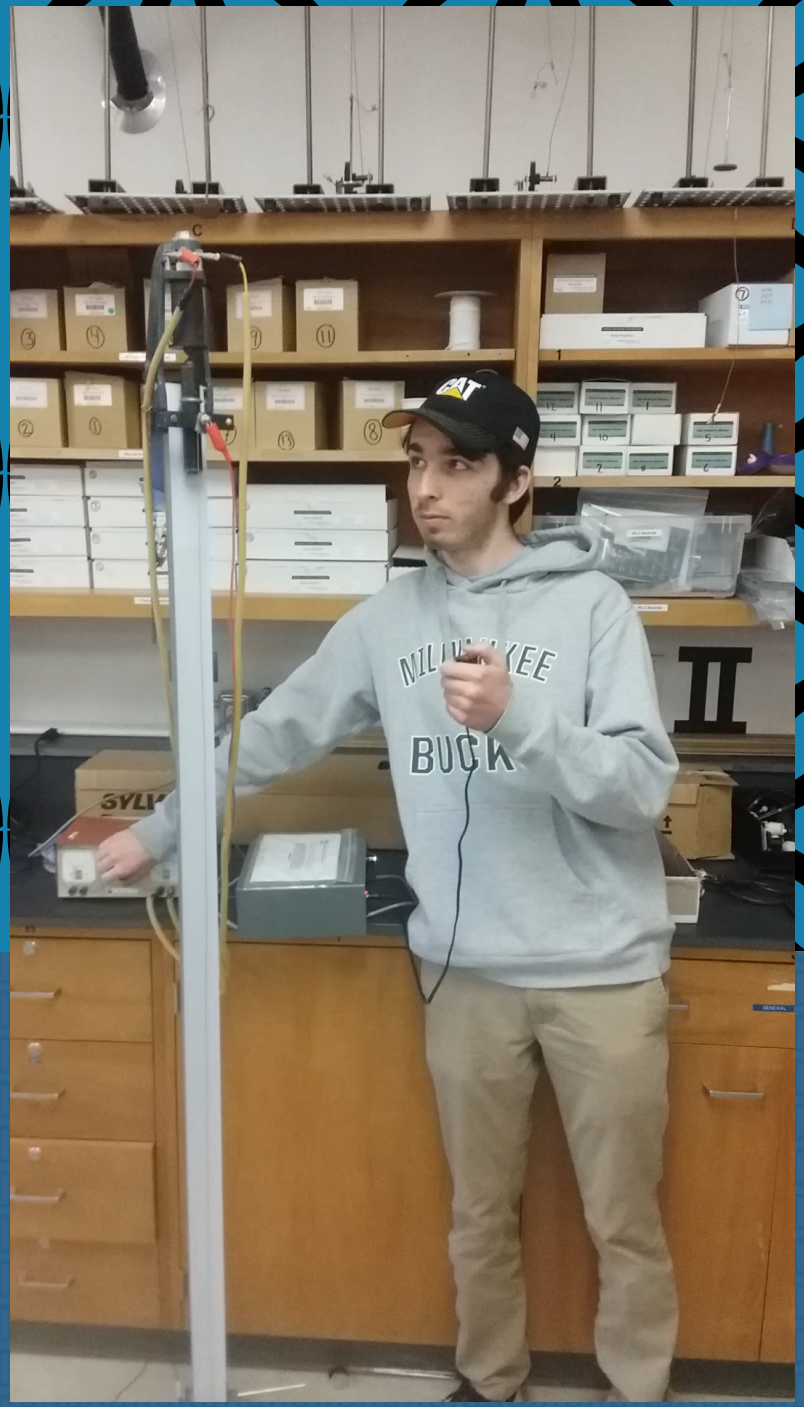


IMPROVED BEHR FREE FALL APPARATUS

Jacob Brauer

METHODS

Design Test Build

And all possible permutations of sequence between these.

CONVENTIONAL BEHR FREE FALL APPARATUS

Electricity arc through air

Need to use disposable paper for every use

Impossible in vacuum

IMPROVED BEHR FREE FALL APPARATUS

Uses Vernieer cart sensor

Vertical drop

IR instead of arc of electricity

Can be used in a vacuum

No disposable waste per trial once machine is established

<u>Best test data so far comes from machine at right</u>

IMPROVED BEHR FREE FALL APPARATUS

Uses Vernieer cart sensor

Vertical drop

IR instead of arc of electricity

Can be used in a vacuum

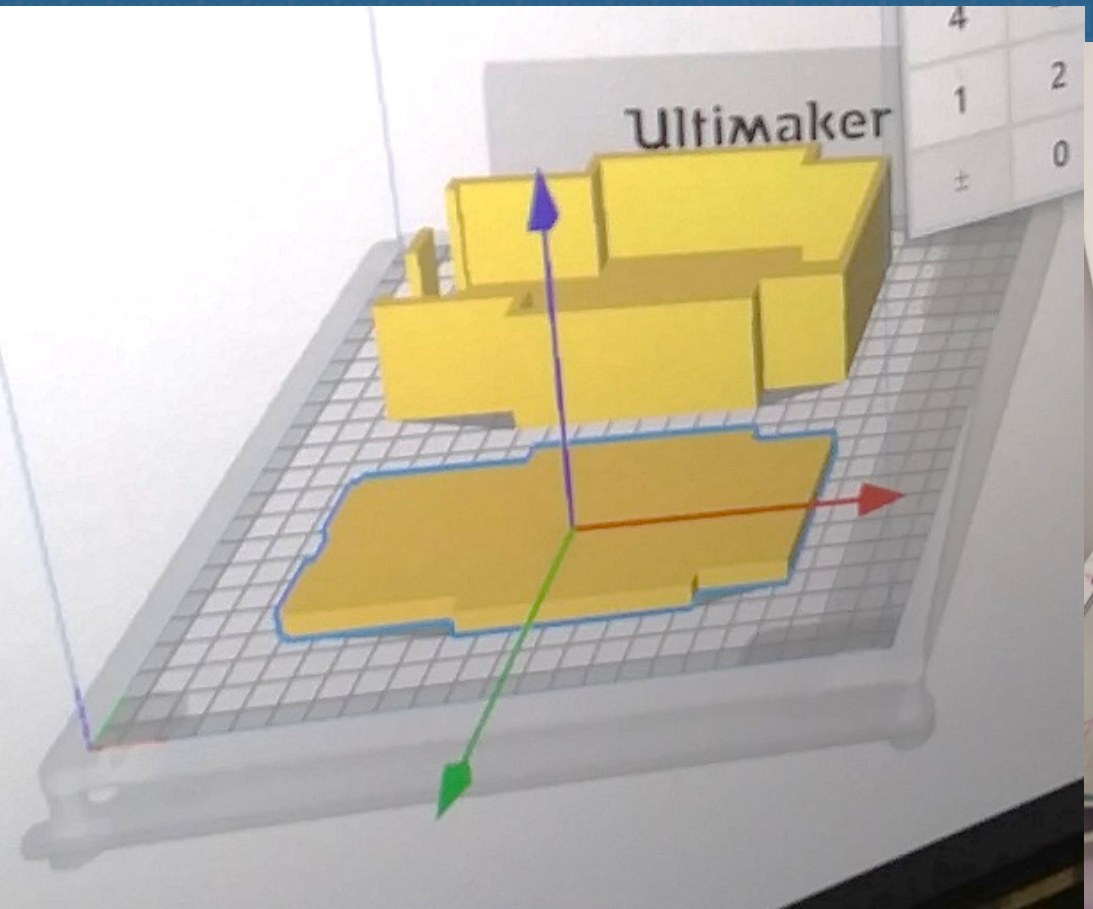
No disposable waste per trial once machine is established

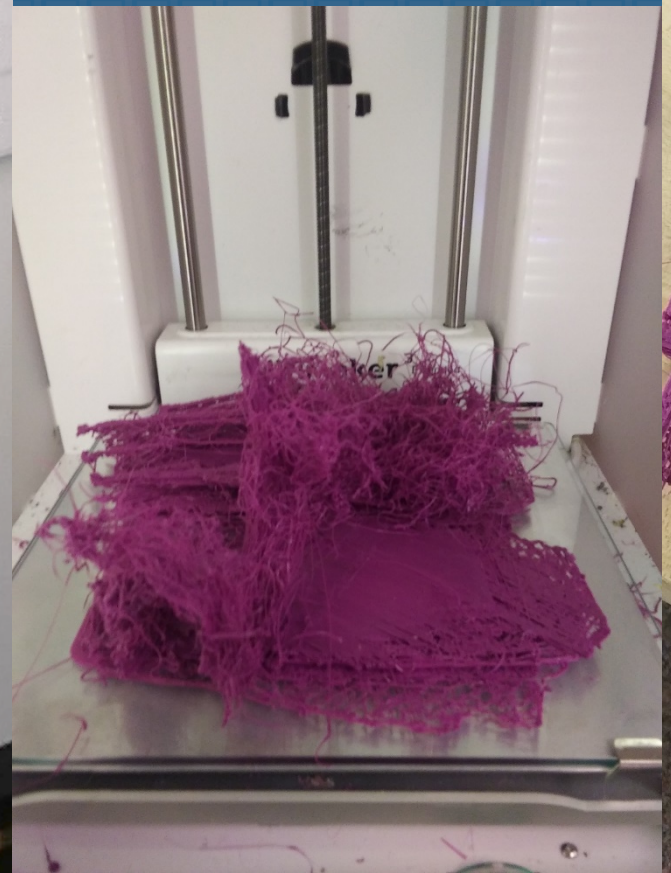
Best test data so far in table to the right

2 meter drop, aerodynamic cart data	
trial number	acceleration due to gravity (m/(s^2))
average of trial number 1--> 10	9.192
average of trial number 2 --> 10	9.653
standard deviation of trial number 1 -->10	1.389
standard deviation of trial number 2 -->10	0.1431

3D PRINTED CART

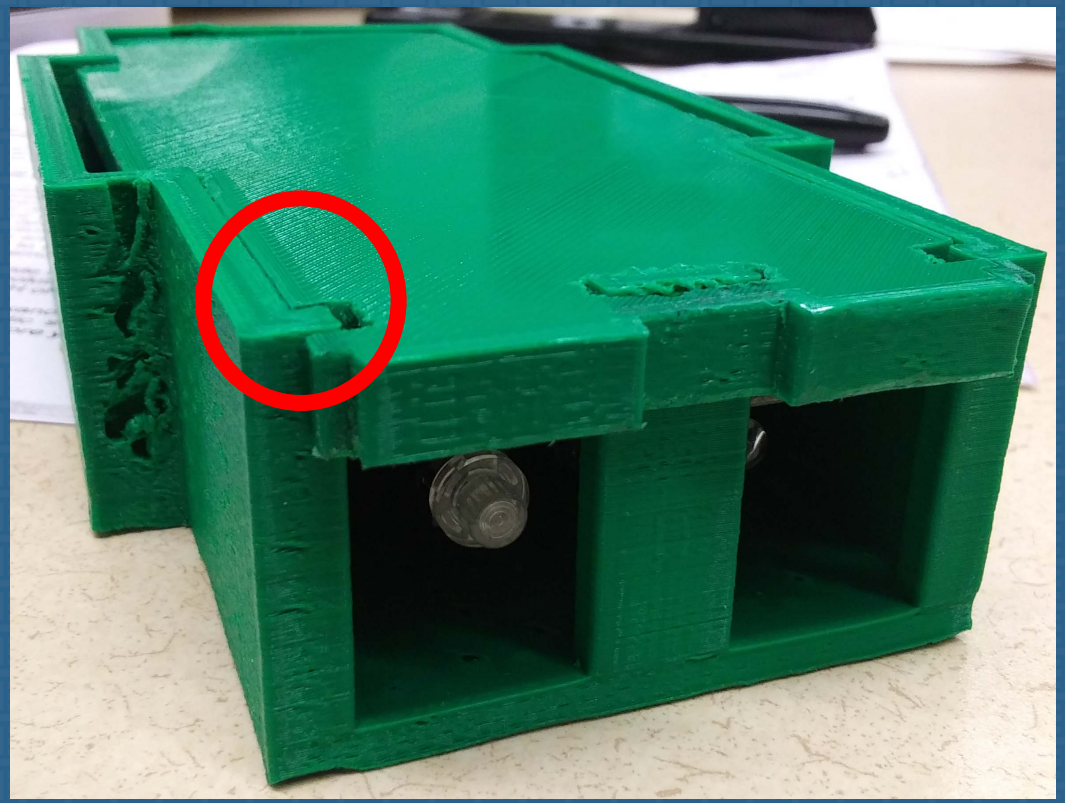
Design and implementation

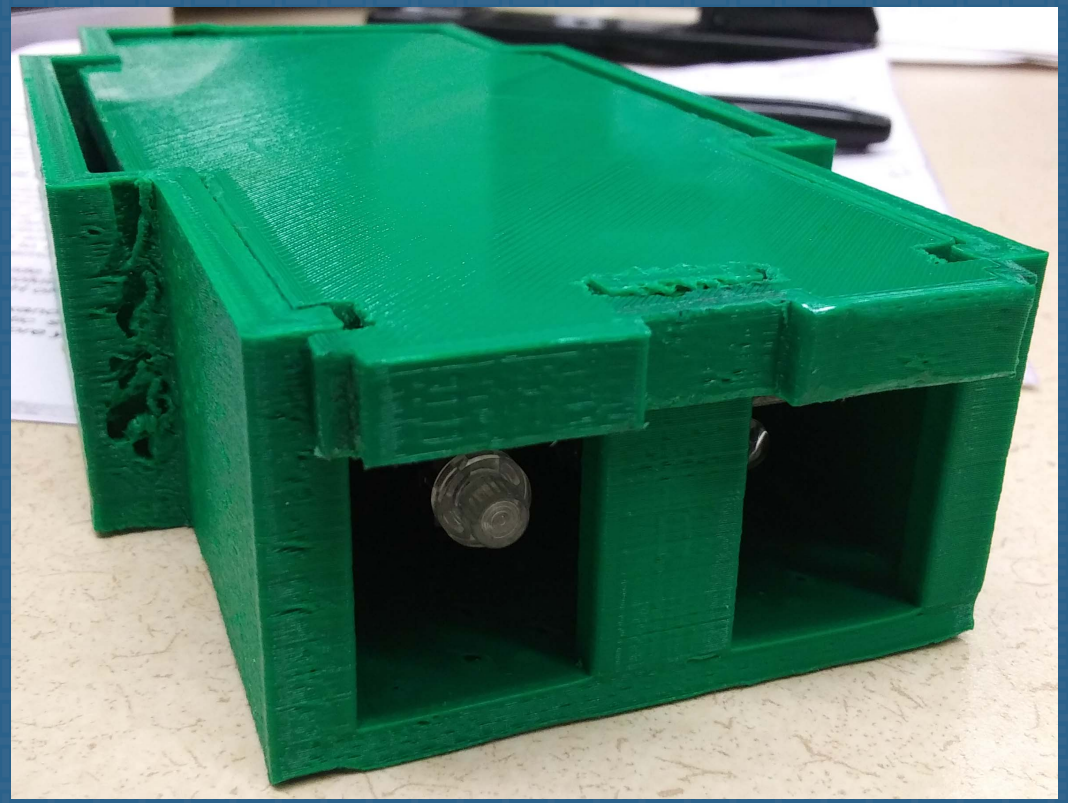




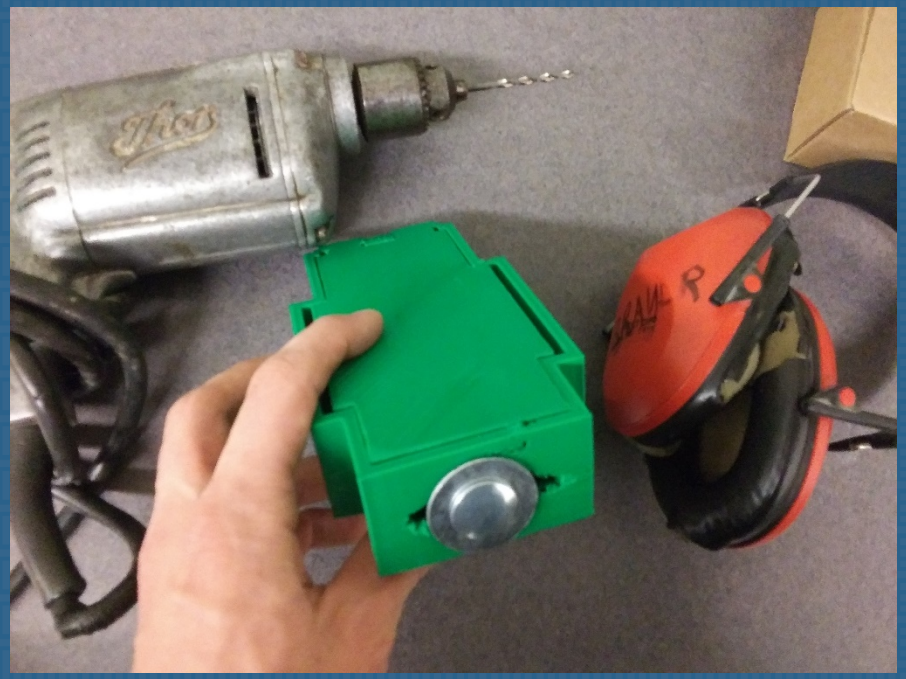
3D PRINTED CART V1.0

Had to manually cut some sections of cat, but the print made most of the shape needed





WEIGHT IN MANUALLY CUT SLOT IN BOTTOM TO PROTOTYPE CENTER OF MASS

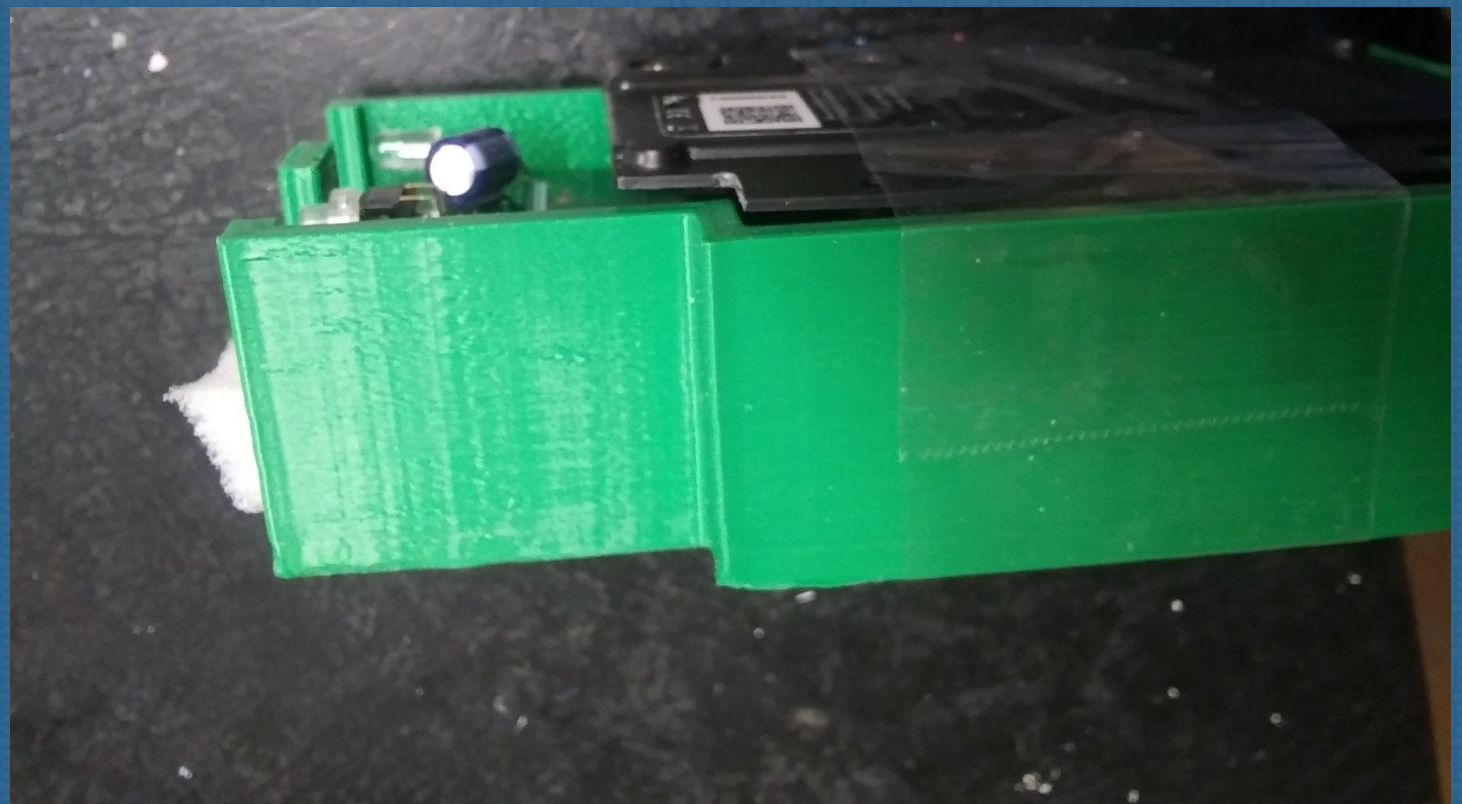


CART V 1.01 CLEAR PACKING TAPE FIASCO

Clear tape was used. It was taped over sensor on bottom of cart.

This partially obstructed barcode sensor on bottom of cart.

Partially good data was obtained, and the machine knew it was moving sometimes.



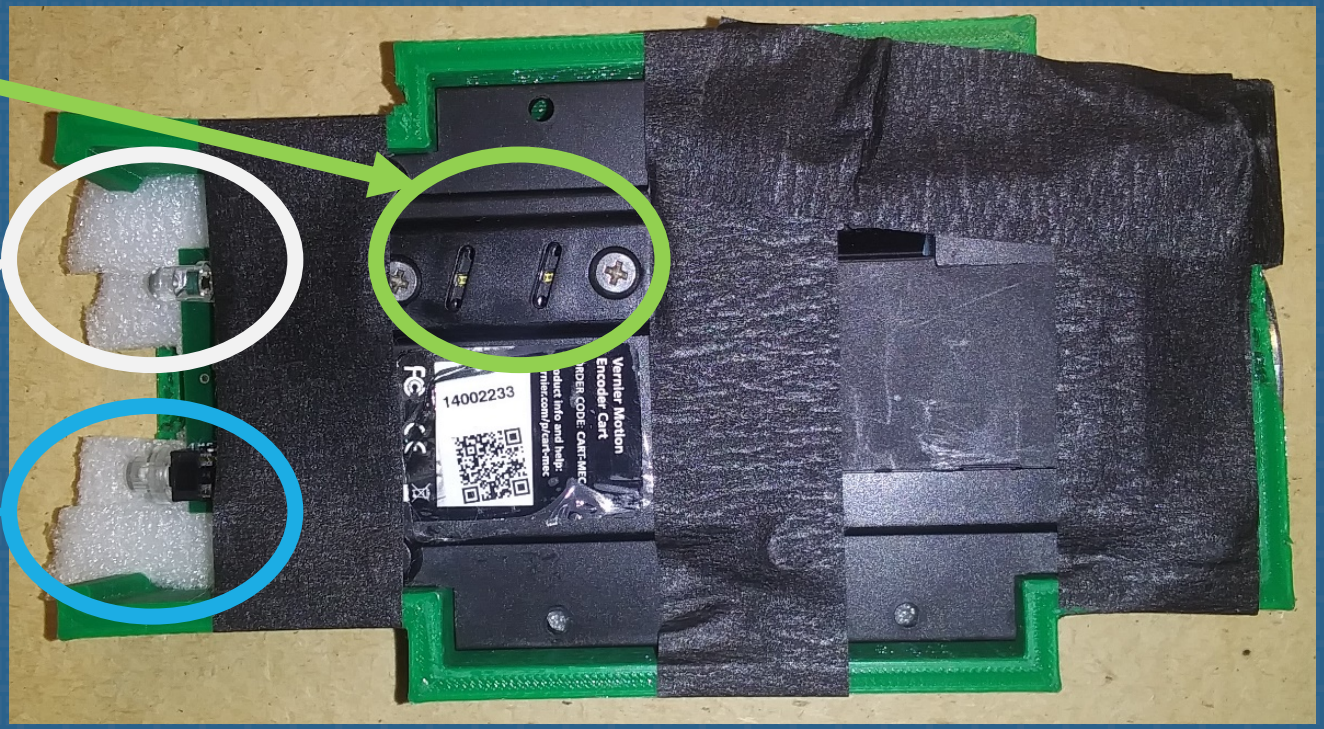
CART V1.1

Taping over two holes in bottom of cart leads to malfunctioning of sensor readout

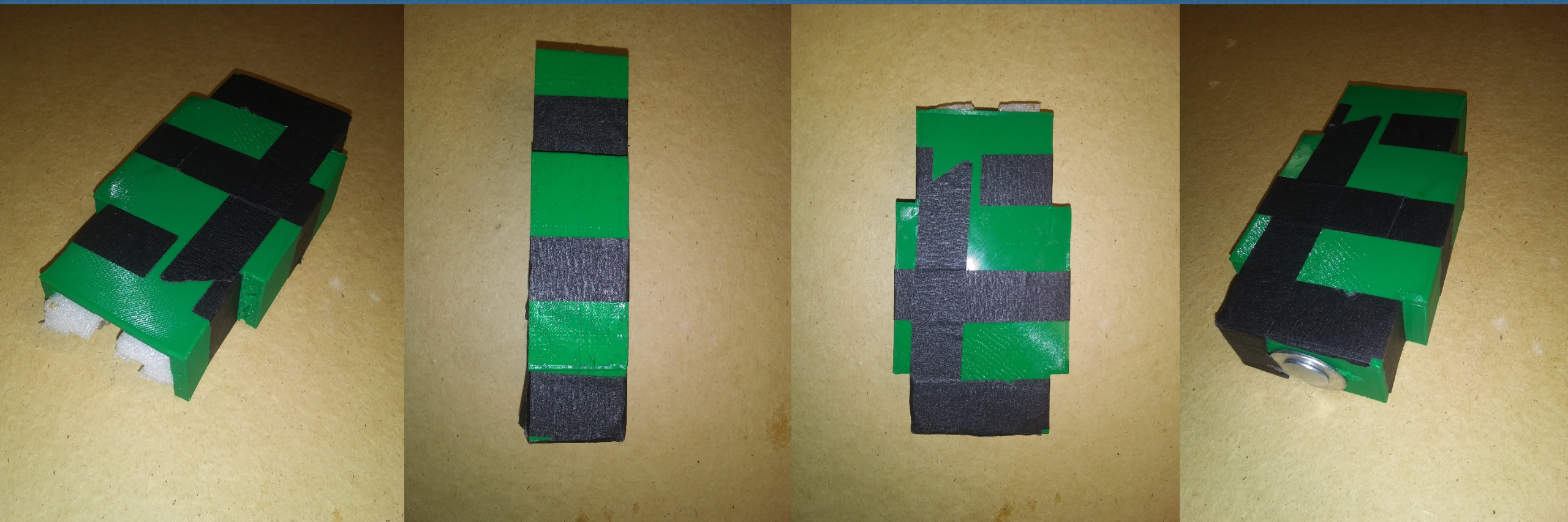
Barcode sensors

IR communicator

On button

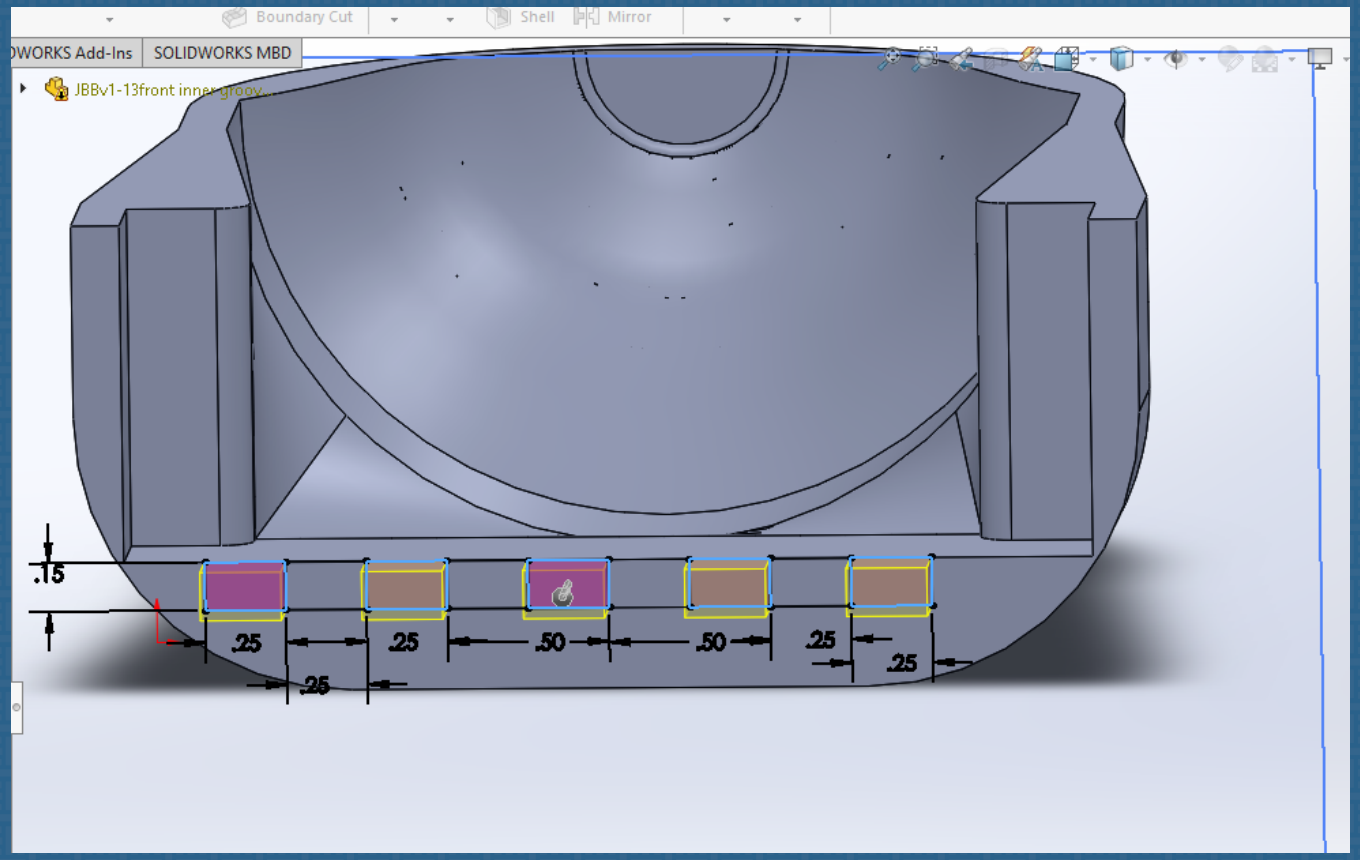


CART V1.1 DIFFERENT VIEWS

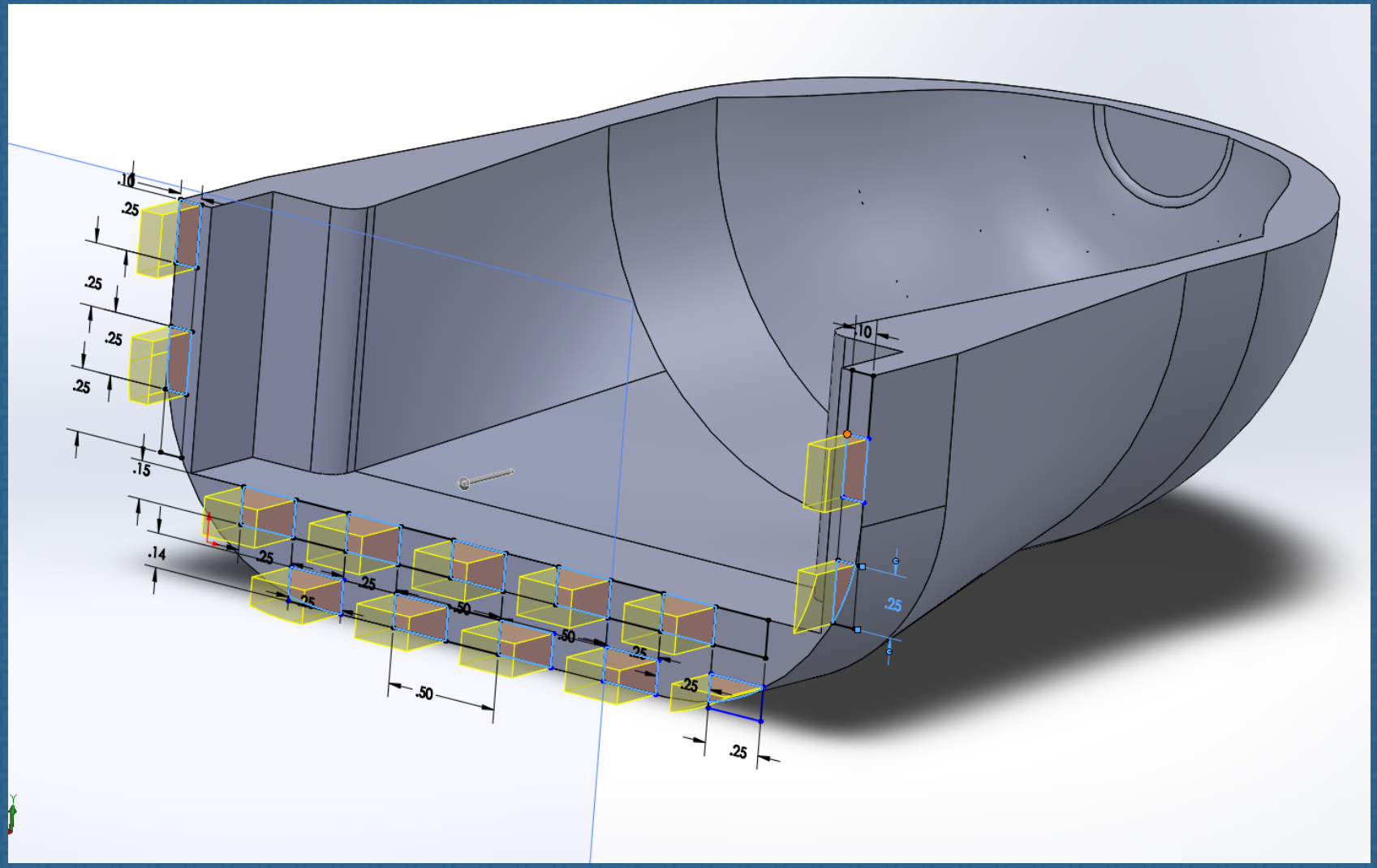


GROOVE EXTRUSION -- SOLIDWORKS

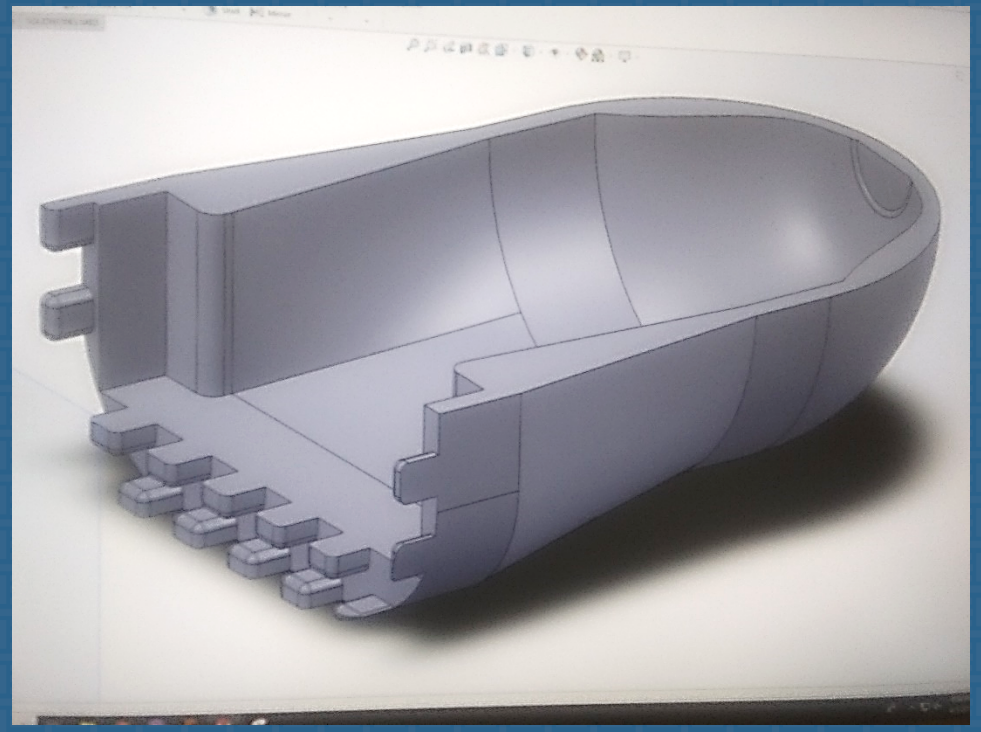
Needing better air flow, the loft and bevel tools were used. To fit the cart better and match reality up with cad design, the interior 90 degree angles were beveled (rounded).

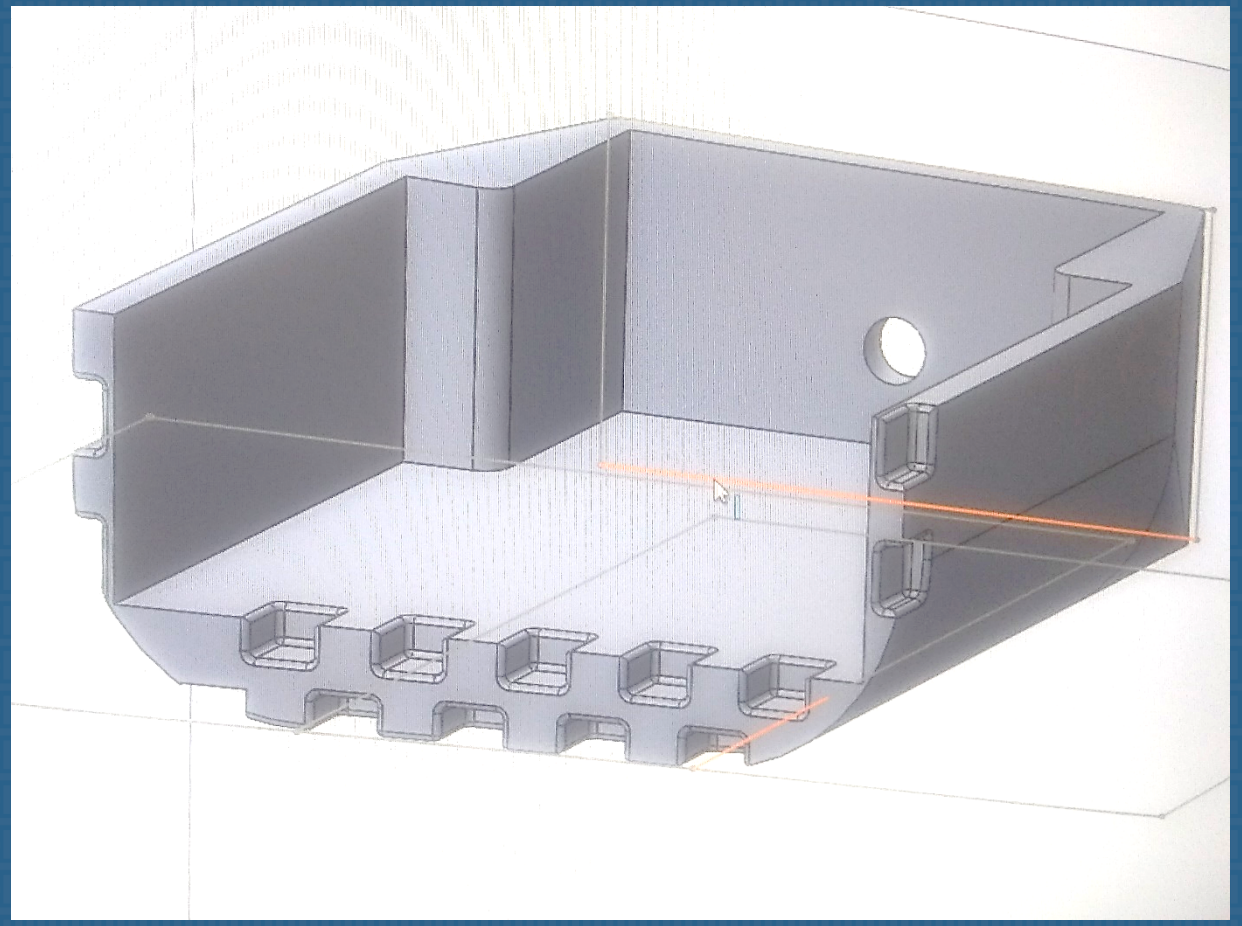


GROOVE EXTRUSION -- SOLIDWORKS



CART REDESIGN – TWO MODULAR HALVES GROOVE TOGETHER





CART V2 – REMOVING FROM BASE PRINT PLATE

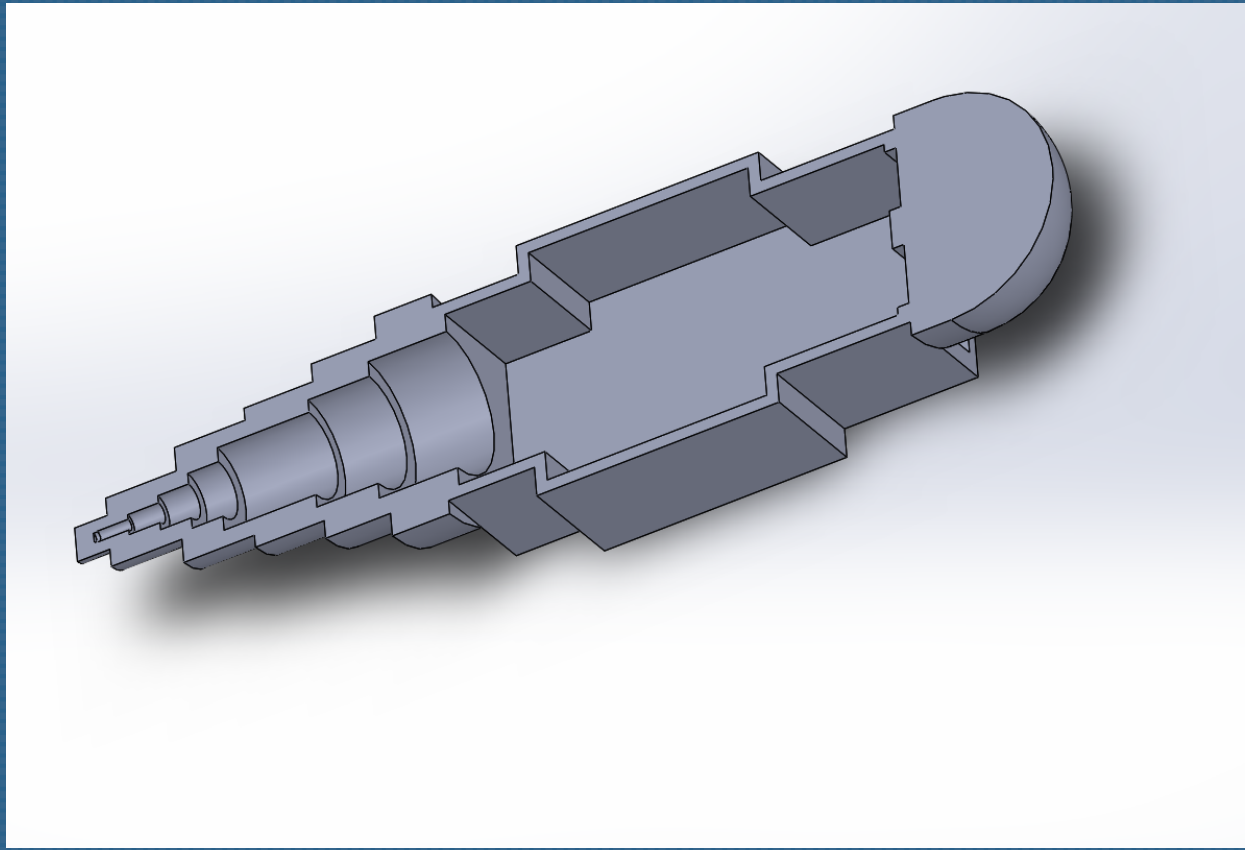
CART V3

Measurement errors result in redesign.

See figure at right for midway through redesign process.

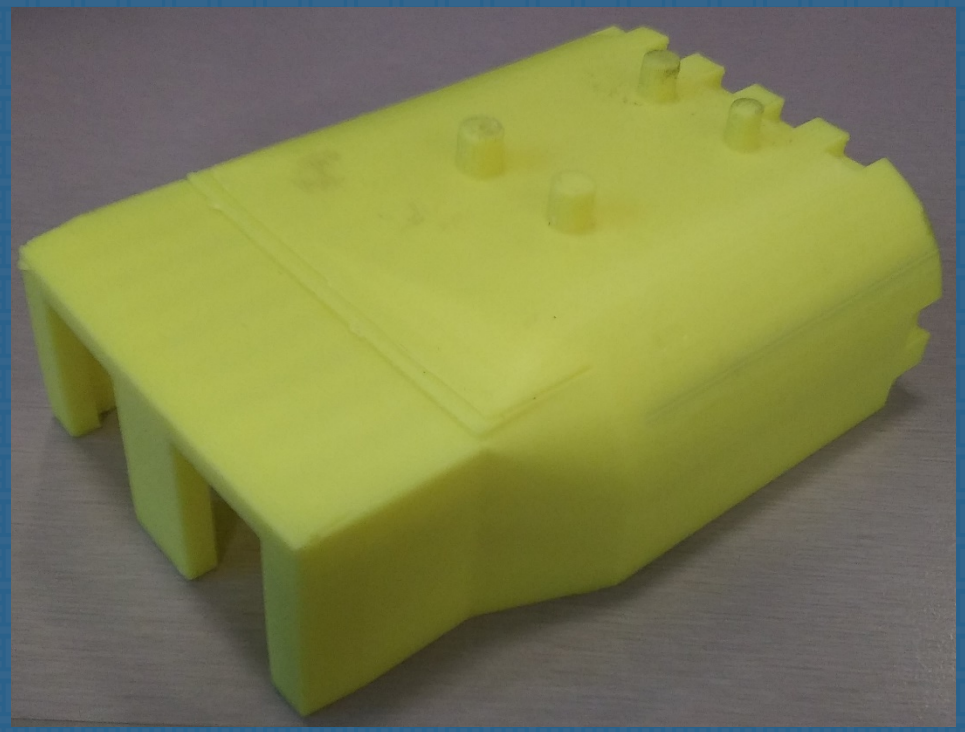
This design is directly pre-lofting the second nose cone

Lofting is done by selecting all the shapes desired to be blended together at once.



CART V3

Two extensions were printed from the same .stl/ gcode file to see the printing speed on the relative orientation of the objects to be printed on the mats. One printed in 6 hours and the other in 8 hours. This printing speed difference just depended on the amount of filler support material the program generated so that the interior of the cart wouldn't collapse on itself while printing. The 4 pegs were added for ease of removal of the support plate printed.



CART V3

Cart V2 was modular, but extruded incorrectly, so cart v3 was made.

Grooves for connection between top and bottom were manually made in CAD.

Loft and bevel tools were used for increasing aerodynamiticiy. String used for dropping.

‘On’ button emitting blue light

CART V3

Barcode sensors

IR communicator

On button

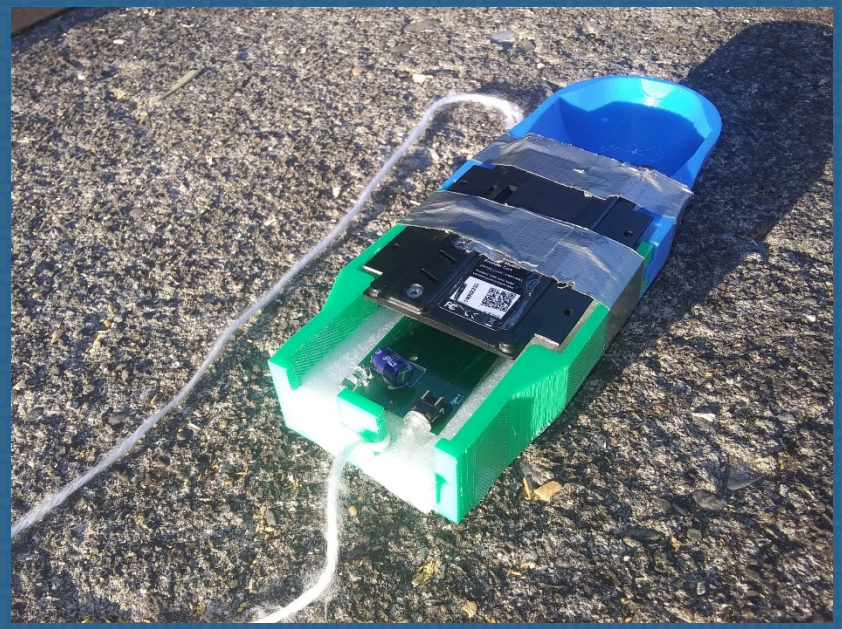
CART V3 MULTIPLE ANGLES

Side

Bottom

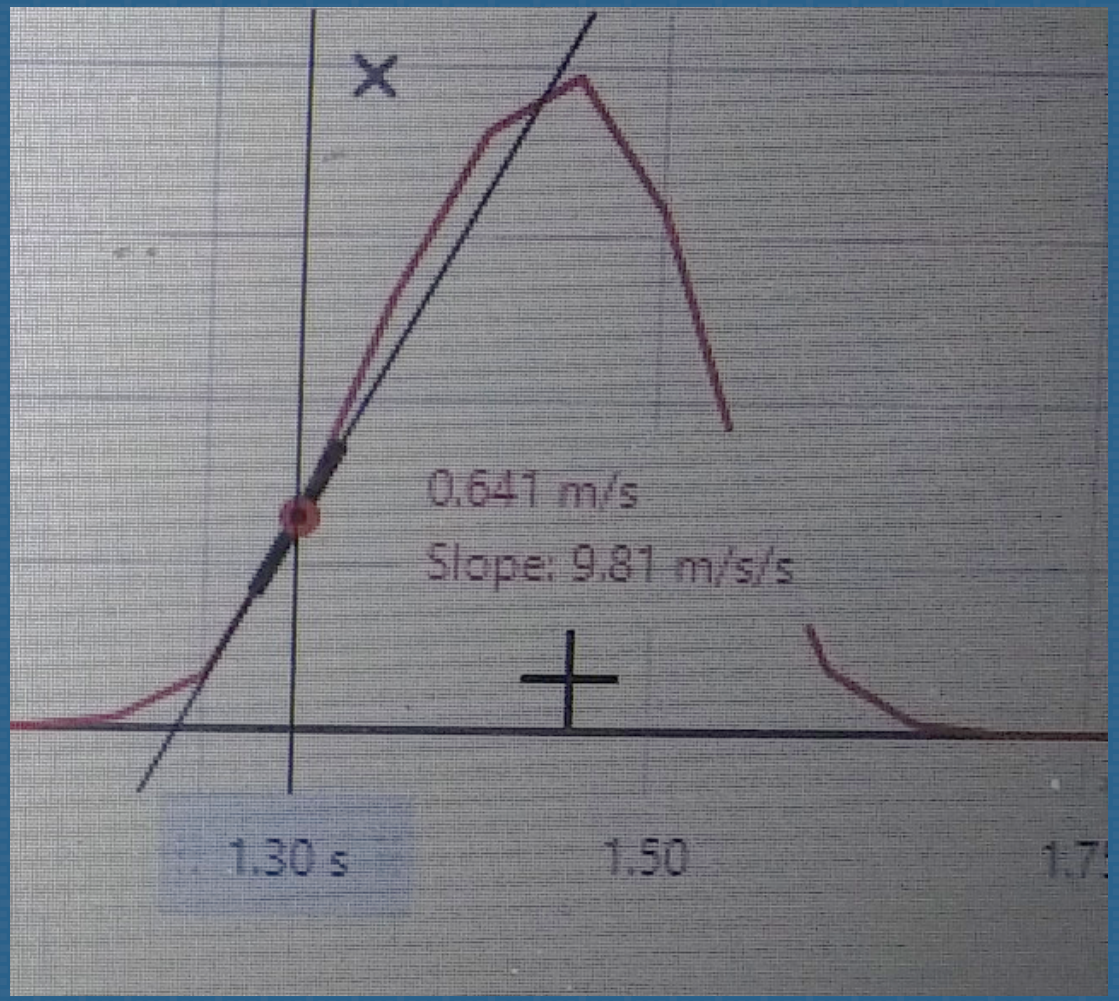
TOP

Orthographic



DATA COLLECTION

Tangent velocity at a point doesn't take accurate enough data. As this is a discrete instrument, it is necessary to take linear regression, to account for all the actual data, and not a derivative that the computer makes a curve fit of.



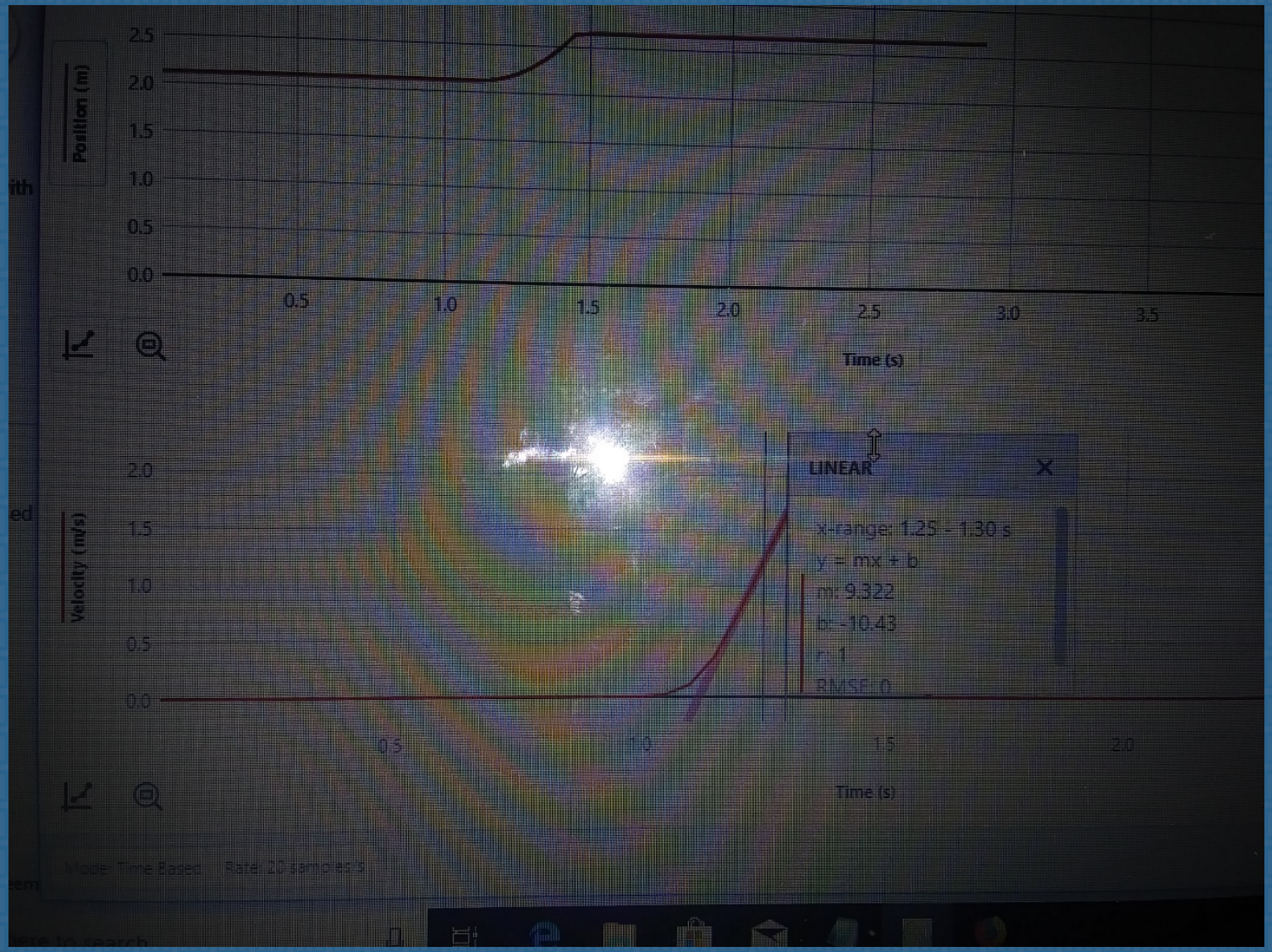
DATA COLLECTION

- Sample rate here: 20 Hz
- Using 'linear' gave this graph
- Curve fit → linear while looking at the velocity graph gives the acceleration. Only the data that is desired to be looked at will be selected.
- (Ignore **v**(x) = 0 m/s)

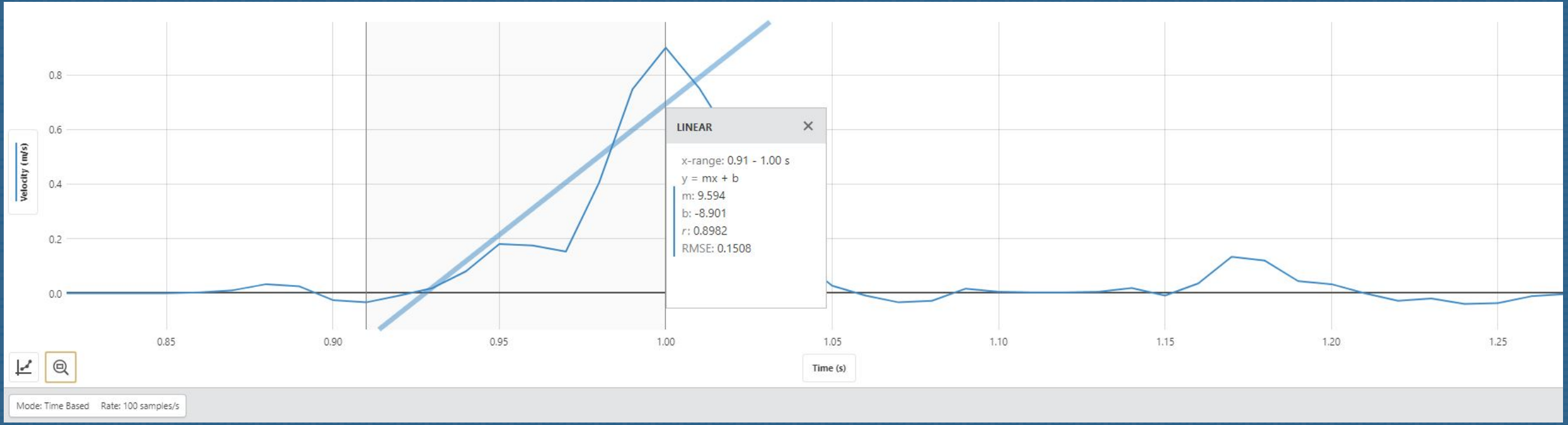
SMALLER RANGE GIVES BETTER DATA – TO A POINT

Less of the v(x) graph is selected (less blue on bottom screen)

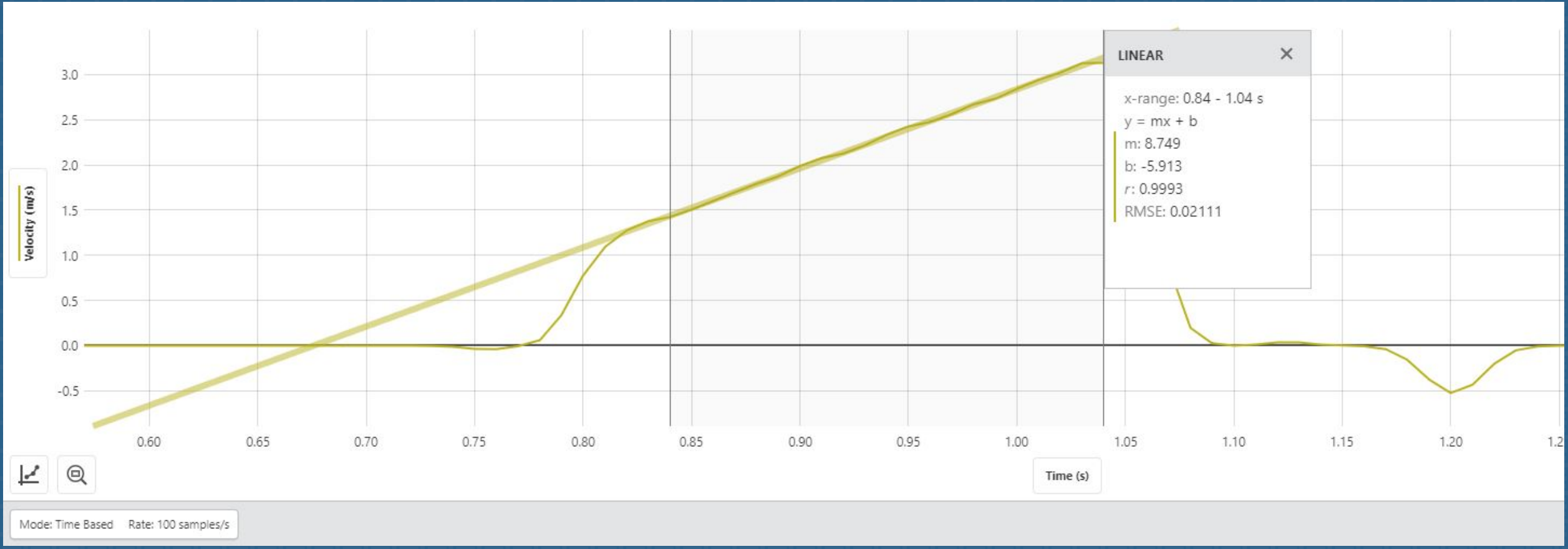
m = **a**(x) = 9.322



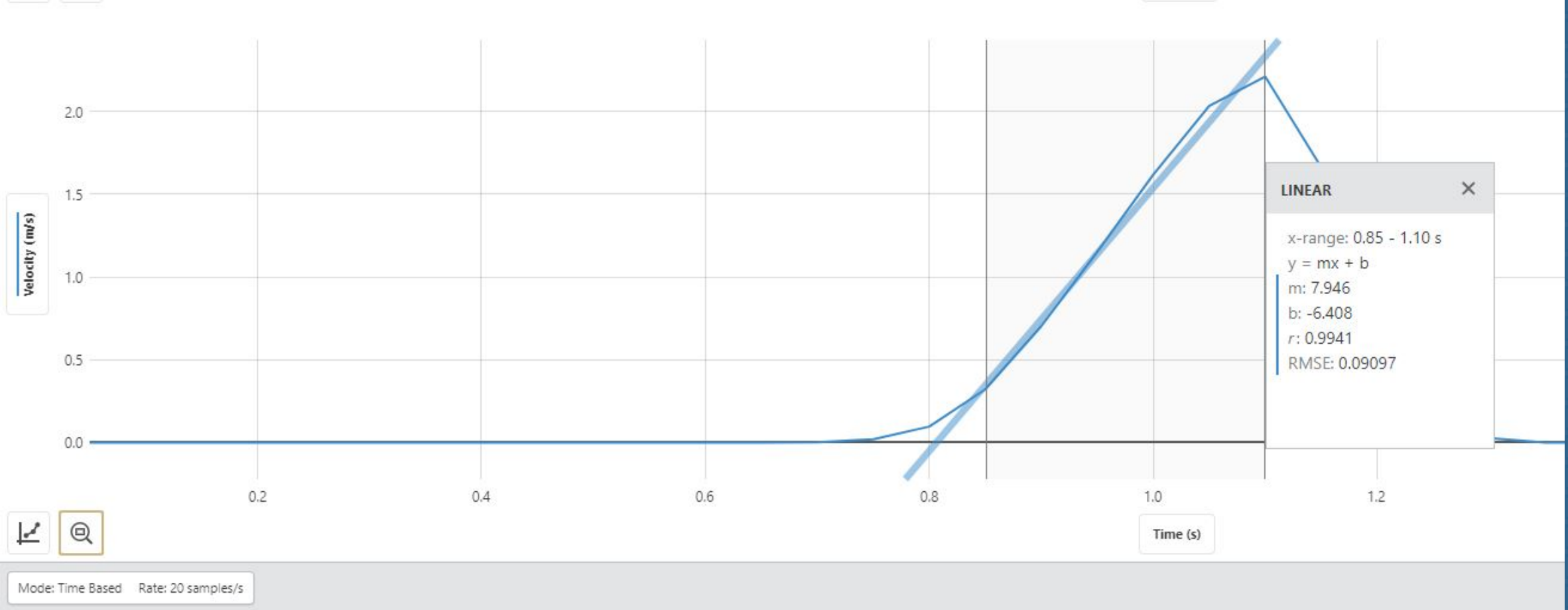
FALSE POSITIVE ‘GOOD’ DATA – 20 HZ SAMPLE RATE



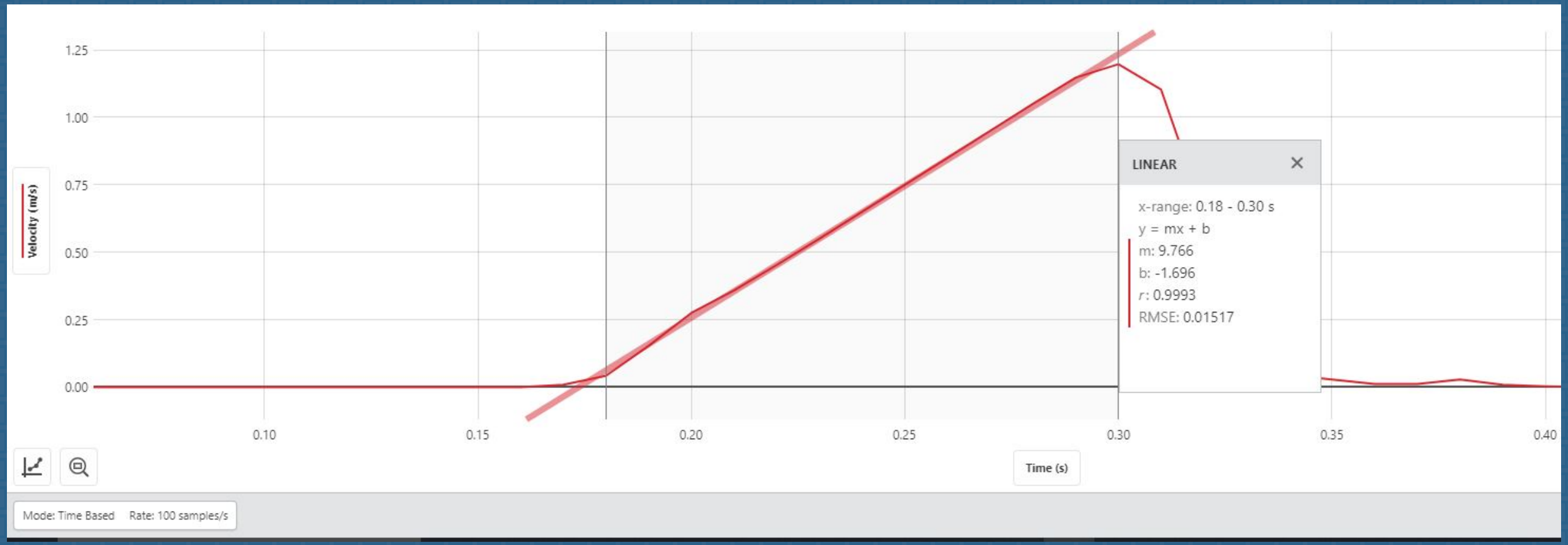
MORE DATA — WOODEN TRACK UNALIGNED, 100 HZ SAMPLE RATE



TWO DIFFERENT ACCELERATION VALUES – WOODEN TRACK

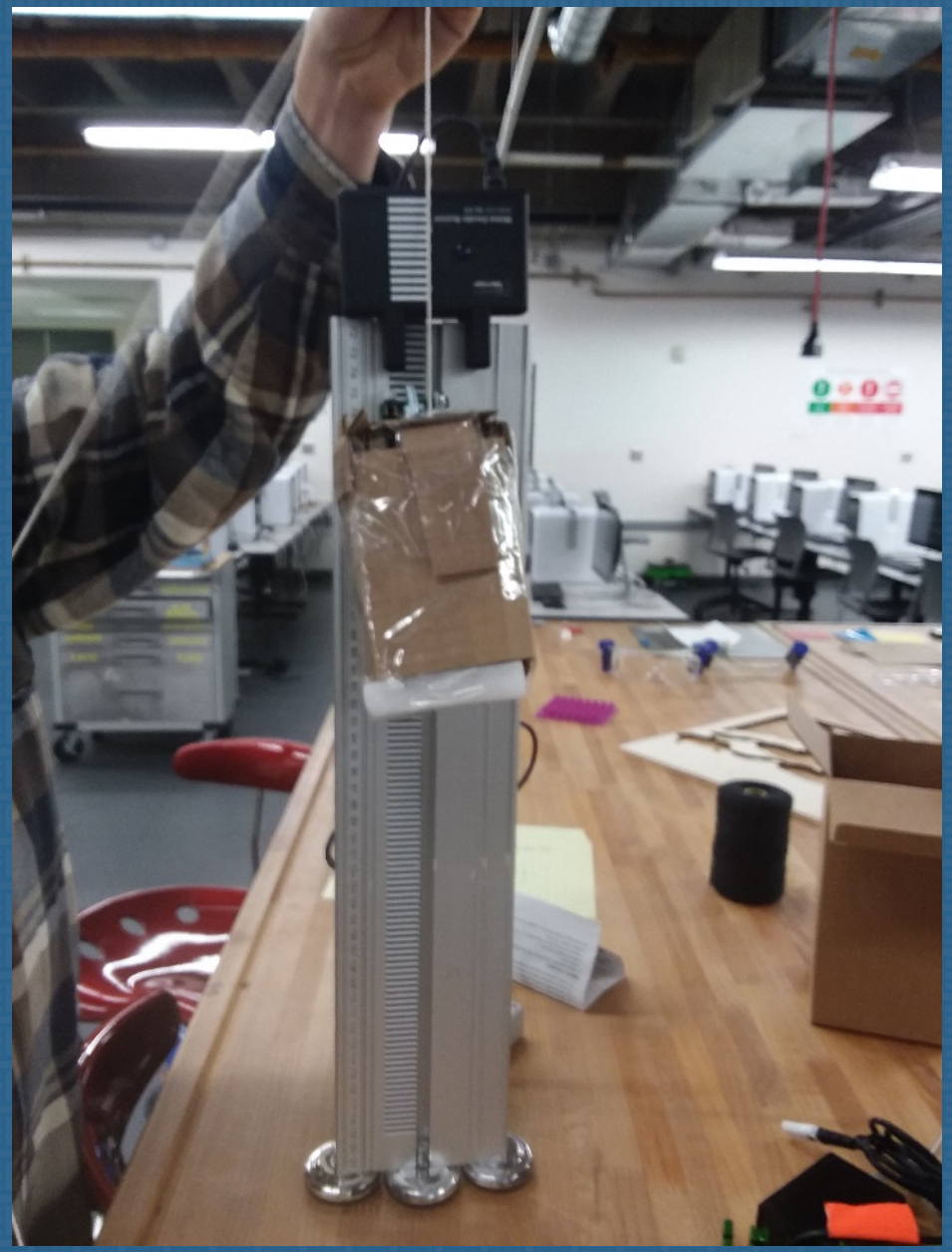


BEST DROP SO FAR — 2 METER ALUMINUM TRACK 100 HZ SAMPLE RATE — MATCHES ORIGINAL BEHR GRAVITY VALUE



TOWER V 0.1

20 cm high



ATTACHING ALUMINUM FOR MOTION ENCODER SENSOR FUNCTIONING

Sensor fits into groove on this type of aluminum 2d shape extrusion . This was attached to top of track with 2 part epoxy

EARLY DAYS:
LOTS OF UNSUCCESSFUL TRIALS

Many hours of patiently iterating over different geometrical permutations leads to barely any data reading from the sensor.

The cause was the physical obstruction of the sensor seeing the track, and the vast misalignment of the cart. This was fixed by the addition of a launch pad later on.

Green cart is in catcher at base of tower in this picture.

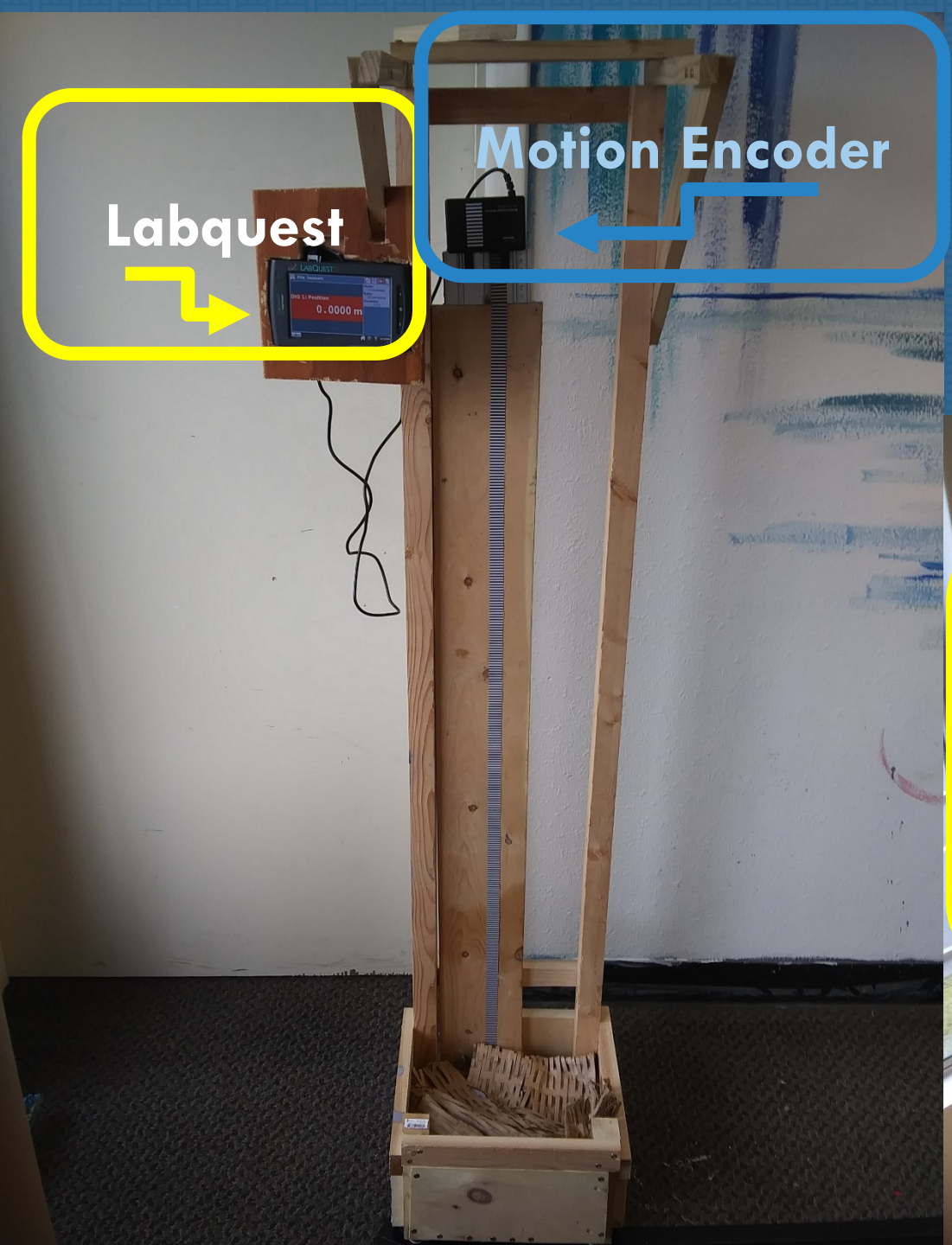
String was used to drop from the top of the beams, with several inches of string between the solid contact and the cart itself.

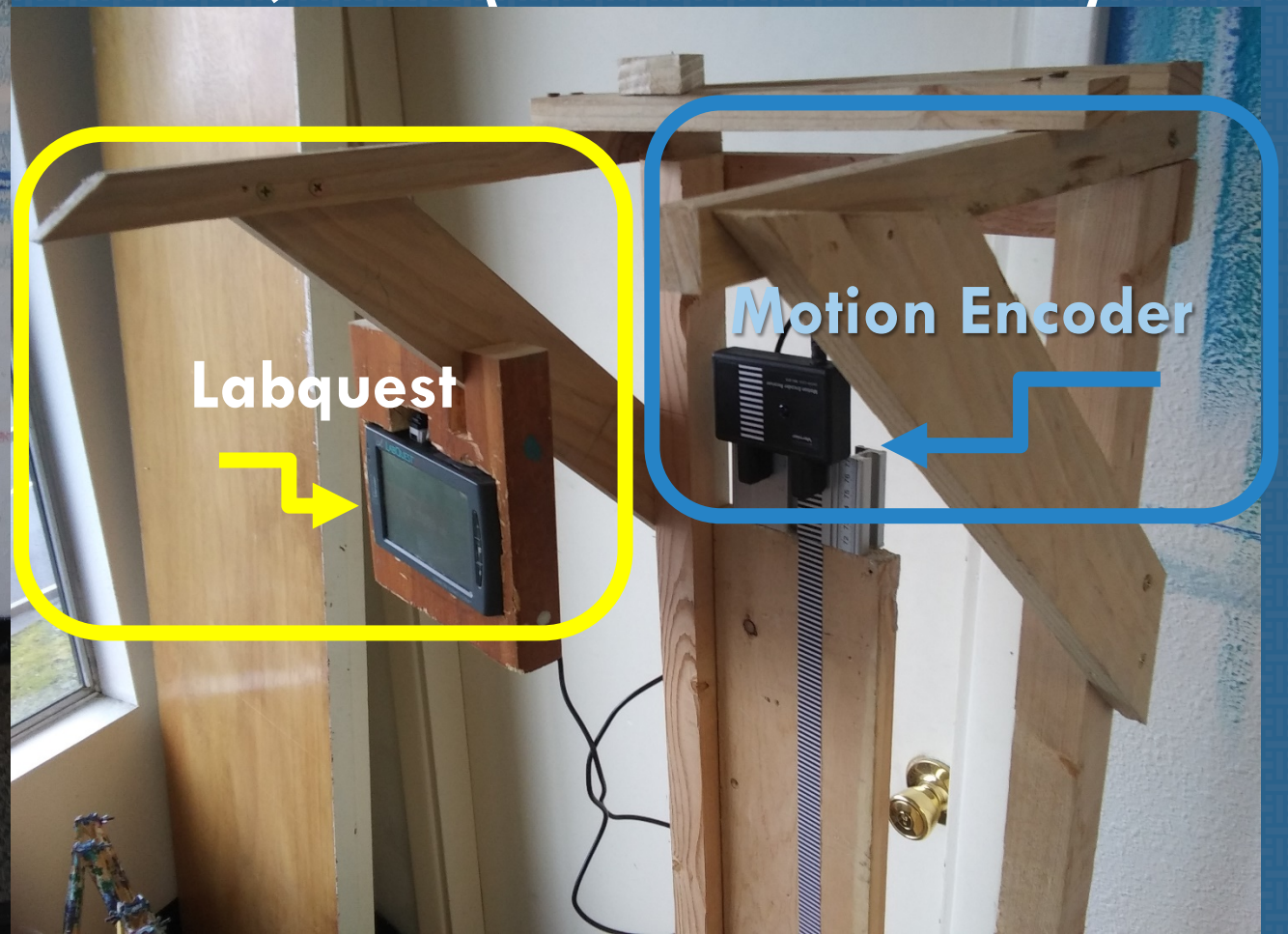
LABQUEST HOLDER

Labquest touchscreen interface holder was made with :

1. Skillsaw
2. Oscillating multi-tool with wood cutting bit

FIRST FUNCTIONAL DROP TOWER- WOOD, BARCODE TAPE, MOTION ENCODER SENSOR, & LAB QUEST (NO LAUNCH PAD)





DROP TOWER PATH

- BARCODE TAPE ADDED TO BOARD, LEVELLED.
ALUMINUM STOCK TRACK 6 CM PIECE ON TOP FOR MOTION ENCODER TO CONNECT TO.

IMPROVED V1 TOWER

Alignment attempts were made and succeeded at improving the drop alignment, but couldn't get the two linear sections of data down to one linear section of data. The launch pad was put on after this picture was taken and the tests were performed.

TOWER V2

2 linear regions of acceleration data for V1. V1 was a wooden track, and was bowed.

2 meter aluminum track used.

This gave 1 linear region of acceleration data.

TOWER V2 ALUMINUM TRACK

Top Half of track
On left

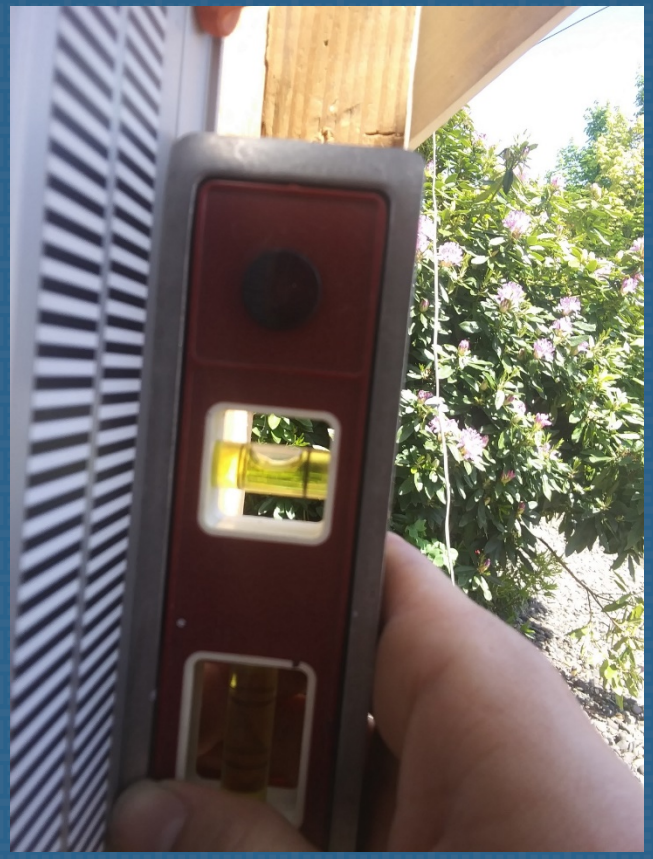
Bottom half of track
On right

BUBBLE LEVEL

Level Side – adjust wooden base to make level. It's level by the bubble being in the middle of the two black lines in the oil immersion

HOW LEVEL IS A BUBBLE LEVEL?

IS PRETTY LEVEL LEVEL ENOUGH? INTERFEROMETRY?



V2 RELEASE MECHANISM – LAUNCH PAD AND MOTION ENCODER – TOP VIEW

MORE TOP VIEW

To launch it worked best to get on the stairs next to the tower and look down the tower while dropping

TESTING SET UP AFTER ALIGNMENT

String dropping mechanism

Cords were all too short

VACUUM TUBE 1 – BASE PLATE + PVC TUBE 1.5 METER TALL

VACUUM TUBE IS BEING SET UP, TO BE TIG WELDED

A Iron bedframe was donated to project. It contains stronger extension base screws, angle iron. Paint was grinded off to prep for welding column support chassis for cart retrieval pulley system.

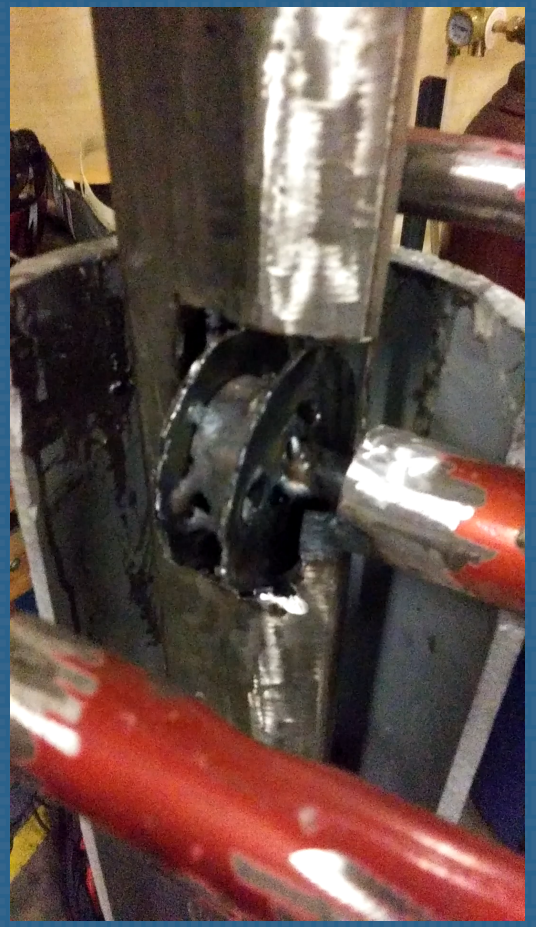
Angle griding, TIG welding prep, tig welding practiced.

TIG= Tungsten Inert Gas. Tungsten electrode with 10% lanthanides is used, and Argon floods the cup to prevent oxidation.

BEDFRAME ANGLE IRON RECOVERY

Metal band saw being used to cut the bed frame angle iron down to size.

WELDING GEAR FOR PULLEY SYSTEM – CART IS OFFICIALLY IN FRONT OF HORSE



Metal drop mechanism is installed with pulley inside of cut vacuum tube. 3 bearings are used to allow for axle to spin in this manner.

VACUUM TUBE V2 – PLEXIGLASS, WOOD, DUCT TAPE REINFORCEMENTS

Skillsaw used for DATO-like cutting of wooden supports so Plexi-glass would fit in grooves.

VACUUM CHAMBER V2 UPRIGHT, WITH NO DROP TOWER

- Scrap wood used for prototyping
- Plexiglas obtained from SCRAP used supply store in Portland for $2-- $3/ sheet (26x52cm)

VACUUM CHAMBER V2 -SET UP

Plexi glass sheeting (blue)

Vacuum pump with hose

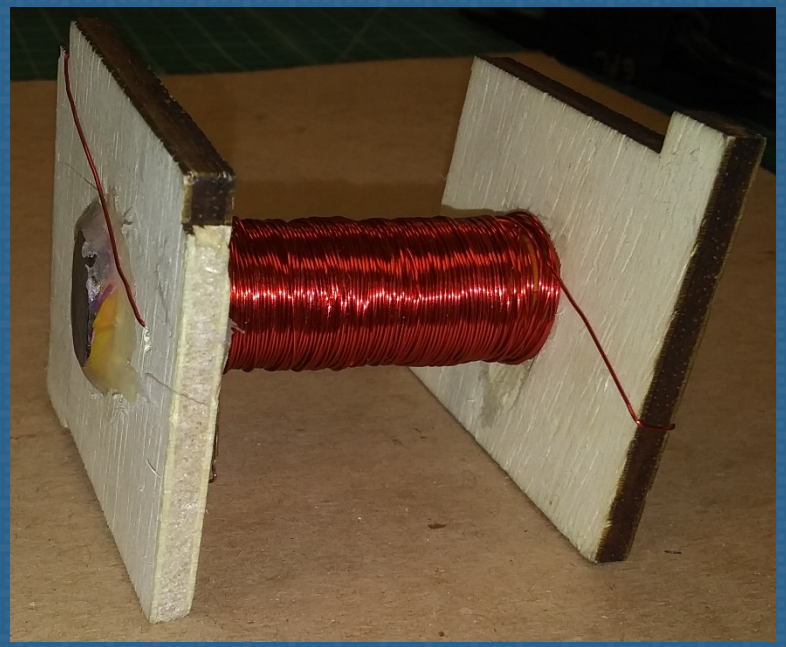
Yellow glove for researcher holding string to drop cart when vacuum is on and chamber is sealed

Duct tape is sealant, screws for chassis connections

VACUUM TUBE V3

Thick walled paper tubing with a metal end was used. It was a shipping tube that steel bars for formula racing chassis construction were shipped in.

ELECTROMAGNET V1



Hand wound,

iron core machined from:

rectangular prism of iron.

Winding technique and direction are essential.

Barely pulls a paperclip, while heating up when supplied 12 V 2 amp.

Multimeter used to find it's resistance, which can be taken to find the conductance with R^-1 = the conductance. This can be used for electromagnetic calculations, and approximations for pulling power given the gauge of wire, number of turns, voltage and amperage supplied, the surface geometry of the contact, etc.

ELECTROMAGNET V3 WIRING

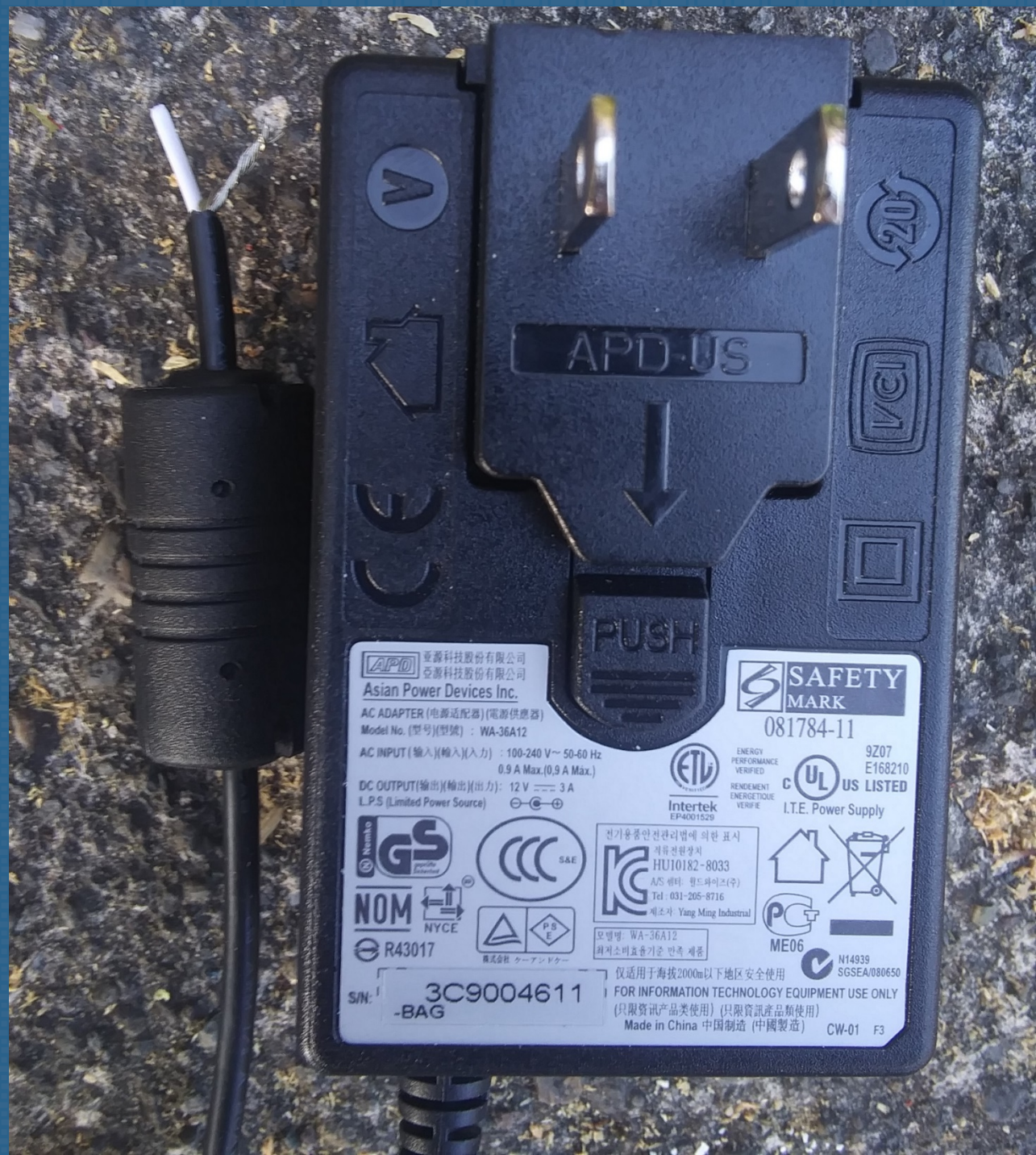
- Electromagnet was purchased from amazon of the correct geometry. This was wired using a scrap power supply. The +/- direction doesn't matter with electromagnets for this project, because the electromagnet will pull either way it's wired.
- Inside the:
  - White wire (top) was hot (+ for electrical engineers, - for chemists)
  - Silver bare wire coil (bottom) is cold (- for electrical engineerers, + for chemists)

12V 3A OUTPUT
120 V 60 HZ INPUT

Power supply scrap part.

Power supplies in the garbage

are always good to save for later.



ELECTROMAGNET V3 WIRED

Inside black part is wound copper wire around the steel core with the steel coating. The black is epoxy with dye. Purchased from amazon.

ELECTROMAGNET FIXTURE

Scrap wood for spacing adjustment

for rapid prototyping:
duct tape
Clamps
Scrap wood,
skillsaw

ELECTROMAGNET DROPPING

Cart being levelled after drop tower v2 has been levelled, to test before entering vacuum chamber testing.

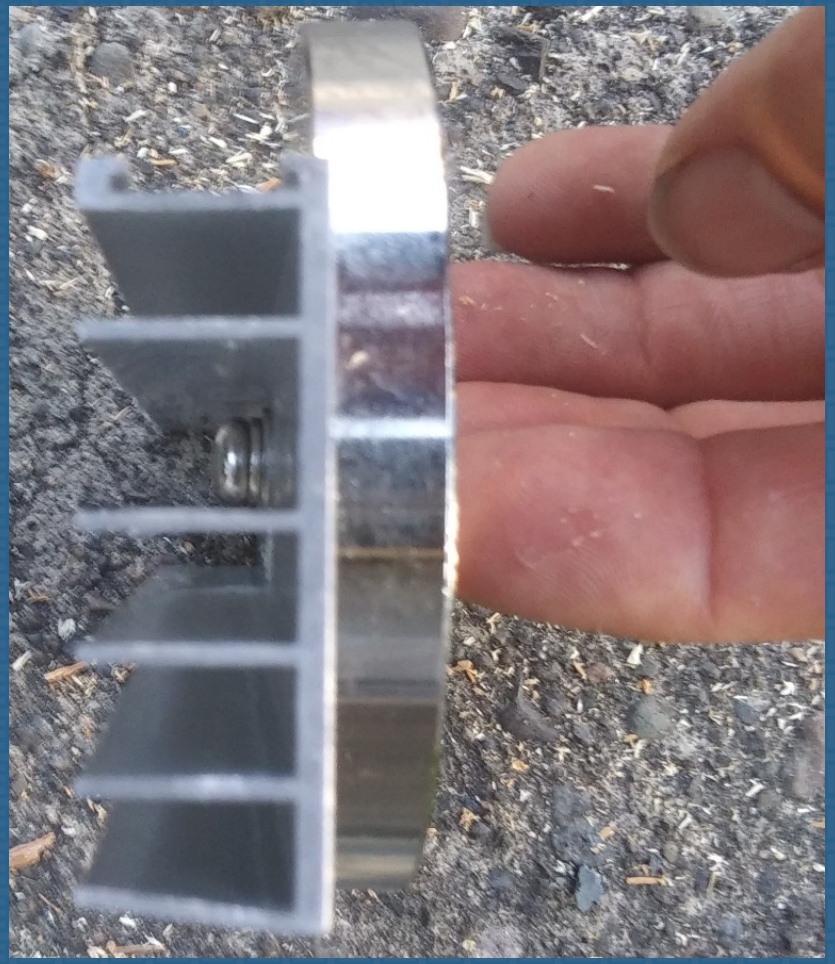
ELECTROMAGNET OVERHEATING

3 amps continuous makes the electromagnet (as is) hot to the touch.

Use a scrap Heat sink!!

This is a aluminum heat sink. It was one of many pulled out of a scrap plasma screen TV months ago.

No more cooling problems!!

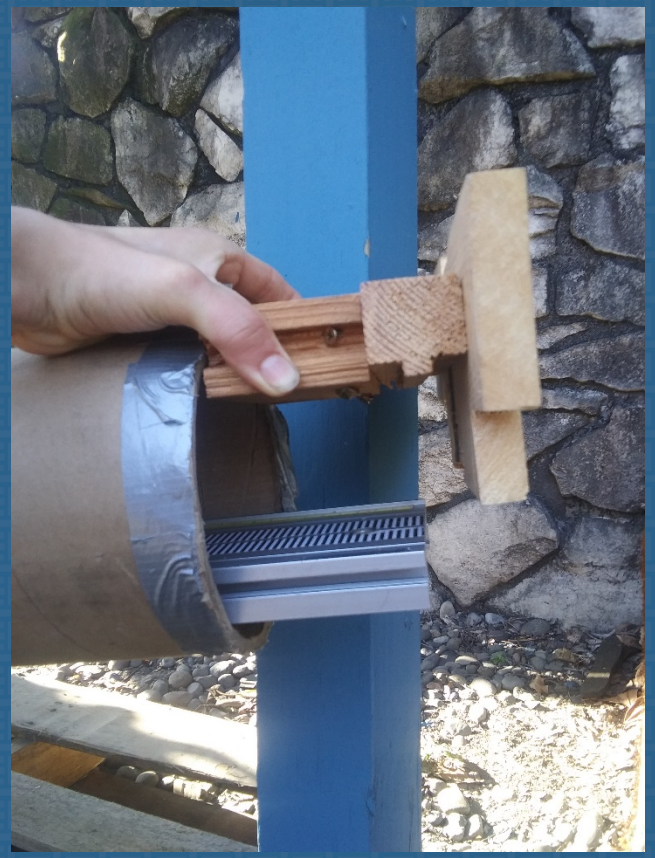


ELECTROMAGNET FIXTURE REASSEMBLED WITH HEAT SINK

VACUUM TUBE V3 + ELECTROMAGNET V3

The alignment was a problem with the existing size of the vacuum tube and the size of the electromagnet holder.

FITTING ELECTROMAGNET HOLDER FOR VACUUM CHAMBER

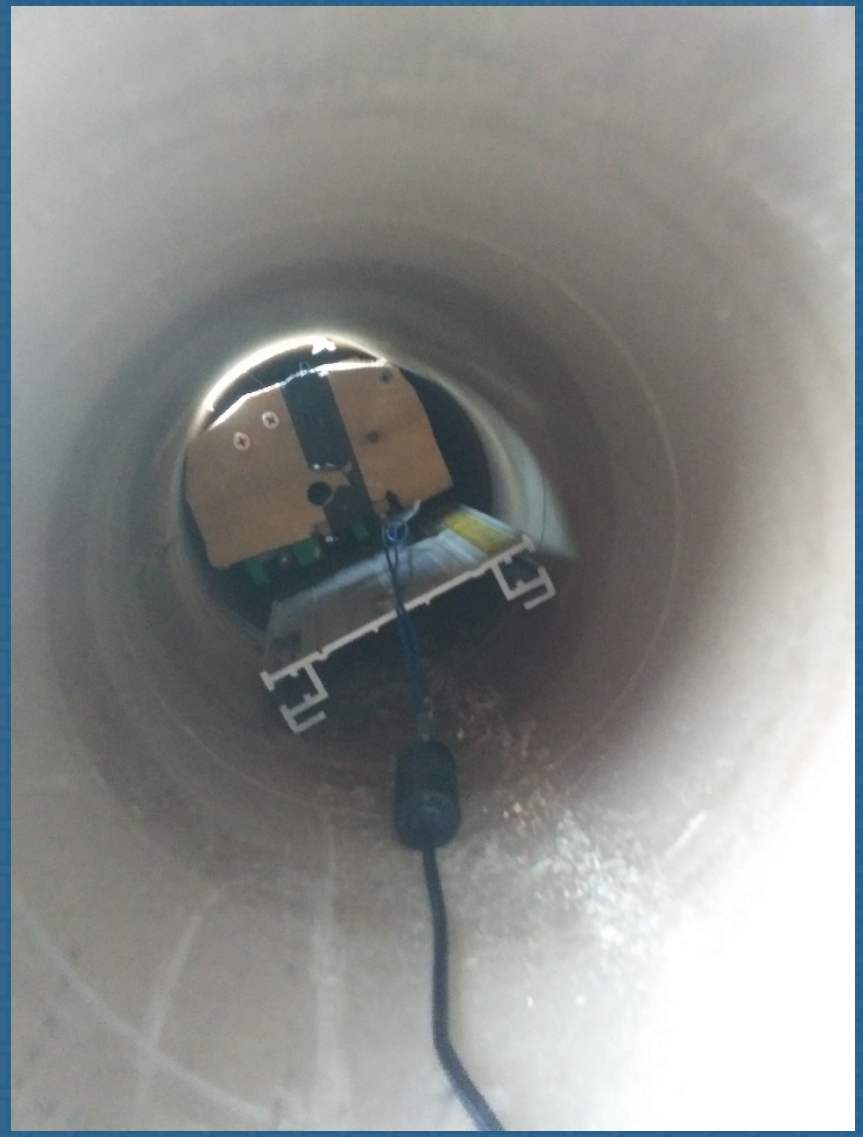


+ time,
cutting, size
alignment

SECURING ELECTROMAGNET HOLDER ALONG VACUUM TUBE

FITTING: TRACK, HOLDER, TUBE

CART AND ALL IT'S QUANDARIES - FARADAY CAGE



Electromagnet vs. sensitive electronics?

The third piece of pure aluminum that greatly helped advance this project.

No malfunctioning electronics!

Small holes poked for the IR barcode reader

IMPROVEMENTS TO BE MADE

1. Obtain data with electromagnet in:

vacuum chamber

Vacuum chamber @ atmospheric pressure (760 mmHg/ 1 atm)

Vacuum chamber @ high pressure

2. Make 3d printed parts that clip on in repeatable, measurable fashion, instead of screwing wood in @ angles.

2. Interferometry with gear ratio for precision alignment based on reverse engineering of optics table and light microscope gear ratios.

3. Make O ring system with clamp-on loading doors to load vacuum chamber

4. Hand crank vacuum pump/ pressurized vessel pump with flywheel, gear ratio, etc.

5. Measure gravity to the accuracy to detect lunar gravitational pull

LEARNED/USED

Loft, bevel tools in Solid works to solve aerodynamic problems

Running 3d printer, obtaining part, cleaning up print from superfluous plastic to design chassis

Exact-o knife, box cutter, belt sander, for sculpting 3d printed parts post successful print

Screwdrivers, drills

Skill saw, oscillating hand saw use

Launch pad to solve torque problem

TIG welding prep and implementation

Wiring a solenoid by hand

Electromagnet heating problem solved with heat sink

Change power supply wiring: soldering, heat shrink

Gravity is as gravity does

Manufacturing of vacuum tube, best scrap parts to use

Alignment engineering with bubble level, shims

Sample rate settings with vernieer equipement

SPECIAL THANKS TO!

Toby Dittrich for being an amazing mentor!

Hayden Reinhold for being a stellar, methodical partner!

David Vernieer for kindly supplying us with equipement!

PCC Sylvania makerspace for letting us prototype in their space, use 3d printer stations, testing in their space!!!!

--GRAVITY--

PSU EPL makerspace for providing suggestions on methodology

PSU Viking motorsports for allowing me to practice tig welding on vacuum chamber, pulley assembly

Friends and Family who have supported me through this report and helped me on long work days!

NASA SCORE FOR FUNDING!!!

FUNDING

NATIONAL SPACE GRANT COLLEGE AND FELLOWSHIP PROGRAM

NASA

NASA

Portland Community College

‘LASER LEVEL’ METHOD + LATER INTERFEROMETRY

- Laser alignment projects where the surface that the laser is on would extrapolate too, if that plane extended in space

- Problem – laser casing may be flush with plane and may be aligned with Z axis, but laser beam does not emit in parallel with outer casing of laser holder, as was tested with 2 common red lasers.

- Interferometry is different and could be used to get alignment down to the wavelength of the laser emitted using a beam splitter, like the semi see through silver plate in SLR/DSLR cameras.