The CAD of the laser bed can be seen here

Notes on the Coherent laser manual:

1. ~~We need to angle the laser 10 degrees, to prevent back reflections~~
    a. ~~We should measure out where that would end up sending back reflections, accounting for focal length, to see where that would make the beam hit~~
        i. ~~If the beam is hitting the ceiling, that'd probably be safe as the light would be very spread out by then~~
        ii. ~~If the beam is hitting a part of the laser, we may want to add shielding there~~
        iii. ~~At 10 degrees, it's almost entirely going to still hit the lens still~~
2. We need purge gas to give the laser and the fiber core a positive pressure with clean air.
    a. This can just be a tank of breathable clean air
    b. There are strict tolerances on the amount of hydrocarbon in the air, so bottled air may be the only option
    c. Tubing can't have rubber, talc, or oil, as that will contaminate the air
    d. 0.5lpm, 10-15psi
    e. They recommend running the purge gas 24/7 in humid environments
    f. Suggest clean ~¼" PE tubing
        i. Lowes $8
3. There is no nozzle that I could find, in the packaged materials or the documentation as far as I can tell
    a. They don't mention cutting for the applications, only welding, cladding, brazing, and heat treating
    b. I think we need a nozzle there to be able to measure capacitance. Might just need to make it on the lathe
    c. Where does the assist gas come out of then?
    d. We generally want a nozzle that has the smallest opening possible source
        i. And we position the bottom of the nozzle to be about a nozzle-diameter away from the workpiece
    e. This is because we need a separate head for cutting, I think that the head we have is for welding
4. Fiber cable has an LLK-B connector to the laser receiver / process head
    a. Do we need a process head?
5. We need to prevent the cooler from freezing
6. We need to prevent condensation on the laser-cooled parts by reducing the humidity of the ambient air
    a. Maybe we seal the laser system with acrylic?
7. We need 3 gallons of DI for the whole system
    a. Adding DI is a two step process, you add 2 Gallons of DI, then top it off
    b. We need to drain it if not in use for >4weeks, or if there's a risk of freezing
8. The fiber ends need to be *very* clean
    a. The fiber optic can't be cleaned, but can have dust blown off
9. They mention a CD with a GUI application for monitoring

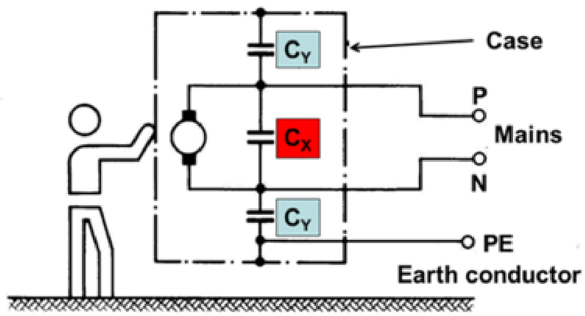
    a. **Todo** do we have this?
10. Dust on the optical components reduces efficiency and is not really possible to clean, so we might want to assemble the laser when there's no woodwork going on
    a. We're not supposed to use compressed air, as that contains oil
11. **Todo** we may need a new DI filter
    a. We should have an extra filter, and Eric is getting a new one soon
12. **Todo** we may need to change the PLC battery
    a. [This battery]()
13. Power requirements
    a. Laser is 4kw
    b. Chiller is 2.8kw
    c. The electrical input is listed as 230V 20A 50/60 Hz single phase
        i. The chiller has the same requirements listed, but assuming the power listed is correct it will use ~12A

Power setup

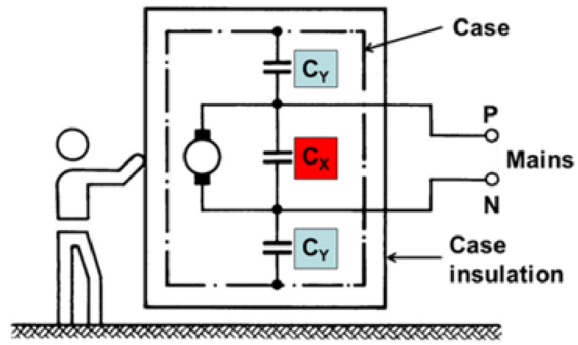
- Getting 220V 20A from the wall is not a problem, just use the
- 12 gauge wire
- 2x 220V plugs
    - **Todo** we need to figure out what the laser/chiller plug look like
- 2x 20A breakers
    - These are cheap
    - **Todo** figure out what exact breaker
- Do we need shielding for the electrical?
- We can pull from the breaker box near the tormach, and the breaker box near where the band saws are
    - **Todo** measure

Shielding

1. Enclosure will be connected at one spot to the wall outlet's Earth potential
2. Signal ground for motors/encoder/limit switches all share a connection at single points
3. We might want to connect signal ground to enclosure via a resistor + capacitor
    a. Or maybe just a capacitor. Perhaps a 25uF electrolytic, doesn't need to be safe
4. The bed is energized by the capacitance detection, so it will be noisy and should be disconnected from all other grounds.
    a. People should be advised in class to try to avoid the stock from hitting the enclosure for this reason
    b. We might want to duct tape around the edges of the corners of the bed to ensure isolation



Appliance Class I: Case connected to electrical earth (ground)



Appliance Class II: Case insulated

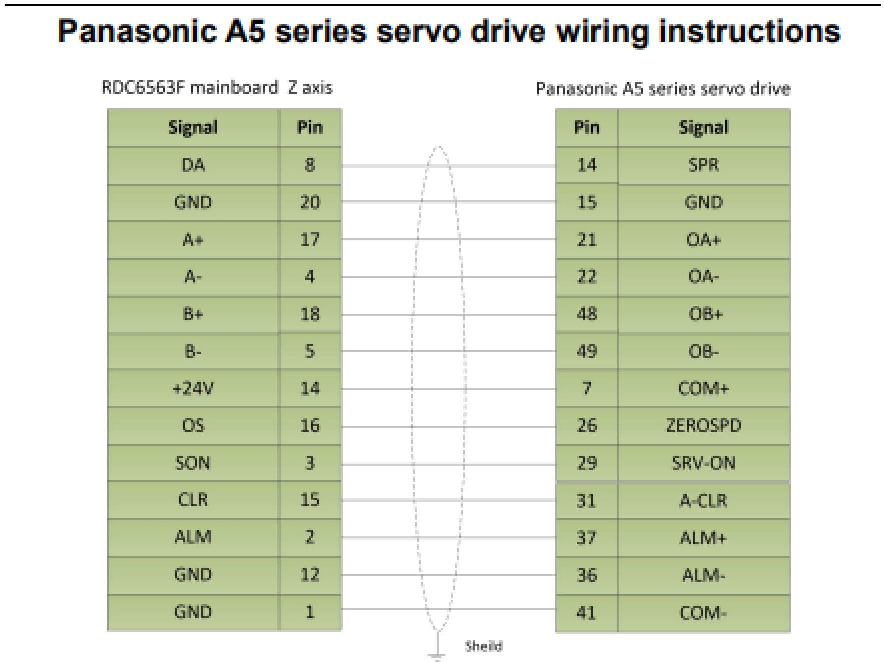
5.
    a. Class X fail closed
    b. Class Y fail open
    c. Normal electrolytic capacitors fail both open/closed, so can't be used
    d. https://www.vishay.com/en/capacitors/rfi-safety-rated-xy/
    e. https://smile.amazon.com/s?k=safety+capacitors&ref=nb_sb_noss_1
        i. Lots of decent cheap options
        ii. We probably want an assortment of capacitances
    f. I sorta expect that the DC power supply we use will internally have class X/Y capacitors

Ruida Controller manual notes

1. 24V >3A dc
2. Need <10Ohm between work piece and machine body
3. Don't hotplug the monitor
4. The mainboard usb is for copying files, the monitor usb port is for firmware upgrades
5. They only support certain servos for z
6. e pay attention to the USB interface on the panel and the
7. Udisk interface on the mainboard. The USB interface on the panel
8. is used for panel firmware upgrade. The U-disk interface on the
9. motherboard is used for cop
10. Leave the machine on for 5 minutes, to allow everything to warm up, before starting the capacitance calibration
11. The guide suggests RDCutist
12. Detects 0-9.9mm with <0.1mm accuracy in Z
13. Z axis drivers
    a. Needs to have direct vector control
    b. Type 1
        i. Panasonic Minas A5 Series
            1. Logic seems to be +24V
            2. Has single phase or three phase 100-200V
            3. Digikey minas A5 driver only $600

a. In stock, 28

4. [Digikey 220V AC driver only]() $410
    a. It's the cheapest driver on digikey other than 18-80Vdc [gecko]() for $115
    b. 0 in stock
5. Compatible motors
    a. [M71X15S4LGA]() $114
6. Wired like



Panasonic A5 series servo drive wiring instructions

RDC6563F mainboard Z axis		Panasonic A5 series servo drive	
Signal	**Pin**	**Pin**	**Signal**
DA	8	14	SPR
GND	20	15	GND
A+	17	21	OA+
A-	4	22	OA-
B+	18	48	OB+
B-	5	49	OB-
+24V	14	7	COM+
OS	16	26	ZEROSPD
SON	3	29	SRV-ON
CLR	15	31	A-CLR
ALM	2	37	ALM+
GND	12	36	ALM-
GND	1	41	COM-

    a.
    b. DA -> Analog output -10V->+10V
        i. Is it really using analog -10V?
        ii. It says 0 to +/-10V, sign controls direction
        iii. Another is 0-10V Analog voltage output
        iv. Normally goes to V-REF
    c. A+/A-/B+.. Encoder signals (two phases)
    d. OS -> Zero speed clamp
    e. SON-> Enable signal
    f. CLR -> alarm clear
    g. ALM -> alarm input
    h. Controller has 5V and 24V output
    i. Settings
        i. Encoder pulse number 2500
            1. Pulses / rev
            2. This is the same for all of them
        ii. Speed gain is set to 500r/min/V
            1. Conversion factor for input analog input
            2. Same for all of them

            iii. Auto-adjust on
    ii. Fuji A5
        1. No prices
    iii. Schneider 23D series
        1. manual
c. Type 2
    i. Sanyo R series servo drive
        1. R series is AC line
        2. We'd want the low inertia ones
        3. Has autotune for speed mapping
        4. Vibration suppression
        5. They're on digikey and mouser, but I can't find the drivers, which is what I really need
            a. They said no one stocks those components, but they can sell it for $905
        6. NA Contact
            a. Emailed them about buying
    ii. Yaskawa∑ Series
        1. 7 series page
            a. This is the series that the controller seems to expect
d. **Todo** What is the difference between type 1 and 2? It says "different servo driver control signals and the level logic"
e. They really recommend a servo that's listed, but I currently still think that it's possible/preferable to just use a normal stepper
    i. Main deciding factor may be weight. We want something that has similar characteristics to those shown with high power density
    ii. They want speed control
    iii. They want a speed gain of 500 rev/min/V
    iv. Encoder pulse value of 2500
        1. Pulses to revolution I think
            a. Actually, I don't think the math works out, 200steps/rev is a 12.5 gain (needs to be a whole number)
            b. It is 5x the speed gain
    v. Zero speed clamp on
    vi. Needs to be wired similarly
    vii. Needs to have an alarm
f. Custom options
    i. Nema17 OMC $100
        1. Does this have speed control?
    ii. Anaheim Automation
        1. AC 50-200W Driver $220
            a. AC speed control driver
            b. Discontinued, which is fine with me
        2. 24-70V dc driver $170

                a. 50W DC $187
                    i. 0.88lb
                b. I think as long as the inputs are the same, we can get away with DC, as that's probably cheapest and lightest. It is weird that they only list AC drives
                    i. I don't think the inputs are the same
                c. AC is lighter comparison
            3. Packages
                a. 200W dc KNC $395
                    i. This still looks over specced to me, which is fine
                    ii. Manual
                    iii. Has analog speed mode, and excellent documentation on how it works
                    iv. Not sure what the max voltage is for AIN
                        1. I think that we can configure max rpm on the ruida and with rpm/V setting on both controllers to limit what the max V is
                        2. Todo Test this with a multimeter to make sure it's correct
                b. 88-126V AC package $555
            4. Guide for sending parameters
        iii. Cloudray $122
            1. AC 50Hz(?), 80V
        iv. Oriental Motor $850
        v. PN00221 $53 largely do-it-yourself board
            1. Has analog resistance-based velocity control
                a. This is fine
            2. Guide
            3. Logic is 5V (I think that's not a problem, either an LDO or v divider)
            4. I don't see a gain or stiffness setting
            5. 10-15A which is plenty
            6. No alarm
        vi. Delta AC Kit $340
            1. Delta servos are mentioned in the Ruida manual, but not for the z axis. Not sure why.
        vii. AC Servo Kit Aliexpress $245
            1. Asked for manual, they sent it
            2. 220V
        viii. Trinamic servo board $60
            1. Really well documented servo chip
            2. Has analog input
                a. Blog post

        b. Involves writing code in TMCL, which will let us make sure it operates the way that the controller expects
        c. Need to make sure the board I use has TMCL support
    3. I think I need multiple boards
        a. Landungsbrücke
            i. Oh those Germans and their love of long words
            ii. I think that this just connects your computer to another board
            iii. Is it possible to use an arduino instead?
            iv. Digikey $63
        b. TMC4671 $61
            i. manual
            ii. Has SPI and UART interfaces
            iii. Does NOT include motor control, or connector boards
        c. Power stage board
            i. TMC-UPS-xAxV-EVAL
                1. Digikey $90
    4. They also have a good BLDC motor here $90

Process Head

1. Ideally one that can do welding and cutting in a single operation
2. Coherent sales rep recommended Precitec and Laser Mechanisms, but I doubt those are cheap options
    a. Options
        i. Raytool 2kW cutting head $900
            1. QBH
            2. Autofocus (we don't need this)
        ii. WSX KC13 2kw $685
            1. QBH
            2. Their site mention KC15, I'd like to ask what the difference is and how much the newer version is
            3. **Purchased**
            4. The mounting holes listed on the site are wrong
            5. Coolant valves are 4mm
            6. Air valves are 8mm
3. Tubing
    a. Coherent recommends using polyethylene, I'm only seeing polyurethane though
    b. Todo how do we connect the 4mm tubing to the chiller?
4. A200 Manual
    a. The lenses need to be cleaned weekly
5. KC15 Manual
    a. We'll need to go through some steps to make sure that the lens is properly aligned

        i. This manual suggests using tape to measure the overlap
6. Video on cleaning / disassembly, similar model
7. Video on installing similar cutting head
8. Video on attaching wsx laser head

Laser is 1kW Coherent HighLight 1000FL

- 5.7 OD
- 1100 +- 20 nm or 1070 += 10nm
- Fiber lasers cut metal. Despite their high power, they are not effective for cutting wood, plastics, or basically anything but metal. Guidelines for the 1000FL seem to be about ⅜" mild steel maximum.
- Quick info pdf
- datasheet
- 15 or 20 A
- ~~**Todo** Does this include the laser cutter head?~~
    - yes
- Fiber-Fiber-Switch (FFS) or Fiber-Fiber-Coupler (FFC)
    - I think this is for using one laser and multiple gantrys/workstations
- How is this laser turned on/off?
    - 24V DC
    - We may need a logic level mosfet to control the laser at that V
        - We want to include a mechanical relay, as those fail-off and mosfets don't
    - Does this support PWM? What freq range?
        - The manual lists a minimum pulse width of 2.5ms so max frequency would be 400Hz

We currently have:

1. ~~4x Nema 34 stepper motor with SINGLE shaft, 1600oz.in~~
    a. ~~34HS5435C-37B2~~
    b. ~~3.5A~~
    c. ~~1.8 degrees / step~~
    d. ~~24.5Ncm~~
2. ~~4xPower supply 350W(60VDC/5.8A)~~
3. 2x Stepper motor driver , peak 7.8A 24-80VDC
    a. DM860A
4. 2x Red Nema 34 Stepper
    a. From the old Gantry
    b. K31SSFS-LEK-SS-02
        i. 5.5A 35V 119W
    c. Both will be used for X
    d. Not sure what torque
5. Ruida Laser Controller
6. This small stepper

    a. What nema #?
7. Danny
    a. Rack and Pinion
    b. maybe working A200MS laser head
    c. Aluminum extrusion I think

Stepper to buy
1. We need one for the Y
2. This only moves the head/drag chain, so it can be fairly light
3. Although, weaker we go the less microstepping we can do
4. Options
    a. Nema 23 3.0 Nm $27
        i. 4.2A
        ii. 3.9lb
    b. Nema 34 4.8Nm $33
        i. 4.8Nm
        ii. 6A
        iii. 5.1lb
    c. Nema 24 Kit with Driver 4Nm $60
        i. 4.2A
        ii. 3.5lb

Power supply
1. The recommendation I'm seeing is >2/3 * total amps, which for us is 2/3 * (5.5 + 5.5 + 4.2) or >10.1A
2. Options
    a. 36V 11A 115/230V $28

Stock metal purchasing
1. 4"x4" ¼ thick mild steel
    a. 2x 5ft
    b. 2x 9ft
    c. 4x 29"
    d. 24ft for $569 so for 38ft total ~**$1,138**
        i. We'll need westbrook to cut it, so this is a lower bound
        ii. Westbrook also mentioned that right now, due to demand, milled products like angles, beams, channels can be cheaper
2. 11 Gauge sheet metal mild steel
    a. 59x 4"x4ft for slats
    b. 3x 3"x9ft for slat support
    c. 4ftx10ft is $385, so for 20ft is **$770** (not including slat support)

TODO

~~1. Get controller~~

2. ~~Model gantry in fusion~~
3. Wire steppers to controller
4. Wire limit switches to controller
5. Wire capacitive height controller
6. Wire controller to laser
7. Figure out the slats
8. Buy
    a. ~~Gantry stuff~~
        i. ~~Wire/Cable guides~~
        ii. ~~V-wheels~~
            1. ~~Amazon 16~~
            2. ~~I think we need 3~~
        iii. ~~V slot corner connectors~~
            1. ~~4x~~
        iv. ~~T slot extrusion for additional support~~
        v. Danny has 2x 12-14 ft sticks of 45mmx90mm Bosch Rextroth aluminum T-slot (metric 80/20)
        vi. Graphite bushings
        vii. Something to hold the laser
        viii. Large gauge wire
        ix. 3 prong AC cable
        x. Casters
            1. Amazon
        xi. Screws
            1. We need something to secure the extrusion to the frame, probably M12
                a. Amazon
            2. Nuts
                a. 32x Lowes
            3. 24x 0.5” Bolt Lowes
            4. 8x 0.5” Bolt Lowes
        xii. Angle Iron
            1. 1.5” Lowes $23
        xiii. Gantry drive mechanism
            1. ~~Timing belt / spokes~~
                a. Danny is getting some high-precision rack and pinion
            2. ~~Lead screw~~
        xiv. Drag chain
            1. Needs to have a large radius, to prolong the life of the laser carrier
                a. Emailed Coherent about recommendation
            2. Length: pi*R + stroke / 2 + 2 * pitch
                a. Main axis R250
                    i. pi * 250mm + 6.42ft / 2
                    ii. 69.4” or 1.76m

            b. Width-wise axis R250
                i. pi * 250mm + 4.25ft / 2
                ii. 56.4” or 1.43m
            c. Up/down axis R200
                i. pi * 200mm + 1ft / 2
                ii. 1.5ft or 0.5m
        3. Amazon R200
        4. Amazon R300
        5. Amazon R250 $53
    xv. Timing Pulleys / Belt
        1. 25mm-30mm
        2. HTD-5 or GT
        3. 25mm fiberglass HTD 10M + 5M $100
            a. Pulleys
                i. Spec says we need at least 22 to 30 (depending on rpm)
                ii. The cable manufacturer said that the min bend radius is 15mm
                iii. 6x T30 HTD-5 ($21)
        4. We also need a belt/pulley to act as a gearbox (2x)
                i. The belt orientation makes us need a >6x reduction
                ii. We could use a stepper gearbox, but those add a lot of backlash
                    1. <15 arc min backlash gearbox for Nema 34 $100
            b. 5:1 ratio belt/pulley $16
            c. 5:1 HTD-5M reduction belt/pulley $32
            d. 3:1 ratio belt/pulley $14
            e. Custom 96:15 (32:5) ratio
                i. 15T AT3 pulley 6mm $7.5
                ii. 96T AT3 pulley 6mm $25
                    1. Only one in stock, same for the next size down
                iii. AT3 6mm timing belt $13
b. Shielding / laser PPE
    i. Kentek appears to be the standard for laser ppe
    ii. They do seem pricey, though
    iii. Laser glasses
c. Computer(**?**)
    i. A small NUC would probably be enough
~~d. Capacitive height controller~~
    ~~i. we might have a BCS100 v3~~
        1. Manual
        2. Works with cypcut

ii. Options
   1. BCS100 v3
      a. Kit for $4,100
      b. Solo for $2,100
      c. Works with Ruida controller $353
         i. That site sells the BCS for $2,700
   2. CHC-1000S
      a. Solo for $1,450
      b. Doc
      c. Mostly in chinese
   3. CHC-1000L
      a. Solo for $1,360
      b. How is this different from S?
      c. "Support Simens, Fagor, Beckhoff, PA8000....most cnc controller for laser cutting,"]
   4. CHS-10000
      a. Doc
      b. Have to call to get a quote
   5. Ruida RDC6563F $1369
      a. Looks like it would be perfect, only concern is a relative lack of documentation relative to the BCS
      b. Purchased

iii. What is the typical capacitance in pF? We might just want to make one with the arduino **~~todo~~**
   1. Normal way to measure capacitance is to look at how long it took to be fully charged at a known voltage, that afaik won't work if you want continuous data
   2. I somewhat think that a laser-based height sensor would be preferable, but there would be a lot of black body induced noise to remove
   3. There's characteristic noise that the splatter produces, which we have to take into account. I don't think we should do this, as it'd be pretty challenging

~~e. Laser components(**?**)~~
   i. Fiber optic cable
      1. QD or QBH
         a. Docs
         b. 150-200mm R
      2. The coherent manual recommends 200mm in some places and 250mm in others
   ii. Process optics

~~f. Laser water cooler~~

g. Possibly some anti-splatter spray for the slats

9. Build gantry

10. Build shielding
11. Figure out safe way to test laser
    a. Does cinderblock reflect withstand this laser?
    b. Can we test at a really low duty cycle?
    c. I have a fancy machine-vision webcam we can use, to run the laser while it's fully covered

Controller Requirements
1. 4+ axis
    a. Not sure if/when we'll add in actual support for 4 axis work, but it'd be best to select a controller that does not preclude that option
2. Integrates with Lightburn
3. Ideally something using grbl
    a. Or Mega-5x
4. Needs to work with a capacitative height controller

Controller options
1. **Arduino Mega with Grbl**
    a. We would hypothetically get better performance with an fpga
    b. Lightburn mentions grbl support
        i. Not sure that means it also supports Mega-5x
    c. Very common option
    d. Doesn't support advanced look ahead/motion planning
        i. Software compensation should really do this just fine
2. ~~Computer/Raspberry PI with LinuxCNC~~
    a. Lightburn can probably send out compatible g-code
    b. Forum person said linuxcnc doesn't work well with lasers
    c. If not a pi, then it needs a parallel port
3. TinyG code
    a. Receives Gcode via USB
    b. Has stepper drivers on-board
    c. Well-reviewed
    d. The chips I found don't have enough power for our steppers, but they do support third party drivers
    e. Fits the acceleration to a sinusoid, which is really cool
    f. Lightburn not supported
4. Cohesion3D $220
    a. Lightburn supported
    b. PWM support
    c. Supports 4th axis
    d. Works with external stepper drivers
    e. Uses smoothieware which is better reviewed than grbl
    f. Would be nice to try that later. I think it might work better than grbl, but I'm not sure

5. G2Core with Arduino Due
    a. Newer version of TinyG
    b. Well reviewed
    c. I think works with lightburn via Gcode?
    d. This seems like the most advanced in terms of motion compensation
6. Acorn CNC ($299)
7. Blackbox ($200)
    a. I think this has its own stepper drivers
8. Ruida Cloudray controller ($350)
    a. Lightburn supported
    b. Highly reviewed
9. Trocen controller
    a. Lightburn supported

GCode sender

- I don't think this is needed when we use lightburn
- Universal GCode sender

Gantry/Linear motion

- I think we have aluminum extrusion that just needs to be cut
    - **Todo** what length/size?
        - My cuts ideally need ~5ft x 3ft min
- Joe says the frame needs to be 4" x 1/4" square pipe steel
    - Like this
    - I think it might be cheaper, for comparable weight support, to use a rectangular stock. If we want the bed to be heavier, it's cheaper to just use concrete
- The front of the laser bed needs to have rollers to help with loading
    - Like this?
- Danny is getting a precision rack and pinion system
    - ~~Will we need to shield this from dust?~~ No
    - **Todo** what are the specs?
- Movement options
    - Rack and pinion
    - Lead screw
        - Highest precision, but most expensive
        - We'll probably use a cheap lead screw for Z. Because we have a capacitive sensor, the Z axis is extremely backlash tolerant, and only needs to move fast enough
    - Belt
        - By far the cheapest option, should work fine if the laser head is light + low friction
        - Will need to replace the belts after a few years
        - Not sure what the gearing ends up being on the motion, we might need to use microstepping to get full position resolution

            - Would require maintaining tension on the belt
            - documentation
            - There are different tooth profiles
                - T5
                    - Large backlash
                - HTD
                    - Higher torque, acceptable backlash
                    - 25mm steel core 1M $16 / meter
                    - Cloudray carries 40mm wide, but only polyurethane
                    - 30mm steel core 10M $120
                    - 25mm fiberglass 10M $100
                        - This is the best one I've seen so far
                - AT
                    - Trapezoidal
                    - Little backlash, low torque
                - GT2
                    - Low backlash, high torque
                    - 15mm pulley belt 10M $65
                        - Fiberglass core, long shipping
                    - 6mm 10M steel core
                        - 6mm I think will be too small
                    - 12mm GT2 fiberglass core
                        - Not certain they sell
                - GT3
                    - Improvement over GT2, seems to not be in use much
            - There are different core material types
                - Polyester
                - Kevlar
                - Fiberglass
                    - I think this is the best option for rigidity + flexibility
                - Steel
                    - Steel is the most rigid, but limits us to fairly large pulleys, and thus less positional resolution

Placement

- Unlikely the fiber laser will get it's own room
- From Jon: "on paper it looks feasible to spin the wood CNC 90º and put the fiber laser between it and the auto bay, also long axis perpendicular to the outside wall. We'd have to find new homes for the panel saw (maybe on the outside wall where the storage shelves are now), air compressor (thinking maybe wall-mount, or on the other side of the overhead door) and the media blaster (maybe the end of the autobay?). sheet storage might have to move too; not sure."
- Another option would be to put it where the Red used to be, then we could also re-use the ventilation system

    - The problem with that is bringing the sheets in. The autobay would make loading sheets easier

Slats
- Standard spacing is 1.75” narrow is 1.25”
- Thickness 11 gauge (source)
- We need to figure out how we’re going to handle slag
    - We could get an electric laser bed slat cleaner
    - We could also just cut new slats as needed
    - Air chisel also seems to work
    - We could get copper plated slats
        - They’re fairly pricey though

Tray
- We need a way to remove cut pieces without the user ever going under the bed itself
- I’m currently thinking having a slide under that bed so that cut pieces will fall onto a tray that can be removed
- The laser will hit that tray / slide, so it’s at risk of being damaged by the laser
    - The laser has a focal length of ~125mm and a beam diameter of <30mm
    - I think a bed->slide distance of 2-3 focal lengths should be enough
    - The JCUT has the slide ~7” below the bed
    - The slide material needs a high heat dissipation
        - Maybe thick-ish mild steel, perhaps coated in graphite
            - Copper would be ideal, but it’s more expensive
            - Definitely nothing galvanized
        - We might want to add a backing of ceramic tile to the steel so that if the steel cherries it won’t collapse

Shielding
- The laser is OD 5.7+
- Most people operating similar lasers just use eye protection
    - Like this $35
- I think we mainly just need to protect people incidentally looking at the beam
- Options
    - Clam shell enclosure
    - ~~Dedicated room~~
    - Curtains
        - I think we can use normal blackout-flame retardant curtains like this $30
        - We just need something stable to hold them up
    - Laser proof acrylic
        - Allied plastics didn't know what I meant when I asked for laser-safe acrylic, I might be able to follow up if I had more details on what kind of polymer we need

University of Nebraska manual

- They don't recommend hot rolled steel because the mill scale will damage the lens
    - This is the first that I've heard this
    - [This article] suggests that it's fine, but can cause blowout, which in turn could damage the lens
    -
- They use 170 psi, for both air and nitrogen
- Their nitrogen appears to be stored in a gas tank (i.e. not a dewar)
- They strongly advise against allowing sparks above the surface of the material
    - I think that this is other than the pierce step
- They seem to use brass fittings for the assist gas

Ventilation
- Cutting steel releases CO, so this needs to be vented
- Ideally the out vent will be below the laser bed. We want smooth laminar flow of the gas away from the laser, as that is what most frequently impairs cut quality

~~Laser cooling~~
- Manual lists DI water or clean filtered water as viable sources
- 8 liters / min
- 24-27C (75-80F) for DI and 15-35C (59-95F) for filtered
    - I think that there might be an errata here, I think the filtered temp range is correct
    - So do we need to cool the water?
    - Maybe add a thermometer here
- Looks like both the laser and the laser cable need cooling
- We will need DI water for this

Laser gas flow
- This laser can cut with N2, O2, air, argon, He
- N2 seems most common
- Flowrate / pressure requirements change with
    - the gas used
    - Cut thickness
    - Nozzle diameter
    - [Graph] for SCFH by material / thickness
- **Todo** Figure out the assist gas tubing
    - And the coolant tubing
- Options
    - N2
        - Fairly common
        - Best for stainless steel
        - Excellent edge quality
        - Most people use a dewar
        - Pressure / flow requirements mean we may need a vaporizer and liquid nitrogen regulator [link]

- I can't find anyone else using a vaporizer. Additionally, they don't look like they're easy to source. I think the person in the video linked may have just been using more flow rate than is strictly needed
- Someone in the comments mentioned not using a vaporizer with N2 at 120psi 12cfm, but that may have been with a high pressure tank

- Reacts with titanium, interestingly
- There is a noticeable difference in cut quality between 99.9% and 99.995% purity
- 1.4cfm of liquid nitrogen
- We might start out with compressed

- O2
  - Cuts deepest
  - Causes mild steel to oxidize, releasing heat, allowing deep cuts but with a larger heat affected zone
  - Best for carbon steel
  - I think everyone uses compressed O2, as the flow rate is not as high as N2, and liquid O2 would be much more complex
  - Creates black dross on stainless
- Air
  - 250psi 70cfm
  - 150-200 psi
  - **Todo** how filtered?
  - We can reduce the pressure needed a lot by switching to a smaller radius nozzle. The only downside to doing so is that the smaller the nozzle is the higher the laser needs to be
  - Air compressor that we have is 135psi
  - Best for aluminum
  - Ok for stainless steel <2mm
- Argon
  - Mainly for titanium
- <=⅛ 150-200 psi

-
- Guide on troubleshooting pressure / height
- Watch out for brazed pipes adding contaminants
  - A 2.5-mm nozzle may require 2,000 cubic feet per hour (CFH), and the 3-mm nozzle may have a gas flow rate of 3,500 CFH
- **Todo** Do we have a filter and dehumidifier hooked up?
  - We do not
  - **Todo** would this filter/dryer ($65) work?
- We may need a vaporizer for liquid nitrogen to get enough flow

Laser Backreflection

- Causes instability to intensity and frequency modes
- More severe for highly reflective materials like copper, brass
- More severe for welding and briefly during piercing
- Modern lasers use Faraday Rotator to turn backreflection into heat
- Legacy lasers detect backreflection via software and disengage the device
- Stainless steel mirror finish can also cause backreflection

4th Axis
- I'll need to check if it's possible to avoid the 4th axis and just cut square tubing in multiple steps, each step rotating the tubing 90 degrees
- Fusion/grbl sorta supports 4th axis link
- These guys used Pipefit software
- Cheap 4th axis chuck $188
    - Talked to the salesperson, it's ~$4,000

Screws
- M6 bolts + nuts
    - 12x for the steppers
    - Bolts $6
    - Nuts $3
- ½" bolts >5in + nuts
    - 24x for the frame
    - I already have washers
    - Bolts $34.8
    - Nuts $8 (this is a 25 pack, so I need to make sure that they actually include it all)
- ~~½" bolts 1in + nuts~~
    - 16x 1" + nuts are needed for the main tubing right corner connection
    - I'm going to hold off on these for now, idk if that corner piece is needed
- 5/16"-18 bolt for extrusion face
    - 24x 0.5" to bolt the gantry to the vertical extrusion
        - At the right angle part
    - 8x for the gantry head
        - 4x outside and 4x inside
    - 8x for the top parts of the x pulley system
    - ~25x for the x axis rails
        - Could be far fewer
    - 4x to connect the z rail to the axis head
    - 12x for the cable holders along the gantry
        - 2x 6 holders
    - 77 0.5" Bolts ~$10
    - nuts
- ~~5/16" bolt 1-¼"~~
    - 12x for the gantry head
        - 4 each side, 4 in the back

- M12
    - 8x for the Y linear rails >3.2”(80mm) long
    - 1.75mm pitch
    - Bolts 100mm
- M5
    - 4x needed to connect the axis y head to the rail cabby
    - 1x needed for the Z axis motor bolt
    - 2x needed for the Y axis motor bolt
    - 12x (+12x bolts) needed to connect the 3 steppers
    - 8x needed to connect plate to z axis
    - 4x needed (+4x bolts) to connect the laser to the plate
    - 6x needed to connect the z axis to the gantry
    - 16x needed to connect the pulley plate to the main frame
        - 4x each corner
    - The recommended hole size for that is 5.2mm, but that seems big to me **todo measure**
    - purchased
- M3
    - 30x needed for all 3 cable clamps (+6x bolts)
        - 3 * (8 + 2)
    - Already have some
    - I think the drag chain should be M3, so
    - **Todo** threading
- Bolt gantry rail to extrusion
    - Eric should have these
    - ½-13
- M4
    - Used for the pulleys

Gearbox components

1. Rods
    a. 8mm rod
        i. 3x 3.5” + 1.5”
        ii. 15” total
    b. 10mm rod
        i. 3x 3.2” + 2.4”
        ii. 16.8” total
    c. 6mm rod
        i. 3x 2.3”
        ii. 6.9” total
2. Couplers
    a. 8-10mm coupler

        i. 3 total
    b. 8-14mm coupler
        i. 2 total
        ii. This connects the x stepper to the 8mm rod
        iii. Also connects the Z axis to the motor
    c. 8-12.7mm coupler
        i. 2 total
        ii. This connects the two y steppers to the 8mm rod
    d. 6-10mm coupler
        i. 3 total
3. Rollers
    a. 6mm
        i. 3x total
    b. 8mm
        i. 6x total
    c. 10mm
        i. 6x total

Total wire line:
forward/left drag radius + up drag chain radius + static drag chain + rail X + rail Y
2 * (pi * 250mm) + (pi * 200mm) + 3 * (pi * 150mm) + 6ft + 4ft
21.85ft