RocketSat VI: Meteoritic Smoke Particles

Colorado Undergraduate Space Research Symposium

April 2010

Mission Statement

- The goal of RSVI is to characterize the atmosphere above Virginia, specifically for the numerical density of large aerosol particles and the charge of these particles

Background

- Meteoric Smoke Particles
  - Build up in the atmosphere due to the disintegration of meteors in the atmosphere
  - These particles are believed to be mostly made out of sodium ions
  - Form large aerosol particles, large than 1 nm in size, when ice forms around the particle

Meteoritic Particles

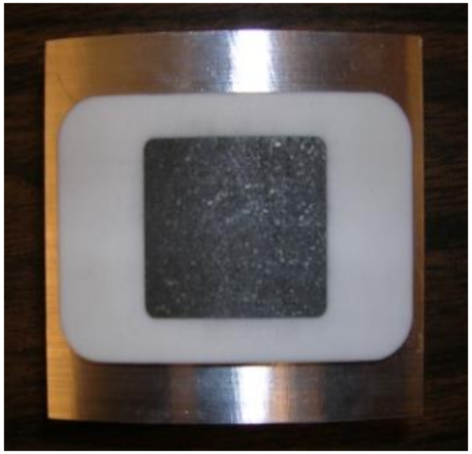
- Effects on Atmosphere
  - Increase the metal budget of the mesosphere
  - Linked to global warming effects
    - Increased amount of methane leads to more water vapor in atmosphere
    - Increased amount of carbon reduces upper atmospheric temperature
  - Believed to be a cause of noctilucent clouds
  - Particles have been detected in great numbers over the polar latitudes

Space Station PMC Photograph
Donald Petit, Space Station Science Officer

Credit: NASA/Donald Petit.

Graphite Patch Detector

- Using patch detector to measure particles
  - Acts as modified electrometer
  - charge is deposited onto graphite as a current
- Higher current corresponds to more particles hitting the detector



Detector Design

- Has built-in magnets, helps repel charged particles less than 1 nm in size
- The Larmor radius, or gyroradius, equation is used to define what size of particles will be deflected by the use of these magnets

$$r_g = \frac{m * v_{perp}}{|q| * B}$$

Determining Numerical Density

- Can calculate the numerical density of the particles as a function of altitude based on the equation:

$$n = \frac{I}{S_{eff} * u * q}$$

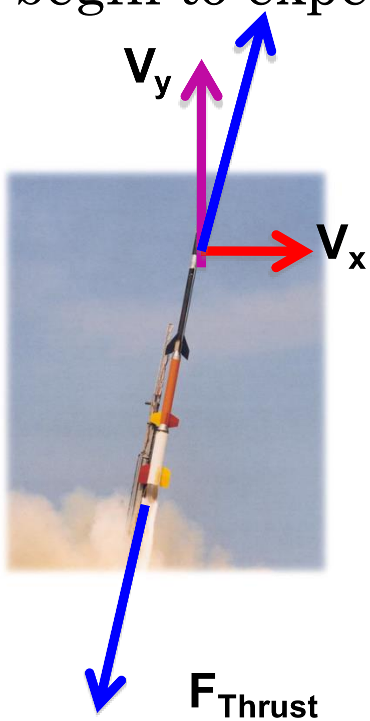
S_{eff} = effective area of the detector,
I = current,
u = rocket velocity,
q = charge of the particle

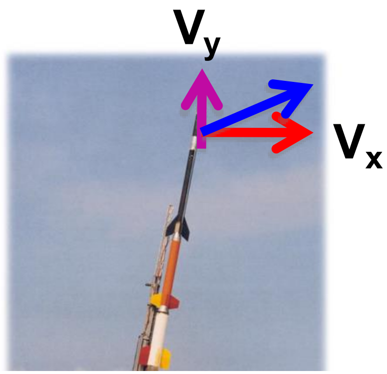
Boundary Layer Effects on Particle Detection

- Concern that the data would be affected by the boundary layer created by the detectors due to the supersonic speed of the rocket
- A Direct Simulation Monte Carlo (DSMC) code was used to simulate the air flow
- Results
  - particles greater than 5 nm in size were not affected
  - Particles between 1 to 5nm in size will be accounted for by adding a bias to one of the two detectors

Analysis

- Orientation of the rocket affects the amount of particles interacting with the detector
  - Before burnout, most of the airflow is parallel to the patch
  - After burnout (when rocket is in parabolic trajectory), will begin to experience particle detection





Attitude Determination

- Need to know the orientation of the rocket to determine the effective area of the detector (how much airflow is hitting the detector)
- Using MEMS gyroscopes and accelerometers on all three axes to measure the attitude
  - Writing an attitude algorithm using quaternions to determine the rocket's attitude after flight

Error Analysis

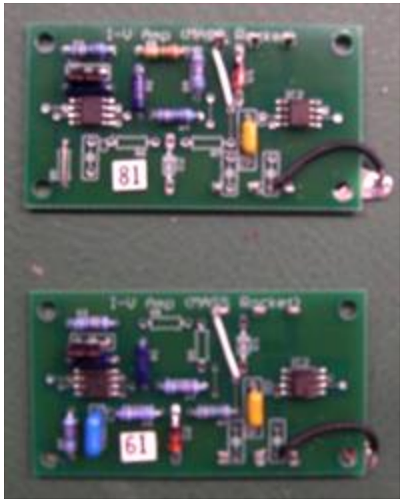
- Possible drift rates from gyroscopes and accelerometers during flight
  - Will measure the drift during spin testing and vibration testing
- Testing will allow drift to be characterized and applied to flight results

AVR Board

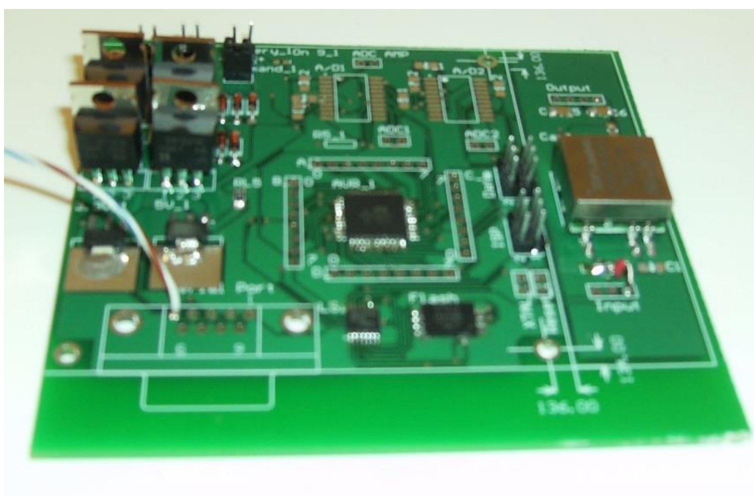
- Mother board
- Measures
  - Temperature and pressure
  - Accelerations in x, y, z axes
- Utilizes Atmega-32 microcontroller, programmed with C basic
- Python GUI and Realterm for data acquisition

AVR Board

MEPO and CVAs



CVAs

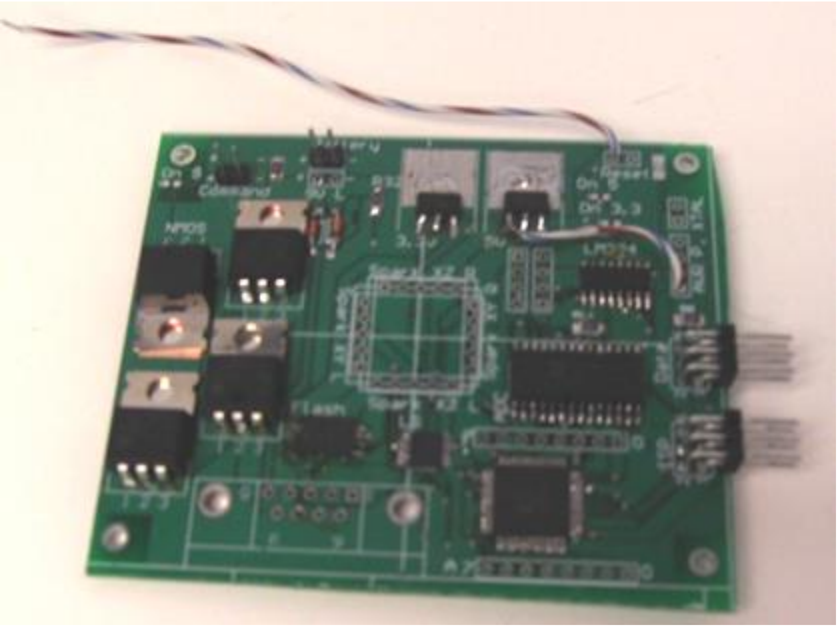


MEPO

- Mesospheric Particle Observation Board and Current to Voltage Amplifiers
- CVAs convert the current signal from detectors to a voltage
- MEPO stores the voltage signals from each CVA
  - External analog to digital converter to allow for sample rate of 1 kHz
  - Utilizes Atmega32A microcontroller and 64Kb flash memory

SCIENCE Board

- Collect angular rates for relative attitude
- LPR and LPY 5150- MEMs gyroscopes
  - Measure pitch, yaw, and roll
  - Measure rates up to +/- 6000°/sec
  - Maximum rocket spin rate 1800°/s (roll)
- Utilizes external ADC (faster sampling rate) and stores signals on Flash memory

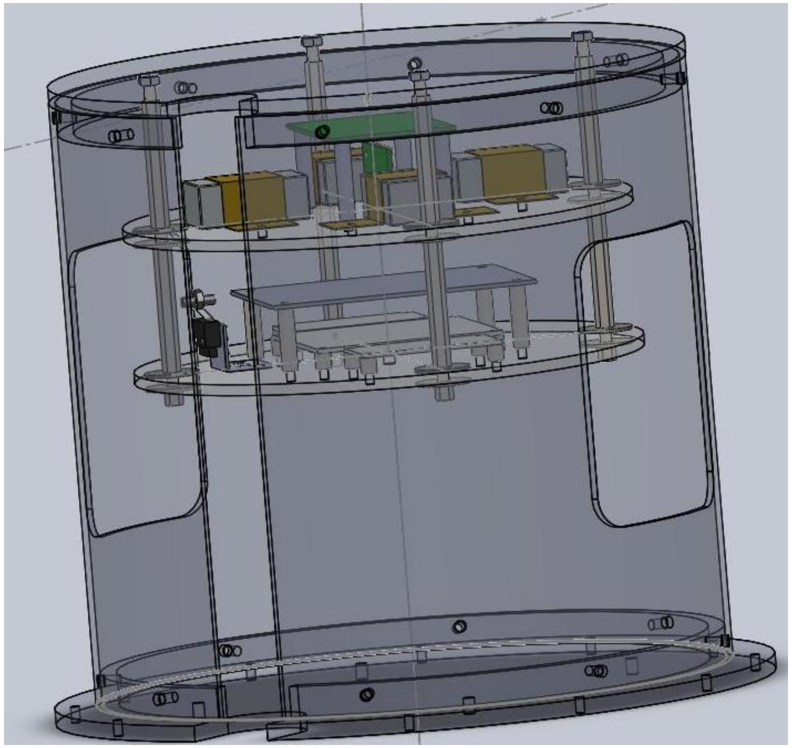


SCIENCE

Overall Design and Interface

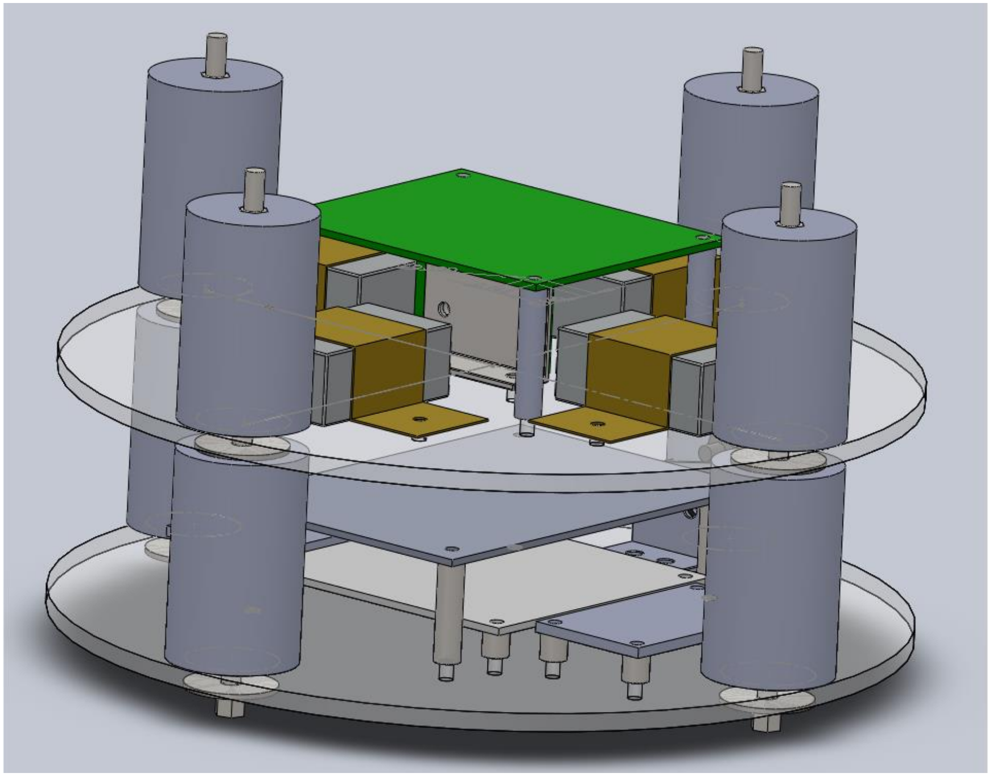
- Payload is flying out of Wallops Flight Facility on a Terrier-Improved Orion
  - Required to fly in aluminum canister
- Must interface with another university's payload
- Ballast masses are around standoffs instead of mounted on plate
  - Steel rods ~ total 4 lbs
  - Need total mass of 6.55 lbs

Canister Design



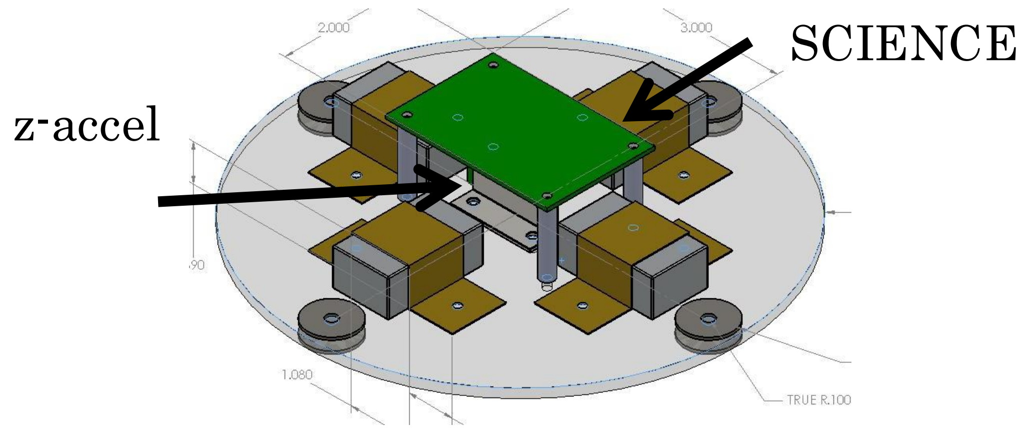
Stack in canister-
Virginia Tech will build up from bottom to connect to our payload

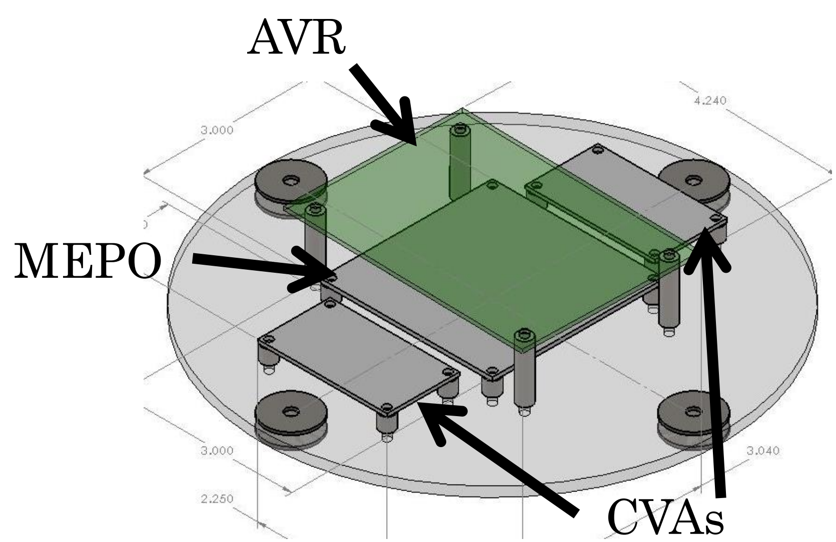
Ballast masses around standoffs



Makrolon Plates

- Top plate
  - Houses 4 batteries, SCIENCE, z accelerometer
- Bottom plate
  - Holds AVR, MEPO, and both CVAs
  - New PCB layout this year with stacked boards on the same plate
- Separated by 2 inch stainless steel standoffs, secured to lid of canister

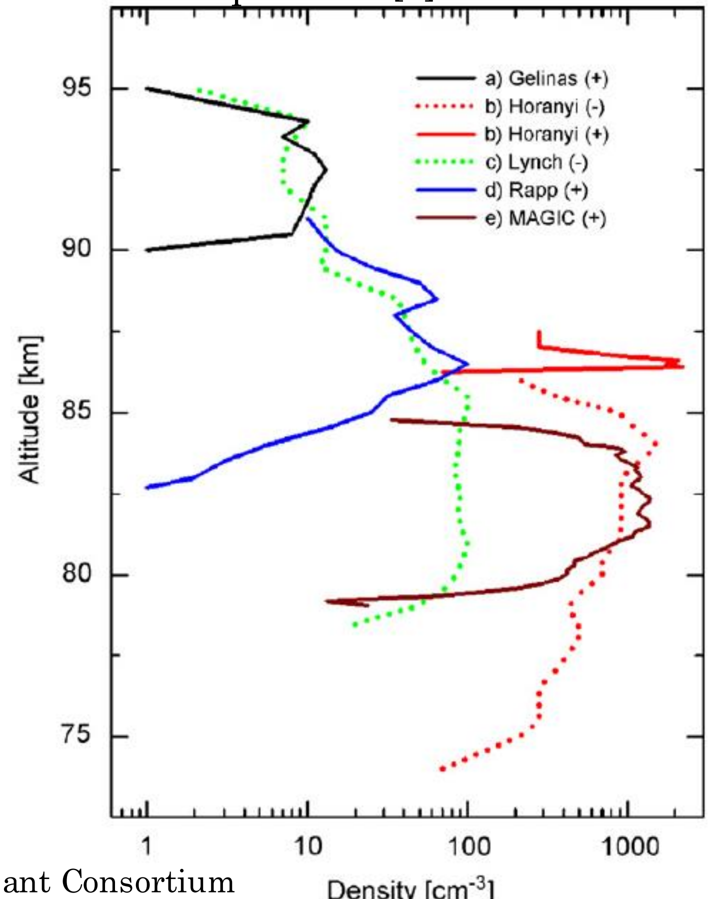




Expected Results

- High concentrations of particles between 75 and 95 km
  - Lower concentrations than experiments at higher latitudes
- Positive current

Results of multiple sounding rocket flights measuring the numerical density of meteoritic smoke particles [1]



Current Progress

- Have completed several tests for electronics and detectors
  - Testing second revision of boards
  - Testing detector functionality
  - Finished manufacturing mounting flanges and makrolon plates
- Scheduled for full integration at the end of May

References

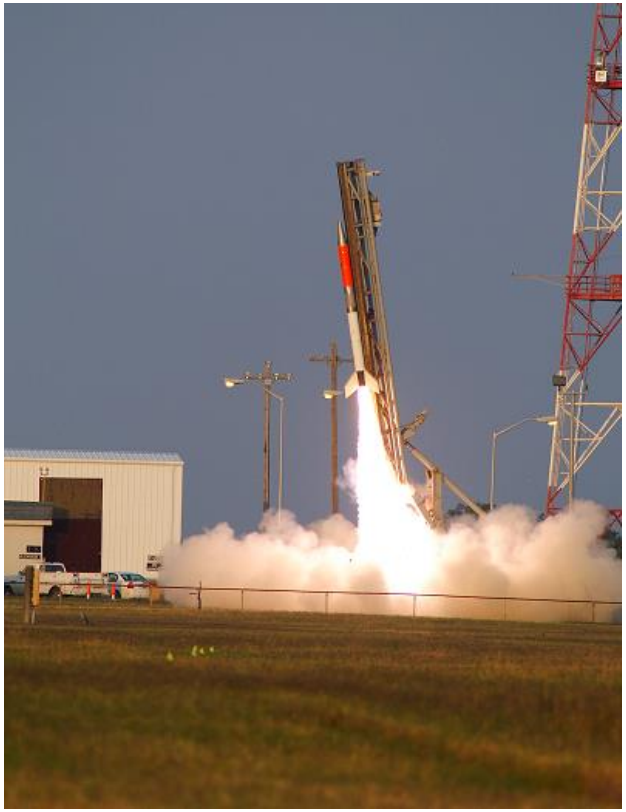
[1] Amyx, K, Z. Sternovsky, S. Knappmiller, S. Robertson, M. Horanyi and J. Gumble. "In-situ Measurement of Meteoritic Smoke Particles in the Wintertime Polar Mesosphere Between 80 and 85km Altitude". Journal of Atmospheric and Solar Terrestrial Physics, 2008.

[2] Williams, P.J.S., N. Mitchell, A. Beard, V. Howellst, and H. Muher. "The Coupling of Planetary Waves, Tides and Gravity Waves in the Mesosphere and Lower Thermosphere." *Advanced Space Research Volume 24* 1999: 1571-1576. Print.

[3] Zoltan Sternovsky. Interviewed by Emily Logan, Kirstyn Johnson, and Marcell Smalley October 2007 through present.

[4] Rapp, Markus, Irina Strelnikova, and Jorg Gumbel. "Meteoritic Smoke Particles: Evidence from Rocket and Radar Techniques." *Advances in Space Research* 40.6 (2007): 809-17. *ScienceDirect*. Web. 20 Mar. 2010. <http://sciencedirect.com>.

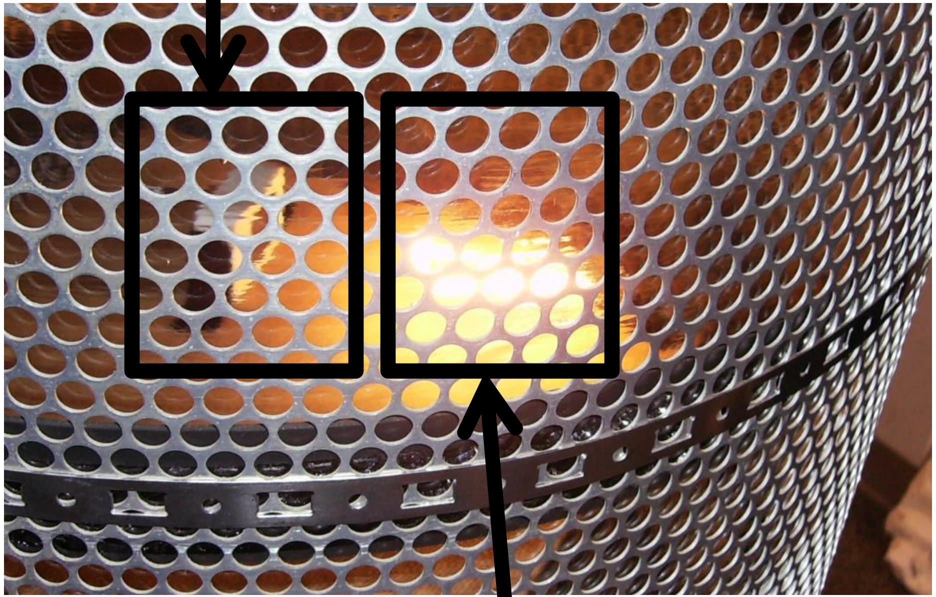
Questions?



BACKUP SLIDES

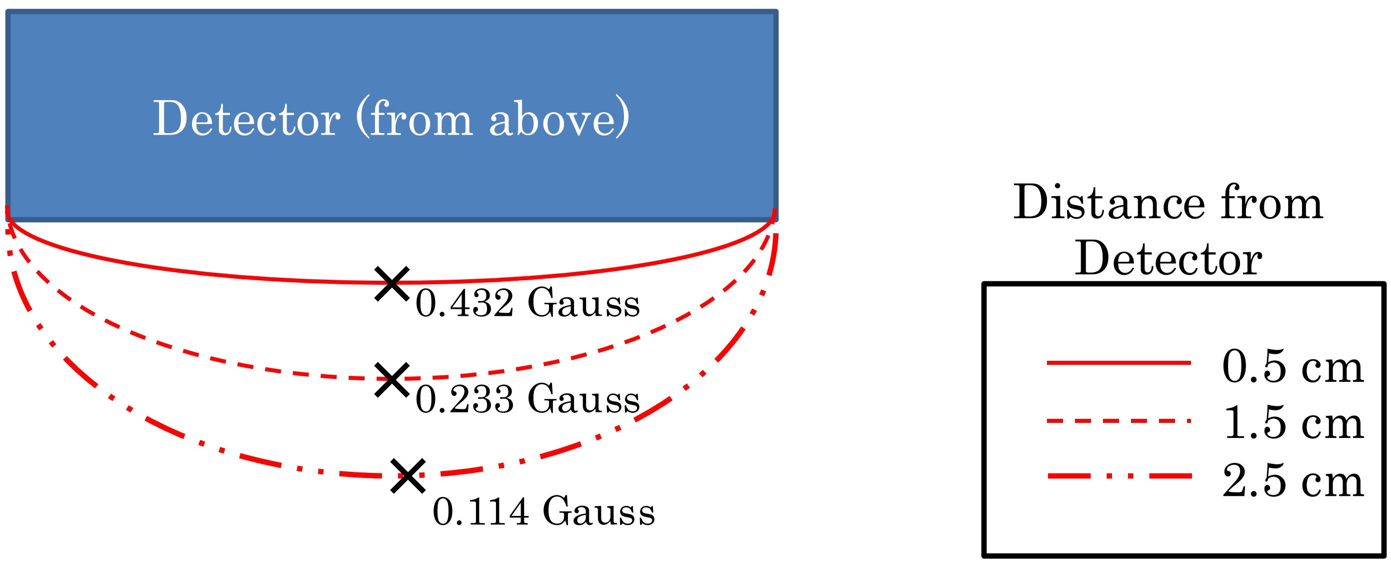
Detector Testing

- Current: Using an electron gun to test what percent of small charged particles the detectors deflect, with and without the magnets installed



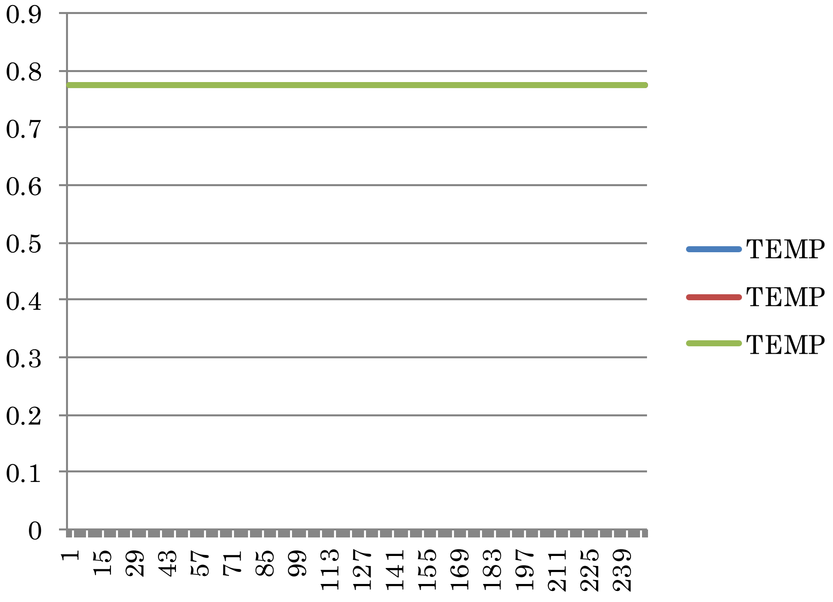
Detector Testing

- Previous: used a magnetometer to test the magnetic strength of the detectors

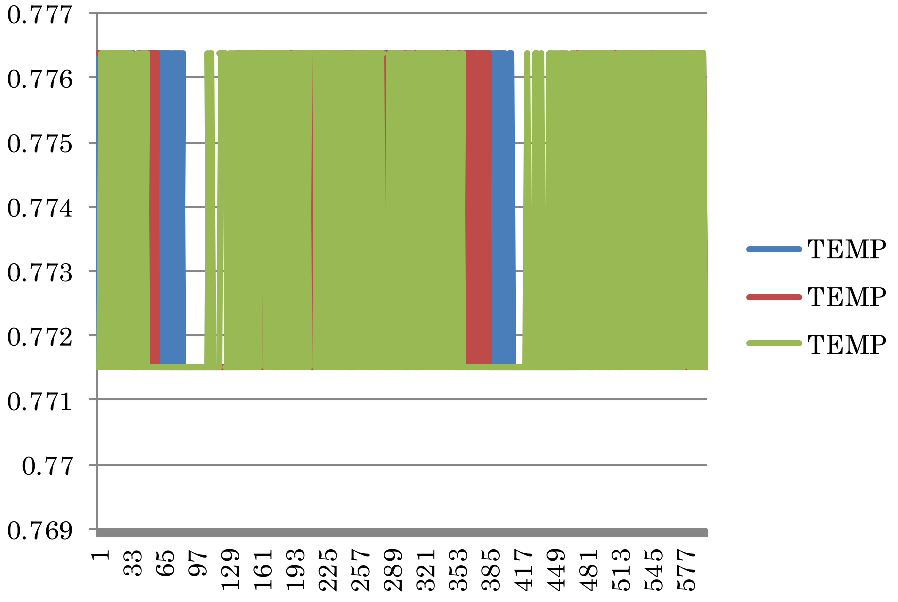


Testing Results - AVR

- Sampling Rates of Temperature Sensor



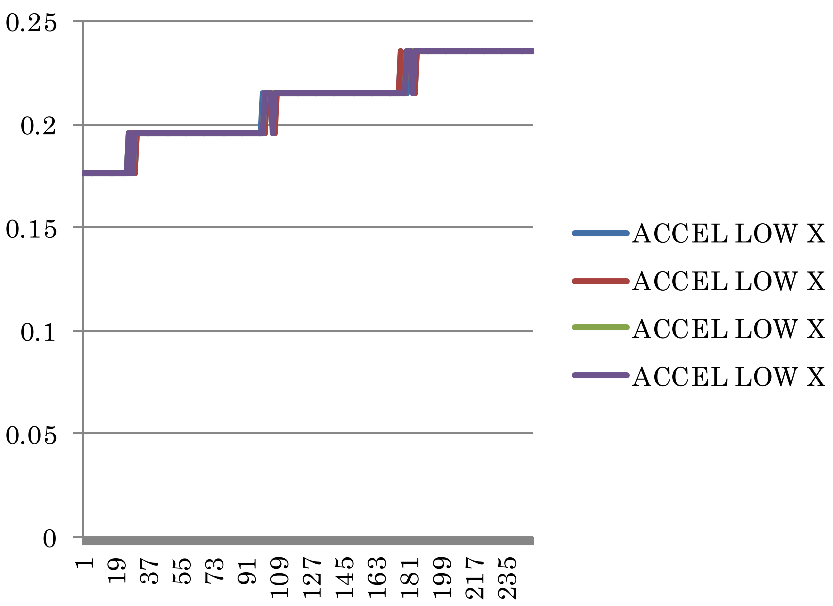
110 Hz



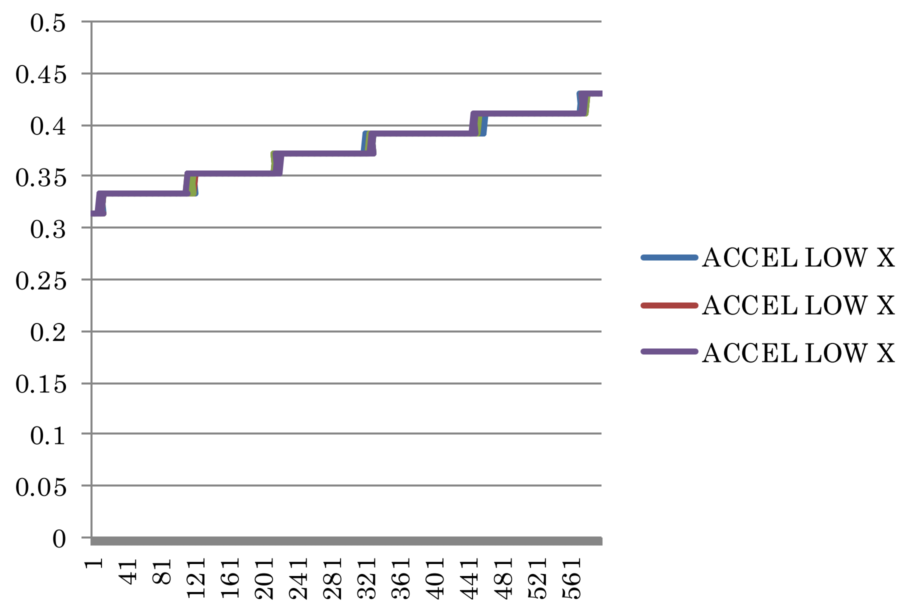
120 Hz

Testing Results - AVR

- Sampling Rates of Accelerometers

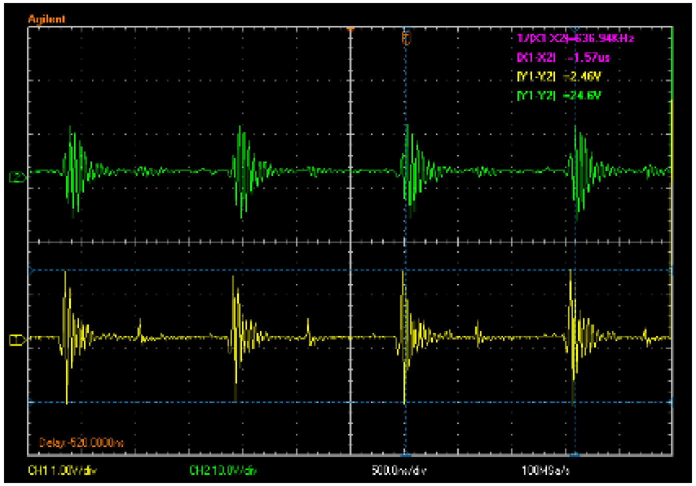


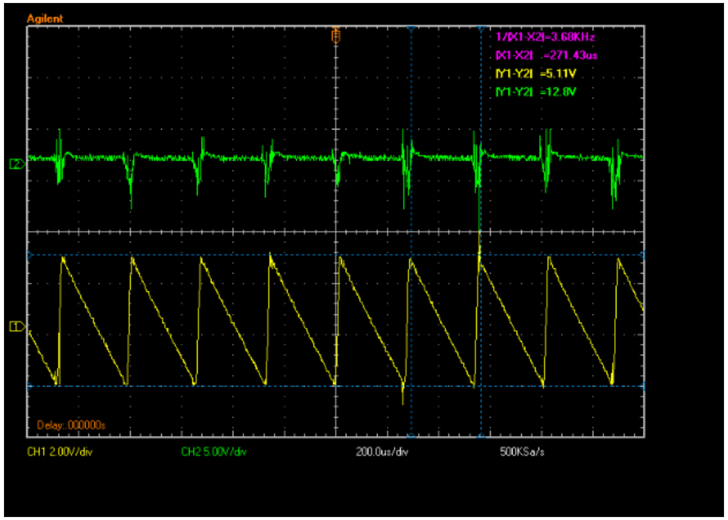
110 Hz



120 Hz

Testing Results-MEPO DC/DC converters





- Periodic switching noise without caps and resistor
  - input(green)
  - output(yellow)
- RC circuit on input and output decreases the total noise
  - Need to add in correct RC Lowpass filters base on the period
    - Measured to be ~3.745khz
  - Test with RLC circuit

Mounting Flanges