Course: ME 430-02

Design of an Independent Star-Clip Organizer (ISO)

Design Report

Submitted to Southwestern Regional Maintenance Center and
Doctor Noori of the Department of Mechanical Engineering

By:

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Date:

June 4th, 2012

Approved by:

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Letter of Transmittal

4th June, 2012

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Dear Ms. Williams:

Attached is one copy of our Final Design Report: NAVSEA Project B, Design of a Sorting and Delivery System.

Sincerely,

Team SDS
Christopher Gonzales
Greg Lovasik
Daniel Silveira

Distribution:

Professor Mohammed Noori: 1 copy

Abstract

Discussed below is a new concept to sort and deliver star clips for flight deck safety net manufacturing. Multiple methods were generated, along with the necessary research, and were narrowed down to a single concept: the tray-loading preprocess design, named ISO (Independent Star-Clip Organizer). The overall design has been finalized and designed. Due to budget constraints, an actual prototype was not built. However, the design of such a prototype is described by this report, backed with calculations and experimental testing.

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CHAPTER 1 - INTRODUCTION

Sponsor Background and Needs

The Navy needs a faster method to sort, orient, and deliver net fasteners to receiver cups for the weaving and crimping of safety nets. After viewing firsthand the Navy's current net manufacturing method, we have researched related systems and proposed a design solution for a clip delivery system that supports rapid net manufacturing. Currently, it takes three workers 10-15 minutes per net to place all necessary bottom "star clip" fasteners to receiver cups on a manufacturing table. The Navy desires to reduce the total work time required to place net fasteners in order to free resources for other tasks while maintaining a production output of 5 nets per day. The main project goals have been outlined in the following two-phase process:

1. Sort and orient star clips.
    a. The star clips need to be vertically oriented so that the prongs point up
    b. The clips also need to have an angle orientation so that the clips are placed within the receiver cup mold properly.
2. Deliver star clips to receiver cups on the safety net production table.
    a. Need to deliver star clips in a manner where the orientation is maintained throughout the process
    b. Up to 594 star clips may be delivered per manufacturing job

Future goals have also been defined for additional projects in two more phases.

3. Complete automation of the star clip sort and delivery process.
    a. Ultimately, minimal star clip delivery time is desired, from the sorting to delivery process.
4. Automate the process for clip tops.
    a. Star clips represent only one set of the clips (the bottom portion of the crimp) that need delivery during the flight deck safety net manufacturing process.
    b. The clip tops, ideally, will also be automatically be sorted, oriented, and delivered to the table as well.

These future projects will be kept in mind during our design process for the first two phases. We have updated NAVSEA with our current progress through conference calls twice a month and continual email correspondence. The first quarter (September – December of 2011) of Senior Project is to determine a concept, the second quarter (January – March of 2012) is to design and build the concept, and the third quarter (March – June of 2012) is for testing and reporting of the prototype of said concept.

As previously mentioned, due to budget constraints, a prototype of the concept was never built and thus never tested. A wooden proof of concept was built, however, and successfully demonstrated the ability of the key concept points on a smaller scale. Unfortunately, an electrical control system was not able to be implemented and thus, could not be demonstrated.

Formal Problem Definition

NAVSEA needs a faster way to sort, orient, and deliver star clips to the safety net production table. Currently, from a box of 10,000 star clips randomly oriented, up to 594 star clips may be placed by hand into receiver cups. Every star clip must face the same direction and be oriented at the same angle within the receiver cup to ensure proper weaving and crimping of the net. We will discuss the concepts and designs to find an expedited method of star clip delivery in the following text.

Literature Review

We believe the success of this project will hinge on the mechanical components, failure rates and automating systems that we choose. From our meeting at San Diego Naval Base, the most modern advancement in the manufacturing of safety nets was the utilization of hydraulics/pneumatics. The newest table, SWRMC 1, uses a hydraulic ram to press the star clips together. This simple machine cut down the time needed to press fit the clips together by 600% and also created standardization among the fits, allowing for more reliable nets. It is from that advancement that we are requested to make advancements in the sorting and delivery aspects of the net creation (Williams).

The star clips arrive unsorted in boxed groups of 10,000. The current method to sort and deliver star clips, as seen and demonstrated in person during our visit, is to sort them by hand and place them into the receiver cups. This manual process can take three sailors anywhere from 10 to 15 minutes per net, depending on size of the net. By using a device to sort all the star clips and then place them into the receiving cups, we aim to only require one sailor and to meet or beat that time. By freeing up several sailors we will free them up to work on other tasks, increasing efficiency (Williams).

This drive to improve efficiency leads to the importance of a failure rate requirement. If failures occur during the sorting, orienting, and delivery process of the proposed concept, then ultimately time will have been wasted – which detracts from the overall goal. We must have a machine that rarely, if ever, fails to properly place a star clip into a receiver cup. Each clip that cannot have steel cable wound through without the user fixing the alignment is wasted time. The sorting device must also consider the process of delivering a bucket of star clips to the placement device, already aligned for the receiver cups. Lastly we must look into automated system design for this all to work. Ideally the sailor only has to pour the clips into the receiver bin and watch as our design sorts and then places the clips in the appropriate spots.

Some research was performed that looked into the bottle cap industry. Several designs were found such as high speed rotary sorters, and other cascade systems. Mostly, Fowler products were investigated and seemed most representative as a solution to the proposed problem (see links in the References section). However, these designs seem more expensive than what was required of the project.

Procedure and Project Requirements

The main goal of the project is to sort, orient and deliver star clips to receiver cups on the safety net production table. The procedure follows the guidelines detailed in Cal Poly's *Senior Design Project Reference Book and Success Guide* (see References), and all progress is documented in individual logbooks maintained by each group member. The process began with the generation of different solutions to the sorting problem, intending to provide a better method of sorting and delivering the star clips. Literary review was conducted at the required project stages, broadening our knowledge and understanding of specific fields. After we finished conceptually designing solutions, each design was evaluated for feasibility, using elimination criteria based upon material constraints, design constraints and decision matrices. NAVSEA was shown the final results in late November and the group came to a decision on which design best solved the problem. January to March had Team SDS focused primarily on Bill of Materials and design components, until, at the end of the second quarter the group was informed that a budget to build the design was no longer available. The team then continued finalizing the design of the project, and for the last quarter of senior project, April to June, Team SDS finalized the product as well as a final design report which encompasses the entire process.

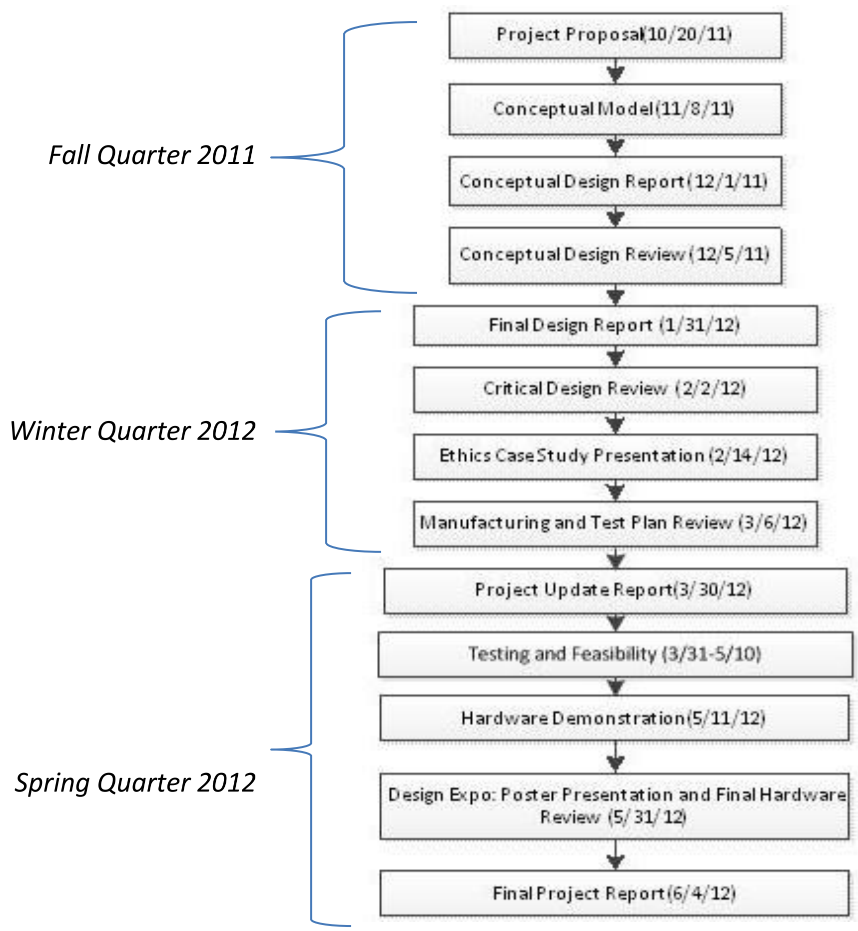


Figure 1: List of project tasks and deadlines from October 2011 through June 2012.

Additionally, a wooden proof of concept was built to demonstrate the feasibility of the design. Figure 1 details the major tasks and deadlines as required by Cal Poly in the Senior Design Project Guideline section.

Finally, below is a detailed list of all project requirements for sorting, orienting, and delivering star clip fasteners to the processing table:

1. Operation Requirements:
    a) One person should be able to operate device
    b) Minimal training required
2. Time Specifications:
    a) Need five nets a day
    b) Total process time for star clip sort, orient, and delivery must be less than 10 minutes
3. Dimensions:
    a) Should be equal to or less than the processing table dimensions
    b) Max size of 18 x 33 holder cups
    c) Design should impact the manufacturing floor with a small footprint
4. Strength Considerations:
    a) Low force requirements (holder clips weight less than 1oz each)
    b) High durability of approximately 3,000 hours (5 years of operation)
5. Orientation:
    a) Approximately 30 degrees tolerance around vertical axis
    b) Must be “upright” within holder cups
6. Reliability:
    a) High precision (>99%)
7. Environmental Considerations:
    a) Materials should be corrosion resistant (exposed to sea air)
    b) No material loss from device/process
8. Power Requirements:
    a) Either electrical, pneumatic, or geared mechanical translation
    b) Initial prototype can be human powered

<u>CHAPTER 2 – PRELIMINARY DESIGN DEVELOPMENT</u>

Brainstorming Summary

Initial idea generation began with our trip to the US Naval Base in San Diego, CA. Our team was presented with the “Bump’n’Slide” cardboard prototype created by NAVSEA as a prospective design starting point. Inspection of the current process of making flight deck safety nets as well as the environment, tools, and tables used in the process also provided a sufficient design perspective. Upon discussion with Ms. Siobhan Williams and Mr. Chris LaPorte, we obtained a general design approach from NAVSEA.

From the on-site meeting with NAVSEA, we began forming individual conceptual designs and simultaneously tested different methods of orienting star clips. The different orientation tests performed included dropping clips onto the floor, sliding clips down a ramp, vibrating clips down a ramp, dropping clips through a fluid, and our most successful test: sending clips through a rolling cylinder. These tests afforded a broader base of idea generation.

In addition to testing those methods of sorting and orienting star clips, individual idea generation and group brainstorming were employed to tackle the problem definition. Each person was to create several solutions individually. Our team then got together and explained each of our ideas. Again, this created a broad base of ideas from which our team further explored and expanded upon via group brainstorming sessions.

After the brainstorming sessions, our team narrowed down our initial concepts into a list of most feasible design approaches. From these feasible design approaches, we investigated via group discussion, comparison of concepts and sketches, pro/con lists, and a decision matrix. These techniques were used to quantify each approach and again narrow down our design approach into two potential design types: a mounted loading system and a detached pre-process system. All of the initial design approaches were investigated by considering the following major parameters: speed of process, design complexity, and star clip delivery reliability.

Decision Matrix

The decision matrix criteria derived from discussion of the advantages and disadvantages of each concept. This discussion led to the discovery of several overlapping components and themes for the sort, orient, and delivery process that we could quantify for ranking our top concepts. These themes became the ranking criteria in the decision matrix for our top eight conceptual designs. See Appendix A for the results of our completed decision matrix. Our top eight designs are defined as follows:

- <u>Tray loading (automated)</u> – Our top design sorts, orients, and places star clips into slots inside stackable trays in preparation of rapid delivery by placing the trays over production table receiver cups. This is a pre-processing system that is completely independent of the net production table. It is “automated” because the trays are automatically stacked during the sort

and orient process.

- Tray loading (manual) – Our other top design is exactly the same as the previous description except that a person must stand over the sort and orient process to manually stack the trays as they are completed.
- Mounted multi loader (manual) – Our next top design mounts to the production table throughout the sort, orient, and delivery process. It is attached to the same rail arm used by the hydraulic hammer and is designed to place an entire row of up to 18 star clips at a time as the rail is manually drawn along the table.
- Mounted multi loader (automated) – This is the same as the previous description except that a motor draws the rail arm along the table instead of being manually pushed or turned.
- Mounted single loader (manual) – This design is also mounted to the hydraulic hammer rail arm but only places one star clip at a time. It is manually drawn along and across the table.
- Mounted single loader (automated) – This is like the previous description except that travel is done automatically.
- Hand drawn tabletop tool – This is a very portable design that allows the user to deliver star clips by simply moving handheld device across rows of receiver cups. It is not attached to anything, though it does require a separate sort and orient system to precede loading of the handheld delivery tool.
- Current process (completely manual) – Currently, all of the star clips are removed by hand from a box of 10,000 clips and hand-delivered to up to 594 receiver cups.

Our eight criteria are defined as follows:

- *Speed of process* – How well does it meet or beat the process time requirement? This was our most heavily weighted criterion as it is our most important design requirement. We believe the tray loading concept could result in the fastest process since it allows for the sorting and orienting of the star clips to occur completely independent of the delivery process.
- *Design feasibility* – Can the design be completed in the time available? Is it easy to manufacture?
- *Safety* – Consider potential hazards (i.e. tipping due to weight of machinery, prevalence of exposed moving parts, repetitive human motion).
- *Cost* – This includes cost to build, operate, and maintain the device.
- *Ease of use* – How much human input is required to operate the device?
- *Table/shop footprint* – How much useful space on the shop floor and/or production table does the design require?
- *Ease of maintenance* – If the machine breaks down, how easily can it be repaired without sacrificing valuable production time? We believe the tray loading concept should receive the highest marks here as it allows for a stockpile of pre-sorted and oriented clips to be stored for future rapid delivery to the net production table.
- *Predicted reliability* – Considers how consistently the clips can be delivered without need for human adjustment. It currently holds the lowest ranking weight because without testing we cannot accurately determine the reliability of each design.

Our results ranked the tray loading detached system designs as our top two concepts. The mounted multi-loader concept intended for manual travel across the table was our next top concept. The current hand-placed process ranked lowest among all eight concepts. This can be seen in Appendix A: Decision Matrix.

Two Main Concepts

As outlined in the "Brainstorming Summary" and "Decision Matrix" sections, two main design approaches had been selected as the most feasible to adequately approach a solution to the stated problem. Both of these designs are detailed below:

Mounted Loader

The mounted loader system has the entire sort, orient, and delivery system mounted to the current gear rack system used by NAVSEA's hydraulic hammer (see Figure 1). This design revolves around using the hydraulic rail as a guide for a mobile dispensing system capable of delivering an entire row of clips at one time. The process would consist of the following three components:

1. Storage
    a. Clips are initially dumped into a hopper and fed into a sort and orient system.
    b. System would be a dynamic system
        i. To prevent clips from bunching and becoming lodged in a static configuration, a method to keep the clips moving during delivery is a must
    c. Large storage capacity to potentially meet the demands of multiple net assemblies
2. Sorting and Orienting
    a. Clips are fed into a device to correctly orient vertically to prepare for placement onto a conveyor belt.
        i. Device could utilize a single spinning tube, vibration, or "Bump'n'Slide"
    b. Clips then fed down conveyor belt and oriented before delivery
        i. Orientation achieved via placing a ridge between star clip feet
        ii. Also, orientation could be achieved via vertical orienting chutes that 'funnel' clips into correct angle
3. Delivery
    a. Delivery chutes orient up to 33 star clips as they travel vertically downward to be dropped into the receiver cups across the desired width of the net production table.

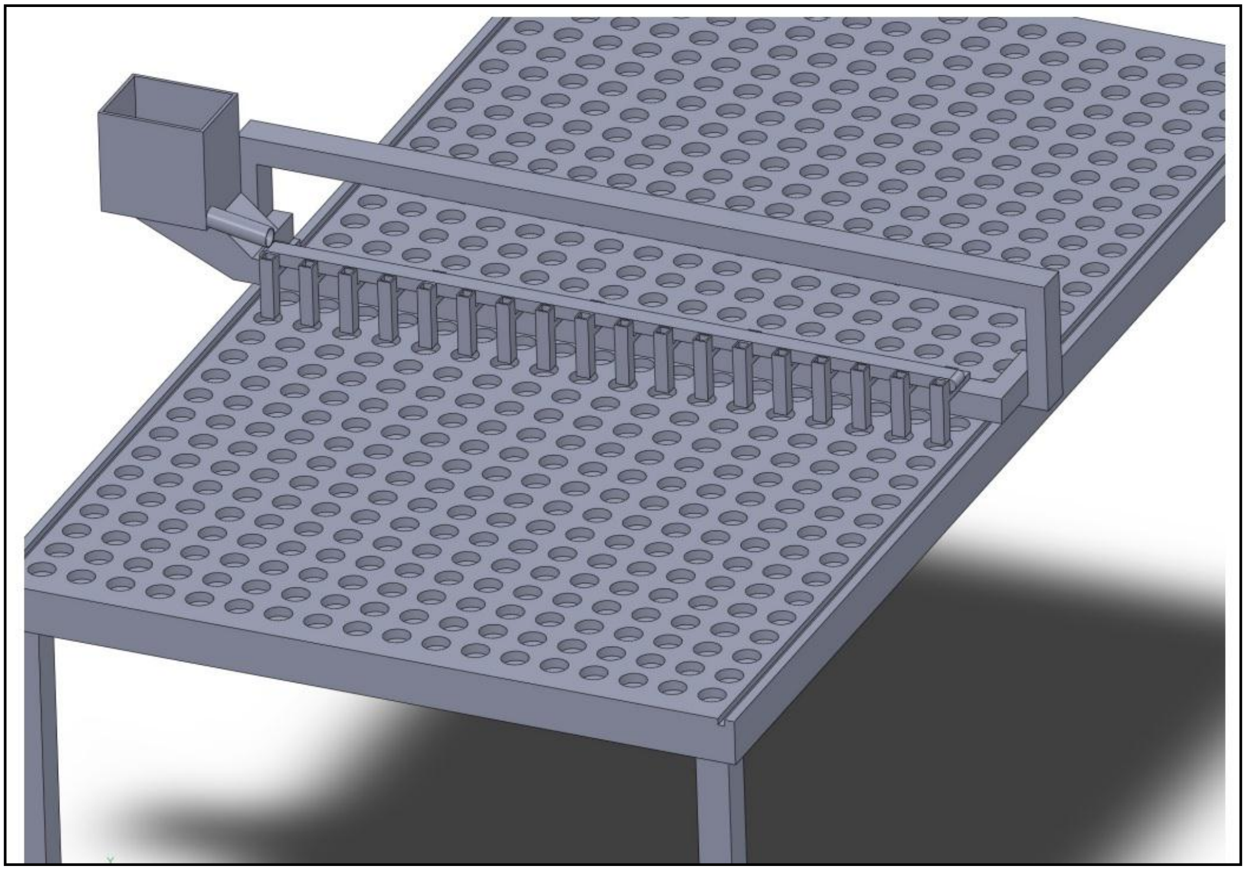


Figure 2: Simplified Mounted Loader System 3-D solid model

Pre-Process Tray Loader

The detached, pre-process tray loader system dealt with the sorting and orienting process separate from the net production table and could be performed completely independent of the star clip delivery and net weaving and crimping process (see Figure 2). The star clips would first be delivered to rectangular, stackable trays as part of the sort and orient process. The trays would then be carried to the net production table to deliver a grid of star clips at one time. The process would consist of the following three components:

1. Storage
    a. Clips are initially dumped into a large hopper and fed into a sort and orient system similarly to the Mounted Loader.
    b. System would be a dynamic system
        i. To prevent clips from bunching and becoming lodged in a static configuration, a method to keep the clips moving during delivery is a must
    c. Large storage capacity to potentially meet the demands of multiple net assemblies
2. Sorting and Orienting
    a. Clips are fed into a device(s) that orients similarly to the Mounted Loader.
        i. Device could utilize a single spinning tube, vibration, or Bump'n'Slide
    b. Through either a single or multiple orientation devices, clips are loaded into different chutes and prepared for delivery.
3. Delivery
    a. Delivery chutes orient star clips as they travel vertically downward to be dropped into a tray row.
        i. Each tray consists of a set amount of rows and columns.
        ii. The delivery chutes will deposit one star clip from each chute and thus drop a row at a time
        iii. This will be repeated until the tray is filled
        iv. A new tray will then be moved into position
    b. Trays are automatically stacked at one end of the sort and orient system. A stockpile of trays is carried to the net production table and trays are placed on top of a grid of receiver cups as needed. The undersides of the trays are designed with a release system to drop star clips into the receiver cups.

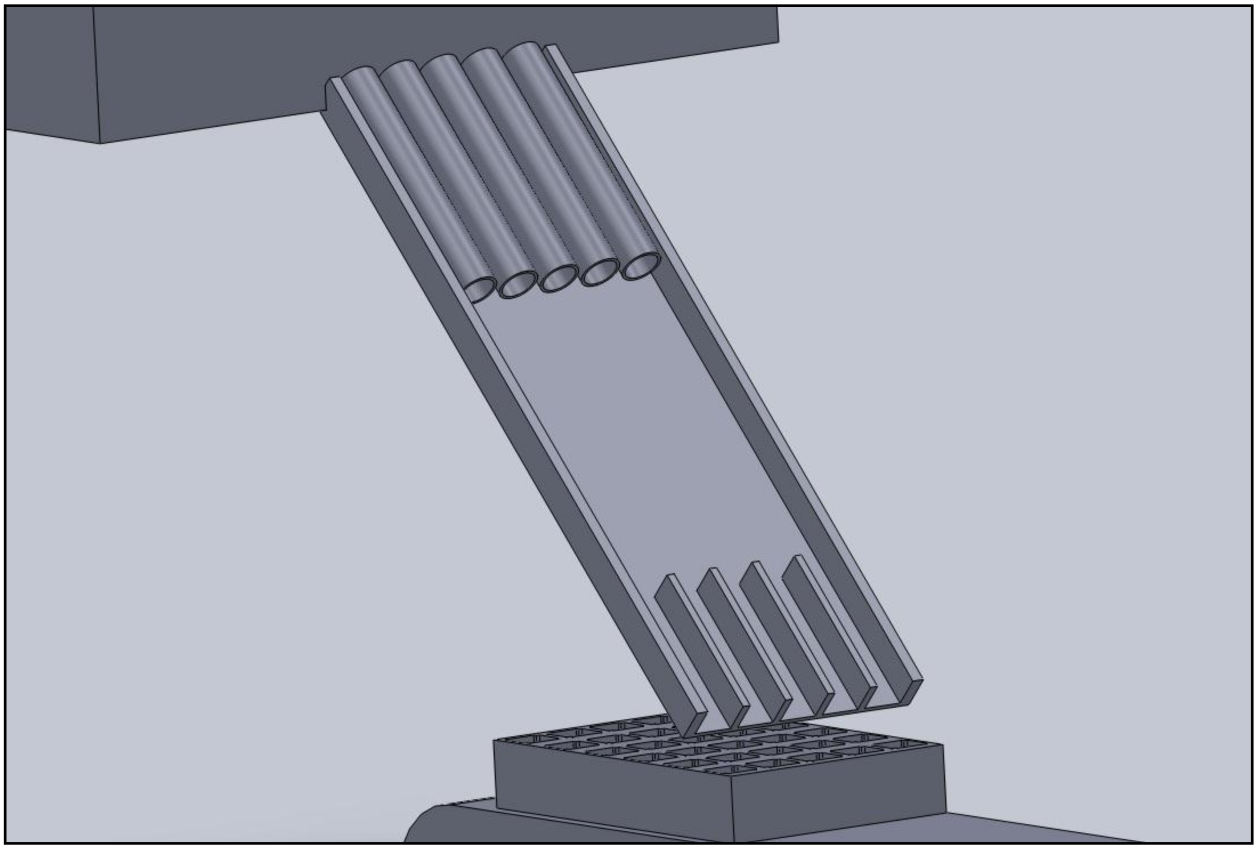


Figure 3: Simplified Pre-Process Tray Loader 3-D solid model

CHAPTER 3 – DESCRIPTION OF THE FINAL DESIGN

Final Design Selection: Tray Loader

After reviewing the possible design concepts with NAVSEA, it was decided that the best concept to pursue was the pre-process tray loader. It allowed for the simplest design and did not add a complicated process and device to the manufacturing table. The tray loader allowed for a separate device that did not impede the overall manufacturing of the safety nets and will provide a more expedited process that will aid in faster star clip delivery.

Overall Description

The tray loader, named ISO (Independent Star-Clip Organizer), utilizes a pre-process device that sorts and orients the star clips into 4 lanes and then delivers them into a tray that consists of a matrix of 24 slots. Multiple trays will be loaded with star clips and stored in a convenient location for quick delivery to the manufacturing table. The concept revolves around three main systems: storage, sorting, and dispensing. These systems are further expanded upon below.

ISO consists of the following eight major components (see Figures 4 and 7):

1) "Alpha" – The Hopper.
2) "Bravo" – The Feeder.
3) "Charlie" – The Drop-Down Box.
4) "Delta" – The Rotating Cylinders.
5) "Echo" – The Chutes.
6) "Foxtrot" – The Tray.
7) "Golf" – The Conveyor.
8) "Hotel" – The Frame.
9) Motor Mounts and Motors
10) Electronics

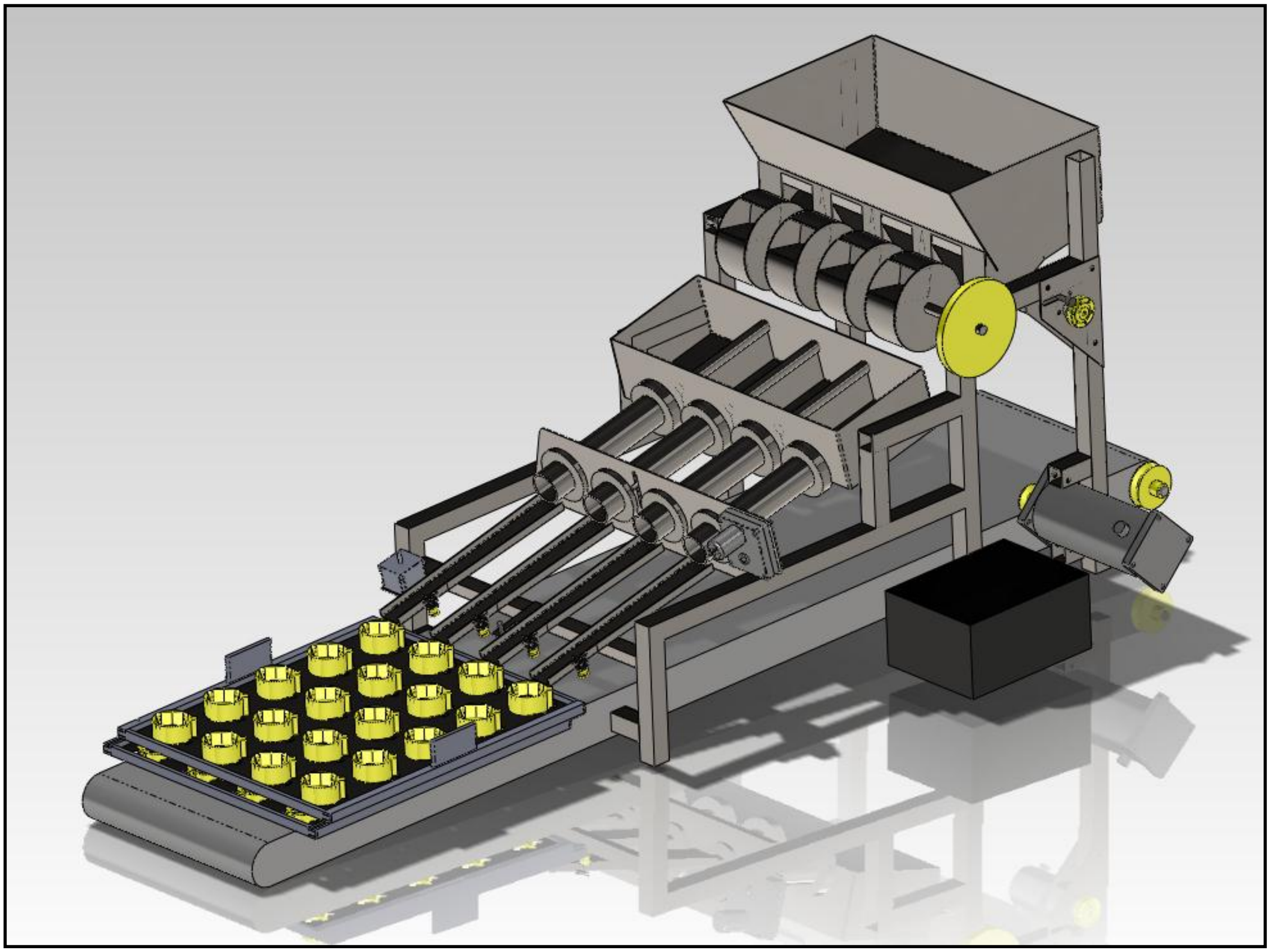


Figure 4: ISO 3-D solid model. The overall dimensions of all components fully assembled are 2.2 feet wide x 5 feet long x 2.7 feet tall.

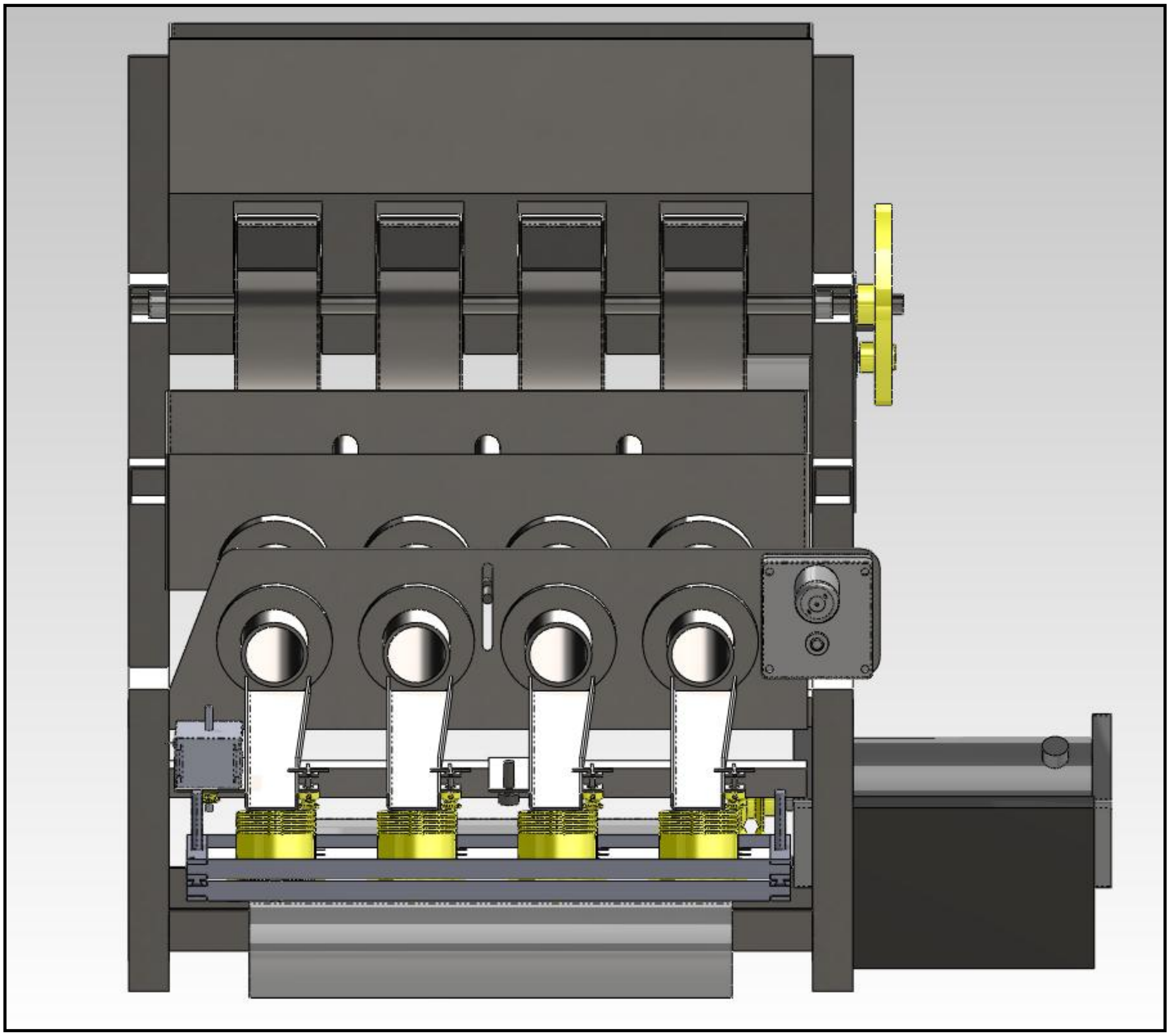


Figure 5: Front view of ISO 3-D solid model.

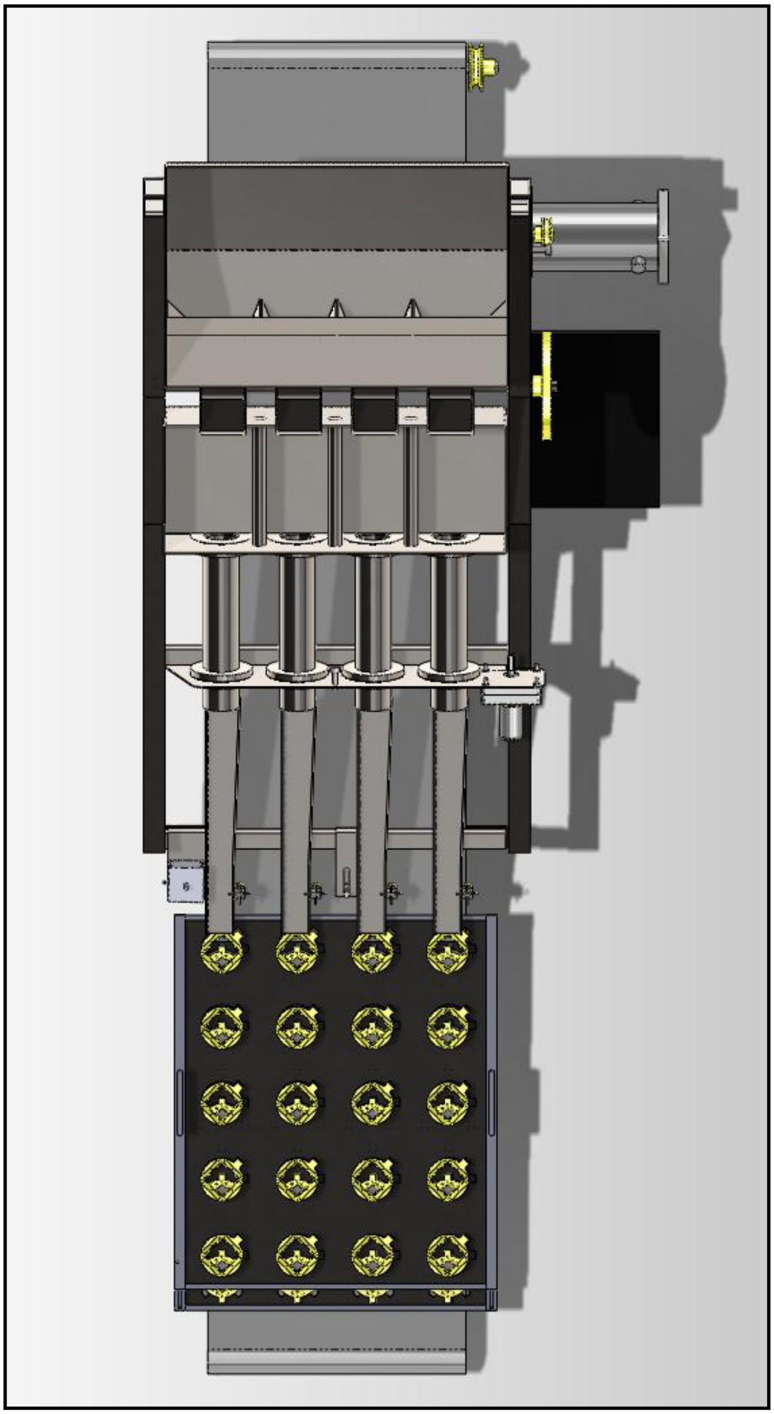


Figure 6: Top View of ISO 3-D model

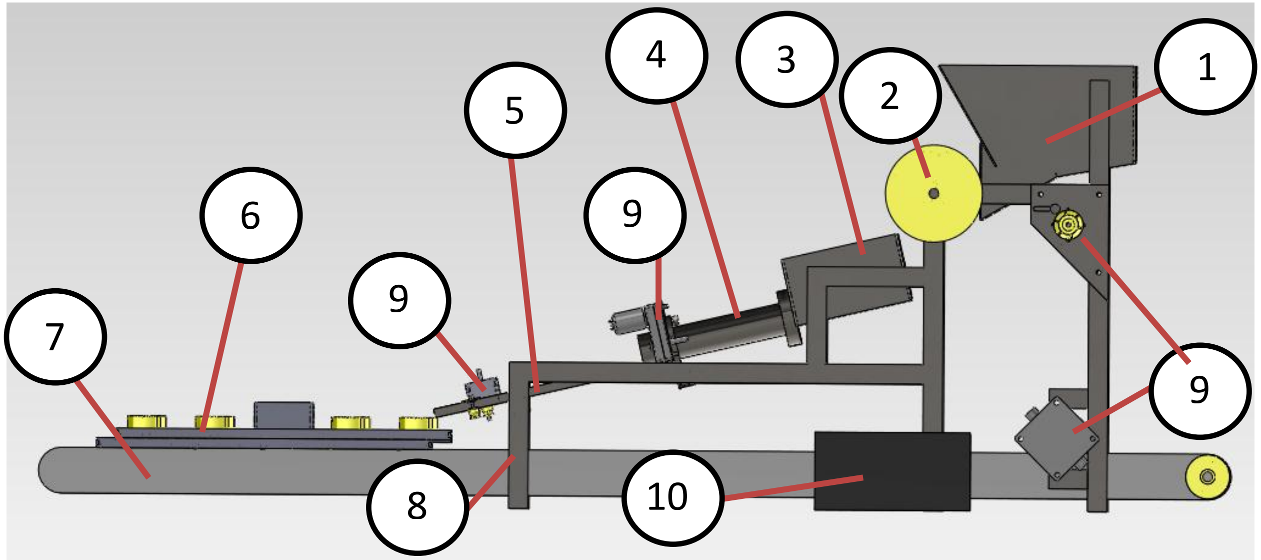


Figure 7: Side view of ISO 3-D solid model. Notice the major components are numbered.

Detailed Design Description

1) "Alpha" – The Hopper. The hopper design has finalized into a specifically shaped container that holds 900 star clips and holds them ready for the feeder. See Figure 8. A large interface between Alpha and Bravo was implemented to prevent jamming, as determined by utilizing the wooden proof of concept. The hopper also contains dividers that guide the star clips to the hopper/feeder interface and prevent jamming.

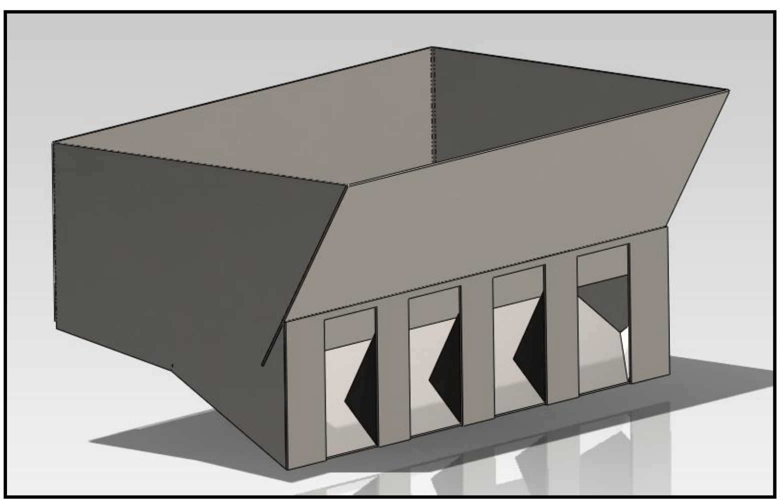


Figure 8: The Hopper.

2) “Bravo” – The Feeder. The Feeder is powered by a motor and has a series of connected scoops which can hold up to four star clips in each depression. The feeder is driven by a v-belt connected to a motor with a 5:1 gear ratio. See Figure 9 below.

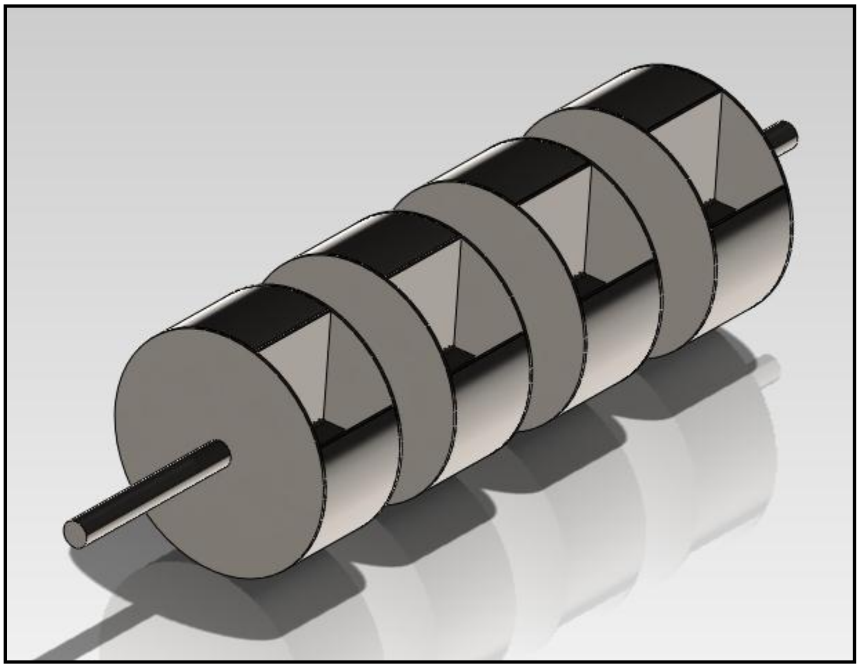


Figure 9: The Feeder (motor not shown).

3) “Charlie” – The Drop-Down Box. The Drop-Down Box receives star clips from Bravo and keeps the individual streams in separate lanes. The short vertical drop ensures that clumped star clips break apart on impact. See Figure 10.

4) “Delta” – The Rotating Cylinders. The Rotating Cylinders are controlled simultaneously by a belt-driven motor and receive the star clips from Charlie. By the precise dimension of the width and the length, any star clip fed into the slowly rotating cylinder exits in a properly aligned upright position. The cylinders are driven by a flat belt connected to a motor. The motor has a defined gear ratio connected directly as a speed reducer. The motor speed should be set according to the most effective speed for orientation of the star clips, as yet to be determined by experimentation with the actual materials. See Figure 10.

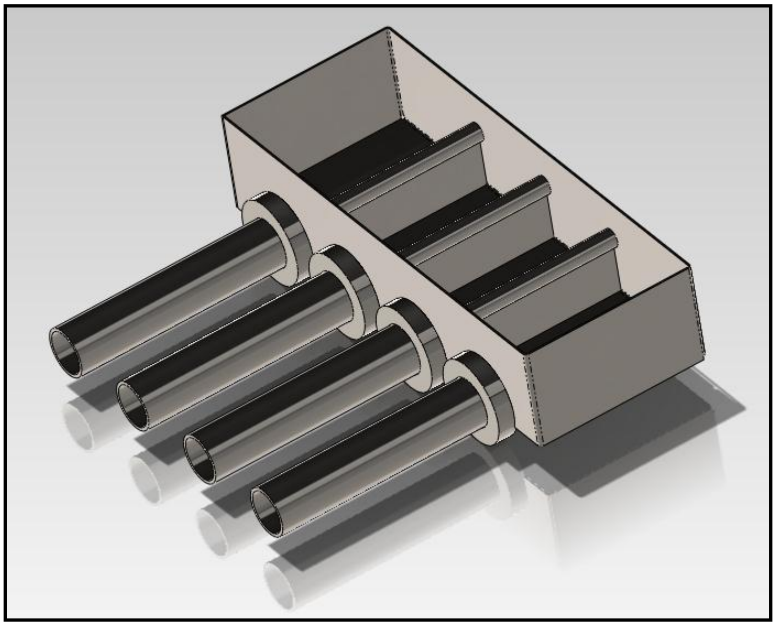


Figure 10: The Drop-Down Box ("Charlie") and Rotating Cylinders ("Delta"; motor not shown).

5) "Echo" – The Chutes. The aligned star clips arrive in the exit chute. Echo has precisely angled chutes so that the star clips all arrive at the end with a precise orientation. A rotating door in each lane catches the star clip and rotates once to allow only one star clip through per lane at a time for delivery to the tray. The rotating doors are controlled simultaneously by a timing belt connected to a stepper motor. See Figure 11.

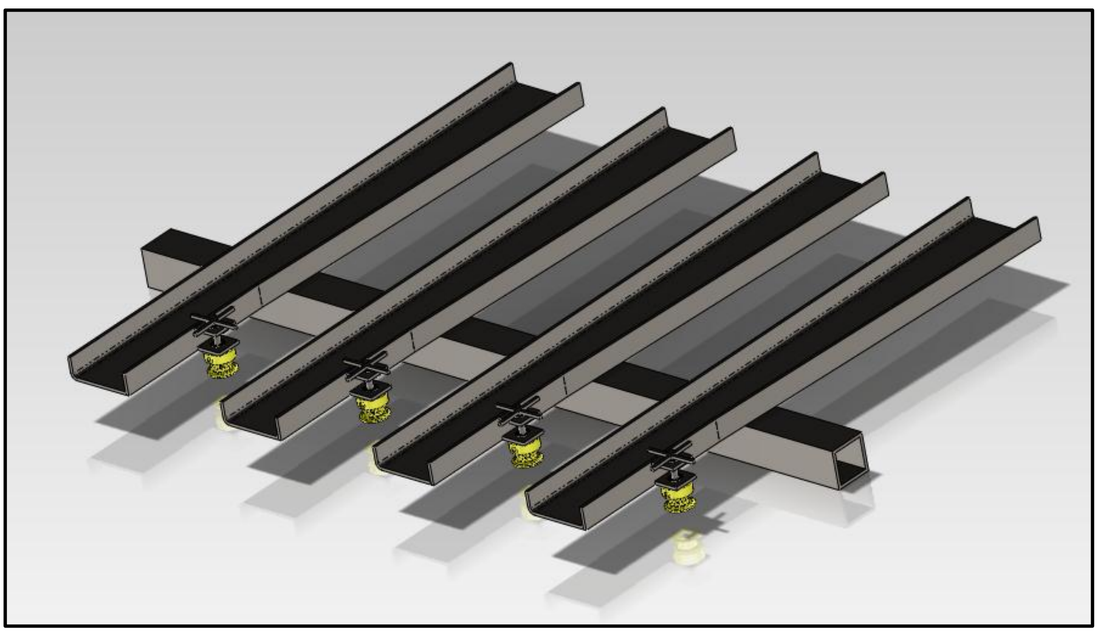


Figure 11: The Chutes (motor not shown).

6) “Foxtrot” – The Tray. The star clips are released from Echo after a signal has been recieved from the sensors. They fall into the hard silicon dispensing cups attached to Foxtrot, aligned for placement on the manufacturing table. The trays are constructed of an outer wooden frame, with two stainless steel sheet metal sheets. Receiver cups, which are plastic formed in a silicone mold, will be press fit into the top and bottom sheets. See Figure 12.

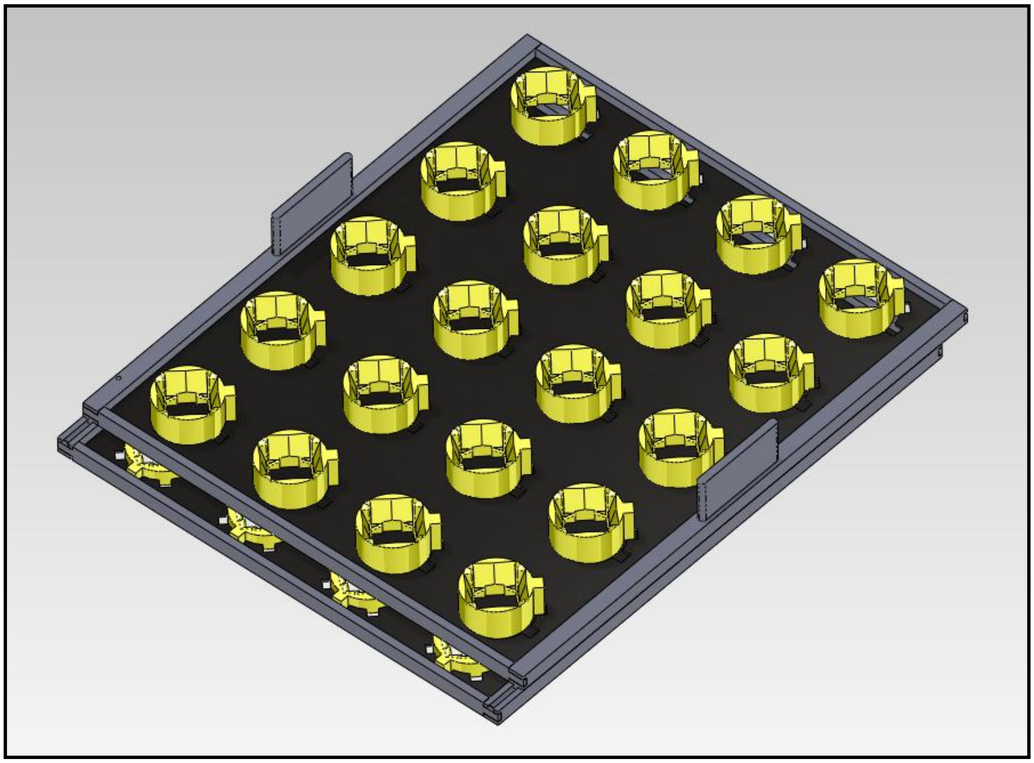


Figure 12: The Tray, shown with one plastic insert for receiving star clips.

7) “Golf” – The Conveyor. The conveyor is controlled to operate as a positional device via the microcontroller. A bump sensor will be placed on the frame of ISO. This sensor will interface with the tray and communicate to the microcontroller where the tray is relative to Echo. Golf delivers completely full trays to the end, ready to be placed. See Figure 13.

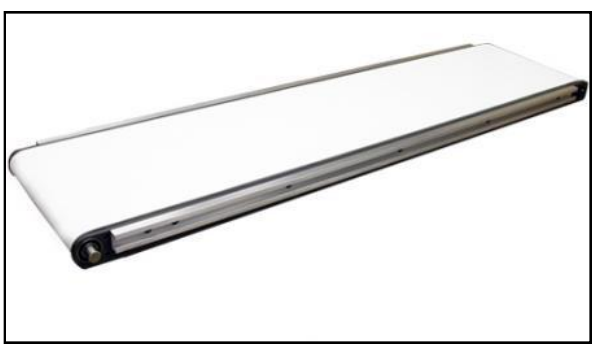


Figure 13: The Mini-Mover LP (low profile), ideal for compact design.

8) “Hotel” – The Frame. The frame is designed to hold all of the parts in their precise spots. It was made of steel square tubing, which is more than sufficient to hold the entirety of the design.
9) Motor Mounts and Motors – The four motors are attached to the frame via motor mounts. The motor mounts serve as an interface for the motors, and allow for a mechanical ground, so as to allow for rotation and power transfer to the components. More information on the motor mounts can be found in the appendices.
10) Electronics – The electronics are relegated to a “black box” within the model. The box of electronics and the controls is best located as shown in the model. The box would contain the power supply as well as all the microcontroller. The box will have motor connections available. These will be wired as seen fit during assembly. The wiring and assembly of the electronics package may be found in the appendix.

Detailed dimensioned drawings of the above components are included at the end of this report in the Appendix section.

Other Components

ISO requires four motors for independent running of the following rotating parts: the feeder in Bravo, the rotating cylinders in Delta, the rotating doors in Echo, and the conveyor in Golf (see previous section “Detailed Design Description”). It will also require at least two independent sets of sensors for accurate dispensing of star clips. Further design and experimentation may reduce both quantities. This current design will require the following electronics:

- A microcontroller (AVR microcontroller).
- The AVR will control the 4 motors and read a bump sensor for proper tray alignment.
- The motors will be controlled through H-Bridges.
- This entire assembly will be powered by a computer power supply.

These are outlined in the appendix section.

Analysis Results

Due to the nature of the project, an analytical approach to the project was not necessary in most aspects of the design. However, because the project called for the use of motors, it was necessary to calculate whether or not the chosen motors would be able to handle a given load. For instance, the motor that was connected to Bravo would have to overcome the inertia of the steel feeder, as well as overcome the friction induced by the star clips on the surface of the feeder (as the feeder is in contact with the star clips within the hopper). This approach was taken with both Bravo and Delta motors. In other words, the moment of inertia as well as the frictionally induced load was taken into account. Given these considerations, the motor torque was then compared to the given load and a conservative rotational acceleration was estimated. If the motor torque was sufficient, then a direct drive configuration was set up. If the motor provided insufficient torque, a gear reduction was required to reduce the load seen by the motor.

The team performed analysis on all moving components: the feeder in Bravo, the rotating cylinders in Delta, and the rotating doors in Echo. The mass moment of inertia terms were found to be insignificant in all component cases. And with low-friction bearings, the frictional losses were also insignificant in Delta and Echo – the torque requirements for both of these cases were almost insignificant for the motors that were being considered, and thus a direct drive configuration was sufficient. However, the feeder in Bravo did have significant frictional losses from the weight of the star clips in the hopper resting against the feeder. The required friction torque for the feeder was 4.12 lb_f-in, which for the motor we selected from McMaster Carr would require at least a 4:1 gear ratio, which the team applied a 5:1 ratio to be conservative. See Appendix D for these calculations.

Lastly, calculations were not possible for the Golf motor due to the lack of information about the conveyor belt system. Additionally, the supplier of the conveyor belt provided a motor selection chart. Therefore, a motor was specified given the motor selections available on the Mini-mover website, which is listed in the references section. A small 2:1 gear reduction was applied in order to provide more positional precision, and to account for any unforeseen loads.

To summarize the required analysis on ISO: the loads that were to be seen by the motors were calculated or looked up in chart in order to properly size the motors/gear boxes for the motors. A conservative approach was taken in the dynamic analysis in order to allow for a wide margin of error and thus enable high reliability for the system as a whole.

Materials Selection

The following materials have been selected for their durability, cost, and performance characteristics.

1. Stainless Steel Type 314
2. Stainless Steel Cylinders
3. Roller Bearings
4. For the trays:
    a. Silicone molds and plastic receiver cups
    b. Wood
    c. Metal Sheeting
    d. Leaf Springs
5. Electronics
    a. Microcontroller
    b. H-Bridges
    c. Power Supply
    d. Motors
    e. Other electrical components

Cost Analysis

The Bill of Materials can be found in Appendix C. The total cost of ISO materials is estimated at $3,350.

Operation Instructions

ISO is intended to function with the following steps:

1) Load the hopper with star clips and load the conveyor with a few trays.
2) Turn on motor switch 1 until all chutes (Echo) are filled.
3) Once the chutes are full, turn on motor switch 2 to activate the conveyor and allow the trays to automatically fill with star clips.
4) Stack completed trays on a table at the end of the conveyor.
5) Store trays under or near the net manufacturing table for easy accessibility.
6) When a net is ready to be made, place as many fully-loaded trays as necessary over the desired receiver cups and push horizontally on the top tier of the tray to drop 24 star clips simultaneously from the tray into the receiver cups.

CHAPTER 4 – DESIGN VERIFICATION

Wooden Proof of Concept

Preliminary testing and proof-of-concept was performed by building a wooden prototype of ISO (see Figure 14). A video of the functioning prototype can be found on YouTube, by searching "ISO Independent Star Clip Organizer." The purpose of the wooden prototype was to finalize design details and dimensions and expose any major design flaws. During construction we discovered that the Drop-Down Box (Charlie) did not require as large a vertical drop as we thought and were able to modify design details for the chutes and rotating doors of Echo to more consistently deliver individual star clips.

Additionally, we have discovered that the interaction between the hopper and the feeder, Bravo and Alpha respectively, resulted in jamming. This was later resolved with a re-design of Alpha, by introducing a large void added in Alpha. This allowed the top of Bravo to have a clearance that was sufficient so as to prevent jamming.

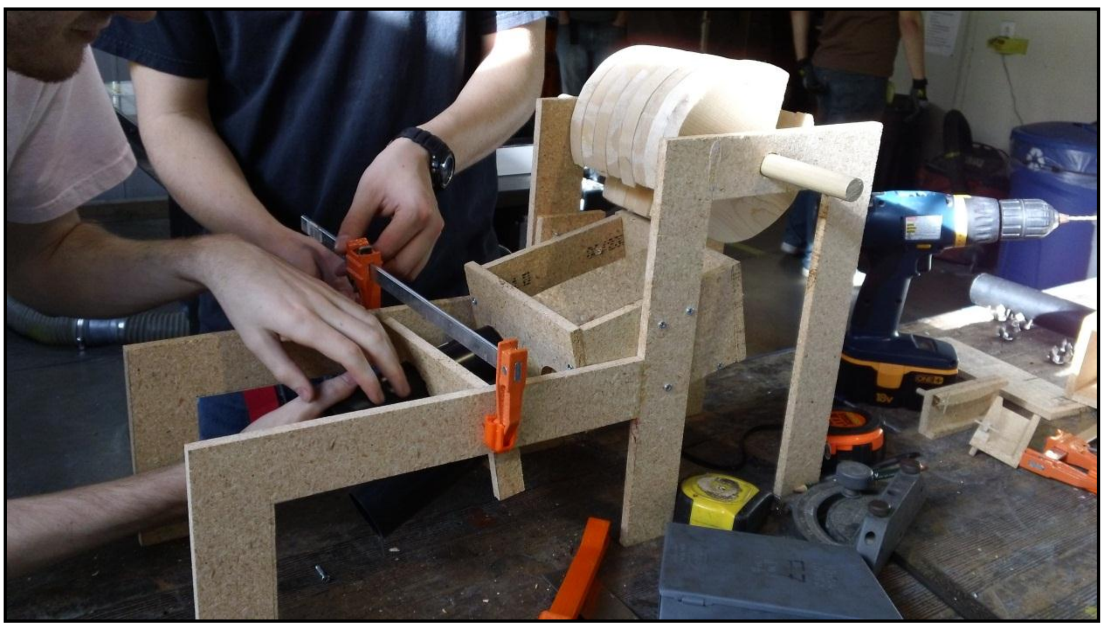


Figure 14: Partial Construction of the Wooden ISO Prototype.

Final Prototype Testing

If NAVSEA so chooses to pursue development of ISO, the team recommends the following testing plan and tuning of ISO:

Once the Bill of Materials is ordered and received, the construction of the final prototype can be completed. Testing will consist of the following steps:

1. Reliability testing: Angles. Determine what angles the ISO components can be attached to the frame to allow reliable sliding of star clips without jamming.
2. Reliability testing: Timing. Determine what speeds the motors can be run at while reliably delivering star clips to trays.
3. Performance testing. Using the reliability data or new tests, determine which angle and motor setting combinations result in the fastest star clip delivery to trays. Use only settings that allow for acceptable reliability while maintaining safe operating conditions.
4. Present results. After testing, present the reliability and performance data to NAVSEA and discuss what reliability and performance results are acceptable.

Unfortunately, the funding from Navy fell through and the team was unable to procure parts for the final prototype. In order to produce some product, the team has funded our wooden proof of concept as well as the SolidWorks model of the final product, ISO.

CHAPTER 5 – CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The design report was completed to fully describe the problem, requirements, and solution for NAVSEA. However, due to unforeseen budget constraints, a final prototype was not able to be constructed through California Polytechnic State University, San Luis Obispo. Therefore, a full set of assembly instructions for the construction of ISO have been included in the Appendices, for NAVSEA to pursue as they so choose. In addition to the full design report, the SolidWorks model of ISO has also been provided along with the wooden proof of concept that was built.

The instruction set includes how to build ISO and the trays required to properly function. Additionally, an electronics assembly package has also been included with a brief summary of the system. However, as described in the appendix, code has not been included within the report due to a lack of an electronics prototype to program on.

Recommendations

Future add-ons to ISO may include the ability to automatically load and stack trays at the beginning and end of the device, respectively. Such an addition would allow for a “set it and forget it” device operation; the user could push a start button without need for manually stacking and loading the trays.

References

Mechanical Engineering Department. *ME428/ME429/ME430 Senior Design Project Reference Book and Success Guide*. San Luis Obispo, CA: California Polytechnic State University, 2011. Portable Document Format.

Williams, Siobhan and David Mierke and Mike Sanchez. Personal Interview at San Diego Naval Base. 14th October, 2011.

Relevant Products:

Fowler Products Company, LLC. Fowler Products. http://www.fowlerproducts.com/index.php
- See "Bottle Cap Sorting / Cap Orienting Equipment"

Mini Mover, Conveyors. Whipple Enterprises. http:// http://www.mini-mover.com/small-conveyors/low_profile-lp-series/

APPENDIX A: Decision Matrix

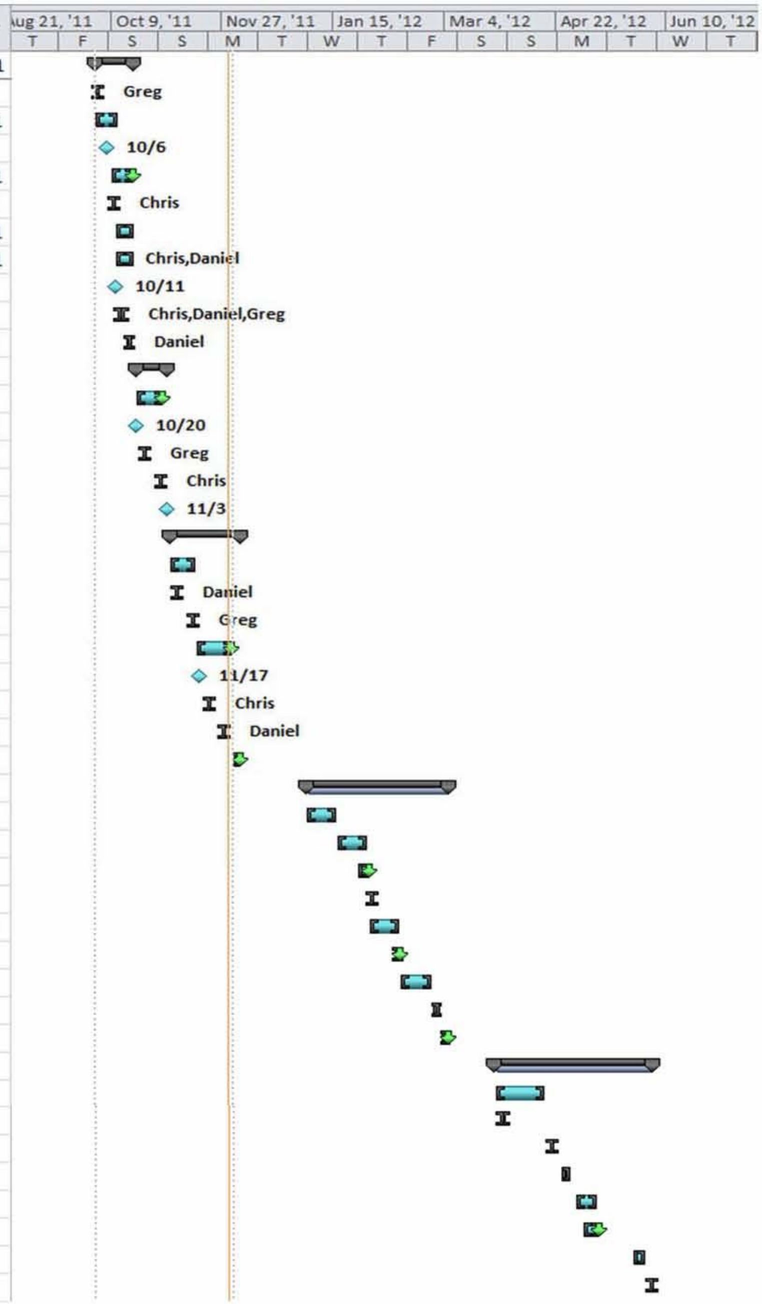
Concept Designs 1:10 Scale, 10 = most advantageous	speed of process			design feasibility			safety			cost			ease of use			table/shop footprint			ease of maint.			predicted reliability			Totals
	DS	CG	GL	DS	CG	GL	DS	CG	GL	DS	CG	GL	DS	CG	GL	DS	CG	GL	DS	CG	GL	DS	CG	GL	
tray loading (automated)	9	7	10	7	4	8	6	8	10	5	7	5	8	5	8	6	5	3	8	4	7	5	8	7	318.6667
tray loading (manual)	7	7	8	8	6	8	5	8	10	7	7	6	6	4	6	7	5	3	8	4	7	6	8	7	311.3333
mounted multi loader (manual)	6	5	7	5	6	6	7	6	7	3	5	5	7	6	7	8	5	5	6	2	4	6	6	5	266
mounted multi loader (automated)	6	6	8	3	3	5	6	4	8	2	5	4	9	7	8	7	5	5	6	2	6	5	6	7	253.3333
mounted single loader (manual)	2	2	5	7	4	6	7	6	7	8	5	6	3	3	6	9	5	7	7	1	6	6	4	6	242.6667
mounted single loader (automated)	2	2	6	3	2	7	6	6	6	7	5	5	9	3	7	8	5	8	7	1	6	5	4	7	234.3333
hand drawn tabletop tool	4	2	4	5	7	6	6	8	7	7	8	7	3	1	6	6	5	6	8	8	8	6	2	6	254.3333
current process (completely manual)	1	1	3	10	10	10	6	1	5	10	10	10	1	1	4	9	1	8	10	8	7	3	1	6	258.6667
Weight	10			8			8			7			5			5			2			1			

NOTES:

speed of process	how well does it meet/beat process time requirement? Receives a weight of 10 because process speed is our number 1 design requirement
design feasibility	time to design, ease of manufacturing
safety	potential hazards (tipping due to weight, moving machinery, repetitve motion, etc.)
cost	always an important factor
ease of use	human labor factor, power considerations (how much human input is required?)
table/shop footprint	how much useful space does the design take up?
ease of maintenance	will still have stockpile if breaks down, advantage category for separate process
predicted reliability	has a weight of 1 because too early in process to tell (delivery consistency without need for adjustment)

APPENDIX B: Gantt

Task Name	Duration	Start	Finish
Background Research	**17 days**	**Sun 10/2/11**	**Wed 10/19/11**
Progress Report Memo	2 days	Sun 10/2/11	Tue 10/4/11
Prob. Statement & Reqs. List	10 days	Sun 10/2/11	Wed 10/12/11
Conference Call	0 days	Thu 10/6/11	Thu 10/6/11
Project Proposal	10 days	Sun 10/9/11	Wed 10/19/11
Progress Report Memo	2 days	Sun 10/9/11	Tue 10/11/11
Conduct literature review	8 days	Tue 10/11/11	Wed 10/19/11
Yellow tag; play with parts	8 days	Tue 10/11/11	Wed 10/19/11
Reserve conference room	0 days	Tue 10/11/11	Tue 10/11/11
Travel to sponsor	1 day	Thu 10/13/11	Fri 10/14/11
Progress Report Memo	2 days	Sun 10/16/11	Tue 10/18/11
Preliminary Designs	**14 days**	**Thu 10/20/11**	**Thu 11/3/11**
Conceptual Model	12 days	Thu 10/20/11	Tue 11/1/11
Conference Call	0 days	Thu 10/20/11	Thu 10/20/11
Progress Report Memo	2 days	Sun 10/23/11	Tue 10/25/11
Progress Report Memo	2 days	Sun 10/30/11	Tue 11/1/11
Conference Call	0 days	Thu 11/3/11	Thu 11/3/11
Narrow Design	**31 days**	**Fri 11/4/11**	**Mon 12/5/11**
2nd sketches and prototype	11 days	Fri 11/4/11	Tue 11/15/11
Progress Report Memo	2 days	Sun 11/6/11	Tue 11/8/11
Progress Report Memo	2 days	Sun 11/13/11	Tue 11/15/11
Conceptual Design Report	15 days	Wed 11/16/11	Thu 12/1/11
Conference Call	0 days	Thu 11/17/11	Thu 11/17/11
Progress Report Memo	2 days	Sun 11/20/11	Tue 11/22/11
Progress Report Memo	2 days	Sun 11/27/11	Tue 11/29/11
Conceptual Design Review	4 days	Thu 12/1/11	Mon 12/5/11
Build Component Prototypes and Test	**63 days**	**Tue 1/3/12**	**Tue 3/6/12**
Build prototypes for components 1-2	13 days	Tue 1/3/12	Mon 1/16/12
Build prototypes for components 3-4	13 days	Tue 1/17/12	Mon 1/30/12
Design Report	5 days	Thu 1/26/12	Tue 1/31/12
Critical Design Review	2 days	Tue 1/31/12	Thu 2/2/12
Build prototypes for components 5-6	13 days	Tue 1/31/12	Mon 2/13/12
Ethics Case Study Presentation	3 days	Sat 2/11/12	Tue 2/14/12
Build prototypes for components 7-8	13 days	Tue 2/14/12	Mon 2/27/12
Select materials, manufacturing plan	3 days	Tue 2/28/12	Fri 3/2/12
Manufacturing and Test Plan Review	3 days	Sat 3/3/12	Tue 3/6/12
Build Final Prototype, Test, and Report	**70 days**	**Mon 3/26/12**	**Mon 6/4/12**
Build Final Prototype	21 days	Tue 3/27/12	Tue 4/17/12
Project Update Report	1 day	Thu 3/29/12	Fri 3/30/12
Perform extensive testing	2 days	Thu 4/19/12	Sat 4/21/12
Make repairs or improvements	4 days	Tue 4/24/12	Sat 4/28/12
Retest & refine prototype as needed	9 days	Tue 5/1/12	Thu 5/10/12
Hardware Demonstration	7 days	Fri 5/4/12	Fri 5/11/12
Design Expo	5 days	Sat 5/26/12	Thu 5/31/12
Final Project Report	2 days	Sat 6/2/12	Mon 6/4/12



APPENDIX C: Bill of Materials

Component	Assembly Name	Model	Details	Vendor	Price/ Unit	Qty.	Total Cost
Items ready for purchase							
Bearings	Delta	18590	1.625" Bore, 2.875" OD, 0.656" Width	Amazon	16.33	8	130.64
Bearings	Echo	57155K205	Ball and Roller Bearing: 1/8" Shaft Diameter, 1/4" O.D.	McMaster-Carr	5.71	10	57.10
Bearings	Bravo	5905K230	Steel Needle-Roller Bearing Open for ½” Shaft Diameter, 11/16” OD	McMaster-Carr	4.98	4	19.92
Belt: V-belt	Bravo	7881K26	2L Rubber V-Belt Trade 25" OC	McMaster-Carr	4.97	1	4.97
Conveyor: LP Series	Golf	LP-Series	5' by 12" with conveyor belt assembled, 1/2" shaft, no motor	Mini-Mover	833.00	1	833.00
Electronics: Microcontroller	ISO	Atmel, AVR	ATMega328 AVR 28 Pin 20MHz 32K 6A/D Microcontroller	Sparkfun.com	4.30	1	4.30
Electronics: Breadboard	ISO	BB400	BB400 Solderless Plug-in BreadBoard, 400 tie-points, 4 power rails	Amazon.com	5.50	2	11.00
Electronics: Wire	ISO	Pico 81223J	22 AWG Wire (with Insulation) - Red, White, Black Colored Spools Pico 81223J 22 AWG Wire 50' per spool	Amazon.com	5.95	2	11.90
Electronics: Wiring Components	ISO	COM-00534	20 MHz clock crystal, Oscillator	Sparkfun.com	0.95	1	0.95
Electronics: Wiring Components	ISO	COM-08571	22 pF Capacitors, Capacitor Ceramic	Sparkfun.com	0.25	4	1.00
Electronics: Male Headers	ISO	Polulu item #: 1065	0.100" Breakaway Male Header: 1x40 pin, Straight, Double-Sided	Pololu.com	1.49	1	1.49
Electronics: Programmer	ISO	PGM-09825	Pocket AVR Programmer	Sparkfun.com	14.95	1	14.95
Electronics: Prog. Adapter	ISO	BOB-08508	AVR Programming Adapter	Sparkfun.com	0.95	1	0.95
Electronics: Serial Port	ISO	FT232RL	Breakout Board for FT232RL USB to Serial	Sparkfun.com	14.95	1	14.95

Electronics: H-bridges	ISO	SN754410	H-Bridge Motor Driver 1A	Sparkfun.com	2.35	3	7.05
Electronics: H-bridges	ISO	VNH2SP30-E-IC	Motor Driver, H-Bridge, 30A, 20PSOP - 8 Amp continuous output current 14-Amp Continuous Output Current	Newark.com	16.00	5	80.00
Electronics: Bump Sensors	ISO	COM-00098	Omron Snap Action Switch, Bump Sensor	Sparkfun.com	1.95	5	9.75
Motor	Bravo	6331K23	12 V DC 5.02 Amp 1.31 in-lb 3456 RPM	McMaster-Carr	94.28	1	94.28
Motor	Delta	6409K18	12 V DC 1.2 Amp 50 RPM 10 in-lbs	McMaster-Carr	37.42	1	37.42
Motor	Echo	S9117M-D13HT	Stepper Motor 22.2 oz-in, 0.9 & 1.8 deg. Steps, 0.95 Amps, Shaft Dia. 0.197"	SDP-SI	87.45	1	87.45
Motor (Conveyor)	Golf	Leeson # M1120046	1/6 hp 12 VDC motor	Amazon	190.00	1	190.00
Pinion Pulley	Bravo	A6Z10-0121508	1.4" Pitch Dia.	sdp-si.com	6.83	1	6.83
Pinion Pulley	Delta	A 6T19-262508	1.024" OD, 0.25" Bore	sdp-si.com	7.25	1	7.25
Pulley: Gear	Bravo	3060K19 4.9" Pitch Dia.	Gear Ratio 3.5:1	McMaster-Carr	18.14	1	18.14
Pulley: Idler	Delta	60885K72	0.5" Dia., 0.25" Bore	McMaster-Carr	18.14	1	18.14
Shaft	Bravo	89325K852	1/2" Dia., 3' Long, 316 Stainless Steel	McMaster-Carr	15.28	1	15.28
Shaft (for wall dividers)	Charlie	89325K832	5/8" Dia., 3' Long, 316 Stainless Steel	McMaster-Carr	22.84	1	22.84
Shaft: Idler	Delta	2435K1	0.25" Dia, 1 1/16" Lg.	McMaster-Carr	6.83	1	6.83
Sheet Metal	ISO	88885K54 & 88885K14	Type 316 Stainless Steel: 26 ft^2 Stainless Steel Super Corrosion Resistant SS 0.06" thick	McMaster-Carr	452.46	1	452.46
Stainless Steel Bar	Hotel	89075K18	Type 316 Stainless Steel 3/4"x3/4" Bar, 3' Length	McMaster-Carr	99.25	1	99.25
Stainless Steel Pipe	Delta	4378K542 Pipe	1.25" Schedule 10 316 Stainless, 1.660" OD, 0.109" WT, 1.442" ID, 3' Length	McMaster-Carr	59.26	1	59.26

Stainless Steel Pipe	Bravo	4378K591	4" Schedule 10 316 Stainless Steel Pipe, 4.5" OD, 0.120" WT, 4.26" ID, 1' Length	McMaster-Carr	52.27	1	52.27
Stainless Steel Square Tubing	Hotel	2937K116	1"x1" Square Tubing 0.065" Wall Thickness, 6' Length, 1"x1" Type 316 Stainless Steel	McMaster-Carr	82.46	4	329.84
Electronics: Wiring Components	ISO	Local Store	220 Ohm Resistors	Local Shop	$1.00	2	$1.00
Electronics: Wiring Components	ISO	Local Store	10k Ohm Resistor	Local Shop	$1.00	1	$1.00
Electronics: Wiring Components	ISO	Local Store	10 uF Capacitors	Local Shop	$1.00	2	$1.00
Plastic	Foxtrot	Smooth-Cast 300	2x 1 Gallon gives 30.8 pounds of white liquid plastic (we require 25 pounds to make 12 trays' worth of inserts). Smooth-Cast 300 has a 10 minute demold, 3 minute pot time)	www.smooth-on.com	85.85	2	171.70
Plastic Release/Sealing Agent	Foxtrot	One Step Gallon Unit	1 Gallon	www.smooth-on.com	47.30	1	47.30
Rubber Mold Material	Foxtrot	Mold Max 10	1 Gallon Pourable RTV Silicone (Shore 10A tin-cure silicone rubber)	www.smooth-on.com	96.54	1	96.54
Wooden Tray Frame	Foxtrot	5068K46	1" x 1" x 14" *2 long: Approximate as 1.25"x1.25"x36"	McMaster-Carr	21.93	1	21.93
Wooden Tray Frame	Foxtrot	5068K46	1" x 1/2" x 44" long: Approximate as 1.25" x .625"x24" (x 2)	McMaster-Carr	21.93	2	43.86
Belt: Flat	Delta	9485T11	31” OC, High-Performance Urethate Flat Belts, 3/8” Wedith	McMaster.com	0.47	31	14.57

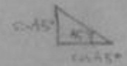
Belt Pulley: Timing	Echo	A 6N16-014DF1204	MXL (miniature extra light) 0.08" Pitch Pulley, 14 grooves	sdp-si.com	10.00	1	10.00
Belt: Timing	Echo	A 6Z16-343012	MXL (miniature extra light) 0.08” Pitch, 1/8” width, Neoprene w/ Fiberglass tension member, 27.44” Pitch Length	sdp-si.com	3.46	1	3.46
Electronics: Power Supply	ISO	TBD	Unknown, to be determined by NAVSEA. Recommend find computer supply at Amazon or Newegg	TBD	100.00	1	100.00
Fasteners for Motor Mounts							
Bolts for Motor Mounts	Bravo	91236A546	¼”-20 Zinc Plated, STL, 100 in pckg	McMaster.com	6.94	1	6.94
Nuts for Bolts	Bravo & Golf	91845A029	¼”-20 Zinc Plated Grade 2 Steel 100 in pckg	McMaster.com	2.68	1	2.68
Mounting Screws	Bravo	91735A144	#6-32 Thread, 50 in pckg	McMaster.com	4.16	1	4.16
Tensioner Shaft	Bravo, Delta, Echo	2435K3	½” Shaft Diameter	McMaster.com	8.83	3	26.49
Tensioner Nuts	Bravo, Delta, Echo	90480A030	5/16”-18 Thread, Machine Screw Hex Nuts	McMaster.com	5.87	1	5.87
Mounting Nuts	Delta	90631A411	#10-32 Thread, Zinc Plated, Nylon-Insert Hex Locknuts, 100 in pckg	McMaster.com	2.81	1	2.81
Washers	Echo	90126A505	#4 Size, 0.02” thick, 100 in pckg	McMaster.com	1.09	1	1.09
Mounting Screws	Echo	90272A106	#4-40 Thread, ¼” length, 100 in pckg	McMaster.com	1.36	1	1.36
Bolts for Mounts	Golf	91309A550	2” Long, Fully Threaded, ¼”-20 Thread, Zinc Plated, 50 in pckg	McMaster.com	5.77	1	5.77

GRAND TOTAL: $3271.00

APPENDIX D: Analysis Hand Calculations

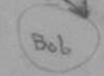
Bob (Moment of Inertia) $\omega = 60$ rpm 1/23/12

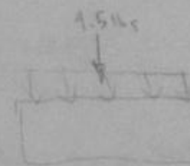
$T = I\alpha + F_f r$



Calculate F_f

4.5 lbs F_f mass of star clips





Cast Stainless Steel

$\boxed{m = 5.04 \text{ lbs}}$ (hollow wheels w/ 1/16" wall thickness and solid steel 3/4" rod)

$\Sigma F_x = 0 = F_f\cos45° - F_p\cos45° + N\cos45° \rightarrow F_p\cos45° = \frac{F_f}{\mu_s}\cos45° + F_f\cos45°$

$F_p = F_f\left(1 + \frac{1}{\mu_s}\right)$

$\Sigma F_y = F_p\sin45° + N\sin45° - F_f\sin45° - mg = 0$

Moment of Inertia

$\boxed{I = 14.95 \text{ lb-in}^2}$

$F_f\sin45° - \frac{F_f}{\mu_s}\sin45° + mg = F_p\sin45° \rightarrow F_f\left(1 - \frac{1}{\mu_s}\right) + \frac{mg}{\sin45°} = F_p$

$\frac{4.5 \text{ lbs}}{170 \text{ clips}} = \frac{x}{1000 \text{ clips}}$

$x = 26.5$ lbs

Research

Belts

Tensioners

Calculate/Design

I, α, F_f, T, required gear ratios

Gearbox design

Motor mounts

$mg = 26.5$ lbs

$N = \frac{F_f}{\mu_k}$

$N = \frac{F_{f\,max}}{\mu_s}$

$F_f\left(1 + \frac{1}{\mu_s}\right) = F_f\left(1 - \frac{1}{\mu_s}\right) + \frac{mg}{\sin45°}$

$F_f\left(\frac{2}{\mu_s}\right) = \frac{mg}{\sin45°}$

just assume $\mu_s = 0.35 \approx \mu_k$

chain-guide.com/basics/2-3-1-coefficient-of-friction.html

$F_f = \frac{\mu_s mg}{2\sin45°} = \frac{(0.35)(26.5 \text{ lbs})}{2\sin45°} = 5.45$ lbf

$r = 2.25$in

$T = \underline{I\alpha} + \underline{F_f r} = (14.95 \text{ lb in}^2)\left(2\pi \frac{\text{rad}}{\text{s}^2}\right) + (5.45 \text{ lbs})(2.25 \text{in})$

$T = 106.2$ lb-in

12.

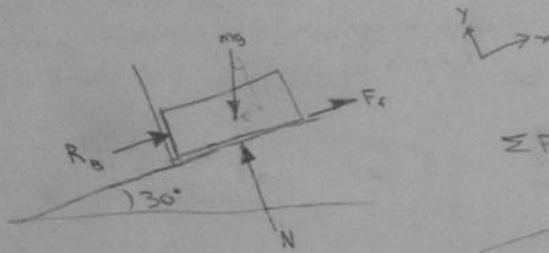
want to get to 60 rpm in 1 sec

$\alpha = \frac{\left(60\frac{\text{rev}}{\text{min}}\right)\left(\frac{2\pi \text{ rad}}{\text{rev}}\right)\left(\frac{1 \text{ min}}{60 \text{ sec}}\right)}{\text{sec}}$

$= 2\pi \text{ rad/sec}^2$

Bob Torque cont'd.

1/23/12



$\mu_s = 0.35$

$$\Sigma F_x = 0 = F_f + R_B - mg\sin 30^\circ$$

$$R_B = mg\sin 30^\circ - F_f$$

$$\Sigma F_y = 0 = N - mg\cos 30^\circ$$

$$N = mg\cos 30^\circ = (26.5\ lbf)(\cos 30^\circ)$$

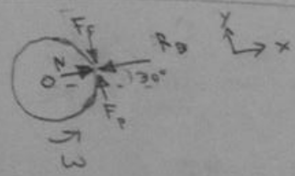
$$N = 22.95\ lbf$$

$$R_B = mg\sin 30^\circ - \mu_s N$$

$$= -(0.35)(22.95\ lbf) + (26.5\ lbf)\sin 30^\circ$$

$$R_B = 13.25 - 8.03\ lbf$$

$$\boxed{R_B = 5.22\ lbf}$$



$$\Sigma F_x = 0 = N - R_B$$

$$N = R_B$$

$$\Sigma F_y = 0 = F_f - F_p \rightarrow F_f = F_p$$

$$F_f = R_B \mu_s = (5.22\ lbf)(0.35)$$

$$\boxed{F_f = 1.83\ lbf}$$

$ma = kg\frac{m}{s^2}$

$$T = I\alpha + F_f r = \frac{(14.95\ lbm\cdot in^2)}{(32.2\ \frac{lbm}{slug})}\alpha + (1.83\ lbf)(2.25\ in)$$

$$T = (0.464\ slug\cdot in^2)(1.05\ \tfrac{rad}{s^2}) + 4.12\ lbf\cdot in$$

$\alpha = 1.05\ \frac{rad}{s^2}$

$$T = (0.464\ slug\cdot in^2)\left(\frac{1\ in^2}{144\ ft^2}\right)\left(1.05\ \frac{rad}{s^2}\right) + 4.12$$

for 5 sec wind-up to 50 rpm for Bob

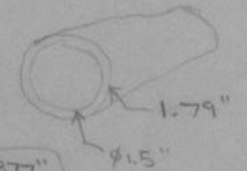
$$T = 0.003\ lbf\cdot in + 4.12\ lbf\cdot in$$

$$\boxed{T = 4.12\ lbf\cdot in}$$

$1\ lb_f = 1\ \frac{slug\cdot ft}{s^2}$

$1\ lb_f = 32.2\ \frac{lb_m\cdot ft}{s^2}$

Danica Frictional Torque 1/24/12



$N = 60$ rpm = 1 rev/sec

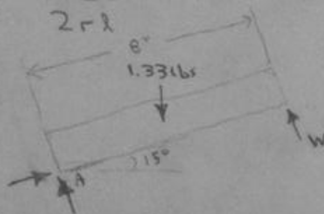
$\mu = ?$ dynamic viscosity (AKA absolute viscosity)

$r = \cancel{(1.5" + 0.145")/2 = 0.8225"}$ $\frac{1.754"}{2} = \boxed{0.877"}$

$l = 1$ "

using standard sizes for bronze sleeve bearings at McMaster-CARR

$P = \frac{W}{2rl}$ ← force on the bearing



$\circlearrowleft^{+} \Sigma M_A = -(1.33\text{ lbs})\, 4" \cos 15° + W \cdot 8" = 0$

$\boxed{W = 0.642 \text{ lbf}}$

$P = \frac{0.642 \text{ lbs}}{2(0.877")(1")} = \boxed{0.366 \text{ psi}}$

$c = \frac{0.0015"}{2}$ ← minimum tolerance for a 1.75" shaft

$= \boxed{0.0008"}$

(clearances can range from .00075" - .0015". smallest is the most conservative estimate)

μ for SAE 10 oil lube @ 75° F (pg. 621 Fig. 12-2 Shigley's Mechanical Engineering Design 9th Ed.)

pg. 635 Fig. 12-14

↳ $\mu = 1 \times 10^{-5}$ reyn

$= \boxed{1 \times 10^{-5} \frac{\text{lbf} \cdot \text{s}}{\text{in}^2}}$

or see Fig. 12-18

$f = 2\pi^2 \frac{\mu N}{P} \frac{r}{c} = 2\pi^2 \frac{(1\times 10^{-5} \frac{\text{lbf}\cdot\text{s}}{\text{in}^2})(1 \frac{\text{rev}}{\text{sec}})}{0.366 \frac{\text{lbf}}{\text{in}^2}} \cdot \left(\frac{0.877\text{in}}{0.0008\text{in}}\right) = 0.591$ ✱

✱ See pg. 662 Table 12-9 for other bearings w/ much lower f ($f = .05$)

$T = fWr = (0.591)(0.642 \text{ lbs})(0.877\text{in}) = 0.333$ in-lbs

× 4 cylinders

$\boxed{T_{tot} = 1.33 \text{ in-lbs}}$

Don't think Sommerfeld # will work w/ such a low pressure and load, and maybe doesn't apply to sleeve bearings.

(Strange that higher loads give lower coefficient of friction)

Danica (Moment of Inertia) $\omega = 60 rpm$ 1/22/12

$I = mr^2$

Mass of brass cylindrical chute (Danica)

$\boxed{m = 1.33 lbs}$

$I = (1.33 lbs)(0.75 in)^2$

$= 0.75 lb \cdot in^2$

Moment of inertia of 1× Danica

$\boxed{I = 0.63 lb \cdot in^2}$

$I_z = \frac{1}{2} m (r_1^2 + r_2^2)$

$= \frac{1}{2}(1.33 lbs)(0.625^2 + 0.75^2) in^2$

$= 0.63 lb \cdot in^2$

Total $I_z = 0.63 \times 4 \ lb \cdot in^2$

$\boxed{I = 2.54 lb \cdot in^2}$

Erika's Doors (Moment of Inertia) $\omega = 60 rpm$ max 100 rpm

Cast stainless steel

$m = 0.00$ pounds

$I = 0.00 lb \cdot in^2$

*(insignificant)

APPENDIX E: Electronics Package

ELECTRONIC ASSEMBLY

The following guide details how the microcontroller, H-bridges, Motors, and Bump Sensor should be setup. Refer to the Bill of Materials (BOM) for the necessary components to purchase. A power supply with a +5V rail and +12V rail needs to be acquired. The schematics will be presented as follows:

1. Microcontroller Setup
2. Microcontroller Wiring to H-bridges
3. H-bridge Setup and Motor Wiring
4. Power supply

1. Microcontroller Wiring Diagram:

In the following schematic, it is detailed how the microcontroller will need to be wired. In other words, this is the necessary setup that a microcontroller needs to power up. This schematic excludes the wiring for the rest of the system (i.e. h-bridge wiring).

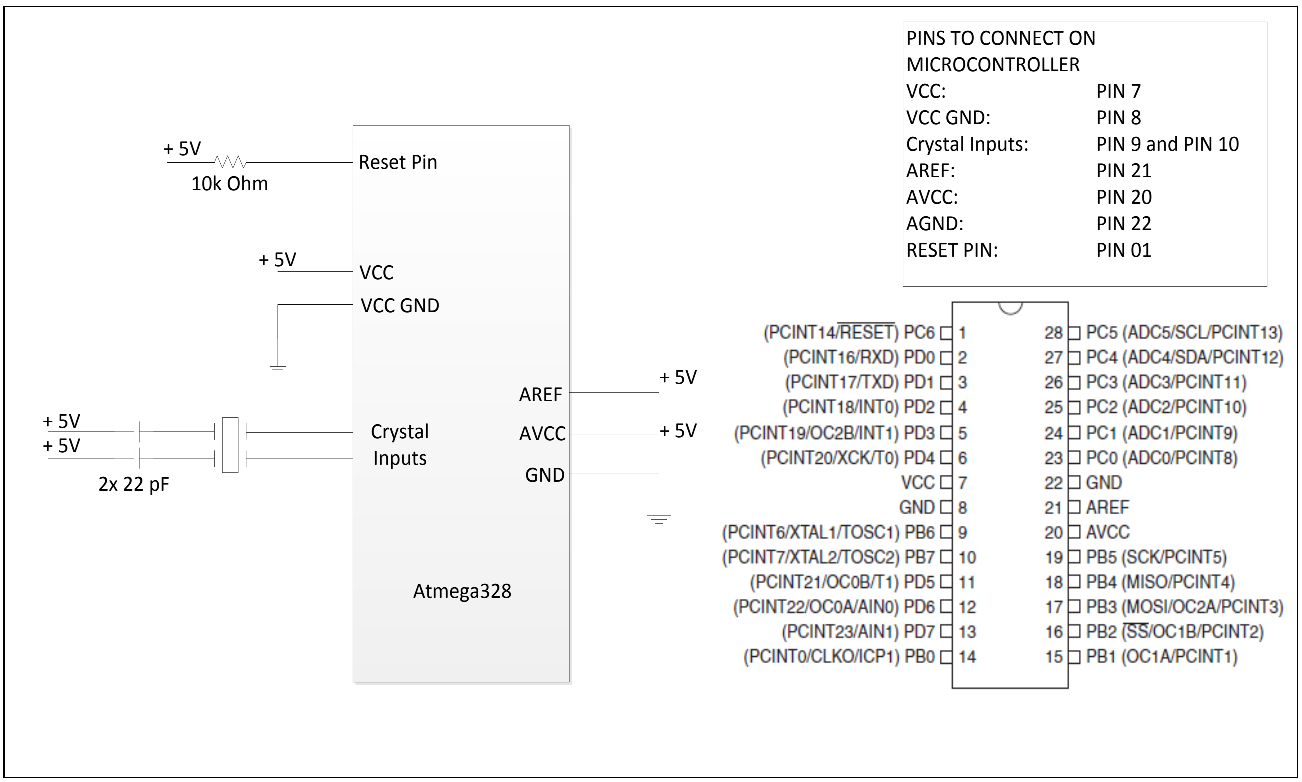


Figure EA1: Microcontroller detailing microcontroller setup. The pin diagram from the ATMEGA328 datasheet was also copied here, for convenience. Refer to the datasheet for more information.

As previously mentioned, a power supply will need to supply a +5V rail. Also, it is recommended to use a breadboard as the utilization of such will make wiring of the microcontroller purchased simpler. Also, a common ground is required for the microcontroller – failure to use a common ground will result in erratic microcontroller behavior.

2. Microcontroller to H-Bridge Wiring Diagram:

After having wired up the microcontroller, it should be ready for use. Programming will be necessary, but that is included in other documentation. The microcontroller's job is to control the motors of ISO. The Atmega328 will interface with the motors via an H-bridge. Simply put, an H-bridge controls the speed and direction of the motors via input logic voltage and a Pulse Width Modulated (PWM) signal. Therefore, the microcontroller needs to give these inputs to the h-bridges. The following schematic details these connections.

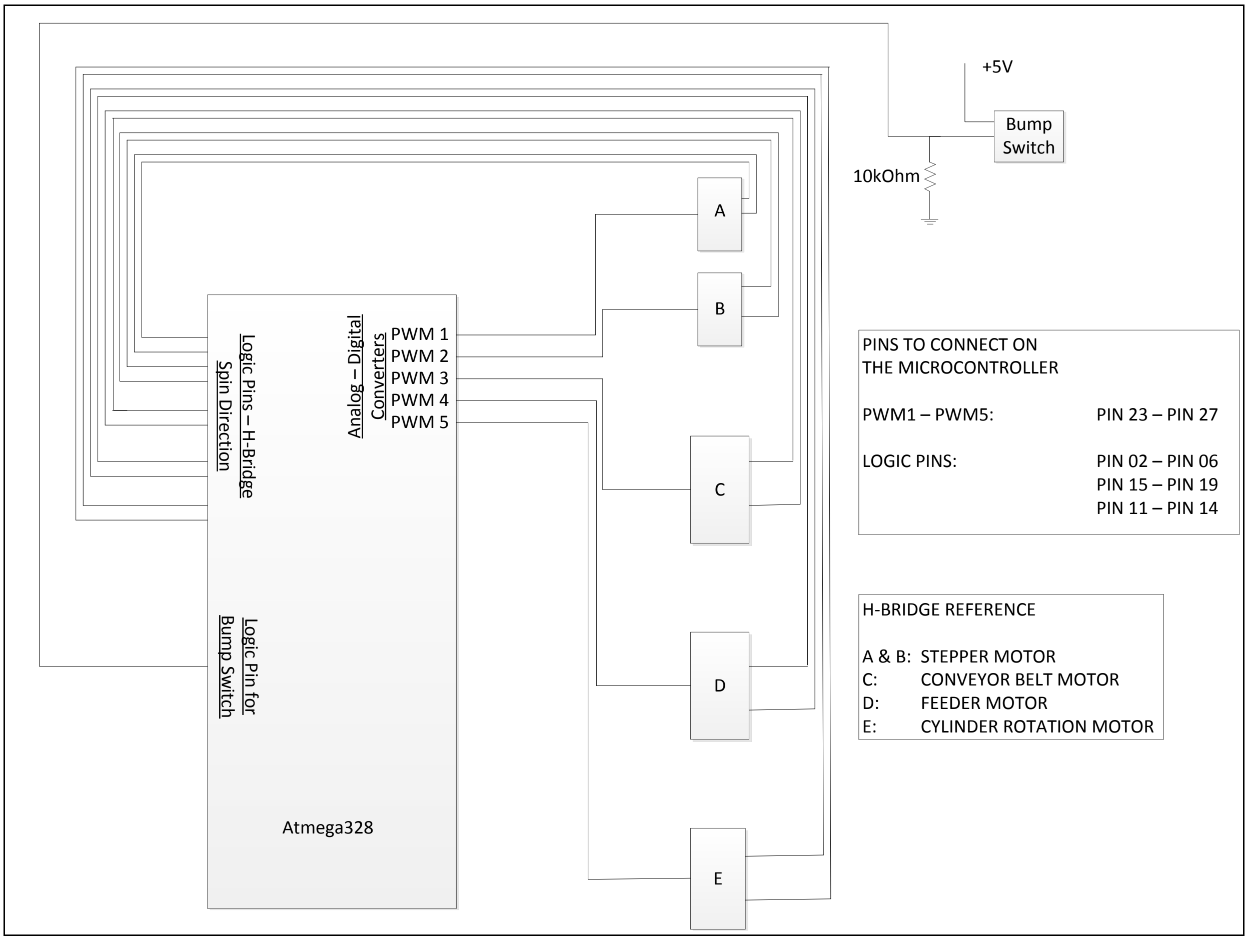


Figure EA2: Overview of the microcontroller wiring diagram to the h-bridges for each of the motors. The design calls for five (5) h-bridges – two (2) for the stepper motor, and one for each remaining motor.

The schematic shows that each of the H-bridges requires a PWM signal. PWM signals are generated via the Digital-Analog Converters, and which are setup in the code (these are pins 23-27 on the pin diagram of the Atmega328). A PWM signal is an oscillatory signal that the h-bridges use to determine how fast to spin the motor. The higher the PWM signal, the faster that the motor spins, or rather, the more current that is supplied to the motor.

The logic pins that are connected to each of the H-bridges are required to tell the motors to spin Clockwise (CW), Counter-Clockwise (CCW), or Brake. Given a specific logic input, the h-bridge will allow

current to flow one way or the other. Another feature of the H-bridge allows for the motors to brake, or in other words, provide electrical resistance to the motor's rotation. The logic pins can be any free pin on the microcontroller that is not being used. Pins in Ports B, C, and D meet this qualification. The free pins that are available on the board are shown in a text box on the schematic.

The last item to wire up to the microcontroller would be the bump switch. The bump switch is a digital component of the system – when the switch is "bumped", contact is made, resulting in a high signal sent to the microcontroller. When the bump sensor has not made contact, the signal is "low," as the logic pin will see ground. As with the H-bridge logic pins, any pin that is open may be used for the bump sensors.

<u>3. H-Bridge Setup and Motor Wiring</u>:

The microcontroller wiring has been completed. Now, the wiring for each of the H-bridges is required. As can be seen in the schematics above, the microcontroller has three (3) inputs to each H-bridge: two logic pins and a PWM signal. Each H-bridge also requires a few more inputs and has a couple outputs. For each type of H-bridge, a schematic will be shown below to detail the necessary wiring for each.

Stepper Motor H-Bridge (SN754410)

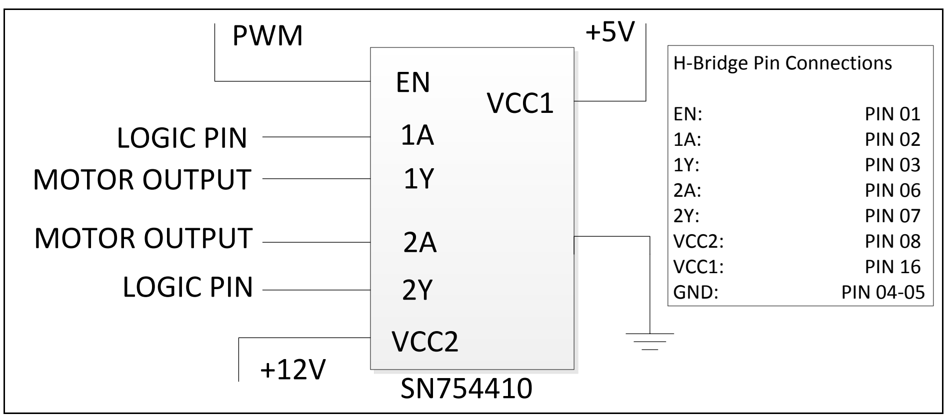


Figure EA3: H-Bridge for the Stepper Motors, the H-Bridge labeled A and B in Figure EA2

There are two (2) H-bridges for the stepper motor. A stepper motor is unique from a regular DC motor in that it has four (4) motor inputs which allow it to move in precise increments. The stepper motor can move in ~2° increments given the condition output by the microcontroller to the two h-bridges. In order to provide this motion, the motor needs to have four inputs, and thus the need for two h-bridges.

The H-bridges need two separate input voltages. The first input voltage is for the logic voltage for the H-bridge, which comes off the +5V rail. The second input voltage is for the motors, which comes off the +12V rail. The Enable pin on this h-bridge allows the flow of current to and from the motor. Thus, by sending the Enable pin a PWM signal, in theory you should be able to drive the motor at different speeds. Through coding and testing it will be determined if a PWM will suffice for the control of the motor. However, it may be sufficient to just send a single pulse of +5V to the enable pin to move the motor at increments, instead of a sinusoidal PWM signal.

Rotating Cylinders, Feeder, and Conveyor Motor H-Bridges (VNH3SP30 and VNH2SP30)

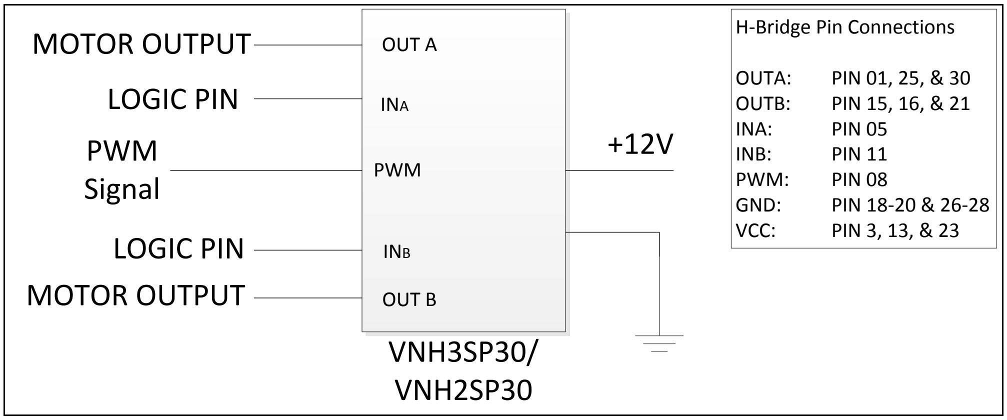


Figure EA4: H-Bridge diagrams for both VNH3SP30 and VNH2SP30 for the Rotating Cylinders, the Feeder, and the Conveyor Motor, labeled as C-E in figure EA2 above. See pin diagram in appendix.

All other motors besides for the stepper motor will utilize either the VNH3SP30 or the VNH2SP30 H-Bridge. The conveyor belt motor will utilize the VNH2SP30, as it has a higher capacity than the VNH3SP30. However, both chips utilize the same pin configuration and operation. There are multiple pins on this h-bridge when compared to the SN754410 chip, however the concept remains the same. Two logic pins, INA and INB, control the motor's condition: spin CW, CCW, or brake. Also, a PWM signal is sent to the PWM pin. In this manner, the speed of the motor is controlled.

These H-bridges appear to only need a +12V supply voltage. This voltage will supply both the logic and the motor voltage requirements. Given that these are intended for automotive use, the +12V makes sense given that the chip would internally regulate to +5V for the logic side of the chip. This is speculative, so testing is needed to confirm.

Also, notice that there are multiple pins for one function. For instance, one motor output has 3 available pins on the chip. It is only necessary to hook up the motor output to one of the available pins. And lastly, all grounds need to be connected to a common ground.

4. The Power Supply

A power supply was not specifically selected within the report or the bill of materials. The requirements of the power supply include: a 5-Volt and 12-Volt rail along with sufficient continuous amperage (as determined from the motors).

Team SDS' original intentions were to modify a computer power supply by directly accessing the 5-Volt and 12-Volt rail of a 700+ Watt power supply. A computer power supply suits the needs of the projects as it provides both a logic power supply and a motor power supply. The team was unable to modify, and thus generate an instruction assembly and wiring diagram, due to budget constraints and the inability to purchase a power supply.

PROGRAMMING OUTLINE

The electronics assembly above is used to control the motors of ISO. The main purpose is to control the deposit of star clips into the trays. This is accomplished by controlling the following:

- **Feeder Motor, aka Bravo Motor**: controls the amount of star clips taken from the storage hopper and fed into the processing section of ISO (everything after Alpha, essentially). The speed of rotation, as well as whether the motor will be run constantly or at set intervals, can be controlled.
- **Rotating Cylinders Motor, aka Delta Motor**: controls the spin of the cylinders. Based upon testing, the rate of rotation for the cylinders will be set in order to accommodate the most efficient orientation of the star clips.
- **Stepper Motor, aka Echo Motor**: controls when a star clip is deposited into the tray. Given the current position of the tray, the controller will spin the gates appropriately to drop one star clip into the tray receiver cups. This control is activated because the position of the tray will be known via the bump sensor.
- **Conveyor Belt Motor, aka Golf Motor**: controls when and how fast the conveyor belt will spin. Given the position of the tray, the conveyor belt motor will move the tray from row to row of the tray. This way, the position of the tray is controlled and the star clips are dropped at specific locations – into the tray receiver cups.
- **Bump Sensor**: indicates what position the tray will be at. The tray will have notches or depressions that will allow for the change of state of the bump sensor. When the bump sensor encounters the depression or the notch, its state will change from either a digital '1' or '0'. This allows for the microcontroller to know that the tray is in position for the star clips. The controller then responds accordingly for each motor.
- **E-Stop**: a simple switch will be provided for an E-Stop, just in case the operator needs to kill the operation. The E-Stop will kill set the power to the motors, bringing them to a stop.

The above is a simple description of the different components of ISO that require control. It is the microcontroller's job to control these components. In order to accomplish this, it needs to program accordingly. As stated in the Electronics Assembly and listed in the Bill of Materials (BOM), the microcontroller that will be used is an AVR Atmega328. In order to program this chip, it is required that a programmer and preferably a USB to Serial communications board be used. The programmer allows for the ability to flash the code to the chip, and the USB to serial communication helps for programming and debugging the code – a necessity in mechatronics programming. The following are the products used to program the chip:

- Pocket AVR Programmer, PGM-09825 from Sparkfun.com, which allows for the microcontroller to be programmed via USB.
- Breakout Board for FT232RL USB to Serial, BOB-00718 from Sparkfun.com, which allows for a USB to microcontroller serial port, for debugging purposes.

The Code Outline

In programming an AVR microcontroller, the language C or C++ is utilized along with a software suite such as AVRDUDE. The scope of this document does not include how to write code for the microcontroller or use AVRDUDE – there are numerous online tutorials that are sufficient. The most important aspect to realize about a microcontroller is that it is executes linearly – it can only execute one task at a time, one line of code, and it proceeds from one line of code to the next, operating in loops. However, it operates *extremely* fast, capable of executing millions of lines a code per second.

The following diagram details the Task-State diagram that will be used for the program that will control ISO. The program will be modeled as a finite state machine. The finite state machine will consist of a total of eight (8) different states

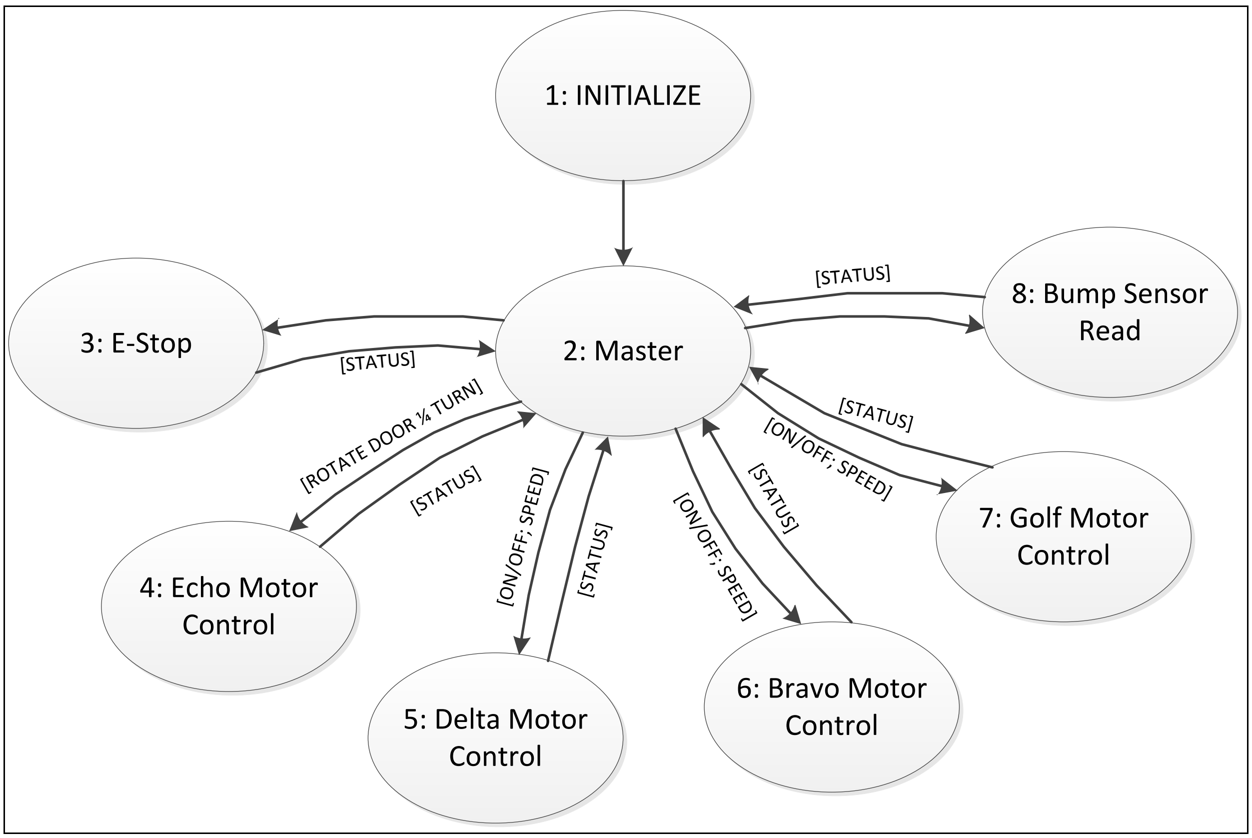


Figure PO1: Task-State Diagram, illustrating the overall code for ISO

The above figure gives a basic overview of the different states that the program will have, as well as the different parameters that will be sent to and from the states. The following better describes the function of each of the states:

1. **Initialize State**: This initializes all of the components, each motor, bump sensor and switch. Additionally, it also initializes any counters and other code parameters that are needed. The code is only in this state once, when the chip is first powered up.

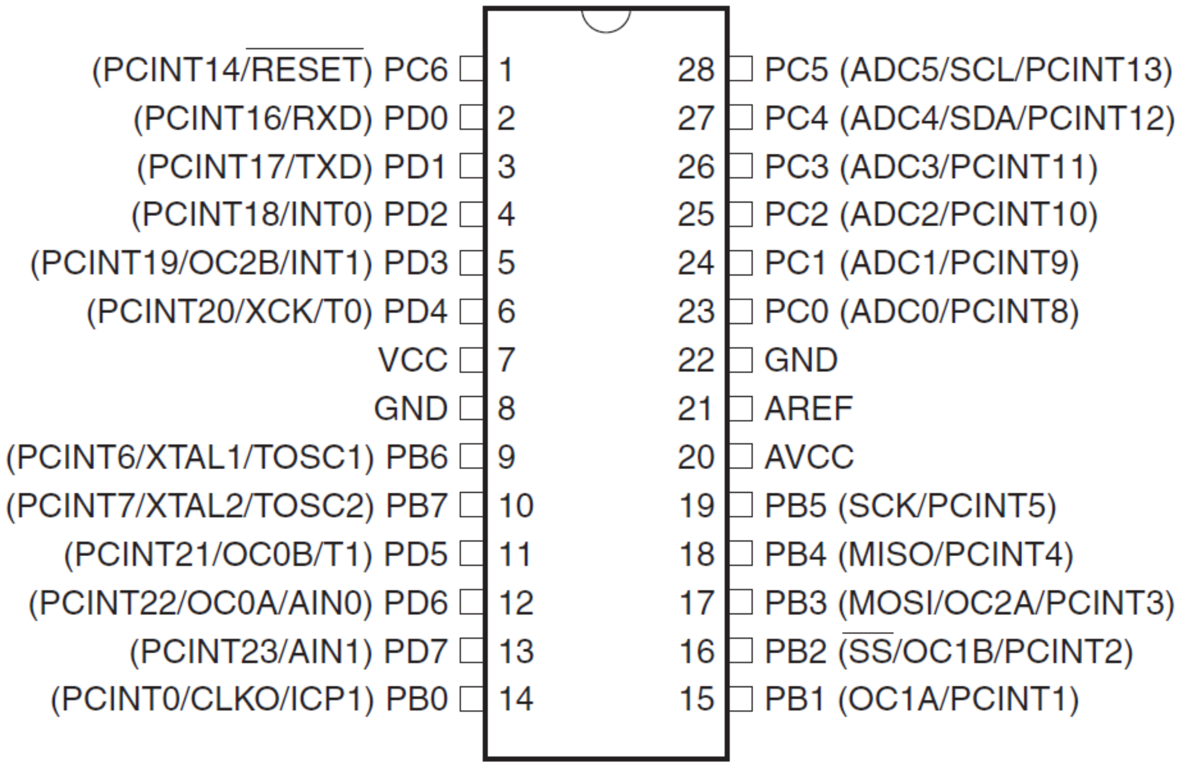
2. **Master State**: This is the brain of the program, and basically “understands” what ISO is currently doing. It commands the motors to turn or off and to spin at specific rates. It also has the necessary logic to know when to rotate the Echo motor, and thus the doors to deposit a star clip. Additionally, it will read the status of the E-Stop Switch and the status of the Bump Sensor in order to determine if either an emergency stop is required or star clips need to be deposited, respectively.
3. **E-Stop**: This state checks to see if the E-Stop switch has been toggled on, thus necessitating an emergency stop of all motors. Master asks for a status, and if the status is ‘STOP’, then Master will need to take the necessary measures to stop all motors.
4. **Echo Motor Control**: This motor control interacts with the stepper motor, and makes sure that the doors only rotate ¼ turn every request from Master. It will send back a status of ‘Done’ once the task has been completed.
5. **Delta Motor Control**: This motor control interacts with the rotating cylinders motor. Master will send an on/off command, and a speed command. It will send back a status of ‘Done’ once the task has been completed.
6. **Bravo Motor Control**: This task is the same as Delta Motor Control. See State 5.
7. **Golf Motor Control**: This task is the same as Delta Motor Control. See State 5.
8. **Bump Sensor Read**: This state is requested when Master wants to know whether the bump sensor has been engaged or not. The program will enter this state most often, as it is required to check on the position of the tray, and precise alignment is needed. It will simply check to see if the pin is ‘HIGH’ or ‘LOW’ and send this status back to Master. Master will then act accordingly.

CODE TO BE WRITTEN BY BUILDER OF DEVICE

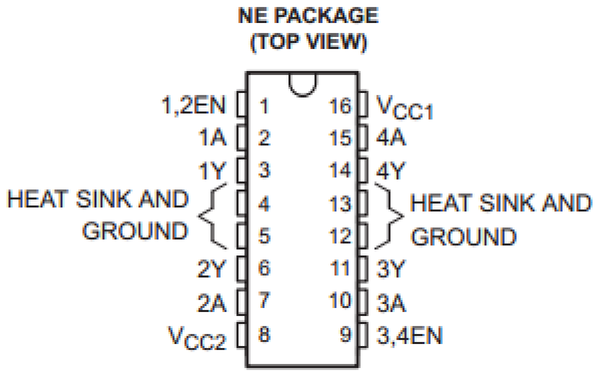
Due to budget constraints, the above electronics system and code was never generated. In order to effectively program, a system needs to be in place in order to test the code. Each device, such as the microcontrollers, h-bridges, and motors are all unique – which makes it impossible to program without actually having the devices to test the program. Code could have been written without a system, but it would have been useless as it would have been filled with bugs and could even be potentially dangerous due to the unknown behavior of the system to the original programmer. Therefore, it is in the best interests of NAVSEA to write and debug the code themselves, and as such, no program code will be provided. What has been provided is a sufficient design template for the electronics package.

Sub-Appendix E: Electronic Assembly

Pin Diagram for Atmega328 Microcontroller

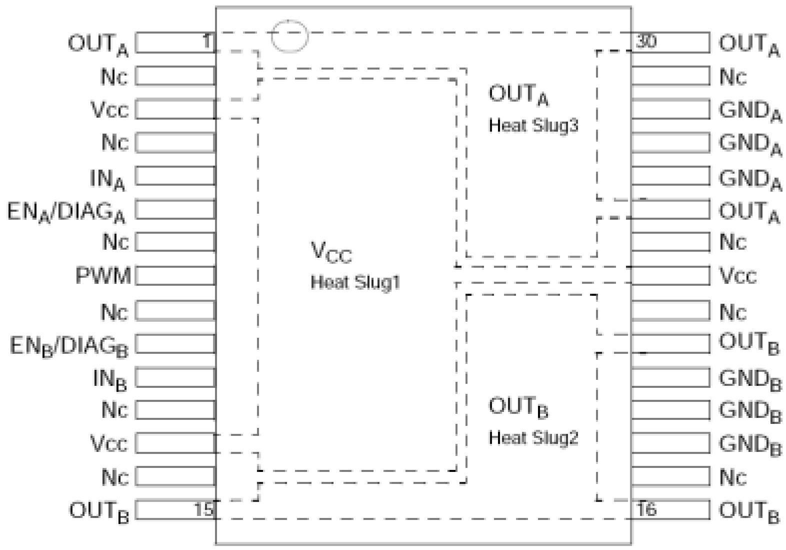


Pin Diagram for the Stepper Motors (SN754410)



Pin 1	1,2 Enable (Enables Motor 2)
Pin 2	1A, Pin Logic Input for Motor 1
Pin 3	1Y, Pin Output for Motor 1
Pin 4	Heat Sink and Ground
Pin 5	Heat Sink and Ground
Pin 6	2Y, Pin Output for Motor 1
Pin 7	2A, Pin Logic Input for Motor 1
Pin 8	Motor Supply Voltage
Pin 9	3,4 Enable (Enables Motor 2)
Pin 10	3A, Pin Logic input for Motor 2
Pin 11	3Y, Pin Output for Motor 2
Pin 12	Heat Sink and Ground
Pin 13	Heat Sink and Ground
Pin 14	4Y, Pin Output for Motor 2
Pin 15	4A, Pin Logic Input for Motor 2
Pin 16	Logic Supply Voltage (5V)

Pin Diagram for the Conveyor, Rotating Cylinders, and Feeder H-Bridges (VNH3SP30-E & VNH2SP30-E)



Pin No	Symbol	Function
1, 25, 30	OUT_A, Heat Slug3	Source of high side switch A / Drain of low side switch A
2, 4, 7, 9, 12, 14, 17, 22, 24, 29	NC	Not connected
3, 13, 23	V_{CC}, Heat Slug1	Drain of high side switches and power supply voltage
6	$EN_A/DIAG_A$	Status of high side and low side switches A; open drain output
5	IN_A	Clockwise input
8	PWM	PWM input
11	IN_B	Counter clockwise input
10	$EN_B/DIAG_B$	Status of high side and low side switches B; open drain output
15, 16, 21	OUT_B, Heat Slug2	Source of high side switch B / Drain of low side switch B
26, 27, 28	GND_A	Source of low side switch A[1]
18, 19, 20	GND_B	Source of low side switch B[1]

1. GND_A and GND_B must be externally connected together.

APPENDIX F: Assembly Instructions

The following document is included and may be printed separately for assembly instructions. As this appendix is intended to be a separate document unto itself, the page numbers are not continuous with the final report for the project.

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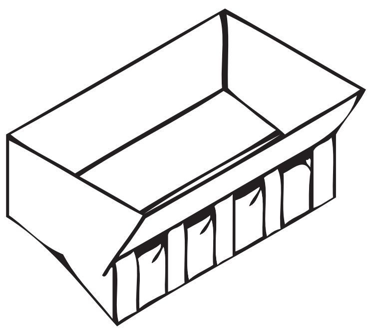
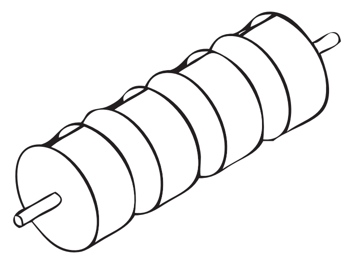
Indepedent Star-Clip Organizer Sub-Assembly Manufacturing Instructions

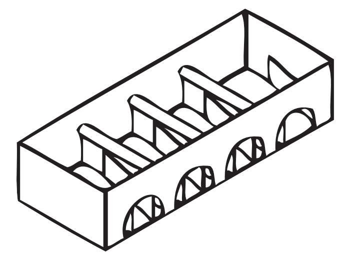
By Chris Gonzales, Greg Lovasik, and Daniel Silveira
Team SDS



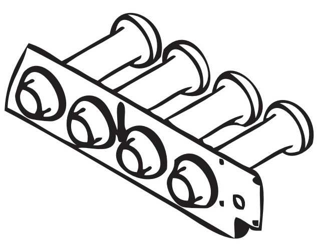
ALPHA



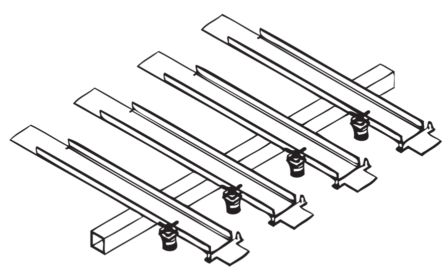
BRAVO



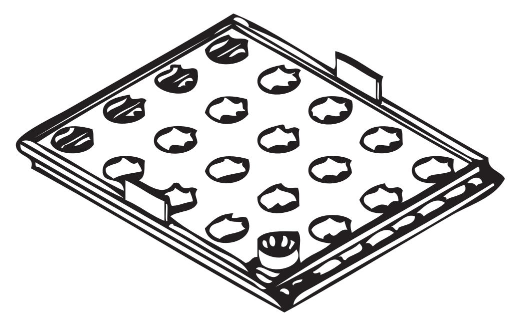
CHARLIE



DELTA



ECHO



FOXTROT

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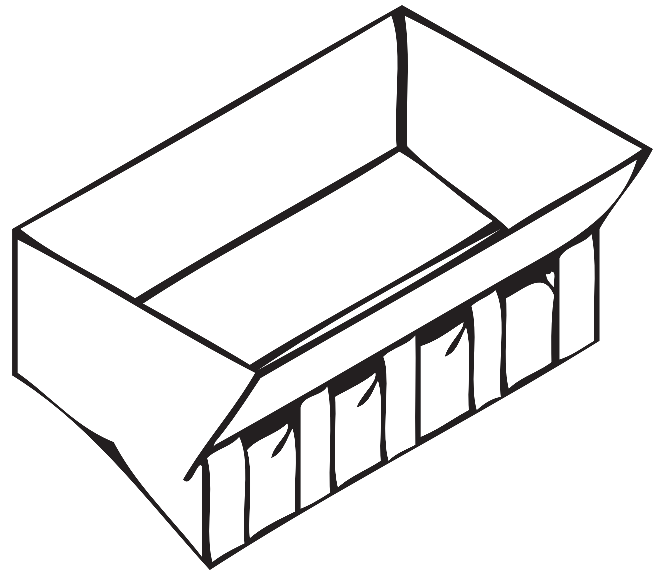
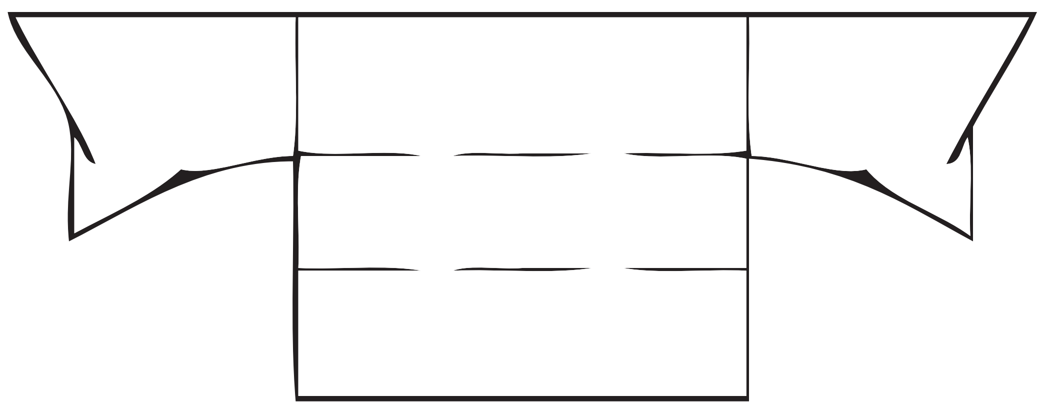
Alpha Assembly

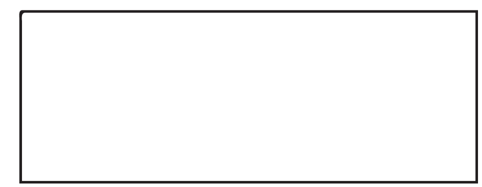


You will need the following part numbers (and quantities) to assemble Alpha:

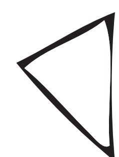
A1000
(1X)



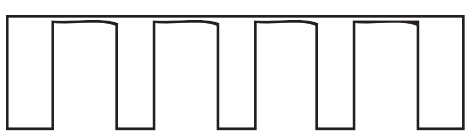
A1020
(1X)



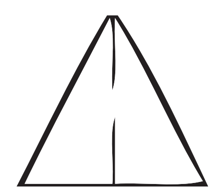
A1030
(2X)



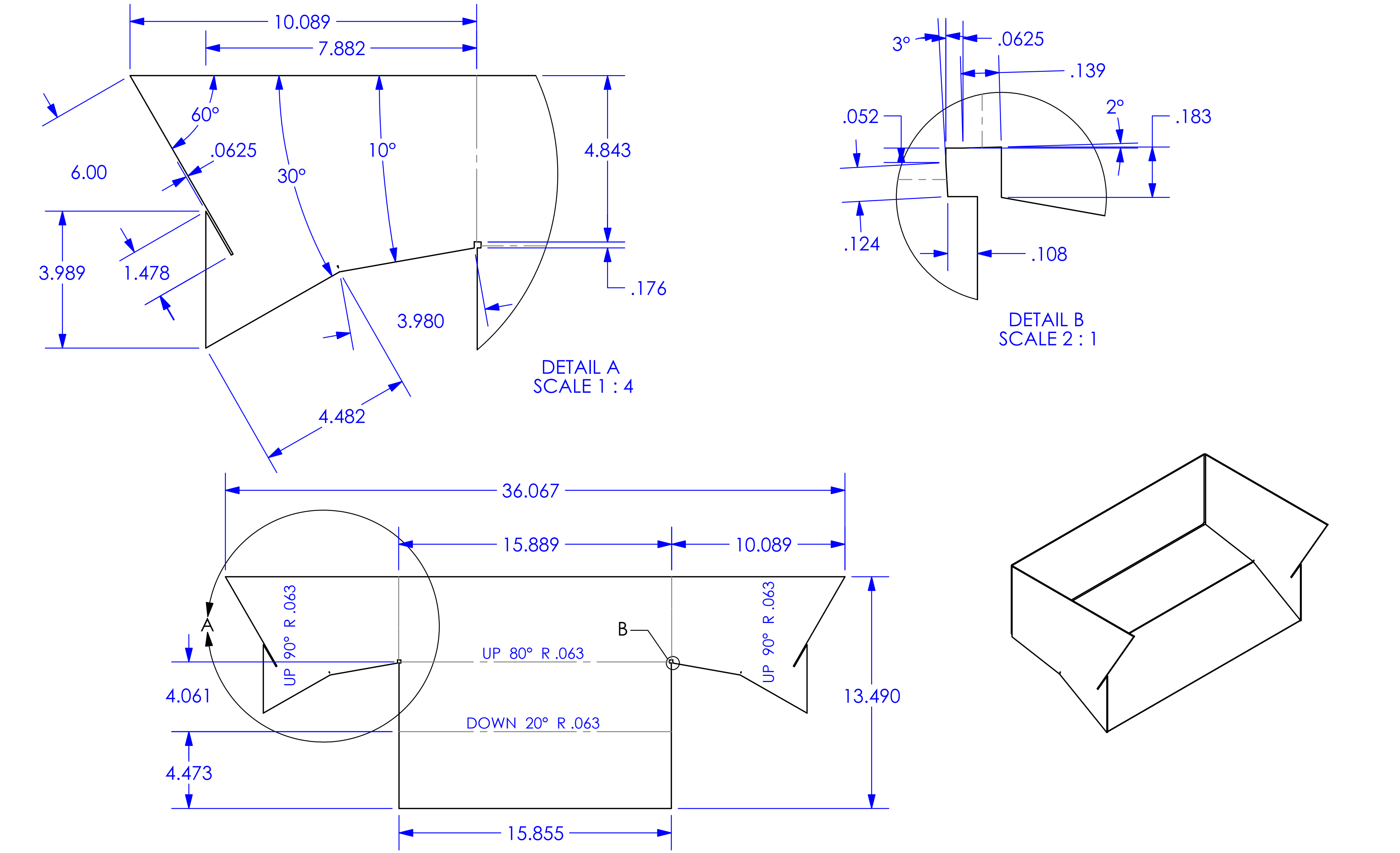
A1010
(1X)



A1040
(3X)

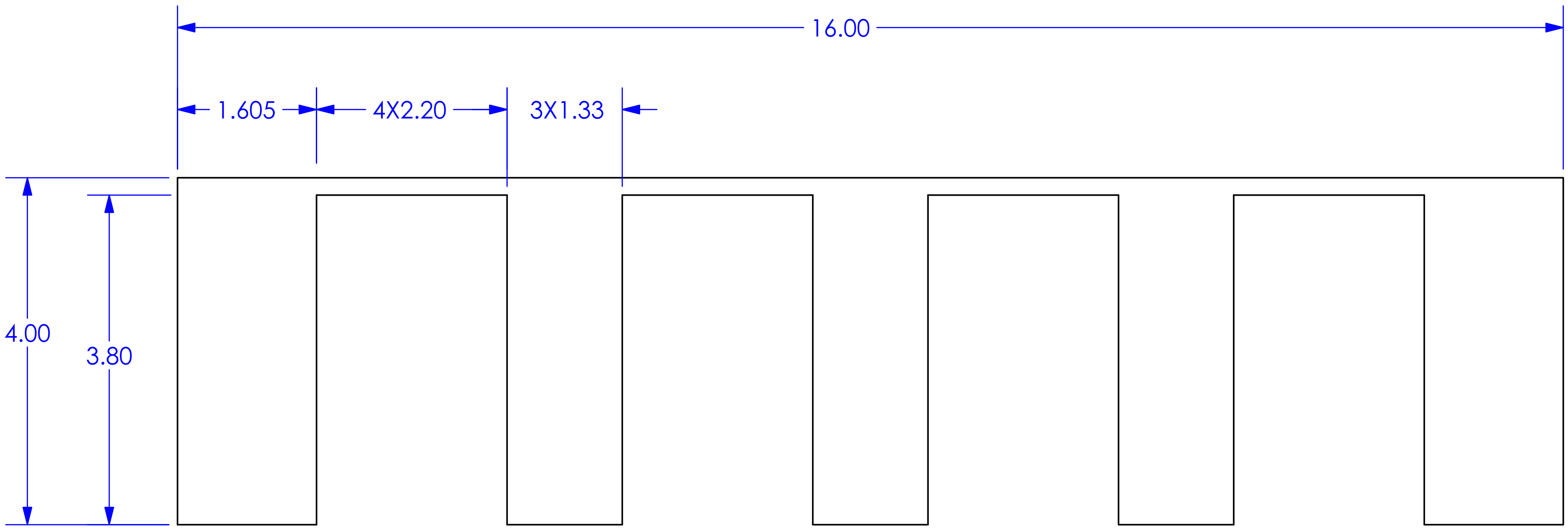


See pages 2-8 for detailed parts and assembly instructions for Alpha.

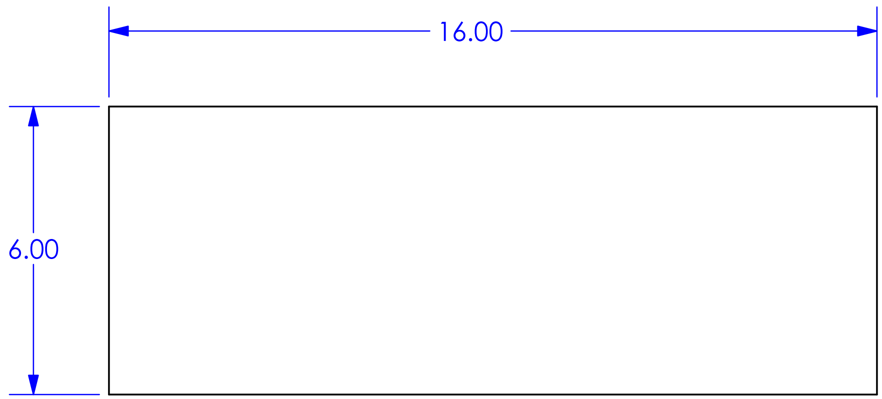


ALPHA PROCEDURE:
1. Follow the cut and bend dimensions for part # A1000.

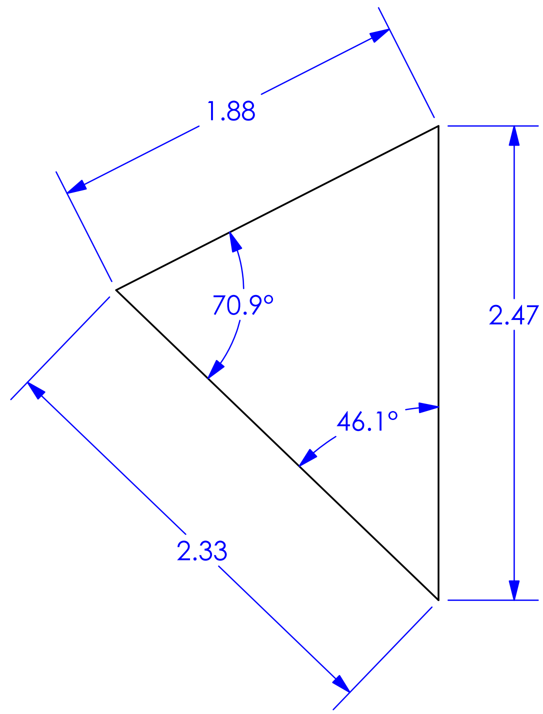
DATE: 2/27/2012	UNITS: INCHES	MATERIAL: TYPE 316 S.S., SHEET METAL 1/16"
TOLERANCE: 0.01	SCALE: 1:8	TITLE: SHEET METAL LAYOUT, HOPPER BODY
PART #: A1000	NEXT ASSY #: A100	NAME: CHRISTOPHER GONZALES, TEAM SDS
	DRAWING #: 1000	Page 2



ALPHA PROCEDURE: 2. Follow the cut dimensions for part # A1010.	DATE: 2/27/2012	UNITS: INCHES	MATERIAL: TYPE 316, S.S. SHEET METAL 1/16"
	TOLERANCE: 0.01	SCALE: 1:2	TITLE: HOPPER FACEPLATE
	PART #: A1010	NEXT ASSY #: A110	NAME: CHRISTOPHER GONZALES, TEAM SDS
		DRAWING #: 1010	Page 3



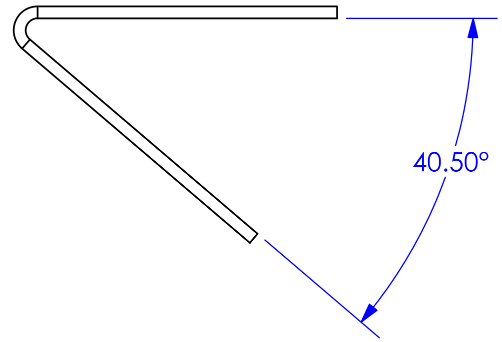
ALPHA PROCEDURE: 3. Follow the cut dimensions for part # A1020.	DATE: 2/27/2012	UNITS: INCHES	MATERIAL: TYPE 316, S.S. SHEET METAL 1/16"
	TOLERANCE: 0.01	SCALE: 1:4	TITLE: HOPPER ANGLED FACEPLATE
	PART #: A1020	NEXT ASSY #: A110	NAME: CHRISTOPHER GONZALES, TEAM SDS
		DRAWING #: 1020	Page 4



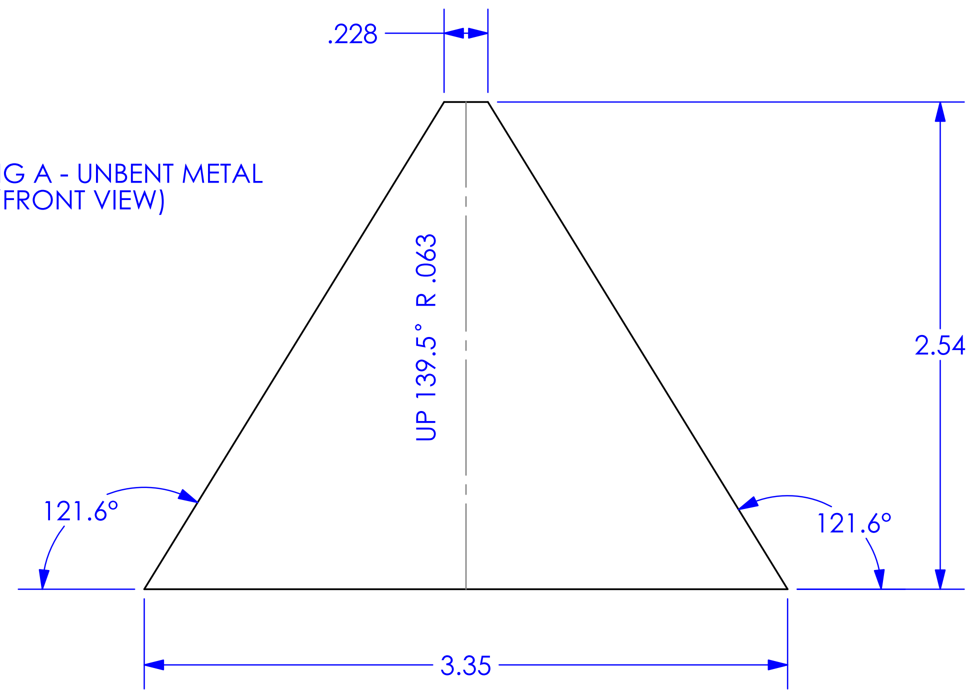
ALPHA PROCEDURE:
4. Cut 2X part # A1030 using the dimensions specified by the drawing.

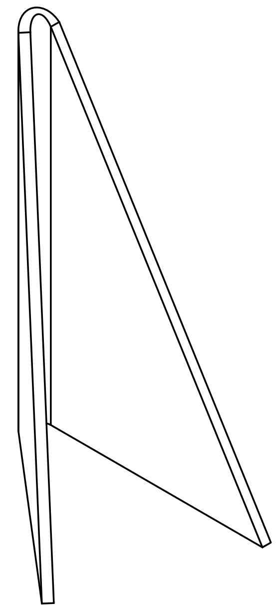
DATE: 5/13/2012	UNITS: INCHES	MATERIAL: TYPE 316, S.S. SHEET METAL 1/16"
TOLERANCE: 0.01	SCALE: 1:1	TITLE: SIDE DIVIDER FOR HOPPER
PART #: A1030	NEXT ASSY #: A100	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 1030	Page 5

DRAWING B - BENT METAL
(TOP VIEW)



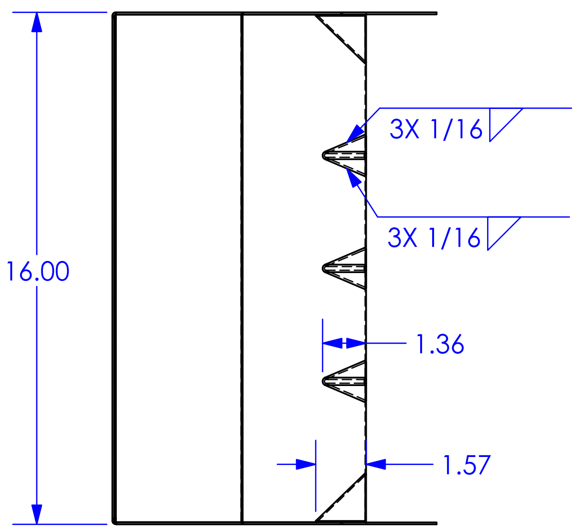
DRAWING A - UNBENT METAL
(FRONT VIEW)

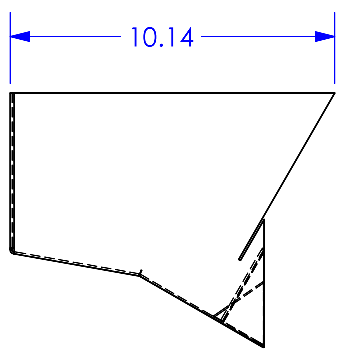


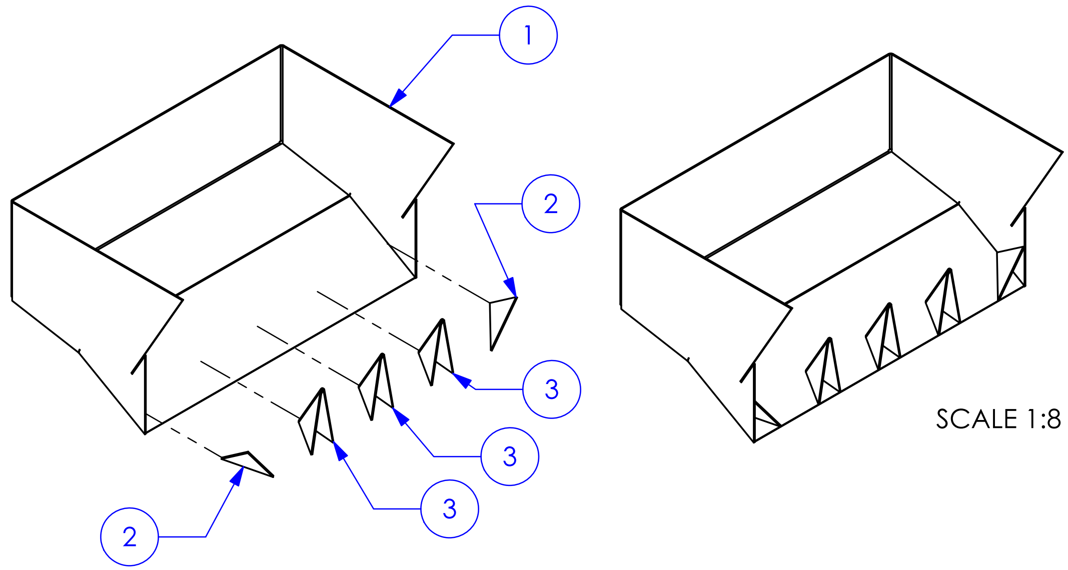


ALPHA PROCEDURE: 5. Cut and bend 3X part # A1040 using the dimensions specified by the drawing.	DATE: 5/13/2012	UNITS: INCHES	MATERIAL: TYPE 316, S.S. SHEET METAL 1/16"
	TOLERANCE: 0.01	SCALE: 1:1	TITLE: MAIN DIVIDER FOR HOPPER
	PART #: A1040	NEXT ASSY #: A100	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 1040	Page 6

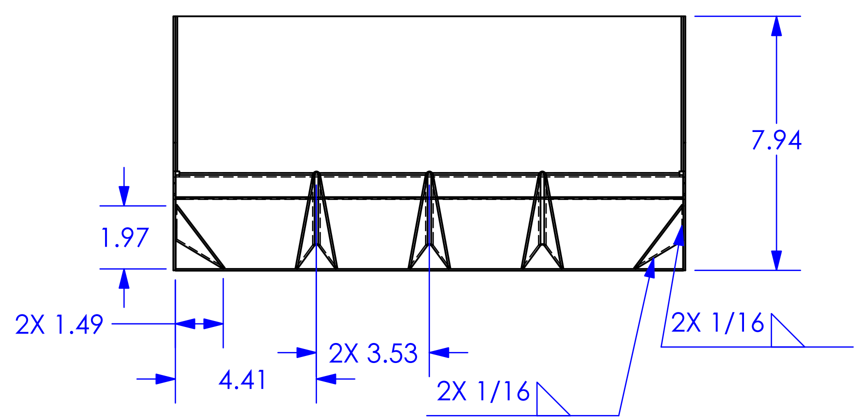
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	A1000	0.06" STAINLESS STEEL BENT SHEET	1
2	A1030	0.06" STAINLESS STEEL SHEET	2
3	A1040	0.06" STAINLESS STEEL BENT SHEET	3





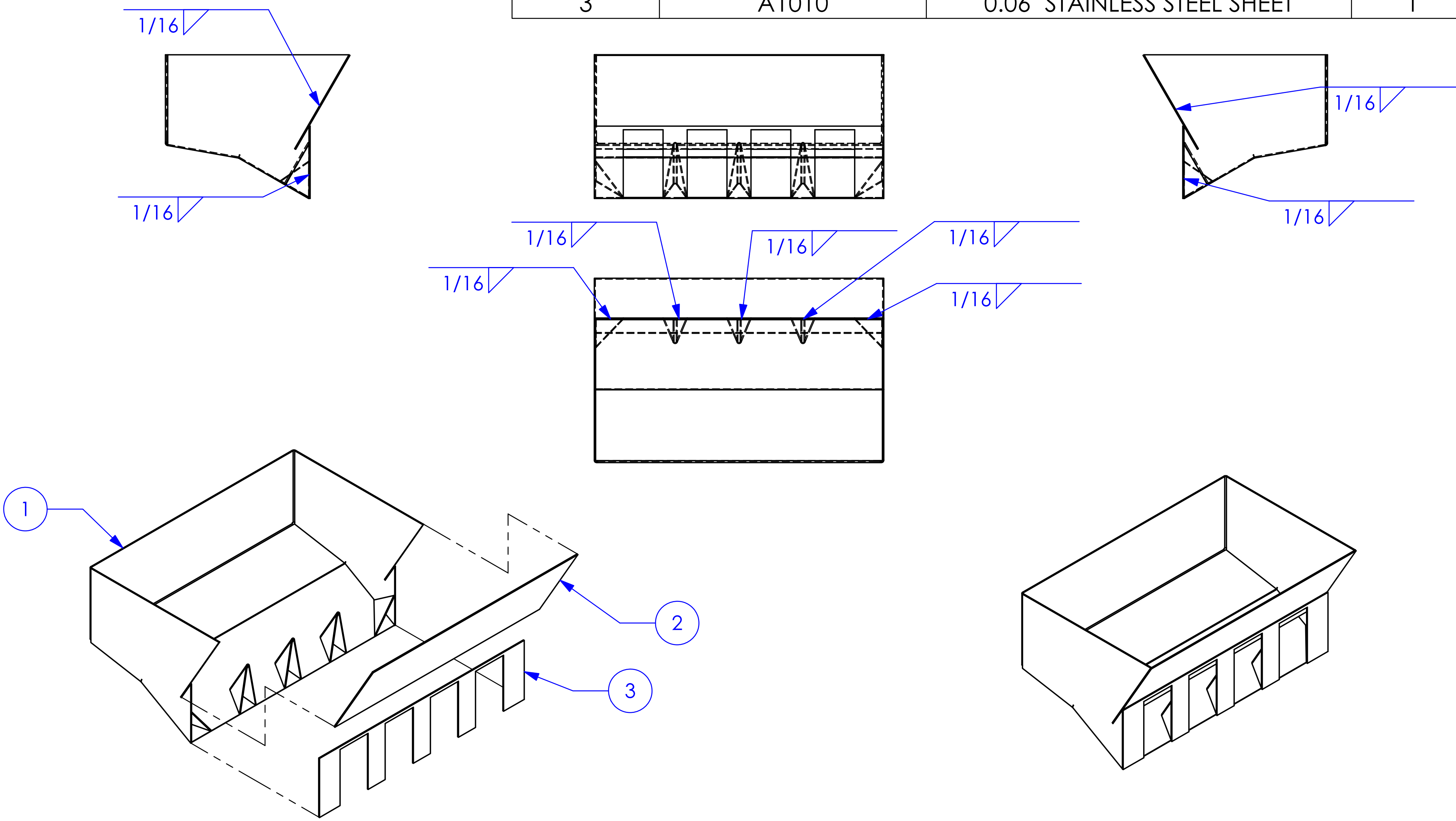


SCALE 1:8



ALPHA PROCEDURE: 6. Weld 3X part # A1040 and 2X # A1030 to part # A1000 at the locations specified by the drawing.	DATE: 3/6/2012	UNITS: INCHES	MATERIAL: SEE BOM
	TOLERANCE: 0.01	SCALE: 1:6	TITLE: ALPHA HOPPER PARTIAL ASSY W/ INSERTS
	ASSY #: A100	NEXT ASSY: ALPHA HOPPER COMPLETE ASSY #A110	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 100	Page 7

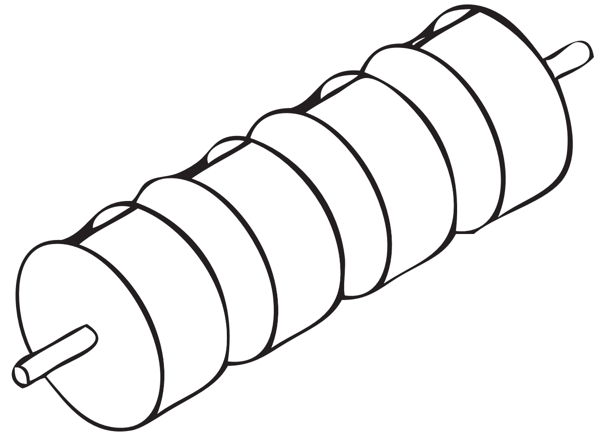
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	A100	ALPHA HOPPER PARTIAL ASSY	1
2	A1020	0.06" STAINLES STEEL SHEET	1
3	A1010	0.06" STAINLESS STEEL SHEET	1



ALPHA PROCEDURE:
7. Weld part # A1020 and # A1010 to assembly # A100 at the locations specified by the drawing. This completes the Alpha Hopper Assembly.

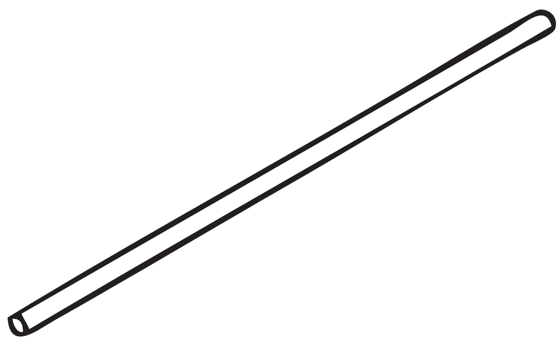
DATE: 3/6/2012	UNITS: INCHES	MATERIAL: SEE BOM
TOLERANCE: 0.01	SCALE: 1:4	TITLE: ALPHA HOPPER COMPLETE ASSY
ASSY #: A110	NEXT ASSY: ISO	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 110	Page 8

Bravo Assembly

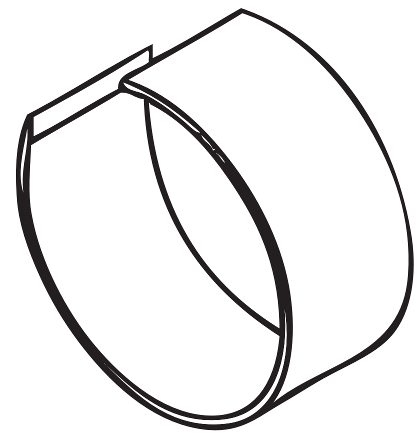


You will need the following part numbers (and quantities) to assemble Bravo:

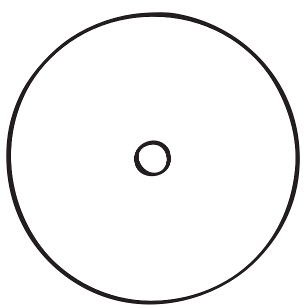
B1000
(1X)



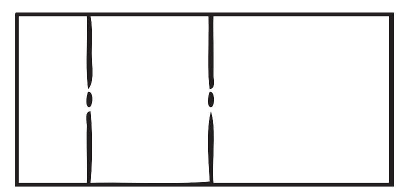
B1020
(4X)



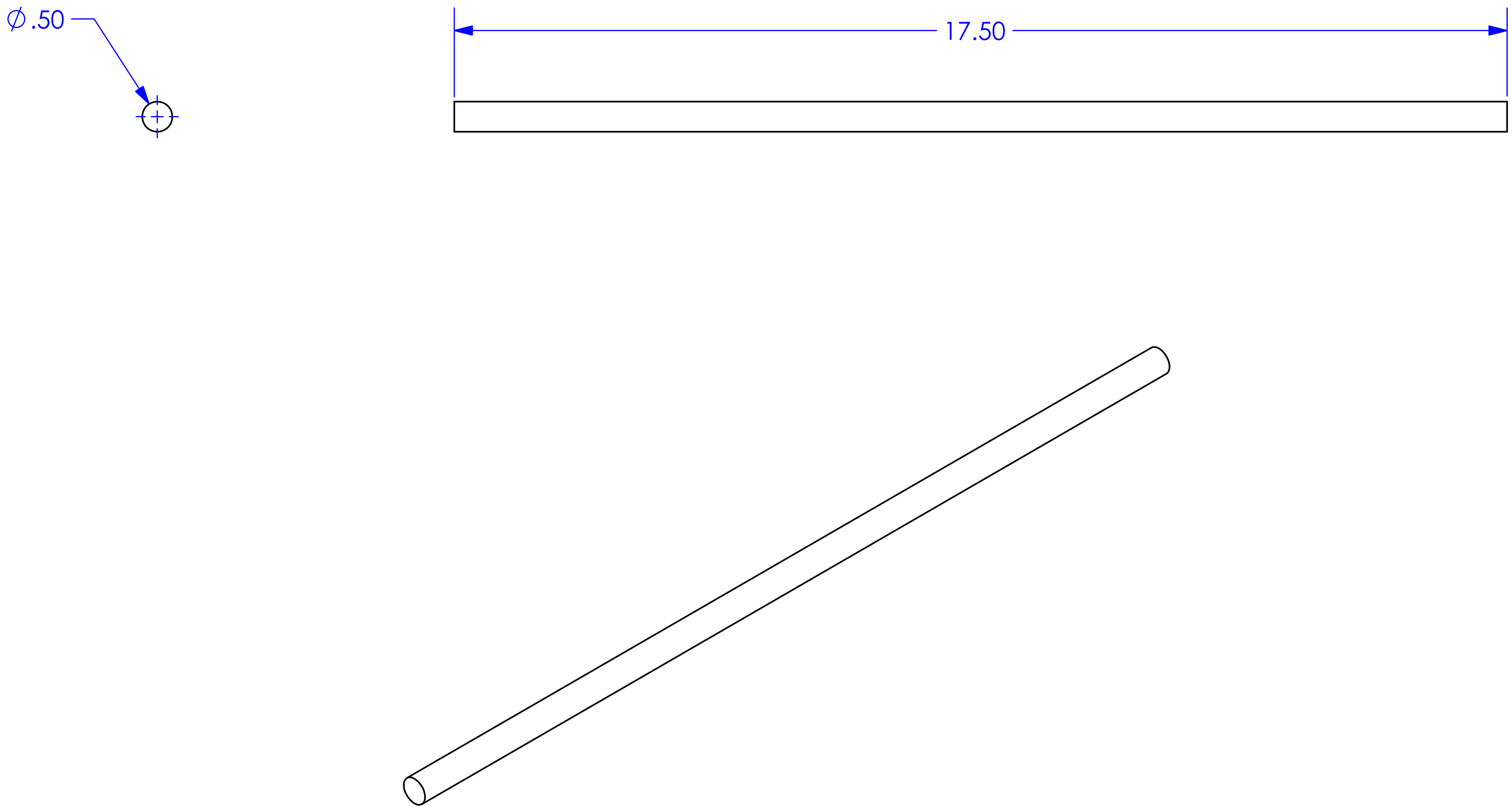
B1010
(8X)



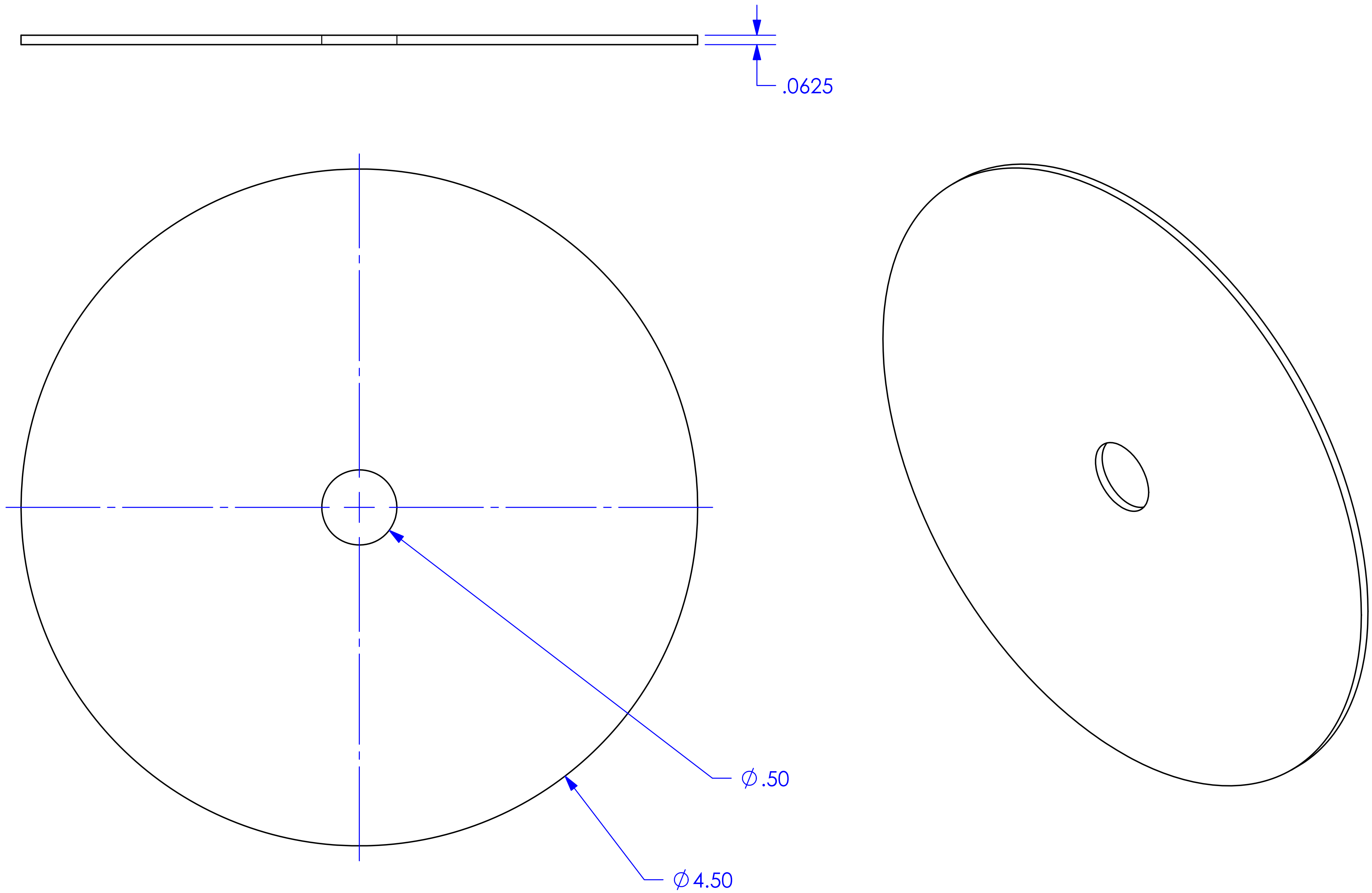
B1030
(4X)



See pages 10-15 for detailed parts and assembly instructions for Bravo.

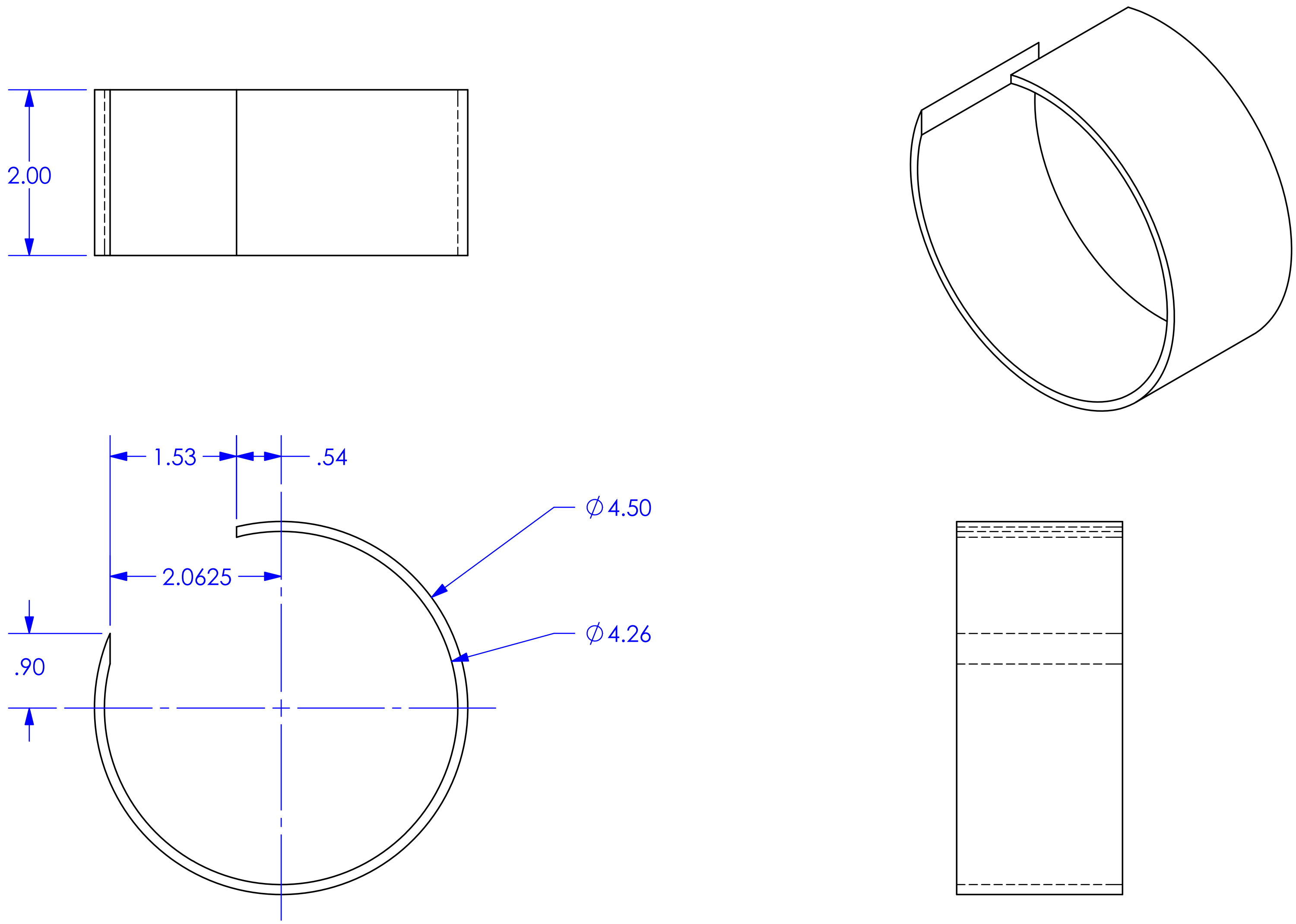


BRAVO PROCEDURE: 1. Cut a 1/2" diameter stainless steel rod to a length of 17.5 inches.	DATE: 5/21/2012	UNITS: INCHES	MATERIAL: TYPE 316, S.S. 1/2" DIA SHAFT
	TOLERANCE: 0.01	SCALE: 1:3	TITLE: FEEDER SHAFT
	PART #: B1000	NEXT ASSY #: B110	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 2000	Page 10



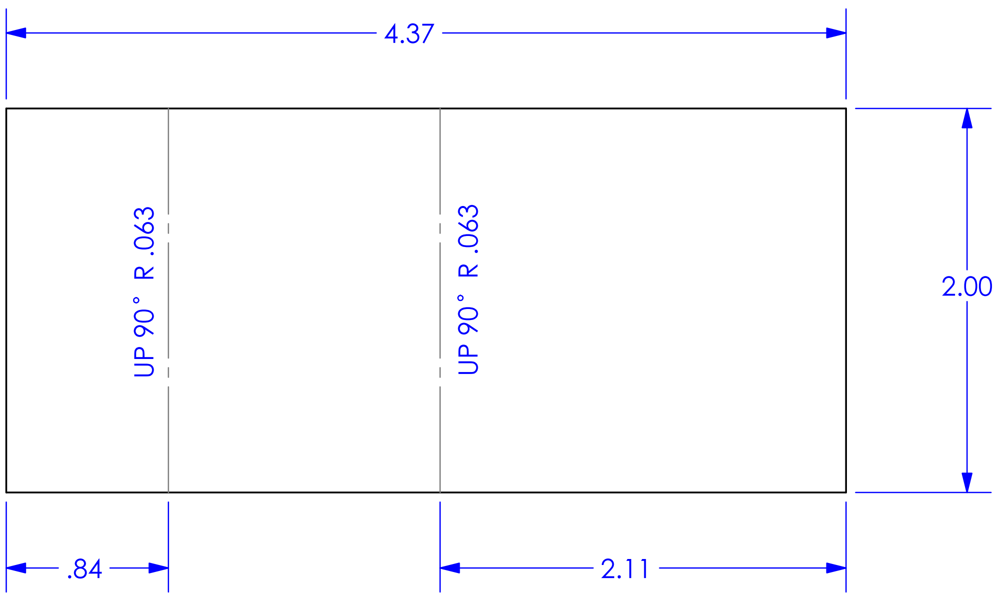
BRAVO PROCEDURE:
2. Cut 8X part # B1010 using the dimensions specified in the drawing.

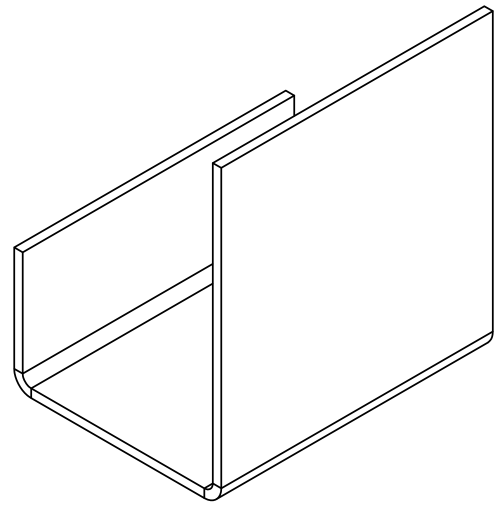
DATE: 5/21/2012	UNITS: INCHES	MATERIAL: TYPE 316, S.S. SHEET METAL 1/16"
TOLERANCE: 0.01	SCALE: 1:1	TITLE: FEEDER SIDEWALL
PART #: B1010	NEXT ASSY #: B100	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 2010	Page 11



BRAVO PROCEDURE:
3. Cut 4X part # B1020 from 4" diameter stainless steel pipe, using the dimensions specified in the drawing.

DATE: 5/21/2012	UNITS: INCHES	MATERIAL: TYPE 316 STAINLESS STEEL 4" PIPE
TOLERANCE: 0.01	SCALE: 1:2	TITLE: FEEDER CUT CYLINDER SECTION
PART #: B1020	NEXT ASSY #: B100	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 2020	Page 12

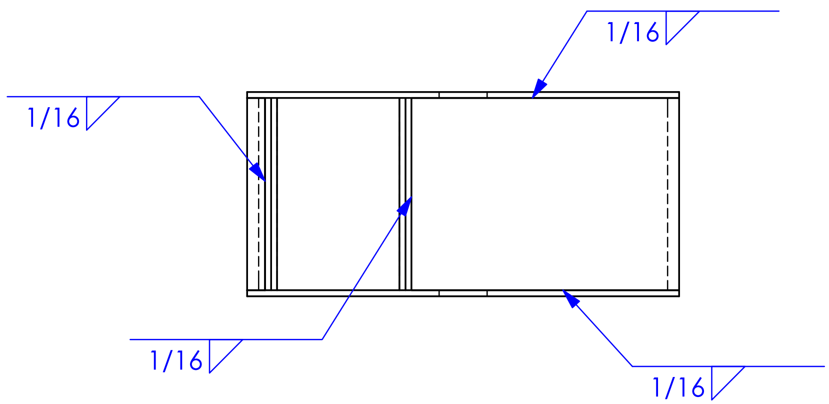


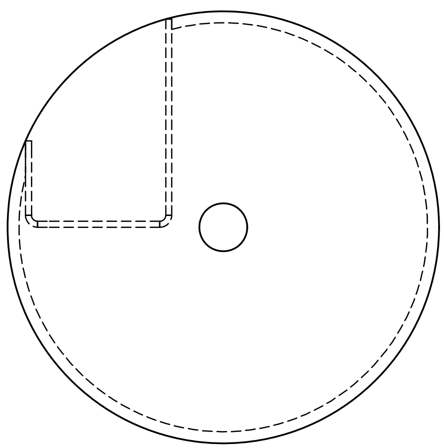


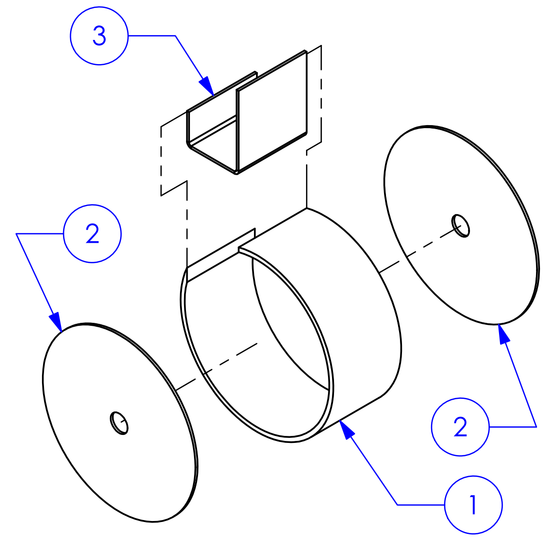
BRAVO PROCEDURE:
4. Cut and bend 4X part # B1030 using the dimensions specified in the drawing.

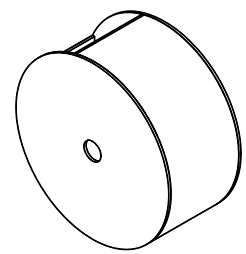
DATE: 5/21/2012	UNITS: INCHES	MATERIAL: TYPE 316 S.S. SHEET METAL 1/16"
TOLERANCE: 0.01	SCALE: 1:1	TITLE: FEEDER TOOTH INSERT
PART #: B1030	NEXT ASSY #: B100	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 2030	Page 13

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	B1020	4" DIA STAINLESS STEEL PIPE	1
2	B1010	0.06" STAINLESS STEEL SHEET	2
3	B1030	0.06" STAINLESS STEEL BENT SHEET	1





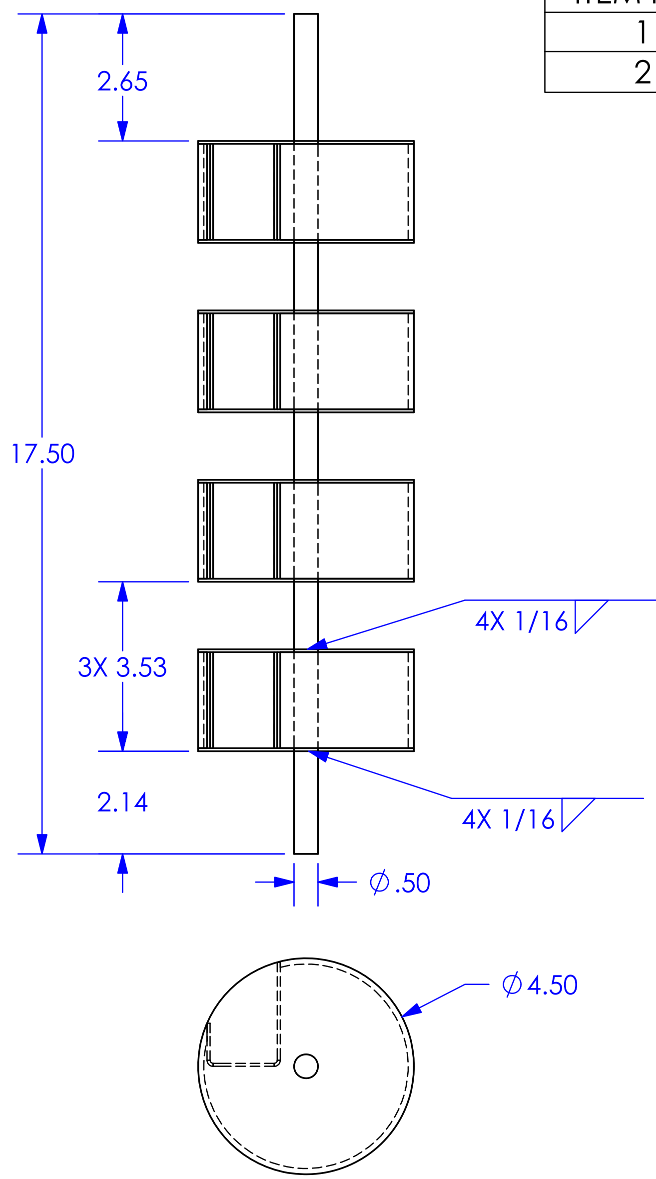


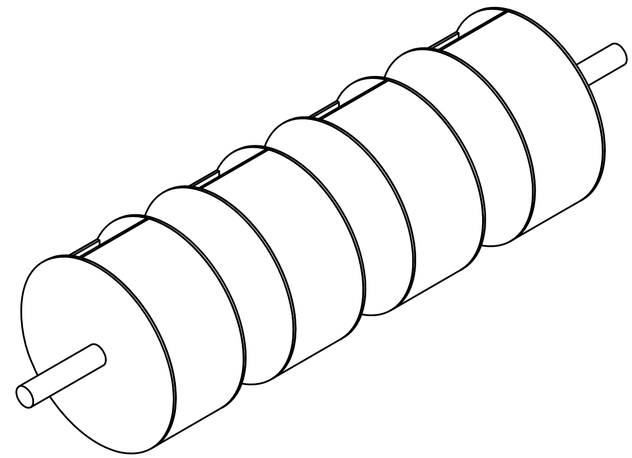


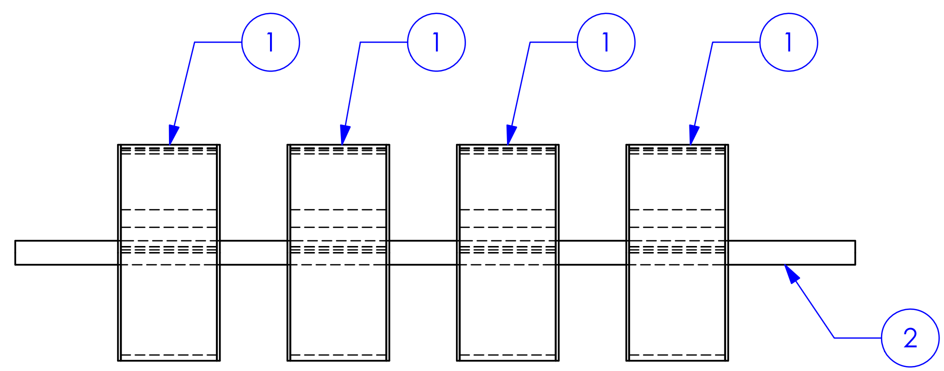
SCALE 1:4

BRAVO PROCEDURE: 5. Weld 2X part # B1010 and 1X # B1030 to part # B1020 in the specified locations. 6. Repeat step five 3X to make a total of four individual feeder assemblies.	DATE: 5/21/2012	UNITS: INCHES	MATERIAL: SEE BOM
	TOLERANCE: 0.01	SCALE: 1:2	TITLE: FEEDER INDIVIDUAL ASSEMBLY
	ASSY #: B100	NEXT ASSY #: B110	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 200	Page 14

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	B100	INDIVIDUAL FEED WHEEL SUB-ASSY	4
2	B1000	1/2" STAINLESS STEEL SHAFT	1

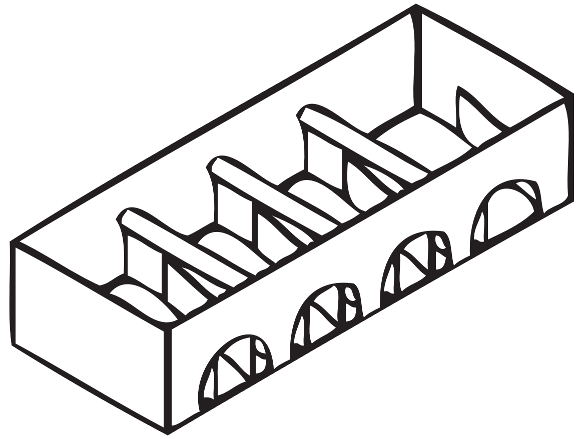






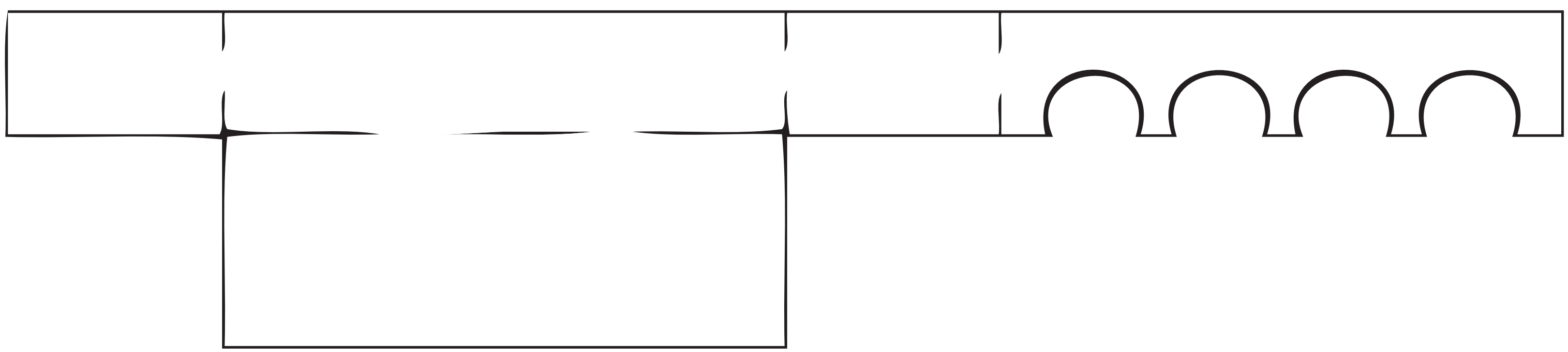
BRAVO PROCEDURE: 7. Weld 4X assembly # B100 (the individual feeder assemblies) to part # B1000 (the shaft) in the specified locations. This completes the Bravo Feeder Assembly.	DATE: 5/21/2012	UNITS: INCHES	MATERIAL: SEE BOM
	TOLERANCE: 0.01	SCALE: 1:4	TITLE: BRAVO COMPLETE FEEDER ASSEMBLY
	ASSY #: B110	NEXT ASSY #: ISO	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 210	Page 15

Charlie Assembly



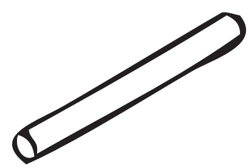
You will need the following part numbers (and quantities) to assemble Charlie:

C1000
(1X)

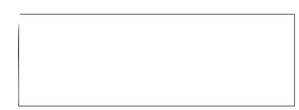


C1010
(3X)

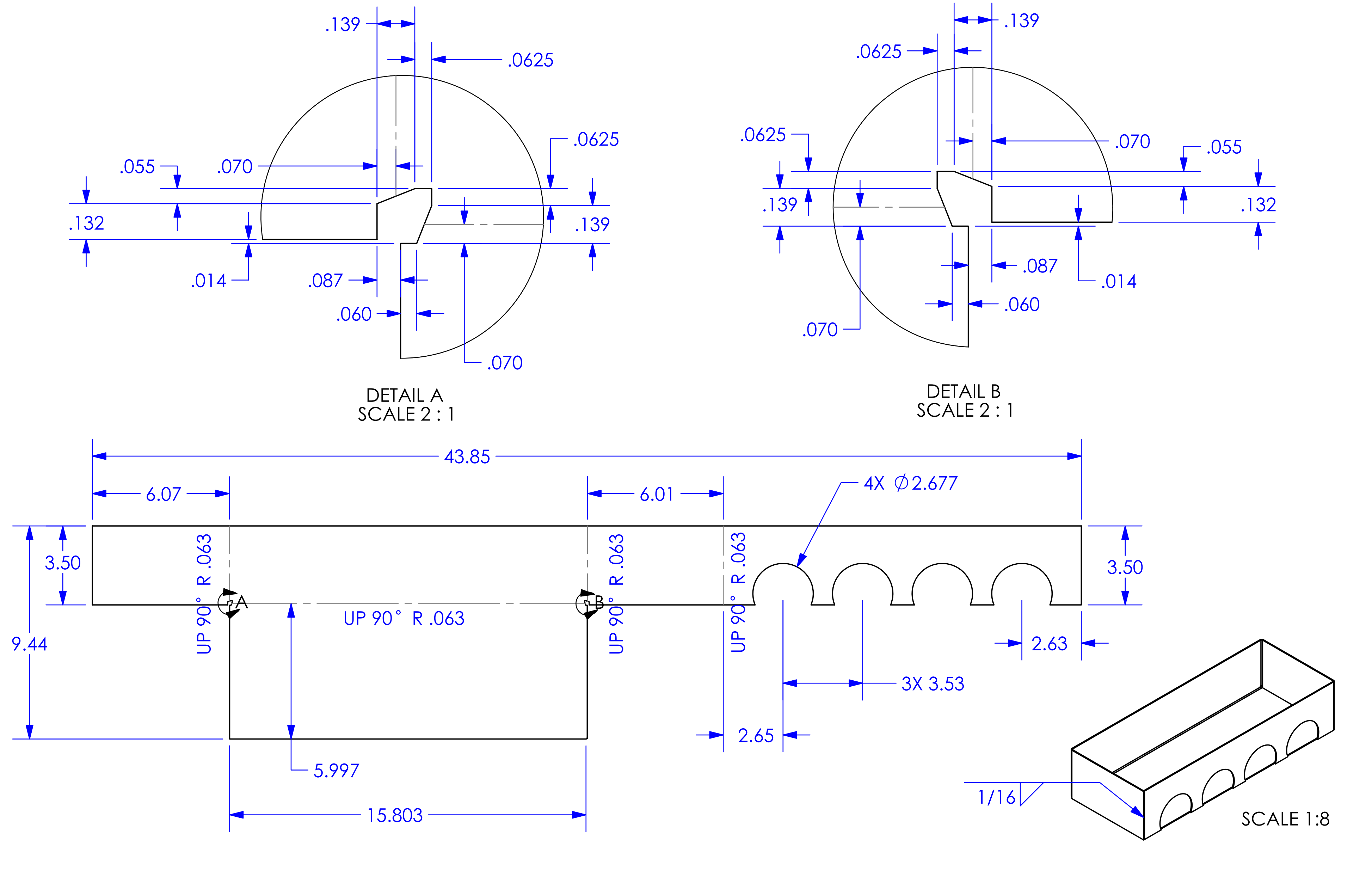
C1020
(3X)



C1030
(8X)

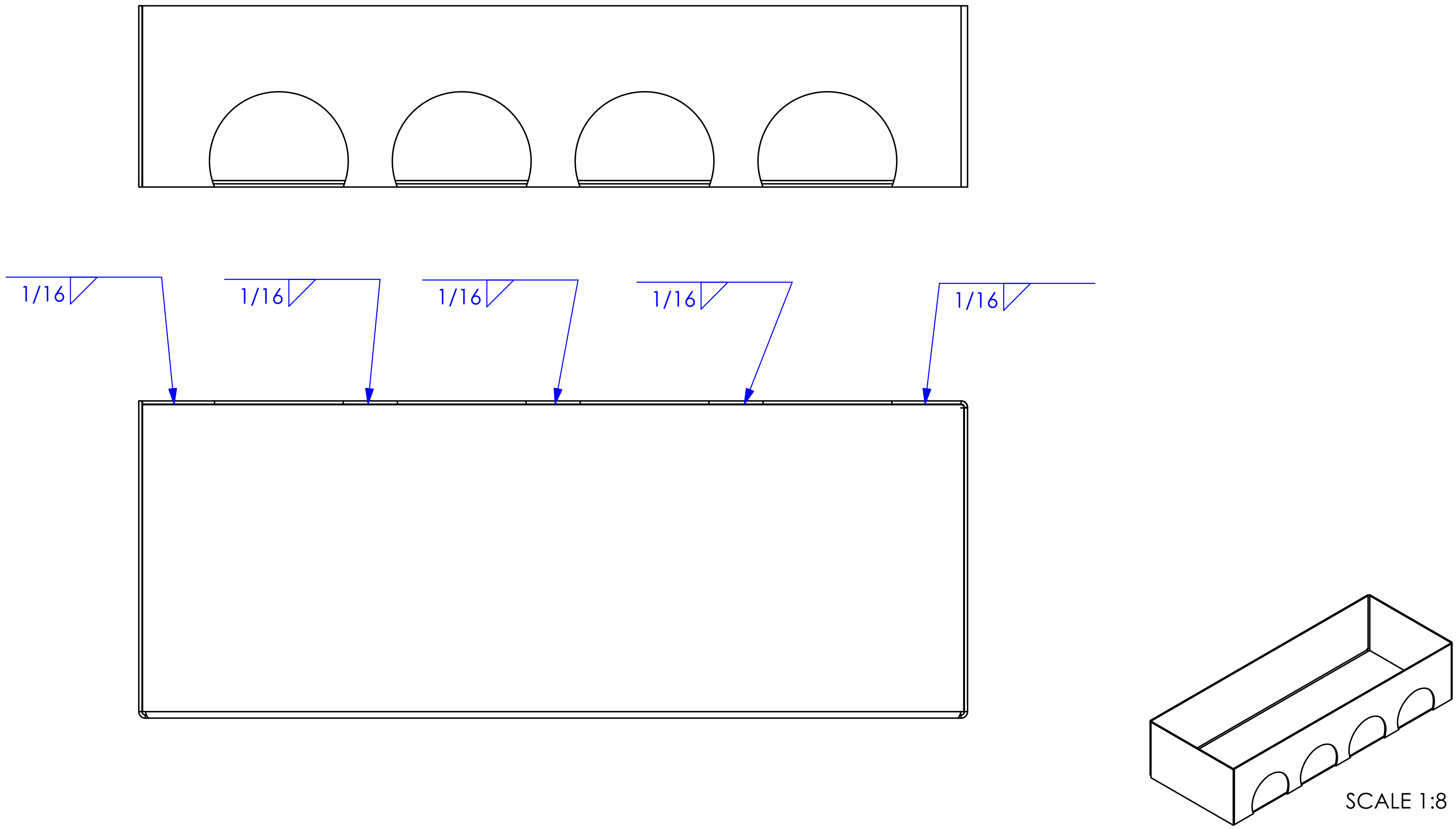


See pages 17-22 for detailed parts and assembly instructions for Charlie.



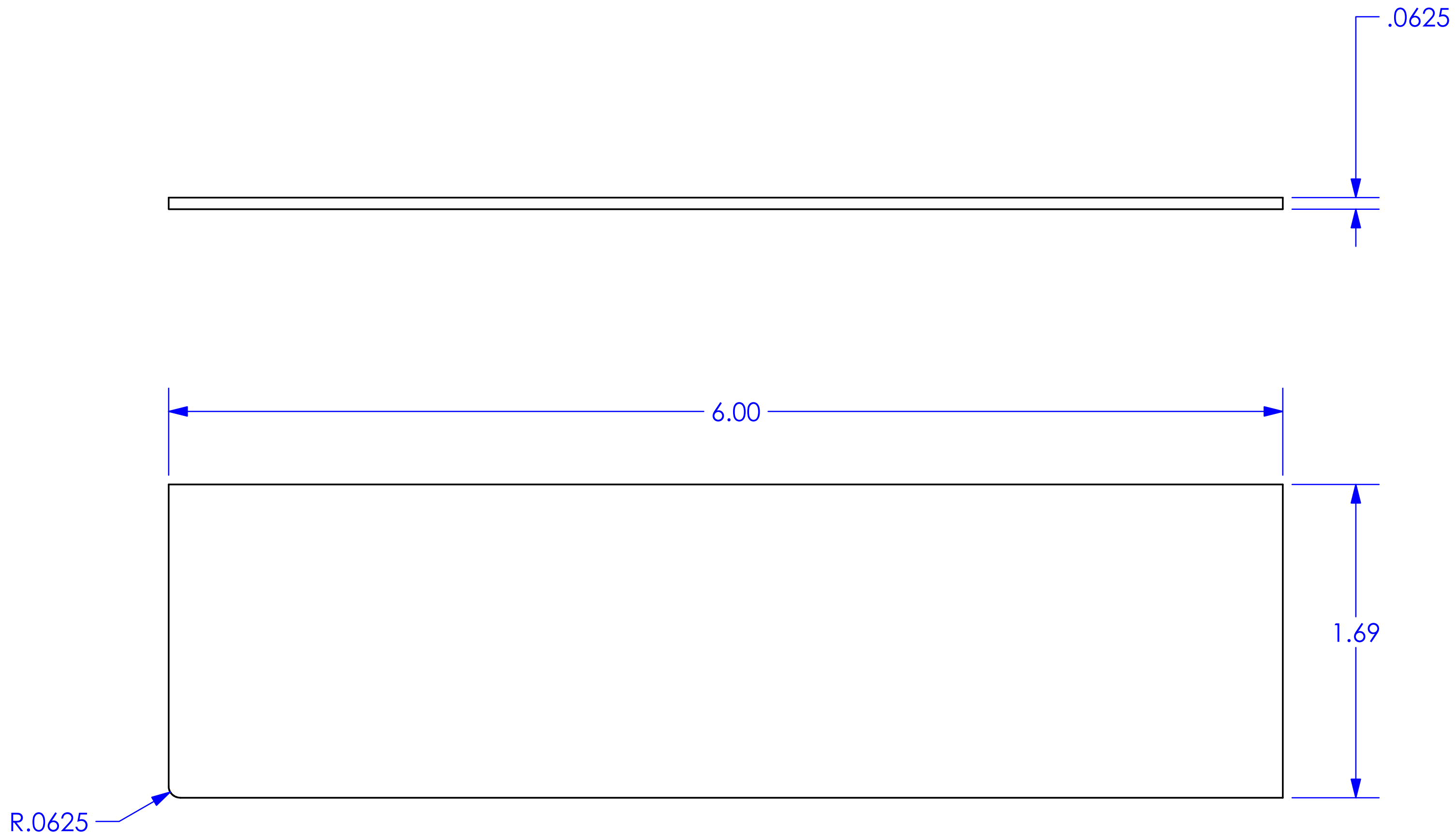
CHARLIE PROCEDURE:
1. Cut and bend part # C1000 to the specified dimensions.
2. Weld the joint specified in the isometric view.

DATE: 5/22/2012	UNITS: INCHES	MATERIAL: TYPE 316 S.S. SHEET METAL 1/16"
TOLERANCE: 0.01	SCALE: 1:6	TITLE: DROPDOWN BODY
PART #: C1000	NEXT ASSY #: C110	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 3000	Page 17



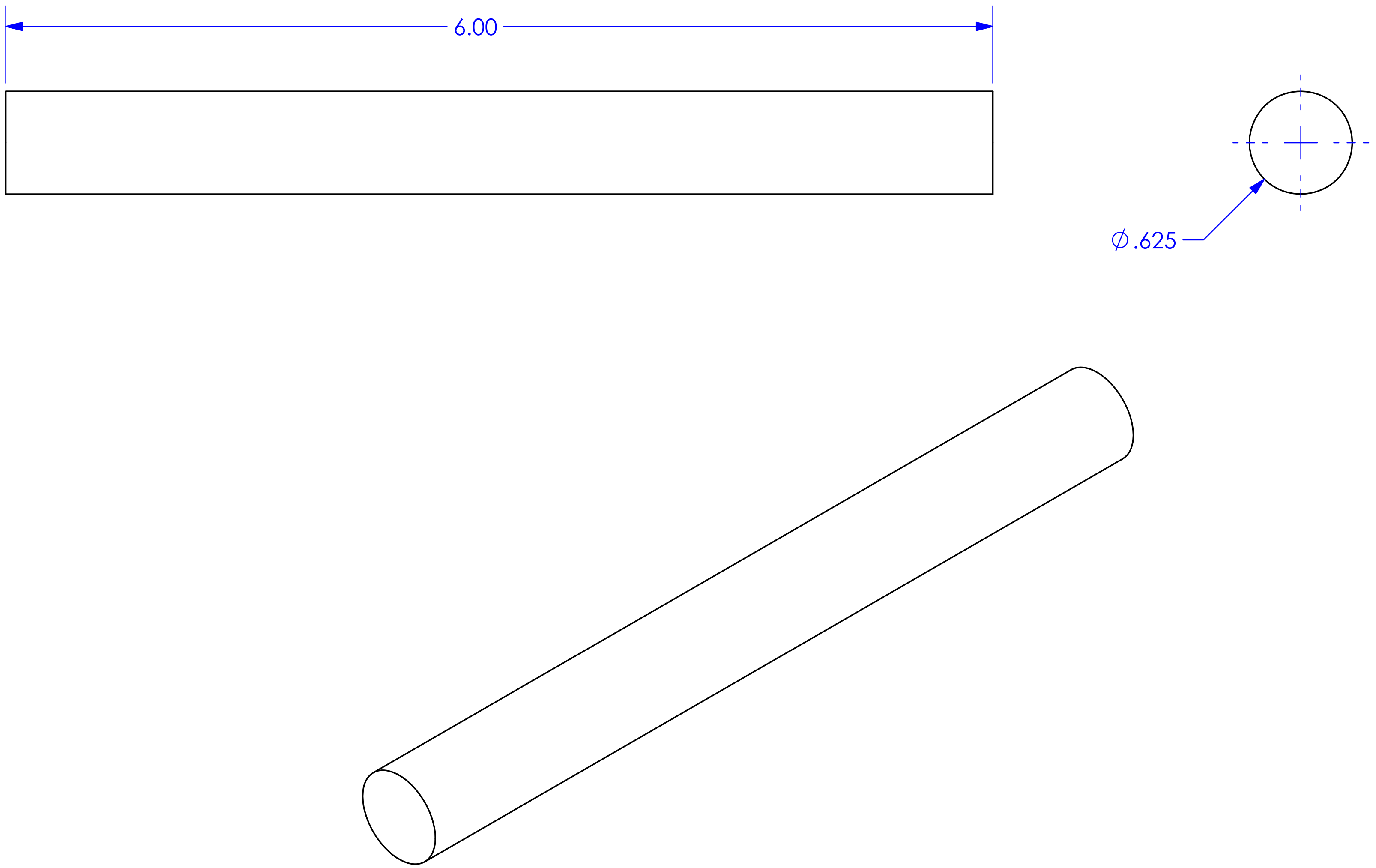
CHARLIE PROCEDURE:
3. Complete the dropdown body by welding the specified joints.

DATE: 5/22/2012	UNITS: INCHES	MATERIAL: TYPE 316 S.S. SHEET METAL 1/16"
TOLERANCE: 0.01	SCALE: 1:3	TITLE: DROPDOWN BODY
PART #: C1000	NEXT ASSY #: C110	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 3001	Page 18

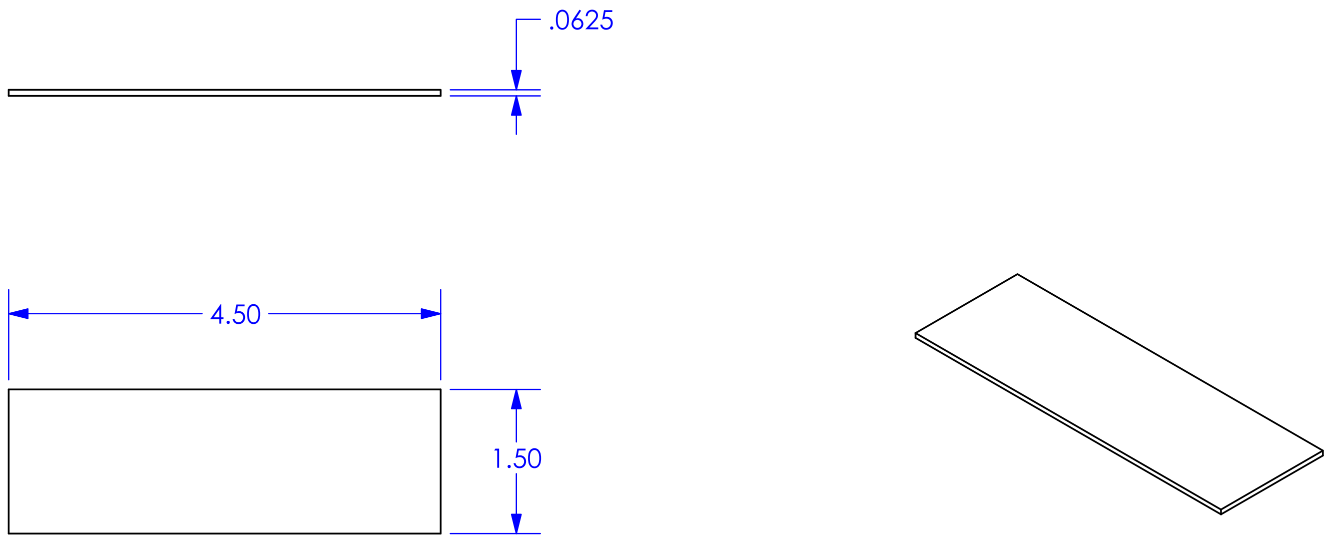


CHARLIE PROCEDURE:
4. Cut 3X part # C1010 to the specified dimensions.

DATE: 5/22/2012	UNITS: INCHES	MATERIAL: TYPE 316, S.S. SHEET METAL 1/16"
TOLERANCE: 0.01	SCALE: 1:1	TITLE: DROPDOWN DIVIDER WALL
PART #: C1010	NEXT ASSY #: C100	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 3010	Page 19

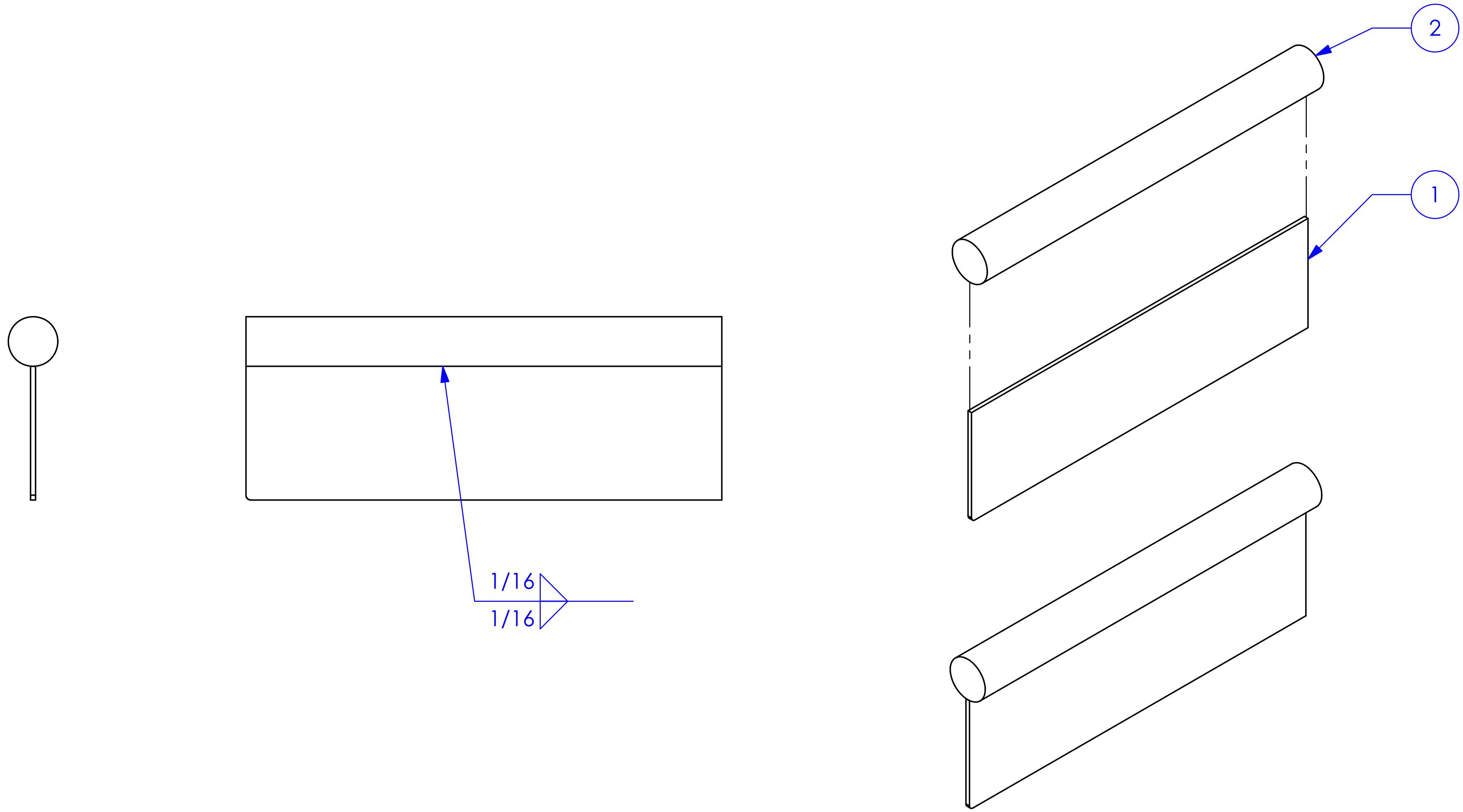


CHARLIE PROCEDURE: 5. Cut 3X part # C1020 from a 5/8" diameter stainless steel rod to a length of 6 inches.	DATE: 5/22/2012	UNITS: INCHES	MATERIAL: TYPE 316, S.S. 5/8" DIA ROD
	TOLERANCE: 0.01	SCALE: 1:1	TITLE: DROPDOWN DIVIDER ROD
	PART #: C1020	NEXT ASSY #: C100	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 3020	Page 20



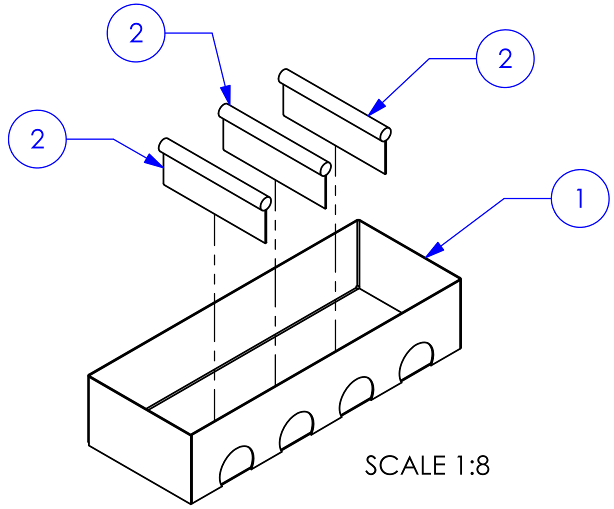
CHARLIE PROCEDURE: 6. Cut 8X part # C1040 to the specified dimensions.	DATE: 5/22/2012	UNITS: INCHES	MATERIAL: TYPE 316 S.S. SHEET METAL 1/16"
	TOLERANCE: 0.01	SCALE: 1:2	TITLE: CHARLIE STAR CLIP GUIDE WALL
	PART #: C1040	NEXT ASSY #: C120	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 3040	Page 21

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	C1010	0.06" STAINLESS STEEL SHEET	1
2	C1020	5/8" DIA STAINLESS STEEL ROD	1



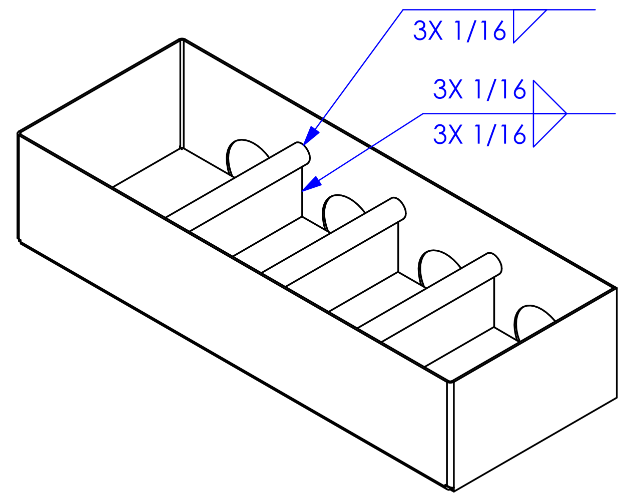
CHARLIE PROCEDURE:
7. Weld part # C1020 to part # C1010 in the specified locations.
8. Repeat step six 2X to make a total of three divider assemblies.

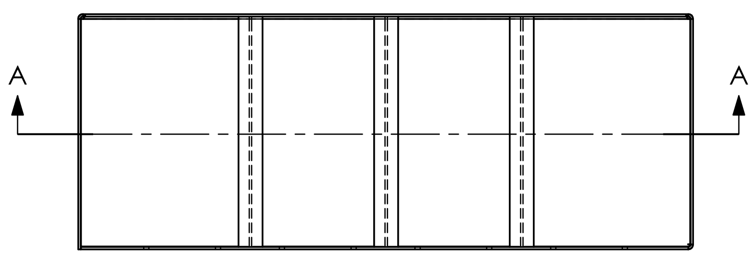
DATE: 5/22/2012	UNITS: INCHES	MATERIAL: SEE BOM
TOLERANCE: 0.01	SCALE: 1:2	TITLE: DROPDOWN DIVIDER ASSEMBLY
ASSY #: C100	NEXT ASSY #: C110	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 300	Page 22



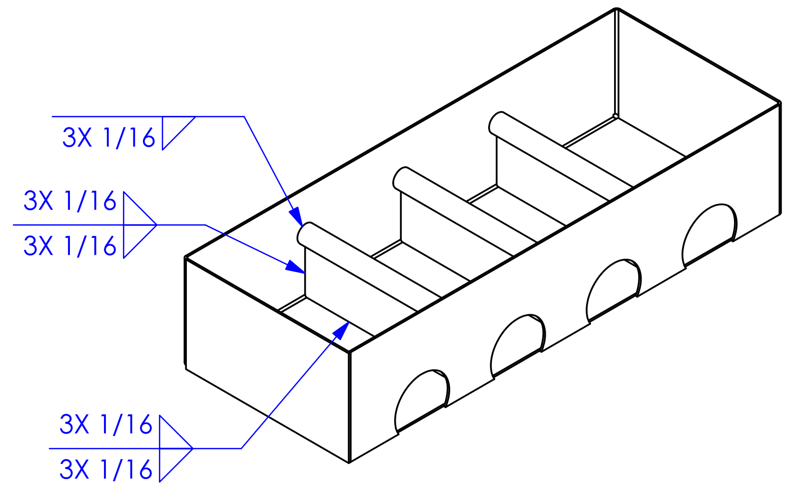
SCALE 1:8

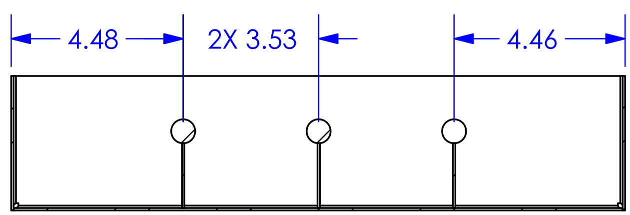
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	C1000	0.06" STAINLESS STEEL BENT SHEET	1
2	C100	BASEPLATE DIVIDER SUB-ASSY	3





TOP VIEW

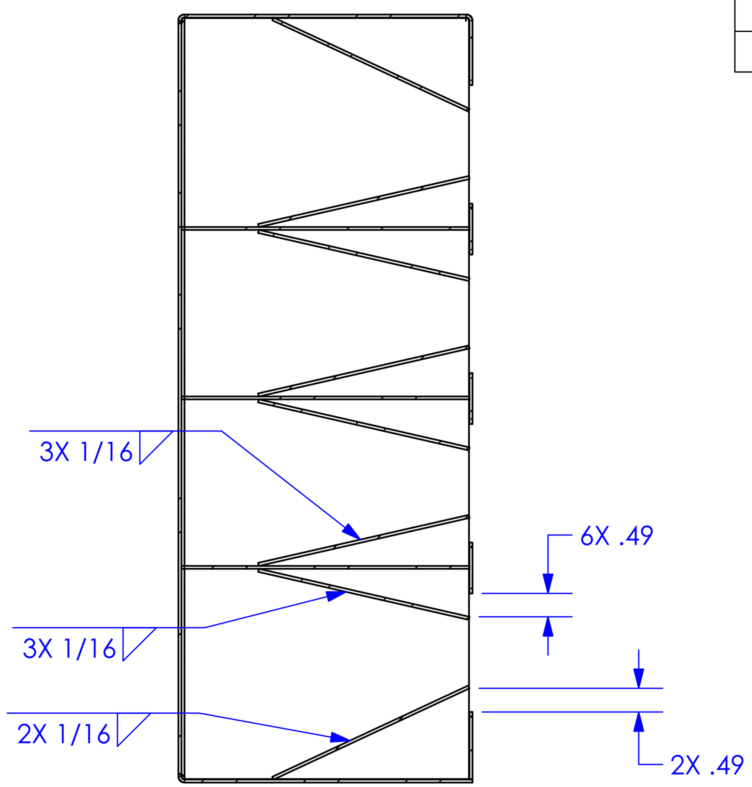




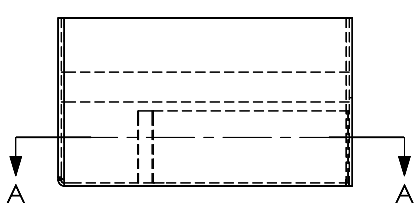
SECTION A-A

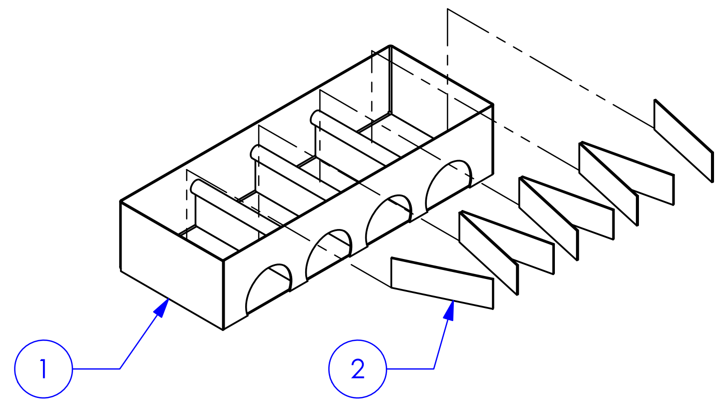
CHARLIE PROCEDURE: 9. Weld 3X assembly # C100 to part # C1000 in the specified locations.	DATE: 5/22/2012	UNITS: INCHES	MATERIAL: SEE BOM
	TOLERANCE: 0.01	SCALE: 1:5	TITLE: DROPDOWN ASSEMBLY PARTIALLY COMPLETE
	ASSY #: C110	NEXT ASSY #: C120	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 310	Page 23

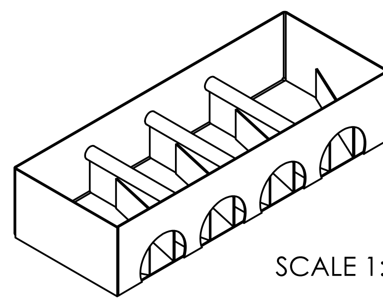
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	C110	PARTIALLY COMPLETE DROPDOWN ASSY	1
2	C1040	CHARLIE STAR CLIP GUIDE WALL	8



SECTION A-A





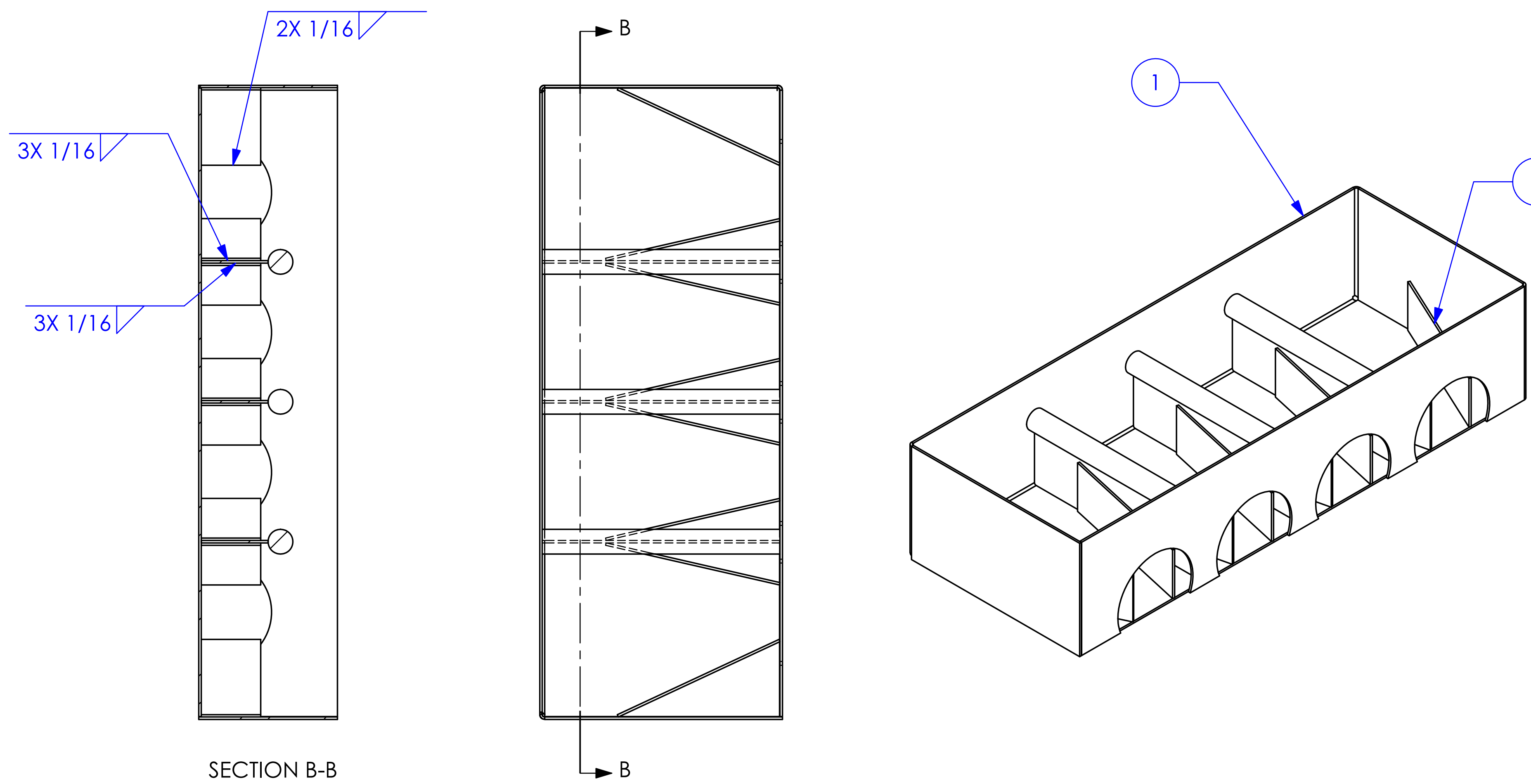


SCALE 1:8

CHARLIE PROCEDURE:
10. Weld 8X part # C1040 to assembly # C110 in the specified locations.

DATE: 5/22/2012	UNITS: INCHES	MATERIAL: SEE BOM
TOLERANCE: 0.01	SCALE: 1:4	TITLE: DROPDOWN ASSEMBLY PARTIALLY COMPLETE
ASSY #: C120	NEXT ASSY #: C120	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 320	Page 24

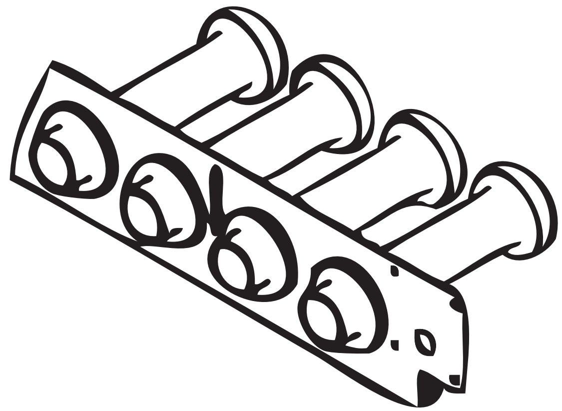
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	C110	PARTIALLY COMPLETE DROPDOWN ASSY	1
2	C1040	CHARLIE STAR CLIP GUIDE WALL	8



CHARLIE PROCEDURE:
11. Continue welding 8X part # C1040 to assembly # C110 in the above locations. This completes the Charlie Dropdown Assembly.

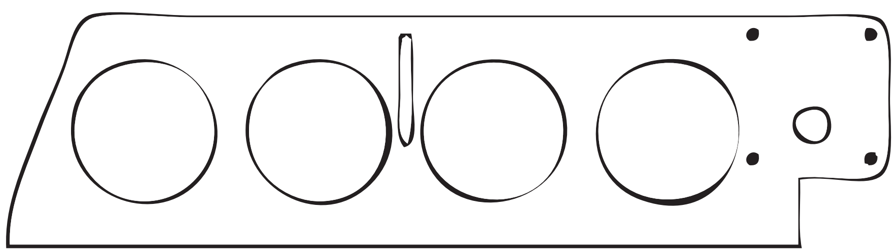
DATE: 5/30/2012	UNITS: INCHES	MATERIAL: SEE BOM
TOLERANCE: 0.01	SCALE: 1:4	TITLE: CHARLIE COMPLETE DROPDOWN ASSY
ASSY #: C120	NEXT ASSY #: ISO	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 330	Page 25

Delta Assembly

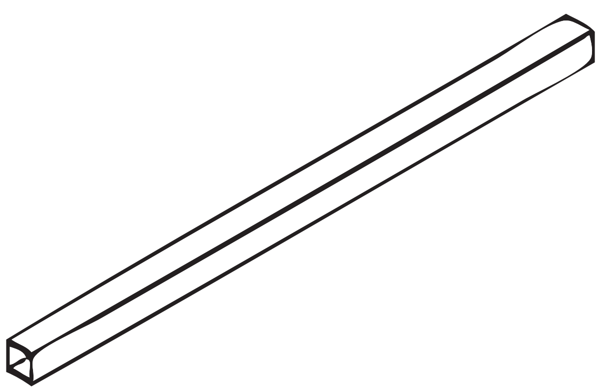


You will need the following part numbers (and quantities) to assemble Delta:

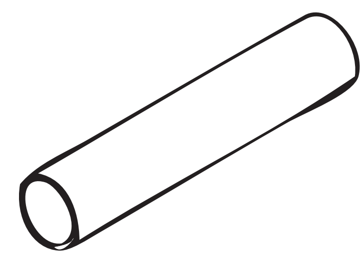
D1000
(1X)



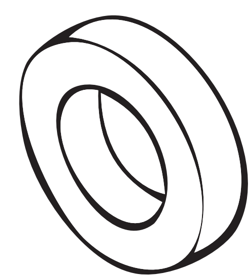
D1010
(1X)



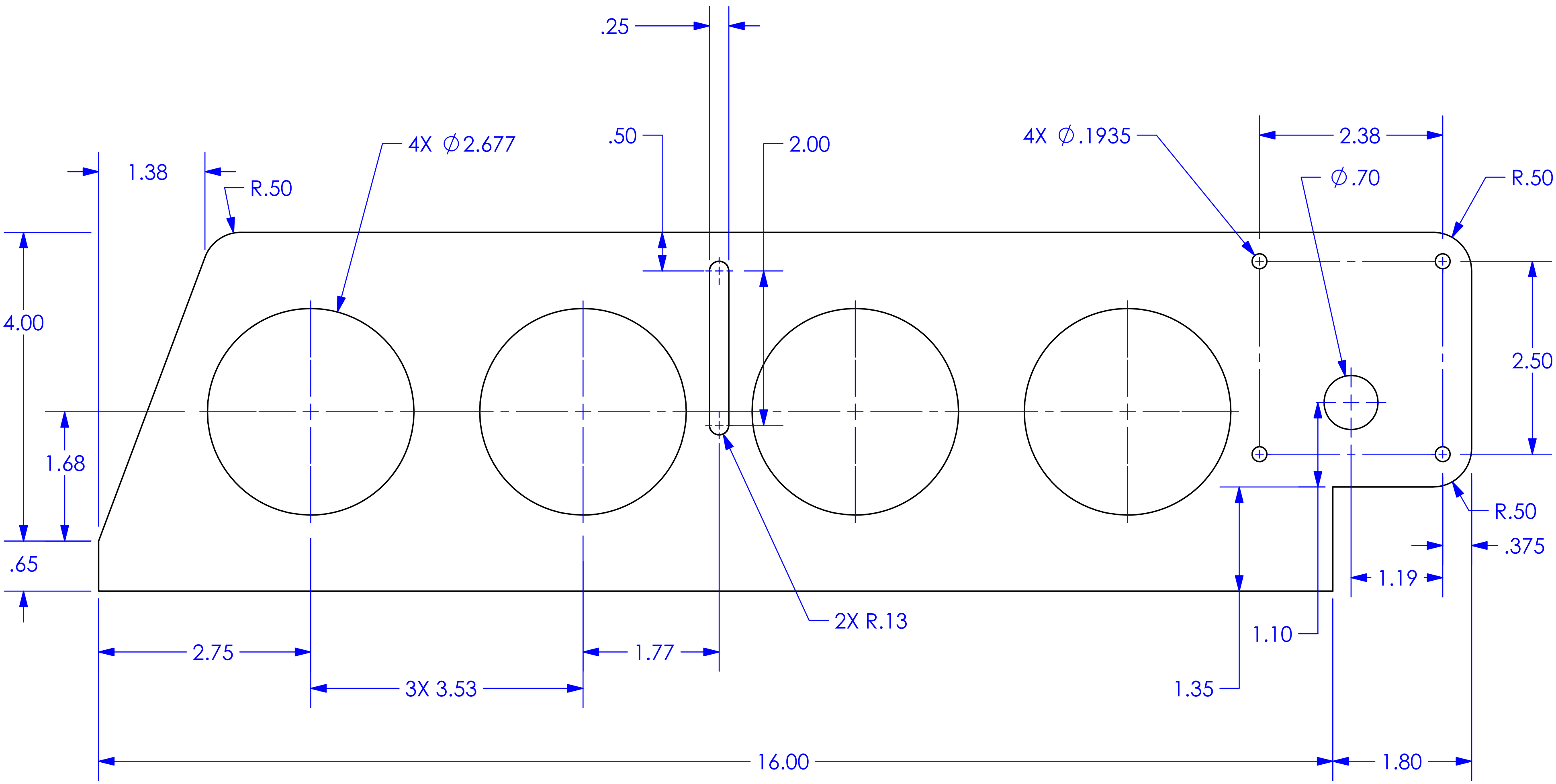
D1020
(4X)



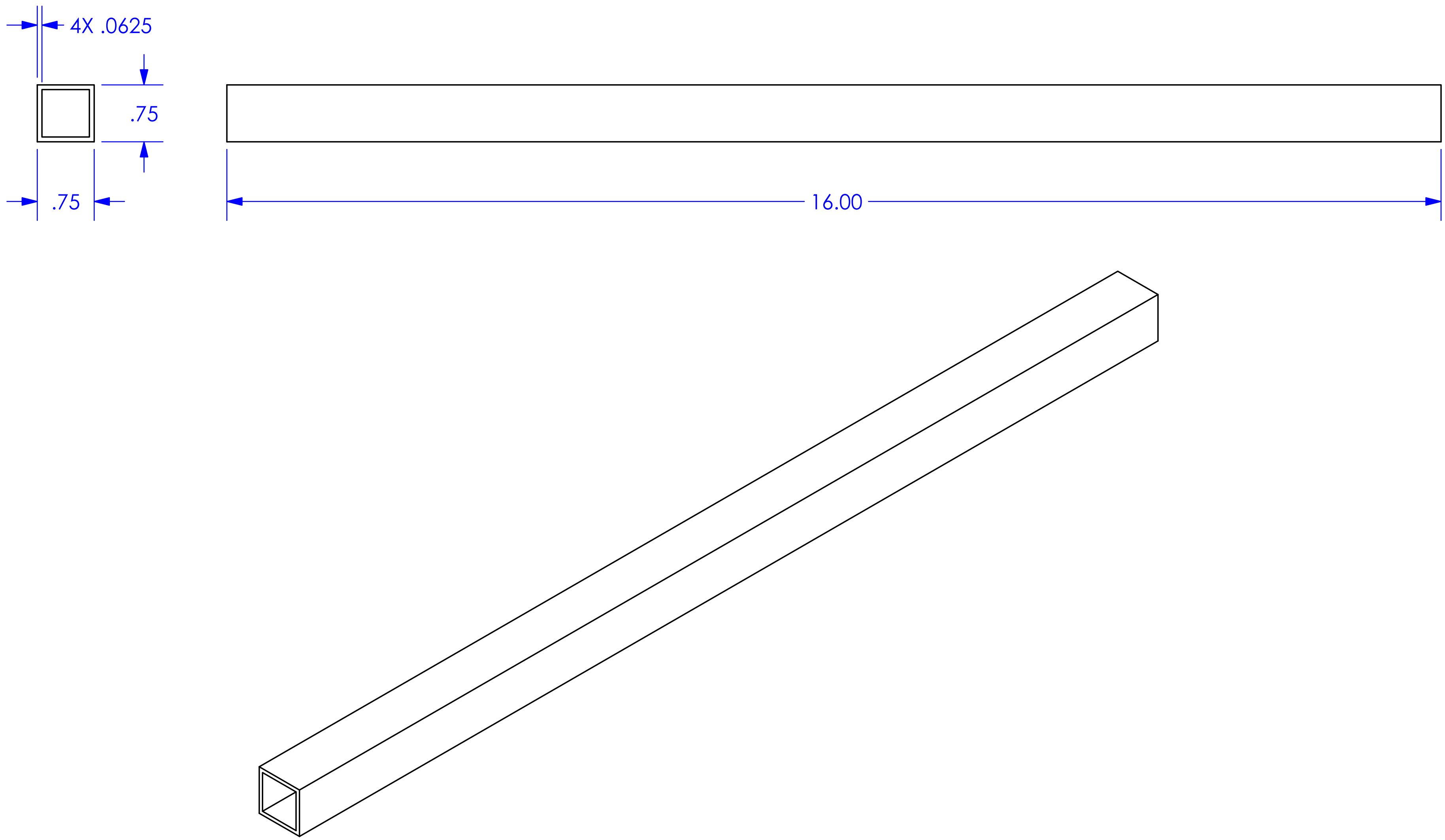
D1030
(8X)



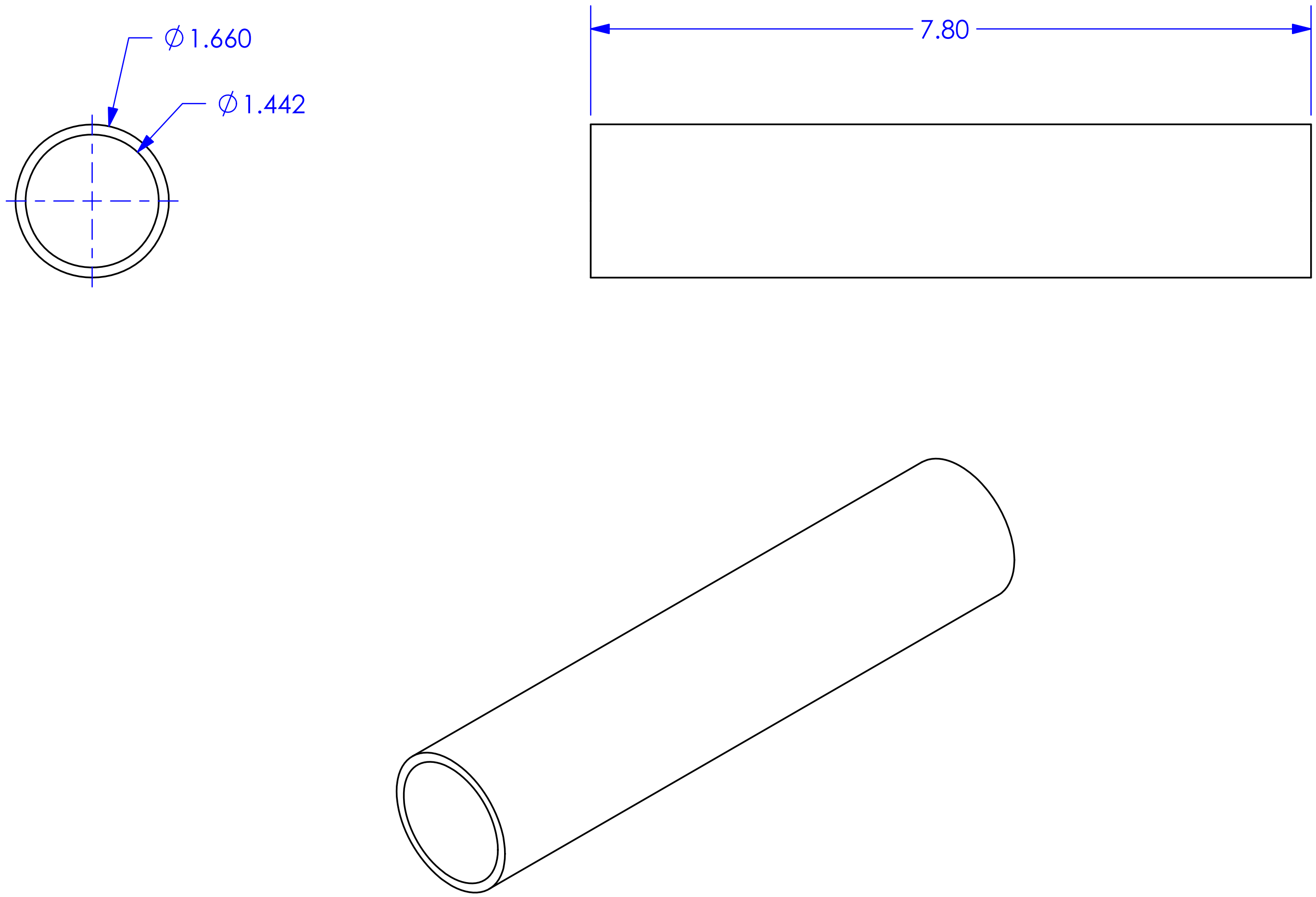
See pages 27-32 for detailed parts and assembly instructions for Delta.



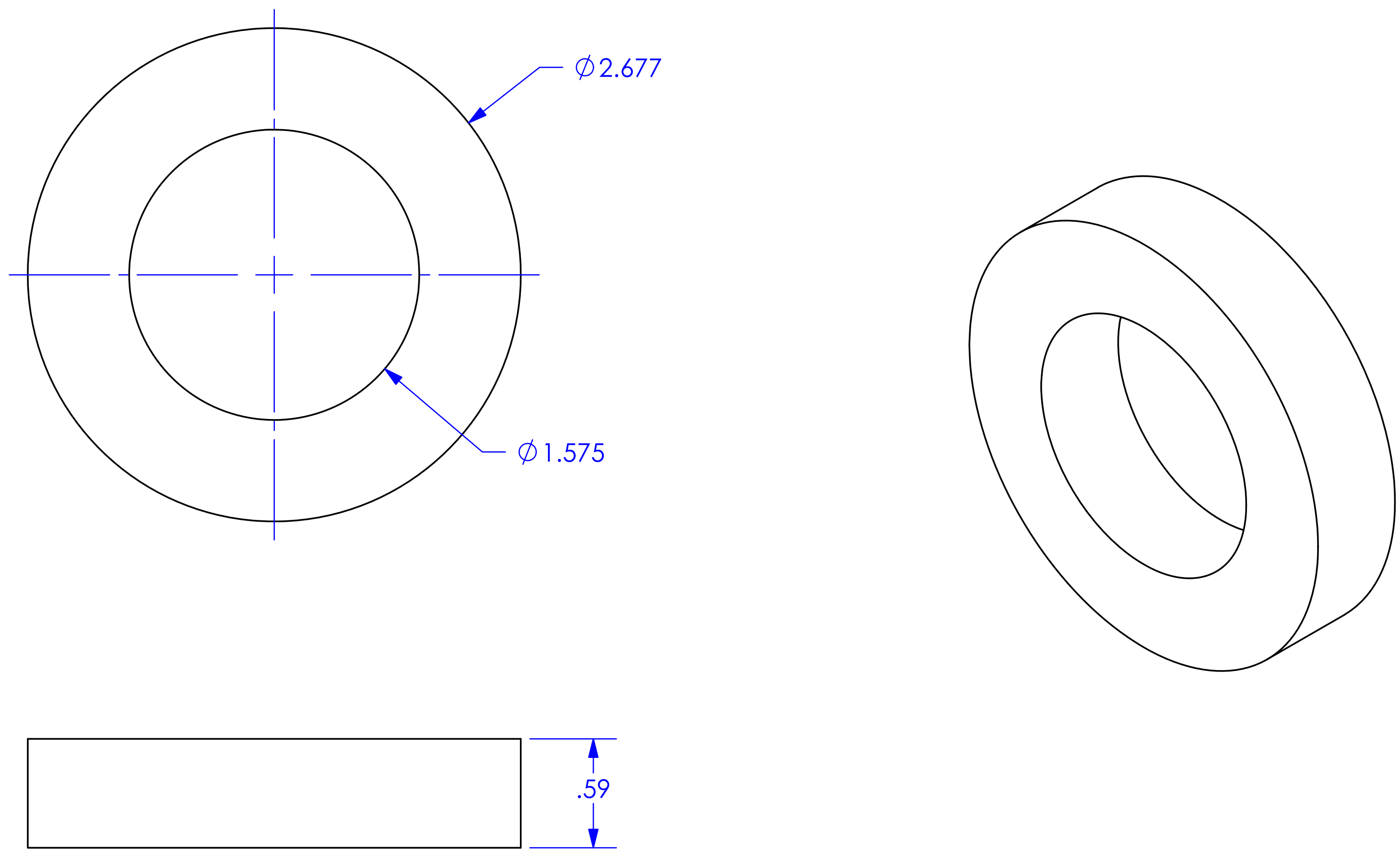
DELTA PROCEDURE: 1. Cut part # D1000 from 1/16" sheet metal using the specified dimensions.	DATE: 5/22/2012	UNITS: INCHES	MATERIAL: TYPE 316, S.S. SHEET METAL 1/16"
	TOLERANCE: 0.01	SCALE: 1:2	TITLE: ROTATING CYLINDER SUPPORT
	PART #: D1000	NEXT ASSY #: D100	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 4000	Page 27



DELTA PROCEDURE: 2. Cut part # D1010 from 3/4" square tubing to a length of 16 inches.	DATE: 5/23/2012	UNITS: INCHES	MATERIAL: TYPE 316, S.S. 3/4" SQUARE TUBE
	TOLERANCE: 0.01	SCALE: 1:2	TITLE: ROTATING CYLINDER SUPPORT BAR
	PART #: D1010	NEXT ASSY #: D100	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 4010	Page 28



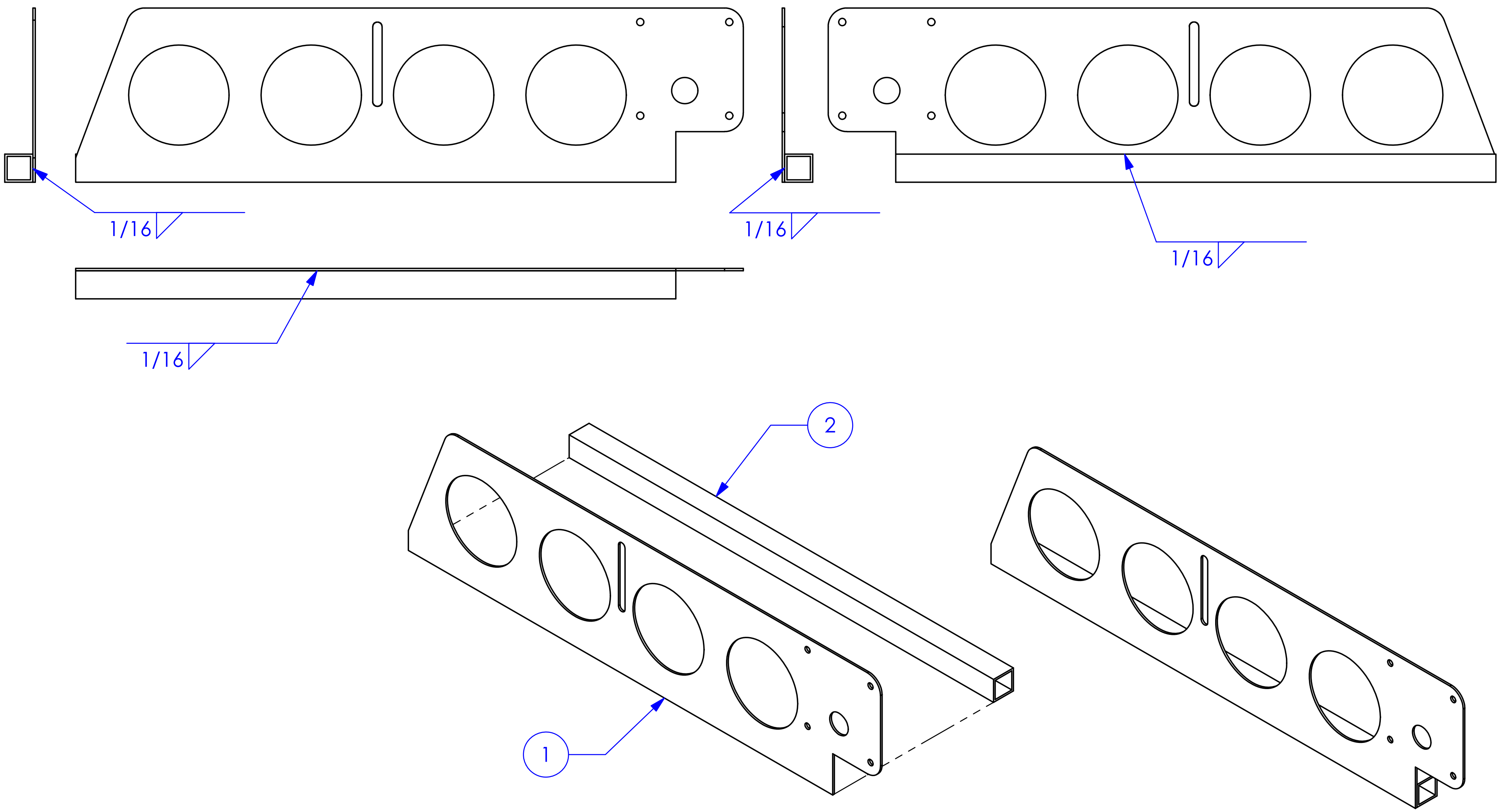
DELTA PROCEDURE: 3. Cut part # D1020 from 1-1/4 pipe size (1.660" OD) to a length of 7.8 inches.	DATE: 5/23/2012	UNITS: INCHES	MATERIAL: TYPE 316, S.S. 1.660" OD PIPE
	TOLERANCE: 0.01	SCALE: 1:2	TITLE: ROTATING CYLINDER
	PART #: D1020	NEXT ASSY #: D110	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 4020	Page 29



DELTA PROCEDURE:
4. Obtain 8X bearings with a 40mm bore, 68mm OD, 15mm length. Note SAE units are shown in drawing.

DATE: 5/23/2012	UNITS: INCHES	MATERIAL: PRESSED STEEL
TOLERANCE: 0.01	SCALE: 1:1	TITLE: 40MM BORE BALL BEARING
PART #: D1030	NEXT ASSY #: D110	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 4030	Page 30

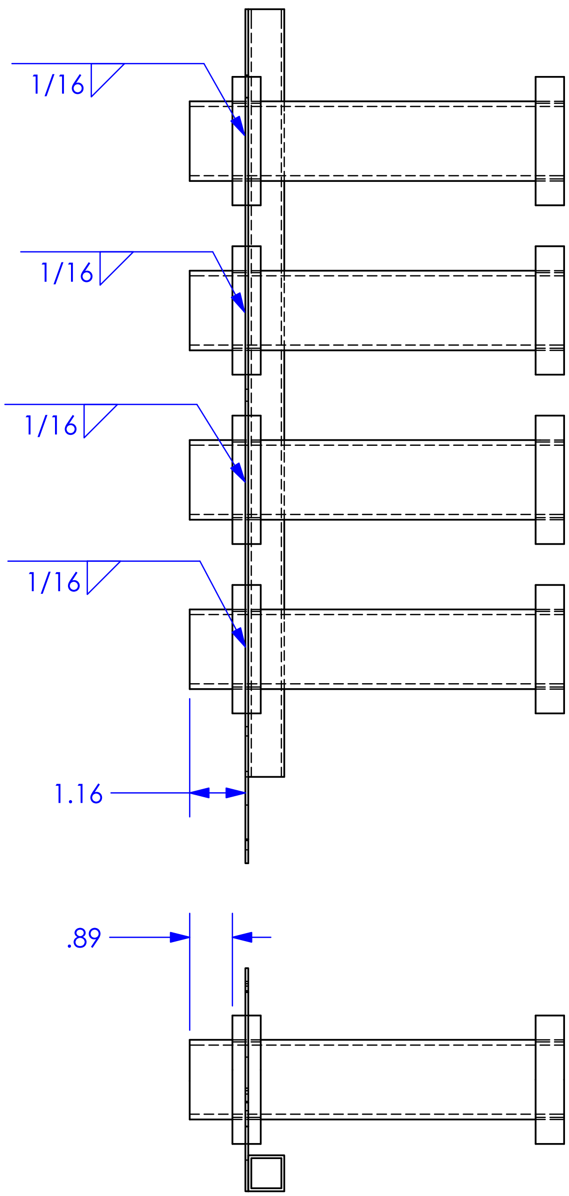
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	D1000	SUPPORT BRACKET FOR ROTATING CYLINDERS	1
2	D1010	3/4" X 3/4" STAINLESS STEEL BAR	1

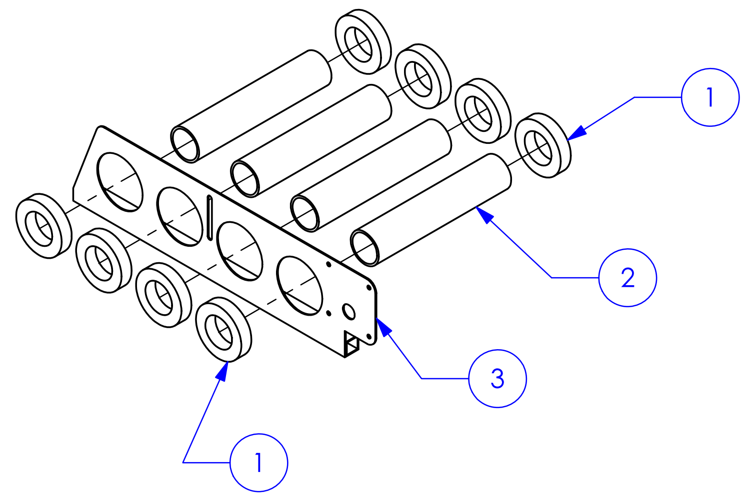


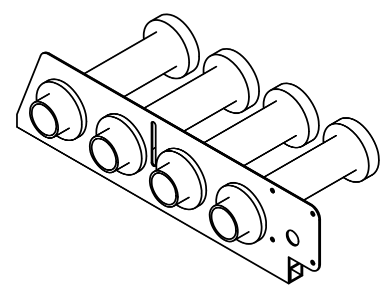
DELTA PROCEDURE:
5. Weld part # D1000 to # D1010 in the locations indicated by the drawing.

DATE: 5/23/2012	UNITS: INCHES	MATERIAL: SEE BOM
TOLERANCE: 0.01	SCALE: 1:4	TITLE: ROTATING CYLINDER SUPPORT ASSY
ASSY #: D100	NEXT ASSY #: D110	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 400	Page 31

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	D1030	40MM BORE BALL BEARING	8
2	D1020	1.660" OD STAINLESS STEEL PIPE	4
3	D100	DELTA SUPPORT AND CROSSBAR	1



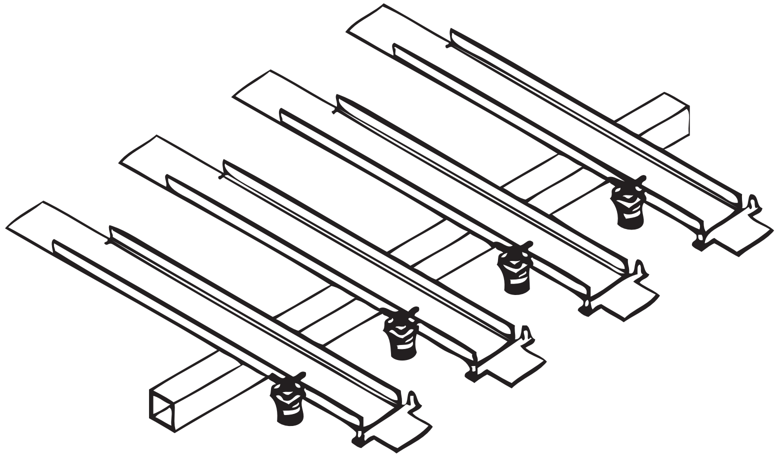




DELTA PROCEDURE:
6. Press 8X part # D1030 (bearings) onto 4X part #D1020 as shown. Additional boring of bearings may be required for successful press-fit.
7. Weld 4X part # D1030 to assy # D100 after the bearings have been pressed onto the cylinders. This completes the Delta Rotating Cylinder Assembly.

DATE: 5/23/2012	UNITS: INCHES	MATERIAL: SEE BOM
TOLERANCE: 0.01	SCALE: 1:4	TITLE: DELTA ROTATING CYLINDER ASSEMBLY
ASSY #: D110	NEXT ASSY #: ISO	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 410	

Echo I Assembly

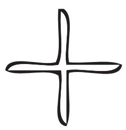


You will need the following part numbers (and quantities) to assemble Echo I:

E1000
(4X)

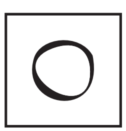
E1010
(4X)

E1020
(4X)



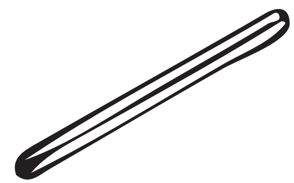
E1030
(4X)

E1040
(8X)

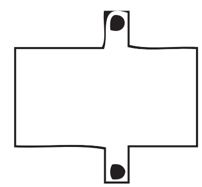


E1050
(4X)

E1060
(1X)



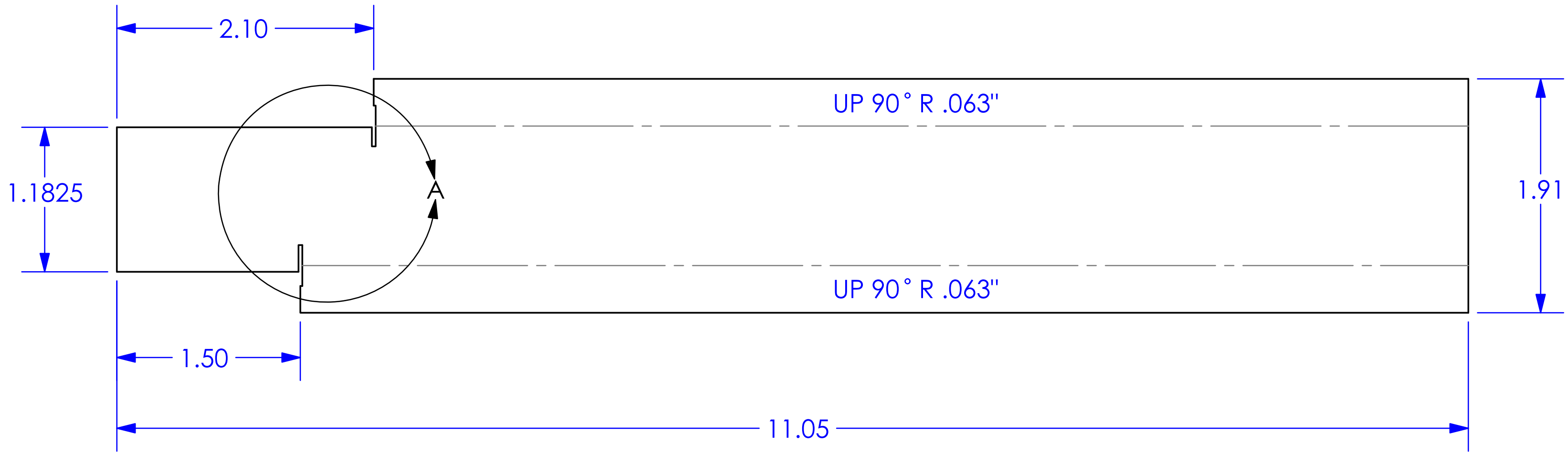
E1080
(4X)

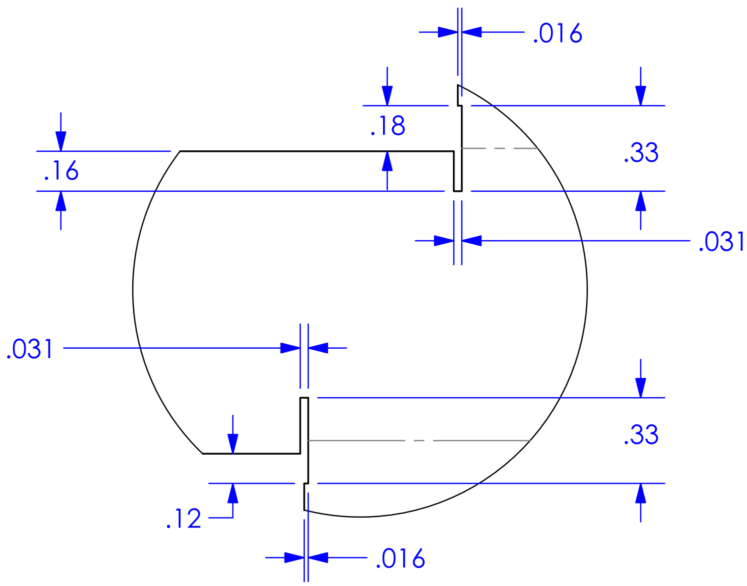


E1090
(8X)

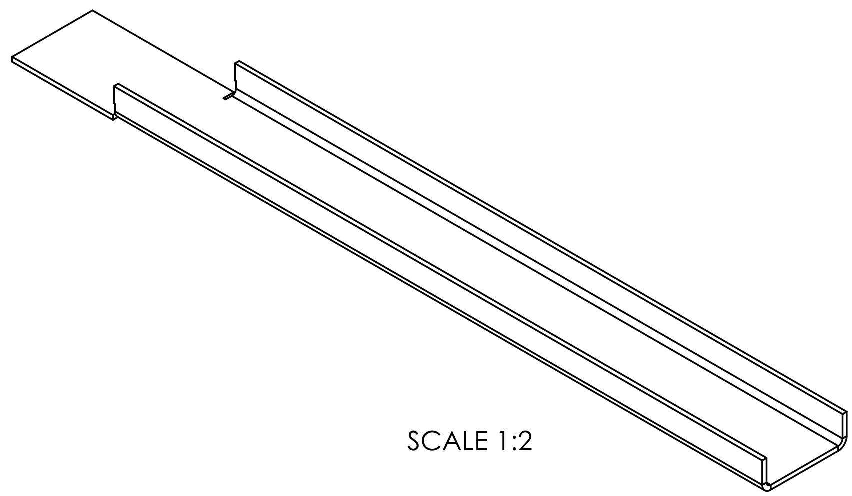
E1100
(4X)

See pages 34-49 for detailed parts and assembly instructions for Echo I.





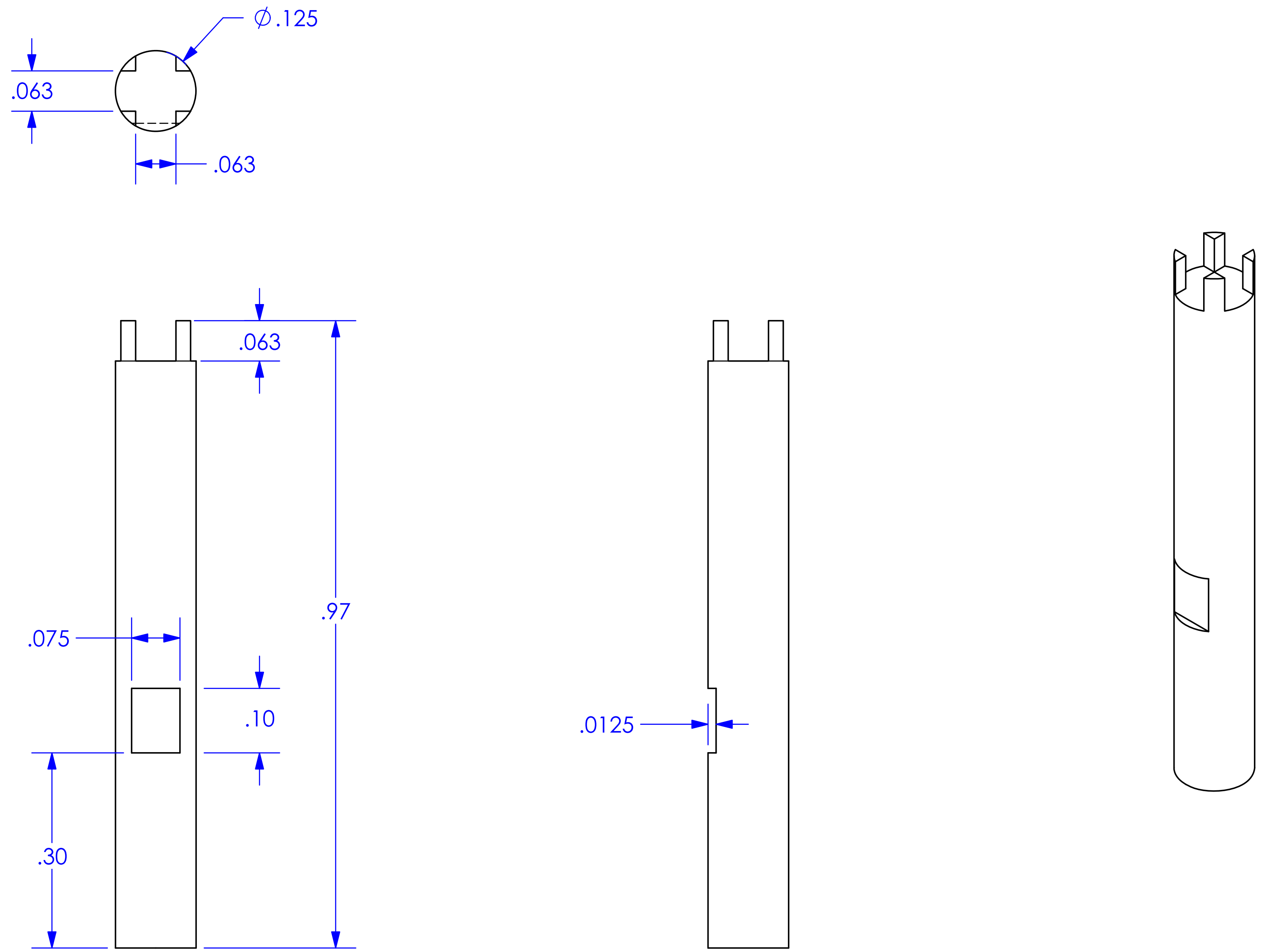
DETAIL A
SCALE 4 : 3



SCALE 1:2

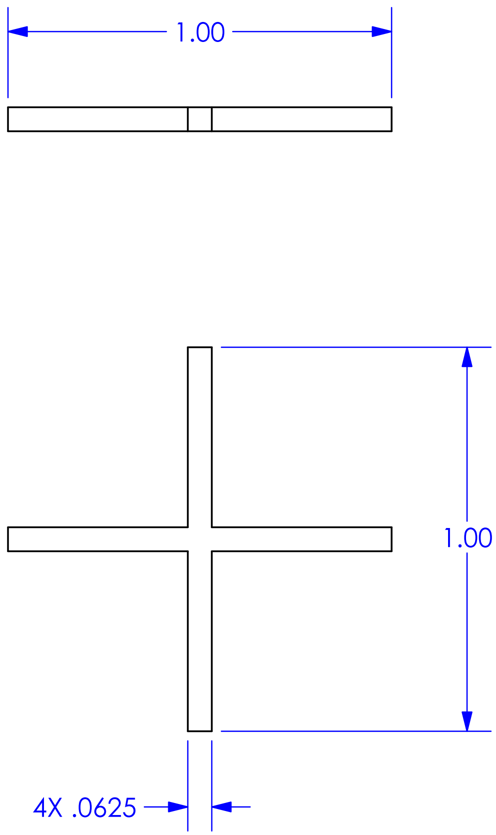
ECHO I PROCEDURE:
1. Cut and bend 4X part # E1000 from 1/16" sheet metal using the specified dimensions.

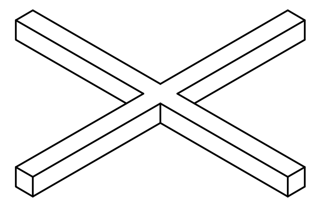
DATE: 5/28/2012	UNITS: INCHES	MATERIAL: TYPE 316 S.S. SHEET METAL 1/16"
TOLERANCE: 0.01	SCALE: 2:3	TITLE: ECHO I RAMP BASE
PART #: E1000	NEXT ASSY #: E120	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 5000	Page 34



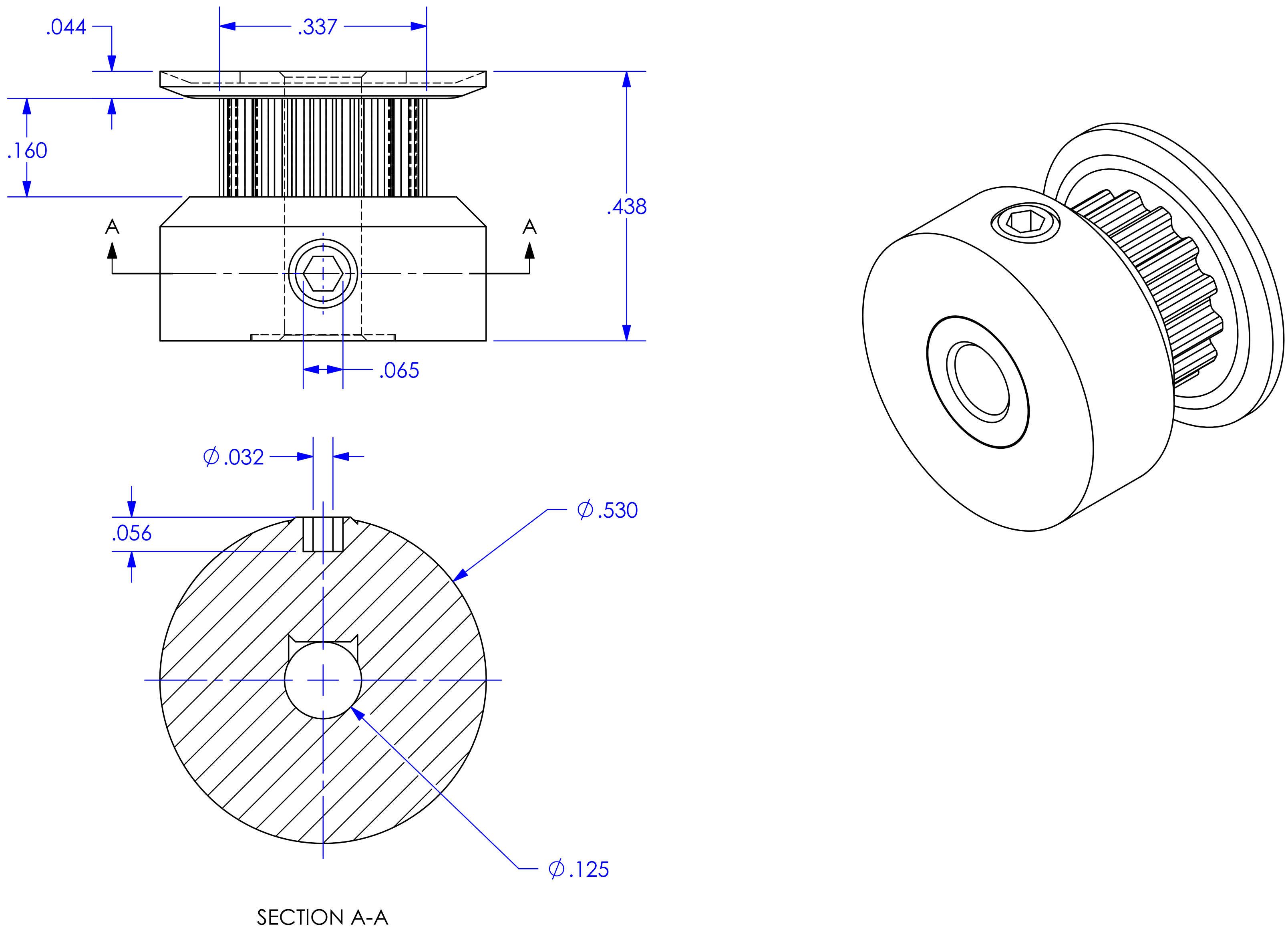
ECHO I PROCEDURE:
2. Cut 4X part # E1010 from 1/8” diameter rod.
3. Using a 1/16” thick hacksaw blade, cut the notches at the top of the rod. Using a 0.10” thick hacksaw blade, cut the notch on the cylindrical surface of the rod. This last notch will be used later to receive a set screw.

DATE: 5/28/2012	UNITS: INCHES	MATERIAL: TYPE 316 1/8" DIA STAINLESS STEEL ROD
TOLERANCE: 0.01	SCALE: 4:1	TITLE: ECHO ROD FOR GATE ASSEMBLY
PART #: E1010	NEXT ASSY #: E100	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 5010	Page 35



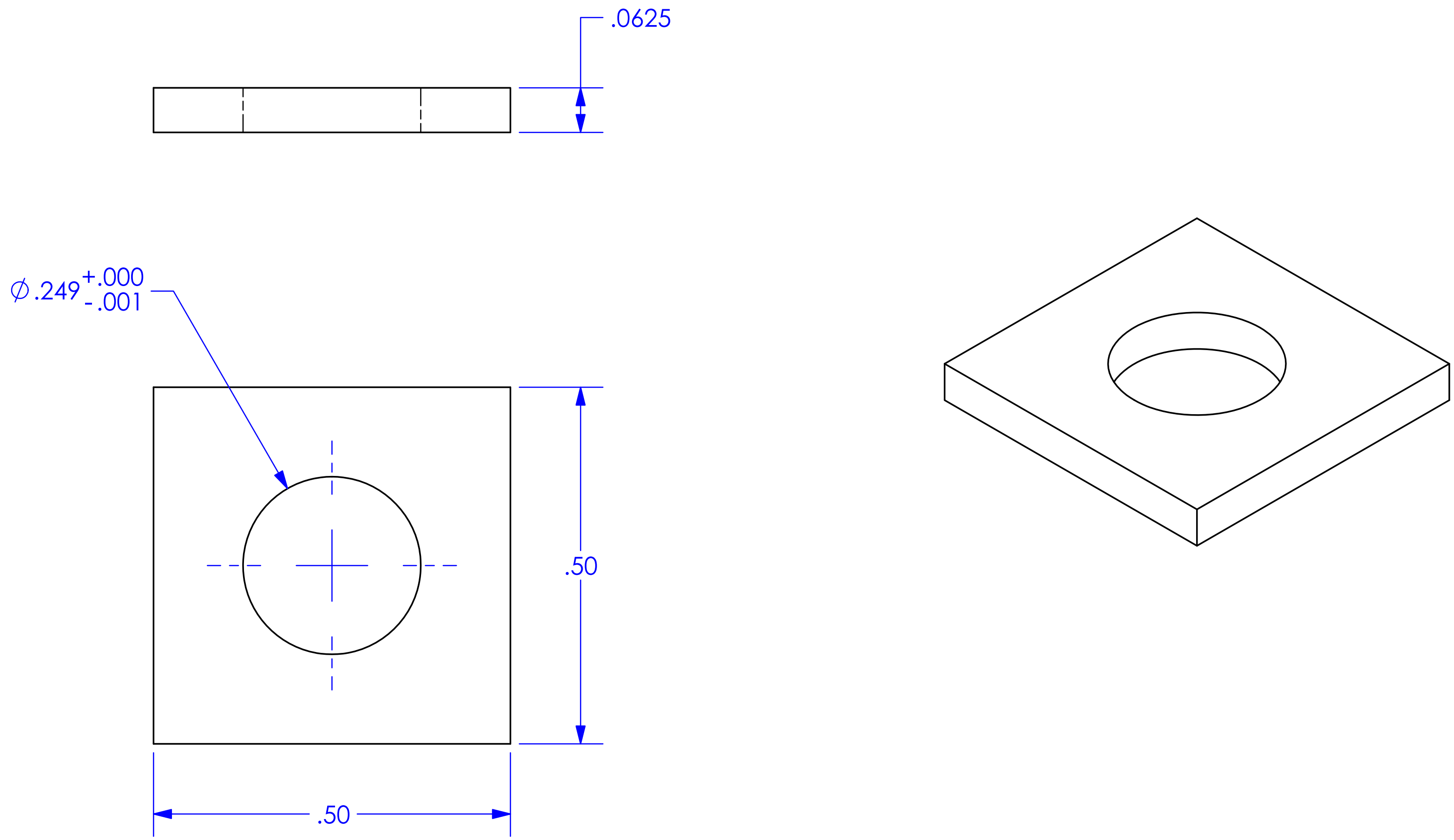


ECHO I PROCEDURE: 3. Cut 4X part # E1020 from 1/16” sheet metal using the specified dimensions.	DATE: 5/28/2012	UNITS: INCHES	MATERIAL: TYPE 316 S.S. SHEET METAL 1/16"
	TOLERANCE: 0.01	SCALE: 2:1	TITLE: ECHO GATE
	PART #: E1020	NEXT ASSY #: E100	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 5020	Page 36



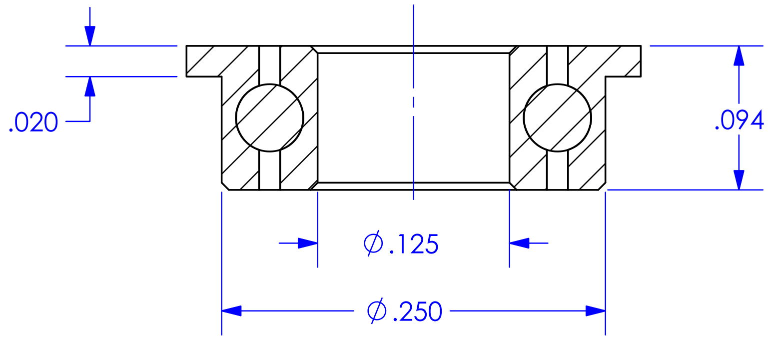
ECHO I PROCEDURE:
4. Obtain 4X part # E1030 0.125” bore timing belt pulleys.

DATE: 5/28/2012	UNITS: INCHES	MATERIAL: ALUMINUM ALLOY
TOLERANCE: 0.01	SCALE: 4:1	TITLE: 0.125" BORE TIMING BELT PULLEY
PART #: E1030	NEXT ASSY #: E130	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 5030	Page 37

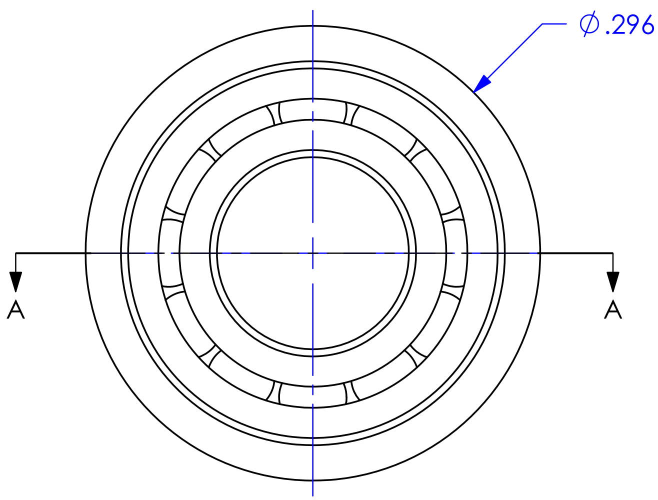


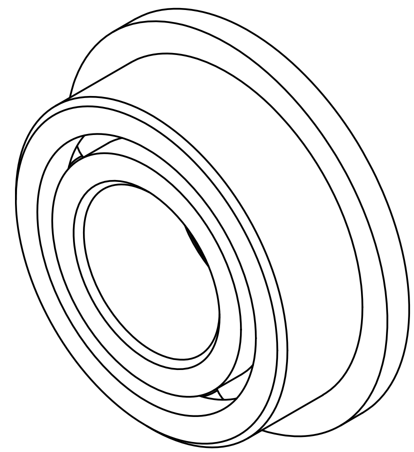
ECHO I PROCEDURE:
5. Cut 8X part # E1040 from 1/16" sheet metal using the specified dimensions.

DATE: 5/28/2012	UNITS: INCHES	MATERIAL: TYPE 316 S.S. SHEET METAL 1/16"
TOLERANCE: 0.01	SCALE: 8:1	TITLE: SUPPORT BRACKET FOR ECHO GATE ASSY
PART #: E1040	NEXT ASSY #: E120	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 5040	Page 38

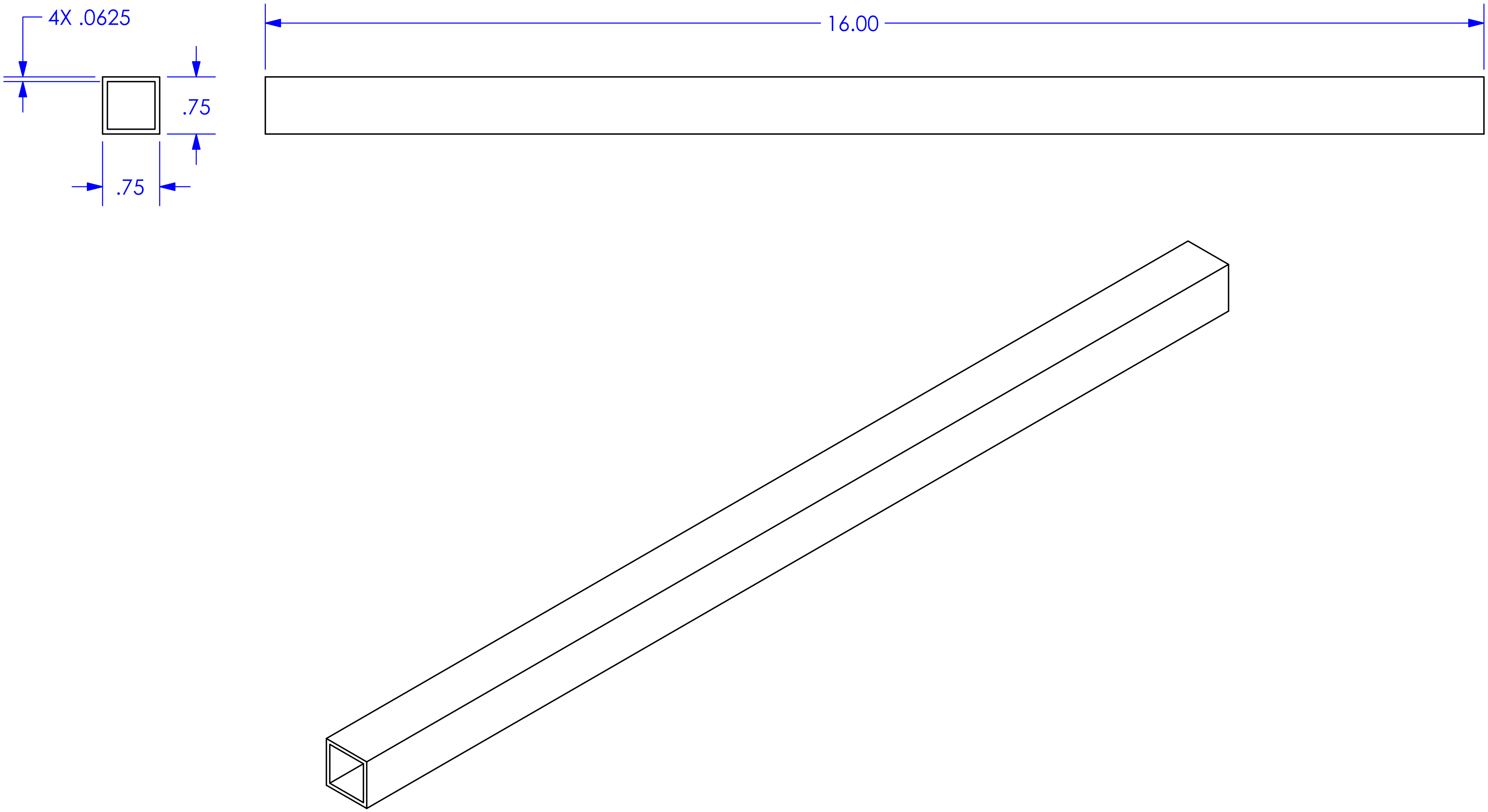


SECTION A-A



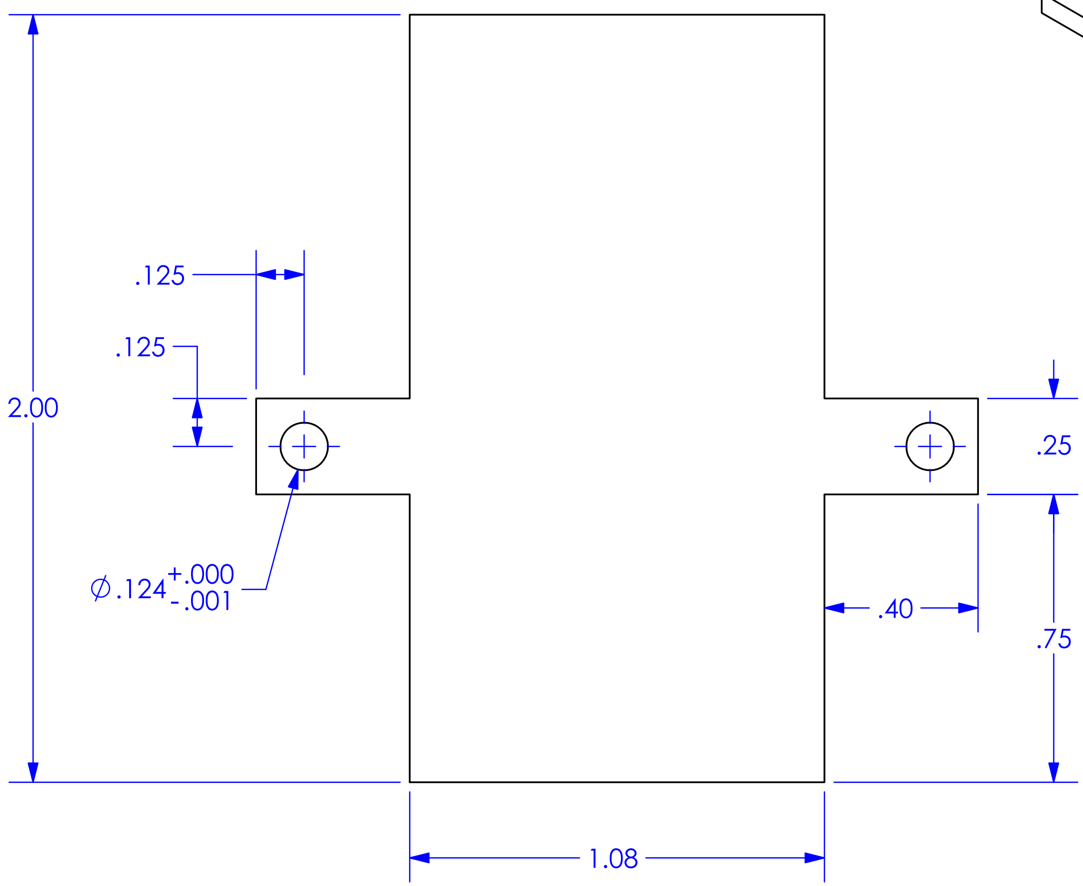


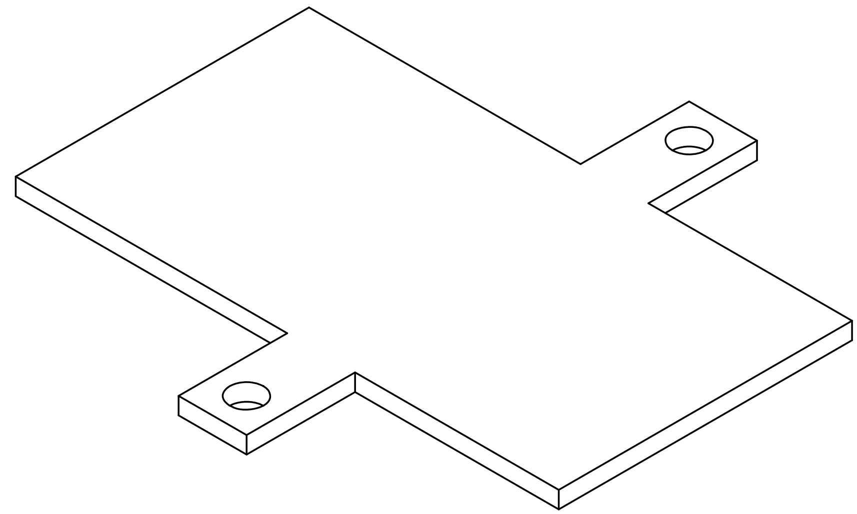
ECHO I PROCEDURE: 6. Obtain 8X part # E1050 miniature ball bearings.	DATE: 5/27/2012	UNITS: INCHES	MATERIAL: STAINLESS STEEL
	TOLERANCE: 0.01	SCALE: 8:1	TITLE: ECHO MINIATURE BALL BEARING
	PART #: E1050	NEXT ASSY #: E130	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 5050	Page 39



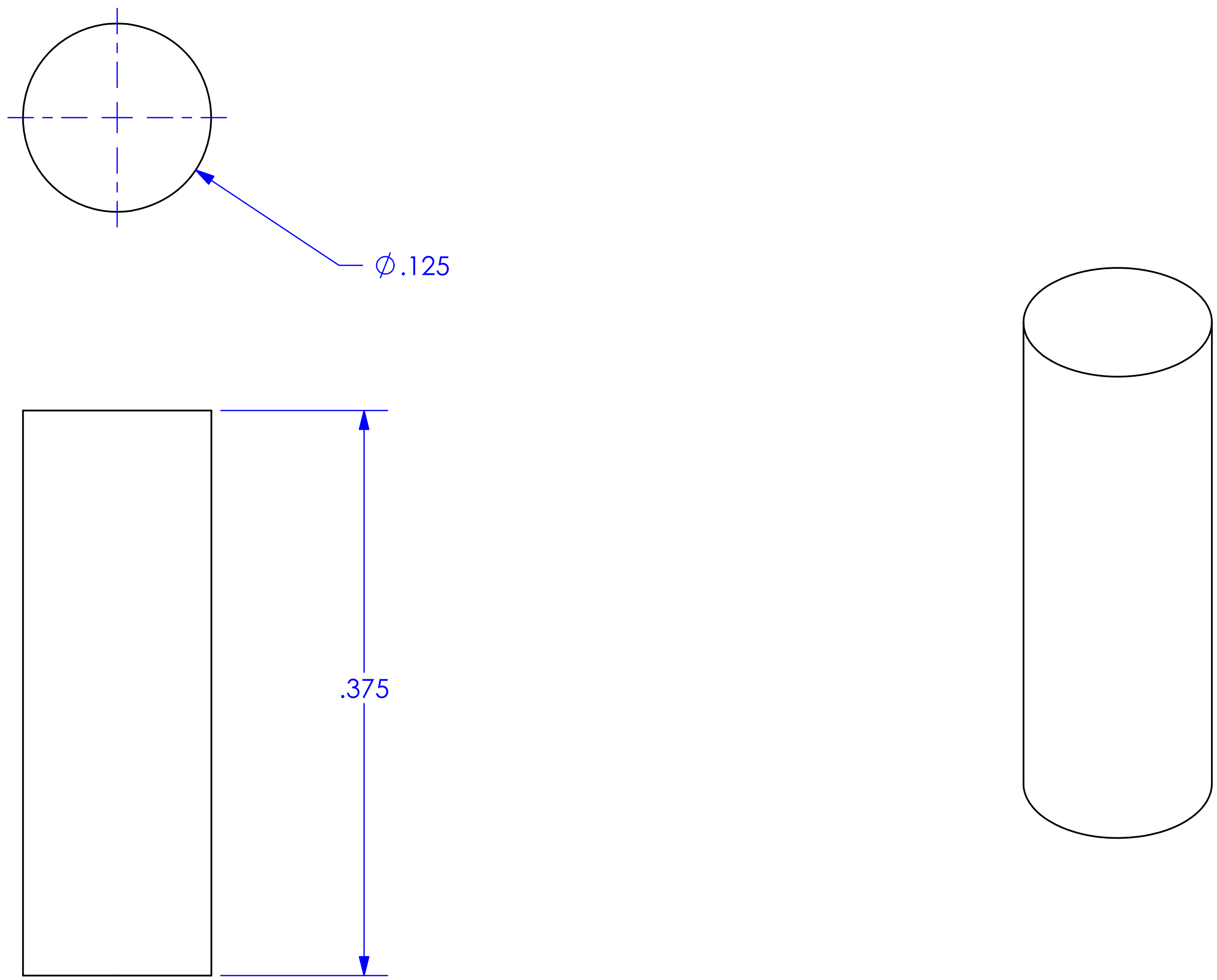
ECHO I PROCEDURE:
7. Cut part # E1060 from type 316 stainless steel 3/4" square bar to a length of 16 inches.

DATE: 5/28/2012	UNITS: INCHES	MATERIAL: TYPE 316 3/4" X 3/4" S.S. BAR
TOLERANCE: 0.01	SCALE: 1:2	TITLE: ECHO CROSSBAR
PART #: E1060	NEXT ASSY #: E150	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 5060	Page 40

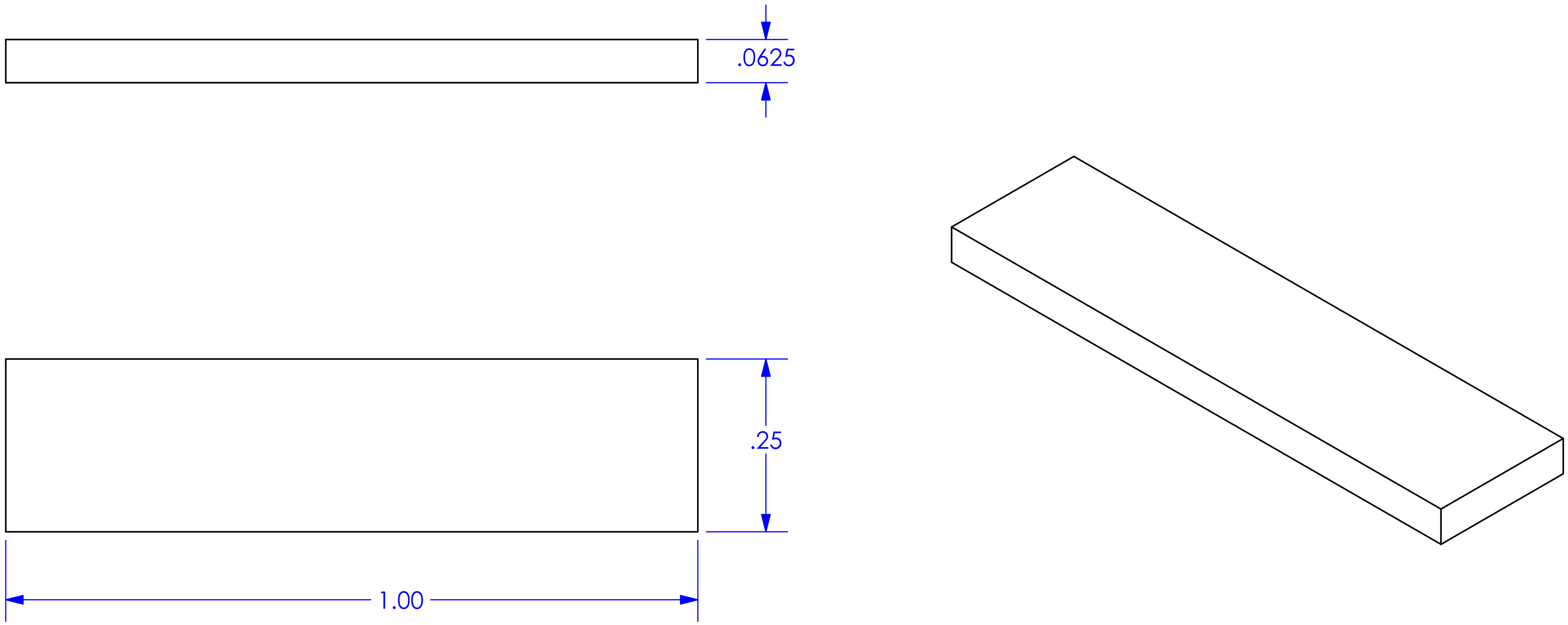




ECHO I PROCEDURE: 8. Cut 4X part # E1080 from 1/16" sheet metal using the specified dimensions.	DATE: 5/28/2012	UNITS: INCHES	MATERIAL: TYPE 316 S.S. SHEET METAL 1/16"
	TOLERANCE: 0.01	SCALE: 2:1	TITLE: ECHO CONNECTING PAD
	PART #: E1080	NEXT ASSY #: E110	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 5080	Page 41

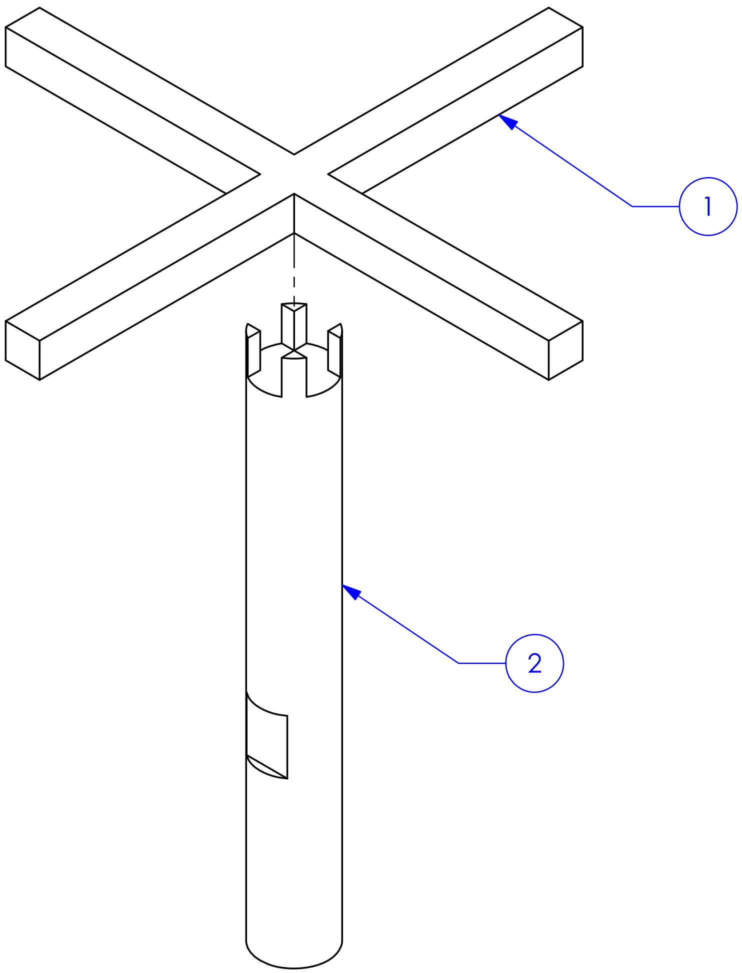


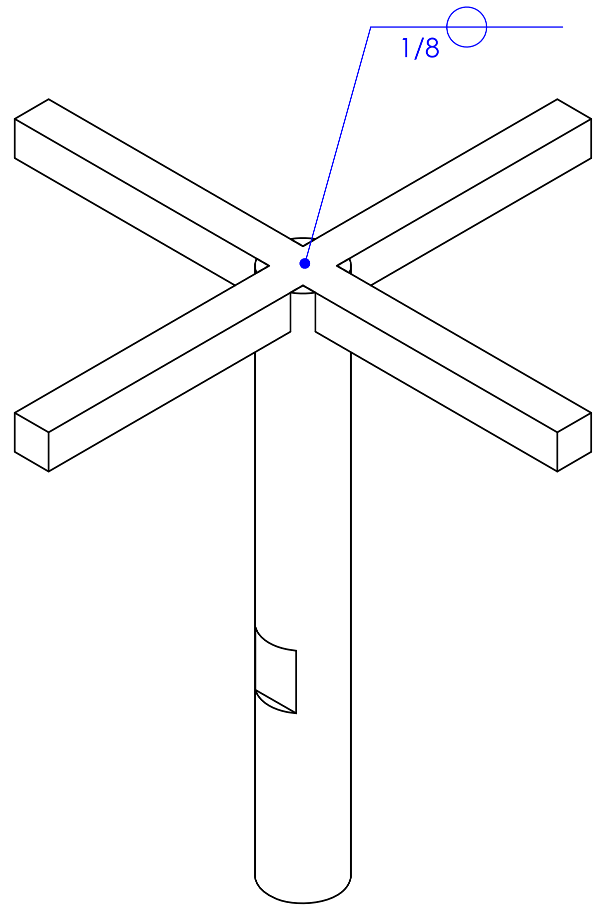
ECHO I PROCEDURE: 9. Cut 8X part # E1090 from 1/8" diameter stainless steel rod.	DATE: 5/28/2012	UNITS: INCHES	MATERIAL: TYPE 316 1/8" DIA STAINLESS STEEL ROD
	TOLERANCE: 0.01	SCALE: 8:1	TITLE: ROD FOR ECHO CONNECTING PAD
	PART #: E1090	NEXT ASSY #: E110	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 5090	Page 42



ECHO I PROCEDURE: 10. Cut 4X part # E1100 from 1/16" sheet metal using the specified dimensions.	DATE: 5/28/2012	UNITS: INCHES	MATERIAL: TYPE 316 S.S. SHEET METAL 1/16"
	TOLERANCE: 0.01	SCALE: 4:1	TITLE: SHIM FOR RAMP CAMBER
	PART #: E1100	NEXT ASSY #: E140	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 5100	Page 43

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	E1020	0.06" STAINLESS STEEL SHEET	1
2	E1010	1/8" STAINLESS STEEL ROD	1

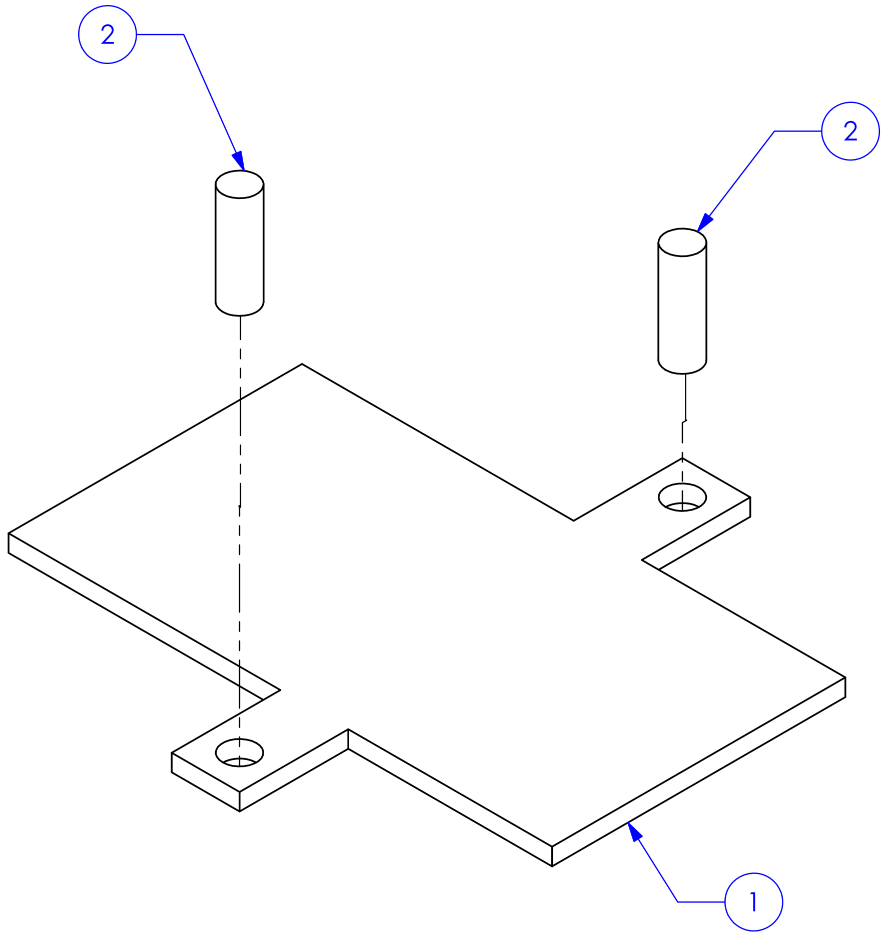


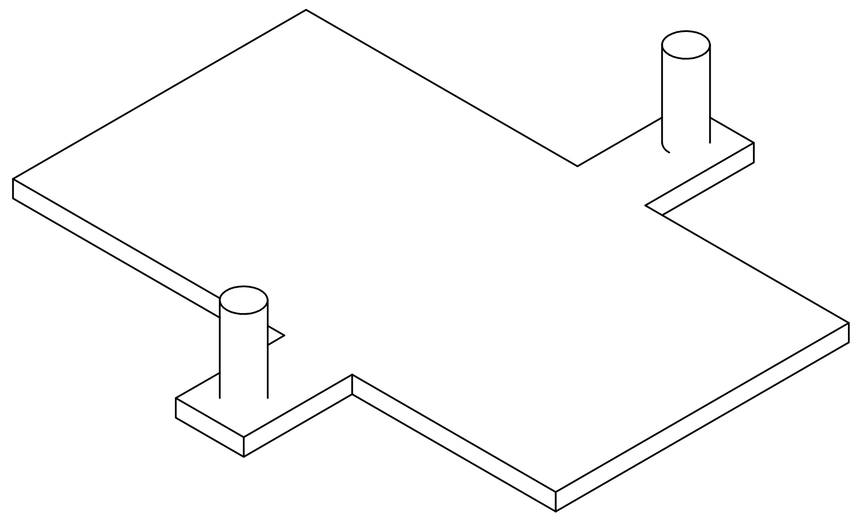


ECHO I PROCEDURE:
11. Spot weld part # E1020 to # E1010 in the specified location. Make a total of 4 assemblies.

DATE: 5/25/2012	UNITS: INCHES	MATERIAL: SEE BOM
TOLERANCE: 0.01	SCALE: 4:1	TITLE: ECHO GATE ASSEMBLY
ASSY #: E100	NEXT ASSY #: E130	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 500	Page 44

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	E1080	0.06" STAINLESS STEEL SHEET	1
2	E1090	1/8" STAINLESS STEEL ROD	2

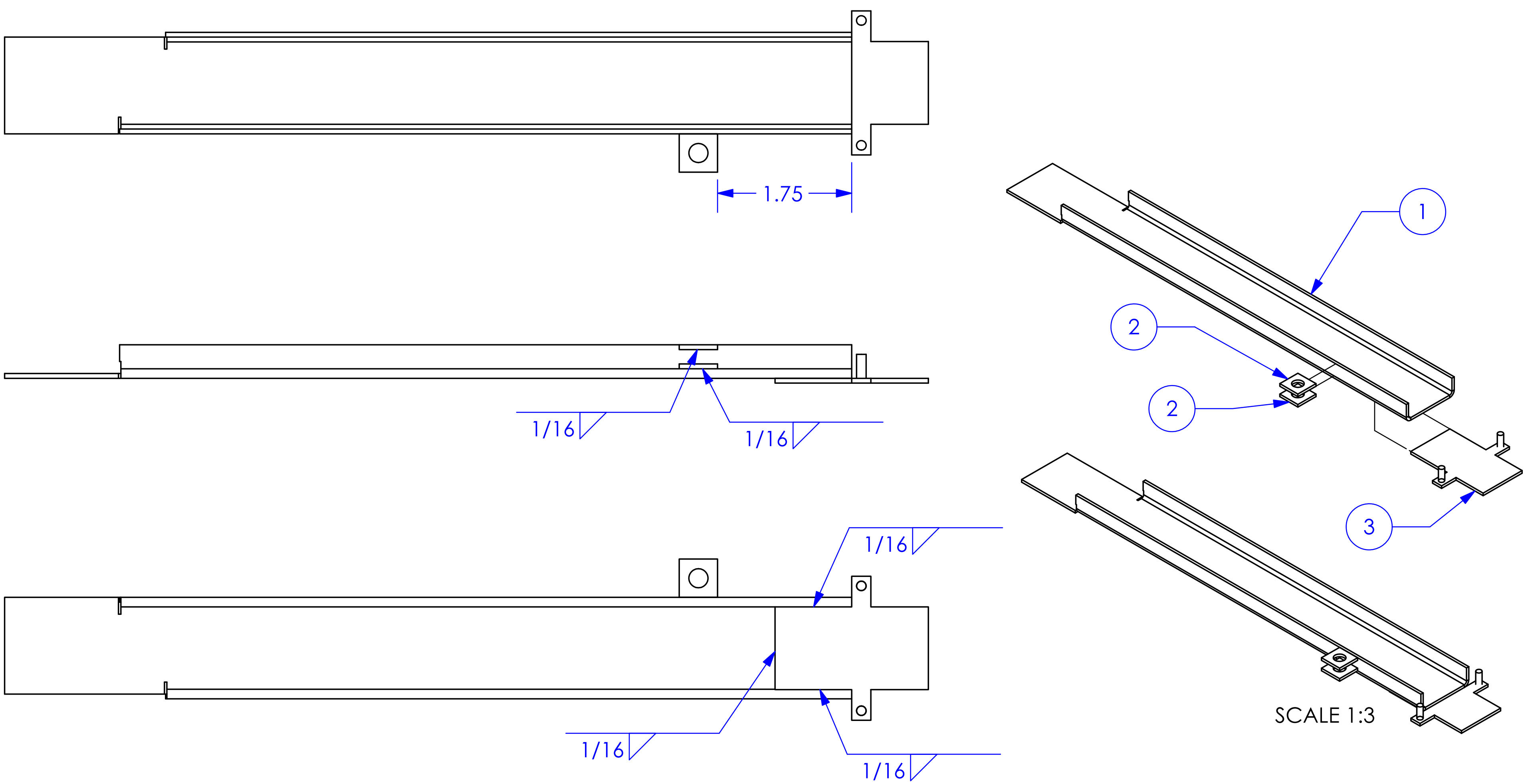




ECHO I PROCEDURE:
12. Press 2X part # E1090 into part # E1080.
Make a total of 4 assemblies.

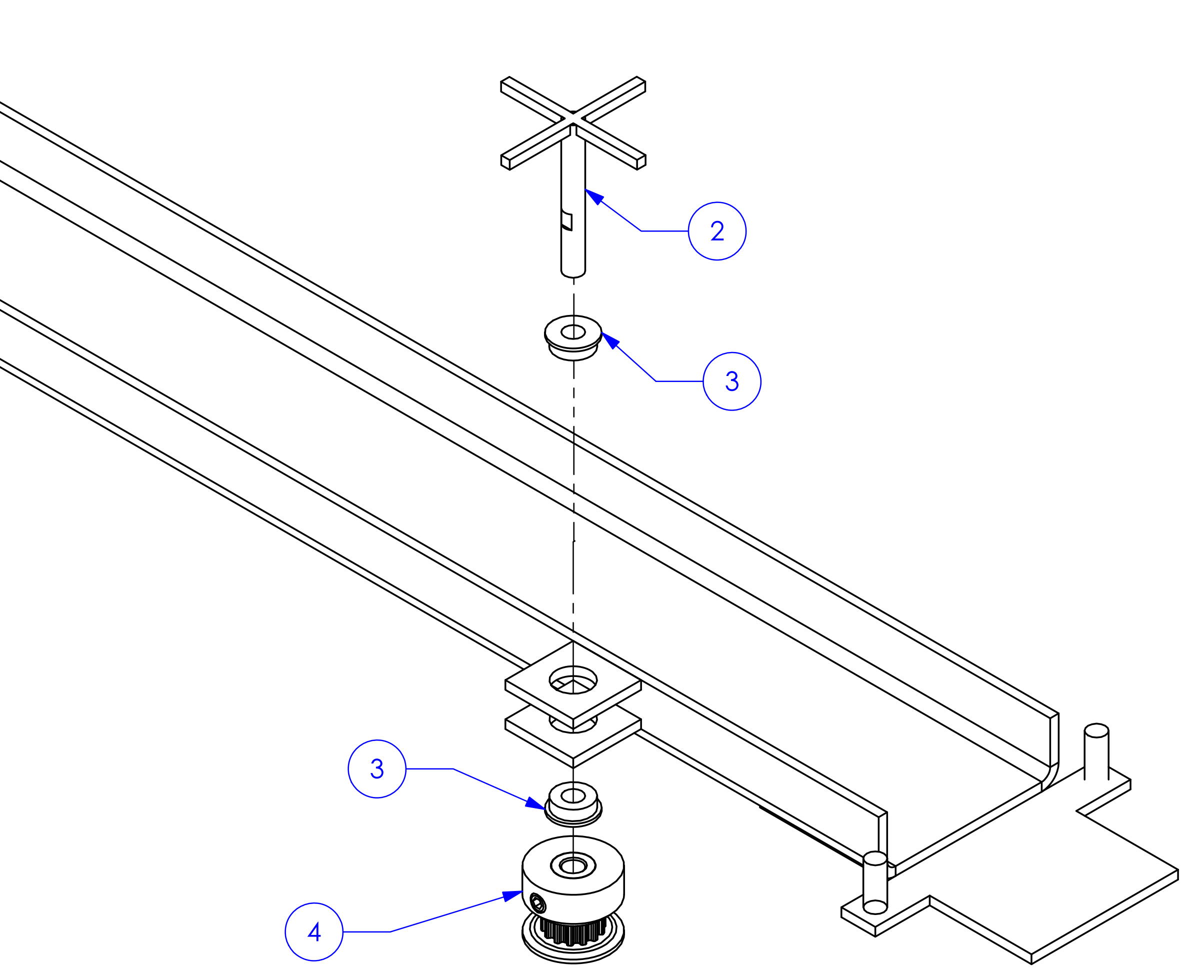
DATE: 5/25/2012	UNITS: INCHES	MATERIAL: SEE BOM
TOLERANCE: 0.01	SCALE: 2:1	TITLE: ECHO CONNECTING PAD ASSEMBLY
ASSY #: E110	NEXT ASSY #: E120	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 510	Page 45

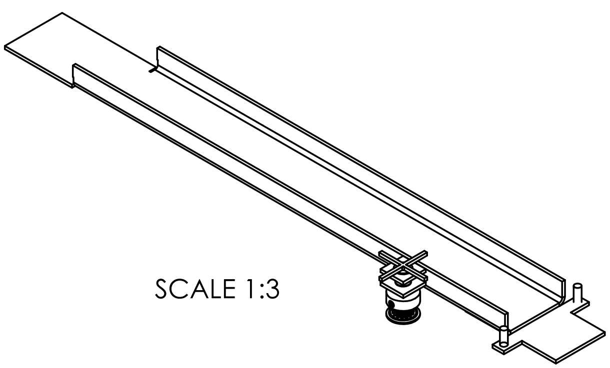
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	E1000	0.06" STAINLESS STEEL BENT SHEET	1
2	E1040	0.06" STAINLESS STEEL SHEET	2
3	E110	CONNECTING PAD ASSEMBLY	1



ECHO I PROCEDURE: 13. Weld 2X part # E1040 and 1X assembly # E110 to part # E1000 in the specified locations. Make a total of 4 assemblies.	DATE: 5/25/2012	UNITS: INCHES	MATERIAL: SEE BOM
	TOLERANCE: 0.01	SCALE: 1:2	TITLE: ECHO I RAMP PARTIALLY COMPLETE
	ASSY #: E120	NEXT ASSY #: E130	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 520	Page 46

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	E120	ECHO I RAMP ASSEMBLY IN PROGRESS	1
2	E100	ECHO GATE ASSEMBLY	1
3	E1050	1/8" INNER SHAFT DIA BEARING	2
4	E1030	0.125" BORE TIMING BELT PULLEY	1

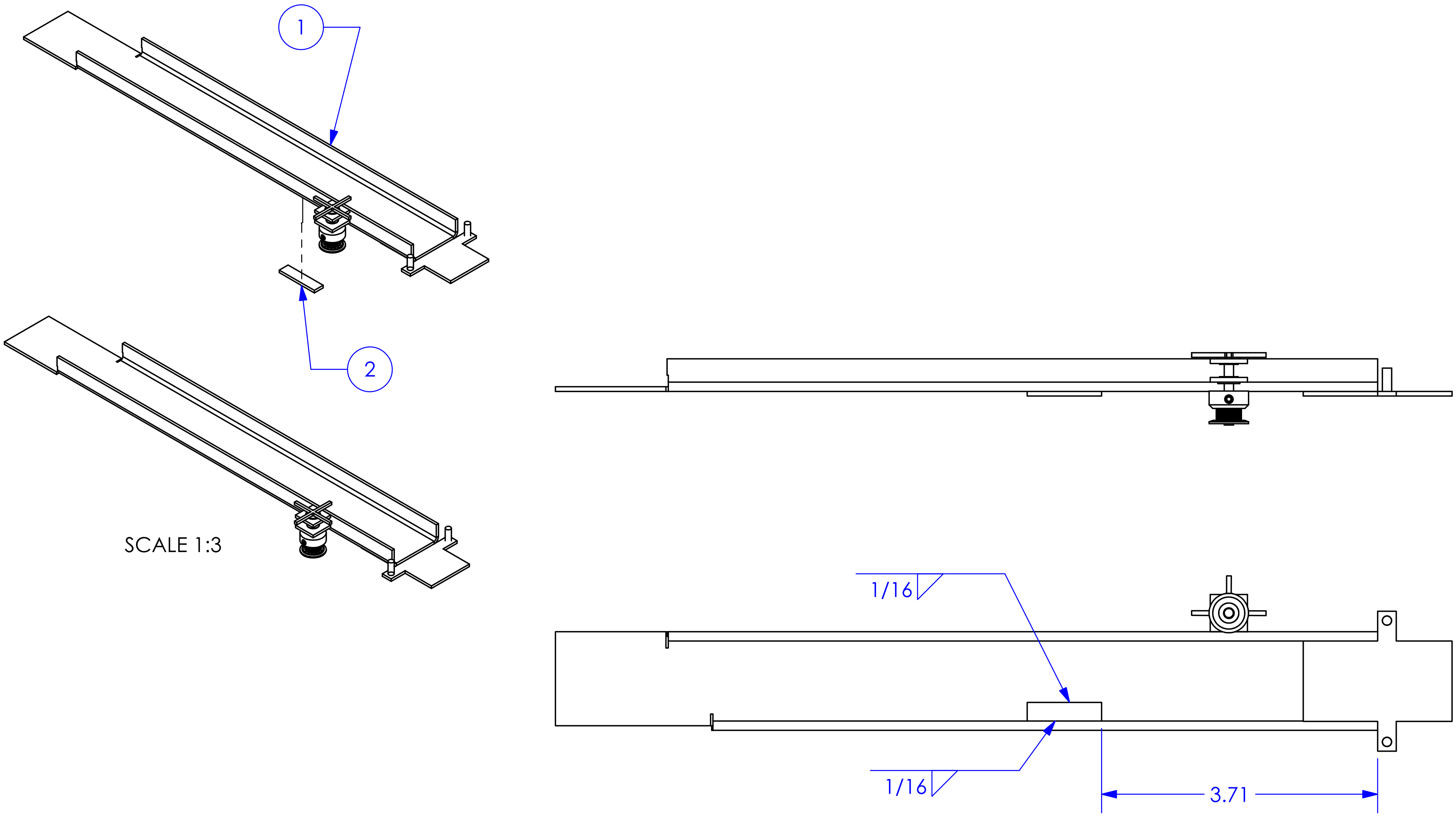




SCALE 1:3

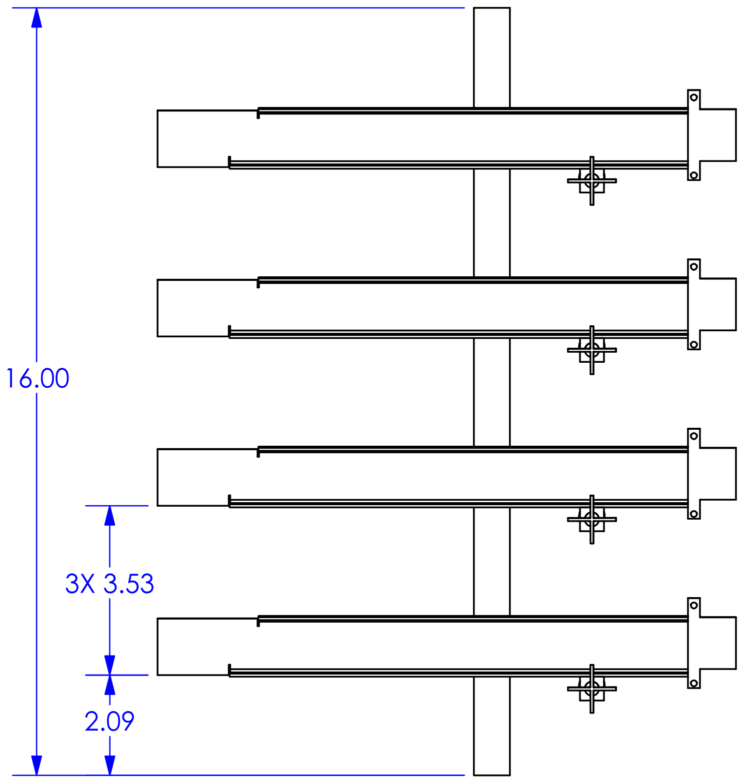
ECHO I PROCEDURE: 14. Press 2X part # E1050 into assembly # E120. 15. Slide assembly # E100 into assembly #E120. 16. Slide part # E1030 onto assembly # E100 and tighten the set screw. 17. Repeat steps 14-16 3X to make a total of four assemblies.	DATE: 5/25/2012	UNITS: INCHES	MATERIAL: SEE BOM
	TOLERANCE: 0.01	SCALE: 1:1	TITLE: ECHO I RAMP PARTIALLY COMPLETE
	ASSY #: E130	NEXT ASSY #: E140	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 530	Page 47

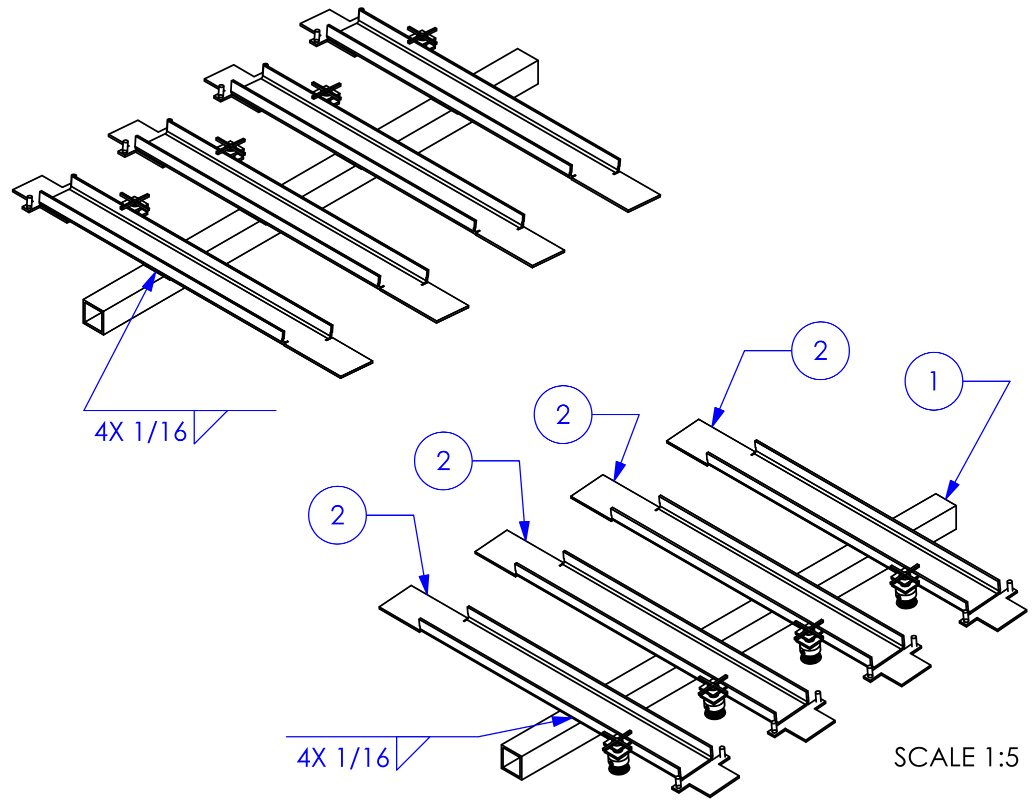
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	E130	PARTIALLY COMPLETE RAMP ASSY	1
2	E1100	0.06" STAINLESS STEEL SHEET	1

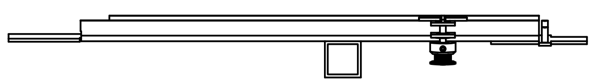


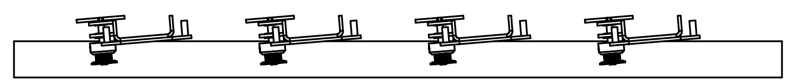
ECHO I PROCEDURE: 18. Weld part # E1100 to assembly # E130. Make a total of 4 assemblies.	DATE: 5/25/2012	UNITS: INCHES	MATERIAL: SEE BOM
	TOLERANCE: 0.01	SCALE: 1:2	TITLE: ECHO I COMPLETE INDIVIDUAL RAMP
	ASSY #: E140	NEXT ASSY #: E150	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 540	Page 48

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	E1060	3/4" X 3/4" STAINLESS STEEL BAR	1
2	E140	ECHO I INDIVIDUAL RAMP ASSEMBLY	4







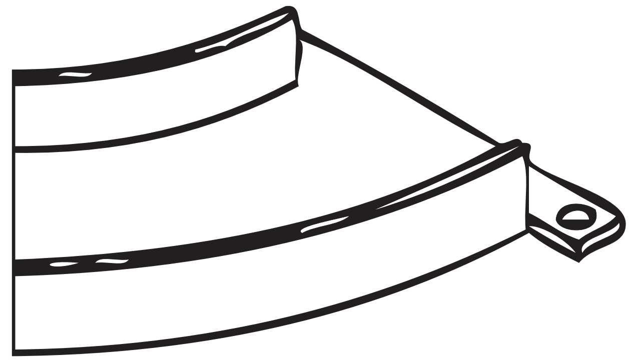


ECHO I PROCEDURE:
19. Weld 4X assembly # E140 to part # E1060 to complete the Echo I Ramp Assembly.

DATE: 5/25/2012	UNITS: INCHES	MATERIAL: SEE BOM
TOLERANCE: 0.01	SCALE: 1:4	TITLE: ECHO I COMPLETE RAMP ASSEMBLY
ASSY #: E150	NEXT ASSY #: ISO	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 550	

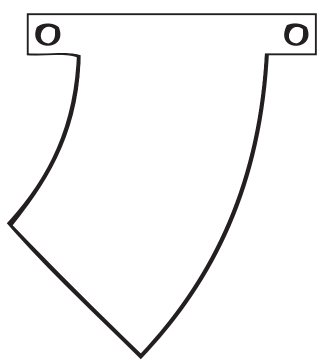
Echo II Assembly

The Echo II attachment slips onto the end of Echo I for regular oriented star-clip delivery. You will need to make four Echo II attachments.

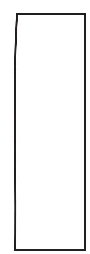


You will need the following part numbers (and quantities) to assemble Echo II:

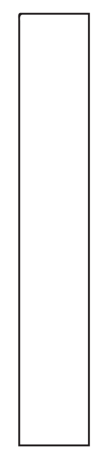
E2000
(4X)



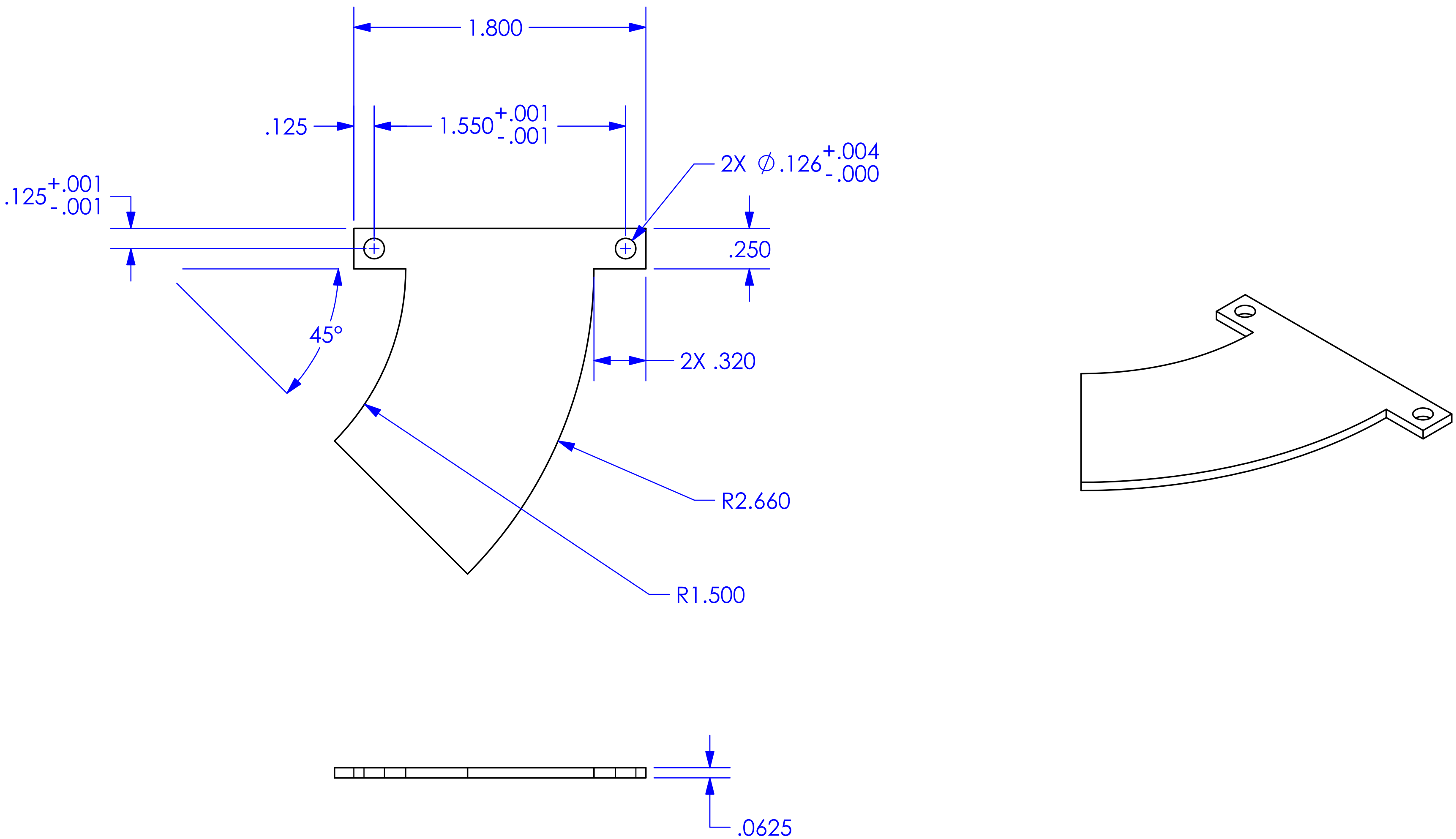
E2010
(4X)



E2020
(4X)

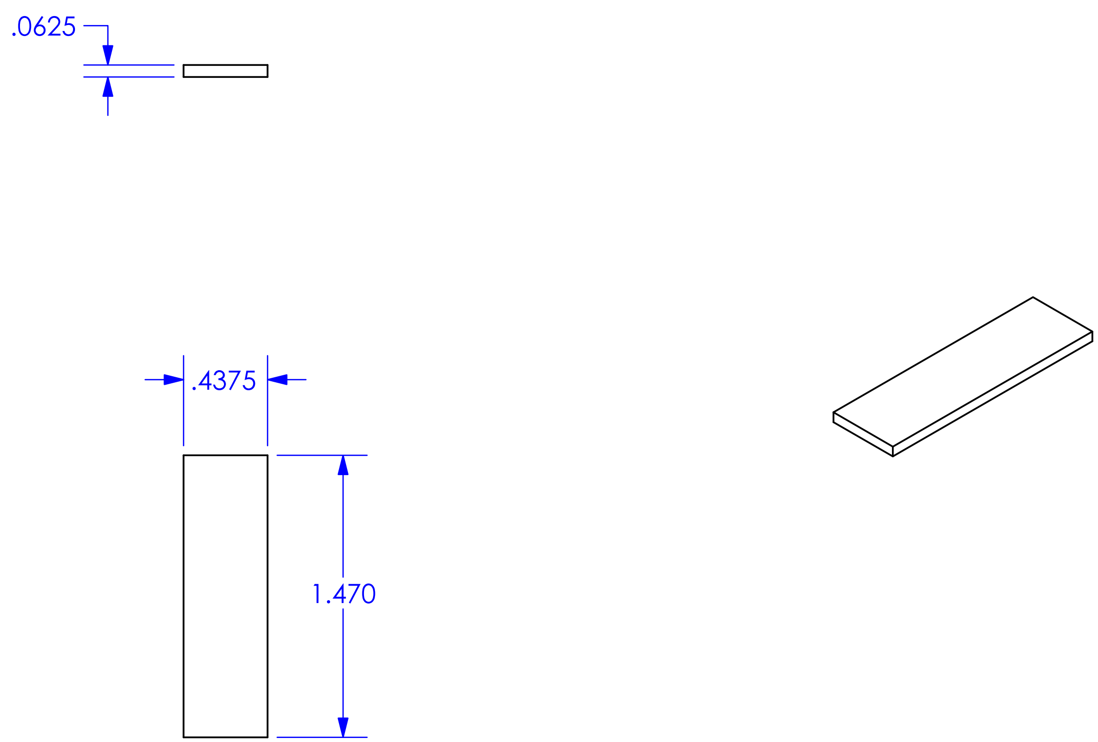


See pages 51-56 for detailed parts and assembly instructions for Echo II.

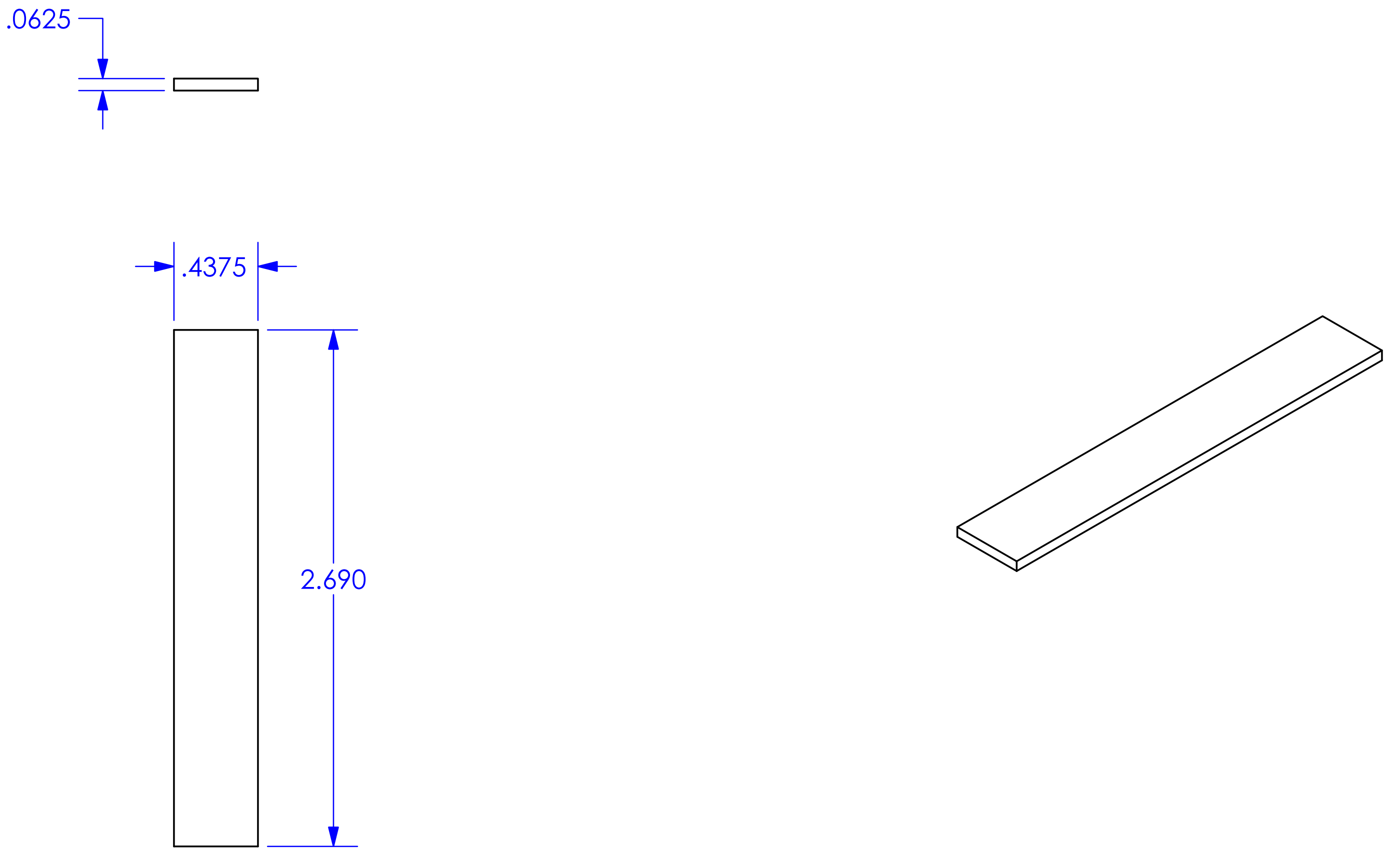


ECHO II PROCEDURE:
1. Cut 4X part # E2000 from 1/16" sheet metal using the specified dimensions.

DATE: 5/29/2012	UNITS: INCHES	MATERIAL: TYPE 316 S.S. SHEET METAL 1/16"
TOLERANCE: 0.01	SCALE: 1:1	TITLE: ECHO ATTACHMENT BASE FOR REGULAR STAR-CLIP DELIVERY
PART #: E2000	NEXT ASSY #: E200	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 5205	Page 51



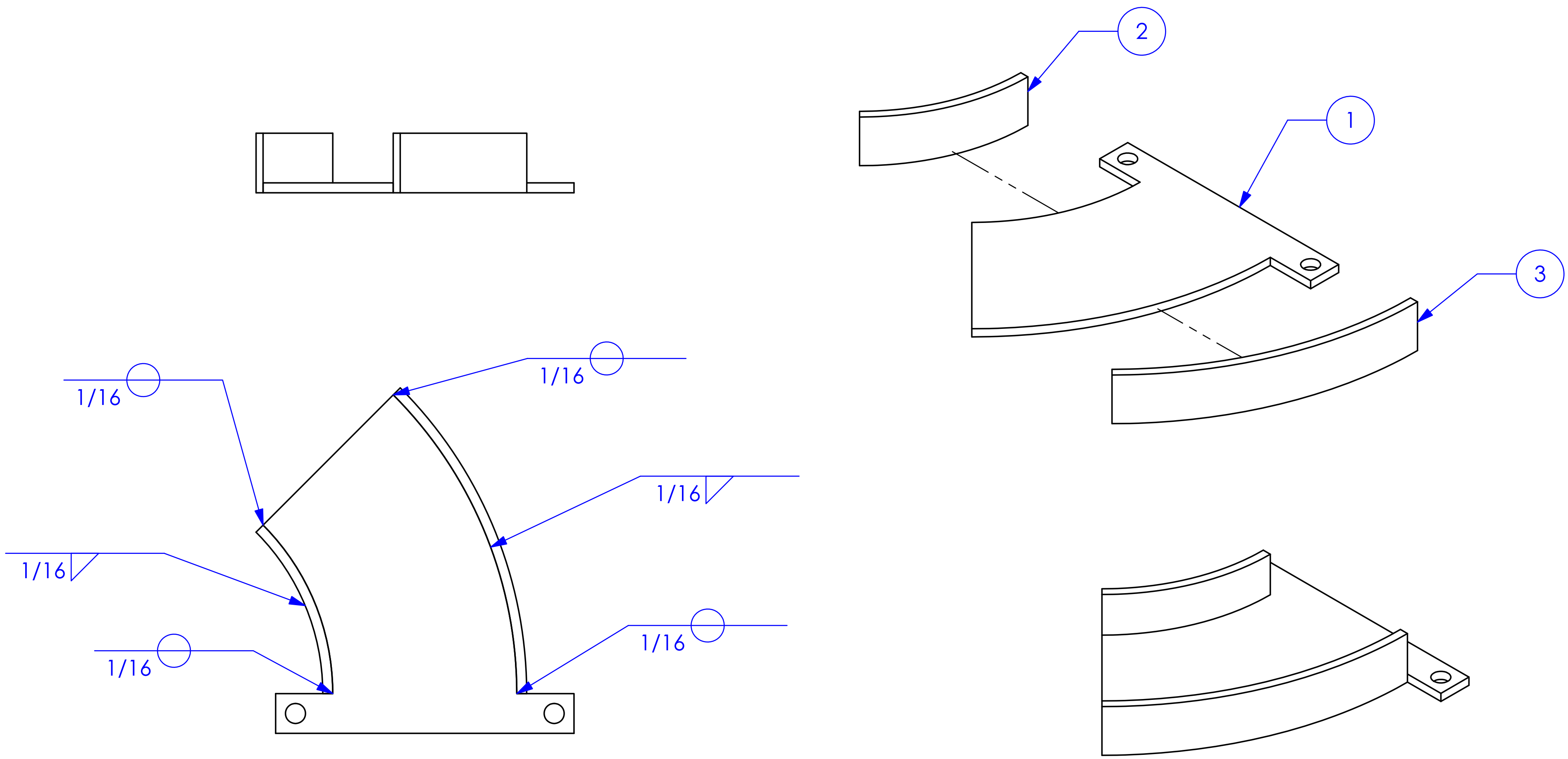
ECHO II PROCEDURE: 2. Cut 4X part # E2010 from 1/16" sheet metal using the specified dimensions.	DATE: 5/29/2012	UNITS: INCHES	MATERIAL: TYPE 316 S.S. SHEET METAL 1/16"
	TOLERANCE: 0.01	SCALE: 1:1	TITLE: SHORT-SIDE WALL FOR ECHO II ATTACHMENT
	PART #: E2010	NEXT ASSY #: E200	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 5215	Page 52



ECHO II PROCEDURE:
3. Cut part # E2020 from 1/16" sheet metal using the specified dimensions.

DATE: 5/29/2012	UNITS: INCHES	MATERIAL: TYPE 316 S.S. SHEET METAL 1/16"
TOLERANCE: 0.01	SCALE: 1:1	TITLE: LONG-SIDE WALL FOR ECHO II ATTACHMENT
PART #: E2020	NEXT ASSY #: E200	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 5225	Page 53

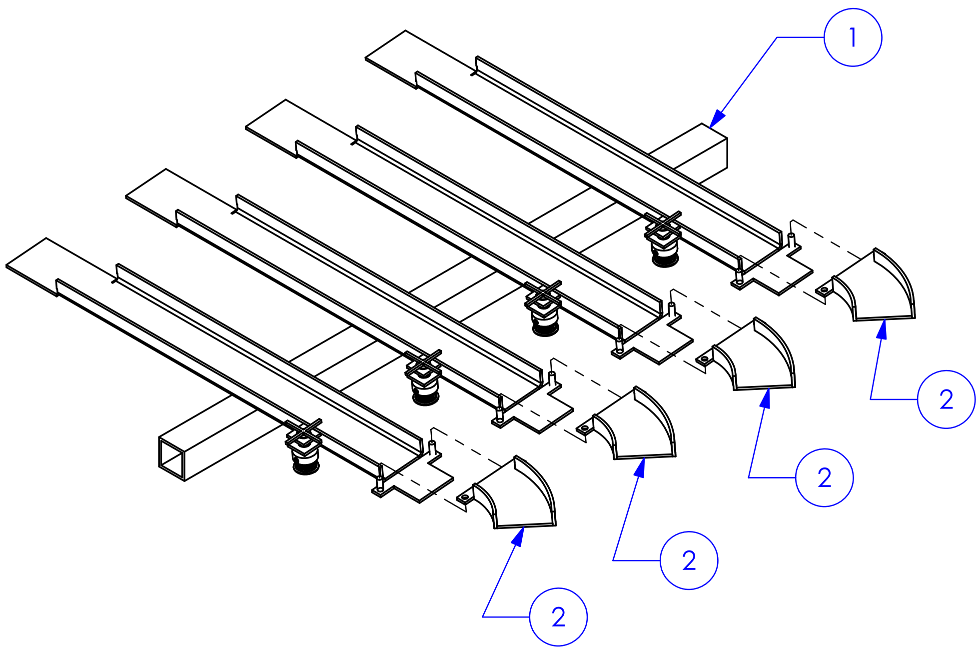
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	E2000	ECHO II ATTACHMENT BASE	1
2	E2010	ECHO II SHORT WALL	1
3	E2020	ECHO II LONG WALL	1

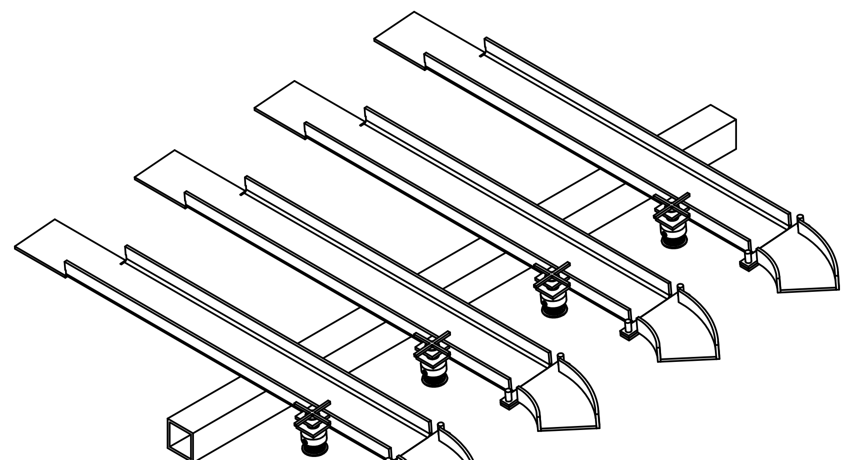


ECHO II PROCEDURE:
4. Press and curve part # E2010 against the curved side of # E2000 and hold in place by spot welding the ends. Repeat for part # E2020. Make a total of 4 assemblies.

DATE: 5/29/2012	UNITS: INCHES	MATERIAL: TYPE 316 S.S. SHEET METAL 1/16"
TOLERANCE: 0.01	SCALE: 1:1	TITLE: ECHO II COMPLETE ATTACHMENT FOR REGULAR STAR-CLIP DELIVERY
ASSY #: E200	NEXT ASSY #: E210	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 525	Page 54

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	E150	ECHO RAMP ASSEMBLY	1
2	E200	ECHO II COMPLETE ATTACHMENT	4

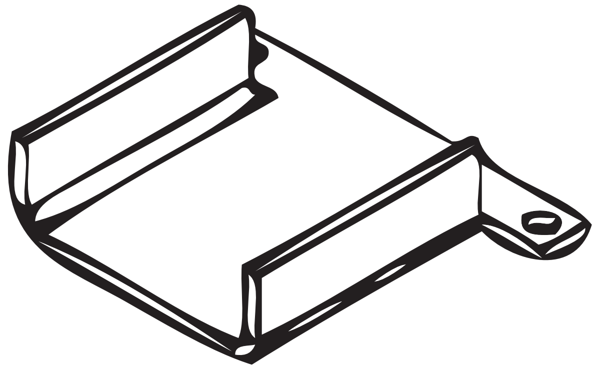




ECHO II PROCEDURE: 5. For regular star-clip delivery, slide 4X assembly # E200 onto assembly # E 150 (Echo I Ramp Assembly).	DATE: 5/29/2012	UNITS: INCHES	MATERIAL: SEE BOM
	TOLERANCE: 0.01	SCALE: 1:4	TITLE: ECHO II COMPLETE WITH ECHO I FOR REGULAR STAR-CLIP DELIVERY
	ASSY #: E210	NEXT ASSY #: ISO	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 526	Page 55

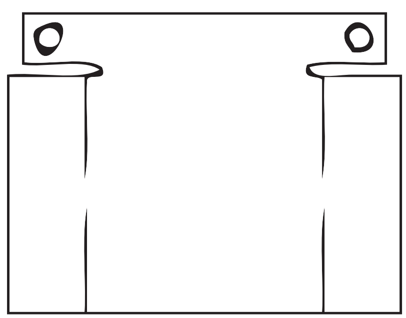
Echo III Assembly

The Echo III attachment slips onto the end of Echo I for 45 degree offset star-clip delivery. You will need to make four Echo III attachments.

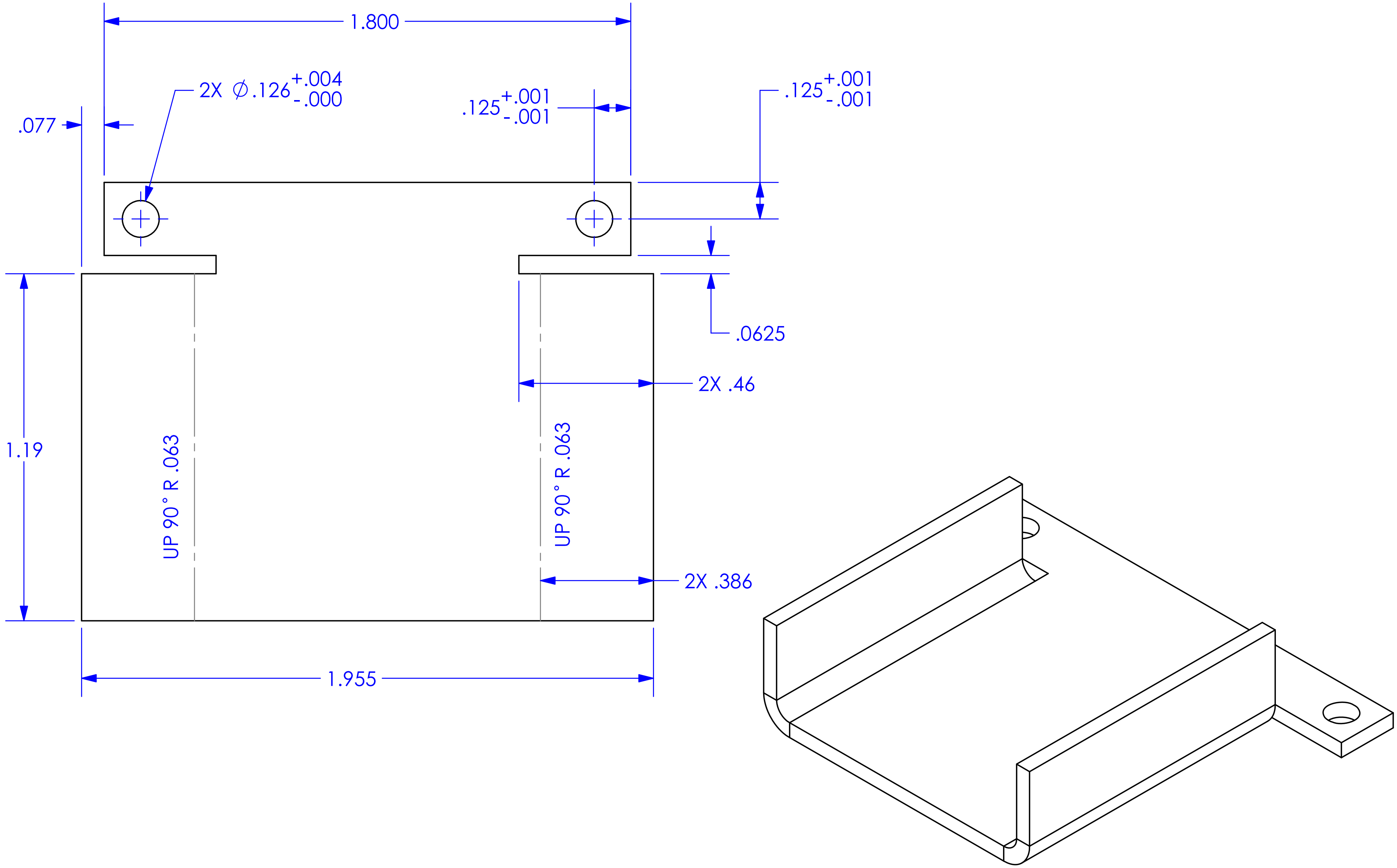


You will need the following part numbers (and quantities) to assemble Echo III:

E3000
(4X)

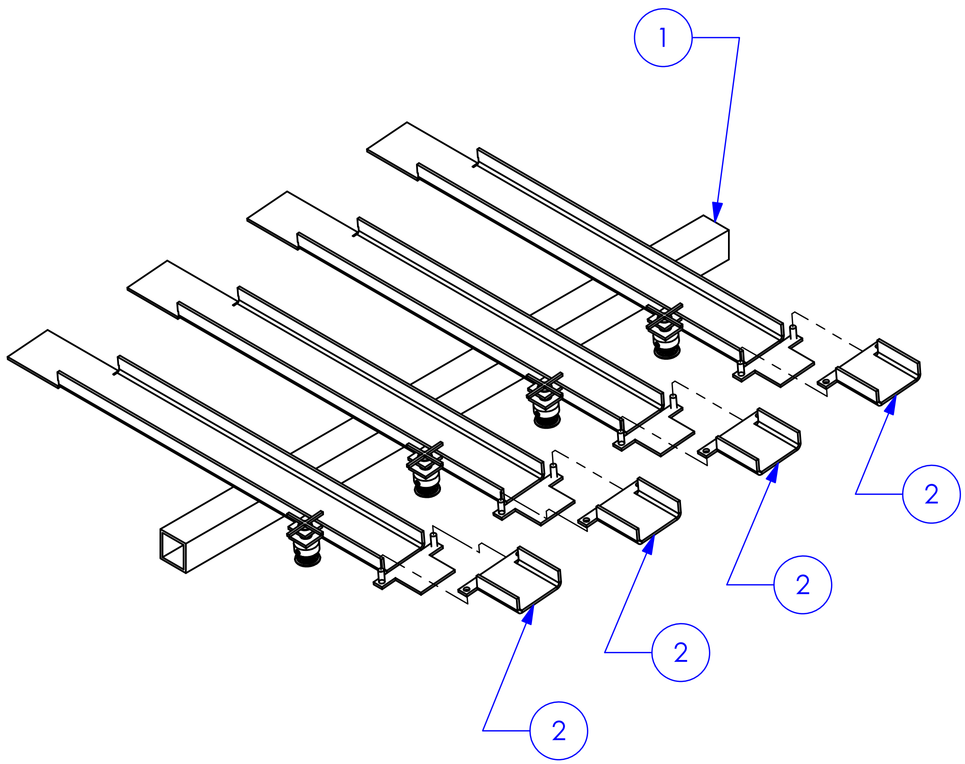


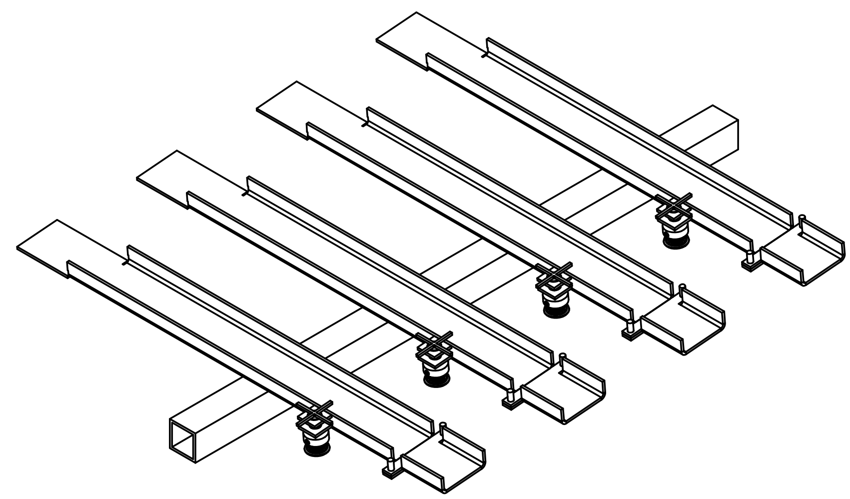
See pages 57-58 for detailed parts and assembly instructions for Echo III.



ECHO III PROCEDURE: 1. Cut and bend part # E3000 from 1/16" sheet metal using the specified dimensions.	DATE: 5/29/2012	UNITS: INCHES	MATERIAL: TYPE 316 S.S. SHEET METAL 1/16"
	TOLERANCE: 0.01	SCALE: 2:1	TITLE: ECHO III COMPLETE ATTACHMENT FOR 45° OFFSET STAR-CLIP DELIVERY
	PART #: E3000	NEXT ASSY #: E300	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 5305	Page 57

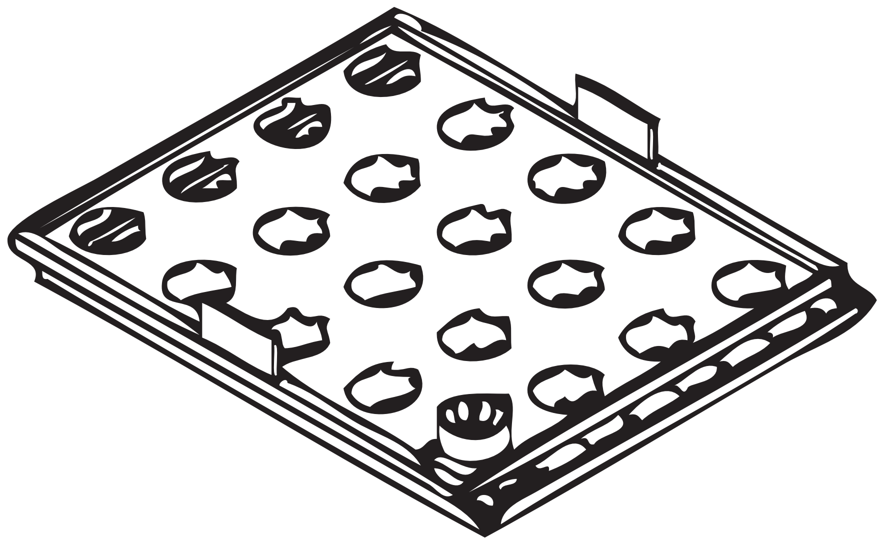
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	E150	ECHO RAMP ASSEMBLY	1
2	E3000	ECHO III COMPLETE ATTACHMENT	4





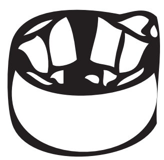
ECHO III PROCEDURE: 2. For 45 degree offset star-clip delivery, slide 4X part # E3000 onto assembly # E 150 (Echo I Ramp Assembly).	DATE: 5/29/2012	UNITS: INCHES	MATERIAL: SEE BOM
	TOLERANCE: 0.01	SCALE: 1:4	TITLE: ECHO III COMPLETE WITH ECHO I FOR 45° OFFSET STAR-CLIP DELIVERY
	ASSY #: E300	NEXT ASSY #: ISO	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 535	Page 58

Foxtrot Assembly

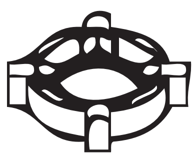


You will need the following part numbers (and quantities) to assemble Foxtrot:

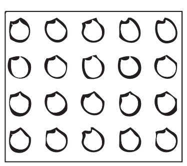
F1000
(20X)



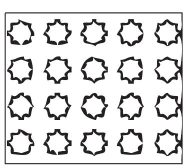
F1010
(20X)



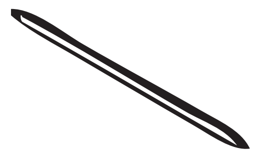
F1020
(1X)



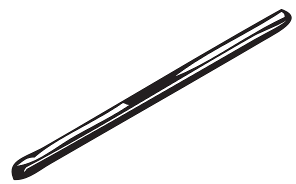
F1030
(1X)



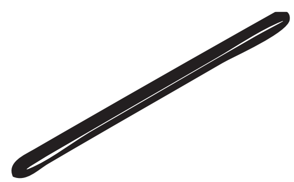
F1040
(4X)



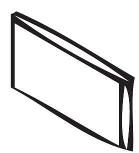
F1050
(2X)



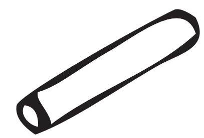
F1060
(2X)



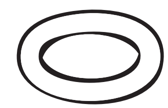
F1070
(2X)



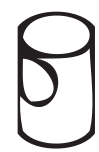
F1080
(1X)



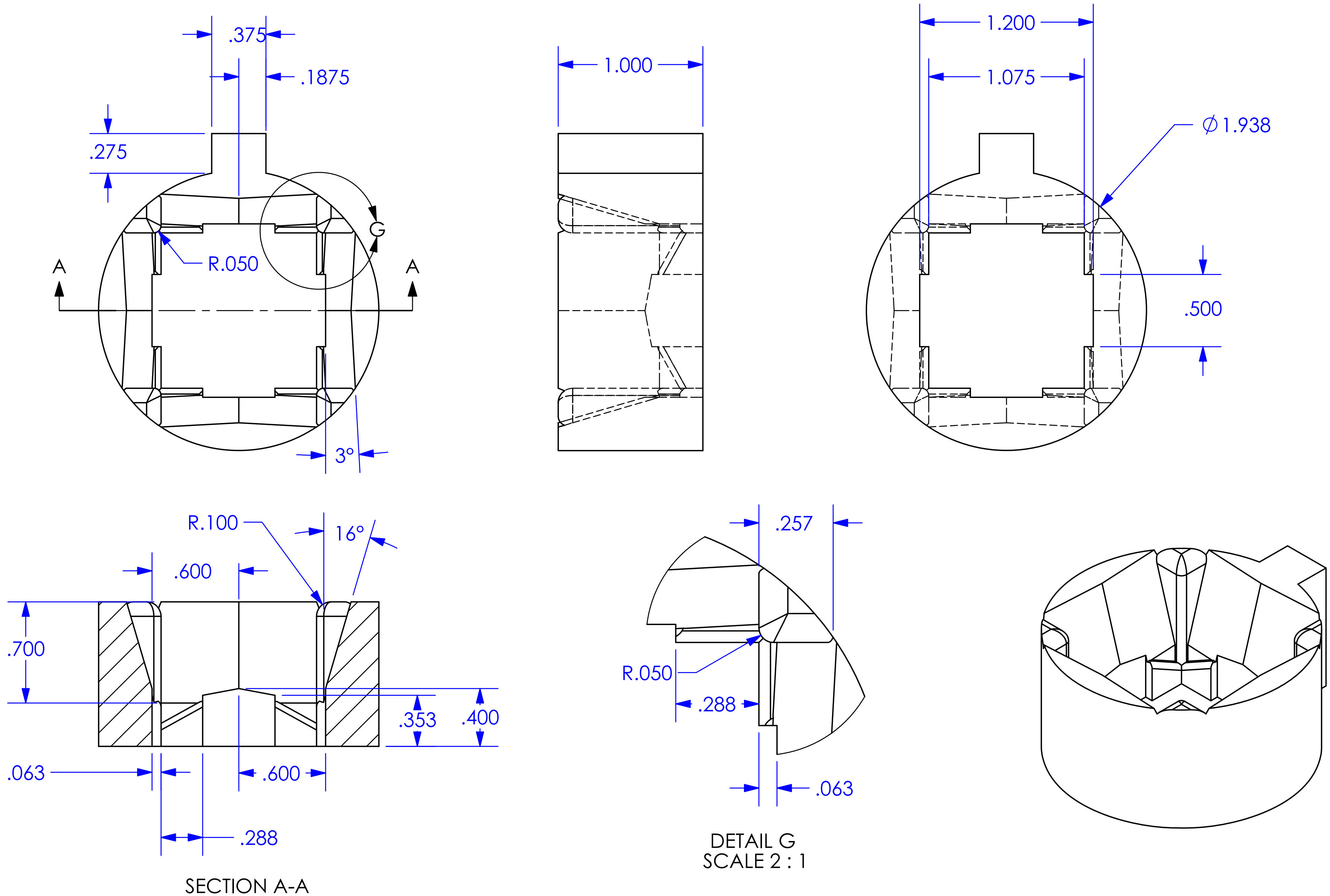
F1090
(1X)



F1100
(1X)

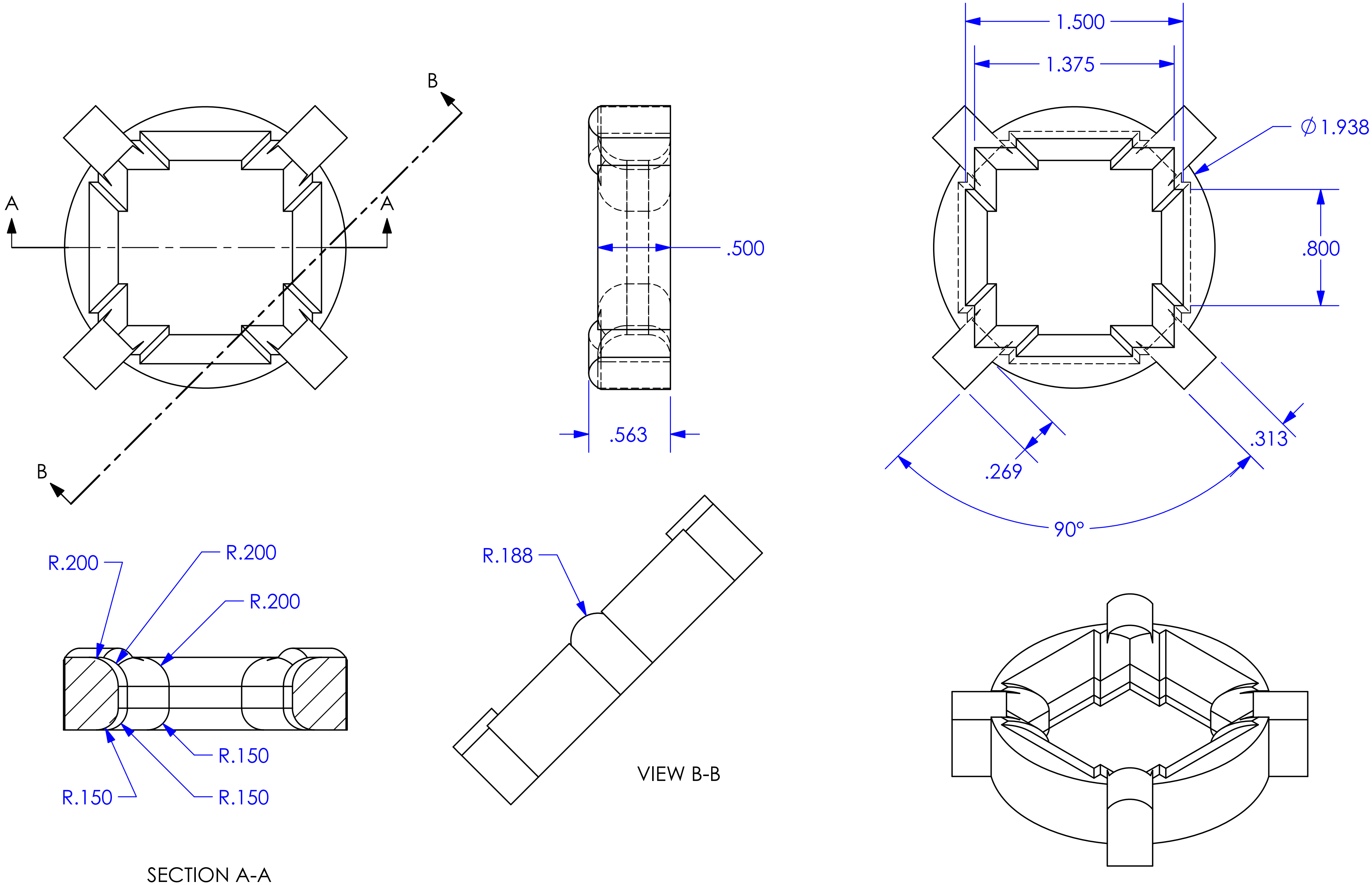


See pages 60-82 for detailed parts and assembly instructions for Foxtrot.

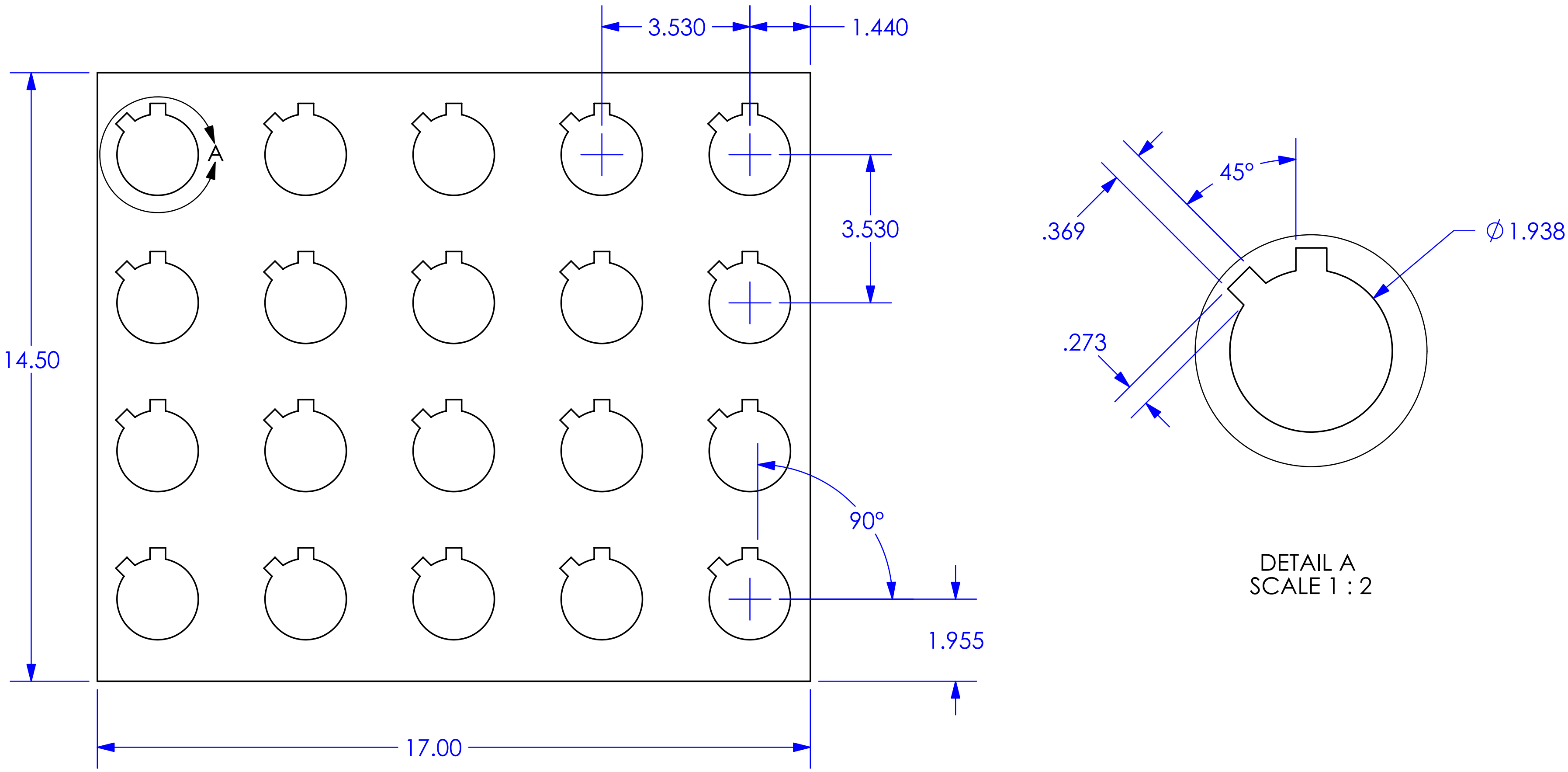


FOXTROT PROCEDURE:
1. Rapid prototype part # F1000 using the dimensions shown to create a mold pattern.
2. Create a silicon mold (or mold rubber of choice) based off the pattern.
3. Use Smooth-Cast 305 (or liquid plastic of choice) to pour into the molds and create 20X of part # F1000.

DATE: 5/29/2012	UNITS: INCHES	MATERIAL: SMOOTH-CAST 305 URETHANE PLASTIC
TOLERANCE: 0.001	SCALE: 1:1	TITLE: FOXTROT TOP INSERT
PART #: F1000	NEXT ASSY #: F130	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 6000	Page 60

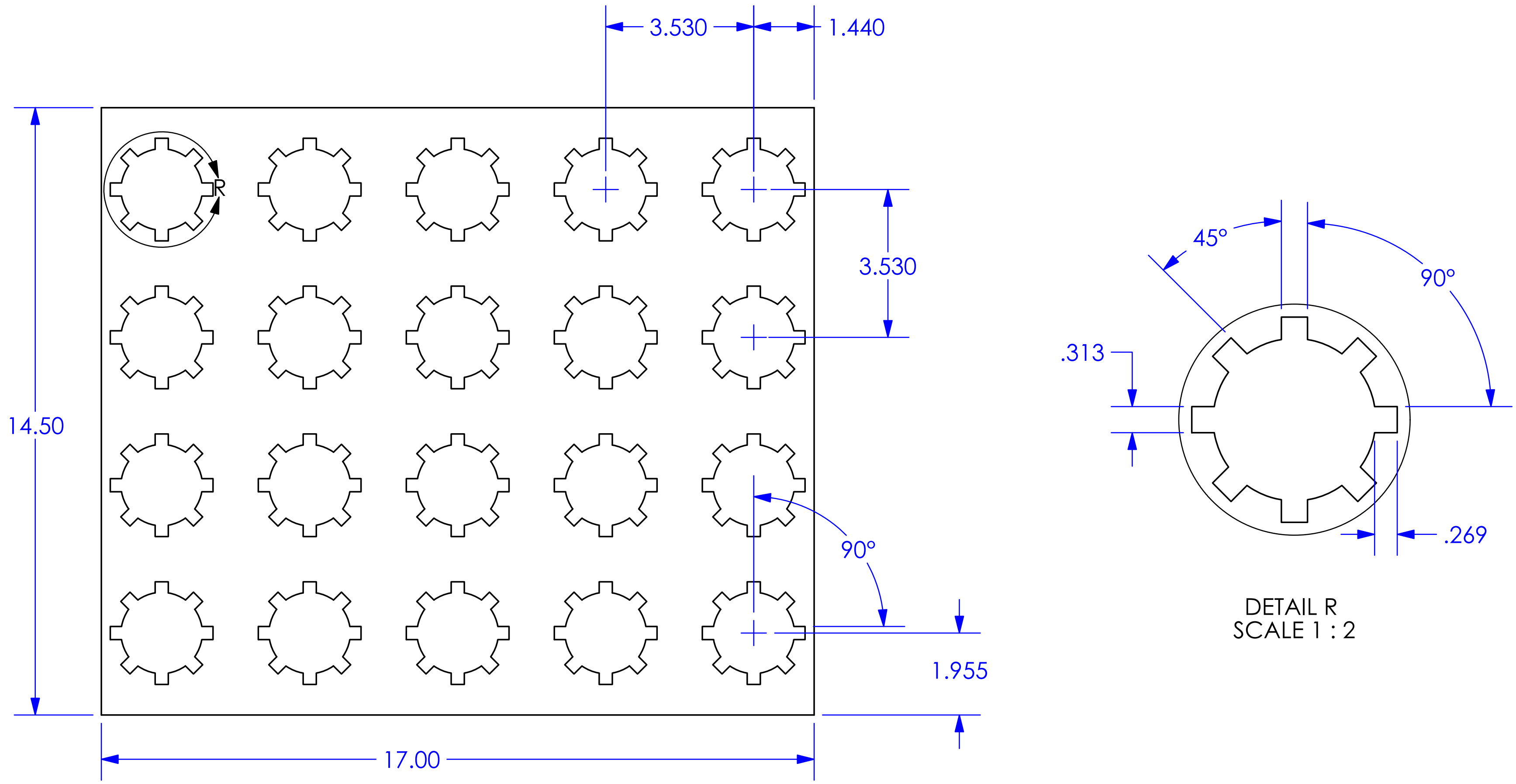


FOXTROT PROCEDURE: 4. Rapid prototype part # F1010 using the dimensions shown to create a mold pattern. 5. Create a silicon mold (or mold rubber of choice) based off the pattern. 6. Use Smooth-Cast 305 (or liquid plastic of choice) to pour into the molds and create 20X of part # F1010.	DATE: 5/29/2012	UNITS: INCHES	MATERIAL: SMOOTH-CAST 305 URETHANE PLASTIC
	TOLERANCE: 0.001	SCALE: 1:1	TITLE: FOXTROT BOTTOM INSERT
	PART #: F1010	NEXT ASSY #: F230	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 6010	Page 61



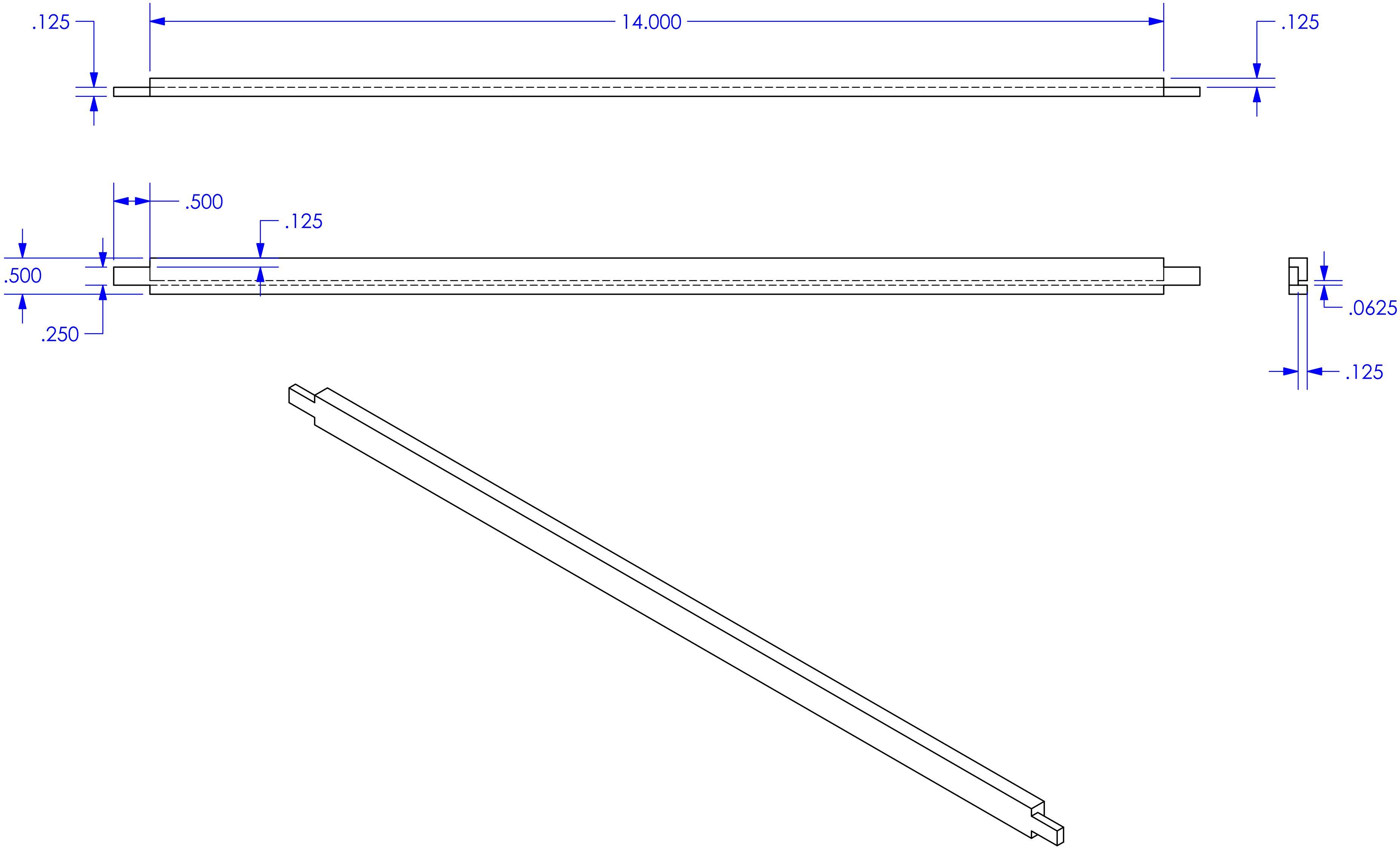
FOXTROT PROCEDURE:
7. Cut part # F1020 from 1/16" sheet metal using the specified dimensions.

DATE: 5/29/2012	UNITS: INCHES	MATERIAL: TYPE 316 S.S. SHEET METAL 1/16"
TOLERANCE: 0.001	SCALE: 1:4	TITLE: FOXTROT TOP SHEET METAL PANEL
PART #: F1020	NEXT ASSY #: F110	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 6020	Page 62

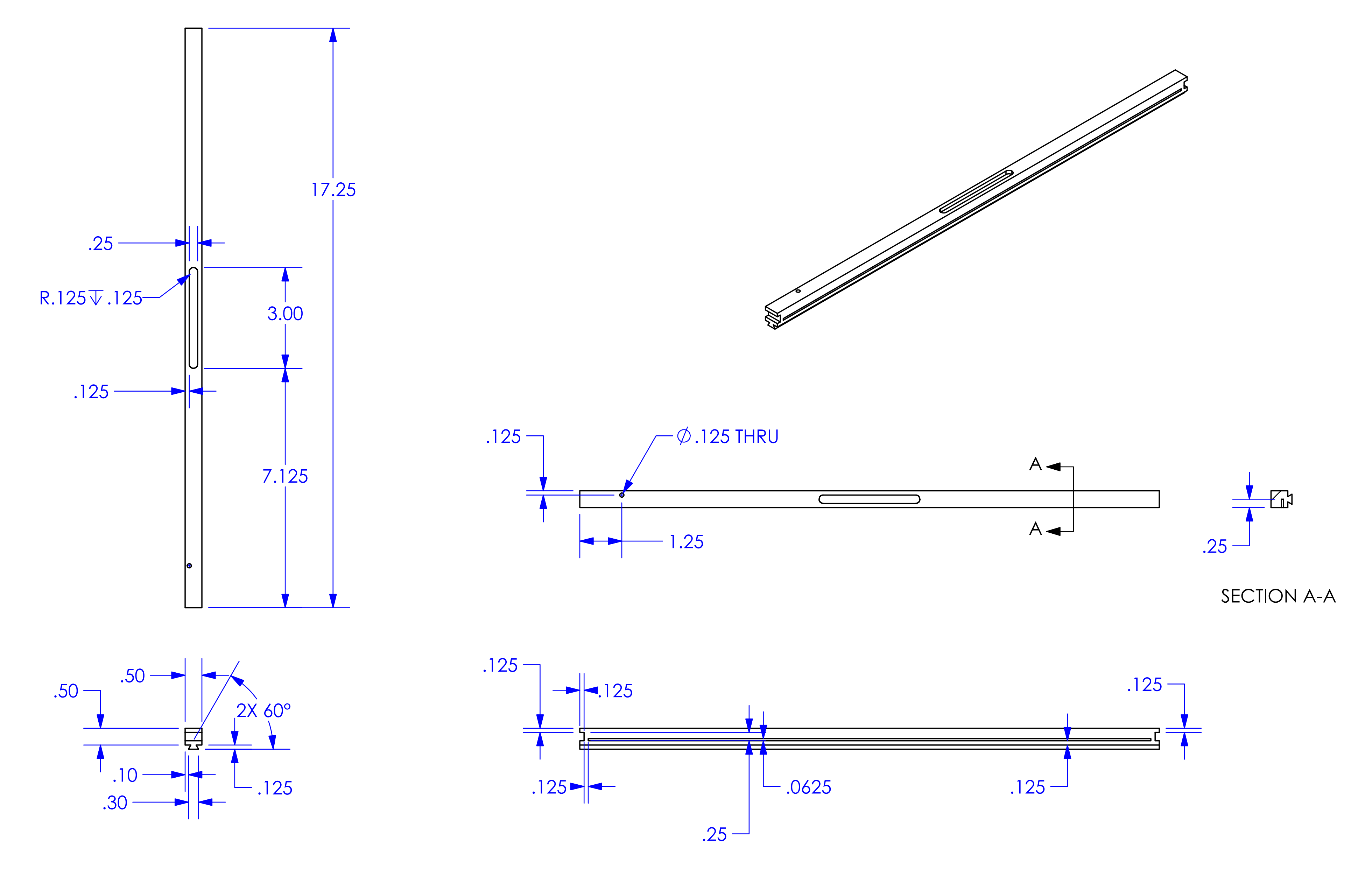


FOXTROT PROCEDURE:
8. Cut part # F1030 from 1/16" sheet metal using the specified dimensions.

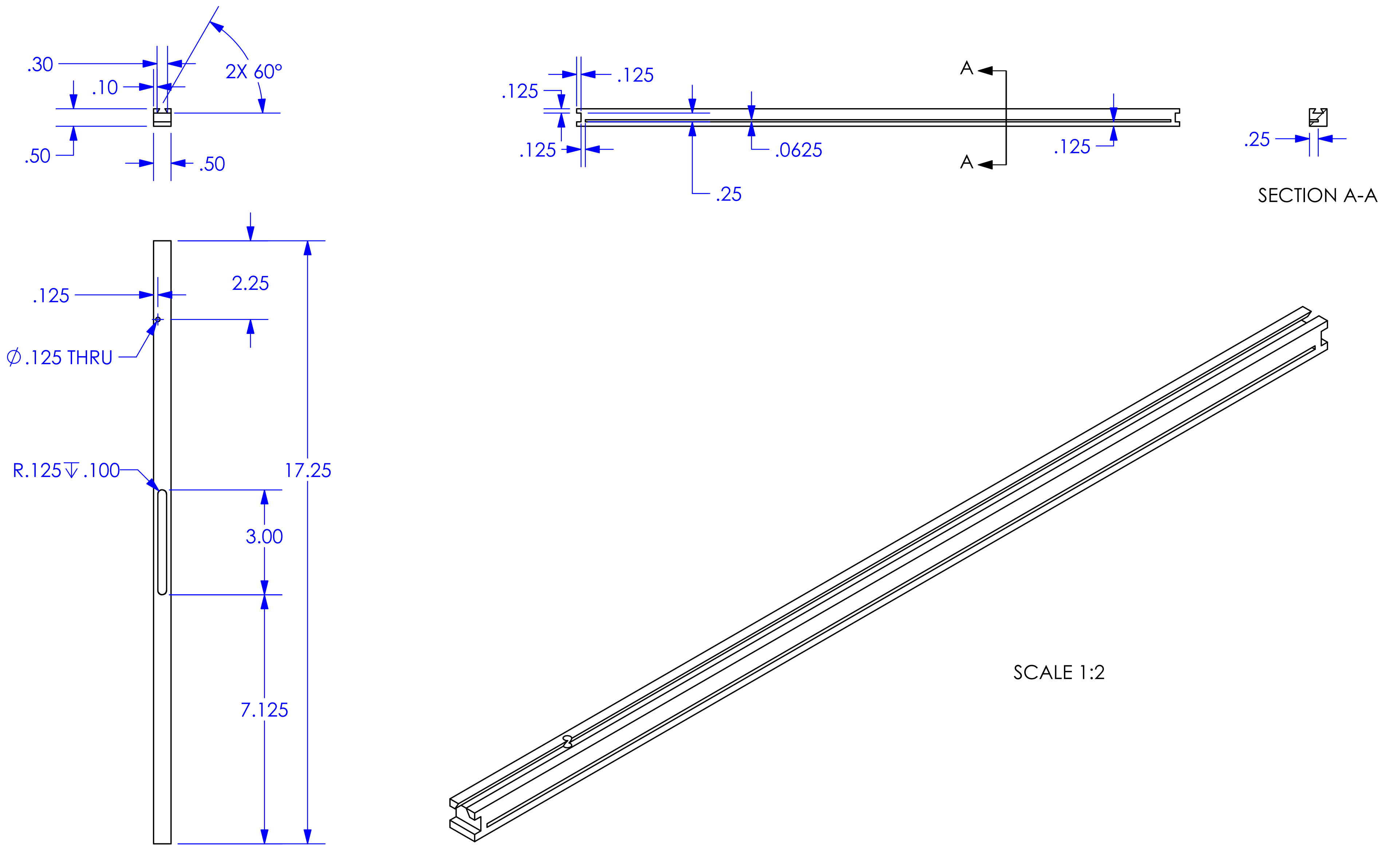
DATE: 5/29/2012	UNITS: INCHES	MATERIAL: TYPE 316 S.S. SHEET METAL 1/16"
TOLERANCE: 0.001	SCALE: 1:4	TITLE: FOXTROT BOTTOM SHEET METAL PANEL
PART #: F1030	NEXT ASSY #: F210	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 6030	Page 63



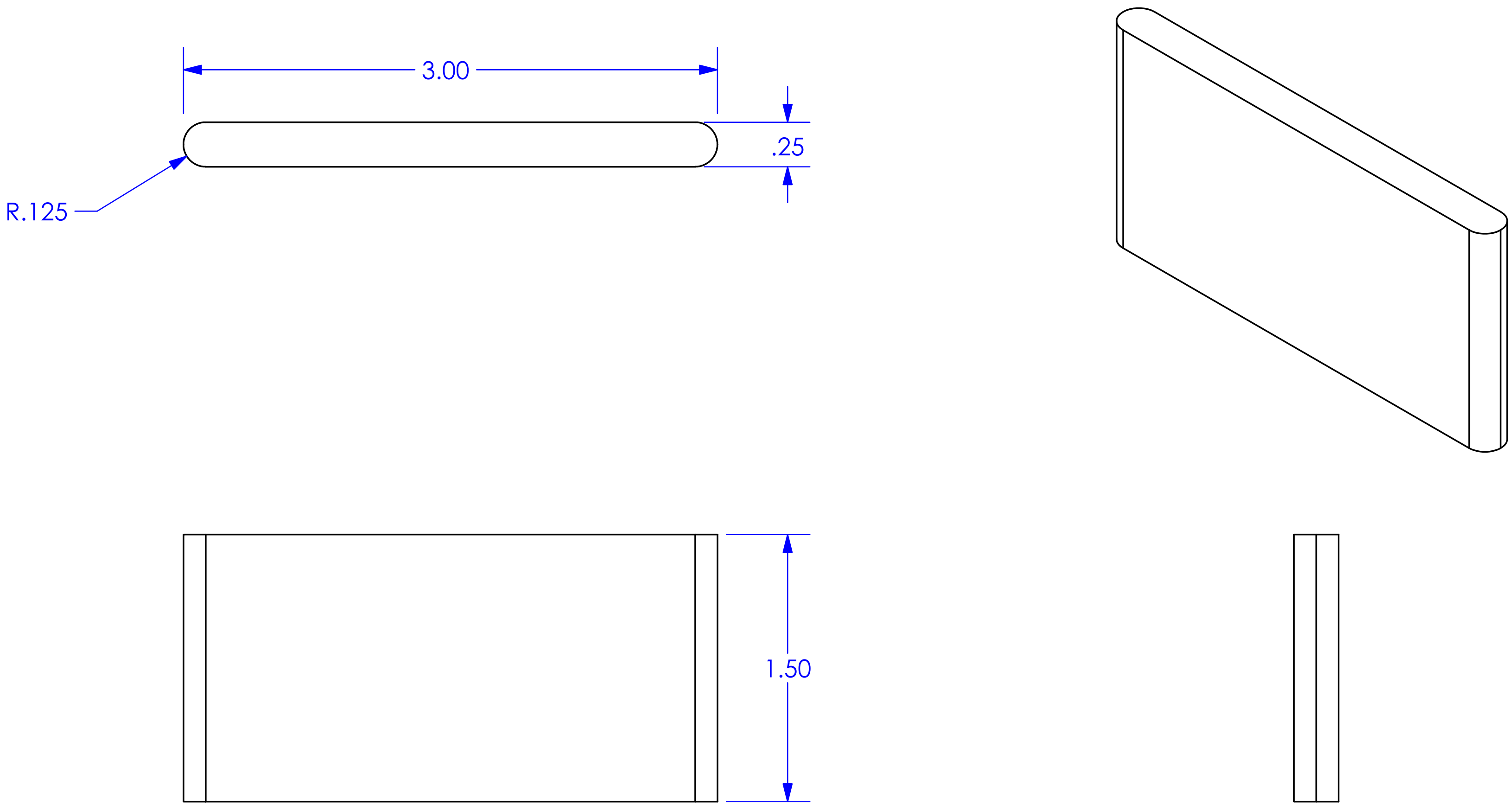
FOXTROT PROCEDURE: 9. Cut 4X part # F1040 from balsa wood using the specified dimensions.	DATE: 5/29/2012	UNITS: INCHES	MATERIAL: BALSA WOOD
	TOLERANCE: 0.01	SCALE: 1:2	TITLE: FOXTROT BOTTOM SHEET METAL PANEL
	PART #: F1040	NEXT ASSY #: F100	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 6040	Page 64



FOXTROT PROCEDURE: 10. Cut 2X part # F1050 from balsa wood using the specified dimensions.	DATE: 5/29/2012	UNITS: INCHES	MATERIAL: BALSA WOOD
	TOLERANCE: 0.01	SCALE: 1:4	TITLE: FOXTROT TOP WOODEN SIDE SUPPORT
	PART #: F1050	NEXT ASSY #: F100	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 6050	Page 65

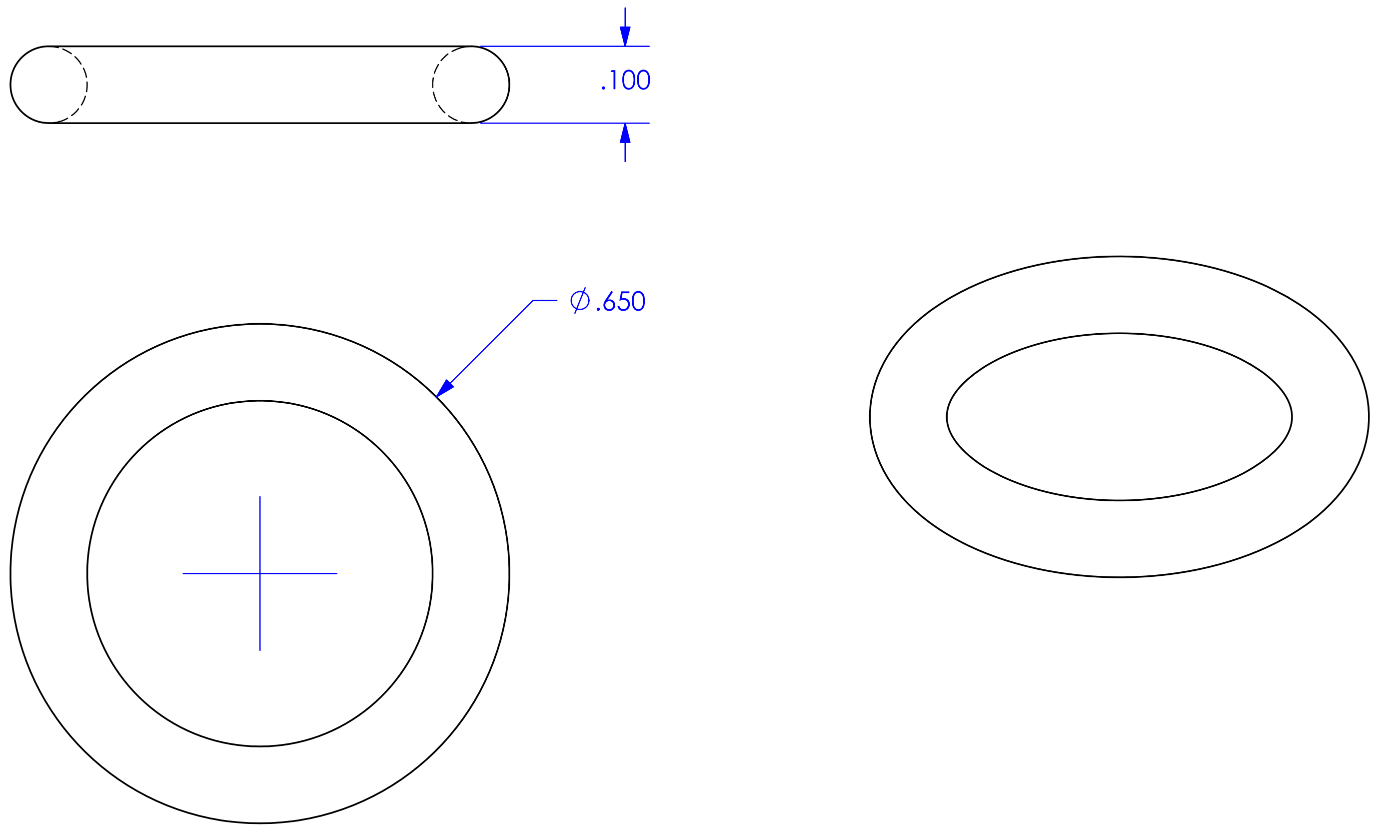


FOXTROT PROCEDURE: 11. Cut 2X part # F1060 from balsa wood using the specified dimensions.	DATE: 5/29/2012	UNITS: INCHES	MATERIAL: BALSA WOOD
	TOLERANCE: 0.01	SCALE: 1:4	TITLE: FOXTROT BOTTOM WOODEN SIDE SUPPORT
	PART #: F1060	NEXT ASSY #: F200	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 6060	Page 66



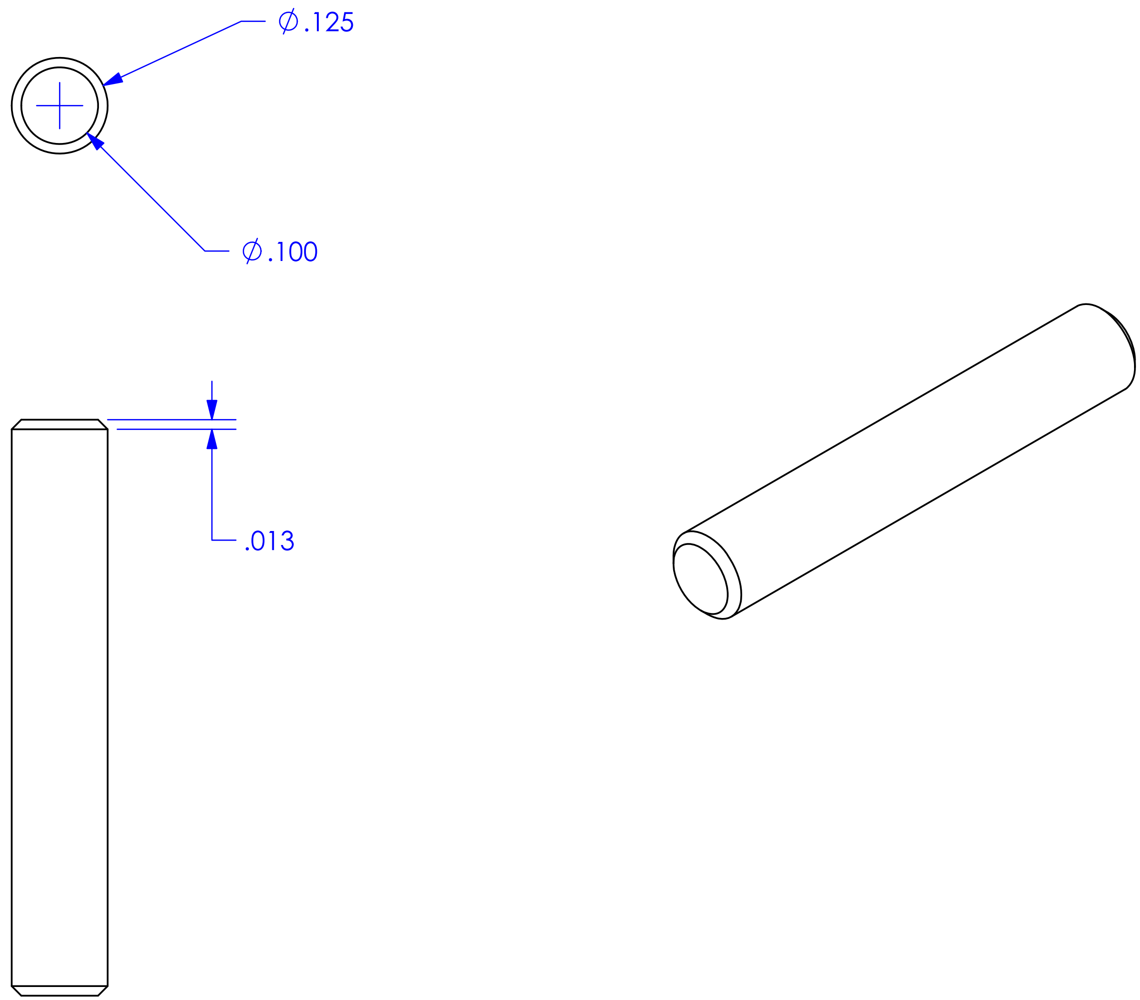
FOXTROT PROCEDURE:
12. Cut 2X part # F1070 from balsa wood using the specified dimensions.

DATE: 5/29/2012	UNITS: INCHES	MATERIAL: BALSA WOOD
TOLERANCE: 0.01	SCALE: 1:1	TITLE: FOXTROT WOODEN INSERT FOR TRAY STACKING
PART #: F1070	NEXT ASSY #: F130	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 6070	Page 67



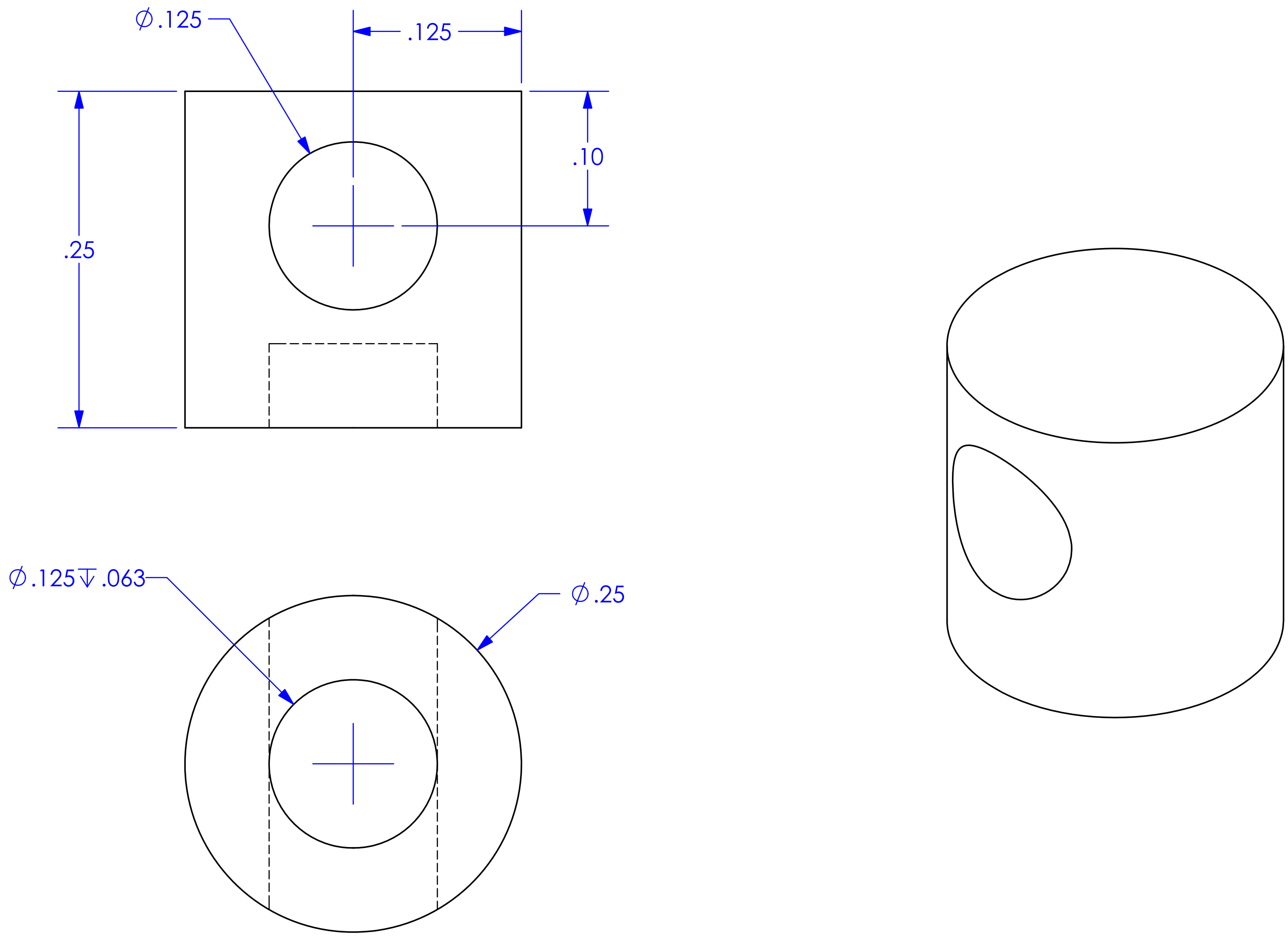
FOXTROT PROCEDURE:
13. Obtain 1X part # F1090. A key ring can be used. The drawing shown is meant to be slid on like a key ring.

DATE: 5/29/2012	UNITS: INCHES	MATERIAL: TYPE 316 STAINLESS STEEL RING
TOLERANCE: 0.001	SCALE: 4:1	TITLE: FOXTROT RING FOR TRAY-LOCKING PIN
PART #: F1090	NEXT ASSY #: F310	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 6090	Page 68



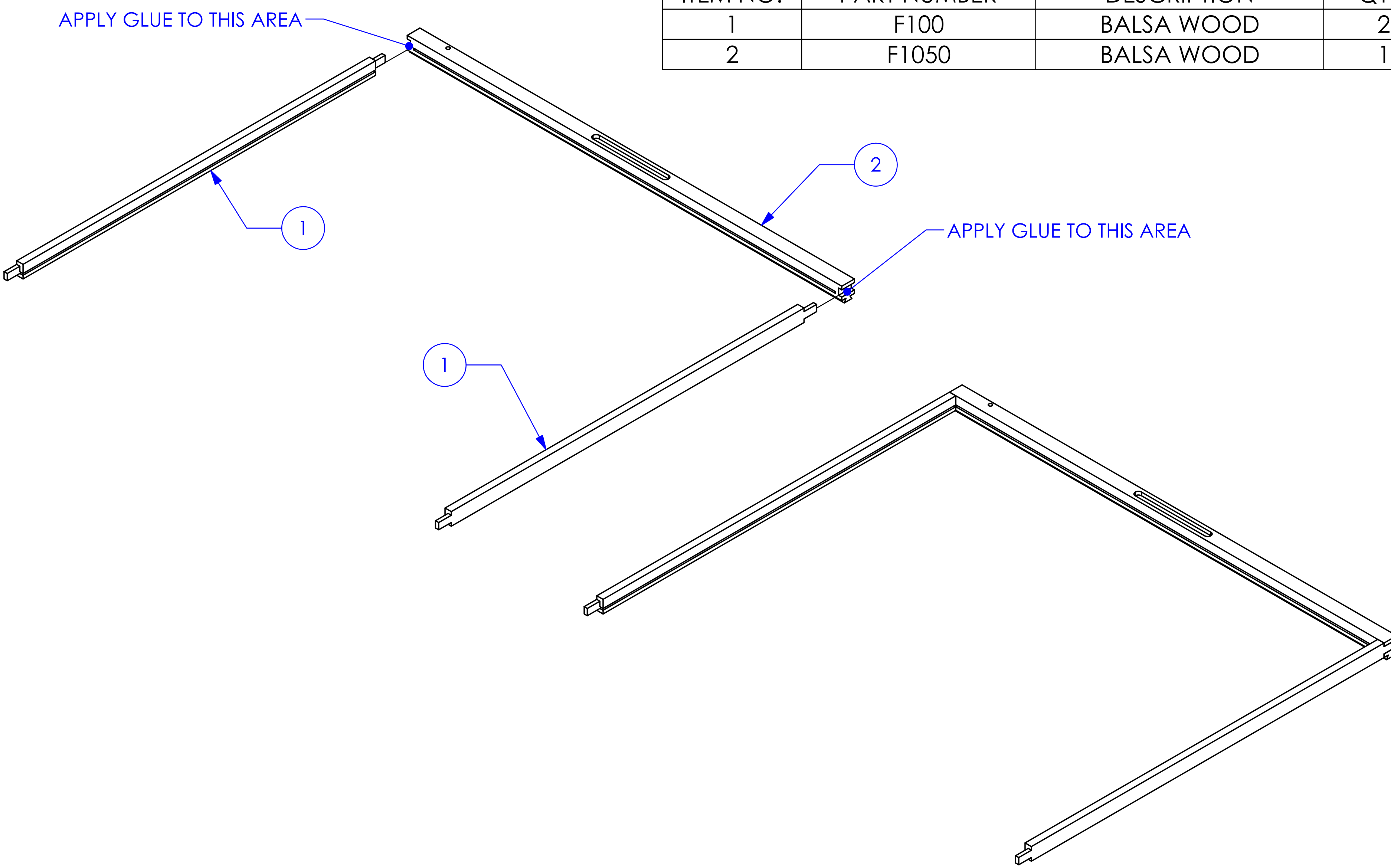
FOXTROT PROCEDURE:
14. Obtain 1X part # F1080 (1/8" dia stainless steel dowel pin).

DATE: 5/29/2012	UNITS: INCHES	MATERIAL: TYPE 316 STAINLESS STEEL PIN
TOLERANCE: 0.01	SCALE: 4:1	TITLE: FOXTROT TRAY-LOCKING PIN
PART #: F1080	NEXT ASSY #: F300	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 6080	Page 69



FOXTROT PROCEDURE: 15. Cut a 1/4" dia wooden dowel to a length of 0.25". 16. Drill a 1/8" through hole through the side and a 1/8" dia hole through the bottom to a depth of 1/16" as shown to complete part # F1100.	DATE: 5/29/2012	UNITS: INCHES	MATERIAL: 1/4" WOOD DOWEL
	TOLERANCE: 0.01	SCALE: 8:1	TITLE: FOXTROT CAP FOR TRAY-LOCKING PIN AND RING
	PART #: F1100	NEXT ASSY #: F300	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 6110	

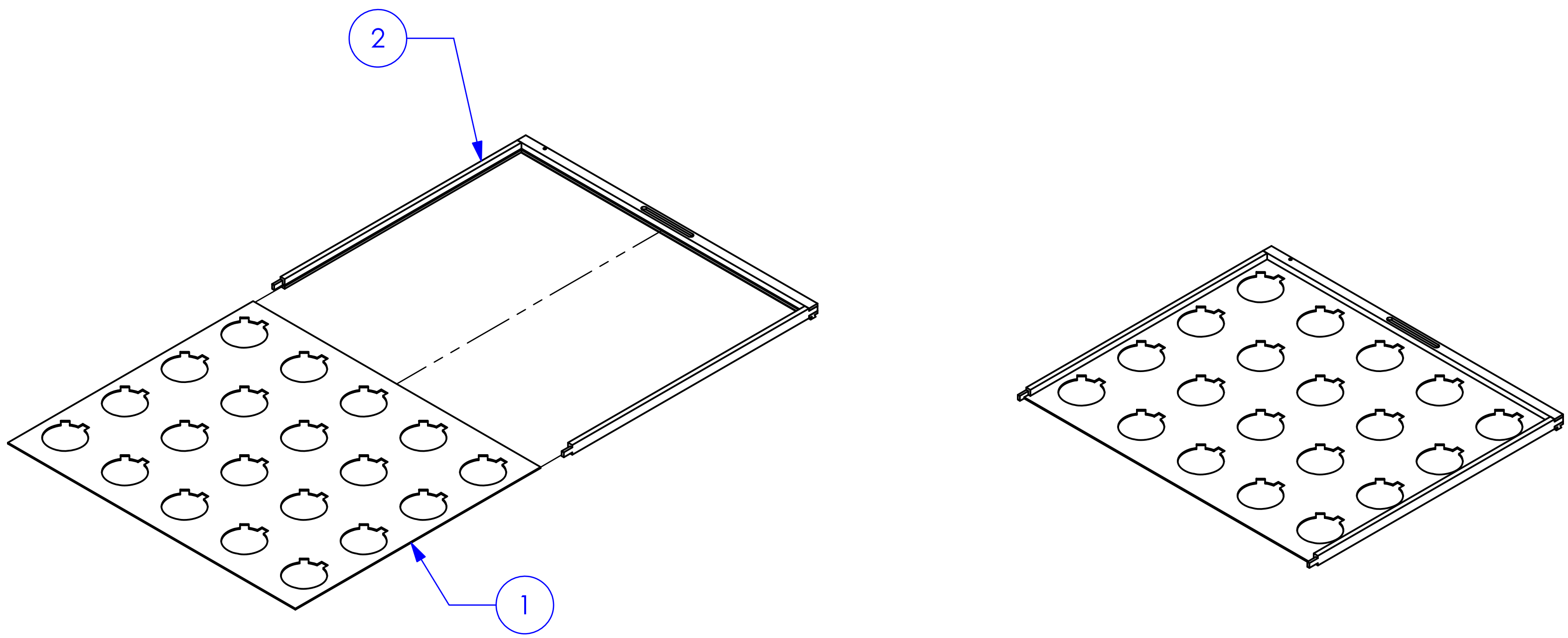
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	F100	BALSA WOOD	2
2	F1050	BALSA WOOD	1



FOXTROT PROCEDURE:
17. Glue 2X part # F1040 to 1X part # F1050 as indicated.

DATE: 5/29/2012	UNITS: INCHES	MATERIAL: SEE BOM
TOLERANCE: 0.01	SCALE: 1:4	TITLE: FOXTROT TOP TRAY PARTIAL ASSEMBLY
ASSY #: F100	NEXT ASSY #: F110	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 600	Page 71

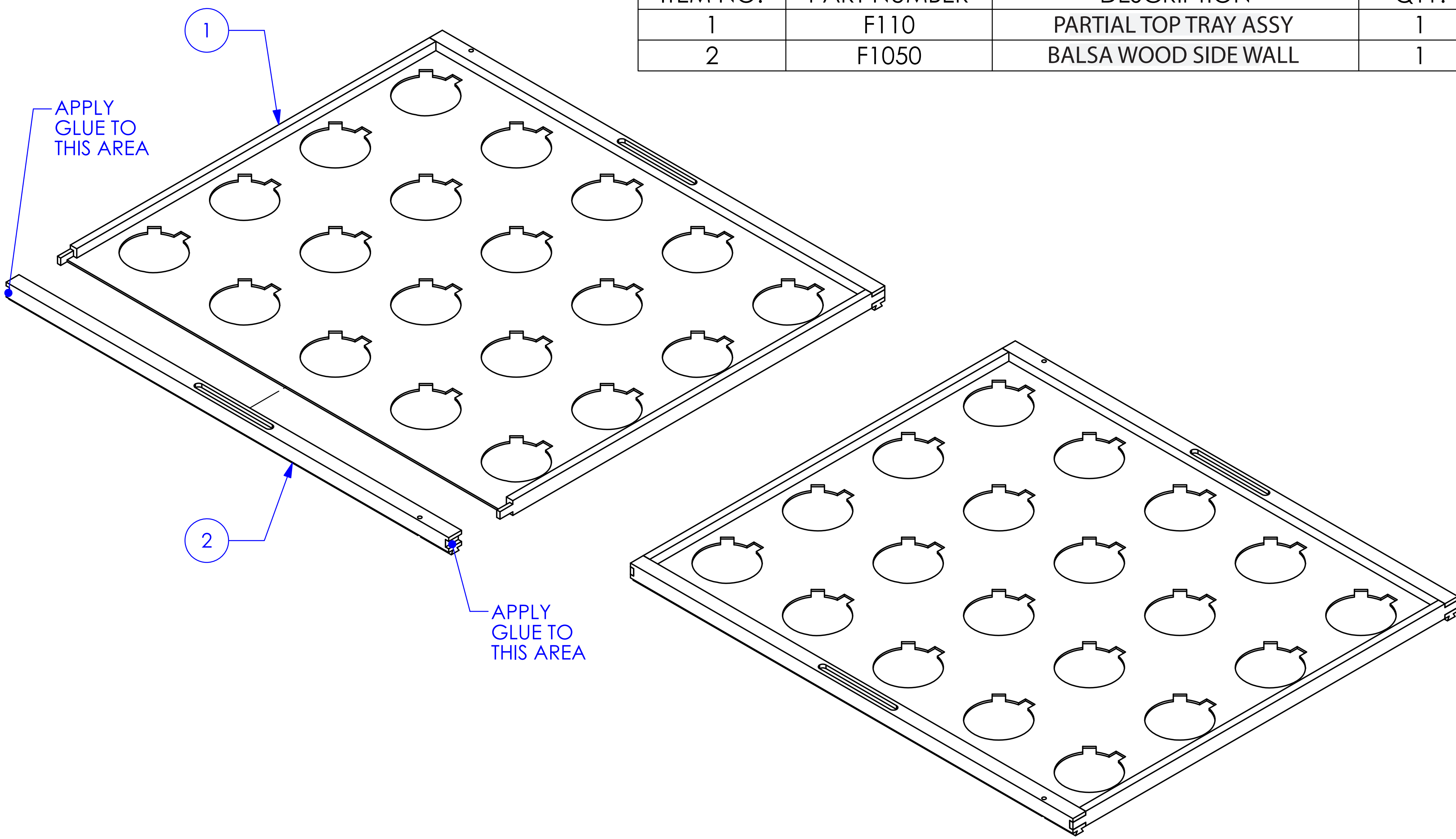
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	F1020	0.06" STAINLESS STEEL SHEET	1
2	F100	BALSA WOOD	1



FOXTROT PROCEDURE:
18. Insert part # F1020 (top sheet metal slide) into assembly # F100 as shown.

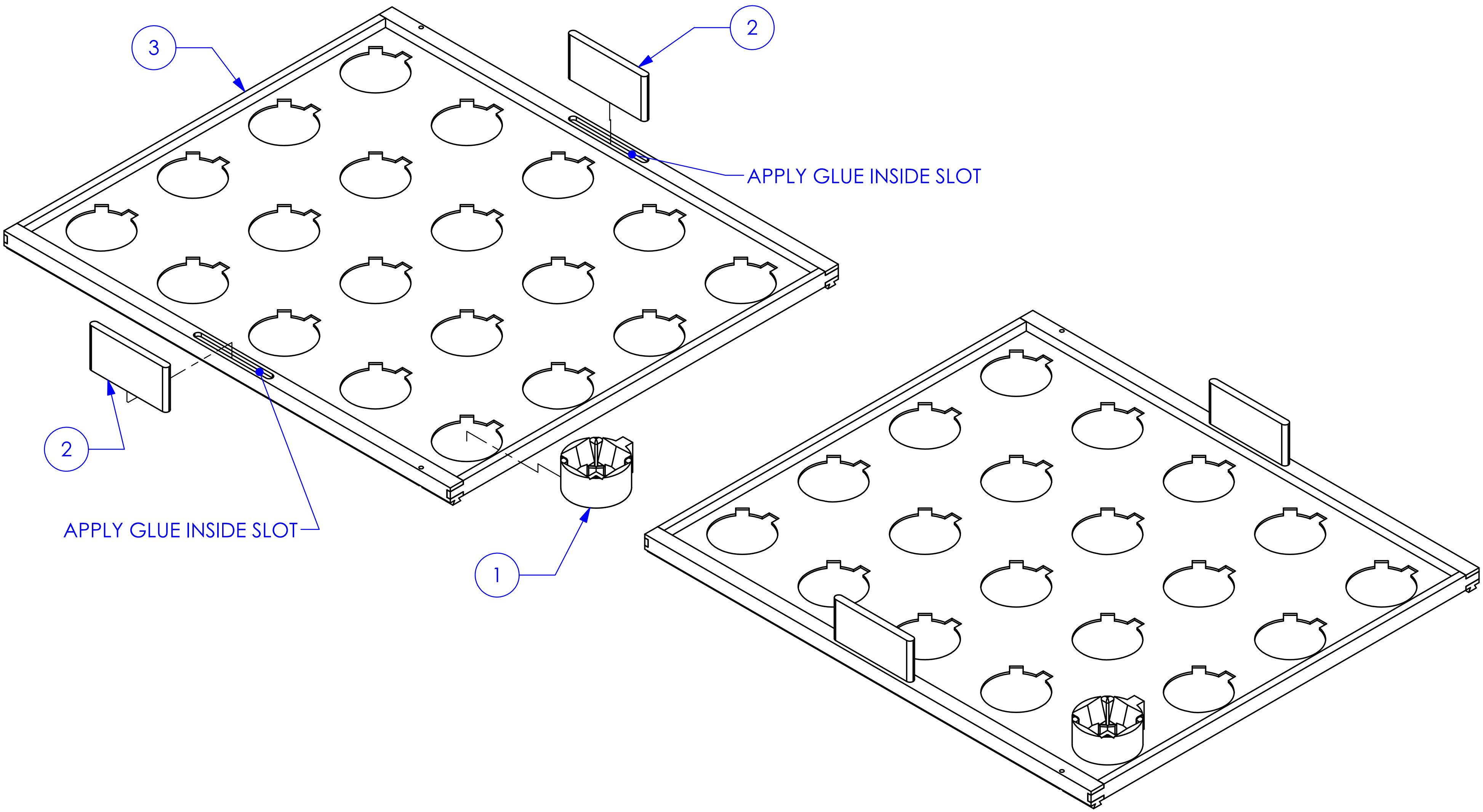
DATE: 5/29/2012	UNITS: INCHES	MATERIAL: SEE BOM
TOLERANCE: 0.01	SCALE: 1:8	TITLE: FOXTROT TOP TRAY PARTIAL ASSEMBLY
ASSY #: F110	NEXT ASSY #: F120	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 610	Page 72

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	F110	PARTIAL TOP TRAY ASSY	1
2	F1050	BALSA WOOD SIDE WALL	1



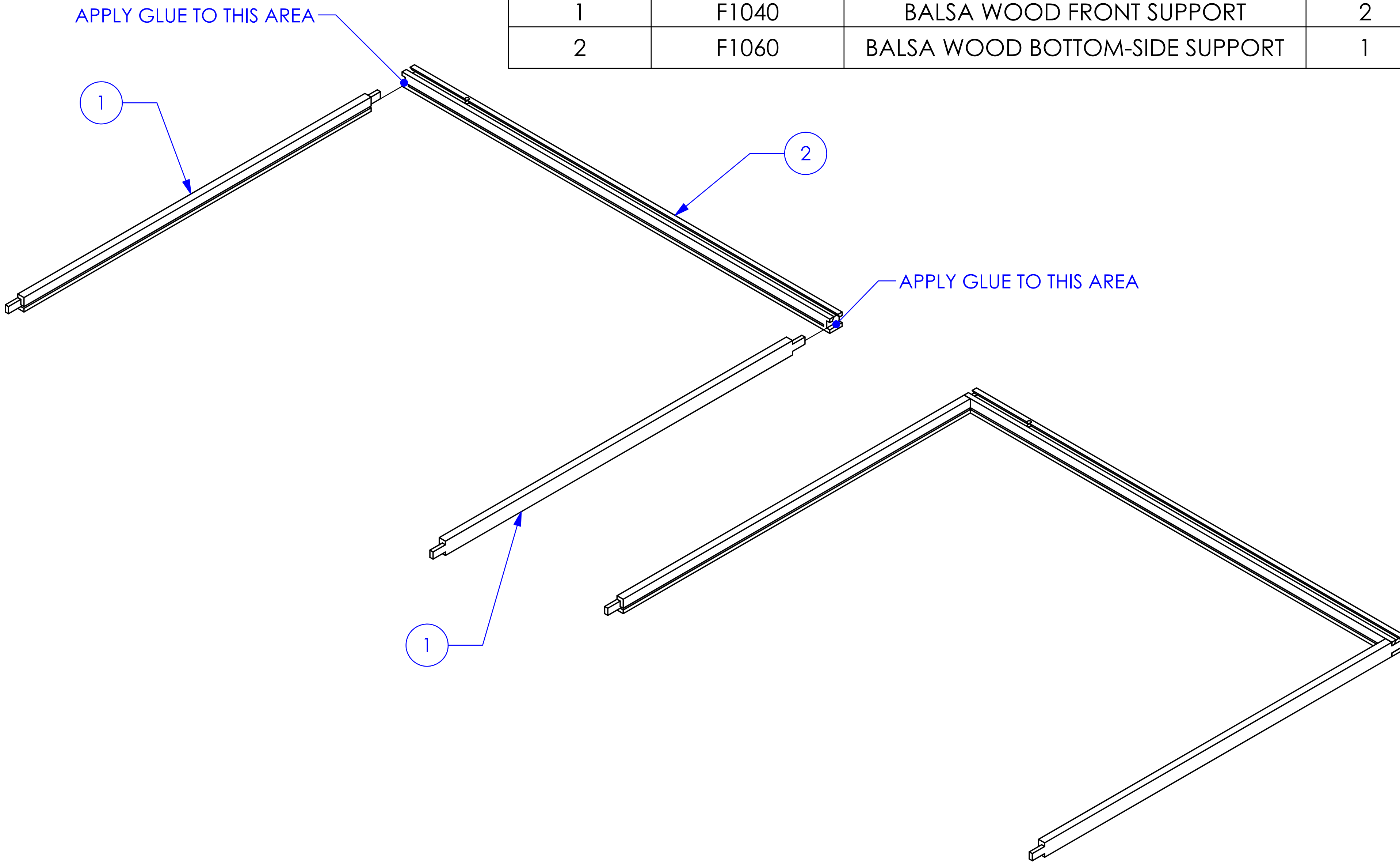
FOXTROT PROCEDURE: 19. Glue part # F1040 to the end of assembly # F110 to hold the sheet metal in place.	DATE: 5/29/2012	UNITS: INCHES	MATERIAL: SEE BOM
	TOLERANCE: 0.01	SCALE: 1:4	TITLE: FOXTROT TOP TRAY PARTIAL ASSEMBLY
	ASSY #: F120	NEXT ASSY #: F130	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 620	Page 73

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	F1000	SMOOTH-CAST 305 WHITE LIQUID PLASTIC	20
2	F1070	WOOD INSERT FOR TRAY STACKING	2
3	F120	PARTIALLY COMPLETE TOP TRAY	1



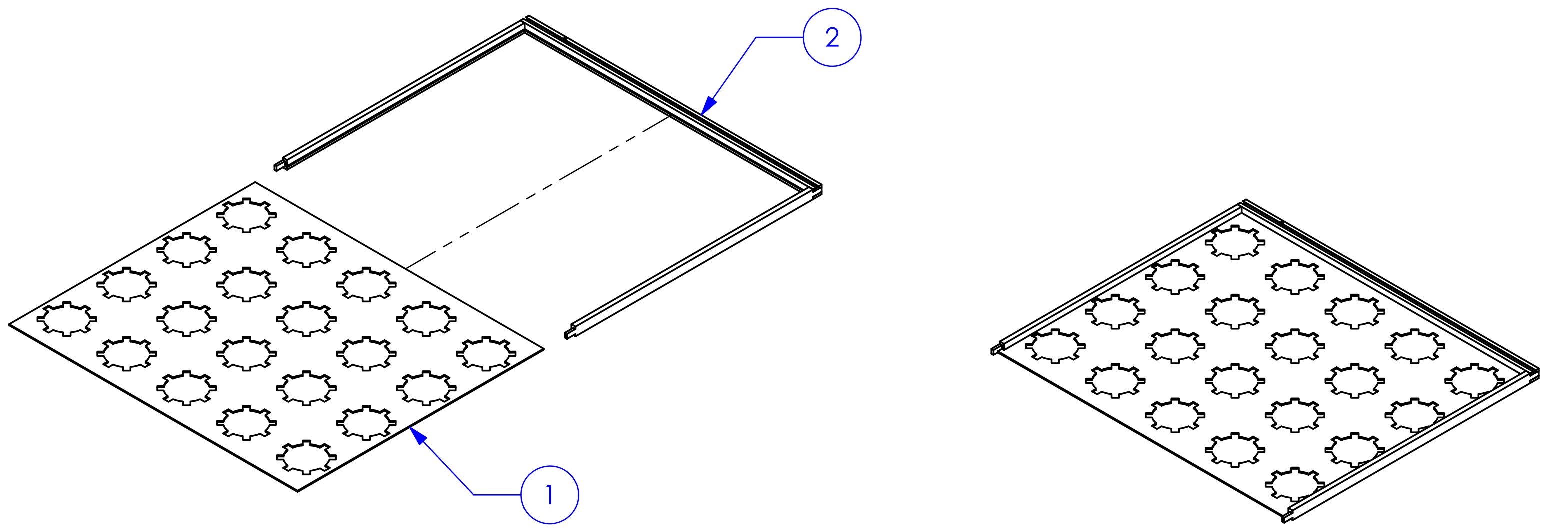
FOXTROT PROCEDURE: 20. Glue 2X part # F1070 to assembly # F120. 21. Press 20X part # F1000 into each hole of assembly # F120 as shown. Note: only one insert is shown. This completes the top half of the tray assembly.	DATE: 5/30/2012	UNITS: INCHES	MATERIAL: SEE BOM
	TOLERANCE: 0.01	SCALE: 1:4	TITLE: FOXTROT COMPLETE TOP TRAY ASSEMBLY
	ASSY #: F130	NEXT ASSY #: F320	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 630	Page 74

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	F1040	BALSA WOOD FRONT SUPPORT	2
2	F1060	BALSA WOOD BOTTOM-SIDE SUPPORT	1



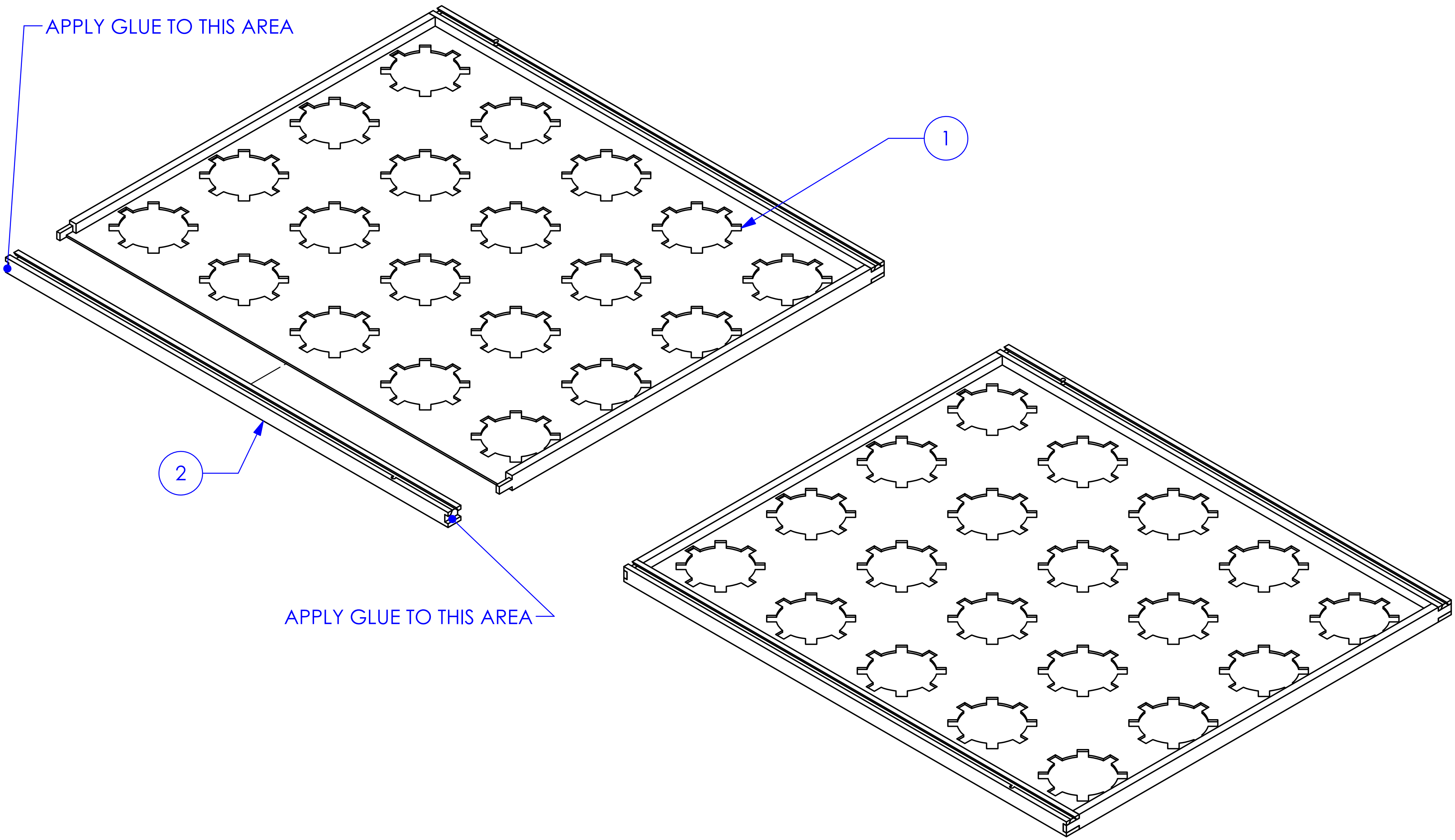
FOXTROT PROCEDURE: 22. Glue 2X part # F1040 to 1X part # F1060 as indicated.	DATE: 5/30/2012	UNITS: INCHES	MATERIAL: SEE BOM
	TOLERANCE: 0.01	SCALE: 1:4	TITLE: FOXTROT PARTIAL BOTTOM TRAY ASSEMBLY
	ASSY #: F200	NEXT ASSY #: F210	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 602	Page 75

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	F1030	0.06" STAINLESS STEEL SHEET	1
2	F200	PARTIAL BOTTOM TRAY ASSY	1



FOXTROT PROCEDURE: 23. Insert part # F1030 (bottom sheet metal slide) into assembly # F200 as shown.	DATE: 5/30/2012	UNITS: INCHES	MATERIAL: SEE BOM
	TOLERANCE: 0.01	SCALE: 1:8	TITLE: FOXTROT PARTIAL BOTTOM TRAY ASSEMBLY
	ASSY #: F210	NEXT ASSY #: F220	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 612	Page 76

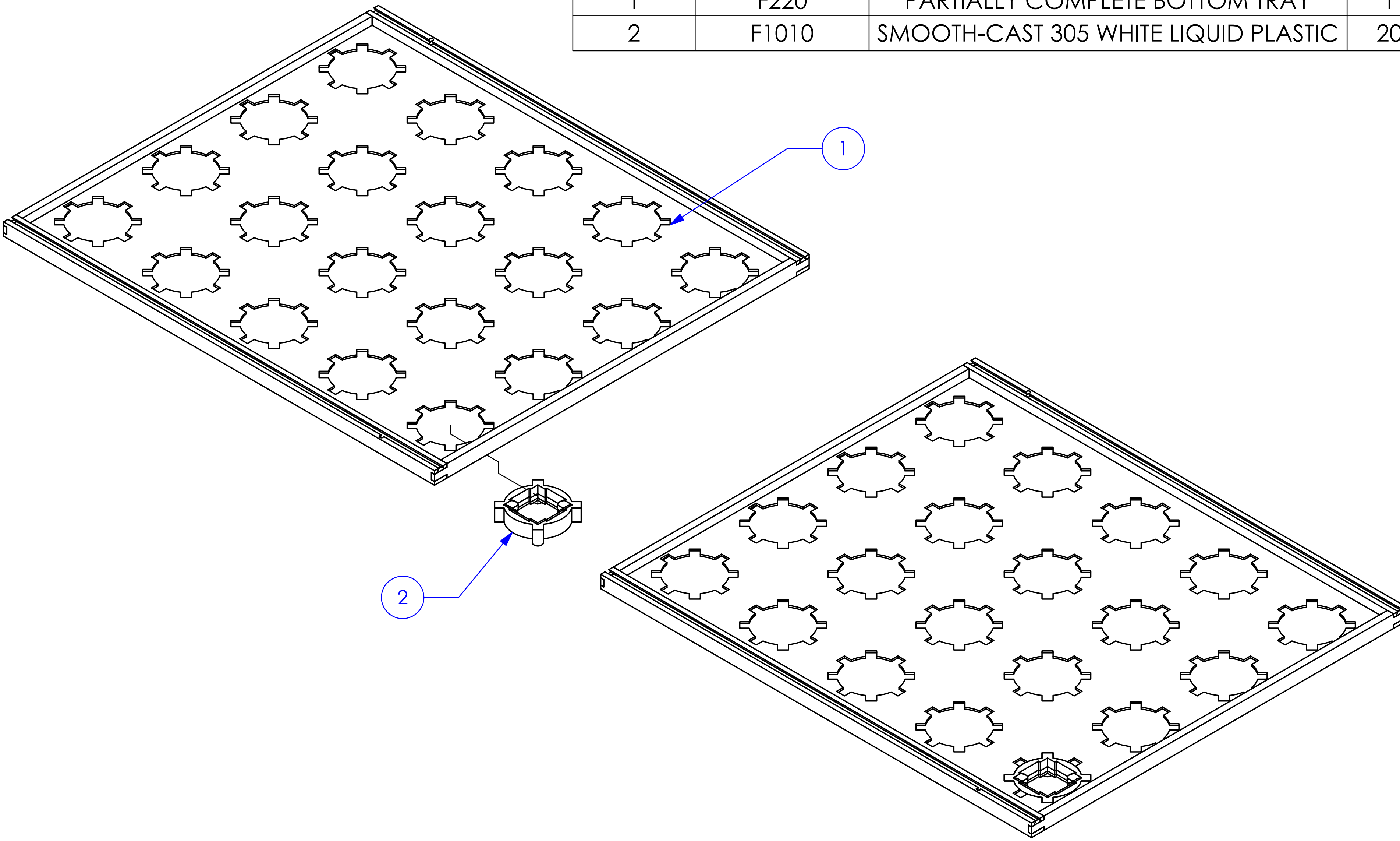
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	F210	PARTIALLY COMPLETE BOTTOM TRAY	1
2	F1060	BOTTOM SIDE WOOD SUPPORT	1



FOXTROT PROCEDURE:
24. Glue part # F1040 to the end of assembly # F210 to hold the sheet metal in place.

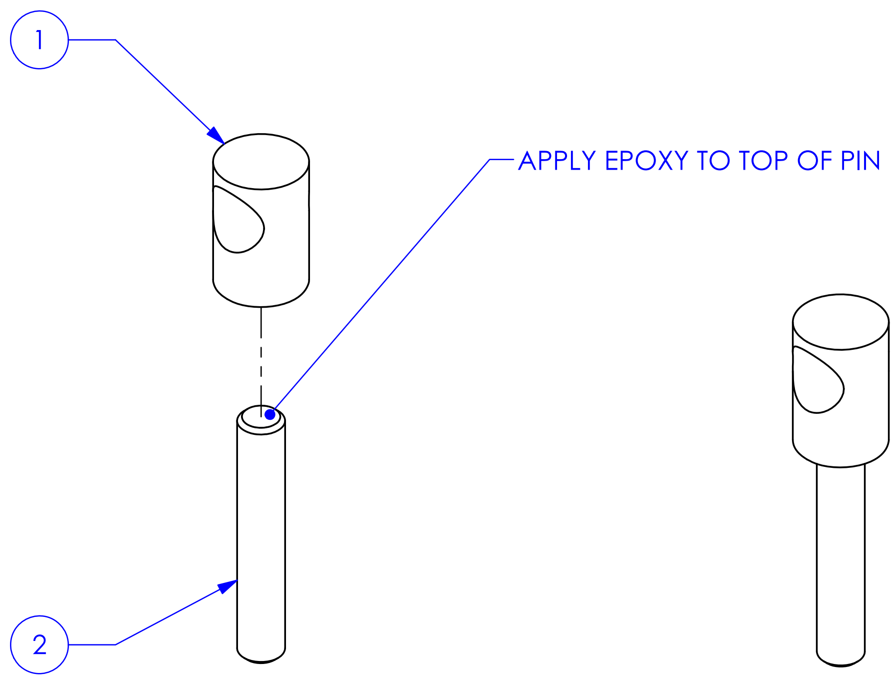
DATE: 5/30/2012	UNITS: INCHES	MATERIAL: SEE BOM
TOLERANCE: 0.01	SCALE: 1:4	TITLE: FOXTROT PARTIAL BOTTOM TRAY ASSEMBLY
ASSY #: F220	NEXT ASSY #: F230	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 622	Page 77

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	F220	PARTIALLY COMPLETE BOTTOM TRAY	1
2	F1010	SMOOTH-CAST 305 WHITE LIQUID PLASTIC	20



FOXTROT PROCEDURE: 25. Press 20X part # F1010 into each hole of assembly # F220 as shown. Note: only one insert is shown. This completes the bottom half of the tray assembly.	DATE: 5/30/2012	UNITS: INCHES	MATERIAL: SEE BOM
	TOLERANCE: 0.01	SCALE: 1:4	TITLE: FOXTROT COMPLETE BOTTOM TRAY ASSY
	ASSY #: F230	NEXT ASSY #: F320	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 632	Page 78

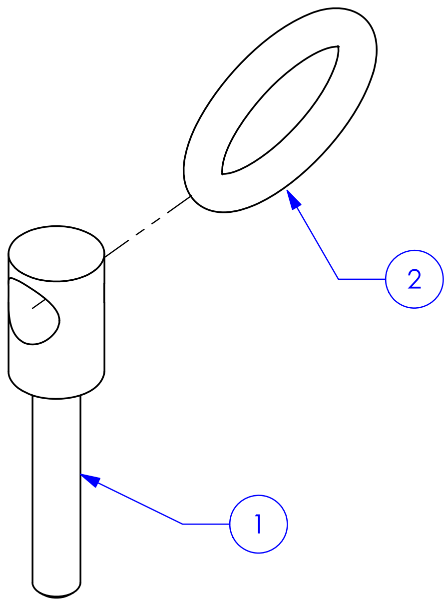
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	F1100	WOODEN CAP FOR TRAY-LOCKING PIN AND RING	1
2	F1080	1/8" DIA STAINLESS STEEL DOWEL PIN	1

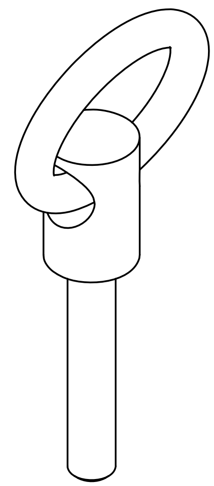


FOXTROT PROCEDURE:
26. Epoxy part # F1100 to part # F1080 as indicated.

DATE: 5/30/2012	UNITS: INCHES	MATERIAL: SEE BOM
TOLERANCE: 0.01	SCALE: 2:1	TITLE: FOXTROT PARTIAL LOCKING PIN ASSY
ASSY #: F300	NEXT ASSY #: F310	NAME: DANIEL SILVEIRA, TEAM SDS
	DRAWING #: 604	Page 79

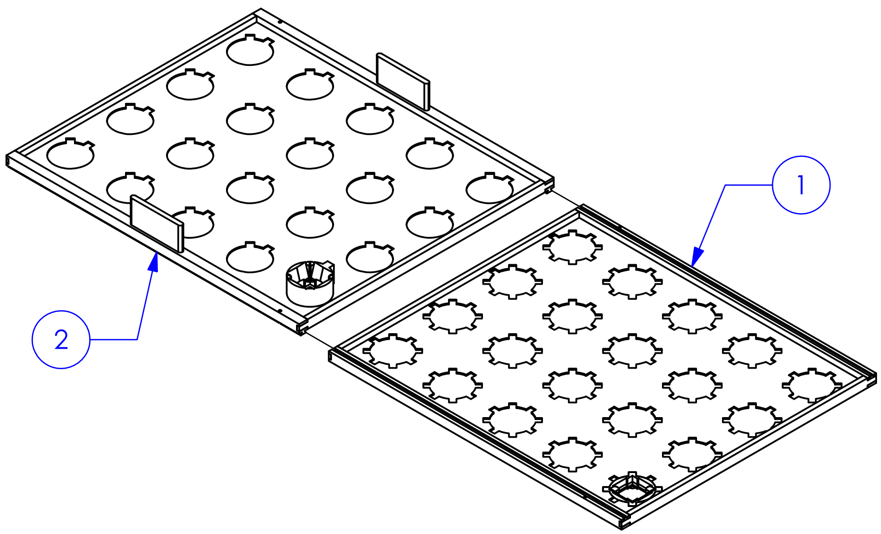
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	F300	PARTIALLY COMPLETE LOCKING PIN ASSY	1
2	F1090	METAL RING FOR TRAY LOCKING PIN	1

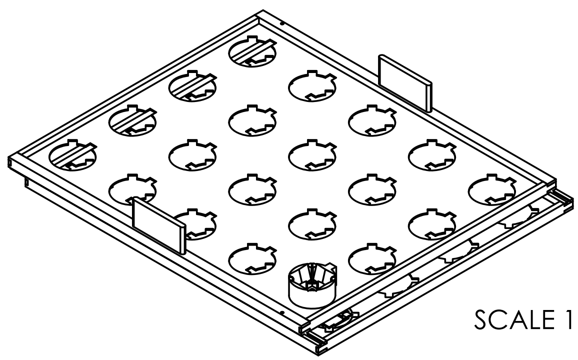




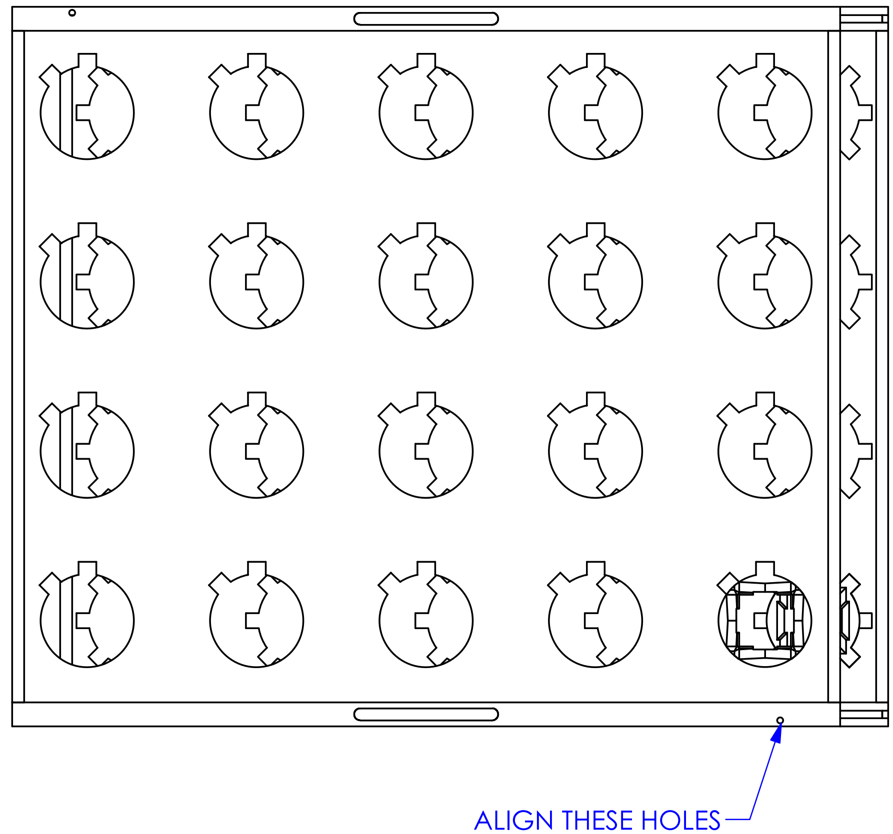
FOXTROT PROCEDURE: 27. Slide part # F1090 onto assembly # F300.	DATE: 5/30/2012	UNITS: INCHES	MATERIAL: SEE BOM
	TOLERANCE: 0.01	SCALE: 2:1	TITLE: FOXTROT COMPLETE LOCKING PIN ASSY
	ASSY #: F310	NEXT ASSY #: F330	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 614	Page 80

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	F230	COMPLETE BOTTOM TRAY ASSY	1
2	F130	COMPLETE TOP TRAY ASSY	1



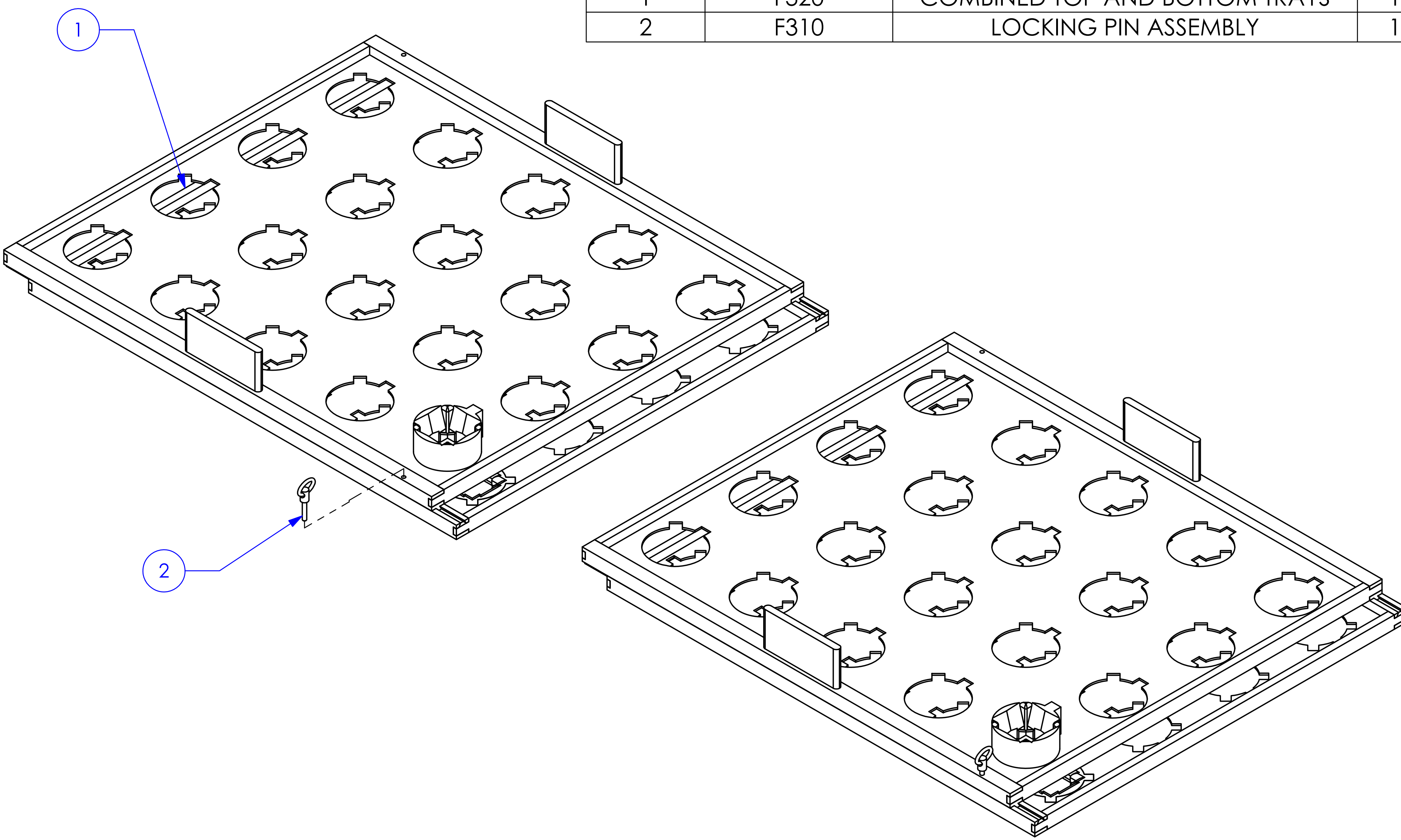


SCALE 1:8



FOXTROT PROCEDURE: 28. Slide assembly # F130 (top tray) onto assembly # F230, aligning the holes as shown in the bottom right of the drawing.	DATE: 5/30/2012	UNITS: INCHES	MATERIAL: SEE BOM
	TOLERANCE: 0.01	SCALE: 1:4	TITLE: FOXTROT COMBINED TOP AND BOTTOM TRAYS
	ASSY #: F320	NEXT ASSY #: F330	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 624	Page 81

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	F320	COMBINED TOP AND BOTTOM TRAYS	1
2	F310	LOCKING PIN ASSEMBLY	1



FOXTROT PROCEDURE: 29. Insert assembly # F310 (the locking pin and ring assembly) into the holes of assembly # F320 as shown. This locks the top tray to the bottom tray and completes the Foxtrot Tray Assembly.	DATE: 5/30/2012	UNITS: INCHES	MATERIAL: SEE BOM
	TOLERANCE: 0.01	SCALE: 1:4	TITLE: FOXTROT COMPLETE ASSEMBLY
	ASSY #: F330	NEXT ASSY #: ISO	NAME: DANIEL SILVEIRA, TEAM SDS
		DRAWING #: 634	Page 82

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