UNIVERSITY OF GEORGIA

Small Satellite Research Laboratory

Structural Design and Optimization of SPOC Satellite

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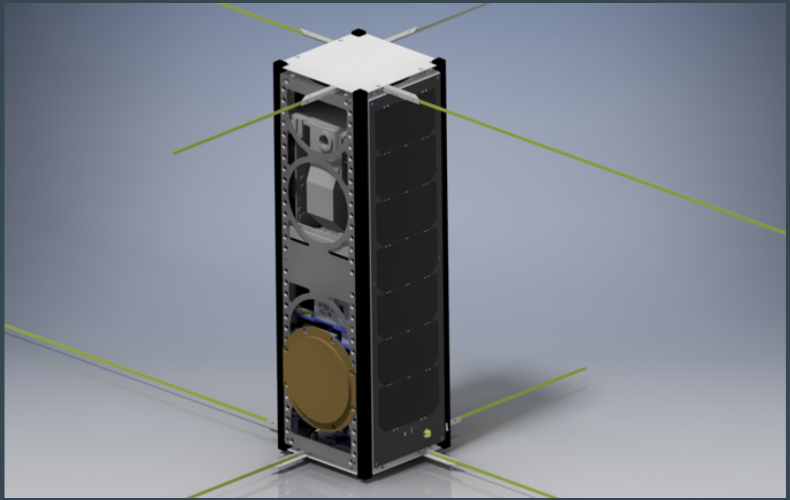
Introduction to CubeSats

- Cube Satellites are small standardized satellites
- Because of this standardization, they are very cost effective when compared to traditional, larger satellites
- The specific structural design of these satellites presents an interesting design challenge
- Stuctures must survive very violent launch conditions while conforming to strict standards

SPOC

- SPOC hosts a hyperspectral sensor, designed by the Small Satellite Research Laboratory.
- Core Avionics are found in a different section of the satellite.
- Most mass in the satellite is found in these areas, therefore failure is likely to occur in those areas.



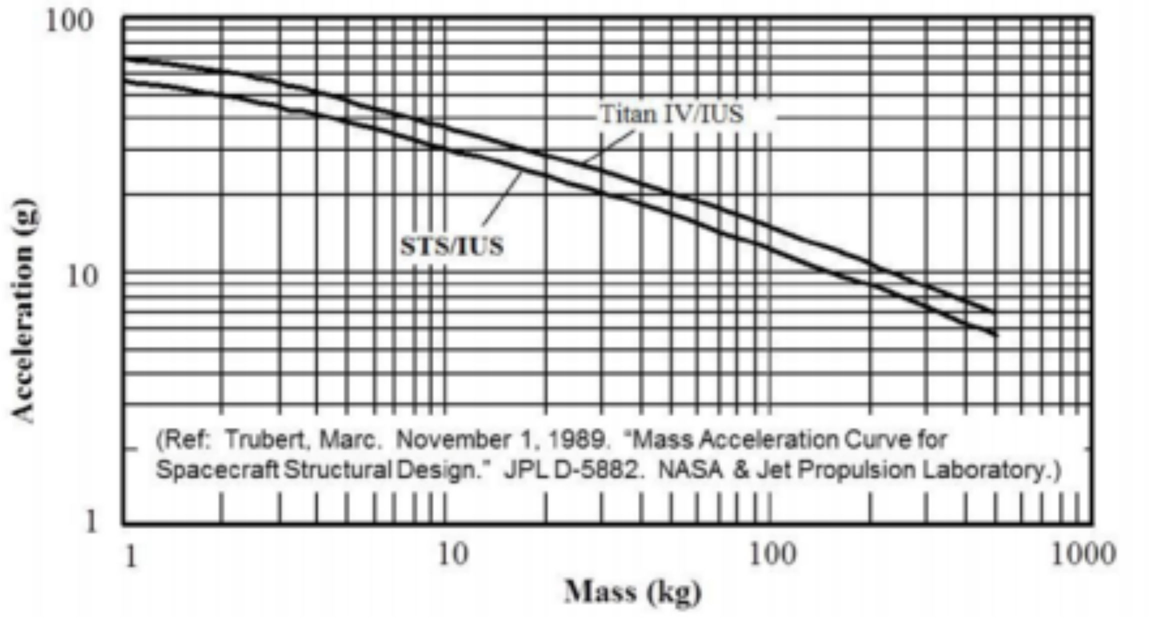
Mass Block Simulation – Material Properties

- Avionics block assigned FR4
- Payload block assigned Al 6061-T6
- Structure assigned Al 6082-T6

	Al 6082-T6	*Al 6061-T6*	*FR4*
Density (ω)	2700 kg-m^{-3}	670 kg-m^{-3} (modified density)	1174 kg-m^{-3} (modified density)
Modulus of Elasticity (E)	72 GPa	68.9 GPa	22 GPa
Poisson's Ratio (μ)	0.33	0.33	0.118
Tensile Ultimate Strength (F_{tu})	330 MPa	290 MPa	320 Pa
Tensile Yield Strength (F_{ty})	270 MPa	255 MPa	--

Inertial Loading

- MAC represents worst case scenario
- Mass of 3.28 kg
- SPOC is expected to experience 43g's or 421.83 $m\text{-}s^{-2}$ upon launch



Inertial Loading

- Analysis is performed to determine if the satellite will survive forces that result from the acceleration of the launch vehicle

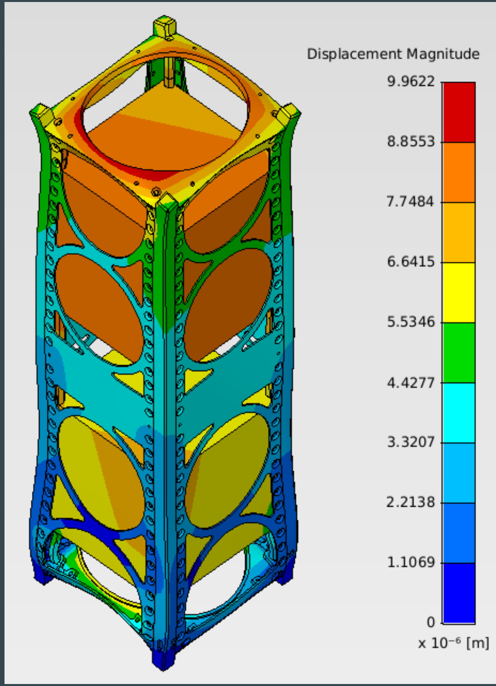
- Factors of Saftey (FOS) are calculated as:

- $FOS_{yield} = \dfrac{Yielding\ Stress}{Max\ Experienced\ Stress}$ $\qquad FOS_{ultimate} = \dfrac{Ultimate\ Stress}{Max\ Experienced\ Stress}$

- Optimal values are $\mathrm{FOS_{yield}} = 2.0$ & $\mathrm{FOS_{ultimate}} = 2.6$

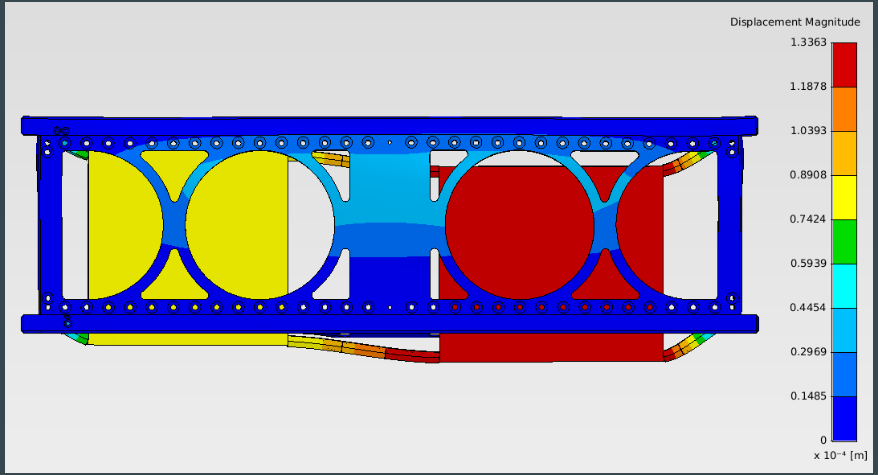
Results – Inertial Loading Analysis

- Supported on the –Z face
- Average stress: 1.647 Mpa
- Max Stress: 57.172 Mpa
- Max stress occurs at Al 6082-T6 standoffs
- $FOS_{yield} = 4.72$
- $FOS_{ultimate} = 5.77$



Results – Inertial Loading Analysis

- Supported on the +Y face
- Average stress: 6.794 Mpa
- Max Stress: 254.77 Mpa
- Max stress occurs at Al 6082-T6 standoffs
- $FOS_{yield} = 1.06$
- $FOS_{ultimate} = 1.39$

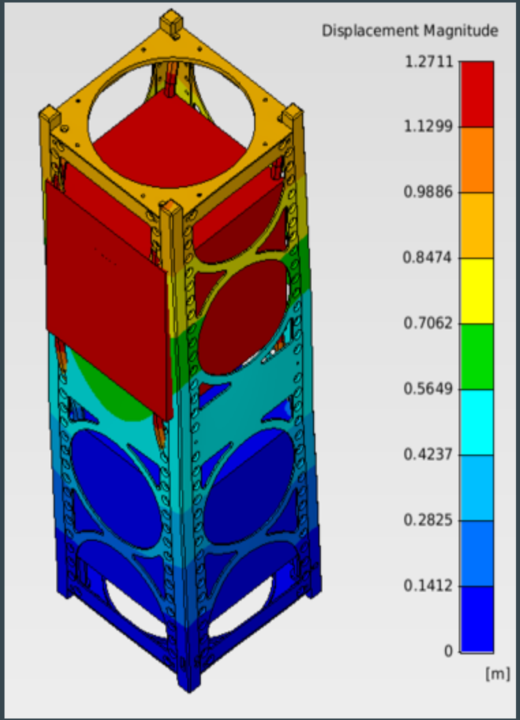


First Mode Analysis

- Analysis is performed to verify that the satellite will not pass through its first natural frequency during launch
- If the satellite passes through its natural frequency, catastophic structural failure can result
- It is recommended that 3U cubesats are designed such that their first natural frequency is above 100 Hz

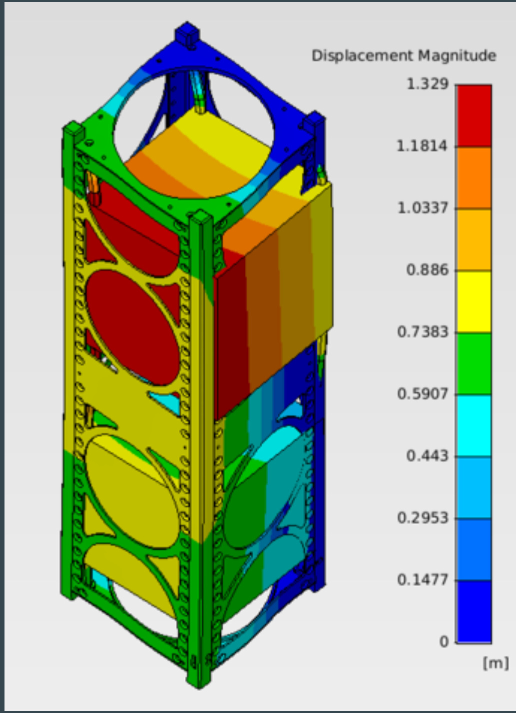
Results – First Mode Analysis

- Supported on the -Z face
- First natural frequency of 180.73 Hz, above the recommended minimum value of 100 Hz
- Maximum displacement occurs at the payload block



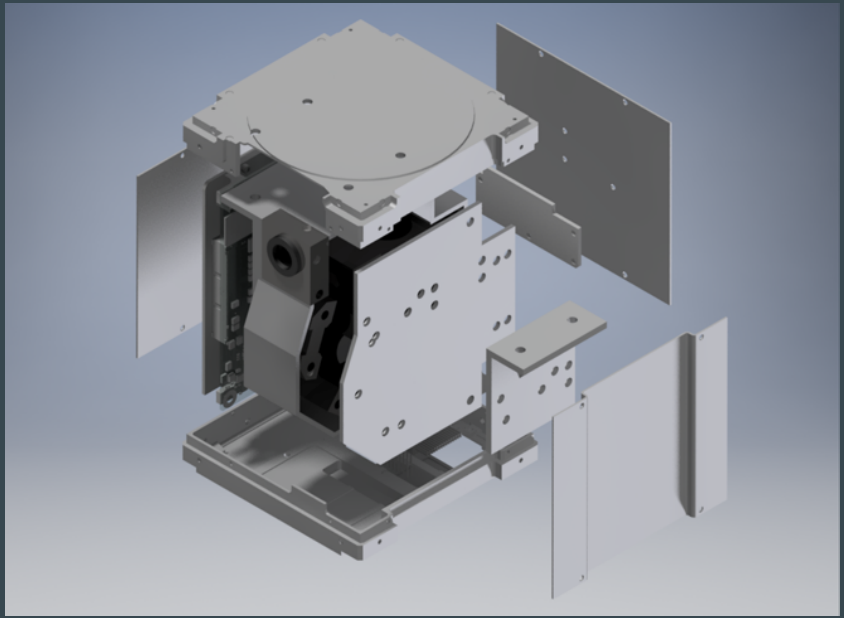
Results – First Mode Analysis

- Supported on the +Y face
- First natural frequency of 246.94 Hz, above the recommended minimum value of 100 Hz
- Maximum displacement again occurs at the payload block



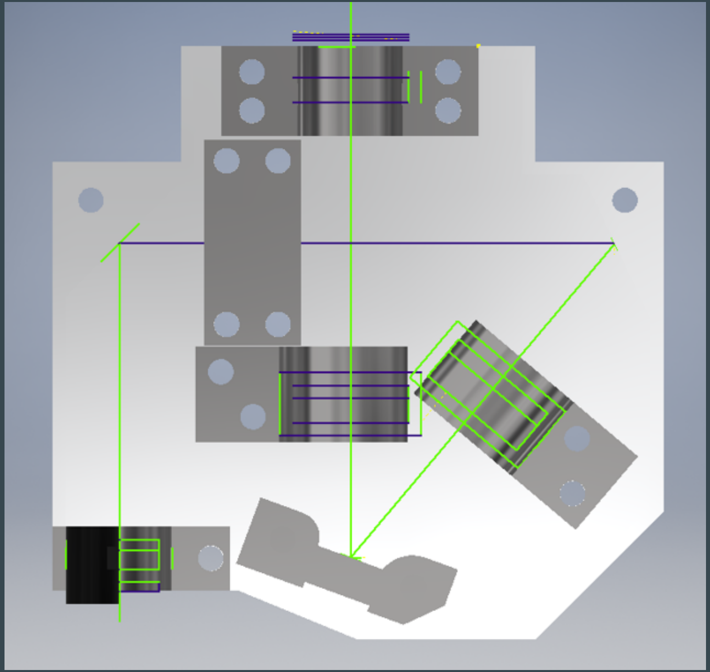
SPOCEye Design

- Hyperspectral sensor based off of similar ground spectrometers.
- Frame and housing must act as structural support for both payload and satellite.
- Extremely sensitive to temperature fluctuations.



SPOCEye Design

- Small size limits lens mount designs.
- Modular design allows for easy integration.
- Materials with low thermal coefficients of expansion are chosen.



Caveats and Sources of Error

- Components within mass blocks are not composed of a singular material—for example, the ADCS reaction wheels within the avionics block are composed of stainless steel
- Doesn't account for drum modes of avionics boards
- Use of mass blocks introduces additional stiffness to structure
- This is just one iteration of a long process – will continue to refine as design is updated

Next Steps

- Adjust satellite design to incorprate better placement of payload and interface ribs.
- Optimize Payload structural design to reduce mass and stress.
- Gradually increase model complexity – include individual boards, fasteners, and cabling.
- Conduct random vibration analyses and shock analyses.
- SPOCeye STOP Analysis

References

AFRL UNP-9 Users Guide

http://www.matweb.com/search/datasheet_print.aspx?matguid=fad29be6e64d4e95a241690f1f6e1eb7

http://www.makeitfrom.com/material-properties/6082-T6-Aluminum

Questions?