NASA/CR-2007-214885/VOL8

Hypervelocity Impact (HVI)

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

Michael R. Gorman and Steven M. Ziola
Digital Wave Corporation, Englewood, Colorado

September 2007

The NASA STI Program Office . . . in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the lead center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA counterpart of peer-reviewed formal professional papers, but having less stringent limitations on manuscript length and extent of graphic presentations.

- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.

- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.

- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or co-sponsored by NASA.

- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.

- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized databases, organizing and publishing research results ... even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at ***http://www.sti.nasa.gov***

- E-mail your question via the Internet to help@sti.nasa.gov

- Fax your question to the NASA STI Help Desk at (301) 621-0134

- Phone the NASA STI Help Desk at (301) 621-0390

- Write to:
  NASA STI Help Desk
  NASA Center for AeroSpace Information
  7115 Standard Drive
  Hanover, MD 21076-1320

NASA/CR-2007-214885/VOL8

Hypervelocity Impact (HVI)

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

Michael R. Gorman and Steven M. Ziola
Digital Wave Corporation, Englewood, Colorado

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23681-2199

Prepared for Langley Research Center
under Contract NNL05AC19T

September 2007

The use of trademarks or names of manufacturers in this report is for accurate reporting and does not constitute an official endorsement, either expressed or implied, of such products or manufacturers by the National Aeronautics and Space Administration.

Available from:

NASA Center for AeroSpace Information (CASI)
7115 Standard Drive
Hanover, MD 21076-1320
(301) 621-0390

National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161-2171
(703) 605-6000

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.

Table of Contents

List of Figures

List of Tables

Hypervelocity Impact (HVI)
Volume 8: Tile Small Targets A-1, Ag-1, B-1, and Bg-1

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)

- 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 Al 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.

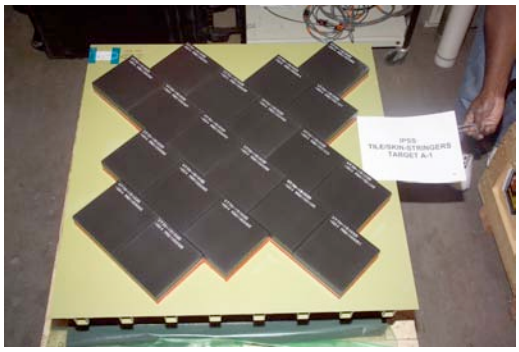

Figure 1: Tile Target A-1

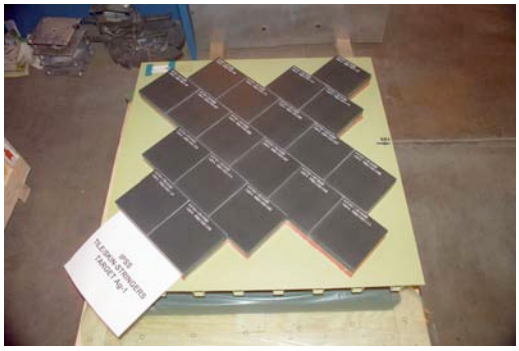

Figure 2: Tile Target Ag-1

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.

Figure 7: Fiberglass Panel Target Ag-1 with 30 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 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

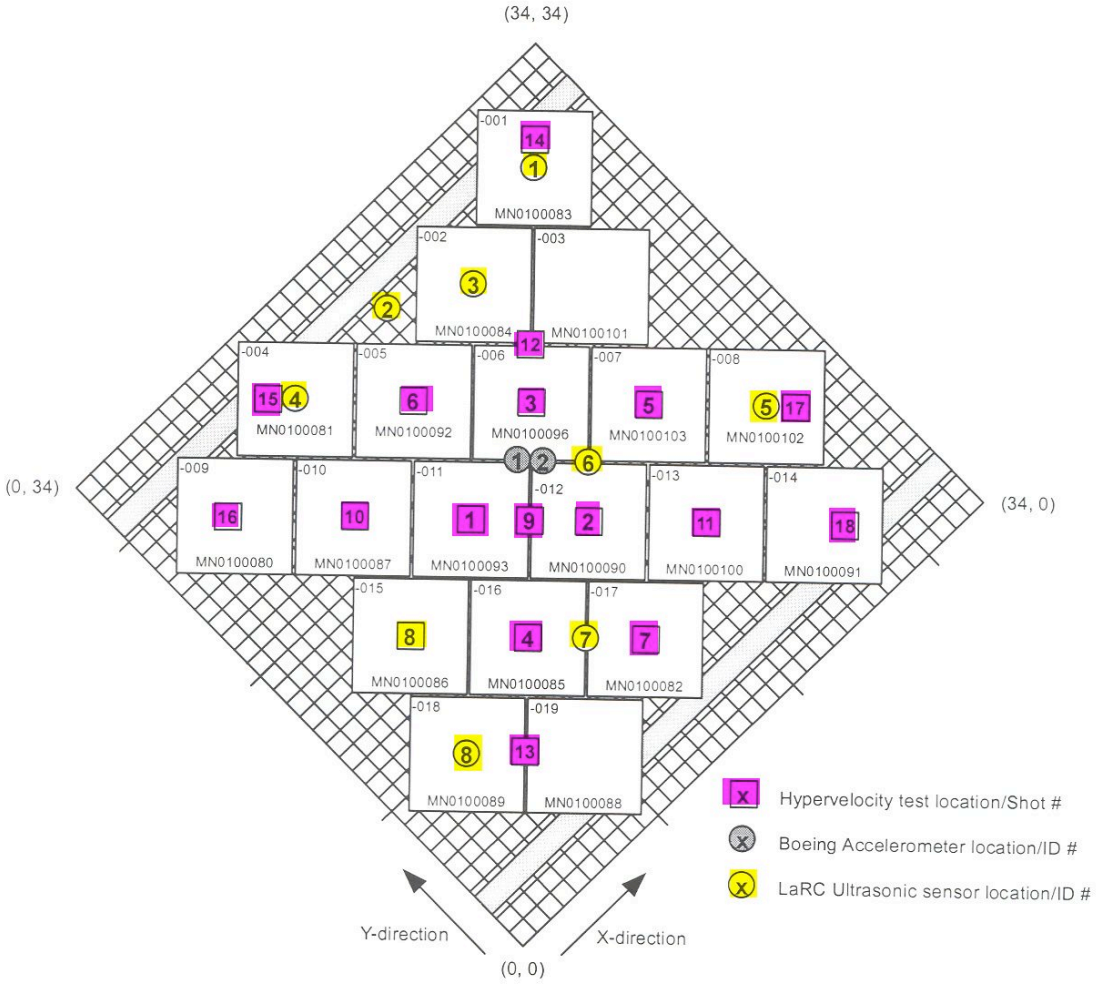

Figure 9: A-1 Diagram of Sensor and Impact Locations. Front View.

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.

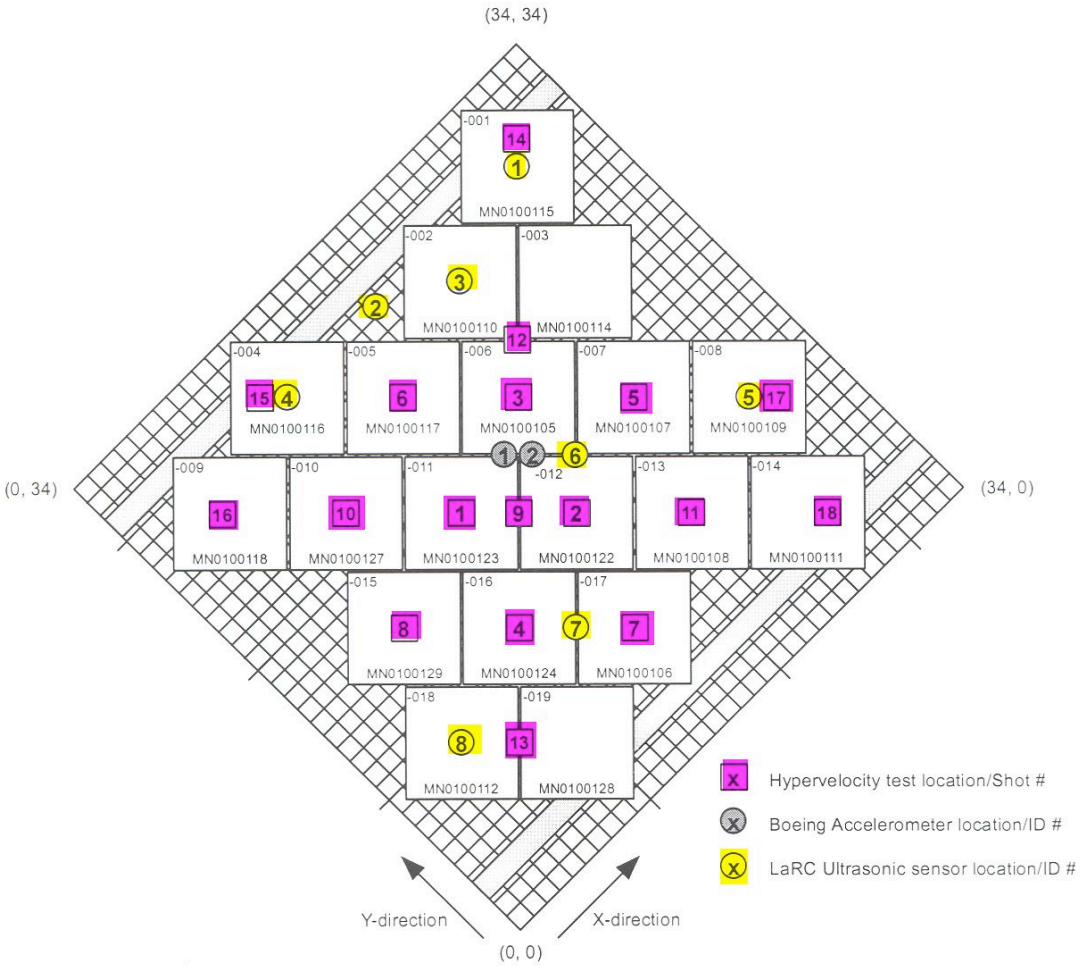

Figure 10: Ag-1 Diagram of Sensor and Impact Locations. Front View.

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.

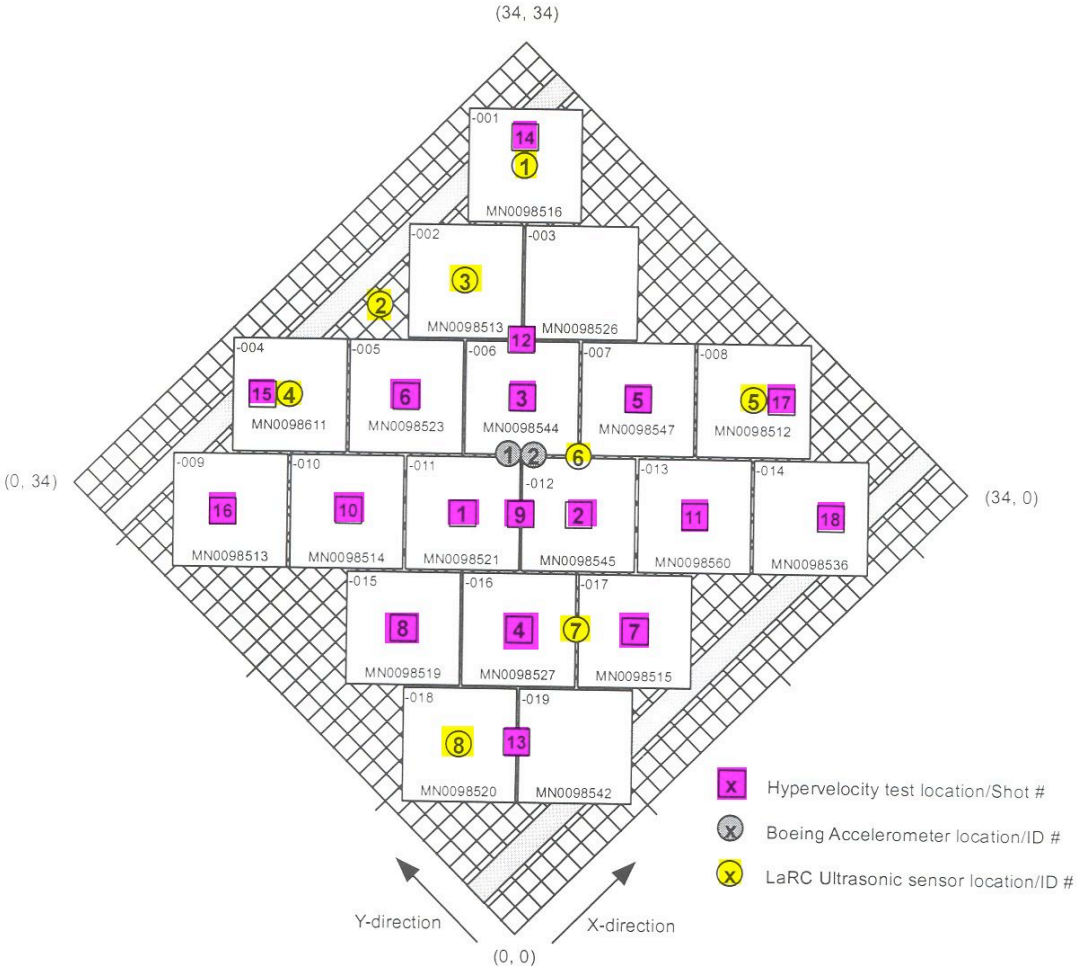

Figure 11: B-1 Diagram of Sensor and Impact Locations. Front View.

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.

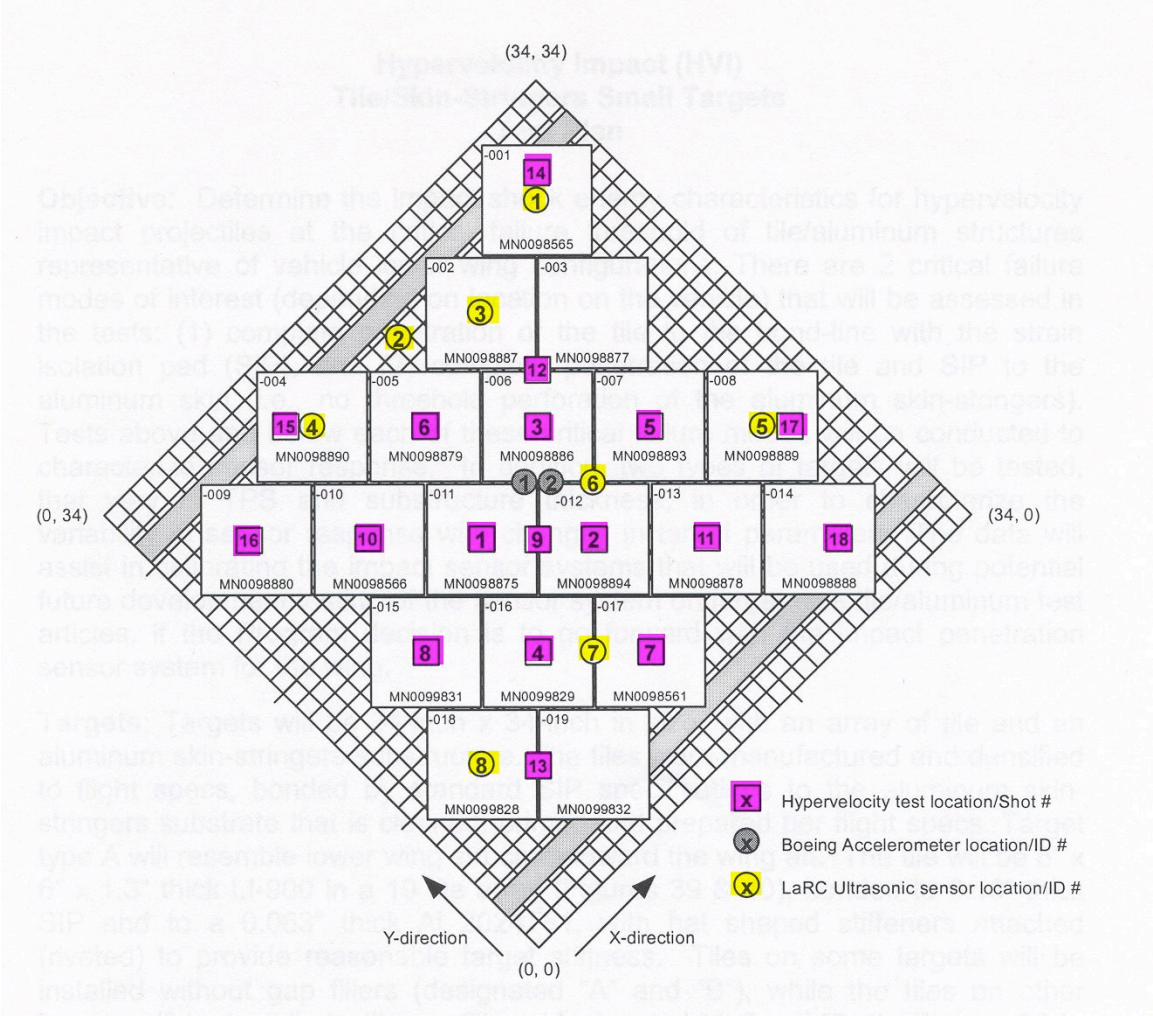

Figure 12: Bg-1 Diagram of Sensor and Impact Locations. Front View.

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.

Figure 13: A-1 Photo of Sensor Locations

Figure 14: Ag-1 Photo of Sensor Locations

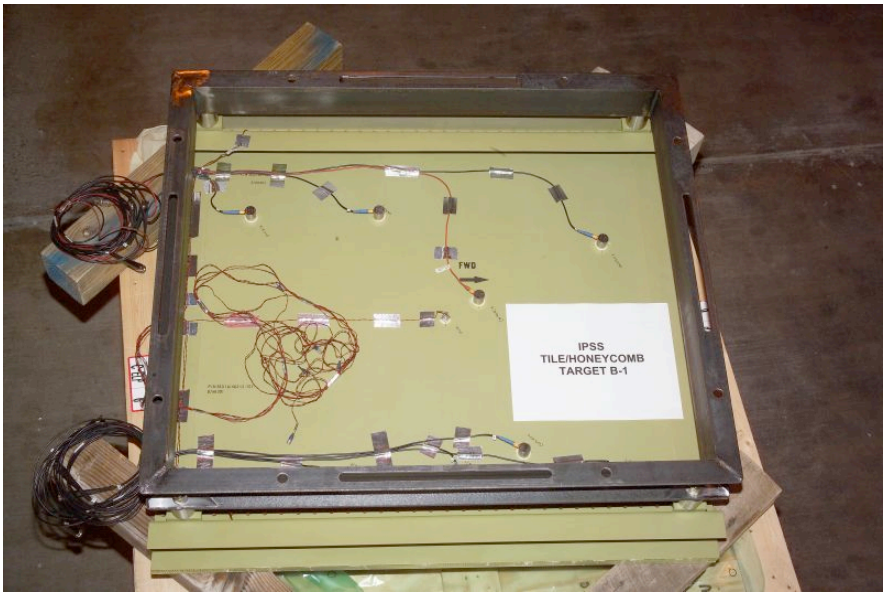

Figure 15: B-1 Photo of Sensor Locations

Figure 16: Bg-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.

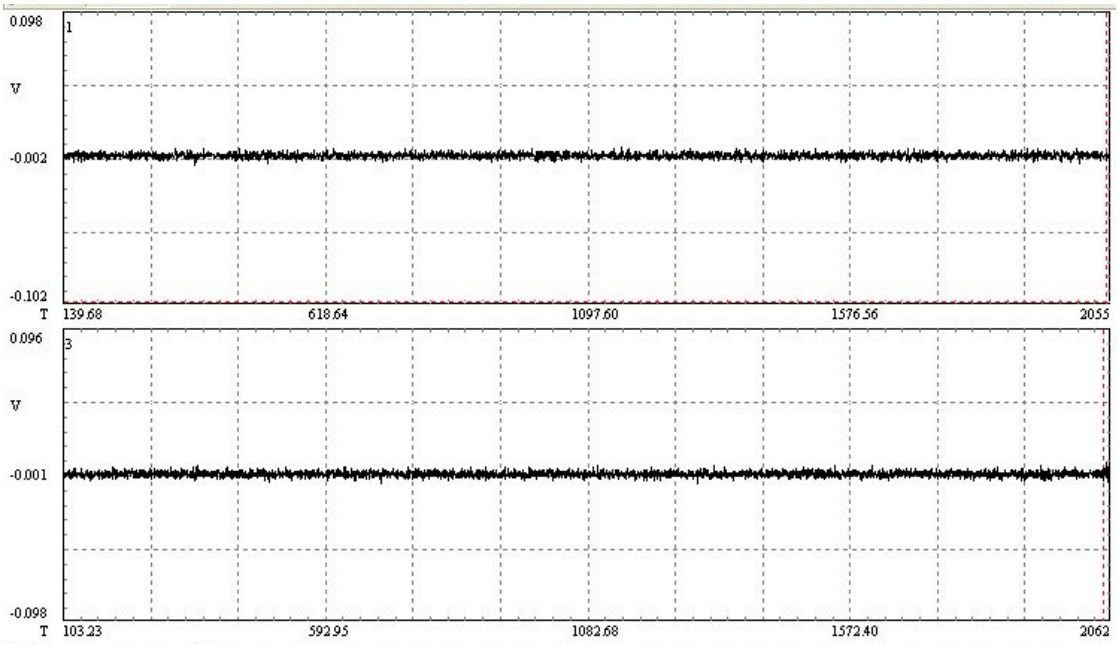

Figure 17: Example of DC Offset

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.

.

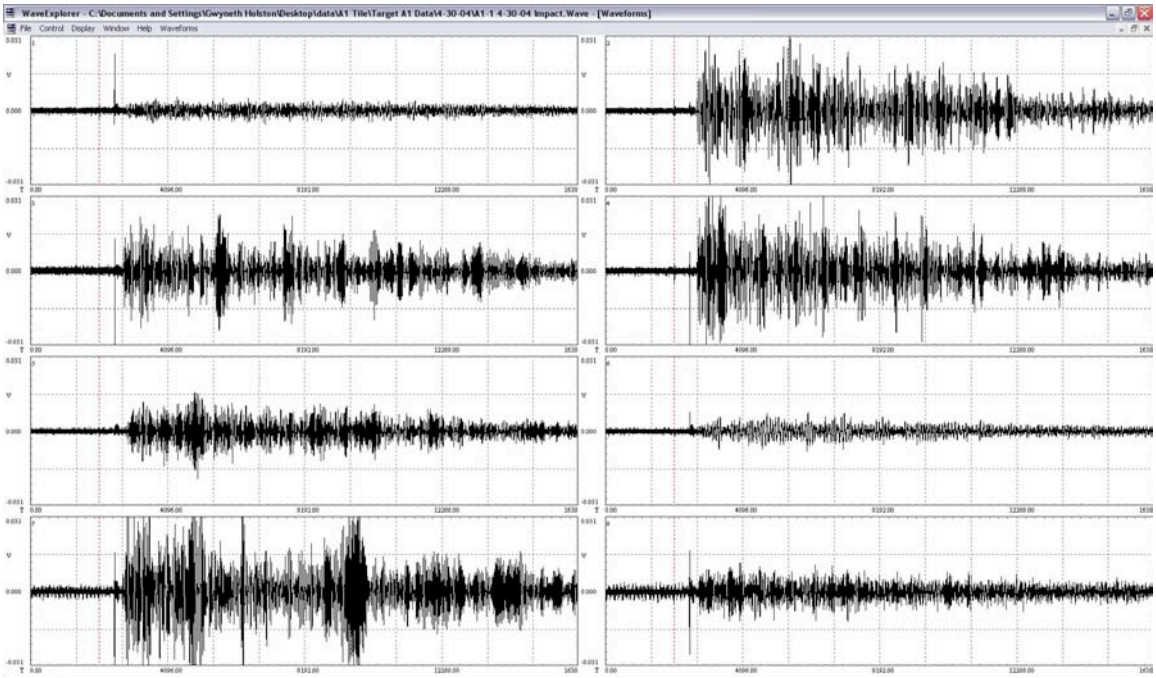

Figure 18: A-1 Impact Signal for Shot #1

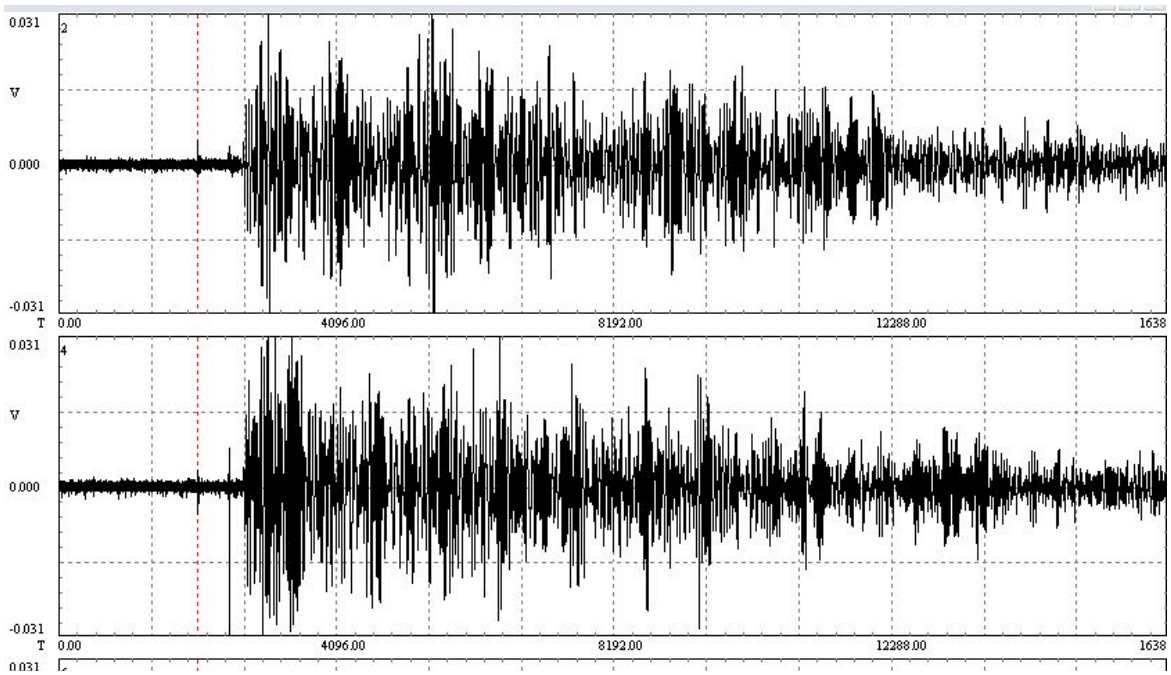

Figure 19: Detail of A-1 Impact Signal for Shot #1, Sensors 2 and 4

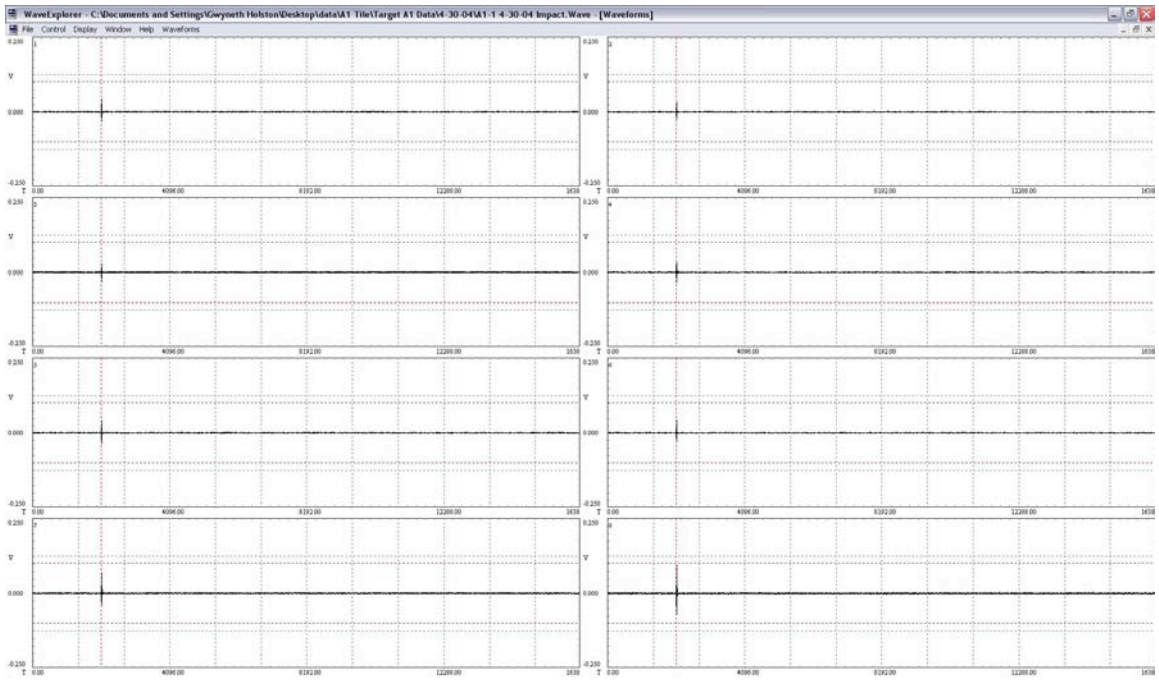

Figure 20: A-1 Electromagnetic Interference for Shot #1

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.

$$W.S.E. = \frac{E_{raw}}{G^2} \qquad \textbf{Equation 1}$$

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

$$\text{M dB} = 20\ \text{Log}_{10}\ (\text{G}) \qquad \textbf{Equation 2}$$

$$G = 10^{\frac{M}{20}} \qquad \textbf{Equation 3}$$

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 K.E. = 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.

Test	Imp Dia	Imp Ang	Total K.E.	Normal K.E.	W.S.E.
No.	mm	deg	J	J	nJ
A1-1	0.4	90	2.09	2.09	2.480E-04
A1-2b	0.6	90	7.06	7.06	2.660E-04
A1-3	1.0	90	32.69	32.69	2.459E-04
A1-4	1.4	90	89.69	89.69	1.580E-04
A1-5	1.6	90	133.88	133.88	6.261E-04
A1-6	1.8	90	190.62	190.62	1.139E-02
A1-7	2.0	45	261.48	130.64	9.778E-04
A1-8	2.2	45	348.03	173.88	6.047E-03
A1-9	2.0	45	261.48	130.64	1.762E-03
A1-10b	1.0	45	32.69	16.33	8.057E-05
A1-11	1.8	45	190.62	95.23	3.142E-04
A1-12	2.0	45	261.48	130.64	7.913E-02
A1-13	2.0	45	261.48	130.64	3.176E-01
A1-14	2.0	30	261.48	65.31	1.699E-02
A1-15	2.2	30	348.03	86.93	2.434E-02
A1-16	2.4	30	451.84	112.86	2.824E-02
A1-17	1.8	30	190.62	47.61	1.485E-02
A1-18	1.6	30	133.88	33.44	2.947E-03

Table 1: A-1 Kinetic Energy and Wave Signal Energy

Test	Imp Dia	Imp Ang	Total K.E.	Normal K.E.	W.S.E.
No.	mm	deg	J	J	nJ
Ag1-1	0.4	90	0.00	0.00	2.275E-04
Ag1-2c	0.6	90	7.02	7.02	1.893E-04
Ag1-3	1.0	90	32.59	32.59	7.941E-05
Ag1-4	1.4	90	88.64	88.64	1.203E-04
Ag1-5	1.6	90	133.09	133.09	5.472E-05
Ag1-6	1.8	90	173.64	173.64	3.373E-03
Ag1-7	2.0	45	258.41	129.10	8.770E-06
Ag1-8	2.2	45	328.85	164.30	3.538E-01
Ag1-9	2.0	45	273.14	136.46	3.195E-04
Ag1-10	1.0	45	33.46	16.72	5.652E-05
Ag1-11	1.8	45	195.13	97.49	1.605E-04
Ag1-12	2.0	45	265.34	132.56	1.986E-04
Ag1-13	2.0	45	281.06	140.42	1.088E-01
Ag1-14	2.0	30	260.71	65.12	1.198E-02
Ag1-15	2.2	30	360.42	90.02	2.184E-02
Ag1-16	2.4	30	450.51	112.52	2.093E-02
Ag1-17	1.8	30	188.38	47.05	8.456E-03
Ag1-18	1.6	30	133.88	33.44	5.518E-03

Table 2: Ag-1 Kinetic Energy and Wave Signal Energy

Test	Imp Dia	Imp Ang	Total K.E.	Normal K.E.	W.S.E.
No.	mm	deg	J	J	nJ
B1-1	1.0	90	30.14	30.14	2.870E-04
B1-2	1.6	90	114.19	114.19	4.671E-05
B1-3	2.8	90	717.50	717.50	2.733E-04
B1-4	3.2	90	1071.03	1071.02	9.890E-02
B1-5	3.6	90	1489.29	1489.28	9.408E-01
B1-6	4.0	90	2110.34	2110.34	1.861E+01
B1-7	4.0	45	2061.20	1029.78	2.001E+00
B1-8	4.8	45	3668.06	1832.57	2.223E+01
B1-9	3.6	45	1489.29	744.05	No data
B1-10	5.6	45	5622.46	2808.99	6.142E-01
B1-11	5.2	45	4464.17	2230.31	3.623E+01
B1-12	3.6	45	1516.00	757.40	2.659E-01
B1-13	3.6	45	1480.43	739.63	7.286E+01
B1-14	3.6	45	1275.91	637.45	4.637E-02
B1-15	4.8	30	3614.71	902.85	1.261E-01
B1-16	5.6	30	5689.49	1421.07	7.300E+00
B1-17	4.4	30	2958.87	739.04	9.330E-02
B1-18	4.0	30	2166.33	541.08	No data

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

Test	Imp Dia	Imp Ang	Total K.E.	Normal K.E.	W.S.E.
No.	mm	deg	J	J	nJ
Bg1-1	1.0	90	32.78	32.78	6.429E-04
Bg1-2	1.6	90	134.27	134.27	7.196E-04
Bg1-3	2.8	90	728.09	728.09	1.045E-02
Bg1-4	3.2	90	1055.33	1055.33	8.272E-01
Bg1-5c	3.6	90	1484.86	1484.86	2.413E+01
Bg1-6	4.0	90	2160.07	2160.07	8.430E-01
Bg1-7	4.0	45	2172.59	1085.43	5.214E+00
Bg1-8	4.8	45	3551.20	1774.19	3.344E+01
Bg1-9b	3.6	45	1484.86	741.84	No data
Bg1-10	5.6	45	5522.65	2759.13	1.997E+02
Bg1-11	5.2	45	4346.44	2171.49	3.191E+01
Bg1-12	3.6	45	1507.07	752.93	1.914E+01
Bg1-13	3.6	45	1529.44	764.11	1.306E-01
Bg1-14b	3.6	30	1579.25	394.45	2.753E-02
Bg1-15	4.8	30	3689.51	921.53	5.219E-01
Bg1-16	5.6	30	5706.31	1425.27	3.506E+00
Bg1-17	4.4	30	2841.87	709.81	6.352E-02
Bg1-18	4.0	30	2116.53	528.65	2.100E-02

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.

Test	Total K.E.	Normal K.E.	Crater Vol	Damage Area
No.	J (± 5%)	J (± 5%)	mm^3	mm^2
A1-1	2.09	2.09	15.3	4.6
A1-2b	7.06	7.06	45.4	10.9
A1-3	32.69	32.69	113.4	19.8
A1-4	89.69	89.69	83.9	25.0
A1-5	133.88	133.88	517.5	35.4
A1-6	190.62	190.62	688.5	39.7
A1-7	261.48	130.64	1622.4	61.5
A1-8	348.03	173.88	1917.0	74.5
A1-9	261.48	130.64	3510.0	936.0
A1-10b	32.69	16.33	62.4	18.7
A1-11	190.62	95.23	1153.2	59.3
A1-12	261.48	130.64	12880.0	980.5
A1-13	261.48	130.64	5796.0	375.0
A1-14	261.48	65.31	1641.5	
A1-15	348.03	86.93	3330.0	
A1-16	451.84	112.86	4300.0	
A1-17	190.62	47.61	1352.0	
A1-18	133.88	33.44	1209.0	

Table 5: A-1 Damage Results

No damage area was recorded for shots #14-18.

Test	Total K.E.	Normal K.E.	Crater Vol	Damage Area
No.	J (± 5%)	J (± 5%)	mm^3	mm^2
Ag1-1	0	0	12.96	5.06
Ag1-2c	7.018514	7.018509	55.08	10.56
Ag1-3	32.58904	32.58902	177.97	20.64
Ag1-4	88.63587	88.63582	378.84	26.5
Ag1-5	133.0918	133.0917	507.84	40.96
Ag1-6	173.6357	173.6356	751.68	40.26
Ag1-7	258.4136	129.1039	1412.46	46.8
Ag1-8	328.8539	164.296	1591.92	63.64
Ag1-9	273.144	136.4632	2660	594
Ag1-10	33.45869	16.71602	252.56	21.62
Ag1-11	195.1311	97.48784	1096.78	51.1
Ag1-12	265.3403	132.5645	5642	625
Ag1-13	281.0608	140.4185	9541	605
Ag1-14	260.7123	65.11816	1641.6	78.3
Ag1-15	360.4228	90.02286	2420.28	90.25
Ag1-16	450.5109	112.5242	7672	900
Ag1-17	188.3835	47.05258	1455.3	68
Ag1-18	133.8782	33.43877	740.08	39.6

Table 6: Ag-1 Damage Results

Test	Total K.E.	Normal K.E.	Crater Vol	Damage Area
No.	J (± 5%)	J (± 5%)	mm^3	mm^2
B1-1	30.14	30.14	158.4	No data
B1-2	114.19	114.19	687.5	No data
B1-3	717.50	717.50	1665.6	54.4
B1-4	1071.03	1071.02	3933.0	110.0
B1-5	1489.29	1489.28	5724.0	332.5
B1-6	2110.34	2110.34	8280.0	1053.0
B1-7	2061.20	1029.78	31284.0	4340.0
B1-8	3668.06	1832.57	50778.0	6232.0
B1-9	1489.29	744.05	95940.0	3782.0
B1-10	5622.46	2808.99	93000.0	5929.0
B1-11	4464.17	2230.31	62400.0	4118.0
B1-12	1516.00	757.40	80640.0	344.5
B1-13	1480.43	739.63	30100.0	1254.0
B1-14	1275.91	637.45	23205.0	1365.0
B1-15	3614.71	902.85	137514.0	6800.0
B1-16	5689.49	1421.07	36300.0	12644.0
B1-17	2958.87	739.04	93351.0	4977.0
B1-18	2166.33	541.08	41400.0	4350.0

Table 7: B-1 Damage Results

Test	Total K.E.	Normal K.E.	Crater Vol	Damage Area
No.	J (± 5%)	J (± 5%)	mm^3	mm^2
Bg1-1	32.78	32.78	168.8	25.0
Bg1-2	134.27	134.27	450.0	36.0
Bg1-3	728.09	728.09	3307.5	161.0
Bg1-4	1055.33	1055.33	3420.0	175.5
Bg1-5c	1484.86	1484.86	4657.5	377.0
Bg1-6	2160.07	2160.07	7500.0	3024.0
Bg1-7	2172.59	1085.43	20160.0	1480.0
Bg1-8	3551.20	1774.19	54400.0	5254.0
Bg1-9b	1484.86	741.84	40950.0	4675.0
Bg1-10	5522.65	2759.13	66240.0	8736.5
Bg1-11	4346.44	2171.49	70470.0	6552.0
Bg1-12	1507.07	752.93	58080.0	2750.0
Bg1-13	1529.44	764.11	24255.0	2120.0
Bg1-14b	1579.25	394.45	31584.0	3296.0
Bg1-15	3689.51	921.53	233200.0	5688.0
Bg1-16	5706.31	1425.27	304290.0	7644.0
Bg1-17	2841.87	709.81	95948.0	2912.0
Bg1-18	2116.53	528.65	47320.0	5159.0

Table 8: Bg-1 Damage Results

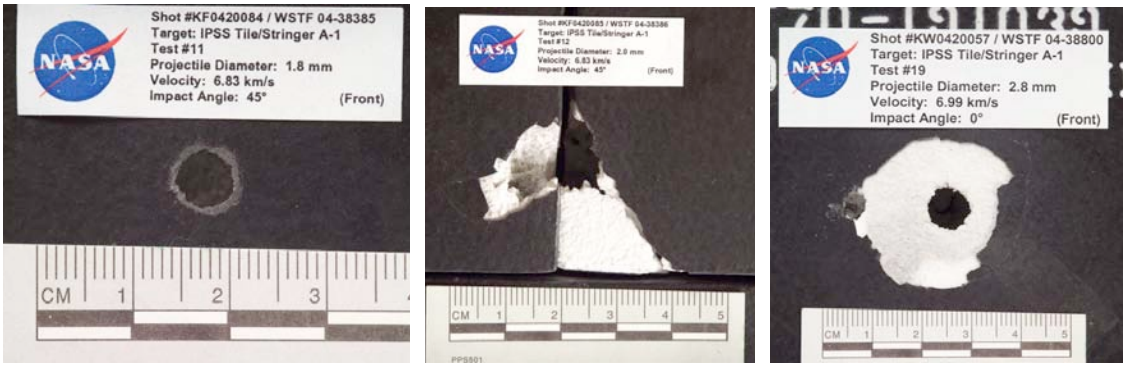

Figure 21: A-1 Impact Damage Area for (Left to Right) Shots #11, 12, and 19

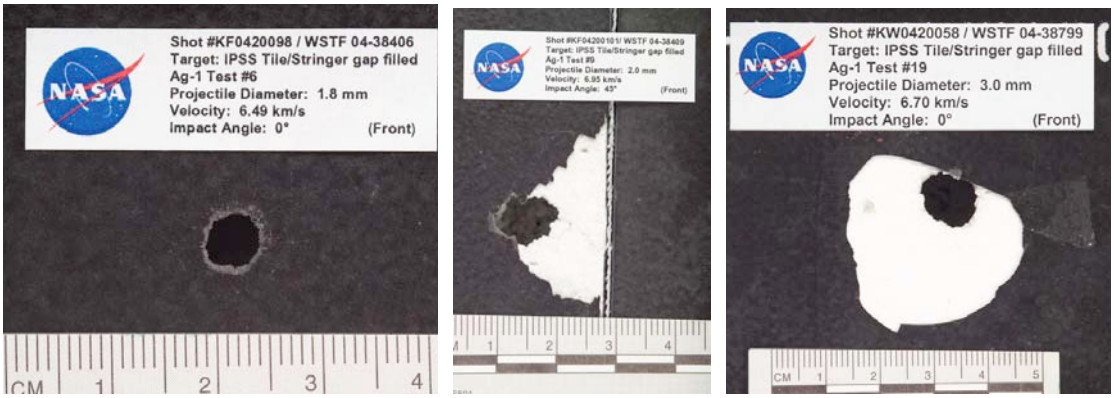

Figure 22: Ag-1 Impact Damage Area for (Left to Right) Shots #6, 9, and 19

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

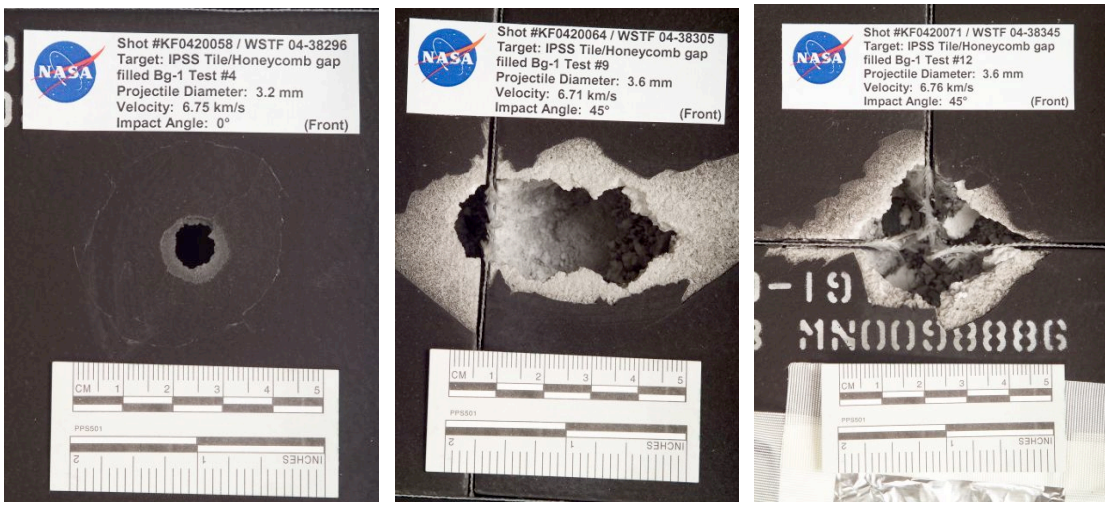

Figure 24: Bg-1 Impact Damage Area for (Left to Right) Shots #4, 9, and 12

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.

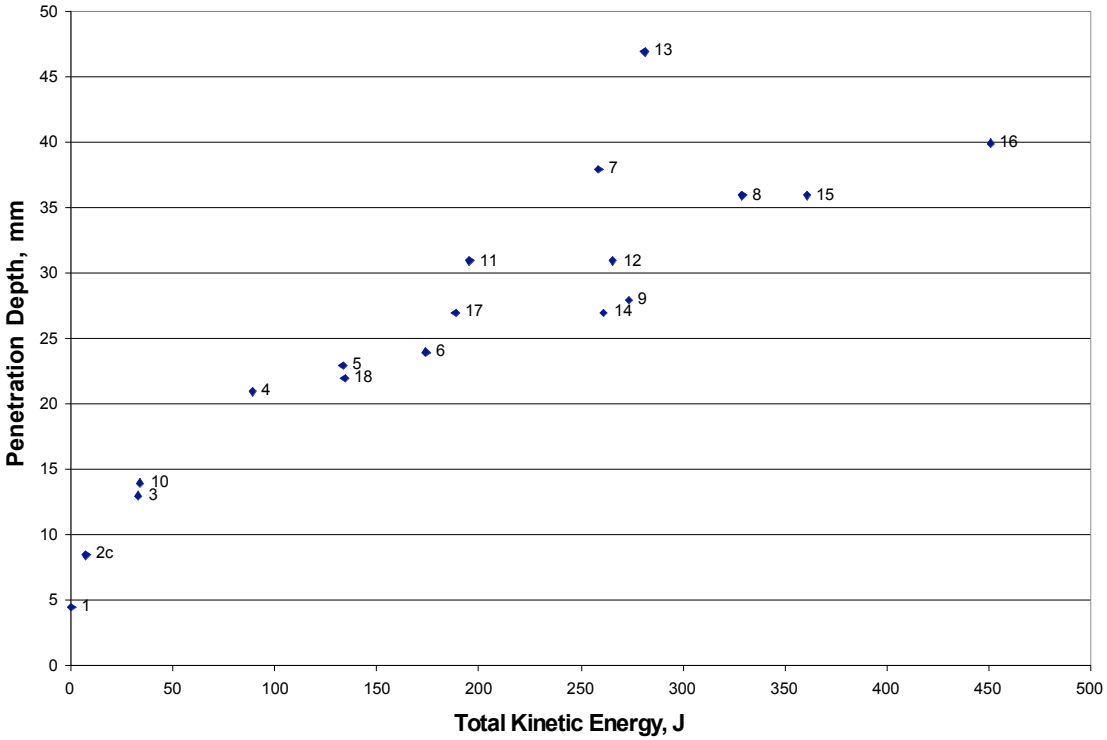

Figure 25: Penetration Depth vs. Total Kinetic Energy for Target Ag-1

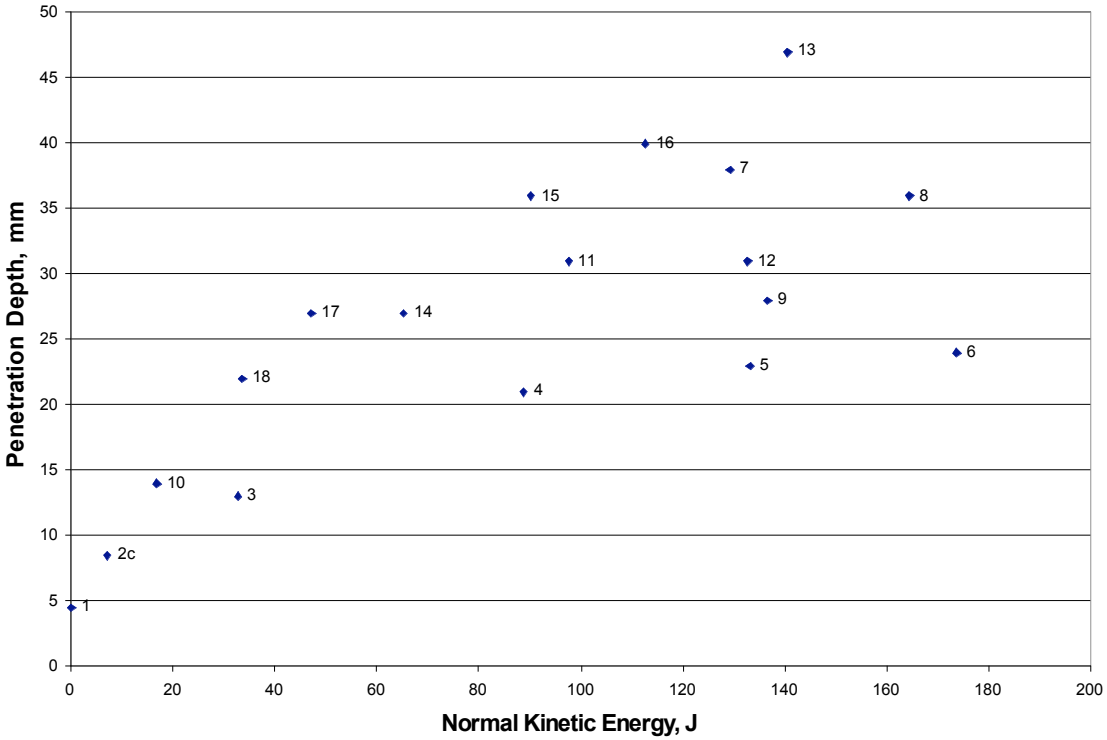

Figure 26: Penetration Depth vs. Normal Kinetic Energy for Target Ag-1

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.

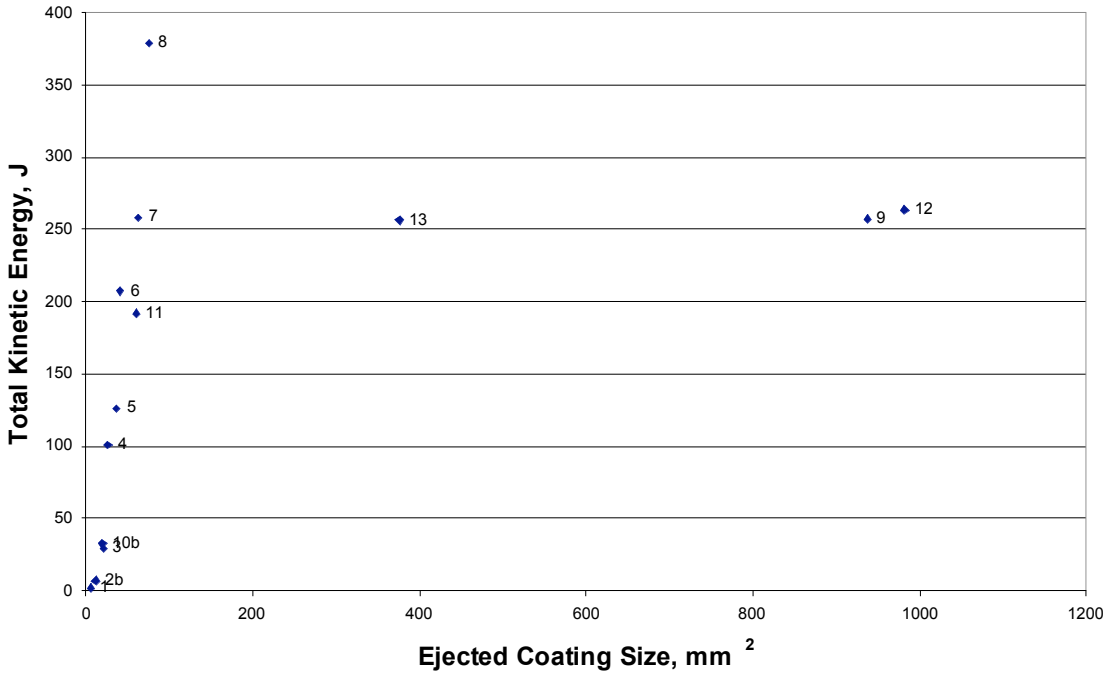

Figure 27: A-1 Total Kinetic Energy vs. Coating Area Damage

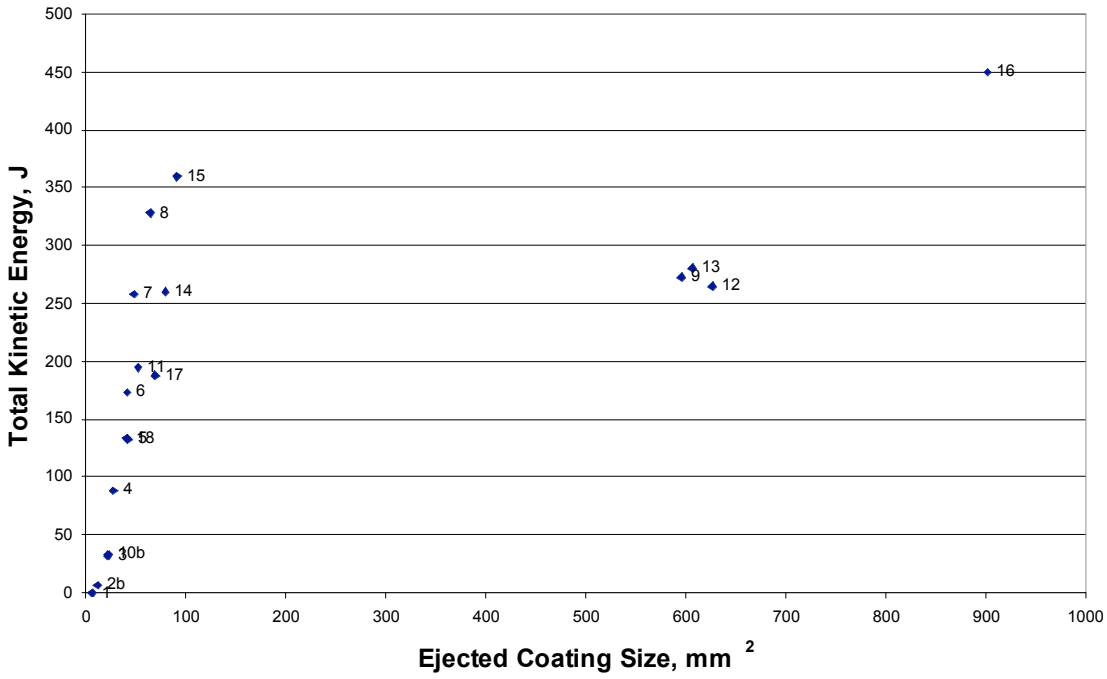

Figure 28: Ag-1 Total Kinetic Energy vs. Coating Area Damage

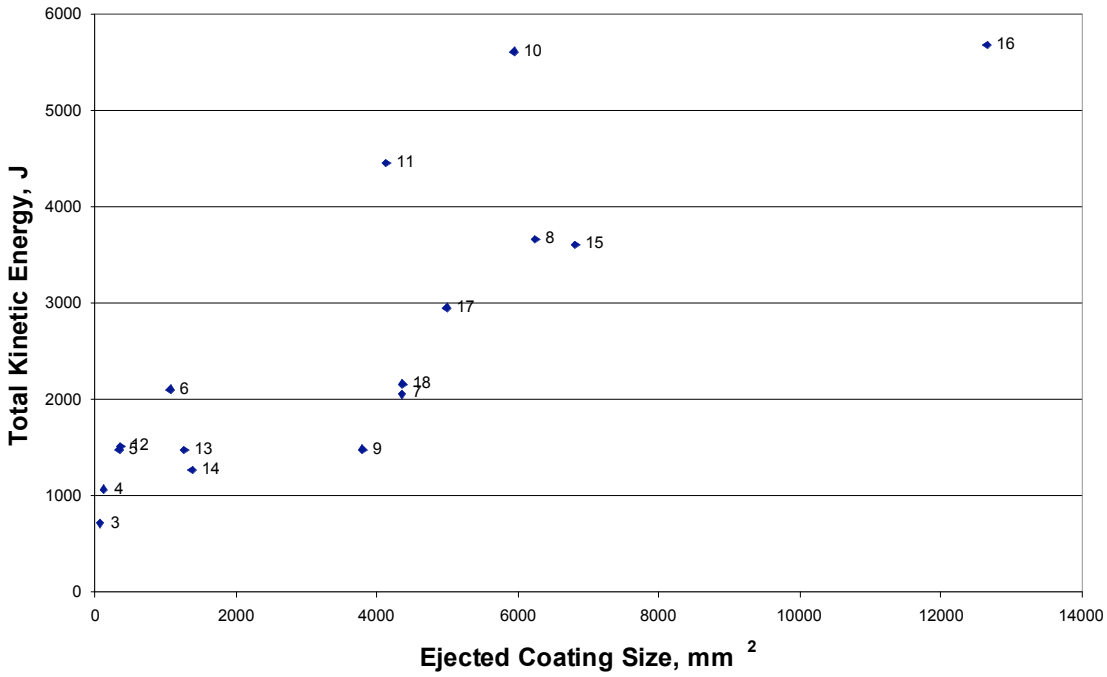

Figure 29: B-1 Total Kinetic Energy vs. Coating Area Damage

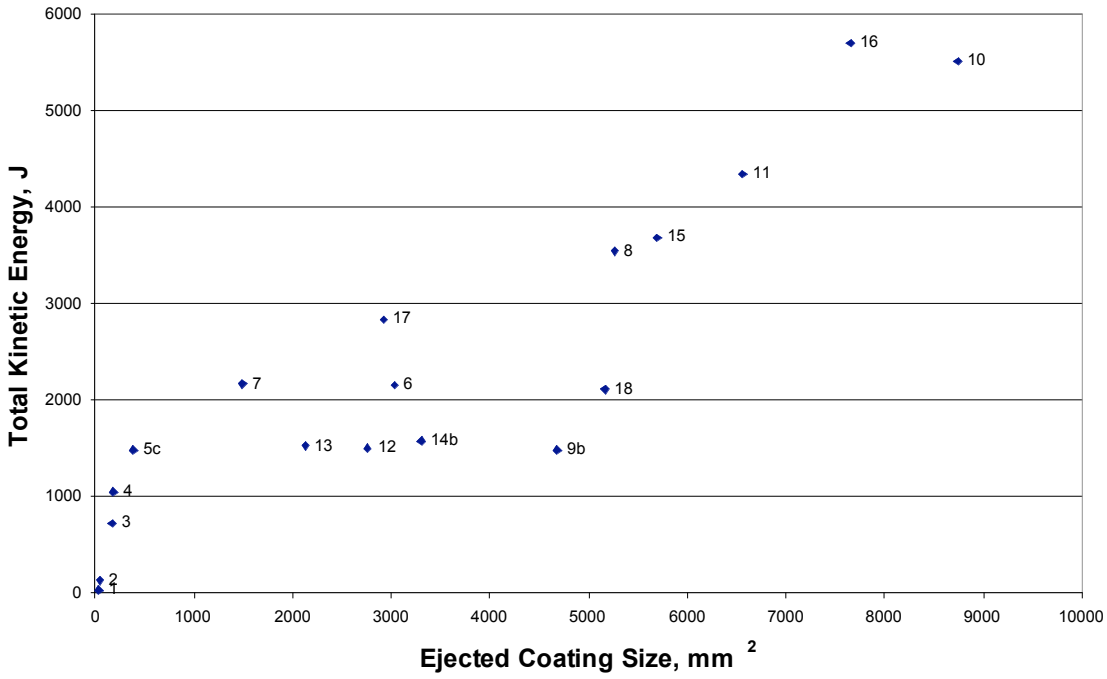

Figure 30: Bg-1 Total Kinetic Energy vs. Coating Area Damage

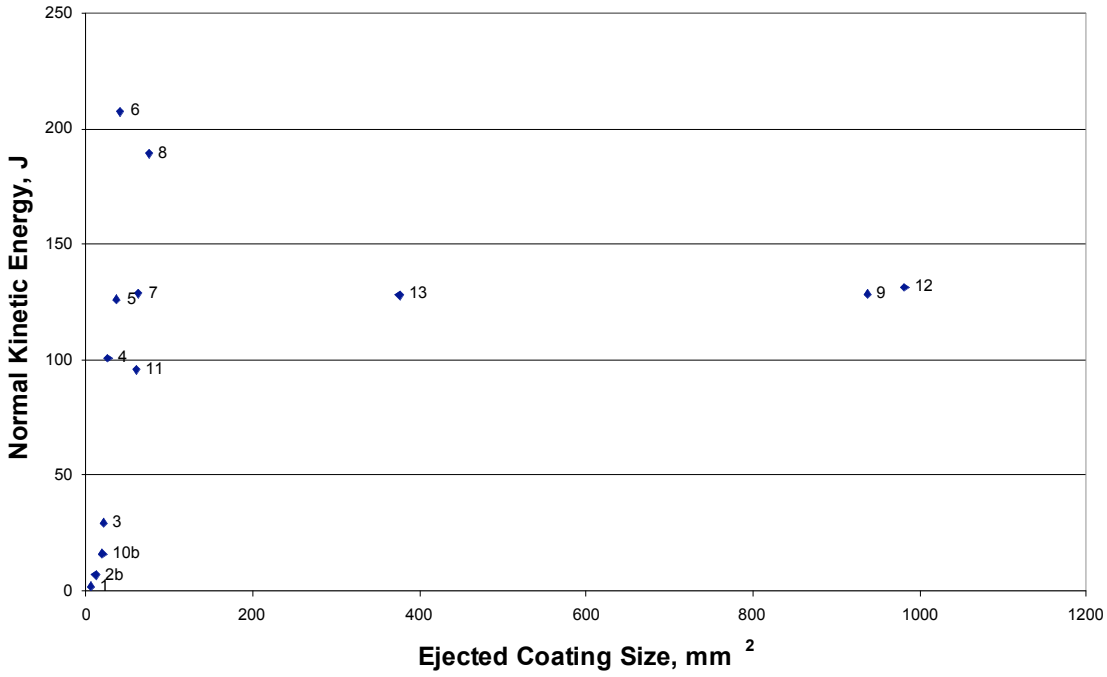

Figure 31: A-1 Normal Kinetic Energy vs. Coating Area Damage

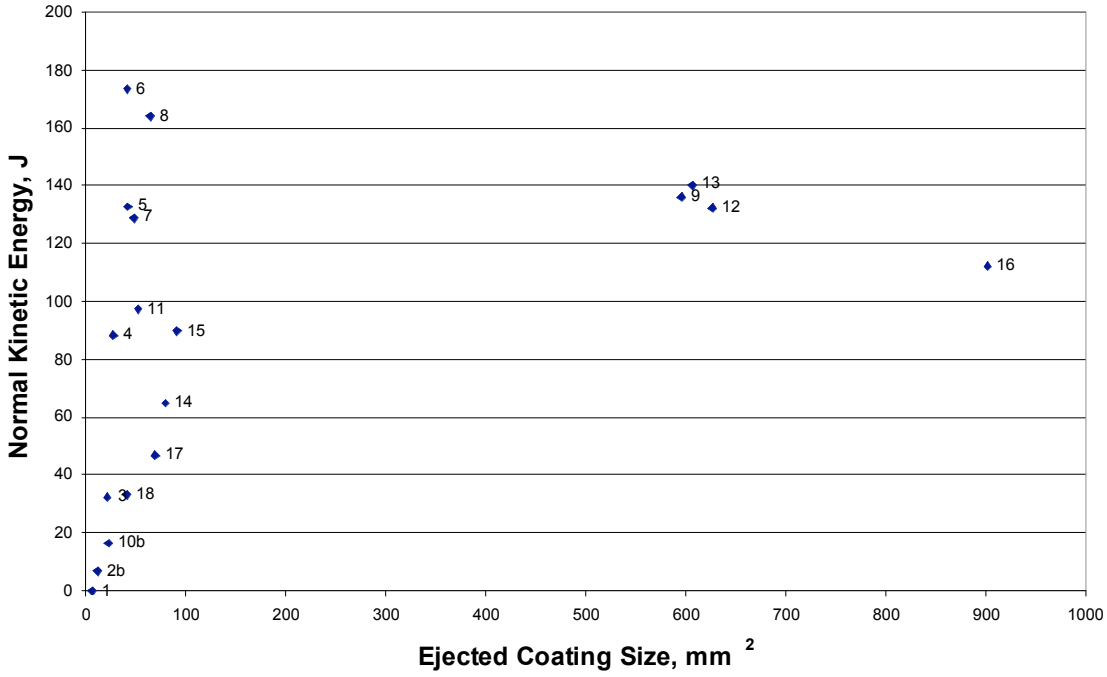

Figure 32: Ag-1 Normal Kinetic Energy vs. Coating Area Damage

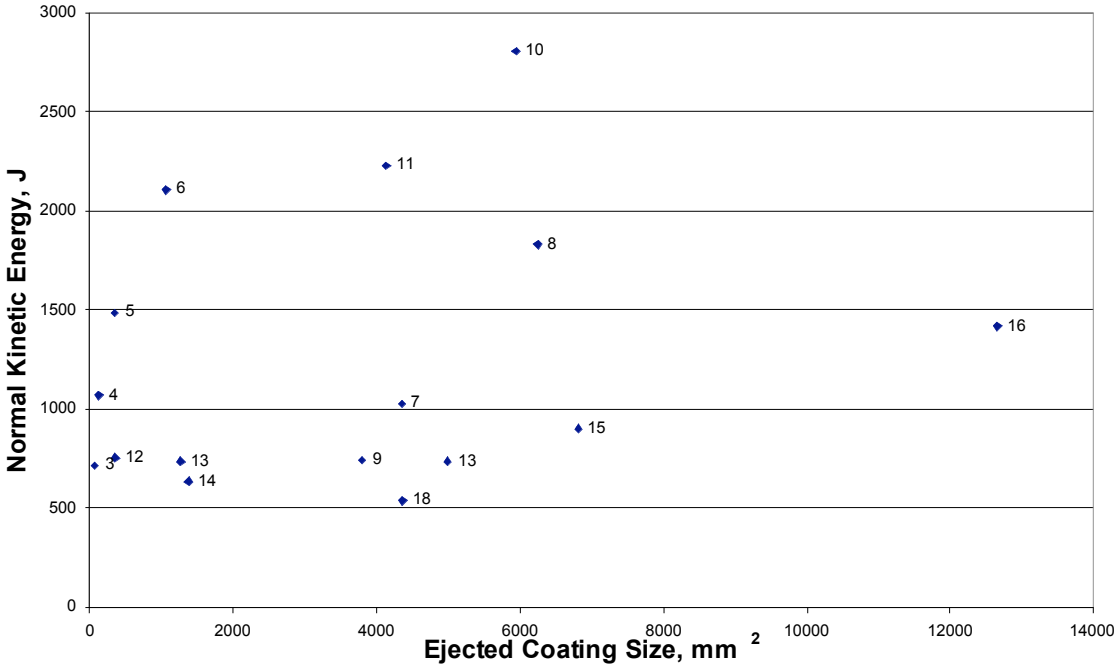

Figure 33: B-1 Normal Kinetic Energy vs. Coating Area Damage

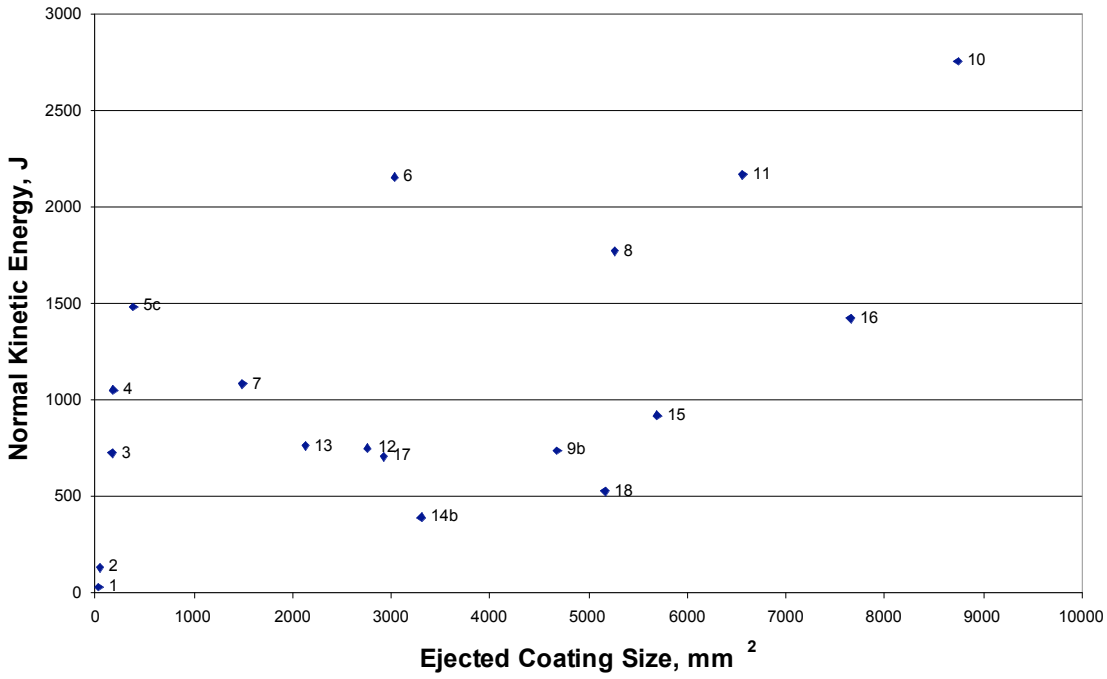

Figure 34: Bg-1 Normal Kinetic Energy vs. Coating Area Damage

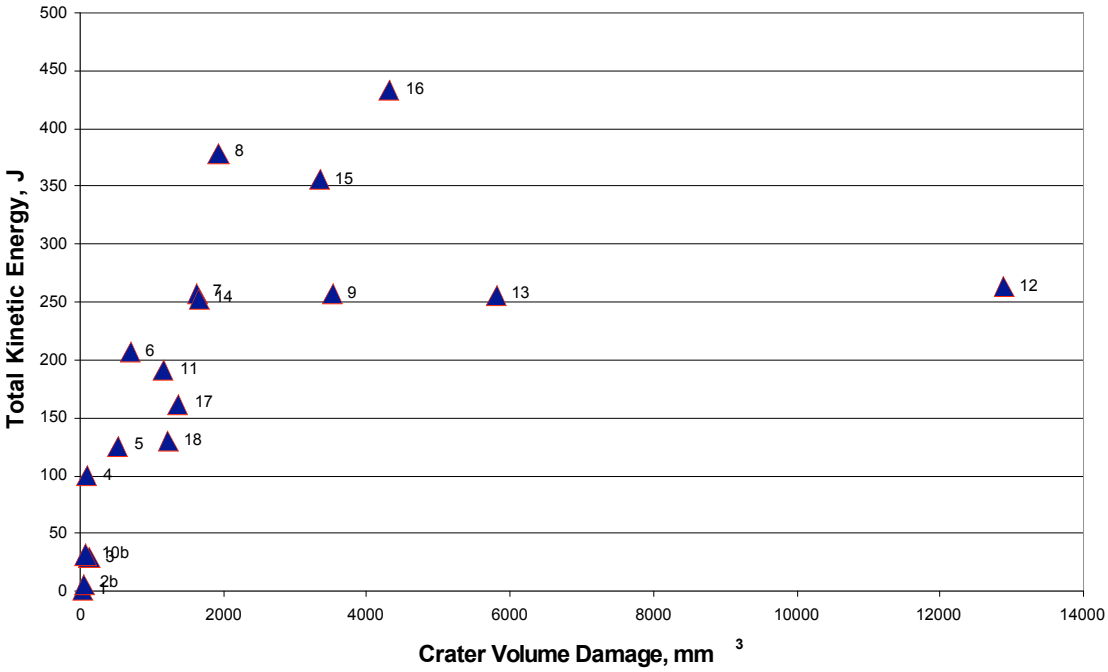

Figure 35: A-1 Total Kinetic Energy vs. Crater Volume Damage

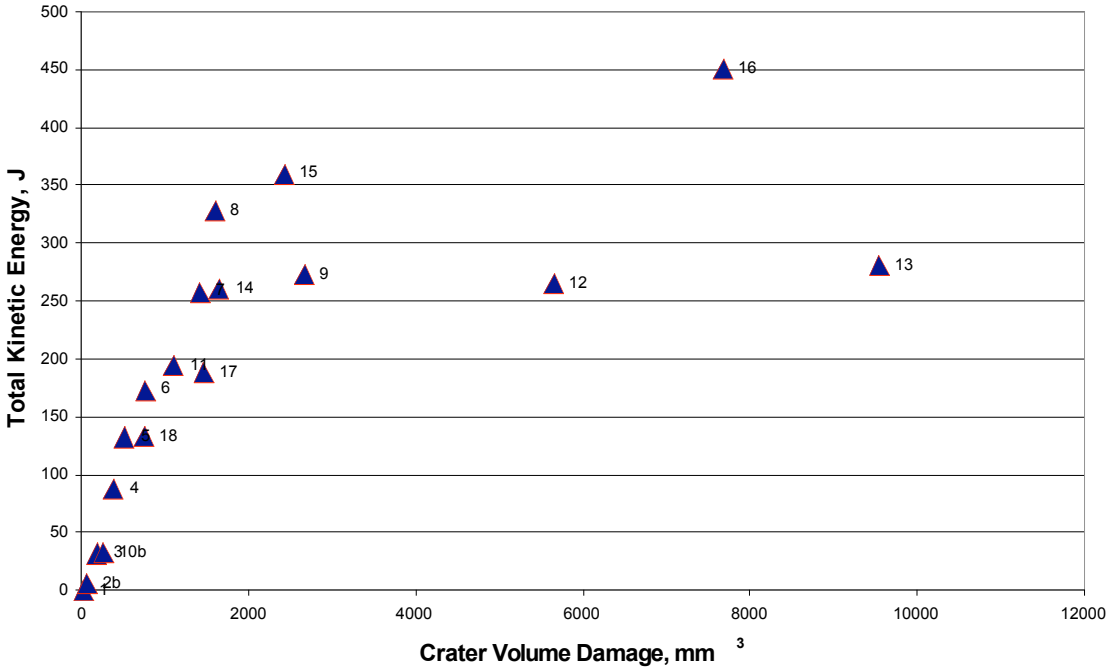

Figure 36: Ag-1 Total Kinetic Energy vs. Crater Volume Damage

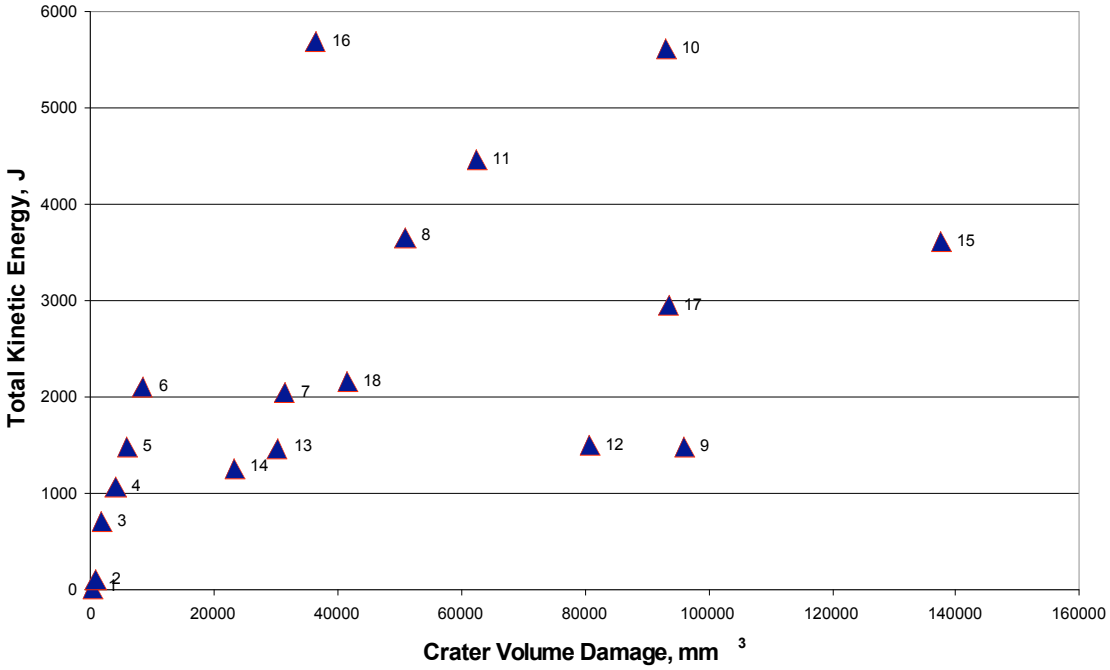

Figure 37: B-1 Total Kinetic Energy vs. Crater Volume Damage

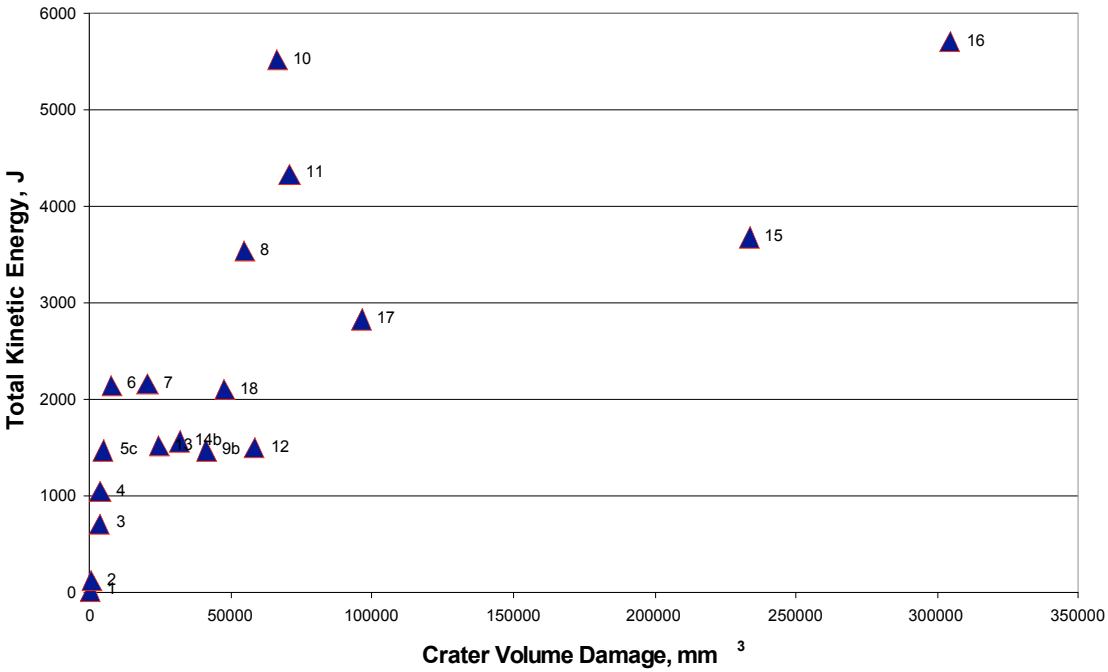

Figure 38: Bg-1 Total Kinetic Energy vs. Crater Volume Damage

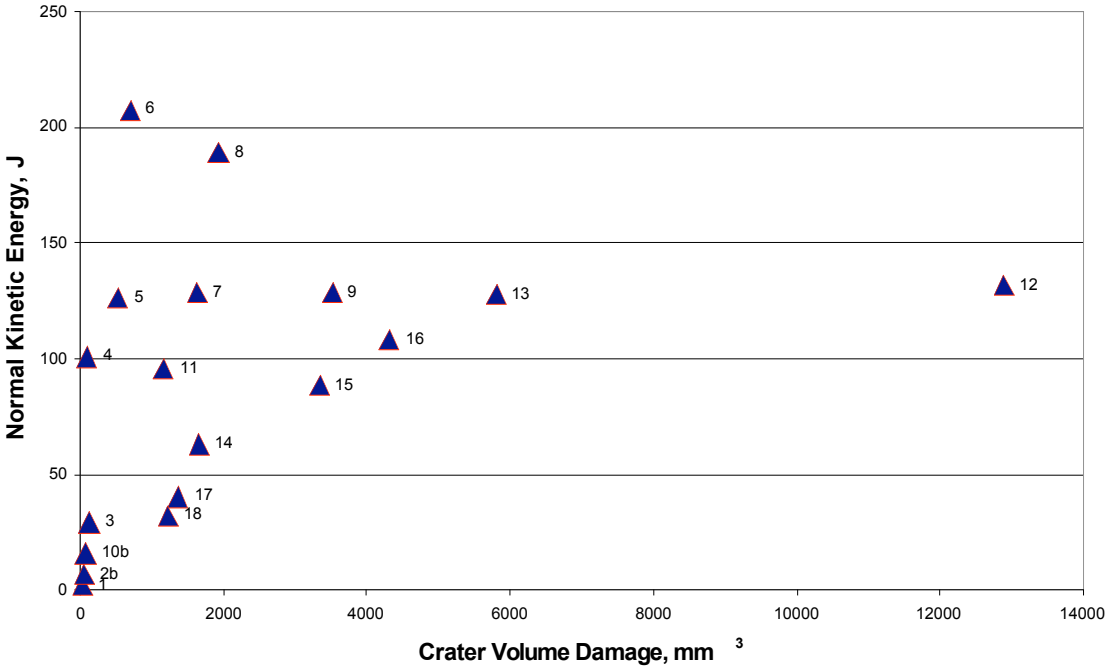

Figure 39: A-1 Normal Kinetic Energy vs. Crater Volume Damage

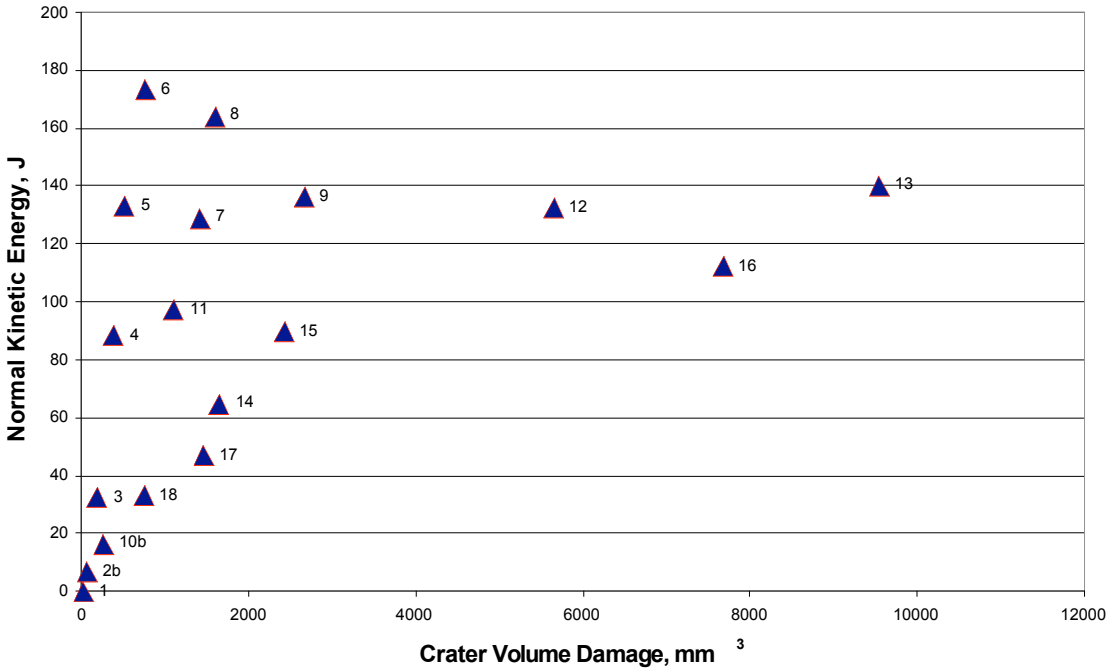

Figure 40: Ag-1 Normal Kinetic Energy vs. Crater Volume Damage

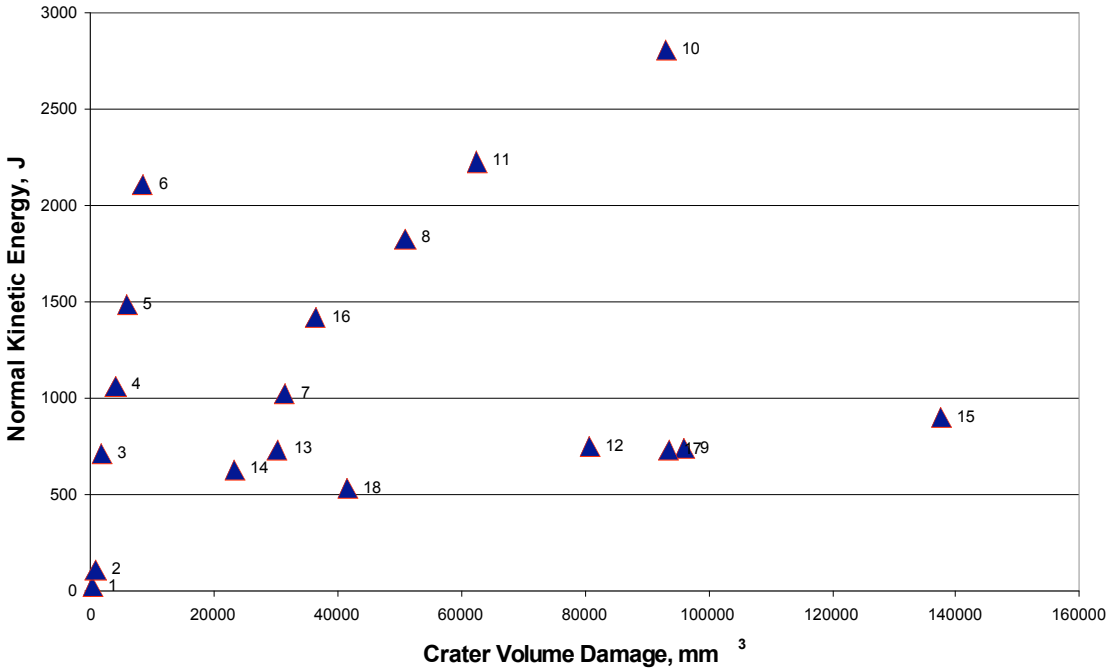

Figure 41: B-1 Normal Kinetic Energy vs. Crater Volume Damage

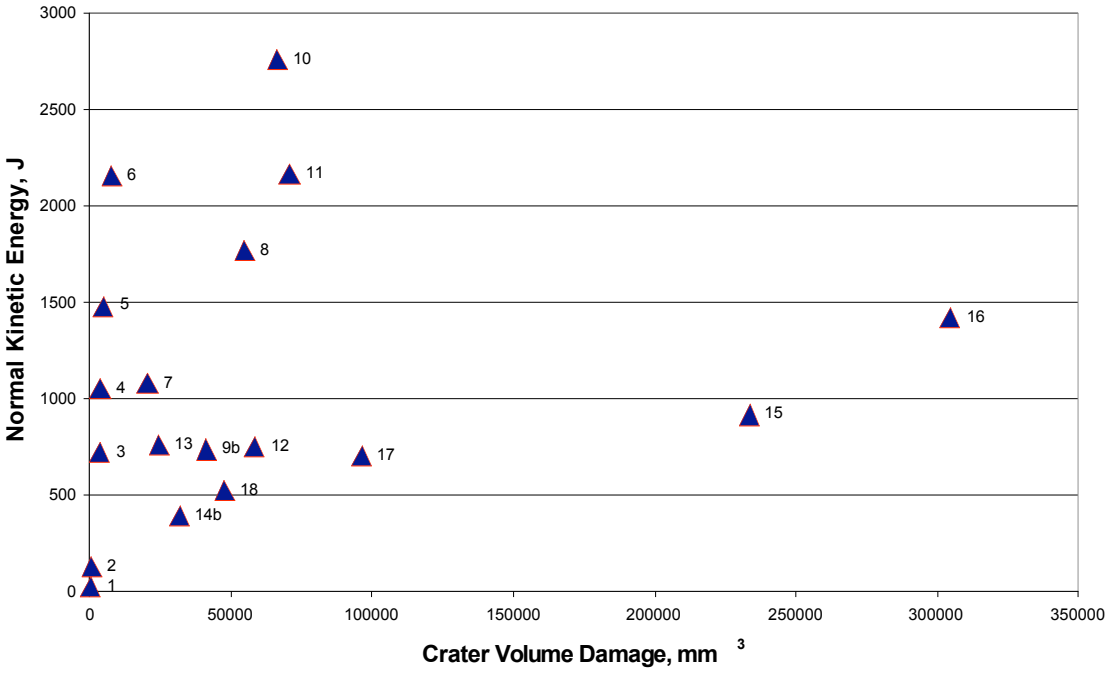

Figure 42: Bg-1 Normal Kinetic Energy vs. Crater Volume Damage

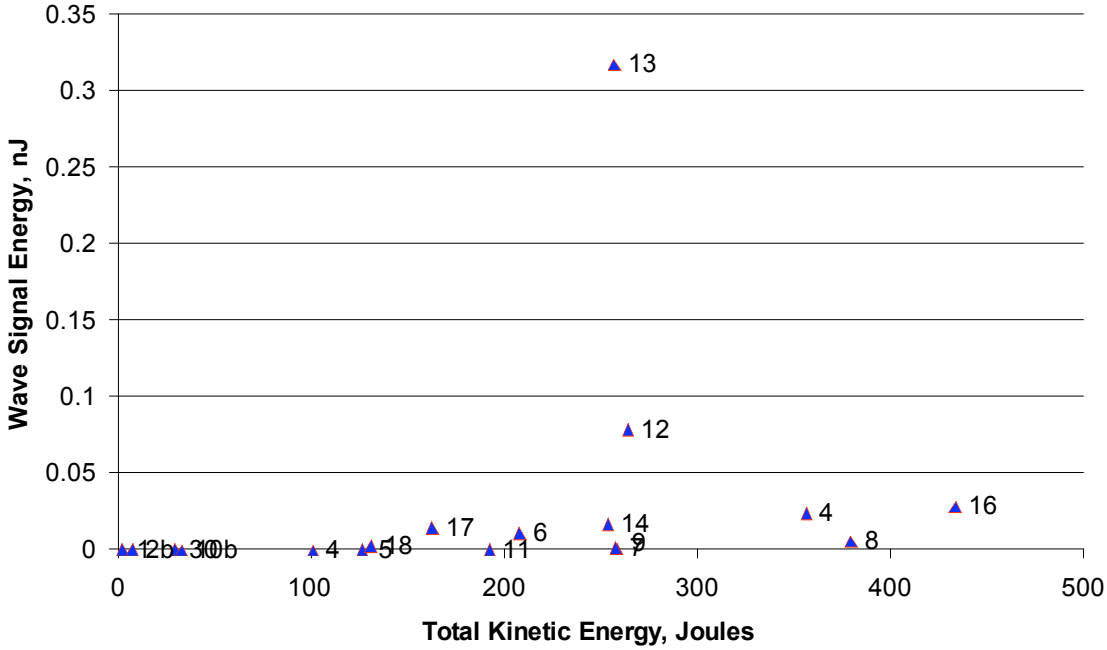

Figure 43: A-1 Wave Signal Energy vs. Total Kinetic Energy

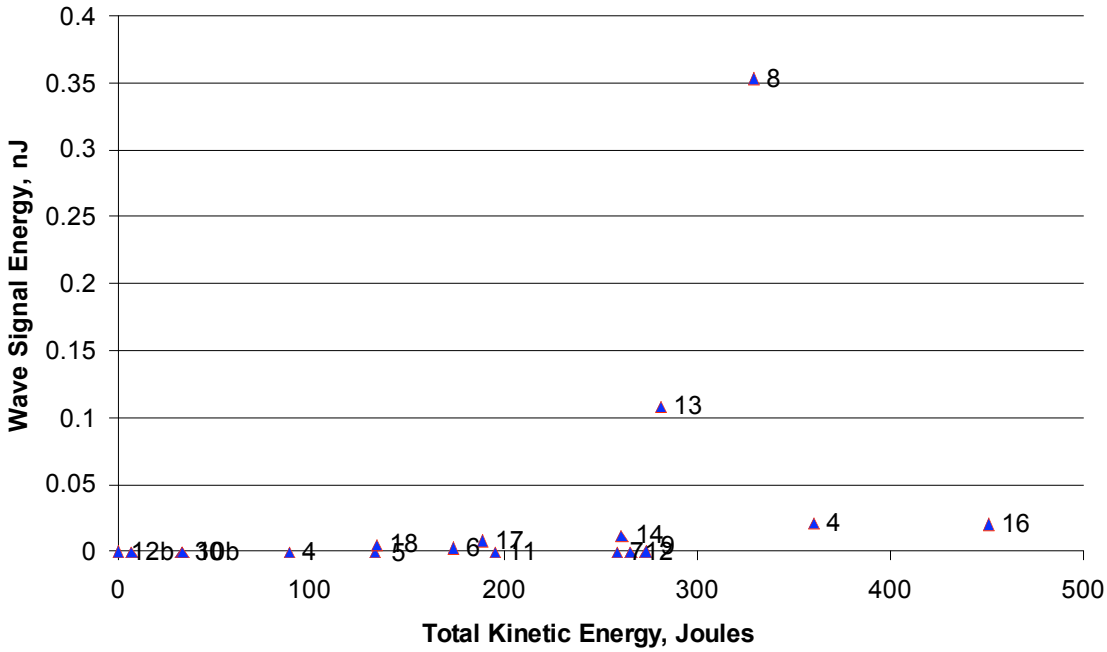

Figure 44: Ag-1 Wave Signal Energy vs. Total Kinetic Energy

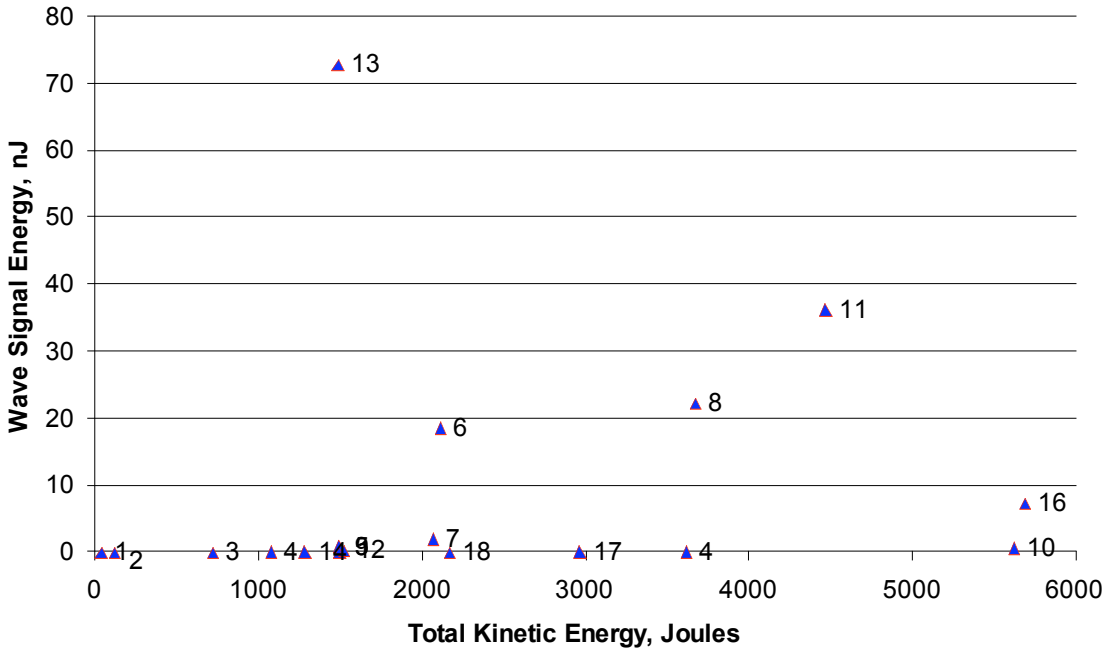

Figure 45: B-1 Wave Signal Energy vs. Total Kinetic Energy

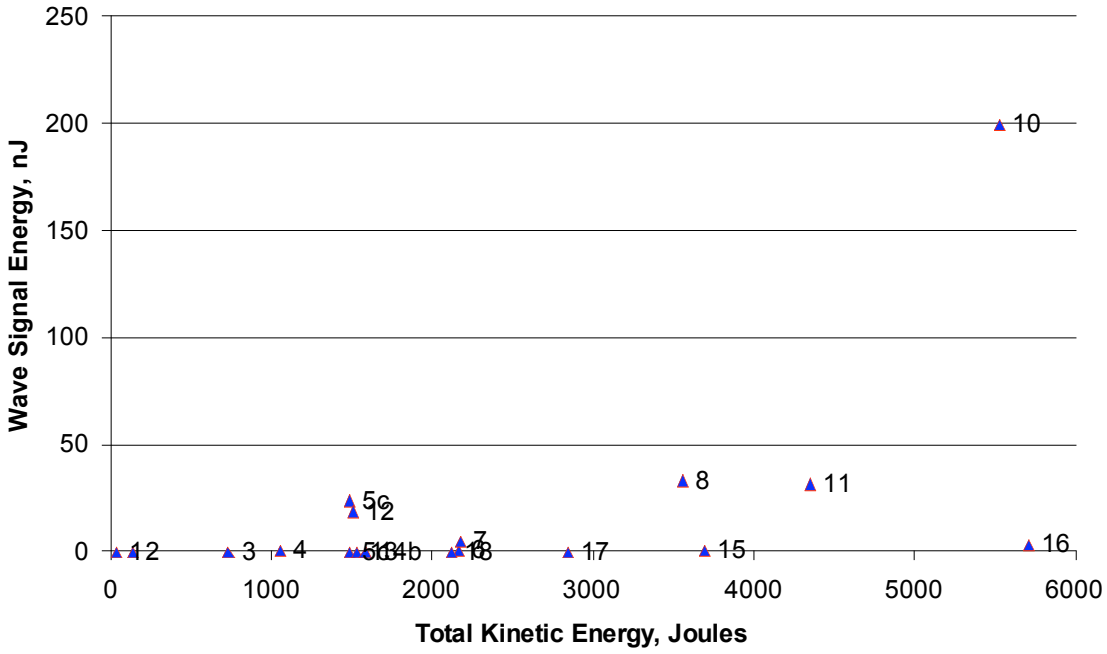

Figure 46: Bg-1 Wave Signal Energy vs. Total Kinetic Energy

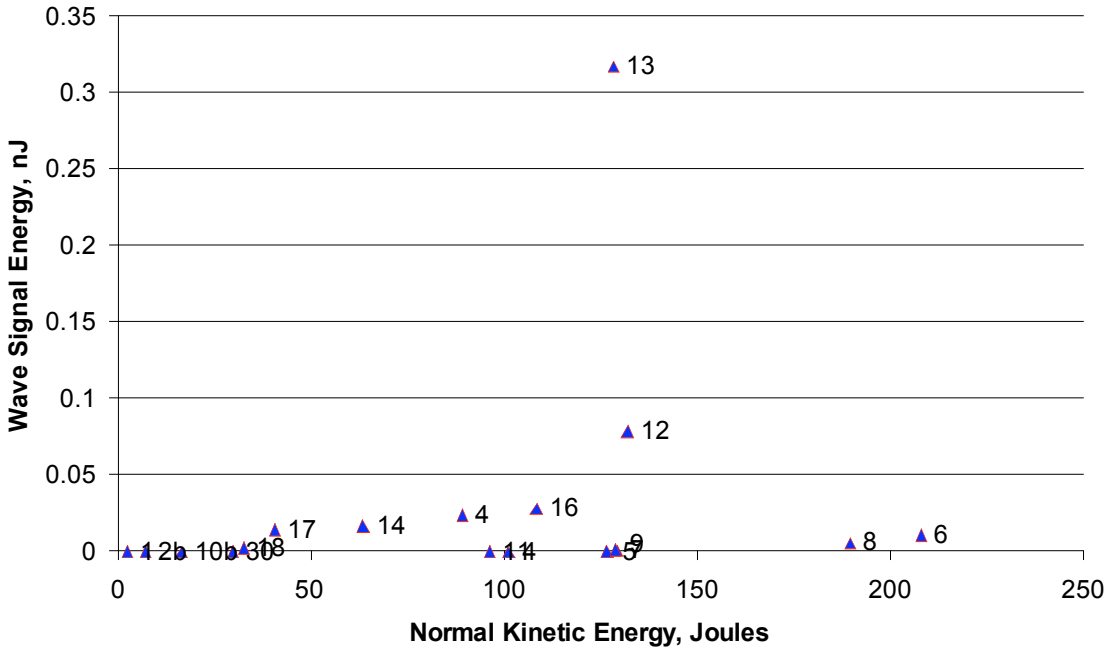

Figure 47: A-1 Wave Signal Energy vs. Normal Kinetic Energy

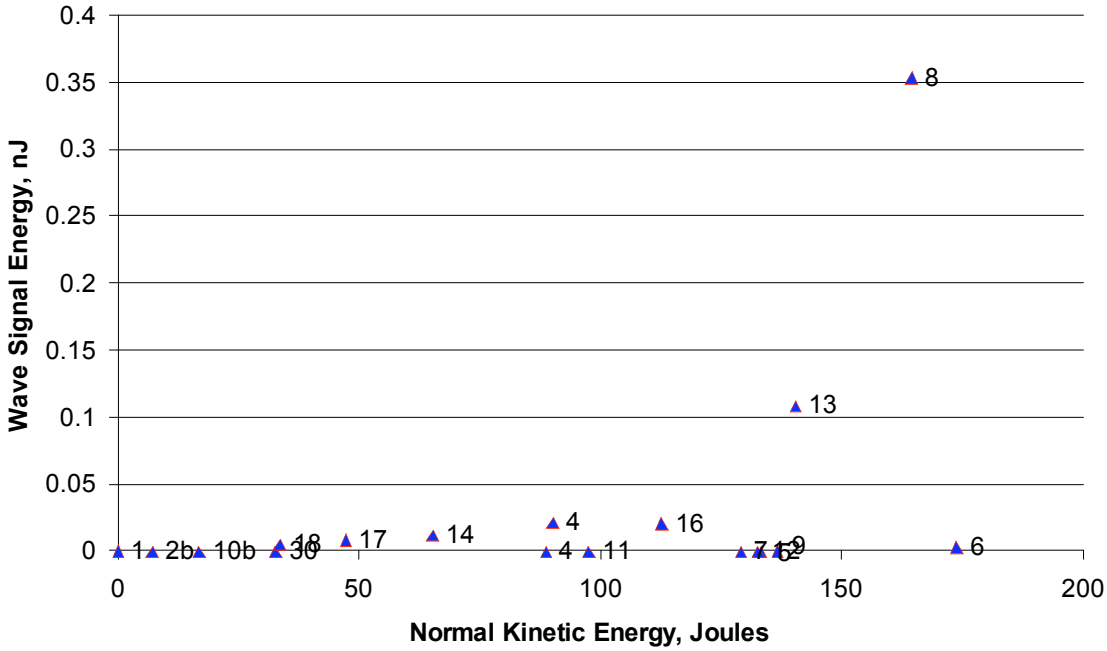

Figure 48: Ag-1 Wave Signal Energy vs. Normal Kinetic Energy

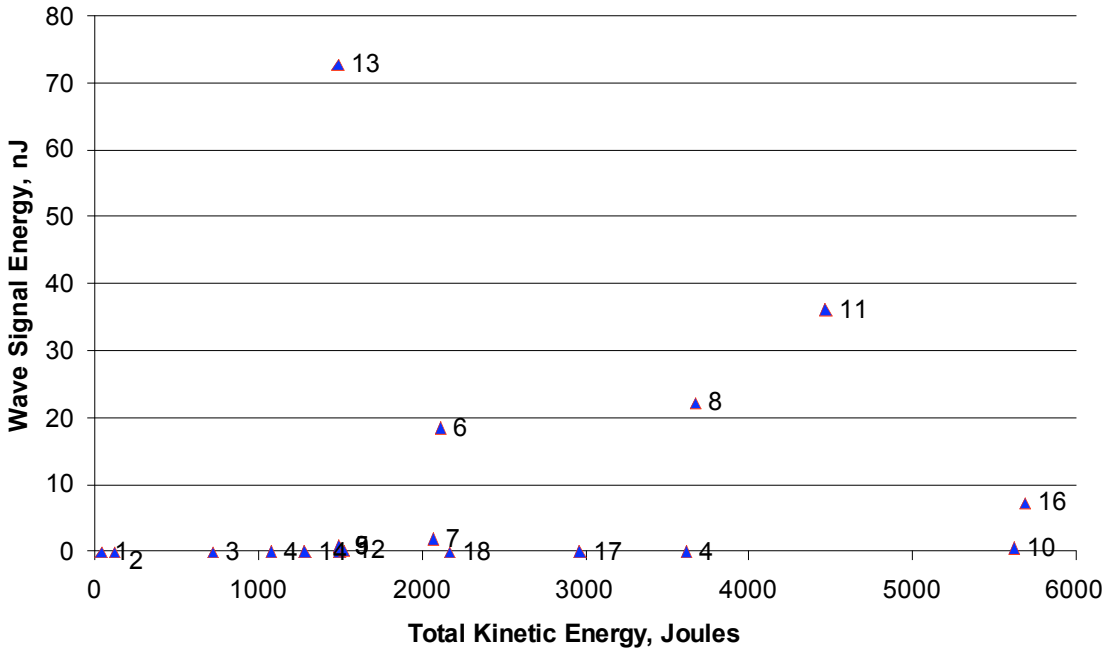

Figure 49: B-1 Wave Signal Energy vs. Normal Kinetic Energy

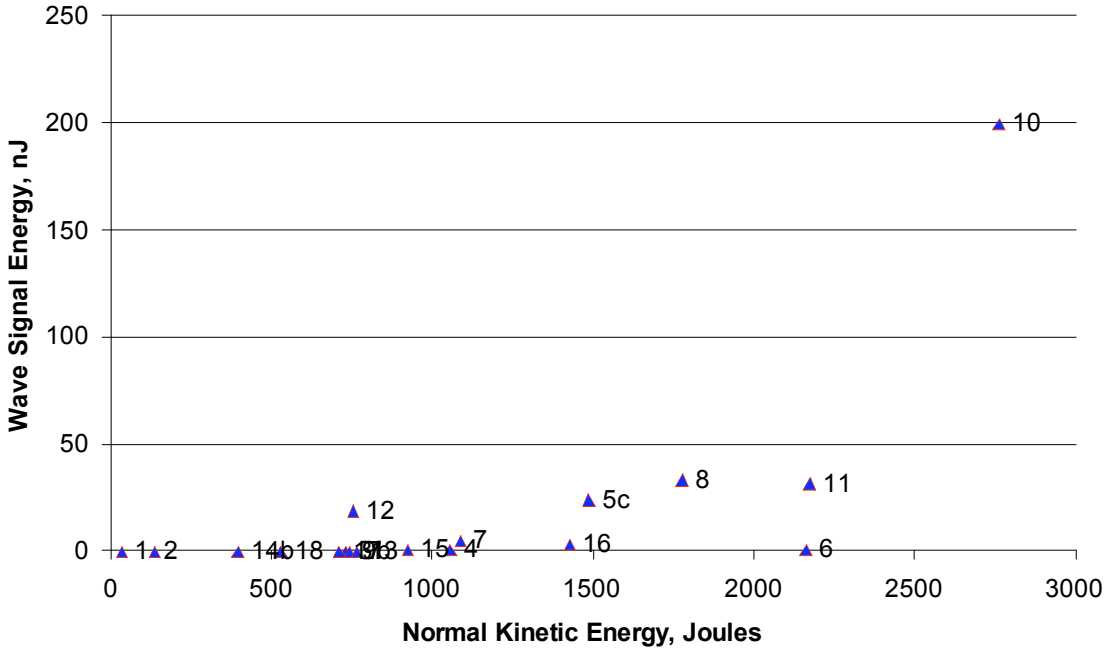

Figure 50: Bg-1 Wave Signal Energy vs. Normal Kinetic Energy

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.

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:

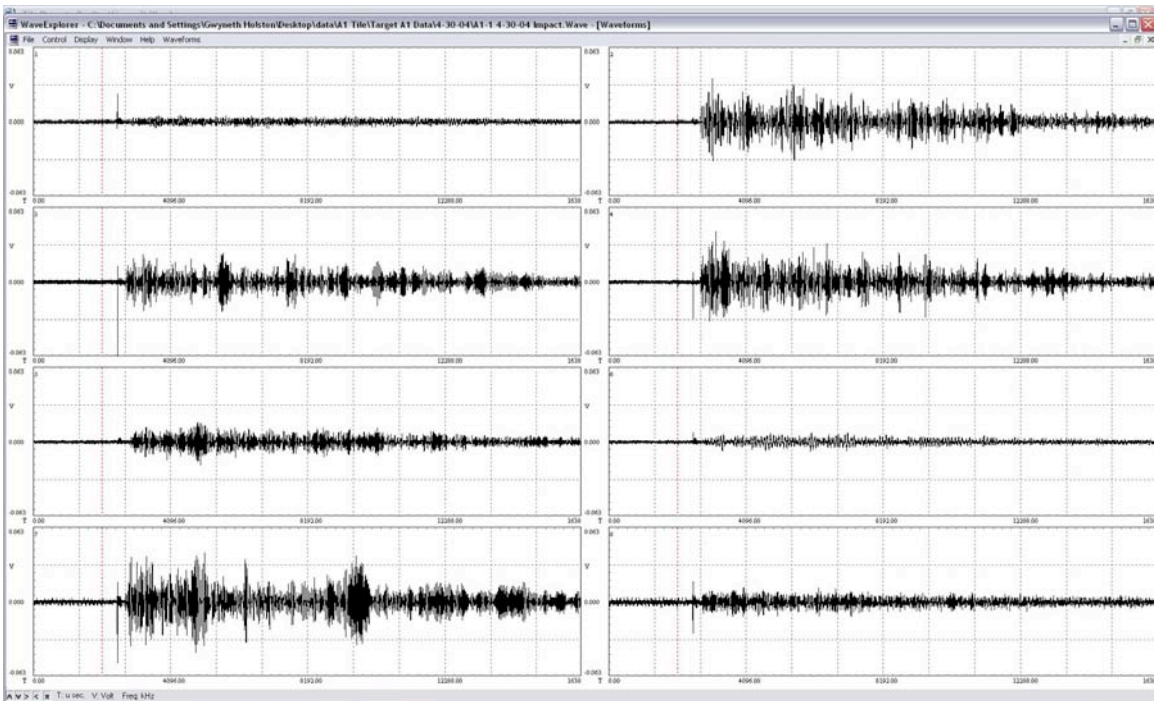

Figure 51: A-1 Shot #1 Impact Waveform

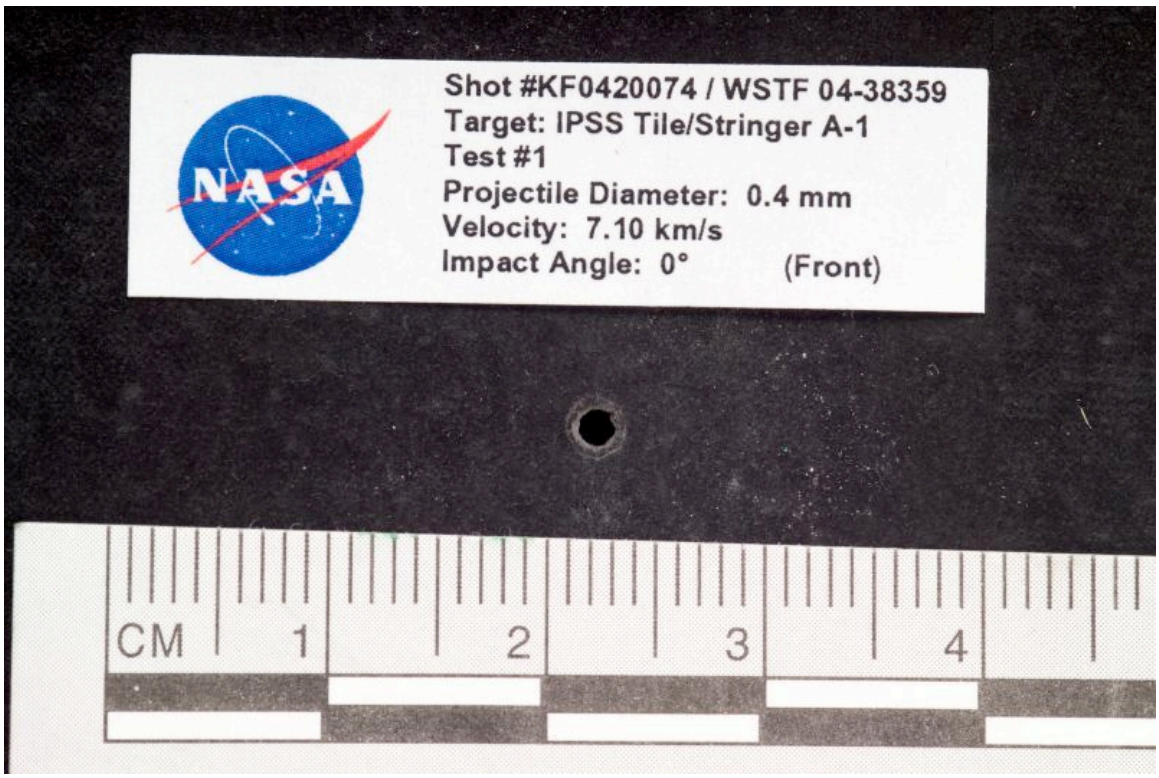

Figure 52: A-1 Shot #1 Impact Damage

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
Comments: Impact on event 5. Data looks good.

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:

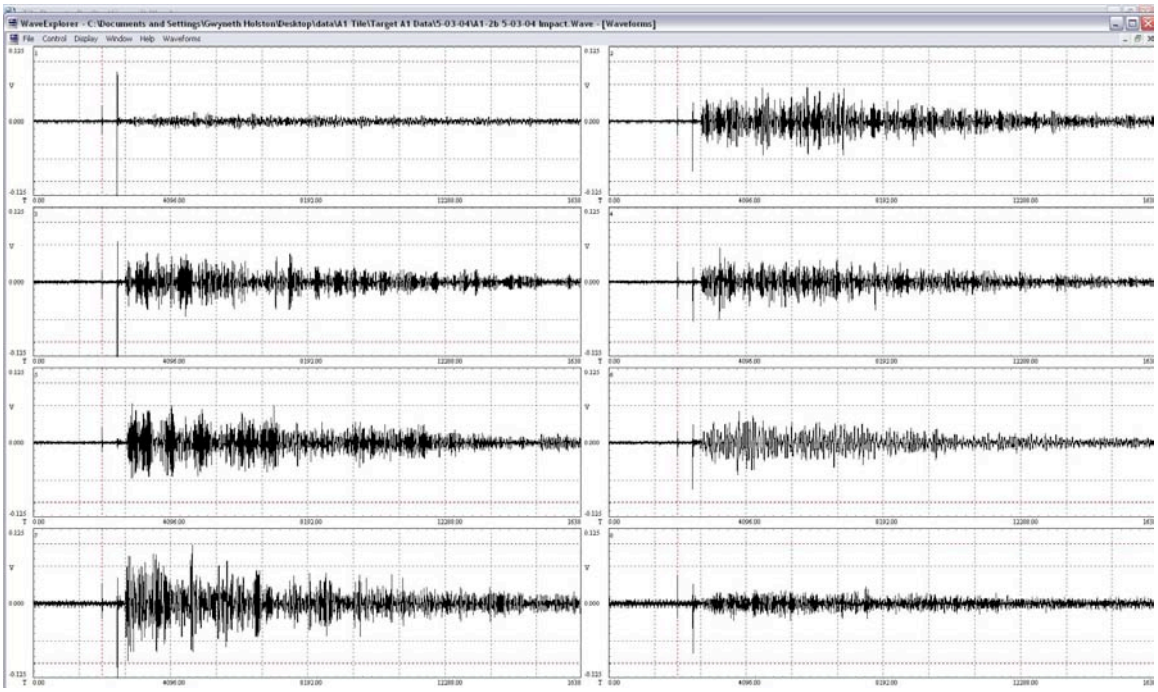

Figure 53: A-1 Shot #2 Impact Waveform

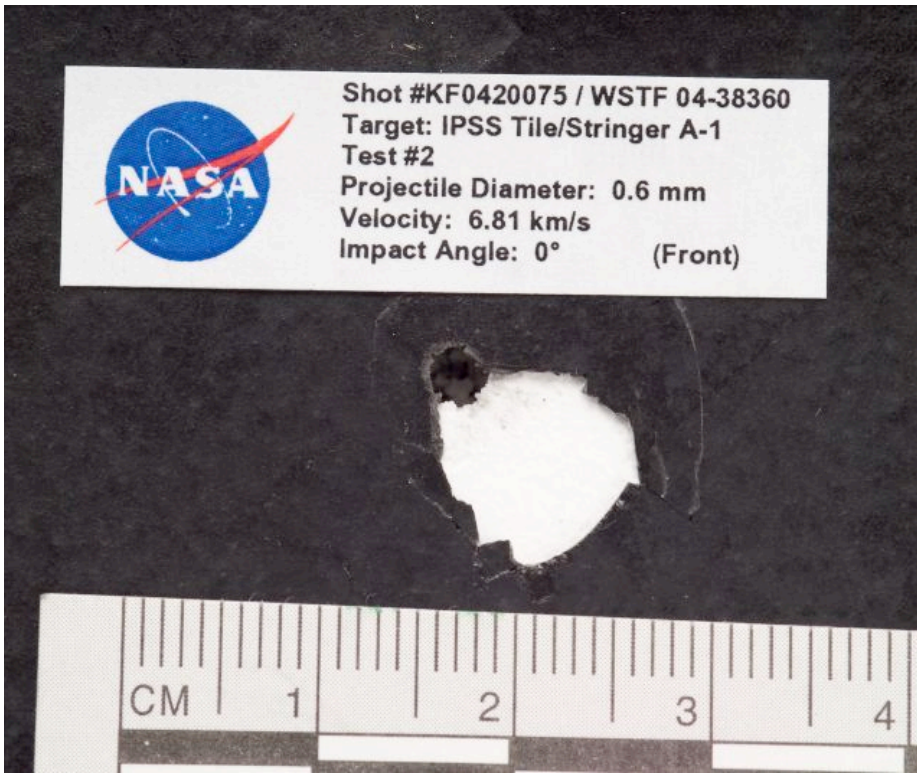

Figure 54: A-1 Shot #2 Impact Damage

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
Comments: Impact on event 8. Data looks good.

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:

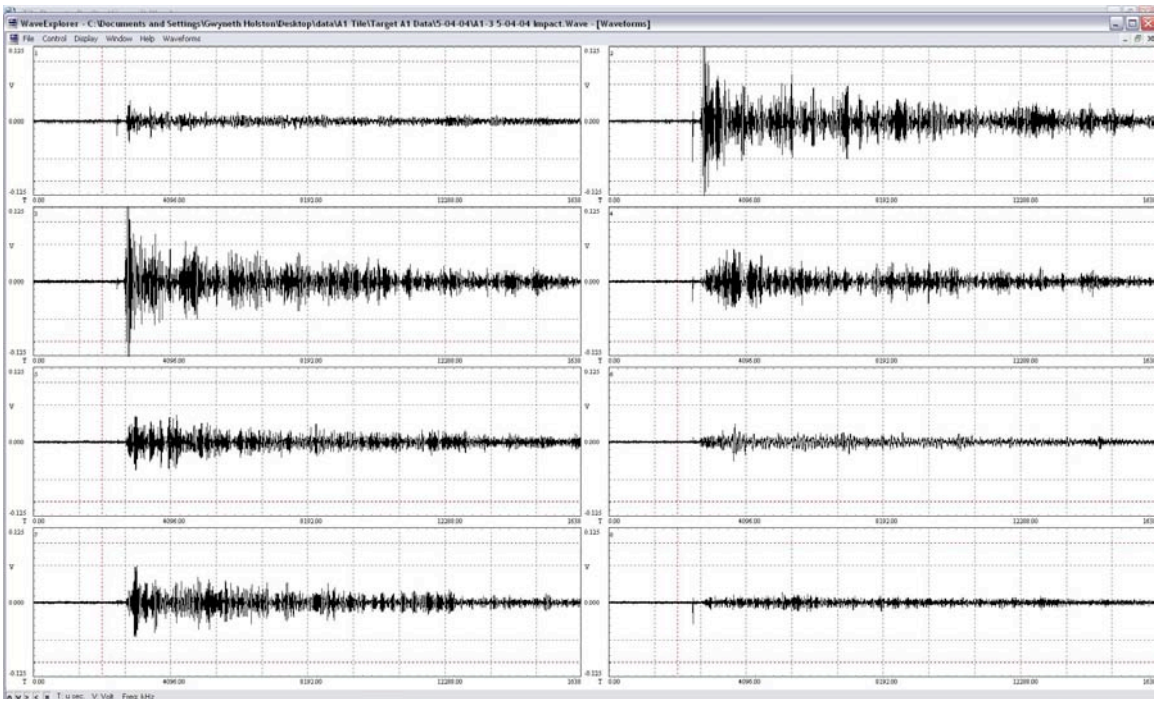

Figure 55: A-1 Shot #3 Impact Waveform

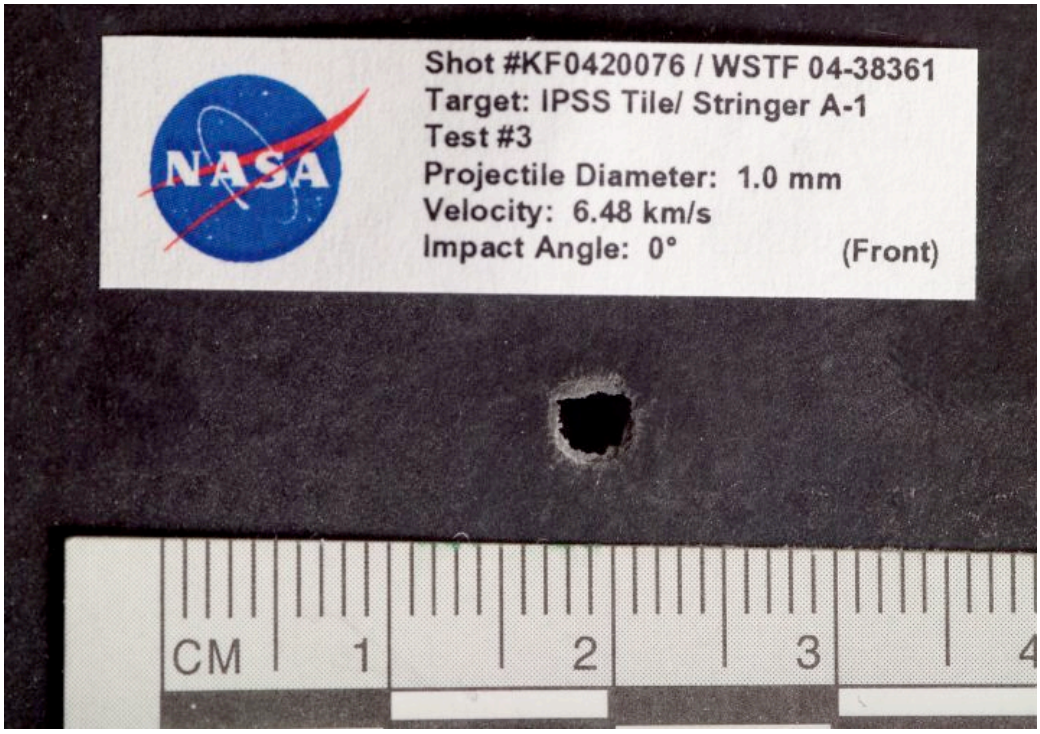

Figure 56: A-1 Shot #3 Impact Damage

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:

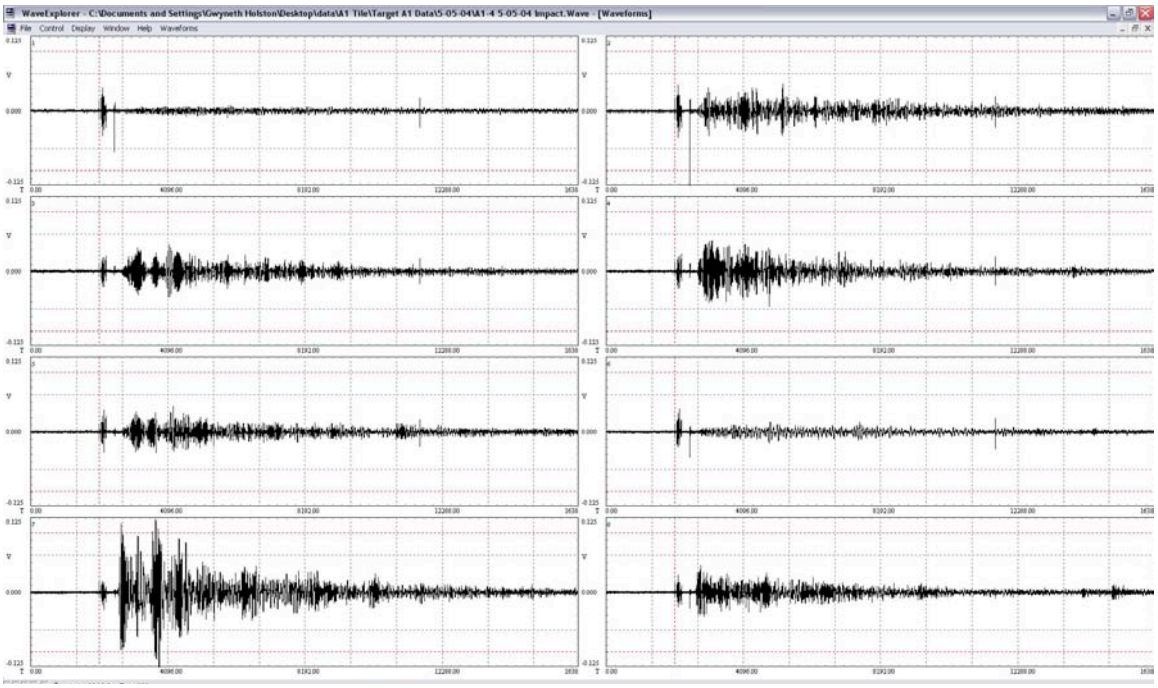

Figure 57: A-1 Shot #4 Impact Waveform

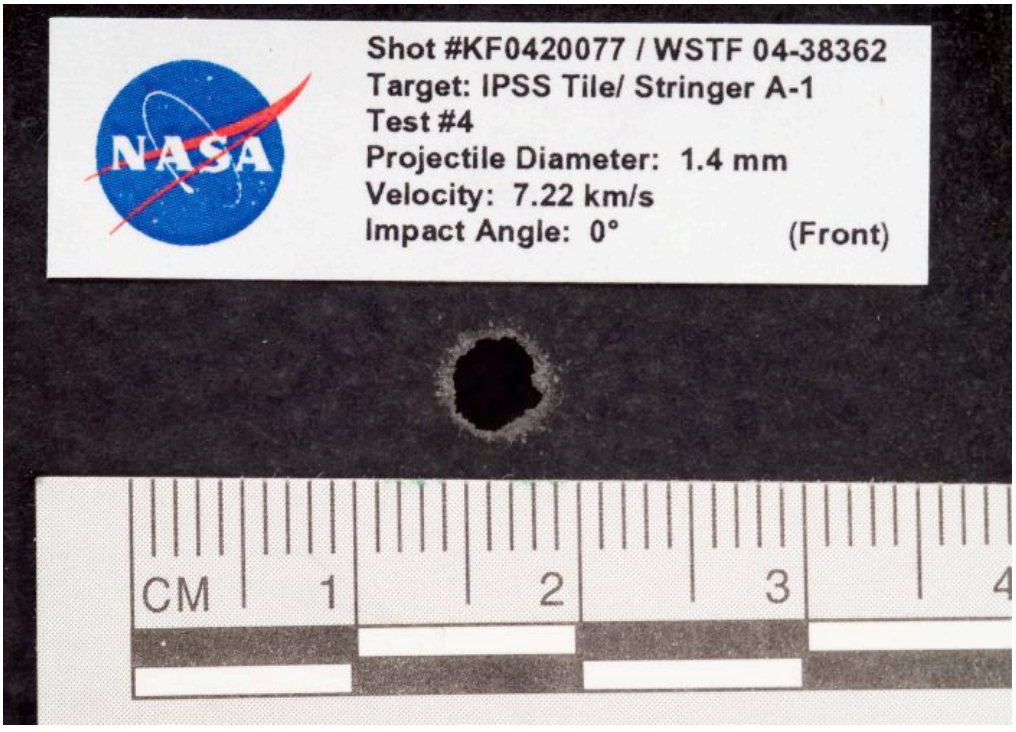

Figure 58: A-1 Shot #4 Impact Damage

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:

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
Comments: Impact on event 6. Looks good.

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:

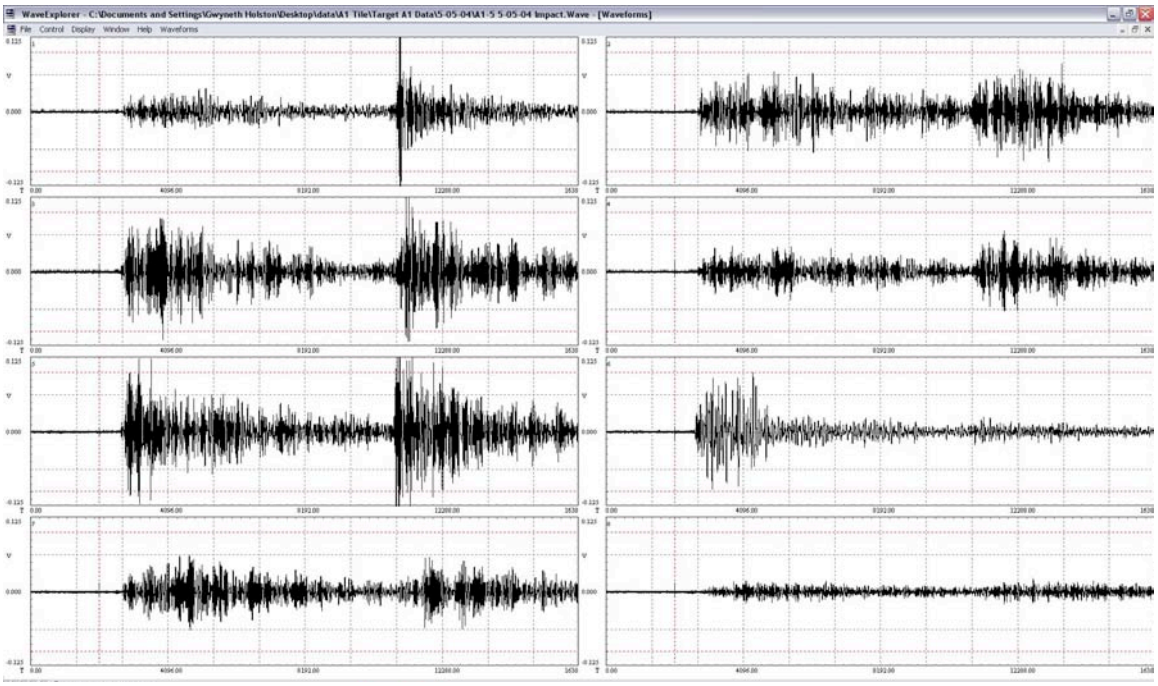

Figure 59: A-1 Shot #5 Impact Waveform

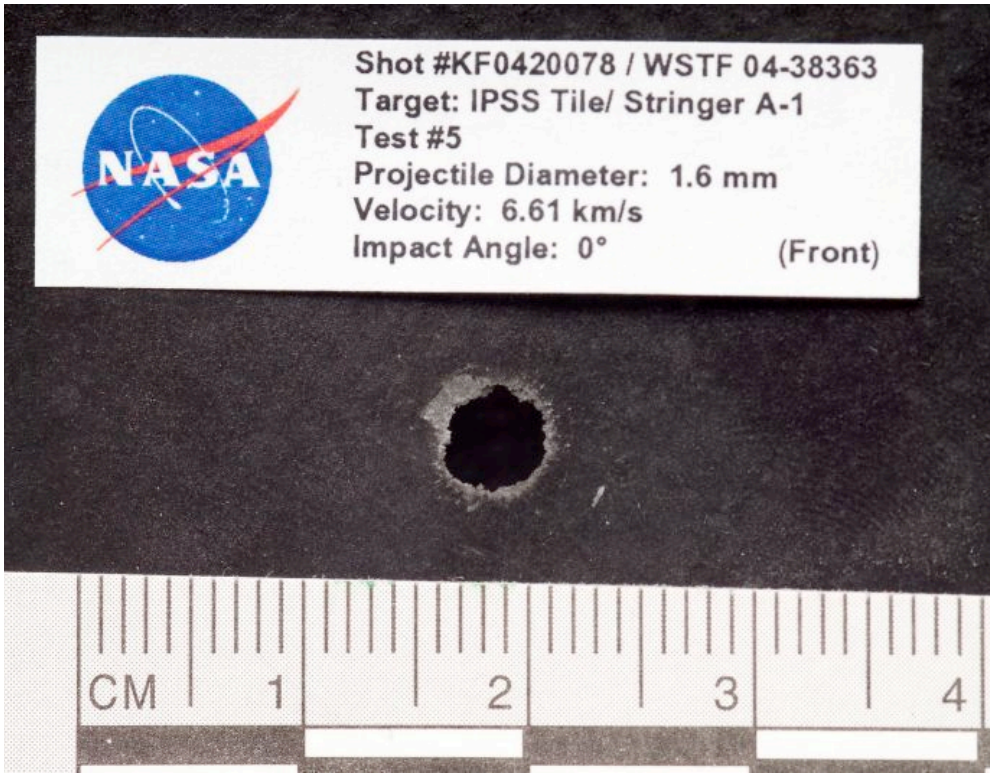

Figure 60: A-1 Shot #5 Impact Damage

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:

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:

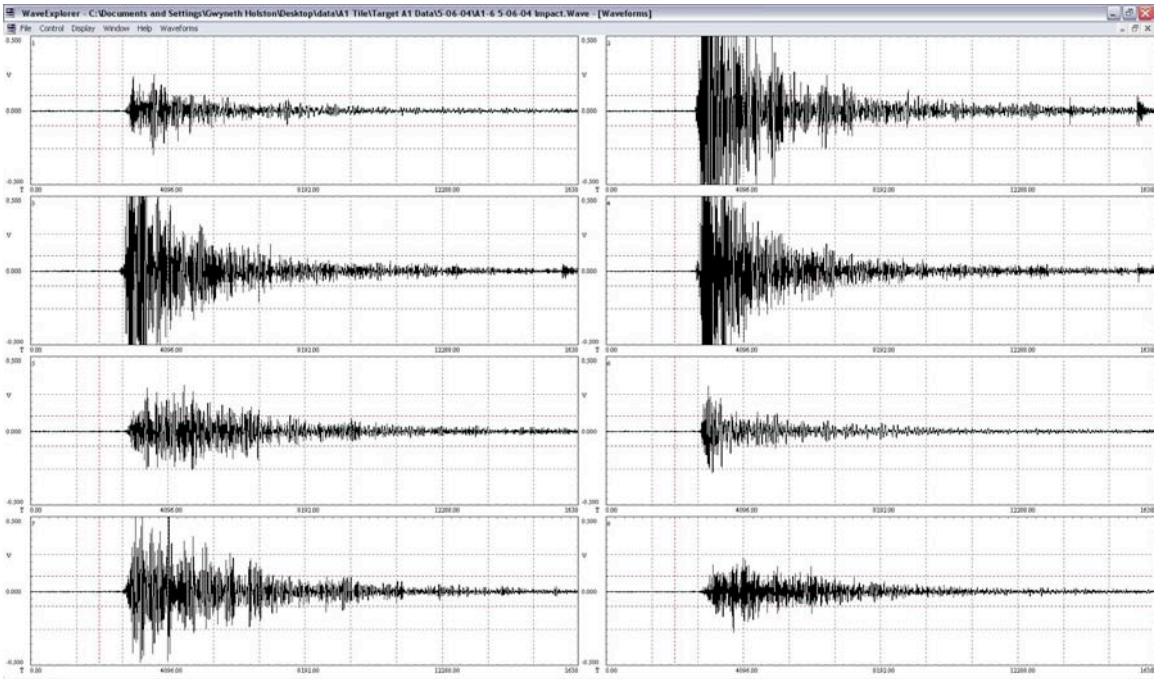

Figure 61: A-1 Shot #6 Impact Waveform

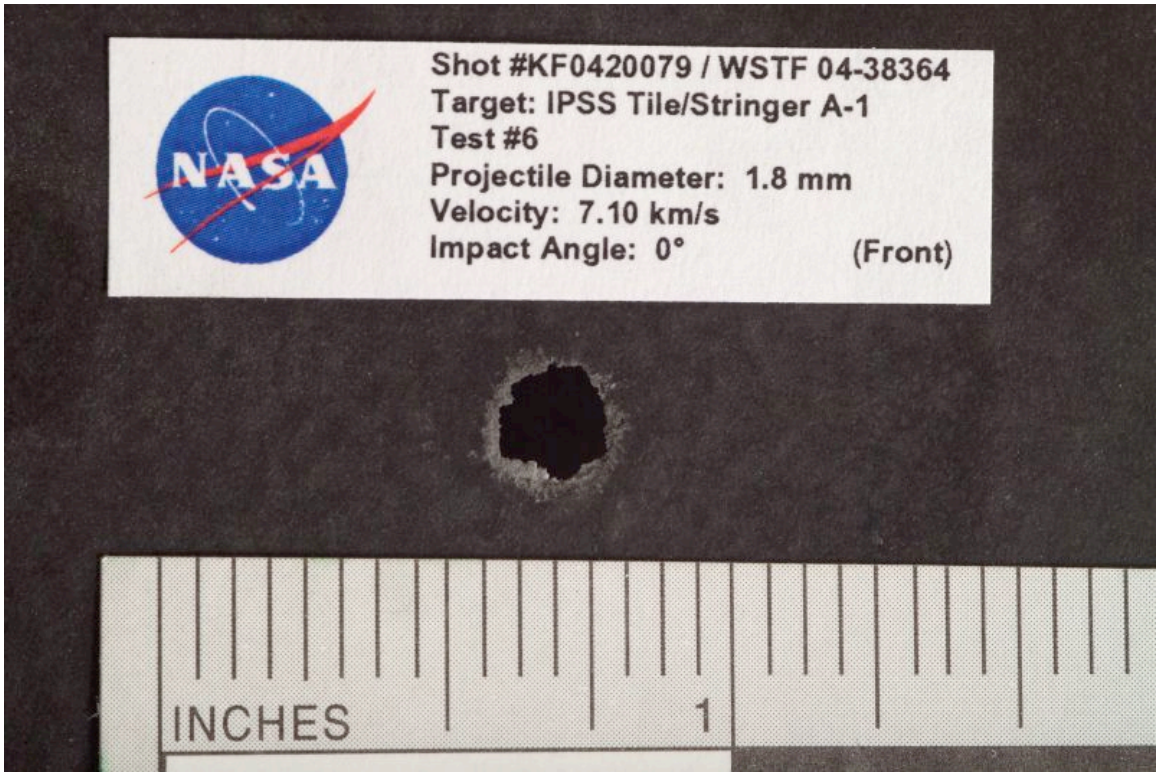

Figure 62: A-1 Shot #6 Impact Damage

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 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 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 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:

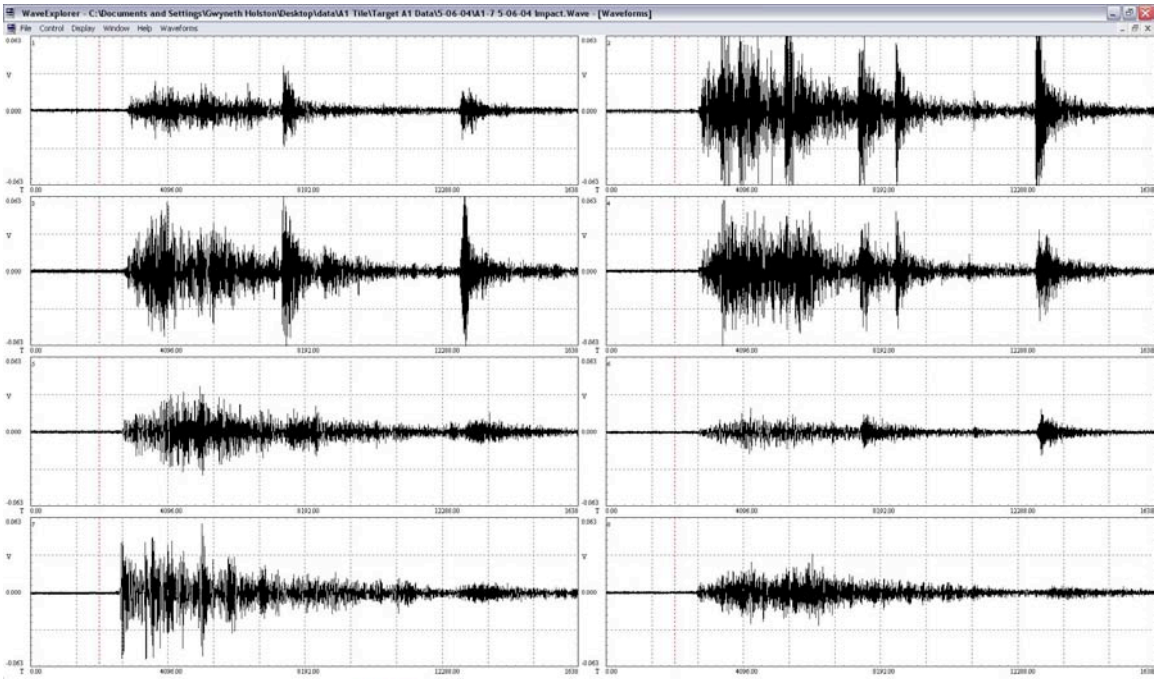

Figure 63: A-1 Shot #7 Impact Waveform

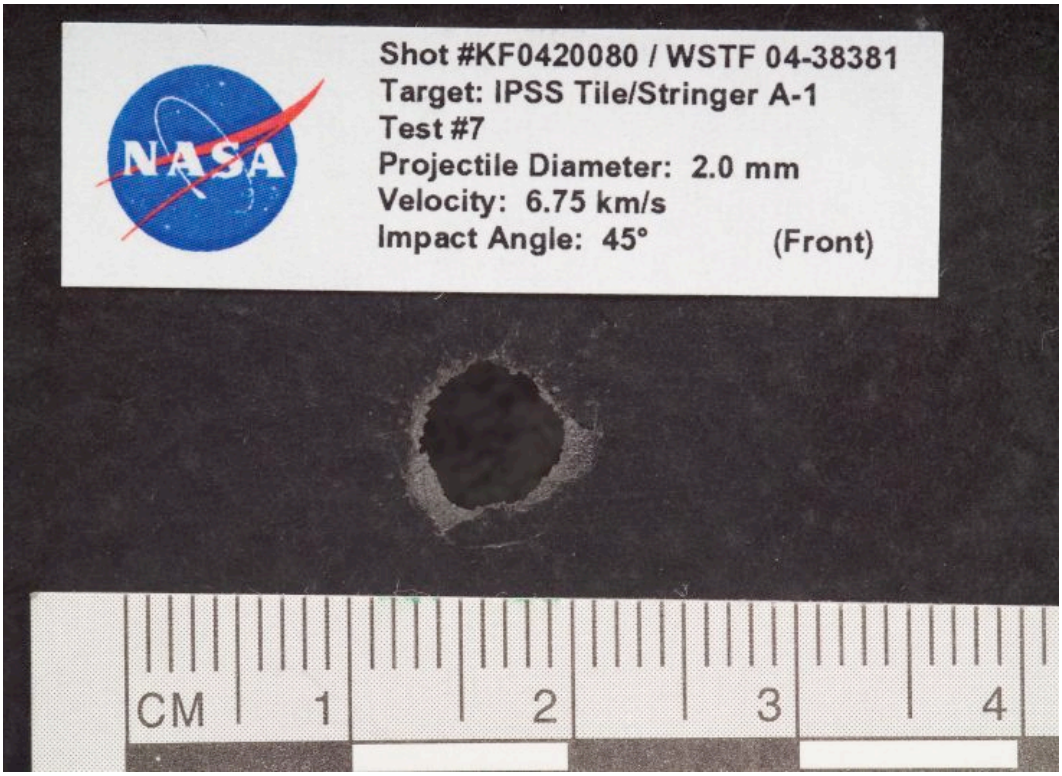

Figure 64: A-1 Shot #7 Impact Damage

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:

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: A1-8 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:

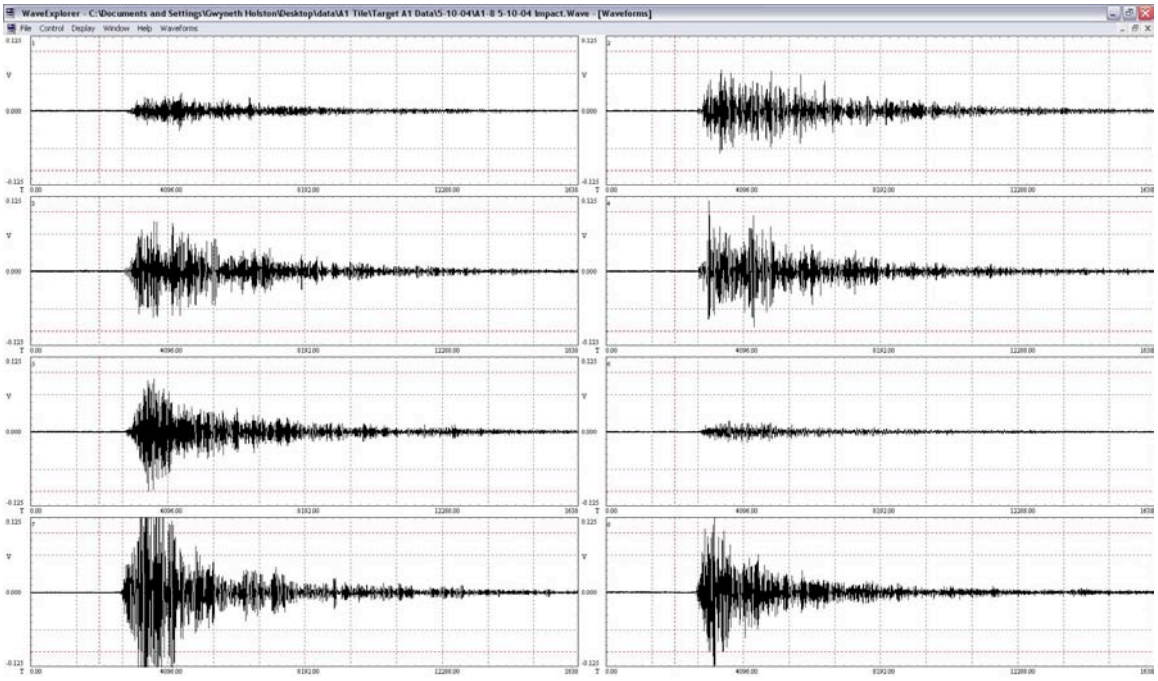

Figure 65: A-1 Shot #8 Impact Waveform

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
Comments: Impact on event 21. 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: 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:

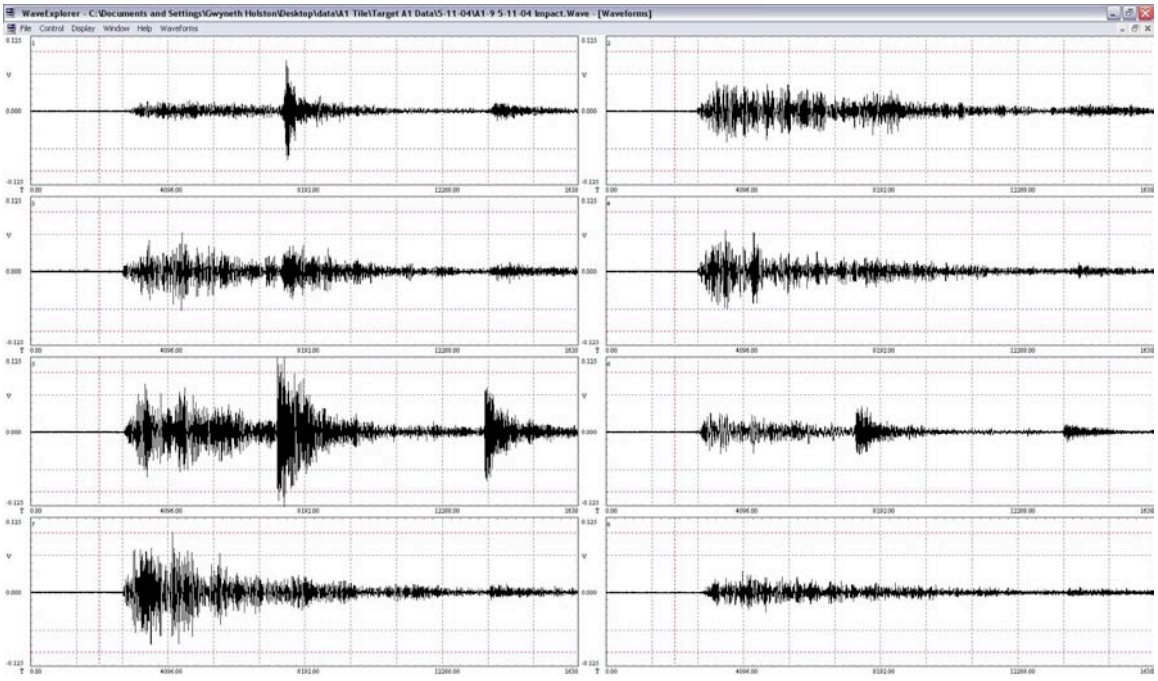

Figure 67: A-1 Shot #9 Impact Waveform

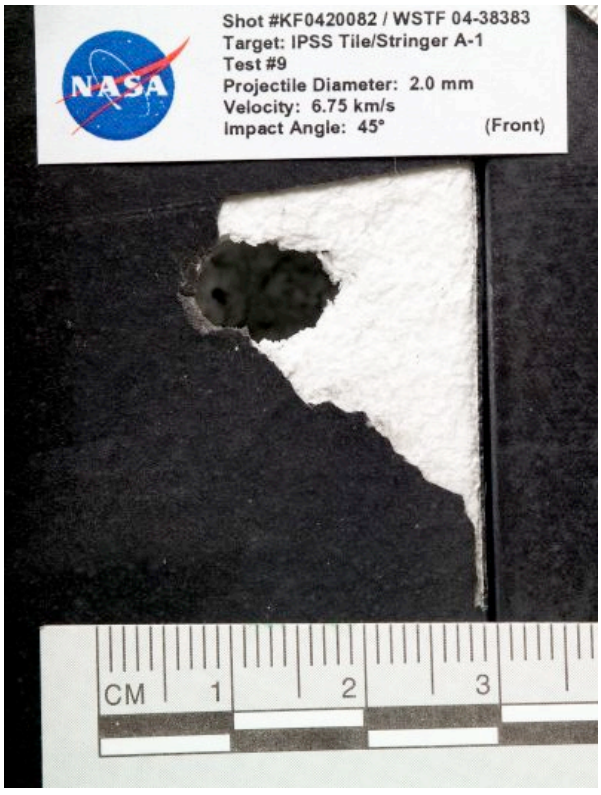

Figure 68: A-1 Shot #9 Impact Damage

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., 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
Comments: Impact on event 8. Data looks good.

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:

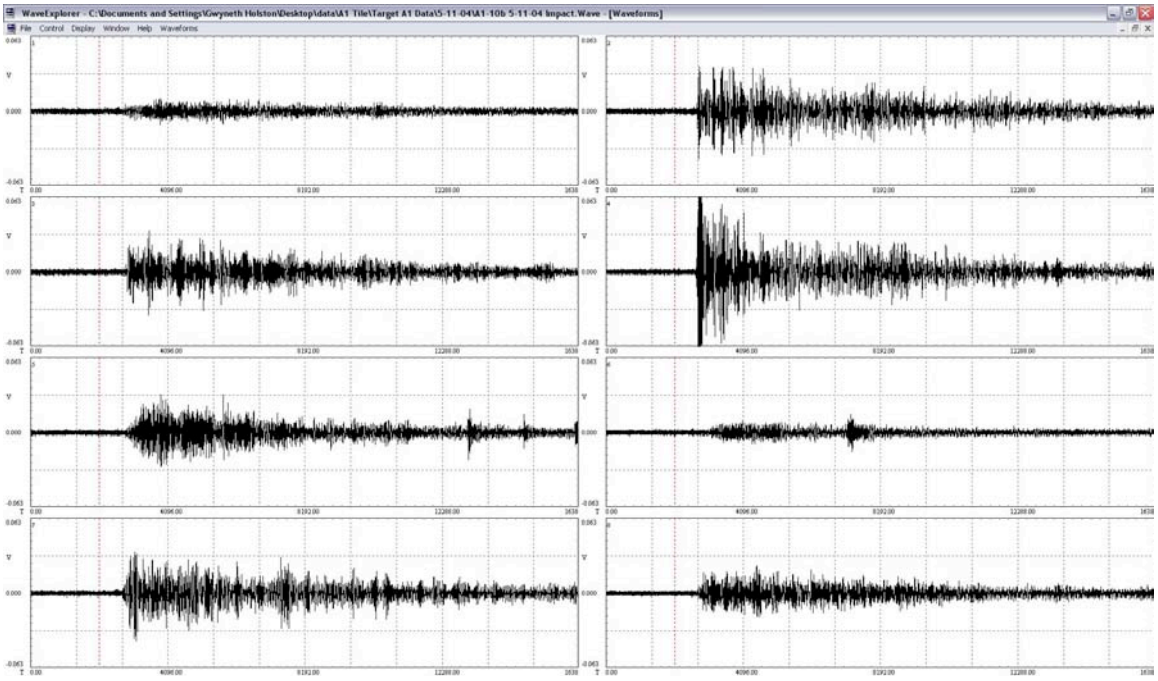

Figure 69: A-1 Shot #10 Impact Waveform

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 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: A1-11 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:

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:

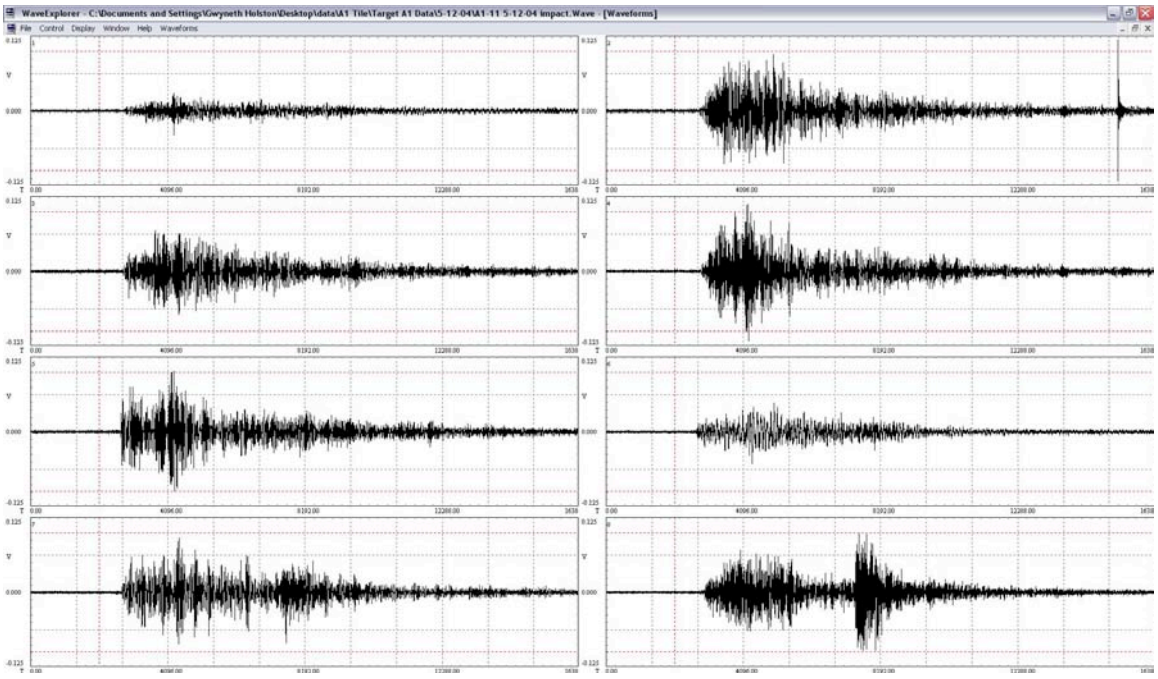

Figure 71: A-1 Shot #11 Impact Waveform

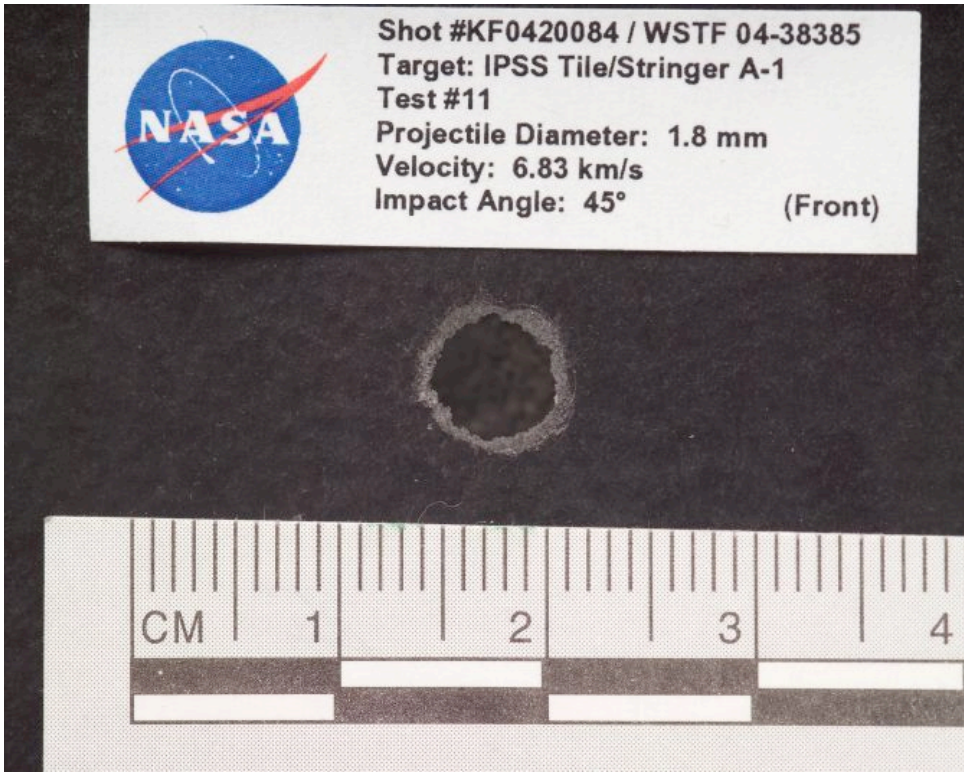

Figure 72: A-1 Shot #11 Impact Damage

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:

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:

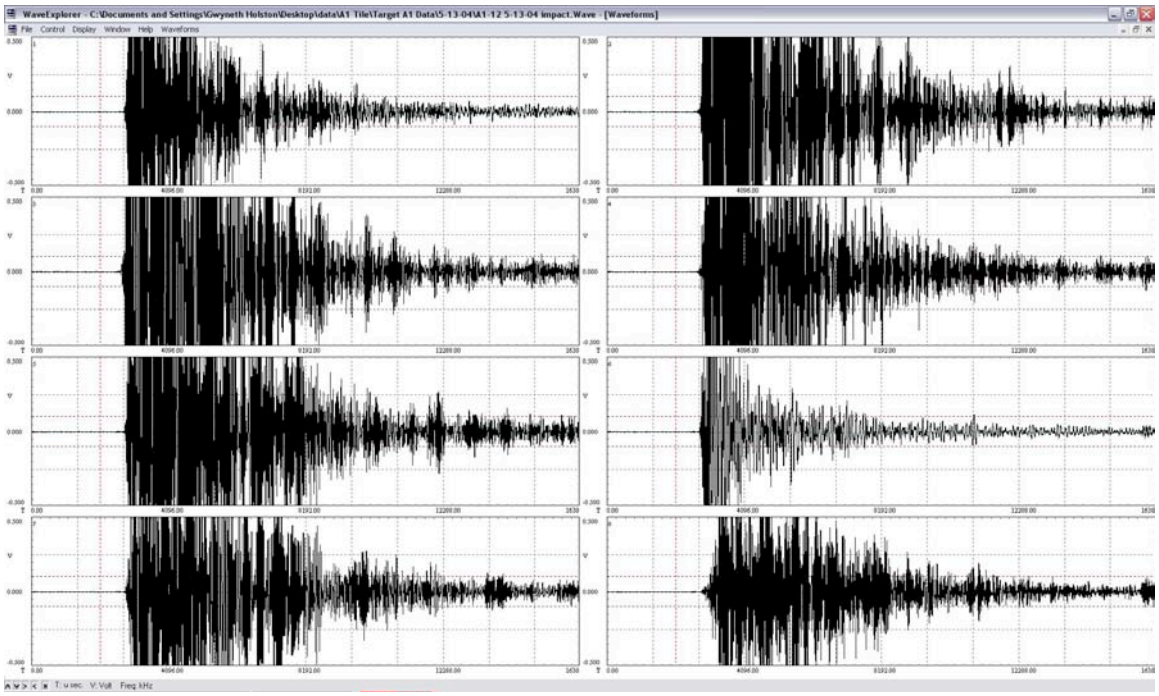

Figure 73: A-1 Shot #12 Impact Waveform

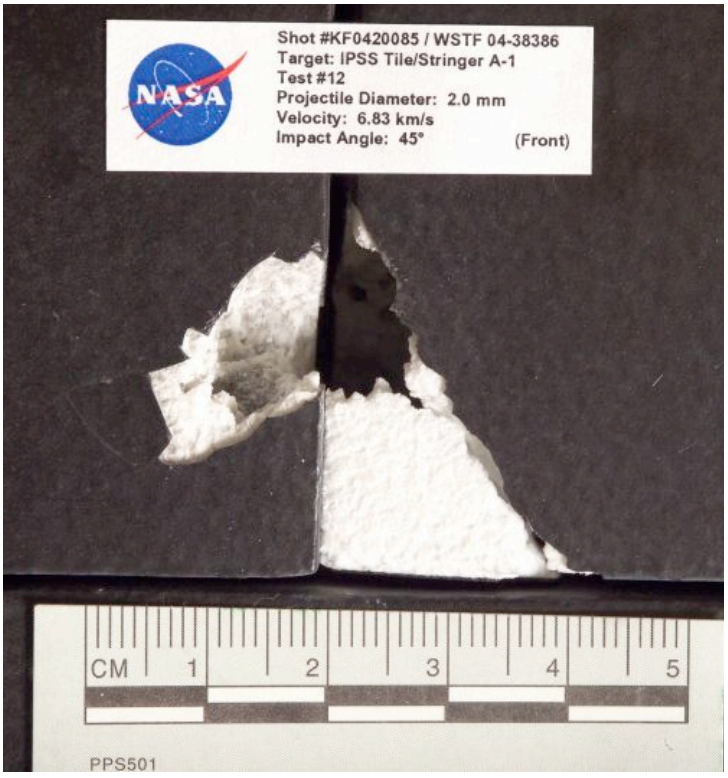

Figure 74: A-1 Shot #12 Impact Damage

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:

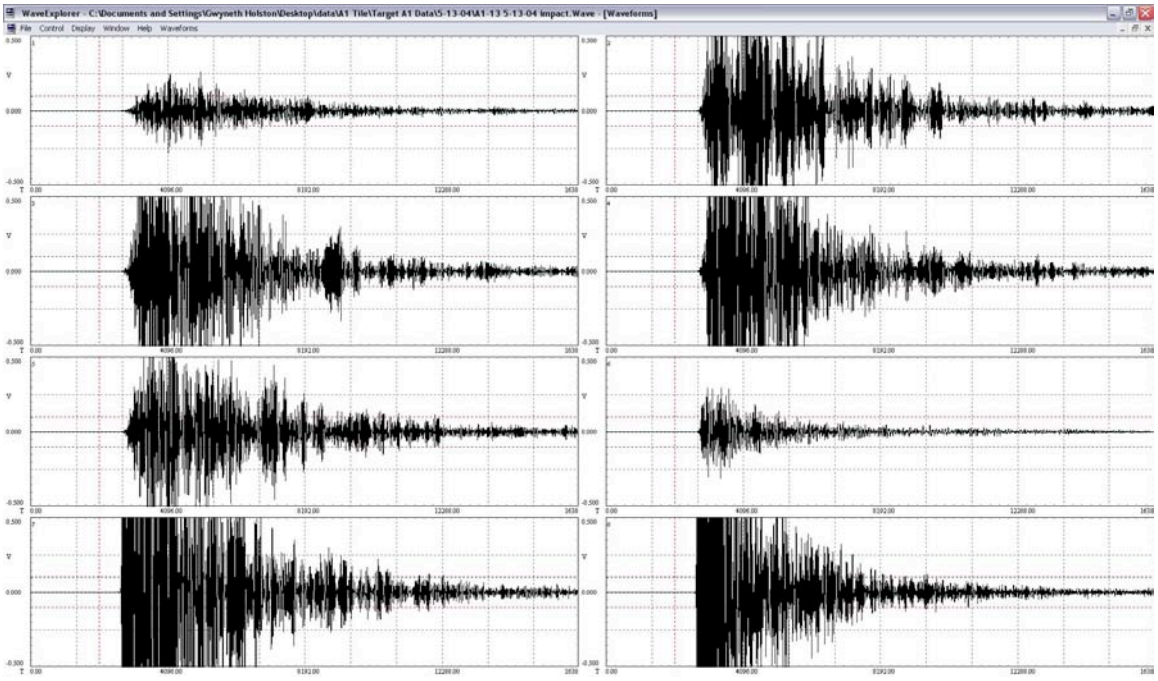

Figure 75: A-1 Shot #13 Impact Waveform

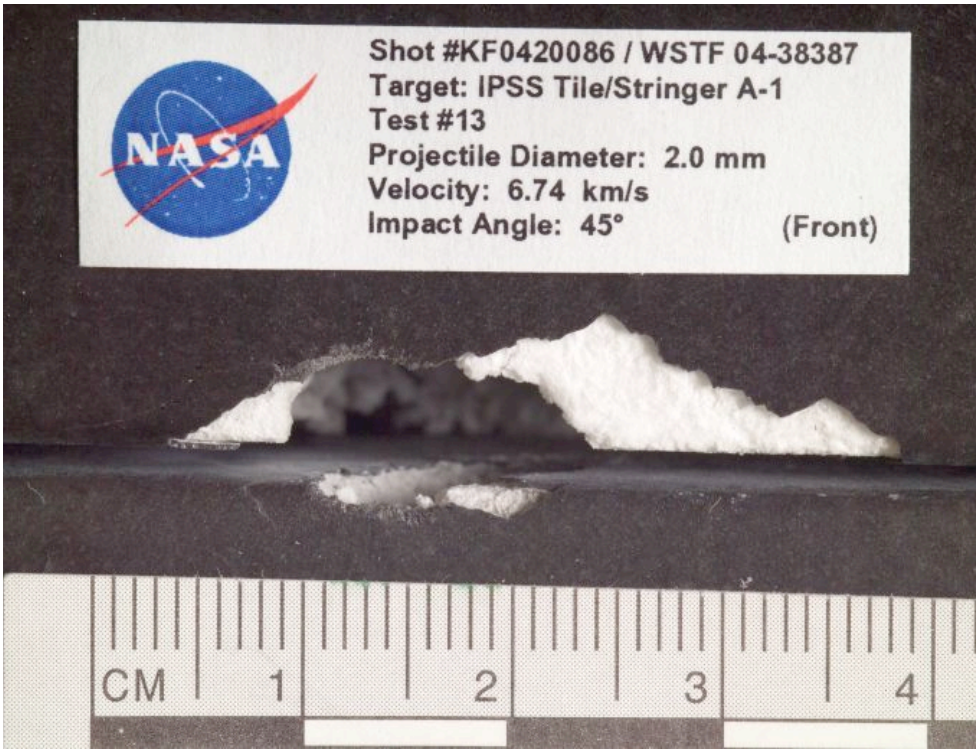

Figure 76: A-1 Shot #13 Impact Damage

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:

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:

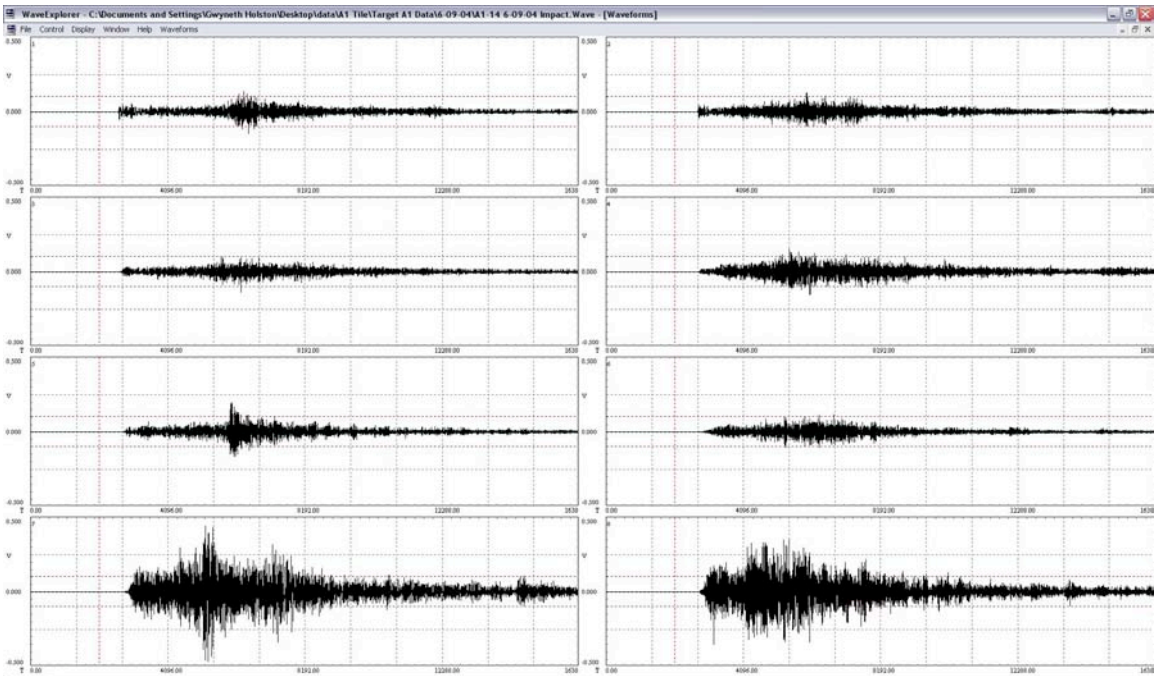

Figure 77: A-1 Shot #14 Impact Waveform

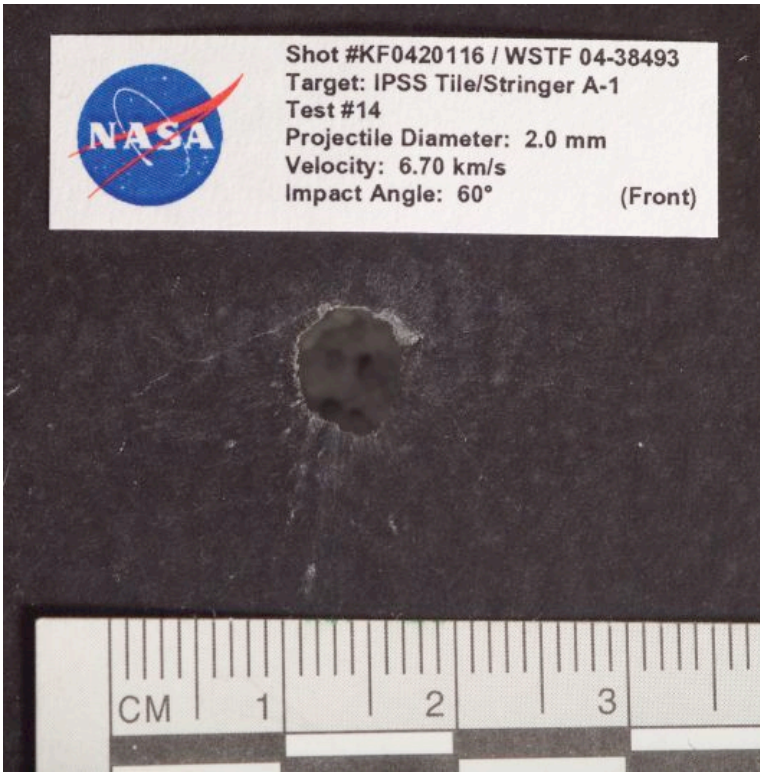

Figure 78: A-1 Shot #14 Impact Damage

AE Test Data/Checklist

I. Record pretest information:

Test date: 6/09/04 Specimen ID: A-1

Test number: A1-15 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:

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: A1-15 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:

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: A1-15 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:

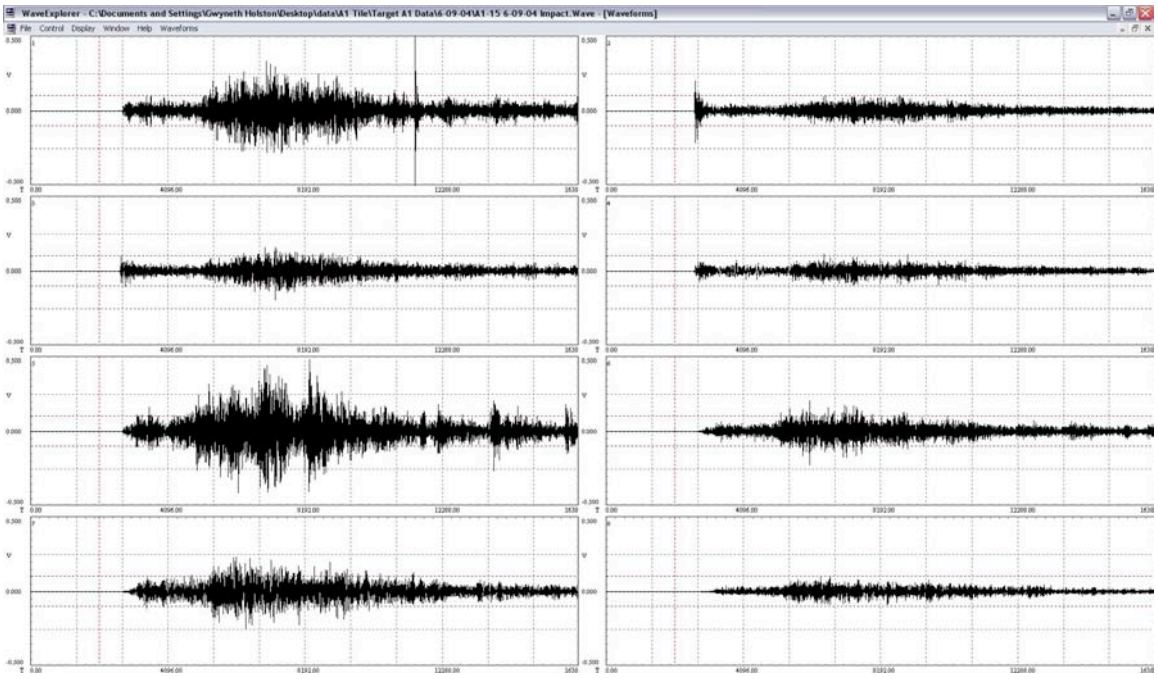

Figure 79: A-1 Shot #15 Impact Waveform

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 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: 6.66 km/s.
Impact coordinates:
Damage description and comments:

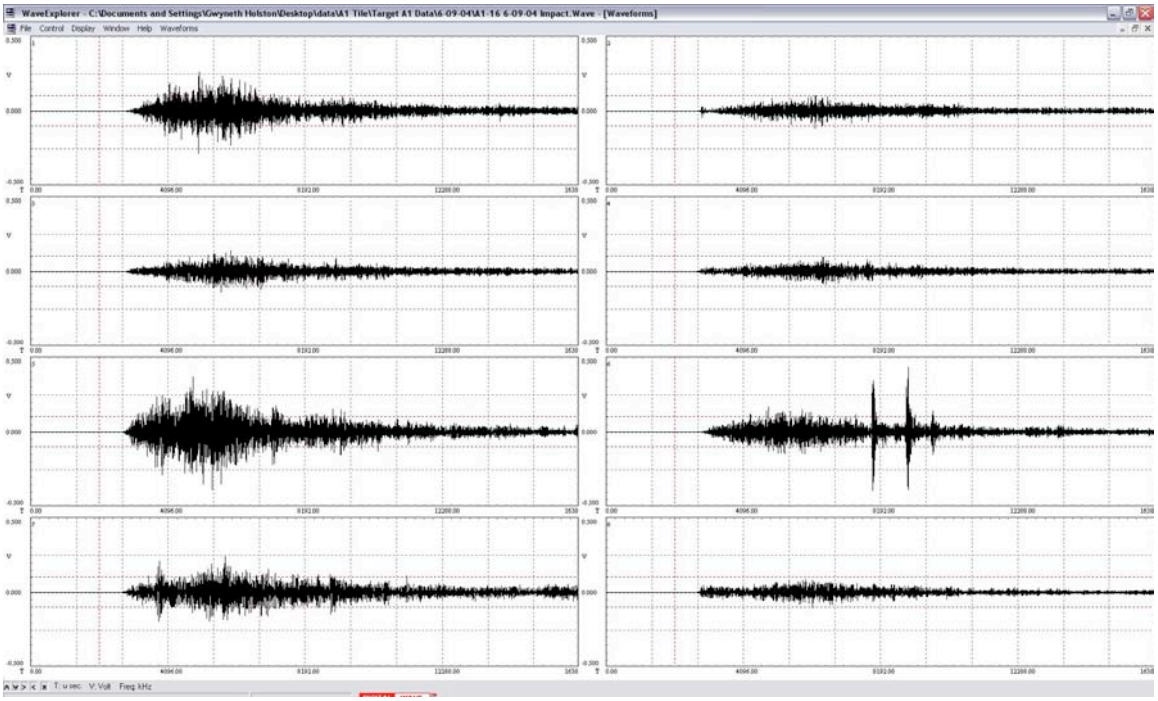

Figure 81: A-1 Shot #16 Impact Waveform

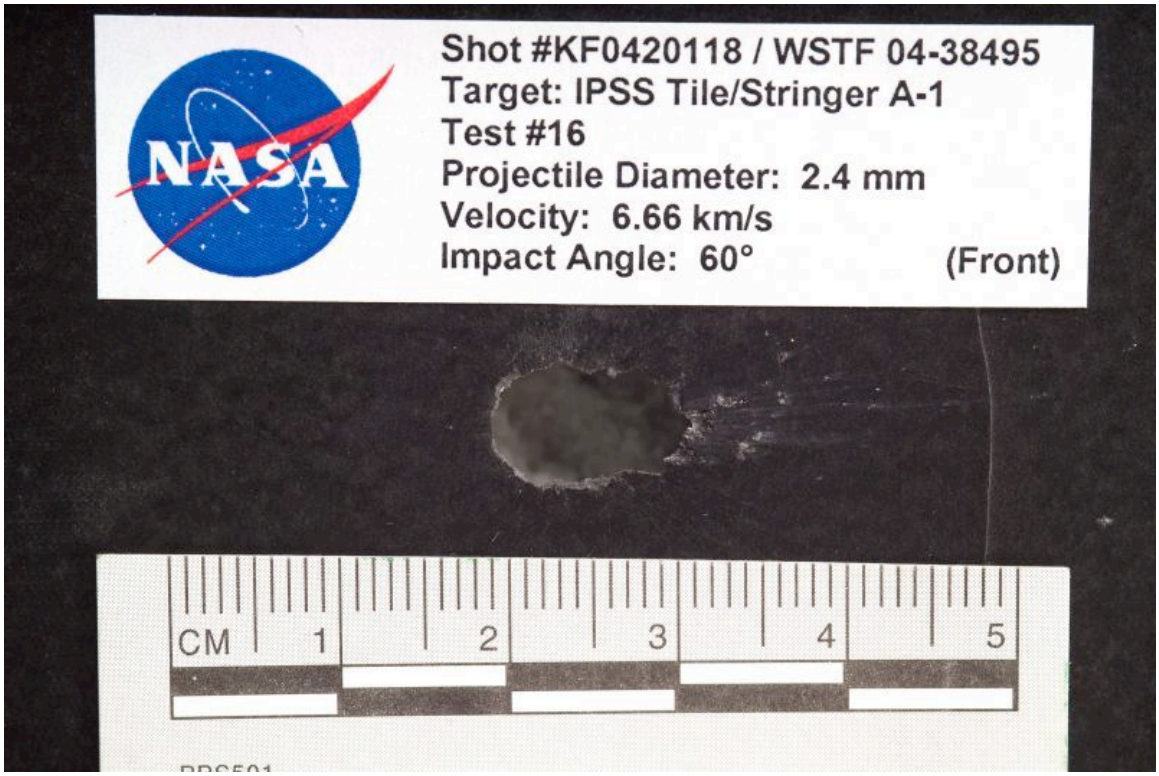

Figure 82: A-1 Shot #16 Impact Damage

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:

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 4.

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:

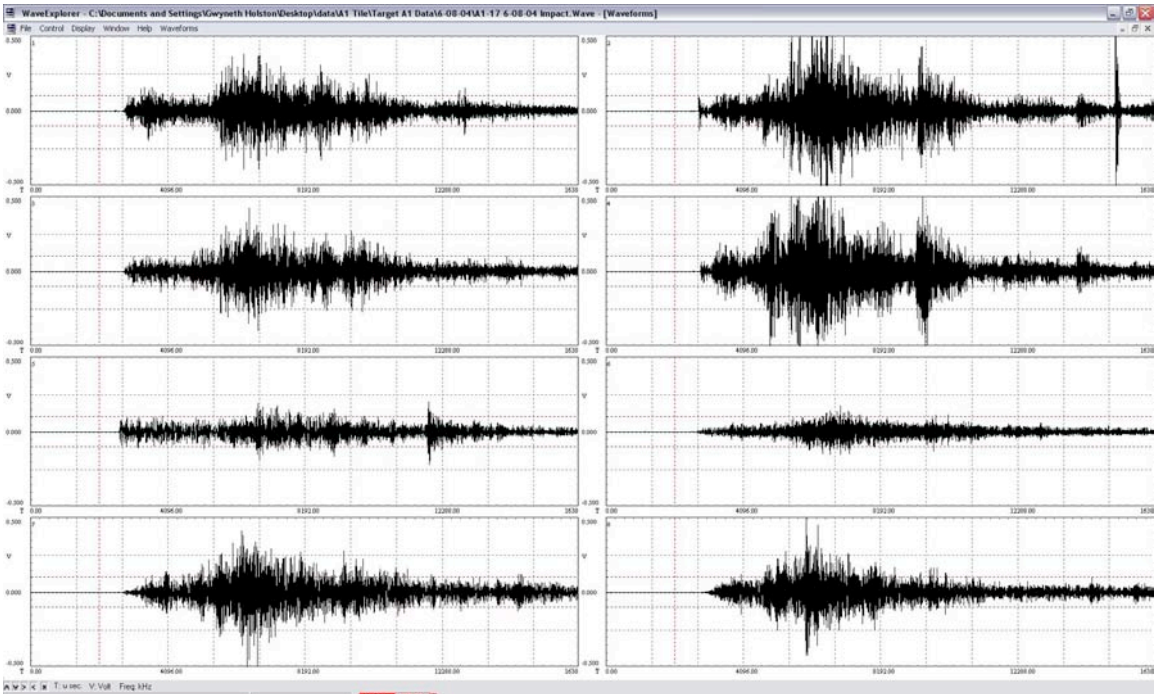

Figure 83: A-1 Shot #17 Impact Waveform

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:

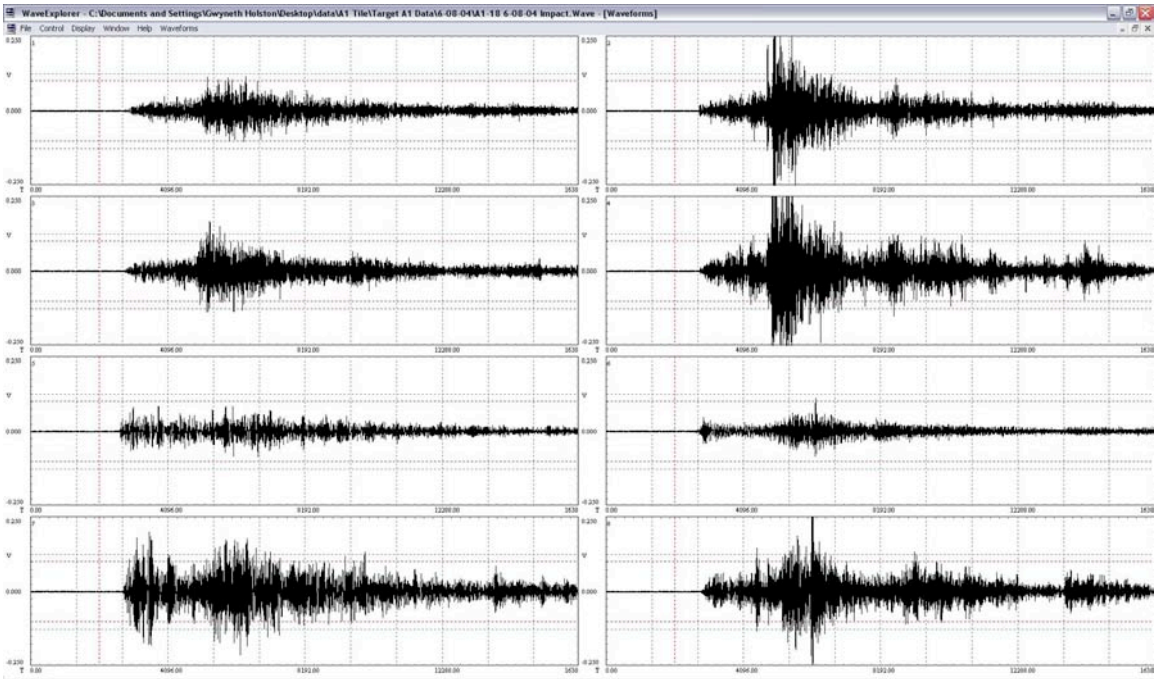

Figure 85: A-1 Shot #18 Impact Waveform

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:

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:

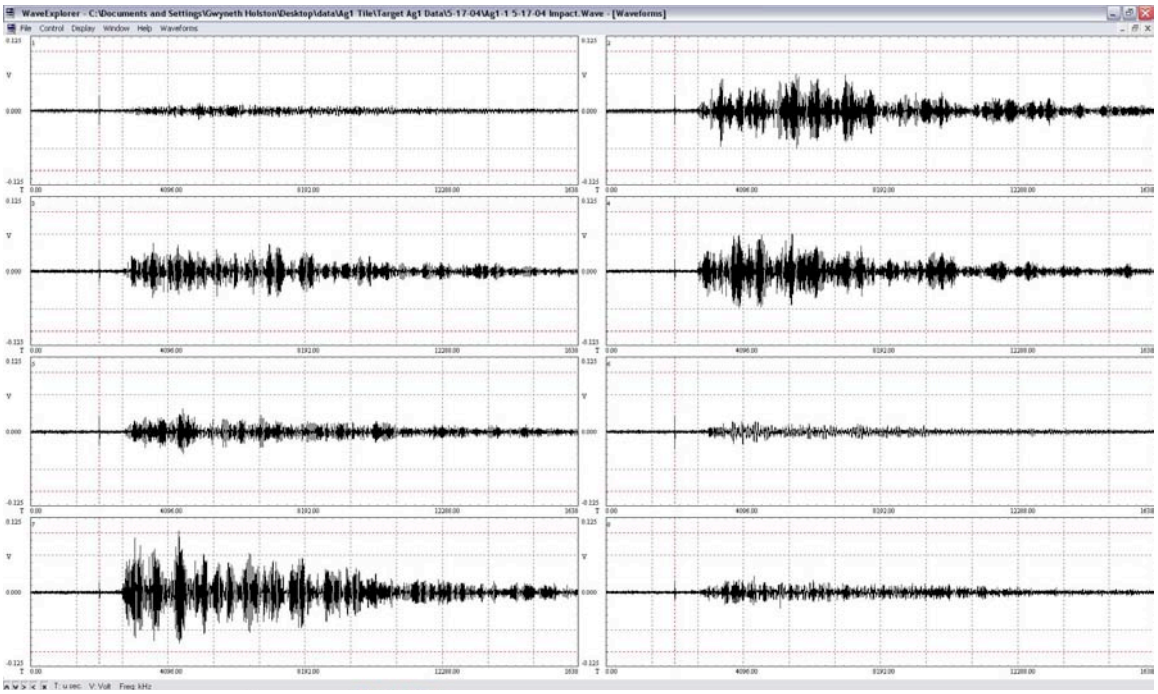

Figure 87: Ag-1 Shot #1 Impact Waveform

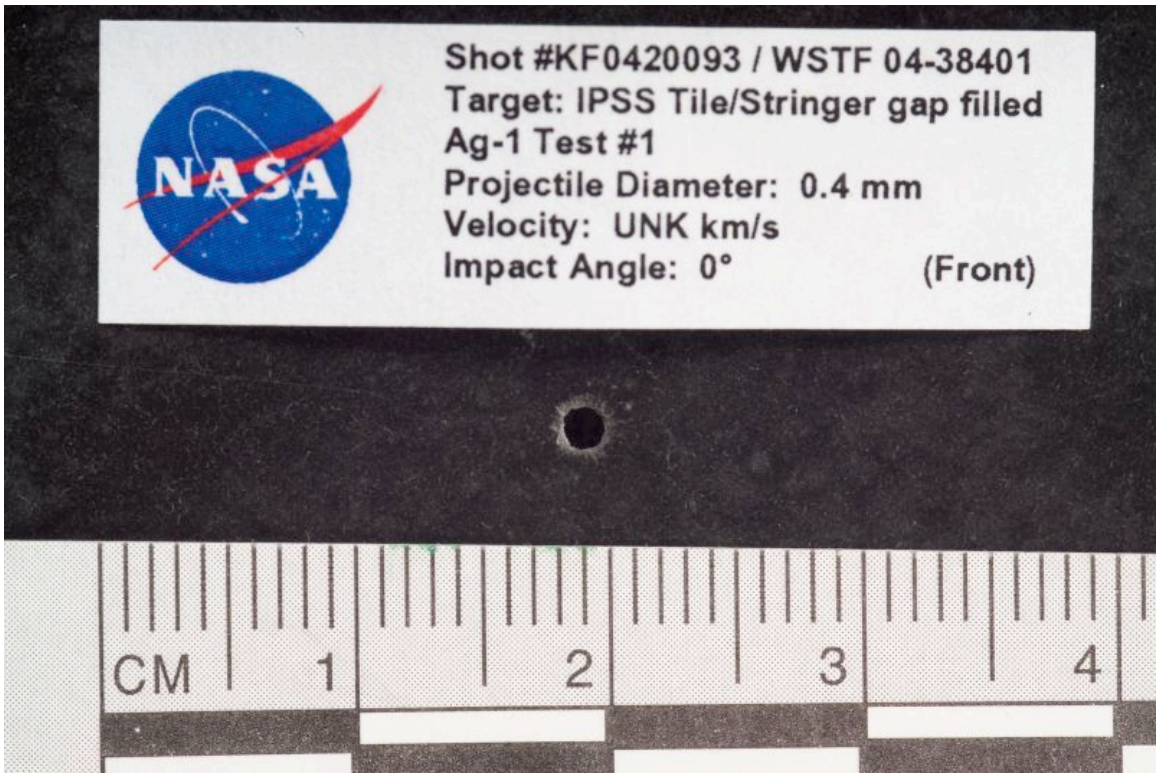

Figure 88: Ag-1 Shot #1 Impact Damage

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:

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:
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: 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:

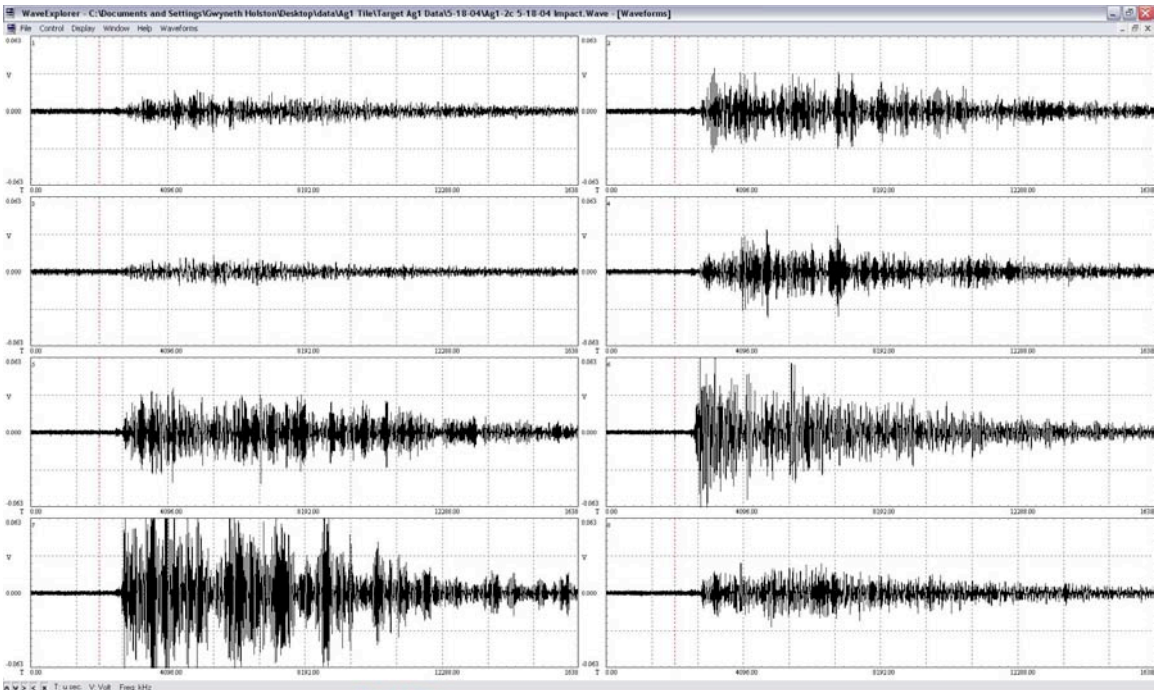

Figure 89: Ag-1 Shot #2 Impact Waveform

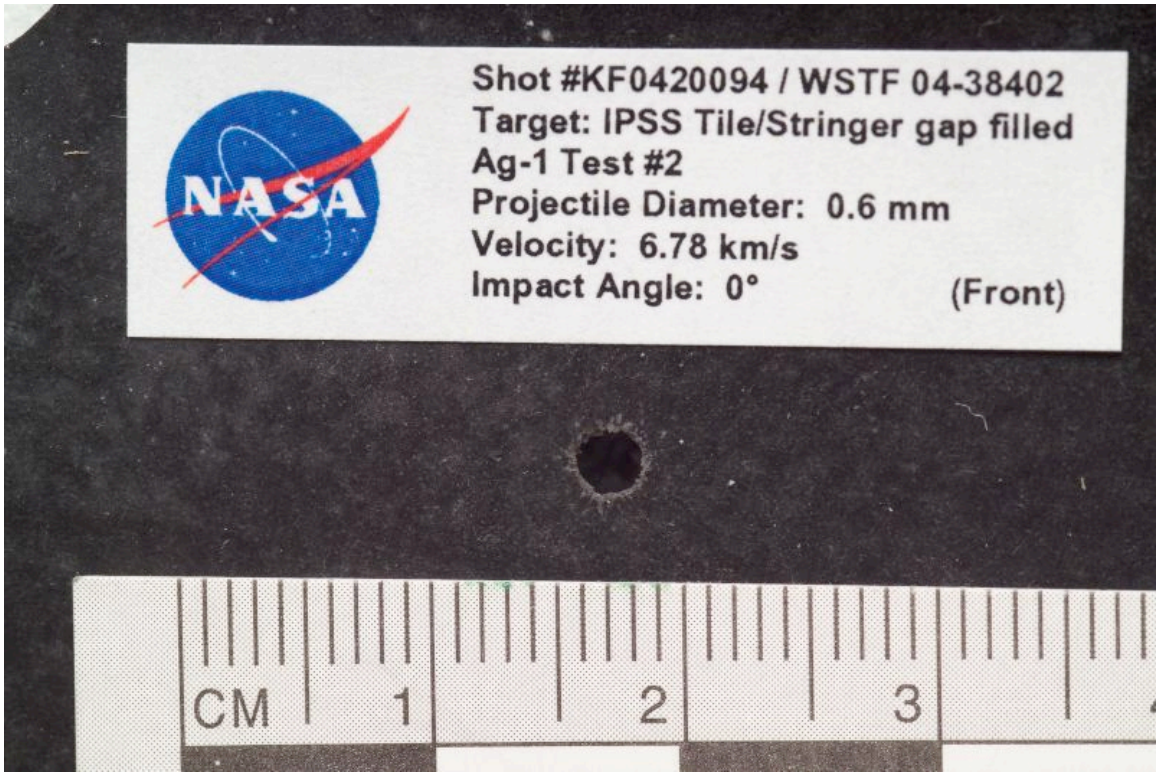

Figure 90: Ag-1 Shot #2 Impact Damage

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:

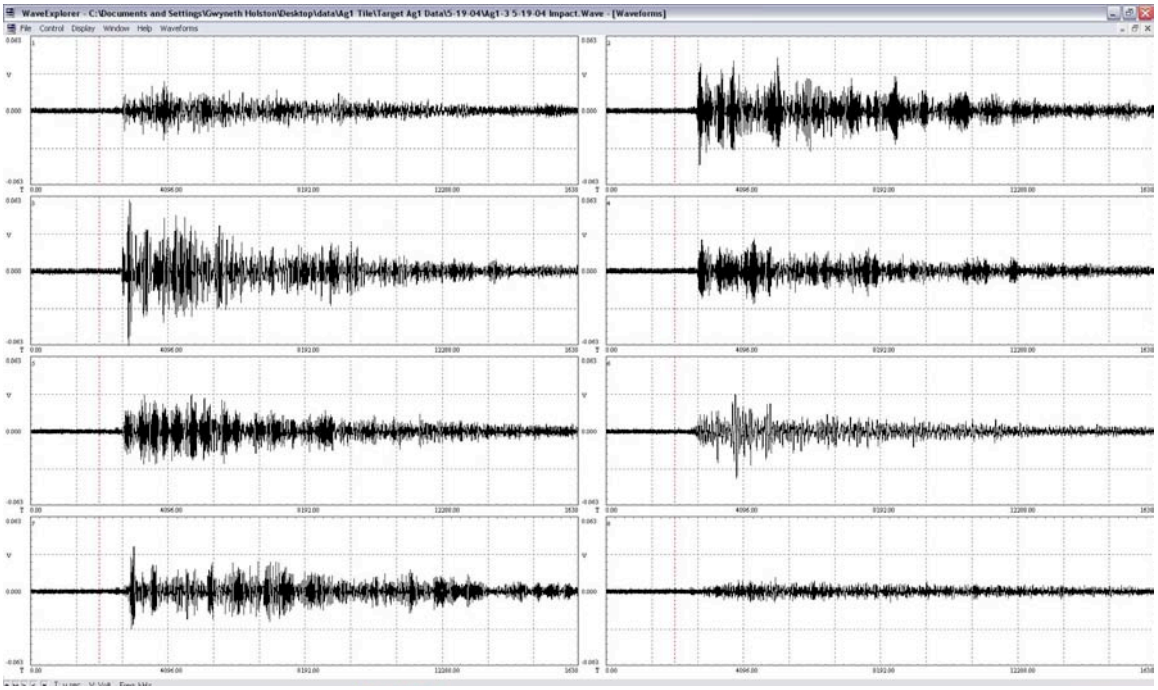

Figure 91: Ag-1 Shot #3 Impact Waveform

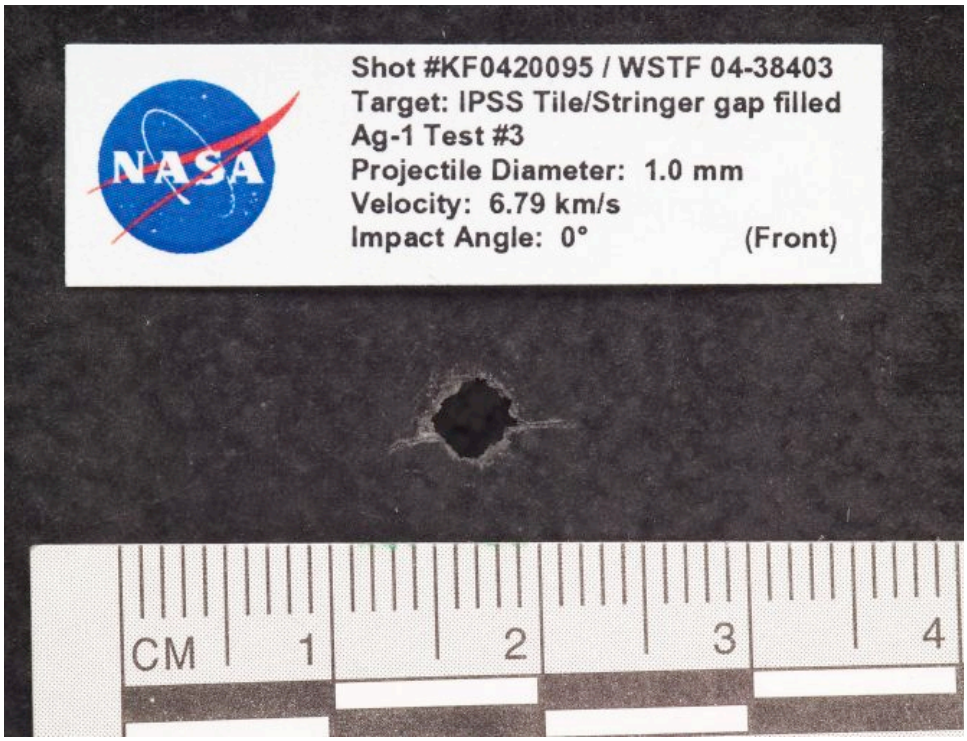

Figure 92: Ag-1 Shot #3 Impact Damage

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:

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: Ag1-4 5-19-04 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:
Impact coordinates:
Damage description and comments:

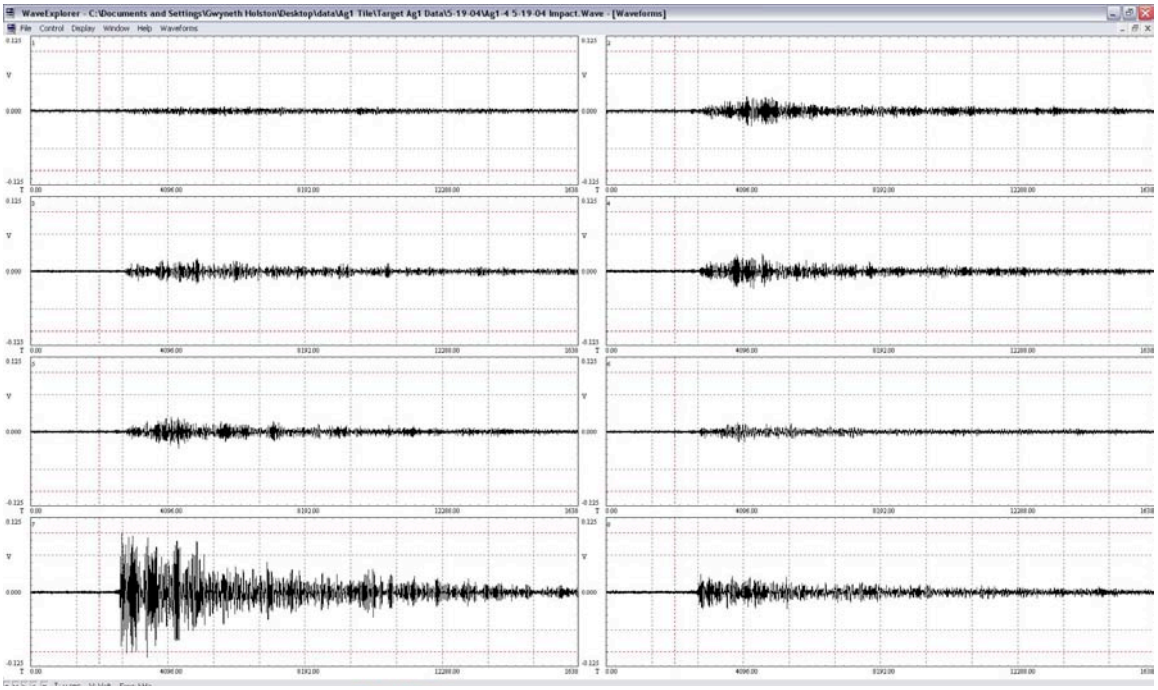

Figure 93: Ag-1 Shot #4 Impact Waveform

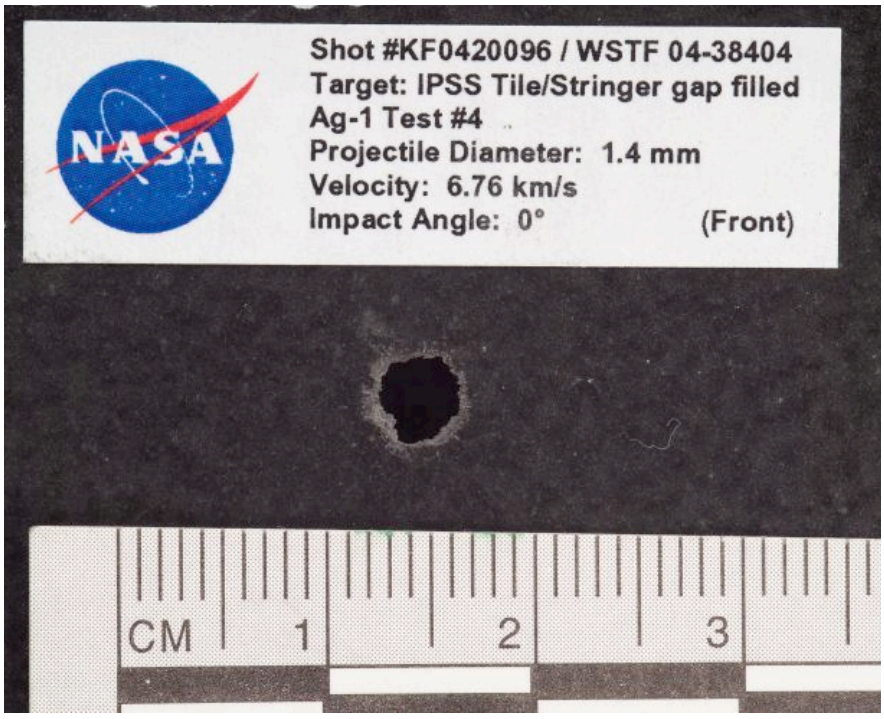

Figure 94: Ag-1 Shot #4 Impact Damage

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:

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: Ag1-5 5-20-04 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: 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:

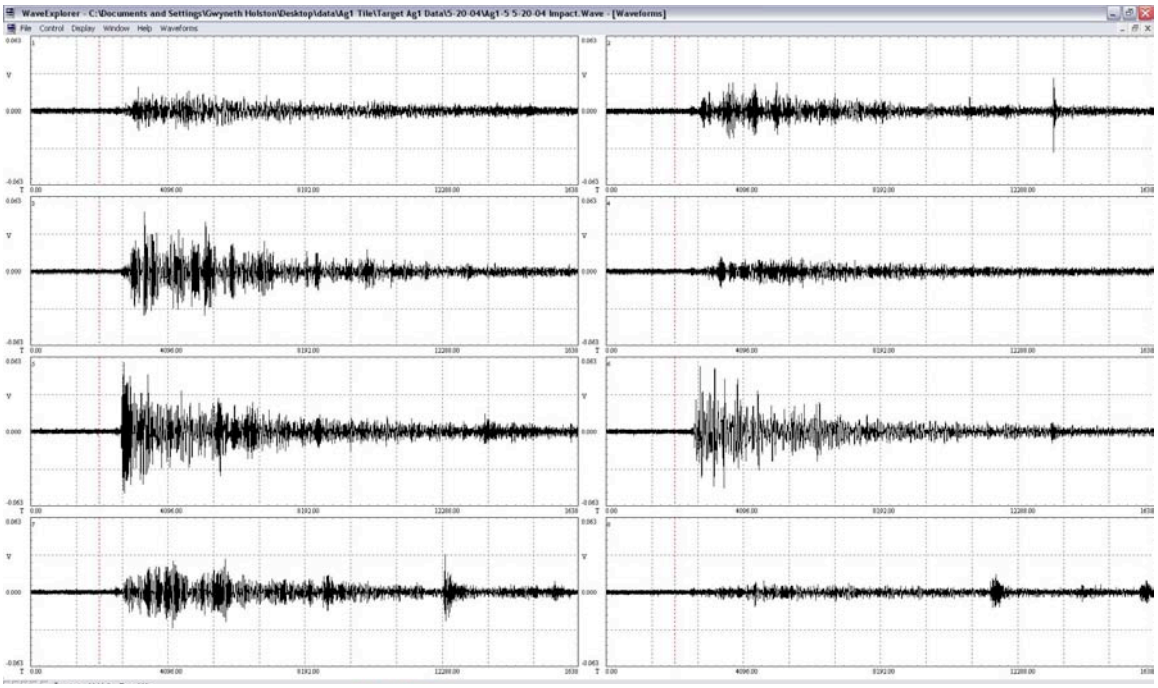

Figure 95: Ag-1 Shot #5 Impact Waveform

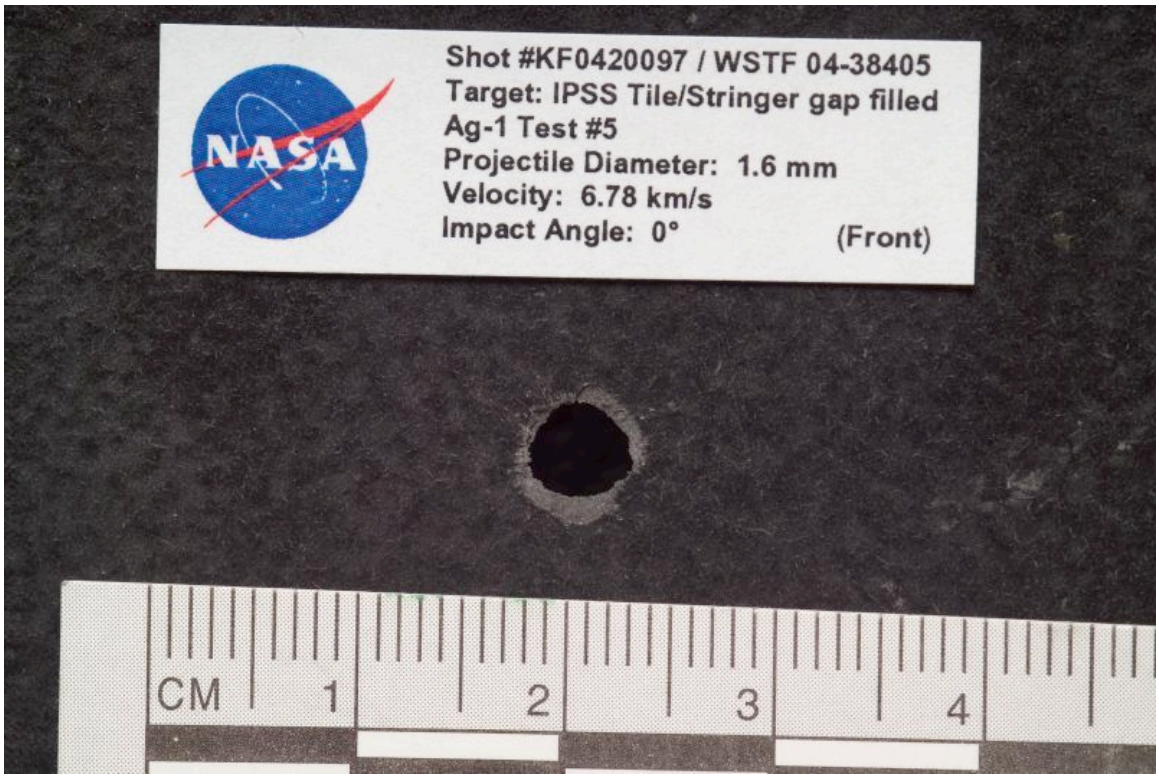

Figure 96: Ag-1 Shot #5 Impact Damage

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:

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:

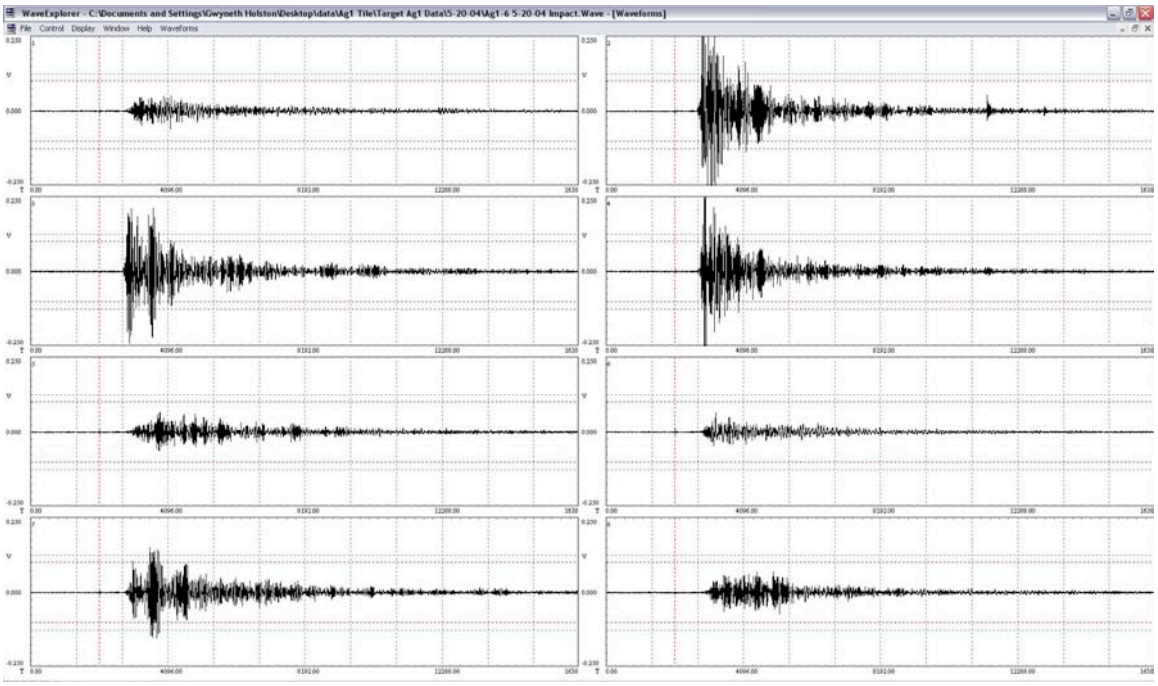

Figure 97: Ag-1 Shot #6 Impact Waveform

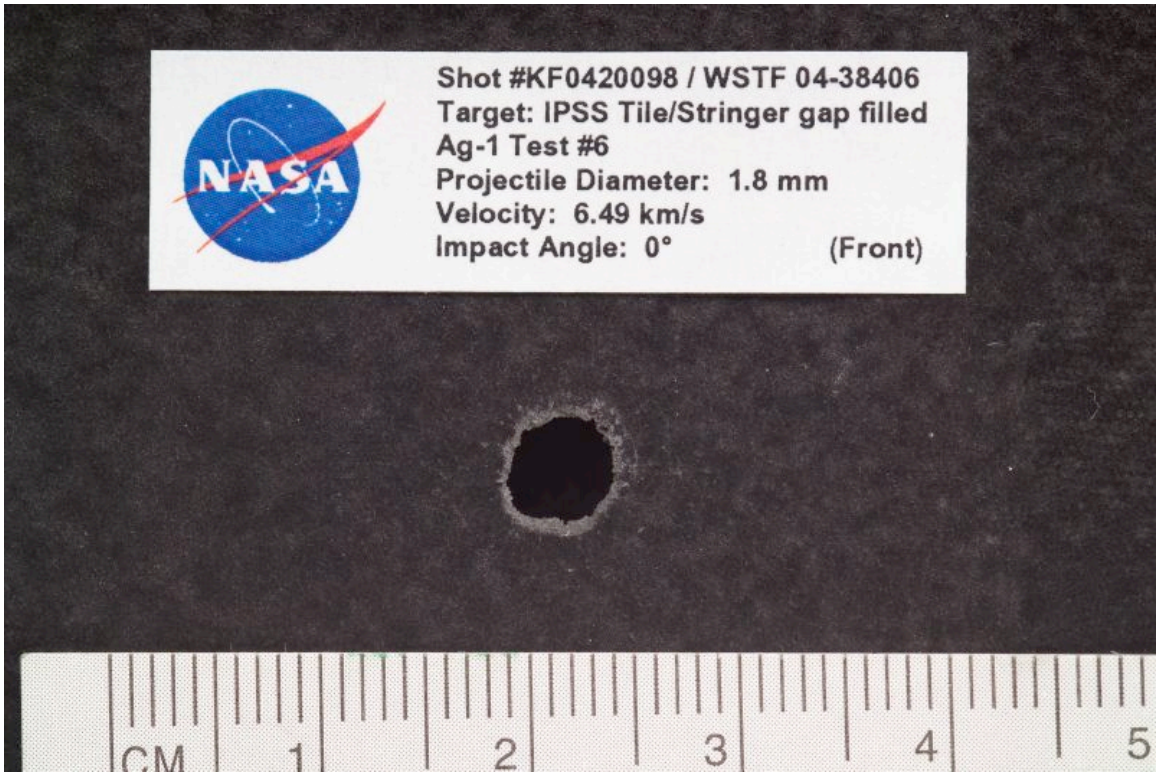

Figure 98: Ag-1 Shot #6 Impact Damage

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:

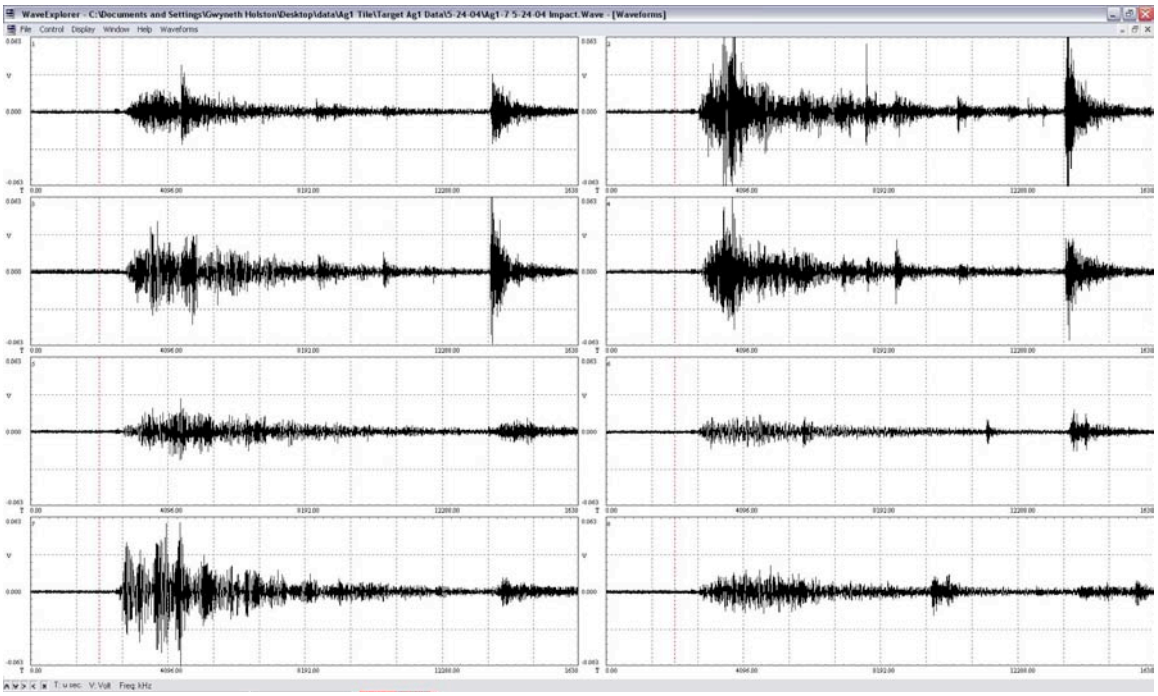

Figure 99: Ag-1 Shot #7 Impact Waveform

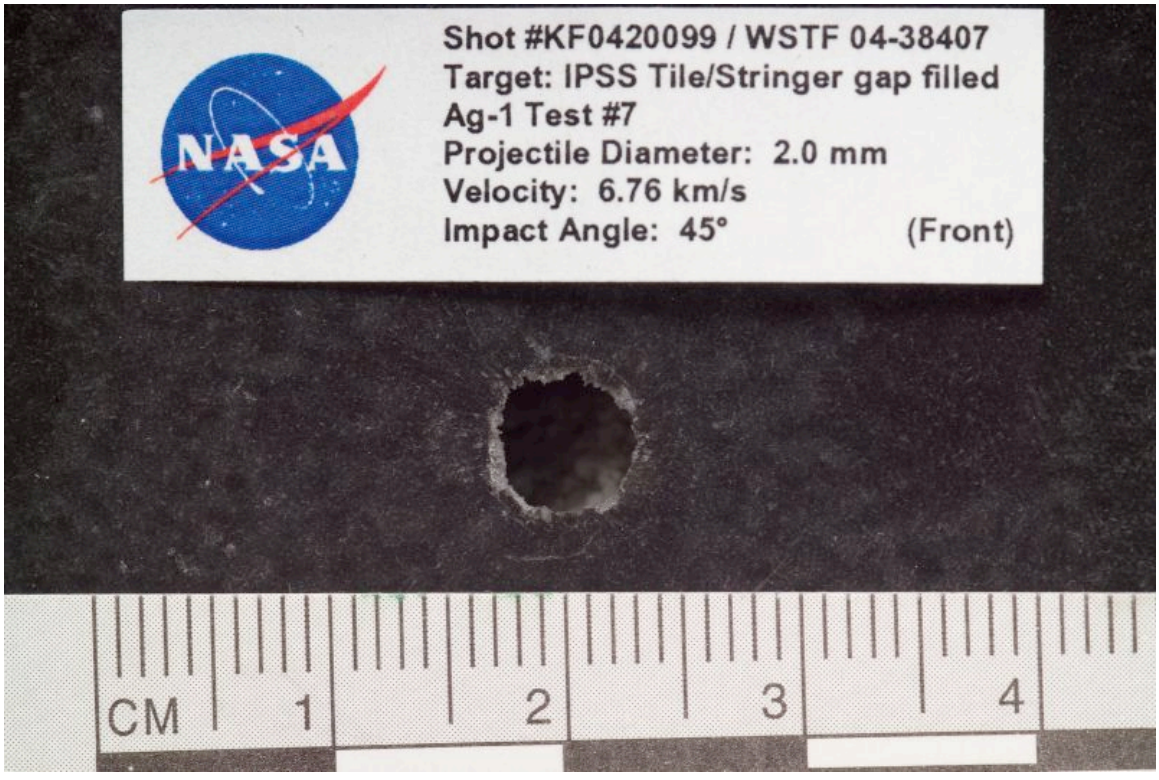

Figure 100: Ag-1 Shot #7 Impact Damage

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:

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
Comments: Impact on event 6. Signals clipped unexpectedly.

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:

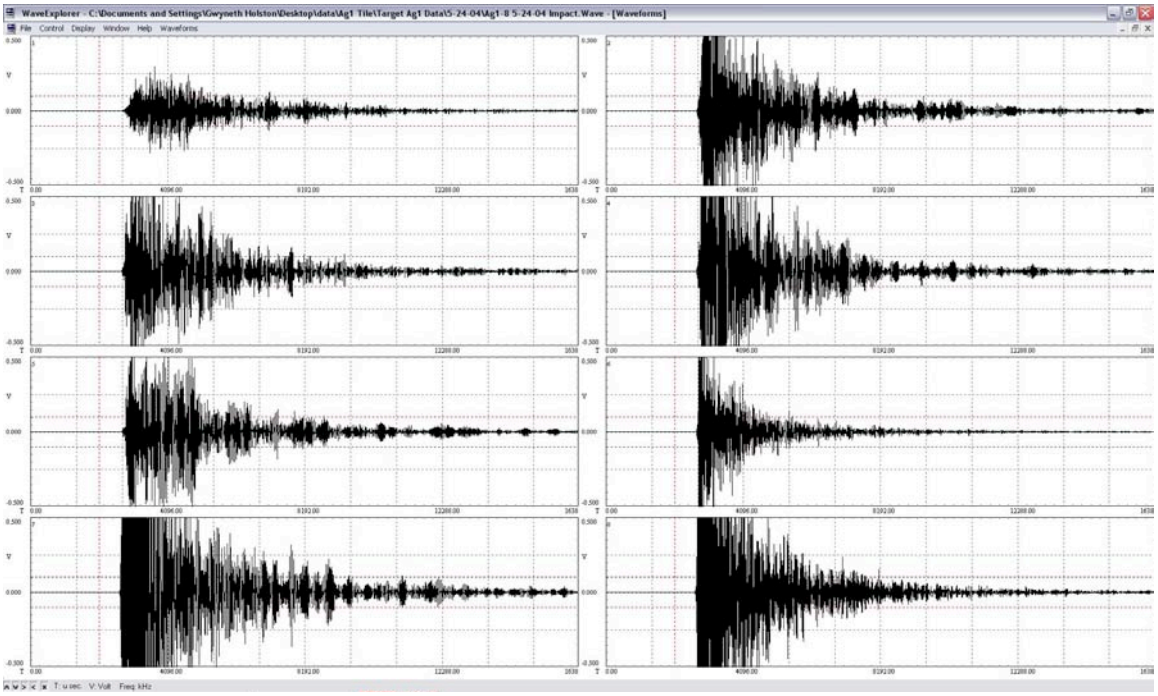

Figure 101: Ag-1 Shot #8 Impact Waveform

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. 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: Ag1-9 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:

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:

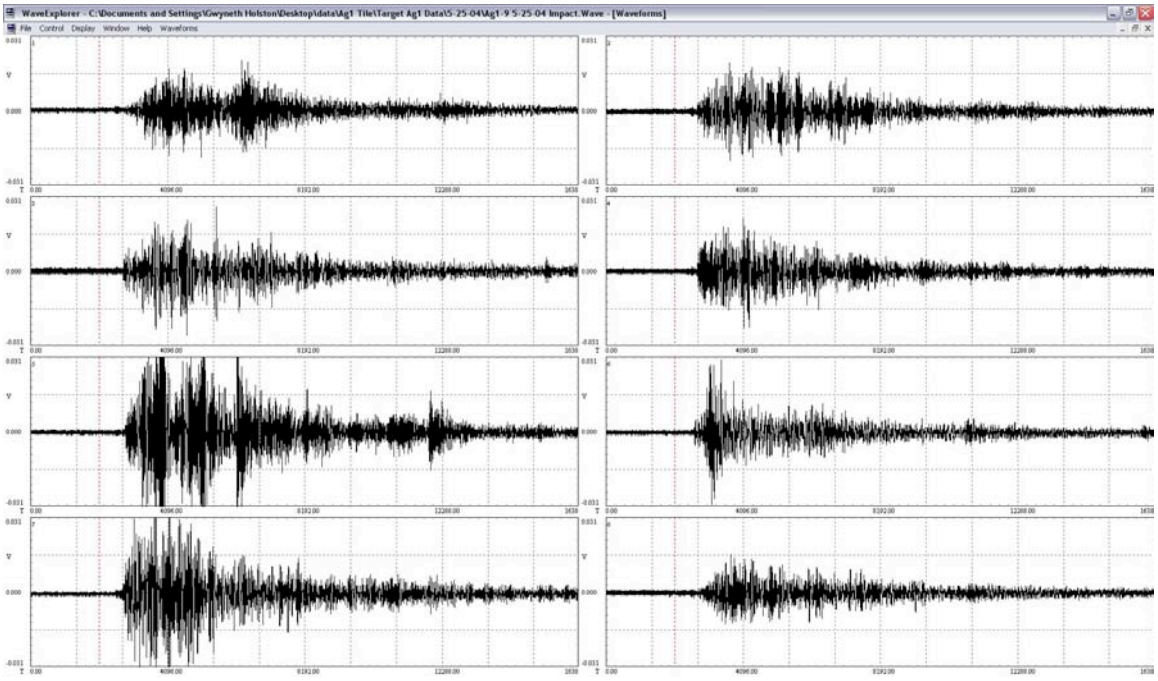

Figure 103: Ag-1 Shot #9 Impact Waveform

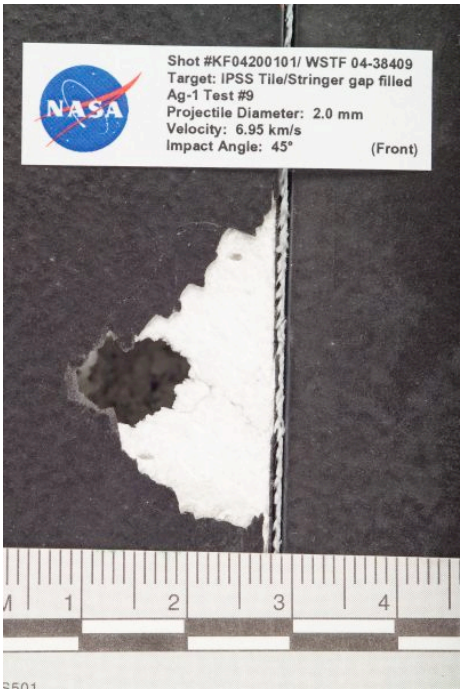

Figure 104: Ag-1 Shot #9 Impact Damage

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:

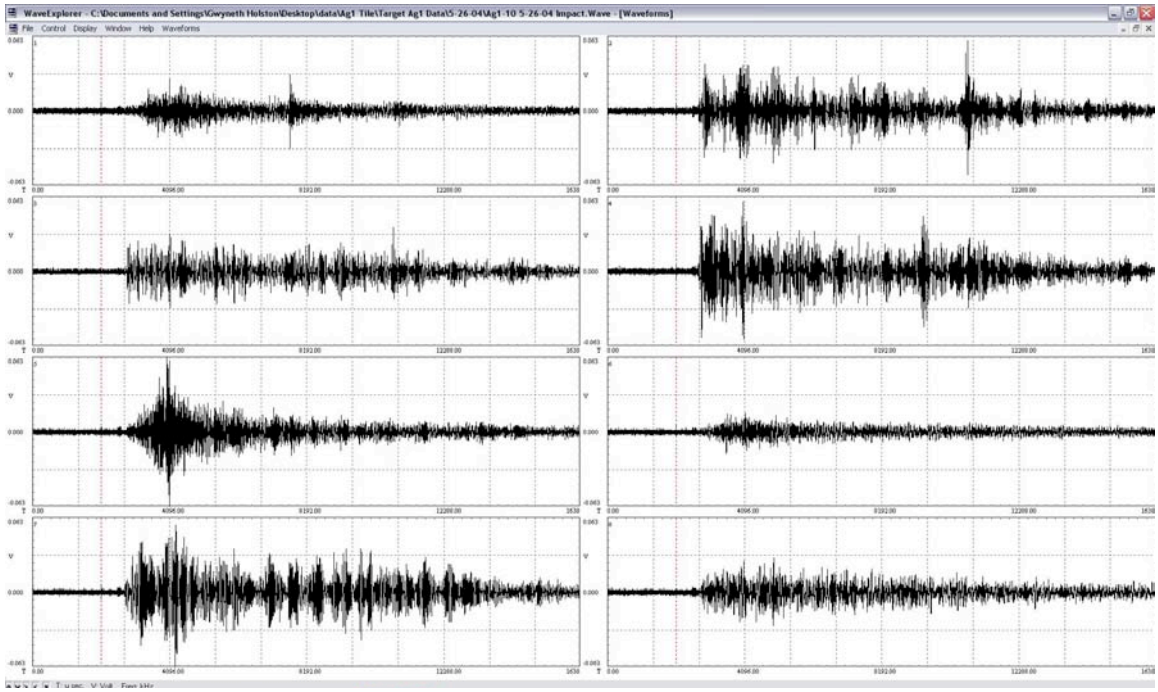

Figure 105: Ag-1 Shot #10 Impact Waveform

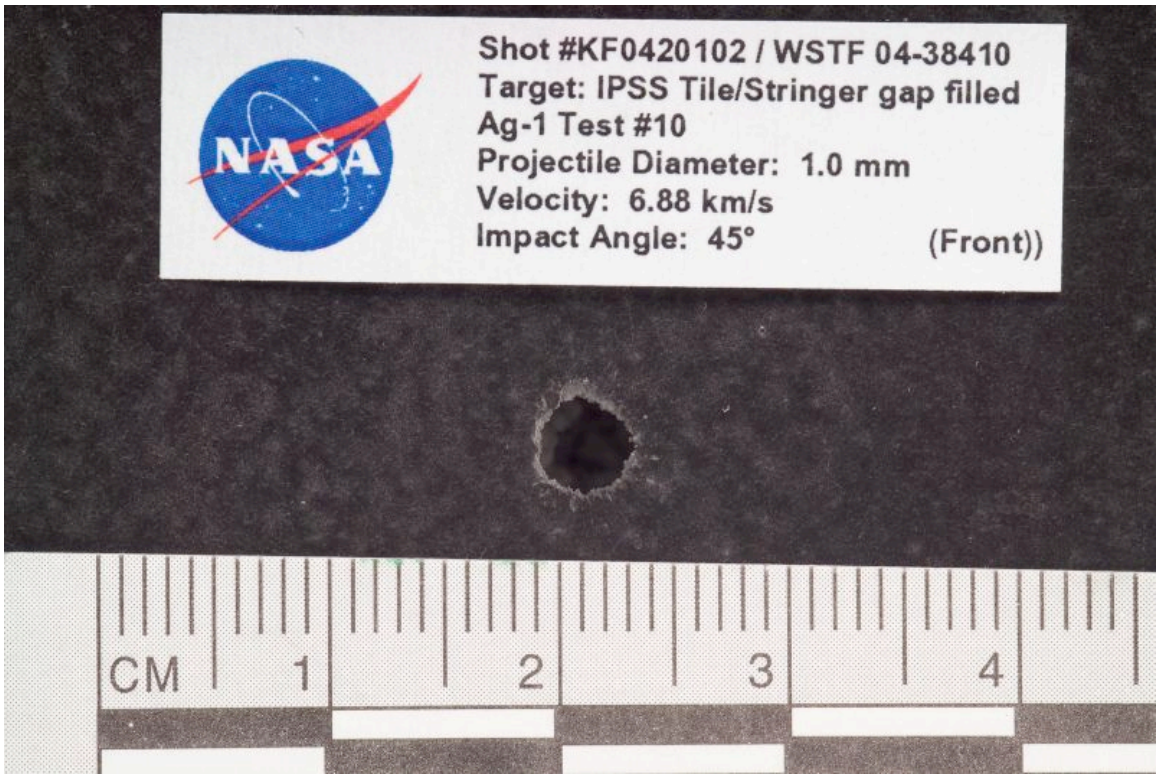

Figure 106: Ag-1 Shot #10 Impact Damage

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:

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:

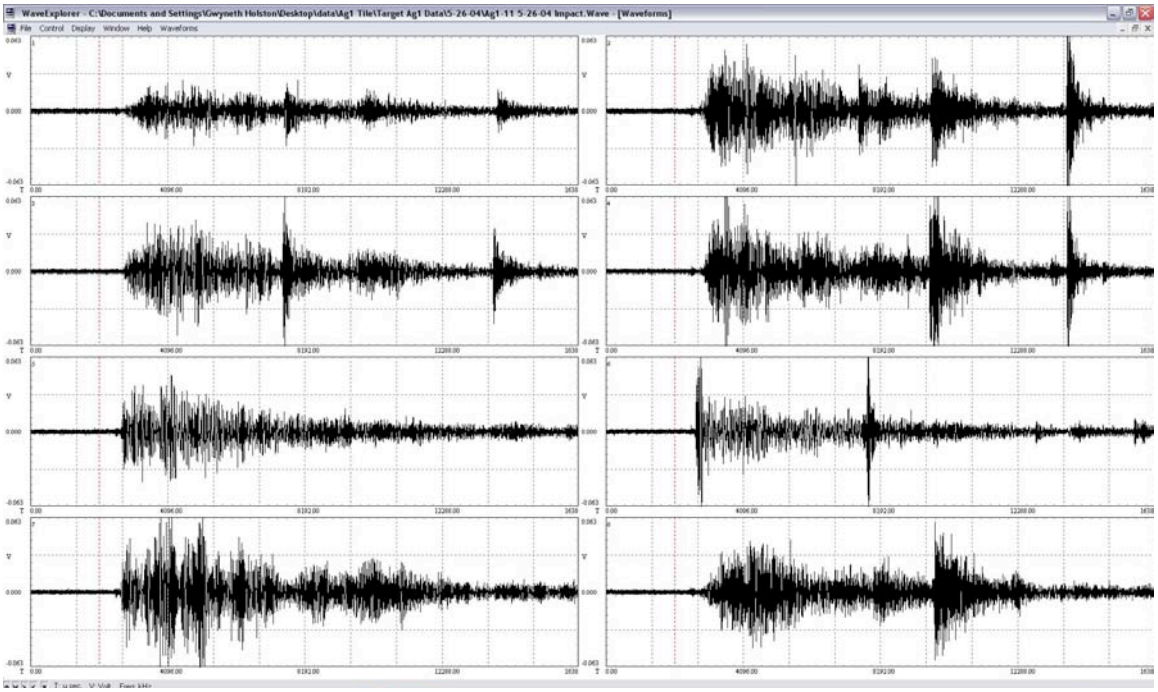

Figure 107: Ag-1 Shot #11 Impact Waveform

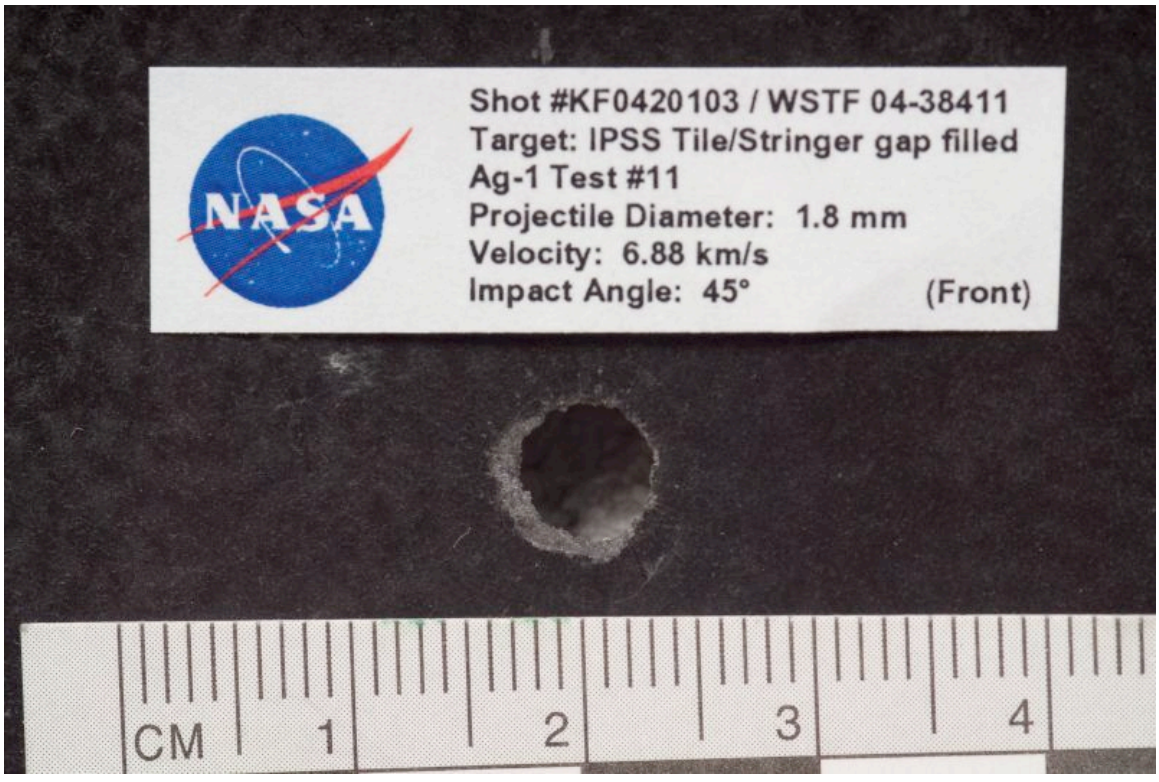

Figure 108: Ag-1 Shot #11 Impact Damage

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:

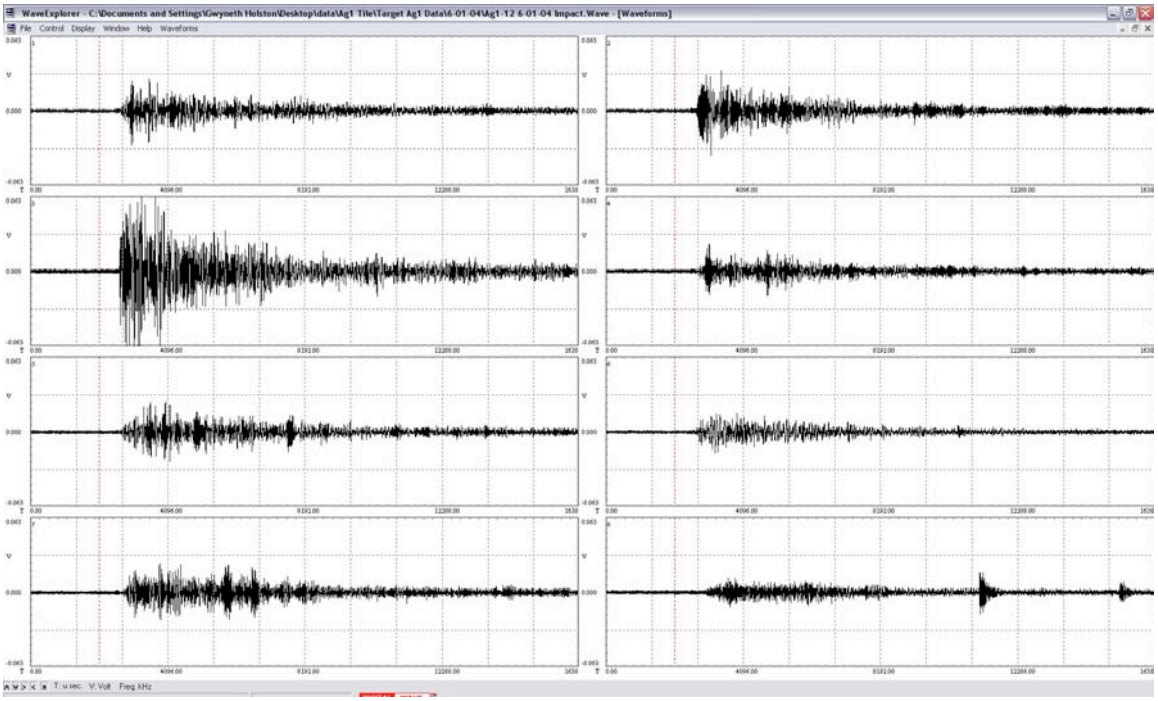

Figure 109: Ag-1 Shot #12 Impact Waveform

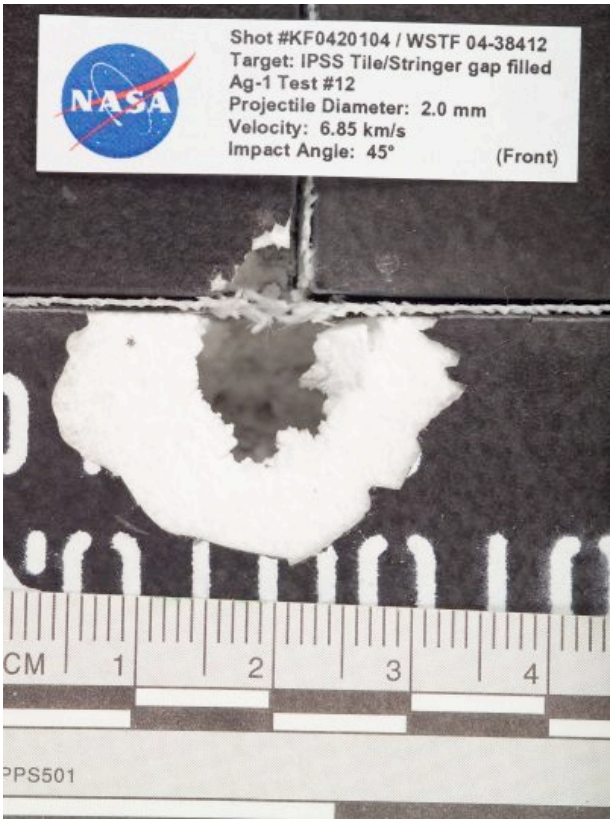

Figure 110: Ag-1 Shot #12 Impact Damage

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
Comments: Impact on event 8. Clipping.

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:

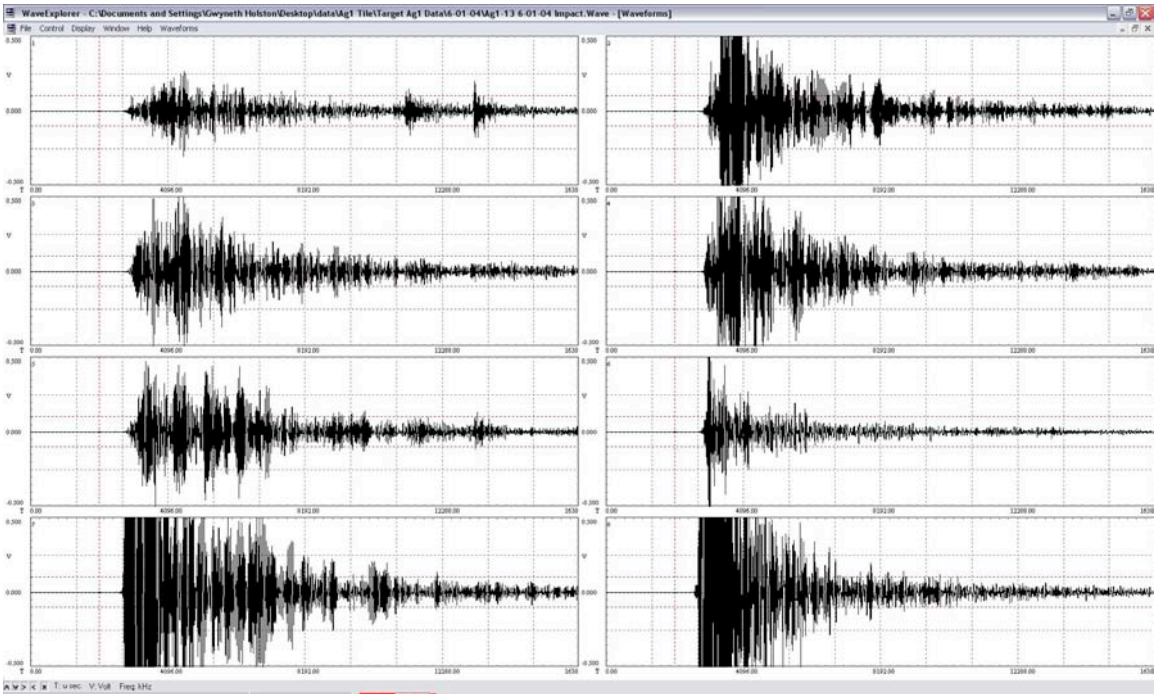

Figure 111: Ag-1 Shot #13 Impact Waveform

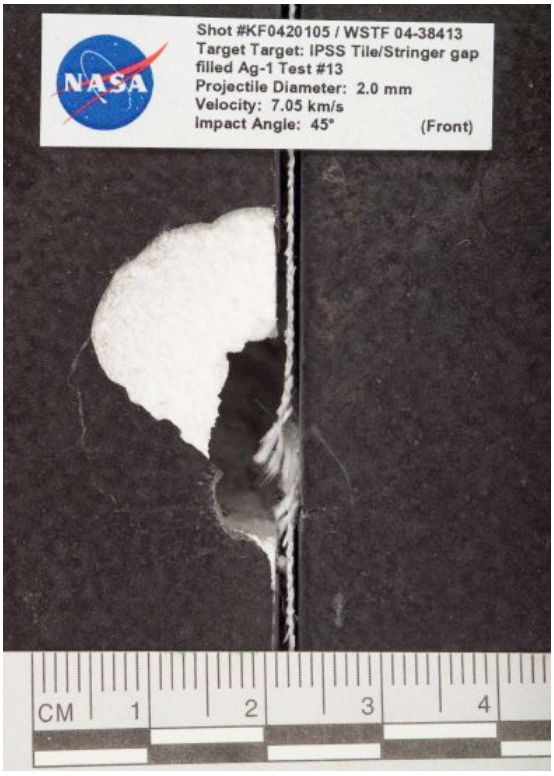

Figure 112: Ag-1 Shot #13 Impact Damage

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:

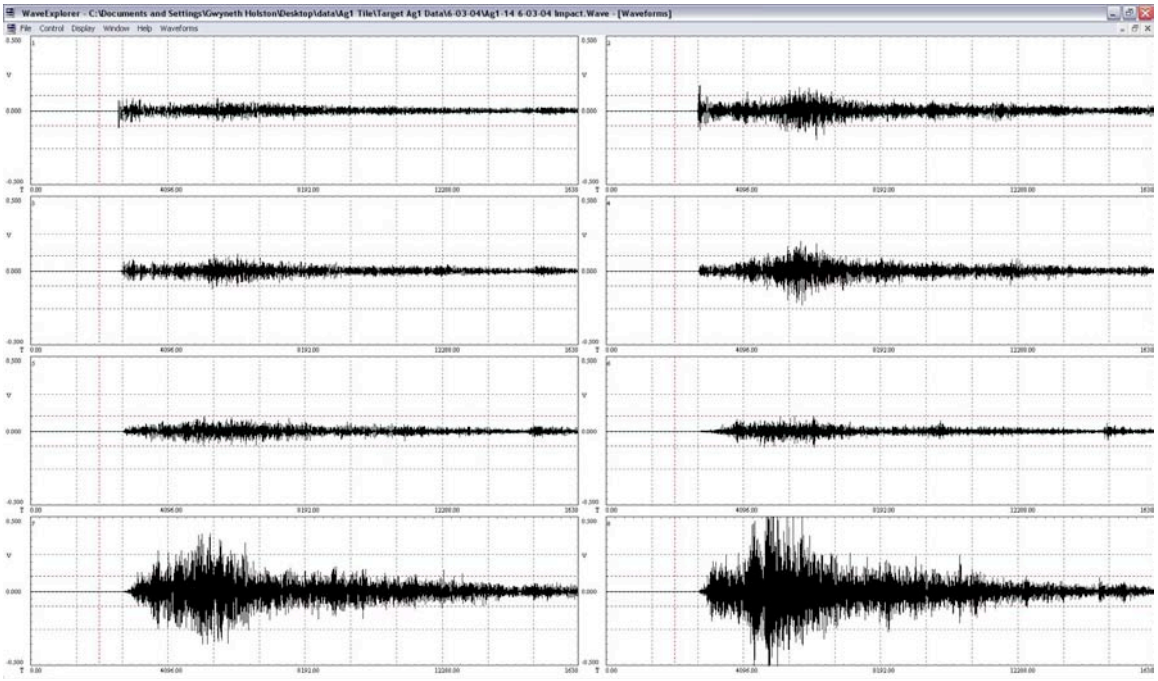

Figure 113: Ag-1 Shot #14 Impact Waveform

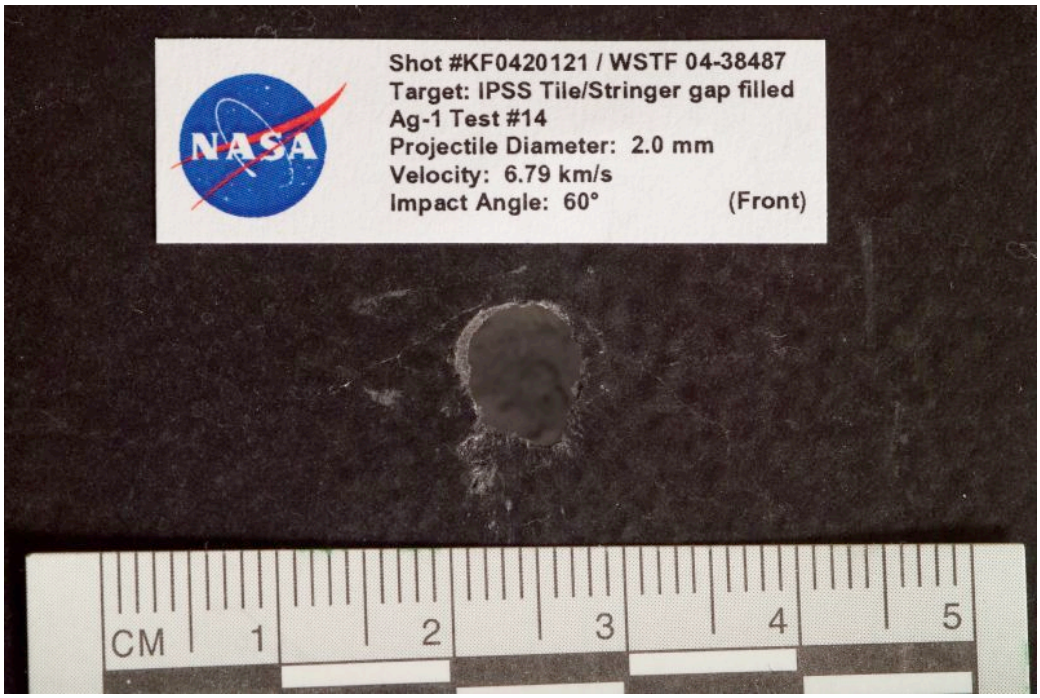

Figure 114: Ag-1 Shot #14 Impact Damage

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 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: Ag1-15 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: 6
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:

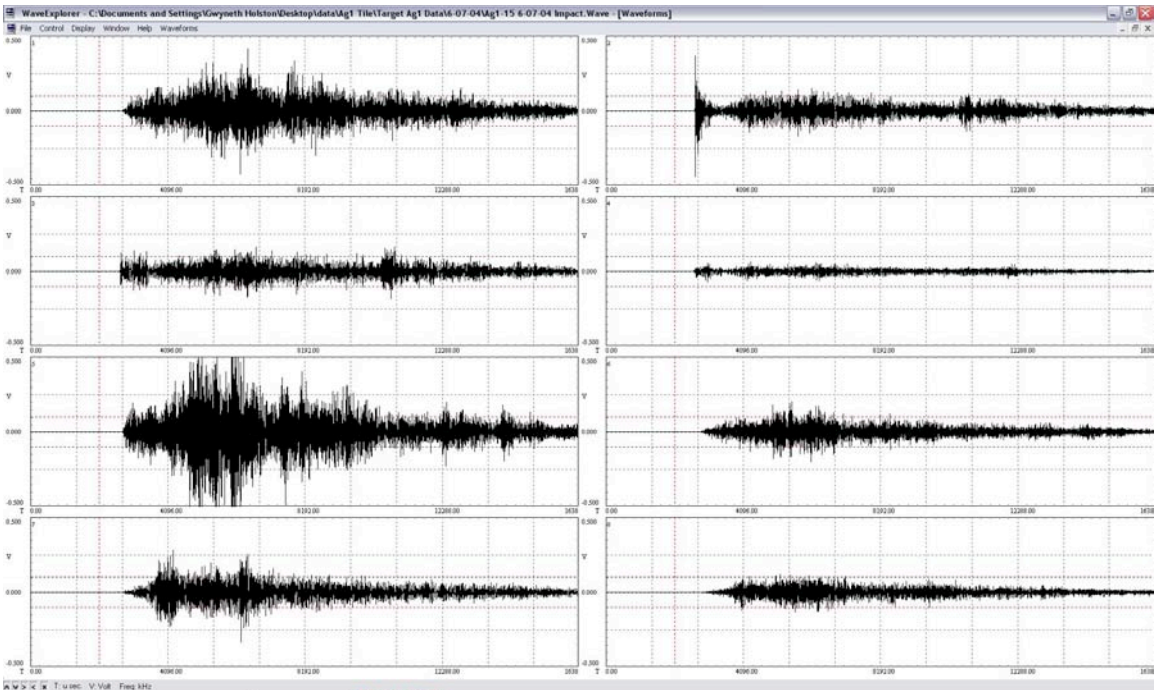

Figure 115: Ag-1 Shot #15 Impact Waveform

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:

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:

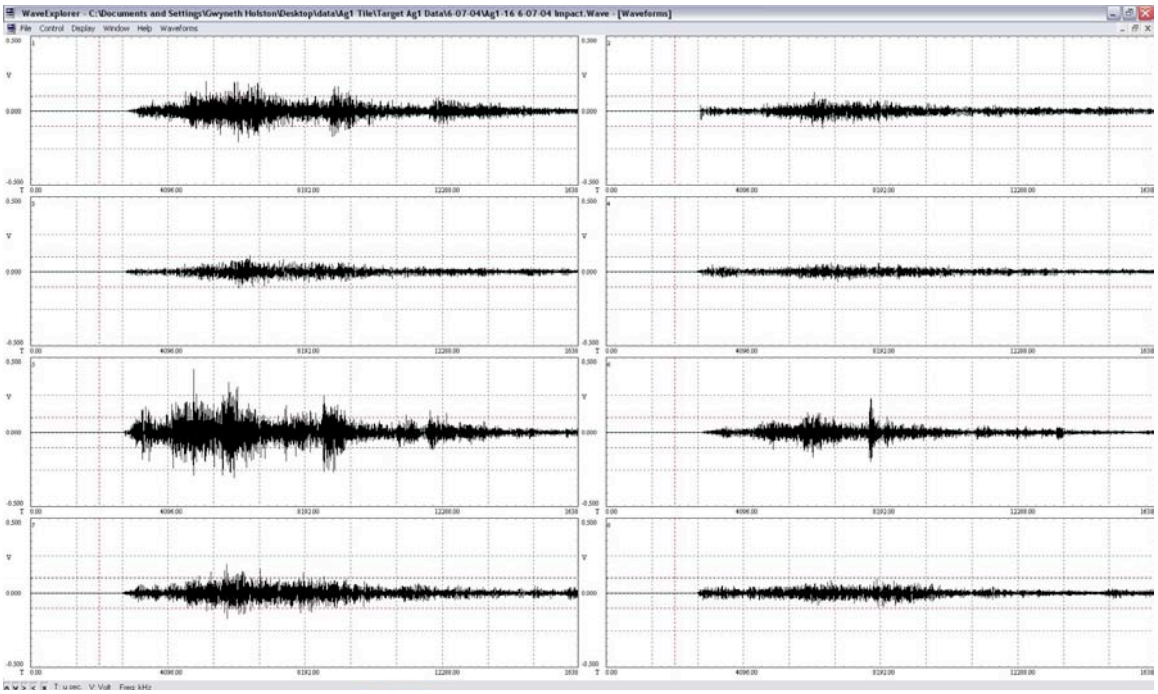

Figure 117: Ag-1 Shot #16 Impact Waveform

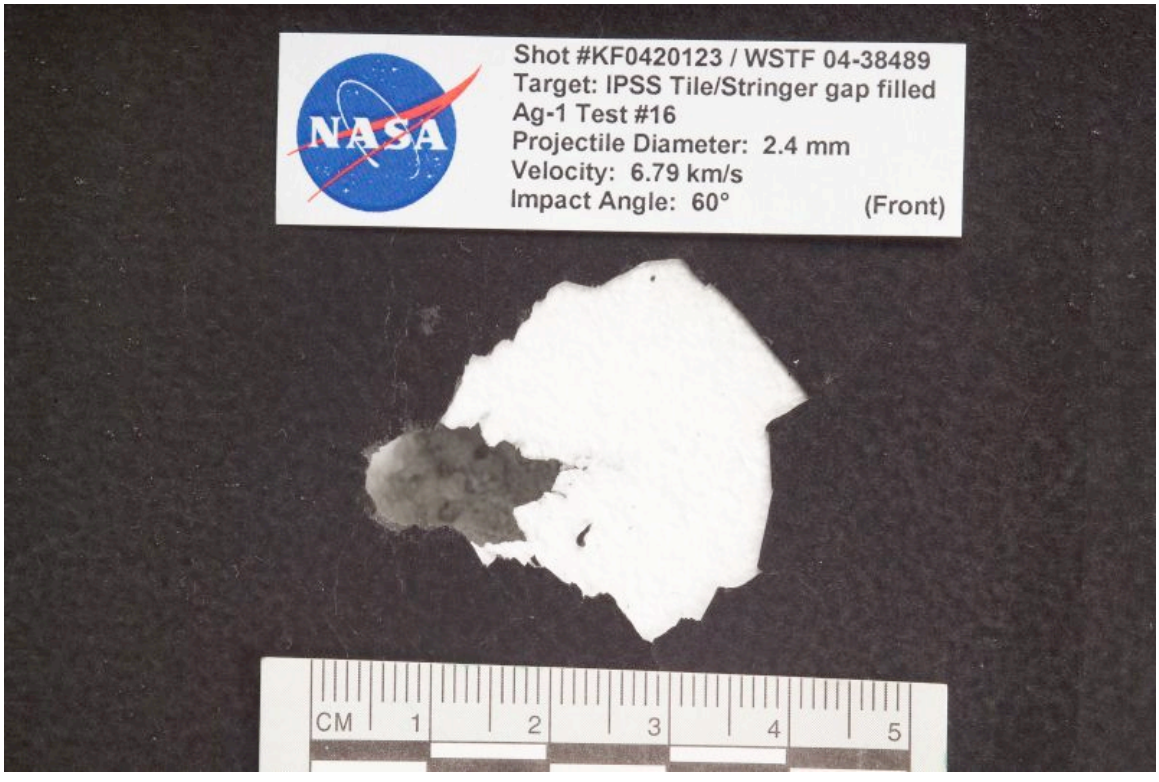

Figure 118: Ag-1 Shot #16 Impact Damage

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.
PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
01- 09 - 2007	Contractor Report	

4. TITLE AND SUBTITLE

Hypervelocity Impact (HVI) - Volume 8: Tile Small Targets A-1, Ag-1, B-1, and Bg-1

5a. CONTRACT NUMBER

NNL05AC19T

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Gorman, Michael R.; and Ziola, Steven M.

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

377816.06.03.03.06

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

NASA Langley Research Center
Hampton, VA 23681-2199

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSOR/MONITOR'S ACRONYM(S)

NASA

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

NASA/CR-2007-214885/Vol8

12. DISTRIBUTION/AVAILABILITY STATEMENT

Unclassified - Unlimited
Subject Category 70
Availability: NASA CASI (301) 621-0390

13. SUPPLEMENTARY NOTES

Langley Technical Monitor: Eric I. Madaras
An electronic version can be found at http://ntrs.nasa.gov

14. ABSTRACT

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.

15. SUBJECT TERMS

Hypervelocity impact tests; Space shuttle; Wing leading edge; Debris; Impact damage

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			STI Help Desk (email: help@sti.nasa.gov)
					19b. TELEPHONE NUMBER *(Include area code)*
U	U	U	UU	154	(301) 621-0390