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SATELLITE TECHNOLOGY US

Preliminary Design Review

FISH & CHIPS

FeatherCraft **I**ntegrated **S**tructural **H**ousing & **C**omputer, **H**ardware **I**nterface **P**rocessing **S**uite

Team: Larry Burkey, Jorge Cervantes, Lewis Gillis, Evan Graser, Andrei Iskra, Megan Howard, Taylor Maurer, Davis Peterson, Maggie Williams
Customer: Michael Brown
Advisor: Joe Tanner

PROJECT MOTIVATION

- Commercialization of International Space Station provides a launch opportunity not only to cubesats but larger **100 kg spacecraft**
- Spacecraft are launched on ISS cargo resupply missions, allowing for soft-stowed configuration and less stress on structure in launch environment
- Surrey Satellite Technology US plans to offer the FeatherCraft system as a cost-effective platform for **payloads of 45 kg** or less.

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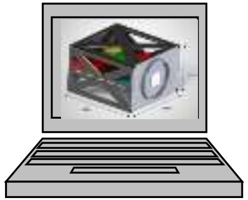
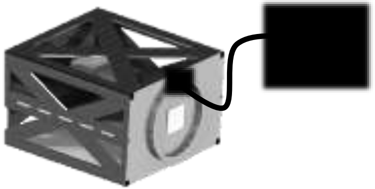
PROJECT STATEMENT:

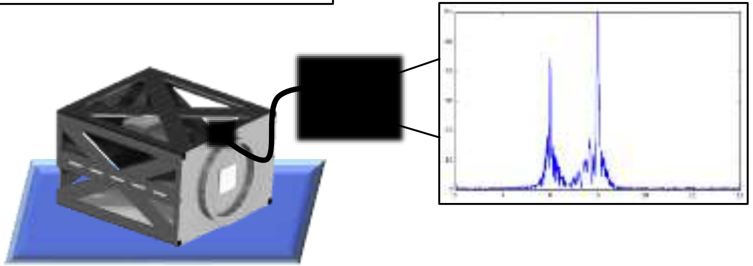
The **5 kg FeatherCraft structure** shall provide support for a **100 kg total mass** commercial spacecraft with reduced structural manufacturing time and materials cost, and enable the spacecraft to **survive launch** to and **deployment from the ISS** for a nadir facing mission.

CONOPS:

1. Select suitable lightweight material and create design for structure → 2. Fabricate structural test model → 3. Design and build data acquisition system to verify structure's behavior is as modeled → 4. Test structural test model on a vibration table with mass loadings → 5. Analyze accelerometer data and verify requirements are met







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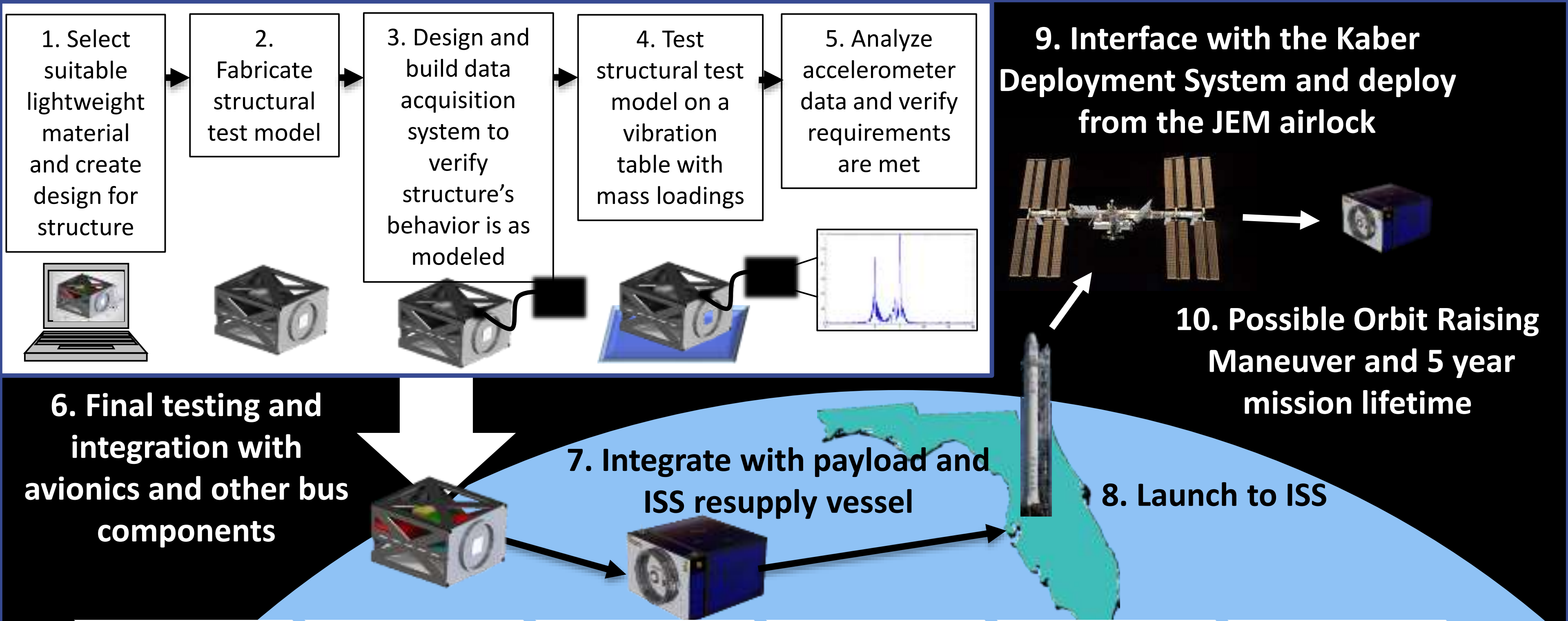
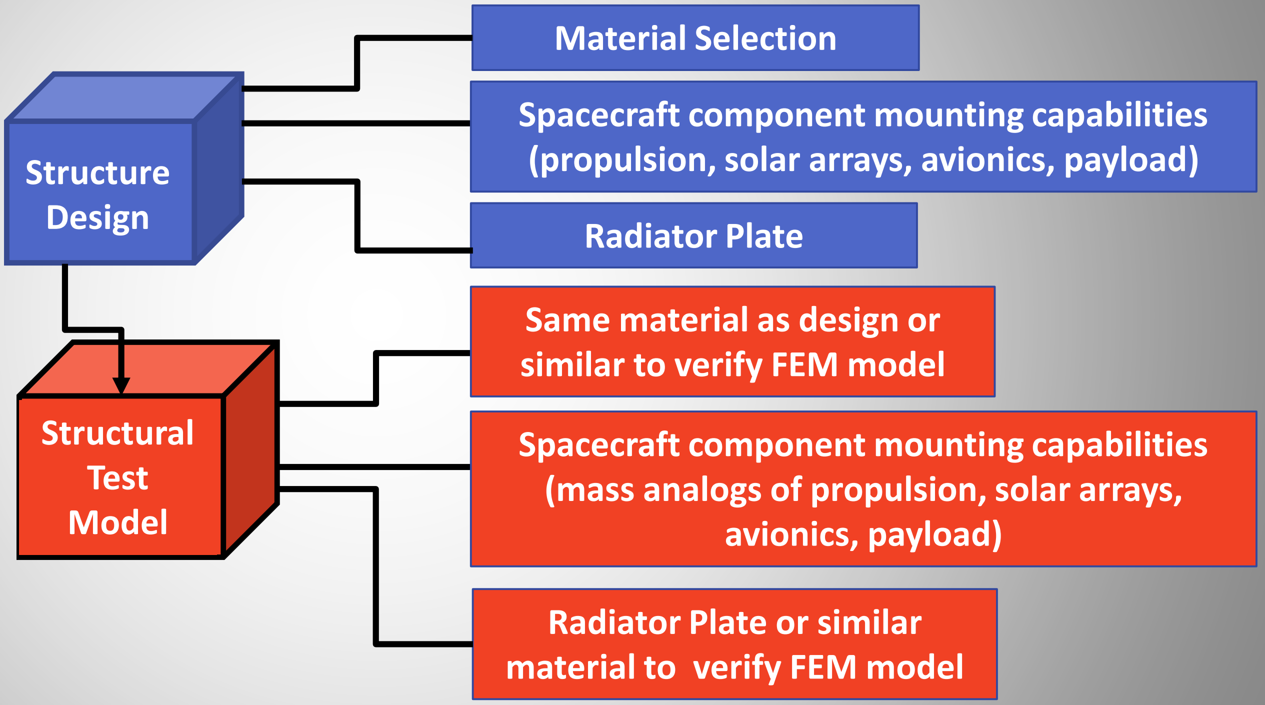

1. Select suitable lightweight material and create design for structure
2. Fabricate structural test model
3. Design and build data acquisition system to verify structure's behavior is as modeled
4. Test structural test model on a vibration table with mass loadings
5. Analyze accelerometer data and verify requirements are met
6. Final testing and integration with avionics and other bus components
7. Integrate with payload and ISS resupply vessel
8. Launch to ISS
9. Interface with the Kaber Deployment System and deploy from the JEM airlock
10. Possible Orbit Raising Maneuver and 5 year mission lifetime

FUNCTIONAL BLOCK DIAGRAM:

KEY

- Acquired
- Designed and Built
- Provided
- Designed



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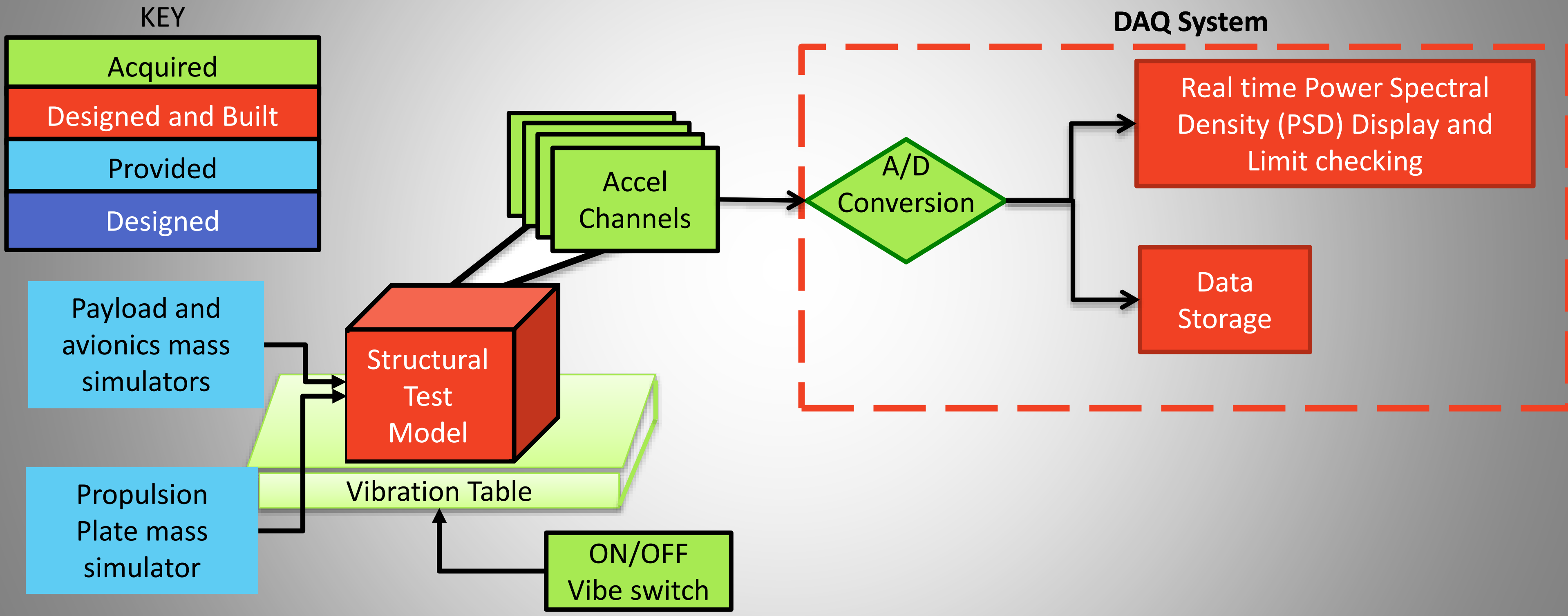
FUNCTIONAL BLOCK DIAGRAM:



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FUNCTIONAL REQUIREMENTS:

FR 1	The Feathercraft structure design shall have a **mass of less than 5 kg.**
FR 2	The Feathercraft structure design shall **reduce manufacturing time and material cost** from SST-US's typical spacecraft estimates.
FR 3	FeatherCraft Structure shall be designed to **deploy from the ISS.**
FR 4	FeatherCraft structure design shall **interface with SST-US-provided spacecraft components and mission design**.
FR 5	An **equivalent manufactured STM** of the FeatherCraft structure design shall be used to **demonstrate the feasibility of the FeatherCraft structure** through a **random vibration test** to the requirements of NASA GEVS documentation.

CRITICAL PROJECT ELEMENTS:

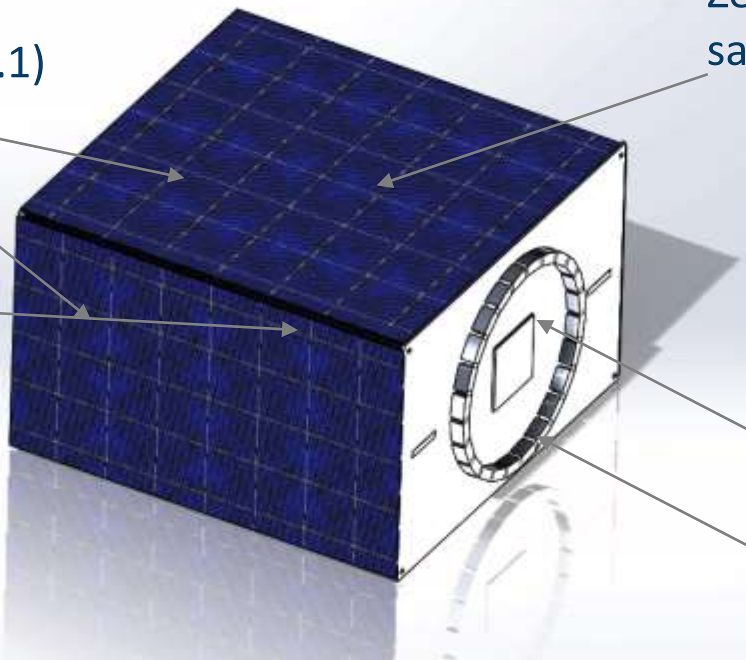
Structure:	Electrical Hardware:
▪ Extreme load cases (FR3) ▪ Adhesives (FR4) ▪ Manufacturability (FR2 and 5)	▪ Accelerometers (FR5) ▪ Signal Conditioning (FR5) ▪ Data Transfer (FR5)
Testing:	**Software:**
▪ Soft-stowed configuration (FR3 and 5) ▪ Vibration table facility (FR5)	• Python (FR5) • GUI interface (FR5)

STRUCTURE OVERVIEW

MECHANICAL DESIGN TRADE STUDY:

		Metallic Weight Relieved Panels	Honeycomb Weight-Relieved Panels	Columns	Traditional Design
Criteria:	Weight:	Score:	Score:	Score:	Score:
Material Cost (FR 2)	16%	10	6	8	9
Mass (FR 1)	35%	2	10	9	2
Ease of Manufacturing (FR 2)	26%	7	6	7	5
Ease of Analysis (FR 5)	23%	8	8	6	8
Weighted Total:		5.95	7.86	7.63	5.26

DESIGN OVERVIEW:



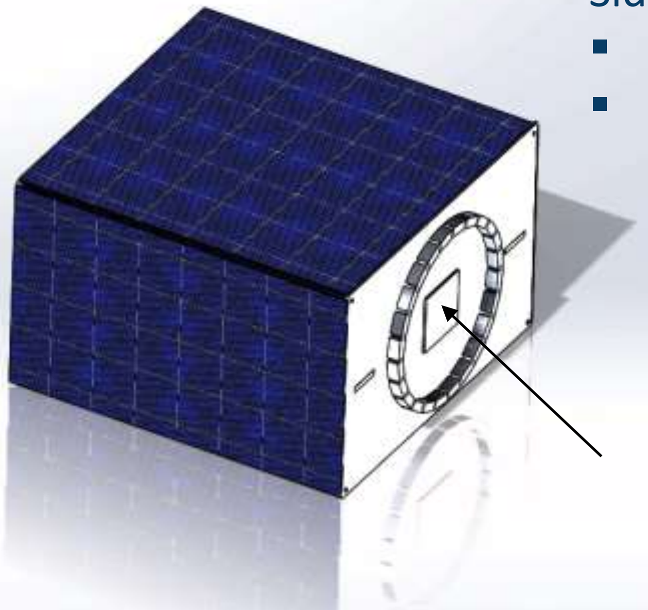
INTEGRATION:

Customer supplies:

- Solar Panels (mass analogs)
- Avionics (mass analogs)
- Payload (mass analog)
- Propulsion Plate

We supply:

- Structure



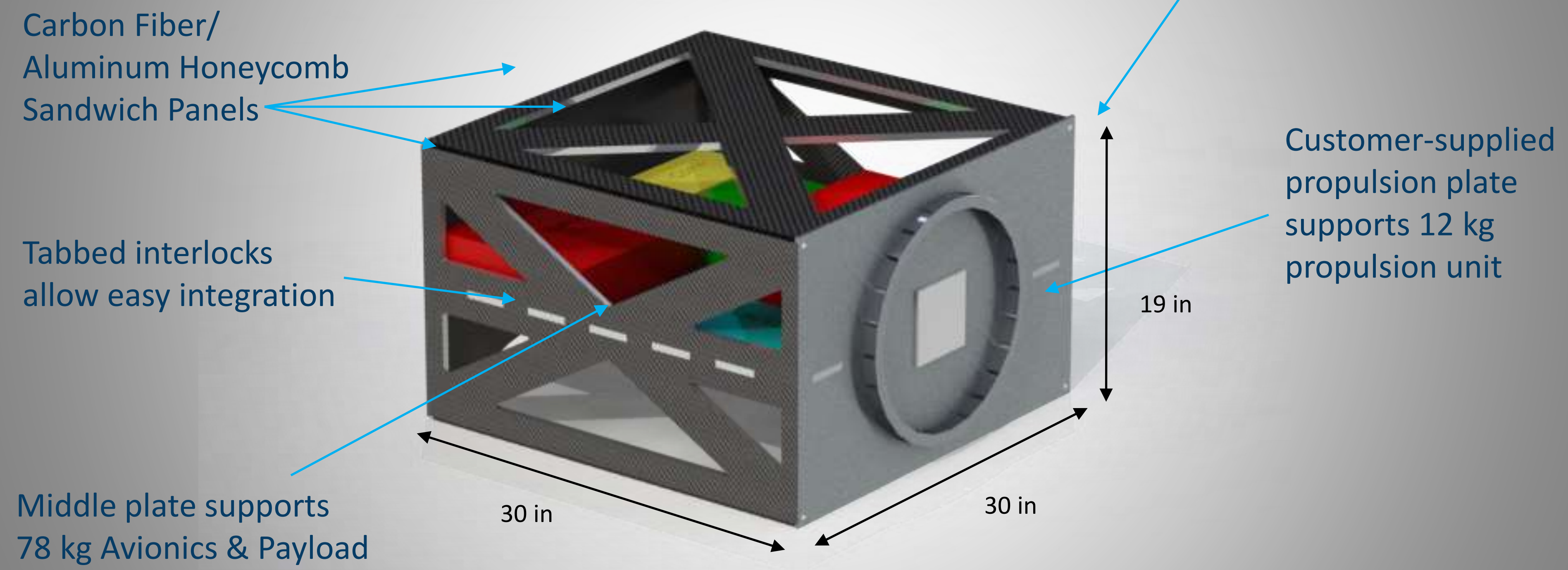
Side Panels:

- Woven Carbon Fiber skin
- Aluminum Honeycomb Core

Propulsion Plate

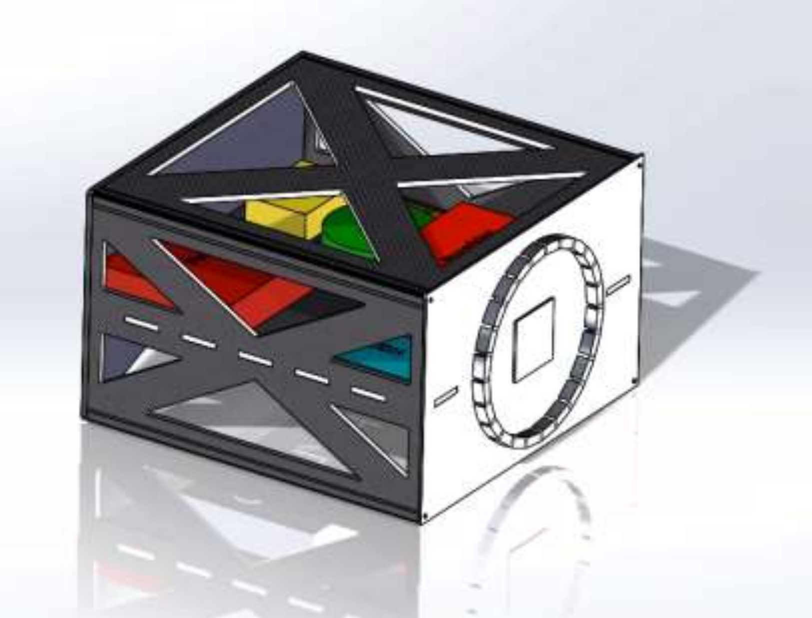
- Al Skin
- Al Honeycomb Core

DESIGN OVERVIEW:



STRICTURAL CONNECTIONS:

- Panels
  - Slots allow physical interface with middle plate
  - Outer face sheets are bonded to column sides
- Endplates
  - Slots allow connection to middle plate
  - Bolt into helicoil threaded plug
    - Greater adhesive area



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STRUCTURE FEASIBILITY

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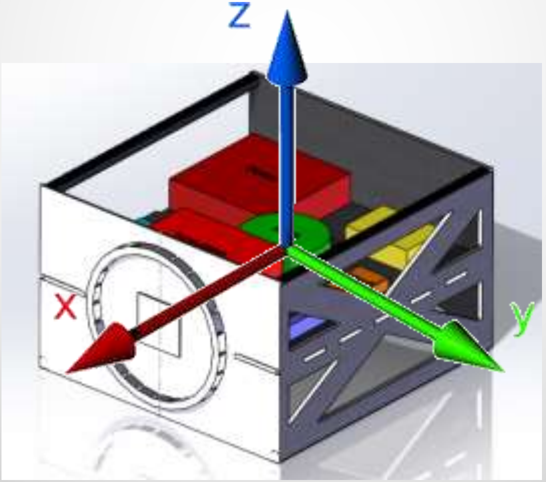
STRUCTURE FEASIBILITY

- Feasible design < 5kg (FR 1)
- STM will handle specified vibration loads in X, Y, Z (FR 3,5) (GSFC-STD-7000 2005.04)
- Nominal acceleration 1σ = 1.29 grms (FR 3)



Quasi-Static Load Assumptions:

- static load = 9.81 m/s^2
- 4σ dynamic load = 5.16 grms

$$F = ma$$

$$F = mg(1 + (4 \times 1.29))$$

F = 6.55 kN

Project Overview | **Structure** | Testing | Electrical Hardware | Software | Conclusion

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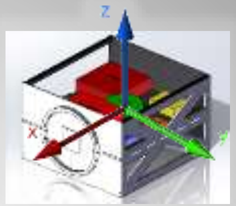
VIBRATION LOADING:



Interfaces are analyzed using **worst case** loading (FR 3)

Axis:	Description:	Type of load:	Factor of Safety:	Design Margin:
X	Tube – Plate Interface	Shear	1.9	12.8
	Column	Buckling	3.9	6.8
Y	Column	Bending	1.9	0.25
	Side panel	Bending	1.9	TBD
Z	Middle panel	Bending	1.9	0.034
	Mid panel tabs	Shear	1.9	6.5

Factor of Safely (FOS):

$$FOS = 1.9 \times Expected\ Stress$$

(GSFC-STD-7000 2005.04)

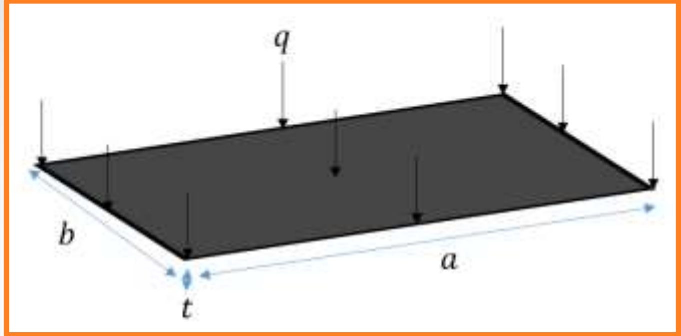
Design Margin:

$$\frac{Material\ Strength}{FOS \times Expected\ Stress} - 1$$

Design Margin > 0
FEASIBLE

MIDDLE PANEL BENDING:

Assume: simply supported plate, uniform load



Edges are simply supported

Maximum Deflection = 6 mm

$$y = \frac{2K_1 q b^4 \lambda}{E_f t_f h^2} = 6mm$$

Axis:	*Nominal Stress (MPa)*	*Stress Description*	*Maximum Stress* $\sigma_{max} = \sigma_0 * FOS\ (MPa)$	Material Property $\sigma_{ult}\ (MPa)$	Design Margin:
Z	σ_n = 56	Normal	σ_{max} = 106.4	110	0.034
	$\tau_c = 0.2$	In-plane shear	$\tau_c = 0.38$	260	6000

ADHESIVES:

Adhesives will be used for mounting all subsystem components and most structural components (FR 1, 2, 4, 5)

- Hysol EA 9394 Aerospace Adhesive
  - 1 qrt attainable online $184.89 - $210.00 (**FR 2)**
- Scotch-Weld 2216 Epoxy
  - 1 qrt attainable online $275.74 - $282.58 (**FR 2)**
  - Removable with heat

Assumptions:

- Properties assume aluminum (ASTM D) adhesion (small scale testing to confirm for carbon fiber)
- Volume estimate assuming thin film (0.005in)

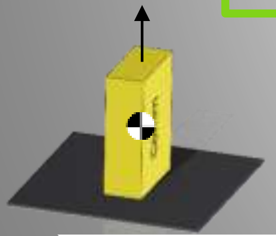
Property (25°C)	Hysol EA 9394	Scotch-Weld 2216
Tensile Lap Shear	28.9 MPa	22.1 MPa
T-peel shear	0.88 N/mm	4.37 N/mm
Density	1360 kg/m^3	1330 kg/m^3
Mass needed	**0.3 kg**	**0.3 kg**

Low mass fulfills **FR 1**
FEASIBLE

ADHESIVES ANALYSIS:

Assume: 50% effective adhesion area

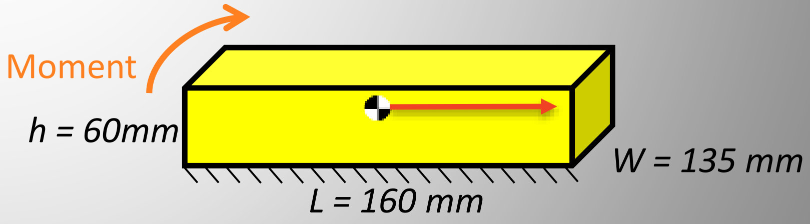
- **Largest component**
  - Communications module: **10 kg**,
  - 160 x 135 x 60 mm
- **Normal Stress**
  - $\sigma_n = \mathbf{0.15\ MPa} < \mathbf{22.1\ MPa}$



Scotch-Weld 2216
Epoxy fulfills **FR 4**
FEASIBLE

Peel Stress

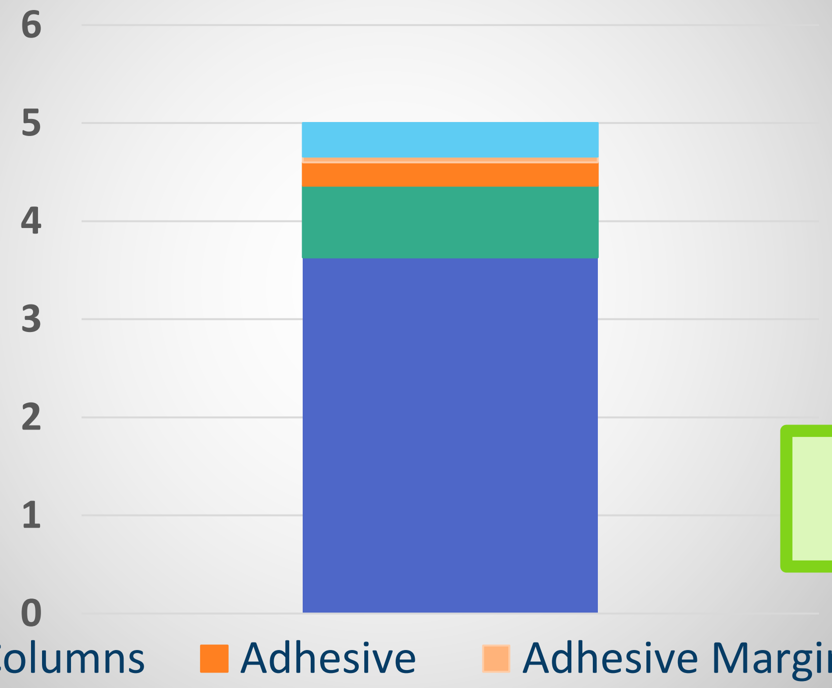
- Assuming uniform stress distribution
- Moment = 19.3 Nm
- Max induced stress = 286 N
- Max peel = $\frac{286N}{160mm} = \mathbf{1.8\left(\frac{N}{mm}\right)} < \mathbf{4.37\left(\frac{N}{mm}\right)}$



MASS BUDGET:

Mass Limit (FR 1): 5kg

Mass of Design: **4.7kg**

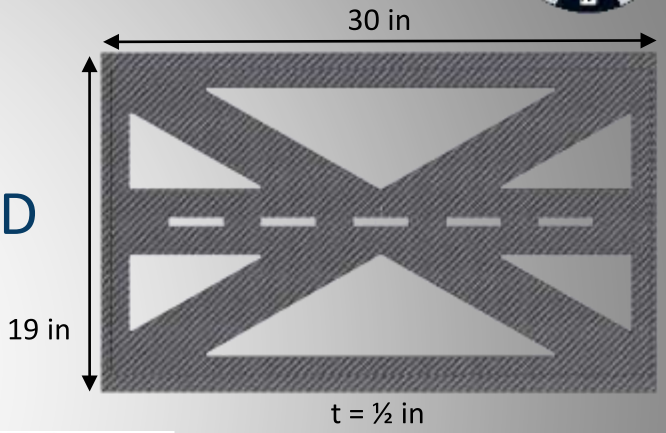


$M_{design} < M_{FR\ 1}$

FEASIBLE

MANUFACTURING:

- FR 2,5
- Most weight relief and support tabs are 2D
  - Achievable with Water Jet Cutter
    - Available at the Physics machine shop
    - Min. Radius = .006”
    - Positional Tolerance < .005”
- Panel edges still need milling

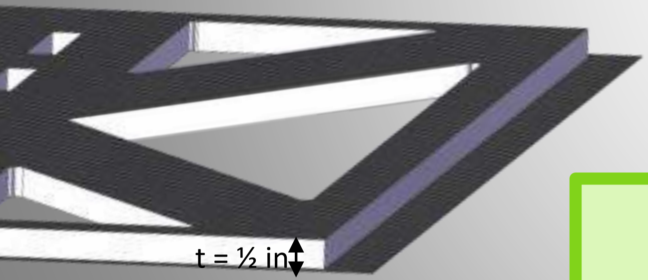


Fulfill **FR 5**
FEASIBLE

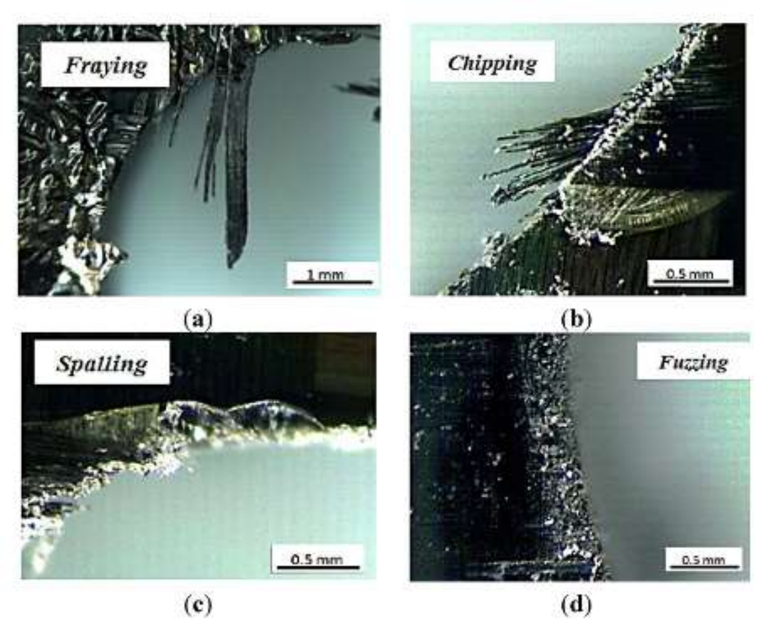
FR 2 requires further analysis

MANUFACTURING:

- Machining of Panel Edges
  - Required allow overlap of face sheet
  - Fiber layer will possibly fray and delaminate from core.
  - Design options still being weighed



Fulfill **FR 5**
FEASIBLE



Experimental Analysis of the Influence of Drill Point Angle and Wear on the Drilling of Woven CFRPs (Feito, 2014)

TESTING OVERVIEW

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RANDOM VIBRATION TEST:

Profile specified by NASA Document (DR 5.2):

- ISS Pressurized Volume Hardware Common Interface Requirements

- Random Vibration Profile Characteristics
  - 20 Hz. – 2000 Hz. Frequency Range
  - Random vibration loads specified for different frequencies
- Unattenuated Load= Known maximum launch load of 9.47 grms
- Attenuated Load = Predicted load in foam & CTB of 1.29 grms

Fulfil FR 5
FEASIBLE

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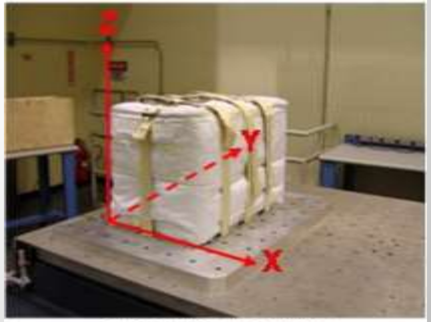
TEST FACILITY:

- Facility: Cascade Tek
  - 1530 Vista View Dr, Longmont, CO (~30min) (DR 5.2)
- Cost: $1800 for 8 hour use of Vibration Table
  - Currently factored into budget, may be donated by Surrey
  - May require less than 8 hours, requires preliminary testing
- Testing will occur in March with direct assistance from Cascade Tek test engineers

STRUCTURE MOUNTING:

- Structure will be wrapped in specified Pyrell ½” Foam (DR 5.4)
  - Attenuates Vibration Loading
- Two ratchet straps will secure the structure to the table
  - Hooked to ½” by 13 eyebolts (4), bolted directly to vibration table



Above: Cascade Tek Vibration Table
Left: Example structure wrapping & strapping configuration

Fulfil FR 5
FEASIBLE

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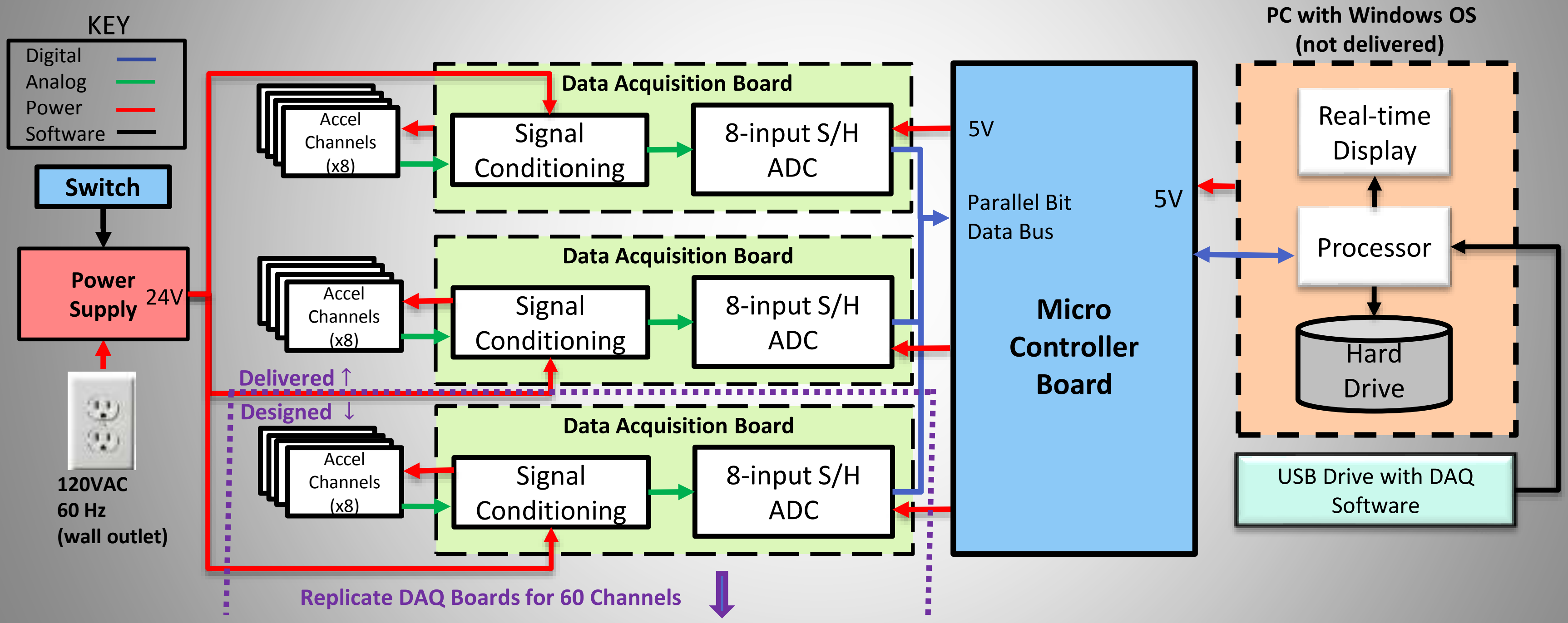
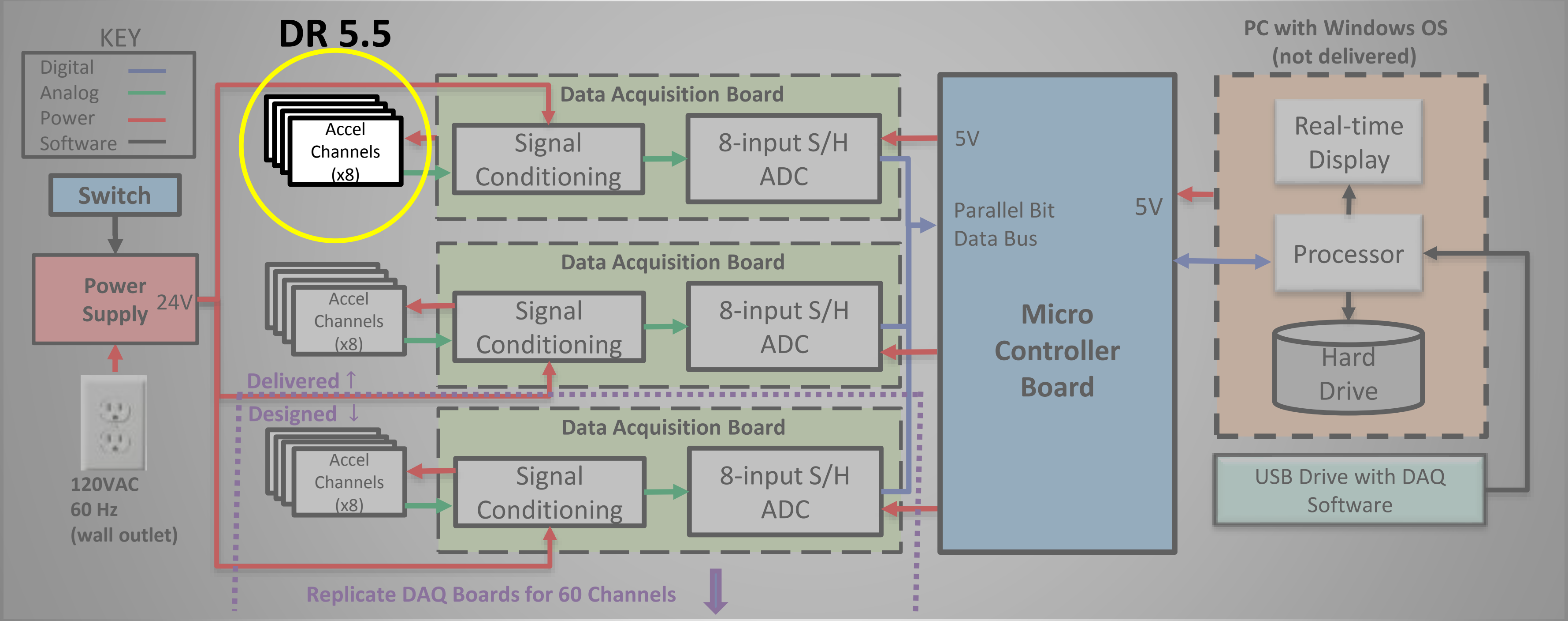
ELECTRICAL HARDWARE OVERVIEW

DAQ HARDWARE FBD:



ELECTRICAL HARDWARE FEASIBILITY

Accelerometers:



ACCELEROMETERS:

10.2 mm

Single Axis (PCB-333B30)

14.0 mm

Tri-axial (PCB-356A16)

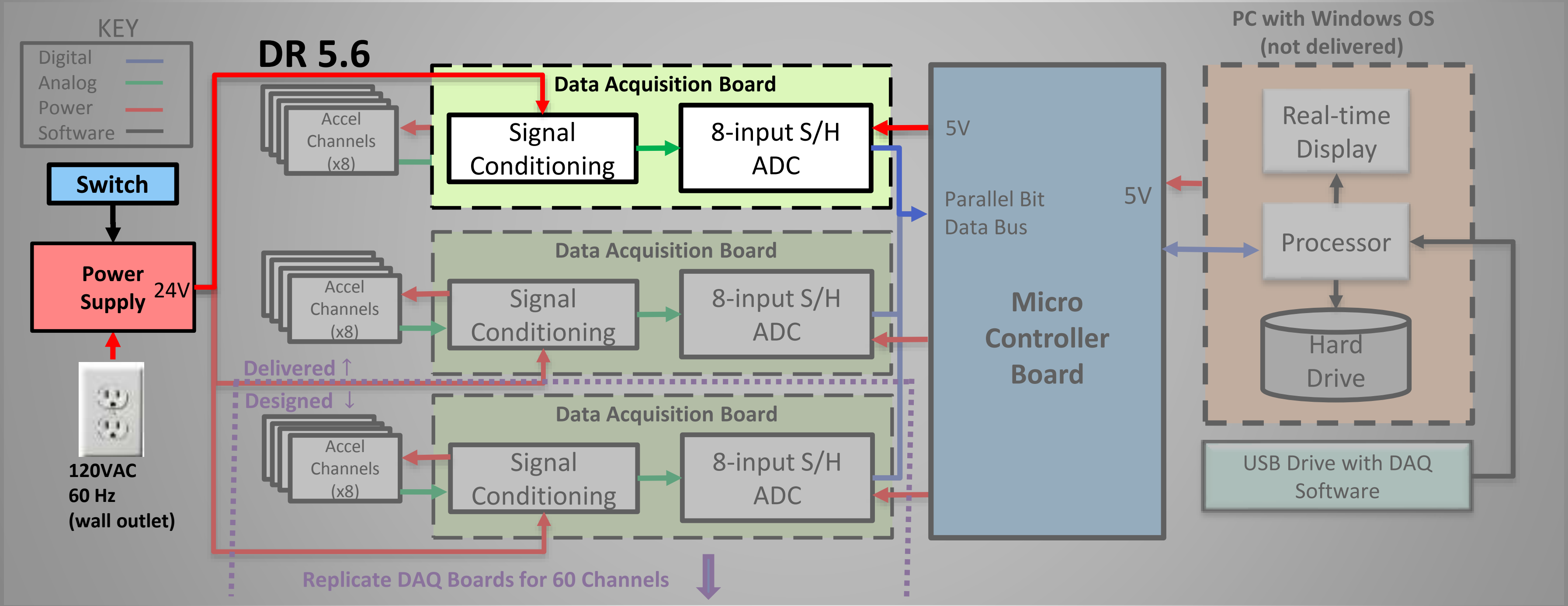
Resources:

- Trudy Schwartz
- Christine Buckler (ITLL) for barrowing accelerometers and cables
- The Modal Shop for renting accelerometers for 30 days

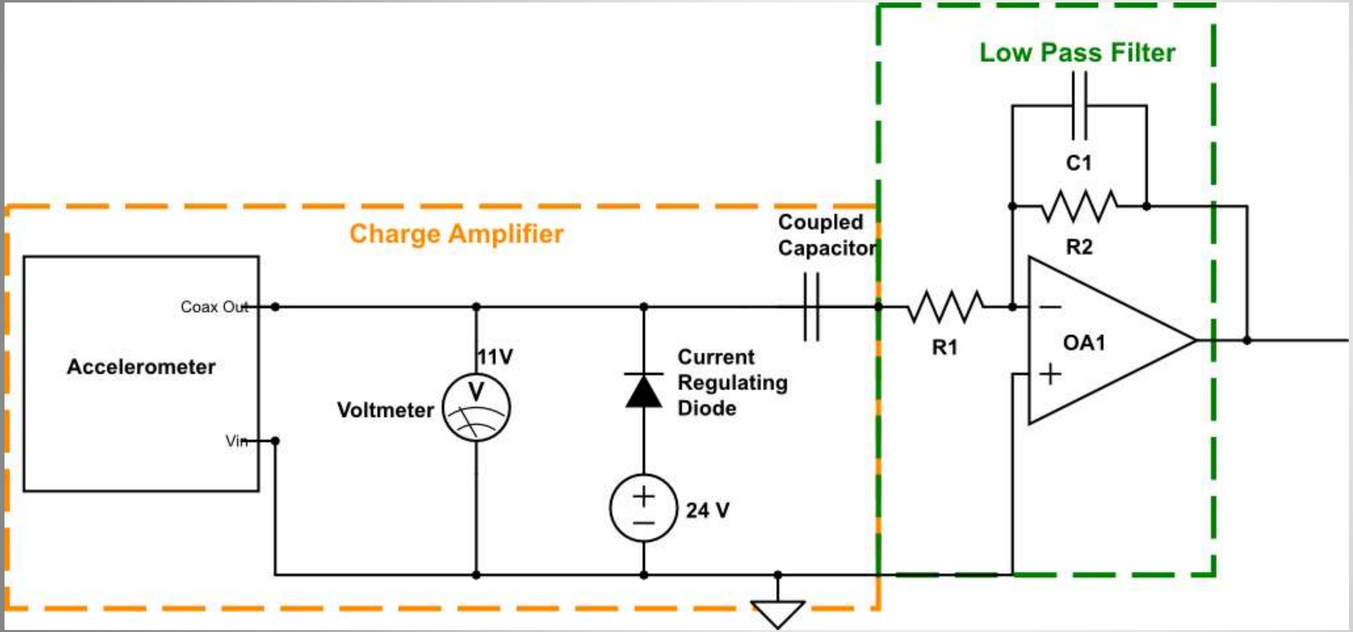
Fulfil FR 5
FEASIBLE

Accelerometer	Buy Price	Rent Price	Mass	Size
Single axis	$297	$60/ month	4 grams	10.2x16.0x10.2 mm
Tri-axial	$931.50	$200/ month	7.4 grams	14.0x20.3x14.0 mm

DATA AQUISTION BOARD:



DATA ACQUISITION CIRCUIT:



*Circuit diagram provided by PCB

Resources:

- Trudy Schwartz and the Instrumentation Shop
- TIRESIAS project involved a similar accelerometer circuit
- PCB Piezoelectric and ADC manuals for circuit designs
- Altium Designer software available for student use
- PCB Designer Software through Advanced Circuits available

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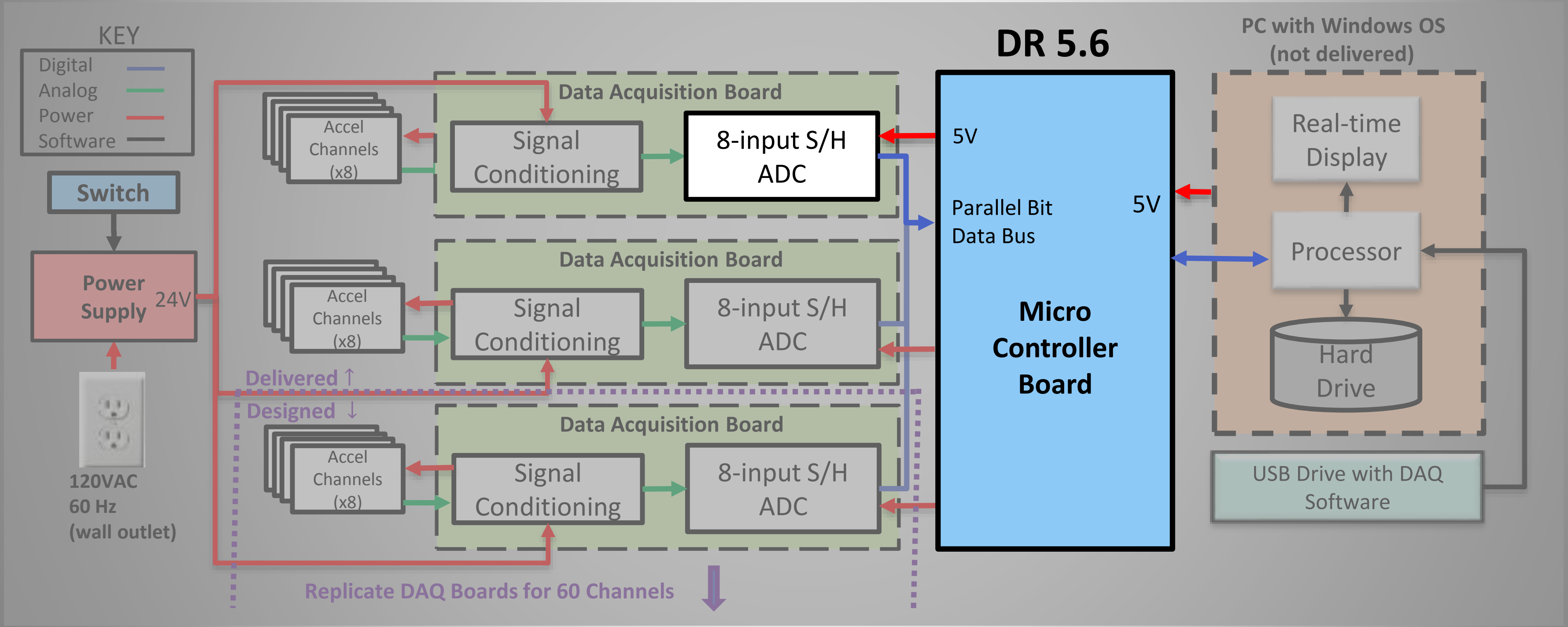
FEASIBLE

Data Transfer:



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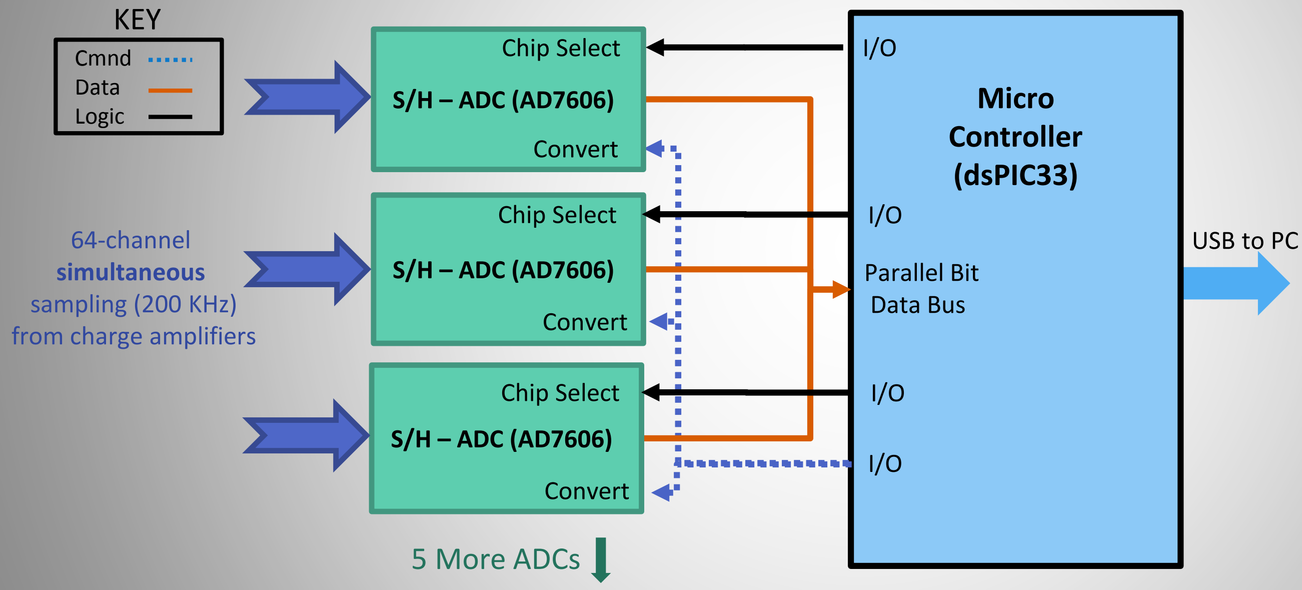
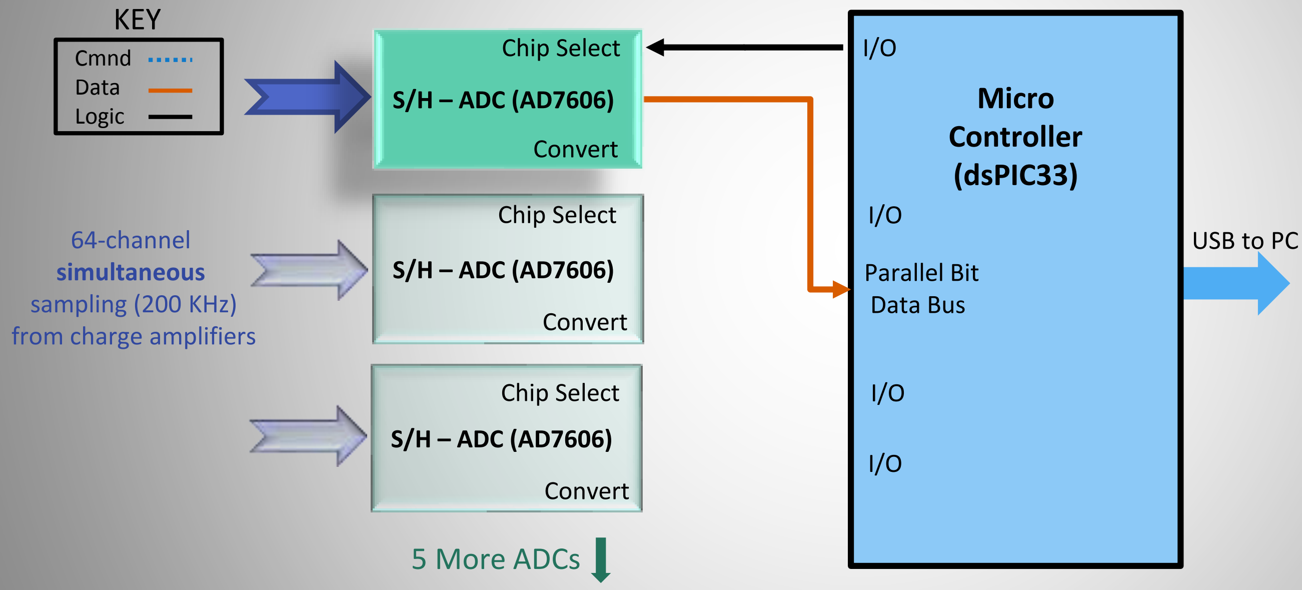
DATA TRANSFER TO PC:



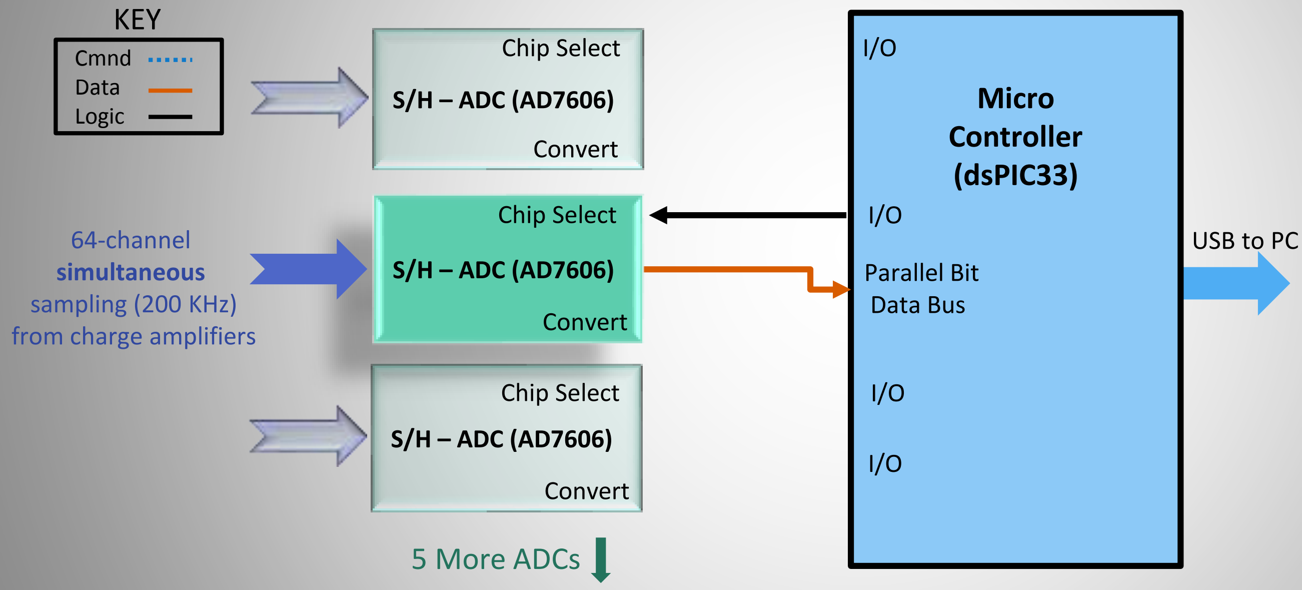
All channels sample and hold simultaneously by toggling **convert** pin

DATA TRANSFER TO PC:



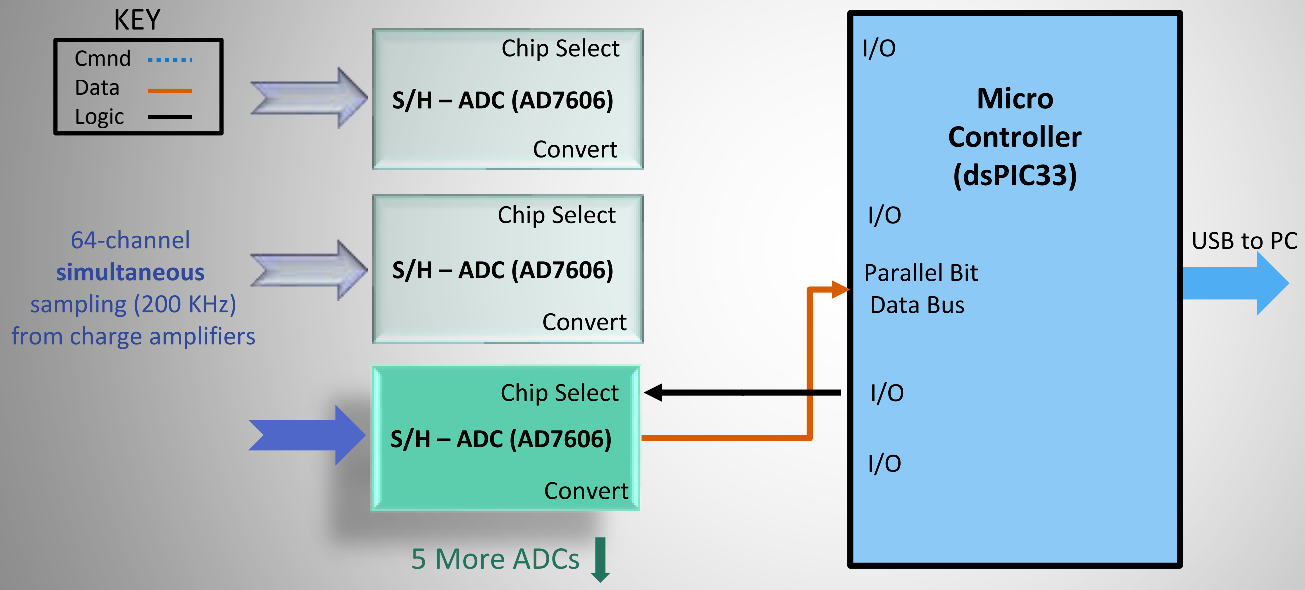
First 8 data channels collected and stored.

DATA TRANSFER TO PC:



Second 8 data channels collected and stored.

DATA TRANSFER TO PC:



Next 8 data channels collected and stored.

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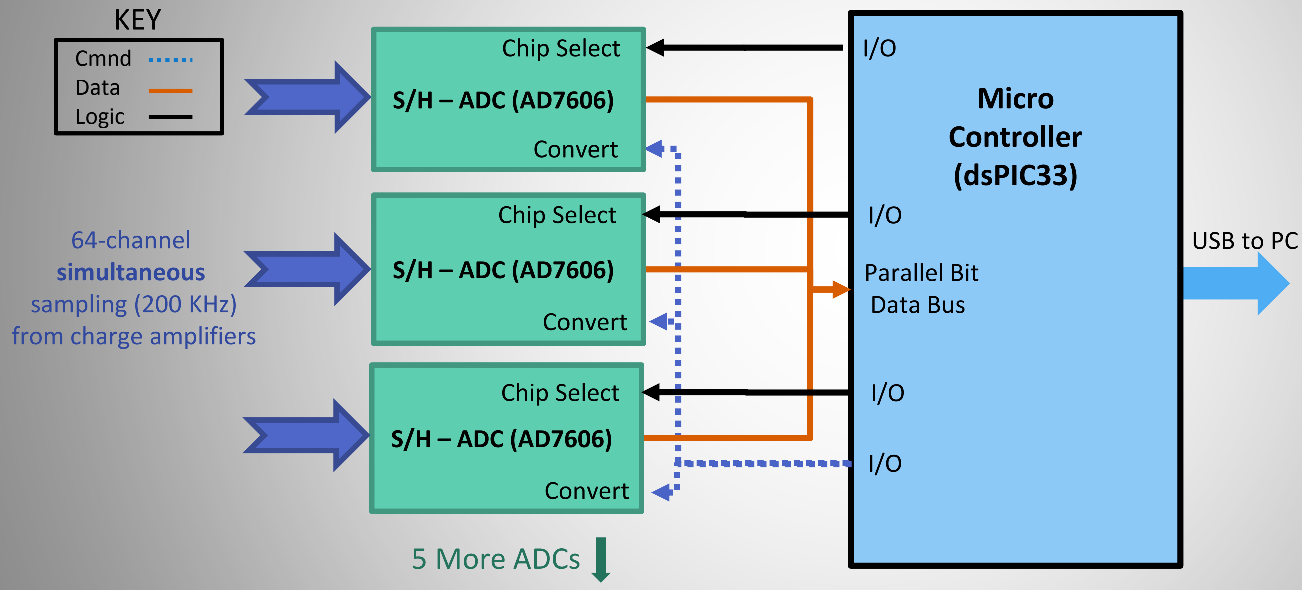
DATA TRANSFER TO PC:



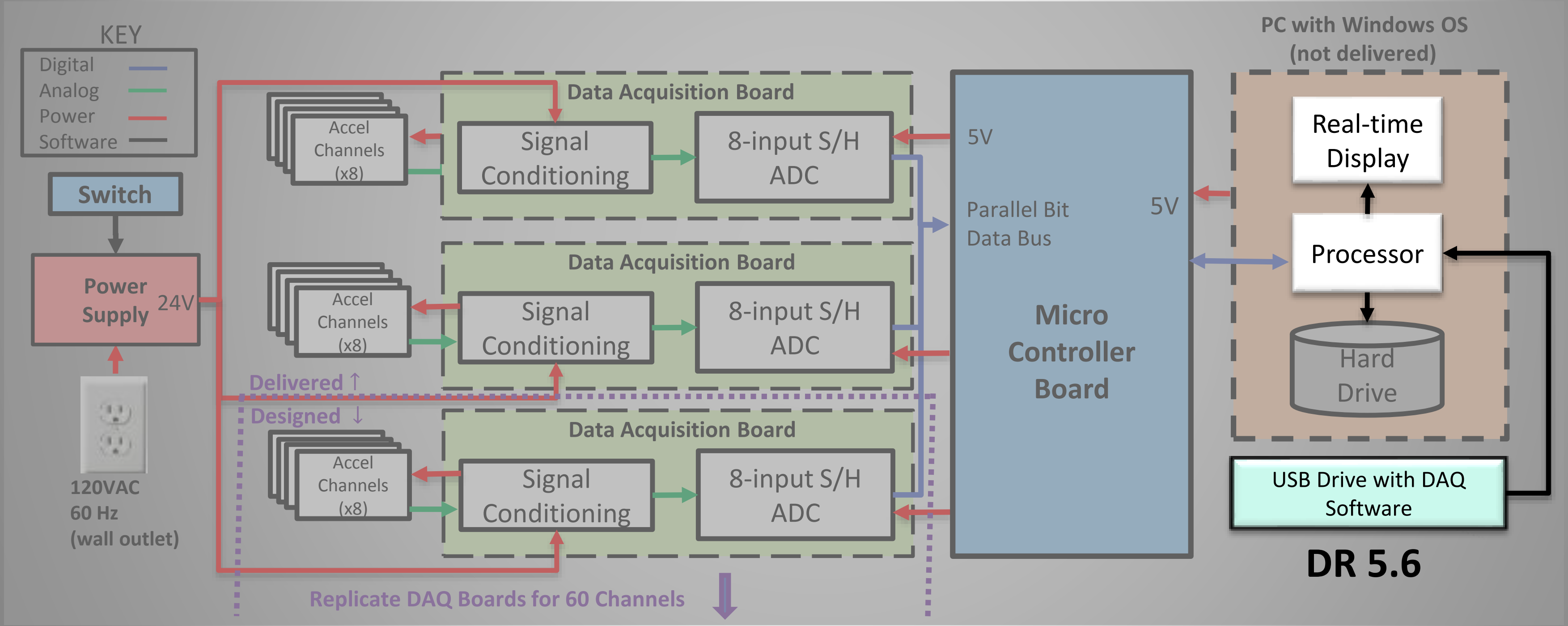
Data transferred to PC via UART (17.5 Mbps)

Process repeats

Fulfil DR 5
FEASIBLE

SOFTWARE OVERVIEW

SOFTWARE:

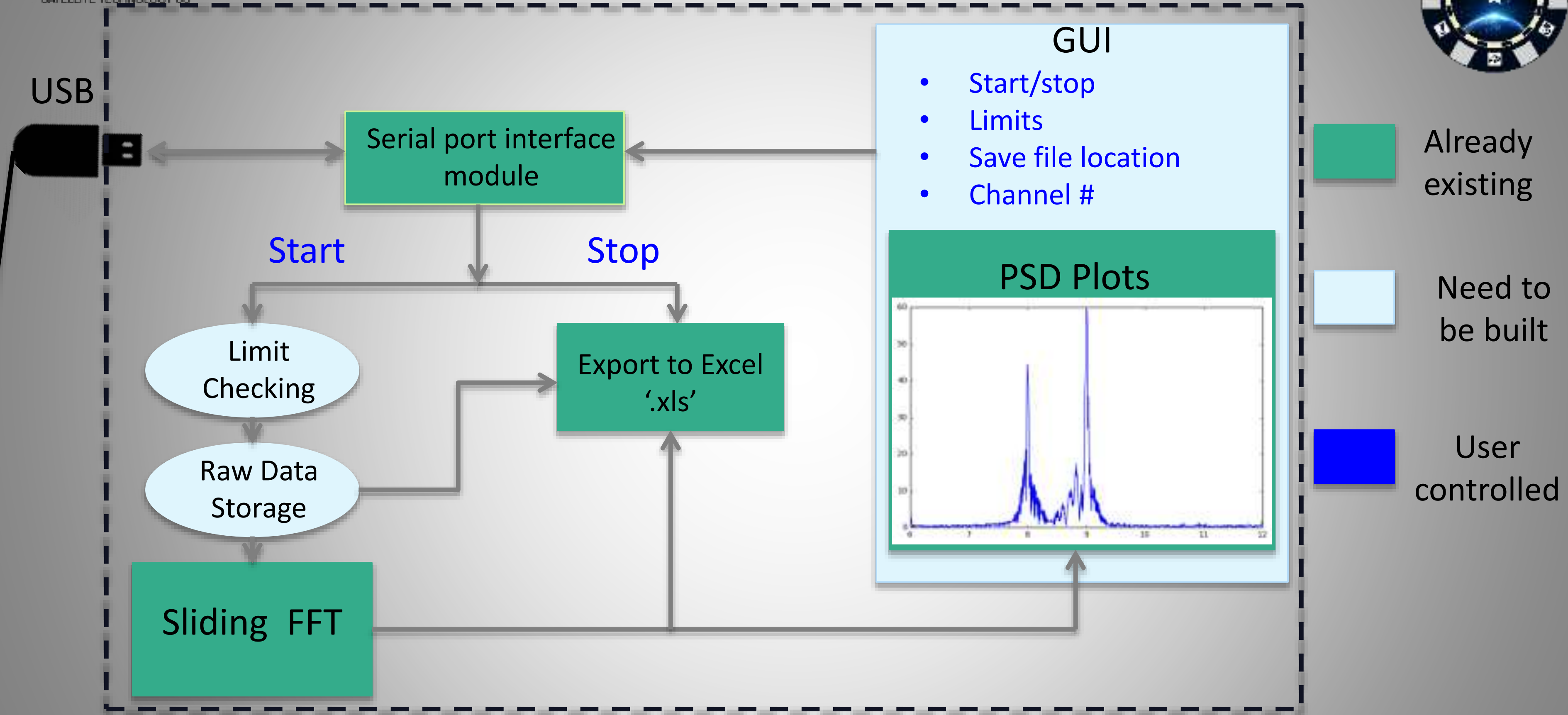


KEY
Digital
Analog
Power
Software
Switch
Power Supply
24V
120VAC
60 Hz
(wall outlet)
Data Acquisition Board
Accel Channels (x8)
Signal Conditioning
8-input S/H ADC
Data Acquisition Board
Accel Channels (x8)
Signal Conditioning
8-input S/H ADC
Delivered ↑
Designed ↓
Data Acquisition Board
Accel Channels (x8)
Signal Conditioning
8-input S/H ADC
Replicate DAQ Boards for 60 Channels
5V
Parallel Bit Data Bus
5V
Micro Controller Board
PC with Windows OS (not delivered)
Real-time Display
Processor
Hard Drive
USB Drive with DAQ Software
DR 5.6

DESIGN:

- **Python**, packaged as executable (.exe)
- GUI created for user input
- Implement already created python modules and libraries
- Plot quasi-real-time **PSD (power spectral density)** plots (DR 5.6.3)
- Capability of saving data to **Excel** (.xls) (DR 5.6.4)
- Transferable to a PC via USB (DR 5.6.5)

External Computer (Windows)



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SOFTWARE FEASIBILITY

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PYTHON LIBRARIES AVAILIBLE:

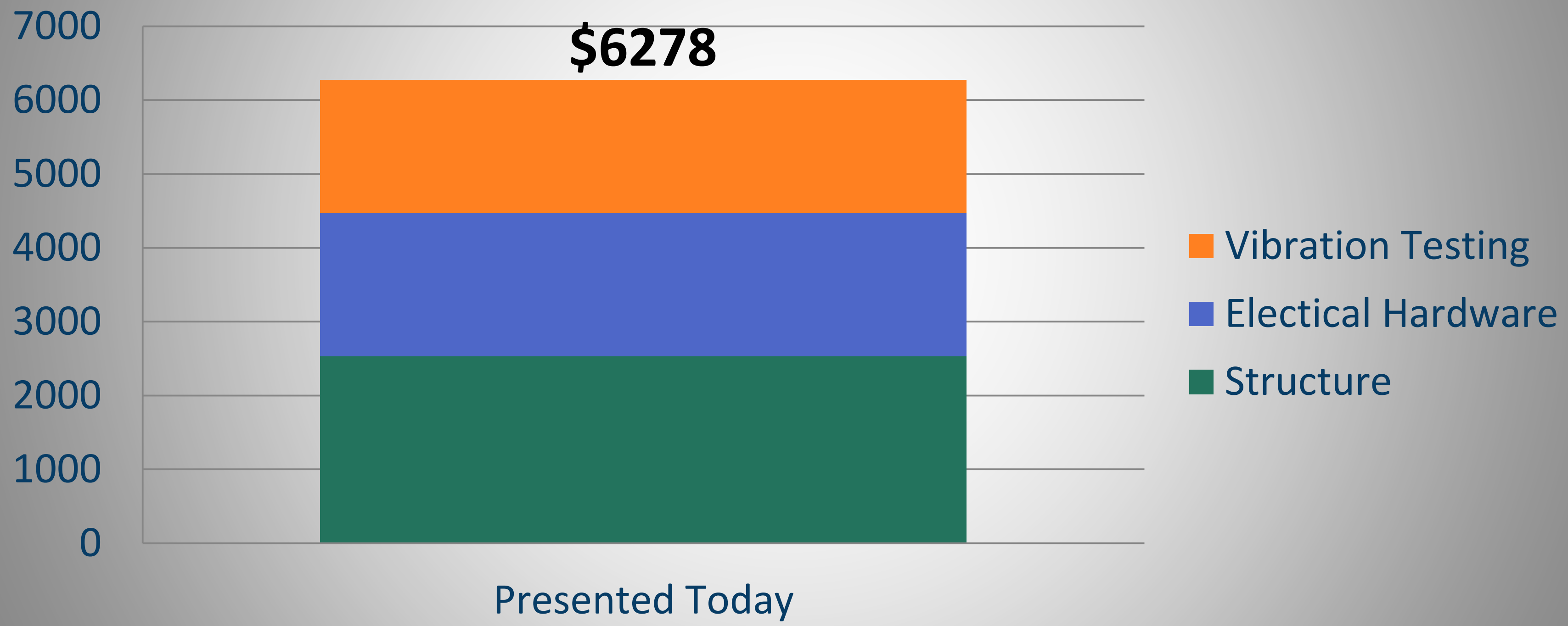
- Serial interface
  - PySerial
- FFT function
  - NumPy
- Excel implementation
  - xlwings, xlsxwriter
- PSD plotting
  - matplotlib

- Executable packager
  - cx freeze
- GUI Development
  - Qt, tkinter
- All libraries have been downloaded and verified with current Python version

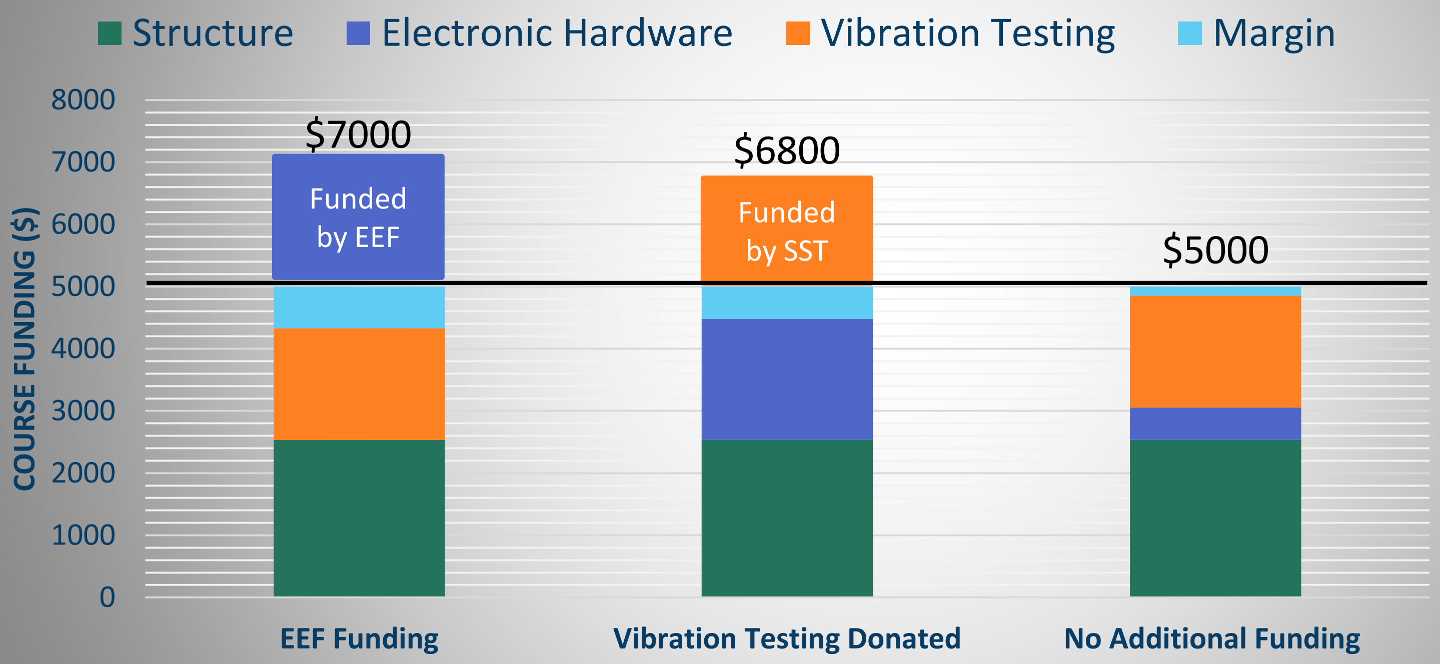
Fulfil DR 5
FEASIBLE

CONCLUSION

BUDGET:


$6278
7000
6000
5000
4000
3000
2000
1000
0
Presented Today
Vibration Testing
Electical Hardware
Structure

BUDGET:



Budget Reduction:

- Rent Accelerometers
- Borrow Co-Axial Cables
- Less expensive panel materials
  - Nomex Core
  - Solid Aluminum

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FEASIBILITY AND NEXT STEPS

	Functional Requirement	Feasibility Shown	Next Steps
FR 1	Design shall have a **mass of less than 5 kg.**	Mass budget ✓	Detailed **mass estimates** of fasteners, adhesives
FR 2	Design shall **reduce manufacturing time and material cost** from SST-US's estimates	Manufacturing options ✓ Budget✓	Manufacturing time estimates and **small scale testing, final component selection**
FR 3	Structure shall be designed to **deploy from the ISS.**	Vibration Loading ✓ Baseline Design ✓	Numerical **FEM modelling**
FR 4	Design shall **interface with SST-US-provided spacecraft components and mission design**.	Adhesive Analysis ✓ Structural Analysis ✓	**Adhesive research and small scale testing**
FR 5	An **equivalent manufactured STM** shall **demonstrate the feasibility of the structure** through a **random vibration test** to NASA standards.	Hardware Design ✓ Software Feasibility ✓ Vibration Testing Feasibility ✓ Manufacturing Options ✓	Detailed **hardware design** and selection, **software package testing, schedule vibration table test**, testing manufacturing options

PATH MOVING FORWARD :

OCT	NOV	DEC	JAN	FEB	MAR	APR

Finalizing designs and component testing

FEM modelling, detailed circuit analysis

CDR

FFR

Winter Break

Manufacturing structure and creating DAQ

MSR

Vibration Testing

TRR

Validation of Model

SFR

PFR

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References

[1] Materion Coroporation. AlBeMet Property Datasheet. Elmore, OH: Beryllium & Composites, n.d. Print.

[2] Sandwich Panel Fabrication Technology. N.p.: Hexcel Composites, 2001. Print.

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[4] Roark, Raymond J., and Warren C. Young. Formulas for Stress and Strain. New York: McGraw-Hill, 1975. Print.

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QUESTIONS

BACK-UP SLIDES

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APPENDIX: MAIN

APPENDIX: BACK-UP

REQUIREMENTS :

- FR 1
- FR 2
- DR 3.1
- DR 3.2
- FR 4
- DR 4.4
- FR 5
- DR 5.3
- DR 5.4
- DR 5.6
- DR 5.6.3

INITIAL DESIGNS:

STR:
- TA
- WRP
- CLNM

DAQ:
- **DIG. ACC**
- **1 μC**
- **Multi μC**

TRADE STUDIES:

STR:
- MET. DEF
- TS
- MAT. PROP

DAQ:
- ACC MET. DEF
- ACC TS
- HW MET. DEF
- HW TS

SW:
- MET. DEF
- TS

DETAILED ANALYSIS:

STR:
- NAT FREQ
- MID PL BEND
- FOS & LOADS
- TUBE – PLATE
- CLMN BUCK
- SP FAIL 1
- SSP FAIL 2

ADHESIVES:
- MASS PROPERTIES
- OUTGASSING
- SCOTCH 2216

MANUFACTURING:

- TILE SAW
- END MILL
- E. CLOSE

RADIATOR:

- DESCRIP.
- RADIATION PLOT
- CONDUCTIV

TESTING:

- PROFILE DES.
- TABLE
- WI GRMS
- GRMS METHOD
- WRAPPING
- ACC. MOUNTING

SW FLOW CHART:

- INITALIZATION
- RUN
- STOP
- RESET
- LIB

DAQ HARDWARE:

- A/C CON FBD
- A/D CON TIMING DIAGRAM
- ACC MOUNT
- DATA SAMP SPEEDS
- CHARGE AMP
- WHY 60?

BUDGET:

- OUTLINED
- VIBE DONATED
- EEF APPROVED
- NO ADTL. FUNDING
- ALL THE FUNDING

NEXT STEPS:

- SMALL SCALE TESTING
- HARDWARE
- SOFTWARE

NUMERICAL MODELING

- CHALLENGES
- MAT. PROPERTIES
- BOUNDARY COND & LOADS
- EDU. LICENSE

Requirements: FR1

- **FR 1:** The FeatherCraft structure design shall have a mass of less than 5 kg.
    - *Source:* Customer requirement. Increasing the structural mass beyond 5 kg would prevent SST-US from providing a profitable weight class of payloads
    - Verification: Modeling and analysis, comparison with measurement of STM

Requirements: FR2

- **FR 2:** The Feathercraft structure design shall reduce manufacturing time and material cost from SST-US's typical spacecraft estimates.
  - DR 2.1: Structure design material cost shall be less than $20,000.
    - *Source:* Customer requirement, SST-US typically expends $40,000 on a spacecraft material and this design shall reduce that metric by 50%.
    - Verification: Budget analysis
  - DR 2.2: Structure design manufacturing and assembling shall take less than 9 months.
    - *Source:* Customer requirement, SST-US typically spends 18 months on spacecraft manufacturing and assembling and this design shall reduce that metric by 50%.
    - Verification: Manufacturing estimates and analysis
  - DR 2.3: Structure design manufacturing and building labor shall cost less than $80,000.
    - *Source:* Customer requirement. This is a 50% reduction of SST-US's typical manufacturing and building cost of $160,000 and will help the company meet the goal total price of $6 million.
    - Verification: Budget estimates and analysis

Requirements: FR3

- **FR 3:** FeatherCraft Structure shall be designed to launch from the ISS.
  - DR 3.1: FeatherCraft structure in launch configuration shall be designed to not be damaged by simulated launch environment, up to a 9.47 grms random vibration environment with safety factors as outlined in the GEVS ISS Pressured Volume Hardware Common Interface Requirements Document Rev C.
    - *Source* : Customer requirement. To remain profitable, the FeatherCraft package needs to be reliable and provide a robust platform for their customers, as well as meet all NASA requirements for launch to the ISS.
    - Verification: Vibration test executed on STM in FR 6 and measurement of STM before and after vibration test

Requirements: FR3

- DR 3.2 FeatherCraft structure design including mounted components shall fit within the volume of 30”x30”x19”.
  - *Source:* The spacecraft as a whole must be placed within the Kaber volume to be deployed and begin its mission. This volume ensures at least 2’’ of space between the spacecraft volume and the edge of the JEM airlock. Soft stowed as defined by GEVS ISS Pressured Volume Hardware Common Interface Requirements Document Rev C.
  - Verification: Inspection of drawings, demonstration with measurement

Requirements: FR4

- **FR 4:** FeatherCraft structure design shall interface with SST-US-provided spacecraft components and mission design.
  - DR 4.1: FeatherCraft structure design shall provide mounting positions on three sides of the structure for one 30’’x30’’x0.125’’ solar panels of mass 2 kg and two 30’’x18.976’’x0.125’’ solar panel of mass 1.5 kg.
    - *Source*: Customer requirement, three solar panel arrays in the configuration provides the customer enough power for the spacecraft
    - Verification: Modeling and analysis in STK, STM demonstration in FR 5.
  - DR 4.2: FeatherCraft structure design shall provide a mounting position for a 29.094’’x18.976’’x0.125’’ propulsion plate of mass 12 kg on Side 1.
    - Source: Customer requirement. The propulsion plate design has been finalized, and its dimensions necessitate its mounting location.
    - Verification: modeling and inspection of drawings, STM demonstration in FR 5
  - DR 4.3 FeatherCraft structure design shall have an internal structural component equally bisecting the 19’’ height dimension to provide mounting capabilities to the avionics components and payload components.
    - *Source:* Customer requirement. The mounting capabilities are necessary for the customer to assemble the spacecraft easily and safely. This bisecting structural component defines a payload bay and avionics bay so that a payload volume is defined for potential customers.
    - Verification: Inspection of drawings, Test (measure STM)

Requirements: FR4

- DR 4.4 FeatherCraft structure design shall dissipate up to 100 W of heat generated equally by avionics and payload bays at an operating temperature of -20 to 50 degrees C.
  - *Source:* Customer requirement. The maximum power output is estimated by the customer to remain below 100W. The specifics of this analysis are presented in Section 4.1.4.
  - Verification: Analysis
  - DR 4.4.1: FeatherCraft structure design shall have a radiative material on a side of the structure facing deep space.
    - *Source:* Customer requirement, derived from DR 4.4. This shall be determined in the same STK analysis that determines which sides of the spacecraft experience the most direct sunlight over a year.
    - Verification: Inspection of model, STK analysis
- DR 4.5 FeatherCraft structure design shall keep side 5 open.
  - *Source:* Customer requirement, payload use and space for antenna(s) facing nadir.
  - Verification: modeling, demonstration in STM

Requirements: FR5

- **FR 5:** A manufactured STM of the FeatherCraft structure design shall be used to validate the design through a modal vibration sweep and a random vibration test to the requirements of SSP 50835.
  - DR 5.1 STM shall be manufactured with sufficient similarity to the structural design such that it can be used for validation of the designed structure. It shall fulfill all of the requirements of the designed structure with the exception of the 5kg structural mass requirement, which may be exceeded.
    - *Source:* Customer requirement. A physical test must be performed to provide a baseline of feasibility; this can only be proved if the STM is similar to the design. However, the materials of the STM are constrained to the FeatherCraft team budget.
    - Verification: Analysis of materials
  - DR 5.2 STM shall be tested on a vibration table for a vibration profile provided in GEVS table 3.1.1.2.1.2.3.2-1
    - *Source:* Page 3-17 of ISS Pressured Volume Hardware Common Interface Requirements Document Rev C. It is estimated by this document that with a vibration table setting of 9.47 grms, the bubble-wrapped structure should experience 1.29 grms.
    - Verification: Inspection of test plan, test

Requirements: FR5

- DR 5.3 STM shall support loads through vibration testing that are equivalent to the required loading of the designed structure.
  - *Source:* Validation of FR 5
  - Verification: Demonstration
  - DR 5.3.1 STM shall have a provided mass analog propulsion plate of mass and size specified in DR 3.2 mounted to side 1
    - *Source:* Validation of DR 5.2 and FR 5.
    - Verification: Inspection
  - DR 5.3.2 STM shall have provided solar panel mass analog plates mounted on sides determined from DR 4.1 with mass and size specified in DR 4.1
    - *Source:* Validation of DR 4.1 and FR 5.
    - Verification: Inspection
  - DR 5.3.3 STM shall have an internal loading of 35 kg mounted inside the structure in the avionics bay to represent the avionics mass.
    - *Source:* Validation of DR 4.3 and FR 5. This is the total mass of all spacecraft components SST-US intends to place inside the avionics bay.
    - Verification: Measure mass, Inspection of drawings of vibration test configuration
  - DR 5.3.4 STM shall have an internal loading of 47.5 kg mounted inside the structure in the payload bay to represent the payload mass.
    - *Source:* Validation of DR 4.3 and FR 5. This is the SST-US provided estimate it will allow for payload mass.
    - Verification: Measure mass, inspection of drawings of vibration test configuration

Requirements: FR5

- DR 5.4: STM shall be wrapped in Pyrell Foam prior to testing.
  - *Source:* Customer Requirement stemming from ISS Pressured Volume Hardware Common Interface Requirements Document Rev C. The test shall be performed with the STM in the flight configuration.
  - Verification: Demonstration, inspection
- DR 5.5 FEM model shall be verified using structural accelerometer information.
  - *Source:* Provides evidence for completion of FR 6 and allows data collection for later correlation to designed structure. The number of accelerometers necessary and their positons will be determined after the structural design is determined.
  - Verification: Analysis of FEM model, inspection of drawings of vibration test configuration

Requirements: FR5

- DR 5.6 A data acquisition and analysis system shall be designed and created for this test and further tests of structural STMs to validate structural properties.
  - *Source:* Customer requirement, it will save the project money to own a data acquisition system, and this can be used for custom data collection and future tests
  - Verification: Demonstration
  - DR 5.6.1 Accelerometers determined by DR 5.5 shall be acquired for the testing of the STM, with one tri-axial accelerometer and one single-axis accelerometer retained by the design team.
    - *Source:* Customer requirement. The number of accelerometers needed to validate the FEM model will be determined by the structure shape, and SST-US would like one accelerometer to base an expanded data acquisition system on if they could acquire it at the end of the project.
    - Verification: Analysis of FEM model, demonstration
  - DR 5.6.2 DAQ shall contain 60 channels for the possibility of 20 tri-axial accelerometer inputs.
    - *Source:* Customer requirement, although the budget of the project limits the number of accelerometers to be used for the test in spring, future tests with 20 tri-axial accelerometers may be performed and data would be taken from all 20 at the same time.
    - Verification: Analysis of circuitry and inspection of design drawings

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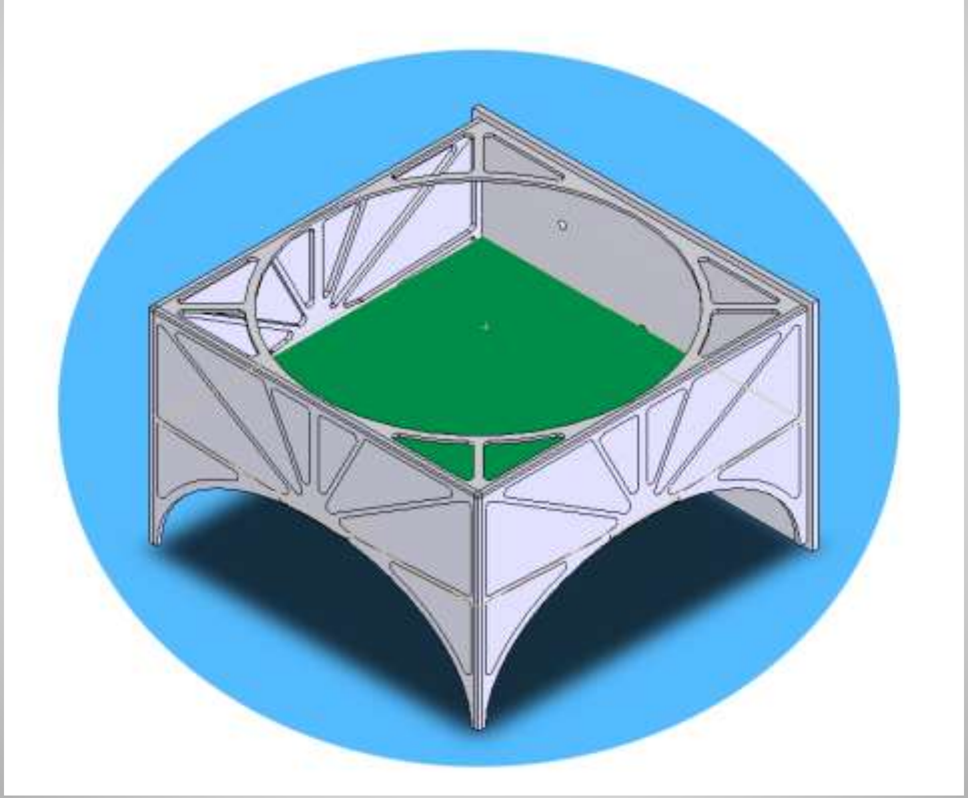
Requirements: FR5

- DR 5.6.3: Accelerometer data shall display in the form of power spectral density plots during each test
  - *Source:* Customer requirement, safety for structure during test, real-time performance analysis
  - Verification: Demonstration
- DR 5.6.4 Accelerometer data shall be saved during each test in an Excel-compatible format
  - *Source:* Customer requirement, post-test analysis
  - Verification: Demonstration
- DR 5.6.5 Accelerometer data shall be transferable via USB from the microprocessor collecting data to any personal computer running Microsoft Windows operating systems.
  - *Source:* Customer Requirement. To prevent errors and wasted time, data should be easy to transfer to any of SST-US' computers.
  - Verification: Demonstration

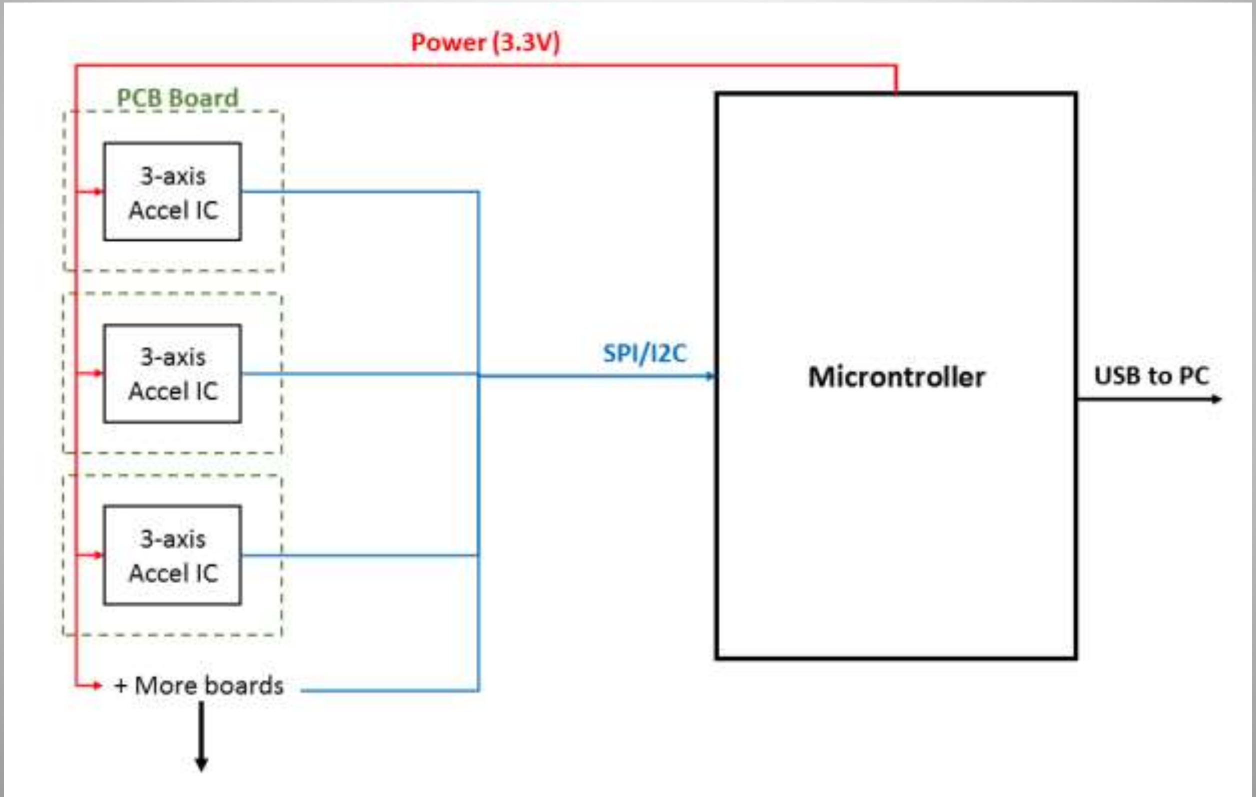
TRADITIONAL APPROACH:



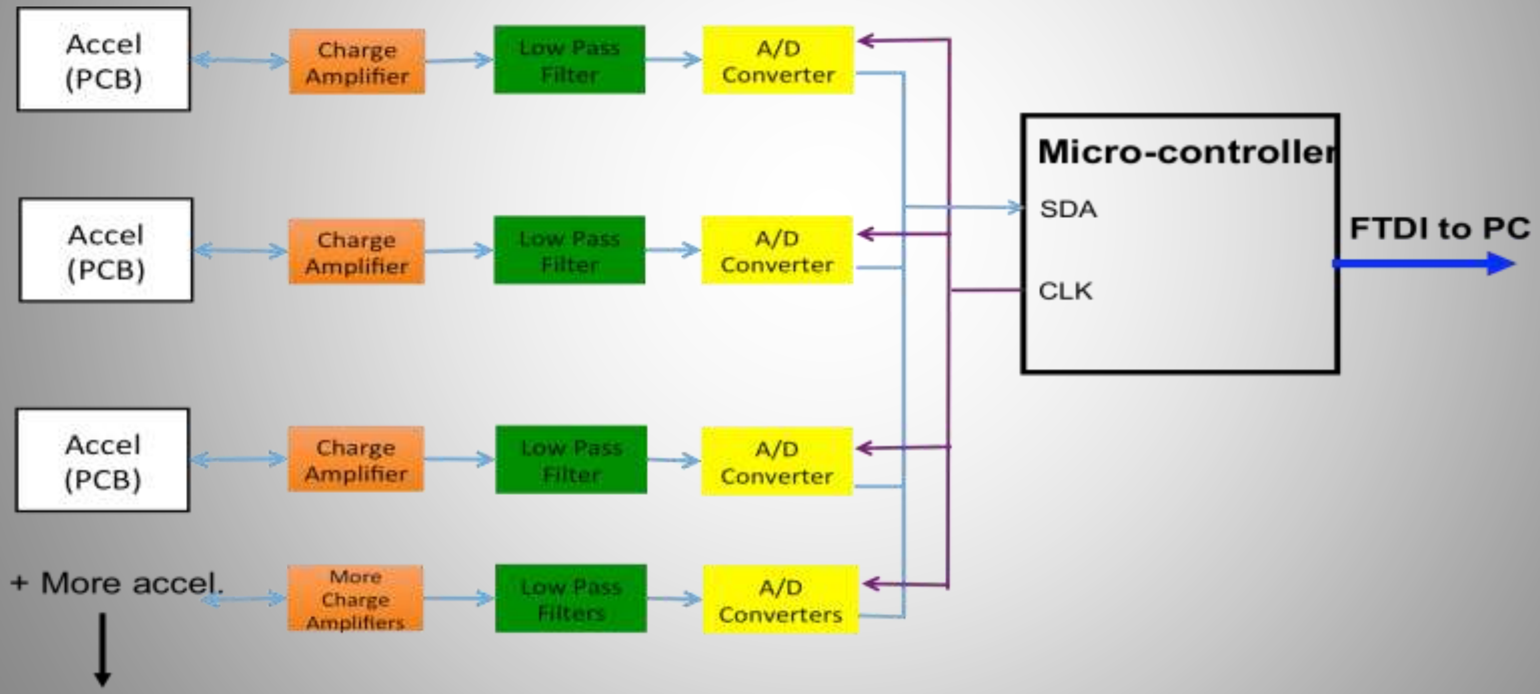
WEIGHT RELIEVED PANELS:

COLUMNS:

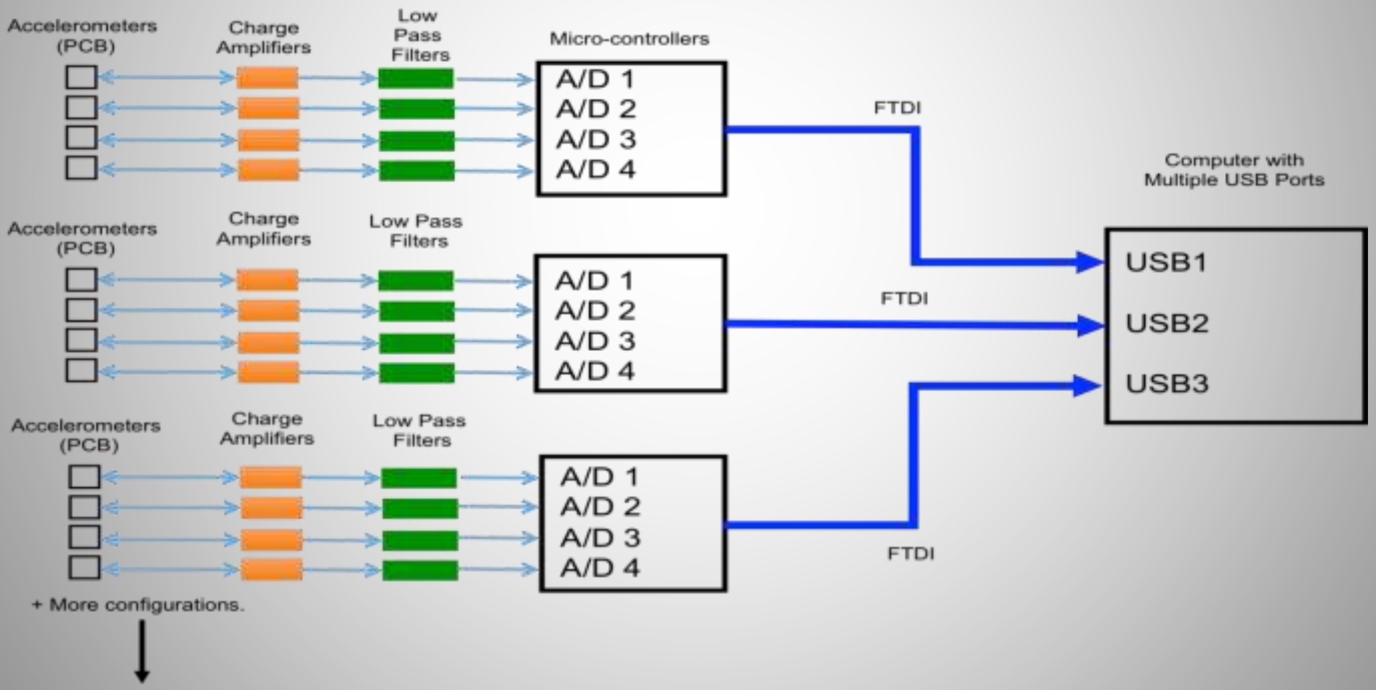
Digital Output Accelerometers:



Build DAQ System w/ 1 Micro-Controller:



Build DAQ System w/ Multiple Micro-Controllers:



Structure Trade Study – Metric Definitions:

	10	9	8	7	6	5	4	3	2	1
Material Cost: [kg]	1	2	3	5	7.5	10	12.5	15	17.5	20
Mass [kg]	4	5	5.5	6	6.5	7	7.5	8	9	>10
Ease of Manufacturing: [hrs]	10	20	30	40	50	60	70	80	90	100
Ease of Analysis:	A monkey could do it	Plug and play	Very little effort required	Little effort required	Some effort required	Neutral	Effort required	Much effort required	Too much effort required	I quit

Chosen Materials

Facing Material

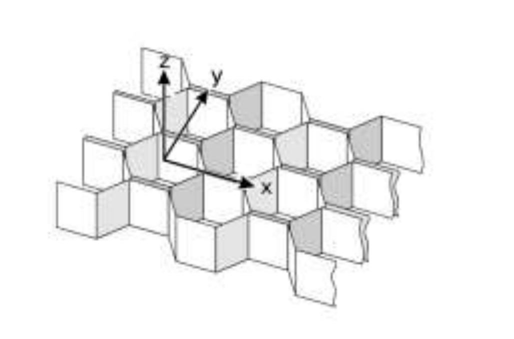
Woven Carbon Epoxy (G793-5HS)

- 1 ply (.3mm, ~12 mils)
- $\sigma_{u,c} = 600\ MPa$
- $\sigma_{u,,t} = 700\ MPa\ \sigma_{u,c} = 600\ MPa$
- $Ex_t = 70GPa, \quad Ex_c = 60GPa$
- $\rho = .45 \frac{kg}{m^2}$

Core Material

5052 Expanded Aluminum Honeycomb

- ½" thickness, ¼" cell size
- $\rho = 1.612 \frac{kg}{m^2}$
- $\sigma_z = 10\ MPa,\ E_z = 2.345GPa$
- $\tau_x = 4.8MPa, G_{xz} = .896GPa$
- $\tau_y = 2.9MPa, G_{yz} = .364\ GPa$



Also looking at M55J fibers (0/90 Fabric)

- $\sigma_u = 827\ MPa$
- $E_x = 134GPa$
- $\rho = .478 \frac{kg}{m^2}$

Also HRH10 Nomex Honeycomb

- ½" thickness, 1/8" cell size
- $\rho = 1.56 \frac{kg}{m^2}$
- $\sigma_z = 11.5\ MPa, E_z = .5GPa$
- $\tau_x = 3\ MPa, G_{xz} = .1GPa$
- $\tau_y = 1.9MPa, G_{yz} = .06\ GPa$

Accelerometer Trade Study – Metric Definitions:

	10	9	8	7	6	5	4	3	2	1
Unit Cost	< $1	$1-$5	$5-$10	$10-$50	$50-$100	$100-$250	$250-$500	$500-$750	$750-$1000	>$1000
Reliability	90-100%	80-90%	70-80%	60-70%	50-60%	40-50%	30-40%	20-30%	10-20%	0-10%
Ease of interface to the structure	A baby can do it	Plug and play	Very little effort required	Little effort required	Some effort required	Neutral	Effort required	Much effort required	Too much effort required	I quit
Ease of design (including time invested)	Done!	Very easy	Easy	Somewhat easy	Neutral	Some what hard	Hard	Very hard	Uber hard	Impossible
Size/mass	0 - 0.5g	0.5 - 1g	1 - 1.5g	1.5 - 2g	2 - 2.5g	2.5 - 3g	3 - 3.5g	3.5 - 4g	4 - 4.5g	>4.5g

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Accelerometer Trade Study:

		Digital Accelerometers	Buy Piezoelectric Accelerometers	Rent Piezoelectric Accelerometers
Criteria:	Weight:	Score:	Score:	Score:
Unit Cost	37.5%	8	2	5
Reliability	37.5%	1	10	9
Ease of Interface to the Structure	5%	6	9	9
Ease of Design (including time invested)	15%	4	10	10
Size/mass	5%	8	2	2
Weighted Total:		4.625	6.55	7.3

DAQ Hardware – Metric Definitions:

	10	9	8	7	6	5	4	3	2	1
Manufacturing Difficulty	A baby can do it	Plug and play	Very little effort required	Little effort required	Some effort required	Neutral	Effort required	Much effort required	Too much effort required	I quit
Total Cost	<$20	$20-$75	$75-$150	$150-$250	$250-$375	$375-$525	$525-$700	$500-$700	$700-$1000	>$1000
Complexity of Design	No work involved	Extremely Simple	Very Simple	Simple	Somewhat simple	Neutral	Somewhat Complex	Complex	Extremely Complex	Impossible
Reliability	90-100%	80-90%	70-80%	60-70%	50-60%	40-50%	30-40%	20-30%	10-20%	0-10%

DAQ Hardware Trade Study:

		Digital DAQ	Single μC	Multiple μC
Criteria:	Weight:	Score:	Score:	Score:
Manufacturing Difficulty	10%	7	4	3
Total Cost	40%	8	4	5
Complexity of Design	10%	5	4	3
Reliability	40%	1	9	8
Weighted Total		4.8	6.0	5.8

Software Trade Study – Metric Definitions:

	10	9	8	7	6	5	4	3	2	1
Cost	Free	$50-$100	$100-$150	$150-$200	$200-$250	$250-$300	$300-$350	$350-$450	$400-$450	>$450
Ease of implementation	A baby can do it	Plug and play	Very little effort required	Little effort required	Some effort required	Neutral	Effort required	Much effort required	Too much effort required	I quit
Resources Available	You can ask your mom for help	Courses taught on this, easy tutorials	Resident experts along with lower level resources	Profs., peers, online material	Peers, abundant online material	Peers, some online resources	Manuals, few online resources	Few online resources	Select books offer resources	No help from any resource

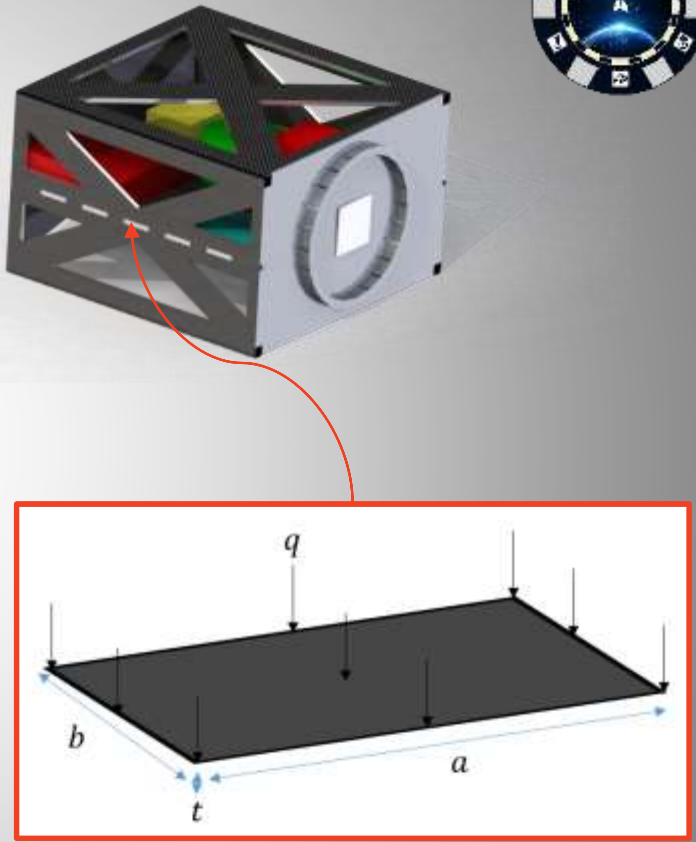
SURREY
SATELLITE TECHNOLOGY US

Data Analysis Software Trade Study:

		Python	Perl	LabVIEW
Criteria:	Weight:	Score:	Score:	Score:
Cost	20%	10	10	5
Ease of implementation	60%	6	4	7
Resources Available	20%	9	9	8
Weighted Total		7.4	6.2	6.8

Natural Frequency

- Tough without a good numerical model
- For sandwich panels, bending stiffness is:
  - $D = \frac{E_f}{(1-\nu^2)}\left(\frac{t^2h^2}{2t}\right) = 1455Nm$
- From *Roark,*
  - $f_n = \frac{K_n}{2\pi}\sqrt{\frac{Dg}{qa^4}}$
    - $K_1 = 19.7, K_2 = 49.3$ (from $\frac{a}{b} = 1$)
    - $q = \frac{6.16 \cdot 9.81 \cdot 80}{.761^2} = 9.38KPa$
    - $a = .7614m$
  - First two modes: 6.7 Hz, 16.7 Hz
- Bad from a spacecraft point of view – should be ~30-60
- More study needed
  - Frequency coupling in Cargo Transport
  - Stiffeners (post in middle of plate)



Edges simply supported

Factors of Safety and Loads

- NASA: GSFC-STD-7000 April 2005

Table 2.2-3
Flight Hardware Design/Analysis Factors of Safety Applied to Limit Loads [1,2]

Type	Static	Sine	Random/Acoustic[4]
Metallic Yield	1.25[3]	1.25	1.6
Metallic Ultimate	1.4[3]	1.4	1.8
Stability Ultimate	1.4	1.4	1.8
Beryllium Yield	1.4	1.4	1.8
Beryllium Ultimate	1.6	1.6	2.0
Composite Ultimate	1.5	1.5	1.9
Bonded Inserts/Joints Ultimate	1.5	1.5	1.9

- Safety factor of 1.9 is chosen to apply to all analysis
- Additional FOS=2 is applied to buckling due to moment growth with deflection, this shall prevent catastrophic failure.

- Jacob Job Wijker, Spacecraft Structures, © 2008 Springer-Verlag Berlin Heidelberg

Table 6.2 Transportation limit load factors [NASA-HDBK-7005]

Medium/Mode	Longitudinal load factors	Lateral load factors	Vertical load factors
Water	±0.5	±2.5	±2.5
Air	±3.0	±1.5	±3,0
Ground			
• Truck	±3,5	±2.0	±6.0
• Rail (humping shocks)	±6.0 to ±30.0	±2.0 to ±5.0	±4.0 to ±15.0
• Rail (rolling)	±0.25 to ±3.0	±0.25 to ±0.75	±0.2 to ±3.0
• Slowly moving dolly	±3,1	±0.75	±2.0

The transportation loads should be included in the design analysis unless special protection is provided to assure that they contribute negligible damage compared with the other (flight) loads.

- Current design is based on quasi-static load of 6.16 times the surface acceleration
- Structure can handle truck transportation loads

STRUCTURE DETAIL: Tube - Plate

Assume: 8 bonding places, fs=1.9, 50% effective bonding area

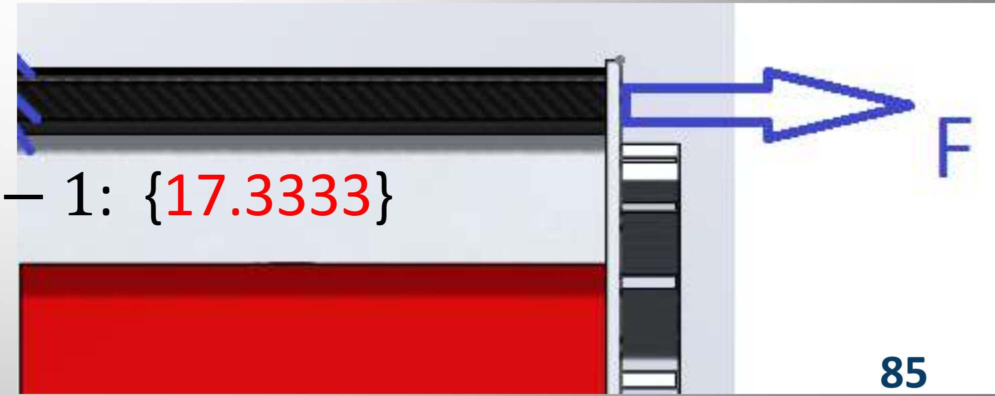
tt = 1/16”(thickness of tube wall); W = 1”(inside width)

L = 1”(length of glue-in insert); A = W*L*4*0.5 (m2)

$\tau = F * \frac{fs}{A}$: {1.20546*10^6 Pa}

epoxyShearStr=22.1*10^6 Pa

Design Margin = $\frac{epoxyShearStr}{\tau 2} - 1$: {17.3333}



STRUCTURE DETAIL: Column buckling

Assume: full load is taken by 1 column, FS = 1.9*2

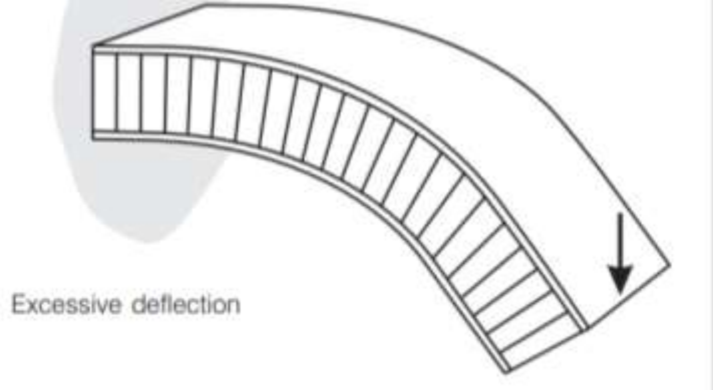
W = 1.3”; L = 28”; E = $7 * 10^{10}$ (Pa - carbon fiber fabric’ modulus)

$I = \frac{2}{3} * t * W^3$: {3.81*10^{-8} m^4 }; $Pcr = \pi^2 * \frac{EI}{L^2}$ (N)

CriticalLoad = $\frac{Pcr}{2*1.9}$: {12767 N}

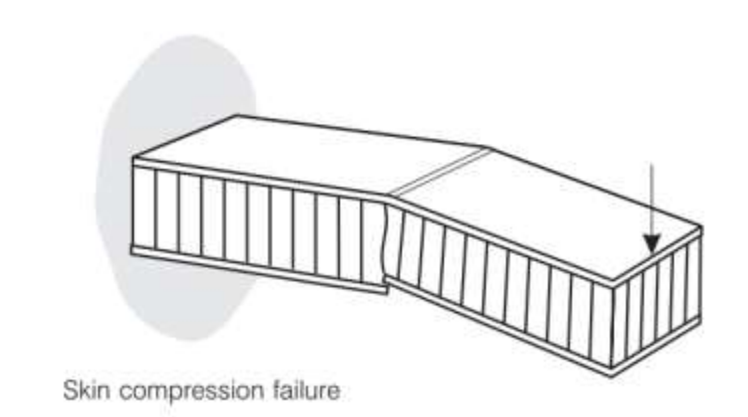
Design Margin = $\frac{CriticalLoad}{F} - 1$: {1.09}

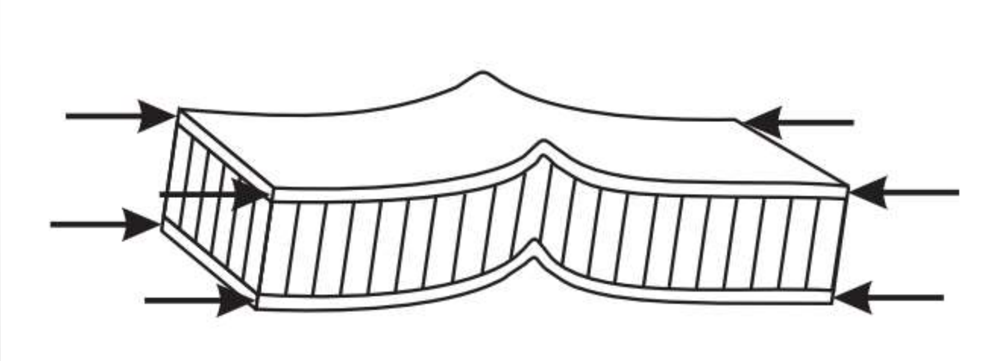
Sandwich Panel Failure Modes



Main failure modes of sandwich panels:

- Skin strength (below)
- Insufficient panel stiffness (above, right)
- Panel buckling (below, right)



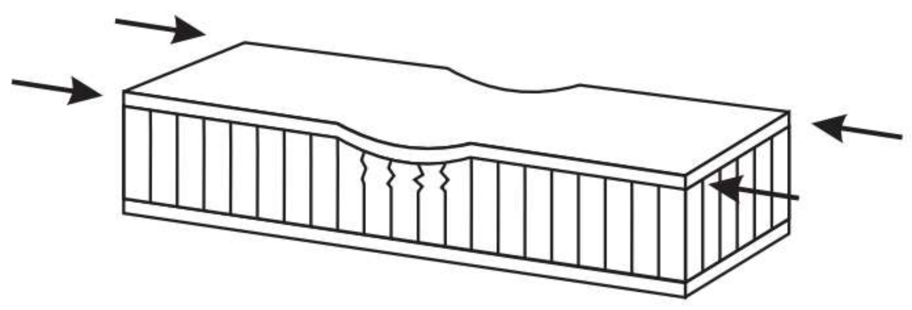


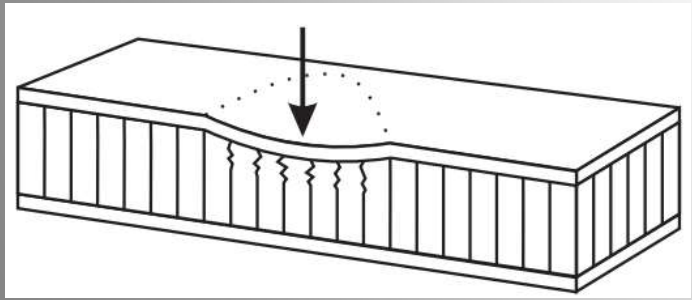
All images from *Honeycomb Design Technology,* Hexcel, 2000

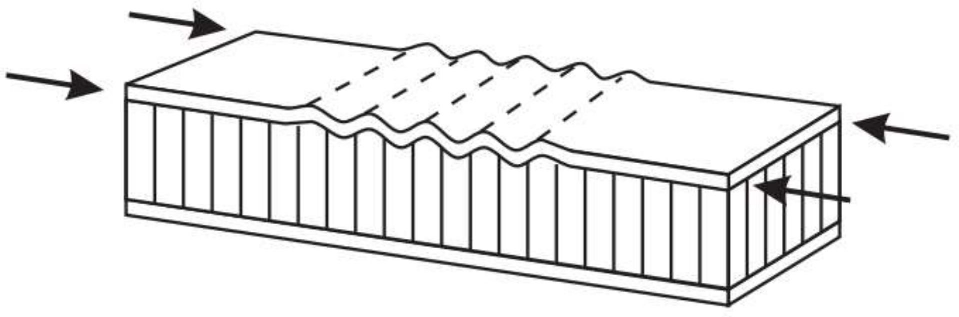
Sandwich Panel Failure Modes

Main failure modes of sandwich panels (cont.)

- Local Compression (below)
- Skin wrinkling (above, right)
- Intra-cell buckling (below, right)







All images from *Honeycomb Design Technology,* Hexcel, 2000

Adhesives Analysis

- Total adhesive needed
  - Assuming largest surface area, total of avionics components is 0.467 m^2.
  - Payload surface area is not known, so assuming entire mid-plate is used for mounting, (30''x30'') this totals to 0.581 m^2.
  - Joints are assumed to use much less adhesive than payload and avionics mounting because of the small area, so an estimate of 25% the total payload and avionics surface area is assumed for a total surface area of 1.39 m^2.
  - Assumed thickness of 0.005'' (standard as defined by MasterBonds.com) and adding a realistic margin of 0.001'', the total volume of adhesive required is $V = 0.000154\, m * 1.39\, m^2 = 0.000212\, m^3 = 0.224$ qrt.
  - For mass calculations, density is taken as 1360 kg/m^3 thus $m = 1360 \frac{kg}{m^3} * 0.000212\, m^3 = 0.288\, kg$

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ADHESIVES:

- Hysol EA 9394 Aerospace Adhesive
  - Customer recommended
  - 1 qrt attainable at skygeek.com – $184.89
  - 1 qrt attainable at chemcenters.com - $210.00
  - Bonded in composites lab, curing takes 24 hours with support tooling with full strength attained after 3-5 days
- Scotch-Weld 2216 Epoxy
  - Customer recommended, can be removed with heat
  - 1 qrt attainable at amazon.com – $275.74
  - 1 qrt attainable at ellsworth.com - $282.58
  - Handling strength at 10 hours, cured for 7 days

SURREY
SATELLITE TECHNOLOGY US

Scotch-Weld 2216 Epoxy

- Rated for temperatures up to 82 ^{o}C but significant drop in shear strength at this temperature (From 22.1 MPa to 2.8 MPa)
- Tested on fiber-reinforced polyester and polycarbonate
- Testing will be performed for expected heat range on carbon fiber aluminum
- Data sheet: http://www.farnell.com/datasheets/692030.pdf
- Safety data sheet: http://multimedia.3m.com/mws/mediawebserver?mwsId=SSSSSuUn_zu8l00x4Yt94x_Gnv70k17zHvu9lxtD7SSSSSS--

Outgassing

- Adhesives
  - Hysol 9394 – 0.0023% CVCM (http://matdb.jaxa.jp/OutgassingRate/pdf/0204-2.pdf)
  - 2216 Epoxy – 0.04% CVCM (http://multimedia.3m.com/mws/media/153955O/3mtm-scotch-weldtm-epoxy-adhesive-2216-b-a.pdf)
  - CVCM – Collected Volatile Condensable Materials

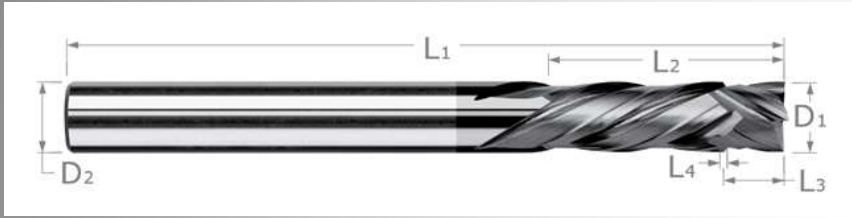
TILE SAW TO CUT PANELS:

Skil 7-inch Wet Tile Saw

ITLL recently purchased a wet tile saw for cutting ASEN 2001 carbon fiber tubes

- Panels
  - Could manufacture platform to make table larger and decrease blade height
  - Add fence to keep stock straight
- Columns
  - Feasible option for quickly cutting to 30 inch length

COMPOSITE CUTTING END MILLS:



Harvey Tool advertises both of these end mill-style tools as ideal for composite materials.

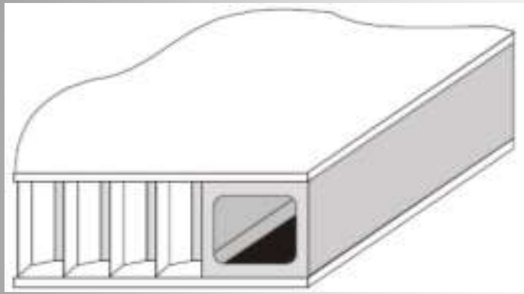
Top: Compression tool helps prevent delamination

Bottom: Diamond cut functions as an abrasive cutter

CNC router table to avoids coolant

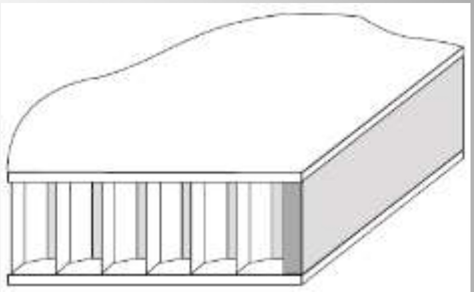
EDGE CLOSE OUT:

Box Extrusion:



- Use end mill or router table with a fly cutter to clear core
- Used where panels interface with columns

Epoxy Fill In:



- Use block to push core back from edge
- Fill with Loctite TF 3056FR

SURREY SATELLITE TECHNOLOGY US

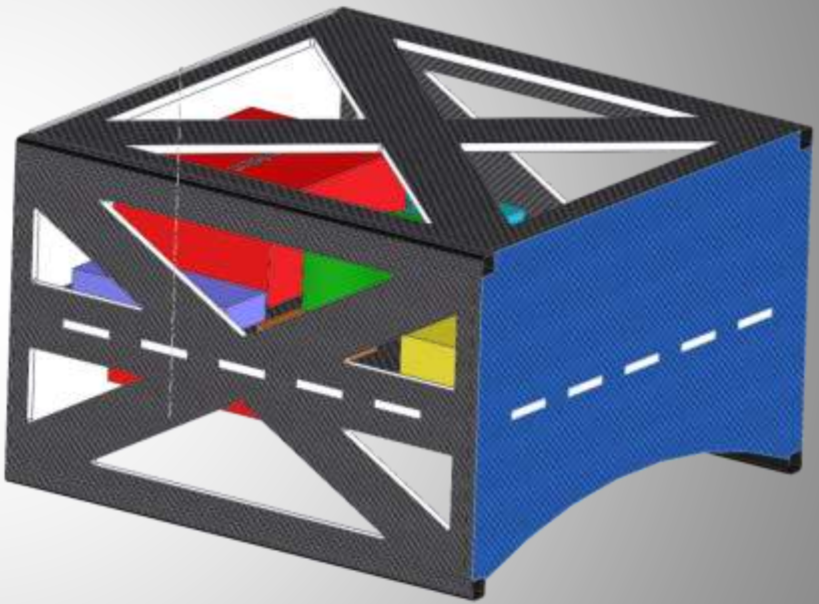
RADIATOR DESCRIPTION:

Requirement: Use one 19” x 30” panel of the structure as a radiator capable of dissipating 100 W

- Back of the Envelope performed using Stefan Boltzmann Law

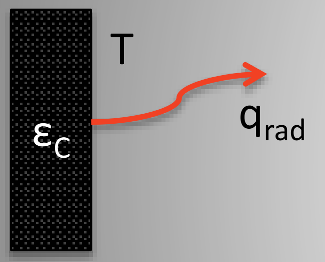
Assumptions:

- Radiator panel is facing deep space (T_∞ = 4 K)
- Panel temperature ~25°C (nominal operating temperature)



Thermal Radiation:

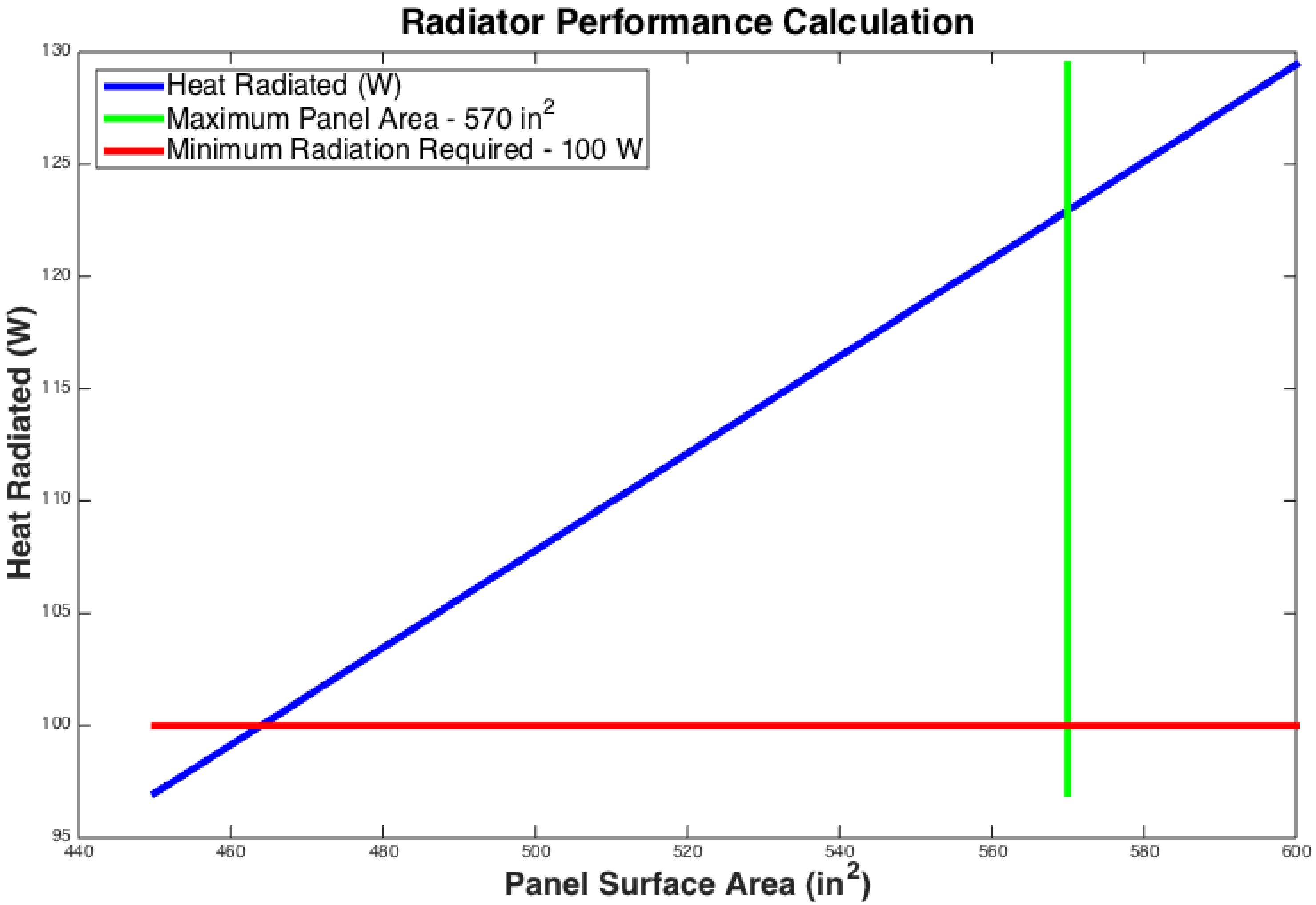
Thermal Radiation – Stefan-Boltzmann Law



$$q_{rad} = Radiated\ Energy$$
$$A = Panel\ Surface\ Area$$
$$\sigma = 5.67 * 10^{-8} \frac{W}{m^2 K^4}$$
$$\epsilon = Emissivity = 0.75$$
$$T = Panel\ Temperature = 298K$$

- BotE Calculation – Show that a structural (carbon fiber aluminum honeycomb) panel is capable of radiating 100 W
- Principles:
  - Stefan-Boltzmann Law. Find q as a function of panel surface area A
- Assumptions:
  - Panel is at 25°C, an estimated s/c operating temperature
  - Radiator is facing deep space
- Result:
  - Feasible within an area range of 460-570 square inches
  - Will use 460 square inches to help meet mass requirement

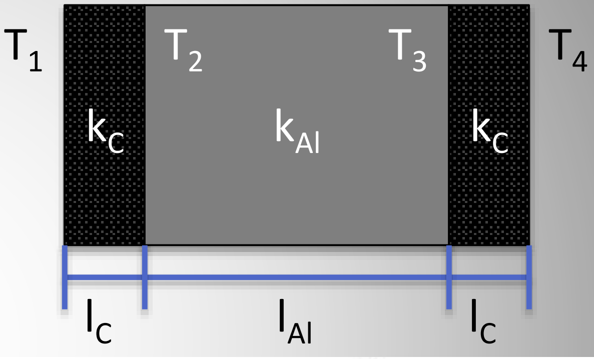
$$q_{rad} = A\sigma\epsilon T^4 = A * \left(5.67 * 10^{-8} \frac{W}{m^2 K^4}\right)(0.75)(298\ K)^4$$



Radiator Performance Calculation
Heat Radiated (W)
Maximum Panel Area - 570 in2
Minimum Radiation Required - 100 W
Heat Radiated (W)
Panel Surface Area (in2)
130
125
120
115
110
105
100
95
440
460
480
500
520
540
560
580
600

Thermal Conductivity

- BotE Calculation – Find the change in temperature from internal to external wall needed to conduct 100 W
- Principles:
  - 1-dimensional composite wall heat conduction
  - Thermal Resistance & Circuits
- Assumptions:
  - 1-dimensional heat conduction
  - Spacecraft nominal operating temperature of 25°C
- Result:
  - Needs ~0.3 K difference to conduct 100W
  - With deep space facing assumption, this is clearly feasible



$$R_{tot} = \frac{1}{\left(\frac{l_c}{k_c A}\right) + \left(\frac{l_{Al}}{k_{Al} A}\right) + \left(\frac{l_c}{k_c A}\right)}$$

$$= \frac{1}{\left(\frac{0.0003m}{156\frac{W}{mK} \cdot 460m^2}\right) + \left(\frac{0.0127m}{14.8\frac{W}{mK} \cdot 460m^2}\right) + \left(\frac{0.0003m}{156\frac{W}{mK} \cdot 460m^2}\right)} = 0.002904\frac{K}{W}$$

$$q_x = \frac{T_1 - T_4}{R_{tot}} \rightarrow T_4 = T_1 - q_x R_{tot} =$$

$$298K - 100\,W \cdot 0.002904\frac{K}{W} = 297.7\,K$$

SURREY
SATELLITE TECHNOLOGY US

Random Vibration Profile:

- Gives Random Vibration (RV) max envelopes for different frequencies and ranges of frequencies in g^2/Hz.
- Specifies RV max envelopes for unattenuated and attenuated environments
  - Unattenuated (9.47 grms): RV experienced by unwrapped cargo i.e. the input to the vibration table
  - Attenuated (: RV experienced by cargo wrapped in this specific configuration – SECO 88 and single Cargo Transfer Bag (CTB). This is what FISH will experience in flight and what it is being designed to survive.

Random Vibration Profile:

TABLE 3.1.1.2.1.2.3.2-1 UNATTENUATED AND ATTENUATED RANDOM VIBRATION ENVIRONMENTS FOR END ITEMS SOFT-STOWED IN A SINGLE CTB, X/Y/Z AXIS

Frequency (Hz)	Max. Flight RV Env[1]	20 lb ORU in Pyrell in a Single CTB
20	0.057 (g^2/Hz)	0.1465 (g^2/Hz)
20-153	0 (dB/oct)	-9.76 (dB/oct)
153	0.057 (g^2/Hz)	0.0002 (g^2/Hz)
153-190	+7.67 (dB/oct)	0 (dB/oct)
190	0.099 (g^2/Hz)	0.0002 (g^2/Hz)
190-250	0 (dB/oct)	0 (dB/oct)
250	0.099 (g^2/Hz)	0.0002 (g^2/Hz)
250-750	-1.61 (dB/oct)	0 (dB/oct)
750	0.055 (g^2/Hz)	0.0002 (g^2/Hz)
750-2000	-3.43 (dB/oct)	0 (dB/oct)
2000	0.018 (g^2/Hz)	0.0002 (g^2/Hz)
OA (grms)	**9.47**	**1.29**

Note:

1) Unattenuated RV levels are from Table 3.1.1.2.1.2.1-1.

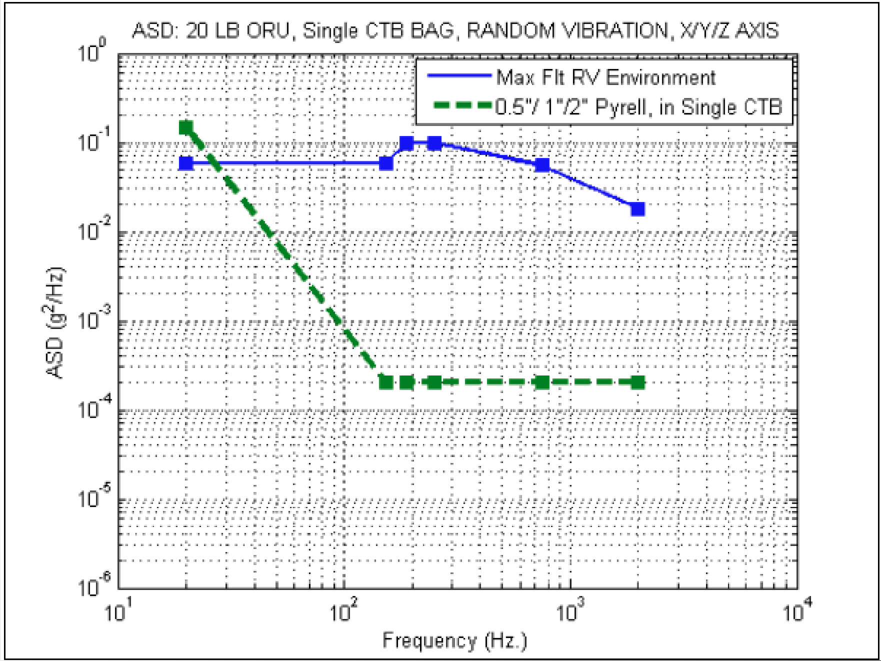
FAQ: What is grms?

- I'm glad you asked, allow me to explain:
- grms is the "Root Mean Square" of acceleration, and is the preferred method to characterize Random Vibration Loading
- Random Vibration response curves are plotted as Frequency (Hz.) vs. Acceleration Spectral Density (ASD, g^2/Hz.)
  - To calculate grms: Average the squared acceleration over frequency, and take the square root

grms Methodology

- Calculation of grms for random vibration test (20 Hz. – 2 kHz.):

$$grms = \sqrt{\int_{0}^{2000} ASD(f)\, df}$$



Sample ASD Plot for unattenuated and attenuated random vibration

Structure Wrapping

- Random vibration profile applies to a specific method of storage on launch vehicle
- Structure will be wrapped in ½” Pyrell Foam Type 2
- Structure will be stowed in single Cargo Transport Bag (CTB)
- Price and attainability of both the foam and CTB are currently being investigated

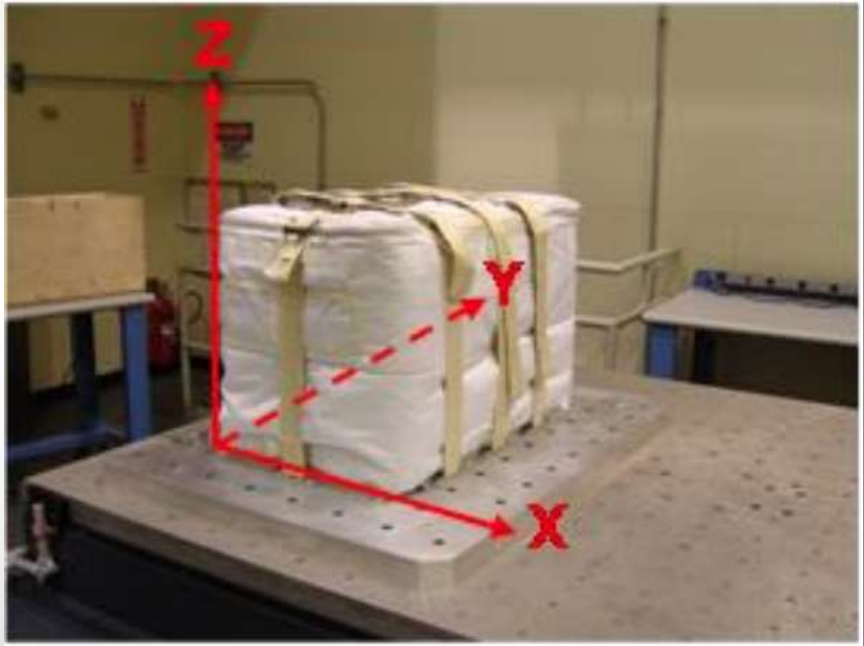


FIGURE 3.1.1.2.1.2.3.2-6 AXIS OF EXCITATION

ACCELEROMETER MOUNTING:

- Stiff adhesive recommended by manual
  - Superglue applied to bottom and pressed onto structure
- Signal transfer via shielded coaxial cable

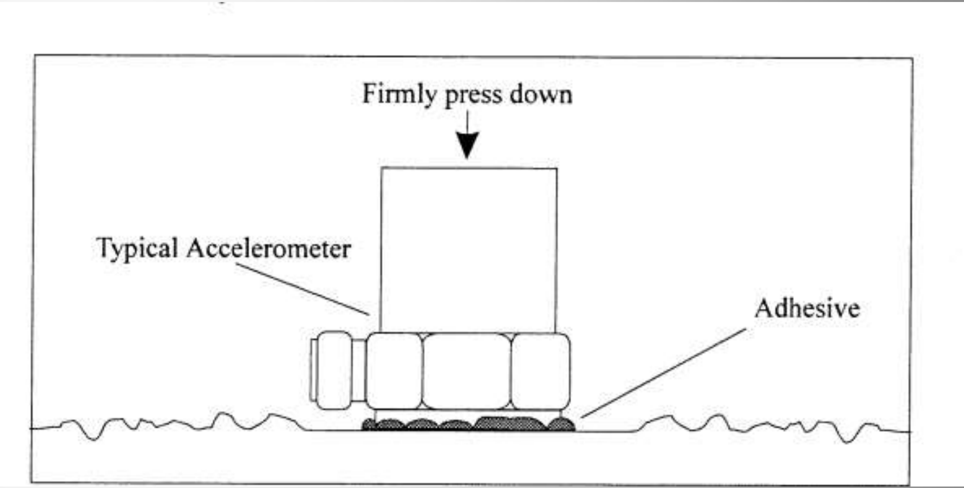
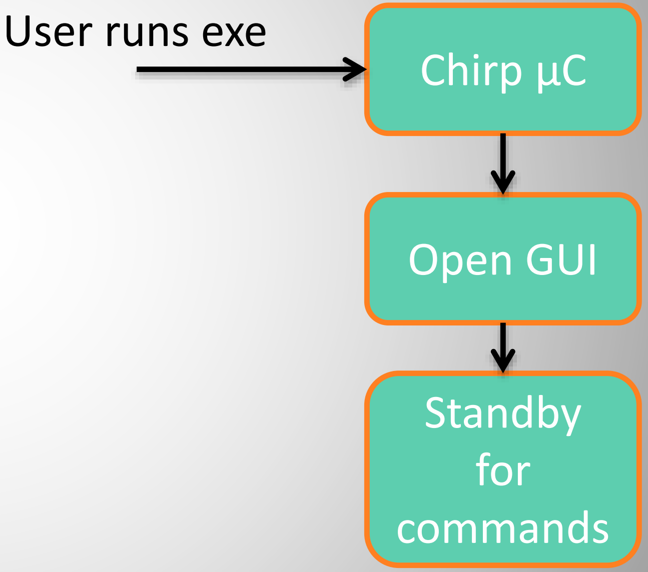


*Diagram provided by PCB

INITIALIZATION:

Description

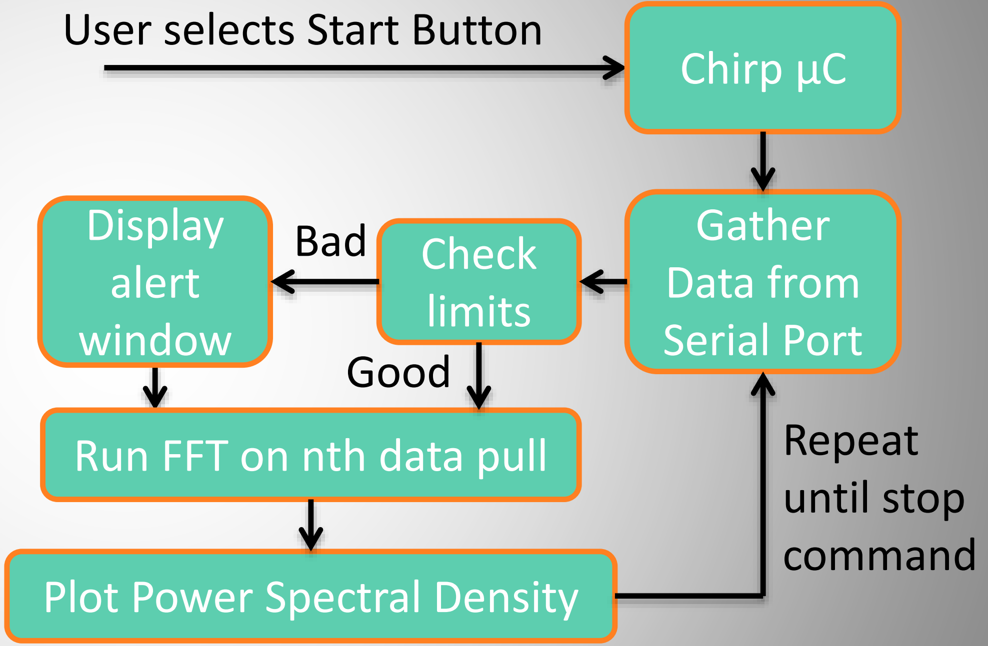
- Run from an executable off a USB stick.
- Created using libraries:
  - cx freeze
  - tkinter
  - pyserial
- Chirp µC to standby



RUN TEST:

Description

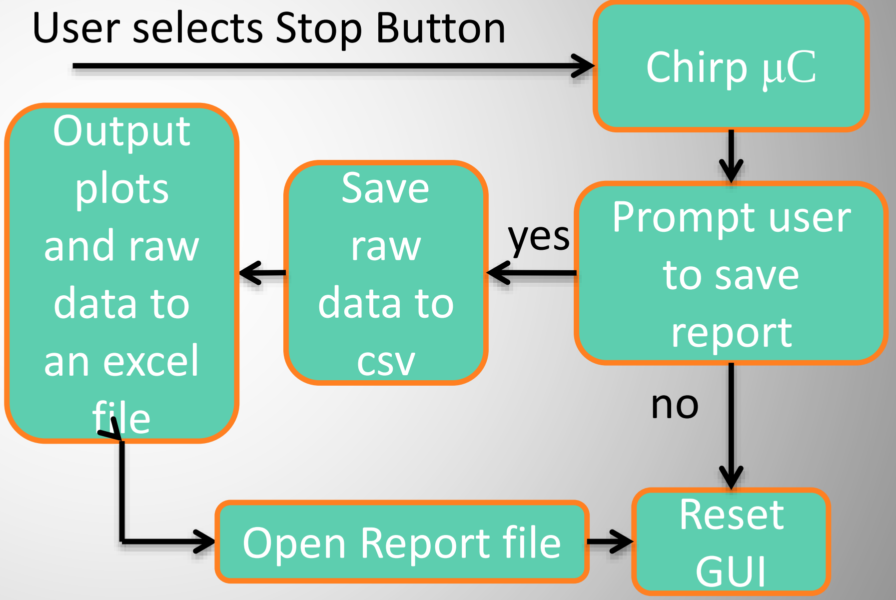
- Run from GUI button "Start."
- Created using libraries:
  - pyserial
  - matplotlib
  - numpy
- Chirp µC to gather data



STOP TEST:

Description

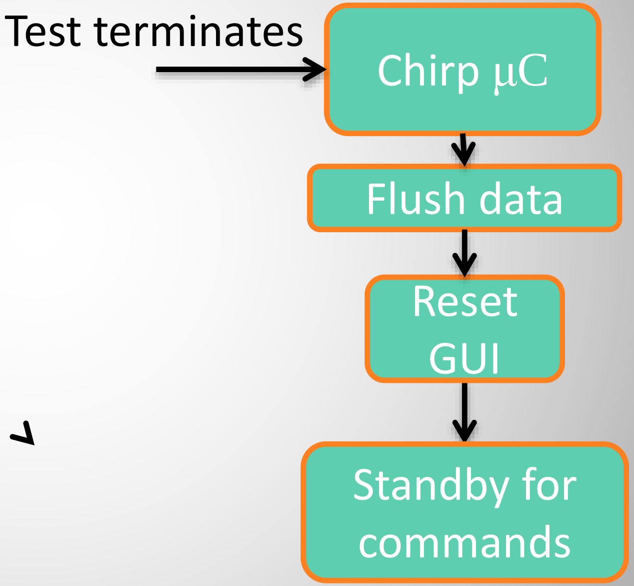
- Run from GUI button "Stop."
- Created using libraries:
  - pyserial
  - matplotlib
  - numpy
  - xlsxwriter
- Chirp µC to standby



RESET GUI:

Description

- Run automatically after a test has been stopped.
- Created using libraries:
  - pyserial
  - tkinter
- Chirp µC to standby



SELECTED LIBRARIES:

Library:	Function:	Python Release:
cx freeze	Converts Python to MS Executable	3.1 – 3.4
tkinter	GUI generation	3.1 – 3.5
pyserial	Serial port communications	3.0 – 3.4
numpy	Scientific computing package including FFT	3.2 – 3.4
matplotlib	Graphic plotting capability	3.1 – 3.4
xlsxwriter	Data read and write to MS excel format	3.1 – 3.5

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Analog to Digital Converter - FBD

FUNCTIONAL BLOCK DIAGRAM

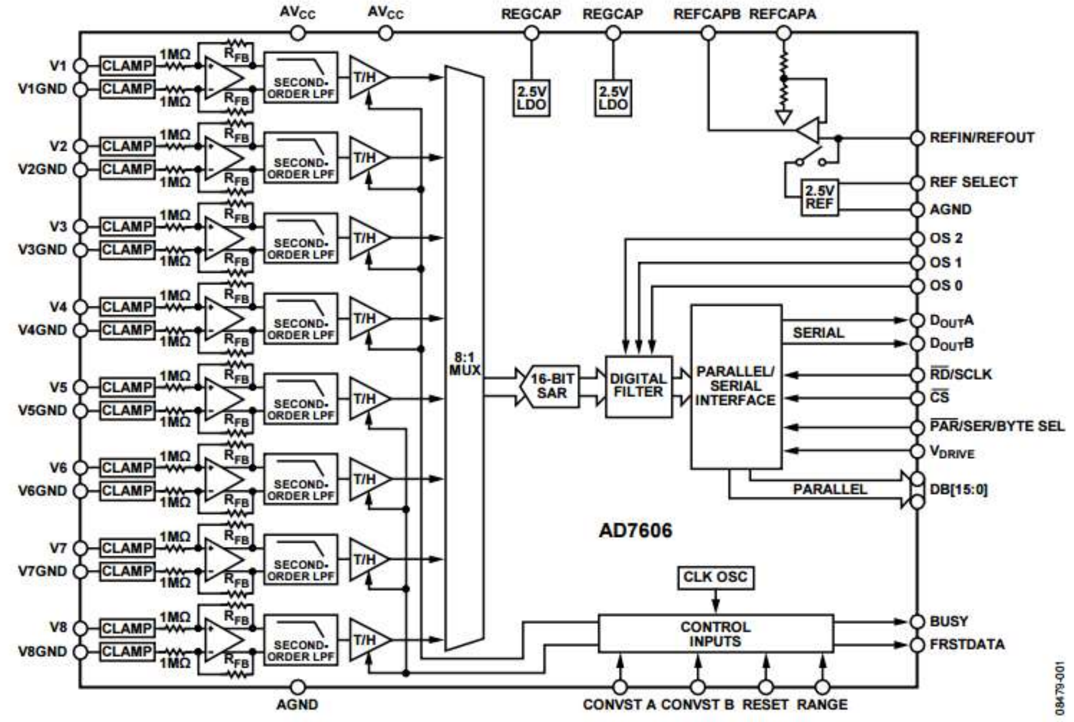
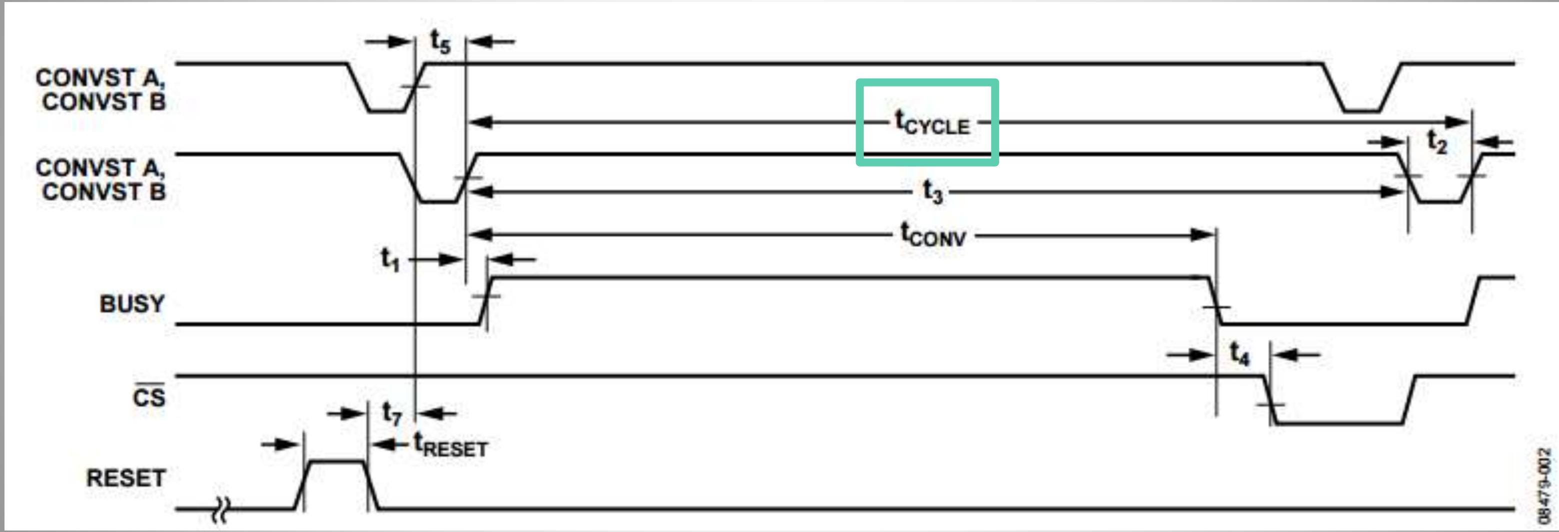


Figure 1.

- 16-bit simultaneous sampling
- Bipolar input range 5V
- Single 5V supply
- Parallel port data output
- Up to 200 kSPS on every channel

Analog to Digital Converter - Operation



t1 = 45ns   tconv = 4μs tcycle = 5μs

Accelerometer Mounting

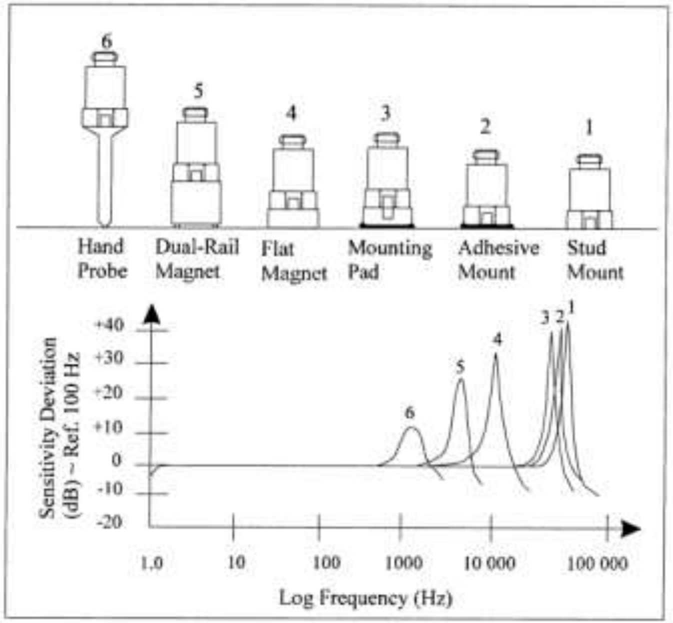


Figure 1. Assorted Mounting Configurations and Their Effects on High Frequency

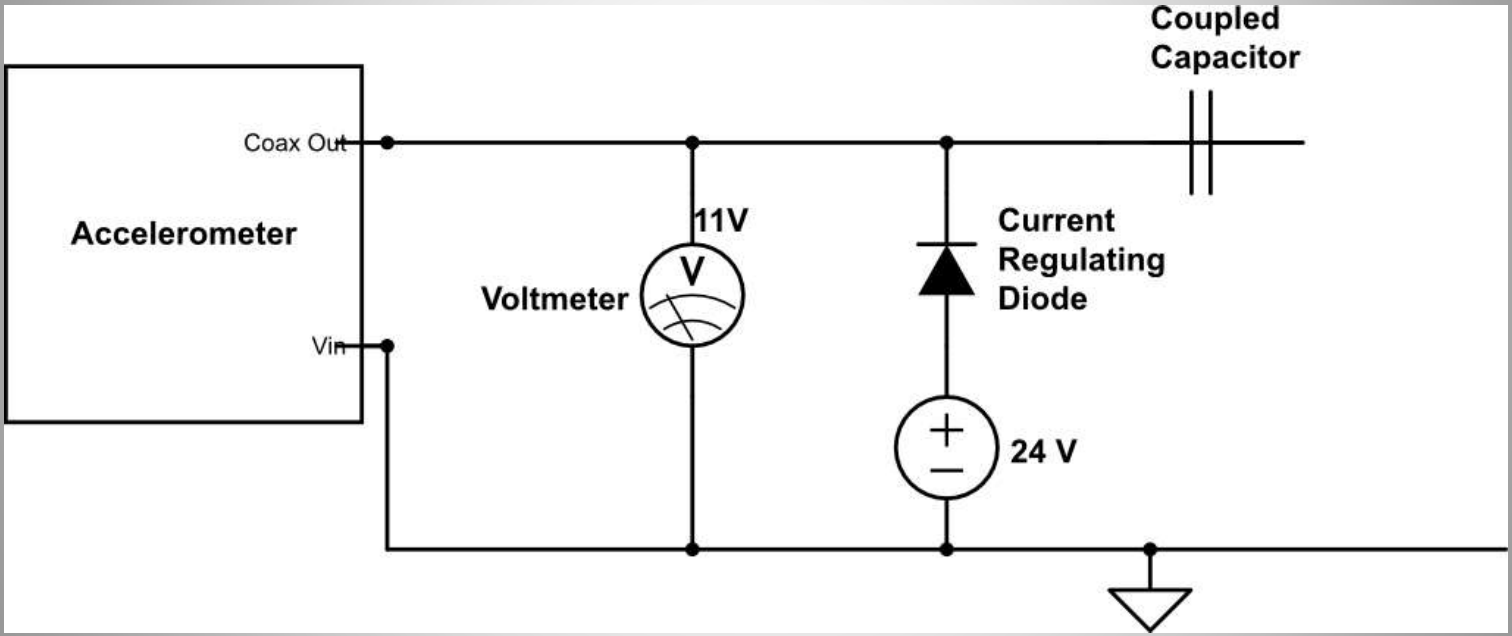
- Stud mounts impractical since they would require holes in structure

Data sampling speeds

uC features:
- 17.5Mbps UART
- Parallel Bit Data Port
- 70 mega instruction cycles per second

1. uC prompts ADC's to convert data
2. 4μs wait for conversion
3. Data retrieval requires 120 instruction cycles on parallel port, 1.7μs
4. Data parsing requires 3 instruction cycles per channel, 180 cycles, 2.6μs
5. Data to PC via UART 11 bit words (8-E-1), 75 μs
6. Total ~ 84μs
7. 4KHz requires data sample every 0.25 ms, leaves 0.15ms margin

CHARGE AMPLIFIER:



Why 60 Channels?

An estimate from Surrey's experienced mechanical engineer until we are able to perform a modal analysis test on the structure

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OUTLINED IN PRESENTATION:

Total Funds Available: $5000

Structure:		**Electronics HW:**		**Testing:**	
Panels	2000	Triple Axis Acc (purchase)	938	Cascade Tek (8 hours)	1800
Columns	332	Single Acis Acc (purchase)	297		
Adhesive	200	Power Supply	149		
		Triple Axis Acc (rent)	200		
		Single Acis Acc (rent)	60		
		Micro Controller	12		
		Acc PCB Board	33		
		Micro Controller PCB	33		
		AD Converter	31		
		Coaxial Cable	46		
		Coaxial Cable	147		
Sub - Total	2532		1946		1800
Project Budget:	6278	**Margin:**	-1278		

**** does NOT include: foam, shipping cost, sales tax, edge fillers****

PROJECT BUDGET – Surrey Pays for Vibe:

Total Funds Available: $6800

Structure:		**Electronics HW:**		**Testing:**	
Panels	2000	Triple Axis Acc (purchase)	938	Cascade Tek (8 hours)	0
Columns	332	Single Acis Acc (purchase)	297		
Adhesive	200	Power Supply	149		
		Triple Axis Acc (rent)	200		
		Single Acis Acc (rent)	60		
		Micro Controller	12		
		Acc PCB Board	33		
		Micro Controller PCB	33		
		AD Converter	31		
		Coaxial Cable	46		
		Coaxial Cable	147		
Sub - Total	2532		1946		0
Project Budget:	4478	**Margin:**	523		

**** does NOT include: foam, shipping cost, sales tax, edge fillers****

SURREY SATELLITE TECHNOLOGY US

PROJECT BUDGET – EEF Approved

Total Funds Available: $7000

Structure:		**Electronics HW - Covered by EEF:**		**Testing:**	
Panels	2000	Triple Axis Acc (purchase)	0	Cascade Tek (8 hours)	1800
Columns	332	Single Acis Acc (purchase)	0		
Adhesive	200	Power Supply	0		
		Triple Axis Acc (rent)	0		
		Single Acis Acc (rent)	0		
		Micro Controller	0		
		Acc PCB Board	0		
		Micro Controller PCB	0		
		AD Converter	0		
		Coaxial Cable	0		
		Coaxial Cable	0		
Sub - Total	2532		0		1800
Project Budget:	4332	**Margin:**	668		

**** does NOT include: foam, shipping cost, sales tax, edge fillers****

SURREY SATELLITE TECHNOLOGY US

PROJECT BUDGET – No Add. Funding:

Total Funds Available: $5000

Structure:		**Electronics HW:**		**Testing:**	
Panels	2000	Triple Axis Acc (purchase)	0	Cascade Tek (8 hours)	1800
Columns	332	Single Acis Acc (purchase)	0		
Adhesive	200	Power Supply	149		
		Triple Axis Acc (rent)	200		
		Single Acis Acc (rent)	60		
		Micro Controller	12		
		Acc PCB Board	33		
		Micro Controller PCB	33		
		AD Converter	31		
		Coaxial Cable	0		
		Coaxial Cable	0		
Sub - Total	2532		518		1800
Project Budget:	4850	**Margin:**	150		
	**** does NOT include: foam, shipping cost, sales tax, edge fillers****				

Margin still too small to cover currently unknown costs

Addition Cost Savings Options:

- Less expensive panel material (Nomex core, foam core, aluminum)
- Aluminum column material
- Borrow all accelerometers from aerospace department and ITLL

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PROJECT BUDGET – All the Funding

Total Funds Available: $8800

Structure:		**Electronics HW - Covered by EEF Funds:**		**Testing - Covered By Surrey Funds:**	
Panels	2000	Triple Axis Acc (purchase)	0	Cascade Tek (8 hours)	0
Columns	332	Single Acis Acc (purchase)	0		
Adhesive	200	Power Supply	0		
		Triple Axis Acc (rent)	0		
		Single Acis Acc (rent)	0		
		Micro Controller	0		
		Acc PCB Board	0		
		Micro Controller PCB	0		
		AD Converter	0		
		Coaxial Cable	0		
		Coaxial Cable	0		
Sub - Total	2532		0		0
Project Budget:	2532	**Margin:**	2468		

**** does NOT include: foam, shipping cost, sales tax, edge fillers****

Next Steps: Small Scale Modelling

- Vibration testing of carbon fiber plate components in ITLL
- Vibration testing of mass analogs bonded to carbon fiber with adhesive
- Obtaining foam samples for soft-stowed configuration and predicting attenuation properties on small components

ITLL Vibration Table

NEXT STEPS - HARDWARE

- Begin board design
  - Design the two boards and order one to begin integration
- Start acquiring hardware
  - Set numbers for resistors and capacitors
  - Begin ordering parts for first test board

NEXT STEPS - SOFTWARE:

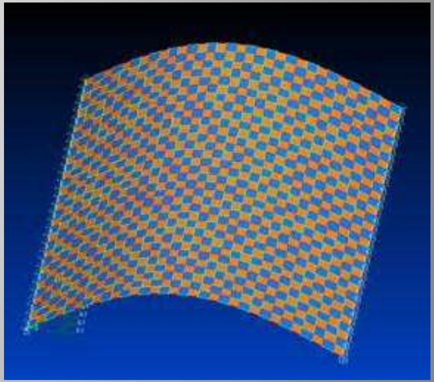
- All tools needed are downloadable and installable
  - Need to find out how they work – possible limitations
  - Start creating example scripts using new libraries
- Start becoming experts with python

Numerical Modeling

- Challenges of using ANSYS to do in-depth analysis
  - Good material properties
  - Correct use of loads, boundary conditions, and element types
  - Limitations of educational license (<40k elements)

Material Properties

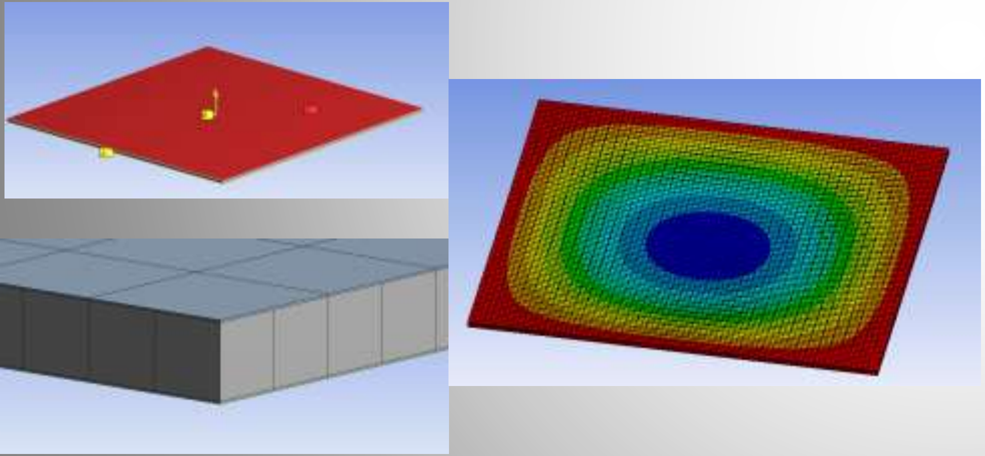
- Using honeycomb properties provided from Hexcel corp.
  - Orthotropic
- Carbon Fiber more difficult
  - Found that fabric orthotropic properties are not enough to describe buckling
  - Used M55J fiber properties as generated by AJ Gemer, using a modeled simulated layup of alternating uni-directional cells=



LASP HyperDust Instrument CDR

Applications of Boundary Conditions and Loads

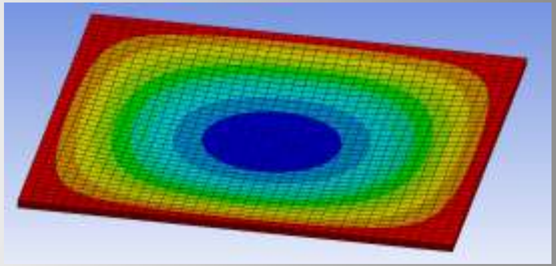
- Boundary Conditions are TBD on final model
- For feasibility, used simple supports and uniform load distribution on middle panel



- Used shell elements for face skin, 3d elements for core
  - Concerned about 1-element through t
- Deflections within 10% of analytical solution
- Stresses within ~25%

Getting around educational license

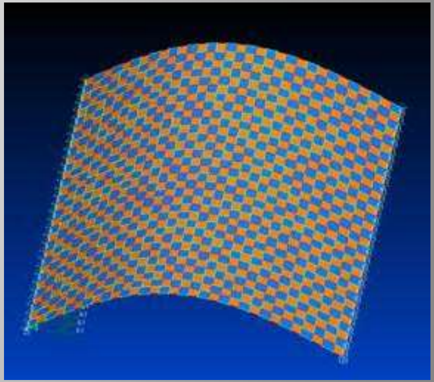
- Having 3 layers of elements quickly creates too many elements.
- Can use 1 layer of shell element (2D) and describe it's material properties with a layered section
- Deformation still within 16% of analytical
- Stresses show ~no change



Layer	Material	Thickness (m)	Angle (°)
(+Z)			
3	Woven Carbon Epoxy	0.0003	0
2	Aluminum Core Material (5052 1/4" 127)	0.0127	0
1	Woven Carbon Epoxy	0.0003	0
(-Z)			

Material Properties

- Using honeycomb properties provided from Hexcel corp.
  - Orthotropic
- Carbon Fiber more difficult
  - Found that fabric orthotropic properties are not enough to describe buckling
  - Used M55J fiber properties as generated by AJ Gemer, using a modeled simulated layup of alternating uni-directional cells=



LASP HyperDust Instrument CDR