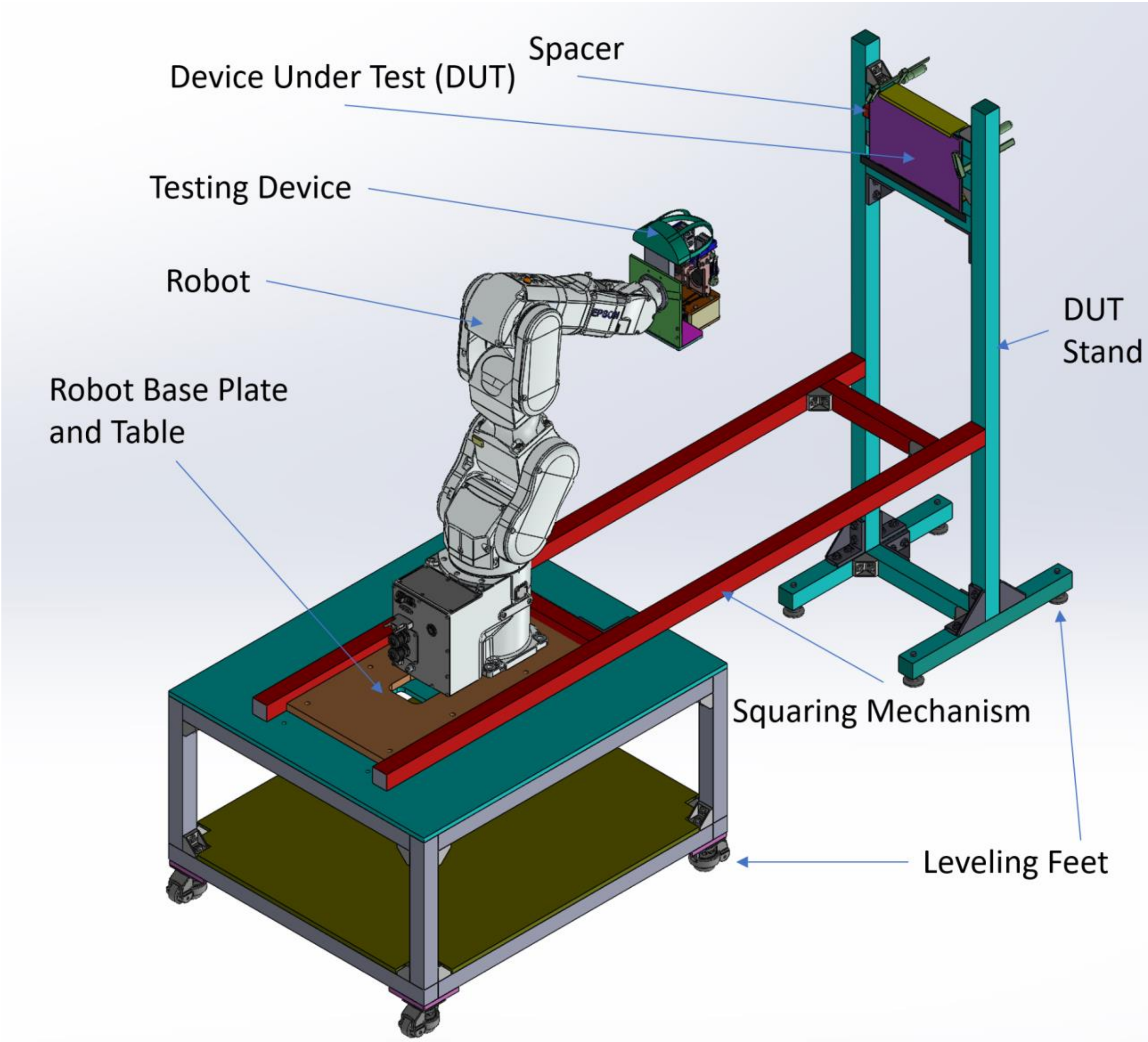
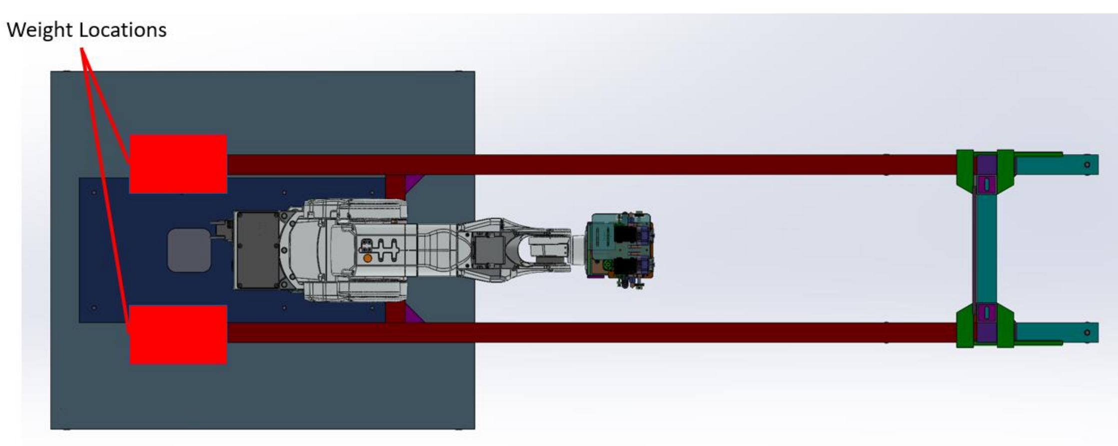
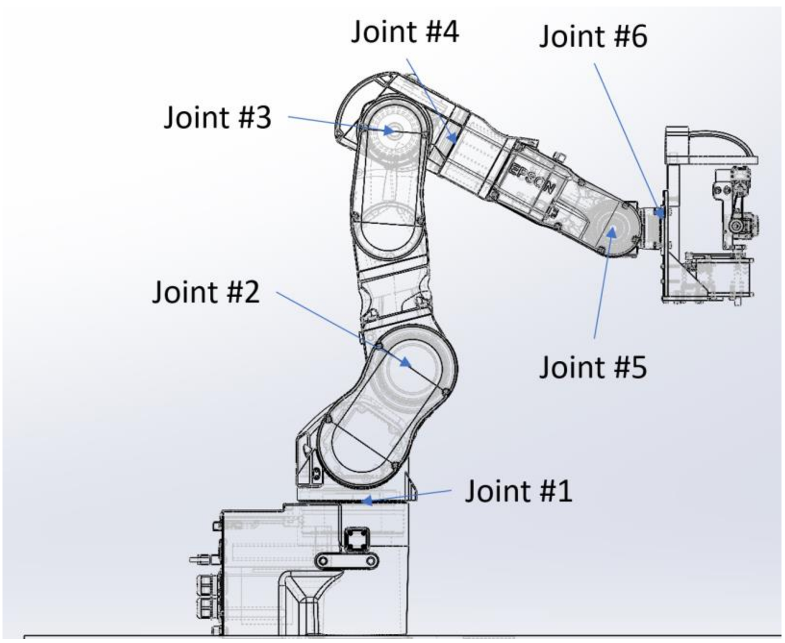
Calibration Procedure

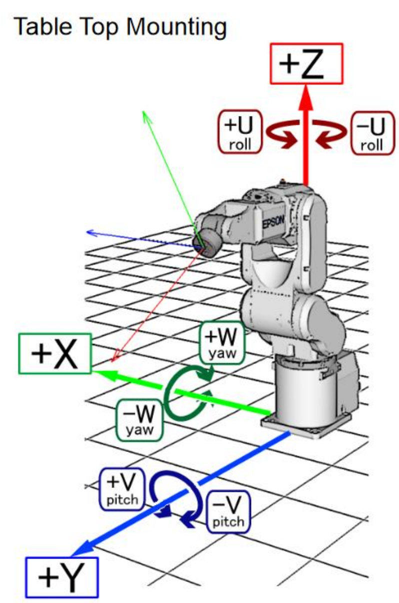




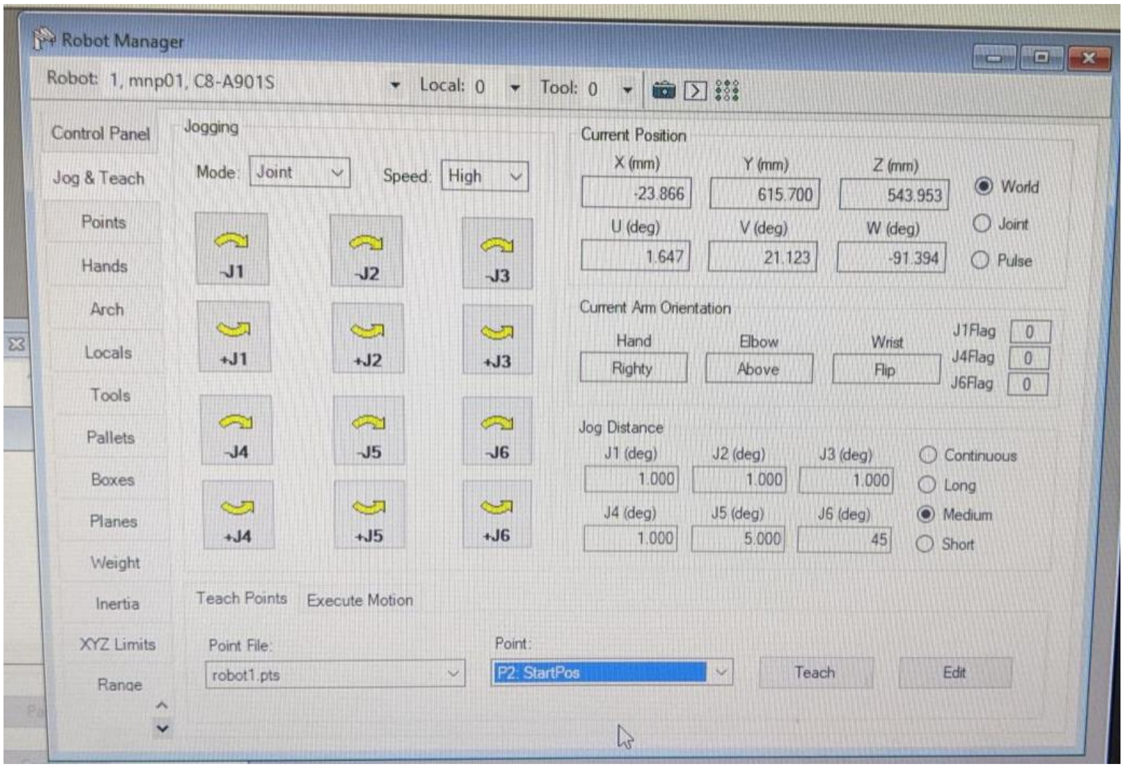
1. Set robot to elbow up position so that the robot wrist is relatively level with Joint 2 as shown below.
    a. In order to keep the robot in the upright position and the end effector plate parallel relative to device under test (DUT), the following shows an example of how our robot rotation angles were implemented in the system.

U	V	W	Local	Hand	Elbow	Wrist
0.000	17.000	-90.000	0	Righty	Above	Flip
0.000	17.000	-90.000	0	Righty	Above	Flip
0.000	17.000	-90.000	0	Righty	Above	Flip
0.000	17.000	-90.000	0	Righty	Above	Flip



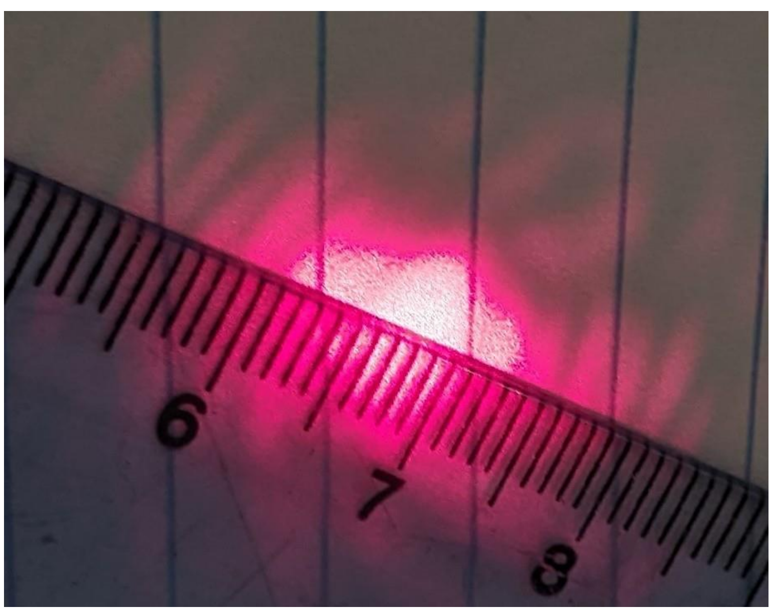


2. Rotate robot arm about laser to ensure orthogonality
    a. This should be done through the Jog&Teach function at Tools>RobotManager>Jog&Teach. Set the robot motion buttons to Joint control and use +J6 and -J6 to turn the end plate only. This can be iterated by adjusting the magnitude of angle change to be 45°.

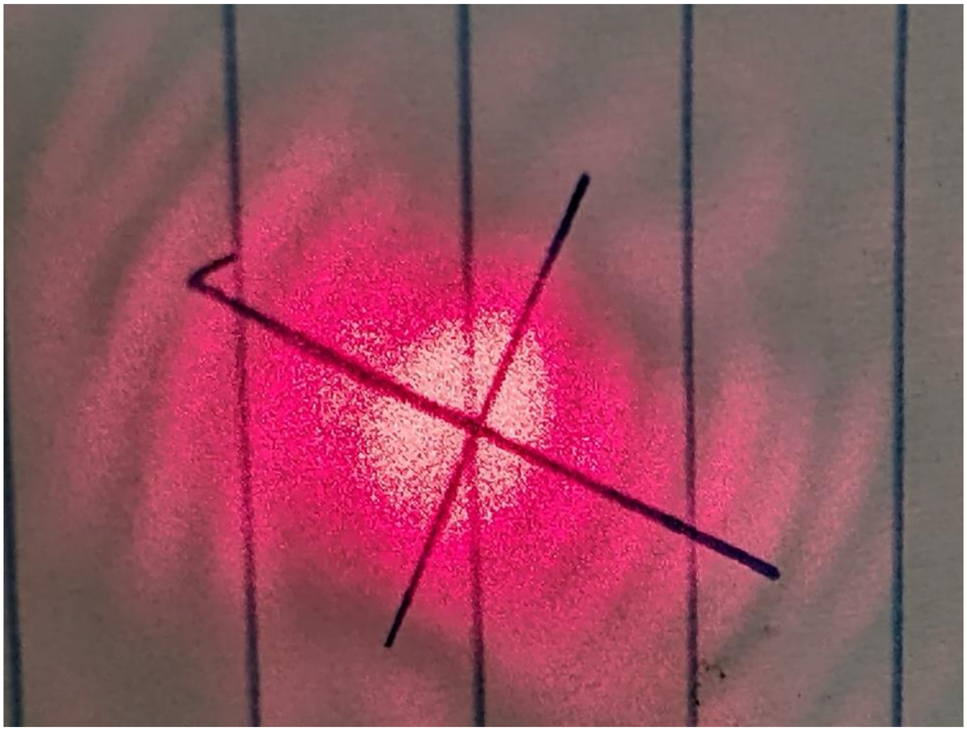


b. The distance this should be performed at should be much greater than the distance for testing by a factor of about 10. The laser dot will be much larger than under test, in order to ensure accuracy, measure the diameter of the brightest part of the laser. In the figure below, the maximum diameter of the ovular shape is roughly 13mm. The largest distance should be taken in order to remain conservative.

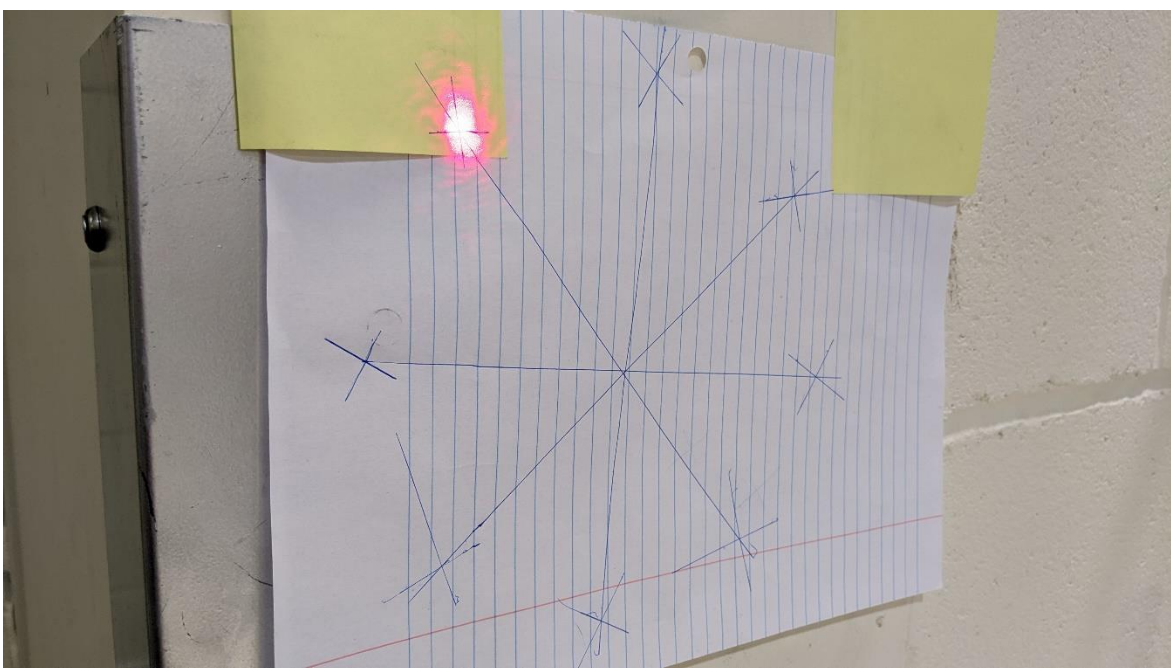
c. Note: this process would be best handled with at least two people, one doing the jog function on the computer, and one marking points where the laser is pointing.



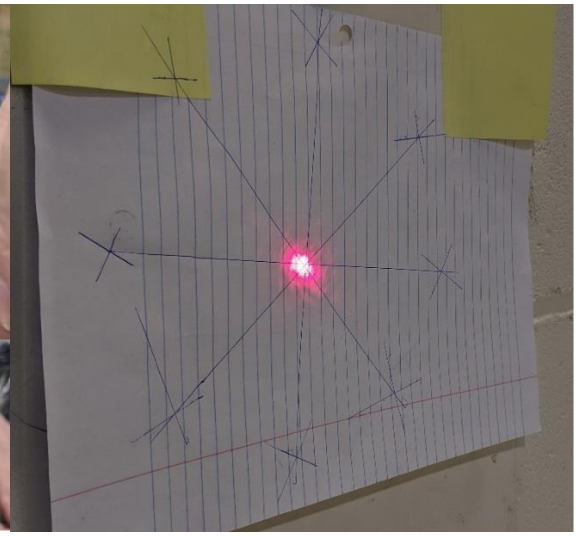
3. The laser should draw out a circular pattern with all points found in Step 2. At each point, with a ruler, make a cross estimating the center of the laser.



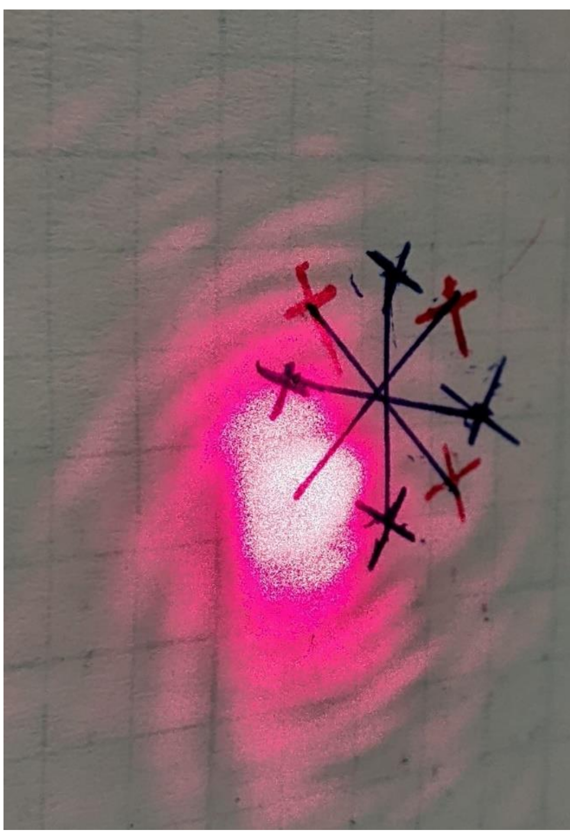
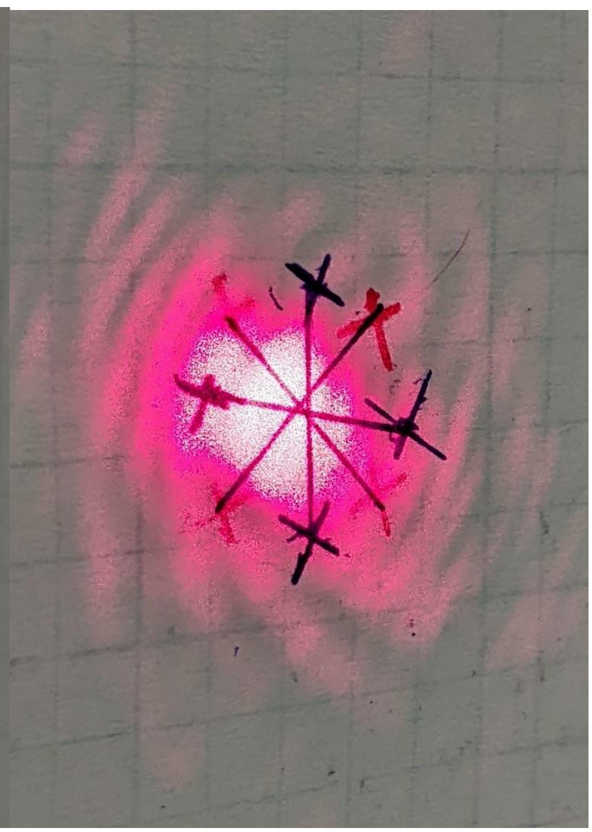
4. Repeat step 3 for at least 270° of rotation in order to be able to draw intersecting lines between points
    a. Draw a line from cross points to their opposite point as shown below, if done correctly these lines should all intersect at the center of the circle.



5. Adjust the set screws until the laser points at the center point
    a. Set screws should be adjusted first, if those are not working to adjust the laser, the spring plunger on the opposite side of the laser adjustment apparatus may be used for adjustment. If neither are working, the other axis set of screws may need to be loosened

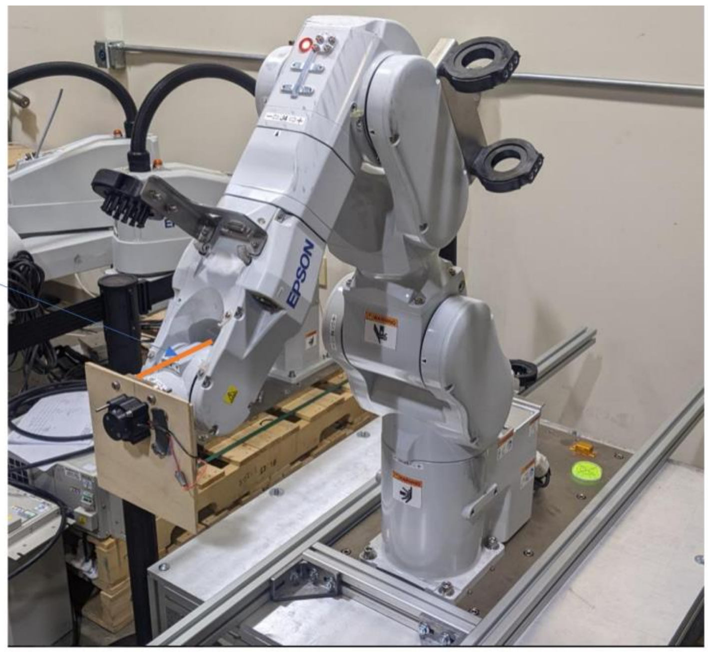



6. Iterate this process with the tighter circle if necessary

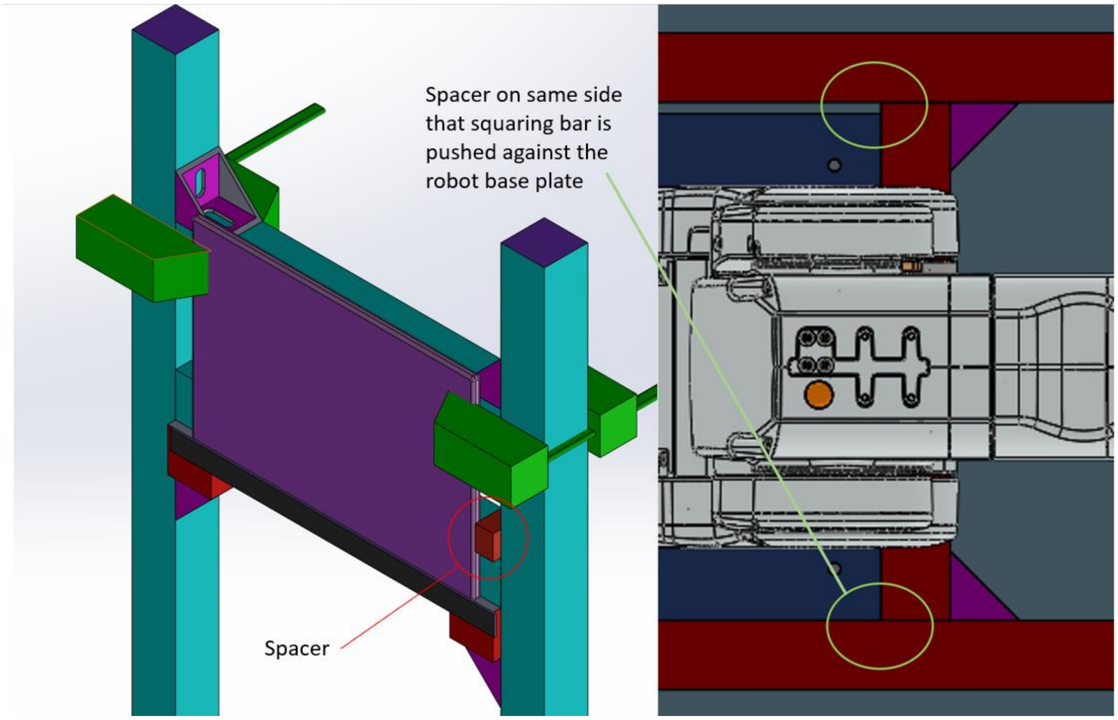



7. Ensure robot table is level (This is not necessary for the rotation calibration, because that calibration is only to get the laser beam orthogonal to the robot's end effector.)
    a. Measure with a carpenter's level (2-1/2' minimum with 1mm/m accuracy or better)
    b. Use the adjustable feet to adjust as needed (hand adjustment)
8. Ensure device under test (DUT) and DUT's stand are level
    a. Measure with a carpenter's level
    b. Adjust feet and/or Bosch gusset connections as needed (18mm wrench required)
9. Ensure robot end effector is level
    a. The level should be placed on Joint 5 of the robot to make sure that joint is level. With some slight variation in other joints of the robot, while each joint may be close to perfect, they add up and may make the end of the arm slightly unlevel.

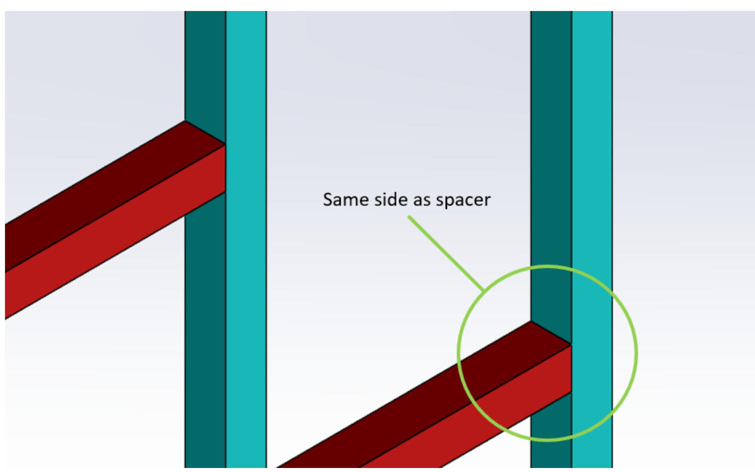
Level using this flat surface



10. Place DUT squaring mechanism on table and add weight to the end of the mechanism on the table to ensure the mechanism does not lift off the table while squaring.
    a. Note, there is a spacer for the device under test, this spacer should go on the same side as the spacer whose corner goes into the corner of the robot base plate

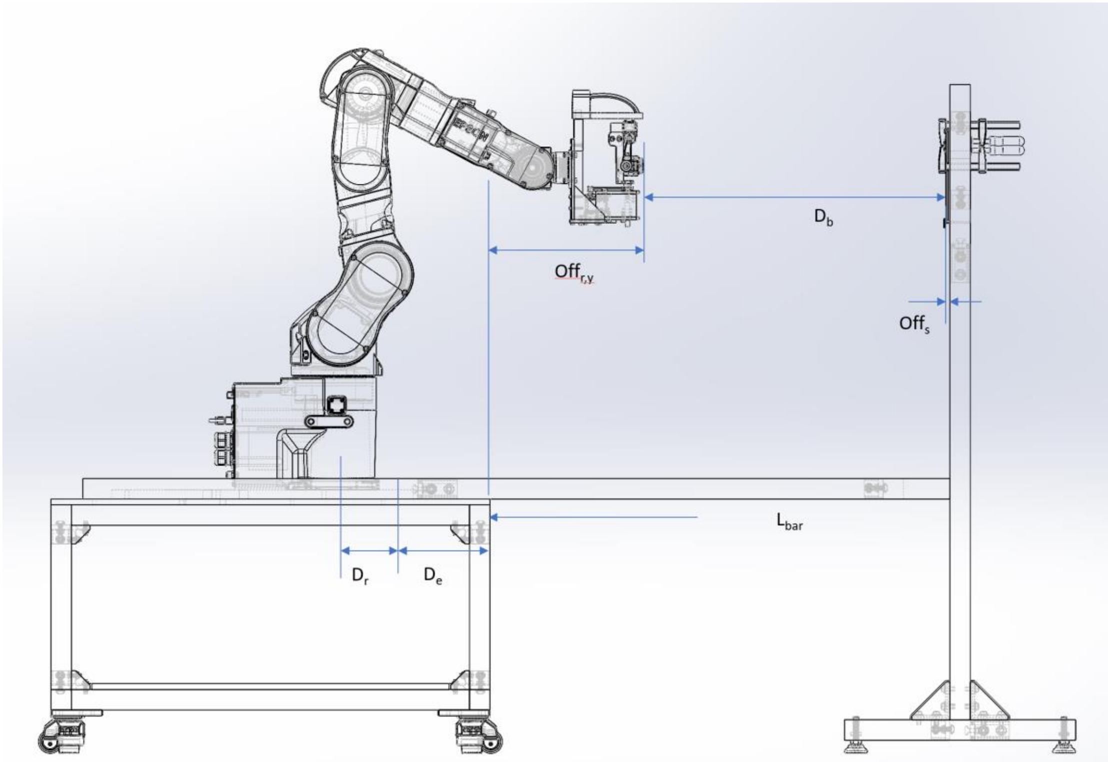


11. Align DUT stand with squaring bars to make outside edges flush on the same side as the spacer as shown in step 3.

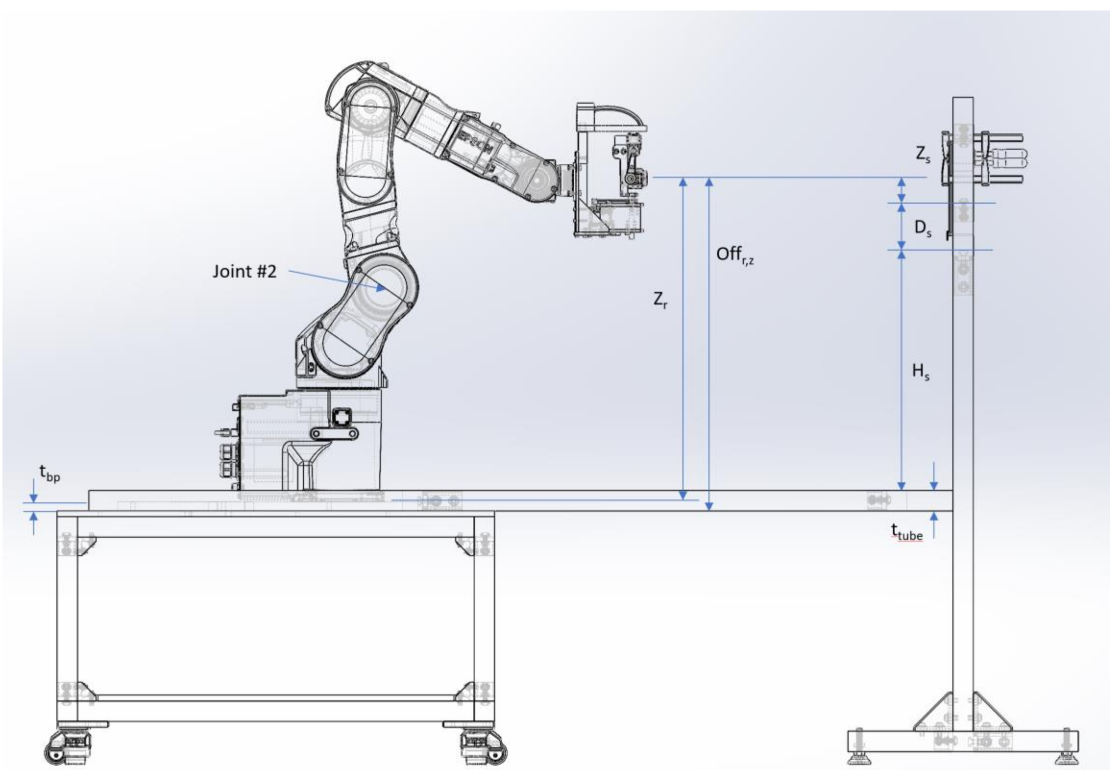


12. Position vertical offset of DUT to desired height
    a. This position will usually be around the location of Joint 2 on the robot for elbow up orientation of the robot.

13. Measure DUT stand distance relative to the edge of the robot base plate



14. Measure DUT base height relative to squaring bar



The following are some simple calculations to make measurements easy.

$$L_{bar} = D_b + Off_{r,y} + Off_s$$

$$H_s = Off_{r,z} - t_{tube} - D_s - Y_s$$

$$Off_{r,y} = Y_r - D_r - D_e - Off_{t,y}$$

$$Off_{r,z} = Z_r - t_{bp} - Off_{t,z}$$

(note, the x position should be centered to the robot world reference for ease and accuracy of measurements)

Once robot has been aligned so that the laser dot is pointing to the center of the screen, perform the following additional steps:

15. Once robot is adjusted to the correct position where it is lined up and 65 cm away, teach the point to the robot within the Jog&Teach position as P2. This is the point to reference for all points in the future

Nomenclature

Symbol	References in Distance	Length if fixed
D_s	DUT edge-> DUT center	3.95”
D_r	robot center->robot base edge	3.92”
D_e	Robot base edge->edge of table	[measure]
D_b	Robot face->DUT face	65cm or 25.6”
$Off_{r,y}$	Robot overhang from edge of table	
$Off_{r,z}$	Robot vertical offset from base	
Off_s	DUT overhang from stand	0.33”
$Off_{t,y}$	Tool offset (y-direction)	
$Off_{t,z}$	Tool offset (z-direction)	
L_{bar}	Bar overhang from table edge	
t_{tube}	Thickness of bosch tube	45mm or 1.77”
t_{bp}	Thickness of base plate	0.75”
H_s	Bottom of DUT->top of squaring tube	
Y_r	Y distance of robot face from software (world)	
Z_r	Z distance of robot face from software (world)	
Z_s	Vertical offset from robot eyes to DUT center	