CP7
ORBITAL PARTICLE DAMPER EVALUATION

Presenters

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CP7 Project Lead & Head Electrical Engineer
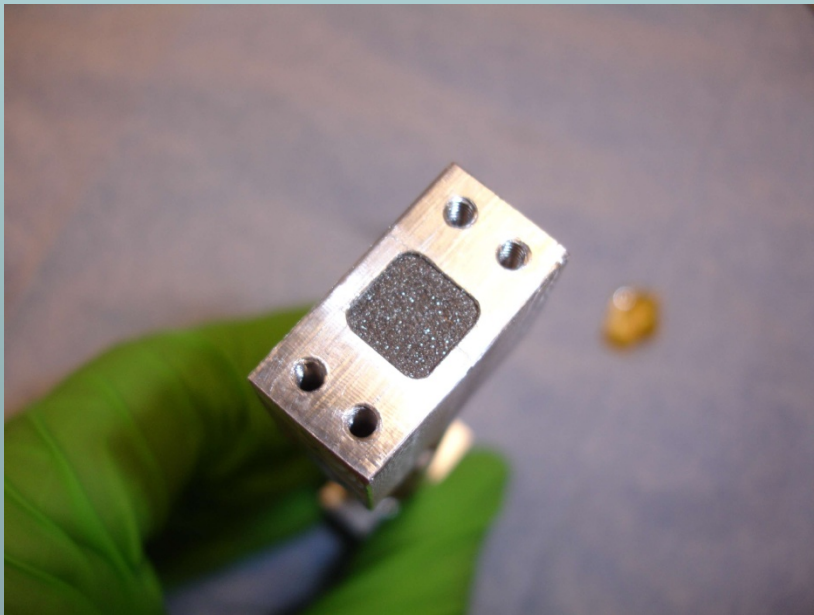
Daniel Walker

CP7 Head Software Engineer

John Brown

CP7 Head Mechanical Engineer

2010 Cubesat Developers Workshop

Mission

Northrop Grumman has gifted the PolySat lab a grant to implement a 1U CubeSat that will achieve orbital data to characterize particle dampers in space.

Particle damper with cap removed. Crystalline tungsten powder visible.

What is a particle damper?
A particle damper is a mechanical vibration damper device that consists of an enclosed cavity filled with particles. Frictional forces and momentum exchanges between the particles create a damping effect suitable for many jitter mitigation applications.

Mission Justification

- Particle dampers offer a robust, simple and cheap solution to many vibration damping requirements.

- These dampers could be embedded within satellite structures to reduce the propagation of vibration detrimental to sensitive payloads such as optical assemblies.

- The nonlinearity of particle dampers complicates the development of accurate models, which must be based on experimentally derived data.

- CP7 will provide the data needed to evaluate particle damper zero gravity characteristics that can not be achieved from ground based tests.

Mission History

Summer 2009

A proof of concept system was flown on a NASA reduced gravity parabolic flight. This effort provided insight into future design considerations.
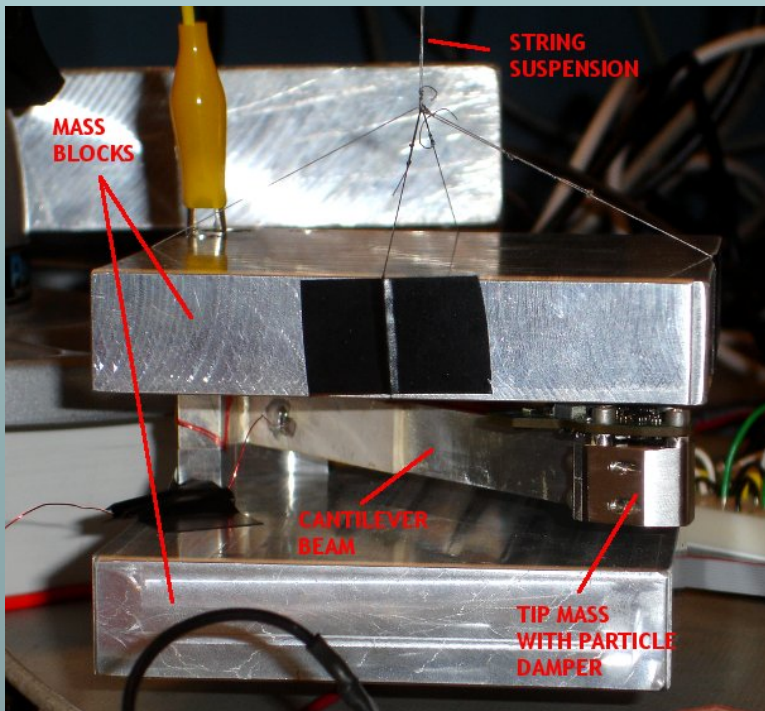
Mission History

Winter 2010

Finite element modeling was used to develop a mechanical system suitable to actuate and measure the response of a particle damper within the constraints of a 1U cubesat.

A representative system was machined to be used to validate the mechanical design, data acquisition electronics and software algorithms.


A particle damper is machined into the tip mass of a cantilever beam. The acceleration of the tip mass is measured over a frequency and amplitude dwell to measure the damping characteristics of the beam. Two blocks bolt onto the beam to simulate the mass distribution of a 1U cubesat. During testing the structure is suspended by a string to reduce coupling to outside bodies.
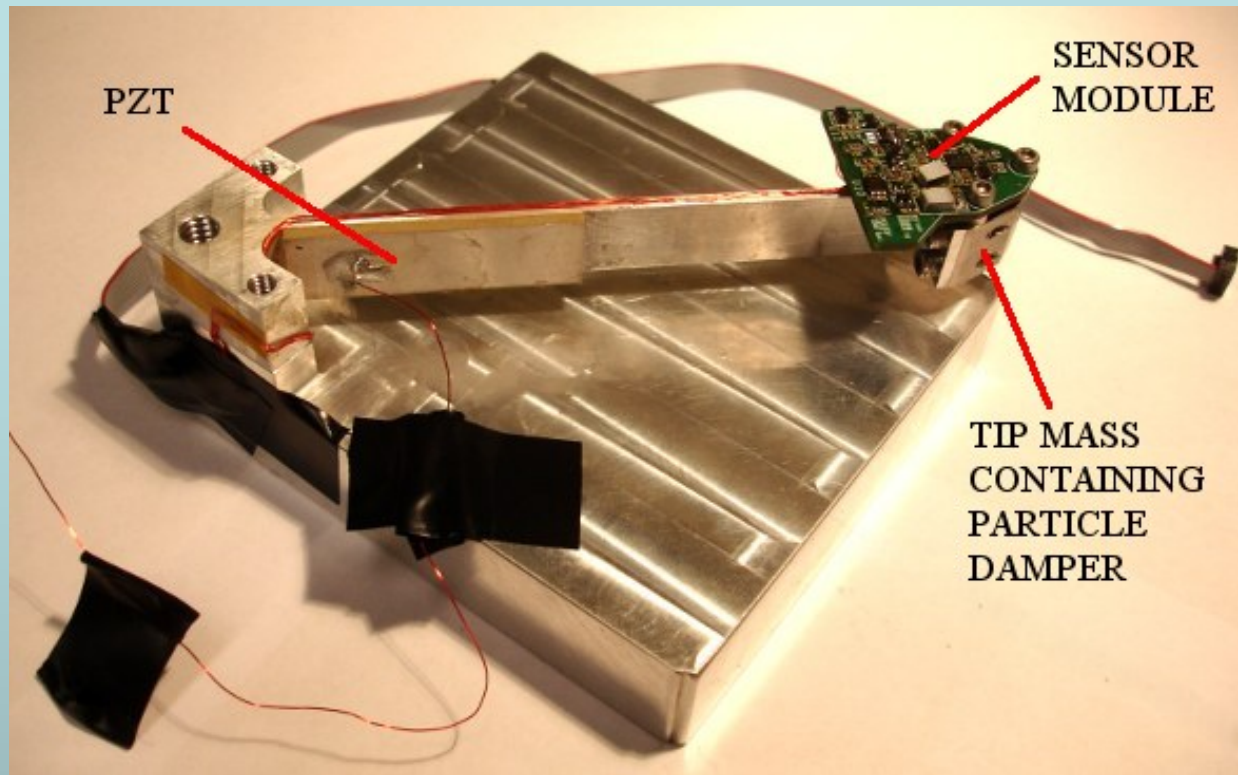
Test beam with top mass removed to show detail

A sinusoidal high voltage electrical signal produces a proportional forcing function to the cantilever beam via a piezoelectric actuator. The steady state response of the cantilever beam is detected; then acceleration phase and magnitude values are measured using the sensor module affixed above the tip mass.
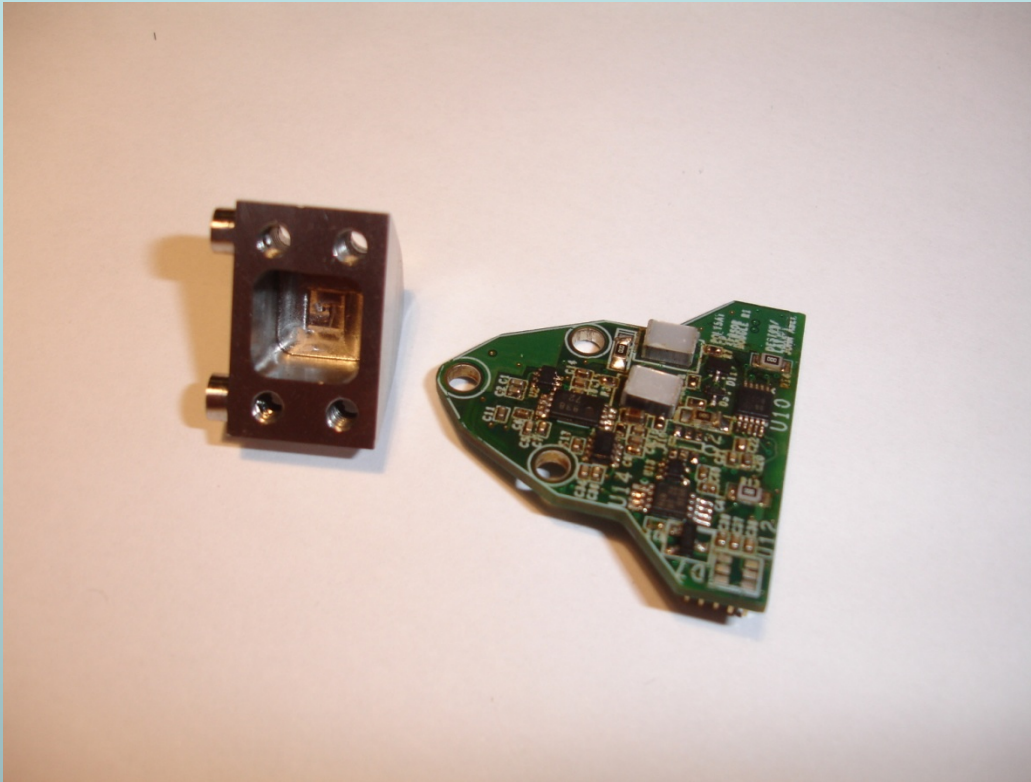
Sensor module alongside tip mass with particle damper cavity exposed

The sensor module houses a 6g MEMS type analog accelerometer. An automatic gain control circuit / software algorithm is used to maximize signal fidelity. Peak and valley values of the waveform are captured using analog circuitry and then converted to digital values. This technique negates the need for high speed data acquisition and minimizes the amount of data needed to downlink.
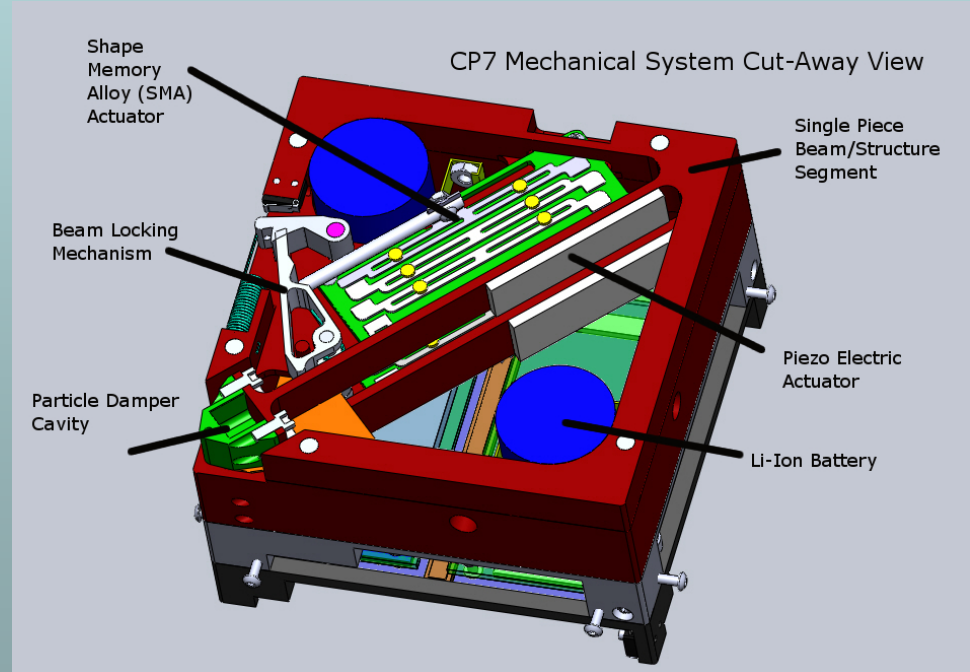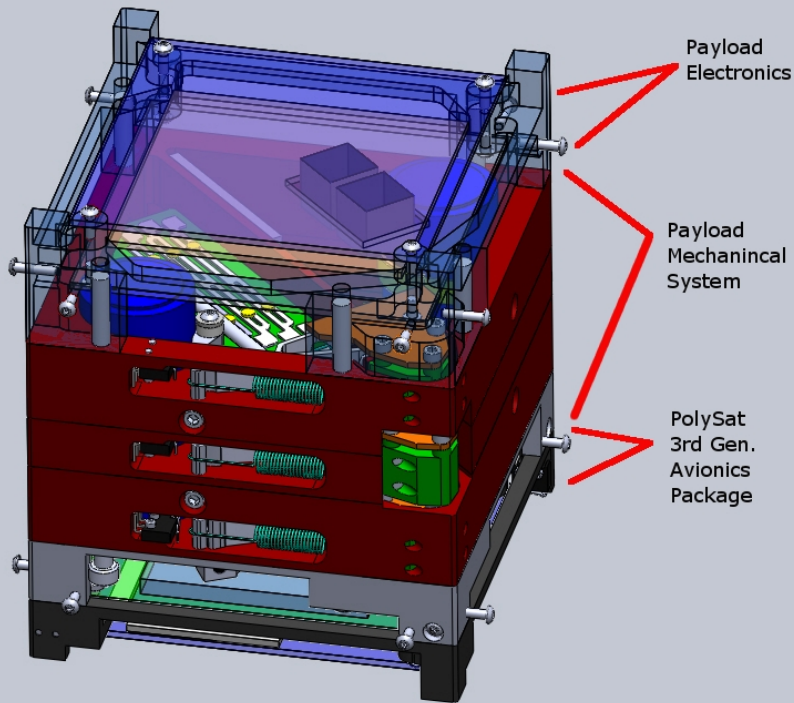
A low power microcontroller is used to implement the data acquisition algorithms and data handling.

The data achieved from this test set up has reproduced many of the particle damper properties observed in other works. This does much to confirm proper mechanical design as well as accurate data acquisition.
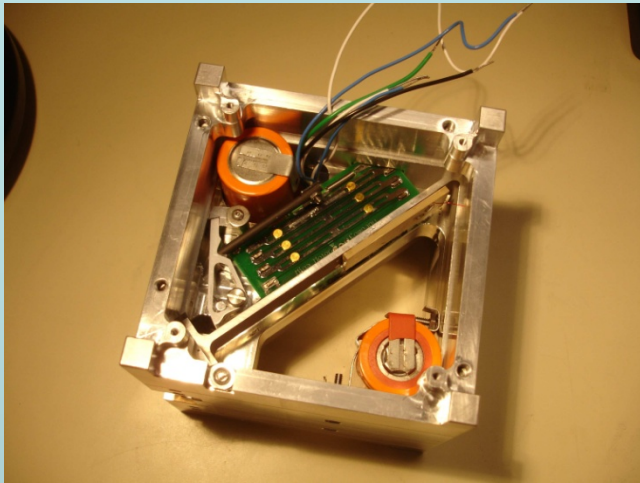

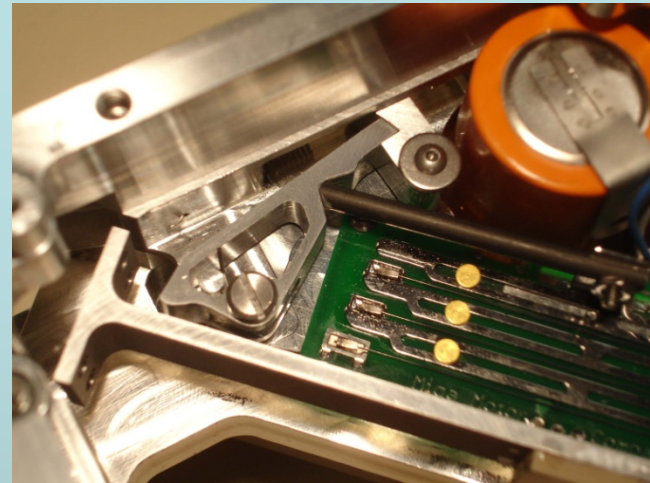Test Beam Magnitude Response
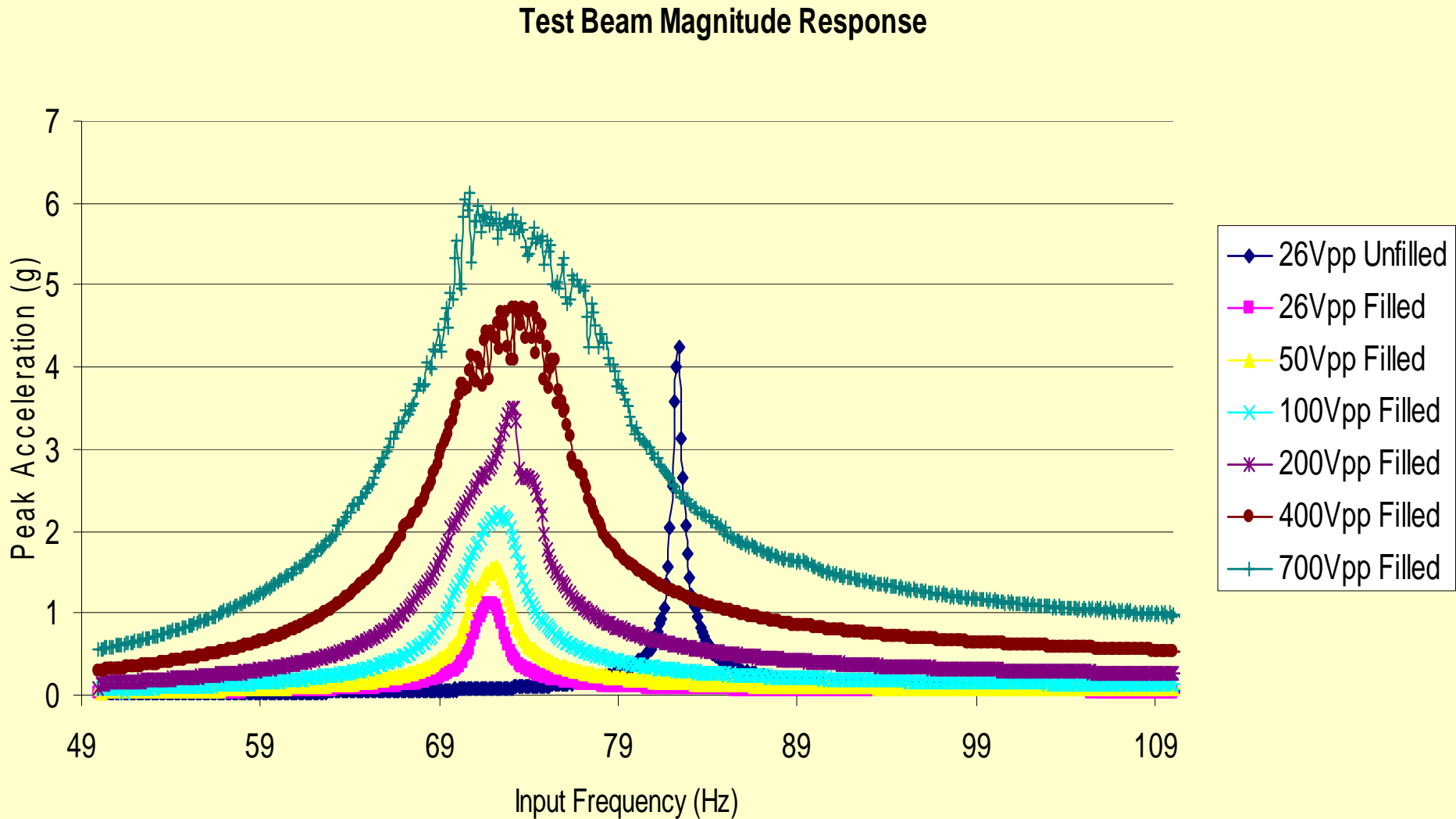
Current Efforts

With the success of the test beam, work has begun on the CubeSat. Complete CAD drawings have been developed and machining of the structure has begun. Electronics and software are also in a mature design stage.
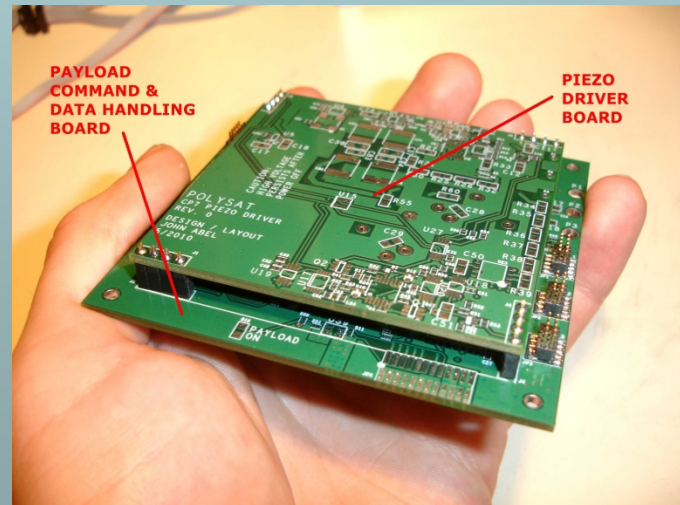

Payload Electronics

Payload Mechanincal System

PolySat 3rd Gen. Avionics Package

Shape Memory Alloy (SMA) Actuator

CP7 Mechanical System Cut-Away View

Beam Locking Mechanism

Single Piece Beam/Structure Segment

Particle Damper Cavity

Piezo Electric Actuator

Li-Ion Battery

CAD drawings of CP7.

Top view of mechanical portion of the payload.

Close up of one of the mechanisms used to lock beams in place to reduce mechanical coupling

Assembled structure with model of PolySat's third generation bus attached

Payload electronics stack up (unpopulated)

Mechanisms built around shape memory alloy actuators are used to selectively lock the three beams within CP7. This helps to mechanically isolate each beam to reduce coupling that might otherwise provide parasitic damping to the beams.

When needed the beams can be unlocked using a similar mechanism.
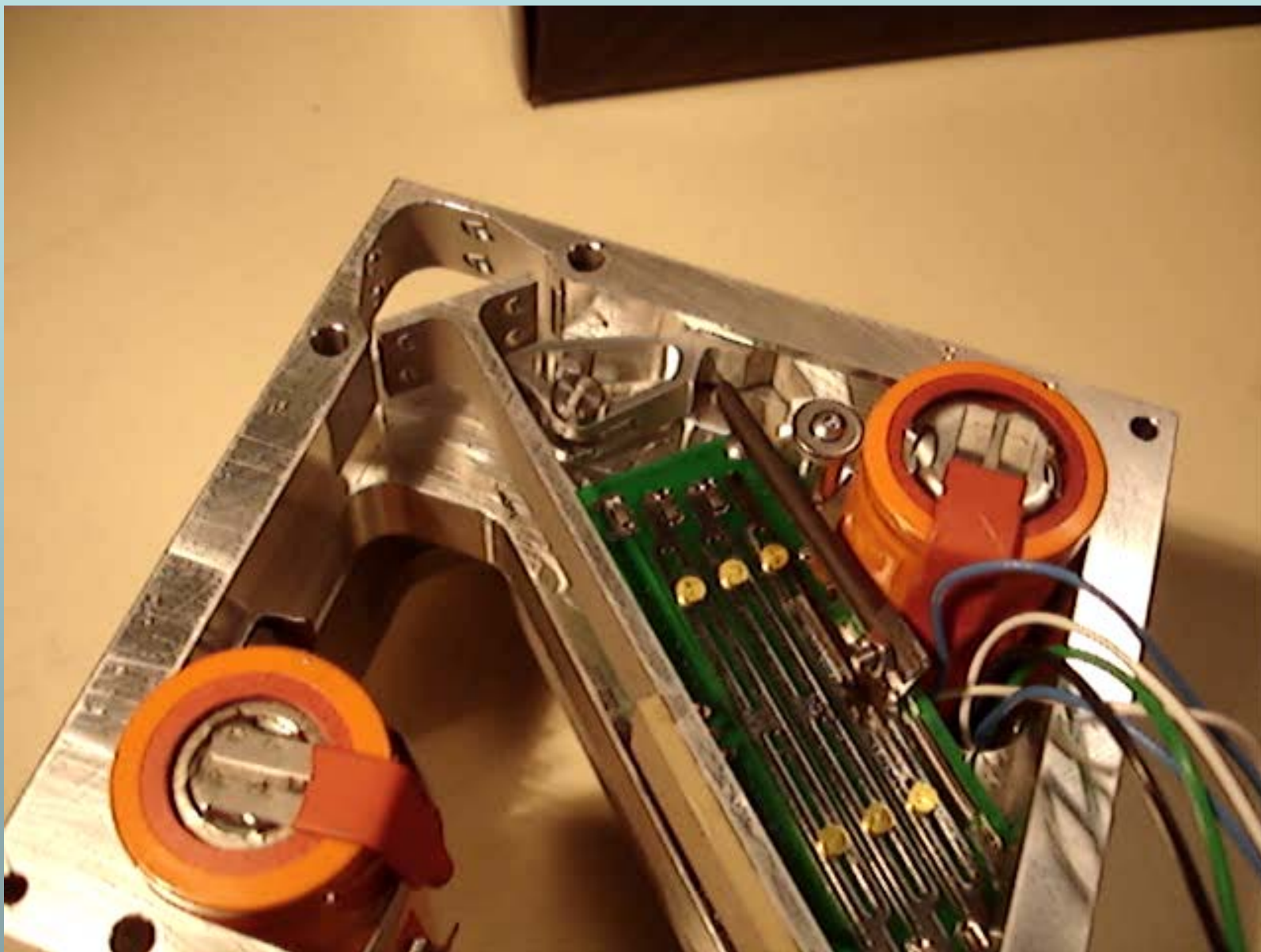
PolySat's 3RD Generation Avionics

Processor:
- 400Mhz Atmel AT91SAM9G20
- Runs embedded Linux. Open source code has already proven extremely useful.
- Extensive power saving features (80mW with all peripherals active).

Memory:
- 64MB of 32-bit Mobile LPSDRAM dynamic memory running at 133MHz.
- 512MB of 8-bit NAND Flash static memory using parallel interface.
- 3 x 8MB of Atmel DataFlash static memory using SPI interface.

COM:
- Dynamically adjustable RF transmit power up to 2W.
- Supports FSK, PSK, OQPSK, MSK with baseband filtering
- 9.6kbps data rate with flexible filtering to optimize receive sensitivity.

Power:
- Four high efficiency power regulators provide 2.8-5.5V at 5W each.
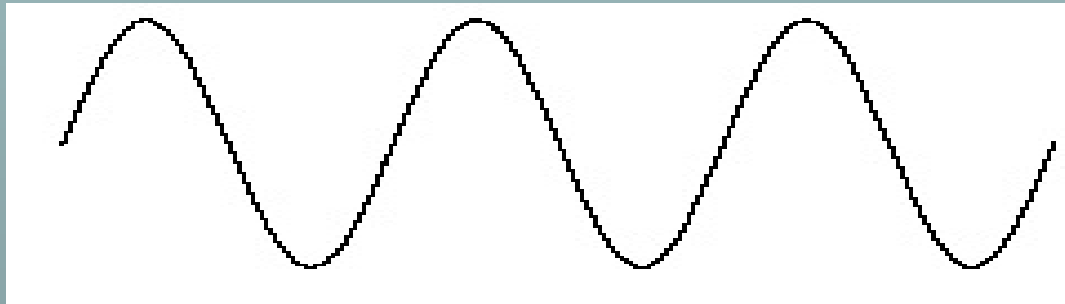- 3V3 and 5V fixed low power regulators
- Unregulated battery
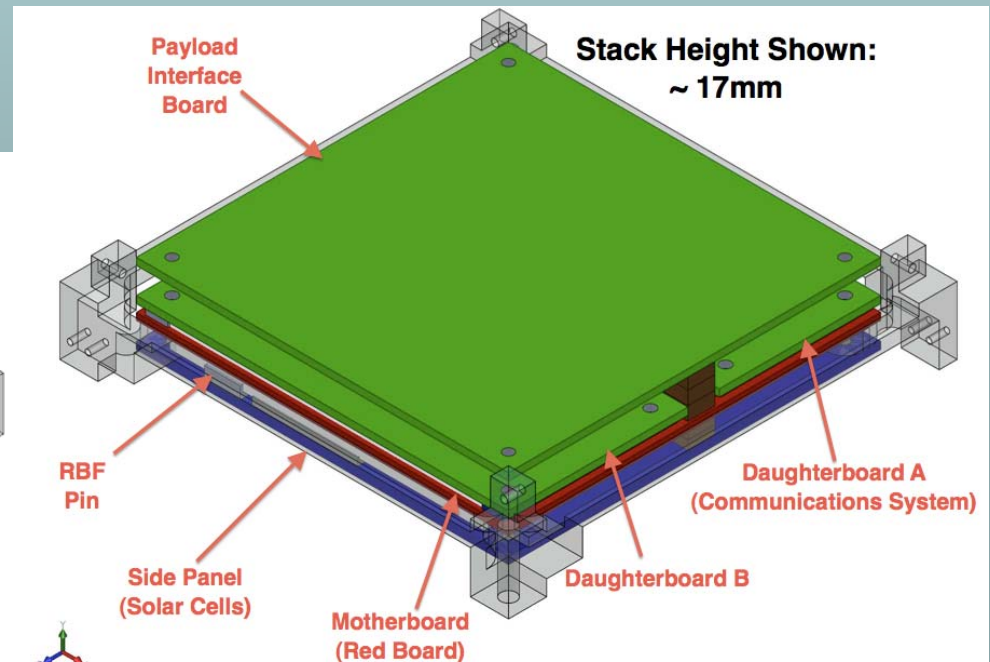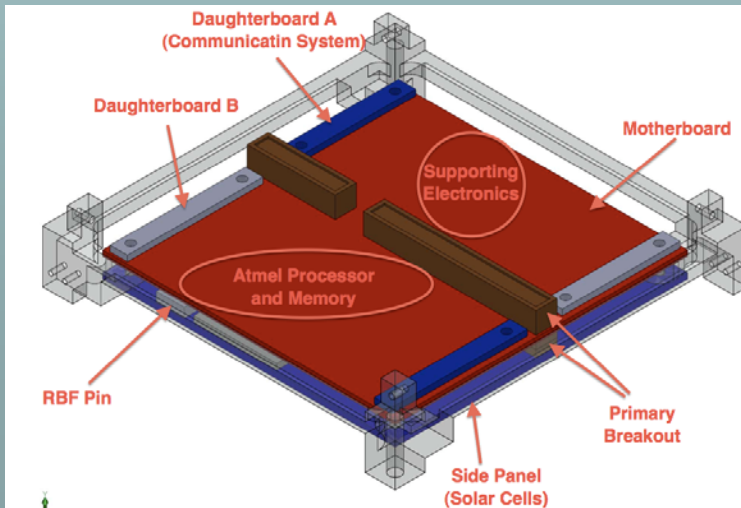
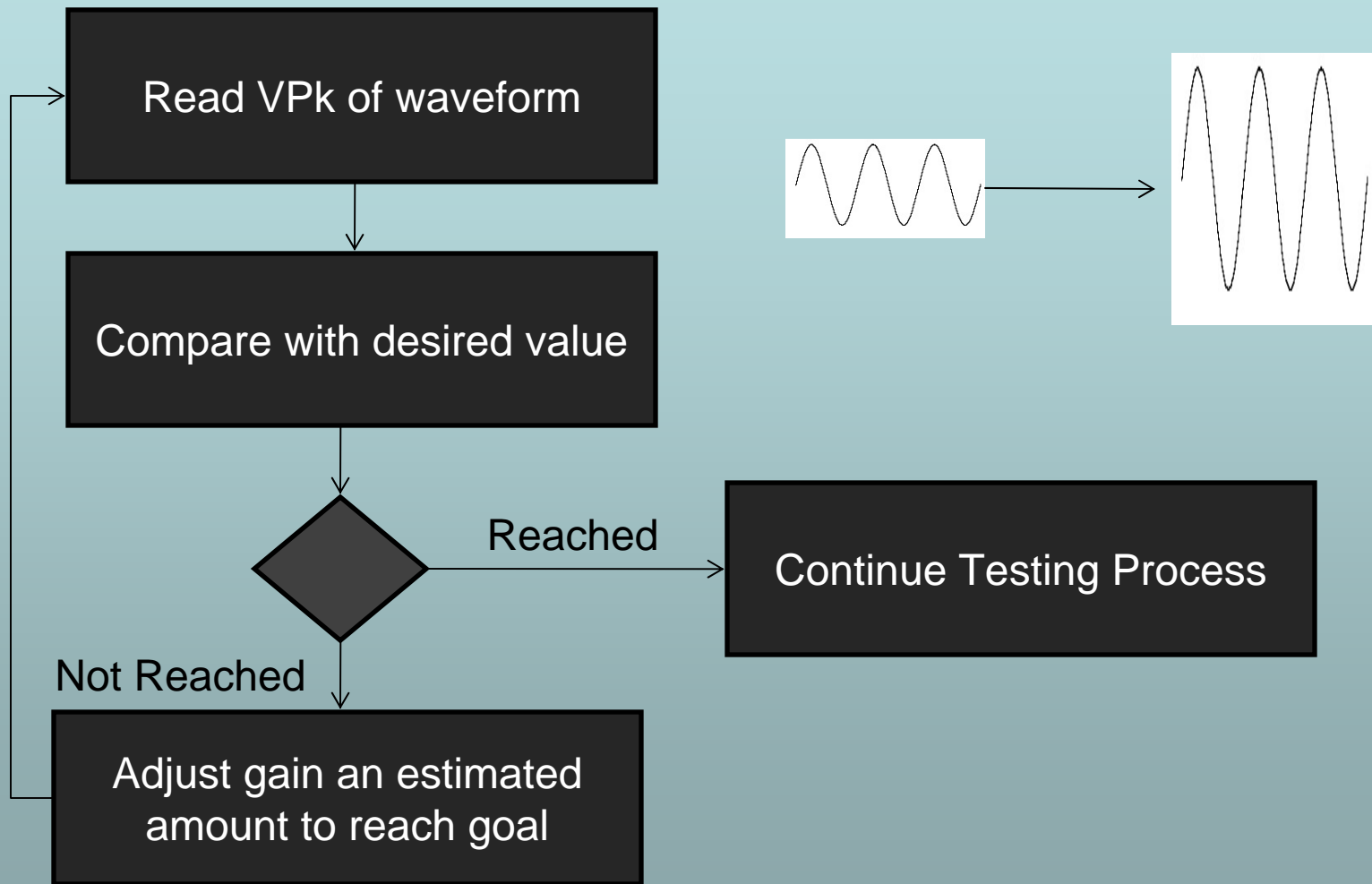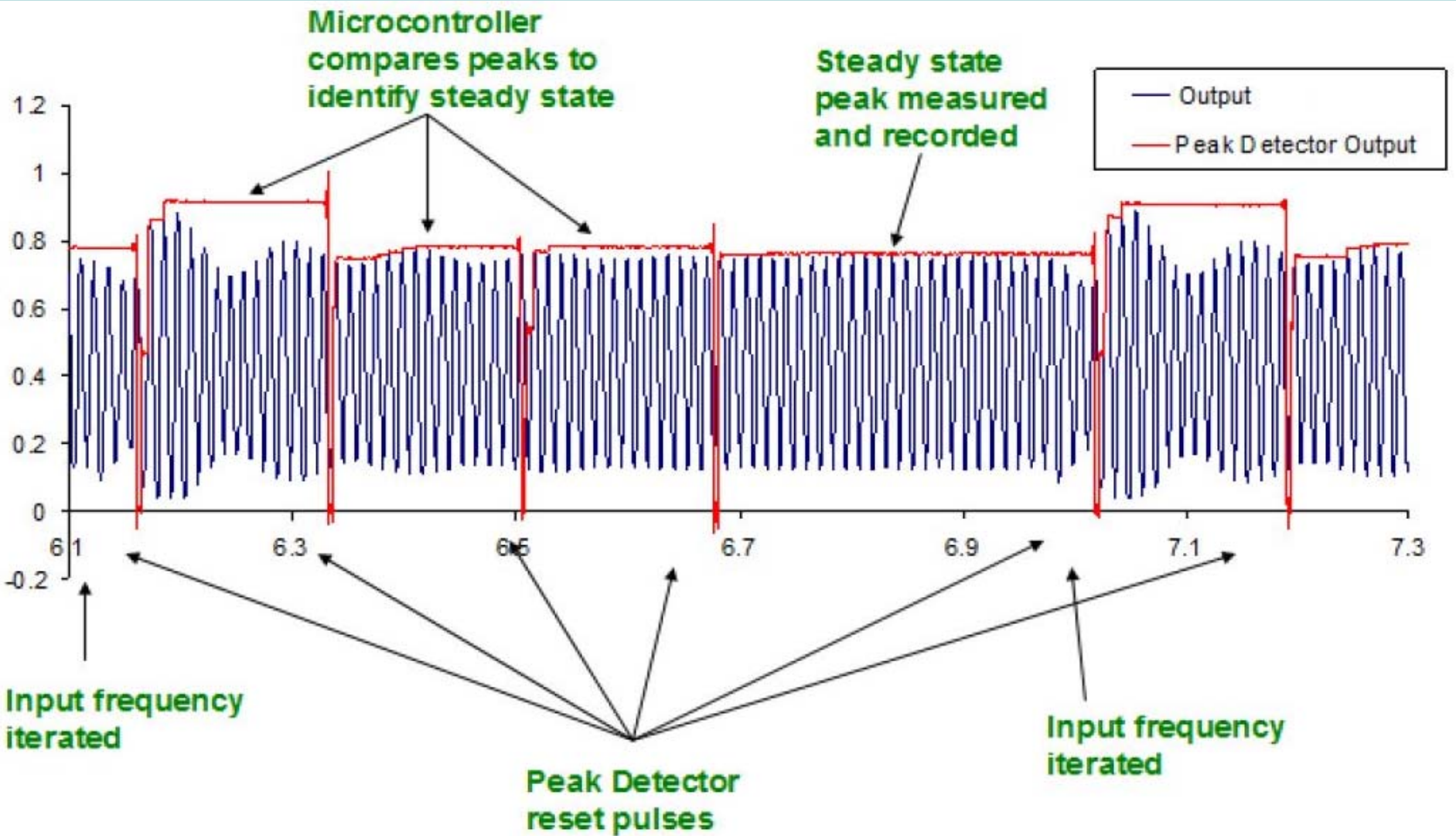# Automated Experiment Procedure
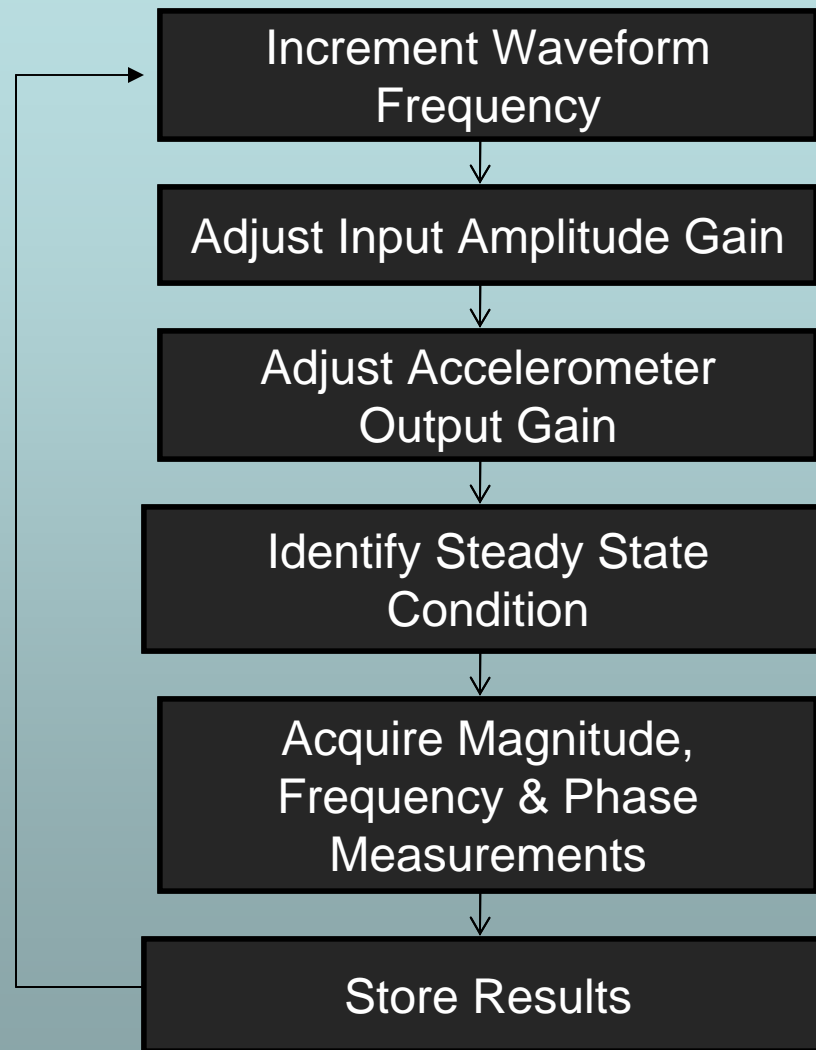
Waveform Generation

- **Prototype:** Dedicated PIC micro controller
  - Processor overhead complicates timing requirements
  - Redundant code required

- **Flight Revision:** Direct Digital Syntheses (DDS) IC
  - Single command programmable frequency
  - High resolution sine wave generation
  - Milli-Hz frequency step size
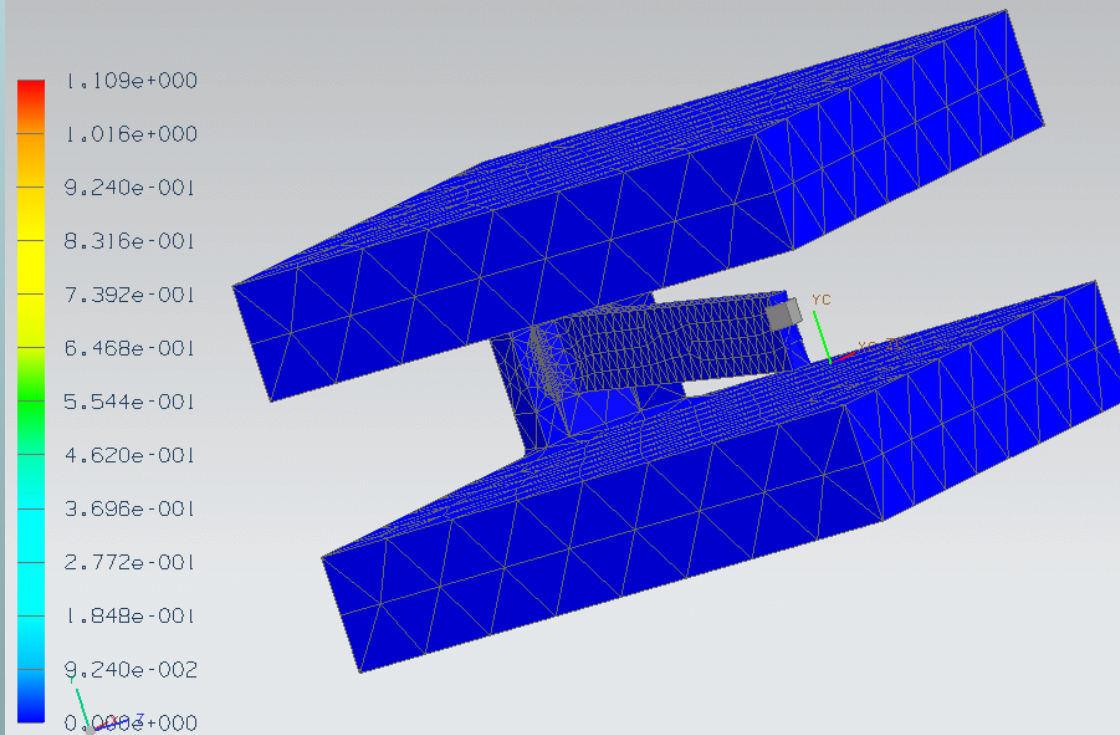
Utilizing Automatic Gain Control

Read VPk of waveform

Compare with desired value

Reached

Continue Testing Process

Not Reached

Adjust gain an estimated amount to reach goal

Identification of Particle Damper Steady State Response

Hand Calculations vs. FEA
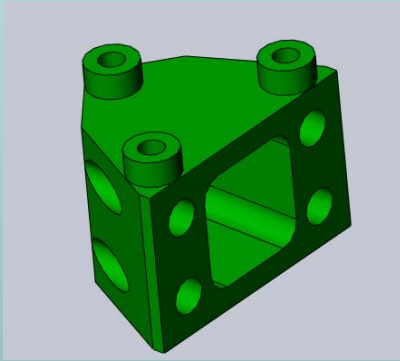
Experiment
until < 3% error

Move ahead
with prototype

beaml.3.2_sldprt_sim3 : Solution 1 Result
Load Case 1, Mode 1, 7.932e+001 Hz
Rotation - Nodal, Magnitude
Min : 0.000e+000, Max : 1.109e+000, degrees
Deformation : Displacement - Nodal
Animation Frame 1 of 8

1.109e+000
1.016e+000
9.240e-001
8.316e-001
7.392e-001
6.468e-001
5.544e-001
4.620e-001
3.696e-001
2.772e-001
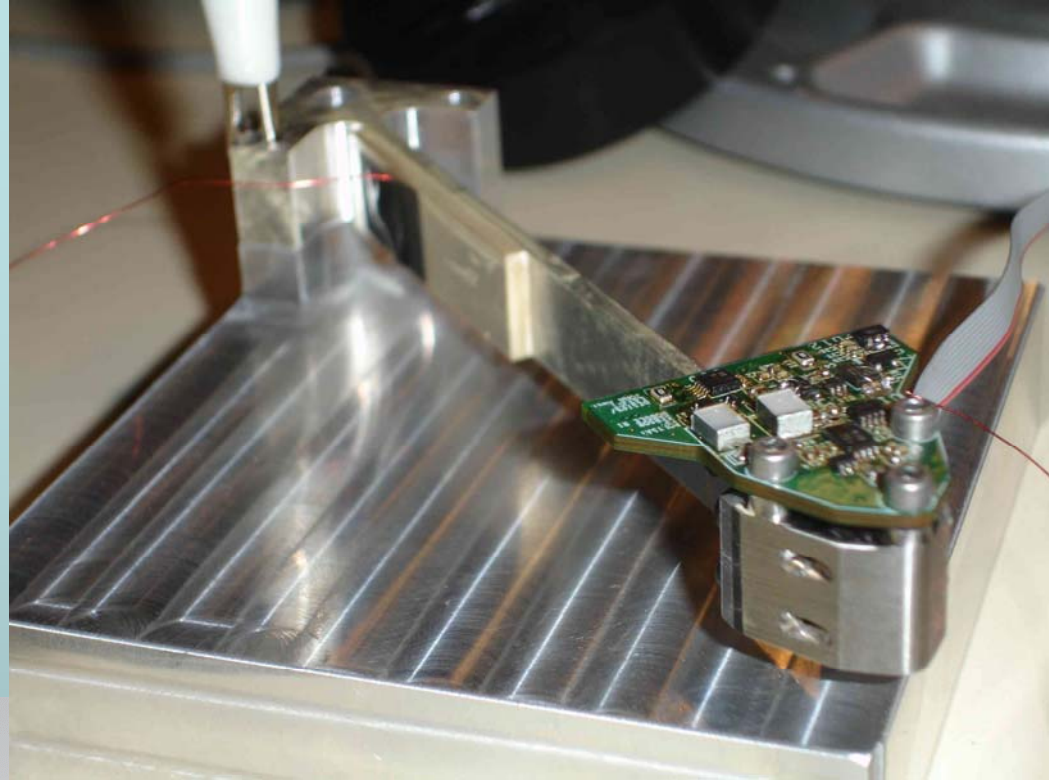1.848e-001
9.240e-002
0.000e+000

Particle Cavity

Cap has accelerometer and supporting electronics mounted directly to it.
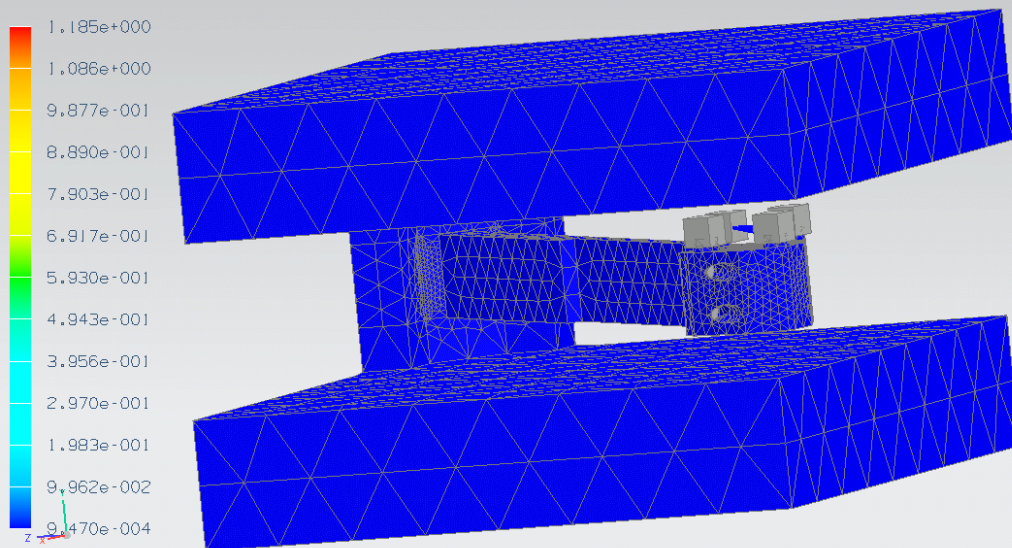
Tip Mass is increased by SS instead of Al
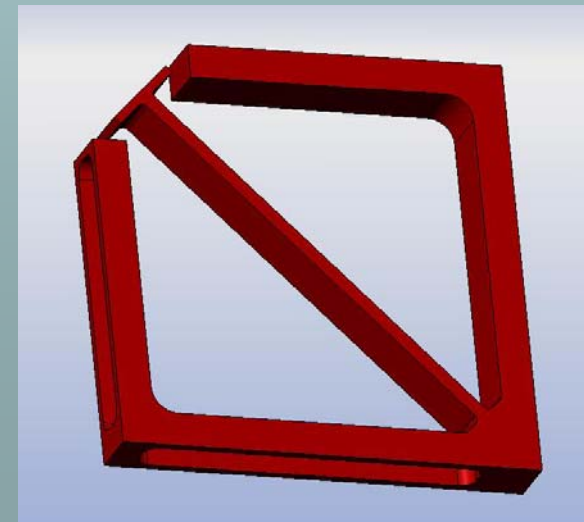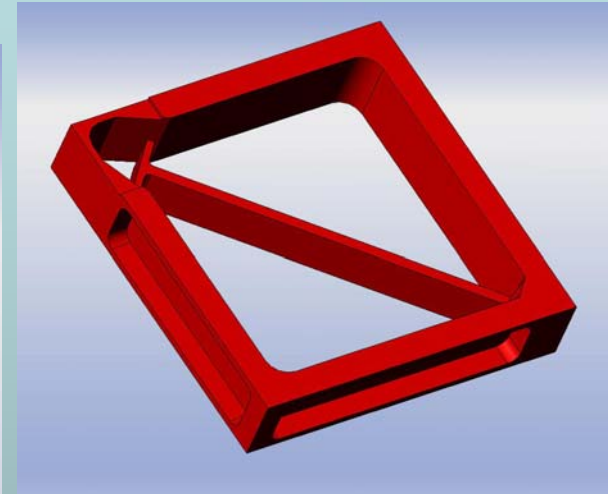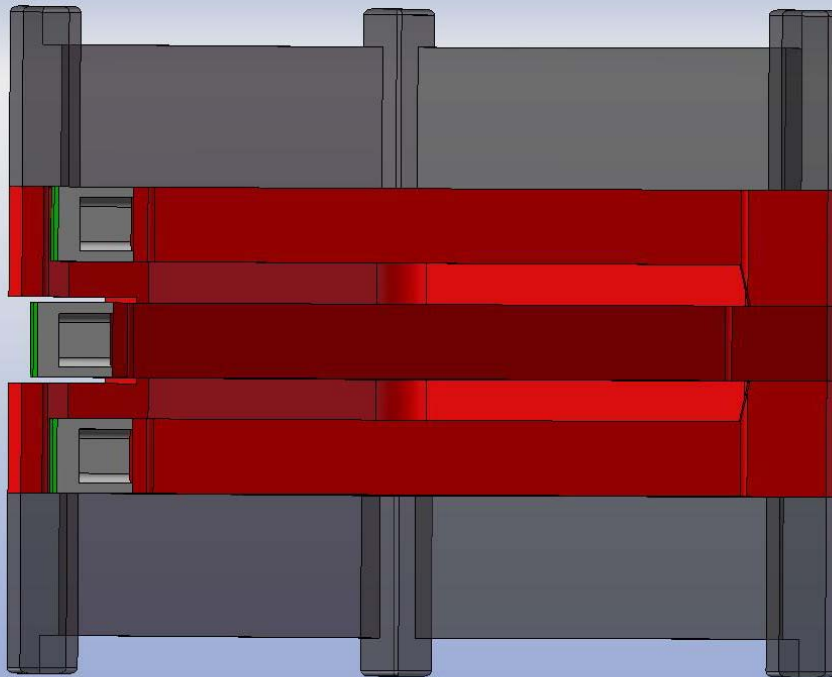
Cavity volume is accurate
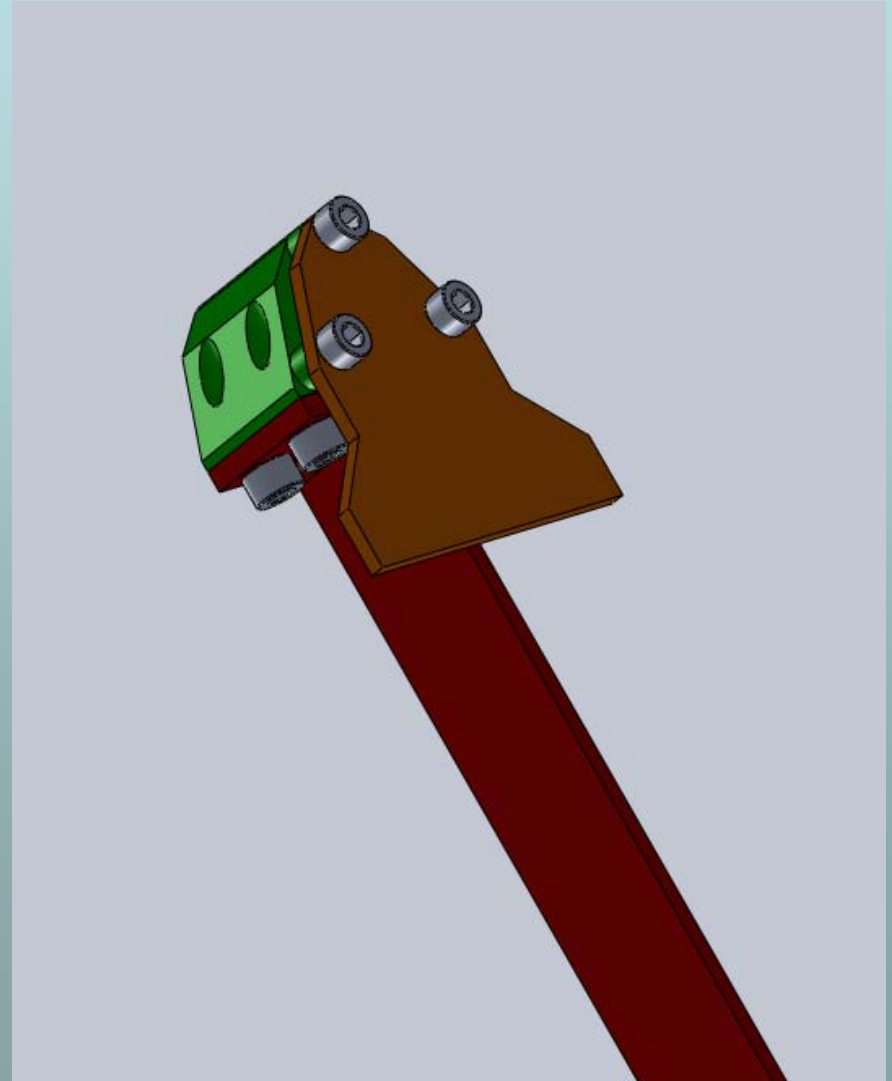
Prototype Beam and Sensor

complete test setup_sldasm_sim1 : Solution 1 Result
Load Case 1, Mode 1, 8.873e+001 Hz
Displacement - Nodal, Magnitude
Min : 9.470e-004, Max : 1.185e+000, mm
Deformation : Displacement - Nodal
Animation Frame 1 of 8

Adjust Piezo characteristics in the FEA until the results are in agreement with the experimental

Final Beam Geometry

Account for moment of inertia

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