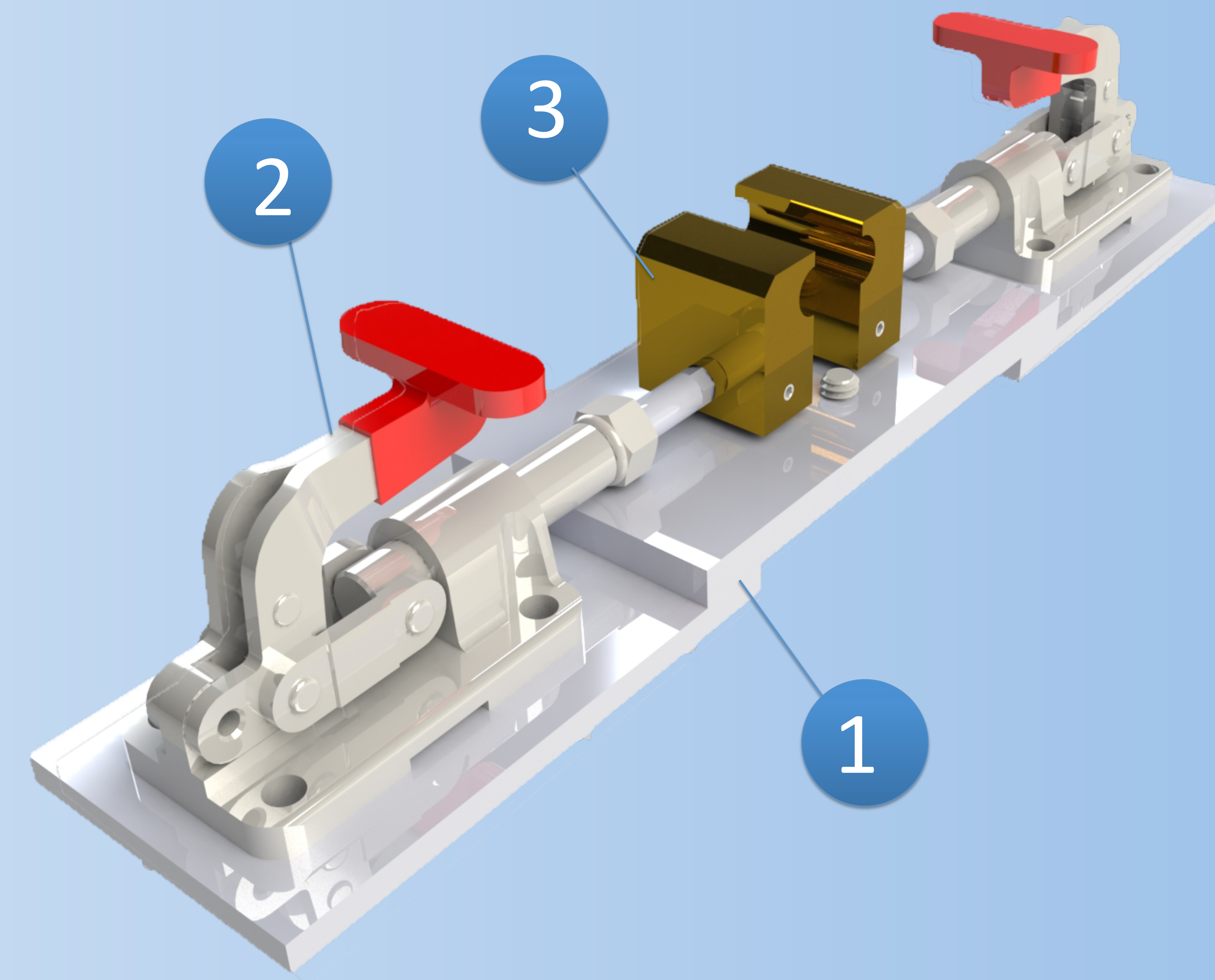
Snowfall Simulator Quick-Release Retrofit

Nicholas Runyan, STAR Participant, Cal Poly San Luis Obispo
University Corporation for Atmospheric Research // Boulder, Colorado
Mentor: Scott Landolt[1], PhD
[1]National Center for Atmospheric Research

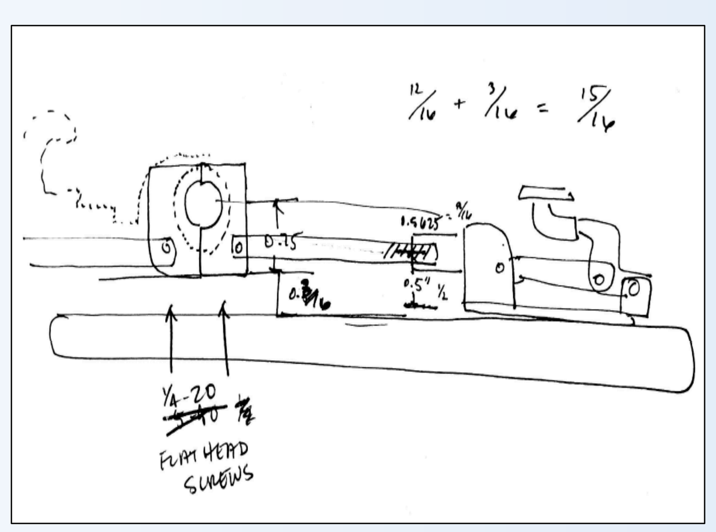


Purpose

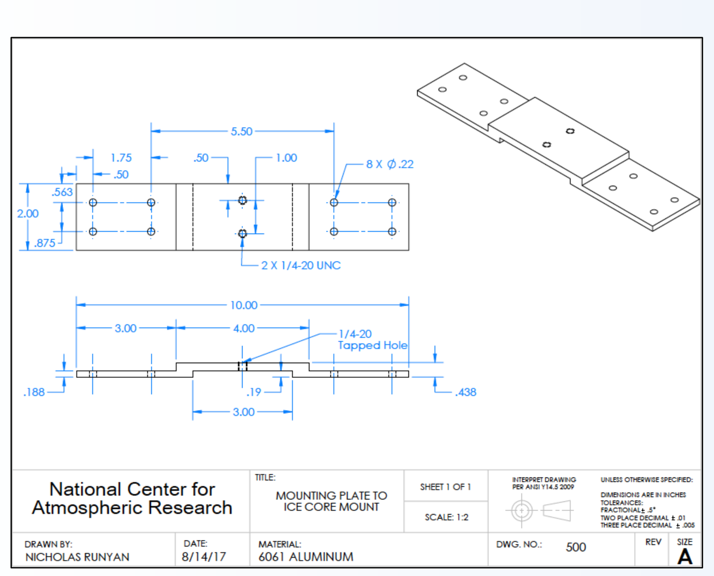
In the early 1990s, UCAR fabricated a snowfall simulator that they have used to test deicing fluids for aircraft, among other applications. Ice cores are actuated by a stepper motor turning a lead screw and travel along a linear guide rail feeding it into an auger bit. This bit shaves the ice core, creating conditions that simulate snowfall. When one ice core has been exhausted, the motor controlling the carriage must be actuated in reverse back to reloading position, which can take upwards of three minutes. The purpose of this project is to retrofit the simulator with a quick release system that allows for the user to manually unlock the carriage and quickly pull it back into the reloading position, decreasing turn around time in the testing process. The final design is a symmetric 2-clamp system that is installed directly onto the ice core mount. To reload the ice cores, the user must simply lift the *Destaco* clamps on each side and pull the entire carriage back to the original position at the front of the simulator.

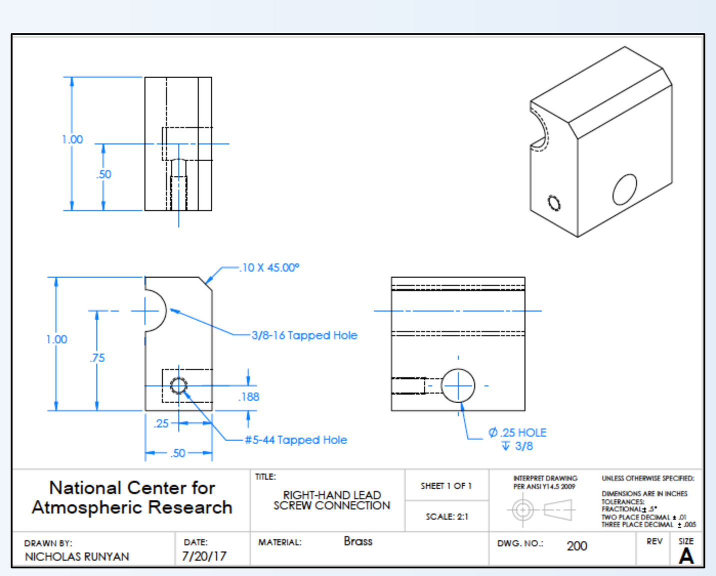
Preliminary Design

Customer requirements were determined, which led the rest of the design process. It was determined that the most important factors of the design is that it can be integrated directly onto the existing equipment, and uses the least amount of user input.



The existing front end of the simulator was removed and inspected Notebook sketching of the possible design. This shows the geometry decisions to overcome space constraints.

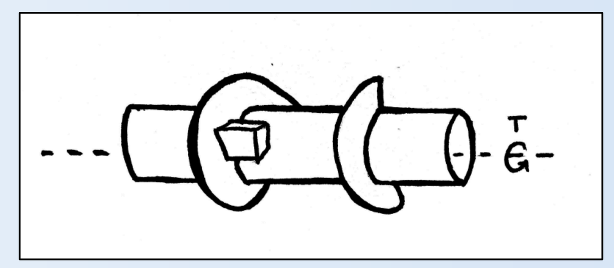


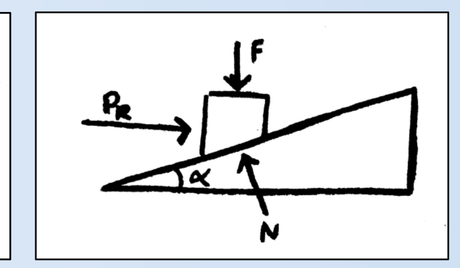


Engineering plan drawings were developed for the 4 custom manufactured components in the assembly. Above is the engineering drawing for the mounting plate component.

Analysis

The design was verified to ensure that the connecting rod between the clamp and the lead screw would not fail due to the supplied torque from the motor. We first visualize the force against the threaded connection as:



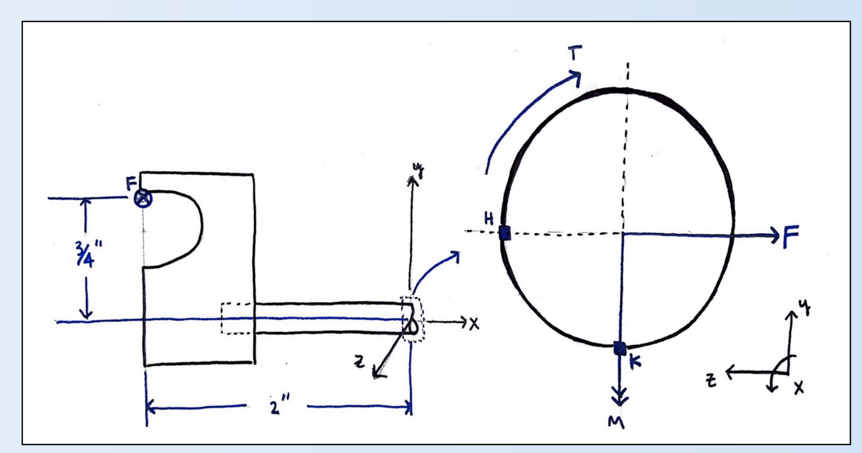


T = Torque
d = diameter of screw
α = thread lead angle

The force applied onto the threads, inducing a bending stress is:

$$F = \frac{2T}{d}\frac{\cos\alpha}{\sin\alpha} = \frac{2(160oz-in)}{3/8in}\frac{\cos(85^{\circ})}{\sin(85^{\circ})} = 4.84lbf$$

The following diagram is used to visualize the effect of the force on the connecting rod, and calculate the stress states at points *H* and *K* (most susceptible locations for failure). These stress states are used to calculate the principal stresses (using Mohr's Circle):

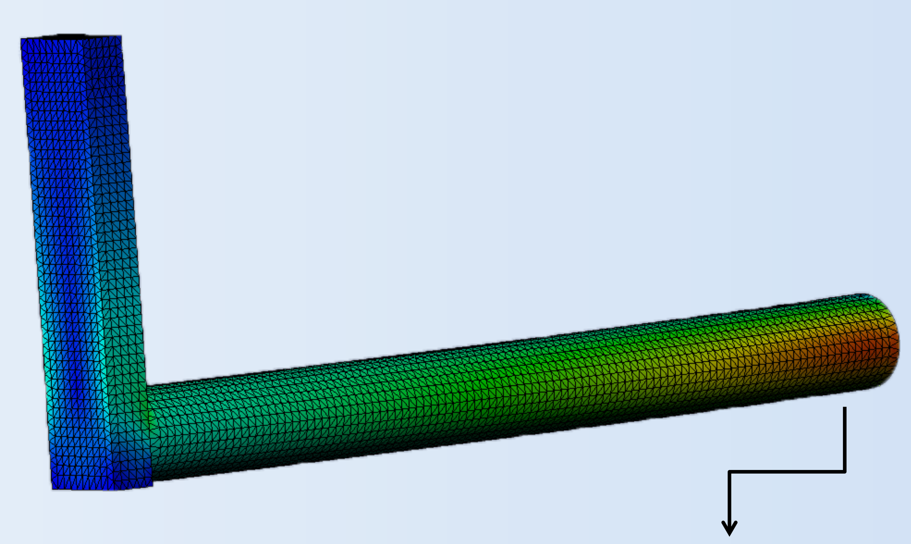


$$\sigma = \frac{P}{A} + \frac{Mc}{I} \qquad \sigma_H = 1.86ksi \qquad \sigma_K = 0ksi$$

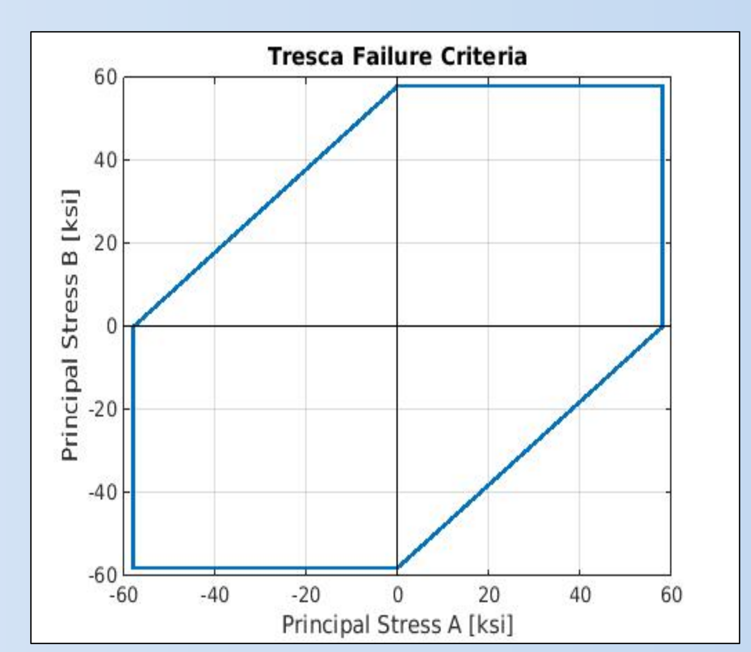
$$\tau = \frac{VQ}{It} + \frac{Tr}{J} \qquad \tau_H = 0.35ksi \qquad \tau_H = 0.41ksi$$

Principal Stresses: $\sigma_A = 1.93ksi$, $\sigma_B = 0.07ksi$

Finite Element Analysis was used to validate the hand calculations, resulting in predictions that are within 22.6% of each other. There is an expected factor of safety of 36 for this system. Failure due to static loading, as predicted by Tresca standards are also shown below, within which the stress states exist well inside.



Most affected zone:
Max stress = 1.5 ksi



Final Design

(1) Mounting plate: attaches to the current ice core mount by ¼-20 screws. Locates the clamps off of the face of the carriage.
(2) *DESTACO* Clamps: attach to the mounting plate with machine screws and lock nuts to prevent loosening from vibrational loads. The clamp pulls up to disengage the lead screw connections.
(3) Lead Screw Connections: 3/8-16 tapped holes engage the lead screw from the left and right to transmit power from the motor to the carriage. These connections are easily disengaged by pulling up on the clamps.

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