<u>Truss Design</u>

E - 231
Section B
Group 8
Date: November 21, 2017

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I pledge my honor that I have abided by the Stevens Honor System.

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Abstract

As engineers, it is important to be able to create a product that serves a purpose and be able to maintain that purpose for the duration of its use. It is for this reason that every engineering course brings up the Tacoma Narrow Bridge collapse as a lesson to all engineering students. At the time, the suspension bridge was designed to be cheaper, slimmer, and more elegant than any structure built. However, the engineers were not prepared for the environmental forces to affect the bridge significantly. Due to its flexibility, the bridge had little resistance to torsional forces and as a result the wind flow increased creating a wind vortex that ultimately led to its collapse.

A simple project to teach engineering students about the design, fabrication, and testing of strong bridges will be told in the following pages. A typical truss bridge consists of two planar trusses; one at each side of the bridge. The planar truss is characterized by joining numerous small structural members into a series of interconnected triangles. Different designs of planar trusses produces different loads. Therefore, purpose of this project will test the student's understanding of how the design of their members, joints, and gusset plates distribute loads in order to create a strong structure. The students will not only focus on the form on of their bridge, but they will also need to take into account its function - things that the engineers of the Tacoma Narrow Bridge did not take into consideration before building.

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Introduction

The purpose of this report is to explain the process of designing, fabricating, and testing of group 8's most optimal single planar truss that can withstand a max load of 494 lbs.

Overall, the competition consisted of each group in each section competing with each other to design a plane truss that can withstand the highest load. The bridge design had to span 15 inches horizontally and have a vertical dimensions of 4 inches. The bridge also had to have a minimum calculated failure load of 325 lbs in order to be accepted into the competition. Each group needed to create a truss design using the graphic MATLAB-based software analysis tool. This tool allowed students to create and change the design of their truss while displaying the axial loading forces in each of the members.

Materials for this truss design were limited to the following items: one 36" length piece of brass tubing, four 12" lengths of brass tubing, one 1"x 12" x 0.016" brass strip to be cut as necessary to make gusset-plates, and any soldering, flux, flux brush, emery cloth, propane torch, refractory bricks and wettable rags to avoid soldering.

The groups were limited to only the provided materials (including soldering). Truss members had to be single straight pieces of hollow brass ⅛ inch (outside dimensions) tubing with a 0.014 inch thickness. Multiple/adjacent thickness of tubing will not be allowed.

To approach this project, Group 8 knew that in order to succeed, they needed to be organized and understand the concepts introduced in earlier labs in the course. Throughout the process, Group 8 kept a Gantt chart and a work breakdown structure to keep each member participating and completing necessary deliverables. The course itself implemented important topics that were required to make a successful truss bridge. Once the group understood the concepts of tension, compression, shear, factor of safety, and 3 point bends, the group was ready to design the truss. Using the MATLAB-based software tool, each member of the group designed their own trusses. After deciding on which truss had the maximum load of the three, each group member took the design and moved each member until they reached the maximum load of 494 lbs.

Discussion

Introductory Paragraph to the Design Section Content

Trusses are structures that serve as a basis for construction, mainly bridge design. In order to design a successful truss, there are a few key factors to consider. First, constructing a truss that can hold the desired maximum load requires multiple trials and design proposals. Next, the truss designs must consider using the limited brass material in an efficient manner. It is also important to note the complexity of physically building each of the trusses: some may have a greater number of members of varying sizes, making it more complicated to accurately assemble.

Before beginning construction, Group 8 needed to set a work breakdown structure (WBS) (*see Figure 1*) and a Gantt chart (*see Figure 2)* to keep themselves organized. A work organization chart was also created to further and specifically split up the work within the group. (*see Figure 3).* In terms of the WBS, Group 8 decided that there were 5 major milestones needed to cover in this project. The first was initiation which included having the problem set given to each group and a review of the past concepts learned throughout the course. The next milestone included planning. This involved creating a WBS, Gantt Chart, and practicing soldering techniques. The largest and most important milestone was execution. Group 8 had to use the MATLAB Truss tool to design their bridge, have it approved for the competition by the professor, recreate the truss on graph paper, and finally measure, cut, and solder each components together. This milestone was the defining factor for the truss design's execution in the test. Group 8 knew that in order to successfully complete the test, they had to be systematic and detailed about this step. The last two milestones include control and closeout. Control included the testing of the bridge and reviewing the results. In other words, the group needed to see if there were any errors in their calculations or construction of the bridge. The closeout milestone required the group to write the written report and give an oral presentation as a reflection of their project.

Figure 1: Gantt Chart

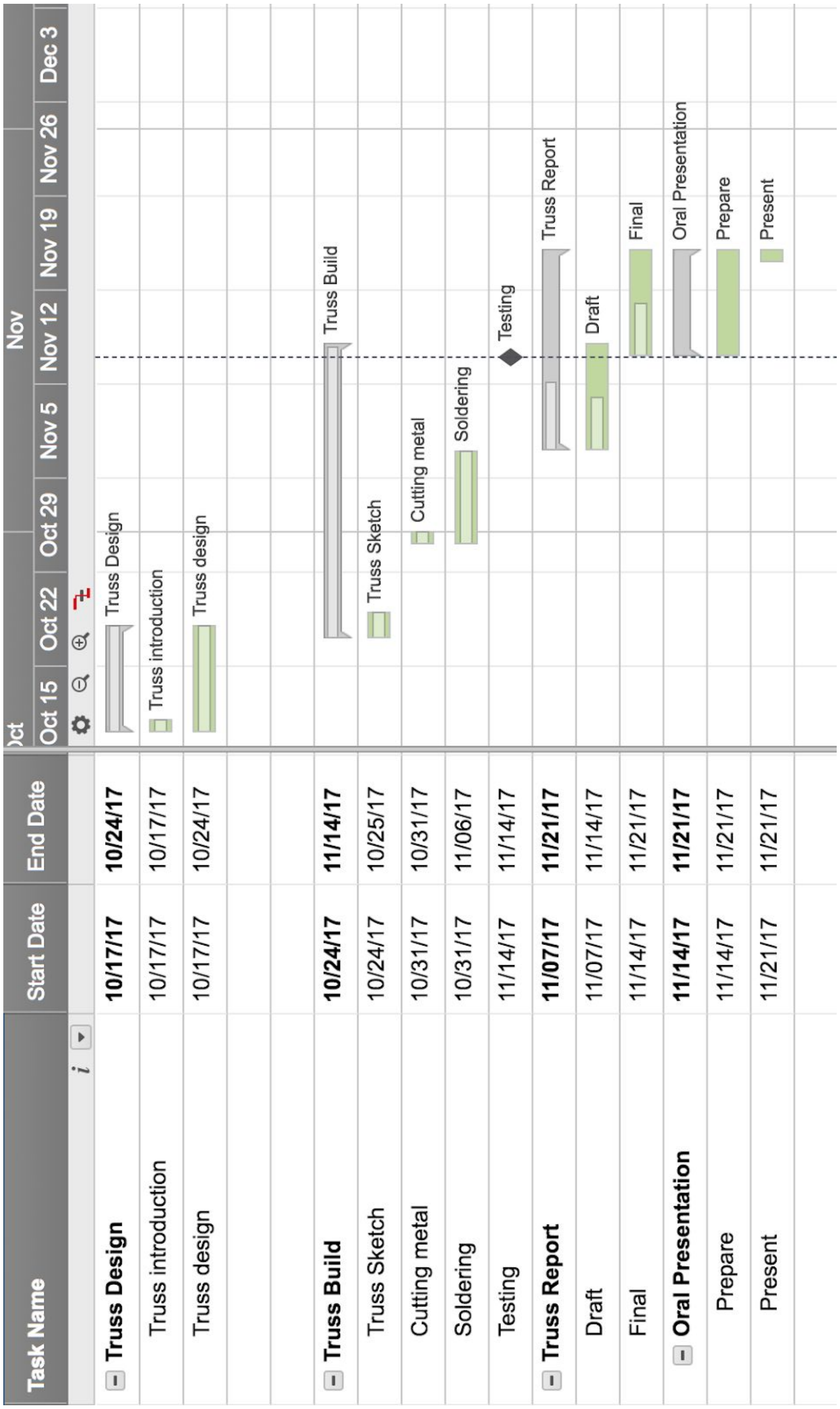


Figure 2: Work Breakdown Structure

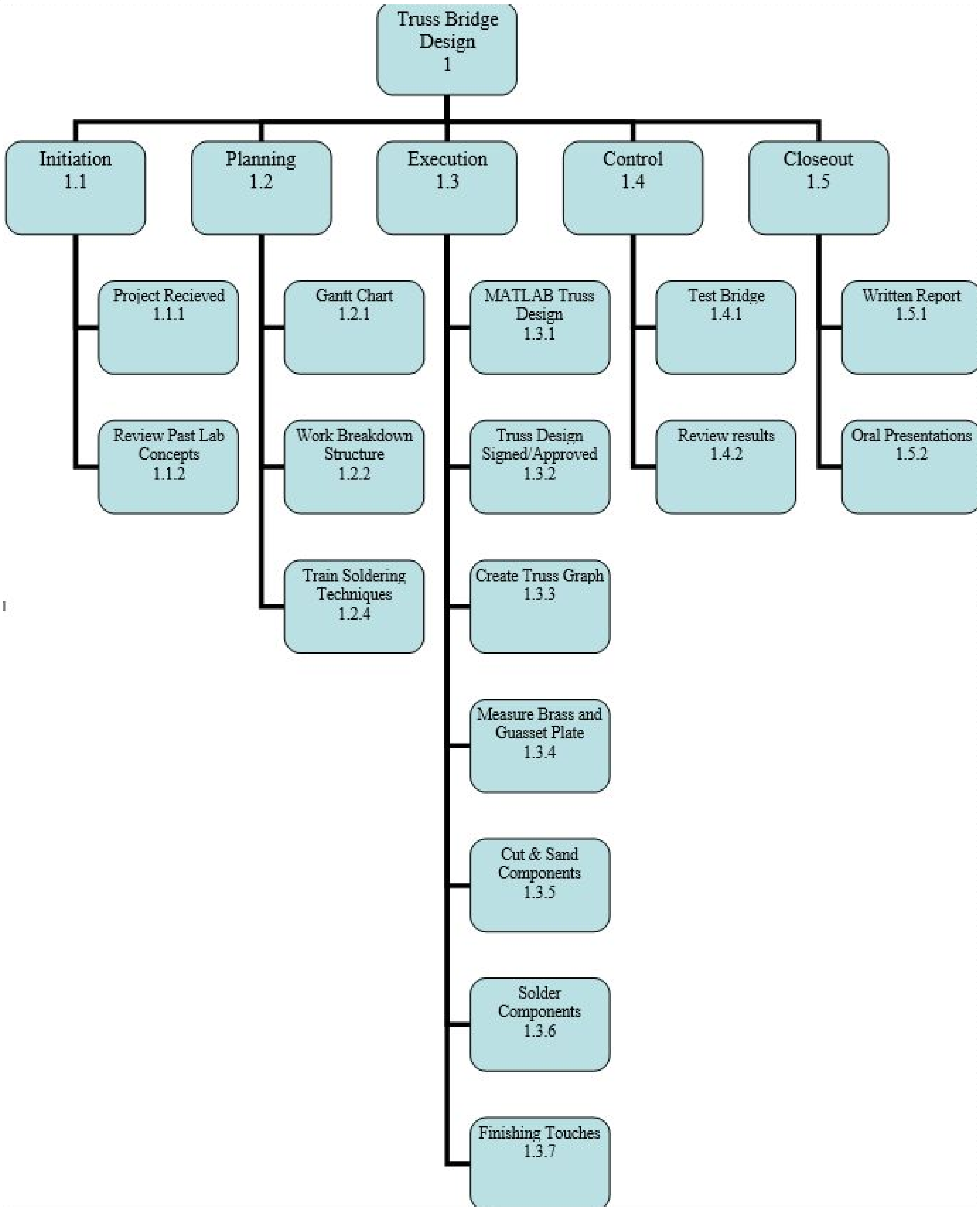


Figure 3: Work Organizing Chart

Task name	Chloe Quinto	Teny Odaimi	Chenxin Xu
Truss Designs	X	X	X
Truss Sketch	X		
Measure Brass & Gusset Plate	X		
Cut & Sand Components	X	X	X
Soldering Components	X	X	
Written Report	X	X	X
Oral Presentation	X	X	X
Gantt Chart			X

Design Section

Overview of the Design Process

The design process consisted of coming up with multiple truss designs using a MATLAB Truss Analyzer program. This program allowed us to assess our truss designs by indicating the length of each member, the force on each member, and amount of material used to hold the desired minimum force of 325 lbs. After multiple trials with the program and analyzing each of the designs, we selected one final truss design. The selected truss design was sketched out onto a large graph paper, delineating all the member measurements. After this planning and preparation, we were able to proceed to cutting the brass and soldering the members of the truss together. On the following pages are the three designs that Group 8 created.

Truss Preliminary Designs

Figure 4: Truss Design 1

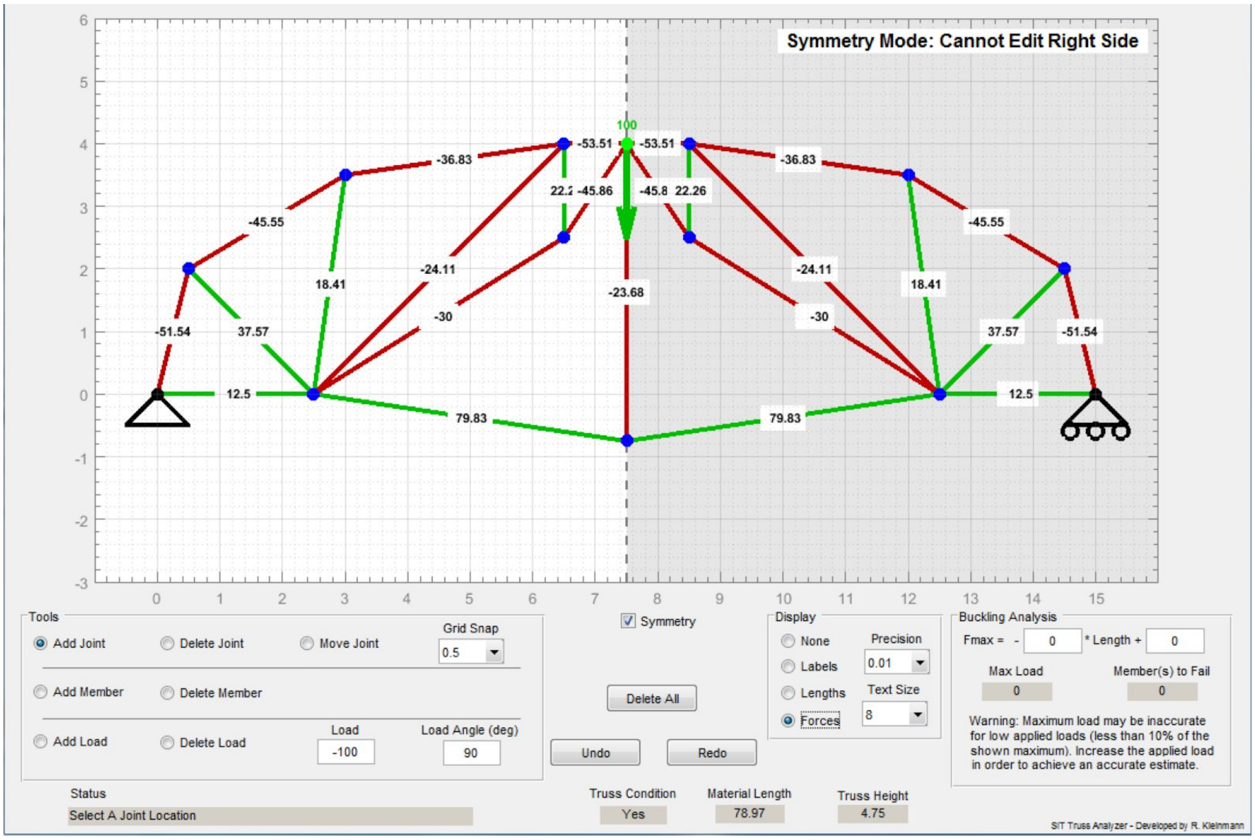


Figure 5: Truss Design 2

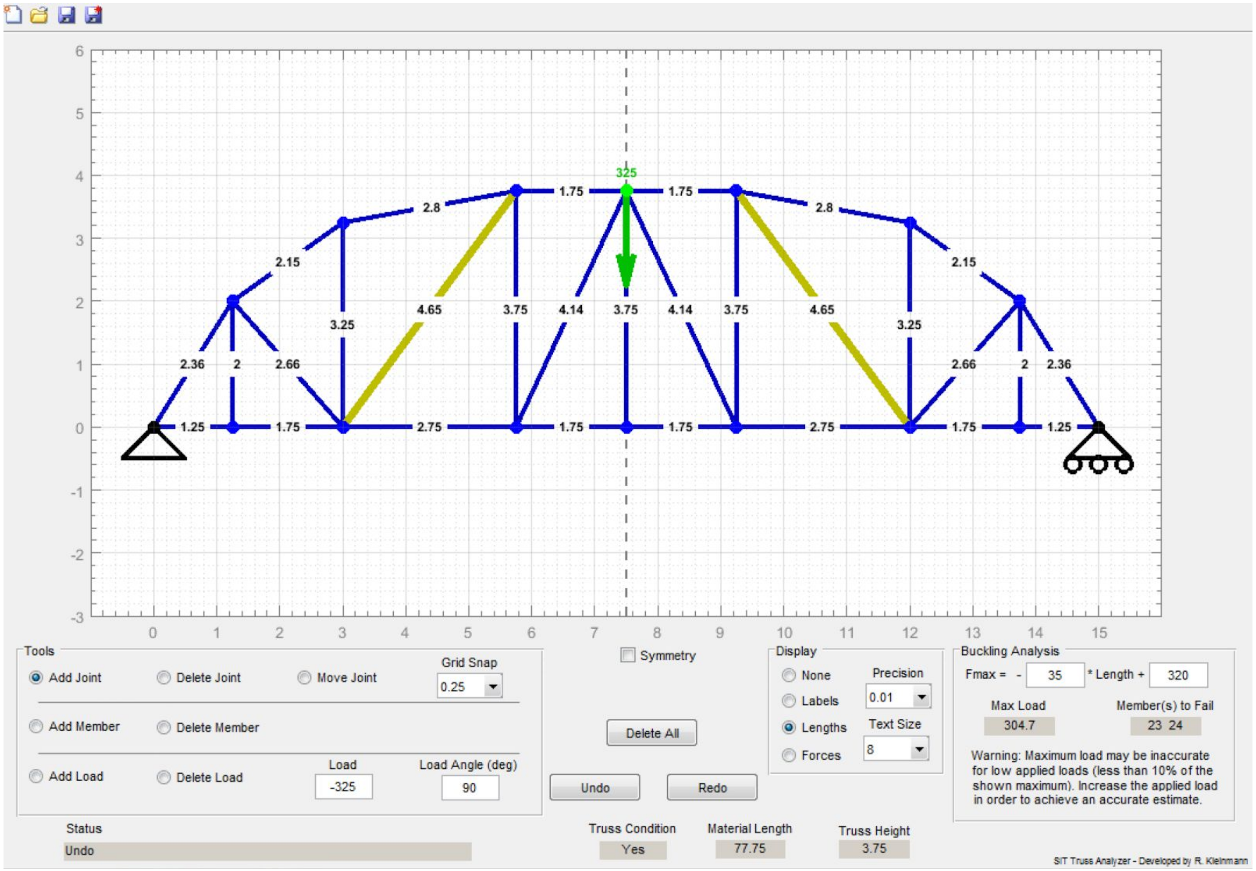
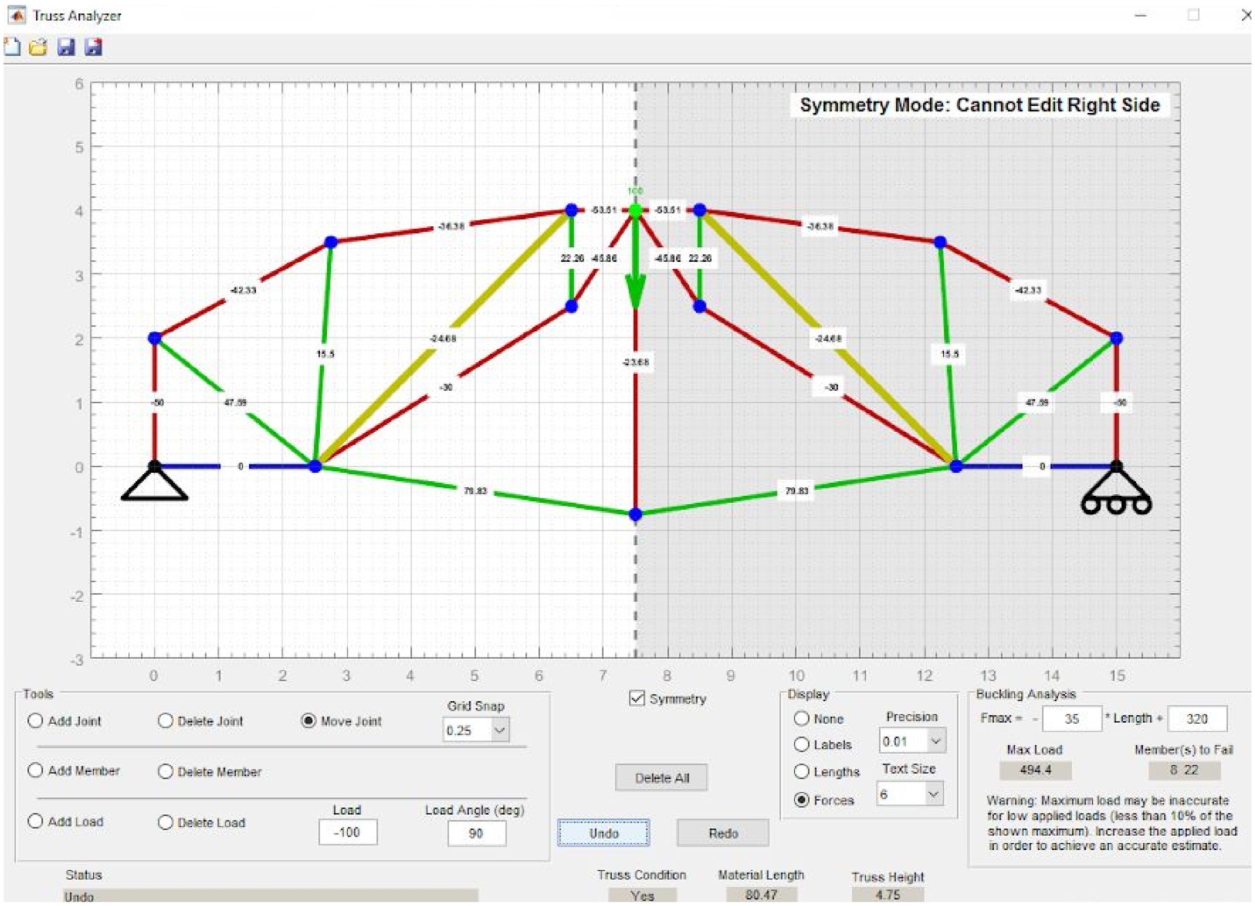


Figure 6: Truss Design 3



A table was created to analyze the advantages of the different factors of each truss design, helping us decide which design would be our final (*see Table 1)*. The group calculated the most optimal design using a Pugh Matrix method. The group ranked the number of joints on a scale from 1-3. Since Design 1 and Design 2 had the same scoring, they were given the average of 1.5. The group ranked the number of members on a scale from 1-3. Since Design 1 and Design 2 had the same scoring, they were given an average of 1.5 as well. Since the material length was the second most important in our analysis of designs, we based the scaling of of a magnitude of 2. The scaling range was 2, 4, 6. In other words, 2 meant that the design had the most in terms of the amount of material length and 6 had least amount of material. The group considered the maximum load as the most important aspect of the design. Therefore, they chose to score the designs based of of a magnitude of 3. The scaling range was from 3,6,and 9. In other words, 3 meant that it could hold the least out of the designs and 9 meaning that it could hold the most out of the designs.

Table 1: Truss Design with Alternatives Table

Truss Design	Number of Joints	Number of Members	Material Length	Max Load
Design 1	16	29	78.97	478.5
Design 2	16	29	77.75	304.7
Design 3	14	25	80.47	494.4

Truss Design	Number of Joints	Number of Members	Material Length	Max Load	Total Points
Design 1	1.5	1.5	4	6	13
Design 2	1.5	1.5	6	3	12
Design 3	3	3	2	9	17

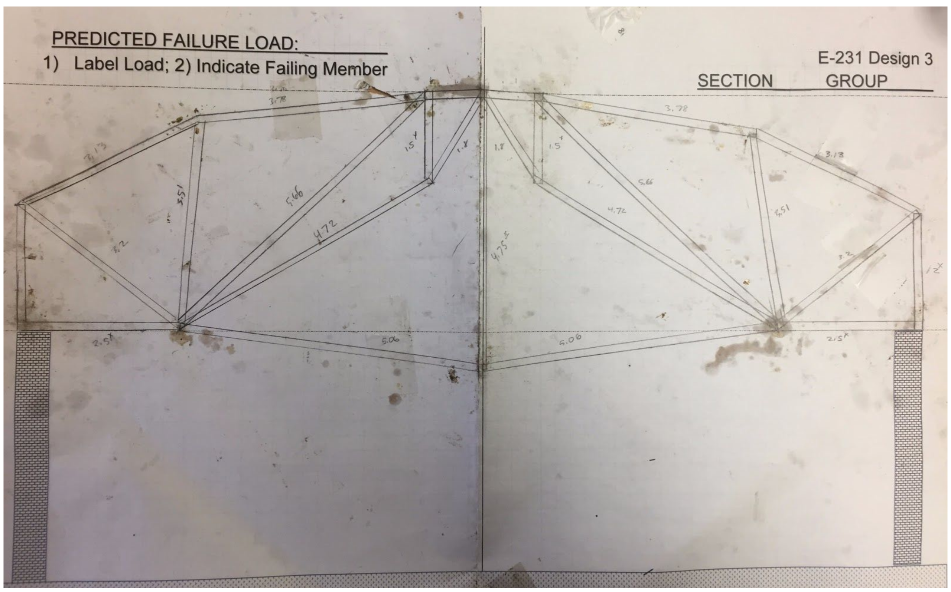
Table 1. Design 3 is highlighted because it was chosen as the best truss design

Since holding the highest maximum load is one of the major goals, factors such as number of joints and members weighs in less. Design 3 has a maximum load of 494.4, which is significantly larger than those of Design 1 and Design 2, 478.5 and 304.7 respectively. Another important consideration is the amount of material used to construct each design. Although Design 3 has the greatest maximum load, it uses the most material, with the length being 80.47 as opposed to Design 1 and Design 2 which use 78.97 and 77.75 respectively.

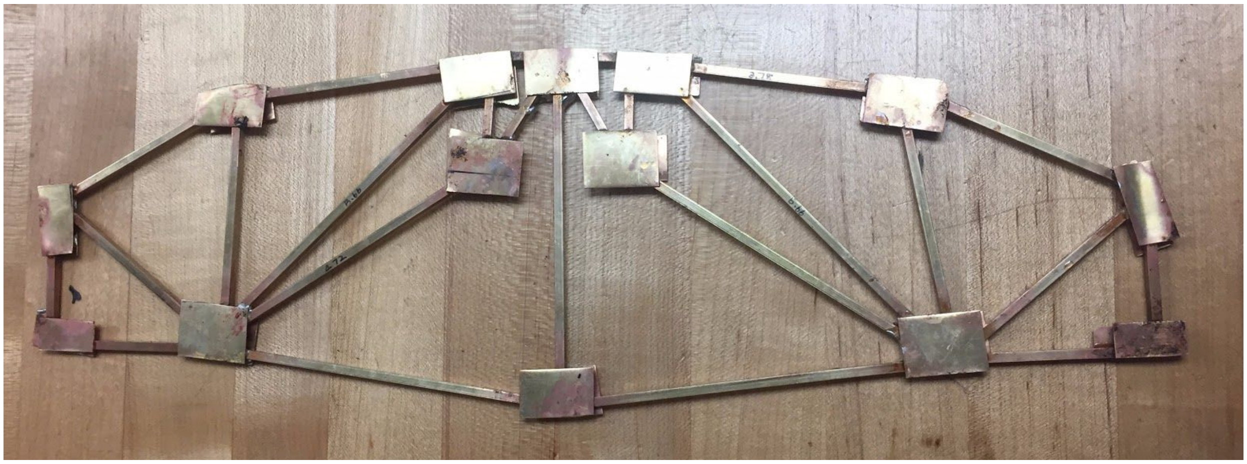
Although different in material length and maximum load, truss Design 1 and Design 2 have a total of 16 joints and 29 members. Design 3, is essentially the better option among the three, as it has not only the greatest maximum load, but also has a less members and joints, 14 joints and 25 members. This affects the complexity of the cutting and soldering process of constructing the truss. With a design that requires less members to cut, sand and solder, the measurements and assembly are more likely to be precise.

The picture 1 displays the design template that was used to solder the components to the correct design specifications. Picture 2 shows the final truss design model that was created by group 8.

Picture 1: Design Template



Picture 2: Finalized Truss Design

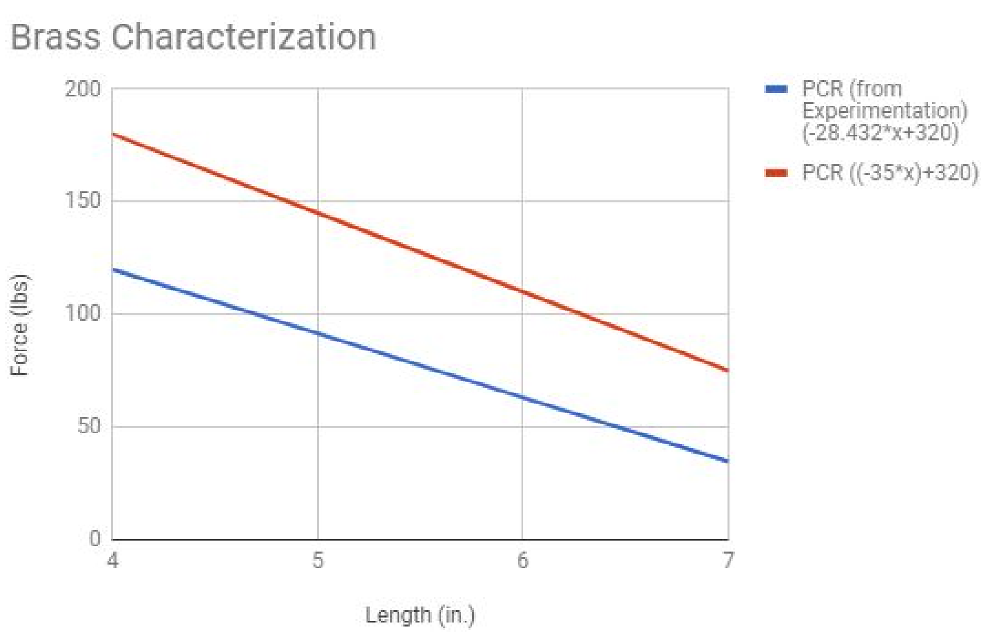


Design Analysis Summary

The final truss design selected had a maximum load of 494.4 lbs. The idea behind the design was to distribute the load among the members as evenly as possible, to maximize the allowable load. The design, although not perfectly following this criteria, was able to hold the load fairly well. The truss remains assembled and functioning until the member or members with the smallest allowable load fail. In this final design, Member 8 and Member 22 fail first, with an allowable load of approximately 122 lbs (*see Figure 6 and Table 4)*. To strengthen and connect the assembly of members at each joint, the team measured, cut and soldered gusset plates to either side of each joint. Out of the three proposed designs, the final design required the least number of joints and members, making it the most desirable. This is because this final design requires the least amount of material, while having greatest maximum load. Furthermore, this symmetrical design, is a bit simpler to construct being that there are less members to cut, solder and assemble. The relative complexity of the truss design, however, does not hinder the effectiveness of the truss and its capability. In fact, the measurements and assembly are more precise with less members, resulting in a lower chance for error.

To calculate the allowable loads of the members, the group had to look back at one of their labs. Specifically, the brass compression lab. In this lab, each group learned about the concepts of buckling in brass material. There are several parameters that affect buckling load. That is material type, cross sectional area, shape of the column (moment of inertia), length of column, and column end conditions. Through experimentation, the group found that the most accurate critical axial load on the column just before it buckles through experimentation has a slope of $y = -28.342 * x + 233.71$, where x is the length of the material and y is the max load. After all the groups in the class recorded their answers, design 3 professors gave an a new equation $y = -35 * x + 320$ for brass compression. This equation would allow all groups to accurately analyze their truss designs during creation. (*see Chart 1*)

Chart 1: Brass Characterization



Calculations of Predicted Failure Load and Failure Members

Table 2: Design 1 - Max Load : 478.5

Members	Lengths	Member Forces	Allowable Load
1	2.061552813	-51.53865887	247.8456516
2	2.5	12.50033341	232.5
3	2.061552813	-51.53865887	247.8456516
4	2.5	12.50033337	232.5
5	2.828427125	37.56522589	221.0050506
6	2.915475947	-45.55419746	217.9583418
7	3.535533906	18.41430639	196.2563133
8	5.656854249	-24.11289522	122.0101013
9	5.055937104	79.83065541	143.0422014
10	4.716990566	-29.99832186	154.9053302
11	3.535533906	-36.8283569	196.2563133
12	1	-53.50856169	285
13	1.5	22.25883022	267.5
14	4.75	-23.68421052	153.75
15	1.802775638	-45.8600291	256.9028527
16	1	-53.50856151	285
17	1.802775638	-45.86002902	256.9028527
18	5.055937104	79.83065543	143.0422014
19	2.828427125	37.56522591	221.0050506
20	2.915475947	-45.55419747	217.9583418
21	3.535533906	18.41430637	196.2563133
22	5.656854249	-24.11289522	122.0101013
23	4.716990566	-29.99832188	154.9053302
24	3.535533906	-36.8283569	196.2563133
25	1.5	22.25883022	267.5

Table 3: Design 2 - Max Load : 204 lbs

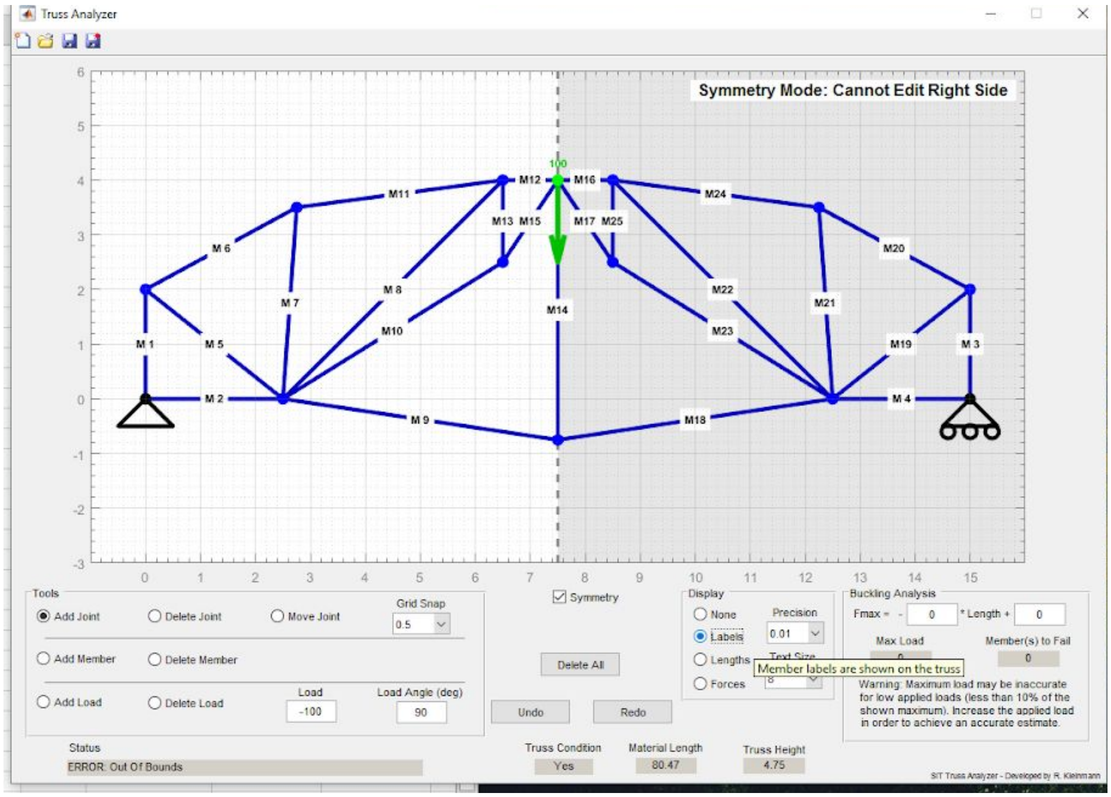
Members	Lengths	Member Forces	Allowable Forces
1	3.25	79.87145762	206.25
2	2.75	249.1719085	223.75
3	2.795084972	-152.4554046	222.172026
4	3.75	162.500359	188.75
5	1.75	325.0019196	258.75
6	3.75	162.500359	188.75
7	1.75	325.0019196	258.75
8	2.795084972	-152.4554046	222.172026
9	3.25	79.87145762	206.25
10	2.358495283	-191.6233492	237.4526651
11	2.150581317	-184.3341177	244.7296539
12	1.25	101.5702363	276.25
13	2	0.00284290369	250
14	1.75	101.5658098	258.75
15	2.657536453	73.55947368	226.9862241
16	2.150581317	-184.3341177	244.7296539
17	2.358495283	-191.6233492	237.4526651
18	1.75	101.5658097	258.75
19	2	0.00284290369	250
20	1.25	101.5702365	276.25
21	2.657536453	73.5594737	226.9862241
22	2.75	249.1719085	223.75
23	4.650268809	-167.6898663	157.2405917
24	4.650268809	-167.6898663	157.2405917
25	3.75	0.00000001184237893	188.75
26	1.75	-249.1619831	258.75
27	1.75	-249.1619832	258.75
28	4.138236339	-179.3232977	175.1617281
29	4.138236339	-179.3232978	175.1617281

Table 4: Design 3 - Max Load : 494.4 lbs

Members	Lengths	Member Forces	Allowable Load
1	2	-49.99990818	250
2	2.5	0.0003728573006	232.5
3	2	-49.99990818	250
4	2.5	0.0003727862463	232.5
5	3.201562119	47.59097839	207.9453258
6	3.132491022	-42.33079774	210.3628142
7	3.508917212	15.5020454	197.1878976
8	5.656854249	-24.67948661	122.0101013
9	5.055937104	79.83065593	143.0422014
10	4.716990566	-29.9983205	154.9053302
11	3.783186488	-36.37667872	187.5884729
12	1	-53.50856572	285
13	1.5	22.25882816	267.5
14	4.75	-23.68421054	153.75
15	1.802775638	-45.86003111	256.9028527
16	1	-53.50856555	285
17	1.802775638	-45.86003109	256.9028527
18	5.055937104	79.83065597	143.0422014
19	3.201562119	47.59097841	207.9453258
20	3.132491022	-42.33079774	210.3628142
21	3.508917212	15.5020454	197.1878976
22	5.656854249	-24.67948661	122.0101013
23	4.716990566	-29.99832049	154.9053302
24	3.783186488	-36.37667872	187.5884729
25	1.5	22.25882816	267.5

The allowable failure load was calculated with the Brass Equation $y = -35(x) + 320$ *where x is the length of the member and y is the allowable failure load.*

Figure 7: Truss Members Labeled on Design



Fabrication Concerns

There were several fabrication concerns that had to be considered in this design phase. One of the major concerns that Group 8 had to take into consideration is the angles between each members. The group had to manually calculate the angles, otherwise the design of the truss would not be correct. If the angles were slightly bigger or slightly smaller on one member, the measurements for all the other members would change. Another fabrication concern was how the group was going to place the gausset joints. One technique that the group considered was to place a small amount of solder on one side of the gusset plate and then flip it over onto the members. This was a hard technique to master. Therefore, the group decided to do this and in addition, add more solder to the connected member and gusset plate.

Fabrication

After completing the design, the next step is to solder these pieces together. The group would be given one 36” length and four 12” lengths pieces of brass tubing and one 1” x 12” x 0.016” brass strip to be cut as necessary to make gusset-plates. The group need to program materials properly.

Before starting to cut the brass tube, the group should draw their design on the paper in true size, which help to organize materials. After that, according to the drawing and length, the brass tubings were marked the correct length leaving around 2 inches to avoid the deviation. Then the group used cutting machine to cut the metal and put them on the paper with tape to fix. When all brass tubings were cutted and fixed on the paper, the group adjusted pieces to accurate lengths depending on the angle and soldering. After that, the next is to solder them together.

To do soldering, the group need solder, flux with flux brush, emery cloth, propane torch, refractory bricks and wettable rags to avoid soldering. Then the group did what students practiced several weeks ago.There are some problems found when doing soldering. The first one is how to determine the angle. When putting two brass pieces on the bricks, it is hard to determine the same angle as the drawing, which coursed the deviation and influenced other pieces. The group tried several ways to fix this problem. Finally it determined to stretch the angle on the gusset-plates and to adjust them until getting the correct angle. However, it is hard to fix the drawing perfectly, which leaded to the other problem. When doing soldering, the group gradually found that two pieces of brass tubing were too short to to attach the joint. Considering the whole structure, finally, gusset-plates were used to help brass tubings at that joint connect each other. This problem reminders that when adjusting the length of the tubing, it should do with soldering, which provides the opportunity to avoid such problem.

Besides, when soldering is using two gusset-plates when the joints have more than three tubes. However, after finishing soldering, there are several gusset-plates left. Hence every joint was used gusset-plates.

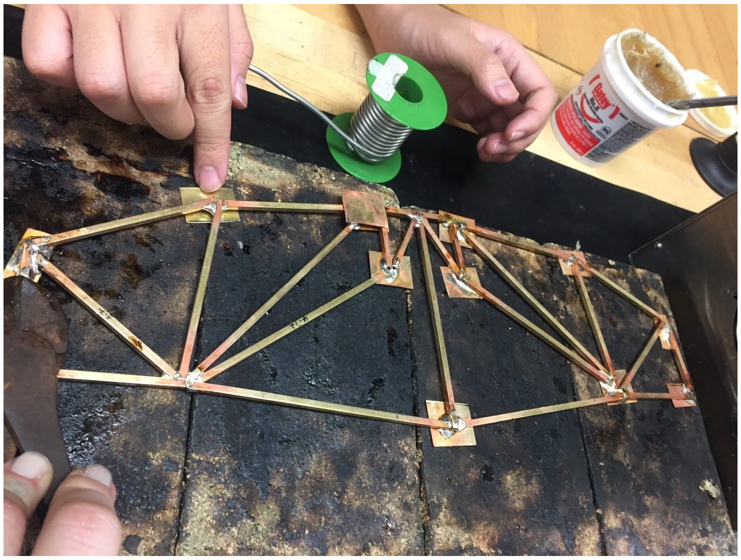
After soldering, the group should make sure the gusset-plates on the top and the bottom of the truss should not exceed the structure. Then the truss can be tested in the lab. The following two pages includes pictures of group 8 during the fabrication phase.

Picture 1: Group member cutting brass members

Picture 2: Group member soldering members together

Picture 3: Group member working on the written report

Picture 4: Soldering gusset plates on one side of the truss



Picture 5: Gusset plates soldered onto the corresponding members

Testing

Using the Truss Buster, a single point load was applied to the truss at the center of the span and at the top of the truss. Load was applied at the center vertically downward. The group's finalized truss model had a predicted load to failure of 494.4 lbs. During testing however, the group found that their truss model had a load to failure of 283.3 lbs. This was significantly lower than what the group had expected. This could have been due to a number of factors. One reason could have been that the angles at which the group soldered the members could be slightly different from the design. The team found it difficult to precisely solder the members at the specific angle. With one angle off calculation, the entire design truss angle calculations could be different. This would massively affect the maximum load during testing.

The members that failed during testing was member 8. This was predicted by the group to fail first earlier within the design of the truss because it had a maximum allowable load of 122 lbs. The group rationalized that the reason why the member did not break at that weight, but instead at a higher weight was because the soldering of the gusset plates were stronger than anticipated (*See Picture 6).*

Picture 6: Gusset Plate Bending

Figure 8: Buster

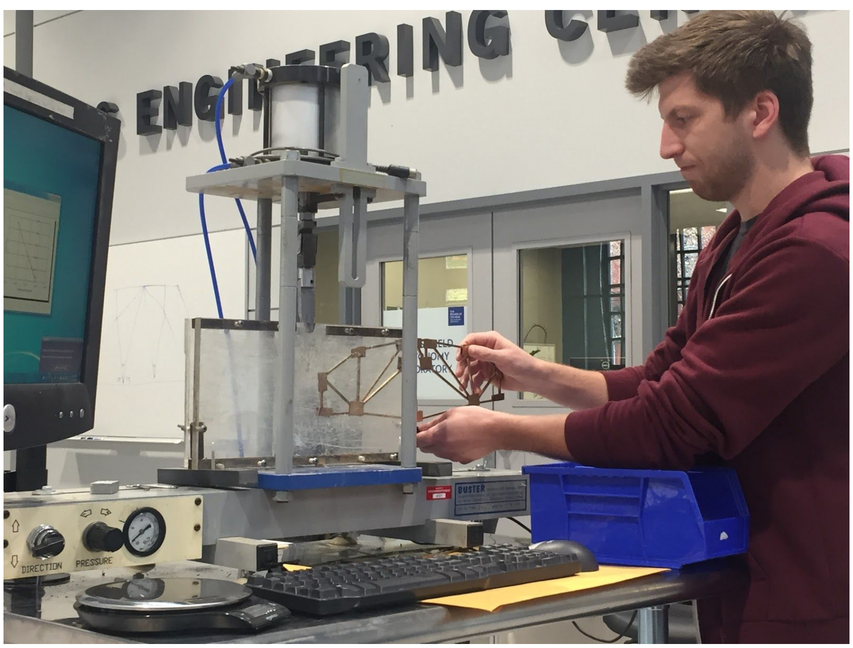


Figure 9: Failed Member

Conclusions and Recommendations

Finally, the truss can accepted 283.33 pounds, which is lower than what the group expected. However it still shows a successful teamwork. There are some accomplishments when processing the project but also some defects.

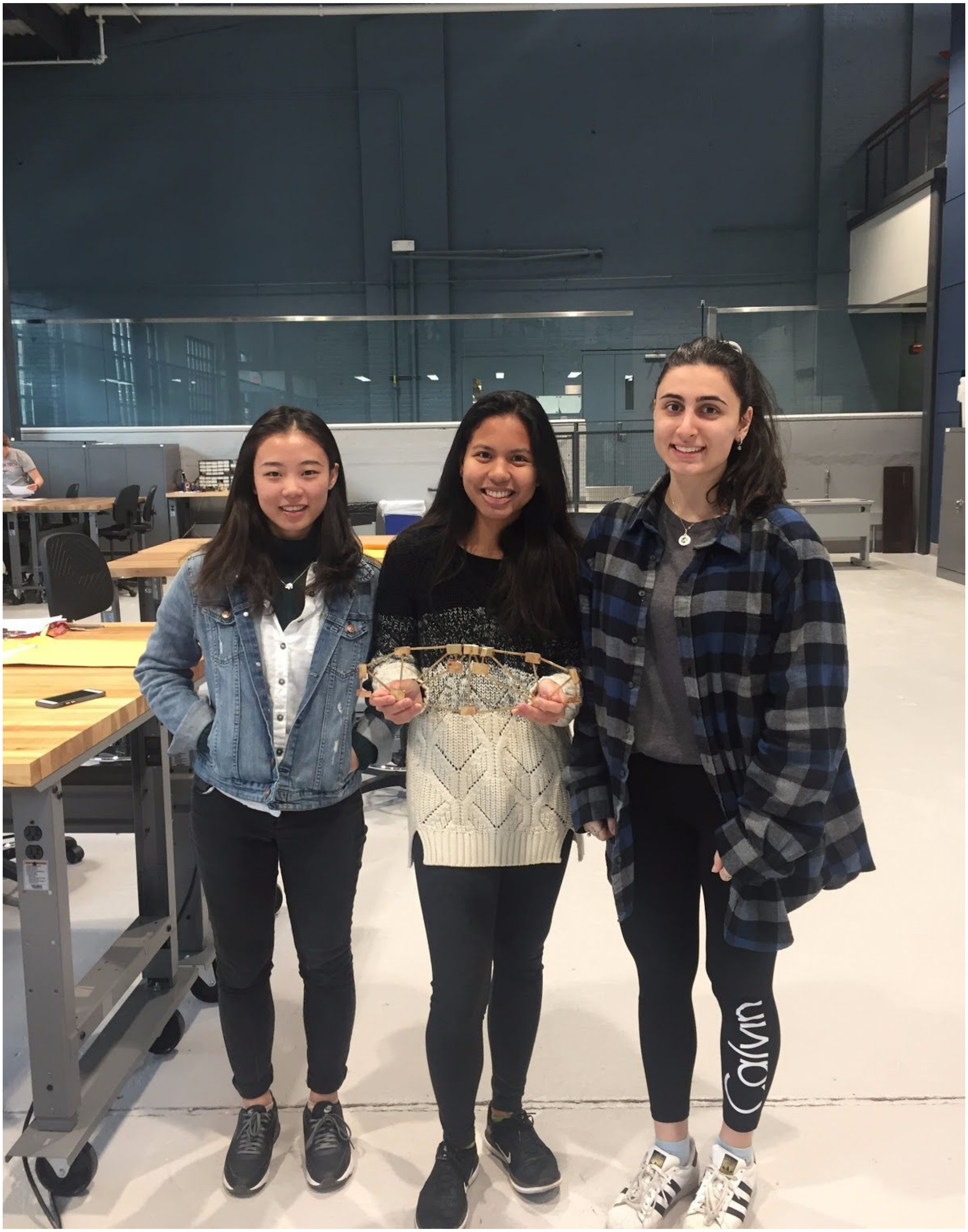
Designing the truss is the hardest part of this project. Hence the group chose to share their designs and enhance the one that could suffer highest load. Eventually, the design shows that the truss can accept over four-hundred-pound force. The group learned how important the teamwork is in a project. Also, the group learned and understand the truss deeply when trying to design it. When finished the design and started to build the truss, one measured and marked the length and the rest cutted. Such good accomplishment enhance the efficiency and followed the gantt chart well. The successful teamwork was also showed when facing some problems. When soldering the brass tubing, the angle was hard to determined. However, everyone in the group stated their ways to fix it and finally angles got close to the design. All of those indicate the group worked hard and cooperate well.

However, there are also some defects. One is when building the truss, the group ignored that the deviation of the angle would cause the length of components changed. Thus, some brass tubing lost touch, which caused the truss cannot accept more load. The truss finally broke at the joint where the brass tubings do not connect each other. Hence if there is an opportunity to rebuild it, the deviation must be considered when build the truss.

A recommendation the team strongly highlights is managing time efficiently. Planning out the steps of the project and the goals for each week are essential to make sure the group does not fall behind. Furthermore, a Gantt chart is extremely useful in making sure the team has sufficient time to complete each segment of the project. Weekly meetings with team members ensures that every member is updated, focused and involved with each week's project goals.

Another major recommendation is to utilize the full three hours of class, especially if the team falls too close to the deadlines. In addition, once the truss is constructed, class time can be used to work on the written report alongside teammates, integrating time to work on the report each week. While designing the truss, it is extremely important to precisely measure and sketch the final truss design in order to cross-reference after cutting and sanding each member. This way, the measurements of the members, angles of the connected members at each joint, and all around cohesiveness of the design assembly is as accurate as possible. Before assembling the members together and adding the gusset plates, it is important to make sure that each teammate is confident and meticulous in their soldering skills. To best ensure this, teams should practice soldering scrap members together until they reach a consistent clean and strong soldering product. A helpful tip is to take photos throughout each stage of building the truss to be able to analyze the progression of the project, and later include in the report and presentation. Another tip for the report is keeping track of any obstacles or significant results throughout the process is important for discussion and analysis of the project design.

All together, communication with teammates, management of time, and diligence with design/construction technique are key components to a successful Truss Design project!



Picture of Group 7

Attachments

Figures:

Figure 1: Gantt Chart

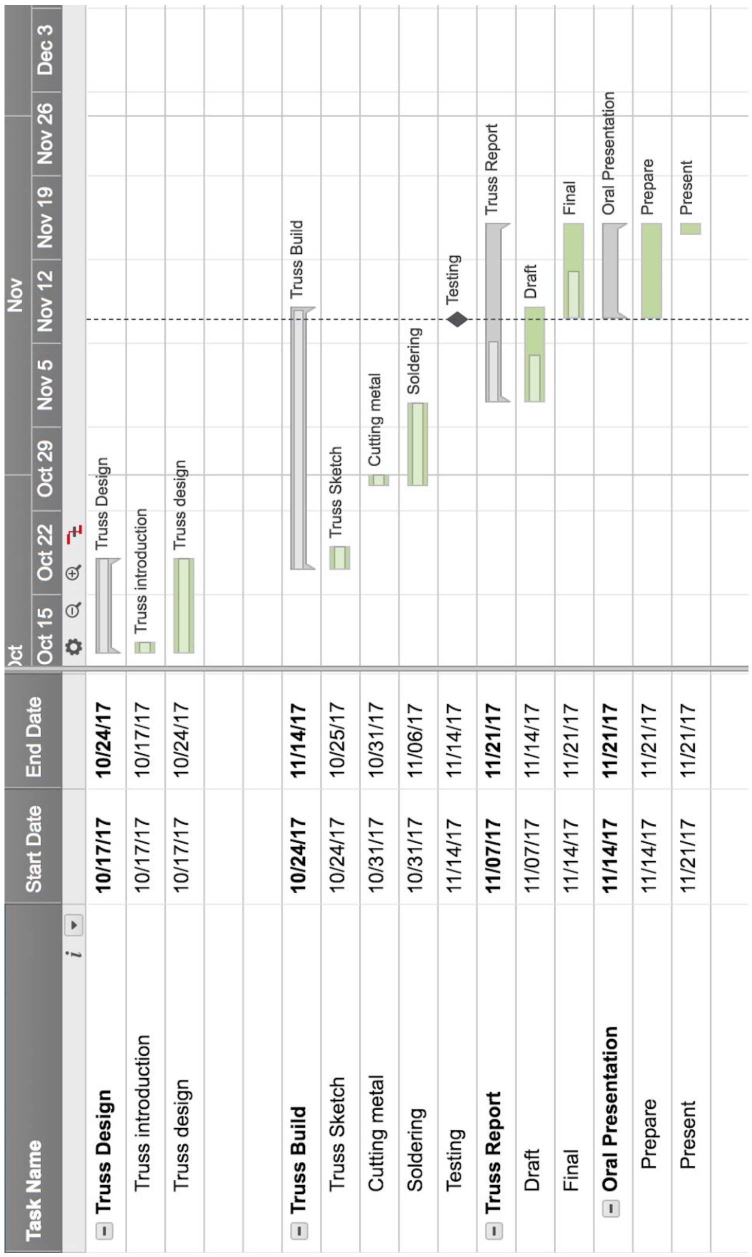


Figure 2: Work Breakdown Structure

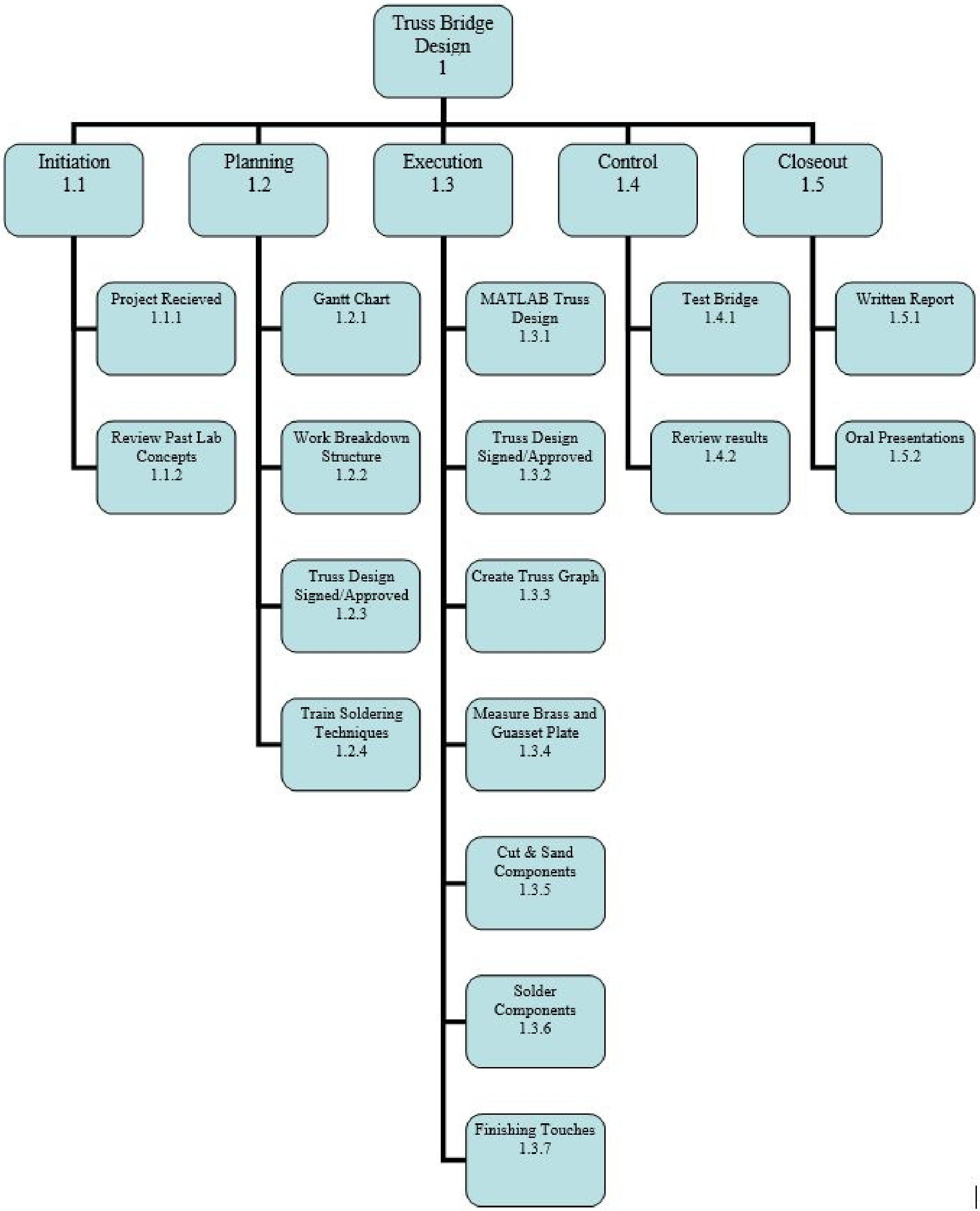


Figure 3: Work Organizing Chart

Task name	Chloe Quinto	Teny Odaimi	Chenxin Xu
Truss Designs	X	X	X
Truss Sketch	X		
Measure Brass & Gusset Plate	X		
Cut & Sand Components	X	X	X
Soldering Components	X	X	
Written Report	X	X	X
Oral Presentation	X	X	X
Gantt Chart			X

Figure 4: Truss Design 1

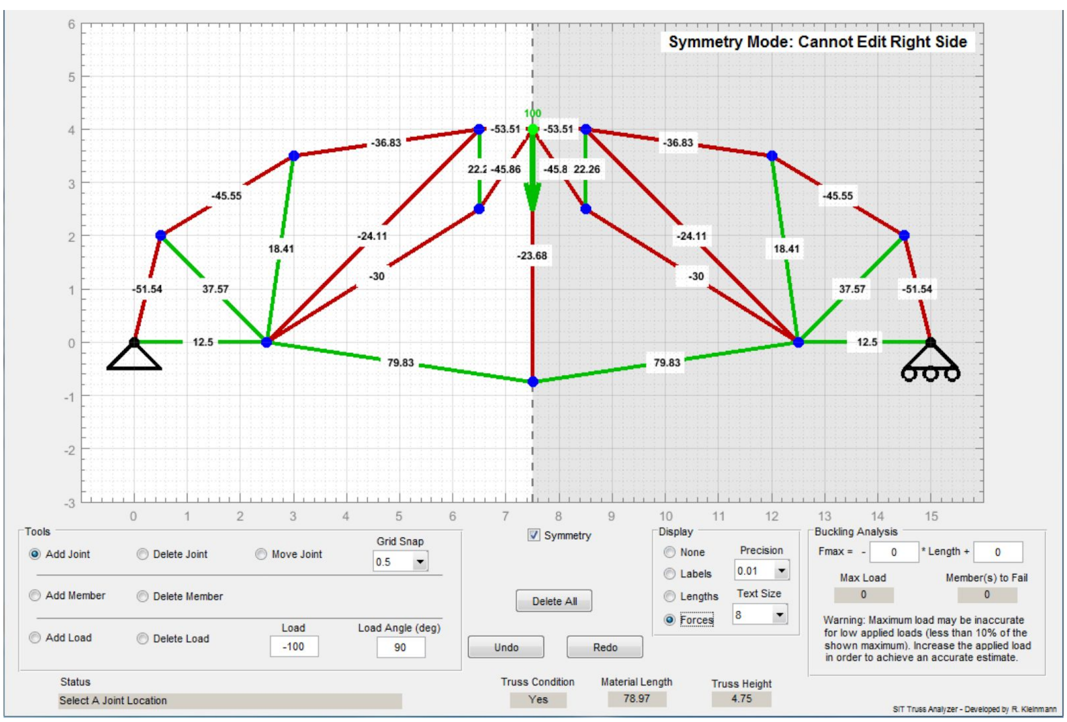


Figure 5: Truss Design 2

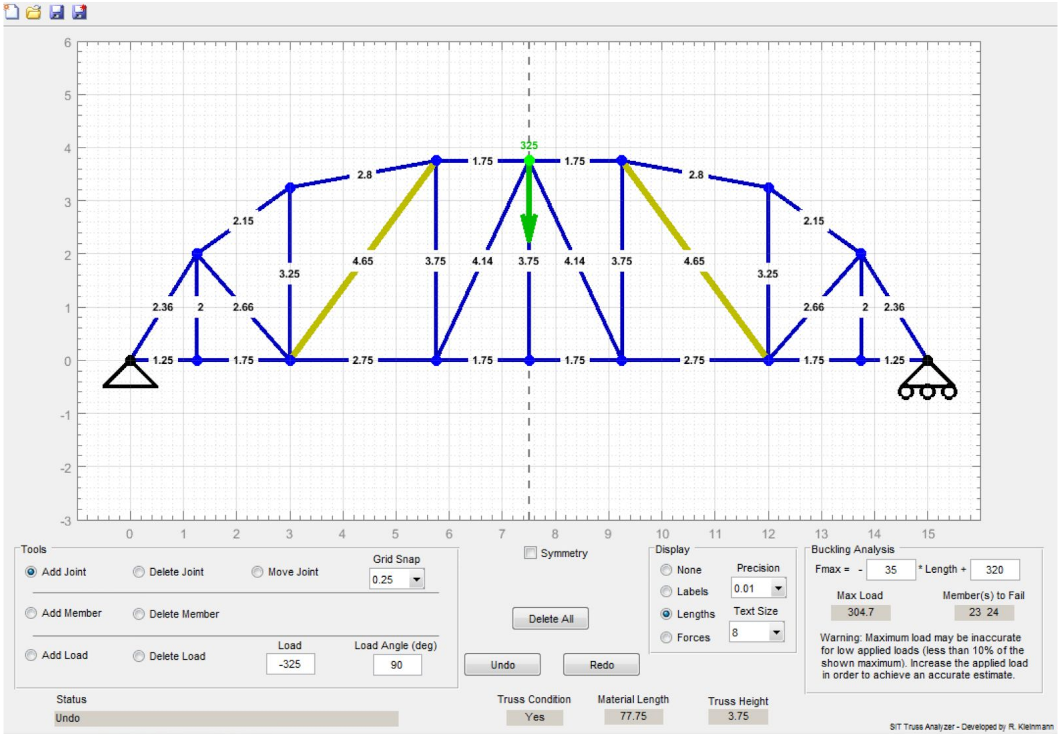


Figure 6: Truss Design 3

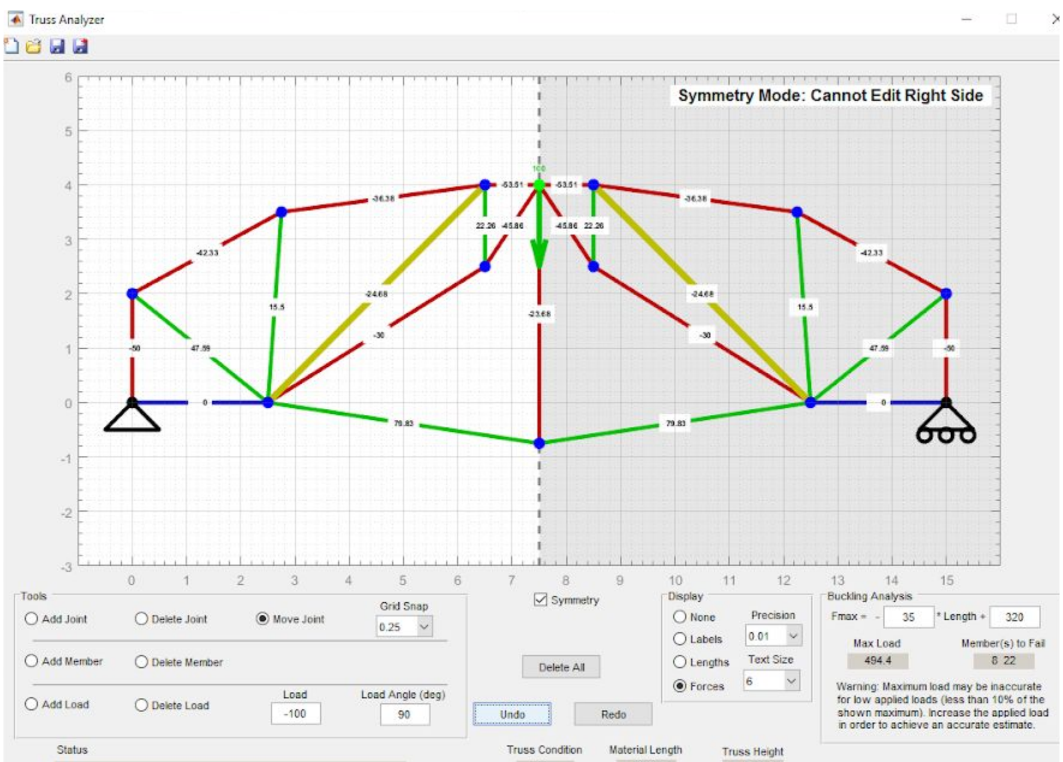


Figure 7: Truss Members Labeled on Design

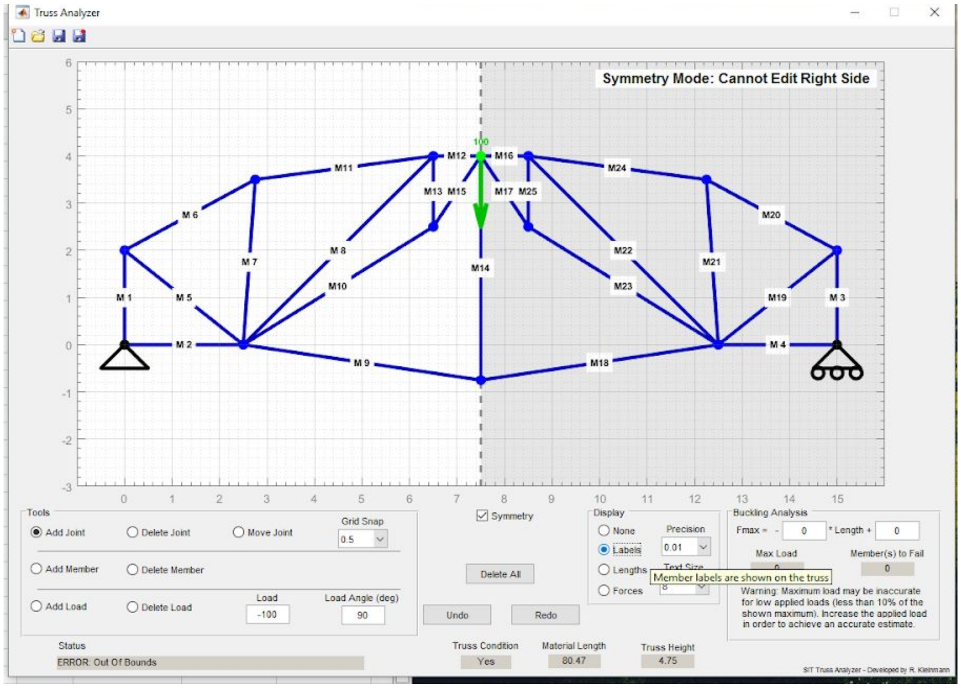


Figure 8: Buster

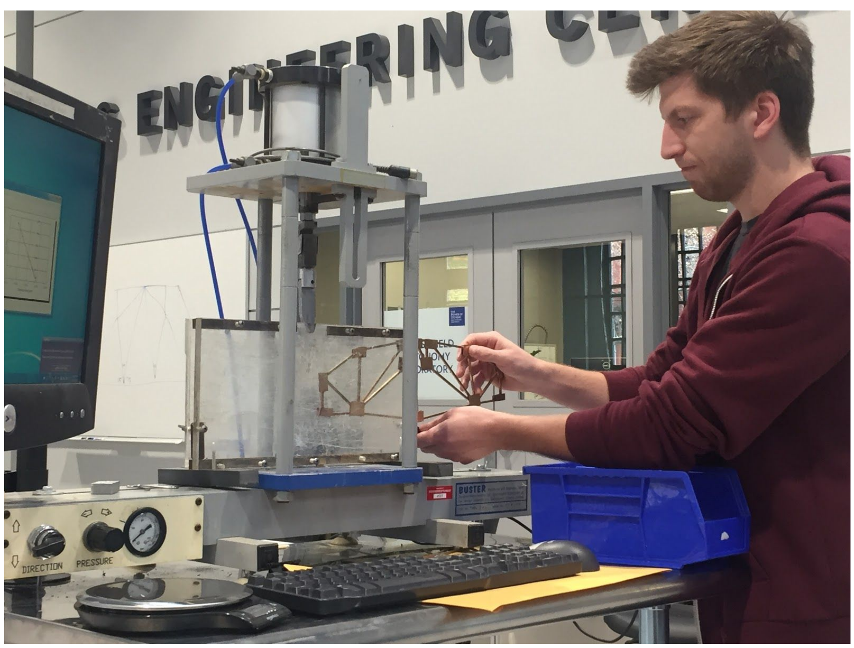
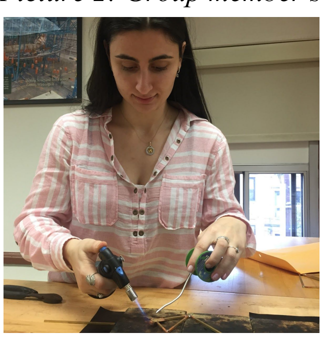


Figure 9: Failed Member

Pictures:

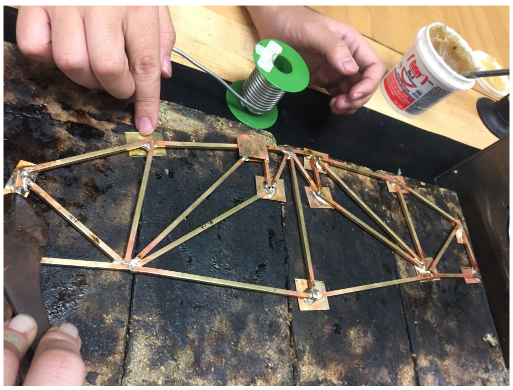
Picture 1: Group member cutting brass members

Picture 2: Group member soldering members together



Picture 3: Group member working on the written report

Picture 4: Soldering gusset plates on one side of the truss



Picture 5: Gusset plates soldered onto the corresponding members

Picture 6: Gusset Plate Bending

Tables:

Table 1: Truss Design with Alternatives Table

Truss Design	**Number of Joints**	**Number of Members**	**Material Length**	**Max Load**
Design 1	16	29	78.97	478.5
Design 2	16	29	77.75	304.7
Design 3	14	25	80.47	494.4

Truss Design	**Number of Joints**	**Number of Members**	**Material Length**	**Max Load**	**Total Points**
Design 1	1.5	1.5	4	6	13
Design 2	1.5	1.5	6	3	12
Design 3	3	3	2	9	17

Table 2: Design 1 - Max Load : 478.5

Members	Lengths	Member Forces	Allowable Load
1	2.061552813	-51.53865887	247.8456516
2	2.5	12.50033341	232.5
3	2.061552813	-51.53865887	247.8456516
4	2.5	12.50033337	232.5
5	2.828427125	37.56522589	221.0050506
6	2.915475947	-45.55419746	217.9583418
7	3.535533906	18.41430639	196.2563133
8	5.656854249	-24.11289522	122.0101013
9	5.055937104	79.83065541	143.0422014
10	4.716990566	-29.99832186	154.9053302
11	3.535533906	-36.8283569	196.2563133
12	1	-53.50856169	285
13	1.5	22.25883022	267.5
14	4.75	-23.68421052	153.75
15	1.802775638	-45.8600291	256.9028527
16	1	-53.50856151	285
17	1.802775638	-45.86002902	256.9028527
18	5.055937104	79.83065543	143.0422014
19	2.828427125	37.56522591	221.0050506
20	2.915475947	-45.55419747	217.9583418
21	3.535533906	18.41430637	196.2563133
22	5.656854249	-24.11289522	122.0101013
23	4.716990566	-29.99832188	154.9053302
24	3.535533906	-36.8283569	196.2563133
25	1.5	22.25883022	267.5

Table 3: Design 2 - Max Load : 204 lbs

Members	Lengths	Member Forces	Allowable Forces

1	3.25	79.87145762	206.25
2	2.75	249.1719085	223.75
3	2.795084972	-152.4554046	222.172026
4	3.75	162.500359	188.75
5	1.75	325.0019196	258.75
6	3.75	162.500359	188.75
7	1.75	325.0019196	258.75
8	2.795084972	-152.4554046	222.172026
9	3.25	79.87145762	206.25
10	2.358495283	-191.6233492	237.4526651
11	2.150581317	-184.3341177	244.7296539
12	1.25	101.5702363	276.25
13	2	0.00284290369	250
14	1.75	101.5658098	258.75
15	2.657536453	73.55947368	226.9862241
16	2.150581317	-184.3341177	244.7296539
17	2.358495283	-191.6233492	237.4526651
18	1.75	101.5658097	258.75
19	2	0.00284290369	250
20	1.25	101.5702365	276.25
21	2.657536453	73.5594737	226.9862241
22	2.75	249.1719085	223.75
23	4.650268809	-167.6898663	157.2405917
24	4.650268809	-167.6898663	157.2405917
25	3.75	0.00000001184237893	188.75
26	1.75	-249.1619831	258.75
27	1.75	-249.1619832	258.75
28	4.138236339	-179.3232977	175.1617281
29	4.138236339	-179.3232978	175.1617281

Table 4: Design 3 - Max Load : 494.4 lbs

Members	Lengths	Member Forces	Allowable Load
1	2	-49.99990818	250
2	2.5	0.0003728573006	232.5
3	2	-49.99990818	250
4	2.5	0.0003727862463	232.5
5	3.201562119	47.59097839	207.9453258
6	3.132491022	-42.33079774	210.3628142
7	3.508917212	15.5020454	197.1878976
8	5.656854249	-24.67948661	122.0101013
9	5.055937104	79.83065593	143.0422014
10	4.716990566	-29.9983205	154.9053302
11	3.783186488	-36.37667872	187.5884729
12	1	-53.50856572	285
13	1.5	22.25882816	267.5
14	4.75	-23.68421054	153.75
15	1.802775638	-45.86003111	256.9028527
16	1	-53.50856555	285
17	1.802775638	-45.86003109	256.9028527
18	5.055937104	79.83065597	143.0422014
19	3.201562119	47.59097841	207.9453258
20	3.132491022	-42.33079774	210.3628142
21	3.508917212	15.5020454	197.1878976
22	5.656854249	-24.67948661	122.0101013
23	4.716990566	-29.99832049	154.9053302
24	3.783186488	-36.37667872	187.5884729
25	1.5	22.25882816	267.5

Charts:

Chart 1: Brass Characterization