Hypervelocity Impact (HVI)

Volume 8: Tile Small Targets A-1, Ag-1, B-1, and Bg-1

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Hypervelocity Impact (HVI)

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Hypervelocity Impact (HVI)
Tile Small Targets A-1, Ag-1, B-1, and Bg-1

During 2003 and 2004, the Johnson Space Center’s White Sands Testing Facility in Las Cruces, New Mexico conducted hypervelocity impact tests on the space shuttle wing leading edge.

Hypervelocity impact tests were conducted to determine if Micro-Meteoroid/Orbital Debris impacts could be reliably detected and located using simple passive ultrasonic methods.

The objective of Targets A-1, Ag-1, B-1, and Bg-1 was to study hypervelocity impacts on the reinforced Shuttle Heat Shield Tiles of the Wing.

Impact damage was detected using lightweight, low power instrumentation capable of being used in flight.
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Introduction

In the wake of the Columbia accident, NASA personnel decided to test the idea that impacts during space flight could be detected by acoustical sensors at ultrasonic frequencies. The substance of this idea rested on the knowledge that in laboratory experiments lower velocity impacts had created signals with frequencies in the 20 – 200 kHz range. If Shuttle engine and aerodynamic noise were down in the sonic range then locating impacts would be easier in the 20-200 kHz range. The questions were what frequencies would be created during hypervelocity impacts by tiny objects, what would their energies be, and what would be the best way to detect them, keeping in mind the potential need for lightweight, simple installation procedures and low electrical energy consumption.

A further basis for selecting this method was that recent fundamental research had elucidated the basic physics of the ultrasonic signals created by the impacts in a variety of aerospace materials and geometries. This made it more likely that signal and noise could be separated and that subsequent analysis of the signals would yield the desired information about impact severity and location. All of the above reasoning proved to be correct. Hypervelocity impact by tiny aluminum spheres created signals in the 20-200 kHz frequency range easily detectable with small piezoelectric sensors similar to equipment being flown.

Targets A-1, Ag-1, B-1, and Bg-1 were four of several targets (see below) used for hypervelocity impact testing. There is a section in this Report for each of the other targets. The structure of this report includes a General Introduction that contains the overall goals, the personnel involved, the test methods, instrumentation, calibration, and overall results and conclusions. Only abbreviated descriptions of the test methods, instrumentation, and calibration are given in each of the Target sections such as this one.

This section describes Targets A-1, Ag-1, B-1, and Bg-1, the test equipment, features tables of energy and damage results, and a discusses the relationship between kinetic energy, wave signal energy and damage. Also discussed are wave propagation effects, the modes and their velocities, and location of impacts by sound wave analysis.

The Appendix has test condition data sheets, impact waveforms, and photos of the damage for each shot. Also included are tables of impact data, gain settings, recorded wave signals, and damage results.

The number of targets tested in the overall HVI study was extensive as shown in the list below:

- A-1 – Fiberglass plate and aluminum plate with standoff rods (with grommets)
Tile Targets A-1, Ag-1, B-1, and Bg-1

- A-2 – Fiberglass plate and aluminum plate with standoff rods (no grommets)
- B-1 – Two fiberglass plates and aluminum plate with standoff rods
- C-1 – Fiberglass flat plate
- C-2 – Fiberglass flat plate
- FG-1 – Fiberglass in the shape of Wing Leading Edge
- FG-2 – Fiberglass in the shape of Wing Leading Edge
- RCC16R – Carbon-Carbon Actual WLE
- A-1 Tile – Tile structure of forward part of wing with no gap filler
- A-1g Tile – Tile structure of forward part of wing with gap filler
- B-1 Tile – Tile structure of aft part of wing with no gap filler
- B-1g Tile – Tile structure of aft part of wing with gap filler

It is everyday experience that when a solid material is struck, sound is created. This new passive ultrasonic technique has been designated modal acoustic emission (MAE) due to its (physical) similarity to an older, but less robust technique known as acoustic emission. In structures built of plate-like sections (aircraft wings, fuselages, etc.) the sound waves of interest are the extensional mode (in-plane stretching and compressing of the plate) and the flexural mode (bending of the plate). These are called plate waves and they propagate in bounded media where the wavelength of the wave is larger than the thickness of the plate. The frequency spectrum typically ranges from the low kilohertz to about one megahertz. Plate waves can be detected with simple piezoelectric transducers that convert mechanical motion into electrical voltage.

By analyzing mode shapes, and taking into account the material and loading, sources can be identified and located. The direct connection to fundamental physics is a key characteristic of MAE. For simple geometries the wave shapes and velocities have been calculated from wave equations derived from Newton’s laws of motion and they compare well with measurements. (See General Introduction to this report for a fuller discussion of modal AE.) By using arrival times at transducers with known positions, the location of the source can be triangulated by various mathematical methods (similar to methods used in SONAR).

**Experimental Description**

Targets A-1, Ag-1, B-1, and Bg-1 were 34” x 34” in size, with an array of tile and aluminum skin-stringers substructure. The tiles were manufactured and densified to flight specs, bonded by standard SIP specifications to the aluminum skin-stringers substrated that was cleaned, primed and prepared per flight specs. Target type A resembled lower wing structure toward the wing aft. The tiles were 6” x 6” x 1.3” thick L1-900 in a 19 tile array, bonded to 0.16” thick SIP and to a 0.063” thick AI 2024T81, with hat shaped stiffeners attached (riveted) to provide reasonable target stiffness. Tiles on some targets were installed without gap fillers (designated “A-1” and “B-1”), while the tiles on other targets were installed with gap fillers (designated “Ag-1” and “Bg-1”). Figure 1, Figure 2, Figure 3, and Figure 4 show images of the targets.
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 1: Tile Target A-1

Figure 2: Tile Target Ag-1

Figure 3: Tile Target B-1

Figure 4: Tile Target Bg-1
There were 18 shots fired at each target. The targets were oriented at 90 degrees for shots #1 – 6, at 45 degrees for shots #7-13 and at 30 degrees for shots #14 - #18 (Figure 5, Figure 6, and Figure 7).

Figure 5: Fiberglass Panel Target Ag-1 with 90 deg Impact Angle. Back Side View.

Figure 6: Fiberglass Panel Target Ag-1 with 45 deg Impact Angle. Back Side View.
The tests were conducted on the 0.50 caliber hypervelocity launcher range at the White Sands Test Facility (WSTF). The flight range for the hypervelocity projectile and target chamber were evacuated to near vacuum pressure (6-8 Torr) prior to each shot. The AE recording equipment was connected by feed-throughs to the sensors on the target inside the vacuum chamber. The connectors were BNC type.

The projectiles were small spheres made of 2017 T-4 aluminum. They ranged in diameter from 1.0 mm to 5.16 mm. Impact velocity was measured with WSTF diagnostic equipment on each shot. The projectile kinetic energy for these shots ranged from 2.09 J to 5706.31 J.

Eight acoustic (ultrasonic) emission sensors were coupled to the back of the target with Lord 202 acrylic adhesive (Figure 8). Diagrams of the sensor layouts are shown in Figure 9, Figure 10, Figure 11, and Figure 12. Photos of the sensor layouts are shown in Figure 13, Figure 14, Figure 15, and Figure 16. A complete description of the type of sensor used and calibration is given in the General Introduction to this report.

Figure 7: Fiberglass Panel Target Ag-1 with 30 deg Impact Angle. Back Side View.
Figure 8: Detail of Acoustic Emission Sensors. Clockwise from Upper Left: Sensor 2 on Target A-1, Sensor 1 on Target Ag-1, Sensor 5 on Target B-1, and Sensor 4 on Target Bg-1
Figure 9: A-1 Diagram of Sensor and Impact Locations. Front View.

Acoustic emission sensors are highlighted in yellow with the following coordinates:

#1(29, 29), #2(17.25, 29.5), #3(21.5, 27), #4(13, 29),
#5(29, 11.75), #6(21, 15.5), #7(13, 9.5), #8(5, 9.5) Dimensions are inches.

Impact locations are highlighted in magenta with the following coordinates:

#1(13.75, 18.25), #2(18.25, 14), #3(20.25, 20.5), #4(11.5, 11.75), #5(25, 16), #6(16, 25),
#7(16, 7), #8(7.25, 16), #9(16, 16), #10(9.5, 22.75), #11(22.5, 9.5), #12(22.5, 23),
#13(7.25, 7.25), #14(30, 30), #15(10.8, 30), #16(4.2, 27.7), #17(30, 10.8), #18(27.8, 4.2)

Note: Impact points #1-6 are to the center of tiles and impact points #7-18 are off-set on tiles.
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 10: Ag-1 Diagram of Sensor and Impact Locations. Front View.

Acoustic emission sensors are highlighted in yellow with the following coordinates:

#1(29, 29), #2(17.25, 29.5), #3(21.5, 27), #4(13, 29),
#5(29, 11.75), #6(21, 15.5), #7(13, 9.5), #8(5, 9.5)
Dimensions are inches.

Impact locations are highlighted in magenta with the following coordinates:
#1(13.75, 18.25), #2(18.25, 14), #3(20.25, 20.5), #4(11.5, 11.75), #5(25, 16), #6(16, 25),
#7(16, 7), #8(7.25, 16), #9(16, 16), #10(9.5, 22.75), #11(22.5, 9.5), #12(22.5, 23),
#13(7.25, 7.25), #14(30, 30), #15(10.8, 30), #16(4.2, 27.7), #17(30, 10.8), #18(27.8, 4.2)

Note: Impact points #1-6 are to the center of tiles
and impact points #7-18 are off-set on tiles.
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 11: B-1 Diagram of Sensor and Impact Locations. Front View.

Acoustic emission sensors are highlighted in yellow with the following coordinates:
#1(29, 29), #2(18.5, 29.5), #3(22.5, 27), #4(11.5, 29),
#5(29, 11.75), #6(20.25, 16), #7(13.75, 9.5), #8(5, 9.5) Dimensions are inches.
Impact locations are highlighted in magenta with the following coordinates:
#1(13.75, 18.25), #2(18.25, 14), #3(20.25, 20.5), #4(11.5, 11.75), #5(25, 16), #6(16, 25),
#7(16, 7), #8(7.25, 16), #9(16, 16), #10(9.5, 22.75), #11(22.5, 9.5), #12(22.5, 23),
#13(7.25, 7.25), #14(30, 30), #15(10.8, 30), #16(4.2, 27.7), #17(30, 10.8), #18(27.8, 4.2)

Note: Impact points #1-6 are to the center of tiles and impact points #7-18 are off-set on tiles.
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 12: Bg-1 Diagram of Sensor and Impact Locations. Front View.
Acoustic emission sensors are highlighted in yellow with the following coordinates:
#1(29, 29), #2(18.5, 29.5), #3(22.5, 27), #4(11.5, 29),
#5(29, 11.75), #6(20.25, 16), #7(13.75, 9.5), #8(5, 9.5) Dimensions are inches.
Impact locations are highlighted in magenta with the following coordinates:
#1(13.75, 18.25), #2(18.25, 14), #3(20.25, 20.5), #4(11.5, 11.75), #5(25, 16), #6(16, 25),
#7(16, 7), #8(7.25, 16), #9(16, 16), #10(9.5, 22.75), #11(22.5, 9.5), #12(22.5, 23),
#13(7.25, 7.25), #14(30, 30), #15(10.8, 30), #16(4.2, 27.7), #17(30, 10.8), #18(27.8, 4.2)
Note: Impact points #1-6 are to the center of tiles
and impact points #7-18 are off-set on tiles.
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 13: A-1 Photo of Sensor Locations

Figure 14: Ag-1 Photo of Sensor Locations
The piezoelectric sensors converted the sound wave energy to electrical voltages. The energy computed from the voltage data collected by each sensor channel is referred to as the wave signal energy. (A complete description of the type of sensor used and calibration is given in the General Introduction to this report.)

The wave signal energy for each channel was analyzed and compared to the impact energy. A full description of the wave recording instrumentation is given in the General Introduction to this Report. (Each individual sensor was connected to a separate
amplification and filtering channel and the voltage produced by the sensor recorded and stored on a computer.)

The wave signal energy was computed by integrating the squared voltage with respect to time and dividing this number by the impedance at the preamp input. The voltage versus time values of the wave, which were displayed in the waveform window on the computer screen for each channel, were not corrected for any applied gain (or attenuation).

Attenuation was the norm because hypervelocity impact produced very energetic signals that in most cases would have saturated the A/D converter on the recording card in the computer had the amplitude not been reduced.

Some recorder channels were found to have a slight DC offset (Figure 17). This added significantly to the wave energy when the integral of squared voltage versus time signal was computed. To eliminate the offset, the average wave signal voltage for the impact event was subtracted from each data point. This resulted in a zeroed raw wave signal (no DC offset. Correcting the offset was more important for small signals than large signals.

![Figure 17: Example of DC Offset](image-url)

The top signal is centered at -0.002 V whereas the bottom signal is centered at -0.001V.

A typical impact signal is shown in Figure 18. The impact signal has a distinct waveform and varies in both in arrival time and amplitude on each channel. The distinct modal characteristics can be seen in a time expanded view in Figure 19. The E mode is seen to arrive first with its lowest frequency in front followed by progressively higher frequencies. This is followed by the flexural (F) wave. The F wave characteristics are harder to discern because of the filtering of the attenuators and other effects discussed elsewhere in this report.
In some cases, the F wave characteristics are much more visible. The vastly different velocities of the modes were used to confirm the modes’ presence.

The sound waves produced by impact are shown complete in the Appendix. It can be seen that the impact waves have the plate mode characteristics, i.e., the extensional wave arrives first, with its low frequency components out front followed by higher frequency components, and the F wave with just the opposite frequency arrangement. This differs, for example, from noise caused by electromagnetic interference (EMI). In contrast, EMI noise typically looks the same on every channel and arrives simultaneously (Figure 20). EMI exhibits no plate wave propagation characteristics.

![Figure 18: A-1 Impact Signal for Shot #1](image-url)
The MAE software computed the raw wave signal energy in Joules uncorrected for any analog gain or attenuation that may have been applied to the signal path. In order to compare the wave energies from shot to shot, the raw wave signal energy was converted by applying Equation 1 where $E_{raw}$ is the energy computed using the recorded wave (with DC offset eliminated) and $G$ is the system gain.
Tile Targets A-1, Ag-1, B-1, and Bg-1

\[ W.S.E. = \frac{E_{raw}}{G^2} \]  \hspace{1cm} \text{Equation 1}

The gain \( G \) was computed by converting the logarithmic gain, \( M \), in decibels with Equation 2 or Equation 3.

\[ M \text{ dB} = 20 \log_{10} (G) \]  \hspace{1cm} \text{Equation 2}

\[ G = 10^\frac{M}{20} \]  \hspace{1cm} \text{Equation 3}

The gains, raw wave signals, and wave energies for each shot are listed in the data tables in the Appendix to this section.

High velocity impact produced signals on the order of a few volts directly out of the transducer. These were much larger signals than typically found in most acoustic emission measurements of, say, crack growth in metals. For most shots, attenuators were placed in the signal lines between the sensors and the digital recorders. Greater attenuation was applied for the higher energy shots which made the raw energy appear to be much less. The energy was restored to its full value by compensating in the analysis for the greater attenuation, Equation 3 above.

Results

The most important quantities used in the analysis of the wave signals were the wave signal energy and projectile kinetic energy for each shot. These are given in Table 1, Table 2, Table 3, and Table 4 along with the test number, impactor size, and angle of impact. Wave signal energy is the sum of the energy, in nano-Joules, detected by all of the sensors. Kinetic energy is calculated based on the velocity and mass of projectile (density of aluminum = 2700 kg/m\(^3\)) according to the usual formula \( \text{K.E.} = \frac{mv^2}{2} \). The kinetic energy correlated with the damage. As will be seen, the kinetic energy correlated fairly well with the damage. Normal KE is just the kinetic energy associated with the projectile velocity component normal to the target surface at the point of impact.
Tile Targets A-1, Ag-1, B-1, and Bg-1

<table>
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Table 1: A-1 Kinetic Energy and Wave Signal Energy

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Table 2: Ag-1 Kinetic Energy and Wave Signal Energy
Tile Targets A-1, Ag-1, B-1, and Bg-1

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Table 3: B-1 Kinetic Energy and Wave Signal Energy

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Table 4: B-1 Kinetic Energy and Wave Signal Energy
The damage for each shot is given in Table 5, Table 6, Table 7, and Table 8. The crater volume damage and damage area measurements were rough approximations. Each impact created a different fracture type. Impact photos (Figure 21-Figure 24) record a variety of holes, cracks, and chips. Damage on tile targets was more difficult to quantify than damage on fiberglass targets.

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<th>Normal K.E. (J ± 5%)</th>
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Table 5: A-1 Damage Results
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<td>88.63587</td>
<td>88.63582</td>
<td>378.84</td>
<td>26.5</td>
</tr>
<tr>
<td>Ag1-5</td>
<td>133.0918</td>
<td>133.0917</td>
<td>507.84</td>
<td>40.96</td>
</tr>
<tr>
<td>Ag1-6</td>
<td>173.6357</td>
<td>173.6356</td>
<td>751.68</td>
<td>40.26</td>
</tr>
<tr>
<td>Ag1-7</td>
<td>258.4136</td>
<td>129.1039</td>
<td>1412.46</td>
<td>46.8</td>
</tr>
<tr>
<td>Ag1-8</td>
<td>328.8539</td>
<td>164.296</td>
<td>1591.92</td>
<td>63.64</td>
</tr>
<tr>
<td>Ag1-9</td>
<td>273.144</td>
<td>136.4632</td>
<td>2660</td>
<td>594</td>
</tr>
<tr>
<td>Ag1-10</td>
<td>33.45869</td>
<td>16.71602</td>
<td>252.56</td>
<td>21.62</td>
</tr>
<tr>
<td>Ag1-11</td>
<td>195.1311</td>
<td>97.48784</td>
<td>1096.78</td>
<td>51.1</td>
</tr>
<tr>
<td>Ag1-12</td>
<td>265.3403</td>
<td>132.5645</td>
<td>5642</td>
<td>625</td>
</tr>
<tr>
<td>Ag1-13</td>
<td>281.0608</td>
<td>140.4185</td>
<td>9541</td>
<td>605</td>
</tr>
<tr>
<td>Ag1-14</td>
<td>260.7123</td>
<td>65.11816</td>
<td>1641.6</td>
<td>78.3</td>
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<td>Ag1-15</td>
<td>360.4228</td>
<td>90.02286</td>
<td>2420.28</td>
<td>90.25</td>
</tr>
<tr>
<td>Ag1-16</td>
<td>450.5109</td>
<td>112.5242</td>
<td>7672</td>
<td>900</td>
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<tr>
<td>Ag1-17</td>
<td>188.3835</td>
<td>47.05258</td>
<td>1455.3</td>
<td>68</td>
</tr>
<tr>
<td>Ag1-18</td>
<td>133.8782</td>
<td>33.43877</td>
<td>740.08</td>
<td>39.6</td>
</tr>
</tbody>
</table>

Table 6: Ag-1 Damage Results

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Total K.E. J (± 5%)</th>
<th>Normal K.E. J (± 5%)</th>
<th>Crater Vol mm³</th>
<th>Damage Area mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1-1</td>
<td>30.14</td>
<td>30.14</td>
<td>158.4</td>
<td>No data</td>
</tr>
<tr>
<td>B1-2</td>
<td>114.19</td>
<td>114.19</td>
<td>687.5</td>
<td>No data</td>
</tr>
<tr>
<td>B1-3</td>
<td>717.50</td>
<td>717.50</td>
<td>1665.6</td>
<td>54.4</td>
</tr>
<tr>
<td>B1-4</td>
<td>1071.03</td>
<td>1071.02</td>
<td>3933.0</td>
<td>110.0</td>
</tr>
<tr>
<td>B1-5</td>
<td>1489.29</td>
<td>1489.28</td>
<td>5724.0</td>
<td>332.5</td>
</tr>
<tr>
<td>B1-6</td>
<td>2110.34</td>
<td>2110.34</td>
<td>8280.0</td>
<td>1053.0</td>
</tr>
<tr>
<td>B1-7</td>
<td>2061.20</td>
<td>1029.78</td>
<td>31284.0</td>
<td>4340.0</td>
</tr>
<tr>
<td>B1-8</td>
<td>3668.06</td>
<td>1832.57</td>
<td>50778.0</td>
<td>6232.0</td>
</tr>
<tr>
<td>B1-9</td>
<td>1489.29</td>
<td>744.05</td>
<td>95940.0</td>
<td>3782.0</td>
</tr>
<tr>
<td>B1-10</td>
<td>5622.46</td>
<td>2808.99</td>
<td>93000.0</td>
<td>5929.0</td>
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<td>B1-11</td>
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<td>62400.0</td>
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<tr>
<td>B1-12</td>
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<td>344.5</td>
</tr>
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<td>B1-13</td>
<td>1480.43</td>
<td>739.63</td>
<td>30100.0</td>
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<tr>
<td>B1-14</td>
<td>1275.91</td>
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<td>23205.0</td>
<td>1365.0</td>
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<tr>
<td>B1-15</td>
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<td>B1-16</td>
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<td>1421.07</td>
<td>36300.0</td>
<td>12644.0</td>
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<tr>
<td>B1-17</td>
<td>2958.87</td>
<td>739.04</td>
<td>93351.0</td>
<td>4977.0</td>
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<tr>
<td>B1-18</td>
<td>2166.33</td>
<td>541.08</td>
<td>41400.0</td>
<td>4350.0</td>
</tr>
</tbody>
</table>

Table 7: B-1 Damage Results
<table>
<thead>
<tr>
<th>Test No.</th>
<th>Total J (± 5%)</th>
<th>Normal J (± 5%)</th>
<th>Crater K.E.</th>
<th>Vol mm³</th>
<th>Area mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bg1-1</td>
<td>32.78</td>
<td>32.78</td>
<td>168.8</td>
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<td>25.0</td>
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<td>Bg1-2</td>
<td>134.27</td>
<td>134.27</td>
<td>450.0</td>
<td></td>
<td>36.0</td>
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<tr>
<td>Bg1-3</td>
<td>728.09</td>
<td>728.09</td>
<td>3307.5</td>
<td></td>
<td>161.0</td>
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<tr>
<td>Bg1-4</td>
<td>1055.33</td>
<td>1055.33</td>
<td>3420.0</td>
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<td>175.5</td>
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<tr>
<td>Bg1-5c</td>
<td>1484.86</td>
<td>1484.86</td>
<td>4657.5</td>
<td></td>
<td>377.0</td>
</tr>
<tr>
<td>Bg1-6</td>
<td>2160.07</td>
<td>2160.07</td>
<td>7500.0</td>
<td></td>
<td>3024.0</td>
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<tr>
<td>Bg1-7</td>
<td>2172.59</td>
<td>1085.43</td>
<td>20160.0</td>
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<td>Bg1-8</td>
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<td>1774.19</td>
<td>54400.0</td>
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<td>5254.0</td>
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<td>Bg1-9b</td>
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<td>741.84</td>
<td>40950.0</td>
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<td>4675.0</td>
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<tr>
<td>Bg1-10</td>
<td>5522.65</td>
<td>2759.13</td>
<td>66240.0</td>
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<td>8736.5</td>
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<tr>
<td>Bg1-11</td>
<td>4346.44</td>
<td>2171.49</td>
<td>70470.0</td>
<td></td>
<td>6552.0</td>
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<tr>
<td>Bg1-12</td>
<td>1507.07</td>
<td>752.93</td>
<td>58080.0</td>
<td></td>
<td>2750.0</td>
</tr>
<tr>
<td>Bg1-13</td>
<td>1529.44</td>
<td>764.11</td>
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<td>Bg1-14b</td>
<td>1579.25</td>
<td>394.45</td>
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</tr>
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<td>Bg1-15</td>
<td>3689.51</td>
<td>921.53</td>
<td>233200.0</td>
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<td>Bg1-16</td>
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<td>7644.0</td>
</tr>
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<td>Bg1-17</td>
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<td>709.81</td>
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<td>Bg1-18</td>
<td>2116.53</td>
<td>528.65</td>
<td>47320.0</td>
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<td>5159.0</td>
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</tbody>
</table>

Table 8: Bg-1 Damage Results

Figure 21: A-1 Impact Damage Area for (Left to Right) Shots #11, 12, and 19
Figure 22: Ag-1 Impact Damage Area for (Left to Right) Shots #6, 9, and 19

Figure 23: B-1 Impact Damage Area for (Left to Right) Shots #2, 12, and 16

Figure 24: Bg-1 Impact Damage Area for (Left to Right) Shots #4, 9, and 12
Discussion

For design engineering and threat analysis purposes, shots were performed at various angles to the normal to the target at the point of impact. It was suggested by Summers (NASA TN D-94, 1959) that only the normal kinetic energy be used to compare with crater depth. The kinetic energy for the normal velocity component was computed (sine squared of the angle, ninety degrees is normal). Normal KE is just the kinetic energy associated with the projectile velocity component normal to the target surface at the point of impact. Figure 25 and Figure 26 below show the relationship between penetration depth and kinetic energy.

![Penetration Depth vs. Total Kinetic Energy for Target Ag-1](image)

Figure 25: Penetration Depth vs. Total Kinetic Energy for Target Ag-1
Sound waves containing both sonic and ultrasonic frequencies were created by each impact. The energy in the waves is some fraction of the energy of the impactor. An analysis method was sought that would allow a straightforward and simple technique for comparing the wave energies to the projectile kinetic energy, and thus the damage figures. One way would be to look at the energy sensor by sensor. For example, the wave energy for shot #1 could be computed from just the signal at sensor 1, then the energy from shot #2 could be computed from the signal at sensor 1, and so forth, and then the energies could be graphed.

The problem with this method would be that the impact position changed from shot to shot. The method might work if new identical targets were available each time and the sensor 1 position and shot location were always the same. Given this was not feasible, perhaps correction factors could be developed, but it would be arduous, if not impossible, to compare shot energies by correcting for the all the source to receiver relative positional changes because there are so many effects for which to account. Geometric spreading in 3-D means that the intensity varies as $1/r^2$. In plates the spreading is circular and the intensity only drops as $1/r$. Calculating the $1/r$ attenuation caused by geometric spreading would account for just one effect. There is also attenuation due to material properties which is a function of both frequency and direction. Waves that cut across the main fiber directions were attenuated more than waves that propagated along the fiber directions. This is known as material anisotropy.
In order to reduce the effect of varying impact positions on the acoustical energy values, the energies of the waves at all the transducers on the target were summed together for each shot. This was approach was based on the following reasoning: If a given sensor records the signals for two impacts that have the same kinetic energy, the closer impact would appear to have a larger wave signal energy. Since the sensors surrounded the impacts, variations in the propagation paths would be roughly accounted for by adding the wave signal energy collected by all sensors. This approach also makes use of symmetry: Two symmetric impacts would have symmetric propagation paths and thus the same total wave signal energy if the energies collected by all the sensors were summed. The graphs show that this turned out to be an efficacious approach. Symmetry could not be invoked in every case so there were outliers.

The damage measurements themselves were crude. Although some damage in the interior plies seemed apparent, the “damage area” value that was plotted against KE was related solely to the area the damaged fibers occupied as measured with a ruler on the outside (the impact side) surface.

Overall, the correlations exhibited the correct trend of greater impact energy resulting in larger wave energy.

![Graph](image-url)

**Figure 27: A-1 Total Kinetic Energy vs. Coating Area Damage**
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 28: Ag-1 Total Kinetic Energy vs. Coating Area Damage

Figure 29: B-1 Total Kinetic Energy vs. Coating Area Damage
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 30: Bg-1 Total Kinetic Energy vs. Coating Area Damage

Figure 31: A-1 Normal Kinetic Energy vs. Coating Area Damage
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 32: Ag-1 Normal Kinetic Energy vs. Coating Area Damage

Figure 33: B-1 Normal Kinetic Energy vs. Coating Area Damage
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 34: Bg-1 Normal Kinetic Energy vs. Coating Area Damage

Figure 35: A-1 Total Kinetic Energy vs. Crater Volume Damage
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 36: Ag-1 Total Kinetic Energy vs. Crater Volume Damage

Figure 37: B-1 Total Kinetic Energy vs. Crater Volume Damage
Figure 38: Bg-1 Total Kinetic Energy vs. Crater Volume Damage

Figure 39: A-1 Normal Kinetic Energy vs. Crater Volume Damage
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 40: Ag-1 Normal Kinetic Energy vs. Crater Volume Damage

Figure 41: B-1 Normal Kinetic Energy vs. Crater Volume Damage
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 42: Bg-1 Normal Kinetic Energy vs. Crater Volume Damage

Figure 43: A-1 Wave Signal Energy vs. Total Kinetic Energy
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 44: Ag-1 Wave Signal Energy vs. Total Kinetic Energy

Figure 45: B-1 Wave Signal Energy vs. Total Kinetic Energy
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 46: Bg-1 Wave Signal Energy vs. Total Kinetic Energy

Figure 47: A-1 Wave Signal Energy vs. Normal Kinetic Energy
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 48: Ag-1 Wave Signal Energy vs. Normal Kinetic Energy

Figure 49: B-1 Wave Signal Energy vs. Normal Kinetic Energy
Location Analysis

Location of the source of a wave is part and parcel of the MAE technique just as it is in SONAR methods. It contributes to understanding of the type and magnitude of the source and is a crucial step in tracking down and stopping leaks in manned spacecraft.

In these studies the location of the impact was known by visual observation. This enabled a study of the accuracy of locating a source purely by analysis of the wave arrival at different transducers. The source position was triangulated when the source to receiver path was reasonably homogeneous. This was shown in detail for Target Fg(RCC)-1 and the reader is referred to that Section of this Report. The analysis was not repeated here.

The velocities of the direct arrivals were measured in advance. Pencil lead breaks were done to create the modes. This is discussed under Wave Propagation below.

Wave Propagation

The wave signal energy collected by any given sensor is composed of direct energy and reflected energy. After an impact occurs, a wave propagates radially outward from the impact site. This direct wave is the first signal recorded by a sensor. When this wave reaches the edges of the target, it is reflected back to the sensor. These reflected waves are lower in amplitude than the direct waves and have later arrival times. In general, reflected waves did not contribute not a significant fraction of the signal energy.

Figure 50: Bg-1 Wave Signal Energy vs. Normal Kinetic Energy
The direct wave is composed of two types of waves: extensional and flexural. Extensional waves have two displacements components with the larger displacements perpendicular to the normal to the plate. A sensor on the surface detects the out-of-plane component of the E wave. The largest displacement of the flexural wave motion is perpendicular to the plane of the plate. This motion is caused by bending at the impact location. The E and F modes have very distinct characteristics (see General Introduction and also Figure 18) that can be readily identified. For one thing, the front part of the E wave travels much faster than the F wave.

Wave speed is determined by performing a lead break at one sensor and measuring the time it takes for a direct wave to arrive at another sensor at a known distance away. Examples of wave speed calculations are given for Targets C-1, C-2, Fg(RCC)-1, Fg(RCC)-2, and RCC16R.
Conclusions

The results of the hypervelocity impact test on tile Targets A-1, Ag-1, B-1, and Bg-1 are as follows:

- Ultrasonic Sensors were successfully bonded to tile Targets A-1, Ag-1, B-1, and Bg-1 with a Lord 202 Acrylic Adhesive.

- Ultrasonic Sensors operated well in near-vacuum (6-8 Torr) inside the vacuum chamber at Johnson Space Center’s White Sands Testing Facility.*

- Impacts created detectable ultrasonic signals at high (>50 kHz) frequencies which should be above flight noise.†

- Ultrasonic signals were detected with small, lightweight sensors capable of space flight.‡§

- Wave propagation characteristics of the cross-ply fiberglass target were measured and used in the analysis of the wave signal energy.

- Wave signal energy correlated well with kinetic energy and impact damage.

This test successfully demonstrated the ability for a wing leading edge impact detection system (WLEIDS) to model the kinetic energy response and material damage below, at and above complete penetration of the projectile through the target.

Appendix

* B1025 sensors also functioned well in deep vacuum of ESEM. Michael Horn, NASA LaRC, email 2005.
† Based on measurement of noise spectra on F16 bulkhead at full throttle, there will not be significant noise power above 50kHz.
‡ Sensors passed 18,000 g shock test. Henry Whitesel, Naval Surface Warfare Center, verbal communication 1998.
§ DWC sensors survived intense radiation environment. Dane Spearing, LANL, verbal communication 2003.
The appendices contain the information for each shot and the waveforms. For completeness, and, for usefulness when judging the energy versus damage plots shown in the discussion section above, Tables are given at the end that summarize and group together the data for the key test variables.

Test Condition Data Sheets
AE Test Data/Checklist

I. Record pretest information:
   Test date: 4/30/04
   Specimen ID: A-1
   Test number: A1-1
   Projectile size: 0.4mm/90deg.
   Planned velocity: 6.8 km/s
   Planned impact coordinates: (13.75, 18.25)

II. Prebonding sensor tests performed: Yes
(Only for first test in series or when replacing or rebonding sensors
between tests, otherwise indicate N/A)
   Comments: All sensors good. Sensors were taken from targets B-1 and Bg-1.
   One sensor from Bg-1 destroyed during removal.
   Sensor serial numbers and locations verified by QA. Some sensor coordinates
   slightly different from B-1 and Bg-1.

III. Record sensor serial number and coordinates:

   Sensor 1: S/N 101146  Sensor 2: S/N 190014
   Sensor 3: S/N 190015  Sensor 4: S/N 190016
   Sensor 5: S/N 190017  Sensor 6: S/N 1099011
   Sensor 7: S/N 190019  Sensor 8: S/N 190020

   Sensor 1: (29, 29)  Sensor 2: (17.25, 29.5)
   Sensor 3: (21.5, 27)  Sensor 4: (13, 29)
   Sensor 5: (29, 11.75)  Sensor 6: (21, 15.5)
   Sensor 7: (13, 9.5)  Sensor 8: (5, 9.5)

IV. Pretest sensor check:
   Verify settings:
   SCM trigger source: X
   20 dB PA gain, 3 dB signal gain: X
   20 kHz HP filter, 1500 kHz LP filter: X
   5 MHz SR, 4096 points, 1024 pretrigger: X
   Test sensors and record file name: A1-1 4-30-04 pretestlb
   Comments: Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check: X

VI. Impact test:
   Verify settings:
   External (gun) trigger source: X
   20 kHz HP filter, 1500 kHz LP filter: X
   2 MHz SR, 32 K points, 4096 pretrigger: X
8 channel recording mode: X
Data acquisition in record mode: X
(DWC logo spinning)
Record and verify gain settings:

Sensor 1: Attenuators: 0 Preamp: 20 SCM: 12
Sensor 2: Attenuators: 0 Preamp: 20 SCM: 12
Sensor 3: Attenuators: 0 Preamp: 20 SCM: 12
Sensor 4: Attenuators: 0 Preamp: 20 SCM: 12
Sensor 5: Attenuators: 0 Preamp: 20 SCM: 12
Sensor 6: Attenuators: 0 Preamp: 20 SCM: 12
Sensor 7: Attenuators: 0 Preamp: 20 SCM: 12
Sensor 8: Attenuators: 0 Preamp: 20 SCM: 12

Record file name: A1-1 4-30-04 Impact
Comments: Impact on event 9. Amplitude small but O.K.

VII. Post test sensor check:
Verify settings:
  20 dB PA gain, 3 dB signal gain X
  20 kHz HP filter, 1500 kHz LP filter X
  5 MHz SR, 4096 points, 1024 pretrigger X
Test sensors and record file name: A1-1 4-30-04 Posttest lb
Comments: All Sensors good.

VIII: Post test
Review data and backup files on CD X
Record actual impact parameters:
  Projectile velocity: 7.1 km/s.
  Impact coordinates: ________
Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 51: A-1 Shot #1 Impact Waveform

Figure 52: A-1 Shot #1 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 5/03/04          Specimen ID: A-1
   Test number: A1-2b          Projectile size: 0.6mm/90deg.
   Planned velocity: 6.8 km/s
   Planned impact coordinates: (18.25, 14)

II. Prebonding sensor tests performed: N/A
   (Only for first test in series or when replacing or rebonding sensors between tests, otherwise indicate N/A)
   Comments:

III. Record sensor serial number and coordinates:

   Sensor 1: S/N 101146          Sensor 2: S/N 190014
   Sensor 3: S/N 190015          Sensor 4: S/N 190016
   Sensor 5: S/N 190017          Sensor 6: S/N 1099011
   Sensor 7: S/N 190019          Sensor 8: S/N 190020

   Sensor 1: (29, 29)            Sensor 2: (17.25, 29.5)
   Sensor 3: (21.5, 27)          Sensor 4: (13, 29)
   Sensor 5: (29, 11.75)         Sensor 6: (21, 15.5)
   Sensor 7: (13, 9.5)           Sensor 8: (5, 9.5)

IV. Pretest sensor check:
   Verify settings:
   SCM trigger source: X
   20 dB PA gain, 3 dB signal gain: X
   20 kHz HP filter, 1500 kHz LP filter: X
   5 MHz SR, 4096 points, 1024 pretrigger: X
   Test sensors and record file name: The target tank door was not opened
   after the first shot
   Comments: Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check: X

VI. Impact test:
   Verify settings:
   External (gun) trigger source: X
   20 kHz HP filter, 1500 kHz LP filter: X
   2 MHz SR, 32 K points, 4096 pretrigger: X
   8 channel recording mode: X
   Data acquisition in record mode: X
   (DWC logo spinning)
   Record and verify gain settings:
Sensor 1: Attenuators: 0  Preamp: 20  SCM: 18
Sensor 2: Attenuators: 0  Preamp: 20  SCM: 18
Sensor 3: Attenuators: 0  Preamp: 20  SCM: 18
Sensor 4: Attenuators: 0  Preamp: 20  SCM: 18
Sensor 5: Attenuators: 0  Preamp: 20  SCM: 18
Sensor 6: Attenuators: 0  Preamp: 20  SCM: 18
Sensor 7: Attenuators: 0  Preamp: 20  SCM: 18
Sensor 8: Attenuators: 0  Preamp: 20  SCM: 18

Record file name: A1-2b 5-03-04 Impact

VII. Post test sensor check:
   Verify settings:
   20 dB PA gain, 3 dB signal gain  X
   20 kHz HP filter, 1500 kHz LP filter  X
   5 MHz SR, 4096 points, 1024 pretrigger  X
Test sensors and record file name: A1-2b 5-03-04 Posttest LB
Comments: All sensors good.

VIII. Post test
   Review data and backup files on CD  X
   Record actual impact parameters:
      Projectile velocity: 6.83 km/s.
      Impact coordinates:
      Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 53: A-1 Shot #2 Impact Waveform

Figure 54: A-1 Shot #2 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 5/04/04  Specimen ID:  A-1
   Test number: A1-3  Projectile size: 1.0mm/90deg.
   Planned velocity: 6.8 km/s
   Planned impact coordinates: (20.25, 20.5)

II. Prebonding sensor tests performed: N/A
   (Only for first test in series or when replacing or rebonding sensors
    between tests, otherwise indicate N/A)
   Comments:

III. Record sensor serial number and coordinates:
   Sensor 1: S/N 101146  Sensor 2: S/N 190014
   Sensor 3: S/N 190015  Sensor 4: S/N 190016
   Sensor 5: S/N 190017  Sensor 6: S/N 1099011
   Sensor 7: S/N 190019  Sensor 8: S/N 190020
   Sensor 1: (29, 29)  Sensor 2: (17.25, 29.5)
   Sensor 3: (21.5, 27)  Sensor 4: (13, 29)
   Sensor 5: (29, 11.75)  Sensor 6: (21, 15.5)
   Sensor 7: (13, 9.5)  Sensor 8: (5, 9.5)

IV. Pretest sensor check:
   Verify settings:
   SCM trigger source:  X
   20 dB PA gain, 3 dB signal gain:  X
   20 kHz HP filter, 1500 kHz LP filter:  X
   5 MHz SR, 4096 points, 1024 pretrigger:  X
   Test sensors and record file name: A1-3 5-04-04 Pretest LB
   Comments: Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check:  X

VI. Impact test:
   Verify settings:
   External (gun) trigger source:  X
   20 kHz HP filter, 1500 kHz LP filter:  X
   2 MHz SR, 32 K points, 4096 pretrigger:  X
   8 channel recording mode:  X
   Data acquisition in record mode:  X
   (DWC logo spinning)
   Record and verify gain settings:
Sensor 1: Attenuators: 0  Preamp: 20  SCM: 18
Sensor 2: Attenuators: 0  Preamp: 20  SCM: 18
Sensor 3: Attenuators: 0  Preamp: 20  SCM: 18
Sensor 4: Attenuators: 0  Preamp: 20  SCM: 18
Sensor 5: Attenuators: 0  Preamp: 20  SCM: 18
Sensor 6: Attenuators: 0  Preamp: 20  SCM: 18
Sensor 7: Attenuators: 0  Preamp: 20  SCM: 18
Sensor 8: Attenuators: 0  Preamp: 20  SCM: 18

Record file name: A1-3 5-04-04 Impact

VII. Post test sensor check:
Verify settings:
- 20 dB PA gain, 3 dB signal gain  X
- 20 kHz HP filter, 1500 kHz LP filter  X
- 5 MHz SR, 4096 points, 1024 pretrigger  X
Test sensors and record file name: A1-3 5-04-04 Posttest LB
Comments: All sensors good.

VIII: Post test
Review data and backup files on CD  X
Record actual impact parameters:
Projectile velocity: 6.48 km/s.
Impact coordinates:
Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 55: A-1 Shot #3 Impact Waveform

Figure 56: A-1 Shot #3 Impact Damage
Tile Targets A-1, Ag-1, B-1, and Bg-1

AE Test Data/Checklist

I. Record pretest information:
   Test date: 5/05/04   Specimen ID:  A-1
   Test number:  A1-4   Projectile size:  1.4mm/90deg.
   Planned velocity:  6.8 km/s
   Planned impact coordinates:  (11.5, 11.75)

II. Prebonding sensor tests performed:  N/A
   (Only for first test in series or when replacing or rebonding sensors
   between tests, otherwise indicate N/A)
   Comments:

III. Record sensor serial number and coordinates:
   Sensor 1:  S/N  101146   Sensor 2:  S/N  190014
   Sensor 3:  S/N  190015   Sensor 4:  S/N  190016
   Sensor 5:  S/N  190017   Sensor 6:  S/N  1099011
   Sensor 7:  S/N  190019   Sensor 8:  S/N  190020
   Sensor 1:  (29, 29)   Sensor 2:  (17.25, 29.5)
   Sensor 3:  (21.5, 27)  Sensor 4:  (13, 29)
   Sensor 5:  (29, 11.75)  Sensor 6:  (21, 15.5)
   Sensor 7:  (13, 9.5)   Sensor 8:  (5, 9.5)

IV. Pretest sensor check:
   Verify settings:
   SCM trigger source:  X
   20 dB PA gain, 3 dB signal gain:  X
   20 kHz HP filter, 1500 kHz LP filter:  X
   5 MHz SR, 4096 points, 1024 pretrigger:  X
   Test sensors and record file name:  A1-4 5-05-04 Pretest LB
   Comments:  Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check:  X

VI. Impact test:
   Verify settings:
   External (gun) trigger source:  X
   20 kHz HP filter, 1500 kHz LP filter:  X
   2 MHz SR, 32 K points, 4096 pretrigger:  X
   8 channel recording mode:  X
   Data acquisition in record mode:  X
   (DWC logo spinning)
   Record and verify gain settings:
Sensor 1: Attenuators: 0  Preamp: 20  SCM: 18
Sensor 2: Attenuators: 0  Preamp: 20  SCM: 18
Sensor 3: Attenuators: 0  Preamp: 20  SCM: 18
Sensor 4: Attenuators: 0  Preamp: 20  SCM: 18
Sensor 5: Attenuators: 0  Preamp: 20  SCM: 18
Sensor 6: Attenuators: 0  Preamp: 20  SCM: 18
Sensor 7: Attenuators: 0  Preamp: 20  SCM: 18
Sensor 8: Attenuators: 0  Preamp: 20  SCM: 18

Record file name: A1-4 5-05-04 Impact
Comments:

VII. Post test sensor check:
Verify settings:
20 dB PA gain, 3 dB signal gain  X
20 kHz HP filter, 1500 kHz LP filter  X
5 MHz SR, 4096 points, 1024 pretrigger  X
Test sensors and record file name: A1-4 5-05-04 Posttest LB
Comments: All sensors good.

VIII. Post test
Review data and backup files on CD  X
Record actual impact parameters:
Projectile velocity: 7.22 km/s.
Impact coordinates:
Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 57: A-1 Shot #4 Impact Waveform

Figure 58: A-1 Shot #4 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 5/05/04                      Specimen ID:  A-1
   Test number:  A1-5                    Projectile size:  1.6mm/90deg.
   Planned velocity:  6.8 km/s
   Planned impact coordinates:  (25, 16)

II. Prebonding sensor tests performed:  N/A
    (Only for first test in series or when replacing or rebonding sensors
     between tests, otherwise indicate N/A)
    Comments:

III. Record sensor serial number and coordinates:
    Sensor 1:  S/N 101146                  Sensor 2:  S/N 190014
    Sensor 3:  S/N 190015                  Sensor 4:  S/N 190016
    Sensor 5:  S/N 190017                  Sensor 6:  S/N 1099011
    Sensor 7:  S/N 190019                  Sensor 8:  S/N 190020
    Sensor 1:  (29, 29)                  Sensor 2:  (17.25, 29.5)
    Sensor 3:  (21.5, 27)                Sensor 4:  (13, 29)
    Sensor 5:  (29, 11.75)               Sensor 6:  (21, 15.5)
    Sensor 7:  (13, 9.5)                 Sensor 8:  (5, 9.5)

IV. Pretest sensor check:
    Verify settings:
    SCM trigger source:              X
    20 dB PA gain, 3 dB signal gain:  X
    20 kHz HP filter, 1500 kHz LP filter:  X
    5 MHz SR, 4096 points, 1024 pretrigger:  X
    Test sensors and record file name:  A1-5 5-05-04 Pretest LB
    Comments:  Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check:  X

VI. Impact test:
    Verify settings:
    External (gun) trigger source:  X
    20 kHz HP filter, 1500 kHz LP filter:  X
    2 MHz SR, 32 K points, 4096 pretrigger:  X
    8 channel recording mode:  X
    Data acquisition in record mode:  X
    (DWC logo spinning)
    Record and verify gain settings:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Sensor 1: Attenuators: 0     Preamp: 20     SCM: 18
Sensor 2: Attenuators: 0     Preamp: 20     SCM: 18
Sensor 3: Attenuators: 0     Preamp: 20     SCM: 18
Sensor 4: Attenuators: 0     Preamp: 20     SCM: 18
Sensor 5: Attenuators: 0     Preamp: 20     SCM: 18
Sensor 6: Attenuators: 0     Preamp: 20     SCM: 18
Sensor 7: Attenuators: 0     Preamp: 20     SCM: 18
Sensor 8: Attenuators: 0     Preamp: 20     SCM: 18

Record file name: A1-5 5-05-04 Impact

VII. Post test sensor check:
Verify settings:
20 dB PA gain, 3 dB signal gain     X
20 kHz HP filter, 1500 kHz LP filter X
5 MHz SR, 4096 points, 1024 pretrigger X
Test sensors and record file name: A1-5 5-05-04 Posttest LB
Comments: All sensors good.

VIII. Post test
Review data and backup files on CD     X
Record actual impact parameters:
  Projectile velocity: 6.62 km/s
Impact coordinates:
Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 59: A-1 Shot #5 Impact Waveform

Figure 60: A-1 Shot #5 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 5/06/04  Specimen ID: A-1
   Test number: A1-6  Projectile size: 1.8mm/90deg.
   Planned velocity: 6.8 km/s
   Planned impact coordinates: (16, 23.5)

II. Prebonding sensor tests performed: N/A
   (Only for first test in series or when replacing or rebonding sensors between tests, otherwise indicate N/A)
   Comments:

III. Record sensor serial number and coordinates:

   Sensor 1: S/N 101146  Sensor 2: S/N 190014
   Sensor 3: S/N 190015  Sensor 4: S/N 190016
   Sensor 5: S/N 190017  Sensor 6: S/N 1099011
   Sensor 7: S/N 190019  Sensor 8: S/N 190020

   Sensor 1: (29, 29)  Sensor 2: (17.25, 29.5)
   Sensor 3: (21.5, 27)  Sensor 4: (13, 29)
   Sensor 5: (29, 11.75)  Sensor 6: (21, 15.5)
   Sensor 7: (13, 9.5)  Sensor 8: (5, 9.5)

IV. Pretest sensor check:
   Verify settings:
   SCM trigger source: X
   20 dB PA gain, 3 dB signal gain: X
   20 kHz HP filter, 1500 kHz LP filter: X
   5 MHz SR, 4096 points, 1024 pretrigger: X
   Test sensors and record file name: A1-6 5-06-04 Pretest LB
   Comments: Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check: X

VI. Impact test:
   Verify settings:
   External (gun) trigger source: X
   20 kHz HP filter, 1500 kHz LP filter: X
   2 MHz SR, 32 K points, 4096 pretrigger: X
   8 channel recording mode: X
   Data acquisition in record mode: X
      (DWC logo spinning)
   Record and verify gain settings:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Sensor 1: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 2: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 3: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 4: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 5: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 6: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 7: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 8: Attenuators: 0_______ Preamp: 20____ SCM: 18____

Record file name: A1-6 5-06-04 Impact
Comments: Four channels clipped unexpectedly. Impact on event 8.

VII. Post test sensor check:
Verify settings:
20 dB PA gain, 3 dB signal gain X
20 kHz HP filter, 1500 kHz LP filter X
5 MHz SR, 4096 points, 1024 pretrigger X
Test sensors and record file name: A1-6 5-06-04 Posttest LB
Comments: All sensors good.

VIII: Post test
Review data and backup files on CD X
Record actual impact parameters:
   Projectile velocity: 7.1 km/s.
   Impact coordinates:
   Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 61: A-1 Shot #6 Impact Waveform

Figure 62: A-1 Shot #6 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 5/06/04                  Specimen ID:  A-1
   Test number:  A1-7                 Projectile size:  2.0mm/45deg.
   Planned velocity:  6.8 km/s
   Planned impact coordinates:  (16, 07)

II. Prebonding sensor tests performed:  N/A
    (Only for first test in series or when replacing or rebonding sensors  
     between tests, otherwise indicate N/A)
    Comments:

III. Record sensor serial number and coordinates:

   Sensor 1:  S/N  101146               Sensor 2:  S/N  190014
   Sensor 3:  S/N  190015               Sensor 4:  S/N  190016
   Sensor 5:  S/N  190017               Sensor 6:  S/N  1099011
   Sensor 7:  S/N  190019               Sensor 8:  S/N  190020
   Sensor 1:  (29, 29)                Sensor 2:  (17.25, 29.5)
   Sensor 3:  (21.5, 27)              Sensor 4:  (13, 29)
   Sensor 5:  (29, 11.75)             Sensor 6:  (21, 15.5)
   Sensor 7:  (13, 9.5)               Sensor 8:  (5, 9.5)

IV. Pretest sensor check:
    Verify settings:
    SCM trigger source:  X
    20 dB PA gain, 3 dB signal gain:  X
    20 kHz HP filter, 1500 kHz LP filter:  X
    5 MHz SR, 4096 points, 1024 pretrigger:  X
    Test sensors and record file name:  A1-7 5-06-04 Pretest LB
    Comments:  Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check:  X

VI. Impact test:
    Verify settings:
    External (gun) trigger source:  X
    20 kHz HP filter, 1500 kHz LP filter:  X
    2 MHz SR, 32 K points, 4096 pretrigger:  X
    8 channel recording mode:  X
    Data acquisition in record mode:  X
    (DWC logo spinning)
    Record and verify gain settings:
### Sensor Settings

| Sensor 1: | Attenuators: 0 | Preamp: 20 | SCM: 9 |
| Sensor 2: | Attenuators: 0 | Preamp: 20 | SCM: 9 |
| Sensor 3: | Attenuators: 0 | Preamp: 20 | SCM: 9 |
| Sensor 4: | Attenuators: 0 | Preamp: 20 | SCM: 9 |
| Sensor 5: | Attenuators: 0 | Preamp: 20 | SCM: 9 |
| Sensor 6: | Attenuators: 0 | Preamp: 20 | SCM: 9 |
| Sensor 7: | Attenuators: 0 | Preamp: 20 | SCM: 9 |
| Sensor 8: | Attenuators: 0 | Preamp: 20 | SCM: 9 |

Record file name: A1-7 5-06-04 Impact
Comments: Impact on event 19. Data O.K.

### VII. Post test sensor check:
Verify settings:
- 20 dB PA gain, 3 dB signal gain
- 20 kHz HP filter, 1500 kHz LP filter
- 5 MHz SR, 4096 points, 1024 pretrigger

Test sensors and record file name: A1-7 5-06-04 Posttest LB
Comments: All sensors good.

### VIII. Post test
Review data and backup files on CD
Record actual impact parameters:
- Projectile velocity: 7.1 km/s
Impact coordinates:
Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 63: A-1 Shot #7 Impact Waveform

Figure 64: A-1 Shot #7 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 5/10/04  Specimen ID: A-1
   Test number: A1-8  Projectile size: 2.2mm/45deg.
   Planned velocity: 6.8 km/s
   Planned impact coordinates: (7.25, 16)

II. Prebonding sensor tests performed: N/A
   (Only for first test in series or when replacing or rebonding sensors
    between tests, otherwise indicate N/A)
   Comments:

III. Record sensor serial number and coordinates:
   Sensor 1: S/N 101146  Sensor 2: S/N 190014
   Sensor 3: S/N 190015  Sensor 4: S/N 190016
   Sensor 5: S/N 190017  Sensor 6: S/N 1099011
   Sensor 7: S/N 190019  Sensor 8: S/N 190020

   Sensor 1: (29, 29)  Sensor 2: (17.25, 29.5)
   Sensor 3: (21.5, 27)  Sensor 4: (13, 29)
   Sensor 5: (29, 11.75)  Sensor 6: (21, 15.5)
   Sensor 7: (13, 9.5)  Sensor 8: (5, 9.5)

IV. Pretest sensor check:
   Verify settings:
   SCM trigger source: x
   20 dB PA gain, 3 dB signal gain: x
   20 kHz HP filter, 1500 kHz LP filter: x
   5 MHz SR, 4096 points, 1024 pretrigger: x
   Test sensors and record file name: A1-8 5-10-04 Pretest LB
   Comments: Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check: x

VI. Impact test:
   Verify settings:
   External (gun) trigger source: x
   20 kHz HP filter, 1500 kHz LP filter: x
   2 MHz SR, 32 K points, 4096 pretrigger: x
   8 channel recording mode: x
   Data acquisition in record mode: x
   (DWC logo spinning)
   Record and verify gain settings:
Tile Targets A-1, Ag-1, B-1, and Bg-1

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<th>Attenuators</th>
<th>Preamp</th>
<th>SCM</th>
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<td>20</td>
<td>6</td>
</tr>
</tbody>
</table>

Record file name: A1-8 5-10-04 Impact
Comments:

VII. Post test sensor check:
Verify settings:
- 20 dB PA gain, 3 dB signal gain X
- 20 kHz HP filter, 1500 kHz LP filter X
- 5 MHz SR, 4096 points, 1024 pretrigger X
Test sensors and record file name: A1-8 5-10-04 Posttest LB
Comments: All sensors good.

VIII: Post test
Review data and backup files on CD X
Record actual impact parameters:
- Projectile velocity: 7.1 km/s.
Impact coordinates:
Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 65: A-1 Shot #8 Impact Waveform

Figure 66: A-1 Shot #8 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 5/11/04    Specimen ID:  A-1
   Test number: A1-9    Projectile size: 2.0mm/45deg.
   Planned velocity: 6.8 km/s
   Planned impact coordinates: (16, 16)

II. Prebonding sensor tests performed:  N/A
(Only for first test in series or when replacing or rebonding sensors
between tests, otherwise indicate N/A)

Comments:

III. Record sensor serial number and coordinates:

   Sensor 1: S/N 101146    Sensor 2: S/N 190014
   Sensor 3: S/N 190015    Sensor 4: S/N 190016
   Sensor 5: S/N 190017    Sensor 6: S/N 1099011
   Sensor 7: S/N 190019    Sensor 8: S/N 190020

   Sensor 1: (29, 29)    Sensor 2: (17.25, 29.5)
   Sensor 3: (21.5, 27)  Sensor 4: (13, 29)
   Sensor 5: (29, 11.75) Sensor 6: (21, 15.5)
   Sensor 7: (13, 9.5)   Sensor 8: (5, 9.5)

IV. Pretest sensor check:
   Verify settings:
   SCM trigger source:  X
   20 dB PA gain, 3 dB signal gain:  X
   20 kHz HP filter, 1500 kHz LP filter:  X
   5 MHz SR, 4096 points, 1024 pretrigger:  X
   Test sensors and record file name: A1-9 5-11-04 Pretest LB
   Comments: Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check:  X

VI. Impact test:
   Verify settings:
   External (gun) trigger source:  X
   20 kHz HP filter, 1500 kHz LP filter:  X
   2 MHz SR, 32 K points, 4096 pretrigger:  X
   8 channel recording mode:  X
   Data acquisition in record mode:  X
   (DWC logo spinning)
   Record and verify gain settings:
Sensor 1: Attenuators: 0   Preamp: 20   SCM: 9   
Sensor 2: Attenuators: 0   Preamp: 20   SCM: 9   
Sensor 3: Attenuators: 0   Preamp: 20   SCM: 9   
Sensor 4: Attenuators: 0   Preamp: 20   SCM: 9   
Sensor 5: Attenuators: 0   Preamp: 20   SCM: 9   
Sensor 6: Attenuators: 0   Preamp: 20   SCM: 9   
Sensor 7: Attenuators: 0   Preamp: 20   SCM: 9   
Sensor 8: Attenuators: 0   Preamp: 20   SCM: 9   

Record file name: A1-9 5-11-04 Impact

VII. Post test sensor check:
Verify settings:
20 dB PA gain, 3 dB signal gain   X
20 kHz HP filter, 1500 kHz LP filter   X
5 MHz SR, 4096 points, 1024 pretrigger   X
Test sensors and record file name: A1-9 5-11-04 Posttest LB
Comments: All sensors good.

VIII: Post test
Review data and backup files on CD   X
Record actual impact parameters:
   Projectile velocity: 6.75 km/s.
   Impact coordinates:
   Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 67: A-1 Shot #9 Impact Waveform

Figure 68: A-1 Shot #9 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 5/11/04 Specimen ID: A-1
   Test number: A1-10b Projectile size: 1.0mm/45deg.
   Planned velocity: 6.8 km/s
   Planned impact coordinates: (9.5, 22.6)

II. Prebonding sensor tests performed: N/A
    (Only for first test in series or when replacing or rebonding sensors between tests, otherwise indicate N/A)
    Comments:

III. Record sensor serial number and coordinates:

   Sensor 1: S/N 101146 Sensor 2: S/N 190014
   Sensor 3: S/N 190015 Sensor 4: S/N 190016
   Sensor 5: S/N 190017 Sensor 6: S/N 1099011
   Sensor 7: S/N 190019 Sensor 8: S/N 190020

   Sensor 1: (29, 29) Sensor 2: (17.25, 29.5)
   Sensor 3: (21.5, 27) Sensor 4: (13.29)
   Sensor 5: (29, 11.75) Sensor 6: (21, 15.5)
   Sensor 7: (13.1, 9.5) Sensor 8: (5, 9.5)

IV. Pretest sensor check:
    Verify settings:
     SCM trigger source: X
     20 dB PA gain, 3 dB signal gain: X
     20 kHz HP filter, 1500 kHz LP filter: X
     5 MHz SR, 4096 points, 1024 pretrigger: X
    Test sensors and record file name: A1-10b 5-11-04 Pretest LB
    Comments: Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check: X

VI. Impact test:
    Verify settings:
     External (gun) trigger source: X
     20 kHz HP filter, 1500 kHz LP filter: X
     2 MHz SR, 32 K points, 4096 pretrigger: X
     8 channel recording mode: X
     Data acquisition in record mode: X
     (DWC logo spinning)
    Record and verify gain settings:
Sensor 1: Attenuators: 0       Preamp: 20       SCM: 18
Sensor 2: Attenuators: 0       Preamp: 20       SCM: 18
Sensor 3: Attenuators: 0       Preamp: 20       SCM: 18
Sensor 4: Attenuators: 0       Preamp: 20       SCM: 18
Sensor 5: Attenuators: 0       Preamp: 20       SCM: 18
Sensor 6: Attenuators: 0       Preamp: 20       SCM: 18
Sensor 7: Attenuators: 0       Preamp: 20       SCM: 18
Sensor 8: Attenuators: 0       Preamp: 20       SCM: 18

Record file name: A1-10b 5-11-04 Impact

VII. Post test sensor check:
   Verify settings:
   20 dB PA gain, 3 dB signal gain       X
   20 kHz HP filter, 1500 kHz LP filter       X
   5 MHz SR, 4096 points, 1024 pretrigger       X
Test sensors and record file name:
Comments:

VIII. Post test
   Review data and backup files on CD   X
Record actual impact parameters:
   Projectile velocity: 6.80 km/s.
   Impact coordinates:
   Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 69: A-1 Shot #10 Impact Waveform

Figure 70: A-1 Shot #10 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 5/12/04         Specimen ID: A-1
   Test number: A1-11         Projectile size: 1.8mm/45deg.
   Planned velocity: 6.8 km/s
   Planned impact coordinates: (9.5, 22.6)

II. Prebonding sensor tests performed: N/A
   (Only for first test in series or when replacing or reboning sensors between tests, otherwise indicate N/A)
   Comments:

III. Record sensor serial number and coordinates:

   Sensor 1: S/N 101146       Sensor 2: S/N 190014
   Sensor 3: S/N 190015       Sensor 4: S/N 190016
   Sensor 5: S/N 190017       Sensor 6: S/N 1099011
   Sensor 7: S/N 190019       Sensor 8: S/N 190020

   Sensor 1: (29, 29)         Sensor 2: (17.25, 29.5)
   Sensor 3: (21.5, 27)       Sensor 4: (13.29)
   Sensor 5: (29, 11.75)      Sensor 6: (21, 15.5)
   Sensor 7: (13, 9.5)        Sensor 8: (5, 9.5)

IV. Pretest sensor check:
   Verify settings:
   SCM trigger source: X
   20 dB PA gain, 3 dB signal gain: X
   20 kHz HP filter, 1500 kHz LP filter: X
   5 MHz SR, 4096 points, 1024 pretrigger: X
   Test sensors and record file name: A1-11_5-12-04 Pretest LB
   Comments: Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check: X

VI. Impact test:
   Verify settings:
   External (gun) trigger source: X
   20 kHz HP filter, 1500 kHz LP filter: X
   2 MHz SR, 32 K points, 4096 pretrigger: X
   8 channel recording mode: X
   Data acquisition in record mode: X
   (DWC logo spinning)
   Record and verify gain settings:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Sensor 1: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 2: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 3: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 4: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 5: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 6: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 7: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 8: Attenuators: 0_______ Preamp: 20____ SCM: 18____

Record file name: A1-11 5-12-04 Impact
Comments:

VII. Post test sensor check:
Verify settings:
20 dB PA gain, 3 dB signal gain X
20 kHz HP filter, 1500 kHz LP filter X
5 MHz SR, 4096 points, 1024 pretrigger X
Test sensors and record file name:
Comments:

VIII: Post test
Review data and backup files on CD X
Record actual impact parameters:
Projectile velocity:
Impact coordinates:
Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 71: A-1 Shot #11 Impact Waveform

Figure 72: A-1 Shot #11 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 5/13/04 Specimen ID: A-1
   Test number: A1-12 Projectile size: 2 mm/45deg.
   Planned velocity: 6.8 km/s
   Planned impact coordinates: (23.5, 23.5)

II. Prebonding sensor tests performed: N/A
    (Only for first test in series or when replacing or rebonding sensors
     between tests, otherwise indicate N/A)
    Comments:

III. Record sensor serial number and coordinates:
   Sensor 1: S/N 101146 Sensor 2: S/N 190014
   Sensor 3: S/N 190015 Sensor 4: S/N 190016
   Sensor 5: S/N 190017 Sensor 6: S/N 1099011
   Sensor 7: S/N 190019 Sensor 8: S/N 190020
   Sensor 1: (29, 29) Sensor 2: (17.25, 29.5)
   Sensor 3: (21.5, 27) Sensor 4: (13, 29)
   Sensor 5: (29, 11.75) Sensor 6: (21, 15.5)
   Sensor 7: (13, 9.5) Sensor 8: (5, 9.5)

IV. Pretest sensor check:
    Verify settings:
    SCM trigger source: X
    20 dB PA gain, 3 dB signal gain: X
    20 kHz HP filter, 1500 kHz LP filter: X
    5 MHz SR, 4096 points, 1024 pretrigger: X
    Test sensors and record file name: A1-12 5-13-04 Pretest LB
    Comments: Sensors O.K. PLB are events 5-12. 1-4 are back of pencil
               taps for M.G. purposes.

V. Switch to external (gun) trigger source and complete pretest trigger check: X

VI. Impact test:
    Verify settings:
    External (gun) trigger source: X
    20 kHz HP filter, 1500 kHz LP filter: X
    2 MHz SR, 32 K points, 4096 pretrigger: X
    8 channel recording mode: X
    Data acquisition in record mode: X
    (DWC logo spinning)
    Record and verify gain settings:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Sensor 1: Attenuators: 0_______ Preamp: 20_______ SCM: 18____
Sensor 2: Attenuators: 0_______ Preamp: 20_______ SCM: 18____
Sensor 3: Attenuators: 0_______ Preamp: 20_______ SCM: 18____
Sensor 4: Attenuators: 0_______ Preamp: 20_______ SCM: 18____
Sensor 5: Attenuators: 0_______ Preamp: 20_______ SCM: 18____
Sensor 6: Attenuators: 0_______ Preamp: 20_______ SCM: 18____
Sensor 7: Attenuators: 0_______ Preamp: 20_______ SCM: 18____
Sensor 8: Attenuators: 0_______ Preamp: 20_______ SCM: 18____

Record file name: A1-12 5-13-04 Impact
Comments: Signals saturated on all channels. Impact created much more damage than previous shots.

VII. Post test sensor check:
Verify settings:
- 20 dB PA gain, 3 dB signal gain X
- 20 kHz HP filter, 1500 kHz LP filter X
- 5 MHz SR, 4096 points, 1024 pretrigger X
Test sensors and record file name:
Comments:

VIII: Post test
Review data and backup files on CD X
Record actual impact parameters:
- Projectile velocity:
- Impact coordinates:
- Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 73: A-1 Shot #12 Impact Waveform

Figure 74: A-1 Shot #12 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 5/13/04  Specimen ID:  A-1  
   Test number:  A1-13  Projectile size:  2 mm/45deg.  
   Planned velocity:  6.8 km/s  
   Planned impact coordinates:  (7.25,7.25)  

II. Prebonding sensor tests performed:  N/A  
   (Only for first test in series or when replacing or rebonding sensors between tests, otherwise indicate N/A)  
   Comments:  

III. Record sensor serial number and coordinates:  
   Sensor 1:  S/N 101146  Sensor 2:  S/N 190014  
   Sensor 3:  S/N 190015  Sensor 4:  S/N 190016  
   Sensor 5:  S/N 190017  Sensor 6:  S/N 1099011  
   Sensor 7:  S/N 190019  Sensor 8:  S/N 190020  
   Sensor 1:  (29, 29)  Sensor 2:  (17.25, 29.5)  
   Sensor 3:  (21.5, 27)  Sensor 4:  (13, 29)  
   Sensor 5:  (29, 11.75)  Sensor 6:  (21, 15.5)  
   Sensor 7:  (13, 9.5)  Sensor 8:  (5, 9.5)  

IV. Pretest sensor check:  
   Verify settings:  
   SCM trigger source:  X  
   20 dB PA gain, 3 dB signal gain:  X  
   20 kHz HP filter, 1500 kHz LP filter:  X  
   5 MHz SR, 4096 points, 1024 pretrigger:  X  
   Test sensors and record file name:  A1-13 5-13-04 Pretest LB  
   Comments:  Sensors O.K. PLB are events 5-12. 1-4 are back of pencil taps for M.G. purposes.  

V. Switch to external (gun) trigger source and complete pretest trigger check:  X  

VI. Impact test:
   Verify settings:  
   External (gun) trigger source:  X  
   20 kHz HP filter, 1500 kHz LP filter:  X  
   2 MHz SR, 32 K points, 4096 pretrigger:  X  
   8 channel recording mode:  X  
   Data acquisition in record mode:  X  
   (DWC logo spinning)  
   Record and verify gain settings:
Sensor 1: Attenuators: 0_______ Preamp: 20____ SCM: 9____
Sensor 2: Attenuators: 0_______ Preamp: 20____ SCM: 9____
Sensor 3: Attenuators: 0_______ Preamp: 20____ SCM: 9____
Sensor 4: Attenuators: 0_______ Preamp: 20____ SCM: 9____
Sensor 5: Attenuators: 0_______ Preamp: 20____ SCM: 9____
Sensor 6: Attenuators: 0_______ Preamp: 20____ SCM: 9____
Sensor 7: Attenuators: 0_______ Preamp: 20____ SCM: 9____
Sensor 8: Attenuators: 0_______ Preamp: 20____ SCM: 9____

Record file name: A1-13 5-13-04 Impact
Comments: Because signals saturated on last 2mm shot, SCM gains were reduced 9 dB.

VII. Post test sensor check:
Verify settings:
20 dB PA gain, 3 dB signal gain X
20 kHz HP filter, 1500 kHz LP filter X
5 MHz SR, 4096 points, 1024 pretrigger X
Test sensors and record file name:
Comments:

VIII: Post test
Review data and backup files on CD X
Record actual impact parameters:
Projectile velocity: 6.74 km/sec
Impact coordinates:
Damage description and comments:
Figure 75: A-1 Shot #13 Impact Waveform

Figure 76: A-1 Shot #13 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 6/09/04          Specimen ID:  A-1
   Test number:  A1-14          Projectile size:  2.0mm/30deg.
   Planned velocity:  6.8 km/s
   Planned impact coordinates:  (30, 30)

II. Prebonding sensor tests performed:  N/A
    (Only for first test in series or when replacing or rebonding sensors
     between tests, otherwise indicate N/A)
    Comments:

III. Record sensor serial number and coordinates:

   Sensor 1:  S/N  0799051
              Sensor 2:  S/N  0799044
   Sensor 3:  S/N  101157
              Sensor 4:  S/N  101160
   Sensor 5:  S/N  101148
              Sensor 6:  S/N  1099011
   Sensor 7:  S/N  190014
              Sensor 8:  S/N  101146

   Sensor 1:  (29, 29)          Sensor 2:  (17.25, 29.5)
   Sensor 3:  (21.5, 27)        Sensor 4:  (13, 29)
   Sensor 5:  (29, 11.75)       Sensor 6:  (21, 15.5)
   Sensor 7:  (13, 9.5)         Sensor 8:  (5, 9.5)

IV. Pretest sensor check:
    Verify settings:
    SCM trigger source:  X
    20 dB PA gain, 3 dB signal gain:  X
    20 kHz HP filter, 1500 kHz LP filter:  X
    5 MHz SR, 4096 points, 1024 pretrigger:  X
    Test sensors and record file name:  A1-14 6-09-04 Pretest LB
    Comments:  All Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check:  X

VI. Impact test:
    Verify settings:
    External (gun) trigger source:  X
    20 kHz HP filter, 1500 kHz LP filter:  X
    2 MHz SR, 32 K points, 4096 pretrigger:  X
    8 channel recording mode:  X
    Data acquisition in record mode:  X
       (DWC logo spinning)
    Record and verify gain settings:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Sensor 1: Attenuators: 0       Preamp: 20       SCM: 9
Sensor 2: Attenuators: 0       Preamp: 20       SCM: 9
Sensor 3: Attenuators: 0       Preamp: 20       SCM: 9
Sensor 4: Attenuators: 0       Preamp: 20       SCM: 9
Sensor 5: Attenuators: 0       Preamp: 20       SCM: 9
Sensor 6: Attenuators: 0       Preamp: 20       SCM: 9
Sensor 7: Attenuators: 0       Preamp: 20       SCM: 9
Sensor 8: Attenuators: 0       Preamp: 20       SCM: 9

Record file name: A1-14 6-09-04 Impact
Comments: Impact on event 5. Data O.K.

VII. Post test sensor check:
Verify settings:
20 dB PA gain, 3 dB signal gain   X
20 kHz HP filter, 1500 kHz LP filter   X
5 MHz SR, 4096 points, 1024 pretrigger   X
Test sensors and record file name:
Comments:

VIII. Post test
Review data and backup files on CD   X
Record actual impact parameters:
  Projectile velocity: 6.7 km/s.
Impact coordinates:
Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 77: A-1 Shot #14 Impact Waveform

Figure 78: A-1 Shot #14 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
- Test date: 6/09/04
- Test number: A1-15
- Specimen ID: A-1
- Projectile size: 2.2mm/30deg.
- Planned velocity: 6.8 km/s
- Planned impact coordinates: (10.8, 30)

II. Prebonding sensor tests performed: N/A
   (Only for first test in series or when replacing or rebonding sensors between tests, otherwise indicate N/A)
   Comments:

III. Record sensor serial number and coordinates:

   Sensor 1: S/N 0799051
   Sensor 2: S/N 0799044
   Sensor 3: S/N 101157
   Sensor 4: S/N 101160
   Sensor 5: S/N 101148
   Sensor 6: S/N 1099011
   Sensor 7: S/N 190014
   Sensor 8: S/N 101146

   Sensor 1: (29, 29)
   Sensor 2: (17.25, 29.5)
   Sensor 3: (21.5, 27)
   Sensor 4: (13, 29)
   Sensor 5: (29, 11.75)
   Sensor 6: (21, 15.5)
   Sensor 7: (13, 9.5)
   Sensor 8: (5, 9.5)

IV. Pretest sensor check:
- SCM trigger source: X
- 20 dB PA gain, 3 dB signal gain: X
- 20 kHz HP filter, 1500 kHz LP filter: X
- 5 MHz SR, 4096 points, 1024 pretrigger: X
- Test sensors and record file name: A1-15 6-09-04 Pretest LB
- Comments: All Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check: X

VI. Impact test:
- External (gun) trigger source: X
- 20 kHz HP filter, 1500 kHz LP filter: X
- 2 MHz SR, 32 K points, 4096 pretrigger: X
- 8 channel recording mode: X
- Data acquisition in record mode: X
  (DWC logo spinning)
- Record and verify gain settings:
Sensor 1: Attenuators: 0_______ Preamp: 20____ SCM: 9__
Sensor 2: Attenuators: 0_______ Preamp: 20____ SCM: 9__
Sensor 3: Attenuators: 0_______ Preamp: 20____ SCM: 9__
Sensor 4: Attenuators: 0_______ Preamp: 20____ SCM: 9__
Sensor 5: Attenuators: 0_______ Preamp: 20____ SCM: 9__
Sensor 6: Attenuators: 0_______ Preamp: 20____ SCM: 9__
Sensor 7: Attenuators: 0_______ Preamp: 20____ SCM: 9__
Sensor 8: Attenuators: 0_______ Preamp: 20____ SCM: 9__

Record file name: A1-15 6-09-04 Impact
Comments: Impact on event 4. Data O.K.

VII. Post test sensor check:
Verify settings:
  20 dB PA gain, 3 dB signal gain     X
  20 kHz HP filter, 1500 kHz LP filter  X
  5 MHz SR, 4096 points, 1024 pretrigger X
Test sensors and record file name:
Comments:

VIII. Post test
Review data and backup files on CD X
Record actual impact parameters:
  Projectile velocity: 6.88 km/s.
Impact coordinates:
Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 79: A-1 Shot #15 Impact Waveform

Figure 80: A-1 Shot #15 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 6/09/04  Specimen ID:  A-1
   Test number:  A1-16  Projectile size:  2.4mm/30deg.
   Planned velocity:  6.8 km/s
   Planned impact coordinates:  (4.2, 27.7)

II. Prebonding sensor tests performed:  N/A
    (Only for first test in series or when replacing or rebonding sensors
      between tests, otherwise indicate N/A)
    Comments:

III. Record sensor serial number and coordinates:
    Sensor 1:  S/N  0799051  Sensor 2:  S/N  0799044
    Sensor 3:  S/N  101157  Sensor 4:  S/N  101160
    Sensor 5:  S/N  101148  Sensor 6:  S/N  1099011
    Sensor 7:  S/N  190014  Sensor 8:  S/N  101146
    Sensor 1:  (29, 29)  Sensor 2:  (17.25, 29.5)
    Sensor 3:  (21.5, 27)  Sensor 4:  (13, 29)
    Sensor 5:  (29, 11.75)  Sensor 6:  (21, 15.5)
    Sensor 7:  (13, 9.5)  Sensor 8:  (5, 9.5)

IV. Pretest sensor check:
    Verify settings:
    SCM trigger source:  X
    20 dB PA gain, 3 dB signal gain:  X
    20 kHz HP filter, 1500 kHz LP filter:  X
    5 MHz SR, 4096 points, 1024 pretrigger:  X
    Test sensors and record file name:  A1-16 6-09-04 Pretest LB
    Comments:  All Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check:  X

VI. Impact test:
    Verify settings:
    External (gun) trigger source:  X
    20 kHz HP filter, 1500 kHz LP filter:  X
    2 MHz SR, 32 K points, 4096 pretrigger:  X
    8 channel recording mode:  X
    Data acquisition in record mode:  X
    (DWC logo spinning)
    Record and verify gain settings:
Sensor 1: Attenuators: 0_______ Preamp: 20____ SCM: 6__
Sensor 2: Attenuators: 0_______ Preamp: 20____ SCM: 6__
Sensor 3: Attenuators: 0_______ Preamp: 20____ SCM: 6__
Sensor 4: Attenuators: 0_______ Preamp: 20____ SCM: 6__
Sensor 5: Attenuators: 0_______ Preamp: 20____ SCM: 6__
Sensor 6: Attenuators: 0_______ Preamp: 20____ SCM: 6__
Sensor 7: Attenuators: 0_______ Preamp: 20____ SCM: 6__
Sensor 8: Attenuators: 0_______ Preamp: 20____ SCM: 6__

Record file name: **A1-16 6-09-04 Impact**
Comments: Impact on event 5. Data O.K.

VII. Post test sensor check:
Verify settings:
- 20 dB PA gain, 3 dB signal gain
- 20 kHz HP filter, 1500 kHz LP filter
- 5 MHz SR, 4096 points, 1024 pretrigger
Test sensors and record file name:
Comments:

VIII: Post test
Review data and backup files on CD  **X**
Record actual impact parameters:
- Projectile velocity: 6.66 km/s.
- Impact coordinates:
- Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 81: A-1 Shot #16 Impact Waveform

Figure 82: A-1 Shot #16 Impact Damage
Tile Targets A-1, Ag-1, B-1, and Bg-1

AE Test Data/Checklist

I. Record pretest information:
   Test date: 6/08/04          Specimen ID: A-1
   Test number: A1-17          Projectile size: 1.8mm/30deg.
   Planned velocity: 6.8 km/s
   Planned impact coordinates: (30, 10.8)

II. Prebonding sensor tests performed: N/A
   (Only for first test in series or when replacing or rebonding sensors
    between tests, otherwise indicate N/A)
   Comments:

III. Record sensor serial number and coordinates:

   Sensor 1: S/N 0799051         Sensor 2: S/N 0799044
   Sensor 3: S/N 101157          Sensor 4: S/N 101160
   Sensor 5: S/N 101148          Sensor 6: S/N 1099011
   Sensor 7: S/N 190014          Sensor 8: S/N 101146

   Sensor 1: (29, 29)           Sensor 2: (17.25, 29.5)
   Sensor 3: (21.5, 27)         Sensor 4: (13.29)
   Sensor 5: (29, 11.75)        Sensor 6: (21, 15.5)
   Sensor 7: (13, 9.5)          Sensor 8: (5, 9.5)

IV. Pretest sensor check:
   Verify settings:
   SCM trigger source:          X
   20 dB PA gain, 3 dB signal gain:  X
   20 kHz HP filter, 1500 kHz LP filter:  X
   5 MHz SR, 4096 points, 1024 pretrigger:  X
   Test sensors and record file name: A1-17 6-08-04 Pretest LB
   Comments: All Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check:  X

VI. Impact test:
   Verify settings:
   External (gun) trigger source:  X
   20 kHz HP filter, 1500 kHz LP filter:  X
   2 MHz SR, 32 K points, 4096 pretrigger:  X
   8 channel recording mode:        X
   Data acquisition in record mode:  X
      (DWC logo spinning)
   Record and verify gain settings:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Sensor 1: Attenuators: 0_______ Preamp: 20____ SCM: 15____
Sensor 2: Attenuators: 0_______ Preamp: 20____ SCM: 15____
Sensor 3: Attenuators: 0_______ Preamp: 20____ SCM: 15____
Sensor 4: Attenuators: 0_______ Preamp: 20____ SCM: 15____
Sensor 5: Attenuators: 0_______ Preamp: 20____ SCM: 15____
Sensor 6: Attenuators: 0_______ Preamp: 20____ SCM: 15____
Sensor 7: Attenuators: 0_______ Preamp: 20____ SCM: 15____
Sensor 8: Attenuators: 0_______ Preamp: 20____ SCM: 15____

Record file name: A1-18 6-08-04 Impact

VII. Post test sensor check:
Verify settings:
- 20 dB PA gain, 3 dB signal gain           X
- 20 kHz HP filter, 1500 kHz LP filter     X
- 5 MHz SR, 4096 points, 1024 pretrigger   X
Test sensors and record file name:
Comments:

VIII: Post test
Review data and backup files on CD  X
Record actual impact parameters:
Projectile velocity: 6.72 km/s.
Impact coordinates:
Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 83: A-1 Shot #17 Impact Waveform

Figure 84: A-1 Shot #17 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 6/08/04  Specimen ID:  A-1
   Test number:  A1-18  Projectile size:  1.6mm/30deg.
   Planned velocity:  6.8 km/s
   Planned impact coordinates:  (27.8, 4.2)

II. Prebonding sensor tests performed:  N/A
    (Only for first test in series or when replacing or rebonding sensors
    between tests, otherwise indicate N/A)
    Comments:

III. Record sensor serial number and coordinates:
   Sensor 1:  S/N 0799051    Sensor 2:  S/N 0799044
   Sensor 3:  S/N 101157    Sensor 4:  S/N 101160
   Sensor 5:  S/N 101148    Sensor 6:  S/N 1099011
   Sensor 7:  S/N 190014    Sensor 8:  S/N 101146
   Sensor 1:  (29, 29)    Sensor 2:  (17.25, 29.5)
   Sensor 3:  (21.5, 27)  Sensor 4:  (13, 29)
   Sensor 5:  (29, 11.75)  Sensor 6:  (21, 15.5)
   Sensor 7:  (13, 9.5)   Sensor 8:  (5, 9.5)

IV. Pretest sensor check:
    Verify settings:
    SCM trigger source:  X
    20 dB PA gain, 3 dB signal gain:  X
    20 kHz HP filter, 1500 kHz LP filter:  X
    5 MHz SR, 4096 points, 1024 pretrigger:  X
    Test sensors and record file name:  A1-18 6-08-04 Pretest LB
    Comments:  All sensors replaced since last test on this article.  All Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check:  X

VI. Impact test:
    Verify settings:
    External (gun) trigger source:  X
    20 kHz HP filter, 1500 kHz LP filter:  X
    2 MHz SR, 32 K points, 4096 pretrigger:  X
    8 channel recording mode:  X
    Data acquisition in record mode:  X
    (DWC logo spinning)
    Record and verify gain settings:
Sensor 1: Attenuators: 0_______ Preamp: 20____ SCM: 15____
Sensor 2: Attenuators: 0_______ Preamp: 20____ SCM: 15____
Sensor 3: Attenuators: 0_______ Preamp: 20____ SCM: 15____
Sensor 4: Attenuators: 0_______ Preamp: 20____ SCM: 15____
Sensor 5: Attenuators: 0_______ Preamp: 20____ SCM: 15____
Sensor 6: Attenuators: 0_______ Preamp: 20____ SCM: 15____
Sensor 7: Attenuators: 0_______ Preamp: 20____ SCM: 15____
Sensor 8: Attenuators: 0_______ Preamp: 20____ SCM: 15____

Record file name: A1-18 6-08-04 Impact
Comments: Impact on event 3. Data O.K.

VII. Post test sensor check:
Verify settings:
20 dB PA gain, 3 dB signal gain X
20 kHz HP filter, 1500 kHz LP filter X
5 MHz SR, 4096 points, 1024 pretrigger X
Test sensors and record file name:
Comments:

VIII. Post test
Review data and backup files on CD X
Record actual impact parameters:
Projectile velocity: 6.72 km/s.
Impact coordinates:
Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 85: A-1 Shot #18 Impact Waveform

Figure 86: A-1 Shot #18 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 5/17/04   Specimen ID: Ag-1
   Test number: Ag1-1   Projectile size: 0.4mm/90deg.
   Planned velocity: 6.8 km/s
   Planned impact coordinates: (13.75, 18.25)

II. Prebonding sensor tests performed: Yes
    (Only for first test in series or when replacing or rebonding sensors between tests, otherwise indicate N/A)
    Comments: All sensors good.

III. Record sensor serial number and coordinates:

   Sensor 1: S/N 101146   Sensor 2: S/N 190014
   Sensor 3: S/N 190015   Sensor 4: S/N 190016
   Sensor 5: S/N 190017   Sensor 6: S/N 1099011
   Sensor 7: S/N 190019   Sensor 8: S/N 190020

   Sensor 1: (29, 29)   Sensor 2: (17.25, 29.5)
   Sensor 3: (21.5, 27) Sensor 4: (13, 29)
   Sensor 5: (29, 11.75) Sensor 6: (21, 15.5)
   Sensor 7: (13, 9.5)   Sensor 8: (5, 9.5)

IV. Pretest sensor check:
    Verify settings:
    SCM trigger source: X
    20 dB PA gain, 3 dB signal gain: X
    20 kHz HP filter, 1500 kHz LP filter: X
    5 MHz SR, 4096 points, 1024 pretrigger: X
    Test sensors and record file name: Ag1-1 5-17-04 pretestlb
    Comments: Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check: X

VI. Impact test:
    Verify settings:
    External (gun) trigger source: X
    20 kHz HP filter, 1500 kHz LP filter: X
    2 MHz SR, 32 K points, 4096 pretrigger: X
    8 channel recording mode: X
    Data acquisition in record mode: X
    (DWC logo spinning)
    Record and verify gain settings:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Sensor 1: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 2: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 3: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 4: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 5: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 6: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 7: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 8: Attenuators: 0_______ Preamp: 20____ SCM: 18____

Record file name: Ag1-1 5-17-04 Impact
Comments:

VII. Post test sensor check:
Verify settings:
   20 dB PA gain, 3 dB signal gain   X
   20 kHz HP filter, 1500 kHz LP filter   X
   5 MHz SR, 4096 points, 1024 pretrigger   X
Test sensors and record file name: Ag1-1 5-17-04 Posttest lb
Comments: All Sensors good.

VIII: Post test
Review data and backup files on CD   X
Record actual impact parameters:
   Projectile velocity: The launcher data acquisition system failed to store
   the test data. Velocity could not be obtained.
   Impact coordinates: ________
Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 87: Ag-1 Shot #1 Impact Waveform

Figure 88: Ag-1 Shot #1 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 5/18/04  Specimen ID: Ag-1
   Test number: Ag1-2c  Projectile size: 0.6mm/90deg.
   Planned velocity: 6.8 km/s
   Planned impact coordinates: (18.25, 14)

II. Prebonding sensor tests performed: N/A
(Only for first test in series or when replacing or rebonding sensors
between tests, otherwise indicate N/A)
Comments:

III. Record sensor serial number and coordinates:

<table>
<thead>
<tr>
<th>Sensor</th>
<th>S/N</th>
<th>Sensor</th>
<th>S/N</th>
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<tr>
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<td>Sensor 4</td>
<td>190016</td>
</tr>
<tr>
<td>Sensor 5</td>
<td>190017</td>
<td>Sensor 6</td>
<td>1099011</td>
</tr>
<tr>
<td>Sensor 7</td>
<td>190019</td>
<td>Sensor 8</td>
<td>190020</td>
</tr>
</tbody>
</table>

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</thead>
<tbody>
<tr>
<td>Sensor 1</td>
<td>(29, 29)</td>
<td>Sensor 2</td>
<td>(17.25, 29.5)</td>
</tr>
<tr>
<td>Sensor 3</td>
<td>(21.5, 27)</td>
<td>Sensor 4</td>
<td>(13, 29)</td>
</tr>
<tr>
<td>Sensor 5</td>
<td>(29, 11.75)</td>
<td>Sensor 6</td>
<td>(21, 15.5)</td>
</tr>
<tr>
<td>Sensor 7</td>
<td>(13, 9.5)</td>
<td>Sensor 8</td>
<td>(5, 9.5)</td>
</tr>
</tbody>
</table>

IV. Pretest sensor check:
Verify settings:
   SCM trigger source:  X
   20 dB PA gain, 3 dB signal gain:  X
   20 kHz HP filter, 1500 kHz LP filter:  X
   5 MHz SR, 4096 points, 1024 pretrigger:  X
   Test sensors and record file name:
   Comments:

V. Switch to external (gun) trigger source and complete pretest trigger check:  X

VI. Impact test:
Verify settings:
   External (gun) trigger source:  X
   20 kHz HP filter, 1500 kHz LP filter:  X
   2 MHz SR, 32 K points, 4096 pretrigger:  X
   8 channel recording mode:  X
   Data acquisition in record mode:  X
   (DWC logo spinning)
   Record and verify gain settings:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Sensor 1: Attenuators: 0 _______ Preamp: 20 _______ SCM: 18 _______
Sensor 2: Attenuators: 0 _______ Preamp: 20 _______ SCM: 18 _______
Sensor 3: Attenuators: 0 _______ Preamp: 20 _______ SCM: 18 _______
Sensor 4: Attenuators: 0 _______ Preamp: 20 _______ SCM: 18 _______
Sensor 5: Attenuators: 0 _______ Preamp: 20 _______ SCM: 18 _______
Sensor 6: Attenuators: 0 _______ Preamp: 20 _______ SCM: 18 _______
Sensor 7: Attenuators: 0 _______ Preamp: 20 _______ SCM: 18 _______
Sensor 8: Attenuators: 0 _______ Preamp: 20 _______ SCM: 18 _______

Record file name: Ag1-2c 5-18-04 Impact
Comments: Impact on event 8. Data O.K.

VII. Post test sensor check:
Verify settings:
20 dB PA gain, 3 dB signal gain X
20 kHz HP filter, 1500 kHz LP filter X
5 MHz SR, 4096 points, 1024 pretrigger X
Test sensors and record file name:
Comments: All sensors good.

VIII: Post test
Review data and backup files on CD  X
Record actual impact parameters:
  Projectile velocity: 6.78 km/s.
  Impact coordinates:
  Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 89: Ag-1 Shot #2 Impact Waveform

Figure 90: Ag-1 Shot #2 Impact Damage
Tile Targets A-1, Ag-1, B-1, and Bg-1

AE Test Data/Checklist

I. Record pretest information:
   Test date: 5/19/04  Specimen ID: Ag-1
   Test number: Ag1-3  Projectile size: 1.0mm/90deg.
   Planned velocity: 6.8 km/s
   Planned impact coordinates: (20.25, 20.5)

II. Prebonding sensor tests performed: N/A
   (Only for first test in series or when replacing or rebonding sensors
    between tests, otherwise indicate N/A)
   Comments:

III. Record sensor serial number and coordinates:
   Sensor 1: S/N 101146  Sensor 2: S/N 190014
   Sensor 3: S/N 190015  Sensor 4: S/N 190016
   Sensor 5: S/N 190017  Sensor 6: S/N 1099011
   Sensor 7: S/N 190019  Sensor 8: S/N 190020
   Sensor 1: (29, 29)  Sensor 2: (17.25, 29.5)
   Sensor 3: (21.5, 27)  Sensor 4: (13, 29)
   Sensor 5: (29, 11.75)  Sensor 6: (21, 15.5)
   Sensor 7: (13, 9.5)  Sensor 8: (5, 9.5)

IV. Pretest sensor check:
   Verify settings:
   SCM trigger source: X
   20 dB PA gain, 3 dB signal gain: X
   20 kHz HP filter, 1500 kHz LP filter: X
   5 MHz SR, 4096 points, 1024 pretrigger: X
   Test sensors and record file name: Ag1-3 5-19-04 Pretest LB
   Comments: Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check: X

VI. Impact test:
   Verify settings:
   External (gun) trigger source: X
   20 kHz HP filter, 1500 kHz LP filter: X
   2 MHz SR, 32 K points, 4096 pretrigger: X
   8 channel recording mode: X
   Data acquisition in record mode: X
   (DWC logo spinning)
   Record and verify gain settings:
Sensor 1: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 2: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 3: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 4: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 5: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 6: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 7: Attenuators: 0_______ Preamp: 20____ SCM: 18____
Sensor 8: Attenuators: 0_______ Preamp: 20____ SCM: 18____

Record file name: Ag1-3 5-19-04 Impact
Comments: Impact on event 5. Data O.K., but lower than expected.

VII. Post test sensor check:
Verify settings:
20 dB PA gain, 3 dB signal gain X
20 kHz HP filter, 1500 kHz LP filter X
5 MHz SR, 4096 points, 1024 pretrigger X
Test sensors and record file name: Ag1-3 5-19-04 Posttest LB
Comments: All sensors good.

VIII: Post test
Review data and backup files on CD X
Record actual impact parameters:
Projectile velocity:
Impact coordinates:
Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 91: Ag-1 Shot #3 Impact Waveform

Figure 92: Ag-1 Shot #3 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 5/19/04                      Specimen ID:  Ag-1
   Test number:  Ag1-4                      Projectile size:  1.4mm/90deg.
   Planned velocity:  6.8 km/s
   Planned impact coordinates:  (11.5, 11.75)

II. Prebonding sensor tests performed:  N/A
   (Only for first test in series or when replacing or rebonding sensors between tests, otherwise indicate N/A)
   Comments:

III. Record sensor serial number and coordinates:

   Sensor 1:  S/N 101146                      Sensor 2:  S/N 190014
   Sensor 3:  S/N 190015                      Sensor 4:  S/N 190016
   Sensor 5:  S/N 190017                      Sensor 6:  S/N 1099011
   Sensor 7:  S/N 190019                      Sensor 8:  S/N 190020

   Sensor 1:  (29, 29)                      Sensor 2:  (17.25, 29.5)
   Sensor 3:  (21.5, 27)                    Sensor 4:  (13.29)
   Sensor 5:  (29, 11.75)                   Sensor 6:  (21, 15.5)
   Sensor 7:  (13, 9.5)                     Sensor 8:  (5, 9.5)

IV. Pretest sensor check:
   Verify settings:
      SCM trigger source:  X
      20 dB PA gain, 3 dB signal gain:  X
      20 kHz HP filter, 1500 kHz LP filter:  X
      5 MHz SR, 4096 points, 1024 pretrigger:  X
   Test sensors and record file name:  Ag1-4 5-19-04 Pretest LB
   Comments:  Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check:  X

VI. Impact test:
   Verify settings:
      External (gun) trigger source:  X
      20 kHz HP filter, 1500 kHz LP filter:  X
      2 MHz SR, 32 K points, 4096 pretrigger:  X
      8 channel recording mode:  X
      Data acquisition in record mode:  X
         (DWC logo spinning)
   Record and verify gain settings:
II. Post test sensor check:
   Verify settings:
   20 dB PA gain, 3 dB signal gain  X
   20 kHz HP filter, 1500 kHz LP filter  X
   5 MHz SR, 4096 points, 1024 pretrigger  X
   Test sensors and record file name:
   Comments: All sensors good.

VIII. Post test
   Review data and backup files on CD  X
   Record actual impact parameters:
   Projectile velocity:
   Impact coordinates:
   Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 93: Ag-1 Shot #4 Impact Waveform

Figure 94: Ag-1 Shot #4 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 5/20/04  Specimen ID:  Ag-1
   Test number:  Ag1-5  Projectile size:  1.6mm/90deg.
   Planned velocity:  6.8 km/s
   Planned impact coordinates:  (25, 16)

II. Prebonding sensor tests performed:  N/A
    (Only for first test in series or when replacing or rebonding sensors
     between tests, otherwise indicate N/A)
    Comments:

III. Record sensor serial number and coordinates:
   Sensor 1:  S/N  101146  Sensor 2:  S/N  190014
   Sensor 3:  S/N  190015  Sensor 4:  S/N  190016
   Sensor 5:  S/N  190017  Sensor 6:  S/N  1099011
   Sensor 7:  S/N  190019  Sensor 8:  S/N  190020
   Sensor 1:  (29, 29)  Sensor 2:  (17.25, 29.5)
   Sensor 3:  (21.5, 27)  Sensor 4:  (13, 29)
   Sensor 5:  (29, 11.75)  Sensor 6:  (21, 15.5)
   Sensor 7:  (13, 9.5)  Sensor 8:  (5, 9.5)

IV. Pretest sensor check:
    Verify settings:
    SCM trigger source:  X
    20 dB PA gain, 3 dB signal gain:  X
    20 kHz HP filter, 1500 kHz LP filter:  X
    5 MHz SR, 4096 points, 1024 pretrigger:  X
    Test sensors and record file name:  Ag1-5 5-20-04 Pretest LB
    Comments:  Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check:  X

VI. Impact test:
    Verify settings:
    External (gun) trigger source:  X
    20 kHz HP filter, 1500 kHz LP filter:  X
    2 MHz SR, 32 K points, 4096 pretrigger:  X
    8 channel recording mode:  X
    Data acquisition in record mode:  X
    (DWC logo spinning)
    Record and verify gain settings:
VII. Post test sensor check:
Verify settings:
20 dB PA gain, 3 dB signal gain X
20 kHz HP filter, 1500 kHz LP filter X
5 MHz SR, 4096 points, 1024 pretrigger X
Test sensors and record file name:
Comments: All sensors good.

VIII. Post test
Review data and backup files on CD X
Record actual impact parameters:
   Projectile velocity: 6.78 km/s.
Impact coordinates:
   Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 95: Ag-1 Shot #5 Impact Waveform

Figure 96: Ag-1 Shot #5 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 5/20/04   Specimen ID: Ag-1
   Test number: Ag1-6   Projectile size: 1.8mm/90deg.
   Planned velocity: 6.8 km/s
   Planned impact coordinates: (16, 23.5)

II. Prebonding sensor tests performed: N/A
    (Only for first test in series or when replacing or rebonding sensors
    between tests, otherwise indicate N/A)
    Comments:

III. Record sensor serial number and coordinates:

   Sensor 1: S/N 101146   Sensor 2: S/N 190014
   Sensor 3: S/N 190015   Sensor 4: S/N 190016
   Sensor 5: S/N 190017   Sensor 6: S/N 1099011
   Sensor 7: S/N 190019   Sensor 8: S/N 190020

   Sensor 1: (29, 29)   Sensor 2: (17, 25, 29.5)
   Sensor 3: (21, 5, 27) Sensor 4: (13, 29)
   Sensor 5: (29, 11.75) Sensor 6: (21, 15.5)
   Sensor 7: (13, 9.5)   Sensor 8: (5, 9.5)

IV. Pretest sensor check:
    Verify settings:
    SCM trigger source: X
    20 dB PA gain, 3 dB signal gain: X
    20 kHz HP filter, 1500 kHz LP filter: X
    5 MHz SR, 4096 points, 1024 pretrigger: X
    Test sensors and record file name: Ag1-6 5-20-04 Pretest LB
    Comments: Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check: X

VI. Impact test:
    Verify settings:
    External (gun) trigger source: X
    20 kHz HP filter, 1500 kHz LP filter: X
    2 MHz SR, 32 K points, 4096 pretrigger: X
    8 channel recording mode: X
    Data acquisition in record mode: X
    (DWC logo spinning)
    Record and verify gain settings:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Sensor 1: Attenuators: 0  Preamp: 20  SCM: 12
Sensor 2: Attenuators: 0  Preamp: 20  SCM: 12
Sensor 3: Attenuators: 0  Preamp: 20  SCM: 12
Sensor 4: Attenuators: 0  Preamp: 20  SCM: 12
Sensor 5: Attenuators: 0  Preamp: 20  SCM: 12
Sensor 6: Attenuators: 0  Preamp: 20  SCM: 12
Sensor 7: Attenuators: 0  Preamp: 20  SCM: 12
Sensor 8: Attenuators: 0  Preamp: 20  SCM: 12

Record file name: Ag1-6 5-20-04 Impact
Comments: Impact on event 3. Data O.K.

VII. Post test sensor check:
Verify settings:
20 dB PA gain, 3 dB signal gain X
20 kHz HP filter, 1500 kHz LP filter X
5 MHz SR, 4096 points, 1024 pretrigger X
Test sensors and record file name:
Comments: All sensors good.

VIII: Post test
Review data and backup files on CD X
Record actual impact parameters:
Projectile velocity: 6.78 km/s.
Impact coordinates:
Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 97: Ag-1 Shot #6 Impact Waveform

Figure 98: Ag-1 Shot #6 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 5/24/04  Specimen ID:  Ag-1
   Test number: Ag1-7  Projectile size: 2.0mm/45deg.
   Planned velocity: 6.8 km/s
   Planned impact coordinates: (16, 07)

II. Prebonding sensor tests performed: N/A
(Only for first test in series or when replacing or rebonding sensors
between tests, otherwise indicate N/A)
   Comments:

III. Record sensor serial number and coordinates:
   Sensor 1: S/N 101146  Sensor 2: S/N 190014
   Sensor 3: S/N 190015  Sensor 4: S/N 190016
   Sensor 5: S/N 190017  Sensor 6: S/N 1099011
   Sensor 7: S/N 190019  Sensor 8: S/N 190020
   Sensor 1: (29, 29)  Sensor 2: (17.25, 29.5)
   Sensor 3: (21, 5, 27)  Sensor 4: (13, 29)
   Sensor 5: (29, 11.75)  Sensor 6: (21, 15.5)
   Sensor 7: (13, 9.5)  Sensor 8: (5, 9.5)

IV. Pretest sensor check:
   Verify settings:
   SCM trigger source:  X
   20 dB PA gain, 3 dB signal gain:  X
   20 kHz HP filter, 1500 kHz LP filter:  X
   5 MHz SR, 4096 points, 1024 pretrigger:  X
   Test sensors and record file name: Ag1-7 5-24-04 Pretest LB
   Comments: Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check:  X

VI. Impact test:
   Verify settings:
   External (gun) trigger source:  X
   20 kHz HP filter, 1500 kHz LP filter:  X
   2 MHz SR, 32 K points, 4096 pretrigger:  X
   8 channel recording mode:  X
   Data acquisition in record mode:  X
   (DWC logo spinning)
   Record and verify gain settings:
Sensor 1: Attenuators: 0 Preamp: 20 SCM: 12
Sensor 2: Attenuators: 0 Preamp: 20 SCM: 12
Sensor 3: Attenuators: 0 Preamp: 20 SCM: 12
Sensor 4: Attenuators: 0 Preamp: 20 SCM: 12
Sensor 5: Attenuators: 0 Preamp: 20 SCM: 12
Sensor 6: Attenuators: 0 Preamp: 20 SCM: 12
Sensor 7: Attenuators: 0 Preamp: 20 SCM: 12
Sensor 8: Attenuators: 0 Preamp: 20 SCM: 12

Record file name: Ag1-7 5-24-04 Impact
Comments: Impact on event 4. Data O.K.

VII. Post test sensor check:
Verify settings:
20 dB PA gain, 3 dB signal gain  X
20 kHz HP filter, 1500 kHz LP filter X
5 MHz SR, 4096 points, 1024 pretrigger X
Test sensors and record file name:
Comments:

VIII. Post test
Review data and backup files on CD  X
Record actual impact parameters:
Projectile velocity: 6.74 km/s.
Impact coordinates:
Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 99: Ag-1 Shot #7 Impact Waveform

Figure 100: Ag-1 Shot #7 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 5/24/04  Specimen ID: Ag-1
   Test number: Ag1-8  Projectile size: 2.2mm/45deg.
   Planned velocity: 6.8 km/s
   Planned impact coordinates: (7.25, 16)

II. Prebonding sensor tests performed: N/A
    (Only for first test in series or when replacing or rebonding sensors
    between tests, otherwise indicate N/A)
    Comments:

III. Record sensor serial number and coordinates:

   Sensor 1: S/N 101146  Sensor 2: S/N 190014
   Sensor 3: S/N 190015  Sensor 4: S/N 190016
   Sensor 5: S/N 190017  Sensor 6: S/N 1099011
   Sensor 7: S/N 190019  Sensor 8: S/N 190020

   Sensor 1: (29, 29)  Sensor 2: (17.25, 29.5)
   Sensor 3: (21.5, 27)  Sensor 4: (13, 29)
   Sensor 5: (29, 11.75)  Sensor 6: (21, 15.5)
   Sensor 7: (13, 9.5)  Sensor 8: (5, 9.5)

IV. Pretest sensor check:
    Verify settings:
    SCM trigger source: X
    20 dB PA gain, 3 dB signal gain: X
    20 kHz HP filter, 1500 kHz LP filter: X
    5 MHz SR, 4096 points, 1024 pretrigger: X
    Test sensors and record file name: Ag1-8 5-24-04 Pretest LB
    Comments: Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check: X

VI. Impact test:
    Verify settings:
    External (gun) trigger source: X
    20 kHz HP filter, 1500 kHz LP filter: X
    2 MHz SR, 32 K points, 4096 pretrigger: X
    8 channel recording mode: X
    Data acquisition in record mode: X
    (DWC logo spinning)
    Record and verify gain settings:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Sensor 1: Attenuators: 0 Preamp: 20 SCM: 6
Sensor 2: Attenuators: 0 Preamp: 20 SCM: 6
Sensor 3: Attenuators: 0 Preamp: 20 SCM: 6
Sensor 4: Attenuators: 0 Preamp: 20 SCM: 6
Sensor 5: Attenuators: 0 Preamp: 20 SCM: 6
Sensor 6: Attenuators: 0 Preamp: 20 SCM: 6
Sensor 7: Attenuators: 0 Preamp: 20 SCM: 6
Sensor 8: Attenuators: 0 Preamp: 20 SCM: 6

Record file name: Ag1-8 5-24-04 Impact

VII. Post test sensor check:
Verify settings:
- 20 dB PA gain, 3 dB signal gain X
- 20 kHz HP filter, 1500 kHz LP filter X
- 5 MHz SR, 4096 points, 1024 pretrigger X
Test sensors and record file name:
Comments:

VIII. Post test
Review data and backup files on CD X
Record actual impact parameters:
- Projectile velocity: 6.74 km/s.
Impact coordinates:
Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 101: Ag-1 Shot #8 Impact Waveform

Figure 102: Ag-1 Shot #8 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 5/25/04   Specimen ID: Ag-1
   Test number: Ag1-9   Projectile size: 2.0mm/45deg.
   Planned velocity: 6.8 km/s
   Planned impact coordinates: (16, 16)

II. Preboning sensor tests performed: N/A
    (Only for first test in series or when replacing or rebonding sensors
     between tests, otherwise indicate N/A)
    Comments:

III. Record sensor serial number and coordinates:

   Sensor 1: S/N 101146   Sensor 2: S/N 190014
   Sensor 3: S/N 190015   Sensor 4: S/N 190016
   Sensor 5: S/N 190017   Sensor 6: S/N 109901
   Sensor 7: S/N 190019   Sensor 8: S/N 190020

   Sensor 1: (29, 29)   Sensor 2: (17.25, 29.5)
   Sensor 3: (21.5, 27) Sensor 4: (13, 29)
   Sensor 5: (29, 11.75) Sensor 6: (21, 15.5)
   Sensor 7: (13, 9.5)   Sensor 8: (5, 9.5)

IV. Pretest sensor check:
    Verify settings:
    SCM trigger source: X
    20 dB PA gain, 3 dB signal gain: X
    20 kHz HP filter, 1500 kHz LP filter: X
    5 MHz SR, 4096 points, 1024 pretrigger: X
    Test sensors and record file name: Ag1-9 5-25-04 Pretest LB
    Comments: Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check: X

VI. Impact test:
    Verify settings:
    External (gun) trigger source: X
    20 kHz HP filter, 1500 kHz LP filter: X
    2 MHz SR, 32 K points, 4096 pretrigger: X
    8 channel recording mode: X
    Data acquisition in record mode: X
    (DWC logo spinning)
    Record and verify gain settings:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Sensor 1: Attenuators: 0_______ Preamp: 20____ SCM: 9____
Sensor 2: Attenuators: 0_______ Preamp: 20____ SCM: 9____
Sensor 3: Attenuators: 0_______ Preamp: 20____ SCM: 9____
Sensor 4: Attenuators: 0_______ Preamp: 20____ SCM: 9____
Sensor 5: Attenuators: 0_______ Preamp: 20____ SCM: 9____
Sensor 6: Attenuators: 0_______ Preamp: 20____ SCM: 9____
Sensor 7: Attenuators: 0_______ Preamp: 20____ SCM: 9____
Sensor 8: Attenuators: 0_______ Preamp: 20____ SCM: 9____

Record file name: Ag1-9 5-25-04 Impact
Comments: Impact on event 4. Data O.K.

VII. Post test sensor check:
 Verify settings:
  20 dB PA gain, 3 dB signal gain        X
  20 kHz HP filter, 1500 kHz LP filter   X
  5 MHz SR, 4096 points, 1024 pretrigger   X
Test sensors and record file name:
Comments: All sensors good.

VIII: Post test
 Review data and backup files on CD   X
 Record actual impact parameters:
  Projectile velocity:   6.95 km/s.
  Impact coordinates:
  Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 103: Ag-1 Shot #9 Impact Waveform

Figure 104: Ag-1 Shot #9 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 5/26/04  
   Specimen ID: Ag-1  
   Test number: Ag1-10  
   Projectile size: 1.0mm/45deg.  
   Planned velocity: 6.8 km/s  
   Planned impact coordinates: (9.5, 22.6)

II. Prebonding sensor tests performed: N/A
   (Only for first test in series or when replacing or rebonding sensors
    between tests, otherwise indicate N/A)
   Comments:

III. Record sensor serial number and coordinates:

   Sensor 1: S/N 101146  
   Sensor 2: S/N 190014  
   Sensor 3: S/N 190015  
   Sensor 4: S/N 190016  
   Sensor 5: S/N 190017  
   Sensor 6: S/N 1099011  
   Sensor 7: S/N 190019  
   Sensor 8: S/N 190020  

   Sensor 1: (29, 29)  
   Sensor 2: (17, 25, 29.5)  
   Sensor 3: (21, 5, 27)  
   Sensor 4: (13, 29)  
   Sensor 5: (29, 11, 75)  
   Sensor 6: (21, 15.5)  
   Sensor 7: (13, 9.5)  
   Sensor 8: (5, 9.5)

IV. Pretest sensor check:
   Verify settings:
   SCM trigger source: X
   20 dB PA gain, 3 dB signal gain: X
   20 kHz HP filter, 1500 kHz LP filter: X
   5 MHz SR, 4096 points, 1024 pretrigger: X
   Test sensors and record file name: Ag1-10 5-26-04 Pretest LB
   Comments: Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check: X

VI. Impact test:
   Verify settings:
   External (gun) trigger source: X
   20 kHz HP filter, 1500 kHz LP filter: X
   2 MHz SR, 32 K points, 4096 pretrigger: X
   8 channel recording mode: X
   Data acquisition in record mode: X
   (DWC logo spinning)
   Record and verify gain settings:
Sensor 1: Attenuators: 0 _______ Preamp: 20 _______ SCM: 21 _______
Sensor 2: Attenuators: 0 _______ Preamp: 20 _______ SCM: 21 _______
Sensor 3: Attenuators: 0 _______ Preamp: 20 _______ SCM: 21 _______
Sensor 4: Attenuators: 0 _______ Preamp: 20 _______ SCM: 21 _______
Sensor 5: Attenuators: 0 _______ Preamp: 20 _______ SCM: 21 _______
Sensor 6: Attenuators: 0 _______ Preamp: 20 _______ SCM: 21 _______
Sensor 7: Attenuators: 0 _______ Preamp: 20 _______ SCM: 21 _______
Sensor 8: Attenuators: 0 _______ Preamp: 20 _______ SCM: 21 _______

Record file name: Ag1-10 5-26-04 Impact
Comments: Impact on event 4. Data O.K.

VII. Post test sensor check:
Verify settings:
20 dB PA gain, 3 dB signal gain X
20 kHz HP filter, 1500 kHz LP filter X
5 MHz SR, 4096 points, 1024 pretrigger X
Test sensors and record file name:
Comments:

VIII: Post test
Review data and backup files on CD X
Record actual impact parameters:
Projectile velocity: 6.88 km/s.
Impact coordinates:
Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 105: Ag-1 Shot #10 Impact Waveform

Figure 106: Ag-1 Shot #10 Impact Damage
Tile Targets A-1, Ag-1, B-1, and Bg-1

AE Test Data/Checklist

I. Record pretest information:
   Test date: 5/26/04  Specimen ID:  Ag-1
   Test number:  Ag1-11  Projectile size:  1.8mm/45deg.
   Planned velocity:  6.8 km/s
   Planned impact coordinates:  (22.7, 9.4)

II. Prebonding sensor tests performed:  N/A
   (Only for first test in series or when replacing or rebonding sensors
    between tests, otherwise indicate N/A)
   Comments:

III. Record sensor serial number and coordinates:

   Sensor 1:  S/N 101146  Sensor 2:  S/N 190014
   Sensor 3:  S/N 190015  Sensor 4:  S/N 190016
   Sensor 5:  S/N 190017  Sensor 6:  S/N 1099011
   Sensor 7:  S/N 190019  Sensor 8:  S/N 190020

   Sensor 1:  (29, 29)  Sensor 2:  (17.25, 29.5)
   Sensor 3:  (21.5, 27)  Sensor 4:  (13, 29)
   Sensor 5:  (29, 11.75)  Sensor 6:  (21, 15.5)
   Sensor 7:  (13, 9.5)  Sensor 8:  (5, 9.5)

IV. Pretest sensor check:
   Verify settings:
   SCM trigger source:  X
   20 dB PA gain, 3 dB signal gain:  X
   20 kHz HP filter, 1500 kHz LP filter:  X
   5 MHz SR, 4096 points, 1024 pretrigger:  X
   Test sensors and record file name:  Ag1-11 5-26-04 Pretest LB
   Comments:  Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check:  X

VI. Impact test:
   Verify settings:
   External (gun) trigger source:  X
   20 kHz HP filter, 1500 kHz LP filter:  X
   2 MHz SR, 32 K points, 4096 pretrigger:  X
   8 channel recording mode:  X
   Data acquisition in record mode:  X
   (DWC logo spinning)
   Record and verify gain settings:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Sensor 1:  Attenuators: 0 Preamp: 20 SCM: 18
Sensor 2:  Attenuators: 0 Preamp: 20 SCM: 18
Sensor 3:  Attenuators: 0 Preamp: 20 SCM: 18
Sensor 4:  Attenuators: 0 Preamp: 20 SCM: 18
Sensor 5:  Attenuators: 0 Preamp: 20 SCM: 18
Sensor 6:  Attenuators: 0 Preamp: 20 SCM: 18
Sensor 7:  Attenuators: 0 Preamp: 20 SCM: 18
Sensor 8:  Attenuators: 0 Preamp: 20 SCM: 18

Record file name: Ag1-11 5-26-04 Impact
Comments: Impact on event 4. Data O.K.

VII. Post test sensor check:
Verify settings:
20 dB PA gain, 3 dB signal gain X
20 kHz HP filter, 1500 kHz LP filter X
5 MHz SR, 4096 points, 1024 pretrigger X
Test sensors and record file name:
Comments:

VIII: Post test
Review data and backup files on CD X
Record actual impact parameters:
Projectile velocity: 6.88 km/s.
Impact coordinates:
Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 107: Ag-1 Shot #11 Impact Waveform

Figure 108: Ag-1 Shot #11 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 6/1/04  Specimen ID: Ag-1
   Test number: Ag1-12  Projectile size: 2 mm/45deg.
   Planned velocity: 6.8 km/s
   Planned impact coordinates: (23.5, 23.5)

II. Prebonding sensor tests performed: N/A
    (Only for first test in series or when replacing or rebonding sensors
     between tests, otherwise indicate N/A)
    Comments:

III. Record sensor serial number and coordinates:

   Sensor 1: S/N 101146  Sensor 2: S/N 190014
   Sensor 3: S/N 190015  Sensor 4: S/N 190016
   Sensor 5: S/N 190017  Sensor 6: S/N 1099011
   Sensor 7: S/N 190019  Sensor 8: S/N 190020

   Sensor 1: (29, 29)  Sensor 2: (17.25, 29.5)
   Sensor 3: (21.5, 27)  Sensor 4: (13, 29)
   Sensor 5: (29, 11.75)  Sensor 6: (21, 15.5)
   Sensor 7: (13, 9.5)  Sensor 8: (5, 9.5)

IV. Pretest sensor check:
    Verify settings:
    SCM trigger source: X
    20 dB PA gain, 3 dB signal gain: X
    20 kHz HP filter, 1500 kHz LP filter: X
    5 MHz SR, 4096 points, 1024 pretrigger: X
    Test sensors and record file name: Ag1-12 6-1-04 Pretest LB
    Comments: .

V. Switch to external (gun) trigger source and complete pretest trigger check: X

VI. Impact test:
    Verify settings:
    External (gun) trigger source: X
    20 kHz HP filter, 1500 kHz LP filter: X
    2 MHz SR, 32 K points, 4096 pretrigger: X
    8 channel recording mode: X
    Data acquisition in record mode: X
    (DWC logo spinning)
    Record and verify gain settings:
Sensor 1: Attenuators: 0_______ Preamp: 20____ SCM: 12____
Sensor 2: Attenuators: 0_______ Preamp: 20____ SCM: 12____
Sensor 3: Attenuators: 0_______ Preamp: 20____ SCM: 12____
Sensor 4: Attenuators: 0_______ Preamp: 20____ SCM: 12____
Sensor 5: Attenuators: 0_______ Preamp: 20____ SCM: 12____
Sensor 6: Attenuators: 0_______ Preamp: 20____ SCM: 12____
Sensor 7: Attenuators: 0_______ Preamp: 20____ SCM: 12____
Sensor 8: Attenuators: 0_______ Preamp: 20____ SCM: 12____

Record file name: Ag1-12 6-1-04 Impact
Comments: Impact on event 6. Data O.K.

VII. Post test sensor check:
Verify settings:
20 dB PA gain, 3 dB signal gain X
20 kHz HP filter, 1500 kHz LP filter X
5 MHz SR, 4096 points, 1024 pretrigger X
Test sensors and record file name:
Comments:

VIII: Post test
Review data and backup files on CD X
Record actual impact parameters:
  Projectile velocity:
  Impact coordinates:
  Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 109: Ag-1 Shot #12 Impact Waveform

Figure 110: Ag-1 Shot #12 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 6/1/04 Specimen ID: Ag-1
   Test number: Ag1-13 Projectile size: 2 mm/45deg.
   Planned velocity: 6.8 km/s
   Planned impact coordinates: (7.25, 7.25)

II. Prebonding sensor tests performed: N/A
    (Only for first test in series or when replacing or rebonding sensors between tests, otherwise indicate N/A)
    Comments:

III. Record sensor serial number and coordinates:

   Sensor 1: S/N 101146  Sensor 2: S/N 190014
   Sensor 3: S/N 190015  Sensor 4: S/N 190016
   Sensor 5: S/N 190017  Sensor 6: S/N 1099011
   Sensor 7: S/N 190019  Sensor 8: S/N 190020

   Sensor 1: (29, 29)  Sensor 2: (17.25, 29.5)
   Sensor 3: (21.5, 27)  Sensor 4: (13, 29)
   Sensor 5: (29, 11.75)  Sensor 6: (21, 15.5)
   Sensor 7: (13, 9.5)  Sensor 8: (5, 9.5)

IV. Pretest sensor check:
    Verify settings:
    SCM trigger source:  X
    20 dB PA gain, 3 dB signal gain: X
    20 kHz HP filter, 1500 kHz LP filter: X
    5 MHz SR, 4096 points, 1024 pretrigger: X
    Test sensors and record file name: Ag1-13 6-1-04 Pretest LB
    Comments: .

V. Switch to external (gun) trigger source and complete pretest trigger check:  X

VI. Impact test:
    Verify settings:
    External (gun) trigger source: X
    20 kHz HP filter, 1500 kHz LP filter: X
    2 MHz SR, 32 K points, 4096 pretrigger: X
    8 channel recording mode: X
    Data acquisition in record mode: X
    (DWC logo spinning)
    Record and verify gain settings:
Sensor 1: Attenuators: 0_______ Preamp: 20_______ SCM: 12_______
Sensor 2: Attenuators: 0_______ Preamp: 20_______ SCM: 12_______
Sensor 3: Attenuators: 0_______ Preamp: 20_______ SCM: 12_______
Sensor 4: Attenuators: 0_______ Preamp: 20_______ SCM: 12_______
Sensor 5: Attenuators: 0_______ Preamp: 20_______ SCM: 12_______
Sensor 6: Attenuators: 0_______ Preamp: 20_______ SCM: 12_______
Sensor 7: Attenuators: 0_______ Preamp: 20_______ SCM: 12_______
Sensor 8: Attenuators: 0_______ Preamp: 20_______ SCM: 12_______

Record file name: Ag1-13 6-1-04 Impact

VII. Post test sensor check:
Verify settings:
20 dB PA gain, 3 dB signal gain X
20 kHz HP filter, 1500 kHz LP filter X
5 MHz SR, 4096 points, 1024 pretrigger X
Test sensors and record file name:
Comments:

VIII. Post test
Review data and backup files on CD  X
Record actual impact parameters:
  Projectile velocity:
  Impact coordinates:
  Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 111: Ag-1 Shot #13 Impact Waveform

Figure 112: Ag-1 Shot #13 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 6/03/04
   Specimen ID: Ag-1
   Test number: Ag1-14
   Projectile size: 2.0mm/30deg.
   Planned velocity: 6.8 km/s
   Planned impact coordinates: (16, 07)

II. Prebonding sensor tests performed: N/A
    (Only for first test in series or when replacing or rebonding sensors between tests, otherwise indicate N/A)
    Comments:

III. Record sensor serial number and coordinates:

   Sensor 1: S/N 101146
   Sensor 2: S/N 190014
   Sensor 3: S/N 190015
   Sensor 4: S/N 190016
   Sensor 5: S/N 190017
   Sensor 6: S/N 1099011
   Sensor 7: S/N 190019
   Sensor 8: S/N 190020

   Sensor 1: (29, 29)
   Sensor 2: (17.25, 29.5)
   Sensor 3: (21.5, 27)
   Sensor 4: (13, 29)
   Sensor 5: (29, 11.75)
   Sensor 6: (21, 15.5)
   Sensor 7: (13, 9.5)
   Sensor 8: (5, 9.5)

IV. Pretest sensor check:
    Verify settings:
    SCM trigger source: X
    20 dB PA gain, 3 dB signal gain: X
    20 kHz HP filter, 1500 kHz LP filter: X
    5 MHz SR, 4096 points, 1024 pretrigger: X
    Test sensors and record file name: Ag1-14 6-03-04 Pretest LB
    Comments: Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check: X

VI. Impact test:
    Verify settings:
    External (gun) trigger source: X
    20 kHz HP filter, 1500 kHz LP filter: X
    2 MHz SR, 32 K points, 4096 pretrigger: X
    8 channel recording mode: X
    Data acquisition in record mode: X
    (DWC logo spinning)
    Record and verify gain settings:
Sensor 1:  Attenuators: 0_______ Preamp:  20____ SCM: 12___
Sensor 2:  Attenuators: 0_______ Preamp:  20____ SCM: 12___
Sensor 3:  Attenuators: 0_______ Preamp:  20____ SCM: 12___
Sensor 4:  Attenuators: 0_______ Preamp:  20____ SCM: 12___
Sensor 5:  Attenuators: 0_______ Preamp:  20____ SCM: 12___
Sensor 6:  Attenuators: 0_______ Preamp:  20____ SCM: 12___
Sensor 7:  Attenuators: 0_______ Preamp:  20____ SCM: 12___
Sensor 8:  Attenuators: 0_______ Preamp:  20____ SCM: 12___

Record file name:  Ag1-14  6-03-04 Impact
Comments: Impact on event 6. Ch-8 slightly clipped. Otherwise, data

O.K.

VII. Post test sensor check:
Verify settings:
20 dB PA gain, 3 dB signal gain      X
20 kHz HP filter, 1500 kHz LP filter X
5 MHz SR, 4096 points, 1024 pretrigger X
Test sensors and record file name:
Comments:

VIII. Post test
Review data and backup files on CD  X
Record actual impact parameters:
  Projectile velocity: 6.79 km/s.
  Impact coordinates:
  Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 113: Ag-1 Shot #14 Impact Waveform

Figure 114: Ag-1 Shot #14 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 6/7/04  Specimen ID:  Ag-1  
   Test number:  Ag1-15  Projectile size:  2.2 mm/30deg.  
   Planned velocity:  6.8 km/s  
   Planned impact coordinates:  (10.8, 30)

II. Prebonding sensor tests performed:  N/A  
   (Only for first test in series or when replacing or rebonding sensors  
    between tests, otherwise indicate N/A)  
   Comments:

III. Record sensor serial number and coordinates:
   Sensor 1:  S/N  101146  
   Sensor 3:  S/N  190015  
   Sensor 5:  S/N  190017  
   Sensor 7:  S/N  190019  
   Sensor 2:  S/N  190014  
   Sensor 4:  S/N  190016  
   Sensor 6:  S/N  1099011  
   Sensor 8:  S/N  190020  
   Sensor 1:  (29, 29)  
   Sensor 3:  (21, 27)  
   Sensor 5:  (29, 11.75)  
   Sensor 7:  (13, 9.5)  
   Sensor 2:  (17.25, 29.5)  
   Sensor 4:  (13, 29)  
   Sensor 6:  (21, 15.5)  
   Sensor 8:  (5, 9.5)  

IV. Pretest sensor check:
   Verify settings:
   SCM trigger source:  X  
   20 dB PA gain, 3 dB signal gain:  X  
   20 kHz HP filter, 1500 kHz LP filter:  X  
   5 MHz SR, 4096 points, 1024 pretrigger:  X  
   Test sensors and record file name:  Ag1-15 6-7-04 Pretest LB  
   Comments: Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check:  X

VI. Impact test:
   Verify settings:
   External (gun) trigger source:  X  
   20 kHz HP filter, 1500 kHz LP filter:  X  
   2 MHz SR, 32 K points, 4096 pretrigger:  X  
   8 channel recording mode:  X  
   Data acquisition in record mode:  X  
   (DWC logo spinning)  
   Record and verify gain settings:
Sensor 1: Attenuators: 0 Preamp: 20 SCM: 12
Sensor 2: Attenuators: 0 Preamp: 20 SCM: 12
Sensor 3: Attenuators: 0 Preamp: 20 SCM: 12
Sensor 4: Attenuators: 0 Preamp: 20 SCM: 12
Sensor 5: Attenuators: 0 Preamp: 20 SCM: 12
Sensor 6: Attenuators: 0 Preamp: 20 SCM: 12
Sensor 7: Attenuators: 0 Preamp: 20 SCM: 12
Sensor 8: Attenuators: 0 Preamp: 20 SCM: 12

Record file name: Ag1-15 6-7-04 Impact
Comments: Because the impact point was very close to sensor #4, reduced gain. Impact on event #5. Unexpected clipping on ch-5 (gain settings correct). Otherwise, data O.K.

VII. Post test sensor check:
Verify settings:
20 dB PA gain, 3 dB signal gain X
20 kHz HP filter, 1500 kHz LP filter X
5 MHz SR, 4096 points, 1024 pretrigger X
Test sensors and record file name:
Comments:

VIII: Post test
Review data and backup files on CD X
Record actual impact parameters:
Projectile velocity: 6.92 km/s.
Impact coordinates:
Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 115: Ag-1 Shot #15 Impact Waveform

Figure 116: Ag-1 Shot #15 Impact Damage
AE Test Data/Checklist

I. Record pretest information:
   Test date: 6/7/04  Specimen ID: Ag-1
   Test number: Ag1-16  Projectile size: 2.4 mm/30deg.
   Planned velocity: 6.8 km/s
   Planned impact coordinates: (4.2, 27.7)

II. Prebonding sensor tests performed: N/A
   (Only for first test in series or when replacing or rebonding sensors between tests, otherwise indicate N/A)
   Comments:

III. Record sensor serial number and coordinates:
   Sensor 1: S/N 101146  Sensor 2: S/N 190014
   Sensor 3: S/N 190015  Sensor 4: S/N 190016
   Sensor 5: S/N 190017  Sensor 6: S/N 1099011
   Sensor 7: S/N 190019  Sensor 8: S/N 190020
   Sensor 1: (29, 29)  Sensor 2: (17.25, 29.5)
   Sensor 3: (21.5, 27)  Sensor 4: (13, 29)
   Sensor 5: (29, 11.75)  Sensor 6: (21, 15.5)
   Sensor 7: (13, 9.5)  Sensor 8: (5, 9.5)

IV. Pretest sensor check:
   Verify settings:
   SCM trigger source: X
   20 dB PA gain, 3 dB signal gain: X
   20 kHz HP filter, 1500 kHz LP filter: X
   5 MHz SR, 4096 points, 1024 pretrigger: X
   Test sensors and record file name: Ag1-16 6-7-04 Pretest LB
   Comments: Sensors O.K.

V. Switch to external (gun) trigger source and complete pretest trigger check: X

VI. Impact test:
   Verify settings:
   External (gun) trigger source: X
   20 kHz HP filter, 1500 kHz LP filter: X
   2 MHz SR, 32 K points, 4096 pretrigger: X
   8 channel recording mode: X
   Data acquisition in record mode: X
   (DWC logo spinning)
   Record and verify gain settings:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Sensor 1: Attenuators: 0_______ Preamp: 20____ SCM: 6____
Sensor 2: Attenuators: 0_______ Preamp: 20____ SCM: 6____
Sensor 3: Attenuators: 0_______ Preamp: 20____ SCM: 6____
Sensor 4: Attenuators: 0_______ Preamp: 20____ SCM: 6____
Sensor 5: Attenuators: 0_______ Preamp: 20____ SCM: 6____
Sensor 6: Attenuators: 0_______ Preamp: 20____ SCM: 6____
Sensor 7: Attenuators: 0_______ Preamp: 20____ SCM: 6____
Sensor 8: Attenuators: 0_______ Preamp: 20____ SCM: 6____

Record file name: Ag1-16 6-7-04 Impact
Comments: Impact on event 5. Data O.K.

VII. Post test sensor check:
Verify settings:
20 dB PA gain, 3 dB signal gain [X]
20 kHz HP filter, 1500 kHz LP filter [X]
5 MHz SR, 4096 points, 1024 pretrigger [X]
Test sensors and record file name:
Comments:

VIII: Post test
Review data and backup files on CD [X]
Record actual impact parameters:
Projectile velocity: 6.86 km/s.
Impact coordinates:
Damage description and comments:
Tile Targets A-1, Ag-1, B-1, and Bg-1

Figure 117: Ag-1 Shot #16 Impact Waveform

Figure 118: Ag-1 Shot #16 Impact Damage
During 2003 and 2004, the Johnson Space Center's White Sands Testing Facility in Las Cruces, New Mexico conducted hypervelocity impact tests on the space shuttle wing leading edge. Hypervelocity impact tests were conducted to determine if Micro-Meteoroid/Orbital Debris impacts could be reliably detected and located using simple passive ultrasonic methods. The objective of Targets A-1, Ag-1, B-1, and Bg-1 was to study hypervelocity impacts on the reinforced Shuttle Heat Shield Tiles of the Wing. Impact damage was detected using lightweight, low power instrumentation capable of being used in flight.