A CubeSat Constellation to Investigate the Atmospheric Drag Environment

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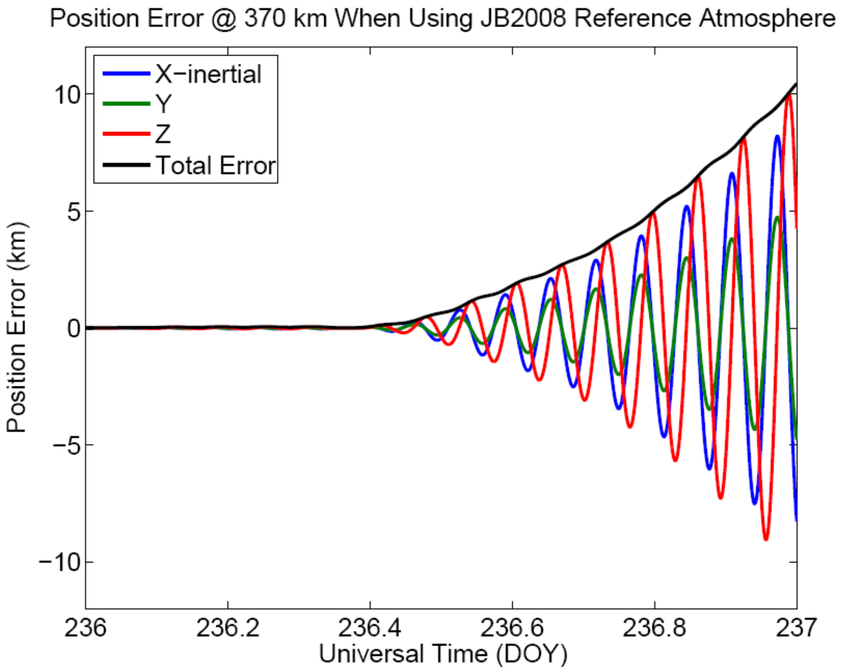
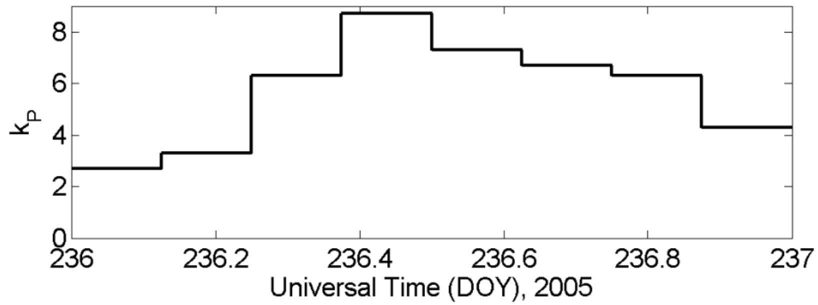
Mission Motivation

- State-of-the-art empirical models fail to model the storm-time behavior of the thermosphere
- Satellite orbit prediction assuming perfect knowledge of the geomagnetic indices begins to degrade during and after a geomagnetic storm.





Satellite Prediction Capabilities in the Presence of Geomagnetic Disturbances

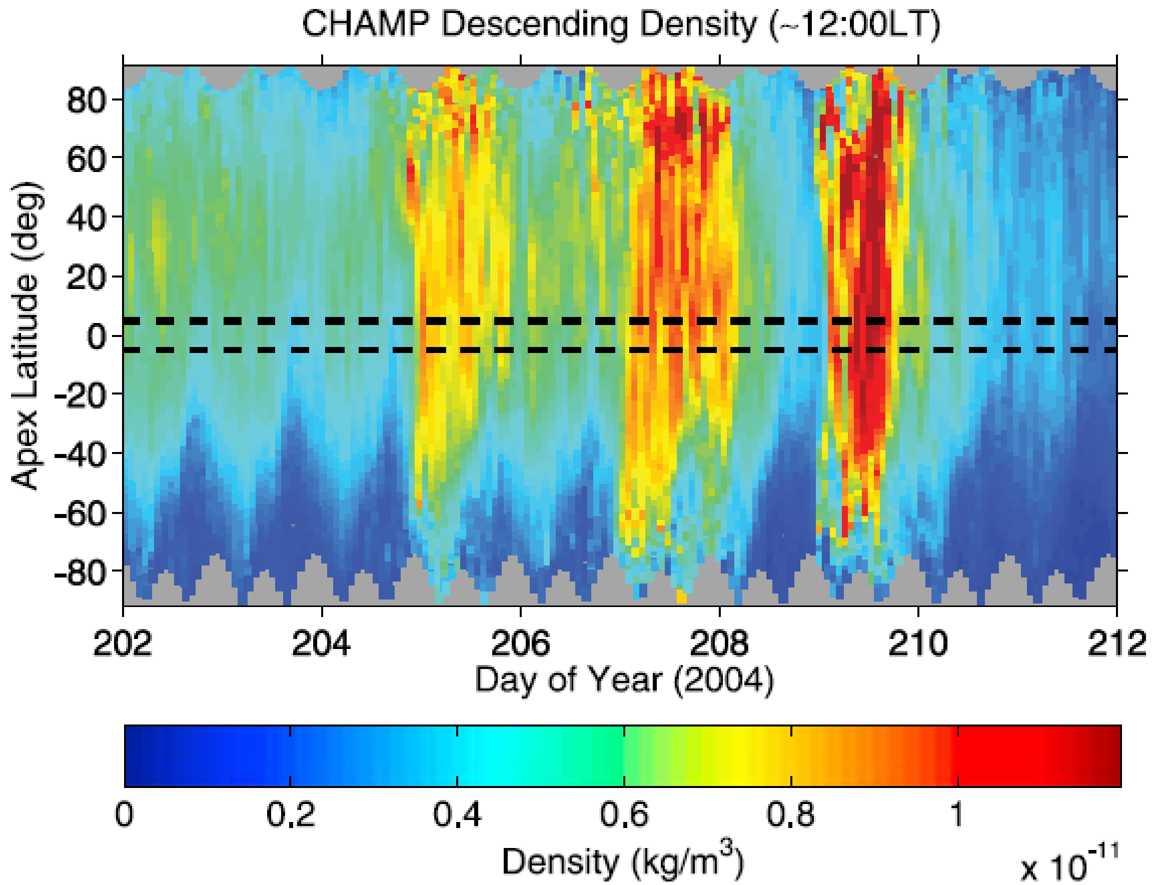
- AFSPC orbit prediction goal:

  72-hour prediction during disturbed conditions with an RMS to within 5% of that achieved during quiet conditions.
- Current capabilities:
  - 30% @ 200km
  - 65% @ 400km
  - 105% @ 600km

Scientific Objectives

- Provide global observations of the neutral upper atmosphere to drive a physics-based assimilation model
- Primary measurement goal:
  - Provide global coverage of neutral density in the upper atmosphere
- Secondary measurement goals:
  - Neutral wind/temperature
  - Ionosphere density/drift/ temperature
  - Energy input characterization

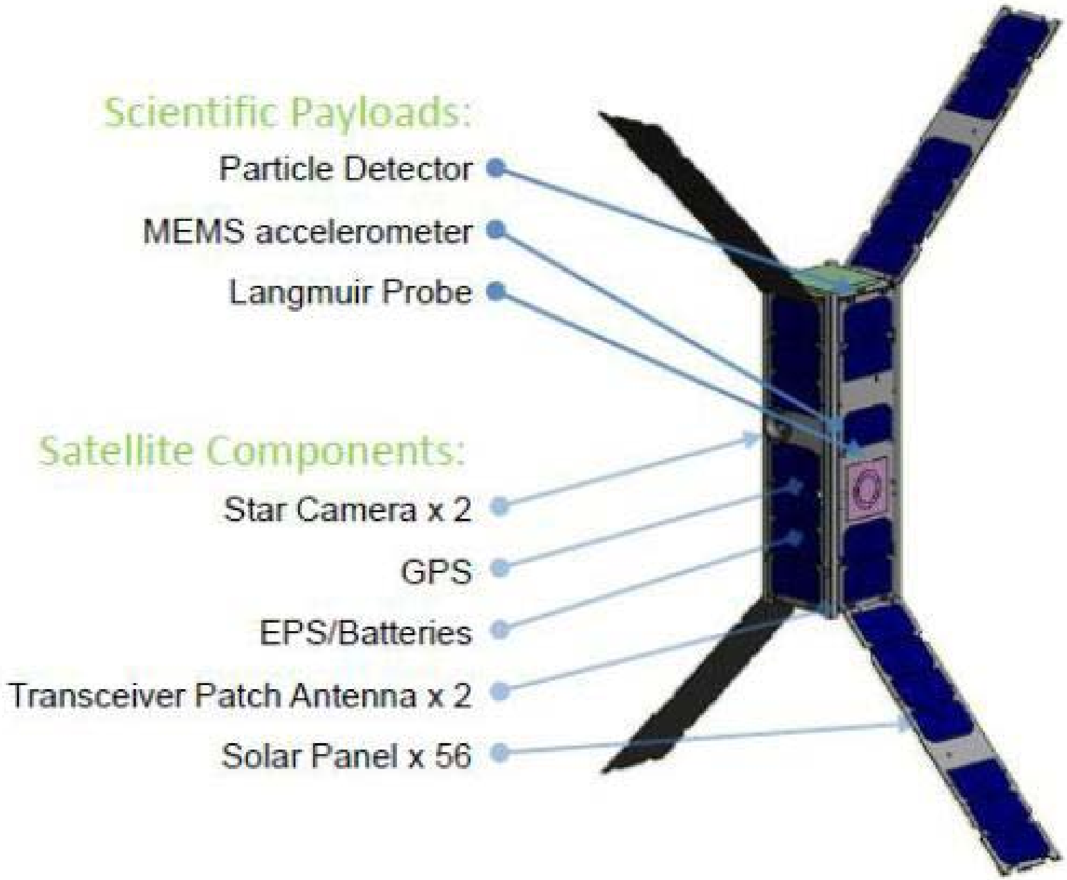
Champ Density Data



Mission Profile

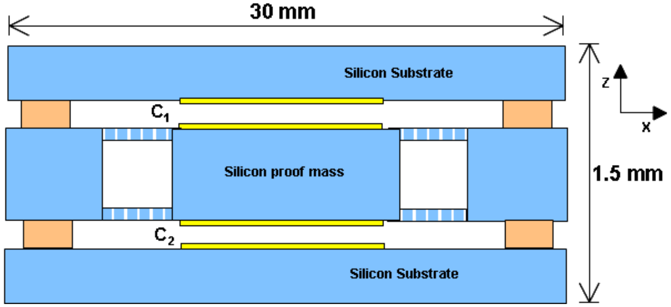
- Initial design studies show that a suite of thermosphere/ ionosphere sensors can fit in the envelope of a 3-axis stabilized 3U CubeSat
- Deployable solar panels are required to satisfy the power requirements
- Magnetorquers are capable of providing the necessary attitude actuation: attitude control requirements are fairly relaxed, attitude knowledge requirements are much more stringent

CubeSat Mission Profile

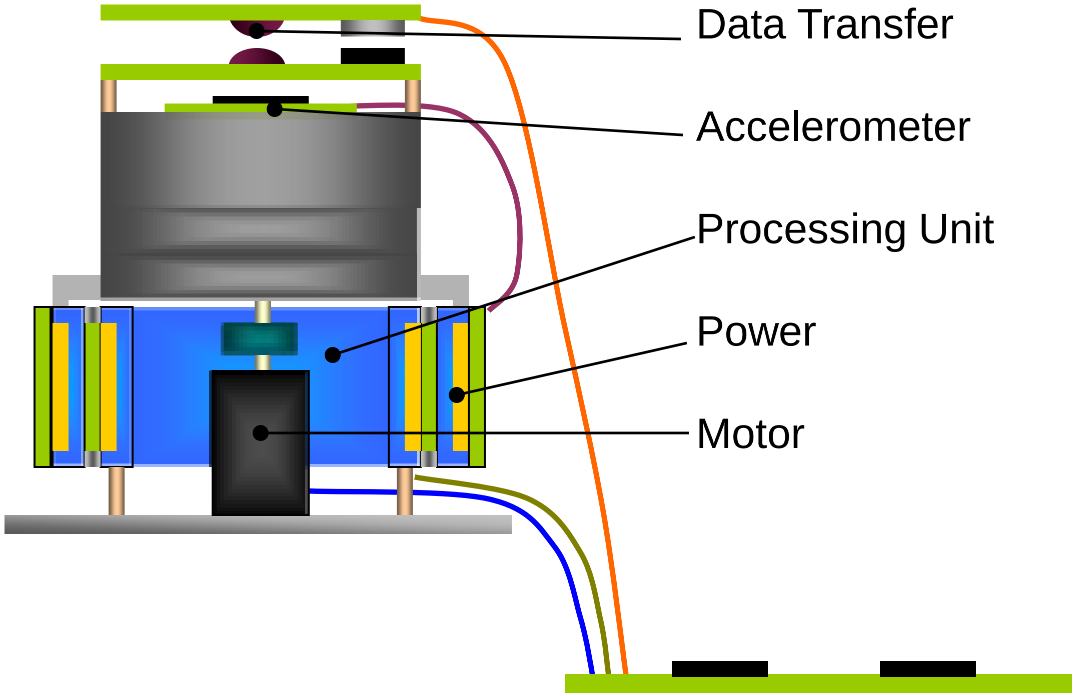


Overview of MEMS Accelerometer Concept

Accelerometer Device



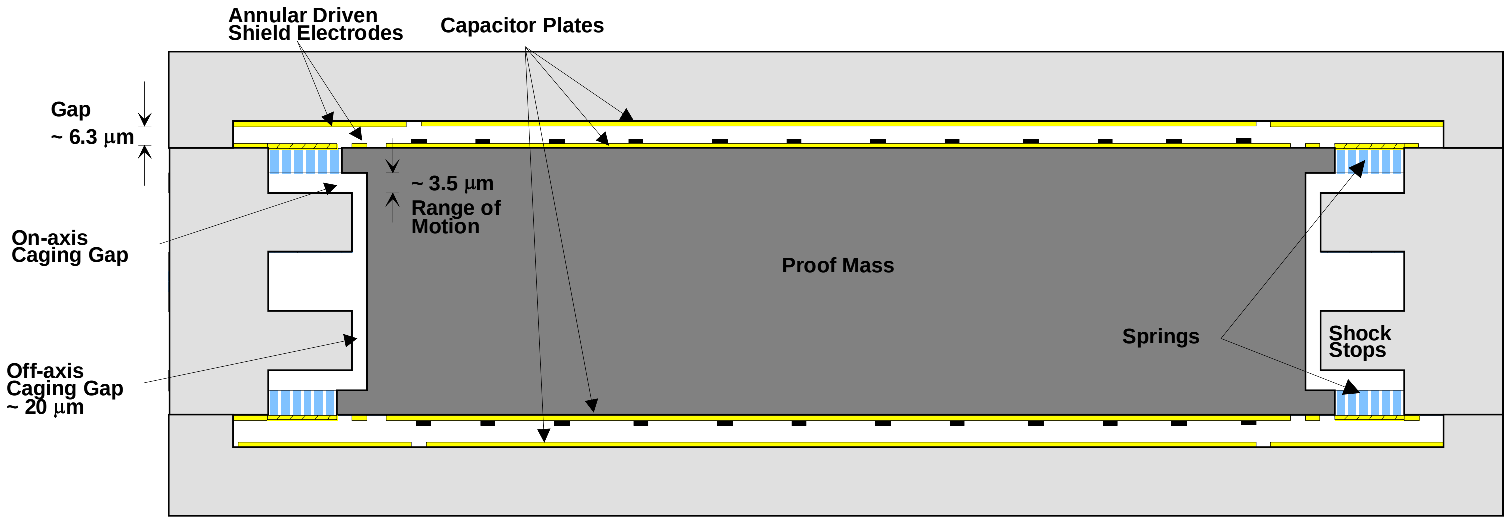
Rotating Assembly



Main Processor Board

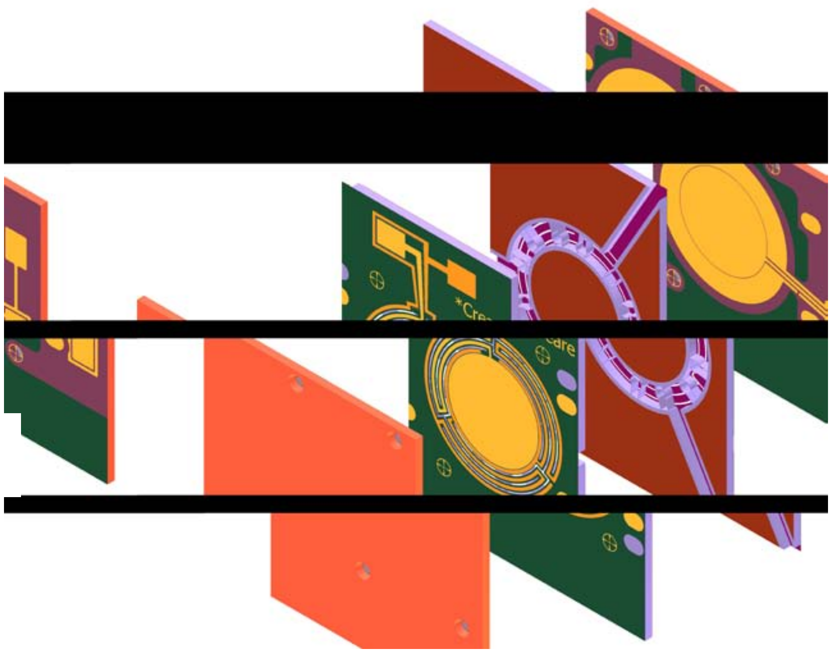
MEMS Device Overview

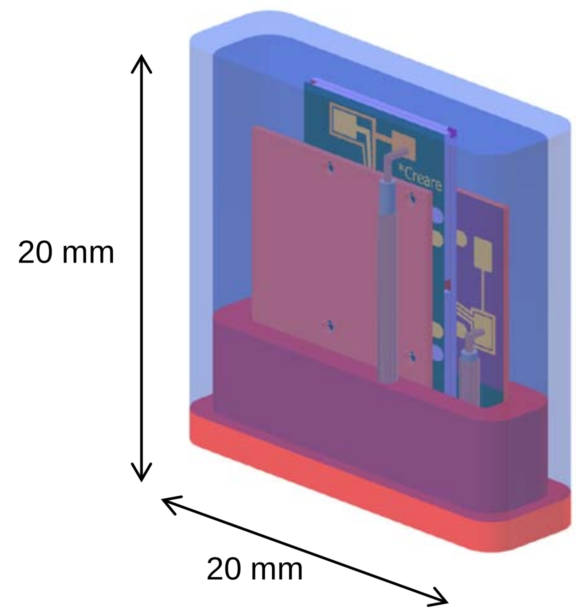
- 100 mg proof mass
- Differential capacitive position sensors with micron-scale gaps
- Nominally stress-free Si springs
- On-axis and off-axis shock stops
- Antistiction features
- Manufactured from precision silicon wafers



(Illustration not to scale or proportion)

MEMS Device Design Overview





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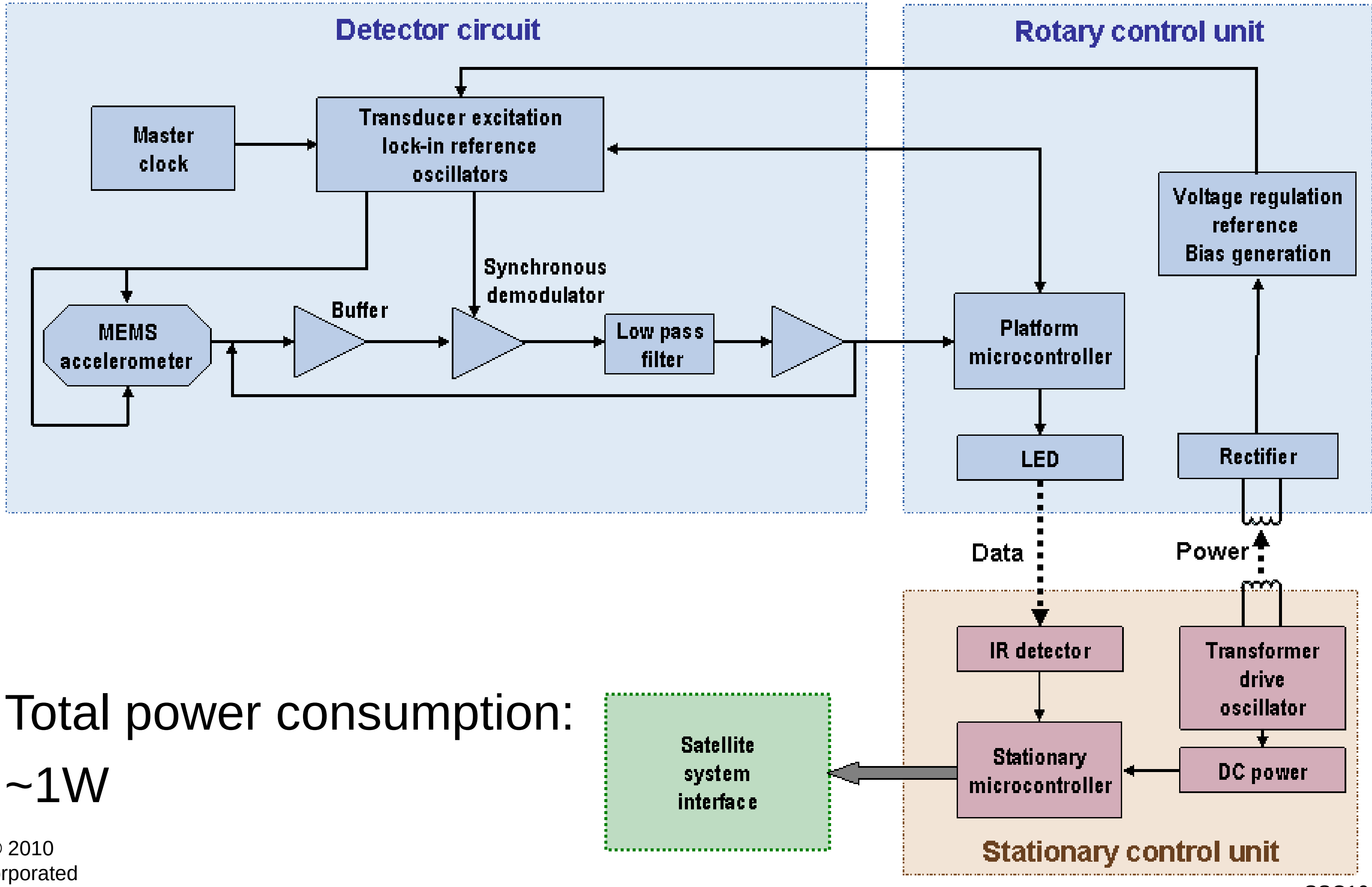
Creare MEMS Accelerometer Summary

	Creare	Commercial OTS (ADXL)
Mass size	50 to 100 milligrams	0.0005 milligrams
Capacitance sensitivity	~100 x 10^{-18} F/**1 nano-g**	~100 x 10^{-18} F/**g**
Deflection	~1 nanometer/**100 nano-g**	~1 nanometer/**g**
Gap size	5 to 10 microns	1 micron
Resolution	10 nano-g	230 micro-g

- Larger mass $\Rightarrow$ larger deflection for given acceleration
- Larger deflection $\Rightarrow$ larger signal for given acceleration

High sensitivity in a small package

Accelerometer System Block Diagram

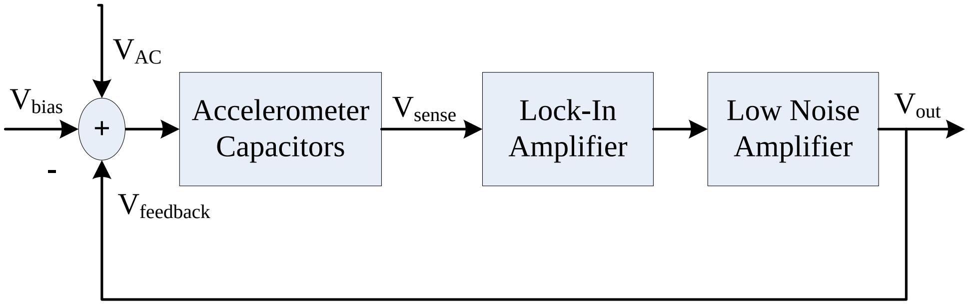


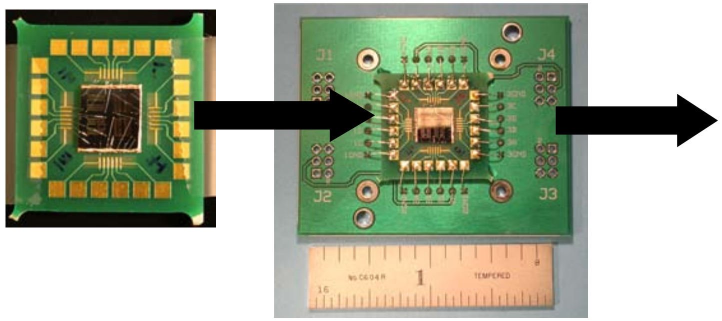
Total power consumption:

~1W

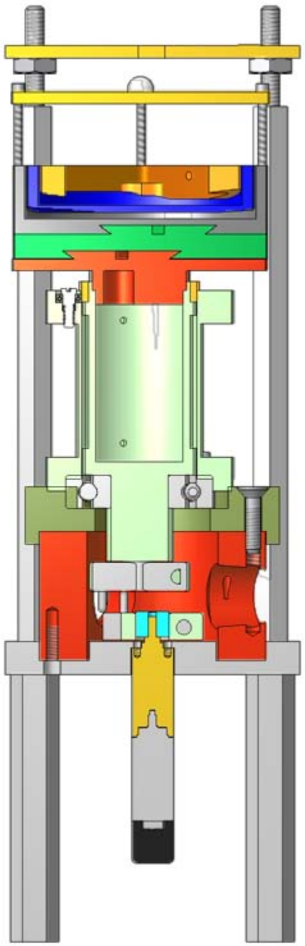
Detector Circuit

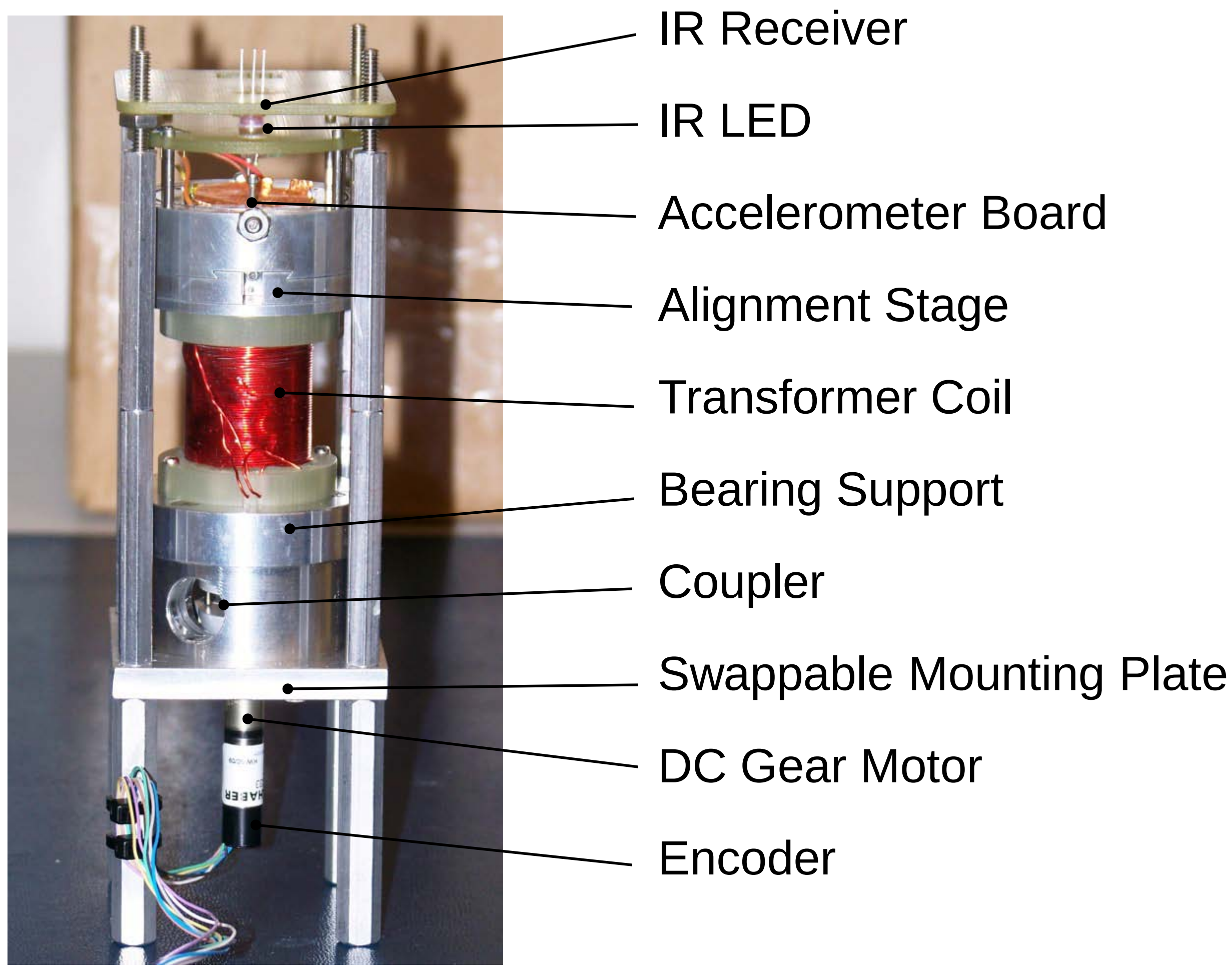
- Lock-in amplifier circuit measures changes in capacitance
- Feedback circuit keeps proof mass motion in the linear range
- Total noise estimated at 0.5µV RMS at 1 Hz
  - Corresponds to noise floor of ~0.1 nano-g RMS at 1 Hz





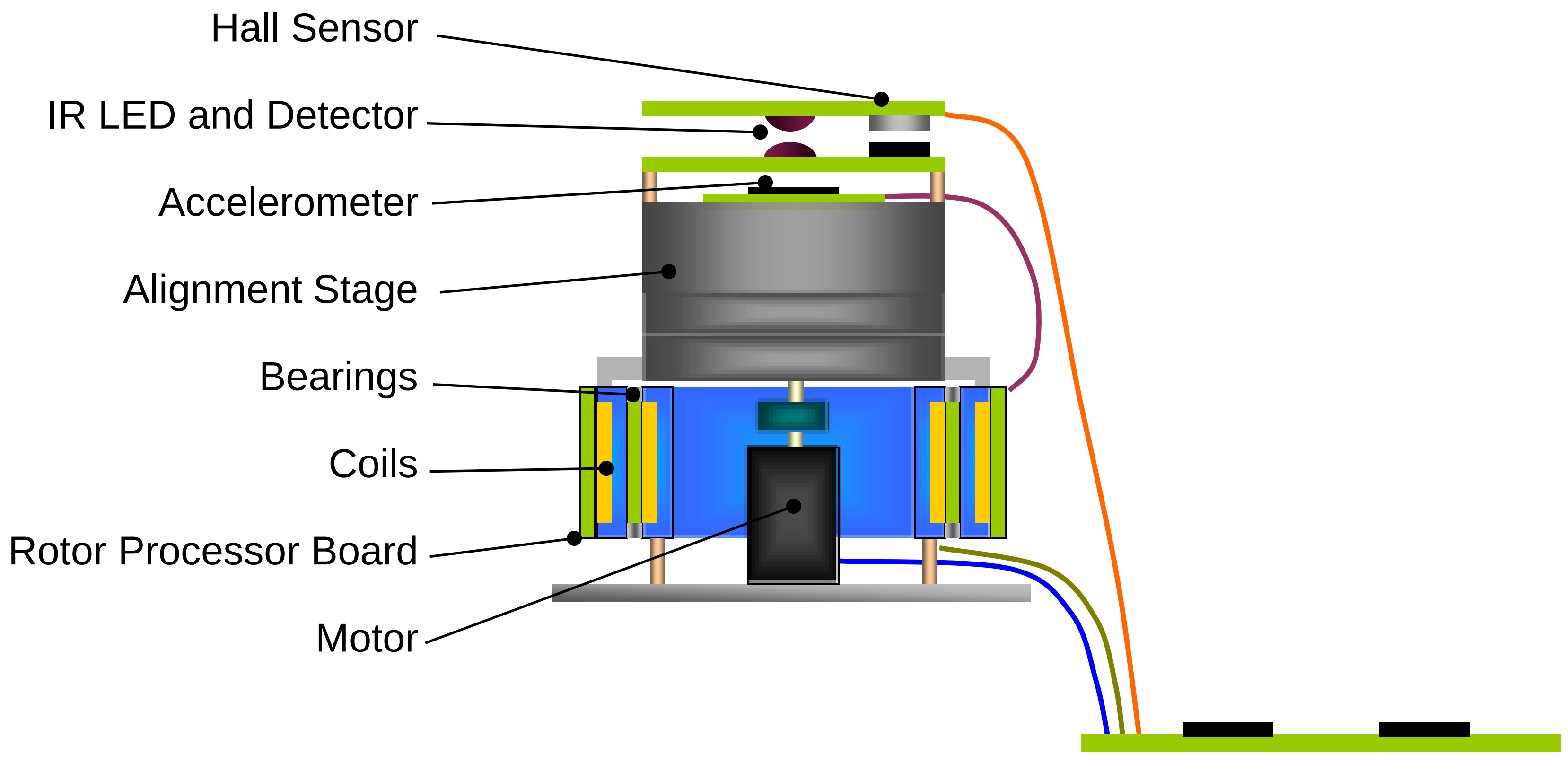
Accelerometer Assembly: Benchtop Simulation





Overall: 19 × 5.5 × 5.5 cm

Next Generation Assembly



Not to Scale

Conclusions

- AFRL planning CubeSat mission to measured orbital drag using MEMS accelerometer
- After initial mission, CubeSat constellation will provide multiple sensors to investigate orbital drag

- Creare is building a high sensitivity MEMS accelerometer
- Creare MEMS accelerometer designed to have much higher mass and lower noise than existing MEMS COTS devices
- Creare's accelerometer can rotate in orbit to modulate signal away from low frequency noise
- Expecting the first prototype accelerometer by Spring 2011.