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Hypervelocity Impact (HVI)

Volume 7: WLE High Fidelity Specimen RCC16R

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

September 2007

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National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23681-2199

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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 Target RCC16R was to study hypervelocity impacts through the reinforced carbon-carbon (RCC) panels of the Wing Leading Edge.

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 7: WLE High Fidelity Specimen RCC16R

Introduction

In the wake of the Columbia accident, NASA personnel decided to test the idea that acoustical sensors at ultrasonic frequencies could detect impacts during space flight. 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.

Target RCC16R was one 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 Target RCC16R and the test equipment, features tables of kinetic energy and damage results, and discusses the linear relationship between kinetic energy, ultrasonic wave signal energy and damage. Also discussed are wave propagation effects, the wave modes and their velocities, and location of impacts by analysis of wave arrival times.

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(RCC)-1 – Fiberglass in the shape of Wing Leading Edge
- Fg(RCC)-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
- Ag-1 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
- Bg-1 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

Target RCC16R consisted of an actual wing leading edge panel. Figure 1 shows the WLE panel with its complex metal joints. The spar was fastened to a support mount and floated into the target tank on a rail system designed and fabricated by WSTF Engineering (Figure 2 and Figure 3).

Figure 1: WLE Target RCC16R on Spar

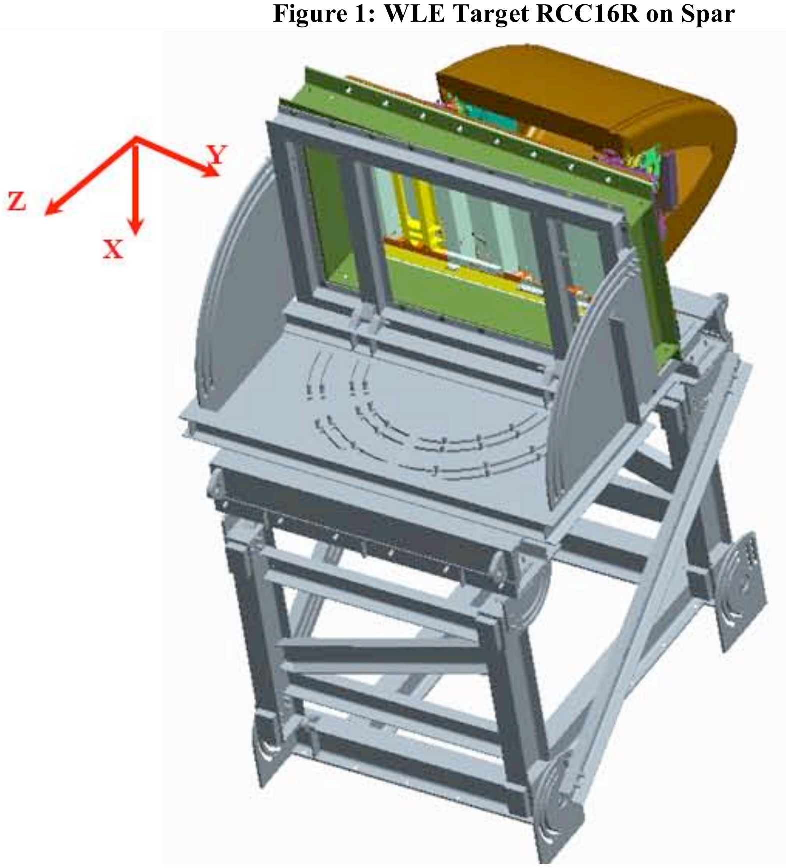

Figure 2: Model of Target RCC16R (brown), Spar (green), and Mount (gray)

Figure 3: Target RCC16R on Rail System.
Left: Left Side View. Right: Right Side View.

There were a total of 20 shots fired. The impact angle of the shots varied from 30 degrees to 90 degrees from the surface of the target.

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 0.4 mm to 2.8 mm. Impact velocity was measured with WSTF diagnostic equipment on each shot. The projectile kinetic energy for these shots ranged from 1.97 J to 736.62 J.

Four acoustic (ultrasonic) emission sensors were coupled to the flange, eight sensors were coupled to the inner surface of the target, and an additional four sensors were coupled to the spar with Lord 202 acrylic adhesive (Figure 4). On the shuttle, all sensors would be on the spar to be protected from the extreme heat of the WLE. Diagrams of the sensor layout are shown in Figure 5, Figure 6, Figure 7 and Figure 8. A photo of the post-test impact locations is shown in Figure 9.

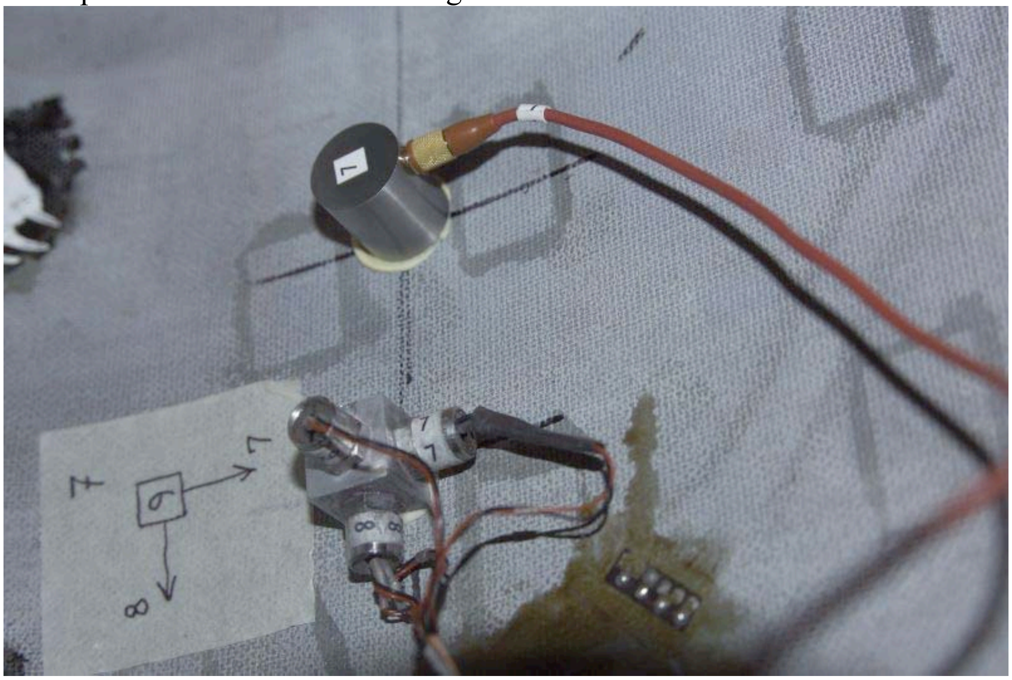

Figure 4: Detail of Sensor 7 on Target RCC16R. A triaxial accelerometer can also be seen adjacent.

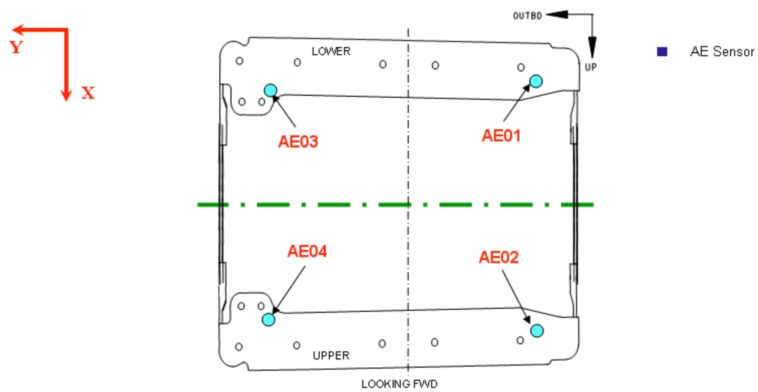

Figure 5: RCC16R Sensor Locations. Lower Flange.

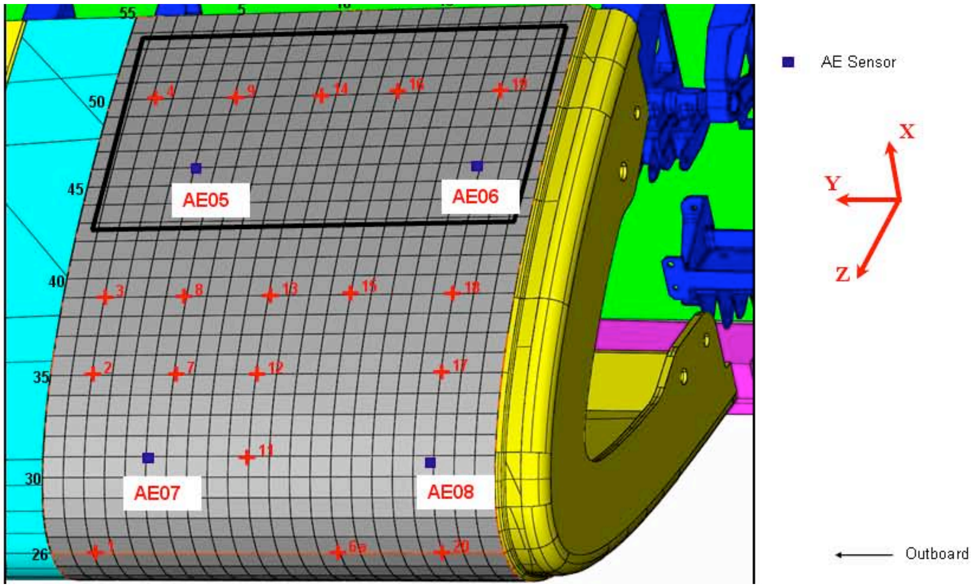

Figure 6: RCC16R Sensor and Impact Locations. Upper Panel.
Sensors have the following coordinates:
#5(46, 5), #6(46, 19), #7(31, 5), #8(31, 19) Dimensions are inches.
Impacts have the following coordinates:
#1(26, 2), #2(35, 2), #3(39, 2), #4(50, 2), #6a(26, 14), #7(35,6), #8(39,6), #9(50, 6), #11(31,10), #12(35,10), #13(39, 10), #14(50, 10), #15(39, 14), #16(50, 14), #17(35,19), #18(39,19), #19(50,19), #20(26, 19)

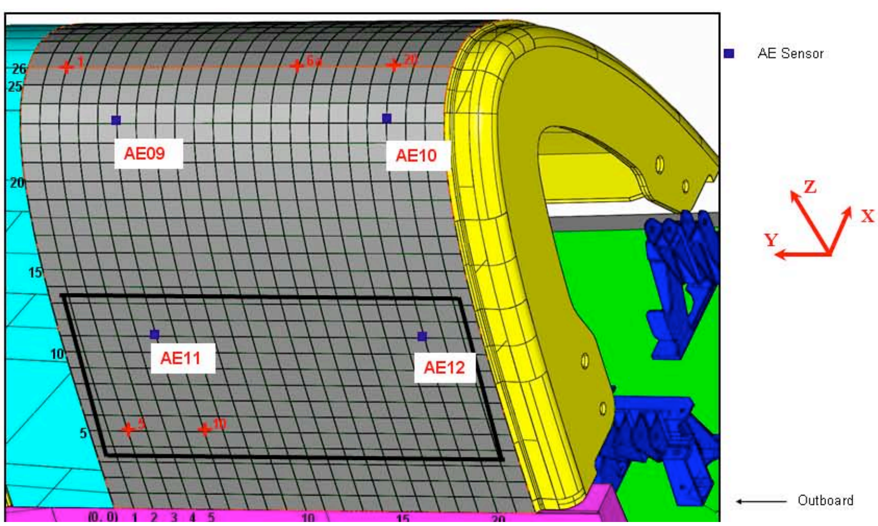

Figure 7: RCC16R Sensor and Impact Locations. Lower Panel.
Sensors have the following coordinates:
#9(23, 5), #10(23, 19), #11(11, 5), #12(11, 19) Dimensions are inches.
Impacts have the following coordinates:
#1(26, 2), #5(5, 2), #6a(26, 14), #10(5, 6), #20(26, 19)

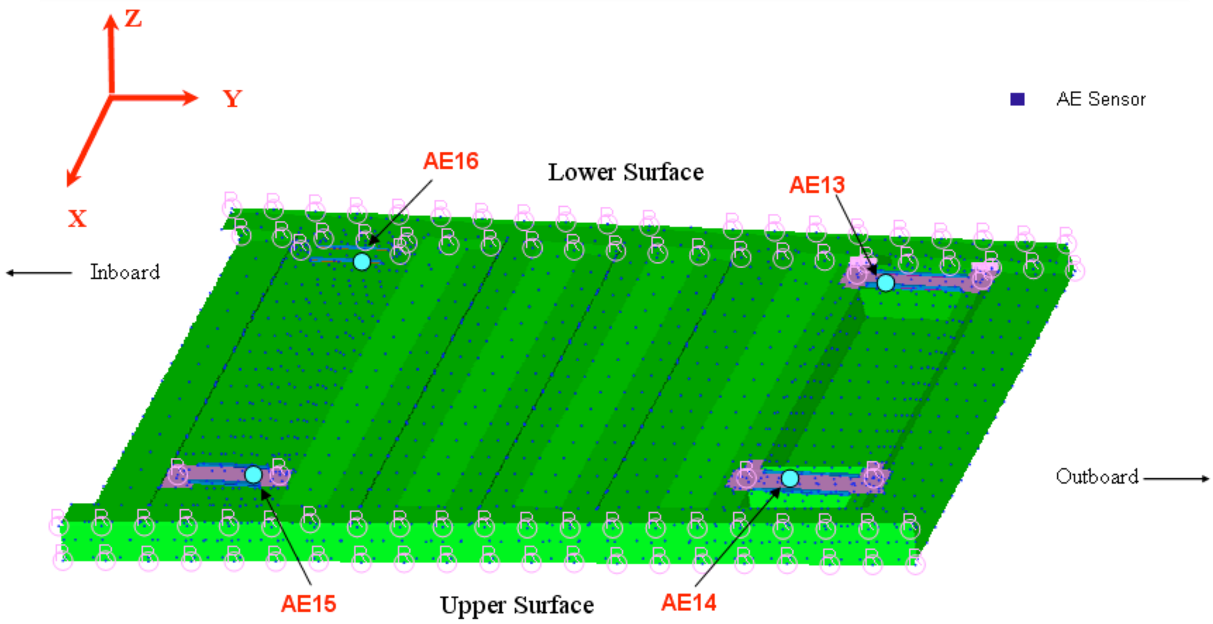

Figure 8: RCC16R Sensor Locations. Spar.

Figure 9: RCC16R Post-test Impact Locations. Left: Front View. Upper Right: Right View. Lower Right: Left View.

The piezoelectric sensor converted the sound wave energy to an electrical voltage. 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 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 10). 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.

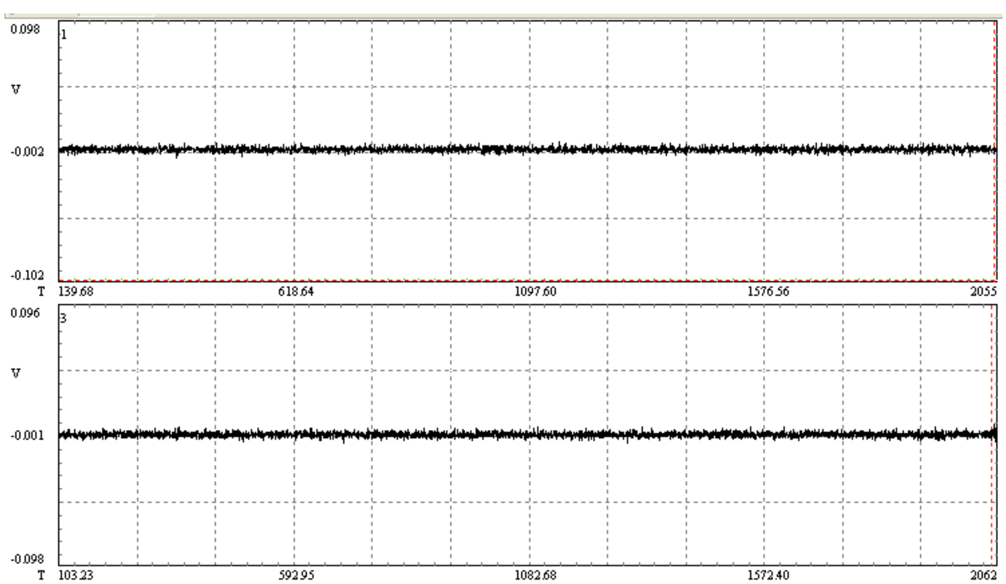

Figure 10: Example of DC Offset

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

A typical impact signal is shown in Figure 11. 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 12. 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 than the E wave characteristics. The vastly different velocities of the modes were used to confirm the modes's presence.

The sound waves produced by impact are shown complete in the Appendix to this section. 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 13). EMI exhibits no plate wave propagation characteristics.

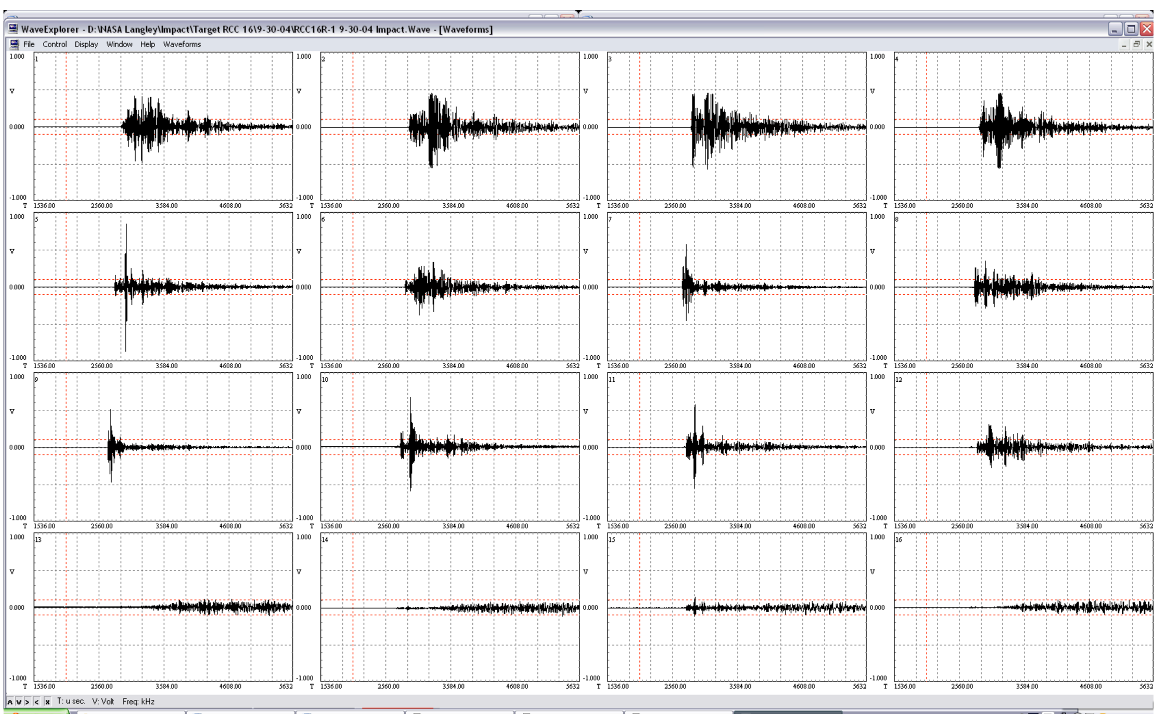

Figure 11: RCC16R Impact Signal for Shot #1

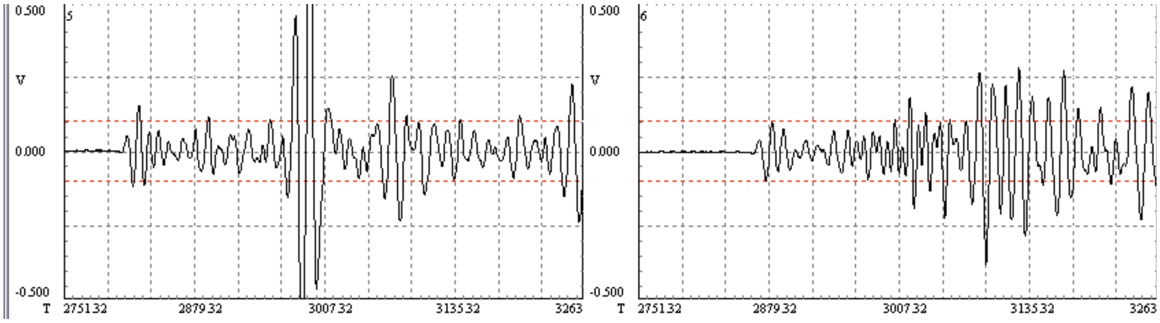

Figure 12: Detail of RCC16R Impact Signal for Shot #1, Channels 5 and 6

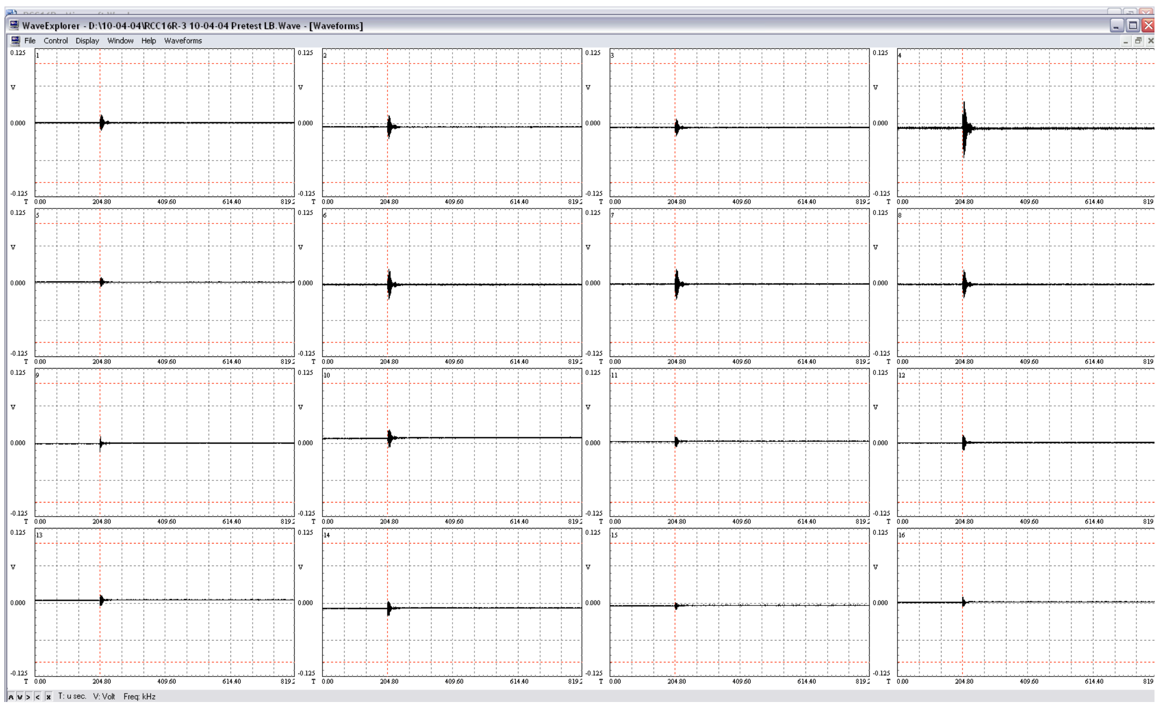

Figure 13: RCC16R Electromagnetic Interference for Shot #1

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 3.

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

$$G = 10^{\frac{M}{20}}$$ **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 along with the test number, impactor diameter, 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. = $mv^2/2$. 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.

	Imp Dia	Imp Ang	Normal K.E.	Total K.E.	W.S.E.
Test No.	mm	deg	J (± 5%)	J (± 5%)	nJ
RCC16R-1	0.4	90	2.14	2.14	4.233E+03
RCC16R-2	0.4	60	1.48	1.98	4.581E+03
RCC16R-3	1.0	45	17.30	34.64	6.522E+04
RCC16R-4	0.4	30	0.54	2.15	2.449E+03
RCC16R-5	0.6	45	3.35	6.71	1.539E+04
RCC16R-6a	0.8	90	17.68	17.68	4.637E+04
RCC16R-7	1.0	30	8.16	32.69	7.762E+04
RCC16R-8	0.8	60	12.40	16.54	3.361E+04
RCC16R-9b	1.2	30	14.11	56.48	1.742E+05
RCC16R-10	0.8	30	4.23	16.93	2.536E+04
RCC16R-11	1.2	60	42.96	57.31	1.988E+05
RCC16R-12	1.6	45	67.28	134.67	1.678E+05
RCC16R-13	2.0	45	126.07	252.33	1.375E+05
RCC16R-14	2.0	30	67.83	271.57	2.685E+05
RCC15R-15	0.8	60	12.36	16.49	3.541E+04
RCC16R-16	1.6	45	68.67	137.45	2.267E+05
RCC16R-17	2.4	30	117.89	471.99	1.946E+05
RCC16R-18	1.2	60	41.71	55.65	9.876E+04
RCC16R-19	2.4	45	223.75	447.86	3.988E+05
RCC16R-20	2.8	90	736.62	736.62	7.646E+05

Table 1: RCC16R Kinetic Energy and Wave Signal Energy (All Sensors).

The damage measurements were crude. Although some damage in the interior plies seemed apparent, see Figure 14, the “coating area damage” value that was plotted against KE was related solely to the area the damaged coating occupied as measured with a ruler on the outside (the impact side) surface. ‘Crater volume damage’ is the product of the crater length, width, and depth measurements. If a shot created a hole, the crater depth was assumed to be the thickness of the panel, 6 mm. ‘Spalling volume damage’ refers to the amount of material that detached from the target after impact. Due to low kinetic energy, there was no recorded coating area damage for shots #1, 2, or 4 and no recorded spalling damage for shots #1, 2, 4, 5, 8, or 10.

	Total K.E.	Normal K.E.	Crater Vol	Coating Damage	Spalling Volume
Test No.	J (± 5%)	J (± 5%)	mm^3	mm^2	mm^3
RCC16R-1	2.14	2.14	7.0		
RCC16R-2	1.98	1.48	13.0		
RCC16R-3	34.64	17.30	44.6	115.5	41.0
RCC16R-4	2.15	0.54	2.4		
RCC16R-5	6.71	3.35	20.9	37.5	
RCC16R-6a	17.68	17.68	29.7	138.0	27.0
RCC16R-7	32.69	8.16	187.6	120.8	49.5
RCC16R-8	16.54	12.40	14.8	52.5	
RCC16R-9b	56.48	14.11	75.1	126.5	38.7
RCC16R-10	16.93	4.23	25.6	56.0	
RCC16R-11	57.31	42.96	30.0	210.0	111.6
RCC16R-12	134.67	67.28	195.0	390.0	132.5
RCC16R-13	252.33	126.07	432.0	517.0	280.8
RCC16R-14	271.57	67.83	198.0	430.0	183.8
RCC15R-15	16.49	12.36	36.7	99.8	22.3
RCC16R-16	137.45	68.67	84.0	387.0	198.9
RCC16R-17	471.99	117.89	567.0	568.1	45.8
RCC16R-18	55.65	41.71	52.5	175.0	63.0
RCC16R-19	447.86	223.75	630.0	832.0	497.3
RCC16R-20	736.62	736.62	1261.5	1278.0	519.5

Table 2: RCC16R Damage Results.
No coating damage was recorded for shots #1, 2, and 4. No spalling volume damage was recorded for shots #1, 2, 4, and 5.

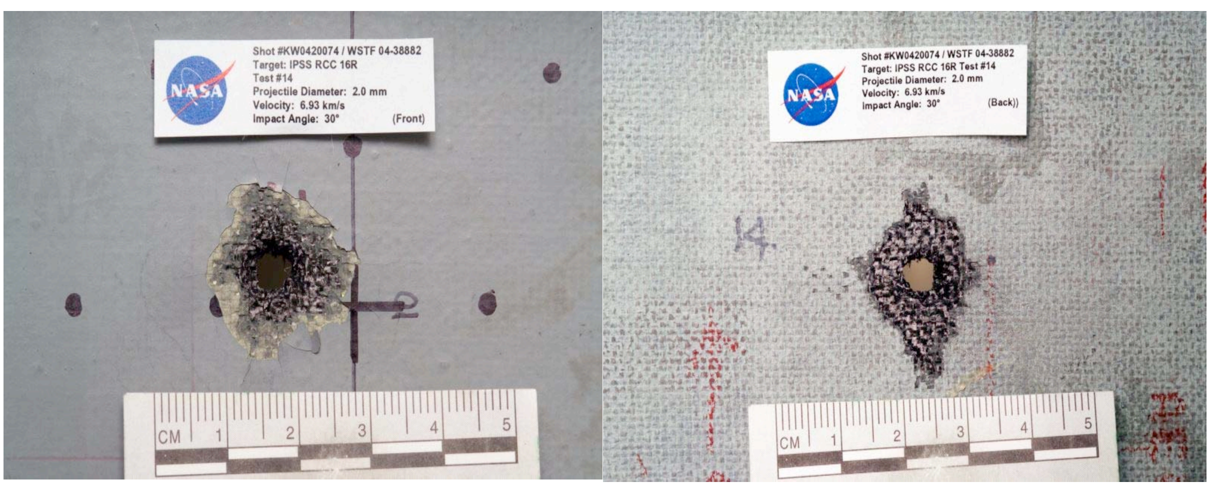

Figure 14: RCC16R Photographs of Impact Damage for Shot #14.
Top: Front Side View. Bottom: Back Side View.

Discussion

Filtering low frequency noise did not affect the arrival time for ultrasonic sensors. For example, see RCC16R impacts #16 and #20 (Figure 15- Figure 18). Frequencies under 50 kHz may be eliminated using a digital highpass filter without affecting the recorded arrival times.

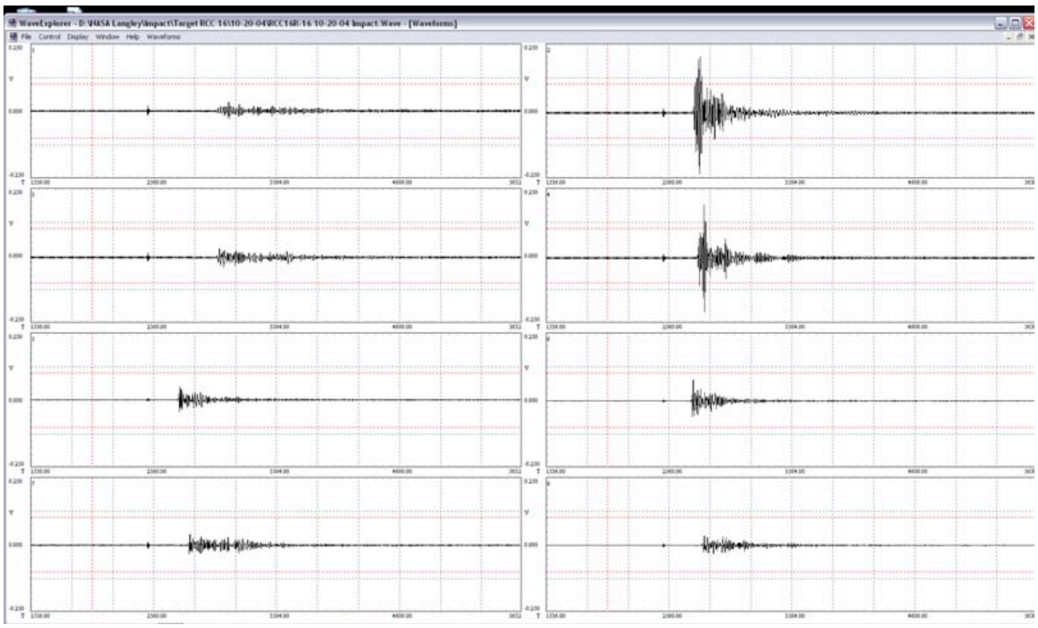

Figure 15: RCC16R Shot #16 Impact Waveform – Unfiltered

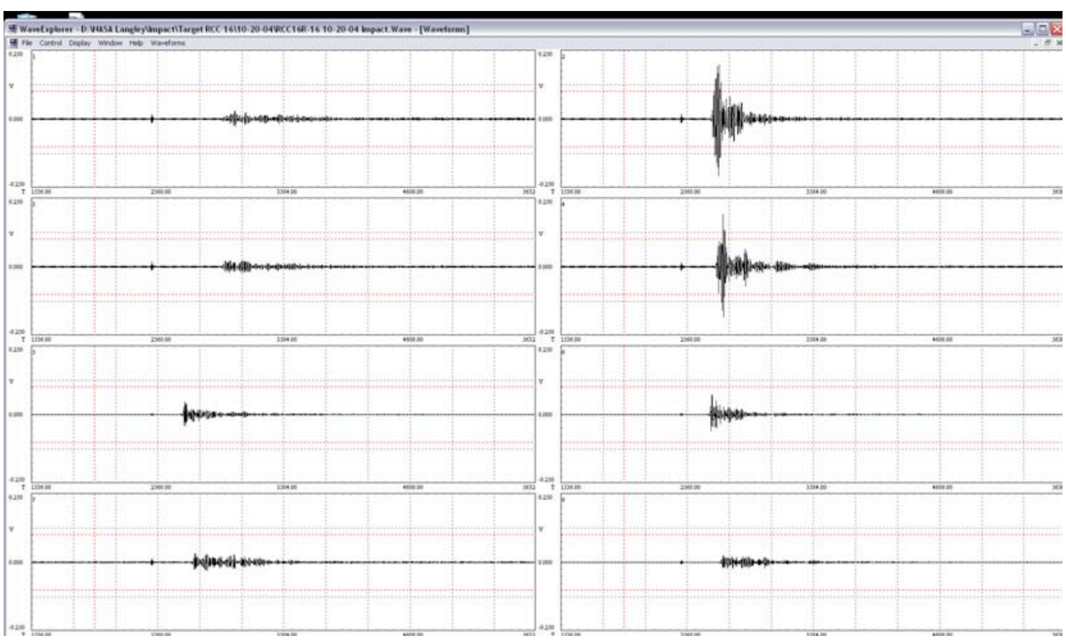

Figure 16: RCC16R Shot #16 Impact Waveform - 50 kHz Highpass Filter

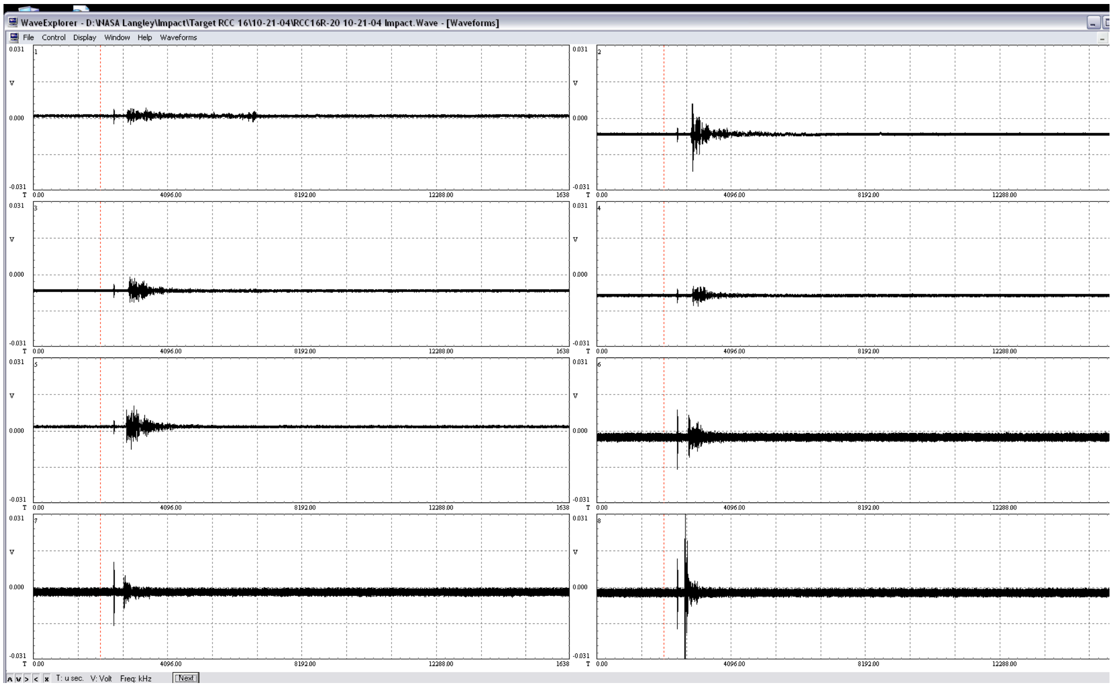

Figure 17: RCC16R Shot #20 Impact Waveform – Unfiltered

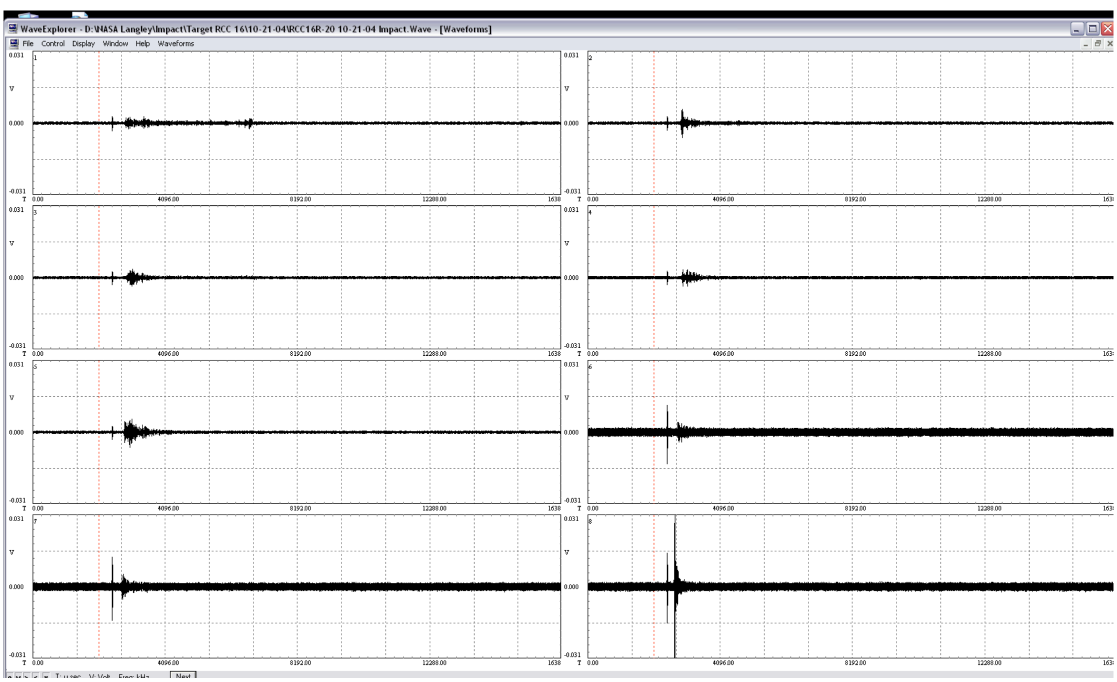

Figure 18: RCC16R Shot #20 Impact Waveform - 50 kHz Highpass Filter

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.

Saturation occurred on shot #4, sensor 3. Shot #8 exhibited very small signals on sensors 1-12.

For design engineering and threat analysis purposes, shots were performed at various angles to the normal to the target at the point of impact. In order to compare all shots on the same graph, the kinetic energy for the normal velocity component was computed (sine squared of the angle, ninety degrees is normal). Whether this component alone creates all the damage is debatable, but there is a general trend of increasing normal kinetic energy leading to increasing coating area damage (Figure 19 and Figure 20). Crater volume damage appears to correlate better with total kinetic energy (Figure 21and Figure 22) based on results from Targets C-1, C-2, Fg(RCC)-1, Fg(RCC)-1, and RCC16.

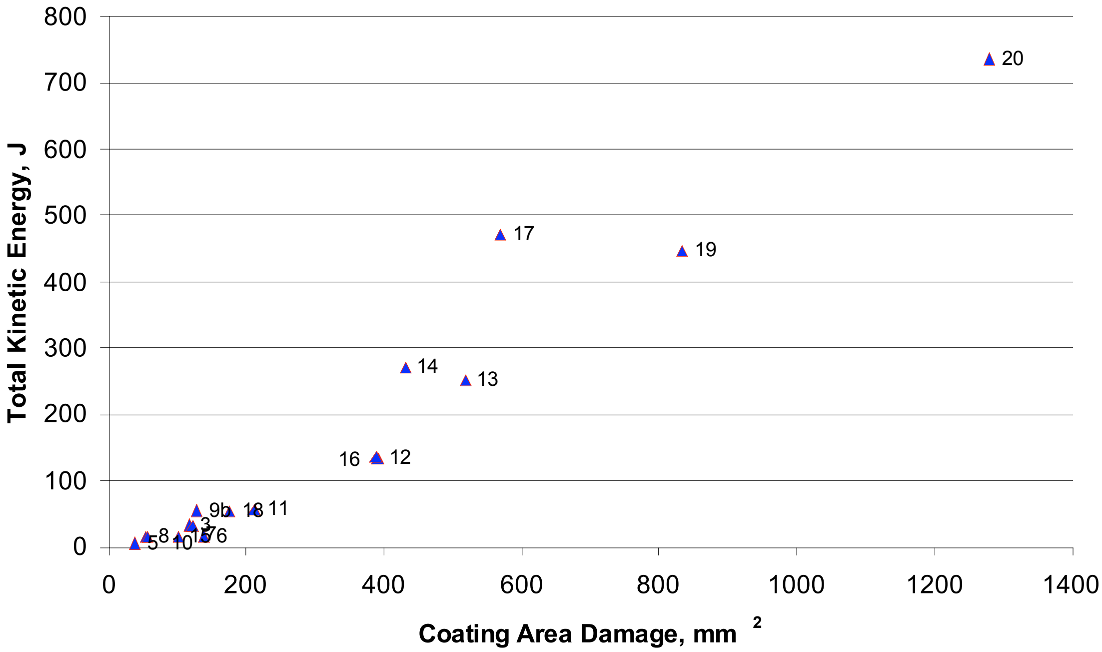

Figure 19: RCC16R Total Kinetic Energy vs. Coating Area Damage

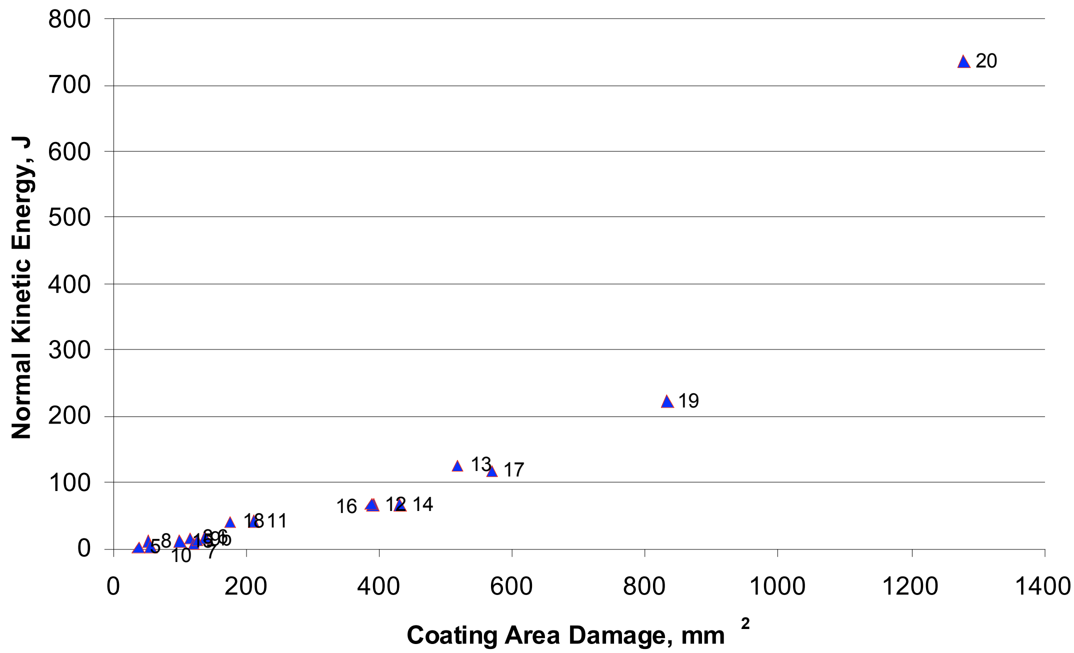

Figure 20: RCC16R Normal Kinetic Energy vs. Coating Area Damage

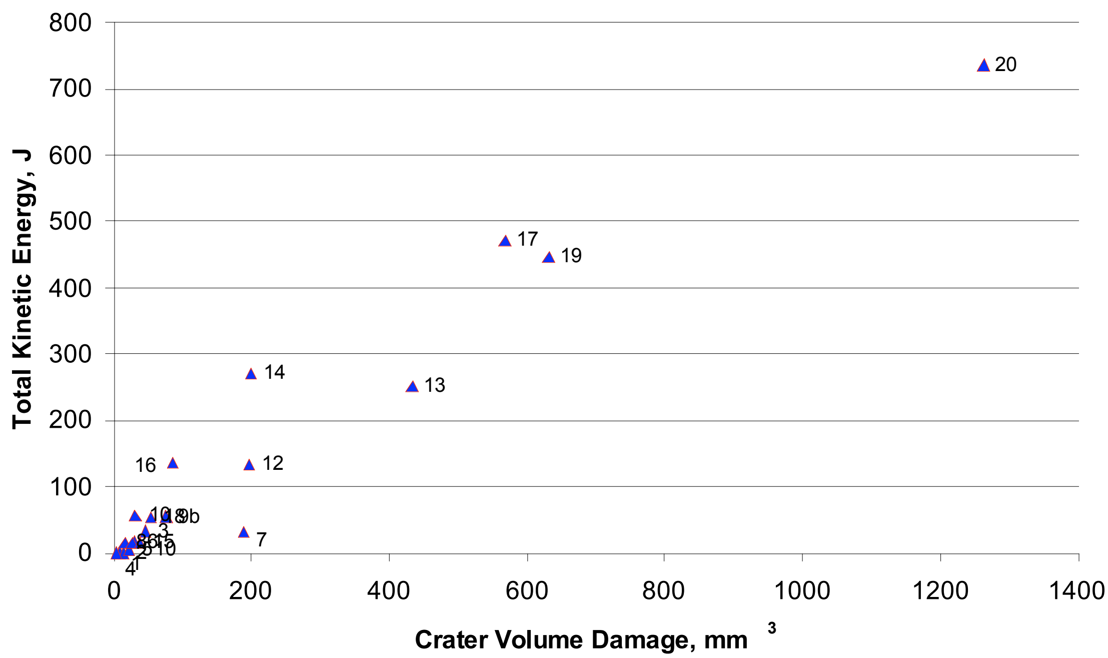

Figure 21: RCC16R Total Kinetic Energy vs. Crater Volume Damage

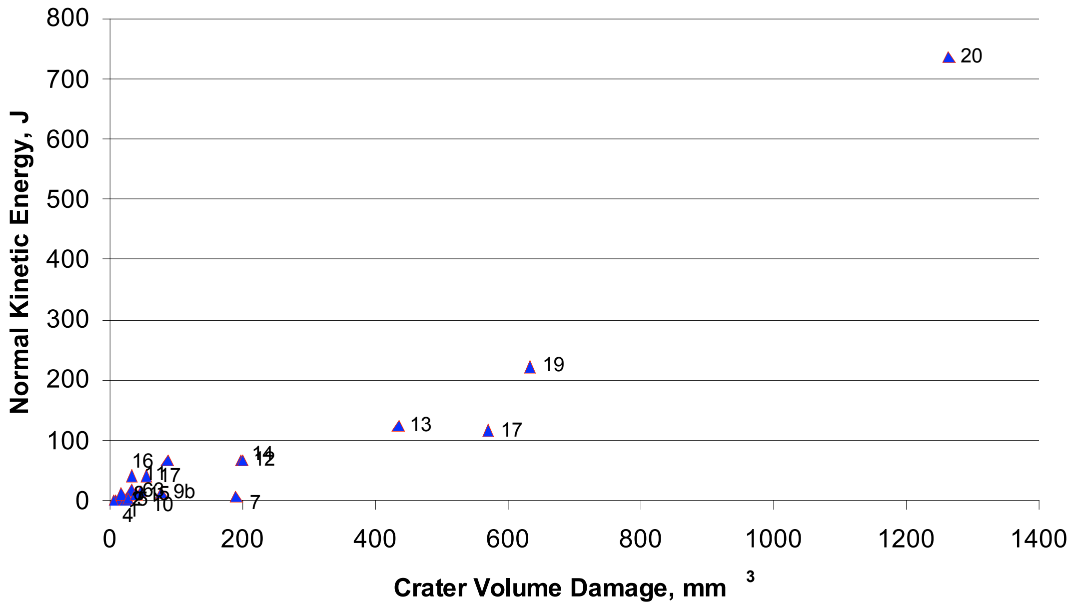

Figure 22: RCC16R Normal Kinetic Energy vs. Crater Volume Damage

All Sensors

"All Sensors" included sensors located on the back surface of the target, the spar, and the flange. The surface sensors were closest to the impacts so they contributed the largest fraction of the total wave signal energy collected by all the sensors.

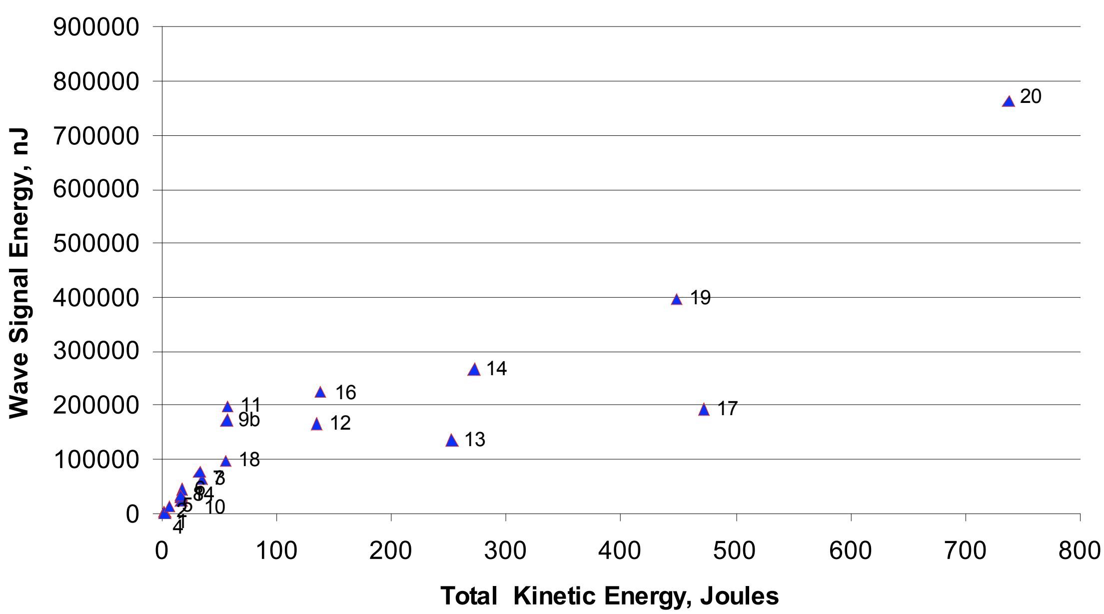

Figure 23: RCC16R Wave Signal Energy vs. Total Kinetic Energy - All Sensors

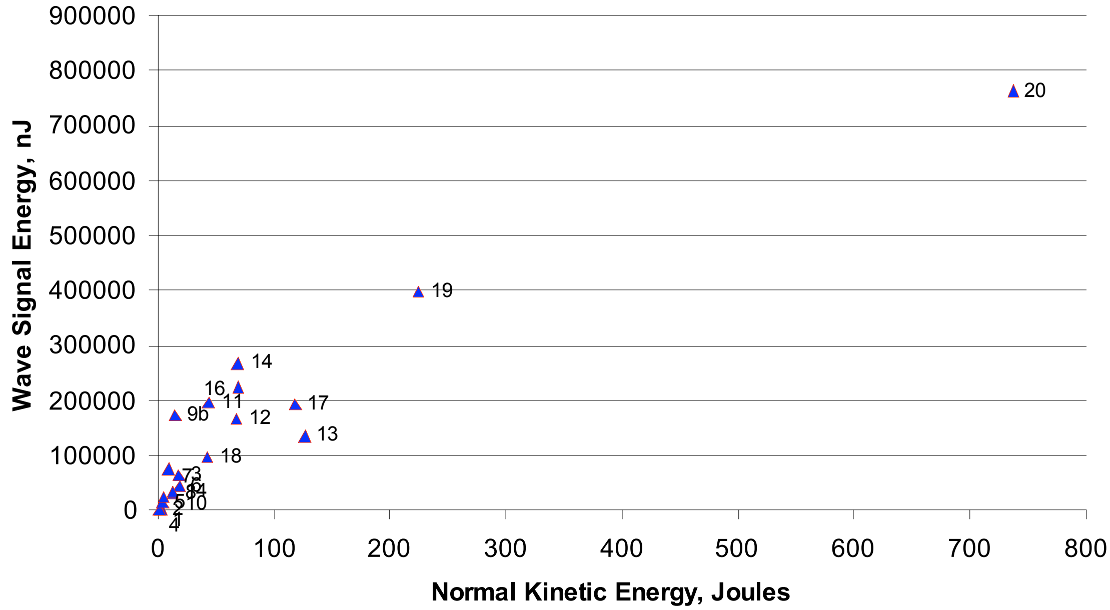

Figure 24: RCC16R Wave Signal Energy vs. Normal Kinetic Energy - All Sensors

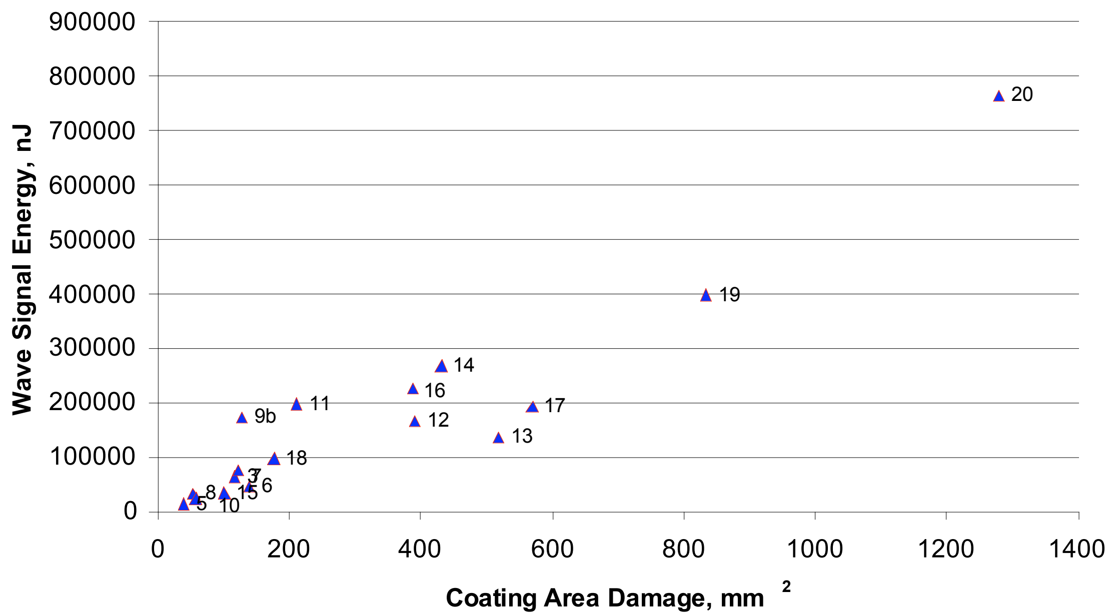

Figure 25: RCC16R Wave Signal Energy vs. Coating Area Damage - All Sensors

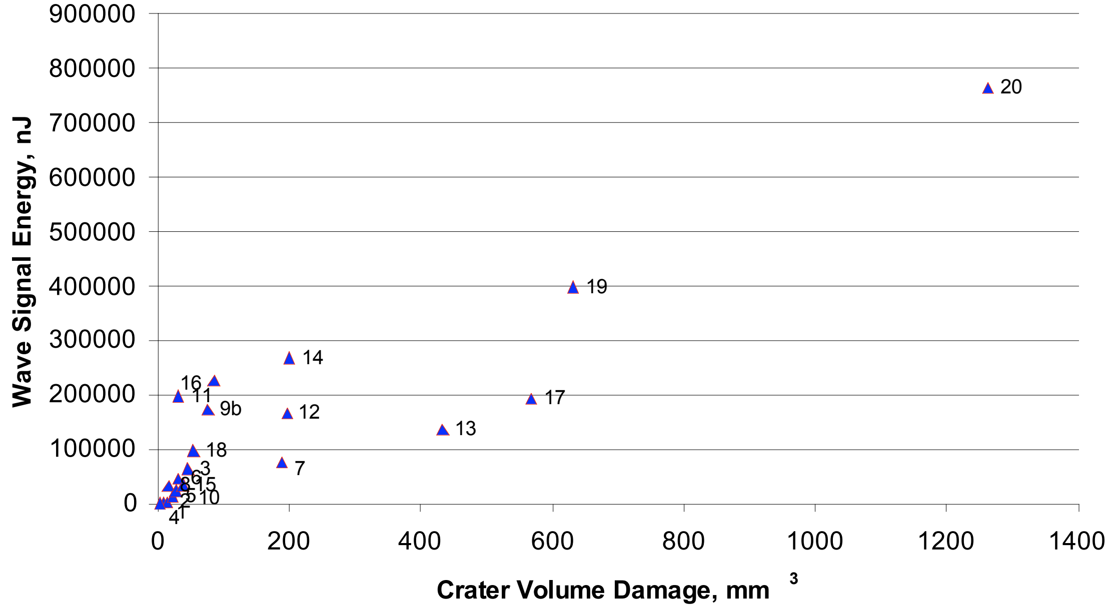

Figure 26: RCC16R Wave Signal Energy vs. Crater Volume Damage - All Sensors

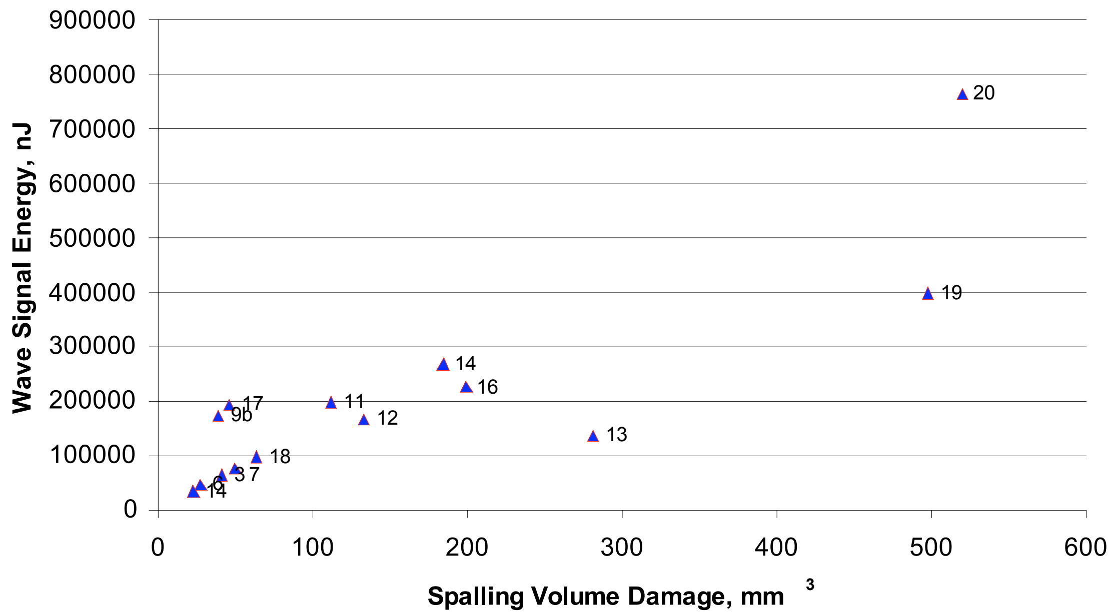

Figure 27: RCC16R Wave Signal Energy vs. Spalling Volume Damage- All Sensors

A separate sum was performed for the set of flange sensors and the set of spar sensors, the reason being that the spar sensors ultimately would be the ones used in an actual flight since they would not be subject to the extreme heat of the RCC. The waves at the RCC, flange and spar sensors died out before the end of the recording time window so the total energy available was captured. The same recording time was used for every shot. Flange and spar wave signal energies are shown in the following figures.

Flange Sensors

The flange sensors collect less impact energy than the surface sensors, but more than the spar sensors. The flange graphs help to describe how the waves propagate through the target from the surface to the spar.

Shot #20 appears to have an unusually low wave signal energy on the flange sensors (Figure 35). One difference between shot #20 and the rest of the high kinetic energy shots is that it has the greatest attenuation settings (-50dB). In Fg(RCC)-1 and Fg(RCC)-2, attenuations settings on the order of -55 dB were associated with unusually high wave signal energies for select shots.

Another explanation for the low W.S.E. of shot #20 may be its location. Shots #14, 16, and 19 had the highest flange wave signal energies and they were located along the upper edge of the target. Shots #12, 13, and 17 had low flange wave signal energies and were located closer to the center of the target like shot # 20.

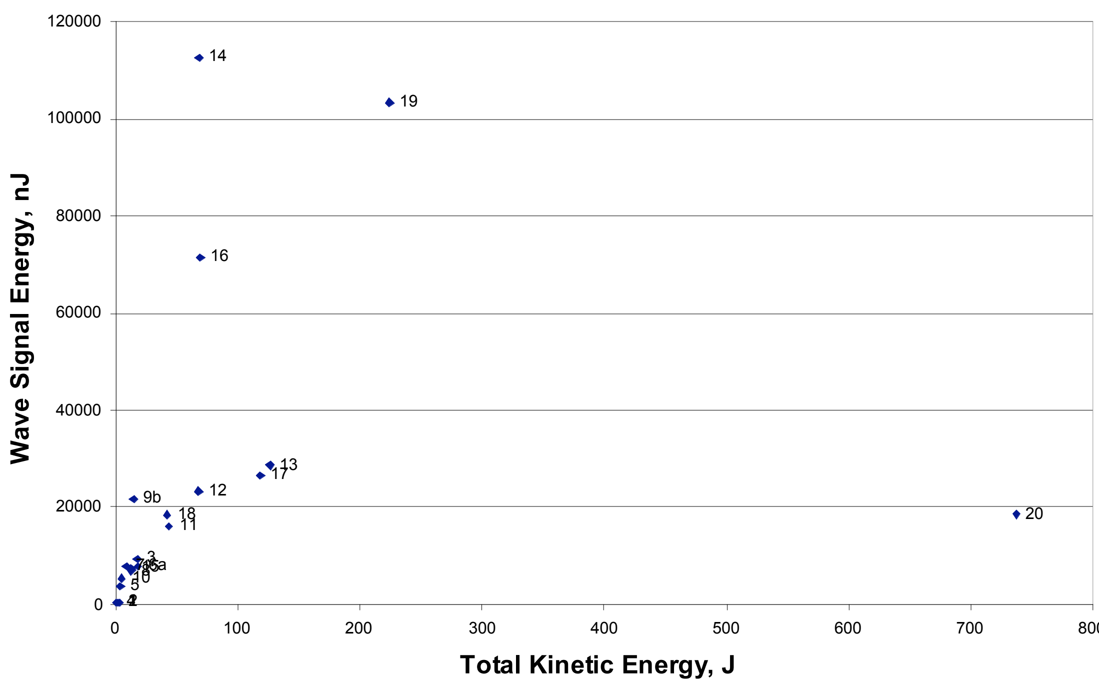

Figure 28: RCC16R Wave Signal Energy vs. Total Kinetic Energy – Flange Sensors Only

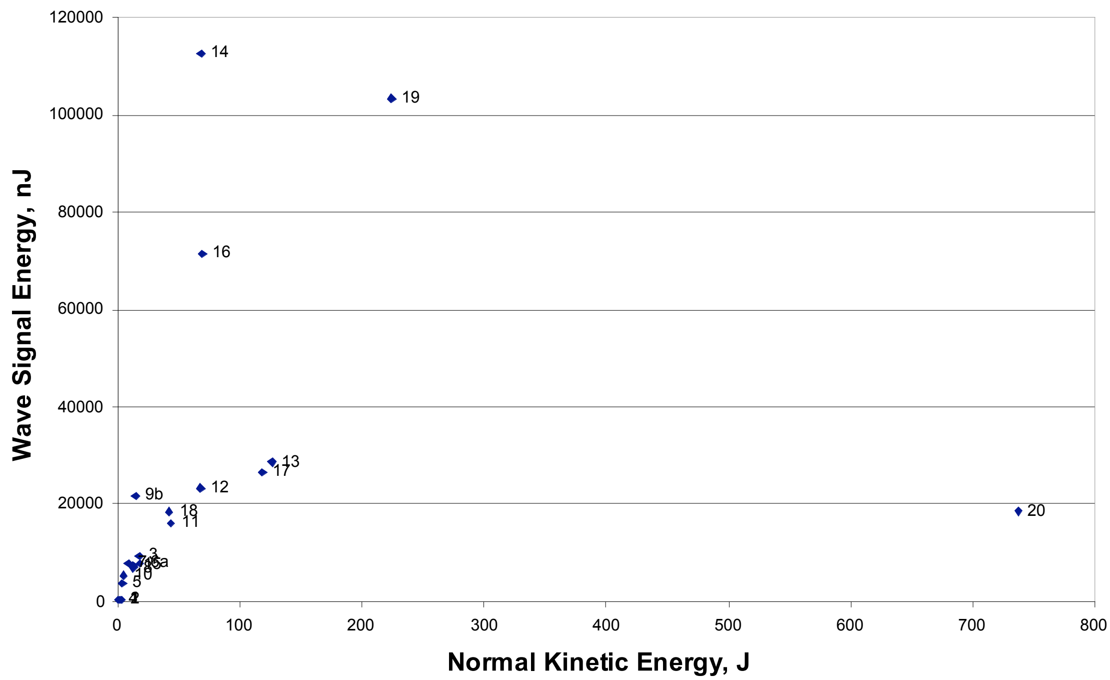

Figure 29: RCC16R Wave Signal Energy vs. Normal Kinetic Energy - Flange Sensors Only

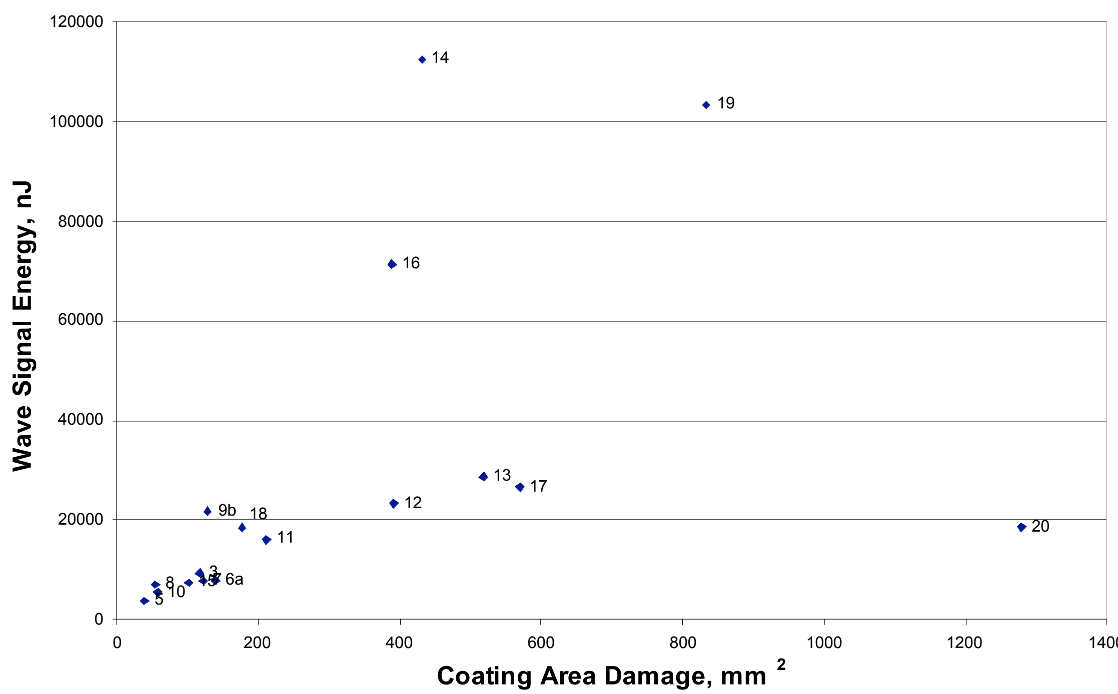

Figure 30: RCC16R Wave Signal Energy vs. Coating Area Damage - Flange Sensors Only

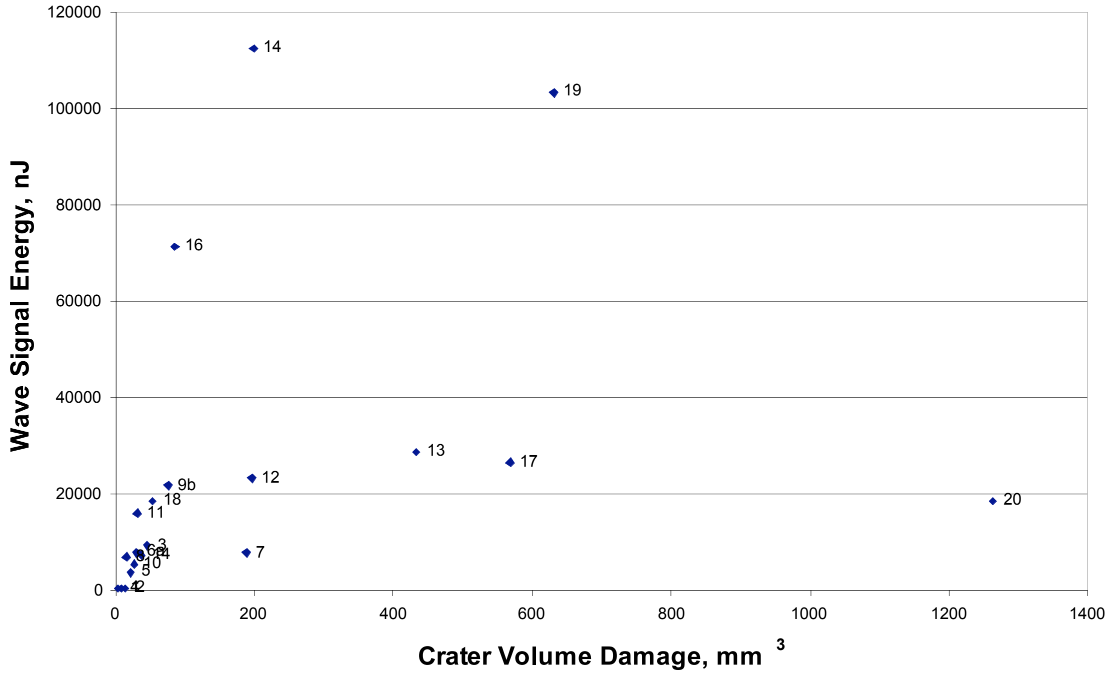

Figure 31: RCC16R Wave Signal Energy vs. Crater Volume Damage - Flange Sensors Only

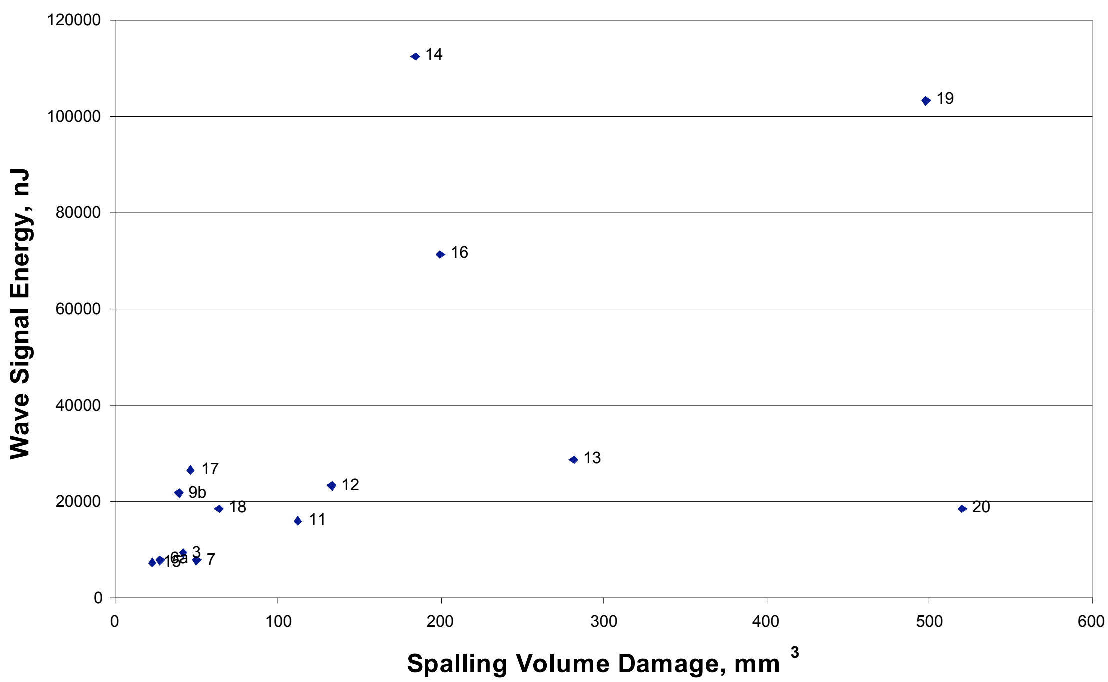

Figure 32: RCC16R Wave Signal Energy vs. Spalling Volume Damage - Flange Sensors Only

Spar Sensors

The magnitude of wave signal energy recorded at the spar sensor was several orders of magnitude smaller than at the flange sensors. The plots at the spar sensors exhibited similar linear trends as at the flange sensors, just with smaller signals.

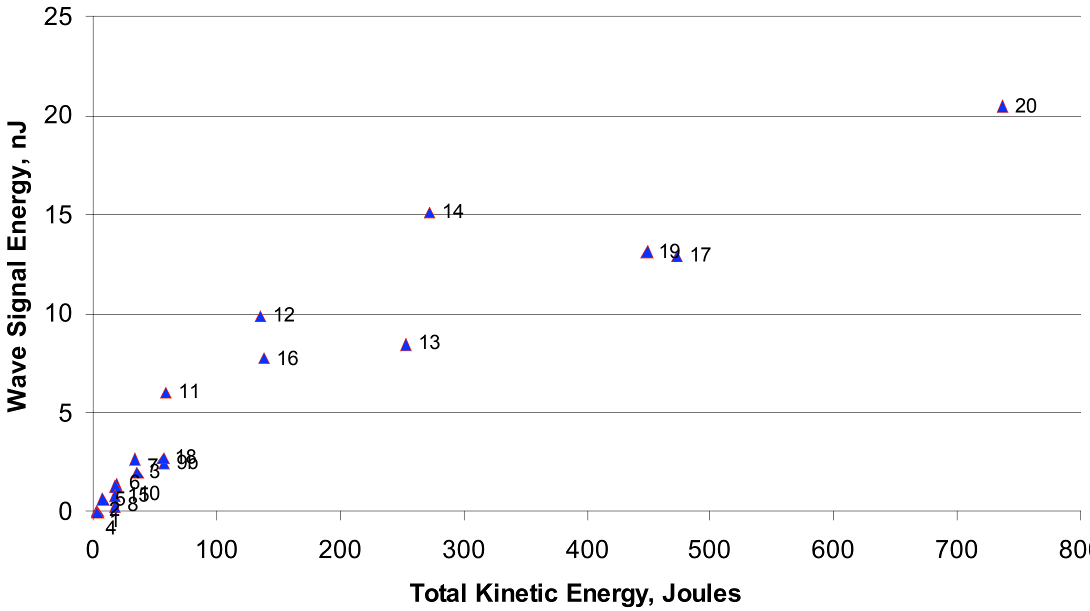

Figure 33: RCC16R Wave Signal Energy vs. Total Kinetic Energy - Spar Sensors Only

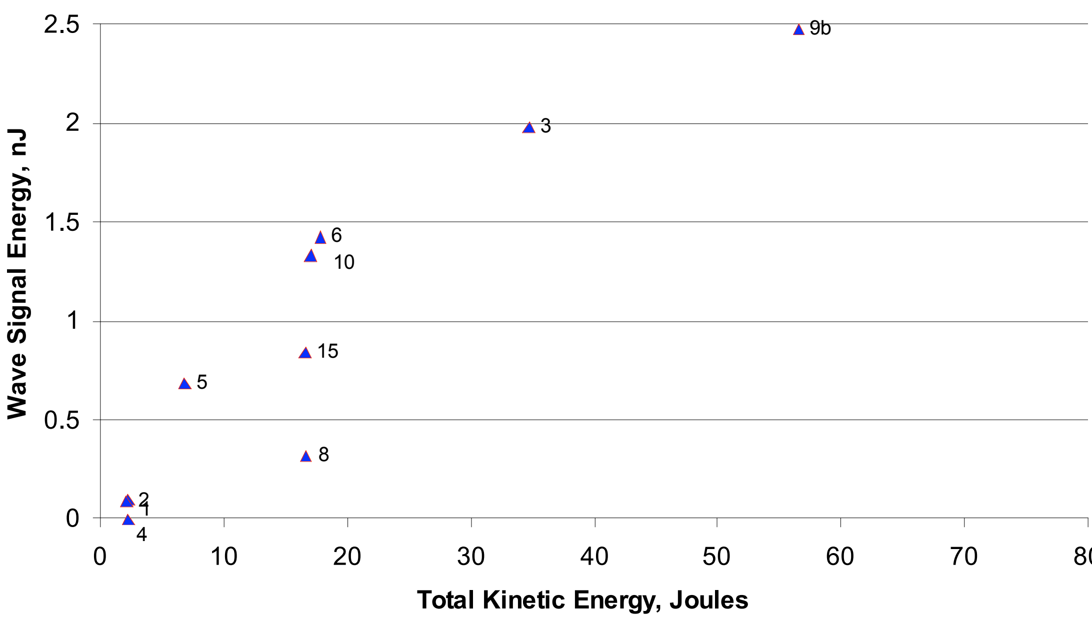

Figure 34: Detail of RCC16R Wave Signal Energy vs. Total Kinetic Energy – Spar Sensors Only

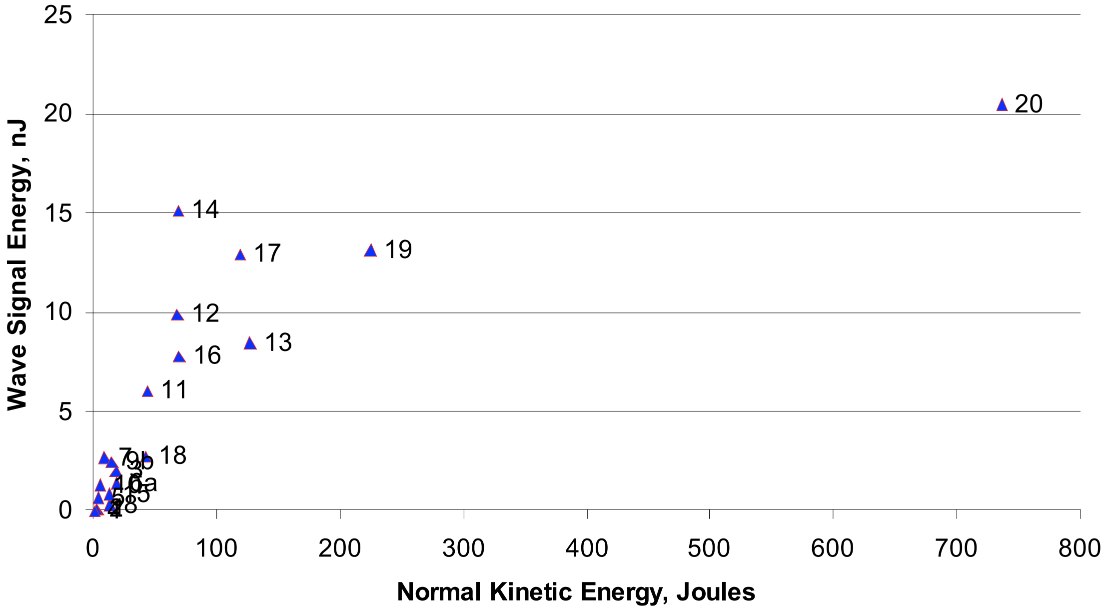

Figure 35: RCC16R Wave Signal Energy vs. Normal Kinetic Energy - Spar Sensors Only

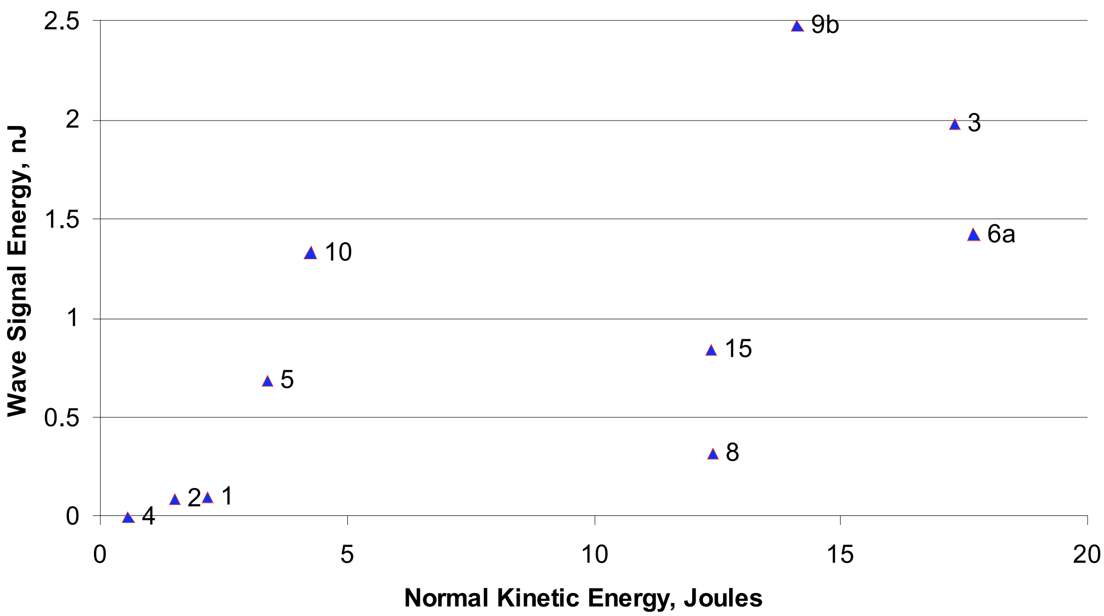

Figure 36: Detail of RCC16R Wave Signal Energy vs. Normal Kinetic Energy - Spar Sensors Only

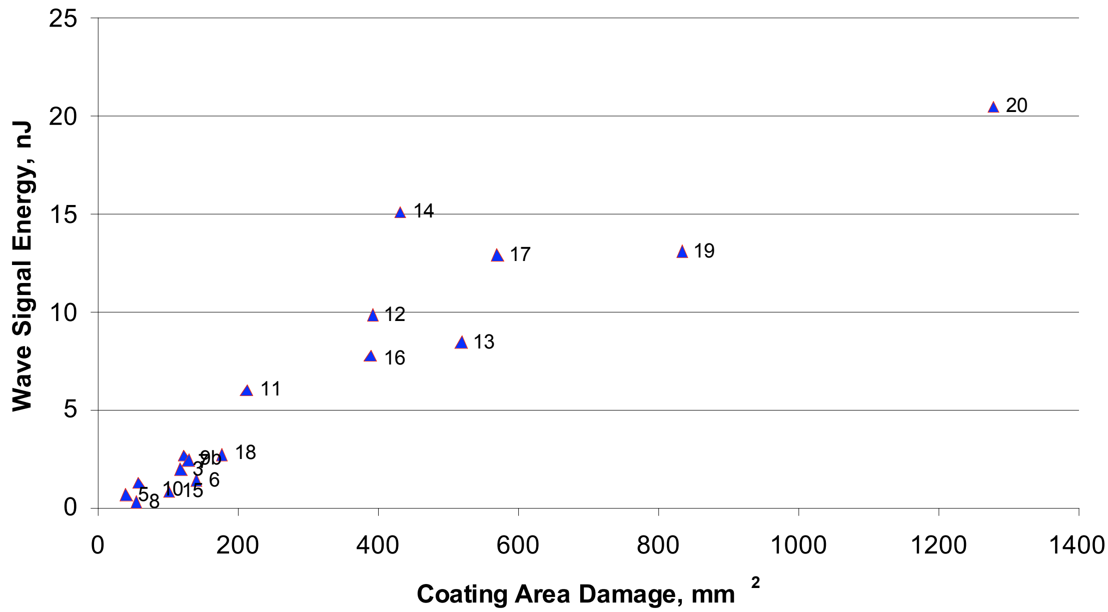

Figure 37: RCC16R Wave Signal Energy vs. Coating Area Damage - Spar Sensors Only

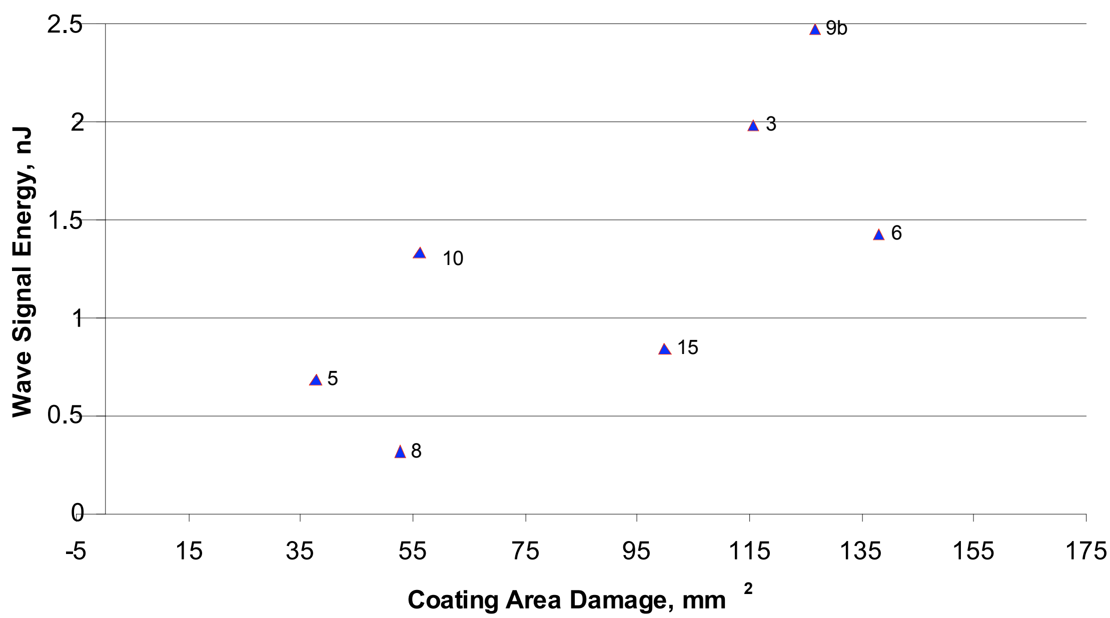

Figure 38: Detail of RCC16R Wave Signal Energy vs. Coating Area Damage – Spar Sensors Only

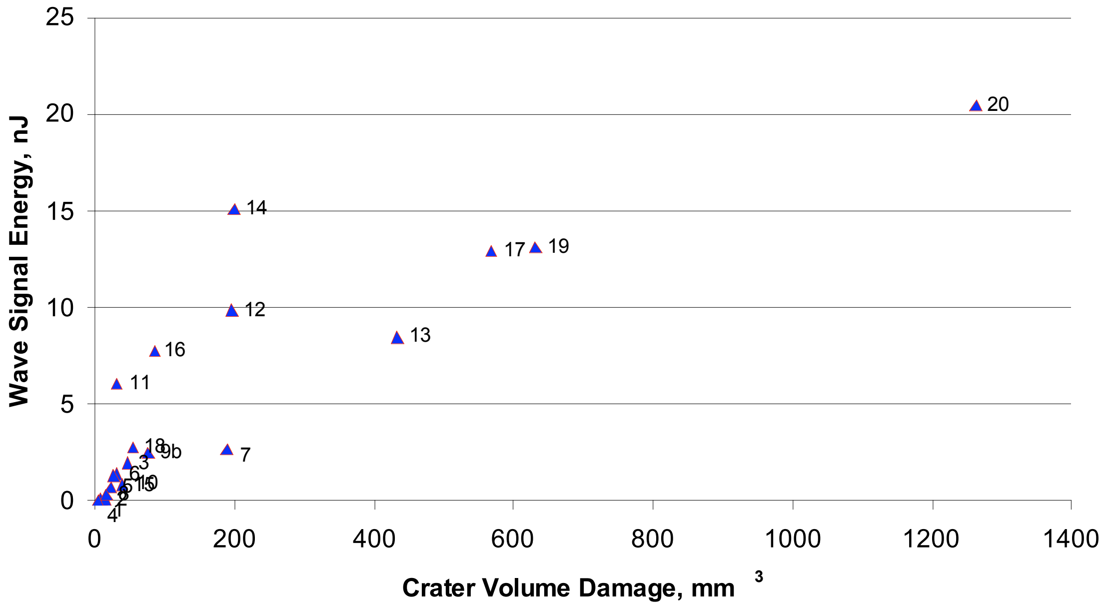

Figure 39: RCC16R Wave Signal Energy vs. Crater Volume Damage - Spar Sensors Only

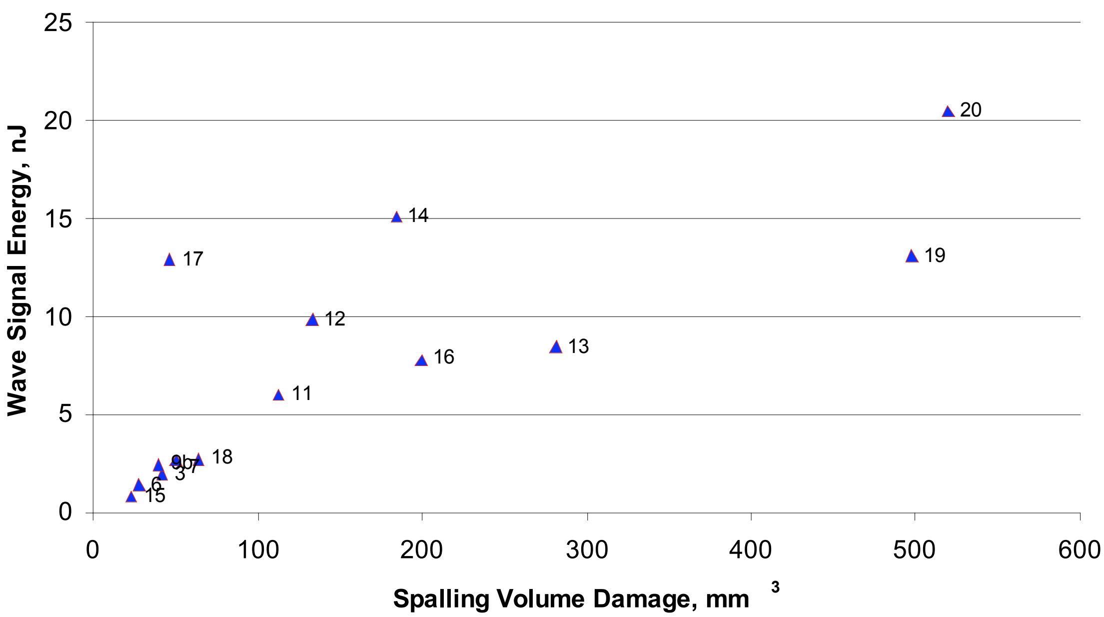

Figure 40: RCC16R Wave Signal Energy vs. Spalling Volume Damage - Spar Sensors Only

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 is 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 the section on 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 41) that can be readily identified. For one thing, the front part of the E wave travels much faster than any frequency component of the F wave.

Wave speed was determined by performing a lead break at one sensor and measuring the time it took for a direct wave to arrive at another sensor at a known distance away. Figure 41 shows a lead break signal at sensor 5. The extensional wave arrived at sensor 5 at t_1 = 200.2 μs and at sensor 6 at t_2 = 294.4 μs. The sensors were located 14 inches apart, which gave a velocity of 0.155 in/μs in the x-direction. Performing this calculation in the y-direction and the diagonal gave extensional wave velocities of 0.145 in/μs and 0.14 in/μs, respectively. The same calculation for flexural waves yielded velocities of 0.08 in/μs in the x-direction, 0.07 in/μs in the y-direction, and 0.07 in/μs in the diagonal. Figures 38 and 39 are diagrams of sensor locations.

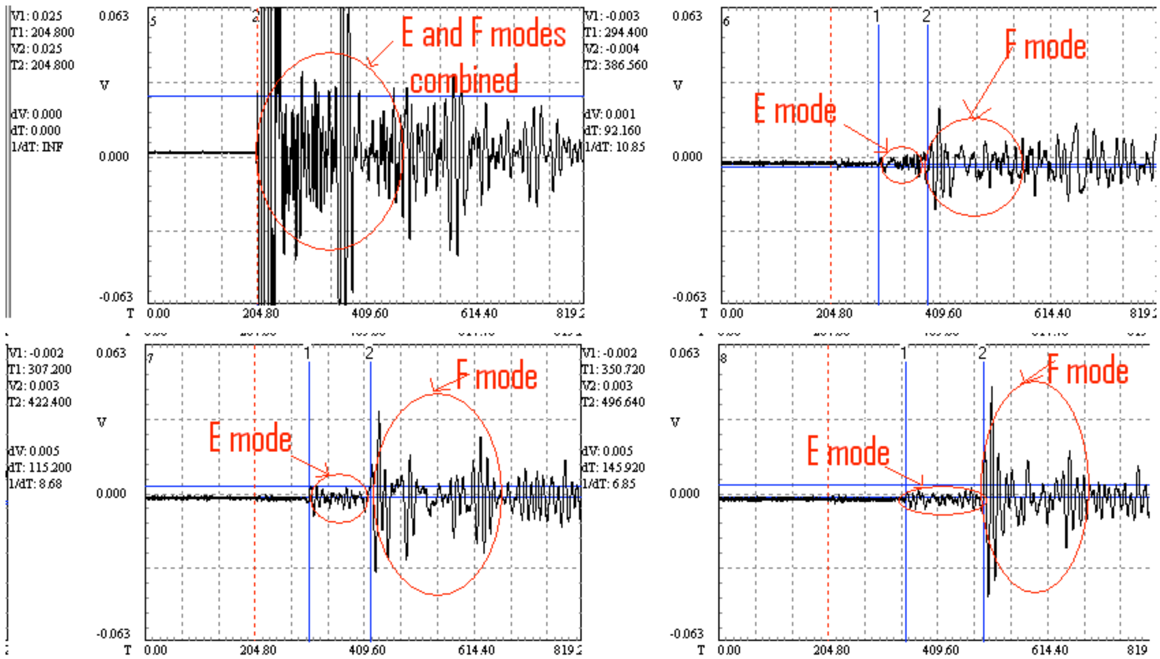

Figure 41: RCC16R Lead Break on Sensors 5, 6, 7, and 8 Shot #1 Pretest

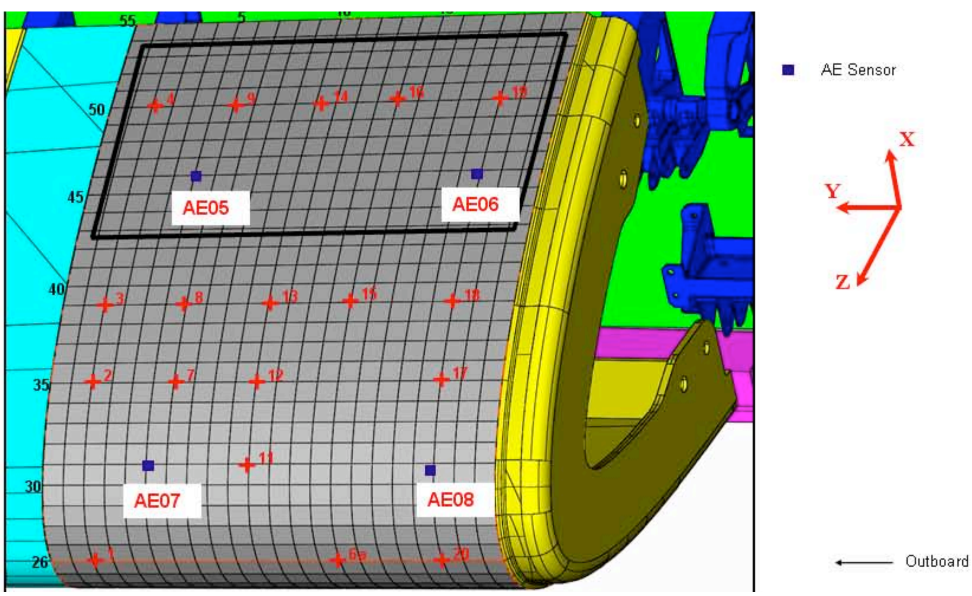

Figure 42: RCC16R Sensor and Impact Locations. Upper Panel. (Repeat of Figure 6)

Sensors have the following coordinates:
#5(46, 5), #6(46, 19), #7(31, 5), #8(31, 19) Dimensions are inches.
Impacts have the following coordinates:
#1(26, 2), #2(35, 2), #3(39, 2), #4(50, 2), #6a(26, 14), #7(35,6), #8(39,6), #9(50, 6), #11(31,10), #12(35,10), #13(39, 10), #14(50, 10), #15(39, 14), #16(50, 14), #17(35,19), #18(39,19), #19(50,19), #20(26, 19)

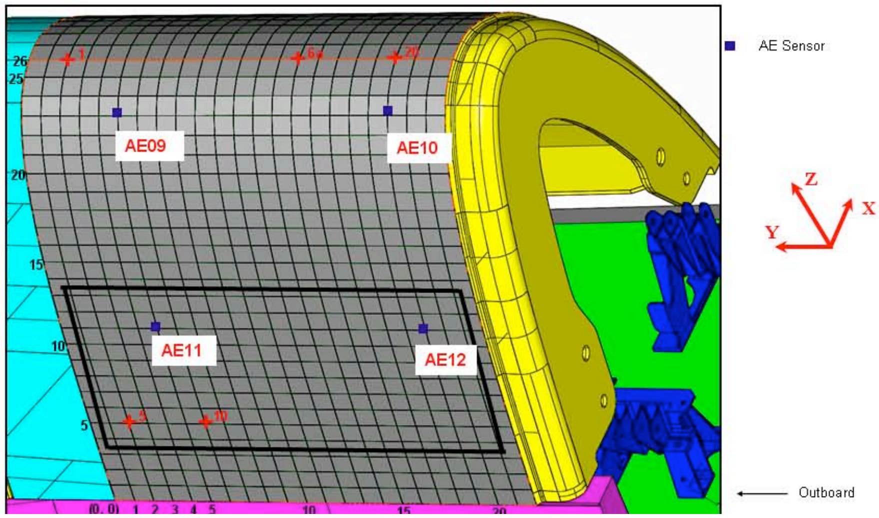

Figure 43: RCC16R Sensor and Impact Locations. Lower Panel. (Repeat of Figure 7)
Sensors have the following coordinates:
#9(23, 5), #10(23, 19), #11(11, 5), #12(11, 19) Dimensions are inches.
Impacts have the following coordinates:
#1(26, 2), #5(5, 2), #6a(26, 14), #10(5, 6), #20(26, 19)

Impact #19 was aligned with sensors 6 and 8 (see Figure 42). Performing the same calculation mentioned above yielded an extensional velocity of 0.14 in/μs and a flexural velocity of 0.08 in/μs, both in the y-direction. The impact waveform is shown in Figure 44.

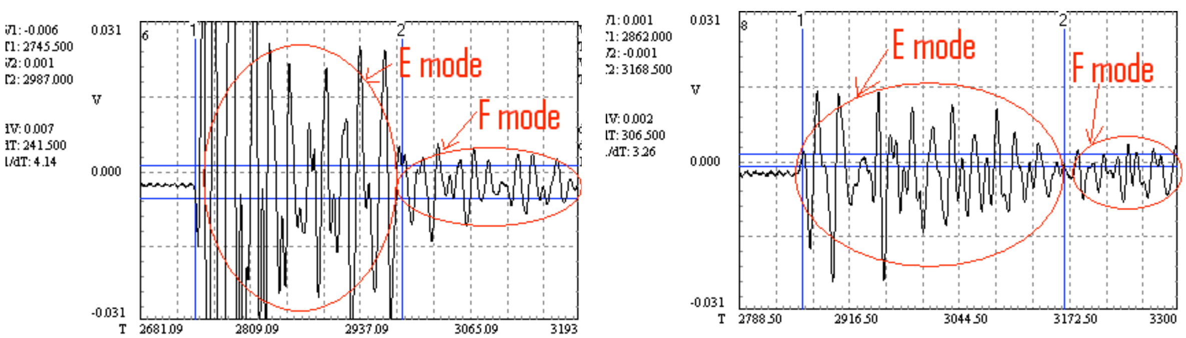

Figure 44: Detail of RCC16R Shot #19 Impact Waveform, Sensors 6 (left) and Sensor 8 (right)

Impact #11 was aligned with sensors 7 and 8 (Figure 43). This impact yielded an extensional velocity of 0.16 in/μs and a flexural velocity of 0.08 in/μs, both in the x-direction. The impact waveform is shown in Figure 45.

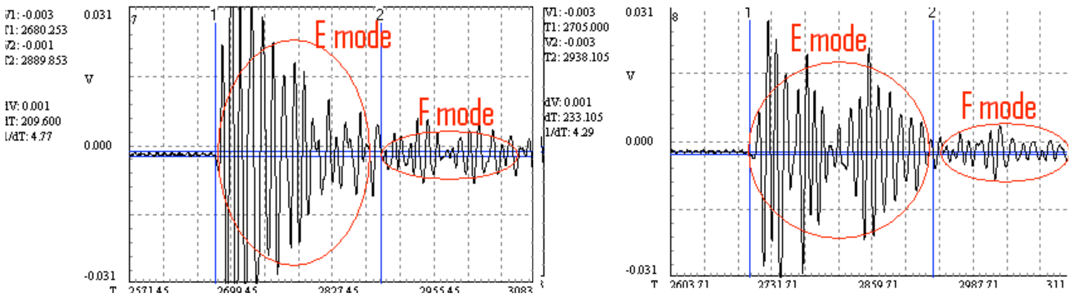

Figure 45: Detail of RCC16R Shot #11 Impact Waveform, Sensor 7 (left) and Sensor 8 (right)

In the fiberglass panel, fibers are aligned in the x and y directions (see Figure 42 and Figure 43). In addition to having slower speeds, waves that travel diagonally are attenuated more than waves that travel along the fiber direction. This is generally known as material anisotropy and is referred to here as the diagonal attenuation effect. Compensation for this effect is described in detail for Targets C-1 and C-2.

Conclusions

The results of the hypervelocity impact test on WLE Target RCC16R are as follows:

- Ultrasonic Sensors were successfully bonded to Target RCC16R 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.[1]
- Impacts created detectable ultrasonic signals at high (>50 kHz) frequencies which should be above flight noise.[2]
- Ultrasonic signals were detected with small, lightweight sensors capable of space flight.[3,4]
- Wave propagation characteristics of reinforced carbon-carbon were measured and used in the analysis of the wave signal energy.
- Wave signal energy correlated well with kinetic energy and impact damage.
- Ultrasonic energy propagated through WLE attachment joints and was detected by sensors attached on the wing spar. These sensors would not be exposed to the high temperatures of the WLE itself. The spar signals were useable for detecting impacts but the location analysis was limited to determining which quadrant of the WLE was impacted.

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

[1] B1025 sensors also functioned well in deep vacuum of ESEM. Michael Horn, NASA LaRC, email 2005.
[2] Based on measurement of noise spectra on F16 bulkhead at full throttle, there will not be significant noise power above 50kHz.
[3] Sensors passed 18,000 g shock test. Henry Whitesel, Naval Surface Warfare Center, verbal communication 1998.
[4] 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: 9/30/04 Specimen ID: RCC16R
Test number: RCC16R-1 Projectile size: 0.4 mm/90deg.
Planned velocity: 6.8 km/s
Planned impact coordinates: (26, 2)

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 101147 Sensor 2: S/N 084016
Sensor 3: S/N 084021 Sensor 4: S/N 084018
Sensor 5: S/N 084027 Sensor 6: S/N 084024
Sensor 7: S/N 084028 Sensor 8: S/N 084011
Sensor 9: S/N 084015 Sensor 10: S/N 084022
Sensor 11: S/N 084017 Sensor 12: S/N 084023
Sensor 13: S/N 190022 Sensor 14: S/N 190033
Sensor 15: S/N 190034 Sensor 16: S/N 190036

Sensor 1: Lower Outboard Flange Corner (up) Sensor 2: Upper Outboard Flange Corner (up)
Sensor 3: Lower Inboard Flange Corner (down) Sensor 4: Upper Inboard Flange Corner (down)
Sensor 5: Upper Surface (46, 05) Sensor 6: Upper Surface (46, 19)
Sensor 7: Upper Surface (31, 05) Sensor 8: Upper Surface (31, 19)
Sensor 9: Lower Surface (23, 05) Sensor 10: Lower Surface (23, 19)
Sensor 11: Lower Surface (11, 05) Sensor 12: Lower Surface (11, 19)
Sensor 13: Lower Outboard Underside Spar Sensor 14: Upper Outboard Underside Spar
Sensor 15: Upper Inboard Underside Spar Sensor 16: Lower Inboard Underside Spar

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: RCC16R-1 9-30-04 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

16 channel recording mode: X

Data acquisition in record mode: X

(DWC logo spinning)

Record and verify gain settings:

Sensor	Attenuators	Preamp	SCM
Sensor 1:	0	0	3
Sensor 2:	0	0	3
Sensor 3:	0	0	3
Sensor 4:	0	0	3
Sensor 5:	0	-20	12
Sensor 6:	0	-20	15
Sensor 7:	0	-20	9
Sensor 8:	0	-20	15
Sensor 9:	0	-20	6
Sensor 10:	0	-20	15
Sensor 11:	0	-20	12
Sensor 12:	0	-20	15
Sensor 13:	0	20	12
Sensor 14:	0	20	12
Sensor 15:	0	20	12
Sensor 16:	0	20	12

Record file name: RCC16R-1 9-30-04 Impact

Comments: 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:

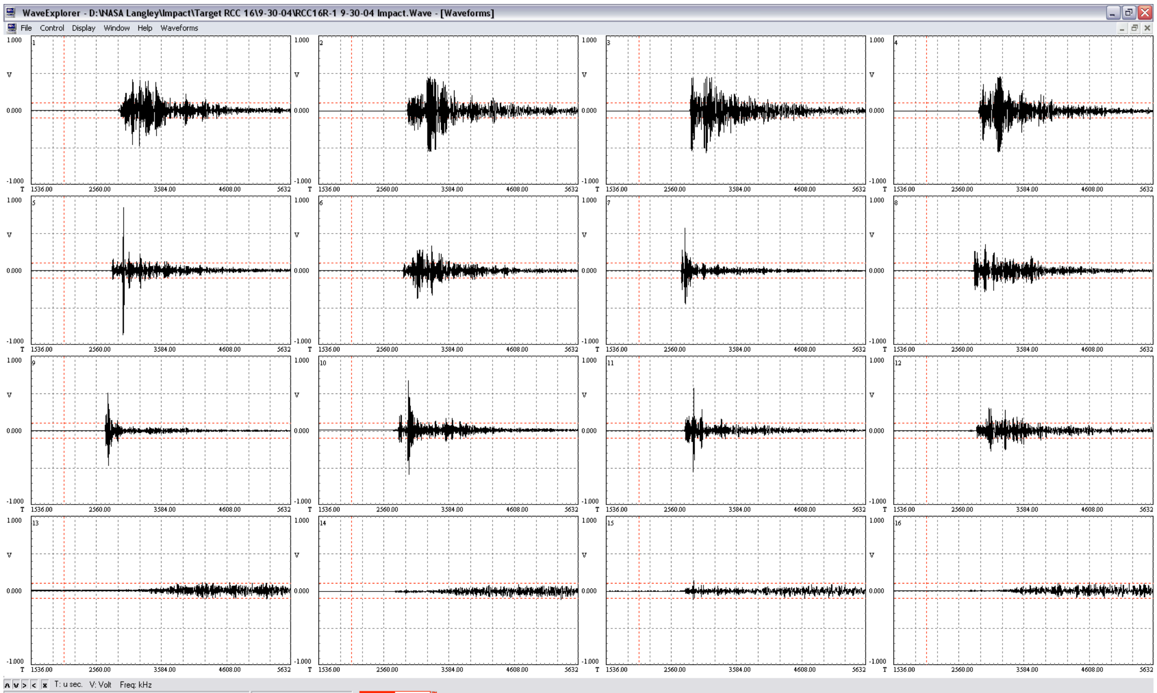

Figure 46: RCC16R Shot #1 Impact Waveform

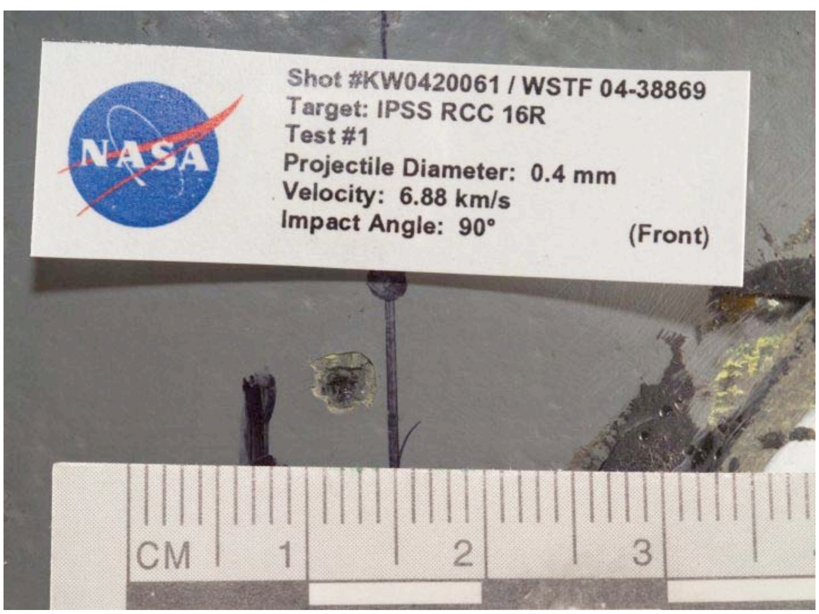

Figure 47: RCC16R Shot #1 Impact Damage

AE Test Data/Checklist

I. Record pretest information:

Test date: 10/01/04 Specimen ID: RCC16R

Test number: RCC16R-2 Projectile size: 0.4 mm/60deg.

Planned velocity: 6.8 km/s

Planned impact coordinates: (35, 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: All sensors good.

III. Record sensor serial number and coordinates:

Sensor 1: S/N 101147 Sensor 2: S/N 084016

Sensor 3: S/N 084021 Sensor 4: S/N 084018

Sensor 5: S/N 084027 Sensor 6: S/N 084024

Sensor 7: S/N 084028 Sensor 8: S/N 084011

Sensor 9: S/N 084015 Sensor 10: S/N 084022

Sensor 11: S/N 084017 Sensor 12: S/N 084023

Sensor 13: S/N 190022 Sensor 14: S/N 190033

Sensor 15: S/N 190034 Sensor 16: S/N 190036

Sensor 1: Lower Outboard Flange Corner (up) Sensor 2: Upper Outboard Flange Corner (up)

Sensor 3: Lower Inboard Flange Corner (down) Sensor 4: Upper Inboard Flange Corner (down)

Sensor 5: Upper Surface (46, 05) Sensor 6: Upper Surface (46, 19)

Sensor 7: Upper Surface (31, 05) Sensor 8: Upper Surface (31, 19)

Sensor 9: Lower Surface (23, 05) Sensor 10: Lower Surface (23, 19)

Sensor 11: Lower Surface (11, 05) Sensor 12: Lower Surface (11, 19)

Sensor 13: Lower Outboard Underside Spar Sensor 14: Upper Outboard Underside Spar

Sensor 15: Upper Inboard Underside Spar Sensor 16: Lower Inboard Underside Spar

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: RCC16R-2 10-01-04 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______
16 channel recording mode: X______
Data acquisition in record mode: X______
(DWC logo spinning)

Record and verify gain settings:

Sensor 1:	Attenuators: 0	Preamp: 0	SCM: 3
Sensor 2:	Attenuators: 0	Preamp: 0	SCM: 3
Sensor 3:	Attenuators: 0	Preamp: 0	SCM: 3
Sensor 4:	Attenuators: 0	Preamp: 0	SCM: 3
Sensor 5:	Attenuators: 0	Preamp: -20	SCM: 6
Sensor 6:	Attenuators: 0	Preamp: -20	SCM: 15
Sensor 7:	Attenuators: 0	Preamp: -20	SCM: 0
Sensor 8:	Attenuators: 0	Preamp: -20	SCM: 15
Sensor 9:	Attenuators: 0	Preamp: -20	SCM: 9
Sensor 10:	Attenuators: 0	Preamp: -20	SCM: 15
Sensor 11:	Attenuators: 0	Preamp: -20	SCM: 15
Sensor 12:	Attenuators: 0	Preamp: -20	SCM: 18
Sensor 13:	Attenuators: 0	Preamp: 20	SCM: 18
Sensor 14:	Attenuators: 0	Preamp: 20	SCM: 18
Sensor 15:	Attenuators: 0	Preamp: 20	SCM: 18
Sensor 16:	Attenuators: 0	Preamp: 20	SCM: 18

Record file name: RCC16R-2 10-01-04 Impact

Comments: 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:

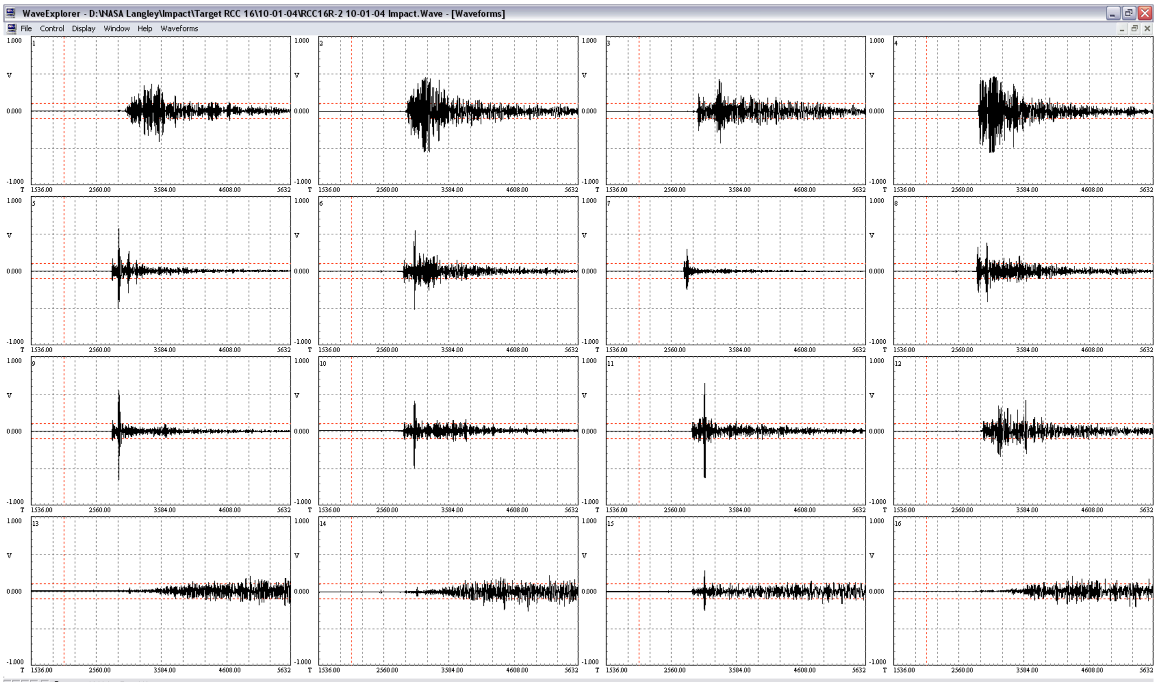

Figure 48: RCC16R Shot #2 Impact Waveform

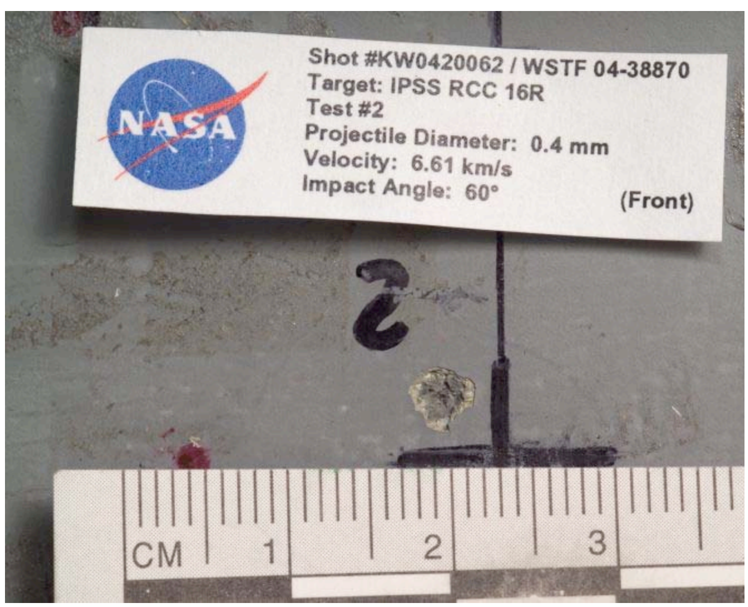

Figure 49: RCC16R Shot #2 Impact Damage

AE Test Data/Checklist

I. Record pretest information:

Test date: 10/04/04 Specimen ID: RCC16R
Test number: RCC16R-3 Projectile size: 1.0 mm/45deg.
Planned velocity: 6.8 km/s
Planned impact coordinates: (39, 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: All sensors good.

III. Record sensor serial number and coordinates:

Sensor 1: S/N 101147
Sensor 2: S/N 084016
Sensor 3: S/N 084021
Sensor 4: S/N 084018
Sensor 5: S/N 084027
Sensor 6: S/N 084024
Sensor 7: S/N 084028
Sensor 8: S/N 084011
Sensor 9: S/N 084015
Sensor 10: S/N 084022
Sensor 11: S/N 084017
Sensor 12: S/N 084023
Sensor 13: S/N 190022
Sensor 14: S/N 190033
Sensor 15: S/N 190034
Sensor 16: S/N 190036

Sensor 1: Lower Outboard Flange Corner (up)
Sensor 2: Upper Outboard Flange Corner (up)
Sensor 3: Lower Inboard Flange Corner (down)
Sensor 4: Upper Inboard Flange Corner (down)
Sensor 5: Upper Surface (46, 05)
Sensor 6: Upper Surface (46, 19)
Sensor 7: Upper Surface (31, 05)
Sensor 8: Upper Surface (31, 19)
Sensor 9: Lower Surface (23, 05)
Sensor 10: Lower Surface (23, 19)
Sensor 11: Lower Surface (11, 05)
Sensor 12: Lower Surface (11, 19)
Sensor 13: Lower Outboard Underside Spar
Sensor 14: Upper Outboard Underside Spar
Sensor 15: Upper Inboard Underside Spar
Sensor 16: Lower Inboard Underside Spar

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: RCC16R-3 10-04-04 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______
16 channel recording mode:	X______
Data acquisition in record mode: (DWC logo spinning)	X______

Record and verify gain settings:

Sensor	Attenuators	Preamp	SCM
Sensor 1:	30	20	6
Sensor 2:	30	20	6
Sensor 3:	30	20	6
Sensor 4:	30	20	6
Sensor 5:	30	0	6
Sensor 6:	30	0	15
Sensor 7:	30	0	9
Sensor 8:	30	0	15
Sensor 9:	30	0	12
Sensor 10:	30	0	15
Sensor 11:	30	0	15
Sensor 12:	30	0	18
Sensor 13:	0	20	9
Sensor 14:	0	20	9
Sensor 15:	0	20	9
Sensor 16:	0	20	9

Record file name: RCC16R-3 10-04-04 Impact

Comments: 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: 7.00 km/s.
Impact coordinates: ________________
Damage description and comments:

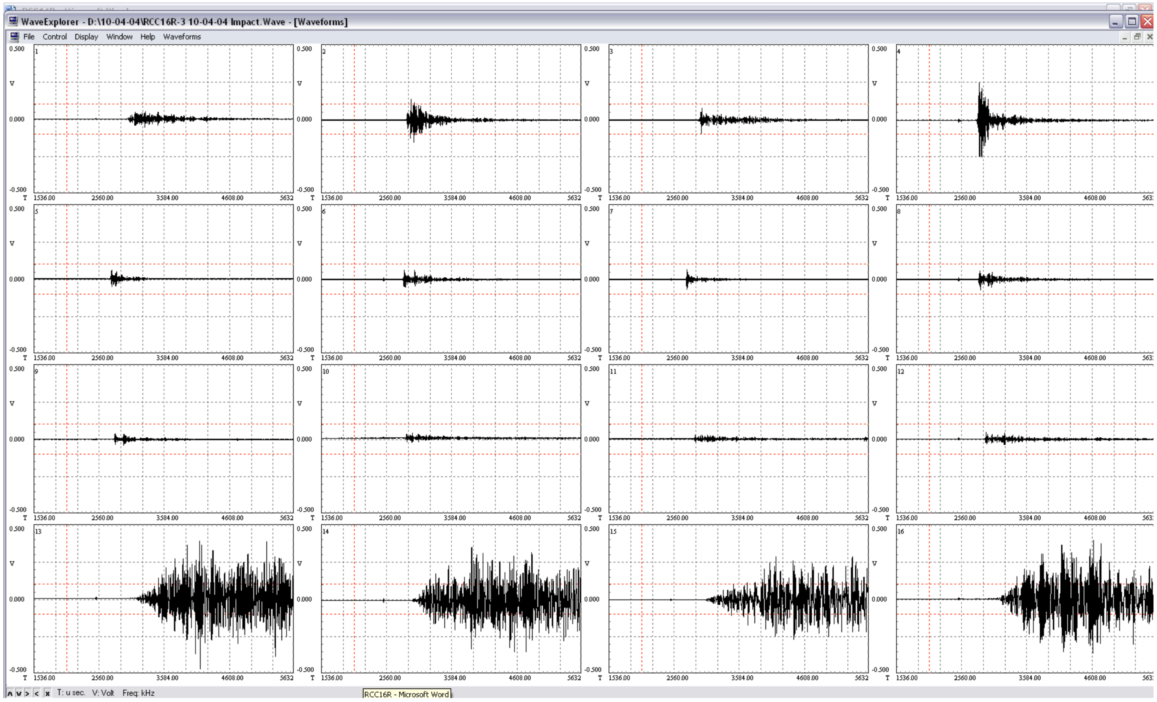

Figure 50: RCC16R Shot #3 Impact Waveform

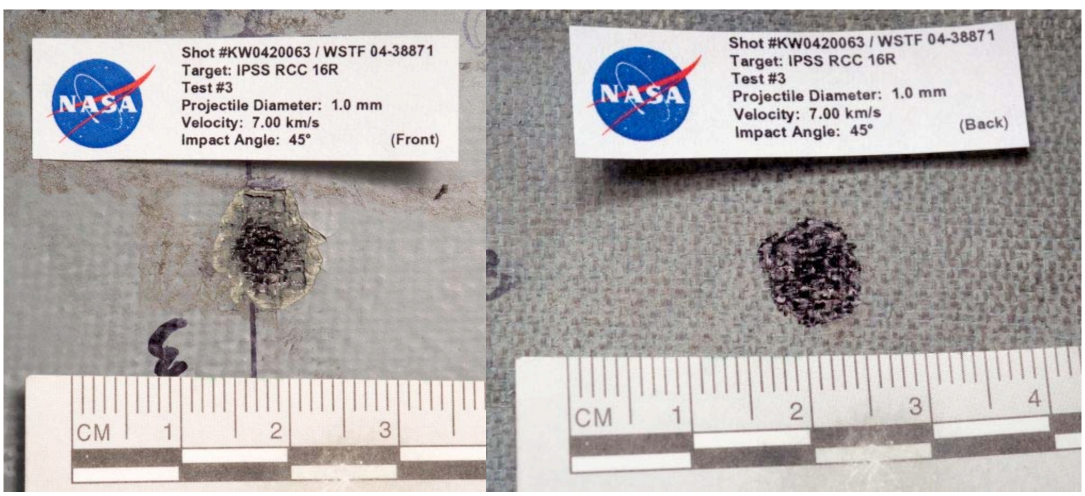

Figure 51: RCC16R Shot #3 Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:
Test date: 10/05/04 Specimen ID: RCC16R
Test number: RCC16R-4 Projectile size: 0.4 mm/30deg.
Planned velocity: 6.8 km/s
Planned impact coordinates: (50, 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: All sensors good.

III. Record sensor serial number and coordinates:

Sensor 1: S/N 101147 Sensor 2: S/N 084016
Sensor 3: S/N 084021 Sensor 4: S/N 084018
Sensor 5: S/N 084027 Sensor 6: S/N 084024
Sensor 7: S/N 084028 Sensor 8: S/N 084011
Sensor 9: S/N 084015 Sensor 10: S/N 084022
Sensor 11: S/N 084017 Sensor 12: S/N 084023
Sensor 13: S/N 190022 Sensor 14: S/N 190033
Sensor 15: S/N 190034 Sensor 16: S/N 190036

Sensor 1: Lower Outboard Flange Corner (up) Sensor 2: Upper Outboard Flange Corner (up)
Sensor 3: Lower Inboard Flange Corner (down) Sensor 4: Upper Inboard Flange Corner (down)
Sensor 5: Upper Surface (46, 05) Sensor 6: Upper Surface (46, 19)
Sensor 7: Upper Surface (31, 05) Sensor 8: Upper Surface (31, 19)
Sensor 9: Lower Surface (23, 05) Sensor 10: Lower Surface (23, 19)
Sensor 11: Lower Surface (11, 05) Sensor 12: Lower Surface (11, 19)
Sensor 13: Lower Outboard Underside Spar Sensor 14: Upper Outboard Underside Spar
Sensor 15: Upper Inboard Underside Spar Sensor 16: Lower Inboard Underside Spar

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: RCC16R-4 10-05-04 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______
16 channel recording mode:	X______
Data acquisition in record mode: (DWC logo spinning)	X______

Record and verify gain settings:

Sensor	Attenuators	Preamp	SCM
Sensor 1:	0	0	18
Sensor 2:	0	0	9
Sensor 3:	0	20	6
Sensor 4:	0	-20	12
Sensor 5:	0	-20	6
Sensor 6:	0	-20	21
Sensor 7:	0	-20	18
Sensor 8:	0	0	3
Sensor 9:	0	-20	21
Sensor 10:	0	0	3
Sensor 11:	0	0	3
Sensor 12:	0	0	12
Sensor 13:	0	20	27
Sensor 14:	0	20	27
Sensor 15:	0	20	27
Sensor 16:	0	20	27

Record file name: RCC16R-4 10-05-04 Impact

Comments: Clipping on some channels.

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:

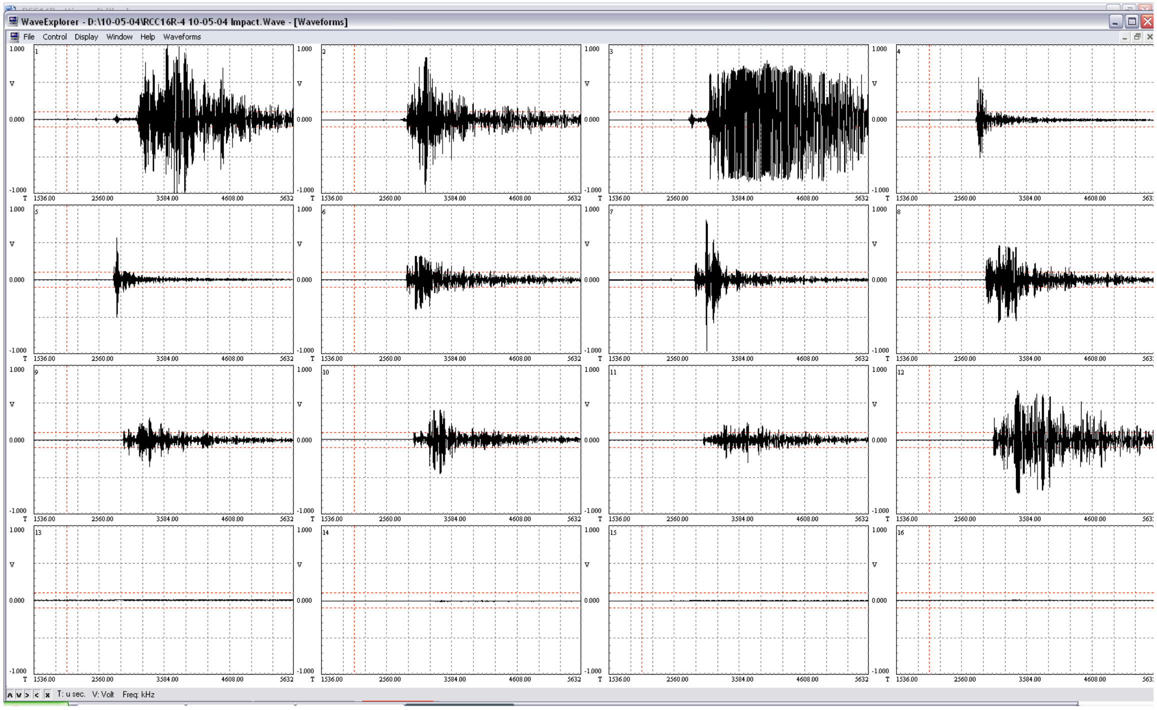

Figure 52: RCC16R Shot #4 Impact Waveform

Figure 53: RCC16R Shot #4 Impact Damage

AE Test Data/Checklist

I. Record pretest information:

Test date: 10/06/04_____ Specimen ID: _RCC16R________

Test number: RCC16R-5___ Projectile size: 0.6 mm/45deg.

Planned velocity: _6.8 km/s____

Planned impact coordinates: (5, 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: All sensors good.

III. Record sensor serial number and coordinates:

Sensor 1: S/N_101147 Sensor 2: S/N_084016
Sensor 3: S/N_084021 Sensor 4: S/N_084018
Sensor 5: S/N_084027 Sensor 6: S/N_084024
Sensor 7: S/N_084028 Sensor 8: S/N_084011
Sensor 9: S/N_084015 Sensor 10: S/N_084022
Sensor 11: S/N_084017 Sensor 12: S/N_084023
Sensor 13: S/N_190022 Sensor 14: S/N_190033
Sensor 15: S/N_190034 Sensor 16: S/N_190036

Sensor 1: _Lower Outboard Flange Corner (up) Sensor 2: _Upper Outboard Flange Corner (up)
Sensor 3: _Lower Inboard Flange Corner (down) Sensor 4: _Upper Inboard Flange Corner (down)
Sensor 5: _Upper Surface (46, 05) Sensor 6: _Upper Surface (46, 19)
Sensor 7: _Upper Surface (31, 05) Sensor 8: _Upper Surface (31, 19)
Sensor 9: _Lower Surface (23, 05) Sensor 10: _Lower Surface (23, 19)
Sensor 11: _Lower Surface (11, 05) Sensor 12: _Lower Surface (11, 19)
Sensor 13: _Lower Outboard Underside Spar Sensor 14: _Upper Outboard Underside Spar
Sensor 15: _Upper Inboard Underside Spar Sensor 16: _Lower Inboard Underside Spar

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: RCC16R-5 10-06-04 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______

16 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: 15
Sensor 3:	Attenuators: 0	Preamp: -20	SCM: 3
Sensor 4:	Attenuators: 0	Preamp: -20	SCM: 15
Sensor 5:	Attenuators: 0	Preamp: -20	SCM: 9
Sensor 6:	Attenuators: 0	Preamp: -20	SCM: 12
Sensor 7:	Attenuators: 0	Preamp: -20	SCM: 9
Sensor 8:	Attenuators: 0	Preamp: -20	SCM: 9
Sensor 9:	Attenuators: 0	Preamp: -20	SCM: 6
Sensor 10:	Attenuators: 0	Preamp: -20	SCM: 9
Sensor 11:	Attenuators: 0	Preamp: -20	SCM: 0
Sensor 12:	Attenuators: 0	Preamp: -20	SCM: 9
Sensor 13:	Attenuators: 0	Preamp: 20	SCM: 12
Sensor 14:	Attenuators: 0	Preamp: 20	SCM: 12
Sensor 15:	Attenuators: 0	Preamp: 20	SCM: 6
Sensor 16:	Attenuators: 0	Preamp: 20	SCM: 15

Record file name: RCC16R-5 10-06-04 Impact

Comments: 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: 6.80 km/s.
Impact coordinates: ________________
Damage description and comments:

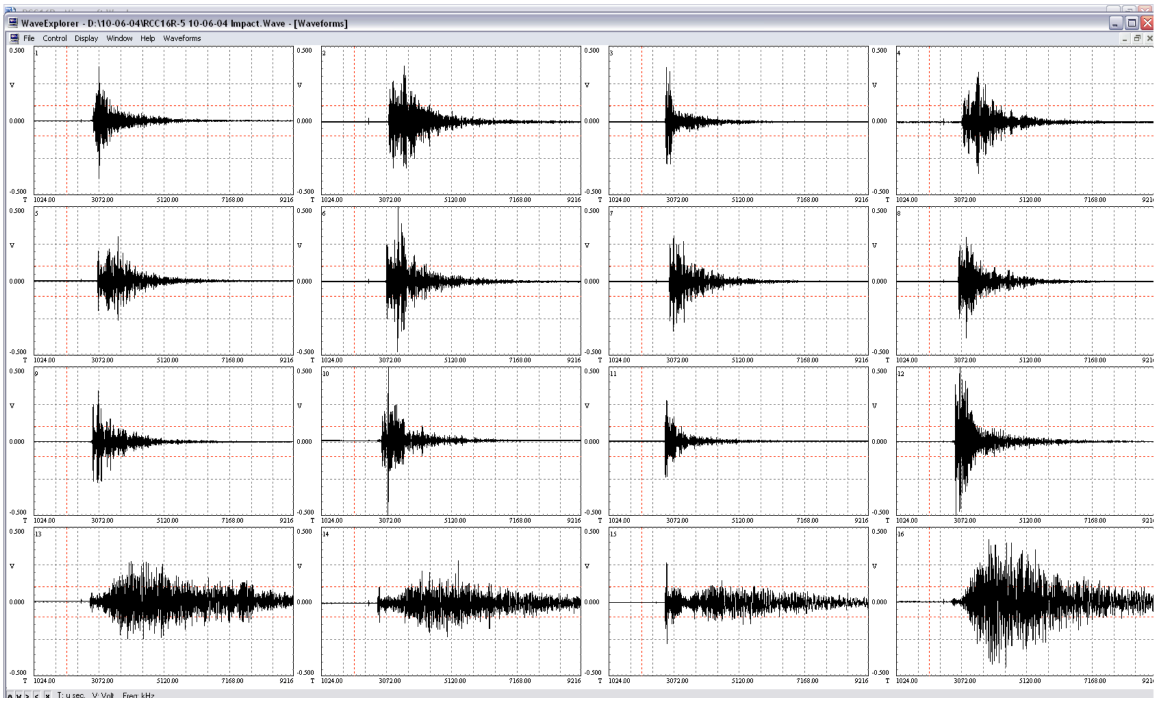

Figure 54: RCC16R Shot #5 Impact Waveform

Figure 55: RCC16R Shot #5 Impact Damage

AE Test Data/Checklist

I. Record pretest information:
Test date: 10/19/04 Specimen ID: RCC16R
Test number: RCC16R-6a Projectile size: 0.8 mm/90deg.
Planned velocity: 6.8 km/s
Planned impact coordinates: (26, 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: All sensors good.

III. Record sensor serial number and coordinates:

Sensor 1: S/N 101147 Sensor 2: S/N 084016
Sensor 3: S/N 084021 Sensor 4: S/N 084018
Sensor 5: S/N 084027 Sensor 6: S/N 084024
Sensor 7: S/N 084028 Sensor 8: S/N 084011
Sensor 9: S/N 084015 Sensor 10: S/N 084022
Sensor 11: S/N 084017 Sensor 12: S/N 084023
Sensor 13: S/N 190022 Sensor 14: S/N 190033
Sensor 15: S/N 190034 Sensor 16: S/N 190036

Sensor 1: Lower Outboard Flange Corner (up) Sensor 2: Upper Outboard Flange Corner (up)
Sensor 3: Lower Inboard Flange Corner (down) Sensor 4: Upper Inboard Flange Corner (down)
Sensor 5: Upper Surface (46, 05) Sensor 6: Upper Surface (46, 19)
Sensor 7: Upper Surface (31, 05) Sensor 8: Upper Surface (31, 19)
Sensor 9: Lower Surface (23, 05) Sensor 10: Lower Surface (23, 19)
Sensor 11: Lower Surface (11, 05) Sensor 12: Lower Surface (11, 19)
Sensor 13: Lower Outboard Underside Spar Sensor 14: Upper Outboard Underside Spar
Sensor 15: Upper Inboard Underside Spar Sensor 16: Lower Inboard Underside Spar

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: RCC16R-6a 10-19-04 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______

16 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: 0
Sensor 6:	Attenuators: 0	Preamp: -20	SCM: 0
Sensor 7:	Attenuators: 0	Preamp: -20	SCM: 0
Sensor 8:	Attenuators: 0	Preamp: -20	SCM: 0
Sensor 9:	Attenuators: 0	Preamp: -20	SCM: 0
Sensor 10:	Attenuators: 0	Preamp: -20	SCM: 0
Sensor 11:	Attenuators: 0	Preamp: -20	SCM: 0
Sensor 12:	Attenuators: 0	Preamp: -20	SCM: 0
Sensor 13:	Attenuators: 0	Preamp: 20	SCM: 6
Sensor 14:	Attenuators: 0	Preamp: 20	SCM: 6
Sensor 15:	Attenuators: 0	Preamp: 20	SCM: 6
Sensor 16:	Attenuators: 0	Preamp: 20	SCM: 6

Record file name: RCC16R-6a 10-19-04 Impact

Comments: 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: 6.99 km/s.
Impact coordinates: _________________
Damage description and comments:

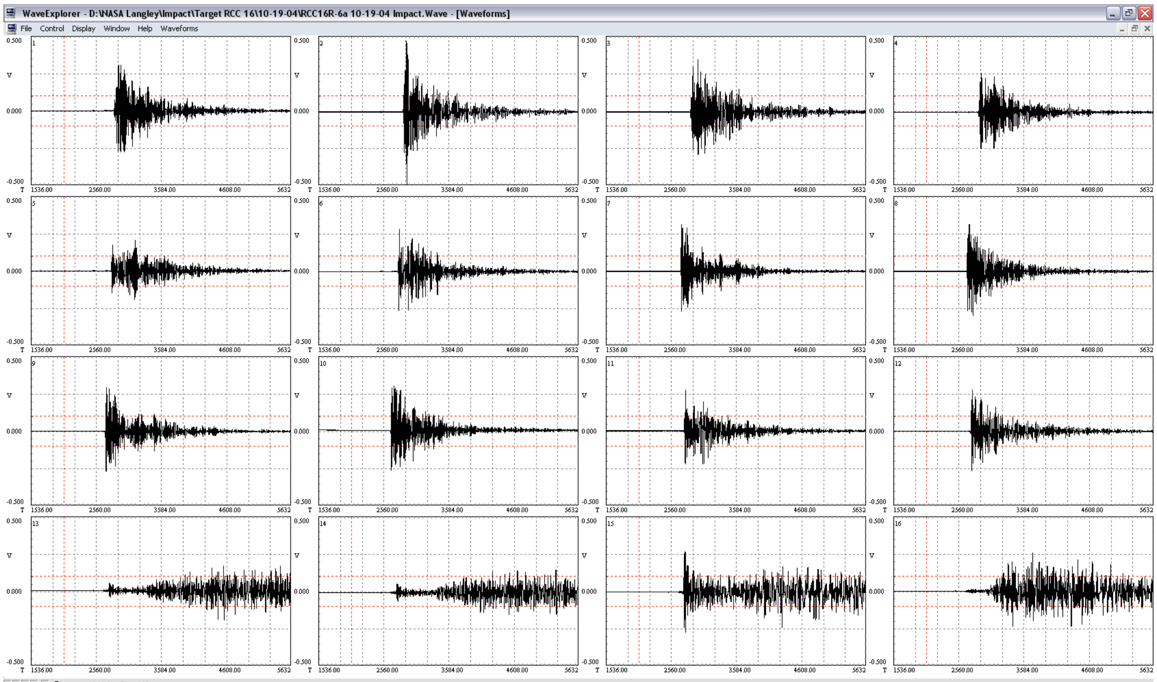

Figure 56: RCC16R Shot #6a Impact Waveform

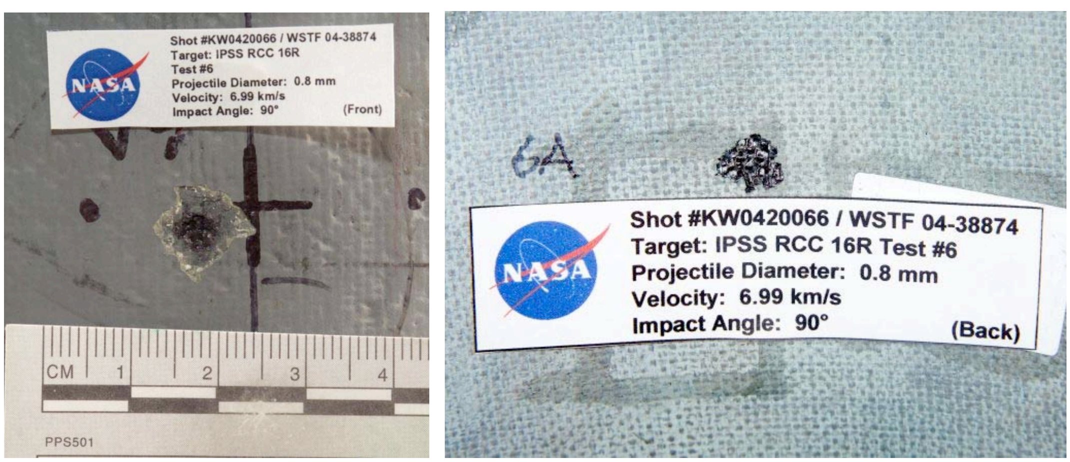

Figure 57: RCC16R Shot #6a Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:

Test date: 10/07/04_____ Specimen ID: _RCC16R________

Test number: RCC16R-7___ Projectile size: 1.0 mm/30deg.

Planned velocity: _6.8 km/s____

Planned impact coordinates: (35, 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: All sensors good.

III. Record sensor serial number and coordinates:

Sensor 1: S/N_101147 Sensor 2: S/N_084016
Sensor 3: S/N_084021 Sensor 4: S/N_084018
Sensor 5: S/N_084027 Sensor 6: S/N_084024
Sensor 7: S/N_084028 Sensor 8: S/N_084011
Sensor 9: S/N_084015 Sensor 10: S/N_084022
Sensor 11: S/N_084017 Sensor 12: S/N_084023
Sensor 13: S/N_190022 Sensor 14: S/N_190033
Sensor 15: S/N_190034 Sensor 16: S/N_190036

Sensor 1: _Lower Outboard Flange Corner (up) Sensor 2: _Upper Outboard Flange Corner (up)

Sensor 3: _Lower Inboard Flange Corner (down) Sensor 4: _Upper Inboard Flange Corner (down)

Sensor 5: _Upper Surface (46, 05) Sensor 6: _Upper Surface (46, 19)

Sensor 7: _Upper Surface (31, 05) Sensor 8: _Upper Surface (31, 19)

Sensor 9: _Lower Surface (23, 05) Sensor 10: _Lower Surface (23, 19)

Sensor 11: _Lower Surface (11, 05) Sensor 12: _Lower Surface (11, 19)

Sensor 13: _Lower Outboard Underside Spar Sensor 14: _Upper Outboard Underside Spar

Sensor 15: _Upper Inboard Underside Spar Sensor 16: _Lower Inboard Underside Spar

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: RCC16R-7 10-07-04 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______
16 channel recording mode: X______
Data acquisition in record mode: X______
(DWC logo spinning)
Record and verify gain settings:

Sensor	Attenuators	Preamp	SCM
Sensor 1:	30	20	0
Sensor 2:	30	20	0
Sensor 3:	30	20	0
Sensor 4:	30	20	0
Sensor 5:	30	0	6
Sensor 6:	30	0	15
Sensor 7:	30	0	6
Sensor 8:	30	0	12
Sensor 9:	30	0	9
Sensor 10:	30	0	15
Sensor 11:	30	0	15
Sensor 12:	30	0	15
Sensor 13:	0	20	6
Sensor 14:	0	20	6
Sensor 15:	0	20	6
Sensor 16:	0	20	6

Record file name: RCC16R-7 10-07-04 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: 6.80 km/s.

Impact coordinates: _________________

Damage description and comments:

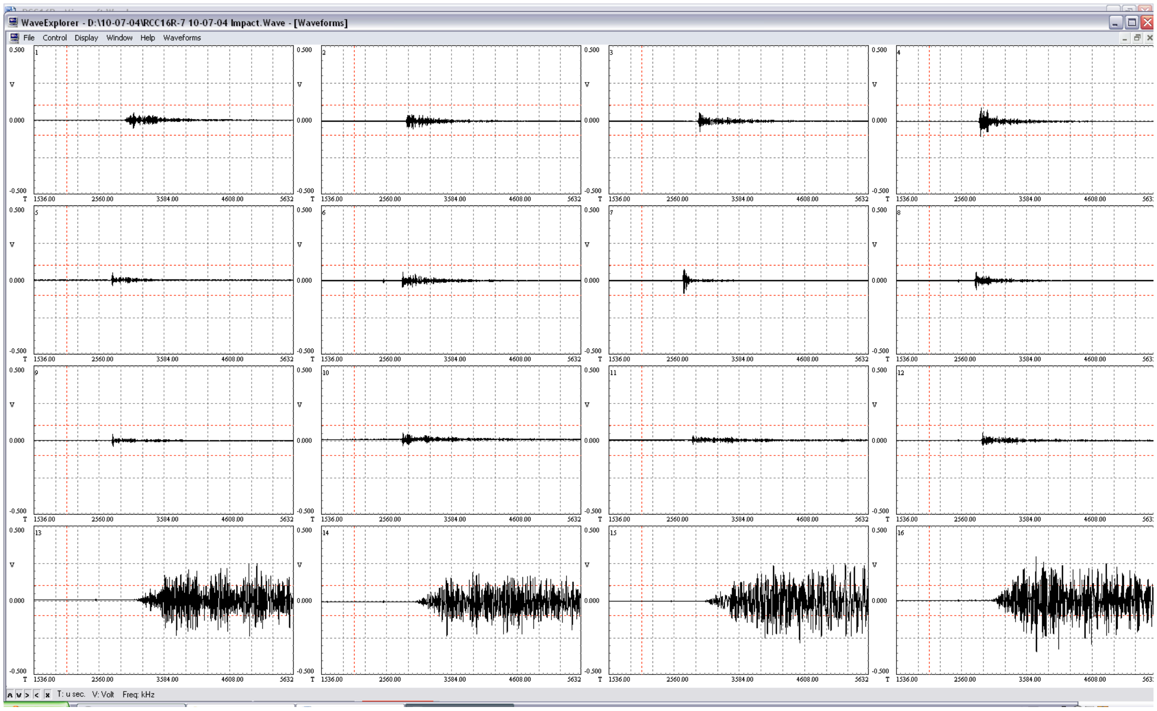

Figure 58: RCC16R Shot #7 Impact Waveform

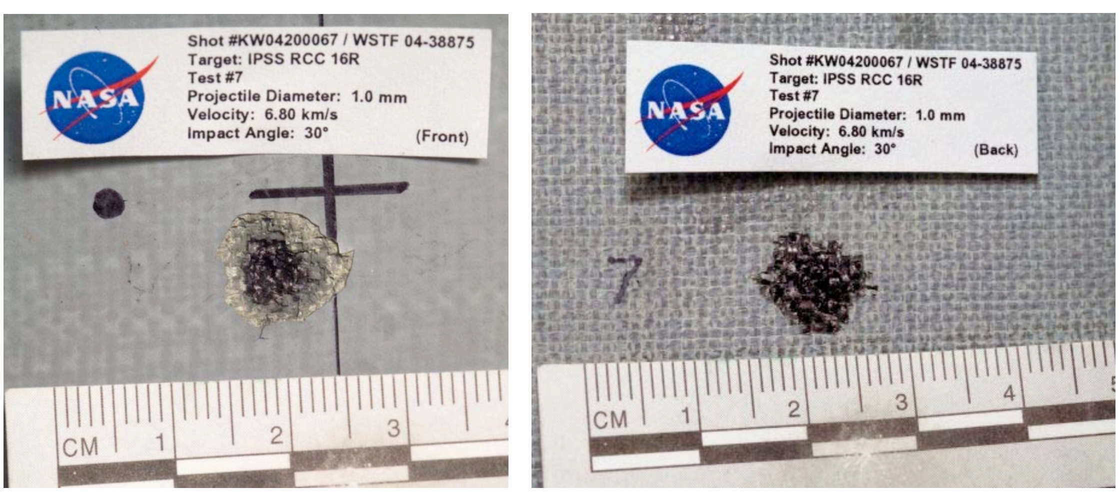

Figure 59: RCC16R Shot #7 Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:

Test date: 10/07/04_____ Specimen ID: RCC16R________

Test number: RCC16R-8___ Projectile size: 0.8 mm/60deg.

Planned velocity: 6.8 km/s____

Planned impact coordinates: (39, 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: All sensors good.

III. Record sensor serial number and coordinates:

Sensor 1: S/N 101147 Sensor 2: S/N 084016
Sensor 3: S/N 084021 Sensor 4: S/N 084018
Sensor 5: S/N 084027 Sensor 6: S/N 084024
Sensor 7: S/N 084028 Sensor 8: S/N 084011
Sensor 9: S/N 084015 Sensor 10: S/N 084022
Sensor 11: S/N 084017 Sensor 12: S/N 084023
Sensor 13: S/N 190022 Sensor 14: S/N 190033
Sensor 15: S/N 190034 Sensor 16: S/N 190036

Sensor 1: Lower Outboard Flange Corner (up) Sensor 2: Upper Outboard Flange Corner (up)

Sensor 3: Lower Inboard Flange Corner (down) Sensor 4: Upper Inboard Flange Corner (down)

Sensor 5: Upper Surface (46, 05) Sensor 6: Upper Surface (46, 19)

Sensor 7: Upper Surface (31, 05) Sensor 8: Upper Surface (31, 19)

Sensor 9: Lower Surface (23, 05) Sensor 10: Lower Surface (23, 19)

Sensor 11: Lower Surface (11, 05) Sensor 12: Lower Surface (11, 19)

Sensor 13: Lower Outboard Underside Spar Sensor 14: Upper Outboard Underside Spar

Sensor 15: Upper Inboard Underside Spar Sensor 16: Lower Inboard Underside Spar

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: RCC16R-8 10-07-04 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______
16 channel recording mode: X______
Data acquisition in record mode: X______
(DWC logo spinning)
Record and verify gain settings:

Sensor 1:	Attenuators: 30	Preamp: 0	SCM: 18
Sensor 2:	Attenuators: 30	Preamp: 0	SCM: 18
Sensor 3:	Attenuators: 30	Preamp: 0	SCM: 18
Sensor 4:	Attenuators: 30	Preamp: 0	SCM: 18
Sensor 5:	Attenuators: 30	Preamp: 0	SCM: 0
Sensor 6:	Attenuators: 30	Preamp: 0	SCM: 0
Sensor 7:	Attenuators: 30	Preamp: 0	SCM: 0
Sensor 8:	Attenuators: 30	Preamp: 0	SCM: 0
Sensor 9:	Attenuators: 30	Preamp: 0	SCM: 0
Sensor 10:	Attenuators: 30	Preamp: 0	SCM: 0
Sensor 11:	Attenuators: 30	Preamp: 0	SCM: 0
Sensor 12:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 13:	Attenuators: 0	Preamp: 20	SCM: 12
Sensor 14:	Attenuators: 0	Preamp: 20	SCM: 12
Sensor 15:	Attenuators: 0	Preamp: 20	SCM: 12
Sensor 16:	Attenuators: 0	Preamp: 20	SCM: 12

Record file name: RCC16R-8 10-07-04 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: 6.80 km/s.
Impact coordinates: ________________
Damage description and comments:

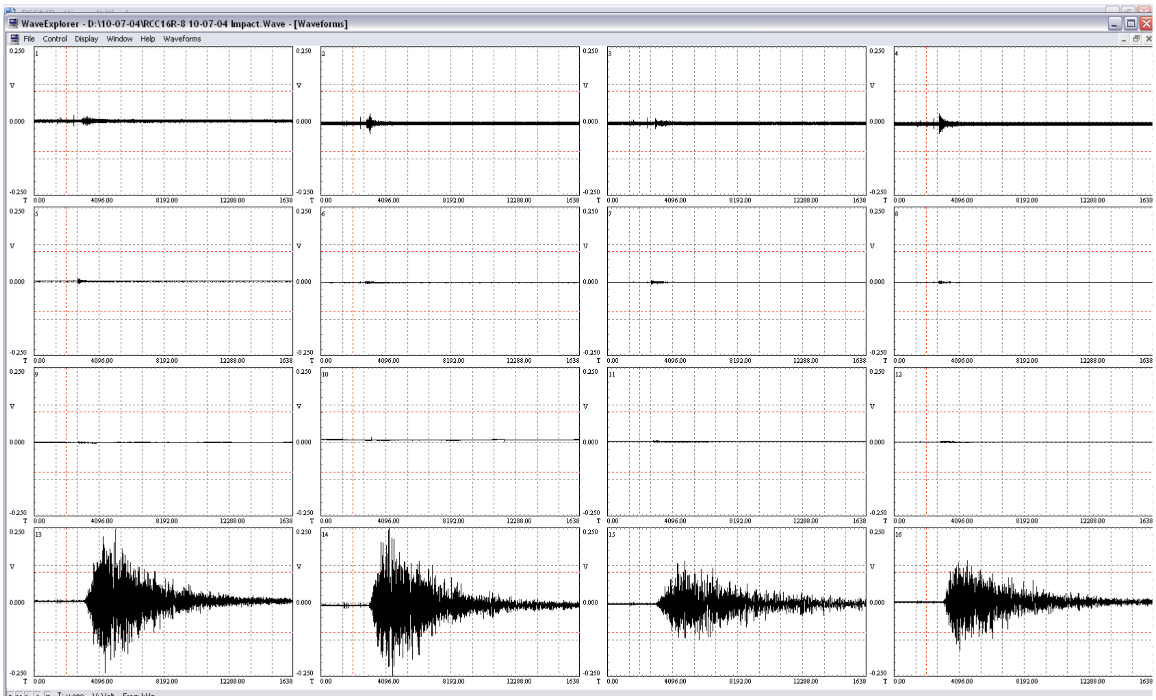

Figure 60: RCC16R Shot #8 Impact Waveform

Figure 61: RCC16R Shot #8 Impact Damage

AE Test Data/Checklist

I. Record pretest information:

Test date: 10/12/04_____ Specimen ID: _RCC16R________

Test number: RCC16R-9b___ Projectile size: 1.2 mm/30deg.

Planned velocity: _6.8 km/s____

Planned impact coordinates: (50, 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: All sensors good.

III. Record sensor serial number and coordinates:

Sensor 1: S/N_101147 Sensor 2: S/N_084016

Sensor 3: S/N_084021 Sensor 4: S/N_084018

Sensor 5: S/N_084027 Sensor 6: S/N_084024

Sensor 7: S/N_084028 Sensor 8: S/N_084011

Sensor 9: S/N_084015 Sensor 10: S/N_084022

Sensor 11: S/N_084017 Sensor 12: S/N_084023

Sensor 13: S/N_190022 Sensor 14: S/N_190033

Sensor 15: S/N_190034 Sensor 16: S/N_190036

Sensor 1: _Lower Outboard Flange Corner (up) Sensor 2: _Upper Outboard Flange Corner (up)

Sensor 3: _Lower Inboard Flange Corner (down) Sensor 4: _Upper Inboard Flange Corner (down)

Sensor 5: _Upper Surface (46, 05) Sensor 6: _Upper Surface (46, 19)

Sensor 7: _Upper Surface (31, 05) Sensor 8: _Upper Surface (31, 19)

Sensor 9: _Lower Surface (23, 05) Sensor 10: _Lower Surface (23, 19)

Sensor 11: _Lower Surface (11, 05) Sensor 12: _Lower Surface (11, 19)

Sensor 13: _Lower Outboard Underside Spar Sensor 14: _Upper Outboard Underside Spar

Sensor 15: _Upper Inboard Underside Spar Sensor 16: _Lower Inboard Underside Spar

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: RCC16R-9b 10-12-04 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______
16 channel recording mode: X______
Data acquisition in record mode: X______
(DWC logo spinning)
Record and verify gain settings:

Sensor 1:	Attenuators: 30	Preamp: 0	SCM: 21
Sensor 2:	Attenuators: 30	Preamp: 0	SCM: 18
Sensor 3:	Attenuators: 30	Preamp: 0	SCM: 21
Sensor 4:	Attenuators: 30	Preamp: 0	SCM: 18
Sensor 5:	Attenuators: 30	Preamp: 0	SCM: 0
Sensor 6:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 7:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 8:	Attenuators: 30	Preamp: 0	SCM: 12
Sensor 9:	Attenuators: 30	Preamp: 0	SCM: 12
Sensor 10:	Attenuators: 30	Preamp: 0	SCM: 12
Sensor 11:	Attenuators: 30	Preamp: 0	SCM: 12
Sensor 12:	Attenuators: 30	Preamp: 0	SCM: 12
Sensor 13:	Attenuators: 0	Preamp: 20	SCM: 3
Sensor 14:	Attenuators: 0	Preamp: 20	SCM: 3
Sensor 15:	Attenuators: 0	Preamp: 20	SCM: 3
Sensor 16:	Attenuators: 0	Preamp: 20	SCM: 3

Record file name: RCC16R-9b 10-12-04 Impact
Comments: 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: 6.80 km/s.

Impact coordinates: _______________

Damage description and comments:

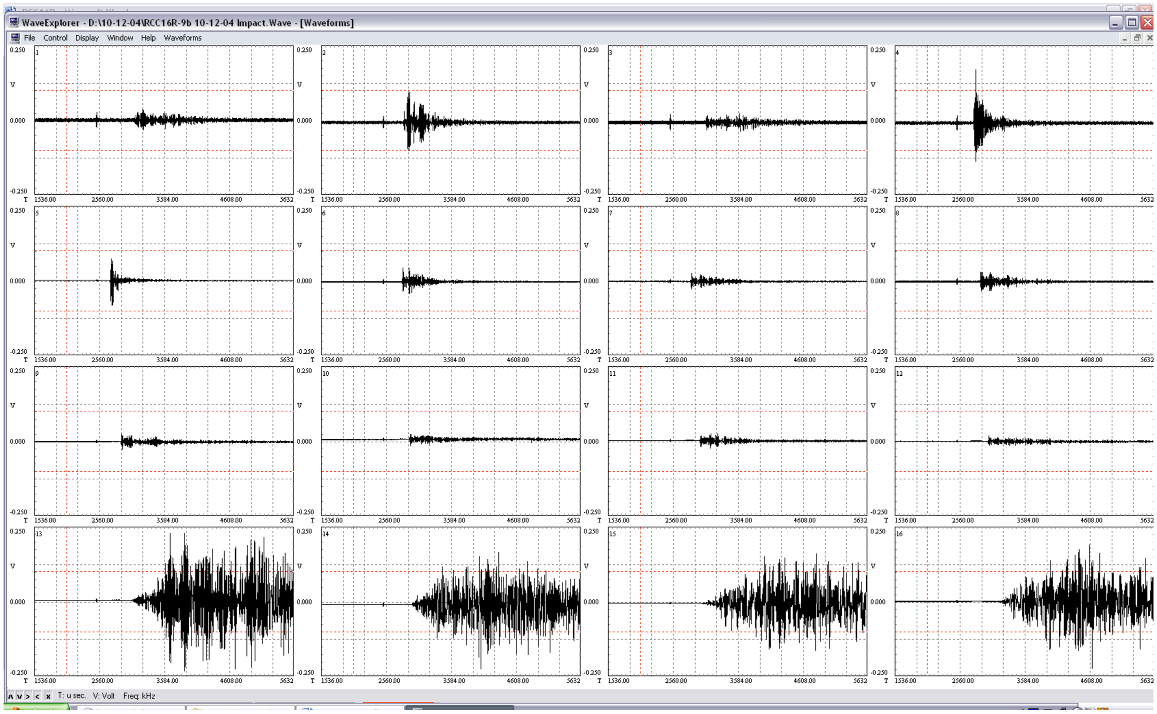

Figure 62: RCC16R Shot #9b Impact Waveform

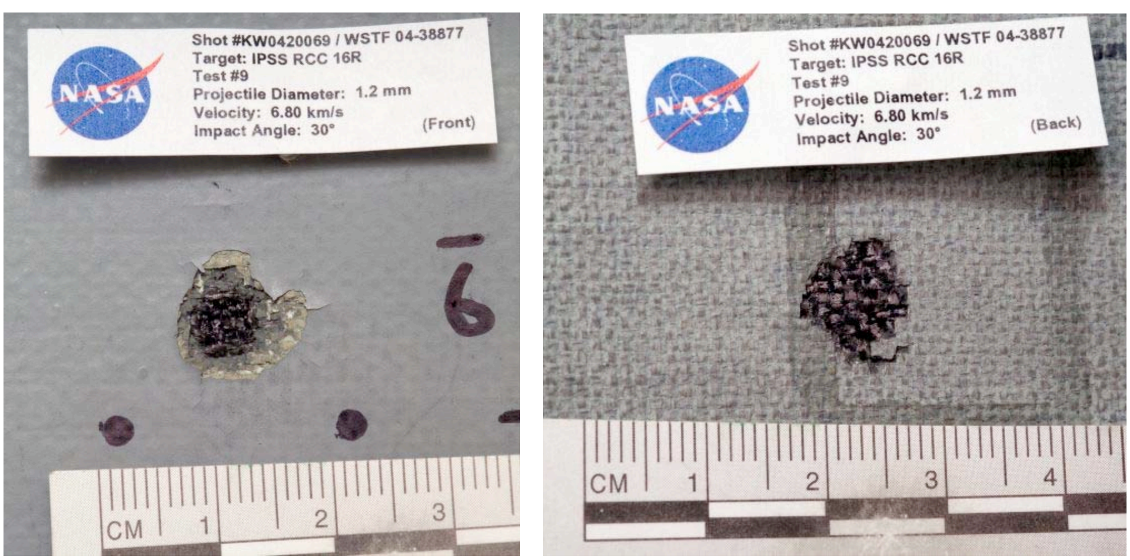

Figure 63: RCC16R Shot #9b Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:

Test date: 10/13/04_____ Specimen ID: _RCC16R________

Test number: RCC16R-10___ Projectile size: 0.8 mm/30deg.

Planned velocity: _6.8 km/s____

Planned impact coordinates: (5, 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: All sensors good.

III. Record sensor serial number and coordinates:

Sensor 1: S/N_101147 Sensor 2: S/N_084016

Sensor 3: S/N_084021 Sensor 4: S/N_084018

Sensor 5: S/N_084027 Sensor 6: S/N_084024

Sensor 7: S/N_084028 Sensor 8: S/N_084011

Sensor 9: S/N_084015 Sensor 10: S/N_084022

Sensor 11: S/N_084017 Sensor 12: S/N_084023

Sensor 13: S/N_190022 Sensor 14: S/N_190033

Sensor 15: S/N_190034 Sensor 16: S/N_190036

Sensor 1: _Lower Outboard Flange Corner (up) Sensor 2: _Upper Outboard Flange Corner (up)

Sensor 3: _Lower Inboard Flange Corner (down) Sensor 4: _Upper Inboard Flange Corner (down)

Sensor 5: _Upper Surface (46, 05) Sensor 6: _Upper Surface (46, 19)

Sensor 7: _Upper Surface (31, 05) Sensor 8: _Upper Surface (31, 19)

Sensor 9: _Lower Surface (23, 05) Sensor 10: _Lower Surface (23, 19)

Sensor 11: _Lower Surface (11, 05) Sensor 12: _Lower Surface (11, 19)

Sensor 13: _Lower Outboard Underside Spar Sensor 14: _Upper Outboard Underside Spar

Sensor 15: _Upper Inboard Underside Spar Sensor 16: _Lower Inboard Underside Spar

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: RCC16R-10 10-13-04 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______
16 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: 3
Sensor 2:	Attenuators: 0	Preamp: -20	SCM: 3
Sensor 3:	Attenuators: 0	Preamp: -20	SCM: 0
Sensor 4:	Attenuators: 0	Preamp: -20	SCM: 3
Sensor 5:	Attenuators: 0	Preamp: -20	SCM: 0
Sensor 6:	Attenuators: 0	Preamp: -20	SCM: 0
Sensor 7:	Attenuators: 0	Preamp: -20	SCM: 0
Sensor 8:	Attenuators: 0	Preamp: -20	SCM: 0
Sensor 9:	Attenuators: 0	Preamp: -20	SCM: 0
Sensor 10:	Attenuators: 0	Preamp: -20	SCM: 0
Sensor 11:	Attenuators: 0	Preamp: -20	SCM: 0
Sensor 12:	Attenuators: 0	Preamp: -20	SCM: 0
Sensor 13:	Attenuators: 0	Preamp: 20	SCM: 9
Sensor 14:	Attenuators: 0	Preamp: 20	SCM: 9
Sensor 15:	Attenuators: 0	Preamp: 20	SCM: 9
Sensor 16:	Attenuators: 0	Preamp: 20	SCM: 9

Record file name: RCC16R-10 10-13-04 Impact
Comments: 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: 6.84 km/s.

Impact coordinates: ________________

Damage description and comments:

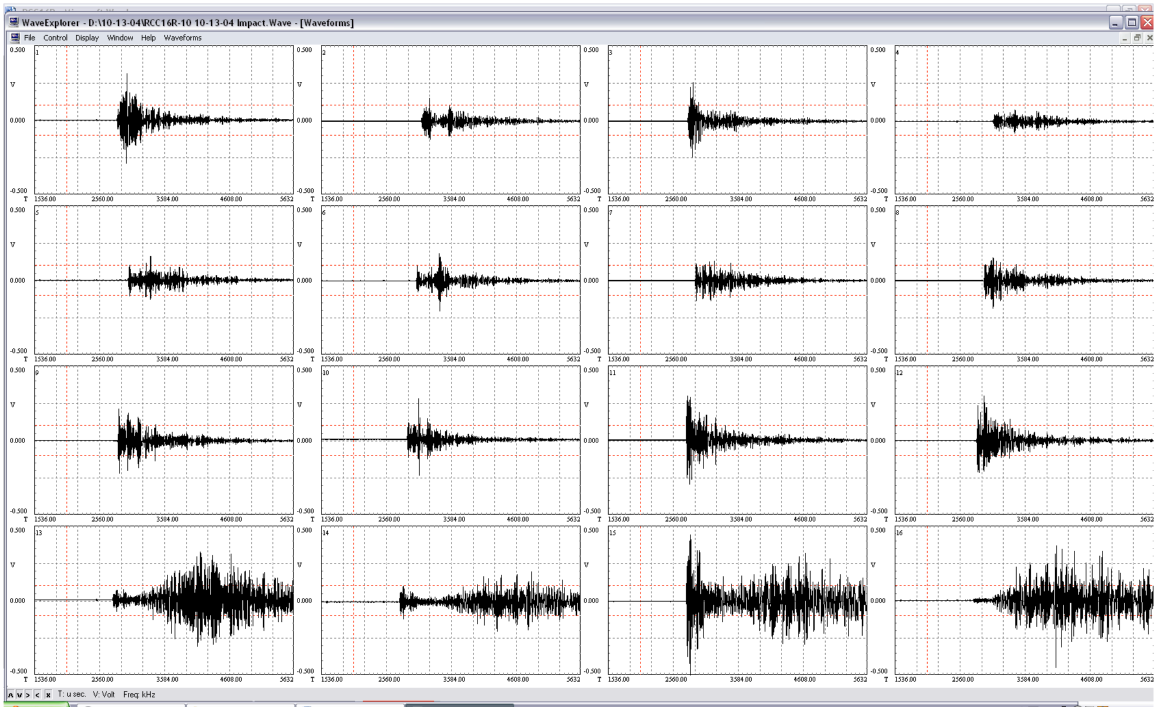

Figure 64: RCC16R Shot #10 Impact Waveform

Figure 65: RCC16R Shot #10 Impact Damage

AE Test Data/Checklist

I. Record pretest information:

Test date: 10/14/04 Specimen ID: RCC16R

Test number: RCC16R-11 Projectile size: 1.2 mm/60deg.

Planned velocity: 6.8 km/s

Planned impact coordinates: (31, 10)

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: All sensors good.

III. Record sensor serial number and coordinates:

Sensor 1: S/N 101147 Sensor 2: S/N 084016

Sensor 3: S/N 084021 Sensor 4: S/N 084018

Sensor 5: S/N 084027 Sensor 6: S/N 084024

Sensor 7: S/N 084028 Sensor 8: S/N 084011

Sensor 9: S/N 084015 Sensor 10: S/N 084022

Sensor 11: S/N 084017 Sensor 12: S/N 084023

Sensor 13: S/N 190022 Sensor 14: S/N 190033

Sensor 15: S/N 190034 Sensor 16: S/N 190036

Sensor 1: Lower Outboard Flange Corner (up) Sensor 2: Upper Outboard Flange Corner (up)

Sensor 3: Lower Inboard Flange Corner (down) Sensor 4: Upper Inboard Flange Corner (down)

Sensor 5: Upper Surface (46, 05) Sensor 6: Upper Surface (46, 19)

Sensor 7: Upper Surface (31, 05) Sensor 8: Upper Surface (31, 19)

Sensor 9: Lower Surface (23, 05) Sensor 10: Lower Surface (23, 19)

Sensor 11: Lower Surface (11, 05) Sensor 12: Lower Surface (11, 19)

Sensor 13: Lower Outboard Underside Spar Sensor 14: Upper Outboard Underside Spar

Sensor 15: Upper Inboard Underside Spar Sensor 16: Lower Inboard Underside Spar

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: RCC16R-11 10-14-04 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______
16 channel recording mode: X______
Data acquisition in record mode: X______
(DWC logo spinning)

Record and verify gain settings:

Sensor 1:	Attenuators: 30	Preamp: 0	SCM: 12
Sensor 2:	Attenuators: 30	Preamp: 0	SCM: 12
Sensor 3:	Attenuators: 30	Preamp: 0	SCM: 12
Sensor 4:	Attenuators: 30	Preamp: 0	SCM: 12
Sensor 5:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 6:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 7:	Attenuators: 30	Preamp: 0	SCM: 0
Sensor 8:	Attenuators: 30	Preamp: 0	SCM: 0
Sensor 9:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 10:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 11:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 12:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 13:	Attenuators: 0	Preamp: 20	SCM: 3
Sensor 14:	Attenuators: 0	Preamp: 20	SCM: 3
Sensor 15:	Attenuators: 0	Preamp: 20	SCM: 3
Sensor 16:	Attenuators: 0	Preamp: 20	SCM: 3

Record file name: RCC16R-11 10-14-04 Impact
Comments: 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: 6.84 km/s.

Impact coordinates: ________________

Damage description and comments:

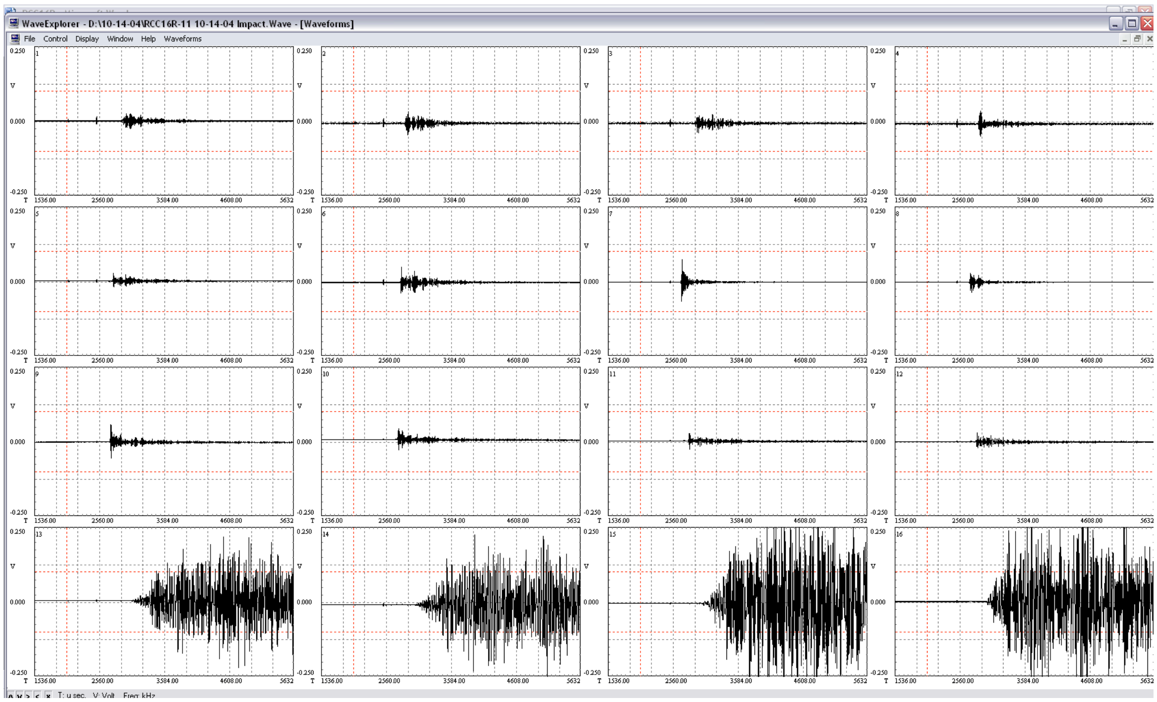

Figure 66: RCC16R Shot #11 Impact Waveform

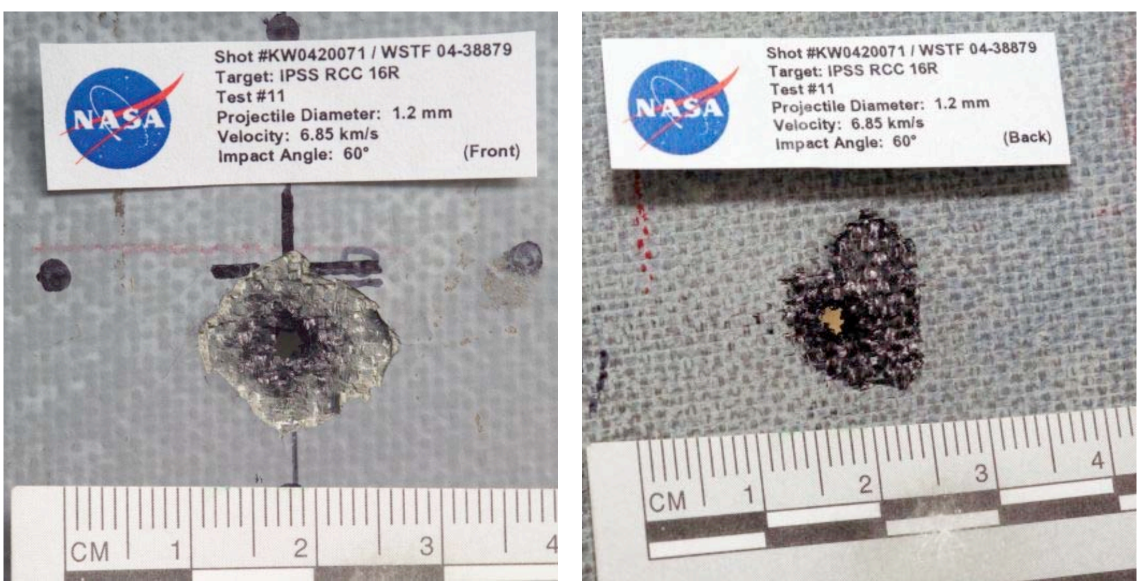

Figure 67: RCC16R Shot #11 Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:

Test date: 10/15/04 Specimen ID: RCC16R

Test number: RCC16R-12 Projectile size: 1.6 mm/45deg.

Planned velocity: 6.8 km/s

Planned impact coordinates: (35, 10)

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: All sensors good.

III. Record sensor serial number and coordinates:

Sensor 1: S/N 101147 Sensor 2: S/N 084016
Sensor 3: S/N 084021 Sensor 4: S/N 084018
Sensor 5: S/N 084027 Sensor 6: S/N 084024
Sensor 7: S/N 084028 Sensor 8: S/N 084011
Sensor 9: S/N 084015 Sensor 10: S/N 084022
Sensor 11: S/N 084017 Sensor 12: S/N 084023
Sensor 13: S/N 190022 Sensor 14: S/N 190033
Sensor 15: S/N 190034 Sensor 16: S/N 190036

Sensor 1: Lower Outboard Flange Corner (up) Sensor 2: Upper Outboard Flange Corner (up)
Sensor 3: Lower Inboard Flange Corner (down) Sensor 4: Upper Inboard Flange Corner (down)
Sensor 5: Upper Surface (46, 05) Sensor 6: Upper Surface (46, 19)
Sensor 7: Upper Surface (31, 05) Sensor 8: Upper Surface (31, 19)
Sensor 9: Lower Surface (23, 05) Sensor 10: Lower Surface (23, 19)
Sensor 11: Lower Surface (11, 05) Sensor 12: Lower Surface (11, 19)
Sensor 13: Lower Outboard Underside Spar Sensor 14: Upper Outboard Underside Spar
Sensor 15: Upper Inboard Underside Spar Sensor 16: Lower Inboard Underside Spar

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: RCC16R-12 10-15-04 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______
16 channel recording mode: X______
Data acquisition in record mode: X______
(DWC logo spinning)
Record and verify gain settings:

Sensor 1:	Attenuators: 30	Preamp: 0	SCM: 15
Sensor 2:	Attenuators: 30	Preamp: 0	SCM: 15
Sensor 3:	Attenuators: 30	Preamp: 0	SCM: 15
Sensor 4:	Attenuators: 30	Preamp: 0	SCM: 15
Sensor 5:	Attenuators: 30	Preamp: 0	SCM: 0
Sensor 6:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 7:	Attenuators: 30	Preamp: 0	SCM: 0
Sensor 8:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 9:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 10:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 11:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 12:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 13:	Attenuators: 0	Preamp: 0	SCM: 18
Sensor 14:	Attenuators: 0	Preamp: 0	SCM: 18
Sensor 15:	Attenuators: 0	Preamp: 0	SCM: 18
Sensor 16:	Attenuators: 0	Preamp: 0	SCM: 18

Record file name: RCC16R-12 10-15-04 Impact
Comments: 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: 6.82 km/s.

Impact coordinates: ________________

Damage description and comments:

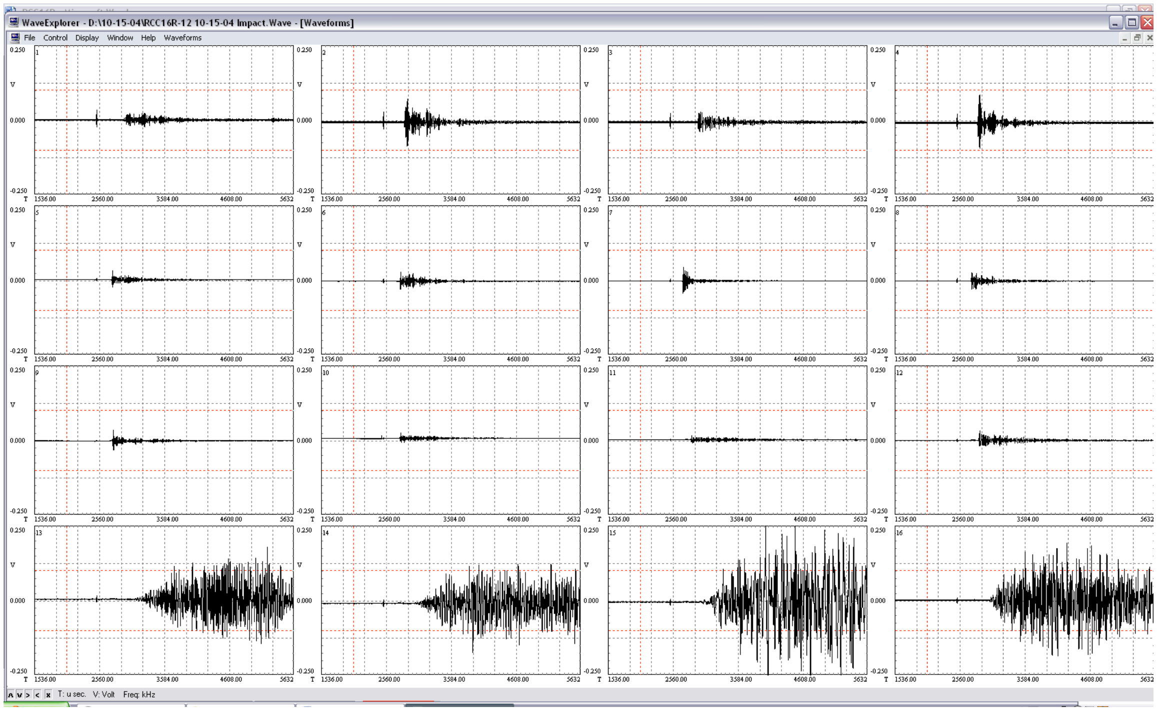

Figure 68: RCC16R Shot #12 Impact Waveform

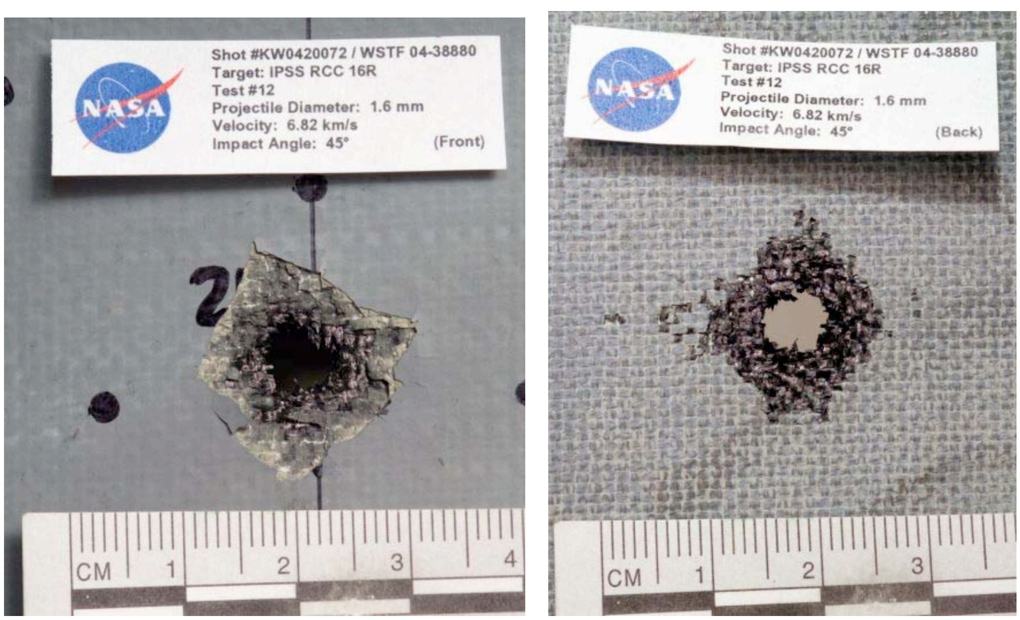

Figure 69: RCC16R Shot #12 Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:

Test date: 10/15/04 Specimen ID: RCC16R
Test number: RCC16R-13 Projectile size: 2.0 mm/45deg.
Planned velocity: 6.8 km/s
Planned impact coordinates: (39, 10)

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: All sensors good.

III. Record sensor serial number and coordinates:

Sensor 1: S/N 101147 Sensor 2: S/N 084016
Sensor 3: S/N 084021 Sensor 4: S/N 084018
Sensor 5: S/N 084027 Sensor 6: S/N 084024
Sensor 7: S/N 084028 Sensor 8: S/N 084011
Sensor 9: S/N 084015 Sensor 10: S/N 084022
Sensor 11: S/N 084017 Sensor 12: S/N 084023
Sensor 13: S/N 190022 Sensor 14: S/N 190033
Sensor 15: S/N 190034 Sensor 16: S/N 190036

Sensor 1: Lower Outboard Flange Corner (up) Sensor 2: Upper Outboard Flange Corner (up)
Sensor 3: Lower Inboard Flange Corner (down) Sensor 4: Upper Inboard Flange Corner (down)
Sensor 5: Upper Surface (46, 05) Sensor 6: Upper Surface (46, 19)
Sensor 7: Upper Surface (31, 05) Sensor 8: Upper Surface (31, 19)
Sensor 9: Lower Surface (23, 05) Sensor 10: Lower Surface (23, 19)
Sensor 11: Lower Surface (11, 05) Sensor 12: Lower Surface (11, 19)
Sensor 13: Lower Outboard Underside Spar Sensor 14: Upper Outboard Underside Spar
Sensor 15: Upper Inboard Underside Spar Sensor 16: Lower Inboard Underside Spar

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: RCC16R-13 10-15-04 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______

16 channel recording mode: X______

Data acquisition in record mode: X______

(DWC logo spinning)

Record and verify gain settings:

Sensor 1:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 2:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 3:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 4:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 5:	Attenuators: 30	Preamp: 0	SCM: 0
Sensor 6:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 7:	Attenuators: 30	Preamp: 0	SCM: 0
Sensor 8:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 9:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 10:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 11:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 12:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 13:	Attenuators: 0	Preamp: 0	SCM: 12
Sensor 14:	Attenuators: 0	Preamp: 0	SCM: 12
Sensor 15:	Attenuators: 0	Preamp: 0	SCM: 12
Sensor 16:	Attenuators: 0	Preamp: 0	SCM: 12

Record file name: RCC16R-13 10-15-04 Impact

Comments: 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: 6.82 km/s.
Impact coordinates: ________________
Damage description and comments:

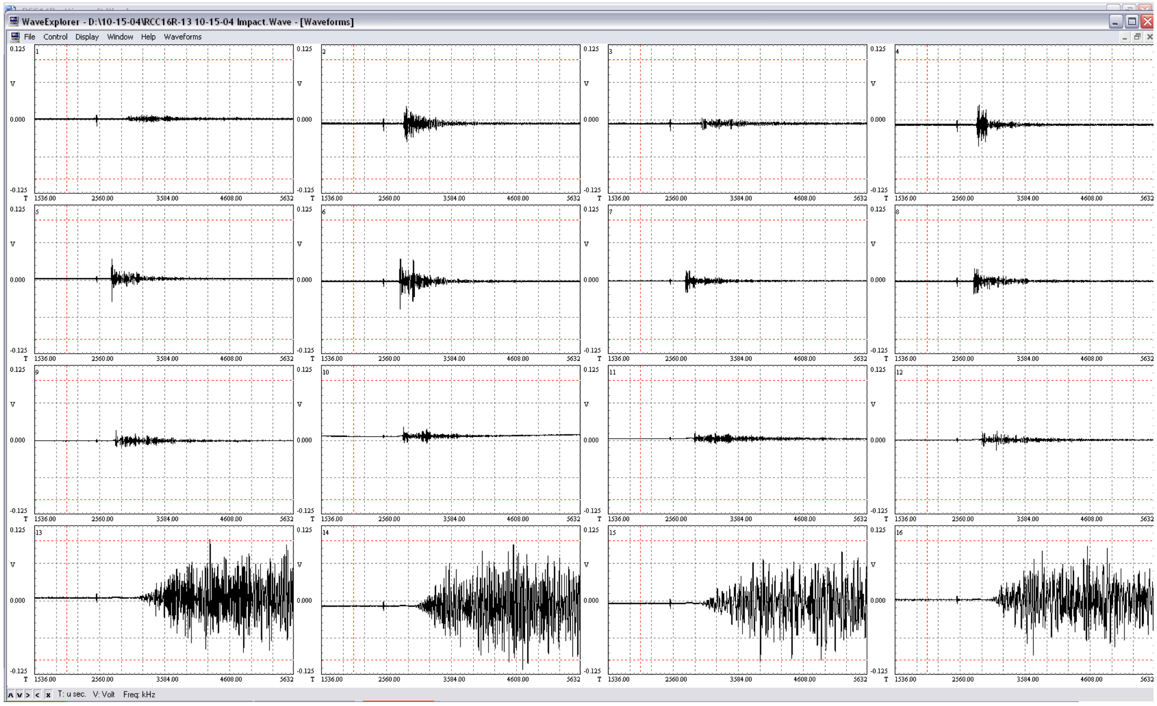

Figure 70: RCC16R Shot #13 Impact Waveform

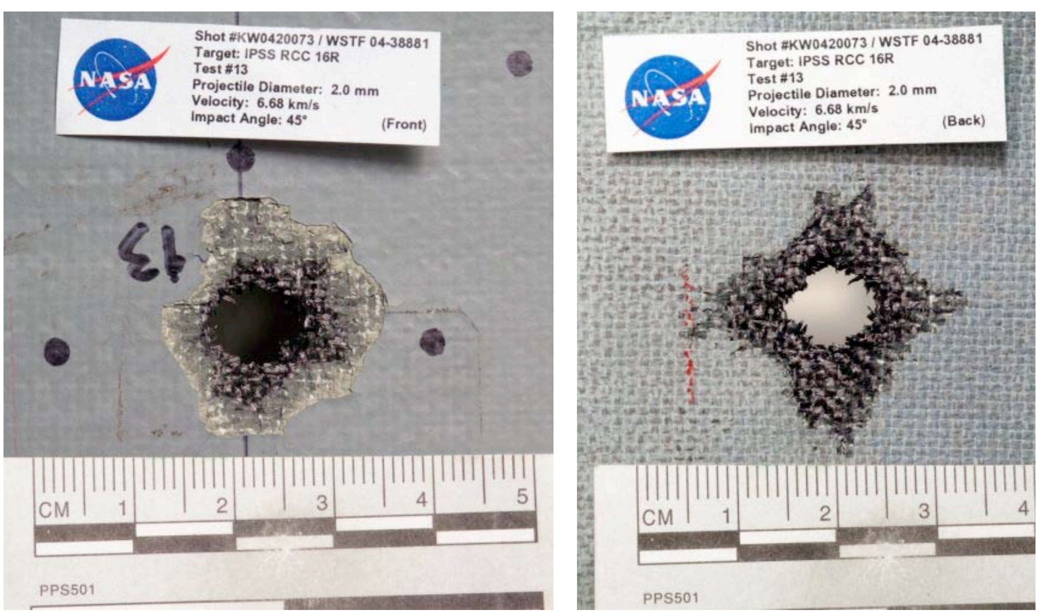

Figure 71: RCC16R Shot #13 Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:

Test date: 10/18/04 Specimen ID: RCC16R
Test number: RCC16R-14 Projectile size: 2.0 mm/30deg.
Planned velocity: 6.8 km/s
Planned impact coordinates: (50, 10)

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: All sensors good.

III. Record sensor serial number and coordinates:

Sensor 1: S/N 101147 Sensor 2: S/N 084016
Sensor 3: S/N 084021 Sensor 4: S/N 084018
Sensor 5: S/N 084027 Sensor 6: S/N 084024
Sensor 7: S/N 084028 Sensor 8: S/N 084011
Sensor 9: S/N 084015 Sensor 10: S/N 084022
Sensor 11: S/N 084017 Sensor 12: S/N 084023
Sensor 13: S/N 190022 Sensor 14: S/N 190033
Sensor 15: S/N 190034 Sensor 16: S/N 190036

Sensor 1: Lower Outboard Flange Corner (up) Sensor 2: Upper Outboard Flange Corner (up)
Sensor 3: Lower Inboard Flange Corner (down) Sensor 4: Upper Inboard Flange Corner (down)
Sensor 5: Upper Surface (46, 05) Sensor 6: Upper Surface (46, 19)
Sensor 7: Upper Surface (31, 05) Sensor 8: Upper Surface (31, 19)
Sensor 9: Lower Surface (23, 05) Sensor 10: Lower Surface (23, 19)
Sensor 11: Lower Surface (11, 05) Sensor 12: Lower Surface (11, 19)
Sensor 13: Lower Outboard Underside Spar Sensor 14: Upper Outboard Underside Spar
Sensor 15: Upper Inboard Underside Spar Sensor 16: Lower Inboard Underside Spar

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: RCC16R-14 10-18-04 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______
16 channel recording mode: X______
Data acquisition in record mode: X______
(DWC logo spinning)

Record and verify gain settings:

Sensor 1:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 2:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 3:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 4:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 5:	Attenuators: 30	Preamp: 0	SCM: 0
Sensor 6:	Attenuators: 30	Preamp: 0	SCM: 0
Sensor 7:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 8:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 9:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 10:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 11:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 12:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 13:	Attenuators: 0	Preamp: 0	SCM: 15
Sensor 14:	Attenuators: 0	Preamp: 0	SCM: 15
Sensor 15:	Attenuators: 0	Preamp: 0	SCM: 15
Sensor 16:	Attenuators: 0	Preamp: 0	SCM: 15

Record file name: RCC16R-14 10-18-04 Impact

Comments: 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: 6.68 km/s.
Impact coordinates: ________________
Damage description and comments:

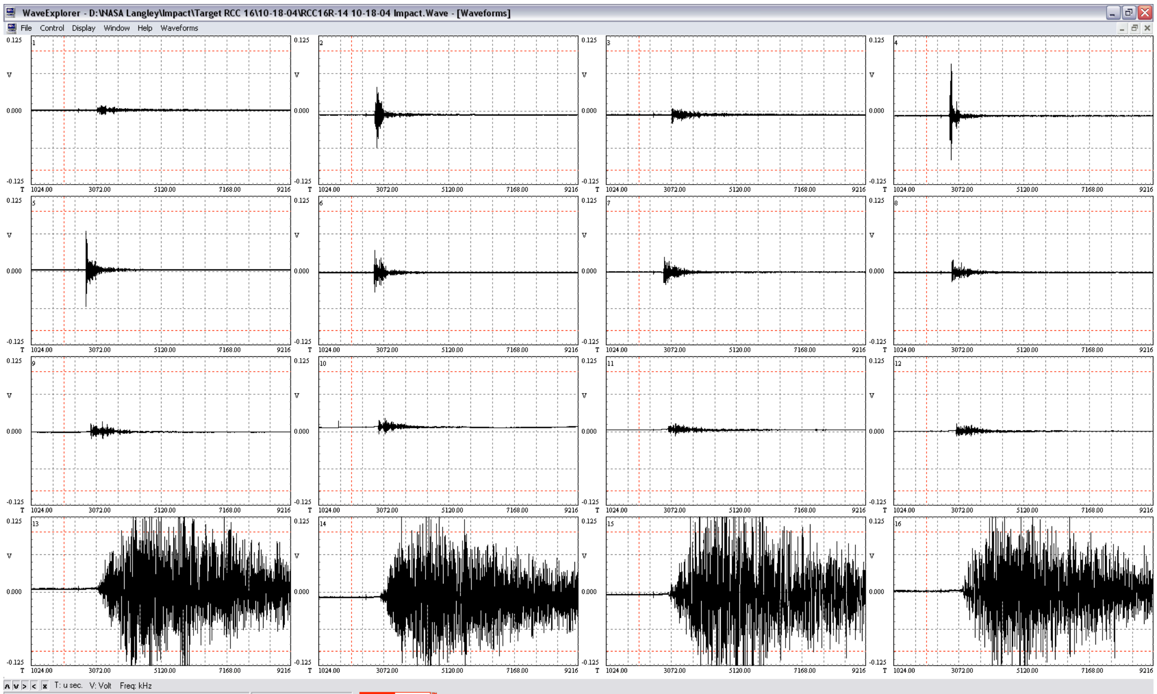

Figure 72: RCC16R Shot #14 Impact Waveform

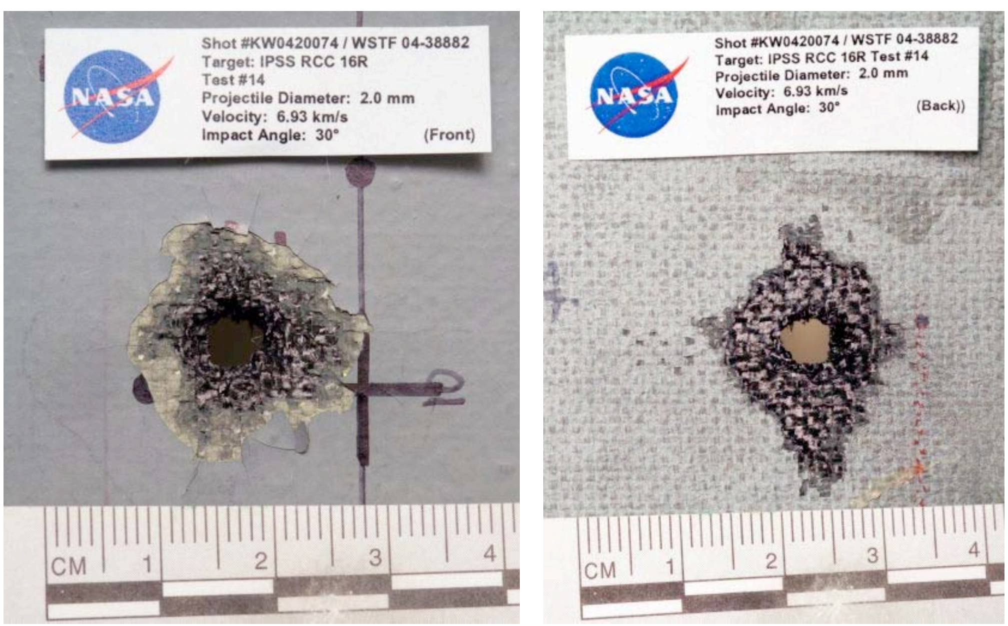

Figure 73: RCC16R Shot #14 Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:

Test date: 10/19/04 Specimen ID: RCC16R
Test number: RCC16R-15 Projectile size: 0.8 mm/60deg.
Planned velocity: 6.8 km/s
Planned impact coordinates: (39, 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: All sensors good.

III. Record sensor serial number and coordinates:

Sensor 1: S/N 101147 Sensor 2: S/N 084016
Sensor 3: S/N 084021 Sensor 4: S/N 084018
Sensor 5: S/N 084027 Sensor 6: S/N 084024
Sensor 7: S/N 084028 Sensor 8: S/N 084011
Sensor 9: S/N 084015 Sensor 10: S/N 084022
Sensor 11: S/N 084017 Sensor 12: S/N 084023
Sensor 13: S/N 190022 Sensor 14: S/N 190033
Sensor 15: S/N 190034 Sensor 16: S/N 190036

Sensor 1: Lower Outboard Flange Corner (up) Sensor 2: Upper Outboard Flange Corner (up)
Sensor 3: Lower Inboard Flange Corner (down) Sensor 4: Upper Inboard Flange Corner (down)
Sensor 5: Upper Surface (46, 05) Sensor 6: Upper Surface (46, 19)
Sensor 7: Upper Surface (31, 05) Sensor 8: Upper Surface (31, 19)
Sensor 9: Lower Surface (23, 05) Sensor 10: Lower Surface (23, 19)
Sensor 11: Lower Surface (11, 05) Sensor 12: Lower Surface (11, 19)
Sensor 13: Lower Outboard Underside Spar Sensor 14: Upper Outboard Underside Spar
Sensor 15: Upper Inboard Underside Spar Sensor 16: Lower Inboard Underside Spar

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: RCC16R-15 10-19-04 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______

16 channel recording mode: X______

Data acquisition in record mode: X______

(DWC logo spinning)

Record and verify gain settings:

Sensor 1:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 2:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 3:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 4:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 5:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 6:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 7:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 8:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 9:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 10:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 11:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 12:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 13:	Attenuators: 0	Preamp: 20	SCM: 6
Sensor 14:	Attenuators: 0	Preamp: 20	SCM: 6
Sensor 15:	Attenuators: 0	Preamp: 20	SCM: 6
Sensor 16:	Attenuators: 0	Preamp: 20	SCM: 6

Record file name: RCC16R-15 10-19-04 Impact

Comments: 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: 6.75 km/s.
Impact coordinates: ________________
Damage description and comments:

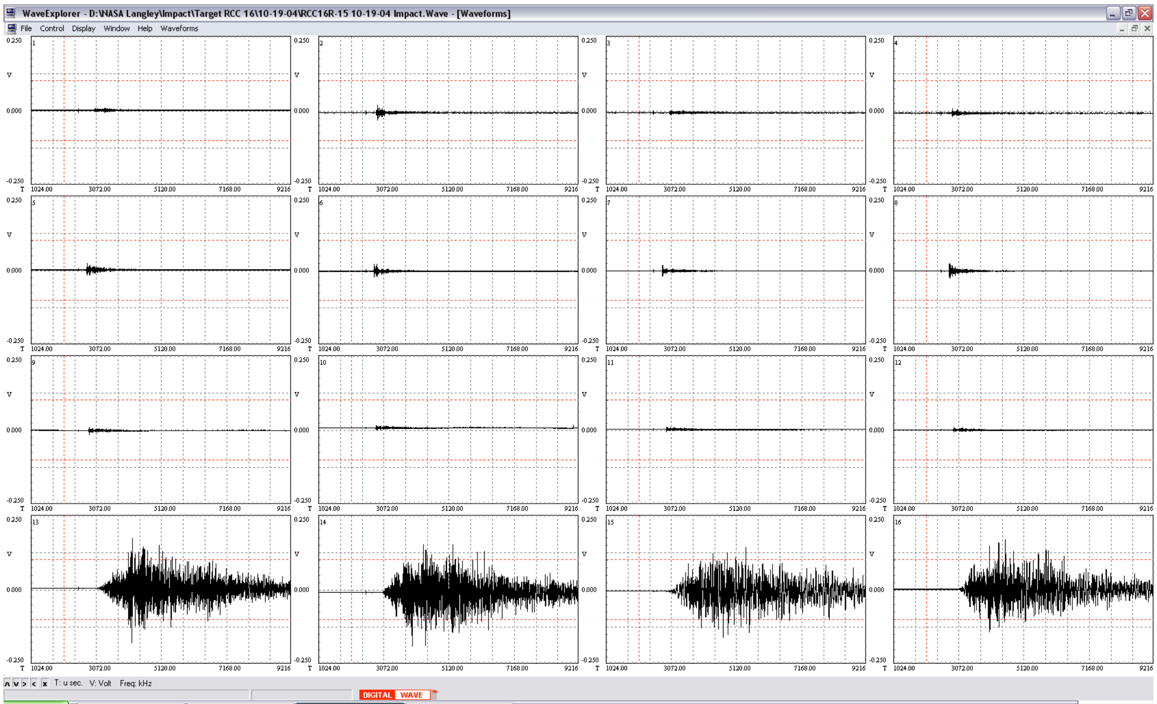

Figure 74: RCC16R Shot #15 Impact Waveform

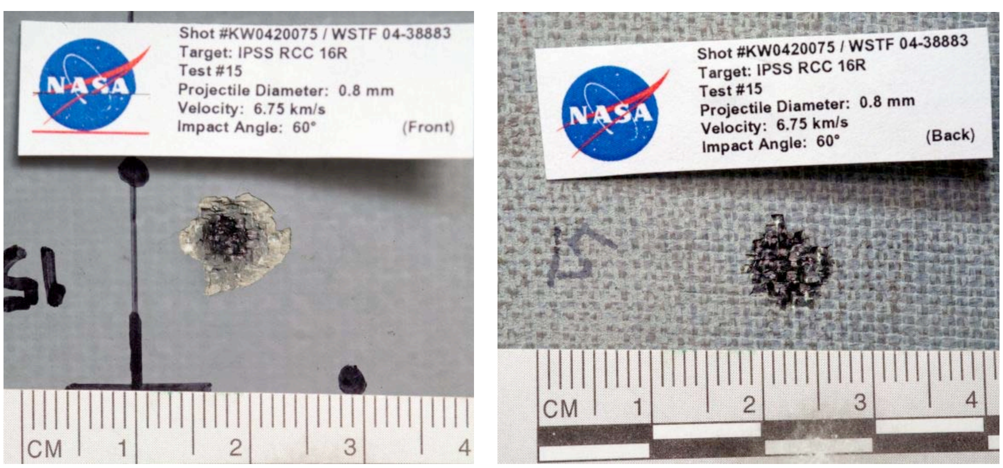

Figure 75: RCC16R Shot #15 Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:
Test date: 10/20/04_____ Specimen ID: _RCC16R________
Test number: RCC16R-16___ Projectile size: 1.6 mm/45deg.
Planned velocity: _6.8 km/s____
Planned impact coordinates: (50, 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: All sensors good.

III. Record sensor serial number and coordinates:

Sensor 1: S/N_101147 Sensor 2: S/N_084016
Sensor 3: S/N_084021 Sensor 4: S/N_084018
Sensor 5: S/N_084027 Sensor 6: S/N_084024
Sensor 7: S/N_084028 Sensor 8: S/N_084011
Sensor 9: S/N_084015 Sensor 10: S/N_084022
Sensor 11: S/N_084017 Sensor 12: S/N_084023
Sensor 13: S/N_190022 Sensor 14: S/N_190033
Sensor 15: S/N_190034 Sensor 16: S/N_190036

Sensor 1: _Lower Outboard Flange Corner (up) Sensor 2: _Upper Outboard Flange Corner (up)
Sensor 3: _Lower Inboard Flange Corner (down) Sensor 4: _Upper Inboard Flange Corner (down)
Sensor 5: _Upper Surface (46, 05) Sensor 6: _Upper Surface (46, 19)
Sensor 7: _Upper Surface (31, 05) Sensor 8: _Upper Surface (31, 19)
Sensor 9: _Lower Surface (23, 05) Sensor 10: _Lower Surface (23, 19)
Sensor 11: _Lower Surface (11, 05) Sensor 12: _Lower Surface (11, 19)
Sensor 13: _Lower Outboard Underside Spar Sensor 14: _Upper Outboard Underside Spar
Sensor 15: _Upper Inboard Underside Spar Sensor 16: _Lower Inboard Underside Spar

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: RCC16R-16 10-20-04 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
16 channel recording mode: X
Data acquisition in record mode: X
(DWC logo spinning)
Record and verify gain settings:

Sensor 1:	Attenuators: 30	Preamp: 0	SCM: 15
Sensor 2:	Attenuators: 30	Preamp: 0	SCM: 15
Sensor 3:	Attenuators: 30	Preamp: 0	SCM: 15
Sensor 4:	Attenuators: 30	Preamp: 0	SCM: 15
Sensor 5:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 6:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 7:	Attenuators: 30	Preamp: 0	SCM: 12
Sensor 8:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 9:	Attenuators: 30	Preamp: 0	SCM: 12
Sensor 10:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 11:	Attenuators: 30	Preamp: 0	SCM: 12
Sensor 12:	Attenuators: 30	Preamp: 0	SCM: 12
Sensor 13:	Attenuators: 0	Preamp: 0	SCM: 18
Sensor 14:	Attenuators: 0	Preamp: 0	SCM: 18
Sensor 15:	Attenuators: 0	Preamp: 0	SCM: 18
Sensor 16:	Attenuators: 0	Preamp: 0	SCM: 18

Record file name: RCC16R-16 10-20-04 Impact
Comments: 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: 6.68 km/s.

Impact coordinates: ________________

Damage description and comments:

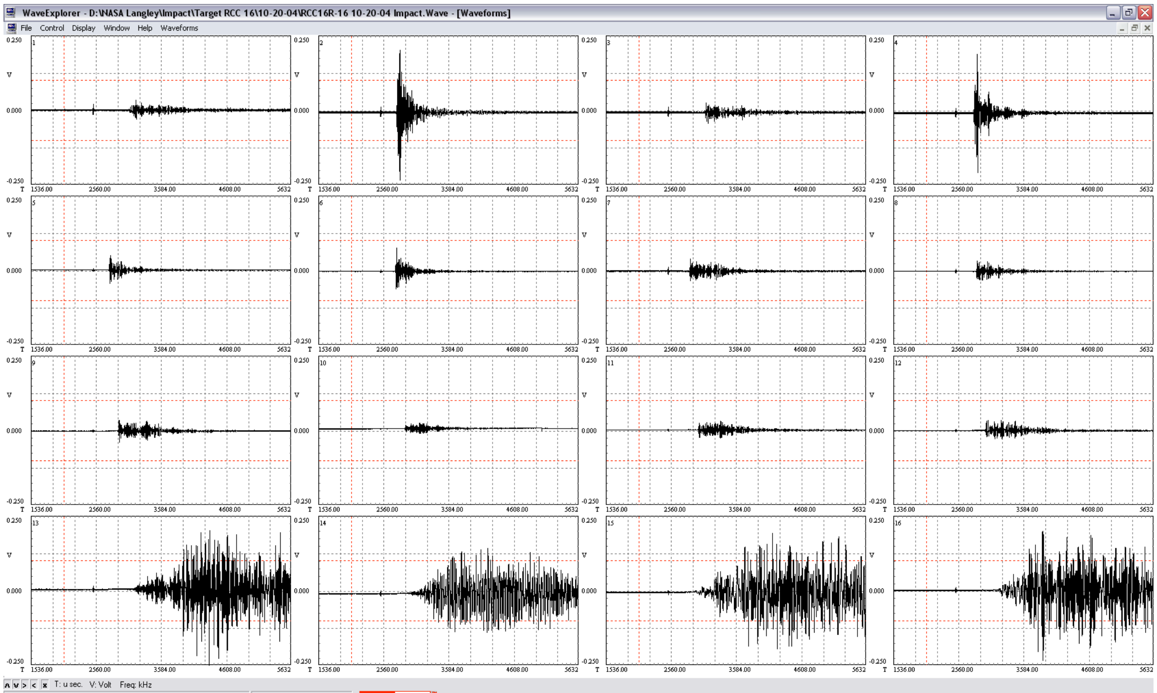

Figure 76: RCC16R Shot #16 Impact Waveform

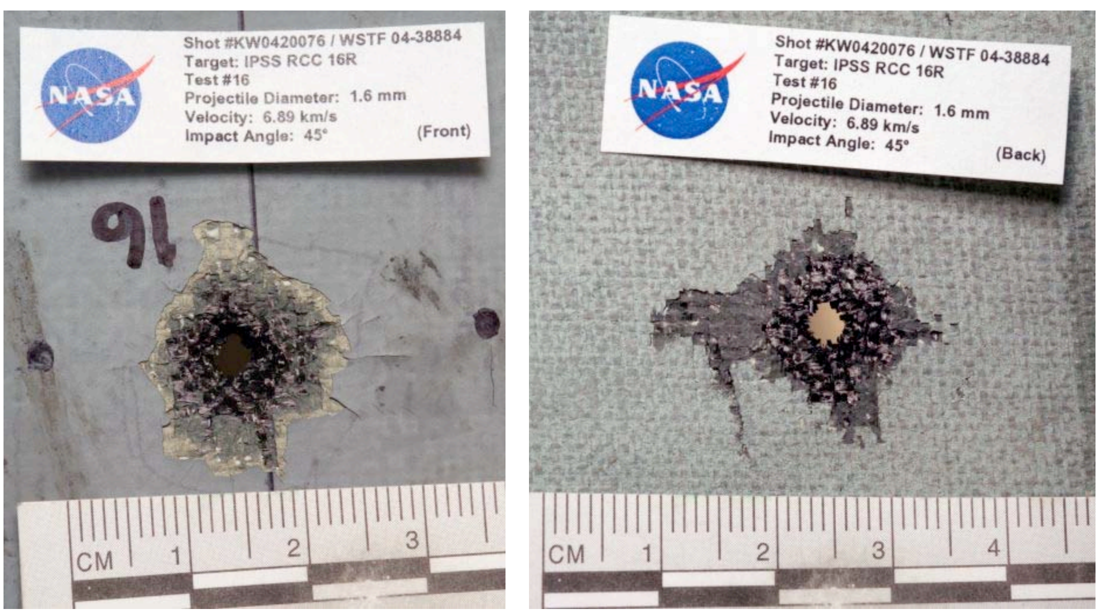

Figure 77: RCC16R Shot #1 Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:

Test date: 10/25/04 Specimen ID: RCC16R
Test number: RCC16R-17 Projectile size: 2.4 mm/30deg.
Planned velocity: 6.8 km/s
Planned impact coordinates: (35, 19)

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: All sensors good.

III. Record sensor serial number and coordinates:

Sensor 1: S/N 101147 Sensor 2: S/N 084016
Sensor 3: S/N 084021 Sensor 4: S/N 084018
Sensor 5: S/N 084027 Sensor 6: S/N 084024
Sensor 7: S/N 084028 Sensor 8: S/N 084011
Sensor 9: S/N 084015 Sensor 10: S/N 084022
Sensor 11: S/N 084017 Sensor 12: S/N 084023
Sensor 13: S/N 190022 Sensor 14: S/N 190033
Sensor 15: S/N 190034 Sensor 16: S/N 190036

Sensor 1: Lower Outboard Flange Corner (up) Sensor 2: Upper Outboard Flange Corner (up)
Sensor 3: Lower Inboard Flange Corner (down) Sensor 4: Upper Inboard Flange Corner (down)
Sensor 5: Upper Surface (46, 05) Sensor 6: Upper Surface (46, 19)
Sensor 7: Upper Surface (31, 05) Sensor 8: Upper Surface (31, 19)
Sensor 9: Lower Surface (23, 05) Sensor 10: Lower Surface (23, 19)
Sensor 11: Lower Surface (11, 05) Sensor 12: Lower Surface (11, 19)
Sensor 13: Lower Outboard Underside Spar Sensor 14: Upper Outboard Underside Spar
Sensor 15: Upper Inboard Underside Spar Sensor 16: Lower Inboard Underside Spar

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: RCC16R-17 10-25-04 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______
16 channel recording mode: X______
Data acquisition in record mode: X______
(DWC logo spinning)
Record and verify gain settings:

Sensor 1:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 2:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 3:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 4:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 5:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 6:	Attenuators: 30	Preamp: 0	SCM: 0
Sensor 7:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 8:	Attenuators: 30	Preamp: 0	SCM: 0
Sensor 9:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 10:	Attenuators: 30	Preamp: 0	SCM: 0
Sensor 11:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 12:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 13:	Attenuators: 0	Preamp: 0	SCM: 12
Sensor 14:	Attenuators: 0	Preamp: 0	SCM: 12
Sensor 15:	Attenuators: 0	Preamp: 0	SCM: 12
Sensor 16:	Attenuators: 0	Preamp: 0	SCM: 12

Record file name: RCC16R-17 10-25-04 Impact
Comments: 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: 6.95 km/s.

Impact coordinates: ________________

Damage description and comments:

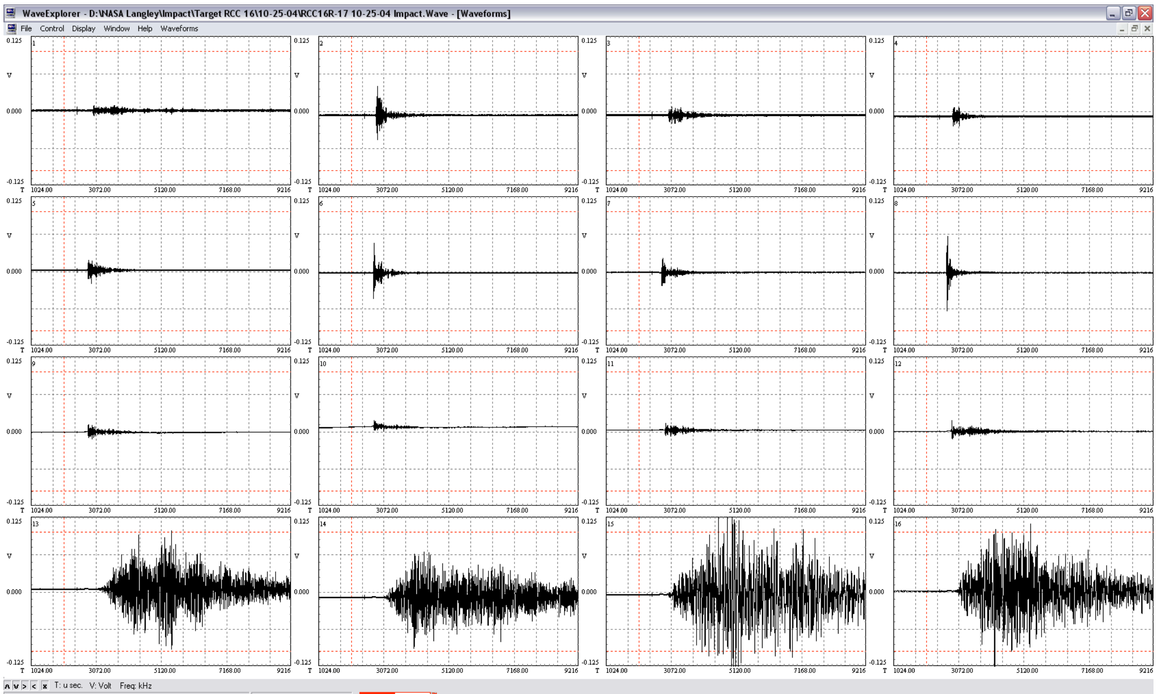

Figure 78: RCC16R Shot #17 Impact Waveform

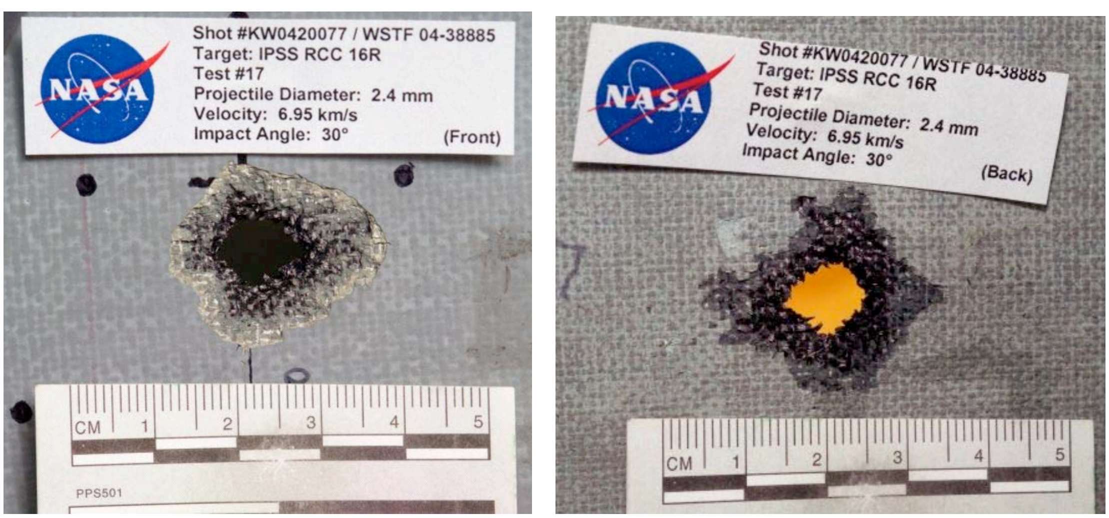

Figure 79: RCC16R Shot #17 Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:

Test date: 10/25/04 Specimen ID: RCC16R

Test number: RCC16R-18 Projectile size: 1.2 mm/60deg.

Planned velocity: 6.8 km/s

Planned impact coordinates: (39, 19)

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: All sensors good.

III. Record sensor serial number and coordinates:

Sensor 1: S/N 101147 Sensor 2: S/N 084016
Sensor 3: S/N 084021 Sensor 4: S/N 084018
Sensor 5: S/N 084027 Sensor 6: S/N 084024
Sensor 7: S/N 084028 Sensor 8: S/N 084011
Sensor 9: S/N 084015 Sensor 10: S/N 084022
Sensor 11: S/N 084017 Sensor 12: S/N 084023
Sensor 13: S/N 190022 Sensor 14: S/N 190033
Sensor 15: S/N 190034 Sensor 16: S/N 190036

Sensor 1: Lower Outboard Flange Corner (up) Sensor 2: Upper Outboard Flange Corner (up)
Sensor 3: Lower Inboard Flange Corner (down) Sensor 4: Upper Inboard Flange Corner (down)
Sensor 5: Upper Surface (46, 05) Sensor 6: Upper Surface (46, 19)
Sensor 7: Upper Surface (31, 05) Sensor 8: Upper Surface (31, 19)
Sensor 9: Lower Surface (23, 05) Sensor 10: Lower Surface (23, 19)
Sensor 11: Lower Surface (11, 05) Sensor 12: Lower Surface (11, 19)
Sensor 13: Lower Outboard Underside Spar Sensor 14: Upper Outboard Underside Spar
Sensor 15: Upper Inboard Underside Spar Sensor 16: Lower Inboard Underside Spar

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: RCC16R-18 10-25-04 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______
16 channel recording mode: X______
Data acquisition in record mode: X______
(DWC logo spinning)
Record and verify gain settings:

Sensor 1:	Attenuators: 30	Preamp: 0	SCM: 15
Sensor 2:	Attenuators: 30	Preamp: 0	SCM: 12
Sensor 3:	Attenuators: 30	Preamp: 0	SCM: 15
Sensor 4:	Attenuators: 30	Preamp: 0	SCM: 12
Sensor 5:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 6:	Attenuators: 30	Preamp: 0	SCM: 0
Sensor 7:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 8:	Attenuators: 30	Preamp: 0	SCM: 0
Sensor 9:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 10:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 11:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 12:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 13:	Attenuators: 0	Preamp: 20	SCM: 3
Sensor 14:	Attenuators: 0	Preamp: 20	SCM: 3
Sensor 15:	Attenuators: 0	Preamp: 20	SCM: 3
Sensor 16:	Attenuators: 0	Preamp: 20	SCM: 3

Record file name: RCC16R-18 10-25-04 Impact
Comments: 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: 6.76 km/s.

Impact coordinates: ________________

Damage description and comments:

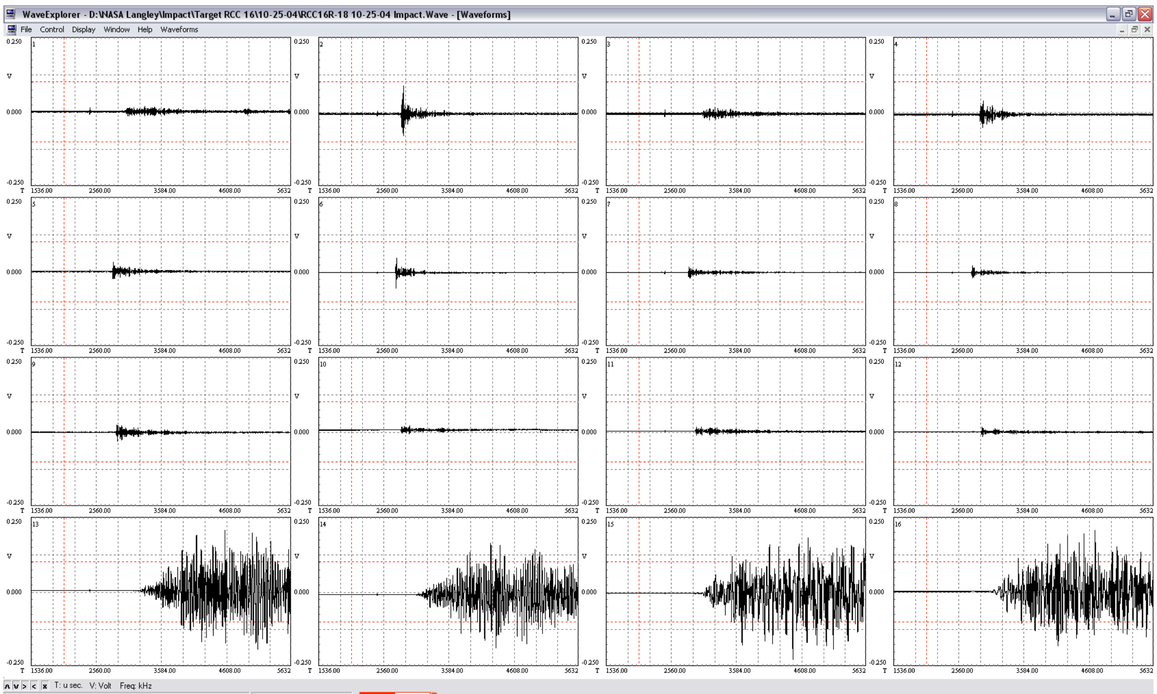

Figure 80: RCC16R Shot #18 Impact Waveform

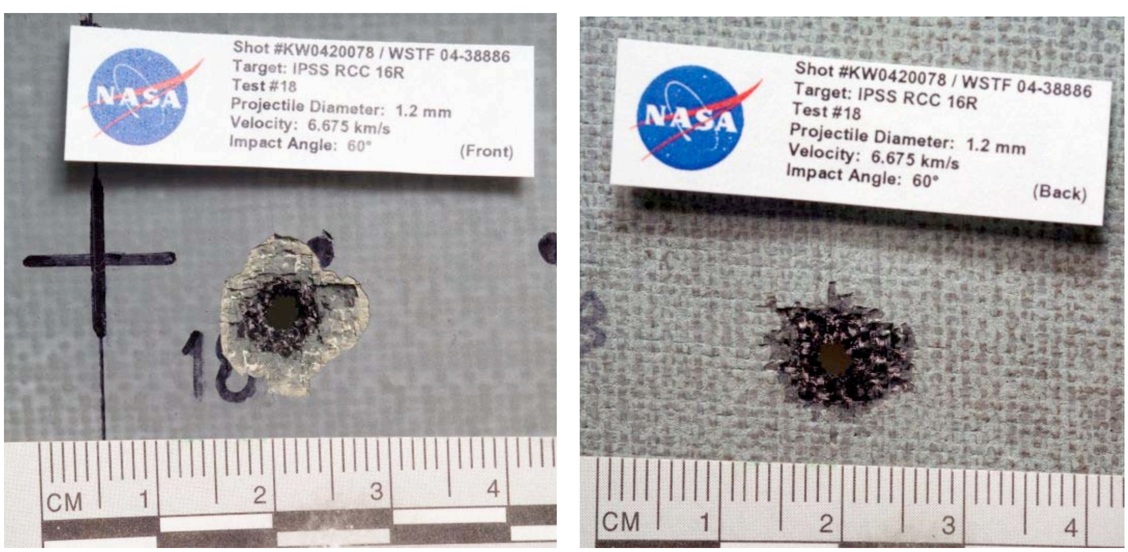

Figure 81: RCC16R Shot #18 Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:

Test date: 10/26/04 Specimen ID: RCC16R

Test number: RCC16R-19 Projectile size: 2.4 mm/45deg.

Planned velocity: 6.8 km/s

Planned impact coordinates: (50, 19)

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: All sensors good.

III. Record sensor serial number and coordinates:

Sensor 1: S/N 101147 Sensor 2: S/N 084016
Sensor 3: S/N 084021 Sensor 4: S/N 084018
Sensor 5: S/N 084027 Sensor 6: S/N 084024
Sensor 7: S/N 084028 Sensor 8: S/N 084011
Sensor 9: S/N 084015 Sensor 10: S/N 084022
Sensor 11: S/N 084017 Sensor 12: S/N 084023
Sensor 13: S/N 190022 Sensor 14: S/N 190033
Sensor 15: S/N 190034 Sensor 16: S/N 190036

Sensor 1: Lower Outboard Flange Corner (up) Sensor 2: Upper Outboard Flange Corner (up)

Sensor 3: Lower Inboard Flange Corner (down) Sensor 4: Upper Inboard Flange Corner (down)

Sensor 5: Upper Surface (46, 05) Sensor 6: Upper Surface (46, 19)

Sensor 7: Upper Surface (31, 05) Sensor 8: Upper Surface (31, 19)

Sensor 9: Lower Surface (23, 05) Sensor 10: Lower Surface (23, 19)

Sensor 11: Lower Surface (11, 05) Sensor 12: Lower Surface (11, 19)

Sensor 13: Lower Outboard Underside Spar Sensor 14: Upper Outboard Underside Spar

Sensor 15: Upper Inboard Underside Spar Sensor 16: Lower Inboard Underside Spar

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: RCC16R-19 10-26-04 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______
16 channel recording mode: X______
Data acquisition in record mode: X______
(DWC logo spinning)
Record and verify gain settings:

Sensor 1:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 2:	Attenuators: 30	Preamp: 0	SCM: 0
Sensor 3:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 4:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 5:	Attenuators: 30	Preamp: 0	SCM: 0
Sensor 6:	Attenuators: 30	Preamp: 0	SCM: 0
Sensor 7:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 8:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 9:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 10:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 11:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 12:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 13:	Attenuators: 0	Preamp: 0	SCM: 12
Sensor 14:	Attenuators: 0	Preamp: 0	SCM: 12
Sensor 15:	Attenuators: 0	Preamp: 0	SCM: 12
Sensor 16:	Attenuators: 0	Preamp: 0	SCM: 12

Record file name: RCC16R-19 10-26-04 Impact
Comments: Data O.K. Hyper IPSS complete. "Little Bill" signing off...

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: 6.77 km/s.
Impact coordinates: _________________
Damage description and comments:

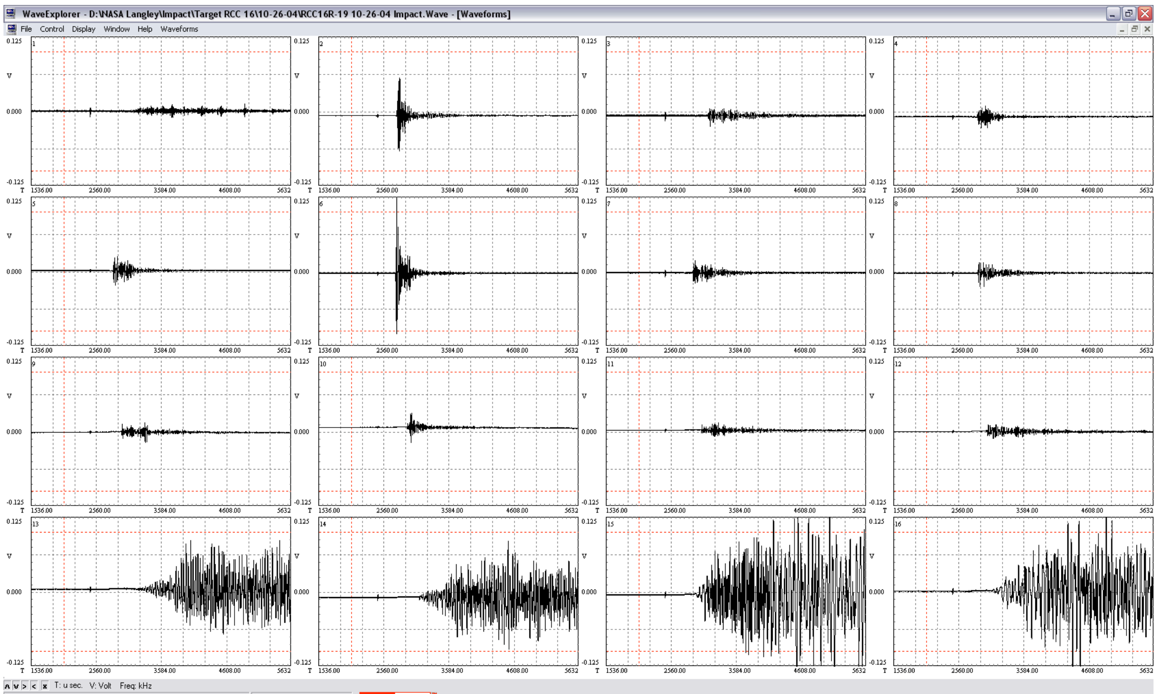

Figure 82: RCC16R Shot #19 Impact Waveform

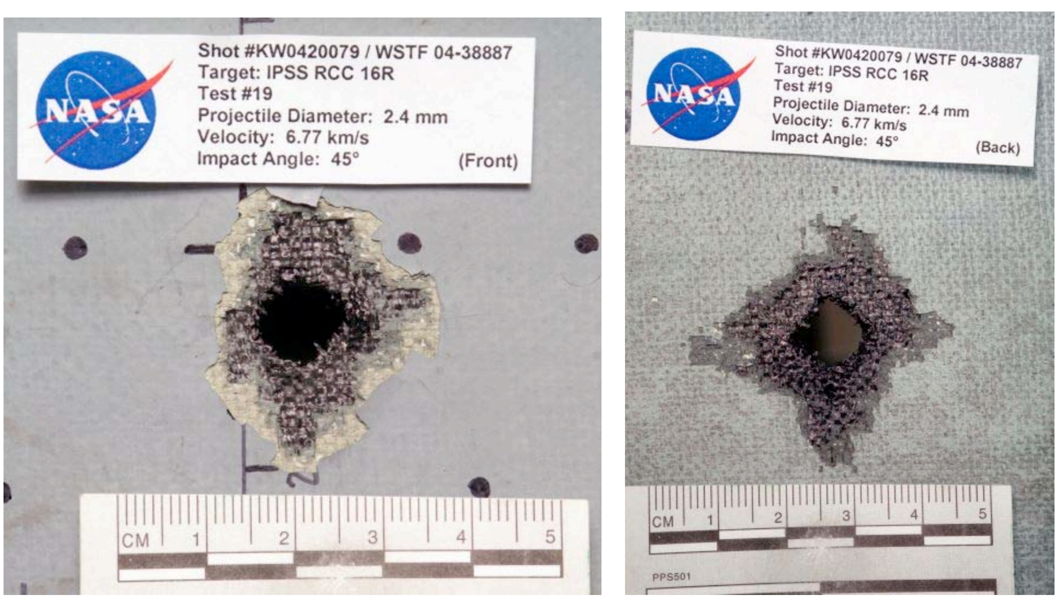

Figure 83: RCC16R Shot #19 Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:

Test date: 10/21/04 Specimen ID: RCC16R

Test number: RCC16R-20 Projectile size: 2.8 mm/90deg.

Planned velocity: 6.8 km/s

Planned impact coordinates: (26, 19)

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: All sensors good.

III. Record sensor serial number and coordinates:

Sensor 1: S/N 101147
Sensor 2: S/N 084016
Sensor 3: S/N 084021
Sensor 4: S/N 084018
Sensor 5: S/N 084027
Sensor 6: S/N 084024
Sensor 7: S/N 084028
Sensor 8: S/N 084011
Sensor 9: S/N 084015
Sensor 10: S/N 084022
Sensor 11: S/N 084017
Sensor 12: S/N 084023
Sensor 13: S/N 190022
Sensor 14: S/N 190033
Sensor 15: S/N 190034
Sensor 16: S/N 190036

Sensor 1: Lower Outboard Flange Corner (up)
Sensor 2: Upper Outboard Flange Corner (up)
Sensor 3: Lower Inboard Flange Corner (down)
Sensor 4: Upper Inboard Flange Corner (down)
Sensor 5: Upper Surface (46, 05)
Sensor 6: Upper Surface (46, 19)
Sensor 7: Upper Surface (31, 05)
Sensor 8: Upper Surface (31, 19)
Sensor 9: Lower Surface (23, 05)
Sensor 10: Lower Surface (23, 19)
Sensor 11: Lower Surface (11, 05)
Sensor 12: Lower Surface (11, 19)
Sensor 13: Lower Outboard Underside Spar
Sensor 14: Upper Outboard Underside Spar
Sensor 15: Upper Inboard Underside Spar
Sensor 16: Lower Inboard Underside Spar

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: RCC16R-20 10-21-04 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______
16 channel recording mode:	X______
Data acquisition in record mode: (DWC logo spinning)	X______

Record and verify gain settings:

Sensor	Attenuators	Preamp	SCM
Sensor 1:	30	0	0
Sensor 2:	30	0	0
Sensor 3:	30	0	0
Sensor 4:	30	0	0
Sensor 5:	30	0	0
Sensor 6:	30	-20	12
Sensor 7:	30	-20	12
Sensor 8:	30	-20	12
Sensor 9:	30	-20	12
Sensor 10:	30	-20	12
Sensor 11:	30	0	0
Sensor 12:	30	-20	12
Sensor 13:	0	0	12
Sensor 14:	0	0	12
Sensor 15:	0	0	12
Sensor 16:	0	0	12

Record file name: RCC16R-20 10-21-04 Impact
Comments: 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: 6.89 km/s.
Impact coordinates: ________________
Damage description and comments:

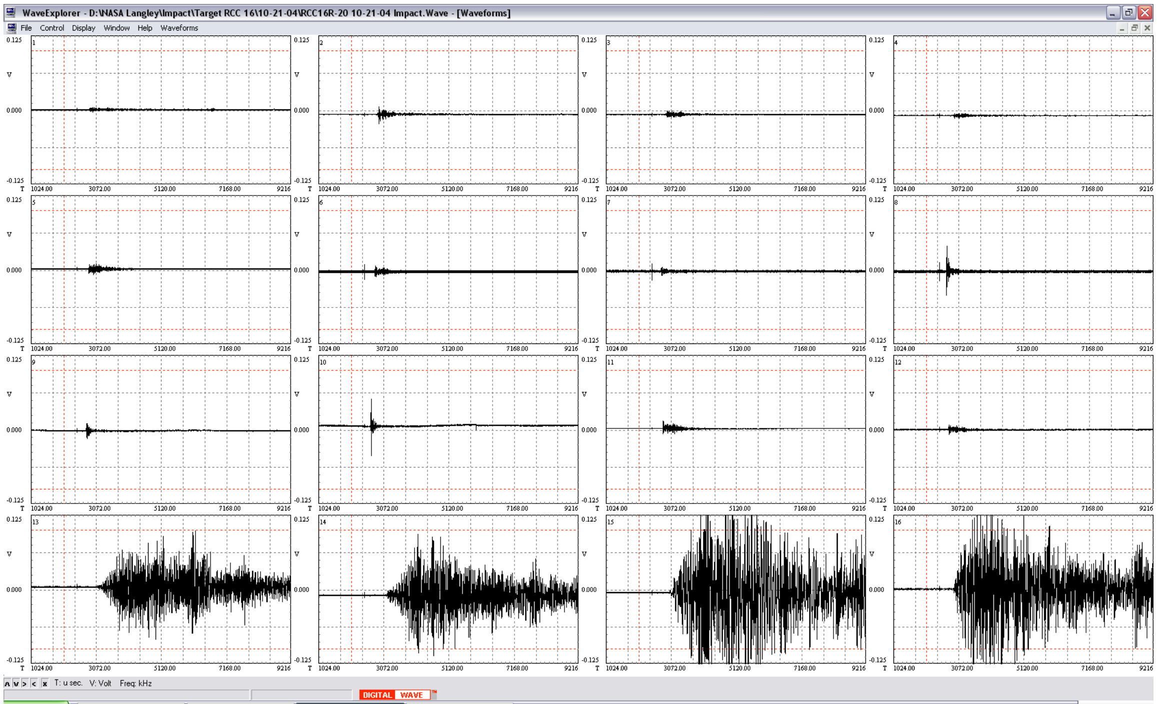

Figure 84: RCC16R Shot #20 Impact Waveform

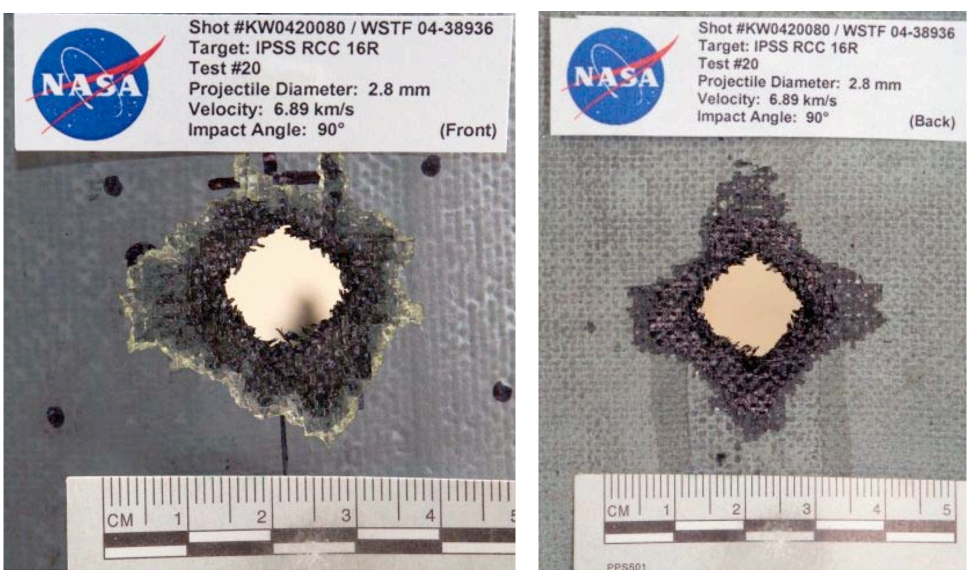

Figure 85: RCC16R Shot #20 Impact Damage (Left: Front Side, Right: Back Side)

Data Tables

Test	Imp Size	Imp Vel	Imp Ang	Normal K.E.	Total K.E.	Location	
No.	mm	km/s	deg	J	J	x	y
RCC16R-1	0.4	6.88	90	2.14	2.14	26	2
RCC16R-2	0.4	6.61	60	1.48	1.98	35	2
RCC16R-3	1.0	7.00	45	17.30	34.64	39	2
RCC16R-4	0.4	6.89	30	0.54	2.15	50	2
RCC16R-5	0.6	6.63	45	3.35	6.71	5	2
RCC16R-6	0.8	6.99	90	17.68	17.68	26	14
RCC16R-7	1.0	6.80	30	8.16	32.69	35	6
RCC16R-8	0.8	6.76	60	12.40	16.54	39	6
RCC16R-9b	1.2	6.80	30	14.11	56.48	50	6
RCC16R-10	0.8	6.84	30	4.23	16.93	5	6
RCC16R-11	1.2	6.85	60	42.96	57.31	31	10
RCC16R-12	1.6	6.82	45	67.28	134.67	35	10
RCC16R-13	2.0	6.68	45	126.07	252.33	39	10
RCC16R-14	2.0	6.93	30	67.83	271.57	50	10
RCC15R-15	0.8	6.75	60	12.36	16.49	39	14
RCC16R-16	1.6	6.89	45	68.67	137.45	50	14
RCC16R-17	2.4	6.95	30	117.89	471.99	35	19
RCC16R-18	1.2	6.75	60	41.71	55.65	39	19
RCC16R-19	2.4	6.77	45	223.75	447.86	50	19
RCC16R-20	2.8	6.89	90	736.62	736.62	26	19

Table 3: RCC16R Impactor Diameter, Impactor Velocity, Impactor Angle, Normal Kinetic Energy, Total Kinetic Energy, and Location

	Normal	Total	Crater Dims			Crater	Coating Dims		Coating Area	Spalling Dims			Spalling
Test	K.E.	K.E.	x	y	z	Volume	x	y	Damage	x	y	z	Volume
No.	J	J	mm	mm	mm	mm3	mm	mm	mm^2	mm	mm	mm	mm3
RCC16R-1	2.14	2.14	2.5	3.0	0.94	7.1							
RCC16R-2	1.48	1.98	3.5	4.0	0.93	13.0							
RCC16R-3	17.30	34.64	4.5	4.5	2.2	44.6	10.5	11.0	115.5	9.0	9.5	0.48	41.0
RCC16R-4	0.54	2.15	2.5	2.5	0.38	2.4							
RCC16R-5	3.35	6.71	3.5	4.5	1.33	20.9	5.0	7.5	37.5				
RCC16R-6a	17.68	17.68	3.5	4.0	2.12	29.7	12.0	11.5	138.0	8.0	7.5	0.45	27.0
RCC16R-7	8.16	32.69	7.0	8.0	3.35	187.6	11.5	10.5	120.8	11.0	9.0	0.5	49.5
RCC16R-8	12.40	16.54	3.5	3.5	1.21	14.8	7.5	7.0	52.5				
RCC16R-9b	14.11	56.48	5.0	5.5	2.73	75.1	11.5	11.0	126.5	9.0	10.5	0.41	38.7
RCC16R-10	4.23	16.93	4.0	4.5	1.42	25.6	8.0	7.0	56.0				
RCC16R-11	42.96	57.31	2.0	2.5	6.0	30.0	14.0	15.0	210.0	12.0	15.5	0.6	111.6
RCC16R-12	67.28	134.67	6.5	5.0	6.0	195.0	19.5	20.0	390.0	16.0	18.0	0.46	132.5
RCC16R-13	126.07	252.33	9.0	8.0	6.0	432.0	22.0	23.5	517.0	27.0	26.0	0.4	280.8
RCC16R-14	67.83	271.57	6.0	5.5	6.0	198.0	20.0	21.5	430.0	21.5	28.5	0.3	183.8
RCC15R-15	12.36	16.49	4.0	4.5	2.04	36.7	10.5	9.5	99.8	7.5	8.5	0.35	22.3
RCC16R-16	68.67	137.45	3.5	4.0	6.0	84.0	18.0	21.5	387.0	25.5	19.5	0.4	198.9
RCC16R-17	117.89	471.99	10.5	9.0	6.0	567.0	25.3	22.5	568.1	30.5	25.0	0.06	45.8
RCC16R-18	41.71	55.65	2.5	3.5	6.0	52.5	12.5	14.0	175.0	12.5	12.0	0.42	63.0
RCC16R-19	223.75	447.86	10.0	10.5	6.0	630.0	26.0	32.0	832.0	39.0	37.5	0.34	497.3
RCC16R-20	736.62	736.62	14.5	14.5	6.0	1261.5	36.0	35.5	1278.0	37.0	39.0	0.36	519.5

Table 4: RCC16R Damage Results: Normal Kinetic Energy, Total Kinetic Energy, Crater Dimensions, Crater Volume, Coating Damage Dimensions, Coating Area Damage, Spalling Dimensions, Spalling Volume.
Blank fields indicate no damage was recorded.

	Channel Gain															
Test No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	15	16
RCC16R-1	3	3	3	3	-8	-5	-11	-5	-14	-5	-8	-5	32	32	32	32
RCC16R-2	3	3	3	3	-14	-5	-20	-5	-11	-5	-5	-2	38	38	38	38
RCC16R-3	-24	-24	-24	-24	-44	-35	-41	-35	-38	-35	-35	-32	29	29	29	29
RCC16R-4	18	9	26	-8	-14	1	-2	3	1	3	3	12	47	47	47	47
RCC16R-5	-11	-5	-17	-5	-11	-8	-11	-11	-14	-11	-20	-11	32	32	26	35
RCC16R-6a	-14	-14	-14	-14	-20	-20	-20	-20	-20	-20	-20	-20	26	26	26	26
RCC16R-7	-30	-30	-30	-30	-44	-35	-44	-38	-41	-35	-35	-35	26	26	26	26
RCC16R-8	-32	-32	-32	-32	-50	-50	-50	-50	-50	-50	-50	-47	32	32	32	32
RCC16R-9b	-29	-32	-29	-32	-50	-41	-41	-38	-38	-38	-38	-38	23	23	23	23
RCC16R-10	-17	-17	-20	-17	-20	-20	-20	-20	-20	-20	-20	-20	29	29	29	29
RCC16R-11	-38	-38	-38	-38	-47	-41	-50	-50	-44	-44	-44	-44	23	23	23	23
RCC16R-12	-35	-35	-35	-35	-50	-47	-50	-47	-47	-47	-47	-41	18	18	18	18
RCC16R-13	-44	-44	-44	-44	-50	-47	-50	-47	-47	-47	-47	-47	12	12	12	12
RCC16R-14	-44	-47	-44	-47	-50	-50	-47	-47	-47	-47	-47	-47	15	15	15	15
RCC15R-15	-41	-41	-41	-41	-44	-44	-44	-44	-44	-44	-44	-44	26	26	26	26
RCC16R-16	-35	-35	-35	-35	-47	-47	-38	-44	-38	-44	-38	-38	18	18	18	18
RCC16R-17	-41	-44	-41	-44	-47	-50	-47	-50	-47	-50	-47	-47	12	12	12	12
RCC16R-18	-35	-38	-35	-38	-44	-50	-44	-50	-41	-44	-41	-44	23	23	23	23
RCC16R-19	-41	-50	-41	-47	-50	-50	-44	-47	-44	-47	-44	-44	12	12	12	12
RCC16R-20	-50	-50	-50	-50	-50	-58	-58	-58	-58	-58	-30	-58	12	12	12	12

Table 5: RCC16R Channel Gain Settings

Test	S1 RawEn	S2 RawEn	S3 RawEn	S4 RawEn	S5 RawEn	S6 RawEn	S7 RawEn	S8 RawEn
No.	V^2-μs	V^2-μs	V^2-μs	V^2-μs	V^2-μs	V^2-μs	V^2-μs	V^2-μs
RCC16R-1	1.963E+03	2.883E+03	2.818E+03	2.398E+03	1.068E+03	9.296E+02	4.798E+02	7.975E+02
RCC16R-2	1.508E+03	3.222E+03	1.516E+03	3.668E+03	5.076E+02	8.877E+02	9.849E+01	7.686E+02
RCC16R-3	2.575E+01	9.651E+01	2.782E+01	2.255E+02	8.856E+00	1.845E+01	7.899E+00	1.981E+01
RCC16R-4	1.576E+04	5.940E+03	5.669E+04	6.308E+02	4.186E+02	1.552E+03	2.245E+03	3.263E+03
RCC16R-5	6.673E+02	1.433E+03	4.451E+02	1.086E+03	7.359E+02	1.369E+03	8.666E+02	8.112E+02
RCC16R-6a	7.862E+02	9.716E+02	8.626E+02	5.738E+02	3.634E+02	4.924E+02	4.554E+02	5.865E+02
RCC16R-7	1.564E+01	1.701E+01	1.502E+01	3.155E+01	4.818E+00	1.464E+01	1.191E+01	1.142E+01
RCC16R-8	8.952E+00	1.272E+01	8.628E+00	1.445E+01	3.914E-01	1.973E-01	2.611E-01	2.438E-01
RCC16R-9b	2.078E+01	5.149E+01	1.936E+01	6.645E+01	1.194E+01	8.350E+00	4.370E+00	8.311E+00
RCC16R-10	4.319E+02	1.313E+02	2.368E+02	6.804E+01	1.534E+02	1.605E+02	1.738E+02	2.047E+02
RCC16R-11	5.067E+00	7.850E+00	6.802E+00	5.955E+00	2.629E+00	9.056E+00	7.332E+00	3.062E+00
RCC16R-12	7.588E+00	2.851E+01	1.082E+01	2.728E+01	2.120E+00	4.889E+00	4.561E+00	3.295E+00
RCC16R-13	8.291E-01	4.704E+00	1.346E+00	4.589E+00	2.430E+00	6.303E+00	1.297E+00	2.415E+00
RCC16R-14	8.470E-01	7.675E+00	1.427E+00	1.367E+01	6.508E+00	3.981E+00	2.495E+00	1.798E+00
RCC15R-15	1.034E+00	2.566E+00	8.926E-01	1.471E+00	1.977E+00	1.917E+00	1.137E+00	2.490E+00
RCC16R-16	8.735E+00	1.320E+02	1.081E+01	7.465E+01	7.378E+00	1.291E+01	1.087E+01	6.704E+00
RCC16R-17	1.652E+00	6.839E+00	2.385E+00	1.770E+00	2.078E+00	5.297E+00	2.003E+00	6.603E+00
RCC16R-18	5.768E+00	1.468E+01	5.876E+00	9.023E+00	3.187E+00	3.893E+00	1.540E+00	1.120E+00
RCC16R-19	1.629E+00	9.022E+00	2.238E+00	1.683E+00	2.489E+00	2.310E+01	1.992E+00	2.083E+00
RCC16R-20	2.504E-01	9.584E-01	3.947E-01	2.654E-01	7.101E-01	1.948E+00	1.586E+00	3.891E+00

Table 6: RCC16R Raw Wave Signal, Sensors 1-8

Test No.	S9 RawEn V^2-μs	S10 RawEn V^2-μs	S11 RawEn V^2-μs	S12 RawEn V^2-μs	S13 RawEn V^2-μs	S14 RawEn V^2-μs	S15 RawEn V^2-μs	S16 RawEn V^2-μs
RCC16R-1	3.737E+02	9.688E+02	6.952E+02	6.995E+02	4.698E+02	3.443E+02	4.094E+02	3.743E+02
RCC16R-2	4.836E+02	6.065E+02	9.560E+02	1.244E+03	1.491E+03	1.514E+03	1.380E+03	1.417E+03
RCC16R-3	7.204E+00	7.865E+00	7.020E+00	1.415E+01	4.380E+03	3.833E+03	3.488E+03	4.059E+03
RCC16R-4	8.833E+02	1.571E+03	7.337E+02	8.961E+03	1.386E+00	1.393E+00	8.794E-01	7.546E-01
RCC16R-5	5.924E+02	9.575E+02	2.716E+02	1.758E+03	2.625E+03	1.410E+03	1.029E+03	5.542E+03
RCC16R-6a	4.477E+02	6.113E+02	4.091E+02	4.685E+02	9.693E+02	8.699E+02	2.114E+03	1.733E+03
RCC16R-7	4.593E+00	1.315E+01	8.309E+00	1.039E+01	1.906E+03	1.709E+03	4.039E+03	3.109E+03
RCC16R-8	2.751E-01	9.997E-01	1.846E-01	1.978E-01	1.624E+03	1.800E+03	8.062E+02	8.687E+02
RCC16R-9b	5.409E+00	4.321E+00	4.916E+00	3.739E+00	1.793E+03	1.076E+03	1.131E+03	9.450E+02
RCC16R-10	3.200E+02	1.967E+02	3.935E+02	3.802E+02	2.845E+03	1.172E+03	3.751E+03	2.829E+03
RCC16R-11	7.671E+00	6.488E+00	3.141E+00	4.215E+00	1.627E+03	1.781E+03	5.203E+03	3.486E+03
RCC16R-12	2.659E+00	2.034E+00	1.309E+00	5.133E+00	9.517E+02	8.240E+02	3.090E+03	1.371E+03
RCC16R-13	1.413E+00	1.749E+00	1.023E+00	1.349E+00	2.882E+02	4.062E+02	3.703E+02	2.816E+02
RCC16R-14	1.665E+00	2.004E+00	9.780E-01	1.217E+00	1.181E+03	9.801E+02	1.605E+03	1.015E+03
RCC15R-15	1.058E+00	1.097E+00	7.231E-01	7.094E-01	7.464E+02	9.198E+02	9.847E+02	7.174E+02
RCC16R-16	1.167E+01	3.816E+00	9.009E+00	1.138E+01	1.187E+03	8.804E+02	1.564E+03	1.290E+03
RCC16R-17	1.049E+00	1.172E+00	9.612E-01	1.327E+00	3.200E+02	2.777E+02	9.321E+02	5.213E+02
RCC16R-18	4.577E+00	2.009E+00	2.513E+00	1.648E+00	1.243E+03	9.651E+02	2.012E+03	1.292E+03
RCC16R-19	1.713E+00	2.490E+00	1.272E+00	1.562E+00	2.873E+02	2.606E+02	1.007E+03	5.284E+02
RCC16R-20	7.490E-01	3.013E+00	8.021E-01	5.215E-01	2.883E+02	3.586E+02	1.634E+03	9.709E+02

Table 7: RCC16R Raw Wave Signal, Sensors 9-16

Test No.	S1 En J x 10^{-10}	S2 En J x 10^{-10}	S3 En J x 10^{-10}	S4 En J x 10^{-10}	S5 En J x 10^{-10}	S6 En J x 10^{-10}	S7 En J x 10^{-10}	S8 En J x 10^{-10}
RCC16R-1	9.838E+02	1.445E+03	1.412E+03	1.202E+03	6.737E+03	2.940E+03	6.041E+03	2.522E+03
RCC16R-2	7.559E+02	1.615E+03	7.597E+02	1.839E+03	1.275E+04	2.807E+03	9.849E+03	2.430E+03
RCC16R-3	6.468E+03	2.424E+04	6.988E+03	5.664E+04	2.225E+05	5.833E+04	9.945E+04	6.264E+04
RCC16R-4	2.498E+02	7.477E+02	1.424E+02	3.980E+03	1.052E+04	1.233E+03	3.559E+03	1.636E+03
RCC16R-5	8.401E+03	4.531E+03	2.231E+04	3.435E+03	9.264E+03	8.640E+03	1.091E+04	1.021E+04
RCC16R-6a	1.975E+04	2.441E+04	2.167E+04	1.441E+04	3.634E+04	4.924E+04	4.554E+04	5.865E+04
RCC16R-7	1.564E+04	1.701E+04	1.502E+04	3.155E+04	1.210E+05	4.630E+04	2.990E+05	7.205E+04
RCC16R-8	1.419E+04	2.015E+04	1.367E+04	2.290E+04	3.914E+04	1.973E+04	2.611E+04	2.438E+04
RCC16R-9b	1.651E+04	8.161E+04	1.538E+04	1.053E+05	1.194E+06	1.051E+05	5.502E+04	5.244E+04
RCC16R-10	2.164E+04	6.581E+03	2.368E+04	3.410E+03	1.534E+04	1.605E+04	1.738E+04	2.047E+04
RCC16R-11	3.197E+04	4.953E+04	4.292E+04	3.757E+04	1.318E+05	1.140E+05	7.332E+05	3.062E+05
RCC16R-12	2.400E+04	9.015E+04	3.422E+04	8.628E+04	2.120E+05	2.450E+05	4.561E+05	1.651E+05
RCC16R-13	2.083E+04	1.182E+05	3.380E+04	1.153E+05	2.430E+05	3.159E+05	1.297E+05	1.211E+05
RCC16R-14	2.128E+04	3.847E+05	3.584E+04	6.849E+05	6.508E+05	3.981E+05	1.251E+05	9.012E+04
RCC15R-15	1.302E+04	3.230E+04	1.124E+04	1.852E+04	4.965E+04	4.814E+04	2.857E+04	6.255E+04
RCC16R-16	2.762E+04	4.174E+05	3.420E+04	2.361E+05	3.698E+05	6.471E+05	6.861E+04	1.684E+05
RCC16R-17	2.080E+04	1.718E+05	3.002E+04	4.446E+04	1.041E+05	5.297E+05	1.004E+05	6.603E+05
RCC16R-18	1.824E+04	9.262E+04	1.858E+04	5.693E+04	8.006E+04	3.893E+05	3.869E+04	1.120E+05
RCC16R-19	2.051E+04	9.022E+05	2.818E+04	8.433E+04	2.489E+05	2.310E+06	5.003E+04	1.044E+05
RCC16R-20	2.504E+04	9.584E+04	3.947E+04	2.654E+04	7.101E+04	1.229E+06	1.000E+06	2.455E+06

Table 8: RCC16R Wave Signal Energy, Sensors 1-8

Test	S9 En	S10 En	S11 En	S12 En	S13 En	S14 En	S15 En	S16 En	TOT W.S.E.
No.	J x 10^{-10}	J x 10^{-10}	J x 10^{-10}	J x 10^{-10}	J x 10^{-10}	J x 10^{-10}	J x 10^{-10}	J x 10^{-10}	nJ
RCC16R-1	9.386E+03	3.064E+03	4.386E+03	2.212E+03	2.964E-01	2.172E-01	2.583E-01	2.362E-01	4.233E+03
RCC16R-2	6.088E+03	1.918E+03	3.023E+03	1.971E+03	2.363E-01	2.399E-01	2.187E-01	2.245E-01	4.581E+03
RCC16R-3	4.545E+04	2.487E+04	2.220E+04	2.242E+04	5.514E+00	4.825E+00	4.391E+00	5.110E+00	6.522E+04
RCC16R-4	7.016E+02	7.872E+02	3.677E+02	5.654E+02	2.765E-05	2.779E-05	1.755E-05	1.506E-05	2.449E+03
RCC16R-5	1.488E+04	1.205E+04	2.716E+04	2.213E+04	1.656E+00	8.894E-01	2.584E+00	1.753E+00	1.539E+04
RCC16R-6a	4.477E+04	6.113E+04	4.091E+04	4.685E+04	2.435E+00	2.185E+00	5.309E+00	4.353E+00	4.637E+04
RCC16R-7	5.782E+04	4.159E+04	2.628E+04	3.285E+04	4.788E+00	4.294E+00	1.015E+01	7.808E+00	7.762E+04
RCC16R-8	2.751E+04	9.997E+04	1.846E+04	9.916E+03	1.025E+00	1.136E+00	5.087E-01	5.481E-01	3.361E+04
RCC16R-9b	3.413E+04	2.726E+04	3.102E+04	2.359E+04	8.988E+00	5.394E+00	5.669E+00	4.736E+00	1.742E+05
RCC16R-10	3.200E+04	1.967E+04	3.935E+04	3.802E+04	3.582E+00	1.476E+00	4.723E+00	3.561E+00	2.536E+04
RCC16R-11	1.927E+05	1.630E+05	7.889E+04	1.059E+05	8.152E+00	8.927E+00	2.608E+01	1.747E+01	1.988E+05
RCC16R-12	1.332E+05	1.019E+05	6.559E+04	6.462E+04	1.508E+01	1.306E+01	4.898E+01	2.172E+01	1.678E+05
RCC16R-13	7.081E+04	8.765E+04	5.126E+04	6.761E+04	1.818E+01	2.563E+01	2.336E+01	1.777E+01	1.375E+05
RCC16R-14	8.343E+04	1.004E+05	4.902E+04	6.099E+04	3.734E+01	3.099E+01	5.075E+01	3.209E+01	2.685E+05
RCC15R-15	2.658E+04	2.756E+04	1.816E+04	1.782E+04	1.875E+00	2.310E+00	2.473E+00	1.802E+00	3.541E+04
RCC16R-16	7.361E+04	9.586E+04	5.684E+04	7.179E+04	1.881E+01	1.395E+01	2.478E+01	2.044E+01	2.267E+05
RCC16R-17	5.258E+04	1.172E+05	4.817E+04	6.649E+04	2.019E+01	1.752E+01	5.881E+01	3.289E+01	1.946E+05
RCC16R-18	5.762E+04	5.045E+04	3.164E+04	4.140E+04	6.230E+00	4.837E+00	1.009E+01	6.474E+00	9.876E+04
RCC16R-19	4.303E+04	1.248E+05	3.194E+04	3.925E+04	1.813E+01	1.644E+01	6.353E+01	3.334E+01	3.988E+05
RCC16R-20	4.726E+05	1.901E+06	8.021E+02	3.290E+05	1.819E+01	2.263E+01	1.031E+02	6.126E+01	7.646E+05

Table 9: RCC16R Wave Signal Energy, Sensors 9-16 and Total W.S.E.

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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 Target RCC16R was to study hypervelocity impacts through the reinforced carbon-carbon (RCC) panels of the Wing Leading Edge. Impact damage was detected using lightweight, low power instrumentation capable of being used in flight.

15. SUBJECT TERMS
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