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:
Christopher Gonzales
Greg Lovasik
Daniel Silveira

Date:
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Approved by:
Professor Mohammad Noori, ME
Advisor
Letter of Transmittal

4th June, 2012

Team SDS
86 Johe Lane
San Luis Obsipo, CA 93405

SWRMC Engineering
Naval Architecture Branch Head
3755 Brinser St, STE 1, Code 225
San Diego, CA 92136

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
CHAPTER 2 – PRELIMINARY DESIGN DEVELOPMENT

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’S’lide” 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:

- **Tray loading (automated)** – 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’S’lide”
   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
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.
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).](image)

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.
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.
6) “Foxtrot” – The Tray. The star clips are released from Echo after a signal has been received 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.](image)

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.](image)
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-ft, 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


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

Relevant Products:

- See “Bottle Cap Sorting / Cap Orienting Equipment”

### APPENDIX A: Decision Matrix

#### Concept Designs

1 to 10 Scale, 10 = most advantageous

|                        | DS  | CG  | GL  | DS  | CG  | GL  | DS  | CG  | GL  | DS  | CG  | GL  | DS  | CG  | GL  | DS  | CG  | GL  | DS  | CG  | GL  | Totals |
|------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|
| tray loading (automated) | 9   | 7   | 7   | 4   | 8   | 6   | 8   | 10  | 5   | 7   | 5   | 8   | 5   | 8   | 6   | 5   | 3   | 8   | 4    | 7    | 5    | 8    | 7 | 313.667 |
| tray loading (manual)   | 7   | 7   | 8   | 8   | 8   | 5   | 8   | 10  | 7   | 7   | 6   | 6   | 4   | 6   | 7   | 5   | 3   | 8   | 4    | 7    | 6    | 8    | 7 | 311.333 |
| 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 | 265 |
| 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 | 253.333 |
| mounted single loader (manual) | 2   | 2   | 5   | 7   | 4   | 6   | 2   | 6   | 7   | 8   | 5   | 6   | 3   | 3   | 6   | 9   | 5   | 7   | 7    | 1    | 6    | 6    | 4    | 4 | 242.667 |
| 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 | 234.333 |
| 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 | 254.333 |
| current process (completely manual) | 1   | 1   | 3   | 10  | 10  | 10  | 6   | 1   | 5   | 10  | 10  | 10  | 3   | 11  | 4   | 9   | 1   | 8    | 10   | 8    | 7    | 3    | 1 | 258.667 |

#### Weight

<table>
<thead>
<tr>
<th>10</th>
<th>8</th>
<th>8</th>
<th>7</th>
<th>5</th>
<th>5</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
</table>

#### 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, repetitive 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

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Duration</th>
<th>Start</th>
<th>Finish</th>
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<tbody>
<tr>
<td><strong>Background Research</strong></td>
<td>17 days</td>
<td>Sun 10/2/11</td>
<td>Wed 10/19/11</td>
</tr>
<tr>
<td>Progress Report Memo</td>
<td>2 days</td>
<td>Sun 10/2/11</td>
<td>Tue 10/4/11</td>
</tr>
<tr>
<td>Prob. Statement &amp; Reqs. List</td>
<td>10 days</td>
<td>Sun 10/2/11</td>
<td>Wed 10/12/11</td>
</tr>
<tr>
<td>Conference Call</td>
<td>0 days</td>
<td>Thu 10/6/11</td>
<td>Thu 10/6/11</td>
</tr>
<tr>
<td><strong>Project Proposal</strong></td>
<td>10 days</td>
<td>Sun 10/9/11</td>
<td>Wed 10/19/11</td>
</tr>
<tr>
<td>Progress Report Memo</td>
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<td>Tue 10/11/11</td>
</tr>
<tr>
<td>Conduct literature review</td>
<td>8 days</td>
<td>Tue 10/11/11</td>
<td>Wed 10/19/11</td>
</tr>
<tr>
<td>Yellow tag; play with parts</td>
<td>8 days</td>
<td>Tue 10/11/11</td>
<td>Wed 10/19/11</td>
</tr>
<tr>
<td>Reserve conference room</td>
<td>0 days</td>
<td>Tue 10/11/11</td>
<td>Tue 10/11/11</td>
</tr>
<tr>
<td>Travel to sponsor</td>
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<td>Thu 10/13/11</td>
<td>Fri 10/14/11</td>
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<td>Fri 11/4/11</td>
<td>Mon 12/5/11</td>
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<td>2nd sketches and prototype</td>
<td>11 days</td>
<td>Fri 11/4/11</td>
<td>Tue 11/15/11</td>
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<td>Sun 11/6/11</td>
<td>Tue 11/8/11</td>
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<td>Tue 11/29/11</td>
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<td>Tue 12/1/11</td>
<td>Mon 12/5/11</td>
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<td>63 days</td>
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<tr>
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<td>13 days</td>
<td>Tue 1/3/12</td>
<td>Mon 1/16/12</td>
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<tr>
<td>Build prototypes for components 3-4</td>
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<td>Mon 3/30/12</td>
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<tr>
<td>Design Report</td>
<td>5 days</td>
<td>Thu 1/26/12</td>
<td>Thu 1/31/12</td>
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<tr>
<td>Critical Design Review</td>
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<td>Thu 2/2/12</td>
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<td>Mon 2/13/12</td>
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<td>3 days</td>
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<td>Tue 2/14/12</td>
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<tr>
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<td>Tue 2/14/12</td>
<td>Mon 2/27/12</td>
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<tr>
<td>Select materials, manufacturing plan</td>
<td>3 days</td>
<td>Tue 2/28/12</td>
<td>Fri 3/2/12</td>
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<tr>
<td>Manufacturing and Test Plan Review</td>
<td>3 days</td>
<td>Sat 3/3/12</td>
<td>Tue 3/6/12</td>
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<tr>
<td><strong>Build Final Prototype, Test, and Report</strong></td>
<td>70 days</td>
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<td>Build Final Prototype</td>
<td>21 days</td>
<td>Tue 3/27/12</td>
<td>Tue 4/17/12</td>
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<td>Project Update Report</td>
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<td>Thu 3/29/12</td>
<td>Fri 3/30/12</td>
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<tr>
<td>Perform extensive testing</td>
<td>2 days</td>
<td>Thu 4/19/12</td>
<td>Sat 4/21/12</td>
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<td>Make repairs or improvements</td>
<td>4 days</td>
<td>Tue 4/24/12</td>
<td>Sat 4/28/12</td>
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<tr>
<td>Retest &amp; refine prototype as needed</td>
<td>9 days</td>
<td>Tue 5/1/12</td>
<td>Thu 5/10/12</td>
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<tr>
<td>Hardware Demonstration</td>
<td>7 days</td>
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<td>Design Expo</td>
<td>5 days</td>
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<td>Thu 5/31/12</td>
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<tr>
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<td>2 days</td>
<td>Sat 6/2/12</td>
<td>Mon 6/4/12</td>
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## APPENDIX C: Bill of Materials

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<tr>
<th>Component</th>
<th>Assembly Name</th>
<th>Model</th>
<th>Details</th>
<th>Vendor</th>
<th>Price/Unit</th>
<th>Qty.</th>
<th>Total Cost</th>
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<td><strong>Items ready for purchase</strong></td>
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<tr>
<td>Bearings</td>
<td>Delta</td>
<td>18590</td>
<td>1.625&quot; Bore, 2.875&quot; OD, 0.656&quot; Width</td>
<td>Amazon</td>
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<td>130.64</td>
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<tr>
<td>Bearings</td>
<td>Echo</td>
<td>57155K205</td>
<td>Ball and Roller Bearing: 1/8&quot; Shaft Diameter, 1/4&quot; O.D.</td>
<td>McMaster-Carr</td>
<td>5.71</td>
<td>10</td>
<td>57.10</td>
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<tr>
<td>Bearings</td>
<td>Bravo</td>
<td>5905K230</td>
<td>Steel Needle-Roller Bearing Open for ½&quot; Shaft Diameter, 11/16&quot; OD</td>
<td>McMaster-Carr</td>
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<td>19.92</td>
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<td>Belt: V-belt</td>
<td>Bravo</td>
<td>7881K26</td>
<td>2L Rubber V-Belt Trade 25&quot; OC</td>
<td>McMaster-Carr</td>
<td>4.97</td>
<td>1</td>
<td>4.97</td>
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<tr>
<td>Conveyor: LP Series</td>
<td>Golf</td>
<td>LP-Series</td>
<td>5' by 12&quot; with conveyor belt assembled, 1/2&quot; shaft, no motor</td>
<td>Mini-Mover</td>
<td>833.00</td>
<td>1</td>
<td>833.00</td>
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<tr>
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<td>Atmel, AVR</td>
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<td>ISO</td>
<td>BB400</td>
<td>BB400 Solderless Plug-in BreadBoard, 400 tie-points, 4 power rails</td>
<td>Amazon.com</td>
<td>5.50</td>
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<td>Electronics: Wire</td>
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<td>Pico 81223J</td>
<td>22 AWG Wire (with Insulation) - Red, White, Black Colored Spools</td>
<td>Amazon.com</td>
<td>5.95</td>
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<td>ISO</td>
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<td>Sparkfun.com</td>
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<td>COM-08571</td>
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<td>1.49</td>
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<td>AVR Programming Adapter</td>
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<td>Breakout Board for FT232RL USB to Serial</td>
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<td>Quantity</td>
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<td>Electronics: H-bridges</td>
<td>ISO</td>
<td>SN754410</td>
<td>H-Bridge Motor Driver 1A</td>
<td>Sparkfun.com</td>
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<td>Electronics: H-bridges</td>
<td>ISO</td>
<td>VNH2SP30-E-IC</td>
<td>Motor Driver, H-Bridge, 30A, 20PSOP - 8 Amp continuous output current 14-Amp Continuous Output Current</td>
<td>Newark.com</td>
<td>16.00</td>
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<td>80.00</td>
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<td>Electronics: Bump Sensors</td>
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<td>COM-00098</td>
<td>Omron Snap Action Switch, Bump Sensor</td>
<td>Sparkfun.com</td>
<td>1.95</td>
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<td>Motor</td>
<td>Bravo</td>
<td>6331K23</td>
<td>12 V DC 5.02 Amp 1.31 in-lb 3456 RPM</td>
<td>McMaster-Carr</td>
<td>94.28</td>
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<td>Motor</td>
<td>Delta</td>
<td>6409K18</td>
<td>12 V DC 1.2 Amp 50 RPM 10 in-lbs</td>
<td>McMaster-Carr</td>
<td>37.42</td>
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<tr>
<td>Motor</td>
<td>Echo</td>
<td>S9117M-D13HT</td>
<td>Stepper Motor 22.2 oz-in, 0.9 &amp; 1.8 deg. Steps, 0.95 Amps, Shaft Dia. 0.197&quot;</td>
<td>SDP-SI</td>
<td>87.45</td>
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<td>Motor (Conveyor)</td>
<td>Golf</td>
<td>Leeson # M1120046</td>
<td>1/6 hp 12 VDC motor</td>
<td>Amazon</td>
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<td>Pinion Pulley</td>
<td>Bravo</td>
<td>A6210-0121508</td>
<td>1.4&quot; Pitch Dia.</td>
<td>sdp-si.com</td>
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<td>A 6T19-262508</td>
<td>1.024&quot; OD, 0.25&quot; Bore</td>
<td>sdp-si.com</td>
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<td>Pulley: Idler</td>
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<td>60885K72</td>
<td>0.5&quot; Dia., 0.25&quot; Bore</td>
<td>McMaster-Carr</td>
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<td>Bravo</td>
<td>89325K852</td>
<td>1/2&quot; Dia., 3' Long, 316 Stainless Steel</td>
<td>McMaster-Carr</td>
<td>15.28</td>
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<td>Shaft (for wall dividers)</td>
<td>Charlie</td>
<td>89325K832</td>
<td>5/8&quot; Dia., 3' Long, 316 Stainless Steel</td>
<td>McMaster-Carr</td>
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<td>Shaft: Idler</td>
<td>Delta</td>
<td>2435K1</td>
<td>0.25&quot; Dia, 1 1/16&quot; Lg.</td>
<td>McMaster-Carr</td>
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<tr>
<td>Sheet Metal</td>
<td>ISO</td>
<td>88885K54 &amp; 88885K14</td>
<td>Type 316 Stainless Steel: 26 ft² Stainless Steel Super Corrosion Resistant SS 0.06&quot; thick</td>
<td>McMaster-Carr</td>
<td>452.46</td>
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<td>Stainless Steel Bar</td>
<td>Hotel</td>
<td>89075K18</td>
<td>Type 316 Stainless Steel 3/4&quot;x3/4&quot; Bar, 3' Length</td>
<td>McMaster-Carr</td>
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<td>4378K542 Pipe</td>
<td>1.25&quot; Schedule 10 316 Stainless, 1.660&quot; OD, 0.109&quot; WT, 1.442&quot; ID, 3' Length</td>
<td>McMaster-Carr</td>
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<td>Total</td>
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<td>Stainless Steel Pipe</td>
<td>Bravo</td>
<td>4378K591</td>
<td>4&quot; Schedule 10 316 Stainless Steel Pipe, 4.5&quot; OD, 0.120&quot; WT, 4.26&quot; ID, 1' Length</td>
<td>McMaster-Carr</td>
<td>52.27</td>
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<tr>
<td>Stainless Steel Square Tubing</td>
<td>Hotel</td>
<td>2937K116</td>
<td>1&quot;x1&quot; Square Tubing 0.065&quot; Wall Thickness, 6' Length, 1&quot;x1&quot; Type 316 Stainless Steel</td>
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<td>4</td>
<td>329.84</td>
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<td>Local Store</td>
<td>10k Ohm Resistor</td>
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<td>$1.00</td>
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<tr>
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<td>ISO</td>
<td>Local Store</td>
<td>10 uF Capacitors</td>
<td>$1.00</td>
<td>2</td>
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<tr>
<td>Plastic</td>
<td>Foxtrot</td>
<td>Smooth-Cast 300</td>
<td>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</td>
<td><a href="http://www.smooth-on.com">www.smooth-on.com</a></td>
<td>85.85</td>
<td>2</td>
<td>171.70</td>
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<td>Plastic Release/Sealing Agent</td>
<td>Foxtrot</td>
<td>One Step Gallon Unit</td>
<td>1 Gallon</td>
<td><a href="http://www.smooth-on.com">www.smooth-on.com</a></td>
<td>47.30</td>
<td>1</td>
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<td>Rubber Mold Material</td>
<td>Foxtrot</td>
<td>Mold Max 10</td>
<td>1 Gallon Pourable RTV Silicone (Shore 10A tin-cure silicone rubber)</td>
<td><a href="http://www.smooth-on.com">www.smooth-on.com</a></td>
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<td>Wooden Tray Frame</td>
<td>Foxtrot</td>
<td>5068K46</td>
<td>1&quot; x 1&quot; x 14&quot; * 2 long: Approximate as 1.25&quot;x1.25&quot;x36&quot;</td>
<td>McMaster-Carr</td>
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<td>5068K46</td>
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<td>Delta</td>
<td>9485T11</td>
<td>31&quot; OC, High-Performance Urethate Flat Belts, 3/8&quot; Wedith</td>
<td>McMaster.com</td>
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<td><strong>Echo</strong></td>
<td><strong>A 6N16-014DF1204</strong></td>
<td><strong>MXL (miniature extra light) 0.08” Pitch Pulley, 14 grooves</strong></td>
<td><strong>sdp-si.com</strong></td>
<td><strong>10.00</strong></td>
<td><strong>1</strong></td>
<td><strong>10.00</strong></td>
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<td>---------------------------------------------------------------</td>
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<tr>
<td><strong>Belt: Timing</strong></td>
<td><strong>Echo</strong></td>
<td><strong>A 6Z16-343012</strong></td>
<td><strong>MXL (miniature extra light) 0.08” Pitch, 1/8” width, Neoprene w/ Fiberglass tension member, 27.44” Pitch Length</strong></td>
<td><strong>sdp-si.com</strong></td>
<td><strong>3.46</strong></td>
<td><strong>1</strong></td>
<td><strong>3.46</strong></td>
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<tr>
<td><strong>Electronics: Power Supply</strong></td>
<td><strong>ISO</strong></td>
<td><strong>TBD</strong></td>
<td><strong>Unknown, to be determined by NAVSEA. Recommend find computer supply at Amazon or Newegg</strong></td>
<td><strong>TBD</strong></td>
<td><strong>100.00</strong></td>
<td><strong>1</strong></td>
<td><strong>100.00</strong></td>
</tr>
</tbody>
</table>

**Fasteners for Motor Mounts**

| **Bolts for Motor Mounts** | **Bravo** | **91236A546** | **¾”-20 Zinc Plated, STL, 100 in pckg** | **McMaster.com** | **6.94** | **1** | **6.94** |
| **Nuts for Bolts**        | **Bravo & Golf** | **91845A029** | **¾”-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) $\omega = 60 \text{ rpm}$

$T = I\omega + F_r r$

Calculate $F_r$

$F_r = \frac{m g}{\sin \alpha}$

$\alpha = 5.04 \text{ in}$ (hollow wire) = 1/8" wall thickness and solid steel 3/4" ID)

$E = I_\theta = F_r \cos 45^\circ - F_p \cos 45^\circ + mg \sin 45^\circ$

$F_p = F_r \sin 45^\circ + mg \sin 45^\circ$

$F_p \sin 45^\circ - mg \sin 45^\circ = 0$

$I = 14.05 \text{ in}^2$

$170 \text{ lb} \cdot \text{in} \times 1000 \text{ rpm} = F_p$

$F_p = 265 \text{ lb}$

$mg = 265 \text{ lb}$

$N = \frac{F_p}{\mu_s}$

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

Research

Bolts

Tensioners

Calculate/Design

$I$, $\alpha$, $F_r$, $T$, gear ratios

Spur gear design

Motor mounts

$F_r (1 - \frac{1}{\mu_s}) = F_r (1 - \frac{1}{\mu_s}) + mg \sin 45^\circ$

$F_r (\frac{1}{\mu_s}) = mg \sin 45^\circ$

$F_r (\frac{1}{\mu_s}) = \frac{mg}{\sin 45^\circ}$

$F_r = \frac{\mu_s mg}{2 \sin 45^\circ}$

$F_r = \frac{0.35(26.5 \text{ lb})}{2 \sin 45^\circ} = 5.45 \text{ lb}$

$T = I\alpha + F_r r = (14.05 \text{ in}^2)(27 \text{ rad/rev}) + (5.45 \text{ lb})(2.25 \text{ in})$

$T = 106.2 \text{ lb} \cdot \text{in}$

$\alpha = \frac{(60 \text{ rev/rev})(2.7 \text{ rad/rev})}{1 \text{ sec}}$

$\alpha = 270 \text{ rad/sec}^2$
\[ \Sigma F_x = 0 = F_\alpha + R_B - m g \sin 30^\circ \]
\[ R_B = m g \sin 30^\circ - F_\alpha \]
\[ \Sigma F_y = 0 = N - m g \cos 30^\circ \]
\[ N = m g \cos 30^\circ = (26.5 \text{ lb}) (\cos 30^\circ) \]
\[ N = 22.95 \text{ lb} \]
\[ R_B = m g \sin 30^\circ - \mu_s N = (0.35)(22.95 \text{ lb}) + (26.5 \text{ lb}) \sin 30^\circ \]
\[ R_B = 13.25 \text{ lb} - 8.03 \text{ lb} \]
\[ R_B = 5.22 \text{ lb} \]

\[ T = \sum \tau = \frac{(4.95 \text{ lb} \cdot \text{in}^2)}{(32.2 \text{ lb} \cdot \text{in})} \alpha + \frac{(1.83 \text{ lb} \cdot \text{in})}{(2.25 \text{ in})} \]
\[ T = 0.464 \text{ lb} \cdot \text{in} (1.05 \frac{\text{lb}}{\text{in}^2}) + 4.12 \text{ lb} \cdot \text{in} \]
\[ T = (0.464 \text{ lb} \cdot \text{in}^2) \left( \frac{11^2}{144 \text{ ft}^2} \right) \left( 1.05 \frac{\text{lb}}{\text{in}^2} \right) + 4.12 \text{ lb} \cdot \text{in} \]
\[ T = 0.003 \text{ lb} \cdot \text{in} + 4.12 \text{ lb} \cdot \text{in} \]
\[ T = 4.12 \text{ lb} \cdot \text{in} \]

\[ \mu_s = \frac{F_c}{N} \]
\[ \mu_s = \frac{1.83 \text{ lb}}{22.95 \text{ lb}} \]

\[ \mu_s = 0.35 \]
Danica Frictional Torque

N = 60 rpm = 1 rev/sec
\( \mu = \) dynamic viscosity (AKA absolute viscosity)
\( r = \frac{(1.50 + 0.145)}{2} = 0.8225 \) in
\( l = 1 \) in

\( P = \frac{W}{2\pi l} \) for bronze sleeve bearing

Using std. size 12)

\( Z \) in MA = 
\( 1.33 \text{lbs} \times \cos 15^\circ + W \times 0.75'' = 0 \)

\( W = 0.642 \text{ lbf} \)

\( P = \frac{0.642 \text{ lbf}}{2(0.877'')(1'')} = 0.366 \text{ psi} \)

\( C = \frac{0.0015''}{2} = 0.0008'' \)

1. For 5# lube @ 75°F (pg. 631)

2. \( \mu = 1 \times 10^{-5} \text{ Reyn} \)

\( \mu = 1 \times 10^{-5} \frac{\text{ lbf-s}}{\text{ in}^2} \)

\( f = 2\pi^2 \frac{MN}{P} \)

\( f = 2\pi^2 \frac{1000 \text{ lbf} \times (1 \times 10^{-5} \text{ lbf-s} \text{ in})}{0.366 \frac{\text{ lbf}}{\text{ in}^2}} \times 0.0008\text{ in} = 0.591 \)

\( T = fW = (0.591)(0.642 \text{ lbf}) = 0.333 \text{ in-lbs} \times 4 \text{ cylinders} \)

\( T_{\text{tot}} = 1.33 \text{ in-lbs} \)

Don't think Sommerfeld #6 (slippery surface) would give lower coefficient for low pressure and load; and more friction doesn't apply to sleeve bearings.
Danica (Moment of Inertia) \( \omega = 60 \text{ rpm} \)

\[ I = m r^2 \]

\[ I = (1.33 \text{ lbs})(0.75 \text{ in.})^2 \]

\[ = 0.75 \text{ lb} \cdot \text{in.}^2 \]

\[ \text{Moment of inertia of } 1 \times \text{ Danica} \]

\[ I = 0.63 \text{ lb} \cdot \text{in.}^2 \]

\[ I_2 = \frac{1}{2} m (r_1^2 + r_2^2) \]

\[ = \frac{1}{2} (1.33 \text{ lbs}) (0.625^2 + 0.75^2) \]

\[ = 0.63 \text{ lb} \cdot \text{in.}^2 \]

Total \( I_z = 0.63 \times 4 \text{ lb} \cdot \text{in.}^2 \)

\[ I = 2.54 \text{ lb} \cdot \text{in.}^2 \]

Erica's Door (Moment of Inertia) \( \omega = 60 \text{ rpm} \)

\[ \text{Cast stainless steel} \]

\[ m = 0.00 \text{ pounds} \]

\[ I = 0.00 \text{ lb} \cdot \text{in.}^2 \]

\( \Rightarrow \text{ insignificant} \)
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).

![Microcontroller Wiring Diagram]

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.

![Diagram of microcontroller wiring diagram to H-bridges](image)

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.

3. H-Bridge Setup and Motor Wiring:

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)**

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 executed 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 of 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.

![Task-State Diagram](image)

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 on 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)

<table>
<thead>
<tr>
<th>Pin</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,2 Enable (Enables Motor 2)</td>
</tr>
<tr>
<td>2</td>
<td>1A, Pin Logic Input for Motor 1</td>
</tr>
<tr>
<td>3</td>
<td>1Y, Pin Output for Motor 1</td>
</tr>
<tr>
<td>4</td>
<td>Heat Sink and Ground</td>
</tr>
<tr>
<td>5</td>
<td>Heat Sink and Ground</td>
</tr>
<tr>
<td>6</td>
<td>2Y, Pin Output for Motor 1</td>
</tr>
<tr>
<td>7</td>
<td>2A, Pin Logic Input for Motor 1</td>
</tr>
<tr>
<td>8</td>
<td>Motor Supply Voltage</td>
</tr>
<tr>
<td>9</td>
<td>3,4 Enable (Enables Motor 2)</td>
</tr>
<tr>
<td>10</td>
<td>3A, Pin Logic input for Motor 2</td>
</tr>
<tr>
<td>11</td>
<td>3Y, Pin Output for Motor 2</td>
</tr>
<tr>
<td>12</td>
<td>Heat Sink and Ground</td>
</tr>
<tr>
<td>13</td>
<td>Heat Sink and Ground</td>
</tr>
<tr>
<td>14</td>
<td>Heat Sink and Ground</td>
</tr>
<tr>
<td>15</td>
<td>4A, Pin Logic Input for Motor 2</td>
</tr>
<tr>
<td>16</td>
<td>Logic Supply Voltage (5V)</td>
</tr>
</tbody>
</table>
Pin Diagram for the Conveyor, Rotating Cylinders, and Feeder H-Bridges (VNH3SP30-E & VNH2SP30-E)

<table>
<thead>
<tr>
<th>Pin No</th>
<th>Symbol</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 25, 30</td>
<td>OUT₁, Heat Slug3</td>
<td>Source of high side switch A / Drain of low side switch A</td>
</tr>
<tr>
<td>2, 4, 7, 9, 12, 14, 17, 22, 24, 29</td>
<td>NC</td>
<td>Not connected</td>
</tr>
<tr>
<td>3, 13, 23</td>
<td>VCC, Heat Slug1</td>
<td>Drain of high side switches and power supply voltage</td>
</tr>
<tr>
<td>6</td>
<td>EN₁/DIAG₁</td>
<td>Status of high side and low side switches A; open drain output</td>
</tr>
<tr>
<td>5</td>
<td>IN₁</td>
<td>Clockwise input</td>
</tr>
<tr>
<td>8</td>
<td>PWM</td>
<td>PWM input</td>
</tr>
<tr>
<td>11</td>
<td>IN₂</td>
<td>Counter clockwise input</td>
</tr>
<tr>
<td>10</td>
<td>EN₂/DIAG₂</td>
<td>Status of high side and low side switches B; open drain output</td>
</tr>
<tr>
<td>15, 16, 21</td>
<td>OUT₂, Heat Slug2</td>
<td>Source of high side switch B / Drain of low side switch B</td>
</tr>
<tr>
<td>26, 27, 28</td>
<td>GND₁</td>
<td>Source of low side switch A(1)</td>
</tr>
<tr>
<td>18, 19, 20</td>
<td>GND₂</td>
<td>Source of low side switch B(1)</td>
</tr>
</tbody>
</table>

1. GND₁ and GND₂ 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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Alpha Assembly pages 1-8
Bravo Assembly pages 9-15
Charlie Assembly pages 16-25
Delta Assembly pages 26-32
Echo Assembly pages 33-58
Foxtrot Assembly pages 59-82
Independent Star-Clip Organizer Sub-Assembly
Manufacturing Instructions

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

ALPHA

BRAVO

CHARLIE

DELTA

ECHO

FOXTROT
Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha</td>
<td>1</td>
</tr>
<tr>
<td>Bravo</td>
<td>9</td>
</tr>
<tr>
<td>Charlie</td>
<td>16</td>
</tr>
<tr>
<td>Delta</td>
<td>26</td>
</tr>
<tr>
<td>Echo I</td>
<td>33</td>
</tr>
<tr>
<td>Echo II</td>
<td>50</td>
</tr>
<tr>
<td>Echo III</td>
<td>56</td>
</tr>
<tr>
<td>Foxtrot</td>
<td>59</td>
</tr>
</tbody>
</table>
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.
ALPHA PROCEDURE:
2. Follow the cut dimensions for part # A1010.

<table>
<thead>
<tr>
<th>DATE: 2/27/2012</th>
<th>UNITS: INCHES</th>
<th>MATERIAL: TYPE 316, S.S. SHEET METAL 1/16&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOLERANCE: 0.01</td>
<td>SCALE: 1:2</td>
<td>TITLE: HOPPER FACEPLATE</td>
</tr>
<tr>
<td>PART #: A1010</td>
<td>NEXT ASSY #: A110</td>
<td>NAME: CHRISTOPHER GONZALES, TEAM SDS</td>
</tr>
<tr>
<td>DRAWING #: 1010</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ALPHA PROCEDURE:
3. Follow the cut dimensions for part # A1020.

<table>
<thead>
<tr>
<th>DATE: 2/27/2012</th>
<th>UNITS: INCHES</th>
<th>MATERIAL: TYPE 316, S.S. SHEET METAL 1/16&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOLERANCE: 0.01</td>
<td>SCALE: 1:4</td>
<td>TITLE: HOPPER ANGLED FACEPLATE</td>
</tr>
<tr>
<td>PART #: A1020</td>
<td>NEXT ASSY #: A110</td>
<td>NAME: CHRISTOPHER GONZALES, TEAM SDS</td>
</tr>
<tr>
<td>DRAWING #: 1020</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Page 4
ALPHA PROCEDURE:
4. Cut 2X part # A1030 using the dimensions specified by the drawing.
5. Cut and bend 3X part # A1040 using the dimensions specified by the drawing.
ALPHA PROCEDURE:
6. Weld 3X part # A1040 and 2X # A1030 to part # A1000 at the locations specified by the drawing.
### ALPHA PROCEDURE:

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

### MATERIAL:
- TYPE 316, S.S. SHEET METAL 1/16"

### TOLERANCE:
- 0.01

### DATE:
- 5/13/2012

### SCALE:
- 1:1

### UNITS:
- INCHES

### DRAWING #:
- 1030

### TITLE:
- SIDE DIVIDER FOR HOPPER

### PART #:
- A1030

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

### Item List:

1. A100 - ALPHA HOPPER PARTIAL ASSY
2. A1020 - 0.06" STAINLESS STEEL SHEET
3. A1010 - 0.06" STAINLESS STEEL SHEET

### ALPHA PROCEDURE:

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

### MATERIAL:
- SEE BOM

### TOLERANCE:
- 0.01

### DATE:
- 3/6/2012

### SCALE:
- 1:6

### UNITS:
- INCHES

### DRAWING #:
- 100

### TITLE:
- ALPHA HOPPER PARTIAL ASSY W/ INSERTS

### ASSY #:
- A100

### NEXT ASSY:
- ALPHA HOPPER COMPLETE ASSY # A110

### DRAWING #:
- 110

### ITEM NO. | PART NUMBER | DESCRIPTION | QTY.
--- | --- | --- | ---
1 | A100 | ALPHA HOPPER PARTIAL ASSY | 1
2 | A1020 | 0.06" STAINLESS 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.

### MATERIAL:
- SEE BOM

### TOLERANCE:
- 0.01

### DATE:
- 3/6/2012

### SCALE:
- 1:4

### UNITS:
- INCHES

### DRAWING #:
- 110

### TITLE:
- ALPHA HOPPER COMPLETE ASSY

### ASSY #:
- A110

### NEXT ASSY:
- ISO

### DRAWING #:
- 110

### ITEM NO. | PART NUMBER | DESCRIPTION | QTY.
--- | --- | --- | ---
1 | A100 | ALPHA HOPPER PARTIAL ASSY | 1
2 | A1020 | 0.06" STAINLESS STEEL SHEET | 1
3 | A1010 | 0.06" STAINLESS STEEL SHEET | 1
Bravo Assembly

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

- B1000 (1X)
- B1010 (8X)
- B1020 (4X)
- 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.
**BRAVO PROCEDURE:**
2. Cut 8X part # B1010 using the dimensions specified in the drawing.

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>QTY.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>B1020</td>
<td>4&quot; DIA STAINLESS STEEL PIPE</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>B1010</td>
<td>0.06&quot; STAINLESS STEEL SHEET</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>B1030</td>
<td>0.06&quot; STAINLESS STEEL BENT SHEET</td>
<td>1</td>
</tr>
</tbody>
</table>

**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
BRAVO PROCEDURE:
3. Cut 4X part # B1020 from 4” diameter stainless steel pipe, using the dimensions specified in the drawing.
BRAVO PROCEDURE:
4. Cut and bend 4X part # B1030 using the dimensions specified in the drawing.
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.

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>QTY.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>B1020</td>
<td>4&quot; DIA STAINLESS STEEL PIPE</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>B1010</td>
<td>0.06&quot; STAINLESS STEEL SHEET</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>B1030</td>
<td>0.06&quot; STAINLESS STEEL BENT SHEET</td>
<td>1</td>
</tr>
</tbody>
</table>
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.
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.

<table>
<thead>
<tr>
<th>DATE: 5/22/2012</th>
<th>UNITS: INCHES</th>
<th>MATERIAL: TYPE 316 S.S. SHEET METAL 1/16”</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOLERANCE: 0.01</td>
<td>SCALE: 1:6</td>
<td>TITLE: DROPDOWN BODY</td>
</tr>
<tr>
<td>PART #: C1000</td>
<td>NEXT ASSY #: C110</td>
<td>NAME: DANIEL SILVEIRA, TEAM SDS</td>
</tr>
<tr>
<td>DRAWING #: 3000</td>
<td></td>
<td>Page 17</td>
</tr>
</tbody>
</table>
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: DROPOUT BODY
PART #: C1000	NEXT ASSY #: C110	NAME: DANIEL SILVEIRA, TEAM SDS
DRAWING #: 3001

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

<table>
<thead>
<tr>
<th>DATE: 5/22/2012</th>
<th>UNITS: INCHES</th>
<th>MATERIAL: TYPE 316, S.S. SHEET METAL 1/16&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOLERANCE: 0.01</td>
<td>SCALE: 1:1</td>
<td>TITLE: DROPPDOWN Divider Wall</td>
</tr>
<tr>
<td>PART #: C1010</td>
<td>NEXT ASSY #: C100</td>
<td>NAME: DANIEL SILVEIRA, TEAM SDS</td>
</tr>
<tr>
<td>DRAWING #: 3010</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CHARLIE PROCEDURE:
5. Cut 3X part # C1020 from a 5/8" diameter stainless steel rod to a length of 6 inches.
CHARLIE PROCEDURE:
6. Cut 8X part # C1040 to the specified dimensions.
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.
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
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

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>QTY.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C110</td>
<td>PARTIALLY COMPLETE DROPDOWN ASSY</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>C1040</td>
<td>CHARLIE STAR CLIP GUIDE WALL</td>
<td>8</td>
</tr>
</tbody>
</table>

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

TITLE: DROPDOWN DIVIDER ASSEMBLY
NAME: DANIEL SILVEIRA, TEAM SDS
MATERIAL: SEE BOM
TOLERANCE: 0.01
DATE: 5/22/2012
NEXT ASSY #: C110
SCALE: 1:2
UNITS: INCHES
DRAWING #: 300
ASSY #: C100
<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>QTY.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C110</td>
<td>PARTIALLY COMPLETE DROPDOWN ASSY</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>C1040</td>
<td>CHARLIE STAR CLIP GUIDE WALL</td>
<td>8</td>
</tr>
</tbody>
</table>

**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**
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.
DELTA PROCEDURE:
2. Cut part # D1010 from 3/4" square tubing to a length of 16 inches.
DELTA PROCEDURE:
3. Cut part # D1020 from 1-1/4 pipe size (1.660" OD) to a length of 7.8 inches.
DELTA PROCEDURE:
4. Obtain 8X bearings with a 40mm bore, 68mm OD, 15mm length. Note SAE units are shown in drawing.
DELTA PROCEDURE:
5. Weld part # D1000 to # D1010 in the locations indicated by the drawing.

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>QTY.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>D1000</td>
<td>SUPPORT BRACKET FOR ROTATING CYLINDERS</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>D1010</td>
<td>3/4&quot; x 3/4&quot; STAINLESS STEEL BAR</td>
<td>1</td>
</tr>
</tbody>
</table>

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
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.

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>QTY.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>D1030</td>
<td>40MM BORE BALL BEARING</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>D1020</td>
<td>1.660&quot; OD STAINLESS STEEL PIPE</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>D100</td>
<td>DELTA SUPPORT AND CROSSBAR</td>
<td>1</td>
</tr>
</tbody>
</table>

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.
ECHO I PROCEDURE:
1. Cut and bend 4X part # E1000 from 1/16" sheet metal using the specified dimensions.
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.
**ECHO I PROCEDURE:**
3. Cut 4X part # E1020 from 1/16” sheet metal using the specified dimensions.

<table>
<thead>
<tr>
<th>DATE: 5/28/2012</th>
<th>UNITS: INCHES</th>
<th>MATERIAL: TYPE 316 S.S. SHEET METAL 1/16”</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOLERANCE: 0.01</td>
<td>SCALE: 2:1</td>
<td>TITLE: ECHO GATE</td>
</tr>
<tr>
<td>PART #: E1020</td>
<td>NEXT ASSY #: E100</td>
<td>NAME: DANIEL SILVEIRA, TEAM SDS</td>
</tr>
<tr>
<td>DRAWING #: 5020</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

5. Cut 8X part # E1040 from 1/16” sheet metal using the specified dimensions.

<table>
<thead>
<tr>
<th>DATE: 5/28/2012</th>
<th>UNITS: INCHES</th>
<th>MATERIAL: TYPE 316 S.S. SHEET METAL 1/16”</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOLERANCE: 0.01</td>
<td>SCALE: 8:1</td>
<td>TITLE: SUPPORT BRACKET FOR ECHO GATE ASSY</td>
</tr>
<tr>
<td>PART #: E1040</td>
<td>NEXT ASSY #: E120</td>
<td>NAME: DANIEL SILVEIRA, TEAM SDS</td>
</tr>
<tr>
<td>DRAWING #: 5040</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ECHO I PROCEDURE:
6. Obtain 8X part # E1050 miniature ball bearings.

<table>
<thead>
<tr>
<th>DATE: 5/27/2012</th>
<th>UNITS: INCHES</th>
<th>MATERIAL: STAINLESS STEEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOLERANCE: 0.01</td>
<td>SCALE: 8:1</td>
<td>TITLE: ECHO MINIATURE BALL BEARING</td>
</tr>
<tr>
<td>PART #: E1050</td>
<td>NEXT ASSY #: E130</td>
<td>NAME: DANIEL SILVEIRA, TEAM SDS</td>
</tr>
<tr>
<td>DRAWING #: 5050</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SECTION A-A
ECHO I PROCEDURE:
7. Cut part # E1060 from type 316 stainless steel 3/4” square bar to a length of 16 inches.
### ECHO CONNECTING PAD

- **Part #:** E1080
- **Material:** Type 316 S.S. Sheet Metal 1/16”
- **Tolerance:** 0.01
- **Date:** 5/28/2012
- **Next Assy #:** E110
- **Scale:** 2:1
- **Units:** Inches
- **Drawing #:** 5080

#### ECHO PROCEDURE:
8. Cut 4X part # E1080 from 1/16” sheet metal using the specified dimensions.

---

### ECHO MINIATURE BALL BEARING

- **Part #:** E1050
- **Material:** Stainless Steel
- **Tolerance:** 0.01
- **Date:** 5/27/2012
- **Next Assy #:** E130
- **Scale:** 8:1
- **Units:** Inches
- **Drawing #:** 5050

---

### ECHO CROSSBAR

- **Part #:** E1060
- **Material:** Type 316 3/4” x 3/4” S.S. Bar
- **Tolerance:** 0.01
- **Date:** 5/28/2012
- **Next Assy #:** E110
- **Scale:** 1:2
- **Units:** Inches
- **Drawing #:** 5060

---

### SHIM FOR RAMP CAMBER

- **Part #:** E1100
- **Material:** Type 316 1/8” Dia Stainless Steel
- **Tolerance:** 0.01
- **Date:** 5/28/2012
- **Next Assy #:** E140
- **Scale:** 4:1
- **Units:** Inches
- **Drawing #:** 5100

---

### SUPPORT BRACKET FOR ECHO GATE

- **Part #:** E1040
- **Tolerance:** 0.01
- **Date:** 5/28/2012
- **Next Assy #:** E120
- **Scale:** 8:1
- **Units:** Inches
- **Drawing #:** 5040

---

**Page 41**
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.

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>QTY.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>E1080</td>
<td>0.06” STAINLESS STEEL SHEET</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>E1090</td>
<td>1/8” STAINLESS STEEL ROD</td>
<td>2</td>
</tr>
</tbody>
</table>

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
ECHO I PROCEDURE:
11. Spot weld part # E1020 to # E1010 in the specified location. Make a total of 4 assemblies.
ECHO I PROCEDURE:
12. Press 2X part # E1090 into part # E1080. Make a total of 4 assemblies.
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.
<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>QTY.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>E120</td>
<td>ECHO I RAMP ASSEMBLY IN PROGRESS</td>
<td>1</td>
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<tr>
<td>2</td>
<td>E100</td>
<td>ECHO GATE ASSEMBLY</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>E1050</td>
<td>1/8&quot; INNER SHAFT DIA BEARING</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>E1030</td>
<td>0.125&quot; BORE TIMING BELT PULLEY</td>
<td>1</td>
</tr>
</tbody>
</table>

**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
ECHO I PROCEDURE:
18. Weld part # E1100 to assembly # E130. Make a total of 4 assemblies.

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

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
ECHO I PROCEDURE:
19. Weld 4X assembly # E140 to part # E1060 to complete the Echo I Ramp Assembly.
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.
ECHO II PROCEDURE:
2. Cut 4X part # E2010 from 1/16” sheet metal using the specified dimensions.

<table>
<thead>
<tr>
<th>DATE: 5/29/2012</th>
<th>UNITS: INCHES</th>
<th>MATERIAL: TYPE 316 S.S. SHEET METAL 1/16”</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOLERANCE: 0.01</td>
<td>SCALE: 1:1</td>
<td>TITLE: SHORT-SIDE WALL FOR ECHO II ATTACHMENT</td>
</tr>
<tr>
<td>PART #: E2010</td>
<td>NEXT ASSY #: E200</td>
<td>NAME: DANIEL SILVEIRA, TEAM SDS</td>
</tr>
<tr>
<td>DRAWING #: 5215</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Diagram of part E2010]
**ECHO II PROCEDURE:**

3. Cut part # E2020 from 1/16” sheet metal using the specified dimensions.

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>QTY.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>E2020</td>
<td>ECHO II ATTACHMENT</td>
<td>1</td>
</tr>
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</table>

**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
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.
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
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.
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
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.
<table>
<thead>
<tr>
<th>FOXTROT PROCEDURE:</th>
<th>DATE: 5/29/2012</th>
<th>UNITS: INCHES</th>
<th>MATERIAL: TYPE 316 S.S. SHEET METAL 1/16&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Cut part # F1020 from 1/16&quot; sheet metal using the specified dimensions.</td>
<td>TOLERANCE: 0.001</td>
<td>SCALE: 1:4</td>
<td>TITLE: FOXTROT TOP SHEET METAL PANEL</td>
</tr>
<tr>
<td></td>
<td>PART #: F1020</td>
<td>NEXT ASSY #: F110</td>
<td>NAME: DANIEL SILVEIRA, TEAM SDS</td>
</tr>
<tr>
<td></td>
<td>DRAWING #: 6020</td>
<td></td>
<td>Page 62</td>
</tr>
</tbody>
</table>
FOXTROT PROCEDURE:
8. Cut part # F1030 from 1/16" sheet metal using the specified dimensions.

<table>
<thead>
<tr>
<th>DATE: 5/29/2012</th>
<th>UNITS: INCHES</th>
<th>MATERIAL: TYPE 316 S.S. SHEET METAL 1/16&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOLERANCE: 0.001</td>
<td>SCALE: 1:4</td>
<td>TITLE: FOXTROT BOTTOM SHEET METAL PANEL</td>
</tr>
<tr>
<td>PART #: F1030</td>
<td>NEXT ASSY #: F210</td>
<td>NAME: DANIEL SILVEIRA, TEAM SDS</td>
</tr>
<tr>
<td>DRAWING #: 6030</td>
<td></td>
<td>Page 63</td>
</tr>
</tbody>
</table>
FOXTROT PROCEDURE:
9. Cut 4X part # F1040 from balsa wood using the specified dimensions.
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 PROEDURE:
12. Cut 2X part # F1070 from balsa wood using the specified dimensions.
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  

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

<table>
<thead>
<tr>
<th>DATE: 5/29/2012</th>
<th>UNITS: INCHES</th>
<th>MATERIAL: TYPE 316 STAINLESS STEEL PIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOLERANCE: 0.01</td>
<td>SCALE: 4:1</td>
<td>TITLE: FOXTROT TRAY-LOCKING PIN</td>
</tr>
<tr>
<td>PART #: F1080</td>
<td>NEXT ASSY #: F300</td>
<td>NAME: DANIEL SILVEIRA, TEAM SDS</td>
</tr>
<tr>
<td>DRAWING #: 6080</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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## 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.

### Table

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>QTY.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F1020</td>
<td>0.06&quot; STAINLESS STEEL SHEET</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>F100</td>
<td>BALSA WOOD</td>
<td>1</td>
</tr>
</tbody>
</table>

### Details

- **DATE:** 5/29/2012
- **UNITS:** INCHES
- **MATERIAL:** SEE BOM
- **TOLERANCE:** 0.01
- **SCALE:** 1:8
- **TITLE:** FOXTROT CAP FOR TRAY-LOCKING PIN AND RING
- **PART #:** F1100
- **NEXT ASSY #:** F300
- **NAME:** DANIEL SILVEIRA, TEAM SDS
- **DRAWING #:** 6100
**FOXTROT PROCEDURE:**
17. Glue 2X part # F1040 to 1X part # F1050 as indicated.
FOXTROT PROCEDURE:
18. Insert part # F1020 (top sheet metal slide) into assembly # F100 as shown.
19. Glue part # F1040 to the end of assembly # F110 to hold the sheet metal in place.
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.
<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>QTY.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F1040</td>
<td>BALSA WOOD FRONT SUPPORT</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>F1060</td>
<td>BALSA WOOD BOTTOM-SIDE SUPPORT</td>
<td>1</td>
</tr>
</tbody>
</table>

FOXTROT PROCEDURE:
22. Glue 2X part # F1040 to 1X part # F1060 as indicated.

DATE: 5/30/2012
UNIT: 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
FOXTROT PROCEDURE:
23. Insert part # F1030 (bottom sheet metal slide) into assembly # F200 as shown.
FOXTROT PROCEDURE:
24. Glue part # F1040 to the end of assembly # F210 to hold the sheet metal in place.
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.
FOXTROT PROCEDURE:
26. Epoxy part # F1100 to part # F1080 as indicated.

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>QTY.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F1100</td>
<td>WOODEN CAP FOR TRAY-LOCKING PIN AND RING</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>F1080</td>
<td>1/8&quot; DIA STAINLESS STEEL DOWEL PIN</td>
<td>1</td>
</tr>
</tbody>
</table>

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
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
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 SD
DRAWING #: 624  PAGE: 81
<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>QTY.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F320</td>
<td>COMBINED TOP AND BOTTOM TRAYS</td>
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<tr>
<td>2</td>
<td>F310</td>
<td>LOCKING PIN ASSEMBLY</td>
<td>1</td>
</tr>
</tbody>
</table>

**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  

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Acknowledgements

Doctor Mohammad Noori, Professor at Cal Poly

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