94TH SHOCK & VIBRATION SYMPOSIUM

NOVEMBER 3 - 7, 2024

INSIDE COVER - PURPOSEFULLY LEFT BLANK

Welcome

WELCOME TO DALLAS AND THE 94TH SHOCK AND VIBRATION SYMPOSIUM!

Since the first meeting in 1947, the Shock and Vibration Symposium has become the oldest continual forum dealing with the response of structures and materials to vibration and shock. The symposium was created as a mechanism for the exchange of information among government agencies concerned with design, analysis, and testing. It now provides a valuable opportunity for the technical community in government, private industry, and academia to meet and discuss research, practices, developments, and other issues of mutual interest.

The symposium is presented by the **Shock and Vibration Exchange**.

Thank You

WE WOULD LIKE TO RECOGNIZE OUR TECHNICAL ADVISORY GROUP (TAG) MEMBERS WHO PARTICIPATED ON THE 94TH SHOCK AND VIBRATION SYMPOSIUM SUMMER PLANNING COMMITTEE AND/OR AWARD REVIEW COMMITTEE:

Austin Alvarez, Consultant**
Jeff Averett, US Army ERDC*
Thomas Brodrick, NAVSEA*
Sloan Burns, NAVSEA**
Justin Caruana, Cardinal Engineering*
Fred Costanzo, Consultant**
Dr. Jacob Dodson, AFRL*
Rebecca Grisso, NSWC Carderock[++]
Greg Harris, Consultant**
Roger Ilamni, NSWC Indian Head*
Dr. Bryan Joyce, NSWC Dahlgren**
Alan Klembczyk, Taylor Devices*
Russell Kupferer, IDA*
Brian Lang, NSWC Carderock[++/*]
Kenneth Lussky, BAE Systems*
Bart McPheeters, Gibbs & Cox*
Jeff Morris, HI-TEST Laboratories**
Drew Perkins, SAVE/HI-TEST*
Michael Poslusny, Gibbs & Cox*
Jeff Rybak, PCB Piezotronics*
Ashley Shumaker, SAVE/HI-TEST*
Domenic Urzillo, NSWC Carderock**
Lauren Yancey, HI-TEST Laboratories*
Bill Yancey, HI-TEST Laboratories*

*TAG members in attendance at summer meeting for 94TH S&V program review (held at NSWC Carderock)
**TAG members who peer-reviewed award nomination packages
[++]NSWC Carderock host

THANK YOU

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taylor devices inc.

Shock Tech

ENIDINE

Viper Applied Science

Schedule at a Glance

(WITH DAILY OUTLINE AND HOURS)

FOOD & BEVERAGE EVENTS

(ALL SYMPOSIUM ATTENDEES ARE WELCOME TO ATTEND EVENTS LISTED BELOW)

MONDAY (11/04)	**WELCOME RECEPTION** (REUNION BALLROOM / EXHIBIT HALL) *BEVERAGES & HEAVY HORS D'OEUVRES* **GUESTS OF SYMPOSIUM ATTENDEES ARE WELCOME.*	6:30PM - 8:30PM
TUESDAY (11/05)	**BREAKFAST & NETWORKING** (REUNION BALLROOM / EXHIBIT HALL)	7:00AM - 8:00AM
	GENERAL SESSION 1: KEYNOTE ADDRESS & EXHIBITORS LUNCHEON (REUNION BALLROOM / EXHIBIT HALL)	11:00AM - 1:00PM
	ICE CREAM SOCIAL (REUNION BALLROOM / EXHIBIT HALL)	3:00PM - 3:40PM
WEDNESDAY (11/06)	**BREAKFAST & NETWORKING** (REUNION BALLROOM / EXHIBIT HALL)	7:00AM - 8:00AM
	GENERAL SESSION 2: AWARDS PRESENTATION AND LUNCHEON (REUNION BALLROOM / EXHIBIT HALL)	NOON - 1:30PM
	AFTERNOON SNACK BREAK & PASSPORT PROGRAM DRAWING (REUNION BALLROOM / EXHIBIT HALL)	3:30PM - 4:15PM
	SYMPOSIUM SOCIAL/DINNER **AT OFF-SITE LOCATION (HOUSE OF BLUES)** **COMMERCIALLY SPONSORED BY HI-TEST LABORATORIES** **GUESTS OF SYMPOSIUM ATTENDEES ARE WELCOME.*	7:30PM - 9:30PM
THURSDAY (11/07)	**BREAKFAST & NETWORKING** (REUNION BALLROOM / EXHIBIT HALL)	7:00AM - 8:00AM

**PLEASE NOTE THAT ALL MEALS ARE COMMERCIALLY SPONSORED THROUGH EXHIBITOR AND CORPORATE SUPPORTER REVENUES. NO COSTS FOR MEALS ARE DIRECTLY INCLUDED IN INDIVIDUAL ATTENDANCE FEES.*

SYMPOSIUM BUSINESS CENTER

LOCATED IN EXHIBIT HALL

AN ADDED CONVENIENCE FOR ATTENDEES TO OPEN DOCUMENTS, REVIEW PRESENTATIONS, PRINT BOARDING PASSES, AND/OR BROWSE THE INTERNET.

SPONSORED BY REL

EXTENDED TUTORIAL SESSION
9:00AM - 4:00PM

OPTIONAL SIX-HOUR COURSE WITH ONE-HOUR LUNCH BREAK. ATTENDEES WILL RECEIVE A CERTIFICATE OF COMPLETION AND MAY RECEIVE CEUs/PDHs (VARIES BY STATE). ADDITIONAL FEES APPLY TO ATTEND.

MIL-DTL-901E SHOCK QUALIFICATIONS & SHOCK EXTENSIONS
Kurt Hartsough (901 E&T)

PEGASUS A

MIL-DTL-901E SHOCK QUALIFICATIONS
Instructor will be presenting the requirements for shock qualification testing as detailed in MIL-DTL-901E and interpreted by NAVSEA 05P1. Shock testing theory, MIL-DTL-901E shock test devices and facilities, detailed specification requirements, cost avoidance and clarification and MIL-DTL-901E IC#2 will be covered. Attendees should include anyone involved in the acquisition, specification, review and approval of Navy shipboard equipment including PARMs and LCMs and contracting officers, contractors having to deal with the Navy and wishing to supply shock qualified equipment to the Navy, Ship Program Managers and Ship Logistic Managers responsible for the acquisition & maintenance of shock hardened Navy ships and shock qualification test facilities.

MIL-DTL-901E SHOCK EXTENSIONS
Instructors will also be presenting the requirements for shock qualification extensions as detailed in MIL-DTL-901E and interpreted by NAVSEA 05P1. Shock extension specification requirements, MIL-DTL-901E design guidelines and shock design lessons learned will be covered. Attendees should include anyone involved in the acquisition, specification, review and approval of Navy shipboard equipment including PARMs and LCMs and contracting officers, contractors having to deal with the Navy and wishing to supply shock qualified equipment to the Navy, Ship Program Managers and Ship Logistic Managers responsible for the acquisition & maintenance of shock hardened Navy ships and shock qualification test facilities.

**If you enroll in this course, the two separate courses of similar names on Monday will be duplicate material.*

TUTORIAL SESSION I
8:00 - 11:00AM

OPTIONAL THREE HOUR COURSES. ATTENDEES WILL RECEIVE A CERTIFICATE OF COMPLETION AND MAY RECEIVE CEUs/PDHs (VARIES BY STATE). ADDITIONAL FEES APPLY TO ATTEND.

MIL-DTL-901E SHOCK QUALIFICATION TESTING
Kurt Hartsough (901 E&T)

PEGASUS A

Instructor will be presenting the requirements for shock qualification testing as detailed in MIL-DTL-901E and interpreted by NAVSEA 05P1. Shock testing theory, MIL-DTL-901E shock test devices and facilities, detailed specification requirements, cost avoidance and clarification and MIL-DTL-901E IC#2 will be covered. Attendees should include anyone involved in the acquisition, specification, review and approval of Navy shipboard equipment including PARMs and LCMs and contracting officers, contractors having to deal with the Navy and wishing to supply shock qualified equipment to the Navy, Ship Program Managers and Ship Logistic Managers responsible for the acquisition & maintenance of shock hardened Navy ships and shock qualification test facilities.

FUNDAMENTALS OF SINE AND RANDOM SHAKER TESTING
Chris Sensor (Siemens)

GASTON

This tutorial will cover the fundamental concepts of shaker Sine and Random vibration testing. Swept Sine, Sine Dwell, Random, Sine-on-Random, Random-on-Random and Time Waveform Replication test modes will be covered. Additional topics such as response limiting, control channel averaging, kurtosis, and practical shaker considerations will also be discussed. Subjects will be accompanied by live demos of shaker tests, with opportunities for hands on participation by attendees.

MIMO VIBRATION TESTING AND ANALYSIS USING OPEN-SOURCE SOFTWARE
Daniel Rohe (Sandia National Laboratories)

BRYAN-BEEMAN

Open-Source Tools have become widespread in several scientific disciplines. The free and open-source Python programming language has become a serious competitor to Matlab as a scripting language for performing scientific analyses. There are now several major Structural Dynamics Python packages that are in development or have been released, such as PyFBS, Rattlesnake Vibration Controller, SDynPy, and SDyPy. It is now possible to perform the entire Structural Dynamics workflow using only free and open-source software. Moving Structural Dynamics into open source provides numerous benefits: students can examine code to learn exactly how various algorithms work, researchers can tinker with the code to explore new solutions without having to write everything from scratch, and practitioners can execute their tests or analyses in software that isn't simply a "black box."

This tutorial will introduce and demonstrate two software tools developed at Sandia National Laboratories that have been released open source. SDynPy is a Python package for performing structural dynamics analyses. It provides many common structural dynamics and signal processing operations as built-in functions and provides numerous tools to visualize data. Rattlesnake is a Multiple-Input, Multiple-Output (MIMO) vibration controller that can perform Random and Transient vibration control, as well as modal testing, using various hardware devices. First, the SDynPy Python package will be used to perform pre-test analysis: a finite element model of the test article will be loaded and analyzed to select optimal instrumentation and shaker locations. Then Rattlesnake will be used to perform Modal, MIMO Random, and MIMO Transient testing. SDynPy will then be used to analyze the results of the tests and compare back to the model.

TUTORIAL SESSION I
8:00 - 11:00AM
(CONTINUED)

ANALYSIS FOR A MEDIUM WEIGHT SHOCK TEST

PEGASUS B

Josh Gorfain (Quartus Engineering)

While a shock test is essentially the bottom line for a shock qualification, a lot of analysis often goes into the mix before the test. The reasons for this are many: The equipment manufacturer wants his equipment to pass and will often commission some kind of pre-test prediction to maximize the likelihood of success or to high-light design problems. Since the weight and frequency of the tested equipment can affect the response of the test significantly, the system may need to be examined to assure that the tested environment is correct. This tutorial will first review the Medium Weight Shock Machine (MWSM) and its use in shock qualification testing, followed by presentation of the test environment. Next, the types of analysis that can be performed to estimate the test environment experienced by a given piece of equipment will be described. The intention of these analyses is to provide an assessment of equipment response subject to a MWSM test in an effort to assure a successful test. Additionally, the merits and limits of these methods are discussed so the most appropriate method may be rationally selected for a given application. Examples will be presented that illustrate the different types of analyses and how they may be applied.

PLANNING LIFE CYCLE DESIGN, ANALYSIS, AND SHOCK AND VIBE QUALIFICATION OF NAVY EQUIPMENT

MORENO

Dr. Christopher Merrill (CM&A Engineering)

This tutorial provides general simple techniques for use in parallel with long term Classical and Numerical Dynamic Analysis of Systems subjected to US Navy shock and vibration requirements over Navy equipment life cycles to maximize accuracy and minimize errors in Dynamic Analysis and Qualification of electronic and mechanical systems. The interaction of the US Navy shock and vibration requirements is a major driver of the efficacy of long-term Dynamic Analysis from the start. Apart from major issues that occur on any major long-term developmental programs, simple, seemingly minor, errors present in the analysis from the beginning can lead to huge cost and schedule impacts generally at the worst time for the program (FAT). Fortunately, there are procedural long-term Dynamic Analysis Quality Control techniques that can be used from the beginning and in parallel during the long-term dynamic analysis to mitigate the risk of such errors. This tutorial will provide examples of types and genesis of such errors, as well as, a process to perform at the beginning and in parallel with the long-term dynamic analysis in order to perform quality control comparisons to mitigate these errors. Finally, the importance of comparison of FAT dynamic test results to dynamic analysis including failure and use of prototyping will be included. The tutorial will end with an exercise where the trainer will attempt to stump the trainee with balky computer model results. The trainee will leave the tutorial with a list of types and genesis of discrete and basic errors, a process chart and algorithm for applying these Quality Control Techniques at the start and in parallel with the long-term dynamic analysis, and insight on improving techniques for planning Life Cycle Design, Analysis, and Shock and Vibe Qualification of Navy Equipment.

TUTORIAL SESSION II
NOON - 3:00PM

OPTIONAL THREE HOUR COURSES. ATTENDEES WILL RECEIVE A CERTIFICATE OF COMPLETION AND MAY RECEIVE CEUs/PDHs (VARIES BY STATE). ADDITIONAL FEES APPLY TO ATTEND.

MIL-DTL-901E SHOCK QUALIFICATION TESTING EXTENSIONS
Kurt Hartsough (901 E&T)

PEGASUS A

Instructor will be presenting the requirements for shock qualification extensions as detailed in MIL-DTL-901E and interpreted by NAVSEA 05P1. Shock extension specification requirements, MIL-DTL-901E design guidelines and shock design lessons learned will be covered. Attendees should include anyone involved in the acquisition, specification, review and approval of Navy shipboard equipment including PARMs and LCMs and contracting officers, contractors having to deal with the Navy and wishing to supply shock qualified equipment to the Navy, Ship Program Managers and Ship Logistic Managers responsible for the acquisition & maintenance of shock hardened Navy ships and shock qualification test facilities.

AN INTRODUCTION TO ALIASING, FFT, FILTERING, SRS & MORE FOR FEA USERS AND TEST ENGINEERS
Dr. Ted Diehl (Bodie Technology)

PEGASUS B

Working with either physical test data and/or numerical simulations related to severe mechanical shock, impact, failure, etc. is extremely challenging. Some of the biggest challenges in this type of work are 1) properly collecting the initial raw data while avoiding aliasing [especially from numerical simulations], 2) utilizing robust methods to identify and separate the "noise & distortions" from the "true" frequency-rich content in the data, and 3) determining what portion of the "true" frequency-rich content is meaningful and what does it tell you. For a given problem, the initial appearance of raw time-domain data in this class of work may be vastly different between physical testing and data derived from transient simulation codes (LS-Dyna, Abaqus/Explicit, RADIOSS…). While the data might look different, the rules of DSP (Digital Signal Processing) are the same. Most importantly, understand and utilizing DSP properly is a critical requirement to success in BOTH types of approaches, especially to obtain correlation between physical tests and simulation of the same specific problem.

The 3-hour seminar provides guidance to both simulation analysts and test engineers on how to properly collect and process such data; ultimately uncovering significantly improved results. The course covers highlights of DSP theory in the language of Mechanical Engineering pertinent to simulation analysts and test engineers. This seminar introduces key aspects of working with transient data – specifically, clearly explaining time-domain and frequency domain analysis (DFS, FFT, PSD); data collection (sampling, up-sampling, decimation, and aliasing); filtering (lowpass, highpass, IIR, and FIR), how to avoid aliasing, calculating Shock Response Spectrum (Accel SRS & PVSS) from transient data, and numerous unique aspects related to explicit dynamics FEA data (non-constant time increments, massively over-sampled data, short transient signals with non-zero end conditions, and more). Simplified demonstrations are presented to solidify key DSP aspects, along with many relevant real-world examples. Both FEA users and experimentalists will benefit from this training.

DATA INTEGRITY
John Hiatt (DEWESoft)

MORENO

The data integrity training is designed as an overview of the data acquisition process and how each step in the measurement chain can affect your measured data. Primary focus of this session is on the data acquisition system (DAS). We will learn what happens in each step of the process and how to mitigate common measurement errors. The idea is to get the best possible data first time. Its hard to make good decisions with bad data. We also cover DAS specifications so users can be better prepared to compare system specifications.

TUTORIAL SESSION II
NOON - 3:00PM
(CONTINUED)

FUNDAMENTALS OF CLASSIC SHOCK AND SRS SHAKER TESTING

GASTON

Chris Sensor (Siemens)
Bob Metz (PCB Piezotronics)

This tutorial will cover the fundamental concepts of shaker shock testing, from field data acquisition to Classic Shock and Shock Response Spectrum (SRS) wavelet synthesis in a vibration controller. The tutorial will cover shock data acquisition and analysis, classic shock pulses, SRS concepts, SRS and Pseudo Velocity Shock Spectrum (PVSS) data analysis, a review of Classic Shock and SRS test methods in MIL-STD-810H (including the “new” method of Te and TE), shock test tailoring and SRS wavelet synthesis for shaker SRS testing. A segment covering specialty shock sensors and instrumentation will also be presented. Subjects will be accompanied by live demos of data acquisition and shaker tests, with opportunities for hands on participation by attendees.

EFFECTIVE SOLUTIONS FOR SHOCK AND VIBRATION CONTROL

REVERCHON

Alan Klembczyk (Taylor Devices)
Ken Lussky (BAE Systems)

Part 1 of this Tutorial provides an outline of various applications and methods for implementing isolation control of dynamic loads and damping within a wide array of dynamic systems and structures. Photos, videos, and graphical results are presented of solutions that have been proven effective and reliable in the past. Design examples are given and typical applications are reviewed. Additionally, key definitions and useful formulae are presented that will provide the analyst or systems engineer with the methods for solving isolation problems within the commercial, military, and aerospace sectors. A wide range of isolation mounts and systems are covered including liquid dampers, elastomer and wire rope isolators, tuned mass dampers, and engineered enclosures. Engineering guidelines are presented for the selection and evaluation of isolation control products.

Part 2 of this Tutorial addresses characterization of shock and vibration environments and finite element analysis (FEA) of shock and vibration isolation performance. Methods used to characterize shock and vibration responses and their application are defined. For shock these include spectral definitions (SRS shock response spectrum and PVSS pseudo velocity shock spectrum) and time-history definitions (peak velocity, peak acceleration, average acceleration and displacement). These are discussed with respect to their application to shock input severity, and equipment fragility and damage potential. Shock test qualification methods, their input definitions, and how they are represented in FEA are discussed. Also addressed are the value of damping in shock isolation and how shock and vibration isolation systems are represented in FEA. For vibration the spectral definition of Acceleration Spectral Density (ASD) is discussed. Other topics addressed are the application of UERD Tools for shock characterization, and when to engage with the appropriate shock and vibration Technical Warrant Holders (TWH).

INTRODUCTION TO MIL-STD-461 ELECTROMAGNETIC INTERFERENCE TESTING

BRYAN-BEEMAN

Jeff Viel (Element US Space & Defense)

This 3 hour tutorial provides a detailed technical overview of MIL-STD-461G addressing the electromagnetic interference (EMI) emission and susceptibility test methods and control requirements for subsystems and equipment and subsystems designed or procured for the Department of Defense (DoD). This tutorial starts from the very beginning discussing the basis for EMI control testing, including a historical case study, to the progressive development of test methods and requirements adapted to modern day technologies and electromagnetic environments. While the standard is broadly designed to address all DOD platforms, this tutorial is focused to specifically address shipboard and submarine application requirements.

TUTORIAL SESSION III
3:30 - 6:30PM

OPTIONAL THREE HOUR COURSES. ATTENDEES WILL RECEIVE A CERTIFICATE OF COMPLETION AND MAY RECEIVE CEUs/PDHs (VARIES BY STATE). ADDITIONAL FEES APPLY TO ATTEND.

MIL-DTL-901E SUBSIDIARY COMPONENT SHOCK TESTING & ALTERNATIVE TEST VEHICLES

PEGASUS A

Kurt Hartsough (901 E&T)

The MIL-DTL-901E Subsidiary Component Shock Testing and Alternate Test Vehicles course will cover the following areas: NAVSEA 05P1's current policy for testing subsidiary components, description of test environment requirements, examples of recent successful test programs, alternate test vehicle descriptions, alternate test vehicle limitations, discussions on shock spectra, Multi-Variable Data Reduction (MDR) and various shock isolation systems. This course is intended to give the necessary information to equipment designers and program managers who intend to shock qualify COTS equipment that will require frequent upgrades due to obsolescence, equipment upgrades, change in mission, etc. Although not required, it is recommended that those attending this course also attend courses on Shock Policy, MIL-DTL-901E testing and particularly MIL-DTL-901E extensions offered by the same instructor (Hartsough).

DIGITAL SIGNAL PROCESSING - FILTERING AND THE FOURIER TRANSFORM (GOING FROM TIME TO FREQUENCY DOMAIN)

MORENO

John Hiatt (DEWESoft)

Two of the most common Digital Signal Processing (DSP) techniques are filtering and transforming data from the time domain to the frequency domain with the Fourier transform (FFT). Both mathematical processes can create unwanted effects on the data. This session will examine these effects on your data and how they can be mitigated. For the Fourier transform, we will also discuss the assumptions, inputs to the FFT and possible reasons FFT's calculated with two different software packages do not match. This training is designed to help new users understand how these processes and how they work to help prevent data processing mistakes.

INTRODUCTION TO DESIGNING SHOCK MOUNTED SYSTEMS USING SHOCK ISOLATION MOUNT PREDICTION & LOADING ESTIMATES (SIMPLE) SOFTWARE

BRYAN-BEEMAN

Dave Callahan (HII Newport News Shipbuilding)

This course will introduce a process for designing and assessing shock isolation systems with special emphasis on applications related to the design of shipboard equipment for shock loads produced by underwater explosions utilizing the analytical software tool "Shock Isolation Mount Prediction & Loading Estimates" (SIMPLE). This process is split into two parts: 1) initial analysis using classic Shock Response Spectrum (SRS) and 2) assessment, confirmation, iteration or comparison of isolation system designs using SIMPLE simulation methods. Attendees will learn how to build six Degree of Freedom (DOF) SIMPLE models of isolated systems, select shock mounts and modify mount properties, select shock inputs, evaluate the isolation system performance and iterate designs rapidly. This course is intended for anyone that desires validation and assurance that shock and vibration mounts are properly selected for equipment racks, consoles, cabinets, and other structures using SIMPLE software. Examples of SIMPLE users are: engineers, program & project managers, equipment integrators, shock and vibration analysts, mount vendors, and shock qualification reviewers/approvers.

ACOUSTIC ENVIRONMENT ORIGINS, EFFECTS, AND SIMULATION

SANGER

Zeev Sherf (Consultant)

In this tutorial an overview of the acoustic noise environment will be presented. In this environment, the hardware that is used to fulfill different functions, is exposed to changing level and spectral content pressure fluctuations. They are three aspects on which the presentation will focus: the generation of acoustic noise, its effects and its simulation.

TUTORIAL SESSION III
3:30 - 6:30PM
(CONTINUED)

AIR BLAST AND CRATERING: AN INTRODUCTION TO THE ABC'S OF EXPLOSION EFFECTS IN AIR AND ON LAND

GASTON

Denis Rickman (USACE ERDC)

This three-hour course introduces the effects of explosions in air and on land. Topics covered include airblast, soil/rock/pavement cratering, and ground shock phenomena produced by explosive detonations. There is a little math, but for the most part, the focus is on aspects and principles that are of practical use to those conducting (and utilizing) blast-related research. Most researchers in the blast arena have some grasp of explosion effects fundamentals, but very few have a good, broad-based understanding of how it all works. The goal is to provide the participants with enough of an understanding that they can appreciate the various explosion phenomena and those parameters that affect blast propagation and blast loading of objects in a terrestrial setting.

DDAM 101

REVERCHON

George D. (Jerry) Hill (SERCO)

The U.S. Navy Dynamic Design Analysis Method (DDAM) has been in general use since the early 1960s. It is a method of estimating peak shock response of equipment and outfitting on naval combatants using normal mode theory, originally extended from earthquake analysis methods. The DDAM requires linearelastic model behavior and employs a statistical method of modal superposition yet has persisted to today as the U.S. Navy required method for shock qualification by analysis. This, in spite of the rapid advancement of dynamic transient simulation technology and techniques for representing nonlinearities including material plasticity and contact behavior. The tutorial will address: how the method works, how the shock spectral input values are presented in DDS-072-1, what is the role of modal weights and participation factors, why has the method persisted including what are its strengths and also what are its weaknesses. The tutorial will provide a basic understanding of the method, requirements, and procedures to those who expect to be involved in shock analysis and will demystify the procedure for many who are current users.

DISCUSSION GROUP
MIL-STD-810J: PLANNED CHANGES
NOON - 4:00PM

REUNION A

PANELISTS:
Matt Lucas (Army Test and Evaluation Command)
Bill Barber (Redstone Test Center)
Dr. Luke Martin (NSWC Dahlgren)
Joseph Cavaleri (USN)
Jesse Porter (Redstone Test Center/HTSI)
Dr. Michael Hale (Redstone Test Center/Trideum)
Randy Patrick (Yuma Test Center)
Mike Barry (Aberdeen Test Center)

This group discussion will delve into structural and technical changes to the shock and vibration test methods in MIL-STD-810 that are currently in progress. In addition to administrative changes (i.e., method level updates to MIL-STD-810), the focus of this session will be technical changes to Methods 514, 516, 527, 528, creation of two new Methods, 530 (loose cargo) and 531 (large assembly transport), and a new Part IV (specification development).

Contributors from the MIL-STD-810 Working Group will be presenting updates to these test methods and soliciting feedback from the SAVE community to ensure technical concerns are being properly considered in this major update.

Welcome Reception

HI-TEST Laboratories, Inc.

ALL SYMPOSIUM ATTENDEES AND GUESTS ARE INVITED TO ATTEND.

6:30 - 8:30PM
HEAVY HORS D'OEUVRES & DRINKS
REUNION BALLROOM (EXHIBIT HALL)

End Monday Events

BREAKFAST + NETWORKING

7:00 - 8:00AM | EXHIBIT HALL

AFTER BREAKFAST, ENJOY THE OPPORTUNITY TO NETWORK WITH OTHER ATTENDEES AND INTERACT WITH EXHIBITORS.

TUTORIAL SESSION IV
8:00 - 11:00AM

OPTIONAL THREE HOUR COURSES. ATTENDEES WILL RECEIVE A CERTIFICATE OF COMPLETION AND MAY RECEIVE CEUs/PDHs (VARIES BY STATE). ADDITIONAL FEES APPLY TO ATTEND.

OVERVIEW OF UNDERWATER EXPLOSION PHENOMENOLOGY AND BULK CHARGE WEAPON EFFECTS
Greg Harris (Consultant)

REVERCHON

NOTE: LIMITED DISTRIBUTION D (SECURITY PAPERWORK REQUIRED)

This tutorial will provide an overview of underwater explosion (UNDEX) phenomenology relevant to bulk charge underwater warheads. The phenomenology discussion includes UNDEX shock wave propagation, bulk cavitation effects, and UNDEX bubble dynamics. UNDEX testing and analysis procedures for characterizing the shock wave and bubble performance of explosive compositions will be described. Finally, a brief discussion of the damage mechanisms used by bulk charge underwater weapons such as mines and torpedoes will be given using illustrative examples from UNDEX testing programs and recent naval encounters.

MIL-DTL-901E ENGINEERING TOPICS
Domenic Urzillo (NSWC Carderock)

GASTON

MIL-DTL-901E Engineering topics is a follow-on course to the MIL-DTL-901E Test and Extension training courses and is aimed at providing the NAVSEA acquisition and engineering communities with a more in-depth review of engineering mathematics routinely used in equipment shock qualification. Topics covered include shock spectrum as it relates to MIL-DTL-901E testing, digital data filtering, shock response frequency, shock test fixture design fundamentals and FSP deck simulation fixtures.

BLAST PRESSURE MEASUREMENT
Troy Skinner (N2L, Inc.)
Bob Metz (PCB Piezotronics)
Denis Rickman (USACE ERDC)

MORENO

When researchers collect poor blast pressure data, they often conclude "it must be the gauge!" Truth be known, sensors rarely insert themselves into a blast test. Instead, they bravely go into whatever location the test engineer commands, often producing poor data or worse, experiencing an untimely death. These brave, and costly, soldiers deserve better!

To make matters more complicated, there are two sensing technologies to choose from. Quartz piezoelectric and silicon MEMS piezoresistive transducers are both successfully used for air-blast pressure measurements. This tutorial will objectively compare strengths and weaknesses of MEMS piezoresistive and ICP piezoelectric pressure transducers focused only on their applicability to the air-blast environment. The analysis considers measurement errors found in air blast, which include thermal transients, acceleration/strain, and cable length effects. Transducer performance parameters of dynamic range, ruggedness/survivability, and frequency response will be compared.

TUTORIAL SESSION IV
8:00 - 11:00AM
(CONTINUED)

REMOVING THE BOUNDARY CONDITION HOBGOBLINS IN VIBRATION QUALIFICATION TESTING WITH MODAL TECHNIQUES

PEGASUS A

Troy Skousen (Sandia National Laboratories)
Randy Mayes (Consultant)

How a modal technique provides a simple modification to the base input mitigating the field-to-laboratory impedance mismatch for high confidence component qualification

Random vibration laboratory testing is used to qualify components to survive in-service responses to system environments. Using realistic research hardware and an analytical rocket system, we show that traditional single degree of freedom (SDOF) shaker test specifications guarantees large response uncertainties when compared with the field environment responses due to the difference in laboratory boundary conditions. A brief review is provided showing how fixed-base mode shapes are derived from test data. A model utilizing fixed-base and rigid body modes of the component on its vibration test fixture is used to decompose the component field motion into a few intuitive responses. This model demonstrates why 6DOF laboratory control can eliminate large uncertainties in traditional SDOF testing with a corresponding boost in qualification confidence. In fact, the model leads to modified base inputs for a greatly improved SDOF or 3DOF test.

TWO APPROACHES TO RANDOM VIBRATION ANALYSIS

PEGASUS B

Dr. Thomas Paez (Thomas Paez Consulting)

Two fundamental approaches exist for analysis of random vibration. The approach used most commonly is based on knowledge of the spectral densities of forces and motions. In practice, an experimentalist measures a physical environment applied to a structure. A data analyst uses the measured data to estimate the spectral density of the environment. That spectral density is used either by a model developer to compute the response spectral density of a critical structure, or by a laboratory experimentalist to control the input to a critical structure whose responses are measured, then used to estimate response spectral densities. The procedure can be extended in many ways to establish important features of the critical structure and its response.

The other approach to random vibration analysis has its roots in the work of Einstein. This latter approach is known as the diffusion approach. His intent was to investigate the motion of very small particles suspended in a liquid, i.e. Brownian motion, and draw inferences about the dimension of the molecules of the liquid. Einstein did not say it in his paper, but the problem he solved was the random vibration of a rigid mass attached to ground by a dashpot, and excited by a white noise input. Later, he and others solved for the random vibration of a mass attached to ground by both a spring and a dashpot.

One year following the publication of Einstein's paper, a completely different approach was specified by Smoluchowski. He analyzed a discrete time/discrete space problem that came to be known as the "drunkard's walk." A particle starts at the origin and during the first time interval, moves one step to the right with probability p or one step to the left with probability q=1-p. Motion proceeds at each time/space step in the same manner. Following n steps, the probability distribution of particle location can be developed. When the limit is taken appropriately as time step duration and spatial step length approach zero, the governing equation and solution approach those implied by Einstein.

This presentation develops both approaches to random vibration analysis. Some MATLAB code and a PDF of the color slides are distributed electronically.

BREAKFAST + NETWORKING

7:00 - 8:00AM | EXHIBIT HALL

AFTER BREAKFAST, ENJOY THE OPPORTUNITY TO NETWORK WITH OTHER ATTENDEES AND INTERACT WITH EXHIBITORS.

TUTORIAL SESSION IV
8:00 - 11:00AM
(CONTINUED)

COMMON ROADBLOCKS AND LESSONS LEARNED FROM SHOCK QUALIFICATION; PRACTICAL GUIDANCE AND CASE STUDIES

BRYAN-BEEMAN

Lisa McGrath (HII Newport News Shipbuilding)

This course will focus on errors and missteps common to the shock qualification process and how they can be avoided by walking attendees through qualification efforts for several real-life examples. The instructor will provide details on the issues which were faced, the utilized testing/analysis methodologies, related 901 requirements, and lessons learned. The end-goal of the training is to provide attendees with a better practical understanding of shock qualification by test and extension. This course is aimed at those who are or will be responsible for shock qualifying naval equipment per 901 requirements. This course assumes the attendees have at least a base understanding of 901 methodologies and requirements. Therefore it is recommended (but not required) that attendees have sat through previous 901 trainings or at least have a base understanding of 901 requirements. There will also be a portion of the tutorial set aside for specific attendee questions and hypothetical scenarios.

Exhibitor Passport Program

PLAY ★PASSPORT★ CHALLENGE

HOW IT WORKS:

- Each Symposium attendee is given a "Passport" with a listing of participating exhibitors.
- Participating exhibitors are provided a custom stamp/sticker.
- As the attendees visit the participating exhibitors, exhibitors "stamp" the passport of the attendee.
- Attendees who collect the stamp of at least 20 participating vendors are entered into the drawing.
- Prizes range from gift cards to gadgets to new exhibitor products!
- *Drawing to be held during the Wednesday afternoon break* (3:30 - 4:15pm).

Thank You to the exhibitors participating in the Passport Program:

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VR VIBRATION RESEARCH

TUESDAY
NOVEMBER 5

EXHIBITORS LUNCHEON (GENERAL SESSION I) *WITH KEYNOTE ADDRESS* 11:00AM - 1:00PM

SALON BALLROOM

11:00AM—11:10AM	**CALL TO ORDER** Mr. Drew Perkins, SAVE / HI-TEST Laboratories
11:10AM—11:15AM	**KEYNOTE INTRODUCTION** John Rhatigan, Marine Machinery Association
11:15AM—NOON	**KEYNOTE ADDRESS** Matthew Sermon, Executive Director, PEO Strategic Submarines
NOON—1:00PM	**LUNCH** **FOLLOWED BY EXHIBITOR MEET & GREET**

Exhibitor Meet & Greet

Enjoy time to peruse the exhibit hall and meet the vendors.

DON'T FORGET TO GET STARTED ON YOUR PASSPORT PROGRAM ENTRY FORM!
DRAWING TO BE HELD DURING WEDNESDAY'S AFTERNOON BREAK IN THE EXHIBIT HALL.
PRIZES TO INCLUDE:

SAVE PROGRAM PRIZES
- $250 AMAZON GIFT CARD
- APPLE IPAD
- APPLE WATCH
- APPLE AIRPOD PROS
- RING VIDEO DOORBELL
- DJI DRONE

VENDOR DONATED PRIZES
- YETI MERCHANDISE
- VARIOUS GIFT CARDS
- MISC. ELECTRONICS
- EXHIBITOR APPAREL & SWAG

Meet the Speaker

MATTHEW SERMON
EXECUTIVE DIRECTOR
PEO STRATEGIC SUBMARINES

MR. MATTHEW SERMON is the Executive Director of Program Executive Office, Strategic Submarines. Previously, Mr. Sermon served as the Executive Director for Program Executive Office Columbia Class Submarine and as the Executive Director, Amphibious, Auxiliary and Sealift Office, Program Executive Office, Ships. In his current role, he provides executive leadership to the Columbia Class Submarine acquisition program and the In Service SSBN/SSGN program, while also being assigned responsibility for revitalization of the Submarine Industrial Base. In this portfolio, he provides enterprise leadership for more than 250 acquisition personnel and approximately $130 Billion in acquisition and sustainment programs.

Mr. Sermon entered the Senior Executive Service in February 2019, and has been in federal service for more than 20 years. He has served in a variety of key leadership positions throughout his career, including Deputy Program Manager for the Columbia Class Submarine program (2016-2019), a $100 billion DoD Major Defense Acquisition Program. During his tenure, he led the program through detail design, construction readiness, and significant sustainment planning activities. Before leading the Columbia Class, he was the Deputy Program Manager for the Zumwalt Class Destroyer (2014-2016) during test, trials, and delivery of the lead ship (DDG 1000). Prior to DDG 1000, he was the Deputy Program Manager for International Fleet Support in the Naval Sea Systems Command's Surface Warfare Directorate (2010- 2014), where was responsible for the management of more than $5 billion in Foreign Military Sales cases for more than 40 partner nations.

Other previous assignments include Principal Assistant Program Manager in the Support Ships, Boats, and Craft Program Office (PMS 325) in PEO Ships (2007-2010), where he led the $1.1 billion Egyptian Navy Missile Craft project while providing program management expertise for numerous other boat building projects.

Prior to starting in Navy civilian service, Mr. Sermon was a U.S. Navy Surface Warfare Officer (Nuclear). He received his Surface Warfare Officer qualification aboard USS Ramage (DDG 61). Additionally, Mr. Sermon served as nuclear engineering officer aboard USS Dwight D. Eisenhower (CVN 69) before leaving the uniformed Navy in 2004. He is a veteran of Operations Enduring Freedom and Iraqi Freedom.

Mr. Sermon is a member of the Acquisition Professional Community and has a Level III Certification in Program Management. He holds Defense Acquisition Workforce Improvement Act certifications in Production, Quality, and Manufacturing and Test & Evaluation, and has completed certification as a Project Management Professional (PMP). He received a Bachelor of Science degree in economics from the United States Naval Academy in 1999, and a Master of Science degree in engineering management from The Catholic University of America in 2006. He is a 2012 graduate of the Defense Systems Management College's Program Manager Course. During his distinguished federal service career, Mr. Sermon has received three Navy Civilian Meritorious Service Awards and one Navy Civilian Superior Service Award.

	Session 1: **Shock Isolation** 1:00-2:35PM / Unlimited Dist. A Chair(s): Alan Klembczyk (Taylor Devices) Shawn Czerniak (Hutchinson)	*Session 2:* **Instrumentation** 1:00-3:00PM / Unlimited Dist. A Chair(s): Bob Metz (PCB Piezotronics)	*Session 3:* **DYSMAS** 1:00-2:35PM / Limited Dist. D 2:40-3:00PM / Unlimited Dist. A Chair(s): Dr. Jeff St. Clair (NSWC Indian Head) Roger Ilamni (NSWC Indian Head)
	Bryan-Beeman	Gaston	Pegasus B
	(##) following each paper title indicates associated page number in the abstract book appendix.		
1:00	**Transient Shock Response of an Isolated Rigid Body to transient shock base excitation varying: ratio of CG elevation to horizontal separation of base isolators; and ratio of isolation system initial stiffnesses to final stiffnesses 10x more (1)** *Dr. Christopher Merrill (CM&A Engineering)*	**Measurements of the Speed of Sound in Snow and its Relation to Snow Density (3)** *Dr. Sean Cooper, Dr. Paul Cammarata, Dr. Mohsen Sanai, Dr. Waylon Weber, Grant Speer, & Joe Crepeau (Applied Research Associates)*	**DYSMAS Application to Sea Bed UNDEX: Summary of Results from Recent UNDEX Testing (5)** *Dr. Brad Klenow & Roger Ilamni (NSWC Indian Head Division), Tobias Timm & Swen Metzler (WTD-71), Greg Harris, Kathrine Knowles, & Daniel Page (ATR), Manfred Krueger & Ralf Tewes (iABG)*
1:25	**Experimental Testbed Design to Dynamically Characterize Wire Rope Shock Isolators (1)** *Luke Nester & Dr. Pablo Tarazaga (Texas A&M University), Dr. Bryan Joyce, Jacob Hoppel, & Jonathan Matteson (NSWC Dahlgren)*	**Measurement Standard for Calibrating Dynamic Pressure Sensors (3)** *Dr. Richard Hogstrom, Antti Lakka, Jussi Hamalainen, & Leevi Salonen (VTT MIKES)*	**DYSMAS Application to Sea Bed UNDEX: Simulations of Recent UNDEX Testing (5)** *Dr. Brad Klenow & Roger Ilamni (NSWC Indian Head Division), Manfred Kruger (iABG), Kathrine Knowles & Jason Yuan (ATR)*
1:50	**Stainless Steel High Damping Wire Rope Isolators (HDWRI) (2)** *Ozzie Irowa & Robert Filec (Socitec US)*	**Cryogenic Performance of High-G Damped Accelerometers (4)** *James Nelson (PCB Piezotronics)*	**Internal Blast DYSMAS Calculations of Bare and Cased Charges for Blastx TSM Generation (6)** *Colin Burns (ATR), Dr. Cameron Stewart & Dr. Tom McGrath (NSWC Indian Head)*
2:15	**Passing the MIL-DTL-901E DSSM Shock Test Through the Use of a New Wire Rope Isolator (WRI) Design with Improved Multi-Axis Performance Characteristics (2)** *Joshua Partyka & Eric Jansson (Isolation Dynamics Corporation)*	**Additional Understanding and Comparison of MEMS and IEPE Accelerometers in Pyrotechnic Shock Applications (4)** *Brian Solomon & Gerald Leavitt (Northrop Grumman)*	**Expanding the Capability of DYSMAS (6)** *Dr. Thomas McGrath, Dr. Alan Luton, Dr. Jeff St. Clair, Mr. Jim Warner, & Dr. Brad Klenow (NSWC Indian Head), Mitul Pandya (ATR)*
2:40			**Simulating the Underwater Shock Dynamics of Human Lung and Rib Simulants (6)** *Dr. Emily Guzas & Eugenia Weiss (NUWC Newport), Brandon Casper & Matt Babina (Naval Submarine Medical Research Laboratory)*

3:00 - 3:40

ENIDINE

Ice Cream Social

REUNION BALLROOM (EXHIBIT HALL)

E-LABS FREDERICKSBURG, VIRGINIA - USA

	Session 4: **IMPACT & PENETRATION MECHANICS** 1:00-3:00PM / LIMITED DIST. D CHAIR(S): Jeff Averett (USACE ERDC)	*Vendor Session A:* **EXHIBITOR PRESENTATIONS INCLUDING CASE STUDIES, NEW DEVELOPMENTS, TESTING & PRODUCTS** 1:00-3:00PM / UNLIMITED DIST. A CHAIR(S): Dr. Ted Diehl (Bodie Technology)	*Training I:* **901E FLOW CHARTS** 1:00-2:00PM / UNLIMITED DIST. A **BLAST DATA PROCESSING & ANALYSIS** 2:00-3:00PM / UNLIMITED DIST. A TRAINING
	PEGASUS A	REVERCHON	REUNION A
	(##) following each paper title indicates associated page number in the abstract book appendix.		
1:00	**Technical Advantages and Capabilities of Elastic Plastic Impact Computation (EPIC) in Finite Element Analysis (7)** *Samuel Grinberg (Picatinny Arsenal)*	**Full-Field Vibration Measurements with High-Speed Digital Cameras (9)** *Dr. Kyle Gilroy (Vision Research)*	**901E Flow Charts (11)** *Kurt Hartsough* *(901 E&T)* 1:00-2:00PM
1:25	**Development of Simplified and Detailed Finite Element Projectile Model Library (7)** *Logan Rice, David Lichlyter, & Dr. Mark Adley (US Army Corps of Engineers ERDC)*	**Resonant Plate Testing for Low-Level Oscillatory Shocks (9)** *Dr. Carl Sisemore (ShockMec Engineering)*	
1:50	**High Velocity Impact of a Tungsten-Nose Payload Delivery Vehicle Against a Steel Plate Backed with Welded Beams and Against Two Concrete Walls (8)** *Dr. Zane Roberts, Logan Callahan, Dr. Z. Kyle Crosby, & Dr. John Q. Ehrgott Jr. (US Army Corps of Engineers ERDC)*	**Enhancing Experimental Modal Analysis Workflow: Supporting Occasional and Expert Users (10)** *Brian Cremeans (HEAD Acoustics)*	**Blast Data Processing & Analysis (11)** *Denis Rickman* *(USACE ERDC)* 2:00-3:00PM
2:15	**Evaluation of Penetration Resistance of Conventional Concrete Slabs Repaired with Sprayable Ultra-High-Performance Concrete (8)** *Jeffrey Holmes (US Army Corps of Engineers ERDC)*	**Taking T&M to the Edge (10)** *Mike Ciosys (RDI Technologies)*	
2:40	**Perforation of Steel Backed Concrete Slabs with Onboard Data Recorders (9)** *Glynn Harrington, Logan Callahan, Dr. Zane Roberts, Dr. Kyle Crosby, & Dr. John Q. Ehrgott, Jr. (US Army Corps of Engineers ERDC)*	**Kornucopia® ML™ Capabilities to Synthesize a Realistic Transient Acceleration Shock Signal to Represent and Bound Diverse Oscillatory Shock Time-Histories (10)** *Dr. Ted Diehl (Bodie Technology, Inc.)*	

3:00 - 3:40

ENIDINE

Ice Cream Social

REUNION BALLROOM (EXHIBIT HALL)

E-LABS FREDERICKSBURG, VIRGINIA - USA

	SESSION 5:	SESSION 6:	SESSION 7:
	VIBRATION ISOLATION 3:45-4:55PM / UNLIMITED DIST. A **VIBRATION TEST METHODS** 5:00-5:45PM / UNLIMITED DIST. A CHAIR(S): Dr. Michael Hale (Trideum Corp) William Barber (Redstone Test Center)	**SHOCK MITIGATION TECHNOLOGIES** 3:45-4:30PM / UNLIMITED DIST. A **BALLISTICS** 4:35-5:45PM / UNLIMITED DIST. A CHAIR(S): Sara Fisher (NSWC Carderock) DeBorah Luckett (USACE ERDC)	**DEDICATED SESSION: NAVY ENHANCED SIERRA MECHANICS (NESM)** 3:45-5:45PM / LIMITED DIST. D CHAIR(S): Dr. Nicholas Reynolds (NSWC Carderock) Tim McGee (NSWC Carderock)
	BRYAN-BEEMAN	GASTON	PEGASUS B
3:45	**Replacement of traditional viscoelastic material in a constrain layer damper (CLD) with Liquid Crystal Elastomer (LCE) material (12)** *Dr. James Rall, Dr. Amir Torbati, Risheng Zhou, & Tristan Collette (Impressio Inc.)*	**Leveraging Radioss for High-Velocity Impact Simulations: Enhancing Armored Vehicle Design (14)** *Kory Soukup, Jason Krist, & Giri Prasanna (Altair Engineering)*	**Automated Fluid Mesh Generator (15)** *Dr. Nicholas Reynolds (NSWC Carderock)*
4:10	**Dual-phase-lagging thermoelastic dissipation for cylindrical shell resonator model with initial-stress field (12)** *Prof. Jung-Hwan Kim (Wonkwang University)*		**Improvements in Computational Efficiency of NEMO hydrocode (16)** *Michael Miraglia, Rohan Bardhan, Meredith Blanco, Ari Bard, & Dr. Nicholas Reynolds (NSWC Carderock)*
4:35	**Transient Modal Response of an Isolated Rigid Body to sinusoidal base excitation varying: ratio of CG elevation to horizontal separation of base isolators; and ratio of isolation system initial stiffnesses to final stiffnesses 10x more (13)** *Dr. Christopher Merrill (CM&A Engineering)*	**Modeling the Response of Multi-layered Multi-material Targets Using ALE-Based Finite Element Methods (14)** *DeBorah Luckett & Dr. Andrew Bowman (US Army Corps of Engineers ERDC)*	**Navy Shock Isolating Mount (NMount) Capability in Sierra/SD (16)** *Dr. Nicholas Reynolds, Michael Miraglia, Rohan Bardhan, Meredith Blanco, & Ari Bard (NSWC Carderock)*
5:00	**Improves Vibration Testing with Application Intelligent Processing (13)** *Stewart Slykhous (Spectral Dynamics)*	**Use of Liquid Crystal Elastomers (LCE) for increased and reliable energy impact absorption in helmet liners (15)** *Dr. James Rall, Dr. Amir Torbati, & Lyssa Bell (Impressio, Inc.)*	**Population of Data for Generalized Shock Lookup (16)** *Ari Bard, Dr. Nicholas Reynolds, Michael Miraglia, Rohan Bardhan, & Meredith Blanco (NSWC Carderock)*
5:25	**Use of Spectral Analysis of Singular Values as a Test Metric for IMMAT Trials (14)** *Dr. Michael Hale (Trideum Corporation), Jacob Davis & William Barber (Redstone Test Center), Dr. James Akers (NASA)*		**Hull 3000 Finite Element Model (17)** *Dr. Nicholas Reynolds, Michael Miraglia, Rohan Bardhan, Meredith Blanco, Rachel McIntyre, Tyler Rea, & Christian Castillo (NSWC Carderock)*

Thank you for participating at the 94th Shock & Vibration Symposium!

	SESSION 8: **DEDICATED SESSION: ELECTRONICS EVALUATION AND SENSING FOR HIGH-G ENVIRONMENTS** 3:45-5:20PM / LIMITED DIST. D 5:25-5:45PM / UNLIMITED DIST. A CHAIR(S): Dustin Landers (ARA) Richard Clayson (Sandia National Labs)	*VENDOR SESSION B:* **EXHIBITOR PRESENTATIONS INCLUDING CASE STUDIES, NEW DEVELOPMENTS, TESTING & PRODUCTS** 3:45-5:45PM / UNLIMITED DIST. A CHAIR(S): Bob Metz (PCB Piezotronics)	*TRAINING II:* **INTRODUCTION TO UERDTOOLS** 3:45-5:45PM / LIMITED DIST. C TRAINING
	PEGASUS A	REVERCHON	REUNION A
3:45	**Experimental Evaluation of Electronic Packaging Strategies on Functional Fireset Electronics (17)** *Zachary Jowers, Dr. Adriane Moura, Jared Hammerton, Dr. Alain Beliveau, & James Scheppegrell (Applied Research Associates), Dr. Matthew Neidigk & Dr. Jacob Dodson (AFRL)*	**Endevco's New Piezoresistive Combobulator (19)** *Bob Metz (PCB Piezotronics)*	**Introduction to UERDTools (22)** *Rachel McIntyre* *Brian Lang, & Paul Mantz* *(NSWC Carderock)* 3:45 - 5:45PM
4:10	**Thermal and Mechanical Shock Testing of Hardened Forward Assemblies (17)** *Dustin Landers (Applied Research Associates), Dr. Jacob Dodson (Air Force Research Laboratory)*	**CAN-MD®: Vibration Sensing Evolved (20)** *Kevin Westhora (Dytran by HBK)*	
4:35	**Development of a Physics Based Model to Characterize G-Switch Behavior for Smart Fuzing Systems (18)** *Philip Randall, Ryan Jensen, Joshua Dye, & Victor Nevarez (Sandia National Laboratories)*	**Computing the frequency response function (FRF) from a modal hammer's force response using digital image correlation (DIC); plus, an overview of a new DIC stress analyzer for all materials (20)** *Elisha Byrne (Correlated Solutions)*	
5:00	**Equipment Blast Fragility (18)** *Dr. John Sajdak (Test & Evaluation Solutions)*	**Viper::Blast for Advanced Airblast Simulations (21)** *Dr. Peter McDonald (Viper Applied Science)*	
5:25	**Towards Active Structural Control Strategies for Electronic Assemblies in High-rate Dynamic Environments (19)** *Trotter Roberts, Ryan Yount, & Prof. Austin Downey (University of South Carolina), Dr. Jacob Dodson (AFRL), Dr. Adriane Moura (Applied Research Associates)*	**The Use of SYMOS software for Naval applications (22)** *Ali Shehadeh (Societec US)*	

Visit our staff in the Cotton Bowl Room with any questions!

SAVE Awards & Nomination Instructions

Henry C. Pusey Best Paper Award

KEEP A LOOKOUT IN THE PROGRAM FOR THIS QR CODE! SCAN TO NOMINATE ANY PRESENTATION DESERVING OF OUR ANNUAL ***HENRY C. PUSEY BEST PAPER AWARD.*** FULL AWARD CRITERIA AND NOMINATION FORM AVAILABLE BY SCANNING THE QR CODE.

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Lifetime Achievement Award

THE LIFETIME ACHIEVEMENT AWARD IS BESTOWED TO A MEMBER OF THE SHOCK AND VIBRATION COMMUNITY WHO HAS MADE SIGNIFICANT TECHNICAL CONTRIBUTIONS TO THE FIELD WITH A LIFETIME OF CAREER DEDICATION.

REACH OUT TO DREW PERKINS OR ASHLEY SHUMAKER FOR ADDITIONAL AWARD CRITERIA AND/OR A NOMINATION PACKAGE FOR THIS PRESTIGIOUS AWARD.

NETWORKING & DISCUSSION GROUP
YOUNG ENGINEERS & NEW SAVE ATTENDEES
5:45 - 7:00PM

BRYAN-BEEMAN

PANELISTS:
Drew Perkins (SAVE)
Alan Klembczyk (Taylor Devices)
Dr. Jason Foley (AFRL)

This discussion group is targeted at young enginners, students, and/or attendees who are new to the SAVE Symposium and/or shock and vibration community. The tenured panelists will each discuss unique aspects that the Symposium and community can offer to attendees, ranging from capitalizing on networking opportunities, training and continuing education, and career connections and development.

There will be ample opportunity for question and answer, open discussion, and social engagement amongst the attendees. We strongly encourage the target audience to attend to maximize the potential of this discussion group and their own experience.

Feedback from this discussion group will also be used to improve our outreach to the target audience and their experience at future SAVE events.

Each attendee (young engineer or new attendee) participating in this discussion group will be eligible to receive a free gift card!

End Tuesday Events

BREAKFAST WITH THE EXHIBITORS
REUNION BALLROOM | 7:00-8:00AM

	SESSION 9: **MIL-DTL-901E TESTING & SHOCK DATA** 8:00-9:35AM / UNLIMITED DIST. A CHAIR(S): Tom Brodrick (NSWC Carderock) Patrick Minter (NSWC Philadelphia)	*SESSION 10:* **APPLICATIONS OF VIBRATION TEST METHODS** 8:00-9:35AM / UNLIMITED DIST. A CHAIR(S): Dr. Luke Martin (NSWC Dahlgren) Matt Forman (NSWC Dahlgren)	*SESSION 11:* **NAVY SHOCK DDAM & TEST ANALYSIS** 8:00-9:35AM / UNLIMITED DIST. A CHAIR(S): Justin Caruana (Cardinal Engineering) Mark Cotler (NSWC Philadelphia)
	BRYAN-BEEMAN	GASTON	PEGASUS B
8:00	**MIL-DTL-901 Subsidiary Shock Program Development (22)** *Matthew Forman (NSWC Dahlgren), Sloan Burns (NAVSEA)*	**Acoustic monitoring of component condition for microreactor applications (24)** *Rajarshi Bose & Dr. Andrew Delorey (Los Alamos National Laboratory), Dr. Timothy Ulrich & Dr. Paul Geimer (Los Alamos National Laboratories)*	**Electro-Welded stud technology shock test procedure and results (26)** *Dr. Alfonso Barbato & Francesco Miselli (Fincantieri Naval Vessel B.U.)*
8:25	**Determining an estimate for MIL-DTL-901 Figure 13 channel frequency (23)** *Patrick Minter (NSWC Philadelphia)*	**Inverse test based estimation of equivalent acoustic excitation based on aircraft cabin response measurements (25)** *Prof. Benedikt Plaumann, Prof. Habil, Thomas Kletschkowski, Ashish Chodvadiya, & Eugen Hein (Hamburg University of Applied Sciences)*	**Automated Shock Analysis of Shipboard Pipe Hanger Foundations (26)** *Justin Caruana & David Batol (Cardinal Engineering)*
8:50	**Determination of Fundamental Deck Frequency to meet requirements for MIL-DTL-901E (23)** *Calvin Milam (Element US Space & Defense)*	**Packaged and Palletized Ordnance Response Characterization: Do We Care About High Frequency? (26)** *Matthew Forman, Dr. Luke Martin, & Shawn Schneider (NSWC Dahlgren)*	**Optimization of structures under Shock loading (Non-Linear Dynamic) as per MIL-DTL-901E using Equivalent Static Load Method (27)** *Giri Prasanna, Jason Krist, & Kory Soukup (Altair Engineering)*
9:15	**Shock Response Spectrum Analysis and Data Validation Tool for Shipboard Shock, Pyroshock, and More (23)** *Seth Mitchell, Dr. Logan McLeod, & Calvin Milam (Element US Space & Defense)*		**Adapter Plate Analysis and Approval Process for Medium Weight Shock Testing (27)** *Spencer Fallon & Michael Poslusny (Leidos Gibbs & Cox)*

9:35 - 10:00

COFFEE BREAK
with the Exhibitors

EXHIBIT HALL / REUNION BALLROOM

BREAKFAST WITH THE EXHIBITORS
REUNION BALLROOM | 7:00-8:00AM

	SESSION 12: **BLAST EFFECTS MODELING & SIMULATION** 8:00-9:10AM / LIMITED DIST. D 9:15-9:35AM / UNLIMITED DIST. A CHAIR(S): Ernesto Cruz-Gutierrez (USACE ERDC)	*VENDOR SESSION C:* **EXHIBITOR PRESENTATIONS INCLUDING CASE STUDIES, NEW DEVELOPMENTS, TESTING & PRODUCTS** 8:00-9:35AM / UNLIMITED DIST. A CHAIR(S): Lauren Yancey (HI-TEST Laboratories)	*TRAINING III:* **SHOCK RESPONSE SPECTRUM PRIMER** 8:00-9:00AM / UNLIMITED DIST. A TRAINING
	PEGASUS A	REVERCHON	REUNION A
8:00	**Enhancing Ground Shock Predictions for Critical Infrastructure: Development of the SABER-NX Tool (28)** *Ernesto Cruz-Gutierrez, Logan Rice, Dr. Mark Adley, & Dr. Will McMahon (US Army Corps of Engineers ERDC)*	**Unique 6 Degree of Freedom Isolation System Composed of Isolators and Overtravel Snubbers, With Power Input Considerations and Limited Sway Space (30)** *Gordon Fox (Taylor Devices)*	**Shock Response Spectrum Primer (31)** *Dr. Carl Sisemore (ShockMec Engineering)* 8:00 - 9:00AM
8:25	**Applications of Second-Order Finite Element Analysis to Explosive-Structure Interactions and Groundshock (28)** *Dr. Ivan Arnold & Dr. Kent Danielson (US Army Corps of Engineers ERDC)*	**Improved Performance in Wire Rope applications Utilizing High Damped Elastomer (30)** *Timothy Manta (ITT)*	
8:50	**Calculations of 3/8 Scale Earth-Covered Magazines to Investigate Earth Cover Effects (29)** *Dr. Paul Mead, Christopher Shackelford, Dr. Laura Walizer, Dr. T. Neil Williams, Joshua Payne, Dr. John Q. Ehrgott, Jr., Denis Rickman, & Susan Hamilton (US Army Corps of Engineers (ERDC), Spencer Hovey & Andrea O'Brien (DAC/USATCES)*	**From measurements to insights in minutes – Revolutionizing Integrated NVH Testing and Analysis (30)** *Christian Fritz (DEWETRON)*	
9:15	**Second-Order Pyramids Supporting Explicit Solid Dynamics for Simulation of Extreme Events (29)** *Dr. Robert Browning (Battelle Memorial Institute), Dr. Kent T. Danielson (US Army Corps of Engineers ERDC)*	**The Complaint Department gets the most difficult Test Specifications (30)** *Deepak Jariwala (Spectral Dynamics)*	SAVE SHOCK & VIBRATION EXCHANGE

9:35 - 10:00

COFFEE BREAK
with the Exhibitors

EXHIBIT HALL / REUNION BALLROOM

	SESSION 13: **MECHANICAL SHOCK TESTING I** 10:00-NOON / UNLIMITED DIST. A CHAIR(S): Dr. Ted Diehl (Bodie Technology) David Soine (Sandia National Labs)	*SESSION 14:* **DEDICATED SESSION: AERIAL DELIVERY METHODOLOGIES, TECHNOLOGIES, AND SOLUTIONS** 10:00-NOON / UNLIMITED DIST. A CHAIR(S): Dr. Daryoush Allaei (QRDC, Inc.)	*SESSION 15:* **SHIP SHOCK** 10:00-NOON / LIMITED DIST. D CHAIR(S): Dr. Ken Nahshon (NSWC Carderock) David Umansky (NSWC Carderock)
	BRYAN-BEEMAN	GASTON	PEGASUS B
10:00	**Using Test Configuration Transmissibility Functions to Limit Shock Responses (31)** *Guillermo Anaya & Vit Babuska (Sandia National Laboratories)*	**Reusable Universal Skid Board for Airdrop Platforms (34)** *Dr. Daryoush Allaei (QRDC, Inc.)*	**Residual Strength of Damaged Ship Structures (36)** *Dr. Nicholas Reynolds (NSWC Carderock)*
10:25	**Shockfuge: Generating High-Amplitude Pulse Shocks Using a Centrifuge-Based Mechanism (31)** *David Siler, Forrest Arnold, & Eli Lynn (Sandia National Laboratories)*	**Reusable Energy Absorbing Layer (34)** *Dr. Daryoush Allaei (QRDC, Inc.)*	**Development of a Hull Girder Whipping Model from 3D LiDAR Data (37)** *David Umansky, Dr. Ken Nahshon, M. Rodriguez, J. Clark, & M. Kipp (NSWC Carderock), James Krafcik & Samuel Schemmer (AFRL), Derek Bruneis (IS4S)*
10:50	**Quantitative Analysis of Pulse Shape Modeling for Mechanical Shock Tests (32)** *Abigail Smith, Zachary Boeringa, Adam Krzywosz, Dr. Nancy Winfree, Tyler Alvis, Adam Slavin, & David Soine (Sandia National Laboratories)*	**Results of Statically Loading REAL-M12 (35)** *Pete Wolf (Robinson Rubber Products Co.), Dr. Daryoush Allaei (QRDC, Inc.)*	**Data Collection During Fleet SINKEX Events - Recent Advancements (37)** *Dr. Ken Nahshon (NSWC Carderock)*
11:15	**A Practical Approach to Defining Shock Response Spectrum (SRS) Test Specifications (32)** *Jade Vande Kamp (Vibration Research)*	**Field Testing of REAL and RUSB in CDS Bundles (35)** *Kenneth Womack, John Bamburg, & Kevin Williams (Little Rock AFB), Dr. Daryoush Allaei (QRDC, Inc.)*	**Using Drift Compensation to Correct Late-Time Velocity Meter Data with UERDTools (37)** *Tom Thomas (NSWC Carderock)*
11:40	**Synthesizing a Realistic Transient Acceleration Shock Signal to Represent and Bound Diverse Oscillatory Shock Time-Histories (33)** *Dr. Ted Diehl (Bodie Technology, Inc.), Kris Altiero (Bechtel Plant Machinery)*	**LCE-Integrated Release Block - An Effective Replacement Mechanism for the Timing Release Block Used by the Aerial Delivery Community (36)** *Dr. James Rall, Dr. Amir Torbati, & Tristan Collette (Impressio, Inc.)*	**Navy Standard Bookend Fixtures for Shock Testing (37)** *Michael Poslusny & Mike Parnin (Leidos)*

Tip

DON'T FORGET TO VISIT THE EXHIBIT HALL AND COMPLETE YOUR "PASSPORT" FOR A CHANCE TO WIN GIFT CARDS, GADGETS, & MORE!

	SESSION 16: **BLAST & FRAGMENTATION** 10:00-NOON / LIMITED DIST. D CHAIR(S): Dr. t. Neil Williams (USACE ERDC) Christopher Shackelford (USACE ERDC)	*TRAINING IV:* **INTRODUCTION TO MULTI SHAKER TESTING** 10:00-NOON / UNLIMITED DIST. A	*TRAINING V:* **INTRO. TO NONLINEAR ANALYSIS** 10:00-11:00AM / UNLIMITED DIST. A **BUILDING DIGITAL SHOCK TEST MOD-ELS FOR MIL-DTL-901E COMPLIANCE** 11:00AM-NOON / UNLIMITED DIST. A
	PEGASUS A	REVERCHON	REUNION A
10:00	**FABEL V2.0 Features and Application to Multi-Hit Terminal Performance Calculations (38)** *Christopher Shackelford, William Furr, Dr. T. Neil Williams, & Dr. John Q. Ehrgott, Jr. (US Army Corps of Engineers ERDC)*	**Introduction to Multi Shaker Testing (41)** *Raman Sridharan (NVT Group)* 10:00AM - NOON	**Introduction to Nonlinear Analysis (41)** *Bart McPheeters (Gibbs & Cox)* 10:00 - 11:00AM
10:25	**Modeling the Ballistic Behavior of Simulated Fragments against Steel Targets (39)** *David Lichlyter, Dr. T. Neil Williams, & Christopher Shackelford (US Army Corps of Engineers ERDC)*		
10:50	**Characterization of Simplified Surrogate Munition (39(** *Marcus Barksdale (US Army Corps of Engineers ERDC)*		**Optimization of Structures under Shock Loading as per MIL-DTL-901E Working Demonstration (41)** *Giri Prasanna, Jason Krist, & Kory Soukup (Altair Engineering)* 11:00 - NOON
11:15	**Digital Twin Machine Learning for Irregular Fragment Field Characterization (40)** *Dr. Eddie O'Hare & Matt Barsotti (Protection Engineering Consultants), David Chambers & Abe Garza (Southwest Research Institute), Michael Tarbell (Midland Research), Eric Scarborough & Kirk Vanden (AFRL/RQ)*		
11:40	**Modeling a Fragmenting Munition's Close-in Blast Environment (41)** *Dr. T. Neil Williams (US Army Corps of Engineers ERDC)*		

SEE A PRESENTATION WORTHY OF OUR HENRY C. PUSEY AWARD?
REMEMBER TO NOMINATE THAT PAPER USING THE PROVIDED QR CODE!

AWARDS LUNCHEON
(GENERAL SESSION II)
NOON - 1:30PM

REUNION BALLROOM

NOON—12:05PM	**CALL TO ORDER** Mr. Drew Perkins (SAVE / HI-TEST Laboratories)	
12:05PM—12:15PM	**HENRY PUSEY BEST PAPER AWARD** PRESENTED TO:	Dr. Michael Hale (Trideum Corporation), William Barber & Jesse Porter (Redstone Test Center), Dr. Bryan Joyce, Dr. Luke Martin, & Shawn Schneider (NSWC Dahlgren)
12:15PM—12:20PM	**AWARD FOR EXCELLENCE IN INSTRUCTION AWARD** PRESENTED TO:	Joshua Gorfain (Quartus Engineering)
12:20PM—12:40PM	**LIFETIME ACHIEVEMENT AWARD** PRESENTED TO: PRESENTED TO:	Dr. Michael Talley (HII Newport News Shipbuilding) Dr. Jeffrey Dosch (PCB Piezotronics)

Henry Pusey Best Paper Award

PRESENTED TO:

"A Proposed Update to the Common Carrier Vibration Specification"

Dr. Michael Hale (Trideum Corporation), William Barber & Jesse Porter (Redstone Test Center), Dr. Bryan Joyce, Dr. Luke Martin, & Shawn Schneider (NSWC Dahlgren)

The default Common Carrier vibration specification defined in MIL-STD-810H dates to the 1983 release of MIL-STD-810D. While test duration and associated mileage are provided, there is no meta-data provided to address issues such as applied time compression, trailer types, and payload weights. In addition, the wide variation in spectral shapes between the lateral degrees-of-freedom in the current specifications is suspect. This paper takes advantage of a comprehensive set of field measurements acquired by the US Navy on multiple vehicles to propose an updated common carrier specification. Multi-Axis options and examples are also provided.

Award for Excellence in Instruction

PRESENTED TO:

Joshua Gorfain, Quartus Engineering

for his tutorial "Analysis for a Medium Weight Shock Test"

While a shock test is essentially the bottom line for a shock qualification, a lot of analysis often goes into the mix before the test. The reasons for this are many: The equipment manufacturer wants his equipment to pass and will often commission some kind of pre-test prediction to maximize the likelihood of success or to high-light design problems. Since the weight and frequency of the tested equipment can affect the response of the test significantly, the system may need to be examined to assure that the tested environment is correct. This tutorial will first review the Medium Weight Shock Machine (MWSM) and its use in shock qualification testing, followed by presentation of the test environment. Next, the types of analysis that can be performed to estimate the test environment experienced by a given piece of equipment will be described. The intention of these analyses is to provide an assessment of equipment response subject to a MWSM test in an effort to assure a successful test. Additionally, the merits and limits of these methods are discussed so the most appropriate method may be rationally selected for a given application. Examples will be presented that illustrate the different types of analyses and how they may be applied.

AWARDS LUNCHEON
(GENERAL SESSION II)
NOON - 1:30PM

Dr. Michael Talley
2024 LIFETIME ACHIEVEMENT AWARD WINNER

Lifetime Achievement Award

PRESENTED TO:
Dr. Michael Talley
HII Newport News Shipbuilding

Dr. Michael Talley has consistently provided technical leadership, mentoring, and innovation in shock qualification methods and design for over 38 years. His efforts have resulted in significant positive cost and schedule impacts to Navy programs through the development of new test methods, engineering tools, and improved shock designs.

Dr. Jeffrey Dosch
2024 LIFETIME ACHIEVEMENT AWARD WINNER

Lifetime Achievement Award

PRESENTED TO:
Dr. Jeffrey Dosch
PCB Piezotronics

Dr. Jeffrey Dosch's career has been dedicated to pushing vibration measurement boundaries. From pioneering self-sensing actuators as a PhD student to developing piezoelectric technology at PCB, he's left an indelible mark. His leadership in R&D led to breakthroughs in shock and accelerometer calibration, redefining standards and driving the field forward. His innovations are used in calibration labs worldwide, cementing his legacy as a visionary in vibration technology.

Congratulations to our Award Winners!

	SESSION 17: **MAST MOUNTED EQUIPMENT TEST METHODS** 1:30-2:15PM / UNLIMITED DIST. A **VIBRATION: INSTRUMENTATION & DATA ANALYSIS** 2:20-3:30PM / UNLIMITED DIST. A CHAIR(S): EDWARD PEMBERTON (HI-TEST)	*SESSION 18:* **DEDICATED SESSION: DATA ACQUISITION INTEGRATED WITH SPACE TECHNOLOGY** 1:30-3:30PM / UNLIMITED DIST. A CHAIR(S): JAMES ZHUGE (CRYSTAL INSTRUMENTS)	*SESSION 19:* **IMPLOSION** 1:30-2:15PM / LIMITED DIST. D **NUMERICAL ADVANCEMENTS IN SHOCK AND LOADING** 2:20-3:30PM / UNLIMITED DIST. A CHAIR(S): ADAM HAPIJ (THORNTON TOMASETTI)
	BRYAN-BEEMAN	GASTON	MORENO
1:30	**Testing Mast-Mounted Equipment Using Shakers and a Resonant Fixture (42)** *Garrett Wiles & Daniel Moore (NSWC Dahlgren)*	**Locating Acoustic Sources using Timestamped Signals (43)** *Simran Parmar & Dr. James Zhuge (Crystal Instruments)*	**Phorcys – End-to-End Solution for Assessing Implosion Risk Assessment (46)** *Adam Hapij & Dr. Abilash Nair (Thornton Tomasetti), Benjamin Medina (NSWC Carderock), Dr. Joseph Ambrico (NUWC Newport)*
1:55	**Adapting Spring Mass Oscillation to Pneumatic Spring Systems in Shock Testing (42)** *Edward Pemberton (HI-TEST Laboratories)*	**Fully Autonomous Data Acquisition Systems Integrated with Aviation and Space Technology (44)** *Sandeep Mallela & Dr. James Zhuge (Crystal Instruments)*	**Implosion Database Utility – Innovative ML Pipelines for Implosion Assessment (47)** *Dr. Abilash Nair & Christopher Craig (Thornton Tomasetti), Benjamin Medina (NSWC Carderock), Dr. Joseph Ambrico (NUWC Newport)*
2:20	**Innovative Clipping Method Reduces Peaks on the Vibration Shaker Table (43)** *Thomas Woltjer (Vibration Research)*	**Advancing Building Vibration Studies with Distributed Handheld Systems and Patented GPS Timestamp Technology (45)** *Aahash Umesh Mange, Dr. Jeff Zhao, Dr. Zhaoshuo Jiang, Matt Chen, & Dr. James Zhuge (Crystal Instruments)*	**Improving Fracture Modelling of Thin-Walled Structured under Bending Loads (47)** *Dr. Juan G. Londono, Dr. Pawel Woelke (Thornton Tomasetti)*
2:45		**Acquire the Dynamic Data Across the Globe (45)** *Dr. James Zhuge (Crystal Instruments)*	**A Digital Twin for the JASSO Shock Machine (47)** *Dr. Fraser Mackay, Dr. Daniel Clark, Oliver Craggs, Alan Ferguson & Nicholas Misselbrook (Thornton Tomasetti)*
3:10		**NASA QUESST – Measuring Quiet Sonic Booms (46)** *Larry Cliatt II, Samuel Kantor, Sky Yarbrough, & Edward Haering, Jr. (NASA Armstrong Flight Research Center)*	**Numerical Analysis of Air-Backed Structures Under UNDEX Loading (48)** *Dr. Daniel Clark, Dr. Fraser Mackay, Alan Ferguson, Dr. Eric Hansen & Dr. John Mould (Thornton Tomasetti)*

3:30 - 4:15 *Afternoon Dessert Break & Passport Program Drawing*

REUNION BALLROOM/EXHIBIT HALL

SESSION 20: **AIRBLAST MODELING** 1:30-3:05PM / LIMITED DIST. D 3:10-3:30PM / UNLIMITED DIST. A CHAIR(S): Zoran Nadzakovic (USACE ERDC) Joshua Payne (USACE ERDC)	*PANEL:* **MULTI-DEGREE-OF-FREEDOM VIBRATION TESTING CURRENT CAPABILITIES, HURDLES, & PATH FORWARD FOR WIDESPREAD ADOPTION** 1:30PM-3:30PM / UNLIMITED DIST. A	*TRAINING VI:* **INTRODUCTION TO HEAVYWEIGHT SHOCK TESTING** 1:30-3:30PM / UNLIMITED DIST. A
PEGASUS A	SANGER	REUNION A

PEGASUS A — Session 20: Airblast Modeling

1:30 — **Experimental and Numerical Study on Air-Blast Performance in the Presence of Large Debris (48)**
Jakob Brisby, Craig Watry, Dr. Sean Cooper, Dr. Peter Dunn, & Sheera Lum (Applied Research Associates)

1:55 — **BlastX Time-Dependent Breach and Gas Intrusion Model Updates (49)**
Zoran Nadzakovic & Gustavo Emmanuelli-Gonzalez (US Army Corps of Engineers ERDC)

2:20 — **Shock Tube Facilities for Blast Response Testing and Modeling (49)**
Dr. Sean Cooper, Mohsen Sanai, Joe Crepeau, & Waylon Weber (Applied Research Associates)

2:45 — **High-Speed Video Techniques for Airblast Parameter Extraction in Explosive Detonations (50)**
Joshua Payne, Jeffrey Holmes, & Denis Rickman (US Army Corps of Engineers ERDC)

3:10 — **Accelerating Fluid-Structure Interaction Simulations with Viper::Blast and OpenRadioss (50)**
Dr. James Wurster, Andrew Nicholson, Dr. Peter McDonald, Christopher Stirling (Viper Applied Science)

SANGER — Panel

Multi-Degree-of-Freedom Vibration Testing Current Capabilities, Hurdles, and Path Forward for Widespread Adoption (51)

This panel discussion will brief out current lab technologies used to accomplish multi-degree-of-freedom (MDOF) tests and survey the audience to gather perspective on obstacles which have held up the community from more widespread adoption. Feedback will be incorporated to assist in development of a "MDOF Roadmap" to continue adoption efforts.

Panelists:
Matt Forman (NSWC Dahlgren)
Dr. Luke Martin (NSWC Dahlgren)
Troy Skousen (Sandia National Labs)
Ryan Schultz (Sandia National Labs)
Dr. Chris Roberts (UK MOD)
William Barber (Redstone Test Center)

1:30-3:30PM

REUNION A — Training VI

Introduction to Heavyweight Shock Testing (51)

Travis Kerr
(HI-TEST Laboratories)

1:30 - 3:30PM

3:30 - 4:15 — ***Afternoon Dessert Break & Passport Program Drawing***
REUNION BALLROOM/EXHIBIT HALL

TUTORIAL SESSION V
3:30 - 6:30PM

OPTIONAL THREE HOUR COURSES. ATTENDEES WILL RECEIVE A CERTIFICATE OF COMPLETION AND MAY RECEIVE CEUs/PDHs (VARIES BY STATE). ADDITIONAL FEES APPLY TO ATTEND.

SHOCK TEST FAILURE MODES
Kurt Hartsough (901 E&T)

PEGASUS B

This tutorial will cover examples of shock test failures typically experienced by equipment exposed to MIL-DTL-901E shock levels. MIL-DTL-901E provides guidance for designers responsible for meeting the requirements of MIL-DTL-901E. This tutorial will show how and why equipment failures occur and show how minor design changes can prevent shock failures. Hands on demonstrations, real time high speed video and analysis will be used to demonstrate both failures and corrective actions.

QUANTITATIVE METHODS FOR SURVIVABLE ELECTRONICS PACKAGING FOR COMBINED LOADING OF THERMAL AND HIGH AMPLITUDE MECHANICAL SHOCK
NOTE: LIMITED DISTRIBUTION D (SECURITY PAPERWORK REQUIRED)
Dr. Adriane Moura (ARA)
Dr. Matthew Neidigk (AFRL)

REVERCHON

Fuze electronics intended for hard target defeat must survive both MIL-STD thermal cycle environments and extreme mechanical shock. Fuzes are often potted to prevent printed circuit board (PCB) flexure associated with component failure during impact. Potting techniques, or packaging strategies, may vary significantly by vendor and are often developed through trial and error. In many cases they are proprietary. Some packaging strategies include the application of elastomeric coatings to PCBs and components, or the use of epoxy underfills beneath components. Because most packaging materials are polymers, the disparity in thermal expansion between them and other fuze materials leads to a whole new series of problems during thermal cycling. As such, the DoD and the DOE have devoted considerable effort in the areas of material characterization, model development, and experimental validation, all with the goal of identifying survivable packaging strategies for use in both conventional and nuclear weapon stockpiles. Upon completion of this course, the user should have a basic understanding of the properties of common packaging materials, modeling and simulation tips and tricks, and latest developments in the design and evaluation of survivable packaging strategies for high-g electronics.

MISSION SYNTHESIS FROM FIELD DATA TO SHAKER REFERENCE PROFILES
Umberto Musella (Siemens)
Alberto Garcia De Miguel (Siemens)

MORENO

Vibration control tests are performed to verify that an aerospace system and all its sub-components can withstand the vibration environment during the operational life. These tests aim to accurately replicate the in-service environment that a Device Under Test (DUT) will experience in-service via controlled shaker excitation. For aerospace systems and subsystems, random and/or sine vibration tests are required for all the main mechanical and electrical components. These types of tests are performed to replicate in the laboratory the response of the DUT to the broadband random inputs (e.g. transportation or in-flight environments) or responses to sweeping tonal phenomena. Many manufacturers rely upon ASTM, IEEE, MIL or ISO standard to define the vibration profiles. These profiles are typically the results of enveloping a very large set of possible in-service events and also include conservative safety margins. Some events used for standard profiles may not be representative for a specific DUT and yet drive the design leading to potentially unacceptable and costly overdesign. More dangerously, events that may be critical for a specific DUT may not be well-captured by the legacy standardized profiles. This could lead to product field failures, consumer dissatisfaction and warranty/recall costs. In this tutorial we describe a robust methodology to derive shaker test specification directly from field data.

TUTORIAL SESSION V
3:30 - 6:30PM
(CONTINUED)

INTRODUCTION TO WEAPONS EFFECTS AND SHIP COMBAT SURVIVABILITY ANALYSIS
Jan Czaban (Zenginworks Limited)

REUNION A

This short course provides a practical understanding of naval ship combat survivability and methods to assess the effects of various weapons. The introduction will review terminology, concepts and current practice involved in setting, achieving and verifying survivability requirements. Naval threats and weapon types will be reviewed and methods for predicting their resultant loads and damage mechanisms explained. Primary weapons effects will include attacks from underwater explosions, above water explosions, internal blast, fragments and ballistic projectiles. Sample problems will be provided to demonstrate how to estimate the extent of damage sustained by ship structures and how to apply and interpret damage using standard terms of capability degradation. Methods for hardening ship systems and structures will be reviewed with an introduction provided to explain dynamic load effects tolerance, armour systems and simplified pass/fail global design assessment techniques. The course material will be entirely based on public domain sources and includes a comprehensive list of references and applicable military standards.

A PRIMER ON VIBRATION TESTING AND DATA ANALYSIS
Dr. Luke Martin (NSWC Dahlgren)

BRYAN-BEEMAN

This tutorial will give an introduction to vibration testing and will be concept focused. The tutorial will begin with an understanding of a typical laboratory vibration test setup, followed by a deeper dive of the fundamental components. Specifically, a typical single degree of freedom vibration test will be decomposed into its pieces: amplifier, shaker, slip table, test item, vibration controller, and reference profiles. Once the components of the control loop are understood, the tutorial will focus on data analysis required by both the vibration controller to conduct a test and by a user who wishes to use measured field data to develop a tailored vibration test profile.

Along the way concepts that will be covered are: electrodynamic shakers, servo-hydraulic shakers, single degree of freedom testing, multiple degree of freedom testing, control vs measurement transducers, Miner’s Rule, sinusoidal testing, random testing, mixed mode testing, MIL-STD-167, MIL-STD-810, need for tailored vibration data, and digital signal processing used for data analysis.

SEVERAL ISSUES IN THE ANALYSIS, GENERATION, AND SIMULATION OF SHOCK
Zeev Sherf (Consultant)

SANGER

Given a shock spectrum, many shock time histories can be generated from it, although from one time history only one shock spectrum can be generated. This is a well known fact. And also a limiting one, in the use of the shock spectrum as a measured shock's, descriptive tool. The presentation starts by demonstrating, how from one shock spectrum, several different shock time histories can be generated. They differ not only in shape and duration but also in several characteristic parametersthat can be given numerical values. As such are the vibro-acoustic indexes, the energy of the shock and the damage induced by it. The work starts by the description of the shock time history generation process from a given shock spectrum. From the same shock spectrum several shock time histories are generated. Characteristic shock descriptive parameters can be evaluated: the energy, the induced damage and the vibro acoustic indexes. In the present paper the energy is used.

WEDNESDAY NIGHT SOCIAL

NOVEMBER 6

7:00-10:00 PM

ALL ATTENDEES & GUESTS WELCOME

DINNER & DRINKS PROVIDED TO ALL SAVE ATTENDEES AND GUESTS.

BRING YOUR CONFERENCE BADGE FOR ENTRY.

ALL FOOD, DRINKS, AND ACTIVITIES ARE SPONSORED IN FULL BY OUR COMMERCIAL SPONSOR.

HI-TEST Laboratories, Inc.

Transportation not provided.
The House of Blues is an approximate 3/4 mile walk from the Hyatt Regency Dallas.
Please use the private event entrance to avoid concert ticketing/wait lines.

ATTENDEE BREAKFAST
REUNION BALLROOM | 7:00-8:00AM

	SESSION 21: **MECHANICAL SHOCK TESTING II** 8:00-10:00AM / UNLIMITED DIST. A **APPLICATIONS OF NOVEL SHOCK AND VIBRATION INSTRUMENTATION** 8:50-10:00AM / UNLIMITED DIST. A CHAIR(S): Dr. Pablo Tarazaga (Texas A&M) Dr. Carl Sisemore (ShockMec Eng.)	*SESSION 22:* **SHOCK NUMERICAL TOOL ENHANCEMENT** 8:00-10:00AM / UNLIMITED DIST. A CHAIR(S): Jerome Cap (Sandia National Labs) Brian Lang (NSWC Carderock)	*SESSION 23:* **MODELING AND SIMULATION VALIDATIONS** 8:00-8:45AM / LIMITED DIST. D **SHOCK QUALIFICATION** 8:50-10:00AM / LIMITED DIST. D CHAIR(S): Jordan Poehler (NSWC Carderock) Ryan Shorts (NSWC Carderock)
	BRYAN-BEEMAN	GASTON	PEGASUS B
8:00	**Miniaturized Resonant Plate Testing with High Shock Loads (52)** *Dr. Carl Sisemore (ShockMec Engineering), Elliott Pelfrey (Sandia National Laboratories)*	**Using Rainflow Fatigue Damage Spectra to Characterize Shock and vibration Environments (54)** *Jerome Cap & Eric Pulling (Sandia National Laboratories)*	**Elastic Plastic Impact Characterization Modeling and Simulation Validation (56)** *Matt Stevens (NSWC Carderock)*
8:25	**Parametric Tuning of a Resonant Plate Shock Test SRS (52)** *Trevor Turner & Dr. Pablo Tarazaga (Texas A&M University), Chase Zion, Dr. Washington DeLima, & William Zenk (Honeywell Federal Manufacturing & Technology)*	**Rotation Matrix Used in SIMPLE (54)** *Dr. Michael Talley (HII-Newport News Shipbuilding)*	**Abaqus Fully Coupled Acoustic Fluid-Structure Analyses Characterization Study (56)** *Sara Fisher (NSWC Carderock)*
8:50	**Rapid Characterization of Compact Granular Materials Using Laser Doppler Vibrometry and Resonant Ultrasound Spectroscopy (53)** *Joshua Bartlett, Caleb Fryer, & Dr. Pablo Tarazaga (Texas A&M University), Dr. TJ Ulrich (Los Alamos National Laboratory)*	**GPU-Accelerated CFD for Near Surface UNDEX Explosion Simulations: Capabilities and Experimental Validation (55)** *Andrew Nicholson & Chris Stirling (Viper Applied Science), Dain Farrimond, Adam Dennis, Genevieve Langdon, Andy Tyas, Lewis Tetlow, & Tommy Lodge (Univ. of Sheffield), Piotr Nowak, Piort Sielicki, & Tomasz Gajewski (Poznan Univ. of Tech.)*	**Navy Additive Manufacturing (AM) Shock Qualification and R&D (57)** *Jake Mason (NSWC Carderock)*
9:15	**Towards In-situ Resonant Ultrasound Spectroscopy of Additive Manufactured Parts by Tackling the Build Plate-Specimen Coupling (53)** *Jeriel Jammullamudy, Dr. Pablo Tarazaga, & Dr. Satish Bukkpatnam (Texas A&M University), Dr. TJ Ulrich (Los Alamos National Laboratory)*	**A Computational Geers-Hunter Model Parameterised for Depth and CFD Inputs (55)** *Dr. James Wurster, Andrew Nicholson, & Ben Evans (Viper Applied Science)*	**Bolt-On Paddlewheel Test Vehicle (57)** *Timothy McGee (NSWC Carderock)*
9:40			**Development of an Alternative Reduced-Blow Low-Impact Shock Test Informed by Simulation (57)** *LeeYung Chang (NSWC Carderock)*

ATTENDEE BREAKFAST
REUNION BALLROOM | 7:00-8:00AM

	SESSION 24: **SHOCK & VIBRATION TESTING FOR FLIGHT SYSTEMS** 8:00-8:20AM / LIMITED DIST. D 8:25-10:00AM / LIMITED DIST. C CHAIR(S): Dr. Ricky Stanfield (Corvid Technologies) Dr. Richard Jepsen (Sandia National Labs)	*TRAINING VII:* **INTRODUCTION TO MEDIUM WEIGHT SHOCK TESTING** 8:00-10:00AM / UNLIMITED DIST. A	*TRAINING VIII:* **CAN I TRUST MY FEA MODEL?** 8:00-9:00AM / UNLIMITED DIST. A **INTRODUCTION TO MIMO VIBRATION TESTING** 9:00-10:00AM / UNLIMITED DIST. A
	PEGASUS A	REVERCHON	MORENO
8:00	**Sounding Rocket Flight Vibration versus Reynold's and Strouhal Numbers (57)** *Dr. Ricky Stanfield (Corvid Technologies)*	**Introduction to Medium Weight Shock Testing (59)** *Jeff Morris (HI-TEST Laboratories)* 8:00-10:00AM	**Can I Trust My FEA Model? (60)** *Bart McPheeters (Gibbs & Cox)* 8:00-9:00AM
8:25	**Combined Shock, Vibration, and Inertial Testing for Component Flight Environments (58)** *Dr. James Nicholas, Peter Yeh, Ron Hopkins, Dr. Richard Jepsen, Leticia Mercado, & Jason Wilke (Sandia National Laboratories)*		
8:50	**Implementing a Shock Tube on the Superfuge (58)** *Dr. Richard Jepsen, Sameer Sheth, Dr. James Nicholas, Peter Yeh, & Ian Minervini (Sandia National Laboratories)*		
			Introduction to Multiple-Input/ Multiple-Output Vibration Testing (60) *Dr. Ryan Schultz (Sandia National Laboratories)* 9:00-10:00AM
9:15	**Multi-Axis Distributed Excitation Environmental Testing - Exploring Test Specification (59)** *Aaron Feizy & Kai Newhouse (Los Alamo National Laboratory)*		
9:40	**The Potential for Combined Vibration and Shock Testing for Component Flight Environments (59)** *David Soine, Forrest Arnold, Steve Carter, Kevin Cross, Greg Melendez, & Dr. Ryan Schultz (Sandia National Laboratories)*		

THURSDAY (NOVEMBER 7)

	SESSION 25: **PYROSHOCK ANALYSIS & DATA PROCESSING** 10:00-11:35AM / UNLIMITED DIST. A **MATERIAL STUDIES** 11:15-NOON / UNLIMITED DIST. A CHAIR(S): Dr. Vasant Joshi (NSWC Indian Head) Dr. Nancy Winfree (Sandia Ntl Labs)	*SESSION 26:* **VIBRATION DAMAGE & FATIGUE** 10:00-11:10AM / UNLIMITED DIST. A **ADVANCEMENTS IN VIBRATION TESTING & MEASUREMENT** 11:15AM - NOON / UNLIMITED DIST. A CHAIR(S): Dr. Peter Vo (Raytheon) Dr. Arup Maji (Sandia National Labs)	*SESSION 27:* **MECHANICAL SHOCK TESTING & ANALYSIS** 10:00-11:10AM / LIMITED DIST. D 11:15-NOON / LIMITED DIST. C CHAIR(S): Mackenzie Wilson (HII-NNS) Christina Backes (NSWC Philadelphia)
	BRYAN-BEEMAN	GASTON	PEGASUS B
10:00	**Evaluation of Viscoelastic Passive Damping for Shock Response Mitigation (60)** *Brandon Sobecki, Matt Butner, & Steve Rudolph (Damping Technologies, Inc.)*	**Multi-Axis Durability Testing: Challenges of an Innovative Testing Practice (62)** *Dr. Alberto Garcia de Miguel, Ruben Araujo, Umberto Musella, Dr. Matta dal Borgo, & Dr. Bram Cornelis (Siemens Digital Industries Software)*	**Combat System Standard Foundation Analysis Tool (65)** *Mackenzie Wilson & Ify Amene (HII-Newport News Shipbuilding)*
10:25	**Quantitative Evaluation of Measurement System Transfer Functions for Shock Response Spectrum Calculations (61)** *Douglas Firth, Dr. Thomas Gerber, & Alan Szary (Precision Filters)*	**Evaluation of Fatigue Damage from Random Vibration and Sine-Sweep (63)** *Dr. Arup Maji (Sandia National Laboratories)*	**Load Cell Drop Test Data Integration with FEA Simulation for Combustible Case Materials (65)** *Arhum Mirza (Picatinny Arsenal)*
10:50	**Validating a Mechanical Impulse Pyroshock Simulator (MIPS) Finite Element Model (61)** *Claudia Navarro-Northrup & Dr. Logan McLeod (Element US Space & Defense)*	**Perspectives of Fatigue Estimation in Random Vibration using Accelerometers and Machine Learning (63)** *Dr. Charles Hull (Lockheed Martin)*	**Printed Hybrid Electronic (PHE) Assemblies Subject to Extreme Mechanical Shock (100,000G) at Elevated Temperatures (150° C) (66)** *Maj. Hayden Richards & Dr. Abhijit Dasgupta (Univ. of Maryland College Park), Andres Bujanda, Dr. Harvey Tsang, & Matt Bowman (DEVCOM Army Research Lab)*
11:15	**Detection of Degradation of Polymers using Improved Method of Acoustic Waves Transfer Function in Resonance Apparatus (62)** *Dr. Vasant Joshi & Michael Meade (NSWC Indian Head)*	**Advanced 3D Modeling of High-Frequency Problems using SEA Methods (64)** *Kory Soukup & Sravan Kuma Reddy Mothe (Altair Engineering)*	**The History of Hard Target Electronics Packaging Techniques at Sandia (66)** *Shane Curtis & Mike Patridge (Sandia National Laboratories)*
11:40		**Camera-Based Modal Analysis and Motion Amplification (64)** *Dr. Jeff Hay (RDI Technologies)*	**Microbeaded Encapsulants as Shock Mitigation for Electronic Survivability (67)** *Natasha Wilson, Alex Chen, Cayden Boll, Dr. Damon Burnett, & Dr. Jeff Hill (Sandia National Laboratories)*

1:00 - 2:00

SAVE TECHNICAL ADVISORY GROUP (TAG) MEETING

REUNION A

The annual meeting of the members of the SAVE Technical Advisory Group (TAG) will convene to review the 94th Shock & Vibration Symposium and discuss plans for 2025.

SESSION 28: **BLAST EFFECTS** 10:00-NOON / LIMITED DIST. D CHAIR(S): Stephen Turner (USACE ERDC) Dr. Jay Ehrgott (USACE ERDC)	*DISCUSSION GROUP:* **DYNAMIC ENVIRONMENTS QUALIFICATION WORKING GROUP** 10:00-NOON / UNLIMITED DIST. A	*TRAINING IX:* **SIMPLIFIED FINITE ELEMENT MODEL GENERATION & POST-PROCESSING FOR EXODUS II AND SIERRA SD/SM** 10:00AM - NOON / UNLIMITED DIST. A
PEGASUS A	REUNION A	MORENO

PEGASUS A

10:00	**Methodology and Equation Development for Predicting Pressure Event Propagation in Complex Subterranean Environments (68)** *Jasiel Ramos-Delgado, Joshua Payne, & Dr. John Q. Ehrgott, Jr. (US Army Corps of Engineers ERDC), Cindy Negreo Carrion (Univ. of Puerto Rico)*
10:25	**Investigation of Methodologies for Predicting Airblast from Below Ground Detonations (68)** *William Myers, Denis Rickman, & Dr. John Q. Ehrgott, Jr. (US Army Corps of Engineers ERDC)*
10:50	**Repair and Enhancement of Barrier Systems Using High Performance Shotcrete (68)** *Stephen Turner (US Army Corps of Engineers ERDC)*
11:15	**Validation Experiments of High-Explosive Shock Propagation through Rock Joints Using Concrete Surrogate Targets (69)** *Adam Mayatt (US Army Corps of Engineers ERDC)*
11:40	**Perforation of Reinforced Concrete and Stiffened Steel Targets Using a Payload Delivery Vehicle with Multiple Payload Types (69)** *Logan Callahan, Dr. Zane A. Roberts, Z. Dr. Kyle Crosby, and Dr. John Q. Ehrgott, Jr (US Army Corps of Engineers ERDC)*

REUNION A

Dynamic Environments Qualification Working Group

Troy Skousen & David Soine
(Sandia National Laboratories)

10:00AM - NOON

The goal of dynamic environments qualification is to demonstrate that designs can withstand vibration inducing in-service loads while performing as required. Qualification evidence is often collected through laboratory testing intended to mimic field environment conditions with some conservatism. The objective of the working group is to shepherd the advancement of ideas and methods for shock and vibration environments qualification through test and analysis in the Shock & Vibration Symposium community. It is a forum to bring together the people that will lead the community to advance the state of the art in dynamic environments qualification. Collaborative discussion will include:

- *Discuss and evaluate the effectiveness of dedicated sessions, tutorials, trainings, and discussion groups held at the symposium this year.*
- *Identify thoughts, traditions, and standard practices that may be holding us back.*
- *Sharing thoughts on the research needed to advance the state of the art.*
- *What actions should the working group take within and external to the Shock and Vibration Symposium?*

MORENO

Simplified Finite Element Model Generation & Post-Processing for Exodus II and Sierra SD/SM (70)

Jason Krist, Giri Prasanna, & Kory Soukup
(Altair Engineering)

10:00AM - NOON

1:00 - 2:00

SAVE TECHNICAL ADVISORY GROUP (TAG) MEETING

REUNION A

The annual meeting of the members of the SAVE Technical Advisory Group (TAG) will convene to review the 94th Shock & Vibration Symposium and discuss plans for 2025.

Exhibitor List

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104	BOEING - LMTF
105	SPECTRAL DYNAMICS
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201	TAYLOR DEVICES
202	PCB PIEZOTRONICS
203	PCB PIEZOTRONICS
204	ELEMENT US SPACE&DEF
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305	HBK/DYTRAN
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402	ETS SOLUTIONS
403	SHOCK TECH
404	DEWESOFT
405	DATA PHYSICS/TEAM
406	VIPER APL. SCIENCE
501	VIBRATION RESEARCH
502	SOCITEC
503	REL, INC.
504	JOHNS EVANS' SONS
505	ISOLATION DYNAMICS CORP
506	901 ENGINEERING & TRAINING
507	SOC. OF EXP. MECHANICS
508	ALTAIR
601	SIEMENS
602	ROBINSON RUBBER
603	HII
604	DEWETRON
605	THORNTON TOMASETTI
606	SHOCKMEC ENGINEERING
607	CRYSTAL INSTRUMENTS
F1	MECALC
F2	MECALC
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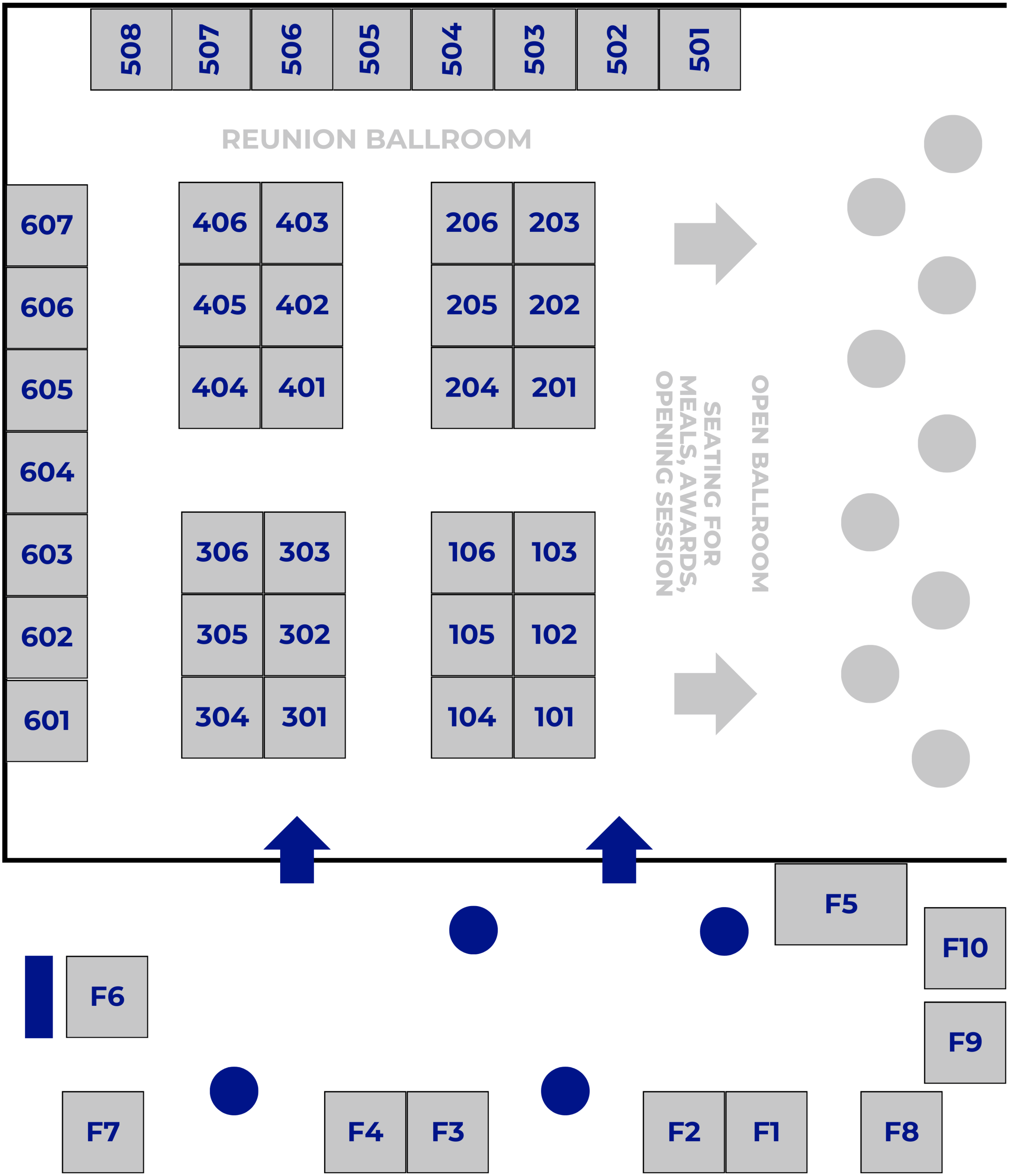
F6	UNHOLTZ-DICKIE CORP
F7	HI-TECHNIQUES
F8	NAC IMAGE TECH.
F9	SPECIALISED IMAGING
F10	ADV. TEST EQUIP. RENTALS

Exhibit Hall Layout



Exhibitor Descriptions

901E&T provides an extensive training course on MIL-DTL-901E. Presented by a previous Delegated Approval Authority (DAA) of NAVSEA, the instructor provides a history of the MIL-Spec and delves into the comprehensive arena of shipboard equipment shock qualification. By the end of the course, participants will have the knowledge/strategies to craft a streamlined, cost-effective shock qualification test schedule.

ADVANCED TEST EQUIPMENT RENTALS primary focus is providing a complete rental solution of measurement and test equipment to industries such as Aerospace, Defense, Communications, EMC, and more. Our wide inventory, custom solutions, flexible terms, and quality support differentiates us from competitors as a complete solution for all test and measurement needs. Our inventory covers most electronic test applications and we are always expanding to remain the leading rental provider.

ALTAIR is a global leader in computational science and artificial intelligence (AI) that provides software and cloud solutions in simulation, high-performance computing (HPC), data analytics, and AI. Altair enables organizations across all industries to compete more effectively and drive smarter decisions in an increasingly connected world – all while creating a greener, more sustainable future.

BODIE TECHNOLOGY provides engineers with excellent software, training, and consulting resources to help analyze complex nonlinear mechanics problems, especially those involving problematic or noisy transient data. Bodie offers guidance on how to tackle a nonlinear mechanics problem, including best practices for utilizing FEA and physical testing methods.

BOEING is the world's largest aerospace company and leading manufacturer of commercial jetliners and defense, space and security systems. A top U.S. exporter, the company supports airlines and U.S. and allied government customers in 150 countries. Boeing products and tailored services include commercial and military aircraft, satellites, weapons, electronic and defense systems, launch systems, advanced information and communication systems, and performance-based logistics and training.

CORRELATED SOLUTIONS, INC. develops and manufactures turn-key Digital Image Correlation (DIC) measurement systems for non-contact full-field analysis of shape, motion, deformation, strain, and vibration applications. The VIC-3D HS FFT system is capable of measuring ODS's with frequencies up to 50 kHz with nanometer resolution and has a large dynamic range. Visit the booth to see new windowing function options and how they can be used to see distinct amplitude peaks in the frequency domain.

CRYSTAL INSTRUMENTS (CI) Is a leading worldwide supplier of vibration controllers, portable dynamic signal analyzers, and dynamic measurement systems for product testing, machine monitoring, and vibration and acoustic analysis. CI's products are used across a wide range of industries, including aerospace, defense, and medical device manufacturing.

DATA PHYSICS has been pioneering high-performance vibration testing and signal analysis in the aerospace, defense and automotive industries since 1984. We design and manufacture a range of air and water-cooled electrodynamic shakers, vibration controllers, and dynamic signal analyzers. Data Physics controllers lead the industry in multi-shaker vibration control, and our MIMO controllers are trusted to control the world's most advanced multi-shaker vibration tables. Data Physic control and safety technology was critical to the successful pre-launch testing of the James Webb Space Telescope, and Sierra Space Dream Chaser spaceplane.

DAYTON T. BROWN's tenured engineers provide experience in adapting our test equipment to meet the most challenging customer requirements. Our extensive test facility includes several shakers, anechoic EMI/EMC rooms, multiple chambers to perform a myriad of environmental tests and our newly expanded structural testing area with its 40ft ceiling. DTB is an A2LA and NVLAP accredited laboratory in accordance with ISO/IEC 17025 requirements and is ISO 9001:2008 and AS9100C registered.

Exhibitor Descriptions

DEWESOFT, a privately held company, is a World leading provider of data acquisition software and hardware serving all. The DEWESoft software and hardware synchronizes Analog, Digital, Video, GPS, CAN, ARINC 429/1553, PCM and Chapter 10 support. The instruments have wide temperate and shock ranges and are available in many configurations.

DEWETRON, an Austrian manufacturer, offers highly intuitive, end-to-end test and measurement systems designed to enhance predictability, efficiency, and safety across the globe. Our modular systems provide reliable measurement data and flexible, needs-based data acquisition capabilities, catering to the energy, automotive, transportation, and aerospace industries. Our strength lies in delivering customized measurement solutions that are ready-to-use and can be quickly adapted to the evolving needs of test environments and advanced technologies. With over 30 years of experience, innovation, and collaboration, DEWETRON has earned the trust and respect of the global market, with more than 25,000 DEWETRON measurement systems and over 400,000 measurement channels in operation at renowned companies worldwide.

E-LABS is a full-service testing laboratory featuring state of the art facilities, knowledgeable personnel, and simulation services such as test planning and fixture design. We perform climatic and dynamic testing, offer full EMI and EMC testing, and conduct specialized testing such as explosive atmosphere, high pressure, and helium leak detection.

Founded as NTS Technical Systems, today **ELEMENT U.S. SPACE & DEFENSE** brings more than 60 years of experience and expertise being tasked with the most complex projects and programs in the world. From centrifuge testing for the latest Mars rover, vibration testing for the Space Launch System (SLS), or environmental simulations for next-generation missiles, Element U.S. Space & Defense is the pioneering partner for highly custom, end-to-end, testing design and implementation.

ENDEVCO provides a complete range of dynamic test and measurement sensor solutions, including piezoelectric, piezoresistive, MEMS, and variable capacitance accelerometers, as well as angular rate, shock, and 6 DoF sensors, miniature pressure sensors, signal conditioners, cables and accessories. Our brand is recognized for highly reliability products with a wide range of testing applications, including automotive design and crash testing, aircraft and space vehicle testing, weapons and munition testing, and general lab testing. Endevco is an assumed name of PCB Piezotronics of North Carolina, Inc., which is a wholly-owned subsidiary of PCB Piezotronics, Inc. More info www.endevco.com

ETS SOLUTION is a world leader in High performance shakers, designed to enable the better test. We are discussing our IPA series amp, designed to never fail a fuse, and our Extreme Acceleration Solid armature Y-connection "EASY" Ring, designed for up to 220 g sine and 180 g RMS Random. ETS Solutions offers affordable, high quality vibration test equipment. Utilizing extensive and innovative technical expertise ETS delivers a reliable long term solution to meet your test requirements. All systems comply with the European CE standards with full testing and certification from TUV-SUD Product Service GmbH.

EXPERIOR LABORATORIES, INC is a Southern California based, third-party test laboratory providing independent design verification and qualification testing services to component and system manufacturers, military contractors, integrators and system providers within the Telecommunication, Military, Aerospace, Space, Industrial, Medical and many other industries. Recognized throughout the industry for superior customer service, consistent on-time delivery, project management by experts and end-to-end accountability, Experior Labs offers customers cost-effective, highly qualified testing services that add value to any organization, regardless of size.

DYTRAN BY HBK. is a leading manufacturer and designer of piezoelectric and DC MEMS sensors. Dytran offers a complete range of impulse hammers, piezoelectric force and pressure sensors, electronics, cables, and accessories for dynamic measurements, with full in-house customization capabilities.

Exhibitor Descriptions

Since foundation in 1986, **HEAD ACOUSTICS** has been a reliable partner wherever acoustics, vibrations, or speech, audio and sound quality play an important role. We are not only one of the world's leading companies in the comprehensive analysis of sound and vibration; our expertise and pioneering role in measurement and optimization of speech and audio quality in communications technology are recognized worldwide. Our customers value the combination of cutting-edge measurement technology with decades of experience. With our hardware and software, we offer scalable solutions for specific problems posed by a variety of applications. As a service, our experts develop acoustic optimization approaches – in close cooperation with our customers and tailored to their individual needs.

HII is America's largest military shipbuilder. HII specializes in providing shock and vibration qualification and support through recognized expertise in testing and advanced shock analysis. HII is also the creator of the patented Deck Simulating Shock Machine (DSSM), the newest Navy approved test method in MIL-DTL-901E.

HI-TECHNIQUES has been a leader in High Performance Data Acquisition Systems for nearly 30 years. Initially founded as a spin off of Norland Corporation, Hi-Techniques has specialized in transient recorders, data acquisition systems and high resolution Digital Oscilloscope products for a variety of applications and markets. Our latest product range, the Synergy, is Hi-Techniques' 7th Generation of Data Acquisition Products. Designed from the ground up, Synergy offers unparalleled performance in data acquisition.

HI-TEST LABORATORIES, INC. is an unparalleled facility that has provided engineering, testing, and evaluation services to government and industry since 1975. HI-TEST is the undisputed leader in MIL-DTL-901E shock testing, housing all approved platforms at one convenient location. From pre-test analysis to post-test report generation, we offer our analytical engineering tools and expertise alongside our testing and design capabilities to make your test run as smoothly and efficiently as possible.

HUTCHINSON Defense and Mobility products have proven performance in all major modern conflicts from the first Gulf War to the Balkans, Iraq, Afghanistan and Syria. Hutchinson is trusted worldwide by soldiers to ensure their mobility and protection in all terrains and combat situations. Hutchinson provides innovative products and proactive support that exceeds customers' expectations and meets the demands of tomorrow's lighter and more survivable vehicles.

Headquartered in Long Island, NY, **IDC** is a leader in the design, engineering, and manufacture of Shock & Vibration Isolation systems for both military and commercial applications. Specializing in rugged, all-metallic wire rope isolators. IDC has amassed an impressive list of shock qualified systems for the US Navy and all branches of the military. IDC's unsurpassed experience and knowledge in the field of shock and vibration isolation, makes it possible for us to engineer a solution from early concept to final product. All of IDC's products are proudly made in the USA using only the highest quality domestic materials.

ITT ENIDINE DEFENSE designs and manufactures energy absorption, vibration isolation and shock systems for defense applications. These engineered products support applications in weapon systems, naval, transportation, and aviation. Products include elastomeric, hydraulic, mechanical shock isolation, as well as standard off the shelf products such as HERMS and Wire Rope Products.

JOHN EVANS', an international leader in spring design & production with proven expertise in precision, utilizing advanced design & manufacturing technology. Industries with sensitive equipment, such as, aerospace, military, and medical can especially benefit from vibration isolators. If your device falls within one of these applications or you frequently deal with shock and vibration problems, our helical vibration isolators may be an ideal solution. They provide superior shock and vibration protection on all axes using aircraft-quality aluminum and stainless steel cable. Our isolators resist corrosion and withstand extreme environments. We offer several counterbalance options to assist/enhance articulated instruments & assemblies, many medical equipment designers utilize constant force springs, constant force spring motors, spiral torsion springs or spring reels. Our Engineering staff is eager to discuss the design requirements & challenges in your design & prototype phase.

Exhibitor Descriptions

M+P INTERNATIONAL is a worldwide provider of high-quality test and measurement solutions for vibration control, noise & vibration analysis and general data acquisition. By working closely with our customers, we understand their applications from an engineer's point of view and this is apparent in our products. A policy of continuous research and development, which has led to many pioneering solutions, ensures that our products demonstrate superior performance and quality.

MECALC is announcing the release of its newest Module for shock data acquisition. This Module is the industry's first 5 MSa/s 24-bit digitizer for PyroShock with a flat frequency response to 2.1 MHz. Not all shock capture systems are the same. This Module includes Bridge/Signal Conditioning, Advanced Trigger options, and scales to over 1000 channels. Come by our booth to hear why this solution is unique in the market and how it can help you. MECALC provides advanced signal conditioning and data acquisition solutions. Our QuantusSeries platform is used globally at the world's leading manufacturers in Automotive, Aerospace, Space, and Defense.

MIDE / ENDAQ is a Hutchinson Company with brands that include: enDAQ shock, vibration & environmental sensors & software; Piezo.com Offering high-value piezoelectric products and expert solutions; and Mide's HydroActive Seal Products. Midé is a leading provider of advanced engineering products and services. Midé is committed to providing customers with high-quality deliverables that are on-time, on budget, and meet their expectations through the use of a quality management system focused on continual improvement. Midé uses industry best practices in both execution and cost effectiveness.

NAC IMAGE TECHNOLOGY is the most experienced name in high speed camera systems. Since 1958, NAC's reputation for technical and digital innovation and comprehensive, integrated line-up of products have set industry standards for performance and reliability. NAC cameras feature industry leading, clean, crisp image quality, combined with the fastest frame rates and unmatched light sensitivity.

PCB manufactures vibration, pressure, force and strain, shock, and acoustic sensors used by design engineers and predictive maintenance professionals worldwide for test, measurement, monitoring, and control requirements. Our sensors support testing in aerospace and defense, automotive, transportation, civil engineering, and general R&D industries. Primary sensing technologies include piezoelectric (ICP®), piezoresistive, and capacitive MEMS. With a worldwide customer support team, 24-hour SensorLine, and a global distribution network, PCB is committed to Total Customer Satisfaction. PCB Piezotronics is a wholly-owned subsidiary of Amphenol Corporation.

PHOTRON has continually expanded their product line to aid in the advancement of photo optics and electronic technologies furthering research and development in the areas of digital imaging and slow motion analysis. Markets include microfluidics, military testing, aerospace engineering, automotive, broadcast, particle image velocimetry (PIV), digital image correlation (DIC), ballistics testing, and more.

PRECISION FILTERS, INC. is a global provider of instrumentation for test measurements. You can rely on a single source for signal conditioning and switching—a complete range of instrumentation—products optimized to work together to provide high performance at reasonable cost. PFI designs and manufactures precision solutions that include a family of analog signal conditioning, filtering and switching systems. The 28000 Signal Conditioning System provides a complete range of transducer conditioning with up to 256 channels per chassis. Precision's solid-state switch provides up to 256x256 cross-point switching and replaces tedious manual patch panels. The PF-1U provides 8 or 16 channels of high performance filter/amplifiers in a compact package with Ethernet control.

RDI TECHNOLOGIES, INC. was founded in 2013 to commercialize video-based sensing technologies created in the lab at the University of Louisville. Since the beginning, our commitment has been to innovate using relatable video technology and easy-to-use software. In 2015 RDI Technologies invented and began the development of the first-to-market Motion Amplification® platform technology for motion and vibration detection and analysis using video. This product was released to the market in 2016 with rapid market adoption. With the release of the Iris M™, RDI created a new category of motion and vibration detection and revolutionized the way the Predictive Maintenance industry saw motion. We are poised to do the same in the Test and Measurements market over the next few years.

Exhibitor Descriptions

REL, INC. is a World Class Original Equipment Manufacturer for LED Lighting and High Strain Rate Testing Solutions. REL provides solutions that are used in world class research and development institutions worldwide for bleeding edge product development. LED spectral output with spectral intensities higher than thermobaric explosions and testing timescales measured in microseconds are common environments for tested, tough REL products. Call 906-337-3018 to discuss your specific Dynamic Testing Challenge.

For over three-quarters of a century, **ROBINSON RUBBER** has been a beacon of innovation and quality in the rubber manufacturing industry. Delivering optimal seals for various aviation applications, from light aircraft to commercial airliners, helicopters, and spacecraft. Our proven performance extends across diverse systems, including flight controls, actuation, landing gear, wheels, brakes, fuel controls, engines, interiors, and aircraft airframes.

SHOCK TECH brings higher value and quality products to meet the most stringent industry standards. We design, manufacture and test shock attenuation and vibration isolation systems for the most demanding environments. We provide solutions for your equipment's dynamic protection problems and are experts at quick-turn, affordable results.

SHOCKMEC ENGINEERING is a small startup research and development company focused on shock testing and analysis. We have designed and produced our own resonant plate shock test system that is sized for convenient installation in almost any laboratory space. Resonant plate shock testing is intended to be representative of pyroshock and other similar high-energy, low-displacement shock events. Our company also performs shock design and analysis work as well as acoustics testing and design.

Simcenter is the **SIEMENS** software brand for addressing Predictive Engineering Analytics. The Simcenter portfolio consists of solutions that span 3D simulation, 1D simulation, and testing solutions. It is comprised of a number of well-known products such as Simcenter Test.Lab, NX Nastran, STAR-CCM+, Simcenter Imagine.Lab and Simcenter 3D. Simcenter Test Solutions specializes in testing for Acoustics, Structural Dynamics, Rotating Machinery, Durability/Fatigue and Vibration Control and are the market leader for high-end data acquisition and test results visualization and post processing.

The **SOCIETY FOR EXPERIMENTAL MECHANICS** is composed of members from academia, government, and industry who are committed to application, research and development, education, and promotion of experimental methods to: (a) increase knowledge of physical phenomena; (b) further understanding of the behavior of materials, structures and systems; and (c) provide the necessary physical basis and verification for analytical and computational approaches to the development of engineering solutions.

SOCITEC US is the leading American manufacturer of shock and vibration control systems. Our solutions protect and extend the life of the equipment and its surrounding. Socitec US leverages its expertise in vibration, shock, and dynamics to develop high performance solutions. These solutions are tested and approved by multiple international companies. The optimal solution requires comprehensive analysis of the dynamic system and a precise understanding of its reactions. Our team adopts a global approach that includes research, analysis, study, and solution design followed by installation and rigorous monitoring.

SPECTRAL DYNAMICS (SD) is a technically innovative company that has served the Shock and Vibration community for 56 years. Whether it's Sine control of challenging tests, innovative MIMO control of multiple shakers, Shock data capture at 5 Msample/s/channel or accurate Phase-locked acquisition of hundreds of channels of data, Spectral Dynamics uses mathematics effectively to reduce the total costs of dynamic testing. Call Spectral Dynamics for a customized solution to your needs in Vibration, Shock or Acoustic Test Control; Multi-Channel Data Acquisition; Modal Analysis or PIND Testing.

Exhibitor Descriptions

TAYLOR DEVICES has provided innovative solutions for shock and vibration control since 1955. Our customers include all branches of the US Military and NASA Space Programs. Products include precise positioning shock isolators, fluid, elastomer and hydropneumatic spring-dampers, high capacity fluid dampers, and modular machined springs. Made 100% in the USA.

TEAM CORPORATION continues to define the future of advanced, high-performance vibration test systems and solutions that advance the aerospace, defense and automotive industries. Pioneering the world of multi-axis test systems has led to the introduction of many state-of-the-art high frequency hydraulic and electrodynamic multi-axis test solutions, such as the CUBE and Tensor test systems. Utilizing advanced hydrostatic bearing technology that has been refined over the past 65 years, Team Corporation implements leading hydraulics engineering to solve unique problems that others cannot. Team has designed and engineered many ground-breaking test systems, some noteworthy examples are active within NASA's Space Environments Complex (SEC). This includes the most powerful spacecraft Reverberant Acoustic Test Facility (RATF), and the world's highest capacity and most powerful spacecraft shaker system – the Mechanical Vibration Facility (MVF)—where test programs for Orion/Artemis, and the Sierra Space Dream Chaser spaceplane were completed.

THORNTON TOMASETTI provides engineering design, investigation and analysis services to clients worldwide on projects of every size and complexity. We have 70 years of experience in research, testing and software development for the U.S. Navy and Department of Defense in the fields of blast, underwater shock, impact and vibration effects.

Over the past 60 years, **UNHOLTZ-DICKIE** has engineered vibration test solutions for thousands of customers in hundreds of industries in 45 countries. We are a unique source for vibration test systems because of our complete product offering and understanding of the total test system. Products include advanced high-efficiency air-cooled power amplifiers, high-performance electrodynamic shakers, long-stroke thrusters, integrated slip table assemblies for 3-axis testing, support instrumentation for measuring vibration environments, and Windows-based digital vibration control and analysis workstations. Together, these products, well regarded for high performance and reliability, provide complete and reliable test solutions for the vibration test industry. All UD equipment is designed, built and tested in the USA at our World Headquarters in Wallingford, Connecticut.

VIBRATION RESEARCH (VR) has been the innovator in vibration control, data acquisition, and dynamic signal analysis since 1995. VR builds reliable and user-friendly software and hardware at its headquarters in Michigan, USA. It is attentive to emerging technologies and changes to the industries it serves. With every software release, the customer can expect new and relevant features meticulously tested before they reach them. Testing labs worldwide trust VR for the industry's best testing systems and support that delivers unrivaled value. Visit the VR booth to discuss your testing and analysis requirements with industry experts.

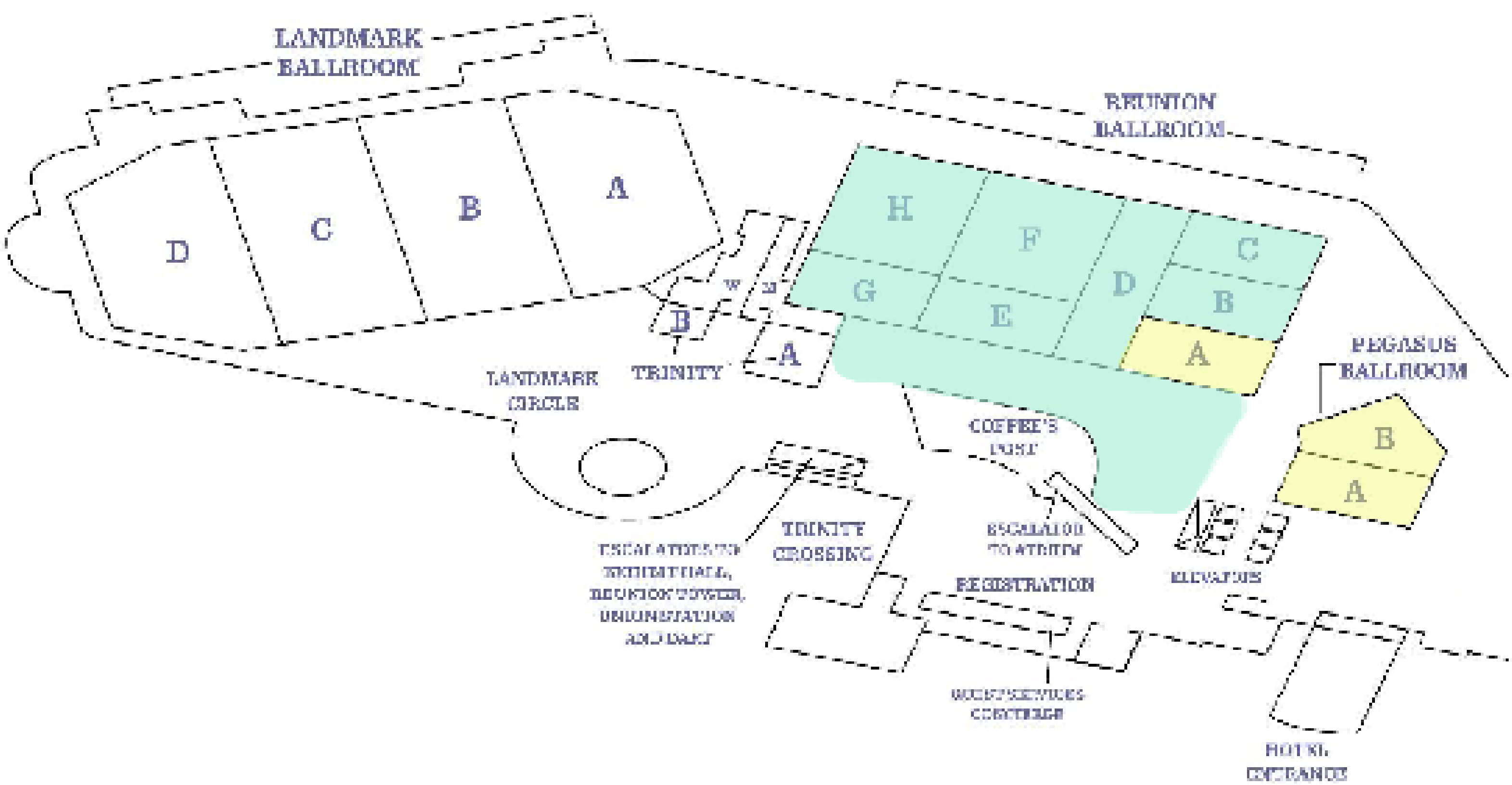
VIPER APPLIED SCIENCE has over three decades of experience between them in the fields of Blast, Shock & Vibration, Structural Dynamics, Computational Physics & Numerical Methods. All our team have a background in Engineering Consultancy, and the software we write and services we offer our clients reflect this. We pride ourselves in developing practical, usable, real world solutions that don't cost the earth.

VISION RESEARCH designs and manufactures high-speed digital imaging systems that are used in military, industrial, academic, machine vision, and entertainment sectors. Phantom cameras allow you to analyze physical phenomena when it's too fast to see, and too important not toTM. Vision Research prides itself in the high resolution of its images, the power of its software, the reliability of its products and its high level of attentiveness and dedication to its customers. The company's innovative approach to high speed electronic "digital" imaging was recognized by the US Patent Office and was granted US Patent #5,625,412.

Hyatt Meeting Space Layout

LOBBY LEVEL

REUNION BALLROOM & FOYER:	EXHIBITS/GENERAL SESSION/MEALS
REUNION A:	TECHNICAL SESSIONS/TRAININGS
PEGASUS BALLROOM A/B:	TECHNICAL SESSIONS/TRAININGS

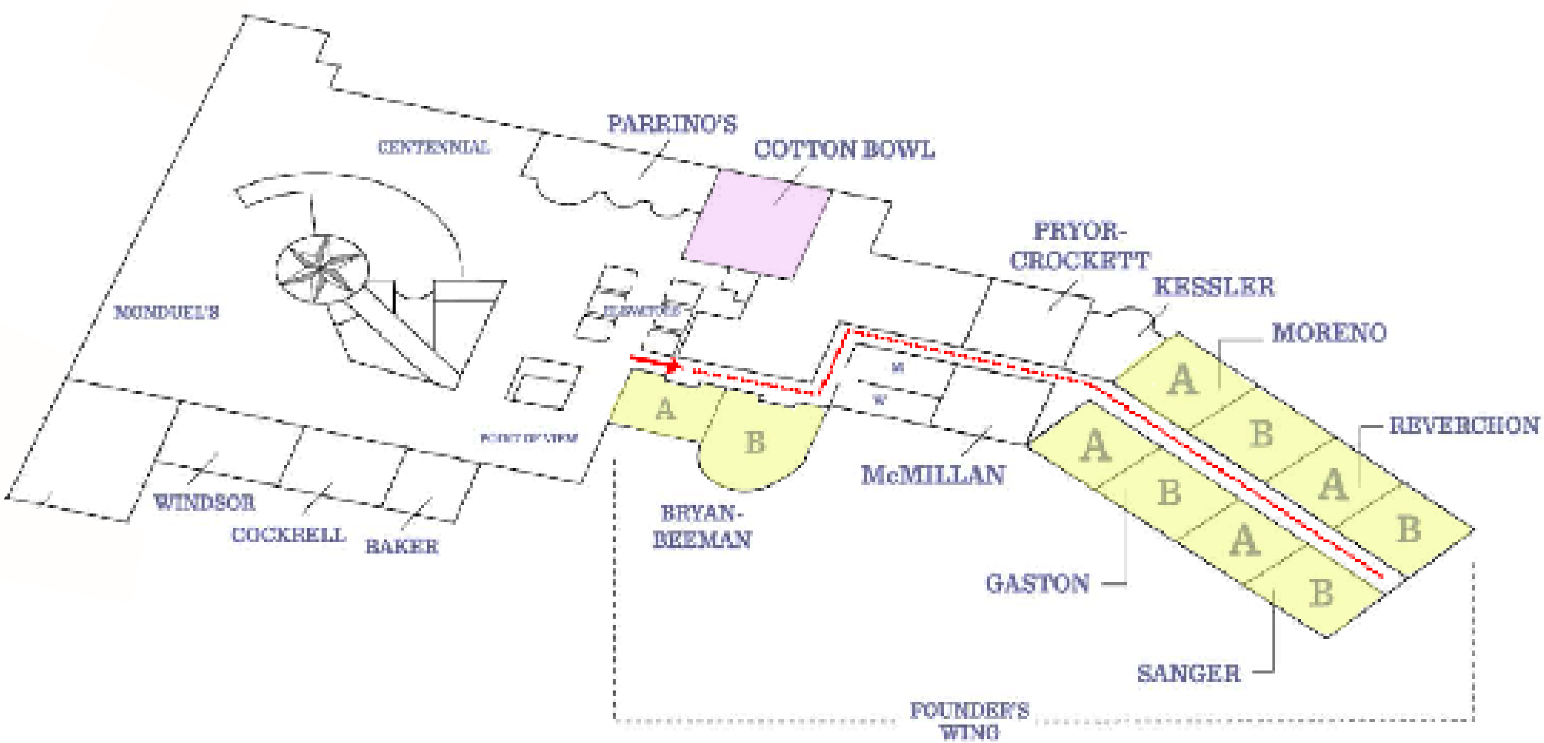


- EXHIBITS/MEALS
- MEETING ROOMS
- REGISTRATION / OPERATIONS

Hyatt Meeting Space Layout

ATRIUM LEVEL

COTTON BOWL:	REGISTRATION & OPERATIONS
BRYAN-BEEMAN:	TECHNICAL SESSIONS/TRAININGS
MORENO:	TECHNICAL SESSIONS/TRAININGS
REVERCHON:	TECHNICAL SESSIONS/TRAININGS
GASTON:	TECHNICAL SESSIONS/TRAININGS
SANGER:	TECHNICAL SESSIONS/TRAININGS
ALSO:	HOTEL RESTAURANTS & BAR



EXHIBITS/MEALS

MEETING ROOMS

REGISTRATION / OPERATIONS

Save the Date!

95TH Shock & Vibration Symposium

September 21 - 25, 2025

SAVE
SHOCK & VIBRATION EXCHANGE

ABSTRACTS

94th Shock & Vibration Symposium

November 3 - 7, 2024
Dallas, Texas

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SESSION 1: SHOCK ISOLATION

TRANSIENT SHOCK RESPONSE OF AN ISOLATED RIGID BODY TO TRANSIENT SHOCK BASE EXCITATION VARYING: RATIO OF CG ELEVATION TO HORIZONTAL SEPARATION OF BASE ISOLATORS; AND RATIO OF ISOLATION SYSTEM INITIAL STIFFNESSES TO FINAL STIFFNESSES 10X MORE

Dr. Christopher Merrill, CM&A Engineering

Dynamics analysis will be performed on a vibration isolated Rigid Body of constant mass and isolator base plate connection geometry subjected to transient shock base excitation similar to MWSM inputs along any 2 of 3 orthogonal axis to determine the transient shock response (transmitted acceleration and deflection shape) function T at given ratio: α – a selected geometric ratio of CG elevation to the fixed minor axis horizontal separation of base plate isolator connections, and given ratio: ϒ – a isolation system with selected fixed horizontal stiffness and vertical stiffness from an initial state to a second selected pair of stiffnesses ten times (10X) the initial selected stiffnesses in order to generate a transient response function data point set T (α, ϒ). Set T (α, ϒ) will be determined by investigating a small number n of selected values of interest i=1,n used to evaluate the modal response function at 4 specific M (αi , ϒ i) data points where n=2. The resulting transient response function data point set will used to build a trade space to determine whether hypothetical trends in the transient response function occur where expected and to evaluate and identify trends of system transient response over the data space.

Expected behavior hypothesis: 1) At α = 2, ϒ =1k where 1k = (1kv,, 1kh) the resultant transient response function will be driven by the rigid body mass double eccentricity of isolator minor axis width to centerline and the initial vertical and horizontal stiffness set; 2) At α = 1, ϒ =1k where 1k = (1kv,, 1kh) the resultant transient response function will be driven by halved eccentricity and maintain similar mode shape with less deflection and resonances at higher frequency; 3) At α = 1 or 2 , ϒ =10k where 10k = (10kv,10kh) the resultant transient response function will tend to maintain similar mode shape with less deflection and resonances at higher frequencies than in 1 and then 2 above. Transmitted transient response function acceleration will increase from case 1 through 3.

EXPERIMENTAL TESTBED DESIGN TO DYNAMICALLY CHARACTERIZE WIRE ROPE SHOCK ISOLATORS

Luke Nester, Texas A&M University
Dr. Pablo Tarazaga, Texas A&M University,
Dr. Bryan Joyce, NSWC Dahlgren
Jacob Hoppel, NSWC Dahlgren
Jonathan Matteson, NSWC Dahlgren

Wire rope shock isolators (WRIs) are frequently used in shock environments but lack readily available dynamic characterization data relating force and deflection. Being able to correctly fit an isolator to in-field applications is essential for optimal performance and safety. Currently, the data available for WRIs is most commonly collected from quasi-static testing that observes the specimen under extremely slow deflection speeds. This data is collected in an environment that may not accurately reflect real-world conditions and therefore might not be representative of realistic performance. The purpose of this study is to explore an experimental testbed designed to characterize the response of WRIs in a dynamic loading scenario and produce more accurate measurements. The ultimate aim of this study is to provide specifications for individual WRIs to assist engineers with selecting the appropriate isolator for any given use case, giving greater protection and predictability to the system.

Stainless Steel High Damping Wire Rope Isolators (HDWRI)

Ozzie Irowa, Socitec US
Robert Filec, Socitec US

For applications undergoing MIL-DTL-901(E) Shock Qualification, seismic loads, and other shock environments, often increased damping is needed to properly attenuate these high amplitude shock/vibration inputs. High Damping Wire Rope Isolators (HDWRI) have been a very successful product for the SOCITEC Group. To improve the environmental range of use, the SOCITEC Group has now developed a Stainless-Steel High Damping Wire Rope Isolator (HDSSWRI). To ensure that the HDWRI and HDSSWRI are the proper isolators for specific applications, SOCITEC Group uses SYMOS, which is a 500-DOF dynamic modeling software to confirm HDSSWRI isolator responses and estimate performance with a high level of accuracy under the given environments.

Passing the MIL-DTL-901E DSSM Shock Test Through the Use of a New Wire Rope Isolator (WRI) Design with Improved Multi-Axis Performance Characteristics

Joshua Partyka, Isolation Dynamics Corporation
Eric Jansson, Isolation Dynamics Corporation

The challenges of passing MIL-DTL-901E tests are well-known within the naval shock and vibration community, and the relatively new Deck Simulating Shock Machine (DSSM) is no exception. The baseline requirement to withstand the difficult series of high energy drops is already challenging, even when incorporating isolation systems. Isolation systems will work to limit acceleration levels experienced by sensitive equipment due to testing, but these systems often must fit into tight design envelopes and not allow response motion due to drop shocks greater than the available sway space. Further challenges can be introduced by unexpected design changes after isolation systems and their mounting provisions have been finalized, which increases the level of difficulty to successfully survive DSSM testing.

In this paper, the new Four Bar Series Wire Rope Isolator with increased compression and shear spring rates will be presented. This new isolator series was developed and tested within the context of a challenging program where last-minute design changes necessitated the incorporation of a new, higher performing isolator to fit within the fixed design and sway space envelope. In addition to a review of the application and testing, the performance improvements the FB offers over the standard design WRI will be reviewed. Improvements will be reviewed using testing data, and will make comparisons solely at the isolator level, as well as how the performance improvements specifically contribute to an improved system level result in the DSSM test.

SESSION 2: INSTRUMENTATION

MEASUREMENTS OF THE SPEED OF SOUND IN SNOW AND ITS RELATION TO SNOW DENSITY

Dr. Sean Cooper, Applied Research Associates
Dr. Paul J. Cammarata, Applied Research Associates
Grant Speer, Applied Research Associates
Dr. Mohsen Sanai, Applied Research Associates
Joe Crepeau, Applied Research Associates
Dr. Waylon M. Weber, Applied Research Associates

The speed of sound in varying snowpack densities is essential to the understanding of wave propagation resulting in avalanches and predicting such events as well as in predicting blast effects in snow for hazard mitigation. To this end, a novel sensing device was developed for detecting and measuring the speed of sound in various density snowpacks. The sensor is compact, portable, inexpensive and requires a minimal amount of electronics and power. The sensor suite can also be deployed for on demand measurements or installed in the field to continuously collect data allowing for the study of the speed of sound as a function of time, and thereby density, as the snow melts or compacts due to environmental conditions. A suite of sound speed data was collected with snows of known densities between 300 and 500 kg/m3. Results from the device are compared with historical data as a benchmark of wave velocity as a function of density whereby a strong correlation is observed. Through collecting a correlation between density and sound speed in varying snow densities, the device can be deployed to remotely measure sound speed and, therefore, density.

MEASUREMENT STANDARD FOR CALIBRATING DYNAMIC PRESSURE SENSORS

Dr. Richard Högström, VTT MIKES
Antti Lakka, VTT MIKES
Jussi Hämäläinen, VTT MIKES
Leevi Salonen, VTT MIKES

Dynamic pressure measurements at very high pressures, up to 800 MPa, are important for development, performance analysis and safety testing of weapons, ammunition, and explosives. However, the current practice of calibrating dynamic pressure sensors using static pressure standards limits the achievable measurement accuracy — errors of up to 10 % can occur when sensors are used at dynamically changing conditions. This is unacceptable for quality and safety assurance, and it impedes further technological advancement. Reliable and accurate measurements of dynamic pressure can only be realised by calibrating sensors against a dynamic measurement standard traceable to the International System of Units (SI). Progress in developing SI traceable calibration methods for dynamic pressure has been made in recent years, e.g., within the European metrology research project DynPT (Development of measurement and calibration techniques for dynamic pressures and temperatures; 2018 - 2021). Measurement standards based on the drop-weight method and interferometric measurement of impact have been developed for realizing SI traceability for dynamic pressures. Despite of this, industry still performs measurements by means of static or quasi-static methods, mainly because current dynamic measurement standards are laborious to use and require highly skilled operators, making them impractical for daily calibration work. The main challenges are related to the interferometric measurement of the acceleration (or deceleration) of the drop-weight during impact. At high pressures, i.e., high impact forces, deformation, tilt and vibrations of the drop-weight introduce errors and noise to the measured interferometric signal and in worst cases the signal is completely lost. To overcome this

limitation, a new design of a high-pressure measurement standard for dynamic pressures has been realized by VTT MIKES, the National Metrology Institute of Finland. A novel approach of applying air bearings instead of conventional mechanical rods or rails for guiding the drop-weight was successfully implemented. The inherent properties of the air bearing technology with micrometre clearances and air cushioning effectively minimizes tilt and vibrations of the drop-weight during impact. As a result, the quality of the acceleration signal is significantly improved, which not only improves the usability of the device, but also reduces the uncertainty of dynamic pressure calibration. Based on this novel technology, a high-pressure measurement standard was developed for the National Metrology Institute of Poland, Central Office of Measures (GUM). The device was designed to generate half-sine pressure pulses in the millisecond range up to 600 MPa, comparable to pressure profiles in ballistic testing. The operation of the device is fully automated using a dedicated programmable logic controller (PLC) and a computer program for control, data acquisition, signal processing and analysis. Up to 4 sensors can be calibrated at a time. Initial studies and test results show that an uncertainty level of 1 % (k = 2) is achieved, which is a significant improvement compared to the current state-of-the-art of around 2 %. As an outcome of this project, a SI traceable measurement standard for high pressures was developed to enable practical, yet cost-effective, calibrations of dynamic pressure sensors with unprecedented accuracy.

CRYOGENIC PERFORMANCE OF HIGH-G DAMPED ACCELEROMETERS
James Nelson, PCB Piezotronics

Testing is always messy – our test environments are often hotter, colder, wetter, or noisier than we anticipate. It’s important to account for unexpected conditions, yet we can’t control every variable. As users, the best we can do is to select equipment that performs well in key areas. And as manufacturers of test equipment, the best we can do is to design products to perform in a wide range of use cases, and be transparent about that performance.

High-G shock accelerometers typically comply with the standard military temperature range of -67°F to +250°F. Special applications, such as aerospace, may require operation to cryogenic temperatures of -300°F and below. It is therefore prudent to select sensors with proven performance in that environment. This paper demonstrates the performance at cryogenic temperatures for an Endevco high-G piezoresistive accelerometer. The test results include metrics like shock survivability, amplitude linearity, and long-term exposure. The cryogenic results are compared to the corresponding room-temperature results, to clarify how the sensor changes at temperature extremes. The shock accelerometer was not originally rated for cryogenic temperature applications, but the results show that it performs competently in this environment.

ADDITIONAL UNDERSTANDING AND COMPARISON OF MEMS AND IEPE ACCELEROMETERS IN PYROTECHNIC SHOCK APPLICATIONS
Brian Solomon, Northrop Grumman
Gerald Leavitt, Northrop Grumman

A variation of opinion exists within the dynamic test community as to which transducer technology is best to measure pyroshock events; MEMS or IEPE. Numerous organizations have had varying success with the two technologies, but primarily use IEPE type gages due to their overall reliability and ease of use. In our experience, MEMS gages are less reliable, harder to use, require more sophisticated cabling and amplifiers, while often producing questionable results when health checked posttest. Despite this general experience, MEMS gages have their benefits and cannot be dismissed. Side-by-side comparisons of the two transducer types were performed during multiple series of pyroshock tests. These comparisons show good agreement in some axis directions and frequency bands, but some unexplainable variations in others. To further understand the differences a sub-scale test was devised on a simple plate structure and an additional test matrix was performed along with more in-depth analysis of the resulting data. During this process, the cause of some of these variations was discovered. This included a particularly interesting finding that the MEMS gages were susceptible to a signal to noise ratio issue withing the lower frequencies of the data. This effort has resulted in a more in depth understanding of the two gage types as well as some additional ranging limitations that exist with the MEMS transducers.

SESSION 3: DYSMAS

DYSMAS Application to Sea Bed UNDEX: Summary of Results from Recent UNDEX Testing

Dr. Bradley Klenow, NSWC Indian Head Division
Roger Ilamni, NSWC Indian Head Division
Tobias Timm, WTD-71
Swen Metzler WTD-71
Greg Harris, ATR
Kathrine Knowles, ATR
Daniel Page, ATR
Manfred Krueger, iABG
Ralf Tewes, iABG

The U.S.-Germany DYSMAS Test Team completed the first of a three-part underwater explosion (UNDEX) test program at WTD-71's test facility in Elpersbüttel, Germany during December 2023. The primary objective of this test series was to gather pressure measurements in the seabed resulting from explosive charges placed on or near the sea bottom. A total of seven shots were conducted, each involving either a mid-depth or bottom charge, with two different charge sizes. This talk will present a review of the test setup and the pressure measurements collected. These test data are critical for the ongoing validation of the DYSMAS code which focuses on buried mine neutralization and effectiveness studies.

DYSMAS Application to Sea Bed UNDEX: Simulations of Recent UNDEX Testing

Dr. Bradley Klenow, NSWC Indian Head Division
Roger Ilamni, NSWC Indian Head Division
Manfred Kruger, iABG
Kathrine Knowles, ATR
Jason Yuan, ATR

As part of a multi-year effort on simulating the transmission of underwater explosion (UNDEX) loading into sea bottom materials, DYSMAS has been applied to simulate tests recently conducted at WTD-71's test facility in Elpersbüttel, Germany during December 2023. This paper reviews the characterization of the test site's sea bottom material parameters and their application within DYSMAS, the setup of the DYSMAS simulations, and provides a discussion on the comparison of the simulation results to the test measurements. These comparisons support the ongoing validation of the DYSMAS code, and will serve as the basis for supporting the planning of the next series of sea bed UNDEX tests that will be conducted in 2025.

INTERNAL BLAST DYSMAS CALCULATIONS OF BARE AND CASED CHARGES FOR BLASTX TSM GENERATION

Colin Burns, ATR
Dr. Cameron Stewart, NSWC Indian Head Division
Dr. Tom McGrath, NSWC Indian Head Division

BlastX is a fast-running code that can calculate the transient pressure effects of a detonating charge. Calculations include the shock wave, quasi-static pressure of the confined detonation products, and venting between rooms. To generate this information, BlastX requires a First Principle Code such as DYSMAS to generate Tabulated Source Models (TSMs) to quantify the pressure distribution around the detonating charge. A generated TSM is specific to the charge's HE material, aspect ratio, and for cased charges, charge weight to cased weight (M/C) ratio. We have created an automated DYSMAS framework that generates TSMs for a selected range of HE materials, including both bare and cased charges. We compare the DYSMAS simulations, and subsequent BlastX calculations to internal blast experiments done in the Indian Head bombproofs.

EXPANDING THE CAPABILITY OF DYSMAS

Dr. Thomas McGrath, NSWC Indian Head Division
Dr. Alan Luton, NSWC Indian Head Division
Dr. Jeff St. Clair, NSWC Indian Head Division
Dr. Brad Klenow, NSWC Indian Head Division
Jim Warner, NSWC Indian Head Division
Mitul Pandya, ATR

The DYSMAS development team at NSWC Indian Head has been tasked for the coming years to expand DYSMAS capability, portability, and performance. This brief will highlight some of the current as well as planned future efforts in DYSMAS development to achieve these gains. New, planned features within the DYSMAS code will be discussed, as well as efforts underway in coupling the Gemini fluid solver to structural solvers not distributed within the DYSMAS package. A newly proposed DYSMAS lethality framework will also be presented, which aims to be a novel capability that will allow for mission capability assessments driven by high-fidelity calculations. The multi-fidelity framework will link directly to system or engineering models such as the Navy's ASAP or Air Force's DEWD, providing lethality and weapon effectiveness predictions that are not possible with current engineering level models. Automation features both in execution and post-processing will provide DYSMAS users with the opportunity to run parametric type studies quickly and efficiently. Progress on all of these development efforts will be summarized with a projection of the development path forward.

SIMULATING THE UNDERWATER SHOCK DYNAMICS OF HUMAN LUNG AND RIB SIMULANTS

Dr. Emily Guzas, NUWC Newport
Brandon M. Casper, Naval Submarine Medical Research Laboratory
Matt A. Babina, Naval Submarine Medical Research Laboratory
Eugenia Stanisauskis Weiss, NUWC Newport

This presentation covers computational model development for a series of physical experiments performed with mechanical simulants of human lungs to better understand diver lung response to underwater explosions (UNDEX). Researchers at the Naval Submarine Medical Research Laboratory (NSMRL) have developed several variations of instrumented mechanical simulants of the human thoracic region and subjected these to UNDEX loading in tank test experiments at the University of Rhode Island (URI). Analysts at the Naval Undersea Warfare Center, Division Newport (NUWCDIVNPT), have developed computational models of a subset of these experiments using the Navy fluid-structure interaction code DYSMAS. This presentation discusses model development and validation to test data.

SESSION 4: IMPACT & PENETRATION MECHANICS

Technical Advantages and Capabilities of Elastic Plastic Impact Computation (EPIC) in Finite Element Analysis

Samuel Grinberg, Picatinny Arsenal

The Elastic Plastic Impact Computation (EPIC) program is a Lagrangian explicit dynamics code primarily used for wave propagation, elastic-plastic flow, material failure, fragmentation, and complex interfaces. Since the 1970s, it has proven to be capable in modelling high-distortion problems caused by intense impulsive loading due to impact and explosive detonation. Recent development in EPIC have focused on leveraging its explicit dynamics and contact capabilities to utilize it as a general purpose dynamic explicit code, specifically in cases of gun launched munitions. Advancements in interaction have been implemented and benchmarked against commercial software such as Abaqus Explicit to provide a complementary toolset to DEVCOM Armaments Center in the modelling of gun launched structures and electromechanical assemblies.

Development of Simplified and Detailed Finite Element Projectile Model Library

Logan Rice, USACE ERDC
David Lichlyter, USACE ERDC
Dr. Mark Adley, USACE ERDC

ERDC has been a leader in air delivered penetrating weapons research for many decades. Recent research efforts have focused on improving fast running weaponeering tools to provide improved weapon survivability estimates due to deformation of the weapon case and pre-mature failure of the explosive fill. In order to accomplish this and retain run times that are fast enough for weaponeering analysis, a projectile library was developed containing finite element models of Army and Air Force weapons. Simplified models, using relatively coarse finite element meshes are designed to provide accurate results for case damage based on levels of effective plastic strain, predictions of penetrator trajectory, and overall warhead deformation. Higher fidelity models include finer meshes more detailed geometry at the cost of slightly longer runtimes. The more detailed models include finer meshes for the case and fill, a slide line at the case/fill interface, and additional model details such as surrogate models of the internal plumbing that is present in many older warhead designs. The more detailed models require somewhat longer runtimes, but in addition to the results provided by the simplified models also predict the level of risk of explosive fill deflagration by capturing the movement of the explosive fill inside the weapon. The level of case damage and the risk of explosive deflagration can both be computed automatically, removing the need for a finite element expert to interpret the simulation results and making the models even more appropriate for mission planning type applications. This paper will detail the development of the simplified and detailed models and how the survivability criteria based on finite element analysis of the projectile is evaluated.

High Velocity Impact of a Tungsten-Nose Payload Delivery Vehicle Against a Steel Plate Backed with Welded Beams and Against Two Concrete Walls

Dr. Zane Roberts, USACE ERDC
Logan Callahan, USACE ERDC
Dr. Z. Kyle Crosby, USACE ERDC
Dr. John Q. Ehrgott, Jr., USACE ERDC

When evaluating the response of protective structures and armor materials, it is critical that developers conduct well controlled dynamic experiments to examine the performance over a range of projectile types and velocities. To support this research the US Army Engineer Research and Development Center (ERDC) Impact and Explosion Effects Branch (IEEB) houses the Mobile Ballistic Research System (MBRS), which is comprised of a 12 m long barrel with a 152 mm diameter bore, a recoil dampening system, and hydraulic lifter on a semi-trailer designed to travel to remote field test sites. The MBRS can fire research projectiles vertically into the ground or horizontally at upright targets. One program studied the effects of high velocity (>1500 m/s) impact of a 102 mm diameter thin-walled, aluminum, missile-body projectile (payload delivery vehicle (PDV)) with a tungsten nose. This projectile was fired against a steel maritime surrogate target backed by welded beams, and against two reinforced concrete walls. Of interest was the target damage, spall, weld behavior, and projectile response among others. Example videos will be presented alongside analysis of the targets to the PDV impact.

Evaluation of Penetration Resistance of Conventional Concrete Slabs Repaired with Sprayable Ultra-High-Performance Concrete

Jeffrey Holmes, USACE ERDC

A rapid repair method for damaged concrete structures is a desirable technology for protecting soldiers in conflict zones. To address this, the U.S. Army Corps of Engineers Engineer Research and Development Center (USACE ERDC) has been tasked with an effort to evaluate the projectile penetration resistance of conventional-strength concrete targets repaired with a sprayable Ultra-High-Performance Concrete (UHPC). This study will assess the resistance of concrete targets to penetration from a projectile fired from an 83-mm smooth bore powder gun located at the USACE ERDC. As part of the evaluation, a set of controlled experiments were conducted by launching 3-in. diameter, 17.7-in long 4340 steel projectiles into conventional concrete targets using predetermined muzzle velocity and impact conditions. The baseline for comparison will be the pristine conventional concrete slabs. After firing, the damaged concrete targets will be sprayed with a UHPC material using a rapid repair method for which results will be compared to the baseline concrete targets. Parameters for comparison will include perforation hole size and residual velocity. Residual velocities were measured using high-speed video. Photogrammetry was also utilized to analyze the dimensions of the target impact and exit craters. In addition, digital photography and measurement tools documented the effects of munition(s) and response of the target materials. This presentation serves as an overview of the experiment design and the results from this effort.

PERFORATION OF STEEL BACKED CONCRETE SLABS WITH ONBOARD DATA RECORDERS

Glynn Harrington, USACE ERDC
Logan J. Callahan, USACE ERDC
Dr. Zane A. Roberts, USACE ERDC
Dr. Z. Kyle Crosby, USACE ERDC
Dr. John Q. Ehrgott, Jr., USACE ERDC

Accurate penetration prediction models are critical for the design of structures used for force protection; however, there is limited data for penetration into concrete structures utilizing a steel backing. The US Army Engineer Research and Development Center (ERDC) conducted a series of eight tests specifically to validate models that represent concrete with steel backing. These tests employ a 2.5 in. diameter, 4340 steel cased penetration projectile housing a one-axis, 1.2 MHz sampling rate accelerometer for comprehensive data capturing. Impact velocities were kept constant at 1500 ft/s for four distinct target types. The first target type consisted of a 6 ft x 6 ft, 30 in. thick conventional strength Portland limestone cement (CSPLC) concrete slab with an approximate strength of 6500 psi. Subsequent targets were variations of this target: target two incorporated a 0.25 in. A36 steel plate attached to the exit face of the concrete while target three further enhances the structure with Nelson studs for increased steel adherence to the concrete. Target four was a 0.25 in. thick A36 steel plate to obtain data for a standalone plate. Data from these tests was gathered via onboard accelerometers, high-speed video, and photogrammetry. These data aim to supplement existing penetration data and establish a sound methodology for predicting penetration of steel-encased concrete. Specifically, the acceleration data was used to compare the steel plate and concrete slab targets to the steel-backed concrete. This comparison will quantify the effects of the steel backing on the concrete slab. These results will be used to validate high fidelity and engineering models used to predict penetration through steel-backed concrete targets.

VENDOR SESSION A: EXHIBITOR CASE STUDIES, NEW DEVELOPMENTS, TESTING & PRODUCT

FULL-FIELD VIBRATION MEASUREMENTS WITH HIGH-SPEED DIGITAL CAMERAS

Dr. Kyle Gilroy (Vision Research)

Scientists and engineers have classically used contact sensors (i.e., strain gauges, accelerometers) to quantify strain, vibration, and/or kinematics of rapidly deforming materials. Many of these same groups have been transitioning to ‘non-contact’ sensing based on the deployment of high-speed digital cameras coupled with simple open-source code for the extraction of motion data. In this talk, this recent progress will be discussed together with notable examples from government-, industrial-, and academic-applications dealing with full-field vibration. Also discussed are frame-data synchronization techniques that are required to validate these emerging non-contact measurement techniques.

RESONANT PLATE TESTING FOR LOW-LEVEL OSCILLATORY SHOCKS

Dr. Carl Sisemore, ShockMec Engineering

Resonant plate shock testing is traditionally associated with high acceleration pyrotechnic shock simulation in the laboratory. In contrast, low-level oscillatory shocks have historically been performed on an electrodynamic shaker system. However, there is often a range of shock requirements that have not traditionally worked well on either system. This happens when the shock level is too high for modest sized electrodynamic shakers and too low for traditional resonant plate shock machines. ShockMec Engineering has implemented an upgrade to their resonant plate shock test machine that allows for oscillatory shock testing in an amplitude range that has traditionally been unavailable. This presentation shows the results of experimental results on various sized resonant plates straddling the shock regime between electrodynamic shakers and traditional high-energy resonant plate testing. This is accomplished by using lightweight pneumatic hammers in combination with short barreled gas guns to produce a highly repeatable, low amplitude oscillatory test capability for resonant plates.

ENHANCING EXPERIMENTAL MODAL ANALYSIS WORKFLOW: SUPPORTING OCCASIONAL AND EXPERT USERS
Brian Cremeans, HEAD Acoustics

This presentation outlines significant advancements in the experimental modal analysis (EMA) workflow at HEAD acoustics. The focus is on enhancing the workflow to support both occasional and expert users. The EMA process involves several critical steps, including the determination of measurement points, reference points, and the setup of input parameters for curve fitting algorithms. The presentation highlights the integration of algorithmic support to improve objectivity and reduce user influence, particularly in the parameter extraction phase.

A key innovation discussed is the use of AI-supported parameterization of the Least Squares Complex Frequency (LSCF) method. This approach simplifies the extraction of modal parameters from measurement data, ensuring higher accuracy and efficiency. The presentation also explores the challenges of determining the correct model size, emphasizing the balance between computational effort and the completeness of the modal model.

The use of neural networks to synthesize Frequency Response Functions (FRFs) and predict modal parameters is another highlight. This method provides robust support for a wide variety of structures, enhancing the overall reliability of the EMA workflow. The presentation concludes with examples of real test data, demonstrating the practical application and benefits of the proposed enhancements.

TAKING T&M TO THE EDGE
Mike Ciosys, RDI Technologies

RDI Technologies presents Iris Edge, a novel vibration monitoring system featuring a compact, noncontact design that ensures quick deployment and enhanced operational efficiency. Iris Edge leverages advanced camera technology to quickly deliver accurate vibration data. Its non-contact nature eliminates the need for direct attachment, eliminating downtime for installation. The device's compact form allows for easy integration into various testing environments without significant spatial requirements. Additionally, Iris Edge supports open protocol integration, facilitating seamless interoperability with existing control and monitoring systems. Through comprehensive testing, the proposed solution demonstrates superior performance in detecting and analyzing vibrational anomalies in testing and measurement applications.

KORNUCOPIA® ML™ CAPABILITIES TO SYNTHESIZE A REALISTIC TRANSIENT ACCELERATION SHOCK SIGNAL TO REPRESENT AND BOUND DIVERSE OSCILLATORY SHOCK TIME-HISTORIES
Dr. Ted Diehl, Bodie Technology, Inc.

This presentation showcases the powerful and efficient features of Kornucopia® ML™ software being utilized to synthesize credible transient acceleration shock signals from a large repository of actual field-test data. These synthesized signals that statistically encapsulate the nature of the repository of signals are crucial for developing bounding profiles for shaker shock testing, catering to military, aerospace, and commercial requirements. The importance of capable software in managing the numerous complex subtasks in this comprehensive analysis cannot be overstated, especially for the widespread adoption of such a synthesis approach across various industrial sectors.

The primary objective is to create one or a few realistic, highly transient oscillatory acceleration time-histories that represent a statistically significant range derived from extensive raw measured signals. The process typically begins with a hard drive containing tens or hundreds of folders, each with numerous raw acceleration time-history files from various sources.

Kornucopia offers a guided workflow to tackle this challenging problem through several key steps, including but not limited to:

1. Organizing raw data from various sources and formats into a searchable, compact database.
2. Cleaning and salvaging each raw acceleration time-history using specialized highpass and lowpass filters, as well as integration and differentiation operations to produce credible signals from raw signals that generally have a number of distortions making them non-credible initially.
3. Characterizing the transient signals through Pseudo Velocity Shock Spectrum (PVSS) analysis and other methods.
4. Computing a statistically-based PVSS envelope from a user-selected subset of database records. The PVSS envelope is deemed the target to synthesize against.
5. Identifying the best PVSS-based shaped-matched seed-transient signals from the database that best match the shape of the target PVSS over selected frequency bands.
6. Combining and scaling the seed transient signals using bandpass filtering and other processing to create an initial estimate of the desired transient signal.
7. Making necessary modifications to the initial transient estimate using additional bandpass filtering, rescaling, and incorporating shaker-wavelet components as needed.
8. Confirming that a PVSS of the final synthesized acceleration time-history aligns with the target PVSS within user-defined tolerances.

These tasks will be demonstrated using example standard Navy shock test data. The case studies highlight a well-documented, robust and efficient approach, synthesizing transient signals that are visually indistinguishable from the original measured signals they emulate.

TRAINING I

901E FLOW CHARTS
Kurt Hartsough, 901E&T

No abstract available.

BLAST DATA PROCESSING & ANALYSIS
Denis Rickman, US Army ERDC

I developed this material for the purpose of improving the general understanding of data processing methods with specific application to blast data. I have found that most of our researchers manage pretty well with processing and analyzing well-behaved data records, but as Mike Tyson once said, “Everybody has a plan, until they get punched in the mouth”. My goal is to provide the participants with enough of an understanding of blast data processing that when they do get punched in the mouth by their data, they’re ready to punch back. I may not cover every trick in the book, but hopefully enough that you'll be able to show that unruly data who's boss!

SESSION 5: VIBRATION ISOLATION

REPLACEMENT OF TRADITIONAL VISCOELASTIC MATERIAL IN A CONSTRAIN LAYER DAMPER (CLD) WITH LIQUID CRYSTAL ELASTOMER (LCE) MATERIAL

Dr. James Rall, Impressio
Dr. Amir Torbati, Impressio
Risheng Zhou, Impressio
Tristan Collette, Impressio

Constrain layer dampers (CLDs) are utilized in various applications, from aircraft fuselage to airducts, to reduce structure-borne noise. CLDs are primarily composed of a viscoelastic material (usually a type of rubber) between a layer of thin metal (i.e. aluminum) and an adhesive layer for attachment to the structure. Viscoelastic properties are primarily responsible for the composite performance of a CLD to reduce structure vibrations. Shear modulus and damping are two key parameters for an effective CLD. Due to Liquid Crystal Elastomer (LCE) anisotropy, rate dependency, and high damping, LCEs would be an ideal candidate to replace traditional rubbers as a viscoelastic material in CLDs.

Material properties relevant to CLD applications were determined using a sandwich beam test per ASTM E756 with three formulations of LCEs for the viscoelastic layer: (1) Monodomain, (2) Polydomain, and (3) Resin. The beams were comprised of 0.33 mm, 0.25 mm, and 0.18 mm LCE (Monodomain, Polydomain, Resin) between 1.6 mm thick 0.5- x 11.5-inch metal beams. Reduced frequency nomograms, shear and loss factor temperature dependence for 100 and 1000 Hz, and shear and loss factor frequency dependence at 26.7 C (80 F) for each LCE formulation was obtained. LCEs demonstrate elevated damping (loss factor) for large temperature and frequency ranges. These are not unusual characteristics for LCE materials due to the damping mechanism of liquid crystal molecule rearrangement which is absent in other types of viscoelastic rubbers. Composite loss factor of CLDs using LCE were predicted and experimentally tested. A comparative sample CLD used in the automotive industry was performed at the same time as the experimentally tested LCE-CLD.

DUAL-PHASE-LAGGING THERMOELASTIC DISSIPATION FOR CYLINDRICAL SHELL RESONATOR MODEL WITH INITIAL-STRESS FIELD

Prof. Jung-Hwan Kim, Wonkwang University

Research on thermoelastic damping (TED) is necessary for the development of high-performance and high-frequency vibration structures. In particular, single-walled carbon nanotube (SWCNT) has a high frequency, which is essential for research such as precision sensors, and thus the cylindrical shell model is predicted to be valid. In this study, the TED is investigated including the initial-stress and the time-delays of the temperature gradient and heat flux for a tubular shell. Actually, cylindrical shells are subjected to static loads, represented by stress fields, due to internal pressures and so on, and nanotubes are no exception. Firstly, the equation of motion is established, and the heat equation is introduced including thermal moment. Then the complex eigenfrequency of a thin shell is obtained according to Donnell–Mushtari–Vlasov's (DMV) assumption. Moreover, the difference between the real part of the complex result and the traditional isothermal frequency gives an idea of the accuracy improvement. Then the TED in the form of a quality factor (Q) is obtained through approximation assumptions. It is also found that multiple independent variables can predict more actual parameter results for cylindrical shells. The trends demonstrate the potential of the method to help predict results and get high efficiency under various extreme environments in the study of realistic resonator structures.

SESSION 5: VIBRATION TEST METHODS

TRANSIENT MODAL RESPONSE OF AN ISOLATED RIGID BODY TO SINUSOIDAL BASE EXCITATION VARYING: RATIO OF CG ELEVATION TO HORIZONTAL SEPARATION OF BASE ISOLATORS; AND RATIO OF ISOLATION SYSTEM INITIAL STIFFNESSES TO FINAL STIFFNESSES 10X MORE

Dr. Christopher Merrill, CM&A Engineering

Dynamic analysis will be performed on a vibration isolated Rigid Body of constant mass and isolator base plate connection geometry subjected to sinusoidal base excitation between 4 and 50 Hz along 3 orthogonal axis to determine the modal response (modes and mode shapes) function M at given ratio: α – a selected geometric ratio of CG elevation to the fixed minor axis horizontal separation of base plate isolator connections, and given ratio: ϒ – a isolation system with selected fixed horizontal stiffness and vertical stiffness from an initial state to a second selected pair of stiffnesses ten times (10X) the initial selected stiffnesses in order to generate a modal response function data point set M (α, ϒ). Set M (α, ϒ) will be determined by investigating a small number n of selected values of interest i=1,n used to evaluate the modal response function at 4 specific M (αi , ϒ i) data points where n=2. The resulting modal response function data point set will used to build a trade space to determine whether hypothetical trends in the modal response function occur where expected and to evaluate and identify trends of system modal response over the data space.

Expected behavior hypothesis: 1) At α = 2, ϒ =1k where 1k = (1kv,, 1kh) the resultant modal information will be driven by the rigid body mass double eccentricity of isolator minor axis width to centerline and the initial vertical and horizontal stiffness set; 2) At α = 1, ϒ =1k where 1k = (1kv,, 1kh) the resultant modal information will be driven by halved eccentricity and maintain similar mode shape with less deflection and resonance at higher frequency; 3) At α = 1 or 2 , ϒ =10k where 10k = (10kv,10kh) the resultant modal information will tend to maintain similar mode shape with less deflection and resonance at higher frequencies than in 1 and then 2 above. Transmitted acceleration will increase from case 1 through 3.

SPECTRAL DYNAMICS IMPROVES VIBRATION TESTING WITH APPLICATION INTELLIGENT PROCESSING

Stewart Slykhous, Spectral Dynamics

The advent of modern powerful tiny processors enables advanced signal processing specific to each Vibration Control application. The historical methods of vibration control back to the analog days will be explained and contrasted to the modern application specific advances where both narrowband and wideband processing including optimal adaptive filters enhances both MISO and MIMO applications. Details of the benefits of Application Intelligent solutions for Sine, Random, Mixed Mode, and Arbitrary Waveform based control processing including enhanced data acquisition speed and accuracy will be presented. The increase in processing power enables fast and immediate results using true mathematically correct convolution solutions. Getting correct solutions results in dramatically lower testing costs. This modern approach will be contrasted to the old traditional linear approximate algorithms and the popular Lincoln convolution approach.

USE OF SPECTRAL ANALYSIS OF SINGULAR VALUES AS A TEST METRIC FOR IMMAT TRIALS

Dr. Michael Hale, Trideum Corporation
Jacob Davis, Redstone Test Center
William Barber, Redstone Test Center
Dr. James Akers, NASA

One of many challenges in the implementation of multiple exciter testing is establishing a reasonable set of test metrics to measure the quality of testing. This is especially true in the application of Impedance Matched Multi-Axis Testing; in that it is possible to have very large spectral density matrices that serve as reference criteria. While there exist plotting schemes to view a spectral density matrix, it is often necessary to break the overlay of reference and test results into subsections of the matrices to get sufficient resolution to interpret the data. In addition, as one attempts to control multiple locations on a structure, implementation of classical single degree-of freedom test tolerances is simply not feasible. The use of spectral views of the dominant singular values (eigenvalues) as a potential metric of test quality will be proposed. A physical example from a laboratory experiment will be included to demonstrate the proposed technique.

SESSION 6: SHOCK MITIGATION TECHNOLOGIES

LEVERAGING RADIOSS FOR HIGH-VELOCITY IMPACT SIMULATIONS: ENHANCING ARMORED VEHICLE DESIGN

Kory Soukup, Altair Engineering
Giri Prasanna, Altair Engineering
Jason Krist, Altair Engineering

High-velocity impact simulations have remained an indispensable tool in defense applications, providing engineers and analysts with invaluable insights into the intricate behavior of structures and materials when subjected to extreme dynamic loads. The accurate prediction of structural response and damage mechanisms remains a fundamental requirement in this domain.

This presentation aims to delve into the utilization of Radioss, an advanced simulation software, to investigate the performance characteristics of diverse defense systems under high-velocity impact conditions, encompassing scenarios involving ballistic projectiles, explosive blasts, and collisions. The comprehensive case study encompasses an array of critical evaluations, ranging from the meticulous assessment of armored vehicle integrity during combat operations to the thorough examination of protective armor systems' effectiveness against penetrating projectiles. By leveraging the capabilities of Radioss, an in-depth understanding of the complex phenomena associated with high-velocity impacts can be achieved, ultimately facilitating the enhancement of defense system design, optimization, and protection strategies.

SESSION 6: BALLISTICS

MODELING THE RESPONSE OF MULTI-LAYERED MULTI-MATERIAL TARGETS USING ALE-BASED FINITE ELEMENT METHODS

DeBorah Luckett, USACE ERDC
Dr. Andrew Bowman, USACE ERDC

Modeling ballistic impacts in high ductility materials requires techniques to handle large mesh distortions that occur during projectile penetration. Arbitrary Lagrangian–Eulerian (ALE) based finite element (FE) methods can be used to model such behaviors while maintaining accuracy of material damage/failure evolution. The ALE3D software, developed by Lawrence Livermore National Lab, is used in this work to solve 3D ballistic impacts on a multilayered target containing either polymer/polymer or polymer/metal variations in different layout configurations. The aim was to simulate and capture the extreme deformation observed in the multilayer configurations with respect to each individual layer's distortion and the multilayer target as a whole. Simulations were validated against experiments conducted on various individual and multilayered targets. Failure modes of the materials were analyzed and compared to FE models. Further investigation was made to identify the multilayer material layout that provided the optimal kinetic energy dissipation and deformation failure modes under impact.

USE OF LIQUID CRYSTAL ELASTOMERS (LCE) FOR INCREASED AND RELIABLE ENERGY IMPACT ABSORPTION IN HELMET LINERS

Dr. James Rall, Impressio
Dr. Amir Torbati, Impressio
Lyssa Bell, Impressio

Liquid Crystal Elastomers (LCEs) exhibit unique properties (high energy dissipation and strain rate dependence), making them ideal for personal protective equipment such as combat helmets. The award winning LCE technology was first successfully applied to sports helmets during the NFL HeadHealth Tech Challenge. LCE-Lattice Liner (3L) technology is currently being developed for use in combat helmet systems. The 3L technology addresses major disadvantages present in traditional foam helmet liners. Traditional foam liners have reduced protection after first impact and at higher energies, trap heat to cause hotspots, and create localized pressure creating discomfort and causing headaches. By integrating LCE into a lattice matrix, blunt-impact performance is more consistent between impacts and adaptively adjusts based on impact energy. The use of additive manufacturing allows for open structures to increase thermal circulation and customize interface and fit with a Warfighter, reducing both hotspots and pressure localization.

To demonstrate LCE's blunt-impact protection advantage within a lattice matrix, flat pad samples were tested using a 5 kg hemisphere impactor on a linear drop test. The impactor was dropped at appropriate heights to achieve 10 fps and 14.1 fps impact speeds. An accelerometer was attached to the impactor to collect peak accelerations based on similar setup for helmet testing. For the 14.1 pfs impact energy, the peak acceleration of the first impact reduced by 50% (250 g to 125 g) through the inclusion of an LCE. The difference between the first and second impact was reduced from 100 g to 20 g for the lattice only and with LCE, respectively. The results gained during flat pad testing were used as a foundation for application to a combat helmet system and can be extended to other applications such as combat vehicles or in areas where repeated impact dissipation is required.

SESSION 7: NAVY ENHANCED SIERRA MECHANICS (NESM)

AUTOMATED FLUID MESH GENERATOR

Dr. Nicholas Reynolds, NSWC Carderock

The process of setting up high fidelity analyses of underwater explosion events has historically been a tedious, time-consuming process, largely based on the design/layout of fluid grids. For problems pertaining to arbitrary shot geometries around large marine structures, this has limited the ability of the underwater explosion community from employing advanced numerical techniques (e.g., uncertainty quantification, optimization, sensitivity, machine learning) that require parameterization and automation as part of preprocessing. In response, the Automated fluid Mesh Generator (AMG) preprocessing tool was developed for UNDEX analyses Navy-Enhanced Sierra Mechanics (NESM). This tool has been generalized to work with other high fidelity solvers. It is also undergoing active development to become more robust. This talk will address its current design, capabilities, and ongoing enhancements.

IMPROVEMENTS IN COMPUTATIONAL EFFICIENCY OF NEMO HYDROCODE

Michael Miraglia, NSWC Carderock
Rohan Bardhan, NSWC Carderock
Meredith Blanco, NSWC Carderock
Ari Bard, NSWC Carderock
Dr. Nicholas Reynolds, NSWC Carderock

Navy Enhanced Sierra Mechanics (NESM) is a suite computational mechanics tools to predict ship response and damage during threat weapon encounters. Within the NESM context explosive loadings are computed by the NEMO hydrocode. As part of ongoing NESM development improvements to NEMO data structures, memory utilization and parallel communication have resulted in significant improvements to computational efficiency. Case studies will be presented demonstrating >30% improvements to computation speed for realistic modeling scenarios.

NAVY SHOCK ISOLATING MOUNT (NMOUNT) CAPABILITY IN SIERRA/SD

Dr. Nicholas Reynolds, NSWC Carderock
Michael Miraglia, NSWC Carderock
Meredith Blanco, NSWC Carderock
Rohan Bardhan, NSWC Carderock
Ari Bard, NSWC Carderock

Navy Shock Isolating Mount(s) in Sierra Structural Dynamics (Sierra/SD) enable users to program custom constitutive relationships for arbitrary shock isolating mounts for linear elements. This feature, along with Sierra/SD''s massively parallel solvers and coupling to Eulerian fluid solvers, provides the survivability with a unique capability to simulate and evaluate the response of mounted equipment in realistic shipboard environment. This capability is highlighted along with recent usability enhancements.

POPULATION OF DATA FOR GENERALIZED SHOCK LOOKUP

Ari Bard, NSWC Carderock
Dr. Nicholas Reynolds, NSWC Carderock
Michael Miraglia, NSWC Carderock
Meredith Blanco, NSWC Carderock
Rohan Bardhan, NSWC Carderock

General Shock Lookup (GSL) is a Data Driven Module (DDM) used by the Navy's Advanced Survivability Assessment Program (ASAP) used for predicting equipment kills due from shock loading in engineering level models. This powerful capability enables numerous scenarios to be evaluated as part of survivability and lethality efforts. This DDM relies on prepopulated data in order to capture the load paths unique to each ship platform. This talk will give an overview of GSL DDM as well as how GSL data is generated for a given ship class using the high fidelity solvers in NESM.

HULL 3000 FINITE ELEMENT MODEL

Dr. Nicholas Reynolds, NSWC Carderock
Michael Miraglia, NSWC Carderock
Ari Bard, NSWC Carderock
Rohan Bardhan, NSWC Carderock
Meredith Blanco, NSWC Carderock
Rachel McIntyre, NSWC Carderock
Christian Castillo, NSWC Carderock
Tyler Rea, NSWC Carderock

This talk presents Hull 3000, a publicly releasable surface ship finite element model developed by Naval Surface Warfare Center, Carderock Division. The hullform, layout, and structural details of Hull 3000 are intended to be realistic, but not representative, of surface ships, and the model as a whole serving the NESM community at large for training, demonstrating workflows/examples, code regression, and troubleshooting user support tickets. This talk gives an overview of the model in general as well as resources that will aid uses in working with it.

SESSION 8: ELECTRONICS EVALUATION AND SENSING FOR HIGH-G ENVIRONMENTS

EXPERIMENTAL EVALUATION OF ELECTRONIC PACKAGING STRATEGIES ON FUNCTIONAL FIRESET ELECTRONICS

Zachary Jowers, Applied Research Associates
Dr. Matthew Neidigk, Air Force Research Laboratory
Dr. Adriane Moura, Applied Research Associates
Jared Hammeron, Applied Research Associates
Dr. Alain Beliveau, Applied Research Associates
James Scheppegrell, Applied Research Associates
Dr. Jacob Dodson, Air Force Research Associates

Experiments were performed to evaluate the effectiveness of various packaging strategies for electronic survivability under simultaneous thermal and dynamic mechanical loading. Packaged fireset printed circuit boards (PCBs) were thermally preconditioned and subjected to mechanical shock via drop-tower impact. PCB strain and electrical functionality, monitored *in situ*, were used as metrics for comparing the different packaging methods. The severity of mechanical shock was increased until loss of fireset PCB electrical functionality. The various packaging approaches were then ranked with respect to effectiveness.

THERMAL AND MECHANICAL SHOCK TESTING OF HARDENED FORWARD ASSEMBLIES

Dustin Landers, Applied Research Associates
Dr. Jacob Dodson, Air Force Research Laboratory

The Air Force Research Lab is conducting testing to evaluate the performance and functionality of a new embedded fuzing system designed by Sandia National Labs (SNL) to function and survive high deacceleration events experienced during high velocity target engagement. AFRL has worked with SNL to develop a fireset (also known as a forward assembly or FA) to survive the extreme environment, while also providing improved functionality and capabilities over legacy embedded fuze designs. Initial laboratory and shock testing will be used to validate the design, and testing will be extended to include temperature cycling and shock testing at the upper and lower temperatures within the Mil Spec temperature range. This paper presents an overview of the fireset, the setup for thermal and mechanical shock testing, and results from laboratory testing.

Development of a Physics Based Model to Characterize G-Switch Behavior for Smart Fuzing Systems

Philip Randall, Sandia National Laboratories
Ryan Jensen, Sandia National Laboratories
Joshua Dye, Sandia National Laboratories
Victor Nevarez, Sandia National Laboratories

Robust sensing methods are needed to detect acceleration environments to perform complex tasks such as smart fuzing. One affordable solution utilizes gravity switches (g-switches) as a detection method and relies on the closure duration of these switches to identify critical acceleration events. The behavior of the g-switches will vary based on the geometry and materials of the g-switch, and the algorithm that identifies the acceleration events needs to be calibrated to the specific device to ensure the overall system can make decisions accurately. To achieve this, physics models of the g-switches have been developed to predict closure data from acceleration datasets acquired from various flight, cannon, and drop tower tests. A high-fidelity model allows for the generation of g-switch closure data to calibrate and develop smart fuzing algorithms without the need to re-perform expensive field testing to characterize the switches under realistic acceleration environments. Recent miniaturization efforts have prompted the shift to significantly smaller micro-electromechanical system (MEMS) g-switches that require analysis and testing to develop a new model.

Equipment Blast Fragility

Dr. John Sajdak, Test & Evaluation Solutions LLC

Degraded or disrupted electrical power delivery may impact the mission capabilities of a United States Navy ship. Since nearly all ship systems rely on electric power, either directly or indirectly, an investigation of the blast response of equipment of the electrical distribution systems was conducted to assess the vulnerability of mission critical systems under potential combat conditions. Furthermore, as damage to electrical equipment in the power distribution system may introduce detrimental transients into the system that could cascade within the power system and lead to unexpected consequences, the investigation of the blast response of equipment was performed at the system level while fully energized.

Fifteen full system level tests were conducted within a 40 foot long by 24 foot wide by 16 foot high test fixture funded by the Director, Operational Test and Evaluation (DOT&E), under the Joint Live Fire (JLF) Program and constructed at the Littoral Warfare Environment Annex at Aberdeen Test Center. These tests were conducted as a part of the DDG 51 Class Flight III Live Fire Test and Evaluation (LFT&E) strategy. Two additional LFT&E Programs, the Amphibious Assault Ship (LHA) and Amphibious Transport Dock (LPD), both within PMS 377, additionally collaborated with PMS 400D in funding this test program.

Each of these 15 tests included between 12 and 19 individual pieces of equipment bulkhead mounted on six pallet assemblies and wired in one of eight power system configurations representative of shipboard 450 and 115 power distribution systems. Each power distribution system was energized to between 80 and 100kVA prior to the detonation of a high explosive centrally located within the test fixture whereupon power monitoring data (voltage and amperage) and blast loading data (pressure and acceleration) was collected for each of the energized shipboard electrical distribution equipment.

Within this presentation, the blast fragility (operational performance, failure modes and recoverability) of the energized shipboard electrical distribution equipment will be discussed for bus transfer, power panel, distribution box, uninterruptible power supply, motor control starter, and transformer type equipment. Additionally, updated equipment failure criteria under blast loading conditions will be summarized.

TOWARDS ACTIVE STRUCTURAL CONTROL STRATEGIES FOR ELECTRONIC ASSEMBLIES IN HIGH-RATE DYNAMIC ENVIRONMENTS

Trotter Roberts, University of South Carolina
Dr. Jacob Dodson, Air Force Research Laboratory
Dr. Adriane Moura, Applied Research Associates
Prof. Austin Downey, University of South Carolina
Ryan Yount, University of South Carolina

Electronic assemblies subjected to high impact and shock loadings could be integrated with transducers to actively mitigate their deflection during extreme dynamic events. Active structural control schemes have been proposed and explored for the mitigation of structural vibrations, however, their use for the active suppression of structural deflection in a system experiencing shock has received significantly less attention. Moreover, the investigation of active shock control in high-rate dynamic environments is an unstudied area. High-rate dynamic events are characterized by large uncertainties in external loads, high levels of non-stationarities and heavy disturbances, and unmodeled dynamics generated from changes in system configurations. This paper presents an experimental framework aimed at enhancing the resilience and endurance of electronic assemblies through the incorporation of active control elements. In this study, a circular printed circuit board equipped with representative electronic components is subjected to controlled high-energy impacts. Finite element modeling complements the experimental tests, offering insights into the complex interactions between structural deflections and control mechanisms during shock. The initial phase of this research establishes a crucial foundation for developing sophisticated active control strategies. In particular, it gathers essential data on how electronic assemblies respond under high-impact conditions, which is vital for informing the layout, control methodologies, and the potential quantity of actuators needed for effective active shock mitigation. By closely analyzing the acceleration data and structural responses during these tests, this work pinpoints where actuators would be most beneficial in reducing deflections and absorbing shocks. This information is critical in determining the optimal configuration of actuators—where they should be placed, how they should be controlled, and in what numbers—to maximize their protective effects. Additionally, this work seeks to quantify the potential benefits of these active control systems, such as increased durability and extended operational life of electronic assemblies, setting a targeted path for future enhancements.

VENDOR SESSION B: EXHIBITOR CASE STUDIES, NEW DEVELOPMENTS, TESTING & PRODUCT

ENDEVCO'S NEW PIEZORESISTIVE COMBOBULATOR

Bob Metz, PCB Piezotronics

Endevco’s new 4840 sensor simulator is really a hand held, battery operated combobulator. In simple terms, it is a signal generator designed specifically to simulate the electrical output of common types of testing sensors and create order in an otherwise chaotic testing environment. The instrument contains a highly accurate oscillator with an adjustable output level and is ideal for setting up, testing and the diagnosis of faults within data acquisition systems, environmental test systems, or simply as a flexible signal generator.

The new simulator provides AC output signals that mimic those of either voltage mode ICP (IEPE) accelerometers or charge mode accelerometers (both single ended and differential configurations). But the newest and most relevant feature for mechanical shock and blast pressure measurement is its ability to simulate piezoresistive bridge sensors.

The simulation outputs are conveniently scaled in units of measure that can be configured by the user (g, PSI, Bar, dB, dBA, kPa), as mV(millivolt)/UOM or pC(pico-coulomb)/UOM signals as appropriate. When units of measure are selected as "g", an auto-calculating on screen "Vibration Calculator" provides the user with corresponding values in respect of m/s^2, ips, mils, mm and m/s based units.

Simulation parameters can be selected, adjusted, and saved as a "profile" either by the front panel keypad or using the supplied utility program. Use of the utility program not only allows profiles to be created and saved but also organized into specific "profile sets" which can be conveniently stored on a PC. Up to 40 user profiles may be downloaded to the simulator at any one time.

CAN-MD®: VIBRATION SENSING EVOLVED
Kevin Westhora, Dytran by HBK

Dytran by HBK introduces the CAN-MD® platform -- a revolutionary approach to machinery diagnostics through its advanced digital sensor network. This presentation delves into the CAN-MD® system, highlighting its core functionalities, applications, and future developments. CAN-MD® processes raw analog data directly within each sensor, enabling a streamlined bussed architecture that outputs actionable insights rather than mere raw data. Key features include the ability to accommodate up to 31 sensors on a single CAN network, various condition indicators for real-time monitoring, and integration ease with existing CAN-supported systems.

The presentation covers:

1. 1.Introduction to CAN-MD®: Overview of the platform and its digital vibration sensing capabilities.
2. 2.Applications and Benefits: Diverse use cases in aerospace, industrial monitoring, and more, showcasing cost reduction, ease of installation, and enhanced data processing.
3. 3.Developer Kits and Software Offerings: Tools available for developers to integrate and optimize CAN-MD® within their systems.
4. 4.Future Product Line Developments: Upcoming innovations and enhancements to the CAN-MD® product line.

Attendees will gain insights into how CAN-MD® can revolutionize their monitoring and diagnostics processes, making their systems more efficient and responsive to real-time conditions.

COMPUTING THE FREQUENCY RESPONSE FUNCTION (FRF) FROM A MODAL HAMMER'S FORCE RESPONSE USING DIGITAL IMAGE CORRELATION (DIC); PLUS, AN OVERVIEW OF A NEW DIC STRESS ANALYZER FOR ALL MATERIALS
Elisha Byrne, Correlated Solutions

Utilizing high-speed cameras and three-dimensional digital image correlation (DIC) to measure operation deflection shapes (ODS) of materials under excitation has been a common and successful measurement technique due to its ease of use, affordability, and ability to measure ODS' from transient events.

However, one of the key elements to properly characterize the behavior of a material under excitation is to accurately compute the frequency response function (FRF) or “transfer function.” This is typically performed by using the force response from a modal hammer. However, performing full modal analysis has proven to be challenging because computing the FRF in the DIC analysis software has not been available until now. To compute the FRF, the force response from a modal hammer must be accurately recorded and synchronized with the image capture, which requires advanced acquisition software. Furthermore, the DIC analysis software must have the ability to perform similar FFT analysis on the acquired force data. This talk will explain how to a) properly capture DIC and force data from an aluminum plate that is impacted using a modal hammer, and b) analyze the FRF and DIC data with stunning visualization.

Computing stress from DIC data has shown to be challenging because a) the material’s mechanical properties must be known or computed, b) the load input must be accurately synchronized with the DIC data, and c) the cross-sectional area changes for experimental materials must be measured during the test. Even when the material properties are known, third party software or custom software code is required to compute stress-strain curves making the process time-consuming, cumbersome, and often volatile. Two facing stereo DIC systems have been utilized to measure the change in the cross-sectional area, but this often requires assumptions and/or predictions to be incorporated in the measurement. If the material’s mechanical properties are known, the material’s model may be entered into the VIC-3D Stress Analyzer which will accurately compute and display the stress distribution on the test article’s surface. This talk will demonstrate how the stress distribution can be obtained for a specimen under tensile loading.

VIPER::BLAST FOR ADVANCED AIRBLAST SIMULATIONS

Dr. Peter McDonald, Viper Applied Science

Join us for an insightful vendor session where we explore the advanced capabilities of the Viper::Blast Computational Fluid Dynamics (CFD) tool, specifically designed for airblast simulations. Viper::Blast is a leading tool in the areas of blast analysis and extreme loads, utilizing GPU acceleration to deliver exceptional performance and usability. This session will highlight the unique features that make Viper::Blast an indispensable tool for engineers and researchers in blast analysis and beyond.

We will begin by examining the GPU-accelerated performance of Viper::Blast, which significantly enhances simulation speed and efficiency, allowing for faster turnaround times without compromising accuracy. The session will also showcase the user-friendly interface and intuitive workflows that make Viper::Blast accessible to both new and experienced users.

Next, we will provide a comprehensive overview of the various workflows supported by Viper::Blast, addressing critical aspects of blast analysis such as building damage assessment, coupled simulations, and injury prediction. Real-world examples and case studies will be presented to illustrate the practical applications and benefits of these workflows.

In addition to current capabilities, we will offer an exclusive sneak peek into the future developments of the Viper toolchain. This segment will focus on the upcoming advancements in underwater explosion CFD and Fluid-Structure Interaction (FSI) capabilities. Attendees will gain insights into how these new features will expand the scope and functionality of Viper::Blast, enabling it to tackle even more complex and diverse simulation scenarios.

Whether you are involved in defense, aerospace, civil engineering, or any field requiring advanced blast analysis, this session will equip you with the tools and knowledge to enhance your blast analysis capabilities. This session is ideal for professionals eager to explore cutting-edge CFD solutions for airblast scenarios and those interested in the future trajectory of Viper::Blast's development.

THE USE OF SYMOS SOFTWARE FOR NAVAL APPLICATIONS

Ali Shehadeh, Societec US

SYMOS is a proprietary software developed by Socitec specializing in multi-directional shock and vibration analysis. With its advanced analysis and comprehensive simulation capabilities, SYMOS accurately predicts the response of dynamic environmental forces on isolated systems (including UNDEX applications). This allows engineers to design and optimize ship components for improved durability and operational efficiency. By simulating real-world scenarios, SYMOS helps mitigate risks associated with shock and vibration, ensuring the safety and reliability of naval fleets.

TRAINING II

INTRODUCTION TO UERDTOOLS

Rachel McIntyre, NSWC Carderock
Brian Lang, NSWC Carderock
Paul Mantz, NSWC Carderock

The UERDTools program is a collection of data processing and analysis routines integrated into a single package to provide a comprehensive tool for on-site data analysis. The real-time analysis of acquired test data necessitates a convenient, easy to use package for data processing, plotting, and manipulation routines to support rapid assessment and interpretation of measured test results. This suite of data analysis routines is designed to help standardize the way Navy shock programs analyze and process data. It also facilitates ease of generation of comparison plots of both measured and computed results in support of analytical correlations studies. This training summarizes the UERDTools suite of programs, illustrates its basic features (including curve comparisons), and describes the built in user-defined macro capability. Details of the development, architecture, and resident analysis modules are outlined.

SESSION 9: MIL-DTL-901E TESTING & SHOCK DATA

MIL-DTL-901 SUBSIDIARY SHOCK PROGRAM DEVELOPMENT

Matthew Forman, NSWC Dahlgren
Sloan Burns, NAVSEA 05P1

Navy electronics cabinets require periodic updates to internal components throughout its lifecycle due to obsolescence or performance improvements. MIL-DTL-901 qualification requires any changes made to a previously qualified principal unit must be accompanied by a new principal unit test or qualification extension with supporting rationale and OQE (i.e. subsidiary component shock test). Each subsidiary component shock test requires upfront DAA/TWH discussions, analysis, and review prior to test execution which can be costly and time consuming for both the customer and approvers.

In the early 2000's, Aegis Technical Insertion program developed a "Subsidiary Shock Process Document" for the Class I/II Mission Critical Enclosure (MCE) which standardized the following to remove iterative DAA input/approval:

- Class I cabinet configuration and hardware
- Class II portion isolator type, PN, #, and configuration
- Class II portion payload capacity
- Class II portion C.G. location and X/Y/Z tolerances (nicknamed the "C.G. Cube")
- Shock pulse input for each axis for replication on a shaker table

NSWC Dahlgren Division (NSWCDD) in collaboration with NAVSEA 05P1 is developing a standardized process for new electronics cabinet programs to follow, allowing the creation of similar "Subsidiary Shock Process Documents." The planned standardized process will be presented, along with example data points and steps completed to date from a current electronics cabinet program.

DETERMINING AN ESTIMATE FOR MIL-DTL-901 FIGURE 13 CHANNEL FREQUENCY

Patrick Minter, NSWC Philadelphia

Medium Weight shock tests conducted in accordance with MIL-DTL-901 generally require the use of a supporting array of structural steel beams (channels) between the test item and the anvil table. The arrangement of these channels is called out by Figure 13 of the 901 specification. These channels are essential to developing the appropriate testing environment for simulating shipboard installations. Through Figure 13, MIL-DTL-901 simplifies the testing setup by standardizing selection of the channels, and therefore requires no calculation of structural frequency. However, sometimes it is advantageous or even necessary to determine the approximate response frequency of the channel bed. Several methods of determining this channel bed frequency have been proposed previously. The author has researched these previous methods and compared them to instrumented tests and FEA to provide insight into which method(s) provide the best channel frequency estimate and determine whether a simplified method exists to estimate channel frequency accurately.

DETERMINATION OF FUNDAMENTAL DECK FREQUENCY TO MEET REQUIREMENTS FOR MIL-DTL-901E

Calvin Milam, Element US Space & Defense

Heavyweight, deck mounted items tested in accordance with MIL-DTL-901E are typically tested at a fundamental vertical frequency of 8±1 Hz, 14±2 Hz or 25 +5/-0 Hz. This presentation will review typical methods used for determining deck frequency. A brief description of deck simulator fixtures (DSFs) used for heavyweight shock testing will be provided. Data from control instrumentation mounted on DSFs will be provided and methodologies for determining fundamental vertical frequency using UERD Tools will be provided. Methods will include FFT, SRS and time-period from velocity response. Methods for tuning DSFs and factors influencing response will be discussed.

SHOCK RESPONSE SPECTRUM ANALYSIS AND DATA VALIDATION TOOL FOR SHIPBOARD SHOCK, PYROSHOCK, AND MORE

Seth Mitchell, Element US Space & Defense
Dr. Logan McLeod, Element US Space & Defense
Calvin Milam, Element US Space & Defense

Shipboard and pyrotechnic shock tests create severe multi-axis acceleration environments that can be difficult to measure and quantify with accuracy. Historically, more publications, workshops, and industry standards from the shock community have focused on the methodologies ensuring data integrity and in the field of pyroshock validation in the time, SRS, and measurement domains. Fewer studies have investigated the validation of shipboard shock, as the industry has long been aligned with the Navy shock analysis software UERDTools. Thus, Element U.S. Space & Defense has expanded the capabilities of their internally developed shock analysis software to include shipboard shock validation.

During a typical shipboard shock test series, the measured shock acceleration and relevant data such as the deck frequency response, FFT, SRS, and velocity are processed in UERDTools. The results are subsequently reported to the Navy's Technical Authority for test approval. This multi-step process prevents the test facility from independently validating preliminary test data and presents opportunities for failed testing and wasted resources. Shipboard shock acceleration data is inherently coupled with the frequency response of the test setup and the capabilities of the test engineer to analyze shock data during test checkouts and make the necessary modifications. Therefore, the EUSSD Shock Tool serves as an additional resource to UERDTools, by combining processing capabilities from UERDTools, requirements from MIL-DTL-901E, as well as recommendations derived from decades of combined engineering experience to provide test engineers a shock validation resource immediately after the shock test.

The validation tool can analyze both control deck and near-EUT accelerations and process the profiles and corresponding relevant data against a series of validation algorithms and test requirements. The results of the validation checks provide the test engineer with immediate feedback on the test performance. When necessary, the program provides recommendations for manipulating the deck or hull frequency response through methods such as adding or subtracting mass, changing the distances between the test article and key fixturing, or even checking for loosened bolts. Shock profiles and test setup attributes are validated against a library of MIL-DTL-901E requirements, and profiles are checked for potentially erroneous data.

Capable of processing either shipboard and pyroshock acceleration data against their respective validation algorithms, the shock tool provides numerous tunable analysis features such as custom filtering, drift compensation, optimized dampening coefficients, nominal variance analysis, and more. The program provides a graphical presentation of a transient acceleration, integrated velocity, and positive and negative SRS in a summary report format, along with any relevant test information useful for the test engineer to replicate the test and analysis and generate reports. The SRS is verified in the time and frequency domains with warnings presented if the test equipment settings are insufficient or limiting relative to the test profile or showing signs of corruption. Each of the verifications provide distinct insight, such that several industry standard concerns can be addressed in real-time at the test facility. As an EUSSD developed tool, additional features are continuously added, and test engineer requests can be accommodated.

SESSION 10: APPLICATIONS OF VIBRATION TEST METHODS

Acoustic Monitoring of Component Condition for Microreactor Applications

Rajarshi Bose, Los Alamos National Laboratory
Dr. Andrew A. Delorey, Los Alamos National Labs
Dr. Timothy James Ulrich II, Los Alamos National Labs
Dr. Paul Richmond Geimer, Los Alamos National Labs

As advancements in microreactor technology push nuclear power into smaller and more adaptable form factors, the extreme operating environments associated with the technology necessitate in-situ methods to predict component-level damage before structural issues arise. One approach in development seeks to utilize the unstructured vibration sources found in reactor environments, where durable embedded fiber-optic sensors could measure vibration signals within microreactor components that contain information about damage state or location. Through combined application of modal analysis, laser vibrometry, and machine learning techniques, here we show how in-situ monitoring of these systems can be enabled. As a benchtop proxy for embedded fiber sensing, we used a state-of-the-art 3D laser Doppler vibrometer to non-destructively measure the response of a representative damaged test article to random noise. Neural networks trained on this data correctly predicted the real stress state label about 85% of the time, with remaining predictions missing by a single stress increment. Key to this effort was the acquisition of high-quality acoustic measurements, including resonance mode shapes and the nonlinear elastic response at different excitation levels. While more data will lead to further refinement of this specific model, the implications of this work go beyond nuclear reactors. The developed techniques and methodologies are adaptable to other industries where predictive maintenance of critical components can create safer and more reliable systems.

Inverse Test Based Estimation of Equivalent Acoustic Excitation Based on Aircraft Cabin Response Measurements

Prof. Benedikt Plaumann, Hamburg University of Applied Sciences
Prof. Dr. Habil Thomas Kletschkowski, Hamburg University of Applied Sciences
Ashish Chodvadiya, Hamburg University of Applied Sciences
Eugen Hein, Hamburg University of Applied Sciences

Calculations of aircraft vibro-acoustics require adequate model data for the transfer path from outside to the cabin as well a suitable excitation model. However, vibroacoustic sources of aircraft noise include but are not limited to engine vibration, Turbulent Boundary Layer (TBL) excitation, as well as other direct sources mounted on the primary aircraft structure like pumps. It is therefore difficult to include all sources in one modeling approach. Here, an inverse approach has been used that is based on cabin response measurements for equivalent acoustic excitation. In the test setup described in the contribution, an A320 fuselage section with complete cabin is excited by airborne acoustic noise generated with loudspeakers. The fuselage as well as the acoustic sources have been integrated in a climate chamber hall room. Measurement of the excitation outside the fuselage as well as of the response in the cabin give a very general description of the transfer path. More detailed analysis work has been published on the main transfer path contributions and how these can be optimized for weight and acoustic transmission loss. The current contribution will focus on the replication of sound pressure spectrums measured in public commercial flights in the given test setup. The required excitation spectrum is then measured and analyzed. It can be used as an equivalent excitation for lab testing changes in the transfer path of airborne and structureborne sound and vibration. This can be done for several response-equivalent excitations of different flight phases, like cruise, approach, take-off etc. For example, new hardware modifications in the transfer path of the cabin (i.e. like mounting different isolators in the structural sound path) can be tested under the equivalent excitations to estimate the changes the modifications makes to the overall cabin sound pressure spectrum. The contribution will also look at non-linear influences from different excitation levels from low level white noise random to realistic excitation levels of different flight phases. Some first insight in resulting transfer measurements of sound pressure and acceleration will be given. Limitations of that first test setup will be discussed, too.

PACKAGED AND PALLETIZED ORDNANCE RESPONSE CHARACTERIZATION: DO WE CARE ABOUT HIGH FREQUENCY?

Matthew Forman, NSWC Dahlgren
Dr. Luke Martin, NSWC Dahlgren
Shawn Schneider, NSWC Dahlgren

Military ordnance qualification includes vibration testing to assess safety and functionality requirements. For transportation modes, ordnance is typically packaged or palletized. To assess transportation modes, ordnance is exposed to combined temperature and vibration tests.

Advancements and prevalence of commercial multi-degree-of-freedom (MDOF) vibration tables allow the potential to increase the efficiency and testing safety compared to traditional single-degree-of-freedom (SDOF). Many MDOF shakers are limited to a 500 Hz bandwidth due to physical constraints, which can conflict with certain military modes of transport to include propeller and jet aircraft that contain energy up to 2 kHz.

NSWC Dahlgren Division (NSWCDD) performed a study to determine the expected structural response of common ordnance types to high frequency inputs when configured in their transportation configuration. The study included a historical data review of previous testing, as well as a recent test with a pallet of ordnance subjected to full 2 kHz and truncated 500 Hz aircraft environments. Findings on the ordnance structural response, and discussion about future implications and efforts will be presented.

SESSION 11: NAVY SHOCK DDAM & TEST ANALYSIS

ELECTRO-WELDED STUD TECHNOLOGY SHOCK TEST PROCEDURE AND RESULTS

Dr. Alfonso Barbato, Fincantieri/Naval Vessel B.U.
Francesco Miselli, Fincantieri Naval Vessel B.U.

The electro welded stud technology is a reliable procedure, already adopted in shipbuilding, in order to connect, through automatic electric welding, small metallic parts to ship structures. The process is widely adopted for the installation of all kinds of plants onboard, also in the naval shipbuilding field, when applicable. Considered the constructive advantages of this technology, that have been confirmed in Fincantieri experience, a study has been conducted about the possibility of applying it onboard of naval ship with UNDEX requirements. The results of the experimental campaign, its description and relevant design criteria are described in the paper.

AUTOMATED SHOCK ANALYSIS OF SHIPBOARD PIPE HANGER FOUNDATIONS

Justin Caruana, Cardinal Engineering
David Batol, Cardinal Engineering

This presentation will explain how Cardinal Engineering developed and applied an innovative solution to automate shipboard pipe hanger foundations for a shipyard customer.
The primary technical challenge to solve on this project was to conduct shock analyses of more than 1,000 unique pipe hanger foundations using limited manpower resources to support an aggressive program schedule.

Using the Femap Application Program Interface (API) coupled with Python scripts, Cardinal developed a series of program utilities integrated seamlessly within FEMAP to automate the steps that would have otherwise been conducted manually, such as developing detailed finite element models, conducting the analyses, and postprocessing the analysis results.

The powerful capabilities of these automated tools allowed Cardinal to successfully complete this project for the shipyard customer in a timely manner, which would have otherwise not have been possible using traditional manual methods.

OPTIMIZATION OF STRUCTURES UNDER SHOCK LOADING (NON-LINEAR DYNAMIC) AS PER MIL-DTL-901E USING EQUIVALENT STATIC LOAD METHOD

Kory Soukup, Altair Engineering
Giri Prasanna, Altair Engineering
Jason Krist, Altair Engineering

The MIL-DTL-901E standard outlines the rigorous procedures required for high-impact shock testing of equipment designed for harsh environments, such as military vessels. This study focuses on the optimization of structures subjected to shock loading under non-linear dynamic conditions, adhering to the guidelines specified in MIL-DTL-901E.

The Equivalent Static Load (ESL) method is employed to streamline the complex dynamic optimization typically associated with shock loading scenarios. By converting the dynamic load effects into equivalent static loads, the ESL method facilitates a more efficient optimization process without compromising accuracy. This research encompasses the development and validation of a robust ESL-based optimization framework. Structural performance under shock loading is evaluated using detailed finite element models, ensuring compliance with MIL-DTL-901E standards. The optimization process aims to enhance the structural resilience and performance while minimizing weight and material usage. Results demonstrate the effectiveness of the ESL method in achieving optimal designs that meet stringent military specifications, providing valuable insights for the development of resilient structures capable of withstanding severe shock environments.

Key benefits of this methodology include significant time/cost reductions, enhanced safety, and the ability to iteratively optimize design performance before physical prototypes are constructed. Our results demonstrate the efficacy of using Altair's suite of simulation tools to meet MIL-DTL-901E requirements, providing a robust and flexible solution for manufacturers.

ADAPTER PLATE ANALYSIS AND APPROVAL PROCESS FOR MEDIUM WEIGHT SHOCK TESTING

Spencer Fallon, Leidos Gibbs & Cox
Michael Poslusny, Leidos Gibbs & Cox

Shock testing of base, back or in-line pipe mounted equipment on the Medium Weight Shock Machine typically requires the use of an adapter plate to interface the equipment with the car building channels of the shock machine. The adapter plate is considered a "non-standard test fixture" per MIL-DTL-901E and requires Navy approval. This presentation provides a quick method (developed by Leidos Gibbs & Cox and NAVSEA 05P) for determining adapter plate resonance using Blevin's equations to ensure the equipment is subject to proper shock loading. The presentation also details the process for obtaining Navy approval prior to test; utilizing eShock or other means.

SESSION 12: BLAST EFFECTS MODELING & SIMULATION

ENHANCING GROUND SHOCK PREDICTIONS FOR CRITICAL INFRASTRUCTURE: DEVELOPMENT OF THE SABER-NX TOOL

Ernesto Cruz-Gutierrez, USACE ERDC
Logan Rice, USACE ERDC
Dr. Mark Adley, USACE ERDC
Dr. Will McMahon, USACE ERDC

The understanding of ground shock behaviors resulting from buried high explosives holds immense value in predicting potential damage to critical structures. Weapon systems designed to penetrate into the ground and detonate once they are fully buried can generate large ground shock loads that interact with nearby structures. One of the missions of the U.S. Army Engineer Research and Development Center (ERDC) is to conduct research to better understand the effects of explosions on buried structures. Critical to the mission is the need to accurately predict the ground shock loads that propagate from the source of the explosion to the structural element and the ability to understand how these loads interact with the structure and its various components. To address the need for understanding the ground shock loads generated by such attacks, ERDC is developing the SABER-NX software package, which estimates the ground shock environment from a fully contained conventional explosive using 1-D finite element models. By modeling the explosive as a spherical charge, SABER-NX calculates ground shock loads as a function of time and distance, and these loads can be used as tabular source models to apply ground shock loads to surfaces of buried structures, runways, foundations, and other elements in contact with the ground. This tool aims to improve ground shock predictions by providing both rapid assessments and higher fidelity simulations of ground shock environments, enabling accurate modeling of facility responses to ground shock loads. By assessing the effects of explosive charge size, explosive type, and soil material properties on the ground shock environment, SABER-NX becomes an invaluable resource for modeling the potential lethality of various weapon systems and assisting in mission planning and sustainment evaluations of crucial military assets. This paper provides a general summary of the current state of development of SABER-NX, highlighting its current capabilities and new features, aiming to enhance the understanding and application of this advanced software package for predicting the ground shock environment.

APPLICATIONS OF SECOND-ORDER FINITE ELEMENT ANALYSIS TO EXPLOSIVE-STRUCTURE INTERACTIONS AND GROUNDSHOCK

Dr. Ivan Arnold, USACE ERDC
Dr. Kent T. Danielson, USACE ERDC

Solid dynamics programs used to model shock for explosive interactions with structures, soil, and rock have typically used first-order elements, even though second-order elements provide a more accurate representation of flexure and curved surfaces, as well as reduce wave propagation dispersion error. This is due to several factors, including some second-order elements suffering from the lack of a satisfactory mass lumping. For example, second-order “serendipity” elements can have zero or negative nodal masses using row summation. Over the last decade, however, a viable suite of higher order elements suitable for use with solid dynamics programs has been identified, and their application to a variety of benchmark problems using the MPI-based finite element code ParaAble has demonstrated robust performance [1]. These higher order elements include 1) the fifteen node tetrahedron (TET15), 2) the twenty-seven node hexahedron (HEX27), 3) the twenty-one node wedge (WEG21), and 4) the nineteen node pyramid (PYR19). This previous work has been leveraged herein to investigate explosive-structure interactions in concrete using both ParaAble and the Lagrangian explicit dynamics code EPIC. Comparisons to test data and

simulations using first-order elements are presented and discussed, along with efforts to evaluate these techniques for the modeling and simulation of explosive groundshock.

[1] K.T. Danielson, M.D. Adley, T.N. Williams, Second-order finite elements for hex-dominant explicit methods in nonlinear solid dynamics, Finite Elem. Anal. Des. 119 (2016) 63–77, http://dx.doi.org/10.1016/j.finel.2016.02.008

CALCULATIONS OF 3/8 SCALE EARTH-COVERED MAGAZINES TO INVESTIGATE EARTH COVER EFFECTS

Dr. Paul Mead, USACE ERDC
Christopher Shackelford , USACE ERDC
Dr. Laura Walizer, USACE ERDC
Dr. T. Neil Williams, USACE ERDC
Joshua Payne, USACE ERDC
Dr. John Q. Ehrgott, Jr., USACE ERDC
Denis Rickman, USACE ERDC
Susan Hamilton, U.S. Army Engineering and Support Center
Spencer Hovey, Defense Ammunition Center/U.S. Army Technical Center for Explosives Safety
Andrea R. O'Brien, Defense Ammunition Center/U.S. Army Technical Center for Explosives Safety

Earth-covered magazines (ECMs) for storing ammunition and explosives are designed to have a minimum of 2 ft of earth cover as specified in DoD 6055.09-M, DoD Ammunition and Explosives Safety Standards. Over time, the earth cover may erode resulting in an earth cover that is less than the required 2-ft thickness, thereby reclassifying the ECM as an aboveground magazine (AGM) and significantly reducing the allowable storage capacity. A series of experiments were developed to investigate the effects of varying earth-cover thicknesses for ECMs. These experiments provide data to establish confidence in the numerical simulations. This presentation will focus on evaluating the numerical methodology applied to the most recent test event, which utilized a concrete arch magazine as the donor ECM and instrumented testbed and berm to capture air blast and ground shock data transmitted to the near-field area.

SECOND-ORDER PYRAMIDS SUPPORTING EXPLICIT SOLID DYNAMICS FOR SIMULATION OF EXTREME EVENTS

Dr. Robert Browning, Battelle Memorial Institute
Dr. Kent Danielson, USACE ERDC

Explicit dynamic methods are frequently used to simulate extreme events, such as car crash and other severe impacts, as well as weapon effects and accidental explosions. Frequently, the structural geometry can be tedious to mesh, which has given rise to hex-dominant meshing algorithms. Leveraging such methods, however, typically requires the use of not only hexahedral (hex) and tetrahedral (tet) elements, but also transition elements providing compatible faces with each. When the parts being meshed contain curved edges and/or surfaces, second-order elements also become advantageous by allowing geometric features to be modeled more accurately with fewer elements. Such approaches have been more prevalent in implicit models, but are gaining attention in explicit methods. A key to successful hex-dominant meshing with second-order elements for explicit nonlinear solid dynamics, was the development of a robust 19-node pyramid element (PYR19), that is compatible with other robust second-order solid elements. The PYR19 has been shown to behave well in flexure with very few elements. It also resists volumetric locking in problems involving metal plasticity and shows no signs of hourglassing (i.e., problems caused by spurious modes) by virtue of its robust quadrature. The PYR19 and its compatible elements are now available for use in multiple explicit dynamic solid mechanics codes suitable for various nonlinear applications. The elements are also supported in popular meshing and visualization software.

VENDOR SESSION C: EXHIBITOR CASE STUDIES, NEW DEVELOPMENTS, TESTING & PRODUCT

UNIQUE 6 DEGREE OF FREEDOM ISOLATION SYSTEM COMPOSED OF ISOLATORS AND OVERTRAVEL SNUBBERS, WITH POWER INPUT CONSIDERATIONS AND LIMITED SWAY SPACE

Gordon Fox, Taylor Devices

This is a case study of a shock and vibration isolation system using isolation mounts to mitigate severe but small-displacement vibration with hydraulic snubbers to efficiently mitigate MIL-DTL-901 shock events. This presentation will include how to most efficiently use the limited sway space and to minimize internally generated heat during vibration.

IMPROVED PERFORMANCE IN WIRE ROPE APPLICATIONS UTILIZING HIGH DAMPED ELASTOMER

Timothy Manta, ITT

Wire rope isolators have been historically used to protect sensitive electronics from shipboard shock and vibration. Encasing the wire rope isolator in elastomer improves attenuation performance and has been successfully implemented in High Energy Rope Mount (HERM) isolators. For these applications, added damping is a key attribute for achieving improved performance. ITT Enidine has developed a silicone elastomeric compound with exceptionally high damping characteristics and evaluated the advantages compared to wire rope isolators. This paper will discuss the testing methodology and outcomes, as well as other benefits of utilizing a high damped silicone HERM.

FROM MEASUREMENTS TO INSIGHTS IN MINUTES – REVOLUTIONIZING INTEGRATED NVH TESTING AND ANALYSIS

Christian Fritz, DEWETRON

This presentation will introduce a cutting-edge hardware and software solution for NVH and power measurements. The product is a result of the collaboration of two industry leaders and offers a revolutionary approach creating an interconnected and decentralized environment for comprehensive data analysis.

We will demonstrate how this integration transforms isolated measurement systems into a unified platform, enabling seamless data collection from a wide variety of sensors. The solution encompasses DEWETRONs' OXYGEN software and transfers high-precision measurement data to Mueller-BBMs' PAK cloud, where it can be combined with NVH data from other sources. Attendees will learn how this system allows for real-time analysis and clear correlation of data, enhancing the efficiency and accuracy of NVH analytics.

THE COMPLAINT DEPARTMENT GETS THE MOST DIFFICULT TEST SPECIFICATIONS

Deepak Jariwala, Spectral Dynamics

Spectral Dynamics, Inc. has continuously developed control systems which do not only control the most difficult, but Non-linear test articles - the ones that test engineers understand is where the "complaints" come from their customers! You will hear about just what to do with those difficult tests that customers send out to the test laboratories! These are not only Random and Sine Tests, but Mixed Mode tests (i.e. narrow band random or sinusoidal tones - sweeping or fixed, on wideband random and often with something on the test stand that is running under its own power independent of the shaker vibration!!

Of course, we will discuss how the most difficult tests are sent to the SD control systems, and how you can get it done! Our latest Windows 11 based control system for driving Electrodynamic and Servo-hydraulic shakers is here to help you with its Host PC to USB3, Ethernet or Wi-Fi connectivity and using SD patented Adaptive Control for vibration and shock testing your most complex challenges.

TRAINING III

SHOCK RESPONSE SPECTRUM PRIMER

Dr. Carl Sisemore, ShockMec Engineering

The shock response spectrum (SRS) is the most common way of characterizing transient excitation. The SRS is advantageous due to its ubiquity and ability to substantially reduce the shock data complexity to a manageable level. An overview of the origins and methods for calculating the SRS will be provided. The various types of shock spectra will be discussed in detail along with their applications. A comparison of SRS results from both classical and oscillatory shocks will be presented along with a discussion of the important characteristics of each type of shock when transformed to the SRS.

SESSION 13: MECHANICAL SHOCK TESTING I

USING TEST CONFIGURATION TRANSMISSIBILITY FUNCTIONS TO LIMIT SHOCK RESPONSES

Guillermo Anaya, Sandia National Laboratories
Vit Babuska, Sandia National Laboratories

Shock testing is important for many systems to demonstrate reliability and survivability. When conducting shaker shock testing, the shaker table and fixture typically do not represent the dynamic configuration from the field which leads to unrepresentative lab responses. In most cases, lab testing is more damaging to the test article than the in-service loads. Excessive responses to shaker shock inputs can be mitigated by applying shaker shock response limiting. For shaker shock testing implementing limits is not as straight-forward as random vibration testing because shaker shocks are run in open loop. Typically, shock tests involve a step-up process starting at a low level (-12 dB) and proceeding to the full level. This provides an opportunity to use transmissibility functions measured in the test configuration between the control point and the response limiting locations to determine the notched control inputs so that the responses of interest stay below intended levels. This paper describes the process of obtaining transmissibility functions from a low-level pre-test random vibration test and the low-level shocks during the step-up phase, defining limits at response locations, and providing new shaker shock inputs that will not exceed desired responses. This makes it possible to observe how the shock responses evolve as the shock level increases. We found that using the transmissibility functions computed from the “step-up shocks” exposes non-linearities of the shock response which enables better full-level shaker shocks.
SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525

SHOCKFUGE: GENERATING HIGH-AMPLITUDE PULSE SHOCKS USING A CENTRIFUGE-BASED MECHANISM

David Siler, Sandia National Laboratories
Forrest Arnold, Sandia National Laboratories
Eli Lynn, Sandia National Laboratories

This work investigates the application of high-amplitude pulse shocks on inertial switch payloads by utilizing a centrifuge-based testing mechanism, the “shockfuge.” Like vertical freefall impact systems, shockfuge uses a sliding carriage and a seismic mass but leverages the hypergravity centrifuge environment to accelerate a free-sliding carriage to high velocities. Mechanical shocks are imparted to inertially-sensitive payloads by securing them to the carriage, releasing at a predetermined acceleration, and rapidly halting their motion with the seismic mass. The system's design, experimental validation, and detailed analysis for high-impact shock testing are presented. The findings validate the shockfuge's potential for evaluating inertial switches under highly dynamic conditions and explore novel methods for optimizing mechanical shock testing using centrifuge-based systems.

SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

QUANTITATIVE ANALYSIS OF PULSE SHAPE MODELING FOR MECHANICAL SHOCK TESTS

Abigail Smith, Sandia National Laboratories
Zachary Boeringa, Sandia National Laboratories
Adam Krzywosz, Sandia National Laboratories
Dr. Nancy Winfree, Sandia National Laboratories
Tyler Alvis, Sandia National Laboratories
Adam Slavin, Sandia National Laboratories
David Soine, Sandia National Laboratories

Wool felt is an important programming material to provide a Haversine acceleration pulse in impact mechanical shock testing. During recent tests, difficulty was encountered in achieving the desired pulse shape and final velocity of the test article. It became apparent that better understanding the felt's response during the impact event may aid in reaching the targets. Felt has a non-linear stress-strain response in compression, stiffening significantly at the stresses imposed on it during these tests. This type of response can support compressive shock waves, which were thought to be observed during tests. In this investigation, a parametric solid mechanics model was created to investigate the response of the felt and compare to mechanical shock tests. Using this model, various choices and arrangements of felt were investigated to mitigate the shock waves and thereby decrease kinetic energy losses. Simulation results were compared to test data and high-speed video. Finally, graded-density programming stacks were analyzed for production of a more Haversine-like acceleration pulse to assess the feasibility of lower energy loss and a higher test article velocity.

Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. SAND2024-08413A

A PRACTICAL APPROACH TO DEFINING SHOCK RESPONSE SPECTRUM (SRS) TEST SPECIFICATIONS

Jade Vande Kamp, Vibration Research

Vibration test engineers use the shock response spectrum (SRS) to run complex shock events on a vibration shaker. SRS test profiles can replicate complex shock events from the real world more accurately than generating time-domain pulses to represent multiple shock events. This presentation will discuss the process of developing SRS test specifications, including common problems and suggested practices. Properly defined specifications help ensure that the test laboratory replicates the spectrum as intended. If the client, test development team, or laboratory does not thoroughly define its SRS test specifications, synthesizing a waveform to meet the required response spectrum (RRS) is up to the subjective decisions of the engineer. While some room for interpretation can be acceptable, there are characteristics that, if

undefined, can result in widely different SRS test profiles. Laboratories should define SRS test specifications with some tolerances, such as pulse duration, desired Te/TE, peak amplitude, and peak velocity. Doing so reduces the possible solutions to meet a desired SRS, resulting in a test profile that more closely reflects the field data used to generate the RRS.

This presentation will review a practical approach to SRS analysis, specification development, profile creation, and overall validation. It will discuss the limiting characteristics of SRS development through a series of case studies. Finally, it will present an SRS test profile development approach using field data.

SYNTHESIZING A REALISTIC TRANSIENT ACCELERATION SHOCK SIGNAL TO REPRESENT AND BOUND DIVERSE OSCILLATORY SHOCK TIME-HISTORIES

Dr. Ted Diehl, Bodie Technology Inc.
Kris Altiero, Bechtel Plant Machinery, Inc.

Development of bounding profiles for shaker shock testing and shock simulation of naval, aerospace, and other equipment requires processing and managing extensive repositories of transient acceleration data from diverse shock tests. Signals reflecting the accelerations experienced at the mounting points of tested components or sub-components are characterized by their high transience, oscillations, and frequency richness; these bear little resemblance to idealized shock pulses like half-sine or haversine pulses.

To facilitate cost-effective and risk-appropriate mechanical shock testing of naval shipboard equipment and components, it becomes imperative to synthesize a single or a limited number of oscillatory transient acceleration time-history signals that encapsulate a statistically representative range from the vast array of raw measured signals from testing or field data. Such a synthesized signal, if credibly representative, could serve as the input signal for conducting transient shaker-shock component and sub-component testing.

This paper delineates and demonstrates the requisite steps, along with their corresponding algorithms, necessary to develop a credible representative transient oscillatory shock signal from a repository of raw data files. The effort is structured into three primary tasks: raw data processing, computing a statistically-based Pseudo Velocity Shock Spectrum (PVSS) envelope, and synthesizing a credible transient signal that closely matches the PVSS envelope within a reasonable tolerance band.

The initial task encompasses several steps, starting with the organization of raw data (originally provided from various sources in multiple formats) into a standard and compact database structure. Subsequently, each raw acceleration signal undergoes integration to velocity and displacement, a process often yielding non-physical and implausible results due to inherent distortions/errors in the measured data. To salvage the signals, a specialized combination of highpass and lowpass filters is applied to the velocity, followed by a re-computation of acceleration and displacement, after which PVSS and other characterizations are performed, with all results systematically stored in a searchable database.

The second primary task starts with down selection to a subset of database records meeting logical groupings such as desired response direction and/or testing type. From the individual PVSS curves within this subset, a statistically-based PVSS envelope is computed, serving as the target for the synthesis task.
The synthesis task comprises multiple steps, starting with identifying the shock spectra of the underlying data that best match the shape of the target PVSS. Selection of the best-match transients is conducted across a few user-defined frequency bands guided by the nature of the PVSS curves, i.e. local variations.

Each selected trace is then bandpass filtered to retain only its frequency content from its associated user-defined frequency band.

The process then combines these bandpass-filtered time-history signals, incorporating automatically computed rescaling factors, to derive an initial version of a synthesized transient signal. Further adjustments to the synthesized signal may be made as required, utilizing additional bandpass filtering and rescaling operations on other user-specified frequency bands, and/or by including shaker-wavelet components as locally needed.

The case studies presented demonstrate a robust and efficient approach yielding synthesized transient signals so realistic that they are visually indistinguishable from actual measured signals.

SESSION 14: AERIAL DELIVERY METHODOLOGIES, TECHNIQUES, AND SOLUTIONS

REUSABLE UNIVERSAL SKID BOARD FOR AIRDROP PLATFORMS

Dr. Daryoush Allaei, QRDC, Inc.

The Reusable Universal Skid Board (RUSB) is designed, manufactured, and flight tested for application in military airdrop training. The Container Delivery System (CDS) commonly utilizes gravity drops. CDS's deliver equipment too heavy for a single paratrooper to carry as well as bundles of supplies for units on the ground. Since the Korean and Vietnam Wars, CDS has been developed to handle darkness and bad weather, giving aircraft an advantage in supplying troops without revealing their location. Such efficiency has made the CDS bundles the most common form of aerial supply for soldiers and civilian's aid. Eighty-five (85) to ninety percent (90%) of US military airdrops are for training riggers and pilots. One of the most dropped platforms is CDS bundles weighing in the range of 550 to 2,200 lbs. RUSB is initially designed for airdrop training for CDS airdrop bundles. However, it can be applied to other airdrop platforms, such as CEPs, LCLAs, & Door Bundles.

RUSB replaces the currently used plywood skid that can be dropped only 1 to 2 times before it is rendered unworthy to be dropped. It is anticipated that RUSB can be dropped thirty-five (35) times. The deployment of RUSB will improve AF readiness by increasing or maintaining the number of training airdrop flights for aircrews. The RUSB will combat this USAF-wide issue by enhancing the reusability of airdrop training items. The RUSB solution will result in significant financial savings for the Air Force and pay for itself in less than 12 months. RUSB was successfully tested in the field at Little Rock Air Force Base in AR in the week of March 4, 2024. RUSB has received UAT (Unilateral Authorization for Training) so it can be purchased and utilized by US Air Force bases.

REUSABLE ENERGY ABSORBING LAYER

Dr. Daryoush Allaei, QRDC, Inc.

The Reusable Energy Absorbing Layer (REAL) is designed, manufactured, and flight tested for application in military airdrop training and application to the Container Delivery System (CDS) commonly utilizes gravity drops. CDS's deliver equipment too heavy for a single paratrooper to carry as well as bundles of supplies for units on the ground. Since the Korean and Vietnam Wars, CDS has been developed to handle darkness and bad weather, giving aircraft an advantage in supplying troops without revealing their location. Such efficiency has made the CDS bundles the most common form of aerial supply for soldiers and civilian's aid. Eighty-five (85) to ninety percent (90%) of US military airdrops are for training riggers and pilots. One of the most dropped platforms is CDS bundles weighing in the range of 550 to 2,200 lbs. REAL is initially designed for airdrop training for CDS airdrop bundles. However, it can be applied to other airdrop platforms, such as CEPs, LCLAs, & Door Bundles.

REAL replaces the currently used expendable (cardboard honeycomb) products that can be dropped only once before they are rendered unworthy for airdrop. The deployment of REAL will improve AF readiness by increasing or maintaining the number of training airdrop flights for aircrews. Expendable (cardboard honeycomb) products are increasingly difficult to maintain due to supply chain issues. REAL will combat this USAF-wide issue by enhancing the reusability of airdrop training items.

The current cardboard honeycomb survives only 1 airdrop. REAL will survive at least at least 35 airdrops. However, an older version of REAL has been dropped 104 times without any sign of performance degradation. Because REAL survive 35 to 104 airdrops, our solutions will result in significant financial savings for the Air Force and pay for itself in less than one year.

REAL has been successfully flight tested that resulted in issuance of UAT (Unilateral Airdrop Training) that allows Air Force bases to purchase and utilize REAL in their training exercises. REAL is a US-made product.

RESULTS OF STATICALLY LOADING REAL-M12

Pete Wolf, Robinson Rubber Products Company
Dr. Daryoush Allaei, QRDC, Inc.

In this work, we have subjected REAL-M12 (Reusable Energy Absorbing Layer module 12”) to 195 lbs static load for 14 days. This is equivalent to 1755 lbs of load on an airdrop platform. The purpose is to answer these questions: (1) how much does REAL-M12 deflect, and (2) does it rebound to its original height of 3”? Our team conducted this static load test over 15 days. The starting day was day zero (no load), and the test ended on day 15 when the load was removed. As a way of background, our team has designed, manufactured, and successfully flight-evaluated REAL (Reusable Energy Absorbing Layer) for application in military airdrop training and application to the Container Delivery System (CDS), which commonly utilizes gravity drops. The CDS bundles are employed most in aerial supply for soldiers and civilian aid. One of the most dropped platforms is CDS bundles weighing in the range of 550 to 2,200 lbs. We Initially designed REAL for airdrop training for CDS airdrop bundles. However, REAL applies to other airdrop platforms, such as CEPs, LCLAs, & Door Bundles. The 15-day test showed that REAL's nominal height was not changed meaningfully, and it bounced back to its original height once the load was removed.

FIELD TESTING OF REAL AND RUSB IN CDS BUNDLES

Kenneth Womack, Little Rock AFB
John Bamburg, Little Rock AFB
Kevin Williams, Little Rock AFB
Dr. Daryoush Allaei, QRDC Inc

REAL (Reusable Energy Absorbing Layer) and RUSB (Reusable Universal Skid Board) have been field tested at Little Rock Air Force Base in AR. A CDS (Container Delivery Systems) bundle was rigged using 9 REAL-12M (12 by 12 by 3”) and 6 REAL-6M (6 by 6 by 3”). Four barrels of water, totaling 650 lbs, were used as the payload. The water barrels were contained in an A-22 Sling and dropped with a 26 foot High Velocity Parachute. The plywood skid was replaced with RUSB. The CDS bundle was loaded on C130 and dropped from 1,500 ft and descended at a rate of 41 to 76 fps. The CDS bundle has been dropped 9 times with no sign of degradation on REAL or RUSB. Based on these successful tests, cardboard honeycomb and plywood skid can be replaced with REAL and RUSB, respectively. The use of REAL and RUSB is anticipated to save cost, improve readiness, and offer a non-expendable alternative for Aerial Delivery production.

LCE-Integrated Release Block – An effective replacement mechanism for the timing release block used by the aerial delivery community

Dr. James Rall, Impressio
Dr. Amir Torbati, Impressio
Tristan Collette, Impressio

The U.S. Air Force, and DOD, utilize timing release blocks for aerial delivery of equipment during combat and training operations. Current timing release blocks have a high number of malfunctions each year. In 2022, timing release block malfunctions resulted in 18 complete losses of airdrops resulting in the replacement of $650,000 worth of Type V platforms. Additionally, in combat operations a loss of a payload may result in aborting a mission or risking mission success.

For over 10 years, the Air Mobility Command has intended on replacing the timing release block with a device with a low malfunction rate. However, no permanent solution currently exists for replacing the timing release block. Over the 20 year period of using timing release blocks, it is estimated that the Air Force has spent over $13M on replacing Type V platforms instead of fixing the timing release blocks. Based on conversations with the former Aerial Delivery Manager at HQ Air Mobility Command, the U.S. Air Force is still looking for an approved permanent solution to the timing release block's malfunctions.

Liquid Crystal Elastomers (LCEs) exhibit unique properties (high energy dissipation and strain rate dependence), making them an ideal mechanism to replace the current timing release block. The award winning LCE technology was first successfully applied to sports helmets during the NFL HeadHealthTech Challenge. LCEs display a non-linear rate dependent property which allows for passively adapting to the different load conditions during an air delivery. A cargo undergoes four distinct loading conditions during air delivery: (1) snatch, (2) opening, (3) descent, and (4) landing. LCEs behave differently within each of these regions and can be used to trigger the current block release for the parachutes upon landing. By replacing the current hand-tightened timing coil with LCE, the risk of failure due to overtightening the coil is eliminated.

SESSION 15: SHIP SHOCK

Residual Strength of Damaged Ship Structures

Dr. Nicholas Reynolds, NSWC Carderock

The hull-girder strength of surface ships degrades with the onset of damage, affecting their continued functioning. This talk highlights recent work to quantify residual hull-girder strength in support of survivability assessments. Specifically, a new method for automatically mapping the damage observed in the results of full-ship finite-element models to corresponding ULTSTR models is presented.

Development of a Hull Girder Whipping Model from 3D LiDAR Data

David Umansky, NSWC Carderock
Dr. Ken Nahshon, NSWC Carderock
M. Rodriguez, NSWC Carderock
J. Clark, NSWC Carderock
M. Kipp, NSWC Carderock
James Krafcik, Air Force Research Laboratory
Samuel Schemmer, Air Force Research Laboratory
Derek Bruneis, IS4S

M/V MONARCH Countess will be used for upcoming trials of QUICKSINK, an AFRL-led Underwater Explosions (UNDEX) weapon development program. The HULLWHIP beam whipping code was used to perform weaponeering and pre-test analysis. Due to a lack of drawings and limited available data, the process of model development was based primarily on the use of Light Detection & Ranging (LiDAR) scans. This talk will discuss the process of model development, which included ship inspection, development of ballasting and mass distributions, calculation of ultimate strength properties, and finally analysis execution within the HULLWHIP code.

Data Collection During Fleet SINKEX Events— Recent Advancements

Dr. Ken Nahshon, NSWC Carderock

The US Navy regularly conducts Sinking Exercises (SINKEX) in which decommissioned ship targets are subjected to air and underwater delivered weapons. SINKEX's provide a regularly occurring and cost leveraged manner to conduct weapons effects data collection. However, doing so requires addressing unique technical and operational challenges due to the rapid sequence of events and long standoff ranges. This talk will provide a description of recent advancements in this realm, specifically regarding telemetry, 3D reconstruction, and high-speed photography.

Using Drift Compensation to Correct Late-time Velocity Meter Data with UERDTools

Tom Thomas, NSWC Carderock

This brief will provide a methodology for improving the accuracy of late-time structural response test data by removing numerical drift that accumulates as data is being recorded. Using various algorithms and techniques provided in UERDTools, drift compensation was performed on underwater explosion (UNDEX) test data recorded with velocity meters that showed signs of numerical drift. The approach and limitations of each algorithm will be explained, and the settings specific to each algorithm will be presented. An example problem will be shown in order to illustrate how the results vary depending on the algorithm and settings chosen. Comparisons between test data and modeling and simulation (M&S) results will also be shown that demonstrate how using drift correction incorrectly, or not at all, can lead to an inaccurate assessment in the ability of M&S tools to predict late-time structural response to UNDEX.

Navy Standard Bookend Fixtures for Shock Testing

Mike Parnin, Leidos
Michael Poslusny, Leidos

Shock testing of shipboard equipment is conducted in accordance with MIL-DTL-901E, "Detail Specification, Shock Tests, H.I. (High Impact) Shipboard Machinery, Equipment, and Systems, Requirements For," dated 20 June 2017. Within this specification, Section 3.1.7.1 states, "Components supported by piping or other flexible connections where simulation of the flexibility is not considered conservative shall be tested by mounting between rigid support structure such as block hangers or bookends."

When shock testing common equipment like valves, eductors, and other in-line pipe components, bookend test fixtures are typically designed and fabricated by a certified shock test facility. The bookend fixture designs are considered, "non-standard" and require submission of associated drawings, models, and analyses to the Delegated Approval Authority for review and approval prior to execution of testing. This is a costly process which adds labor and delays which could be avoided if there was an option to utilize a standardize, pre-qualified bookend fixture.

Gibbs & Cox (Leidos) and Ingalls shipbuilding are conducting the NSRP project with a projected final report in Q1 of 2025. The goal of this project is to create up to four, qualified Navy Standard Bookend Shock Test Fixtures for a range of component weights and sizes to be used on Lightweight and Medium-weight Shock Test Machines. The objective is to reduce cost and schedule associated with test fixture development for in-line pipe components; for all shock hardened, US Navy ships. This presentation will include the bookend fixture designs and preliminary shock test results.

SESSION 16: BLAST & FRAGMENTATION

FABEL V2.0 Features and Application to Multi-hit Terminal Performance Calculations

Christopher Shackelford, USACE ERDC
William Furr, USACE ERDC
Dr. T. Neil Williams, USACE ERDC
Dr. John Q. Ehrgott, Jr., USACE ERDC

A primary initiative of the U.S. Army Engineer Research and Development Center's Terminal Weapons Effects (TWE) program is to support and enhance the capabilities of the warfighter through the development and improvement of fast running weapons effects codes and tools to accurately predict the weapon's terminal performance and lethality against structures and other critical targets. Part of this initiative is the development of a methodology to predict cumulative damage effects from combined blast-fragment loading on structural targets subjected to multiple shots of a munition. This methodology is based on munition fragmentation data obtained through arena tests and high-fidelity simulations. Using data obtained from ERDC arena tests, the ERDC developed Fragmentation and Blast Effects Library (FABEL) creates a fragment environment superimposed on targets of interest, executes Sierra/Solid Mechanics calculations to obtain a structural response of a target of interest, and post-processes the results into user-friendly summary files and images. The work presented here provides an overview of new features available within FABEL and how they are used to predict terminal performance against steel targets subjected to multiple detonations of a single munition from a recent ERDC Simplified Cylindrical Surrogate (SCS) munition test series.

Modeling the Ballistic Behavior of Simulated Fragments Against Steel Targets

David Lichlyter, USACE ERDC
Dr. T. Neil Williams, USACE ERDC
Christopher Shackelford, USACE ERDC

As part of the ERDC's Terminal Weapons Effects (TWE) program, research is currently underway to evaluate and improve high-fidelity modeling and simulation capabilities for materials and structural response to predict weapons effects against structures and critical assets. As part of this effort, the TWE program has conducted an experimental series of a fragmenting surrogate munition's effect on steel targets. The Elastic Plastic Impact Computations (EPIC) code has been previously validated for penetration/perforation into steel targets. This effort focuses on using EPIC to generate the ballistic limit curves for simplified, representative fragments, and compare the results with the existing formulas in the literature.

Characterization of Simplified Surrogate Munition

Marcus Barksdale, USACE ERDC

The ability to rapidly evaluate the impact of innovative munitions on targets is essential for advancing munition design in modern warfare. Continued development of advanced weapon systems and high-performance target materials creates capability gaps in the current weapons effects analysis tools. These gaps necessitate the evolutionary development of enhanced modeling and simulation capabilities. By improving these models, the effectiveness and lethality of new munitions and their effects against advanced high-performance target materials can be assessed. However, these advanced tools can not be fully developed without validation from physical experiments. Thus, the U.S. Army Engineer Research and Development Center (ERDC) has conducted multiple full-scale blast and fragmentation experiments. The initial experimental series consisted of two arena experiments designed to characterize the fragment distribution and velocities of a simplified surrogate munition. Subsequently, the ERDC conducted another series of arena experiments to examine the cumulative damage effects of surrogate munitions against steel and concrete targets. In recent months, the ERDC has performed a sequel to the previous experiments by conducting eight additional target arena experiments. The purpose of these experiments was to introduce new targets of interest to gain additional insight into the lethality of the simplified surrogate munition against steel, concrete, steel-plated concrete, and stiffened steel targets. These experimental efforts will provide the ERDC's numerical modeling and tool developers with additional data to fill gaps from the previous experimental series. The data from these experiments consisted of blast overpressures, blast side-on pressures, peak midspan deflection of targets, maximum residual midspan deflection of targets, target perforation areas, fragment velocities, and concrete spall measurements. This presentation provides an overview of the latest test series, compares results to previous experimental series, and highlights the importance of high-fidelity experimental data in the development of new tools critical to the U.S. Army's mission.

DIGITAL TWIN MACHINE LEARNING FOR IRREGULAR FRAGMENT FIELD CHARACTERIZATION

Dr. Eddie O'Hare, Protection Engineering Consultants
Matt Barsotti, Protection Engineering Consultants
David Chambers, Southwest Research Institute
Abe Garza, Southwest Research Institute
Michael Tarbell, Midland Research
Eric Scarborough, Air Force Research Laboratory
Kirk Vanden, Air Force Research Laboratory

The traditional approach to fragment field characterization will not work for irregular fragment fields. The standard approach of measuring fragments in one azimuth zone is no longer sufficient, and measuring fragments in all zones within an irregular fragment field is not feasible. A new paradigm for testing and modeling is required for characterization of irregular fragment fields.

Digital twin data from finite element models is the cornerstone of a new paradigm for ir-regular fragment field characterization. Digital twin simulations can provide data for the entire fragment field, but they can only estimate this information. Physical tests can provide real fragment data, but they can only be collected over patches of the fragment field. The ability to synthesize digital twin debris data with collected debris data is a transformative outcome of this Phase II effort. The key result of this effort will be a next-generation debris model for accurate predictions of irregular fragment fields.

Protection Engineering Consultants (PEC) has teamed with Southwest Research Institute (SwRI) and Midland Research (MR) to develop an accurate and effective technique for characterizing irregular fragment fields. We are accomplishing this objective by developing a machine-learning (ML) debris model to synthesize collected and digital twin data. The ML framework consists of two primary modules: 1) a Generative Adversarial Network to synthesize digital twin and collected data, and 2) a Bayesian Neural Network to estimate the uncertainty of the fragment field.

Collected and digital twin data are being synthesized by applying a deep learning method referred to as Generative Adversarial Networks (GANs) . GANs are commonly used for synthetic image generation. A GAN can learn to produce unique facial pictures that mimic real human faces, without replicating or copying the original images used to train the GAN. This adversarial image generation technique is being applied to predict complete irregular fragment fields from collected data containing gaps.

There are a variety of advanced deep learning architectures designed to fill data gaps. Currently, two varients are being investigated, particularly Semantic In-Paiting GANs and Partial Convolution Networks. Digital twin data is being used used to train these Gap-Filling Models by masking various regions of the datasets. Once the models learn to fill gaps based on limited data, they can be applied to real-world collected data, which will be similar to masked data with nu-merous gaps.

The second module in the proposed ML framework is currently being implemented and will quantify uncertainty by wrapping the Gap-Filling GAN with a Bayesian Neural Network (BNN). This new capability will assist in determining the most beneficial number digital twin datasets and locations for physical data collection. Ultimately, BNNs will provide an accurate method to calculate a debris model that best describes irregular fragment fields, while accounting for uncertainties in the model and data.

MODELING A FRAGMENTING MUNITION'S CLOSE-IN BLAST ENVIRONMENT
Dr. T. Neil Williams, USACE ERDC

This presentation provides an update on the high fidelity simulation method the ERDC Terminal Weapons Effects (TWE) program is investigating to create synthetic blast and fragmentation data. This presentation will show predicted fragmentation results determined using Zapotec, which couples CTH with Sierra/SM, the resulting interaction between the fragments and more complex structures, and compare the simulations with recent ERDC test results.

TRAINING IV

INTRODUCTION TO MULTI SHAKER TESTING
Raman Sridharan, NVT Group

This training course will cover the basics of multi shaker (MIMO) testing. The training will begin with a focus on a two shaker setup and expand to cover full 6 Degree of Freedom (DOF) testing. The training will utilize a dual shaker table to reinforce concepts and offer attendees insight into the challenges of multi-shaker control.

The course will include:

- Vibration Fundamentals
- Digital representation of a vibrating system
- Degrees of Freedom and the effect of modes
- Multi-Shaker Control
- Common Multi-Shaker Configurations
- Impedance Matched Multi Axis Testing (IMMAT)

TRAINING V

INTRODUCTION TO NONLINEAR ANALYSIS
Bart McPheeters, Gibbs & Cox

This class will introduce a new FEA user (or at least one new to nonlinear analysis) to the concepts of FE nonlinearity and their implementation in a typical FEA program. It is not a 'how-to' so much as a simple introduction to the concepts. It will discuss the different types of nonlinearity and how they are implemented in an FEA program. It will discuss some of the issues that come up in trying to run a nonlinear analysis and some broad strategies for getting a run to complete. We will wrap up with a discussion of some of the different types of FEA programs

OPTIMIZATION OF STRUCTURES UNDER SHOCK LOADING AS PER MIL-DTL-901E (WORKING DEMONSTRATION)
Kory Soukup, Altair Engineering
Giri Prasanna, Altair Engineering
Jason Krist, Altair Engineering

This training is designed to equip participants with the skills to develop digital shock test models in accordance with the MIL-DTL-901E standard, using Altair Simulation tools. As traditional shock testing methods are costly and pose safety risks, our training offers a comprehensive approach to creating accurate and efficient digital models that replicate high-impact shock conditions.

Participants will learn the step-by-step process of constructing a digital shock test model, including:

- Model Construction: Techniques for building a detailed digital model that mirrors the physical conditions specified by MIL-DTL-901E.
- Structural Analysis with Optistruct: Applying Optistruct to evaluate structural integrity and behavior under shock loads.
- Dynamic Impact Simulation with Radioss: Using Radioss for simulating and analyzing dynamic impacts to predict real-world performance.
- Finite Element Modeling with Hypermesh: Creating and refining finite element models for precise simulation results.
- Performance Optimization with AI Studio: Leveraging AI Studio to optimize model performance and enhance design efficiency.

The class will also cover best practices for integrating these tools to ensure accurate and reliable results. By the end of the session, participants will be proficient in developing digital shock test models that reduce the need for extensive physical testing, offering significant cost and safety benefits.

This training is ideal for engineers and designers involved in equipment testing and design optimization, providing practical knowledge to enhance compliance with MIL-DTL-901E and streamline the shock testing process.

SESSION 17: MAST MOUNTED EQUIPMENT TEST METHODS

TESTING MAST-MOUNTED EQUIPMENT USING SHAKERS AND A RESONANT FIXTURE

Garrett Wiles, NSWC Dahlgren
Daniel Moore, NSWC Dahlgren

Like all shipboard support materiel, mast-mounted equipment must be shock tested and qualified. However, due to the severity of the shock response environment of the mast, alternative test methods to those defined in Military Detail (MIL-DTL) 901E must be exercised. This presentation covers multiple approaches to testing mast environments with high damage potential by leveraging hydraulic shakers and a resonant fixture. Improved test design methods detailing wave synthesis techniques, dynamic modeling and simulation, and test execution are discussed.

ADAPTING SPRING MASS OSCILLATION TO PNEUMATIC SPRING SYSTEMS IN SHOCK TESTING

Edward Pemberton, HI-TEST Laboratories

In systems where the spring mass is a significant fraction of the hanging mass, simple harmonic motion equations break down. We adapt these modified equations to a pneumatic spring system shock testing vehicle, the Large Displacement Shock Simulator, developing predictive formulae for peak acceleration, peak velocity, and frequency, in order to improve testing setup and reduce calibration requirements.

SESSION 17: VIBRATION: INSTRUMENTATION & DATA ANALYSIS

INNOVATIVE CLIPPING METHOD REDUCES PEAKS ON THE VIBRATION SHAKER TABLE

Thomas Woltjer, Vibration Research

Random vibration testing on expensive or volatile equipment poses the challenge of running sufficient levels without exceeding system limits. Engineers aim to generate a test profile that meets the required response without over-testing at specific frequencies. Aerospace and defense engineers, in particular, must be mindful of exceeding limits due to their test item's detail, cost, and weight.
To avoid tripping system limits, engineers turn to methods of signal manipulation with varying success. Clipping is a signal manipulation methodology whose function in the vibration test industry has often been misunderstood. Standard clipping limits the drive signal's voltage peaks, but many incorrectly believe it limits peak amplitudes on the shaker table. Engineers that apply standard clipping to protect their shaker system or test items may unknowingly put them at risk of damage.

This presentation introduces TruClip™, a new method of signal clipping that utilizes closed-loop vibration control to reduce high-sigma peaks on the shaker table. TruClip predicts the drive signal and removes peaks that exceed the shaker's acceleration, velocity, or displacement limits. Engineers can minimize peak amplitudes to protect a sensitive DUT or run a test near the shaker's maximum acceleration, velocity, or displacement without tripping system limits. The presentation includes an introduction to the software and applications in aerospace and defense testing.

SESSION 18: DATA ACQUISITION INTEGRATED WITH SPACE TECHNOLOGY

LOCATING ACOUSTIC SOURCES USING TIMESTAMPED SIGNALS

Simran Parmar, Crystal Instruments
Dr. James Zhuge, Crystal Instruments

The location of a sound source can be estimated using samples of acoustic data captured on microphones that are separated by some distance, and several techniques for doing so have been developed. These technologies mainly discuss using a microphone array with a centralized data acquisition system (DAQ) or using spatially distributed microphones and time-domain based processing algorithms. These methods either have limited range or poor accuracy. The technology described in this paper addresses and resolves the limitations of earlier approaches.

DAQs can be used to record acoustic signals and then pair-wise delay estimations, derived from the recordings, can be computed to estimate the location of the acoustic source. The correlation function is an ideal tool for this estimation. Although the correlation function relating two signals is normally calculated in the time-domain, there is an advantage to instead compute the cross-spectrum function in the frequency domain and to then perform an inverse Fourier transform to generate the correlation function; Signal processing techniques can be applied to the pre-processed recordings to reduce noise and other contaminations prior to calculating the correlation function.

Acoustic measurements are acquired using microphones that convert sound pressure to an analog voltage, which is then converted to a digital format using analog-to-digital converters (ADCs). The cross-spectrum calculation requires that all signals in the computation be digitized simultaneously. This presents a problem since multiple disconnected DAQs are driven by ADCs that may differ in their clock rates. The

Grounder Recorder System (GRS) is a DAQ equipped with a GPS module and can derive its location and reference time base using satellites. This makes it possible to apply time stamps to acoustic data with an accuracy higher than 100ns. The initially asynchronous recordings can then be used to generate a reliable correlation function, and an edge or peak detection algorithm can be employed to locate the acoustic source.

This paper shows the algorithm of locating sound source outdoors, such as a gunfire, based on cross-correlation signal processing techniques. A real test in a gun range is presented and the results are satisfactory.

FULLY AUTONOMOUS DATA ACQUISITION SYSTEMS INTEGRATED WITH AVIATION AND SPACE TECHNOLOGY

Sandeep Mallela, Crystal Instruments
Dr. James Zhuge, Crystal Instruments

Data Acquisition Systems have undergone remarkable advancements in recent decades. Crystal Instruments has pioneered the latest generation of the Data Acquisition Systems (DAQ) that are fully autonomous and are integrated with the aviation and space technologies, which greatly enhance the measurement of noise, shock and vibrations. A prime example is the Ground Recorder System (GRS), developed in collaboration with NASA. This innovative system leverages advanced avionic communication technologies, GPS technology and Satellite communications to create a fully automated, remotely deployable DAQ.

Continuously monitoring and analyzing the analog inputs, digital inputs and signals from the peripheral modules enables fully customizable automated functionality and recording. A dedicated circular buffer continuously stores up to 300 seconds of current data enabling the capture of sufficient pre-trigger data automatically. GRS also features the ability to analyze and record data from dual ADCs on each channel simultaneously. This facilitates recording of small amplitude signals with great precision while also having the ability to capture signals of large magnitudes.

Integration of ADS-B (Automatic Dependent Surveillance–Broadcast) enables automated monitoring of the aircraft's location, speed and direction of travel that enables precise monitoring of the vibrations and sound generated from an aircraft. This technology will be used by NASA to precisely measure the sonic boom generated by aircraft travelling at supersonic speeds automatically. The integrated GPS technology gives extremely precise location and timing to the DAQ.

In addition, the integration of cellular and satellite communications modules ensures that the DAQ communicates remotely from anywhere on the planet including the ability to remotely view and download the data. This paper presents all the integrated aviation and space technologies with automation techniques that have been integrated into the GRS and their remarkable advantages over the current DAQ technologies.

ADVANCING BUILDING VIBRATION STUDIES WITH DISTRIBUTED HANDHELD SYSTEMS AND PATENTED GPS TIMESTAMP TECHNOLOGY

Aakash Umesh Mange, Crystal Instruments
Dr. Jeff Zhao, Crystal Instruments
Dr. James Zhuge, Crystal Instruments
Dr. Zhaoshuo Jiang, San Francisco State University
Matt Chen, Crystal Instruments

Non-destructive techniques, such as operational modal analysis, are commonly used to study building vibrations. These methods can detect changes in a building's stiffness properties caused by deterioration, defects, or cracks, which in turn alter the building's modal parameters. When performing experimental modal tests on large buildings, challenges often arise due to the fixed location of data acquisition systems and the need for extensive cabling to place sensors throughout the structure. This setup can be cumbersome, especially when measuring responses to ambient excitations like wind or foot traffic.

Distributed data acquisition systems offer a practical solution by simplifying the measurement process across large civil structures. These systems, combined with advanced GPS timestamp technology, enable precise synchronization of data collected from multiple data acquisition units that are not physically wired together. This paper presents findings from an experimental investigation using this approach to capture the frequency signature of a building in response to ambient excitations. The goal is to analyze the building's dynamic properties and leverage the results for effective structural health monitoring.

ACQUIRE THE DYNAMIC DATA ACROSS THE GLOBE

James Zhuge, Crystal Instruments

In year 2021, Crystal Instruments is awarded with a multi-million dollar contract by NASA to develop GRS (Ground Recording System) an advanced data acquisition system that fully integrates with space technology including GPS, ADS-B, 4G LTE cellular modem and satellite communications. The GRS will be used to measure the sound boom of X-59, the next generation of supersonic aircraft. The project at NASA is still in progress. So far all the tests are successful.

Over the course of development, several advances are made. One of them is that the GRS is able to time-stamp the sampling data to 50ns accuracy at the hardware level using the time base derived from the GPS. At the software level a new algorithm is developed to adjust the phase of cross spectrum between any pair of data are acquired while the measurement devices are not physically wired-connected. This method lets us calculate the FRF (Frequency Response Function) between signals acquired across very long distances, miles or thousands of miles.

Crystal Instruments alone is willing to submit several papers to address several aspects of this major development. We propose that a dedicated session is to be held to discuss this exciting topic. We will also solicit papers from other potential presenters.

NASA QUESST – MEASURING QUIET SONIC BOOMS

Larry J. Cliatt, II, NASA Armstrong Flight Research Center
Samuel Kantor, NASA Armstrong Flight Research Center
Sky Yarbrough, NASA Armstrong Flight Research Center
Edward A. Haering, Jr., NASA Armstrong Flight Research Center

As part of the Quesst mission, the National Aeronautics and Space Administration (NASA) will design and build a research aircraft called the X-59. The X-59 is designed to achieve supersonic cruise flight (at Mach ≥ 1.4) while creating a quiet sonic boom signature with a predicted loudness level of 75 PLdB (perceived level, in decibels) or less.

To prepare for the extensive ground measurements needed to verify the quiet sonic boom from the X-59, NASA is developing a state-of-the-art Ground Recording System (GRS). The sonic boom footprint of the X-59 will be up to approximately 50 nmi wide on the ground. The GRS has been designed with unique capabilities specifically for the data acquisition of quiet sonic booms over large areas. The GRS must have the acoustic resolution and dynamic range to produce detailed sound level metrics, all while being deployed in remote regions for extended periods of time. The GRS also includes the ability to operate autonomously, triggering just before the GRS estimates the sonic boom is expected to arrive. The GRS may be used without human involvement for several days.

As the GRS is developed, NASA has performed exhaustive verification and validation testing. NASA has also conducted a series of flight campaigns to evaluate the GRS in situ with sonic booms in real atmospheres.

SESSION 19: IMPLOSION

PHORCYS – END-TO-END SOLUTION FOR ASSESSING IMPLOSION RISK ASSESSMENT

Adam Hapij, Thornton Tomasetti
Dr. Abilash Nair, Thornton Tomasetti
Benjamin J. Medina, NSWC Carderock
Dr. Joseph M. Ambrico, NUWC Newport

The effects on a submerged asset due to the implosion of external volumes are commonly assessed with high-fidelity computational mechanics analyses and/or large-scale physical testing. Even with the recent advances in computational performance of fluid and structural dynamics simulation technology, the large demand of computational resources to accurately simulate the highly coupled and non-linear fluid response due to implosion makes virtual assessments time consuming. In recent years, due to its lower latency and generally higher throughput, data driven technologies have become an attractive choice to quickly predict implosion-induced response of submerged structures.

The Phorcys solution builds on several software, data, and AI/ML solutions, providing a robust assessment methodology for different types of implosion phenomena. This work provides an overview of how external volume arrangements can be assessed. The case-study will demonstrate the usage of the Phorcys solution, as well as the value that this framework offers over high-fidelity analyses.

IMPLOSION DATABASE UTILITY – INNOVATIVE ML PIPELINES FOR IMPLOSION ASSESSMENT

Christopher Craig, Thornton Tomasetti
Dr. Abilash Nair, Thornton Tomasetti
Benjamin J. Medina, NSWC Carderock
Dr. Joseph M. Ambrico, NUWC Newport

The implosion database utility (IDU) was proposed as an infrastructure to both house implosion data from multiple sources (including simulation and experimental) and generate neural network based machine learning (ML) models that can predict implosion time-histories from untested implodable volumes. In this update to the utility, we create more pipelines originating from the database to continually improve predictions by aggregating existing data with new synthetic data from calculations. This talk will present the IDU pipeline to automate a workflow that determines prediction holes (where data may be insufficient), deploys new calculations to better sample the parameter space, post-processes data from new calculations, and creates and evaluates new ML models to predict implosion time-histories.

SESSION 19: NUMERICAL ADVANCEMENTS IN SHOCK AND LOADING

IMPROVING FRACTURE MODELLING OF THIN-WALLED STRUCTURED UNDER BENDING LOADS

Dr. Juan Londono, Thornton Tomasetti
Dr. Pawel Woelke, Thornton Tomasetti

The adequate prediction of ductile fracture in thin-walled structures requires to also capture key sub-thickness effects that are neglected in classical shell elements. These elements, inherently in a state of plane-stress and traditionally used for their computational efficiency, are unable to correctly predict the plane-strain fracture under both bending and tension loads, i.e. thin metal plates under plane-strain tension are likely to fail at a smaller plastic strain that those under plane-strain bending. This difference is driven by the localized necking that develops on the plane-strain tension case preceding fracture, which is absence in the case of the bending case. The critical location where the crack initiates (center of the neck/thickness on the tension case vs. tensile face on the bending case) develops significantly different stress triaxiality in each case which are not captured by the shell elements. This work expands on the fundamentals driving these differences and proposes solutions to address this in shell elements simulations. A characterization and calibration framework is also presented, as well as some examples where the enhanced elements can be applied to metal structures akin to those in defense and transportation industries.

A DIGITAL TWIN FOR THE JASSO SHOCK MACHINE

Dr. Fraser Mackay, Thornton Tomasetti
Dr. Daniel Clark, Thornton Tomasetti
Oliver Craggs, Thornton Tomasetti
Alan T. Ferguson, Thornton Tomasetti
Nicholas K. Misselbrook, Thornton Tomasetti

This paper presents the development of a JASSO digital twin which aims to replicate the real-world testing environment using a numerical coupled fluid-structure interaction methodology. The JASSO digital twin allows for fast prototyping, facilitating more efficient design iterations of modifications as well as allowing for enhanced pre-test calibration and evaluation of equipment, especially in the development of a test program requiring non-standard shock loading.

NUMERICAL ANALYSIS OF AIR-BACKED STRUCTURES UNDER UNDEX LOADING

Dr. Daniel Clark, Thornton Tomasetti
Dr. Fraser Mackay, Thornton Tomasetti
Alan Ferguson, Thornton Tomasetti
Dr. Eric Hansen, Thornton Tomasetti
Dr. John Mould, Thornton Tomasetti

This paper investigates the effect of UNDEX loading on a generic shock target vehicle via numerical simulation. The fluid-structure interaction is captured using a coupled computational fluid and solid dynamics methodology.

SESSION 20: AIRBLAST MODELING

EXPERIMENTAL AND NUMERICAL STUDY ON AIR-BLAST PERFORMANCE IN THE PRESENCE OF LARGE DEBRIS

Jakob Brisby, Applied Research Associates
Craig Watry, Applied Research Associates
Dr. Sean Cooper, Applied Research Associates
Dr. Peter Dunn, Applied Research Associates
Sheera Lum, Applied Research Associates

Defense applications routinely require the use of air-blast in environments laden with dust and debris. Understanding how this dust and debris affects the air-blast is crucial for determining its performance. A dearth in the literature on the effectiveness of an air-blast in the presence of large debris required the development of a test series to understand this interaction.

The test series includes pairing shock tube experiments with high-fidelity simulations to explore the parameter space. Pre-test predictions using SHAMRC (Second-order Hydrodynamic Automatic Mesh Refinement Code) were completed to explore sensitivities of the flowfield when an air-blast impinges on a wall of stacked debris. Pre-test predictions revealed that the flowfield is very sensitive to initial driver tube temperature and distribution of blockage in the cross-section of a shock tube. The flowfield was also sensitive to size and shape of the individual pieces of debris but to a lesser extent. These aided in determining the debris setup for the actual experiments.

Physical experiments used a lab-scale shock tube to impact a wall of stacked debris of varying debris size and spacing with pressurized nitrogen gas. The shock tube consisted of a 6.75-in x 6.75-in cross-section, a 2-ft driver section, and an 18-ft driven section. Pressurizing the driver section to 1000 psi ruptured a calibrated diaphragm without the aid of explosives. The released gas subsequently impacted a wall of samples with controlled spacing located in the driven section of the shock tube. Each test used a custom-made debris wall with its own unique configuration (i.e., debris geometry, mass, and material).

The data from the experimentation phase were used to develop modeling capabilities in characterizing and understanding the effect of large debris on air-blast. High-speed cameras captured the initial wall break-up and the downstream debris velocities and trajectories in three-dimensions. Pressure gauges on both the driver and driven sections of the shock tube provided data for characterizing the pressure trends for each test. Experimentation data were used to refine and validate the high-fidelity simulations with

SHAMRC. The data were also used to assess the accuracy of current capabilities to perform fully-coupled FSI (fluid-structure interaction) simulations.

BLASTX TIME-DEPENDENT BREACH AND GAS INTRUSION MODEL UPDATES

Zoran Nadzakovic, USACE ERDC
Gustavo Emmanuelli-Gonzalez, USACE ERDC

BlastX is an engineering-level, fast-running code designed to predict the airblast environment associated with explosive detonations in complex multi-room structures. Department of Defense (DoD) High Performance Computing (HPC) systems are used to run first-principles codes to generate data for BlastX model developments and improvements. Updates in BlastX are underway to support breaches and subsequent blast propagation through the newly failed structural elements. The new time-dependent breach (TDB) model will specifically evaluate failure resulting from the combined blast and fragment loading generated by cased munitions. The TDB model identifies breach size and its growth versus time at varying standoff distances for different types of target materials. The initial implementation of the TDB model supports steel targets of varying thicknesses and spans. In addition to the TDB model, blast propagation through openings is being investigated to improve BlastX accuracy. This presentation outlines the development of the TDB model for steel plates and the 3D numerical modeling being done to improve blast propagation through openings.

Permission to publish was granted by the Director, Geotechnical and Structures Laboratory. The abstract is approved for public release; distribution is unlimited.

SHOCK TUBE FACILITIES FOR BLAST RESPONSE TESTING AND MODELING

Dr. Sean Cooper, Applied Research Associates
Mohsen Sanai, Applied Research Associates
Joe Crepeau, Applied Research Associates
Waylon Weber, Applied Research Associates

Prediction of blast and explosion environments and their effects on existing infrastructure is essential to design hardened infrastructure and minimize the loss of both life and infrastructure during these events. Therefore, full- and sub-scale tests are required to develop and validate high fidelity modeling and simulation (M&S) to understand the physics of these events and, therefore, to better predict their effects on existing infrastructure. To satisfy this requirement, ARA has built the ARA Moriarty Range (AMR) to conduct both full- and sub-scale testing. Sub-scale tests mimic large-scale operation environments and provide data that can be used for M&S of full-scale events, thereby reducing the technical risks (test bed design, shot characteristics, instrumentation, etc.) of larger events to ensure high-quality data acquisition. AMR accommodates a Medium-Scale Shock Tube (MSST) and a Small-Scale Shock Tube (SSST) designed and built to test fundamental blast loading effects on materials, structures, and the environment. This paper describes the shock tube facilities and discusses pressure data, high-speed video observations, and SHAMRC computer simulations of representative tests. Downstream pressure and synchronized high-speed imaging allow for characterization of the stagnation, static, and dynamic pressure environments, and three-dimensional particle tracking, respectively.

The MSST, a compressed gas-driven shock tube, consists of two main sections a 4-ft-diameter, 81-ft-long driver section and an 8-ft diameter, 60-ft-long driven section. A diaphragm, ruptured into a six-petal configuration using linear shape charges, separates the driver from the driven section. A 4 ft diameter moveable section allows for ease of diaphragm access and shape charge placement. An advanced pressurization system is used to remotely pressurize the driver section up to 500 psi to produce external air blast overpressures up to 40 psi and positive phase durations of up to 200 ms, which is adequate for testing full-scale walls and structures. The MSST is utilized as a risk reduction tool for costly field experiments and/or larger shock tube tests at sites such as the Large Blast and Thermal Simulator (LBTS). The 62-ft-long explosive-driven SSST was built to investigate the fragmentation of common building materials exposed to high-pressure loads (up to 6000 psi) at the sub-scale. The inside diameter of the explosive driver is 6.5 in., which increases in two steps to 10 in. at the muzzle end where the test specimen is placed.

Two methods are used to measure the characteristics of debris generated from full- and sub-scale tests. The first involves a "soft catch" frame where curtains of soft material capture the fragments without further breakup. The second uses high-speed video cameras to capture stereoscopic images of the fragments in flight. Utilizing ProAnalyst® image analysis software, these high-resolution images are used to obtain three-dimensional distributions of fragment size, velocity, and vector.

Both shock tube facilities are utilized to develop a database of loading response data for high-fidelity code development like SHAMRC and Tether (a coupled code between SHAMRC and LS-Dyna). Representative results from this ongoing testing and modeling effort are presented herein.

HIGH-SPEED VIDEO TECHNIQUES FOR AIRBLAST PARAMETER EXTRACTION IN EXPLOSIVE DETONATIONS

Joshua Payne, USACE ERDC
Jeffrey Holmes, USACE ERDC
Denis Rickman, USACE ERDC

Understanding the shock environment from high explosives is crucial for characterizing blast effects on structures, geomaterials, and equipment. Traditional airblast measurement methods rely on physical sensors which offer high accuracy but may face placement constraints and sometimes data loss in high-energy environments or due to recording errors. The analysis of high-speed video data may offer a solution when sensor data is unavailable by providing data that allows tracking of shockwave motion over time, enabling the calculation of key parameters like peak overpressure, impulse, and shock velocity. This paper presents a methodology for deriving airblast parameters from high explosive detonations using high-speed video techniques and compares these results with conventional sensor data.

ACCELERATING FLUID-STRUCTURE INTERACTION SIMULATIONS WITH VIPER::BLAST AND OPENRADIOSS

Dr. James Wurster, Viper Applied Science
Andrew Nicholson, Viper Applied Science
Peter McDonald, Viper Applied Science
Christopher Stirling, Viper Applied Science

When a blast strikes a structure, how fast does the structure react? Often, the structure's response lags behind the rapid blast, allowing for a simplified, uncoupled simulation. But in scenarios where the structure's reaction is nearly as quick as the blast—such as in large-scale or close-proximity explosions—uncoupled models fall short. Here, a fully coupled fluid-structure interaction (FSI) simulation becomes essential.

FSI simulations are notoriously complex, demanding intensive computational resources for both the fluid and structural domains, especially when these systems interact dynamically. However, the need for fully coupled simulations shouldn't mean sacrificing efficiency or ease of use or accuracy.

In this talk, we introduce Viper::Defence, a powerful yet user-friendly solution for fast and accurate FSI simulations. By leveraging Viper::Blast for fluid dynamics on the GPU and OpenRadioss for structural analysis on the CPU, Viper::Defence optimizes the strengths of each platform. This dual approach enables large, fully coupled simulations to run efficiently—even on a personal laptop—without compromising accuracy or user experience. We'll demonstrate how Viper::Defence brings FSI modelling within reach, making it both computationally efficient and user-friendly for a wide range of users.

PANEL: MULTI-DEGREE-OF-FREEDOM VIBRATION TESTING CURRENT CAPABILITIES, HURDLES, & PATH FORWARD FOR WIDESPREAD ADOPTION

MULTI-DEGREE-OF-FREEDOM VIBRATION TESTING CURRENT CAPABILITIES, HURDLES, AND PATH FORWARD FOR WIDESPREAD ADOPTION

Matt Forman, NSWC Dahlgren
Dr. Luke Martin, NSWC Dahlgren
Troy Skousen, Sandia National Labs
Ryan Schultz, Sandia National Labs
Dr. Chris Roberts, UK MOD
William Barber, Redstone Test Center

This panel discussion will brief out current lab technologies used to accomplish multi-degree-of-freedom (MDOF) tests and survey the audience to gather perspective on obstacles which have held up the community from more widespread adoption. Feedback will be incorporated to assist in development of a "MDOF Roadmap" to continue adoption efforts.

TRAINING VI

INTRODUCTION TO HEAVYWEIGHT SHOCK TESTING

Travis Kerr, HI-TEST Laboratories

An understanding of both the history and physics of mass ratio are presented. For the layperson, the ratio requirement was introduced into the shock specifications to keep the tail from wagging the dog. Onboard Navy ships, decks are typically relatively massive compared to the equipment installed so that under shock loadings, the deck drives the equipment.

In the shock qualification test world, the goal is to simulate the physics onboard shipboard installations in order to demonstrate the survivability or shock hardness of shipboard equipment during an underwater explosion (UNDEX) event. There are several parameters that affect whether or not a test setup reasonably simulates the shipboard installation. This presentation discusses the impact of mass ratio on heavyweight shock tests and applicable parameters established in MIL-DTL-901E.

SESSION 21: MECHANICAL SHOCK TESTING II

MINIATURIZED RESONANT PLATE TESTING WITH HIGH SHOCK LOADS

Dr. Carl Sisemore, ShockMec Engineering
Elliott Pelfrey, Sandia National Laboratories

Resonant plate shock testing is a common technique for simulating pyrotechnic shock events in the laboratory. The technique typically involves using a relatively long pneumatic gas gun to accelerate a heavy projectile into the back of a modest sized resonant plate. It is also a method that typically requires a significant amount of floor space in the laboratory. While this configuration is often quite reasonable, it is occasionally necessary to perform this type of testing in a highly confined environment. This may happen in a testing scenario where multiple environments are required to be tested simultaneously. In order to study this, a series of extremely short pneumatic gas gun barrels was fabricated and tested against a range of different resonant plates. As the gun barrel length becomes very short, the diameter must be increased in order to allow for sufficient projectile mass. This paper presents the results of multiple resonant plate shock test experiments using pneumatic gas guns as short as 5.2 inches and compares these results to similar testing using more traditional 36 inch long gun barrels. In addition to barrel length, a comparison is also made with projectile diameter. Several projectiles were tested with diameters ranging from less than one inch up to two inches to understand how projectile frontal area affects resonant plate shock test results. The results show that it is in fact possible to obtain extremely high shock test levels from miniaturized pneumatic gas guns. Potentially opening the door to some highly specialized shock testing.

PARAMETRIC TUNING OF A RESONANT PLATE SHOCK TEST SRS

Trevor Turner, Texas A&M University
Dr. Pablo Tarazaga, Texas A&M University
Chase Zion, Honeywell Federal Manufacturing & Technologies
Dr. Washington DeLima, Honeywell Federal Manufacturing & Technologies
William Zenk, Honeywell Federal Manufacturing & Technologies

Resonant plate shock testing is a well-established technique used to evaluate the structural integrity and reliability of various mechanical systems subjected to transient loads. The underlying theory behind the shock response spectrum (SRS) in relation to shock testing posits that two shock events yielding identical SRS profiles have the same potential for inducing damage. As such, recreating an in-situ shock event by mirroring the corresponding SRS within a controlled environment is the primary goal of these types of tests. This study examines several parameters of the resonant plate shock test setup and their effect on the SRS. By manipulating these parameters and understanding their interplay, the SRS can be tuned to a more desirable profile and to fit within a qualification envelope. When more accurately recreating the desired SRS, components can be qualified to the required specifications while minimizing the risk of damage due to over-testing.

Rapid Characterization of Compact Granular Materials Using Laser Doppler Vibrometry and Resonant Ultrasound Spectroscopy

Joshua Bartlett, Texas A&M University
Caleb Fryer, Texas A&M University
Dr. Pablo Tarazaga, Texas A&M University
Dr. TJ Ulrich, Los Alamos National Laboratory

Compact granular materials, often shaped as compressed pellets, are a common delivery system frequently utilized in the chemical, energy, and pharmaceutical industries. While traditional techniques exist to ensure the quality control of these pellets, they typically require large specimen samples and result in the destruction or damage of the specimen upon completion. This study aims to develop an accurate, reliable, and non-destructive technique using Laser Doppler Vibrometry (LDV) and Resonance Ultrasound Spectroscopy (RUS) to determine the structural and physical properties of a material within a rapid characterization process. This is accomplished by using a piezoelectric transducer contained within an acoustically dead stage to vibrate a test specimen. An LDV is then used to collect the frequency response behavior and Operational Deflection Shapes (ODS) of the specimen. The recorded measurements are then processed to determine the degree of collinearity with an ideal, simulated model through Modal Assurance Criterion (MAC) values. This modal information is finally sent to the RUS algorithm, an iterative approach to the generalized eigenvalue problem, to solve for the elastic tensor of the test sample. With a better understanding of the mechanical properties of granular pellets, it becomes possible to quantify the functionality and longevity of the specimen while conducting structural health monitoring.

Towards in-situ Resonant Ultrasound Spectroscopy of Additive Manufactured Parts by Tackling the Build Plate-Specimen Coupling

Jeriel Jammullamudy, Texas A&M University
Dr. Pablo Tarazaga, Texas A&M University
Dr. Satish Bukkapatnam, Texas A&M University
Dr. TJ Ulrich, Los Alamos National Laboratory

The ability to determine the elastic material properties of additively manufactured (AM) parts while being built is critical for design and quality assurance. This work poses RUS as an acceptable method to accomplish this task. RUS utilizes the natural frequencies of a specimen to calculate its elastic tensor, from which desired material properties may be extracted. Traditionally, RUS is used on samples that undergo preparation steps that place the specimen in “free-free” boundary conditions. With the goal being to characterize AM specimens in-situ, one must consider the fact that AM parts are built a top a build plate which can be modeled using “fixed-free” boundary conditions. This work progresses RUS from being able to only examine parts in “free-free” to “fixed-free” boundary conditions by studying a cuboid sample fixed a top a build plate. Using commercial finite element software, COMSOL, consideration is given to navigating the coupled dynamics of the specimen and build plate. Upon successfully demonstrating this technique, continued effort may be made to evaluate complex geometries, multi-material specimens, and increase processing time and accuracy for fixed-free mounted specimens.

SESSION 22: SHOCK NUMERICAL TOOL ENHANCEMENT

USING RAINFLOW FATIGUE DAMAGE SPECTRA TO CHARACTERIZE SHOCK AND VIBRATION ENVIRONMENTS

Jerome Cap, Sandia National Laboratories
Eric Pulling, Sandia National Laboratories

The ability to compare the relative fatigue damage associated with vibration and repetitive low amplitude shock environments can greatly streamline the effort needed to conduct laboratory testing as well as allowing the analyst to assess the need to requalify existing hardware when new environments arise.

Tim Edwards introduced the Input Energy Spectrum (IES) at Sandia [1] as a means for accomplishing this goal. Energy models allow for the combining of modal energies, and hence reduce the damage potential for each environment to a scalar value that in turn can be summed to predict the total fatigue damage, which greatly simplifies interpretation. However, energy-based models do not agree with commonly accepted values of the fatigue exponent for a Minors-Palmgren fatigue power law model.

This paper describes an adaptation of the energy methods that combines a power law model with the concept of summing damage across modes. The key feature is the generation of relative velocity waveforms for each fixed base resonant frequency and then applying rainflow cycle counting to assess the fatigue damage based on the desired power law model – hence the name Rainflow Fatigue Damage Spectra or RFDS. Weighted values of the modal fatigue damage are summed in a manner analogous to the energy methods, thereby yielding scalar damage values for each environment.

Examples comparing RFDS, IES, and Fatigue Damage Spectra [2] will be provided.

[1] Edwards, Timothy; "Energy Methods for the Characterization and Simulation of Shock and Vibration"; 78th Shock and Vibration Symposium, Nov 2007.
[2] McNeill, Scot; "Implementing the Fatigue Damage Spectrum and Fatigue Damage Equivalent Vibration Testing"; 79th Shock and Vibration Symposium, October 26-30, 2008, Orlando Florida.

ROTATION MATRIX USED IN SIMPLE

Dr. Michael Talley, HII-NNS

The Shock Isolation Mount Predictions and Loading Estimates (SIMPLE) software uses a rotation matrix A and its inverse to transform coordinates, velocities, forces, etc. in and out of a rotated frame relative to a reference frame. Static or dynamic angle inputs to the rotation matrix are specified as Tait-Bryan rotation angles. This presentation discusses the derivation of rotation matrix A and its inverse and its application when using SIMPLE to orient: 1) rigid bodies, 2) Medium Weight Shock Machine (MWSM) fixtures, and 3) mounts. Also discussed is the derivation of Tait-Bryan rotation angles using direction cosines and the process for specifying the rotation sequence if more than one angle is involved.

GPU-ACCELERATED CFD FOR NEAR SURFACE UNDEX EXPLOSION SIMULATIONS: CAPABILITIES AND EXPERIMENTAL VALIDATION

Andrew Nicholson, Viper Applied Science
Chris Stirling, Viper Applied Science,
Dain Farrimond, University of Sheffield
Adam Dennis, University of Sheffield
Genevieve Langdon, University of Sheffield
Andy Tyas, University of Sheffield
Lewis Tetlow, University of Sheffield
Tommy Lodge, University of Sheffield
Piotr Nowak, Poznan University of Technology
Piotr Sielicki, Poznan University of Technology
Tomasz Gajewski, Poznan University of Technology

This paper presents a high-performance computational fluid dynamics (CFD) solver optimized for graphical processing units (GPUs), specifically designed to simulate near-surface underwater explosions using an inviscid multi-material solution. The primary aim is to enhance the computational efficiency and accuracy of modeling these complex fluid dynamics phenomena. Leveraging the parallel processing capabilities of modern GPUs, the solver significantly reduces computational time compared to traditional CPU-based methods, enabling more detailed and extensive simulations within feasible timeframes.

The development of this solver incorporates advanced numerical methods tailored to handle the highly transient and nonlinear nature of near-surface UNDEX. These methods include shock-capturing and interface schemes, crucial for accurately resolving the interface between water and air and capturing the complex dynamics of shock waves and bubble formation. The solver's performance is rigorously evaluated through a series of benchmark tests, comparing its results with both theoretical predictions and experimental data.

To validate the solver's accuracy, we compare to controlled near-surface UNDEX experiments, comparing parameters such as pressure wave propagation, bubble dynamics, and water surface deformation. The experimental setup includes high-speed cameras and pressure sensors. Results from the CFD solver are then compared against these experimental measurements, demonstrating comparisons in aspects such as peak pressure values, bubble collapse periods and traces. Any differences between the two results are also discussed and conclusions drawn.

Overall, this work underscores the potential of GPU acceleration in advancing CFD applications, providing a robust and efficient platform for investigating emerging threats with high precision and reliability. The solver's enhanced capability to provide scale and speed for enhanced spatial and temporal resolution makes it a valuable tool for researchers and engineers in naval defence applications.

A COMPUTATIONAL GEERS-HUNTER MODEL PARAMETERISED FOR DEPTH AND CFD INPUTS

Dr. James Wurster, Viper Applied Science
Andrew Nicholson, Viper Applied Science
Ben Evans, Viper Applied Science

The model presented by Geers & Hunter (2002) provides a robust set of equations to model the radius and depth of a migrating bubble caused by an underwater explosion. Hunter & Geers (2002) expanded this model by introducing equations to calculate the time evolution of pressure at a given position relative

to the initial charge location. Both papers rely on parameters from historical experiments (circa 1946 - 1979), allowing their model to effectively understand bubble behaviour at arbitrary depths caused by various explosives. This makes it a powerful and widely used model in shock analysis for platforms, particularly when combined with the Double Asymptotic Approximation (DAA) for structural response.

Despite being more limited than full Computational Fluid Dynamics (CFD) models, the Geers-Hunter model remains valuable due to its ability to quickly and easily predict bubble properties over extended time and displacement (i.e., well into the far-field). However, it has limitations that CFD models do not. In this paper, we address these limitations by introducing extensions to the Geers-Hunter model.

First, we investigate the effect of varying water properties with depth, salinity, and temperature has on bubble migration with an aim to improving the model's accuracy and applicability. Secondly, the available parameters used in the Geers-Hunter model are based on a limited range of explosives from historical experiments. While users often approximate these using a TNT equivalence, this is not always accurate. To address this, we use high-fidelity CFD simulations using the Viper::Blast code to calibrate and validate the analytical model. Using these results, we generate new input parameters, creating a library of initial conditions based on CFD simulations, in addition to the existing Geers-Hunter parameters. This approach aims to extend the applicability of the models for other explosives and enhances the model's relevance for modern applications.

As part of this work, we also touch on integrating our GPU-accelerated CFD code for early-time simulations with a later-time analytical model for far-field bubble migration as part of our UNDEX calculator tool for development of UNDEX loads for finite element and DAA analysis.

SESSION 23: MODELING AND SIMULATION VALIDATIONS

Elastic Plastic Impact Characterization Modeling and Simulation Validation

Matt Stevens, NSWC Carderock

Testing and subsequent modeling and simulation validation for elastic-plastic response of normal and oblique ball on plate impacts is presented. A series of analysis parameters are evaluated with respect to accuracy of simulation results. Correlations between test data and modeling and simulation predictions are presented for strain, deformation, and velocity.

Abaqus Fully Coupled Acoustic Fluid- Structure Analyses Characterization Study

Sara Fisher, NSWC Carderock

Abaqus, a commercially available finite element analysis (FEA) software, can perform fully coupled acoustic fluid-structure analyses. Naval Surface Warfare Center Carderock Division (NSWCCD) Code 661 desired to understand the potential uses and limitations of these coupled analyses for UNDEX applications. A study was performed to characterize coupled analyses against a set of test data that included frequency characterization and UNDEX testing on several submerged cantilevered beams. Modal analysis, shock wave propagation through an acoustic fluid, and structural response to UNDEX events were all investigated in Abaqus. Analysis choices, successes, and limitations will be discussed.

SESSION 23: SHOCK QUALIFICATION

NAVY ADDITIVE MANUFACTURING (AM) SHOCK QUALIFICATION AND R&D
Jake Mason, NSWC Carderock

The Navy is pursuing increased use of Additive Manufacturing of metals to quickly produce submarine and surface ship parts. The Naval Surface Warfare, Carderock Division (NSWCCD) is helping to manage ongoing shock qualification efforts across the Navy and industrial base. This brief will provide an overview of current ongoing activities including material-level R&D testing, machine shock testing of parts, and Underwater Explosion (UNDEX) testing of select hull penetrations.

BOLT-ON PADDLEWHEEL TEST VEHICLE
Tim Mcgee, NSWC Carderock

The Paddlewheel Test Vehicle (PWTV) is a low cost option for testing small submarine hull penetrations. Naval Surface Warfare Center Carderock Division (NSWCCD) Underwater Explosion Research and Development Branch (Code 661) designed a modified PWTV, replacing the welded target plate with a bolt-on design, to improve operational flexibility and to reduce overall test cost and schedule. NSWCCD conducted a calibration test, using a bolt-on PWTV, and the results showed that the dynamic environment of the bolt-on PWTV is consistent with historical hull penetration testing.

DEVELOPMENT OF AN ALTERNATIVE REDUCED-BLOW LOW-IMPACT SHOCK TEST INFORMED BY SIMULATION
LeeYung Chang, NSWC Carderock

This presentation discusses development of a reduced blow test series for low-impact environments using the Medium Weight Deck Simulating Shock Machine (DSSM). Simulation of potential DSSM environments was conducted using the Shock Isolation Mount Predictions & Loading Estimates (SIMPLE) program. The simulated environments were assessed against the Type A Category 1 environment specified in the Low Impact PPD. This effort is presented to document an additional option for low-impact testing and to demonstrate the utility of simulation software for informing non-standard testing.

SESSION 24: SHOCK & VIBRATION TESTING FOR FLIGHT SYSTEMS

SOUNDING ROCKET FLIGHT VIBRATION VERSUS REYNOLD'S AND STROUHAL NUMBERS
Dr. Ricky Stanfield, Corvid Technologies

The flight vibration environment for sounding rocket class vehicles has been characterized using several approaches through the years. From the mid 1970's to early 2000's, the environments were based on NASA hand-calculated power spectral density data on a limited set of flight vibration measurements. Between 2002 to 2019, work was performed over a much wider set of data to trend flight vibration environments against common flight analysis parameters such as flight dynamic pressure and Reynold's number. More recently, an exploration was started with several new sounding rockets data sets to determine the extent to which the vector components of flow velocity across the diameter of the rocket generate certain spectral features. This crossflow is caused by small airframe flight path angles of attack relative to the vehicle velocity vector and it contributes to vibration features that do not otherwise follow the larger trend with Reynold's number. In this paper, we discuss the empirical correlation between flight vibration magnitude and spectral content to Reynold's Number and Dynamic Pressure; the correlation of some vibration features with airframe angle of attack, crossflow velocity, and Strouhal number; and how other interactions between structural frequencies and aerodynamically driven vortex shedding frequencies generate transient vibratory features.

COMBINED SHOCK, VIBRATION, AND INERTIAL TESTING FOR COMPONENT FLIGHT ENVIRONMENTS

Dr. James Nicholas, Sandia National Laboratories
Peter Yeh, Sandia National Laboratories
Ron Hopkins, Sandia National Laboratories
Dr. Richard Jepsen, Sandia National Laboratories
Leticia Mercado, Sandia National Laboratories
Jason Wilke, Sandia National Laboratories

The Individual Environmental testing approach has the potential to misrepresent realistic performance of flight system components. More recently, a Combined Environment approach has been implemented to test components and systems with more realistic, coupled environments to build confidence before, or in place of, flight testing and for component qualification. Progress in combining vibration and acceleration has demonstrated a significant impact on understanding flight system performance and is becoming integral to development and qualification testing. Shock events that are not possible to test with conventional flight tests or with current combined environmental ground testing has driven the need for a novel approach. Designs of a blast coupled housing fixture have been developed to direct energy from an explosive shock wave and shape a designed shock response at a unit mounting location for testing on a large-scale centrifuge. This work details a proof-of-concept test demonstrating a blast coupled housing fixture in a combined environment test with an inertial load coupled with random vibration and a timed shock event.

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

IMPLEMENTING A SHOCK TUBE ON THE SUPERFUGE

Dr. Richard Jepsen, Sandia National Laboratories
Sameer Sheth, Sandia National Laboratories
Dr. James R. Nicholas, Sandia National Laboratories
Peter Yeh, Sandia National Laboratories
Ian Minervini, Sandia National Laboratories

The high cost and infrequent opportunities for flight testing and the criticality for mission success make ground-based testing essential. More recently, a Combined Environment approach has been implemented to test components and systems with more realistic, coupled environments to build confidence before, or in place of, flight testing. This work is a transition from prior methods to analytically assess components with limited ground test capabilities and then rely on computational simulation and flight tests as part of the qualification evidence. Recent progress in combining vibration and acceleration (Vibrafuge) has demonstrated a significant impact on understanding flight system performance and is becoming integral to development and qualification testing. Other environments such as axial spin, shock, and electromagnetic radiation have been explored and implemented into a capability called "Superfuge" which combines multiple flight environments into one test. Here, we will describe initial designs and development towards adding a shock environment feature to the Superfuge utilizing a shock tube on board a large-scale centrifuge. This builds on prior work from other researchers for explosive shock on the centrifuge and laboratory scale, curved, explosive shock tubes.

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MULTI-AXIS DISTRIBUTED EXCITATION ENVIRONMENTAL TESTING - EXPLORING TEST SPECIFICATION

Aaron Feizy, Los Alamos National Laboratory
Kai Newhouse, Los Alamos National Laboratory

Multi-axis environmental testing of an aerospace ground test structure was performed via distributed excitation using modal style electrodynamic shakers. Various multi-axis environmental specifications were derived from flight test data obtained from a separate flight test structure. Empirically derived frequency response functions were leveraged to generate reference profiles at more locations than obtained in flight. Effects of reference profile smoothing, number of specification locations, and employing frequency response functions from different structures were investigated. External locations for distributed excitation were selected using a genetic algorithm optimization process on an empirically derived frequency response function matrix. Number of excitation locations was explored. Results of various environment specifications and excitation configurations are discussed as well as logistics and challenges of test execution.

THE POTENTIAL FOR COMBINED VIBRATION AND SHOCK TESTING FOR COMPONENT FLIGHT ENVIRONMENTS

David Soine, Sandia National Laboratories
Forrest Arnold, Sandia National Laboratories
Steve Carter, Sandia National Laboratories
Kevin Cross, Sandia National Laboratories
Greg Melendez, Sandia National Laboratories
Dr. Ryan Schultz, Sandia National Laboratories

Multiple-input-multiple-output (MIMO) vibration control equipment and methodology has been steadily advancing to efficiently replicate a variety of vibration environments on test payloads. For smaller payloads or component vibration, there is potentially an order of magnitude equipment cost reduction over single axis shaker testing if a distributed small shaker approach can be utilized. The equipment cost reduction is partially offset by the need for a more sophisticated environment specification, MIMO vibration control, and experienced test practitioners. Sandia National Laboratories has been investigating how a low-cost distributed shaker approach enables novel opportunities for combined environments. This work describes a concept test demonstrating combined flight random vibration and resonant fixture shock, along with some of the challenges remaining to field such a capability.

TRAINING VII

INTRODUCTION TO MEDIUM WEIGHT SHOCK TESTING

Jeff Morris, HI-TEST Laboratories

This training will cover the necessary background information relative to medium weight shock testing. This session is intended for engineers and product developers who are unfamiliar with the medium weight

shock testing process. Subjects covered include pre-test planning, fixture selection, test set-up, test operations, and reporting. Some aspects of medium weight shock machine operation will be covered. Shock test requirements applicable to medium weight shock testing will be discussed.

TRAINING VIII

CAN I TRUST MY FEA MODEL?
Bart McPheeters, Gibbs & Cox

This class will address sources of error that will affect answers for a finite element analysis. It will remind people of some obvious sources that most people know about and check, but will get into some more subtle sources of error and especially uncertainty. It is a follow-on to a presentation I'd made two years ago on checking a finite element model, but going into some of the things that people don't always check or even realize are potential sources of error. I will discuss some strategies for identifying these potential sources of uncertainty and some ways to address and minimize them. Where possible, I will attempt to quantify the magnitude of the error that the different types of uncertainty create.

INTRODUCTION TO MULTIPLE-INPUT/MULTIPLE-OUTPUT VIBRATION TESTING
Dr. Ryan Schultz, Sandia National Laboratories

This Training Lecture introduces multiple-input/multiple-output (MIMO) vibration testing and aims to present concepts and terminology that anyone involved with MIMO testing should be aware of. The training begins with a general discussion on MIMO and when it should or should not be used. Next, example MIMO test setups are shown, including multi-shaker and six degree of freedom tests, along with the general testing workflow. The underlying theory behind the various MIMO test methods is presented, including random and transient vibration and MIMO control methods. Other topics include metrics and data analysis, data quality and typical test issues.

SESSION 25: PYROSHOCK ANALYSIS & DATA PROCESSING

EVALUATION OF VISCOELASTIC PASSIVE DAMPING FOR SHOCK RESPONSE MITIGATION
Brandon Sobecki, Damping Technologies, Inc.
Matt Butner, Damping Technologies, Inc.
Steve Rudolph, Damping Technologies, Inc.

Transient shock loads that result from pyroshock events on launch vehicles can damage valuable payload and are often of concern for the structural dynamics engineer. Isolation systems are the primary design solution for extreme shock loads, but these systems must be purpose designed for the specific launch vehicle and cost significant time to implement. Shock response spectra are often significantly influenced by the structure's reverberant field resulting from such shock loads. In these cases, constrained-layer damping systems using viscoelastic materials are effective in the reduction of the shock response spectrum. The technology is attractive for use in shock response attenuation due to its additive nature and ability to be deployed rapidly. In this paper, the effectiveness of passive damping for use in shock is demonstrated. A method for simulating the effect of an additive passive damping system is presented, and an experimental validation on a Mechanical Impact Pyroshock Simulator (MIPS) is evaluated. Limitations of the use of passive damping for shock attenuation and the associated simulation methodology are discussed.

QUANTITATIVE EVALUATION OF MEASUREMENT SYSTEM TRANSFER FUNCTIONS FOR SHOCK RESPONSE SPECTRUM CALCULATIONS

Douglas Firth, Precision Filters
Dr. Thomas P. Gerber, Precision Filters
Alan R. Szary, Precision Filters

In this presentation, we develop a quantitative method to evaluate and compare the fitness of different measurement system transfer functions for performing a shock response spectrum (SRS) calculation. We quantify the effect of industry-standard low-pass filters on the output of a single-degree-of-freedom oscillator (SDOF) excited by classical shock pulses in terms of an SRS error relative to unfiltered output. Our analysis supports the SRS of the impulse response as a conservative and easily standardized means to quantitatively compare different transfer functions and establish consistent error criteria to guide filter selection for signal acquisition in shock tests. We demonstrate the application of our criteria to a real shock pulse by modeling the output SRS error from a measurement system transfer function configured according to our recommended criteria. We conclude by showing how our model calculations can be performed using a simple web-based application.

VALIDATING A MECHANICAL IMPULSE PYROSHOCK SIMULATOR (MIPS) FINITE ELEMENT MODEL

Claudia Navarro-Northrup, Element US Space & Defense
Dr. Logan McLeod, Element U.S. Space & Defense

Element U.S. Space & Defense (formerly National Technical Systems) previously developed a Mechanical Impulse Pyroshock Simulator (MIPS) finite element model with the goal of developing a finite element analysis (FEA) tool to assist with test configuration design, the equalization phase of a test program, and test iterations, if needed. During a MIPS test the shock is generated by a mechanical impact between a projectile and a test fixture. A MIPS test is often a trial-and-error process during which test parameters and configurations are modified until acceptable SRS levels are attained. A FEA tool can be especially useful for challenging test requirements or configurations. However, for the FEA tool to be predictive and useful, the FE model must be validated with test data and the validated model must have short analysis run times.

The MIPS explicit FEA tool will be developed with a focus on correctly matching the knee in the SRS requirements. A non-linear FEA can have many parameters that can be varied including element formulation (solids versus shells); material modeling (elastic versus elastic-plastic properties); contact formulation; joint connections (bonded or welded versus explicit modeling of fasteners); and boundary conditions on the plate. Other modeling parameters including damping materials and projectile impact location will also be explored to assess the sensitivity of these modeling parameters on the analysis and results. Test data will be used to validate the different FE model parameters by comparing the acceleration-time data and resulting SRS between the test and the analysis. The finite element analysis will be done in LS-DYNA.

SESSION 25: MATERIAL STUDIES

DETECTION OF DEGRADATION OF POLYMERS USING IMPROVED METHOD OF ACOUSTIC WAVES TRANSFER FUNCTION IN RESONANCE APPARATUS

Dr. Vasant Joshi, NSWC Indian Head
Michael Meade, NSWC Indian Head

The frequency response and dynamic modulus of Sylgard 184 was investigated using the resonance method. Traditionally, this method is used to check the quality of polymeric materials as received using a slender stick of cast polymer. The current focus is on determining the relationship between the original 1-D resonance sample and the sample geometry altered from a 1-D sample to an extended 3-D geometry. As the wave dispersion increases with increase in diameter of the sample, detection of losses or transmission of acoustic waves using conventional transfer function also becomes difficult. While coupling of waves from shaker to sample may be simple in case of a slender sample, the complexity increases in coupling of waves into bulk sample. A traditional 1-D slender sample, a transitional rod sample, and 3-D sample were used in conjunction with a special coupler. The samples were excited by B&K shaker with a random noise frequency ranging between 0 and 1600 Hz and the accelerations were measured with B&K Type 4374 accelerometers. It was found that as the aspect ratio decreases, the first resonance frequency increases. Additionally, for the bulk sample, it was found that as accelerometer position moved from the center to radially outward, the magnitude of transmitted wave decreases (1-D to 3-D bulk). The resonant peaks did follow consistent trends and shows promise for comparing polymer samples against each other. Using the transfer function to convert accelerometer ratios and phases to the dynamic modulus resulted in dynamic moduli that decreased with an increase in frequency. The changes in resonance as a function of ageing was also studied and various aspects of measurements and results, which are important for vibration and shock damping of waves will be presented.

SESSION 26: VIBRATION DAMAGE & FATIGUE

MULTI-AXIS DURABILITY TESTING: CHALLENGES OF AN INNOVATIVE TESTING PRACTICE

Dr. Alberto Garcia de Miguel, Siemens Digital Industries Software
Ruben Araujo, Siemens Digital Industries Software
Umberto Musella, Siemens Digital Industries Software
Dr. Mattia dal Borgo, Siemens Digital Industries Software
Dr. Bram Cornelis, Siemens Digital Industries Software

This paper explores the challenges of the design and execution of representative dynamic environmental tests of structures subjected to multiaxial excitations. Manufacturers need to ensure that their components will endure vibration environments that are always more demanding and, in many cases, multiaxial. Consequently, the standard approach to performing durability testing based on uniaxial vibration tests might fail to capture the real damage mechanisms that develop in the tested structure, leading to a wrong estimation of the predicted life span. To address this challenge, current research work is focused on two goals: 1) introduction of innovative test tailoring approaches to synthesize vibration targets based on multiaxial responses recorded in the field, and 2) execution of accelerated tests in multi-axis shaker platforms. In this context, this work presents an initial study performed on an electric vehicle to provide a further understanding of the relation between the cross-correlation between axes and structural damage. To achieve this, a small device was installed on the vehicle and instrumented with accelerometers and strain gauges. The acceleration recordings were processed and combined following a mission synthesis approach to analyze the damage potential in multiple axes based on the Fatigue Damage Spectrum (FDS). Particular attention was given to the derivation of test references that include the cross-correlation between axes. The goal was ultimately to test with a multi-axis shaker using a closed-loop Multiple-Input Multiple-Output (MIMO) control algorithm to replicate the derived references. Preliminary results from various tests performed in a multi-axis vibration platform are discussed. The damage induced in the specimen during the different vibration tests was calculated from the strain measurements and compared against that estimated from the operational tests.

EVALUATION OF FATIGUE DAMAGE FROM RANDOM VIBRATION AND SINE-SWEEP

Dr. Arup Maji, Sandia National Laboratories

A damage based approach is often used for different types of fatigue failure to quantify the relative severity of vibration specifications. Efficient numerical codes based on structural response allow rapid evaluation of the effect of both input and model uncertainties on 'damage'. Damage index is computed using a fatigue damage model (S-N curve) based on stress cycles. The relative significance of damage among different frequencies may be quantified with the modal participation factor (MPF) or other means. Although these approaches are approximate, they provide engineered guidance when greater information is not available, as is often the case in practice.

Comparing the severity of various vibration test specifications is complicated since the Auto-spectral Density (ASD) can be higher or lower at different frequencies. Test durations are also different. An added complexity is that sine-sweep test specifications (from directly coupled engine vibration) can be prescribed to be concurrent with random vibration ASDs (structure borne vibration). A system or component may be subject to vibration during transport and handling vs. during launch or flight. It then becomes important to quantify the consequences of various test specifications to prioritize testing, or to ensure tests done to previous specifications can be used to ascertain safety when requirements and usage has changed later in the development phase.

The presentation will provide the technical basis for evaluating fatigue damage from various types of vibration test specifications. Codes developed with greater computational efficiency and associated theoretical approximations will be discussed, along with results comparing rigorous and approximate methods.

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This paper describes objective technical results and analysis. Any subjective views or opinions that might be expressed in the paper do not necessarily represent the views of the U.S. Department of Energy or the United States Government.

PERSPECTIVES ON FATIGUE ESTIMATION IN RANDOM VIBRATION USING ACCELEROMETERS AND MACHINE LEARNING

Dr. Charles Hull, Lockheed Martin

Vibration induced fatigue is a well known failure mode of engineered equipment and structures. Cumulative fatigue damage can be predicted using traditional math modeling and analysis methods. Alternatively, learning based algorithms may be leveraged to map acceleration data into estimated fatigue damage. In this work, machine learning techniques are applied to analytically estimate fatigue life consumption and predict failure in harsh vibration environments. This paper will explore a machine learning perspective to fatigue damage prediction in the context of a notional structure subjected to random vibration.

SESSION 26: ADVANCEMENTS IN VIBRATION TESTING & MEASUREMENT

ADVANCED 3D MODELING OF HIGH-FREQUENCY PROBLEMS USING SEA METHODS

Kory Soukup, Altair Engineering
Sravan Kumar Reddy Mothe, Altair Engineering

High-frequency noise and vibration pose significant challenges in military applications, where precise modeling and analysis are crucial for ensuring the performance and reliability of complex systems. The Statistical Energy Analysis (SEA) method is an established tool for addressing these issues, yet traditional implementations often fall short in capturing the intricacies of three-dimensional structures.

This paper presents the advanced capabilities of the Altair SEA solver, SEAM (Statistical Energy Analysis Module), which advances the field by providing comprehensive 3D modeling capabilities. Unlike traditional SEA implementations, SEAM supports detailed three-dimensional representations, enhancing the precision of vibro-acoustic analysis in multi-modal systems. The solver facilitates thorough evaluation of energy transmission, loss factors, and modal density, offering improved insight into vibrational energy distribution and enabling more effective identification of mitigation strategies.

Case studies in this paper illustrate SEAM's application to military contexts, including noise analysis in naval ship compartments, vibration assessments in armored vehicles, sonar signatures in submerged vessels, and noise reduction strategies for electronic equipment. These case studies demonstrate SEAM's capability to address high-frequency noise and vibration issues with greater accuracy and efficiency compared to traditional SEA methods. The findings indicate that SEAM provides a significant advancement in high-frequency vibro-acoustic analysis, offering military engineers a powerful tool for developing more reliable and effective systems in complex operational environments.

CAMERA-BASED MODAL ANALYSIS AND MOTION AMPLIFICATION

Dr. Jeff Hay, RDI Technologies

Motion Amplification is a video-processing technique that detects subtle motion and enhances that motion to a level visible with the naked eye. Motion Amplification Technology can resolve motions as small as 250 nanometers at 1 meter and can be performed live and in real-time on even a modest laptop, making it suitable for a range of applications from product design and testing to field based machinery fault diagnosis and structural testing. The process involves the use of a high definition and high dynamic range video camera where every pixel becomes an independent point sensor creating millions of continuous data points in an instant. This essentially turns a high definition camera into a full field vibration acquisition device with over 2.3 million independent sampling locations or areas of interest.

The latest non-contact, non-destructive capability added to the Motion Amplification® technology is the ability to perform true modal analysis via the camera, either while operating or by artificially exciting a structure. Excessive or unwanted vibrations can significantly reduce the lifetime of a structure or induce unwanted behavior. Noise, Vibration, and Harshness (NVH), product design, and structural resonances are real-world examples of use cases. The camera allows us to extract precise vibration data from thousands of potential locations without physically touching or manipulating our asset or sample, all at safe distances, to best understand the structure's response. The camera measures all locations simultaneously so specifical placement is no longer a requirement and can even be changed after the measurement is made. This allows virtually any location to be measured and reduces the modal analysis to minutes instead of hours or days. The result is quicker time to insights, allowing decisions to be made faster, increased number of tests to be performed and setups to be validated in more timely fashion.

One of the major advantages of the science of Motion Amplification® is that measurements can be done in situ and under actual operating and environmental conditions, providing more accurate data results. This new feature will also allow modes to be automatically detected, measured, characterized and visualized with Motion Amplification®, which can be of special interest and difficult to capture with conventional analysis techniques. The result is better real-world structural testing, and improved FE models can be developed by incorporating and measuring the actual dynamic structural properties. In addition, the camera based solution makes it easier to perform in-field measurements due to portability, ease of use, and quick setup.

A comprehensive set of case studies and applications will be discussed from various industries showing how the technology is being deployed and used, including highlighting how the above capabilities are utilized by practitioners and why utilizing a camera for modal analysis is a significant leap in test, measurement and data analysis.

SESSION 27: MECHANICAL SHOCK TESTING & ANALYSIS

COMBAT SYSTEM STANDARD FOUNDATION ANALYSIS TOOL

Mackenzie Wilson, Huntington Ingalls Industries – Newport News Shipbuilding
Ify Amene, Huntington Ingalls Industries – Newport News Shipbuilding

This paper describes the development of the combat system standard foundation analysis tool. This tool was created for the evaluation of standard foundations developed to reduce cost and schedule impacts for current and future equipment installations on surface ships. The development of the tool has resulted in the following functional capabilities: 1) evaluation of standard foundation configurations; 2) iteration options to determine acceptability of possible future equipment using an existing standard foundation; 3) and ability to create diverse sets of standard foundation configurations for evaluation. Example analyses of the flexible infrastructure standard foundation system are also presented and discussed. This project is an example of leveraging Excel and Visual Basic for Applications (VBA) for engineering shock analysis and demonstrates how spreadsheet applications can be a valuable tool for engineering work.

LOAD CELL DROP TEST DATA INTEGRATION WITH FEA SIMULATION FOR COMBUSTIBLE CASE MATERIALS

Arhum Mirza, Picatinny Arsenal

Drop testing methods are often used to evaluate survivability and feasibility of artillery charges. Often this testing is done with minimal instrumenting and simple high-speed video for post-test analysis. Finite Element Analysis (FEA) design iterations are conducted in conjunction with the test, often with material assumptions that are not applicable to combustible materials used in artillery charges. In this instance, load cells were integrated into the drop testing impact plate to supplement high speed video and to capture greater details on the impulse and forces experienced during impact. Obtaining these additional details of the impact behavior enabled a better understanding of the force interaction between the case and impact plate. The measured forces and impulse are used to calibrate the speed and duration of the ground impact validating FEA simulation results.

Printed Hybrid Electronic (PHE) Assemblies Subject to Extreme Mechanical Shock (100,000 g) at Elevated Temperatures (150 °C): Reliability Assessment and Operational Applications

Major Hayden Richards, University of Maryland, College Park
Dr. Abhijit Dasgupta, University of Maryland
Andres Bujanda, DEVCOM Army Research Lab
Dr. Harvey Tsang, DEVCOM Army Research Lab
Matthew Bowman, DEVCOM Army Research Lab

The Center for Advanced Life Cycle Engineering at the University of Maryland, in partnership with the US Army Research Lab, employs an on-site accelerated-fall drop tower to perform performance evaluation and reliability assessment of various Printed Hybrid Electronic (PHE) assemblies subject to mechanical shock acceleration levels from 5,000 g up to 100,000 g. The drop tower is fitted with an integrated furnace and controller to elevate specimen temperatures from 25 °C up to 150 °C prior to drop. Current research efforts are focused on characterizing the behavior of components and printed silver traces embedded into the faces of injection-molded thermoplastic planar substrates supported in clamped-clamped beam geometries with no secondary impact. For various permutations of these assemblies, we assess 1) the first-drop survivability and 2) long-term reliability for the electronic components, traces, and soldered interconnects. Various failure modes are observed and assessed. Consistent with established electronics reliability methodology, degradation is assessed based on changes in electrical resistance within circuits of interest over time. This resistance is measured real-time, in-situ during the drop event. In combination with high-speed video, thermal cameras, and strain measurements, this resistance data offers insight into the behavior of these PHE assemblies during the impact event and supports the generation of computer models that can predict specimen performance.

Substrate failures are rare for these geometries, despite peak strain values in excess of 20,000 um/m and strain rates of 600 /s. The most common failure modes for embedded circuits are 1) separation of the component from the substrate and 2) degradation and cracking within the sintered silver trace material. At room temperature, trace degradation rates are comparable to previously published work for sintered silver traces on hemispherical substrates. Prior to complete trace failure, circuit resistance consistently spikes instantaneously during the acceleration pulse, which could jeopardize any PHE system that can't handle a momentary discontinuity. Additionally, resistance measurements for traces progressively increases with number of drops, at rates proportional to acceleration magnitude. These trends are also observed for testing at elevated temperatures. Both 2D shell and 3D solid models accurately represent experimental data. Future work will extrapolate the planar data and models discussed in this study to hemispherical geometries. Ultimately, these studies inform Army Research Lab efforts and help direct developmental work on operationally-relevant applications for these technologies.

The History of Hard Target Electronics Packaging Techniques at Sandia

Shane Curtis, Sandia National Laboratories
Mike Partridge, Sandia National Laboratories

Designing electronics and packaging to withstand high shock mechanical environments is a challenging task. It often requires a multidisciplinary team, whose members can straddle the fields of material science, mechanical design, and electronics. The effort is most successful when coupled with an iterative sequence of designing, building, and field testing. Over the course of Sandia National Laboratories' half-century work in this endeavor, high-shock packaging techniques evolved based on the tremendous improvements in computer modeling and simulation along with exponential technological developments. Even despite these advances, which have dramatically increased our understanding, designing electronics to survive these environments is still somewhat of an art, as opposed to a hard science. This presentation will explain Sandia's current state-of-the-art for high shock packaging against a backdrop of the historical evolution of those techniques. We will begin with a primer of mechanical engineering principles that explain structural response to high shock events. We will then use those principles to evaluate previous techniques employed on various legacy programs and provide justification for the current high-shock packaging guidelines. The intent is to inform future designers of what has been attempted in the past to avoid unnecessary rediscovery of successful methodologies.

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MICROBEADED ENCAPSULANTS AS SHOCK MITIGATION FOR ELECTRONIC SURVIVABILITY

Natasha Wilson, Sandia National Laboratories
Alex Chen, Sandia National Laboratories
Cayden Boll, Sandia National Laboratories
Dr. Damon Burnett, Sandia National Laboratories
Dr. Jeff Hill, Sandia National Laboratories

Harsh mechanical shock environments require protection of electronics, which is traditionally achieved using thermoset polymer encapsulants. Encapsulation supports electronics and prevents high voltage breakdown. Despite these advantages, thermoset polymer encapsulants require extended time at elevated temperatures to fully cure which results in residual stresses in the potted components. The residual stress is exacerbated by mismatches in coefficients of thermal expansion (CTE) between electrical components (circuit board, capacitors, etc.) and the encapsulant. Additionally, the nature of these encapsulants makes accessing electronic components for recovery or repair difficult, time consuming, and irreversible, if not impossible.

Several of these issues can be addressed by using glass or ceramic beads as a cureless shock mitigation media in place of polymer encapsulants. These packed beads, or microbeaded encapsulants, have been shown in literature to mitigate damage to electronics due to mechanical shock, reduce high frequency vibration transmission, and do not require thermal curing or vacuum processing. Both lack of physical bonding and better CTE match between microbeads and encapsulated components result in less stress during packaging and varying thermal conditions than is experienced when using polymer encapsulants. Access to encapsulated components for recovery or repair only requires opening the unit and pouring out the microbeads.

This work explores shock tower experimentation data, including repeated shocks, to assess microbeaded encapsulants' efficacy as a shock mitigation technology. Both low and high voltage components are used to assess component survivability in microbeaded encapsulants. Circuit board fixturing methods that improve practical application of microbeaded encapsulants are also examined in testing. The work also includes experimental differences in thermal cycle induced strains between microbeaded encapsulation and polymer encapsulants demonstrating the effect of CTE mismatch. The ability to predict the circuit board response to shock loading within the microbeaded encapsulant using numerical simulation was also explored.

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SESSION 28: BLAST EFFECTS

METHODOLOGY AND EQUATION DEVELOPMENT FOR PREDICTING PRESSURE EVENT PROPAGATION IN COMPLEX SUBTERRANEAN ENVIRONMENTS

Jasiel Ramos-Delgado, USACE ERDC
Cindy Negro Carrion, University of Puerto Rico at Mayaguez
Joshua E. Payne, USACE ERDC
Dr. John Q. Ehrgott Jr., USACE ERDC

Ground forces often face multiple subterranean threats, including tunnels, defensive compounds, and shafts, during maneuver operations. Addressing the need for capabilities to discover unknown enemy shafts and improve tactical operations in these environments, the U.S. Army Engineer Research and Development Center (ERDC) was tasked with developing and evaluating proof-of-concept systems for complex subterranean (SubT) scenarios. Utilizing an instrumented Complex Tunnel Structure facility, a series of tests were conducted to develop methods and empirical equations that can potentially predict the behavior of pressure event propagation. This research focuses on the initial approach and the results obtained from the experimental data collected at our facility. The findings provide insights into pressure propagation patterns, contribute to the development of predictive models, and demonstrate the potential of the proof-of-concept systems to enhance tactical capabilities in SubT environments.

INVESTIGATION OF METHODOLOGIES FOR PREDICTING AIRBLAST FROM BELOW GROUND DETONATIONS

William Myers, USACE ERDC
Dr. John Q. Ehrgott, USACE ERDC
Denis D. Rickman, USACE ERDC

Predictions of blast overpressure are important for use in weaponeering tools to predict the effects of blast overpressure on nearby personnel and structures and for experimental setup and design. Blast overpressure is reduced when detonations occur below the ground when compared to above ground detonations. The U.S. Army Engineer Research and Development Center (ERDC) is working with the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME) to compare experimental data to existing prediction methodologies found in ConWep's subsurface airblast tool and the airblast algorithm for unstemmed subsurface explosions. The experimental data was examined to observe relationships between above ground airblast predictions and the experimental data, and an updated blast overpressure prediction from below ground detonations is provided.

REPAIR AND ENHANCEMENT OF BARRIER SYSTEMS USING HIGH PERFORMANCE SHOTCRETE

Stephen Turner, USACE ERDC

The US military often employs concrete barrier walls for protection of assets in contingency environments. These barriers may be damaged by various threats, causing degradation of their protective performance. Current methodology requires replacement of damaged barriers, which is a time-consuming process. There are currently no deployable methods for repairing barrier systems in the field to restore their useful function. ERDC has been tasked with evaluated different High-Performance shotcrete materials to expediently repair or enhance different barrier systems. This effort will determine if this shotcrete technology can provide an acceptable repair or enhancement of barrier systems. This presentation will give an overview of testing that has been conducted and testing that is planned.

Validation Experiments of High-Explosive Shock Propagation through Rock Joints using Concrete Surrogate Targets

Adam Mayatt, USACE ERDC

The Geotechnical and Structures Laboratory at the U.S. Army Engineer Research and Development Center (ERDC) will conduct experiments to evaluate high-explosive shock propagation through rock joints. The data collected will be used to validate and improve high-fidelity modeling and simulation capabilities. A well-characterized concrete mix will be used to construct each target and serve as the rock surrogate material. An explosive charge will be detonated in contact with each concrete target to generate a planar blast wave through the concrete medium. Experiments will include testing of various concrete configurations, such as homogenous and jointed concrete, to simulate the natural occurrence of voids in rock formations. Comparison of results from both mechanical lab testing and field testing from an explosive charge will be evaluated.

Perforation of Reinforced Concrete and Stiffened Steel Targets Using a Payload Delivery Vehicle with Multiple Payload Types

Logan Callahan, USACE ERDC
Dr. Zane A. Roberts, USACE ERDC
Dr. Z. Kyle Crosby, USACE ERDC
Dr. John Q. Ehrgott, Jr., USACE ERDC

Numerical models that can capture the effects of warheads impacting and penetrating targets at a high velocity are of high interest in military research. To aid in the development and validation of these models, the U.S. Army Engineer Research and Development Center (ERDC) has conducted scaled perforation tests to examine the effects of a multi-component payload delivery vehicle (PDV) impacting both reinforced concrete and stiffened steel targets. A 2.5 in. diameter aluminum body, containing aluminum, steel, and tungsten components was used to represent the surrogate payload delivery vehicle. Three different configurations of the surrogate warheads were used inside the PDV: (1) a tungsten "fragmenting" warhead, (2) a penetrator warhead with an onboard accelerometer, and (3) a PDV with no payload. These projectiles were fired at velocities ranging from 1000 ft/s to 3000 ft/s into reinforced 0.25 in. steel targets, as well as concrete targets from 4 in. up to 18 in. thick. High-speed video was used to measure the velocity, pitch, and yaw of the projectile on the impact and exit side of the targets, as well as the debris spall on the exit side of the concrete targets. Acceleration data was measured to describe the penetrators perforation through reinforced steel targets. This work includes background information on the test series, an overview of the testing facilities and experimental design, and an analysis of the tests that have been conducted to date. These data from these tests will be used to develop engineering level and high-fidelity models for better understanding and prediction of PDV impact effects against various target types.

TRAINING IX

SIMPLIFIED FINITE ELEMENT MODEL GENERATION & POST-PROCESSING FOR EXODUS II AND SIERRA SD/SM

Giri Prasanna, Altair Engineering
Jason Krist, Altair Engineering
Kory Soukup, Altair Engineering

Many companies that perform shock and vibration analysis use government or open-source tools and solvers to perform finite element analysis (FEA). Among these tools are the common Exodus II model and the Sierra Mechanics solvers – developed by Sandia National Laboratories.

The concept of employing Exodus II is to build a common database for multiple solver codes rather than a solver code specific format. Sierra solvers provide simulation capabilities for thermal, fluid, aerodynamics, solid mechanics, and structural dynamics. One of the challenges analysts face with using Exodus II and Sierra solvers is the narrow options for model generation (mesh, material, property, boundary conditions, and other solver-specific parameters).

Through the integration of a commercially available high-performance finite element preprocessor, HyperWorks, model preparation from the import of CAD geometry to the export of a solver run, for Sierra SD/SM disciplines/solvers, is now easily achievable.

Expansion of Structural Dynamics features, the addition of Solid Mechanics support, and an improved process centric interface, has resulted in a more intuitive, innovative, efficient and powerful preprocessing tool.

This training details the current interface to the Exodus II (Sierra SD/SM) user profile and an improved process for building models in the Exodus II and Sierra formats. Within the interface CAD import, geometry modification/creation, model meshing, post-processing, and potential for model optimization will be demonstrated. Editing of existing Exodus II/Sierra formatted models to incorporate design changes will also be illustrated.