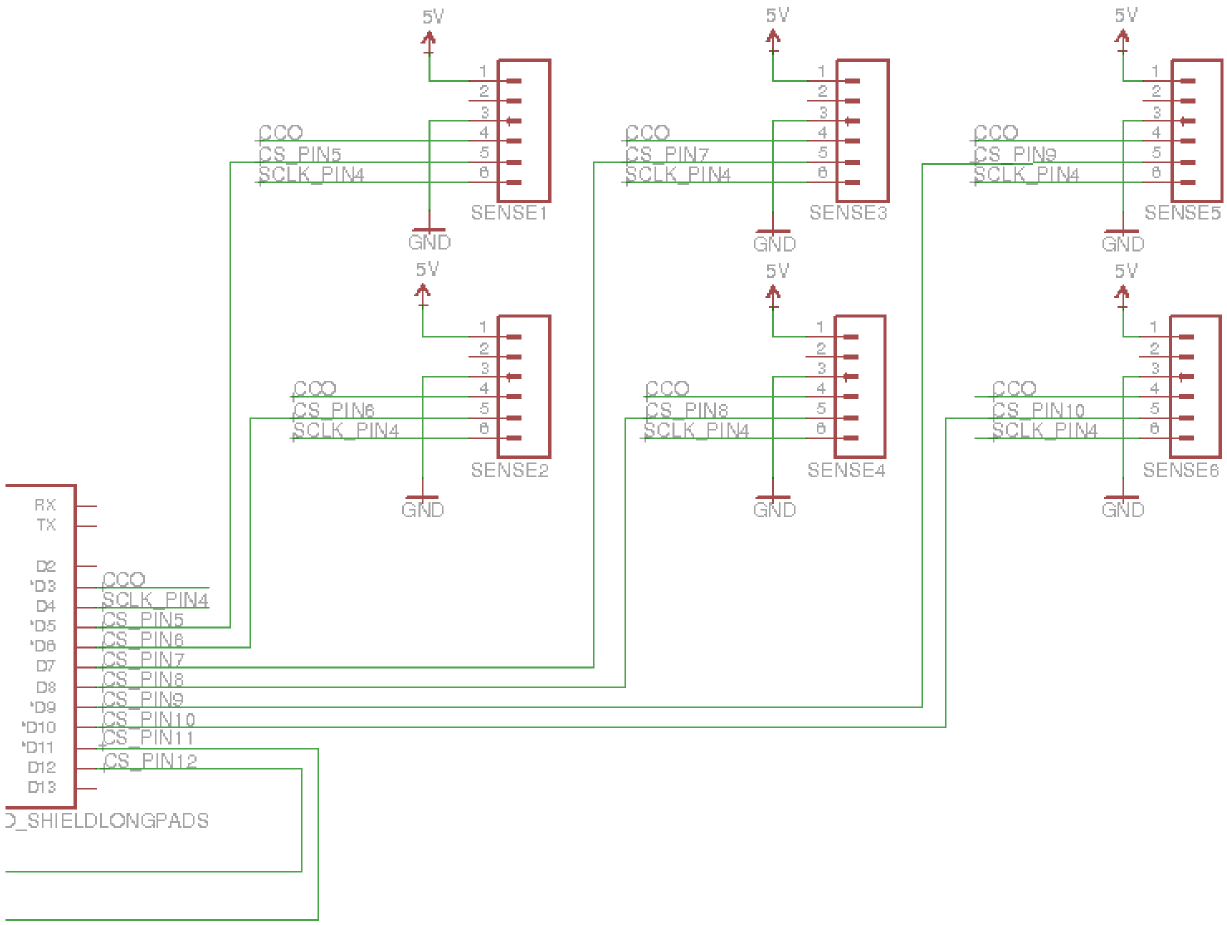
1/31/14 9:30pm Jenner
Board is done! I made a mistake with not enough vias so the bottom headers are offset a little. I checked ohms all over the board and I think everything is OK. Let me know if you run into a problem you can't fix. If it's easier, I can make another board.

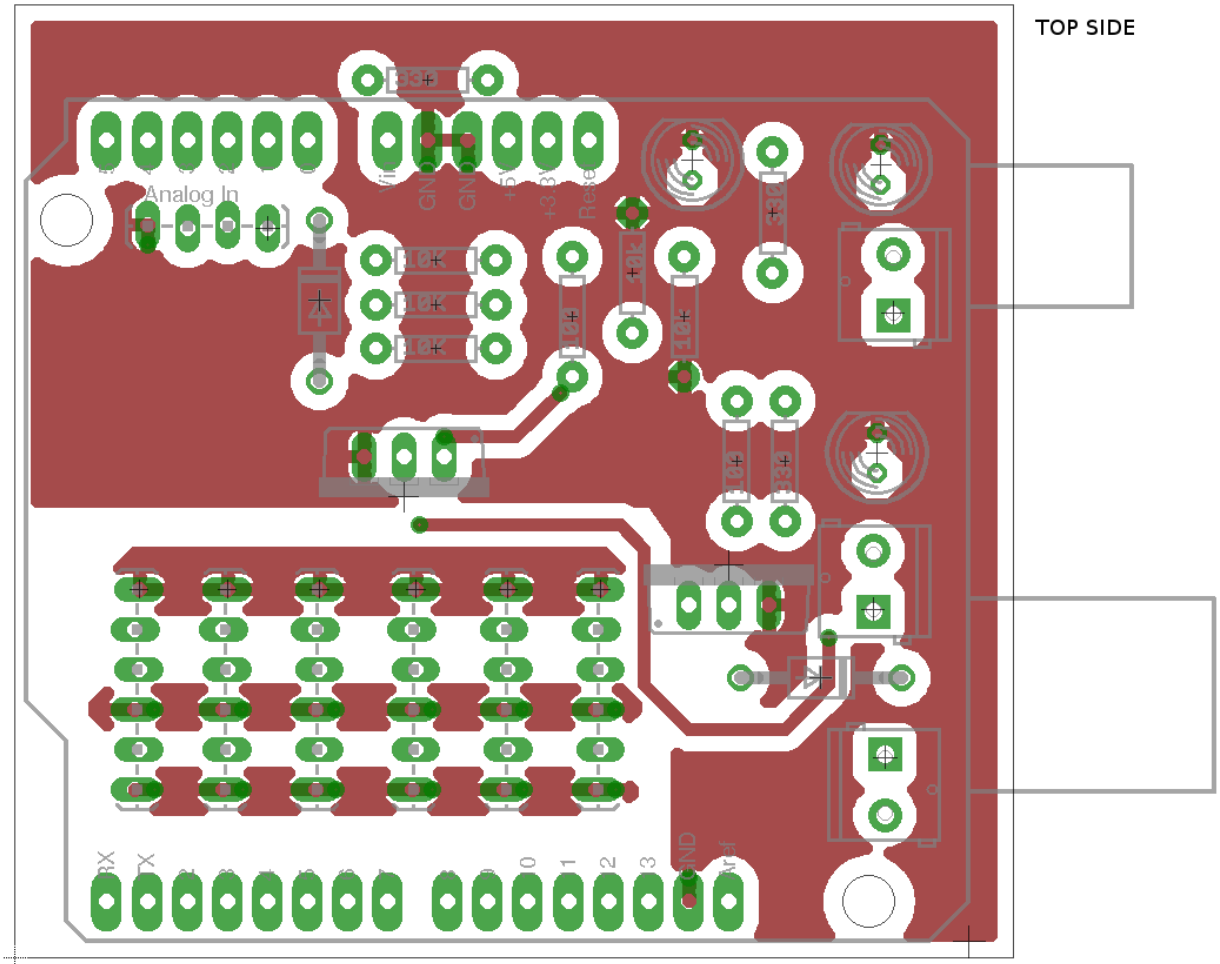
Remember to solder everything on the bottom side!

I did make the isolation bigger so soldering should be easier. The ground plane does not go all over the board! Check the pictures below. The router didn't take away the non-signal parts of the board though so that sucks. I think I know what to do fix next time.

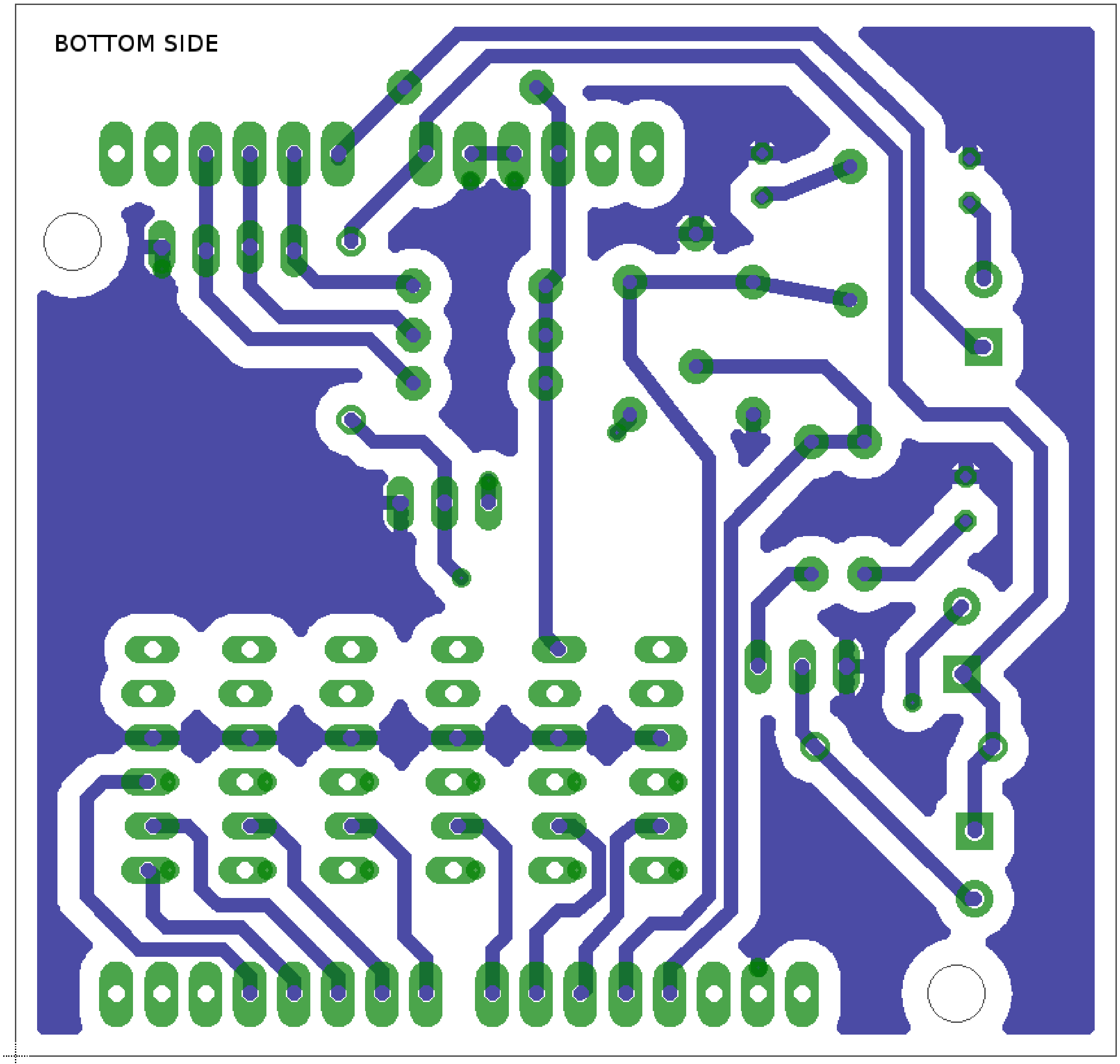
The board is in Lab 84 in a bag. Eagle files at http://github.com/wicker/oven-controller/.




5V
SENSE1
SENSE2
SENSE3
SENSE4
SENSE5
SENSE6
GND
CCO
CS_PIN5
CS_PIN6
CS_PIN7
CS_PIN8
CS_PIN9
CS_PIN10
CS_PIN11
CS_PIN12
SCLK_PIN4
RX
TX
D2
*D3
D4
*D5
*D6
D7
D8
*D9
*D10
*D11
D12
D13
_SHIELDLONGPADS

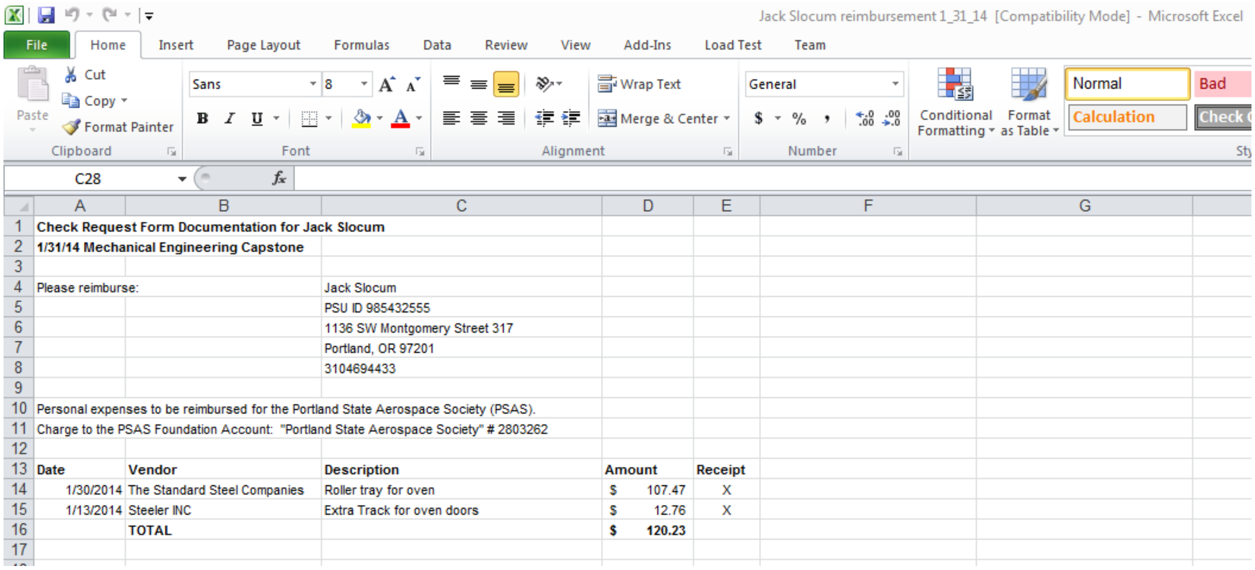


TOP SIDE



1/29/14 9:30pm Jack
Monday Rob will have polishing compound to test finishes on the carbon.

This is how you do a reimbursement.



Date	Vendor	Description	Amount	Receipt
Check Request Form Documentation for Jack Slocum				
1/31/14 Mechanical Engineering Capstone				
Please reimburse:		Jack Slocum		
		PSU ID 985432555		
		1136 SW Montgomery Street 317		
		Portland, OR 97201		
		3104694433		
Personal expenses to be reimbursed for the Portland State Aerospace Society (PSAS).				
Charge to the PSAS Foundation Account: "Portland State Aerospace Society" # 2803262				
1/30/2014	The Standard Steel Companies	Roller tray for oven	$ 107.47	X
1/13/2014	Steeler INC	Extra Track for oven doors	$ 12.76	X
	TOTAL		$ 120.23	

1. Collect receipts
2. Open this spreadsheet
3. replace with your information
4. Staple together with receipts
5. Email Andrew (adg@ece…)

1/29/14 9:30pm Jenner & Tung

*__Update: not going to deal with fan for now, but could be hard wired in for future implementation__
Tung made some changes and sent over v2 of the controller board. We'll add a fan-controlling FET and corresponding LED, and try running 12V through the Arduino. Changes pushed to github: http://github.com/wicker/oven-controller/

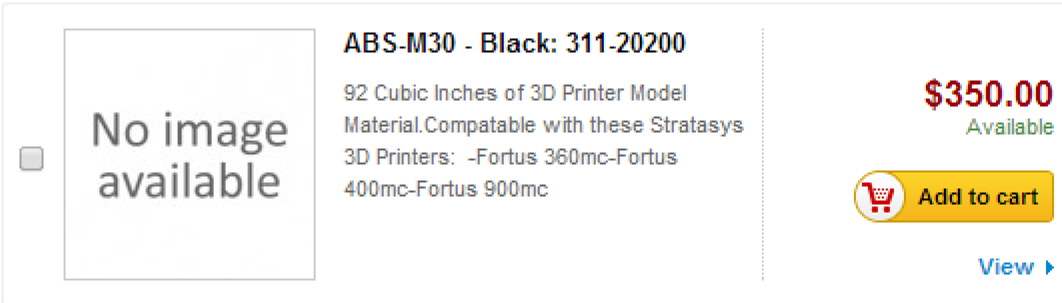
Jenner will increase the isolation between ground and traces for easier soldering and also try out the plated through-hole vias. The plan is to be in the EPL Thursday night to route the v2 board.

1/29/14 6:15 Jack
Had a ridiculous idea for how to make the motor/fin module. We could get Xerox to 3D print us a mold that has the fins integral with the motor module. They could like organically grow out of the sidewalls of the cylinder. This could solve a bunch of problems for us. We could also get them to print a nosecone mold for us. I found a company that has plastic that can be used as a mold material for carbon layup. Epson wanted to make the news, I bet helping the first university team to ever make it to space would fit their idea.

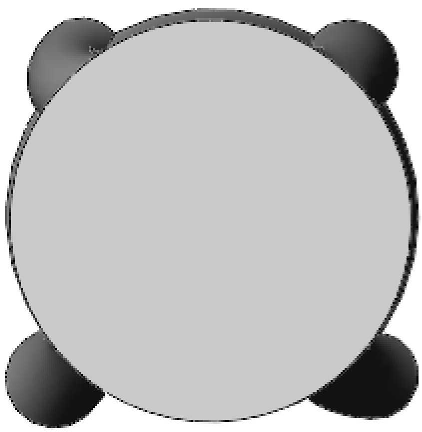
We have a FDM machine, so potentially we could use it with our machine! It appears we cannot use it on our machine. Here is what we think our machine is.

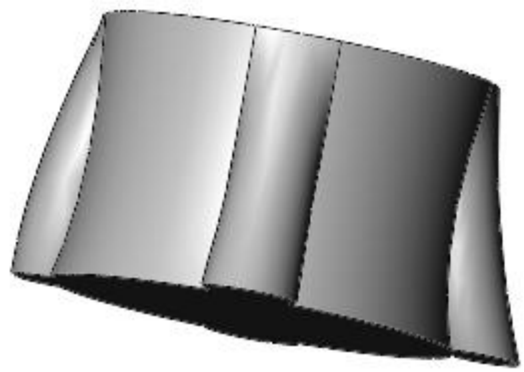
http://www.stratasys.com/~/media/Main/Secure/System_Spec_Sheets-SS/DimensionProductSpecs/uPrintSESellSheet-INTL-ENG-10-13%20WEB.ashx

I talked to brandon who has access to the machines and an other material that he thinks will work. He works at PCC now, but still has good relations with his old employer.



http://www.advancedrp.com/shop/25-abs-m30





1/29/14 6:15 Rob
I uploaded an excel spreadsheet that predict the heating profile for a given material in the oven. I started it in excel but I can re do it as a Google doc later.

To do:

Oven
- Install extra coils
- Get screws
- Install door latches
- Make more shelving
- Install control system
- Finish electrical control system
- Add some insulation for burn protection
- Decide and act on thermocouple location, install
- Decide on fan (110V)

Carbon
- Get vacuum bagging material
  - Ask fiberlay for sponsorship?
- Make dogbones
- Test dogbones
- Try different styles of male and female layups
  - female 2 half, female 1 piece, male with vacuum bag and a combination of perforated shrink wrap. try cocuring rings.

- Research potting

Project Level

- Make schedule
- PDS
- Get ready for meeting with Mark
    - Need to ask mark to deal with the glass mess in lab

Could cover the whole inside with something like this http://www.autozone.com/autozone/accessories/Thermo-Tec-12-x-24-in-adhesive-backed-heat-barrier/_/N-269m?itemIdentifier=398808_0_0_

1/29/2014 3:00pm Jack, Rob

The problem is we can't do heat transfer calculations very well because the only heat loss really comes through convection, and it's a challenge to do that. Instead we can empirically get it. We want to figure out what our universal heat transfer coefficient (U) for the box system as it sits. Because we know the rest of the variables:

$Q=UA\Delta T$
$Q=2096W$
$A=14.86m^2$
$\Delta T=(Th-21C)$
$\mathbf{U_{Experimental} = .9}$

Because we have a realistic value for our heat transfer coefficient, we can extrapolate to what happens when we add more coils.

For 1 coil + 3 coils:

R=20 ohms
$P=V^2/R$
$P=122^2/20=744.2W$
$Q=2840W$
$Q=UA\Delta T$
T=233C=451F

For 2 coil + 3 coils:

R=10 ohms
$P=V^2/R$
$P=122^2/10=1488W$
$Q=3584W$
$Q=UA\Delta T$
T=288C=550F

Heating 45 kg of material

Cp = 1000 J/kg (many material in this range)
$Q_{req} = m\ Cp\ \Delta T$
$Q_{req} = 45 * 1000 * 156 = 7020000$ J

Average Heat Loss During Heating

$Q_{out} = UAT_{avg}$
$Q_{out} = 0.9 * 14.86\ m^2 * 100\ C = 1337\ W$

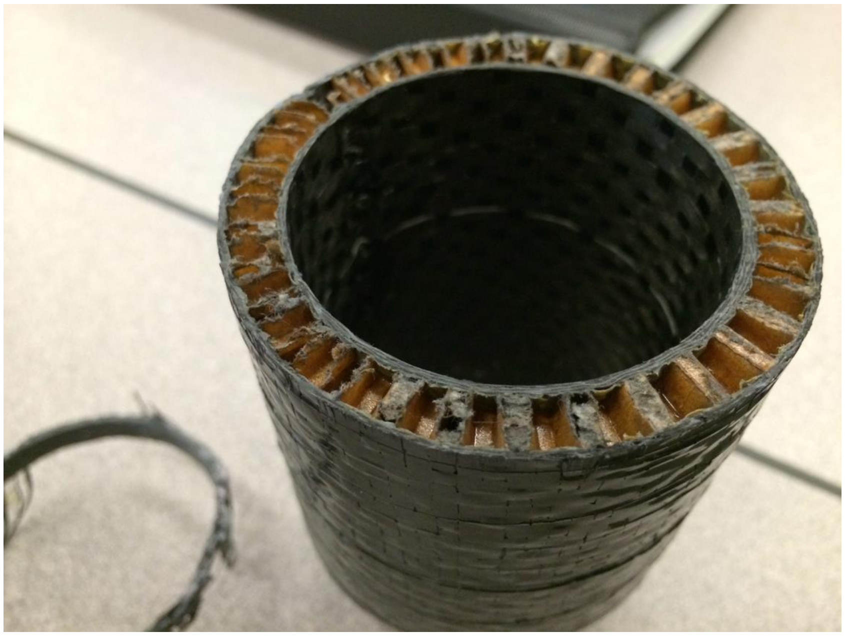
4 Coil Heating

$Q_{net} = Q_{in} - Q_{out}$

Q_{net} = 2706.2 - 1337 = 1368.8 W
t = Q_{heat} / Q_{net}
t = 7020000 J/ 1368.8 W = 5128.6 sec = 85.47 min ~ 3.3 F / min

5 Coil Heating
$Q_{net} = Q_{in} - Q_{out}$
Q_{net} = 3387.7 - 1337 = 2045.3 W
t = Q_{heat} / Q_{net}
t = 7020000 J/ 2045.3 W = 3432.2 sec = 57.20 min ~ 4.9 F / min

1/28/2014 11:00am Jack
We cut the end off of one with a hacksaw. We also sanded a small section and will try buffing it.



1/27/2014 11:40pm Tung

Decide how to supply power to the oven

Options	Pros	Cons
480V	- 16 times power supplier compared to 110V - No need to redesign the control circuit	- Permission - Replace the power cord to 45A - Replace the relay to 45 A
2 110V sources	- 2 times power supplier - No need permission	- Redesign the control circuit - Replace the relay with 2 connectors - 2 power wires come in: not really professional but it works.
110V sources	- Not enough heat for the curing process????	

1/27/2014 9:00pm Sam

Parts 5 and 6 went in the oven on the same tool. The temperature ramped on average 1dpm (~6dpm max and 0-.2dpm at times) and took 120 minutes to reach ~315 degrees, at which point we started the two hour timer. About 30 minutes into the two hour hold, the door popped open and the temp dropped to ~225F almost instantly. The door was closed within a few seconds and the temperature was back to 310F after about 3 minutes. It's doubtful that the part itself dropped in temperature that quickly. For the rest of the cure, the oven maintained an avg. temp around 328F and reached a maximum of 333.6F. The oven was unplugged at exactly 120 minutes into the hold and the doors were left shut for a relative “ramp down”.

The top center of the doors reached a temp of about 250F.

The hot resistance of each element was 7.15ohms according to the little orange multimeter from the formula team.

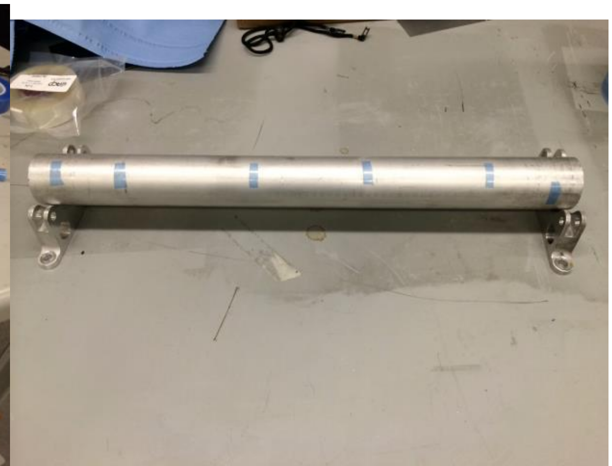
The temperature decreased by 70F in the first 10 minutes (-7dpm). From 10-20min, -30F (-3dpm). From 20-30min, -60F (-6dpm). From 30-40min, -30F (-3dpm).

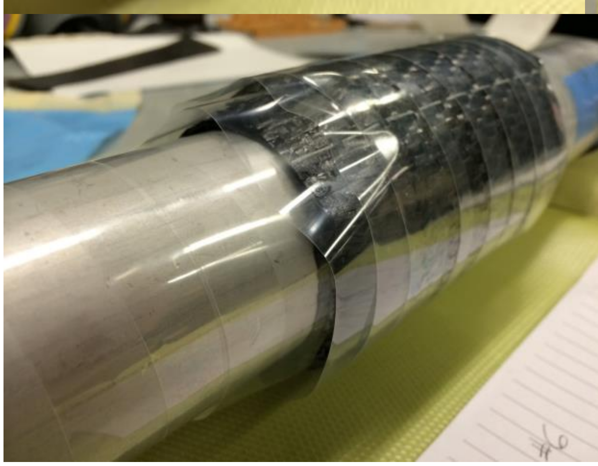
I cracked the door once it hit -3dpm to keep that rate going and it worked fairly well. At around 143F I opened the right side door all the way and just left it open. Upon opening the door I saw that the thermocouple we taped near the part had fallen at some point and was actually measuring right at the door seam vertically centered. It’s quite possible that we actually got 350F at the part.

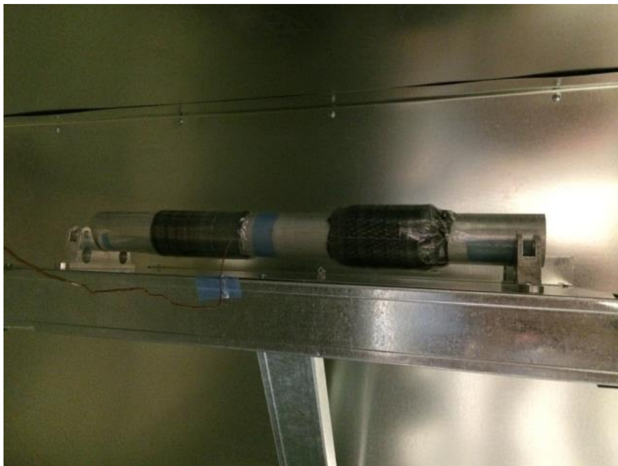
After maybe ten minutes, the IR thermometer showed that the part was still around 140F, so the cooling rate was probably even slower than measured. Once the part hit 100F I took it out and took it apart.

Both parts came out great. They are super stiff and the inside surface is spectacular. The outside surface is a little wavy from the tape and overall it looks a little resin-rich. There were actually a couple puddles of resin on the shelf beneath the tool that had dripped out. Not sure how to handle that. The shrink tape was really easy to take off and the parts came off surprisingly easy with some gentle pulling.

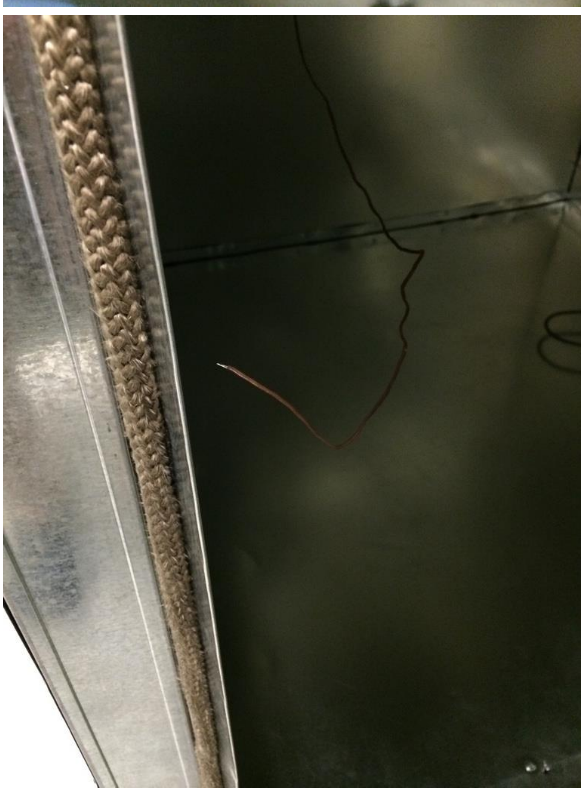
The flashing tape that held the shrink tape came undone in two places, so we should figure out a more secure way to tape it. Otherwise it looked like the shrink tape still did really well, especially considering it squeezed out so much resin.




FLUKE 52 K/J THERMOMETER
ON/OFF
F/C
HOLD
RECORD
T1
T2
T1-T2
VIEW




MAX
138.3 ε=0.95
SCAN
138.3 °F
UP
L/B
DOWN
MODE

1/27/2014 5:00pm Jack, Sam, Barett
Running the oven hardwired into the wall with 3 elements. Test data is in the testing folder in a spreadsheet. We are cooking two carbon 4 layer (one with core).

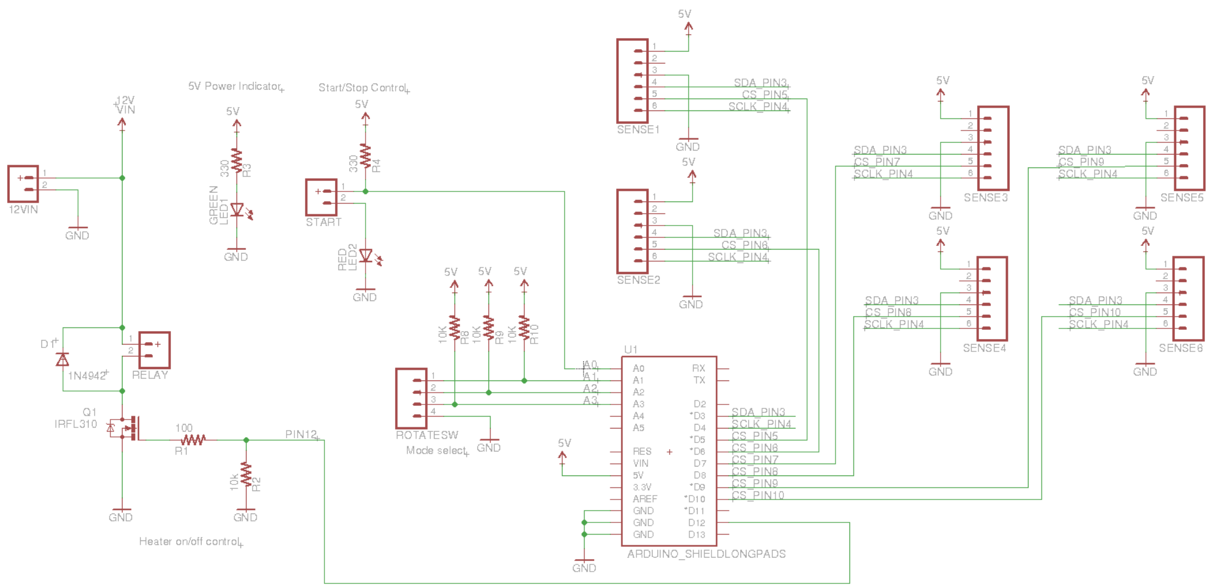
Sam purchased vacuum hose and 3 hose clamps from MFCP Motion flow control products.

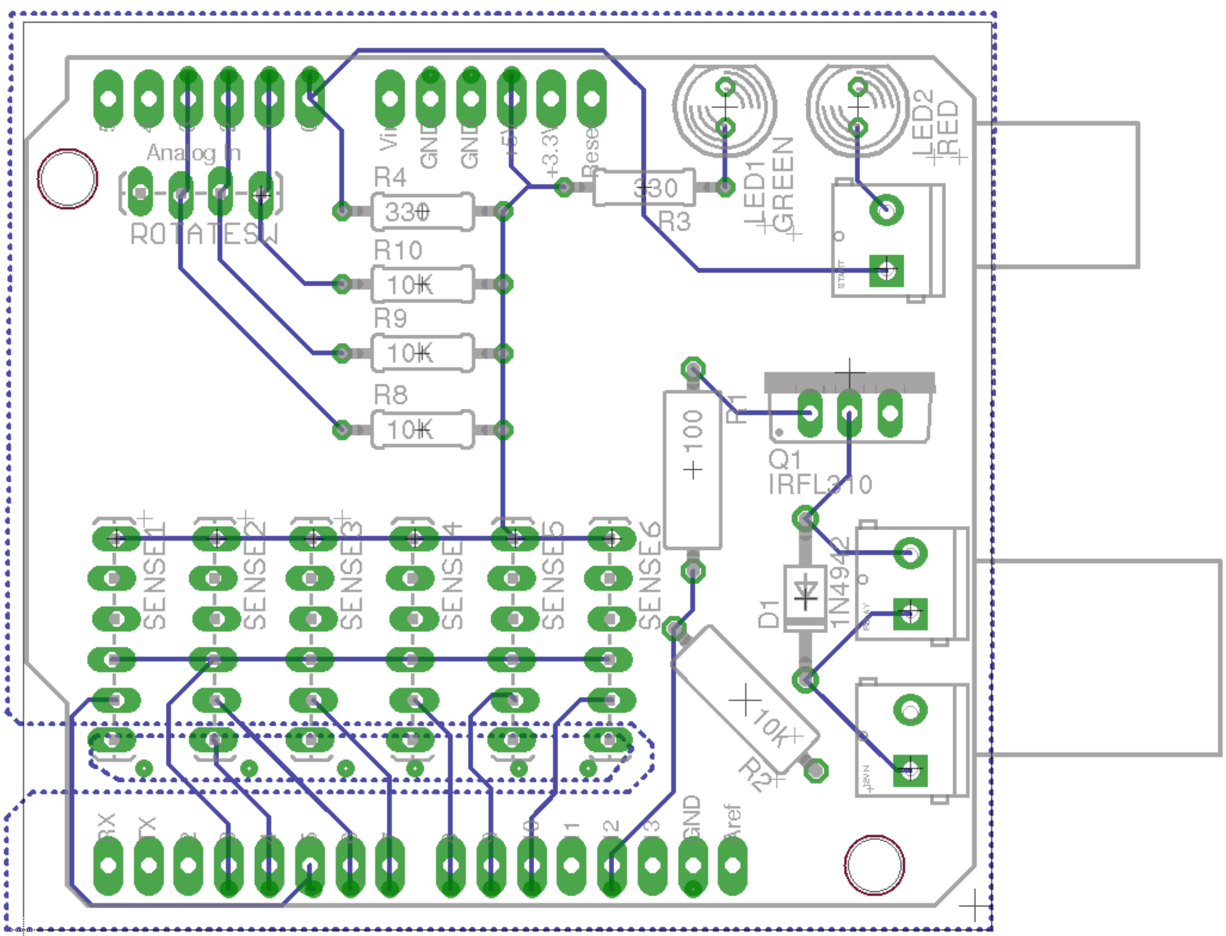
1/26/2014 12:00am Jenner
I worked with Tung to put all the oven control board parts on an Arduino shield layout. I routed it using the LPKF router in the Electronic Prototyping Lab. Definitely once it works it would be great to do a proper OSHPark run to get a proper board because our router doesn't have through-hole plated vias and it meant soldering it was tricky. I did the worst part of the soldering underneath the plastic 0.1" headers and left it for Tung in Lab 84 on Sunday night.

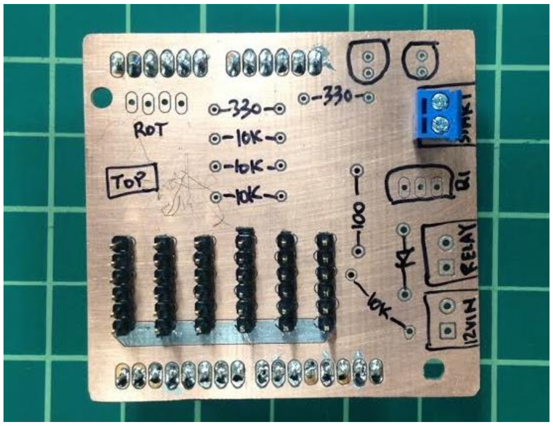
I saved Tung's initial work as version 0. I saved this board as version 1.

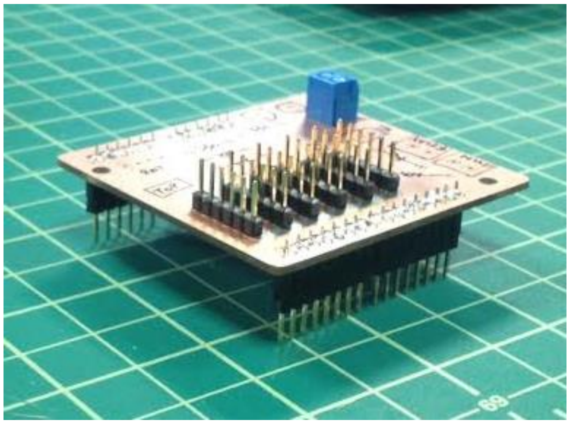
The Github repo for the two-layer board has Eagle files with full-size photos:
http://github.com/wicker/oven-controller

My contact info is Jenner Hanni (503-610-3271) jeh.wicker@gmail.com.
Please let me know if you guys need anything!









1/26/2014 3:00pm Jack
We installed the fiberglass rope using the glue we got from wink's. It appears to be solid. We didn't use quite enough in one small section, but it is fixed now.

There are fairly substantial gaps between the L sheet metal and the box sheet metal. This could be filled in using the glue like caulking.

We have to decide if we want to test the oven the way it is now, or just move ahead to 2 110V systems.

To do Monday 1/27:
- Install and hard wire two new elements
- make the current wiring safer with nuts
- reinstall the fluke thermocouples
- get the new electrical plugs for both circuits at 120V 20A at least
- get the vacuum hosing from fiberlay
- drilling box hole for vacuum hosing
- test 350F cure cycle
- Bake CF under vacuum for cure cycle
- Seal L bracket gap using glue
- Planning meeting to set schedule and decide on future course

1/23/2014 2:00pm Jack
Since we are moving this direction I reposted the running list of variables. Everyone can add extra bullets, notes, sub bullets etc. some of these we could assume like boeing's solution is good enough.

We don't have to get the perfect adhesive joint, just one that will work for us. We could just attempt to build the joint the way we think we want, that we think is best and easiest. If that layout is then good enough, we wouldn't have to bother with testing other parameters.

List of variables we could change for the dogbone testing:
- surface finish of aluminum
    - 20 grit vs 10 grit etc
- cross sectional profile of aluminum
    - single shear lap joint vs stepped. Sloped vs parabolic vs constant
- surface treatments of aluminum
    - Phosphoric vs none vs Boeing solution
- interface length L (as drawn on cad way below)
- cocuring vs post curing
- thickness of carbon
    - Changes peel stress because of bending stiffness

- Autoclave pressure vs bag
    - Might be hard to do

1/22/2014 7:00pm Jack, tung, Barett, Sam, rob, mark

Meeting notes:
Rob-Overview of current events, carbon, oven etc.
Very high potential for using high voltage according to mike
Don mueller might need to be involved for electrical side

Member presentations:
Rob- steady state heat loss calcs, wants to be involved in code and circuit. Minimum viable product
Barett- working on table, not worried about fuel usage from his truck. Estimates 100$ in fuel.
Tung- working a lot on circuits and code, has thought about thermocouples. Need to get PCBS going, thermal break he knows
Sam- administrative things, giving presentations, meeting with Andrew, managing team direction
Jack-
Only feelings on high voltage are political and safety.

Action items-
- Decide on thermocouple usage, tung has opinion
- Need thermal break switch if 480
- Jerry and don about wall amperage
- Take pallet home
- Fix insulation
- Install door hardware
- Install fan
- Install internal barrier between elements and parts
- Figure out wall amperage situation and breaker
- Need to update schedule

Project status assessment-
- Oven is slow moving
- Should divide group to conquer tasks we are about to face.
- Need to set deadlines
- Major milestones
    - Official design process (pds, external, internal, etc)
    - Basic testing, idea for full scale
    - Full system test
    - More tests that process works
    - Monday voltage decision with current electronics
- Table could be 3 feet with a leaf for doors

1/22/2014 7:00pm Jack
Write-up on full system oven testing:
We ran testing on the oven using 3 coils at 110V plugged into the 20A circuit. Our plateau was approximately 295F. The ramp was pretty slow, as slow as .2-1F per minute. There was some external box leakage, that lead to some areas of the box to get up to about 180F. The only prayer of using 110V is by better insulating it. This is worthwhile because we shouldn't have the box getting dangerously hot. The engineering guess we had was about 25% on average, with values from 1% to 50%.

1/22/2014 7:00pm Jack

I was tired of doing all these calculations by hand so I made a calculator. It's in the design section as a spreadsheet doc.

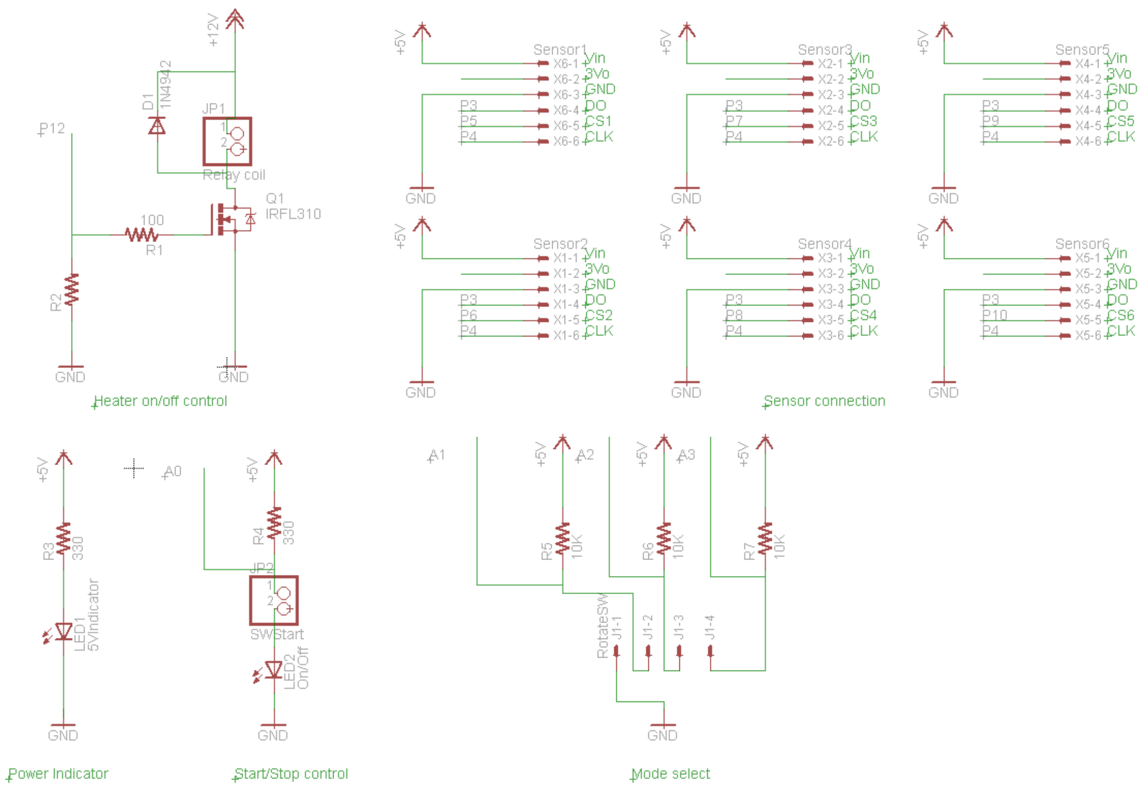
According to the internet the US standard is 120V for the 2 prong, and 125V for the NEMA 2+ ground style outlet. **The wall voltage is important because it changes the safety factor on how much amperage we are drawing.** At 110V our safety factor as it sits now is 17.5%, but if it really is 125V then our safety factor is 6.25%. We didn't pop the circuit when we tested using this method, so maybe 6.25% is enough of a safety. But if this is the case, then **there is no more power we can draw from the wall.**

Sam thinks we should get the ball rolling on the 220V solution now, sounds good to me.

Because we pretty much had plateau at 295F we could validate Rob's calculations. I'm not sure how useful that is of his time though. We had somewhere between 1800W and 2300W in our test.

Wall Voltage	Max Amperage	Max Power
110	20	2200
Resistor value	**Series Resistor**	**Effective resistor**
20	0	6.67
20	0	
20	0	
40	40	
Effective Resistor	**Amperage**	**Power**
6.67	16.5	1815
	Amperage Safety	
	17.50%	

1/22/2014 2:45pm Tung
Oven control schematic



1/21/2014 10:30am Sam

I looked at my space heater last night. It appears that the fan is made of sheet metal and is positioned in front of the heating coils. The motor is mounted in the center of the heating elements. In other words, air flows over the heating elements then through the fan and the fan motor is right in the middle of it all. There is potential for it to be able to handle operating in the oven conditions.

We could put the motor outside the oven and feel confident it won't break.

1/20/2014 8:48pm Rob

I did some quick calculation for heat loss and power generated by the heating elements. In general we will need approximately 1500 W to maintain the oven at 350 F in a 70 F room. The leaking door seal was on the order of 10 W (if there is no sealing at all). To achieve an oven temperature of 125 F-150 F we need 300 W-400 W. This indicates the heating elements resistance is 30-40 ohms. At 220 V the element should produce 1100-1600 W. If we add a second coil at 110 V we should achieve a temperature of 175 F- 230 F.

Right now we are pulling about 3 amps for one coil.

1/20/2014 5:30pm Jack

Installed the second door, purchased some latches and fiberglass cord at the store, and ran system wide test.

We had to use a hole saw to make room for the electrical connectors because they were against the galvanized sheet.

We plugged in one coil to 110V and measured a bunch, and the temp plateau somewhere between 120F and 150F. We used a candy thermometer and the thermocouple wasn't working exactly right, potentially because it was getting pulled out of breadboard. It would read wrong values of temperature. The box wasn't well sealed, and we only had half the potential power input. It might be we have to go to 220V. We will have to add a fan too.

The floor of the welding lab isn't flat at all, which causes the doors to sometimes fit, and sometimes not. We can shim it to get rid of this problem when it is in it's final location.

The sealing fiberglass rope will be a bit of a challenge. We'll try cementing it and using some U-channel next time. Barett and sam have an idea.

1/18/2014 2:00pm Jack

We installed the harder of the two doors today. We ended up using a sheet metal piece to tie the hinge into the structure to try and change it from point loads into pressure and shear loads. This worked well. We then pushed the oven upstairs into the welding lab with no problem. The hinges work perfectly.


RIGHT

1/17/2014 6:00pm Tung
We can test our oven with 1 thermocouples now.
Testing code: On/ Off control 1 thermocouples.

```
/**************************************************
  On/ Off control 1 thermocouples
 **************************************************/

#include "Adafruit_MAX31855.h"

// Pins connection
int thermoDO      = 3;
int thermoCS5     = 5;
int thermoCLK     = 4;
int heaterPins    = 12;
int swStart       = A0;
int swMode1       = A1;
int swMode2       = A2;

// Indicate status variables: 0 off; 1: on
int mode1=0;
int mode2=0;
int start=0;

// constant
double tempSet1        =  85;        // farenheit
double tempErrRange    =  3;
double tempSet1Low     =  tempSet1-tempErrRange;
double tempSet1High    =  tempSet1+tempErrRange;
int ADCThreshold       =  50;
int timeDelay          =  1000;

// variables
double tempErr;
double tempSensor5;

Adafruit_MAX31855 thermocouple5(thermoCLK, thermoCS5, thermoDO);

void setup() {
  Serial.begin(9600);
  pinMode(heaterPins, OUTPUT);
  // wait for MAX chip to stabilize
  delay(1000);
  Serial.println("MAX31855 test");
}

int scan_button(int swButton)
{
  int ADCreading = analogRead(swButton);
//  Serial.println(ADCreading);
  if (ADCreading < ADCThreshold)
         return (1);
  else   return (0);

}

void loop() {

  // scanning all of the sensors and switches
  mode1 = scan_button(swMode1);
```

```
  mode2 = scan_button(swMode2);
  start = scan_button(swStart);
  tempSensor5 = thermocouple5.readFarenheit();
  Serial.print("Set temperature     F  = ");
  Serial.println(tempSet1);
  Serial.print("Current temperature F5 = ");
  Serial.println(tempSensor5);


  // compared and controled
  if (start)
  {
    if (tempSensor5<tempSet1Low)
    {
      digitalWrite(heaterPins, HIGH);  // turn on the heaters
      Serial.println("  ON");
    }
    else
    {
      if (tempSensor5>tempSet1High)
      {
        digitalWrite(heaterPins, LOW);  // turn off the heaters
        Serial.println("  OFF");
      }
    }
   }
   else
   {
     digitalWrite(heaterPins, LOW);  // turn off the heaters
     Serial.println("  OFF");
   }
  delay(timeDelay);
}
```

1/14/2014 11:30am
Oven musts from Kevin @ Pacific Coast Composites:

- Thermocouples select average or specific
- Tool temperature more important than part temperature
- Fan absolutely necessary w horizontal flow for even multi-level heating
- Possibly need to preheat tool
- 3deg/min should be target ramp

Film adhesive role we were given: ~$4k

1/17/2014 12:50am Tung
Electronic parts need to buy

- On/ Off switch which easy to attach the big core of the power cord (around 1/8'' diameter)
- Power cord: 6ft
- 40 Pin Right Angle Single Row Pin Header: 3 rows
- Wire to board connector 6 pins: 6 (6ft x4 and 3ftx2): If these are too expensive I could make somes but need the 12x6-pin female headers + pin headers and multiple core wire to connect the thermocouples.
  The idea is trying to make somethings like this Wire and its connector below

1/15/2014 11:50 pm Jack
Barett, Sam, Jack and Betsy managed to get the oven into the tray (mostly Barett). There was a small bit of buckling damage, but I think it will be find and we can fix it. The tray works like a charm. Super easy to roll around and maneuver. Certainly a job well done by Barett. We rolled it over in front of Mike's office to send him a picture of, as a joke.

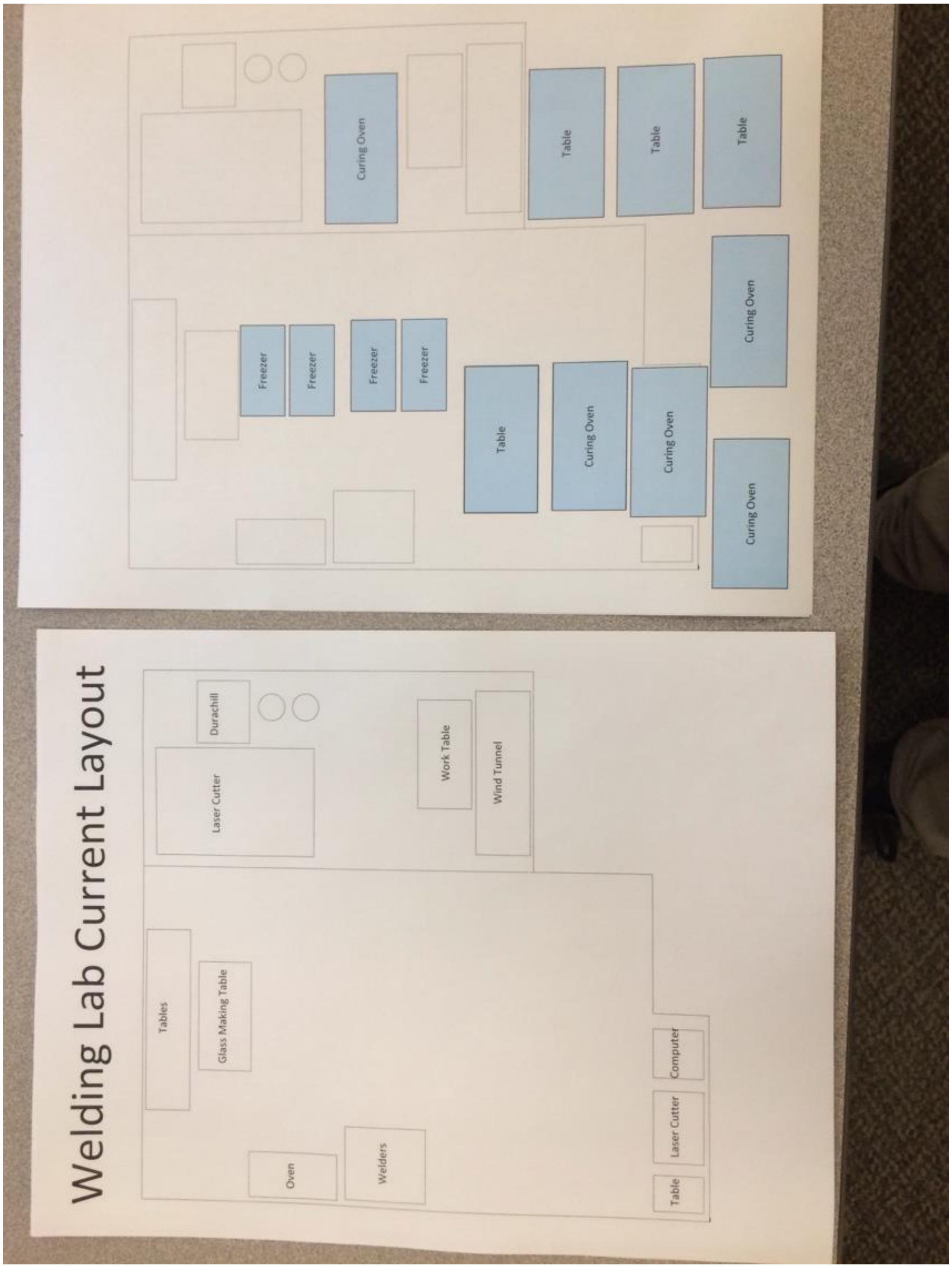
We installed one set of hinges on the box, but didn't hang the door. The hinges didn't go on very pretty or accurate, so we want to get a bigger opinion before we hang the door. We might decide that we should take them off and try a different method. Getting them accurate was difficult, and we didn't nail it.

We rearranged the shop back to the way it was. We put our oven as out of the way as possible, and we swept and cleaned everything. Our stuff is now also behind the Haas, as well as the old 3 axis cnc.

1/15/2014 11:25am Tung
[MOSFET FQP13N10L Datasheet]()

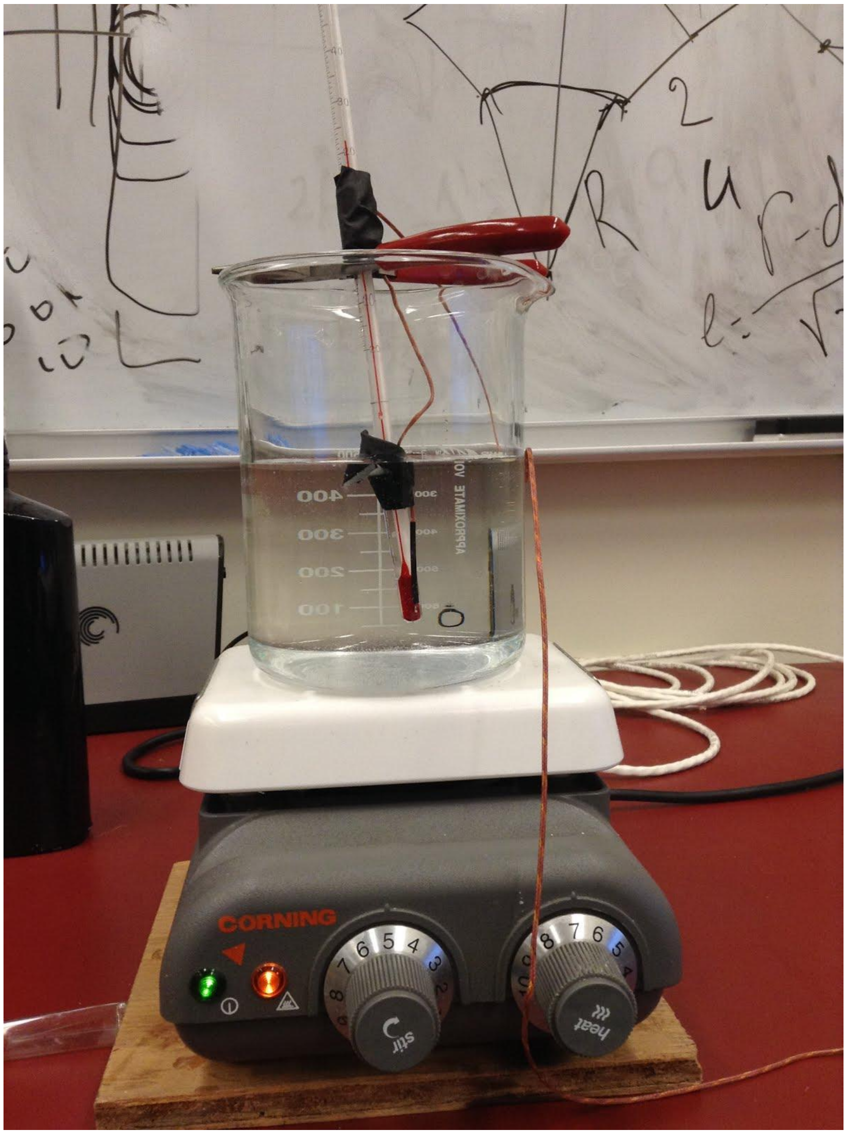
1/14/2014 08:40pm Jack
Need to see if the volatiles need to be vented outside and are toxic when the carbon is curing.

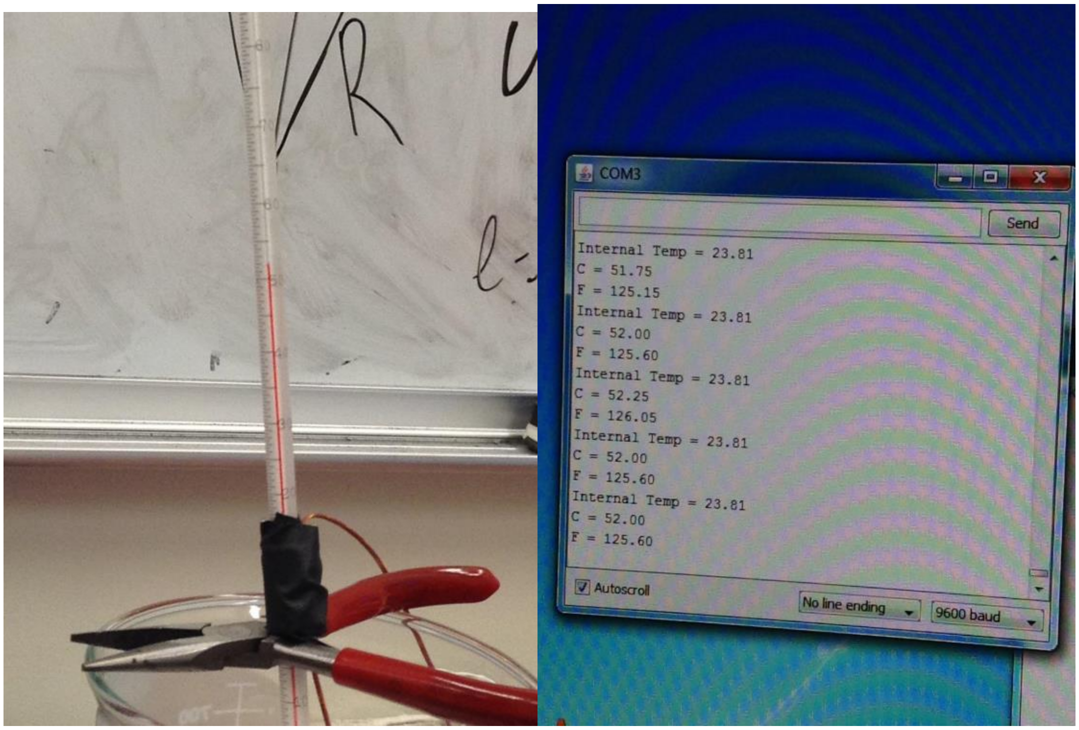
Met with Andrew and wrote an email to Gerry to set a meeting about a composites lab somewhere. Gerry responded a meeting on friday afternoon. Likely about the time our lab gets out. I drew up the layout and created little cut out pieces that are scaled correctly so Gerry can try the different locations the components could fit.



1/14/2014 05:40pm Tung

The thermocouples measured exactly temperature in between 70F to 212F without calibration. By accident, I found that the K thermocouples that we bought can work in water. :))


CORNING
stir
heat



To do:

- Check the thermocouples at 350F. I emailed Dr Sailor to ask for a thermometer working at 350F.
  - The PSAS team has the perfect temperature measurement for us to calibrate with
- Build the control circuit with the new MOSFET, relay and thermocouples.

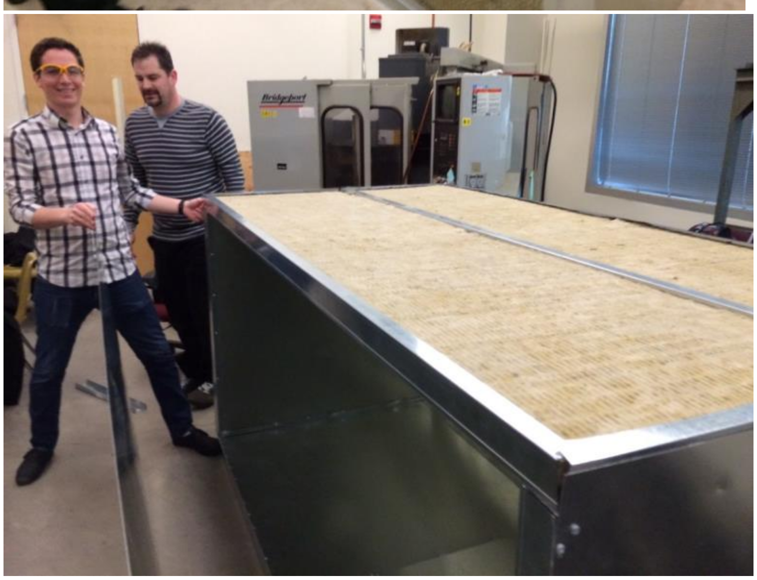
1/14/2014 00:53am Tung
mmw@cecs.pdx.edu
Professor Weislogel is our advisor, here is his email address.

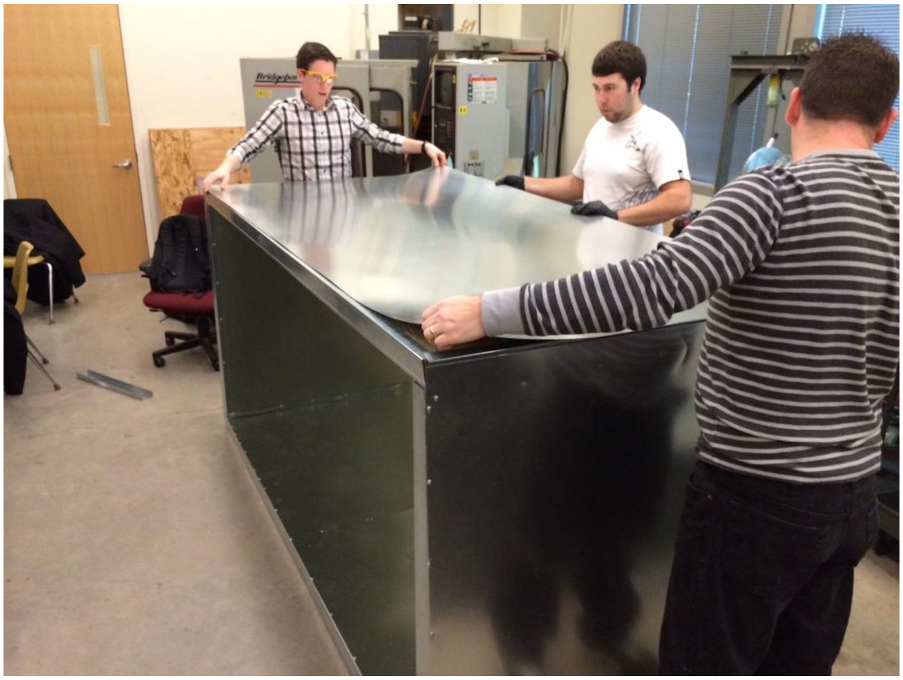
The thermocouples and the circuit work well with their code. Without any addition IC, at least we need 8 digital pins to collect data from all 6 thermocouples. The Arduino Uno has 11 usable digital pins. Thus, there are only 3 pins left for other jobs: LCD, switches, control, which are not enough. I'm thinking of using a select IC to have more 3 pins available but still not enough for our system.
Here are the temperature results from my lamp, quite hot :D

Internal Temp = 25.06
C = 141.50
F = 286.25
Internal Temp = 25.00
C = 141.00
F = 286.25
Internal Temp = 25.00
C = 141.25
F = 286.25
Internal Temp = 25.00
C = 141.50
F = 286.70
Internal Temp = 25.00
C = 142.25
F = 288.05

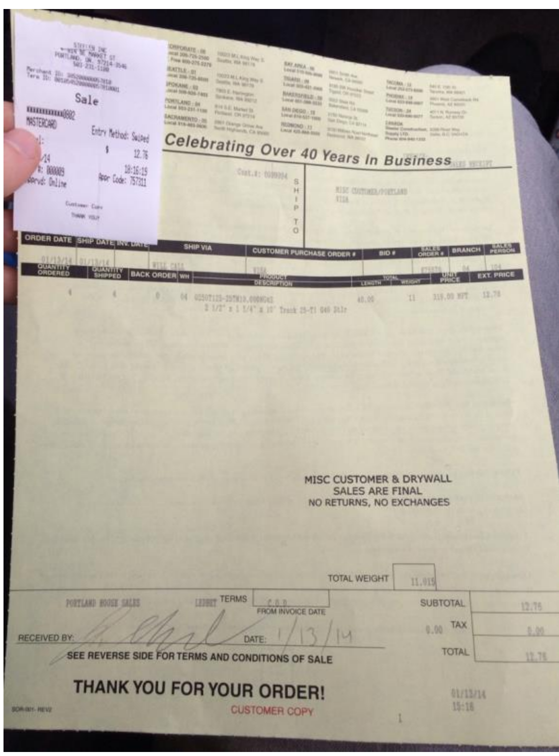
1/13/2014 6:10 pm Jack
We finished the 5th side of the box.
To do:

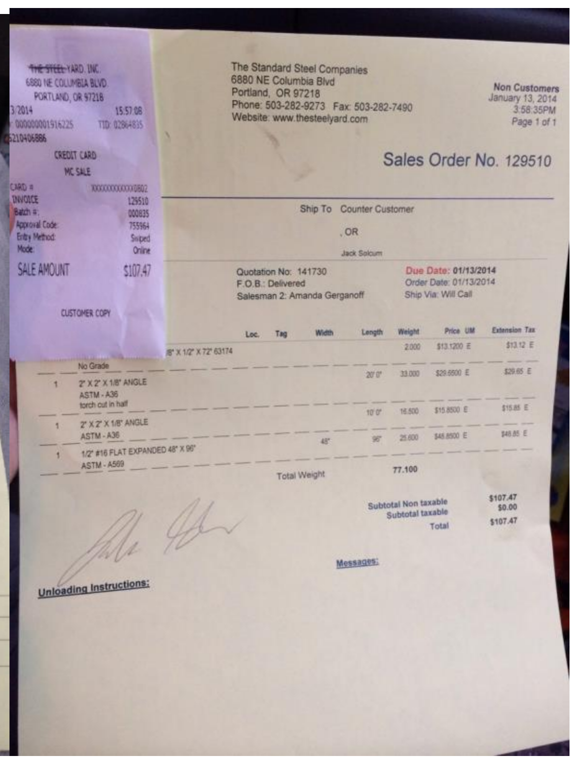
- Finish and hang doors
- Finish building circuit with thermocouples and relays
    - Install electrical system
- Install heating coils
- Clean Perforated sheet
    - Bend and install perforated sheet
- Build rolling tray
    - Miter angle steel
    - Weld
    - Bolt on wheels
- Full system test





1/13/2014 6:00 pm Jack
The Steel Yard Jack spent $107.47 on angle steel, perforated sheet, piano hinge
Steeler Inc Jack spent $12.70 for extra track





1/13/2014 11:50 am Tung
Tutor for attaching thermocouples, amplifier to arduino and coding
Using thermocouples with arduino
Library for b amplifier is used for SPI digital output transmission

The Max31855 has thttps://github.com/adafruit/Adafruit-MAX31855-libraryhe SPI function which used to transmit output data to the controller. The output data is in the format below

Table 4. Thermocouple Temperature Data Format

TEMPERATURE (°C)	DIGITAL OUTPUT (D[31:18])
+1600.00	0110 0100 0000 00
+1000.00	0011 1110 1000 00
+100.75	0000 0110 0100 11
+25.00	0000 0001 1001 00
0.00	0000 0000 0000 00
-0.25	1111 1111 1111 11
-1.00	1111 1111 1111 00
-250.00	1111 0000 0110 00

Note: *The practical temperature ranges vary with the thermocouple type.*

Table 5. Reference Junction Temperature Data Format

TEMPERATURE (°C)	DIGITAL OUTPUT (D[15:4])
+127.0000	0111 1111 0000
+100.5625	0110 0100 1001
+25.0000	0001 1001 0000
0.0000	0000 0000 0000
-0.0625	1111 1111 1111
-1.0000	1111 1111 0000
-20.0000	1110 1100 0000
-55.0000	1100 1001 0000

K thermocouples are not precision thermal measurement devices. There will be definitely offset between each K thermocouples. The offset needs to be corrected using software.

1/13/2014 11:10 am Rob

Received shrink tape. We forgot to order flash break tape, so I ordered it. We should get it by the end of the week (I hope). **Rob paid $18.50 for flash tape.**

ONLINE ORDER CONFIRMATION

Date: 01-13-2014 11:09
Order id: #15737
Order status: Pending
Payment method:
Credit Card
Delivery method - NOTE : ACTUAL SHIPPING CHARGES NOT DISPLAYED:
USPS Express Mail

ACP Composites Inc.
78 Lindbergh Ave., Livermore
94511, California
United States
CALL US: 1-800-811-2009
International: 1-925-443-5900
Fax: 1-925-443-5901
Email: orders@acpsales.com

Email: rjmelchione@msn.com

Billing address

First name:	Rob
Last name:	Melchione
Address:	5247 SE Coot Way
City:	Hillsboro
State:	Oregon
Country:	United States
Zip/Postal code:	97123
Phone:	5034735782
Fax:	

Shipping address

First name:	Rob
Last name:	Melchione
Address:	5247 SE Coot Way
City:	Hillsboro
State:	Oregon
Country:	United States
Zip/Postal code:	97123
Phone:	5034735782
Fax:	

Products ordered

SKU	Product	Item price	Quantity	Total
V-30	1" Flash Breaker Tape 72 Yd. Roll	$18.50	1	$18.50

Subtotal: $18.50
Shipping cost: $0.00
Total: $18.50

1/13/2014 10:30 am Sam

Called Cytec about CYCOM 934 resin system to ask about any issues occurring if cured without autoclave or press-mold pressures. Sent email to laurie.long@cytec.com as instructed and so far have received email delivery confirmation.

1/11/2014 1:30 pm Jack

Thermocouples, amplifiers and aluminum extrusion arrived. The braided section of the thermocouples aren't very long, we might have to get creative on where we place things.

1/8/2014 1:30 pm Jack, Tung
Floor of oven mostly complete. We had to add a cross member inside in between the insulation for extra strength. It's strong now, and could be made even stronger. It took us about 2 hours to build this one sheet, and now we have a system going. It's heavy.

1/7/2014 5:50 pm Jack, Rob
Email from PCC:

> Hi Sam,
> Friday would work best for me. Anytime after 12:00 noon.
>
> I have the samples ready. They are small 12" x 12" of the Adhesive and the Graphite. I also cut you a small piece of the Honeycomb.
>
> But if you folks are going to make the drive you may want to look over the data sheets and have a better Idea of what materials would work best for your current design.
>
> You may also want to take a look at the following link to get a better idea on honeycomb specifications.
> www.hexcel.com%2FResources%2FDataSheets%2FBrochure-Data-Sheets%2FHoneycomb_Attributes_and_Properties.pdf&ei=t1nMUoGQHdaxoQSYuYDIBw&usg=AFQjCNGBY7AfwJyMvxkMjkDOWpJd7ffCyA
>
> Let me know if you want to set a firm time for Thursday or Friday.
>
> Thank you,
>
> Kevin Fochtman
> President, Pacific Coast Composites
> Office: 253.572.6262 | Fax: 253.572.6363
> 11302 Steele St. South Ste. B
> Lakewood, WA 98499

Cycom, DATASHEET, and TDS are the documents he sent us. They are in the Research folder.

CYCOM® 934 **Epoxy Resin**

Description:

CYCOM® 934 is a high flow, 350°F (177°C) curing, epoxy resin with good 200°F (93°C) wet and 350°F (177°C) dry service capability. CYCOM® 934 is formulated for autoclave processing, but it has been successfully processed by press molding. Unidirectional tape and woven fabric impregnated with CYCOM® 934 resin will retain good tack and drape for at least 10 days at 70°F (21°C). Standard cure is for two hours at 350°F (177°C). No post cure is required for 350°F (177°C) dry service capability.

Recommended lay-up procedure is L-3 or L-6. Recommended cure procedure is C-5 or C-9.

CYCOM® 934 can be impregnated via hot melt or solution technique on all available fibers and fabrics.

Typical applications for CYCOM® 934 include structural aircraft components and critical space structures. CYCOM® 934 meets all NASA outgassing requirements.

For more information, contact:
Cytec Engineered Materials
Technical Service
Greenville, Texas
903 457-8500

Features and benefits:

- **350°F (177°C) cure**
- **Available in a broad range of fibers and forms including tape, fabric and roving**
- **Large industry database**
- **Material widely used in aerospace, commercial and military structural applications**
- **350°F (177°C) dry and 200°F (93°C) wet service temperature**
- **Laminate and sandwich panel usage**
- **Autoclave or press-mold processing**
- **Shelf life 6 months at 0°F (-18°C) 10 days at 72°F (22°C)**

1/7/2014 11:50am Jack, Rob
To do:

- Presentation for meeting
- Finish ASME presentation funding application
- Make schematics and build safe circuits
- Get okay from Andrew on Oven design
- Finish oven design
  - Finished enough to start fabrication
- Build oven

Ideas to improve oven controller:
Nice if there were manual mode (selectors for ramp up and down, hold time and hold temperature)

Need to figure out when ASME funding presentation application is due.
Asmeoregon.wordpress.com acteva to register. Only the team lead needs to register.

Need to figure out if Andrew is our faculty advisor. **He is not. We need a separate ME professor as our advisor.**

Want a circuit design review for high voltage safety. We can schedule this for next Monday. Ask them specifically their plans regarding an interface with the oven.

1/6/2014 11:00am Jack, Tung, Rob

Sent in a reimbursement request to Andrew
Jack Purchased $39.97 at Winks

- Nitrile gloves
- Extension cord 110v 15 amp cream colored
- Crimp connectors for coil
- electrical tape
- Sheet metal self tapping screws #8 ½” 250 quantity

To do:

- Measure elevator
- Make budget
- Make Schedule
- Get electrical supplies
  - Test coils
    - Coils do work, might be wise to switch to 220V as they weren’t super hot even after 5 minutes
  - coil connector size is: .375” yellow
- Figure out Github and get team set up
  - Nathan could do this

Brad Lumis woodland company for composites.
Wink’s will sponsor us with gift cards if we approach them. We talked to the owner.

Phase	Item	Description	Cost	Application
A-Minimal Capstone		Minimal funding required to satisfy PDS. Single carbon/aluminum module with minimal testing and single design iteration.		
Think typical capstone	1	Composite tooling	$500	All metal and fasteners necessary to build tooling for layup process
	2	Alumium rings	$200	Rings for module connections
	3	Aluminum treatment	$400	Anodize and Mil Spec treatments
	4	Layup materials	$400	Vacuum bagging, tapes, hoses, release chemicals, post cure chemicals
	5	Paste adhesive	$200	Cocuring of aluminum rings
	6	Composite material	$10,000	Potentially donated by Pacific Coast Composites. Includes, cloth, core, and adhesive film
		Total	**$11,700**	
		Adjusted total including donations	**$1,700**	
B-Enhanced Capstone		Extensive testing of single design.		
Think formula car	1	Curing oven materials	$550	Sheet metal, insulation, electronics, wiring
	2	Layup table materials	$600	
	3	Solid rocket motors	$2,000	Multiple full system tests, dynamic tests, cataloging the temperature and vibrations from a solid booster
	4	data logging equipment and sensors	$2,000	Mobile data logger with instrumentation for temperature, strain, acceleration, pressure, of each module
	5	titanium module rings	$3,000	Potentially sponsored by Precision Cast Parts
		Total	**$8,150**	
		Adjusted total including potential donations	**$5,150**	
C-Ultimate Capstone		Extensive testing of multiple design iterations. Long term knowledge collection.		
Think Apollo era NASA program	1	Contract machine shop for tooling production	$2,000	Tooling could be sent out for fabrication, save hours of manufacturing time
	2	Additional layup consumables	$2,000	If we do many more designs and iterations, we will need more of the composite consumables
	3	Additional composite tooling	$5,000	Multiple iterations of molds will need more materials
	4	Additional titanium rings for multiple iteration designs	$5,000	Could come up with many designs for module interfaces
	5	3D printed composite friendly plastics for building extreme innovative designs	$3,000	Potentially sponsored by Epson, 3D Systems, or NW Rapid
	6	Solid rocket motors	$5,000	Multiple test flights with multiple designs

Made an evolving gantt chart type schedule for our project. We can continually add tasks and the dates they will be worked on.

Composite Rocket Schedule

File Edit View Insert Format Data Tools Help All changes saved in Drive

	A	B	C	D	E	F	G	H
1		**Item**	**Description**	**1/6/2014**	**1/8/2014**	**1/13/2014**	**1/15/2014**	**1/20/2014**
2	**Oven Electrical**	Test coils	make sure 110V system is adequate	x				
3		New relays	Utilizing MOSFET		x			
4		Thermocouples	Arriving in mail, include in software		x			
5		Full schematic	Approved by PSAS and Rob, Evan, Zdenek		x			
6		All parts ordered			x			
7		Full clean/safe/approved assembly			x	x	x	
8		Full system test					x	x
9		Characterizing	Making sure ramps correctly				x	x
10		Composite part test	Full vacuum on composite part, test strength					x
11								
12	**Oven Mechanical**	Agree on conceptual design			x			
13		Detail design	Of how to construct and minimizing heat transfer (we do not want people to touch 300 degree oven)\		x			
14		Collect materials	steel rivots/Self tapping sheet metal screws, etc		x			
15		Build oven	Physical construction		x	x	x	
16		Decide on recirculation of air	fan, pressurized air				x	x
17		Decide on iteration/adjustment	Solve problems with design					x
18								

Ordered one roll of non-perforated release coated shrink tape.

ONLINE ORDER CONFIRMATION

Date: 01-06-2014 16:15
Order id: #15658
Order status: Pending
Payment method:
Credit Card
Delivery method - NOTE : ACTUAL SHIPPING CHARGES NOT DISPLAYED:
UPS Ground

ACP Composites Inc.
78 Lindbergh Ave., Livermore
94511, California
United States
CALL US: 1-800-811-2009
International: 1-925-443-5900
Fax: 1-925-443-5901
Email: orders@acpsales.com

Email: rjmelchione@msn.com

Billing address

First name:	Rob
Last name:	Melchione
Address:	5247 SE Coot Way
City:	Hillsboro
State:	Oregon
Country:	United States
Zip/Postal code:	97123
Phone:	5034735782
Fax:	

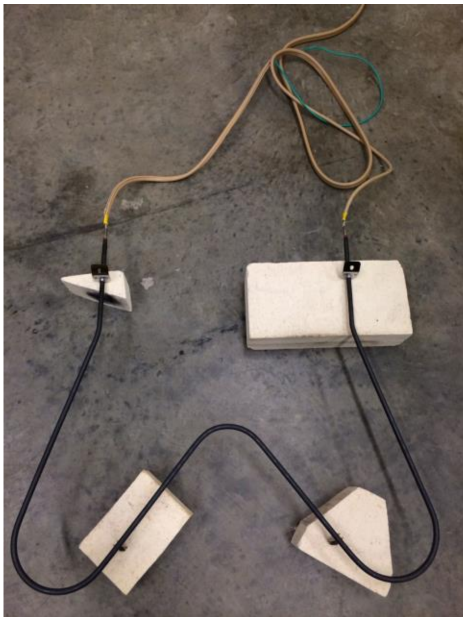
Shipping address

First name:	Rob
Last name:	Melchione
Address:	5247 SE Coot Way
City:	Hillsboro
State:	Oregon
Country:	United States
Zip/Postal code:	97123
Phone:	5034735782
Fax:	

Products ordered

SKU	Product	Item price	Quantity	Total
V-24	1" Shrink Tape - Release Coated	$16.00	1	$16.00

Subtotal: $16.00
Shipping cost: $0.00
Total: $16.00



Called metalsdepot for 6061 T-6 aluminum 6.625" OD with .28" wall costs $360 for 8ft long section. With 2$ shipping ground.

Had the idea of Cast titanium rings from Precision Cast Parts. They were interested in making my wheel. Very possible! Getting stock for aluminum might be tricky because you can't really use plate stock very well.

1/3/2014 8:30pm Jack

Ordered 8ft of aluminum to do our adhesive tests with. Also ordered 6 thermocouples and amplifiers. My father was unhappy with the idea of just using 2 and when I said it was too expensive he said he would pay for it. He said order 15 but I thought that was too many and the arduino couldn't support so many, so I ordered 6. He spent a portion of his career working on the vacuum, near absolute zero chambers, and ovens at his work. He has all sorts of opinions on the subject.

The following are the details of your order.

Products

----

6 x Thermocouple Amplifier MAX31855 breakout board (MAX6675 upgrade) (v2.0)
[ID:269] = $105.00
6 x Thermocouple Type-K Glass Braid Insulated (K) [ID:270] = $60.00

Sub-Total: $165.00
Sales Tax: $0.00
United Parcel Service (1 pkg x 0.80 lbs total) (UPS 2nd Day Air (recommended)): $15.83
Total: $180.83

Checkout - Step 5 of 5

PRINT THIS PAGE

Thank you for your order. Please print out this receipt for your records.
We value your feedback! Click here to fill out our customer survey

Make sure you check your email confirmation! We have included a special promotional discount code for your next order. Use it to receive 5% off your next order with OnlineMetals.com.

New - Increase your discounts by telling your friends, co-workers, and colleagues about OnlineMetals.com. Click here for details.

OnlineMetals.com Order Number 857153

Order Information

Qty	Description - Size	Price	Total
2	Aluminum 6061-T6511 Bare Extruded Rectangle 0.125" x 2" Cut to: 48"	$4.70	**$9.40**

Shipping Cost:	$13.04
Cut Fee:	$0.00
Subtotal:	$9.40
Tax:	$0.00
Total Sale:	**$22.44**
Billing Information	
Contact Name:	jack slocum
Company:	
Address:	333 virginia street, unit 5 el segundo, CA US -- 90245
Phone Number:	(310) 469-4433
Fax Number:	)
Email Address:	jackslocum@me.com
Shipping Information	
Contact Name:	jack slocum
Company:	
Address:	1136 SW MONTGOMERY ST, unit 317 PORTLAND, OR US -- 97201-3206
Phone Number:	(310) 469-4433

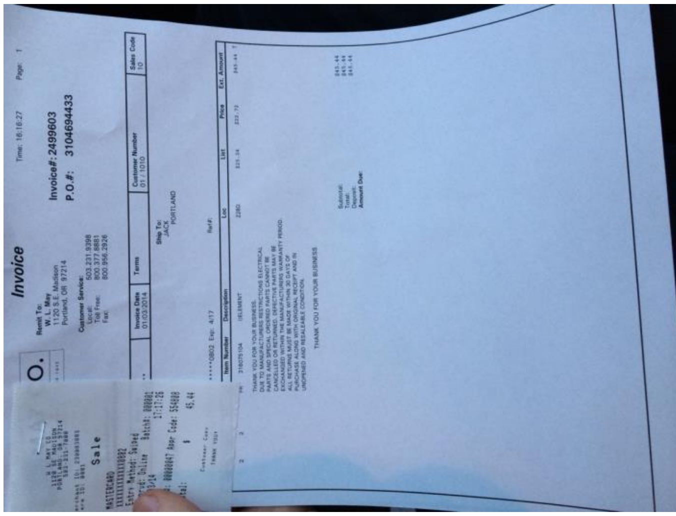
1/3/2014 5:50pm Jack

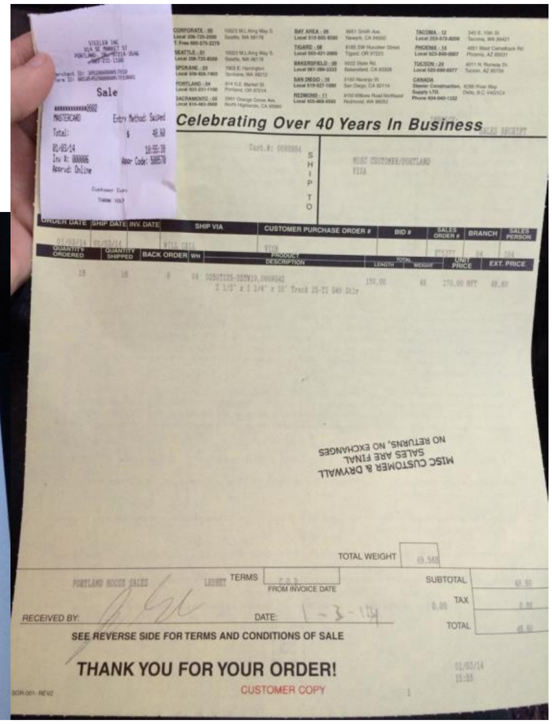
We have a red folder now to put all receipts in. Met a guy in the machine shop named Julien that wants to help us with fabrication. He is a leader of melt and in general a nice guy. He can help us with the sheet metal construction and he said he wants to be our peon for it. Might as well have him help. He seems intelligent.
Julien 415 283 6843 text if you will need help doing something.

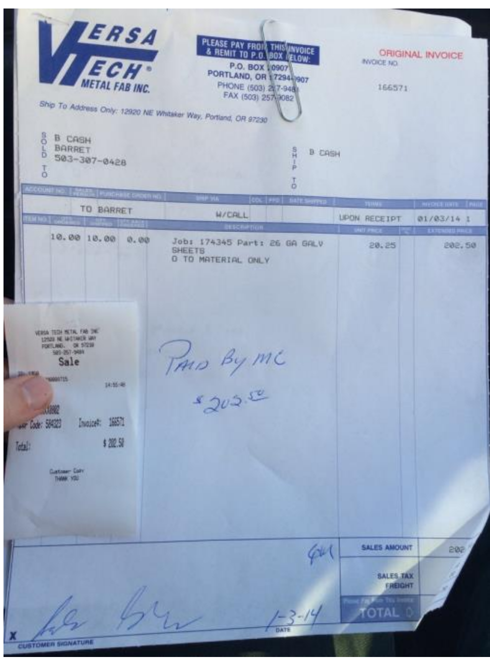
The guy at the insulation store said that mineral wool is nasty stuff, and to wear rubber gloves. If it is nasty by the standards of somebody who works with nasty materials daily, I'd say it's probably pretty bad. He said it makes the floor very slippery too. It'd be nice to minimize our interaction with it.

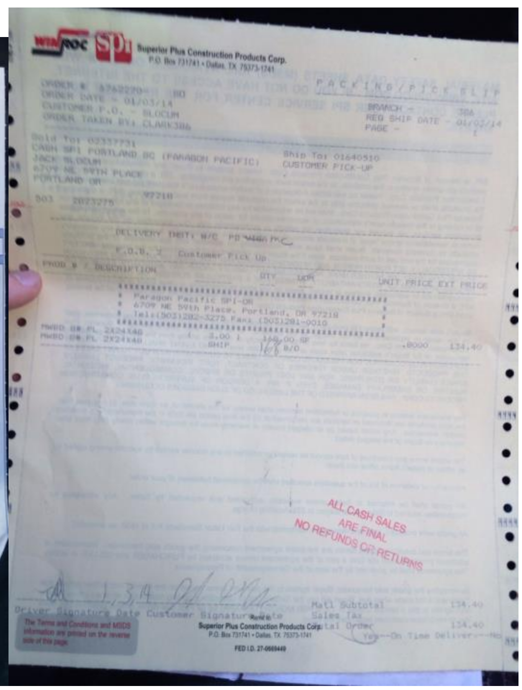
All paid for by Jack
$202.50 to VersaTech for 10 sheets of .02" galvanized sheet 4'x10'
$134.40 to Paragon Pacific Insulation for mineral wool 3 packages

$48.60 to Steeler inc for 18 Simple U 25 gage tracks
$45.44 to WL May for 2 heating coil elements
Total: $430.94



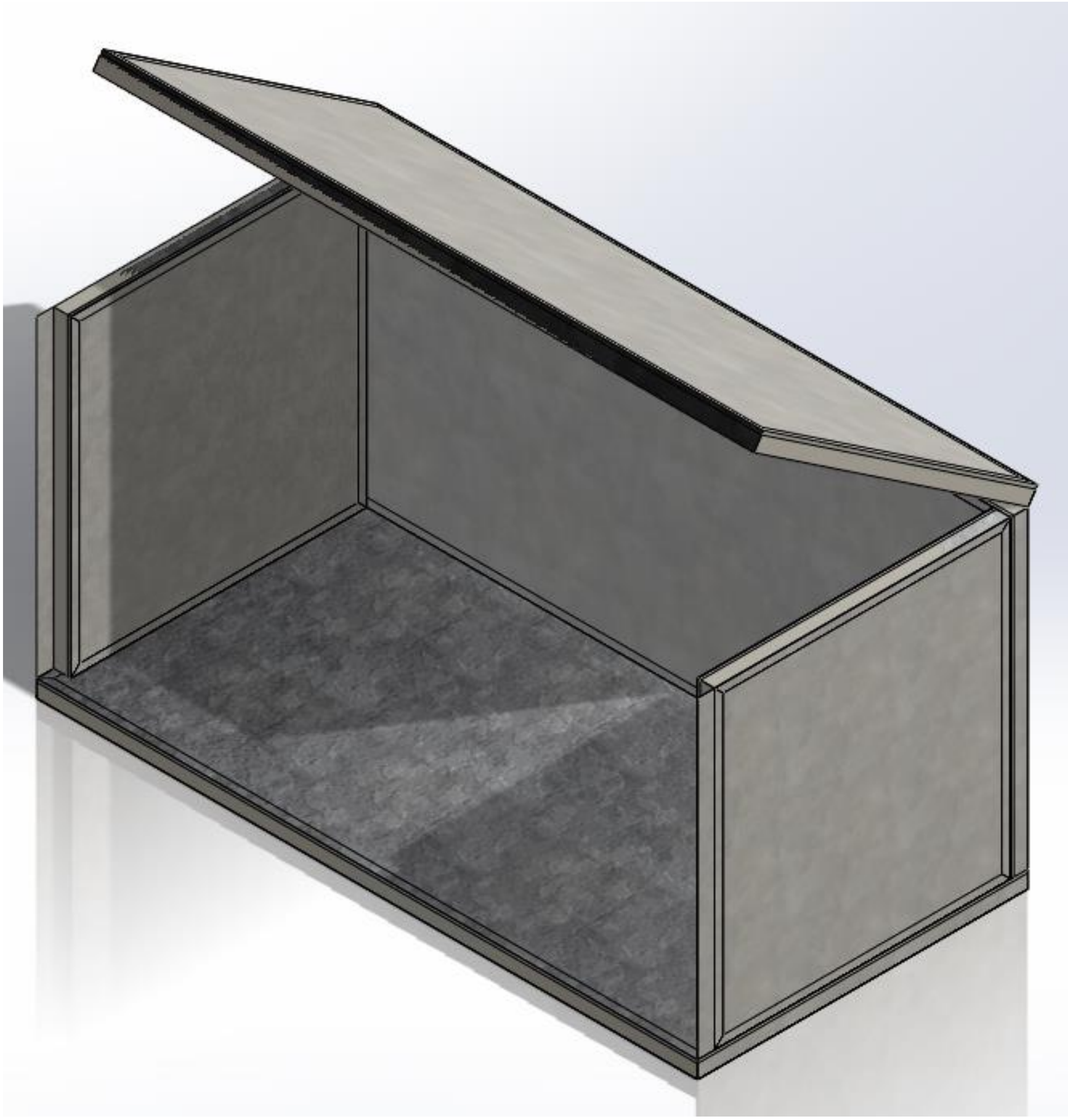






1/3/2014 2:00pm Barett

Jack and I are about to leave to go purchase the sheet metal, insulation, metal studs, and fasteners. Here is the current state of the oven.



1/2/14 8:10 pm Jack
Sent an email to get materials and give a status update to Eric and Andrew. Also, below is the receipt for Rob spending 65.88$ at Surplus Gizmos.

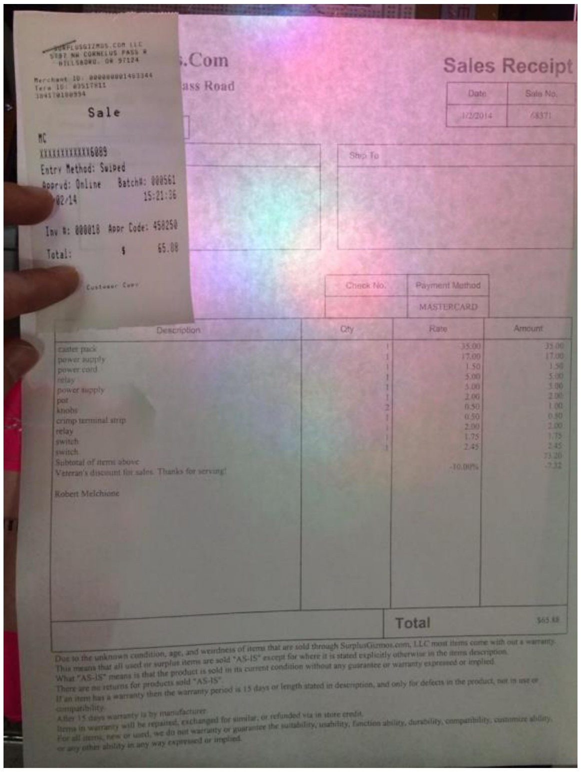
> Eric and Andrew,
>
> Sam is in Korea at a conference, so I'll be the contact for a little while.
>
> For the oven we need a thermal sensor of some kind. As long as it's easy to use, arduino friendly, and okay up to 450F then we are on board. We found ones on spark fun and adafruit but are in the 26$ range for 1 setup. Here are the links. Eric said he thought they could be gotten cheaper.
> https://www.adafruit.com/products/270

https://www.adafruit.com/products/269

After we finish the oven we will move into adhesive joint testing, and tube testing. For this we need 3ft of aluminum flat stock (can be cut into small chunks for shipping) , and 1 roll of shrink tape.
http://www.onlinemetals.com/merchant.cfm?pid=1128&step=4&showunits=inches&id=997&top_cat=60
http://www.shrinktape.com/products/hi-shrink-tape/release-coated.aspx

We will be working in the EB tomorrow, but with only 3 members. You guys can stop by if you want. We are currently able to switch 110V with arduino, and have the controls system, and software concepts all worked out. Tomorrow we will try and collect a bunch more of the materials.

Jack



Sale

MC
XXXXXXXXXXXX6089
Entry Method: Swiped
Apprvd: Online Batch#: 000561
15:21:36
Inv #: 000018 Appr Code: 458250
Total: $ 65.88

Customer Copy

.Com
ass Road

Sales Receipt

Date	Sale No.
1/2/2014	68371

Ship To

Check No.	Payment Method
	MASTERCARD

Description	Qty	Rate	Amount
caster pack	1	35.00	35.00
power supply	1	17.00	17.00
power cord	1	1.50	1.50
relay	1	5.00	5.00
power supply	1	5.00	5.00
pot	1	2.00	2.00
knobs	2	0.50	1.00
crimp terminal strip	1	0.50	0.50
relay	1	2.00	2.00
switch	1	1.75	1.75
switch	1	2.45	2.45
Subtotal of items above			73.20
Veteran's discount for sales. Thanks for serving!		-10.00%	-7.32
Robert Melchione			
		Total	$65.88

1/2/14 7:30 pm Jack, Tung

Everyone keep in mind we will work Mondays and Wednesdays of the next term on the capstone project. Tuesday night is the meeting and we can send whoever is available at that time

1/2/14 5:00 pm Jack, Tung, Rob
Thermocouple for over 400F:
http://forum.arduino.cc/index.php?topic=121522.0
https://www.adafruit.com/products/270
https://www.adafruit.com/products/269

This is the continued code for accepting an input from our rotary switch. This way we can select the type of cycle to use. The cure cycle for the post cure epoxy and the carbon fiber are different. We got the rotary switch to work with this code.

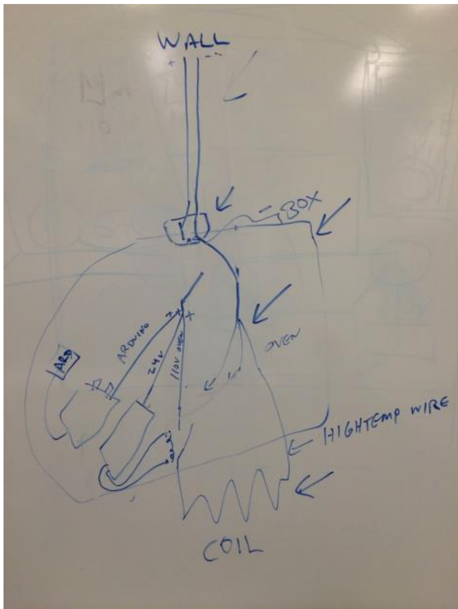
```
int Heater=4;              //defining the heater to pin 4
```

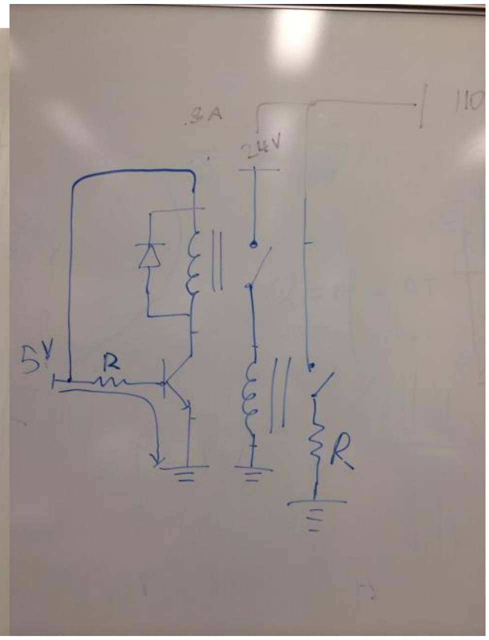
```
int kp=10;                    //controller proportional constant
int temperror;                   //difference between current temperature and desired temperature
int temp;                      //current temperature
int sensorpin=5;                 //thermistor attached to pin5
int cyclepin=6;                 //cycle selector pin
int cycleselect=HIGH;

void setup() {
pinMode( Heater, OUTPUT );          //defining pin 4 as an output
pinMode( cyclepin, INPUT );          //defining pin 4 as an output
Serial.begin(9600);

} void loop() {                    //start a loop that returns nothing
cycleselect=digitalRead(cyclepin);    //accept a reading from digital pin 6, to know whether to enter into
adhesive cure cycle or carbon cure cycle

if( cycleselect==LOW){
if(millis()<10000)               //while the timer is less than 10 seconds, stay inside this loop, millis()<10000
{
temp = analogRead(sensorpin);             //read from the analog inputs in sensorpin (5) and put the value in
temp
temp = map(temp, 0, 1023, 0, 100);        //map(value, fromLow, fromHigh, toLow, toHigh)
Serial.println(temp);
temperror=50-temp;
if (temp<=50) {                  //if the measured temperature is less than 350F, then continue with the loop, if
not, bump out of it and do nothing
digitalWrite(Heater, HIGH);          // high turns heater on
delay(kp*temperror);               // after the oven is turned on, we let it stay on for a little bit of time. delay
time= proportional constant * temperature error
digitalWrite(Heater, LOW);           // Low turns heater off
delay(1000);                     //waits 10 seconds before measures temperature again
}
}
}
}
```

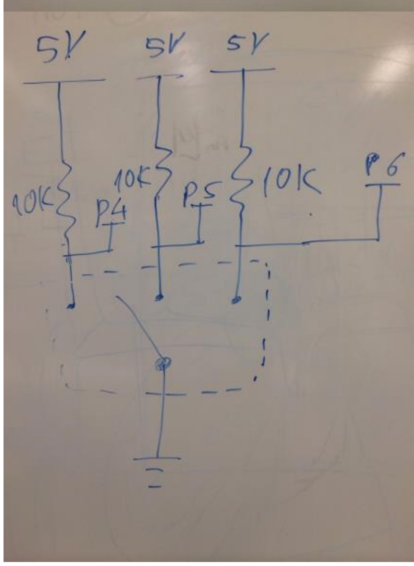
How to move forward:

- Need the rest of the materials
    - wall plug capable of a ton of power
    - wall outlet for the side of our box
    - a bunch of heavy gage wire (maybe in formula lab)
    - heater coil
    - box to start mounting things in
    - thermocouple/thermistor and their calibration (need a heater and a precise thermometer)
- build real circuits, more finalized code
- build insulated oven, decide on a design
- deal with PCC and their materials

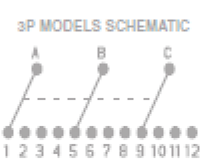
We went to surplus gizmos and purchased $66.88 worth of electrical crap and caster wheels. We hooked together the relays and a transistor and switched 110V! The arduino program drove the show with a digital pin output.

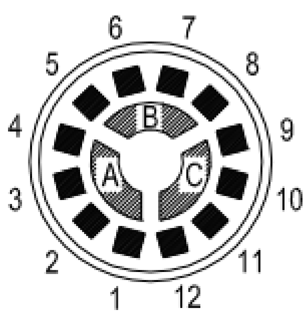






CK rotary switches: http://www.lorlin.co.uk/PDF/CK.pdf



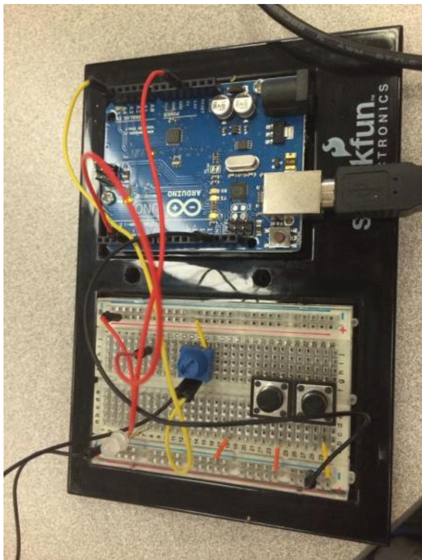


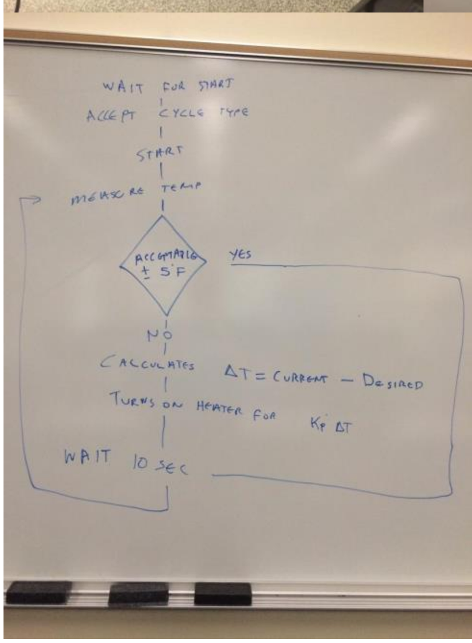
3 Pole 4 Way

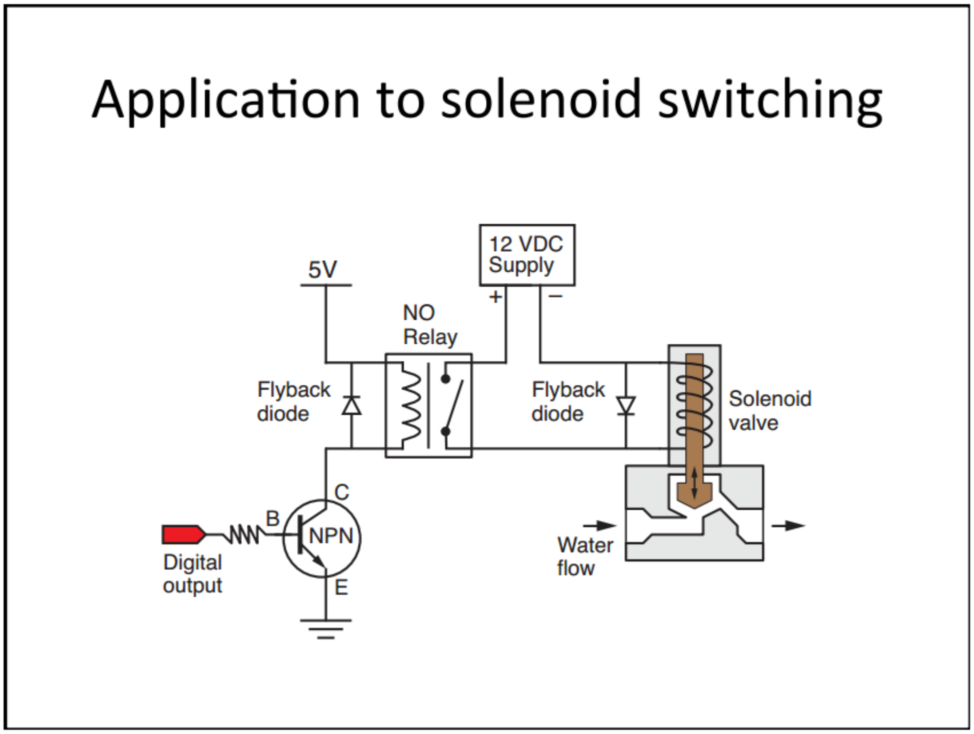
5V relay: Shinmei RSB-5-S datasheet
http://www.jameco.com/Jameco/Products/ProdDS/139977.pdf

Transistor: 2N3904 datasheet: EBC
http://www.fairchildsemi.com/ds/2N/2N3904.pdf

1/2/14 12:00 pm Jack, Tung
We asked Andrew about good electronics stores in Portland. He suggested Radioshack and Oregon Electronics. He said Oregon Electronics has arduino stuff and is in beaverton. I put photos below of our initial circuit that responds to a fake thermistor and blinks the LED with the length of time our coil would be on. We went to Oregon electronics and surplus gizmos and spent $66.88 (Rob) on a bunch of relays and such.

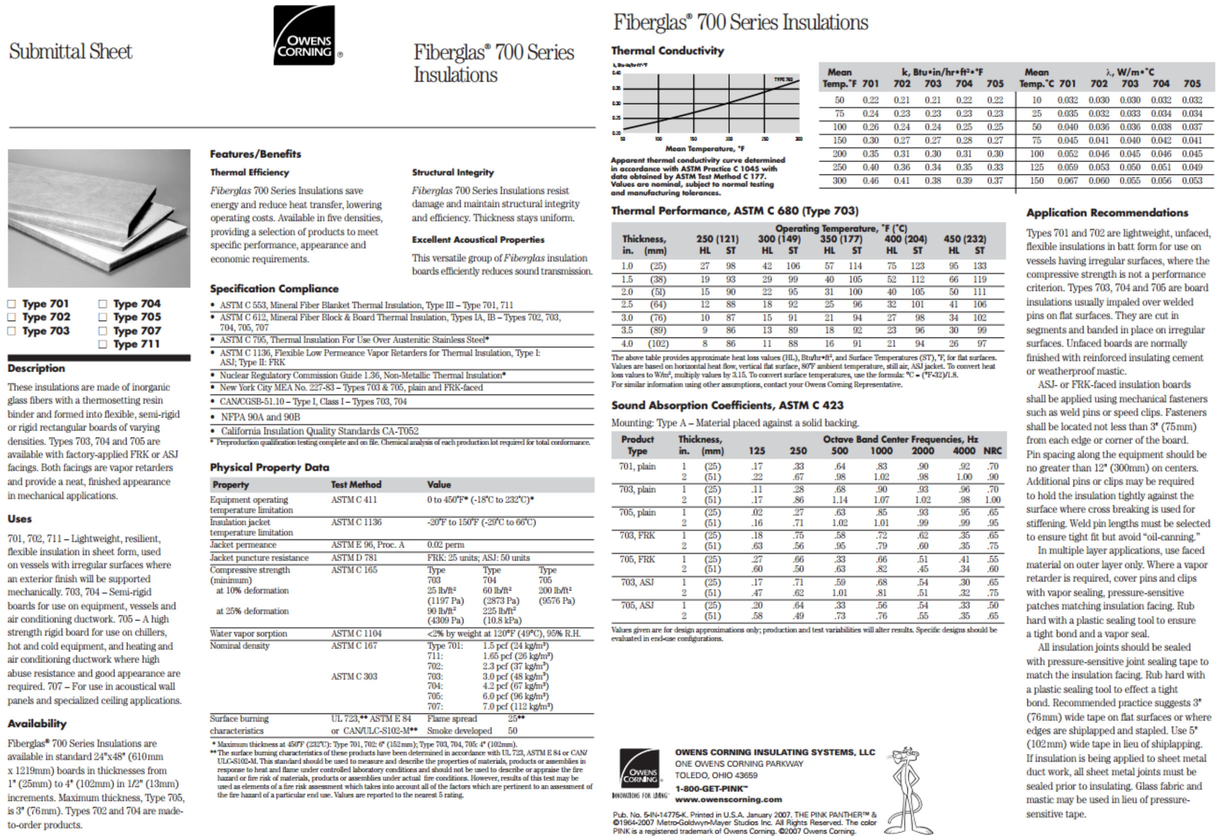






1/2/14 11:45 am Barett

Oven design calls for 2" Rigid Fiberglass board which can handle up 450F. From infor below, the 704 Series is Semi-Rigid and can handle 60 lb/ft^2 at 10% deformation.



Submittal Sheet

Fiberglas® 700 Series Insulations

Features/Benefits

Thermal Efficiency

Fiberglas 700 Series Insulations save energy and reduce heat transfer, lowering operating costs. Available in five densities, providing a selection of products to meet specific performance, appearance and economic requirements.

Structural Integrity

Fiberglas 700 Series Insulations resist damage and maintain structural integrity and efficiency. Thickness stays uniform.

Excellent Acoustical Properties

This versatile group of *Fiberglas* insulation boards efficiently reduces sound transmission.

- ☐ Type 701
- ☐ Type 702
- ☐ Type 703
- ☐ Type 704
- ☐ Type 705
- ☐ Type 707
- ☐ Type 711

Description

These insulations are made of inorganic glass fibers with a thermosetting resin binder and formed into flexible, semi-rigid or rigid rectangular boards of varying densities. Types 703, 704 and 705 are available with factory-applied FRK or ASJ facings. Both facings are vapor retarders and provide a neat, finished appearance in mechanical applications.

Uses

701, 702, 711 – Lightweight, resilient, flexible insulation in sheet form, used on vessels with irregular surfaces where an exterior finish will be supported mechanically. 703, 704 – Semi-rigid boards for use on equipment, vessels and air conditioning ductwork. 705 – A high strength rigid board for use on chillers, hot and cold equipment, and heating and air conditioning ductwork where high abuse resistance and good appearance are required. 707 – For use in acoustical wall panels and specialized ceiling applications.

Availability

Fiberglas® 700 Series Insulations are available in standard 24"x48" (610mm x 1219mm) boards in thicknesses from 1" (25mm) to 4" (102mm) in 1/2" (13mm) increments. Maximum thickness, Type 705, is 3" (76mm). Types 702 and 704 are made-to-order products.

Specification Compliance

- ASTM C 553, Mineral Fiber Blanket Thermal Insulation, Type III – Type 701, 711
- ASTM C 612, Mineral Fiber Block & Board Thermal Insulation, Types IA, IB – Types 702, 703, 704, 705, 707
- ASTM C 795, Thermal Insulation For Use Over Austenitic Stainless Steel*
- ASTM C 1136, Flexible Low Permeance Vapor Retarders for Thermal Insulation, Type I: ASJ; Type II: FRK
- Nuclear Regulatory Commission Guide 1.36, Non-Metallic Thermal Insulation*
- New York City MEA No. 227-83 – Types 703 & 705, plain and FRK-faced
- CAN/CGSB-51.10 – Type I, Class I – Types 703, 704
- NFPA 90A and 90B
- California Insulation Quality Standards CA-T052

* Preproduction qualification testing complete and on file. Chemical analysis of each production lot required for total conformance.

Physical Property Data

Property	Test Method	Value
Equipment operating temperature limitation	ASTM C 411	0 to 450°F* (-18°C to 232°C)*
Insulation jacket temperature limitation	ASTM C 1136	-20°F to 150°F (-29°C to 66°C)
Jacket permeance	ASTM E 96, Proc. A	0.02 perm
Jacket puncture resistance	ASTM D 781	FRK: 25 units; ASJ: 50 units
Compressive strength (minimum) at 10% deformation; at 25% deformation	ASTM C 165	Type 703: 25 lb/ft² (1197 Pa); 90 lb/ft² (4309 Pa). Type 704: 60 lb/ft² (2873 Pa); 225 lb/ft² (10.8 kPa). Type 705: 200 lb/ft² (9576 Pa)
Water vapor sorption	ASTM C 1104	<2% by weight at 120°F (49°C), 95% R.H.
Nominal density	ASTM C 167; ASTM C 303	Type 701: 1.5 pcf (24 kg/m³); 711: 1.65 pcf (26 kg/m³); 702: 2.3 pcf (37 kg/m³); 703: 3.0 pcf (48 kg/m³); 704: 4.2 pcf (67 kg/m³); 705: 6.0 pcf (96 kg/m³); 707: 7.0 pcf (112 kg/m³)
Surface burning characteristics	UL 723,** ASTM E 84 or CAN/ULC-S102-M**	Flame spread 25**; Smoke developed 50

* Maximum thickness at 450°F (232°C): Type 701, 702: 6" (152mm); Type 703, 704, 705: 4" (102mm).
** The surface burning characteristics of these products have been determined in accordance with UL 723, ASTM E 84 or CAN/ULC-S102-M. This standard should be used to measure and describe the properties of materials, products or assemblies in response to heat and flame under controlled laboratory conditions and should not be used to describe or appraise the fire hazard or fire risk of materials, products or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard of a particular end use. Values are reported to the nearest 5 rating.

Thermal Conductivity

Mean Temperature, °F

Apparent thermal conductivity curve determined in accordance with ASTM Practice C 1045 with data obtained by ASTM Test Method C 177. Values are nominal, subject to normal testing and manufacturing tolerances.

Mean Temp. °F	k 701	k 702	k 703	k 704	k 705	Mean Temp. °C	λ 701	λ 702	λ 703	λ 704	λ 705
	k, Btu•in/hr•ft²•°F						λ, W/m•°C				
50	0.22	0.21	0.21	0.22	0.22	10	0.032	0.030	0.030	0.032	0.032
75	0.24	0.23	0.23	0.23	0.23	25	0.035	0.032	0.033	0.034	0.034
100	0.26	0.24	0.24	0.25	0.25	50	0.040	0.036	0.036	0.038	0.037
150	0.30	0.27	0.27	0.28	0.27	75	0.045	0.041	0.040	0.042	0.041
200	0.35	0.31	0.30	0.31	0.30	100	0.052	0.046	0.045	0.046	0.045
250	0.40	0.36	0.34	0.35	0.33	125	0.059	0.053	0.050	0.051	0.049
300	0.46	0.41	0.38	0.39	0.37	150	0.067	0.060	0.055	0.056	0.053

Thermal Performance, ASTM C 680 (Type 703)

Thickness, in.	(mm)	250 (121) HL	250 (121) ST	300 (149) HL	300 (149) ST	350 (177) HL	350 (177) ST	400 (204) HL	400 (204) ST	450 (232) HL	450 (232) ST
		Operating Temperature, °F (°C)									
1.0	(25)	27	98	42	106	57	114	75	123	95	133
1.5	(38)	19	93	29	99	40	105	52	112	66	119
2.0	(51)	15	90	22	95	31	100	40	105	50	111
2.5	(64)	12	88	18	92	25	96	32	101	41	106
3.0	(76)	10	87	15	91	21	94	27	98	34	102
3.5	(89)	9	86	13	89	18	92	23	96	30	99
4.0	(102)	8	86	11	88	16	91	21	94	26	97

The above table provides approximate heat loss values (HL), Btu/hr•ft², and Surface Temperatures (ST), °F, for flat surfaces. Values are based on horizontal heat flow, vertical flat surface, 80°F ambient temperature, still air, ASJ jacket. To convert heat loss values to W/m², multiply values by 3.15. To convert surface temperatures, use the formula: °C = (°F-32)/1.8.
For similar information using other assumptions, contact your Owens Corning Representative.

Sound Absorption Coefficients, ASTM C 423

Mounting: Type A – Material placed against a solid backing.

Product Type	Thickness, in.	(mm)	125	250	500	1000	2000	4000	NRC
			Octave Band Center Frequencies, Hz						
701, plain	1	(25)	.17	.33	.64	.83	.90	.92	.70
	2	(51)	.22	.67	.98	1.02	.98	1.00	.90
703, plain	1	(25)	.11	.28	.68	.90	.93	.96	.70
	2	(51)	.17	.86	1.14	1.07	1.02	.98	1.00
705, plain	1	(25)	.02	.27	.63	.85	.93	.95	.65
	2	(51)	.16	.71	1.02	1.01	.99	.99	.95
703, FRK	1	(25)	.18	.75	.58	.72	.62	.35	.65
	2	(51)	.63	.56	.95	.79	.60	.35	.75
705, FRK	1	(25)	.27	.66	.33	.66	.51	.41	.55
	2	(51)	.60	.50	.63	.82	.45	.34	.60
703, ASJ	1	(25)	.17	.71	.59	.68	.54	.30	.65
	2	(51)	.47	.62	1.01	.81	.51	.32	.75
705, ASJ	1	(25)	.20	.64	.33	.56	.54	.33	.50
	2	(51)	.58	.49	.73	.76	.55	.35	.65

Values given are for design approximations only; production and test variabilities will alter results. Specific designs should be evaluated in end-use configurations.

Application Recommendations

Types 701 and 702 are lightweight, unfaced, flexible insulations in batt form for use on vessels having irregular surfaces, where the compressive strength is not a performance criterion. Types 703, 704 and 705 are board insulations usually impaled over welded pins on flat surfaces. They are cut in segments and banded in place on irregular surfaces. Unfaced boards are normally finished with reinforced insulating cement or weatherproof mastic.

ASJ- or FRK-faced insulation boards shall be applied using mechanical fasteners such as weld pins or speed clips. Fasteners shall be located not less than 3" (75mm) from each edge or corner of the board. Pin spacing along the equipment should be no greater than 12" (300mm) on centers. Additional pins or clips may be required to hold the insulation tightly against the surface where cross breaking is used for stiffening. Weld pin lengths must be selected to ensure tight fit but avoid "oil-canning."

In multiple layer applications, use faced material on outer layer only. Where a vapor retarder is required, cover pins and clips with vapor sealing, pressure-sensitive patches matching insulation facing. Rub hard with a plastic sealing tool to ensure a tight bond and a vapor seal.

All insulation joints should be sealed with pressure-sensitive joint sealing tape to match the insulation facing. Rub hard with a plastic sealing tool to effect a tight bond. Recommended practice suggests 3" (76mm) wide tape on flat surfaces or where edges are shiplapped and stapled. Use 5" (102mm) wide tape in lieu of shiplapping. If insulation is being applied to sheet metal duct work, all sheet metal joints must be sealed prior to insulating. Glass fabric and mastic may be used in lieu of pressure-sensitive tape.

INNOVATIONS FOR LIVING™

OWENS CORNING INSULATING SYSTEMS, LLC
ONE OWENS CORNING PARKWAY
TOLEDO, OHIO 43659
1-800-GET-PINK™
www.owenscorning.com

Called HighTemp Inc about 2" Rigid Fiberglass Insulation:

They forwarded me to Paragon Pacific Insulation

Paragon Pacific Insulation Mon-Fri 730am - 430pm

They have a 4'x10' Rigid Fiberglass board for $95.20

Next they offered "Mineral Wall Board." in 2"x2'x4' sheets

8-lb density for $0.89 per ft^2

4-lb density for $0.69 per ft^2

For a 4'x4'x8' oven we have 160 ft^2 which will cost $142.40 with the recommended 8-lb density board.

1/2/14 Jack, Tung

```
int Heater=4;                 //defining the heater to pin 4
int kp=10;                  //controller proportional constant
int temperror;                 //difference between current temperature and desired temperature
int temp;                   //current temperature
int sensorpin=5;                //thermistor attached to pin5

void setup() {
pinMode( Heater, OUTPUT );          //defining pin 4 as an output
Serial.begin(9600);

} void loop() {                     //start a loop that returns nothing

while(1)               //while the timer is less than 10 seconds, stay inside this loop
{
temp = analogRead(sensorpin);             //read from the analog inputs in sensorpin (5) and put the value in temp
```

```
temp = map(temp, 0, 1023, 0, 100);        //map(value, fromLow, fromHigh, toLow, toHigh)
Serial.println(temp);
temperror=50-temp;
if (temp<=50) {                //if the measured temperature is less than 350F, then continue with the loop, if not, bump out of it and do nothing
digitalWrite(Heater, HIGH);          // high turns heater on
delay(kp*temperror);                // after the oven is turned on, we let it stay on for a little bit of time. delay time= proportional constant * temperature error
digitalWrite(Heater, LOW);           // Low turns heater off
delay(1000);                    //waits 10 seconds before measures temperature again
}
}
}
```

Electronic parts for the oven:

Heater: 2 oven coils

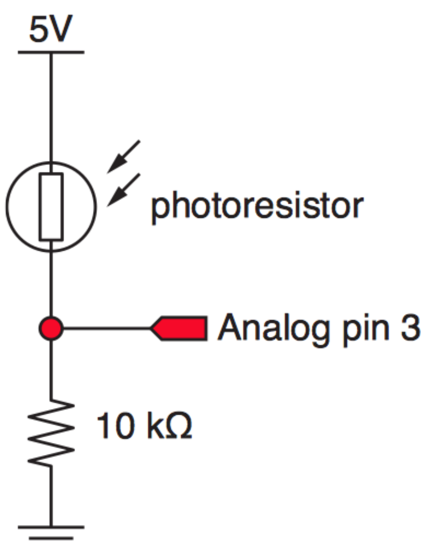
Contactor or Relay: 110v AC 20Amp

Controller:

- Arduino
- LED or LCD
- Switch: 110v Power switch, 12V Start switch
- Rotation switch: Program select
- Electrical box at least 2 plugs
- arduino transformer power plug
- power cord that we can strip 2x. pretty big gauge

12/31/13 6:45 pm Jack

We got the go ahead to make our own oven. I'm working on the programming and electrical to get back in the swing of things with an arduino.

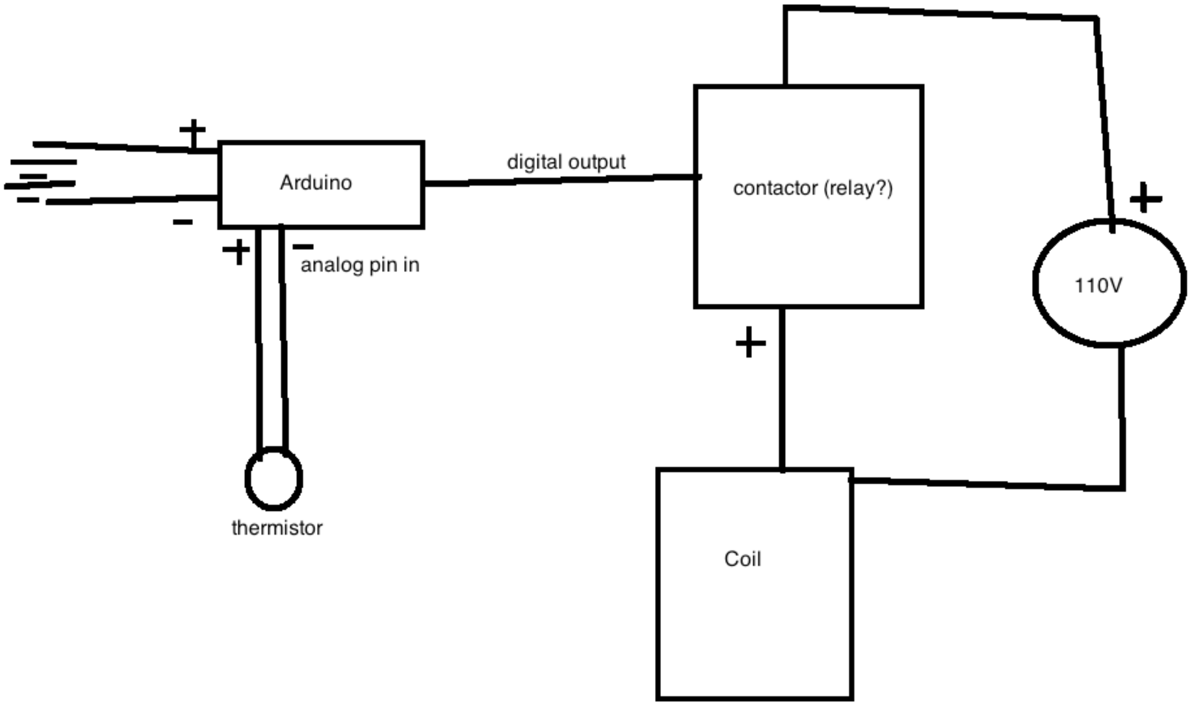


so far the code I have:

```
int Heater=4;                //defining the heater to pin 4
```

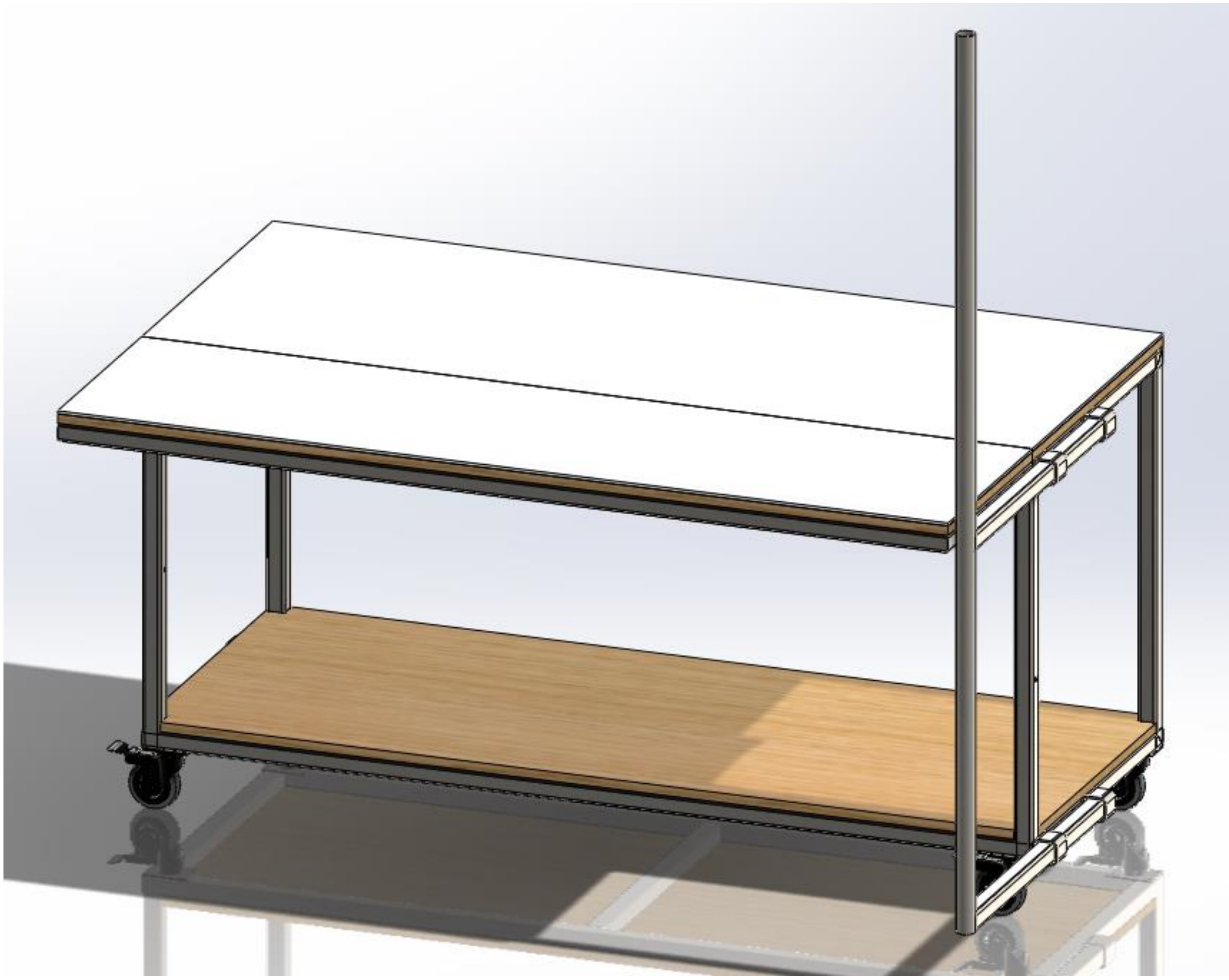
```
int kp=.01;                    //controller proportional constant
int temperror;                 //difference between current temperature and desired temperature
int temp;                      //current temperature
int sensorpin=5;               //thermistor attached to pin5

void setup() {
pinMode( Heater, OUTPUT );          //defining pin 4 as an output
temp = analogRead(sensorpin);            //read from the analog inputs in sensorpin (5) and put the value in temp
temp = map(temp, 0, 1023, 100, 400);       //map(value, fromLow, fromHigh, toLow, toHigh)

} void loop() {                    //start a loop that returns nothing

while(millis()<10000)              //while the timer is less than 10 seconds, stay inside this loop
{
if (temp<=350) {                   //if the measured temperature is less than 350F, then continue with the loop, if not, bump out of it and do nothing
digitalWrite(Heater, HIGH);          // high turns heater on
delay(kp*temperror);                 // after the oven is turned on, we let it stay on for a little bit of time. delay time= proportional constant * temperature error
digitalWrite(Heater, LOW);           // Low turns heater off
delay(1000);                         //waits 10 seconds before measures temperature again
}
}
}
```

I drew up this crude schematic to organize my thoughts on how the circuits would basically look. The thermistor loop will be a voltage divider I just pussed out of drawing it. I'm not knowledgeable on contactors which is what that guy used. I am not sure how to even deal with the AC from the wall. It seemed to work for him, maybe it has a transformer in it and outputs DC. That'd be, like, super handy and stuff. We basically have a small 9v battery power source for the computer, which is used to drive the voltage divider circuit for measuring the current temperature. then a little bit of controls logic and we output a digital signal to click what I imagine is a fancy relay to connect the oven coil circuit. Hopefully I am not messing this all up, I will run it all by PSAS because they are more competent than I.



12/31/13 2:25 pm Jack, Barett
Going to Home Depot to see what they have.
Formula body is 6' by 32" by 20"
Home Depot was kind of a bust
Called spi paragon insulation and they didn't have anything. They suggest a company called high temp inc (503) 737-0345 they were closed for the holiday
Owens Corning 703 looks reasonable

12/31/13 1:25 pm Jack, Sam, Barett
Update on lay-up table



12/30/13 12:00 pm Jack, Sam

From conversation with kevin from PCC:

Cure temp: 177C cure temperature (350F) typically

Ramp up rate: 130-330 (1-5deg/min) 330-335(3-5deg/min) hold 120 minimum at 355 +-10deg. Min time at temp are based. Cure based on coolest temp. Always monitor hottest and coldest points. Monitor parts of tool that may have variable temp. Oven may be 350 but part may not be. Coolest temp is limiter. ramp down 5degF/min. Never de-bag hotter than 140. Leak no more than 5 inMg in 5 minutes. Const. 25 inMg for whole cure is pretty good

Should plan on sustainable material instead of proprietary military grade stuff. Toray sports grade or Hexcel standard is good. This way we can consistently get the material we want from them.

A lot of material specifically designed for autoclave super high pressure (155psi). Need materials with higher resin content. Can most likely only get 14psi with vacuum.

Have lots of core for us. 350 cure carbon material best with phenolic or aluminum core. No closed cell foam with high temp cure.

Don’t want caul plate to block volatiles escaping. Flow and gel window important.

Adhesive film needs to be stored airtight

Have material from 3M expensive stuff $10,000 per roll. Rubber nitro based adhesive. Used on engine. High temp rubber adhesive. Has high flow

Adhesive *paste* good for aluminum bonding. Post-cure assembly doable.
93C Wet

No toray plain weave. Only have T800 uni tape
Have something close to plain weave 350 cure they could give us

Very excited about rocket project. Wants sticker on the rocket

12/30/13 11:00 am Jack, Sam 310-469-4433
Sam contacted pacific coast composites, Kevin Fochtmann: 12/31/13 11:15am
left a voicemail that said we had questions about leftover FSAE Carbon. we need to know the cure profile. asked about sponsorship for more carbon material. He was in a meeting and said he would call back

Figured out that FSAE core came from M.C. Gill:
hshen@mcgillcorp.com, 626-258-2748, Hongbin Shen, Ras made friends with him, he is the CEO or something

Need to ask for:
- Plain weave 12k T700 or T800 if possible
- Nomex OX core in .125, .1875, .25" if possible. but don't believe we got it from PCC

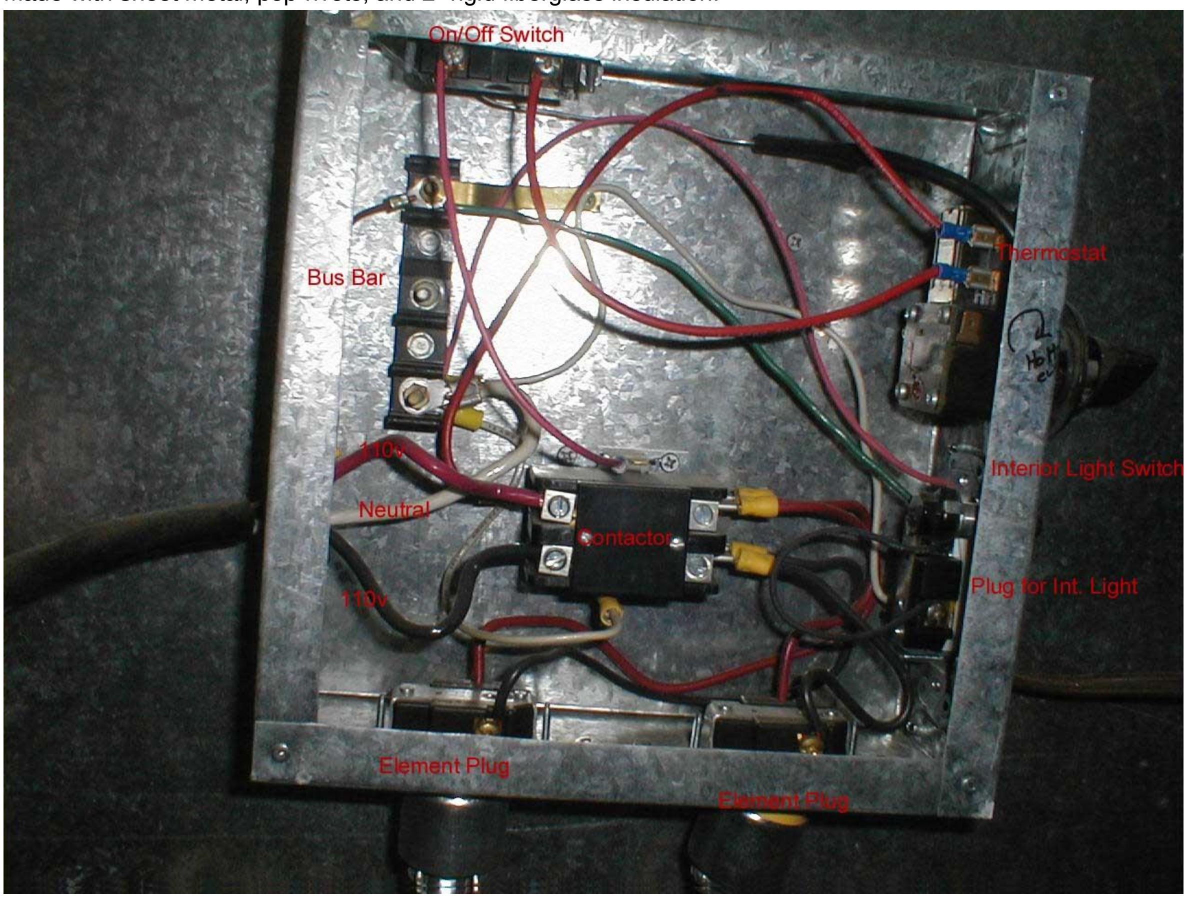
Fiberlay:
- The nylon tubing does go up to 500F

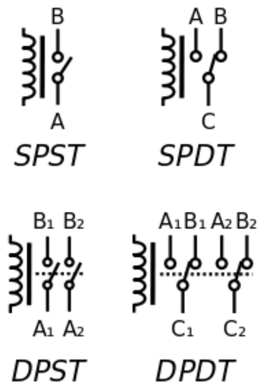
Things we want to buy now:
- Vacuum tubing (fiberlay)
- Extruded 6061 t6 (.125" x 2" x L) at $1.50 per foot
    - http://www.onlinemetals.com/merchant.cfm?pid=1128&step=4&showunits=inches&id=997&top_cat=60
- **OR**
- Extruded 6061 t6 (.25" x 2" x L) at $3.00 per foot
    - http://www.onlinemetals.com/merchant.cfm?pid=1145&step=4&showunits=inches&id=997&top_cat=60
- Shrink tape: http://www.shrinktape.com/products/hi-shrink-tape/release-coated.aspx

12/30/13 6:00 pm Jack, Barett
To do:
- figure out curing temperature schedule for our carbon
- figure out heating situation
- order parts and materials, bagging, shrink wrap, oven materials, etc
- build adhesive test joints!!
- ask robert about potting

12/30/13 5:00 pm Jack, Barett
Home Made Oven Design Page
Designed to be a powder-coating oven, but could easily be modified for our uses.
He has a very well constructed website with a Construction page, Design page, Material BOM, and links to some of his parts sources.


Made with sheet metal, pop-rivets, and 2” rigid fiberglass insulation.

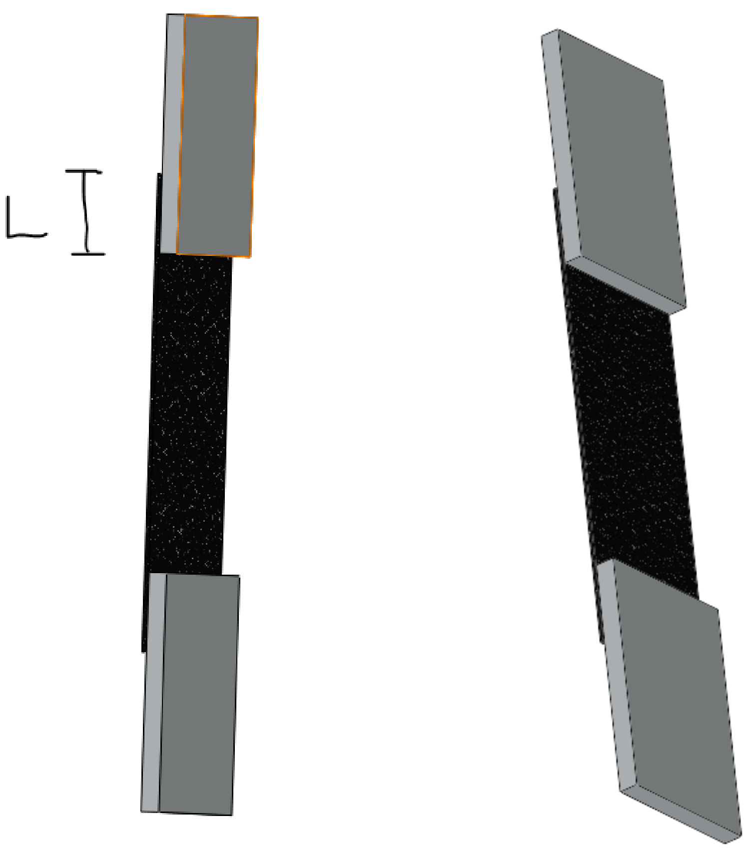




He uses a DPST it appears.

Using 4 kitchen oven heating elements, the oven can heat to 450F in 10 minutes. He built his own circuit box (above). He has a total cost of $300 into this, so i could see us building this for under $600 with our added composite necessities.
Jack believes we could implement a controls system into this design to control the heat schedule in the oven.
If we get support from Gerry/wern and the M.E. department we could build a larger oven that would be a permanent fixture for the school...

12/30/13 4:45 pm Jack, Barett



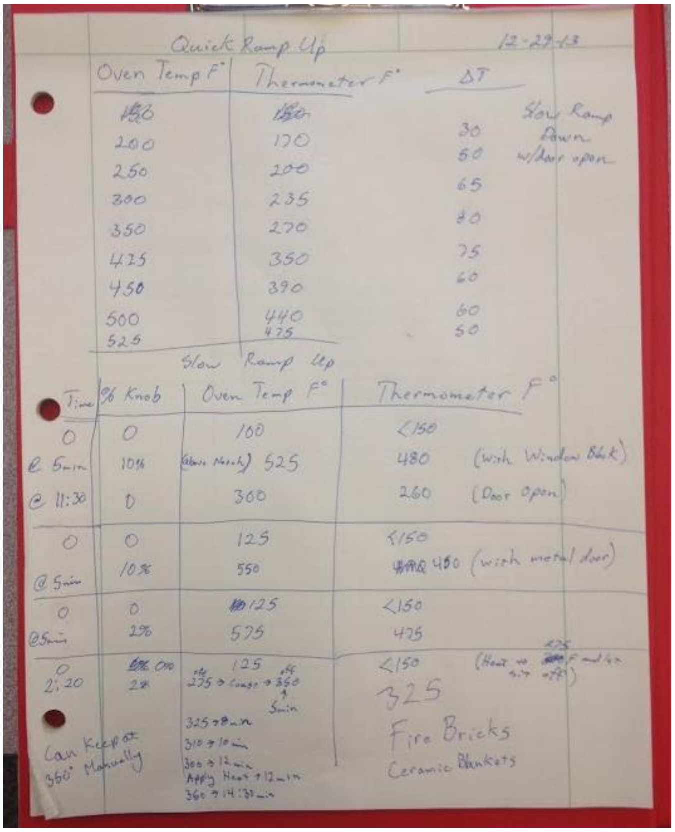
It would be nice to have the joint area be a multiplier away from the real joint area.
C=Pi*d
C=3.14*6
C=18.84 in
So if we made our test pieces 2 inches wide we could say that their strength multiplied by 10 would be the joint strength.

List of variables we could change:
- surface finish of aluminum
- cross sectional profile of aluminum
- anodize or surface treatments of aluminum
- interface length L
- single shear lap joint vs double shear
- cocuring vs post curing
- thickness of aluminum or carbon

Extruded 6061 t6 (.125” x 2” x L) at $1.50 per foot
http://www.onlinemetals.com/merchant.cfm?pid=1128&step=4&showunits=inches&id=997&top_cat=60

Extruded 6061 t6 (.25” x 2” x L) at $3.00 per foot
http://www.onlinemetals.com/merchant.cfm?pid=1145&step=4&showunits=inches&id=997&top_cat=60

12/30/13 3:00 pm Jack, Barett
We tested the oven (Kiln) in EB 480. Write-Up:
First Test:
- We first wanted to see if the analog readout on the oven was consistent with the analog thermometer that we placed in the oven. As seen in the first table, the temperature difference between the two is ~50F.
- Our next test was to see the steady-state temperature at 10%, 20%,...etc of the oven. Unfortunately at only 10% the oven went to 500F in 5 minutes. We tried the same test, but at only 2% with basically the same results.
- Next we tried to manually keep the temperature at 350F.
    - 1st, set the oven to 2% and let it heat up to 275F
    - 2nd, let it “coast” to 350F
    - 3rd, approximately every 5 minutes or so you must turn the oven on for ~30sec to maintain 350F.



Conclusion: Can keep oven at 350F manually. Oven in general runs wayyy too hot (it is designed to be a kiln for temperatures of 1000F - 2000F). Could make add on controls system to modulate temperature, but the oven is not designed to function accurately below 1000F. It makes more sense to look into different options. I would say use this oven only as a last resort.

12/30/13 1:30 pm Jack, Barett

Good well rounded document about composites that is a easy read. **gurit.com**

12/30/13 1:30 pm Jack, Barett

We are trying to solve the vacuum system setup for 350F. We had a failure before with not using the correct fittings and tubing and it nearly ruined the part. I called fiberglasssupply.com and they said that these tubes should work.

Item #	WL 7400 36" Diameter Nylon Bagging Tubing, has good elongation and strength and is ideal for room temperature curing epoxies that may have high temperature exotherms. Use for larger sailboards, higher temperature core bagging and for bagging applications that fit. .002 thickness, 350% elongation to break, Maximum use temperature 400° F. (204 C)	Per Yard	
M13-7879	WL 7400 36" Diameter Nylon Bagging Tubing 1000' Roll (333.34 yards)	$2.25	Buy Now
	Cut per yd Up to 3 yd, WL 7400 36" Diameter Nylon Bagging Tubing	$3.83	Buy Now
	Cut per yd Up to 15 yd, WL 7400 36" Diameter Nylon Bagging Tubing	$2.93	Buy Now
	Cut per yd, 16 yd & Up, WL 7400 36" Diameter Nylon Bagging Tubing	$2.53	Buy Now

I asked them about this vacuum generator which is similar to ours. The guy didn't know if it would work to 350F, but thinks if we replaced plastic fittings with brass ones that it would work. I'm slightly more skeptical. He thinks that the big electric vacuum pumps will be okay.

Item #	Venturi Vacuum Generator with Silencer, develops over 20 Hg (mercury) of vacuum (10 psi) at 1 SCFM. Designed to run off of conventional shop air compressor delivering at least 60 psi at 2 SCFM. Use with vacuum cups and vacuum tubing for an economical vacuum bagging setup.	Each	
M43-0497	Venturi Vacuum Generator (885-6)	$114.98	Buy Now

The venturi vacuum pump we have is the: mscdirect.com
I talked to MSC and they said they will call the vendor and get back to me tomorrow 12/31

Venturi Vacuum Generators | Cubic Feet per Minute: 4.00 | Air Consumption (CFM): 6.40 | Vacuum Pressure (In/Hg): 27.00 | Height: 1.66 (Decimal Inch) | Length: 8.180 (Decimal Inch) | Vacuum Port Size FPT: 3/8

Product Specifications

Cubic Feet per Minute	4.00
Air Consumption (CFM)	6.40
Vacuum Pressure (In/Hg)	27.00
Height (Decimal Inch)	1.66
Length (Decimal Inch)	8.180
Vacuum Port Size FPT	3/8

It might be wise for us to have a vacuum gage to make sure we are getting an acceptable and consistent vacuum. There is already a vacuum gage on the motorized vacuum pump.

Item #	0-30HG Vacuum Gage for determining how much vacuum pressure is under your vacuum bag. 1/8" NPT male thread fitting.	Each	
M43-0973	0-30HG Vacuum Gage (885-5)	$25.38	Buy Now

The formula team also has one of these pumps, this is the operating manual: otctools.com . The manufacturer says this pump is designed to be used with HVAC systems with temperatures in the range of 30-100F and that he doesn't know if it will work.

Because this is looking like a disaster to try and figure out, I think we should cool down the gases before they get to the pump to make this easier. The obvious solution is having a long length of vacuum tubing that is in the ambient air. If we need more cooling we can have it dip into a bath of ice water and use a catch can to make sure condensate doesn't go into the pump. We already have the pump, let's not spend more time on this problem.

12/30/13 1:00 pm Jack, Barett

We are trying to solve the mold release system problem. We searched in the formula lab and found:

- 2 Gallons Orca Skin - High Performance High Temperature Liquid Hybrid Mould Release Agent
- 1 Gallon Orca Clean - Acetone
- Nearly Empty Can of Orca Shimmer - Mould Release Compound
- 2 Gallons Orca Seal - High Performance Mould Sealer

This is the instructions for using this chemical system according to the fiberlay website. It appears that the ORCA system is fiberlay proprietary. These instructions say we shouldn't use ORCA shimmer. Shimmer and skin appear to do the same job (carnauba based wax) just one is liquid and one is paste. It might be wise to confirm this. We have about 1.5 gallons of the liquid stuff, and no paste, so let's use the liquid stuff. http://www.fiberlay.com/upload/techd-2522041-252204_OrcaSkin_Data.pdf

APPLICATION:

1. Clean mold surface thoroughly with ORCA CLEAN.
2. Mix ORCA SKIN HYBRID LIQUID RELEASE AGENT prior to application by shaking or rolling can.
3. Apply by wiping or spraying, when wiping apply with a lint-free cloth in a circular motion and continue in the same manner until entire mold surface has been uniformly and completely covered.
4. Wait 10 minutes for the coating to dry to a haze before hand polishing to a glossy finish using a clean, dry, lint-free
 cotton towel. Do not machine buff.
5. For initial application apply five to seven coats of ORCA SKIN HYBRID LIQUID RELEASE AGENT according to step 3 and 4, and continue with the molding operation. From this point on, multiple pulls may be obtained; however, the exact number of pulls will depend on mold size and configuration. Reapplication of ORCA SKIN HYBRID LIQUID RELEASE AGENT should be done when an increase in difficulty occurs when pulling. At this time, apply 1 to 2 coats according to steps 3 and 4.

ORCA Seal is not listed on the fiberlay website. I found a link to the pdf: http://www.fiberlay.com/upload/techd-252203-252203_OrcaSeal_Data.pdf
It appears that this is used before ORCA Clean. We might not need this since we are going to have machined surfaces everywhere. According to the pdf:

ADVANTAGES:

• Conditions molds – Fills pores and minor defects

• Maximizes the performance of the ORCA release agents
• Excellent for intricate mold configuration
• Will withstand exotherms up to 600ºF
• Maintains and enhances the integrity and detail of the mold surface
• Excellent for seasoning new molds and plugs

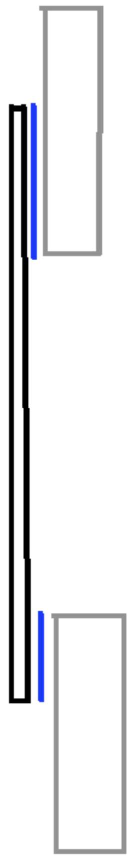
12/29/13 10:35 am Jack

We have some questions and materials to figure out before we can start making parts.
To do list:

- Mould release system
    - Use ORCA system already own
- Vacuum materials rated for 350F (lines, pumps, fittings)
    - Use current pumps
    - Need to buy high temperature tubing
- Carbon curing systems for flat and round pieces (ovens)
    - Current oven is marginally usable
    - group discussion for path to continue down needed
        - silicon blanket
            - not versatile enough
            - blanket curing would be an after design purchase so we can order the correct size
                - Need more knowledge
        - adjust current oven
        - fabricate oven
            - Might be able to squeeze Gerry AND WERN into getting some funding for it as it could be a permanent school fixture in the welding lab. the manufacturing processes students could make like a lathe part mold that they they layup on instead of a plumb bob!!!!
            - a fair amount of work
        - Get a sponsor to let us use their oven (Stohr)
            - pain in the ass
- Source materials like core, etc
    - acpsales.com for overexpanded core. this is kind of expensive still
    - ask for sponsorship (ACP, Boeing, hexcel etc)
    - formula team has limited supply and not all the sizes
- design adhesive test joints

It might be wise for us to visit stohr and check out their systems too. And we could contact Robert story for help answering some of these questions.

12/28/13 11:35 am Jack



We could make wishbones like the one pictured above to do tests on with Tom's tensile tester. We could get an order of magnitude understanding of strength of the epoxy joint, we'd be able to get a std deviation of the strengths of these kind of joints, we could vary shape and size of the joint, and the shape and size of the aluminum. We could do things like change the surface finish of the aluminum, and try post curing. We could extrapolate what we learned from this to our bigger joint, as a way of saving a ton of materials and time.

I met a lead engineer for a missile program in arizona who jokingly told me that there are two kinds of adhesive joints: ones that already failed, and ones that are going to.

I think some sort of testing like this is important to being confident in our adhesive joint.

12/28/13 11:35 am Jack
The PSAS team did a great job writing up a report and running some simulations to try and figure out how a very similar rocket went to the edge of space on one solid booster. The most important realizations to learn are that he used a very lightweight rocket with a large amount of fuel, and that his thrust curve was optimized for the atmosphere. He used a large boost for a few seconds, and then the rocket went into a sustained lighter thrust that was just under half of the initial thrust. This way you don't waste as much energy into drag.

http://psas.pdx.edu/RocketScience/astrobee_d/

Is PSAS planning on tuning the thrust curve for the solid motor?? Is this out of the scope of an amateur team skill level?

> In rockets for a given target orbit, a rocket's mass fraction is the portion of the rocket's pre-launch mass (fully fueled) that does not reach orbit. The propellant mass fraction is the ratio of just the propellant to the entire

mass of the vehicle at takeoff (propellant plus dry mass). In the cases of a single stage to orbit (SSTO) vehicle or suborbital vehicle, the mass fraction equals the propellant mass fraction; simply the fuel mass divided by the mass of the full spaceship. A rocket employing staging, which are the only designs to have reached orbit, has a mass fraction higher than the propellant mass fraction because parts of the rocket itself are dropped off en route. Propellant mass fractions are typically around 0.8 to 0.9.
In aircraft, mass fraction is related to range, an aircraft with a higher mass fraction can go farther. Aircraft mass fractions are typically around 0.5.
When applied to a rocket as a whole, a low mass fraction is desirable, since it indicates a greater capability for the rocket to deliver payload to orbit for a given amount of fuel. Conversely, when applied to a single stage, where the propellant mass fraction calculation doesn't include the payload, a higher propellant mass fraction corresponds to a more efficient design, since there is less non-propellant mass. Without the benefit of staging, SSTO designs are typically designed for mass fractions around 0.9. Staging increases the payload fraction, which is one of the reasons SSTO's appear difficult to build.
For example, the complete Space Shuttle system has: [1]

- fueled weight at liftoff: 1,708,500 kg
- dry weight at liftoff: 342,100 kg

Given these numbers, the propellant mass fraction is $1-(342,100/1,708,500)=0.7998$
.
The mass fraction plays an important role in the rocket equation:

$$\Delta v=-v_e\ln(m_f/m_0)$$

Where m_f/m_0 is the ratio of final mass to initial mass (i.e., one minus the mass fraction), Δv is the change in the vehicle's velocity as a result of the fuel burn and v_e is the effective exhaust velocity (see below).
The term effective exhaust velocity is defined as:

$$v_e=g_nI_{sp}$$

where I_{sp} is the fuel's specific impulse in seconds and g_n is the standard acceleration of gravity (note that this is not the local acceleration of gravity).

http://en.wikipedia.org/wiki/Delta-v_budget

Launch/landing[edit]

The delta-v requirements for sub-orbital spaceflight are much lower than for orbital spaceflight. For the Ansari X Prize altitude of 100 km, Space Ship One required a delta-v of roughly 1.4 km/s. To reach low earth orbit of the space station of 300 km, the delta-v is over six times higher about 9.4 km/s. Because of the exponential nature of the rocket equation the orbital rocket needs to be considerably bigger.

- Launch to LEO — this not only requires an increase of velocity from 0 to 7.8 km/s, but also typically 1.5–2 km/s for atmospheric drag and gravity drag

Looking at the rocket equation, and estimating our delta-v budget would give us our mass fraction. This means that we could figure out how much the empty rocket could weigh for how much fuel we have.

The conclusion of all I learned seems to be that the rocket must be light, have a ton of fuel in it, and have a tuned thrust curve or staging if is going to go to 100km.

12/16/13 7:45 pm Jack
Downloaded open rocket and tried some simulations. Attempted to define our rocket like it is now and was getting 20k ft launches. Because the engine is so heavy you have to add a ton of weight to the nose come. I am not sure I understand why our body has to be so light. Just to concentrate the mass at the top doesn't seem like it would save

much weight. I'm not sure. I tried to input it with the future design. The program seems a bit tedious but isn't too hard to learn.

12/16/13 7:45 pm Sam jack rob
Measurements from PSAS current airframe:
Antenna module: 5lb 3oz
Motor module: 11+lb
Fiberglass sleeve: 1lb 3.5oz
Nose module: 3lb 1oz
Loaded module: 6lb 7.5oz

12/16/13 7:45 pm Jack:
Materials in VMS lab:

Adhesive film 36" by 3 yards:
3M Scotch-weld structural film AF 191-M has flexible cure temp ~275-400degF
Data sheet:
[data sheet for adhesive film]

Twill weave 3 feet wide and a lot length. Very tacky. Could look up on pcc

5 harness yellow roll. Lots. 0210-12069-1 hmf937a/5hs epoxy type. Very tacky 2 ft ish wide. From internet search appears to be 350F cure temperature. boeing proprietary helicopter material, so we cannot get specs

BHT-CONSUMABLES LIST

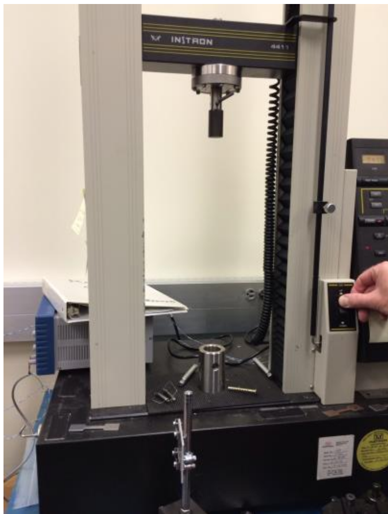
Bell Helicopter
A Textron Company

ITEM	NOMENCLATURE	SPECIFICATION	HISTORICAL SPECIFICATION	BELL ORDER NUMBER	ORDER QTY	MATERIAL	CAGE / FSCM / SOURCE	NOTES	ADDITIONAL INFORMATION
C-155	Carbon Fabric, Woven, Epoxy Resin-Impregnated	299-947-321, Type II, Class B	None	299-947-321TYIICLB	1 LB	HMF 937A/5HS			

12/16/13 2:45 pm Jack, Sam

Instron tensile test machine setup and other testing machines:






12/16/2013 Evening: Barett, Sam, Jack, Rob
<u>GFR Composites Lab:</u>
Tubing Lay-Up:

- Aluminum Pipe Inner Mandrel
- 350F Pre-Preg
- “Shrink-Tape” instead of Vacuum Bagging (See circumferental glue lines on below tubing)
- CF Tube ends sanded
- 12k plain weave CF
- Airtech Tape - Flashbreaker 1

Oven:

- Vacuum Hoses - Airtech Airflow 65R

High Stress carbon Lay-Up:

- 4-core-4 front wing for impact strength
- Impact attenuator 3-layer (no core with 4 separate tubes)
- ~ ¼” Core for wings
- ~ 1” Core for chassis
- Outside skin cook first then cook core + inner skin
- Cook all at once for wings (suggest for tube)

Sample 8” Tube:

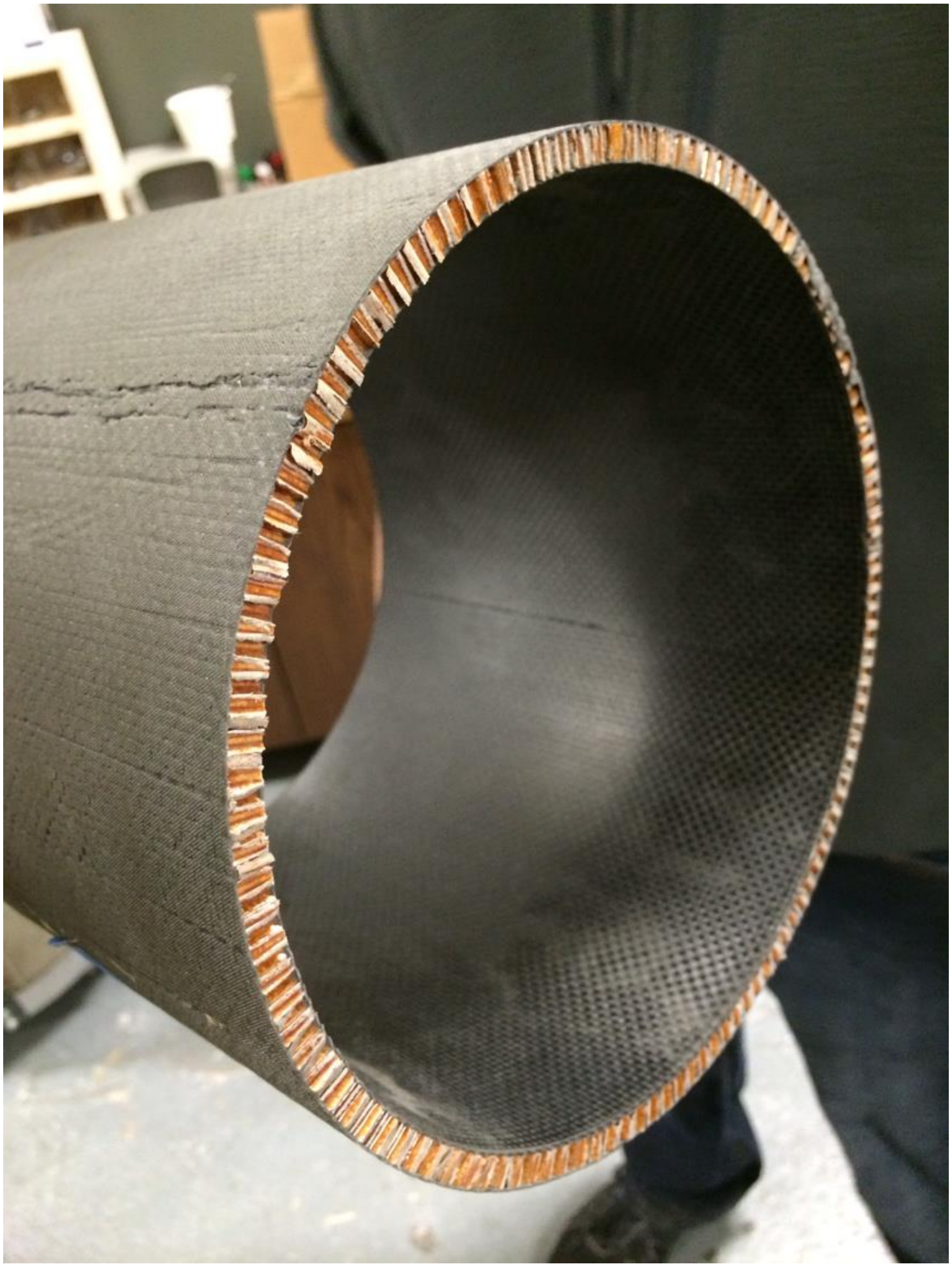
- 2-core-2 Not hex core 0.25”

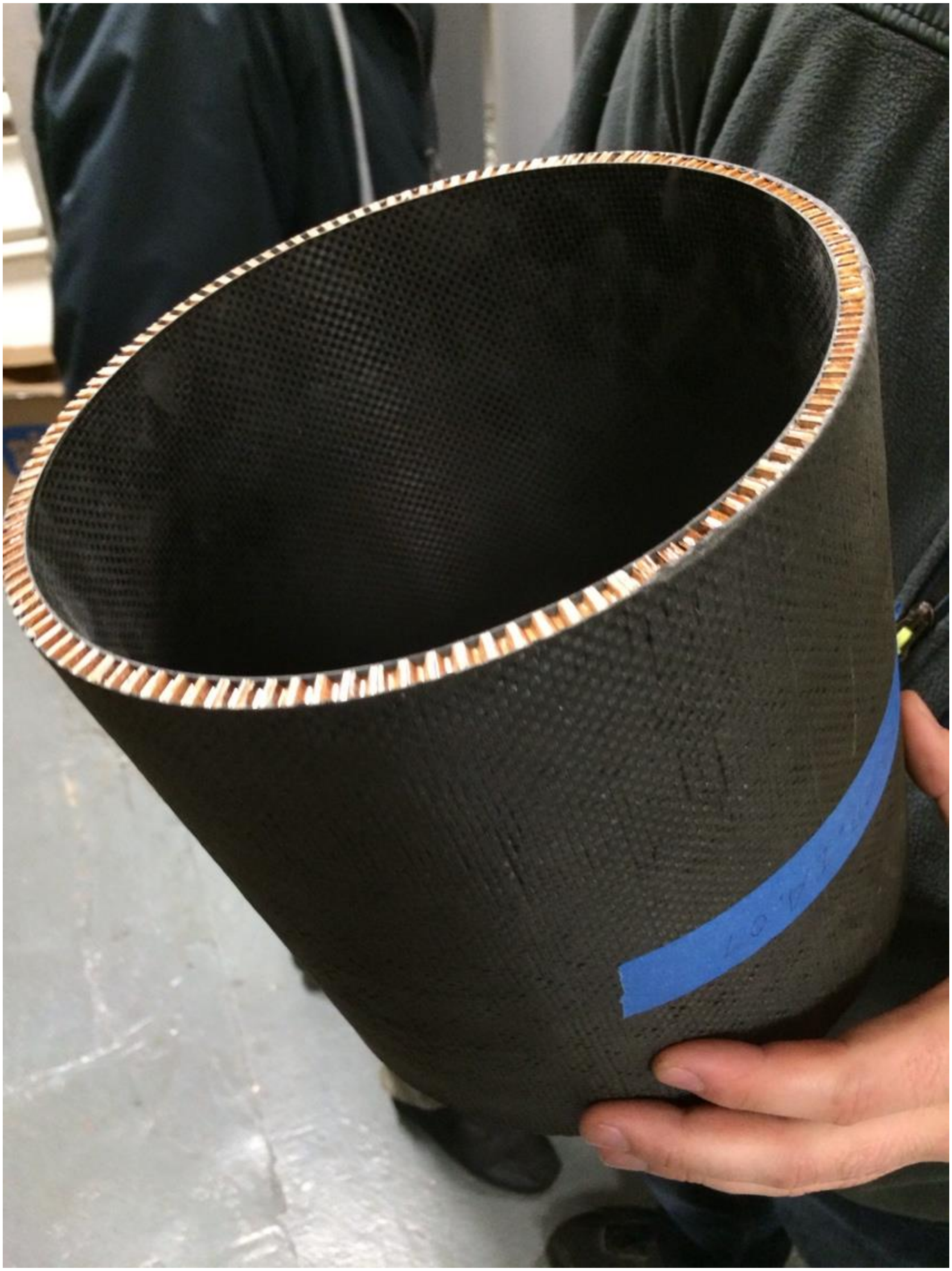
- 8” Tall x 8” Dia -> 272 Grams
- Suggest Tackier Resin for lay-up purposes
- Aluminum tube Mould (Inner)
- Preferred Core Material - “Over-Expanded” is better for curves (OX)
- Use heat with film adhesive to make it tacky
- Lay-up Schedule
    - 0-45-core-45-0

Tools:

- Green Painters tape still sticky at 250F





GFR Composites stuff:

FREKOTE
700-NC
RELEASING INTERFACE

12/16/13 2:00 pm Jack, Rob, Sam
Tom has tensile/compression tester to 1100 lbf, concrete compression tester to 20klbf, and MKS machine
Dog bone 1: failed at .62 kN
Dog bone 2: failed at .58 kN
Dog bone 2: failed at .55 kN
Dog bone 2: failed at .76 kN

12/16/13 2:00 pm Jack, Rob

Mike says Gerry has tons of connections at boeing! maybe we could score that tc800 carbon! and potentially a tour of their lab.

Simple curing oven:
http://www.privatedata.com/byb/rocketry/composites/ovens/Airframe%20Composite%20Curing%20and%20Post%20Curing%20Oven.html

Structural Adhesive Selection Guide:
http://www.huntsman.com/portal/page/portal/advanced_materials/Media%20Library/global/files/EUR_Aerospace%20-%20Adhesives_Syntactics_Performance_Araldite.pdf

Shrink Tape: http://www.shrinktape.com/index.aspx

Flash Tape and Other Bagging Materials: http://www.airtechintl.com/

Henkel Product Website (not the easiest to find stuff):
http://www.henkelna.com/industrial/product-search-1554.htm?redDotUID=productfinder&parentredDotUID=0000000GHE&BU=industrial&countryCode=us&param1=mode%3Dadvanced%7C

Online Catalog (easier to find stuff):
https://asp-cn.secure-zone.net/v2/index.jsp?id=19/92/527&lng=en

Interesting Processes:
Parlee Bikes - http://www.youtube.com/watch?v=22AnlUprKs0#t=358

12/16/13 2:00 pm Jack, Andrew, Nathan

- Want a once a week meeting for status with top 3. Working technical discussion meeting
- Tuesday evening updates via in person or email. Just to show off what we have been doing
- Funding will trickle in the next 3 months, purchase items through email to Andrew
- Electronics won't be sorted out for hole pattern by June
- Don't use airframe to electrical ground on rocket
- We can do our own uniforms and logo. They use mission patches
- They do have the 4 axis cnc and we can give parts to the guy and he will make them for us, or we could go over there and watch him do it. His name is Dave

12/14/13 10:45am - Jack
We are doing a learning experience laying up fiberglass pieces. We are testing things such as number of layers vs qualitative strength, the real effect of a caul plate, and difficulties of laying up on a tube.

List of tools we already think we need:
Disposable gloves, cups, stirrers, and glue spreaders
Good broom, good little broom, good dustpan
two tables seems like a good idea. One for tools, one for working on
real respirators
big garbage can
terry blue automotive towels
foam brush for PVA
Stainless tabletop? plastic tabletop like gfr? wood doesn't seem right
Parts shelf
Coat/ backpack rack that is away from the dirtiness

12/14/13 10:45am - Sam
Created new design log. Jack had the genius idea to add new entries to the top of the page so the log is in reverse

chronological order. From now on, we will plan on organizing the log this way.

12/13/13 12:00 pm - Capstone meeting

Build joints

- Build a few tubes, few flat joints. Need order of magnitude understanding of joints. Wet layup etc okay

Monday first thing need to call companies

- Need to get numbers, need to come up with materials, talk to PSAS about

Need materials, could steal from formula

- Understand constraints and construction flow and difficulties
- decide

Start table design

- What does everyone think should be features on the table?
- Air line built in
- Roll holding
- Mounting points for the male tool
- Wheels
- Cubbies for all tools. Not tool board, but more like extra working space
- Container holders for epoxy to make it not tip over, brush holder. Don't want epoxy to drip everywhere
- On board outlets and air facilities.
- Built in carbon storage
- Only a single width entrance
- Built in cutting accurate cutting
- calculator
- conversions notesheet
- mass/weight scale

Documentation of everything specifically models

- Shared school drive and VPN Sam set up
- get github up and running?

Teach everybody all the skills

- Lowest skilled person drives the compute
- Everyone wants to learn to mastercam etc

Testing machine

- Making press in shop work
- Need new pressure readout, high resolution in the 1000 pounds
- Need load cell to validate pressure gauge (School doesn't have load cell for us)
- We can make our own steel press using the hydraulic components already existing

Talk to Eric from PSAS

- about specifications, tools access to, how do we spend their money, timelines, how much total money realistic, what they expect from us at the meetings.
- Slowly get in by asking technical questions, potentially ask for engineering samples
- Uniforms, logo
- Outline exactly what we need to design, and get deeper understanding. He needs to figure out electrical

10 to 2 Saturday

Monday Tuesday more substantial day. Full day. Go to GFR Monday

Jack 10/3/13 10:30 am:

Meeting with rob, Barett, Sam.

Action items:

Sam meeting notes in doc, standardization, create email about companies wanting a capstone project

Rob, Barett make more company list

Jack create templates

Everyone read FSAE documents rob shared to share thoughts at next Thursday meeting

Sam's notes from initial meeting: Capstone brainstorming

- Low volume digital manufacturing
- Open source design
- Vehicle parts, motors, frames
- Maker culture
- Maker curriculum
- Open source farm machinery design

Meetings every week Thursdays 10:30 am

Jack 10/4/13 10:30 am:

Meeting with Rob, Sam, jack

Vision for our capstone: exciting, couldn't get from an outside party, Sam is certainly interested in creating his own job into the future. Something that leaves a lasting impression, something to be proud of.

Are we better off leaving the class? Does it support the vision?

- Camping/high adventure
  - Redesigned sleeping bag
  - Alcohol cook stove
- Vehicles
  - Racing recumbent bicycle
- Tools for vehicles
- Commuter vehicle
  - Ultimate urban transport
- Bicycling
  - Urban trailer
- Home automation
- Boats
- Airplanes/UAV/remote vehicles
- Clean energy generation
  - Open source diesel electric generator
  - Open source Diesel engine

- Green building design/ decentralized power creation

Meet up on Monday: 12 noon at the same Starbucks

If we come up with a viable idea by Monday, we will continue with the class

Barett 10/7/2013 12:01pm:

I am currently on my lunch break. I like a lot of the above ideas although I also believe some of them to be too “big” for a capstone project. In addition to this I do not want to spend the time on a product in this business class that is always going to be just an idea for the sake of getting through the business class. I would rather divert my attention to a better capstone project and not worry about this business class.

...so...if you three feel that we have a minimal viable product that would also stir interest from a MBA student, then I will join you in the business class.

In the end I feel that we do not need the business class, that we can be more successful without it...the business class will be a distraction from OUR team goal.

Sorry I am not at the meeting today, I would much rather see you guys than bust my ass.

Sam 10/7/13 1:30pm:

Discussed project ideas and mgmt class

Project Ideas included:

- Urban commuter concept vehicle
- Open source, scalable engine design
- Open source, scalable chassis design
- Alcohol backpacking stove or better alternative

Rob, Jack, Sam decided in conversation that the group's vision would be hindered more than helped by the startup mgmt class. The skills and motivation of the group are enough substitute for the benefits of the class.

Going forward:

More group deliberation is necessary for choosing a final project. We will meet again **Thursday 10:30am** at Broadway Starbucks.

***Final project decision will be made at a tentative meeting **Monday 12:30pm.**

Action items:

- Individually record pros and cons for each project to be shared next Monday
- Determine Capstone requirements for original project from Yi or other ME resource
- Sam will research and develop file structure medium
- Jack and Sam fill Barett in on project option details Barett has been filled in.
- Jack start pro vs con list

Jack, Rob 10/7/13 2:27 pm:

Met up with Etasami in the computer lab.

Brain dump:

Capstone project requirements: Scope is up to us but wants a physical prototype at the end. Most important thing is following the design process, scope has little effect on grade. If we want to do our own project, loose requirements on industrial sponsor. If we were to be making our own company, that would suffice. (*We need an industrial advisor). Typical projects only build one prototype (but not because that's the way it should be done). Multiple iteration style project acceptable. Grade might be slightly prejudiced against small trivial scope projects. Intellectual property is tricky. If we are to give a presentation for the public (sponsor) we must have a provisional patent in place already. (*Rob and Jack think that being open source about it could be wise to not deal with that complexity and money). Companies will be coming in over the course of the term to give 5 minute presentations about their projects. He asks the class if anyone is interested and the people that are form the group. The first group to tell him this is our group and we want this project gets it. If we form our own project and group we have full control of its members. Typical group is 4-6. We can get started right away, no need to wait. In fact, it's better to start now. Etasami's website (http://web.cecs.pdx.edu/~far/) has all the documents available on it to look at to move forward. Basically any info we would from a professor, is already available on the website. The website is a good resource for planning to be successful in the class. Etasami will be available to answer questions, and tomorrow he will be teaching the capstone class instead of Yi. We should follow the 7 step design process outlined in 491, and all the other processes.

Jack 10/7/13 3:00 pm:

We elected to use a pro/con sheet to try and help us decide on which project to choose, and whether or not we should take the business class also.

Color code: Jack, Sam, Rob, Barett

Open source scalable vehicle components (engine, chassis, other)

Pro:

Incredibly cool

Likely won't have the opportunity to work on a project like this again

Potentially could create open source community around the engine (FSAE?)

Learn a ton

Large potential market

Could lead to world changing company

industry professional Evan would likely be super helpful

Could potentially reduce scope by focusing on simpler, but still valuable, component (example, repackage existing engine components into a new package, possible FSAE engine)

Could springboard into more vehicle design like we've discussed

Greater sense of fulfillment/accomplishment

Doing this for Capstone means failure isn't really a big deal, as long as we deliver something

Love idea of being a game changer

Group already has lots of vehicle design knowledge

Chance to do something out of the ordinary

Potentially patent something

Sponsor connections through this could create a job after graduation

Con:

Enormous scope agreed

Potential for failure

Wouldn't have much time for testing

Higher total project cost agreed

Engine design could be way over our heads

Iterating may be difficult agreed

Testing may be difficult additional testing equipment/fixture may be required

Potential for complex manufacturing

Sponsors are basically a requirement, which may restrict our freedom to satisfy the sponsor

Backpacking/Adventuring Stove (Potentially alcohol)

Pro:

Seems to fit capstone requirements very well

Reasonable scope/likely to be very successful

Able to do iterative design and testing

Could potentially turn into a company after graduation

Cheaper total project cost

Many contacts of people who we could have test our designs

Allan Slocum will be helpful Potentially an easy sponsor

Could scale to larger market, developing countries

Could lead to more products and larger markets

We know that people want this

There is a hole in the market for this right now

Could use the “green” marketing in our favor

Many local companies that could have interest in the finished product

Safe bet for capstone (iterations will make for better capstone project)

Con:

Not as interesting

IP frustrations will make it not a viable company

May require cost of patents (if we decide to protect design)

Small market desires product

Might not have much impact on the world

Safe bet for capstone (might be to easy)

We might finish to quickly

Many many DIY ways to do this

Taking Startup MGMT Class

Pro:

Additional experience beyond regular capstone

Forces us to be creative, go the extra mile

Forces us to work in a team with business people

Better chance of ending up with a viable business

Extra funding/support beyond capstone

Could potentially learn something outside of engineering

Con:

Additional workload could take away from design work

Demands a finished product ready for market

Forces us to work with business people we don’t know

Cost of extra two credits

Limits creativity by requiring smaller scope and because of the need for a viable product

Did not see any MBA students I would want to go into business with

Just no, I see it as a distraction

Sam 10/7/13 8:15pm:

Group documentation standards:

File structure:

- Capstone
  - Design log document
  - Research
    - Articles
    - Reports
    - Technical documents
    - Interview transcripts
    - Photos
    - etc.
  - Design
    - Scanned sketches, hand-calculations
    - Solid models
    - Mathematical models
    - Prototype photos
    - Presentations
    - etc.
  - Testing
    - Data
    - Reports
    - Photos
    - etc.
  - Business/Marketing*
    - Budget
    - Other business stuff?

  **Maybe unnecessary (May want to use even if we don't pursue the business class, it will be useful for project management.)*

File naming structure:

Category_ItemName_DateModified_DateVersion_MemberInitials.FileExtenstion

Example: ENG_PistonRing_100713_2_SA.sldprt

Example: PRES_ProjectOverview_111213_1_JS.pptx

Categories will probably make themselves obvious as we start working. The idea is that they make it easy to sort and glance at a big list of files to find what you're looking for quickly.

File creation and storage:

All files will be stored in a shared "Capstone" folder on Google Drive, including photos, powerpoints, spreadsheets, etc. We should utilize Drive for its collaboration functionality when possible. **I am still seeing if Google Drive will work as our FTP server. This could change to DropBox or something else.**

Email template for soliciting funding:

Subject: PSU Engineering Capstone Opportunity

[Company Contact],

I am a senior mechanical engineering student at Portland State University. For our final capstone project, our group is developing a [insert project name and a few details]. We think this is a really exciting project and we want to invite you to support our innovation efforts by sponsoring the project. This project can't be successful without funding from community members like [insert company name]. By offering your support, you would [help secure] [ensure] our project's success and be responsible for invaluable contributions to our education as well as to the local and global community.

If your company has any interest in sponsoring our capstone project, let me know and I can send you some additional information about the project as well as more details regarding sponsorship.

Thank you for your consideration,

[Insert your name here]

...This sound good, sweet and simple

Rob 10/8/13 9:09 am:

Here is a cool stove I found on youtube:

- Petal Stove II - http://www.youtube.com/watch?v=WkW-fhQAZjE

Here is a video on electrolysis (I know we all know this)

- http://www.youtube.com/watch?v=X3qb1Wc1j5g
- Increase the surface area, and a lot more hydrogen - http://www.youtube.com/watch?v=Q0ak7f8RpAM

Here is a video on a 12v earth battery

- http://www.youtube.com/watch?v=eztcSWZpfJg

How about a gas stove run on hydrogen stored in a balloon !!!

- http://www.youtube.com/watch?v=0xmRWw9LWFw
- How about fun with hydrogen filled balloons : http://nighthawkinlight.wonderhowto.com/how-to/make-clean-burning-and-inexpensive-hydrogen-gas-home-0134775/ (this guy actually make a lot of cool things if you look at his youtube channel)

Rough calculation:

Assuming: 100% heat transfer offers energy to water, .7 L water, 30* C initial, 100* C final.

Q=mct

Q=200,000 joules needed to boil water.

Attempt to correct:

Half of energy from fuel goes into water

Needs to constant temperature boil for 5 minutes with large thermal losses

Barett 10/8/2013 6:22pm

This is a more involve alcohol stove http://www.youtube.com/watch?v=2BTzZFcIr3Q

Rob 10/9/13 10:21am

Backpack Stove - Market Research

Jetboil reviews with spec (a little older (2010) but still good info)

- Jetboil Flash - http://www.youtube.com/watch?v=7iFRwfw-Eh4 (gas stove)
- Jetboil Helios - http://www.youtube.com/watch?v=_HoWGo9f4xI (this is really just a liquid style stove)

Stoves examples (by category) available at REI

- Canister (gas) - (18 models)
  - Jetboil ($79-$149) -http://www.rei.com/product/813621/jetboil-sol-titanium-stove
  - MSR ($59-$179) - http://www.rei.com/product/736977/msr-reactor-stove-system
    - Jetboil vs MSR comparison -http://www.youtube.com/watch?v=G6Un0MboZbk - conclusion - same performance
  - Ohters - http://www.rei.com/search?cat=4500001_Stoves&cat=4500028&cat=4500453&jxBrand=Optimus&jxBrand=Primus&jxBrand=Snow+Peak&jxBrand=Soto&hist=cat%2C4500001_Stoves%3AStoves%5Ecat%2C4500028%3ABackpacking+Stoves%5Ecat%2C4500453%3ACanister+Stoves%5EjxBrand%2COptimus%5EjxBrand%2CPrimus%5EjxBrand%2CSnow+Peak%5EjxBrand%2CSoto
- Ultralight - (10 models)
  - Trangia Mini ($35) alcohol stove -http://www.rei.com/product/657906/trangia-mini-trangia-28-t-backpacking-stove
  - Same as the others in the canister category
- Liquid Fuel (6 Models)
  - MSR ($99-$139) - http://www.rei.com/product/830342/msr-whisperlite-universal-backpacking-stove
  - Trangia Mini ($35) alcohol stove
  - Vargo Decagon ($29) alcohol stove - http://www.rei.com/product/767750/vargo-outdoors-decagon-stove
- Alt. Fuel (5 Models)
  - BioLite Wood Stove + Power Generation ($129) - http://www.rei.com/product/846334/biolite-wood-burning-campstove
  - Others - http://www.rei.com/search?cat=4500001_Stoves&cat=4500028&cat=4500455&hist=cat%2C4500001_Stoves%3AStoves%5Ecat%2C4500028%3ABackpacking+Stoves%5Ecat%2C4500455%3AAlternate+Fuel+Stoves

Comments:

- Rob
  - What is the problems we are attempting to solve? It appears that that liquid stove solves the problems with the alcohol stoves and you can burn any type of combustible fuel you wish (kerosene, gas ,diesel, alcohol, etc…)

  There are laundry lists of issues with the different types of stoves. It would be wise to lay it all out as a group. It would be totally cool to have a stove that was able to utilize most any common liquid fuel.

  The whisper light you listed was the standard stove I saw about 7 years ago. It's the one I hate the most. Actually using it is challenging and requires some knowledge to work, it's fairly dangerous and annoying. One problem I'd like to solve in stoves is how totally annoying putting them on the ground is. Rocks aren't flat.

Are we just attempting to make a liquid fuel version of the Jetboil?

We are trying to make the ultimate backpacking stove. Jetboil happens to have some good ideas. I think we can innovate and change the industry. One obvious idea is that you can't eat bread on backpacking trips because it goes bad so fast and isn't really packable. Just like 5 years ago nobody thought you could have lasagna and now you totally can with melted cheese and everything (mountain house freeze dried packages). I think that we could make a dent in any number of aspects in backpacking cooking. I wouldn't be satisfied with the project if we made just an alcohol jet boil.

- Is the Jetboil just clever design and marketing? My pots at home don't have a heat sink and work just fine.

Jet boil boils water in 30 seconds. More efficient=less fuel carried. Weight is extraordinarily important in people's decision making on equipment. I totally love my jet boil and regard it as my go-to stove if I'm going to do something. I think we can do better though. Our design doesn't even have to have a heat sink.

Rob 10/9/2013 12;53 pm

Side note: Low cost hydrogen storage possibility - http://www.youtube.com/watch?v=OXAf7MsuPjI

Company: http://www.cellaenergy.com

Rob 10/9/2013 6:00pm

Capillary Hoop Stove "Ultimate Alcohol Stove" - http://www.youtube.com/watch?v=fbHHQrh9m58

Barett 10/10/2013 10:30pm Meeting Notes

Vote was made on the MGMT510 business class. 0 votes yes. 4 votes no.

Still undecided with the backpacking stove

Moving forward with compiling a list of companies to contact about capstone projects

Minimum of 1 idea and 2 companies per person. (Research folder)

Beginning email/letter/call send out to companies 10/15/201315/2013

Put your name next to the company you would like to contact (call)

Talking about the open source engine design

Sam 10/14/13 11:15am

Company phone call talking points:

- Hello, I'm a senior engineering student at Portland State University. I was wondering if there is someone at the company I can talk to about collaborating on a capstone engineering project
- My capstone team is looking for industry engineering projects. We'd like to take on a mechanical design and prototyping project for your company if you have a need for it.
- I can give you more details now or later if you'd like some time to consider. Ideally we'd

like to make a final decision on our project by [Thurs. October 26?]

Important project details:

- Project scope must allow for completion by June

Jack 10/30/13 1:15pm

Link to a paper about carbon fiber orientation vs material properties as talked about in the PSAS meeting. Highlights are that strength is cut to 40% when at 20 degree fiber angle. Unidirectional cloth is amazing, but need to understand stresses on rocket.

http://web.ornl.gov/~webworks/cpr/v823/rpt/106099.pdf

Links from Rob's email:

NASA Composites

http://www.youtube.com/watch?v=tZhH2B-EI1I

Composite Jet Partsjoint

http://www.youtube.com/watch?v=u7joyui3A6o&list=TLJMSgERUJ3Nhcl9673cgrEahHXcXRajRY

Composite Aircraft Parts

http://www.youtube.com/watch?v=FTUw0OWWMLU

NASA Composite Joint

http://www.youtube.com/watch?v=N8dcsrvujKY

NASA Fiber-Metal Laminate

http://www.youtube.com/watch?v=hEPDR9FAJxw

NASA Thermo-Plastic Tape Composite

http://www.youtube.com/watch?v=U0hFnkrDjy4

Simple bladder construction

http://vimeo.com/10665397

another one

http://www.flickr.com/photos/zhefei/sets/72157616010742940/

Prepreg and Resign Infusion

http://www.composite-sourcing.com/bladderadv.html

Simple Tube Fabrication

http://www.nammo-cs.com/capabilities/bladder-molding

Interesting Process

http://www.ou.edu/composites/papers/Anderson%20and%20Altan%20JEMT%20(2012).pdf

Crazy Part Molds

http://www.loftingservices.co.uk/capabilities/plaster-mould-tools

Inflatable Mandrels

https://www.google.com/search?q=inflatable+mandrel&tbm=isch&tbo=u&source=univ&sa=X&ei=EhlxUq7cC8jziQKXpIDoDQ&ved=0CCkQsAQ&biw=1483&bih=903

Jack 11/5/13 10:30 pm:

The whole team met with the rocket group for the second time tonight at their 7 pm meeting. Eric wasn't there so we talked to the guy that seems to run the show. He mentioned a lot of the same design goals for the project as we have been hearing, so it was pretty exciting. I am feeling excited to work on the project for them, and think we should do this capstone. We can't really get going on it until the rest of our projects clear up though. I hope we can get started during winter break.

We talked about how totally difficult it is to work on their rocket because each module has many screws around it, and there are no common busses between modules. Wires have to be fed through multiple modules and are fairly shitty. We mentioned that we thought it would be so cool in a dream world to have like a quarter turn click and then the two modules are solid mated. We will have to look into creative solutions for mounting the modules together. Also, coming up with a cable routing system might be useful. It might not be possible to stress the inner containers, and we might actually have to isolate them.

We have been researching composites modeling and analysis softwares. Tonight we did a basic "does solidworks return meaningful results" test against abaqus and it did. Solidworks has a composite layup add on and FEA software built in. It was incredibly simple and easy to learn. It also handled buckling, but we did not verify with hand calculations. We thought that making some carbon angstrom test pieces and validating the FEA results would be the way to go. We could build rockets that have a realistic safety factor as opposed to just overbuild them. Abaqus and Autocad also all do composites. Autocad is free for students, and solidworks is likely available to us through FSAE. Abaqus is on the school computers and Zareh mentioned he has tutorials he can give us. It would be cool in my mind to learn a powerful software while we have the chance. But it might just be easy enough to use solidworks.

Rob 11/6/13 12:37 pm

I upload a NASA pdf on Durable Redundant Joints for composites in our research section.

Jack 11/6/13 5:00 pm:
Notes from the meeting:
funding: expect $1,000, and they will foot the bill. They want us to do the presentation competition. They would like us to create a budget for the 1k+.

Models: I have a splattering of models on my thumb drive. I attempted to upload it to the research section of our drive but my internet was too slow to do it completely. Hopefully it will finish tonight.

The Airframe section of the website seems a little disheveled. We will spruce it up and do a good job documenting for their future.
Rough proposed design specs:
ID/OD expect 6 8 or 12 inch internal diameter

approximate loads: motor puts out about 800 pounds, and the 75 pound rocket accelerates about 10 g. there are about 50 pounds above the rocket motor.
Buckling is primary failure mode and is one of the top reason these rockets don't make it up super high
they want it stiff in bending because the measurements will get all messed up if it vibrates and the 6 dof control needs accurate measurements.

Rob 11/7/2013 9:19 am

I imported the LV2 Sept 04 launch data into excel. Here are the maxima from the data

TIME (sec)	Thrust (lbs)	Drag Coeff.	Accel. (ft/sec2)	Accel. (g)	Velocity (ft/sec)	Speed of Sound	Mach No.	Velocity (mph)	Altitude (feet)
Max	760	0.543	415.167	12.90541	1548.4	1149.32	1.361	1055.7	20835.69

I uploaded the file to the research section.

A quick mass calculation from the thrust/accel indicate that initial mass to be approximately 68.3 lbm. The approximate mass when the rocket fuel burned out was approximately 64.7 lbm. Indicating approximately 3.6 lbm of propellent was burned in 4.3 sec.

Rob 11/7/13 10:25 am

I uploaded the lecture slide from a space systems class (ME342 from Princeston) to the research folder. The first few lecture are very relevant, lectures 3&4 specifically.

Insrtuctors site: http://www.princeton.edu/~stengel/MAE342Lectures.html

Rob 11/7/2013 9:55

I have 25 books coming from the library related to rocket and composites.
There are are the the following books available online from the library:

Composite Aircraft Design
http://portlandstate.worldcat.org/title/design-and-analysis-of-composite-structures-with-applications-to-aerospace-structures/oclc/836405247&referer=brief_results

Spacecraft Systems Engineering
http://portlandstate.worldcat.org/title/spacecraft-systems-engineering/oclc/760056962&referer=brief_results

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	Composite airframe structures : practical design information and data	Pending	PSU Library Circulation	Summit
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Cancel	Composite materials for aircraft structures /	Requested	PSU Library Circulation	ILLiad
Cancel	International reference guide to space launch systems /	Requested	PSU Library Circulation	ILLiad
	Missile aerodynamics	Shipped	PSU Library Circulation	Summit
	Design and analysis of composite structures : with applications to aerospace structures	Shipped	PSU Library Circulation	Summit
	Rocket propulsion elements	Shipped	PSU Library Circulation	Summit
	History of liquid propellant rocket engines	Shipped	PSU Library Circulation	Summit
	Modern engineering for design of liquid-propellant rocket engines	Shipped	PSU Library Circulation	Summit
	Introduction to composite materials design	Shipped	PSU Library Circulation	Summit

Showing 11 to 20 of 25 entries First Previous 1 2 3 Next Last

	Title / Author	Status	Pickup Location	Account
	Principles of composite material mechanics	Shipped	PSU Library Circulation	Summit
	Liquid rocket engine combustion instability	Shipped	PSU Library Circulation	Summit
	Finite element analysis of composite materials with Abaqus	Shipped	PSU Library Circulation	Summit
	Rocket propulsion elements : an introduction to the engineering of rockets	Shipped	PSU Library Circulation	Summit
	Introduction to rocket science and engineering	Shipped	PSU Library Circulation	Summit

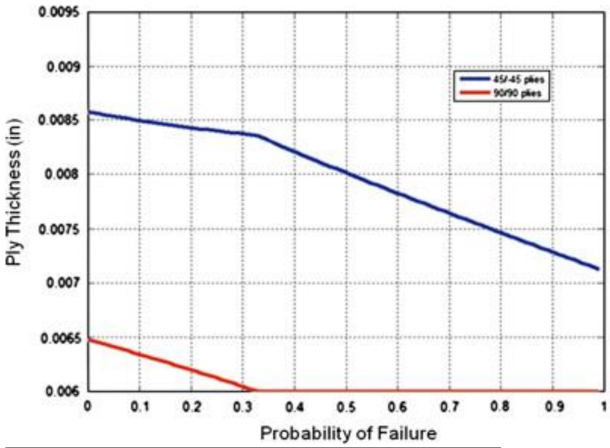
Showing 21 to 25 of 25 entries First Previous 1 2 3 Next La

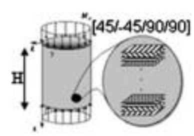
Jack 11/8/13 4:25 pm:
Here is a link to an awesome resource on manufacturing high end rocket parts with garage tooling. It has seemingly good quality 20 minute videos with step by step instructions. This is a good thing for us to look at to realize that there are super low end ways to make good parts. for example, we don't necessarily have to only think about only an aluminum female mold, he uses a piece of mylar sheet clear plastic and just wraps it around his layup so that it is smooth. He also lays up sometimes on cardboard tubes and such.

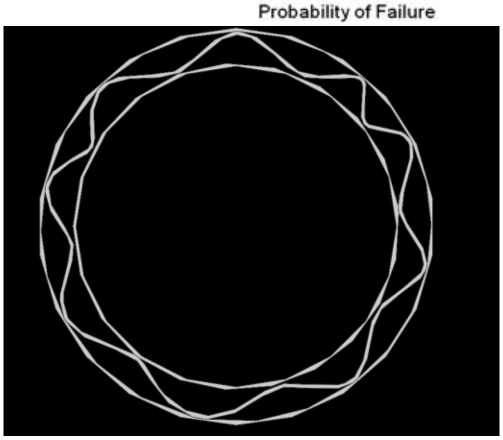
http://www.jcrocket.com/howto.shtml

One thing to think about: if fiberglass isn't conductive, it might be wise to look into it as a material choice at least for the one section that has that big antenna. It'd be sweet not to have that stupid thing hanging off the side of our sex rocket. My father says that fiberglass is an insulator and that the front dome on airliners are usually fiberglass because all the radar antennas and crap are behind it. Attenuation is not constant across frequencies though, so we should ask/test if we decide to go down this route.

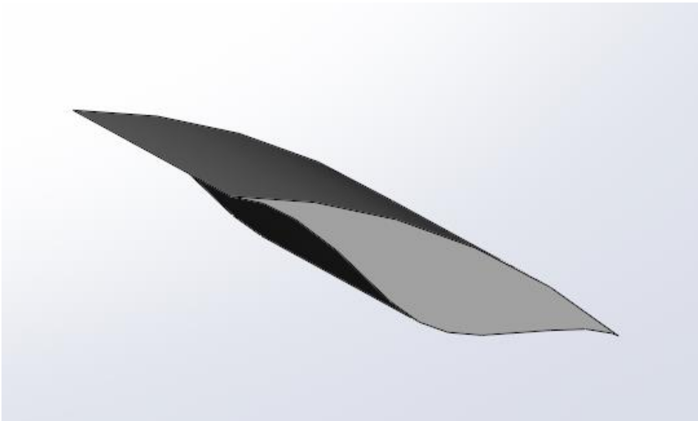
I saw a graph that shows that buckling is better mitigated by axial and radial fiber directions rather than 45 45 directions.

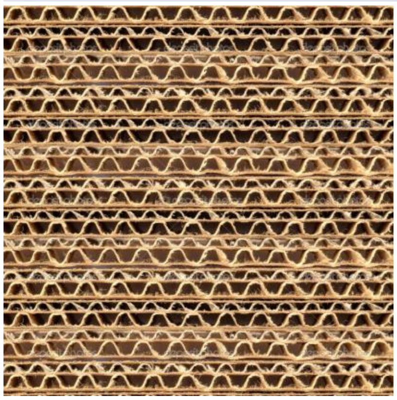






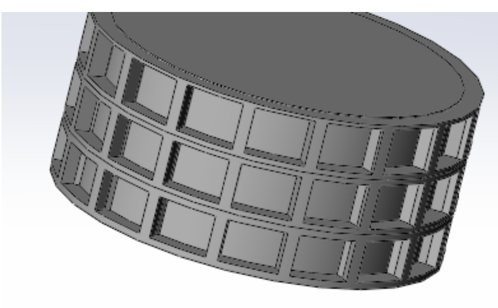
I am trying to think of what the skin could look like. Cardboard looks like this. We could build this using styrofoam plugs that fit into each hole that we lay up on top of. We could leave the styrofoam or melt it out with gasoline. We would have to have complex shaped styrofoam though in a shape sort of like this that is 18 inches long.





Another idea is to use a polystyrene tube as both the core and the shape. So we could layup directly on the styrofoam so we wouldn't have to have a fancy jig with vacuum bags and stuff. This seems a lot more like garage building, but I think it's worthwhile to think of the simplest way to do things before we up the complexity. That way we have a real reason for extra complexity.

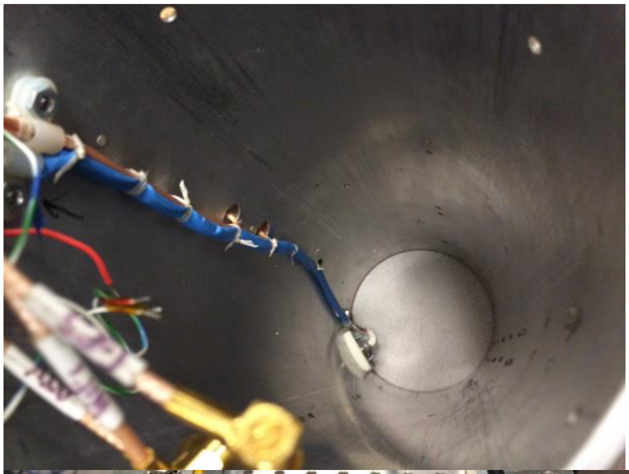
I think a solution like this is the standard way to do it. Using several layers, then some sort of nomex type core, then a few more layers. We have to use a mold with this option but that's certainly doable.

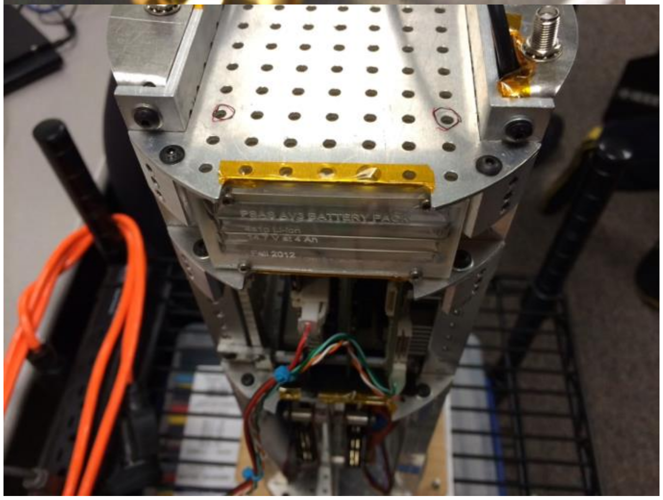


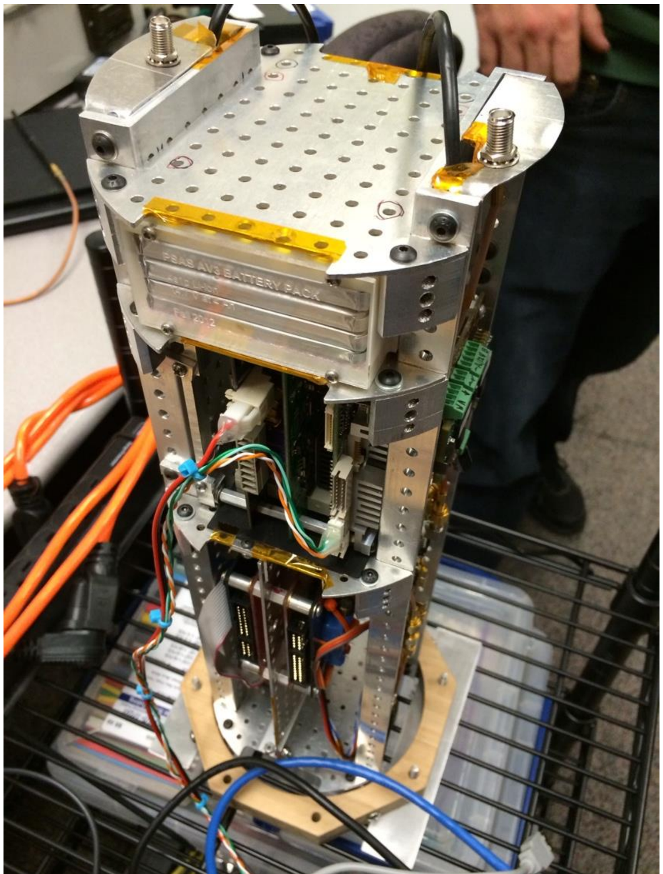
Notes	Variable	Value
k for free free ends like a rocket is 1.5?	k	1.5
modulus for aluminum is 10e6 psi	E	1.00E+07
length in inches	L	18
Inside diameter	Di	6
Outside diameter	Do	6.125
second moment of area in in^4. Pi*(do^4-di^4)/64	I	5.5
Critical force: F= pi^2*E*I/(K*L)^2	F	739354.7
Expected load in pounds		500
Safety factor		1478.709

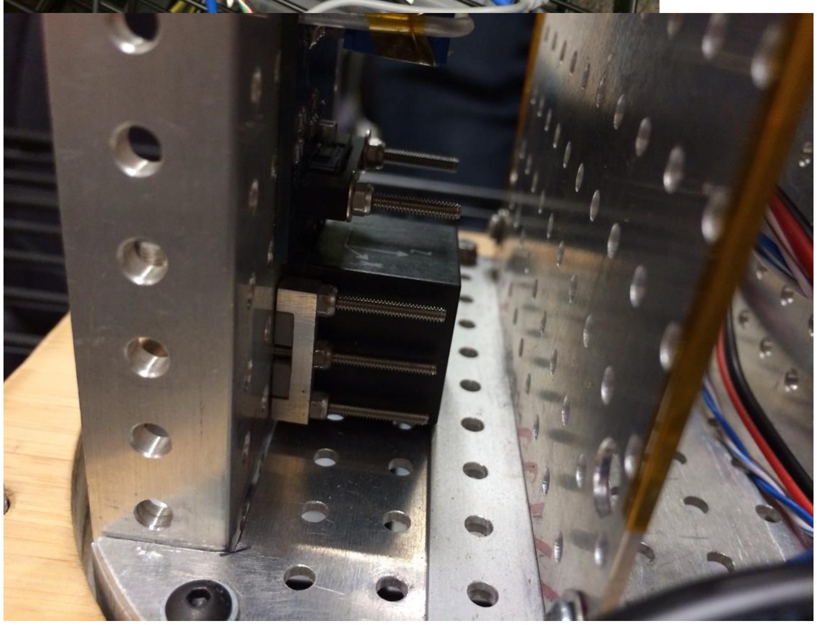
I wanted to do the rough calculation by hand to see if the solidworks buckling calculation was of the right order of magnitude. According to this rough calculation it seems as though it was. This is important because I don't think we can do theoretical calculations by hand when we get to composites. We might have to use FEA and then try and validate it using the angstrom. So it is important we at least have some faith in our FEA results. Even if we are off by a factor of 5 with FEA we will have a better idea using it, than if we tried just guessed.

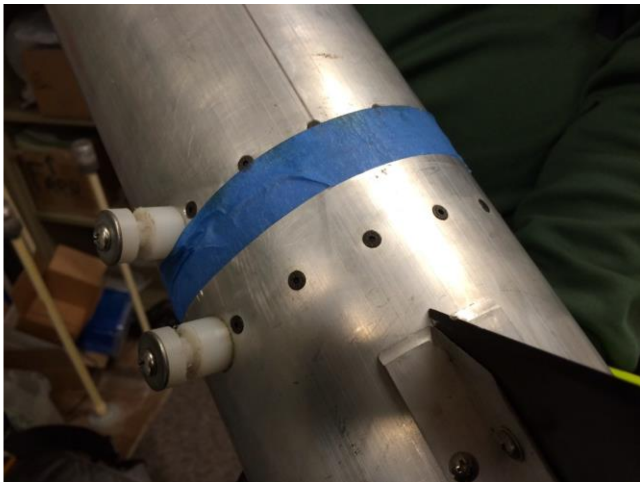
Jack 11/10/13 12:26 pm:
Barett and I took photos of the current rocket system to use as reference. I pasted them below.

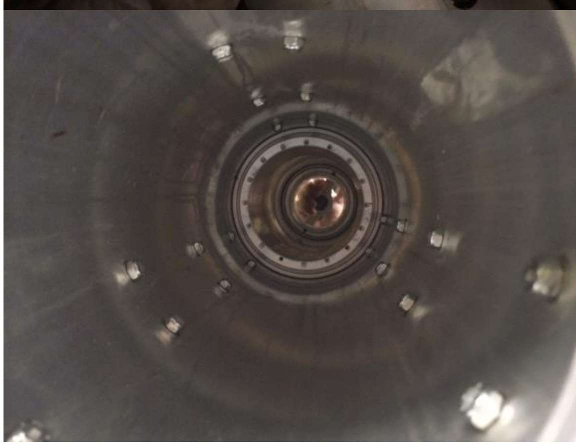


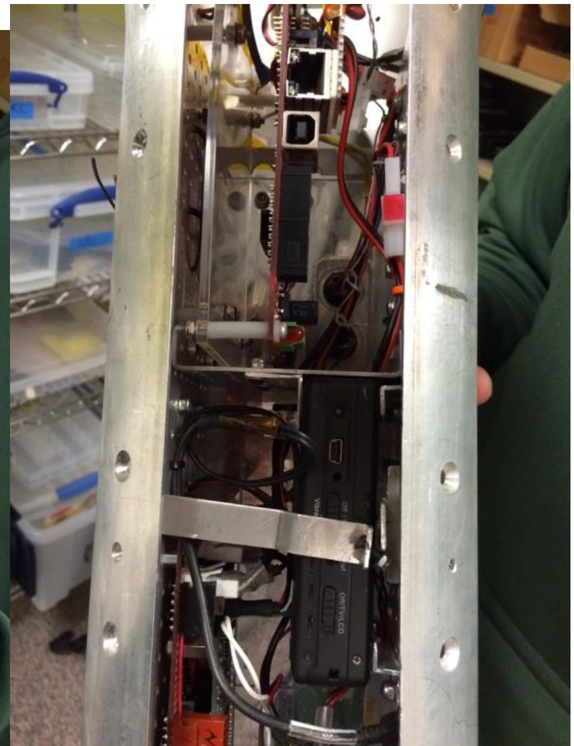


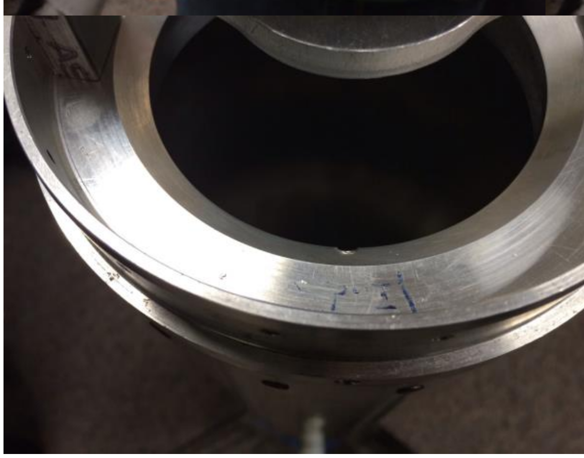
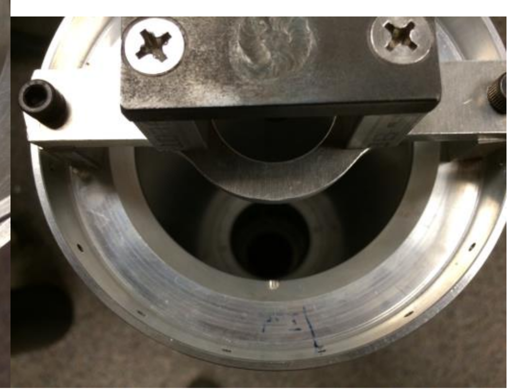


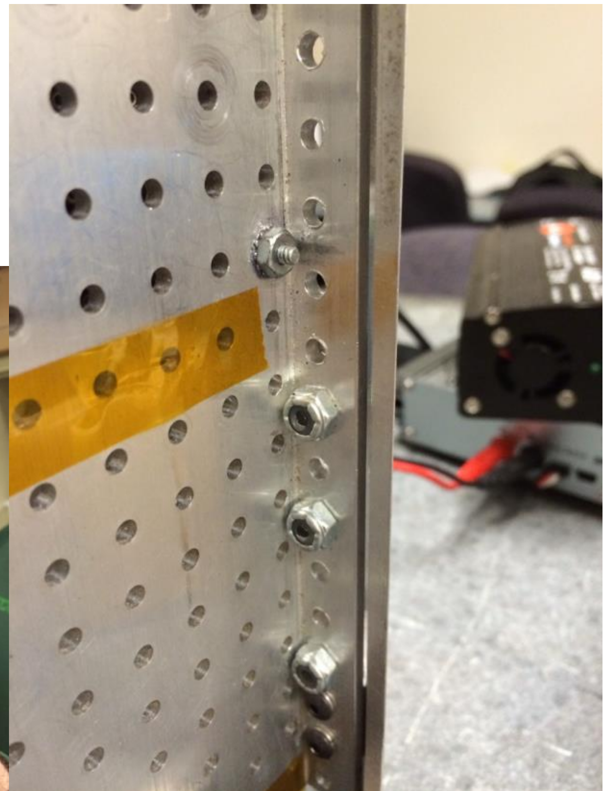


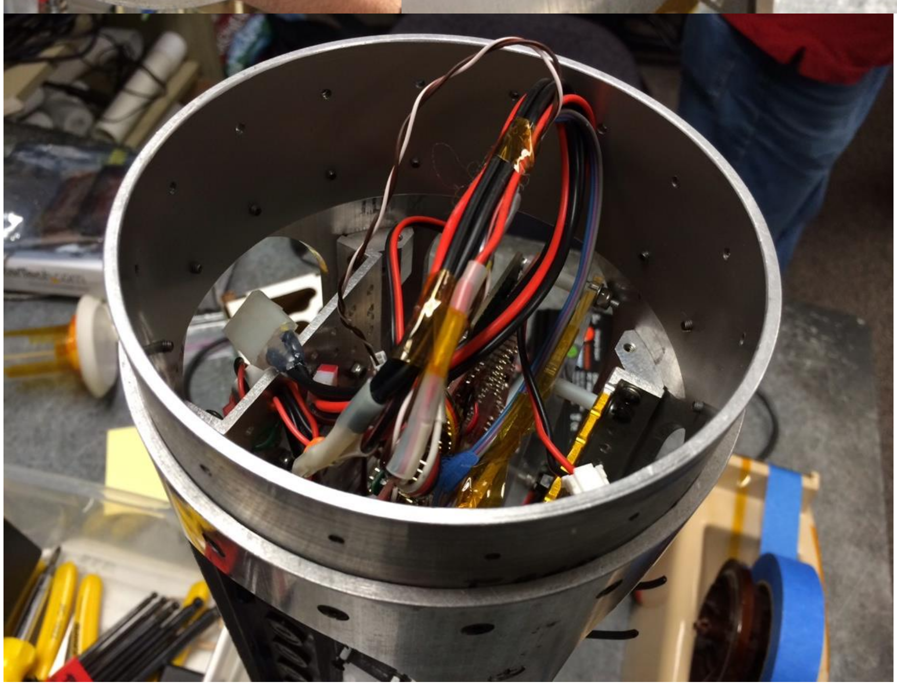


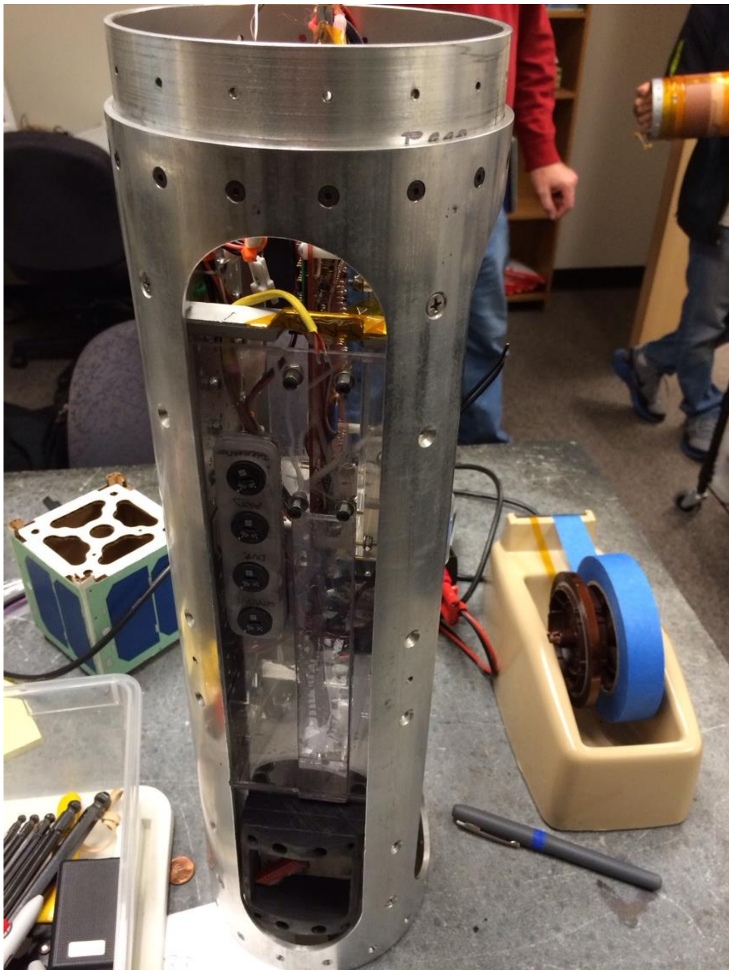
IEEE






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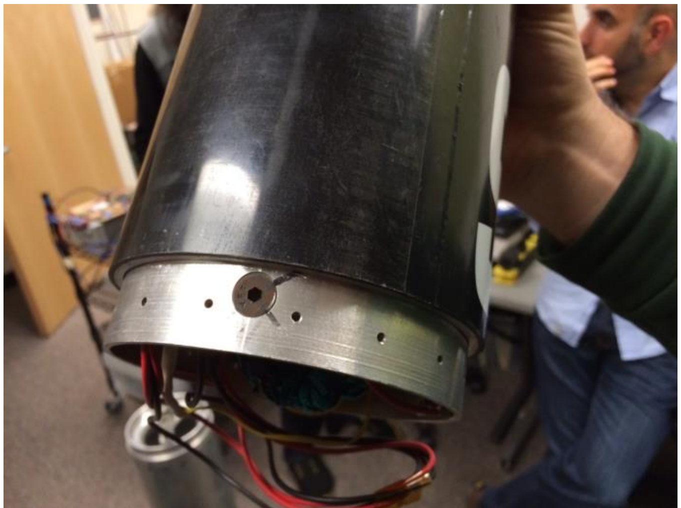
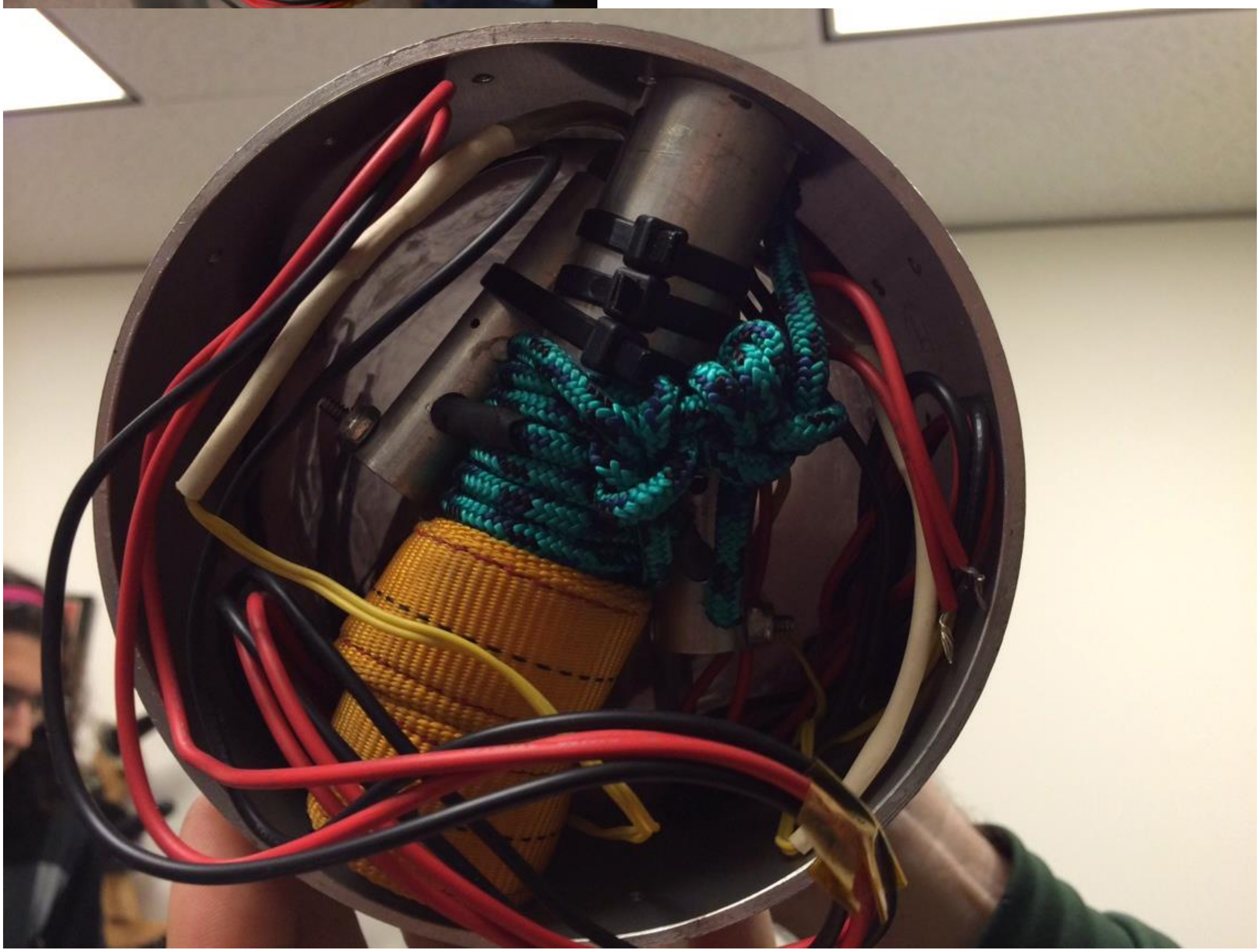




Jack 11/8/13 12:30 pm:
I think it would be really cool to give the rocket team something like a textbook, that could be built in with the instruction manual. Since we have to do so much research and work, I think it is highly worthwhile to have it in mind

to put it all together at the end. This occurred to me because I went to Powell's technical and was taking photos of all the important info from a composites book I found, and I realized we might as well make our own version of a composites book with the information necessary to explain why and how we did what we did. I typed up the notes below. We can discuss whether we would like to do this idea at the tuesday meeting.

Aramid (Kevlar) Fiber

DuPont's aramid product is called kevlar. A high modulus version called kevlar 49 is widely used for composites. Kevlar 149 has higher stiffness but less strength, and Kevlar 29 is not very stiff but is used in body armor.The compression strength of a Kevlar laminate, however, is limited by the apparent inability of any resin matrix to wet the fine fibrils that make up the fiber bundle; the outside of the bundle gets surrounded by the resin and attached to it, but individual fibrils do not. As a result, when a laminate is loaded in compression, the individual fibrils buckle when the stress exceeds about one fifth of what it would take in tension. Thus, the properties of the laminate become dominated by the characteristics of the resin matrix, and a Kevlar laminate's strength in compression is limited to relatively low values.

On the other hand, the gradual buckling of the fibers acting under the restraint of the matrix means that an aramid laminate does not fail in a brittle manner like those made from other structural fibers, but "yields" much like metals. In the process of failing in this way, a substantial amount of energy gets absorbed, which makes it attractive to manufacturers of aircraft and race cars. This property together with its all around toughness (which is why kevlar is very difficult to cut cleanly) also makes it very popular for lightweight canoes and kayaks.

Kevlar can be used by itself or in combination with other fibers. Either as one or more separate plies, or woven together into a hybrid fabric. Combined in these ways with CF, it is widely applied in race car construction as a hedge against the brittleness of carbon. You won't see much crumpled carbon fiber in crashes- it just explodes into dust when it is grossly overloaded in this way.

Another significant feature of kevlar is its light weight. An aramid based laminate will typically wind up about 20% lighter than a part of the same thickness using glass or, for that matter, carbon. Used as a direct substitute for glass reinforcement in lightly stressed body panels, kevlar cloth yields a part that is about ⅕ lighter yet stronger than the part it replaces. Kevlar deteriorates slowly when exposed to ultraviolet light, so some sort of paint or other covering is needed to exclude UV from a kevlar laminate. This hardly matters in practice because Kevlar is invariably combined with epoxy resin, which itself needs protection from UV, no matter what the reinforcement.

Composites made from Kevlar 49 compare unfavorably to carbon fiber composites in terms of stiffness, both on a per volume and a per weight basis. On a same weight basis, a Kevlar 49 laminate will give one half to one quarter the stiffness of one made from carbon.

Fabrics

There are tons of different kinds of fabrics. Unidirectional fabric has most of the fibers running one way, with just a light crossweave at wide intervals to hold the whole thing together. This means all of its strength is in one direction. Others have an equal number of yarns running in both the lengthwise (called the warp), and the crosswise direction (the fill), producing a balanced, bi-directional fabric with equal strength properties in both the lengthwise and crosswise directions. Of course strength and stiffness are degraded heavily when you rotate the carbon between 0 and 90 degrees.

Weaves

For any basic type of weave, the strength and stiffness of the finished product depends on the volume fraction of fiber. Tight weaves give the best strength and stiffness values, but are more difficult to wet out; open weaves are easier to saturate, but yield a laminate which is less strong because of the greater proportion of weak plastic in relation to the amount of strong reinforcement.

Satin Weave

Crimping of the yarns is reduced if each warp yarn crosses over more than one fill yarn before crossing under one. Such patterns are generally termed satin weaves, and are further identified by the number of successive fill threads that are skipped over; thus there are five-harness and seven-harness satins etc. Because of this more advantageous geometry, laminates using satin weave fabrics generally show slightly superior strengths than those made from square weave materials, especially when loaded in compression. Because the yarns in a satin weave can skew more easily than in a square weave, they have superior drapeability, it is easier to get them to conform to tight curves, especially ones with complex changes in radius. Also, satins yield a smoother surface finish than a square weave of the same height. Taken together, these advantages often justify the slightly higher cost of satin weave fabrics.

Polyester

Although other resin systems are starting to make inroads, especially for high performance applications, the overwhelming majority of FRP work (>90%) is based on polyester. Epoxies usually produce stronger laminates than polyester. the surface of kevlar just doesn't seem to connect well with polyester.

Beyond the fact that they are cheaper than epoxies by half or more, polyesters remain predominant for the very good reason that they are easy to work with. First, they are low in viscosity, which means it is easier to pour pump mix etc. The cure rate of polyester can be adjusted over a wide range varying the amount of catalyst added, which is absolutely not the case with epoxy. Finally, polyester is arguably less hazardous to work with than epoxy, though it might be better to say that the hazard is different.

Polyester has several drawbacks, however. It is generally inferior in strength to laminates done with epoxy…

Styrene-Suppressed Resins

If you have read or heard anything about FRP work, you will probably have encounter a distinction made between laminating resin and surfacing resin. A feature of conventional polyester blends is that their cure is inhibited by exposure to oxygen in the atmosphere. What that means is that while the bulk of the resin will cure soid, a very thin layer on the top surface will remain tacky. This helps subsequent layers to bond to one another, so this laminating resin is used wherever additional plies are to be added.

Epoxy

Laminates using epoxy generally have greater strength and better chemical resistance than those using polyester, especially at higher temperatures. Epoxy also shrinks less than polyester (40 to 50% less) depending on the curing agent used. As well, some fibers like kevlar and carbon are incompatible with polyester. On the other hand, epoxies are distinctly trickier to handle than polyester, introduce different health risks, and both they and their curing agents are significantly more expensive.

Epoxy resins used in composite fabrication are more viscous and sticky than polyesters. This makes it more difficult both to ensure complete mixing of the resin and hardener, and to wet out the reinforcement, adding to labor and increasing the risk of areas of incompletely saturated resin reinforcement. It is worth emphasizing here that the neccessity for complete and thorough mixing of epoxies. To ensure that all of the resin is mixed with all of the hardener, suppliers urge that you change containers during the mixing. Here's how: dispense resin into A, and mix thoroughly, scraping the side of the container to deal with either component that may be sticking to the sides. Then pour this mixture into cup B, and continue to mix. Any unmixed resin or hardener remaining in cup A will have been left behind. If you are prportioning the two components by weight, rather than by using a proportioning pump, then you may even have to resort to a three cup technique. This sounds a bit obsessive, but there is little doubt that most problems with epoxy result either from an incorrect resin to hardener ratio, or from inadequate mixing.

Thinners are available to reduce the viscosity of epoxy resins. Although these are reactive with dilutents, they cross link with the resin in much the same way that styrene does with polyester, they should be employed with caution. Dilutents may reduce the strength and chemical resistance of the finished product, and certainly will if added in sufficient quantity to make the resin as easily worked as polyester. Some thinners are particularly toxic.

Mixing is the second problem with epoxies. Epoxies must be mixed with the resin in a specific proportion, and some require very accurate measurement. If off by more than a smidgen the result can be anything from an incomplete cure, to no cure at all. What's more, this intolerance of variability in the hardener to resin ratio makes it so the cure rate of epoxy systems cannot be adjusted by varying the amount of hardener. If you want to speed up the cure, you have to pick a different curing agent, or increase the temperature of mold/workspace.

The very strongest laminate produced with epoxy systems have to have an elevated curing temperature usually from 100F to 350F.

Gel Coat

To produce parts with a smooth shiny surface comparable to painted metal, something needs to be done about the appearance of raw fiberglass mat, or the fabric weave of cloth. For such parts, a coating of pure plastic resin containing no class or other fiber is usually applied to the mold surface and permitted to cure before any glass is applied. Conventional gel coat is nothing more than polyester resin, with a few added ingredients. To prevent runs and sags when the gel coat is applied to a vertical surface, a thixotropic agent, usually silica gel, is blended in, to add body and so resist the flowing under the effect of gravity.

MEKP

MEKP is a clear colorless liquid. It is explosively unstable in its pure form and so is supplied as a diluted solution in an inert liquid buffer. While it is not itself highly flammable, it is a powerful oxidizer which may cause some readily flammable substances- like paper, rags, or sawdust- to ignite spontaneously if it comes in contact with them. It is also quite corrosive, and prolonged contact will cause skin burns. Splashed in the eyes can cause permanent damage. The vapors may cause headaches and intoxication, and corrosive damage to the nose, throat and lungs.

PVA

With a new mold, you first wax and thoroughly buff several times, at least three. (You don't need that much wax, but you might have missed a few spots the first time. Terry-cloth toweling seems to work well for the waxing and buffing. Next, you apply a coat of polyvinyl alcohol, which dries to form a thin barrier film that provides a second line of defence against the nightmare of a part firmly stuck in the mold. PVA is not only unnecessary in a well made, aged mold, it is undesirable since the PVA leaves a slightly pebbly, orange peel texture on the surface of the finished part that has to be polished out.

It is possible to apply without a spray gun (a small piece of old tshirt seems to work better as an applicator than a brush), but spraying is definitely preferable. The PVA shoudl be sprayed in stages, starting with a very light misting, and finishing with several heavier coats. Obtaining a uniform and, above all, a continuous film of PVA is much easier if the mold has a color that contrasts well with the PVA, which is green.

Elevated Temperature Curing Epoxies

For applications where minimum weight and maximum strength are important, higher performance resins may be selected, and that often means epoxy resin systems designed to cure at higher than room temperatures. For a true high temperature cure (HTC), the temperatures required with some resin systems are so high (up to 400F) and the demand for close control of the heating so strict that homemade arrangements are inadequate. The only solution is a purpose-built oven, fitted with precision timers and automatic temperature controls. Large and expensive industrial ovens are available for this purpose.

Heating Methods

Never forget that an oven is simply an insulated box with a heat source inside; in some cases it may be quite practical to make your own. It is not prohibitively expensive to construct a frame for a simple shed-like structure out of steel (not wood), with sheetrock walls and ceiling, heavily insulated on the back side with rock wool or fiberglass batts (forget about foam insulation; apart from increased fire risk, insulating foams may soften at the temperatures involved).

Cautions- while undiluted epoxies do not include flammable, low boiling point solvents, like the styrene in polyester and vinylester resins, these materials are nevertheless flammable, and extreme care must be taken to avoid fire. That pretty much limits the possible heat sources to electricity, steam and hot water, through the use of water is obviously limited to temperatures below its boiling point of 212F.

Heating the mold is another alternative to heating the air. Possible to use electric resistance heaters.

Expansion

Another factor to bear in mind whenever exposing a laminate and mold assembly to elevated temperatures is the issue of compatibility of the mold and laminate materials. For one thing, their comparative thermal expansion has to be considered, especially if the dimensions of the part are critical. For example, some carbon fibers exhibit negative thermal expansion- they get smaller as they heat up. Other forms of carbon fiber do have a positive thermal expansion coefficient, but they grow much less with heat than most other FRP materials. For this reason, the molds for carbon fiber reinforced race car and aircraft components using ETC resin systems are themselves usually made from the same CF as the part, to ensure that the mold and laminate shrink and grow in sync.

Fabric impregnator

There is also a method of working that involves something like a homemade prepreg, using a machine called a fabric impregnator. This apparatus mechanically draws woven or unidirectional goods through a bath of resin and then passes it through a set of pinch rollers, yielding more uniform resin distribution and a higher reinforcement to resin ratio than is usually possible with hand work. At the same time, labor is reduced.Virtually any liquid resin system can be used in this process., for unless the material is going to be used almost immediately it is obviously an advantage if the resin either cures very slowly at room temperature or can have its cure postponed in some way. Epoxy based systems which can be arrested at the b-stage are well suited to this technique, and this, in fact, is the way commercial prepregs are made. There is also the possibility of using UV curing polyester or vinylester resins. If the dipping were done under a "safe" light, the impregnated fabric could be rewound onto a roll, using a sheet of polythylene to prevent layers from sticking together, and would store indefinitely until exposed to UV light, such as by being taken outdoors. The cost of fabric impregnating equipment generally limits its use to those who either need large quantities of material or are working with weight and strength critical goods, or both. Prepregs can also be produced by a filament winder.

Male or Female?

Assuming conventional hand layup, the surface of the finished product that contacts the mold will have a glossy surface, while the back face will be rough, so for goods where visual appearance is importatnt, the surface that is exposed determines which way it must be molded. Thus, a bathtub would be formed over a male mold, while a canoe would be made in a female mold.

The Expendable or Sacrificial Mold

One is a technique for making tanks of all sorts by carving a chunk of foam to the desired shape, wrapping it entirely with resin saturated reinforcement, and then dissolving out the foam plug with a suitable solvent once the shell has cured. This is undeniably an intriguing technique, but there are a few intrinsic limitations: the foam must be unaffected by the resin system; the resin must be impervious to the solvent used to purge the core; the thickness of the wrapping may need to be taken into account when shaping the core; and the outer surfaces of the finished tank necessarily has the texture of the fabric used.

Fatigue

An advantage of composite materials sometimes touted in print is that they do not fatigue. This is simply not so, though it is true to say that the fatigue resistance of composites is generally superior to that of metals. Unidirectional laminates using kevlar retain about ¾ of their static strength after ten million cycles of loading in tension (though they do less well when the loading reverses between compression and tension); similar carbon fiber laminates keep perhaps two thirds of their original strength; glass fiber composites are down to about half by that point.

Sandwich Structures

Sandwich structures present particular problems around bolted connections, and anyplace else where loads are highly localized. One technique for dealing with this is to remove the core in the area surrounding the attachment, and bring the two skins together, locally reinforced with additional layers of laminate. It is common for at least some of this extra material to be a thin sheet of aluminum, to take advantage of its isotropic, ductile nature.

Surface Bonding

Provided the surface is properly prepared, aluminum will bond securely to an epoxy laminate. The key phrase is properly prepared. Understand first that aluminum oxidizes- exposed to air, the bare surface of a piece of aluminum almost instantly reacts with the oxygen in the atmosphere to form aluminum oxide. If you attempt to stick anything to an untreated piece of aluminum, what you wind up doing is gluing to the oxide, not the aluminum itself. In principle, that ought not to be a problem, provided, first, that the oxide is well and truly attached to the metal beneath and, second, that the adhesive is well and truly bonded to the oxide. There are potential problems on both scores, as the aerospace industry discovered when they began gluing airplanes together.

To cut a very long story short, the procedures that Boeing and the other heavy hitters involve a succession of steps to de-grease, acid etch, and anodize with phosphoric acid, with rinsing in deionized water after each step.

How FRP Composites Carry Loads

Many people believe that the strength of an frp laminate is unnecessarily reduced whenever any of the fibers in it are broken. This is definitely not so. It is equally untrue that a fiber has to extend from one end of a load carrying part to the other in order to contribute to the strength of the laminate.

First realize that a fiber, by definition, is something that is many times longer than its diameter. Now, in a properly constructed laminate, all of the surface of each fiber is firmly attached to the resin that surrounds it, and the area of that contact is many times greater than the cross sectional area of the fiber. Now imagine a small zone within the laminate where two fibers, lay side by side, fairly close to each other, but only partly overlapped in strength, so one is closer to one end of the laminate, overall, and the other closer to the opposite end.

If we anchor one end of the laminate and pull on the other, there will be a tendency for the two fibers to slide past each other. Each, however, is stuck to the surrounding resin, so the interface between fiber and resin is stressed in shear- the fiber is trying to slide through the resin, and the "hands off" the load to the next adjacent fiber. Provided each fiber is leong enough in relation to its diameter, then even though the shear strength of the resin is a mere fraction of the tensile strength of the fiber, there will be so much more resin carrying the shear load than there is fiber carrying the tension load that the the fiber will break before the plastic does.

There is some minimum length of fiber for which this will be true, and that is why a laminate made with say, short chopped strand reinforcement will not be as strong as one using longer fibers. On the other hand, if the minimum length criterion is met, longer fibers will not make the laminate any stronger. Equally any more resin than is needed to pass the load from one fiber to the next does nothing to increase the strength of the laminate and just adds weight.

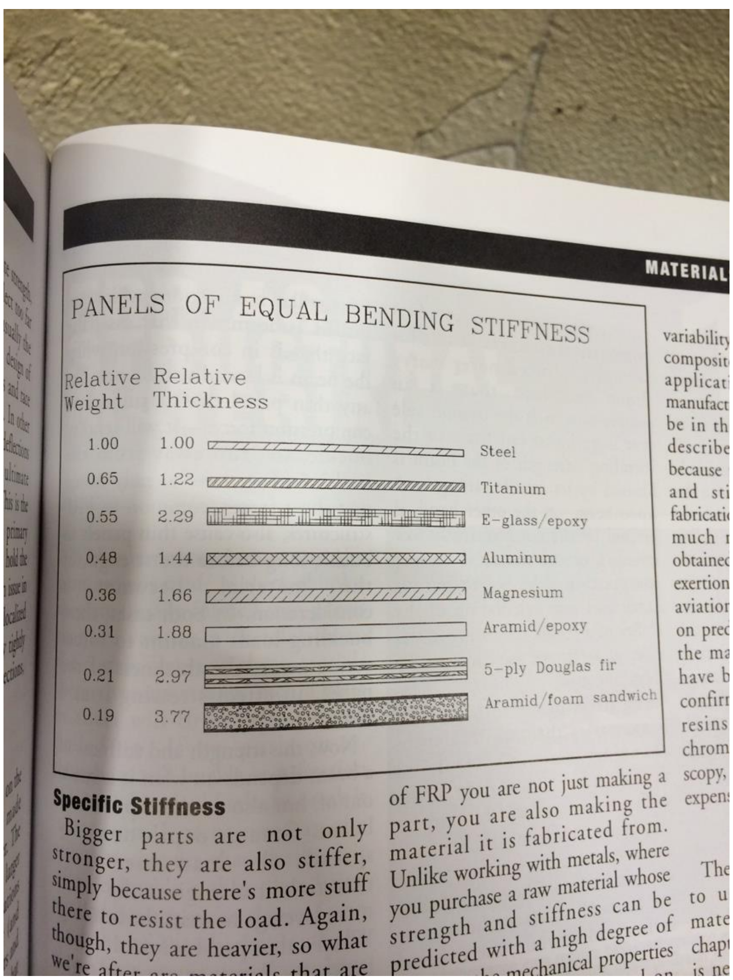
Another way to look at it is on the basis of tensile stresses. In the previous chapter, we saw that any material which is pulled lengthwise will stretch somewhat, or strain, and that amount of this strain depends on just two things- the stress and the elastic modulus. Now when a composite is stress, all of it grows longer- the fibers and the resin have equal strains. The fiber, however is many times stiffer than the resin, so assuming that half the volume of the composite is fiber and half is resin (a representative figure), then the stresses in the two will be in the same ratio as their elastic moduli- about 25 to 1! Clearly, the matrix is lightly stressed, even when the fibers are carrying a very large load, and since the area of contact between the fiber and the plastic extends over the whole surface of the fiber, the matrix has no problem transmitting the load from one fiber to another.

Wet Lay-up

When honeycomb core is used in wet lay-ups, it is common to first produce one skin, then for the core to be set down on the still wet laminate, so the laminating resin serves as the adhesive for this connection. The second skin is more problematic. If a wet lay-up is applied over the core to produce the second skin, there will be a tendency for the resin to drain out of the reinforcement and into the cells. About the only practical alternative is to produce the second skin independently, then to assemble it to the core using a film type adhesive. This obviously demands closer than typical control over the shape and dimensions of both core and skins.

Pre-Preg

When the facings are produced from prepregs, this problem is avoided, and the choice is then between production of the two skins, allowing them to fully cure, followed by assembly to the core using film adhesive, or by letting the resin in the prepreg serve as the glue and completing the assembly before either skin is cured, a technique called co-curing. Notably, the force required to peel the skin away from the core is different for the upper surface than from the under surface. This occurs because the differences in the shape and size of the fillet of resin that forms and the junction between each cell and the skin, in turn cause by the flow of the resin under gravity during the cure.



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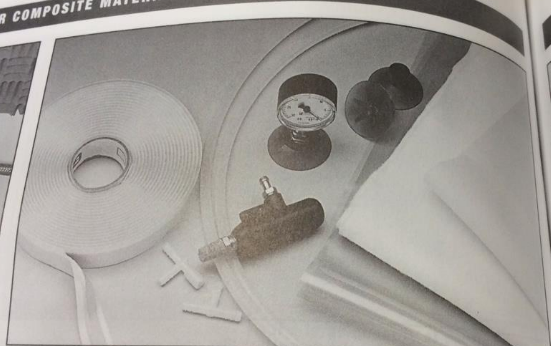
When applying more resin, use a paintbrush, but don't "brush," as shown above. Instead, use a poking or "stippling" motion to coat the mat. Photo by Michael Lutfy.

Thorough and vigorous working of laminate with a ribbed roller is essential to uniform resin distribution and to exclude air and consolidate the laminate. N



Ingenious vacuum pump using shop compressed air and venturi principle (black object in center) is part of the assortment of vacuum bagging supplies available from Gougeon Brothers. Photo courtesy Gougeon Brothers Inc.

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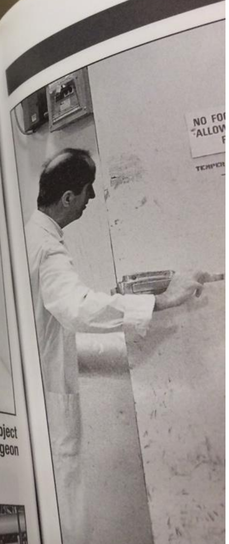
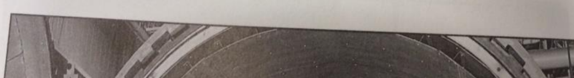
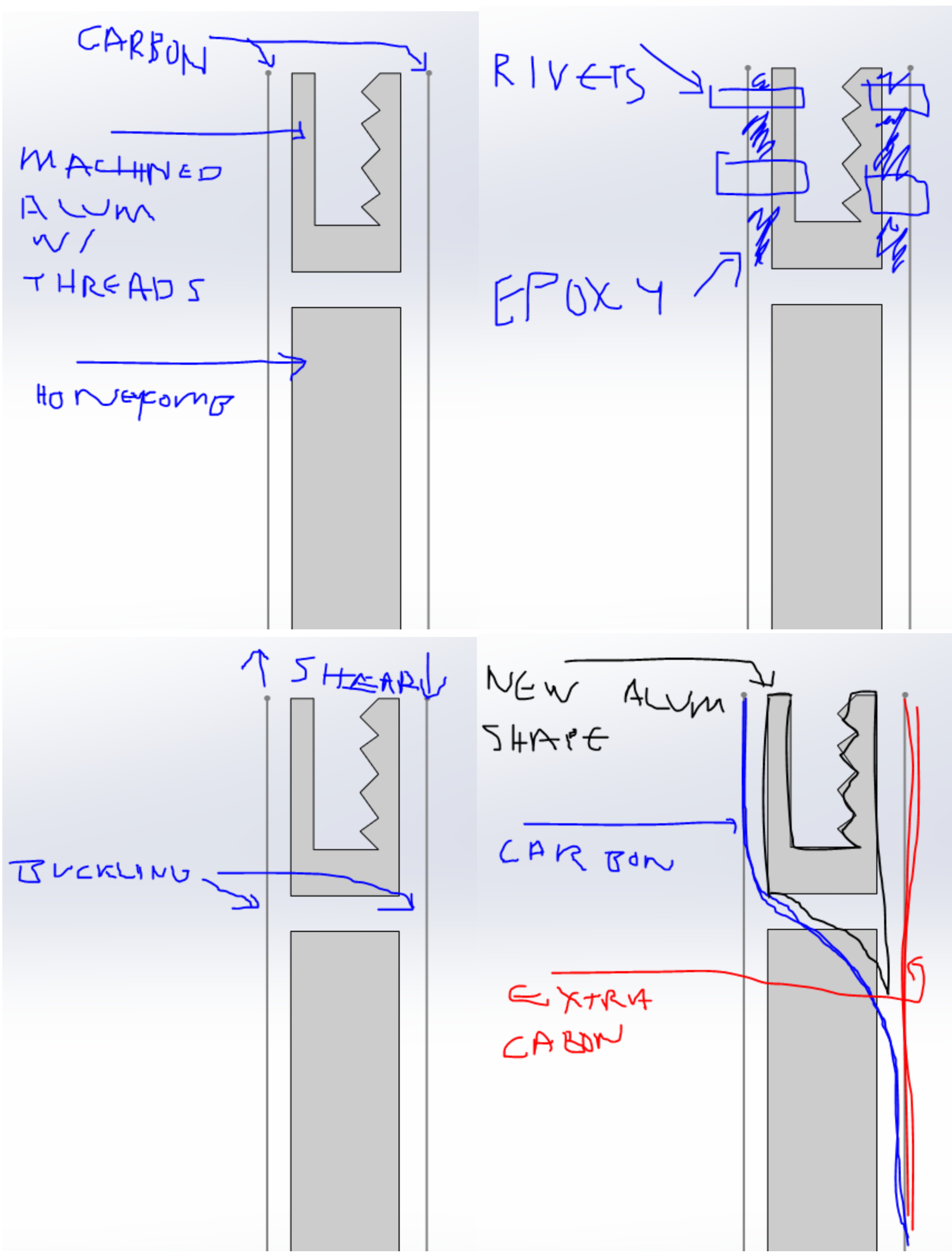




Simple, hand-cranked fabric impregnator from Gougeon Brothers. Photo courtesy Gougeon Brothers Inc.

stem can be used in this process, but unless the material is going to be used almost immediately it is obviously an advantage if the resin either cures very slowly at room temperature or can have its cure postponed in some way. Epoxy-based systems which can be arrested at the B-stage are well suited to this technique, and this is, in fact, the way commercial pre-pregs are made. There is also the possibility of using ultra-violet curing polyester or vinylester resins. If the dipping were done under a "safe" light, the impregnated fabric could be re-wound onto a roll, using a sheet of polyethylene to prevent layers from sticking together, and would store indefinitely until exposed to UV light, such as by being taken outdoors. The cost of fabric impregnating equipment generally limits its use to those who either need large quantities of material or who are working with weight- and strength-critical goods, or both. Pre-pregs can also be produced by filament winding, as mentioned in the next chapter.

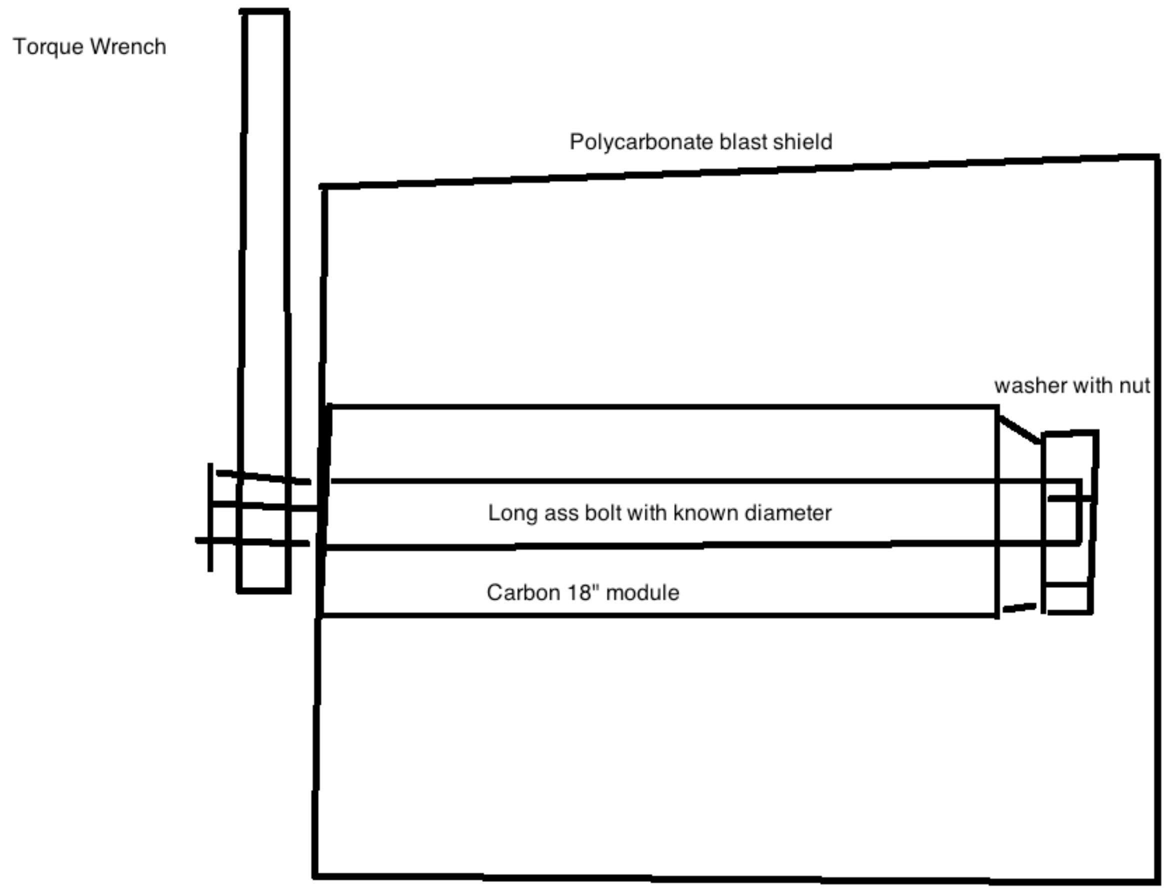
Jack 11/10/13 12:26 pm:
I had an idea for what the module ends could look like. I drew it below as a cross section with labels. I put threads but that is just a representation of some sort of creative solution for attaching modules to each other. We talked about the idea of some sort of quarter turn or quick disconnecting joint would be super cool. We could install whatever idea that is in that aluminum piece. We could lay it up with a placeholder to make sure that the gap is just right and then afterwards bond and rivet in our aluminum piece as seen in the second photo. This would be sensitive to shear and buckling shown in 3rd photo. We could have carbon from one side go to the other side so that the two wouldn't be able to shear from each other, and we could use extra reinforcement and tapering to reduce buckling as seen in the last drawing.



Jack 11/10/13 5:00 pm:
I was thinking we could pretty easily make our own buckling test rig if we decide we don't want to deal with the

school. Just a big bolt down the center of the module, use a torque wrench to clamp it and measure the force on it, and then put it in a polycarbonate blast shield so noone gets hurt. We could use my gopro to get high quality video of the destruction if we feel it's necessary.

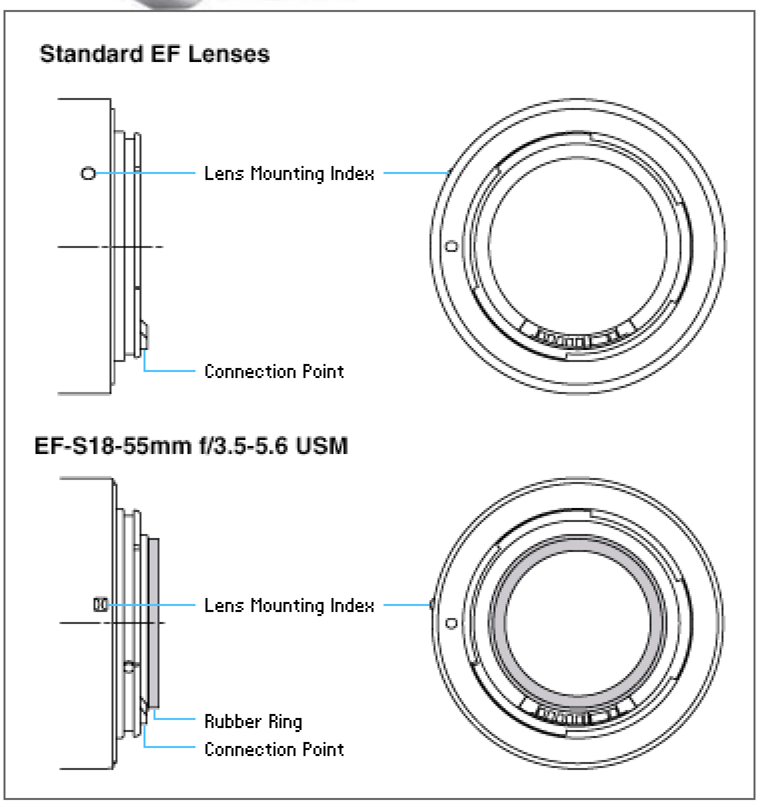
We might also want to get a vacuum with a HEPA filter for after the carbon is made. I was thinking about where we could do all this composites work. We could use HPV but the school might not love that idea.



Tung 11/11/2013 12am: Ideas for the rocket's parts connection
Camera mounts:

http://nikonrumors.com/2011/01/04/nikon-files-a-patent-for-optical-communication-between-lens-and-body.aspx/

The lens mount for DSLR camera is a good model for connecting our rocket's parts. It has the electric connection between the lens and camera body which is a good idea for electric wires through the rocket


Standard EF Lenses
Lens Mounting Index
Connection Point
EF-S18-55mm f/3.5-5.6 USM
Lens Mounting Index
Rubber Ring
Connection Point

Pressure connection

Jack, Rob, Barett, Sam 11/12/13 11:00 am:

How do we move forward?
Figure out presentation for yi
Research and documentation, want to do final textbook keeping a list of where we got the info
Looking into other sponsors
Composite tooling research

Start making test parts

Jack 11/13/13 2:30 pm:
Fiber volume fraction
The volume of fiber in a cured composite. The fiber volume of a composite material may be determined by chemical matrix digestion, in which the matrix is dissolved and the fibers weighed and calculated from substituent weights and densities or a photomicrographic technique may be used in which the number of fibers in a given area of a polished cross section is counted and the volume fraction determined as the area fraction of each constituent. Typical values for boron/epoxy and for graphite/epoxy, based upon the fiber type, is 55-67% fiber.

Jack 11/17/13 5:30 pm:

	aluminum	steel	
D	6	6	
alpha	12.3	6	
Troom	40	40	
Toven peak	400	400	
delta T	360	360	
DeltaD	0.026568	0.01296	0.013608
NewD	6.026568	6.01296	

Immersing metal parts in a cool medium is used consistently in shrink-fit assemblies. To calculate the contraction in these metal parts, one needs to know the thermal expansion coefficient of the metal, the original dimensions of the part, and the temperature change. For example, if one immerses a solid cylinder that is at room temperature in cool medium such as dry ice/alcohol or liquid nitrogen, the reduction in the outer diameter of the cylinder can be calculated as

$\Delta D = D\alpha(T_{\text{fluid}} - T_{\text{room}})$, (1)

where:
D = outer diameter of the cylinder,
α = coefficient of thermal expansion coefficient at room temperature,
T_{fluid} = temperature of cool medium
T_{room} = room temperature

However, the coefficient of thermal expansion of steel varies considerably with temperature, as shown in this table:

temperature (°F)	instantaneous thermal expansion (μin / in / °F)
80	6.47
0	6.00
−80	5.43
−160	4.72
−240	3.83
−340	2.45

I made a calculator for cylinder growth for future reference and use.
Under the assumption of a 40 degree room to a 400 degree max curing temperature:
A 6” aluminum tube will grow 27 thousandths
A 6” steel tube will grow 13 thousandths approximately, but is nonlinear with temperature.

Rob 11/18/13 8:00 am:
A few notes while watching the tour of SpaceX:

- Testing
  - Thermal cycle testing
  - Vibration testing
- Terms
  - Engineering Pathfinder
  - Flight Fidelity Article
- Components
  - Propulsion Section Skirt

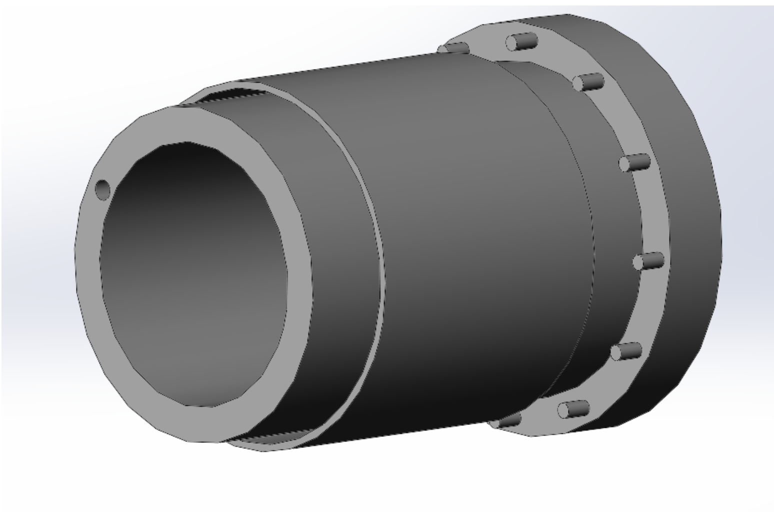
Jack, Sam, Tung 11/18/13 8:30 pm:

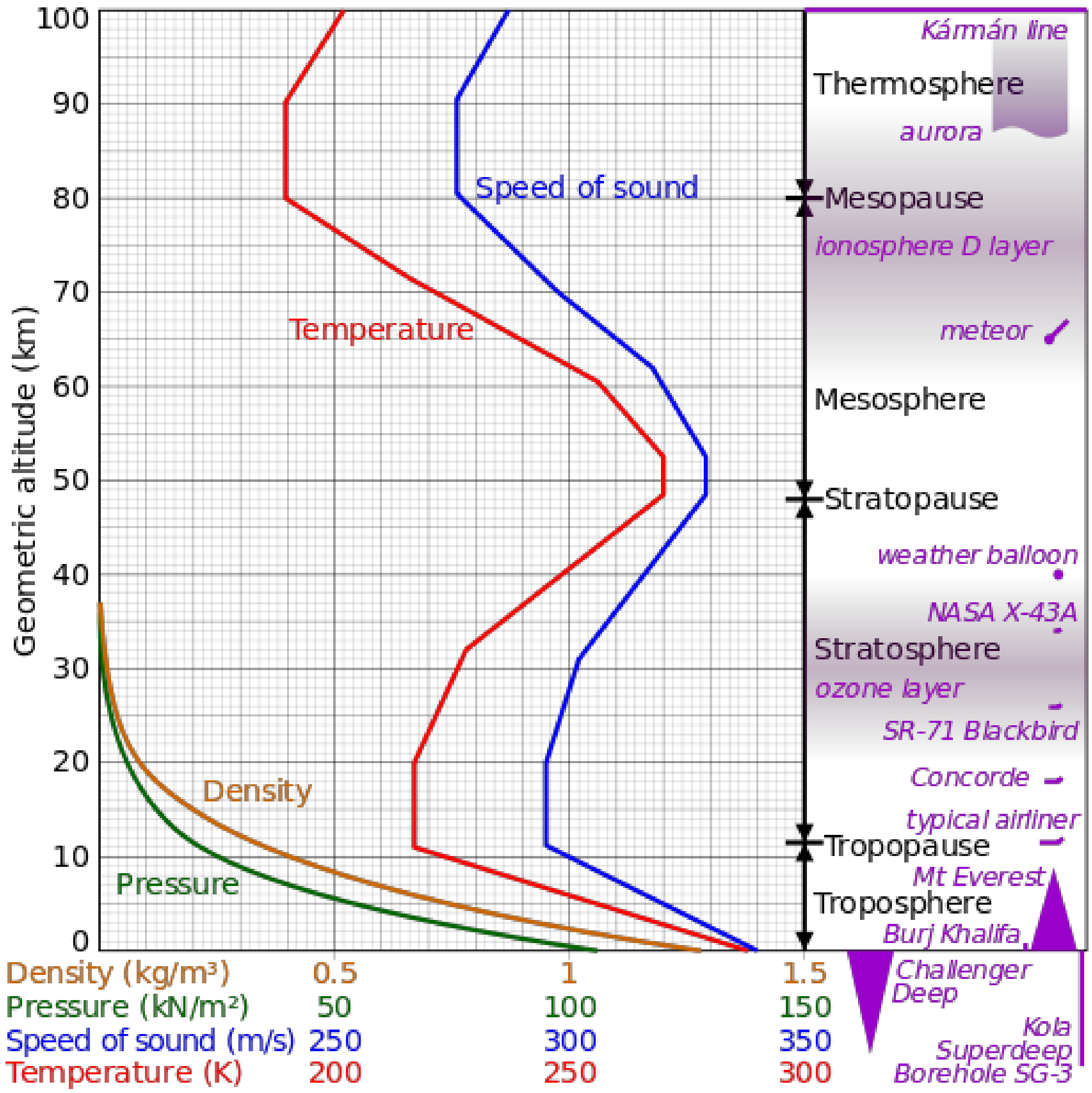
http://www.briskheat.com/p-355-sr-silicone-rubber-composite-curing-heating-blankets.aspx

http://www.briskheat.com/p-423-new-silicone-rubber-heating-blankets-with-controller-with-psa.aspx

These are heating blankets used to cure epoxy. The first you need a controller with, the second has a white knob on it for temperature control. both cost about $280.00 and will go up to 400F

http://www.discountsteel.com/items/Bare_Steel_Pipe.cfm?item_id=198&size_no=25
steel tubing is super cheap. A male mold has a lot of potential. The propulsion skirt and the nose might not be able to be done like this





Hexcel has an incredible website full of info. It's like paint by number. Everything from equations to datasheets, to technology manuals. The honeycomb sandwich design tech manual is particularly good (below). Hexcel could be a fantastic sponsor for us.

http://www.hexcel.com/Resources/DataSheets/Brochure-Data-Sheets/Honeycomb_Sandwich_Design_Technology.pdf

http://www.hexcel.com/resources/datasheets

http://www.hexcel.com/resources/technology-manuals

http://www.hexcel.com/Resources/DataSheets/Brochure-Data-Sheets/Prepreg_Technology.pdf (added by Rob)

Epoxy Selection
https://asp-cn.secure-zone.net/v2/index.jsp?id=19/92/527&lng=en (added by Rob)

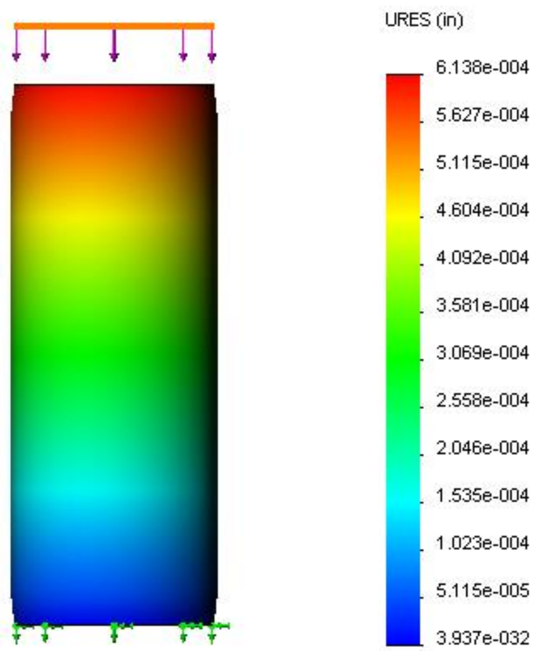
http://www.hexcel.com/Resources/DataSheets/Brochure-Data-Sheets/Honeycomb_Sandwich_Design_Technology.pdf

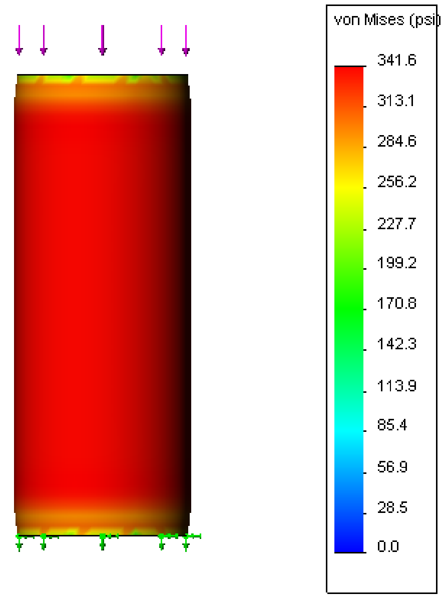
This is where I am getting the numbers for the solidworks finite element analysis

Rob 11/20/13 8:20 pm:

Here is a link to a good composite structure reference site (actually it is a set of pdf copies of our bible “Composite Airframe Structures”).
http://www.aerostudents.com/master/advancedDesignAndOptimizationOfCompositeStructures.php

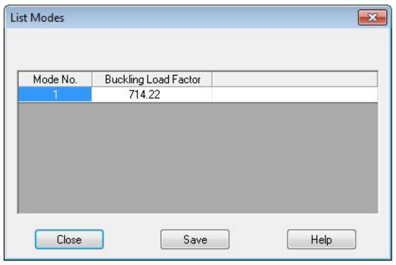
Jack 11/25/13 8:30 pm:
Playing around with simulations on the current airframe module design.
Solidworks analysis with 800 lbf with a .125” Aluminum T-6 6061 6 inch diameter tube. This is their current design, which is not deflecting very much. The buckling simulation gives me nothing but trouble when using surfaces.

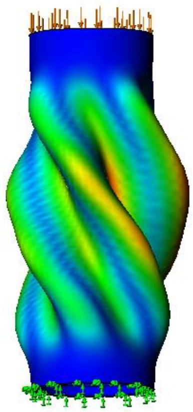




Boundary Conditions	Theoretical Effective Length L_{eff}^T	Engineering Effective Length L_{eff}^E	Buckling Mode Shape
Free-Free	L	$(1.2 \cdot L)$	$\sin \frac{\pi x}{L}$
Hinged-Free	L	$(1.2 \cdot L)$	$\sin \frac{\pi x}{L}$
Hinged-Hinged (Simply-Supported)	L	L	$\sin \frac{\pi x}{L}$
Guided-Free	$2 \cdot L$	$(2.1 \cdot L)$	$\sin \frac{\pi x}{2L}$
Guided-Hinged	$2 \cdot L$	$2 \cdot L$	$\cos \frac{\pi x}{2L}$
Guided-Guided	L	$1.2 \cdot L$	$\cos \frac{\pi x}{L}$
Clamped-Free (Cantilever)	$2 \cdot L$	$2.1 \cdot L$	$1 - \cos \frac{\pi x}{2L}$
Clamped-Hinged	$0.7 \cdot L$	$0.8 \cdot L$	$\sin kx - kL \cos kx + kL\left(1 - \frac{x}{L}\right)$ where $k = 1.4318 \frac{\pi}{L}$
Clamped-Guided	L	$1.2 \cdot L$	$1 - \cos \frac{\pi x}{L}$
Clamped-Clamped	$0.5 \cdot L$	$0.65 \cdot L$	$1 - \cos \frac{2\pi x}{L}$

$$F_{cr} = \frac{EI\pi^2}{L_{\text{eff}}^2}$$





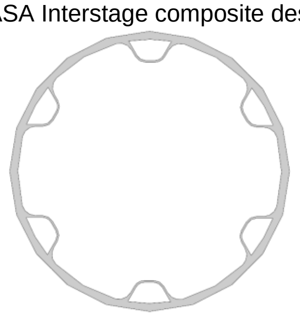
This buckling analysis agrees approximately with hand calculations. This solidworks analysis was using extrusions, and not surfaces. If we want to do composites, we need to use surfaces. Looking at the equation posted above, I suggest we try a hand calculation and breaking some real stuff.

Rob 11/26/13 1:02 pm

Freeman Supplyhttp://www.freemansupply.com/ has a DIY/Hobby Company http://www.miapoxy.com/default.aspx

Rob 11/26/13 5:00 pm

NASA Interstage composite design - http://hypersizer.com/industry/projects/NASA-Ares-V-Interstage.php



*Drew a hat design for future reference

I also added several pdf in the research folder.

NASA search site - http://naca.larc.nasa.gov/search.jsp

NASA Umbilical Design - http://www.nasaspaceflight.com/2012/11/nasa-sls-mobile-launcher-umbilical-plans/

Jack 12/2/13 5:00 pm:
According to solidworks, current rocket design weighs approximately 4.5 pounds per module empty. According to rough calculations because of a carbon fiber bear canister my father has that I am guessing has similar loading magnitude to our rocket. The carbon fiber cylinder, 9 inches in diameter weighs approximately 1.25 oz/linear length inch. So our 18" design would weigh approximately 22 oz or 1.4 pounds per module. This aligns with the rule of thumb that a carbon part could weigh about ⅓ as much as a comparable aluminum one.

rob has 4” pipe usable for mandrels

Talk to mike about access from the 14 to the 17, and the 2 through the 6 (he said it will be open)
Make plan about projects to work on during winter break. ideas include, sponsorship securing, composite table production/design, mold tooling design, Test fixtures and test design, Dynamic and static load determination, overall rocket design, joint tests etc.
Talk to team about how to get access to tools, and realistic tool capabilities

Jack, rob, Tung, Barett, Sam 12/13/1312:00 pm:
Build joints
- Build a few tubes, few flat joints. Need order of magnitude understanding of joints. Wet layup etc okay

Monday first thing need to call companies
- Need to get numbers, need to come up with materials, talk to PSAS about

Need materials, could steal from formula
- Understand constraints and construction flow and difficulties
- decide

Start table design
- What does everyone think should be features on the table?
- Air line built in
- Roll holding
- Mounting points for the male tool
- Wheels
- Cubbies for all tools. Not tool board, but more like extra working space
- Container holders for epoxy to make it not tip over, brush holder. Don't want epoxy to drip everywhere
- On board outlets and air facilities.
- Built in carbon storage
- Only a single width entrance
- Built in cutting accurate cutting

Documentation of everything specifically models
- Shared school drive and VPN Sam set up

Teach everybody all the skills
- Lowest skilled person drives the compute
- Everyone wants to learn to mastercam etc

Testing machine
- Making press in shop work
- Need new pressure readout, high resolution in the 1000 pounds
- Need load cell to validate pressure gauge

Talk to Eric from PSAS
- about specifications, tools access to, how do we spend their money, timelines, how much total money realistic, what they expect from us at the meetings.
- Slowly get in by asking technical questions, potentially ask for engineering samples
- Uniforms, logo
- Outline exactly what we need to design, and get deeper understanding. He needs to figure out electrical

10 to 2 Saturday
Monday Tuesday more substantial day. Full day. Go to GFR Monday?

Composites Design Textbook

Abstract:

The purpose of this manual is to provide a space for documentation of knowledge and research necessary to the Composite Airframe Capstone Team. It will serve as a running manual for sharing information between team members, and as a textbook style resource for future airframe designers on PSAS to use for future iterations. Information for this book was taken from various texts, videos and conversations with industry professionals. It is supposed to be a concentration of data from available sources.

Bibliography:

Fiberglass and Other Composite Materials- A guide to high performance non metallic materials for race cars, street rods, body shops, boats and aircraft. HP books. Forbes Aird

Introduction to Composite Materials Design. Ever J Barbero, department of mechanical and aerospace engineering, West Virginia University, USA. Taylor and Francis group

Taylor, Travis. *Introduction to Rocket Science and Engineering*. CRC Press 2009. Boca Raton, FL.

Composite Airframe Structures, Michael Chun-Yung Niu. 978-9627128113. Hong Kong Conmilit Press Ltd.

Aramid (Kevlar) Fiber

DuPont's aramid product is called kevlar. A high modulus version called kevlar 49 is widely used for composites. Kevlar 149 has higher stiffness but less strength, and Kevlar 29 is not very stiff but is used in body armor.The compression strength of a Kevlar laminate, however, is limited by the apparent inability of any resin matrix to wet the fine fibrils that make up the fiber bundle; the outside of the bundle gets surrounded by the resin and attached to it, but individual fibrils do not. As a result, when a laminate is loaded in compression, the individual fibrils buckle when the stress exceeds about one fifth of what it would take in tension. Thus, the properties of the laminate become dominated by the characteristics of the resin matrix, and a Kevlar laminate's strength in compression is limited to relatively low values.

On the other hand, the gradual buckling of the fibers acting under the restraint of the matrix means that an aramid laminate does not fail in a brittle manner like those made from other structural fibers, but "yields" much like metals. In the process of failing in this way, a substantial amount of energy gets absorbed, which makes it attractive to manufacturers of aircraft and race cars. This property together with its all around toughness (which is why kevlar is very difficult to cut cleanly) also makes it very popular for lightweight canoes and kayaks.

Kevlar can be used by itself or in combination with other fibers. Either as one or more separate plies, or woven together into a hybrid fabric. Combined in these ways with CF, it is widely applied in race car construction as a hedge against the brittleness of carbon. You won't see much crumpled carbon fiber in crashes- it just explodes into dust when it is grossly overloaded in this way.

Another significant feature of kevlar is its light weight. An aramid based laminate will typically wind up about 20% lighter than a part of the same thickness using glass or, for that matter, carbon. Used as a direct substitute for glass reinforcement in lightly stressed body panels, kevlar cloth yields a part that is about ⅕ lighter yet stronger than the part it replaces. Kevlar deteriorates slowly when exposed to ultraviolet light, so some sort of paint or other covering is needed to exclude UV from a kevlar laminate. This hardly matters in practice because Kevlar is invariably combined with epoxy resin, which itself needs protection from UV, no matter what the reinforcement.

Composites made from Kevlar 49 compare unfavorably to carbon fiber composites in terms of stiffness, both on a per volume and a per weight basis. On a same weight basis, a Kevlar 49 laminate will give one half to one quarter the stiffness of one made from carbon.

Fabrics

There are tons of different kinds of fabrics. Unidirectional fabric has most of the fibers running one way, with just a light crossweave at wide intervals to hold the whole thing together. This means all of its strength is in one direction. Others have an equal number of yarns running in both the lengthwise (called the warp), and the crosswise direction (the fill), producing a balanced, bi-directional fabric with equal strength properties in both the lengthwise and crosswise directions. Of course strength and stiffness are degraded heavily when you rotate the carbon between 0 and 90 degrees.

Weaves

For any basic type of weave, the strength and stiffness of the finished product depends on the volume fraction of fiber. Tight weaves give the best strength and stiffness values, but are more difficult to wet out; open weaves are easier to saturate, but yield a laminate which is less strong because of the greater proportion of weak plastic in relation to the amount of strong reinforcement.

Satin Weave

Crimping of the yarns is reduced if each warp yarn crosses over more than one fill yarn before crossing under one. Such patterns are generally termed satin weaves, and are further identified by the number of successive fill threads that are skipped over; thus there are five-harness and seven-harness satins etc. Because of this more advantageous geometry, laminates using satin weave fabrics generally show slightly superior strengths than those made from square weave materials, especially when loaded in compression. Because the yarns in a satin weave can skew more easily than in a square weave, they have superior drapeability, it is easier to get them to conform to tight curves, especially ones with complex changes in radius. Also, satins yield a smoother surface finish than a square weave of the same height. Taken together, these advantages often justifyn the slightly higher cost of satin weave fabrics.

Polyester

Although other resin systems are starting to make inroads, especially for high performance applications, the overwhelming majority of FRP work (>90%) is based on polyester. Epoxies usually produce stronger laminates than polyester. the surface of kevlar just doesn't seem to connect well with polyester.

Beyond the fact that they are cheaper than epoxies by half or more, polyesters remain predominant for the very good reason that they are easy to work with. First, they are low in viscosity, which means it is easier to pour pump mix etc. The cure rate of polyester can be adjusted over a wide range varying the amount of catalyst added, which is absolutely not the case with epoxy. Finally, polyester is arguably less hazardous to work with than epoxy, though it might be better to say that the hazard is different.

Polyester has several drawbacks, however. It is generally inferior in strength to laminates done with epoxy…

These are the cheapest of all the resins. They have poor bonding capability and should never be used for any structural carbon or aramid work. They typically work well only on fiberglass. One should generally never consider using this resin with structural applications with Carbon Fiber or Aramid.

Styrene-Suppressed Resins

If you have read or heard anything about FRP work, you will probably have encounter a distinction made between laminating resin and surfacing resin. A feature of conventional polyester blends is that their cure is inhibited by exposure to oxygen in the atmosphere. What that means is that while the bulk of the resin will cure soid, a very thin layer on the top surface will remain tacky. This helps subsequent layers to bond to one another, so this laminating resin is used wherever additional plies are to be added.

Epoxy

Laminates using epoxy generally have greater strength and better chemical resistance than those using polyester, especially at higher temperatures. Epoxy also shrinks less than polyester (40 to 50% less) depending on the curing agent used. As well, some fibers like kevlar and carbon are incompatible with polyester. On the other hand, epoxies are distinctly trickier to handle than polyester, introduce different health risks, and both they and their curing agents are significantly more expensive.

Epoxy resins used in composite fabrication are more viscous and sticky than polyesters. This makes it more difficult both to ensure complete mixing of the resin and hardener, and to wet out the reinforcement, adding to labor and increasing the risk of areas of incompletely saturated resin reinforcement. It is worth emphasizing here that the neccessity for complete and thorough mixing of epoxies. To ensure that all of the resin is mixed with all of the hardener, suppliers urge that you change containers during the mixing. Here's how: dispense resin into A, and mix thoroughly, scraping the side of the container to deal with either component that may be sticking to the sides. Then pour this mixture into cup B, and continue to mix. Any unmixed resin or hardener remaining in cup A will have been left behind. If you are proportioning the two components by weight, rather than by using a proportioning pump, then you may even have to resort to a three cup technique. This sounds a bit obsessive, but there is little doubt that most problems with epoxy result either from an incorrect resin to hardener ratio, or from inadequate mixing.

Thinners are available to reduce the viscosity of epoxy resins. Although these are reactive with dilutents, they cross link with the resin in much the same way that styrene does with polyester, they should be employed with caution. Dilutents may reduce the strength and chemical resistance of the finished product, and certainly will if added in sufficient quantity to make the resin as easily worked as polyester. Some thinners are particularly toxic.

Mixing is the second problem with epoxies. Epoxies must be mixed with the resin in a specific proportion, and some require very accurate measurement. If off by more than a smidgen the result can be anything from an incomplete cure, to no cure at all. What's more, this intolerance of variability in the hardener to resin ratio makes it so the cure rate of epoxy systems cannot be adjusted by varying the amount of hardener. If you want to speed up the cure, you have to pick a different curing agent, or increase the temperature of mold/workspace.

The very strongest laminate produced with epoxy systems have to have an elevated curing temperature usually from 100F to 350F.

Carbon Fiber parts will absorb radar microwaves.

Note that most epoxies are slightly amber in color. When you apply the typical amount of resin to a composite, that is just enough to wet-out the composite, the epoxy is clear.

There are only about 4 epoxies in the market that will not yellow over time. The West System 207 is the best of them all (that is the reason we sell West System's Epoxy). Even for indoor applications, UV will eventually yellow your epoxy. So if you don't plan on painting you piece/application and you want your piece to look good and last as long as possible, plan either protecting it with UV coating (such as a UV urethane), and/or use the 207 hardener.

Gel Coat

To produce parts with a smooth shiny surface comparable to painted metal, something needs to be done about the appearance of raw fiberglass mat, or the fabric weave of cloth. For such parts, a coating of pure plastic resin containing no class or other fiber is usually applied to the mold surface and permitted to cure before any glass is applied. Conventional gel coat is nothing more than polyester resin, with a few added ingredients. To prevent runs and sags when the gel coat is applied to a vertical surface, a thixotropic agent, usually silica gel, is blended in, to add body and so resist the flowing under the effect of gravity.

MEKP

MEKP is a clear colorless liquid. It is explosively unstable in its pure form and so is supplied as a diluted solution in an inert liquid buffer. While it is not itself highly flammable, it is a powerful oxidizer which may cause some readily flammable substances- like paper, rags, or sawdust- to ignite spontaneously if it comes in contact with them. It is also quite corrosive, and prolonged contact will cause skin burns. Splashed in the eyes can cause permanent damage. The vapors may cause headaches and intoxication, and corrosive damage to the nose, throat and lungs. This is the catalyst for polyester resins.

PVA

With a new mold, you first wax and thoroughly buff several times, at least three. (You don't need that much wax, but you might have missed a few spots the first time. Terry-cloth toweling seems to work well for the waxing and buffing. Next, you apply a coat of polyvinyl alcohol, which dries to form a thin barrier film that provides a second line of defence against the nightmare of a part firmly stuck in the mold. PVA is not only unnecessary in a well made, aged mold, it is undesirable since the PVA leaves a slightly pebbly, orange peel texture on the surface of the finished part that has to be polished out.

It is possible to apply without a spray gun (a small piece of old t-shirt seems to work better as an applicator than a brush), but spraying is definitely preferable. The PVA should be sprayed in stages, starting with a very light misting, and finishing with several heavier coats. Obtaining a uniform and, above all, a continuous film of PVA is much easier if the mold has a color that contrasts well with the PVA, which is green.

Elevated Temperature Curing Epoxies

For applications where minimum weight and maximum strength are important, higher performance resins may be selected, and that often means epoxy resin systems designed to cure at higher than room temperatures. For a true high temperature cure (HTC), the temperatures required with some resin systems are so high (up to 400F) and the demand for close control of the heating so strict that homemade arrangements are inadequate. The only solution is a purpose-built oven, fitted with precision timers and automatic temperature controls. Large and expensive industrial ovens are available for this purpose.

Heating Methods

Never forget that an oven is simply an insulated box with a heat source inside; in some cases it may be quite practical to make your own. It is not prohibitively expensive to construct a frame for a simple shed-like structure out of steel (not wood), with sheetrock walls and ceiling, heavily insulated on the back side with rock wool or fiberglass batts (forget about foam insulation; apart from increased fire risk, insulating foams may soften at the temperatures involved).

Cautions- while undiluted epoxies do not include flammable, low boiling point solvents, like the styrene in polyester and vinylester resins, these materials are nevertheless flammable, and extreme care must be taken to avoid fire. That pretty much limits the possible heat sources to electricity, steam and hot water, through the use of water is obviously limited to temperatures below its boiling point of 212F.

Heating the mold is another alternative to heating the air. Possible to use electric resistance heaters.

Expansion

Another factor to bear in mind whenever exposing a laminate and mold assembly to elevated temperatures is the issue of compatibility of the mold and laminate materials. For one thing, their comparative thermal expansion has to be considered, especially if the dimensions of the part are critical. For example, some carbon fibers exhibit negative thermal expansion- they get smaller as they heat up. Other forms of carbon fiber do have a positive thermal expansion coefficient, but they grow much less with heat than most other FRP materials. For this reason, the molds for carbon fiber reinforced race car and aircraft components using ETC resin systems are themselves usually made from the same CF as the part, to ensure that the mold and laminate shrink and grow in sync.

Fabric impregnator

There is also a method of working that involves something like a homemade prepreg, using a machine called a fabric impregnator. This apparatus mechanically draws woven or unidirectional goods through a bath of resin and then passes it through a set of pinch rollers, yielding more uniform resin distribution and a higher reinforcement to resin ratio than is usually possible with hand work. At the same time, labor is reduced.Virtually any liquid resin system can be used in this process., for unless the material is going to be used almost immediately it is obviously an advantage if the resin either cures very slowly at room temperature or can have its cure postponed in some way. Epoxy based systems which can be arrested at the b-stage are well suited to this technique, and this, in fact, is the way commercial prepregs are made. There is also the possibility of using UV curing polyester or vinylester resins. If the dipping were done under a “safe” light, the impregnated fabric could be rewound onto a roll, using a sheet of polythylene to prevent layers from sticking together, and would store indefinitely until exposed to UV light, such as by being taken outdoors. The cost of fabric impregnating equipment generally limits its use to those who either need large quantities of material or are working with weight and strength critical goods, or both. Prepregs can also be produced by a filament winder.

Male or Female?

Assuming conventional hand layup, the surface of the finished product that contacts the mold will have a glossy surface, while the back face will be rough, so for goods where visual appearance is important, the surface that is exposed determines which way it must be molded. Thus, a bathtub would be formed over a male mold, while a canoe would be made in a female mold.

The Expendable or Sacrificial Mold

One is a technique for making tanks of all sorts by carving a chunk of foam to the desired shape, wrapping it entirely with resin saturated reinforcement, and then dissolving out the foam plug with a suitable solvent once the shell has cured. This is undeniably an intriguing technique, but there are a few intrinsic limitations: the foam must be unaffected by the resin system; the resin must be impervious to the solvent used to purge the core; the thickness of the wrapping may need to be taken into account when shaping the core; and the outer surfaces of the finished tank necessarily has the texture of the fabric used.

Fatigue

An advantage of composite materials sometimes touted in print is that they do not fatigue. This is simply not so, though it is true to say that the fatigue resistance of composites is generally superior to that of metals. Unidirectional laminates using kevlar retain about ¾ of their static strength after ten million cycles of loading in tension (though they do less well when the loading reverses between compression and tension); similar carbon fiber laminates keep perhaps two thirds of their original strength; glass fiber composites are down to about half by that point.

Sandwich Structures

Sandwich structures present particular problems around bolted connections, and anyplace else where loads are highly localized. One technique for dealing with this is to remove the core in the area surrounding the attachment, and bring the two skins together, locally reinforced with additional layers of laminate. It is common for at least some of this extra material to be a thin sheet of aluminum, to take advantage of its isotropic, ductile nature.

Surface Bonding

Provided the surface is properly prepared, aluminum will bond securely to an epoxy laminate. The key phrase is properly prepared. Understand first that aluminum oxidizes- exposed to air, the bare surface of a piece of aluminum almost instantly reacts with the oxygen in the atmosphere to form aluminum oxide. If you attempt to stick anything to an untreated piece of aluminum, what you wind up doing is gluing to the oxide, not the aluminum itself. In principle, that ought not to be a problem, provided, first, that the oxide is well and truly attached to the metal beneath and, second, that the adhesive is well and truly bonded to the oxide. There are potential problems on both scores, as the aerospace industry discovered when they began gluing airplanes together.

To cut a very long story short, the procedures that Boeing and the other heavy hitters involve a succession of steps to de-grease, acid etch, and anodize with phosphoric acid, with rinsing in deionized water after each step.

How FRP Composites Carry Loads

Many people believe that the strength of an frp laminate is unnecessarily reduced whenever any of the fibers in it are broken. This is definitely not so. It is equally untrue that a fiber has to extend from one end of a load carrying part to the other in order to contribute to the strength of the laminate.

First realize that a fiber, by definition, is something that is many times longer than its diameter. Now, in a properly constructed laminate, all of the surface of each fiber is firmly attached to the resin that surrounds it, and the area of that contact is many times greater than the cross sectional area of the fiber. Now imagine a small zone within the laminate where two fibers, lay side by side, fairly close to each other, but only partly overlapped in strength, so one is closer to one end of the laminate, overall, and the other closer to the opposite end.

If we anchor one end of the laminate and pull on the other, there will be a tendency for the two fibers to slide past each other. Each, however, is stuck to the surrounding resin, so the interface between fiber and resin is stressed in shear- the fiber is trying to slide through the resin, and the "hands off" the load to the next adjacent fiber. Provided each fiber is long enough in relation to its diameter, then even though the shear strength of the resin is a mere fraction of the tensile strength of the fiber, there will be so much more resin carrying the shear load than there is fiber carrying the tension load that the the fiber will break before the plastic does.

There is some minimum length of fiber for which this will be true, and that is why a laminate made with say, short chopped strand reinforcement will not be as strong as one using longer fibers. On the other hand, if the minimum length criterion is met, longer fibers will not make the laminate any stronger. Equally any more resin than is needed to pass the load from one fiber to the next does nothing to increase the strength of the laminate and just adds weight.

Another way to look at it is on the basis of tensile stresses. In the previous chapter, we saw that any material which is pulled lengthwise will stretch somewhat, or strain, and that amount of this strain depends on just two things- the stress and the elastic modulus. Now when a composite is stress, all of it grows longer- the fibers and the resin have equal strains. The fiber, however is many times stiffer than the resin, so assuming that half the volume of the composite is fiber and half is resin (a representative figure), then the stresses in the two will be in the same ratio as their elastic moduli- about 25 to 1! Clearly, the matrix is lightly stressed, even when the fibers are carrying a very large load, and since the area of contact between the fiber and the plastic extends over the whole surface of the fiber, the matrix has no problem transmitting the load from one fiber to another.

Wet Lay-up

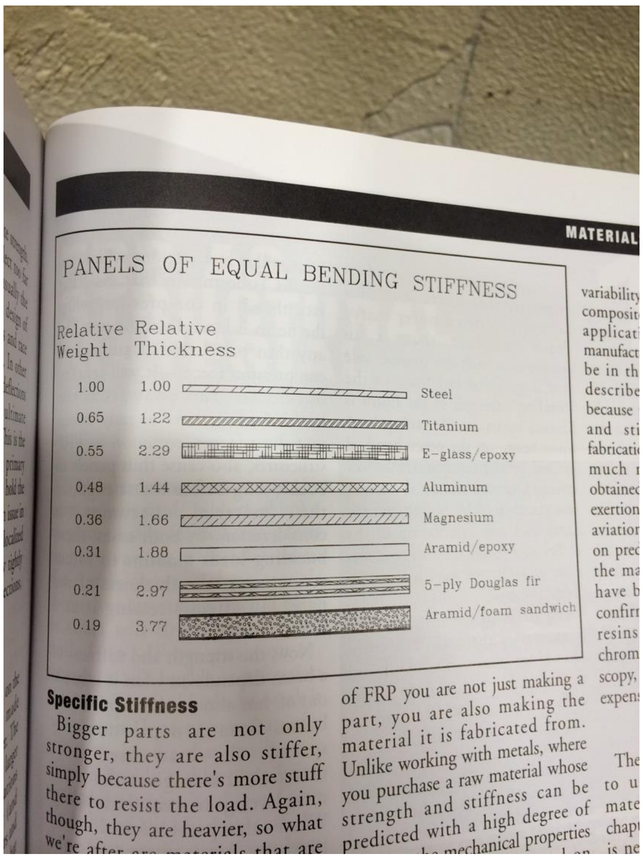
When honeycomb core is used in wet lay-ups, it is common to first produce one skin, then for the core to be set down on the still wet laminate, so the laminating resin serves as the adhesive for this connection. The second skin is more problematic. If a wet lay-up is applied over the core to produce the second skin, there will be a tendency for the resin to drain out of the reinforcement and into the cells. About the only practical alternative is to produce the second skin independently, then to assemble it to the core using a film type adhesive. This obviously demands closer than typical control over the shape and dimensions of both core and skins.

Pre-Preg

When the facings are produced from prepregs, this problem is avoided, and the choice is then between production of the two skins, allowing them to fully cure, followed by assembly to the core using film adhesive, or by letting the resin in the prepreg serve as the glue and completing the assembly before either skin is cured, a technique called co-curing. Notably, the force required to peel the skin away from the core is different for the upper surface than from the under surface. This occurs because the differences in the shape and size of the fillet of resin that forms and the junction between each cell and the skin, in turn cause by the flow of the resin under gravity during the cure.

Fiber volume fraction

The volume of fiber in a cured composite. The fiber volume of a composite material may be determined by chemical matrix digestion, in which the matrix is dissolved and the fibers weighed and calculated from substituent weights and densities or a photomicrographic technique may be used in which the number of fibers in a given area of a polished cross section is counted and the volume fraction determined as the area fraction of each constituent. Typical values for boron/epoxy and for graphite/epoxy, based upon the fiber type, is 55-67% fiber.



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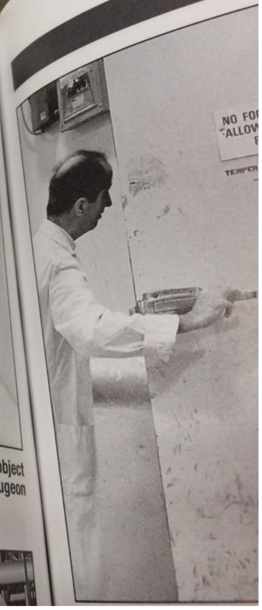
When applying more resin, use a paintbrush, but don't "brush," as shown above. Instead, use a poking or "stippling" motion to coat the mat. Photo by Michael Lutfy.

Thorough and vigorous working of laminate with a ribbed roller is essential to uniform resin distribution and to exclude air and consolidate the laminate. N



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Ingenious vacuum pump using shop compressed air and venturi principle (black object in center) is part of the assortment of vacuum bagging supplies available from Gougeon Brothers. Photo courtesy Gougeon Brothers Inc.

Simple, hand-cranked fabric impregnator from Gougeon Brothers. Photo courtesy Gougeon Brothers Inc.

system can be used in this process, but unless the material is going to be used almost immediately it is obviously an advantage if the resin either cures very slowly at room temperature or can have its cure postponed in some way. Epoxy-based systems which can be arrested at the B-stage are well suited to this technique, and this is, in fact, the way commercial pre-pregs are made. There is also the possibility of using ultra-violet curing polyester or vinylester resins. If the dipping were done under a "safe" light, the impregnated fabric could be re-wound onto a roll, using a sheet of polyethylene to prevent layers from sticking together, and would store indefinitely until exposed to UV light, such as by being taken outdoors. The cost of fabric impregnating equipment generally limits its use to those who either need large quantities of material or who are working with weight- and strength-critical goods, or both. Pre-pregs can also be produced by filament winding, as mentioned in the next chapter.

Mat, fabric and veil

A mat is formed by randomly oriented chopped filaments, short fibers, or swirled filaments loosely held together with a very small amount of adhesive. A veil is a thin matt used as a surfacing layer to improve corrosion resistance of the composite. Veils and mats have fibers oriented randomly in every direction, leading to isotropic properties in the composite. Nonwoven fabrics are made directly from strands without the intermediate twisting of the strand into yarns.

Epoxy Resins

Epoxies shrink less than other materials (1-4% by volume) which helps explain their excellent bond characteristics when used as adhesives. Epoxies are less affected by water and heat than other polymer matrices. Epoxy resins are also favored for their simple cure process that can be achieved at any temperature between 5C and 150C.

Isotropic/Anisotropic

Isotropic materials (aluminum, steel) have the same mechanical properties in any direction. A typical example is the modulus of elasticity of wood, which is higher along the length of the tree and lower across the growth rings. The stiffness of an isotropic material is completely described by two properties, for example, the modulus of elasticity E and poisson's ratio V. In contrast, up to 21 properties may be required to describe anisotropic materials.

Micromechanics and Fiber volume

The stiffness of the equivalent CFRP material can be represented by five elastic properties:
E1: modulus of elasticity in the fiber direciton
E2: modulus of elasticity in the direction transverse to the fibers
G12: inplane shear modulus
G23: out of plane shear modulus
v12: inplane Poisson's ratio
All of these are functions of the fiber volume fraction
These are of a similar naming scheme to how solidworks and ABAQUS call their variables

Thermal Expansion

The thermal expansion coefficient of all resins are positive (about 30 to 100 E-6 /C) which is higher than steel alloys. Carbon fibers have a negative expansion in the fiber direction (-.99 E-6/C) and a relatively large expansion in the transverse direction (16.7 E-6/C). This means that depending on the amount of fibers (fiber volume fraction) it is possible to tailor the coefficient of thermal expansion of the composite to the user's needs. Especially, it is possible to produce a composite material with a very low coefficient of thermal expansion, which is useful when dimensional stability is required.

Symmetric laminates experience no bending extension coupling. This is very important during fabrication because curing and subsequent cooling of the composite induces thermal forces. If the laminate is not symmetric, these forces will induce warping of the final part.

Longitudinal Tensile Strength

The simplest model for tensile strength of a continuous composite is derived by assuming that all the fibers have the same tensile strength. Actually the tensile strength of fibers is not uniform. Instead, it is well approximated by a Weibull distribution. But as a first approximation it is assumed that all the fibers have the same strength equal to the average strength.

The second assumption is that both the fibers and the matrix behave linearly up to failure. This is not true for most polymer matrices that exhibit either elastic nonlinear or plastic behavior after a certain elongation. The behavior of polymers is further complicated by their load-rate dependency. That is, polymers are viscoelastic or viscoplastic.

The third assumption is that the fibers are brittle with respect to the matrix. Such large elongations to failure for fibers hold only in ideal conditions, with some fibers breaking at much lesser strain levels.

The fourth assumption is that the fibers are stiffer than the matrix. This is valid.

Under the assumptions listed, the composite will usually break when the stress in the fibers reaches their strength (average strength). After the fibers break, the matrix is unable to carry the load. Therefore, the composite elongation to failure, is equal to the fiber elongation to failure. At this strain level, the matrix has not failed yet because it is more compliant and can sustain larger strains. Under these conditions, it can be assumed that the longitudinal tensile strength is controlled by the fiber strength. This assumes the strain in the matrix and the fibers are the same, which is true if the fiber-matrix bond is perfect. The ultimate strain or stress of the matrix is not realized, because the fibers are more brittle.

Longitudinal Compressive Strength

Compressive strength of continuous composites is lower than the tensile strength, about one half or less. The mode of failure is usually triggered by fiber microbuckling, when individual fibers buckle inside the matrix. The buckling process is controlled by fiber misalignment, shear modulus, and shear strength of the composite.

Fiber misalignment measures the waviness of the fibers in the composite. Fiber waviness is always present to some extent, even when great care is taken to align the fibers during processing. Waviness occurs because of several factors. The fibers are wound in spools as soon as they are produced, which induces a nature curvature in the fibers. Then fibers tend to curl when stretched on a flat mold. Furthermore, many fibers are wound together over a spool to form a tow or roving during fiber production. The fibers wound on the outside of the spool are longer than those wound in the inside. When the tow is stretched, the longer fibers are loose and microcatenary is formed.

Microcatenary can be shown by stretching a tow horizontally and letting the longer fibers hang under their own weight. The longer fibers hang in a catenary shape, just as electrical power lines do. In the final composite part, microcatenary appears as fiber misalignment.

The first formula for compressive strength was proposed recognizing the fact that compression failure is triggered by fiber microbuckling. The first approximation to the problem is to assume that the buckling load of the fibers is the limiting factor for compressive strength. To obtain the buckling load, some guy performed a stability analysis of straight fibers laterally supported by the matrix. Furthermore, the shear stress-strain law of the composite was assumed to be linear. Actually, PMCs have a nonlinear stress-strain law, as shown below. Such behavior is better represented by the relationship 4.66: tao= F6 tanh(g12 gamma /F6)
This approach can be used with an empirical correction, with testing for compressive strength.
Dimensionless compressive strength can be modeled in terms of dimensionless numbers, with the following formula 4.75: F1c=(X/a+1)^b G12. On page 94 from Intro to Composite materials design.

Laminate Description

The notation used to describe laminates has its roots in the description used to specify the lay-up sequence for hand layup using prepreg. When using prepreg, all layers have the same thickness and only the angles need to be specified. In the hand layup process the laminate is built starting from the tool surface, or bottom of the laminate, adding layers on top. Therefore, the layers are numbered starting at the bottom and the angles are given from the bottom up. For example, a two-layer laminate may be [30/-30], a three layer one [-45/45/0] etc.

If the laminate is symmetric, like [30/0/0/30], an abbreviated notation is used where only half of the stacking sequence is given and a subscript 's' is added to specify symmetric. The last example becomes [30/0]s. Since most laminates used are symmetric, there is the possibility of confusion when no subscript is used. To eliminate the possibility of confusion, a subscript 't' may be used to indicate that the given is the total for example [90/0]T. A subscript number may be used to indicate a repeating pattern. For example [(90/0)2]T.

If the thicknesses are different use a subscript next to the degree marker. For example [90t1/90t2/0t1/0t1]S would mean a layer of the first thickness at 90, a layer of the second thickness at 90 etc. If all layers have the same thickness, the laminate is called regular.

Symmetric laminates experience no bending extension coupling. This is very important during fabrication because curing and subsequent cooling of the composite induces thermal forces. If the laminate is not symmetric, these forces will induce warping of the final part.

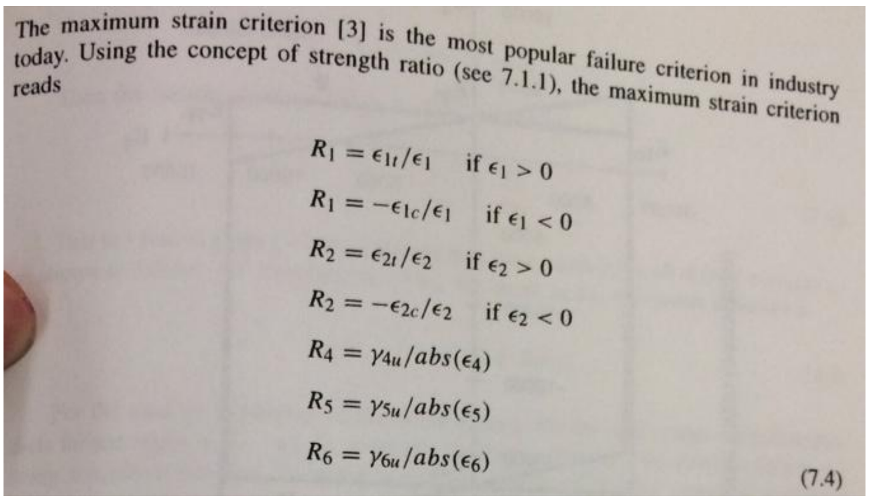
Failure Modes

The most popular criteria for composites failure are:
1. max stress criterion

2. max strain criterion
3. Tsai- Hill failure criterion
4. Tsai-Wu failure criterion
5. Truncated maximum strain criterion

Maximum Strain Criterion

The maximum strain criterion is the most popular failure criterion in industry today. Using the concept of a strength ratio (load/strength) the strain criteria becomes. R=Strain/strain at break
Since elongations to failure are usually reported in percent values in the literature, they would have to be divided by 100 to be used.


The maximum strain criterion [3] is the most popular failure criterion in industry today. Using the concept of strength ratio (see 7.1.1), the maximum strain criterion reads

$$R_1 = \epsilon_{1t}/\epsilon_1 \quad \text{if } \epsilon_1 > 0$$
$$R_1 = -\epsilon_{1c}/\epsilon_1 \quad \text{if } \epsilon_1 < 0$$
$$R_2 = \epsilon_{2t}/\epsilon_2 \quad \text{if } \epsilon_2 > 0$$
$$R_2 = -\epsilon_{2c}/\epsilon_2 \quad \text{if } \epsilon_2 < 0$$
$$R_4 = \gamma_{4u}/abs(\epsilon_4)$$
$$R_5 = \gamma_{5u}/abs(\epsilon_5)$$
$$R_6 = \gamma_{6u}/abs(\epsilon_6) \quad (7.4)$$

Truncated Max Strain Criterion

The failure criterion can be summarized as to just checking every layer for fiber strain. This procedure is popular in the aerospace industry because of simplicity, and is reported to be quite accurate. The truncated maximum strain criterion goes one step further by limiting the strains in the tension compression quadrants to account for shear failure

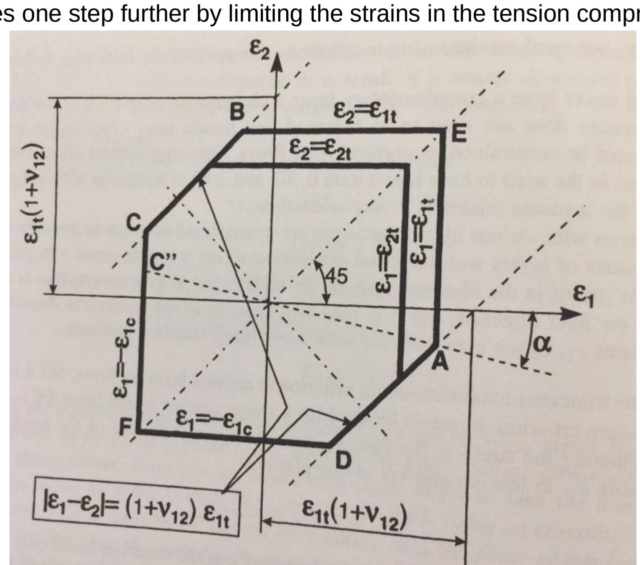


Figure 7.8 Truncated maximum strain criterion.

of the fibers.

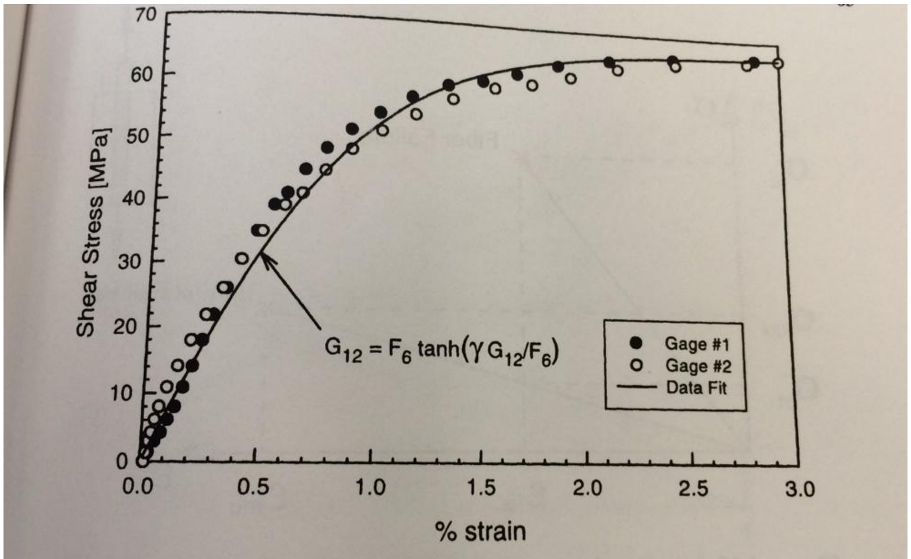


Figure 4.12 Inplane shear stress–strain behavior of unidirectional carbon–epoxy (experimental data according to ASTM D5379).

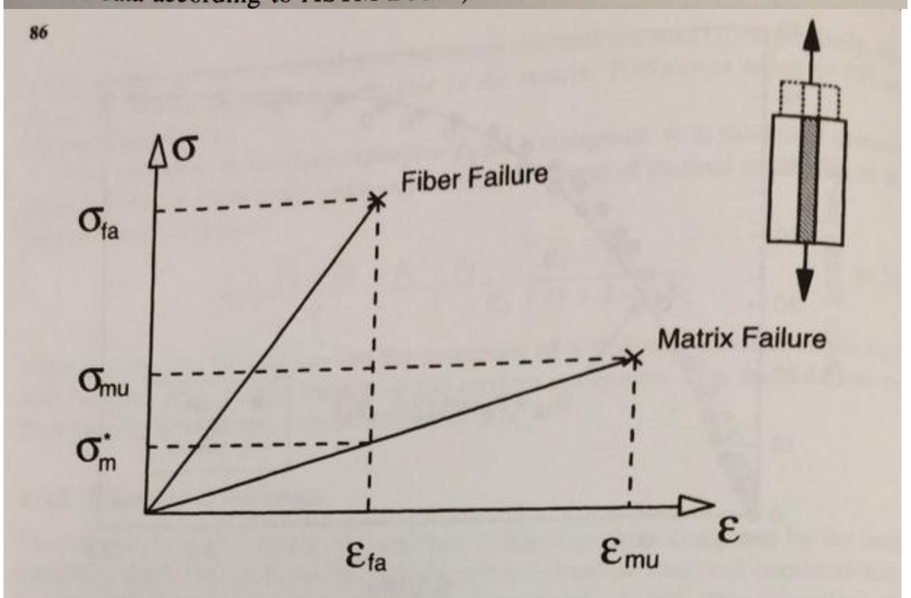


Figure 4.13 Micromechanics of strength assuming uniform fiber strength.

Thermoset Matrices

Undergo chemical change when cured. Process is not reversible. Low viscosity matrix material. Long 2 hour cure. Tacky pre preg. Relatively low processing temperature, good fiber wetting, formable into complex shapes. Requires refrigeration.

Filament

The basic structural fibrous element. It is continuous, or at least very long compared to its average diameter, which is usually 5-10 microns.

Yarn

A small, continuous bundle of filaments, generally fewer than 10,000. The filaments are lightly stranded together so they can be handled as a single unit and may be twisted to enhance bundle integrity.

Tow

A large bundle of continuous filaments, not twisted. The number of filaments in a bundle is usually 3k, 6k, or 12k. 12k tow is the cheapest. 3K is the most expensive. The smaller tow sizes are normally used in weaving, winding, and braiding applications while large tow sizes are used in unidirectional tapes. Very thin tapes are also made from low filament-count tow for satellite applications.

Woven Fabrics

2D woven fabrics are more expensive than unidirectional tapes. However, significant cost savings are often realized in the manufacturing operation because layup labor requirements are reduced. Complex part shapes for processes require careful positioning of the reinforcement can benefit from the use of more handleable woven forms of fiber. Fabrics are generally described according to the types of weave and the number of yarns per inch, first in the warp direction (parallel to the length of the fabric, then in the fill direction(perpendicular to the warp).

Unidirectional fabrics

Fabrics are essentially unidirectional and in these fabrics the reinforcements are oriented in one direction (warp) and held in position by tie yarns (fill) of a non structural nature which go over and under the structural fibers; the fibers (warp) lie straight with the same characteristics as tape.

Plain Weave

In this construction, one warp yarn is repetitively woven over one fill yarn and under the next. It is the firmest, most stable construction, which provides minimum slippage. Plain-weave fabrics are less flexible and are suitable for flat or simply-contoured parts; a slight sacrifice in fiber property translation occurs. Strength is uniform in both directoins.

Satin Weave

In this construction, one warp yarn is woven over several successive fill yarns, then under one fill yarn. A configuration haing one warp yarn passing over four and under one fill yarn is calld a 5 harness satin weave. Satin weaves are less open than other weaves and strength is high in both directions. In particular the commonly used 8 harness satin retains most of the fiber characteristics of tape ad can be easily draped over complex mold shapes.

Woven Fabrics

They are usually based on the more expensive 3k filament tows to ensure a thin uniform sheet. Because the fibers are necessarily kinked, the product cannot be expected to yield its full potential strength. Fiber discontinuities and overlapped splices are required. Lower fiber volume fraction than tapes. Greater scrap rates than tapes. Fabric distortion (bowing and skewing) causes part warping.

Sandwich core materials

The challenge of making a structure as light as possible without sacrificing strength is fundamental in aircraft design. Inevitably the requirement leads to the need to stabilize thin surfaces to withstand tensile and compressive loads and combinations of the two, in shear, torsion and bending. Traditional airframe structural design in has in the past, and does still to some extent, overcome this difficulty by the use of longitudinal stiffeners and stabilizing rings with stringers, and ribs or frames. But it is an inelegant solution and, in fact, the stabilization of a surface- creating a resistance to deforming forces- can be more efficiently effected by the use of twin skins with a stabilizing medium between them- what is now termed a sandwich structure. It is noteworthy, however, that scientific design has been paralleled, or rather anticipated, by nature and evolution, for the structure of the human skull bears a remarkable resemblance to a sandwich structure.

Potting compound

Potting compound is a low density material which has the following uses: material inserts, edge filling, preventing crushing by local concentrated loads in a honeycomb core, Joining material in honeycomb constructions, securing inserts installed in either honeycomb or foram core.

Release film

These films are used to prevent the composite part from adhering to tool surfaces. Release film is also placed between the bleeder and breather plies as a separator film. It is used to prevent resin flow into the breather plies, to which the vacuum system vents. Resin in the vacuum system can clog it and break it. For resins that produce volatiles during cure or consolidation, a release film with small perforations which are widely spaced is used to prevent the breather from becoming clogged with resin and unable to perform its function. For resins that produce no volatiles during cure, an unperforated release film is frequently used so that resin removal can be controlled.

Peel ply

Peel ply film or teflon coated fabric materials are placed on top of the layup serve to restrict but not prevent resin flow from the laminate. Most peel plies are porous or perforated and the size and spacing of perforations or the porosity of the material determines the amount of resin flow from the surface of the laid up laminate. If no resin removal during cure is desired, unperforated peel ply film should be used. The peel ply also serves to to control the surface roughness and finish of the composite. Surfaces that are to be adhesively bonded as a secondary operation after curing often use a peel ply to obtain a rough surface finish and also to keep them clean until ready for joining operation.

Bleeder ply

Bleeder plies are normally required to absorb excess resin and permit the escape of volatiles. Various solvents and other chmeicals in the prepreg that take part in the chemical reactoin during layups must be vented, or an unacceptably porous structure will result. There are basically two options:
1) Bleedout may occur through the edges (edge bleed). This is used on smaller parts (less than a foot) because there is a chance of bridging. Bagging costs are reduced due to the absence of bleeder, separator and vent cloths. There is less chance of surface wrinkles. It is much easier to debag when there is no bleeder to be removed. Considerations are: there is a greater chance of volatiles being left in the cured part. Variations in resin flow are very likely to result in the laminate being resin rich in the center and resin starved near the edges.

Caul plate

A caul plate is a rigid smooth sheet or plate (metal or hard rubber material) with the same size and shape as the finished part and in direct contact with the composite layup in order to:
Provide a smooth bag side surface, prevent excessive resin washout, smooth the angle and prevent wrinkles at tapered areas, regulate configuration of joggles, prevent wrinkles and surface irregularities from forming when an elastomeric caul plate is used, most rubber cauls are used for high temperature thermoplastics, help distribute pressure evenly over the part.

Breather plies

Breather plies are usually fiberglass or synthetic fabric which is placed on top of the release film to allow dispersion of vacuum pressure over the layup and removal of entrapped air or volatiles during cure. Coarse, open weave fabrics are used, otherwise bridging and bag failure may occur.

Vacuum bags

the vacuum bag provides the means of removing vapors, and encouraging the required resin flow, so its design and implementation are important. The vacuum is used to assist removal of trapped air. The vacuum and pressure temperature cycles are adjusted to permit maximum removal of air, with maximum resin flow. The vacuum bag is the final item in a composite layup for autoclave or oven cure. The bag must be vacuum tight so no autoclave gas can enter the layup. Should bag or edge sealant failure occur, the autoclave gas enters the layup, neutralizing air and volatile removal. The choice of bag material and its compatibility with the tool shape and sealing arrangements are major decisions in the composites manufacturing process. Bags that are stretched too tight tend to leak, break or, on convex radii, span the layup, reducing effective pressure. In any event, leaks in the film or in the sealing of the bag are definitely unacceptable especially when curing thermoset parts because it results in the scrap of the part.

Vacuum/Vent lines

Vacuum ports shall be placed beneath the vacuum bag or diaphragm at intervals which will ensure that any portion inside the layup laminate can be vented out through the lines. Some pressure/vacuum gauge are required to monitor the vacuum pressures. A vacuum of a minimum of 20 inches of mercury shall be used to check for leaks prior to autoclave processing. During the check, a loss of greater than 2 inches of mercury in 5 minutes is unacceptable.

Debulking

When initially laid up, any number of plies are bound to trap a certain amount of air between them, and on contours their elasticity may prevent their laying smoothly on top of each other. The more plies that are laid up, the more likely it is that wrinkles will result and be cured into the laminate, resulting in an unacceptable laminate. A debulking procedure used in conjunction with squeezing the plies onto the tool surface is repeated as often as necessary during the layup of thick laminates to reduce rwrinkles and to fit the prepreg smoothly into the tool. However applying debulking on thin laminates or slightly contoured laminates results in little improvement in structural performance. Prior to cure, the layup laminate may need to be debulked under 20 inches Hg after every 5 to 10 plies are laid down. The debulking bagging arrangement usually conforms to to the general configuration.

Scarf joint

The shear stress in the adhesive of a scarf joint is virtually constant. This means that a sufficiently small scarf angle can be selected to provide 100% joint efficiency (the joint adhesive strength equals the laminate failure load). To insure that laminate failure occurs outside the joint (for optimum strength) the scarf angle should be between 6 and 10 degrees. At large angles, failure will occur prematurely. When extremely small scarf angles are used there is the danger of breaking off the tip of the stiffer laminate. Actual joint efficiencies are less than 100% because the manufacturing constraints often require angles greater than optimal.

Stepped lap joint

Like the scarf joint, the stepped lap joint, offers considerably greater efficiencies for thick laminates than is possible with single and double lap joints. It has been used for composite to titanium bonded joints with both carbon and boron epoxy laminates. This joint shares some of the characteristics of both the double lap and scarf joints. The joint strength can be increased by increasing the number of steps and approximating more closely the scarf joint design. However, once the maximum number of steps possible has been attained by equalling the number of plies in the laminate, no further strength increase can be developed. Strength may be increased by tapering the outer adherends of the laminates in the overlap area so as to keep the combined adherend extensional stiffness essentially constant (by matching stiffnesses of adherends t) throughout the joint. If the adherend is thick enough to warrant this procedure, the design and fabrication methods should allow for it. Otherwise, the adhesive will be fully utilized only at one end of the joint. The critical detail in this joint design is the tail end of the thin step where fatigue failure is likely to occur. There are obvious problems of fit associated with both scarf and stepped lap joints if both laminates have been precured or machined.

Flush single strap joint

Variations of this configuration are often found where a flush surface is needed. Highest peel stress of common joint types. Advisable to make ts>t to reduce stresses due to moment even though it does increase eccentricity. increased overlap is very beneficial in reducing peel. Laminate ends should be tapered.

Bonded joints

In summary, adhesive bonding is most appropriate for thin laminates while mechanical fasteners are more suitable for thick laminates (unless a stepped lap joint is used). Bonding of structures provides an alternative to mechanically fastening assemblies. Some of the factors affecting joint strength are assembly types, layup and type of adhesive. Generally, adhesively bonded assembled structures are lighter and have reduced manufacturing and maintenance costs over mechanically fastened structures. Some characteristics of secondary bonding are: Requires excellent fit up, requires additional cure cycles, allows precured parts to be inspected prior to assembly.

For maximum effectiveness and confidence, adhesive bonds should be designed in accordance with following general principles: the bonded area should be as large as possible, a maximum percentage of the bonded area should contribute to the strength of the joint, the adhesive should be stressed in the direction of its maximum strength. The strength of bonded single lap and double lap joints depends primarily on the overlap length and the extensional stiffness of the laminates for a specific adhesive system. Theory and test have generally shown that the highest strength is attained when the value of Et [laminate material modulus of elasticity (E) times its thickness (t)] for the two laminates are equal to one another.

Bonded joint design guidelines

A. Joints with short overlap lengths are more efficient in avoiding adhesive shear failure from peak shear stress
B. To minimize peel stress consider the following
    a. In double lap joints peel stress is a function of outer laminate bending stiffness
    b. In unsupported single lap joints, peel stress is an inverse function of overlap
    c. In eccentric joints, much larger overlaps are needed for shear strength are often required to allow alleviation of eccentricities by gentle deformations
    d. taper ends to a thickness of about 30 thou and slope of 1/10
C. Reduce joint eccentricity
D. Do not use 90 degree plies on outer surfaces of the laminate (use 45 or 0 plies)

Cocuring

One of the most attractive features of composite materials is that sections can be molded into complex shapes. Thus, panels that normally would have to be fabricated individually can often be cocured into single parts to eliminate the need for fasteners entirely. Cocuring will be defined as the curing of a laminate with stiffeners and attachments all in one process operation. There are many advantages to cocuring parts in airframe structures; in addition to the integrity of a one-piece construction, there are weight savings and most important is the savings in the cost of assembly labor. A typical commercial transport for example, may have as many as two million different types of fasteners. Thus the elimination of fasteners, which includes fastener cost and installation cost, can result in substantial savings.

Various combinations of resins can be cocured, but it is important to match the cure cycles, especially the temperature and speed of reaction. How the two resins react with each other must be examined, and they should be compatible, because the prepreg resin serves as the adhesive. Design considerations for cocuring include:

A. Cocuring is inherently more complex, so there is a greater probability of a bad layup, with significantly more at risk.
B. Misalignment of parts is possible, so tooling to hold the part properly becomes very important. As the component gets more complex, the parts are more difficult to keep in their proper place, therefore tooling needs to be more innovative.
C. Part shrinkage during cooling must be accounted for. The tooling should have the same CTE as the part. Hence, composite tooling is preferred, especially for large parts.
D. In cocuring, some areas are difficult to inspect because they are hidden.

E. Controlling dimensions in center areas may be more difficult when cocuring
F. If the part is too thick, applied heat combined with the heat generated from the chemical reaction may damage the part. Therefore the cure cycle should be adjusted to meet this phenomenon.

Composite to metal splice joining guidelines

A. Bonding composites to metals (consider thermal expansion)
    a. Titanium (preferred)
    b. steel (acceptable)
    c. aluminum (not recommended) composite to aluminum (corrosion resistant aluminum) splice joints may be used under special circumstances
B. Bonded step joints are preferred to scarf joints- more consistent results, design flexibility and lower costs for thicker laminate joints
C. where possible, 0 degree plies should be placed adjacent to the bondline. 45 plies are also acceptable. 90 plies should never be placed adjacent to the bondline unless it is also the primary load direction.
D. For a stepped joint, the metal thickness at the end step should be thick enough to prevent metal failure
E. If possible, have 45 plies end on the first and last step of bonded step joints to reduce peak interlaminar shear stresses at the end steps.
F. If possible, do not end too many of the 0 plies on any step surface to avoid peak stress

Moisture

The absorption of moisture by the organic matrix of composites is an important factor at high temperatures. The moisture diffuses into the matrix, in both laminates and adhesives, causing them to swell and acts as a plasticizer or softener. The latter phenomenon is by far the most important for airframe applications and results in a decrease of the matrix glass transition temperature. This manifests itself in a decrease of matrix dominated properties at high temperatures. For example, compression strength is clearly reduced, but tension behavior is relatively unaffected, at the upper temperature ranges of the material's usefulness. Composite mechanical properties are dependent upon the amount of water in the matrix and the temperature. Generally 350F composites absorb more moisture than 250F composites. thermosets absorb 1 to 2% moisture. Hot/wet conditions cause the matrix to become more plastic, cold/dry cause the matrix to become more brittle. Cyclical swelling and contracting due to recurring moisture exposure may lead to joint loosening. to minimize moisture egress, seal machined edges and surfaces of the laminates. Provide surface paint or protective coating. However, paint will not prevent moisture from diffusing into the composite matrix. When a part is not painted, a thin film of thermoset or thermoplastic resin should be applied to the surface to reduce porosity. Sealant should be applied when surfaces are exposed to weathering to reduce the effects of static rain, air oxidation, airblown sand and ultraviolet radiation.

Rain and sand erosion

Erosion of composites edge results from exposure to rain, dust, and sand. Preventative measures for structures which will experiences long term exposure are:

A. Aircraft leading edge components should be protected by rubberized coatings
B. Composite surfaces such as leading edges of wing, horizontal or vertical stabilizers etc require some form of protection when exposed to the airstream. Wherever possible, the best protection for leading edge composites is a metallic outer layer. other protection choices include:
    a. use of paint or elastomeric/metallic coatings
    b. application of a polyurethane (which has shown satisfactory results on thermosets)
C. Forward facing edges of laminates which are exposed to the airstream are especially vulnerable and should be protected with edge wrap film or an anti peel ply

Galvanic corrosion

The aircraft industry has vast amounts of data gained from history and research on corrosion to design out corrosion and to manufacture corrosion resistant airframes. galvanic corrosion occurs where two materials from different groups in the galvanic series, are in contact in the presence of moisture. This type of corrosion is usually accompanies by a buildup of corrosion products in the contact area. Corrosion progresses more rapidly the further apart the materials are in the galvanic series. For example, aluminum will corrode when in contact with carbon composites. This is especially a problem with the mechanical fasteners generally used in assemblies. Galvanic corrosion can be reduced by insulating the materials in the areas of contact and by applying protective coatings on both materials. Recommendations:

A. Carbon composites in contact with metals
    a. Carbon will induce corrosion when in contact with aluminum when moisture exists, unless moisture intrusion is prevented
    b. Keep carbon composites out of electrical contact with any adjacent metals
    c. Carbon is highly cathodic and will severely attack aluminum and cadmium unless a protective ply of inert cloth (fiberglass kevlar etc) is used between them and or protective paint or sealant is used.
B. If an aluminum part is to be used in contact with carbon parts, all aluminum and carbon parts should be processed as follows prior to assembly:
    a. Method A
        i. Anodize aluminum parts per MIL-A-8615, type II
        ii. Finish external surfaces of both aluminum and carbon parts per MIL-F-18264
        iii. Two coats of epoxy primer per MIL-P-85582
        iv. Two coats of white polyurethane enamel per MIL-C-83286
    b. Method B
        i. Cure a layer of fiberglass ply to the composite interface
        ii. Seal edges of composites
C. Do not use cadmium plated fasteners in carbon composites, install fasteners wet with corrosion inhibiting sealant

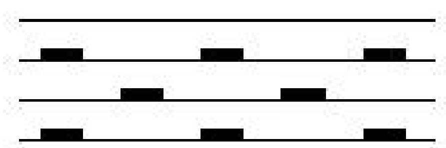
Honeycomb Core

Honeycomb is used extensively in composite panels to add bending stiffness with very little mass penalty. The panel facesheets carry tensile and compressive loads, and the honeycomb carries transverse stresses. In a highly loaded panel, the transverse stresses may approach the strength of the honeycomb. Thus, it is important to use the correct properties when designing a panel.

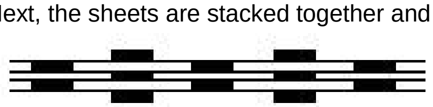
This issue comes up in the shop every once in a while, and I am always surprised when someone does not realize that honeycomb transverse shear properties are dependent upon direction. The two in-plane directions on a panel are called the "L" or ribbon direction and the "W" or transverse-to-ribbon direction. The shear modulus and strength in the ribbon direction are roughly twice that in the transverse direction.

These directions may seem difficult to keep track of, but it is really very easy. All you need to know is how honeycomb is manufactured. After that, you will be able to look at a panel and instantly pick out the ribbon direction, and you will have no trouble remembering which direction is the strongest and stiffest.

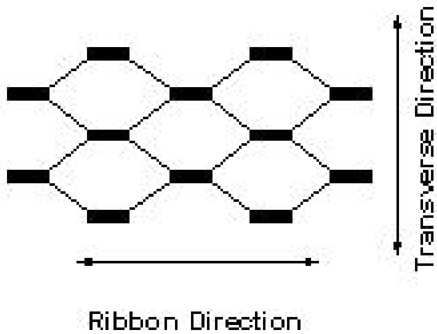
Honeycomb starts out as flat strips of material, or ribbons. Strips of adhesive are placed on the ribbons in a staggered pattern.



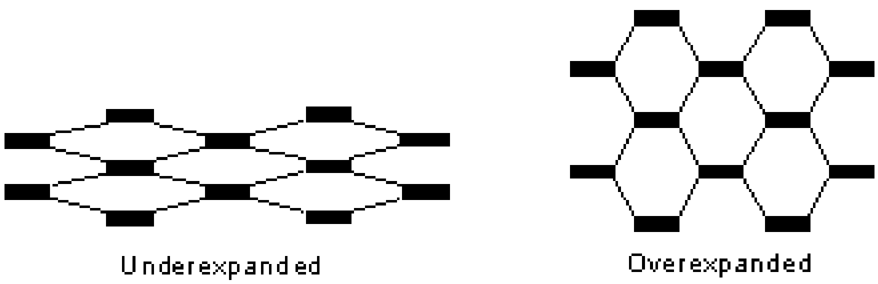
Next, the sheets are stacked together and cured.



Once cured, the blocks are cut to the desired thickness, and then the ribbons are pulled apart or expanded to form honeycomb.



Fully expanded honeycomb forms the familiar hexagon shape. The expansion can be stopped before the hexes are fully formed (underexpanded core) or stopped after the hexes are fully formed (overexpanded or OX core). OX-core cells actually look more like rectangles than I have drawn here.



Normal honeycomb cannot be "bent" very much to form to contours. Underexpanded and overexpanded core can be formed to moderate contours in one direction. For complex, compound contours, Hexcel makes a core called Flex-Core which actually has higher properties when curved than when flat (the shape of the cells is also not hexagonal). By now, it should be obvious why honeycomb is stronger and stiffer in the warp direction.

Empirical Determination of Manufacturing Repeatability of Individual and Assembled Carbon Fiber Rocket Airframe Modules via Strain Measurement at Failure Under Axial Compression

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1. Introduction

Composite materials are becoming more and more ubiquitous in the aerospace industry. Their extremely efficient strength to weight ratios compared to traditional materials like aluminum and steel make composite materials very attractive for high strength, lightweight applications. Additionally, composite structures are highly customizable by taking advantage of their anisotropic material properties. For these reasons, the Portland State Aerospace Society (PSAS) Composite Airframe Capstone Team has chosen to design the next generation PSAS launch vehicle airframe using composite materials.

During a launch event, a rocket airframe experiences a tremendous amount of axial compressive stress. The compressive strength of laminate structures is typically about one half of its respective tensile strength. This is because compressive failure is usually initiated by micro-buckling of individual fibers within the matrix [1].

Thus, the cylindrical laminate structure of the airframe modules is susceptible to two compressive failure modes, the first being local compressive failure due to fiber micro-buckling and the second being macro-scale buckling of the thin-walled cylinder.

Because of the level of uncertainty involved in the buckling of laminate structures [1], this experiment did not seek to compare experimental and theoretical buckling characteristics. Rather, this work examined the consistency and repeatability of the next-generation PSAS airframe module manufacturing process through the measurement of strain at failure during axial compressive loading.

Specifically, the experiment considered the performance of the modules in several categories. First, the ultimate strength of individual and assembled modules was considered. Then, the effect of load distribution around the circumference of the module and on the inside and outside carbon plies was examined. Finally, the post-test performance of the coupling rings was evaluated.

2. Methods

2.1 Airframe Module Design

The PSAS launch vehicle airframe is designed to be modular, so the airframe is broken up into modules that house various components including the avionics, propulsion, and recovery systems shown. A schematic of this design can be found in Appendix A.

The design of the airframe modules used in this experiment consisted of a cylinder composed of single carbon fiber plies oriented at zero degrees and bonded to either side of a quarter inch thick aramid, over-expanded honeycomb core. The laminate structure of the cylinder is also bonded to aluminum coupling rings at each end, as seen in Fig.2.1.1. The material properties for the carbon fiber used may be found in Appendix A [2].

Figure 2.1.1. Cross-sectional view of a prototype airframe module. The single carbon fiber ply honeycomb core composite structure is bonded to aluminum coupling rings. Note: Ring pictured is not the ring used during the experiment.

A male coupling ring (MCR) and a female coupling ring (FCR) are bonded to the ends of each module and facilitate the integration of each module with the rest of the rocket airframe. The MCR and FCR can be seen in Fig.2.1.2.

Figure 2.1.2. Male Coupling Ring (left) and Female Coupling Ring (Right) used during experiment.

2.2 Airframe Module Fabrication

The fabrication of the airframe modules consists of two main processes: the machining of the coupling rings and the composite layup of the complete individual module assemblies.

The coupling rings are machined from 6061-T6 aluminum extruded pipe stock with a modulus of elasticity of $10x10^6$ psi [3]. The dimensions of the MCR and FCR may be found in Appendix A. All machining processes were performed in-house with the goal of maintaining overall assembly tolerances of +/- 0.0025”.

The composite layup process consists of placing the constituent components of the assembly on a male mandrel between a pair of fixed “dummy” mating rings. This assembly is then wrapped with perforated shrink tape that applies pressure to the laminate during the elevated temperature curing cycle. The assembly is then placed in a curing oven that ramps up to 350 °F at 3 °F/min. The part is cured at 350 °F for two hours.

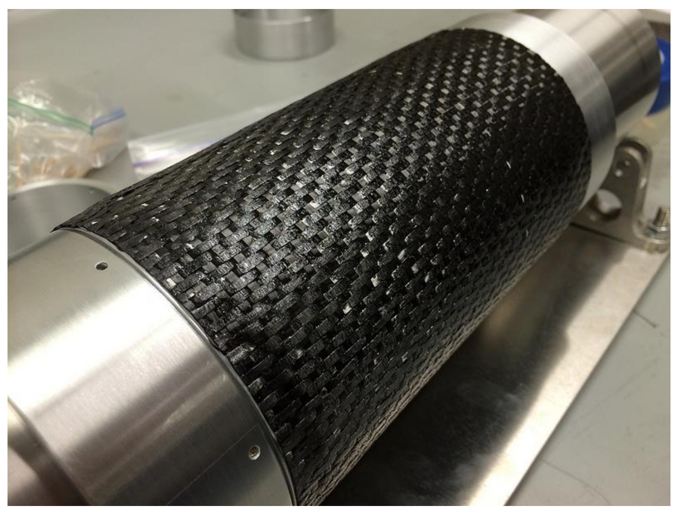


Figure 2.2.1. PSAS airframe module on layup mandrel prior to being wrapped with perforated shrink tape and cured in oven. Note: The large aluminum ring visible on the ends of the carbon fiber enhances the performance of the shrink tape and assists in locating the coupling rings on the mandrel.

2.3 Strain Gauge Theory

A strain gage is a device used to measure strain on an object. For an idealized strain gauge using a quarter Wheatstone bridge, the strain (ε) is a function of the excitation voltage (V_{ex}), the amplifier gain (A), the gauge factor (F), and the output voltage (V_o) as shown in Equation 2.3.1. [4]

$$\varepsilon = \frac{4V_O}{V_{ex} * A * F} \qquad [2.3.1]$$

This strain is then related to stress (σ) by Eqn.2.3.2 using the modulus (E) of the material. [4]

$$\sigma = \varepsilon E \qquad [2.3.1]$$

2.4 Strain Gauge Installation

Data from multiple strain gauges at a variety of module locations was collected during each test. For all tests, a dummy ring was mated to the top of the airframe module to ensure even loading of the module during the test. The dummy ring was fitted with three strain gauges placed radially approximately 120° apart. The fitment of a typical strain gauge may be seen in Fig.2.4.1.

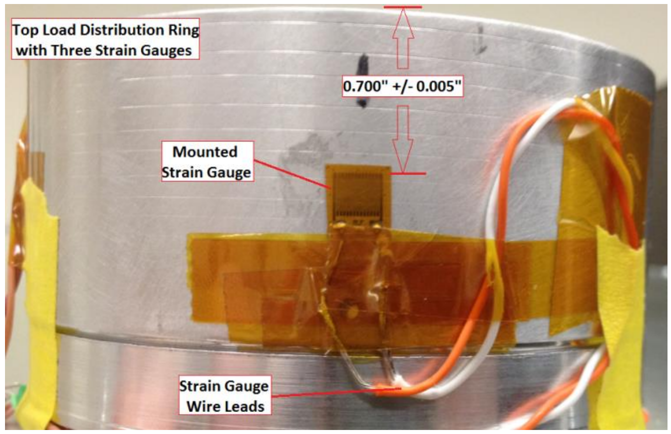


Figure 2.4.1. Typical strain gauge fitment to dummy ring placed atop airframe module during testing.

Each module was fitted with a strain gauge on the inside and outside plies of carbon fiber. A typical fitment to the exterior ply may be seen in Fig.2.4.2.

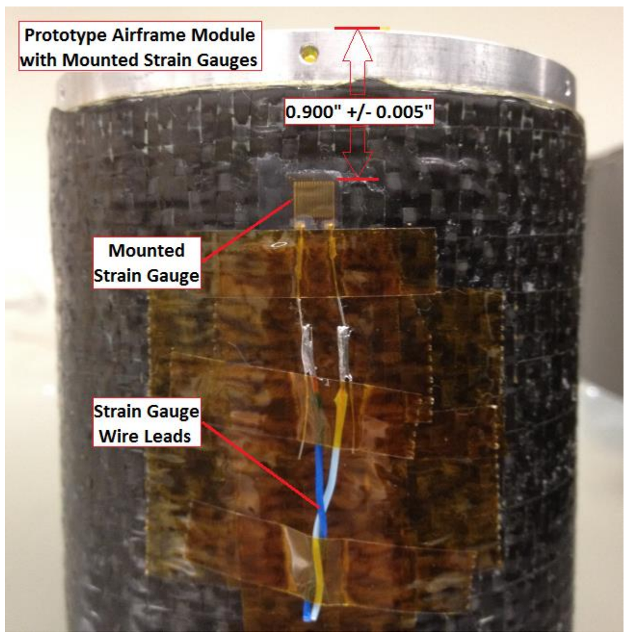


Figure 2.4.2. Typical strain gauge fitment to the exterior ply of an airframe module.

Each strain gauge was connected to a custom Wheatstone bridge and amplifier circuit board with schematic shown in Appendix B. The circuit used a clean 5.0V +/- 5% bench-top power supply. The amplifier gain was set to 100 and the output was sent to an analog input of a National Instruments USB-6008 data acquisition system with 12-bit resolution. A typical set of amplifier connections may be seen in Fig.2.4.3.

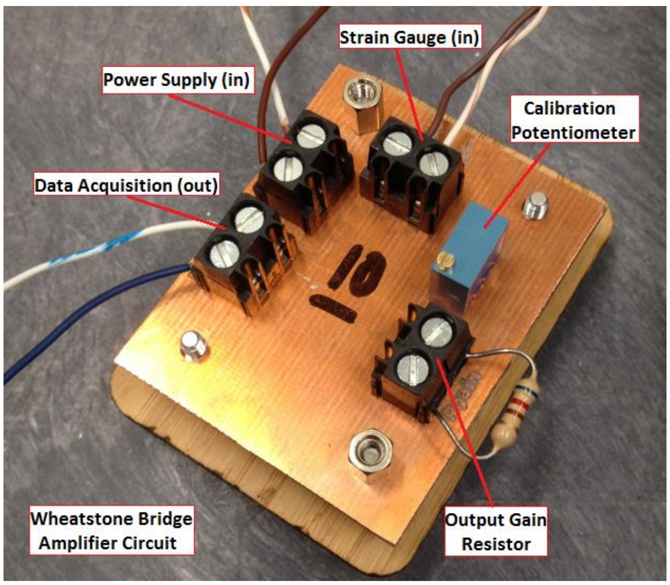


Figure 2.4.3. Typical set of connections made to custom strain gauge circuit boards used to amplify strain gauge signal output to NI USB-6008 DAQ.

2.5 Experimental Procedure

In this experiment, three individual modules and two assembled modules (shown in Fig.2.5.1) were subjected to axial compression loading until failure with a high capacity concrete compression machine. The modules were supported with male and female dummy mating rings through which the load was transferred into the laminate structure. The top, female dummy ring with evenly spaced strain gauges was used to measure the relative distribution of the applied load. The load was applied very slowly until it reached 700 lbf, at which point additional load was applied at a rate of 50 lbf/s until failure.

Figure 2.5.1. Photo of assembled modules placed in compression testing machine

3. Analysis

Analysis was done by first using Eqn.2.3.1, relating strain to voltage across a quarter bridge circuit with an amplifier. This method was compared with strain calculated from Eqn.2.3.2 in conjunction with cross-sectional area and the maximum load reported by the compression machine.

Figure 3.1 analyzes the strain around the aluminum dummy ring that was mated to the top of every module during testing. The maximum reading for each of the three strain gauges was collected and converted from voltage to strain using Eqn.2.3.1. Then, the theoretical strain was calculated for the aluminum using Eqn.2.3.2. The error between average and predicted strain values for each test are shown in Table 3.1.

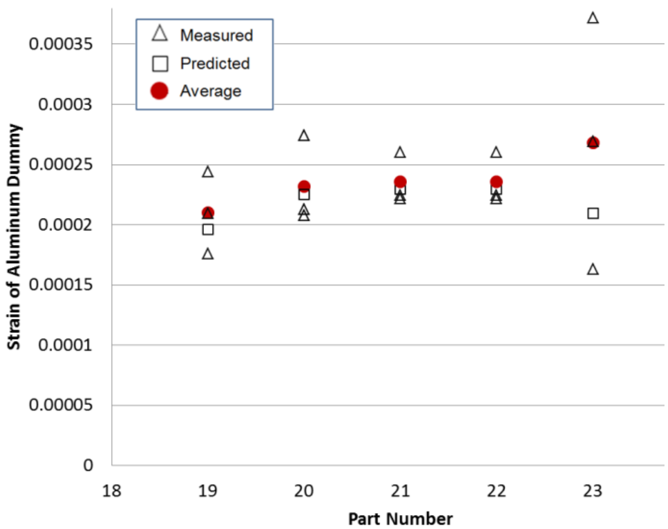


Figure 3.1. Plot of measured, average, and predicted strain at failure of the aluminum dummy ring for each test (labeled by part number). The average was calculated from the three measured strain locations on the dummy ring. The predicted strain was calculated based on the maximum load reported by the compression machine. Note: parts 21 and 22 were the assembled modules, tested at the same time.

Table 3.1. Percent error between measured and predicted strain of aluminum dummy ring for each test.

Part Number	19	20	21/22	23
Error (%)	2.6	2.75	6.56	21.7

This analysis shows that the measured strain is a maximum of 21.7% different than the calculated strain at failure. Thus, there is reason to believe that both the measured strain data and the maximum load reported by the compression machine are valid measurements.

4. Results

The ultimate strength of the individual modules varied from approximately 6220 to 7140 lbf. This is a 13% difference in strength. Buckling was the primary failure mode experienced during the tests. An example of the buckling failure mode may be seen in Figure 4.1. This level of module strength represents a factor of safety of approximately 9 over the anticipated launch load that the modules will experience.

Figure 4.1. Photo of failed individual airframe module with highlighted buckled region

The maximum strain variation observed within the dummy ring during all tests was approximately 20%. There did not appear to be a strong correlation between the load variation and maximum module strength, as the weakest module only experienced 12% load variation.

There was no evidence of failure of the aluminum coupling rings or the bonding of the rings to the carbon structure during any tests. During post-test disassembly, the modules separated easily from dummy rings and fasteners were removed easily from the assembled modules.

The experimental results indicate that both the interior and exterior plies of all modules were loaded relatively evenly. This may be seen in the typical strain gauge data shown in Fig.4.2. For supplemental raw data, see Appendix C.

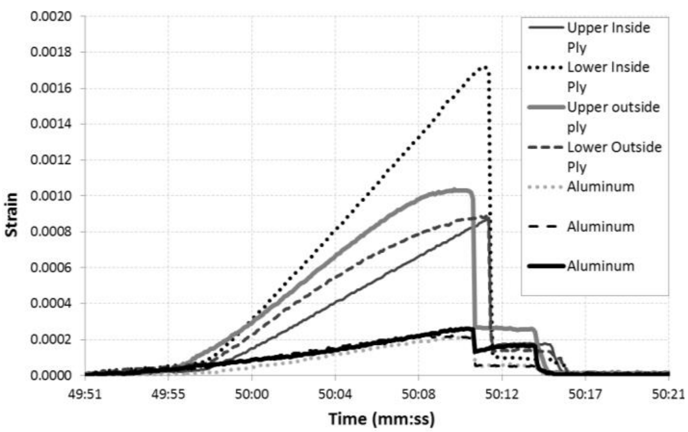


Figure 4.2. Representative plot showing strain vs. time of assembled modules seen in Fig.2.5.1.

The maximum strength of the assembled (stacked) modules was approximately 7220 lbf. This result exceeds the strongest individual module by approximately 1%, indicating that there was no substantial change in module strength when assembled.

5. Discussion & Conclusions

The experimental results indicate that the manufacturing methods used in the fabrication of the tested modules produce variation within the module strength that is accounted for by the design's factor of safety. This indicates that these methods are reliable for fabrication of the PSAS next-generation airframe modules.

During fabrication, inspection of the coupling rings indicated that the thickness of the web between each rib deviated from the specified dimension 0.030”+/-0.0025” by 0.010” to 0.020”. This deviation did not appear to have a significant effect on the strength of the modules.

In the future, the strain data collected from this experiment may compared to strain data collected from actual launches to better correlate these results with actual loads.

6. References

[1]E. J. Barbero, *Introduction to Composite Materials Design, Second Edition*. CRC Press, 2010.

[2] “*CYCOM® 934 EPOXY PREPREG”, Cytec engineered material.* [Online]. Available: http://www.cemselectorguide.com/pdf/CYCOM_934_032012.pdf . [Accessed: 17-Mar-2014].

[3] “Aluminum material properties.”, *Aerospace specification metals*, [Online]. available:http://asm.matweb.com/search/SpecificMaterial.asp?bassnum=MA6061t6. [Accessed: 17-Mar-2014].

[4]D. Tretheway, “Experiment 2: Strain Gauge Dynamic Testing W13.” Portland State University.

Appendix A – Module Design

The contents of this appendix include the current modular rocket design shown in Fig A.1, the material properties for the carbon fiber composite used in testing shown in Table A.1, and the machine drawings for the FCR and MCR rings shown in Fig A.2.

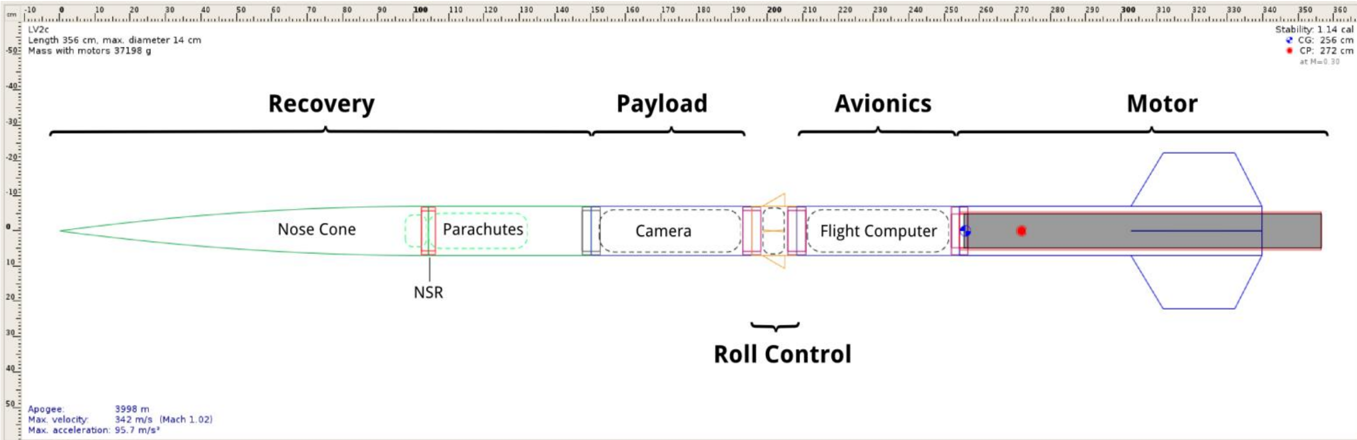


Figure A.1. Diagram showing modular design of rocket airframe

Table A.1. Typical Properties of CYCOM 934 Composite Laminates: High Strength (>500 ksi/>3447 MPa), Standard Modulus (33 Msi/228 GPa Class) Carbon Fiber Reinforced 5 Harness Satin Fabric - CEM Product Codes HMF 398/34, HMF 2323/34, HMF 2454/34

Mechanical Properties	**Test Condition**		
	Room Temperature	**250°F (121°C)**	**250°F (121°C) Wet**
0° Tensile Properties			
Strength, ksi (MPa)	110 – 130 (758 – 896)	110 – 130 (758 – 896)	90 – 100 (620 – 689)
Modulus, Msi (GPa)	11 (76)	11 (76)	8 – 10 (55 – 69)
0° Compressive Properties			
Strength, ksi (MPa)	110 – 120 (758 – 827)	90 – 100 (620 – 689)	60 – 70 (414 – 483)
Modulus, Msi (GPa)	9 – 10 (62 – 69)	9 – 10 (62 – 69)	
0° Flexural Properties			
Strength, ksi (MPa)	160 – 190 (1103 – 1310)	130 – 150 (896 – 1034)	–
Modulus, Msi (GPa)	10 (69)	10 (69)	–
Interlaminar Shear Properties			
Strength, ksi (MPa)	10 – 13 (69 – 90)	8 – 9 (55 – 62)	4 – 5 (28 – 35)

Property values listed are typical for laminates with 55 to 60% fiber volume
Wet = 7 day water immersion at 165°F (74°C)

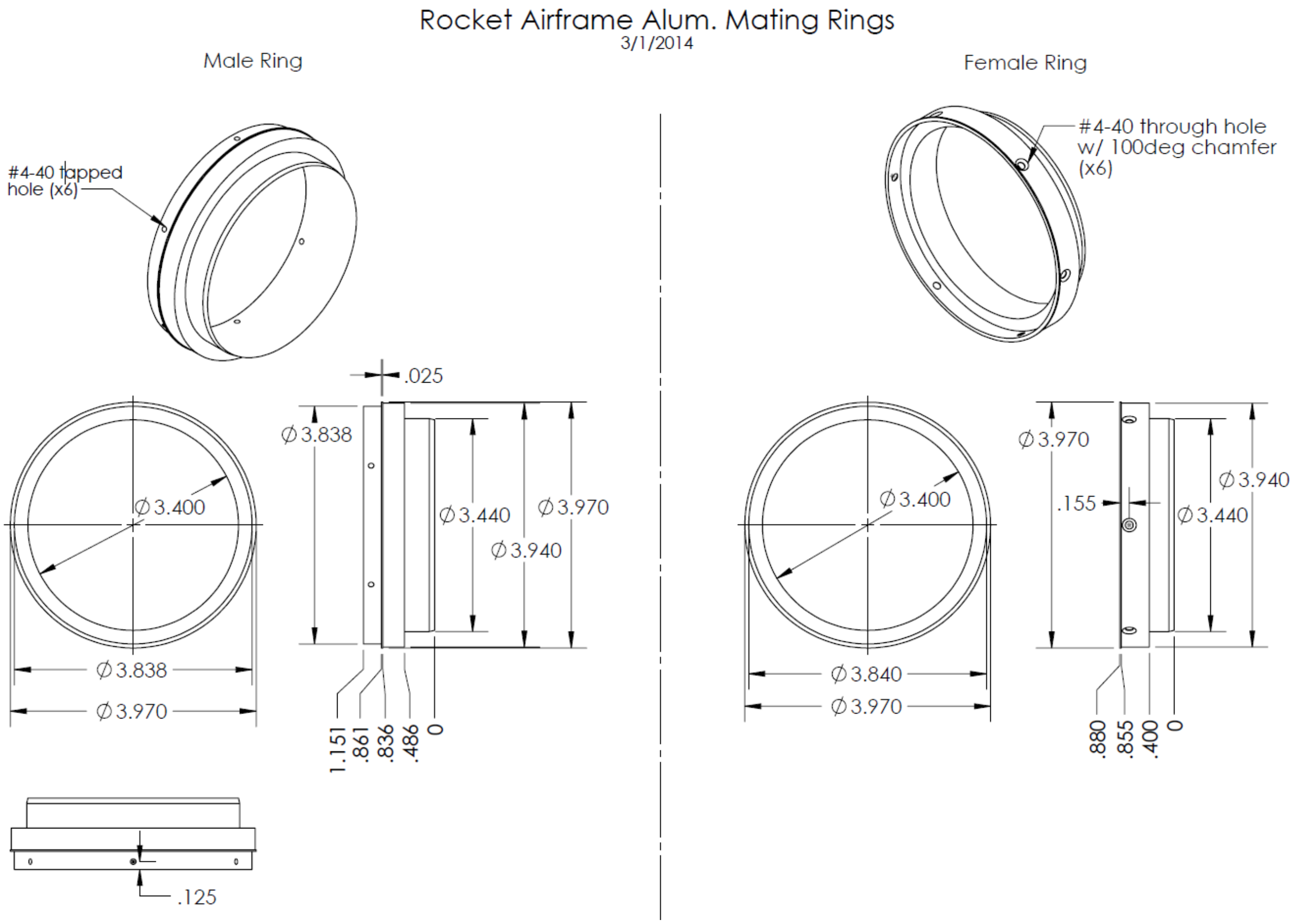


Figure A.2. Machine drawings for female and male coupling rings showing dimensions (in inches)

Appendix B – Experiment Design

The contents of this appendix show a schematic of the Wheatstone bridge amplifier circuit that was used during testing, shown in Fig B.1.

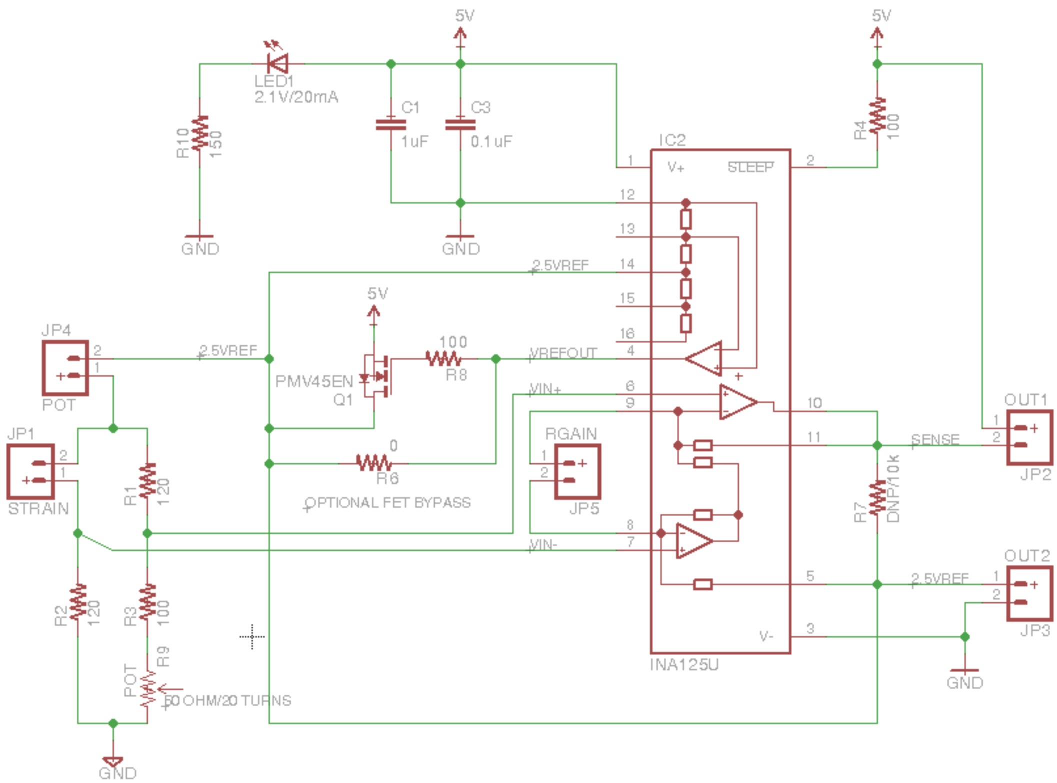


Figure B.1. Schematic of strain gauge amplifier and Wheatstone bridge circuit board used

Appendix C - Raw Data Plots

The contents of this appendix show very basic plots of strain vs. time for every test completed during the experiment. Each test corresponds to a module part number. Parts 19, 20, and 23 were tested individually, shown in Fig C.1, Fig C.2, and Fig C.3, respectively. Parts 21 and 22 were tested as assembled modules, shown in Fig C.4.

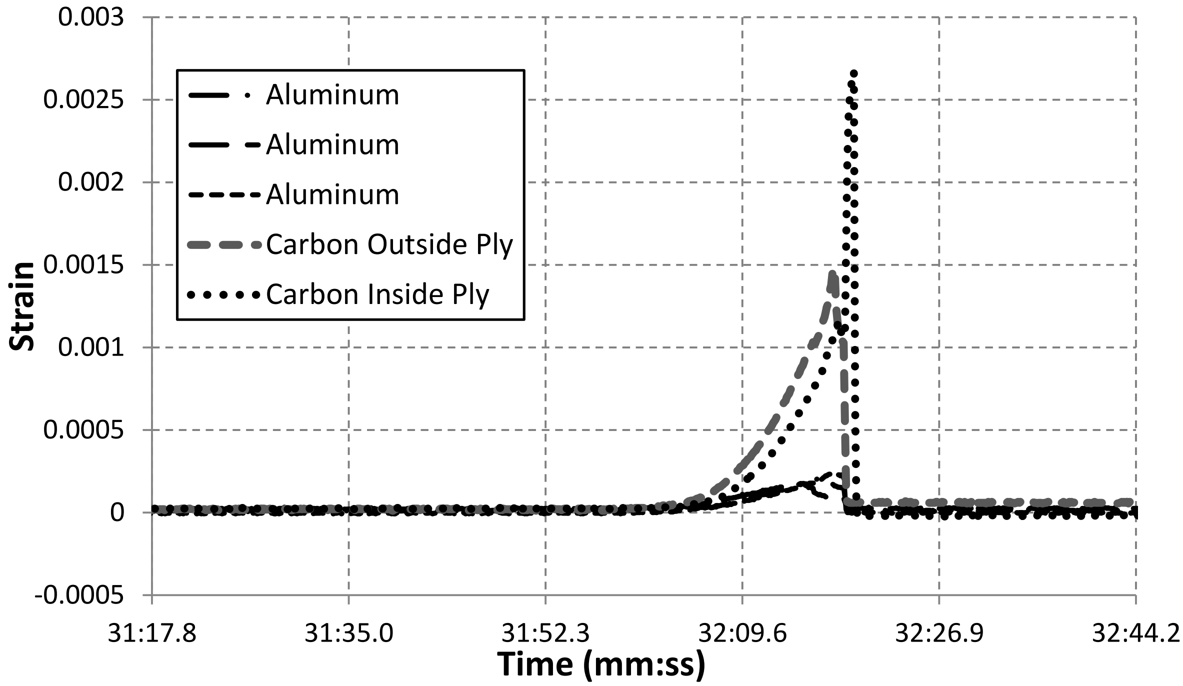


Figure C.1. Individual test part 19 plot of strain vs time

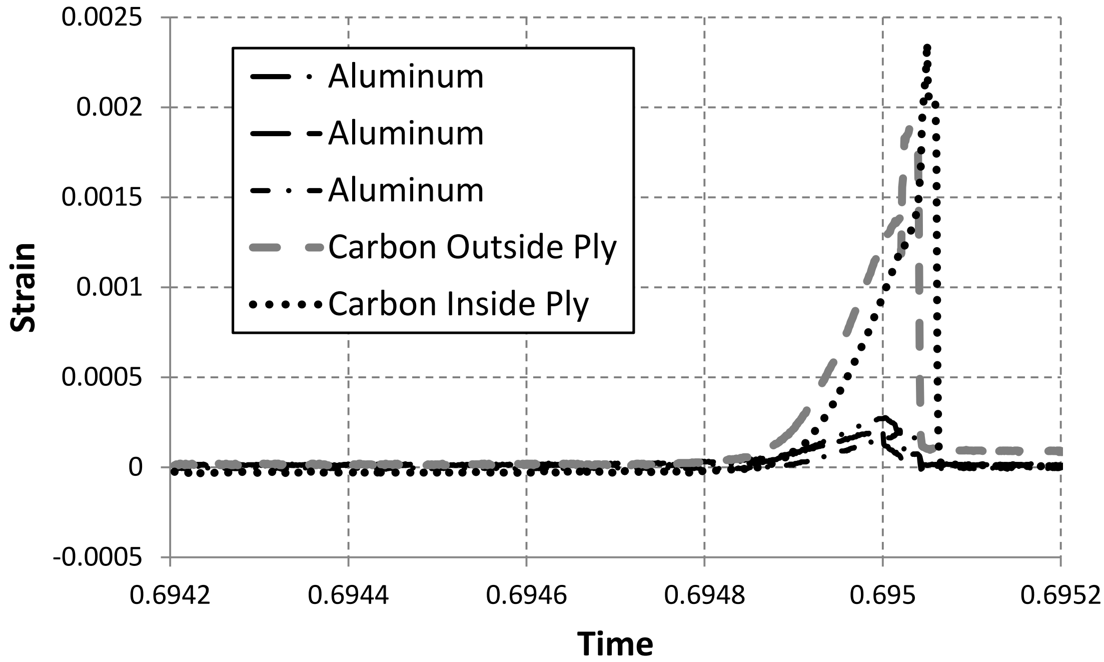


Figure C.2. Individual test part 20 plot of strain vs time

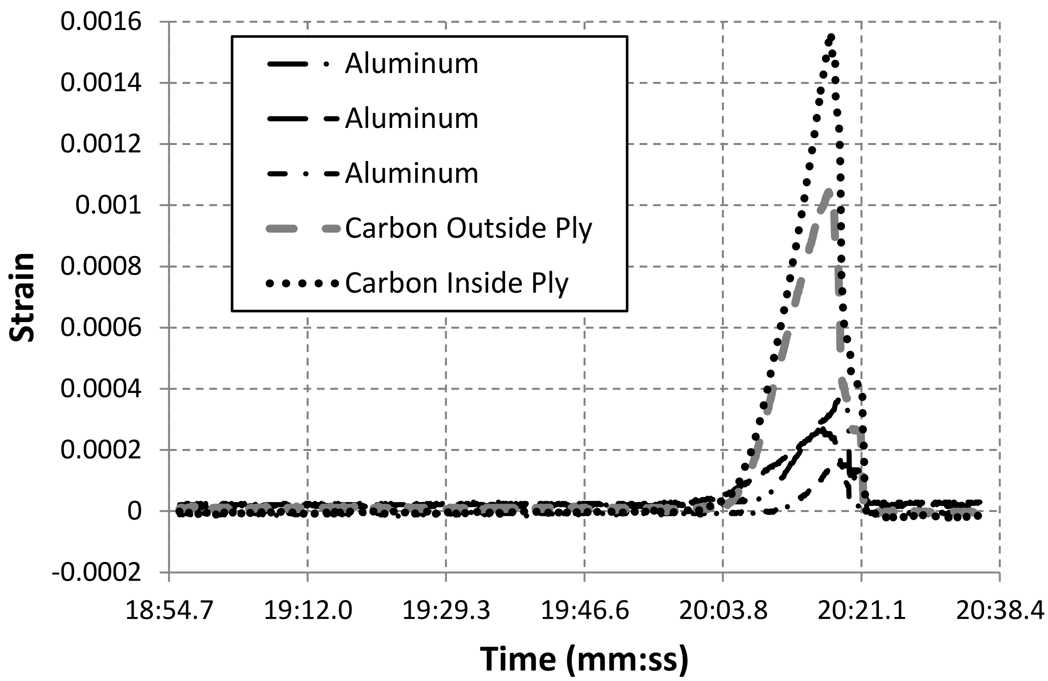


Figure C.3. Individual test part 23 plot of strain vs time

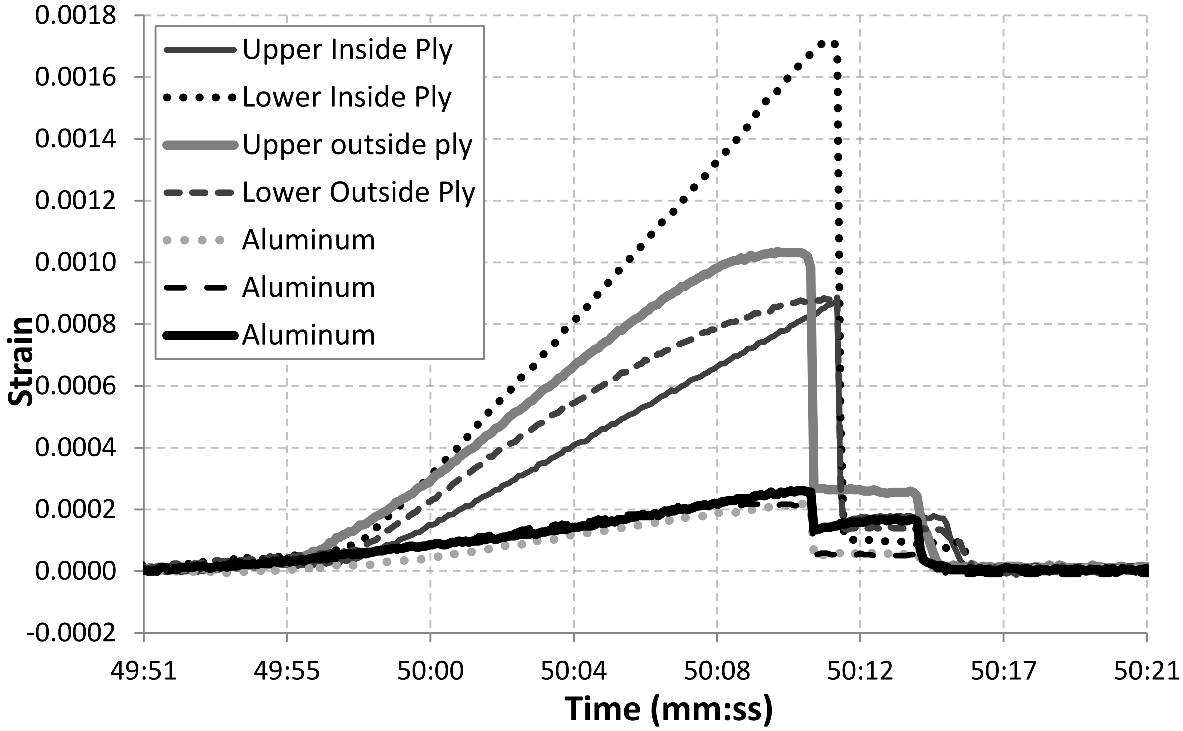


Figure C.4. Assembled test parts 21 & 22 plot of strain vs time

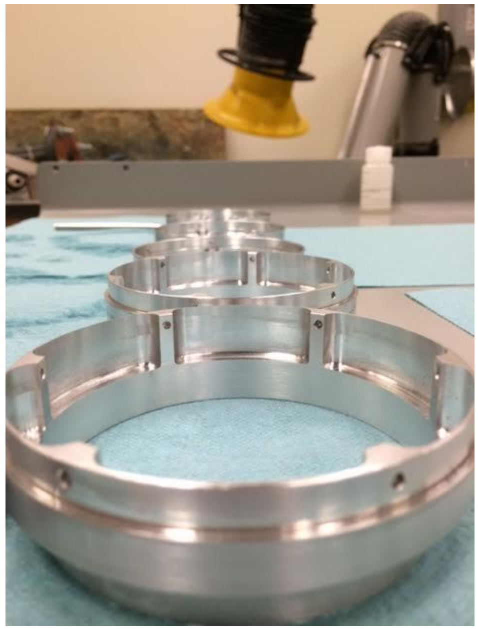
Tips and Tricks

1. Staying clean and organized is very important.
2. A heat gun is super useful for dealing with the adhesive film. However, be careful not to let it get too hot. A little bit goes a long way.
3. Adhesive film is hard to remove from its backing, especially with gloves on. You can use the tongue depressor against the edge after sticking it to the part to get the backing off. Leave the blue side of the adhesive on.
4. The carbon sticks to the adhesive film too well, don't stick it down unless you are sure it is in the correct spot.

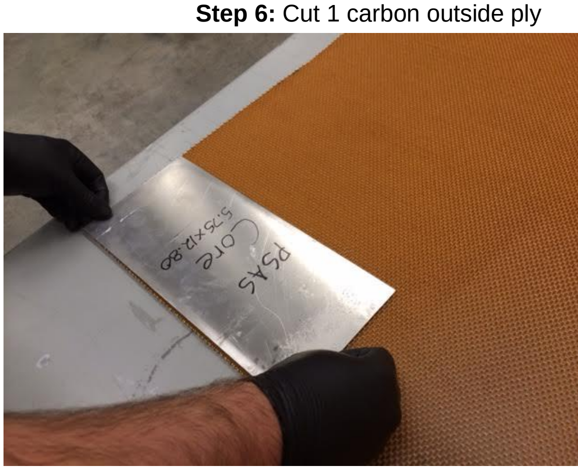
Procedure

1. Clean all surfaces and the floor using acetone, brooms etc.
2. Put on gloves
3. Arrange 4 work surfaces, each with a specific task:
    a. Layup
    b. Tool treatment
    c. Cutting pieces of composite material
    d. Aluminum mating ring treatment
4. Clean all the metal tools and part surfaces using acetone. Each part should cleaned thoroughly so that it leaves no visible residue on the towel.

5. Wax the mandrels using Orca hybrid mold release according to the instructions on the can.
6. Similarly, wax the inside of the aluminum mating rings, making sure not to get any mold release on the carbon bond surfaces of the aluminum rings
7. Thoroughly sand the carbon bond surfaces of each aluminum mating ring to remove the oxide layer. When you're finished sanding, the surfaces must be cleaned thoroughly with acetone.
8. Apply the 3M anti-galvanic corrosion agent to the bond surfaces by following the instructions on the package. In general, the solution should be applied with a brush constantly for about 3 minutes then left to dry and set for at least an hour.

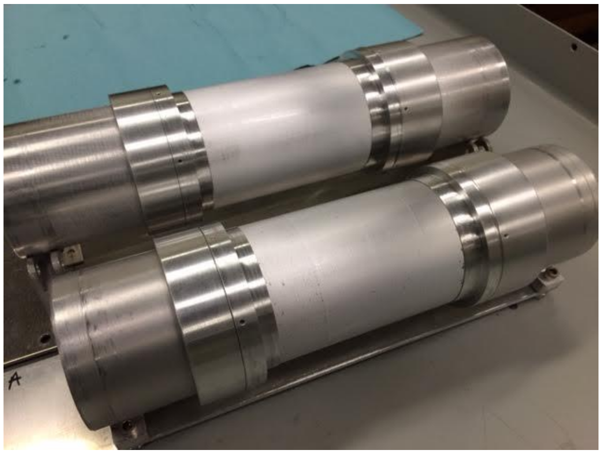


9. Cut the following layers using a sharp razor (except the core) and the cutout templates. Templates are labeled as steps 1-6.
    - **Step 1**: Cut 2 strips of aluminum step adhesive
    - **Step 2**: Cut 1 carbon inside ply
    - **Step 3**: Cut 1 inside film adhesive layer
    - **Step 4**: Mark with sharpie the outline of the honeycomb core layer. Use scissors to cut the core
    - **Step 5:** Cut 1 outside film adhesive layer
    - **Step 6:** Cut 1 carbon outside ply

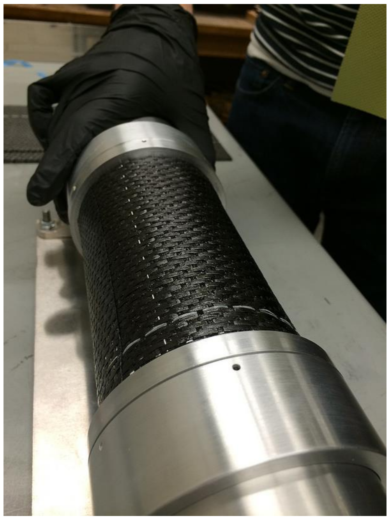



10. Lay everything out. ***If you need more than ~30minutes of time before laying up the module, the carbon and adhesive layers must be put back in the freezer until layup***.

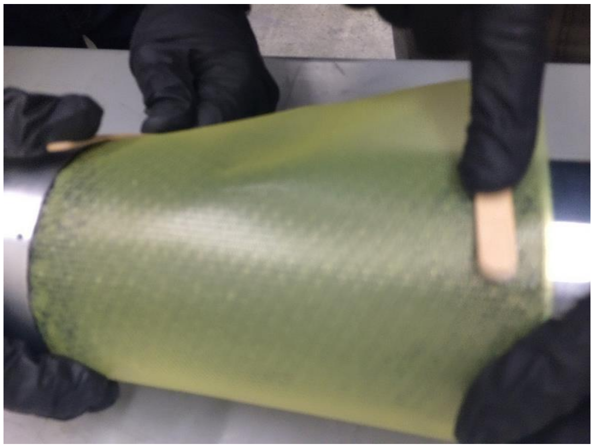
11. Slide the aluminum mating rings over the mandrel, making sure the orientation is correct
12. Slide the dummy layup rings onto the mandrel and fasten them to the mating rings
13. Fasten the dummy rings to the mandrel



14. Wrap the two thin strips of adhesive around the lower bond surface of the mating rings.
15. Wrap the first layer of carbon. Make sure that the adhesive film layer underneath doesn't move off of the step and onto the mandrel. It works best if one person does the aligning and the other rotates the mandrel. Wrap it snugly, but be sure to not introduce any warping of the fibers. Don't allow any air bubbles to remain.

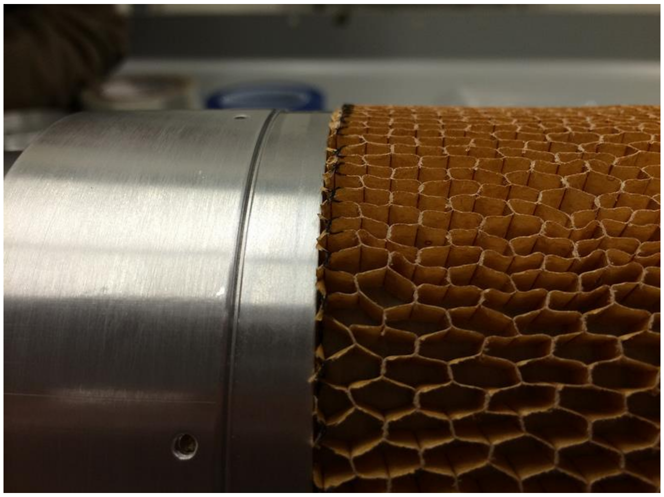


16. Use a tongue depressor in a rocking fashion (perpendicular to mandrel axis) to flatten out the carbon on top of the bond areas. This ensures good contact between the carbon and the bond area.

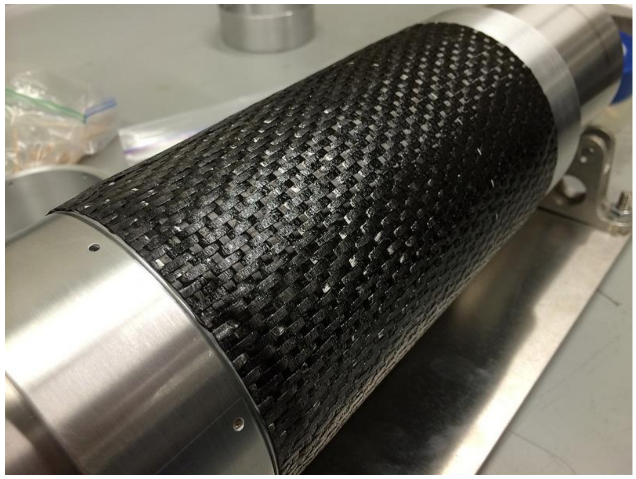


17. Wrap the inside layer of film adhesive on top of the carbon. Try to align the edges as well as possible, but it's okay if there are wrinkles. The adhesive will melt and flow during cure.

18. Wrap the honeycomb core layer. Use the heat gun sparingly to warm the adhesive underneath and press the core onto the adhesive to make it stick.
19. When you get to the end of the core wrap, compress the excess length of core and force it up against the other side. This compressed area will prevent gaps from forming at the core seam during cure.



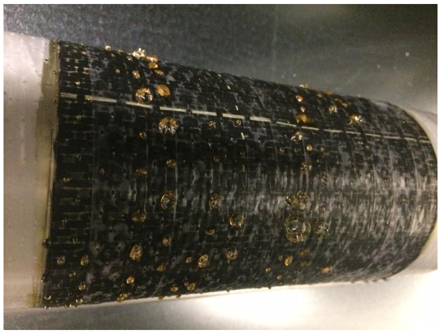
20. Wrap the outside layer of adhesive film. This one will go over both the core and rings. Try to align the edges of the adhesive with the step on the mating ring as well as possible.
21. Wrap the outside layer of carbon. Make sure that the lettering on the carbon does not end up on the outside of the module.



22. Wrap the perforated shrink tape across the length of the mandrel so that it overlaps itself 50% each time. Start the wrap on the dummy, taping it down well with the flash tape (clear blue). Then, have one person rotate the mandrel, one person hold the shrink tape roll, and one person align the tape as it is wrapped. The person aligning the shrink tape should also tension the tape so that it is taught as it is wrapped but not tight. End the shrink tape at the other dummy and secure it with flash tape.

23. Wrap a diaper made from the breather cloth and use flash tape to secure it.

24. Put The mandrel into the oven on the aluminum stands
25. Turn on bake cycle. 3deg/min ramp up to 350F, where it is held for 2 hours.
26. Let cool slowly. The part will crackle as it cools down. This is normal.
27. Sometimes you have to hammer the parts off the mandrel. Whatever method you use, be sure not to damage the aluminum rings



HAAS 3-AXIS CNC

OPERATING INSTRUCTIONS

Jack Slocum
Sam Arnold
Barett Strecker
Robert Melchione

5/28/2014

Portland State
UNIVERSITY

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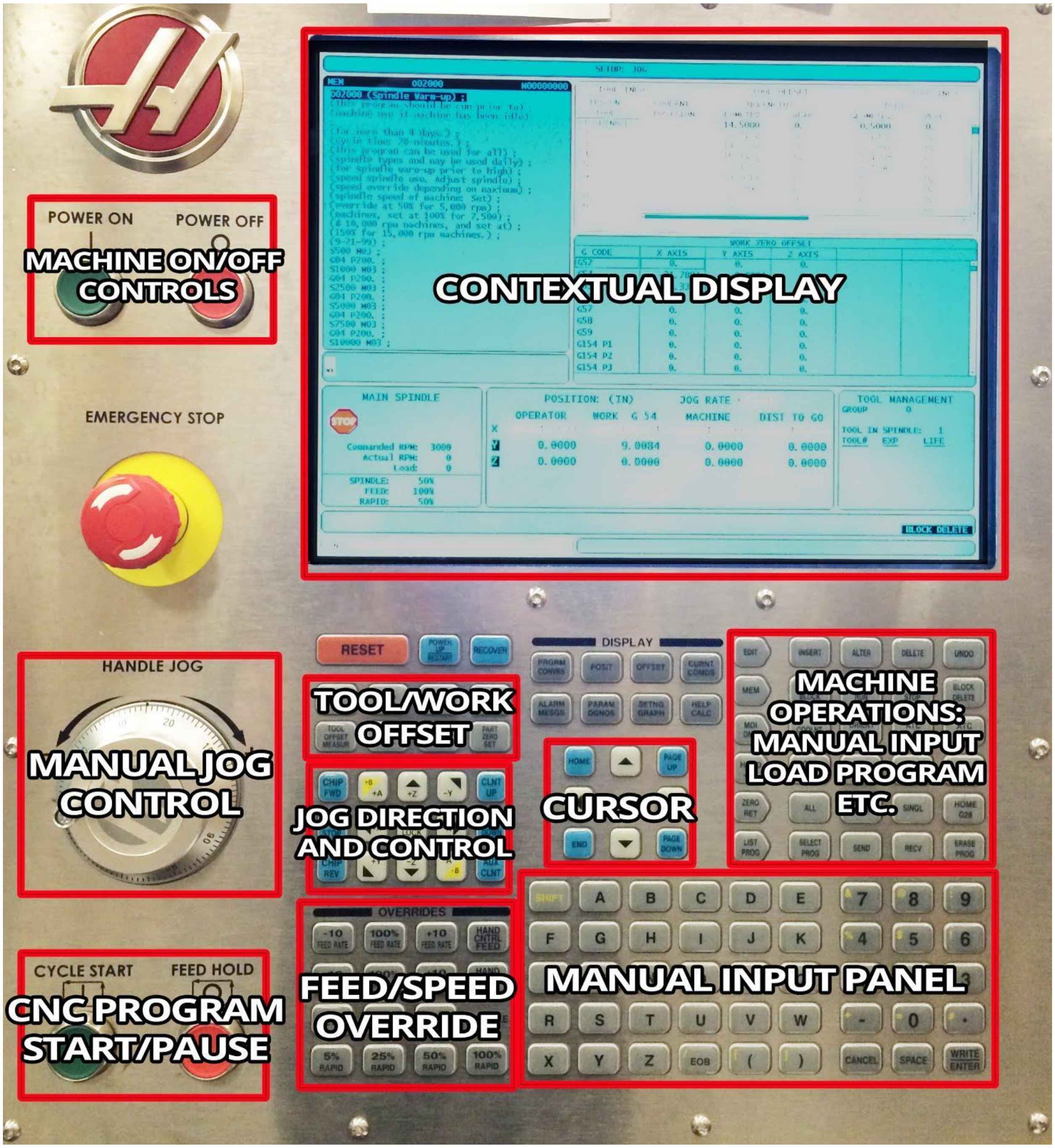
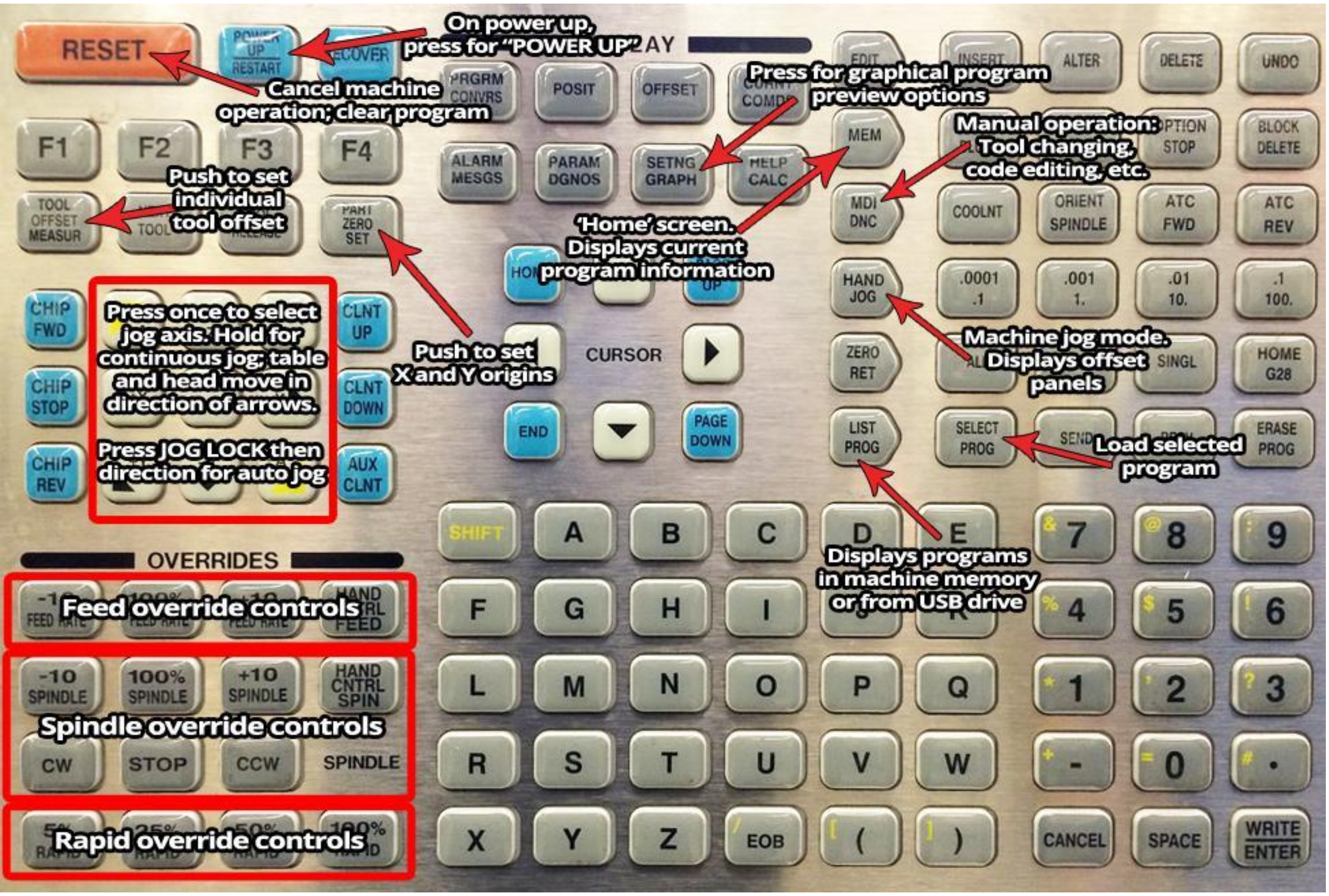
CONTROL PANEL OVERVIEW

General organization:





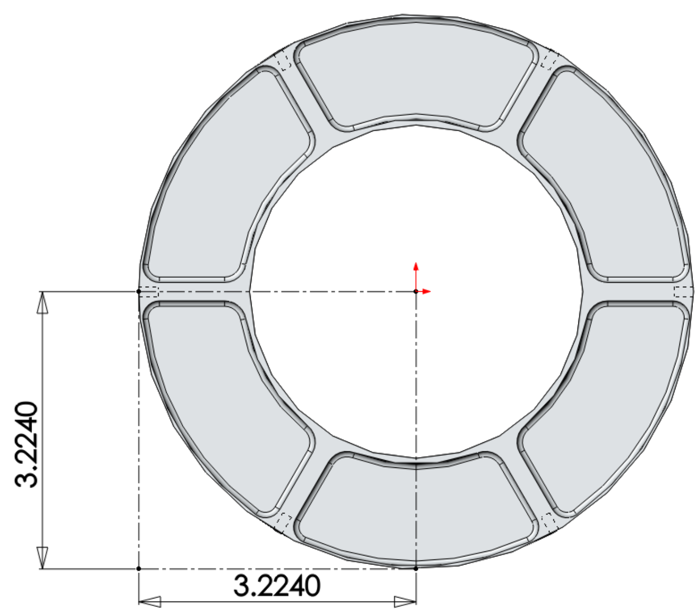
Detail view of common operations:

MACHINE STARTUP INSTRUCTIONS

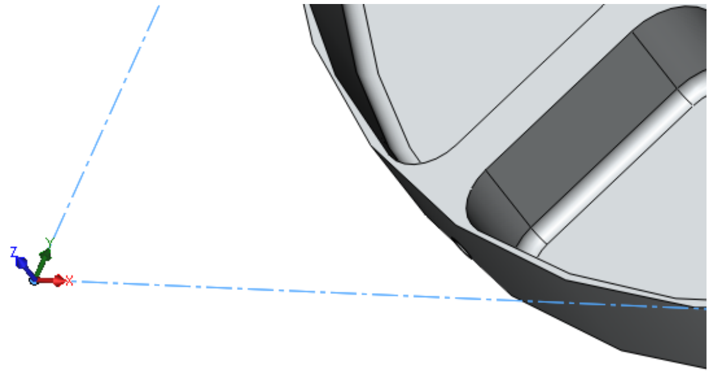
1. Start up machine following the prompts
    a. Push the **POWER ON** button
    b. Follow the prompts in the yellow blinking box on the left side:
        i. **EMERGENCY STOP** on and off
        ii. Close door (make sure the vice handle has been removed or it will crash into the door)
        iii. Push **RESET**
        iv. Push **POWER UP**
            1. Wait until final beep
2. Run spindle warm up program program number **002000**
    a. Push **LIST PROGRAM**
    b. Push **ENTER** to open machine memory tab
    c. Scroll to the **002000** program, so it is highlighted
    d. Push **SELECT PROGRAM**, *not* **ENTER**
    e. Press **MEM** and look at the program in the memory panel to verify that program **002000** is loaded
    f. Use Spindle Override to decrease spindle to 50%. This is necessary based on the max. RPM of the machine, which is 5000 RPM.
    g. Cycle start
        i. This program takes 20 minutes, and will incrementally increase the spindle speed up to 5000 RPM
3. Turn the machine light on. The button is located on the side of the control box, indicated by a light symbol

PROGRAM PREPARATION

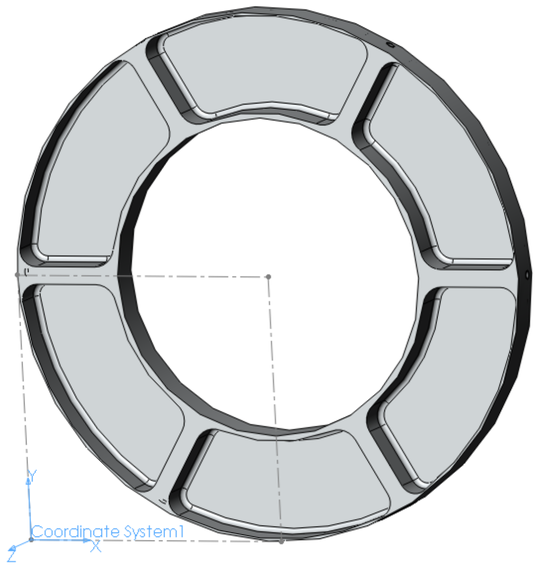
4. Open your part in Solidworks
5. Create coordinate system that will allow you to zero X, Y, and Z coordinates once your stock is in the machine.
    a. Sketch a location you could measure on your stock



    b. Create coordinate system, where Z is out of the screen toward you, X is to your right, and Y is up

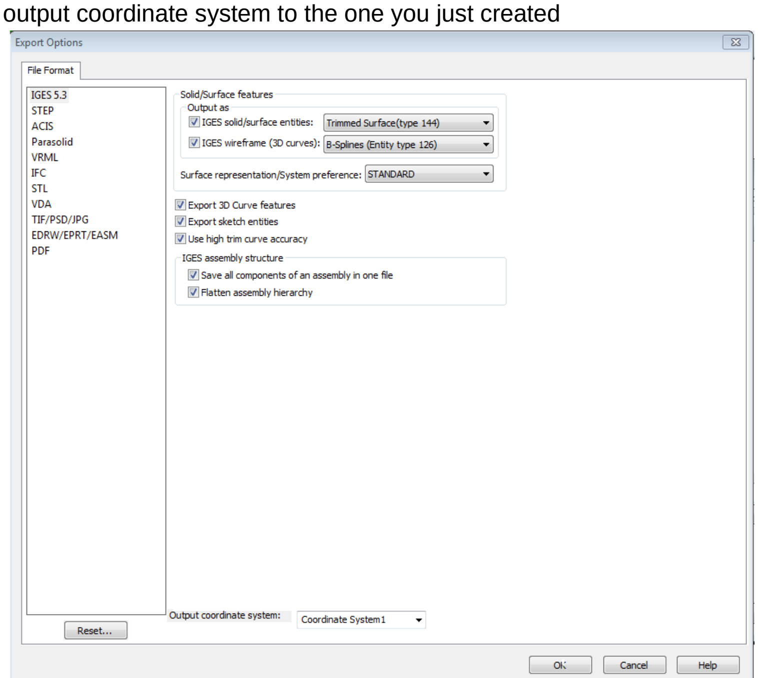


c.



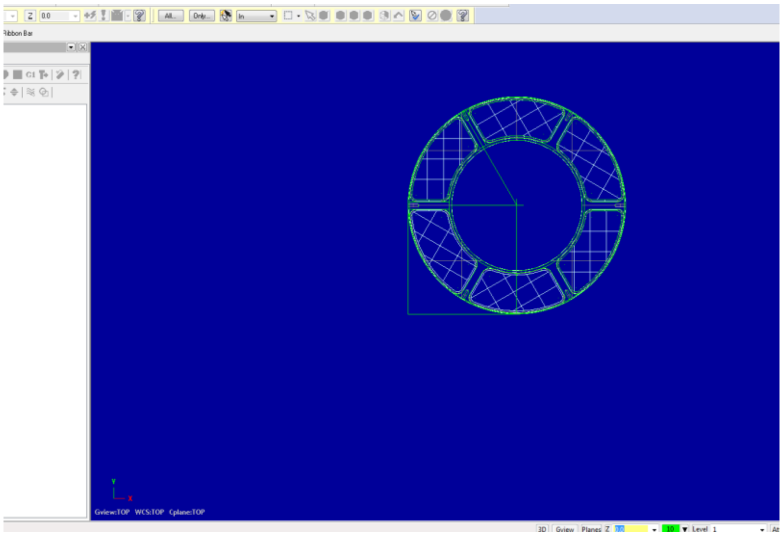
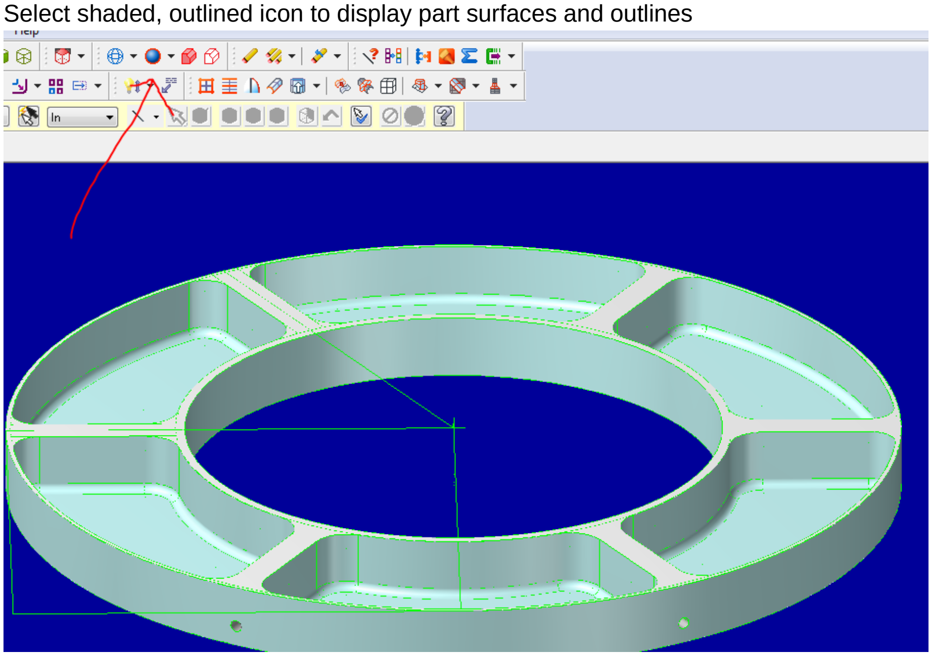
d.

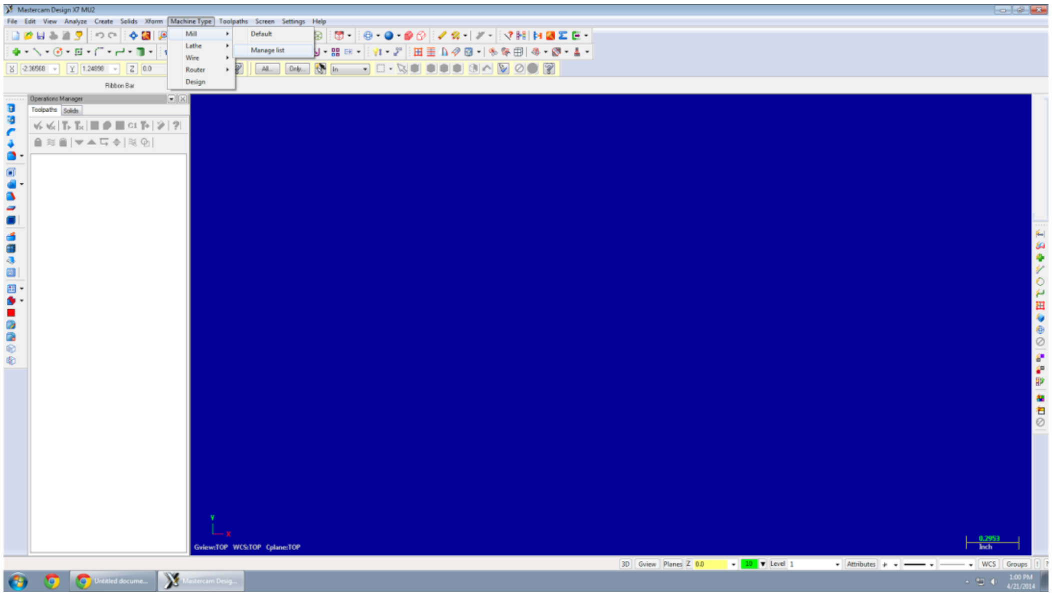
e. Save as IGES file type, and before clicking OK, click **Options** from the dropdown at the bottom of the window, set your output coordinate system to the one you just created



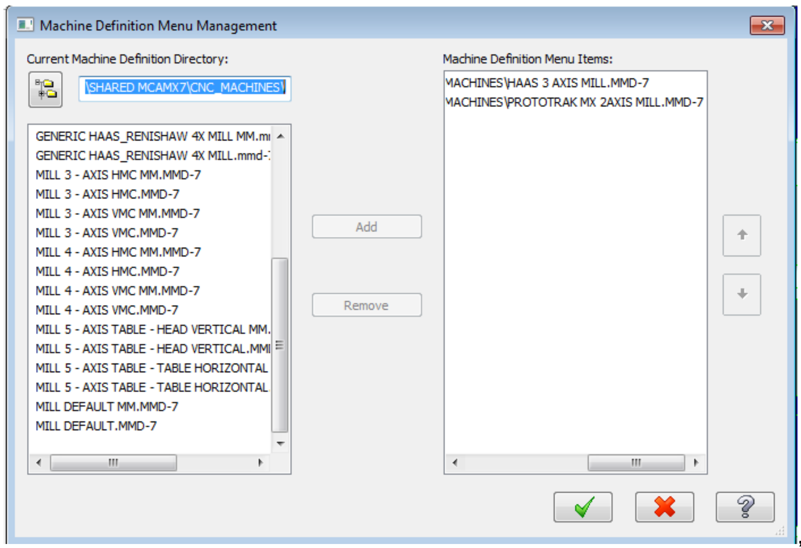
f.

MASTERCAM PROGRAMMING

6. Open MasterCAM x7
7. Open your IGES part
    a. Your part should pop up facing you the way you intend to machine it
    b. 
    c. Select shaded, outlined icon to display part surfaces and outlines
    d. 
8. Click **Machine Type > Mill > Manage List*** (*only necessary if the Haas 3-axis is not already listed)



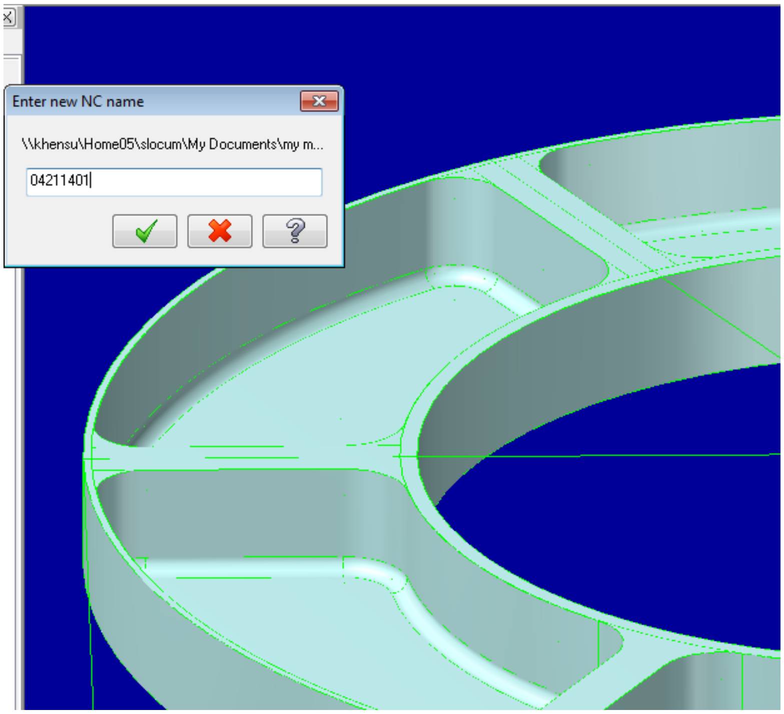
a. Add **Prototrak** and **Haas 3 axis mill**



b. Go back to the dropdown, **Machine Type > Mill > Haas 3 Axis**

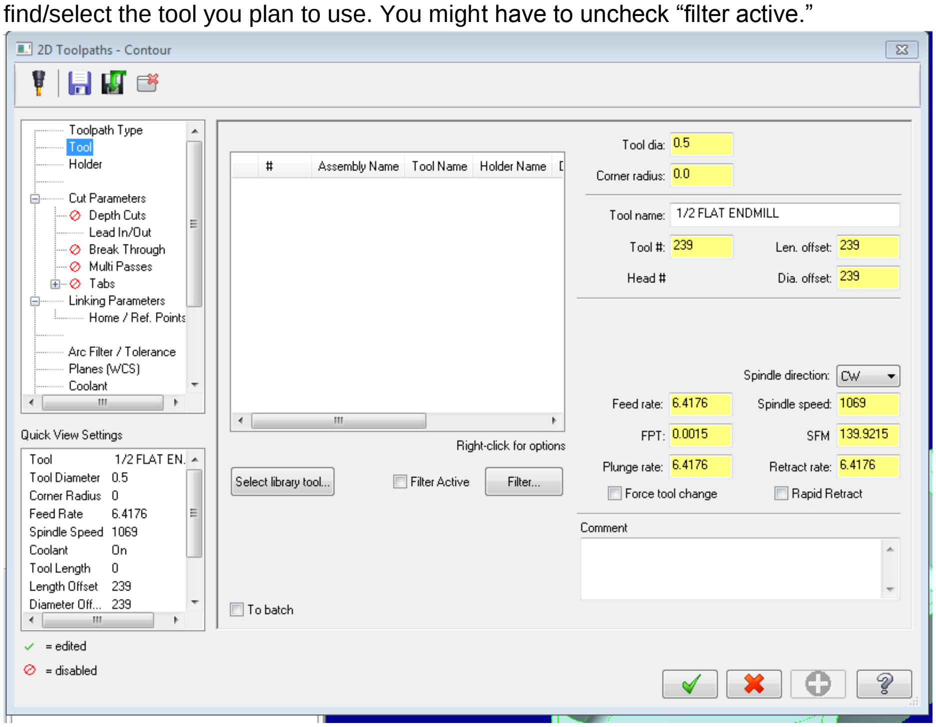
9. At the top of the window, click **Toolpaths > Contour** (a contour path follows the path of a line)

   a. Define the NC file name as the date, followed by a 2 digit number like 01



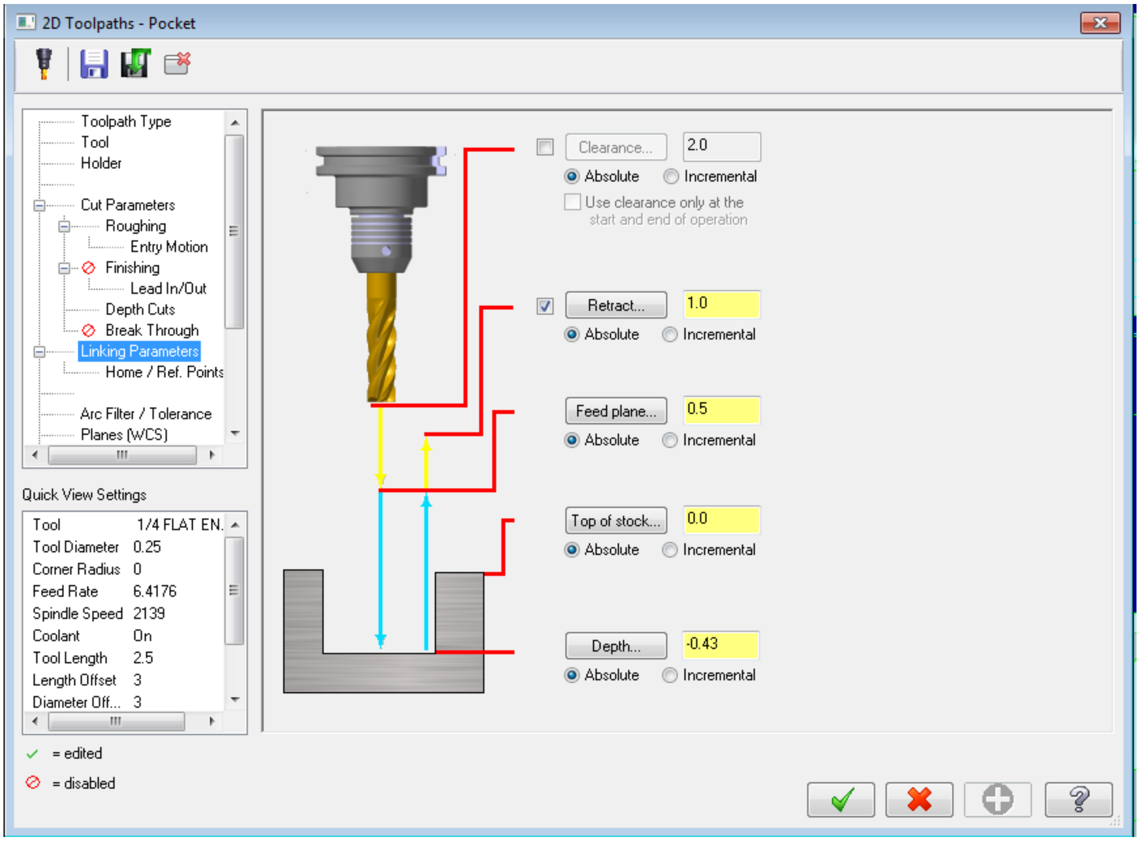
b. Select the contour lines you want to cut on. These lines can often be difficult to see. The red arrow is where your tool will finish its path, the green arrow is where it will begin. In general, you want to green and red arrows to end up on top of each other for a closed path. Click the **Green Checkmark.**

c. In the subsequent toolpaths window, click the **Tool** item in the left column, then click **Select library tool,** and find/select the tool you plan to use. You might have to uncheck "filter active."

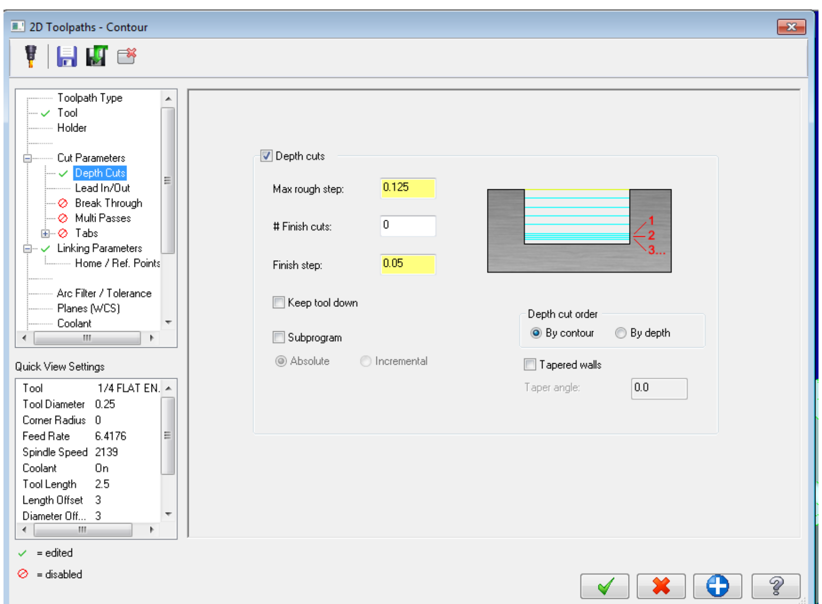


d. On the Haas, it is critical that the **Tool #, Head #, Len. offset** and **Dia. offset** are the same number. This number should match the tool's position number indicated on the Haas tool carousel. This is how the machine knows what the tool geometry is. General feeds and speeds: aluminum, .5" diameter tool > 2200 rpm, 6 feed, 3 plunge. Smaller cutters generally need faster RPM and slower feed. Harder materials generally need slower RPM and slower feed.

e. Select **Linking Parameters** from the options tree on the left. The depth is the final depth of the cutter. Make sure each parameter is **Absolute**.



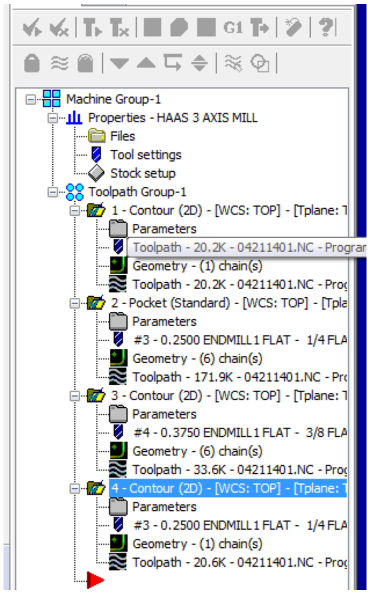
f. Select **Depth Cuts** from the options tree. This defines the depth of cut for each pass.
g. **Max rough step** is depth per pass. The computer figures out the number of passes necessary based on your maximum rough step. For aluminum with 0.5" cutter, 0.25" is a safe depth per pass.
h. Click the **Green Checkmark**



10. Click dropdown, **Toolpaths > Pocket**
   a. For making a pocket with a bottom fillet, you must select the inner contour located on the floor of the pocket for the initial pocketing pass. Click the contours where you want the pocket to be.
   b. Select the chain remembering to click just ahead of the red arrow each time until you get back to the green arrow
   c. When finished, click the **Green Checkmark**
   d. Select **Cut Parameters** from the options tree. Constant overlap and helix entry motion are common for pockets.
   e. Set **Depth Cuts** and **Linking Parameters** the same as in the contour path.
   f. Click the **Green Checkmark**

g. Click **Geometry** in the toolpath tree, then **Right Click > Add Chain**
   i. If the toolpaths are on the wrong side, you can **Right Click > Change Side**, or **Right Click > Reverse Chain**.

11. Create fillet contour path
    a. Click on the line at the top of the fillet against the wall. This is how you will leave the fillet when using a ball end or radiused end mill
12. Select all the programs on the left side (ctrl click) so they are all checkmarked, or simply click on the top **Toolpath Group**. Make sure all paths have a green checkmark next to them.



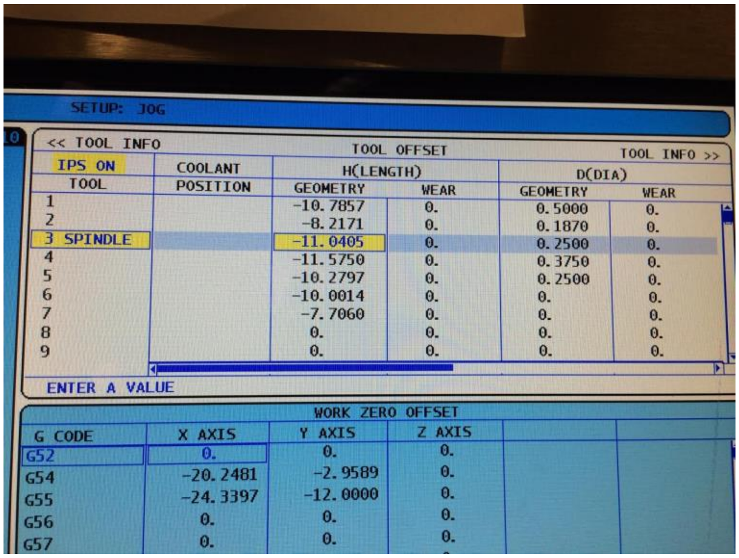
    a. Click the **G1 icon** and then click the **Green Checkmark**
    b. Save the output file to a thumb drive by dragging files from network location into a “Programs” folder on your thumb drive.
    c. Put your thumb drive in the USB port on the side of the machine

MACHINE OPERATION

13. Put the tools you want to use in the machine
    a. Put each tool in the appropriate collet
    b. Rotate the carousel until it is at the tool number you want to put the tool in (the same one you set as the **Tool #, Len. Offset, etc.**)
       i. To rotate the carousel, push the **MDI** button for manual input, then push the **ATC FWD** or **ATC REV** to move to the next or previous tool.
       ii. To skip to a specific tool, enter the tool code+number (ex: “T4”) in the input field, then push **ATC FWD** or **ATC REV**.
    c. Push and hold the round, black button on the spindle column and align the two teeth on the spindle with the slots on the collet
    d. Let go of the button when it is aligned, and the collet should be sucked up into the spindle.
14. Load the stock into the machine and square up the stock. For manual machining operation:
    a. Click **Hand Jog**, then set your jog increment to .01”, then select an axial direction (ex: **X-**). You can either hold the axial direction button to jog, or you can use the hand wheel to jog. Note that each increment on the hand wheel is equal to the selected jog increment. This is how you will be able to manually direct the machine. You must be very careful to not crash the machine. When jogging the machine at a high rate, the machine coasts for a bit after you stop, so it is very easy, especially in the Z direction, to crash into things. **Always check your selected axial direction and jog increment before jogging on the machine.**
    b. To start the spindle, push the **MDI** button and type your desired RPM into the input field (ex: “1500”) and then push the **CW** button.
    c. To start the coolant, push the **COOLNT** button. If the coolant does not start, make sure the valve on the nozzles is open. You can control the flow rate using this valve.
    d. Make sure to take off the vice handle before any machine operations.

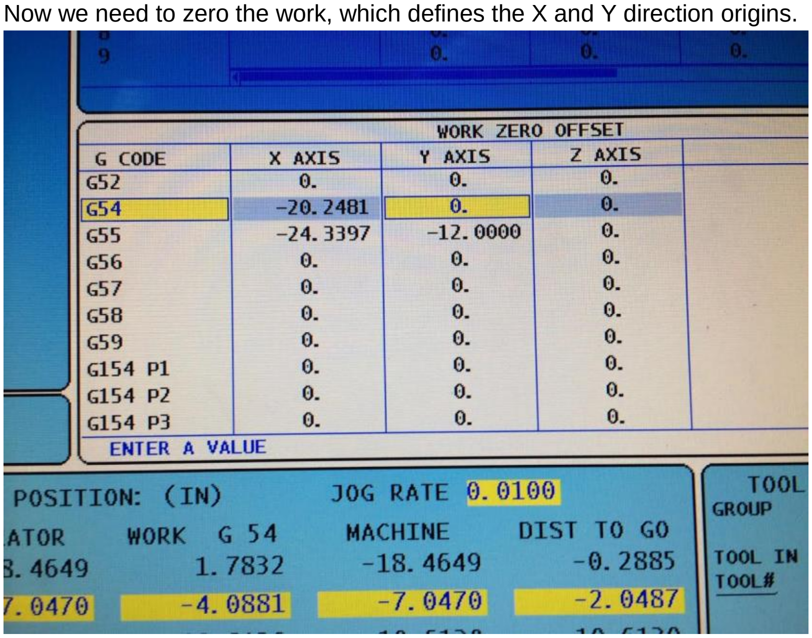
e. You can push the **JOG LOCK** button and then push the axial direction you want to jog in. Push **JOG LOCK** again to stop the machine. Note that there are two ways to control the jog feed rate: the jog increment and the feed override. Make sure you have a reasonable jog feed rate before cutting by jogging away from your workpiece.

15. Define your **Tool Offsets** and **Part Zeros** for the stock. These should match the location of your coordinate system origin that you created in SolidWorks.
    a. Define tool heights, which essentially defines the Z direction origin for each tool.



    i. Jog each tool to down close to the surface of the part with the spindle off
    ii. Take a piece of paper and put it between the tip of the cutter and the surface of the part
    iii. Move the paper back and forth under the tool and move the head down very slowly (.001" jog increment) using the hand wheel until the paper is pinched between the tool and surface (the paper stops moving).
    iv. Push the **OFFSET** button to get to the tool offset panel (the active panel background should be white)
    v. Use the D-pad to move the cursor to highlight the appropriate **H(LENGTH) GEOMETRY** cell for the tool you are trying to zero (ex: Tool 3 in the photo above)
    vi. Push **TOOL OFFSET MEASURE**. Because of the paper method used, you will still be between 0.001" to 0.003" above the part. This is generally within tolerance. For higher precision, use a different method.
    vii. Switch tools and repeat for all tools in your program

    b. Now we need to zero the work, which defines the X and Y direction origins.



    i. Jog the machine to the X and Y origin location using an edge finder tool or by some other method, depending on how you plan to machine your part.
    ii. Push the **OFFSET** button to switch the active offset panel to **WORK ZERO OFFSET**
    iii. Make sure you are working in the **G54** row

iv. Move the cursor over to the **X AXIS** column and push the **PART ZERO SET** button to zero X, then cursor over to the **Y AXIS** column to zero Y.

v. Do not change the **Z AXIS** part zero. This was set by your tool length offsets. You can set Z to a large positive number to make your program run above the part before cutting to check for errors. Be sure to make it larger than your deepest cut. To set this value, enter a value with decimal after the number (ex. “4.”) the hit **F1**, then hit **Y** on the keypad to confirm.

16. Import your program to the machine
    a. Push **LIST PROGRAM**
    b. Cursor over to the **USB DEVICE** tab, then push **ENTER**
    c. Scroll to the program program file to highlight it
    d. Push **SELECT PROGRAM**, _not_ **ENTER**
17. Preview the program graphically by pushing the **SETNG GRAPH** button twice, then push the green **CYCLE START** button. This will verify that there are no errors in the program. Keep an eye on the tool numbers to make sure the program is running as planned.
18. Run the program above your part as described in the part zero section above
    a. Push **MEM**
    b. Make sure to override your feed and rapid rate to very low speeds so you have time to observe and react in case the machine crashes. You can take the spindle to 0% if you want.
    c. For this demo, we are using a 0.25” cutter at 1.5 plunge rate, 9.5 feed and 3000 RPM
    d. Push **CYCLE START** and pay close attention to the toolpaths to make sure everything runs smoothly.
19. Run the final program
    a. Push **OFFSET** to get the the work offset panel, scroll to the **Z AXIS** column in the **G54** row, and enter “0.” in the input field, then push **F1** to submit, **Y** to confirm. This resets your Z zero to the actual origin.
    b. Push **CYCLE START**
    c. Make sure the coolant comes on. If not, push the **COOLNT** button.
    d. To pause the program, push **FEED HOLD**. To resume, push **CYCLE START**.
    e. To stop spindle during feed hold, push **STOP** in the spindle override