Grand Challenge Prediction
Article #: TA3 Series 1 Test 1
Test Apparatus: MTS
Organization: ARDEC

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Modeling and Simulation of a High Fidelity Electronics Assembly Responding to Drop Test

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UNPARALLELED COMMITMENT & SOLUTIONS

Act like someone's life depends on what we do.

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Goals, Scope

- Goals:
  - Joint effort of DOD and DOE to quantify the capabilities of computational codes to accurately predict the response of an instrumented fuze to a known shock.
  - The purpose of the modeling and simulation was to predict the board accelerations in a blind study. Other agencies made similar predictions using a variety of finite element codes. Other tests were also conducted. This paper is limited to the work done at Picatinny Arsenal on a test article 3 (TA3) labeled by the Air Force as Series 1 Test 1.
- Scope
  - Model: MTS TA3, housing, boards and major electronics components filled with potting, MTS test apparatus.
  - Abaqus Explicit 2016HF2, dynamic analysis.
  - Evaluate: Acceleration during the impact. Predict acceleration readings for all 4 accelerometers placed on 4 boards. Compare accelerometer readings during MTS test with FEA predictions.

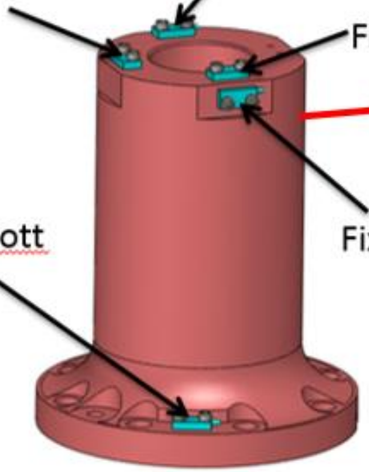
METHOD
MODEL INFORMATION, PROCEDURES

- General Purpose Finite Element Software: Abaqus Explicit 2016HF2
- Analysis: dynamic, non-linear materials, non-linear geometry
- Analysis time: 0.001 seconds
- Full model
- Parts: Imported from CAD or defined in Abaqus CAE. All parts modeled as deformable.
- Elements: 8-node linear brick elements, reduced integration, hourglass control
- Materials: Viscoelastic model, Elastic Plastic model and Crushable Foam model.
- Loads: Shock load per Test Unit104_20H_F1_16_1 (Series 1- short duration) input data - test data from AFRL Eglin).
- Boundary: Constrained Guides and Seismic Mass
- Initial Conditions: Initial velocity 17 ft/s
- Friction: Friction coefficient 0.3, all contact surfaces.
- Damping: material viscoelastic damping.

Method
Possible Errors

- Geometry was defeatured.
- General contact with coefficient of friction 0.30 for all contact. Slipping effects, temperature and pressure dependences are ignored.
- Threaded connections were not modeled, instead contacting surfaces were tied.
- Retainer preload was not applied.
- It is assumed that potting material filled all cavities above the “Potting Cap”. Weight of parts were adjusted to match weight of the assembly. Interaction between Closure Ring and Housing were assumed as glued (tie constraints). Fixture and Retainer materials were assumed as steel AISI 4340.

METHOD: TEST SETUP

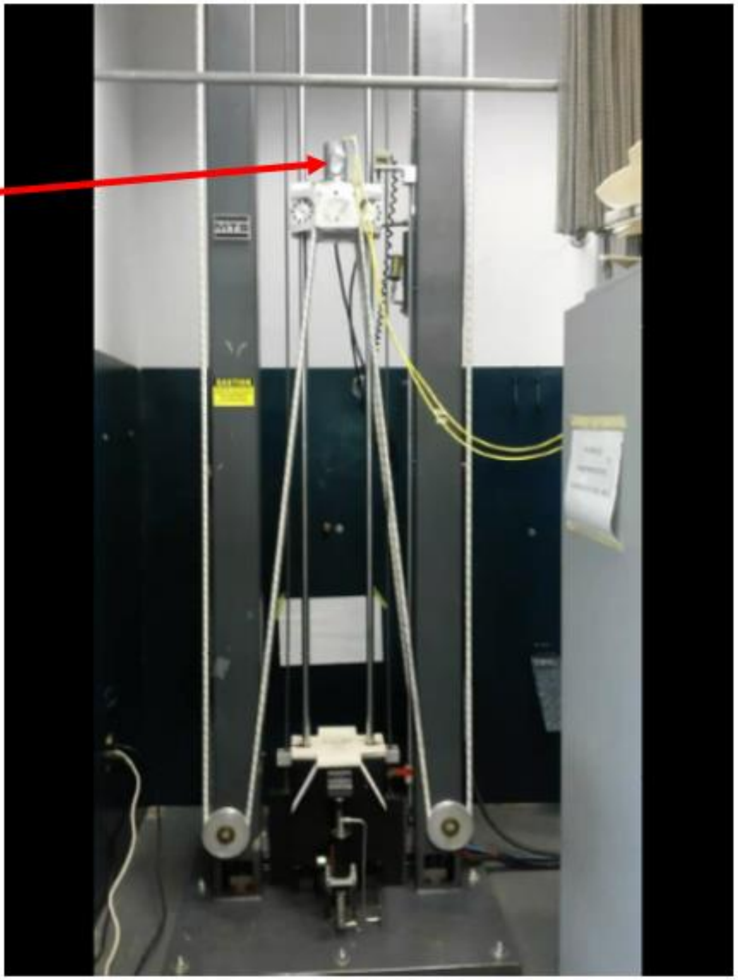


The axial fixture was bolted to the MTS drop tower table adapter plate using 3/8-16 – 1” bolts.

The drop tower table was dropped at heights of 20” and 72”. Mitigating material was used between the drop tower table and the seismic mass to control the pulse shape.

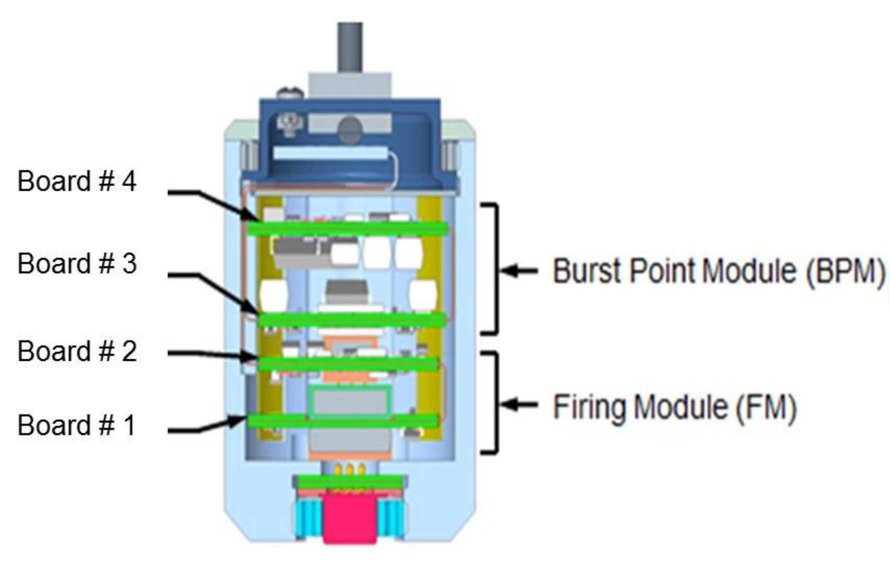
Inputs provided to the performer consist of the measurement of the 5 exterior accelerometers.

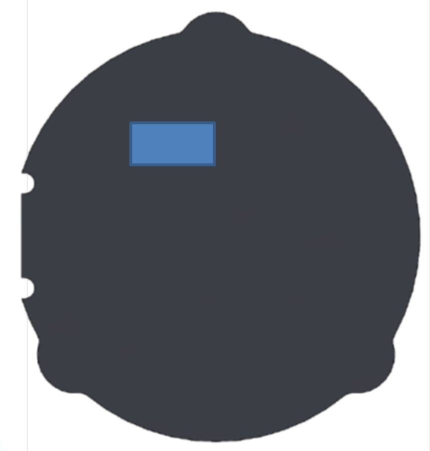
Axial fixture mounted on MTS drop tower table adapter plate which in turn is mounted on the drop tower table.



MTS Drop Test at Eglin AFRL

Method: Accelerometers' Location





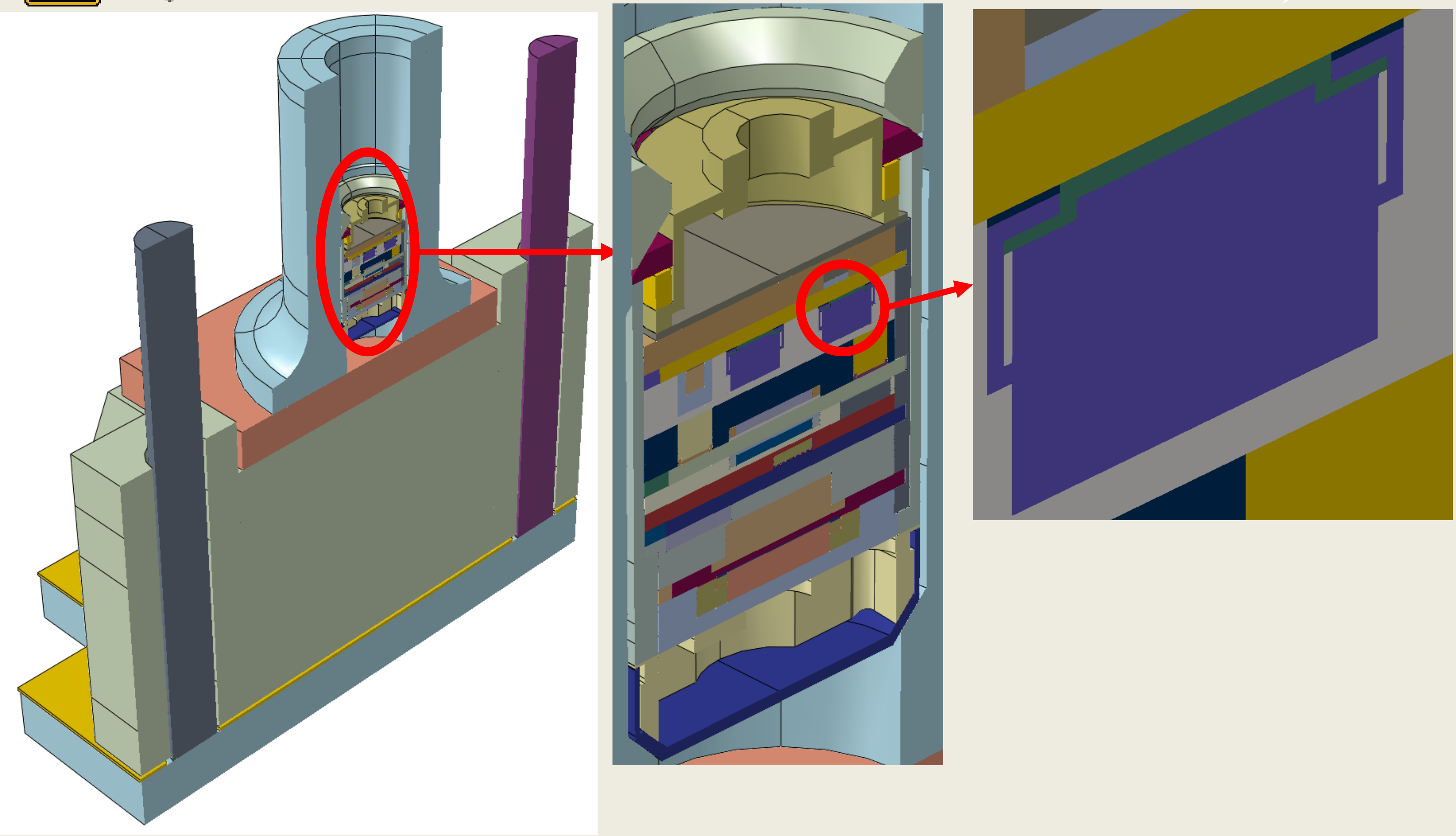
a) Board 4 - Burst Point Module

b) Board 3 - Burst Point Module

c) Board 2 - Firing Module

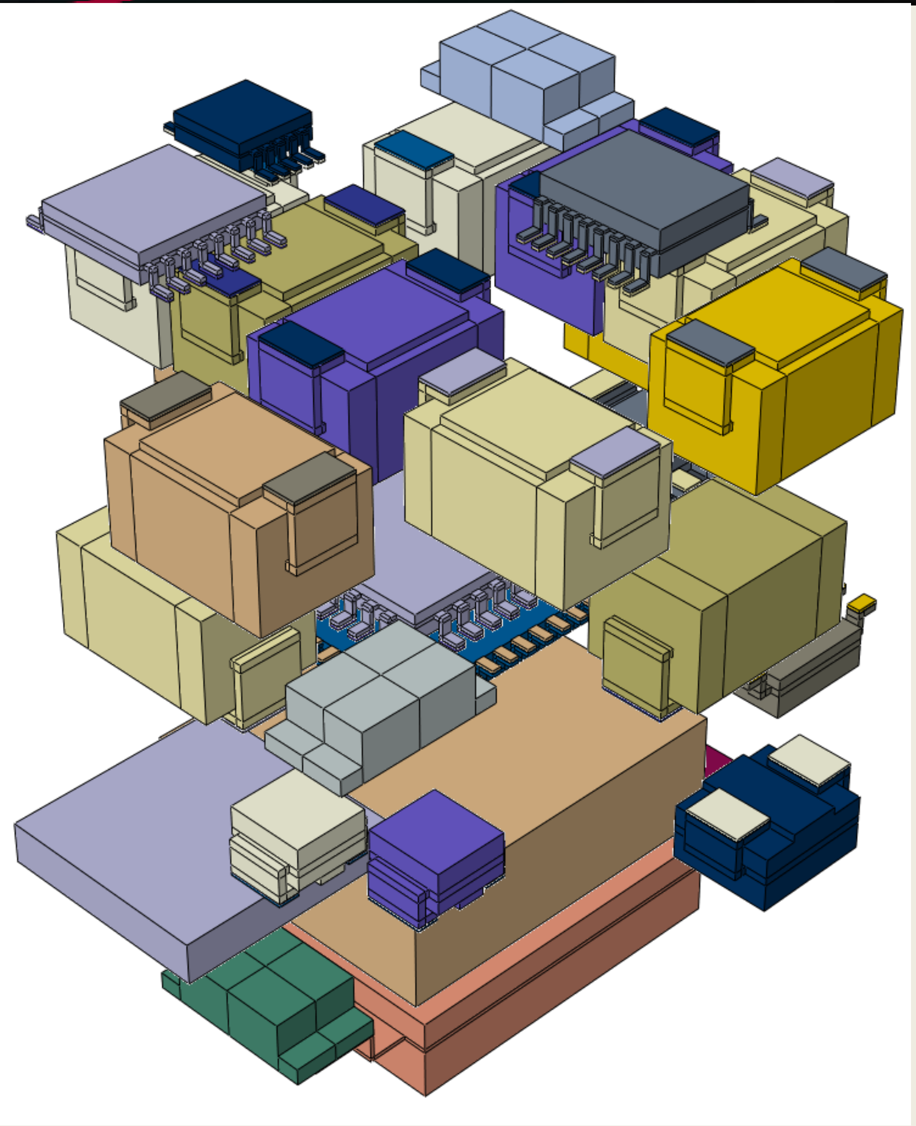
d) Board 1 – Firing Module

Method: Parts and Instances



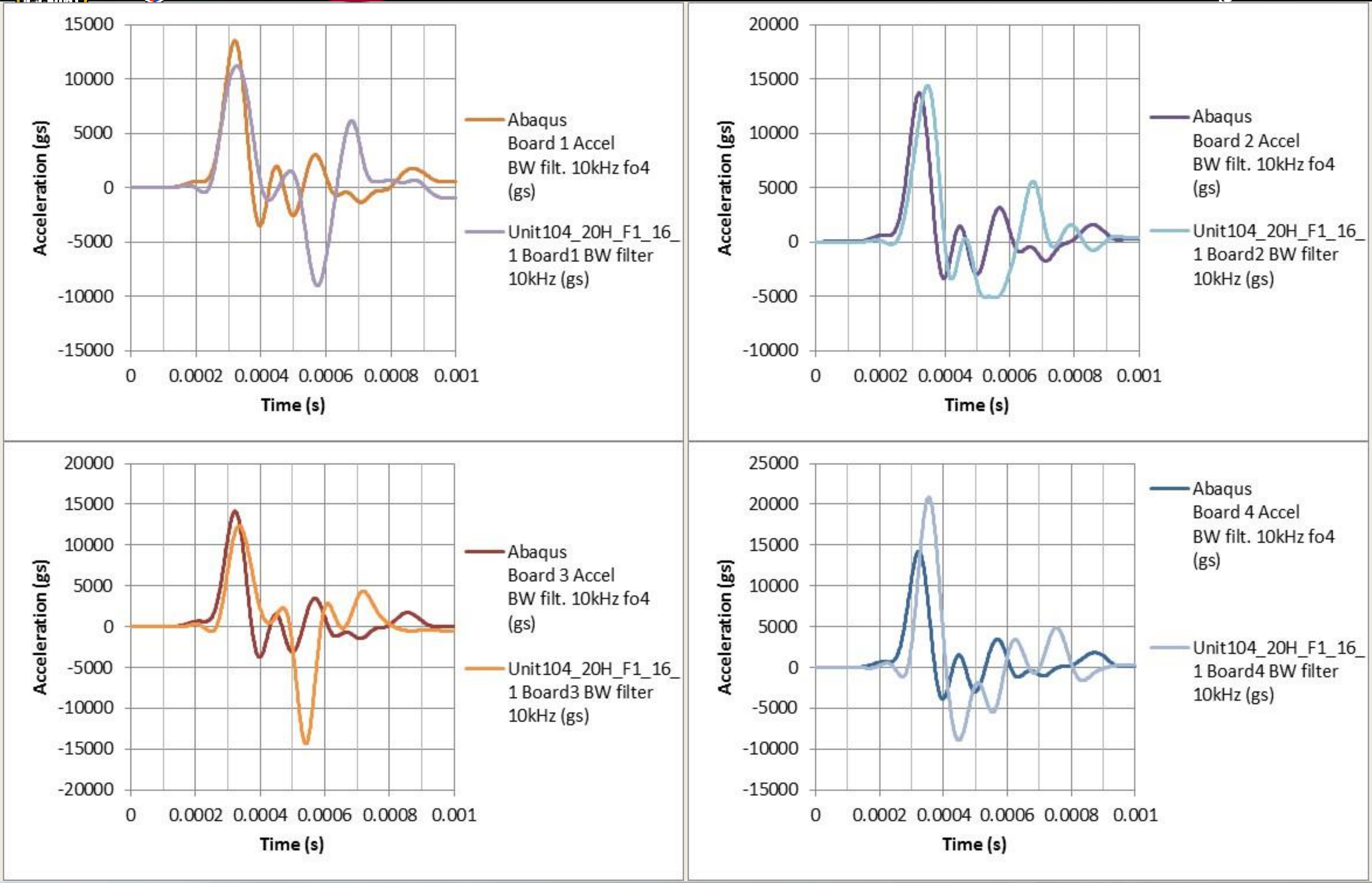
Electronic components modeled

Method: Parts and Instances



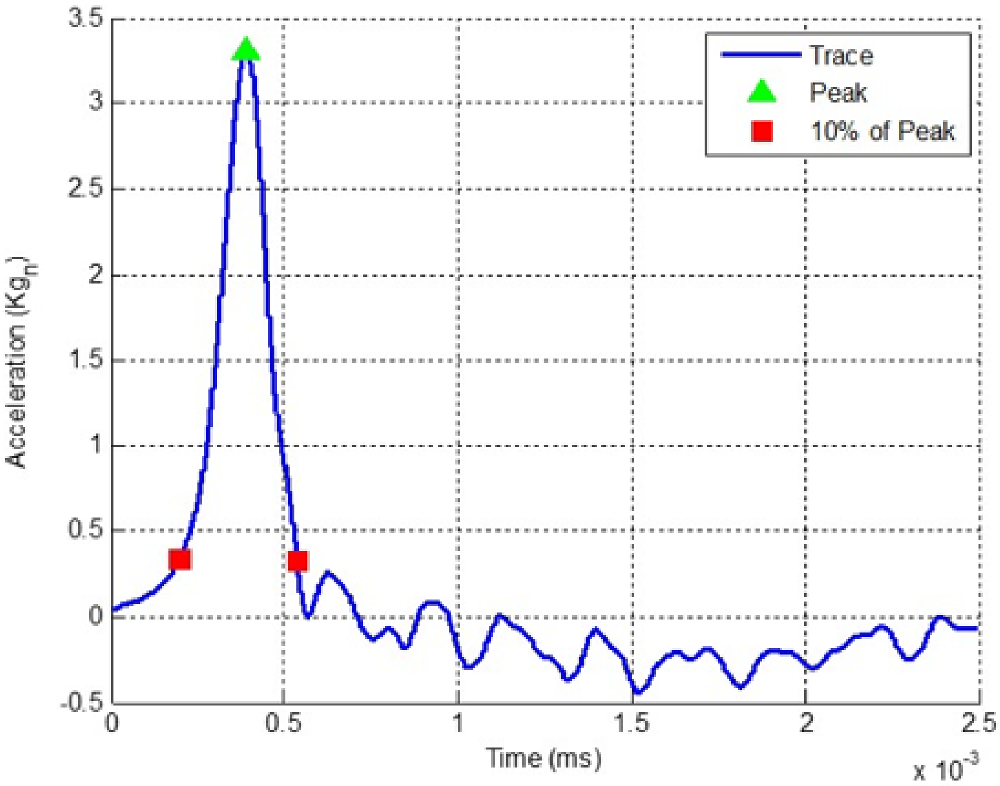
Electronic components modeled

Results
Board Accelerations



RESULTS

Example of the Peak and Duration Calculation

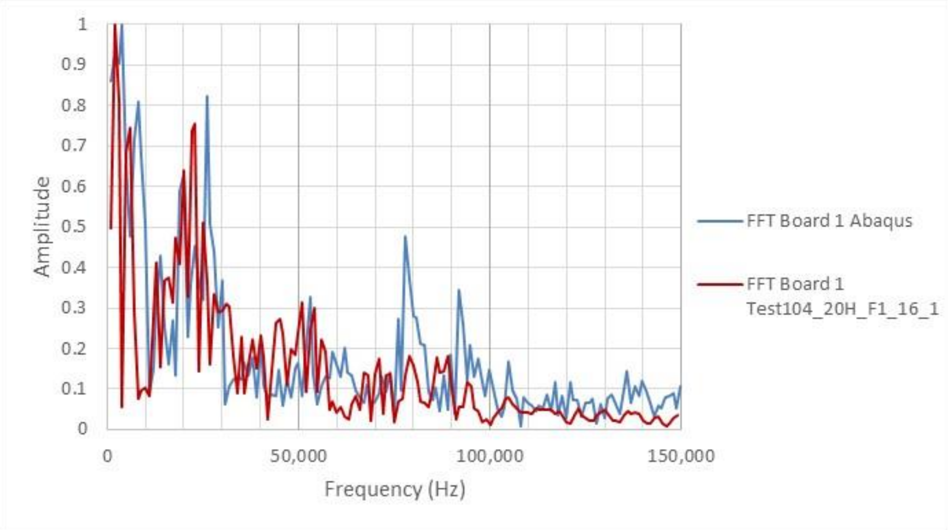


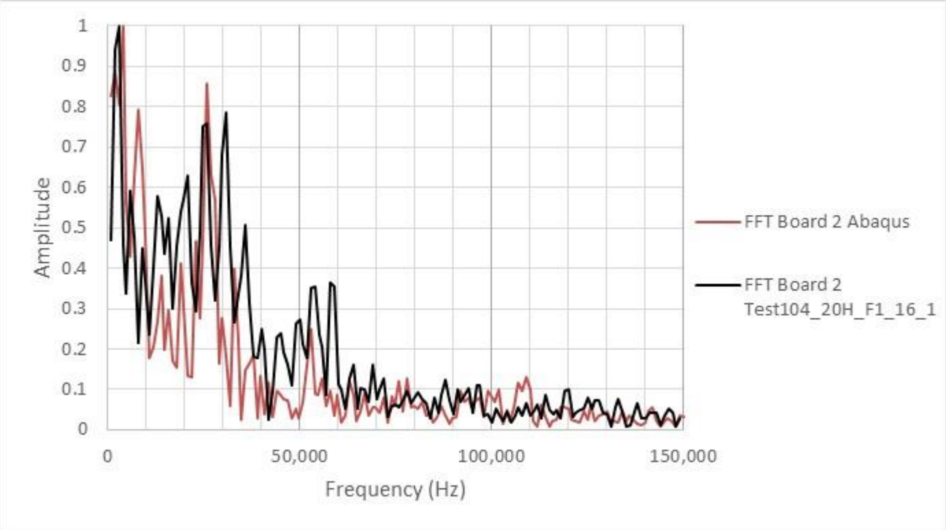
The peak and duration values were extracted from the first pulse. Example of the peak and duration calculation were shown. The value of the green triangle is the peak. The time difference between the red squares is the duration. The values of the red squares were defined as 10 % of the peak values.

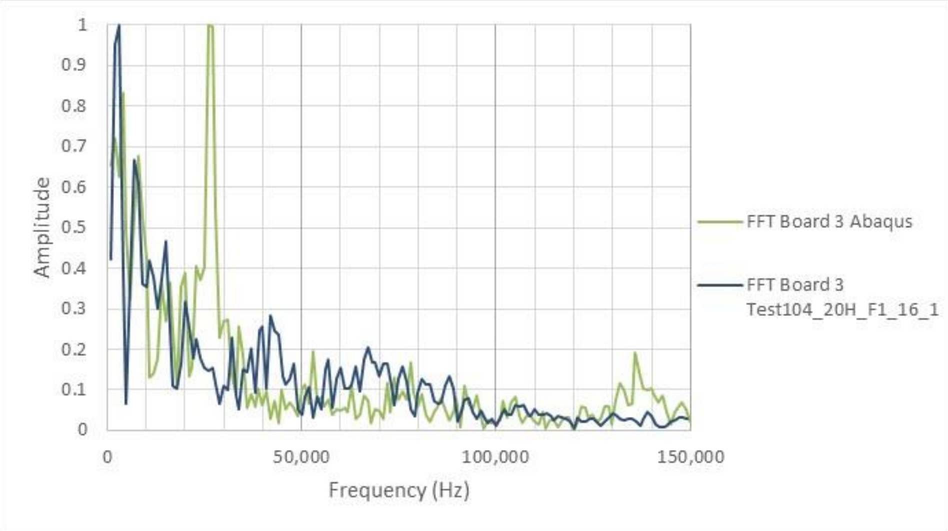
RESULTS

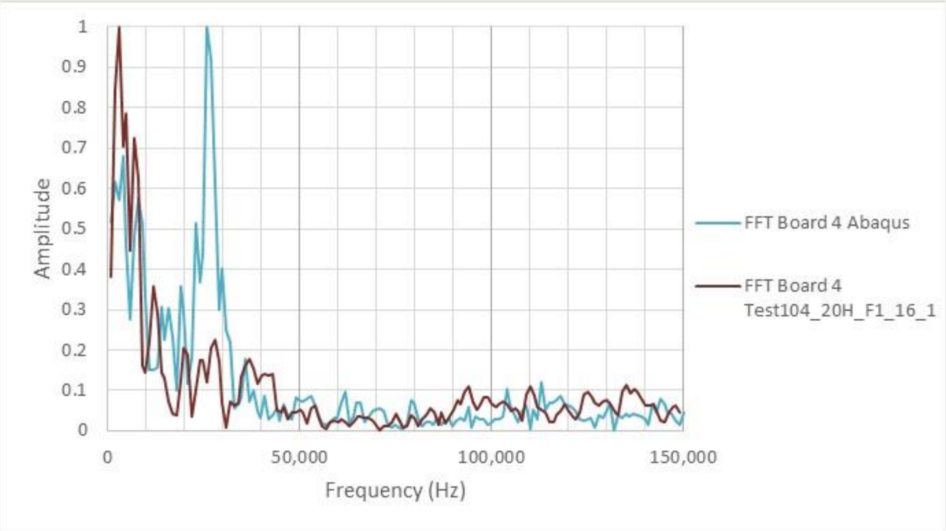
Accelerometer Location	Source	Peak (kGs)	Duration (ms)	% Diff of Peak	% Diff of Duration	Sum of Peak and Duration % Diff
Board 1	Test 104_72H_1	11.181	0.142	N/A	N/A	N/A
	Abaqus (1GC_MTS_TA3_r45)	13.520	0.120	20.9	15.5	36.4
Board 2	Test 104_72H_1	14.416	0.126	N/A	N/A	N/A
	Abaqus (1GC_MTS_TA3_r45)	13.726	0.117	4.8	7.1	11.9
Board 3	Test 104_72H_1	12.360	0.134	N/A	N/A	N/A
	Abaqus (1GC_MTS_TA3_r45)	14.151	0.116	14.5	13.4	27.9
Board 4	Test 104_72H_1	20.852	0.105	N/A	N/A	N/A
	Abaqus (1GC_MTS_TA3_r45)	14.234	0.114	31.7	8.6	40.3
Board Averages	Test 104_72H_1	14.702	0.127	N/A	N/A	N/A
	Abaqus (1GC_MTS_TA3_r45)	13.908	0.117	5.4	7.9	13.3

RESULTS FFT

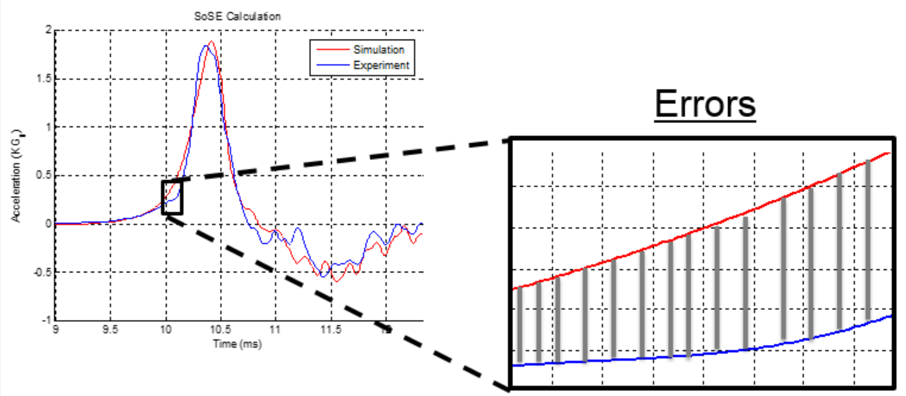

Amplitude
Frequency (Hz)
FFT Board 1 Abaqus
FFT Board 1 Test104_20H_F1_16_1


Amplitude
Frequency (Hz)
FFT Board 2 Abaqus
FFT Board 2 Test104_20H_F1_16_1


Amplitude
Frequency (Hz)
FFT Board 3 Abaqus
FFT Board 3 Test104_20H_F1_16_1

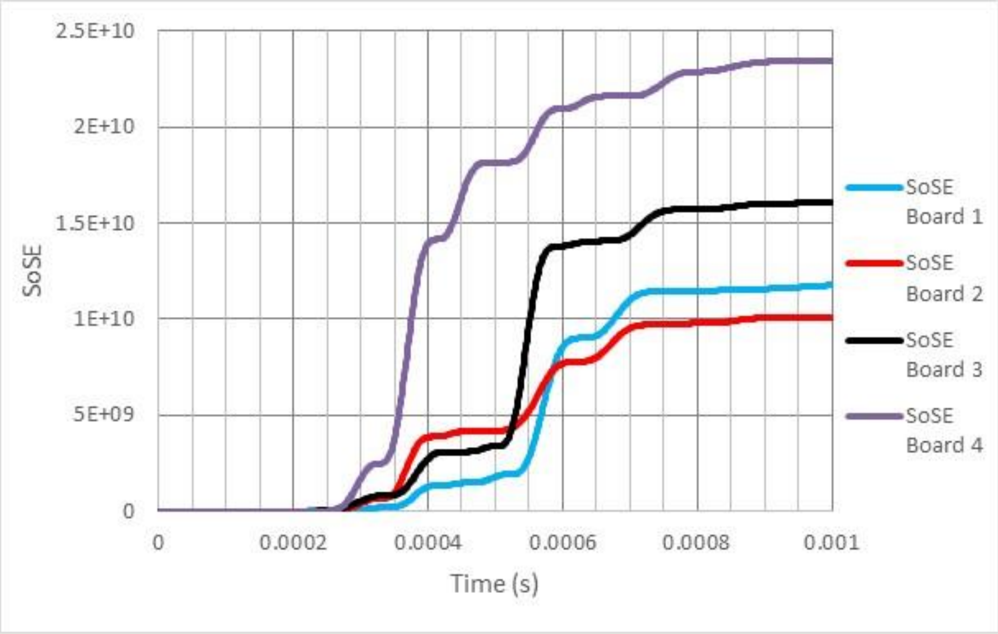

Amplitude
Frequency (Hz)
FFT Board 4 Abaqus
FFT Board 4 Test104_20H_F1_16_1

Results
Sum of Squared Errors (SoSE)



Errors = Experimental - Simulation

$$SoSE = CumSum(Errors^2)$$



RESULTS

- Computational Information (1GC_MTS_TA3_r45):
  - Computer Program Used: Abaqus 2016HF2
  - Number of Elements: 4,575,104
  - Number of Nodes: 5,464,022
  - Number of nodes defined by the user: 5,464,022
  - Total number of variables (degrees of freedom) in the model: 16,423,353
- Analysis Type
  - Solver: Abaqus Explicit
  - Duration: 19 hours
  - Time Step: 2.271e-9 sec
  - Updating Criteria:
- Computer: 72 cpus were used for 19 hours on ARDEC HPCC-4 computer
- Queue Time: None

CONCLUSIONS

Conclusions

- Modeling and simulation should go hand-in-hand with testing. Tests provide loads, validation, and material data for modeling and simulation.
- Exact predictions for accelerations are difficult due to variations in materials, tolerances, loads, directionality of loads, constraints, friction, preloads, contact, etc.
- This analysis demonstrates good match between board accelerations collected during test performed on MTS drop tower and Abaqus predictions. The peak acceleration has a reasonable good match for all four boards. The shape of the acceleration response was also reasonably accurate for the four circuit boards.

QUESTIONS?