

## Senior Capstone Design

Project: Robot Manufacturing Cell

Primary Author: Mark Leitner

Team: Cyber Crew

Date: 11/30/2018

### Design Validation Plan & Results (DVP&R)

Requirement	Test	Test Subject	Target Date	Result	Recommendation
The assembly must be automated	Human must execute the code, and the parts will be assembled without intervention	Manufacturing Cell	8/6/18	Tested 11/25/18 - A trial run of the process was done, the robots assembled two parts without human intervention	Meets requirements - no further action required.
Emergency stop switches are in place and functionable	Press the emergency stop switch while the robot is running	Manufacturing Cell	7/16/18	Tested 7/12/18 - When emergency stop was initialized, robot stopped in its tracks	Meets requirements - no further action required.
Operating Air Pressure is between .1 and .39 Mpa	Use a pressure gauge to measure	Air line	7/16/18	Tested 7/12/18 - Gauge read about 30 psi, which converts to .2 MPa	Meets requirements - no further action required.
The negative x-axis of R2 must not exceed a length of 762 mm	Slowly move the robot arm to the wall, to establish the limit point	Robot 2	7/16/18	Tested 7/31/18 - A trial run of the process was done, the robot stayed within the parameters	Meets requirements - ensure the final process still meets the requirement.
Each arm shall have an initial/rest position to avoid potential collisions.	Use the code to establish points where the robots can rest when not in use	Robots 1 and 2	6/25/18	Tested 6/25/18 - Robot went to the desired location when initialized	Meets requirements - no further action required.
The load on each arm shall be less than 5 kg	Weigh the pusher tool, as well as the gripper and each part to ensure it is under 5 kg	Gripper, Pusher, Male, Female	7/30/18	Tested 7/25/18 - Each end effector weighs a nearly negligible amount compared to the 5 kg limit	Meets requirements - no further action required.
Tools cannot exceed a mass of 2.5 kg	Weigh the pusher tool, as well as the gripper	Gripper, Pusher	7/30/18	Tested 7/25/18 - The heavier end effector had a mass totaling 1.5 kg	Meets requirements - no further action required.
Tools must be able to screw into the arm, containing a 4-hole square pattern, with a 1.266" diagonal	Measure each end effector adapter to make sure it fits onto the arm correctly	Gripper, Pusher	7/30/18	Tested 7/20/18 - Each end effector fits on the specified arm	Meets requirements - no further action required.
Assembly parts used shall be free fit, with a +/- .075 tolerance difference	Measure the inside of the female part and the outside of the rod of the male part	Male, Female	7/18/18	Tested 7/25/18 - The parts fit well together, with a .06" tolerance for the O-Ring to fit	Meets requirements - no further action required.
Fixtures shall have a +/- .05" tolerance for the 2" diameter part.	Measure the inside of the fixture and outside of each part	Male, Female, Fixture	7/23/18	Tested 7/23/18 - Tolerance is exactly .05 inches. Male diameter is .991 inches; Female diameter is 1.041 inches.	Meets requirements - no further action required.
The system shall run until all parts are assembled	Execute the code, making sure the process stops when each parts are assembled	Manufacturing Cell	8/6/18	Tested 9/5/18 - The process stops when all parts are assembled	Meets requirements - no further action required.
The pusher finger shall be adjustable	Screw a screw into the back washer to make sure the rod stays in place	Pusher	7/23/18	Tested 7/18/2018 - Using an allen wrench, the pusher finger can be adjusted to the desired length	Meets requirements - no further action required.

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Parts should come properly oriented on the ramp	Put a line of parts onto the ramp, and take one off at a time	Ramp	9/30/18	Tested 10/31/18 - When putting all the parts into the top of the ramp, the males go to one side, the females go to the other	Meets requirements - no further action required.
Parts should be put together with less than 11 pound force	Stack weights onto the parts in order to measure the amount of weight required to put them together	Male, Female	7/23/18	Tested 7/23/18 - The parts were clamped together with a .44 lbf	Meets requirements - no further action required.
Parts must be put together and not come apart	Grab the male part when the pieces are together and hold it in the air for a minute	Assembly	7/23/18	Tested 7/18/18 - Must be aggressively shaken to come apart, stays if just picked up	Meets requirements - no further action required.
The entire assembly must be movable as a unit	Use the gripper arm to pick them up and move them to another location	Assembly	7/30/18	Tested 7/23/18 - The assembly was inserted together into the gripper and moved without falling out	Meets requirements - no further action required.
The gripper should be able to grab each part without slippage	Use the gripper arm to pick them up and move them to another location	Gripper, Male, Female	7/30/18	Tested 7/23/18 - Each part was inserted into the gripper and moved without falling out	Meets requirements - no further action required.
The gripper shall be parallel when grabbing objects	Close the gripper arm while holding a part in between	Gripper, Male, Female	7/30/18	Tested 7/23/18 - Gripper is tight and nonmoving while in its process	Meets requirements - no further action required.
There shall be a storage for all assembled parts	When the process ends, all parts shall be in the storage	Storage	8/6/18	Tested 7/31/18 - Using the storage fixture for preliminary testing, the assembly will be contained in a specified location	Meets requirements - no further action required.
Coordinates shall be in place in order to accurately grab the desired objects	Calibrate the points manually using the controllers for each robot	Robots 1 and 2	7/23/18	Tested 7/31/18 - A trial run was done to assemble the products. Positions were calibrated accurately	Meets requirements - no further action required.
A construction zone fixture shall be in place to assemble the parts	Parts are assembled while staying upright	Fixture, Male, Female	8/6/18	Tested 7/31/18 - Using the storage fixture for preliminary testing, the male and female parts will have a specified location	Meets requirements - no further action required.
The robots shall work one at a time	Use IP Addresses to ensure signals are being sent when necessary	Robots 1 and 2	8/6/18	Tested 7/24/18 - IP Protocols are in place so that the arms work one at a time to complete the process	Meets requirements - no further action required.
The stepper motor shall move the conveyor belt at a reasonable speed	Run the Arduino program at various speeds until the best option is found	Conveyor Belt	11/16/18	Tested 11/14/18 - For the belt to not get stuck on the bearing, a slower speed is required, but the purpose is met.	Meets requirements - no further action required.

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The Arduino must implement TCP/IP protocol as with the robots	Connect via ethernet to the scanner, using the serial monitor to tell whether it connects	Arduino and Scanner	11/2/18	Tested 11/8/18 - The serial monitor connects and once the signal is received, the arduino runs the program	Meets requirements - no further action required.