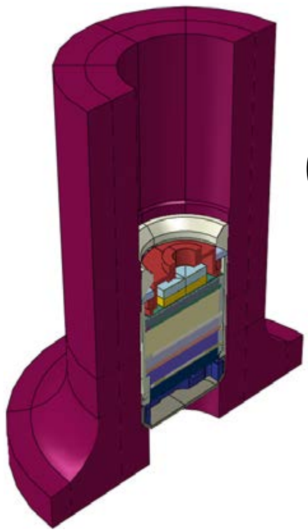
Grand Challenge Prediction
Article #: TA2 Test 4
Test Apparatus: VHG
Organization: ARDEC



Grand Challenge VHG Test Article 2 Test 4

Miroslav Tesla, Jennifer A. Cordes, Janet Wolfson
RDAR-MEF-E, Building 94, 2nd floor
Fuze and Precision Armaments Directorate
AETC, U.S. Army ARDEC, Picatinny Arsenal, NJ 07806-5000
973-724-9503, (fax: 973-724-2417),
miroslav.tesla.civ@mail.mil
December 16, 2015, comments and corrections requested

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 2 (TA2) labeled by the Air Force as Test 4.
- Scope
  - Model: VHG TA2 Test 4, housing and boards filled with potting, no electronics components, VHG test apparatus.
  - Abaqus Explicit 6.14-1, dynamic analysis.
  - Evaluate: Acceleration during the impact. Predict acceleration readings for all 4 accelerometers placed on 4 boards. Compare accelerometer readings during VHG test with FEA predictions.

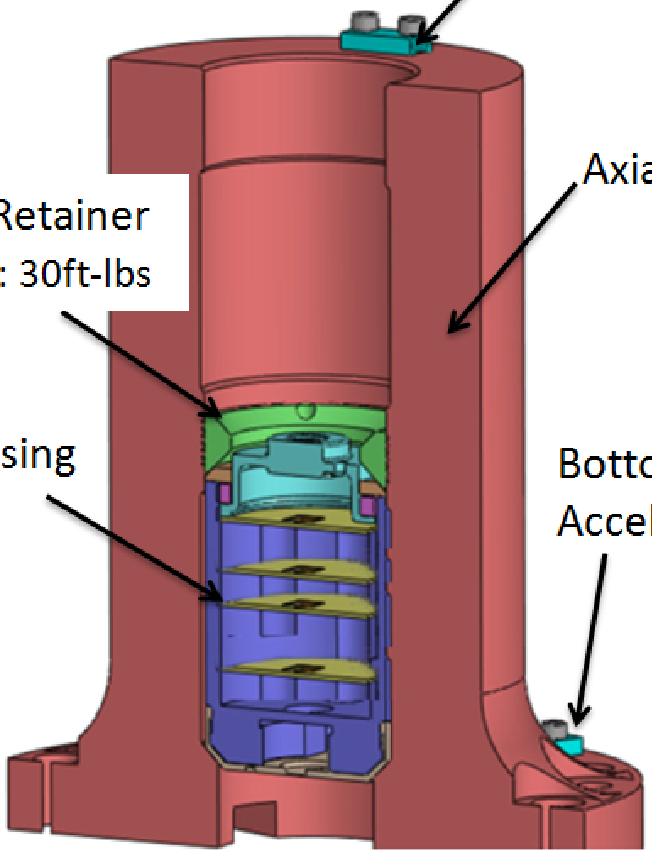
Method: Model Information, Procedures and Possible Errors

- General Purpose Finite Element Software: Abaqus Explicit 6.14-1
- Analysis: dynamic, non-linear materials, non-linear geometry
- Analysis time: 0.004 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
- Materials: Viscoelastic model, Orthotropic elastic plastic model and Crushable Foam model.
- Loads: Shock load per VHG TA2 Test 4 input data (A1 accelerometer “SN102_test04” - test data from Eglin).
- Boundary: Constrained fixture, assumed
- Initial Conditions: No initial velocity
- Friction: Friction coefficient 0.3, all contact surfaces.
- Damping: material viscoelastic damping and Rayleigh mass proportional damping.
- Assumed failure criteria:
  - Mises Stress > Ultimate Tensile Strength, assumed failure
  - Maximum Strain > Material Elongation, assumed failure
  - Plasticity > ¼ wall thickness, assumed failure for design purposes
- 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

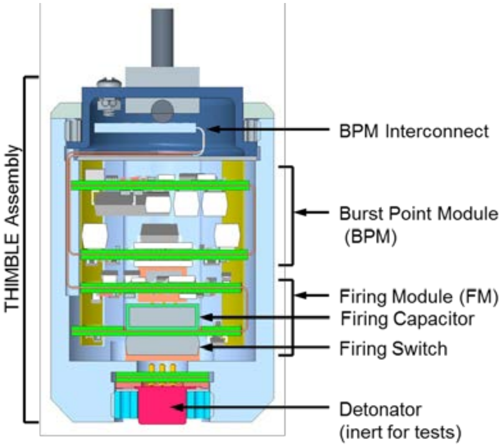
A single HMFT Phase II unit instrumented with accelerometers on each unpopulated board was mounted in an axial fixture and held in place with a dual chamfer retainer torqued at 30ft-lbs.

The axial fixture is instrumented with a bottom accelerometer (an Endevco 7270A-60k) and a top accelerometer (an Endevco 7280A-60k) to measure the input into the fixture.



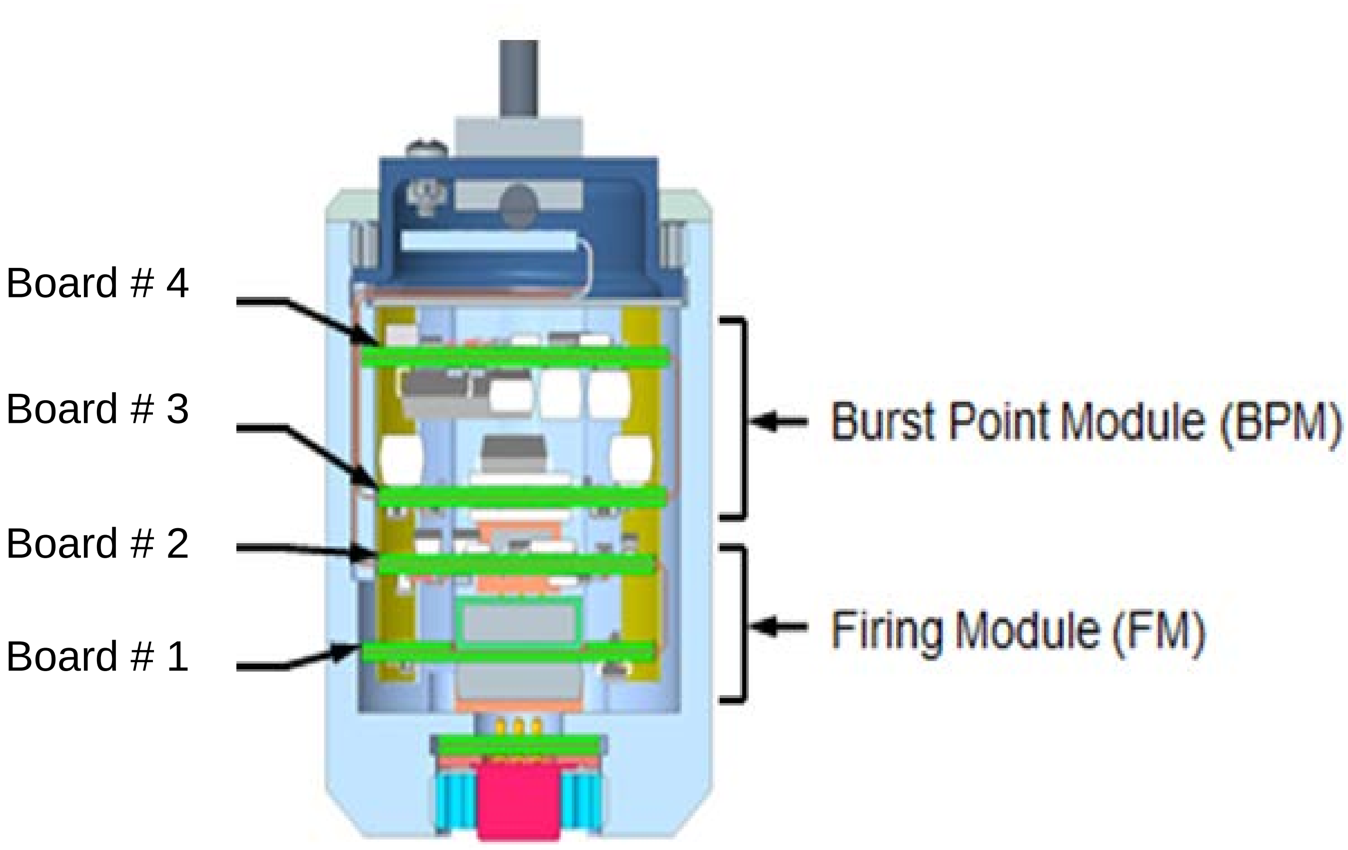
Method: Test Setup

Very High G (VHG) shock machine at Eglin AFRL



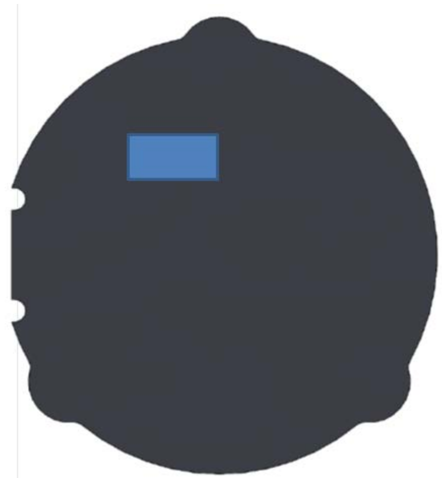
Tail Mounted HMFT

Method: Accelerometers' Location



Method: Accelerometers’ Location

Accelerometer is modeled as point in center of each accelerometer.



a) Board 4 - Burst Point Module

b) Board 3 - Burst Point Module

c) Board 2 - Firing Module

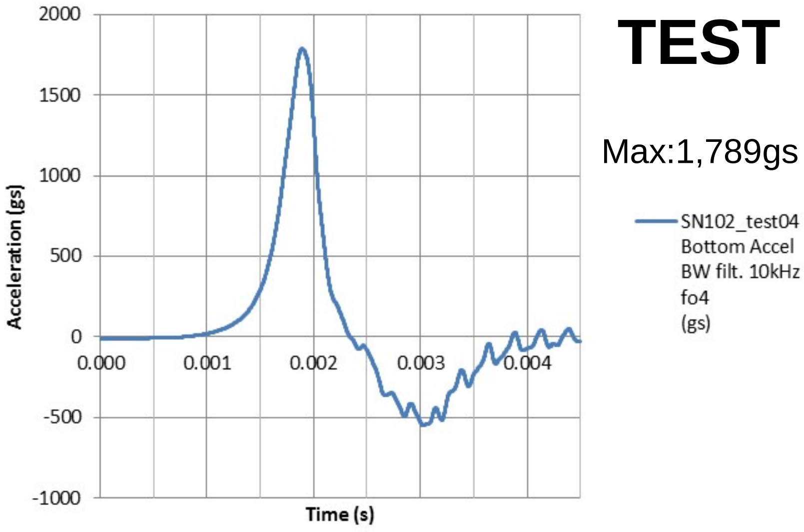
d) Board 1 – Firing Module

Results: Validation Examples

TA2: Test 4 A1 (Bottom Accelerometer)
low pass Butterworth filter, cut off frequency 10 kHz

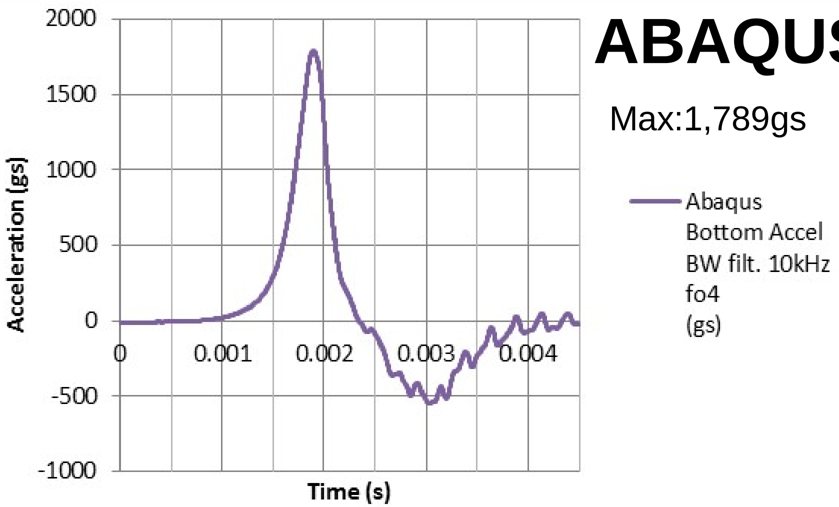
TEST

Max:1,789gs



ABAQUS

Max:1,789gs



Matched well

Input: test 4 raw data, outer bottom ring.

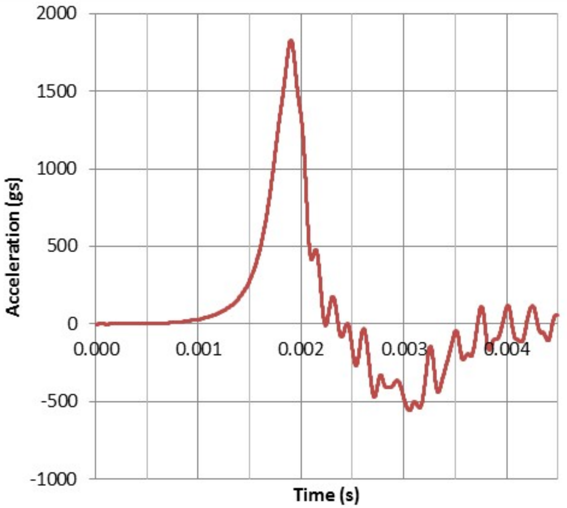
Output: response at bottom accelerometer.
Data filtered using low pass Butterworth filter, cut off frequency 10 kHz and filter order 4.
Purple is ABAQUS and blue is Eglin test data

Abaqus readings match Test 4 bottom accelerometer readings.

Results: Validation Examples

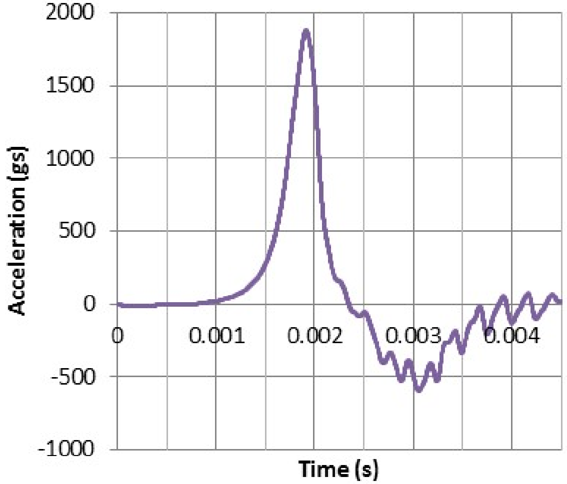
TA2: Test 4 A2 (Top Accelerometer)

low pass Butterworth filter, cut off frequency 10 kHz



TEST

Max:1,831gs



ABAQUS

Max:1,878gs

Matched well

Input: test 4 raw data, outer bottom ring.

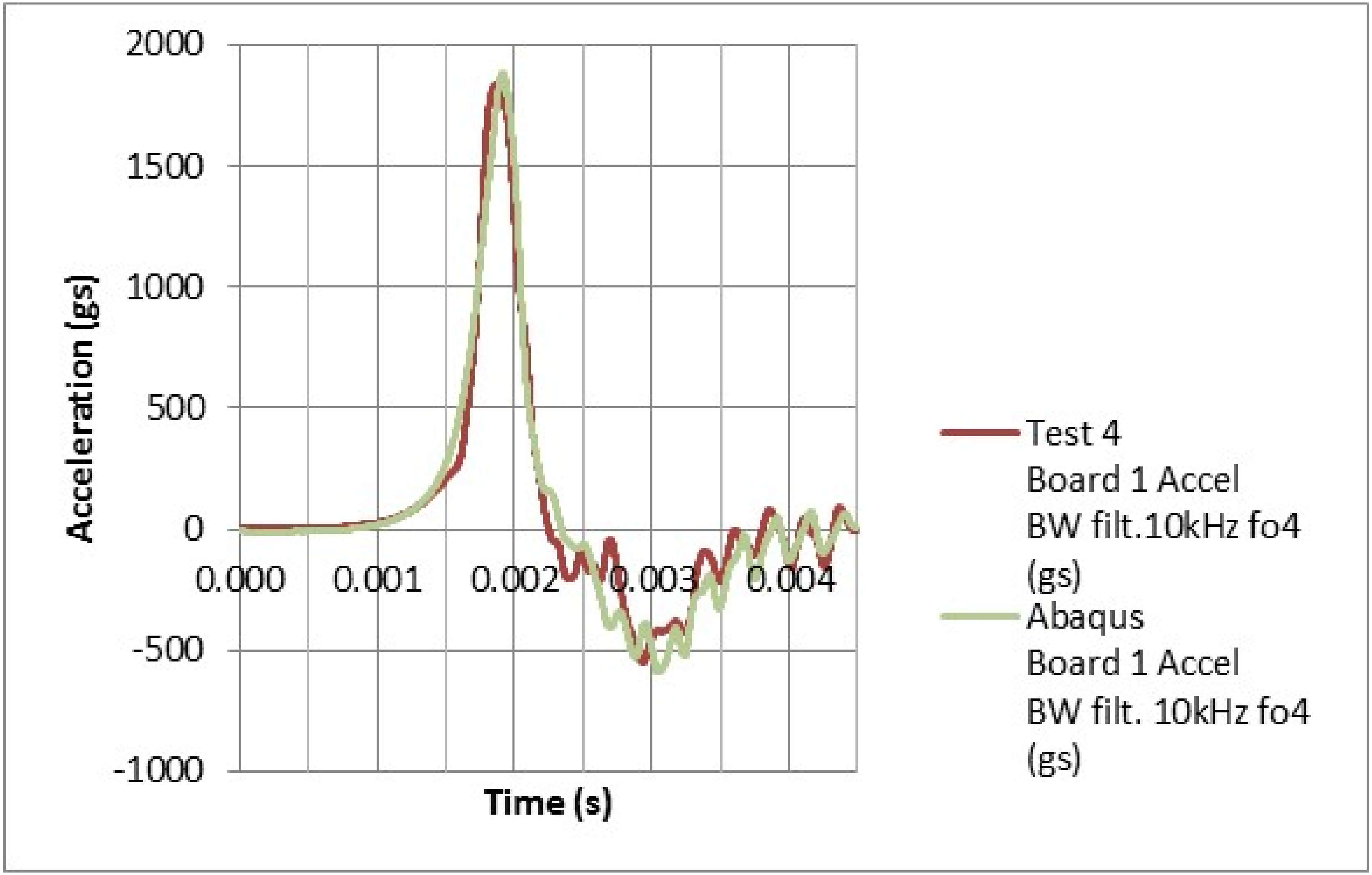
Output: response at top accelerometer. Data filtered using low pass Butterworth filter, cut off frequency 10 kHz and filter order 4.
Purple is ABAQUS and red is Eglin test data

Abaqus readings match Test 4 top accelerometer readings. The Max was within 2.5%.

Results:

TA2:Test 4 Board 1 Accelerometer

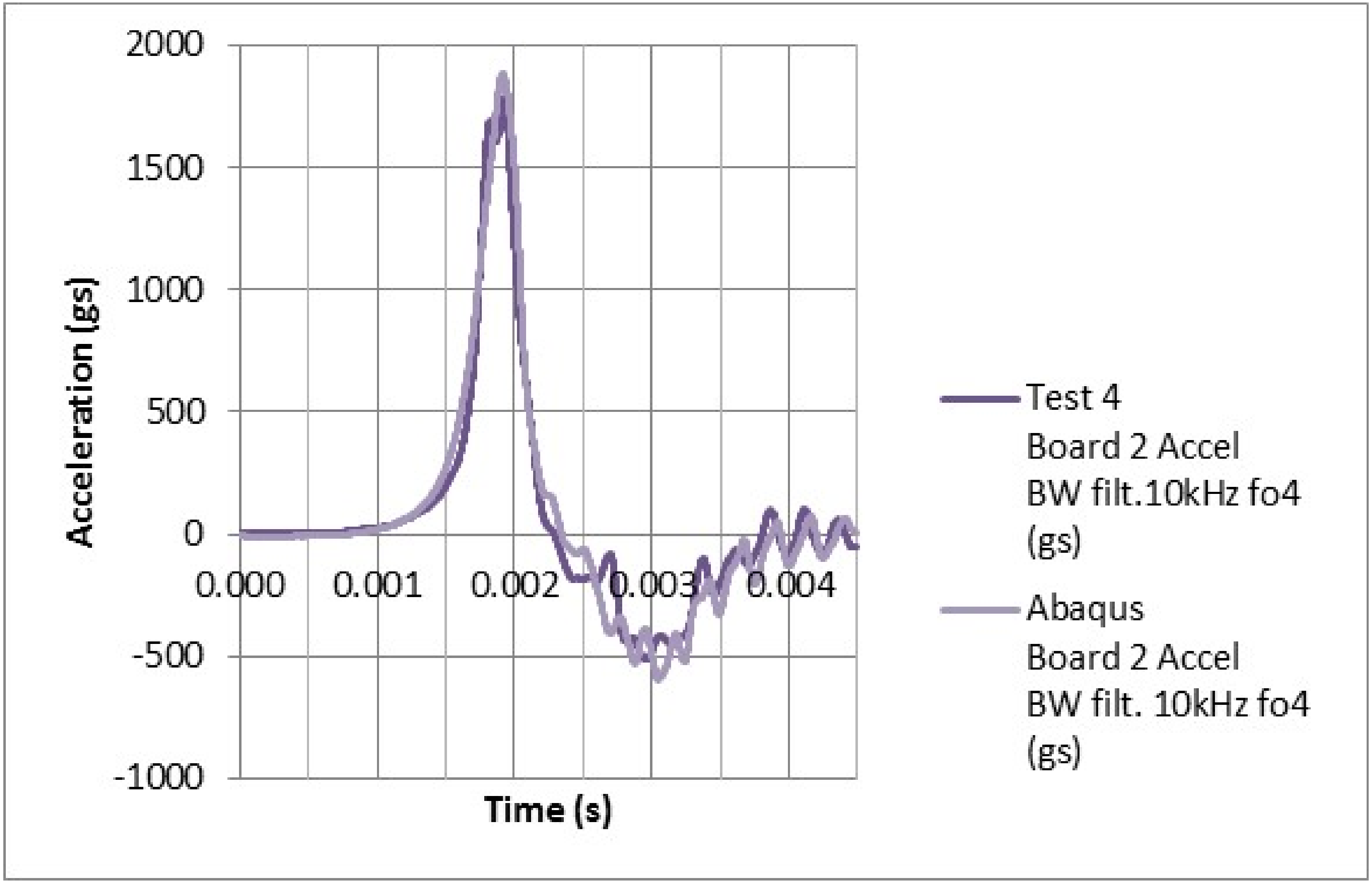
low pass Butterworth filter, cut off frequency 10 kHz



Results:

TA2:Test 4 Board 2 Accelerometer

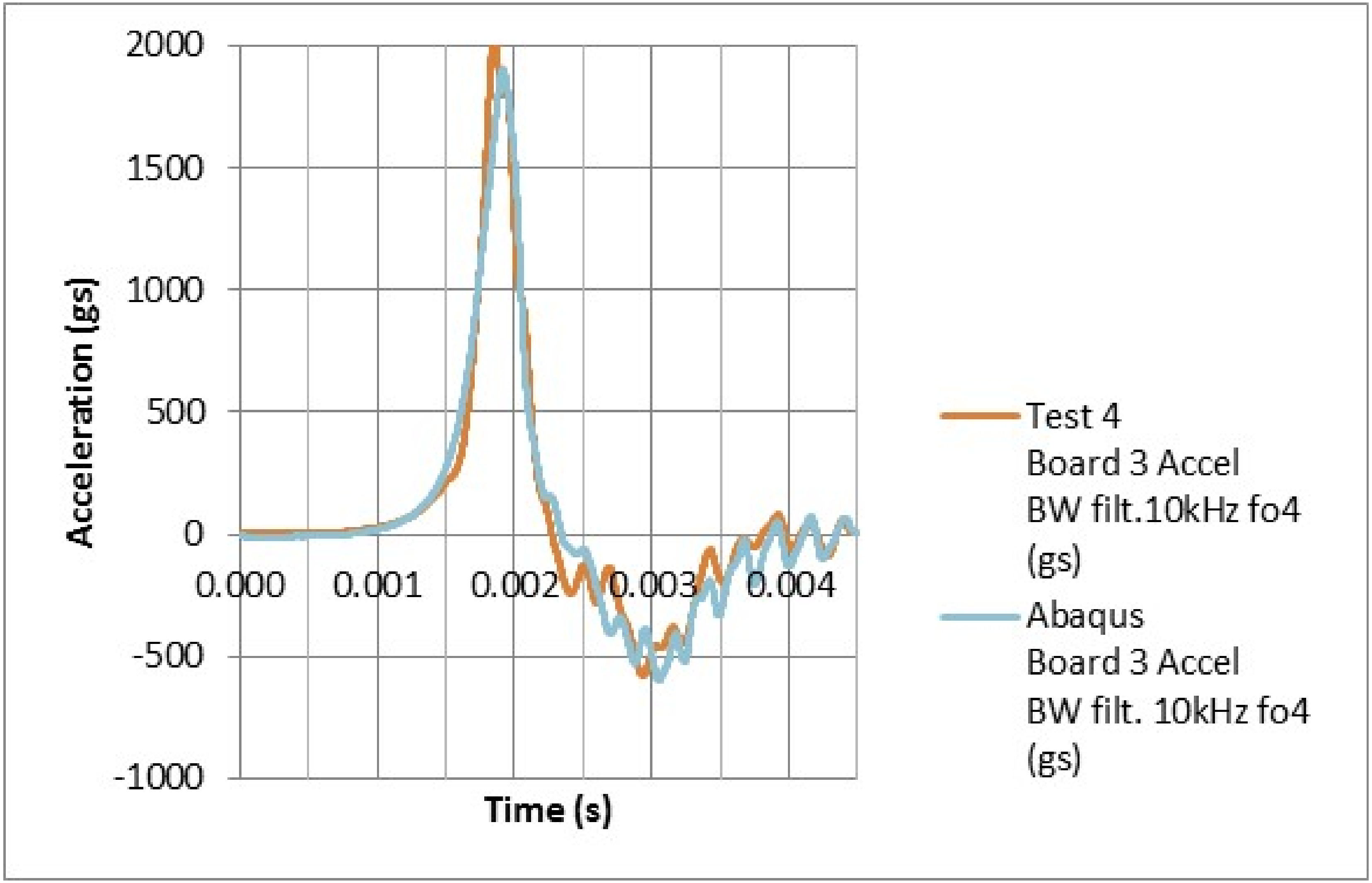
low pass Butterworth filter, cut off frequency 10 kHz



Results:

TA2:Test 4 Board 3 Accelerometer

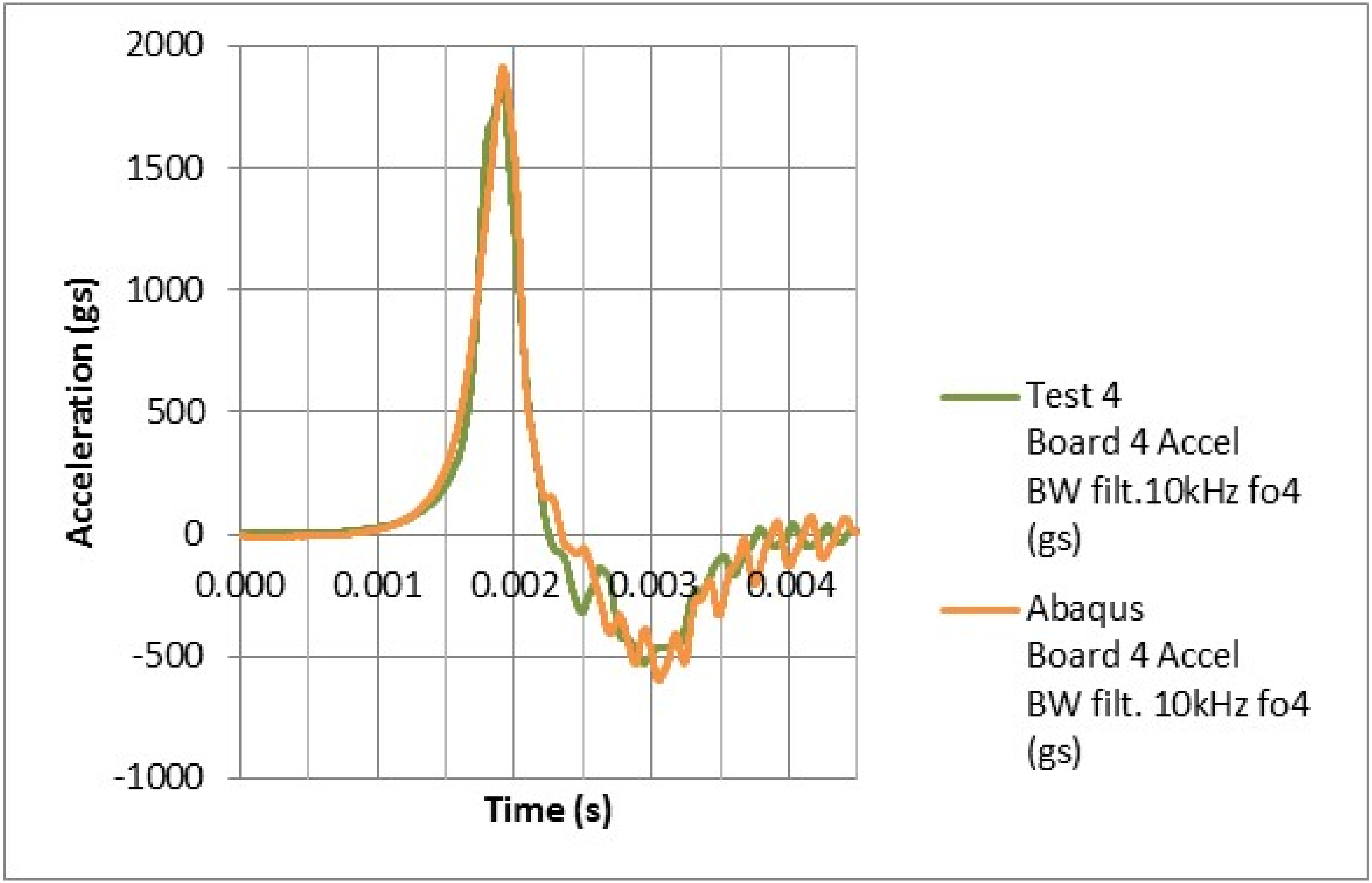
low pass Butterworth filter, cut off frequency 10 kHz



Results:

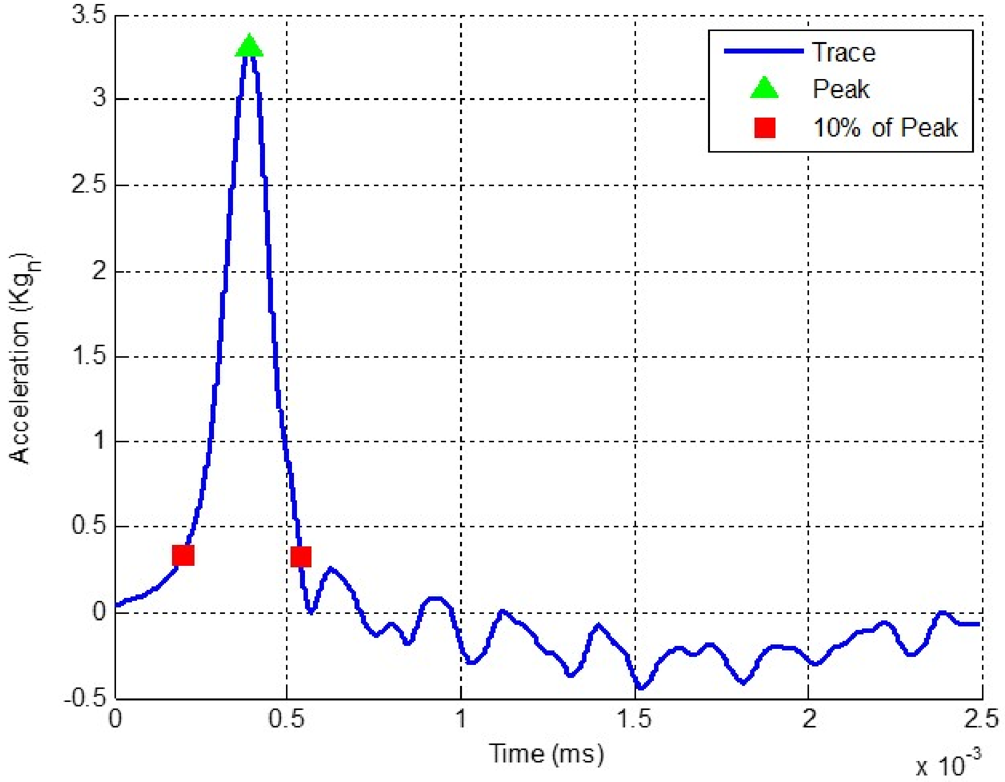
TA2:Test 4 Board 4 Accelerometer

low pass Butterworth filter, cut off frequency 10 kHz



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:
Peak board acceleration and Duration of the peak

Accelerometer Location	Source	Peak (kGs)	Duration (ms)	% Diff of Peak	% Diff of Duration	Sum of Peak and Duration % Diff
Board 1	Test 4	1.838	0.720	N/A	N/A	N/A
	Test 3	1.900	0.731	3.3	1.5	4.8
	Abaqus	1.886	0.770	2.6	6.5	9.1
Board 2	Test 4	1.784	0.695	N/A	N/A	N/A
	Test 3	1.910	0.670	6.8	3.7	10.5
	Abaqus	1.886	0.769	5.5	10.0	15.5
Board 3	Test 4	2.041	0.694	N/A	N/A	N/A
	Test 3	2.057	0.704	0.8	1.4	2.2
	Abaqus	1.903	0.766	-7.0	9.6	16.6
Board 4	Test 4	1.876	0.705	N/A	N/A	N/A
	Test 3	2.027	0.689	7.7	-2.3	10.0
	Abaqus	1.910	0.765	1.8	8.0	9.8

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 4 performed on VHG machine and Abaqus predictions. The peak acceleration was matched within 7.0% for all four boards. The shape of the acceleration response was also reasonably accurate for the four circuit boards.