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University Of Nevada, Reno
Honors Program

Die Driver Project

A thesis submitted to fulfill the requirements for the degree of
Bachelor of Science in Mechanical Engineering under the Honors Program.

By

Team Die Driver

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May 12, 2013

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Team Die Driver

May 12, 2013

**ME 452.1001: Senior Capstone – Design Synthesis
Professor Emil Geiger**

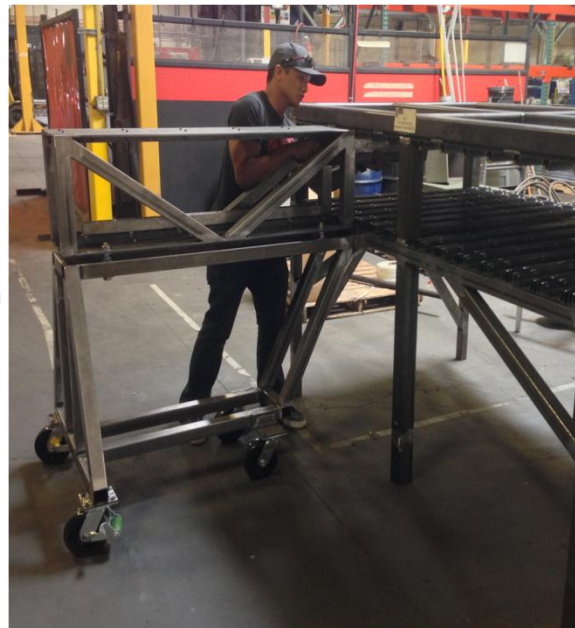
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Executive Summary:

The local sheet metal manufacturer, Jensen MetalTech, uses a press brake as one of its many metal-forming tools. To produce various shapes, punches and dies must be swapped into and out of the press brake repeatedly. Unfortunately, the tool-swapping process at Jensen MetalTech was inefficient and dangerous. This was due to the size and weight of the tools, as well as the method used for storing them. Some of the heavier punches and dies weigh up to 300 pounds, and are up to six feet long. This combination of weight and size creates a lifting risk. In addition, these tools were stored in various orientations and at different heights. This compounded the problem of lifting the tools, since the tools had to be reoriented and lifted to the proper height to be used in the press brake. Team Die Driver was tasked with creating a system for minimizing the risks involved in this process.

The final Die Driver system can be seen in this figure. It consists of a rack and a positioner that have a common interface so that the tools can be moved from the racks to the positioner very easily. It has friction reduction elements that hold the punch and die at the same orientation and height as they are used in the press brake. This allows the tools to slide back and forth easily. This design was mainly created in SolidWorks with commercial off-the-shelf component purchased to complete the system and Finite Element Analysis was used to determine the integrity of the design. In addition, hand calculations proved the system to be sturdy and resist deflection from assumed loaded forces.



This project was an overall success, as the press brake operation process was made safer and more efficient by the Die Driver system. The operator can now slide the larger tools from storage to the positioner without bearing the heaving lifting on his or her person. Because the project was an over-the-wall engineering scenario, there were some issues with the fabrication process, as well as the alignment of friction reduction elements. However, lessons were learned considering cost, Solidworks drawings and designing for manufacturing and assembly for the team. Ultimately, the system was deemed a successful prototype and will soon be in daily use at Jensen MetalTech.

Honors Program: As a result of one of the team members joining in the honors program, an additional presentation of the Die Driver system was presented to the Honors Program staff. Supplementary effort was applied to verify the integrity of the project, as well as its presentation to audiences outside of the engineering field.

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Design Problem and Objectives:

Jensen MetalTech is a large manufacturer that produces a variety of products out of sheet metal. One of the pieces of equipment used to do this is a press brake, which uses punches and dies of various shapes to “press” sheet metal into different shapes (depending upon the shape of the punch and die used.) The figure below shows how the machine works:



The size and shape of these tools varies greatly. Some of these tools are up to ten feet long and weigh up to 600 pounds. While the company already has a method of storing and moving the ten-foot tools, several dies and punches in the four to six foot range were stored in an inconvenient and unsafe manner. The pictures below show examples of this method.



These pictures show some of the tooling on the racks at various orientations. This is inconvenient because some of the tools must be pulled out of the racks, reoriented, and slid into the press brake before use. These long, heavy tools made it a very difficult process. After an injury occurred to the press brake operator, Jensen MetalTech asked for a better storage and

positioning solution for their tooling. Several patents were made to perform similar tasks such as this (ref. Google patents), but it will be very difficult to implement these patents to fulfill the task. Therefore, Team Die driver was assigned to complete this objective.

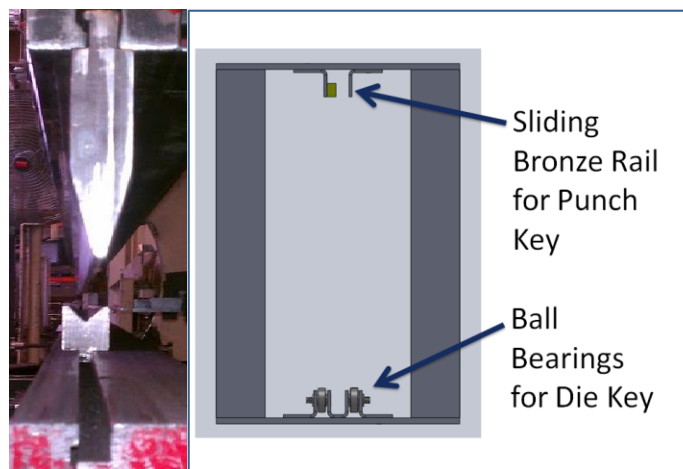
This problem directed the creation of the design objectives for this project. The general design objectives were designated as follows:

- Improve the safety of the storage and positioning process
- Improve the efficiency of the process
- Minimize the amount of force required during the process

More specifically, the team strived to require only 40 pounds of force (lbf) to be exerted by the operator to move the tools back and forth between the racks and the press brake. Other specific design objectives were implicitly defined within the safety objective. In order to safely store the tools, the new system needed to be strong enough to support the 300 pounds wherever the tools were placed. In addition, any positioning system created would need to be reasonably stable in regards to resisting moment or tipping.

Detailed Design Documentation:

To accomplish these objectives, the Die Driver system was created out of sheet metal, square tubing, bearings, and various types of screws. The system consists of a storage rack and a positioner with a common interface for easy swapping and friction reduction. The entire system holds the punches and dies at the same orientation and height as they are used in the press brake. Below is a picture of how the tools fit into the press brake, along with a picture of how the tools fit into the positioner and storage racks.



It can be seen that the Die Driver system accommodates the tools in the exact orientation of the press brake. In addition, two different friction reduction techniques were employed to make tool

exchanging even easier. For the punches, a bronze sliding piece was attached (via countersunk screws) to the top L-shaped pieces of sheet metal. This low-friction metal allows the key of the punches to be safely held, while also minimizing the required force from the operator. For the dies, a set of bearings was placed on both sides of the punch key. This allowed for another drastic reduction in friction. Because these friction reduction elements were a major design consideration, a proof of concept was made to ensure that they worked properly. This proof of concept was referred to as the module because the same friction reduction elements were to be made on the racks and positioner. This module can be seen in the figure above.

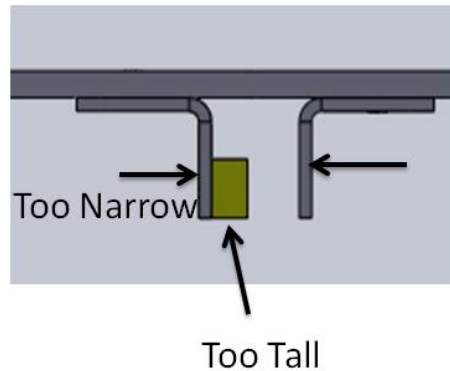
This design allows for easy swapping and storage, because the operator never directly deals with the weight of the tools. Only the friction forces need to be overcome in order to move the tools. Below is a picture of an early model of the entire system.



The positioner is used as a cart to move the tools from the storage rack to the press brake, and vice-versa. The storage rack has 14 slots for dies, and 14 slots for punches, since each interface can hold a single die and a single punch. Adjustment bolts were placed on the chassis of the positioner to connect with the module. These bolts were designed and implemented to allow for adjustment post-fabrication to ensure that the tools could slide easily between the racks and press brake. The positioner was given a slanted front to accommodate interferences with panels on the side of the press brake. The whole system (except for the bronze piece, screws, and wheels) is made from ASTM A36 steel because it is strong and readily available at Jensen MetalTech.

This design was heavily influenced by the need to make fabrication and assembly easy. Due to liability concerns, team Die Driver was unable to proceed with fabrication, and instead relied on the sponsor to do so. In order to accommodate for the gap in communication between the team and the sponsor, an immense amount of time was spent making sure that the design could be built from start to finish without major errors. Many aspects of the design were approached with this in mind. Screws were used to attach the L-shaped pieces of sheet metal to the top and bottom panel. This was done to allow for them to be replaced, which greatly enhanced reliability. Welding these pieces together was considered, but the team decided against it because welding such long pieces would cause them to warp during assembly.

Manufacturing tolerances also became a major consideration after the proof of concept was assembled. After completion, it was discovered that the key on the punches was unable to fit into the top L-shaped pieces. This was because of compounding manufacturing inexactness. The bronze piece was cut too large for the key to fit, and the L-shaped pieces weren't bent at an exact angle. The figure below shows these problems:

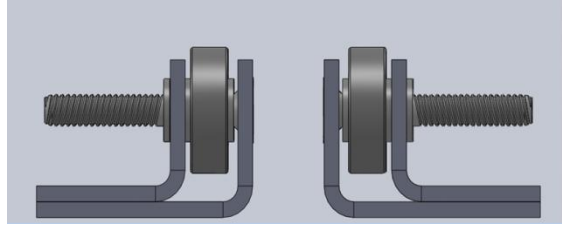


To account for these tolerances, the design was revised to be functional even if perfect manufacturing and assembly was not achieved. The team did this by making the dimensions of the top holder pieces much wider. The channel for the key was widened and the size of the bronze piece was shortened.

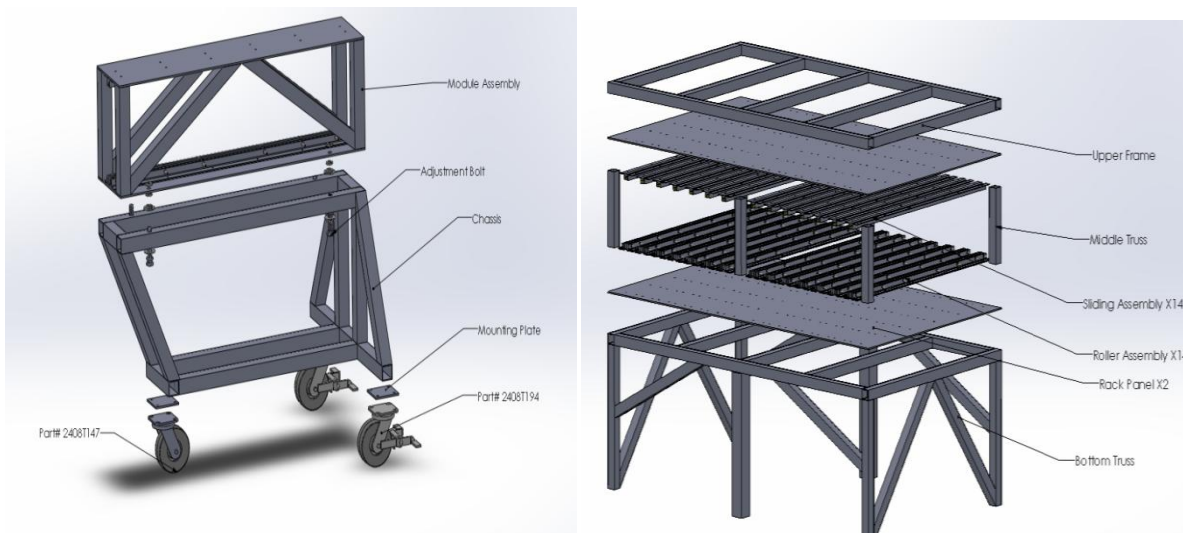
Another change that was made was the channel for the dies on the bottom roller assembly of the module. The initial design called for a U-shaped channel and two L-shaped channels on either side. During the assembly of the proof of concept, it was found that screws could only be inserted into the U-shaped channel by cutting long holes for them. A picture of this initial roller assembly can be found below:



While this assembly did move tools with less than 40 pounds of force, it is clear from the picture that this design was not optimized for assembly. To improve the assembly process, a completely new design was made for the roller assembly. This new design involved 4 L-shaped pieces, and can be seen in the following figure. This new design yielded a much easier fabrication and assembly process. It also allowed for easier maintenance over time as an individual side could be replaced rather than the whole roller assembly.



The final prototype was constructed entirely by the sponsor, and was made on-site by laser cutters, press brakes, and saws. It was assembled by using welds and screws to attach the various pieces. The entire detailed set of assembly instructions can be found in the appendix. Along with these instructions, a set of scanned notes from the assembly team can be found in the appendix. These notes describe the problems that were encountered during the assembly process. The main problem encountered was a lack of detail in regards to all of the truss elements on the racks and positioner chassis. Exploded views of the entire system can be found below:



These exploded views give insight into the elaborate assembly process. Truss elements were cut and welded together at various angles. The frame was constructed from these truss elements and the panel pieces. The friction reduction elements were attached using screws. Most of the process was obvious, except for the truss elements. The difficulty was due to the various angles and lengths that were needed for the truss.

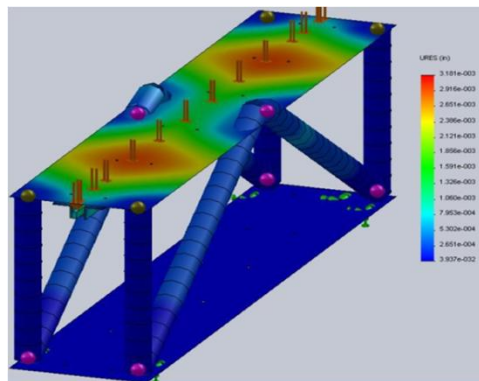
While it was not a major consideration, the design was also improved from a cost perspective. The bronze bar for holding the punches was chosen because it allowed for a reduction in friction while also being reasonably cheap. A set of small, resilient bearings would have reduced the friction much more, but would have been extremely expensive.

Since the Die Driver system was meant to be used on a daily basis in an unforgiving environment, the design was optimized for safety and reliability. The team did this by

conducting multiple rigorous finite element analysis studies. There were three main areas of concern that were studied intensely:

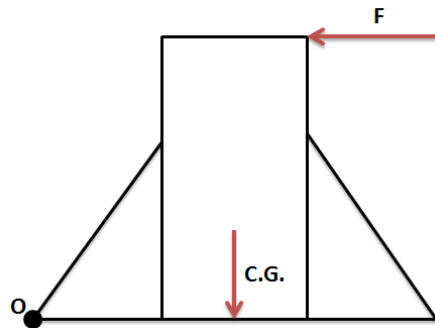
- The module on the positioner
- The punch key supports on the module
- The overall structural integrity of the storage racks

To ensure that these areas of concern were sufficiently strong, Solidworks (ref. Software) was used to verify their resilience. To test the module on the positioner, a study was conducted using a 600 pound load acting downward on the bronze piece of the punch key support. A screenshot of the study can be found below:



This study was done to check the validity of using $\frac{1}{8}$ -inch L-shaped pieces of sheet metal to hold the punch key, and also to ensure that using a $\frac{1}{4}$ -inch piece of sheet metal as the top plate would be sufficiently strong. A 600 pound load is an unrealistic scenario, but the results of the study showed that the module was very resilient to a downward load.

Another check that was performed on the positioner was a stability analysis. To ensure that the positioner did not tip during use, equations for static equilibrium were applied to its chassis. The figure below shows the scenario that was analyzed.



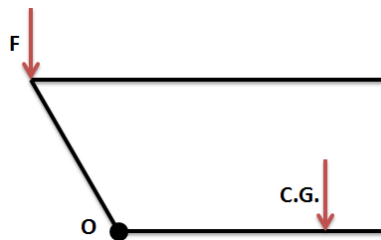
The center of gravity was at the center of the positioner's frame due to symmetry. The mass of the positioner was found to be 220 pounds from using the "mass properties" feature in

Solidworks. To find the force that would have to be exerted on the very top of the frame to tip the positioner, the following equations were applied:

$$\Sigma M_o = 0 = (30\text{in})(220\text{lbs}) - (44\text{in})F$$

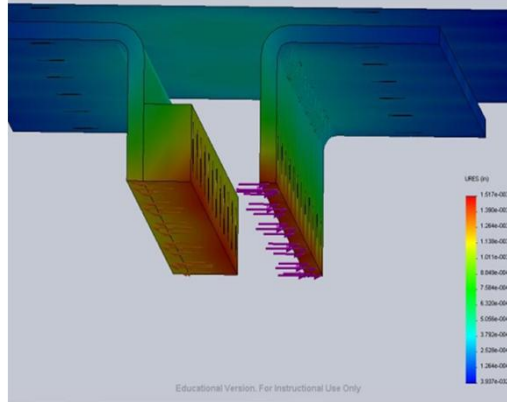
$$F = 150\text{lbs}$$

It would take approximately 150 pounds to tip the positioner, assuming that the operator locked the wheels and pushed at the very top. It should also be noted that this force would have to be applied consistently to move the center of gravity of the positioner over the end of the frame (point O) before the positioner would fall over on its own. The triangular flanges on the back sides of the positioner were designed to keep the positioner stable, and this result confirmed their effectiveness. Another scenario was analyzed in a similar manner to make sure that the positioner would not tip over its front



This time it was found that it would take 500 pounds to tip the positioner over. The slant on the front of the positioner made the team concerned that the positioner would be vulnerable to tipping in this fashion, but these results made the team confident that the positioner was structurally sound and very stable.

Next, to test the strength of the punch key supports, another study was conducted using a 200 pound outward load. This study was a paramount design consideration because of the dire consequences of this failure mode. If the punch key supports were to displace significantly it would cause the punch to fall from them, and damage itself or even the operator. The results of this study can be found below:



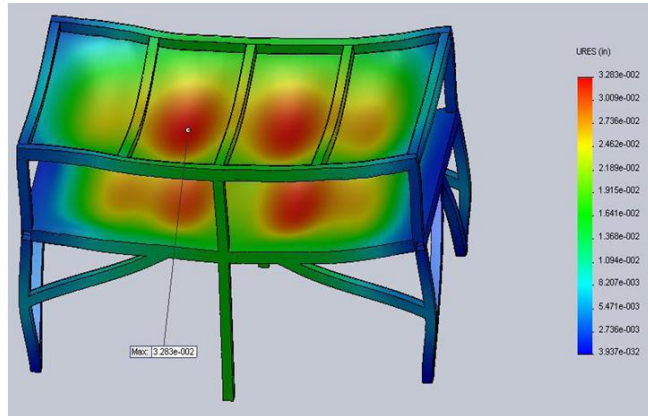
It was found that the punch key supports only displaced 0.004 inches in this loading scenario, which was too little to allow the punch to fall out. To verify this study, analytical equations were also used on this scenario. Specifically, the equation for an end-loaded cantilevered beam was used. It was assumed that the full length of the beam was the distance from the end of the punch key support to the surface of the top panel. In other words, the radius of the sheet metal bend was also included in the length of this beam. These equations can be found below:

$$\delta = \frac{FL^3}{3EI}$$

$$\delta = \frac{(200\text{lbf})(2.1\text{in})^3}{3(29 \times 10^6\text{psi})(.0078125\text{in}^4)} = .0027\text{in}$$

The inertia of the beam was calculated by using the equation for a rectangular section with 1/8-inch height, and 48-inch width. The analytical result matched the results from the FEA well enough that the team felt confident in their validity.

The final study was done to ensure that the racks remained rigid under the immense weight of all of the tools. The simulation involved 28 different 300 pound loads. Although this is an unlikely scenario, the study was done to make sure that the racks were extremely safe. The results of the study can be found below (deformed view):



Being that the project was sponsored by a company, cost became a very relevant issue in that there was no set budget. However, various parameters were designed to keep cost at a minimum and maintain the company's willingness to provide funding for the project. The final prototype is about 98% metal because Jensen MetalTech is a metal fabrication company. The only portions that are not metal are the wheels for the positioner. The initial sponsor contact recommended the use of Solidworks weldments to create a majority of the frame for the racks and positioner as the company had considerable access to steel tubing and cost would be kept low. The final roller design was also greatly influenced by cost as ball bearings became the most expensive commercial off the shelf component, ordered from McMaster-Carr. The initial design for the roller assembly, consisting of shoulder screws and spacers, would have been approximately \$150 for just one slot. Although functional, various combinations of different components were created until the design used basic screws and washers lowering the cost to about \$70 per slot.

The following table introduces an analysis of the cost relative to mass producing the system.

Item	Actual	As-built	Mass Production
Raw Metal	donated	\$1,500	\$1,200
Commercial Off the Shelf	donated	\$2,000	\$1,600
Labor	donated	\$5,500	\$1,200
Total	donated	\$9,000	\$4,000

It may be noted that the sponsor donated every single portion of the prototype, totaling \$9,000. Considering the cost As-built, labor was the most expensive because much indirect labor was wasted by those fabricating the final prototype. This indirect labor was caused by vague drawings and common miscommunication. This is very common and can be expected with over-the-wall

engineering. In a much more ideal scenario, the labor could have been lowered to about \$4,000 for the As-built cost. With mass production, a majority of the components would go down approximately 20% in cost and although machining metal parts still cost around \$70/hr., streamlining the fabrication of parts and assembly of the prototype would allow labor cost to be reduced about 80%.

Laboratory Tests Plans and Results:

Once the racks and the positioner were completely fabricated, the system was tested at the warehouse facility. The initial testing began by simply inserting a 2.5ft., 30 lb. punch and a 3.5ft. 20 lb. die into the positioner and transporting it across the warehouse. Although these tools are much smaller than the system was designed for, they allowed for testing of functionality and alignment of the entire system. From there, the positioner was aligned with the racks in attempt to transfer both the punch and die into each of the 14 respective slots. Separate testing via Solidworks Finite Element Analysis was also performed by the sponsor contact to ensure the integrity of the design for the both the rack and the position. Final testing had one of the operators insert a much larger die and punch into the positioner and determine if the friction reduction elements were still appropriate.

After much discussion with the sponsor contact, various results were gathered from the final prototype testing. Functionally, the system works well. The smaller punches and dies were easily inserted into the positioner and moving the positioner required minimal effort. Once aligned, the tools were moved from the positioner to different slots in the rack with little force required. Although the initial goal of an easier tool sliding system was met, the prototype had a few operational issues. Having free spinning wheels at the front of the positioner made it difficult to maintain initial alignment with the racks. The uneven surface of the warehouse floor also required constant adjustment to the positioner height when moving from slot to slot in the rack. Finally, the friction reduction elements did not prove to be as accurate as designed. The roller system for the dies reduced so much friction that the dies had a possibility of sliding out of the positioner. The strip of bronze only reduced enough friction to where very precise alignment was required to allow the punches to slide easily from the positioner to the rack.

The results from testing the prototype allowed for much insight on how the design could be enhanced through accessories and modification rather than a complete redesign. The front wheels could be easily replaced and allow for the positioner to become more stable. Depending on where the operators decided to keep the storage rack would determine the adjustment in height alignment of the slots. This may be done by replacing the entire slot component or simply losing or tightening the slot's bolts. To help maintain the control of the dies, wedges or rubber stoppers may be added to the roller system and help keep them in place. By simply resizing the bronze strips, enough space could be created to allow more freedom of alignment and make sliding the punches in and out much easier.

Alternatives Considered:

Constant communication with the sponsor contact allowed for the discussion of the best design before any major decisions were made. One major alternative that was considered would be a series of ball bearing for the punch key support rather than using a strip of bronze. Although the ball bearings would have allowed for easier alignment and movement of the punches, the cost of the materials would have greatly increased. To help maximize space and allow for much more variance in height, a scissor jack could have been integrated into the design of the chassis and a second row of slots put into the rack. This was again influenced by cost and the company currently has about 11 dies they would use this system for so having for so having more slots would not be completely necessary.

Ethical and Safety Concerns:

The system as a whole was created to increase the safety of press brake operation. Regardless of how efficient and robust the system is, risk will always be a factor. There will always be the chance that a personal injury, a failure in the device, or damage to property occurs. In order to conduct operational risk management, it was necessary to layout safety precautions, such as hazard warnings or to establish safety regulations.

This project was conceived because an employee was injured while operating the press brake. It was therefore necessary to make safety a paramount criterion for evaluation of the final product. In order to acknowledge that project is safe enough, all risks and dangers were accounted for. Every moving part is visible, so that the operator has full awareness of his surroundings. As determined from prototype testing, one addition to increase the safety use of the design would be the wedges or rubber stoppers to help control the stability of the dies.

Timeline and Team Management:

This project took a total of two semesters so the organization of tasks was very important. The team had to have a clear timeline of what needed to be done throughout the year. Below is a Gantt chart of the team's progress throughout both semesters.

Conclusions:

The Die Driver system did an adequate job of improving the press brake operation process. The equipotential nature of the design made tool movement much easier. This is especially true for the dies, since the required effort is almost nothing. The frame of the racks and the chassis of the positioner are also extremely strong. There is no question that the entire system will last a very long time, even in the unforgiving manufacturing environment where it will be used. The system is also inherently reliable because screws were used to attach most of the pieces together. This means that everything can be taken apart and replaced when necessary.

However, there are a few areas of the design that can improve. The most important part is the alignment of the punch keys. Even though the design was revised after the proof of concept to fit the punch key better, the alignment of some of the punch holders in the storage rack made them almost unusable. The screws that attach the top L-shaped pieces to the top panel could be used to adjust this alignment, but it would be better to have a more robust system to make absolutely sure that the punch slides in properly every time.

In addition, there were many more improvements that could have been made to the presentation of the design in order to make things easier for the sponsor. The clarity of many of the drawings was lacking, and lead to confusion during assembly. Truss elements were especially scrutinized by the fabrication team at Jensen Metaltech. One drawing actually had an incorrect dimension that made the racks and positioner different heights. Luckily this was fixed by the fabrication team during assembly.

There were also minor problems with the bill of materials for the design. The sponsor had a difficult time finding bronze plates for the punch keys. There was also an error in the BOM that called for plastic nuts instead of metal nuts for the adjustment bolt on the positioner. While all of these problems were with the design process and not the design itself, they had a tangible effect on the outcome of the project. The labor costs for Jensen Metaltech were much higher than an average project because of the lack of clarity in the drawings.

If the team were given more time to work on this project, this is the aspect that would be refined the most. This type of sponsor relationship lends itself to an “over-the-wall” engineering setting, where designs are passed over the wall, and then those on the other side must implement them as well as possible. It is in this setting that design presentation and clarity is most important. Good communication is paramount in a corporate setting, and this project was an excellent chance to polish such skills.

Acknowledgments:

Sponsor Jensen MetalTech Austin Miller - Team coordinator (1st semester)
Sponsor Jensen MetalTech Mike Damon – Team coordinator (2nd semester)

Sponsor Jensen MetalTech Joe Gauntt - Team coordinator (2nd semester)

University of Nevada Reno, Dr. Emil Geiger - Professor/Boss

University of Nevada Reno, Tony Berendsen - Development Technician III

References:

Software: SolidWorks - CAD software used to create parts, make drawings, conduct FEAs, and generate STEP fabrication files.

Patents (Google):

5146774 February 27, 1991

5366431 December 12, 1990

Appendices:

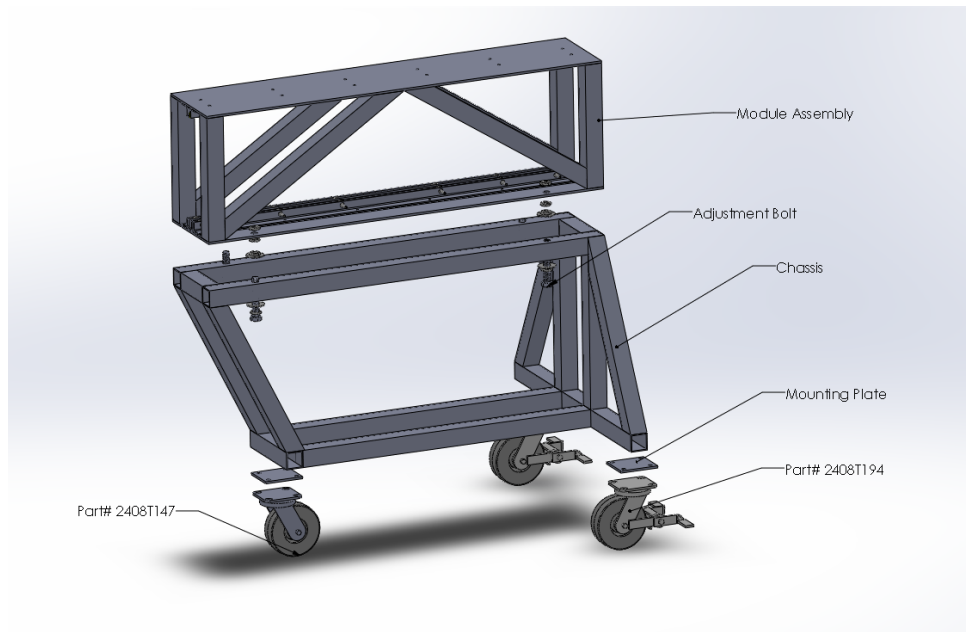
Appendix A – Full Assembly Model

Full Assembly Model

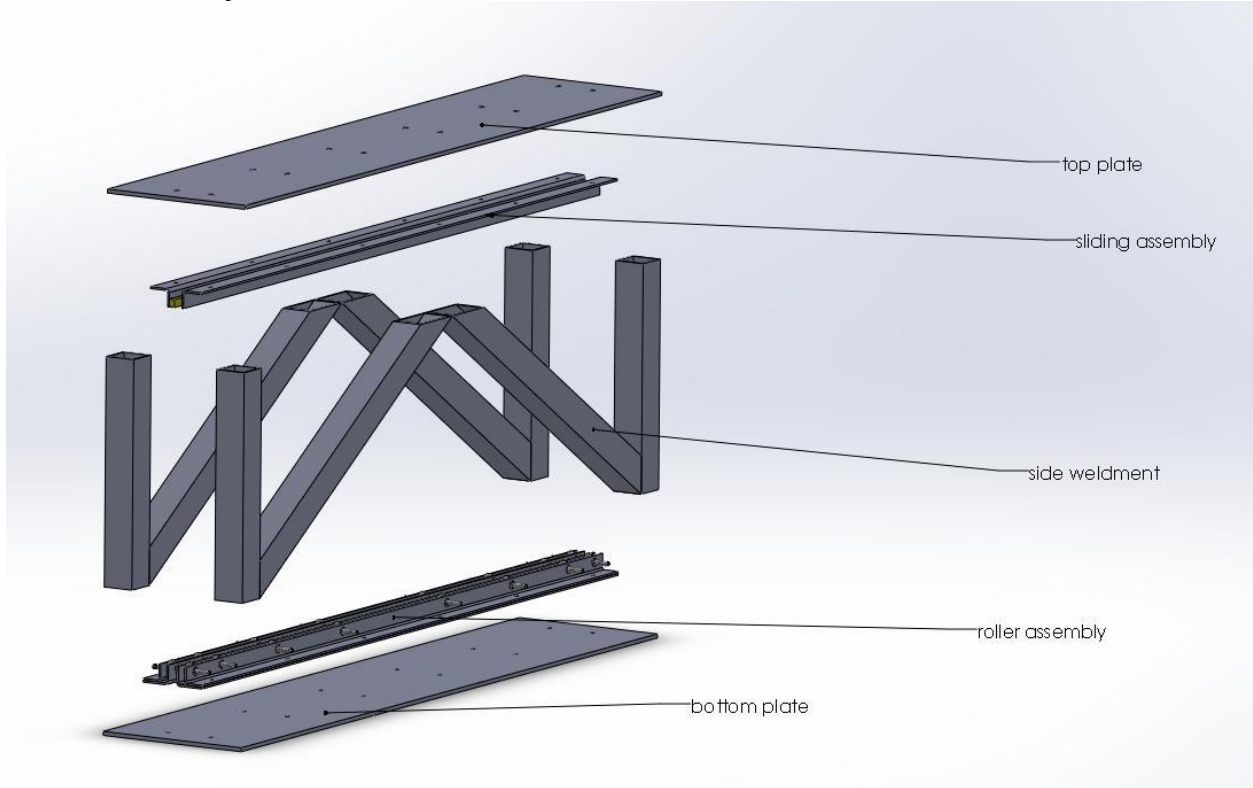
Driver Assembly



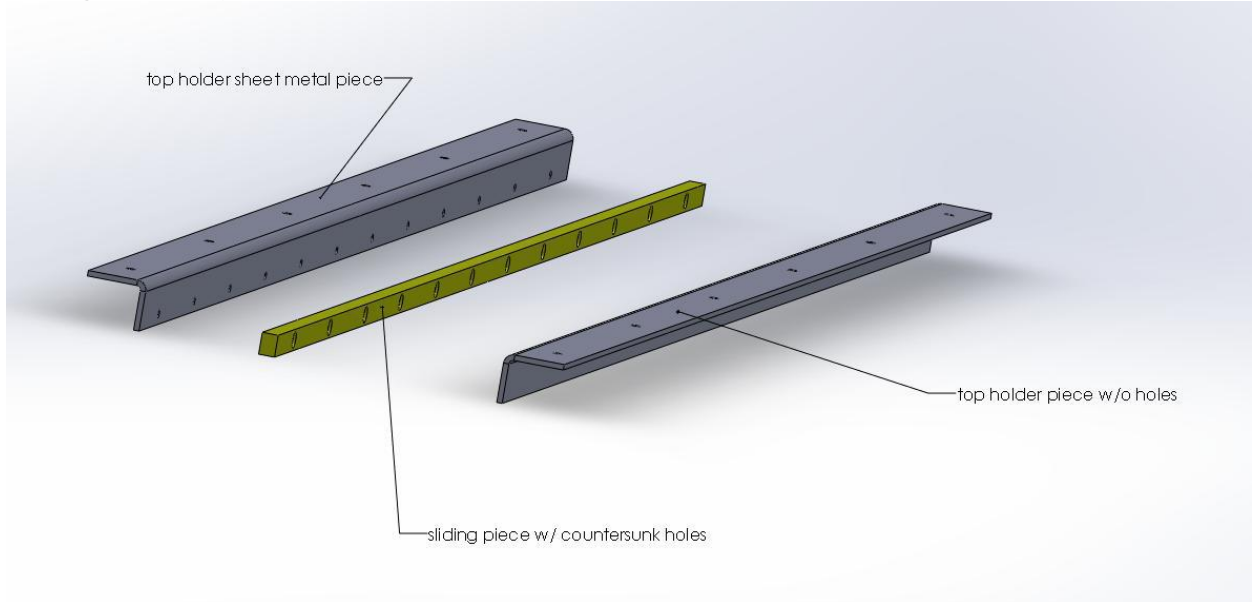
Exploded View



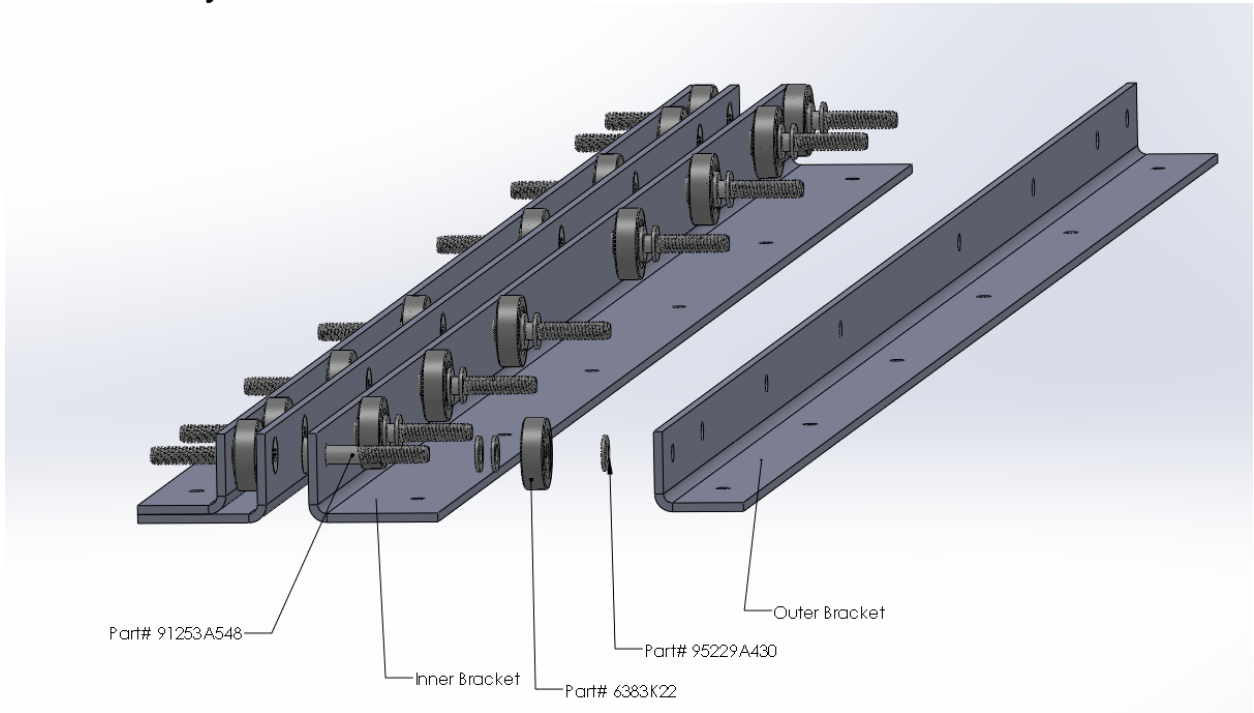
Module Assembly



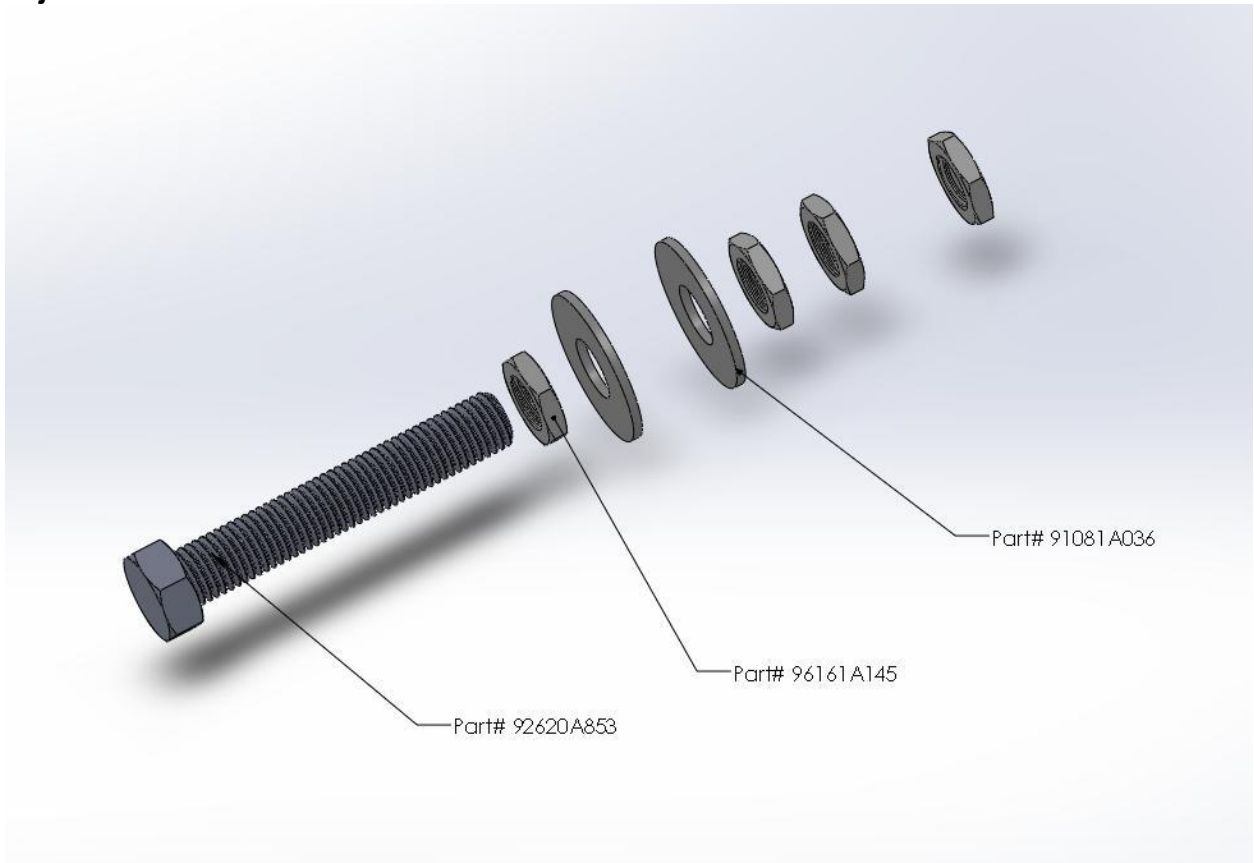
Sliding Assembly



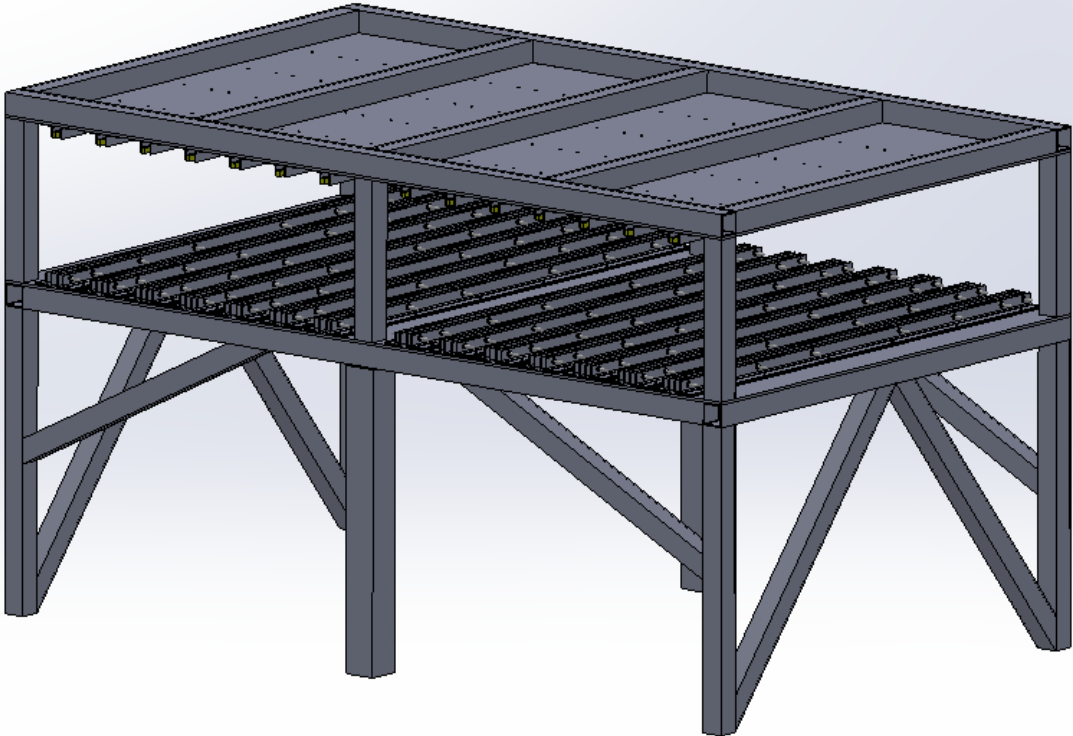
Roller Assembly



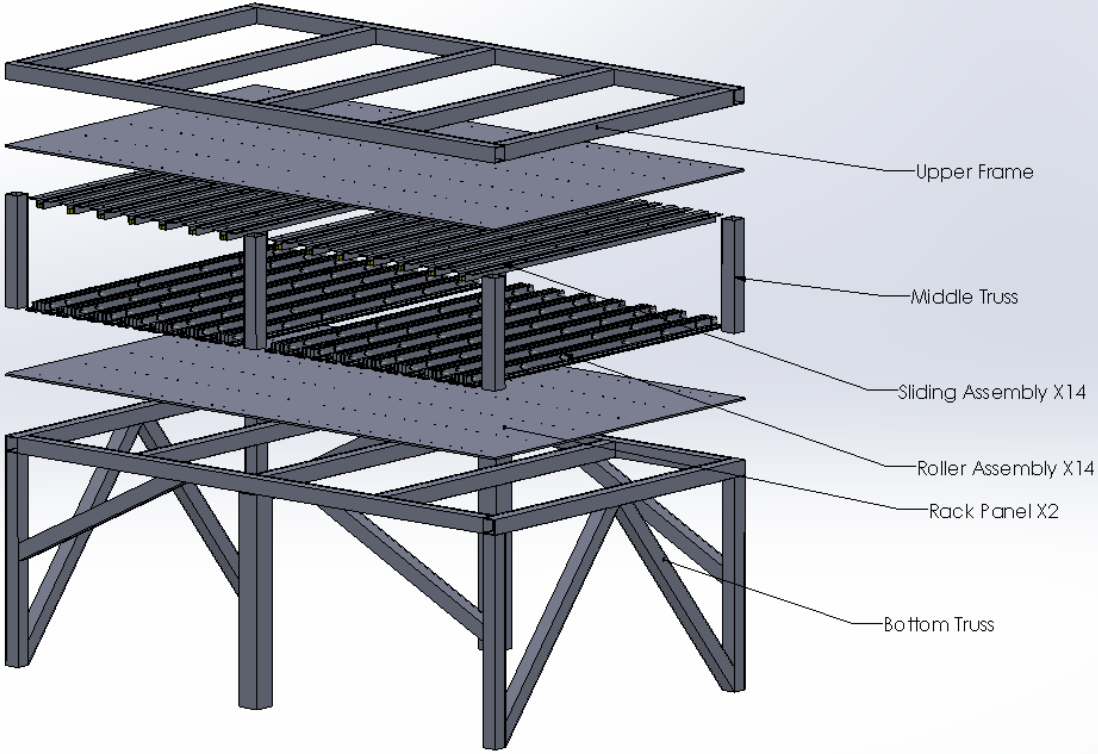
Adjustment Bolt



Racks



Exploded View



Appendix B - Assembly Instructions

For the Postioner:

A. Chassis

- A1. Build chassis frame according to dimensioned part drawing.
- A2. Weld mounting plates to designated areas on the chassis so that the front wheel is centered, and each plate has 1" showing on each side to allow for bolts to mount the caster wheels.
- A3. Attach caster wheels to the bottom of the mounting plates.

B. Module

- B1. Weld module frame according to dimensioned part drawing.

C. Top Holder Piece

- C1. Attach Top holder sheet metal pieces to Module according to dimensioned part drawing.
- C2. Attach Sliding piece with countersunk holes to left top holder sheet metal piece.
- C3. Install Countersunk 1" screws and Top holder 1.5" screws.

D. Roller Preparation

- D1. Attach washer to Screw.
- D2. Attach ball bearing to Screw.
- D3. Attach two washers to Screw.

E. Bottom Roller assembly

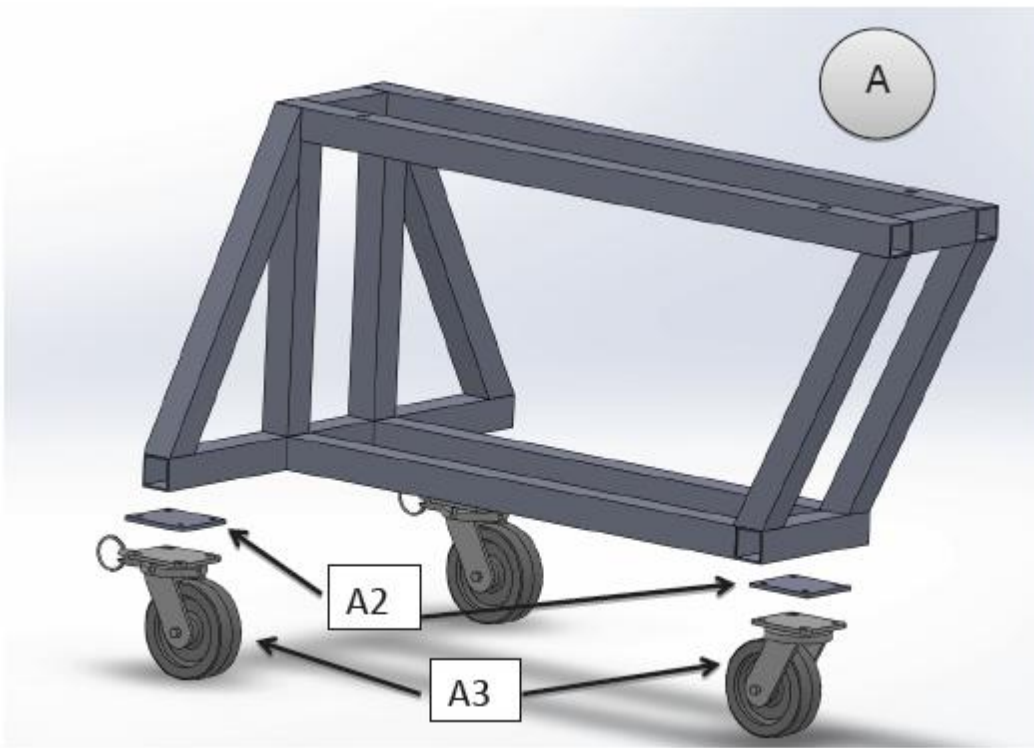
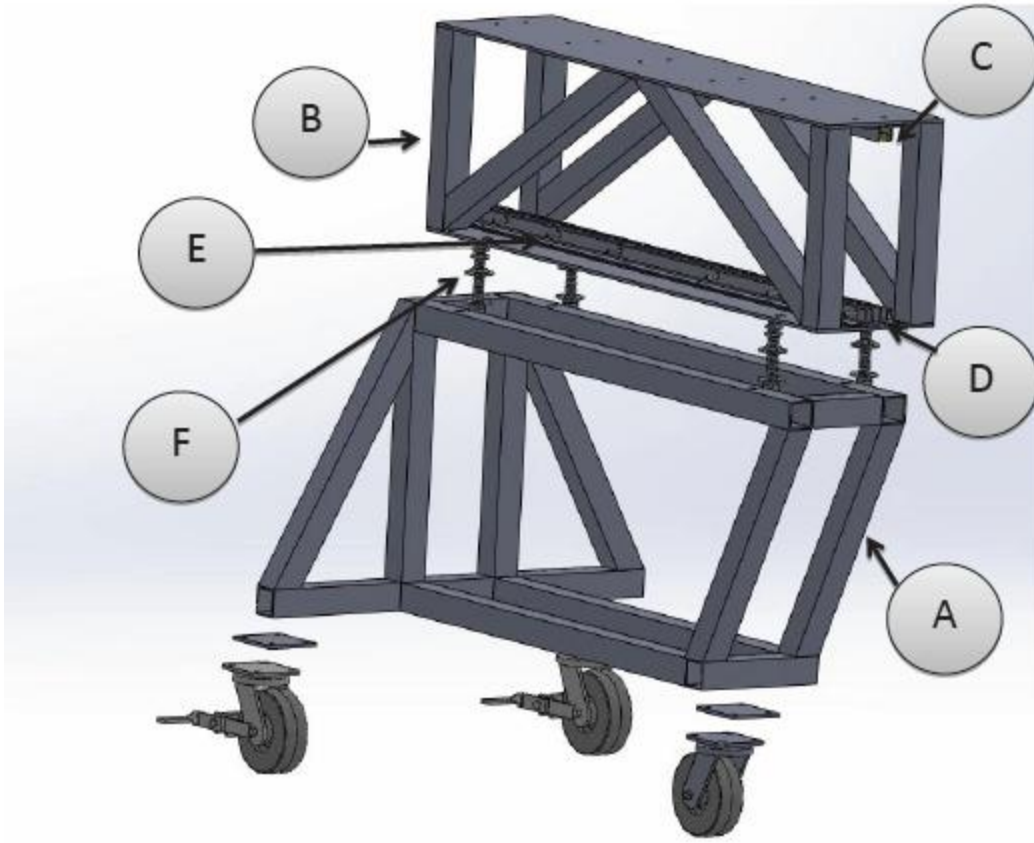
- E1. Attach Rollers to the Outer Support Plate.
- E2. Attach Inner Bottom Support Plate to the Outer Bottom Support Plate (align holes).
- E3. Attach inner and outer L-plates to bottom panel of module.
- E4. Repeat process on other half.

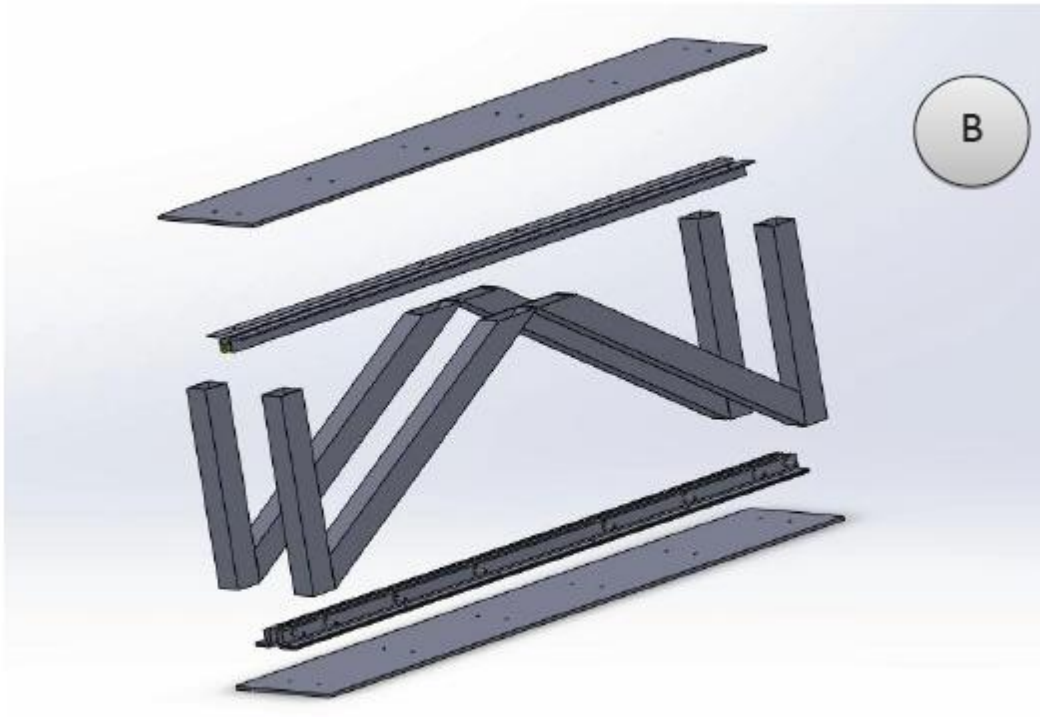
F. Adjustment Bolt Preparation

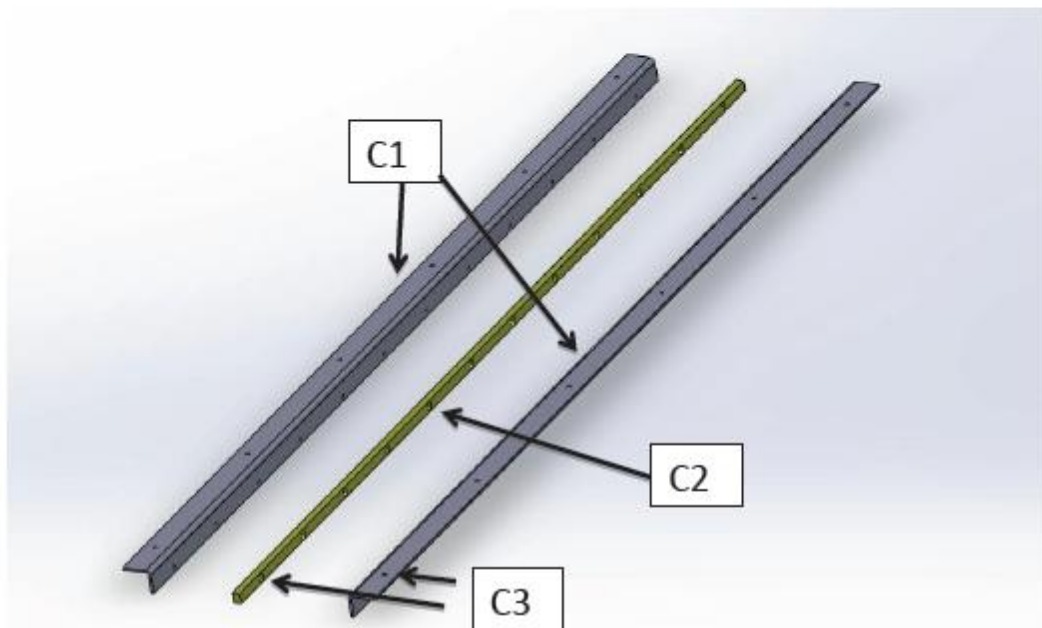
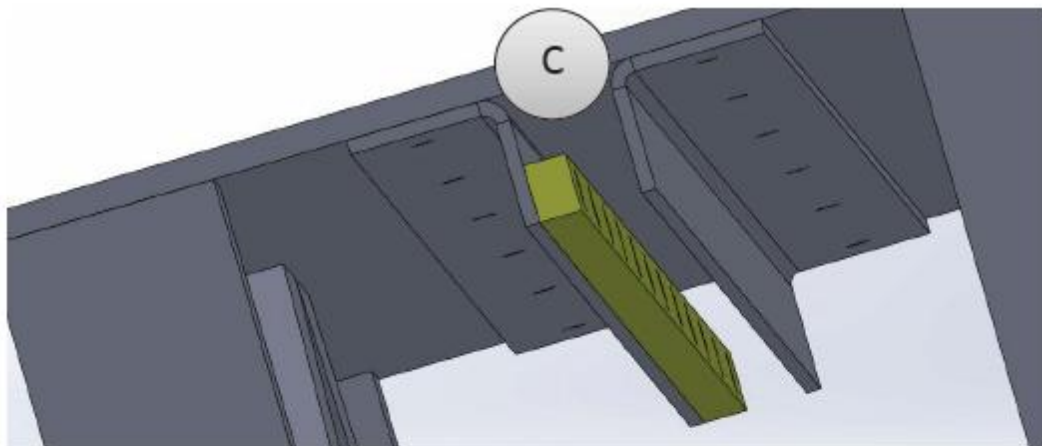
- F1. Attach nut to bolt.
- F2. Attach two washers to bolt.
- F3. Attach three nuts to bolt.

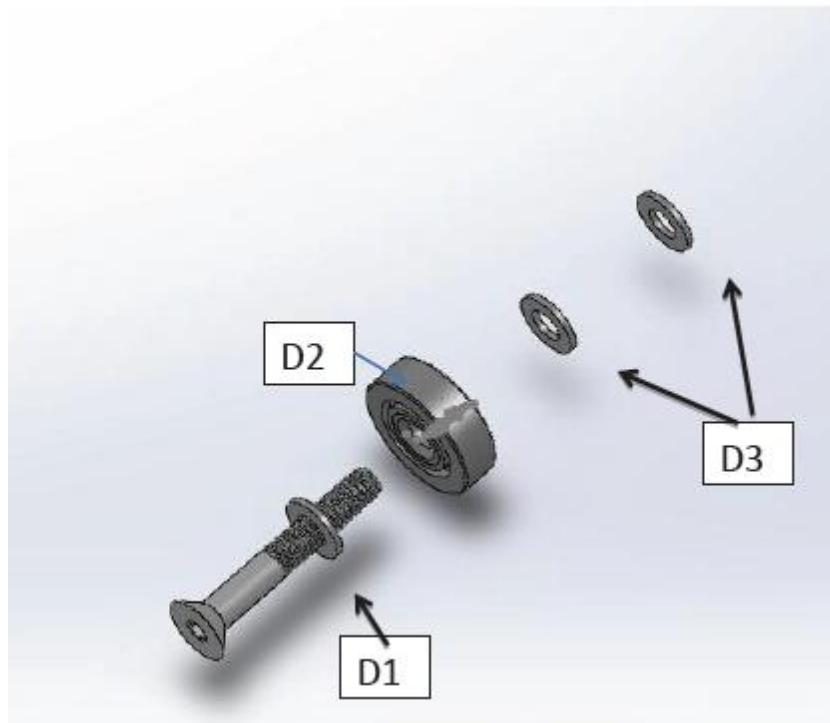
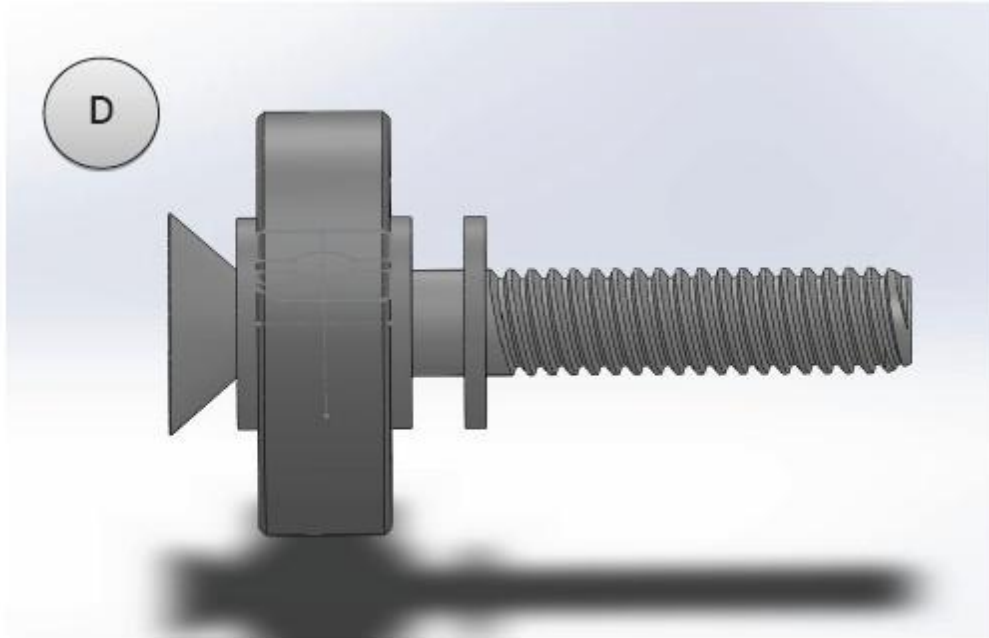
G. Driver Assembly.

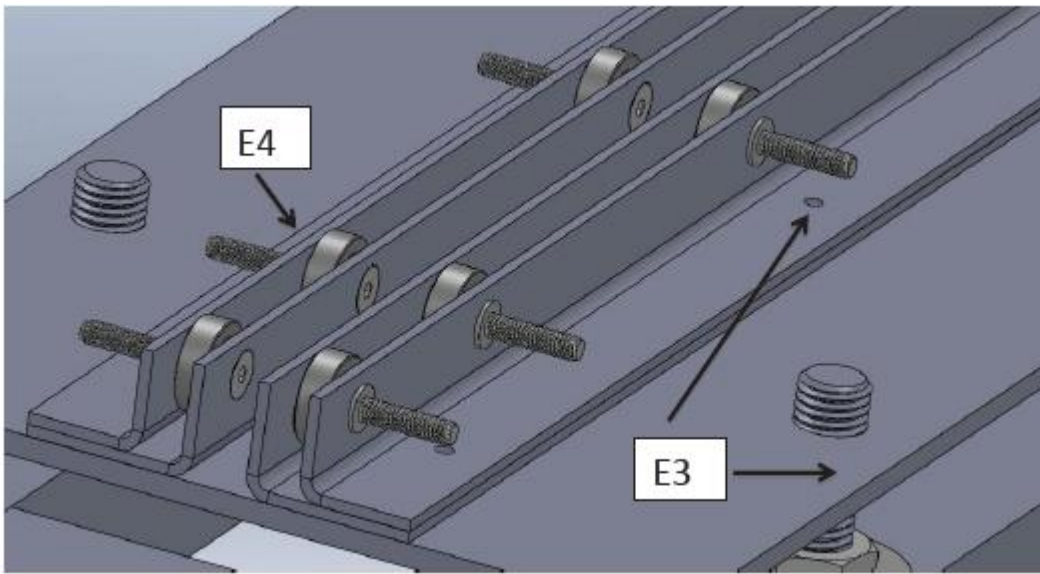
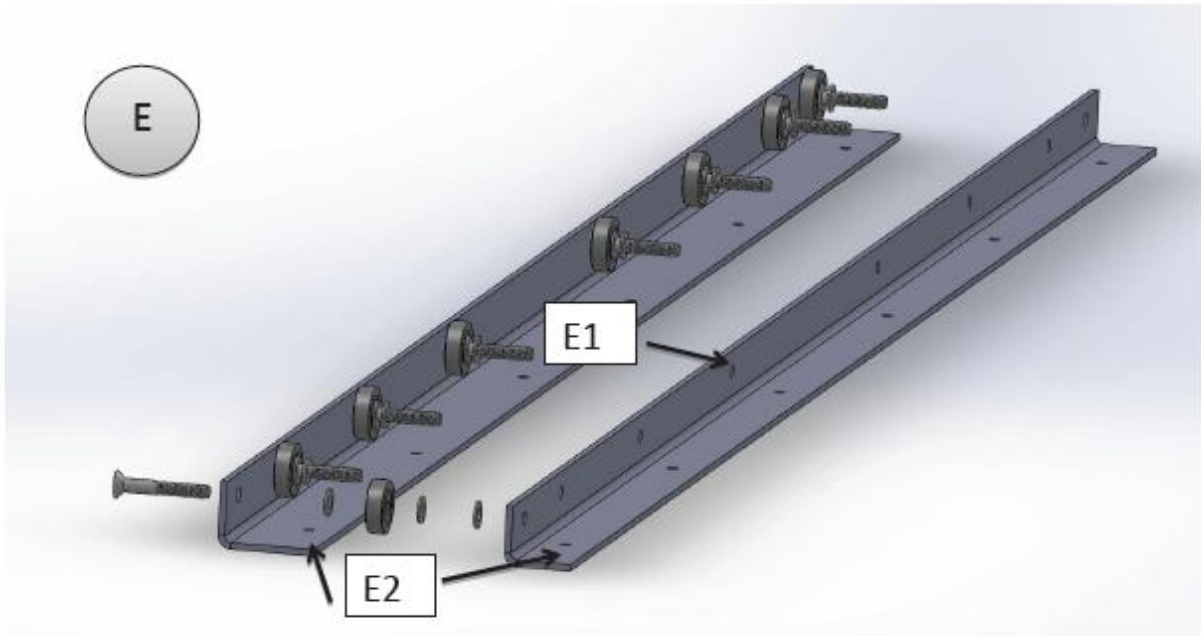
- G1. Attach adjustment bolts to the chassis. The square tubing will be between the first two washers. (Head facing down)
- G2. Attach module to the adjustment bolts by placing the bottom panel of the module to between the latter two nuts.
- G3. Repeat at all other corners when holes are located on the chassis and module.

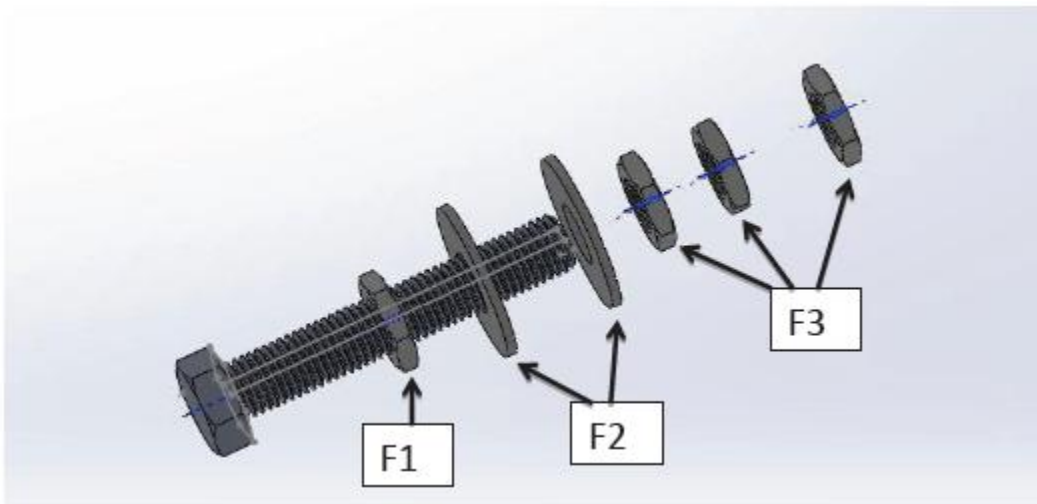
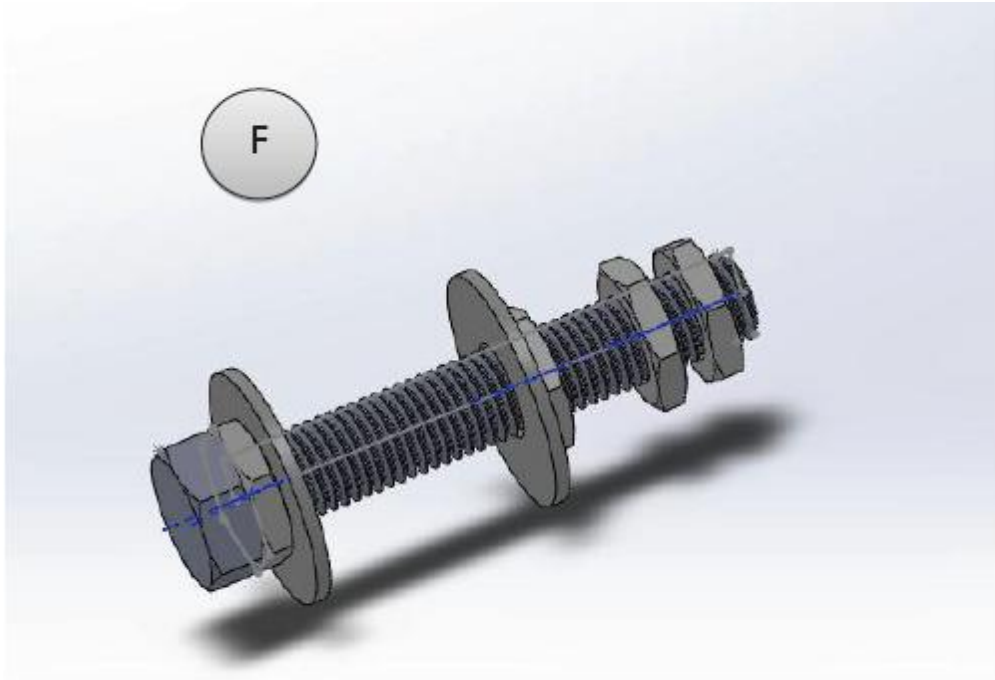


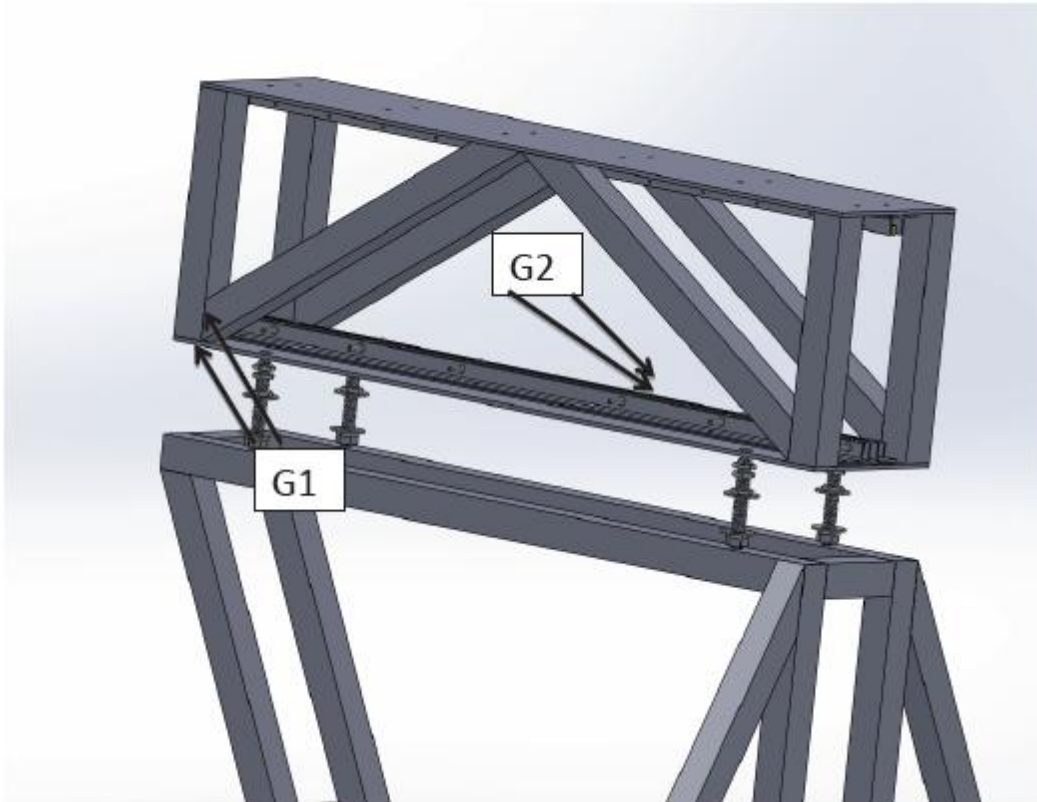
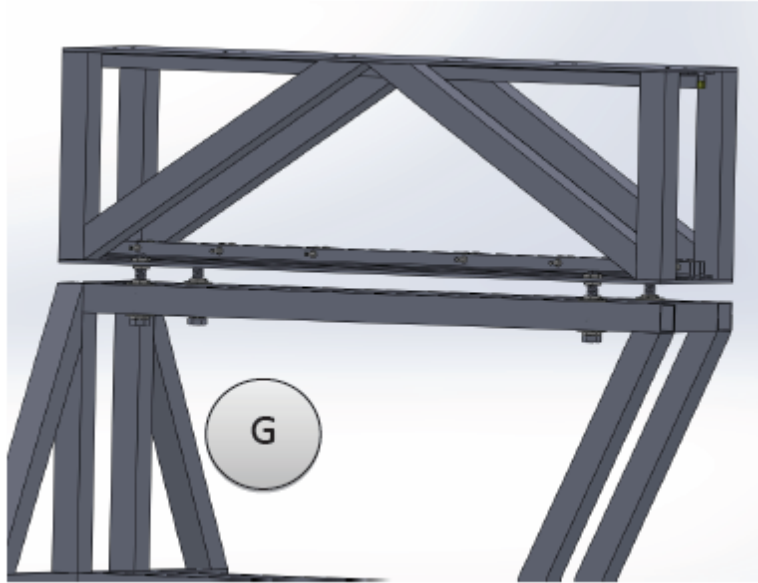












Storage Rack:

H. Storage Rack

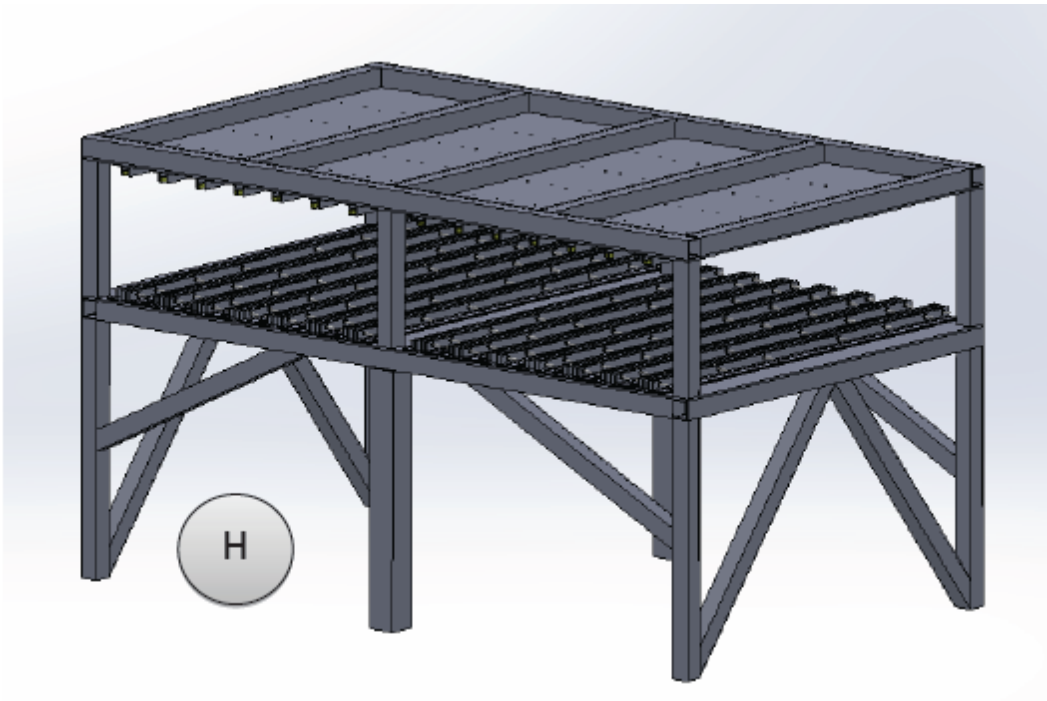
H1. Weld Rack Short side weldment according to dimensioned part drawing..

H2. Weld Rack Long side weldment according to dimensioned part drawing
(ends will be attached perpendicular to short side)

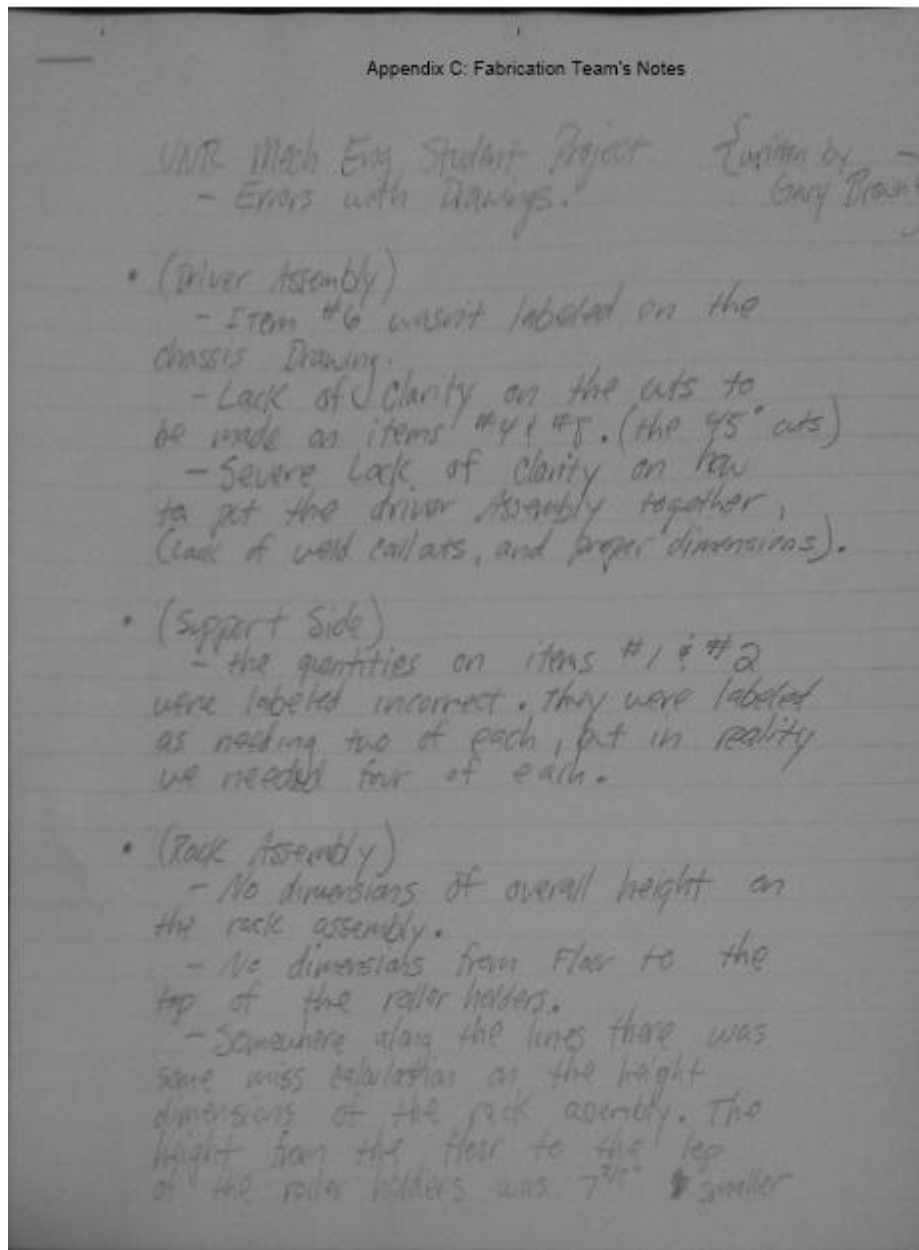
H3. Attach top side weldments according to dimensioned part drawing..

H4. Attach Bottom Panel and top Panel according to dimensioned part drawing..

H5. Attach die and punch supports at designated locations using 1.5" screws and corresponding nuts



Appendix C – Fabrication Team's Notes:



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of the rack assembly compared to
the driver assembly. That dimension
needed to be the exact same
for the whole unit to function
properly. (So to fix this issue we
had to splice 7th long pieces to
the legs on the bottom truss to
raise the rack assembly to the
correct height.)

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