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Hypervelocity Impact (HVI)

Volume 6: WLE High Fidelity Specimen Fg(RCC)-2

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

September 2007

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Hypervelocity Impact (HVI)

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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 Fg(RCC)-2 was to study hypervelocity impacts through the reinforced carbon-carbon (RCC) panels of the Wing Leading Edge. Fiberglass was used in place of RCC in the initial tests.

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

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Introduction

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

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

Target Fg(RCC)-2 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 Fg(RCC)-2 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 Fg(RCC)-2 consisted of a 20-ply fiberglass panel formed to the same dimensions of an actual RCC panel 16R. Figure 1 shows the WLE panel mounted to a green spar with metal joints. The spar is fastened to a blue 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: Target Fg(RCC)-2 on Mounting Fixture

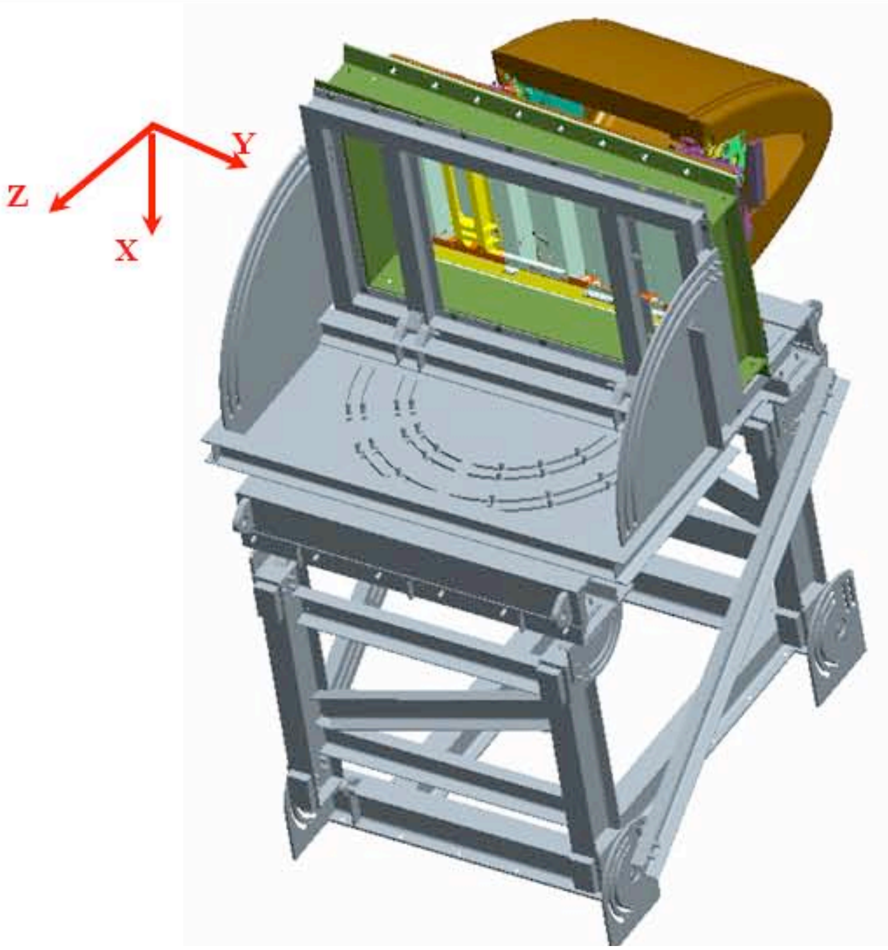

Figure 2: Model of Target Fg(RCC)-2 (brown), Spar (green), and Mount (gray)

Figure 3: Target Fg(RCC)-2 on Rail System. Top: Right Side View. Bottom: Front View.

There were 19 impacts. The impact angle of the shots varied from 30 degrees to 90 degrees from the target surface.

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 2.4 mm. Impact velocity was measured with WSTF diagnostic equipment on each shot. The projectile kinetic energy for these shots ranged from 2.02 J to 485.67 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 and WLE target 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.

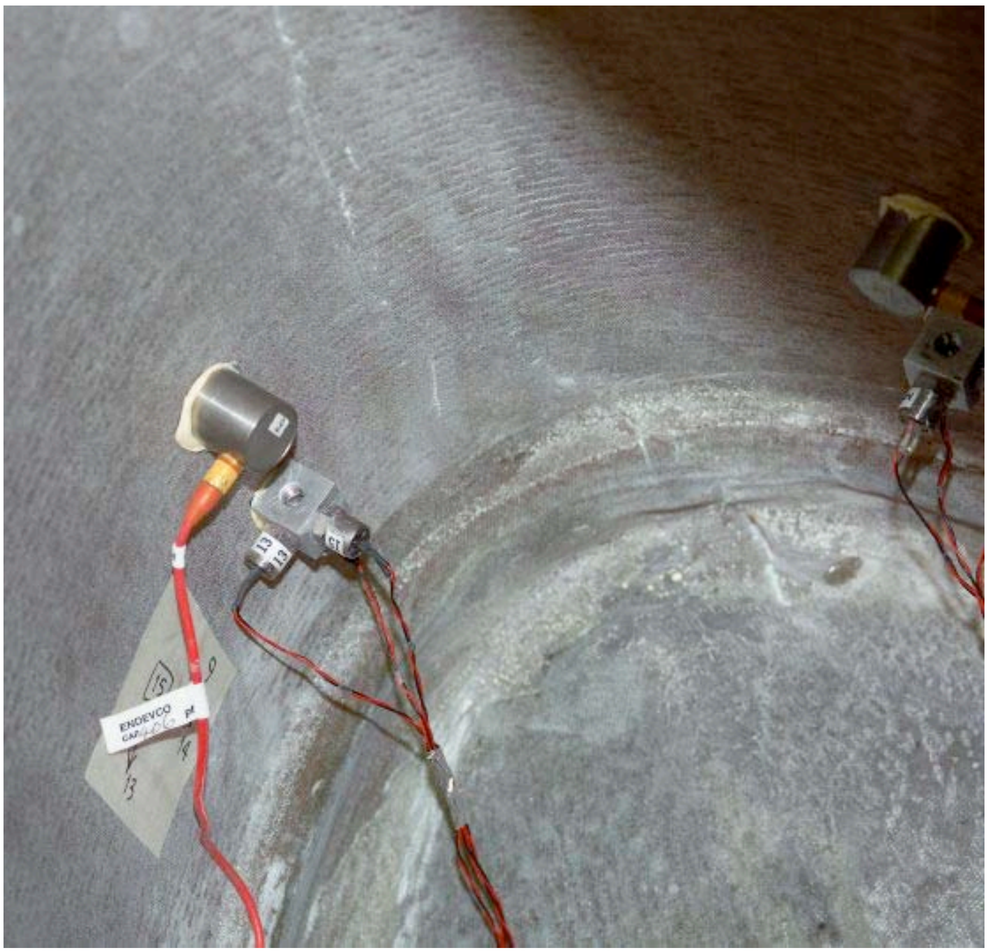

Figure 4: Detail of Sensor 9 on Target Fg(RCC)-2

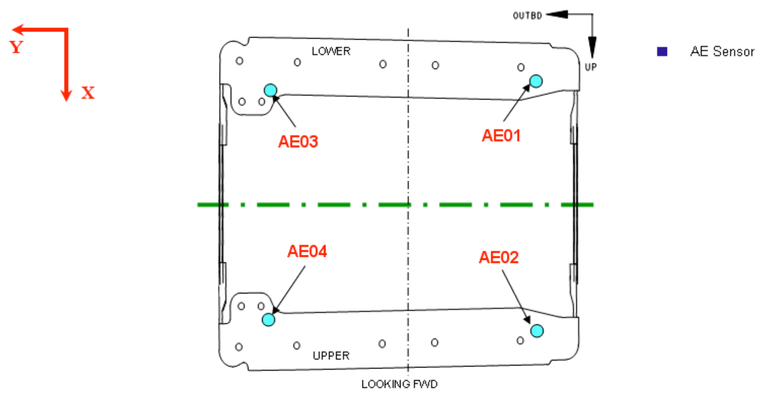

Figure 5: Fg(RCC)-2 Sensor Locations. Lower Flange.

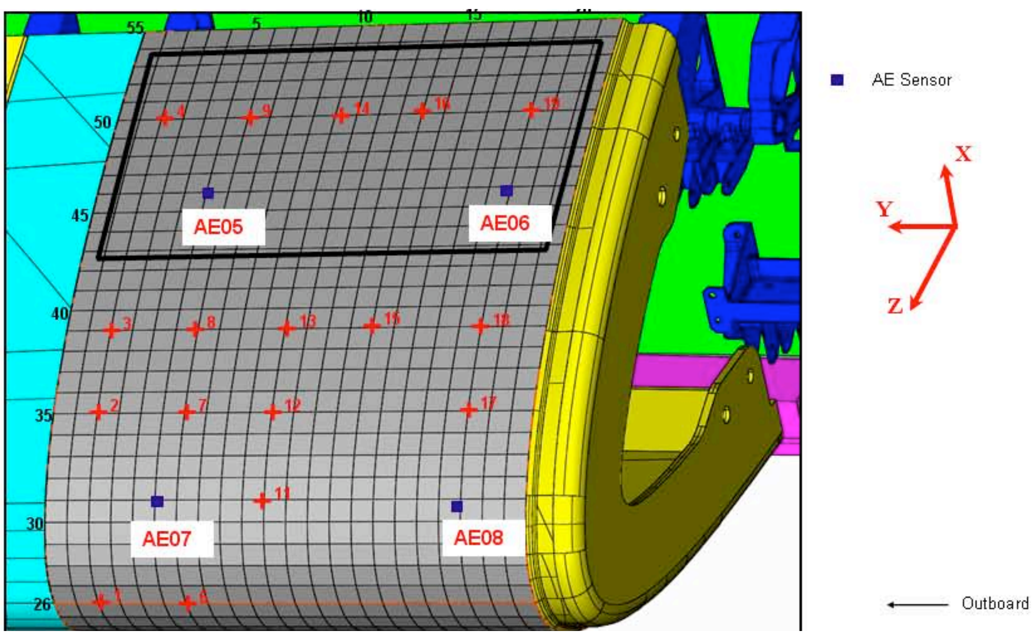

Figure 6: Fg(RCC)-2 Sensor and Impact Locations. Upper Panel.

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), #6(26,6), #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),

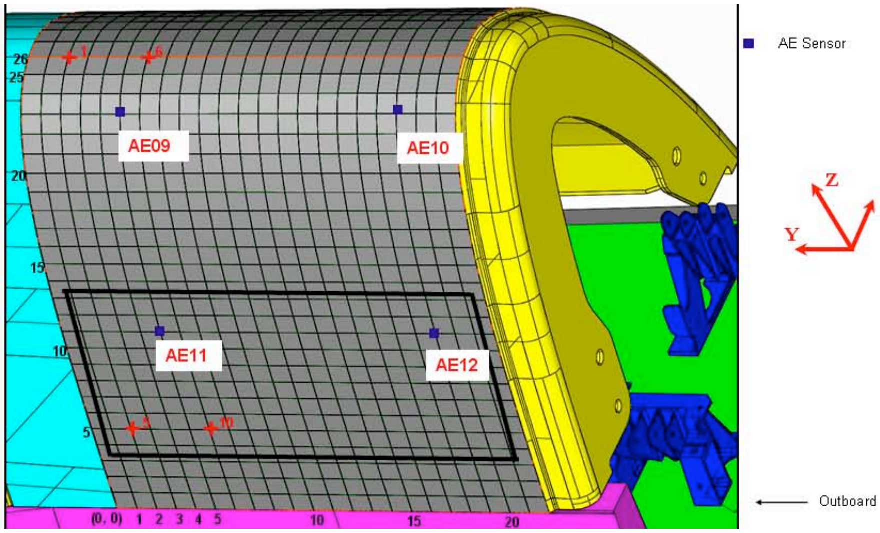

Figure 7: Fg(RCC)-2 Sensor and Impact Locations. Lower Panel.
Sensors have the following coordinates:
#9(23, 5), #10(23, 19), #11(11, 5), #12(11, 19) Dimensions are inches.
Impacts have the following coordinates:
#1(26, 2), #5(5,2), #6(26,6), #10(5, 6)

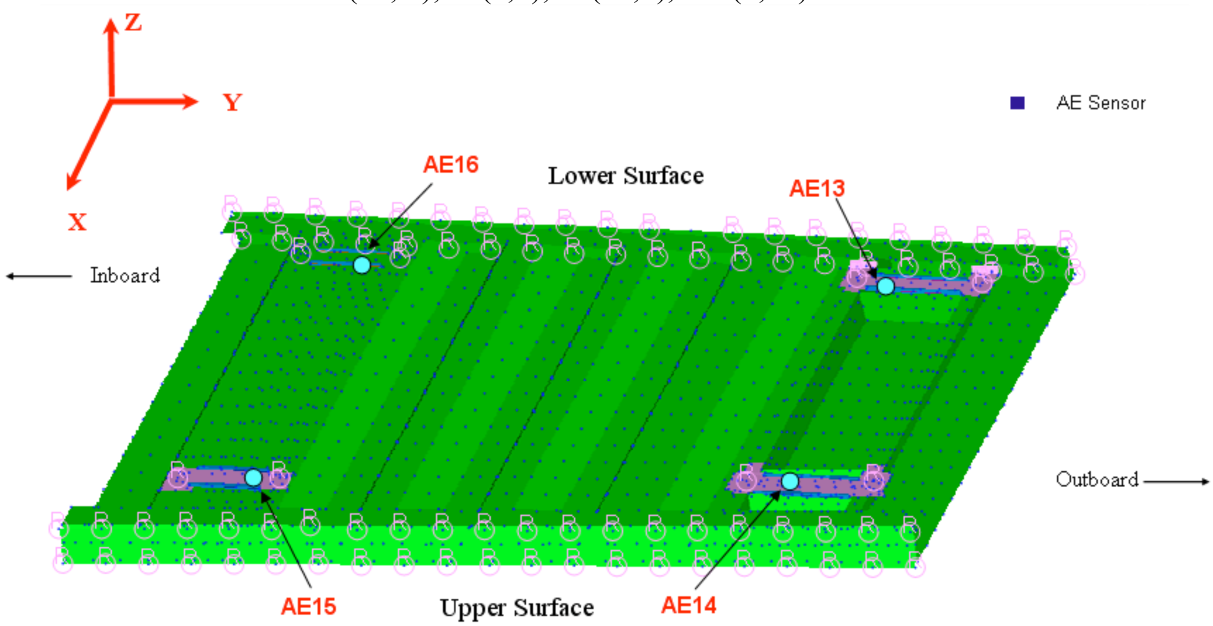

Figure 8: Fg(RCC)-2 Sensor Locations. Spar.

Figure 9: Fg(RCC)-2 Post-test Impact Locations. Top: Front View. Bottom: Left Side 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.

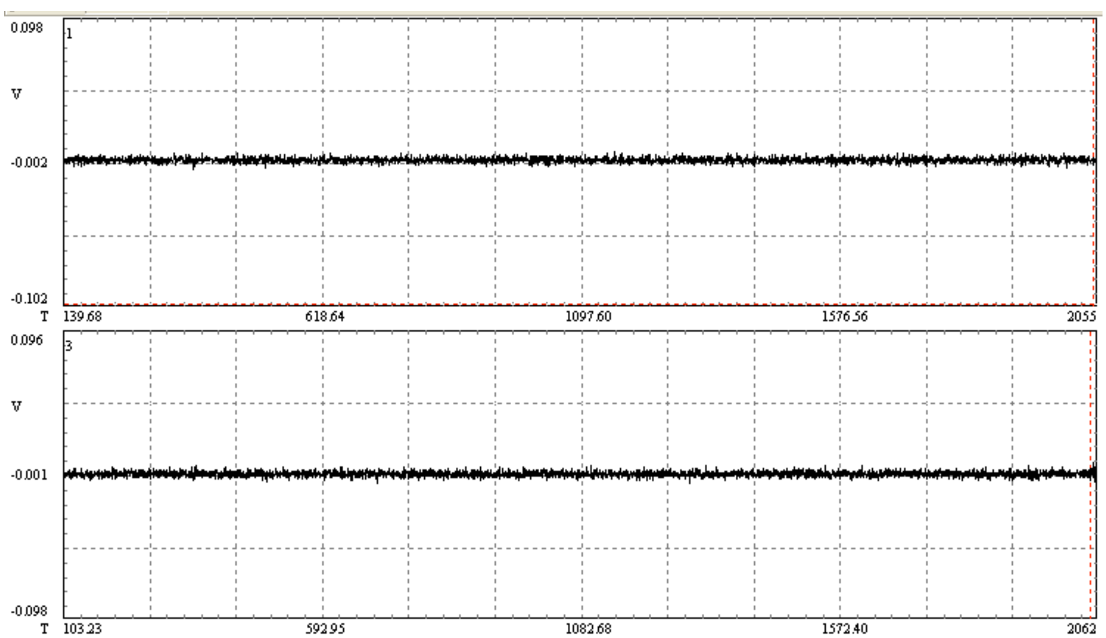

Figure 10: Example of DC Offfset

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

A typical impact signal is shown in Figure 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. The vastly different velocities of the modes were used to confirm the modes' presence.

The sound waves produced by impact are shown complete in the Appendix 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.

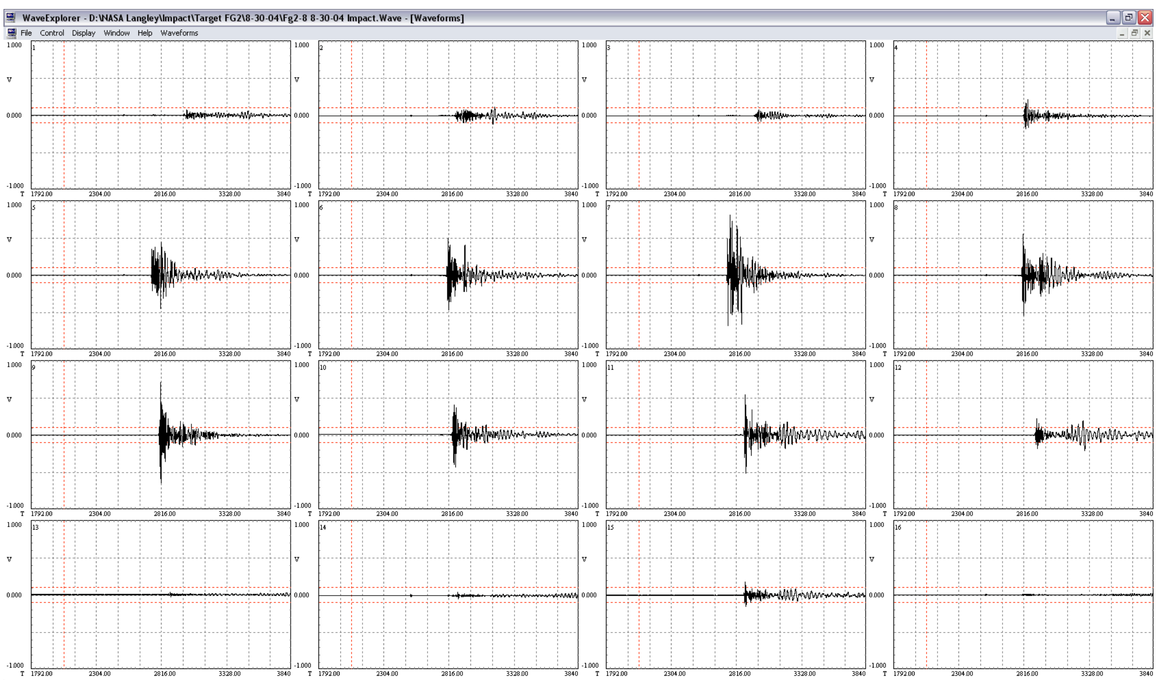

Figure 11: Fg(RCC)-2 Impact Signal for Shot #8

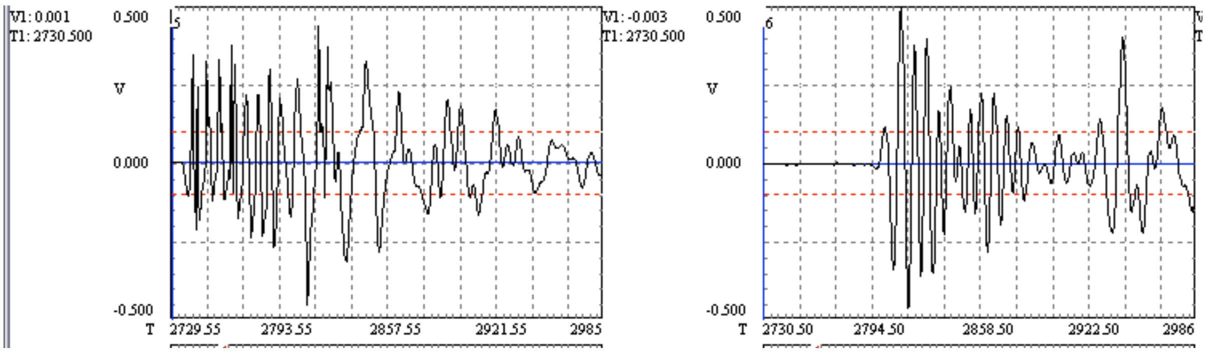

Figure 12: Detail of Fg(RCC)-2 Impact Signal for Shot #8, Channels 5 and 6

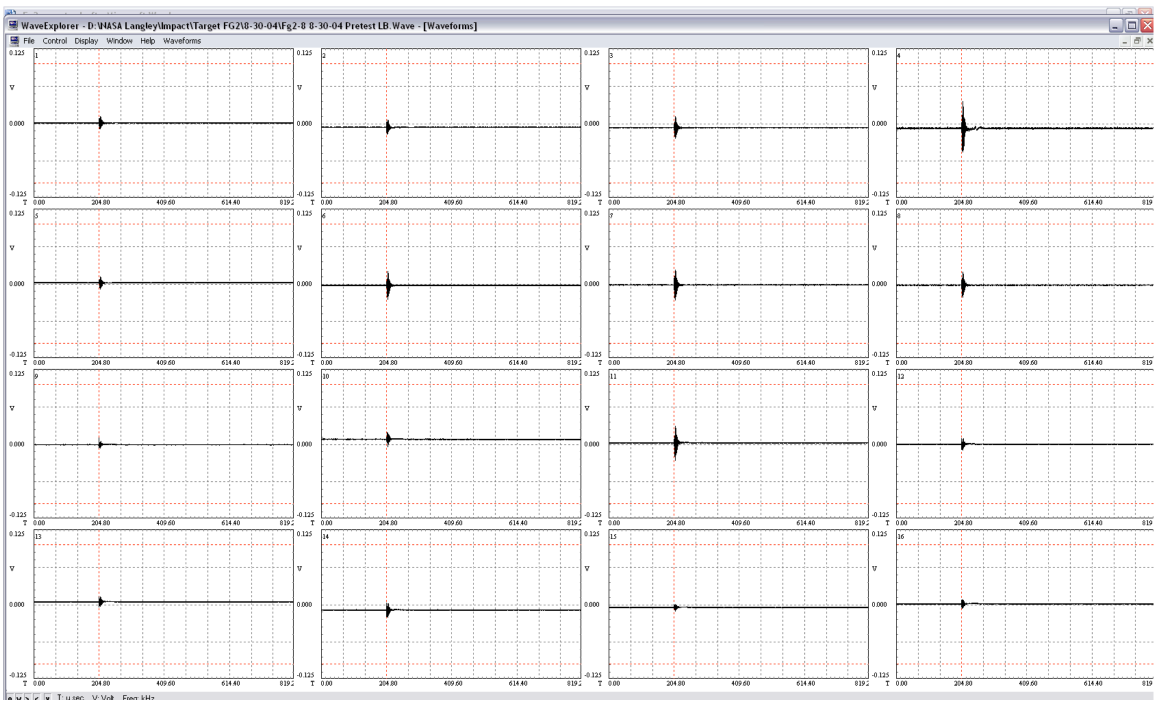

Figure 13: Fg(RCC)-2 Electromagnetic Interference for Shot #8

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

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

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

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

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

Results

The most important quantities used in the analysis of the wave signals were the wave signal energy and projectile kinetic energy for each shot. These are given in Table 1 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
FG2-1	0.4	90	2.02	2.02	8.353E+02
FG2-2	0.4	60	1.61	2.15	1.959E+02
FG2-3	1.0	45	17.55	35.13	3.564E+05
FG2-4	0.4	30	0.53	2.12	3.436E+02
FG2-5	0.6	45	3.56	7.12	4.584E+03
FG2-6	0.8	90	16.64	16.64	2.017E+04
FG2-7	1.0	30	8.45	33.85	4.919E+05
FG2-8	0.6	60	5.32	7.10	9.569E+03
FG2-9	1.2	30	14.19	56.81	4.825E+05
FG2-10	0.8	30	3.76	15.06	
FG2-11	1.2	60	42.71	56.98	2.268E+06
FG2-12	1.6	45	67.08	134.27	1.383E+06
FG2-13	2.0	45	131.41	263.02	2.126E+06
FG2-14	2.0	30	66.86	267.67	1.656E+06
FG2-15	0.8	60	12.03	16.05	1.874E+04
FG2-16	1.6	45	63.01	126.12	7.983E+05
FG2-17	2.4	30	107.28	429.53	3.495E+06
FG2-18	1.2	60	40.98	54.67	1.310E+06
FG2-19	2.4	45	242.64	485.67	5.381E+06

Table 1: Fg(RCC)-2 Kinetic Energy and Wave Signal Energy (All Sensors). No wave signal energy listed for shot #10. Attenuators mistakenly installed on channels 1-12.

The damage for each shot is given in Table 2. The crater volume damage is the product of the recorded length, width, and depth measurements on the front side of the panel for each impact. Damage area is the product of recorded length and width measurements on the front side of the panel. Figure 14 shows the impact damage for shot #13.

Test No.	Normal K.E. J (± 5%)	Total K.E. J (± 5%)	Damage Area mm^2	Crater Volume mm^3
FG2-1	2.02	2.02		0.3
FG2-2	1.61	2.15	38.5	0.1
FG2-3	17.55	35.13	93.5	7.0
FG2-4	0.53	2.12	7.5	0.02
FG2-5	3.56	7.12	47.5	0.8
FG2-6	16.64	16.64	20.3	12.8
FG2-7	8.45	33.85	82.5	4.5
FG2-8	5.32	7.10	45.0	0.4
FG2-9	14.19	56.81	114.0	8.3
FG2-10	3.76	15.06	54.0	2.6
FG2-11	42.71	56.98	123.5	39.1
FG2-12	67.08	134.27	292.5	59.4
FG2-13	131.41	263.02	480.0	108.0*
FG2-14	66.86	267.67	256.0	117.6
FG2-15	12.03	16.05	60.0	4.0
FG2-16	63.01	126.12	240.0	46.1
FG2-17	107.28	429.53	323.0	108.0*
FG2-18	40.98	54.67	168.0	21.6
FG2-19	242.64	485.67	775.0	312.0

Table 2: Fg(RCC)-2 Damage Results.

Shots #13 and #17 created holes. It was assumed that the crater depth for holes was the thickness of the specimen, 6 mm. The recorded depth for shot #19 was 7.8 mm, but was changed to 6 mm so as to not exceed the thickness of the specimen. There was no damage area recorded for shot #1.

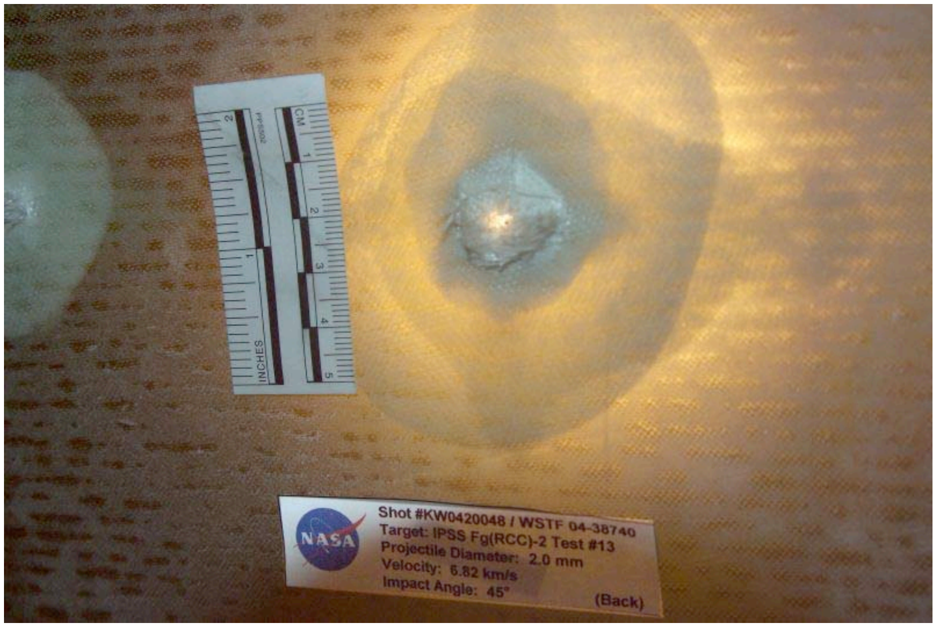

Figure 14: Fg(RCC)-2 Impact Damage Area for Shot #13

Discussion

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 measures themselves were crude. Although some damage in the interior plies seemed apparent, see Figure 14, 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.

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. 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.

For comparison the total energy value was computed for each set of sensors, spar, RCC, and flange, and plotted against kinetic energy. Then all three acoustical energy values were summed together and plotted against kinetic energy. The four plots all exhibited similar trends and showed good correlation with kinetic energy and damage. These plots are shown in the following figures.

It should be kept in mind that 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 alones creates all the damage is debatable, but there is a general trend of increasing normal kinetic energy leading to increasing damage.

There is a strong linear trend for the following graphs especially for Normal Kinetic Energy vs. Damage Area (Figure 16) and for Total Kinetic Energy vs. Crater Volume Damage (Figure 17).

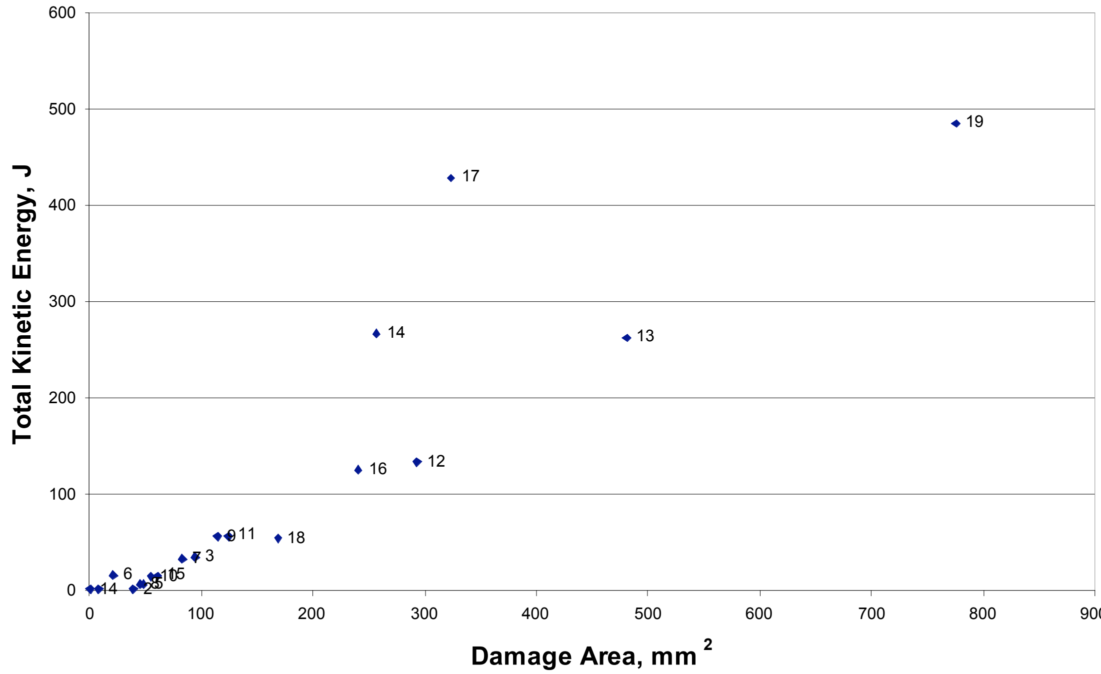

Figure 15: Fg(RCC)-2 Total Kinetic Energy vs. Fiber Damage Area

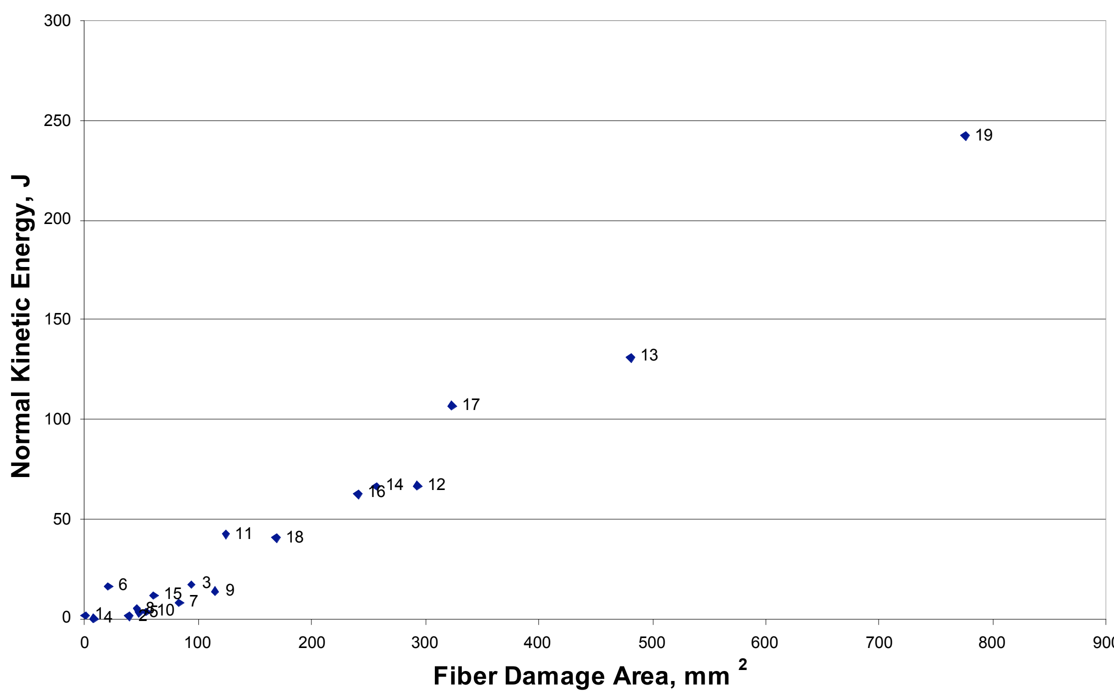

Figure 16: Fg(RCC)-2 Normal Kinetic Energy vs. Fiber Damage Area

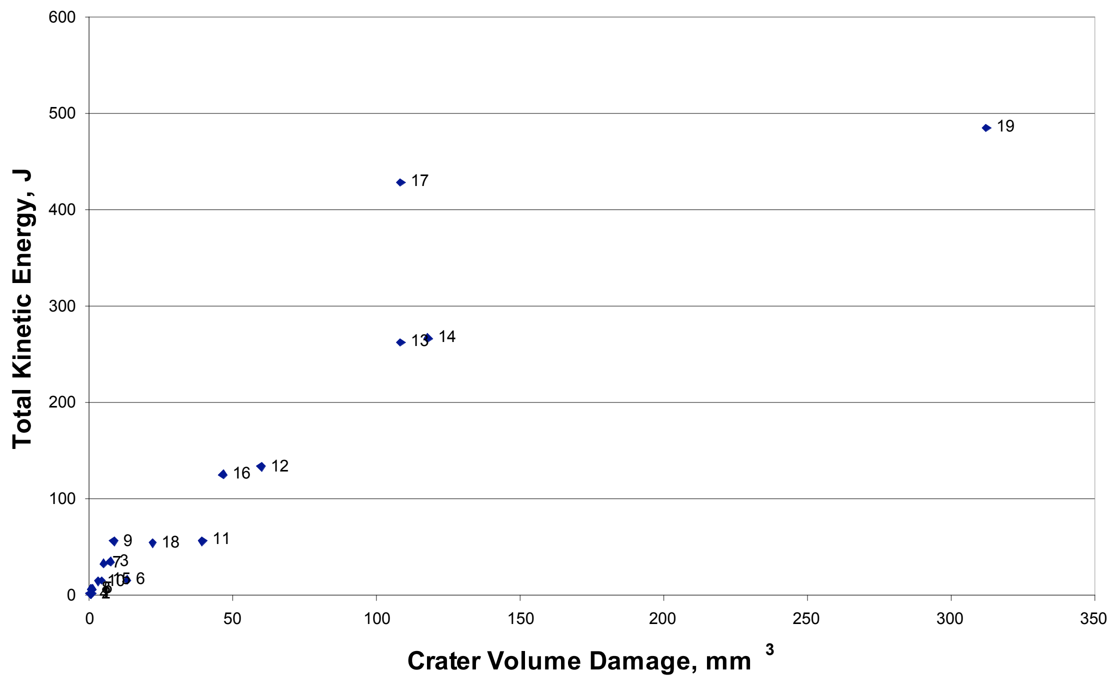

Figure 17: Fg(RCC)-2 Total Kinetic Energy vs. Crater Volume Damage

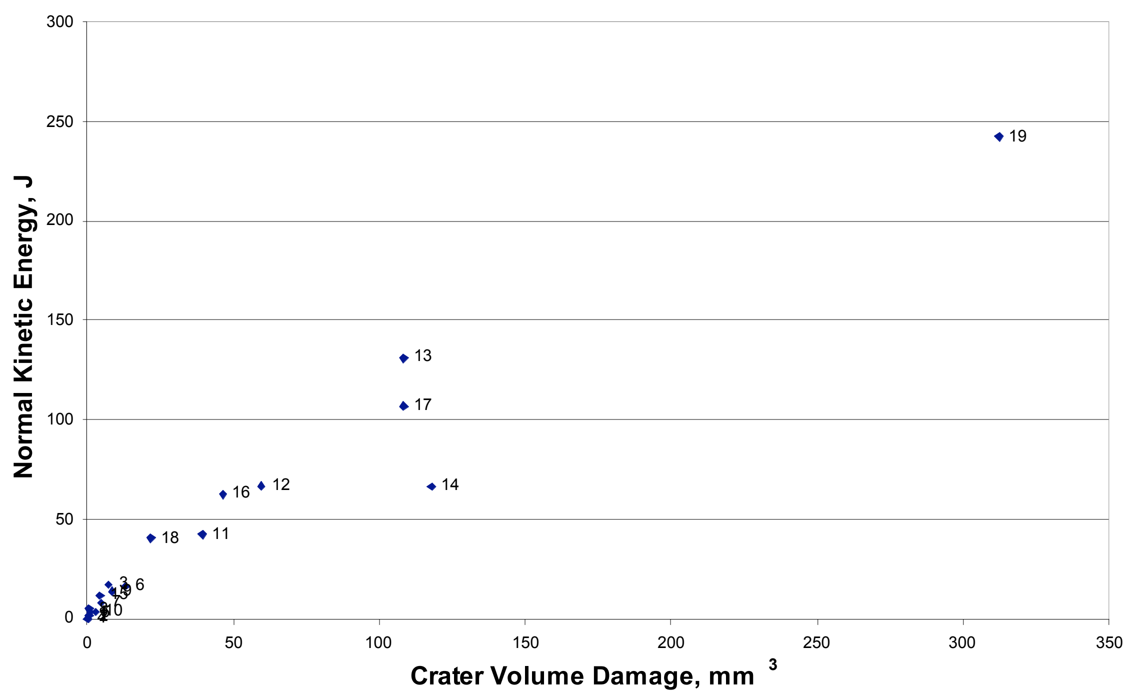

Figure 18: Fg(RCC)-2 Normal Kinetic Energy vs. Crater Volume Damage

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.

There was a linear relationship between wave signal energy, total kinetic energy, normal kinetic energy, fiber damage area, crater volume damage, inside delamination are, and outside delamination area. None of these variables stood out as being best correlated with wave signal energy. Since the damage measurements had a large amount of inherent error due to measurement techniques, it is perhaps best to focus on wave signal energy versus kinetic energy (Figure 19 and Figure 20).

The wave signal energy corresponded to kinetic energy for Target Fg(RCC)-2 as for Target Fg(RCC)-1. Overall, the data points were grouped more closely for Target Fg(RCC)-2. It was difficult to discern from this data whether wave signal energy is more closely related to total kinetic energy or to normal kinetic energy. Target RCC16R data was just as ambiguous.

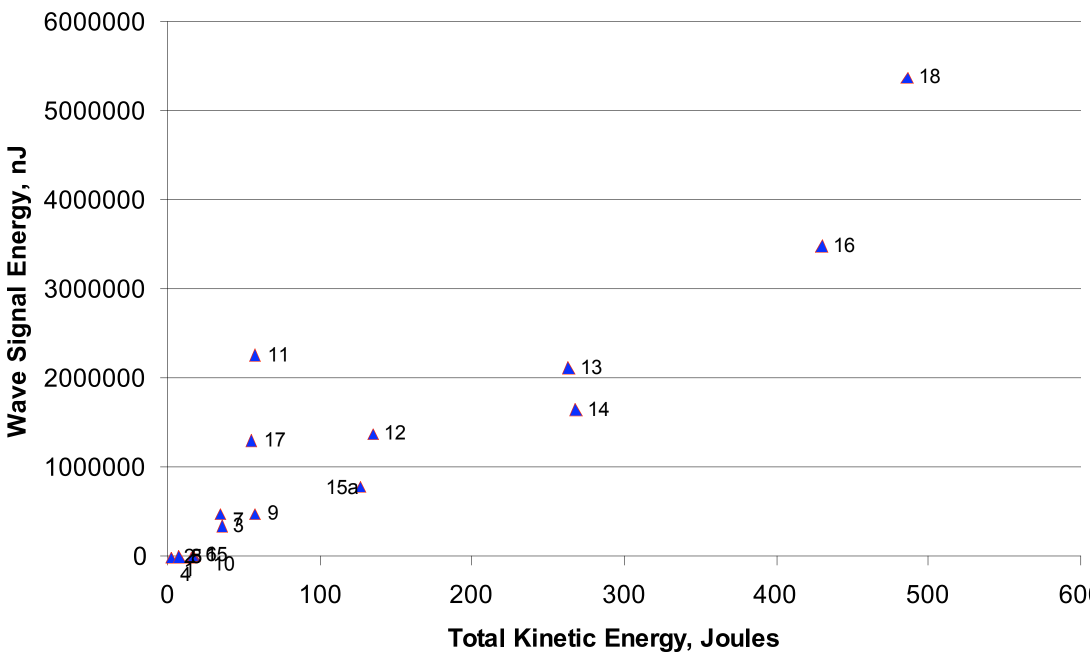

Figure 19: Fg(RCC)-2 Wave Signal Energy vs. Total Kinetic Energy - All Sensors

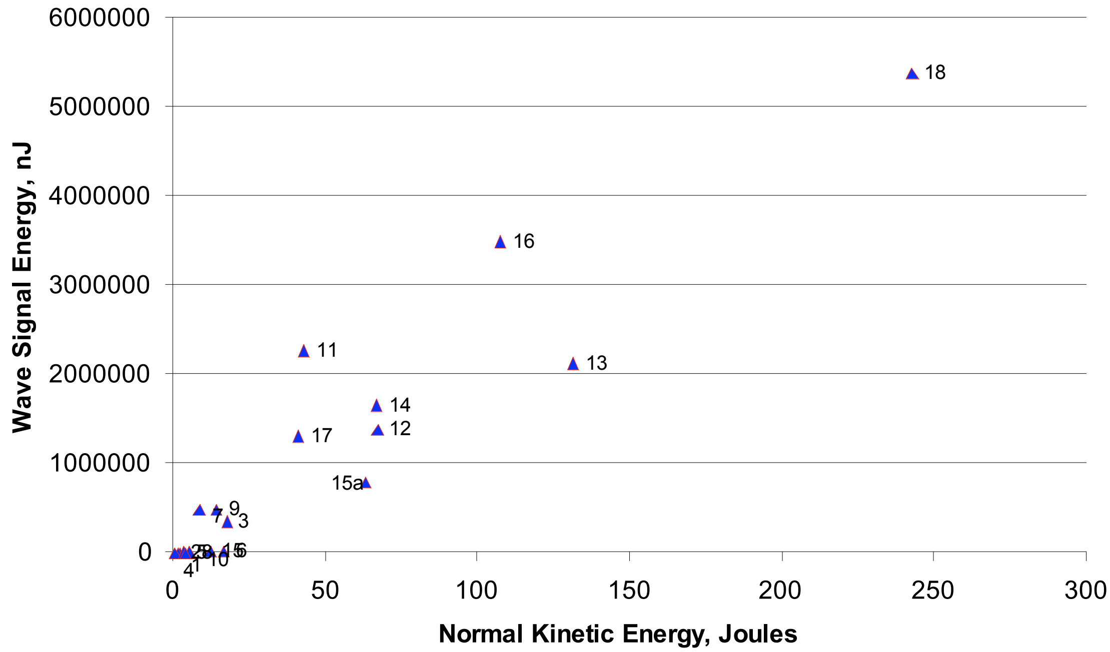

Figure 20: Fg(RCC)-2 Wave Signal Energy vs. Normal Kinetic Energy - All Sensors

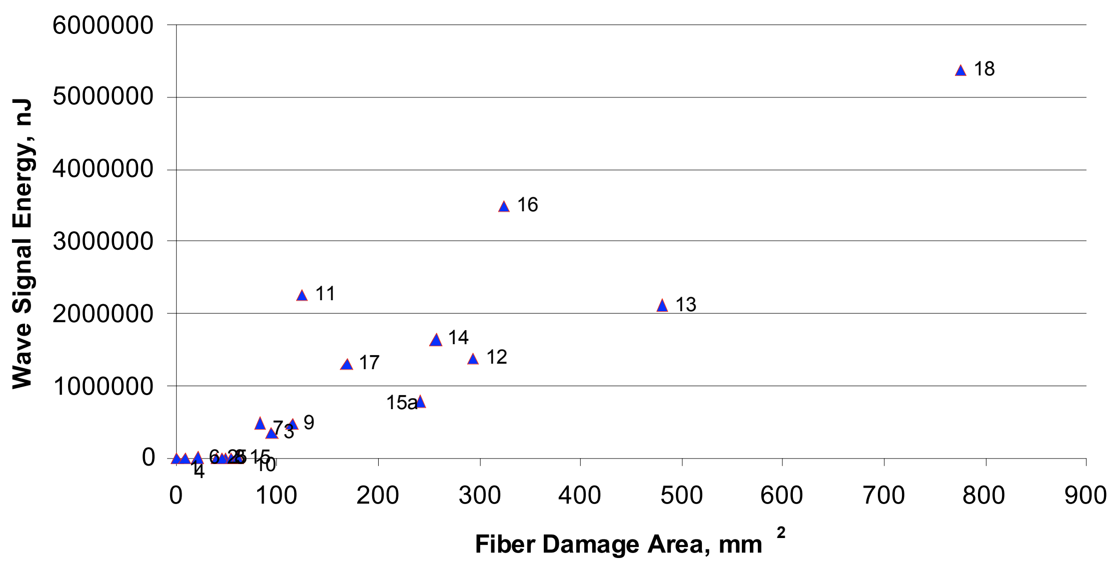

Figure 21: Fg(RCC)-2 Wave Signal Energy vs. Fiber Damage Area – All Sensors

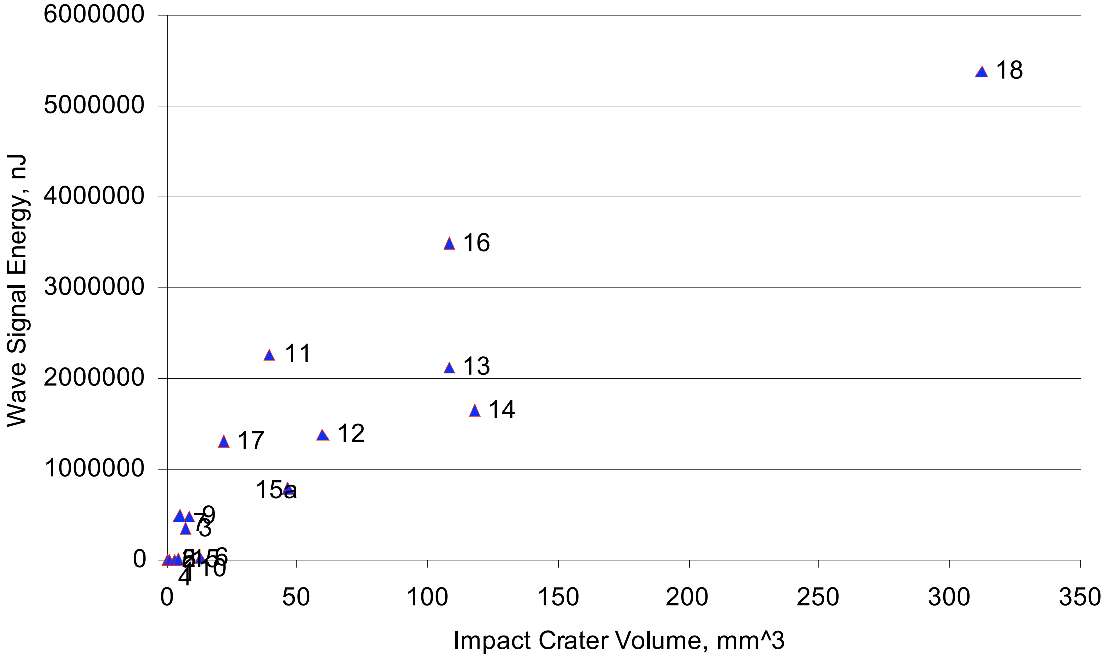

Figure 22: Fg(RCC)-2 Wave Signal Energy vs. Impact Crater Volume - All Sensors

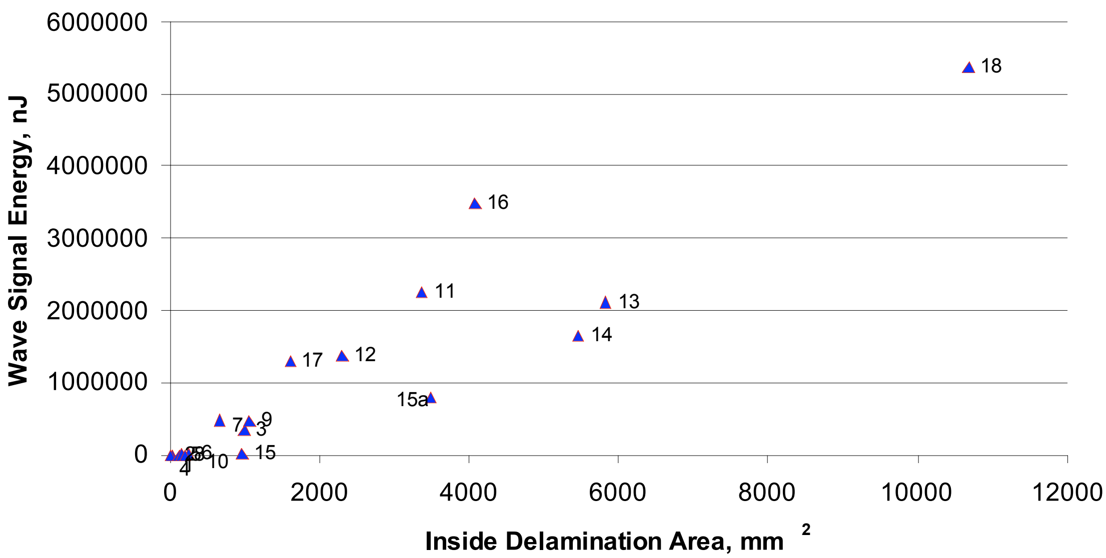

Figure 23: Fg(RCC)-2 Wave Signal Energy vs. Inside Delamination Area - All Sensors

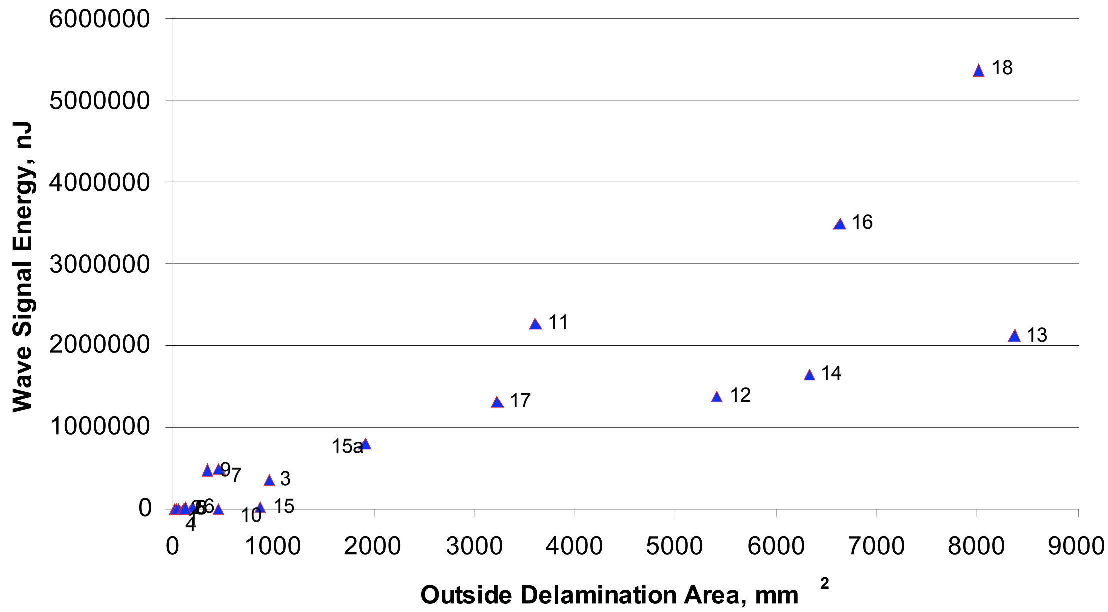

Figure 24: Fg(RCC)-2 Wave Signal Energy vs. Outside Delamination Area - All Sensors

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.

The only outlying point appeared to be the wave signal energy for shot #18 on the flange sensors. There is nothing unusual about the position or gain settings of the shot and it is not saturated.

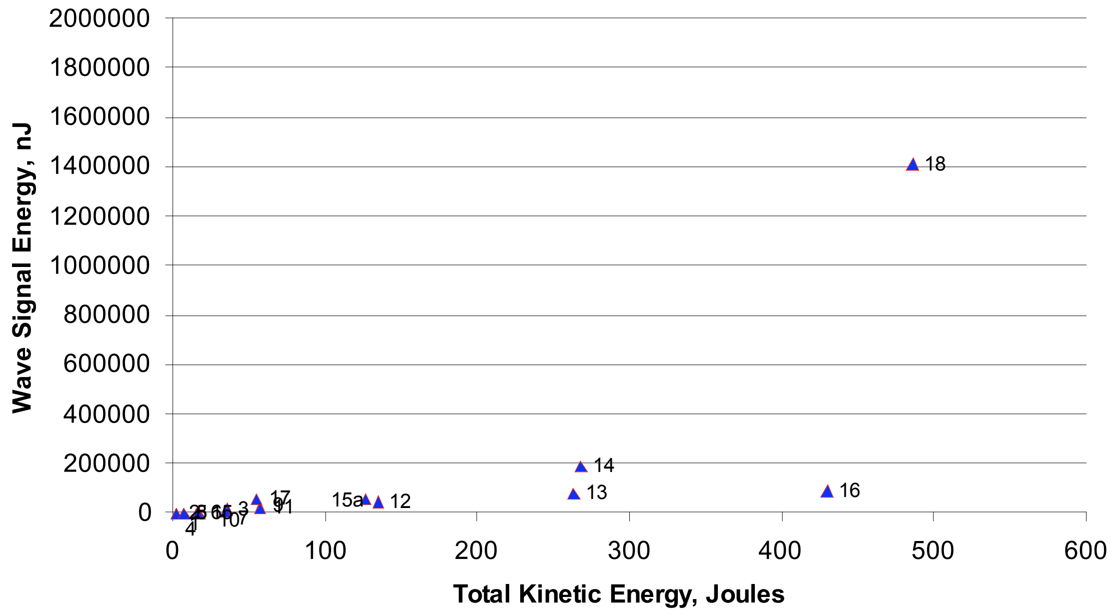

Figure 25: Fg(RCC)-2 Wave Signal Energy vs. Total Kinetic Energy - Flange Sensors Only

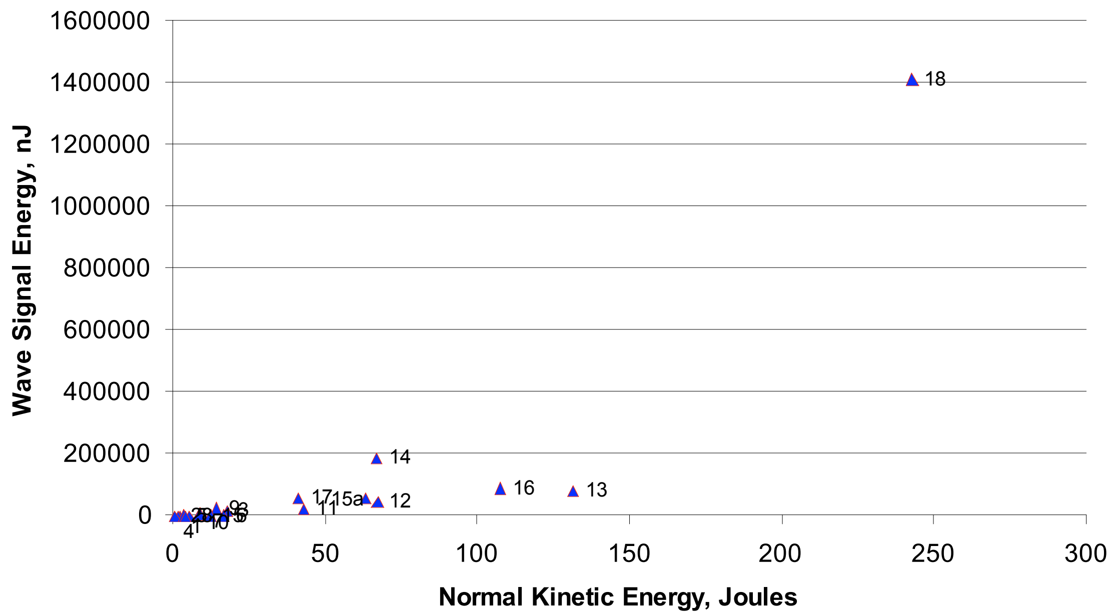

Figure 26: Fg(RCC)-2 Wave Signal Energy vs. Normal Kinetic Energy - Flange Sensors Only

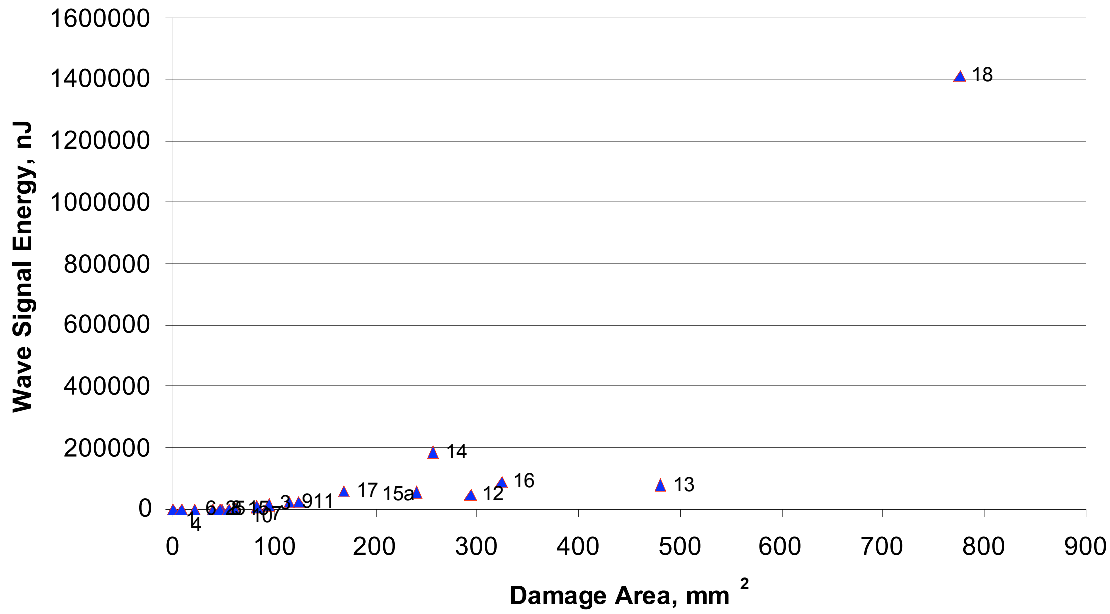

Figure 27: Fg(RCC)-2 Wave Signal Energy vs. Fiber Damage Area - Flange Sensors Only

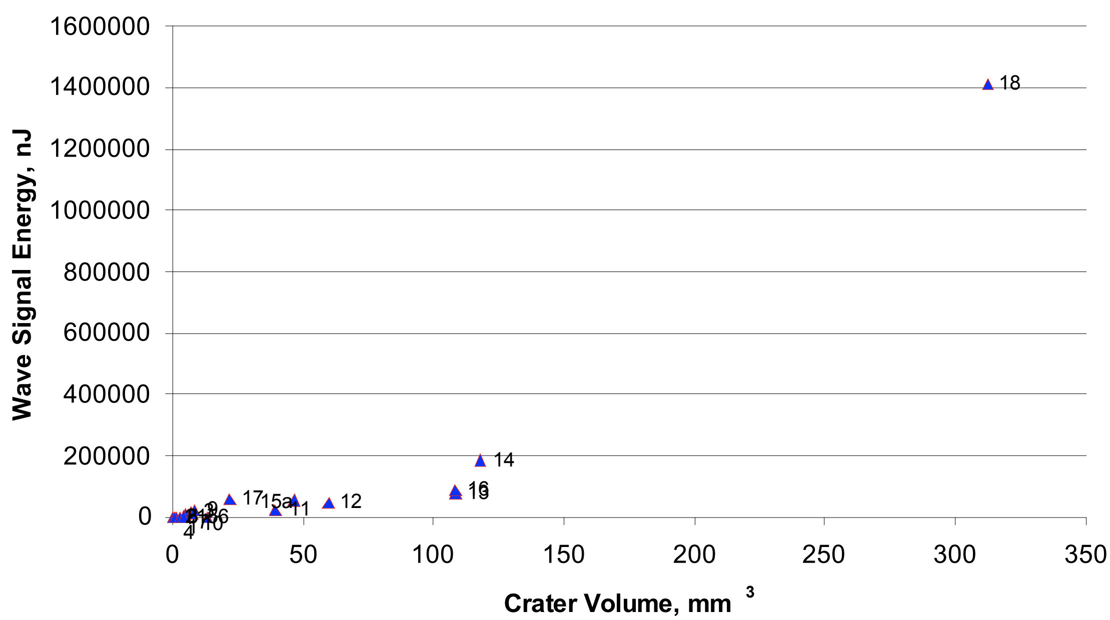

Figure 28: Fg(RCC)-2 Wave Signal Energy vs. Crater Volume Damage- Flange Sensors Only

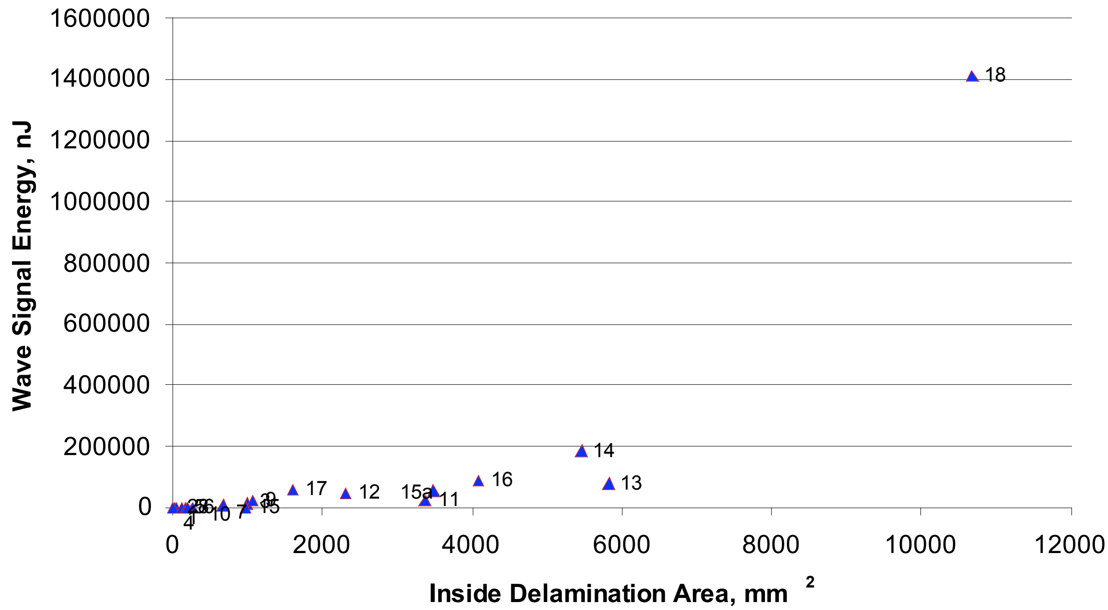

Figure 29: Fg(RCC)-2 Wave Signal Energy vs. Inside Delamination Area - Flange Sensors Only

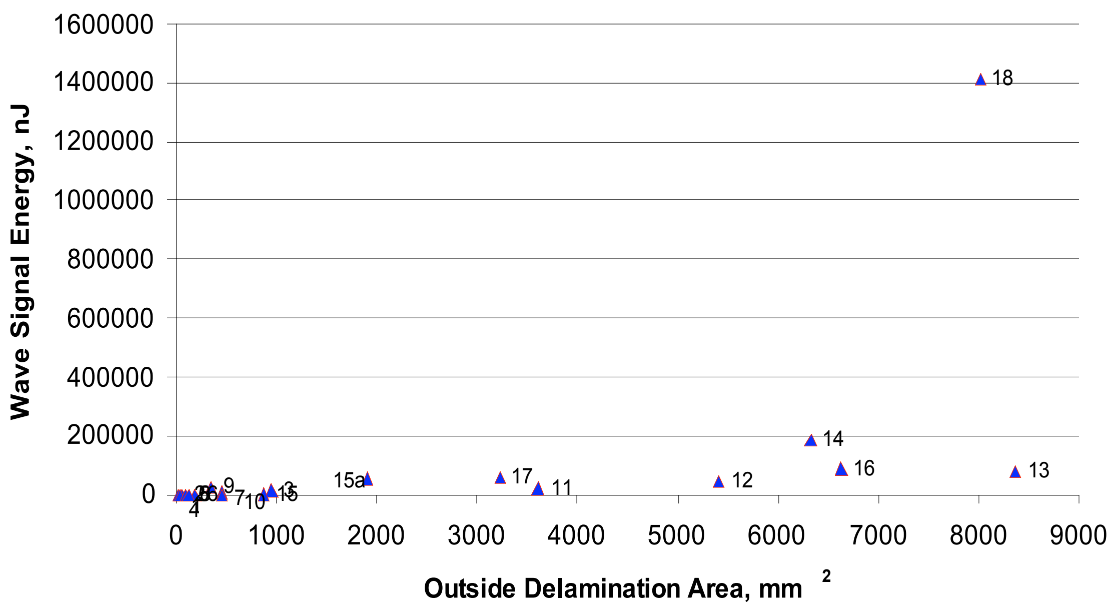

Figure 30: Fg(RCC)-2 Wave Signal Energy vs. Outside Delamination Area - Flange Sensors Only

Spar Sensors

There were a number of shots with small wave signal energies recorded on the spar sensors. These were graphed separately in Figure 32, Figure 34, Figure 36, Figure 38, Figure 40, and Figure 42 in order to illustrate the linearity present for wave signal energy even for small kinetic energy shots.

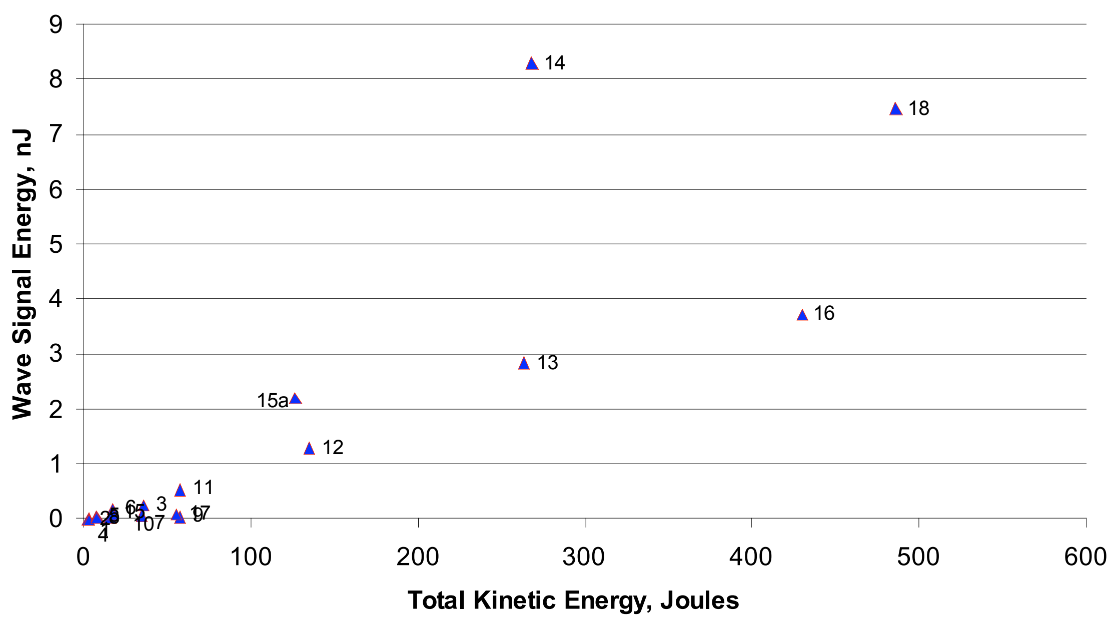

Figure 31: Fg(RCC)-2 Wave Signal Energy vs. Total Kinetic Energy – Spar Sensors Only

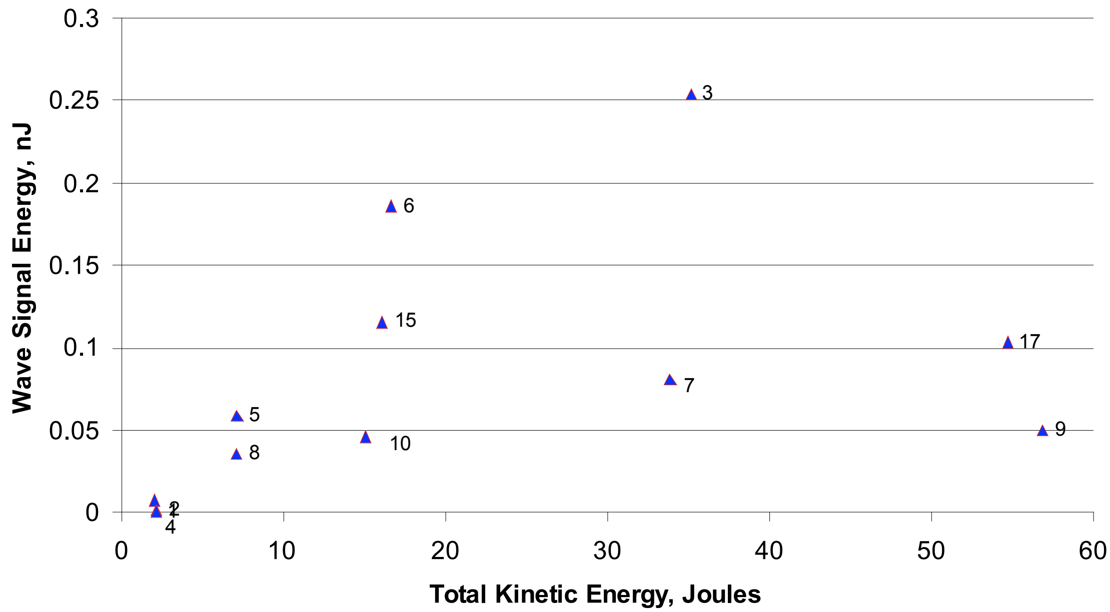

Figure 32: Detail of Fg(RCC)-2 Wave Signal Energy vs. Total Kinetic Energy - Spar Sensors Only

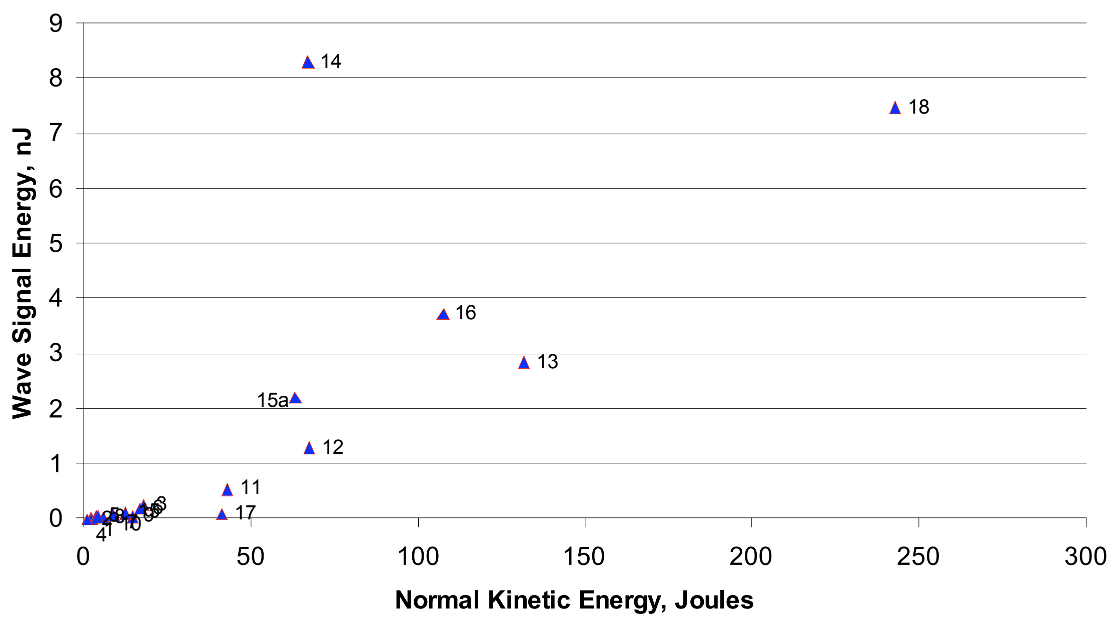

Figure 33: Fg(RCC)-2 Wave Signal Energy vs. Normal Kinetic Energy - Spar Sensors Only

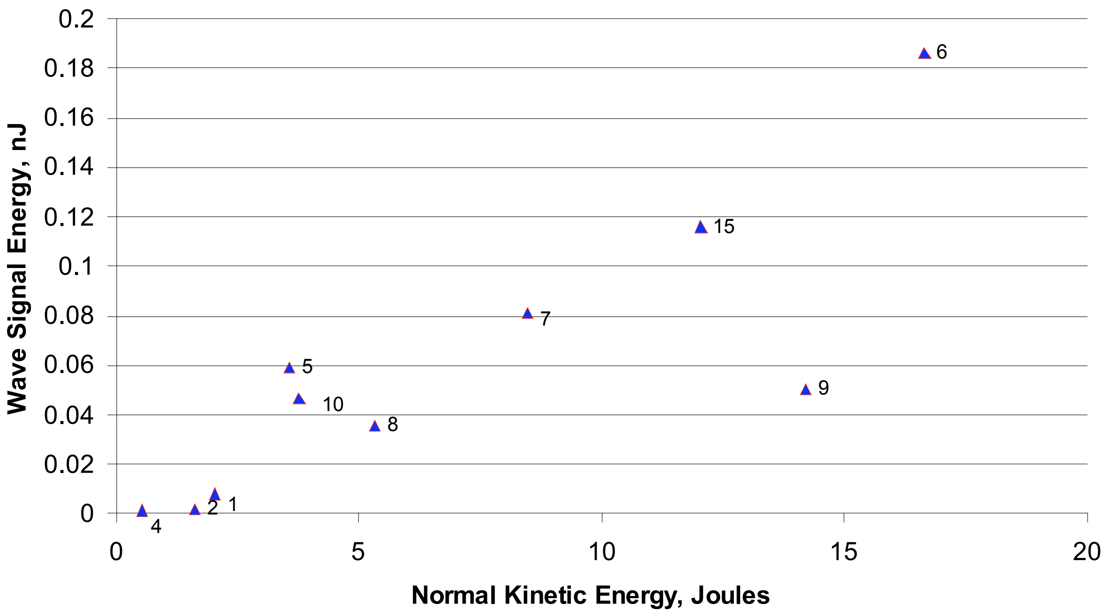

Figure 34: Detail of Fg(RCC)-2 Wave Signal Energy vs. Normal Kinetic Energy - Spar Sensors Only

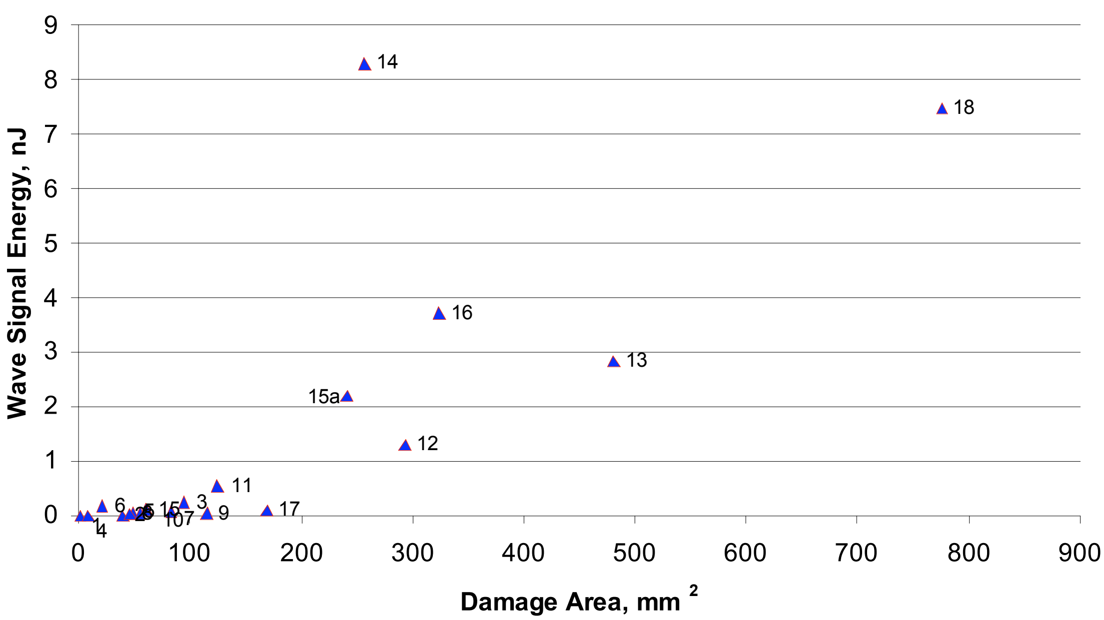

Figure 35: Fg(RCC)-2 Wave Signal Energy vs. Fiber Damage Area - Spar Sensors Only

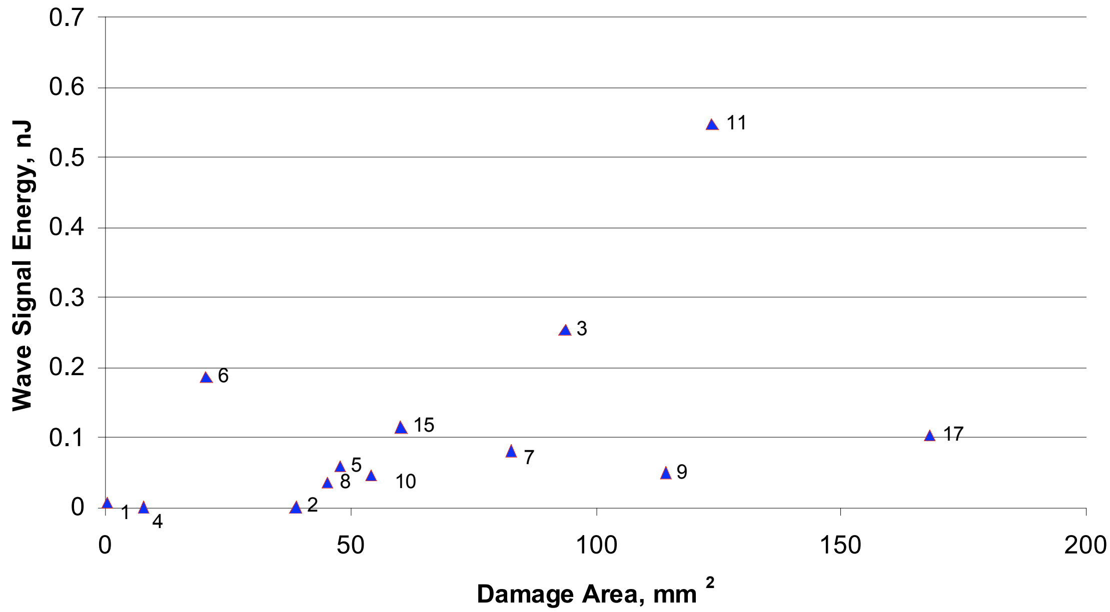

Figure 36: Detail of Fg(RCC)-2 Wave Signal Energy vs. Fiber Damage Area - Spar Sensors Only

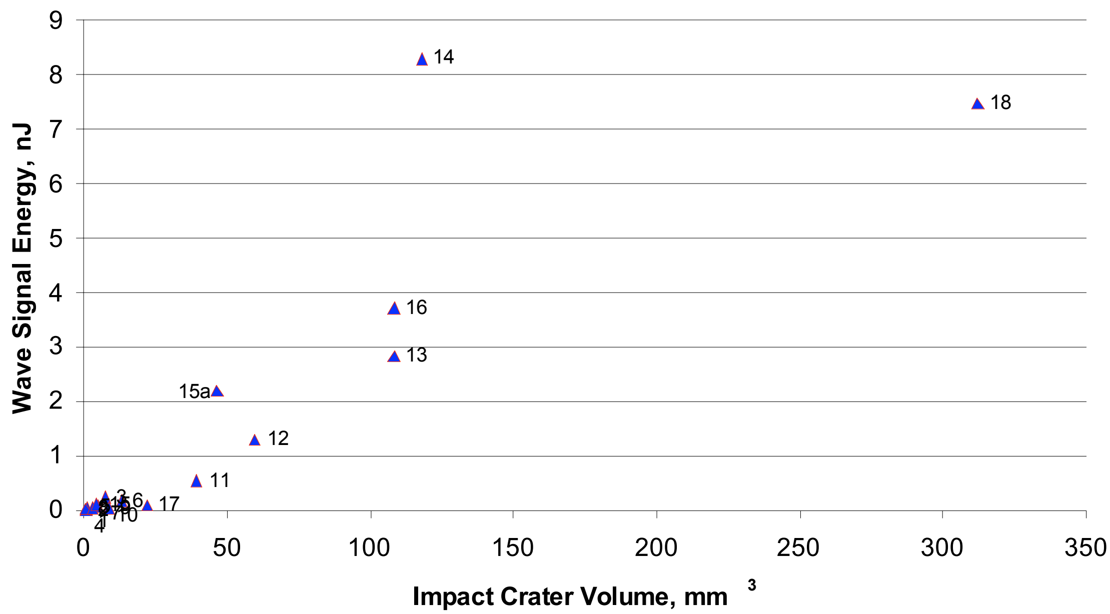

Figure 37: Fg(RCC)-2 Wave Signal Energy vs. Crater Volume Damage - Spar Sensors Only

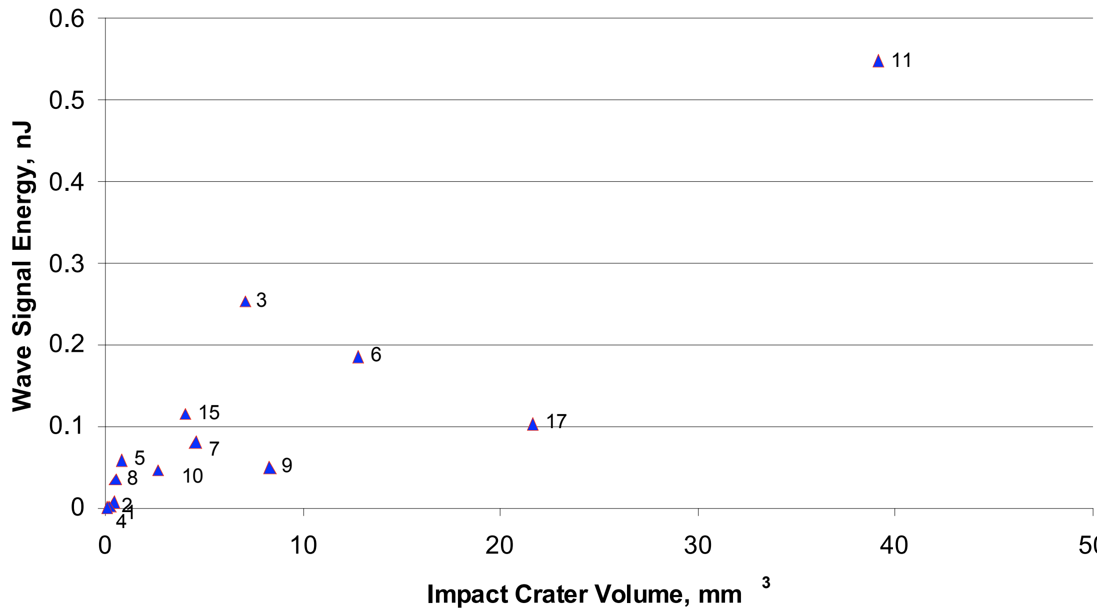

Figure 38: Detail of Fg(RCC)-2 Wave Signal Energy vs. Crater Volume Damage - Spar Sensors Only

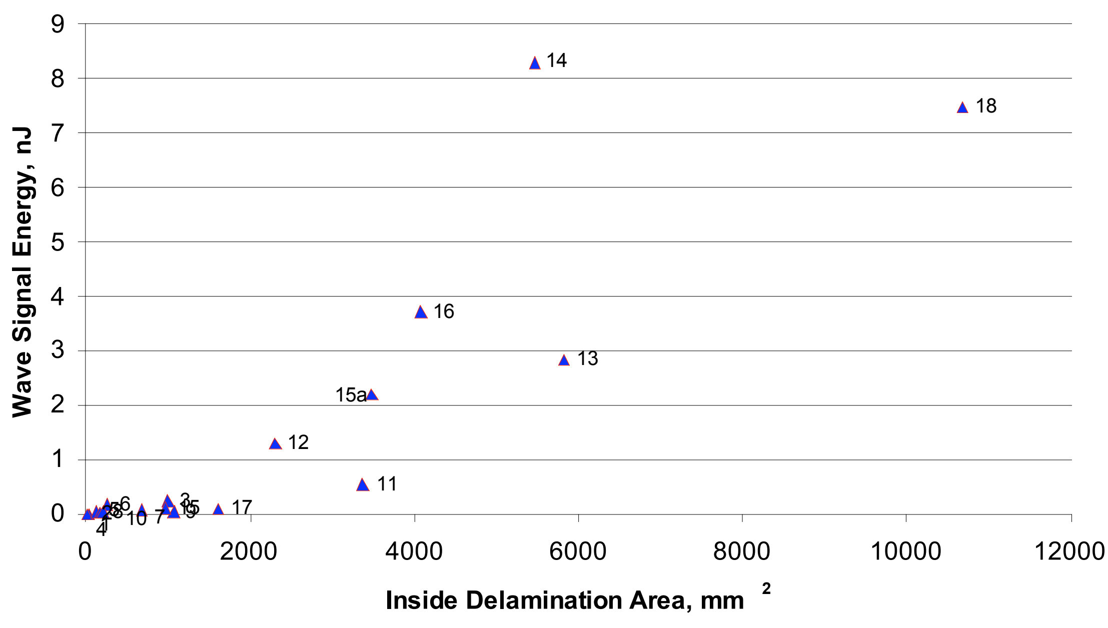

Figure 39: Fg(RCC)-2 Wave Signal Energy vs. Inside Delamination Area - Spar Sensors Only

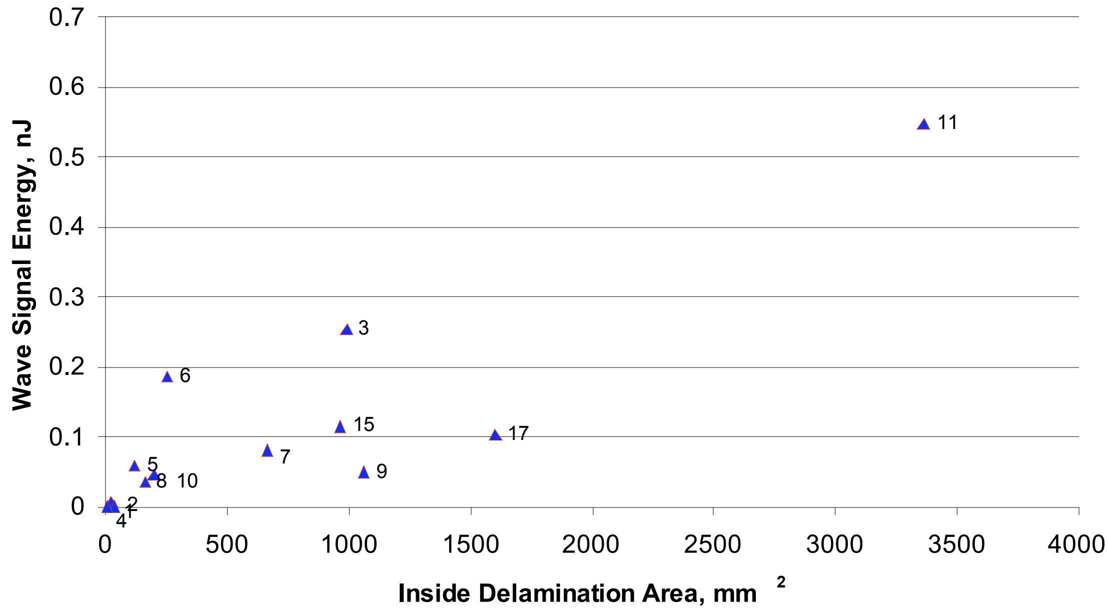

Figure 40: Detail of Fg(RCC)-2 Wave Signal Energy vs. Inside Delamination Area - Spar Sensors Only

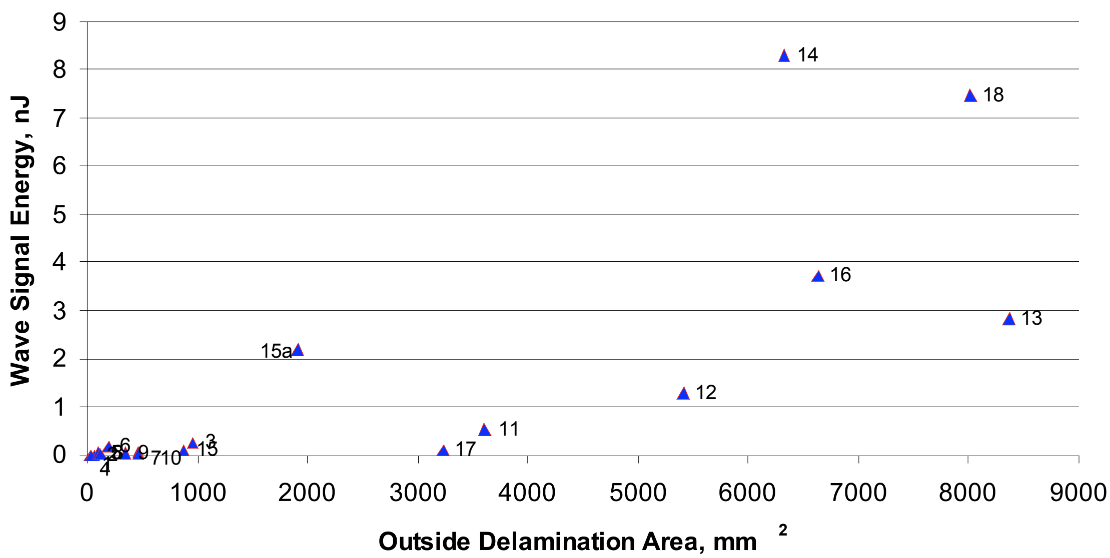

Figure 41: Fg(RCC)-2 Wave Signal Energy vs. Outside Delamination Area - Spar Sensors Only

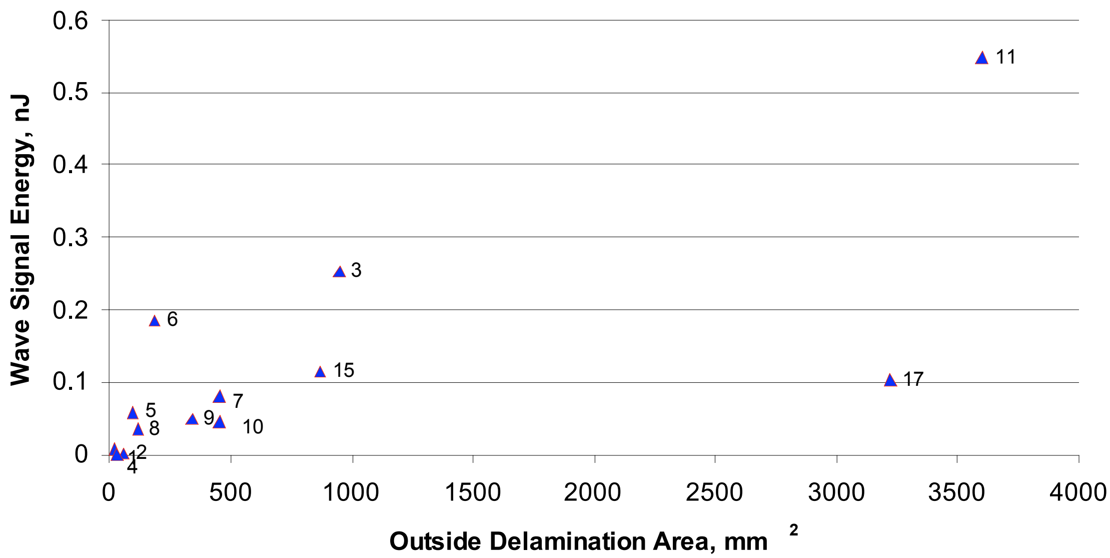

Figure 42: Detail of Fg(RCC)-2 Wave Signal Energy vs. Outside Delamination Area - Spar Sensors Only

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 43) 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 43 shows a lead break signal at sensor 5. Figure 44 and Figure 45 are diagrams of the sensor locations. The extensional wave arrived at sensor 5 at t_1 = 195.8 µs and at sensor 6 at t_2 = 285.8 µs. The sensors were located 14 inches apart which gave a velocity of 0.16 in/µs in the x-direction. Performing this calculation in the y-direction and the diagonal gives extensional wave velocities of 0.16 in/µs and 0.14 in/µs, respectively. The same calculation for flexural waves yields velocities of 0.06 in/µs in the x-direction, y-direction, and in the diagonal.

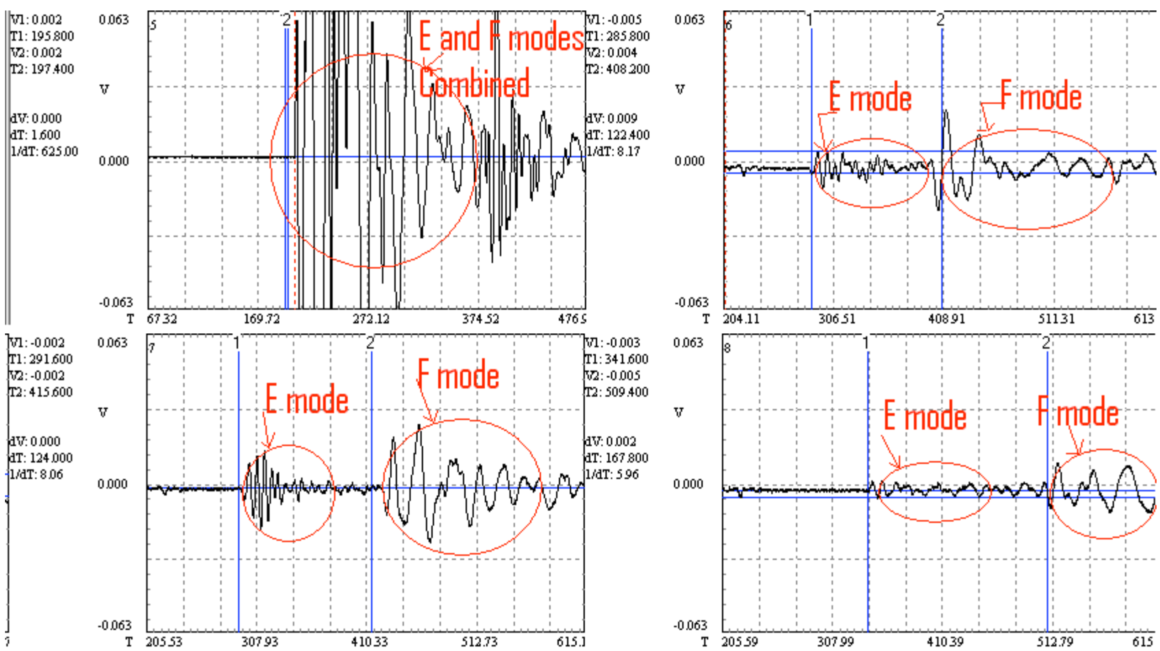

Figure 43: Fg(RCC)-2 Lead Break on Sensors 5, 6, 7, and 8 Shot #1 Pretest

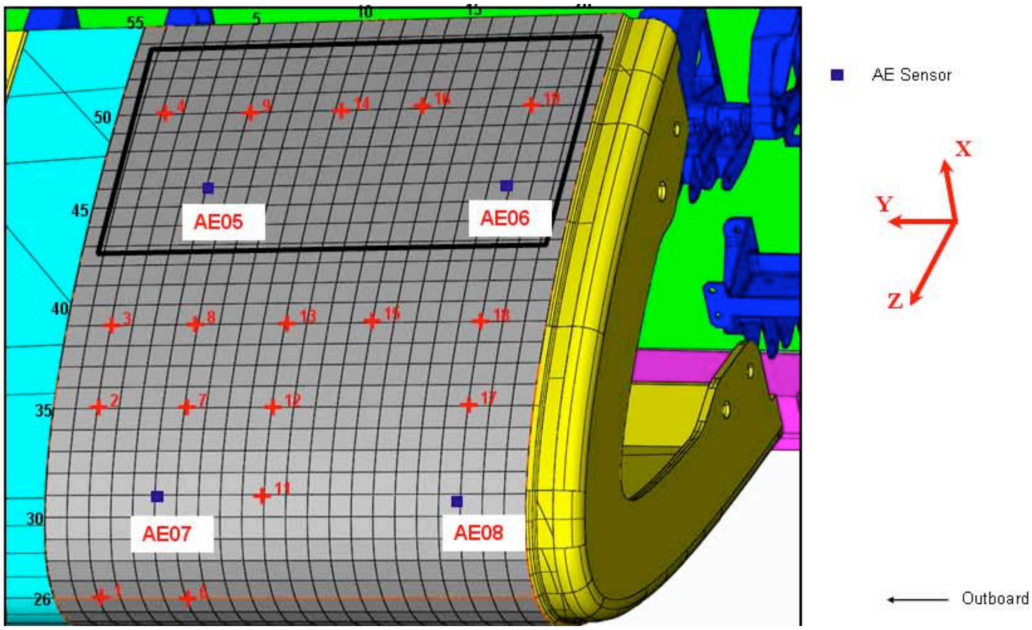

Figure 44: Fg(RCC)-2 Sensor and Impact Locations. Upper Panel. (Repeat of Figure 6)

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), #6(26,6), #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),

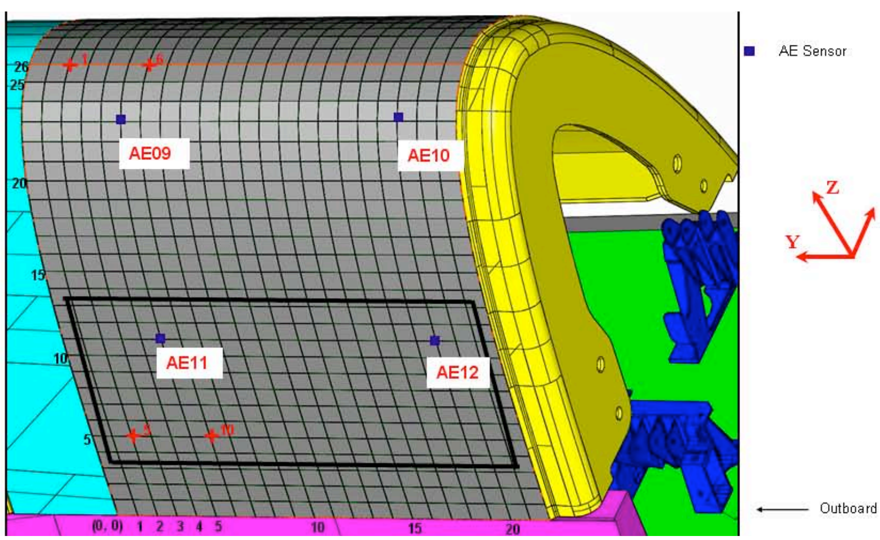

Figure 45: Fg(RCC)-2 Sensor and Impact Locations. Lower Panel. (Repeat of Figure 7)

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), #6(26,6), #10(5, 6)

The wave velocities may be confirmed by considering the impact waveforms. Shot #6, for example, was aligned with sensors 9 and 11 (Figure 44). The impact waves arrived at sensor 9 first and then traveled to sensor 11. This can be seen in Figure 46. The extensional velocity was 0.16 in/µs and the flexural velocity was 0.06 in/µs. These velocities were the same as those calculated with the lead break.

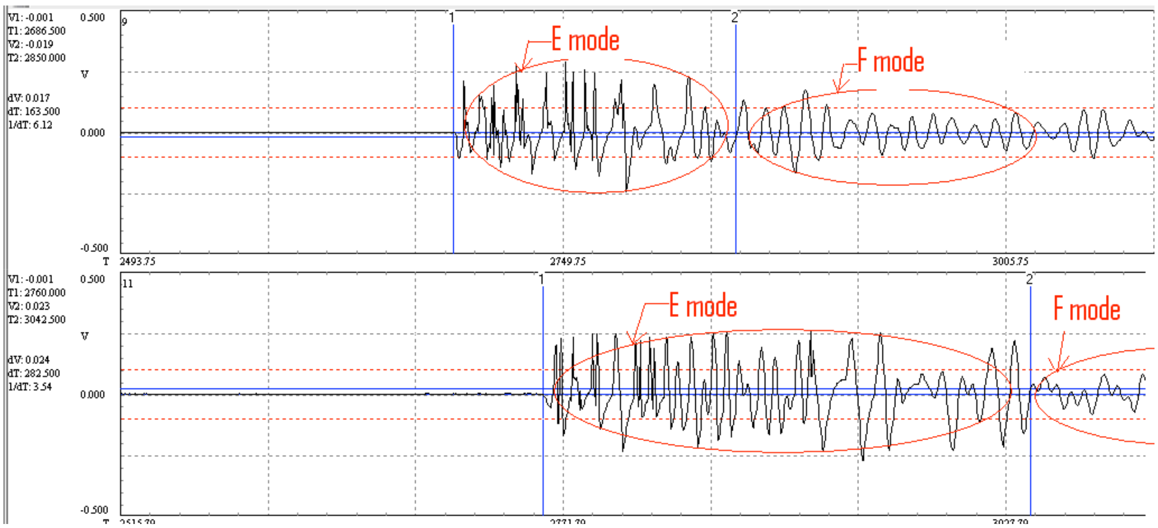

Figure 46: Fg(RCC)-2 Detail of Sensors 9 (Top) and 11 (Bottom) for Shot #6

In the fiberglass panel, fibers are aligned in the x and y directions (see Figure 45 and Figure 46). 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 fiberglass WLE Target Fg(RCC)-2 are as follows:

- Ultrasonic Sensors were successfully bonded to fiberglass Target Fg(RCC)-2 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 the cross-ply fiberglass target were measured and used in the analysis of the wave signal energy.
- Wave signal energy correlated well with kinetic energy and impact damage.
- 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.

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[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.

Appendix

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: 8/20/04 Specimen ID: FG-2

Test number: FG2-1 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: Sensors 1 through 4 replaced with new sensors. Sensors 6 and 11 were destroyed during removal. Sensors nine and ten X-coordinate moved two-inches from 21 to 23 from previous target. All sensors checked O.K.

III. Record sensor serial number and coordinates:

Sensor 1: S/N 084007
Sensor 2: S/N 084001
Sensor 3: S/N 084008
Sensor 4: S/N 084003
Sensor 5: S/N 101146
Sensor 6: S/N 0799051
Sensor 7: S/N 101157
Sensor 8: S/N 101148
Sensor 9: S/N 101147
Sensor 10: S/N 101163
Sensor 11: S/N 190017
Sensor 12: S/N 0799050
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: FG2-1 8-20-04 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: 0	Preamp: 0	SCM: 0
Sensor 2:	Attenuators: 0	Preamp: 0	SCM: 0
Sensor 3:	Attenuators: 0	Preamp: 0	SCM: 0
Sensor 4:	Attenuators: 0	Preamp: 0	SCM: 0
Sensor 5:	Attenuators: 0	Preamp: -20	SCM: 12
Sensor 6:	Attenuators: 0	Preamp: -20	SCM: 12
Sensor 7:	Attenuators: 0	Preamp: -20	SCM: 12
Sensor 8:	Attenuators: 0	Preamp: -20	SCM: 12
Sensor 9:	Attenuators: 0	Preamp: -20	SCM: 12
Sensor 10:	Attenuators: 0	Preamp: -20	SCM: 12
Sensor 11:	Attenuators: 0	Preamp: -20	SCM: 12
Sensor 12:	Attenuators: 0	Preamp: -20	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: FG2-1 8-20-04 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: 6.94 km/s.

Impact coordinates: _______________

Damage description and comments:

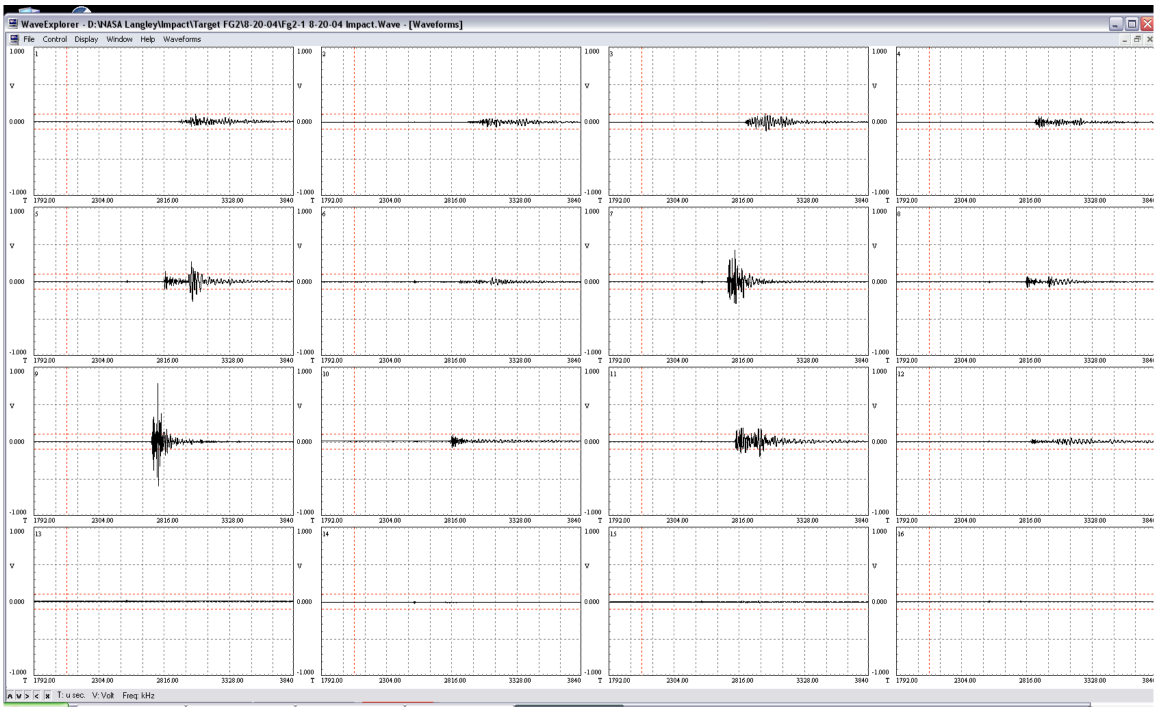


Figure 47: Fg(RCC)-2 Shot #1 Impact Waveform

Figure 48: Fg(RCC)-2 Shot #1 Impact Damage

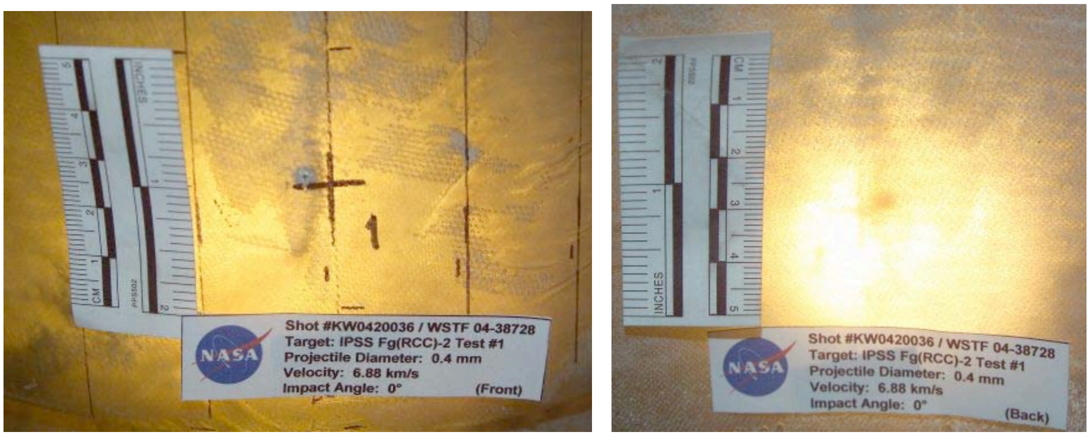


Figure 49: Fg(RCC)-2 Shot #1 Backlit Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:

Test date: 8/23/04 Specimen ID: FG-2

Test number: FG2-2 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:

III. Record sensor serial number and coordinates:

Sensor 1: S/N_084007 Sensor 2: S/N_084001

Sensor 3: S/N_084008 Sensor 4: S/N_084003

Sensor 5: S/N_101146 Sensor 6: S/N_0799051

Sensor 7: S/N_101157 Sensor 8: S/N_101148

Sensor 9: S/N_101147 Sensor 10: S/N_101163

Sensor 11: S/N_190017 Sensor 12: S/N_0799050

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: FG2-2 8-23-04 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: 0
Sensor 2:	Attenuators: 0	Preamp: 0	SCM: 0
Sensor 3:	Attenuators: 0	Preamp: 0	SCM: 0
Sensor 4:	Attenuators: 0	Preamp: 0	SCM: 0
Sensor 5:	Attenuators: 0	Preamp: -20	SCM: 12
Sensor 6:	Attenuators: 0	Preamp: -20	SCM: 12
Sensor 7:	Attenuators: 0	Preamp: -20	SCM: 6
Sensor 8:	Attenuators: 0	Preamp: -20	SCM: 12
Sensor 9:	Attenuators: 0	Preamp: -20	SCM: 6
Sensor 10:	Attenuators: 0	Preamp: -20	SCM: 12
Sensor 11:	Attenuators: 0	Preamp: -20	SCM: 12
Sensor 12:	Attenuators: 0	Preamp: -20	SCM: 12
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: FG2-2 8-23-04 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: 6.94 km/s.
Impact coordinates: _______________
Damage description and comments:

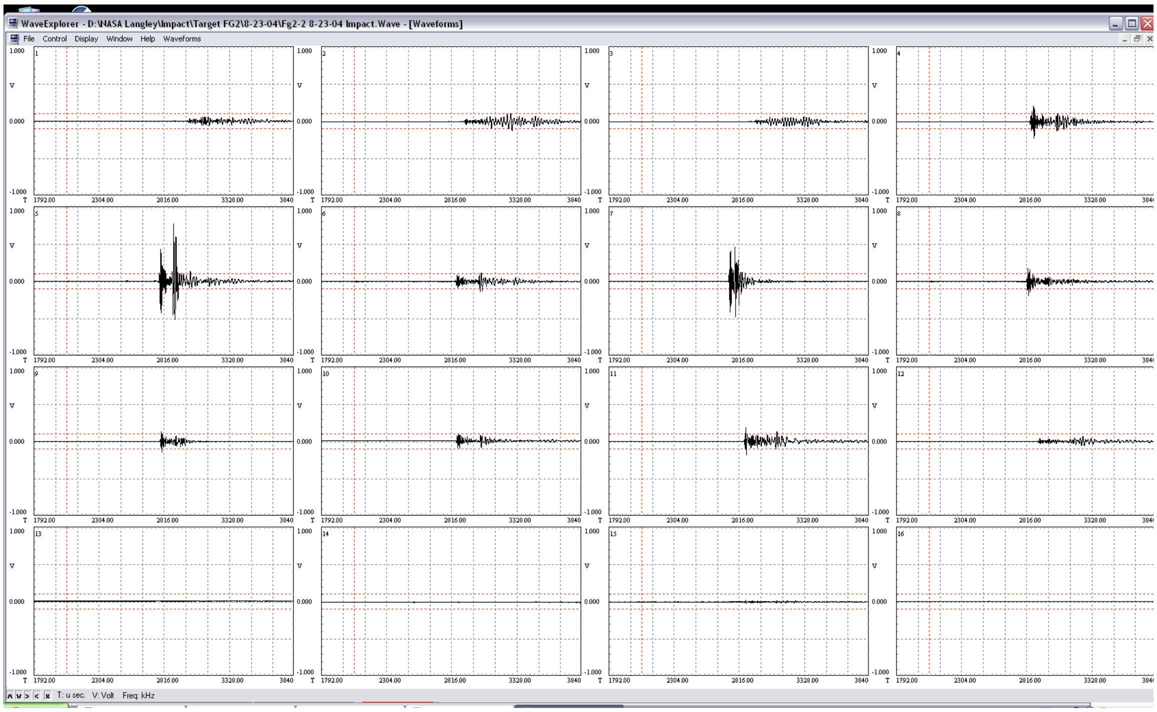


Figure 50: Fg(RCC)-2 Shot #2 Impact Waveform

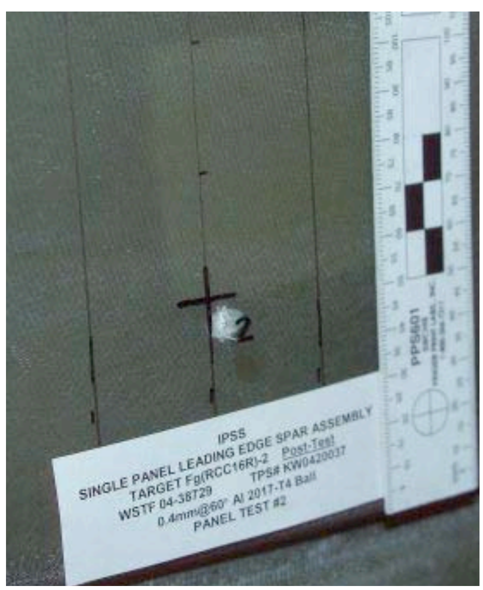


Figure 51: Fg(RCC)-2 Shot #2 Impact Damage

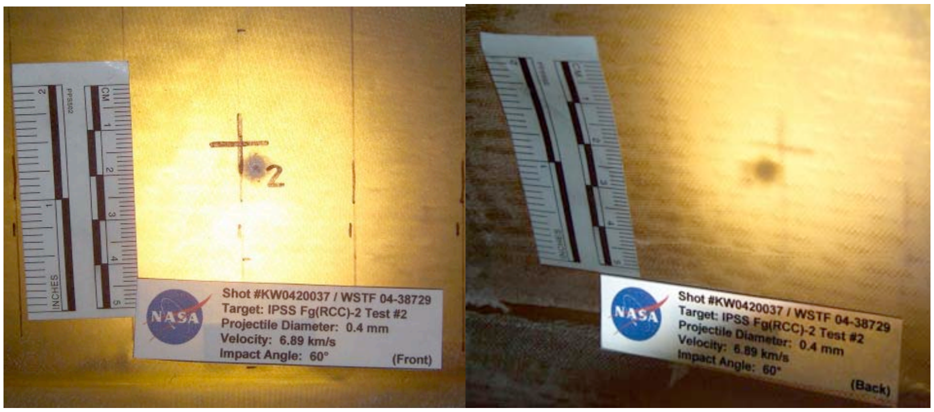


Figure 52: Fg(RCC)-2 Shot #2 Backlit Impact Damage (Left: Front Side, Right: Back Side)

I. Record pretest information:

Test date: 8/24/04 Specimen ID: FG-2

Test number: FG2-3 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:

III. Record sensor serial number and coordinates:

Sensor 1: S/N 084007
Sensor 2: S/N 084001
Sensor 3: S/N 084008
Sensor 4: S/N 084003
Sensor 5: S/N 101146
Sensor 6: S/N 0799051
Sensor 7: S/N 101157
Sensor 8: S/N 101148
Sensor 9: S/N 101147
Sensor 10: S/N 101163
Sensor 11: S/N 190017
Sensor 12: S/N 0799050
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: FG2-3 8-24-04 pretest LB

Comments: Sensors O.K.

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

VI. Impact test:

Verify settings:

External (gun) trigger source: X

20 kHz HP filter, 1500 kHz LP filter: X

2 MHz SR, 32 K points, 4096 pretrigger: X

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: 9
Sensor 6:	Attenuators: 30	Preamp: 0	SCM: 12
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: 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: FG2-3 8-24-04 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: 6.94 km/s.

Impact coordinates: ________________
Damage description and comments:

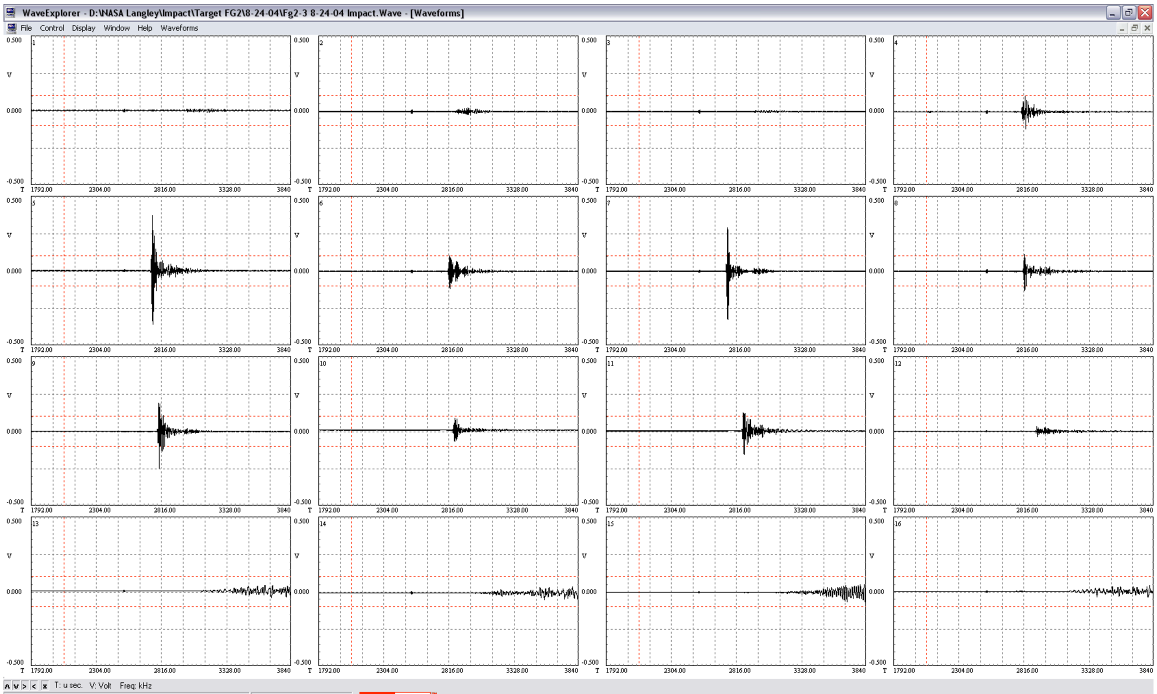


Figure 53: Fg(RCC)-2 Shot #3 Impact Waveform

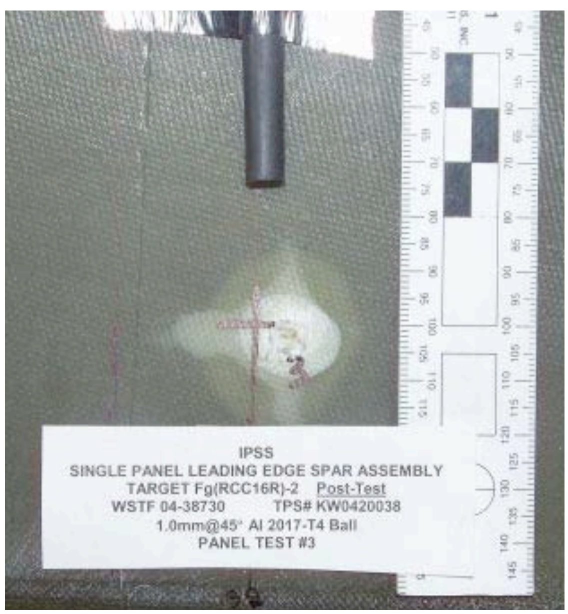


Figure 54: Fg(RCC)-2 Shot #3 Impact Damage

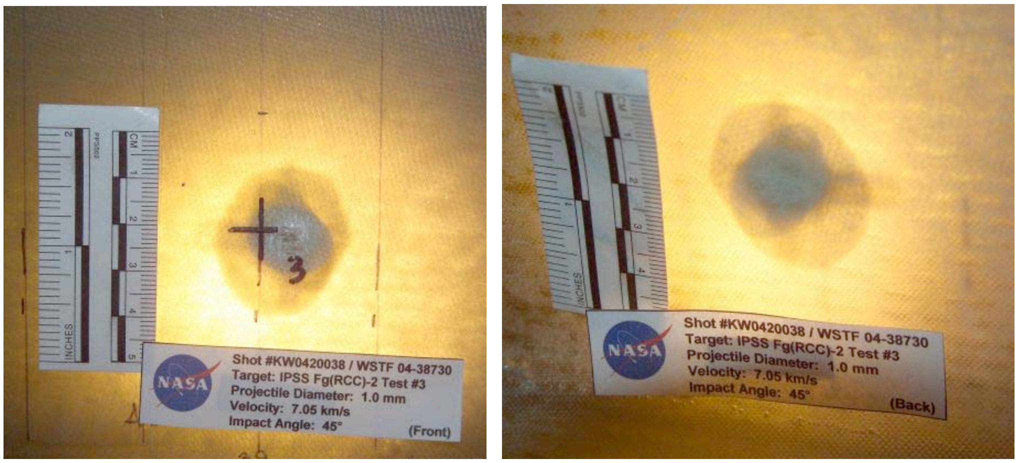


Figure 55: Fg(RCC)-2 Shot #3 Backlit Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:
Test date: 8/24/04 Specimen ID: FG-2
Test number: FG2-4 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:

III. Record sensor serial number and coordinates:

Sensor 1: S/N 084007
Sensor 2: S/N 084001
Sensor 3: S/N 084008
Sensor 4: S/N 084003
Sensor 5: S/N 101146
Sensor 6: S/N 0799051
Sensor 7: S/N 101157
Sensor 8: S/N 101148
Sensor 9: S/N 101147
Sensor 10: S/N 101163
Sensor 11: S/N 190017
Sensor 12: S/N 0799050
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: FG2-4 8-24-04 pretest LB_____
Comments: Sensors O.K.

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

VI. Impact test:

Verify settings:

External (gun) trigger source:	X______
20 kHz HP filter, 1500 kHz LP filter:	X______
2 MHz SR, 32 K points, 4096 pretrigger:	X______
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	0
Sensor 2:	0	0	0
Sensor 3:	0	0	0
Sensor 4:	0	-20	15
Sensor 5:	0	-20	6
Sensor 6:	0	-20	12
Sensor 7:	0	-20	12
Sensor 8:	0	-20	12
Sensor 9:	0	-20	12
Sensor 10:	0	-20	12
Sensor 11:	0	-20	12
Sensor 12:	0	-20	12
Sensor 13:	0	20	12
Sensor 14:	0	20	12
Sensor 15:	0	20	12
Sensor 16:	0	20	12

Record file name: FG2-4 8-24-04 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: 6.94 km/s.
Impact coordinates: ________________
Damage description and comments:

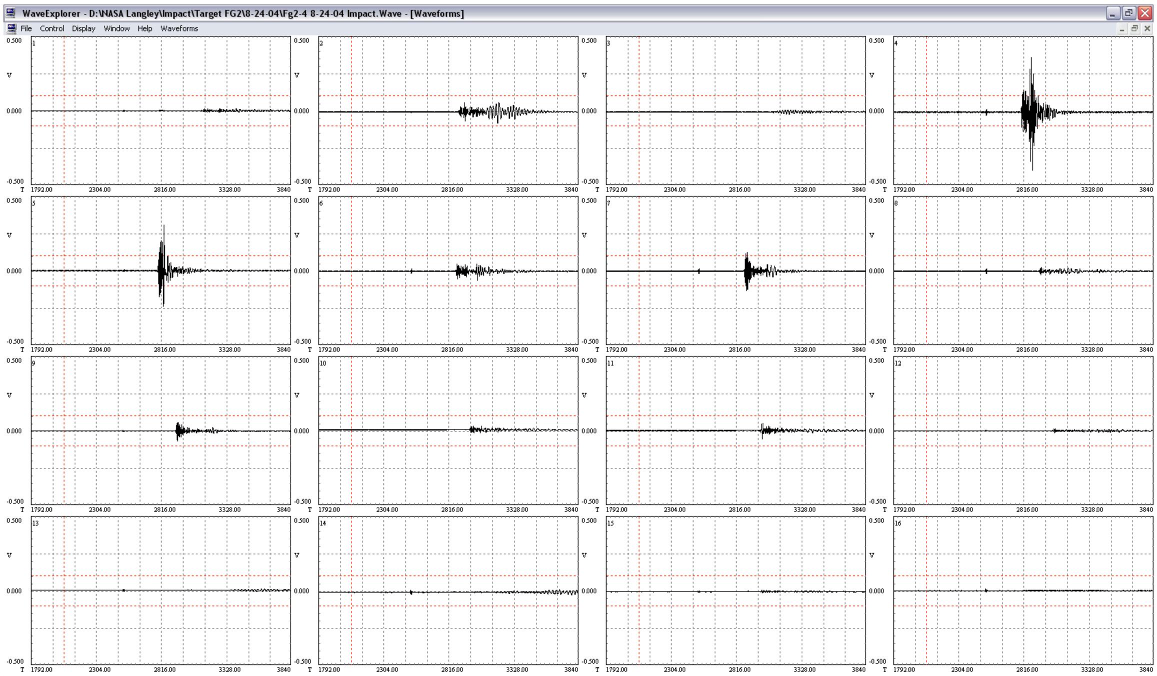


Figure 56: Fg(RCC)-2 Shot #4 Impact Waveform

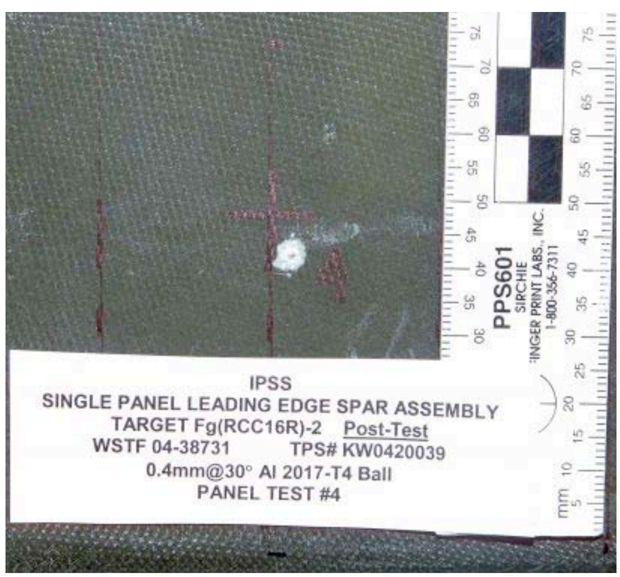
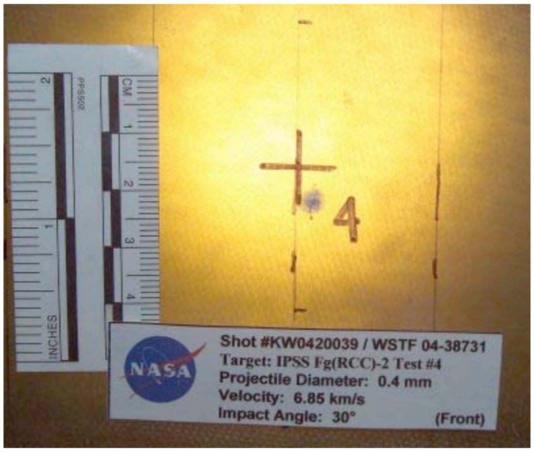


Figure 57: Fg(RCC)-2 Shot #4 Impact Damage



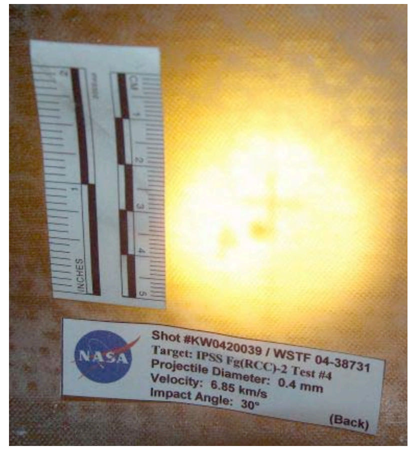


Figure 58: Fg(RCC)-2 Shot #4 Backlit Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:

Test date: 8/25/04 Specimen ID: FG-2
Test number: FG2-5 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:

III. Record sensor serial number and coordinates:

Sensor 1: S/N 084007 Sensor 2: S/N 084001
Sensor 3: S/N 084008 Sensor 4: S/N 084003
Sensor 5: S/N 101146 Sensor 6: S/N 0799051
Sensor 7: S/N 101157 Sensor 8: S/N 101148
Sensor 9: S/N 101147 Sensor 10: S/N 101163
Sensor 11: S/N 190017 Sensor 12: S/N 0799050
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: FG2-5 8-25-04 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: 0	Preamp: -20	SCM: 9
Sensor 2:	Attenuators: 0	Preamp: -20	SCM: 9
Sensor 3:	Attenuators: 0	Preamp: -20	SCM: 3
Sensor 4:	Attenuators: 0	Preamp: -20	SCM: 9
Sensor 5:	Attenuators: 0	Preamp: -20	SCM: 9
Sensor 6:	Attenuators: 0	Preamp: -20	SCM: 9
Sensor 7:	Attenuators: 0	Preamp: -20	SCM: 9
Sensor 8:	Attenuators: 0	Preamp: -20	SCM: 9
Sensor 9:	Attenuators: 0	Preamp: -20	SCM: 9
Sensor 10:	Attenuators: 0	Preamp: -20	SCM: 9
Sensor 11:	Attenuators: 0	Preamp: -20	SCM: 3
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: 12
Sensor 16:	Attenuators: 0	Preamp: 20	SCM: 12

Record file name: FG2-5 8-25-04 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: 6.83 km/s.
Impact coordinates: _______________
Damage description and comments:

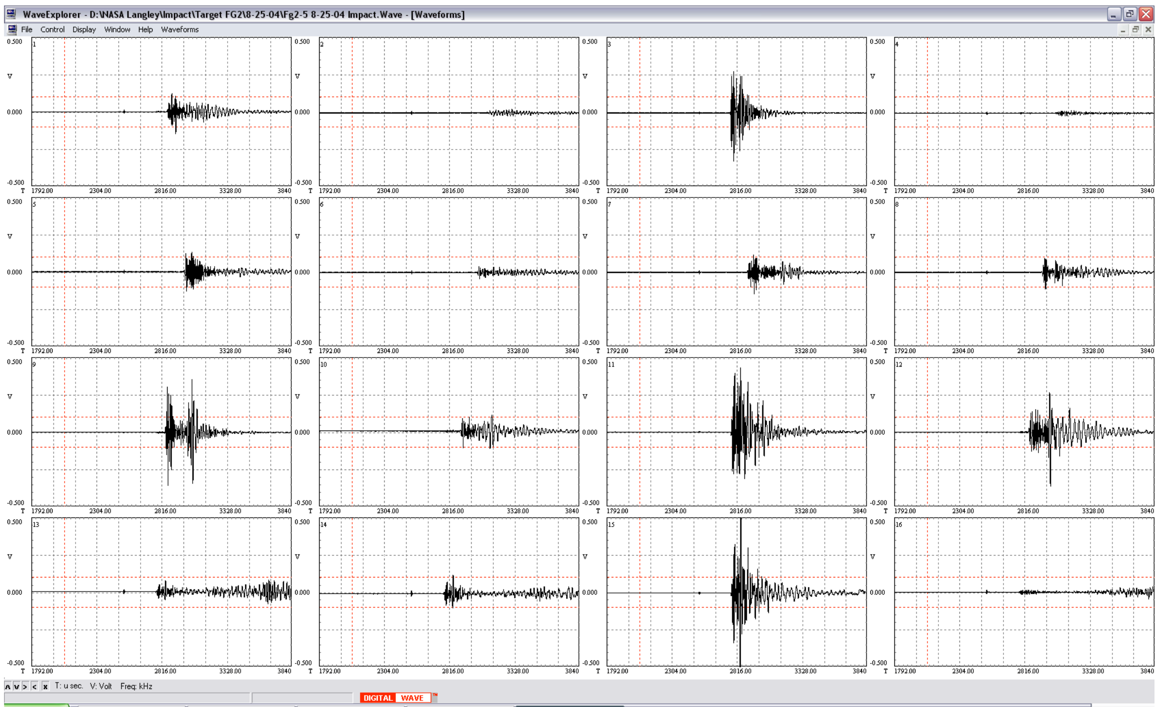


Figure 59: Fg(RCC)-2 Shot #5 Impact Waveform

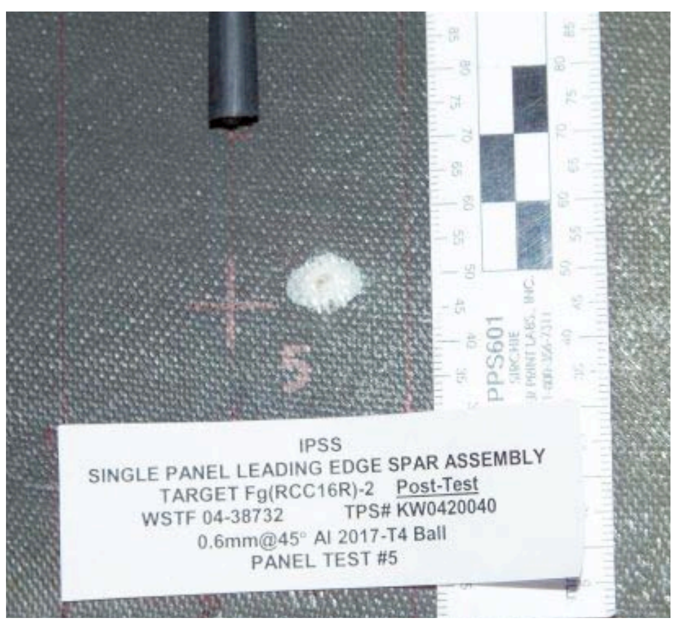


Figure 60: Fg(RCC)-2 Shot #5 Impact Damage

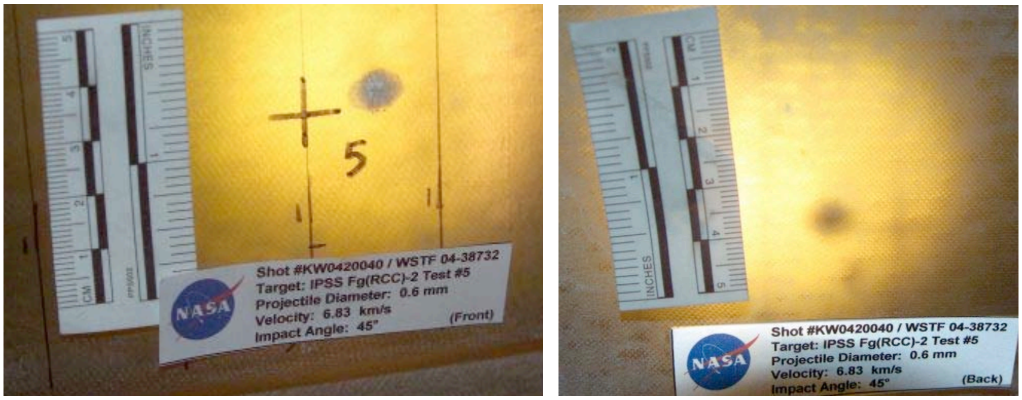


Figure 61: Fg(RCC)-2 Shot #5 Backlit Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:

Test date: 8/26/04 Specimen ID: FG-2

Test number: FG2-6 Projectile size: 0.8 mm/90deg.

Planned velocity: 6.8 km/s

Planned impact coordinates: (26, 6)

II. Prebonding sensor tests performed: N/A

(Only for first test in series or when replacing or rebonding sensors between tests, otherwise indicate N/A)

Comments:

III. Record sensor serial number and coordinates:

Sensor 1: S/N_084007 Sensor 2: S/N_084001

Sensor 3: S/N_084008 Sensor 4: S/N_084003

Sensor 5: S/N_101146 Sensor 6: S/N_0799051

Sensor 7: S/N_101157 Sensor 8: S/N_101148

Sensor 9: S/N_101147 Sensor 10: S/N_101163

Sensor 11: S/N_190017 Sensor 12: S/N_0799050

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: FG2-6 8-26-04 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: (DWC logo spinning)	X______

Record and verify gain settings:

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

Record file name: FG2-6 8-26-04 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: 6.66 km/s.
Impact coordinates: ________________
Damage description and comments:

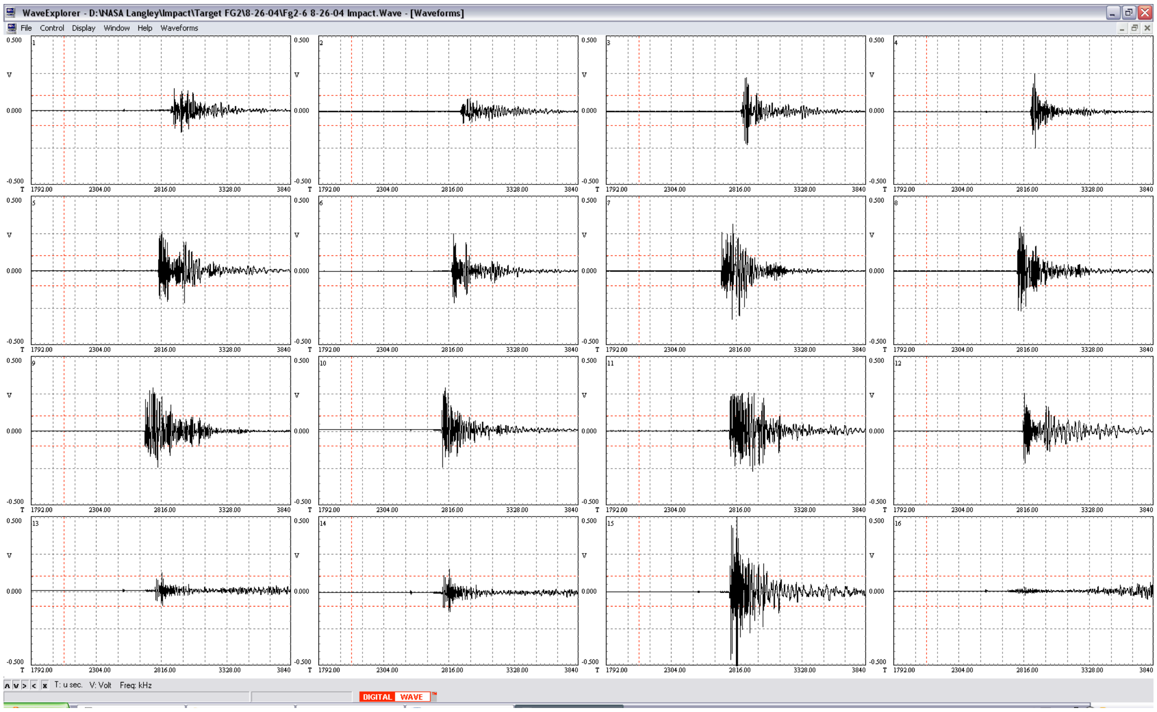


Figure 62: Fg(RCC)-2 Shot #6 Impact Waveform

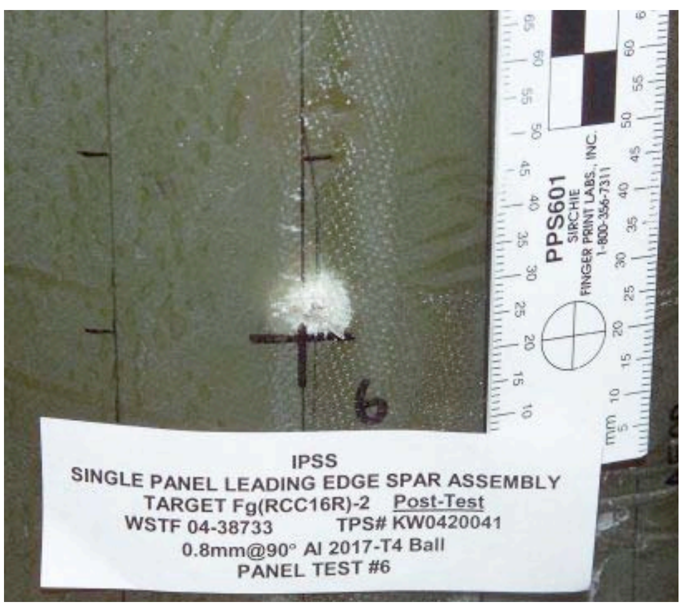


Figure 63: Fg(RCC)-2 Shot #6 Impact Damage

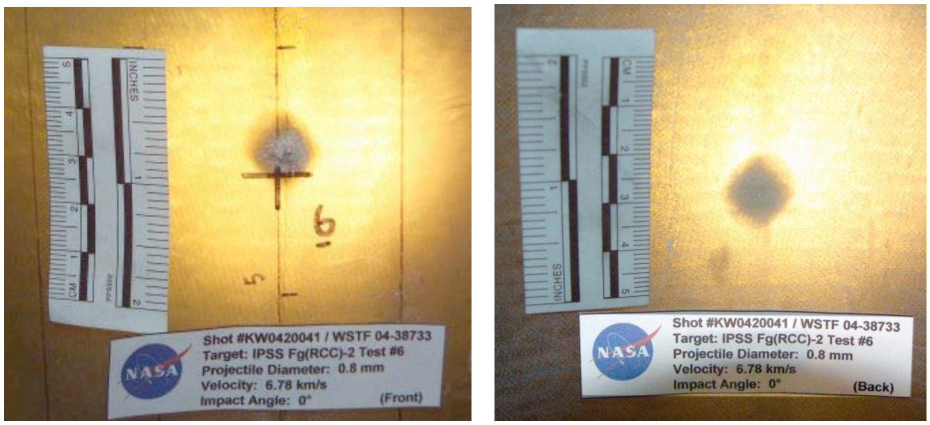


Figure 64: Fg(RCC)-2 Shot #6 Backlit Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:

Test date: 8/26/04 Specimen ID: FG-2

Test number: FG2-7 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:

III. Record sensor serial number and coordinates:

Sensor 1: S/N 084007 Sensor 2: S/N 084001

Sensor 3: S/N 084008 Sensor 4: S/N 084003

Sensor 5: S/N 101146 Sensor 6: S/N 0799051

Sensor 7: S/N 101157 Sensor 8: S/N 101148

Sensor 9: S/N 101147 Sensor 10: S/N 101163

Sensor 11: S/N 190017 Sensor 12: S/N 0799050

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: FG2-7 8-26-04 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: 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: 15
Sensor 6:	Attenuators: 30	Preamp: 0	SCM: 15
Sensor 7:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 8:	Attenuators: 30	Preamp: 0	SCM: 15
Sensor 9:	Attenuators: 30	Preamp: 0	SCM: 15
Sensor 10:	Attenuators: 30	Preamp: 0	SCM: 15
Sensor 11:	Attenuators: 30	Preamp: 0	SCM: 15
Sensor 12:	Attenuators: 30	Preamp: 0	SCM: 15
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: FG2-7 8-26-04 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: 6.92 km/s.
Impact coordinates: ________________
Damage description and comments:

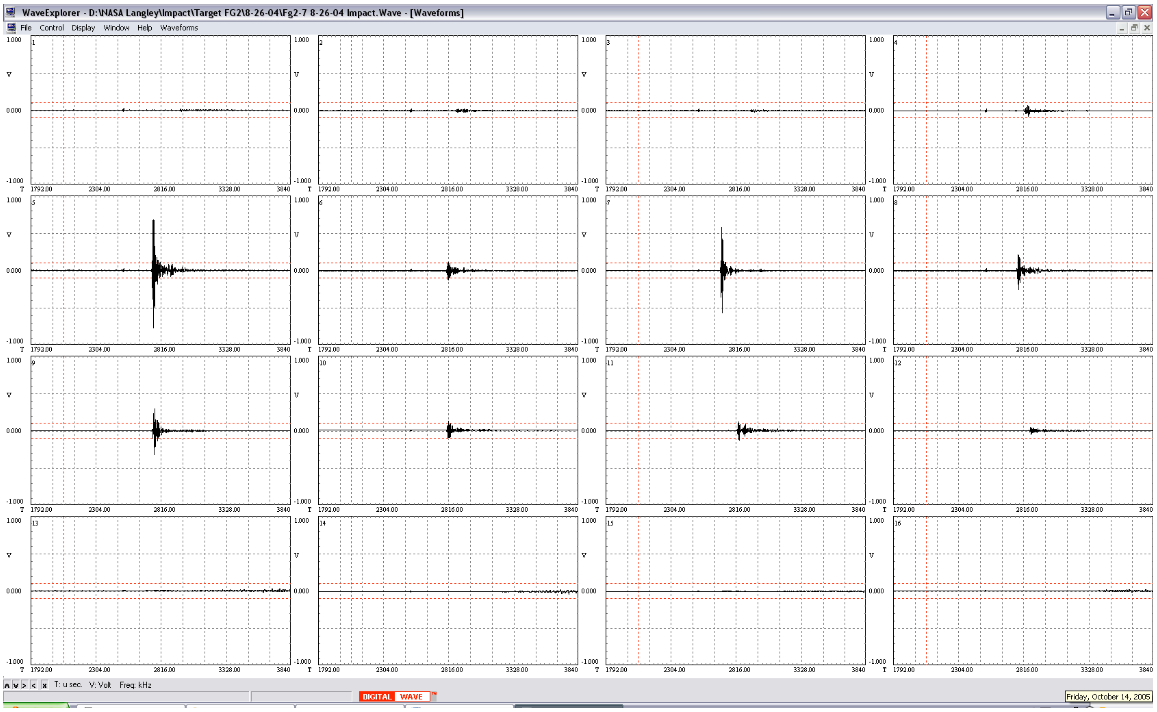


Figure 65: Fg(RCC)-2 Shot #7 Impact Waveform

Figure 66: Fg(RCC)-2 Shot #7 Impact Damage

Figure 67: Fg(RCC)-2 Shot #7 Backlit Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:
Test date: 8/30/04 Specimen ID: FG-2
Test number: FG2-8 Projectile size: 0.6 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:

III. Record sensor serial number and coordinates:
Sensor 1: S/N 084007 Sensor 2: S/N 084001
Sensor 3: S/N 084008 Sensor 4: S/N 084003
Sensor 5: S/N 101146 Sensor 6: S/N 0799051
Sensor 7: S/N 101157 Sensor 8: S/N 101148
Sensor 9: S/N 101147 Sensor 10: S/N 101163
Sensor 11: S/N 190017 Sensor 12: S/N 0799050
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: FG2-8 8-30-04 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 1:	Attenuators: 0______	Preamp: -20	SCM: 9_____
Sensor 2:	Attenuators: 0______	Preamp: _-20	SCM: 9_____
Sensor 3:	Attenuators: 0______	Preamp: _-20	SCM: 9_____
Sensor 4:	Attenuators: 0______	Preamp: _-20	SCM: 9_____
Sensor 5:	Attenuators: 0______	Preamp: _-20	SCM: 3_____
Sensor 6:	Attenuators: 0______	Preamp: _-20	SCM: 9_____
Sensor 7:	Attenuators: 0______	Preamp: _-20	SCM: 9_____
Sensor 8:	Attenuators: 0______	Preamp: _-20	SCM: 9_____
Sensor 9:	Attenuators: 0______	Preamp: -20	SCM: 9_____
Sensor 10:	Attenuators: 0______	Preamp: _-20	SCM: 9_____
Sensor 11:	Attenuators: 0______	Preamp: _-20	SCM: 9_____
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: 12____
Sensor 16:	Attenuators: 0______	Preamp: _20_	SCM: 12____

Record file name: FG2-8 8-30-04 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: 6.82 km/s.
Impact coordinates: _________________
Damage description and comments:

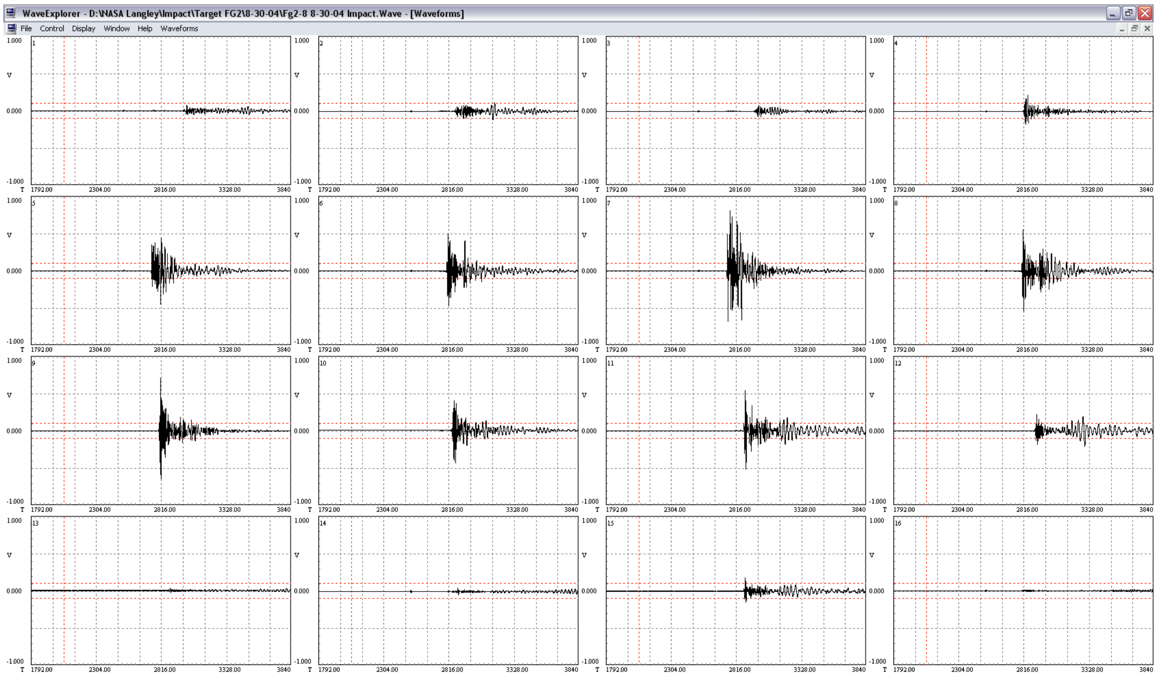


Figure 68: Fg(RCC)-2 Shot #8 Impact Waveform

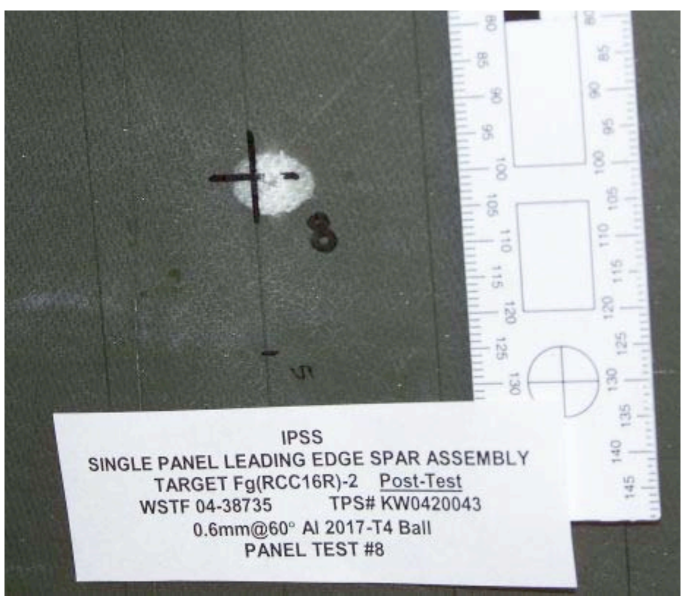


Figure 69: Fg(RCC)-2 Shot #8 Impact Damage

Figure 70: Fg(RCC)-2 Shot #8 Backlit Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:

Test date: 8/31/04 Specimen ID: FG-2

Test number: FG2-9 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:

III. Record sensor serial number and coordinates:

Sensor 1: S/N 084007 Sensor 2: S/N 084001

Sensor 3: S/N 084008 Sensor 4: S/N 084003

Sensor 5: S/N 101146 Sensor 6: S/N 0799051

Sensor 7: S/N 101157 Sensor 8: S/N 101148

Sensor 9: S/N 101147 Sensor 10: S/N 101163

Sensor 11: S/N 190017 Sensor 12: S/N 0799050

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: FG2-9 8-31-04 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: 3
Sensor 5:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 6:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 7:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 8:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 9:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 10:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 11:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 12:	Attenuators: 30	Preamp: 0	SCM: 9
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: FG2-9 8-31-04 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:

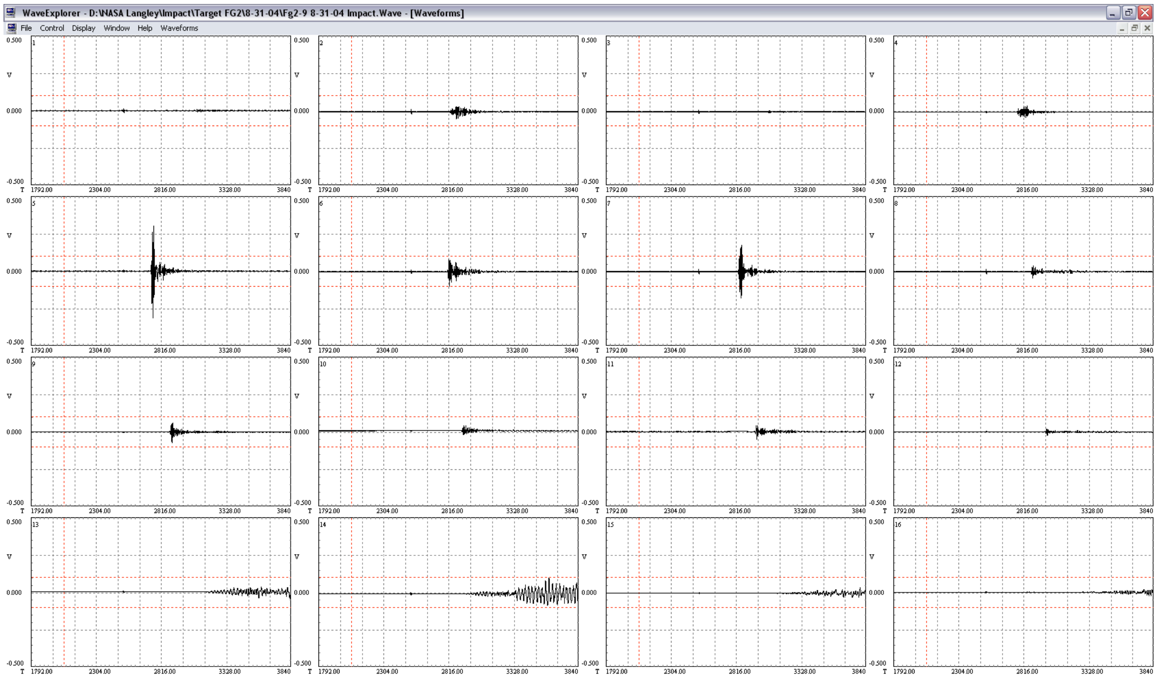


Figure 71: Fg(RCC)-2 Shot #9 Impact Waveform

Figure 72: Fg(RCC)-2 Shot #9 Impact Damage

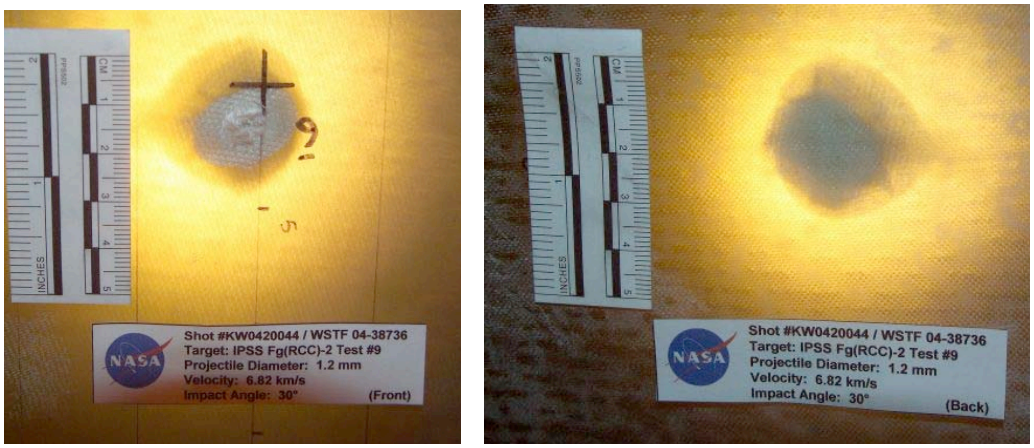


Figure 73: Fg(RCC)-2 Shot #9 Backlit Impact Damage (Left: Front Side, Right: Back Side)

I. Record pretest information:

Test date: 8/31/04 Specimen ID: FG-2

Test number: FG2-10 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:

III. Record sensor serial number and coordinates:

Sensor 1: S/N 084007
Sensor 2: S/N 084001
Sensor 3: S/N 084008
Sensor 4: S/N 084003
Sensor 5: S/N 101146
Sensor 6: S/N 0799051
Sensor 7: S/N 101157
Sensor 8: S/N 101148
Sensor 9: S/N 101147
Sensor 10: S/N 101163
Sensor 11: S/N 190017
Sensor 12: S/N 0799050
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: FG2-10 8-31-04 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: FG2-10 8-31-04 Impact

Comments: Attenuators were mistakedly installed on channels 1 through 12.

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

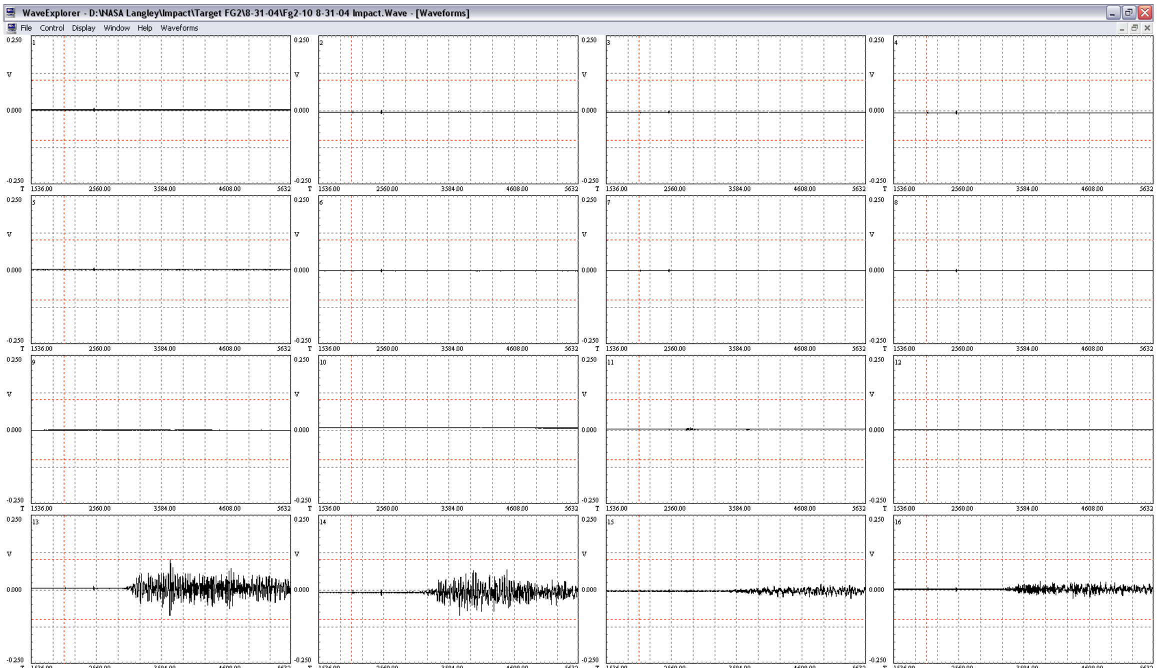


Figure 74: Fg(RCC)-2 Shot #10 Impact Waveform

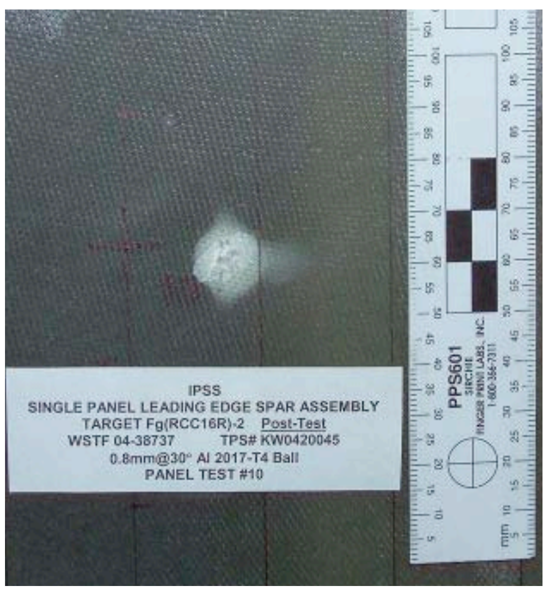
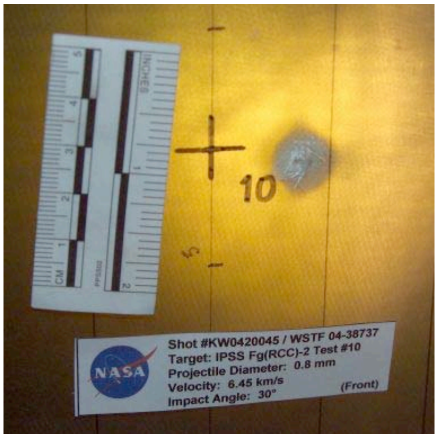


Figure 75: Fg(RCC)-2 Shot #10 Impact Damage



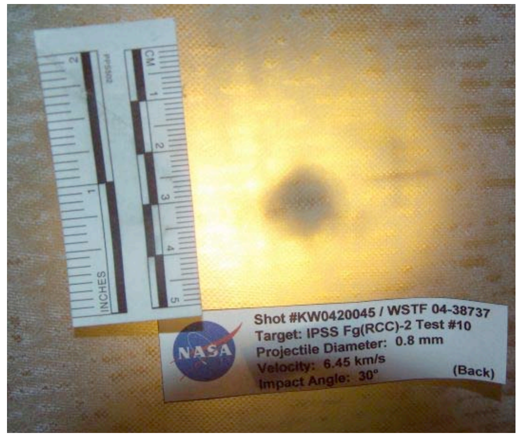


Figure 76: Fg(RCC)-2 Shot #10 Backlit Impact Damage (Left: Front Side, Right: Back Side)

I. Record pretest information:
Test date: 9/01/04 Specimen ID: FG-2
Test number: FG2-11 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:

III. Record sensor serial number and coordinates:

Sensor 1: S/N 084007
Sensor 2: S/N 084001
Sensor 3: S/N 084008
Sensor 4: S/N 084003
Sensor 5: S/N 101146
Sensor 6: S/N 0799051
Sensor 7: S/N 101157
Sensor 8: S/N 101148
Sensor 9: S/N 101147
Sensor 10: S/N 101163
Sensor 11: S/N 190017
Sensor 12: S/N 0799050
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: FG2-11 9-01-04 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: 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: 9
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: 9
Sensor 10:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 11:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 12:	Attenuators: 30	Preamp: 0	SCM: 9
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: FG2-11 9-01-04 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: 6.83 km/s.

Impact coordinates: ________________

Damage description and comments:

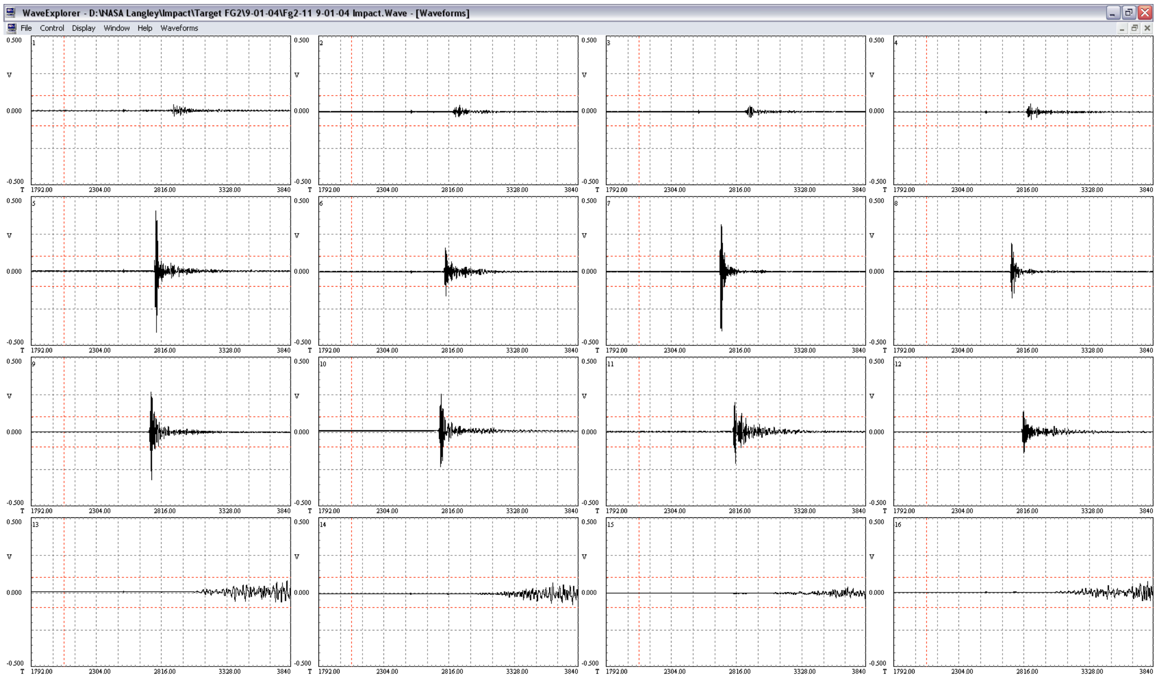


Figure 77: Fg(RCC)-2 Shot #11 Impact Waveform

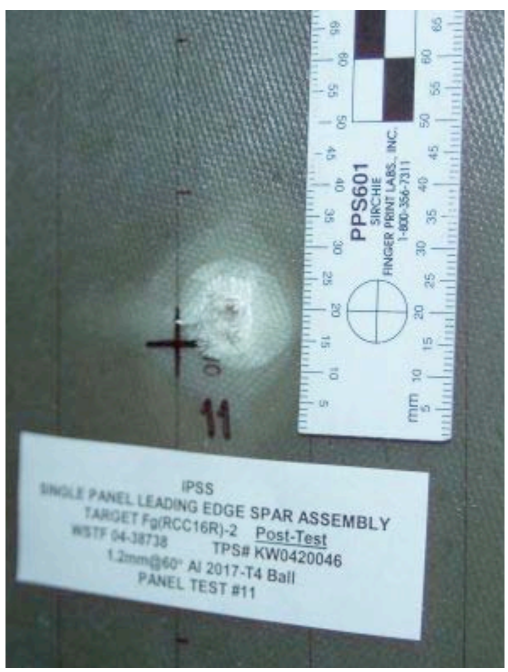


Figure 78: Fg(RCC)-2 Shot #11 Impact Damage

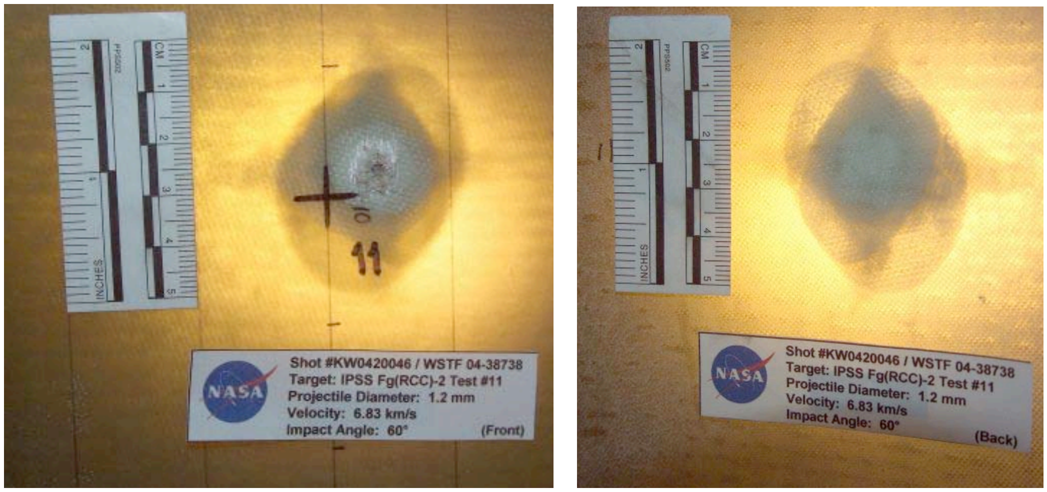


Figure 79: Fg(RCC)-2 Shot #1 Backlit Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:
Test date: 9/02/04 Specimen ID: FG-2
Test number: FG2-12 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:

III. Record sensor serial number and coordinates:

Sensor 1: S/N 084007 Sensor 2: S/N 084001
Sensor 3: S/N 084008 Sensor 4: S/N 084003
Sensor 5: S/N 101146 Sensor 6: S/N 0799051
Sensor 7: S/N 101157 Sensor 8: S/N 101148
Sensor 9: S/N 101147 Sensor 10: S/N 101163
Sensor 11: S/N 190017 Sensor 12: S/N 0799050
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: FG2-12 9-02-04 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: 15____
Sensor 6:	Attenuators: 30_____	Preamp: _0__	SCM: 15____
Sensor 7:	Attenuators: 30_____	Preamp: _0__	SCM: 15____
Sensor 8:	Attenuators: 30_____	Preamp: _0__	SCM: 15____
Sensor 9:	Attenuators: 30_____	Preamp: _0__	SCM: 15____
Sensor 10:	Attenuators: 30_____	Preamp: _0__	SCM: 15____
Sensor 11:	Attenuators: 30_____	Preamp: _0__	SCM: 15____
Sensor 12:	Attenuators: 30_____	Preamp: _0__	SCM: 15____
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: FG2-12 9-02-04 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: 6.94 km/s.

Impact coordinates: ________________
Damage description and comments:

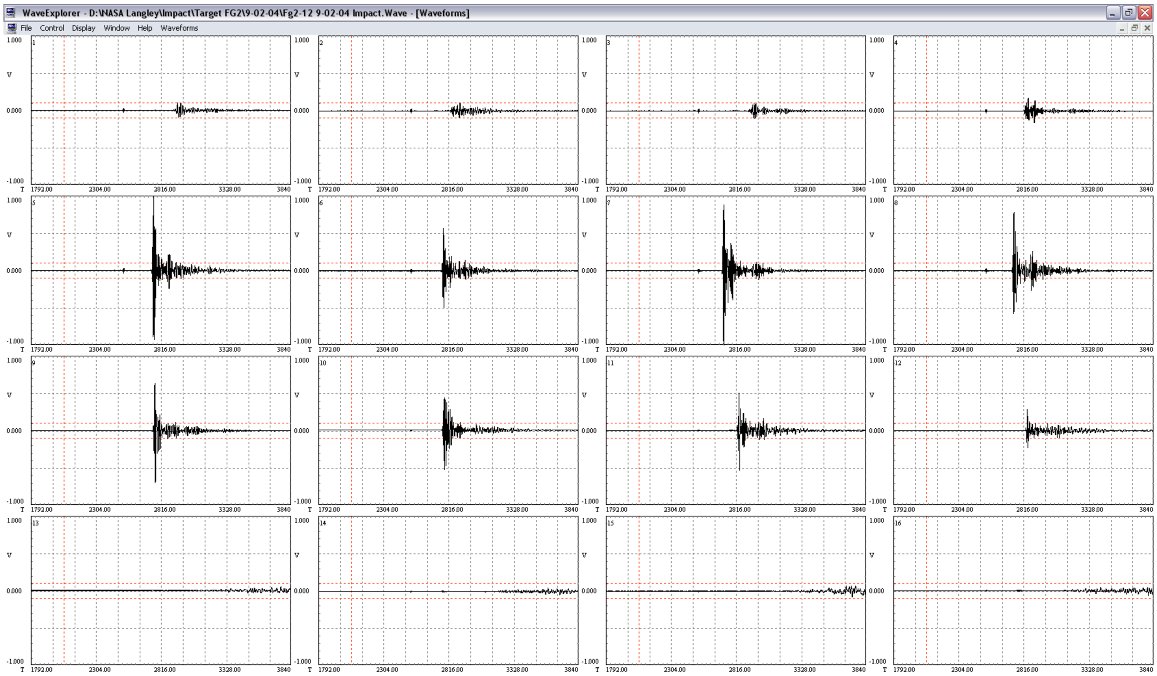


Figure 80: Fg(RCC)-2 Shot #12 Impact Waveform

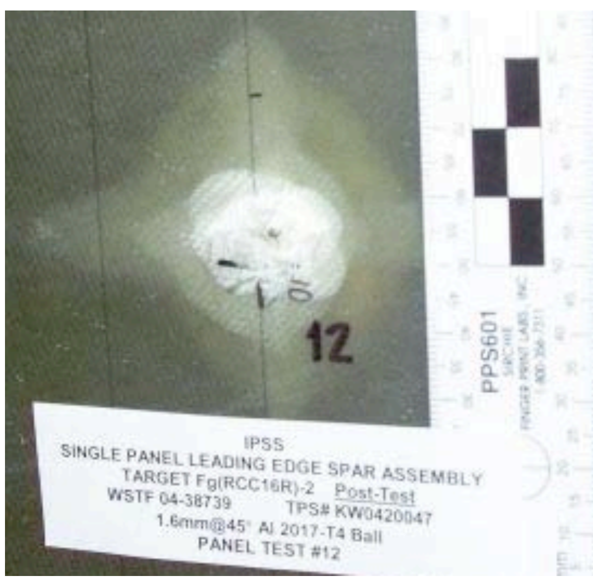


Figure 81: Fg(RCC)-2 Shot #12 Impact Damage

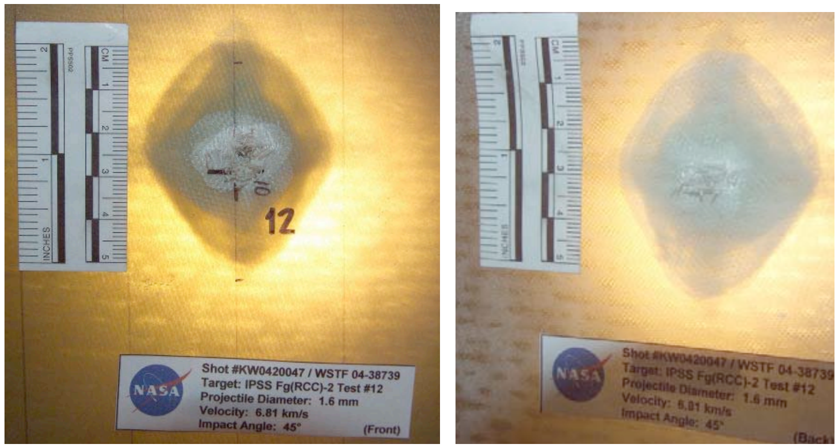


Figure 82: Fg(RCC)-2 Shot #12 Backlit Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:
Test date: 9/02/04 Specimen ID: FG-2
Test number: FG2-13 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:

III. Record sensor serial number and coordinates:

Sensor 1: S/N 084007
Sensor 2: S/N 084001
Sensor 3: S/N 084008
Sensor 4: S/N 084003
Sensor 5: S/N 101146
Sensor 6: S/N 0799051
Sensor 7: S/N 101157
Sensor 8: S/N 101148
Sensor 9: S/N 101147
Sensor 10: S/N 101163
Sensor 11: S/N 190017
Sensor 12: S/N 0799050
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: FG2-13 9-02-04 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: 3
Sensor 2:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 3:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 4:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 5:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 6:	Attenuators: 30	Preamp: 0	SCM: 3
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: FG2-13 9-02-04 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: 6.94 km/s.

Impact coordinates: _______________
Damage description and comments:

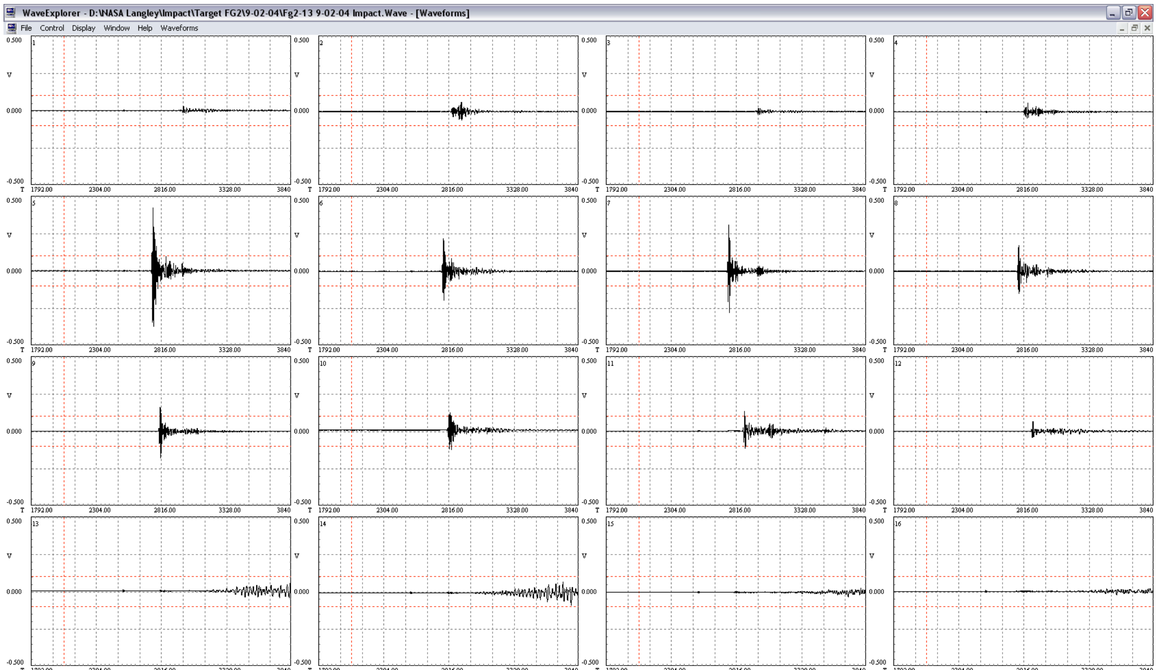


Figure 83: Fg(RCC)-2 Shot #13 Impact Waveform

Figure 84: Fg(RCC)-2 Shot #13 Impact Damage

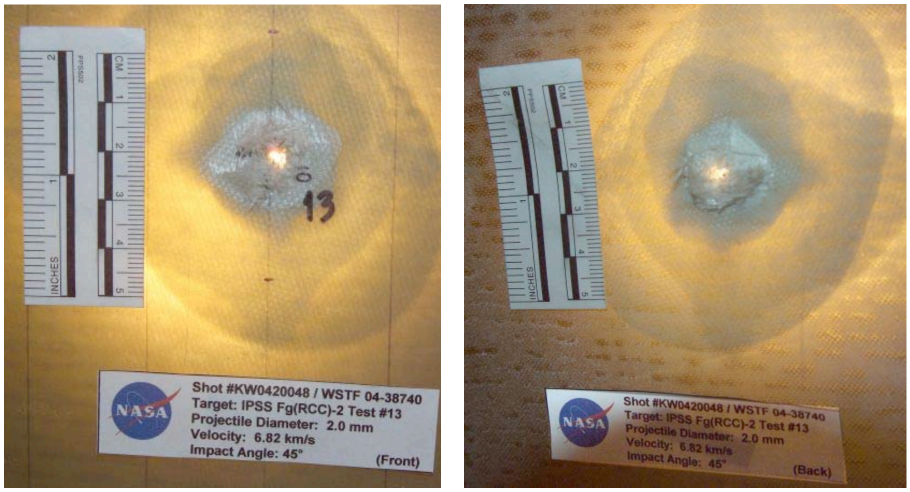


Figure 85: Fg(RCC)-2 Shot #13 Backlit Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:
Test date: 9/03/04 Specimen ID: FG-2
Test number: FG2-14 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:

III. Record sensor serial number and coordinates:

Sensor 1: S/N 084007
Sensor 2: S/N 084001
Sensor 3: S/N 084008
Sensor 4: S/N 084003
Sensor 5: S/N 101146
Sensor 6: S/N 0799051
Sensor 7: S/N 101157
Sensor 8: S/N 101148
Sensor 9: S/N 101147
Sensor 10: S/N 101163
Sensor 11: S/N 190017
Sensor 12: S/N 0799050
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: FG2-14 9-03-04 pretest LB_____
Comments: Sensors O.K.

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

VI. Impact test:

Verify settings:

External (gun) trigger source: X______
20 kHz HP filter, 1500 kHz LP filter: X______
2 MHz SR, 32 K points, 4096 pretrigger: X______
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: 3
Sensor 2:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 3:	Attenuators: 30	Preamp: 0	SCM: 3
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: FG2-14 9-03-04 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: 6.94 km/s.

Impact coordinates: ________________
Damage description and comments:

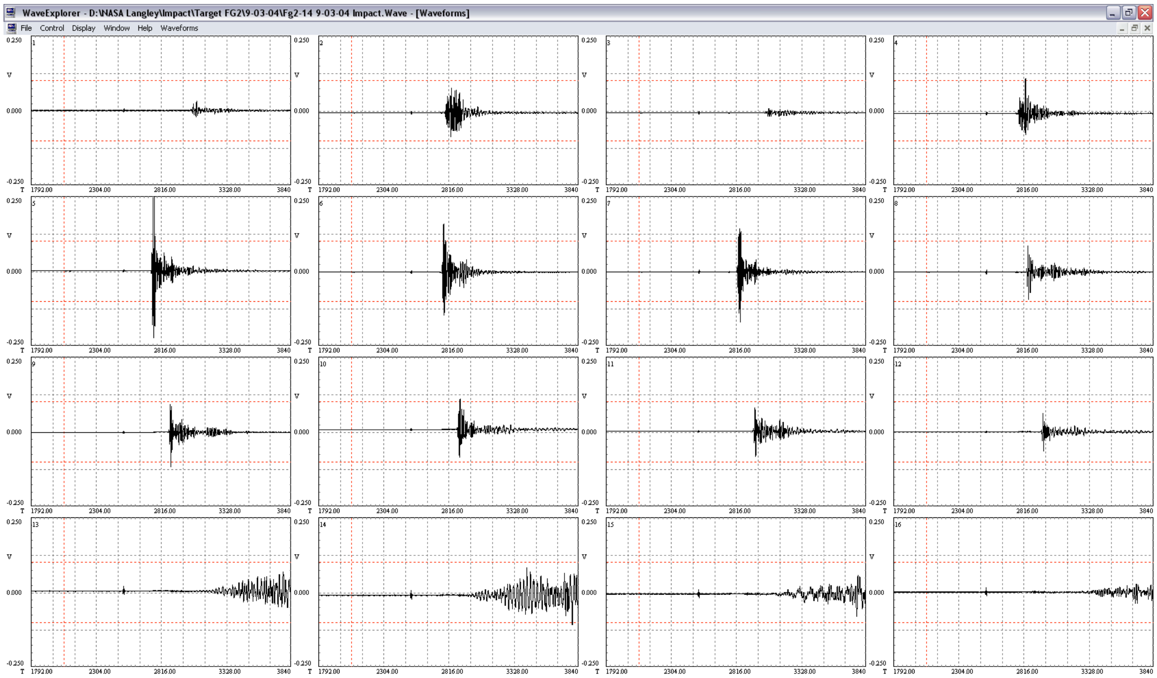


Figure 86: Fg(RCC)-2 Shot #14 Impact Waveform

Figure 87: Fg(RCC)-2 Shot #14 Impact Damage

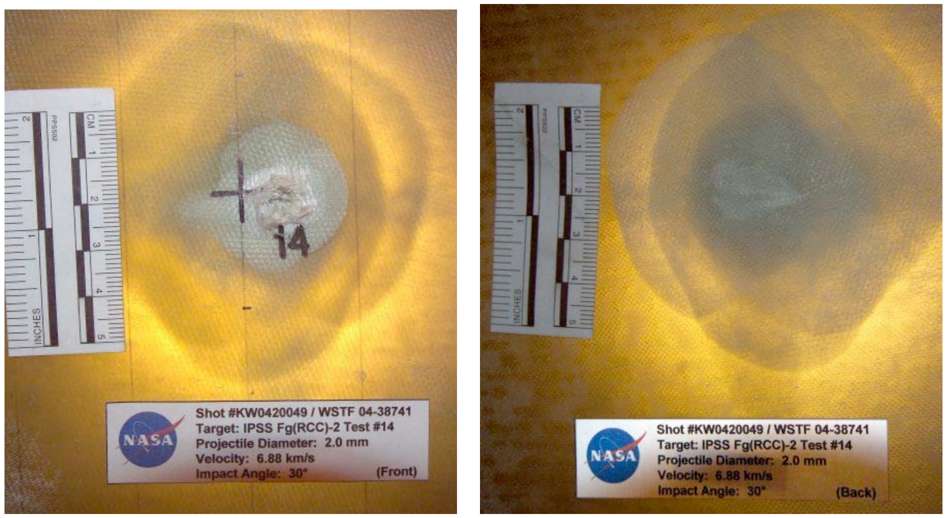


Figure 88: Fg(RCC)-2 Shot #14 Backlit Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:

Test date: 9/07/04 Specimen ID: FG-2

Test number: FG2-15 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:

III. Record sensor serial number and coordinates:

Sensor 1: S/N 084007
Sensor 2: S/N 084001
Sensor 3: S/N 084008
Sensor 4: S/N 084003
Sensor 5: S/N 101146
Sensor 6: S/N 0799051
Sensor 7: S/N 101157
Sensor 8: S/N 101148
Sensor 9: S/N 101147
Sensor 10: S/N 101163
Sensor 11: S/N 190017
Sensor 12: S/N 0799050
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: FG2-15 9-07-04 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: 0	Preamp: -20	SCM: 0
Sensor 2:	Attenuators: 0	Preamp: -20	SCM: 0
Sensor 3:	Attenuators: 0	Preamp: -20	SCM: 0
Sensor 4:	Attenuators: 0	Preamp: -20	SCM: 0
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: FG2-15 9-07-04 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: 6.94 km/s.

Impact coordinates: ________________
Damage description and comments:

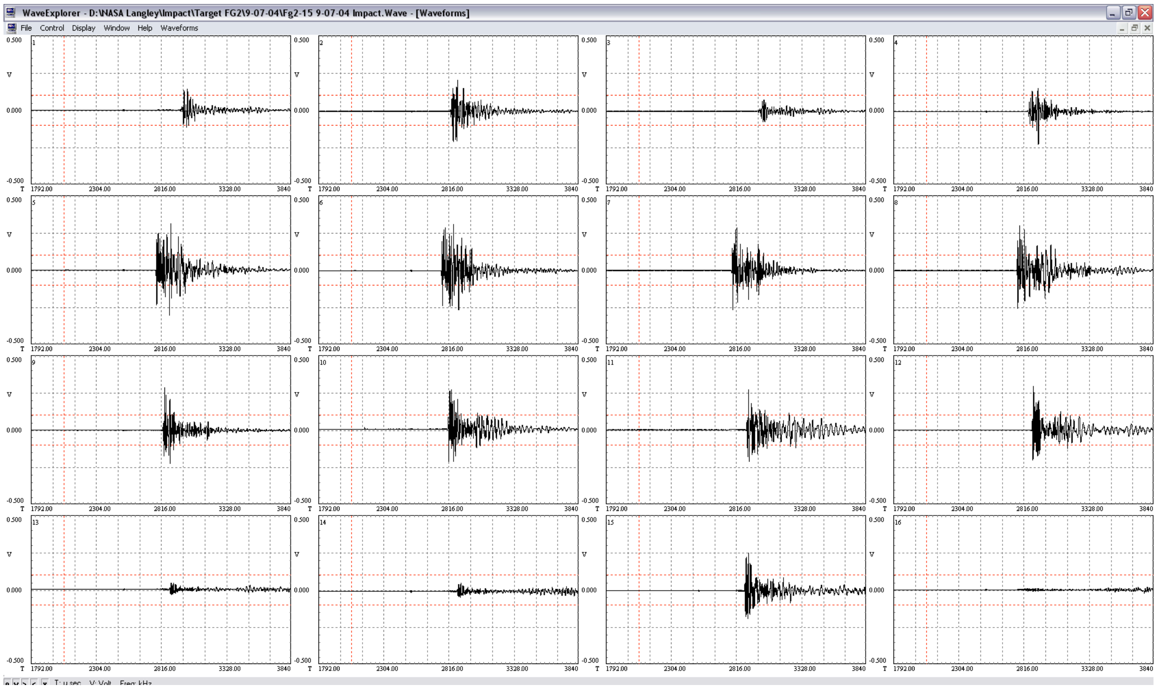


Figure 89: Fg(RCC)-2 Shot #15 Impact Waveform

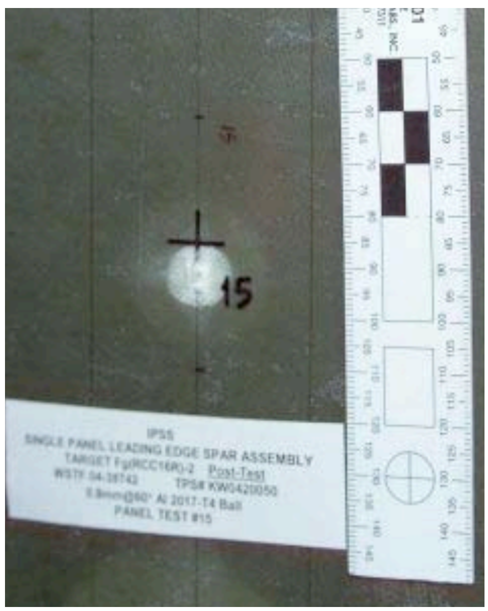


Figure 90: Fg(RCC)-2 Shot #15 Impact Damage

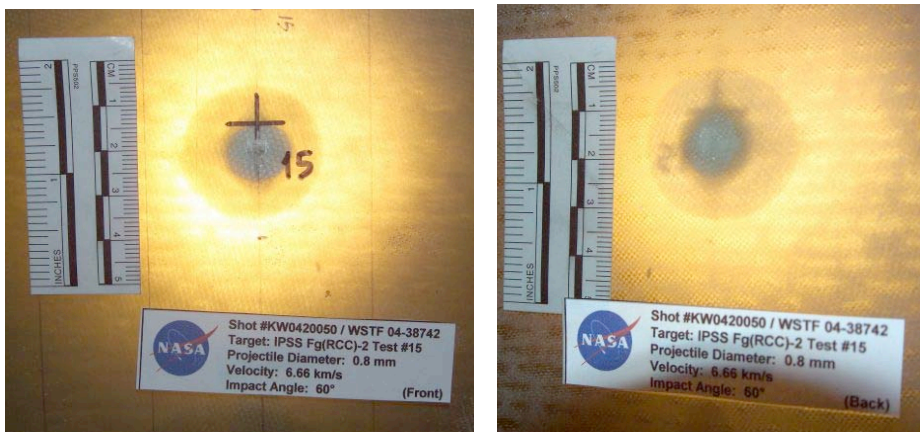


Figure 91: Fg(RCC)-2 Shot #15 Backlit Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:
Test date: 9/08/04   Specimen ID: FG-2
Test number: FG2-16   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:

III. Record sensor serial number and coordinates:
Sensor 1: S/N 084007   Sensor 2: S/N 084001
Sensor 3: S/N 084008   Sensor 4: S/N 084003
Sensor 5: S/N 101146   Sensor 6: S/N 0799051
Sensor 7: S/N 101157   Sensor 8: S/N 101148
Sensor 9: S/N 101147   Sensor 10: S/N 101163
Sensor 11: S/N 190017   Sensor 12: S/N 0799050
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: FG2-16 9-08-04 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: 9
Sensor 3:	Attenuators: 30	Preamp: 0	SCM: 12
Sensor 4:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 5:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 6:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 7:	Attenuators: 30	Preamp: 0	SCM: 12
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: 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: FG2-16 9-08-04 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: 6.94 km/s.

Impact coordinates: ________________
Damage description and comments:

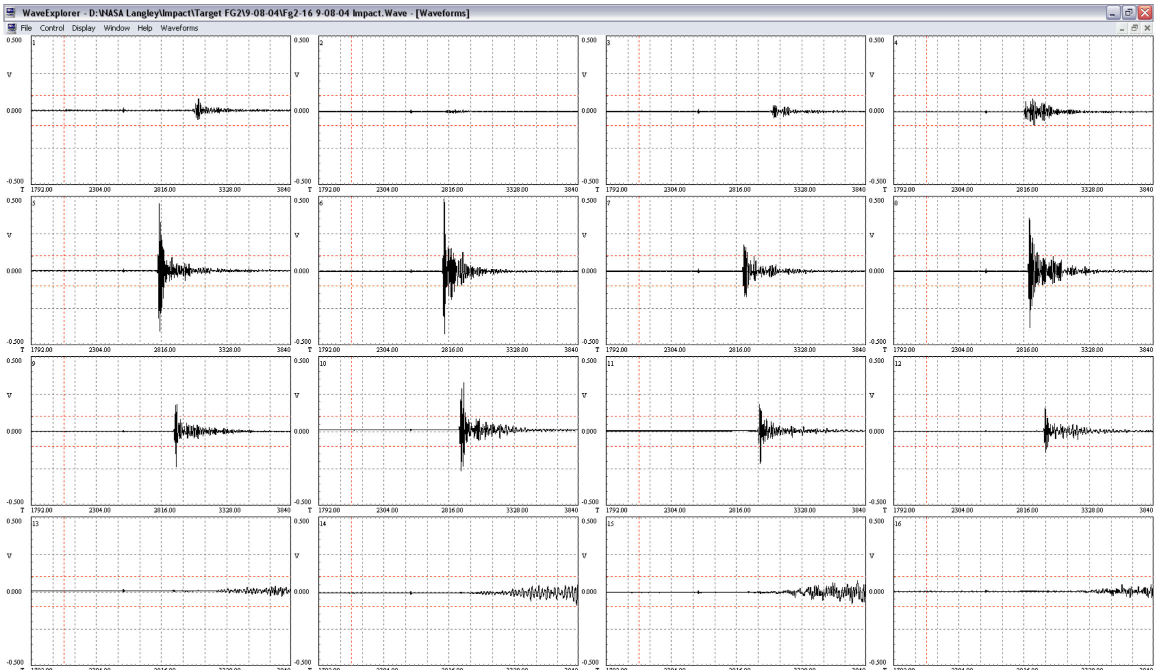


Figure 92: Fg(RCC)-2 Shot #16 Impact Waveform

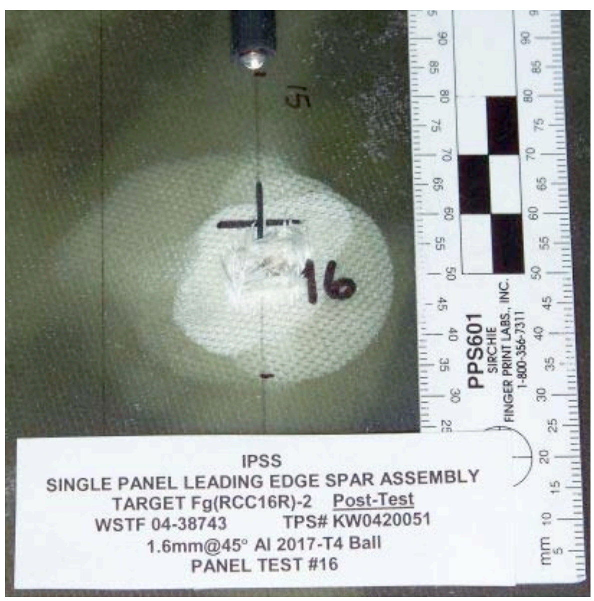
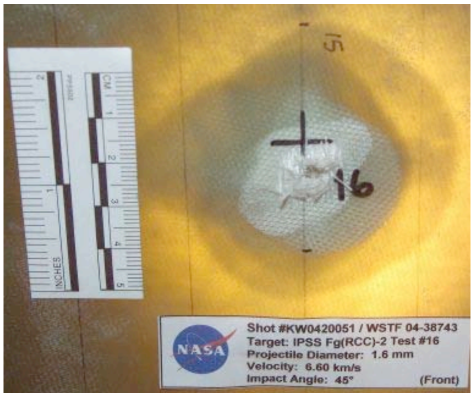


Figure 93: Fg(RCC)-2 Shot #16 Impact Damage



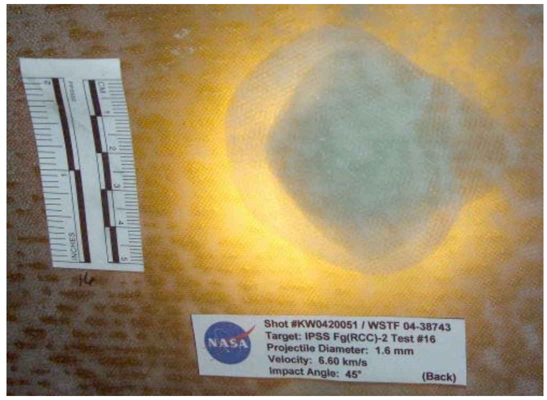


Figure 94: Fg(RCC)-2 Shot #16 Backlit Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:

Test date: 9/09/04 Specimen ID: FG-2

Test number: FG2-17 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:

III. Record sensor serial number and coordinates:

Sensor 1: S/N 084007
Sensor 2: S/N 084001
Sensor 3: S/N 084008
Sensor 4: S/N 084003
Sensor 5: S/N 101146
Sensor 6: S/N 0799051
Sensor 7: S/N 101157
Sensor 8: S/N 101148
Sensor 9: S/N 101147
Sensor 10: S/N 101163
Sensor 11: S/N 190017
Sensor 12: S/N 0799050
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: FG2-17 9-09-04 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: 3
Sensor 2:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 3:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 4:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 5:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 6:	Attenuators: 30	Preamp: 0	SCM: 3
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: -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: FG2-17 9-09-04 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: 6.94 km/s.
Impact coordinates: ________________
Damage description and comments:

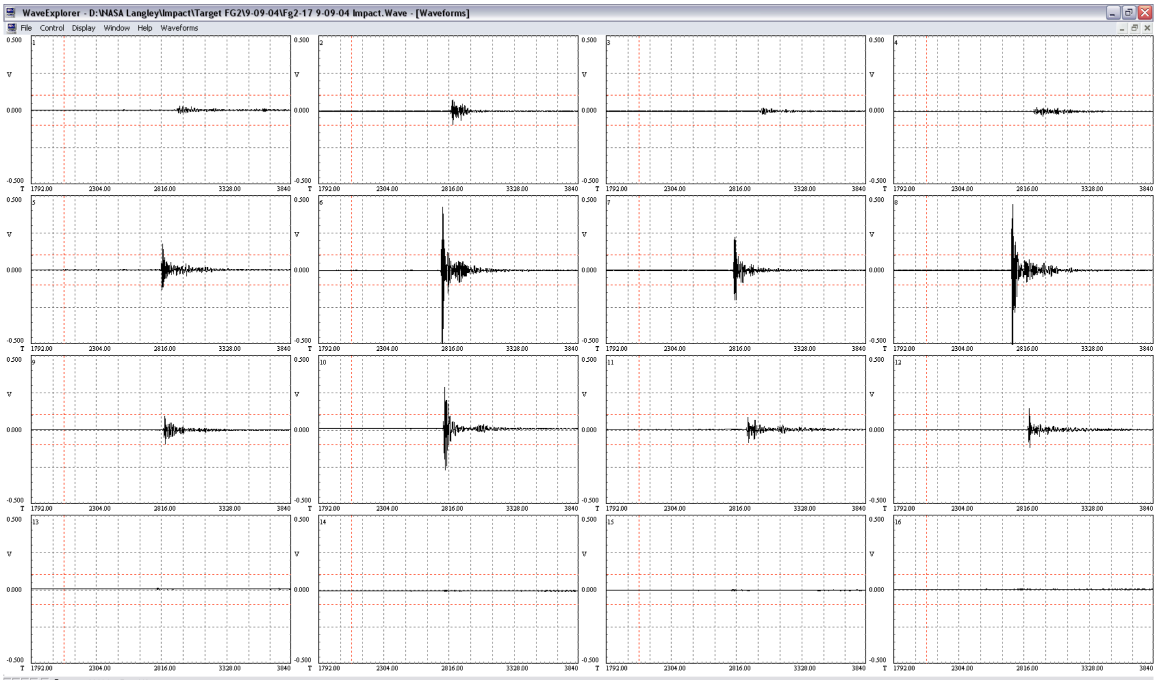


Figure 95: Fg(RCC)-2 Shot #17 Impact Waveform

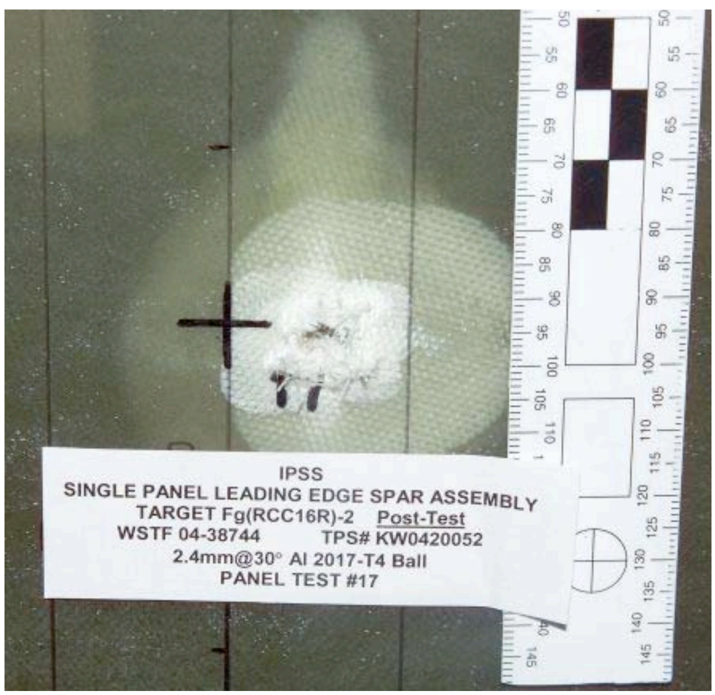


Figure 96: Fg(RCC)-2 Shot #17 Impact Damage

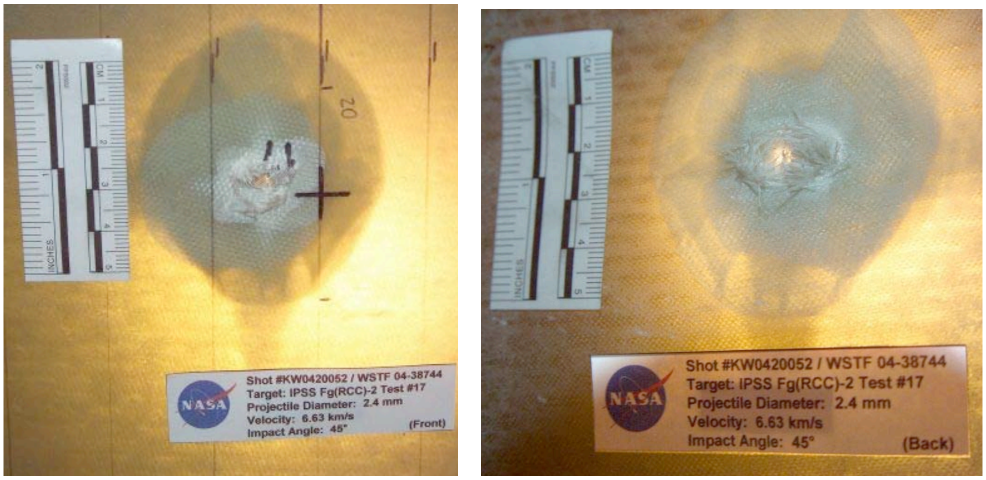


Figure 97: Fg(RCC)-2 Shot #17 Backlit Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:

Test date: 9/09/04 Specimen ID: FG-2

Test number: FG2-18 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:

III. Record sensor serial number and coordinates:

Sensor 1: S/N 084007 Sensor 2: S/N 084001
Sensor 3: S/N 084008 Sensor 4: S/N 084003
Sensor 5: S/N 101146 Sensor 6: S/N 0799051
Sensor 7: S/N 101157 Sensor 8: S/N 101148
Sensor 9: S/N 101147 Sensor 10: S/N 101163
Sensor 11: S/N 190017 Sensor 12: S/N 0799050
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: FG2-18 9-09-04 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 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: 9
Sensor 6:	Attenuators: 30	Preamp: 0	SCM: 3
Sensor 7:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 8:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 9:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 10:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 11:	Attenuators: 30	Preamp: 0	SCM: 9
Sensor 12:	Attenuators: 30	Preamp: 0	SCM: 9
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: FG2-18 9-09-04 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: 6.83 km/s.

Impact coordinates: ________________
Damage description and comments:

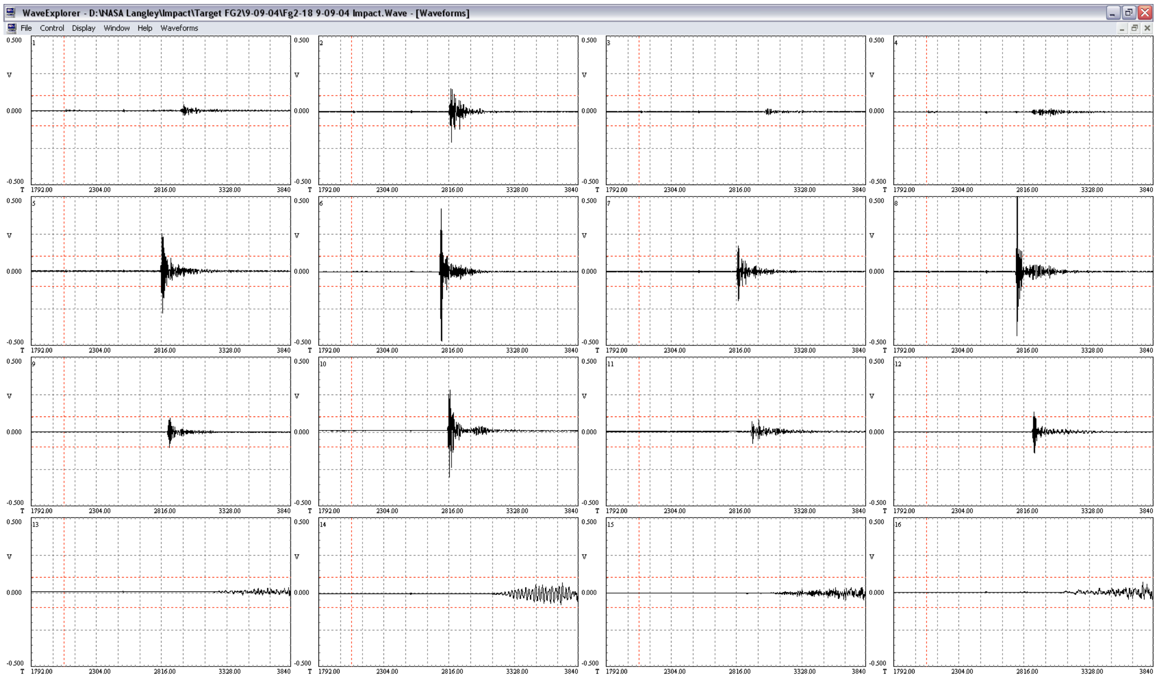


Figure 98: Fg(RCC)-2 Shot #18 Impact Waveform

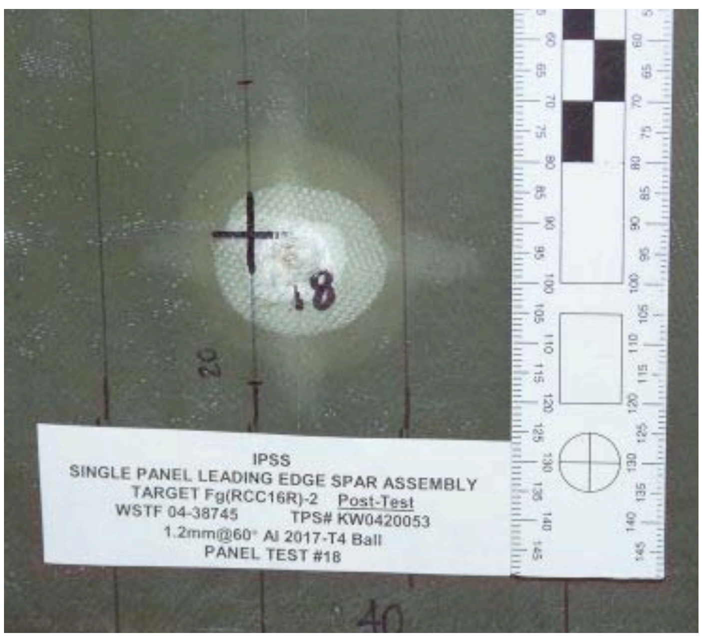


Figure 99: Fg(RCC)-2 Shot #18 Impact Damage

Figure 100: Fg(RCC)-2 Shot #18 Backlit Impact Damage (Left: Front Side, Right: Back Side)

AE Test Data/Checklist

I. Record pretest information:

Test date: 9/13/04 Specimen ID: FG-2
Test number: FG2-19 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:

III. Record sensor serial number and coordinates:

Sensor 1: S/N 084007 Sensor 2: S/N 084001
Sensor 3: S/N 084008 Sensor 4: S/N 084003
Sensor 5: S/N 101146 Sensor 6: S/N 0799051
Sensor 7: S/N 101157 Sensor 8: S/N 101148
Sensor 9: S/N 101147 Sensor 10: S/N 101163
Sensor 11: S/N 190017 Sensor 12: S/N 0799050
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: FG2-19 9-13-04 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: 30	Preamp: 0	SCM: 6
Sensor 2:	Attenuators: 30	Preamp: 0	SCM: 0
Sensor 3:	Attenuators: 30	Preamp: 0	SCM: 6
Sensor 4:	Attenuators: 30	Preamp: 0	SCM: 3
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: 3
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: 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: FG2-19 9-13-04 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: 7.05 km/s.

Impact coordinates: ________________
Damage description and comments:

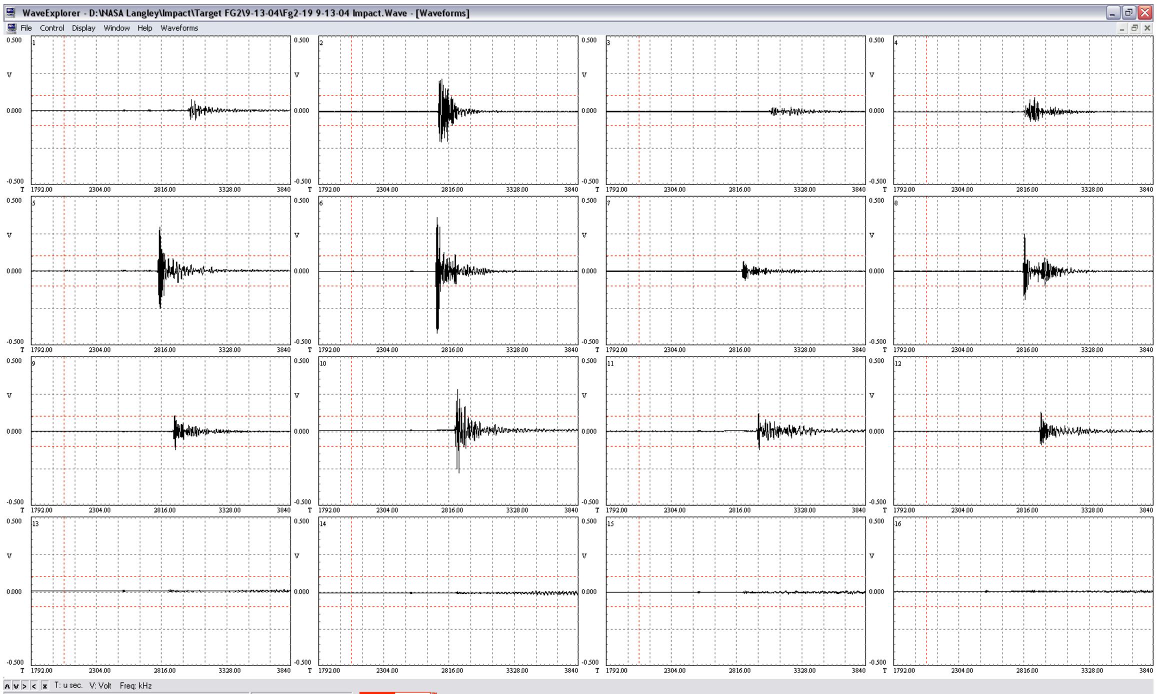


Figure 101: Fg(RCC)-2 Shot #19 Impact Waveform

Figure 102: Fg(RCC)-2 Shot #19 Impact Damage

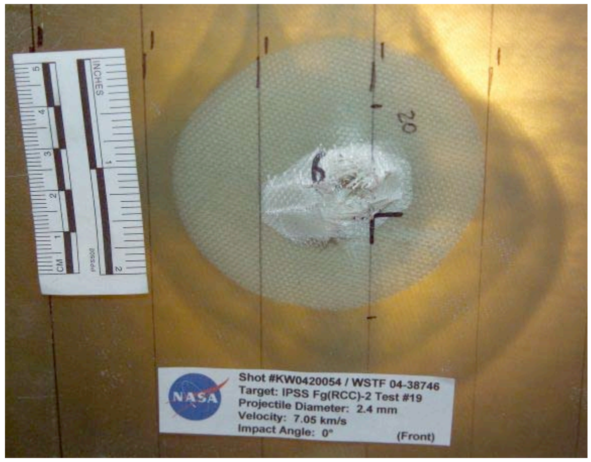


Figure 103: Fg(RCC)-2 Shot #19 Backlit Impact Damage (Front Side only. No Back Side available)

Data Tables

Test	Imp Dia	Imp Vel	Imp Ang	Normal K.E.	Total K.E.	Location	
No.	mm	km/s	deg	J	J	x	y
FG2-1	0.4	6.68	90	2.02	2.02	26	2
FG2-2	0.4	6.89	60	1.61	2.15	35	2
FG2-3	1.0	7.05	45	17.55	35.13	39	2
FG2-4	0.4	6.85	30	0.53	2.12	50	2
FG2-5	0.6	6.83	45	3.56	7.12	5	2
FG2-6	0.8	6.78	90	16.64	16.64	26	6
FG2-7	1.0	6.92	30	8.45	33.85	35	6
FG2-8	0.6	6.82	60	5.32	7.10	39	6
FG2-9	1.2	6.82	30	14.19	56.81	50	6
FG2-10	0.8	6.45	30	3.76	15.06	5	6
FG2-11	1.2	6.83	60	42.71	56.98	31	10
FG2-12	1.6	6.81	45	67.08	134.27	35	10
FG2-13	2.0	6.82	45	131.41	263.02	39	10
FG2-14	2.0	6.88	30	66.86	267.67	50	10
FG2-15	0.8	6.66	60	12.03	16.05	39	14
FG2-16	1.6	6.60	45	63.01	126.12	50	14
FG2-17	2.4	6.63	30	107.28	429.53	35	19
FG2-18	1.2	6.69	60	40.98	54.67	39	19
FG2-19	2.4	7.05	45	242.64	485.67	50	19

Table 3: Fg(RCC)-2 Impactor Diameter, Impactor Velocity, Impactor Angle, Normal Kinetic Energy, Total Kinetic Energy, and Location

	Channel Gain (dB)															
Test No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
FG2-1	0	0	0	0	-8	-8	-8	-8	-8	-8	-8	-8	18	18	18	18
FG2-2	0	0	0	0	-8	-8	-14	-8	-14	-8	-8	-8	26	26	26	26
FG2-3	-38	-38	-38	-38	-41	-38	-41	-38	-38	-38	-38	-38	26	26	26	26
FG2-4	0	0	0	-5	-14	-8	-8	-8	-8	-8	-8	-8	32	32	32	32
FG2-5	-11	-11	-17	-11	-11	-11	-11	-11	-11	-11	-17	-11	32	32	32	32
FG2-6	-17	-17	-17	-17	-20	-20	-20	-20	-20	-20	-20	-20	29	29	29	29
FG2-7	-35	-35	-35	-35	-35	-35	-41	-35	-35	-35	-35	-35	23	23	23	23
FG2-8	-11	-11	-11	-11	-17	-11	-11	-11	-11	-11	-11	-11	32	32	32	32
FG2-9	-41	-41	-41	-47	-47	-41	-41	-41	-41	-41	-41	-41	23	23	23	23
FG2-10	-17	-17	-20	-17	-20	-20	-20	-20	-20	-20	-20	-20	29	29	29	29
FG2-11	-41	-41	-41	-41	-41	-41	-50	-50	-41	-41	-41	-41	23	23	23	23
FG2-12	-35	-35	-35	-35	-35	-35	-35	-35	-35	-35	-35	-35	18	18	18	18
FG2-13	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	15	15	15	15
FG2-14	-47	-47	-47	-47	-50	-50	-47	-47	-47	-47	-47	-47	15	15	15	15
FG2-15	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	26	26	26	26
FG2-16	-41	-38	-41	-41	-41	-38	-38	-38	-38	-38	-38	-38	18	18	18	18
FG2-17	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-8	-8	-8	-8
FG2-18	-41	-41	-41	-41	-41	-47	-41	-41	-41	-41	-41	-41	23	23	23	23
FG2-19	-44	-50	-44	-47	-47	-50	-47	-47	-44	-44	-44	-44	-2	-2	-2	-2

Table 4: Fg(RCC)-2 Gain Settings

Test	K.E.	KE	Crater Dims			Crater	Damage Dims		Damage	Delamination - Outside			Delamination - Inside		
No.	Normal	Total	x	y	z	Vol	x	y	Area	x	y	Area	x	y	Area
	J	J	mm	mm	mm	mm^3	mm	mm	mm^2	mm	mm	mm^2	mm	mm	mm^2
FG2-1	2.02	2.02	0.6	0.6	1.0	0.3	0.0	0.0	0.0	4.5	3.5	15.8	4.5	4.0	18.0
FG2-2	1.61	2.15	1.0	1.0	0.1	0.1	5.5	7.0	38.5	9.0	6.0	54.0	6.0	5.0	30.0
FG2-3	17.55	35.13	2.5	2.5	1.1	7.0	8.5	11.0	93.5	30.5	31.0	945.5	29.0	34.0	986.0
FG2-4	0.53	2.12	0.6	0.5	0.1	0.0	1.5	5.0	7.5	5.5	5.0	27.5	0.0	0.0	0.0
FG2-5	3.56	7.12	2.0	1.0	0.4	0.8	5.0	9.5	47.5	11.0	8.5	93.5	9.5	12.0	114.0
FG2-6	16.64	16.64	2.5	3.0	1.7	12.8	4.5	4.5	20.3	13.0	14.0	182.0	15.0	16.5	247.5
FG2-7	8.45	33.85	2.5	2.0	0.9	4.5	7.5	11.0	82.5	30.0	15.0	450.0	31.5	21.0	661.5
FG2-8	5.32	7.10	1.0	1.0	0.4	0.4	5.0	9.0	45.0	12.5	9.0	112.5	13.0	12.0	156.0
FG2-9	14.19	56.81	3.0	2.5	1.1	8.3	9.5	12.0	114.0	21.0	16.0	336.0	32.0	33.0	1056.0
FG2-10	3.76	15.06	1.5	2.0	0.9	2.6	6.0	9.0	54.0	23.0	19.5	448.5	16.0	12.0	192.0
FG2-11	42.71	56.98	3.5	5.5	2.0	39.1	9.5	13.0	123.5	62.0	58.0	3596.0	60.0	56.0	3360.0
FG2-12	67.08	134.27	4.0	4.5	3.3	59.4	19.5	15.0	292.5	74.0	73.0	5402.0	45.0	51.0	2295.0
FG2-13	131.41	263.02	4.0	4.5	6	108.0	24.0	20.0	480.0	95.0	88.0	8360.0	75.0	77.5	5812.5
FG2-14	66.86	267.67	7.0	6.0	2.8	117.6	16.0	16.0	256.0	78.0	81.0	6318.0	69.0	79.0	5451.0
FG2-15	12.03	16.05	2.5	2.0	0.8	4.0	6.0	10.0	60.0	32.0	27.0	864.0	32.0	30.0	960.0
FG2-16	63.01	126.12	4.5	5.0	2.05	46.1	15.0	16.0	240.0	50.0	38.0	1900.0	62.0	56.0	3472.0
FG2-17	107.28	429.53	4.5	4.0	6.0	108.0	17.0	19.0	323.0	77.0	86.0	6622.0	59.0	69.0	4071.0
FG2-18	40.98	54.67	3.0	4.5	1.6	21.6	12.0	14.0	168.0	55.5	58.0	3219.0	39.0	41.0	1599.0
FG2-19	242.64	485.67	8.0	6.5	6.0	312	31.0	25.0	775.0	88.0	91.0	8008.0	97.0	110.0	10670.0

Table 5: Fg(RCC)-2 Damage Results

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
FG2-1	3.006E+01	2.471E+01	6.703E+01	2.327E+01	1.801E+02	1.439E+01	2.888E+02	2.516E+01
FG2-2	1.018E+01	5.401E+01	1.989E+01	9.513E+00	1.310E+02	1.517E+01	2.351E+01	6.716E+00
FG2-3	2.259E+00	3.539E+00	1.978E+00	1.829E+01	1.255E+02	2.191E+01	7.619E+01	1.758E+01
FG2-4	1.470E+00	3.088E+01	2.020E+00	2.124E+02	9.240E+01	1.318E+01	2.920E+01	4.704E+00
FG2-5	5.470E+01	4.961E+00	2.095E+02	2.650E+00	5.939E+01	1.118E+01	5.105E+01	4.017E+01
FG2-6	7.851E+01	3.492E+01	1.349E+02	9.236E+01	2.130E+02	1.236E+02	2.752E+02	2.089E+02
FG2-7	4.934E+00	6.289E+00	5.294E+00	1.138E+01	4.478E+02	2.478E+01	2.174E+02	5.824E+01
FG2-8	3.320E+01	7.607E+01	2.795E+01	8.143E+01	6.362E+02	6.126E+02	1.596E+03	7.197E+02
FG2-9	1.104E+00	4.841E+00	1.076E+00	3.386E+00	7.556E+01	1.346E+01	3.483E+01	3.112E+00
FG2-10	2.250E-01	2.429E-01	1.166E-01	2.779E-01	1.164E-01	1.113E-01	1.114E-01	1.182E-01
FG2-11	4.364E+00	4.223E+00	4.260E+00	5.518E+00	1.479E+02	2.940E+01	1.390E+02	3.271E+01
FG2-12	2.573E+01	3.181E+01	3.197E+01	5.829E+01	1.040E+03	3.188E+02	9.826E+02	6.314E+02
FG2-13	1.713E+00	7.482E+00	1.476E+00	5.485E+00	1.773E+02	4.670E+01	7.338E+01	2.941E+01
FG2-14	1.499E+00	2.027E+01	9.755E-01	1.481E+01	6.721E+01	3.407E+01	3.101E+01	1.220E+01
FG2-15	4.366E+01	1.073E+02	1.858E+01	6.309E+01	2.633E+02	2.695E+02	1.673E+02	2.437E+02
FG2-16	1.129E+01	1.162E+00	7.513E+00	2.687E+01	2.089E+02	2.194E+02	6.118E+01	2.047E+02
FG2-17	2.550E+00	1.087E+01	1.569E+00	3.164E+00	2.756E+01	2.002E+02	5.444E+01	2.615E+02
FG2-18	2.749E+00	4.029E+01	1.492E+00	2.833E+00	7.760E+01	1.465E+02	3.721E+01	1.678E+02
FG2-19	1.118E+01	1.276E+02	5.002E+00	1.912E+01	1.122E+02	2.478E+02	8.639E+00	6.864E+01

Table 6: Fg(RCC)-2 Raw Wave Signal, Sensors 1-8

Test	S9 RawEn	S10 RawEn	S11 RawEn	S12 RawEn	S13 RawEn	S14 RawEn	S15 RawEn	S16 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
FG2-1	5.655E+02	1.911E+01	1.858E+02	2.195E+01	1.011E+00	1.171E+00	1.971E+00	1.076E+00
FG2-2	2.114E+00	4.628E+00	2.389E+01	1.229E+01	1.980E+00	3.994E+00	1.906E+00	5.549E-01
FG2-3	5.252E+01	9.279E+00	3.226E+01	2.879E+00	1.175E+02	1.645E+02	4.543E+02	2.754E+02
FG2-4	6.663E+00	3.425E+00	6.113E+00	1.522E+00	6.694E+00	1.505E+01	2.733E+00	1.384E+00
FG2-5	3.400E+02	6.928E+01	4.750E+02	2.826E+02	1.741E+02	1.497E+02	5.535E+02	6.672E+01
FG2-6	2.371E+02	1.698E+02	4.199E+02	1.985E+02	9.313E+01	1.125E+02	1.073E+03	2.036E+02
FG2-7	8.803E+01	1.820E+01	2.010E+01	4.907E+00	4.326E+01	5.149E+01	3.957E+01	2.841E+01
FG2-8	5.843E+02	3.664E+02	6.362E+02	3.349E+02	6.053E+01	1.518E+02	2.765E+02	8.070E+01
FG2-9	4.646E+00	1.820E+00	3.378E+00	6.627E-01	2.628E+01	3.092E+01	1.826E+01	2.582E+01
FG2-10	1.779E-01	8.000E-01	5.762E-02	2.155E-02	1.654E+02	1.466E+02	2.998E+01	2.918E+01
FG2-11	8.669E+01	6.941E+01	5.991E+01	2.624E+01	2.657E+02	3.375E+02	2.651E+02	2.268E+02
FG2-12	4.241E+02	3.873E+02	3.429E+02	9.930E+01	1.179E+02	1.151E+02	3.162E+02	2.723E+02
FG2-13	2.673E+01	2.451E+01	2.404E+01	6.001E+00	2.374E+02	3.639E+02	1.809E+02	1.188E+02
FG2-14	1.453E+01	1.482E+01	1.264E+01	5.521E+00	8.759E+02	9.250E+02	4.335E+02	3.924E+02
FG2-15	1.065E+02	1.834E+02	2.290E+02	1.784E+02	5.108E+01	8.902E+01	2.602E+02	6.263E+01
FG2-16	5.327E+01	1.306E+02	5.306E+01	3.383E+01	1.483E+02	2.613E+02	5.647E+02	4.179E+02
FG2-17	1.423E+01	9.035E+01	1.383E+01	1.699E+01	6.471E-01	1.501E+00	2.304E+00	1.453E+00
FG2-18	1.186E+01	8.807E+01	9.126E+00	1.805E+01	3.249E+01	3.360E+01	7.009E+01	7.145E+01
FG2-19	2.172E+01	1.348E+02	3.410E+01	2.456E+01	6.952E+00	1.303E+01	1.675E+01	1.047E+01

Table 7: Fg(RCC)-2 Raw Wave Signal, Sensors 9-16

Test	S1 En	S2 En	S3 En	S4 En	S5 En	S6 En	S7 En	S8 En
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}
FG2-1	3.01E+00	2.47E+00	6.70E+00	2.33E+00	1.14E+02	9.08E+00	1.82E+02	1.59E+01
FG2-2	1.02E+00	5.40E+00	1.99E+00	9.51E-01	8.27E+01	9.57E+00	5.91E+01	4.24E+00
FG2-3	1.43E+03	2.23E+03	1.25E+03	1.15E+04	1.58E+05	1.38E+04	9.59E+04	1.11E+04
FG2-4	1.47E-01	3.09E+00	2.02E-01	6.72E+01	2.32E+02	8.32E+00	1.84E+01	2.97E+00
FG2-5	6.89E+01	6.25E+00	1.05E+03	3.34E+00	7.48E+01	1.41E+01	6.43E+01	5.06E+01
FG2-6	3.93E+02	1.75E+02	6.76E+02	4.63E+02	2.13E+03	1.24E+03	2.75E+03	2.09E+03
FG2-7	1.56E+03	1.99E+03	1.67E+03	3.60E+03	1.42E+05	7.84E+03	2.74E+05	1.84E+04
FG2-8	4.18E+01	9.58E+01	3.52E+01	1.03E+02	3.19E+03	7.71E+02	2.01E+03	9.06E+02
FG2-9	1.39E+03	6.09E+03	1.36E+03	1.70E+04	3.79E+05	1.70E+04	4.39E+04	3.92E+03
FG2-10	1.13E+00	1.22E+00	1.17E+00	1.39E+00	1.16E+00	1.11E+00	1.11E+00	1.18E+00
FG2-11	5.49E+03	5.32E+03	5.36E+03	6.95E+03	1.86E+05	3.70E+04	1.39E+06	3.27E+05
FG2-12	8.14E+03	1.01E+04	1.01E+04	1.84E+04	3.29E+05	1.01E+05	3.11E+05	2.00E+05
FG2-13	8.58E+03	3.75E+04	7.40E+03	2.75E+04	8.88E+05	2.34E+05	3.68E+05	1.47E+05
FG2-14	7.51E+03	1.02E+05	4.89E+03	7.42E+04	6.72E+05	3.41E+05	1.55E+05	6.11E+04
FG2-15	4.37E+02	1.07E+03	1.86E+02	6.31E+02	2.63E+03	2.70E+03	1.67E+03	2.44E+03
FG2-16	1.42E+04	7.33E+02	9.46E+03	3.38E+04	2.63E+05	1.38E+05	3.86E+04	1.29E+05
FG2-17	1.28E+04	5.45E+04	7.86E+03	1.59E+04	1.38E+05	1.00E+06	2.73E+05	1.31E+06
FG2-18	3.46E+03	5.07E+04	1.88E+03	3.57E+03	9.77E+04	7.34E+05	4.69E+04	2.11E+05
FG2-19	2.81E+04	1.28E+06	1.26E+04	9.58E+04	5.63E+05	2.48E+06	4.33E+04	3.44E+05

Table 8: Fg(RCC)-2 Wave Signal Energy Sensors 1-8

Test No.	S9 En J x 10^{-10}	S10 En J x 10^{-10}	S911 En J x 10^{-10}	S912 En J x 10^{-10}	S13 En J x 10^{-10}	S14 En J x 10^{-10}	S15 En J x 10^{-10}	S16 En J x 10^{-10}	TOT WSE nJ
FG2-1	3.57E+02	1.21E+01	1.17E+02	1.38E+01	1.60E-03	1.86E-03	3.12E-03	1.71E-03	8.35E+02
FG2-2	5.31E+00	2.92E+00	1.51E+01	7.76E+00	4.97E-04	1.00E-03	4.79E-04	1.39E-04	1.96E+02
FG2-3	3.31E+04	5.85E+03	2.04E+04	1.82E+03	2.95E-02	4.13E-02	1.14E-01	6.92E-02	3.56E+05
FG2-4	4.20E+00	2.16E+00	3.86E+00	9.60E-01	4.22E-04	9.49E-04	1.72E-04	8.74E-05	3.44E+02
FG2-5	4.28E+02	8.72E+01	2.38E+03	3.56E+02	1.10E-02	9.44E-03	3.49E-02	4.21E-03	4.58E+03
FG2-6	2.37E+03	1.70E+03	4.20E+03	1.99E+03	1.17E-02	1.42E-02	1.35E-01	2.56E-02	2.02E+04
FG2-7	2.78E+04	5.76E+03	6.36E+03	1.55E+03	2.17E-02	2.58E-02	1.98E-02	1.42E-02	4.92E+05
FG2-8	7.36E+02	4.61E+02	8.01E+02	4.22E+02	3.82E-03	9.58E-03	1.74E-02	5.09E-03	9.57E+03
FG2-9	5.85E+03	2.29E+03	4.25E+03	8.34E+02	1.32E-02	1.55E-02	9.15E-03	1.29E-02	4.82E+05
FG2-10	1.78E+00	8.00E+00	5.76E-01	2.16E-01	2.08E-02	1.85E-02	3.77E-03	3.67E-03	2.01E+01
FG2-11	1.09E+05	8.74E+04	7.54E+04	3.30E+04	1.33E-01	1.69E-01	1.33E-01	1.14E-01	2.27E+06
FG2-12	1.34E+05	1.22E+05	1.08E+05	3.14E+04	1.87E-01	1.82E-01	5.01E-01	4.31E-01	1.38E+06
FG2-13	1.34E+05	1.23E+05	1.21E+05	3.01E+04	7.51E-01	1.15E+00	5.72E-01	3.76E-01	2.13E+06
FG2-14	7.28E+04	7.43E+04	6.33E+04	2.77E+04	2.77E+00	2.93E+00	1.37E+00	1.24E+00	1.66E+06
FG2-15	1.06E+03	1.83E+03	2.29E+03	1.78E+03	1.28E-02	2.24E-02	6.54E-02	1.57E-02	1.87E+04
FG2-16	3.36E+04	8.24E+04	3.35E+04	2.13E+04	2.35E-01	4.14E-01	8.95E-01	6.62E-01	7.98E+05
FG2-17	7.13E+04	4.53E+05	6.93E+04	8.52E+04	4.08E-01	9.47E-01	1.45E+00	9.17E-01	3.49E+06
FG2-18	1.49E+04	1.11E+05	1.15E+04	2.27E+04	1.63E-02	1.68E-02	3.51E-02	3.58E-02	1.31E+06
FG2-19	5.46E+04	3.39E+05	8.56E+04	6.17E+04	1.10E+00	2.06E+00	2.65E+00	1.66E+00	5.38E+06

Table 9: Fg(RCC)-2 Wave Signal Energy, Sensors 9-16 and Total Wave Signal Energy

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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 Fg(RCC)-2 was to study hypervelocity impacts through the reinforced carbon-carbon (RCC) panels of the Wing Leading Edge. Fiberglass was used in place of RCC in the initial tests. Impact damage was detected using lightweight, low power instrumentation capable of being used in flight.

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