

**Project Deliverable D**  
**Prototype 1, Progress Presentation, Peer Feedback and Team Dynamic**

**GNG2101 [D]**  
**Introduction to Product Development and**  
**Management for Engineers and Computer Scientists**

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# Introduction

In this report, our team will outline the feedback received during the in-class design review and how we will implement this feedback to ensure we reach our final prototype. We will also outline what we have been able to accomplish in the current prototyping and testing phases of the design. A progress presentation will also accompany this document.

## In-Class Design Review Feedback

On February 10th, 2023, we were able to go through the in-class design review with a project manager for the course. During this meeting, the PM expressed a couple of concerns about our design. His first concern revolved around our desire to laser cut 2 of our pieces out of MDF and then screw our pipe fittings into the MDF. He raised the concern that MDF is a very hard material to screw into and could cause us some problems. Our solution to this issue was to change our manufacturing process from laser-cutting MDF to saw-cutting our parts out of scrap plywood our team had at our disposal. The second concern he raised was revolving our spring. Our spring has a spring coefficient of 42 lb/in. Since the load we need to support is approximately 200 lbs, we can get a compression of approximately 5 inches which does not allow the client to complete a full push-up. After further research from our team, we plan on continuing with the spring we currently have chosen as a proof of concept. All other springs we looked into were either too short in free length, had too high spring coefficients, or had too low maximum weight capacities. The spring will help us prove our concept whereas, in industry, a custom spring would need to be made which is outside of our budget. The third concern the PM raised was regarding our current handle location. As our handle currently is, a large moment is present on the handle when the user would complete the lifting portion of the push-up since his weight is not necessarily applied to the device and most of it is applied on the handle. Our solution to this is to add a wider base plate to the device to counteract the moment. His final concern about our design was about our pipe fittings to connect them to the disks. Our current plan was to 3D print our pipe fittings with wide flanges to screw them into the disks but he raised the concern that the fittings may not be strong enough and may break. He suggested we look into just buying our pipe fittings as they require no manufacturing and would more than likely be stronger. After doing some research into these pre-manufactured pipe fittings, our team decided to attempt to use our custom pipe fittings and test them before making a decision on moving to the pre-manufactured fittings to save money on our budget since these pipe fittings would more than likely put us over budget.

# Prototypes and Test

## Prototypes

### Prototype 1a

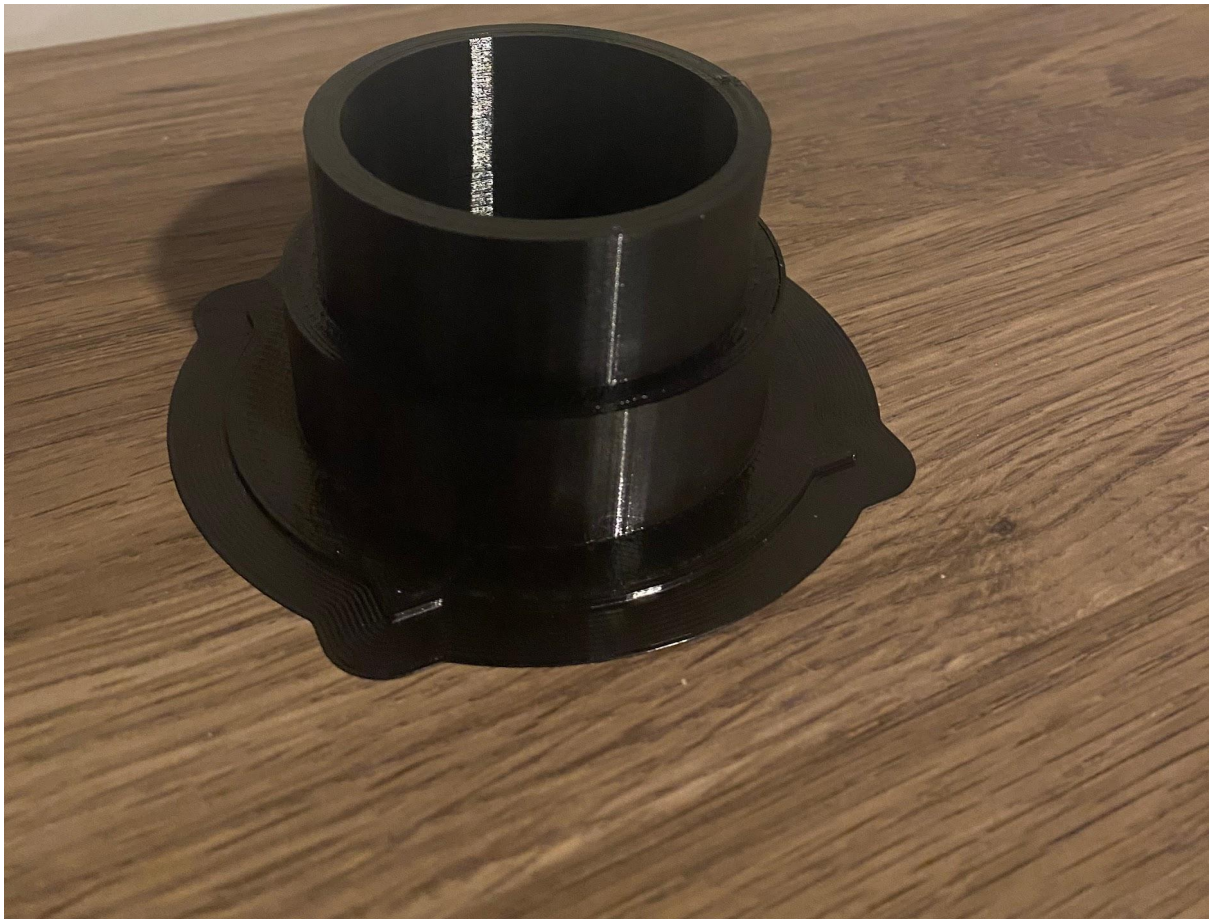
For our first prototype, we wanted to validate if our custom pipe fittings would be useful or if we would need to purchase pipe fittings. We printed 3 different test models of the same fitting. One on a 0.8mm printer (white model), one on a 0.6mm printer (black model) and 1 on a 0.4mm printer (green model). Seen below in Figure 1 are the 3 models. All model flanges were printed smaller to save time on each print. These models are medium-fidelity, focused-physical prototypes.



**Figure 1:** Pipe Fitting Test prints

### Prototype 1b

For our second prototype, we wanted to test out the strength of our custom spring connector. To do this, we decided to print a test model and apply 200 lbs. This first prototype model was printed on a 0.8mm printer. Since this print was 4 hours on the 0.8mm printer, we only printed one test model to save time. This model is a medium-fidelity, focused-physical prototype.



**Figure 2:** Spring Connector

### Prototype 1c

For our 3rd prototype, we wanted to prove our concept mathematically so this prototype is a more theoretical prototype which will outline the numerous known forces and enable us to calculate the other forces in the system by using assumptions and physics. This prototype is a low-fidelity, focused analytical prototype.

### Testing

After printing these three different pipe fittings, some general tests of stability and durability were run to check for the capabilities of these fittings. A general test plan (Table 1) is outlined below to provide details on testing results and objectives.

### Test Plan

**Table 1:** Test Plan

Test ID	Test Objective	Prototype	Results Recorded	Duration
1	Determine the strength of pipe fitting	Prototype 1a	1. Weight Applied 2. Fracture (yes/no) 3. Model Used	Until 200 lb of weight is supported



			4. Time of Applied force	for 1 min
2	Determine the strength of spring connection part	Prototype 1b	1. Weight Applied 2. Fracture (yes/no) 3. Time of Applied force	Until 200 lb of weight is supported for 1 min
3	Determine total forces acting on the system and accompanying stresses	Prototype 1c	1. Total Forces 2. Stress Concentrator 3. Stress	Until forces and stresses are determined

## Test Results

### Test 1

During test 1, we planned on loading each test model with 200 lbs for a duration of 1 minute. For the 0.8mm model, we could not load the model since it was clearly visible that it would fracture under the weight of 200 lbs since it could be easily deformed by hand deformed as seen in figure 3. For the 0.6mm model and the 0.4mm model, 0 deformation and no cracks could be seen after unloading the specimens. This test confirms the hypothesis that these printed parts are strong enough to support the required weight of 200 lbs.



**Figure 3:** 0.8mm Model Deformation

## Test 2

During test 2, we conducted the same test as done during test 1 but this test was applied to prototype 1b. This model was quickly able to withstand the 200 lbs of weight for the 1-minute duration with no visible signs of permanent deformation or signs of failure.

## Test 3

The following test will show all calculations done to determine the force and stress in the part

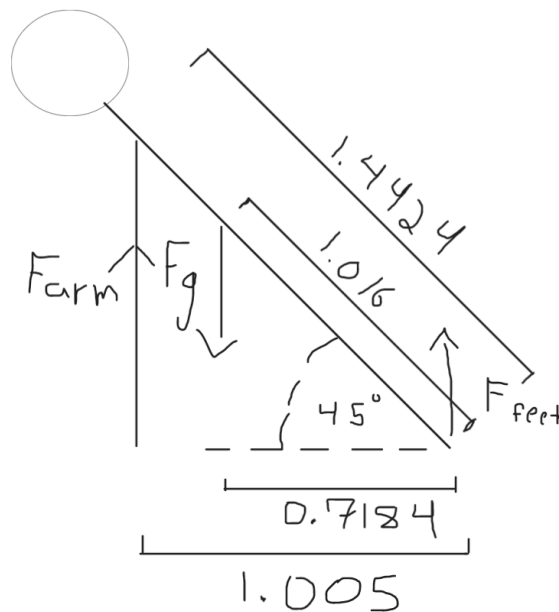
### Weight

$$F = m * g$$

$$F = 90.72 \text{ kg} * 9.81 \text{ m/s}^2$$

$$F = 889.96 \text{ N}$$

### Force in arms analysis



**Figure 4: Beam Analysis**

Assuming an angle of 45 degrees between the body and the floor

$$\sum M_{feet} = 0$$

$$0 = F_g * 0.7184 - F_{arm} * 1.005$$

$$F_{arm} = 636.16 \text{ N} = 318.08 \text{ N/arm}$$

$$\sum F_y = 0 = F_g - F_{arm} - F_{feet}$$

$$F_{feet} = 253.79 \text{ N}$$

Assuming full body weight is the force being applied to the device

$$F = kx$$

$$x = F/k$$

$$x = 889.96 \text{ N} / 7.36 \text{ N/mm}$$

$$x = 120.91 \text{ mm compressions from the spring}$$

At full compression, the force in the spring and on the fittings is 889.96 N in compression

Stress in the fitting

$$\sigma = F/A$$

$$\sigma = 889.96 \text{ N} / (\pi(76.2 \text{ mm}/2)^2 - \pi(50.8 \text{ mm}/2)^2)$$

$$\sigma = 0.35 \text{ MPa} < \sigma_{\text{yield}} = 35.9 \text{ MPa for PLA}$$

## Conclusion

In conclusion, after creating initial concepts and receiving feedback from our client, the prototypes listed above were drafted. Using 3D design software, detailed parts were outlined and printed to undergo preliminary tests using a specific test plan. A meeting with the project manager allowed for modifications to be made to the design and a better understanding of the compression spring coefficient. After thoroughly assessing all client feedback, multiple drafts of prototype one were created and tested using different weight and force applications to measure the overall stability of the part. The earlier prototypes were easily ruled out due to their ability to be deformed with minimum to no weight application; however, the preceding designs were able to withstand a substantially higher weight/force due to modifications made. A mathematical analysis was utilized to determine the forces and stresses in the part. This allows us to calculate the force exerted by the spring at its maximum compression onto the pipe fitting part. Accompanying this deliverable, a progress presentation showcasing the progression of our project was created.