FINAL DESIGN REPORT FOR

DUHA GROUP

FAN DECK COMPLETION SYSTEM

DECEMBER 02, 2013

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LETTER OF TRANSMITTAL

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Date: December 02, 2013
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Dear Dr. Labossiere,

Attached is the Final Design Report for the MECH 4860 Engineering Design Class as completed by Streamline Systems for Duha Group on the 2nd of December, 2013.

This report fulfils the requirements and obligations as laid out in the course outline and our client agreement. Throughout the design process a wide range of different concepts were considered and analyzed using a variety of engineering techniques and approaches. Ultimately a final concept was chosen based on the fore mentioned analysis, and a complete design and detailed analysis was undertaken.

The complete system required for the fan deck assembly process was broken down into individual system operations and equipment and components were specified and analyzed. Streamline Systems was able to prove that the final system design meets Duha's technical requirements as well as being adaptable to future product changes.

We look forward to discussing any questions and clarifications you may have in the near future.

Sincerely,
Streamline Systems (Group #6)

Chris Trenholm	____________	Sean Campbell	____________
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ABSTRACT

Streamline Systems was tasked by Duha Group to increase the automation and efficiency of the fan deck completion cell in the client's Winnipeg manufacturing facility. Specifically, the team's objective was to redesign the fan deck completion process, in order to achieve a throughput of 350 fan decks per hour with no more than six operators working in the cell. Duha Group has indicated a total project budget of $50,000.00 to $60,000.00 CAD, utilization of available power in the cell, and not exceeding the existing cell dimensions as the constraints of the project.

The existing system requires 12 operators to achieve its maximum throughput of 200 fan decks per hour. Based on a provided operator cost of $20 per hour, and an assumed annual production of 1,000,000 fan decks, it was calculated that the current annual operating cost is $1,225,000.00 CAD. This annual operating cost includes 200 tooling changes for the switch over between the different fan deck styles and annual maintenance costs.

The final design selected by Streamline Systems is comprised of four key manufacturing operations: Indexing System, Die Cutting, Post Installation, and Fan Deck Positioning System. The indexing system consists of a linear indexing conveyor. Die cutting operations modify and utilize die cutters currently owned by Duha Group. Post installation is carried out by a two stage Weber screw driving system. Fan deck positioning is accomplished using electronic actuators and a series of adjustable guides. All components are designed to work together through integration of a Programmable Logic Controller.

The new fan deck completion system requires four operators to achieve a throughput of 350 fan decks per hour. Using the same annual production throughput as was utilized for the current system, the first year annual operation cost is $421,413.00 CAD. This first year cost includes the cost to purchase and automate the new equipment and materials, labour, maintenance, as well as 400 tooling changes to reflect the increased fan deck throughput. The cost to purchase the required equipment and materials for this proposed system is

$145,413.00. While this is in excess of the initial budget provided by Duha Group, it was deemed a worthwhile investment based on the following results of the new fan deck completion system implementation.

The new fan deck completion system increases throughput by 75% from 200 to 350 fan decks per hour, while reducing labour by 66% from 12 operators to four. Based on the analysis contained herein, it is shown that the proposed changes create a first year savings of $803,015.00 CAD, which is representative of a return on investment of 452%. The annual operation savings after the first year of production are $944,429.00 CAD.

Based on the analysis and evaluation metrics utilized by Streamline Systems, it is highly recommend that Duha Group takes action to reduce labour requirements and increase fan deck throughput by implementing the fan deck completion system as outlined in this report.

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1 INTRODUCTION

Our Client, Duha Group, is a manufacturing company based out of Winnipeg, MB. The Duha Group manufactures a wide range of colour marketing products for paint companies, suppliers and distributers around the world. The company originally formed as a print shop which printed a variety of paper products from entertainment merchandise to marketing tools, such as brochures. In the last thirty years, company growth coupled with product expansion has allowed the Duha Group to grow its international market presence to Mexico, U.S.A., Germany, China, Singapore, and Australia. The company's current primary focus is on producing marketing products for the paint industry. [1]

Duha Group's product line includes fan decks. A fan deck is an assembly of printed paint chips. An example can be seen in Figure 1.

Figure 1: Sample fan deck [2]

Fan decks are manufactured in Duha Groups' Winnipeg plant. The last stage of the fan deck manufacturing process is called the fan deck completion process.

Our team at Streamline Systems has been presented with the following problem; Duha Group wants a way to make the fan deck completion process faster and less labour intensive. Specifically, Duha Group desires an increase in cell throughput from 200 to 350 fan decks per hour, and a decrease in the number of cell operators from 12 to six or fewer. Our teams' objective is to redesign the fan deck completion process in Duha Group's Winnipeg manufacturing facility, so that a throughput of 350 fan decks per hour can be achieved with no more than six operators.

The fan deck completion process is contained within the fan deck completion cell. In the fan deck completion cell a stack of panels are hole-punched, trimmed and cut into individual fan decks using a punch master, large shear, and auto-cutter, respectively. The fan decks are then die cut to client specifications using a die-cutter. Finally, the fan decks are posted by hand to hold their individual layers together, and packaged to the client's needs. Figure 2 is a schematic of the processes within the fan deck completion cell. The figure highlights our project area in blue.

Figure 2: Schematic of processes within the fan deck completion cell, highlighting our project area in blue [3] [4]

In order for our project to be successful, a list of needs and constraints was developed with collaboration from our client. The needs and constraints are listed below:

- Needs
  - Accommodate fan deck size versatility
  - Accommodate post length versatility
  - Increase fan deck throughput
  - Decrease the number of cell operators
- Constraints
  - Power available in the completion cell
  - Air pressure available in cell
  - Cell size (area of the finishing cell)
  - Budget

In order to fully define the needs and constraints, specifications were assigned to each. These specifications were provided by Duha Group, and they correspond to the product line that Duha Group currently offers its customers. In order to accommodate fan deck size versatility, our design must accept fan decks ranging in width from two inches to nine inches, and in length from three and a quarter inches to 12 inches. To accommodate the various post sizes and types, our design must accept both Chicago style (screw) and punch style posts, ranging in length from one and three quarter inches to five inches. The desired throughput of the redesigned process is 350 fan decks per hour; however, Duha Group has communicated to us that a throughput of 200 fan decks per hour is acceptable if six or fewer cell operators are required. Our design can only make use of the power currently available in the cell (electricity ranging from 110V – 240V, and compressed air at 100 +- 10PSI), and is required to fit within the cell dimensions (a rectangle of dimension 30’ x 20’). Lastly, Streamline Systems has been allotted a budget of $50 000.00 to $60 000.00. These specifications are summarized in TABLE I.

TABLE I: SPECIFICATION VALUES CORRESPONDING TO NEEDS AND CONSTRAINTS

		Metric	Units	Specification Value
Needs	Accommodate fan deck size versatility	Fan deck size range	Inches (Width x Length)	(2 x 3 ¼) – (9 x 12)
	Accommodate post length Versatility	Post length and type	Inches	Chicago style 1¾ – 5 Punch post 1¾ – 5
	Increased throughput	Throughput rate	Units / Hour	200 - 350
	Decrease cell operators	# of cell operators	Integer	1 - 6
Constraints	Power available	Voltage	Voltage	110 – 240
	Air Pressure Available	Air Pressure	PSI	100 +- 10
	Budget	Dollars	Dollars	50,000 – 60,000
	Finishing cell size	Length	Feet	30 x 20

If a redesigned completion process is not implemented, profit margins will remain unchanged. Duha Group is a forward thinking company, and a successful redesign of the fan deck completion process is necessary for Duha Group to move forward with company development.

Using many internal and external methods, Streamline Systems generated a number of concepts as potential solutions to this problem. Each concept was discussed as a group, and concepts were combined to form new ideas. The final integrated concepts were then each evaluated against the identified specifications outlined by the needs and constraints. The three superior designs were chosen for further development.

Detailed research and design was performed on the final three designs, in order to determine an accurate estimate for design performance. With these estimates the best design was selected for final development, analysis and optimization. The main goal of this project was to generate a design that increased the fan deck completion cell throughput, while requiring a maximum of six cell operators. The deliverables of this project include component selection and integration, preliminary engineering drawings of all components and mounting hardware, and a bill of materials.

2 DETAILS OF THE DESIGN

Streamline Systems has been working in collaboration with Duha Group for the past four months to develop a fan deck completion system, with the aim of meeting their needs and target specifications. The final design selected by Streamline Systems is comprised of four key manufacturing operations: Indexing System, Die Cutting, Post Installation, and Fan Deck Positioning System. A three dimensional, (3D) rending of the proposed fan deck completion system, outlining the four key manufacturing operations, can be seen in Figure 3. This section contains an overview of the design, followed by a detailed analysis of each manufacturing operation, cell power requirements, system assembly and versatility, and an overall cost analysis.

Figure 3: 3D rendering of fan deck completion system, outlining the four key manufacturing operations

2.1 DESIGN OVERVIEW

Our project area begins when the fan decks exit the auto-cutter. At this point, flow through the fan deck completion system can commence. The fan deck leaves the auto-cutter with square corners, and the required hole punched for post insertion. Figure 4 shows the state a fan deck is in when entering the fan deck completion system, highlighting the square corners and punched hole.

Figure 4: Fan deck prior to entering the fan deck completion system, highlighting the square corners and punched hole

The fan deck is manually loaded into the start of the completion system by an operator. The operator must ensure the fan deck is placed top down, and pushed tightly against the wall of the indexing system and the cleat of the indexing belt. This desired orientation and position can be seen in Figure 5.

Figure 5: Initial fan deck orientation

The indexing system moves a distance of 14.13” on timed cycles. The frequency and speed of the cycles is dependent on the required throughput of the completion system. All parameters regarding the indexing system can be modified using the Programmable Logic Controller (PLC). The operator must therefore place one fan deck into the completion system for every index cycle of the belt.

Once the fan deck is properly positioned on the indexing system, the fan deck moves into the die cutting process. The die cutting process consists of two die cutters. The die cutters are in a staggered and offset position on opposite sides of the indexing system as shown in Figure 6.

Figure 6: Above view: die cutters in a staggered and offset position on opposite sides of the indexing system

Two electronic actuators are used at each die cutting station to load and unload the fan deck into and out of the die cutter. Figure 7 shows the position and orientation of the loading and unloading actuators.

Figure 7: Position and orientation of the loading and unloading actuators

Each die cutter rounds two of the four corners of the fan deck. An isometric view of a fan deck leaving the first die cutter can be seen in Figure 8.

Figure 8: Fan deck following die cutter 1, two rounded corners

An isometric view of a fan deck leaving the second die cutter can be seen in Figure 9. At this stage all four corners of the fan deck have been rounded.

Figure 9: Fan deck following die cutter 2, four rounded corners

Once the fan deck is actuated back onto the indexing system following the second die cutting process, the fan deck is indexed into the female post insertion process. An electronic actuator pushes the fan deck tightly against the wall of the indexing system. This electronic actuator holds the fan deck in place, and ensures the layers are aligned properly. This process can be seen below in Figure 10.

Figure 10: Actuator positioning fan deck for female post insertion

An automated post insertion system which has been pre-positioned based on the geometry of the fan deck then inserts the female end of the post into the fan deck. This process can be seen in Figure 11.

Figure 11: Female post insertion

The fan deck is then indexed to a second operator, who manually removes the fan deck from the indexing system, flips the fan deck while holding the female post in place and positions the fan deck onto the male post insertion table. Figure 12 shows a plan view of the male post insertion table and its orientation in relation to the operator and indexing system.

Figure 12: Male post insertion table and its orientation in relation to the operator and indexing system

There is a 90˚ v-guide on the male post insertion table that the operator will use as a guide to properly align the fan deck, prior to male post insertion. The 90˚ v-guide with a fan deck in position can be seen in Figure 13.

Figure 13: 90° V-guide with fan deck in position

Once the fan deck is in place, the operator will engage a two hand control start button to initiate the male post insertion process. Following male post insertion, the operator will remove the fan deck in preparation for packaging. This operation concludes the fan deck completion system process.

2.2 INDEXING SYSTEM

The linear indexing system for the fan deck completion system is a critical component of the process. It determines the speed that the fan deck moves through the system and level of automation which can be achieved. The linear indexer needs to be able to accommodate various fan deck sizes and increase fan deck throughput. In addition, the linear indexing system allows Duha Group to decrease the number of operators in the cell, while increasing operator safety.

The linear indexer selected by Streamline Systems is a 3200 series conveyor, manufactured by Dorner Conveyor Systems. This conveyor features an end driven cleated belt with V-guide tracking. The dimensions are 14 feet long, 12 inches wide, and 39 inches in height. The conveyor belt is made of a special low friction material, suitable for loading and unloading fan decks. It features a side mounted variable speed motor and an indexing variable frequency drive, (VFD) control mechanism. Figure 14 shows the indexing conveyor, highlighting the cleated belt and side mounted motor.

Figure 14: Dorner 3200 indexing conveyor system, highlighting the cleated belt and side mounted motor

The cleat spacing specified allows for all required fan deck sizes to be accommodated. The linear conveyor serves as a transport mechanism for fan decks. Currently the process of transporting fan decks is carried out by cell operators. Automating this process contributes to the reduction of operators in the cell, from 12 to four. Additionally, the customizable indexing conveyor enables uninterrupted fan deck processing, increasing fan deck throughput from 200 to 350 fan decks per hour.

2.3 DIE CUTTING

The first fan deck processing operation in the fan deck completion system is the die cutting operation. Die cutting allows Duha Group to cut the corners of the fan deck to any customized shape specified by the customer. Typically, this operation involves rounding of the four fan deck corners. To increase the die cutter throughput, as well as decrease the number of operators in the cell, Streamline Systems will modify and repurpose the two die cutters Duha Group currently owns. The current die cutters can accept the full range of fan deck sizes. As such, utilizing the current die cutters ensures that our design will be capable of accommodating the necessary fan deck size versatility.

Two linear actuators will be used to load and unload the fan decks from the die cutter. In order to make use of the current die cutters, the following die cutter modifications are required:

- A hole will be cut in the rear guard of the die cutter.
- The die cutter will require re-wiring in order to integrate the Programmable Logic Controller.
- The intake guides will be lengthened and widened.

The die cutters positioned for in line operation can be seen in Figure 6.

It is necessary to modify the rear guard so that the rear actuator is able to unload the fan deck from the die cutter and position it back on the indexing system. The rear guard modification can be seen in Figure 15. Under current operations, a cell operator is tasked with loading and unloading fan decks into and out of the die cutter. By using electronic actuators to complete this task, the die cutter operation can be automated, eliminating an operator from the cell and increasing the die cutter throughput. The hole in the rear guard has been cut to a width of three and a half inches; this allows the actuator head to pass through uninterrupted. Engineering drawings of the rear guard modification can be found in Appendix C.

Figure 15: Rear guard modification

The re-wiring specification is beyond the scope of this report, however the die cutter re-wiring will allow for integration with a PLC. Integration with the PLC will allow for an increase in throughput from 200 to 350 fan decks per hour.

The specified modifications to the rear guard and re-wiring of the die cutter will allow the die cutter to be used as a standalone operation. Standalone operating capabilities are important, as Duha Group wants the ability to utilize the die cutters independently from the fan deck completion system.

In order to accommodate in line operation of the die cutter, the die cutter intake guides were lengthened and widened. The redesigned intake guides can be seen in Figure 16.

Figure 16: Redesigned die cutter intake guides

The die cutter intake guides were redesigned to ensure proper alignment of the fan deck in the die cutter. Lengthening and widening of the intake guides increases the catchment area of the die cutter. This ensures the actuators are able to correctly position the fan deck in the die cutter. Without an operator at the die cutter stage, it is important the process is able to correct fan deck misalignments that may occur. Technical drawings of the intake guides can be found in 0.

2.3.1 DIE CUTTER LOADING AND UNLOADING

Electronic actuators were selected to load and unload the die cutters, this eliminates the need for an operator to perform the die cutting operation. For each die cutter, two electronic actuators will be required. A plan view of the die cutter and its corresponding electronic actuators can be seen in Figure 7.

A variable force actuator head was designed for the actuator responsible for loading the fan deck into the die cutter. The variable force actuator head was designed to enable the actuator to apply force to the fan deck while it is being die cut. This application of force is necessary for proper die cutting. The programmable variables for the electronic actuator control are: speed and distance of actuation. In order to allow the actuator to apply an adjustable force to the fan deck while it is loaded in the die cutter, a linear spring was incorporated into the actuator head. This allows for the displacement of the spring to be controlled by adjusting the distance of actuation, and thus the force on the fan deck during die cutting. Three guide bolts are used to allow linear compression of the spring, while keeping the plates of the variable force actuator head parallel to one another. A threaded female mount is used to connect the actuator head to the electronic actuator. An image of the variable force actuator head can be seen in Figure 17.

Figure 17: Variable force actuator head

A second electronic actuator is used to unload the fan deck back onto the indexing system. An image of this unloading actuator head is shown in Figure 18.

Figure 18: Unloading actuator head

As we can see, the path of the unloading actuator is through the modification hole made in the rear guard of the die cutter. The unloading actuator head was sized to accommodate the smallest fan deck length. This ensures fan decks of any size can be properly unloaded from the die cutter.

The recovery actuation process involves both actuators. The loading and unloading actuators move in unison, keeping the variable force actuator head engaged. Figure 19 shows the movement of the loading and unloading actuators, as the fan deck is unloaded from the die cutter. Once the fan deck is in the required position on the indexing system, the variable force actuator retracts, followed by the rear actuator, and the indexing system can then move unobstructed.

Figure 19: Both actuators during fan deck transfer from indexing conveyor to die cutter

2.4 POST INSTALLATION

The final post insertion process selected not only aids in reducing the number of operators in the cell, but increases automation while increasing throughput rate. After consulting with a number of manufacturers regarding available technical support, availability of spare parts, location of technical support personnel, and overall industry reputation, a single vendor was selected. This vendor, Weber Screw Driving Systems Inc., is located in New York in the United States, and has been extremely helpful in providing pricing and technical information throughout the design process.

2.4.1 FEMALE POST INSERTION

The final design called for the female side of the posts to be inserted first. This process begins when the fan deck is pushed by a variable force actuator head against the alignment edge of the indexing system. This ensures that the fan deck is square in position. Figure 20 shows the actuator with spring loaded head squaring the fan deck against the alignment edge of the indexer, in preparation for female post insertion.

Figure 20: Actuator squaring up fan deck for female post insertion

Following proper alignment of the fan deck, a female post is fed to a Weber LCI-10 post inserter, by a Z-150C step feed system. Both the LCI-10 and Z-150C are to be mounted on independent support stands. The female post is fed to the LCI-10 inserter by a flexible vacuum line tube. The LCI-10 head is to be mounted on a stand with a high precision cross-slide base table. Our design incorporates a Velmex manual X-Y table, which can be seen in Figure 21. The x-y coordinates of the table surface are manually adjustable by an operator. The coordinates should be aligned with each fan deck batch to ensure the female post insertion process is carried out properly. The x-y table allows for the head to be adjusted for the location of the fan deck post hole on each different style of fan deck. This allows the female post insertion process to accommodate all fan deck sizes, post positions and post lengths.

Figure 21: Velmex x-y table

The base stand used to connect the Weber LCI-10 to the x-y table will be provided with Weber, as part of a complete post insertion package. The stand will add movement in the z direction to allow for varying thicknesses of fan decks to be processed. The stand will support the 8 kg mass of the drive head, and allow the ability to apply a load of 10 NM when inserting the female post. Figure 22 shows the female post insertion process. The black arrows represent the up/down movement of the Weber LCI-10 as the process is carried out, and the red arrow shows the presented female post being inserted into the fan deck.

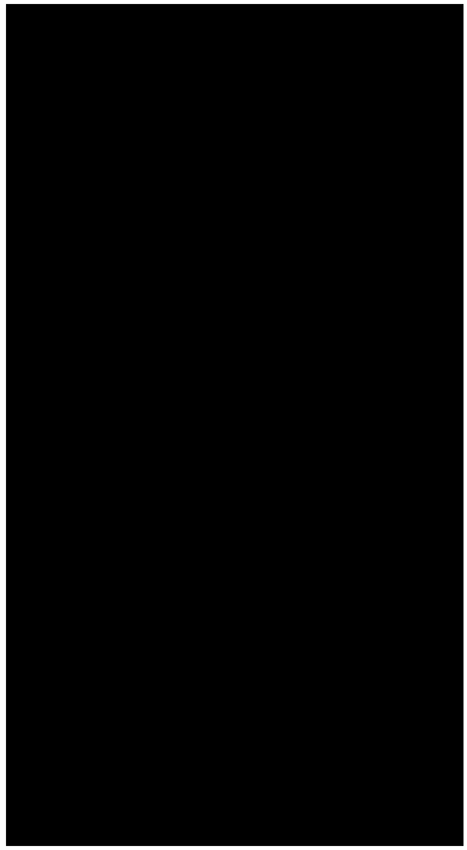

Figure 22: Female post insertion process

2.4.2 MALE POST INSERTION

Once the female post insertion process is complete, the male post insertion process can begin. The two types of male posts used by Duha Group are punch posts, and Chicago style. During the male post insertion process, the male portion of the post is inserted and automatically pressed or threaded into the female post, depending on the style used. Initially the fan deck is removed from the indexing system by an operator, ensuring the female post does not fall out, and is flipped 180° so that the top of the fan deck is facing upwards. The fan deck is then placed into a 90° v-bracket to ensure the fan deck is in the correct position for the male post insertion operation. Similar to the previous process, the location of the automatic tool head is adjustable by a precision slide table and an adjustable stand. For the male post insertion process, a Weber SEB-10 auto feed screw driver is fed by a Weber ZEB-240C vibratory bowl feeder. Following the pressing or screwing of the mating female and male posts, the completed fan deck is removed by the operator and placed into waiting packaging or onto the packaging table. Figure 23 shows the male post insertion process. The black arrows represent the up/down movement of the Weber SEB-10 as the process is carried out, and the red arrow shows the presented male post being inserted into the fan deck.

Figure 23: Male post insertion process

Based on the wide range of products Duha Group produces, versatility in the post insertion process was an important aspect of the design. The aforementioned process for metal screws will also function for the plastic posting media Duha currently uses, with only slight tooling changes required when switching from metal to plastic. Streamline Systems has built in additional versatility by utilizing high precision cross slide tables that are able to support the load applied by the automatic screw feeder and driver. In an effort to reduce set up time and configuration of the post insertion machines, it is recommended that the specific locations of each fan deck hole be permanently marked on the precision cross slide tables to facilitate in tool changes.

2.5 FAN DECK POSITIONING SYSTEM

Electronic actuators were selected to transfer the fan deck into and out of the various processes involved in the fan deck completion system. Two electronic actuators are required for each die cutter, one to load the fan deck and one to unload the fan deck. An additional actuator is utilized to position the fan deck during the female post insertion process. These actuators were chosen primarily to decrease the number of operators required in the fan deck completion cell. Using actuators also takes operators out of harm's way, and increases the safety of the fan deck completion process. Lastly, the actuators increase the throughput of the system, because automated motion is more efficient than manual motion. The motion of the actuators can be coordinated with the rest of the system through integration into the PLC.

The electronic actuators have adjustable actuation distance as well as speed. For the fan deck completion system, adjustable force control is also required. In order to achieve the adjustable force control, a variable force actuator head was designed, and can be seen in Figure 17. This variable force is required for the die cutting process. As the die comes down to cut the fan deck, the force will push the fan deck out of the die cutter. The variable force actuator head will keep the fan deck in the die cutter ensuring all layers of the fan deck are cut to the desired shape. The variable force actuator head threads directly onto the actuator shaft and is securely positioned with a nut.

Each actuator has been fitted with an anti-wear sweep. The anti-wear sweep reduces the friction between the indexing system belt and the actuator head. This guarantees no layers of the fan deck can pass underneath the actuator head, while in motion. The anti-wear sweeps can be seen in Figure 24. Arrows in the figure show the felt sweeps which are connected to the actuator heads using an adhesive backing, commonly provided on felt stripping.

Figure 24: Anti wear felt sweeps

2.6 CELL POWER REQUIREMENTS

It is important that the overall power requirements for the new fan deck completion system operate using power already available in the cell. The power available in the fan deck completion cell is shown in TABLE II.

TABLE II: AVAILABLE POWER IN THE FAN DECK COMPLETION CELL

Available Power	
Electrical	
Power	**Units**
120	Volts
240	Volts
600	Volts
Compressed Air	
Pressure	**Units**
100 ± 10	PSI

Power requirements of the components used in our design are listed in TABLE III.

TABLE III: COMPONENT POWER REQUIREMENTS

Component	Manufacturer	Power	Requirement
Linear Indexer	Dorner	1/2 HP	230V 3-Phase
Actuators	Festo		
Die Cutter	Hickok	1 HP	115V 1-Phase
		1 HP	230V 3-Phase
Male Post Insertion	Weber	1 HP	110V 1-Phase
		12 CFM	85PSI
Female Post Insertion	Weber	1 HP	110V 1-Phase
		12 CFM	85PSI

With the exception of the compressed air supply, the cell is currently capable of powering all components of the design.

With respect to the compressed air supply, it is necessary to install a pressure regulator as to limit the compressed air supply to 85PSI. It should be noted that no consideration was given as to the overall Duha Groups electrical usage in this part of the facility. This is because it was indicated to Streamline Systems that there would be a facility electrical expansion sometime in the future, to cover any facility power shortages.

2.7 SYSTEM ASSEMBLY AND VERSATILITY

Duha Group provides a wide range of fan deck sizes and geometries to their customers. To ensure the varying fan decks could be produced using the proposed fan deck completion system, versatility was a critical and important aspect of the design. Duha Group has made it clear to Streamline Systems that the system not only needed to accept different fan deck sizes, but the components comprising the system need to provide mobility.

Every raised component in the system, other than the die cutters, is supported by Dorner aluminium support stands. These support stands can be purchased in width ranges of 12 – 48 inches, heights of 7 - 99 inches, and depending on the specified height can provide an additional height range of ± 9 inches. [5] This adjustable height range means that operators can modify the working heights of the entire system to an ergonomic and comfortable level. A standard Dorner aluminium support stand can be seen in Figure 25. Arrows outline the adjustability of the support legs.

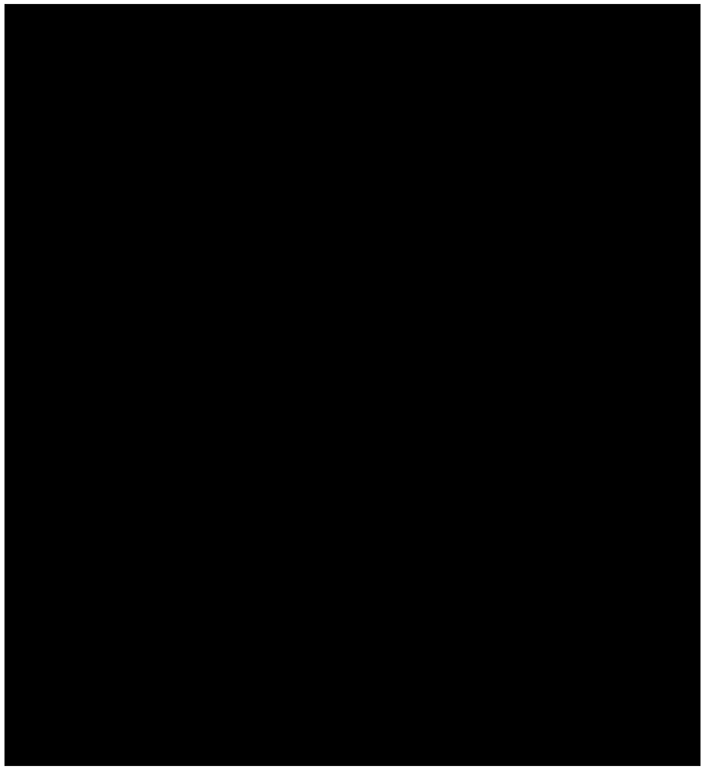

Figure 25: Dorner fully adjustable aluminum support stand

Since the aluminum legs are lightweight, the different system components can easily be lifted by two operators and moved to provide access to the system during maintenance, or if the die cutters need to be taken out of the fan deck completion system line. Being able to automate the die cutters in the fan deck completion system, and independently out of line by an operator is a benefit to Duha Group, as no additional die cutting systems will need to be purchased.

This ease of movement can allow the system components to be moved in different locations along the indexer depending on how the system needs to be set up for a particular batch of fan decks. Additional components can also be added in line along the indexer as Duha Group sees fit in the future.

Although the design and setup of a PLC is beyond the scope of this project, we wanted to ensure Duha Group was provided with an indexer and system actuators that are fully programmable through the use of a PLC system. The indexer and the actuators can provide varying acceleration, deceleration, and speeds (2.3 – 23 ft/min) to allow Duha Group to optimize performance and maximize fan deck throughput.

2.8 OVERALL COST ANALYSIS

In order to justify the implementation of the proposed fan deck completion system, a cost analysis was performed. Streamline Systems was given a project budget in the range of $50,000.00 to $60,000.00 CAD. We began designing a fan deck completion system to meet all of Duha Group's needs, and it was determined all of the needs could not be met within the proposed budget. Streamline Systems has therefore designed a fan deck completion system which meets all of our client's needs, but comes in over budget. A return on investment analysis was performed in order to justify the implementation of our design.

The following assumptions and estimates were made based on consultations with Duha Group:

- Fan deck media i.e. the paper and post material were excluded from this analysis.
- United States Dollars exchange rate of 1.044 CAD was used for all US equipment purchases.
- Annual fan deck throughput of 1,000,000 fan decks.
- Operator labour cost of $20 per hour.

For the purpose of our analysis, no consideration was given to the fan deck raw material costs, as this stays consistent whether our design is implemented or not. The detailed cost analysis of the fan deck completion cell in its current state can be seen in TABLE IV.

TABLE IV: CURRENT FAN DECK COMPLETION CELL COST ANALYSIS

Current Cell			
Description	**Quantity**	**Units**	**OVERALL COST**
Current Annual Throughput	1,000,000	FD/YR.	
Hourly Throughput	200	FD/HR	
Annual Cell Operating Hours	5,000	Hours	
Currently the cell utilizes 12 workers to achieve fan deck output of 200 FD/HR			
Total man hours per annum	60,000	Man Hours	
Worker hourly wage	20	$/HR	
Total Cost of Production Labour			$ 1,200,000
Setup			
Assumed that for every second 10 hour shift there would be a fan deck change	200	Changes/Year	
Duration of tooling change	6	Man Hours	
Total Cost of tooling change			$ 24,000
Annual Maintenance Cost			$ 1,000
	TOTAL COST		$ 1,225,000.00
	Annual Operating Cost		$ 1,225,000.00

From the cost analysis of the existing system it can be seen that the annual operating cost is $1,225,000.00, of which $1,200,000.00 is labour. This current cell should be compared to the proposed new cell cost analysis shown in TABLE V. Streamline Systems selected suppliers for the required components in order to complete a thorough and accurate cost analysis. Duha Group can interchange these components with those of equivalent specifications.

TABLE V: PROPOSED FINAL CELL DESIGN COST ANALYSIS

Proposed Cell Design					
Description	**Quantity**	**Units**	**Rate**		
Current Annual Throughput	1,000,000	FD/Year			
Hourly Throughput	350	FD/HR			
Annual Cell Operating Hours	2,857	Hours			
USD to CAD Currency Exchange	**1.044**	**USD**			
Worker hourly wage 20$/Hr					
	Quantity	**Units**	**Rate**	**Units**	**Subtotal**
Labour (Total 4 Operators)					
Loading	2,857	HOURS	20	$/HR	$ 57,143
Inspection	2,857	HOURS	20	$/HR	$ 57,143
Packaging - 2 Employees	5,714	HOURS	20	$/HR	$ 114,286
Tool Changes - 2X CURRENT	2400	HR/YR	20	$/HR	$ 48,000
Material & Equipment					
Dorner 3200 Series Indexing Conveyor	1	EA	$ 9,919	CAD	$ 9,918.70
Hickock Duplex Round Corner Die Cutter - Guide Modification	2	EA	$ 1,000	CAD	$ 2,000.00
Weber LCI-10 Post Insertion System w/ Weber Z-150C Step Feeder	1	EA	$ 1,000	USD	$ 1,044
Weber SEB-10 Auto Feed Screw Driver w/ Weber ZEB-240C Vibratory Bowl Feeder	1	EA	$ 41,500	USD	$ 43,326
Plastic Tooling Change	2	EA	$5,000.00	USD	$ 10,440
12" Dorner Adjustable Height Stand with Fixed Foot Pads	12	EA	$ 210	USD	$ 2,631
30" Dorner Adjustable Height Stand with Fixed Foot Pads	6	EA	$ 315	CAD	$ 1,890.00
Loading Actuator Head (includes Spring Loaded)	3	EA	$ 500	CAD	$ 1,500.00
Unloading Actuator Head	2	EA	$ 500	CAD	$ 1,000.00
900 mm Festo Actuator	4	EA	$ 5,218		$ 20,871
300 mm Festo Actuator	1	EA	$ 4,530		$ 4,530
Actuator Drive Motor	5	EA	$ 1,936		$ 9,678
900 mm Festo Actuator Support	4	EA	$ 812		$ 3,248
300 mm Festo Actuator Support	1	EA	$ 337		$ 337

	Quantity	Units	Rate	Units	Subtotal
Velmex X-Y Table	2	EA	$ 600	USD	$ 1,253
16" x 16" Support Table	1	EA	$ 500	CAD	$ 500.00
48" x 30" Support Table	2	EA	$ 500	CAD	$ 1,000.00
24" x 30" Support Table	1	EA	$ 500	CAD	$ 500.00
90° V-Bracket	1	EA	$ 500	CAD	$ 500.00
48" x 30" - 1/2" Rubber Mat	1	EA	$ 115	CAD	$ 115.00
Anti-Fatigue Mat	2	EA	$ 203	CAD	$ 406.00
1/4" - 20 UNC - 3.5" Hex Bolt	66	EA	$ 0.35	CAD	$ 23
1/4" - 20 UNC - 3" Hex Bolt	42	EA	$ 0.26	CAD	$ 11
1/4" Lock Washer	120	EA	$ 0.28	CAD	$ 33
1/4" Steel Washer	120	EA	$ 1.25	CAD	$ 150
1/4" - 20 UNC Hex Nuts	120	EA	$ 0.07	CAD	$ 8
Electrical and Controls					
Electrical Wiring Allowance	1	LOT	$ 5,000	CAD	$ 5,000
Controls Allowance	1	LOT	$ 15,000	CAD	$ 15,000
Annual Maintenance Cost ($500 per driver machine)	2	EA	$ 500	CAD	$ 1,000
Annual Maintenance Cost @ 2% of Overall Equipment Cost	2	%	$ 150,000	CAD	$ 3,000
Contingency	1	LOT	4,500	CAD	4,500
		TOTAL LABOUR COST			$ 276,571
		TOTAL MATERIAL AND EQUIPMENT COST			$ 145,413
		TOTAL PROJECT COST			$ 421,985
		Annual Operating Cost			$ 280,571

Based on the cost analysis shown in TABLE IV, and TABLE V, it can be seen that the annual operating cost of the current system is $1,225,000.00. The annual operating cost of our proposed fan deck completion system is $280,571. Two major contributors to the reduction in annual operating cost are:

- Decreasing of the number of operators in the cell from 12 to 4.
- Increasing cell production from 200 to 350 fan decks per hour.

If the throughput was increased to the maximum capacity of the fan deck completion system, it was determined a maximum of 400 fan decks per hour could be achieved. This represents a 60% increase in throughput and an operating cost of $302,000. It should be noted that in order to achieve the increased output, an additional operator would need to be added so that there are two operators loading the fan decks into the completion system. The utilization of five operators still represents a 58% labour reduction, achieving Duha Groups requirement of removing operators from the cell.

Based on this analysis, it was determined that for a fan deck throughput of 350 fan decks per hour, the first year cost of operation would be $421,413.00. This includes the cost of labour, as well as the purchase of new equipment required for the implementation of the fan deck completion system. It should be noted that there has been no allowance carried for the installation of the new equipment, related down time, or operator training time in this cost analysis.

Based on the cost analysis in TABLE V it can be seen that the payback period associated with the implementation of the proposed fan deck completion system is less than one year. If Duha Group implements this fan deck completion system, Streamline Systems has determined that they will see a return on investment of 452 % in the first year of operation.

3 RECOMMENDATIONS

Streamline Systems has developed a number of recommendations for Duha Group to optimize performance moving forward in the fan deck finishing cell, and more specifically regarding the fan deck completion system. These recommendations relate to safety, system timing, system controls, operational maintenance, ergonomics, failure modes and effects, opportunities for improvement and future growth.

3.1 SAFETY RECOMMENDATIONS

The safety of the operators within the fan deck completion cell is an important aspect of our final design, as it is one of the design requirements. In comparison to Duha Group's current means of assembling fan decks, our design offers the following safety improvements and benefits:

- The automated die cutter loading and unloading eliminates the needs for operators to handle the fan decks near the pathway of the dies.
- Automating post insertion and screw fastening eliminates the task of hand insertion and fastening, decreasing the likelihood of a repetitive stress injury.
- Having the linear indexer move the fan decks between processes eliminates the need for an operator to move large amounts of fan decks intermittently throughout the process.

Streamline Systems is aware that new hazards will accompany new manufacturing processes, and identifying these hazards will be fundamental to the safe implementation of the fan deck completion system. As such, it should be noted that we recommend that large emergency stop buttons be placed at each operator location as well as a foot operated photoelectric kill switch. Upon assembly, any unidentified hazards of our design can be identified. In order to mitigate these hazards, Streamline Systems recommends that additions and or modifications be made to the design in the form of guards, and changes to component orientation. The positioning of additional guards will depend on where Duha Group decides to station the cell operators, as well as our designs' proximity to other machinery and walkways within the manufacturing plant. The indexing system ensures that our design has the versatility required to accommodate any changes deemed necessary for the safe operation of the fan deck completion cell.

3.2 TIMING RECOMMENDATIONS

The scope of this report does include exact timing and programming of a PLC system. Estimated timing and sequencing are provided in this section.

In order to properly estimate the timing of our fan deck completion system design, the following parameters must first be specified: fan deck size, average indexing speed, and average actuator speed. A fan deck of nine inches in length, a two inch width and a two and a half inch height, was chosen. The average indexing speed was chosen to be 4.55 inches per second, and the average actuator speed was chosen to be 9 inches per second. These parameters were chosen because they yield the desired fan deck throughput of 350 fan decks per hour. These chosen parameters are summarized in TABLE VI.

TABLE VI: FAN DECK PARAMETERS USED FOR ESTIMATING TIMING AND SEQUENCING

Fan Deck Parameters	
Fan Deck Length (in)	9
Fan Deck Width (in)	2
Fan Deck Height (in)	2.5
Actuator Average Speed (in/s)	9
Indexing Average Speed (in/s)	4.55

The timing recommendations to follow are based on these specified parameters and so any change in the fan deck size, actuator speed or indexing speed would change the timing and sequencing. The method used to determine the timing is outlined in 1.

The fan deck completion system can be broken down into the following stages: loading, die cutter 1, die cutter 2, female post insertion, and male post insertion. Each fan deck goes through the stages in the order listed. In the following table, each stage is further broken down into processes and a time is assigned to each. The longest stage time dictates the interval between indexing of the conveyor system. Not all stages require the entire interval, and so a wait time has been included in the analysis to account for the difference. The stage, process, and timing breakdown for a throughput of 350 fan decks per hour can be seen in TABLE VII.

TABLE VII: STAGE, PROCESS AND TIMING BREAKDOWN FOR THE FAN DECK COMPLETION SYSTEM

Timing Analysis			
Stage	**Process**	**Distance (in)**	**Time (s)**
Loading	Initial Fan Deck Loading	N/A	5.00
	Movement of Indexer	14.13	3.11
	FAN DECK HANDLING TIME		**8.11**
	Wait Time	N/A	2.18
	TOTAL STAGE TIME		**10.28**
Die Cutter 1	Die Cutter Loading	26	2.89
	Die Cutting	N/A	1.40
	Die Cut Unloading	26	2.89
	Movement of Indexer	14.13	3.11
	STAGE FAN DECK HANDLING TIME		**10.28**
	Wait Time	N/A	0.00
	TOTAL STAGE TIME		**10.28**
Die Cutter 2	Die Cutter Loading	26	2.89
	Die Cutting	N/A	1.40
	Die Cut Unloading	26	2.89
	Movement of Indexer	14.13	3.11
	STAGE FAN DECK HANDLING TIME		**10.28**
	Wait Time	N/A	0.00
	TOTAL STAGE TIME		**10.28**
Female Post Insertion	Female Post Insertion Positioning	9.639	1.07
	Female Post Insertion	N/A	2.00
	Movement of Indexer	14.13	3.11
	STAGE FAN DECK HANDLING TIME		**6.18**
	Wait Time	N/A	4.11
	TOTAL STAGE TIME		**10.28**
Male Post Insertion	Male Post Insertion Positioning	N/A	5.00
	Male Post Insertion	N/A	2.00
	Position for Packaging	N/A	2
	STAGE FAN DECK HANDLING TIME		**9.00**
	Wait Time	N/A	1.28
	TOTAL STAGE TIME		**10.28**
	THROUGHPUT (FAN DECKS / HOUR)		**350**

At one time there can be up to 10 fan decks moving through the completion system. As such, there are many processes happening at any given time. Figure 26 outlines the timing of each process, as it would happen, if there were to be fan decks at each stage simultaneously. The successful implementation of our design includes integrating all components into a PLC system. The timing chart for simultaneous fan deck processing is included as a guide when setting up the PLC system. A colour coded legend for Figure 26 is shown in Figure 27.

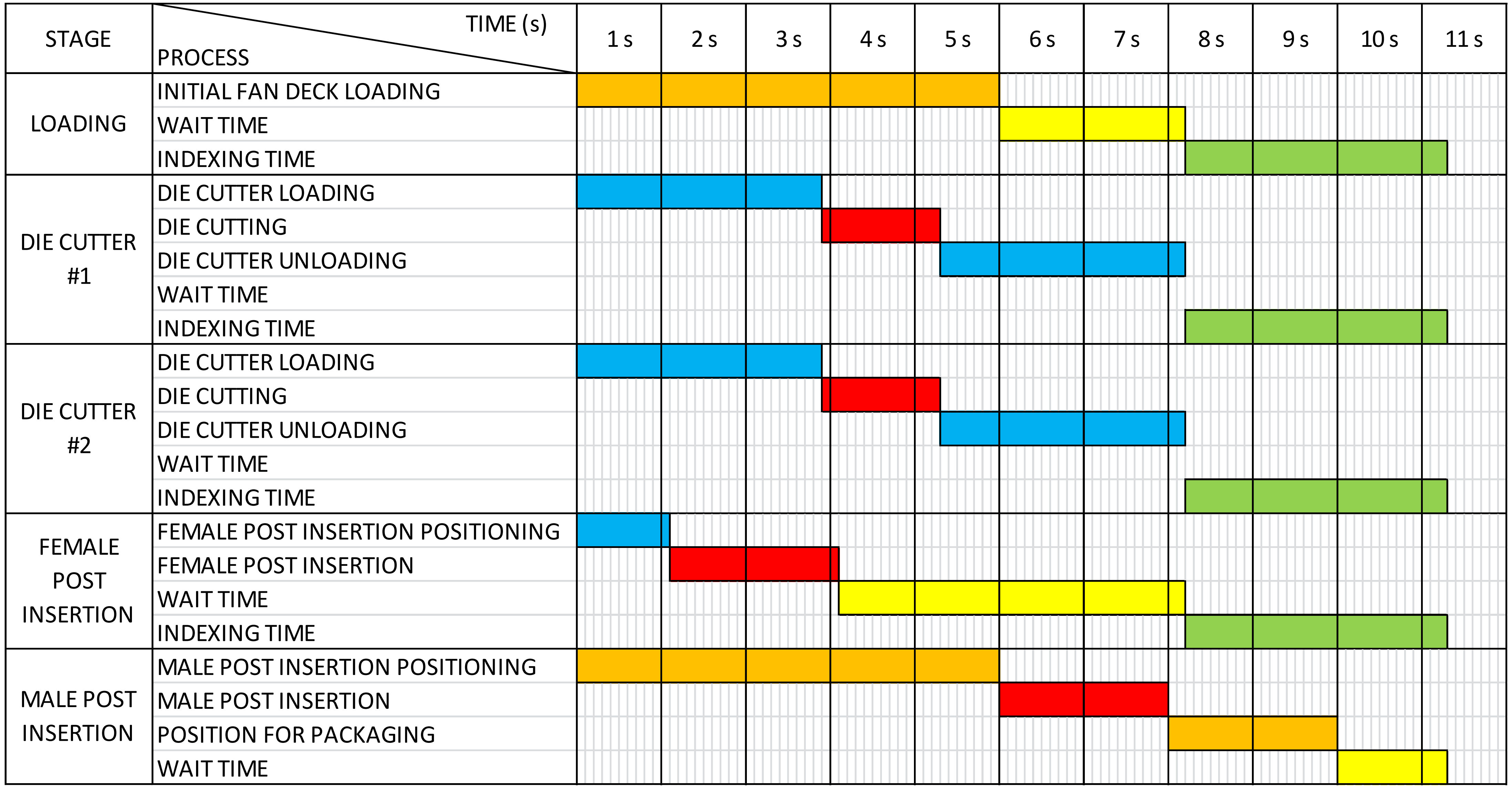

Figure 26: Timing chart for simultaneous fan deck processing

LEGEND	
OPERATOR HANDLING	
WAITING	
INDEXING	
ACTUATOR MOTION	
DIE CUTTING/ POST INSERTION	

Figure 27: Simultaneous fan deck processing legend

Upon implementation of our design, adjustments will need to be made to the speed and acceleration of both the indexing system and electronic actuators, in order to achieve the fastest and most accurate processing of the fan decks. Streamline Systems recommends any indexing system or electronic actuators incorporated into the design must have adjustable speed and acceleration capabilities. This ensures that a functional combination of controls can be determined through testing.

3.3 CONTROL RECOMMENDATIONS

The control specifications are beyond the scope of this report and as such are not included. However, our team at Streamline Systems has designed the fan deck completion process so that all of the electrical equipment specified is currently able to be tied together utilizing a 24V direct current PLC. This main PLC for the overall cell has not been specified however, the two Weber automated drivers have a standalone PLC system that integrates to the main PLC with a “handshake”. What this means is that there will be a hand off by way of detection sensors between the main PLC and the automated Driver PLC for the post insertion process. It is important to note that it is possible to operate the post insertion process without utilizing this “handshake”. However, during consultation with Weber it was determined that utilizing two separate PLC systems offers the greatest amount of control flexibility and simplicity

3.4 MAINTENANCE RECOMMENDATIONS

Due to the nature of the designed system, there will be some periodic and daily maintenance required. Depending on the components selected by Duha Group for the fan deck completion system, maintenance cycles will vary. We recommend all maintenance cycles specified by specific component manufacturers be followed.

The Weber mechanical screw driving system will require additional maintenance beyond daily inspection. Based on conversations with Weber, it has been determined that the driver heads will need to be replaced every year, and the stroking cylinders every third year. The cost to rebuild the driver heads has been assessed at $500 USD per head, while the cost to rebuild the stroking cylinders is $1,500 USD per cylinder. Each drive head contains one cylinder.

3.1 ERGONOMIC RECOMMENDATIONS

When designing new machinery and manufacturing assembly lines, it is important to consider operator ergonomics. The ergonomics must allow easy and seamless operation as well as integration into the existing plant and training of the current employees. In a factory application, ergonomics serve to adjust all elements of the operating environment to allow the employees to work with minimal discomfort. If ergonomics are not considered, productivity will decrease and the rate of workplace injuries will increase. In Duha Groups work environment this is important due to the physical requirements of the loading and unloading of the indexing system, as well as the positioning of the fan deck in the male post insertion process. As such, one needs to consider the various types of operators which range in age, height, health, and physical strength. [6]

Some key things to consider include surfaces that employees will touch, product handling weight, ideal input and output height, and reduction of unneeded strain when standing. For the surfaces that employees will be touching, and for components chosen for integration, it is important that the machinery and products contain no sharp edges or corners.

The working height of the surfaces in our fan deck completion system design are critical, as they affect the points at which an operator must bend when performing loading and unloading of the fan decks into and out of the completion system. These heights affect the bending of the back, elbows, and wrists.

In order to determine the most ergonomically suitable height, it is important to know the average operator height. We have assumed an average operator height of 5’8”, which translates to an average elbow height of 46”. At all operator stations within our design, all working platforms are flat surfaces. For an elbow height of 46”, the working platform would need to be less than 44” high in order to be comfortable. [6] To improve cell ergonomics, our team recommends fan deck cell managers communicate with operators regarding their comfort and fatigue in order to mitigate any ergonomic issues that may arise.

Knowing that the operators will be standing in the same position for extended periods of time, it is important to consider fatigue. To alleviate fatigue, our group recommends the use of anti-fatigue mats, which are low in cost, at all operator stations. These mats reduce fatigue by minimizing the number of pressure points in the operator's feet. This leads to a reduction in the stress experienced in joints, specifically the knees and spine. [6] Figure 28 shows a typical operator anti fatigue mat in a manufacturing facility.

Figure 28: Anti-fatigue mat [7]

In addition to reducing fatigue, the edges are tapered to prevent tripping injuries that may occur with certain mats that tend to have edges that curl up over time. By using these mats, operator fatigue will reduce and as a result, reduced injuries and increased productivity can be achieved. [7]

3.2 FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

The purpose of an FMEA is to identify ways that the product or process can fail, and eliminate or reduce the risk of failure. Specifically, an FMEA estimates the risk associated with causes of failure, and prioritizes the actions that should be taken to reduce risks. [8] Our design of the fan deck completion system consists of many components and processes, each with areas of potential failure. With respect to the commercially manufactured components of our design, failure is mitigated by following the manufacturers' maintenance schedule. In order to mitigate failures associated with the components and processes designed by Streamline Systems, our team has performed an FMEA on said components and processes. This FMEA is contained in the following section.

The methodology behind the FMEA can be found in 0. The first step of the process involves identifying the processes and components to be analyzed. TABLE VIII summarizes the processes and components that our team has designed for the fan deck completion system.

TABLE VIII: PROCESSES AND COMPONENTS DESIGNED BY STREAMLINE SYSTEMS FOR THE FAN DECK COMPLETION CELL

Process #	Process / Component	Description
1	Fan deck loading onto indexer	Operator hand loads the fan deck onto the die cutter
2	Fan deck loaded into die cutter	Loading actuator pushes and applies force to fan deck for the die cutting process
3	Fan deck unloaded from die cutter	Both loading and unloading actuators position fan deck back on conveyor
4	Fan deck positioned for post insertion	Female post actuator positions fan deck for female post insertion
5	Fan deck unloaded from indexer	Operator manually unloads fan deck from actuator into position for male post insertion
6	Variable force actuator head	Actuator head on the loading actuator
7	Rear actuator head	Actuator head on the unloading actuator
8	Die cutter guides	Angled guides that aid in positioning the fan deck in the die cutter
9	V-bracket	Right angle bracket allows for efficient positioning of the fan deck for male post insertion

For each process and component, potential failure modes and their respective effects were identified. The list of these failure modes and effects can be seen in TABLE IX. Refer to the corresponding process number for process and component descriptions.

TABLE IX: POTENTIAL FAILURE MODES AND ASSOCIATED EFFECTS

Process #	Potential Failure Mode	Potential Effect	Effect #
1	Operator loads fan decks the wrong way up	Post is inserted in the wrong direction	1
	Operator loads fan decks with the wrong edge against the guide	Fan deck cannot be processed further	2
2	Fan deck not properly positioned for die cutting	Fan deck not properly die cut	3
	Layers of the fan deck become misaligned	Fan deck not properly die cut	4
3	Fan deck not properly positioned on the conveyor	Fan deck cannot be processes further	5
	Fan deck layers become misaligned	Female post cannot be properly installed	6
4	Fan deck not properly positioned	Female post cannot be properly installed	7
5	Fan deck disassembles during the unloading	Operator unable to keep up with indexing time	8
	Female post falls out of fan deck	operator unable to keep up with indexing time	9
6	Spring fails	Fan deck not properly die cut	10
	Guide bolt comes loose	Fan deck not properly die cut	11
	Felt strip delaminates from bottom of actuator head	Fan deck not properly die cut	12
	Actuator head comes loose from actuator	Fan deck not properly die cut	13
7	Felt strip delaminates from bottom of actuator	Actuator head damages conveyor belt	14
	Actuator head comes loose from actuator	Fan deck not properly positioned on conveyor	15
8	Guide becomes misaligned	Fan deck not properly die cut	16
9	Bracket becomes misaligned	Male post cannot be properly installed	17

With the potential effects of each failure mode identified, a severity ranking must now be assigned to each. Following this step, potential causes are identified for each failure mode, and a frequency of failure is assigned to each potential cause. These values and potential causes are displayed in TABLE X. Refer to effect numbers for effect descriptions and associated failure modes.

TABLE X: SEVERITY RATINGS, POTENTIAL CAUSES, AND FREQUENCY RATINGS OF THE FAILURE MODES

Effect #	Severity	Potential Causes	Frequency
1	5	Operator uneducated on proper loading orientation, human error	5
2	5	Operator uneducated on proper loading orientation, human error	5
3	5	Inappropriate actuation speed and/or velocity	1
4	3	Gap between conveyor belt and die cutter is too large, gap between actuator head and belt is too large	1
5	2	Inappropriate actuation speed and/or velocity	1
6	2	Gap between conveyor belt and die cutter is too large, gap between actuator head and belt is too large	1
7	2	Inappropriate actuation speed and/or velocity	1
8	3	Human error	5
9	3	Human error	6
10	5	Fatigue	3
11	5	Vibration	3
12	5	Adhesive failure	2
13	5	Vibration	3
14	6	Adhesive failure	2
15	2	Vibration	3
16	5	Unintentionally knocked, not properly fastened in place	4
17	2	Unintentionally knocked, not properly fastened in place	4

For each of these failure modes and effects, there may be current controls in place to help mitigate the failure effects. For each effect the current controls must be identified. Given the current controls, a detection rating is given to represent the likelihood of detection. Once this is accomplished, the next step is to calculate the risk priority number, which is simply done by multiplying the severity rating, frequency rating and detection rating together. With the risk priority number known, mitigation recommendations can be given. These steps of the FMEA are summarized in TABLE XI. Refer to effect numbers for effect descriptions and associated failure modes.

TABLE XI: CURRENT CONTROLS, DETECTION RATING, RISK PRIORITY NUMBER AND ACTIONS FOR EACH FAILURE MODE

Effect #	Current Controls	Detection	RPN	Actions
1	Station emergency stop button	2	50	Monitor
2	Station emergency stop button	2	50	Monitor
3	Station emergency stop button	2	10	Monitor
4	Station emergency stop button	2	6	Monitor
5	Station emergency stop button	2	4	Monitor
6	Station emergency stop button	2	4	Monitor
7	Station emergency stop button	2	4	Monitor
8	Station emergency stop button	2	30	Monitor
9	Station emergency stop button	2	36	Monitor
10	Routine maintenance, emergency stop button	2	30	Monitor
11	Routine maintenance, emergency stop button	2	30	Monitor
12	Routine maintenance, emergency stop button	2	20	Monitor
13	Routine maintenance, emergency stop button	2	30	Monitor
14	Routine maintenance, emergency stop button	2	24	Monitor
15	Routine maintenance, emergency stop button	2	12	Monitor
16	Emergency stop button	2	40	Monitor
17	Emergency stop button	2	16	Monitor

Mitigating failure is important to the successful implementation of our design. Potential risks have been identified and scored in order to determine what actions should be taken. The current mitigation strategies include routine maintenance cycles and emergency stop buttons. The results of the FMEA indicate that potential system failure modes should be monitored. Taking this into account, our team at Streamline Systems recommends the addition of a fourth operator to the fan deck completion cell. This operator’s job will be to act as a floating inspector. In addition, all other cell operators should be educated in quality control, and should be made aware of potential cell failures.

3.3 IMPROVEMENT/FUTURE RECOMMENDATIONS

Given Duha Groups current product line, Streamline Systems feels that we have developed a process that provides the best solution to our client's problem. Details of the concept selection process can be found in Appendix A. Streamline Systems identified many areas for potential further improvement in the fan deck completion cell. Given the project time constraints, our team was not able to fully explore all of these identified areas. These improvement recommendations are related to: auto-cutter throughput, fan deck packaging, change in post installation process, and industry communication. These improvement recommendations are discussed below.

Our design is preceded by the auto-cutter, which cuts the layers of fan decks to the desired width. This step currently operates at a maximum output of 200 fan decks per hour. With the fan deck completion system operating at 350 fan decks per hour, the auto-cutter becomes a bottleneck in the fan deck manufacturing process. Because the auto-cutter throughput rate cannot keep up with our design, a sufficient number of fan decks will need to be stock piled (in an area called the auto cut buffer) at the inlet to the indexing system. In order to eliminate the need for the stock piled fan decks, the auto-cutter throughput will need to be increased or the operation time of the auto-cutter will have to be increased in proportion to the increased throughput our design provides. Figure 29 shows the flow of the fan deck from the auto-cutter, into our design area and out to the packaging area. The auto cut buffer is the area reserved for stock piling the fan decks in preparation for the fan deck completion.

[redacted]

Figure 29: Fan deck flow from the Auto Cutter through our design area to the packaging area

After male post insertion, the fan deck must be packaged and shipped to the customer. Currently Duha Group places separate box orders for each fan deck order they receive. This is necessary due to the varying fan deck sizes Duha Group offers its customers. The fan decks are manually packaged in the boxes; this process is time consuming and requires packaging personnel. One of the needs of this project was to reduce the number of operators required in the fan deck completion cell. Successful implementation of our design would reduce the operators in the cell from 12 to four. When packaging, additional operators are required. In order to further reduce the needed personnel in the fan deck completion cell, Streamline Systems recommends the procurement of a custom box making machine, as well as an automated packaging machine.

Duha Group currently has a product line that offers a variety of post lengths and sizes. This is appealing to customers, however it requires Duha Group to place a large amount of post orders, and carry inventory. Duha Group has expressed an interest in decreasing the amount of on hand posting inventory required. A competitor of Duha Group uses a cut to length posting media, where the posting material comes in a spool. This is an option that could be further explored if Duha Group approved the idea of a single posting material and fastening style.

Finally, much of the information contained in this report was obtained through communication with manufacturing companies and suppliers. In order to take our fan deck completion design to the fully operational stage, we recommend continued communication with industry contacts.

4 CONCLUSION

Streamline Systems was tasked with redesigning the fan deck completion process at Duha Groups' Winnipeg manufacturing facility. A fan deck is a paint marketing product consisting of a number of paint samples, stacked and bound with a post. The fan deck completion process involves die cutting the fan decks into client specified shapes, installing and fastening the post, as well as transporting the fan decks to and from each process.

Streamline Systems was presented with the following problem; Duha Group wants a way to make the fan deck completion process faster and less labour intensive. Specifically, Duha Group desires an increase in cell throughput from 200 to 350 fan decks per hour, and a decrease in the number of cell operators from 12 to six or fewer. Our teams' objective was to redesign the fan deck completion process in Duha Group's Winnipeg manufacturing facility, so that a throughput of 350 fan decks per hour could be achieved with no more than six operators.

Many conceptual designs were considered before a final design was selected. The final design utilizes the die cutters currently owned by Duha Group. For post installation, components manufactured by Weber Screw Driving Systems Inc. were selected for both the female post insertion and the male post insertion and fastening. Process to process transportation of the fan deck is accomplished by an indexing system. Positioning of the fan deck in the die cutting, and female post insertion process will be done by electronic actuators.

The purpose of this design was to increase the throughput of the fan deck completion cell from 200 to 350 fan decks per hour, while decreasing the number of cell operators to six or fewer. The presented design requires four cell operators and can achieve a throughput of 350 fan decks per hour, with capabilities of up to 400 fan decks per hour. This exceeds the throughput requirements while allowing Duha Group to reutilize up to eight employees in other areas of the facility.

Lastly it was required that the design be able to accommodate all fan deck and post sizes as well as post materials that Duha Group currently offers its' customers. Our design meets the required versatility. The die cutters are currently used by Duha Group to cut the full range of fan deck sizes, and so utilizing these die cutters ensures our design has the required versatility. With respect to the varying post lengths and materials, the manufacturer of the post installation equipment has ensured the equipment has the required versatility.

Along with these specifications, there were constraints that needed to be considered in the design. These constraints include: only utilizing electrical power and air pressure currently available in the cell, not exceeding the 30’ by 20’ size of the fan deck completion cell, and a budgetary constraint of no more than $60,000.00 `The power requirements of our system are within the cell capabilities, and the total size of our design fits within the dimension of the completion cell. The cost of our design comes in at $145,413.00. This investment into the purchase of the proposed fan deck completion system would allow for a 66% reduction in cell labour requirements and reutilization of up to eight operators. This would result in annual savings of $803,015.00 and a return on investment of 452% in the first year. The annual operation savings after the first year of production are $944,429.00. With Duha Groups` needs, constraints and specifications met, our group at Streamline Systems strongly recommends the implementation of our fan deck completion system design.

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APPENDIX A CONCEPT ANALYSIS AND SELECTION

1. CONCEPT ANALYSIS AND SELECTION

Through the processes discussed in the research and market data acquisition section, a series of ideas were generated for each stage of the fan deck finishing cell process. The next stage of the design process involves selecting 2 or 3 concepts to analyze further and finally to settle on 1 concept to fully design and analyze. Streamline Systems followed a systematic procedure in order to determine the concept that best meets the needs of our client. The following sections will outline the methodology and results of the process used to analyze and select our final design. The methodology begins with the documentation of the concept selection process, and is followed by concept screening, concept scoring, sensitivity analysis, a technical analysis and cost analysis.

1.1 DOCUMENTATION OF CONCEPT SELECTION PROCESS

As discussed previously, we divided the fan deck finishing cell operation into four processes. For each process, a team member was challenged to generate as many ideas as possible. These ideas were presented to the team in a team meeting, and are summarized in the following list:

- Process Flow
  - Passed Manually (Do nothing)
  - Rotational Conveyer System
  - Linear Indexer
- Transfer Method
  - Manually transferred by hand (do nothing)
  - Pick and place
  - Gravity
  - Actuator
- Fan deck posting

- Hand screw Chicago posts and mallet punch posts (do nothing)
- Automated post insertion, hand fasteners
- Hand insertion, automated driver

- Die cutting
    - Manually die cut using current machine (do nothing)
    - 2 die cutters
    - Laser cut
    - 4 corner die cutter

After all the ideas were presented, the team held a group brain storming session is order to integrate and generate as many additional ideas as possible. These additional ideas are shown in the list below:

- Process Flow
    - Rotational indexer
    - Linear conveyer system
- Transfer Method
    - Fluid actuator
    - Friction
    - Conveyer
    - Electronic actuator
- Fan deck posting
    - Hand screw Chicago posts and mallet punch posts (do nothing)
    - Automated post insertion, hand fasteners
    - Hand insertion, automated driver

- Die cutting
    - Manually die cut using current machine (do nothing)
    - 2 die cutters
    - Laser cut
    - 4 corner die cutter

This list of concepts was then pared down, starting with a screening process.

1.2 CONCEPT SCREENING

In order to select the concepts for further analysis, all concepts must first be screened. Concept screening is a benchmarking tool that allows concepts to be compared and scored with respect to one another. This screening process takes the most important design features and assigns 1 of 3 potential values. These values represent the relative score of one concept compared to another. One concept is selected as the reference, and is assigned a neutral value (in our case 0) in all the feature categories. The performance of each of the other concepts is compared to the reference. The other concepts are assigned a positive value (+) if they perform better than the reference, a negative value (-) if they perform worse than the reference or a neutral value (0) if they perform equally to the reference design. Once all the concepts have been assigned ratings for each design feature, the total rating is tallied. This is done by adding the number of positive and negative scores. The top two concepts in each process are the ones with the most positive scores, and the least negative scores. These are the concepts that are chosen for further analysis.

The design features used in the screening matrix were determined using the needs and target specifications identified by our client. This ensures that scope creep is mitigated and the screening process outputs the best concept with respect to our client's needs. The following design features are used as the evaluation criterion in the screening matrix: throughput, safety, operating costs, versatility, and the number of operators.

To simplify screening, each process of the fan deck finishing cell will be screened separately and the final two ideas for each process will be analyzed further. The same evaluation criterion was used for each finishing cell process.

1.2.1 PROCESS FLOW SCREENING

Each concept generated for the process flow was assigned a number. These assigned numbers can be seen In TABLE I.

TABLE I: PROCESS FLOW CONCEPTS

Concept #	Process Flow
1	Passed manually (do nothing)
2	Rotational conveyer system Linear conveyer system
3	Linear indexer
4	Rotational indexer
5	Linear conveyer system

Using the assigned numbers to represent the concepts, the process flow screening matrix was generated. The scores decided on required group consensus, the process flow screening matrix is shown in TABLE II.

TABLE II: PROCESS FLOW SCREENING MATRIX

	Process Flow Concept Variants				
Selection Criteria	**1**	**2**	**3**	**4**	**5**
Throughput	-	0	0	0	0
Safety	+	-	+	-	0
Operating Costs	-	-	0	-	0
Versatility	+	-	+	-	0
# of Operators	-	0	+	0	0
PLUSES	2	0	3	0	
SAMES	0	0	0	0	
MINUSES	3	3	0	3	
NET	-1	-3	3	-3	0
RANK	3	4	1	4	2
CONTINUE?	No	No	Yes	No	Yes

As can be seen in the process flow screening matrix, the linear indexer concept as well as the linear conveyer concept was chosen to undergo more thorough analysis.

1.2.2 TRANSFER METHOD SCREENING

Each concept generated for the transfer method was assigned a number. These assigned numbers can be seen in TABLE III.

TABLE III: TRANSFER METHOD CONCEPTS

Concept #	Transfer Methods
1	Manually transfer by hand (do nothing)
2	Pick and place
3	Fluid actuator
4	Friction
5	Gravity
6	Conveyer
7	Electronic actuator

Using the assigned numbers to represent the concepts, the transfer method screening matrix was generated. The scores decided on required group consensus, the transfer method screening matrix is shown in TABLE IV.

TABLE IV: TRANSFER METHOD SCREENING MATRIX

	Transfer Method Concept Variants						
Selection Criteria	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Throughput	0	-	+	+	-	0	0
Safety	-	-	-	-	-	0	0
Operating Costs	-	-	-	-	+	-	0
Versatility	+	-	0	-	-	-	0
# of Operators	-	0	0	0	0	0	0
PLUSES	1	0	1	1	1	0	0
SAMES	1	1	2	1	1	3	5
MINUSES	3	4	2	3	3	2	0
NET	-2	-4	-1	-2	-2	-2	0
RANK	3	4	2	3	3	3	1
CONTINUE?	No	No	Yes	No	No	No	Yes

As can be seen in the transfer method screening matrix, the fluid actuator concept as well as the electronic actuator concept was chosen to undergo more thorough analysis.

1.2.3 FAN DECK POSTING SCREENING

Each concept generated for the fan deck posting process was assigned a number. These assigned numbers can be seen in TABLE V.

TABLE V:FAN DECK POSTING CONCEPTS

Concept #	Fan Deck Posting
1	Hand screw Chicago posts and mallet punch posts (do nothing)
2	Automated post insertion hand fastening
3	Automated post insertion user operated driver
4	Fully automated posting
5	Hand insertion automated driver

Using the assigned numbers to represent the concepts, the fan deck posting screening matrix was generated. The scores decided on required group consensus, the fan deck posting screening matrix is shown in TABLE VI.

TABLE VI: FAN DECK POSTING SCREENING MATRIX

	Fan Deck Posting Concept Variants				
Selection Criteria	1	2	3	4	5
Throughput	-	-	+	+	0
Safety	-	-	+	+	0
Operating Costs	-	-	+	0	0
Versatility	+	+	+	-	0
# of Operators	-	-	0	+	0
PLUSES	1	1	4	3	0
SAMES	0	0	1	1	5
MINUSES	4	4	0	1	0
NET	-3	-3	4	2	0
RANK	4	4	1	2	3
CONTINUE?	No	No	Yes	Yes	No

As can be seen in the fan deck posting screening matrix, automated post insertion user operated driver concept as well as the fully automated posting concept was chosen to undergo more thorough analysis.

1.2.4 DIE CUT SCREENING

Each concept generated for the die cutting process was assigned a number. These assigned numbers can be seen in TABLE VII.

TABLE VII: DIE CUTTING CONCEPTS

Concept #	Die Cutting
1	Manually die cut using current machine (do nothing)
2	2 die cutters
3	1 die cutter and fan deck is flipped
4	Laser cut
5	CNC milling
6	New die cutter that will do all four corners

Using the assigned numbers to represent the concepts, the die cut screening matrix was generated. The scores decided on required group consensus, the die cut screening matrix is shown in TABLE VIII.

TABLE VIII: DIE CUTTING SCREENING MATRIX

	Die Cutting Concept Variants						
Selection Criteria	1	2	3	4	5	6	7
Throughput	-	0	-	-	-	-	0
Safety	-	0	0	0	-	0	0
Operating Costs	-	+	0	0	-	-	0
Versatility	+	+	-	-	+	+	0
# of Operators	-	0	0	0	0	0	0
PLUSES	1	2	0	0	1	1	0
SAMES	0	3	3	3	1	2	5
MINUSES	4	0	2	2	3	2	0
NET	-3	2	-2	-2	-2	-1	0
RANK	5	1	4	4	4	3	2
CONTINUE?	No	Yes	No	No	No	No	Yes

As can be seen in the die cut screening matrix, the 2 die cutters concept as well as the new die cutter that will do all four corners concept was chosen to undergo more thorough analysis.

1.2.5 CONCEPT SCREENING SUMMARY

Concept screening is a benchmarking tool used to compare concepts to each other. The comparison is based on the relative performance of a concept with respect to the key design features. The screening process for the fan deck finishing cell was divided into four stages; the process flow, transfer method, fan deck posting, and die cutting. Each stage was screening based on the same key design features, these features are; throughput, safety, operating costs, versatility, and number of operators required. Each screening matrix identified 2 concepts per process to be analyzed further, these concept are summarized in TABLE IX.

TABLE IX: CONCEPTS TO BE FURTHER ANALYZED

Finishing Cell Process	Concept 1	Concept 2
Process Flow	Linear indexer	Linear Conveyer System
Transfer method	Electronic actuator	Fluid actuator
Fan Deck Posting	Automated post insertion user operated driver	Fully automated posting
Die Cutting	2 die cutters	New die cutter that will do all four corners

1.3 CONCEPT SCORING

The goal of our team is to focus on one design that excels in customer satisfaction. In order to determine which design to focus on, a concept scoring matrix will be used.

The goal of a concept scoring matrix is to asses, with greater accuracy than the screening matrix, the worth of each design concept chosen for further analysis. Concept scoring matrices determine which of the concepts stand out with respect to the concepts ability to meet target customer specifications. The concept scoring matrix will provide our team with additional information in order to help decide which concepts should be considered for further development.

Our group has divided the fan deck finishing process into four processes. Thus far the number of concepts being considered has been narrowed down to two concepts for each of the four processes. Our team wants to know how each concept scores individually, and also how the entire fan deck finishing process will score when we combine the concepts to complete the entire process. In order to determine this, the concept scoring was broken down into two scoring stages; individual concept scoring, and full process concept scoring.

In order to construct the Individual Concept Scoring Matrix (ICSM), the evaluation criteria as well as its respective importance must be determined. Through interviews with our client, the needs of the project as well as their corresponding target specifications were determined. These needs will be used as the evaluation criterion, and the scores given to each concept will represent the degree to which the concept fulfils that need.

There are two ways in which the relative importance of each need can be determined. The first way is through interaction with the client, and the second is the use of an importance weighing matrix. Interaction with the client is very useful, however, underlying bias tend to skew the importance of each need. For that reason an importance weighting matrix will be used to properly score the conceptual designs.

In order to complete the importance weighting matrix, the following steps were followed: each evaluation criterion is assigned a letter and placed as both column and row header in a matrix. At the intersection of rows and columns, the two intersecting evaluation criterion are compared relative to one another. The letter representing the criterion of greater importance is placed in the intersecting cell. Once the entire criterion has been compared to each other, the number of times each letter has appeared in the matrix is tallied and divided by the total number of row and column intersections. The resulting fraction represents the weighting, or importance of the criterion to the final design. The evaluation criteria used in the importance weighing matrix are the same criteria used in the concept screening process. The importance weighing matrix for the individual concept scoring is shown in TABLE X.

TABLE X: IMPORTANCE WEIGHTING MATRIX FOR THE INDIVIDUAL CONCEPT SCORING

		Throughput	**Safety**	**Operating Costs**	**Versatility**	**# of Operators**
Criteria		**A**	**B**	**C**	**D**	**E**
A	Throughput		B	A	D	E
B	Safety			B	B	B
C	Operating Costs				C	C
D	Versatility					D
E	# of Operators					
	Total Hits	1	4	2	2	1
	Weightings	0.1	0.4	0.2	0.2	0.1

To complete the ICSM, each concept for each process is now assigned a rating from 1 – 5 that represents the concepts performance in each category. The rating is multiplied by the importance of the criteria, and this value is placed in the weighted score column. The weighted scores for each concept are added together to give the overall customer satisfaction rating, the higher the customer satisfaction the better the concept. An ICSM has been completed for the Process Flow concepts, the Transfer Method concepts, the Fan Deck posting concepts, and the Die Cutting concepts.

1.3.1 PROCESS FLOW CONCEPT SCORING

The two process flow concepts that had the highest screening scores were compared in the Process Flow ICSM. The Process Flow ICSM is shown in TABLE XI.

TABLE XI: PROCESS FLOW ICSM

		Process Flow Concepts			
		A		B	
		Linear Indexer		Linear Conveyer System	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score
Throughput	10%	4	0.4	5	0.5
Safety	40%	3	1.2	3	1.2
Operating Costs	20%	3	0.6	4	0.8
Versatility	20%	5	1	2	0.4
# of Operators	10%	5	0.5	5	0.5
	Total Score		3.7		3.4
	Rank		1		2

The linear indexer concept scored higher than the linear conveyer concept, and so in a direct comparison is considered to be the better concept. Both concepts will be given further consideration in the overall process scoring matrix.

1.3.2 TRANSFER METHOD CONCEPT SCORING

The two Transfer Method concepts that had the highest screening scores were compared in the Transfer Method ICSM. The Transfer Method ICSM is shown in TABLE XII.

TABLE XII: TRANSFER METHOD ICSM

		Transfer Method Concepts			
		A		B	
		Electronic Actuator		Fluid Actuator	
Selection Criteria	**Weight**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**
Throughput	10%	3	0.3	4	0.4
Safety	40%	5	2	4	1.6
Operating Costs	20%	5	1	3	0.6
Versatility	20%	3	0.6	3	0.6
# of Operators	10%	5	0.5	5	0.5
	Total Score		4.4		3.7
	Rank		1		2

The electronic actuator concept scored higher than the fluid actuator concept, and so in a direct comparison is considered to be the better concept. Both concepts will be given further consideration in the overall process scoring matrix.

1.3.3 FAN DECK POSTING CONCEPT SCORING

The two Fan Deck Posting concepts that had the highest screening scores were compared in the Fan Deck Posting ICSM. The Fan Deck Posting ICSM is shown in TABLE XIII.

TABLE XIII: FAN DECK POSTING ICSM

		Fan Deck Posting Concepts			
		A		B	
		Automated post insertion user operator driver		Fully automated posting	
Selection Criteria	**Weight**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**
Throughput	10%	4	0.4	5	0.5
Safety	40%	4	1.6	5	2
Operating Costs	20%	5	1	3	0.6
Versatility	20%	5	1	3	0.6
# of Operators	10%	3	0.3	5	0.5
	Total Score		4.3		4.2
	Rank		1		2

The automated post insertion user operated driver concept scored higher than the fully automated posting concept, and so in a direct comparison is considered to be the better concept. Both concepts will be given further consideration in the overall process scoring matrix.

1.3.4 DIE CUTTER CONCEPT SCORING

The two Die Cutting concepts that had the highest screening scores were compared in the Die Cutter ICSM. The Die Cutter ICSM is shown in TABLE XIV.

TABLE XIV: DIE CUTTER ICSM

		Die Cutting Concepts			
		A		B	
		2 die cutters		New die cutter that will do all four corners	
Selection Criteria	**Weight**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**
Throughput	10%	4	0.4	5	0.5
Safety	40%	4	1.6	4	1.6
Operating Costs	20%	5	1	3	0.6
Versatility	20%	5	1	4	0.8
# of Operators	10%	5	0.5	5	0.5
	Total Score		4.5		4
	Rank		1		2

The 2 die cutters concept scored higher than the new die cutter that will do all four corners concept, and so in a direct comparison is considered to be the better concept. Both concepts will be given further consideration in the overall process scoring matrix.

1.3.5 FULL PROCESS CONCEPT SCORING

With each of the ICSM completed, the concepts can now be combined and scored in the Full concept Scoring Matrix (FCSM). Each full process concept that will be scored is comprised of a Process Flow concept, a Transfer Method concept, a Fan Deck Posting concept and a Die Cutting concept. In order to develop a list of the full process concepts, all possible permutations and combinations of the individual process concepts were considered. In order to properly score each of the full process concepts, another importance weighing matrix is completed. In this importance weighing matrix, each of the processes that comprised the full process were compared to each other, the full process importance weighing matrix is shown in TABLE XV.

TABLE XV: FULL PROCESS IMPORTANCE MATRIX

Criteria		A Process Flow	B Transfer Method	C Fan deck Posting	D Die Cutting
A	Process Flow		A	C	D
B	Transfer Method			C	B
C	Fan deck Posting				C
D	Die Cutting				
	Total Hits	1	1	3	1
	Weightings	0.167	0.167	0.500	0.167

Each individual stage has two concepts still under consideration. For each remaining concept, their score was multiplied by the newly determined process weight, to determine the new concept score. Each of these concepts was assigned a value of 0 or 1, and each process was assigned a process digit. TABLE XVI summarizes each of the remaining process concepts.

TABLE XVI: REMAINING PROCESS CONCEPTS

Process Code Digit	Assigned #	Process	Score	Weight	Weighted Score
1		Process Flow			
	0	Linear Indexer	3.7	16.70%	0.617
	1	Linear Conveyor system	3.4	16.70%	0.567
2		Transfer method			
	0	Electronic Actuator	4.4	16.70%	0.733
	1	Fluid Actuator	3.7	16.70%	0.617
3		Fan deck posting			
	0	Automated post insertion user operator driver	4.3	50.00%	2.150
	1	Fully automated posting	4.2	50.00%	2.100
4		Die Cutting			
	0	2 die cutters	4.5	16.70%	0.750
	1	4 corner die cutter	4	16.70%	0.667

In order to determine the overall customer satisfaction for each of the full process concepts, the newly weighted scores for each process concept are added together to determine the overall process score. All of the possible full process concepts, as well as their overall scores are shown in TABLE XVII.

TABLE XVII: FULL PROCESS CONCEPTS AND OVERALL SCORES

	Code digit				Code Digit Score					
Combination #	**4**	**3**	**2**	**1**	**4 Score**	**3 Score**	**2 Score**	**1 Score**	**Total Score**	**Rank**
0	0	0	0	0	0.75	2.15	0.73	0.62	**4.25**	**1**
1	0	0	0	1	0.75	2.15	0.73	0.57	**4.20**	**2**
2	0	0	1	0	0.75	2.15	0.62	0.62	**4.13**	**5**
3	0	0	1	1	0.75	2.15	0.62	0.57	**4.08**	**8**
4	0	1	0	0	0.75	2.10	0.73	0.62	**4.20**	**2**
5	0	1	0	1	0.75	2.10	0.73	0.57	**4.15**	**4**
6	0	1	1	0	0.75	2.10	0.62	0.62	**4.08**	**8**
7	0	1	1	1	0.75	2.10	0.62	0.57	**4.03**	**11**
8	1	0	0	0	0.67	2.15	0.73	0.62	**4.17**	**3**
9	1	0	0	1	0.67	2.15	0.73	0.57	**4.12**	**6**
10	1	0	1	0	0.67	2.15	0.62	0.62	**4.05**	**10**
11	1	0	1	1	0.67	2.15	0.62	0.57	**4.00**	**12**
12	1	1	0	0	0.67	2.10	0.73	0.62	**4.12**	**6**
13	1	1	0	1	0.67	2.10	0.73	0.57	**4.07**	**9**
14	1	1	1	0	0.67	2.10	0.62	0.62	**4.00**	**12**
15	1	1	1	1	0.67	2.10	0.62	0.57	**3.95**	**13**

As shown in TABLE XVII, the final 3 concepts to be given further consideration are combination #0 (with an overall score of 4.25), combination #1 (with an overall score of 4.20), and combination #4 (with an overall score of 4.20). Combination #0 consists of the linear indexer, the electronic actuator, the automated post insertion user operator driver, and the 2 die cutters. Combination #1 consists of the linear conveyer, the electronic actuator, the automated post insertion user operated driver, and the 2 die cutters. Combination #4 consists of the linear indexer, the electronic actuator, the fully automated posting and the 2 die cutters.

1.4 SENSITIVITY ANALYSIS

The weighted evaluation matrix is a numerical procedure, and as such the results may be sensitive to one or more input parameters. In this case the results may be sensitive to the design criteria weightings, as well as the individual concept weightings. In order to determine how sensitive our results are, a sensitivity analysis was performed.

A sensitivity analysis is performed as follows: increase an input parameter suspected of causing sensitivity, this is done by increasing the weighting of the parameter. Once this increase is done, record the changes it has on the output parameter, in our case the output parameter is the weighted score. In order to properly increase the weighting of one parameter, the weighting of another parameter must be decreased.

For our project a sensitivity analysis will be performed for both the individual process criteria, and the weightings given to each process involved in the fan deck finishing cell.

1.4.1 INDIVIDUAL PROCESS SENSITIVITY ANALYSIS

For the individual process sensitivity analysis, the weightings of the main design criteria will be changed. Specifically the weight of the safety criteria will be decreased and the weight of the parameter in question will be increased. This will determine if the overall concept scores are sensitive to the parameter in question. The weighting of the safety criteria will be decreased to zero. The results of the sensitivity analysis are shown in Figure 1 through Figure 4. The legend for the sensitivity figures is shown in figure 5.

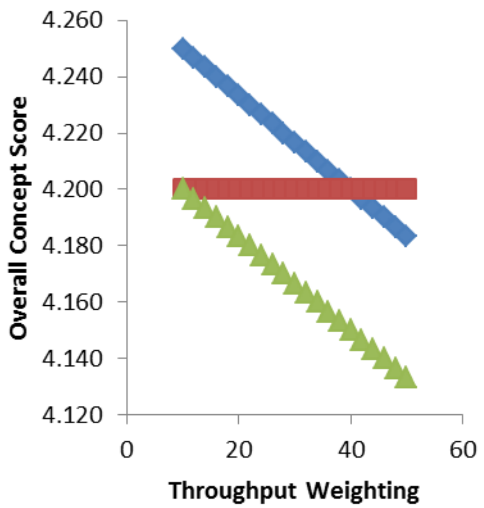


Figure 1: Sensitivity Plot of Throughput Weighting

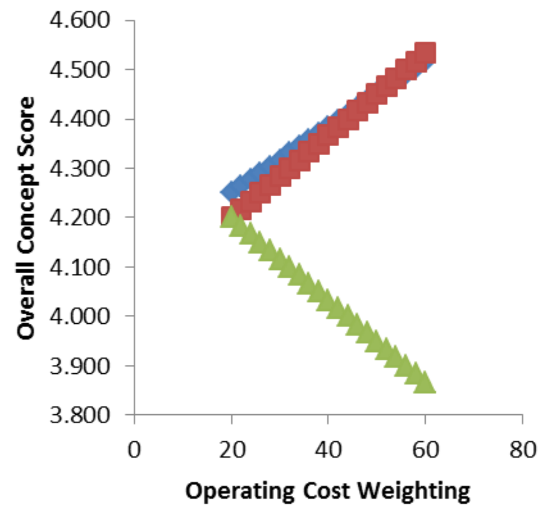


Figure 2: Sensitivity Plot of Operating Cost Weighting

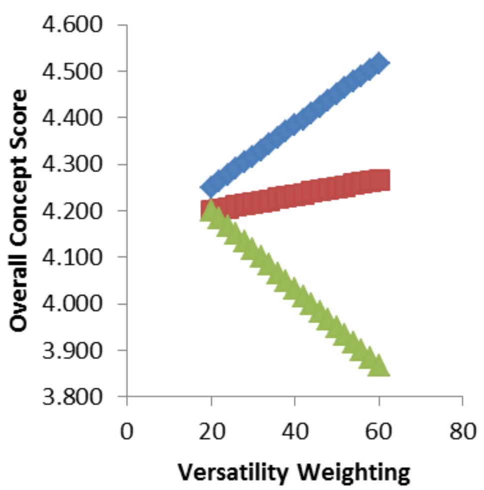


Figure 3: Sensitivity Plot of Versatility Weighting

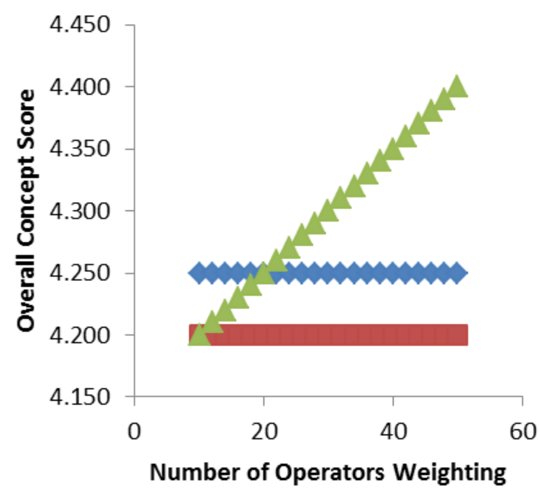


Figure 4: Sensitivity Plot of Number of Operators Weighting

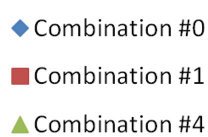


Figure 5: Sensitivity Plot Legend

The plotted data above show that all the concepts demonstrate a degree of sensitivity. Combination #0 is insensitive in the number of operators analysis and appears as the best scored concept at the beginning of all the plots and only at the end of the versatility analysis. Combination #1 is insensitive in two of the four categories, and also appears as the best scored concept in two of the four categories. Combination #4 is sensitive in every analysis and only appears at the top of the number of operators analysis.

From the sensitivity analysis, it can be concluded that the results of our concept scoring analysis is sensitive to the weightings assigned to each design criteria. From meetings with our client, as well as internal brain storming sessions, our team has concluded that the assigned weightings are accurate.

1.4.2 FULL PROCESS SENSITIVITY ANALYSIS

For the full process sensitivity analysis, the weightings of the individual processes will be adjusted, and the changes to the overall concept scores will be recorded. The weighting given to the Fan Deck Posting process will be decreased and the weighting given to each of the other processes will be increased. The results of the full process sensitivity analysis are shown in Figure 6 through Figure 8.

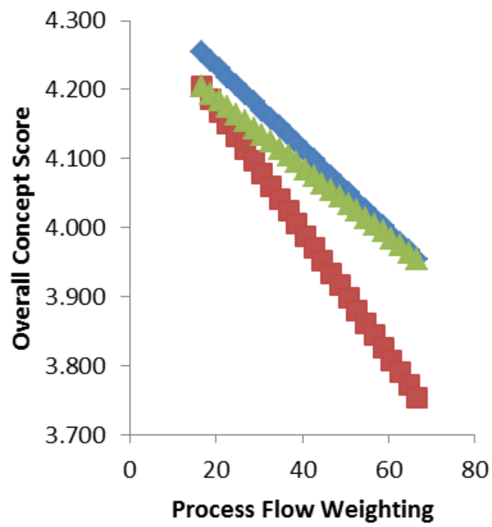


Figure 6: Sensitivity Plot of Process Flow Weighting

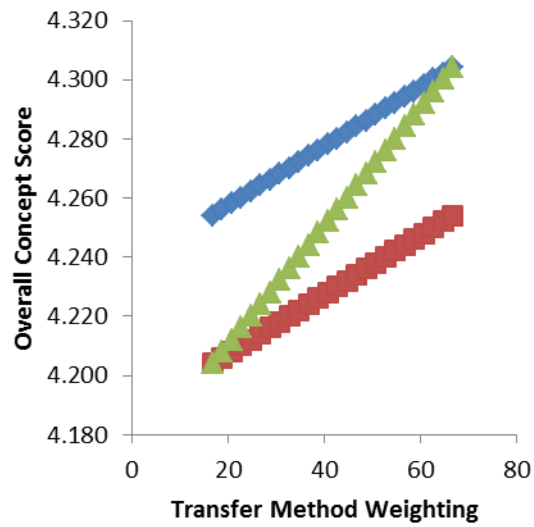


Figure 7: Sensitivity Plot of Transfer Method Weighting

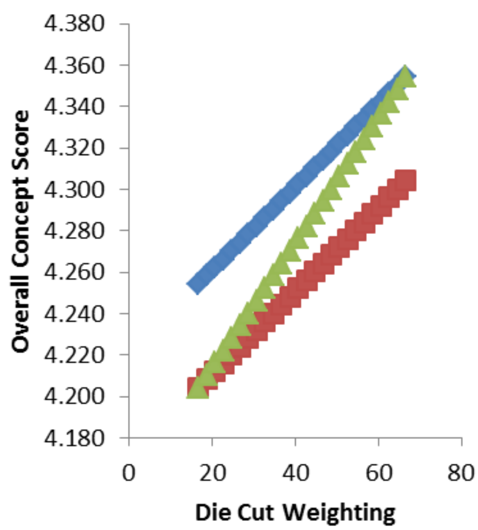


Figure 8: Sensitivity Plot of Die Cut Weighting

From the above plots it can be seen that each concept demonstrates a degree of sensitivity to each weighted process. It can also be seen that design combination #0 remains at the top of the sensitivity analysis in all cases. This is a good sign that combination #0 is the best concept to analyse further.

1.5 TECHNICAL ANALYSIS

Due to the nature of this project, the technical analysis at this point in the design process is limited. The designs that are being analysed currently utilize off the shelf items, because of this our team has focused on sourcing the current machines with specifications to meet our design requirements. In order to determine which of the off the shelf machines meet our design requirements, the specifications need to be further broken down. A preliminary technical analysis can help in the concept selection process.

Our client desires a throughput of up to 350 fan decks / hour which is equal to roughly one fan deck every ten seconds. With this in mind, the linear indexer and the linear conveyer will be compared.

If one fan deck must be output every ten seconds this means that a linear indexer must index every ten seconds or less. If a linear conveyer was used, the conveyer speed would have to be roughly one tenth of a foot per second. The linear indexer provides a ten second working window, this is easier to design around than a constantly moving conveyer, and so with respect to throughput, the linear indexer is the better concept.

The need for a process time less than ten seconds is important to the die cutting process as well. It has been conveyed to Streamline Systems that a two corner die cutter is easier to load and unload than the four corner die cutter. If two die cutters were used, the die cutting process could be split into two operations, each operation having a separate ten second process time. Based on the desired throughput specification, the two die cutter concept is better than the four corner die cutter.

Versatility and operating costs must also be taken into consideration when selecting between concepts. Our team has determined that for the same cost, the automated post insertion with user operated driver is more versatile than utilizing a fully automated posting process. To develop a machine with the same versatility and adaptability as a human, the initial capital cost as well as operational maintenance costs would outweigh any potential future savings due to the extremely long payback period associated with this design. For these reasons the automated post insertion with user operated driver, is the preferred fan deck posting concept.

At this point in the design process, it is difficult to complete a technical analysis with respect to the number of operators or the safety of each concept.

Through the limited technical analysis done, our group recommends the linear indexer system, two die cutters, and the automated post insertion with the user operated driver.

1.6 COST ANALYSIS

Due to the status of the design process at this time, it is difficult to determine an accurate total project cost. However, based on some assumptions and budgetary pricing for the supply of equipment and materials, the following cost analysis was been undertaken. It was assumed that all potential designs would utilize 2,500lbs of painted and fabricated mild steel with a unit price of 1.96$/lb. [9] Unit pricing for the conveyors and linear indexers were loosely based on budgetary quotes received by Duha Group from Eckert Machines. [10] A cash allowance of $7,500 for the electrical and controls package was carried due to this being beyond the scope of our design. Further, due to the preliminary nature and the uncertainty of this design build project, a maximum contingency allowance of $ 4,500 was assigned. The contingency allowance for each design was calculated by allowing a base of $2,500 plus $2,500 multiplied by the level of design uncertainty. No allowance has been made for the installation of the equipment, delivery to site or any taxes associated with the purchase of the goods. TABLETABLE XVIII, TABLE XIX, and TABLE XX show the breakdown of the preliminary cost analysis for the 3 selected designs.

TABLE XVIII: DESIGN 1 COST ANALYSIS

	Design 1 - Linear Indexer, Electronic Actuator, Automated Post Insertion, 2 Die Cutters				
Equipment/Item	**Quantity**	**Units**	**Unit Rate**	**Units**	**Total**
Fabricated and Painted Mild Steel	2500	LBS	$2.25	$/LBS	$5,625.00
Electrical Controls	1	Lot	$7,500	Each	$7,500.00
Contingency - Based on Level of Uncertainty with Design	25	Level of Uncertainty (%)	$2,500	$	$3,125.00
Linear Indexer	25	LF	$650	$/LF	$16,250.00
Electronic Actuator	5	Each	$600	Each	$3,000.00
Automated Post Insertion - Vibratory Screw Feeder w/ Actuator	1	Each	$5,600	Each	$5,600.00
Automated Screw Drivers	2	Each	$3,000	Each	$6,000.00
Die Cutters	2	Each	Currently Own	N.A.	$ -
			Total Cost		$47,100.00

TABLE XIX: DESIGN 2 COST ANALYSIS

	Design 2 - Linear Conveyer, Electronic Actuator, Automated Post Insertion, 2 Die Cutters				
Equipment/Item	**Quantity**	**Units**	**Unit Rate**	**Units**	**Total**
Fabricated and Painted Mild Steel	2500	LBS	$2.25	$/LBS	$5,625.00
Electrical Controls	1	Lot	$7,500	Each	$7,500.00
Contingency - Based on Level of Uncertainty with Design	40	Level of Uncertainty (%)	$2,500	$	$3,500.00
Linear Conveyer	30	LF	$550	$/LF	$16,500.00
Electronic Actuator	6	Each	$600	Each	$3,600.00
Automated Post Insertion - Vibratory Screw Feeder w/ Actuator	1	Each	$5,600	Each	$5,600.00
User Operated Automated Screw Drivers	2	Each	$3,000	Each	$6,000.00
Die Cutters	2	Each	Currently Own	N.A.	$ -
			Total Cost		$48,325.00

TABLE XX: DESIGN 3 COST ANALYSIS

	Design 3 - Linear Indexer, Fully Automated Posting, 2 Die Cutters				
Equipment/Item	**Quantity**	**Units**	**Unit Rate**	**Units**	**Total**
Fabricated and Painted Mild Steel	2500	LBS	$2.25	$/LBS	$5,625.00
Electrical Controls	1	Lot	$7,500	Each	$7,500.00
Contingency - Based on Level of Uncertainty with Design	70	Level of Uncertainty (%)	$2,500	$	$4,250.00
Linear Indexer	25	LF	$650	$/LF	$16,250.00
Electronic Actuator	4	Each	$400	Each	$1,600.00
Fully Automated Post Insertion	1	Each	$25,000	Each	$25,000.00
Die Cutters	2	Each	Currently Own	N.A.	$ -
			Total Cost		$60,225.00

It can be seen that preliminary cost analysis design 1 is the best design financially, as well as technically. Based on the preliminary cost analysis, it can be seen that the projects total projected budget for the overall system is within the client's requirements of $50,000 - $60,000.

1.7 CONCEPT ANALYSIS AND SELECTION SUMMARY

Our team divided the fan deck finishing project into four separate manufacturing processes; Process Flow, Transfer Method, Fan Deck Posting, and Die Cutting. For each of these processes, concepts were generated using brainstorming techniques as well as internal and external searches.

Once the concept generation was complete, the concepts for each process were analyzed using screening and scoring matrices. The screening matrices compare concepts relative to one another, while the scoring matrix scored each concept based on the following design criteria: throughput, safety, versatility, number of operators, and operating cost. Through this systematic approach, the number of concepts was narrowed down to two concepts per each of the four manufacturing processes. These final eight concepts were combined to form 16 complete finishing cell concepts.

These 16 concepts were input into a second scoring matrix and were scored based on the weights assigned to each of the manufacturing processes. Through this analysis three complete finishing cell concepts were determined to be the concepts eligible for further consideration. Finally, a preliminary technical and cost analysis was completed, the result of which yielded the concept that best meets our client's need and target specifications. This final concept was combination #0, consisting of a linear indexer, electronic actuator, automated post insertion with user operated driver, and two die cutters.

APPENDIX B THROUGHPUT AND TIMING ANALYSIS

The timing analysis was calculated using a spreadsheet. Tables created from the spread sheet can be seen in TABLE I and TABLE II. The legend, explaining the colour assignments is shown in TABLE III.

TABLE I: TIMING ANALYSIS CALCULATION TABLE

Timing analysis			
Stage	**Process**	**Distance (in)**	**Time (s)**
Loading	Initial Fan Deck Loading	N/A	5.00
	Movement of Indexer	14.13	3.11
	FAN DECK HANDLEING TIME		**8.11**
	Wait Time	N/A	2.18
	TOTAL STAGE TIME		**10.28**
Die Cutter #1	Die Cutter Loading	26	2.89
	Die Cutting	N/A	1.40
	Die Cut Unloading	26	2.89
	Movement of Indexer	14.13	3.11
	STAGE FAN DECK HANDLEING TIME		**10.28**
	Wait Time	N/A	0.00
	TOTAL STAGE TIME		**10.28**
Die Cutter #2	Die Cutter Loading	26	2.89
	Die Cutting	N/A	1.40
	Die Cut Unloading	26	2.89
	Movement of Indexer	14.13	3.11
	STAGE FAN DECK HANDLEING TIME		**10.28**
	Wait Time	N/A	0.00
	TOTAL STAGE TIME		**10.28**
Female Post Insertion	Female Post Insertion Positioning	9.639	1.07
	Female Post Insertion	N/A	2.00
	Movement of Indexer	14.13	3.11
	STAGE FAN DECK HANDLEING TIME		**6.18**
	Wait Time	N/A	4.11
	TOTAL STAGE TIME		**10.28**
Male Post Insertion	Male Post Insertion Positioning	N/A	5.00
	Male Post Insertion	N/A	2.00
	Position for Packaging	N/A	2
	STAGE FAN DECK HANDLEING TIME		**9.00**
	Wait Time	N/A	1.28
	TOTAL STAGE TIME		**10.28**
	THROUGHPUT (FAN DECKS / HOUR)		**350**

TABLE II: USER CONTROLLED VARIABLES USED IN CALCULATING THE TIMING ANALYSIS TABLE

USER CONTROLLED VARIABLES	
Fan Deck Length (in)	9
Fan Deck Width (in)	2
Fan Deck Height (in)	2.5
Actuator Average Speed (in/s)	9
Indexing Average Speed (in/s)	4.55
Cleat Spacing (in)	14.13

TABLE III: COLOR ASSIGNMENT LEGEND

Legend	
User Controlled Variable (UCV)	
Dependent on UCV	
Calculated	
Fixed	
Wait time	
Stage bottleneck time	

As described by the legend. The green cells are controlled by the user. The orange cells are dependent directly on one of more of the user controlled variable. White cells are calculated using a combination of green and orange data. Blue cells are fixed values either specified by Duha Group, or a component manufacturer. The data in the yellow cells represents the waiting time associated with the respective stages. This is due to the fact that the linear conveyor indexes all fan decks at once and so no fan deck can be indexed until the longest stage has finished processing. The longest stage time is the bottleneck stage time and is indicated by the red cells.

By changing the user controlled variables, the throughput can be determined for any size of fan deck and for any required actuator or indexing speed (within the limitations of the components). The calculations for determining the timing analysis were completed as follows:

The actuators used in positioning the fan decks will have to move different distances depending on the width of the fan deck being processed. The distance calculation used the following equation:

$$Actuation\ distance = d_a = Total\ distance - Fan\ Deck\ Width$$

The total distance was determined by taking measurements for the complete design assembly model.

The actuation time is described by the following equation:

$$Actuation\ time = \frac{d_a}{Actuation\ Velocity}$$

Since a decrease in process time will result in an increase in throughput, it can be seen from the previous equation that an increase in actuation velocity will result in an increase in throughput rate. Limitation of actuation velocity will have to be determined through testing.

The stage fan deck handling time is described by the following equation:

$$Stage\ handling\ time = T_s = \sum_{i=1}^{n} T_{Pn}$$

Where:

$$T_{Pn} = Process\ times\ within\ the\ given\ stage$$

Finally the wait time is calculated by the following equation:

$$Wait\ time = T_w = T_B - T_s$$

Where:

$$T_B = Bottleneck\ stage\ time$$

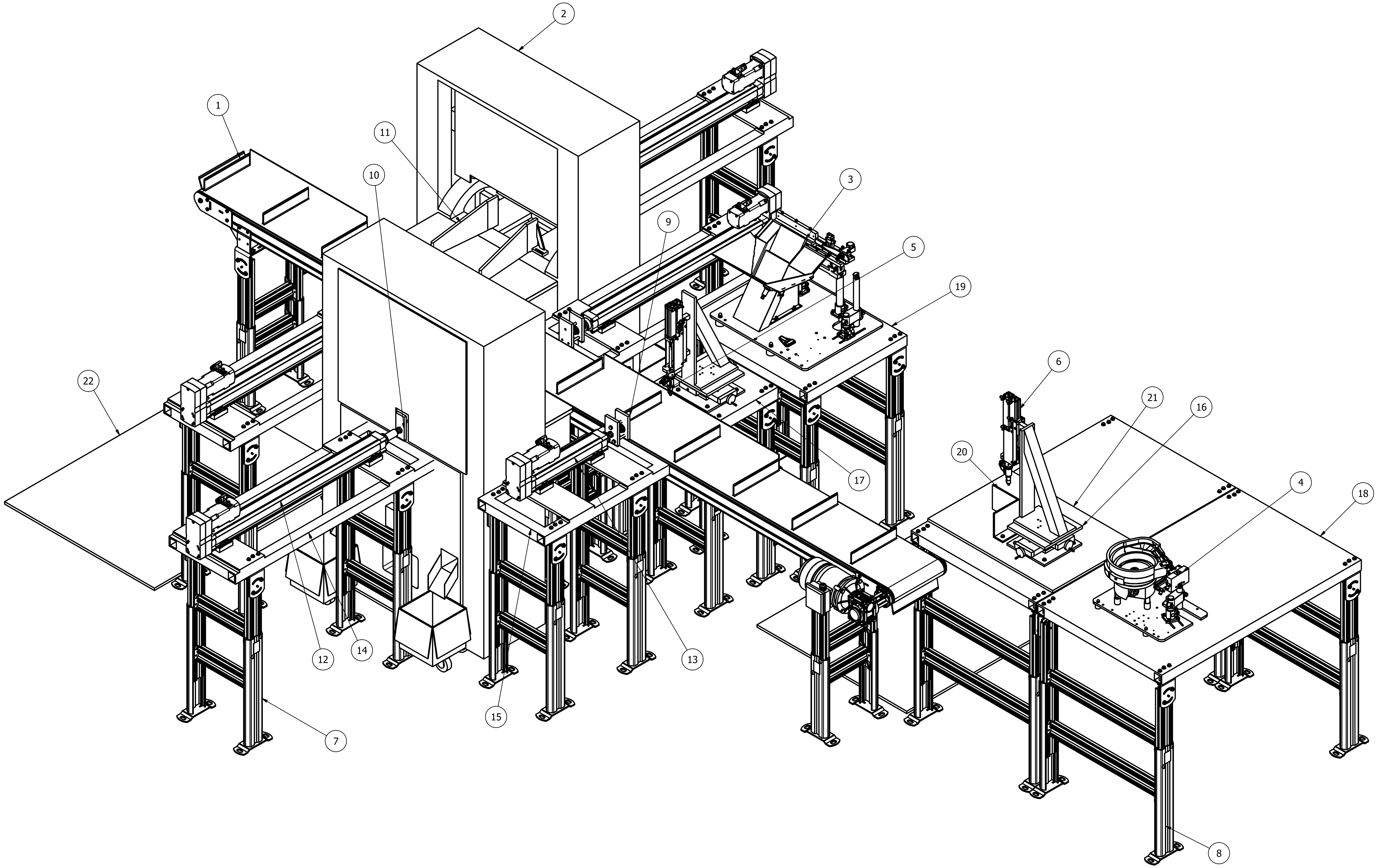
The throughput rate is then determined as follows

$$Throughput\ rate = \dot{T} = \frac{3600}{T_B}$$

Using this methodology throughput rates can be determined for any combination of fan deck size, actuation speed and indexing speed. Also indexing and actuation speeds could be determined for a required fan deck size and throughput.

APPENDIX C PRELIMINARY TECHNICAL DRAWINGS

BILL OF MATERIALS		
ITEM	QTY	DESCRIPTION
1	1	Dorner 3200 Series Indexing Conveyor
2	2	Hickock Duplex Round Corner Die Cutter
3	1	Weber Z-150C Step Feeder
4	1	Weber ZEB-240C Vibratory Bowl Feeder
5	1	Weber LCI-10 Post Insertion System
6	1	Weber SEB-10 Auto Feed Screw Driver
7	12	12" Dorner Adjustable Height Stand with Fixed Foot Pads
8	6	30" Dorner Adjustable Height Stand with Fixed Foot Pads
9	3	Loading Actuator Head (Spring Loaded)
10	2	Unloading Actuator Head
11	2	Die Cutter Guides
12	4	900 mm Festo Actuator
13	1	300 mm Festo Actuator
14	4	900 mm Festo Actuator Support
15	1	300 mm Festo Actuator Support
16	2	Velmex X-Y Table
17	1	16" x 16" Support Table
18	2	48" x 30" Support Table
19	1	24" x 30" Support Table
20	1	90° V-Bracket
21	1	48" x 30" - 1/2" Rubber Mat
22	2	Anit-Fatigue Mat
23	66	1/4" - 20 UNC - 3.5" Hex Bolt
24	42	1/4" - 20 UNC - 3" Hex Bolt
25	120	1/4" Lock Washer
26	120	1/4" Steel Washer
27	120	1/4" - 20 UNC Hex Nuts



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QA		Bill of Materials
MFG		
APPROVED		
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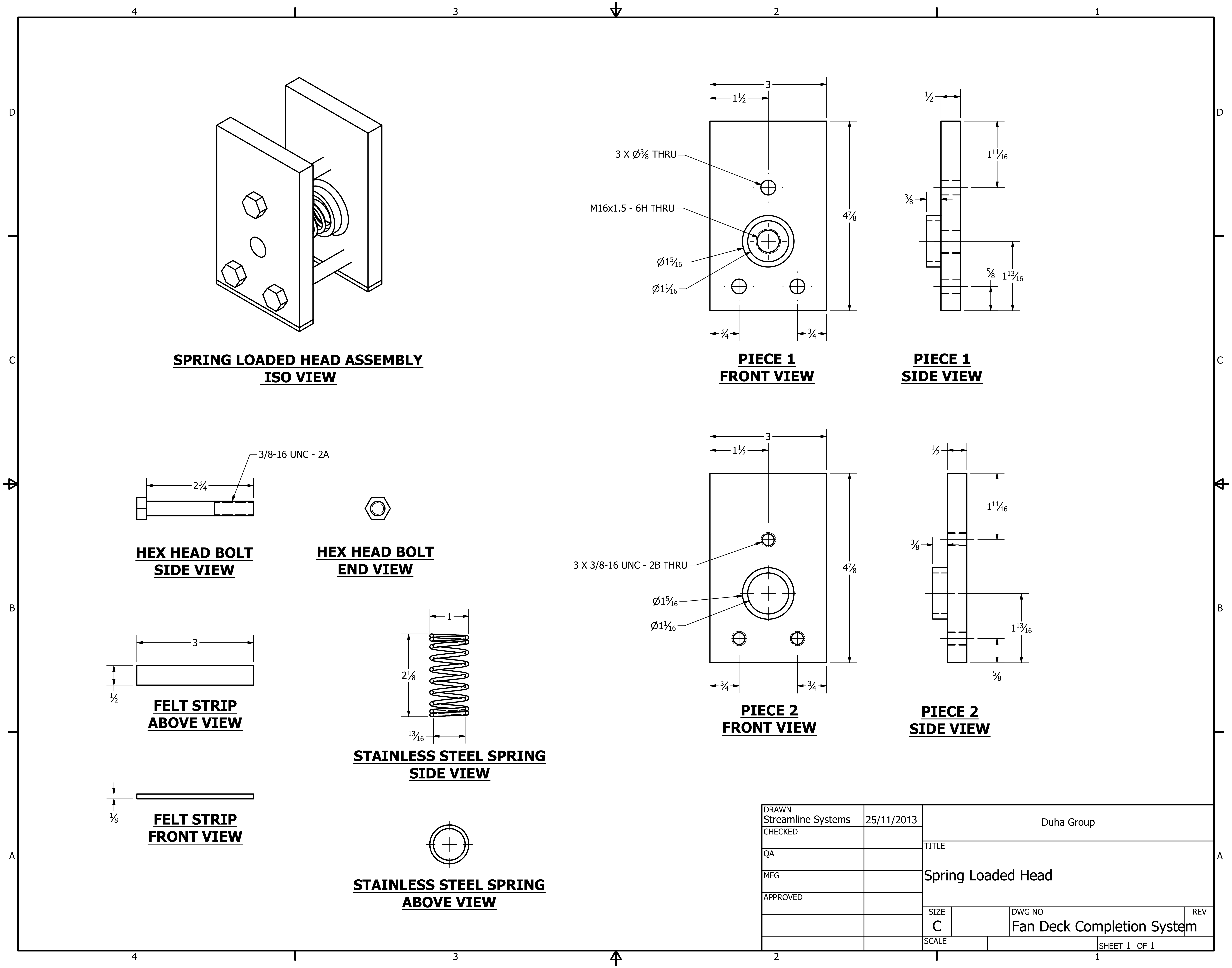
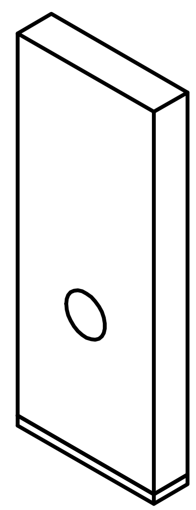
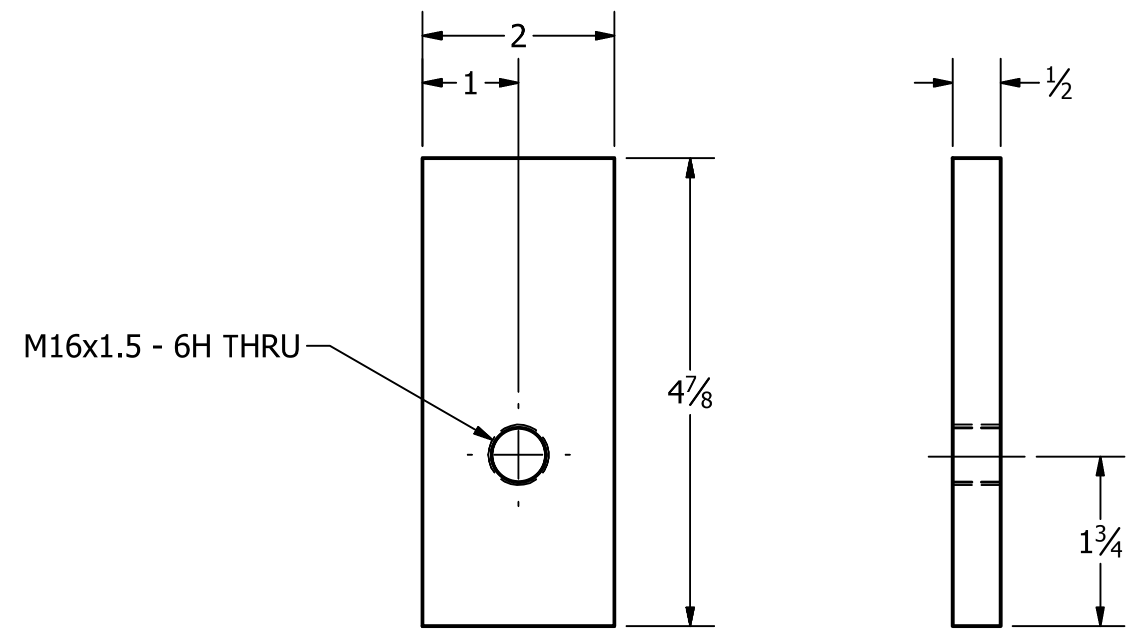
		SCALE — SHEET 1 OF 1


SPRING LOADED HEAD ASSEMBLY
ISO VIEW
3
1½
3 X Ø⅜ THRU
M16x1.5 - 6H THRU
Ø1⁵⁄₁₆
Ø1¹⁄₁₆
4⅞
¾
¾
PIECE 1
FRONT VIEW
½
1¹¹⁄₁₆
⅜
⅝
1¹³⁄₁₆
PIECE 1
SIDE VIEW
3/8-16 UNC - 2A
2¾
HEX HEAD BOLT
SIDE VIEW
HEX HEAD BOLT
END VIEW
3
1½
3 X 3/8-16 UNC - 2B THRU
Ø1⁵⁄₁₆
Ø1¹⁄₁₆
4⅞
¾
¾
PIECE 2
FRONT VIEW
½
1¹¹⁄₁₆
⅜
1¹³⁄₁₆
⅝
PIECE 2
SIDE VIEW
3
½
FELT STRIP
ABOVE VIEW
1
2⅛
¹³⁄₁₆
STAINLESS STEEL SPRING
SIDE VIEW
⅛
FELT STRIP
FRONT VIEW
STAINLESS STEEL SPRING
ABOVE VIEW
DRAWN
Streamline Systems
25/11/2013
CHECKED
QA
MFG
APPROVED
Duha Group
TITLE
Spring Loaded Head
SIZE
C
DWG NO
Fan Deck Completion System
REV
SCALE
SHEET 1 OF 1

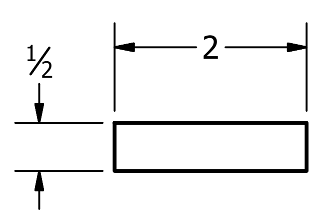


UNLOADING ACTUATOR HEAD
ISO VIEW

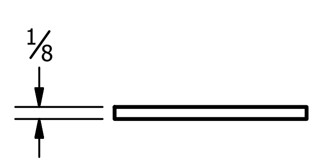


FRONT VIEW

SIDE VIEW

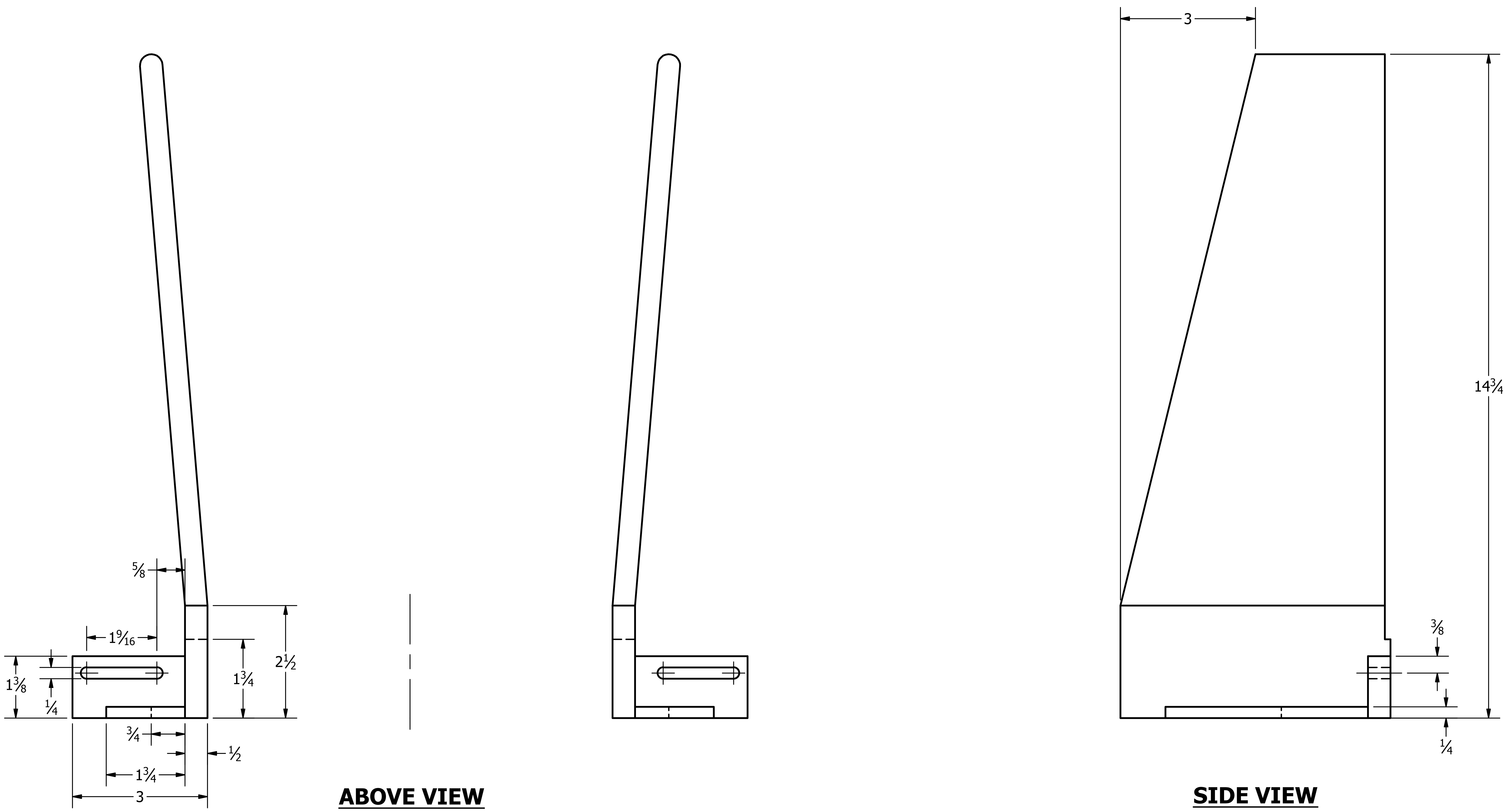


FELT STRIP
ABOVE VIEW



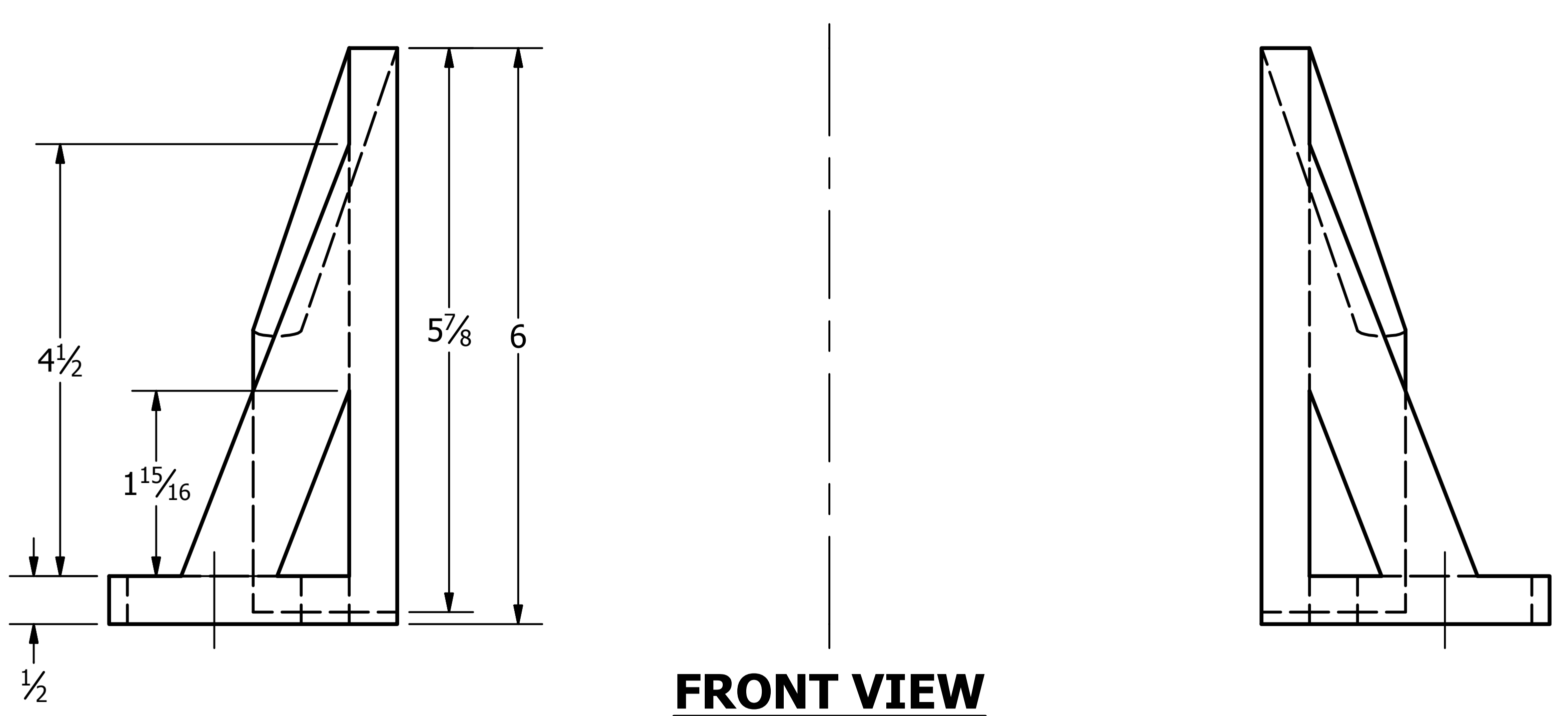
FELT STRIP
FRONT VIEW

DRAWN Streamline Systems	25/11/2013	Duha Group
CHECKED		TITLE Unloading Actuator Head
QA		
MFG		
APPROVED		SIZE B; DWG NO Fan Deck Completion System; REV
		SCALE; SHEET 1 OF 1



ABOVE VIEW

SIDE VIEW



FRONT VIEW

DRAWN Streamline Systems	27/11/2013	Duha Group
CHECKED		TITLE
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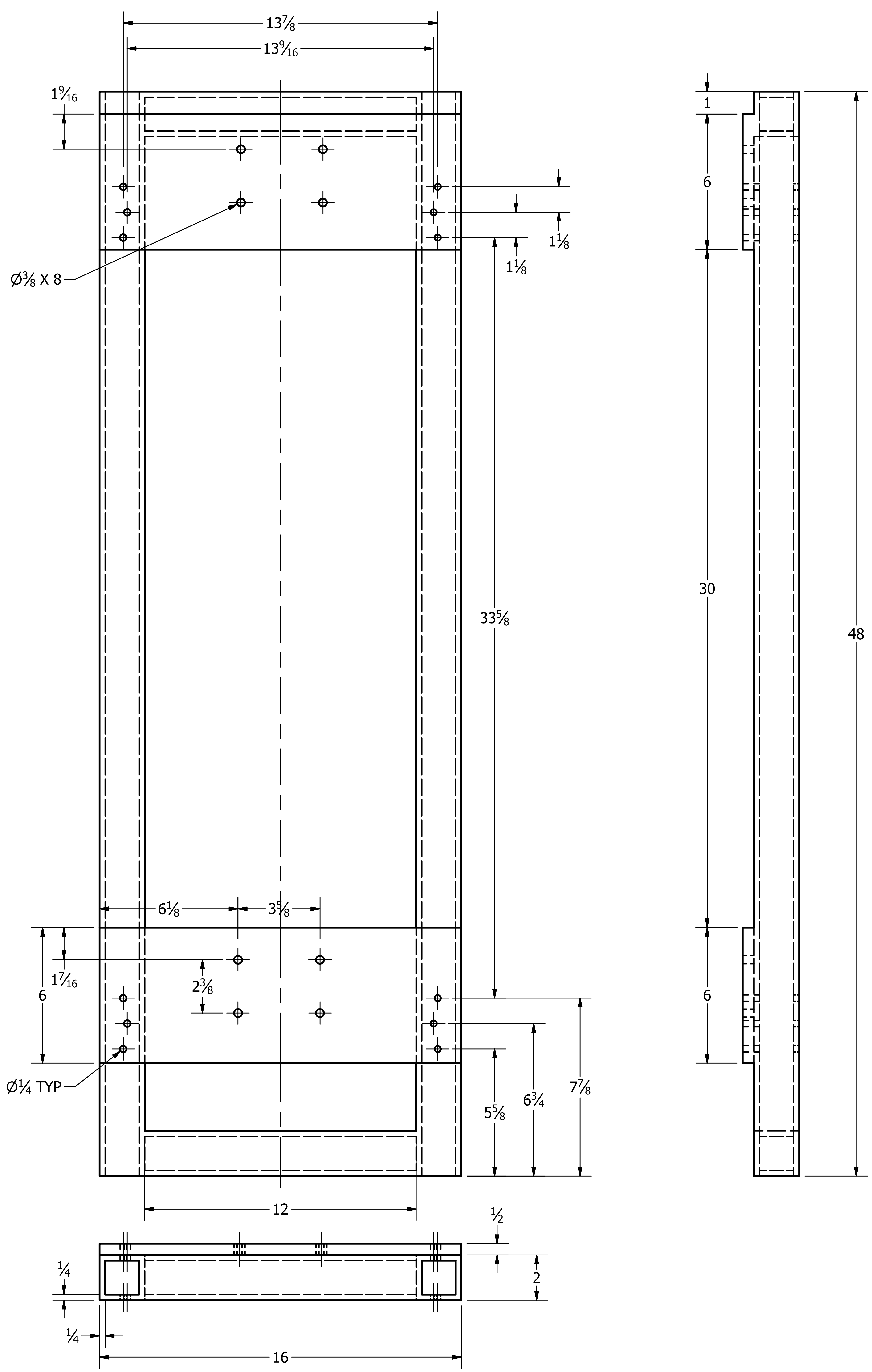
MFG		
APPROVED		SIZE C · DWG NO Fan Deck Completion System · REV
		SCALE · SHEET 1 OF 1



DRAWN Streamline Systems	27/11/2013	Duha Group
CHECKED		TITLE
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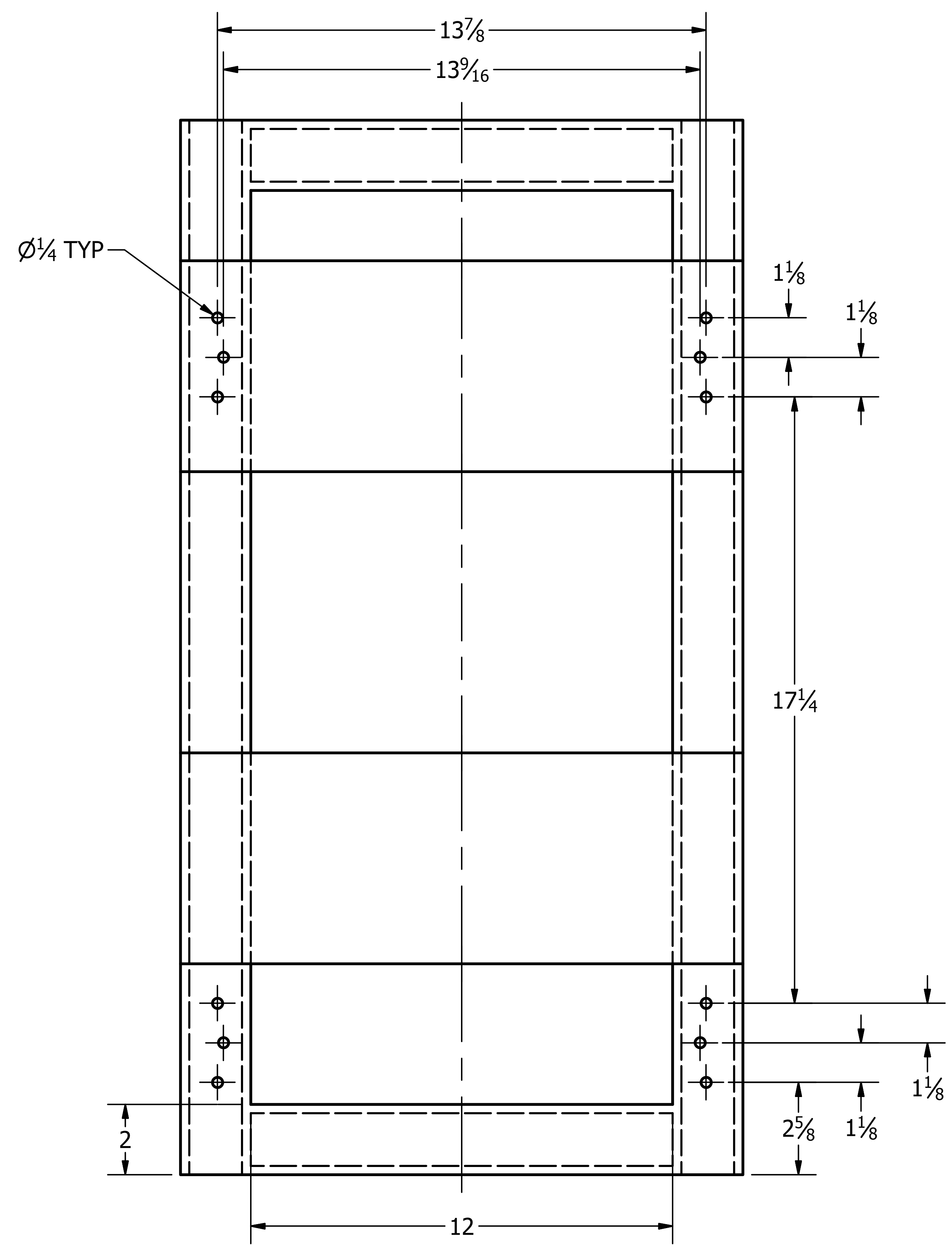
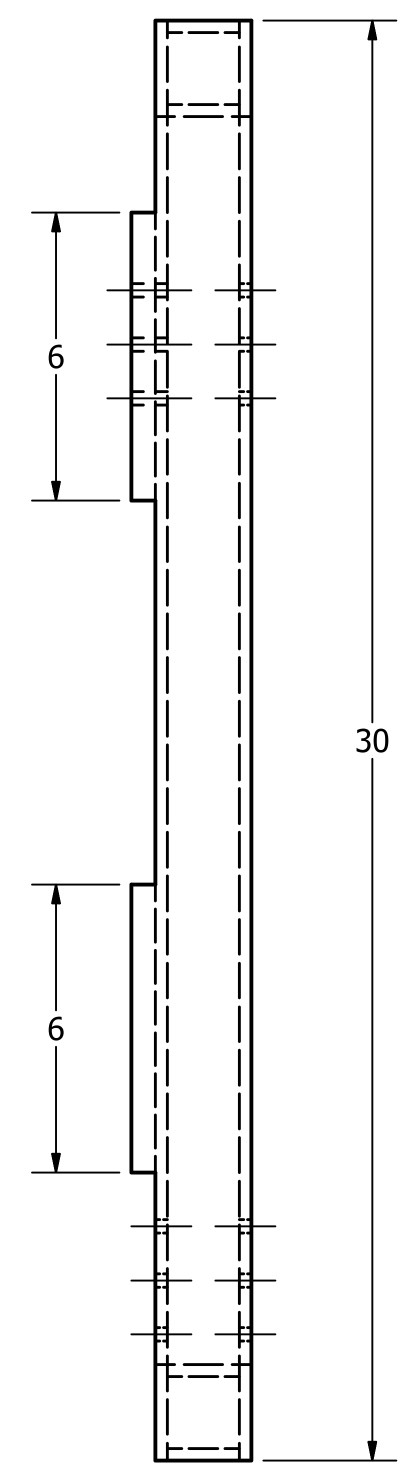
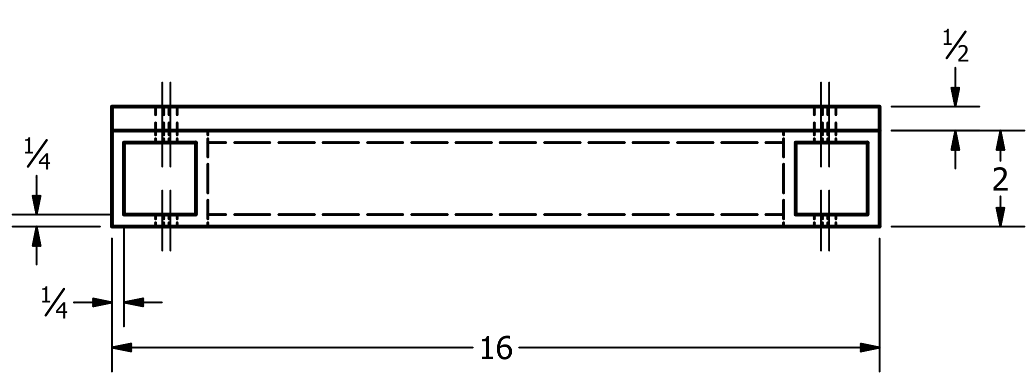
MFG		
APPROVED		
		SIZE C · DWG NO Fan Deck Completion System · REV
		SCALE · SHEET 1 OF 1



ABOVE VIEW



SIDE VIEW



FRONT VIEW

DRAWN Streamline Systems	27/11/2013	Duha Group		
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MFG				
APPROVED				
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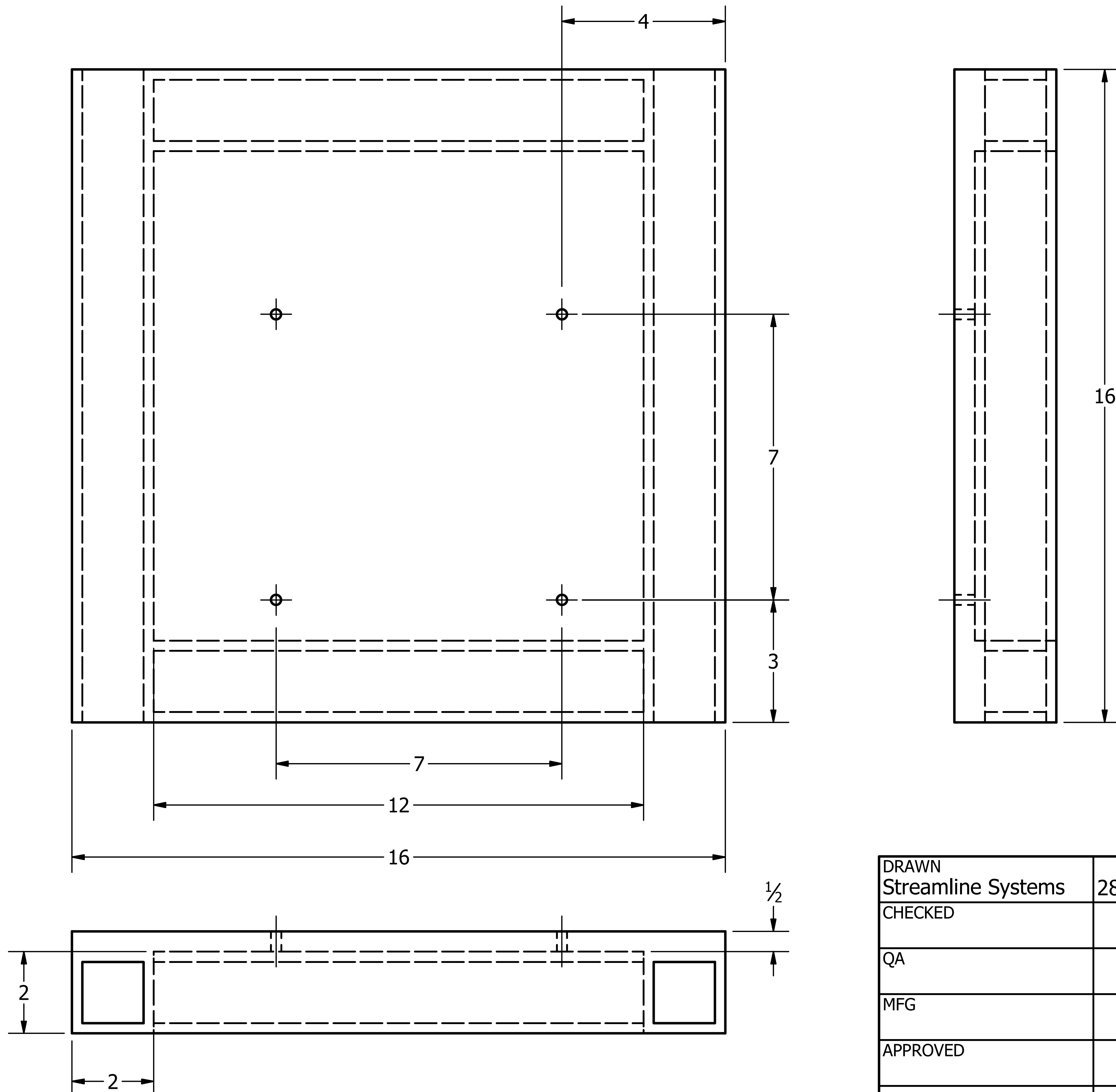
		SCALE	SHEET 1 OF 1	



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MFG		
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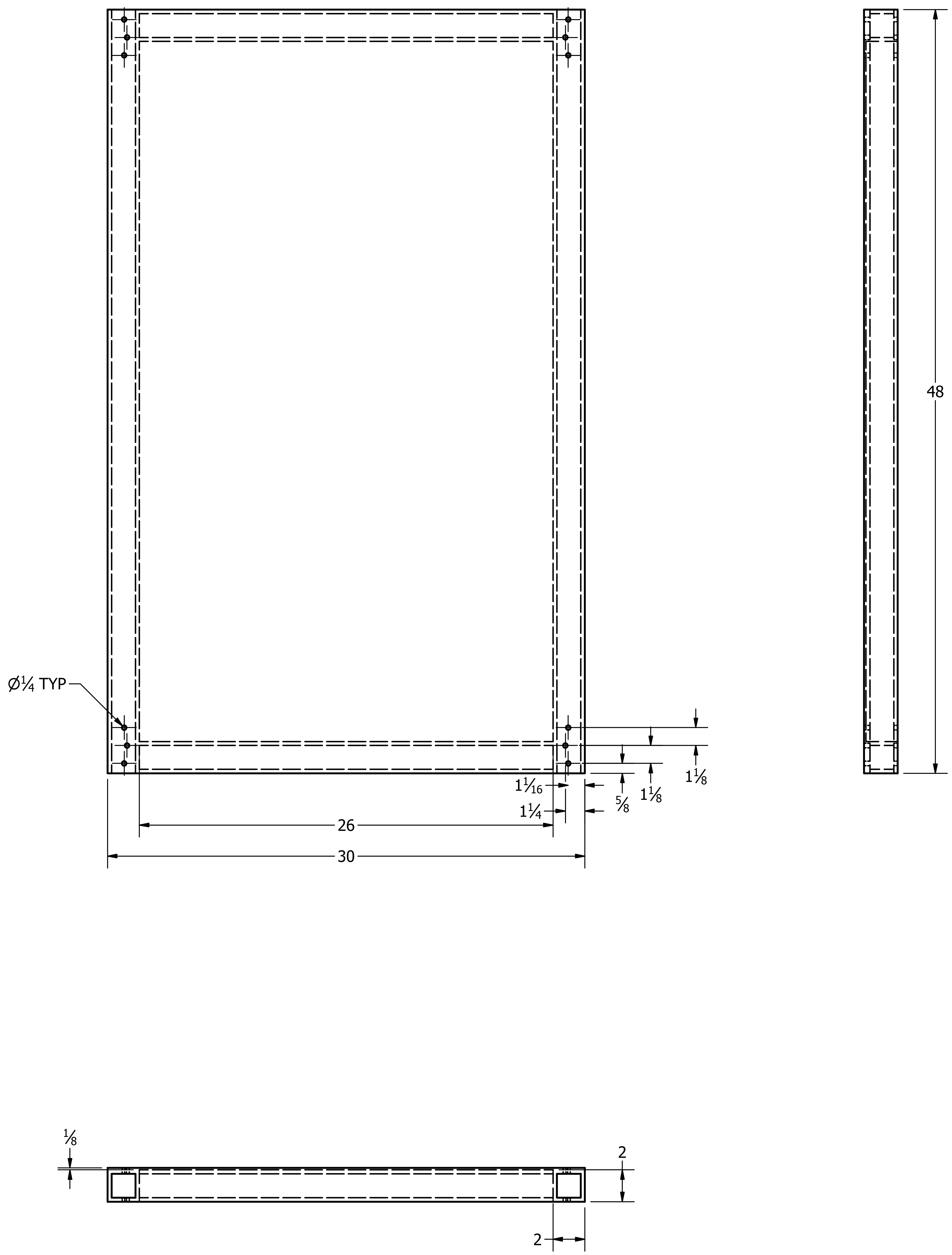
		SCALE — SHEET 1 OF 1



DRAWN Streamline Systems	29/11/2013	Duha Group
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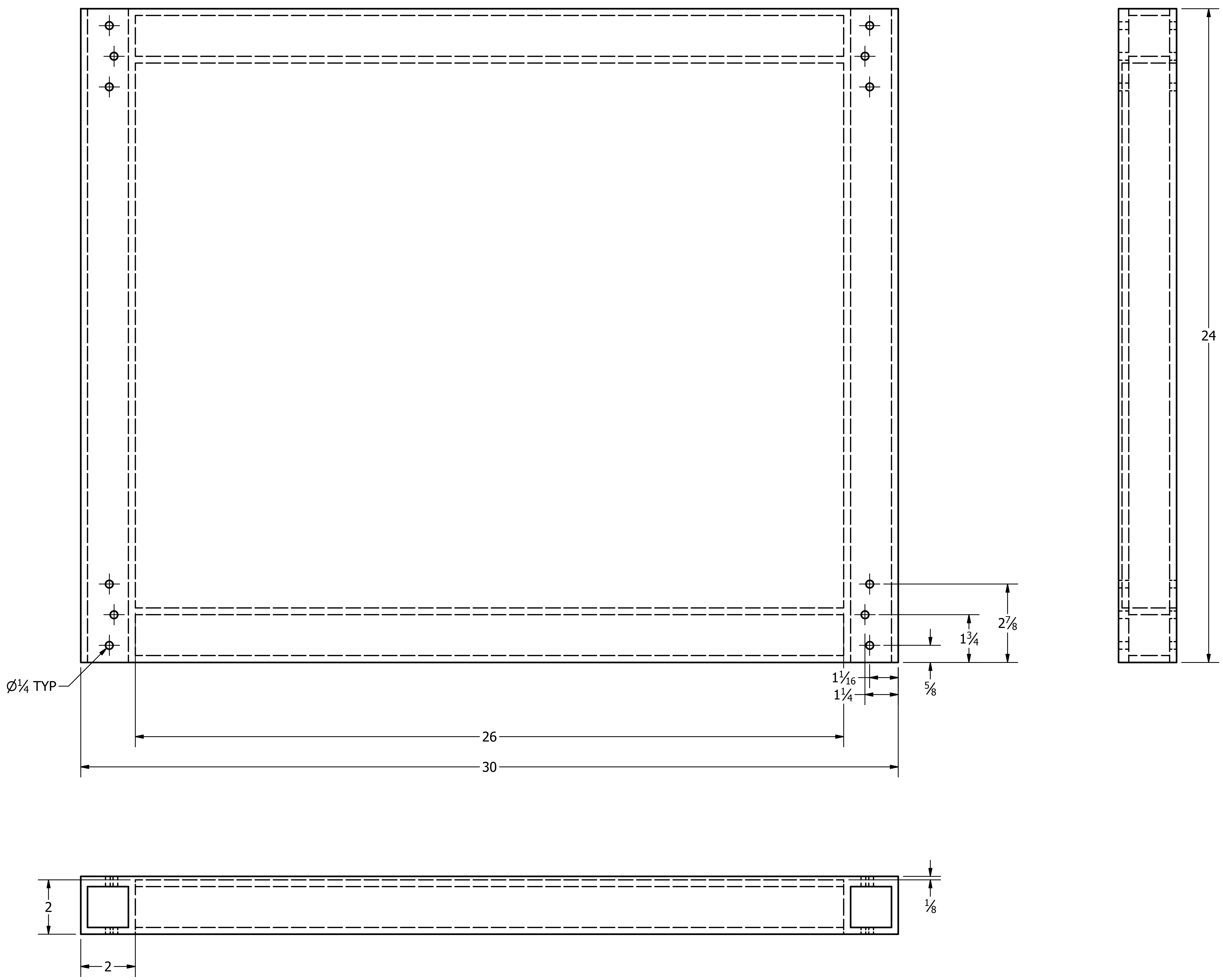
MFG		
APPROVED		SIZE C · DWG NO Fan Deck Completion System · REV
		SCALE · SHEET 1 OF 1



DRAWN Streamline Systems	29/11/2013	Duha Group
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MFG		
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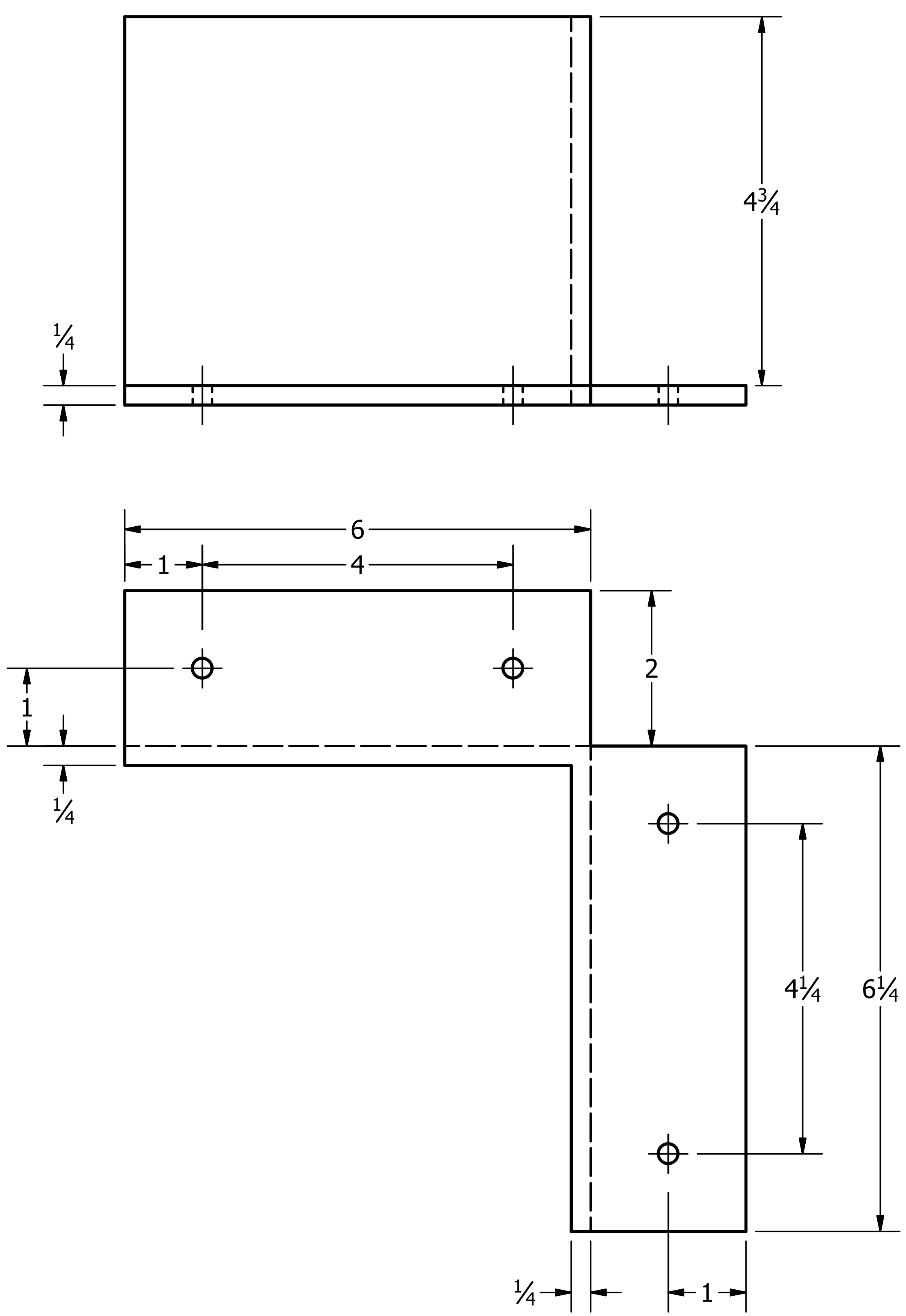

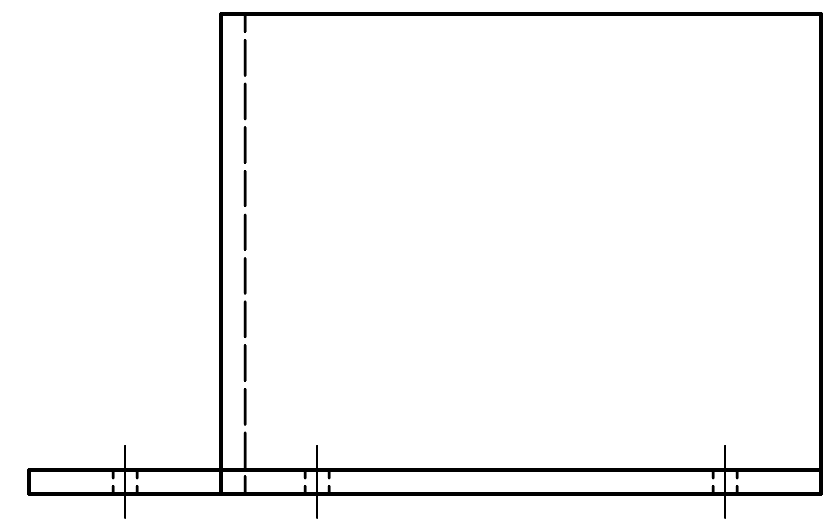

DRAWN Streamline Systems	29/11/2013	Duha Group
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QA		
MFG		
APPROVED		SIZE B / DWG NO Fan Deck Completion System / REV
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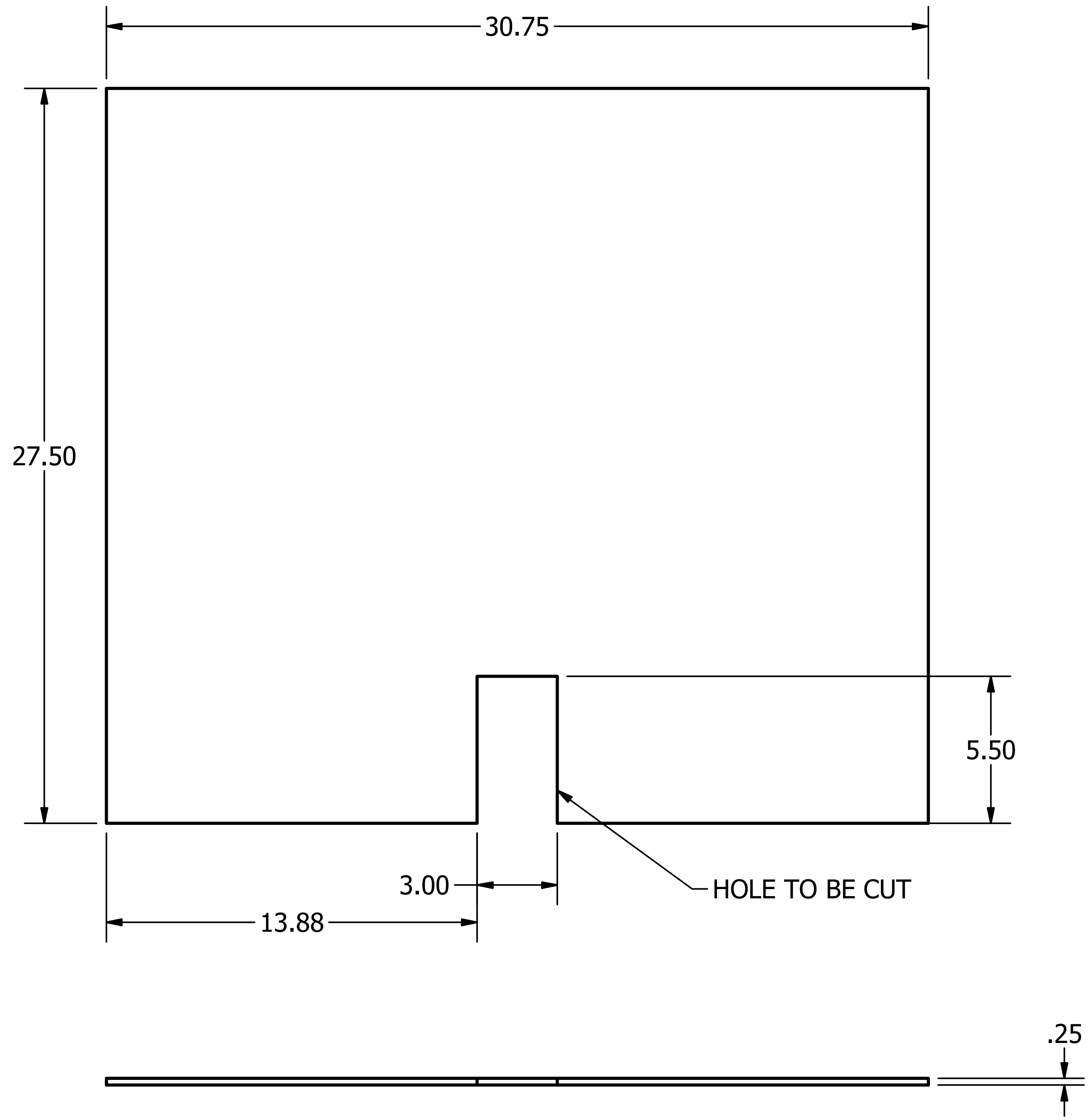

DRAWN Streamline Systems	29/11/2013	Duha Group
CHECKED		TITLE
QA		90 Degree V-Guide
MFG		
APPROVED		SIZE B / DWG NO Fan Deck Completion System / REV
		SCALE / SHEET 1 OF 1

APPENDIX D FAILURE MODES AND EFFECTS ANALYSIS METHODOLOGY

In order to properly perform an FMEA analysis the following steps are followed:

1. Identify the design components and/or processes.

2. Identify potential failure modes for each component and/ or process.

3. Identify the effects of the identified failures.

4. Assign a severity ranking to each effect based on the following table:

TABLE I: FAILURE EFFECT SEVERITY RATING SCALE [1]

Severity of Effect		***Ranking***
Minor	Unreasonable to expect that the minor nature of this failure would cause any substantial effect on system performance or on a subsequent process or service operation. Customer unlikely to either notice or care about the failure.	**1**
Low	Low severity ranking due to nature of failure causing only a slight customer annoyance. Customer will probably notice only a minor degradation of the service performance, or a slight impact on a subsequent action; i.e., some quick, minor rework.	**2**
Moderate	Failure causes some customer dissatisfaction. Customer is made uncomfortable or is annoyed by the failure. Customer will experience some very noticeable inconvenience or performance degradation. May cause either delay due to rework or irreversible damage.	**4,5,6**
High	High degree of customer dissatisfaction due to the negative impact of the failure such as an innacurate payroll run, loss of vital data or an inoperable convenience system (i.e., computer crashes). Does *not* involve safety or noncompliance to government regulations. May cause serious disruption to subsequent processing; may require major rework or loss to customer and/or create significant financial hardship.	**7,8**
Very High	Failure mode involves serious personal safety hazards, potential for civil litigation or noncompliance with government regulations.	**9,10**

5. Identify potential causes that would lead to each failure.

6. Assign a frequency ranking based on the following table:

TABLE II: FREQUENCY RATING SCALE [8]

[redacted]

7. Identify the current controls that are aimed at mitigating each risk.

8. Assign a detection rating, from the following table:

TABLE III: DETECTION RATING SCALE [8]

[redacted]

9. Calculate the risk priority number (RPN) of each risk using the following equation:

$$RPN = (Severity\ Rating) * (Frequency\ Rating) * (Detection\ Rating)$$

Equation1: Risk priority number calculation

10. Assign recommendation to each risk based on the RPN. General guide lines for assigning recommendations are outlined in the following table:

TABLE IV: GUIDELINE FOR ASSIGNING RECOMMENDED ACTIONS [8]

Severity	Frequency	Detection	Result	Actions
1	1	1	Ideal Situation	Monitor
1	1	10	Assured Mastery	Monitor
10	1	1	Failure does not reach user	Monitor
10	1	10	Failure reaches user	Act
1	10	1	Frequently fails, detectable, costly	ACT
1	10	10	Frequently fails, reaches user	ACT!
10	10	1	Frequently fails with major impact	*ACT!*
10	10	10	Big Trouble	***ACT!***

APPENDIX E BILL OF MATERIALS

The following Bill of Materials was developed for the Fan Deck Completion System designed by Streamline Systems for Duha Group.

Table I: Bill of Materials

Item	Qty	Description
1	1	Dorner 3200 Series Indexing Conveyor
2	2	Hickock Duplex Round Corner Die Cutter
3	1	Weber Z-150C Step Feeder
4	1	Weber ZEB-240C Vibratory Bowl Feeder
5	1	Weber LCI-10 Post Insertion System
6	1	Weber SEB-10 Auto Feed Screw Driver
7	12	12" Dorner Adjustable Height Stand with Fixed Foot Pads
8	6	30" Dorner Adjustable Height Stand with Fixed Foot Pads
9	3	Loading Actuator Head (Spring Loaded)
10	2	Unloading Actuator Head
11	2	Die Cutter Guides
12	4	900 mm Festo Actuator
13	1	300 mm Festo Actuator
14	4	900 mm Festo Actuator Support
15	1	300 mm Festo Actuator Support
16	2	Velmex X-Y Table
17	1	16" x 16" Support Table
18	2	48" x 30" Support Table
19	1	24" x 30" Support Table
20	1	90° V-Guide
21	1	48" x 30" - 1/2" Rubber Mat
22	2	Anit-Fatigue Mat
23	66	1/4" - 20 UNC - 3.5" Hex Bolt
24	42	1/4" - 20 UNC - 3" Hex Bolt
25	120	1/4" Lock Washer
26	120	1/4" Steel Washer
27	120	1/4" - 20 UNC Hex Nuts