SUMMARY OF ESP SHORT PUCK MODIFICATIONS

McLane Research Labs, Inc., last revised 05-31-2023 NA, CP, BR

1. Introduction

As part of the NOAA funded ESP PCM-HAB grant, the Environmental Sample Processor (ESP) has undergone design modifications in order to accommodate a shorter profile reaction puck. The short puck ESP option increases the ESP puck capacity from 132 pucks to 198 pucks, effectively increasing the deployment duration and decreasing the cost per sample. Table 1 summarizes the mechanical modifications required for operating an ESP with short pucks. The mechanical modifications have been summarized by sub-assembly. The modifications affect the following; the flush puck and garage, processing clamp, collection clamp, and camera. In addition to mechanical changes, in order to operate the ESP with short pucks there are a number of software changes and modified sub-assembly calibrations that are required. This document will detail all mechanical, software and calibration modifications related to operating the ESP with short pucks.

ESP Short Puck Modifications				
Sub-Assembly	Part Desc.	Part Number	Part Rev.	Required for Short Puck / Robustness Improvement
Flush Puck Garage	Flush Puck Holder Base	M4419	A	Required for Short Puck
Flush Puck Garage	Flush Puck	M4420	A	Required for Short Puck
Processing Clamp	Processing Clamp Top	M3912	A	Required for Short Puck
Collection Clamp	Collection Clamp Top	M3913	A	Required for Short Puck
Camera	Camera Spacer	M4424	A	Required for Short Puck
Camera	Light Seal Flange	M4423	A	Required for Short Puck

Table 1: Summary of short puck mechanical modifications.

Figure 1: Comparison of Standard Puck vs. Short Puck

2. Comparison of Standard and Short Pucks

A general comparison of standard and short pucks is summarized in Figure 1 above. The overall puck height has been reduced by approximately 33%. The reduction in puck height increases the ESP sample capacity to 66 phases (without archival) or 49 phases (including archival). The below figures show side by side comparisons of each puck type in standard and short formats.

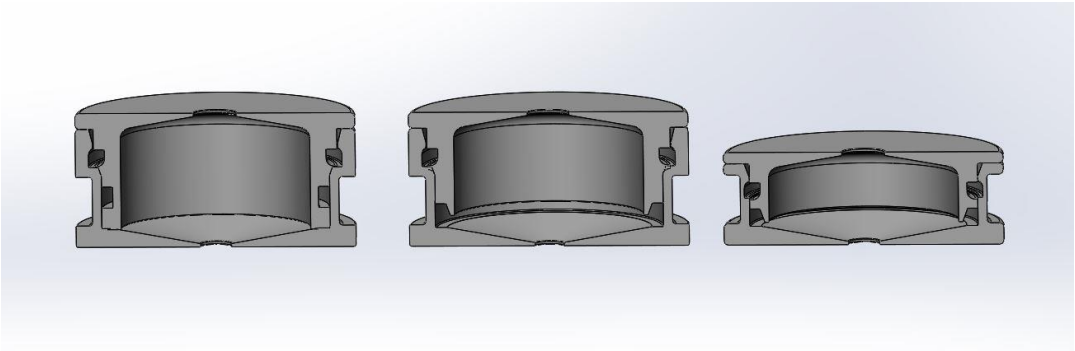


Figure 2: Standard volume and high volume SH1 puck comparison

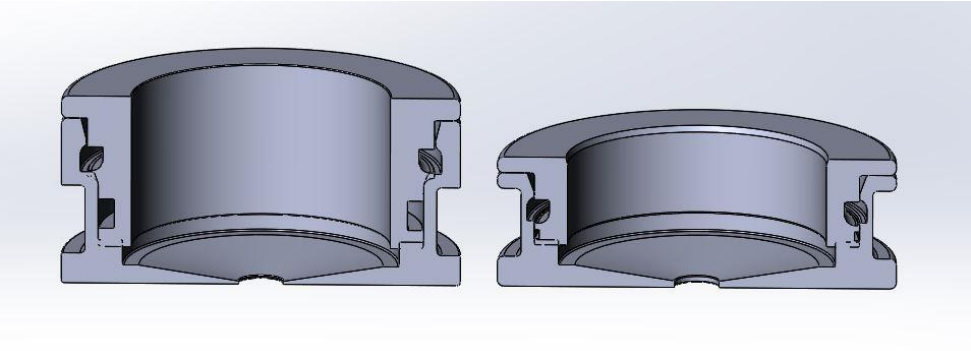


Figure 3: Large Array Format (LAF) puck comparison

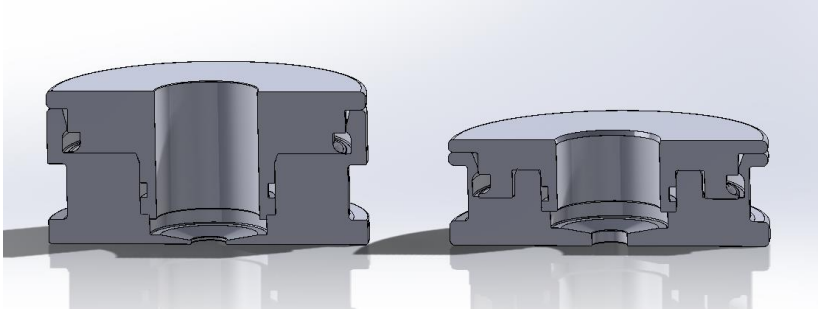


Figure 4: Small Array Format (SAF) puck comparison

Figure 2 shows standard volume and high volume pucks beside a common SH1 puck in the short format. When operating using short pucks, both the collection and lysate filtration will be accomplished using the common SH1 puck. Figure 3 depicts the Large Array Format (LAF) puck in standard and short formats. Figure 4 shows the Small Array Format (SAF) puck in both standard and short formats.

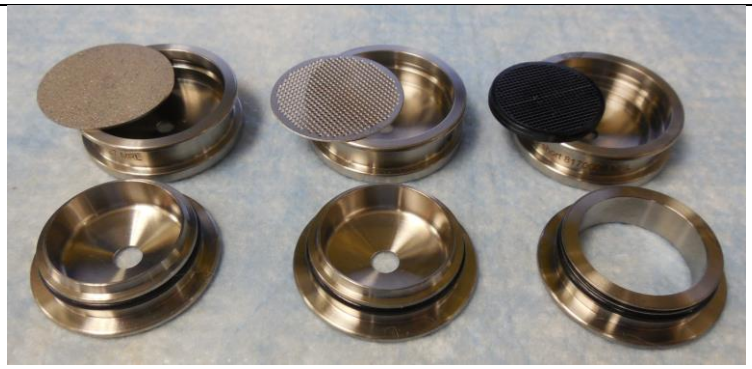


Figure 5: Disassembled short pucks, SH1, Lyfil, LAF

Figure 6: Assembled SH1, Lyfil, LAF pucks in standard and short formats

3. Flush Puck & Flush Puck Garage

The flush puck garage requires modification in order to house the short format flush puck. Follow the below instructions to remove, modify, and reinstall the flush puck garage.

a. Remove the flush puck garage from the ESP main deck by removing (3) #5 screws

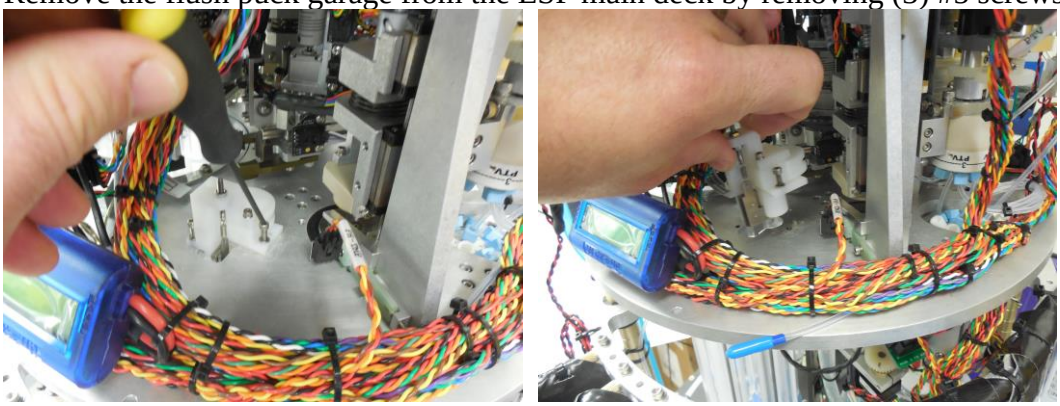


Figure 7

b. Remove the spring connection to the linear slide.

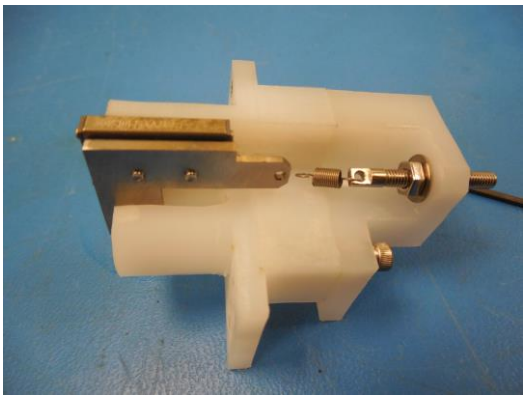


Figure 8

c. Remove the linear slide from the flush puck garage base.

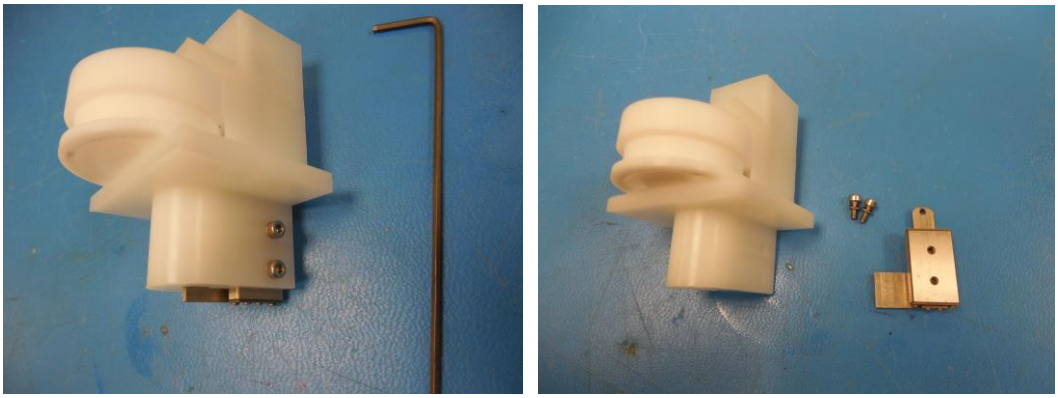


Figure 9

d. Separate the top and bottom halves of the flush puck garage. Remove the plunger and ball bearing from within the bottom half of the flush puck garage.

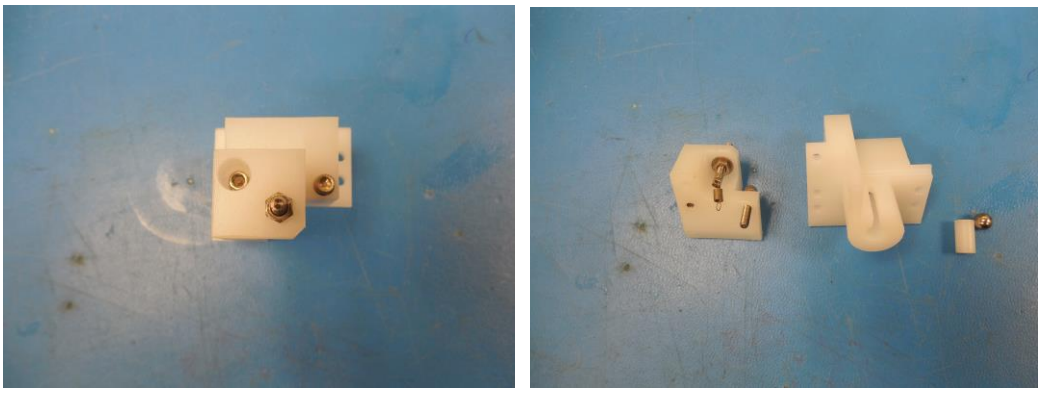


Figure 10

e. The flush puck garage bottom will be replaced with a short puck version (M4419). Remove the locating dowel pin from the flush puck garage bottom (standard size) and insert the dowel pin into the short puck version of the flush puck garage bottom

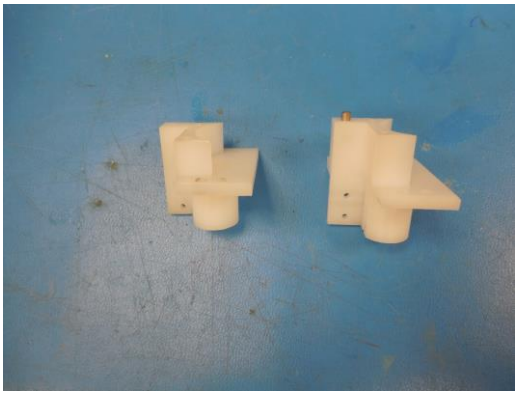


Figure 11

f. Reinstall the flush puck garage top onto the flush puck garage bottom (short puck version, M4419).

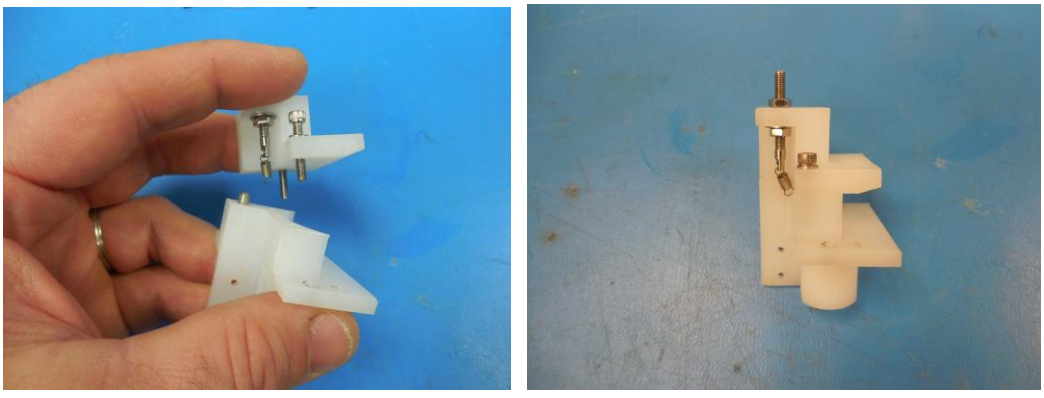


Figure 12

g. Insert the ball bearing and plunger into the slot in the flush puck garage bottom. Reinstall the linear slide onto the flush puck garage bottom; ensure the lifter is freely traveling within the plunger/bearing slot.

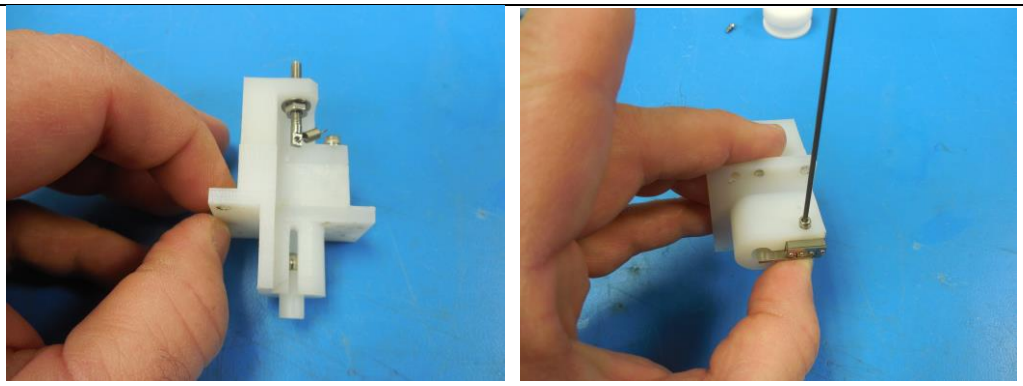


Figure 13

h. Reattach the spring to the linear slide.

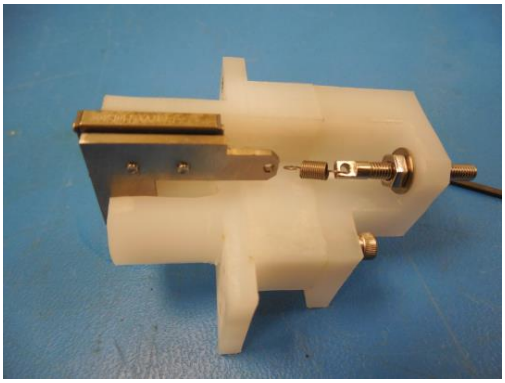


Figure 14

i. Adjust the tension in the spring by adjusting the post position on the flush puck garage top. The spring tension should be such that the flush puck is secured inside the garage, but not so tight to cause manipulator errors when retrieving the flush puck.

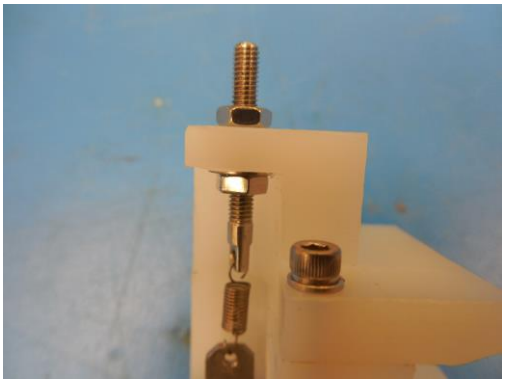


Figure 15

j. Insert the short puck flush puck (M4420) into the modified garage and ensure proper holding force. Reinstall the flush puck garage onto the ESP main deck.

k. The final step is to re-calibrate the Manipulator Forearm and Elbow to the flush puck. With the ESP powered and readied, call the ‘calarm’ routine:

   i. > require ‘calarm’
   ii. > Hand.open
   iii. > calarm Garage

iv. Perform the ‘calarm’ routine at least 3 times and average the encoder values received from each run. Values will be returned for both forearm and elbow. Enter these values into the configure.rb file for both the elbow and forearm Garage location.

4. Processing Clamp

The processing clamp requires modification in order to function properly in the short puck format. Follow the below instructions to remove, modify, and reinstall the processing clamp.

a. Unplug the (5) wired connections associated with the processing clamp and processing top valve.

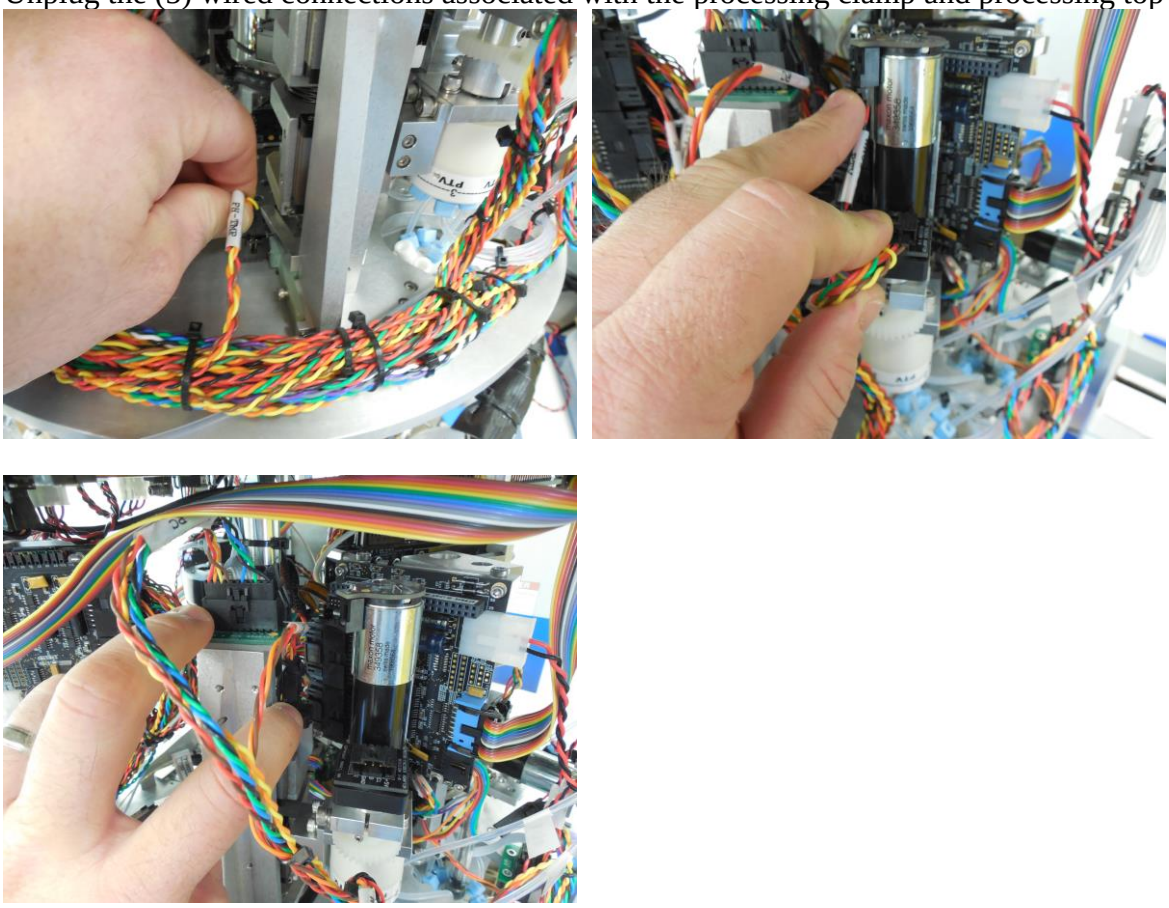


Figure 16

b. Disconnect the processing top valve mount from the processing clamp. Disconnect the fluidic connection at the processing top valve.

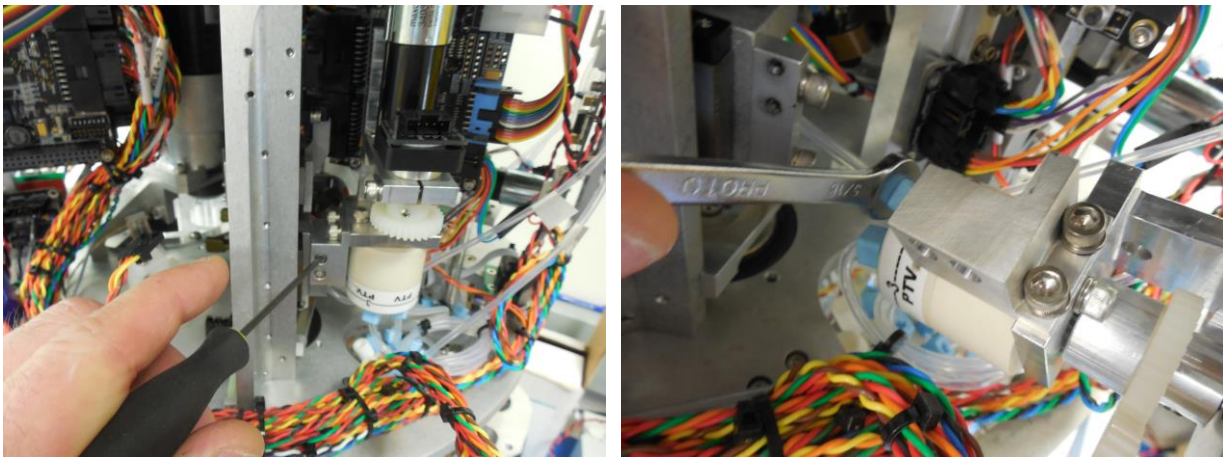


Figure 17

c. Remove the processing clamp from the ESP main deck. Do this by removing the (3) screws holding the clamp to the deck, located on the underside of the main deck.

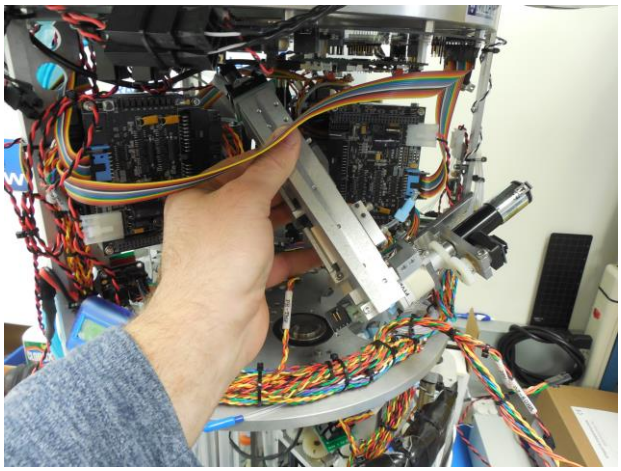



Figure 18

d. Replace the processing clamp top with the short puck format (M3912). Move the fluidic tubing onto the short puck format clamp top.

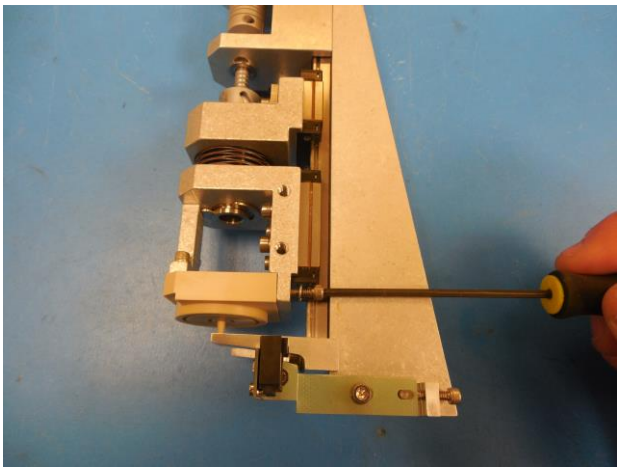
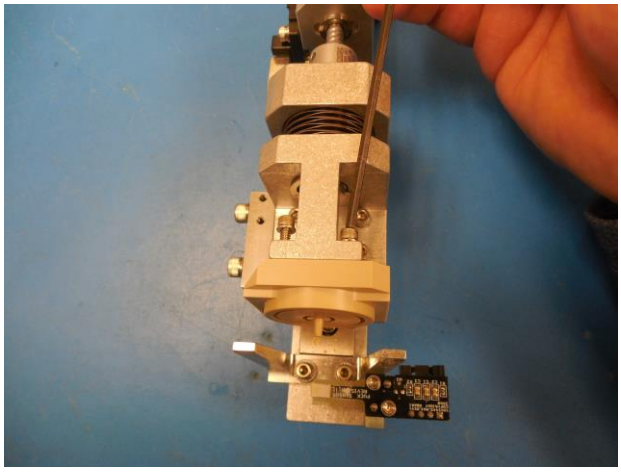
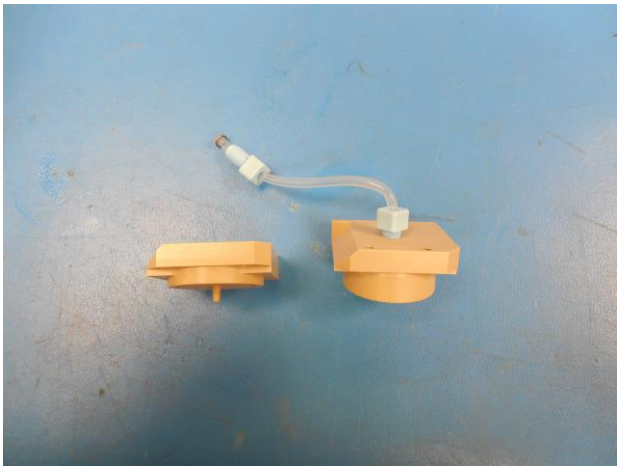




Figure 19

e. Install the new (short puck format, M3912) clamp top onto the clamp.

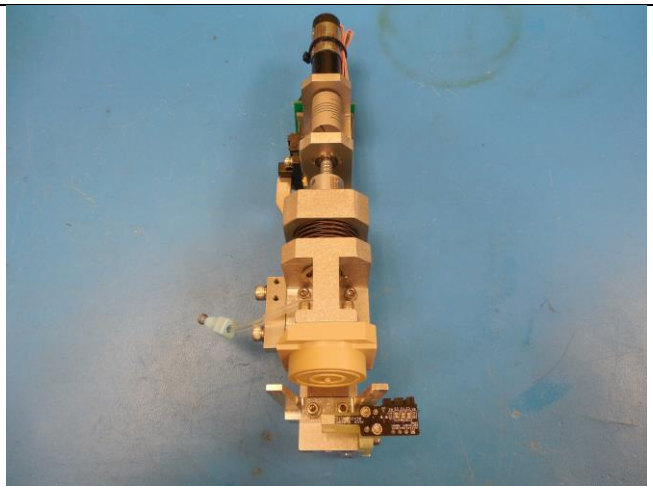


Figure 20

f. At this point, if you intend to complete the modifications to the collection clamp and camera, set the processing clamp aside and continue onto those instructions below. You will need the processing clamp removed from the ESP in order to accomplish the other modifications.

g. Reinstallation of the processing clamp is accomplished by first placing the processing clamp back onto the locating dowel pins on the ESP main deck. Once the clamp is located, install and tighten the (3) #8 screws that hold the processing clamp to the ESP main deck.

h. Reattach the fluidic line connecting the clamp top to the processing top valve. Reattach the processing top valve to the processing clamp by tightening the (2) #4 screws.

i. Reattach the (5) electrical connections to the processing clamp and processing top valve.

5. Collection Clamp

The collection clamp requires modification in order to function properly in the short puck format. Follow the below instructions to remove, modify, and reinstall the collection clamp.

a. The collection clamp modifications involve change out of the clamp top (similar to the processing clamp mods.). In addition, to complete the collection clamp top change, the intake pressure sensor mounted within the clamp top must be moved to the new top and recalibrated.

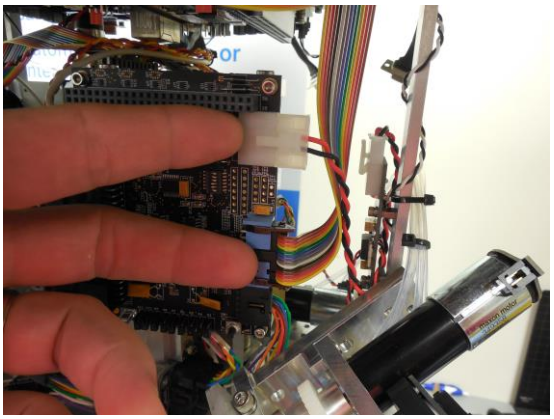
b. Prior to any disassembly, query the intake pressure sensor while at ambient pressure. To do this, issue the command 'CS.status' and take note of the inPress value. The inPress value is the analogue value for the pressure sensor under the current mounting condition. When the sensor is remounted, the inPress value at ambient should be close to this value (+/- 200 counts).

```
@12:53:21.56 -> CS.status
#<struct I2C::Servo::Status enabled=true, pastRLS=false, pastFLS=false, pastThresh
old=false, lost=false, home=true, position=-12164, velocity=0, current=0, pwm=-3,
err=-4, inPress=1066, outPress=1068, deltaPress=2064, voltage=13.7477015218459>
ESPLPjudy:003:0->
```

Figure 21

c. The following directions assume the processing clamp is already removed from the ESP main deck.

d. In order to access the collection clamp for removal, first the manipulator must be removed. Begin by disconnecting the (3) electrical connections to the manipulator assembly.



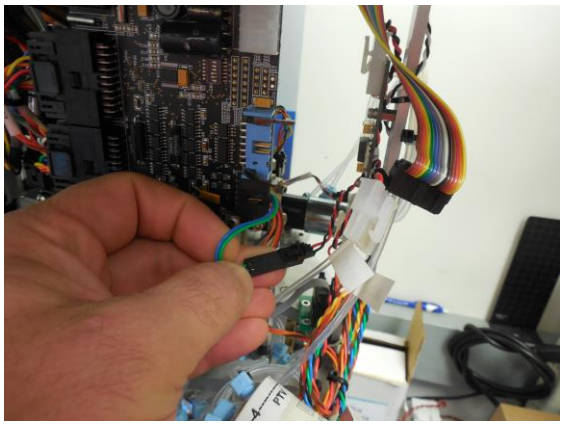


Figure 22

e. Locate the (2) #10 screws which attach the manipulator to the ESP main deck and remove screws to free the manipulator. The screws are located on the underside of the ESP main deck, beside the PBV.

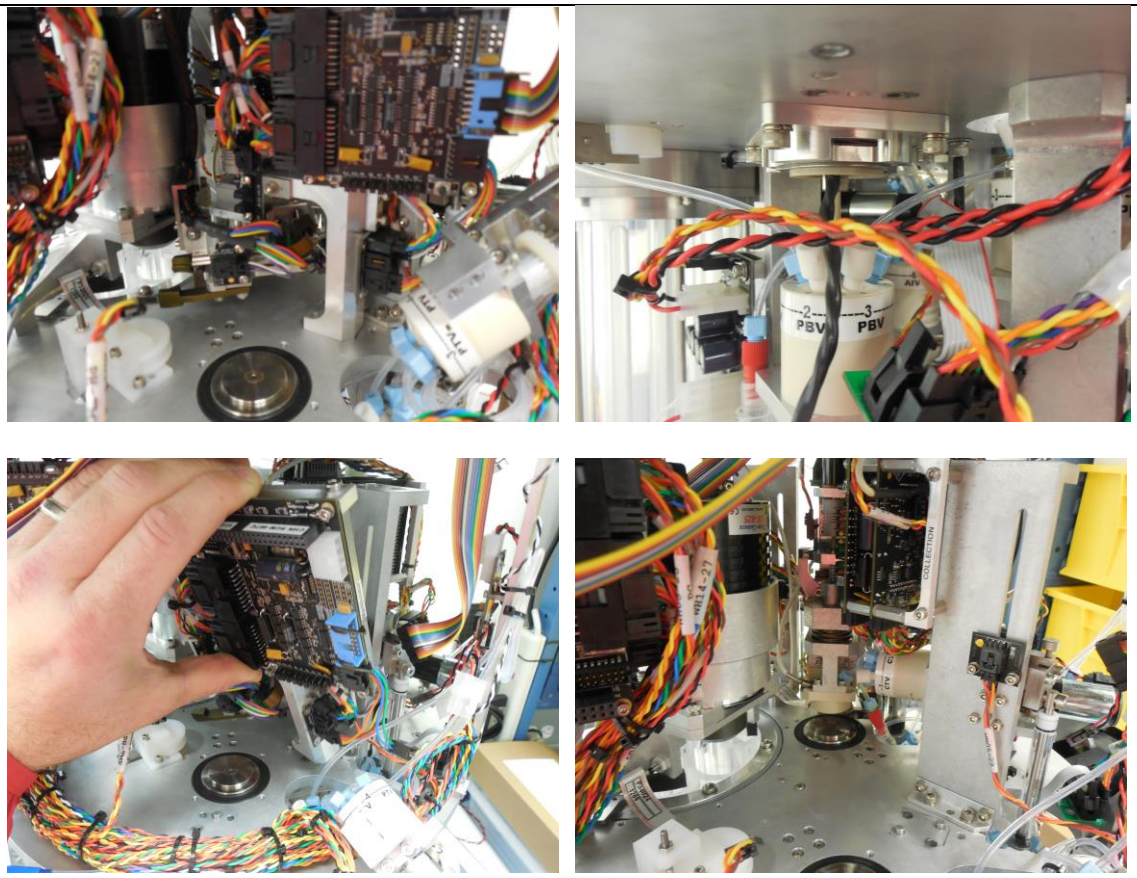


Figure 23

f. With the manipulator removed, access is gained to the collection clamp. Remove the fluidic connection into the collection clamp top.

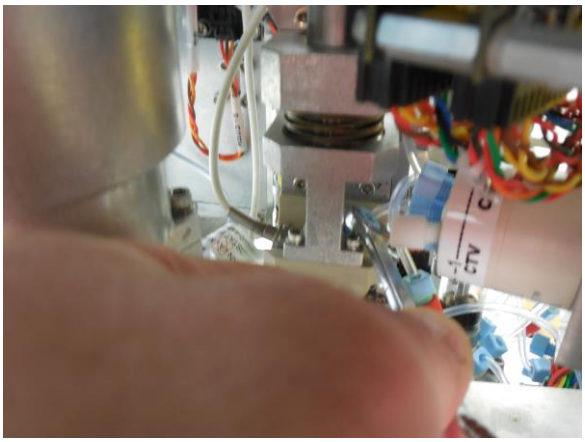


Figure 24

g. Remove the collection top valve from being connected to the collection clamp. Locate and loosen the (2) #8 screws which attach the collection top valve to the collection clamp.

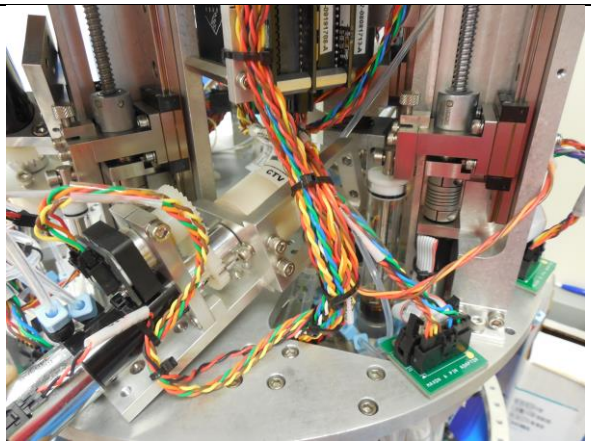


Figure 25

h. Disconnect the electrical connection between the pressure sensor and the collection dwarf electronics stack. Access to disconnect the electrical connection is limited; a tool will be needed to press on the connector while pulling lightly on all wires. In the below image, a plastic o-ring pick is used to accomplish this task. This connector and the associated wires will stay attached to the collection clamp when removed from the ESP main deck.

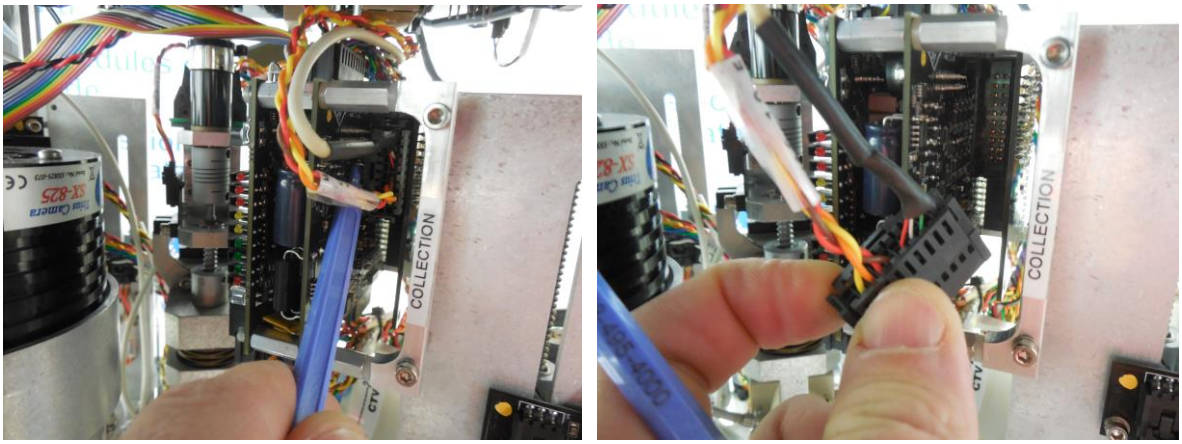


Figure 26

i. Next, disconnect the electrical connections to the collection clamp associated with the drive motor and home sensor.

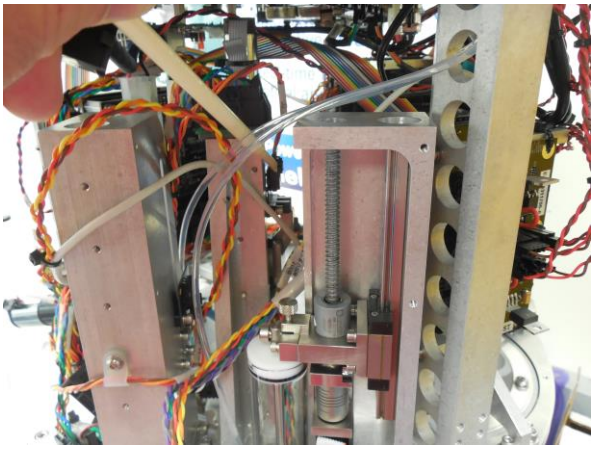


Figure 27

j. Disconnect the collection clamp from the ESP main deck. Locate and remove the (3) #8 screws on the underside of the ESP main deck which attach the collection clamp to the deck.

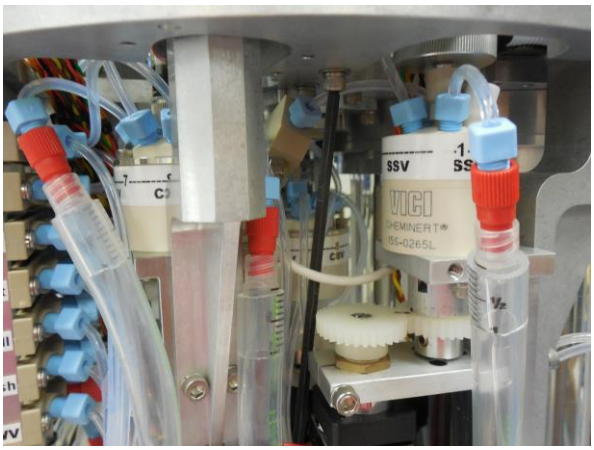
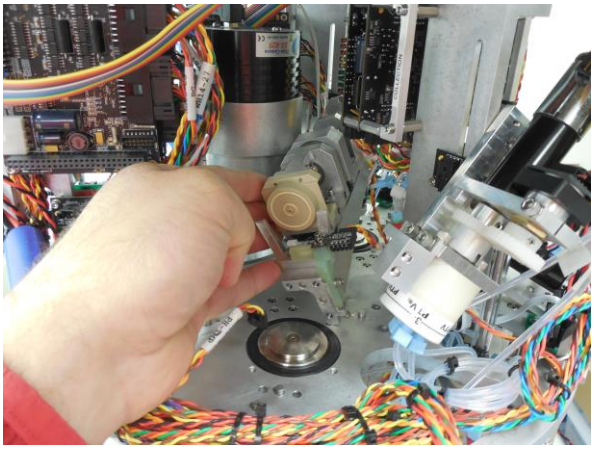


Figure 28

k. Lift the collection clamp off of the locating dowel pins and remove the clamp from the ESP main deck. The clearance to remove the collection clamp is limited. The collection clamp is best removed bottom-first, guiding the attached wires as the clamp is removed.



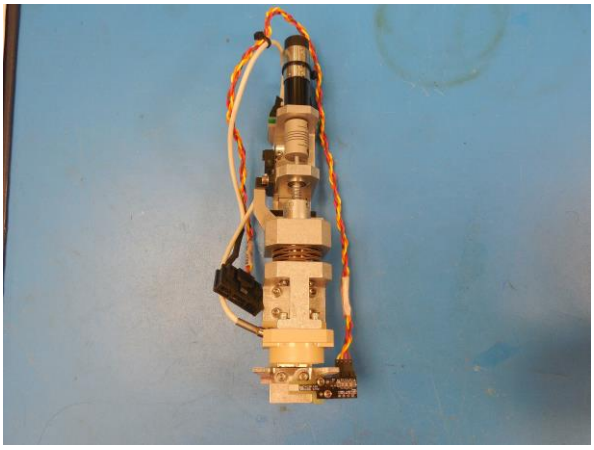
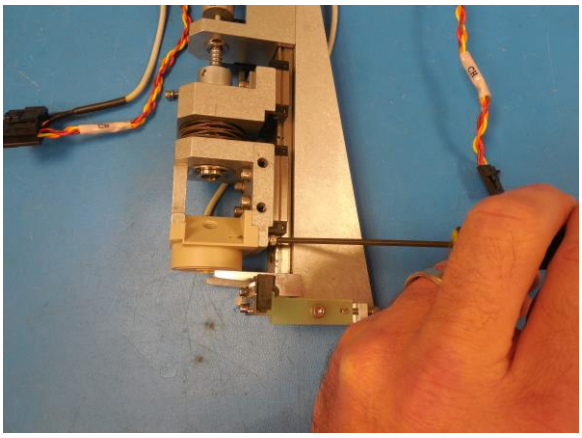


Figure 29

l. With the collection clamp removed and on a work surface, remove the clamp top.



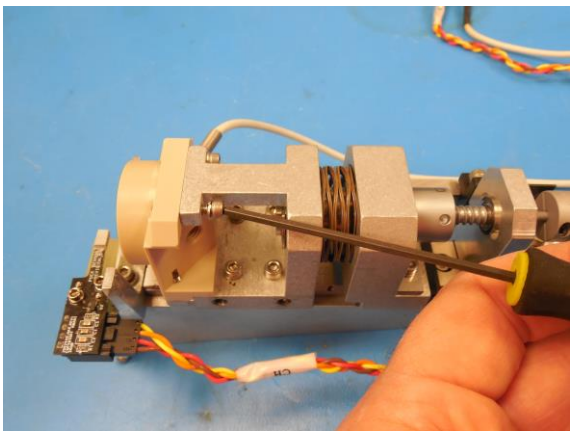


Figure 30

m. Unscrew the pressure sensor from the clamp top and reinstall into the new clamp top (M3913). When installing the pressure sensor into the new clamp top, take care to not over-tighten the pressure sensor. Tighten the pressure sensor hand-tight, followed by a ¼ turn with a 5/16" wrench.

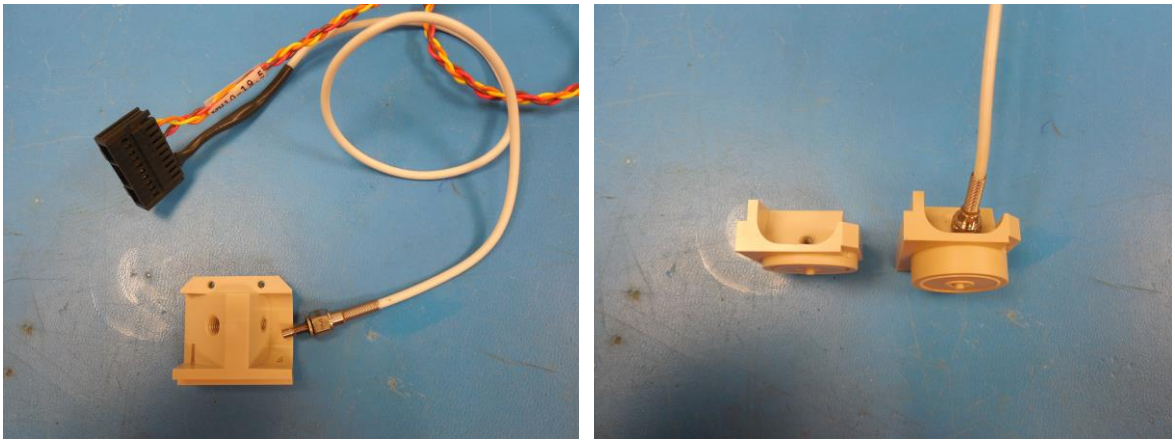


Figure 31

n. With the pressure sensor mounted in the new clamp top, we must check to confirm that the ambient analogue reading of the sensor is reasonably close to that when the sensor was mounted in the previous clamp top. Without reinstalling the clamp top onto the clamp, plug the pressure sensor electrical connection back into the collection dwarf stack. Query the pressure sensor (CS.status) and take note of the inPress value returned. This value should be close to that noted from step (4b) of this procedure (+/- 200 counts). If the new value is significantly higher it is likely that the pressure sensor was overtightened, loosen the pressure sensor and query again. Iterate through tightening and loosening the sensor as needed until a desirable ambient analogue reading is obtained and the sensor is sealed against the clamp top.

o. With the pressure sensor installed into the clamp top, now remove the electrical connection to the Collection stack and continue with rebuilding the clamp

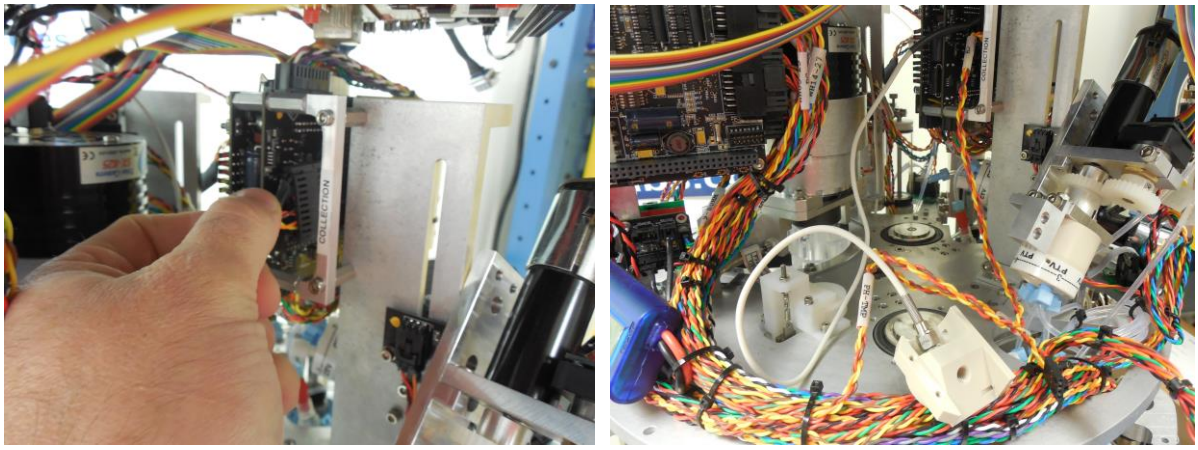


Figure 32

p. Install the new collection clamp top onto the collection clamp using (4) #4 screws which were removed with the previous clamp top.

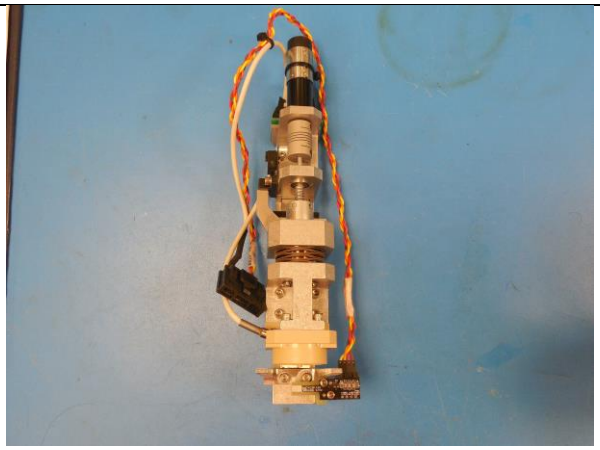


Figure 33

q. At this point, if you intend to complete the modifications to the camera, set the collection clamp aside and continue onto those instructions below. Leaving the collection clamp removed may provide added space to accomplish the camera modifications
.

r. Reinstallation of the collection clamp is accomplished by first placing the collection clamp back onto the locating dowel pins on the ESP main deck. Once the clamp is located, install and tighten the (3) #8 screws that hold the collection clamp to the ESP main deck.

s. Reroute the pressure sensor electrical connection to the collection dwarf stack and plug the connection into the stack.

t. Reconnect the electrical connection associated with the collection clamp drive motor and collection clamp home sensor.

u. Position the collection top valve such that the fluidic connection to the collection clamp top is mating with the port on the clamp top. Secure the collection top valve mount to the collection clamp using (2) #8 screws. Tighten the fluidic connection between the collection top valve and the collection clamp top.

v. Once the ESP is completely reassembled, the pressure sensor will need to undergo a recalibration. Refer to APPENDIX J for direction on how to calibrate the pressure sensor.

6. Camera

In order to operate the ESP in short puck format the camera assembly requires modification. Two parts of the camera assembly will be replaced; the camera spacer and the light seal flange. The following instructions assume that the processing clamp and manipulator have already been removed, as described previously in this procedure.

a. Locate the camera and disconnect the data and power connections to the camera.

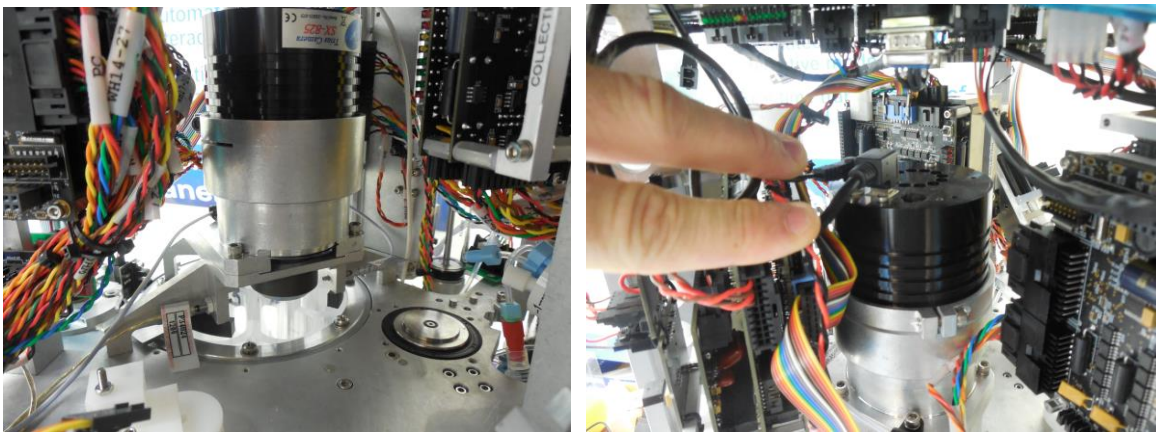


Figure 34

b. Loosen the (1) #10 screw that secures the camera within the camera mount housing.

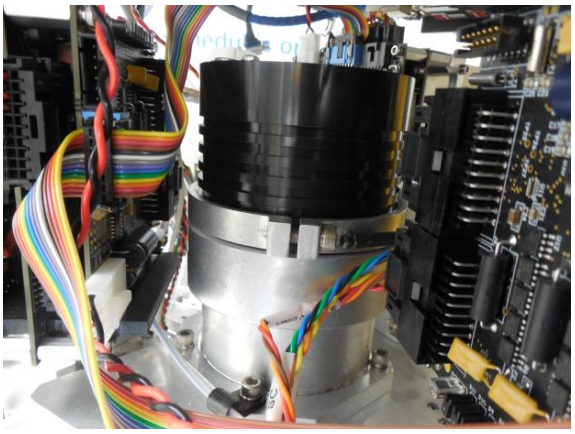


Figure 35

c. Remove the camera from the camera mount and place aside with the lens covered for safety.

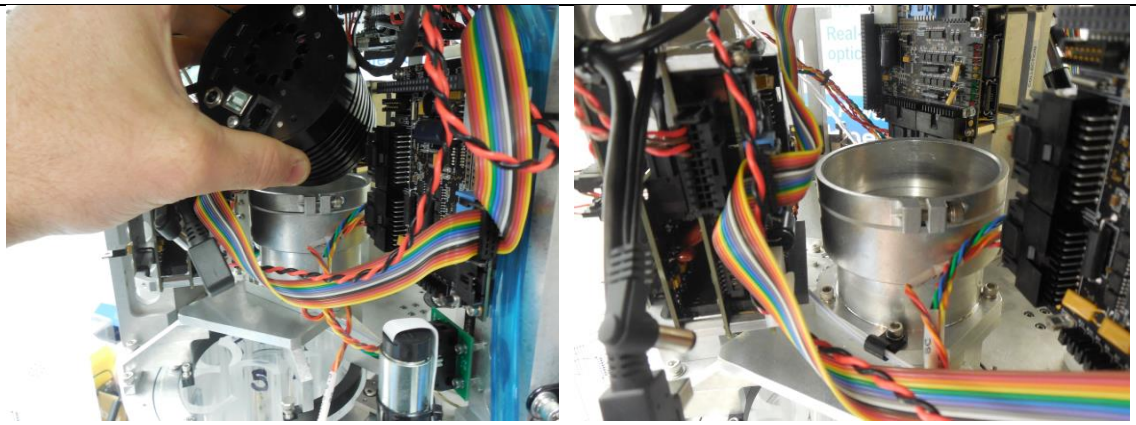


Figure 36

d. Loosen and remove the (4) #8 screws that hold the camera housing mount to the camera base. Remove the camera housing mount from the ESP. Removal of the camera housing mount is best done through the area that the processing clamp would occupy.

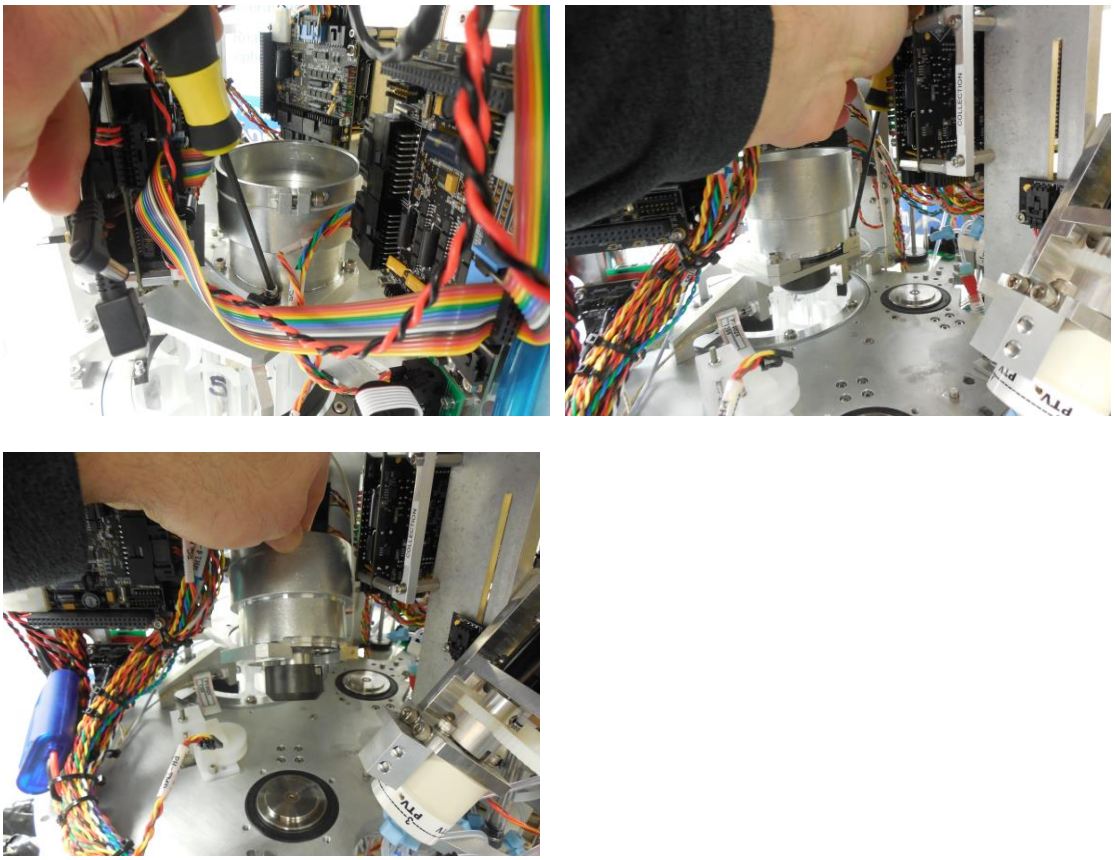


Figure 37

e. Remove the camera spacer that is loose in the camera mount, this will be replaced by a thinner spacer for operating with short pucks.


Figure 38

f. Remove the snap ring that holds the light seal assembly within the camera housing mount.

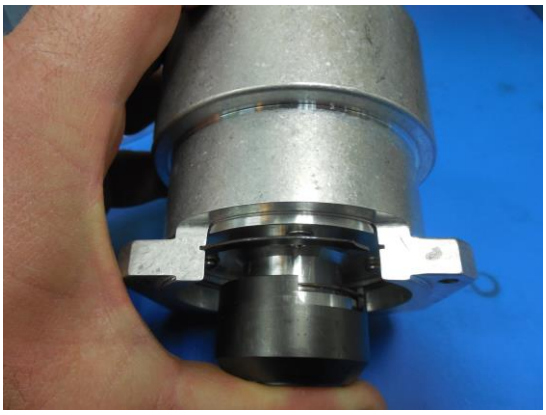



Figure 39

g. Remove the (4) phillips head screws that attach the light seal flange to the light seal shaft.

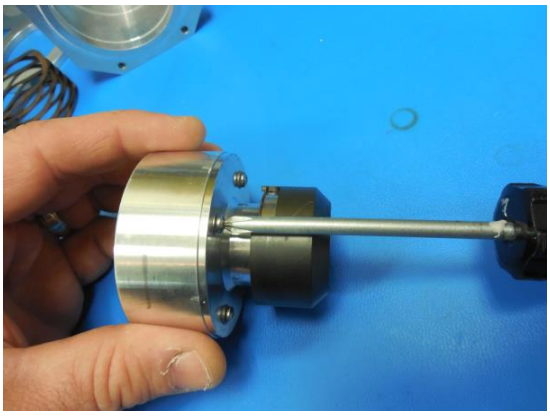
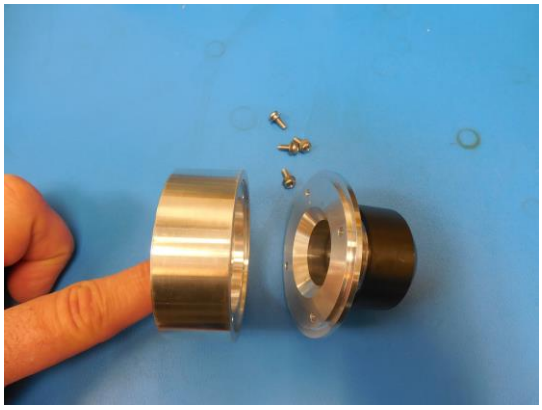



Figure 40

h. Remove the snap ring that holds the puck release onto the light seal flange.

Figure 41

i. Unscrew the light seal from the light seal flange

Figure 42

j. The light seal flange will be replaced with a short puck revision (M4423). Screw the light seal into the short puck revision light seal flange. The short puck revision light seal flange is on the right in the image below, with a longer neck to accommodate imaging using short pucks.

Figure 43

k. Reinstall the puck release onto the light seal flange using the small snap ring to secure. Ensure the small springs (qty: 3) are installed on the posts inside the puck release prior to installing onto the light seal flange. When securing the snap ring inside the groove on the puck release, feed the snap ring in from one side until fully seated inside the groove.

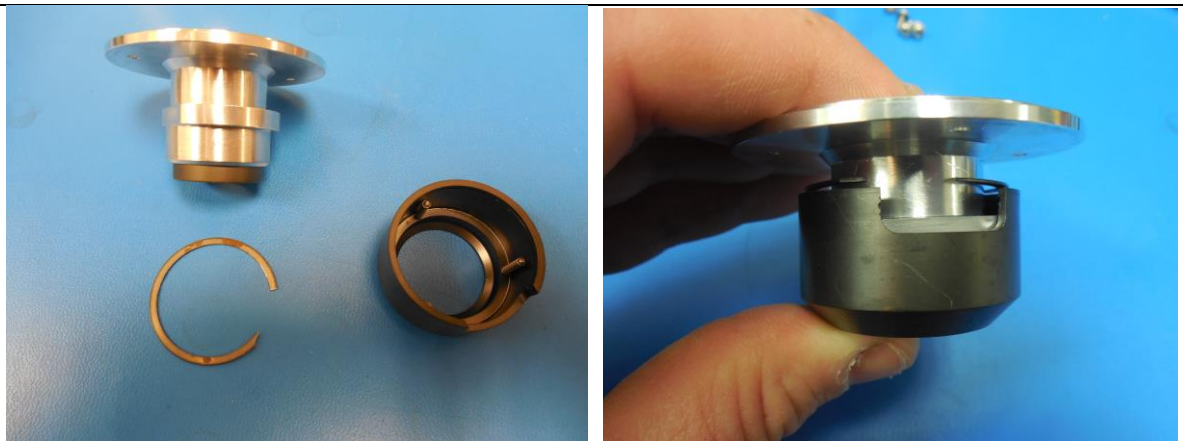


Figure 44

l. Attach the light seal flange to the light seal shaft, using the (4) phillips head screws.

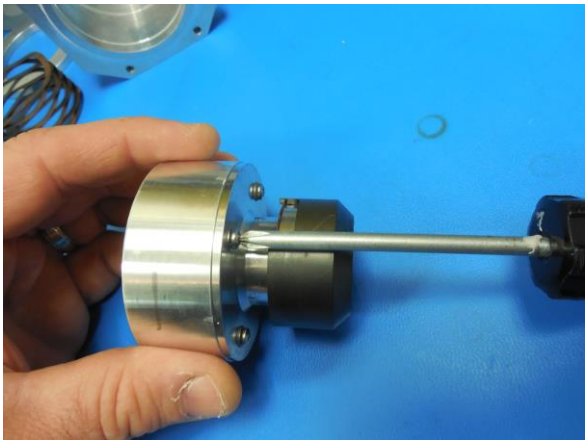
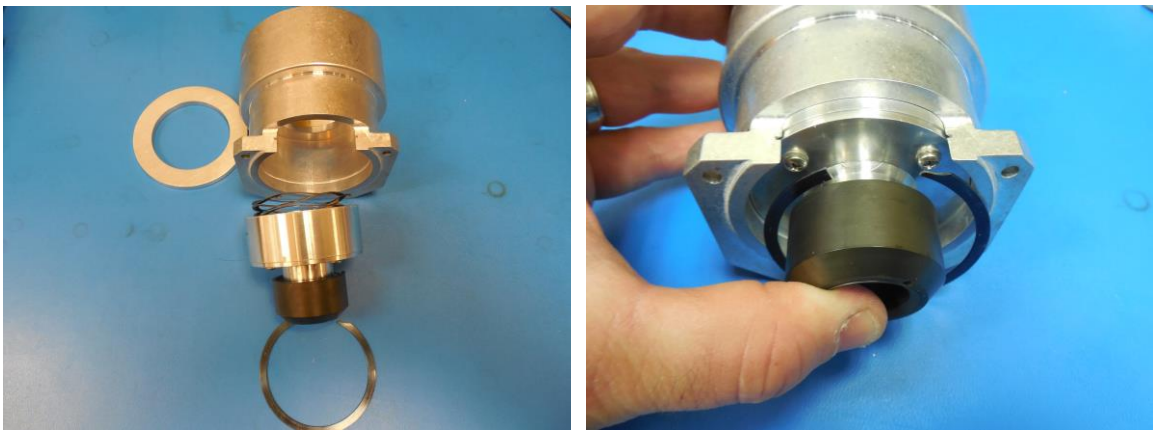


Figure 45

m. Install the light seal assembly into the camera clamp and secure using the large snap ring. Ensure the spring is placed inside the light seal assembly prior to installing into the camera clamp.



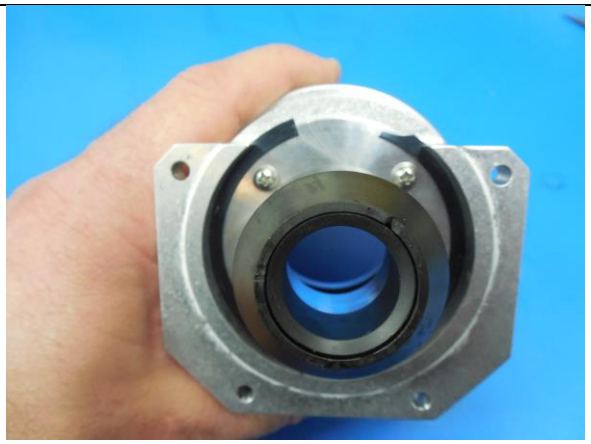


Figure 46

n. Place the camera spacer inside the camera clamp. For short puck operations, the thinner camera spacer is used (M4424).

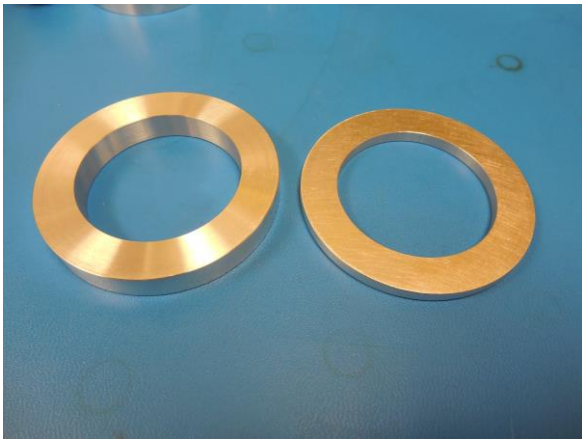
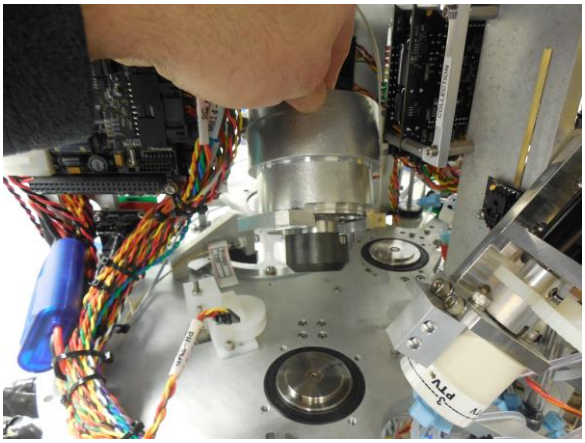


Figure 47

o. Reinstall the modified camera assembly onto the ESP. Use the (4) #8 screws to attach the camera clamp/light seal assembly to the camera base.



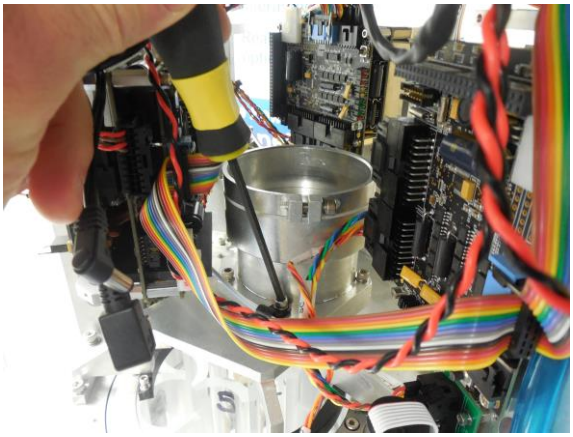
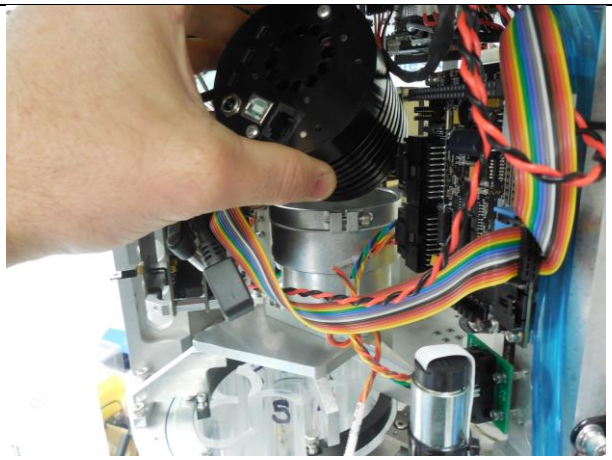


Figure 48

p. Insert the camera into the camera clamp and secure with the (1) #10 screw in the camera clamp.



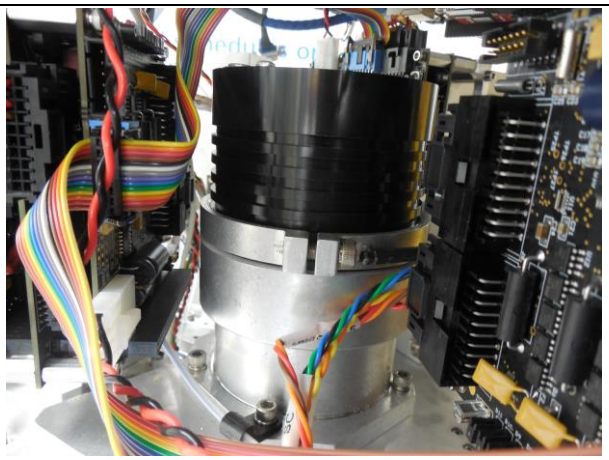


Figure 49

q. Reattach the connections to the camera for power and data.

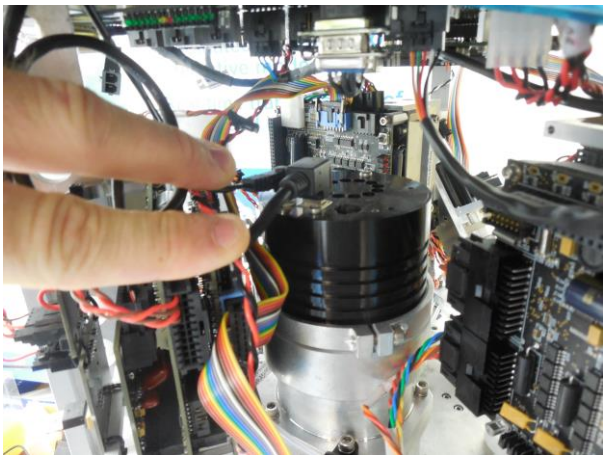


Figure 50

r. With the camera re-installed, it will also need to be re-focused. Prior to re-focusing the camera, the Storage Elevator will require calibration for operation with short pucks. Refer to the Appendices for calibration and focus instructions.

7. Appendix A: Overview of Re-Assembly, Configuration File Update and Calibrations

With the individual sub-assemblies modified for operation with short pucks, re-assembly of the ESP and sub-assembly calibrations is required. The overall re-assembly of the ESP should follow the below order of operations; refer to the previous sections of this procedure for guidance.

- Install the Collection Clamp
    - Re-attach the CTV to the Collection Clamp, including connection of fluidic tubing
    - Reconnect electrical connection to Collection Clamp and CTV
- Install the Camera
    - Reconnect data and power connections to the Camera
- Install the Manipulator
    - Reconnect the electrical connections to the Manipulator
- Install the Flush Puck Garage
- Install the Processing Clamp
    - Re-attach the PTV to the Processing Clamp, including connection of fluidic tubing
    - Reconnect electrical connections to the Processing Clamp and PTV

The ESP configure.rb file format must be updated to the latest version prior to beginning the short puck calibration effort. Contact McLane for the latest version configure.rb file and assistance on updating the ESP configuration settings.

The calibrations must also follow a specific order. Each calibration is detailed individually in the following Appendices. A summary of the calibrations is listed below in the order in which they should be performed.

- Appendix B: Calibrate the Manipulator Elbow and Forearm to the Flush Puck Garage
    - calarm Garage
- Appendix C: Calibrate the Manipulator Elbow and Forearm to the Collection Clamp
    - calarm CC
- Appendix D: Calibrate the Manipulator Elbow and Forearm to the Processing Clamp
    - calarm PC
- Appendix E: Calibrate the Storage Carousel
    - calcar
- Appendix F: Calibrate the Manipulator Elbow and Forearm to each Carousel Tube
    - calarm (1-7)
- Appendix G: Calibrate the Collection Clamp positions
- Appendix H: Calibrate the Processing Clamp positions
- Appendix I: Calibrate the Storage Elevator positions
- Appendix J: Check & re-focus Camera
- Appendix K: Calibrate the Pressure Sensors

8. Appendix B: Calibrate the Manipulator Elbow and Forearm to the Flush Puck Garage

    a. Begin by applying power to the ESP and readying the ESP
        i. > ESP.ready!
    b. Call the calarm.rb file
        i. > require 'calarm.rb'
        ii. A 'true' response should be returned at the command prompt
    c. Open the hand prior to beginning the calibration
        i. > Hand.open
        ii. The calibration will be performed with the Hand empty and open
    d. Ensure that the Flush Puck is installed into the Flush Puck Garage
    e. Call the calibration routine
        i. > calarm Garage
        ii. Allow the routine to complete
    f. Record the values returned for both the Manipulator Forearm and Elbow axis
    g. Perform the calarm Garage routine at least three times and average the Forearm and Elbow values
    h. Enter the averaged value for the Forearm and Elbow into the configure.rb file, save and reload the configure.rb file onto the ESP
    i. Unload and load the Flush Puck from/to the Garage multiple times in order to confirm the calibration
        i. > 25.times {Hand.open; Arm.grab Garage; delay 1; Arm.clear; delay 1; Arm.to Garage; Hand.open; Arm.clear}
    j. If overcurrent or position errors related to the Manipulator occur, recalibrate and try again.

9. Appendix C: Calibrate the Manipulator Elbow and Forearm to the Collection Clamp

    a. Begin by applying power to the ESP and readying the ESP
        i. > ESP.ready!
    b. Call the calarm.rb file
        i. > require 'calarm.rb'
        ii. A 'true' response should be returned at the command prompt
    c. Open the hand prior to beginning the calibration
        i. > Hand.open
        ii. The calibration will be performed with the Hand empty and open
    d. Call the calibration routine
        i. > calarm CC
        ii. Allow the routine to complete
    e. The calibration routine will return both an Elbow and Forearm value. The Elbow value will be the only one used from this routine. Record the Elbow value returned by the calibration routine.
    f. Perform the calarm CC routine at least three times and average the Elbow values that are returned
    g. Enter the averaged value for the Elbow into the configure.rb file, save and reload the configure.rb file onto the ESP
    h. Next, the Forearm value must be attained. This will be done manually (no automated routine). First load an SH1 short puck into the Flush Puck Garage for easy access by the Manipulator.
    i. For the Forearm calibration, things to check are:
        i. Good thermal contact between puck and thermal pad on finger of temperature board.

ii. Finger is slightly lower than center of puck groove, so finger does not hit the bottom of the puck groove when moved into clamp and finger doesn't hit the top of the puck groove when clamped.
iii. Top clamp nipple is centered to puck.

j. Load the SH1 short puck into the Manipulator Hand and clear the Arm
   i. > Hand.open
   ii. > Arm.grab Garage
   iii. > Arm.clear
k. Point the Manipulator Elbow to the CC
   i. > Elbow.CC
l. Jog the Forearm until the clamp nozzle is directly over-top of the opening on the puck.
   i. Axis can be 'jogged' in either (-, extend) or (+, retract) directions. Increments can be on the order of 10's, 100's or 1000's depending upon the distance desired. Be sure to understand direction (+ vs. -) and magnitude prior to attempting fine placement of the axis.
      1. When jogging the forearm in small increments, error will accumulate. Send forearm to clamp (only if you know this position is not far off and will not break finger), jog in small increments 25-100 counts (-, extend) or (+, retract), send back to home then send back to position with added counts.
         a. > Forearm.raw Position # Note position
         b. > Forearm.jog -50
         c. > Forearm.rawPosition #returned position = ***n***
         d. > Forearm.home.to :home
         e. > Forearm.rawPosition #returned position = ***home***
         f. > Forearm.jog ***-d*** # ***d*** = |difference between ***n*** and ***home***|
   ii. Also, be considerate of how the puck is contacting the temperature sensor. The puck should fully contact the temperature sensor, slightly deflecting the arm that the sensor is mounted on. Over aggressively contacting the sensor could cause damage to the sensor or cause Forearm speed errors.
      1. If you are unable to get the top clamp nipple centered without deflecting the finger too far, heater board will need to be backed out.
         a. To do so, remove center screw on G-10 piece on the side of the clamp that the heater board is mounted onto.
         b. Back out the back screw that sets the position of the heater board in small increments, and pull back G-10 mounting piece.
m. Make sure to keep finger leveled and G-10 piece is flush to set screw before putting back the center screw.With the Forearm positioned such that the clamp nozzle is centered on the puck opening, query the Forearm axis for a position reading.
   i. > Forearm.rawPosition
   ii. Record the 'position' value
n. Unload the puck from the Hand and clear the Arm. Leave the SH1 short puck in the Garage for further testing.
   i. > Arm.to Garage
   ii. > Hand.open; Arm.clear
o. Enter the value recorded into the configure.rb file for the Forearm Collection value. Save and reload the configure.rb file onto the ESP.
p. Bring the SH1 short puck from the Garage into the Collection Clamp. Watch to ensure the calibration positions entered for Elbow and Forearm look appropriate (puck positioned directly under clamp and centered on clamp nozzle).
   i. > Hand.open

ii. > Arm.grab Garage
iii. > Arm.to CC

q. Return the SH1 short puck to the Garage and clear Arm
i. > Arm.to Garage
ii. > Hand.open
iii. > Arm.clear

10. Appendix D: Calibrate the Manipulator Elbow and Forearm to the Processing Clamp

a. Begin by applying power to the ESP and readying the ESP
i. > ESP.ready!
b. Call the calarm.rb file
i. > require 'calarm.rb'
ii. A 'true' response should be returned at the command prompt
c. Open the hand prior to beginning the calibration
i. > Hand.open
ii. The calibration will be performed with the Hand empty and open
d. Call the calibration routine
i. > calarm PC
ii. Allow the routine to complete
e. The calibration routine will return both an Elbow and Forearm value. The Elbow value will be the only one used from this routine. Record the Elbow value returned by the calibration routine.
f. Perform the calarm PC routine at least three times and average the Elbow values that are returned
g. Enter the averaged value for the Elbow into the configure.rb file, save and reload the configure.rb file onto the ESP
h. Next, the Forearm value must be attained. This will be done manually (no automated routine). First load an SH1 short puck into the Flush Puck Garage for easy access by the Manipulator.
i. For the Forearm calibration, things to check are:
i. Good thermal contact between puck and thermal pad on finger of temperature board.
ii. Finger is slightly lower than center of puck groove, so finger does not hit the bottom of the puck groove when moved into clamp and finger doesn't hit the top of the puck groove when clamped.
iii. Top clamp nipple is centered to puck.
j. Load the SH1 short puck into the Manipulator Hand and clear the Arm
i. > Hand.open
ii. > Arm.grab Garage
iii. > Arm.clear
k. Point the Manipulator Elbow to the PC
i. > Elbow.PC
l. Jog the Forearm until the clamp nozzle is directly over-top of the opening on the puck.
i. Axis can be 'jogged' in either (-, extend) or (+, retract) directions. Increments can be on the order of 10's, 100's or 1000's depending upon the distance desired. Be sure to understand direction (+ vs. -) and magnitude prior to attempting fine placement of the axis.
1. When jogging the forearm in small increments, error will accumulate. Send forearm to clamp (only if you know this position is not far off and will not break finger), jog in small increments 25-100 counts (-, extend) or (+, retract), send back to home then send back to position with added counts.
a. > Forearm.raw Position # Note position

b. > Forearm.jog -50
c. > Forearm.rawPosition #returned position = ***n***
d. > Forearm.home.to :home
e. > Forearm.rawPosition #returned position = ***home***
f. > Forearm.jog ***-d*** # ***d*** = |difference between ***n*** and ***home***|

2.

ii. Also, be considerate of how the puck is contacting the temperature sensor. The puck should fully contact the temperature sensor, slightly deflecting the arm that the sensor is mounted on. Over aggressively contacting the sensor could cause damage to the sensor or cause Forearm speed errors.
    1. If you are unable to get the top clamp nipple centered without deflecting the finger too far, heater board will need to be backed out.
        a. To do so, remove center screw on G-10 piece on the side of the clamp that the heater board is mounted onto.
        b. Back out the back screw that sets the position of the heater board in small increments, and pull back G-10 mounting piece.

m. Make sure to keep finger leveled and G-10 is flush to set screw before putting back the center screw.With the Forearm positioned such that the clamp nozzle is centered on the puck opening, query the Forearm axis for a position reading.
    i. > Forearm.rawPosition
    ii. Record the 'position' value
n. Unload the puck from the Hand and clear the Arm. Leave the SH1 short puck in the Garage for further testing.
    i. > Arm.to Garage
    ii. > Hand.open; Arm.clear
o. Enter the value recorded into the configure.rb file for the Forearm Processing value. Save and reload the configure.rb file onto the ESP.
p. Bring the SH1 short puck from the Garage into the Processing Clamp. Watch to ensure the calibration positions entered for Elbow and Forearm look appropriate (puck positioned directly under clamp and centered on clamp nozzle).
    i. > Hand.open
    ii. > Arm.grab Garage
    iii. > Arm.to PC
q. Return the SH1 short puck to the Garage and clear Arm
    i. > Arm.to Garage
    ii. > Hand.open
    iii. > Arm.clear

11. Appendix E: Calibrate the Storage Carousel (SC)
    a. Begin by applying power to the ESP and readying the ESP
        i. > ESP.ready!
    b. Call the calcar.rb file
        i. > require 'calcar.rb'
        ii. A 'true' response should be returned at the command prompt
    c. Call the calcar routine.
        i. > calcar
    d. Follow the prompt and rotate the SC to tube 1, then push return.
    e. Repeat the calcar routine 3 times, if needed, and average the returned value from each run for each tube.

f. Enter the values recorded into the configure.rb file for the Storage Carousel tubes, and restart the ESP application.
g. You can verify the SC positions are correct and that the SE plunger is centered to the back slot of each tube.
    i. > to 1
    ii. > SE.coast # slide the elevator up to a position you can see the alignment of the SE to the SC tube slot.
    iii. Return the elevator to the bottom position and repeat for each tube.

12. Appendix F: Calibrate the Manipulator Elbow and Forearm to each Carousel Tube

a. Begin by applying power to the ESP and readying the ESP
    i. > ESP.ready!
b. Call the calarm.rb file
    i. > require 'calarm.rb'
    ii. A 'true' response should be returned at the command prompt
c. Place an SH1 short puck into the Garage and load the puck into the Hand
    i. > Hand.open
    ii. > Arm.grab Garage
    iii. > Arm.clear
d. Call the calarm routine for each carousel tube, starting at tube 1 and ending with tube 7
    i. > calarm #
    ii. Allow the routine to complete for each tube and record the value for Elbow and Forearm positions.
e. Now call the calarm routine for each carousel tube, starting with 7 and ending at 1
    i. > calarm #
    ii. Allow the routine to complete for each tube and record the value for Elbow and Forearm positions
f. Repeat calling calarm from 1-7 and 7-1, if needed, recording the values returned. Do this calibration 3 times and average the values returned from each run for each tube.
g. Enter the value recorded into the configure.rb file for the Forearm and Elbow tube number values. Save and reload the configure.rb file onto the ESP.
h. Once the PC and CC and SE positions are calibrated (detailed in the next Appendices), a shufflepuck will be run and at this point we will be able to verify the calibration just completed

13. Appendix G: Calibrate the Collection Clamp positions
a. Begin by applying power to the ESP and readying the ESP
    i. > ESP.ready!
b. Place an SH1 short puck into the Garage and load into the Hand
    i. > Hand.open
    ii. > Arm.grab Garage
    iii. > Arm.clear
c. Bring the SH1 short puck into position under the clamp
    i. > Arm.to CC
d. Determine the :sealed position
    i. Jog the clamp down until the nozzle is just entering the opening of the puck
        1. > CC.jog 1000
    ii. Using the force command, apply 15% motor power and allow clamp to stall

1. > CC.force 15

iii. When the motor stops turning (stalls), get a position reading and record as the :sealed value within the configure.rb file
1. > CC.rawPosition

e. Determine the :unsealed position
i. With the puck still held by the manipulator and clamped in place, coast the manipulator forearm and slowly jog the clamp open until the puck can slide forward and backward along the forearm axis.
1. > Forearm.coast # coasts the forearm motor
2. > CC.jog -200 # Moves the CC up 200 counts.
a. After each jog, try to slide the gripper/puck back and forth in the clamp. The point at which it is no longer held in place by the clamp is considered :unsealed.

ii. When the puck is free to move in the clamp, get the position and record it for :unsealed
1. > CC.rawPosition

iii. Open the clamp, replace the puck into the garage.
1. > CC.open
2. > Arm.garage
3. > Hand.open
4. > Arm.clear

iv. Enter this value as :unsealed for the Collection Clamp (also enter the sealed value from the previous step) in the configure.rb file and restart the ESP application.

f. Determine the :closed position
i. With the SH1 short puck still in the Garage, load the puck into the Hand and bring under the CC
1. > Hand.open
2. > Arm.grab Garage
3. > Arm.to CC

ii. Send the clamp to the :sealed position
1. > CC.sealed

iii. Using the jog command, determine the appropriate :closed position
1. > CC.jog 500
2. Jog down until the heater pad just barely deflects under the load of the clamp. Generally, this position will be a few thousand counts beyond the sealed position.

iv. Get the position and record it as :closed
1. > CC.rawPosition

v. Enter this value as :closed for the appropriate clamp in the configure.rb file and restart the ESP application.

vi. Check :closed calibration on clamp to verify that the Heater spring is slightly compressed. Check ratio of on/off springs and torque ratio.
1. > Arm.garage
2. > Hand.open
3. > Arm.clear
4. > CC.loadFlush #See torque and sample value.
5. > CC.unloadFlush

vii. Leave the test puck in position at the clamp. Rehome the clamp and try to close. If positions were calibrated correctly the CC should report that it was “on spring” for at least 5 to 7 samples for regular pucks and 10 to 14 samples for short pucks and should have a holding torque ratio of at least 1.6.
1. > Arm.CC

2. > CC.home.to :home
3. > CC.close
    a. If enough “on spring” samples aren’t seen by the system, it will try three times to close but will fail. In this case the clamp needs to move further to close, so adjust the :closed position by a few hundred counts and try again.
    b. If the holding torque is over 2.0 for the PC, or above 2.1 for the CC, then the :closed position must be scaled back as the clamp is over-closing.

viii. Return the test puck to the garage.
1. > CC.open
2. > Arm.garage
3. > Hand.open
4. > Arm.clear

g. Determine the :onguides position
i. With no puck in place, jog the clamp down so that it just touches the puck guides at the base of the clamp assembly.
1. > CC.home.to :home
2. > CC.sealed
3. > CC.jog 500
    a. Jog until the clamp top just comes into contact with the puck guides. Then back off a few hundred counts and log this value as :onguides.
4. > CC.jog -200
5. > CC.rawPosition

ii. Enter this value as :onguides for the appropriate clamp in the configure file and restart the ESP application.
iii. Test that the :onguides position is set appropriately by commanding the clamp to close with no puck in the hand.
1. Remove the flush puck from the garage by hand and place aside
2. Command the ESP to load the flush puck to the clamp
    a. > CC.loadFlush
    b. The following error should appear
        i. `> Slide::Error in MAIN -- No Puck Clamped in Collection Clamp`
    c. > CC.unloadFlush
3. Place the flush puck back into the garage. Assuming the error appeared, the :onguides setting is appropriate.

h. Check overall clamp function with new calibration positions entered.
i. With the test puck still in the flush puck garage, perform multiple load operations and observe the values returned for “onspring” and “torque ratio.”
1. > CC.home.to :home
2. > 10.times {CC.loadFlush; delay 1; CC.unloadFlush; delay 1}
    a. Again, the clamp should go “onspring” for no less than 5 samples and with a torque ratio between 1.3 and 2.0 (for the PC) or 1.6 to 2.1 (for the CC).

14. Appendix H: Calibrate the Processing Clamp positions
a. Begin by applying power to the ESP and readying the ESP
i. > ESP.ready!
b. Place an SH1 short puck into the Garage and load into the Hand
i. > Hand.open
ii. > Arm.grab Garage
iii. > Arm.clear

c. Bring the SH1 short puck into position under the clamp
    i. > Arm.to PC
d. Determine the :sealed position
    i. Jog the clamp down until the nozzle is just entering the opening of the puck
        1. > PC.jog 1000
    ii. Using the force command, apply 15% motor power and allow clamp to stall
        1. > PC.force 15
    iii. When the motor stops turning (stalls), get a position reading and record as the :sealed value within the configure.rb file
        1. > PC.rawPosition
e. Determine the :unsealed position
    i. With the puck still held by the manipulator and clamped in place, coast the manipulator forearm and slowly jog the clamp open until the puck can slide forward and backward along the forearm axis.
        1. > Forearm.coast # coasts the forearm motor
        2. > PC.jog -200 # Moves the PC up 200 counts.
            a. After each jog, try to slide the gripper/puck back and forth in the clamp. The point at which it is no longer held in place by the clamp is considered :unsealed.
    ii. When the puck is free to move in the clamp, get the position and record it for :unsealed
        1. > PC.rawPosition
    iii. Open the clamp, replace the puck into the garage.
        1. > PC.open
        2. > Arm.garage
        3. > Hand.open
        4. > Arm.clear
    iv. Enter this value as :unsealed for the Processing Clamp (also enter the sealed value from the previous step) in the configure.rb file and restart the ESP application.
f. Determine the :closed position
    i. With the SH1 short puck still in the Garage, load the puck into the Hand and bring under the PC
        1. > PC.loadFlush
    ii. Send the clamp to the :sealed position
        1. > PC.sealed
    iii. Using the jog command, determine the appropriate :closed position
        1. > PC.jog 500
        2. Jog down until the heater pad just barely deflects under the load of the clamp. Generally this position will be a few thousand counts beyond the sealed position.
    iv. Get the position and record it as :closed
        1. > PC.rawPosition
    v. Enter this value as :closed for the appropriate clamp in the configure.rb file and restart the ESP application.
    vi. Check :closed calibration on clamp to verify that the Heater spring is slightly compressed. Check ratio of on/off springs and torque ratio.
    vii. Leave the test puck in position at the clamp. Rehome the clamp and try to close. If positions were calibrated correctly the PC should report that it was “on spring” for at least 5 to 7 samples for regular pucks and 10 to 14 samples for short pucks and should have a holding torque ratio of at least 1.6..
        1. > Arm.PC
        2. > PC.home.to :home

3. > PC.close
    a. If enough "on spring" samples aren't seen by the system, it will try three times to close but will fail. In this case the clamp needs to move further to close, so adjust the :closed position by a few hundred counts and try again.
    b. If the holding torque is over 2.0 for the PC, or above 2.1 for the CC, then the :closed position must be scaled back as the clamp is over-closing.

viii. Return the test puck to the garage.
1. > PC.open
2. > Arm.garage
3. > Hand.open
4. > Arm.clear

g. Determine the :onguides position
i. With no puck in place, jog the clamp down so that it just touches the puck guides at the base of the clamp assembly.
1. > PC.home.to :home
2. > PC.sealed
3. > PC.jog 500
    a. Jog until the clamp top just comes into contact with the puck guides. Then back off a few hundred counts and log this value as :onguides.
4. > PC.jog -200
5. > PC.rawPosition

ii. Enter this value as :onguides for the appropriate clamp in the configure file and restart the ESP application.
iii. Test that the :onguides position is set appropriately by commanding the clamp to close with no puck in the hand.
1. Remove the flush puck from the garage by hand and place aside
2. Command the ESP to load the flush puck to the clamp
    a. > PC.loadFlush
    b. The following error should appear
        i. `> Slide::Error in MAIN -- No Puck Clamped in Processing Clamp`
    c. > PC.unloadFlush
3. Place the flush puck back into the garage. Assuming the error appeared, the :onguides setting is appropriate.

h. Check overall clamp function with new calibration positions entered.
i. With the test puck still in the flush puck garage, perform multiple load operations and observe the values returned for "onspring" and "torque ratio."
1. > PC.home.to :home
2. > 10.times {PC.loadFlush; delay 1; PC.unloadFlush; delay 1}
    a. Again, the clamp should go "onspring" for no less than 5 samples for regular pucks and 10 samples for short pucks and with a torque ratio between 1.3 and 2.0 (for the PC) or 1.6 to 2.1 (for the CC).

15. Appendix I: Calibrate the Storage Elevator positions

Below is an excerpt of configure.rb which details the Storage Elevator portion of the configuration file on a short puck instrument. This will be referenced throughout Appendix H.

```
puckInch = slimPucks ? 0.425 : 0.616  #puck height in inches
sePuck=puckInch*SEinch     #counts/puck
```

```
#beam breaks this many (slim or standard) puck height units above top plate
SEbeamHeight = slimPucks ? 1.7136 : 1.234
seBottom=440            #plunger top just contacts bottom of carousel screws
seTop=-29558            #plunger top flush with top plate

SE.scale [" Pucks below Top Plate", "%.2f"], 0=>:home,
   490=>"down", -30718=>"up",
   seTop=>["Top Plate", 0], (seTop+0.06071*sePuck).round=>:place,
   (seTop+sePuck).round=>1, seBottom=>:bottom,
   (seTop-(slimPucks ? 0.225 : 0.2)*sePuck).round=>:pick,
   (seTop-(slimPucks ? 1.3 : 0.25)*sePuck).round=>:beamBreak

SE.configuration :place,
   :threshold=>:positive, thresholdOffset:(0.75*SEinch).round
SE.configuration :pick, :like=>:place, thresholdOffset:(slimPucks ? 428 : -150)
```

a. The SE calibration section of configure.rb has been designed to contain both standard puck and short puck calibration constants which are toggled between using a true/false flag located in the first line of configure.rb code. You will see the format *slimPucks ? ### : ###* indicating a calibration constant that varies dependent upon puck size. The first ### in the argument is associated with short pucks, while the second ### is associated with standard pucks.

b. Set the value of "**down**" (alias **:lowerlimit**, **:retract**)
   i. Coast the carousel and manually rotate to an open slot so that the elevator can travel unobstructed.
      1. > SC.coast
   ii. Coast the elevator and verify that it can be moved in and out of the carousel slot without any collisions.
      1. > SE.coast
         a. Manually move the elevator into and out of the elevator slot.
   iii. Home the elevator to reset the encoder position and coast again.
      1. > SE.home.to :home
      2. > SE.coast
   iv. Push the elevator to its lowest point and then nudge up slightly so that it isn't resting on the home sensor. Hold this position and query the system for the **down** position.
      1. > SE.status # get encoder value from the :position term
         a. Enter this value into the configure file and reboot
   v. Verify that the new value can be held without excess current and that the elevator doesn't rest on the home sensor. Keep carousel in position for this test.
      1. > SE.home.to :home # reset home position
      2. > SE.down # place SE in down position
      3. > SE.status # get status information on SE
         a. Verify that the holding current is less than 10 mA. Note current position.
      4. > SE.coast
         a. The elevator should be able to move down slightly.
      5. > SE.status
         a. Check position compared to previous reading. It should read as a slightly larger number after this small movement.

c. Set the value for **seBottom**

i. Coast the carousel and manually rotate so that the end of one of the tie-rods is directly above the elevator in its down position.
ii. Coast the elevator and push it up so that it touches the bottom of the carousel tie rod bolts.
    1. > SE.coast
iii. Hold this position and query the system for the current position.
    1. > SE.status
        a. Add 60 counts to this value (elevator error) and enter this new value as **seBottom** in the configure file and reboot.
iv. Verify that this value will provide clearance for the carousel during rotation. First manually move the carousel to an empty slot so that the elevator can be re-homed.
    1. > SC.coast
    2. > SE.home.to :home
    3. > SE.down
    4. > SE.bottom
v. With the elevator now parked at the bottom position, rotate the carousel and observe that the bottom bolts do not hit the elevator pad.
    1. If there is a collision, add another 10 counts to the **seBottom** value, reboot and try again.

d. Set the value for **"up"** (alias :upperlimit)
i. Coast the carousel and the elevator and rotate the carousel to an empty tube.
    1. > SC.coast
    2. > SE.coast
ii. With no pucks in the tube manually run the elevator to the top of its travel in the tube slot and hold position.
    1. > SE.status
        a. Add 10 counts to this value and enter the new value as **"up"** in the configure file and reboot.
iii. Keep the carousel in place, re-home the elevator and send it to the upper limit position.
    1. > SE.home.to :home
    2. > SE.upperlimit
        a. The elevator should be able to park at this position without generating an overcurrent error. If it does, add 10 counts to the value and try again.

e. Set the value for **seTop**
i. Verify that the carousel is positioned at an empty tube and that the slot is lined up with the elevator arm to provide unobstructed travel to the top of the carousel.
    1. > SE.top # sends the elevator to the top position
        a. seTop should place the elevator plunger <u>exactly flush</u> with the main plate of the ESP. This can be checked by placing a straight edge or small ruler across the active carousel tube. There should be no gap between the ruler and the top of the plunger and the ruler should touch the top of the carousel tube on both sides.
ii. If necessary make small adjustments using jog commands until the elevator is flush with the top plate.
    1. > SE.jog -20 # raises the elevator by 20 counts
    2. or > SE.jog 20 # lowers the elevator by 20 counts
iii. When the correct position is achieved, query the system to get the position.
    1. > SE.status

a. Enter this value into the configure file and reboot.

iv. Keep the carousel in place, re-home the elevator and send it to the top position.
1. > SE.home.to :home
2. > SE.top
a. The elevator should return to the position that was just set, check with a ruler to verify.
b. ***Note**: it is very important to set this value correctly before continuing calibration. All other positions will reference or be built on this value, so getting the best result possible is critical.

f. Determine **:SEbeamHeight** for short puck operations
i. Load a short puck into an empty Carousel tube.
1. > access 1 # allows user access to tube 1, load puck
2. > to 1 # locates the carousel to work with tube 1
ii. Now count the puck(s) in tube 1 to derive the beam height.
1. > Puck.stackHeight(1)
iii. The counting operation will return a value for complete pucks in tube 1. To derive :SEbeamHeight, use the following equation:
1. > :SEbeamHeight.adjust SEbeamHeight + 1 – ***n*** # ***n*** = the return value for Puck.stackHeight(1)
2. > Puck.stackHeight(1) # verify the output is about 1
3. Enter this into the configure file and restart the ESP application.
iv. Rerun the puck count until the puck count is within +/- 0.0005 puck units.

g. Determine **SE.countsPerUnit** for short puck operations.
i. Load more than one puck in an empty Carousel tube (20 pucks are preferred for accuracy).
ii. > Puck.stackHeight(1)
iii. > SE.countsPerUnit****n***/20/SEinch # ***n*** = the return value for Puck.stackHeight(1)
1. Replace 20 with the number of pucks loaded in the tube, if another number of pucks is used.
iv. Update sePuck in the configure.rb file by replacing the returned value for SE.countsPerUnit into ***X***, as shown below, and restart the ESP application.
1. sePuck = (***X*** * SEinch).round #counts/puck

h. Determine the place position for short puck operations.
i.
ii. Record the number of pucks returned and place this value ***X*** is the configure file, as shown below:
1. (seTop+***X****sePuck).round=>:place
iii. > SE
1. Record the number of pucks returned and place this value ***X*** is the configure file, as shown below, and restart the ESP application:
a. (seTop+***X****sePuck).round=>:pick

i. Set the value for **:place**
i. ***Note:** the next few positions will require calculations based on a nominal puck height sePuck, so this value should be established before moving forward. To date, the best value seems to be <u>(0.615*seInch) for regular pucks and (0.425*seInch) for short pucks.</u>
ii. **:place** is used to position the elevator when there is no puck present. This position should put the plunger just below the top plate (~ 1/20th of an inch). A good visual queue is that the top edge of the plunger should sit at about where the inner chamfer of the carousel tube starts.
1. > SE.place # raises the empty elevator to the place position

iii. If necessary make small adjustments using jog commands until the elevator is in position.
   1. > SE.jog -20 # raises the elevator by 20 counts
   2. or > SE.jog 20 # lowers the elevator by 20 counts

iv. When the correct position is achieved, query the system to get the position.
   1. > SE.rawPosition # record position _____
   2. > SE # record n.nn Pucks below top plate _____
      a. Storage Elevator at n.nn Pucks below Top Plate

v. The format for :place is "(seTop+*n.nn**sePuck)" so the n must be calculated from the encoder value just measured.
   1. ***n* = (measured :place value – seTop) / sePuck**
      a. Example: If the correct position for :place was recorded to be -29200, and seTop had been set to -29400 with sePuck being 0.615*seInch and seInch being 2054, then:
      b. *n* = (-29200 – (-29400)) / (0.615*2054), then *n*=0.19
   2. Alternative: use the value of n.nn pucks returned from SE.
   3. Enter this value for *n* into the configure file and reboot.

vi. Keep the carousel in place, re-home the elevator and send it to the :place position.
   1. > SE.home.to :home
   2. > SE.place

vii. Verify that the calculation was correct by getting the raw position and compare it to the raw measured value. The values should be within a few counts of each other if done correctly.
   1. > SE.rawPosition
   2. > SE

j. Determine SEplace.thresholdOffset for short puck operations
   i. First select a puck for calibrating positions that is close to the average or nominal puck height of .615 +/- .0005. (sePuck)
   ii. Lower the elevator and load this puck into an empty tube.
      1. > access 1 # allows user access to tube 1
      2. > to 1 # locates the carousel to work with tube 1
   iii. Raise the puck to the place position.
      1. > Puck.raiseStack :place, SEplace
         a. This should place the top of the puck at about the same place as the place position (step 5.) procedure, that is, about level with the start of the internal chamfer of the carousel tube.
      2. > SE.rawPosition #record position _____
         a. The value returned is the raw position of the elevator to place a single (known height) puck at the place position. The target is to match this height with the place position already set for a tube with no pucks (5di).
   iv. To calculate the target value; **:newplace = :place + (sePuck)**
      1. Example using above values: :newplace = -29200 + (.615 * 2054) = -27936
   v. To calculate adjustment: **(current position - :newplace) / seInch**
         a. Example using above values: (-27500 - (-27936)) / 2054 = 0.21
            i. Because this value is positive, it means that the puck is higher than it should be so this adjustment value is added to the current value of **SEplace.thresholdOffset** which is currently in the format of n.nn*seInch
               1. So in this care the adjustment would be <u>(n.nn + 0.21)*seInch</u>
   vi. Make the adjustment in the configure file and reboot.

vii. Repeat the command to send the puck to the :place position and see that it matches the target (target being :newplace calculated above).
   1. > Puck.raiseStack :place, SEplace
   2. > SE.rawPosition

k. Determine SEpick.thresholdOffset for short puck operations
   i. Load a short puck into an empty Carousel tube. Select a puck for calibrating positions that is close to the average or nominal puck height [Regular Pucks: .615 +/- .0005. (sePuck); Short Pucks: .425 +/- .0005 (sePuck)]
      1. > access 1 # allows user access to tube 1, load puck
      2. > to 1 # locates the carousel to work with tube 1
   ii. Raise the puck to the pick position.
      1. > Puck.raiseStack :pick, SEpick
         a. This should place the top of the puck well above the top plate such that the gripper fingers will engage the puck at the approximate center of the groove
   iii. > SE.rawPosition
         a. Record the initial position as the starting point.
   iv. Visually using the grippers as a guide (the hand can be closed as well if that is helpful), make small adjustments until the puck sits where the fingers will engage the center of the groove.
      1. > Hand.open
      2. > Arm.to 1 # bring arm into position on tube 1
      3. > Hand.close # hand can be closed if that is helpful or left open
      4. > SE.jog -10 # raises the elevator by 10 counts
      5. or > SE.jog 10 # lowers the elevator by 10 counts
   v. When the position looks good record the puck value at the position.
      1. > SE.rawPosition #record position
         a. The value returned is the raw position of the elevator to place a single (known height) puck at the pick position.
   vi. To calculate the adjustment value; **adjustment = initial pick position – adjusted pick position**
      1. Example using above values: adjustment = -29600 – (-29790) = -436
         a. Because this value is negative, it means that the puck is higher than it should be so this <u>adjustment value is subtracted from the current value</u> of **SEpick.thresholdOffset**
   vii. Make the adjustment in the configure file and restart the ESP application.
   viii. Repeat the command to send the puck to the :pick position and see that it still looks appropriately positioned about the gripper fingers.
      1. > Puck.raiseStack :pick, SEpick
      2. > SE.rawPosition

l. Determine the value of **:pick** for short puck operations (leave the puck in until step c)
   i. **:pick** is used to position the elevator when there is no puck present. This position should put the plunger above the top plate to the same raw position that was derived in the previous procedure.
   ii. The format for :pick is "(seTop-*n.nn**sePuck)" so the n must be calculated from the encoder value just measured (adjusted position from steps above).
      1. ***n* = (seTop – adjusted pick position) / sePuck**
         a. Example: If the correct position for :pick was recorded to be -29790, and seTop had been set to -29400 with sePuck being 0.615*seInch and seInch being 2054, then:

b. *n* = (-29400 – (-29790)) / (0.615*2054), then *n*=0.30
2. *Alternative: > SE*
    a. Returns Storage Elevator at ***-x.xx*** Pucks below Top Plate
    b. Ener the ***n.nn*** pucks number in configure.rb file
3. Enter this value for *n* into the configure file and reboot.

iii. Rotate the carousel to an empty tube, re-home the elevator and send it to the :pick position.
1. > SE.home.to :home
2. > SE.pick

iv. Verify that the calculation was correct by getting the raw position and compare it to the raw measured value. The values should be within a few counts of each other if done correctly.
1. > SE.rawPosition

m. Determine **SEsealOffset** for short puck operations

i. ***Note:** This procedure <u>requires that the Manipulator and Processing clamp have at least had preliminary calibrations</u> performed as the PC must be loaded and then passed back to the puck stack to simulate imaging. DO NOT PERFORM THIS STEP IF NOT READY. This could damage the PC nozzle if not aligned correctly.

ii. Load a short puck into an empty Carousel tube.
1. > access 1
2. > to 1

iii. Load the puck into the Processing clamp to prepare for imaging.
1. > PC.loadPuck :test, 1

iv. Now return the puck to the active tube and raise it into position for imaging.
1. > PC.imagePuck 1 # raises the puck using tube 1
    a. The optimal position of the puck is such that the upper camera spring should compress approximately 1/3 to 1/2 of its full travel.
2. > SE.rawPosition
    a. Record the initial position as the starting point.

v. Make small adjustments until the puck compresses the upper camera spring to about 1/3 to 1/2 of its full travel. If adjustments are made too aggressively, the elevator will generate an overcurrent error and the process must be started again.
1. > SE.jog -10 # raises the elevator by 10 counts
2. or > SE.jog 10 # lowers the elevator by 10 counts

vi. *__Note__: Be careful <u>not to hold the elevator in position and compressing the spring for much longer than 15 to 20 minutes</u> at a time. The holding current will generate enough heat to overheat the motor if exceeding this time limit.

vii. When the correct compression of the spring is set, record the new position (adjusted).
1. > SE.rawPosition

viii. Verify the pwm is between 35 to 70.
1. > SE.rawPosition

ix. Verify the current is below the max current for the Storage Elevator.
1. > SE.status.current # returns the current
2. > SE.config.maxCurrent #returns the max current of the motor

x. The format for SEsealOffset is *nnn*+(0.52*seInch) where *nnn* are raw encoder counts.
1. To calculate the new adjustment: **adjustment = initial position – adjusted position**
2. Adjust current value of nnn by the value just calculated. If negative, subtract. If positive, add to current value of nnn.
3. Save the configure.rb file and restart the ESP application.

xi. Repeat steps iii and iv to check the new values and appropriate camera seal compression.

n. Perform Shuffle and Observe Puck Manipulation
   i. With the calibrations from Appendices B thru H completed, a shuffle puck should be performed and puck manipulation should be watched closely.
      1. Load two short pucks into carousel tube 1
         a. > access 1
      2. Call the shuffle puck routine. A 'true' response will be returned if the file is successfully loaded
         a. > require 'shuffle'
      3. Run the shuffle puck routine
         a. > shuffle2
      4. Observe all aspects of puck manipulation during the shuffle routine, including:
         a. Manipulator grabbing puck out of carousel tubes
         b. Manipulator placing puck into both clamps
         c. Manipulator returning the pucks to the carousel tubes
         d. Elevator raising the puck into the imaging position
      5. Run shuffle multiple times to ensure puck manipulation is error free and reliable.

16. Appendix J: Check & re-focus Camera

The Camera will likely require a focus adjustment following the modifications for short puck operations. Test images will need to be taken, preferably using an LAF puck with focus lines drawn onto a .22*u*m filter (as pictured below).

Figure 51

The figures below show two images, one image is out of focus and the other is in focus. The steps below explain the process to acquire images and adjust the focus on the ESP Camera.

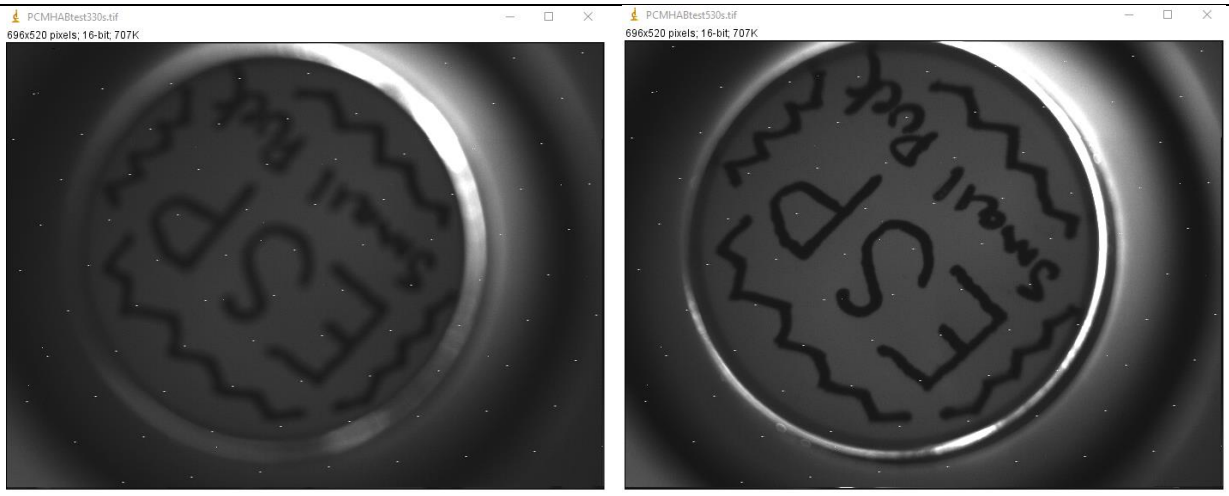


Figure 52

a. Begin by applying power to the ESP and readying the ESP
    i. > ESP.ready!
b. Load the LAF puck with marked filter installed into Carousel tube 2
    i. > access 2
c. Move the LAF puck into the Processing Clamp
    i. > PC.loadPuck :LAFpuck,2
d. Bring the LAF puck under the Camera to take an image
    i. > PC.imagePuck 2, :LAFpuck
e. Apply power to the Camera and wait a minute or so for the Camera to warm up
    i. > Gate.power :camera, :on
f. Perform a fixed length hires exposure
    i. > PuckCamera.snapImages *"FILENAME"*, {:image=> [:hires, 40]}
g. Once image is completed, send image complete command to ESP, puck will be lowered back into tube 2
    i. > Puck.finishImage
h. Access image via FTP (filezilla) and view with ImageJ
    i. The image directory is **~/var/log/esp/hires/** from the root folder
i. If focus adjustment is required, first exit the ESP app and remove power from the ESP
j. Remove the power and data connections from the Camera

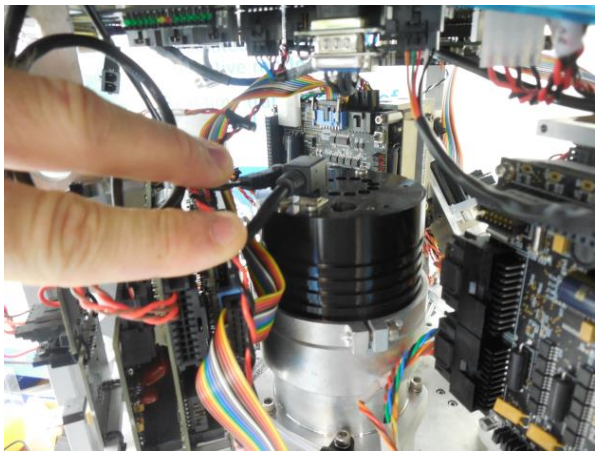


Figure 53

k. Remove the Camera from the Camera mount

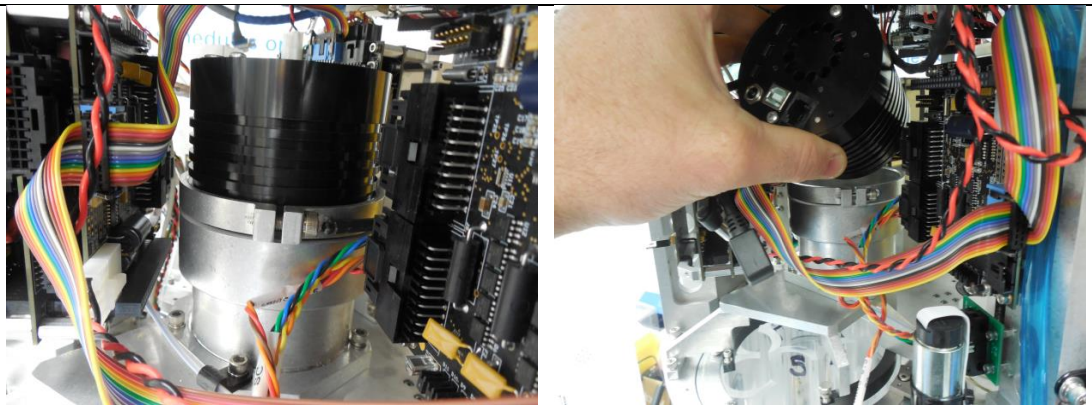


Figure 54

l. Loosen the top thumb screw located on the Camera lens and adjust the lens focus by spinning the focus ring on the lens housing. Small adjustments should be made, noting the starting point. It is likely that multiple iterations will be needed in order to achieve a desirable focus.

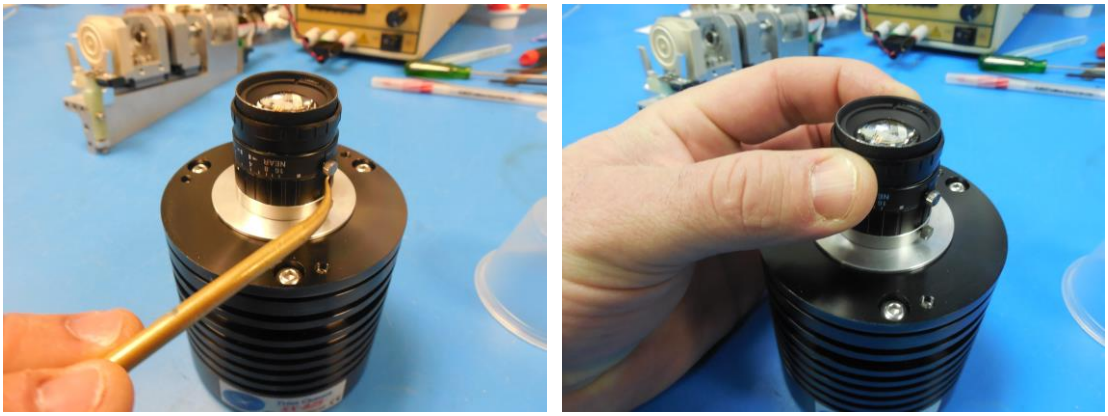


Figure 55

m. Re-install Camera and repeat image acquisition to check if focus has improved, repeat as needed until desired focus is achieved.

17. Appendix K: Calibrate the Pressure Sensors

a. For calibration of the ESP onboard pressure sensors, an external pressure sensor will need to be utilized. This sensor will need to be inserted so pressure can be read in-line with the two onboard ESP pressure sensors. The pressure sensor tubing should be connected into the pressure sensor ‘T’ located beside the SSV. Disconnect the line between the T and the SSV, insert the pressure sensor line.

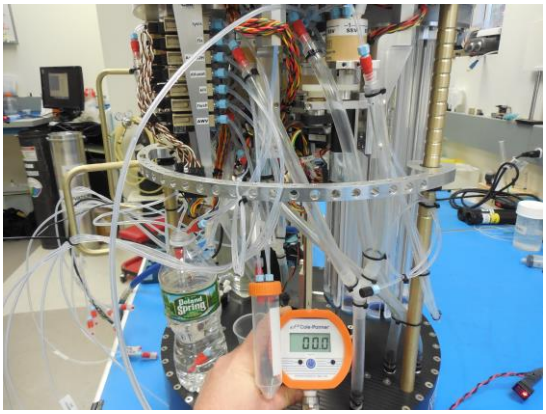


Figure 56

b. The following calibration of the pressure sensors will require the use of a preformatted excel spreadsheet. See the below figure for a blank example.

Calibration 1 (system)														
s/n:		date:												
							SS (outlet)						**CS (intake)**	
	Absolute PSI	Offset					#DIV/0!						#DIV/0!	
	Absolute PSI	Slope					#DIV/0!						#DIV/0!	
	cnts@-15psi	Vacuum					#DIV/0!						#DIV/0!	
	mV/psi*75	Full Scale					#DIV/0!						#DIV/0!	
	mV	Offset					#DIV/0!						#DIV/0!	
	mV/psi	Slope					#DIV/0!						#DIV/0!	
	(10V/3V)	Excitation				3.33	-16.99					3.33	-16.9921875	
	100/1000(mV/V)	Gain			0.1		-5.09765625				0.1		-5.09765625	
	10K	Offset		1			-0.50976563			1			-0.50976563	
	(4096/16/2.5V)	cnts/V	102.4				2.490234375		102.4				2.490234375	
Abs PSI	**Gauge PSI / inHg**	**SS (outlet)**	**(V)**	**(V)**	**(mV)**			**CS (intake)**	**(V)**	**(V)**	**(mV)**			
14.7			0	-1	-10	-33.3333			0	-1	-10	-33.3333		
14.7			0	-1	-10	-33.3333			0	-1	-10	-33.3333		
14.7			0	-1	-10	-33.3333			0	-1	-10	-33.3333		
14.7			0	-1	-10	-33.3333			0	-1	-10	-33.3333		
14.7			0	-1	-10	-33.3333			0	-1	-10	-33.3333		
14.7			0	-1	-10	-33.3333			0	-1	-10	-33.3333		
14.7			0	-1	-10	-33.3333			0	-1	-10	-33.3333		
14.7			0	-1	-10	-33.3333			0	-1	-10	-33.3333		
14.7			0	-1	-10	-33.3333			0	-1	-10	-33.3333		
14.7			0	-1	-10	-33.3333			0	-1	-10	-33.3333		
14.7			0	-1	-10	-33.3333			0	-1	-10	-33.3333		
14.7			0	-1	-10	-33.3333			0	-1	-10	-33.3333		
14.7			0	-1	-10	-33.3333			0	-1	-10	-33.3333		
14.7			0	-1	-10	-33.3333			0	-1	-10	-33.3333		
14.7			0	-1	-10	-33.3333			0	-1	-10	-33.3333		
14.7			0	-1	-10	-33.3333			0	-1	-10	-33.3333		
14.7			0	-1	-10	-33.3333			0	-1	-10	-33.3333		
14.7			0	-1	-10	-33.3333			0	-1	-10	-33.3333		

Figure 57

c. Apply power, log in and ready the ESP

    i. > ESP.ready!

d. Load the Flush Puck into the Collection clamp and draw a full stroke of air into the Collection syringe.

    i. > CC.loadFlush

    ii. > CSV.air

    iii. > CS.fill

e. Perform a pressure sensor reference calibration to set ESP pressure sensors to ambient

    i. Sampler.calibrate

f. Now close the fluidic circuit in order to generate pressure at both sensors.

    i. > CBV.SSV

    ii. > CTV.CSV

    iii. > CSV.CTV

g. The pressure gauge should still read at or near ambient (0 PSIg). Record these values for both sensors in the excel spreadsheet.

    i. > CS.status

        1. "inPress" is the pertinent value for the collection/intake sensor. This value should be between 1200 – 2000 for the CS.

    ii. > SS.status

        1. "outPress is the pertinent value for the sampling/outlet sensor. This value should be between 1000 – 2000 for the SS.

h. Pressure is generated using the Collection Syringe. Use small "push" commands to increase pressure.

    i. > CS.push *n* (start with small moves to generate pressure at both sensors, ~.1 to .5 mL)

    ii. > CS.status

        1. Record gauge pressure and inPress value

    iii. > SS.status

        1. Record gauge pressure and outPress value

i. Record gauge, inPress and outPress values near the following pressures (it is not important to land exactly at each pressure, rather that it is recorded accurately in the spreadsheet):

    i. 0, 3, 7, 15, 30, 50, 75 PSIg ascending, then 50, 30, 15, 7, 3, 0 PSIg descending, then 5, 10, 15, 22, 27 in-hg vacuum.

***Notes:** It will be necessary to refill or empty the syringe (for vacuum) to generate pressure across the entire range. In this case, the CSV should be the only valve that is needed. To fill or empty, send the CSV to "air" (> CSV.air) and perform a > CS.fill or > CS.empty. Then the CSV may be returned to the CTV to continue testing (> CSV.CTV).

***Notes:** There may be a small amount of drop in pressure over time. However, drastic drop off indicates a leaking syringe or plumbing. Leaks must be addressed prior to calibration.

j. Enter values into the Pressure Calibration worksheet to determine the slope and offset for each sensor in the system. Enter those values into the *configure.rb* file.

***Note:** Be aware that when the pressure gauge displays negative values that the units are in-hg and are not equivalent to negative PSI. The Pressure Calibration worksheet makes adjustments for this and calculates absolute PSI for the slope and offset values.

i. IntakeSkew = Skew :gain=>*n.nnnnnn* (slope of intake sensor), :bias=> *n.nnnn* (offset of intake sensor)

ii. OutletSkew = Skew :gain=>*n.nnnnnn* (slope of outlet sensor), :bias=> *n.nnnn* (offset of outlet sensor)

k. Once the configure file has been edited, restart the ESP application and perform a verification of the calibration.

i. Verification is performed much the same way that the calibration except that status commands are not used but rather the commands to display calibrated pressure output.

1. > Sampler.intakePSI or Sampler.outletPSI (returns calibrated value for PSIa)

ii. Record PSIa values from the ESP and PSIg values from the gauge into the verification panel of the Pressure Calibration worksheet. These values should generally be within +/- 1 PSI.