Project Presentation

Shubh Raval

UCLA Mechanical Engineering Senior

Agenda

01. Introduction

Prior project & why talk about this one.

02. Project Overview

What was the overall problem, the scope, and the goal of the project

03. Actions

What did I do through the project and why?

04. Results

How did the project turn out?

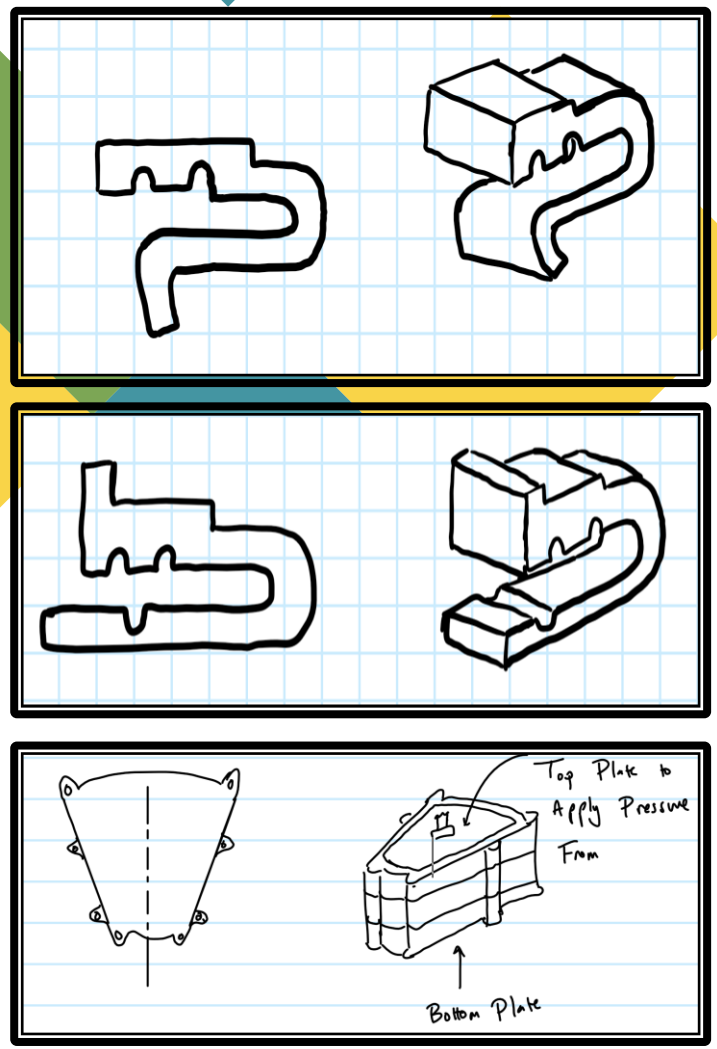
05. Lesson Learned

What have been the key takeaways?

Some Prior Projects

Applied Composites

Amazon Robotics



Kairos Power

Why the Amazon Robotics Project?

It was a 6 month mix of some design, manufacturing, test, and systems/verification engineering that let me explore and build on these skills. It also had a scope of 800,000+ units affected and would be used for next purchase order of thousands of carts.

Project Overview

Prior State: A old specification guiding the design of the existing cart integrated with Robotics System

This specification was unclear, and Amazon did not have any mechanism to verify if the specifications were being met by the vendor in their design or manufacturing of the cart. This presented a risk of damaging goods, the system, or employees in the warehouse.

Project Goal: Lead the Verification of Existing Cart & the Verification of New Cart

To create two verification studies, coordinate certain tests, design remaining tests & test fixtures, collect testing results, identify non-conformities, and offer suggestions based on non-conformities

Project Flow: Understand Specification, Create Verification Study, Perform Testing, Repeat for new Cart

As the verification study's tests became finalized some testing could be started and at the end these Verification Procedures would be released to manufacturer as tests they perform and passing

Final State: Fully Verified Carts that meet all specifications, incorporating findings from Verification Study

A better Amazon specification and two verified carts that are free from non-conformities that the manufacturer tests using this procedure. Inclusion of any recommendations to either process or design for the future iterations.

Verification Goals

Design Tests for Each Specification

Test must be thorough but also be simple were possible

Test procedure must be detailed but also quick to understand

Assign Testing Responsibilities

Tests added may increase cost, but some are needed to ensure design meets critical requirements. Determine if Amazon or the Manufacturer should perform certain tests.

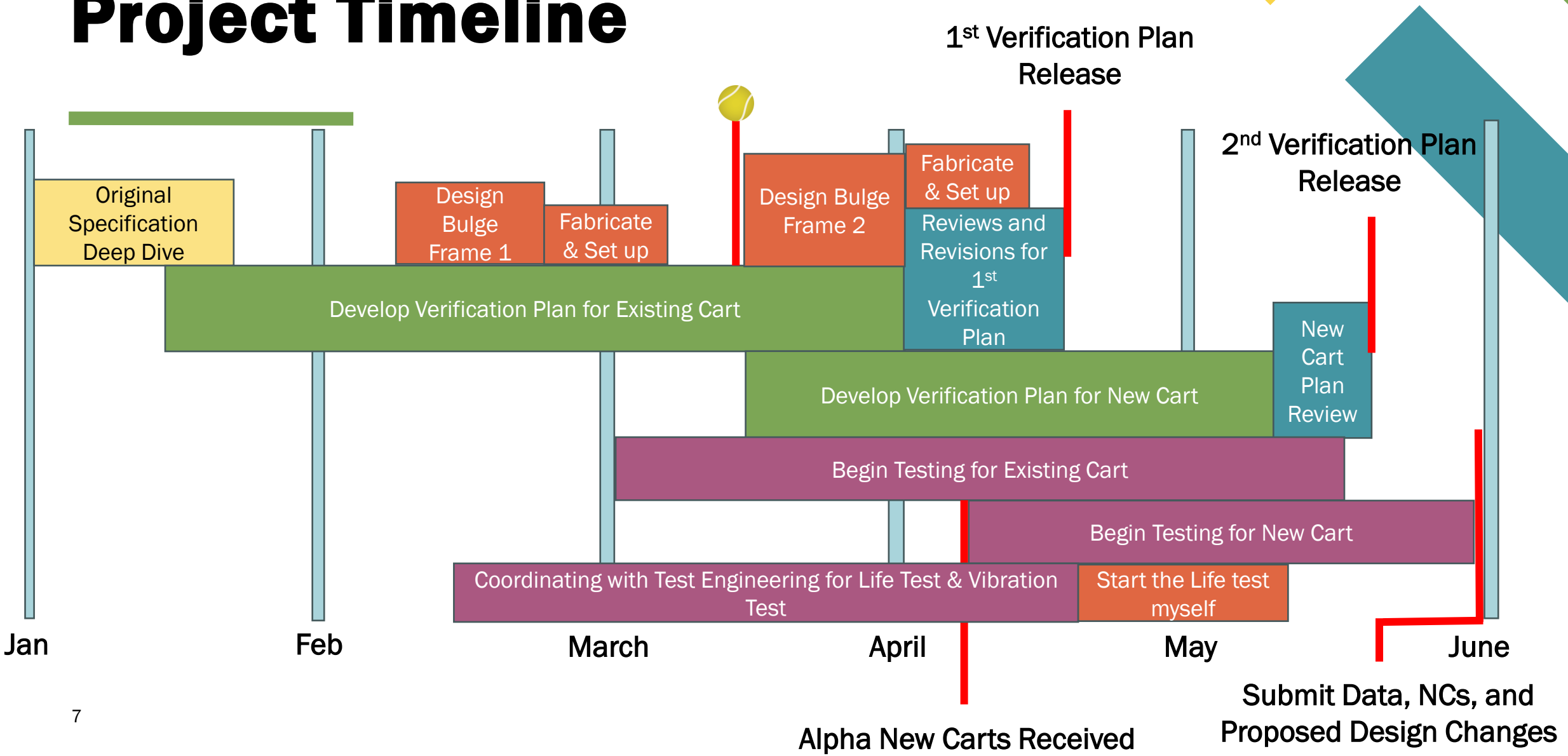
Determine Non-Conformities

Determine what non-conformities require design changes or process changes, but what can be solved by loosening the specification

Design cheap, reusable, safe fixtures

Where can I use existing materials or scrap, what parts between designs can I carry over, how can I ensure the fixture designed will be safe to use

Project Timeline



First Action: Create a Verification Cross Reference Matrix (VCRM)

- **Go through each revision of specification and understand why it is there and where it comes from**
- **Decide how to Verify that specification**
  - Analysis
  - Demonstration
  - Test
  - Inspection
- **Determine if Amazon or Manufacturer be ultimately responsible for testing**

Requirement		Verification Method(s)				
Number	Name	Analysis	Demonstration	Inspection	Modeling & Simulation	Test
VR.1	Space Vehicle First-mode Natural Frequency	X				X
VR.1.1	Natural Frequency Analysis	X				
VR.1.2	Natural Frequency Test					X
VR.2	Appropriate Markings			X		
VR.3	Altitude Accuracy	X				
VR.4	Battery GSE Charge Display		X			
VR.5	Fastener Type			X		

Sample Verification Cross Reference Matrix

Develop Tests

- **Dimensional Specifications**
  - Structure dimensions
  - Envelope Dimensions
  - Vertical Clearance under cart
  - Caster Diameter
- **Life Cycle Specifications**
  - Caster Wheel Wear
  - Lift/Lower accelerated testing
  - Random Vibration testing
- **System Specifications**
  - Compatibility with Sensor
  - Correct Labels
  - Bulge Testing
  - Gloss Reading

- **Additional Specifications – New Cart**
  - Prior Tests
  - Handle Ergonomic dimensions
  - Pinch Hazards
  - Push and Pull forces for operation

One of the systems the Cart is used in

Write the Verification Procedure for Existing Cart

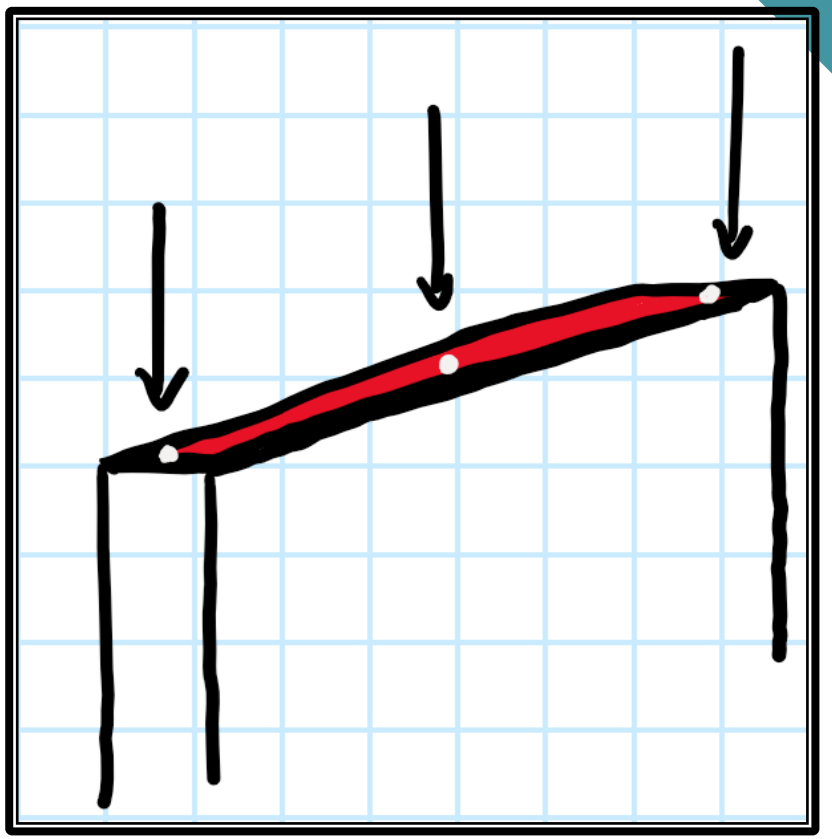
- **Based on understanding the specification and the assigned verification methodology I designed tests**
- **Example: Maximum Envelope Dimensions of Cart (Inspection & Analysis)**

Key Considerations:

- Measurement tool: Tape Measure
- Measurement frequency: 3 measurements along each dimension
- Measurement location: Flat surfaces
- How to create repeatable measurement: Eliminate vagueness in procedure
- How many carts need to be measured: 1 cart

Impact:

- Able to remove an unneeded structure dimensions specification which called out dimensions that were already defined by the envelope specification



Denoting Locations of Measurements on Solidworks Model for procedure

Start Collaboration with Test Engineering for Vibration and Life Testing

Vibration Testing & Lift/Lower Testing

Key factor is creating method for determining if any damaged is caused. For lift/lower is there any fatigue in the plastic deck and under what conditions should the test be done

Resource Allocation & Pushing Testing Schedule

What resources need to be coordinated by me for the testing. Also remove blockers and keep communication to ensure schedule is maintained

Roadblocks & Solutions

A major issue was maintaining schedule & priority. For Lift/Lower allocating resources and finishing all prior steps was a set of unforeseen issues that had to be resolved. I was able to maintain schedule by taking full charge on testing when I noticed things were beginning to slip.

That looked like: coordinating with software & IT, getting brackets fabricated & assembled, coordinating with facilities for floor anchors, and having a technician teach me how to control the robot to start the test.

Lift Lower Testing

Vibration Testing

Test for Door Bulge

Door Bulge was present as a known Non-Conformity

This presented a system risk, as many different modes of how packages/loading could result in bulging.

Specification only defined a ΔXmax

Including a force value to induce the bulge would allow for this to be reasonably designed for and fully defined.

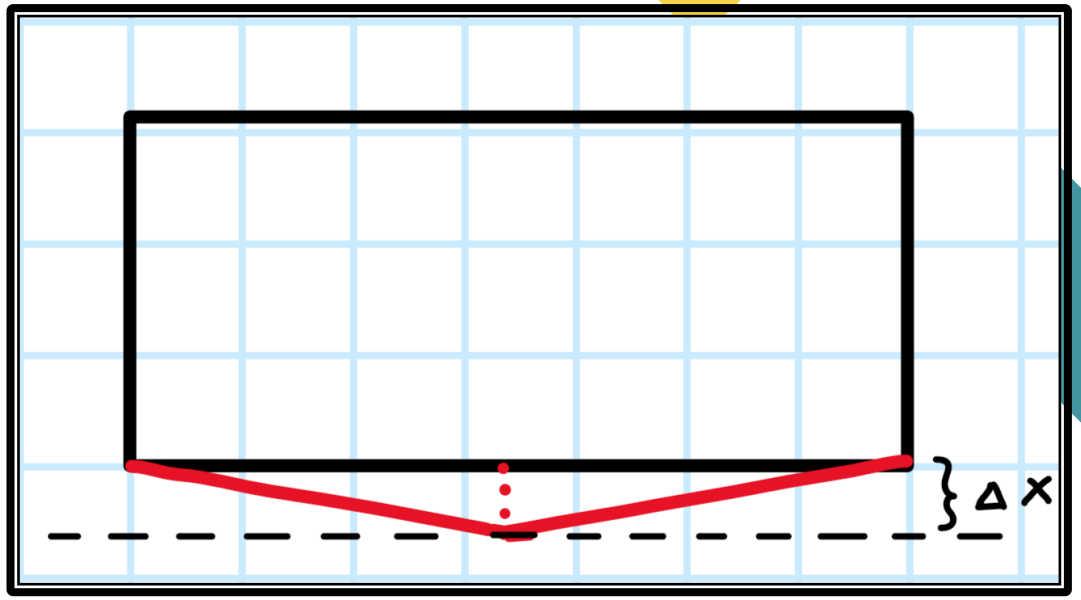
Testing for worst case loading

That would be maximum load occupying full internal volume.

Testing must be transferable to manufacturer

Must be a test that manufacturer is able to perform so, the test must be low in cost and complexity.

Bulge on Both Doors Top View



What if I used water to fill up the cart how might the forces look?

$$F = \int_0^y (\rho * g * y * w) \partial y$$

- y = 2 meters from the base to the fill height
- w = 1 meter the width of the cart
- ρ = 997 kg/m^3
- F = ~19000 N = ~4000lbs of force on the doors
  - Way too much!

Design of Door Bulge Test

Spheres could apply a distributed load

What kind of sphere that is bulk purchasable would fit the bill?

Evaluate different common spheres to see what fills internal volume and desired weight closest:

Maximum Internal Volume = 2m* 1m *.5m = $1m^3$

Maximum Load = 800lbs = ~360kg

Golf Balls: 0.0426m diameter ⟹ V = 0.000040479 m^3

0.04593kg mass ⟹ $\frac{1}{0.000040479}$ * 0.04593 = 1134 kg . Too Much!

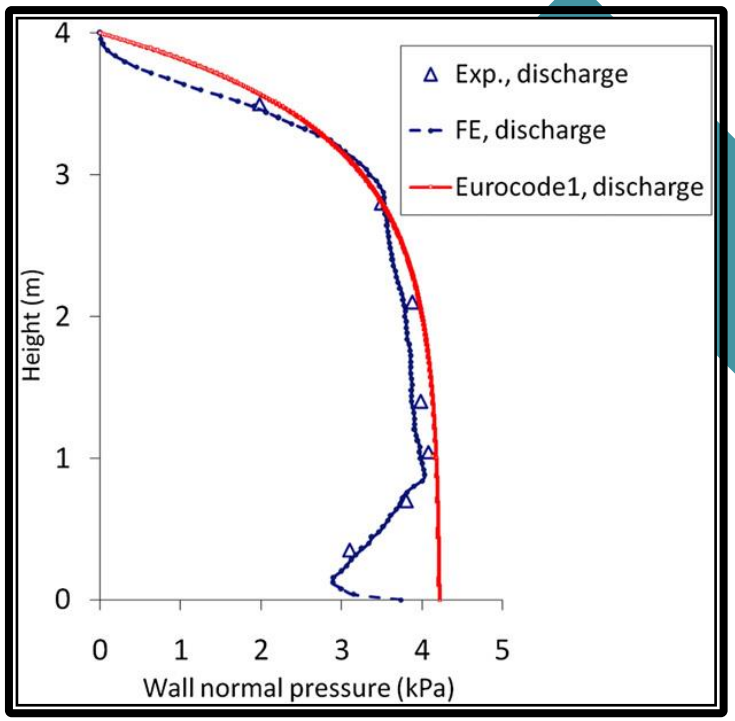
Pool balls ⟹ 1134 kg. Too Much!

Baseball ⟹ 617 kg. Still Too Much.

Ping Pong Balls ⟹ 80 kg. Too Little.

Tennis Balls ⟹ 417 kg. Pretty Good!

..... How many tennis balls do I need...



Grain Silo Wall Pressure gave some inspiration

About 6000….

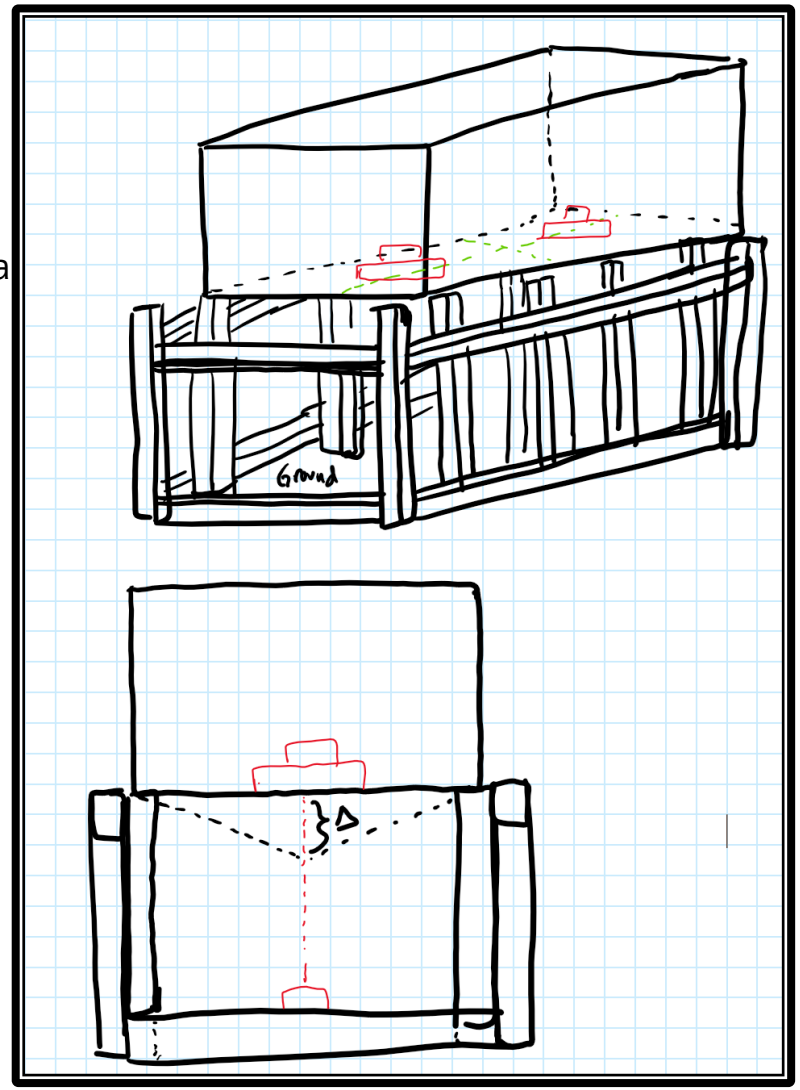
- This was an effort to source in a cost-effective manner
- One aspect was that too many tennis balls in poor shape may deflate and not give the pressure distribution desired
- Price ranged from $1.25 to about $0.30 per ball
- Finally semi-used balls were delivered on a pallet! (with a reshipping label)

Finalized Bulge Test

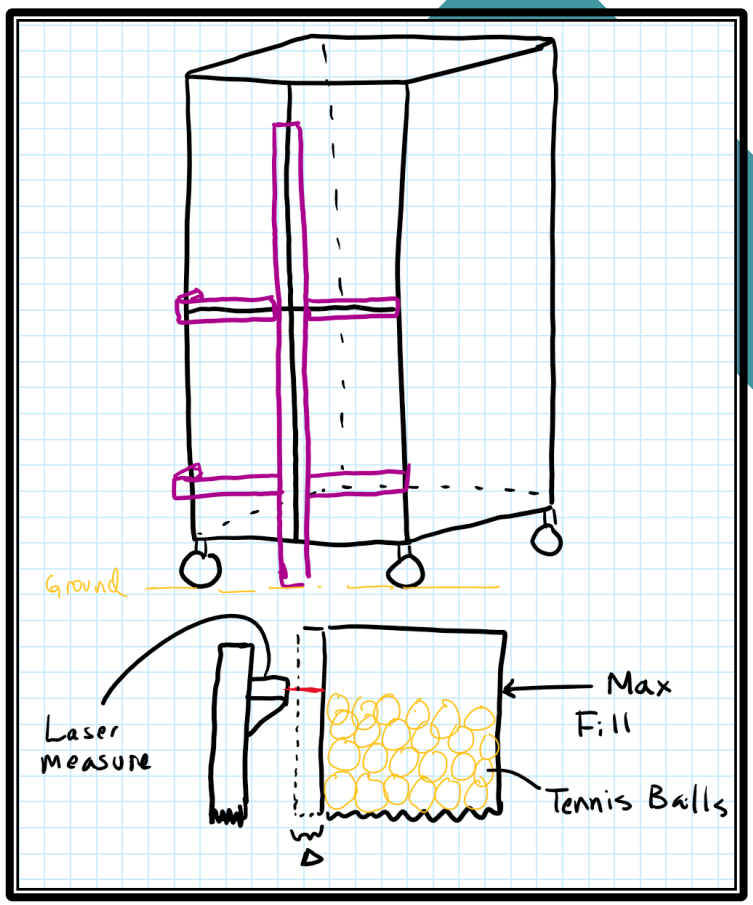
Considerations

- Can't tell manufacturer to buy 6000 tennis balls and these balls will only give a true worst-case deflection not a force
- Need a second part of the test, applying load directly to the doors to determine the deflection
- Need to compare the deflection results of tennis ball and locally loaded test to determine the pass/fail criteria locally loaded test
- Use existing materials at facility to make these to save cost
- The doors will be bulging out slightly when lowered horizontally, how much force is being applied?
- How to measure force and deflection?
    - Laser Measure
    - Force Gauge

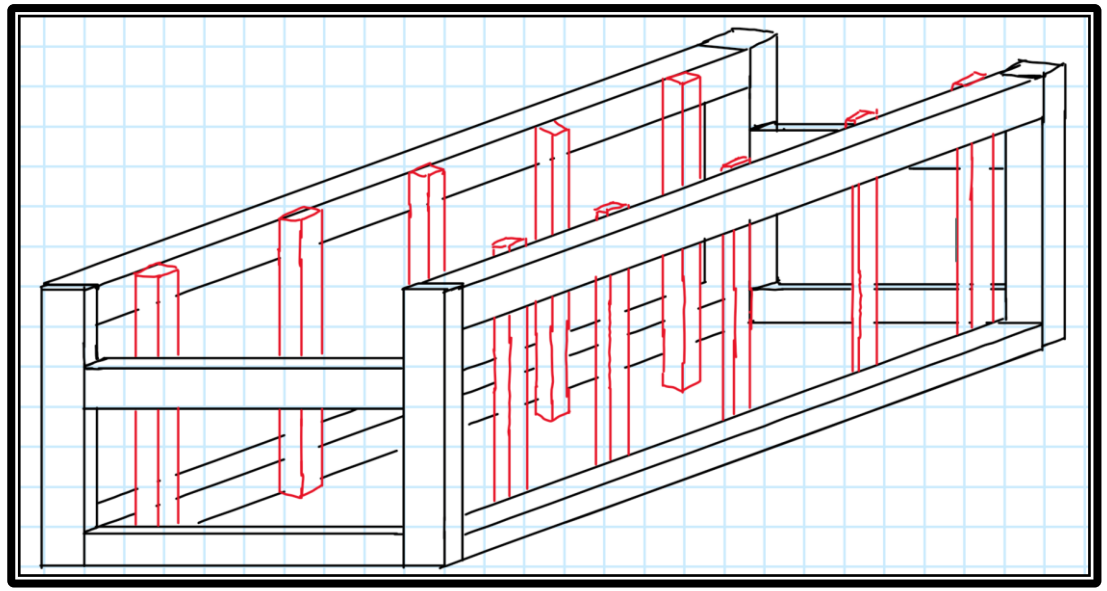
Locally Loaded Test Fixture



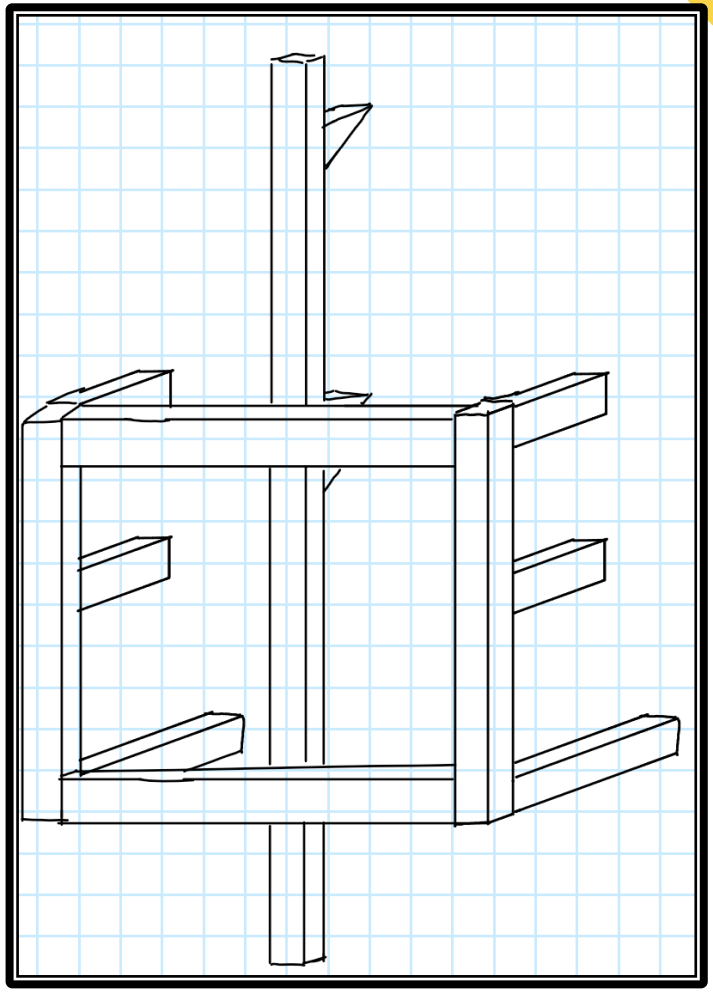
Tennis Ball Test Fixture



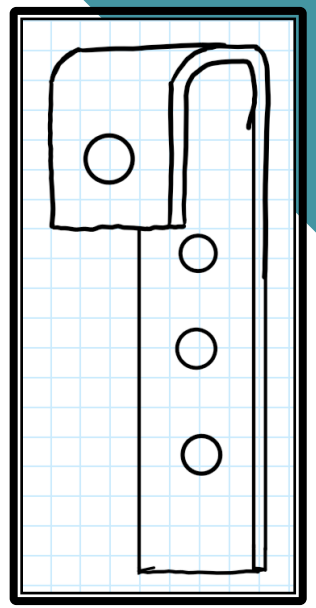
Fixture Design



- Load from Cart must be Grounded
- Frame shouldn't bow (used FEA to check deflection)
- Compatible with both carts
- Cheap to make and easy for manufacturer to replicate
- Give adequate clearance for hinges to rotate making doors bulge, and allow for deflection & force measurement



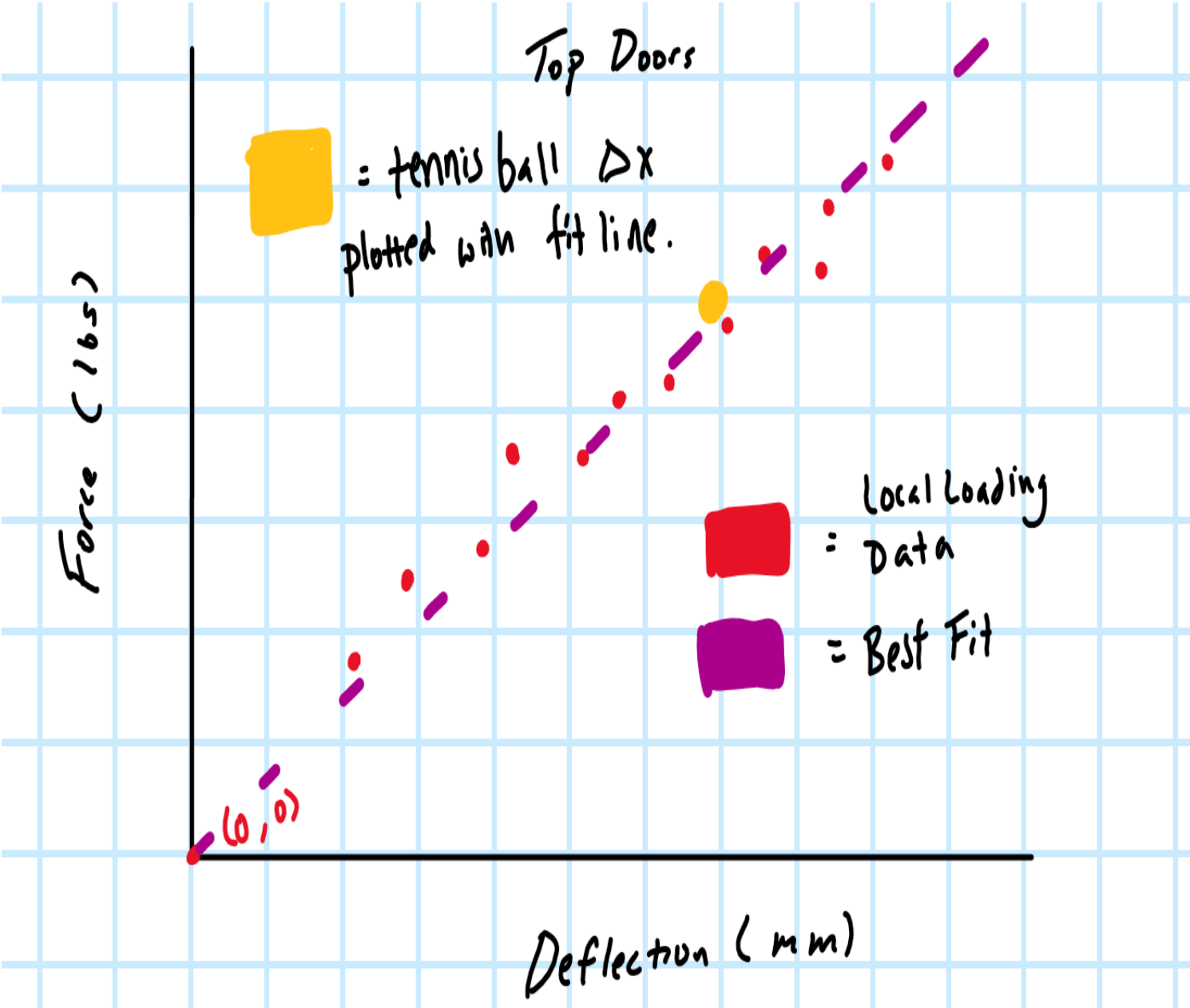
- Must be plumb relative to cart
- Compatible with both carts
- Made with existing material
- Use same mounting bracket as 1st frame



- Use existing sheet metal
- Secured when attached
- Using 3000 series Aluminum

Displacement Vs Force

- Generated two curves from locally loaded test comparing load to deflection. Both had very linear relationships R^2 > .98.
- Used deflection at different %filled from tennis balls to approximate the force being applied
- Determined the top doors were seeing the same deflection from 45lbs applied in the local loading test
- Determined bottom doors were seeing same deflection from 75lbs applied in local loading
- These values then with a margin became part of the new specification for door bulging



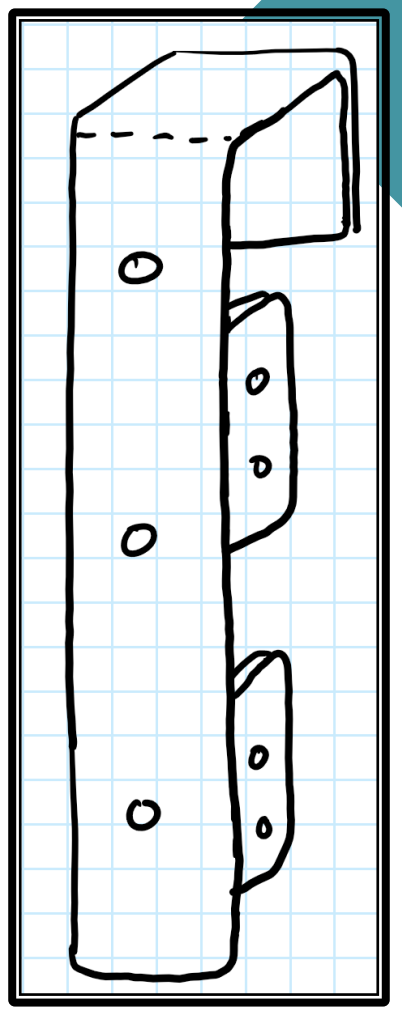
Force Vs Deflection Graph

Notes on Additional Specifications

- **Caster Wear**
  - Determined that a 1/16” wear on the tread would never be tested by maintenance in the field. Double-checked this by talking with Fulfilment center maintenance
  - Proved that this wear was accounted for by the Vertical clearance & by the caster diameter tolerance
  - Determined the caster manufacturer’s life testing was enough to say there should be no life issue and this spec can be removed
- **Cart Sensor**
  - Went through a history of revisions & reaching out to people to find the responsible engineering for the sensor on the specification and determined this specification was obsolete. Meaning that is something the manufacturer does need to test
- **Gloss Reading**
  - Used devices specification to show the device mentioned for the spec is incorrect & that the paint as is produces a gloss reading out of the specification
  - Updated specification to use the correct gloss measurement tool & expanded the tolerance to remove the Non-conformity
- **Improper Labeling**
  - Did a site visit for new carts and got a copy of their First Article Inspection, when I received the new alpha carts I started inspecting their labels and noted they were all incorrect
  - Using their FAI and what I say I noted the root cause was they weren’t scanning their own labels and there were no checks at the end to ensure everything was in order. I then offered my recommendations to improve their inspection

Results of Verification Project

- Overall created & released 2 verification procedures, documented the testing results per those procedures
- These Verification Procedures with assigned test responsibilities were now to be signed on to with the new specification by the manufacturer for contract with Amazon
- Verified new design of plastic deck meets requirements (lift lower test)
- Added key improvements to specification
    - Removed some specifications (Caster wear, structure dimensions, sensor)
    - Improved readability
    - Improve drawing standardization
    - Improved dimensional accuracy on drawings
- Determined 5 Non-Conformities across both carts that could now be addressed
    - Designed prototype guard to prevent pinch occurrence that was a non-conformity in the new carts
    - Labeling
    - Gaps in Carts exceeding dimensions of minimum package size used in them
    - Recommended Stronger Hinges & Latch Spring for bulge
    - Changed Acceptable Gloss Range to be based on measured data



Sheet Metal pinch guard prototype

Lessons Learned

- How specifications are verified and validated and what framework to use to do so
- How to construct tests that are easy to execute on and capture what is intended
- How to juggle several priorities all happening concurrently
    - Testing while writing procedure while noting improvements to specification while leading other tests
- How to create efficient designs especially for tests that need to be exported
    - Designed prototype guard to prevent pinch occurrence that was a non-conformity in the new carts
- How to better plan a schedule and anticipate the expected completion timings, especially on areas with additional stakeholders (testing engineering, fabrication, project management, etc.)
- If I were to attempt this again, I would aim to make this project more serialized. Improve spec -> Write procedure -> do testing. Then repeated that loop for improvements.
- Be more active with communicating and pushing to maintain deadlines with collaborators and engage with potential headwinds early on
- Be more detailed with notes and planning to keep track of how things are going on and how to assign priority
- How to design sheet metal in CAD (have more to learn here)