DUNE
Cold Electronics Cryo Testing
RTS (Robotic Testing Station)
Design Status and Remaining Issues

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Outline

RTS very brief introduction (3 slides, we will skip these)

Requirements for warm RTS operation

Test chamber and DAT support plate production and delivery

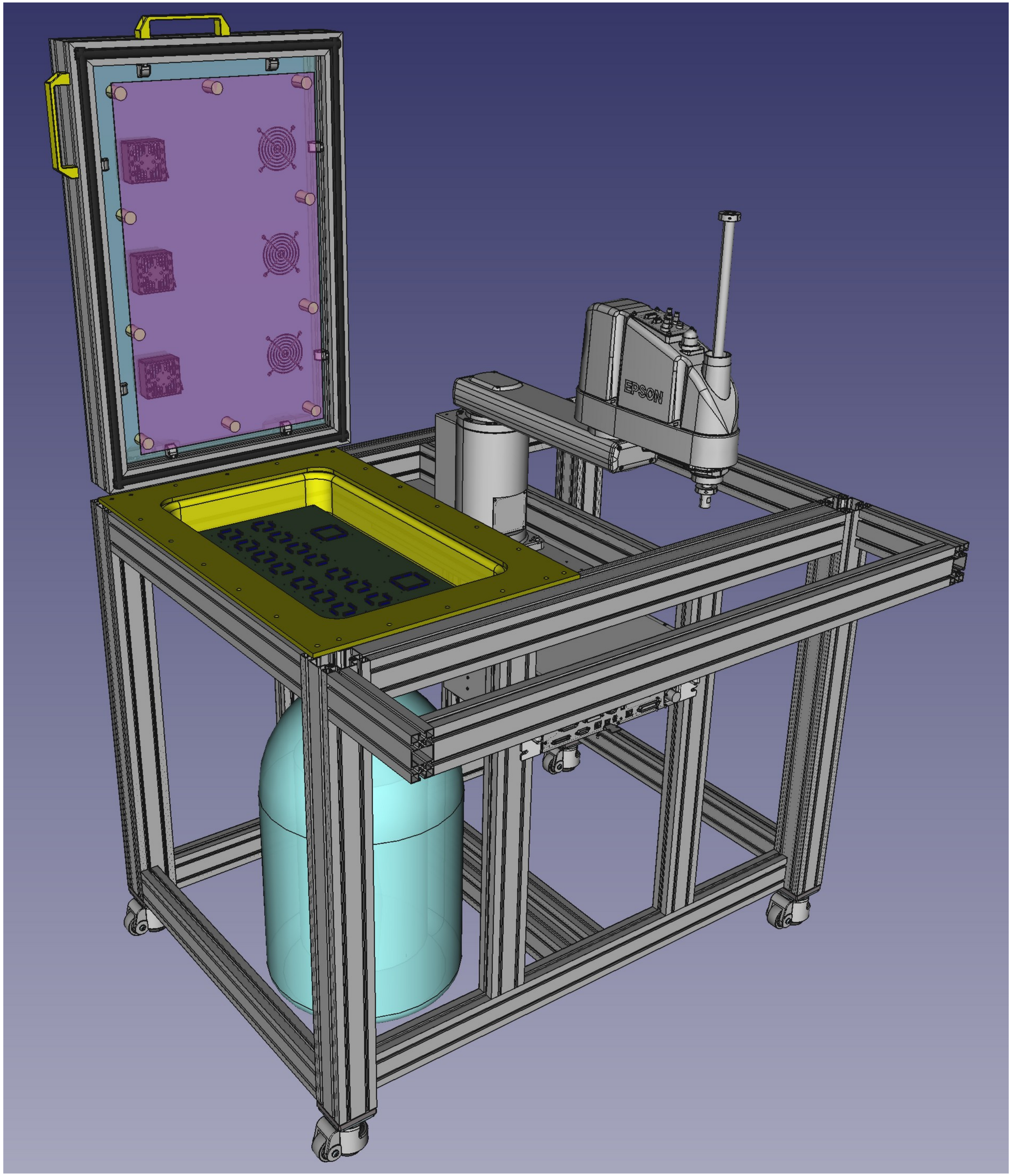
Remaining tasks for cold RTS operation

Cryo system prototype build and testing results

Piping Diagram and Schematics

Cryo controls system

Heated lid current prototype at MSU, build details and schematics
-- Electrical safety requirements and questions
-- Alternate designs that might be better than the current prototype



The RTS comprises:

A commercial robot to pick and place the ASICs from trays to test sockets

Test chambers that support the testing hardware.

Test chambers are also Faraday enclosures.

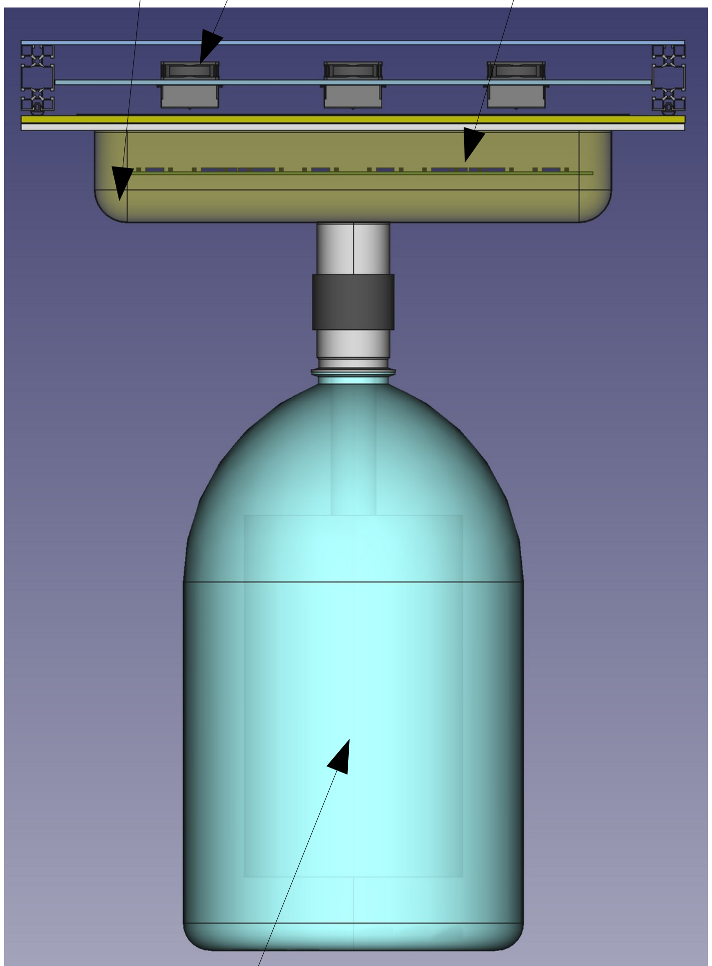
A cryogenics system that can fill and drain the test chambers.

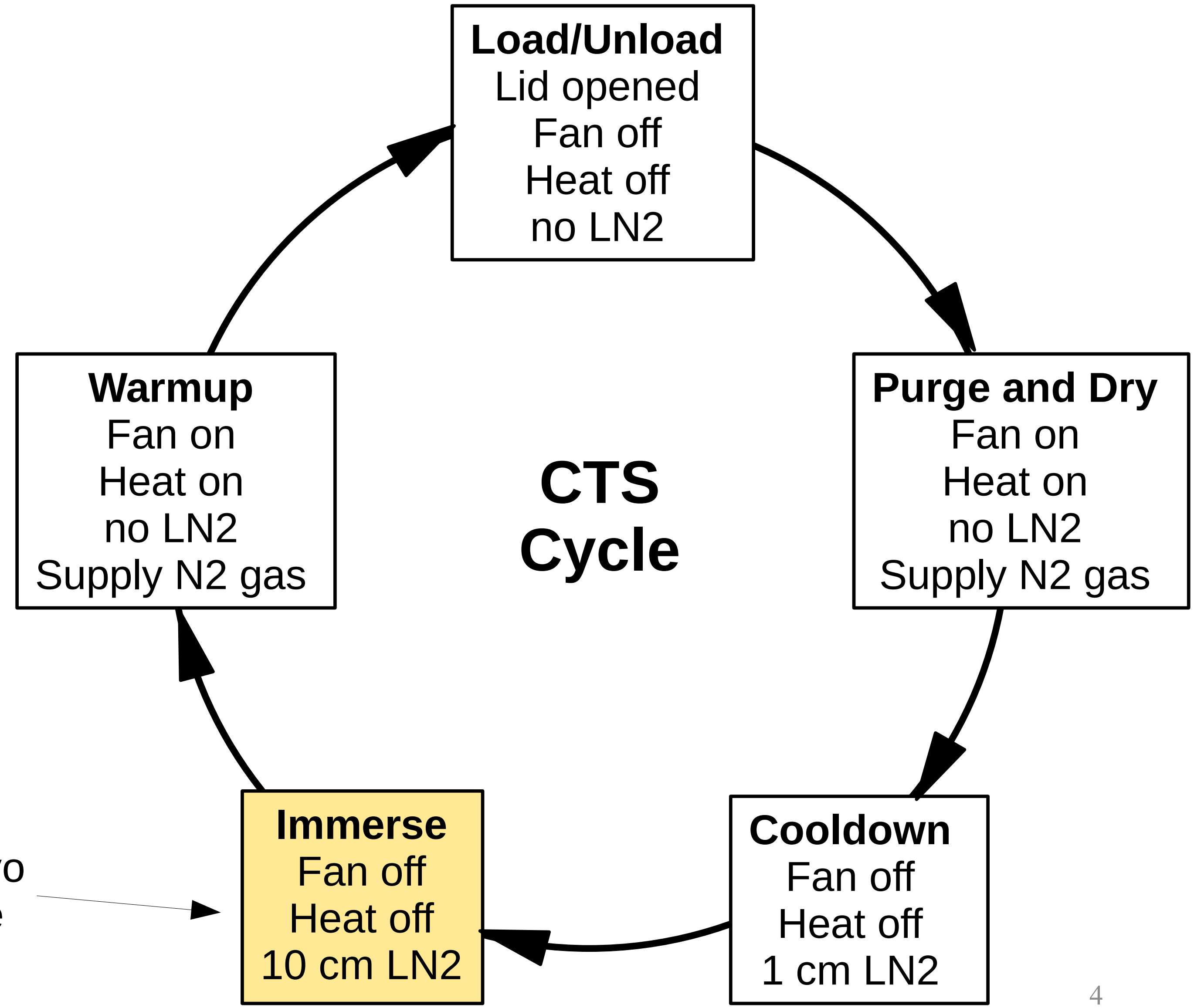
An aluminum strut framework to hold this all together.

RTS system has two test chambers, only one is shown here.

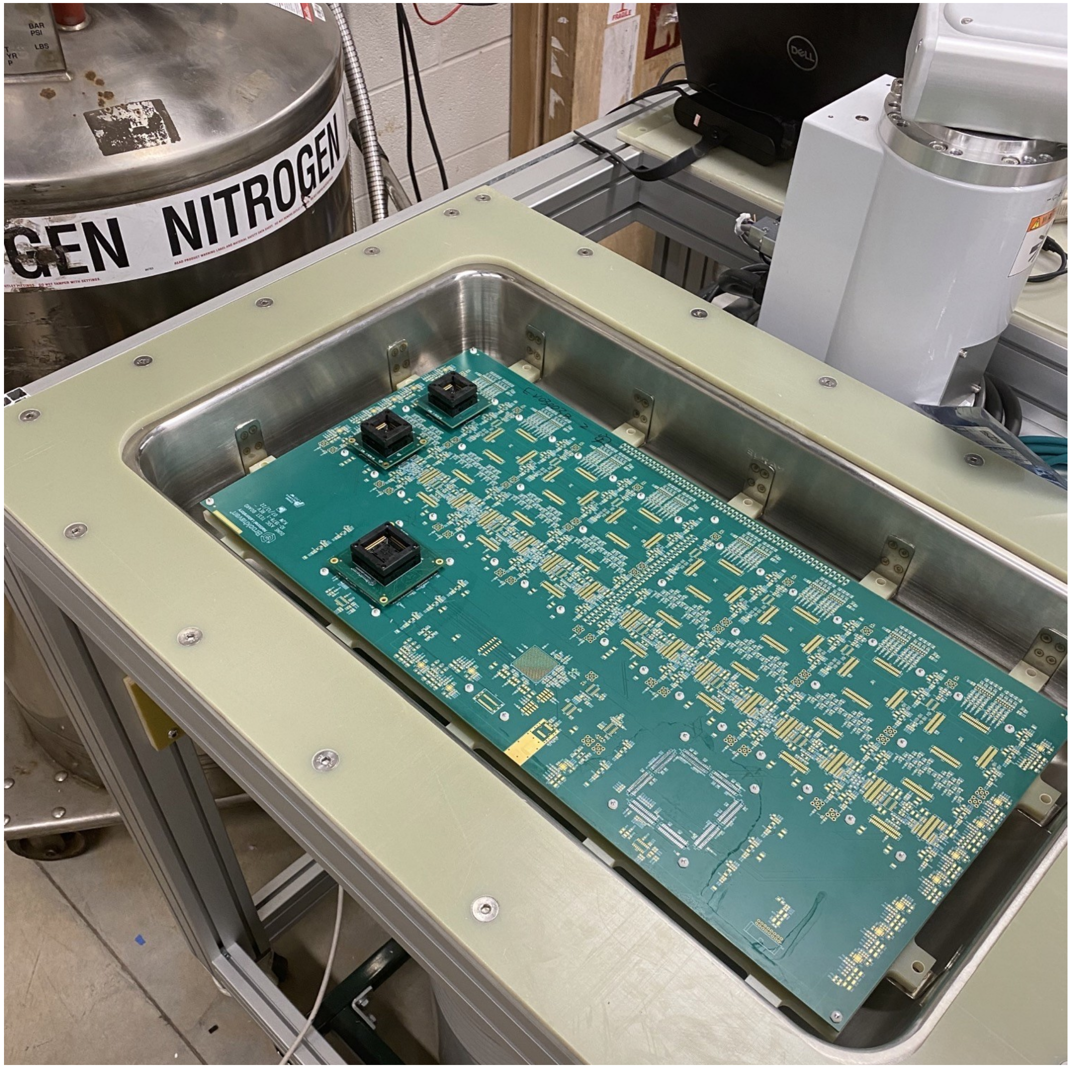
Cryo Testing Station

- Cycle time is roughly one hour (plus electronics testing time)
- Fans and heaters are located inside test chamber headspace
- Slight pressure in Dewar used to raise LN2 into test chamber
- Relieve pressure and LN drains back into Dewar
- CTS cycle keeps DUT dry throughout the cycle





DAT board prototype mounted inside a test chamber



Test chamber and DAT support plate- production and delivery

Test chamber with DAT support plate

Six test chambers welded and insulated

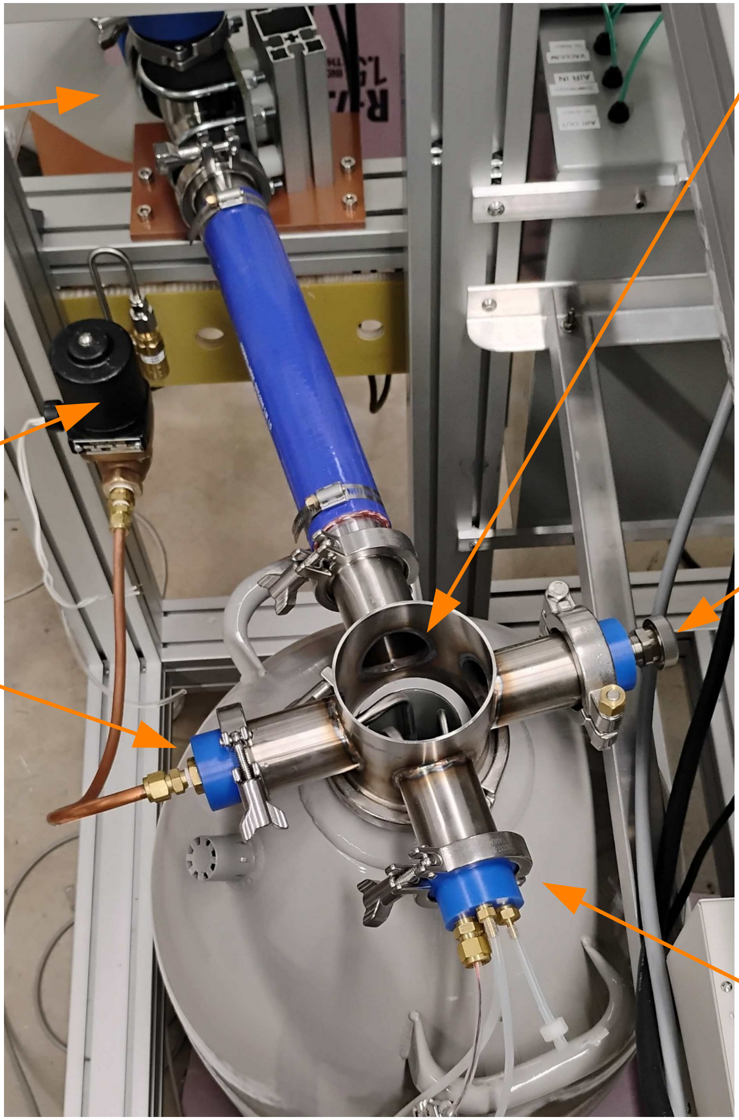
Six more in shop queue

-- Two test chambers and twelve DAT support plates send to BNL- should arrive tomorrow
-- DAT board -to- support plate hardware: BNL decision on best setup (COTS, fast)
-- Can ship two chambers to Fermilab this week or next.
-- 6 more chambers in Machine Shop for welding- shop is rather busy, we need to advise on priority
-- Urethane foam insulation- can complete two units per day

RTS cryo system prototype build

Pneumatic-actuated venting valves
-- Normally open design

LN2 filling valve and port
24 VDC valve
from Magnatrol

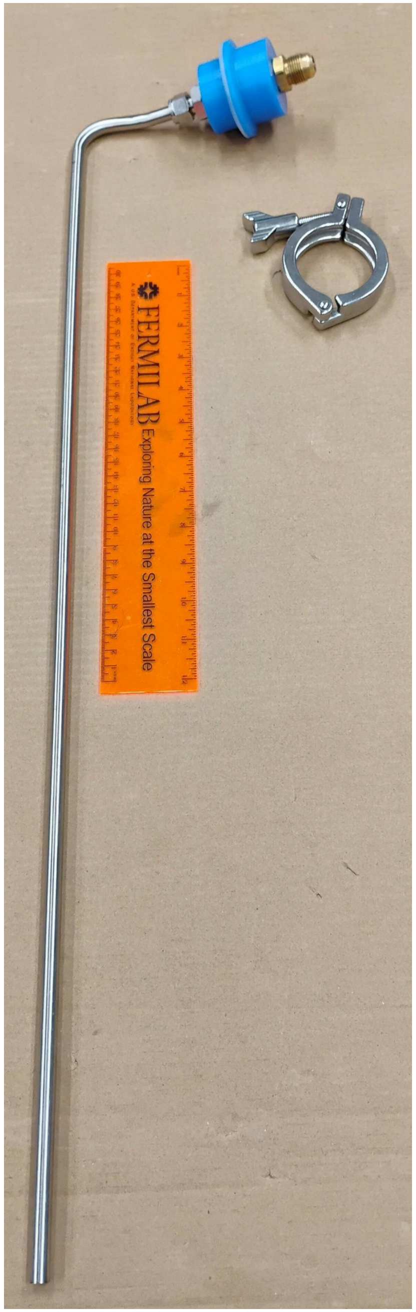


Custom flange welded from COTS sanitary fittings
-- Stainless steel
-- Elastomer or PTFE seals

Safety relief valve
2 PSIG, cryo rated

Pressurization and monitoring port

RTS cryo system prototype build



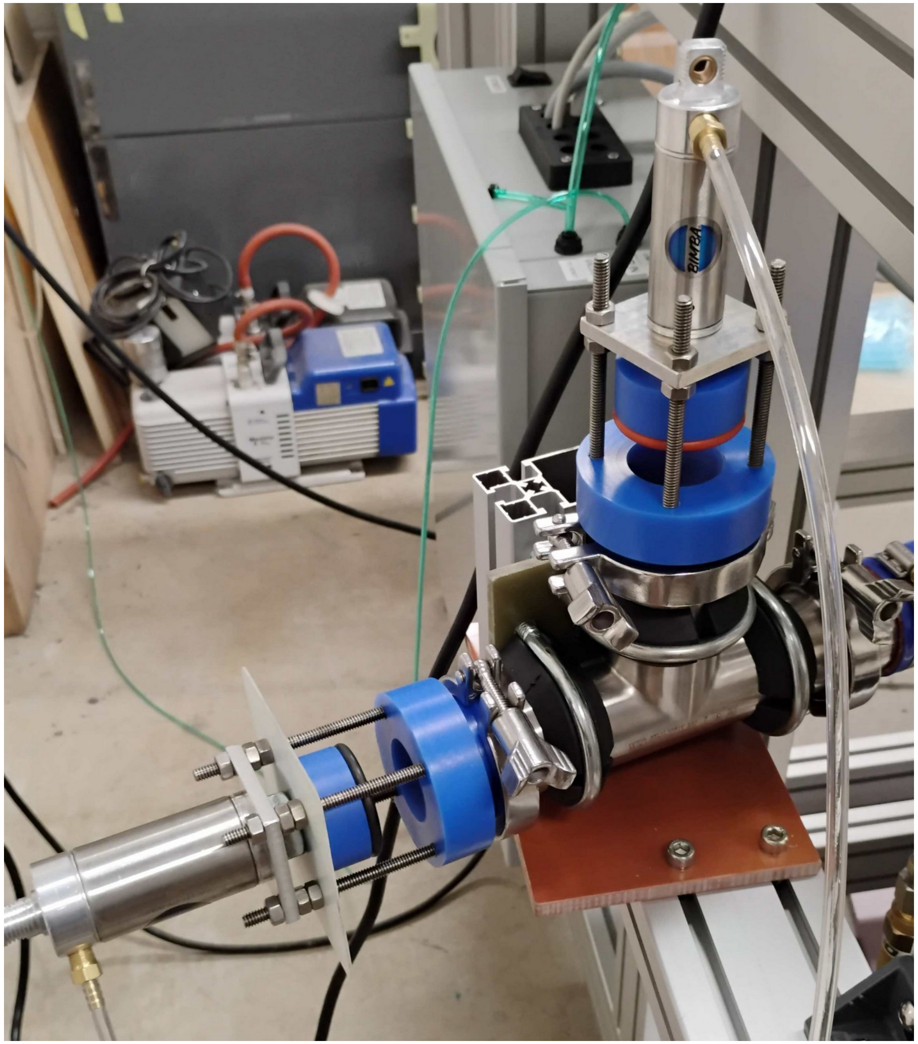
LN2 filling port into dewar
-- Larger diameter plumbing to reduce refill time

The central manifold is welded together from COTS stainless steel sanitary fittings. Our shop can produce these easily

The flange fittings are made from a cryo-rated UHMW polyethylene plastic called Tivar HPV (blue colored).

2 PSIG cryo-rated safety relief valve

Storage dewar venting valves



The storage dewar has two custom venting valves

Venting valve requirements (for storage dewar filling):
-- Very large orifice (else back pressure and long refill time)
-- Only needs to hold about 1 PSIG
-- Best to have normally-open (failsafe) operation

We could not find suitable valves in the market, so we made our own

These are actuated by spring-return pneumatic cylinders
-- lose pressure => fails open (safe)
-- Lose control signal -> fails open (safe)

The mechanics are made from Tivar HPV plastic

The valves mate to standard sanitary fittings with COTS hardware.

Initial results: these work very well.

Recall CTS: the filling vents are pieces of silicone tubing that are installed/removed by hand. This newer design be used for CTS upgrades in the future.

Cryo system performance

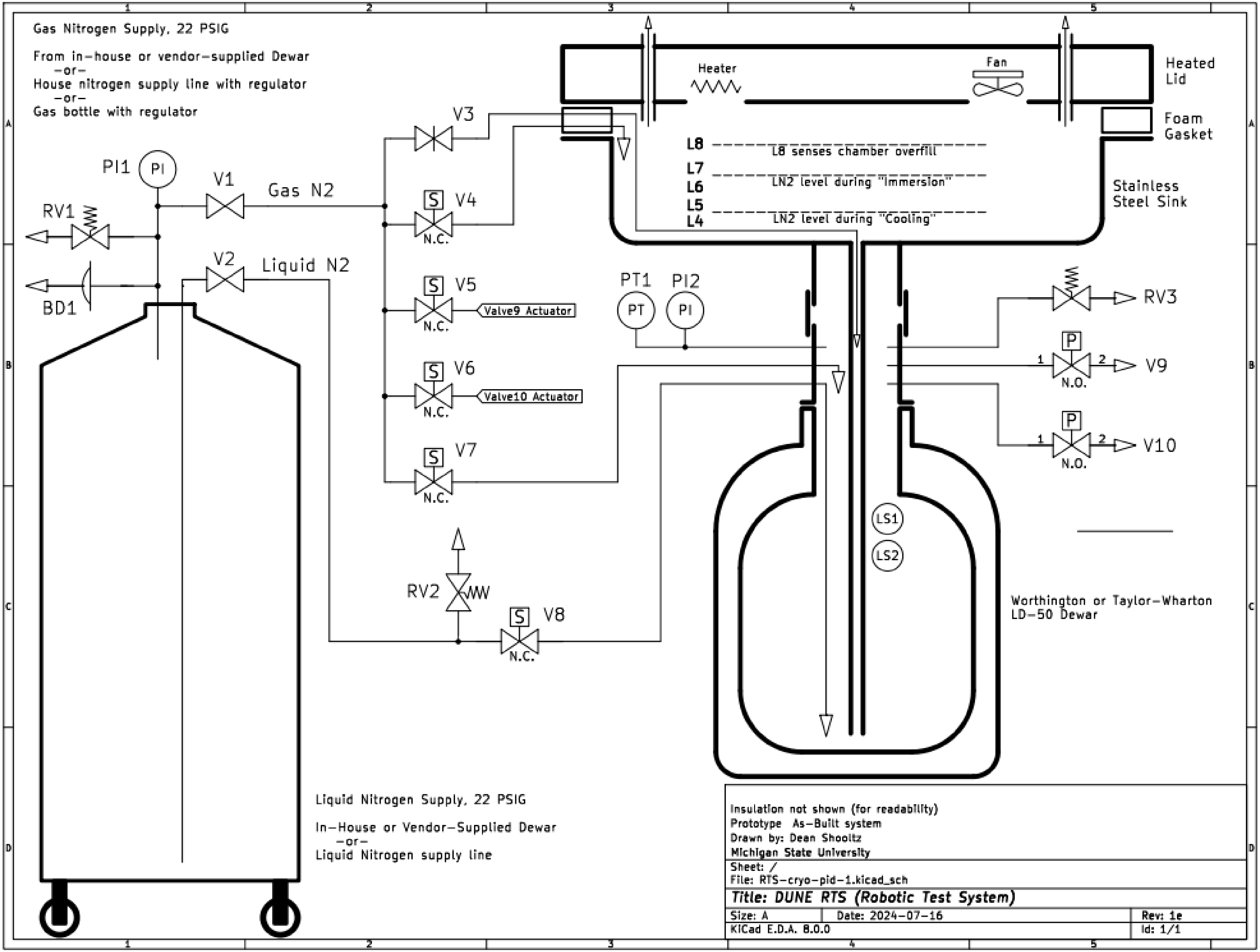
Test chamber can be filled in as little as 3 minutes

Test chamber draining takes less than 1 minute

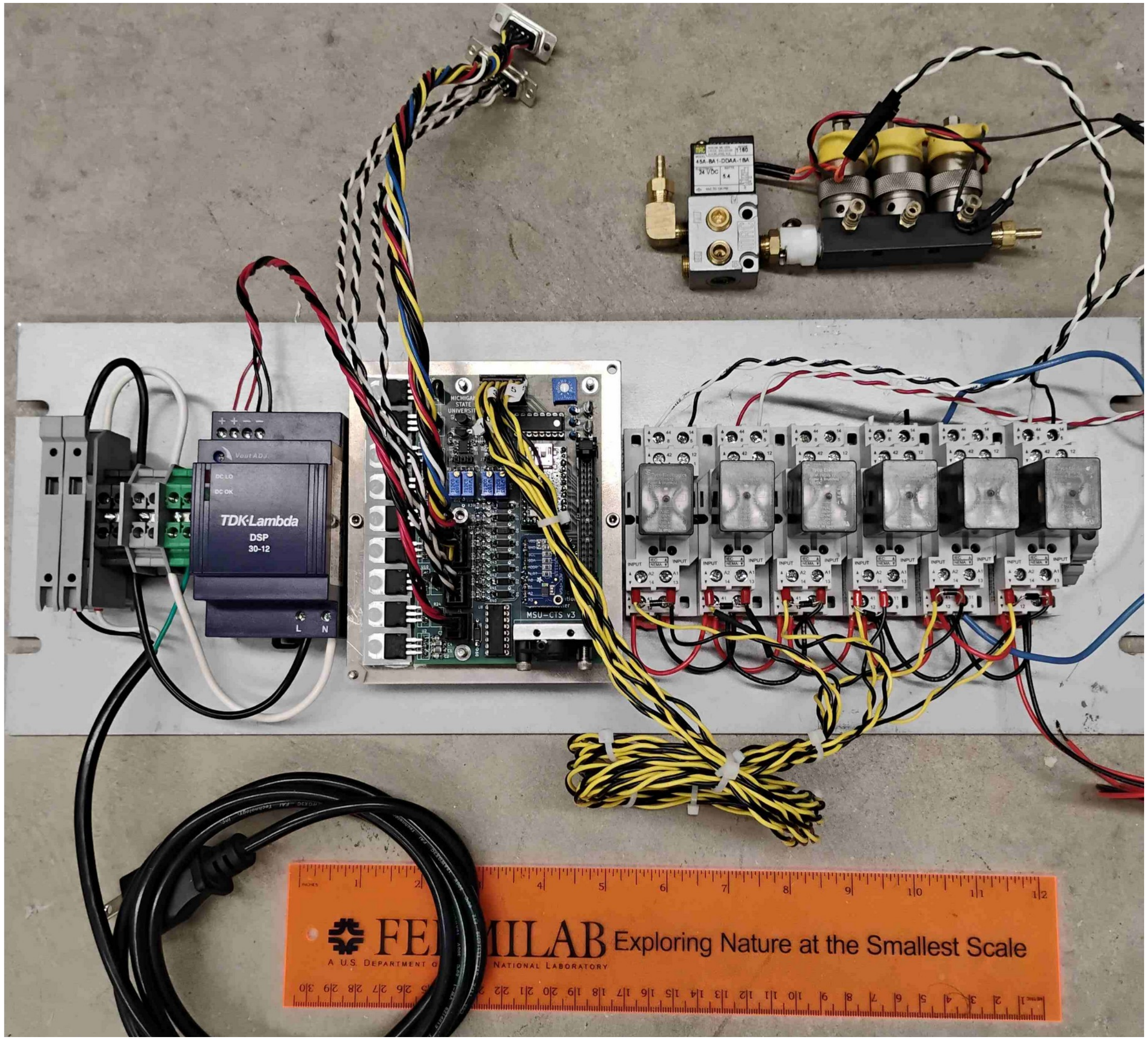
Storage dewar refill after 1 hour immersion cycles takes 6 minutes

Recall: goal is to make DUNE CE cryo testing feasible, cycle times are important

Piping diagram for working prototype is completed- still need to compile BOM and note



Cryo controls (prototype) utilize a spare CTS control board.
User interface is either single mode-select switch, or USB serial command line interface



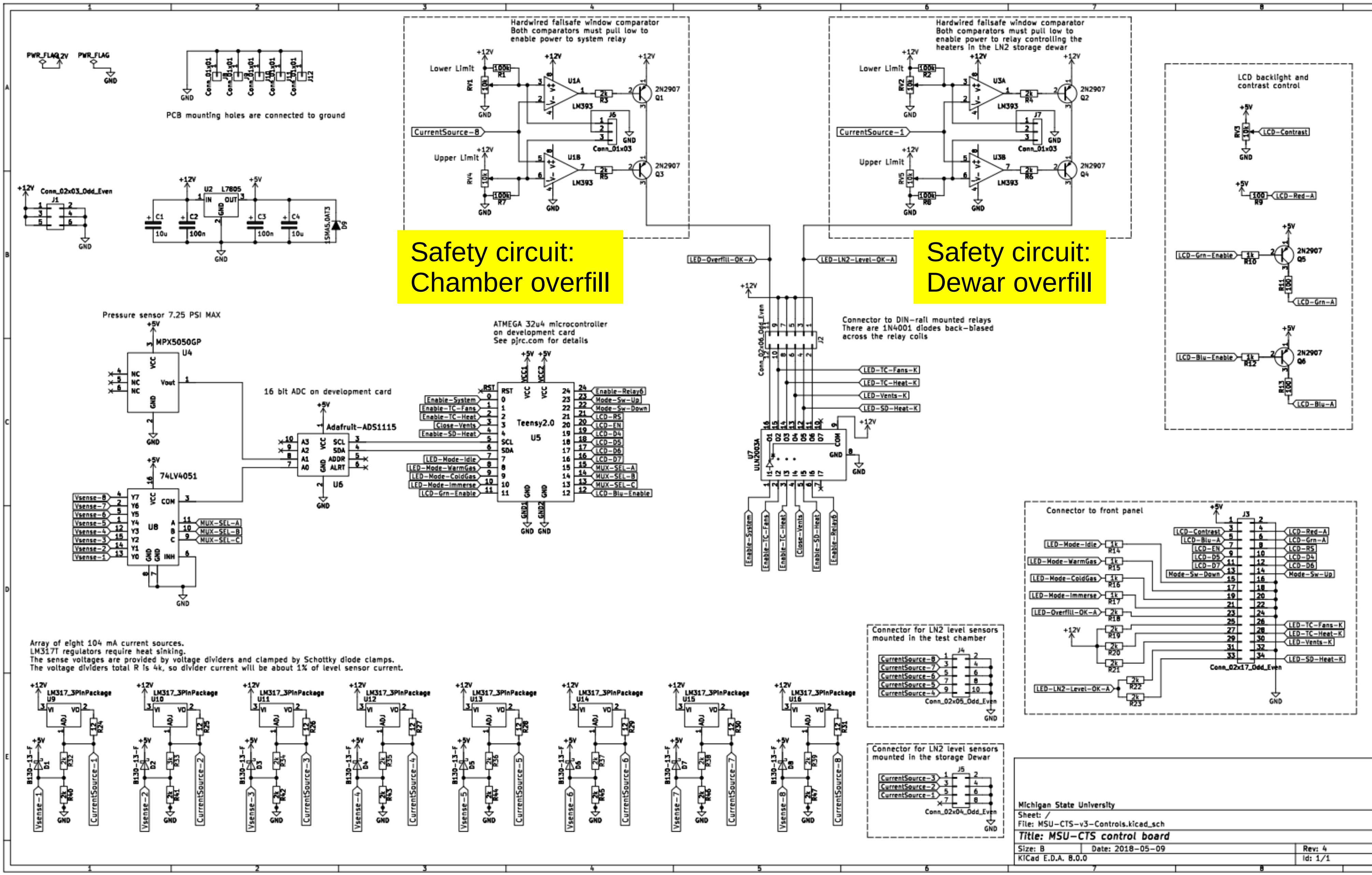
<u>Importantly:</u>
System does not use mains voltage, so everything left of the PCB is the power supply could be replaced with a COTS UL-listed power supply
-- Easier/faster to get through electrical safety?
-- Preferred option?

Bank of six relays are not needed- the small solenoid valves can be driven directly, and the heated lid can be controlled by solid-state relays at the level of the heated lid power distribution.

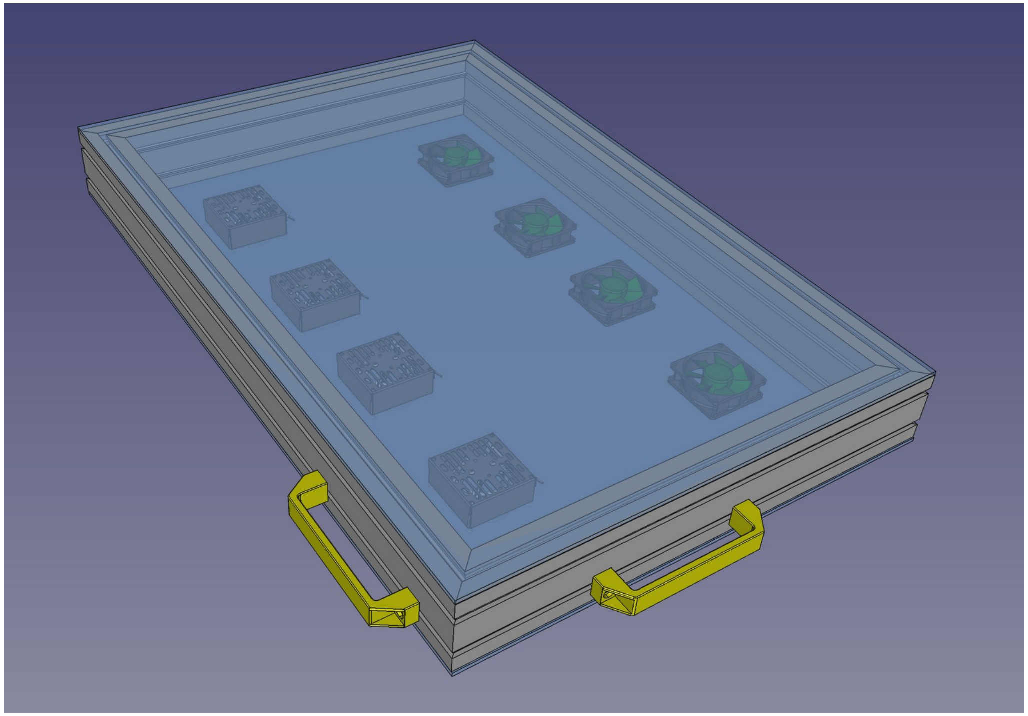
Bottom line: cryo controls are a simplified version of the CTS controls.

<u>To-Do: install in an enclosure and proper wiring.</u>

Cryo controls (prototype) utilize a spare CTS control board.
User interface is either single mode-select switch, or USB serial command line interface
Schematics basically done, but need some small edits for CTS -> RTS usage



RTS Test Chamber Lid Prototype

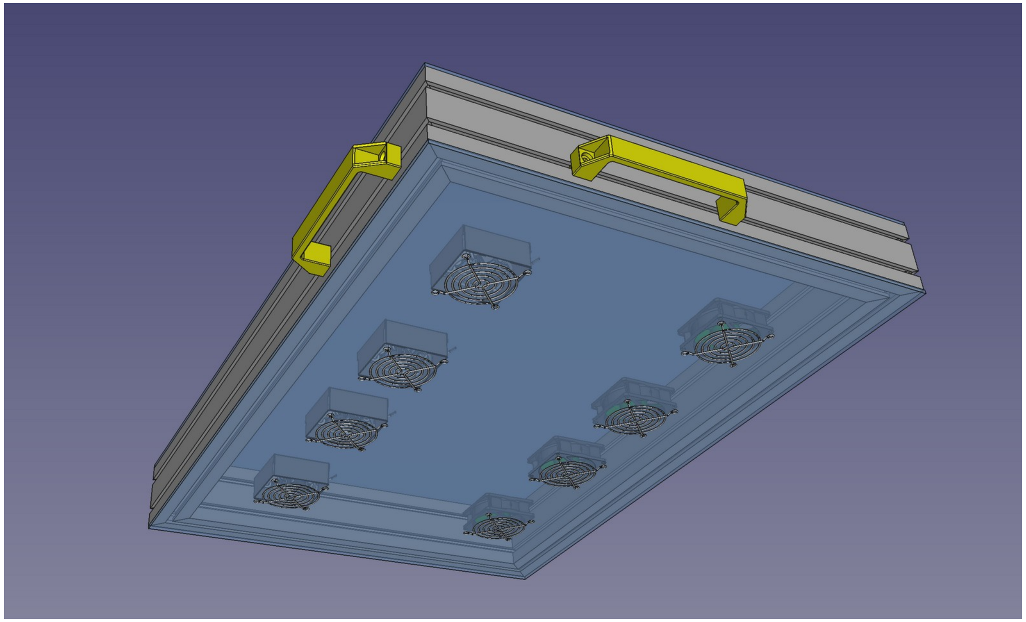


Aluminum strut framework with top and bottom polycarbonate panels.

Internal fans and heaters.

Plenum heaters not shown here.

The four pieces of aluminum strut are hard-coat anodized. So safety grounding probably requires milling through the hard-coat to expose the base metal, and using serrated washers to make good contact to the metal.



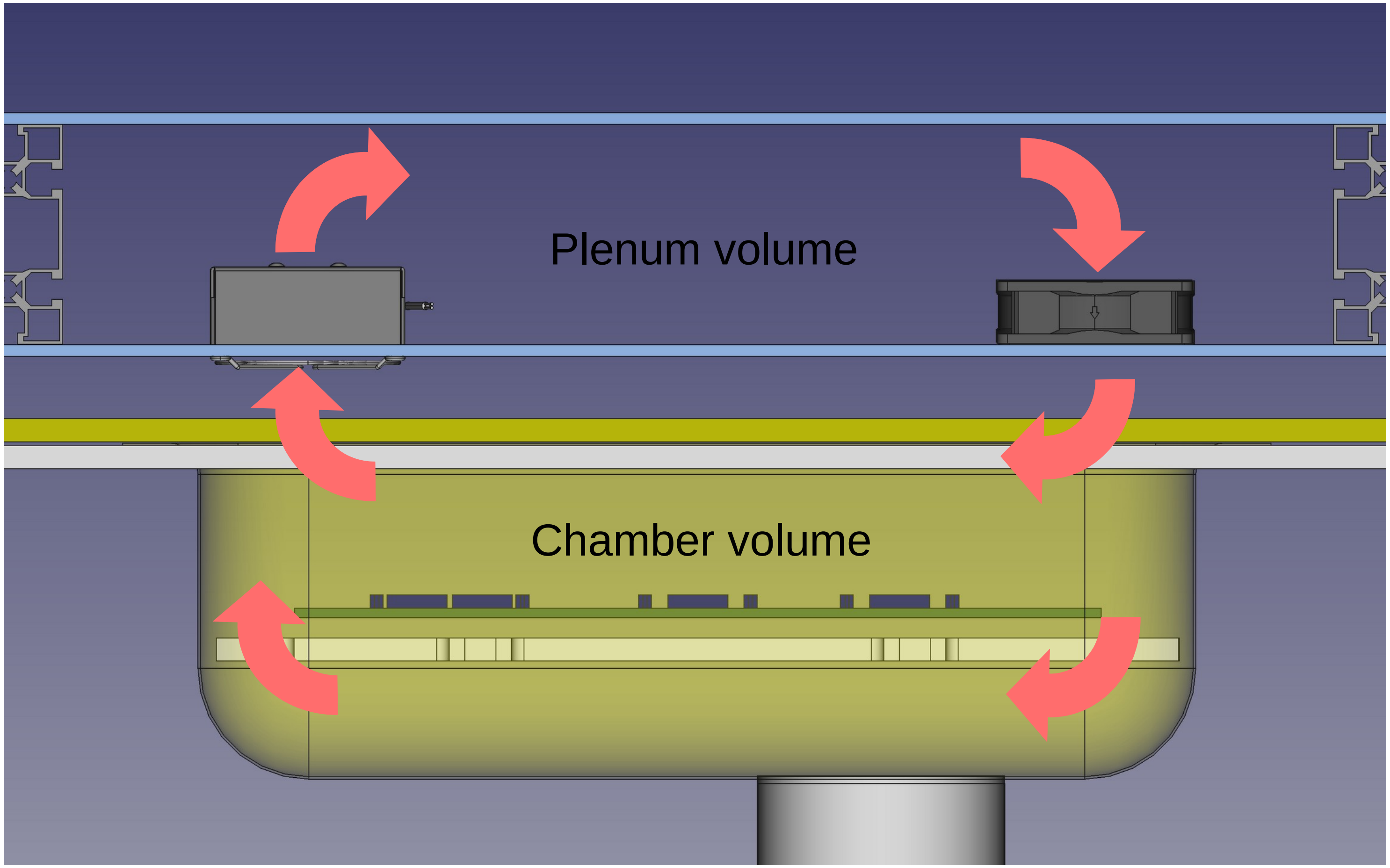
Grounding connections should also be coated with a film of NOALOX anti-oxidant joint compound.

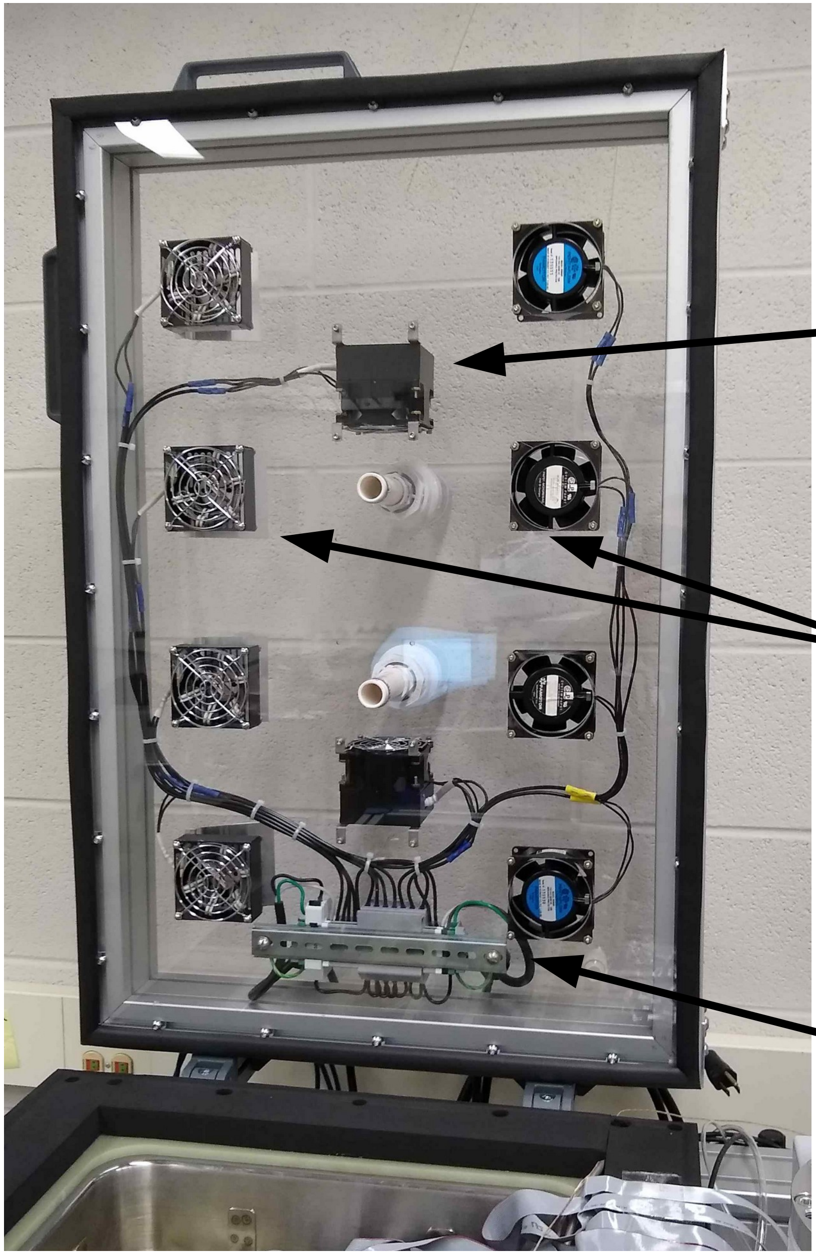
RTS Test Chamber Lid

The warmed N2 gas flow is split to pass above and below the DAT for uniform warming.

In the current prototype the fans and heaters are separated. The goal is to pass the chamber N2 gas over the heaters as it enters the plenum volume.

The number of fan/heaters and placement is easily changed during prototyping (by modifying the bottom polycarbonate sheet)





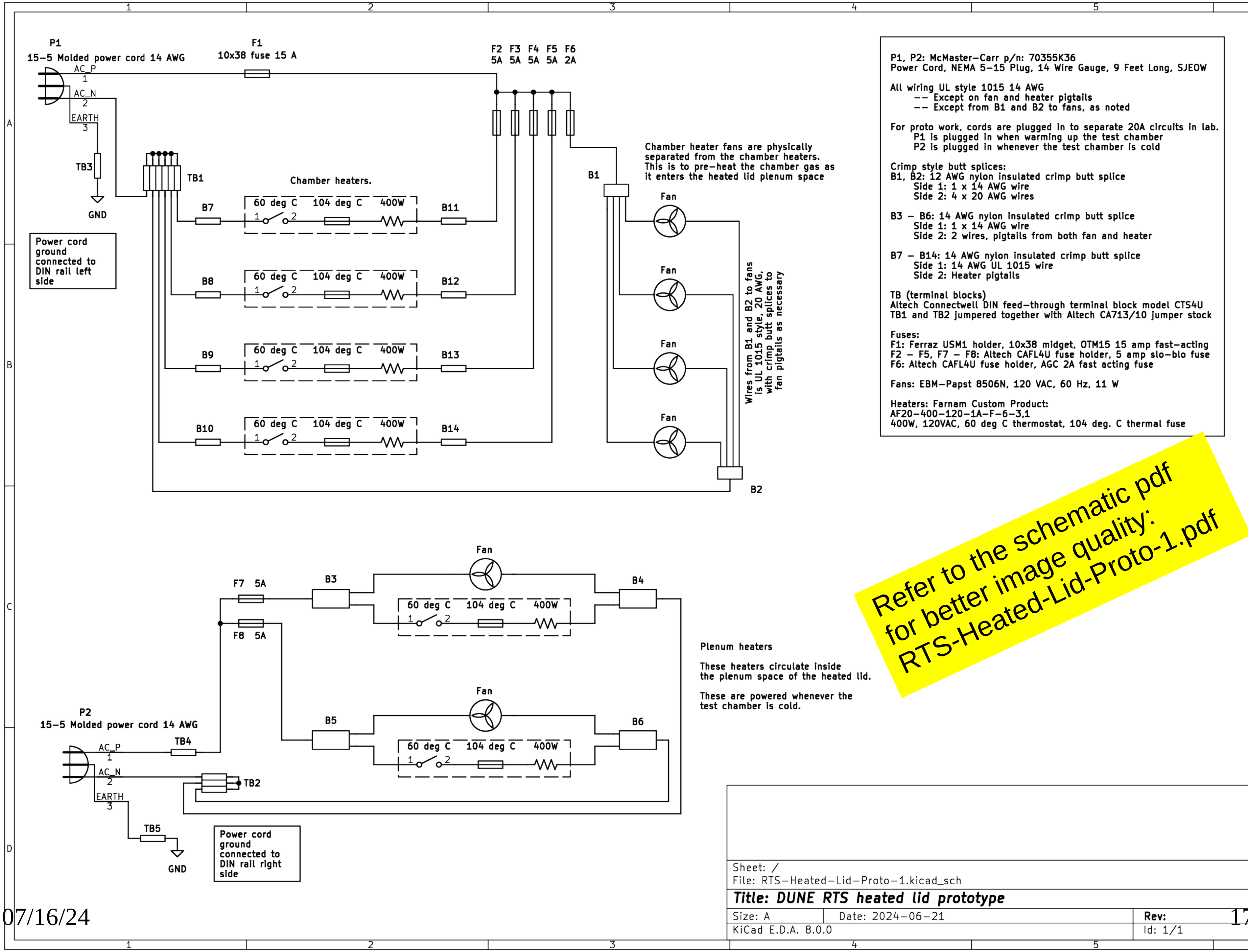
Current prototype RTS heated lid (as-built).

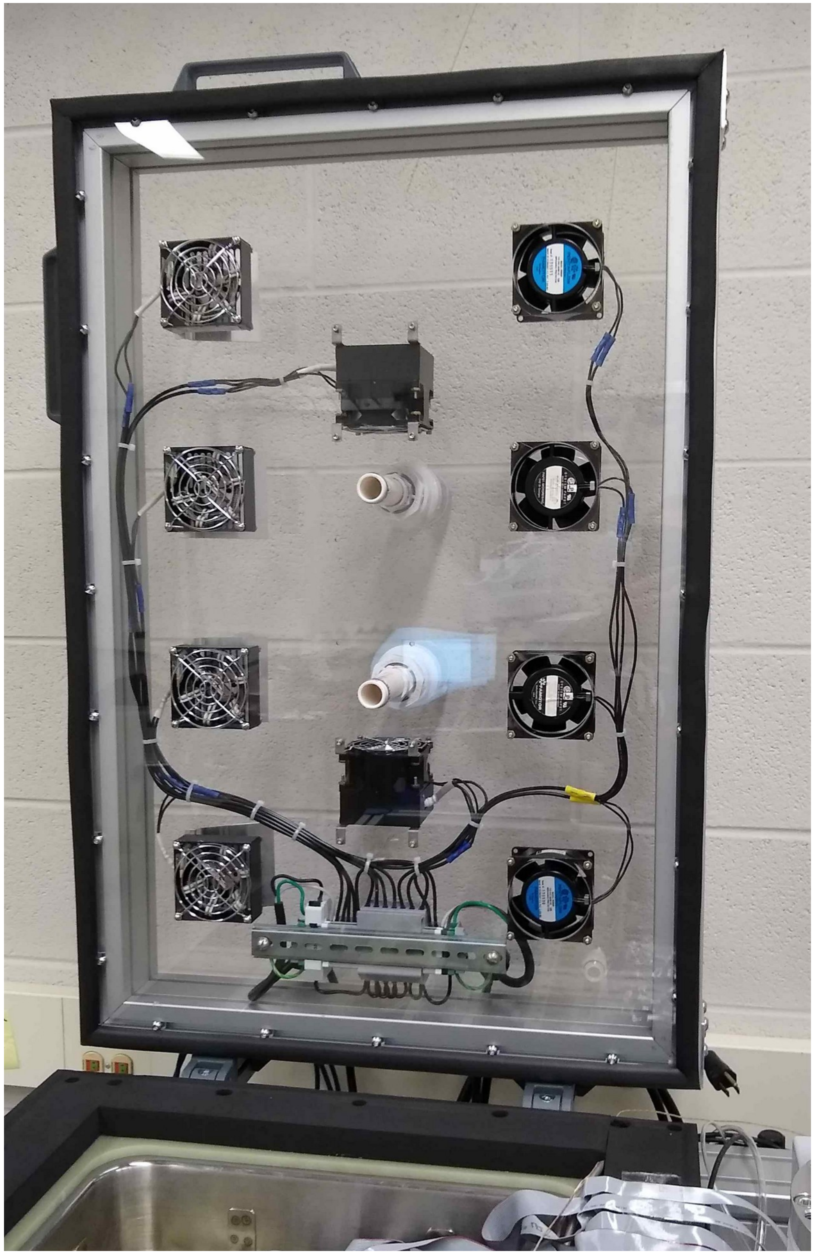
Two 400 watt heater/fan units are installed in the plenum space. The circulation from these two units is primarily inside the plenum space. These keep the heated lid warm during cryogenic cycles in the test chamber.

Chamber heating fans and heaters are physically separated. This is to pass the cold N2 gas over the heaters as it enters the plenum space.

<u>The heaters and fans are not yet safety grounded.</u>
(only for prototype, definitely not for production)

Power distribution and fusing is on a short section of DIN rail mounted inside the plenum volume.


P1
15-5 Molded power cord 14 AWG
AC_P
AC_N
EARTH
F1
10x38 fuse 15 A
F2 F3 F4 F5 F6
5A 5A 5A 5A 2A
TB3
GND
TB1
Chamber heaters.
B7
B8
B9
B10
60 deg C
104 deg C
400W
B11
B12
B13
B14
B1
B2
Fan
Power cord ground connected to DIN rail left side
Chamber heater fans are physically separated from the chamber heaters. This is to pre-heat the chamber gas as it enters the heated lid plenum space
Wires from B1 and B2 to fans is UL 1015 style, 20 AWG, with crimp butt splices to fan pigtails as necessary
P1, P2: McMaster-Carr p/n: 70355K36
Power Cord, NEMA 5-15 Plug, 14 Wire Gauge, 9 Feet Long, SJEOW
All wiring UL style 1015 14 AWG
-- Except on fan and heater pigtails
-- Except from B1 and B2 to fans, as noted
For proto work, cords are plugged in to separate 20A circuits in lab.
P1 is plugged in when warming up the test chamber
P2 is plugged in whenever the test chamber is cold
Crimp style butt splices:
B1, B2: 12 AWG nylon insulated crimp butt splice
Side 1: 1 x 14 AWG wire
Side 2: 4 x 20 AWG wires
B3 - B6: 14 AWG nylon insulated crimp butt splice
Side 1: 1 x 14 AWG wire
Side 2: 2 wires, pigtails from both fan and heater
B7 - B14: 14 AWG nylon insulated crimp butt splice
Side 1: 14 AWG UL 1015 wire
Side 2: Heater pigtails
TB (terminal blocks)
Altech Connectwell DIN feed-through terminal block model CTS4U
TB1 and TB2 jumpered together with Altech CA713/10 jumper stock
Fuses:
F1: Ferraz USM1 holder, 10x38 midget, OTM15 15 amp fast-acting
F2 - F5, F7 - F8: Altech CAFL4U fuse holder, 5 amp slo-blo fuse
F6: Altech CAFL4U fuse holder, AGC 2A fast acting fuse
Fans: EBM-Papst 8506N, 120 VAC, 60 Hz, 11 W
Heaters: Farnam Custom Product:
AF20-400-120-1A-F-6-3,1
400W, 120VAC, 60 deg C thermostat, 104 deg. C thermal fuse
F7 5A
F8 5A
B3
B4
B5
B6
Plenum heaters
These heaters circulate inside the plenum space of the heated lid.
These are powered whenever the test chamber is cold.
P2
15-5 Molded power cord 14 AWG
TB4
TB2
TB5
Power cord ground connected to DIN rail right side
Refer to the schematic pdf for better image quality: RTS-Heated-Lid-Proto-1.pdf
Sheet: /
File: RTS-Heated-Lid-Proto-1.kicad_sch
Title: DUNE RTS heated lid prototype
Size: A
Date: 2024-06-21
Rev:
KiCad E.D.A. 8.0.0
Id: 1/1



Initial concerns from informal discussion with FNAL safety

-- Heaters mounted directly to polycarbonate- OK?

-- Need to ensure proper wire gauges and fusing

-- Safety grounding: exposed metal should be properly grounded (lots of exposed metal in the prototype)

-- Mains power usage- don't draw too much from available circuits

-- Mains power usage- might be best to move "toward a control panel type power distribution design"

Moving forward

Seems best to replace polycarbonate with metal sheet
-- Safety grounding greatly simplified

Current lid heating power is 2400 Watts:
-- two dedicated 20 amp circuits per lid

Note:
Chamber warmup is the slowest phase of the RTS operation.
We would benefit from more heating power and possibly increased gas flow (more fans?)

The heated lid needs more design work. But existing proto could maybe be deployed if safety grounded.

Need to discuss / agree on priorities:

Finish Cryo system documentation, send out.

Heated lid:
Replace polycarbonate with stainless steel sheet?
Power distribution “control panel” approach?
Go any further for now, or run with updated current design?

Three more RTS frames and Six more testing chambers- when to focus on production?

EXTRA - Alternate RTS heated lid designs

These are mentioned here because the issues with the current prototype might lead us towards an alternate design.

Alternate design #1: Replace bottom polycarbonate with stainless steel sheet
-- Discussed already
-- This simplifies the safety grounding - approaches a true electrical enclosure
-- Helps with completing the test chamber Faraday enclosure
-- Can be laser-cut to provide the vent ports for heaters/fans
-- Can add viewing port, with optional conducting cover for better shielding

Alternate design #2: Replace both polycarbonate sheets with stainless steel sheets
-- Extension of above, more complete enclosure

Alternate design #3: Fully construct the lid with stainless steel sheet, folded and spot-welded
-- The stainless structure would include the lid sides
-- This approach might remove the four hard-coated aluminum extrusions from the list of safety-grounded items
-- The design would include an access panel, probably as a screwed-on but removable top panel.

Alternate design #4: Outboard heater/fan unit.
-- Fully separate the heaters and fans as a standalone unit
-- The RTS lid reduced to a piece of ductwork
-- The RTS is minimal weight, which helps operator safety