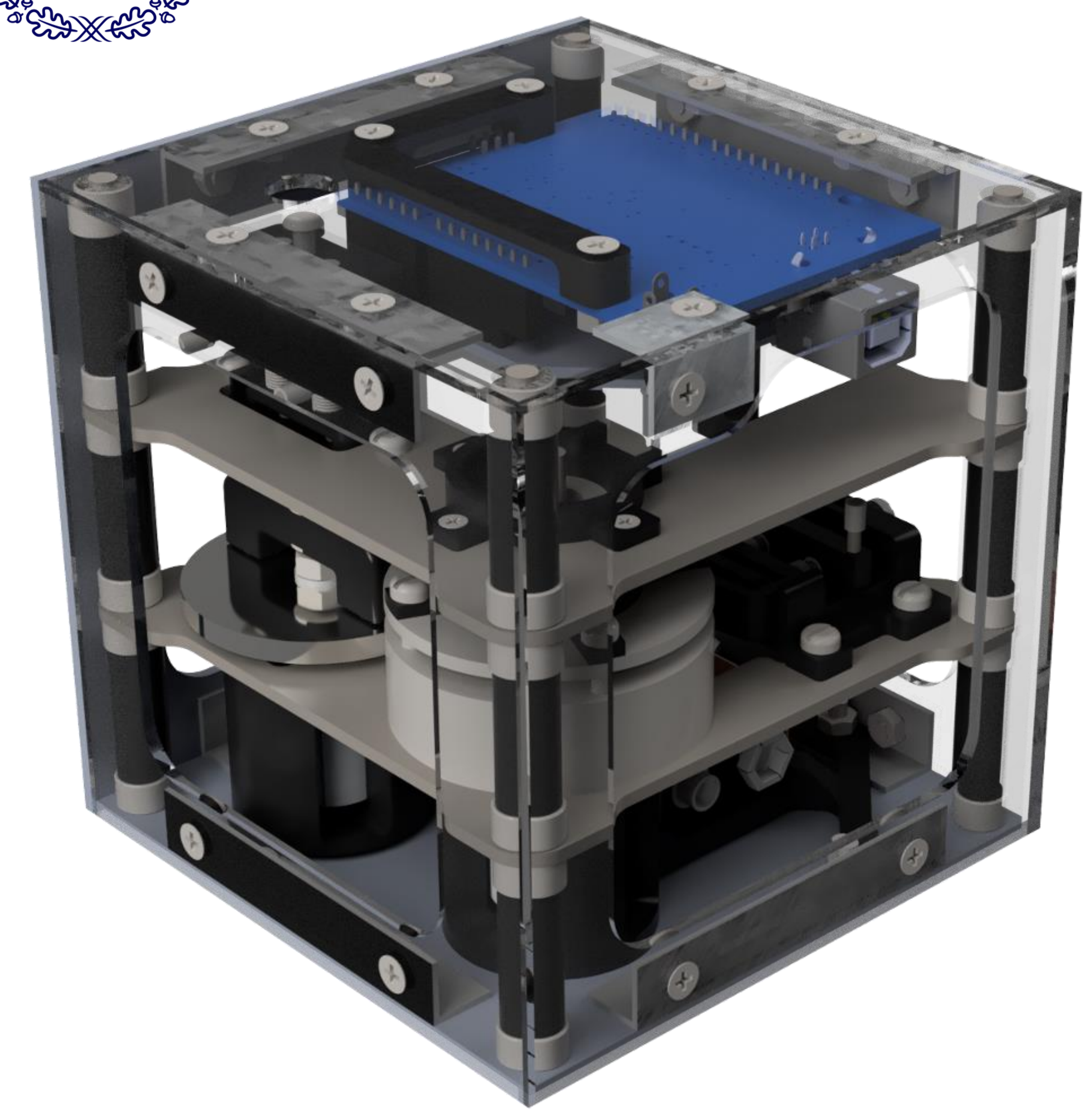
MF2077 Machine Design Advanced Course II 2023

CubeSat Evaluation and Design

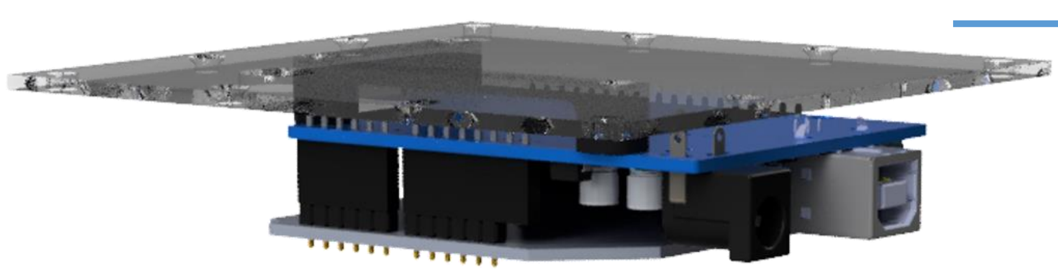


Background

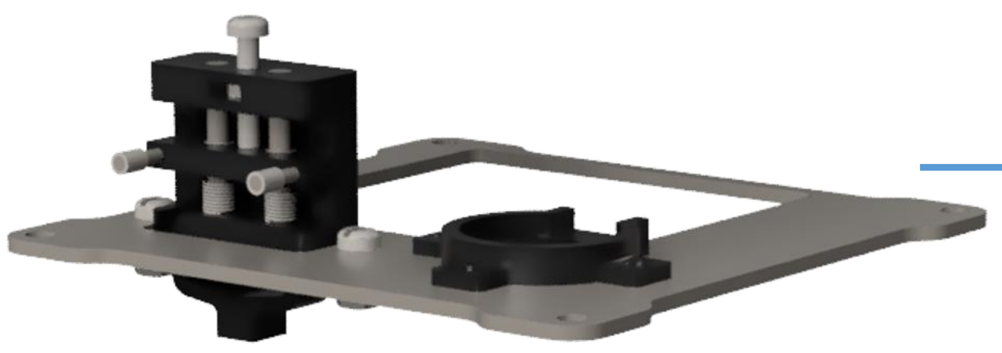
- CubeSats are small satellites used in industry and academia
- A standard unit (U) is 10 cm x10 cm x 10 cm and weighs under 1.3 kg.

Project Goal

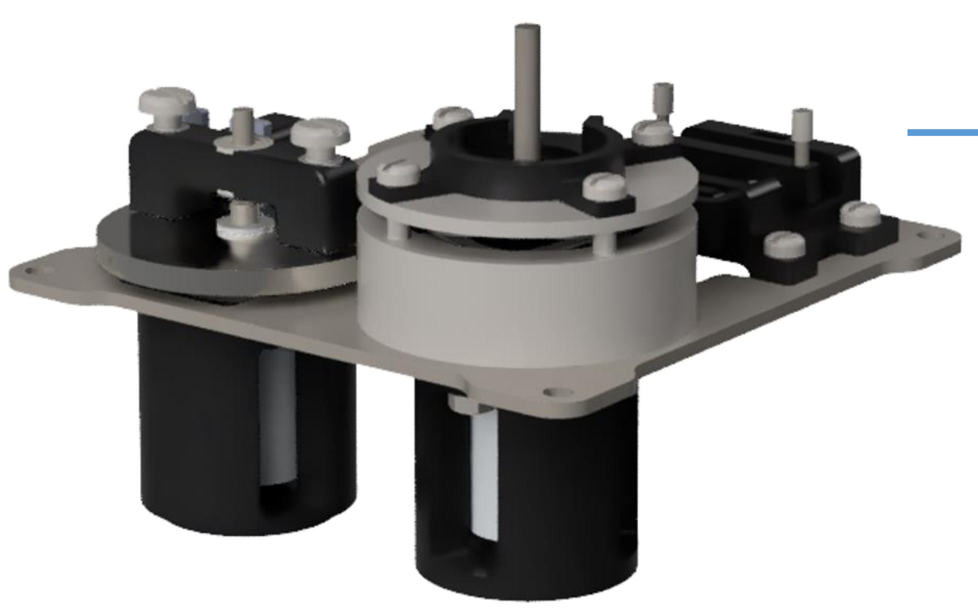
- Design evaluation and redesign of existing CubeSat.
- Develop concepts and design two tribometers.
- Prototype a terrestrial twin of a theoretical space-based CubeSat for tribological testing.
- The tribometers are used to assess the performance of various lubricants for space-based applications.



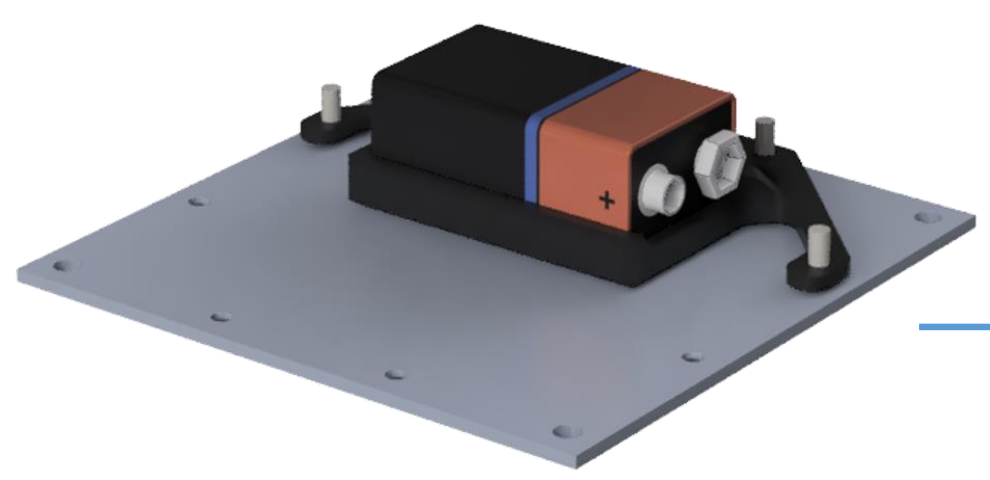
Floor 3
- Arduino and custom PCB
- Custom L brackets mounting



Floor 2
- Pin-on-disc load mechanism mounting



Floor 1
- Pin-on-disc tribometer
- Ball bearing tribometer
- Pin-on-disc load mechanism
- DC Motor mounting
- Cage for ball bearing tribometer, load cell arm for pin-on-disc tribometer
- Encoder and encoder seat

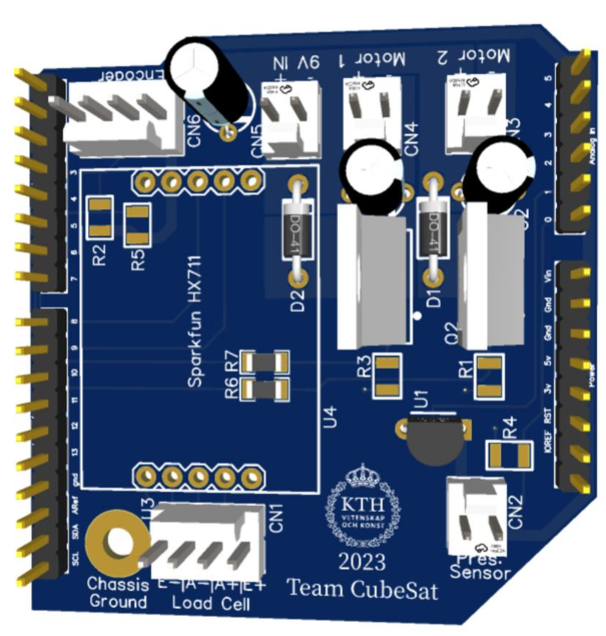


Base Floor
- Battery holder
- Motor support parts

Exploded view of CubeSat

Electronics

- **Circuit Board**
  - Designed to fit on top of Arduino
  - Reduces wire run length
  - Reduces electrical component footprint to conserve space
- **Sensors:**
  - LM35 Temp Sensor
  - Loadcell (pin on disc)
  - Pressure sensor (bearing radial load)
  - Encoder (bearing)
- **Motors**
  - 2 motors connected to N channel mosfets
  - Powered by a 9V battery



3D representation of PCB

Calculations

Ball-bearing Tribometer:
- Friction torque of the bearing is calculated to evaluate the coefficient of friction.
- The friction torque depends
  - lubricant's viscosity,
  - geometry of the bearing,
  - RPM of the bearing,
  - Radial and axial loading of the bearing.
- Friction model was developed using the SKF and Hysteresis model.
- Change in RPM is obtained from the encoder, and radial load from the pressure sensor.

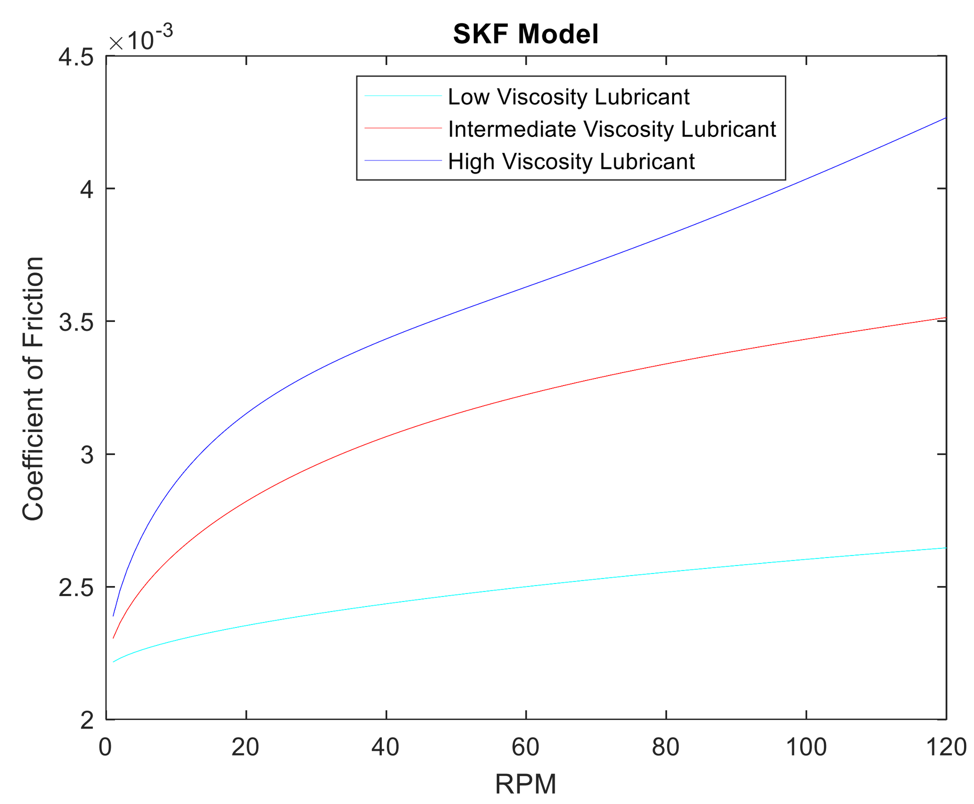
Pin-on-disc Tribometer:
- The coefficient of friction between the pin and disc is calculated from the frictional force and the applied force.
- The friction measurement for this tribometer is dependent on
  - Materials of the disc and the pin,
  - RPM of the disc,
  - Applied axial load.
- Frictional force is measured with a load cell.

SKF Model

$$M = M_{rolling} + M_{sliding}$$

$$M_{rolling} = \varphi_{ish} \varphi_{ors} G_{rr} (\vartheta n)^{0.64}$$

$$M_{sl} = G_{sl} \mu_{sl}$$

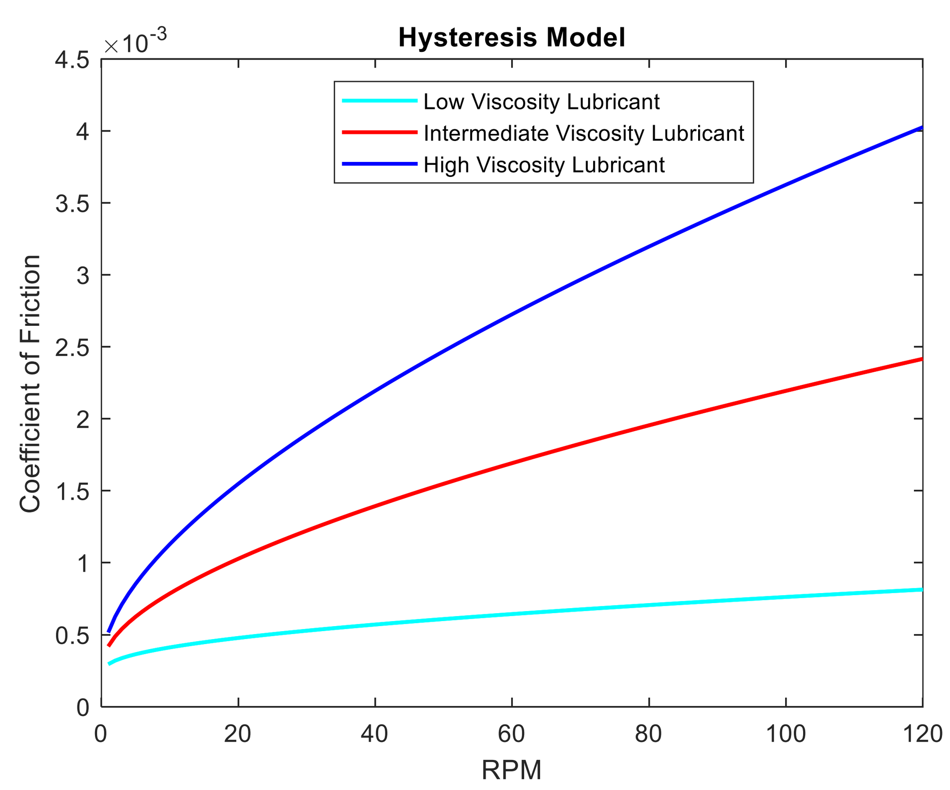


Hysteresis Model

$$T_Z = \frac{MER \times d_m}{d_m} + FR \times d_m + MP - \frac{F_{ib} \times d_m}{4}$$
$$MER$$

$$T_Z = 7.48 \times 10^{-7} \times \left(\frac{d_b}{2}\right)^{0.33} \times Q^{1.33} \times \{1 - 3.519 \times 10^{-3} \times (k-1)^{0.8063}\}$$

$$F_{ib} = -\frac{m_b \times d_m}{2} \times \frac{d\omega_c}{dt}$$



Expected Results

Ball-bearing:
- A low friction coefficient of 0.001-0.0015. Typical for a deep groove ball bearing.
- An increase in rolling friction with increase in RPM which is analogous with viscosity of the lubricant used.

Pin-on-disc:
- An increase in friction will be observed over time as wear increases on the disc.
- A higher value of coefficient of friction is expected from this tribometer compared to the ball-bearing tribometer.

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