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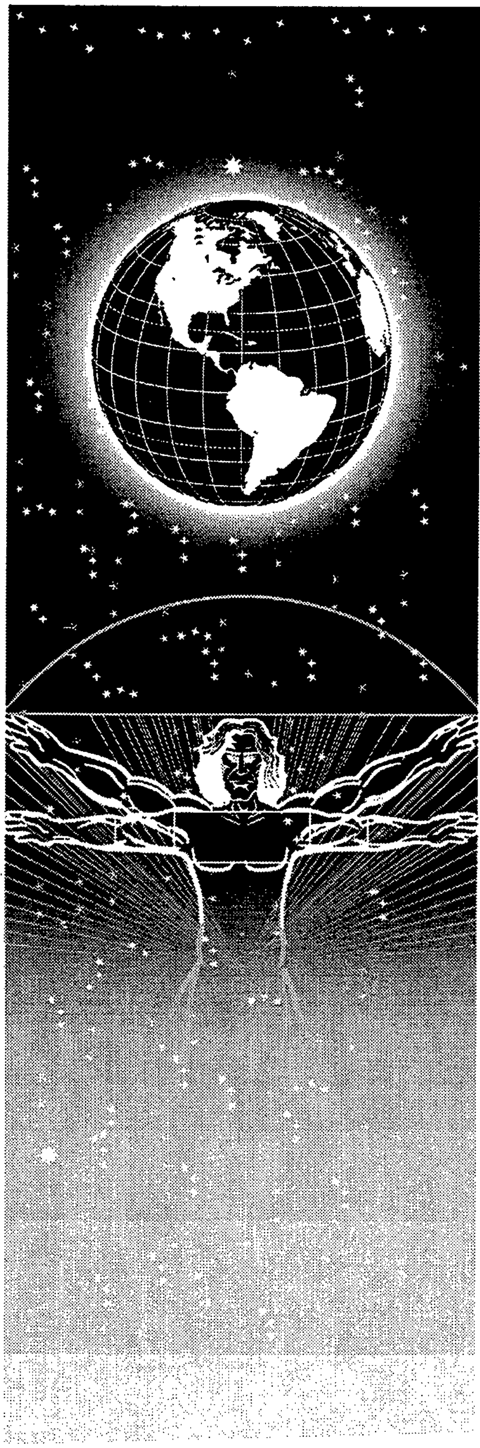

UNITED STATES AIR FORCE
ARMSTRONG LABORATORY

DESIGN OF A WINDBLAST DATA ACQUISITION SYSTEM

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This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

HENDRICK W. RUCK, PhD
Chief, Crew System Interface Division
Air Force Research Laboratory

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Classifying helmets safe to fly is of major importance to the USAF and DoD in general. Helmets are put through numerous rigorous tests before the design is rated flight worthy. One such test is the windblast. This test is designed to simulate the wind's forces and speeds the pilot and helmet will be subject to upon ejecting from a crippled aircraft. Data is collected pertaining to the helmet shift on the head, lift and drag forces experienced by the helmet and it's reaction to them. The Data Acquisition System (DAS), designed and built by AL/CFB utilizing off-the-shelf hardware and software, was used to collect this data. It replaced an older system in which data collected was subject to as much as 30 percent offsets of peak values, was susceptible to noise corruption and was subject to a secondary review costing additional time and money. This report contains detailed information on the design and function of the hardware and software components of the DAS and also a detailed explanation of how the hardware and software processes were validated.

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DESIGN OF A WINDBLAST DATA ACQUISITION SYSTEM

Figures:

DESIGN OF A WINDBLAST DATA ACQUISITION SYSTEM

Background

Collection of reliable and accurate windblast data for the purposes of classifying helmets as safe to fly has been for a large part filled with uncertainty. The developer of the currently used Data Acquisition System (DAS), which is operated by AL/CFB, considers their design proprietary, thus much of how the data is collected and processed is not subject to the secondary reviews that are a normal part of good scientific methods. When reported data is analyzed the lack of second party scrutiny becomes suspect. Offsets as large as 30 percent of the peak value are observed. Many tests show waveforms that do not settle to zero or the initial offset after the event. Poor shielding of cables and hardware increases susceptibility to noise corruption, and reported values of the Knots Equivalent Air Speed (KEAS) are significantly inconsistent with values the test site operators (Dayton T. Brown) report from their equipment. Add to this a $20,000 support cost fee per test sequence to operate the DAS and safety implications of the data seems prudent to develop a new system that eliminates the uncertainty of processing techniques, improves data reliability, and is subject to secondary review.

Using commercially available hardware and software components from National Instruments, the Helmet-Mounted Systems Technology (HMST) has developed a new DAS to address and eliminate the uncertainties associated with the current system. All information on how the data is collected and processed is readily accessible in either the source code of the software or the published literature of National Instruments. Both hardware and software processes are described in comprehensive detail. The major focus of the development was designing and configuring the software and hardware components so that accuracy and reliability of reported data was greater than, or equal to, what is currently used, and validation of the design. An overview of the design is presented and followed by a discussion of the validation of the major processes in the acquisition event.

Design Overview

The DAS collects data from up to 16 different channels. The signals from transducers are routed through 16 conductor shielded twisted pair cable into signal conditioning modules housed in a shielded chassis. Once the modules perform conditioning on the input signals, they are multiplexed and routed to the DAQ Card where the signal is quantized and stored to memory. From there the software processes and reports data in a user-specified format. A more detailed discussion of hardware and software component functions follows. A block diagram of hardware components and a picture of the HMST DAS is shown in Figure 1 and Figure 2 respectively.

16-Conductor Shielded Twisted Pair Cables

The first design trade-off encountered in the design is in the cable construction. It was desired to have the ability to operate the system indoors if necessary while test items remained outdoors. To do this cable lengths needed to be extended to 125 feet compared to 30 feet that would otherwise be required to be a safe distance from the test setup. Increased line length increases susceptibility to noise sources and parasitic capacitive and inductive coupling in the wires. To compensate for that, a shielded twisted pair wire scheme is used. The shielding provides some protection from outside noise sources as well as serves to eliminate capacitive coupling effects due to the distributed capacitance of a "long line."

of a single half twist. Sixteen conductors are used because they provide the signal and excitation lines for four channels which is the number a single terminal block can handle.

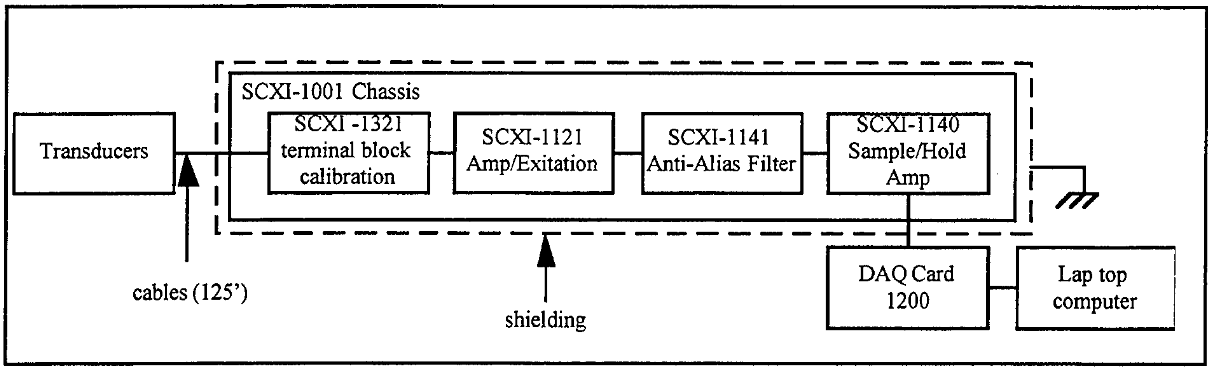


Figure 1: **Block diagram of HMST DAS**

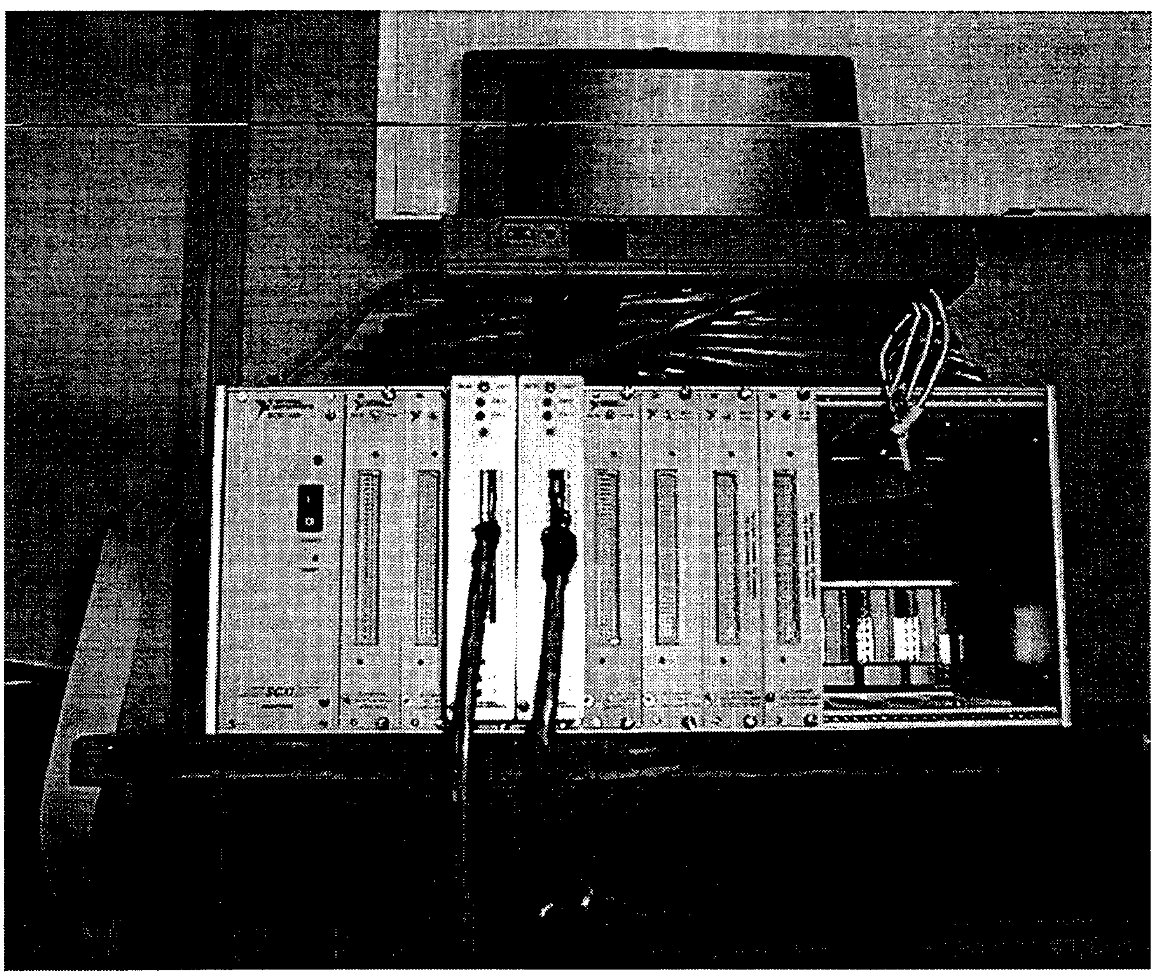


Figure 2: HMST DAS

Twisted pairs work to eliminate common mode noise that enters through the transducer signal lines or that penetrates the conductor shield and reduces inductive coupling effects to no worse than the effects that would be observed if the straight line lengths were the length of a single half twist. Sixteen conductors are used because they provide the signal and excitation lines for four channels which is the number a single terminal block can handle.

SCXI-1001 Chassis

The National Instruments SCXI-1001 chassis houses and provides power and shielding for up to 12 signal conditioning modules. The shielding from the cables is tied to the metallic chassis frame to provide a continuous shield and a single-point ground through the chassis ground. The chassis' backplane serves as a bus line for routing control signals between the modules and from the DAQ Card-1200 to the modules.

DAQ CARD-1200

The National Instruments DAQ Card-1200 is the control board for the data collection process. It has the chassis configuration stored in memory and based on software instructions, can route control signals and clocking signals to the appropriate modules. It also performs 12 bit A/D conversion of the input signal with 2.44mV of resolution full scale, and has a 1024 Finite Input Finite Output (FIFO) buffer. System noise in the card is .3 LSBrms, excluding quantization error.

SCXI-1321 Terminal Block

The primary function of the National Instruments SCXI-1321 terminal block is to provide a variable resistance in parallel with a transducer bridge resistance (Figure 3). Each SCXI-1321 provides the calibration resistances for four channels. Using a screw control adjustment, the bridge can be manually balanced prior to an acquisition providing an effective method of coarsely calibrating the channels for testing. Finer calibration is performed in software by determining the mean voltage across the channel after course calibration. This factor is later applied to the processed data as offset compensation. Details of the process are explained later. The software provides a graphical display of the voltage across the channel during calibration (Figure 4). The operator can use the display to perform course calibration of the channel prior to a test.

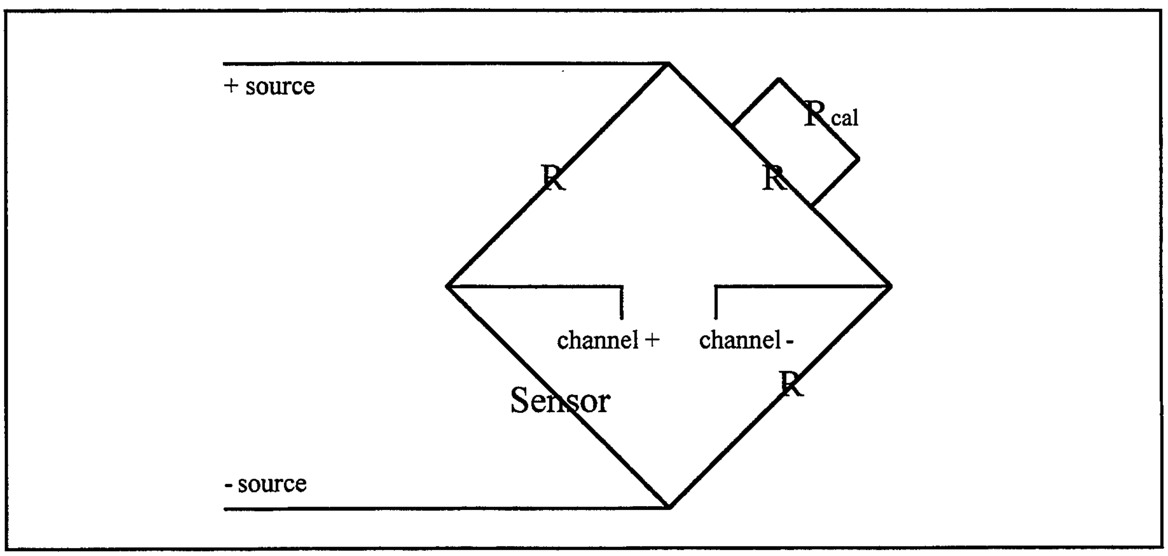


Figure 3: Variable calibration resistance in parallel with bridge resistance

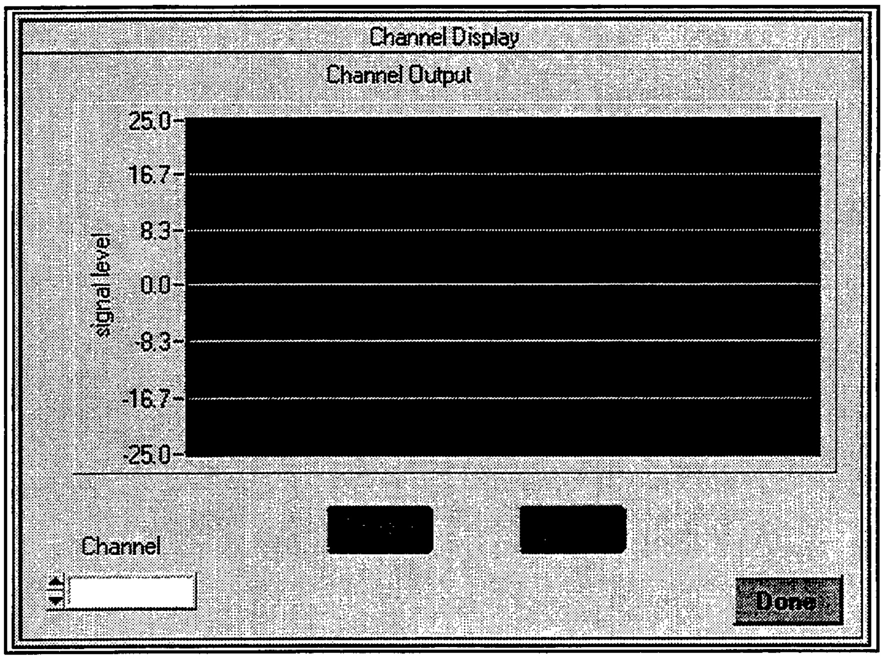


Figure 4: Graphical panel of HMST DAS that shows voltage across channel

SCXI-1121 Isolation Amp and Excitation

From the terminal blocks the signals are routed to the National Instruments SCXI-1121 modules. The modules are four channel signal amplifiers and transducer excitation sources providing jumper selectable gains from 1-2000, and jumper selectable excitations of 10V and 3.33V or .450mA and .150mA. They also provide up to 250 volts rms of isolation between channels and from channels to earth. Most of the windblast transducer signals generate peaks up to about 50mV. The DAQ Card can quantize bipolar inputs up to +/- 5V. Thus, most data channels have good resolution at 100 gain. All currently used transducers require 10V excitation sources. Each of the two SCXI-1121s feed into an SCXI-1141 lowpass filter module.

SCXI-1141 Elliptic Lowpass Filtering Module

The SCXI-1141 is an eight-channel eighth-order programmable, elliptic, lowpass filter which serves as an anti-aliasing filter. The elliptical filter was chosen because elliptic filters provide the sharpest roll off for a given order filter. Additionally, the programmable nature of the filter offers some control of where the rippling will occur. Using the default sampling rate of 4kHz sets the Nyquist frequency to 2kHz. The stopband, which should contain the Nyquist frequency, occurs at 1.5 times the cutoff frequency. The cutoff then becomes a maximum of 1333Hz. This cutoff provides both a flat magnitude response and linear phase response for the useful bandwidth of windblast signals dc-100Hz (Figure 5). Signal content outside of 100Hz can then be filtered out digitally during data processing.

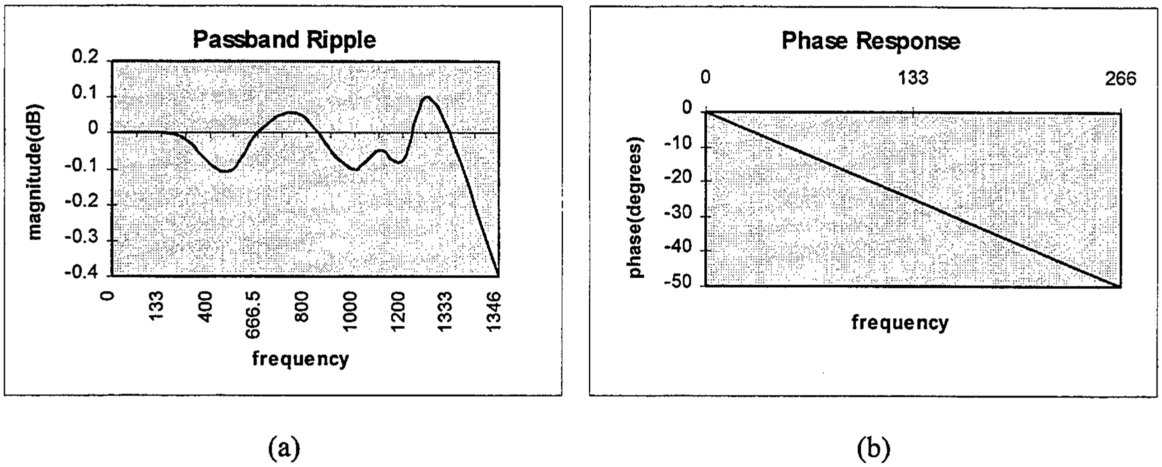


Figure 5: (a) Passband Ripple is essentially flat from dc to 100Hz. (b) Phase response linear from dc to 100Hz. Graphs adapted from SCXI-1141 User Manual

The filter is a hybrid of a continuous time and switched capacitor design. (For details on the programmable nature of the SCXI-1141 see Chapter 4 in the SCXI-1141 User Manual). The hybrid design provides better frequency control associated with a switched capacitor design while avoiding sampling errors as a continuous time filter would. So while it may seem that a conventional Butterworth or Inverse Chebyshev architecture would be more appropriate, the hybrid design of the SCXI-1141 allows us to keep the useful bandwidth of windblast signals flat in magnitude and linear in phase while allowing better frequency control through its switched capacitor characteristics.

SCXI-1140 Sample and Hold Amp

The filtered signal from the SCXI-1141 is routed into an SCXI-1140. The SCXI-1140 operates in two states, track and hold. The state of the module is controlled in software. In track mode, the SCXI-1140 samples the input signals across all eight channels. When the SCXI-1140 receives the hold trigger from either the DAQ-Card or the backplane of the chassis, it will then hold the signal level at that channel. Those values are then multiplexed into a single channel and routed to the DAQ-Card for A/D conversion. The module in effect provides simultaneous sampling capability which allows analysts to compare events from different channels at the same instances in time.

Software Processing

After A/D conversion, the multiplexed signal is written to a disk file. From there it is demultiplexed into individual channel buffers. At that point the offset compensation factors calculated during calibration are applied to the data. The raw data buffers are then decimated to 500Hz by resampling every eighth point. From there, load cell and accelerometer data is Finite Impulse Response (FIR) filtered at 100Hz and pressure data is FIR filtered at 20Hz. The FIR filters were designed to approximate as close as possible the 12-pole digital Butterworth Filters used in the CFB design. A FIR filter was chosen because its linear phase response eliminates signal distortions that can occur from variable time delays (details are presented later). The 12-pole design is used to remove spikes that occur between 1.5-2.3fc of load cell data. This approach was taken so that data acquired using the HMST DAS could still be compared in terms of frequency and magnitude content with data acquired from the CFB design (details are presented later). The filtered data is then written to a separate processed data buffer. Data from either buffer, raw or processed, is available for graphical display and both can be saved in ASCII text format. A threshold analysis routine is available to set load limit criteria on processed data. If the load limits are set to reflect the safety criteria being used, the routine returns all instances that safety criteria were exceeded. The routine is performed by comparing the threshold to each data point and counting the number of consecutive data points that exceeded the value. The software also provides three reset options for configuring later tests. The options include reset with the same configuration and parameter values, same configuration but change some parameter values, and new configuration. It can also save the parameter values of the current configuration so that they can be loaded at a later time after shutdown. A block diagram of the software processes are shown in Figure 6.

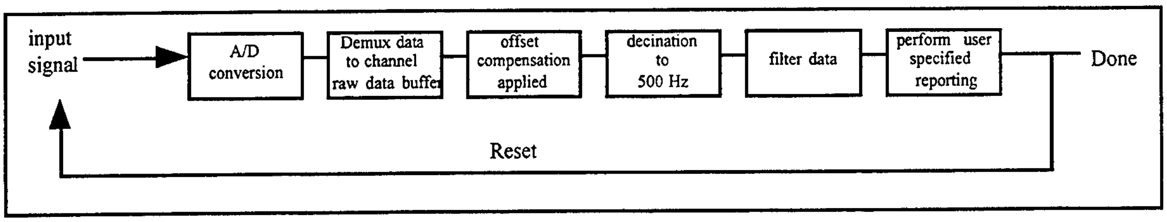


Figure 6: Block diagram of software processes

Validation of Software and Hardware Processes

In order to collect accurate and reliable data, the design of the acquisition system needs to be validated. The major points of concern are:

1. Can the system accurately report back known inputs?
2. Is the sampling rate sufficient and are the samples evenly spaced?
3. Are the channels sufficiently calibrated prior to testing to prevent offset errors?
4. Are the processing algorithms (decimation and filtering) legitimate for the application?

If these concerns are answered affirmatively then there is a minimized risk of data corruption and the reported data can be relied upon as accurate.

Validation with Known Input

Probably the easiest way to measure the accuracy of a device is to compare the output result with that of a known input. The closer they compare, the more accurate the system. This type of testing was done to measure the accuracy of reported data from the HMST DAS.

Step inputs between .5V and 2.5V were generated by a leader DC power source and measured with a Fluke Series 70 digital multimeter. The signals were then acquired by the HMST DAS. Measurements from both the DAS and multimeter were taken with 1mV resolution. Step inputs were used because they would provide a good indication if there would be overshoot problems or long steady state settling times that may cause data corruption, in addition to providing the known amplitudes. Results show that the DAS has accuracy to within .40 percent, with no significant overshoot or settling times. Overshoots were not at all evident in the tests and the signal settled to its steady state value within a single sample. The accuracy percentage also takes into account quantization errors from the DAQ Card-1200. To further validate the reporting accuracy, Sinusoidal signals of varied frequency and amplitude were generated using a BK Precision 3200 Function Generator. The rms voltage of the signal was measured with the Fluke Series 70 digital multimeter and recorded. The signal was then acquired by the DAS. Root mean squared values from the DAS were calculated from the observed peak values and compared with those taken from the multimeter. Resolution of the DAS and meter were again 1mV. Over a series of 15 tests the accuracy on average was calculated to be .52 percent. However; the accuracy is probably much better than that considering that 13 of the 15 tests done showed no difference between measurements made with the DAS or with the meter. Results of both step inputs and sinusoidal signals are shown in Figure 7 below. Relating this to windblast events, a helmet in a 600 KEAS blast under CREST criteria should not exceed 300 lbs peak tension load. At 300 lbs the uncertainty is approximately 1.5 pounds, not enough to significantly impact the pass/fail status of a helmet. Thus, its accuracy is reasonable in reporting windblast events.

Validation of Sampling Rate

Multiplexed data, as mentioned above, is written to a disk file. This was done because the scanning routine libraries provided in the National Instruments software did not provide a large enough buffer for storing data values. Writing to a disk file offers the storage space necessary but requires processing time that may change depending on the computer and processor used. The sampling rate could be limited by the speed of the processor writing to file. The DAS software is loaded on a Toshiba Satellite Pro 415CS and uses a 90MHz Pentium processor. To test for the best sampling rate that could be achieved, a BK Precision 3200 Function Generator was used to generate a sinewave signal the DAS could acquire. From the Nyquist Theorem a signal of half the sampling rate should be fully reconstructable. The point where the input signal is no longer fully reconstructable (aliased) determines the limit of the sampling rate that can be achieved.

	step response						sinusoidal tests		
test#	volts (meter)	volts (DAS)	deviation	%difference	freq	mV(rms) (meter)	mV(rms) (DAS)	deviation (mV)	%difference
1	1.000	1.001	0.001	0.10%	10	9	9	0	0.00%
2	1.000	1.011	0.011	1.10%	20	13	13	0	0.00%
3	0.998	0.996	0.002	0.20%	20	17	17	0	0.00%
4	1.507	1.511	0.004	0.27%	40	24	24	0	0.00%
5	1.504	1.500	0.004	0.27%	40	21	20	1	4.76%
6	1.493	1.500	0.007	0.47%	60	30	30	0	0.00%
7	1.999	2.007	0.008	0.40%	70	33	32	1	3.03%
8	2.005	2.000	0.005	0.25%	90	9	9	0	0.00%
9	2.005	2.012	0.007	0.35%	90	10	10	0	0.00%
10	2.501	2.515	0.014	0.56%	100	31	31	0	0.00%
11	2.512	2.524	0.012	0.48%	100	23	23	0	0.00%
12	2.513	2.524	0.011	0.44%	30	26	26	0	0.00%
13	0.509	0.508	0.001	0.20%	50	12	12	0	0.00%
14	0.508	0.505	0.003	0.59%	80	14	14	0	0.00%
15	0.508	0.510	0.002	0.39%	25	17	17	0	0.00%
		average		0.40%					0.52%

Figure 7: Accuracy measurement of HMST DAS to known inputs. The accuracies are shown for step response measurements and further verified sinusoidal

Sinusoidal data of one half the sampling frequency was acquired and Fast Fourier Transformed. The location of the impulse response on the frequency axis was compared to that of the input wave frequency. If a match was observed the sampling rate and input sinusoid frequency were proportionally increased. The process was repeated until an aliased waveform was observed (impulse location no longer matched input sinusoid). The last match determined the limiting sampling rate. Additionally the width of the impulse would give a relative indication of how evenly spaced the samples were. A sharper impulse corresponds to more evenly spaced samples. The limiting sample rate was determined to be approximately 4100Hz with about +/- 3Hz spacing (Figure 8).

The sampling rate was defaulted to 4000Hz. This was done for two reasons. The first is that load cell data off the CFB DAS was decimated, filtered, and reported at a 500Hz rate.

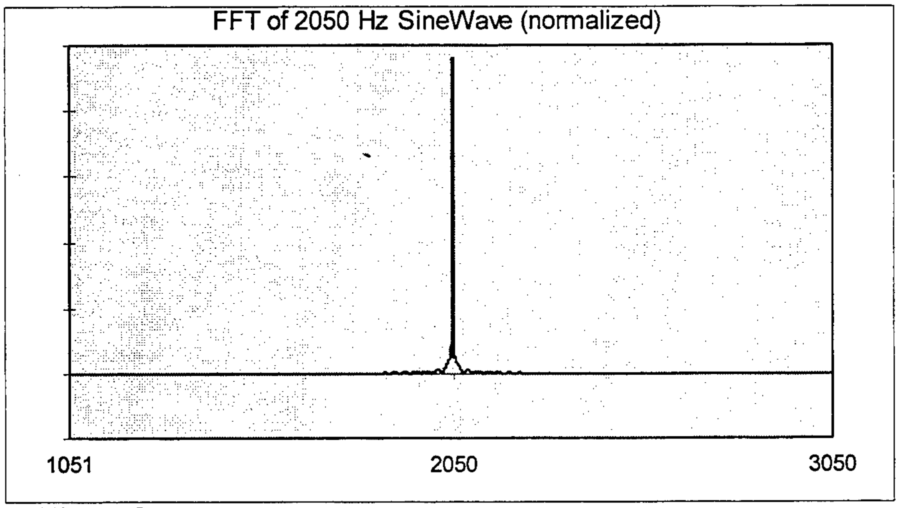


Figure 8: Validation of 4100Hz sample rate. FFT shows an impulse response at 2050Hz the Nyquist frequency

Having the same capability in the HMST DAS would allow for better relative comparisons of data from the two machines. Capitalizing on the maximum 4100Hz would prevent decimation to the 500Hz since an integral decimation factor is required. Secondly, A 4000Hz sample frequency provided a convenient corner frequency for the anti-alias filter. The stopband of the anti-alias filter starts at 1.5fc which should contain the Nyquist frequency. The filter can only achieve cutoffs with a frequency value of an integral divisor of 100,000 (clock speed). A Nyquist frequency that is 1.5fc corresponds to a cutoff frequency one third the sampling frequency. A 4000Hz sampling rate would require a 1333.33 cutoff frequency which just happens to be the value of an integral divisor (75) of the 100kHz clock. All relevant data occurs in the dc to 100Hz bandwidth and the signals are fairly stationary; therefore the data is well within the Nyquist Criteria for signal reconstruction. Thus, the 4 kHz sampling rate is validated.

Offset Compensation Validation

Extracting information from a transducer usually involves setting it in a balanced bridge configuration, i.e., no voltage across the channel lines, and allowing the event to alter some resistance which changes the voltage across the bridge providing a measure of the event. The better the bridge is balanced (calibrated) prior to a test the more accurate the output data is. Since the bridge resistances are usually a fixed value in an unexcited state the adjustment must be made by setting a parallel variable resistance across a bridge resistance and using the parallel equivalent to balance. The parallel resistance must come from the DAS and is independent of the sensor type. Unfortunately, it is virtually impossible to get really close to zero coarsely calibrating with a potentiometer. In a test where channels were coarsely calibrated adjusting a potentiometer the typical offset over 30 measurements was +/-.1909mV at 100 gain. Then measurements were taken again after an offset compensation routine was added in software. With offset compensation the offset was reduced to .0208mV, an 89 percent improvement (Figure 9). This is especially advantageous in pressure data where small pressure changes correspond to significant changes in KEAS. Offsets as large as 1 psi have been observed in various tests using the CFB design, which corresponds to a 204KEAS reading before a blast even starts.

The offset compensation routines work by recording the voltages across the bridge in a circular data buffer during course calibration. When the buffer is full it returns to the beginning and overwrites the previous values so that only the most current ones are saved. Once the operator indicates a stop in the course calibration routine the fine calibration stops recording values. It then takes the mean of the values inside the buffer and applies it digitally as an offset compensation factor. The buffer is 100 elements in size. This makes it large enough to obtain a meaningful average and small enough that the entire buffer can be circulated through at least one time after calibration is completed and the stop button is pressed. Circulating through the buffer once after course calibration ensures that the data used contains only values after actual potentiometer adjustments stopped. The process is shown schematically in Figure 10.

	No Offset Compensation			Offset Compensation		
test#	mV offset	mV offset	mV offset	mV offset	mV offset	mV offset
1	.1294	.1284	.1096	.0090	.0256	.0347
2	.1853	.1873	.2817	.0281	.0251	.0244
3	.2012	.2285	.2302	.0325	.0288	.0283
4	.1833	.1922	.2075	.0068	.0220	.0278
5	.2424	.2661	.2668	.0198	.0188	.0190
6	.0645	.3665	.5176	.0325	.0059	.0198
7	.1814	.1846	.2146	.0183	.0117	.0259
8	.1343	.1262	.0894	.0027	.0078	.0015
9	.0410	.0840	.0996	.0134	.0073	.0134
10	.1025	.1743	.3062	.0186	.0762	.0190
effective offset:		.1909		.0208		
improvement:				89.1%		

Figure 9: Improvement of offset reduction using fine calibration.

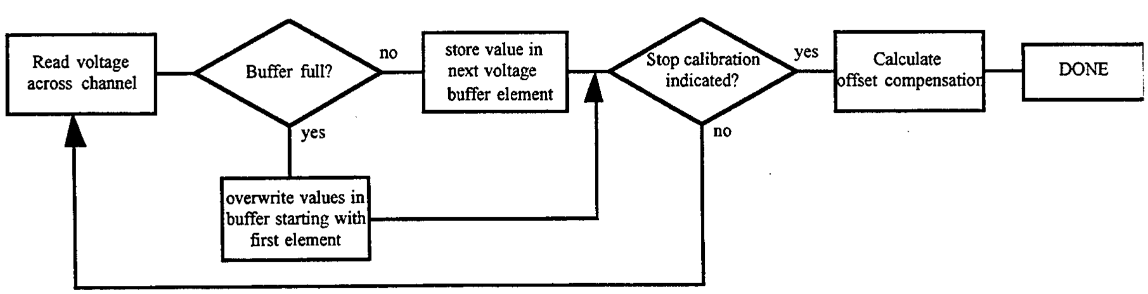
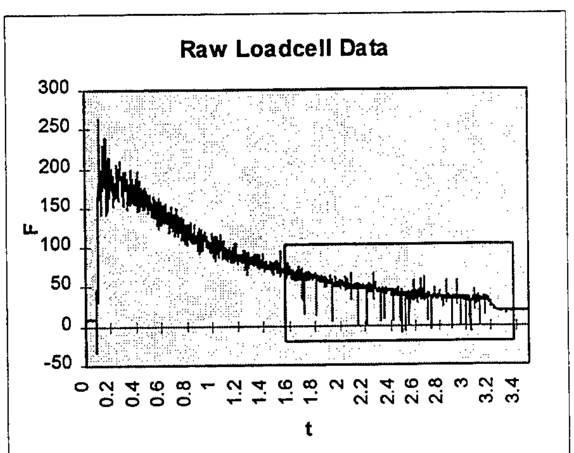


Figure 10: Flow Diagram of Offset compensation process

Validation of Digital Filters

Probably the most important aspect of the data processing is the filtering. Cutting off too much frequency content can eliminate information in the useful bandwidth of the signal corrupting the output. Furthermore, allowing too much unneeded frequency information can corrupt data through the introduction of noise errors. Additionally, the ability to use the current database to evaluate helmet systems is desirable. Much of the current database was generated from the CFB DAS. Assuming the specifications are valid, mimicking them as much as possible assures that data content is consistent in terms of magnitude and frequency content for a given test profile. The design approach taken was to validate the legitimacy of the CFB filter specifications and construct a FIR filter that approximates as much as possible the digital Butterworth filter used in that design. The motivation behind a FIR filter implementation was to eliminate potential group delay distortions inherent in other filter architectures. Distorted signals can give false impressions of the real time event, which must be avoided since the primary objective of testing is determining safety. More details on the FIR implementation are discussed later.

Windblast signals are nominally stationary signals that lend themselves well to Fourier Transform techniques. To validate the filter specifications used in the CFB design, the spectral energy of raw pressure and load cell data from windblasts were analyzed using Fast Fourier Transforms in conjunction with Parseval's Theorem. Parseval's Theorem states that energy, whether analyzed in time or frequency, is conserved. Thus, the total energy of a signal can be determined in the time domain, and spectral contributions to the overall signal can be determined in the frequency domain. The frequency response can then be used to determine if the cutoff and roll off rates are acceptable. The CFB filters cutoff pressure data at 20Hz and load cell data at 100Hz using a twelfth-order Butterworth filter. It was found that roughly 99.3 percent of the signal energy in pressure data is found inside 20Hz. For load cell data 98.3 percent of the signal energy is found inside 100Hz. The cutoffs therefore are reasonable. In many 450 and 600 KEAS blasts there appears significantly large spikes in load cell data that do not show up in pressure data (Figure 11). The force measured on the test item is expected to be proportional to the dynamic pressure and resemble its general profile. Since the spikes are unique to the load cell and not an effect of dynamic pressure and airspeed, it is desirable to eliminate their effect on the data. The spikes correspond to frequencies between 150-230Hz. A twelfth-order filter provides better than 68dBs of attenuation starting at 150Hz reducing most of the spike effect on the processed signal.



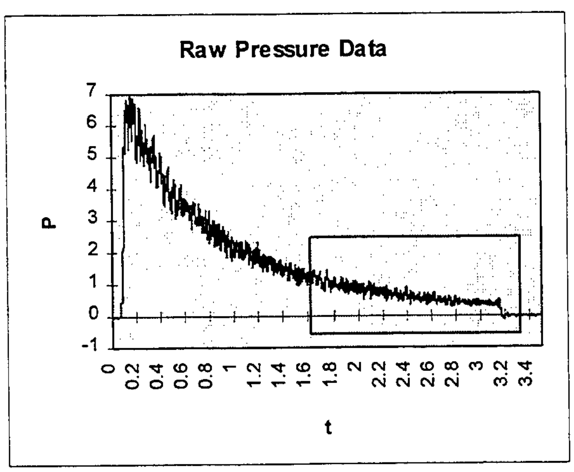


Figure 11: Loadcell data is expected to follow the profile of the dynamic pressure. The spikes in loadcell data do not appear in the dynamic pressure data; therefore, it is desirable that their effect be eliminated.

Once the specifications were validated, the filters needed to be designed. As mentioned above, a FIR filter was constructed. While it is true that the Infinite Impulse Response filter gives much better amplitude response for a given order filter, its phase response is not linear. Linear phase in frequency corresponds to constant delay in time. Variable time delays mean some frequencies are delayed shorter or longer than others. Current safety criteria, in particular Mertz Criteria, is defined by threshold loads and how long they are sustained. A non-linear phase response can distort the time and amplitude nature of the signal during reconstruction. This artifact could be misleading when evaluating a helmet near the safety threshold, giving a false impression of whether criteria was actually exceeded and for how long. Avoiding this potential problem was a key factor in going toward a FIR implementation .

It is equally important to maintain consistency in the output data. This assures that past data collected can be effectively used in evaluating current data sets. To accomplish this, the FIR filter was constructed to mimic a Butterworth response in the passband and roll off equal to or better than the rate of the Butterworth in the transition and stopbands. There is one other limitation of a FIR filter to consider and that is that its stopband attenuation level oscillates between 53 and 100dBs while the Butterworth attenuation increases monotonically. To analyze how data might be affected, windblast data from the filters was normalized to the CFB filter and compared. The normalization process involved filtering the decimated voltage signal (no transducer sensitivity factored in) then dividing through by its maximum value. Normalization was done to remove errors that may have occurred from sensitivity variations in transducer devices. As can be seen in Figure 12, the Butterworth has a slightly better high frequency response but suffers from longer time delays as can be seen in the pressure data of Figure 13. It is important to consider that what is of primary relevance in windblast is how the loads relate to the safety criteria. The CREST Criteria is a function of peak loads and the Mertz Criteria a function of sustained peak loads. In either case, peak loads occur at the onset of the blast where the response of the filtered outputs are remarkably similar (Figures 12-13). Recall that FIR filters give more accurate reconstruction signals in terms of time and amplitude as a consequence of their linear phase response. This would be an important characteristic under the Mertz criteria where both load and duration sustained are relevant. Now look at the CREST Criteria where only the peak loads are considered. Again, the outputs of either DAS are remarkably similar. In quick summary, a helmet that would pass or fail the CREST criteria from the CFB DAS is just as likely to pass or fail with the HMST DAS. However, under the Mertz criteria the HMST DAS will paint a more accurate picture of the windblast response with regards to time and amplitude, validating the implementation of the FIR filter design.

Validation Of Threshold Analysis

One of the unique features incorporated into the HMST DAS was the ability to quickly determine if helmets exceed safety criteria. The HMST DAS can scan through processed waveforms and search for all instances a set threshold was exceeded and report the point data started to exceed criteria, when it stopped exceeding criteria, how long the exceeded level was sustained, and the peak value it held. The analysis routine scans only the processed data. Processed data is decimated to 500Hz or 2ms resolution between points. This report can be used as an early indicator that a helmet passed or failed a blast for both CREST and Mertz criteria.

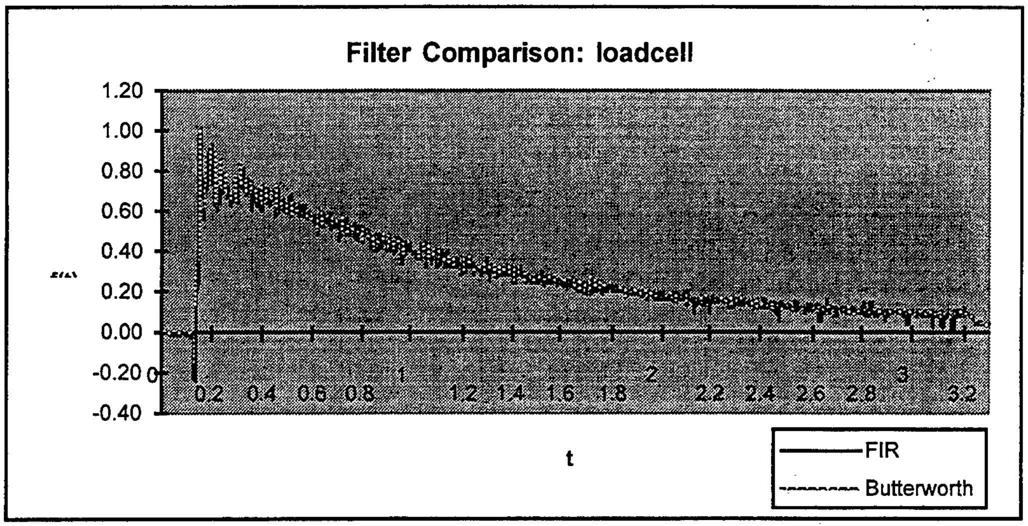


Figure 12: Load cell data reported from CFB Butterworth filter and HMST FIR filter

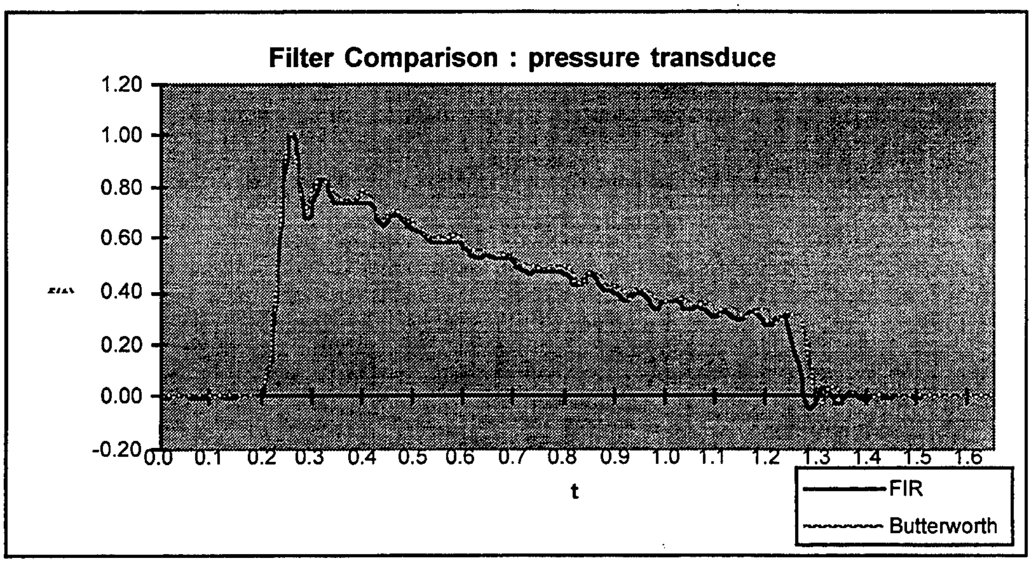
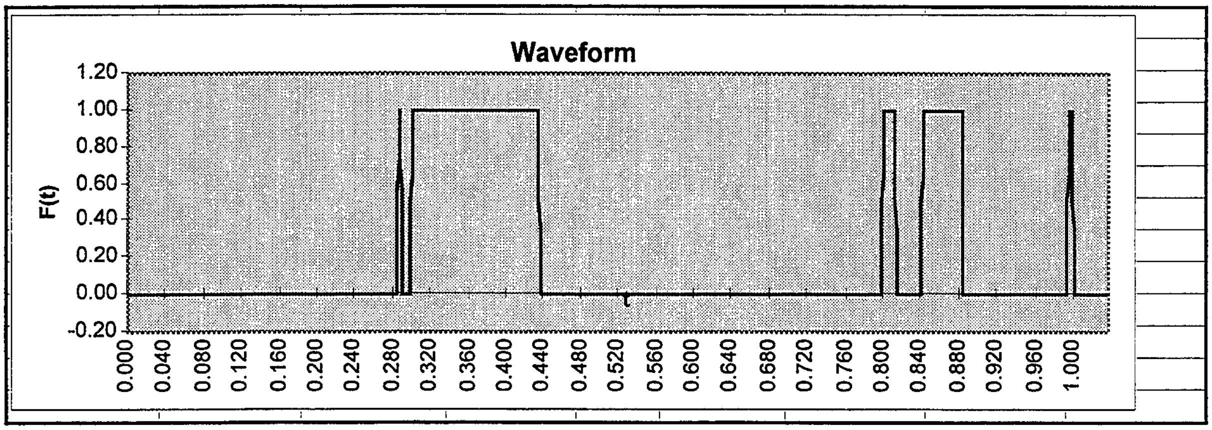


Figure 13: Main rake pressure data reported from CFB Butterworth filter and HMST FIR filter.

To test the routine, arbitrary waveforms of 500 points were analyzed in the threshold analysis routine. The waveforms consisted of one to ten pulses with known variable widths and magnitudes of one. Threshold criteria was set to one half. If the routine was working properly, it should report back the correct number of pulses in the waveform, when they occurred, their correct widths, and peak amplitudes of one. In all cases, the routine reported back correct responses. Figure 14 below shows an example of an arbitrary waveform and its associated report.



threshold	*start time (sec)*	*end time (sec)*	*peak*	*duration (msec)*
0.5	0.286	0.288	1	0.002
0.5	0.300	0.436	1	0.136
0.5	0.800	0.814	1	0.014
0.5	0.842	0.884	1	0.042
0.5	0.994	1.000	1	0.006

Figure 14: Waveform and its associated analysis report

Conclusion

It has been shown and experimentally validated that in actual windblast testing the HMST DAS can perform just as well, if not better than, currently used software and hardware. 1. It is designed to minimize the chances of corrupted data by means of noise introduction into the system and aliasing. 2. The offset compensation routine eliminates most of the signal offset due to transducer bridges. This is a significant improvement over the data generated from the CFB DAS where offsets are as great as 30 percent of the peak value. 3. The decimation and filtering specifications are similar to those of the currently used CFB DAS. This ensures reasonable consistency in past and present data outputs for a given test configuration with regards to data processing. 4. The HMST DAS offers a threshold analysis function that allows test managers to quickly determine the pass/fail status of a helmet for a given test. This facilitates the adjustment and planning of subsequent tests. There are also other minor features in software that help facilitate on site analysis of data. 5. After a brief demonstration, the system can be easily operated by any government personnel. The need for outside contractor involvement and their associated costs are eliminated. In fact, the HMST DAS will pay for itself the first time it is used independently. In short, the HMST DAS is a reliable, accurate, and cost effective 16-channel data collection system for windblast testing.

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