1. **Design (and/or select) the bearings, bearing rails, and actuator to handle the loads and provide the stiffness and accuracy as indicated from your previous error budgeting work: (3 pts)**
    a. **Label the sensitive directions!**
    b. **Hand sketch and create/use design spreadsheets to consider as options sliding contact and rolling elements:**
        i. **How will you preload the bearings and actuator so as to not have too much error due to clearance (aka backlash)?**
            1. **Can you use gravity and a kinematic arrangement?**
            2. **Do you need to use a "captured" design and if so, how will the preload "spring" accommodate alignment and bearing rail errors?**
            3. **How does preload affect life and controllability (sliding friction)?**

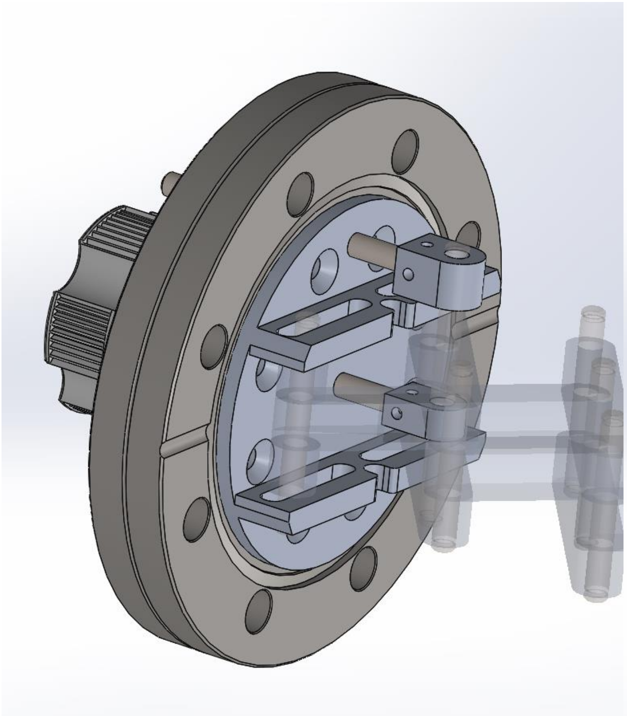
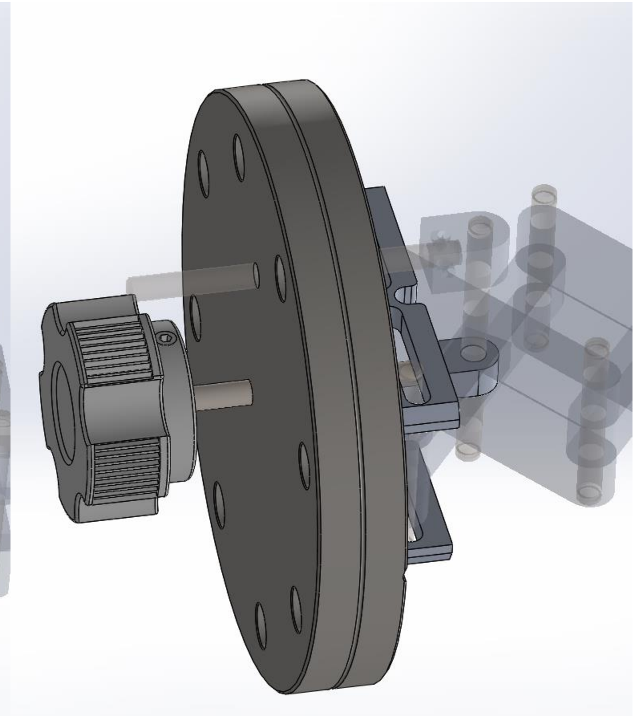
The bearings for my scissor actuator are at the revolute joints that connect the scissor segments to one another. The holes in the segments have been precision reamed to fit the 3/16" dowel pins, so the diametrical clearance is very small (<0.001" by the best measurements I can make). There is no preload mechanism along the diameter, but there is a spring that compresses the segments together at each joint to help eliminate the z-axis sag from Abbe errors. Retaining rings keep the spring in place. The segments sliding against one another will eventually cause some degradation, but the spring should help to compensate for this. The friction between the segments is not ideal, and could perhaps be reduced by adding a thin thrust washer made of a low friction material like PTFE (an idea currently being explored).

        ii. **Perform load life calculations (include preload), to make sure the bearings and actuator will be stiff enough and last**
            1. **You must consider alignment tolerances: how will misalignment affect loads on these elements as the machine moves?**
            2. **If after first round it does not seem like things can work out well… you may have to select a different design and/or bearing or actuator…)**

The lifetime of the scissor actuator segments and pins is hard to calculate, but they will likely degrade as the number of extend and retract cycles increases. This will increase the sag, but fortunately, the current design makes it reasonably easy to replace both segments and pins (<5 minutes once the actuator is removed from the system).

2. **Design the support structures for the bearings and actuator and its attachment (this is where details covered in FUNdaMENTALS and PMD come to bear) to the rest of the machine to meet the stiffness and accuracy required: (2 pts)**

The support structure for the scissor actuator is shown in the SolidWorks renderings below:

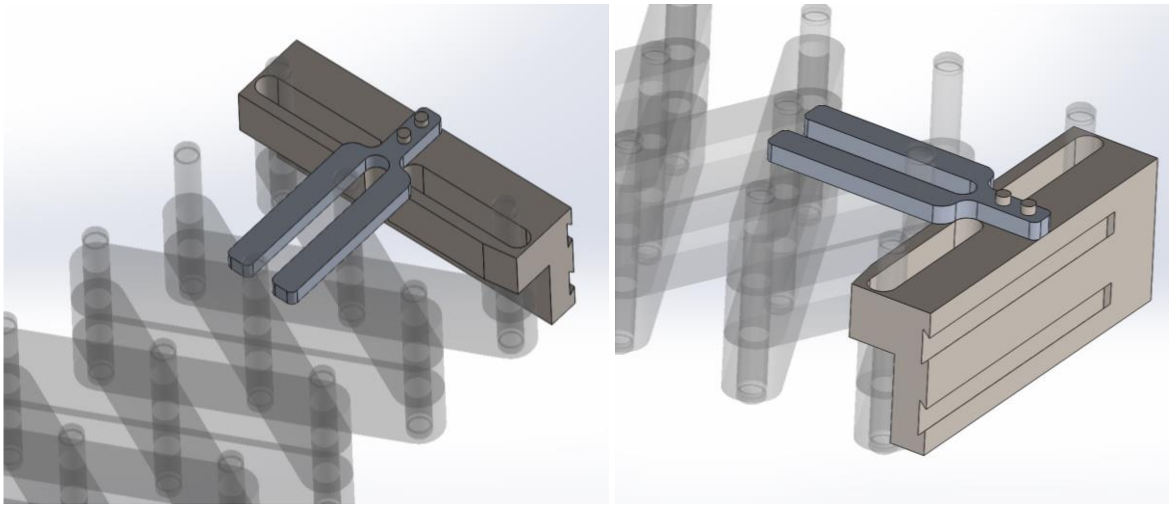
There are two different actuator pins shown. Ideally, the center pin will be used, but it requires making a somewhat complicated segment piece in order to fit. If this proves too unwieldy, the eccentric actuator pin can be used. The knob will be attached to the actuator pin, and be used to extend and retract the actuator. By using carefully dimensioned spacers on the external portion of the actuator pin, the travel of the knob can be controlled, and thus the full extension length of the transfer arm can be controlled. This should make the user experience dead simple ("push it all the way in to load" and "pull it all the way out to unload").

The sliding slots for the scissor actuator will be precision machined and fitted into matching slots machined on the mounting flange. From there they can be fastened to the flange using vented screws (to minimize outgassing) *(the screw holes are shown in the SW model, but the screws themselves are not)*.

See the uploaded SolidWorks model ("Gould_Scissor_Actuator.sldasm") and Excel file ("Gould_PUPS_7_Error_Budget_Scissor.xlsx") for additional details.

3. **Design the carriages and attachment to the bearings (or rails) and to which other elements will be attached, to meet the stiffness and accuracy required: (2 pts)**

The "carriage" structure for the scissor-based transfer arm is shown in the SolidWorks renderings below:



The “carriage” structure, which will be used as the anchoring point for the wafer carrier, has two main parts, the attachment block (tan) and the centering fork (gray). The attachment block has two precision slots that mate to the dowel pins at the furthest edge of the scissor actuator. As the actuator extends (and gets narrower (y-axis)), these pins move toward the center of the slots. The centering fork forces the attachment block to stay centered between these two pins. Whether this specific fork design is stiff enough to reliable keep the attachment block centered is currently being explored. If it proves to compliant, a taller fork, or one that fits totally over the actuator pins could be used. The width of the fork at its tines can also be used as a stop mechanism that prevents further actuation by constraining the motion of the pins along the outer holes of the scissor segments.

The front of the attachment block currently contains two dovetail grooves for mounting the wafer carrier. These grooves should prevent the carrier from sagging and allow the carrier to be loaded and unloaded to the actuator from the side (a key functional requirement for the current load lock). Magnets embedded along the base of the dovetail groove can add some additional holding power (although the expected forces on the chuck will be small).

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

   See the uploaded Excel files (“Gould_PUPS_7_Error_Budget_Scissor.xlsx”) and (“Gould_PUPS_7_FRDPARRC.xlsx”).

5. **Solid model with just enough detail the linear motion axis parts and assembly to enable you to make part toleranced part drawings to build the most critical axis of your machine. (2 pts)**
   a. **Final safety review, considering not only operation, but maintenance.**

   See the uploaded SolidWorks model (“Gould_Scissor_Actuator.sldasm”). Safety isn’t really a big worrying factor with this design; the only real hazard is perhaps pinching yourself between segments of the actuator while servicing it. Before being put into to service, the full mechanism will be cleaned according to our lab’s standard vacuum cleaning process (full degrease, then sonicating in IPA/water for ~1 hour, then vacuum baking overnight).