TUTORIAL: DESIGN OF A LOW-PROFILE SINGLE AXIS LINEAR MOTION STAGE

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OPTI 521 – Fall 2015

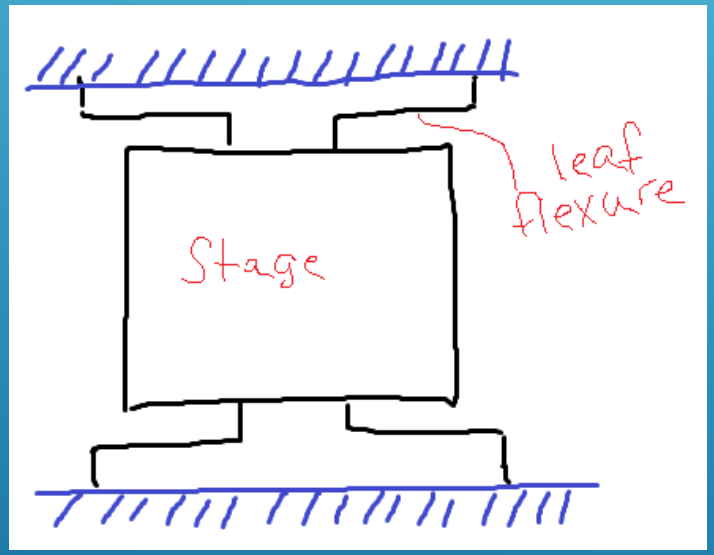
DESIGN CHOICES

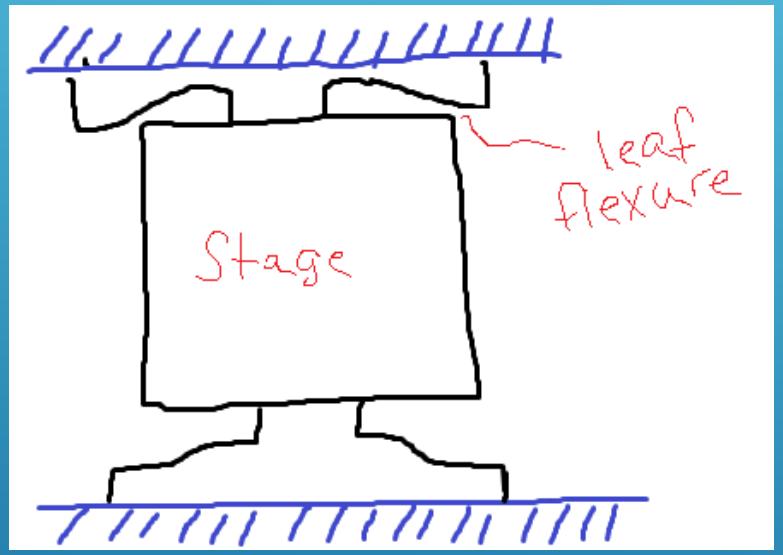
- What is the application?
  - Requirements (travel, accuracy, resolution, etc…)
- How much space is available?
  - Envelope constraints (mounting)
- How much funding is available?
  - Custom vs. COTS ($$$$ or ¢¢¢)

CUSTOM FLEXURE SOLUTION

- Limits of travel
  - < 2 mm
- Limit of payload capacity
  - < 500 grams
- Cost implications
  - 100%-300% similar COTS solution
- Material considerations
  - Costly alloys needed to achieve strength and flexibility
    - Figure of merit : σ_{yield} / E
  - Titanium (6Al-4V), CRES 17-4 PH H1150, Invar-36, Beryllium Copper

- How compliant do the flexures need to be?
- How much force is required to achieve the travel requirements?
- What components are needed to control position?
  - Component limitations on travel and force

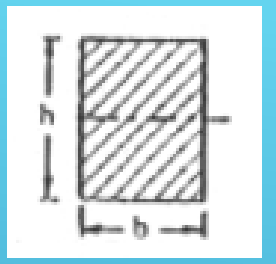


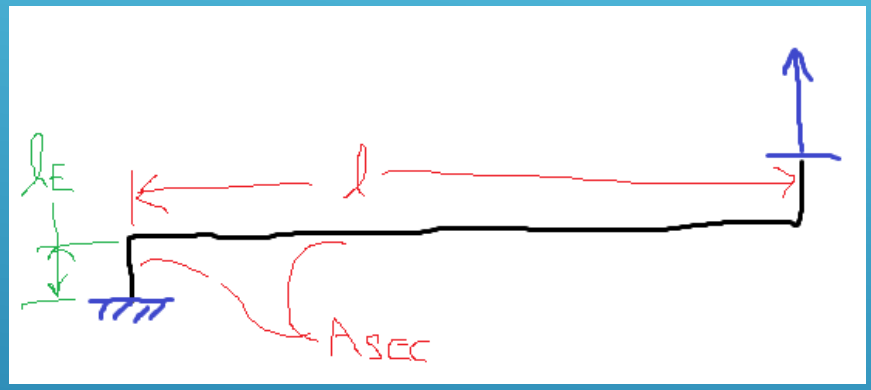


SINGLE PIECE MACHINED DESIGN

BEAM MODEL REPRESENTATION

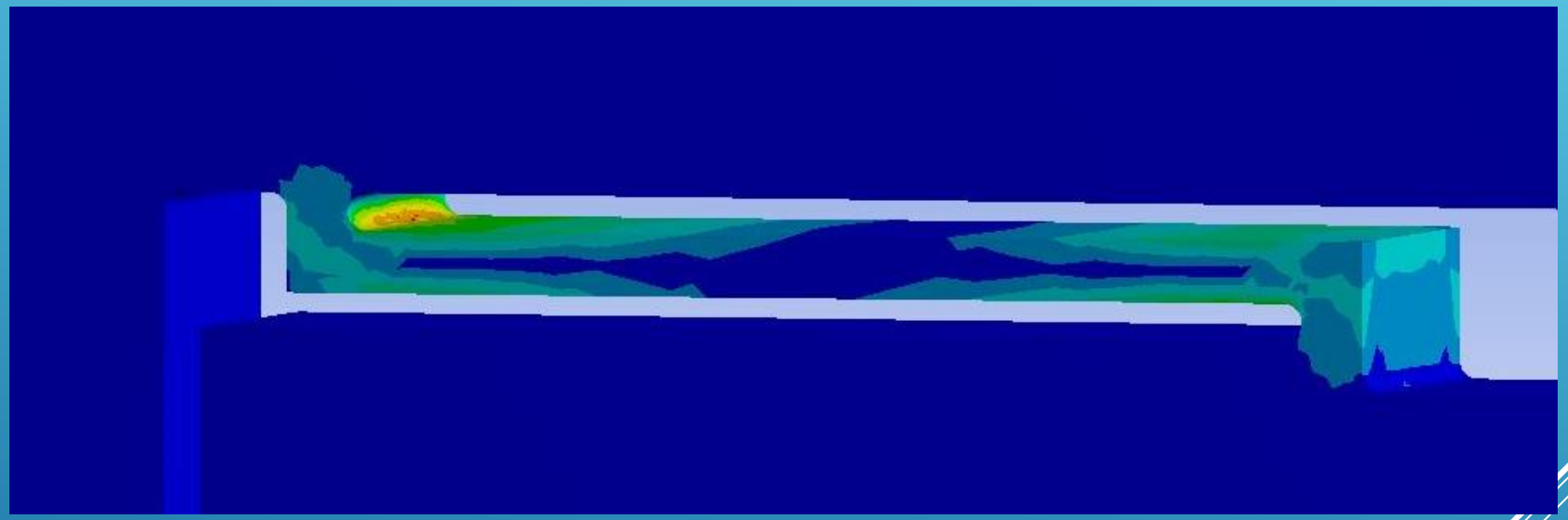
- Fixed- Fixed condition beam bending
  - Section properties, deflection, force and stiffness
    - $I = \frac{bh^3}{12}$ $\delta = \frac{F\ell^3}{6EI}$
    - $F = \frac{6\delta EI}{\ell^3}$ $k_{tot} = \frac{24EI}{\ell^3}$
- Flexure design to match idealized beam model
  - Consider end design!





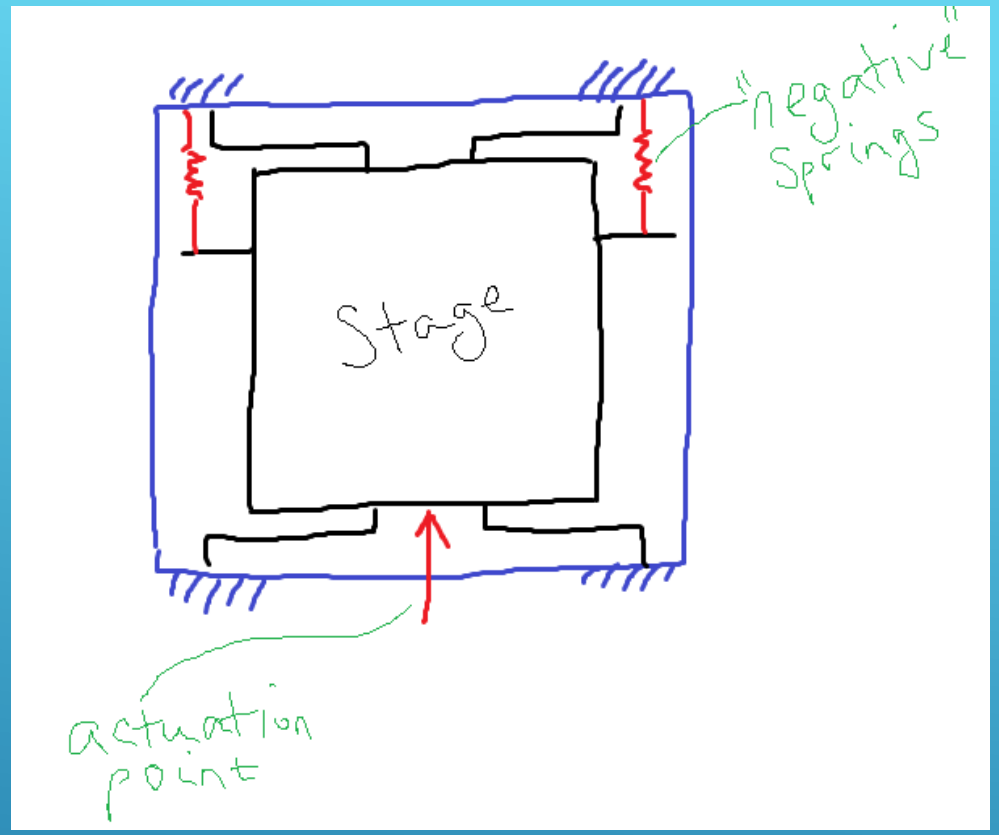
FLEXURE FAILURE CRITERIA

- Stress, stress, stress!
  - Factor of Safety on yield = 4 minimum
  - $\sigma_{max} = \frac{\sigma_{yield}}{FoS}$
  - $\sigma = \frac{F\ell h}{2I}$



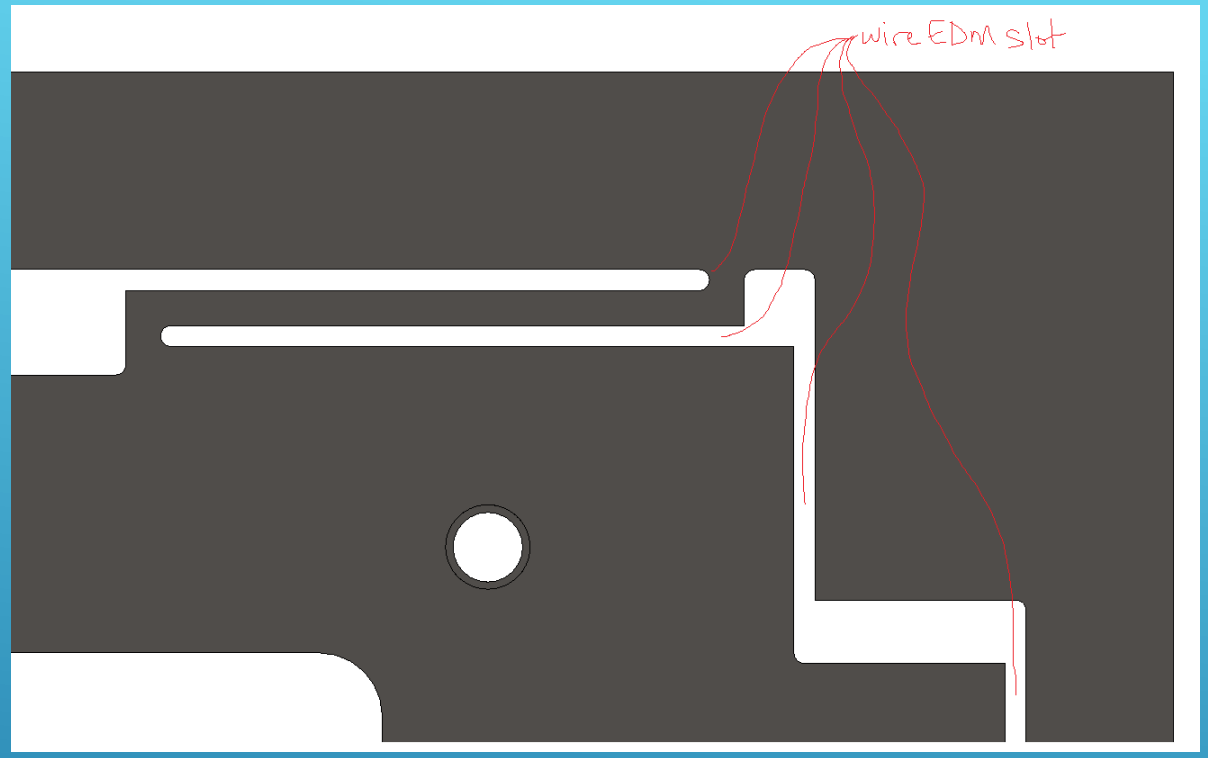
LOADING AND BALANCED MOTION

- Single point actuator limitation
  - Force triangle
  - Overcome flexure reaction
  - Negative springs
    - $F_{springs} = 1.25k_{tot}\delta = 2k_{spring}\delta_{spring}$
    - $F_{max} = F + F_{springs} + 2k_{spring}\delta$



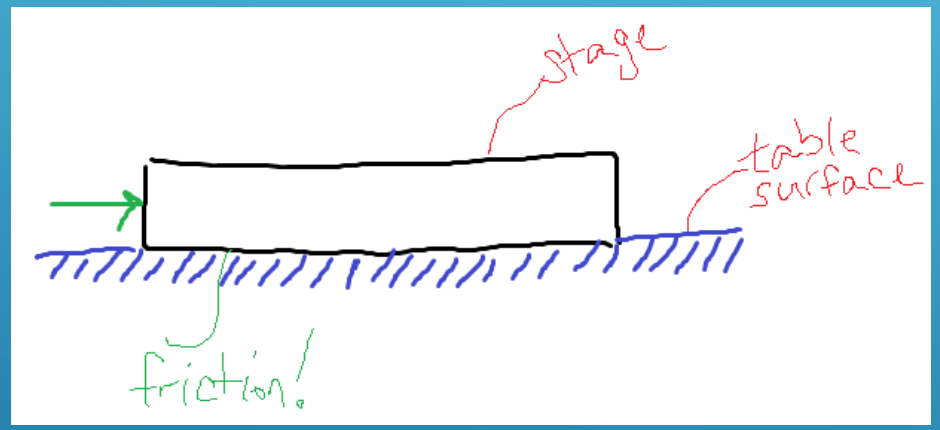
MANUFACTURING

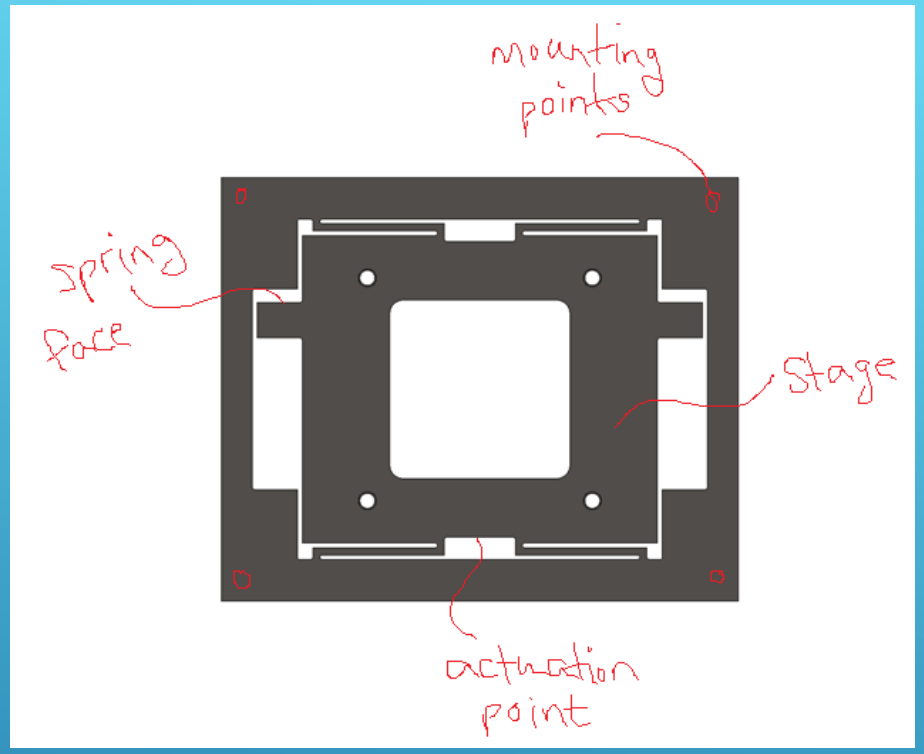
- Use a Blanchard ground plate with good perpendicularity on the edges.
- Common milling practice is good for most features
- Wire-EDM (electronic discharge machining) for the flexure features



MOUNTING AND USAGE

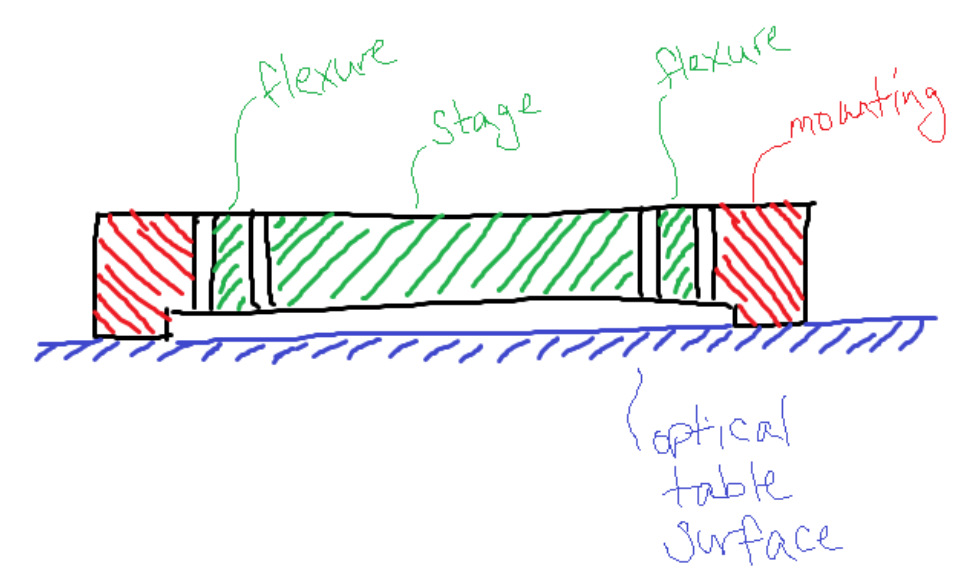
- How will it be mounted?
- How will that affect the performance?

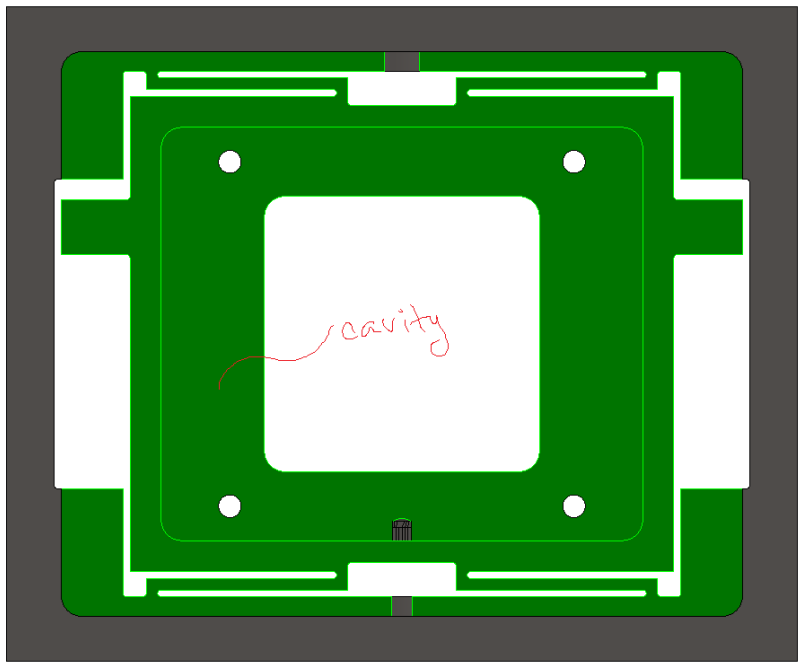




MOUNTING AND USAGE

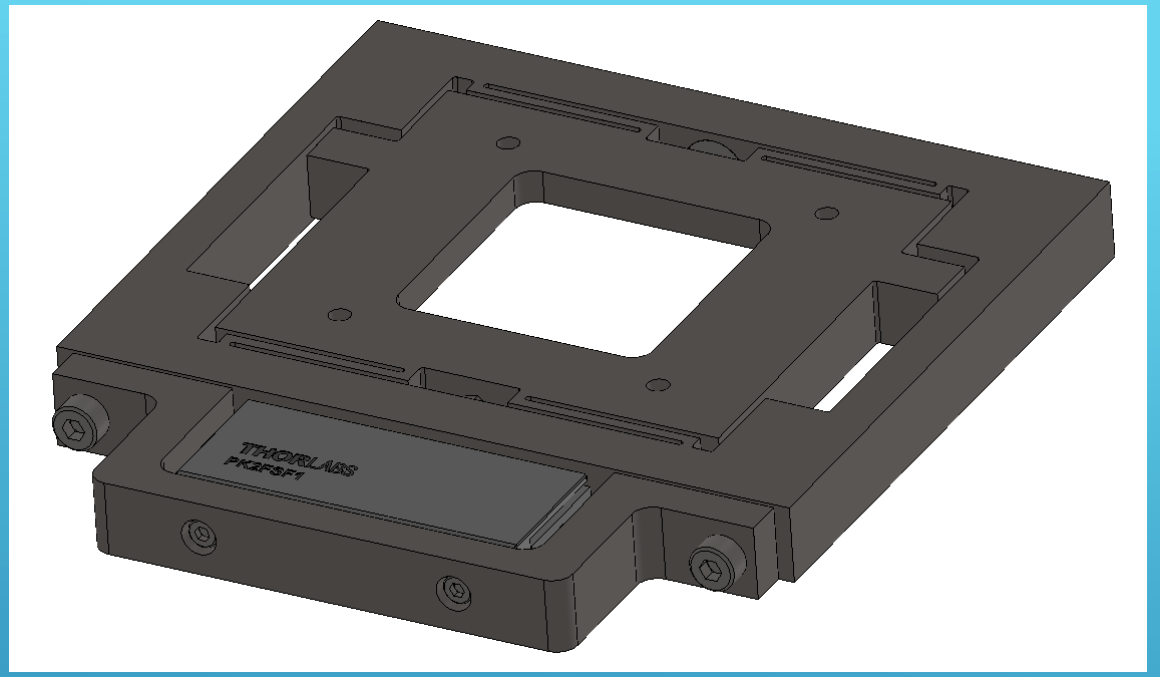
- Machine a cavity to provide stage motion clearance!

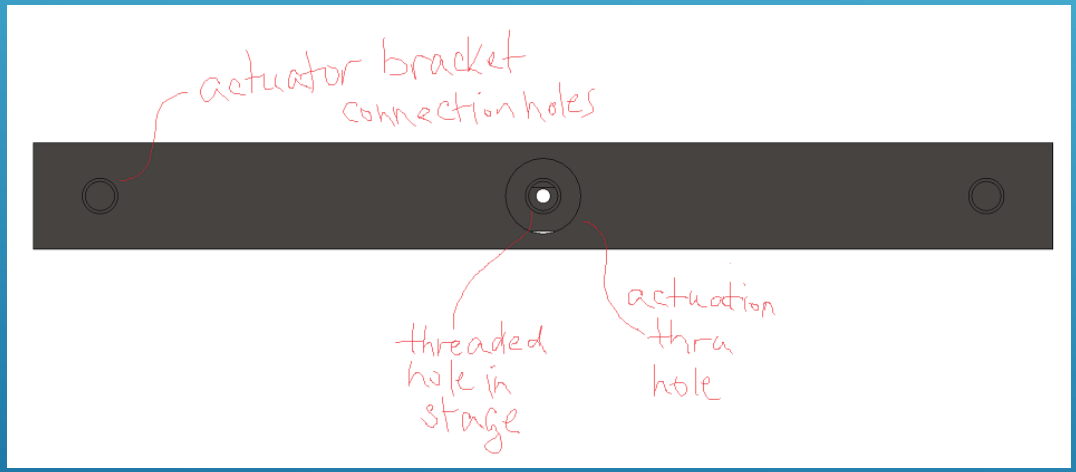


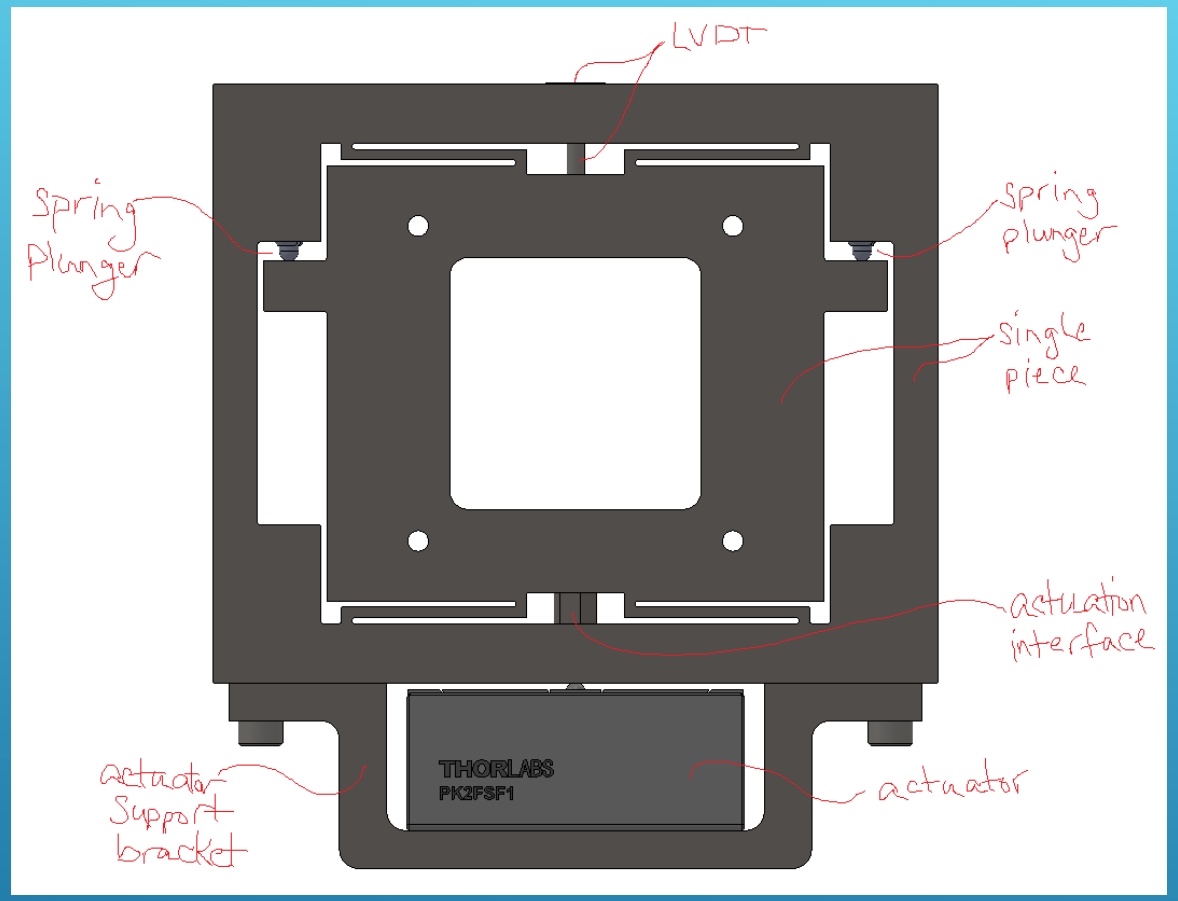


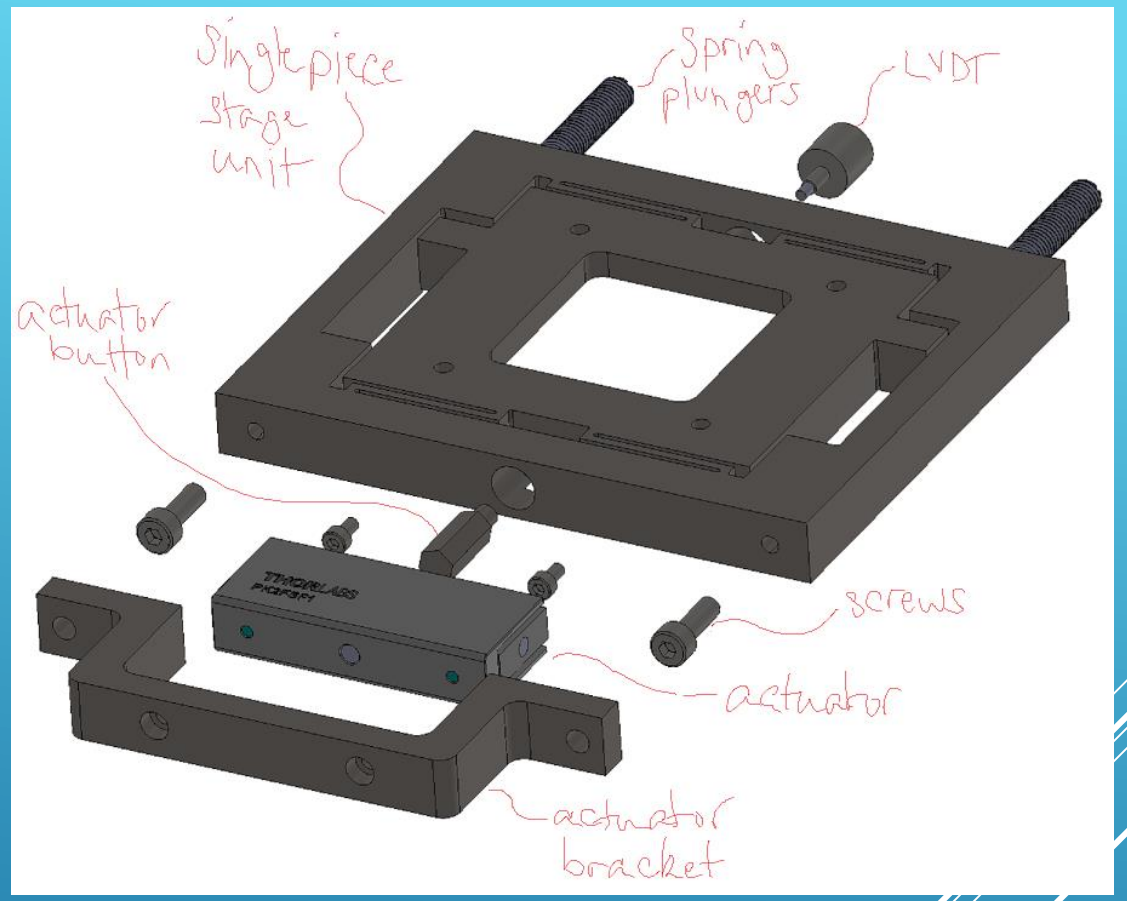
COMPONENT ATTACHMENTS

- To maintain low profile, attach actuator and feedback devices on plate edges.









FINISHED ASSEMBLY!

REFERENCES

- Gonzales, K. L., *"Tutorial: Design of a low profile single axis linear motion stage"*, Complete text, Fall 2015
  - Burge, J. H., *Lecture Notes "Deflections Under Loading"*, Fall 2015
  - Vukobratovich, D., *"Introduction to Opto-Mechanical Design" Course Notes*
  - Schwertz, K., *"Useful Rules of Thumb in Optomechanics"*, Spring 2010
  - Thorlabs.com, parts reference
  - Measurement Specialties, MEAS-SPEC.com, parts reference
  - Physik Instrumente, PI-USA.US, examples of small motion flexure based linear stages