Solutions for Final Design

1. Material Handling

a. Current Process: Part is placed on stiff wire which allows the operator to handle and transport the part during the process. By accessing/grabbing/holding one end of the stiff wire the part is loaded into the chuck. After the printing process is complete, the operator removes the finished part from the chuck by accessing the wire. The operator then transports the painted part on the wire to the WIP fixture.

b. Current Problem(s):

i. **Problem 1:** Workstation allows little room to load and unload part

- The operator has to maneuver their hand in and out of the workstation while balancing the part on the stiff wire. The tip of the micropen is occasionally bumped into due to the minimal allotted space for the operator's hand. After repeated contact, the printing tip is no longer calibrated affecting the accuracy and repeatability of the automated printing process. The calibration process is time consuming and can only be accomplished by one or two employees, resulting in a slowed process

ii. **Problem 2:** Difficult to balance the printed part on the stiff wire while the part is transported from the chuck to the WIP Fixture.

- As stated above, the operator has to unload the part from the chuck and maneuver it out of the workstation, without hitting the tip of the micropen. Next, the operator rotates their body while simultaneously adjusting their grip/hand/arm to a position where they are able to place part into the WIP fixture.

  The part will be scraped if
  - Dropped by sliding off the other end of the wire.
  - paint is smudged by contact with the operator or fixture

c. Suggested Process Improvement (Solution):

i. Solution 1 (obsolete): Placing a kink in the wire

- **Why:** prevents the part from sliding off the end of the wire while transporting. Eliminates the need to balance the part thus reducing the risk of smudging by coming into contact with operator
- **How:** Tooling/device that quickly and easily bends multiple wires at one time. Should be repeatable, placing a uniform kink at the same location every time.
- **Obsolete Because**: testing showed that using the kink in the wire made it more difficult to place the finished part into the WIP fixture.

2. WIP Fixture for Printed Parts

a. Current Process: After the printing process is complete, the finished part is removed from the chuck and transported to the WIP fixture. The part is held perpendicular to the fixture by placing the end of the wire into one of the 64 holes located on the 4"x4" ceramic tile.

b. Current Problem(s):

i. Problem 1: Difficulties securing the part into the WIP fixture due to the close spacing of the holes

- Part placement becomes increasingly difficult as more parts are placed into the WIP fixture. Increase risk of smudging the gold ink of a part already secured in the fixture

ii. **Problem 2:** Difficulties orienting the part for placement into the WIP fixture.
- Part placement requires the operator to rotate their hand and wrist significantly due to the location and orientation of the WIP fixture.

c. **Suggested Process Improvement (Solution):**

i. **Solution 1 (implemented):** Redesign WIP fixture
- **Why:** Improve ease of part placement by increasing spacing between the holes on the tile. Static stresses of muscles is reduced by simplifying process, decreasing the time that the operator's arm is held out for part placement. Decreases risk of smudging the ink on neighboring parts due to accidental contact.
- **How 1:** Increase length of fixture and increase spacing between holes.
- **How 2:** Reduce the number of holes on the WIP fixture tile, this will increase the spacing between holes. Retain the 4"x4" tile size.
- **How 3:** Increase the diameter of the countersink to allow for easier part placement.

ii. **Solution 2 (implemented):** Modify WIP Fixture Stand angle, allow for adjustability.
- **Why:** Allow for the operator to adjust the fixture orientation based on preference. Will help to reduce bending and awkward elbow and shoulder postures
- **How:** Create an incremental back support, similar to a beach chair.

iii. **Solution 3 (suggested):** Modify the location of WIP fixture in the workstation.
- **Why:** The current location of the WIP fixture requires the operator to rotate away from the work and extend their arm to reach the WIP fixture. This may be a factor in the left hand and wrist discomfort.
- **How:** Place the WIP fixture near the part unload area at a height that is equal to or below the chuck/unload area height.

3. Actuating the Opener (Open/Closing Chuck)

a. **Current Process:** Air valve with ball joint lever, placed in a position which makes the operator reach up to press it. This causes shoulder and wrist pain for the operators.

b. **Current Problem(s):**

i. **Problem 1:** Wrist Pain / Exhaustion.

ii. **Problem 2:** Shoulder pain / Exhaustion.

c. **Suggested Process Improvement (Solution):**

i. **Solution 1 (implemented):** Solenoid Air Valve (Button)
- **Why:** Gets rid of twisting motion, and reduces the distance the arm / wrist needs to travel in order to open or close the chuck.
- **How:** Reduces opening / closing the chuck down to just pressing a button.

4. Operator Keyboard and Keypad

a. **Current Process:** There is a keyboard and a keypad set up with the workstation. The keyboard is a computer keyboard that is sometimes used for setup but is not used in the manufacturing process. The keypad is smaller and able to be custom programmed; it is used

for the manufacturing process to verify alignment of the part in the chuck using the "flip" key and to perform the painting process using the "go" key. There are other keys that are used to modify the location of the part, these views are sometimes used to verify painting and touch-up procedures.

b. Current Problem(s):

i. **Problem 1:** The current location of the keypad requires the operator to rotate slightly to press the keys.

ii. **Problem 2:** Not all keys on the keypad are frequently used.

iii. **Problem 3:** There is a plastic cover over the keypad to protect the keys from acetone cleaner. The plastic cover is quite opaque, making it hard for operators to identify the keys.

c. Suggested Process Improvement (Solution):

i. **Solution 1 (obsolete):** Modify the location of the keypad and keyboard.

- **Why:** To reduce the turning motions required by the operator.
- **How:** Relocate the keypad in a location that is very close to the work, near the actuator or the WIP Fixture.
- Obsolete Because: With the way operators now sit to use the new workstation setup, the keypad location is no longer in an awkward position for use.

ii. **Solution 2 (implemented):** Modify keys on the keypad.

- **Why:** Reduce the keypad keys to only those used frequently throughout the touchup process.
- **How:** The keyboard is capable of completing all of the tasks of the keypad. Reduce the number of keys available on the keypad. Identity frequently used keys, remove less frequently used keys.

iii. **Solution 3 (implemented):** Replace smaller keyboard cover with a colored cover to help with identifying the different actions.

- **Why:** To simplify the identification of keys for the operator, and also cheap solution.
- **How:** Colored and labeled keyboard cover outsourced from current keyboard

5. Viewing Part During the "Touch-up" Procedure

a. Current Process: Operators currently view the part during touch up with an adjustable microscope located at the front of the station. Due to height constraints from the chair and micropen machine, the microscope will always be high enough compared to the operator that they are required to flex their neck and back to reach the eyepieces.

b. Current Problem(s):

i. **Problem 1:** Ergonomic issues presented by the operator having to "lean" forward to look through the microscope. Ergonomic issues include neck, lower back, and shoulder pain from using the microscope.

c. Suggested Process Improvement (Solution):

i. **Solution 1 (implemented):** Camera with a Screen

- **Why:** A camera with a screen would allow the operator to sit back and do the process in a more ergonomically safe position. In addition, it would reduce the amount of motion that the operator has to perform throughout the course of the touch-up procedure.
- **How:** The screen would be placed in easy eyesight of the operator, and would be large enough that they would not have to lean forward to view it.
    - Camera is placed on front of tool fixture for optimal view

        - Camera is placed in front of station to replicate operator perspective
    - **Materials:** This solution requires selection of a camera with sufficient zoom and picture quality, a mounting apparatus for the camera, and a compatible monitor placed in an ergonomically friendly position with an adjustable mount.
        - Favored monitor model is 19in Samsung monitor currently used in stations with the mount that Micropen currently uses.

6. Operator Tooling for the "Touch-up" Procedure

a. Current Process: After the printing process is complete part of the gold ink is not connected and the operator is required to "touch-up" this portion of the part. The tool used has a needle like point and a handle similar to a pencil. The distance between the painted part and the location of the operator's hand requires the tool to be long, or requires the operator to hold the far upper end of the tool so that the point can reach the part.

b. Current Problem(s):

i. Problem 1: The tool is not comfortable to hold and use repeatedly all day. The necessary positioning of the hand and arm to perform the touch-up is uncomfortable. The risk factors for the Micropen operators are repetitive hand and arm motions in unsupported, awkward postures. The exposure is in combination with contact stress from grasping tools while applying force, and applied contact stress from the sharp bench edges. The touch up process require operators to lean forward and assume static postures of the arm, neck and torso for extended periods.

c. Suggested Process Improvement (Solution):

i. Solution 1 (implemented: Modify the handle of the tooling to be larger and more ergonomic.

- **Why:** To improve ergonomics related to the operator's right hand and wrist.
- **How:** Create a lightweight slip resistant foam handle to adhere to the tooling handle to improve the ergonomics of the tool.

ii. Solution 2 (implemented): Develop a mechanical system to assist with the touch-up procedure.

- **Why:** To perform the process, the operator places their hand, wrist, and arm in a non-ergonomic position, this position should be eliminated. Precision work demands focus and requires constant efforts and stability. Utilizing a mechanical fixture to hold/support the tool during the touch up process provides more control than moving the tool by hand. The Mechanical fixture gives the operator a stable performance while simultaneously providing flexibility and maneuverability, enabling the operator to manipulate tooling with precision.
- **How:** Develop a mechanical system that places the tooling in the "view" of the screen so the operator is not required to "find" the part within the chuck. (A common issue when testing a microscope with a screen was finding the field of view at the start of the touch up).
    - Keeps wrist in a neutral position (straight wrist).
    - Reduce awkward elbow and shoulder postures.
    - Less effort or rotational movement to use
    - Reduce Touch up time and time spent holding tool.
    - Small, flexible joints for precise positioning.
    - Matches the operator's hand movements.

- Lateral tooling movements are inverted by the pivoting point and can be scaled depending on the tool insertion depth.

iii. **Solution 3 (obsolete):** Redesign plastic shield used to cover exposed/rotating components of the chuck.

- **Why:** The height of the shield is unnecessarily high, placing it directly in the way of the path of the operator during the touch-up. The dimensions and shape of the part aren't standardized or consistent, they vary between work stations.
- **How:** Change size of set screw used. Decrease the distance the shield protrudes out
- **Obsolete Because**: the operators that previously found the shield to be in the way are now using the built in hand rest area of the new tooling fixture and the shield is no longer an obstruction.

7. Arm & Elbow Support During the "Touch-up" Procedure

a. **Current Process:** After the printing process the operator is required to perform a touch-up step where currently they rest their arm and elbow on a platform to keep it even with the top of the Micropen instrument.

b. **Current Problem(s):**

i. **Problem 1:** The static load on the forearm and elbow causes stress in the operator's shoulder

ii. **Problem 2:** The orientation of the operator when leaning on the platform to perform the touch-up procedure is not ergonomic for the operator.

c. **Suggested Process Improvement (Solution):**

i. **Solution 1 (suggested):** Adjustable Elbow Support

- **Why:** Static shoulder tension would be released.
- **How:** The support could be adjusted to the operator's preference, until they feel they have put their arm in a non-painful position.

ii. **Solution 2 (suggested):** Adjustable Forearm Support

- **Why:** When the operator currently performs the touch - up procedure, they have to place their arm on a hard, flat surface. An adjustable forearm support would allow the operator to place a "cushion" down at an angle to their own personal preference.
- **How:** The support would be placed at the location of the touch up.

8. Modification for Proper Seating Position

a. **Current Process:** Throughout the process the operator is required to perform procedures in non-ergonomic positions. Many of the steps in their process are repeated numerous times throughout the day. The operators are required to sit in a somewhat sideways position to reach the microscope when performing the touchup step. For the process the operators also need to place the ceramic part on a small metal wire and use this small wire to transport the part after the process to the WIP fixture.

b. **Current Problem(s):**

i. **Problem 1:** The current workstations, prevents the operator from working in a neutral posture. Due to the lack of legroom at the workstation the operators are forced to sit sideways adapting an awkward posture to complete the process**.** The operator is in a constant state of leaning forward and leaning backward, through the use of the

microscope. The current chairs implemented by Micropen do not provide back support in both of these positions.

c. **Suggested Process Improvement (Solution):**
   i. **Solution 1 (suggested):** Saddle Chair
      - **Why:** Saddle chairs are used in various dental / medical applications which often have many ergonomic issues presented to them daily. They force the operator to sit in an ergonomically "correct" position.
      - **How:** The old chairs would simply be replaced by the new saddle chair. Saddle Chairs are known to have a little breathing period of about a week where the user must break it in, but once the operators get past that, it is a comfortable and ergonomically friendly position.

9. Stretching and Exercises

a. **Current Process:** The operators perform stretches at their discretion.
b. **Current Problem(s):**
   i. **Problem 1:** The operators muscles are repeatedly placed in static positions throughout the day.
   ii. **Problem 2:** The operators are in a sitting position for the majority of the day.
c. **Suggested Process Improvement (Solution):**
   i. **Solution 1 (implemented):** Provide stretch sheets that demonstrate a variety of stretches.
      - **Why:** To encourage the operators to move from their static position more often.
      - **How:** Provide print off sheets or poster size documents to have in the work area that provide both a visual and written description of the stretches.
   ii. **Solution 2 (implemented):** Decrease WIP to increase flow.
      - **Why:** To reduce the muscles repeated static load for long durations.
      - **How:** Decrease the number of holes in the WIP fixture tile to 25 holes in a 5x5 pattern. When 25 parts are completed the operator moves the tile to the next step. This forces the operator to get up from their seating position and use other muscles in their body.

10. Work Schedule Modification

a. **Current Process:** The operators rotate work stations every two or three days.
b. **Current Problem(s):**
   i. **Problem 1:** The operators muscles are placed in static positions throughout the day.
c. **Suggested Process Improvement (Solution):**
   i. **Solution 1 (suggested):** Operators change tasks every two hours.
      - **Why:** To encourage the operators to move from their static position more often.
      - **How:** Modify the schedule for the operators.
   ii. **Solution 2 (suggested):** Operators rotate stations once per day rotation, most likely at the lunch break.
      - **Why:** To reduce the muscles repeated static load for long durations.
      - **How:** Modify the schedule for the operators.