MFGE 421 – Automation and System Design

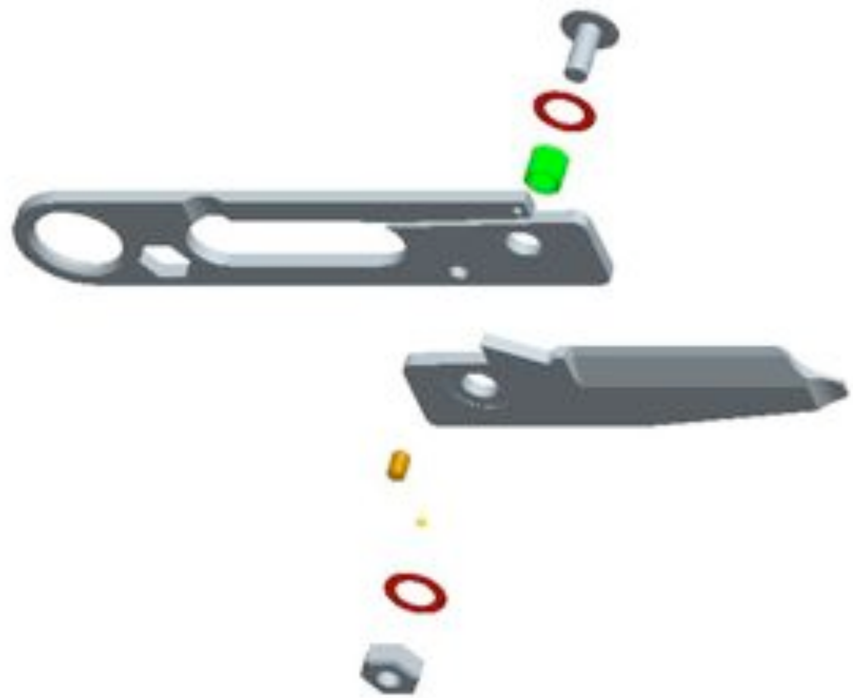
MFGE 422 – Manufacturing Facility Planning

Capstone Term Project

Nicholas Yax

May 6, 2009

Contents



Explode State Default Explode

DFMA

Design for Manufacturing and Automation

<u>Suggested modifications</u>

Rather than using a screw and nut as a fastener, a riveted assembly would remove the need for screwing the components together and could be accomplished with a single fastener rather than a two-piece fastener. This would also decrease the projection of the fastener, reducing the space taken up in final packaging.

Should a rivet not be possible, the use of a symmetrical nut rather than a cap nut would ease the orientation of the nuts, resulting in a cost saving on machinery required.

The inclusion of the pin and ball as a feature of the frame, rather than discrete components, would remove two parts required for the assembly, and thereby their orientation and assembly steps. While this would require the use of thicker material for the frame and the removal of much of that material, it could be a viable option. Research on the pricing of this alternative would need to be carried out before a final decision could be made.

Making the blade symmetrical by beveling the knife and screwdriver blade on both sides as well as eliminating the countersink would eliminate half the possible orientations, and make the mart easier to orient for feeding.

Assembly Overview

Line Type

The assembly line chosen is an inline synchronous line. In this type of system all parts index at the same time, and flow in a straight line. Empty fixtures return to the start of the line automatically, removing the need to collect them and return either by the operator or a secondary conveyor.

As no manual labor is performed, there is no need for a buffer to allow for variable speed of manual operations, a possible drawback of synchronous systems.

The speeds possible via this type of system are compatible with those required for this part.

The station time for a synchronous system is the slowest stations time plus the index time. As 12 parts per minute is requested, this allows for a maximum 5 second station time. The slowest station, shown later in the sequencing forms, is 2.46 seconds. This allows for a significant factor of safety and should provide adequate indexing time.

Controls

Each station will utilize it's own PLC controller, which controls the feeding and assembly operations at that station. This takes inputs from the limit switches on the pick-and-place for that station, as well as the photoelectric sensor used to verify a new part to assemble is present, and outputs controls to the pick-and-place and the feeder line. It will also communicate to the master PLC if a problem occurs and the line needs to be stopped, and turns on a light to alert the operator which station requires attention.

A "master" plc is also located along the line, which indexes the line at appropriate times and stops the line if any of the stations have a problem.

Sensing

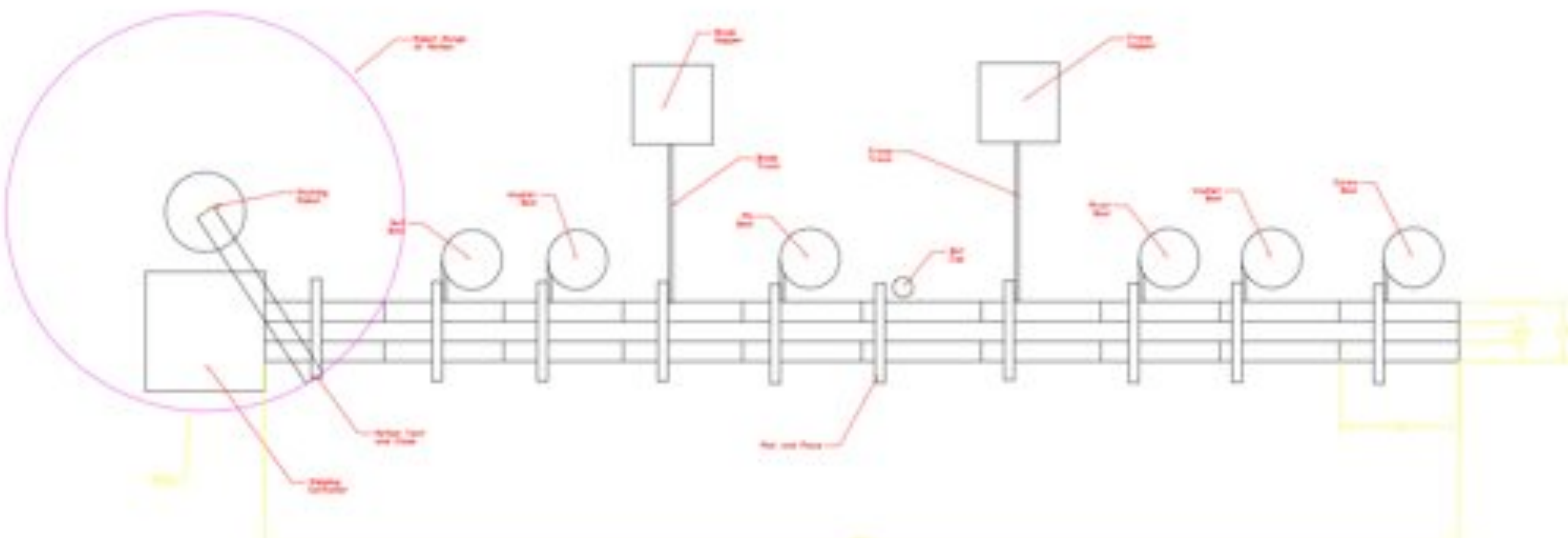
Photoelectric sensors will be used at each station to detect fixture presence before proceeding. While in a synchronous system all stations should receive a part simultaneously, it is still possible that a fixture is out of position or missing. For this reason, work will be done only if a fixture is known to be present to prevent possible damage. This sensor will not be used to begin work, however, only to enable work to be done. The system will send the signal to begin work as soon as indexing has stopped, controlled by a master PLC.

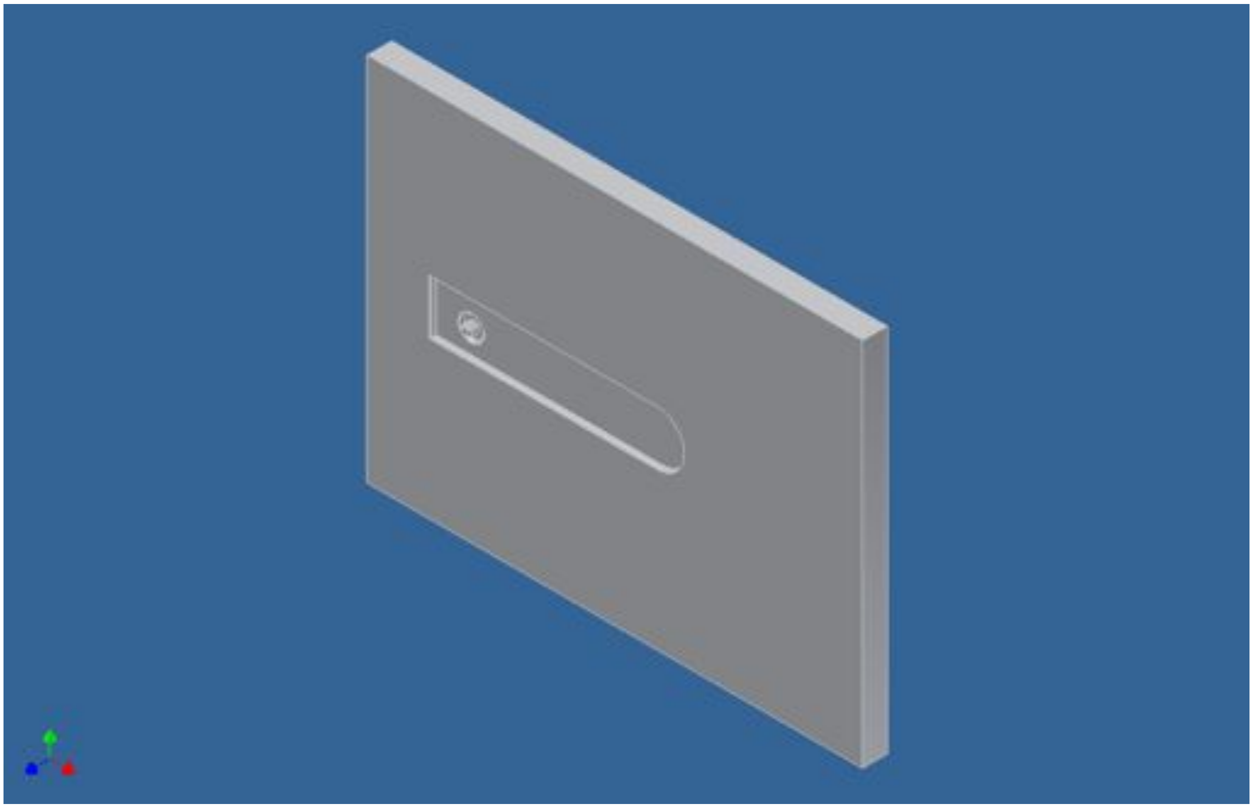
As mentioned above, each station also utilizes a photoelectric sensor to verify part presence. This ensures that a part is being assembled to the assembly.

Mechanical limit switches are used on the pick-and-place mechanisms to detect what position they are in (slide extended, cylinder retracted, etc…). These are also utilized to verify that the motion test was passed.

Vacuum

In the places where it is required, local venturi modules create vacuum pressure. As there are few devices that utilize vacuum, an aspirator system was not felt to be warranted.

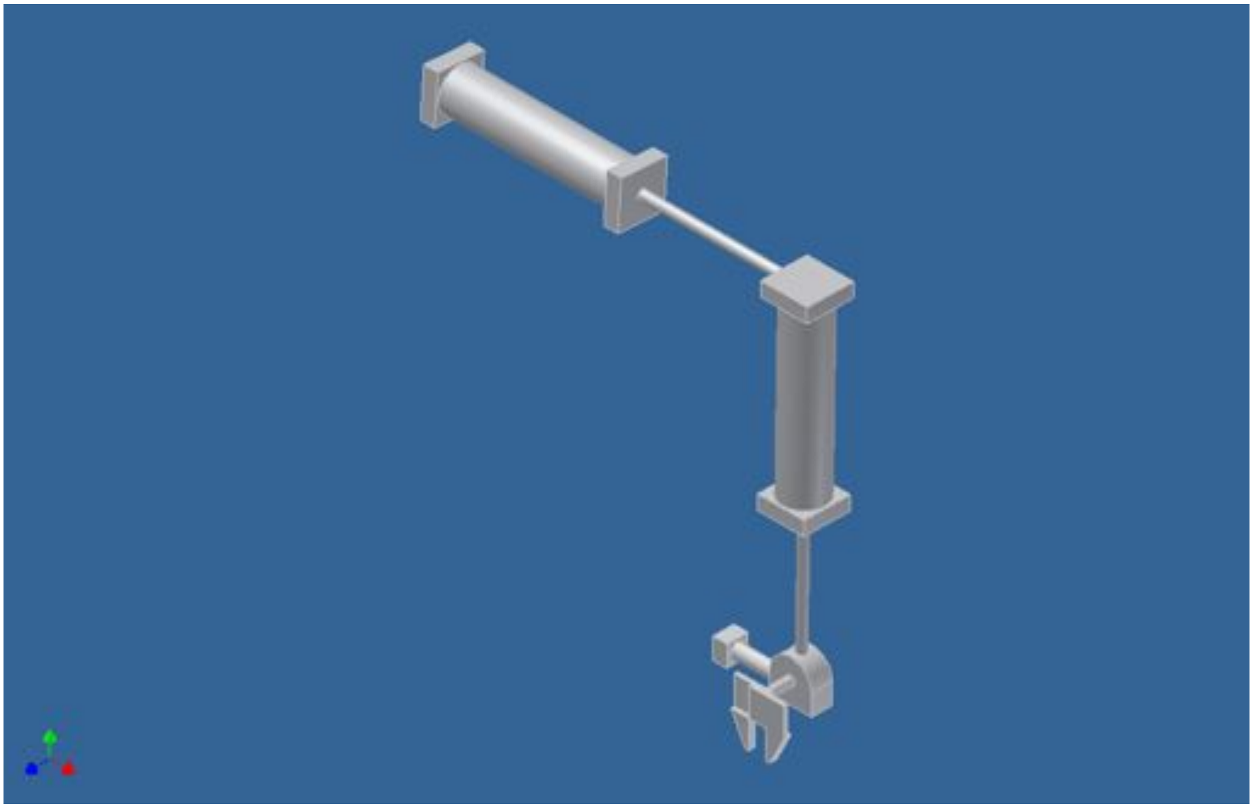




Assembly Fixture

All assembly takes place on a single assembly pallet, which moves from station to station and is fixed to the conveyor system. The pallet has an inset to fit the frame (to hold it tight while screwing on the nut and while testing motion) and a projection to hold the screw in place.

It would be made of a plastic material for lower cost, as steel pallets would be cost prohibitive. As a limited number are required, they would likely be machined from solid pieces, as building an injection mold die would not be cost effective for such a quantity.



Pick and Place

This is an example of the type of pick-and-place mechanism would be used. It consists of a horizontal slide, vertical cylinder, rotator, and gripper. As they are modular components, the rotator may be removed or mounted at different angles as required for the situation. The gripper may also be changed as necessary for the particular item being used.

Depending on the weights being lifted, the slide may include support bars to decrease rod sideload. As the parts involved in this assembly are rather light, they should not pose a problem, but the combined weight of the vertical cylinder and rotator will likely necessitate additional support. For this reason, a cantilever slide is suggested, to provide additional support without the possibility of interference.

The cylinders would preferably be pneumatic for fast and clean operation. Hydraulic may be used, but must be capable of the required speeds, and must be maintained to prevent leaking. Electric linear actuators may also be used, but would be more expensive, and are not necessary.

FERRIS STATE UNIVERSITY
MODULAR AUTOMATION PLANNING WORKSHEET

Engineer:	Nicholas Yax	Project:	MFGE Senior Project	Date:	5/6/09
Operation:	Screw Assembly			Sheet	1 of 10

Step	Motion	Time allowed	Distance	Rotation
1	Extend Cylinder	0.40	8	
2	Close Gripper	0.02	1	
3	Retract Cylinder	0.40	8	
4	Extend Slide	0.36	18	
5	Rotate Gripper CW	0.05		180
6	Extend Cylinder	0.40	8	
7	Open Gripper	0.02	1	
8	Retract Cylinder	0.40	8	
9	Rotate Gripper CCW	0.05		180
10	Retract Slide	0.36	18	
11				
12				

TOTAL 2.46

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MODULAR AUTOMATION PLANNING WORKSHEET

Engineer:	Nicholas Yax	**Project:**	MFGE Senior Project	**Date:**	5/6/09
Operation:	Washer 1 Assembly			**Sheet**	2 of 10

Step	Motion	Time allowed	Distance	Rotation
1	Extend Cylinder	0.40	8	
2	Close Gripper	0.02	1	
3	Retract Cylinder	0.40	8	
4	Extend Slide	0.36	18	
5	Extend Cylinder	0.40	8	
6	Open Gripper	0.02	1	
7	Retract Cylinder	0.40	8	
8	Retract Slide	0.36	18	
9				
10				
11				
12				

TOTAL 2.36

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MODULAR AUTOMATION PLANNING WORKSHEET

Engineer:	Nicholas Yax	**Project:**	MFGE Senior Project	**Date:**	5/6/09
Operation:	Pivot Assembly			**Sheet**	3 of 10

Step	Motion	Time allowed	Distance	Rotation
1	Extend Cylinder	0.40	8	
2	Close Gripper	0.02	1	
3	Retract Cylinder	0.40	8	
4	Extend Slide	0.36	18	
5	Rotate Gripper CW	0.03		90
6	Extend Cylinder	0.40	8	
7	Open Gripper	0.02	1	
8	Retract Cylinder	0.40	8	
9	Rotate Gripper CCW	0.03		90
10	Retract Slide	0.36	18	
11				
12				

TOTAL 2.42

FERRIS STATE UNIVERSITY
MODULAR AUTOMATION PLANNING WORKSHEET

Engineer:	Nicholas Yax	**Project:**	MFGE Senior Project	**Date:**	5/6/09
Operation:	Frame Assembly			**Sheet**	4 of 10

Step	Motion	Time allowed	Distance	Rotation
1	Extend Cylinder	0.40	8	
2	Close Gripper	0.02	1	
3	Retract Cylinder	0.40	8	
4	Extend Slide	0.36	18	
5	Rotate Gripper CW	0.03		90
6	Extend Cylinder	0.40	8	
7	Open Gripper	0.02	1	
8	Retract Cylinder	0.40	8	
9	Rotate Gripper CCW	0.03		90
10	Retract Slide	0.36	18	
11				
12				

TOTAL 2.42

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MODULAR AUTOMATION PLANNING WORKSHEET

Engineer:	Nicholas Yax	**Project:**	MFGE Senior Project	**Date:**	5/6/09
Operation:	Ball Assembly			**Sheet**	5 of 10

Step	Motion	Time allowed	Distance	Rotation
1	Extend Cylinder	0.40	8	
2	Enable Vacuum	0.02	1	
3	Retract Cylinder	0.40	8	
4	Extend Slide	0.36	18	
5	Extend Cylinder	0.40	8	
6	Disable Vacuum	0.02	1	
7	Retract Cylinder	0.40	8	
8	Retract Slide	0.36	18	
9				
10				
11				
12				

TOTAL 2.36

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MODULAR AUTOMATION PLANNING WORKSHEET

Engineer:	Nicholas Yax	**Project:**	MFGE Senior Project	**Date:**	5/6/09
Operation:	Pin Assembly			**Sheet**	6 of 10

Step	Motion	Time allowed	Distance	Rotation
1	Extend Cylinder	0.40	8	
2	Enable Vacuum	0.02	1	
3	Retract Cylinder	0.40	8	
4	Extend Slide	0.36	18	
5	Rotate Gripper CW	0.03		90
6	Extend Cylinder	0.40	8	
7	Disable Vacuum	0.02	1	
8	Retract Cylinder	0.40	8	
9	Rotate Gripper CCW	0.03		90
10	Retract Slide	0.36	18	
11				
12				

TOTAL 2.42

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MODULAR AUTOMATION PLANNING WORKSHEET

Engineer:	Nicholas Yax	**Project:**	MFGE Senior Project	**Date:**	5/6/09
Operation:	Blade Assembly			**Sheet**	7 of 10

Step	Motion	Time allowed	Distance	Rotation
1	Extend Cylinder	0.40	8	
2	Close Gripper	0.02	1	
3	Retract Cylinder	0.40	8	
4	Extend Slide	0.36	18	
5	Rotate Gripper CW	0.05		180
6	Extend Cylinder	0.40	8	
7	Open Gripper	0.02	1	
8	Retract Cylinder	0.40	8	
9	Rotate Gripper CCW	0.05		180
10	Retract Slide	0.36	18	
11				
12				

TOTAL 2.46

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MODULAR AUTOMATION PLANNING WORKSHEET

Engineer:	Nicholas Yax	**Project:**	MFGE Senior Project	**Date:**	5/6/09
Operation:	Washer 2 Assembly			**Sheet**	8 of 10

Step	Motion	Time allowed	Distance	Rotation
1	Extend Cylinder	0.40	8	
2	Close Gripper	0.02	1	
3	Retract Cylinder	0.40	8	
4	Extend Slide	0.36	18	
5	Extend Cylinder	0.40	8	
6	Open Gripper	0.02	1	
7	Retract Cylinder	0.40	8	
8	Retract Slide	0.36	18	
9				
10				
11				
12				

TOTAL 2.36

FERRIS STATE UNIVERSITY
MODULAR AUTOMATION PLANNING WORKSHEET

Engineer:	Nicholas Yax	**Project:**	MFGE Senior Project	**Date:**	5/6/09
Operation:	Nut Assembly			**Sheet**	9 of 10

Step	Motion	Time allowed	Distance	Rotation
1	Extend Cylinder	0.40	8	
2	Close Gripper	0.02	1	
3	Retract Cylinder	0.40	8	
4	Extend Slide	0.36	18	
5	Rotate Gripper CW	0.07		540
6	Extend Cylinder	0.40	8	
7	Open Gripper	0.02	1	
8	Retract Cylinder	0.40	8	
9	Rotate Gripper CCW	0.07		540
10	Retract Slide	0.36	18	
11				
12				

TOTAL 2.50

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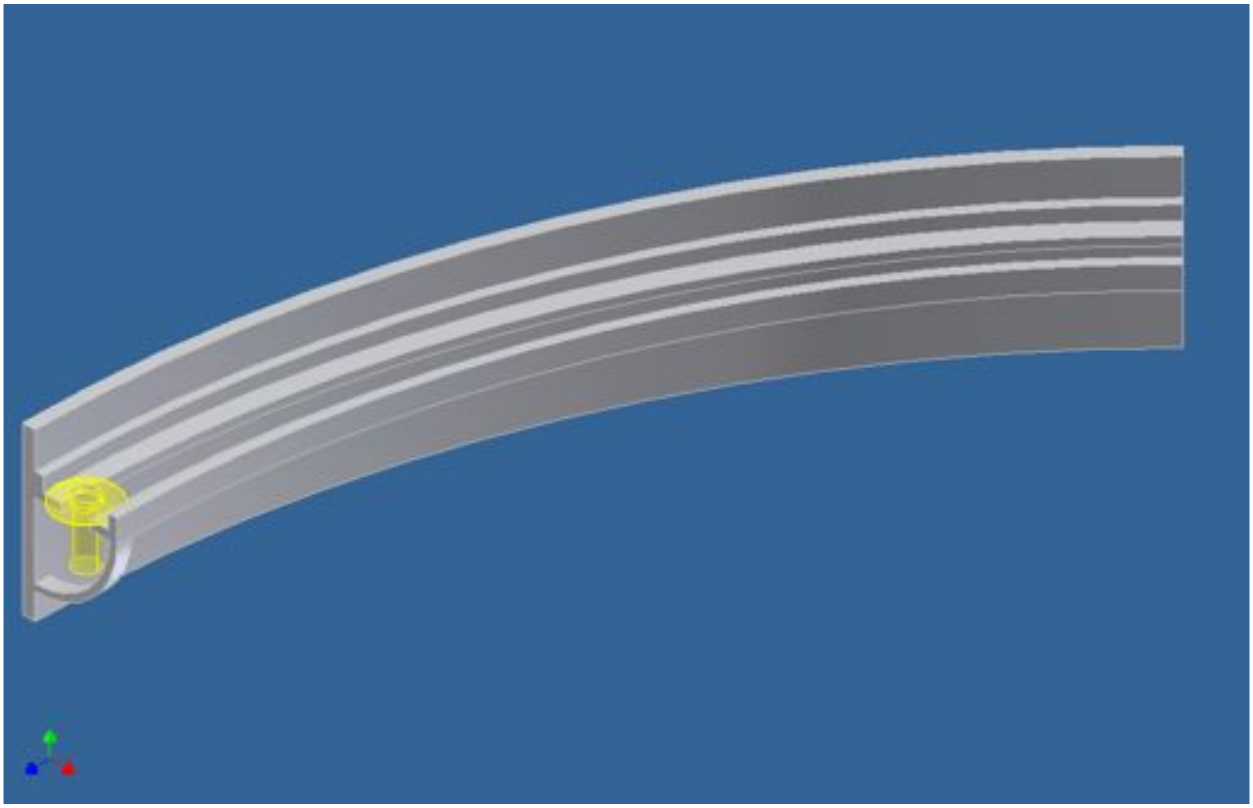
MODULAR AUTOMATION PLANNING WORKSHEET

Engineer:	Nicholas Yax	**Project:**	MFGE Senior Project	**Date:**	5/6/09
Operation:	Motion Check			**Sheet**	10 of 10

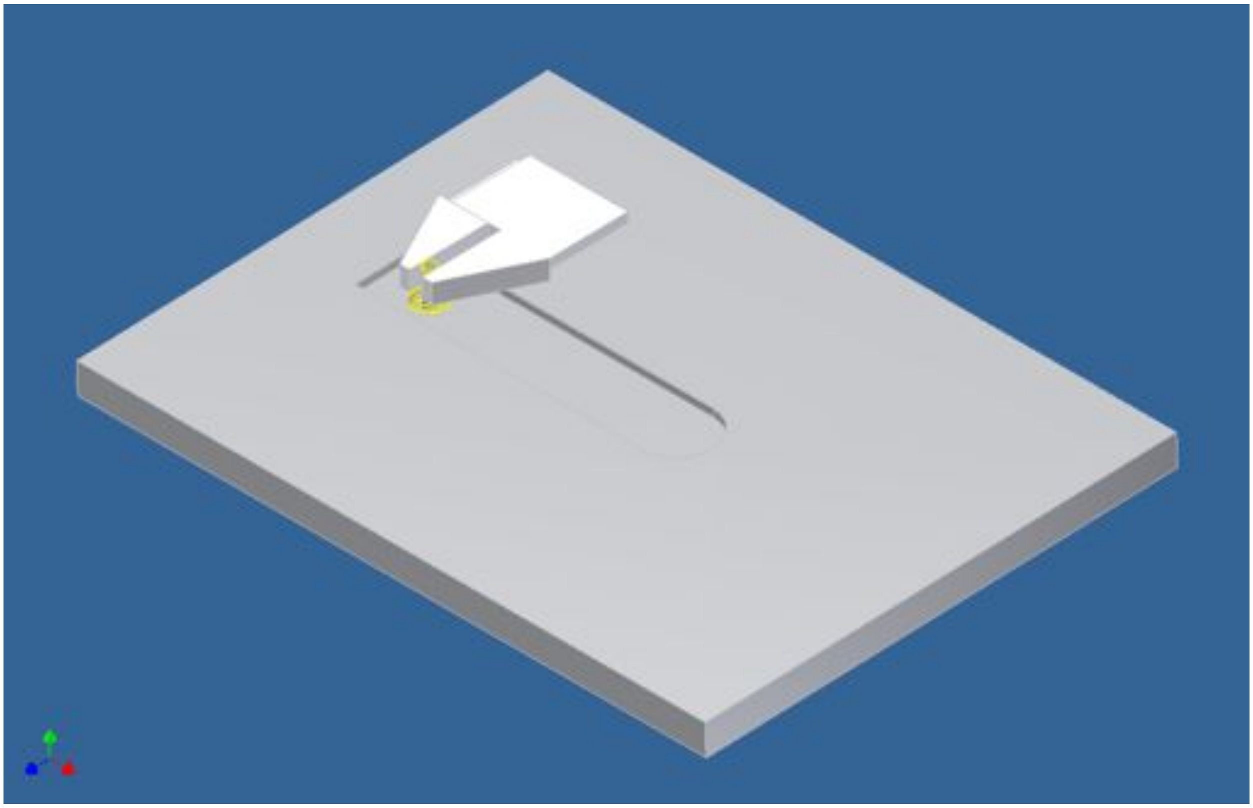
Step	Motion	Time allowed	Distance	Rotation
1	Extend Cylinder	0.40	8	
2	Rotate CW	0.05		180
3	Rotate CCW	0.05		180
4	Retract Cylinder	0.40	8	
5				
6				
7				
8				
9				
10				
11				
12				

TOTAL 0.90



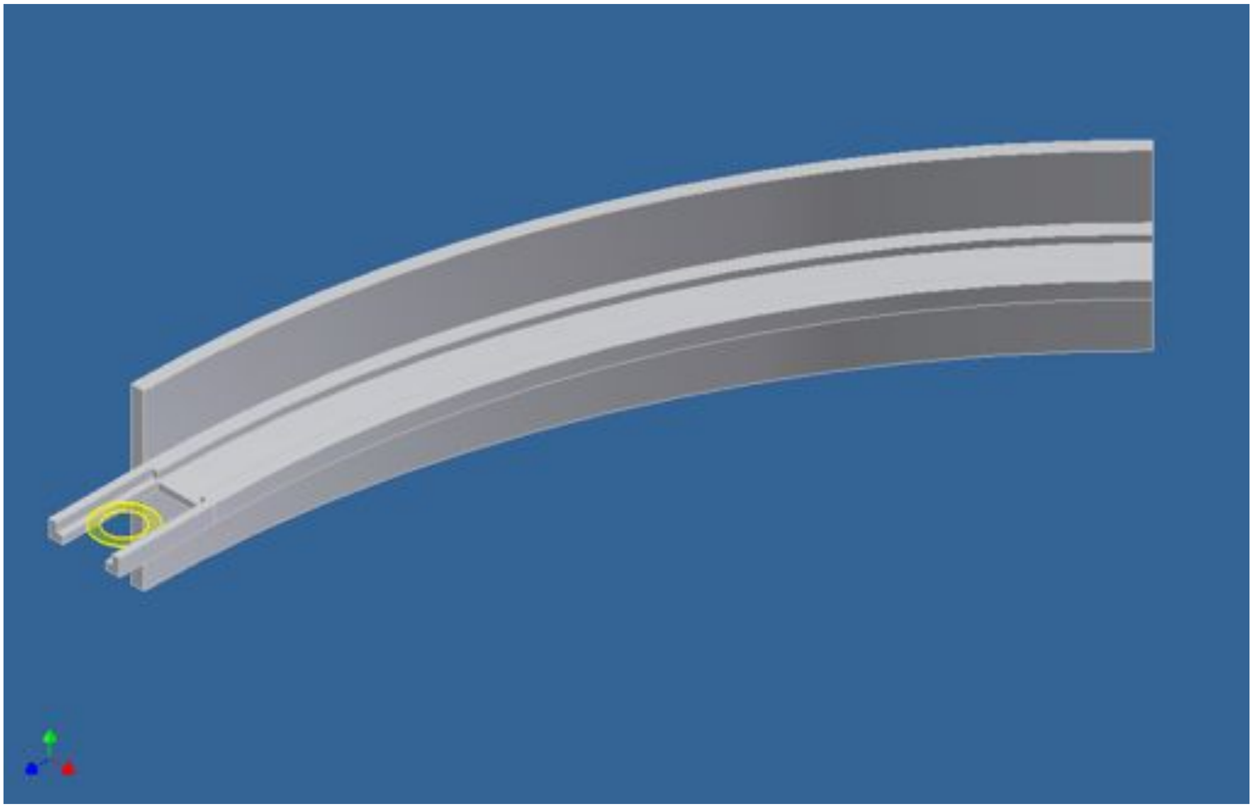
Screw Orientation

To orient the screw, a vibratory bowl feeder was selected. The track will contain an opening in which the threaded portion of the screw can fall, allowing it to ride along on the bottom of its head. This method allows for all possible orientations to be sorted and kept.



Screw Assembly

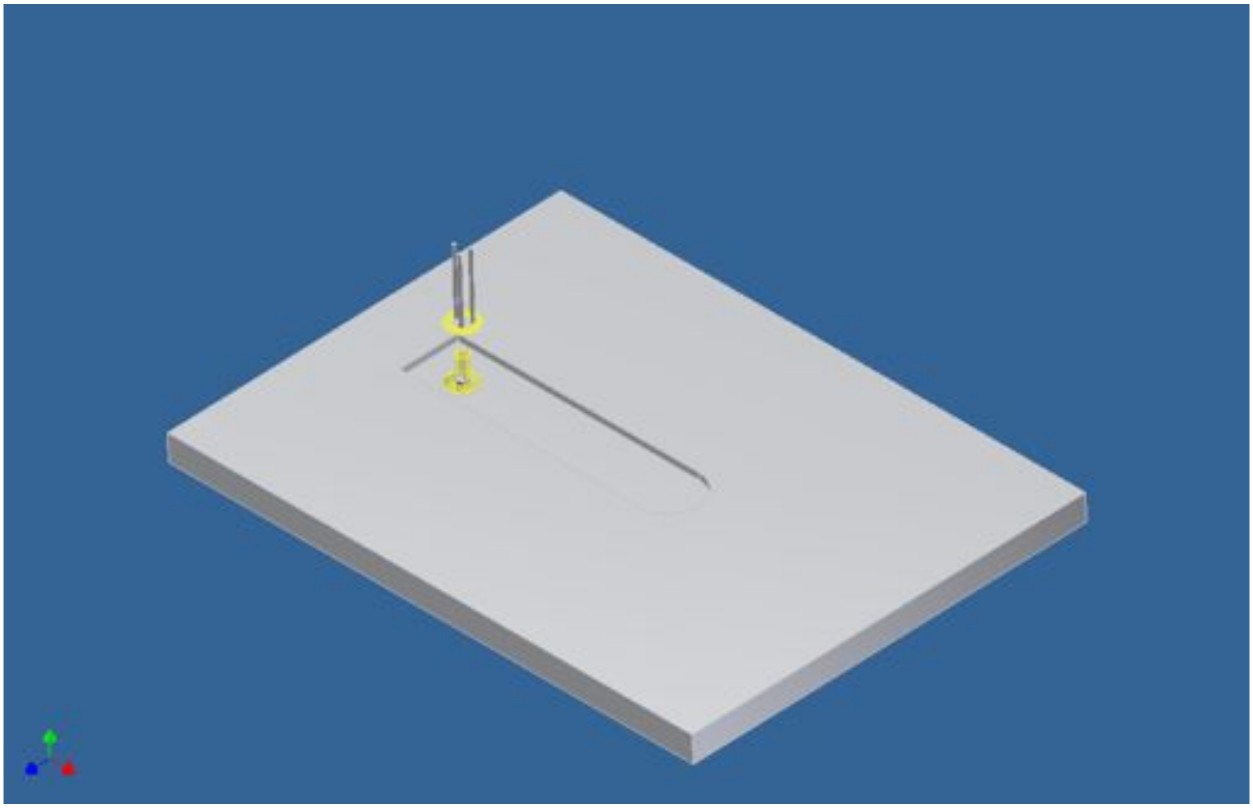
To place the screw, it is picked up from the bowl feeder by the pick-and-place, rotated 180˚, and placed on the hex protrusion in the fixture. The gripper at this station should be made of a nylon-like plastic, to allow the screw to rotate slightly as it is pressed down on the protrusion, which is rounded at the top, so that it will seat properly.



Washer Orientation

A vibratory bowl feeder is used to orient the washers at the second station. The track will contain a small groove on each side, into which the washers slip. Any washers stacked double high will be above the sidewall and slide off. There is no groove and the bottom is open at the end of the track to allow for easier pick up.

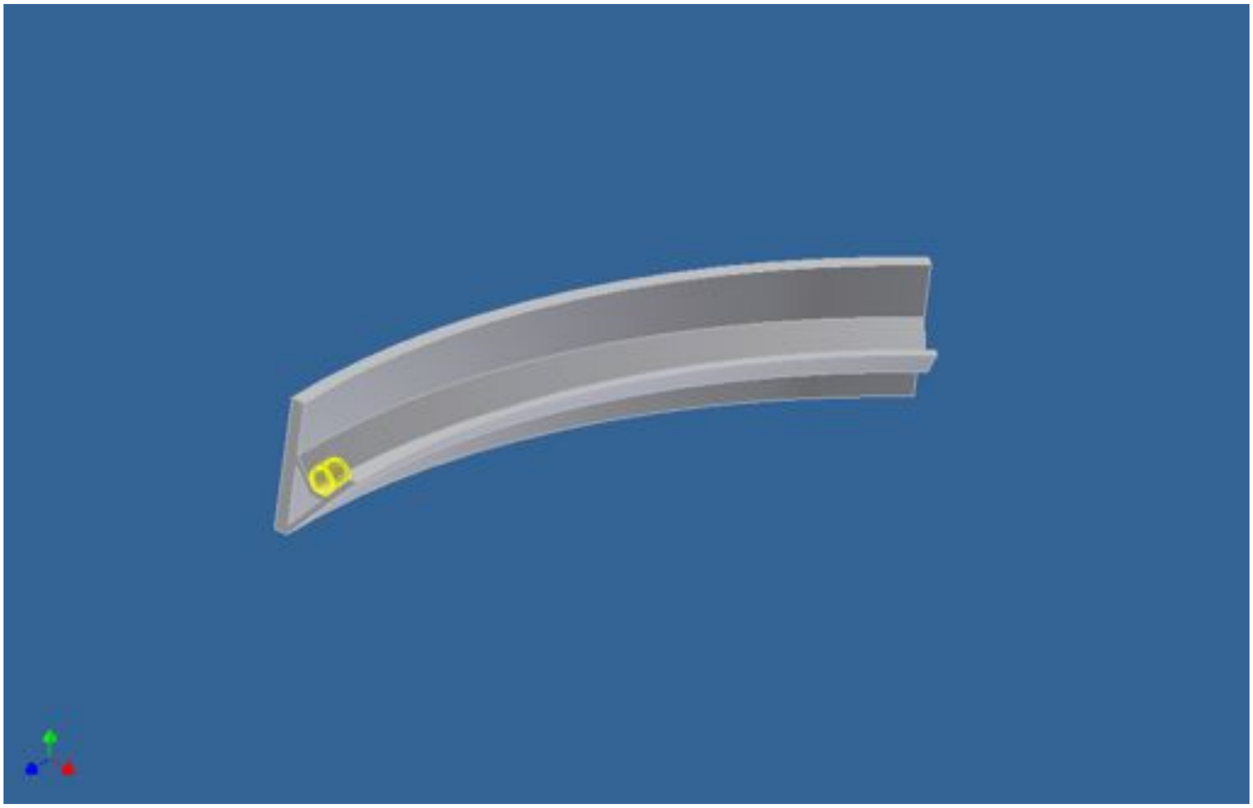
This orientation method is also used later, at station 8, to orient the second washer.



Washer 1 Assembly

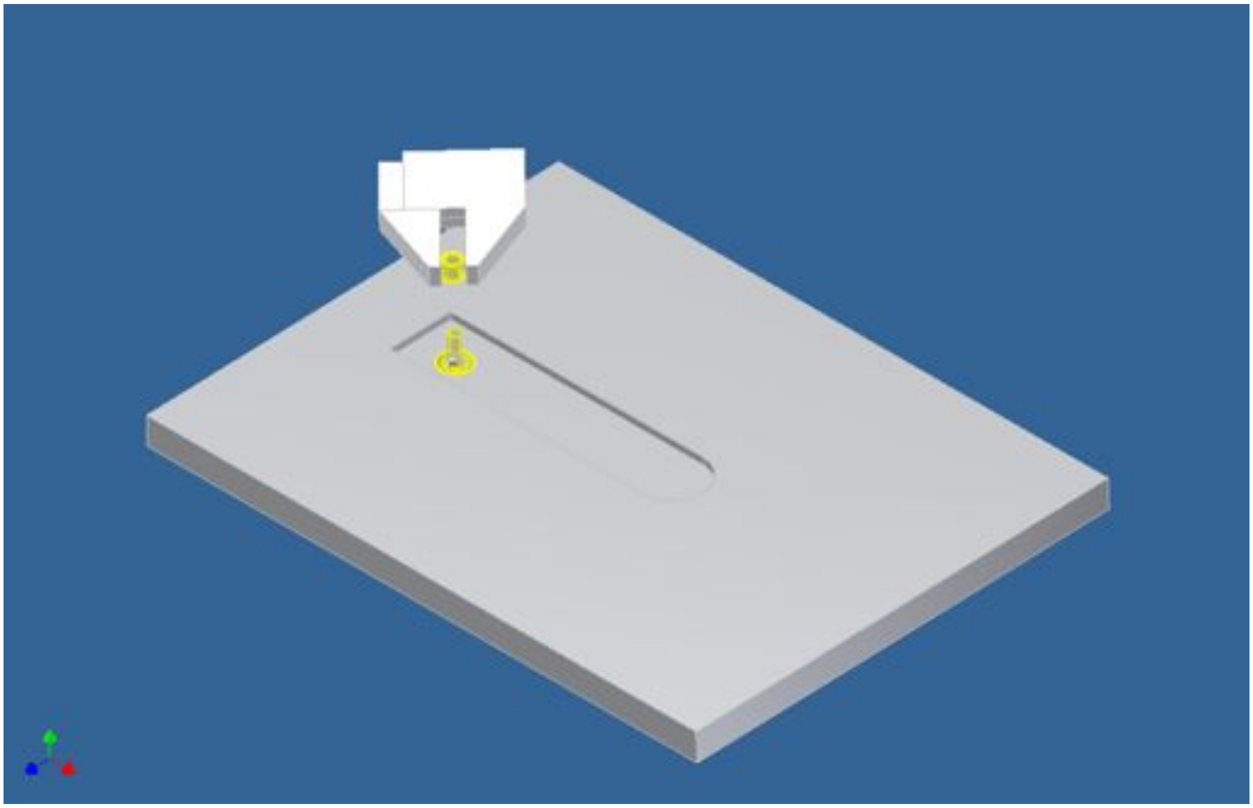
To assemble the washer, a three-pronged tool is inserted into the washer and expands to grip it. The pick-and-place then moves the washer over the screw, nearly touching it, then releases.

The prongs are, when expanded, slightly angled to prevent the washer from slipping off. It is not recommended that hooks be used at the bottom of the prongs, as these would likely snag often, causing incomplete assemblies.



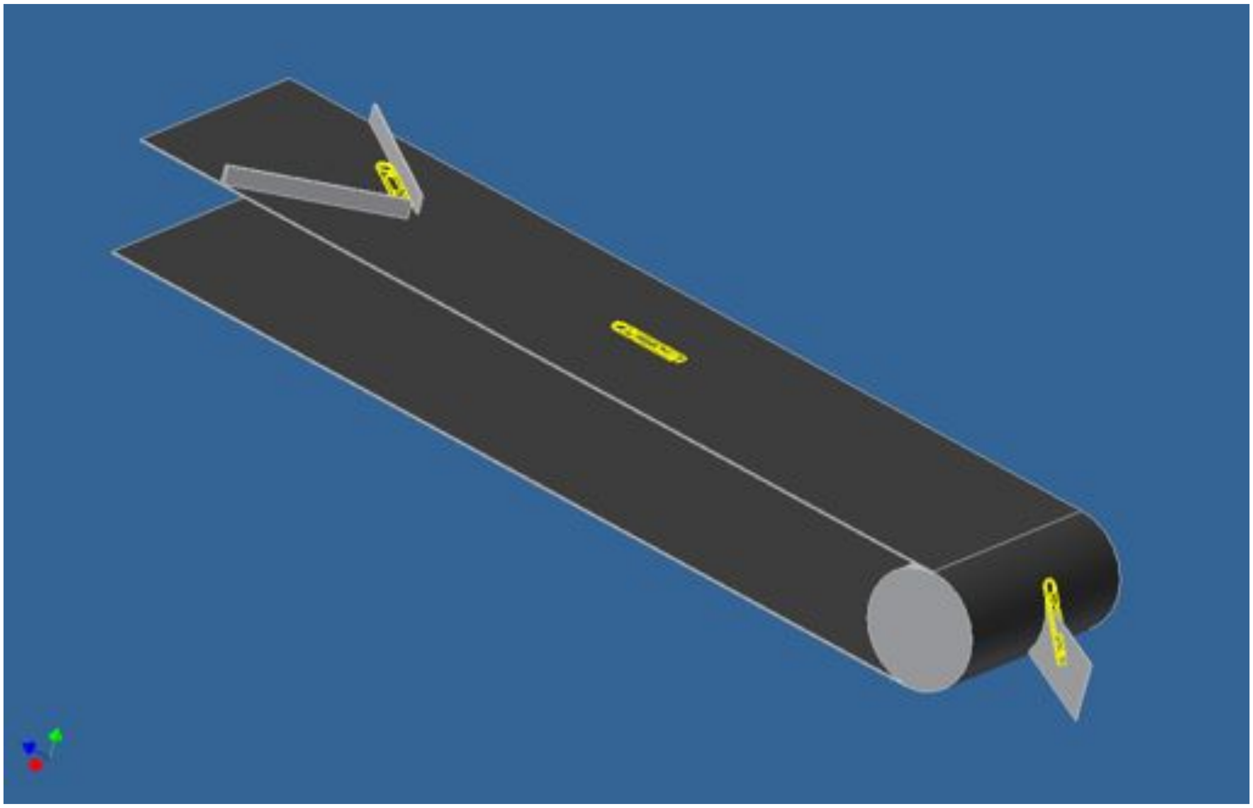
Pivot Orientation

A vibratory bowl feeder also orients the pivots. This track is V-shaped to allow the pivots to slide to the bottom of the track where they are fed forward. Misoriented parts either roll into proper position, or roll off the track to be fed again.



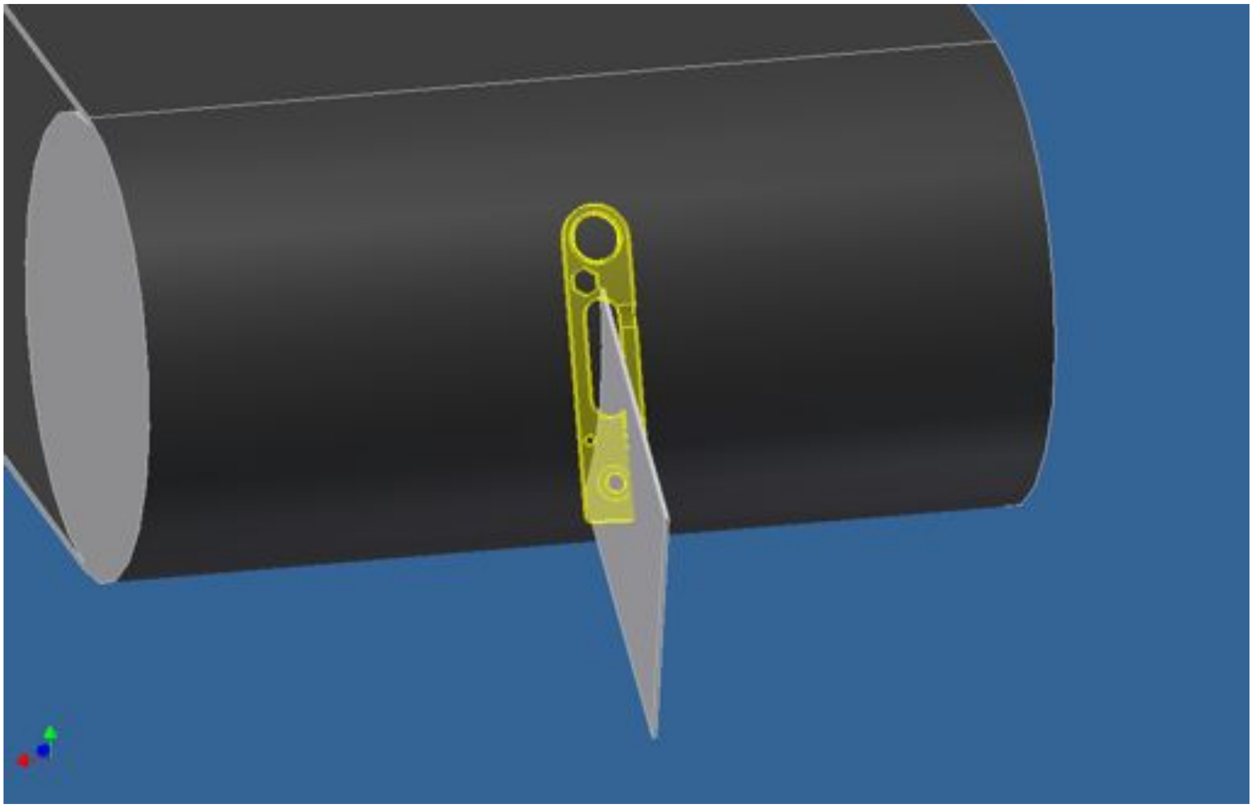
Pivot Assembly

To assemble the pivots, the pick-and-place picks them up from the feeder, rotates them 90˚, and places them onto the screw shaft. Because these are round components, angles jaws are not advised, as they may not be able to properly grip the part. Instead, either parallel or cupped jaws should be used.



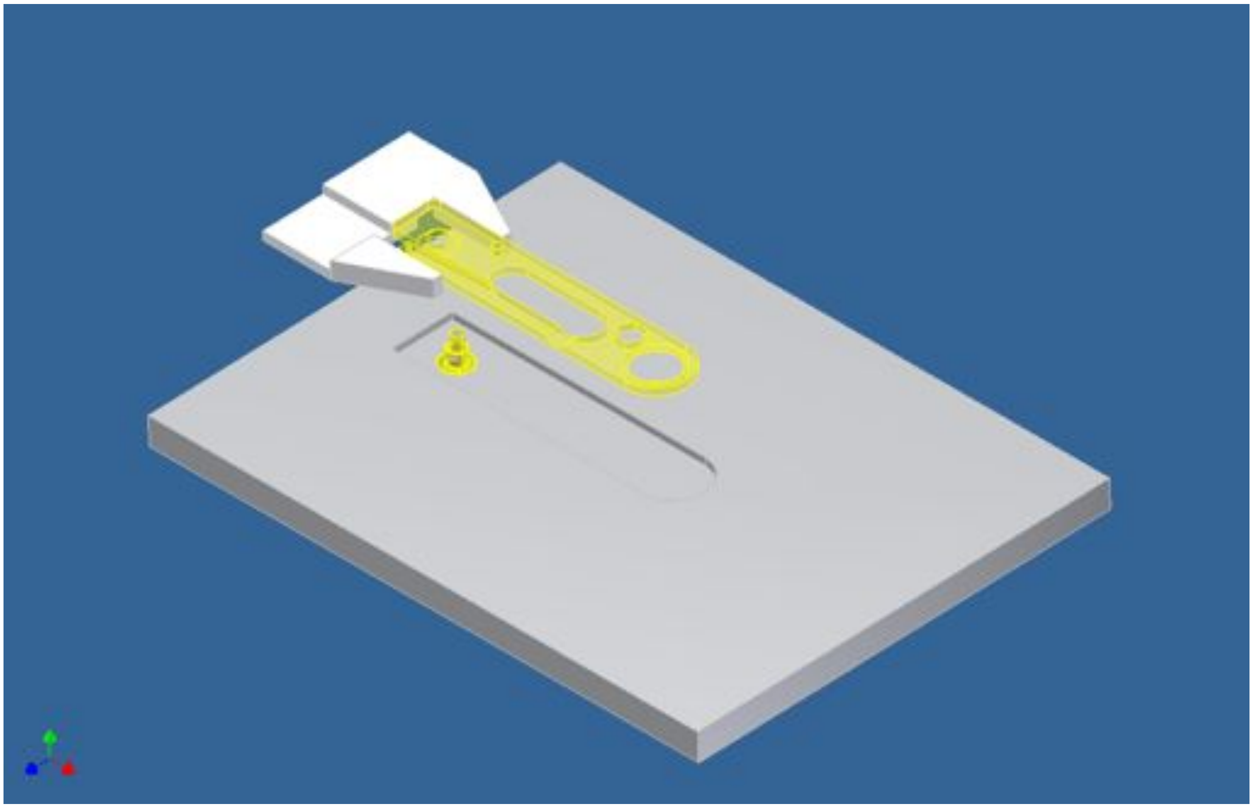
Frame Orientation

To orient the frames, they first feed along a belt out of a hopper. A brush ensures that only a single layer of parts is exiting. They then proceed to a pair of angled gates, which align the frames parallel to the belt and center them. Next, they fall onto a blade, which completes the final sort (explained more on next page). Any parts that are not caught by the blade (3 out of 4) are returned to the hopper via secondary belt feed.



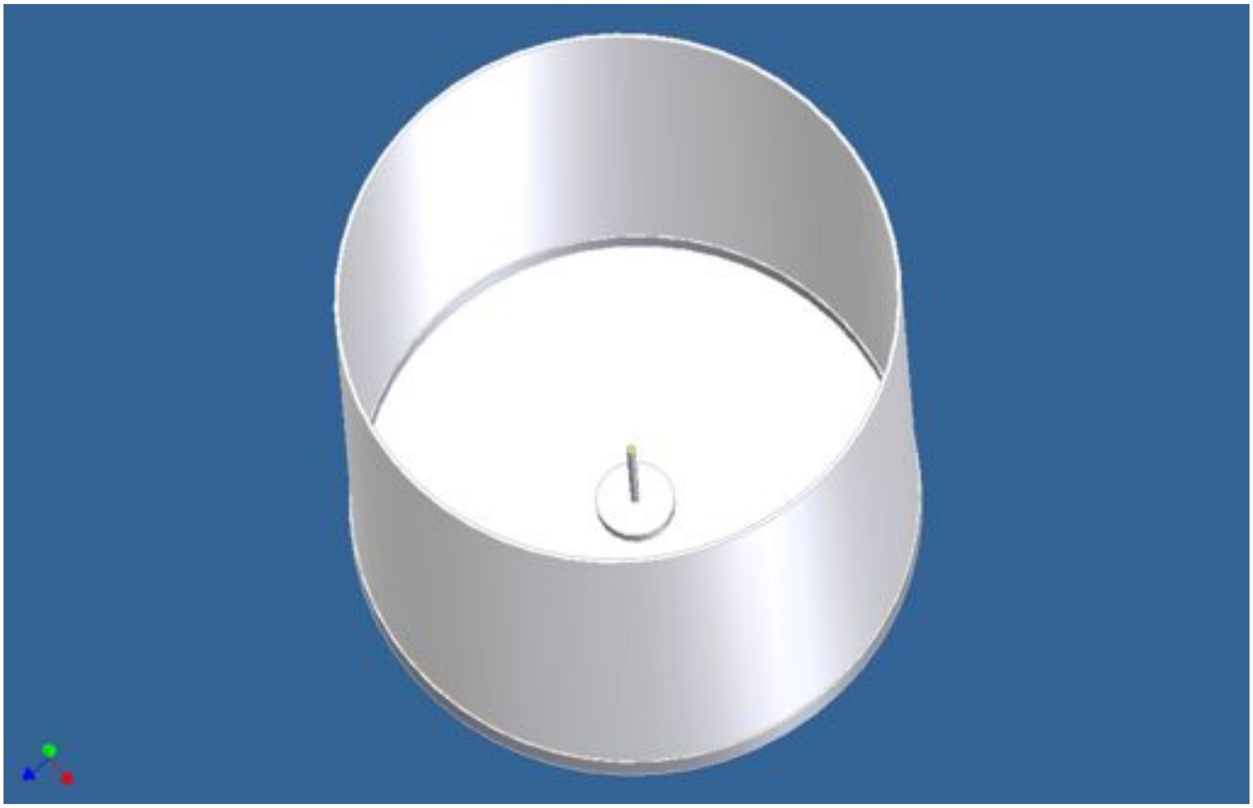
Frame Orientation - Detail

The blade is slightly smaller than the slot in the frame. As the frames approach, 25% will slide onto the blade and be carried to the assembly station. Those which are not properly oriented will not be picked up, and fall to a return conveyor to attempt orientation again.



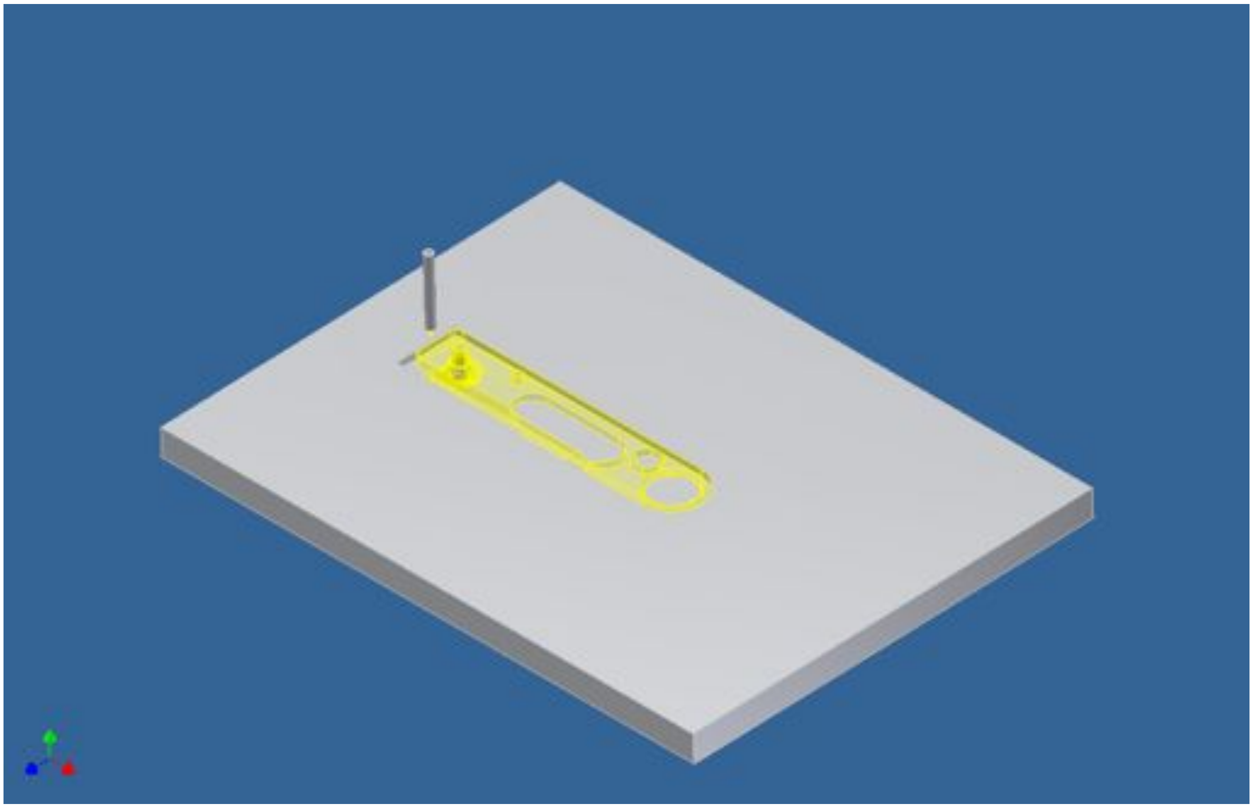
Frame Assembly

To assemble the frames, the pick-and-place takes them from the feeder (where they arrive vertical) and rotates them 90˚ (horizontal) before placing them into their inset in the fixture.



Ball Orientation

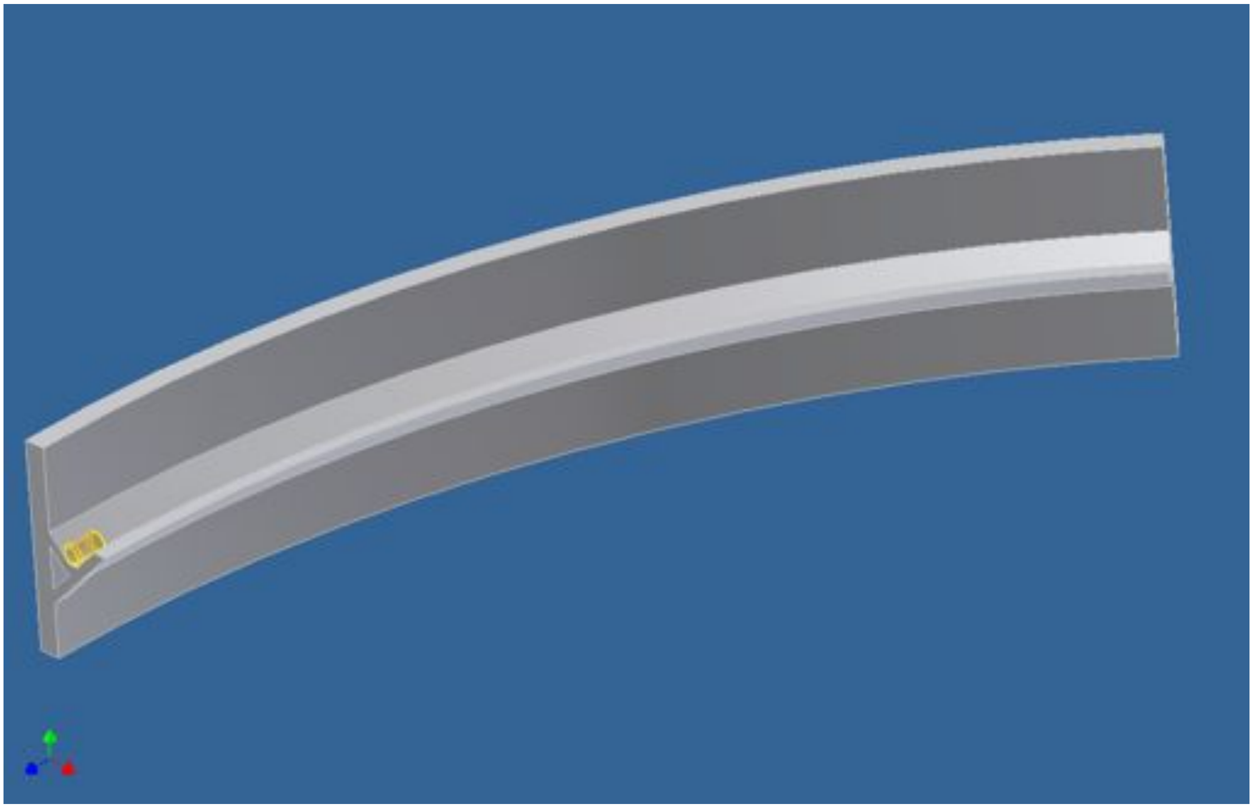
As ball bearings have only 1 orientation, this step is more for separating them. The balls are held in a cup, in which a piston with a small inset strokes up and down. When down, it is below the level of the balls, and picks one up on its trip back up.



Ball Assembly

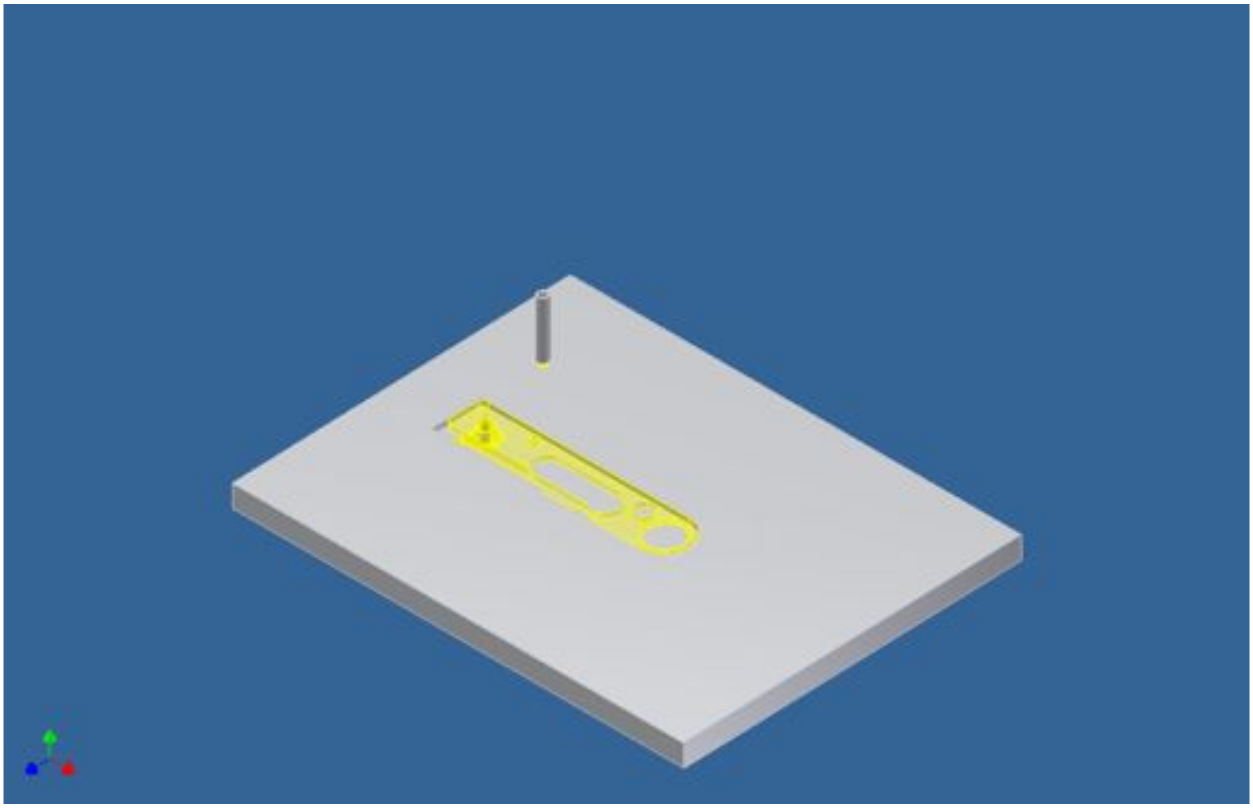
To assemble the ball bearing, the pick-and-place receives one from the feeder, holding it by vacuum pressure through a small tube. The decrease in airflow caused by receiving a ball bearing is used to ensure that one was picked up. The pick-and-place then moves the ball to its spot and presses it into the recess.

This tube will likely need to be changed semi-frequently, as the pressure of pressing the balls in will deform it over time.



Pin Orientation

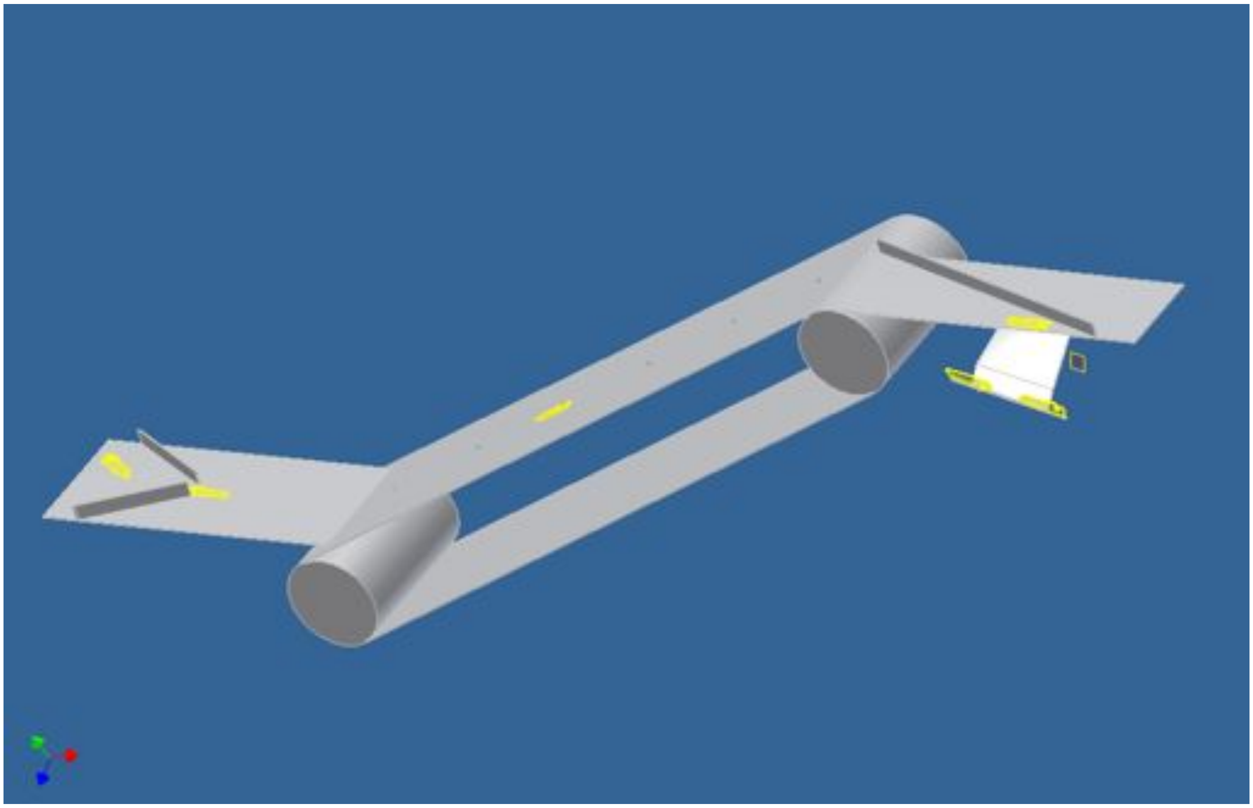
The pin is oriented much like the pivot, in a V-tracked vibratory bowl feeder. This track will have a smaller V, however, as the pin is of smaller diameter than is the pivot.



Pin Assembly

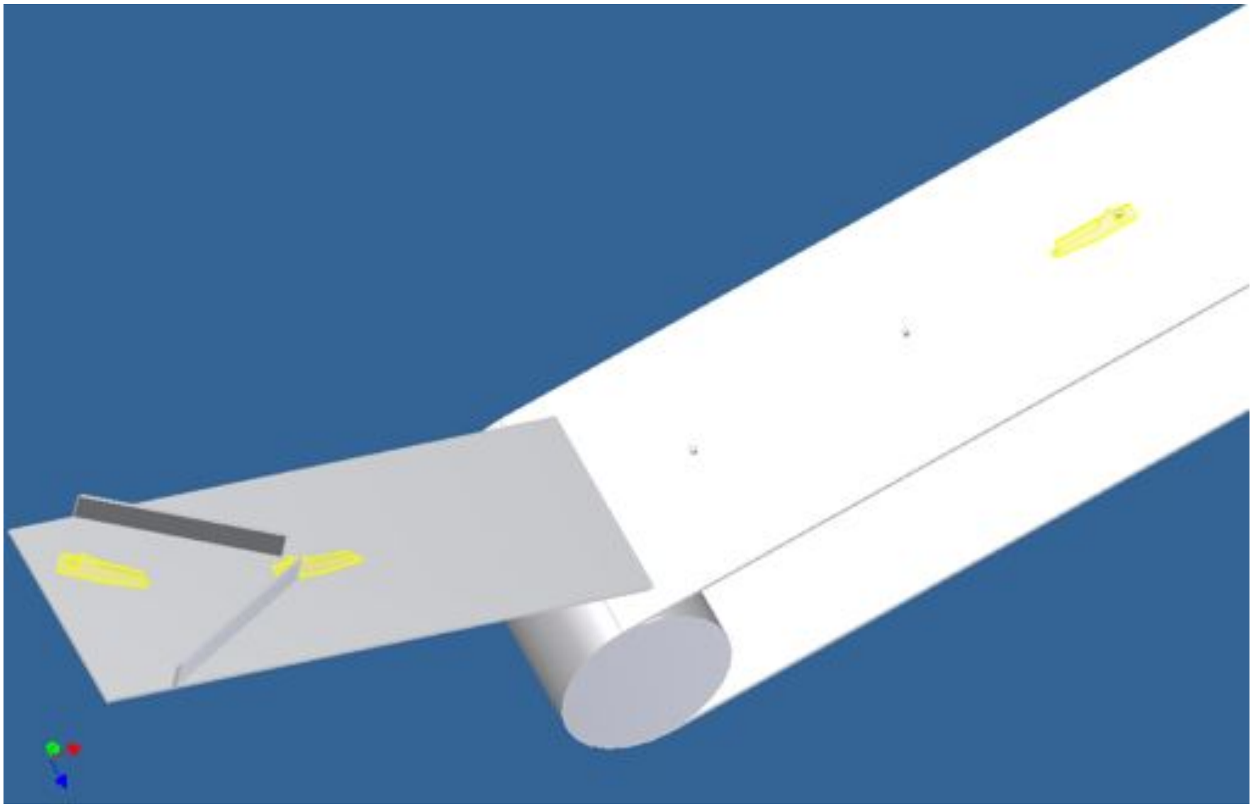
The pin is assembled by picking it up at the feeder using a vacuum tube, rotating the tube 90˚, and moving it too the proper position. It is then pressed into place by the tube. The end of the vacuum tube is tapered, to prevent the pin from sliding too far in, but allowing ~50% insertion.

Like the tube for the ball bearing, this tube will need to be replaced regularly as it will warp form the pressure of seating the pin.



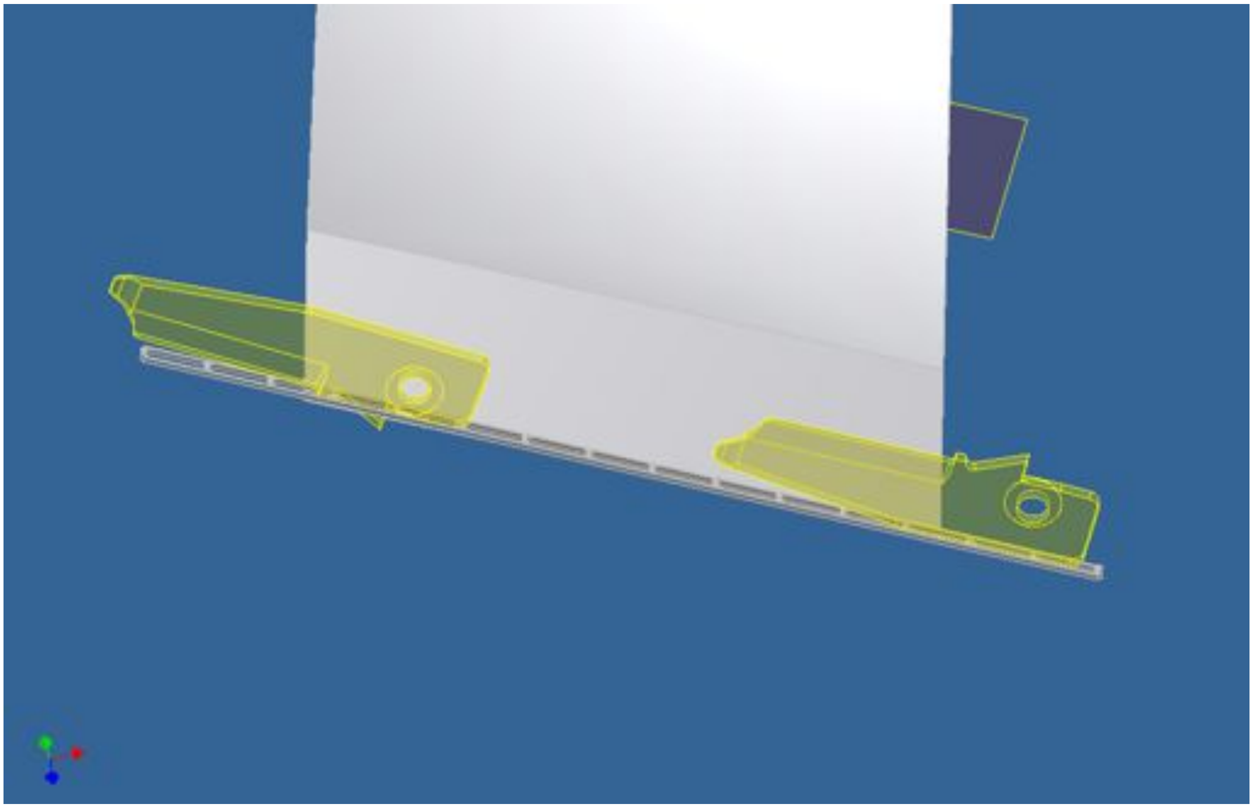
Blade Orientation - Overview

To orient the blades, a multi step process is used. The parts exit a hopper where a brush ensures a single layer. The blades then proceed through a pair of angled gates to align them parallel to the belt and center them. Next, the blades are moved onto an inclined belt, which has small nubs that hook into the screw hole of each blade, pulling them up the conveyor. Finally the blades are pushed off to a final sorter. These steps a re better detailed on the next two pages.



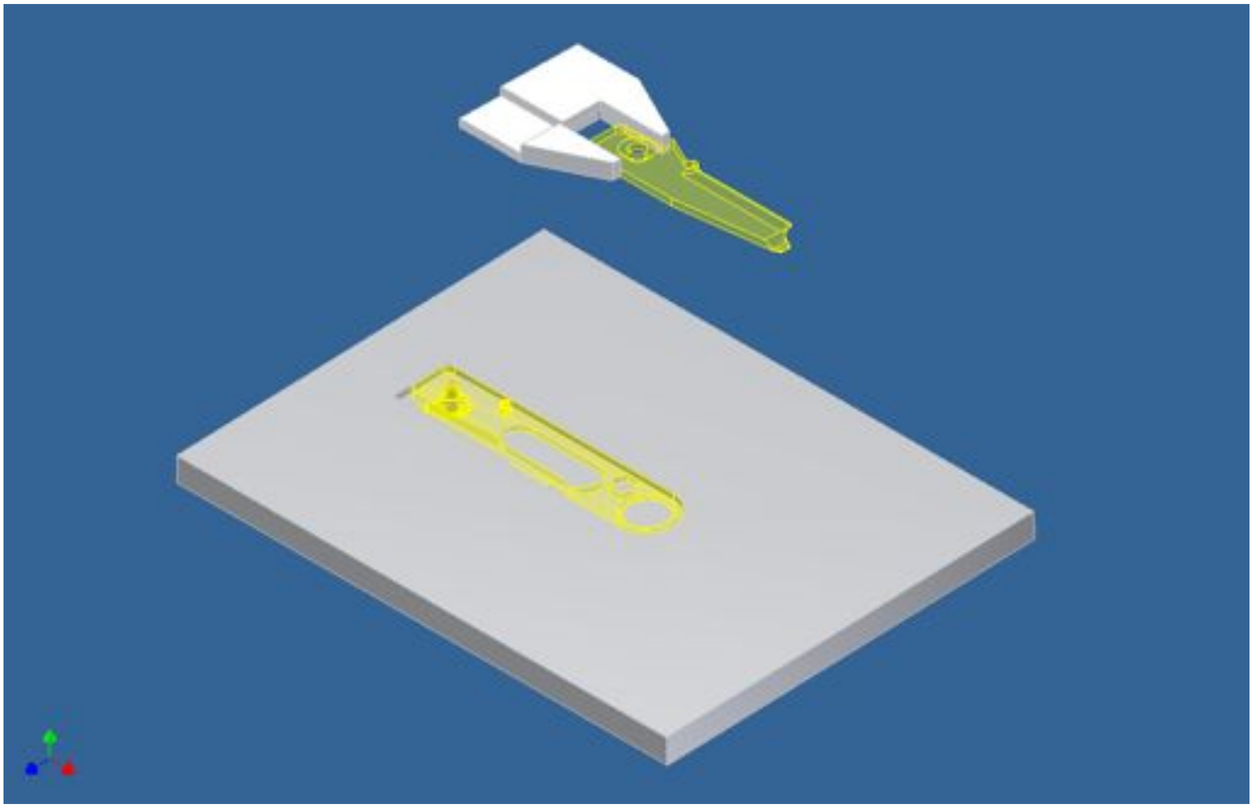
Blade Orientation – Detail 1

After being centered, the blades travel to the inclined belt. Nubs grab the screw-hole of each blade, and use this to pull them up the belt. Gravity will rotate the unsupported end down, thereby reducing the remaining orientations to two.



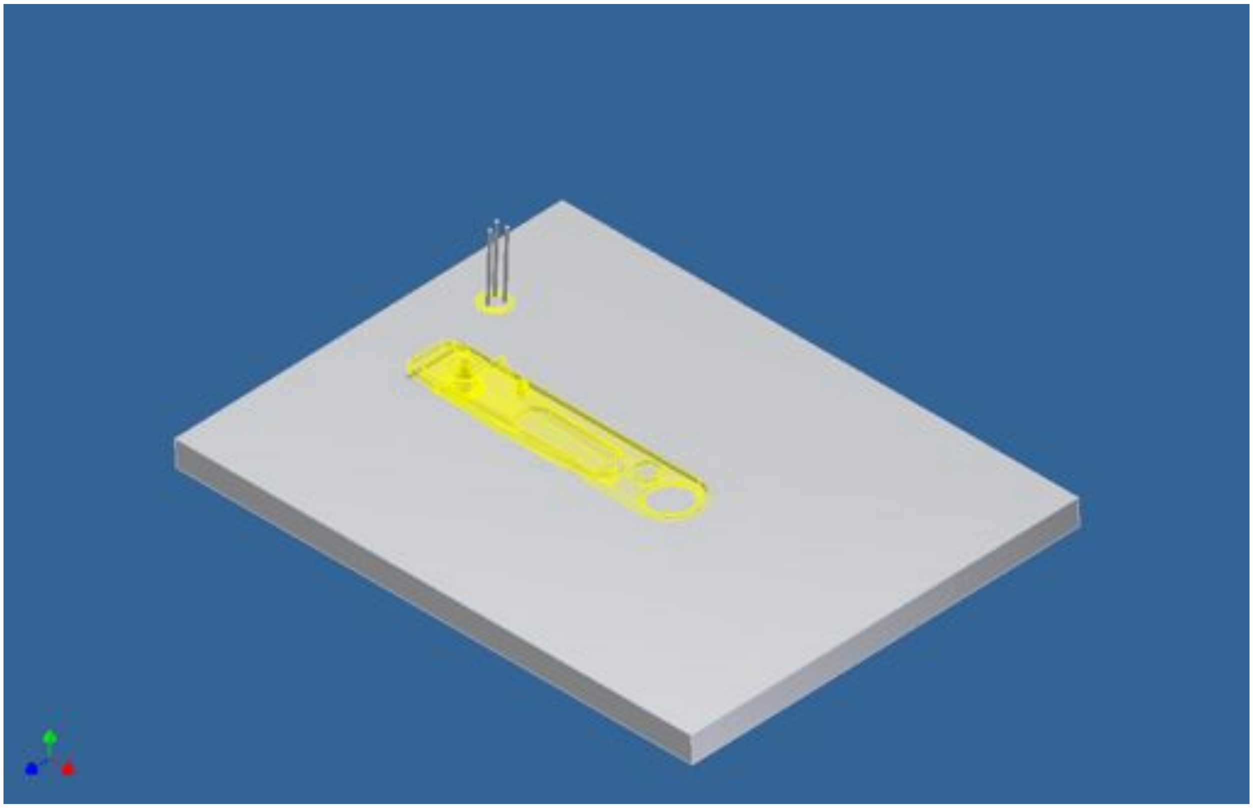
Blade Orientation – Detail 2

The final sorter utilizes a chain to separate the two remaining orientations. Blades with the tab down are caught by the chain and pulled to a second conveyor where they feed to the assembly area. Blades with the tab up are not caught, and slide down to the same conveyor, but following a twisted path, which turns them around to the same orientation as the tab up blades.



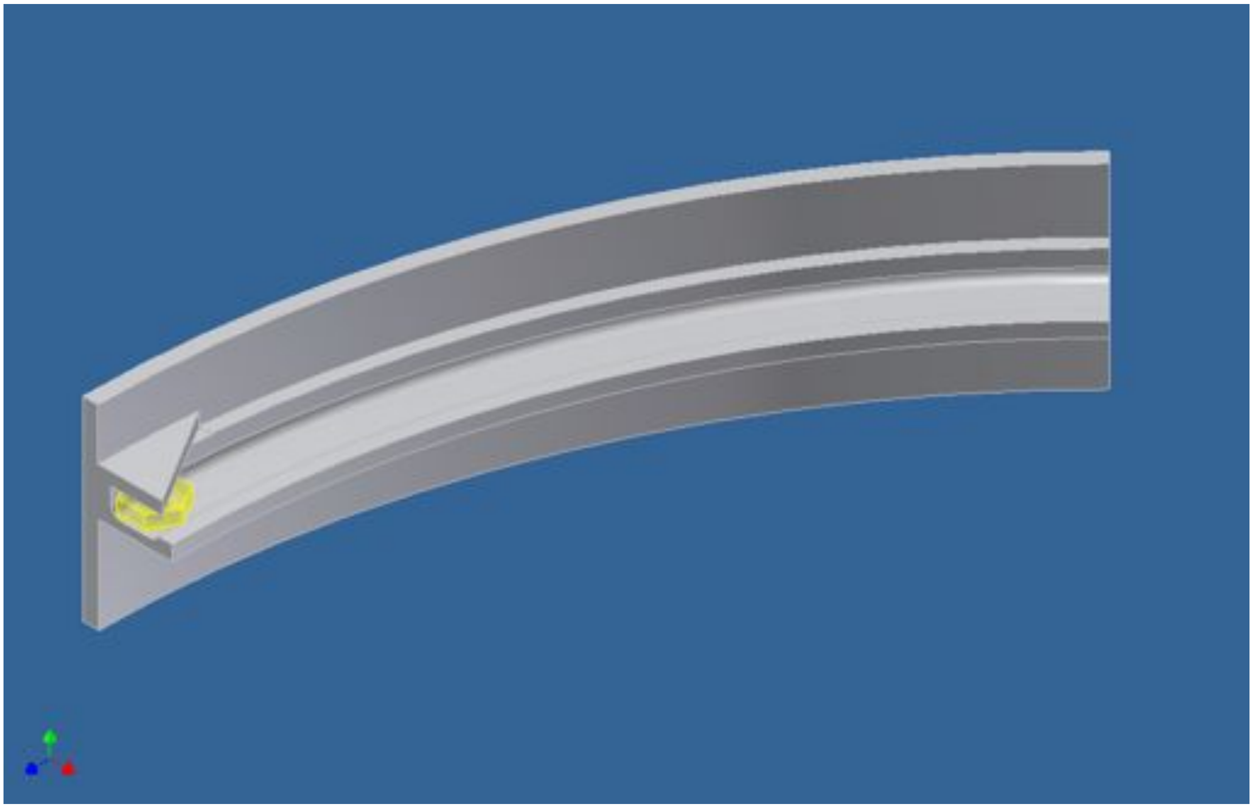
Blade Assembly

To assemble the blades, the pick-and-place picks them up from the feeder, rotates them 180˚, and places them onto the pivot. The blade is placed parallel to the frame, in the closed position. As the inset is only deep enough for the frame, the blade is free to move if rotated.



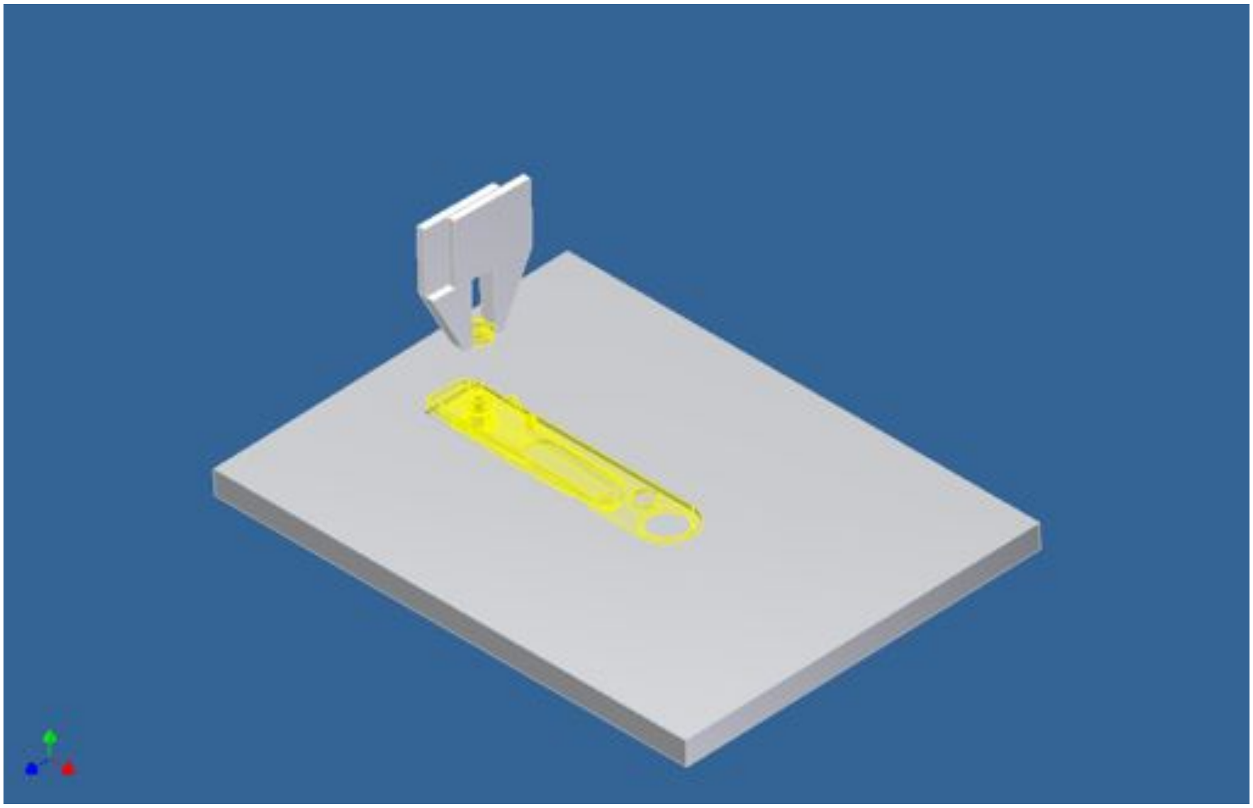
Washer 2 Assembly

The second washer is both oriented and assembled in the same way as the first washer was. Again, angled prongs are used to lift and transport the washer form the feeder to the screw where it is placed.



Nut Orientation

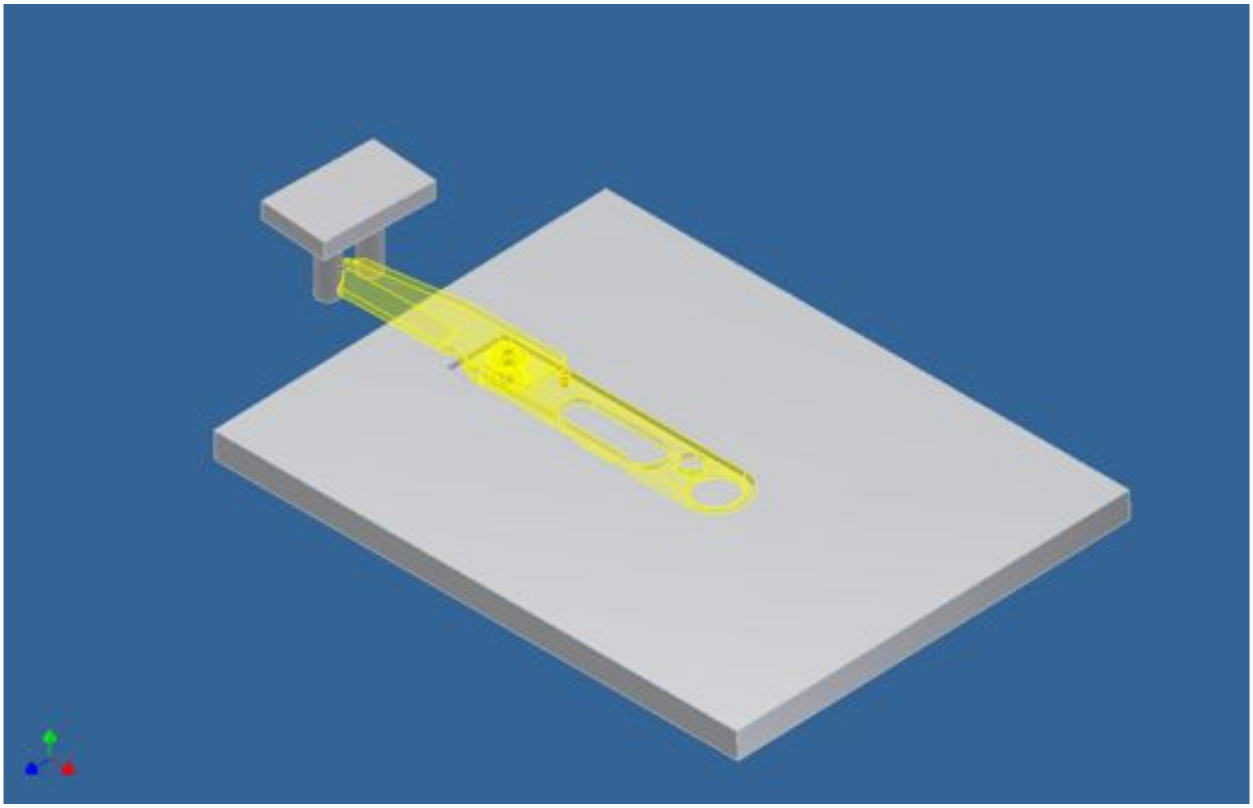
The nut is oriented on a vibratory bowl feeder. The track is rounded at the bottom to match the profile of the nut's cap head. A wiper along the track prevents double-stacked nuts form passing through.



Nut Assembly

The nut picked up by the pick and place, rotated 180˚ to proper orientation, and screwed down by the gripper. A rotator in the pick-and-place rotated the nut 540˚, enough to tighten it down. This requires precise alignment of the fixture to the pick-and-place, however, as rotation must begin with the nut touching the screw, or it will not thread correctly.

The inset in the fixture holds the frame still during this step.



Motion Test

Proper motion of the part is verified at the tenth station. Here, a cylinder extends to the fixture and a gripper contacts the blade. The arm on which the gripper is mounted then rotates, fully opening then closing the blade, verifying its motion.

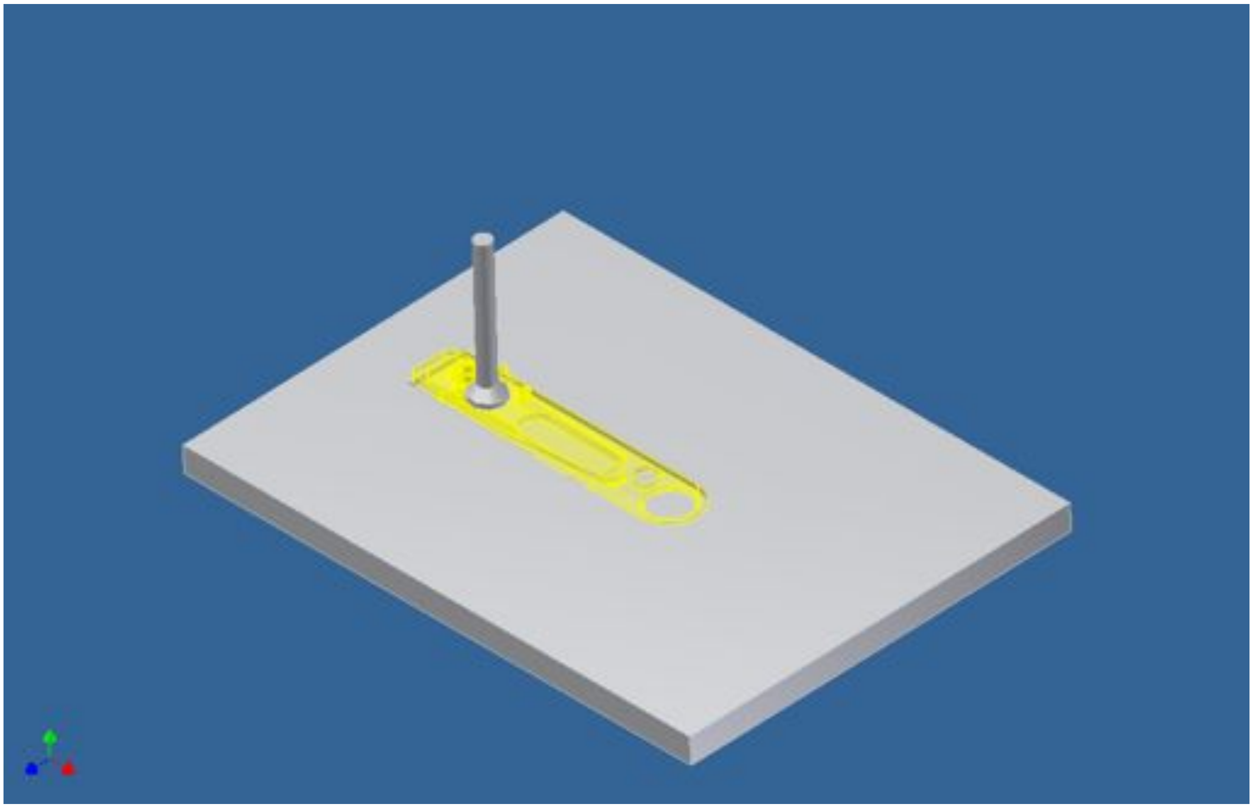
Limit switches used to control the motion also are used to verify the motion. If the arm does not swing fully open, it indicates that the blade cannot open properly, and a light indicates the problem to the operator.

Robot Selection

To pack the assemblies, a hydraulic polar robot was selected. Rotation is provided by electric motors, ensuring precise positioning, while arm extension and gripper action is powered by hydraulic actuators, for strength and simplicity.

A polar robot was chosen for its small footprint and large work envelope. Training software for the robot automatically converts points to the proper coordinate system, so the trainer need not understand the polar coordinates the robot uses (although it would be useful for troubleshooting).

The robot removes finished parts from the assembly line and places them into a shipping container. If desired, it can also pick up and place a separator between layer to prevent parts form scratching each other, such as craft paper or a piece of foam.



Robotic Packaging

The packing robot utilizes a suction cup to grip the finished parts and move them to shipping containers. As mentioned earlier, suction is created be a venturi system.

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LOAD CHART / ROUTING SHEET

Date:

Sheet 1 of 2

No.	Operation Description	Machine Description	Pcs/day req'd	Shifts per day	Pcs/hr req'd	% Scrap	Pcs/hr to start	Pcs/hr machine capacity	Dept. eff. %	Pcs/hr machine actual	Machines req'd	Floorspace required: sq. ft per machine	Floorspace required: total this operation
10	Sheer Blanks	Hydraulic Sheer	3328	2	208	1	211	20	99	19	12	36	432
20	CNC Cut-out	Hurco VM-1	3280	2	205	1	208	7	99	6	35	54	1890
30	Machine 1st Angle	Manual Vertical Mill	3200	2	200	2	205	33	99	32	7	54	378
40	Machine 2nd Angle	Manual Vertical Mill	3136	2	196	2	200	46	99	45	5	54	270
50	Machine Screwdriver	Manual Vertical Mill	3072	2	192	2	196	50	99	49	4	54	216
60	Machine Stop-flat	Manual Vertical Mill	3008	2	188	2	192	75	99	74	3	54	162

Total square feet required: 3348

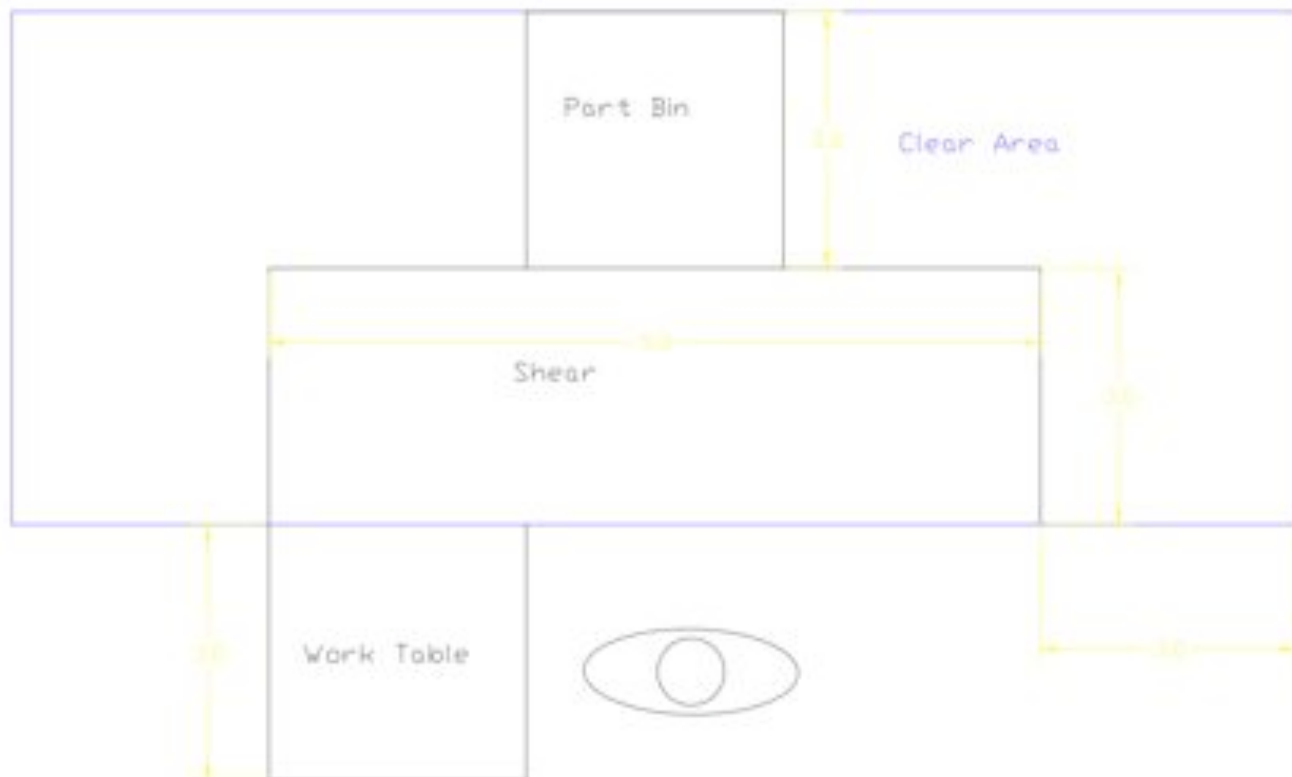
FERRIS STATE UNIVERSITY **LOAD CHART / ROUTING SHEET**

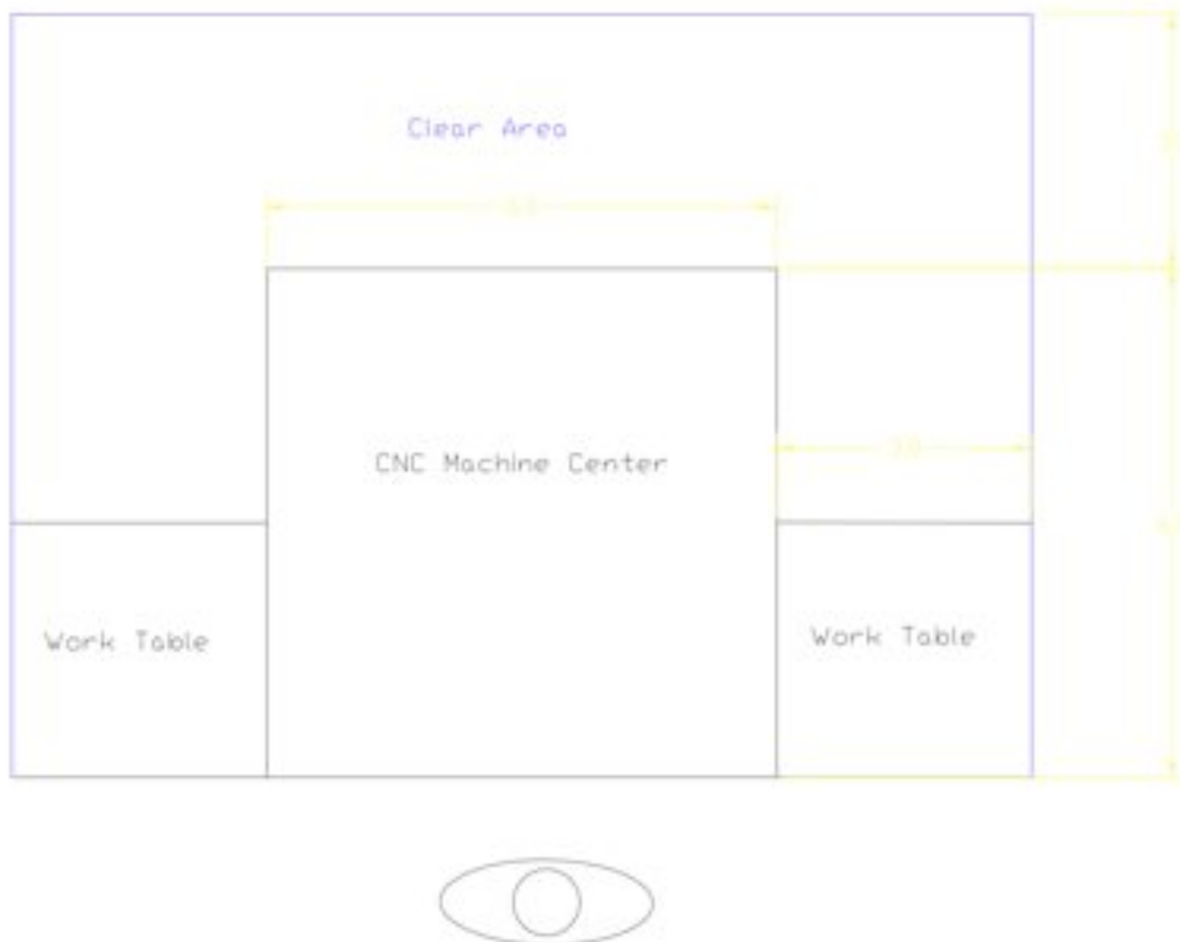
Date:

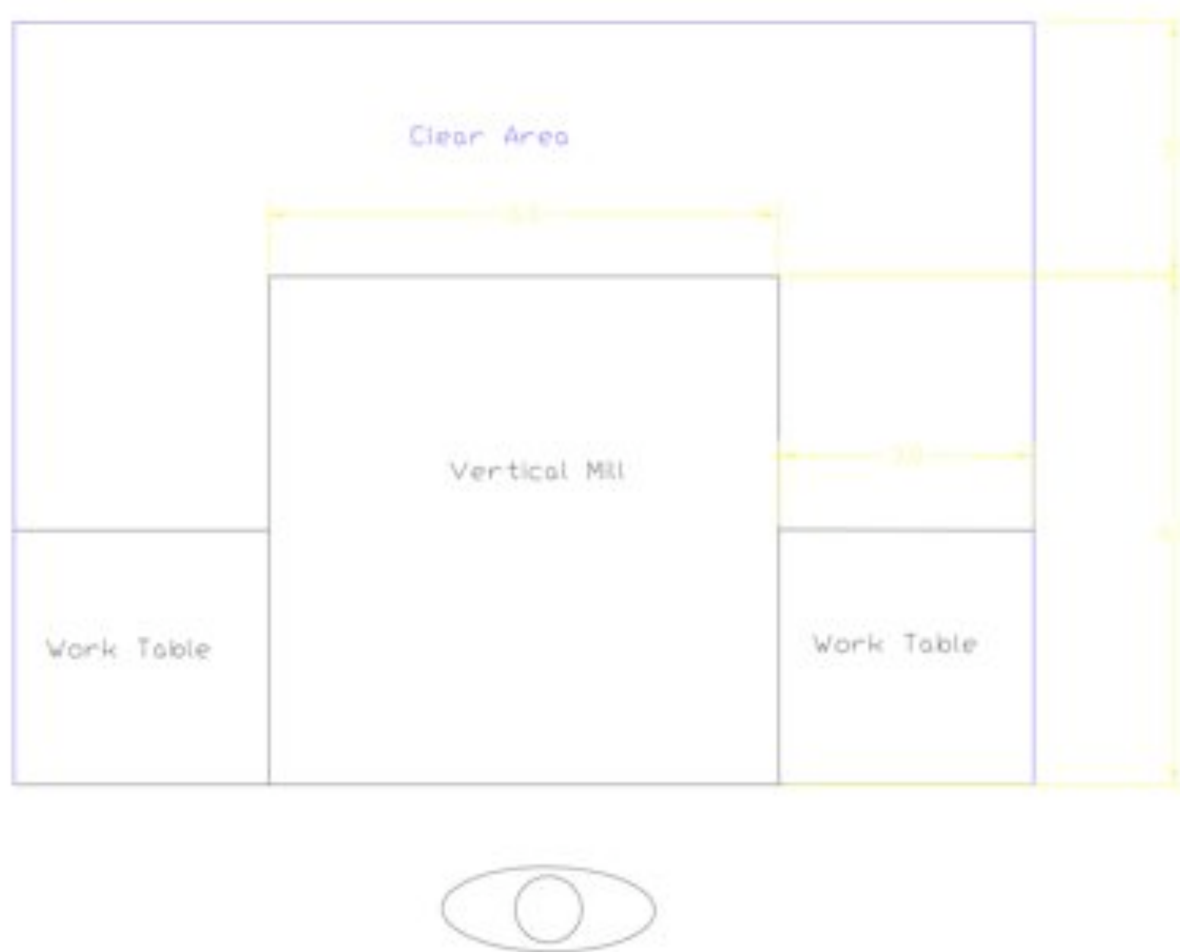
Sheet 2 of 2

No.	Operation Description	Machine Description	Pcs/day req'd	Shifts per day	Pcs/hr req'd	% Scrap	Pcs/hr to start	Pcs/hr machine capacity	Dept. eff. %	Pcs/hr machine actual	Machines req'd	Floorspace required sq. ft per machine	Floorspace required total this operation
70	Final Assembly	Custom Workcell	3000	2	188	1	190	11520	99	11404	1	306	306

Total square feet required: 306


Part Bin
Clear Area
Shear
Work Table


Clear Area
CNC Machine Center
Work Table
Work Table


Clear Area
Vertical Mill
Work Table
Work Table

FERRIS STATE UNIVERSITY

PRODUCTION MATERIAL STORAGE REQUIREMENTS

Item	Part/Material Description	Quantity used per day	Material on hand (days)	Container type	Quantity per container	Loaded container dimensions (L x W x H)	Loaded containers on hand	Loaded container stack height	Number of loaded container stacks	Empty container dimensions (L x W x H)	Empty containers on hand	Empty container stack height	Number of empty container stacks	Method of conveyance	Total storage space required (including access)
1	Wood Stock for Blades	18	2	Strapped Bundles	5	144 x 48 x 0.5	7	2	1	N/A	N/A	N/A	N/A	Crane	48
2	WIP to Op 20	474	0.5	Plastic Tote	30	18 x 10 x 3	8	2	1	18 x 10 x 3	8	2	1	Hi-Lo	8
3	WIP to Op 30	3200	0.5	Plastic Tote	30	18 x 10 x 3	22	2	8	18 x 10 x 3	8	2	1	Operator	19
4	WIP to Op 40	3200	0.5	Plastic Tote	30	18 x 10 x 3	22	2	8	18 x 10 x 3	8	2	1	Operator	19
5	WIP to Op 50	3136	0.5	Plastic Tote	30	18 x 10 x 3	22	2	8	18 x 10 x 3	8	2	1	Operator	19
6	WIP to Op 60	3071	0.5	Plastic Tote	30	18 x 10 x 5	31	2	7	18 x 10 x 5	5	2	1	Operator	21
7	WIP to Assembly	3008	0.5	Plastic Tote	30	18 x 10 x 5	31	2	7	18 x 10 x 5	5	2	1	Operator	21
8	Finished Assembly	3000	1	Cardboard Box	144	18 x 8 x 8	21	2	3	18 x 14 x 0.15	42	2	1	Hi-Lo	13
9	Screws	3000	1	Cardboard Box	200	4 x 6 x 4	20	2	4	10 x 14 x 0.05	30	2	1	Operator	8
10	Washers	6000	1	Cardboard Box	200	4 x 4 x 4	60	2	10	10 x 14 x 0.05	60	2	1	Operator	9
11	Inserts	3000	1	Cardboard Box	200	4 x 4 x 4	30	2	3	10 x 14 x 0.05	30	2	1	Operator	9
12	Frames	3000	1	Cardboard Box	50	4 x 8 x 1	120	2	3	18 x 8 x 0.05	120	2	1	Operator	8
13	Bolts	3000	1	Cardboard Box	200	1 x 4 x 2	30	2	3	4 x 8 x 0.05	30	2	1	Operator	7
14	Pins	3000	1	Cardboard Box	200	4 x 6 x 4	30	2	3	18 x 14 x 0.05	30	2	1	Operator	8
15	Nuts	3000	1	Cardboard Box	200	4 x 6 x 4	30	2	3	18 x 14 x 0.05	30	2	1	Operator	8
16	Scrap	N/A	N/A	Steel Bin	N/A	48 x 48 x 26	8	2	N/A	48 x 48 x 26	2	2	2	Hi-Lo	38
														Total Space Req.	302
						inches		feet		inches		feet			sq.ft.

FERRIS STATE UNIVERSITY **MATERIAL HANDLING PLAN**

Part No.	Part Name / Material Description	From	To	Number in Load	Container	Method	Frequency	Notes
420-10	420 SS Raw Sheet	Receiving	Op 10	1	N/A	Crane	9h 45m	
411-K-10	Sheared Blanks	Op 10	Temp Storage	50	WIP Tote	Hi-Lo	2h 30m	
411-K-10	Sheared Blanks	Temp Storage	Op 20	50	WIP Tote	Hi-Lo	2h 30m	
411-K-20	CNC Cut Blades	Op 20	Temp Storage	50	WIP Tote	Operator	6h 40m	
411-K-20	CNC Cut Blades	Temp Storage	Op 30	50	WIP Tote	Operator	6h 40m	
411-K-30	Single-Bevel Blades	Op 30	Op 40	50	WIP Tote	Operator	1h 20m	
411-K-40	Double-Bevel Blades	Op 40	Op 50	50	WIP Tote	Operator	1h 5m	
411-K-50	Screwdriver Cut Blades	Op 50	Op 60	50	WIP Tote	Operator	1h	
411-K-60	Finished Blades	Op 60	Assembly	50	WIP Tote	Operator	40m	
411-K-F	Finished Assemblies	Assembly	Shipping	144	Shipping Box	Hi-Lo	1h 55m	

FERRIS STATE UNIVERSITY

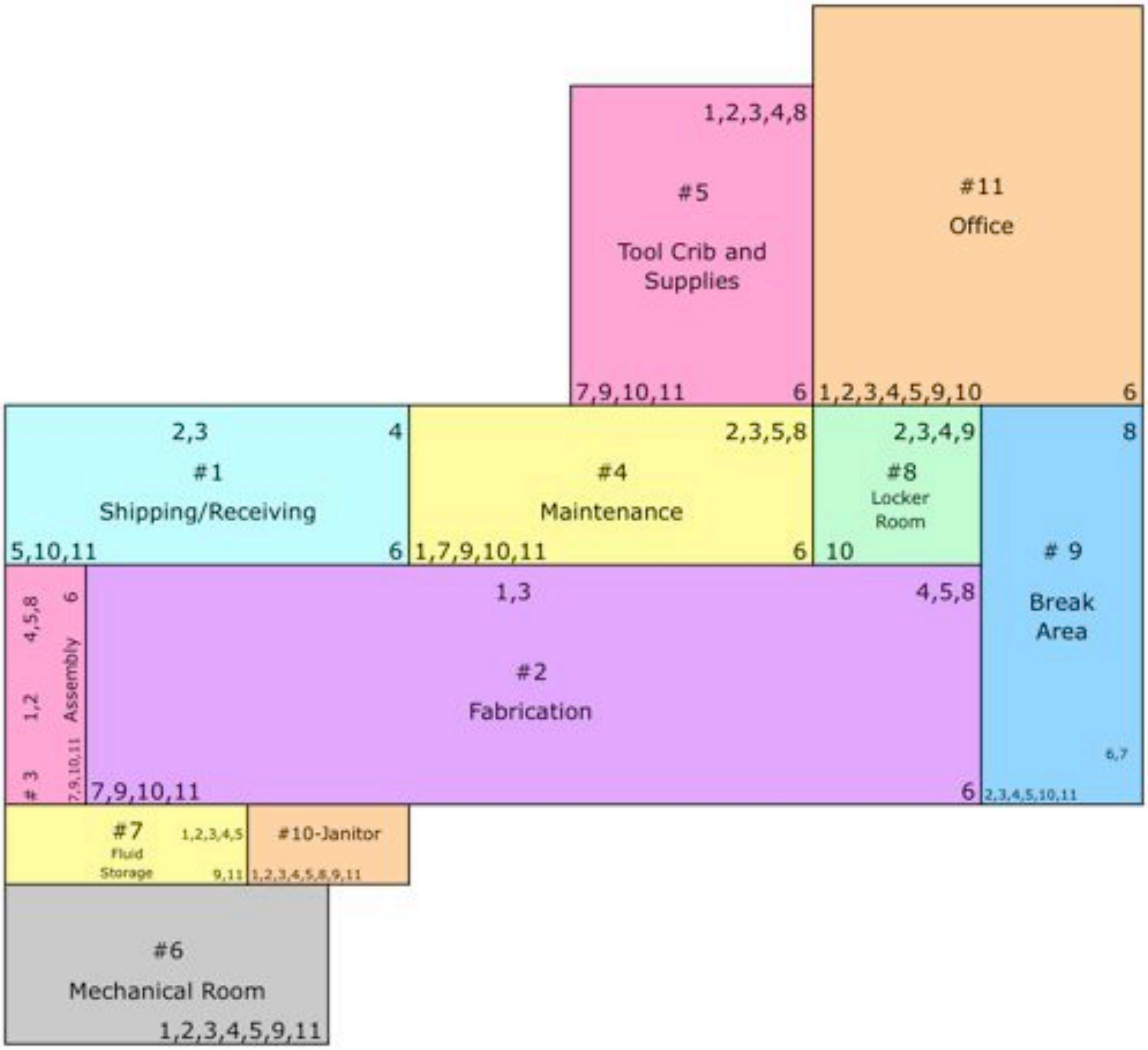
FACILITY SPACE REQUIREMENT SUMMARY

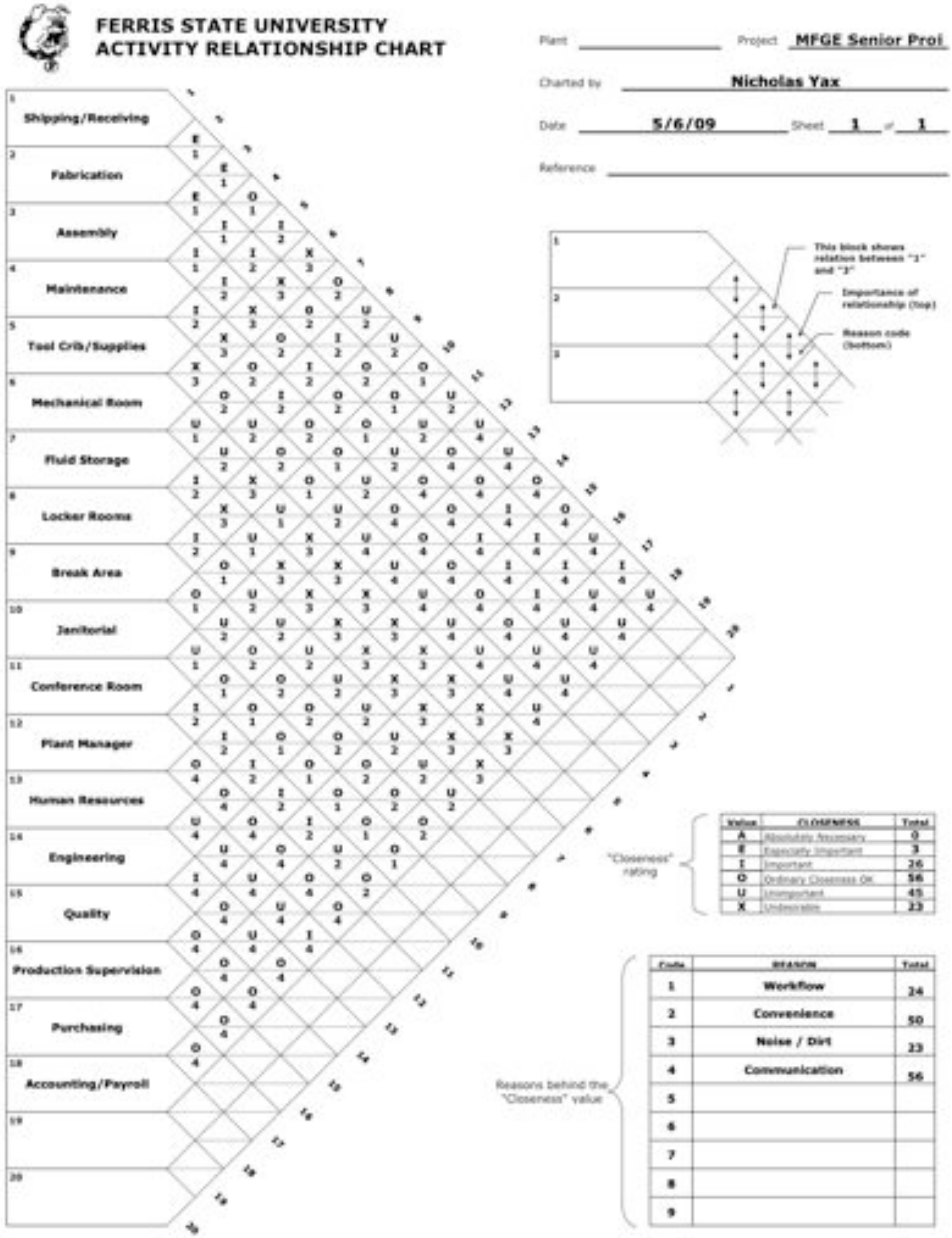
Area / Function	Number of employees: Hourly	Supervision	Salary	Management	Space required	Notes
Shipping/Receiving	2	1			1000	
Fabrication	48	4			3348	
Assembly	2				306	
Maintenance	4	1			1000	
Tool Crib/Supplies	2	1			1200	
Mechanical Room					800	
Fluid Storage					250	
Locker Room					402	
Break Area					1000	
Janitorial	2				150	
TOTALS	60	7	0	0	9456	

FERRIS STATE UNIVERSITY

FACILITY SPACE REQUIREMENT SUMMARY

Area / Function	Number of employees				Space required	Notes
	Hourly	Supervision	Salary	Management		
Conference Room					300	
Plant Manager				1	500	
Human Resources			1		120	
Engineering			4	1	336	
Quality	2		2		256	
Production Supervision		2			128	
Purchasing	2				128	
Accounting/Payroll			2		128	
TOTALS	4	2	9	2	1896	


1,2,3,4,8
#5
Tool Crib and Supplies
7,9,10,11
6
#11
Office
1,2,3,4,5,9,10
6
2,3
4
#1
Shipping/Receiving
5,10,11
6
2,3,5,8
#4
Maintenance
1,7,9,10,11
6
2,3,4,9
#8
Locker Room
10
8
9
Break Area
6,7
2,3,4,5,10,11
4,5,8
6
1,2
Assembly
3
7,9,10,11
1,3
4,5,8
#2
Fabrication
7,9,10,11
6
#7
Fluid Storage
1,2,3,4,5
9,11
#10-Janitor
1,2,3,4,5,8,9,11
#6
Mechanical Room
1,2,3,4,5,9,11



FERRIS STATE UNIVERSITY
ACTIVITY RELATIONSHIP CHART
Plant
Project MFGE Senior Proj
Charted by Nicholas Yax
Date 5/6/09
Sheet 1 of 1
Reference
Shipping/Receiving
Fabrication
Assembly
Maintenance
Tool Crib/Supplies
Mechanical Room
Fluid Storage
Locker Rooms
Break Area
Janitorial
Conference Room
Plant Manager
Human Resources
Engineering
Quality
Production Supervision
Purchasing
Accounting/Payroll
This block shows relation between "1" and "3"
Importance of relationship (top)
Reason code (bottom)
"Closeness" rating
Value
CLOSENESS
Total
A Absolutely Necessary 0
E Especially Important 3
I Important 26
O Ordinary Closeness OK 56
U Unimportant 45
X Undesirable 23
Reasons behind the "Closeness" value
Code
REASON
Total
1 Workflow 24
2 Convenience 50
3 Noise / Dirt 23
4 Communication 56
5
6
7
8
9