Development of Hammer Blow Test to Simulate Pyrotechnic Shock

Final Presentation

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Project Overview

Pneumatic hammer test for simulating pyrotechnic shock [1]

- Harris Corp. and Pyrotechnic Shocks
  - Sensitive electronics that may experience pyrotechnic shock
  - Test for survivability of these components
- Explosive components commonly used in satellite systems
  - Rocket ignition, stage separation, antenna deployment

Project Scope

- Two Year Project:
  - Year 1 – Smaller scale proof-of-concept adaptable testing rig
  - Year 2 – Explore further adaptability at higher force levels

- Needs Statement:

The current shock testing method lacks adaptability, requiring too much trial and error and expenditure of resources.

- Goals:
  - Design and develop a tunable resonant fixture plate
  - Test modeling/analysis software
  - Evaluate methods to tune fixture to achieve different SRS responses

Shock Generation

- Four primary non-explosive means to simulate pyrotechnic shock:
  - Pneumatic Hammer Strike
  - Drop Hammer Strike
  - Drop Table
  - Shock Tube

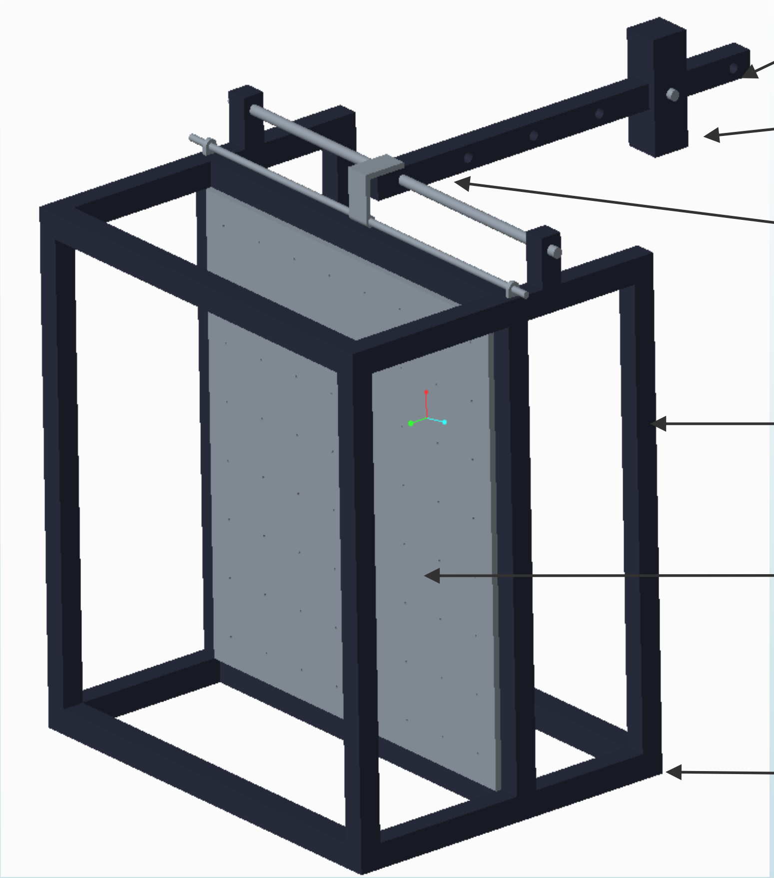
Apparatus	Accuracy	Durability	Assembly	Cost	Adaptability	Total
Air/Pneumatic Hammer	4	4	2	2	4	3.4
Pendulum Hammer	3	4	4	4	4	3.7
Drop Table	2	2	4	3	2	2.4
Shock Tube	1	5	5	3	2	2.5
Weight Factor	0.3	0.1	0.1	0.2	0.3	

Weighted decision matrix for impact method

Constraints & Specifications

- Test article size - up to 8” x 8” x 6”
  - **Selected article: 6” x 6” x 0.5” low carbon steel**
- Test article weight - up to 10 lbs
  - **Article weight: 5.1 lbs**
- SRS response up to 500g acceleration and 10 kHz
  - Stay within tolerances set by MIL-STD-810 G, Method 517.2, Proc III
  - **Anticipated Maximum Force Generated: ~6000g (8.31lb hammer)**
- Project expenses must stay within allotted budget ($4000)
  - **Funds Used: $2093.15**
- Software conversion for raw data to usable SRS curves
  - **Smallwood Recursive Matlab script**
- Variable testing parameters
  - **Test Article Location, Hammer Impact Location, Hammer Tip Size, Plate Boundary Conditions, and Tuning Bands**

Design Iterations



Adjustable Swing Arm

Steel Hammerhead

Quick Release Mechanism

Steel Frame

6061 Aluminum Plate

Welded Joints

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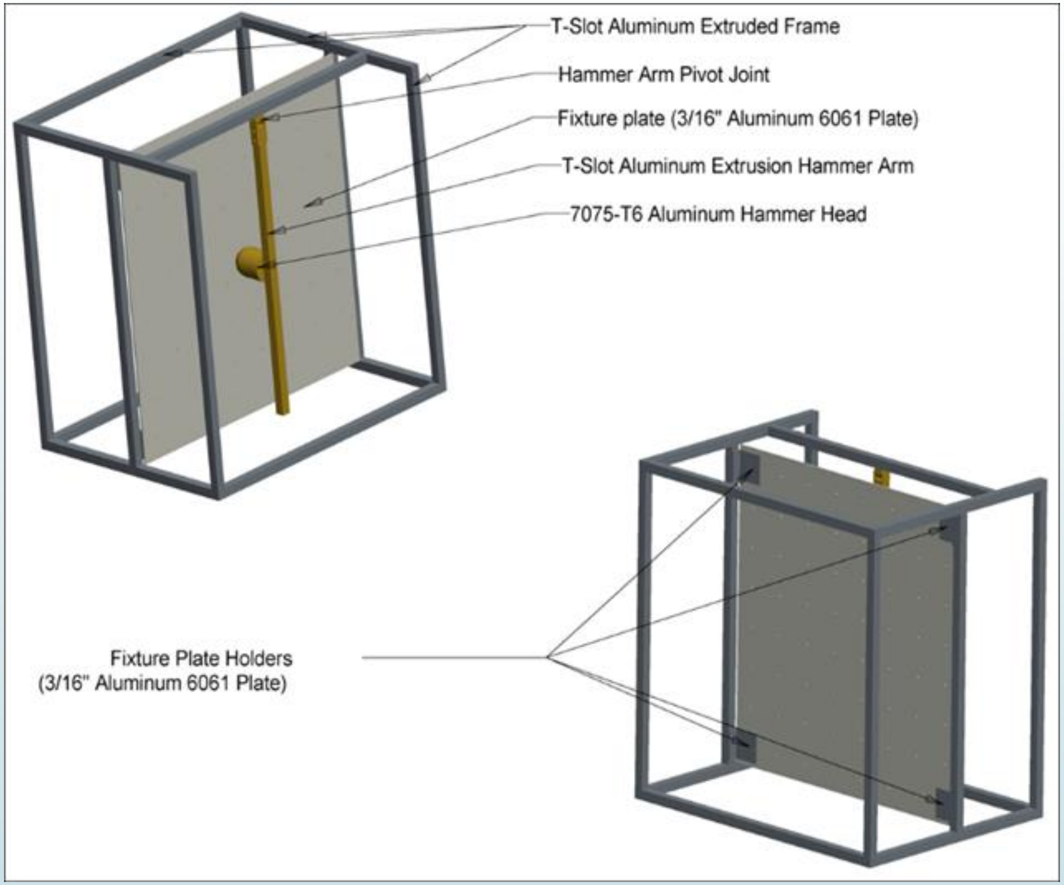
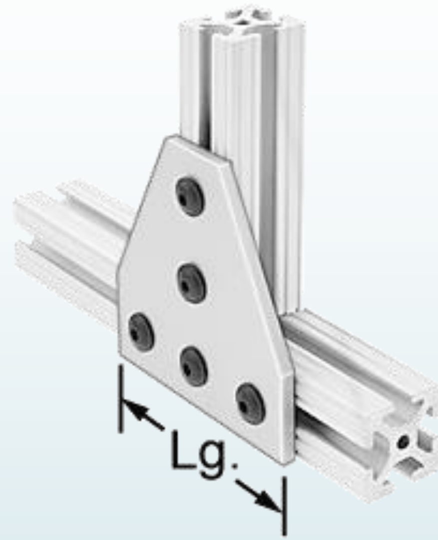
Design Iterations





- Change to Aluminum T-slot frame
- Machine fabricated hammer heads
- Slotted mounting brackets

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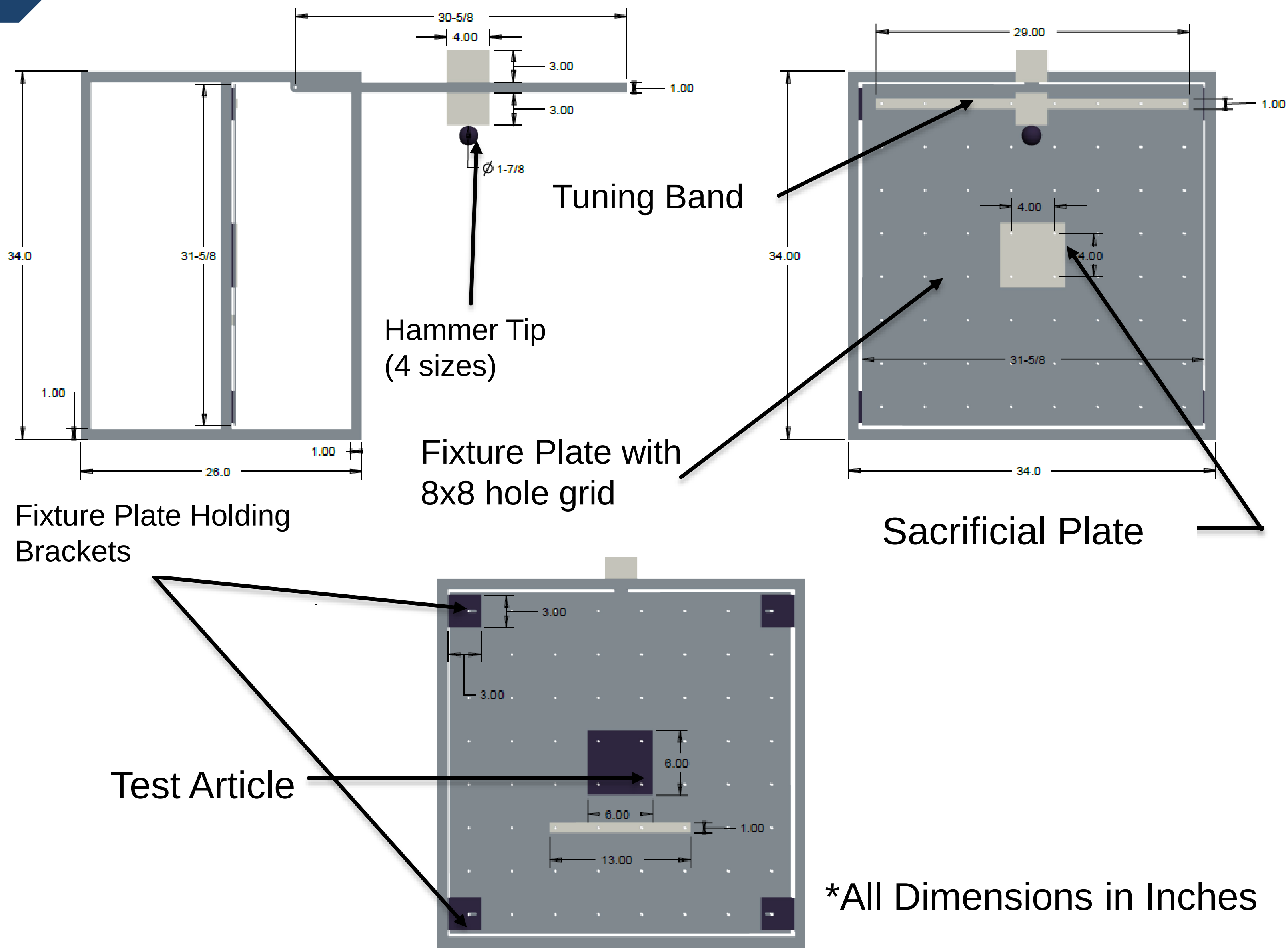
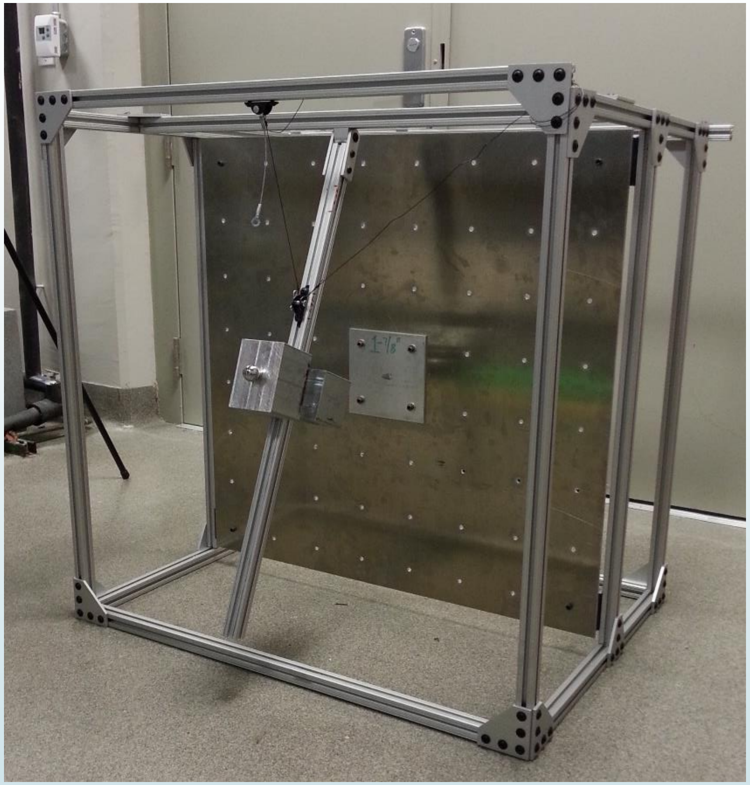
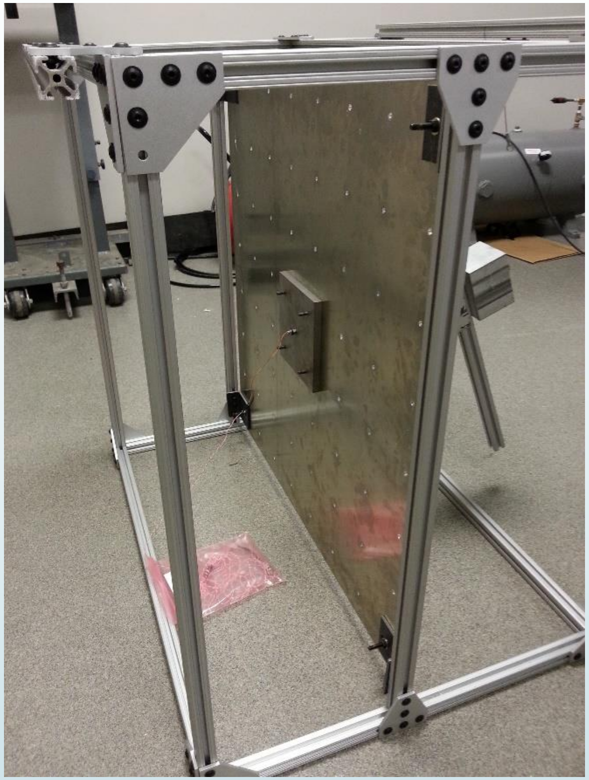
Creo Model – Final Design



Testing Apparatus



Front Side of Test Rig with Hammer Arm



Back Side of Fixture Plate Showing Test Article Centered

Testing Apparatus – Quick Release

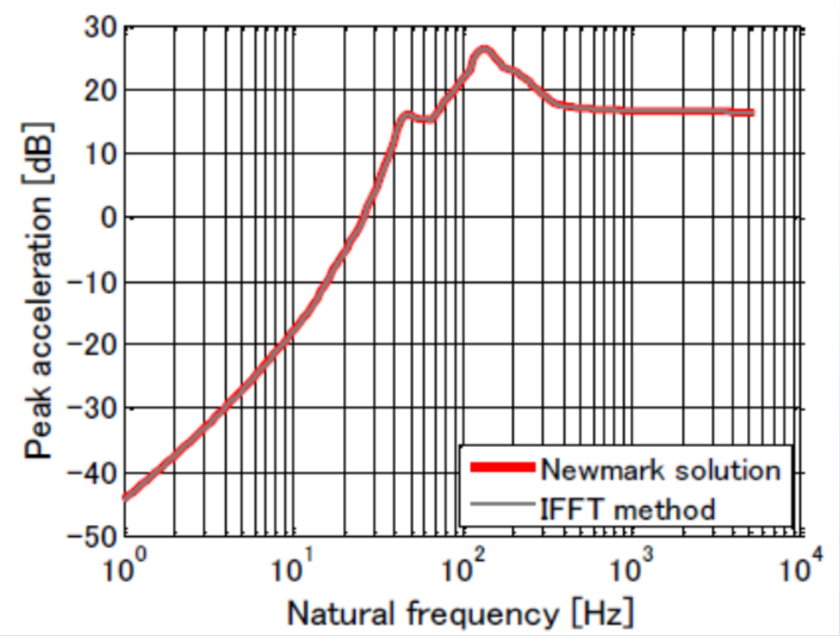
Lanyard with quick release pull pin attached to the T-slotted aluminum swing arm

Explanation of Test Parameters

- Test by varying adjustable fixture parameters
  - Fixture plate boundary conditions
  - Test article location
  - Hammer impact location
  - Hammer tip shape
  - Tuning bands

Theory

- High acceleration, high frequency, transient nature
  - Difficult to specify or recreate
- SRS – Shock Response Spectrum
  - From time domain to frequency domain
  - Provide quantitative measure
- Effects captured by Accelerometer & DAQ system
- Acceleration time history processed into SRS Curve

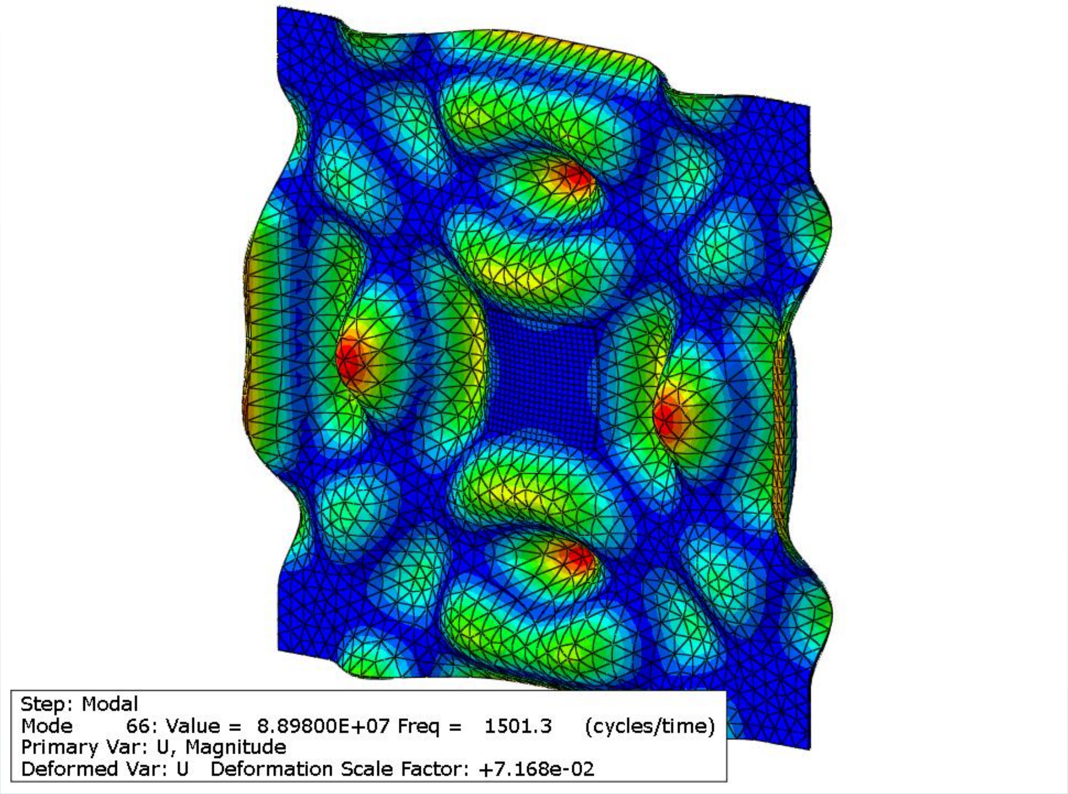


Example of SRS curve derived from experimental data [1]

DAQ Setup

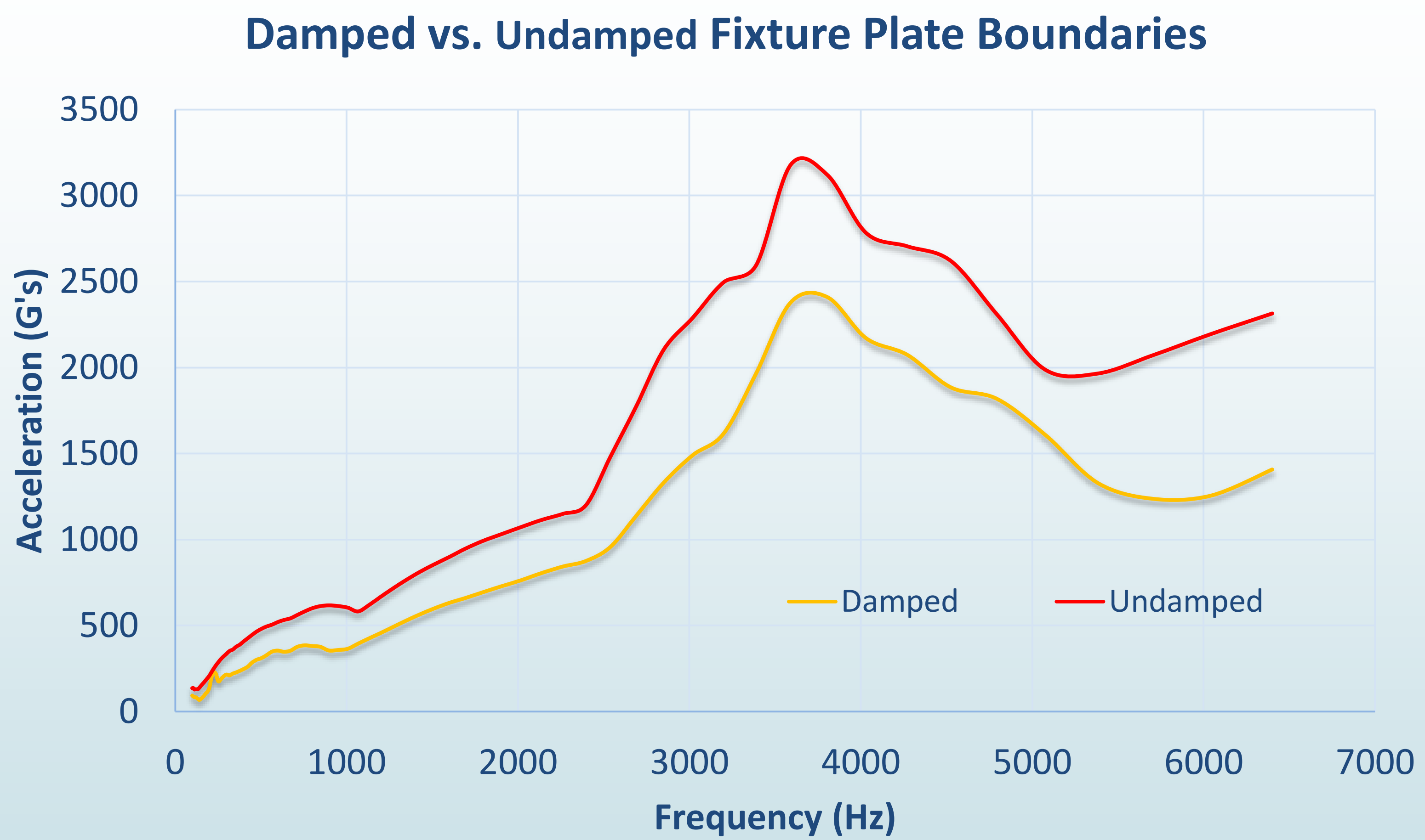
Initial data acquisition setup vs current setup with signal conditioner

Modal Analysis Images



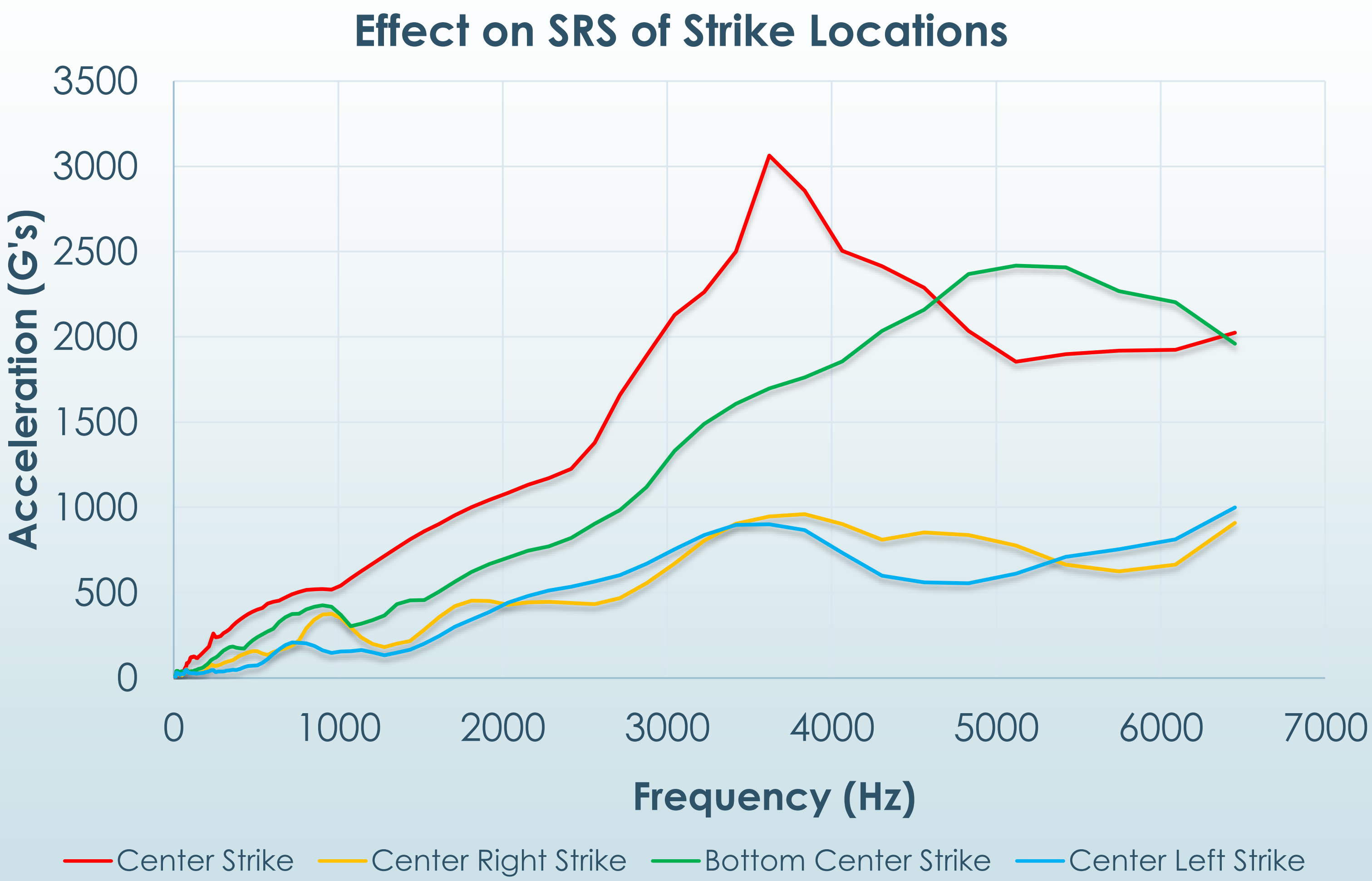
Use of modal analysis to identify optimal stiffening band locations

Testing Results



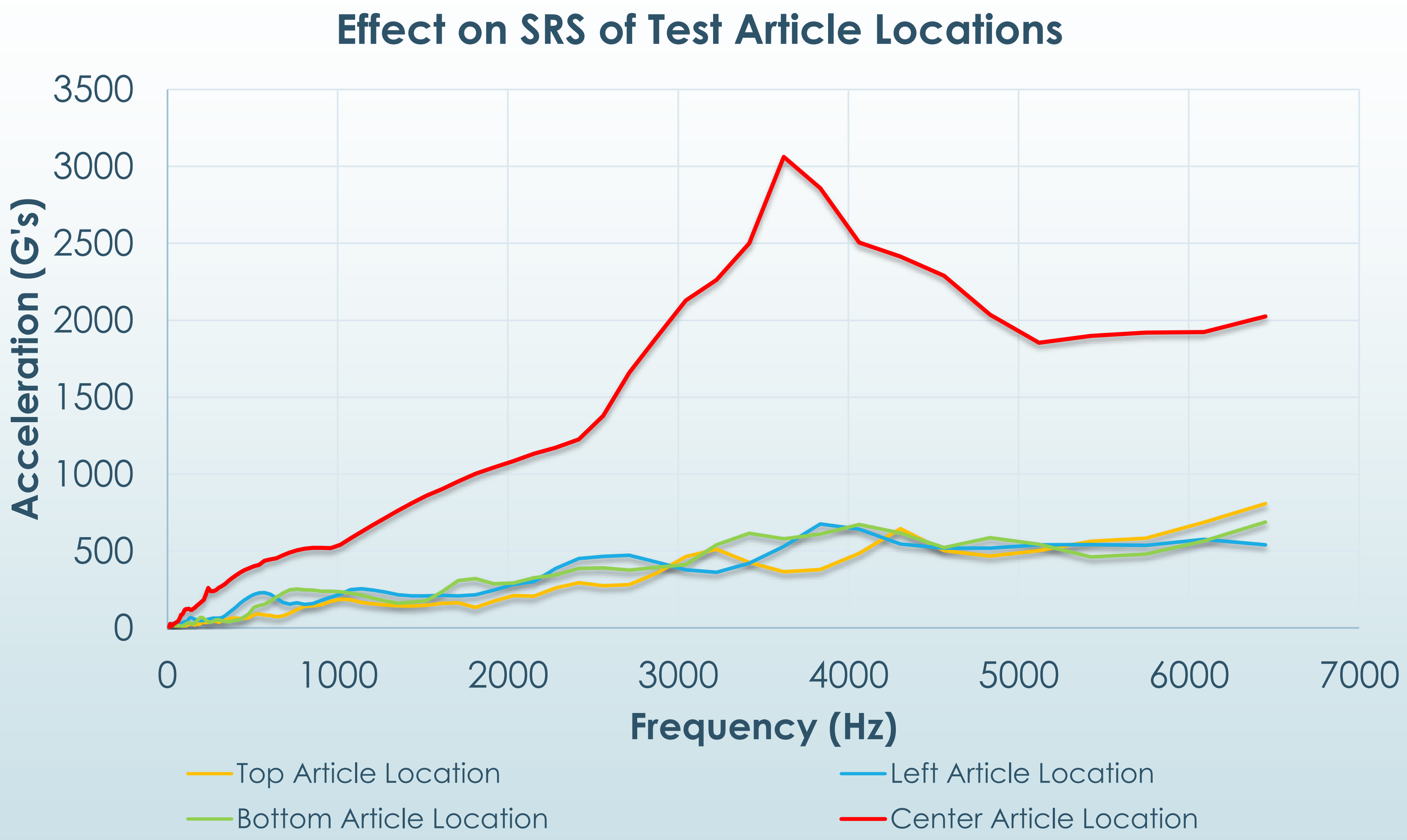
Trend: Downward shift in amplitude at the same peak frequency.

Testing Results



Trend: Changes in amplitude and frequency for each location

Testing Results



Trend: Large decrease in amplitude with small variations in frequency

Project Purpose

Year One

- Design and fabricate a versatile physical testing apparatus
- Develop analytical computer models to simulate tests
- Evaluate methods to tune fixture to achieve different SRS responses
- Identify trends in test results
- Compile data for future reference

Project Management

- Communication
- Timeline
- Resource Management
- Critical Tasks
- Procurement
- Teamwork

Bill of materials

Part	Quantity	Part	Quantity
24" Aluminum Extrusion	4	1-7/8" Diameter Steel Ball	1
30" Aluminum Extrusion	1	1-3/8" Diameter Steel Ball	1
32" Aluminum Extrusion	6	1" Diameter Steel Ball	1
34" Aluminum Extrusion	5	3/4" Diameter Steel Ball	1
T-Bracket	6	1", 10-32 threaded rod	2
L-Bracket	16	1" 1/4-20 threaded rod	2
180 degree pivot	1	1", 3/8-16 threaded rod	2
Fixture Plate	1	3" x 3" x 4" 7075-T6 Aluminum Block	2
Sacrificial Plate	5	Yoke & Pin Set	2
Test Article	1	Adjustable Length Lanyard	30 feet
Fixture Plate Mounting Bracket	4		

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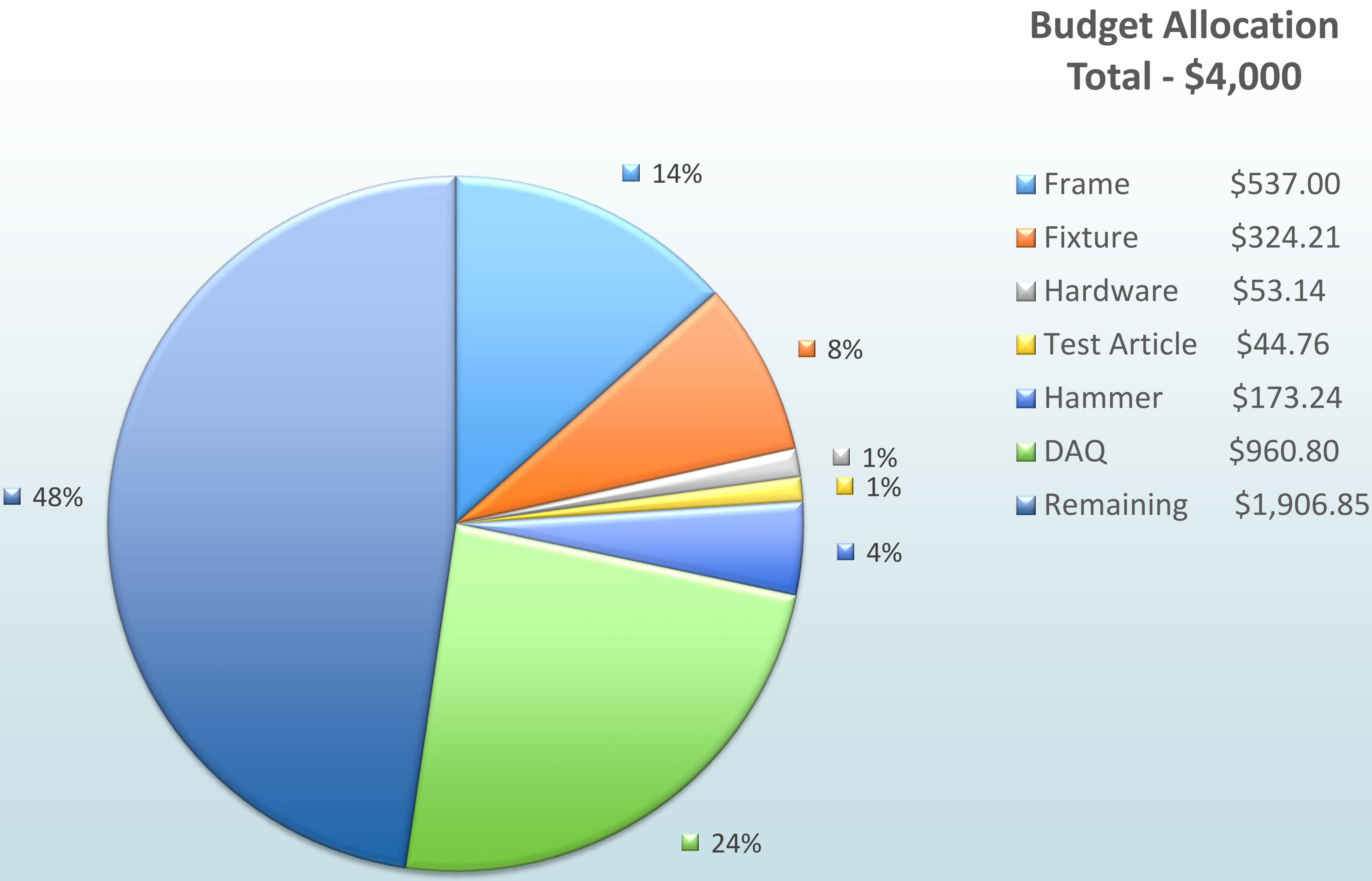
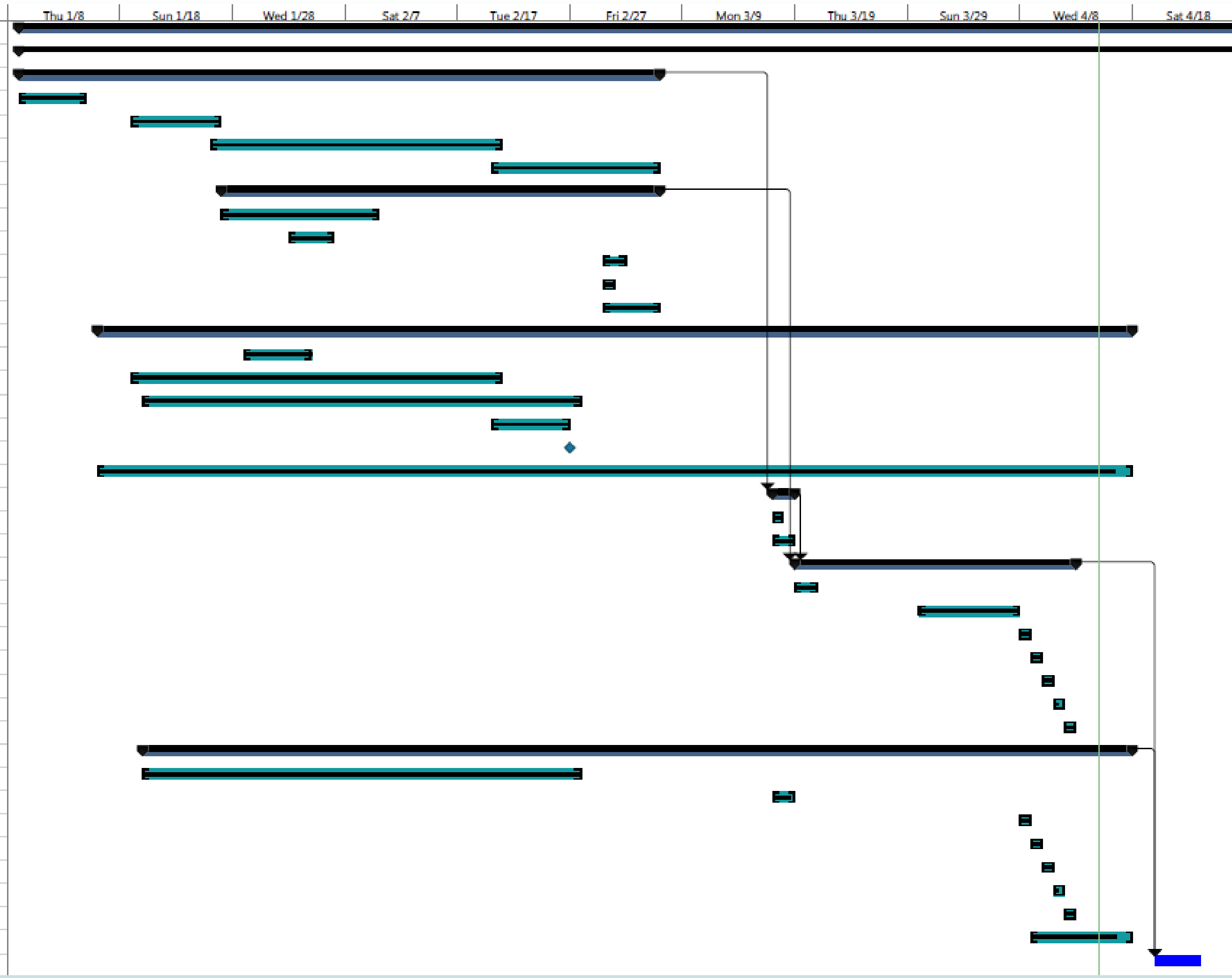
Budget


Budget Allocation
Total - $4,000
14%
8%
1%
1%
4%
24%
48%
Frame $537.00
Fixture $324.21
Hardware $53.14
Test Article $44.76
Hammer $173.24
DAQ $960.80
Remaining $1,906.85

Schedule

1	**1**	**Prototyping**
2	**1.1**	**Reporting**
32	**1.2**	**Procurement**
33	1.2.1	Submit Purchase Orders
34	1.2.2	Inventory Orders
35	1.2.3	Submit Addt'l Orders (if necessary)
36	1.2.4	Submit Addt'l Orders 2 (if necessary)
37	**1.3**	**Manufacturing / Assembly**
38	1.3.1	Submit CAD Drawings for Machining
39	1.3.2	Assemble Chassis
40	1.3.3	Assemble Striking Hammer
41	1.3.4	Mate Chassis & Hammer
42	1.3.5	Test Fit Full Assembly
43	**1.4**	**Analytical Modeling**
44	1.4.1	Obtain & Verify Smallwood Code
45	1.4.2	Verify CAD Models & Simulations
46	1.4.3	Build MATLab SRS Processing Program
47	1.4.4	Test SRS Processing with CAD Sims
48	1.4.5	Submit MATLab Code to Mr. Wells for Verification
49	1.4.6	Continuous Simulations and Refinement
50	**1.5**	**D.A.Q.**
51	1.5.1	Build Lab View Module
52	1.5.2	Test Equipment
53	**1.6**	**Experimental Modeling**
54	1.6.1	Final Assembly: Chassis & Hammer
55	1.6.2	Baseline Testing
56	1.6.3	Test Parameter 1 (Article Location)
57	1.6.4	Test Parameter 2 (Strike Location)
58	1.6.5	Test Parameter 3 (Plate Boundary Conditions)
59	1.6.6	Test Parameter 4 (Hammer Tip Shape)
60	1.6.7	Test Parameter 5 (Stiffining plates)
61	**1.7**	**Documentation**
62	1.7.1	Track MATLab Modifications
63	1.7.2	Record D.A.Q. Setup and Calibration Procedure
64	1.7.3	Record Testing Results (1)
65	1.7.4	Record Testing Results (2)
66	1.7.5	Record Testing Results (3)
67	1.7.6	Record Testing Results (4)
68	1.7.7	Record Testing Results (5)
69	1.7.8	Assemble Database of Results
70	***1.8***	***Final Product***



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Project Summary

- Methods of current shock testing lack efficiency and repeatability
  - Trial and error approach currently
- Prototype constructed utilizes hammer swing to impact plate
  - Aluminum t-slotted frame, swing position adjustable
- Team 15 selected specific test parameters to investigate
  - Hammer tip size, impact location, test article location, tuning bands, damped boundary conditions
- Plate vibration response “tunable”
  - Analytical methods locate optimal placement of tuning bands
- The trends identified will help speed up future testing
  - Knowledge of parameters to create specific shock and SRS curve

Lessons Learned

- Fixed boundary conditions crucial
  - Suggestion: Securing frame to ground, wall
- SRS generation time consuming
  - Suggestion: Develop automated program using, MatLab, LabView, Excel
- Test fixture adjustability time consuming
  - Suggestion: Discrete positioning of hammer swing
- Hammer swing arm gyration
  - Suggestion: Bearing base pivot point
- Measure different quantities
  - Suggestion: Force sensor in addition to accelerometer

References

- [1] Robert, Wells. "University Capstone Development of Hammer Blow Test Device to Simulate Pyrotechnic Shock 2 Year Project." 6 Jan. 2015. Web. 7 Jan. 2015.

Team Website: eng.fsu.edu/me/senior_design/2015/team15/