Report on Generic Hull Live-Fire Test with PRIMUS Dummy

In Accordance with Terms of CRADA Number 21-11

between DEVCOM GVSC and Kistler Instrument Corporation.

SUMMARY

A live-fire test using a Generic Hull vehicle surrogate was conducted at the Fort Polk, LA test range on December 8, 2021. The test was conducted to provide baseline data for a correlation study to determine laboratory to live-fire comparability. Additionally, the test provided an opportunity to evaluate the PRIMUS Dummy performance in an environment of the Occupant Protection Laboratory (OPL).

The hull was fitted with six (6) Commercial-off-the-shelf (COTS) seats, three (3) stroking, and three (3) non-stroking. Six (6) Anthropomorphic Test Devices (ATDs) were positioned in the seats. The ATDs consisted of one (1) PRIMUS Dummy seated in position 2, and five (5) Hybrid III 50th percentile male (HIII) ATDs seated in the remaining positions. Each seat was instrumented with four (4) Endevco model 7270 -2k accelerometers. The accelerometers were arranged to capture the input tri-axial accelerations to the mount of the seat as well as the acceleration of any seat motion in the vertical direction. Data acquisition was accomplished using Diversified Technical Systems (DTS) SlicePro data acquisition systems and the internal Kistler data acquisition system incorporated in the PRIMUS dummy. Seat acceleration data was collected at a sampling rate of 500k sample per second (sps or Hz) and ATD data was collected at a rate of 20kHz.

This report focuses on the responses of the PRIMUS Dummy relative to the input accelerations of the position 2 seat as well as comparing the PRIMUS to the responses of the Hybrid III in position 1. Both ATDs were seated in stroking seats and were arranged side-by-side to allow a direct comparison of the two. The analysis of the collected data shows that the responses of the PRIMUS Dummy closely match those of the HIII. While the inputs to the two seats were not completely identical the differences in the inputs were minor and so a direct comparison is a fair assessment. Considering the inputs, it makes sense to move on to the next phase of the CRADA and continue the assessment of PRIMUS in the laboratory environment at the OPL.

INTRODUCTION

Vehicle occupant injury assessment is a specialized field that requires unique tools to determine the effectiveness of safety technologies designed to reduce injury potential during vehicular events. These events can include frontal car crashes, rear-end impacts, vehicular rollovers, pedestrian impacts, and blast events, such as under-body blasts or even vehicle borne explosives.

To assess developed or developing occupant protection technologies, Anthropomorphic Test Devices are used as vehicle occupant surrogates. ATDs are specially developed surrogates that are designed to respond to impact events seen in vehicular mishaps. The responses of the ATDs are engineered to match those of humans and are based on cadaveric tests that provide data for the injury response mechanisms.

Typically, ATDs are engineered to be biofidelific for certain types of vehicular mishaps, i.e., frontal, side, rear, pedestrian, and vertical. ATDs are also developed to represent certain segments of the population based on size, i.e., 50th (average male), 95th (large male), 5th (small female), and numerous smaller sizes to represent children. The PRIMUS Dummy, and the HIII used in this study, represent an average male. While these ATDs are designed for their specific impact conditions, mainly for vehicle safety certifications, in research environments they are used in areas that tend to fall outside their intended impact conditions. The U.S. Army has used the HIII, a frontal-impact dummy, for many years now to validate vehicle safety systems for under-body blasts. The PRIMUS Dummy was originally designed to be used in pedestrian impacts but it's use in other environments has been growing over the years to include military applications.

The OPL was first introduced to the PRIMUS Dummy during an Engineer Scientist Exchange Program (ESEP) assignment at the Bundeswehr WTD-91 in Meppen, Germany. The Group 450 at the WTD-91 had been using the PRIMUS Dummy for under-body blast evaluations and other assessments. They reported on some of the military applications of the PRIMUS Dummy at the Dummy Crashtest Conference in Muenster, Germany in September of 2021. The PRIMUS Dummy is manufactured by Crash Test Services GmbH (CTS) of Muenster, Germany. Recently, Kistler Instruments, Inc. started marketing the PRIMUS Dummy in North America. As a result, CRADA number: 21-11 (PRIMUS Dummy Demonstrationb) was drawn up between DEVCOM GVSC and Kistler to allow examination of the PRIMUS Dummy in the OPL's environment. Other government organizations, such as the National Highway Traffic Safety Administration (NHTSA) have also taken an interest in PRIMUS and are planning to evaluate its performance in their environment as well.

The CRADA between DEVCOM GVSC and Kistler provides a unique opportunity for both parties to acquire assessment information for the PRIMUS Dummy in a military environment. In the terms of the CRADA the PRIMUS will be tested on a number of systems that the OPL utilizes; live-fire (Generic Hull), CCUBS, SSDT, and the WIAMan whole body certification test. This report details the findings from the first phase of the CRADA effort, a live-fire test conducted using a Generic Hull. Testing using the CCUBS has been planned and is tentatively scheduled for mid-March 2022. In all tests the responses of PRIMUS will be compared to the inputs delivered to it and to those of either a HIII or a WIAMan ATD depending which test system is utilized.

Compared to HIII or WIAMan, PRIMUS is a lower cost alternative that may prove to be useful in some of the unique environments confronted by the OPL, and to those developing injury mitigating technologies. The PRIMUS Dummy in this study had nine accelerometers arranged in tri-axial configurations in the pelvis, chest, and the head, it also had three angular rate sensors in the head to measure head rotations about the three principle axes. The HIII had similar instrumentation and also included the ability to measure forces and moments in the legs, lumbar, and neck. Similar measurements could also be incorporated into a PRIMUS Dummy if needed. For this study the accelerations in the head, chest, and pelvis of the PRIMUS Dummy will be compared to the seat acceleration inputs and to the corresponding measurements from a HIII.

METHOD

In December 2021 a Generic Hull live-fire test was conducted at the Fort Polk, LA test range. The test was specifically designed to provide baseline data to correlate live-fire testing to in-laboratory testing using the CCUBS. The test also provided an opportunity to evaluate the PRIMUS Dummy in an OPL live-fire environment.

The generic hull surrogate was fitted with six (6) COTS seats designed to reduce vertical loading during an under-body blast event. Three (3) of the seats had a stroking capability and three (3) were absent of this capability. Each seat was instrumented with four (4) Endevco model 7270-2k accelerometers, three (3) were arranged in a tri-axial arrangement and mounted near the base of the seat mount, the fourth was mounted to the seats stroking mechanism to capture vertical acceleration of the mechanism. The accelerometers were terminated to a DTS, Inc. SlicePro data acquisition system that was programmed to record the accelerations at 500kHz. Six (6) ATDs were positioned in the seats, all the ATDs had internal data acquisition systems. One (1) ATD was the PRIMUS Dummy, seated in position 2, the remaining ATDs were HIIIs. The ATD data acquisition systems were programmed to sample dummy responses at 20kHz. All data acquisition systems were synchronized by a central trigger that coincided with start of the event.

The ATD and seat acceleration data were post-processed using MATLAB version R2015b. Scripts were written to extract the data of interest from the data files. The data was then run through a routine to eliminate any offset that remained after the zeroing of the amplifiers. This was accomplished by averaging the first 200 points of the steady state of each channel prior to event initiation, this average was then subtracted from the entire data channel to bring the steady state to an engineering value of zero. The data was then truncated from the original size down to the region of interest. The reduced data set was then saved to MATLAB structures for further processing.

Processing of the data mainly consisted of filtering the data to remove noise that did not contribute to further analysis. The data in this test series contained significant noise due to extreme vibrations generated during the test event. This required other than standard SAE Channel Class filters to be used for the comparisons. Therefore, for the purposes of comparing dummy responses to seat input accelerations, and comparing dummy responses to dummy responses, an SAE Channel Class filter CFC60 was applied to all data channels examined.

Determination of the filter applied was accomplished by a method of frequency domain signal analysis and application of engineering judgement. The frequency domain analysis was performed on the seat acceleration data to determine if non-standard “CFC-like” filters were needed. Seat acceleration data was converted to Acceleration Spectral Densities (ASD) using the “pwelch” function in MATLAB. The pwelch function returns the Power Spectral Density (PSD) estimate of the acceleration data using Welch’s overlapped segment averaging estimator, each segment was windowed with a Hamming window.

The PSDs in this study are from acceleration data and are therefore Acceleration Spectral Densities (ASD) with units G^2/Hz. The ASDs are normalized, integrated, and plotted against frequency. The frequency where the normalized-integrated ASD reaches 0.5 units is determined to be the cut-off (-3dB point) for a “CFC-like” filter. CFC-like in this study is a low-pass Butterworth filter with a -24 dB/octave roll-off. Standard SAE CFC Channel Class filters (CFC1000, CFC600, CFC180, CFC60) have -3dB points at 1650Hz, 999Hz, 299Hz, and 99Hz respectively. For the frequency domain analysis in this study additional filters were designed with -3dB points of 12kHz, 10kHz, 7kHz, 6kHz, and 4kHz. These extended filters were designed to be used on the seat acceleration data that had been sampled at 500kHz.

RESULTS

Figure 1, Figure 2, and Figure 3 below shows the PRIMUS and HIII responses, filtered at SAE Channel Class CFC60, overlayed with the corresponding seat accelerations also filtered at SAE Channel Class CFC60. Clear trends in the seat acceleration data and the corresponding ATD response can be identified. Figure 1 (Head responses) ,2 (Chest responses), and 3 (Pelvis responses) below are a series of subplots. One subplot for each direction (x, y, z) at each body segment (Head, Chest, Pelvis). Each plot has two (2) y-axes, one (1) for the seat accelerations (left), and one (1) for the ATD responses (right). The scale for the seat accelerations ranges from -20g to 20g, the scale for the ATD responses ranges from -5g to 5g. The time duration for all the plots in Figure 1 are 150ms. The seat accelerations are in gray, and the ATD responses are black. The PRIMUS responses are the top plot of all subplots, and the HIII are on the bottom.

It's important to note that the seat accelerations were taken at the base of the seat near to the mounting to the floor. Therefore, the horizontal direction accelerations (x, y) for the ATDs do not necessarily correlate to the horizontal seat accelerations.

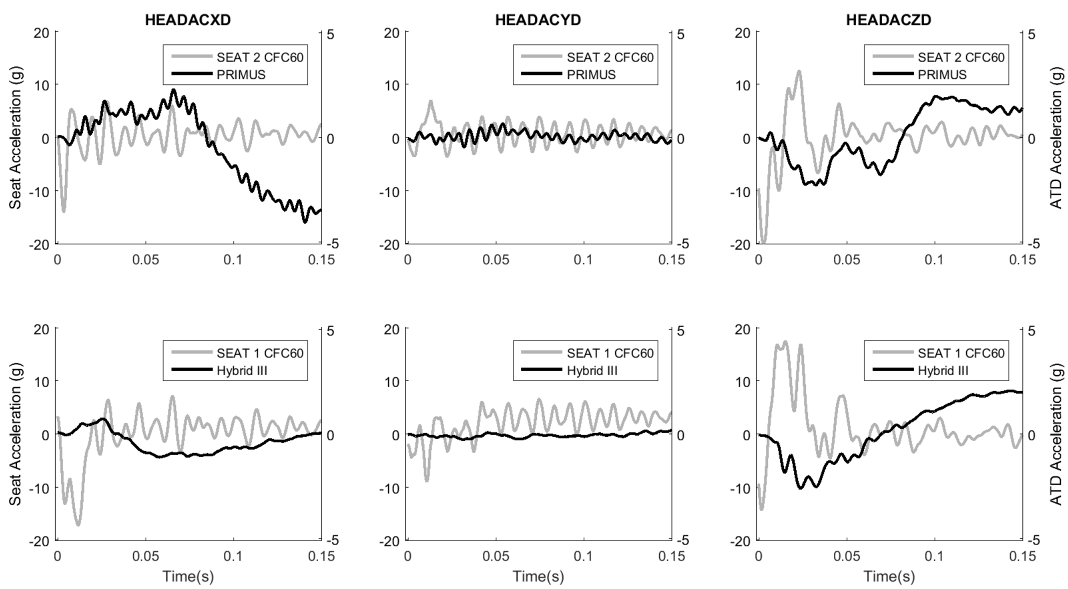

Figure 1 SAE Channel Class CFC60 ATD Head Responses Compared to SAE Channel Class CFC60 Seat Accelerations

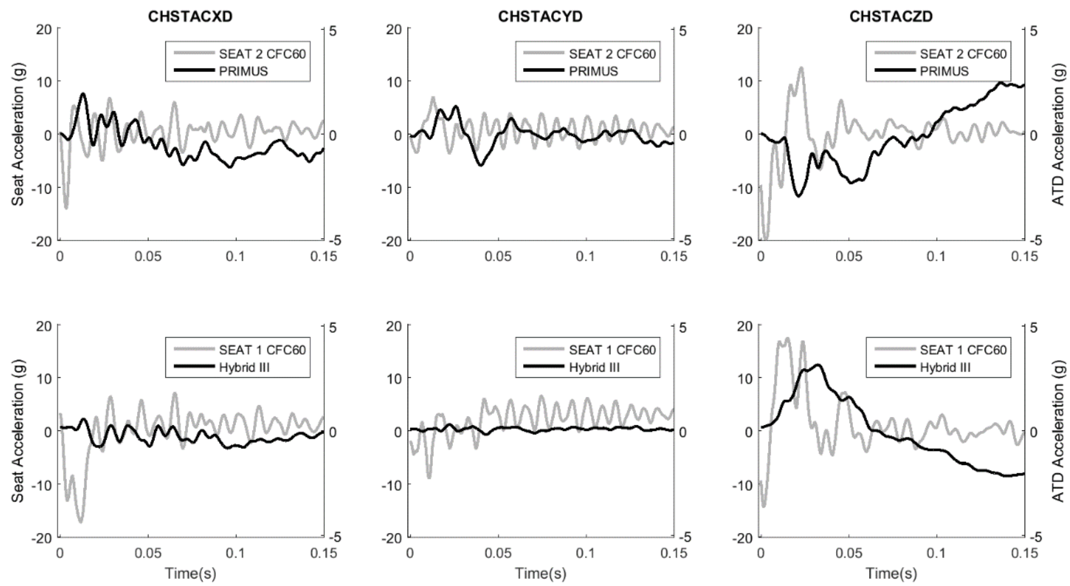

Figure 2 SAE Channel Class CFC60 ATD Chest Responses Compared to

SAE Channel Class CFC60 Seat Accelerations

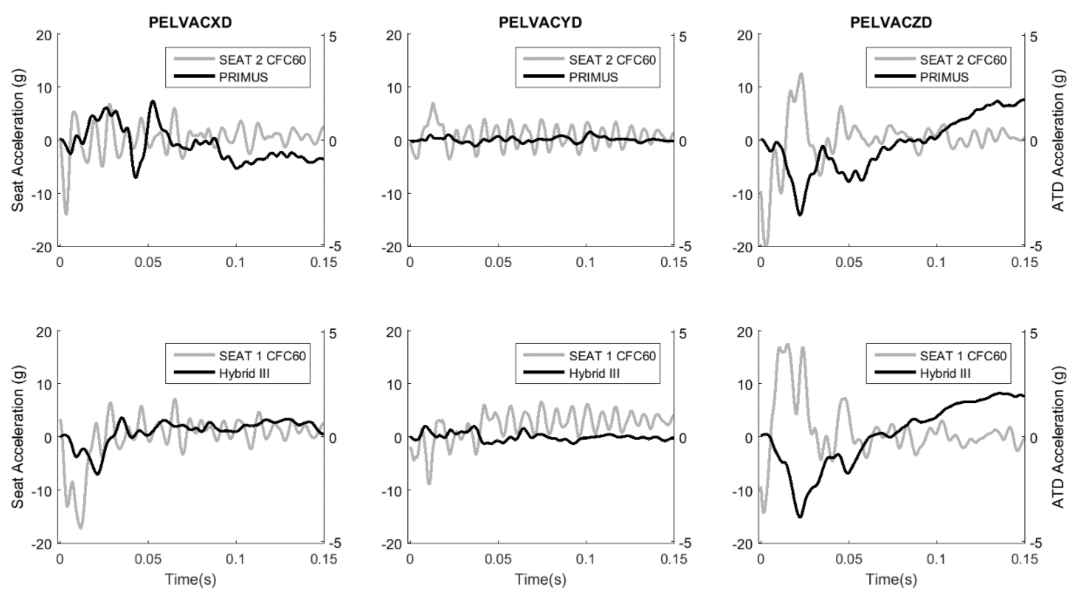

Figure 3 SAE Channel Class CFC60 ATD Pelvis Responses Compared to

SAE Channel Class CFC60 Seat Accelerations

DISCUSSION

A generic-hull live-fire test was conducted in December 2021. The hull was fitted with commercial-off-the-shelf blast mitigating seats, three (3) stroking, three (3) non-stroking. Positioned in the seats were six (6) ATDs, one (1) PRIMUS dummy in position 2, and five (5) HIII 50^{th} male ATDs in the remaining seats. The purpose of the test was to provide baseline data for a live-fire to laboratory correlation using the CCUBS. The test also provided a platform to evaluate the performance of the PRIMUS dummy in the OPL environment in accordance with a CRADA between DEVCOM GVSC and Kistler Instruments, Inc.

Processing live-fire acceleration data is challenging and requires significant engineering judgement to elucidate the important characteristics of signals acquired. Typically, non-standard approaches are needed to “clean up” the acceleration data so that identifiable trends can be seen and conclusions drawn. The data in this study, both seat acceleration data and ATD response data, were contaminated by significant low frequency noise caused by excessive vibrations of the vehicle surrogate structure. Therefore, in addition to frequency domain analysis of the acceleration data, engineering judgement was utilized to determine the final processing of the data from this test.

Seat Acceleration Data Processing

A first step in examining seat acceleration data in this study employed frequency domain analysis of the seat acceleration data. The process involved obtaining the Acceleration Spectral Density of the seat accelerations. This was accomplished, in MATLAB, by utilizing the “pwelch” function. Which, returns the Power Spectral Density (PSD) estimate of the acceleration data using Welch’s overlapped segment averaging estimator.

Welch's overlapped segment averaging PSD estimate of the seat acceleration signals was obtained using segment lengths of 1500 samples with 300 overlapped samples and with 500 DFT (Discrete Fourier Transform) points. A sample of the MATLAB code to accomplish that is shown below.

```
[pxx,f] = pwelch(Seat1AccelZ(:,1),1500,300,500,fs)
```

The ASD can be further processed to generate Velocity Spectral Densities (VSD), and Displacement Spectral Densities (DSD). These are calculated by integrating, or double-integrating the ASD with respect to the square of ω ((2*pi*f)^2). The area under the ASD, VSD, and DSD are the average acceleration, average velocity, and average displacement, respectively. Figure 4 below shows the results of obtaining the ASD, integrating, and normalizing. In Figure 4 below the -3dB points for each of the six accelerometers arranged in a tri-axial fashion on the seat frames in position 1 and position 2 are identified. For Figure 4, the seat 1 ASDs are on the left and seat 2 are on the right, the x-direction ASD is on the top, y-direction in the middle, and the z-direction on the bottom.

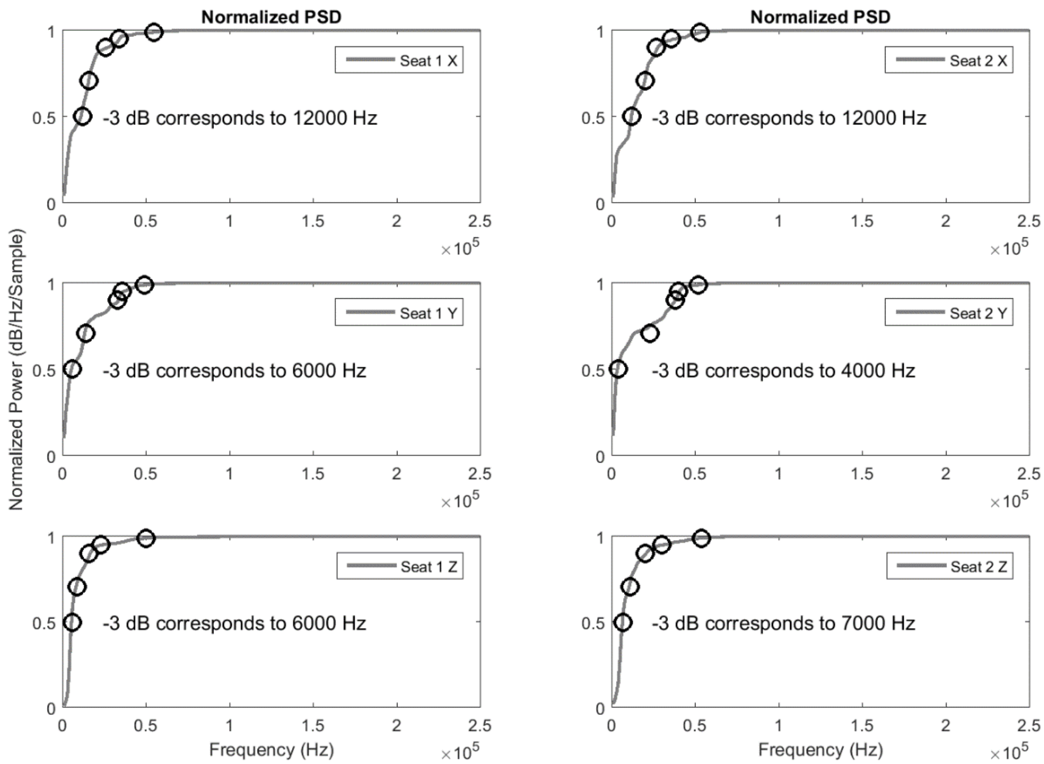

Figure 4 Integrated Normalized Acceleration Spectral Densities for the Position 1 and 2 seats

In Figure 4 above it can be seen that different -3dB points were identified for each direction the seat accelerometers were sensitive to as well as different for each seat. This is the nature of under-body blast energy distribution through the surrogate hull and the effect it has on acceleration measurement. However, it can also be seen that for each acceleration measurement, ASD magnitude did not increase beyond 50kHz.

Figure 5 below shows the seat accelerations from the position 1 and position 2 seats filtered at the -3dB points identified by the frequency domain analysis. While there is a significant reduction in peak values and the identified -3dB points might be useful for further numerical analysis, no clear trends are visible from the filtered data that would allow comparison to ATD responses. Since the lowest -3dB point identified on any of the axes was at 4000Hz the acceleration data for both seats were filtered at "CFC4000" and re-examined.

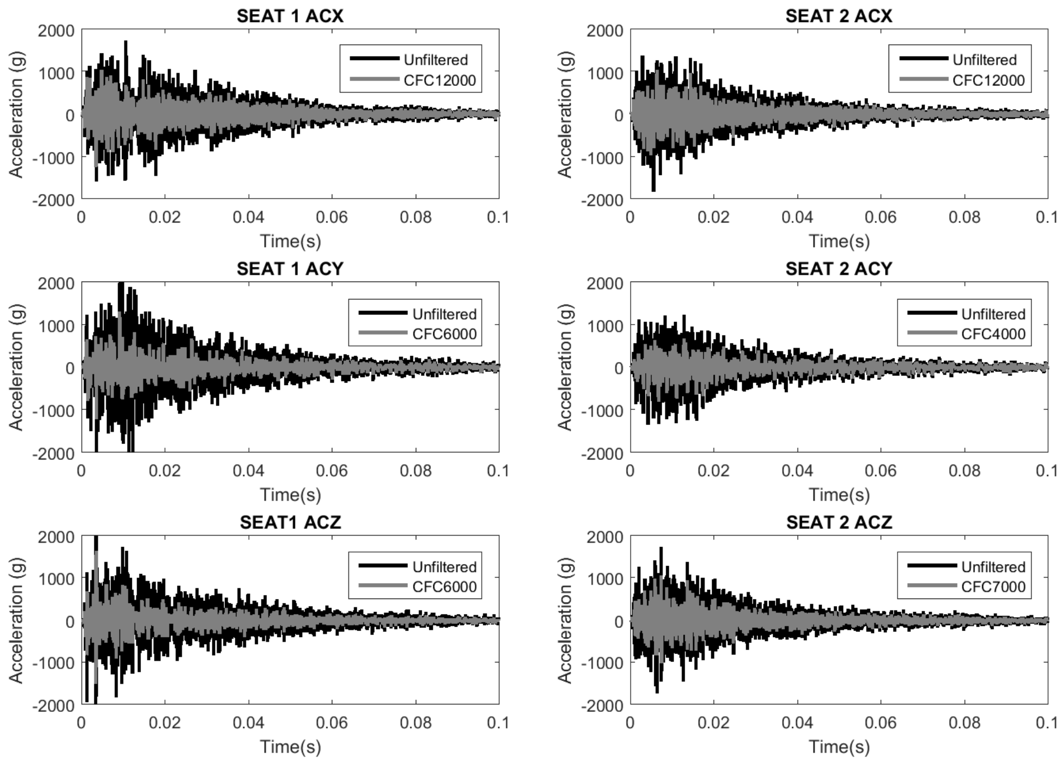

Figure 5 Seat Acceleration Data Filtered at -3dB Points Identified

Since the -3dB points identified in the ASDs did not produce signals with identifiable trends when filtered at the corresponding cutoffs, it was decided to examine the acceleration data at the lowest -3dB point identified, 4000Hz. Figure 6 below shows three different ASDs for the seat 1 and seat 2 accelerometers. Figure 6 is two (2) subplots, each subplot has three separate graphs, the x-axis acceleration ASD is shown in the top plot, the y-axis in the middle, and the z-axis on the bottom. Each plot has three ASDs plotted, one (1) is the ASD calculated from unfiltered acceleration data, one (1) is derived from data filtered at the identified -3dB point for that signal, the final one is from "CFC4000" filtered data. All the plots have a range on the abscissa up to 50kHz, the point where the ASDs did not gain more energy. The ordinate range is set to a maximum of 3, this allows observation of the difference in magnitudes of the PSDs for each of the measurement directions. The data shown in Figure 6 demonstrates the effect of the low-pass filtering, where the higher frequencies are significantly reduced after the respective -3dB points, however for all the signals, a major peak in energy remains above 1kHz. This peak is an indication of the noise due to vibration that contaminates these signals.

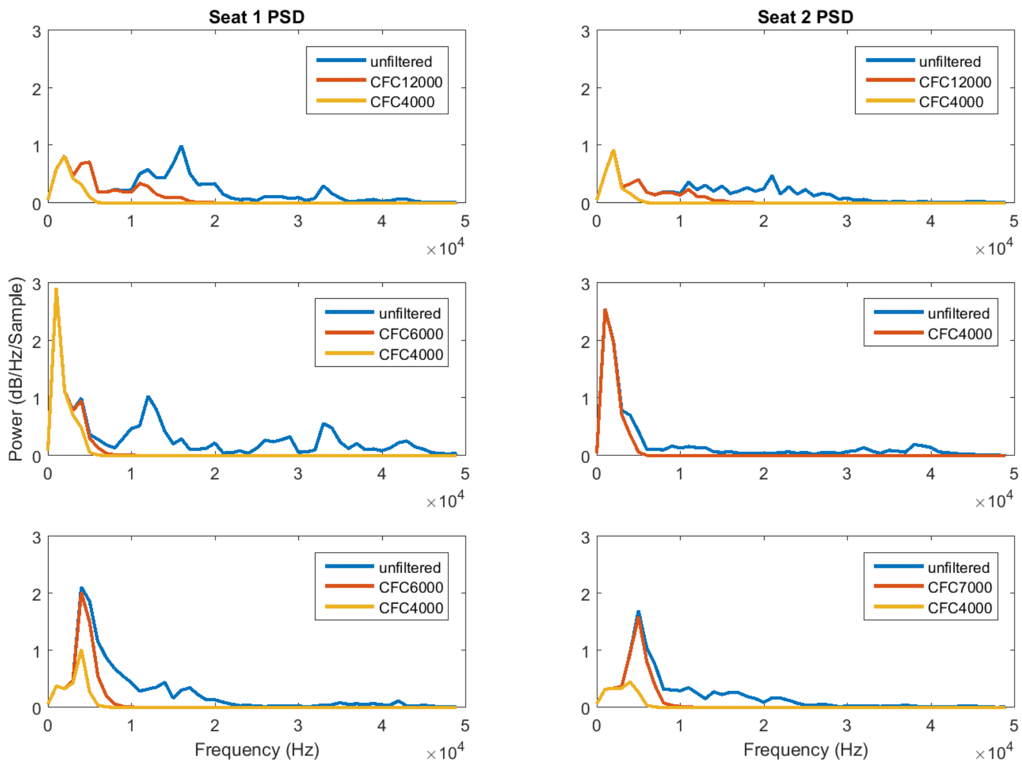

Figure 6 Acceleration Spectral Densities at various -3dB points

Figure 7 below shows the result of integrating the ASDs from Figure 6, this further demonstrates the effect of the low-pass filtering. Figure 7 is two (2) subplots, each subplots has three separate graphs, the x-axis acceleration integrated ASD is shown in the top plot, the y-axis in the middle, and the z-axis on the bottom. Each plot has three integrated ASDs plotted, one (1) is the integrated ASD calculated from unfiltered acceleration data, one (1) is derived from data filtered at the identified -3dB point for that signal, the final one is from "CFC4000" filtered data. All the plots have a range on the abscissa axis up to 50kHz, the point where the ASDs did not gain more energy. The ordinate range is set to a maximum of 20,000, this allows observation of the difference in magnitudes of the PSDs for each of the measurement directions.

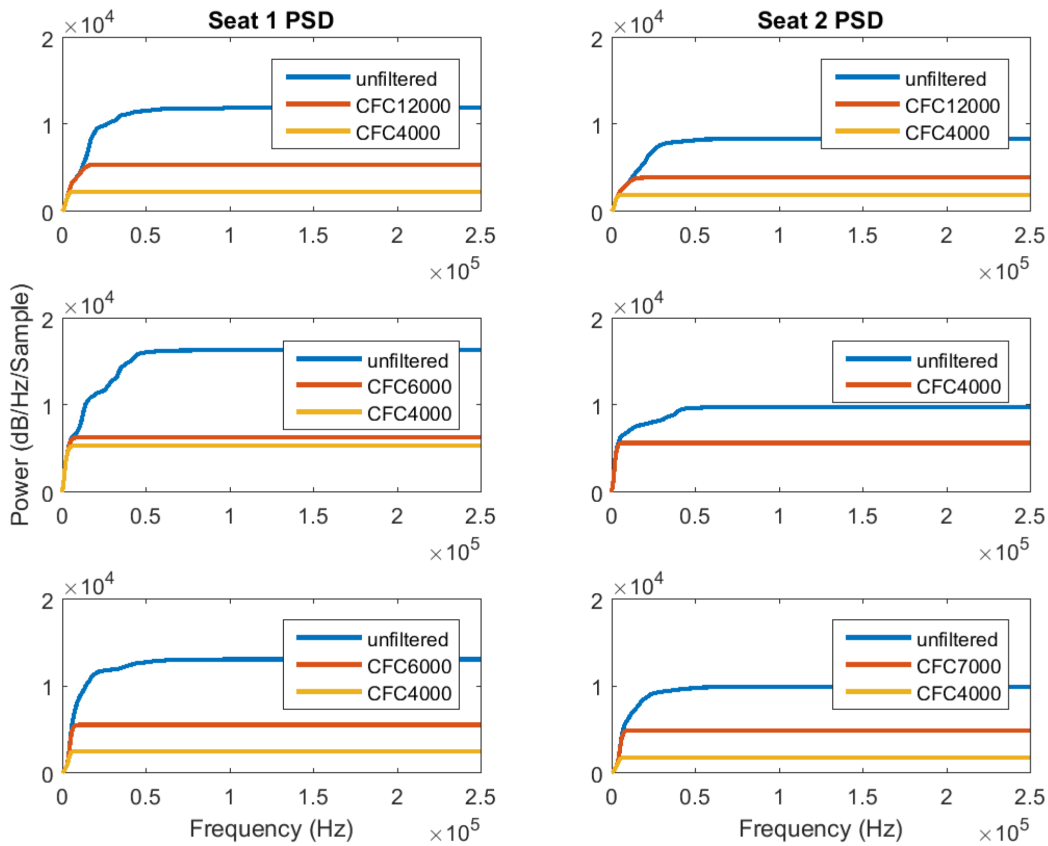

Figure 7 The Integrated ASDs from Figure 6

As demonstrated, filtering the signals with a cutoff at 4000Hz still leaves significant noise present and in fact since the peaks in the ASDs in Figure 6 are located around 1kHz for the x and y axes, and approximately 4kHz for the z-axis, this indicates the need to apply a significantly stronger filter to illuminate any trends in the seat acceleration data. Therefore, it was decided that an SAE Channel Class Filter CFC60 would be needed to reveal these trends. Filtering at CFC60, tends to produce undesirable effects at the beginning of signals and can produce data that doesn't start at a value of zero engineering units. CFC60 filtered data also tends to show negative going reactions before event initiation. Additionally, peak values are significantly reduced from the unfiltered levels, because of that it is unclear what the true peak acceleration values were. However, for the purposes of comparing seat accelerations to ATD responses, it is reasonable to filter the data strongly so that trends can be identified and related to ATD responses.

Figure 8 below shows the seat accelerations from the position 1 and position 2 seats filtered at SAE Channel Class CFC60 compared to the unfiltered acceleration. Clear trends are visible from the filtered data that would allow comparison to ATD responses. Figure 8 below is a series of subplots. One subplot for each direction (x, y, z) at each seat (seat 1, left; seat 2, right. Each plot has two (2) y-axes, one (1) for the unfiltered accelerations (left), and one (1) for the CFC60 filtered acceleration (right). The scale for the unfiltered seat accelerations ranges from -2000g to 2000g, the scale for the CFC60 filtered acceleration ranges from -50g to 50g. The time duration for all the plots in Figure 8 are 100ms. The unfiltered seat accelerations are in gray, and the CFC60 filtered acceleration are black. The x-direction accelerations are the top plot of all subplots, and the z-direction are on the bottom.

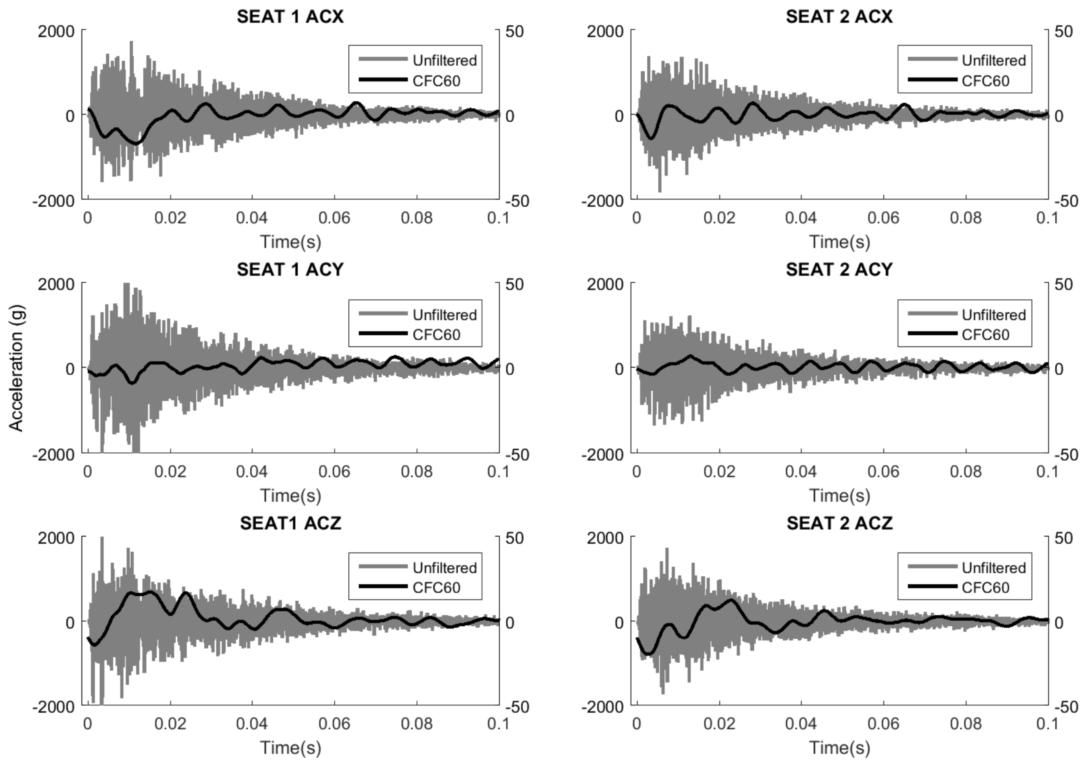

Figure 8 Seat Accelerations Filtered at CFC60

In Figure 8 above the CFC60 filtered acceleration data has significantly less noise compared to the unfiltered data, which is expected. The magnitude of the acceleration is also significantly reduced, also expected. The magnitudes in the filtered data may or may not be true magnitudes, at this point it would be difficult to prove what those magnitudes should be. Once the correlating testing is performed on the CCUBS it may be possible to estimate what the magnitudes should be based on the ATD responses. Additionally, such strong filtering of the acceleration data induces undesirable effects on the beginning portion of the acceleration data. It may be possible to see how much of an effect is being imposed by comparing gradually less harshly filtered data. However, for the purposes of examining ATD responses to seat acceleration inputs, the SAE Channel Class CFC60 filter applied to the seat acceleration data is reasonable.

ATD Response Analysis

In Figure 9 below, the ATD Head z, Chest z, and Pelvic z acceleration responses filtered at the CFC Channel Class CFC1000 recommended by SAE J211, are overlayed on corresponding seat accelerations filtered at “CFC4000”. PRIMUS responses are along the top and HIII are along the bottom. In Figure 9 two things are readily apparent in these comparisons. First, there is still significant noise in the head, chest, and pelvis accelerations due the extreme vibrations in this test. Second, the "CFC4000" filter is not producing a signal that has any identifiable trends that could explain dummy responses. This reinforces the conclusion that both the ATD responses and the seat inputs will need to be filtered at a lower CFC than recommended to remove the noise caused by lower frequency vibrations.

Figure 9 below is a subplot. Each plot has two (2) y-axes, one (1) for the seat accelerations (left), and one (1) for the ATD responses (right). The scale for the seat accelerations ranges from -1000g to 1000g, the scale for the ATD responses ranges from -20g to 20g. The time duration for the plots are 500ms. The seat accelerations are in gray, and the ATD responses are black. The PRIMUS responses are the top plot, and the HIII are on the bottom.

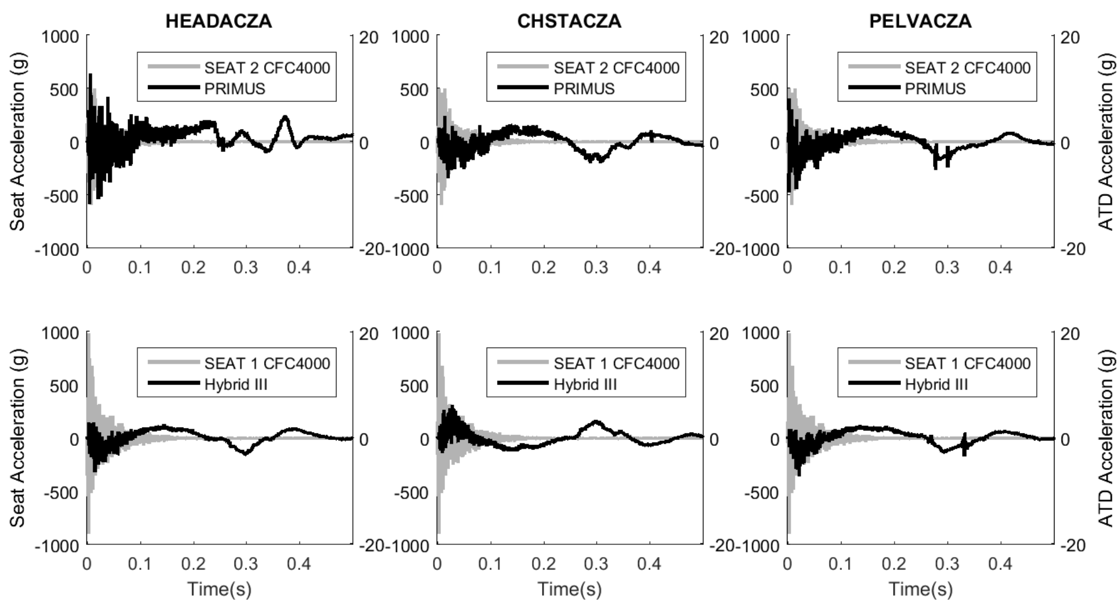

Figure 9 ATD CFC1000 Responses Compared to Seat CFC4000 Accelerations

In Figure 10 below, the PRIMUS and HIII responses are shown filtered at the recommended SAE Channel Class CFC1000 and filtered at SAE Channel Class CFC60, demonstrating the extreme vibratory noise still present in the signal after the CFC1000 filtering. This comparison shows why it was necessary to apply a non-standard filter to remove the noise caused by low frequency vibrations from the signals of interest. For Figure 10 below, 500ms of data is presented to show the ATD responses after the event. The PRIMUS responses are given as gold (CFC1000) and black (CFC60) lines, while the HIII responses are given as orange (CFC1000) and gray (CFC60) lines.

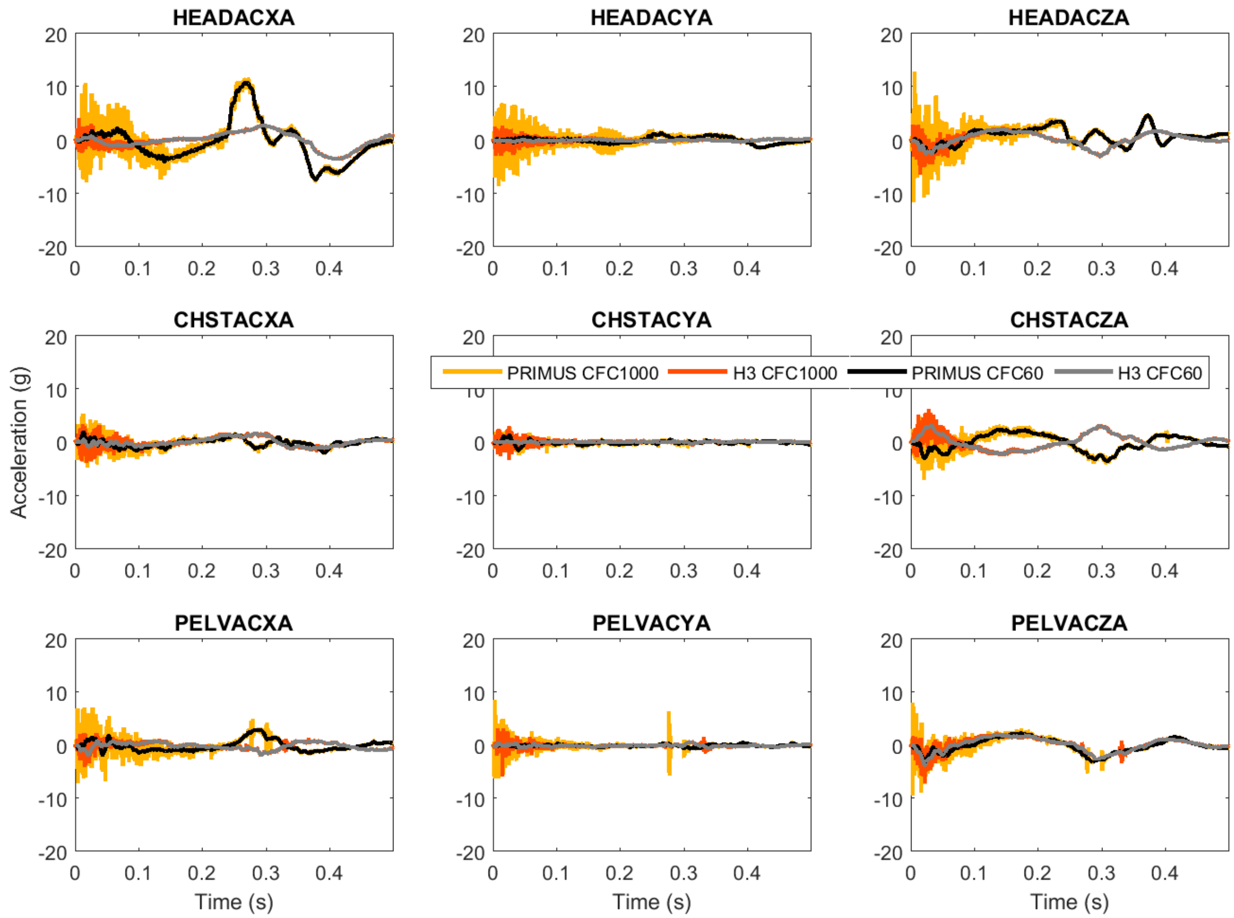

Figure 10 Comparison of ATD Responses at CFC1000 and CFC60

In Figure 10 above the benefit of filtering at SAE Channel Class CFC60 is obvious compared to the recommended CFC1000. The trends in the ATD responses are clearly visible and can be compared to the SAE Channel Class CFC60 seat accelerations. Filtering at this cutoff has negative effects, however for the purposes of comparing responses this is justified. Since both ATDs are filtered using the same Channel Class filter, the effects on both are equal.

ATD to Seat Comparison

With the filters determined for both the ATDs and the seats a comparison of the ATD responses to the seat inputs can be accomplished. Figure 11 below shows the SAE Channel Class CFC60 ATD pelvis accelerations compared to SAE Channel Class CFC60 seat accelerations. For Figure 11, the PRIMUS Dummy seated in position 2 is shown on the top, and the HIII seated in position 1 is shown on the bottom. The plots in Figure 11 are subplots with two (2) y-axes, the axis on the left is the seat acceleration and the axis on the right is the ATD accelerations. The time duration of the plots are 150ms.

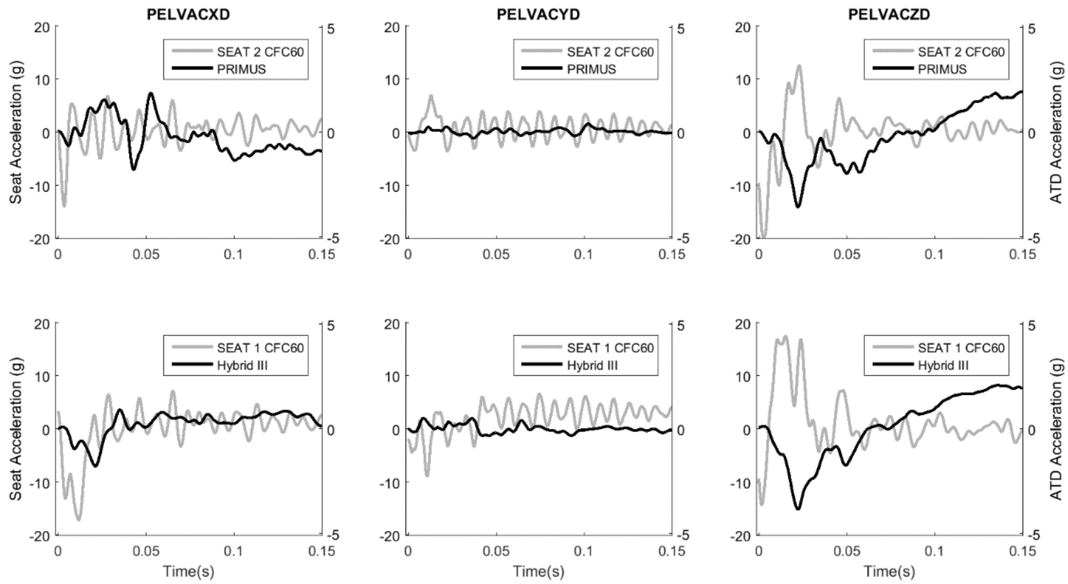

Figure 11 Head and Pelvis Z-direction Acceleration Comparisons

In Figure 11 above the responses of both ATDs to seat accelerations can be clearly observed. The differences in the seat position1 (bottom) and the seat position 2 (top) are minor. The rise of the vertical acceleration profile is nearly at the same time for both seats, while position 1 keeps rising to a peak value, and position 2 experiences a local nadir. Both accelerations have a similar duration, with position 2 slightly longer. Position 2 experiences a second peak before returning to zero. Both positions return to zero at around 3ms, and both show a secondary peak around 4ms.

For the pelvis accelerations the trends are similar. Both ATDs show a clear response to the acceleration profile and the ATD acceleration changes as the seat acceleration changes. The peak magnitude at about 2.5ms is nearly identical for both ATDs. The PRIMUS Dummy pelvis acceleration appears to reach zero at around 3ms and then a secondary response starts which is sustained until approximately 8ms, following the input shown for seat 2.

ATD to ATD Comparisons

Figure 12 below shows the comparison of the ATD responses. All nine measurements are plotted in the figure. The head accelerations are on the top, the chest in the middle, and the pelvis on the bottom. The x-direction accelerations are on the left, the y-direction in the middle, and the z-direction on the right. The plots are scaled from -5g to 5g, and the time duration is 150ms. PRIMUS responses are in gray and HIII in black.

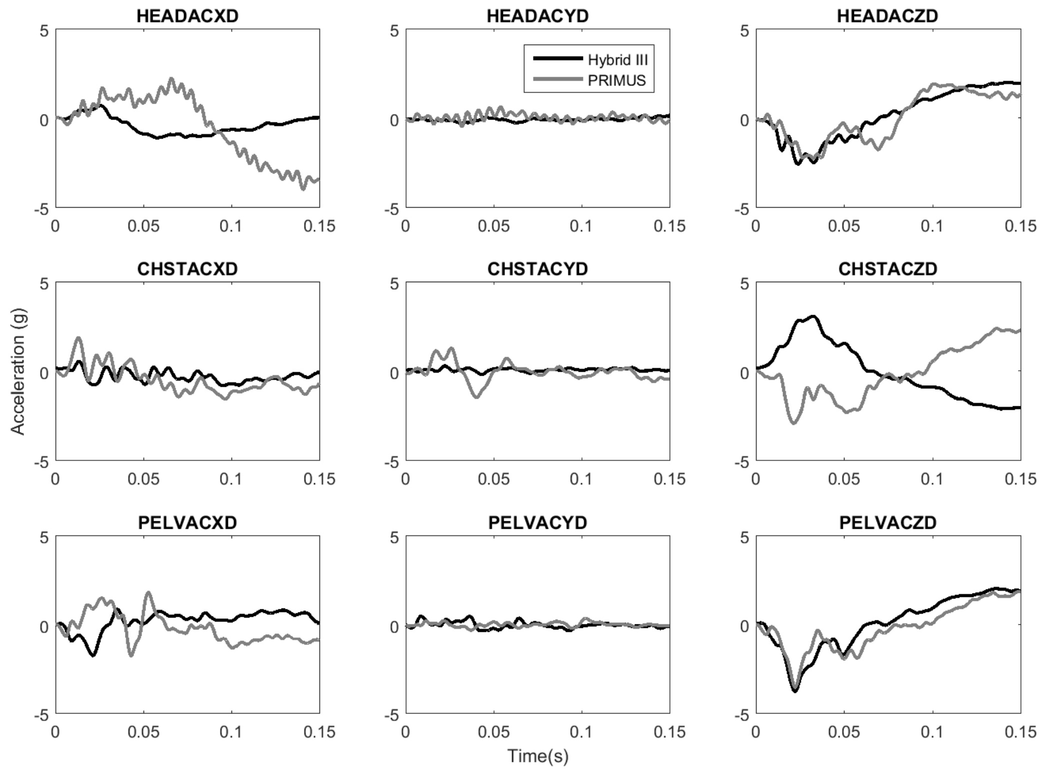

Figure 12 ATD to ATD Response Comparisons

In Figure 12 above for nearly all responses the PRIMUS Dummy matches the HIII responses very well. Differences seen in the Head CG x direction start around 20ms, long after the initial event has happened, and are likely due to the more compliant nature of the PRIMUS Dummy neck. For Chest z it appears that the accelerometer orientation in PRIMUS is 180 degrees of that in the HIII, otherwise the response matches well. Pelvis x accelerations show differences and these are likely driven by the differences in the seat accelerations in that direction.

For this test the main loading direction is vertical so more importance is placed on the vertical responses. Moving from the pelvis upwards, since this is the direction of loading; Pelvis z shows good matching between the PRIMUS Dummy and HIII through the entire 150ms examined; Chest z, as noted matches quite well, albeit inverted, some difference in the response of PRIMUS is noted and is likely due to the more compliant nature of the spine versus the highly stiff spine of the HIII; Head z has a very good match between PRIMUS and HIII up until 50ms, where some deviation is noted and also likely due to the compliance of PRIMUS.

Test Condition Considerations

The loading of the PRIMUS Dummy in position 2 and the HIII in position 1 through the seat are relatively low levels loadings when compared to laboratory scale tests conducted at the OPL. Therefore, the responses from the ATDs are relatively low as well. As an example, a test on the CCUBS would be conducted with a minimum input peak acceleration of 150g, compared to the approximately 10g peak accelerations seen in this test. It will be interesting to see if the comparisons for PRIMUS and HIII remain similar at higher loading conditions.

The input accelerations in this test were contaminated with significant vibrations from the hull's response to the event. This induced significant vibrations in both ATDs. Fortunately, filtering was able to remove the vibrations from the signals of interest and comparisons were able to be accomplished. However, non-standard filtering was needed to clean up the data from both the seats and the ATDs. This same level of filtering is not required in laboratory scale tests.

Conclusion

A live-fire test conducted in December 2021 provided an opportunity to examine the performance of the PRIMUS Dummy in an OPL environment. As part of a CRADA between DEVCOM GVSC and Kistler Instruments, Inc. the PRIMUS Dummy performance will be evaluated in several test systems in OPLs environment. PRIMUS performance will be compared to input accelerations applied as well as companion ATDs such as the Hybrid III 50th percentile male ATD and the WIAMan ATD. This test provided an opportunity to compare PRIMUS to a HIII.

This study found:

- Seat and ATD acceleration data required non-standard filtering to remove vibratory noise
- All acceleration data needed filtering using SAE Channel Class CFC60
- Seat acceleration inputs for position 1 and 2 seat were very similar
- ATD responses between the PRIMUS Dummy and the HIII were very similar
- At this level and direction of loading the PRIMUS Dummy is a suitable surrogate