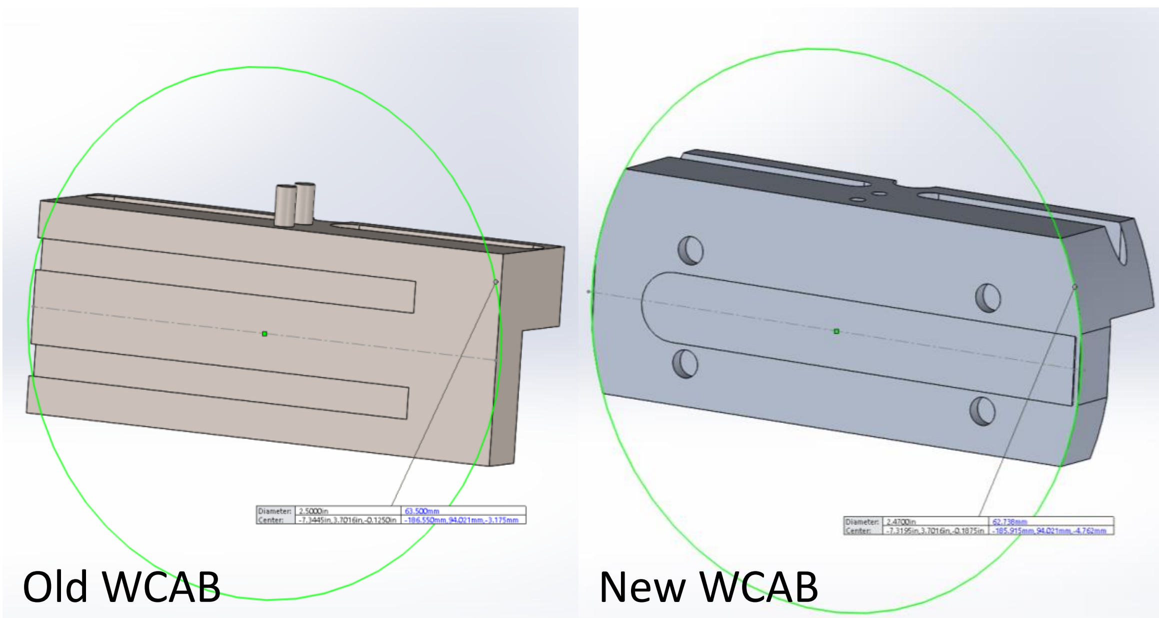
1. **Based on results of testing (and closing the design loop) the MCM, evolve the design for structure, bearings, actuator… for the rest of the machine. (2 pts)**

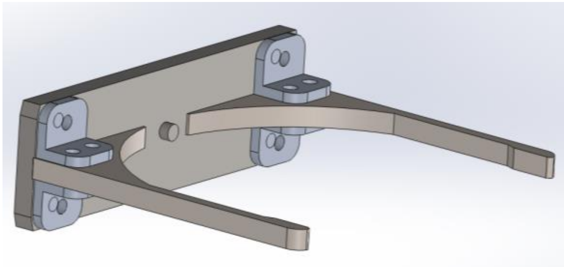
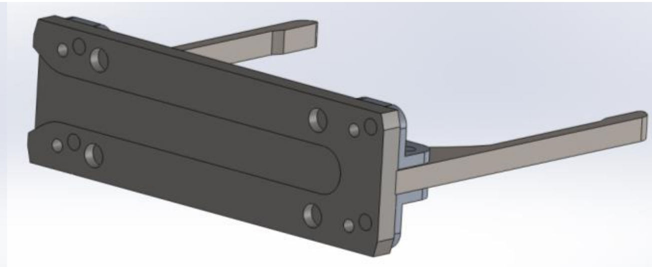
   In the last PUPS, I was able to confirm that the extension and retraction motions of the scissor mechanism were reasonable and could meet all of functional requirements (particularly in terms of the Z-axis sag). With this done, I focused during this PUPS week on finalizing the systems for loading and unloading the wafer carrier onto the scissor actuator and the motor mount for the stepper motor.

   While reviewing my existing CAD for the wafer carrier attachment block (WCAB) I came across one really important error. The existing WCAB met all the dimensioning constraints while the actuator was retracted, but when it was extended to the gate valve, it would be slightly too wide to make it through the 2.5" aperture. To get around this, I modified the WCAB design to have a rounded profile (looking along the X-axis) with an overall diameter of 2.47". Pictures of the old and new WCAB are shown below.



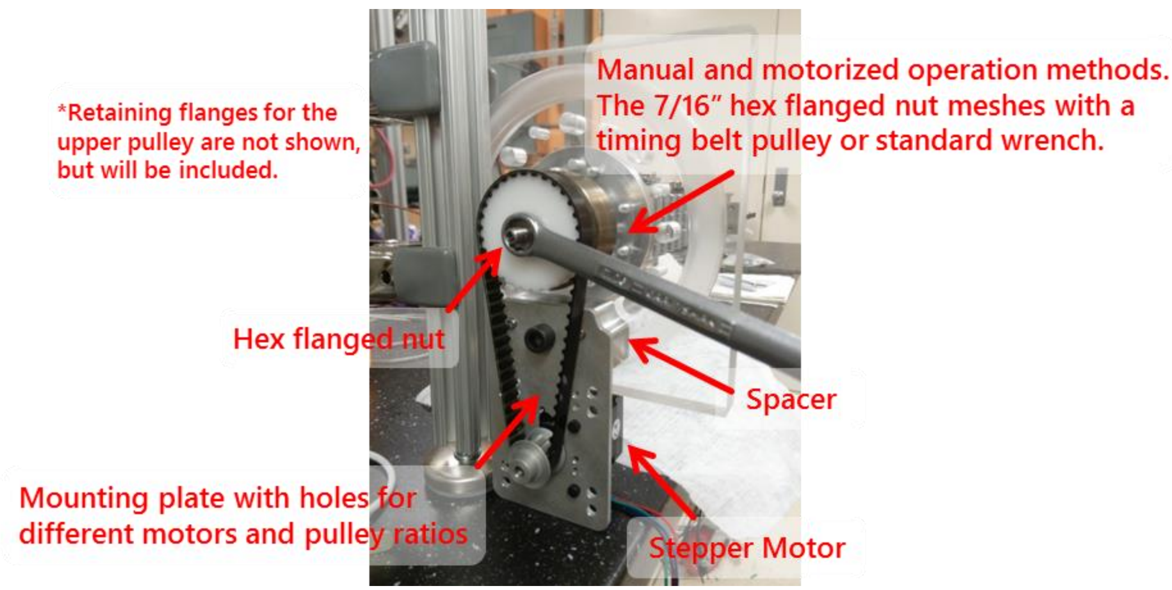
   The new WCAB design also switched to a single male rounded dovetail joint and added four magnet recesses for mating and holding the wafer carrier mount (WCM). These adjustments make it easier to load the WCM (currently a manual process occurring through the door of the load lock).

   The WCM itself must be sized such that it can fit through the load lock door (a Y-axis motion through a 2.75" aperture) and also the same gate valve (X-axis motion through a 2.5" aperture). Front and back view CAD drawings for this part are shown below.

The WCM is designed such that the grabber arms can be easily replaced if they get bent or damaged, or the design of the wafer carrier changes. The outward taper of the dovetail groove makes mounting the WCM to the WCAB simple and not require precise alignment. The magnets mate to the corresponding WCAB magnets and both set the appropriate level of Y-axis engagement and prevent the WCM from being dislodged during the twist-lock procedure used to mate the wafer carrier to the chuck assembly.

The second and last major part designed this week was the stepper motor mount. Previously, all actuation of the scissor mechanism was done manually using fingers or a 7/16” wrench. Eventually, however, a motorized / automatable system will be desired (both manual and motorized operation was an included functional requirement in the specification), and so a simple stepper motor mount was conceived and constructed. The primary design goals for the mount were to avoid adding any extra length (X-axis) to the full mechanism and to provide flexibility in regard to stepper motor choice as well as torque/speed ratios. The end result is shown below.

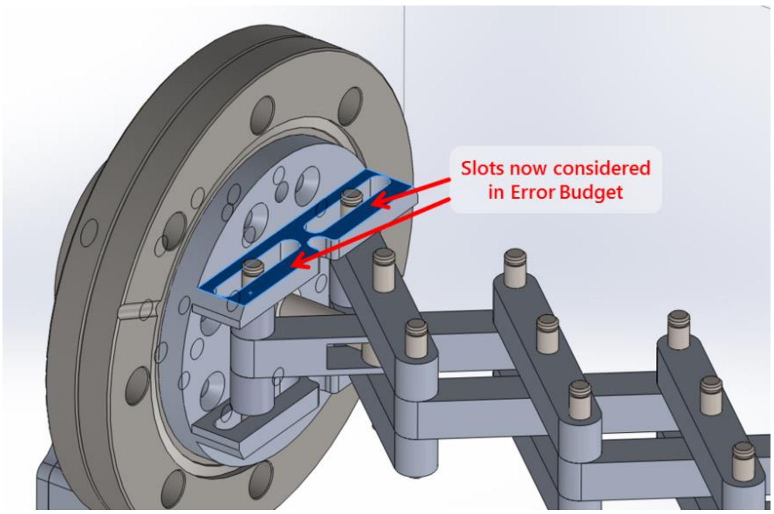


The stepper is mounted below the CF flange and coupled to the scissor actuator using an XL timing belt system. The configuration shown uses a 10 tooth pulley on the stepper motor (positioned as close as possible to the motor housing to prevent excessive loading of the motor bearings) and a 36 tooth pulley on the 7/16” flanged hex nut. Using the supplied NEMA 17 stepper motor, this torque ratio of 3.6 provides plenty of power for extending and retracting the actuator to its limits. The mounting plate was cut on the waterjet and the holes were subsequently reamed to the precise sizes. A spacer plate was also made to make sure the timing pulleys were parallel to one another.

To mount the mounting plate to the flange, two dowel pin holes and a bolt were used. The dowel pin holes provided the precise spacing needed for the timing belts, and the bolt (which is just one of the 8 bolts required for the CF flange) holds it all together.

2. Update error budget and FRDPARRC table and if needed iterate on the design. (1 pt)

The final error budget spreadsheet (“Gould_PUPS_9_Error_Budget_Scissor.xlsx”) and FRDPARRC table (“Gould_PUPS_9_FRDPARRC.xlsx”) are included on the PUPS 9 page. The only major addition to either was the inclusion of a load-induced deflection from the bending of the slots on the flange attachment plate (clarifying picture below) in the sag estimates. Previously, the first set of segments or links were considered to be exactly perpendicular to the YZ-plane, which in reality won’t be true. The math shows that this bending is appreciable when the load on the scissor links or wafer carrier is large (>10N), but the dominating factor is still the link-to-link spacing gap and the Abbe error from the pin-hole diameter mismatch.



3. Complete the solid model of the machine with enough detail to enable you to build your entire machine: (3 pts)

The full SolidWorks model for the scissor actuator system (“Gould_Scissor_Actuator.SLDASM”) is uploaded on the PUPS 9 page. The only things not included are fasteners and retaining rings, etc, since adding these tends to overload and crash my SolidWorks instance.

a. Safety review

i. Would you operate your machine? Your most loved one?

Fortunately, the actuator is pretty safe for human operators (compared to other projects and the tools used to make it), and any possible safety concerns are from the perspective of our etching system (i.e. is it safe for our etching system to include this?). I think it will work just fine in our system, which uses very robust rotary vane pumps and only operates in the low to medium vacuum ranges (a few millitorr at the lowest). Particle generation from the links rubbing and the revolute and slot joints are what could potentially cause a failure (in this sense probably some sort of contamination), but if this happens I can further explore some of the options like PTFE-anodization of the pieces or a more sophisticated bushing/spacer system.

b. Manufacturing review

i. Can you build and test the machine in the time you have left?

Most all of the system is now built (the WCAB and WCM are the only big remaining pieces) and then I am onto final assembly and test. I should not have any troubles finishing.

4. Check the error budget one last time. (1 pt)

Double-checked. See (“Gould_PUPS_9_Error_Budget_Scissor.xlsx”).

5. Make part toleranced part drawings, thinking carefully how everything will fit together. (2 pts)

I have spent a good amount of time confirming that everything will turn out like I plan, and have had my PREPS team and Edgerton shop friends to help iron out all the little problems. All systems are go. The drawings were all drawn from the posted SolidWorks file (“Gould_Scissor_Actuator.SLDASM”), and mechanical drawings were made in MasterCAM (these can be posted if desired), since I’m making most of this stuff via CNC.

6. Bill of Materials so you can acquire everything needed. (1 pt)

The Bill of Materials for the scissor actuator (“Gould_PUPS_9_BoM.xlsx”) is uploaded on the PUPS 9 page. I don’t quite meet my ideal price goal of $200 (it is ~$300), but once the quantities grow, the materials price per unit drop to something I am fine with (~$225 in bulk).