SAVE
SHOCK & VIBRATION EXCHANGE

ABSTRACTS

95th Shock & Vibration Symposium

September 21 - 25, 2025
New Orleans, LA

TABLE OF CONTENTS

SESSION 1: NEW ENGINEERS & ATTENDEES 101

U.S. NAVY EQUIPMENT SHOCK QUALIFICATION
Kurt Hartsough, 901E&T

Since World War II, the U.S. Navy has faced the threat of underwater explosions from mines, torpedoes, and other ordnance. This brief reviews the background and evolution of the Navy's shock program and explains the roles and responsibilities of engineers involved in shipboard equipment shock qualification

SHOCK-PROOF: NAVIGATING MIL-DTL-901E TESTING - AN EXPLOSIVELY ENTERTAINING INTRO TO MIL-DTL-901E TEST METHODS
Jeff Morris, HI-TEST Laboratories

This presentation provides an quick overview and comparative analysis of MIL-DTL-901E shock testing methodologies utilizing the Lightweight Shock Machine (LWSM), Medium Weight Shock Machine (MWSM), Deck Simulating Shock Machine (DSSM), and Heavyweight testing using the Floating Shock Platform (FSP). MIL-DTL-901E is the U.S. Navy military specification that establishes shock testing criteria for shipboard equipment subjected to high-impact shocks, ensuring continued operation during near-miss explosive events. Each test platform addresses different categories of equipment based on weight, type of vessel (surface ship or submarine), equipment mounting orientation, and how the equipment is mounted with respect to Class and location. The LWSM and MWSM are used primarily for qualification testing of small to medium-sized components, offering controlled, repeatable shock environments. Heavyweight testing on a FSP provides full-scale shock testing for missioncritical and large equipment in a floating barge environment, simulating underwater explosion effects in a realistic operational setting. The DSSM serves as an intermediate testing method, simulating deck-mounted equipment shock responses that were generally provided in the past during heavyweight shock testing in a FSP with a Deck Simulating Fixture (DSF).

WHAT IS AN ISOLATOR? FUNDAMENTALS OF THE FUNCTION OF AN ISOLATION MOUNT
Shawn Czerniak, Hutchinson Aerospace & Industry

At a very basic level an Isolator (isolation mount, shock mount, resilient mount, etc.) works as a mechanical filter installed within a system as a way of changing how energy passes from one side of the system (foundation, structure, etc.) to another (equipment, component, etc.). This session will review some key fundamentals of isolation, including the ways in which energy moves into an isolator (shock and/or vibration input) and how the isolator changes that energy as it passes to the other side (displacement and acceleration output). Some common isolator variables (stiffness and damping) will be discussed and their impact on shock/vibration performance will be reviewed. This session should help new/young Engineers in our community better understand how isolators function and the important role that isolators play within the design of a system.

VIBRATION TEST SYSTEMS IN THE LAB
Jade Vande Kamp, Vibration Research Corp.

Understanding the basic mechanics of vibration shaker systems is fundamental to laboratory safety and reliable testing. This presentation provides a practical overview of typical vibration test systems.

Attendees will gain insight into the various types of electrodynamic, servo-electric, and servo-hydraulic shakers, as well as alternative excitation methods of inducing controlled vibration in test articles.

The discussion will include sizing and performance considerations—such as force ratings, displacement limits, frequency range, and fixture mass—that influence the selection and configuration of a vibration system. It will highlight common limitations and trade-offs encountered in real-world test setups, helping engineers design more effective and reliable tests. Whether you're new to vibration testing or looking to refine your understanding of laboratory shaker systems, this session will provide a solid technical foundation and practical guidance.

SAMPLING & SPECTRAL ANALYSIS: FROM FFT TO SRS; A PRACTICAL OVERVIEW FOR ENGINEERS

Dr. Ted Diehl, Bodie Technology, Inc.

This talk offers a practical introduction to Sampling and Spectral Analysis, tailored for Mechanical Engineers. It begins with the fundamentals of sampling theory, emphasizing the risks of aliasing and how to avoid them through proper sample rate selection and anti-alias filtering.

We then explore core frequency-domain analysis techniques, starting with the Discrete Fourier Series (DFS) and Discrete Fourier Transform (DFT), and clarifying the commonly used term FFT (Fast Fourier Transform). For random data analysis, the Power Spectral Density (PSD) is a standard tool, while transient shock analysis often relies on the classical absolute acceleration Shock Response Spectrum (SRS) and the more informative Pseudo Velocity Shock Spectrum (PVSS).

Throughout the presentation, concepts are explained in clear, accessible language, supported by practical examples drawn from physical measurements and numerical transient simulations. Attendees will gain a solid understanding of these foundational tools and their relevance to real-world shock and vibration analysis.

SESSION 2: AERIAL DELIVERY METHODOLOGIES, TECHNOLOGIES AND SOLUTIONS

UPDATE ON DEVELOPMENT AND USE OF RUSB

Dr. Daryoush Allaei, QRDC
Prof. Arezoo Emdadi, Missouri University of Science and Technology

During the 2024 SAVE symposium, the aerial delivery community was presented with an overview on the Reusable Universal Skid Board (RUSB). In this presentation, the development, additional features, and performance of RUSB at various Air Force bases, will be discussed.

RUSB is designed, manufactured, and flight-tested for military airdrop training applications. The Container Delivery System (CDS) typically employs gravity drops to deliver equipment too heavy for individual paratroopers, as well as supply bundles for ground units. Since the Korean and Vietnam Wars, CDS has been refined to operate in darkness and adverse weather conditions, enhancing aircraft capabilities to supply troops covertly. This efficiency has made CDS bundles the most common method of aerial supply for both soldiers and civilian aid. Approximately eighty-five to ninety percent (85 to 90%) of US military airdrops are conducted training riggers and pilots, with CDS bundles weighing between 550 and 2,200 pounds being among the most frequently dropped platforms. Although initially designed for CDS airdrop training, RUSB can also be applied to other airdrop platforms such as CEPs, LCLAs, and Door Bundles.

RUSB replaces the traditional plywood skid, which can only endure 1 to 2 drops before becoming unsuitable for airdrop use. In contrast, RUSB has demonstrated the capability to withstand between thirty-five and one hundred (35-100) drops. The use of RUSB has improved Air Force readiness by sustaining or increasing the number of training airdrop flights for aircrews. Due to supply chain issues, maintaining an inventory of plywood skids has become increasingly challenging. RUSB addresses this issue by enhancing the reusability of airdrop training items. It was field-tested at Little Rock Air Force Base in Arkansas during the week of March 4, 2024. Additionally, RUSB has received Unilateral Authorization for Training (UAT), allowing it to be procured and used by US Air Force bases. RUSB has resulted in substantial financial savings for the Air Force, paying for itself within less than 12 months or 50 airdrops, whichever occurs first. RUSB has been successfully utilized at several Air Force bases in the USA, Germany, and Japan.

UPDATE ON DEVELOPMENT AND USE OF REAL

Dr. Daryoush Allaei, QRDC
Prof. Arezoo Emdadi, Missouri University of Science and Technology

In the 2024 SAVE symposium, the aerial delivery community was presented with an overview on the Reusable Energy Absorbing Layer (REAL). In this presentation, an update on the development, added features and performance of the reusable products at a dozen Air Force bases will be presented.

REAL modules are specifically designed, manufactured, and flight tested for military airdrop training and application within the Container Delivery System (CDS), which typically employs gravity drops. The CDS system is instrumental in delivering equipment that is too heavy for individual paratroopers to carry, as well as bundles of supplies for ground units. Since the Korean and Vietnam Wars, CDS has evolved to function effectively in low-visibility conditions, such as darkness and adverse weather, thereby allowing aircraft to supply troops without exposing their positions. This operational efficiency has established CDS bundles as the predominant method of aerial resupply for both military and humanitarian aid.

A substantial portion, approximately 85% to 90%, of U.S. military airdrops are conducted for the purpose of training riggers and pilots. One of the most frequently deployed platforms involves CDS bundles weighing between 550 to 2,200 pounds. Although REAL was initially conceptualized for CDS airdrop bundle training, its application extends to other airdrop platforms such as CEPs, LCLAs, and Door Bundles. REAL modules have replaced the disposable cardboard honeycomb products, which were only viable for a single use. The implementation of REAL has significantly enhanced Air Force readiness by either increasing or maintaining the number of available training airdrop flights for aircrews. The challenges posed by maintaining an inventory of disposable products due to supply chain disruptions have been mitigated by REAL's reusability and domestic manufacturing in Minnesota, ensuring it is a USA-made product. REAL has been successfully utilized by several Air Force bases across the United States, Germany, and Japan.

STRENGTH TEST - PLYWOOD SKID VERSUS REUSABLE SKID BOARD

Dr. Daryoush Allaei, QRDC
Brad Womack, Little Rock AFB

This report presents the results of strength tests comparing military grade plywood skids and Reusable Universal Skid Boards (RUSB) used in CDS aerial deliveries. Three types of tests were conducted: 1) Pull tests were used to assess the strength of tiedown holes; 2) Bending tests evaluated the structural properties of AA grade plywood skids versus RUSB; 3) Static load applications measured deflection versus load to determine stiffness for both materials. The rigging team at Little Rock AFB in Arkansas performed these tests in 2024 and 2025.

CDS (Container Delivery System) employs gravity drops to deliver equipment and supply bundles too heavy for individual paratroopers, supporting ground units in various operational conditions. Since the Korean and Vietnam Wars, CDS methods have adapted to function in low-visibility and adverse weather, enabling resupply operations in diverse environments. CDS bundles, typically weighing between 550 and 2,200 pounds, are a common means of aerial supply for military and civilian purposes. The platform currently uses AA or AC grade plywood as its base flat board. Plywood generally withstands 1 to 3 uses and is affected by environmental factors such as humidity and rain. RUSB, constructed from high-density polyethylene (HDPE), has been introduced in several Air Force bases as an alternative to plywood. This work compares the performance of Plywood with that of RUSB.

RUSB serves as a substitute for traditional plywood skids, which typically endure 1 to 3 airdrops before becoming unsuitable for further use. RUSB has shown the ability to withstand approximately thirty-five to one hundred drops. Field testing was conducted at Little Rock Air Force Base in March 2024, resulting in RUSB receiving Unilateral Authorization for Training (UAT) for procurement and use at US Air Force bases.

The strength tests indicated that RUSB can support higher loads compared to AA or AC grade plywood. In pull and bending tests, plywood fractured while RUSB experienced reversible deformation, returning to its original shape after being left on a flat surface for 30 minutes. These findings indicate that RUSB performs differently than plywood when used in CDS aerial delivery contexts.

AUTOMATIC AIRDROP COUNT TOTALIZER (AACT)

Casimir Sienkiewicz, Caztek Engineering
Pete Wolf, Robinson Rubber Co.
Dr. Daryoush Allaei, QRDC, Inc.

QRDC, Robinson Rubber, and Caztek have developed an integrated, Automatic Airdrop Count Totalizer (AACT) for reusable REAL and RUSB airdrop protection skid system. These durable skids, designed as replacements for single-use plywood and cardboard, have a finite lifespan, making accurate drop tracking crucial for inventory management and cost efficiency.

AACT is a low-maintenance, robust sensor/counter directly integrated into the RUSB. Utilizing a MEMS accelerometer, it automatically detects and counts landing impacts. Users can query the total impact count via a tactile button, which is then displayed on an LED array.

This battery-powered, low-power consumption system is designed to outlast the RUSB's approximate 100-landing lifespan. Its slim, fully potted enclosure is discreetly installed within the skid's existing thickness, ensuring it withstands the harsh conditions of air drops. By providing precise drop data, AACT helps optimize the use of each RUSB, maximizing the life of the entire inventory and significantly reducing operational costs.

REDESIGNING OF COMBAT EXPANDABLE PLATFORM (CEP)

Dr. Daryoush Allaei, QRDC
Pete Wolf, Robinson Rubber Co.
Dr. Daryoush Allaei, QRDC, Inc.

Our team is developing an advanced replacement for Combat Expandable Platforms (CEPs), referred to as Lightweight Expandable Aerial Delivery (LEAD), with the aim of enhancing platform reusability and strengthening military readiness.

This paper provides an overview of the LEAD design and outlines its key features. For example, the MRZR4-900/Diesel can be rigged on a wooden 144x75” CEP using two G-12E cargo parachutes, configured for low-velocity airdrop operations from C130 or C17 aircraft. The vehicle itself has an empty weight of 1,937 pounds and dimensions of 59.5” in width, 141” in length, and 74” in height. Any additional cargo must not exceed 160 pounds in weight or 22” in height. Similar CEP configurations are employed for airdropping boats and jet skis. The wooden CEP weighs approximately 650 lbs when dry, increasing to around 850 lbs when exposed to moisture or rainfall. This presents a challenge, as platforms often remain outdoors for extended periods, accumulating moisture and subsequently increasing in weight. Heavier platforms necessitate either reduced payloads or larger parachutes. Wooden CEPs are typically suitable for only a few drops before they become unfit for further use, and their construction requires a crew of four over a two-week period.

Our objective is to replace the current wooden CEPs with a lightweight, modular platform featuring integrated energy absorption, thereby addressing the limitations of existing models. LEAD is designed to improve reusability, virtually eliminate the impact of moisture on platform weight, reduce assembly time to two hours with a two-person crew, lower overall weight, and enhance operational readiness. The foundational structure for LEAD will leverage the established Reusable Universal Skid Board (RUSB), which has been successfully deployed in high-velocity airdrops over 450 times by multiple Air Force aerial delivery bases since mid-2024.

SESSION 3: MUNITIONS FOCUSED MATERIAL TESTING AND MODELING

SHELL ELEMENT PERFORMANCE IN PREDICTING PROJECTILE EXIT VELOCITY

Mr. Adam Polakowski, Torch Technologies
Dr. Matthew Neidigk, AFRL
Dr. Jairus Bernard, Torch Technologies

Shell elements offer an alternative approach to modeling thin-walled structures while minimizing computational cost. This presentation aims to provide guidance on when shell elements can be reliably used for impact/penetration simulations as opposed to higher-fidelity hexahedron elements. Penetration simulations were performed using Sandia National Laboratory’s finite element analysis software Sierra/SolidMechanics. The analysis includes a parametric study of varying plate thickness, projectile radius, projectile velocity, and mesh resolution. Accuracy was quantified by comparing the percent difference in residual velocity between the shell and hex models. These results demonstrate whether shell elements can accurately portray impact behavior by offering a balance between computational efficiency and reliable predictions of projectile velocity and structural integrity.

DEVELOPMENT OF HIGH TEMPERATURE SURVIVABLE ELECTRONICS POTTING

Dr. Matthew Neidigk, AFRL
Dalton Gavin, Torch Technologies

This work presents the development and characterization of composite materials designed for high-temperature survivability in electronic potting applications. Each material underwent comprehensive viscoelastic characterization across a range of strain rates and temperatures. The nonlinear viscoelastic Simplified Potential Energy Clock (SPEC) constitutive model was then calibrated for each material to predict time- and temperature-dependent behavior. Finite element simulations were performed using the Sandia National Laboratory (SNL) coupled physics code Sierra/SolidMechanics to model representative packaged electronic assemblies to assess thermal-mechanical response under service-relevant conditions. This integrated experimental-modeling approach provides critical insight into material selection and design criteria for advanced electronics packaging in harsh environments.

MODELING POLYMER-BONDED EXPLOSIVE DAMAGE IN DETONATOR GEOMETRY

Mr. Dalton Gavin, Torch Technologies
Dr. Matthew Neidigk, AFRL
Dr. Michael Nixon, Torch Technologies

Temperature is an important design consideration for ensuring the reliable performance of detonators as material properties of polymer-bonded explosives (PBXs) can vary significantly across their operating temperature range. This study investigates the effects of confinement on the mechanical response of PBX pellets as a function of coefficient of thermal expansion (CTE) mismatch. CTE mismatch between the PBX and surrounding component materials can induce gap formation or closure, thus altering the level of confinement on the pellet. Coupled with the temperature dependency of PBX moduli, the environment prior to mechanical shock can significantly influence the loading conditions experienced by the PBX. Using Sandia National Laboratory's Sierra/SolidMechanics, a coupled implicit-explicit finite element analysis software, we evaluate PBX deformation/damage resulting from thermal cycling and subsequent mechanical shock at temperature. This PBX response is predicted using a new constitutive model that captures complex viscoelastic, viscoplastic, and damage behavior.

VIRTUAL ARENA TEST FOR THE 155MM M795 ARTILLERY SHELL

Dr. Jarius Bernard, Torch Technologies
Dr. Matthew Neidigk, AFRL
Brandon Nesbitt, Torch Technologies

Virtual arena tests offer a cost-effective alternative to traditional arena tests for munition fragmentation, but accurate prediction remains a challenge. This presentation details a methodology for improving virtual arena test fidelity through enhanced material modeling. The objective of this study was to predict the breakup, trajectory, and velocity of fragments for the M795 155mm artillery shell using virtual arena testing and to compare the simulation results to experimental data. Virtual arena tests were performed using the Sandia National Laboratory finite element software, ZAPOTEC. The simulation results were then converted to Joint Munition Effectiveness Manual (JMEM) fragment zone data format thus allowing for direct comparison with experimental arena test data. The approach involved characterizing HF-1 steel, the munition casing material, to populate the Johnson-Cook (JC) strength and damage model. The JC damage model was populated using both traditional and non-traditional specimen geometries, and the results were compared. Key findings show that employing a refined material characterization technique significantly improved the predicted fragment count. This demonstrates the importance of appropriate material characterization for accurate fragmentation predictions.

SESSION 4: DYSMAS I

RESPONSE OF BURIED SURROGATE MINE TARGETS TO SEABED UNDEX: 2025 TEST SUMMARY

Roger Ilamni, NSWC Indian Head
Dr. Brad Klenow, NSWC Indian Head
Greg Harris, ATR
Swen Metzler, WTD-71
Sven Diedrchsen, WTD-71
Manfred Krüger, iABG

Previous symposia have provided updates on a U.S.-Germany DYSMAS Project Arrangement focused on enhancing the capabilities of the DYSMAS code to predict shock transmission of underwater explosion (UNDEX) loading into seabed materials. This collaboration has encompassed the characterization of seabed material, the development of material model parameters for application within DYSMAS, and the execution of multiple tests at WTD-71's Underwater Test Facility (UTA) in Elpersbüttel, Germany, to generate validation datasets that include pressure measurements within the seabed.

The U.S.-Germany DYSMAS Test Team completed the second of a three-part UNDEX test program in June 2025 at the UTA test site. The primary objective of this test was to gather shock response data from a buried surrogate mine target subjected to explosive charges detonated on the seabed. The surrogate mine was instrumented with accelerometers and surface pressure gages to capture the dynamic response under shock loading. This talk will review the test setup and present the collected data. These data are critical for the ongoing validation of the DYSMAS code, particularly in the context of buried mine neutralization studies, allowing for improved prediction of shock propagation and target response in complex seabed environments.

RESPONSE OF BURIED SURROGATE MINE TARGETS TO SEABED UNDEX: SIMULATIONS OF RECENT VALIDATION TESTING

Dr. Brad Klenow, NSWC Indian Head
Roger Ilamni, NSWC Indian Head
Manfred Krüger, iABG

Developing a credible capability to predict scenarios for the neutralization or defeat of buried mines through the use of small, controlled underwater explosions is a current research area that involves two primary topics: the transmission of underwater shock waves into the seabed materials and the response of structures buried in the seabed to those transmitted waves.

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 June 2025. This paper reviews the setup of that test series, the approach to modeling the tests in DYSMAS, 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 to support buried mine neutralization applications.

UNDEX PROPAGATION ALONG NON-UNIFORM SEABED

Dr. Joseph Ambrico, NUWC Newport
Dr. Emily Guzas, NUWC Newport
Ryan Chamberlin, NUWC Newport
Eugenia Stanisauskis Weiss, NUWC Newport

The seafloor consists of a wide variety of topography and material types, all of which affect the reflection, transmission, and propagation of underwater explosions (UNDEX). While parts of this domain are fairly flat, other areas include slopes or localized dips and crests. Physics-based modeling and simulation (M&S) tools can utilize fluid-structure interaction (FSI) to estimate UNDEX propagation in the presence of non-uniform seabed topography. This presentation covers key scenarios for UNDEX on the seabed and discusses the application of FSI simulations, using the Navy's DYSMAS code, to predict shock wave propagation.

SIMULATING NEAR-FIELD UNDEX AGAINST SUBMERGED CONCRETE STRUCTURES

Dr. Emily Guzas, NUWC Newport
Ryan E. Chamberlin, NUWC Newport
Dr. Jay Ehrgott, US Army ERDC
Dr. Josh Payne, US Army ERDC
Roger Ilamni, NSWC Indian Head

The maritime domain encompasses a range of damage effects, including those from above the waterline, near the waterline, and underwater explosions (UNDEX). This domain contains many different structures, composed of largely single-material substances or multi-material, composite substances (e.g. concrete). Physics-based modeling and simulation (M&S) tools can utilize fluid-structure interaction (FSI) to estimate the effects of near-field UNDEX sources on submerged structures composed of concrete material. This presentation covers key scenarios for UNDEX near concrete structures and discusses the application of FSI simulations, using the Navy's DYSMAS code, to predict structural response.

EOS DEVELOPMENT FOR NON-IDEAL EXPLOSIVES

Sujan Bashyal, ATR
Dr. Jeff St. Clair, NSWC Indian Head
Dr. Tom Mcgrath, NSWC Indian Head

No abstract available.

VENDOR SESSION A: EXHIBITOR PRESENTATIONS

PHANTOM CINE ANALYZER – A PYTHON BASED OPEN-SOURCE PLATFORM

Dr. Kyle Gilroy, Vision Research

The Phantom Cine Analyzer is a novel, free, and open-source software platform developed in Python, designed for comprehensive image analysis across diverse applications. Leveraging Python’s robust ecosystem, including libraries such as OpenCV, NumPy, and SciPy, Cine Analyzer enables precise measurements, object tracking, and rotational and vibrational analysis from video data. The platform supports high-resolution video analysis, sub-pixel tracking routines, and customizable workflows, making it accessible to users with varying levels of technical expertise. Its modular architecture

facilitates simple tasks, such as distance and angle measurements, as well as complex analyses, including multi-object tracking, frequency-based vibrational studies, and particle tracking velocimetry (PTV). This abstract outlines the software's technical capabilities and its applications, followed with practical examples spanning academia, industry, and government.

What Should a Resonant Plate Shock Test Sound Like?

Dr. Carl Sisemore, ShockMec Engineering

Resonant plate shock testing is often considered to be an art where it should in fact be very repeatable, consistent and easy to execute. The test method actually has many acoustic characteristics since it is defined by a desired primary response frequency. Just as there is an art to ringing a bell, there is a simple art to ringing a resonant plate. How do you know if the test you just performed was a good test? The simplistic answer is often whether or not the resulting shock response spectrum fell within the test specification tolerance bounds. However, the more correct answer is often how did the test sound? Too often, we have a tendency to look solely at the shock response spectrum and ignore the more simplistic criteria of sound. What is a resonant plate test supposed to sound like and perhaps more importantly, what did your test sound like? Did it sound melodious or did it sound more like a crash? A high-frequency test should sound like a high-frequency musical chord. Likewise, a low-frequency test should ring a low-frequency chord. Resonant plate shock test data will be presented from several low- and high-frequency plates along with analyzed acoustic data recorded during the tests. The data shows that a well executed resonant plate should in fact produce a clear musical chord at the primary test specification frequency.

Viper::Blast for Advanced Airblast Simulations

Dr. Peter McDonald, Viper Applied Science

Join us for an insightful vendor session exploring the advanced capabilities of Viper::Blast — a GPU-accelerated Computational Fluid Dynamics (CFD) tool purpose-built for airblast simulations. Viper::Blast is a leading solution for blast analysis and extreme load modeling, offering high performance and ease of use through GPU acceleration and an intuitive interface. This session will highlight the features that make Viper::Blast indispensable for engineers and researchers working in defense, aerospace, civil engineering, and related fields. We'll begin with a look at the simulation engine's GPU-powered performance, enabling rapid turnaround without compromising accuracy. We'll also demonstrate the user-friendly workflows that make Viper::Blast accessible to both new and experienced users. The session will then showcase key workflows including building damage assessment, coupled simulations, and injury prediction. Real-world examples will highlight practical applications, with a particular focus on the updated post-processing pipeline and new options for integration with finite element tools. Whether you're a current user or exploring modern CFD tools for blast analysis, this session offers valuable insights into the evolving capabilities of Viper::Blast and how it can support your work.

Innovative Approaches to Transient Shock Data Acquisition and Analysis

Jim Churchill, m+p International

Shock Response Spectrum testing typically comes in a few different forms; shaker shock, mechanical shock (MIPS or Tuned beam) or pyro shock. How test engineers go about conducting these tests depends on their facilities and equipment. m+p international has implemented several features to our VibControl software to simplify the process of SRS Shock compliance testing regardless of the methods used. This presentation will explore the features and demonstrate how they can help the test engineer to safely and confidently capture, analyze and verify compliance.

EXPERIMENTAL CHARACTERIZATION OF NONLINEAR STIFFNESS AND DAMPING IN TAYLOR DEVICES' PUMPKIN ISOLATORS IN SHEAR, ROLL, AND ANGLED INSTALLATIONS

Gordon Fox, Taylor Devices

This will present experimental characterization of Taylor Devices' Pumpkin isolators when mounted in shear, roll, and combined shear/roll angled installations. Detailed nonlinear stiffness and damping results will be presented, including effects of input frequency and amplitude. Coupling between axes will be discussed, such as how compression affects shear stiffness. Some ideal applications of Pumpkin isolators will be shown.

TRAINING I: MIL-STD-167 QUALIFICATION AND BEST PRACTICES

MIL-STD-167 QUALIFICATION AND BEST PRACTICES

Thomas Borawski, *NSWC Philadelphia*

Training explaining the basic concept of MIL-STD-167-1A Type I Vibration Testing, responsibilities during and path to gaining qualification. Additionally, a review of some common pitfalls during the qualification process, and best practices to avoid those pitfalls.

SESSION 5: UNDEX

RECENT IMPROVEMENTS IN DSTL'S CAPABILITY FOR MODELLING UNDEX AND ASSOCIATED STRUCTURAL RESPONSE

Elliot Tam, DSTL
Mark Whittaker, DSTL
Ajen Limbu, DSTL
Arno Klomfass, EMI
Andrew Tyas, Blastech
Dan Pope, DSTL

Accurately simulating the action of Underwater Explosive loading on military platforms and other assets is of vital importance when undertaking design and consequence analysis in the field of Defence and Security. Simulating the complex physics associated with loading development within a water environment whilst capturing the response of geometrically-complex, pre-loaded structures presents a significant challenge for numerical software, particularly when dealing with entities fabricated from strain-rate sensitive materials. Recognising this, Dstl has been working with various software developers and collaborative partners to couple the functionality of different codes with the intention of attaining a comprehensive, robust modelling capability. This paper describes the individual strengths of each code together with the approach taken to couple the key functionality associated with the interaction of threats with structures. The work has been underpinned by comparing numerical predictions to the output from a series of controlled experiments involving a number of typical UNDEX-loaded structural entities.

UNDEX, FSI & GPUs: High-Fidelity Blast–Structure Interaction with Viper & OpenRadioss

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

High-fidelity UNDEX and fluid–structure interaction (FSI) studies have typically sat within government labs or large defence contractors. This talk shares early results from our effort to make these analyses more accessible: a GPU-accelerated UNDEX fluid solver (Viper) used alongside the open-source explicit finite element code OpenRadioss to evaluate blast–structure response.
We present validation cases for the UNDEX solver and illustrative FSI applications. The fluid side uses a multi-material inviscid formulation with interface tracking to resolve shock fronts and fluid interfaces; the structural side in OpenRadioss captures large deformations, plasticity and failure. Emphasis is on practical workflows—how loads are generated and transferred, time-integration choices, and how mesh resolution and constitutive modelling influence response metrics.

This session will:

- Outline the numerical approach for UNDEX and FSI and the data-exchange workflow.
- Present initial test cases with simplified geometries and key response features.
- Highlight open challenges (coupling stability, advanced materials, validation gaps).
- Set out near-term directions and planned applications.

The Analysis of Interaction between Bubble and Double-layer Structure with Hole

Dr. Yuanxiang Sun, Beijing Institute of Technology

When ships and submarines are attacked by underwater explosion, they will be subjected to the shock wave and bubble load generated by explosive underwater explosions. The warship is mostly using double-deck grillage structure that are usually filled with ballast water. When it is under the impact of a near-field underwater explosion load produced by torpedoes and other underwater weapons, the outer structure is easy to break. The subsequent bubbles pulsation will be affected by the break. However, there is a lack of systematic studies on bubble pulsation and bubble jet in the double-layer structure with break. To study the interaction between the underwater explosion bubble and the ship's double-layer structure, the double-layer plate model with a circular hole was designed in this paper. The bubble pulsation and wall pressure caused by the bubble were obtained through experiments and numerical simulation. The variation patterns of bubble evolution and bubble loads under different conditions were compared and analyzed. The main conclusions are as follows:

(1) When the inter-plate water level is empty, the high-pressure gas inside the bubble is rapidly ejected into the double-layer plate, so that the inner plate is successively subjected to gas-liquid two-phase jet load, water jet load and surge load, of which the gas-liquid two-phase jet load (Pb1) is notable. When the inter-plate water level is full, the bubble is divided into the "outer bubble" and the "inner bubble", and both "inner bubbles" and "outer bubbles" form upward jets, and the "outer bubbles" collapse load (Pb3) and the water jet load (Pb4) is notable.
(2) When the inter-plate water level is between empty and full, the "outer bubble" forms a downward water jet, which can't load on the inner plate, while the water spike load of the "inner bubble" (Pb2) and the collapse load of "outer bubble" (Pb3) can load on the inner plate, which is the main load forms. The increase of Standoff distance R or Double-layer plate distance l makes the bubble collapse load and water spike load show a decreasing trend, while the increase of d makes the water spike load increase.

SESSION 6: PRACTICAL VIBRATION MODELING

VIRTUAL SHAKER TESTING: SIMULATE AND EMULATE SPACECRAFT RESPONSES FOR NOTCH PREDICTIONS

Umberto Musella, Siemens Digital Industries Software
Dr. Alberto Garcia de Miguel, Siemens Digital Industries Software
Umberto Musella, Siemens Digital Industries Software
Ruben Araujo, Siemens Digital Industries Software
Dr. Mattia Dal Borgo, Siemens Digital Industries Software
Dr. Emilio Di Lorenzo, Siemens Digital Industries Software

Vibration control tests are performed to verify that a spacecraft and all its sub-components can withstand a specified vibration environment. These tests are often carried out under extreme time pressure and the cost of the hardware at stake is extremely high. Early and accurate predictions of the spacecraft responses are critical. A digital twin of the entire vibration control system (spacecraft, shaker and controller) can be adopted to simulate and de-risk the physical system in a virtual environment. The approach, also known in the dynamic environmental testing community as Virtual Shaker testing, proves to be extremely valuable in case transient events need to be predicted. A good example is the evaluation of the spacecraft responses during sine control tests. For these tests, frequency-based forward predictions are not reliable due to the transient nature of the sine excitation and the (re-)action of the controller itself. The goal of this work is to propose a solution that would allow environmental test engineers to predict the responses of a spacecraft during a vibration control test and evaluate beforehand the effects of different setup parameters (e.g. control/notch compression factor).

The proposed architecture opens also the doors for real time response predictions of unmeasurable quantities (virtual sensing).

VIRTUAL SHAKER TESTING BY COMBINING SYSTEM SUBSTRUCTURES

Dr. Mattia Dal Borgo, Siemens Digital Industries Software
Thade Kilian Pfluger, University of Trento
Umberto Musella, Siemens Digital Industries Software
Dr. Silvia Vettori, Siemens Digital Industries Software
Dr. Alberto Garcia de Miguel, Siemens Digital Industries Software
Dr. Emilio Di Lorenzo, Siemens Digital Industries Software

Vibration testing of spacecraft or other device under test (DUT) is used to verify their reliability to the operational environment. These tests consist in fixing the DUT on a shaker platform that is driven by a vibration controller that in turn tries to replicate as close as possible the reference dynamic environment at the shaker-DUT interface.

However, the dynamic interaction between the DUT and the shaker testing facility can compromise the performance of the controller and the accuracy of the replication. To overcome this issue, the so-called virtual shaker test (VST) can be performed by running the controller on a time-domain dynamic model of the system under test (shaker and DUT) in order to predict the results of the physical test ahead of its execution. These VSTs can then be used to fine tune the settings of the control strategy to achieve the desired test outcome.

In the past great dedication went into detailed numerical modelling of the systems involved in the test, where the finite element model (FEM) of the shaker was combined with the FEM of the spacecraft and the electrical or hydraulic circuits of the shaker was then applied to the combined FEM model. Although a number of successful examples exists of such an approach, there are two main drawbacks. The first is related to the difficulty of creating an accurate model of the shaker testing facility that considers changing environmental conditions, ageing, and maintenance, to name a few. The second is sharing confidential "white-box" models between the test facility owner and the spacecraft manufacturer that can only be done in a limited number of projects.

In this paper we present a novel approach to combine the dynamic models of the shaker testing facility and of the DUT. In this approach, initially, the shaker and the DUT are modelled separately, and their respective models can either be data-driven or physics-based, or a mix of these two. Then, the two models are combined into one via frequency based dynamic sub-structuring (FBS). Once the combined frequency domain model is computed, it is then converted to an executable digital twin in discrete state-space form to be used in a VST.

Firstly, we derive the experimental as well as the numerical models of a single-axis electromechanical shaker and an aluminium structure as DUT when they are uncoupled. Secondly, we couple the two models via the FBS approach (using different combinations of experimental and numerical models), and we compare the results with the experimental system identification of the assembled system. Finally, we convert the coupled model to state-space and perform a VST to then compare it with the corresponding physical test to evaluate the accuracy of the prediction.

SOUNDING ROCKET FLIGHT VIBRATION NTL COMPOSITE SPECTROGRAM

Dr. Ricky Stanfield, Corvid Technologies

The traditional approach for combining the Power Spectral Density (PSD) results from different sounding rocket flight vibration data sets is to compute an average PSD profile for each rocket motor stage of a given sounding rocket mission, and then combined it with the PSD profiles of similar data sets using a Normal Tolerance Level (NTL) method. This works well, but forces the analyst to decide about the portion of flight vibration data over which to compute the mean PSD since the underlying data is only approximately stationary for small segments of time. Chose too widely and the average PSD results might be reduced by periods of decreasing vibration. Choose too narrowly and one may miss an important spectral feature outside the selected window. In either case one may lose useful time-varying information. An alternative is to retain all the PSD results from a given data set in the form of a spectrogram that is properly scaled for time increments and frequency bins. The spectrograms from different related data sets can then be aligned in time and frequency like registering the color separations in a newspaper photograph. The NTL calculations can be carried out using all the data values for each "pixel" of the overlayed spectrograms using the appropriate logarithmic mean and standard deviation, and NTL k-Factor to form an NTL Composite Spectrogram. This can be compared to the maximum Composite Spectrogram formed from the maximum value in each frequency bin across all the underlying individual spectrograms. It will be shown that the maximum envelope of the NTL Composite Spectrogram captures the same mean PSD profile at the traditional approach NTL mean PSD approach, while preserving the time-varying insights of a spectrogram and without the need to select down-select a specific evaluation time window a priori.

Introduction to Genetic Algorithms for Vibration and Shock Design

Dr. Charles Hull, Lockheed Martin

Genetic algorithms, a subset of artificial intelligence and machine learning, are becoming increasingly popular for problem solving in mechanical engineering. This study shows how genetic algorithms can be leveraged for the design of structures subjected to vibration and shock. A simple lumped parameter example is presented whereby a motion objective is optimized through selection of stiffness and damping parameters. The example introduces the framework of genetic based design optimization, providing insights while serving as a launching point for applications in complex structures and systems.

Limits of Vibration Response in Aircraft: A Challenge to Current Standard in Avionics Vibration Testing

Marc Heffes, Northrop Grumman

An estimate for maximum random vibration response that occurs on avionics units has been investigated. The estimate covers a wide range of avionics units hard mounted into the vast majority of fuselage locations of a wide range of aircraft. It was arrived at by attempting to create force, stiffness and mass parameters that maximize vibration response. Using Finite Element Analysis (FEA) many permutations of possible stiffness and mass of both the airframe and the avionics unit were used to find a maximum value. The value calculated is 2.0 G RMS for response of the primary mode of avionics units with a mass between 25 to 120 lb for 100 to 600 Hz frequency range. This value is considerably lower than the response that units are often exposed to in standard vibration tests.

This paper challenges the current standard in avionics dynamics which uses simple PSD envelopes of measured vibration and is acceleration controlled. That method consistently results in the overall response of tested units that greatly exceeds the 2.0 g rms estimate and the measured data from which the test condition is based, often by factor of 10. This is not justified when one examines the physics of actual dynamics systems like an airframe. The current standard is based on misunderstanding of how the vehicle interacts with units attached to them. The method doesn’t account for the high apparent mass of a typical unit compared to the low apparent force that the measured acceleration represents. This leads to the incorrect assumption that the measured response will be highly amplified.

This paper shows that there are multiple defendable methods one can use to limit response of hard mounted avionics units in test without collecting in-situ measured response data on units. This is much easier than it may seem because the goal is limited. To justify that the response will be limited, one only need to show dynamics of a given system is not an extreme case. Specifically, that the dynamic forces, stiffness, mass are not well outside the normal range discussed herein.

SESSION 7: MUNITIONS FOCUSED MATERIAL TESTING AND MODELING

SHOCK-SPECIMEN FOR EVALUATING SHOCK HARDENING AND ANISOTROPY

Brandon Nesbitt, Torch Technologies
Dr. Matthew Neidigk, AFRL
Dr. Christopher Neel, AFRL
Dr. Jairus Bernard, Torch Technologies

Shock-induced hardening in a munition case wall is a known phenomenon but is typically not accounted for in conventional material model calibration. This study presents the design of a recoverable shock specimen to enable controlled investigation of shock-induced material behavior, including shock hardening and anisotropy. A series of nonlinear dynamic simulations using the Sandia National Laboratory code Sierra/SolidMechanics were conducted to optimize test configuration geometry to achieve planar shock wave propagation while ensuring post-shock specimen recoverability. The resulting specimen geometry enables post-mortem characterization, where sub-samples of the shock-hardened material may be extracted from the radial and axial orientations and subjected to uniaxial compression to assess both material hardening and anisotropy. The resulting data may then be compared to simulations to identify potential discrepancies in shock-induced anisotropy and strengthening.

EVALUATION OF THE DYNAMIC TENSILE FAILURE IN PRESSED ENERGETIC MATERIALS

Dr. Adriane Moura, Applied Research Associates
Zach Jowers, Applied Research Associates
Dr. Alain Beliveau, Applied Research Associates
Dr. Jacob Dodson, AFRL

The response of pressed energetic materials to high-amplitude mechanical shock can lead to dynamic tensile failure, or spalling. The goal of this work is to measure the dynamic tensile strength of energetic pressed pellets with various binders and particle sizes to provide an optimized composition to minimize spalling in LEEFI (Low Energy Explosive Foil Initiator) pellets. A technique to measure the tensile strength of inert pressed pellets by adapting techniques commonly used for geomaterials was previously developed by the authors. In this method, a Hopkinson bar is used to generate a compressive wave which is then reflected on the free surface of the sample. The sample spalls when the reflected tensile wave is larger than the tensile strength of the sample. The spall strength was determined from the tensile strain at the location of the spall in the sample. In this work, we extended the previous work by expanding the testing capabilities to pressed energetic materials and the results are presented here.

SHOCK SURVIVABILITY TESTING OF EXPLODING FOIL INITIATORS

Fahad Abumohaimed, AFRL

The Direct Header Deposition (DHD) Exploding Foil Initiator (EFI), developed at Sandia National Laboratory, represents a robust design that minimizes interfaces and is hypothesized to exhibit superior shock survivability compared to traditional EFI architectures. The DHD technology has been transferred to Battelle for the development of a Technical Data Package (TDP) suitable for industrial manufacturing. To assess the shock resilience of these units, the Air Force Research Laboratory (AFRL) has conducted shock testing on an initial batch of DHD EFIs using Hopkinson bar test methods. This paper provides an overview of the shock test assembly, details the setup employed for mechanical shock testing, and presents the results obtained from laboratory shock testing. The findings contribute to the

characterization of the DHD EFI's performance under extreme conditions, informing the ongoing development and implementation of this technology.

SESSION 7: STRUCTURAL RESPONSE: ROCKETS

DESIGN, CHARACTERIZATION, AND INSTRUMENTATION OF EXPERIMENTAL TESTS TO SIMULATE FULL-SCALE ROCKET ENVIRONMENTS

Dr. Jason Foley, AFRL
Dr. W. Jacob Monzel, AFRL/RXNP
Kathryn M. Rutherford, UES, Inc.
Dr. Jeroen A. Deijkers, UES, Inc.
Dr. Ming Y. Chen, AFRL
Dr. Malissa D. Lightfoot, AFRL
Dr. Stephen A. Danczyk, AFRL
Dr. Robert J. Jensen, Sierra Lobo, Inc.
Dr. Farhad Davoudzadeh, AFRL/RQRE
Mr. Karsten Lipiec, AFCEC/CXAE
Mr. B. Aaron Pullen, Applied Research Associates, Inc.
Dr. Robert Bocchieri, Applied Research Associates, Inc.
Dr. Tim Rushing, US Army ERDC

Rockets are ubiquitous in military applications; they are commonly used for offensive, defensive, reconnaissance, spacelift, and even logistics operations. AFRL has led an interagency team (including AFCEC, ERDC, NASA, and industry) to simulate, quantitatively measure, and ultimately predict the physical interactions that occur when a rocket plume impinges on a surface during launch or landing events. This paper discusses a novel approach to reproduce extreme environments of full-scale events with sub-scale testing. We will discuss the initial hypotheses and outline the analysis required by our approach. A series of computational analyses (notably coupled fluid-thermal-structural interaction [FTSI] simulations) were used to design an experimental test. The resulting design and representative data from a test campaign will be shown. We will also highlight practical difficulties of collecting data in these tests (spoiler alert: Murphy is alive and well) and provide comments on opportunities for advancing the state-of-the-art in extreme environment sensing and data acquisition.

Material Evolution and Damage Phenomenology of Infrastructure Under Direct Rocket Plume Impingement

Dr. Jason Foley, AFRL
Dr. W. Jacob Monzel, AFRL
Kathryn M. Rutherford, UES, Inc.
Dr. Jeroen A. Deijkers, UES, Inc.
Dr. Ming Y. Chen, AFRL
Dr. Malissa D. Lightfoot, AFRL
Dr. Stephen A. Danczyk, AFRL
Dr. Robert J. Jensen, Sierra Lobo, Inc.
Dr. Farhad Davoudzadeh, AFRL
Karsten Lipiec, AFCEC/CXAE
B. Aaron Pullen, Applied Research Associates, Inc.
Dr. Robert Bocchieri, Applied Research Associates, Inc.
Dr. Tim Rushing, US Army ERDC

AFRL and its R&D partners (AFCEC, ERDC, NASA, and commercial space providers) are executing science and technology (S&T) programs to quantify the effects of rocket launches and landings on defense infrastructure. One of the key technical challenges is understanding the degradation mechanisms of landing surfaces when exposed to the extreme environments of directly-impinging rocket plumes. We review the bounds of the thermal and mechanical environments, emphasizing the transient and highly coupled nature of the loads. We then provide observations from recent experiments with rocket plumes impinging on a variety of geomaterials, including engineered and naturally occurring materials. Notably, the damage mechanisms observed on the surface are highly dependent on the location within the plume and time history, i.e., both the intensity and time dependence of the environment determine the nature of failures at the continuum and microscale. Additional experiments quantify the microstructural changes in the material and this data allows us to correlate environmental features to the observed damage. We conclude with a brief discussion on how this new insight informs the design of more resilient rocket launch and landing surfaces for defense applications.

SESSION 8: DYSMAS II

Extended Holing Rule

Horacio Nochetto, NSWC Indian Head
Sujan Bashyal, ATR

Current ship holing damage rules for underwater weapons are primarily based on data from underwater explosion (UNDEX) experiments against simple air-backed plates. This data was developed from a limited range of experiments which produce error bounds which are further expanded by the omission of ship structures such as decks and bulkheads. Improving this model is of great importance to the weapons community. This presentation highlights recent efforts using DYSMAS high fidelity modeling of a generic representative structures exposed to UNDEX events with the end goal of creating synthetic data that will feed into a new reduced order model. DYSMAS simulation validation, setup, and results will be briefly summarized along with future work.

PARAMETRIC STUDY OF UNDEX CAVITY INTERACTION

James Davis, AFRL/RWTCS
Dr. Brian Taylor, AFRL/RWTCS

This presentation details a parametric study investigating how energetic detonations interact with trailing cavities in water. The study explores the impact of various parameters – including initiation location, energetic aspect ratio, cavity volume, and cavity aspect ratio – on shock wave propagation, cavity pinch-off, the formation of oscillating bubbles, and the resulting vertical velocity of the water column.

DYNAMIC EFFECTS ON UNDERWATER EXPLOSIONS

Dr. Brian Taylor, AFRL

The underwater explosion (UNDEX) of energetic materials transmits an intense shock wave into the surrounding water and produces an oscillating bubble of detonation product gases. It is well known that the motion of this bubble is influenced by gravity, leading to asymmetric collapse that transforms the bubble from a spherical shape at its maximum volume to a toroidal shape near the time of minimum bubble volume. It is also well known that the proximity of the bubble to material boundaries – the gas/liquid interface at a free surface or a nearby rigid wall – also influences the bubble's motion. In this presentation, we focus on the interaction between an underwater explosion and a nearby dynamically evolving gas cavity.

JEMTP WATER ENTRY TEST SERIES SUMMARY

Rachael Busby, NSWC Indian Head
Horacio Nochetto, NSWC Indian Head
David Spencer, NAWC China Lake
Andrew Cammenga, NAWC China Lake

There is a rapidly growing interest regarding hypersonic weapons and their effectiveness against maritime targets. Significant effort has thus been placed on understanding weapon lethality and target vulnerability in both water entry as well as through-target mission configurations. The primary objective of this test series is to characterize the water entry environment for future instrument development as well as high fidelity modeling validation. This presentation summarizes recent water entry tests performed at NAWC China Lake's Weapons Survivability lab. Test details, high speed images, as well as pre and post water tank entry speeds are discussed. Future tests that scale through target missions will also be discussed.

DYSMAS M&S OF RECENT JEMTP WATER ENTRY TEST SERIES

Horacio Nochetto, NSWC Indian Head
Rachael Busby, NSWC Indian Head
Dr. Jeff St. Clair, NSWC Indian Head

There is a rapidly growing interest regarding hypersonic weapons and their effectiveness against maritime targets. Significant effort has thus been placed on understanding weapon lethality and target vulnerability in both water entry as well as through target-mission configurations. The primary objective of this test series is to characterize the water entry environment for future instrument development as well as high fidelity modeling validation. This presentation summarizes recent DYSMAS validation efforts of water entry tests performed at NAWC China Lake's Weapons Survivability lab. DYSMAS setup, vehicle velocity as well as acceleration profiles will be discussed. Future validation efforts will also be discussed.

VENDOR SESSION B: EXHIBITOR PRESENTATIONS

KORNUCOPIA'S ABILITY TO SYNTHESIZE REALISTIC OSCILLATORY TRANSIENT SHOCK INCLUDING STATISTICAL CONSIDERATIONS

Dr. Ted Diehl, Bodie Technology, Inc.

This presentation provides an updated overview of Kornucopia® ML™ software's advanced capabilities for synthesizing credible transient shock signals—specifically those with oscillatory behavior that arise in real-world military, aerospace, and commercial environments. Building on last year's foundational approach, this year's session highlights several new tools and features focused on understanding and addressing the statistical diversity present in large datasets of measured shock time-histories.

The updated workflow begins with field-measured acceleration signals—often numbering in the hundreds—organized and pre-processed using Kornucopia's high-fidelity data preparation tools. These raw records are then characterized using Pseudo Velocity Shock Spectrum (PVSS) analysis. What's new this year is the integration of enhanced statistical evaluation tools that help users assess the nature of statistical variation across the shock signals as viewed in the PVSS spectrum space — ultimately supporting robust and defensible synthesis of representative time-histories.

Users can now explore and adapt to different statistical behaviors—such as normal, log-normal, or other distributions—within the PVSS enveloping process. These insights directly inform the selection and blending of database signals to produce a synthesized waveform that closely represents a user-defined statistical envelope across selected frequency bands. The final waveform is iteratively refined and verified to ensure it aligns with the intended PVSS target within specified tolerances.

The presentation will walk through several illustrative case studies, demonstrating how these statistically informed synthesis methods lead to realistic and justifiable transient inputs for laboratory shaker tests and for driving numerical simulation efforts.

STRENGTHENING SHIPBUILDING SUPPLY CHAINS THROUGH SUPPLIER DEVELOPMENT FUNDING

Lauren Yancey, HI-TEST Laboratories

No abstract available.

PIEZORESISTIVE ACCELEROMETERS WITH AMPLIFICATION AND TEMPERATURE COMPENSATION

Jennifer MacDonell, PCB/Endevco

Piezoresistive sensors are traditionally used to measure shock. Many applications involve high shocks at very short durations and the temperature sensitivity of the piezoresistors is not a major concern. However, some applications seek to measure more moderate shocks for longer durations and temperature gradients can have more influence. Applications like military vehicle testing are conducted in the field and involve temperature gradients due to blasts. It may also be desirable to have enough sensitivity combined with shock survivability to measure the motion experienced by occupants. This paper will report on a new type of accelerometer with both amplified output and temperature compensation.

IMPACT TESTS ACCORDING TO MIL-883H: A NEW SHOCK EXCITER
Michael Mende, SPEKTRA/APS Dynamics

This paper presents the concept of a low-cost impact exciter for small specimens, such as sensors or printed circuit boards (PCBs), that can perform the full range of impact tests defined by the MIL-883H standard. The goal of the development was to create a compact shock exciter that can be set up on a laboratory bench, generate reproducible shocks in an automatic sequence, and achieve amplitudes of up to 30,000 g, as required by the MIL-883H standard. Test specimens can have edge dimensions of up to approximately 2 x 2 inches and weigh several tens of grams. The shocks should have a clean, half sine signal shape, and the path covered by the DUT (device under test) during a shock should be as short as possible to avoid cabling problems.

The presented prototype is a pneumatically driven shock exciter based on the hammer-anvil principle. The impact energy is dissipated by a special concept when the test specimen is braked after impact. Ideally, there are no rebounds, or if there are, they are very small compared to the actual impact. Due to the short deceleration distance of only a few centimeters, a repetition rate of up to one impact per second can be achieved. Deviations in amplitude and shock duration between two shocks are typically less than 10%.

This prototype impact exciter concept should make it possible to test small specimens in all MIL-883H test areas that were previously considered "not feasible" or required large, expensive impact test systems, such as drop machines.

COMPARISON OF NEW ADVANCED CONTROL AND ACQUISITION METHODS TO TRADITIONAL VIBRATION TESTING FOR A SINGLE MISO APPLICATION
Stewart Slykhous, Spectral Dynamics

The new Panther Instrumentation System utilizes revolutionary advances in digital signal processing to improve each Vibration Control application. This presentation will concentrate on one single application in its simplest implementation. Powered by a huge increase in processing power and speed, the Modern advanced approach to Vibration measurements and control will be compared to the old traditional approaches to vibration testing including linear approximate algorithms and the popular Lincoln convolution approach.

TRAINING II: INTRODUCTION TO UERDTOOLS

INTRODUCTION TO UERDTOOLS
Rachel McIntyre, NSWC Carderock
Brian Lang, NSWC Carderock
Ari Bard, 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: SHOCK TESTING & QUALIFICATIONS

REMAIN SAFE SHOCK QUALIFICATION OF LIVE ORDNANCE

Liam Rayner, Thornton Tomasetti
Gavin Colliar, Thornton Tomasetti
Callum Norris, Thornton Tomasetti
Brian Ferguson, Thornton Tomasetti

This session will discuss the difficulties currently faced with replicating real world scenarios in which live ordnance has been subject to UNDEX events. Current testing is unable to replicate these types of environments with a representative UNDEX pulse shape. The solution to this issue was to develop a live ordnance testing capability using the portable shock testing machine or “JASSO”.

The test was carried out in December 2023 against a Lightweight Munition stored in a EDP storage rack and was required to be tested in both the vertical and horizontal loading directions. The goal of this test was to ensure that the munition would “Remain Safe” when subjected to a representative UNDEX event. Following on from testing it was determined that Thornton Tomasetti Defence Limited now have the capability to shock test live munitions to UNDEX load levels, and to do so in a safe and controlled manner.

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.

FOR LWSM OWNERS: CHANGES TO SHOCK TEST FACILITY CERTIFICATION AND INSPECTION PROCESS

Daniel Provenzano, NSWC Philadelphia

No abstract available.

HOW TO FAIL A SHOCK TEST

Dan Moran, Maritime Technology Group, Inc.

“How to Fail a Shock Test” offers a satirical yet technically grounded exploration of the common pitfalls and misguided practices that lead to failure in Navy shock testing for approval under the guidance of MIL-DTL-901E. Structured as a tongue-in-cheek guide, the presentation walks through the full lifecycle of failure—from poor design and procurement choices, to misguided use of isolators, lack of engineering analysis, flawed test procedures, and chaotic test execution.

Attendees will learn how neglecting proven hardware standards, misusing materials, and avoiding analytical rigor can doom a system long before it reaches the shock table. The session highlights the critical importance of proper planning, documentation, and adherence to standards, by illustrating—through counterexample—what not to do. This presentation serves both as a humorous cautionary tale and an insightful reminder of the meticulous attention to detail required for successful shock qualification testing. The presentation is aimed to inform people new to Navy shock but experienced practitioners are equally welcome to join and participate as we share stories of the most fantastic shock failures we have encountered.

SESSION 10: VIBRATION MODELING

REDUCED ORDER MODEL OF A GAP-CONTACT NONLINEARITY USING A GENERALIZED NONLINEAR MODAL BASIS FORMULATION

Dr. Deborah Fowler, Sandia National Laboratories
Dr. Robert J. Kuether, Sandia National Laboratories
Dr. Eric Robbins, Sandia National Laboratories

Nonlinear gap-contact behavior is widely observed under both extreme and normal loading conditions, drastically altering the response spectrum by introducing high frequency content along with stiffness and damping changes. Calculating long-duration dynamic time response of structures exhibiting nonlinear gap-contact behavior allows for valuable insight into system properties during vibration environments. However, full-fidelity finite element models can be prohibitively expensive for these computations, leading to great interest in reduced-order modeling techniques. Projection-based reduced order models are computationally efficient while retaining nearly all the accuracy of the full fidelity model, as long as a sufficient basis is used for the projection subspace. This work applies a novel generalized Nonlinear Modal Basis formulation to a system exhibiting gap contact behavior. The Nonlinear Modal Basis uses nonlinear deformation shapes extracted from Phase Resonant Nonlinear Modes to augment the linear modal basis. The basis is then used in a projection-based reduced order model to compute vibration response with significant computational time savings. The methodology and several example cases will be presented, along with comparisons to other state-of-the-art techniques such as proper orthogonal decomposition. The underlying generalized technique can be extended to a range of nonlinear physics including geometric nonlinearities and bolted joints, allowing for application to systems where gap-contact behavior couples with other sources of nonlinearities.

POWDERED METAL DAMPING IN CANTILEVER BEAMS

Cory Puckett, Los Alamos National Laboratory (LANL)
Dr. Eric Schmierer, Los Alamos National Laboratory (LANL)
Dr. Sandra Zimmerman, Los Alamos National Laboratory (LANL)

Metallic structures, in general, have very low mechanical damping. This is problematic in environments where there is excitation at frequencies near the structure's resonant frequencies. These high acceleration loads can lead to fatigue damage within a part and cause a failure. A method to reduce the damage to the structure is to increase its mechanical damping. The presented work examines the effects on damping within cantilever beams from adding small amounts of powdered metal to pockets within the beams. This increases damping through frictional dissipation, which has been demonstrated in various investigations. This work focuses on quantifying the damping increase as a function of the powder mass.

Multiple powder and beam material combinations were tested with varying powder quantities. Random vibration tests with a typical space flight hardware acceptance level were performed on each beam and the damping ratio was calculated. Results showed up to a three times increase of the first mode damping ratio of cantilever beams with what are deemed, achievable powder to part mass ratios. Additionally results show no change in damping with extended test time. This work provides an engineering basis for implementing this powder-damped method into laser powder bed fusion Additive Manufacturing. This brings additional benefits to the use of additive manufacturing which already allows for much greater design freedom than traditional manufacturing. An application of this is presented theoretically using data obtained in this study.

SESSION 10: CHARACTERIZATION OF RESPONSE OF ISOLATED SYSTEMS

INCLUSION OF SIMPLE OPTIMAL HYBRID DAMPERS INTO SHOCK AND VIBRATION ISOLATION SYSTEMS FOR US NAVY SHIPBOARD EQUIPMENT TO MINIMIZE EXCURSIONS OF, AND TRANSMITTED ACCELERATIONS TO ISOLATED EQUIPMENT

Dr. Christopher Merrill, CM&A Engineering PLC

This paper presents a simple process for developing an optimal hybrid damping system for US Navy shock isolated equipment resulting in normalization of total isolation system elastic and damping force into selected damping function with absolute value such that the isolated mass acceleration approaches but does not exceed the ship spec maximum shock acceleration level during MIL-DTL-901E shock transient excitation event. With sufficient available excursion and equipment fragility limits in the trade space, in theory this approach can reduce the undamped excursion over the transient shock event by 50% depending on magnitude, frequency, and shape characteristics of the transient shock excitation, as well as, multiple shocks and their phasing during the transient shock event. The optimal hybrid damping system can be imbedded in new shock isolations systems or may be installed on existing equipment. Historical precedents will be shared from authors experience where similar passive damping systems were highly effective. The process will be derived using classical analysis, analyzed for a SDOF example with the proposed hybrid damping function using classical analysis. Finally, the SDOF example with elastic springs and proposed hybrid damping will be analyzed numerically with elastic stiffness force only, and then with elastic stiffness force and proposed hybrid damping force capturing maximum excursion and maximum transmitted acceleration to demonstrate transmitted acceleration and excursion effects with or without the hybrid damping system.

Expected Result: Comparison of the numerical analysis of the SDOF example with elastic springs and with or without the proposed hybrid damping will result in a minimal 30% reduction in excursion with no increase in the maximum transmitted acceleration for the SDOF analytical case with superposed elastic stiffness and proposed hybrid damping.

FINAL SELECTED DESIGN: SHOCK AND VIBRATION RESPONSE OF ISOLATED RIGID BODY TO US NAVY TRANSIENT SHOCK BASE EXCITATION AND VIBRATION EXCITATION WITH FIXED RATIO OF CG ELEVATION TO HORIZONTAL SEPARATION OF BASE ISOLATORS; AND FIXED ISOLATION SYSTEM ISOLATOR

Dr. Christopher Merrill, CM&A Engineering PLC

This paper summarizes preliminary engineering information presented in SAVE Symposiums 93 and 94 regarding MIL-DTL-901E Shock and MIL-STD-167 Vibration Response of an example isolated rectangular raft with ship spec stated excursion and equipment fragility standards. The engineering information summary is used here to prepare a final design that will meet ship spec requirements with slight tweaking.

It will then be confirmed analytically that the design will meet or do better than ship spec requirements when shock and vibration tested either with prototypes (or Limited Run Initial Production systems) or that further work is required.

SESSION 11: STRUCTURAL RESPONSE

DOMINO – AUTOMATED PREDICTION OF PROGRESSIVE STRUCTURAL COLLAPSE FROM INITIAL DYNAMIC DAMAGE

Duncan McGeehan, Protection Engineering Consultants
Dr. Jeffrey Honig, Protection Engineering Consultants
Dr. Bryan Bewick, Air Force Research Lab

To quickly analyze a structural response to dynamic loading events such as impulse loading, the analysis is sometimes limited to component-level response, where structural elements such as beams, columns, and slabs are analyzed individually. While effective for predicting local damage, this approach often neglects late-time secondary effects that emerge from the structure's global response. This approach may omit or overly simplify behavior after the dynamic loading event, limiting insight into damage propagation and progressive collapse potential. To enable more comprehensive assessments, capturing the structure's secondary response is critical for assessing residual capacity and overall structural integrity following dynamic events which cause component-level damage.

To capture and understand this post-event behavior, Protection Engineering Consultants has developed Domino—a fast-running collapse prediction tool designed to consider initial damage resulting from dynamic loading events. Domino leverages an open-source finite element code to automatically generate and analyze whole-structure models that incorporate component-level damage. The tool provides a physics-based answer to the question: Does the structure collapse after sustaining dynamic damage? By simulating and visualizing the secondary structural response—including collapse or non-collapse, extent and directionality of deformations, and additional damage—Domino allows users to assess the broader consequences of dynamic events. This enhanced capability allows analysts to quickly and easily predict whole-structure response and evaluate the impact of a range of dynamic loading scenarios, from localized damage to full structural collapse.

VERIFICATION OF MODELING BEARINGS OF UNKNOWN STIFFNESS USING CONNECTORS AND HERTZIAN CONTACT DURING DESIGN DEVELOPMENT

Eddie Gonzalez, HII - Newport News Shipbuilding
Ify Amene, HII - Newport News Shipbuilding

During design development of mechanisms with bearings that undergo transient loading, exact bearing stiffness might be unknown. In finite element analysis software, bearings can be represented via simple 1D elements and their stiffness estimated via Hertzian Contact equations. This study verifies the use of Hertzian Contact equations for estimating bearing stiffness for this application through Abaqus model comparisons. One model utilizes solid elements to represent the bearings with contact defined between the contacting bodies, while the other model utilizes connector elements with force-deflection curves derived using Hertzian Contact equations. Dynamic responses between the two models are compared to each other and to a first principle estimate of the mechanism's response time to verify model assumptions and results.

DEVELOPMENT OF METRICS FOR PREDICTING UNDEX-INDUCED COLLAPSE OF STIFFENED CYLINDERS
Nick Valm, Thornton Tomasetti
Dr. Abilash Nair, Thornton Tomasetti
Adam Hapij, Thornton Tomasetti
Matt Davis, HII - Newport News Shipbuilding
Chris Joseph, HII - Newport News Shipbuilding

No abstract available.

NON-LINEAR RESPONSE HISTORY ANALYSIS OF SEISMIC CRADLES
Dr. Eric Hansen, Thornton Tomasetti
Adam Hapij, Thornton Tomasetti
Harold Carter, General Dynamics Electric Boat

No abstract available.

VENDOR SESSION C: EXHIBITOR PRESENTATIONS

SHOCK PERFORMANCE COMPARISON OF ARCH MOUNTS™ AND INDUSTRY STANDARD WIRE ROPE MOUNTS
Andrew Liberatore, Shock Tech, Inc.
Darko Gjoreski, Shock Tech, Inc.
Richard Rakowski, Shock Tech, Inc.

Wire rope mounts have been used for shock and vibration mitigation since the early 1980s, with minimal changes in design or improvements in performance. In the early 2000s, Shock Tech Inc. introduced the original Arch Mount™—a high-displacement elastomeric solution designed to better mitigate shock, vibration, and noise. The Arch Mounts™ have since been widely adopted across the U.S. Navy's surface and submersible fleets. In this paper, Shock Tech's six-degree-of-freedom (6DOF) discrete dynamic analysis software is used to compare the shock performance, as defined by MIL-DTL-901E, of standard industry wire rope mounts and similarly sized Arch Mounts™.

AN ELECTRODYNAMIC METHOD FOR MIL-STD-810 ACOUSTIC TESTING
Dale Schick, Acoustic Research Systems
Ed Kinsella, EM Acoustics

Traditionally, high-level Acoustic Testing methods for MIL-STD-810 are restricted to reverberant chambers and progressive wave tube methods. Since the publication of 810H, additional research has been made toward using an electrodynamic method to achieve test results for small to medium sized test articles. This presentation will outline the research methodologies used, the current results and limitations of the method.

OPTIMIZATION OF PERFORMANCE AND MECHANICAL DESIGN OF WIRE ROPE ISOLATORS
Robert Filec, Socitec
Ali Shehadeh, Socitec

Wire rope isolators are unique products that have been around for many decades, and because of their rugged nature and damping characteristics, are widely used in the aerospace, defense, seismic, energy

industries and more. Socitec Group is one of the world's leading companies in wire rope isolator engineering and manufacturing, with over 60 years of experience providing solution for a range of applications.

Shock and Vibration Solutions
Neil Donovan, Hutchinson

No abstract available.

TRAINING III: MIL-DTL-901E: TEST IT RIGHT THE FIRST TIME

MIL-DTL-901E: Test It Right The First Time
Kurt Hartsough, 901 Engineering & Training

No abstract available.

TRAINING IV: ADVANCED 3D MODELING OF HIGH-FREQUENCY PROBLEMS SEA METHODS

Advanced 3D Modeling of High-Frequency Problems Using Statistical Energy Analysis (SEA) Methods
Sravan Kumar Reddy Mothe, Altair Engineering

High-frequency noise and vibration present critical challenges in military systems, where accurate modeling is essential to ensure operational performance and reliability. This training introduces participants to advanced Statistical Energy Analysis (SEA) techniques with a focus on three-dimensional modeling approaches that overcome limitations of traditional methods. Using a state-of-the-art SEA solver designed for comprehensive 3D vibro-acoustic analysis, attendees will learn how to model complex multi-modal structures, evaluate energy transmission pathways, calculate loss factors, and analyze modal densities with increased precision.

Through detailed case studies, participants will gain hands-on understanding of how advanced SEA methods can enhance noise and vibration assessment accuracy, support design optimization, and accelerate the development of robust systems in challenging operational environments. By the end of the training, attendees will be equipped with both theoretical knowledge and practical skills to apply 3D SEA modeling effectively, enabling improved high-frequency noise and vibration solutions tailored to demanding military applications.

SESSION 13: PYROSHOCK

Rifle Optics Shock Testing on High-Frequency Resonant Plates
Dr. Carl Sisemore, ShockMec Engineering

Optical sights are a critical component of modern small arms. They are also mounted in close proximity to a fairly significant pyrotechnic event. Testing and qualification of new rifle optics has traditionally been derived from a substantial quantity of live fire testing. Given the difficulty obtaining large quantities of ammunition coupled with its high cost and the need for considerable range time, test and qualification alternatives have been reasonably sought. Laboratory test methods have been pursued for many years but are challenged by the very high-frequency nature of the pyrotechnic event at 4kHz and beyond. This paper presents an analysis of live-fire data collected on a traditional military style rifle at the optics location and compares that result to high-frequency resonant plate testing performed in the laboratory. The results show that a high-frequency resonant plate with a special Picatinny rail fixture is capable of matching the very high-frequency, high-acceleration shock response spectra from the live rifle firing as recorded on the rifle's Picatinny rail well beyond the initial 4kHz primary response. While this proof of concept development work does not currently represent the sustained shock test rate necessary for optics qualification, the high-frequency, high-acceleration responses are very promising.

ESTIMATION OF IMPACT DURATION ON A RESONANT PLATE USING OCCUPIED BANDWIDTH

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

The shape of the Shock Response Spectrum (SRS) is affected by the impact pulse width and amplitude. The nature of projectiles and the loads induced during a traditional resonant plate shock test does not allow for the measurement of the impact. The current method of tuning the frequency content of a shock test is heuristic. To develop a more systematic approach, this impact information must be extracted from the output shock measurement. This is achieved by assuming the shape of the impact pulse and calculating the occupied bandwidth of representative pulses. The occupied bandwidth provides an objective measurement of a pulse's width, through which a relationship can be derived between the ratio of SRS peaks and the duration of the impact. This relationship between SRS peaks and pulse width is then used to provide insight to the frequency content of the pulse, that is often otherwise ignored. This relationship was identified through experimental investigation of a resonant plate shock test analogue.

MECHANICAL IMPACT PYROSHOCK SIMULATOR: AN INVESTIGATION OF DUAL CANNON PERFORMANCE

Claudia Northrup, Element US Space & Defense

A mechanical impact pyroshock simulator (MIPS) system utilizing two independent cannons was evaluated to determine the test performance benefits of adding a secondary impact to the MIPS test setup. Shock test performance profiles can be complex and difficult to achieve using a single cannon, specifically if both the low frequency and high frequency content have high acceleration requirements. These once atypical profiles are increasingly common in the space and defense industry. With a single impact approach, the device under test is subjected to above nominal acceleration in one band to envelop the more extreme acceleration requirements in another band of the spectrum. A dual cannon setup may influence either the low or high frequency bands independently, allowing for closer adherence to nominal acceleration across the entire spectrum. The dual MIPS setup was first evaluated with a previously developed and validated finite element analysis model. In principle, utilizing multiple impacts with different parameters (such as projectile size, velocity, location, timing) can affect a wide range of variations on the resulting SRS, including pulse duration, frequency content, and response acceleration amplitude. Tests were used to verify the effect of a dual cannon MIPS test setup on the SRS.

RESONANT PLATE ANVIL DESIGN AND THE AFFECT ON THE SHOCK PULSE ENERGY CONTENT

Dr. Carl Sisemore, ShockMec Engineering

Anvils have traditionally been used in resonant plate testing primarily as a sacrificial component used to protect the resonant plate from damage. Relatively soft programming materials, such as felt, have often

been used in conjunction with an aluminum anvil to soften or shape the applied shock pulse imparted to the resonant plate. However, the resonant plate anvil can also be used as a mechanical filter to tune the energy content provided to the resonant plate. Anvils can be designed to limit the energy content to specific frequency bands based on material stiffness. This can have significant benefits in testing because the energy applied to the unit under test is filtered before it arrives at the unit under test to better match the desired test specification. This technique can be used to eliminate high-frequency energy in low-frequency tests as well as limiting very high-frequency energy in nominally medium to high-frequency tests. This design, in conjunction with a judicious choice of pneumatic hammer can be used to tailor shock testing to meet very specific test frequency criteria. This paper presents the results of numerous experimental test configurations showing the application of resonant plate anvil design to high-energy resonant plate shock testing.

SHOCK RESPONSE SPECTRUM (SRS) VALIDATION USING DISCRETE DYNAMIC ANALYTICAL METHODS

Darko Gjoreski, Shock Tech, Inc.
Shane Jansen, Shock Tech, Inc.
Richard Rakowski, Shock Tech, Inc.

The rapid expansion of critical LEO (Low Earth Orbit) programs-including missile warning, threat monitoring, and missile defense-has increased demand for shock and vibration mitigation. Pyrotechnic devices, commonly used for stage separation of structural subsystems, payload deployment and the release of attachments, generate intense pyroshock events. These events typically involve a relatively low velocity change, but they produce high peak acceleration and high frequencies which can cause failure of mission critical equipment. This paper investigates the use of the damped-sine synthesis method to generate time-history data for use in Shock Tech's six degree of freedom (6DOF) discrete dynamic analytical software. The analytical results are subsequently validated through laboratory shock testing using CubeSat mounts.

SESSION 14: VIBRATION TEST METHODS

ACCELERATED TEST DEVELOPMENT TECHNIQUES USING FIELD DATA

Jade Vande Kamp, Vibration Research Corporation

Engineers in product reliability use accelerated vibration testing to predict the product's life expectancy and anticipate potential failures with standard use. Properly developed accelerated test profiles can simulate a lifetime of damage in a fraction of the time.

This presentation will review several examples of field data analysis and the steps to convert field data into accelerated vibration tests using the appropriate levels. Engineers can over-accelerate test profiles and risk unintentional damage, or they may have room to increase the acceleration safely and save time. Ultimately, the goal is to properly replicate the real-world environment on a shaker in the laboratory, which requires the correct selection of the test type and parameters.

Specifically, this presentation will examine multiple scenarios that utilize different analysis and test development tools to create an optimal, accelerated, validated test that is representative of the recorded environment. It will look over the data of several case studies, perform a basic analysis to determine the correct test type, and discuss the proper selection of test parameters. Finally, it will compare the accelerated test and the field data to validate the test profile. Engineers running accelerated tests for product reliability will gain insight into test development processes and validation techniques, leading to more realistic test profiles.

DEVELOPMENT OF COMBINED VIBRATION AND SHOCK TESTING FOR COMPONENT FLIGHT ENVIRONMENTS

David Soine, Sandia National Laboratories
Dr. Jelena Paripovic-Stevens, 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. This work describes the continuing development of a test demonstrating combined flight random vibration and resonant fixture shock, along with some lessons learned and challenges remaining to field such a capability.

SESSION 14: MIMO VIBRATION

METHODS TO ENVELOPE MULTIPLE RANDOM VIBRATION ENVIRONMENTS INTO A SINGLE MIMO ENVIRONMENT

Randy Mayes, Sandia National Laboratories

MIMO control of random vibration environments is gaining more widespread use in environmental qualification testing. However, it is known that MIMO control can only match the cross power spectral density (CPSD) matrix of a single random vibration environment. It is desirable from a cost standpoint to be able to qualify a system to multiple environments in a single test. Typical straight line envelopes commonly used for SDOF specs cannot be arbitrarily applied to the diagonals of a CPSD matrix with any guarantee of a match with MIMO control. Two methods are proposed here that provide a new CPSD specification that can be simulated well in the laboratory. A potential energy metric demonstrates how well the MIMO controlled laboratory tests match the potential energy of the maximum combination of three field environments. An analytical beam model of a rocket provides the example for these methods, the control and the metric. The major assumptions are that multiple measured CPSD environments are available, and that the laboratory mode shapes adequately span the space of the field mode shapes.

Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC (NTESS), a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration (DOE/NNSA) under contract DE-NA0003525. This written work is authored by an employee of NTESS. The employee, not NTESS, owns the right, title and interest in and to the written work and is responsible for its contents. Any subjective views or opinions that might be expressed in the written work do not necessarily represent the views of the U.S. Government. The publisher acknowledges that the U.S. Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this written work or allow others to do so, for U.S. Government purposes. The DOE will provide public access to results of federally sponsored research in accordance with the DOE Public Access Plan.

MISSION SYNTHESIS FORMULATION FOR MULTI-AXIAL DURABILITY TESTING

Umberto Musella, Siemens Digital Industries Software
Dr. Alberto Garcia de Miguel, Siemens Digital Industries Software
Umberto Musella, Siemens Digital Industries Software
Ruben Araujo, Siemens Digital Industries Software
Dr. Mattia Dal Borgo, Siemens Digital Industries Software
Dr. Emilio Di Lorenzo, Siemens Digital Industries Software

The increasing complexity of modern structures, coupled with demands for shorter development cycles and more efficient qualification processes, poses significant challenges in vibration testing of aerospace, defense, automotive, and industrial components. Traditional sequential uniaxial testing methods may inadequately capture actual damage mechanisms, potentially leading to unreliable lifetime predictions. While multiaxial approaches have been proposed in literature, their industrial implementation remains limited. This limitation stems from two main challenges: the need for new formulations that properly account for damage severity under multi-axis loading beyond classical uniaxial FDS approaches, and the requirement for testing methods that can leverage modern multi-axis shaker platforms to replicate operational cross-correlations in laboratory conditions.

This research introduces methodologies for designing and executing representative multiaxial dynamic environmental tests to improve durability assessment of structural components. The study evaluates multi-axis formulations, including the recently introduced Fatigue Damage multi-Spectrum (FDmS), against classical uniaxial approaches for assessing potential fatigue damage under various directional loads. The investigation examines how operational cross-correlations affect component responses and presents methods to account for these effects during shaker testing. A new methodology is proposed for analyzing fatigue damage under generic multiaxial loading conditions and synthesizing accelerated test targets for Multiple-Input Multiple-Output vibration control, with particular emphasis on developing appropriate control strategies to simulate actual damage mechanisms.

SESSION 15: UNDEX/SHOCK ANALYSIS PROCESS AND APPLICATIONS

TRANSIENT SHOCK ANALYSIS QUALIFICATION PROCESS

Rebecca Grisso, NSWC Carderock
Matt Stevens, NSWC Carderock

No abstract available.

TRANSIENT SHOCK ANALYSIS QUALIFICATION EXAMPLE AND COMMON ERRORS

Matt Stevens, NSWC Carderock
Rebecca Grisso, NSWC Carderock

No abstract available.

Design and Simulation of a Naval Radar System to Pass MIL-STD-901E Heavyweight Shock Testing Through Implementation of a Lightweight Precision Centered Isolation System

Brandon Flood, Georgia Tech Research Institute
Ryan Gaylo , Georgia Tech Research Institute
Stewart Skiles, Georgia Tech Research Institute
Jeffrey McMichael, Georgia Tech Research Institute
Nathan Compton, Georgia Tech Research Institute

The integration of radar in a Naval deck application typically requires mitigation of multiple, often conflicting, shock, load, and environmental requirements. One of the most taxing requirements to manage is shock defined by MIL-DTL-901E (1). Systems developed to survive this high-shock environment usually require either a large, heavyweight structure, or flexible shock isolation. In the event that shock isolation is implemented, they can struggle to maintain precise and accurate pointing, both before and after a shock event. The system considered in this paper had a mass constraint, required height and width for its function, and deployment environment that precluded the use of a heavy support structure. In order to reduce mass without compromising pointing accuracy or reducing size, which drives functional performance, the assembly was designed to be isolated using preloaded, hard centering struts developed by Taylor Devices Inc (2). The high center of gravity of the system necessitated a neutrally located primary strut mounting configuration with secondary sliding/rotation control struts located under the system. The ability to tune isolation parameters within the double acting strut design allowed for management of maximum deflection so as to fit within the bounds of surrounding structure, reducing stresses on the lightweight structure to acceptable levels, and reducing excitation of the mounted electronics. The novel design resulting from this work is a system expected to be thousands of pounds lighter than a rigidly mounted system, while still maintaining a very high system pointing accuracy, and without expanding the footprint relative to the rigidly mounted system. The focus of this paper is a high-level overview of the general assembly design, with the largest majority of the work detailing the simulation setup and results. While this system has yet to be built and physically tested, this paper will outline the design, simulation, and data post processing required to deliver high confidence that the final system will survive MIL-STD-901E heavy weight barge shock testing (1).

References

1)Naval Sea Systems Command. "MIL-DTL-901E SHOCK TESTS, H.I. (HIGH-IMPACT) SHIPBOARD MACHINERY, EQUIPMENT, AND SYSTEMS, REQUIREMENTS FOR." n.d. everyspec.com. <http://everyspec.com/MIL-SPECS/MIL-SPECS-MIL-DTL/download.php?spec=MIL-DTL-901E.055988.pdf>.
2) Taylor Devices Inc. Precise Positioning. n.d. <https://www.taylordevices.com/wp-content/uploads/14-Precise-Positioning.pdf>

Phalanx Shipboard Equipment Grade B Shock Qualification

Helen Huang, Raytheon - RTX
Jim Landry, Raytheon - RTX
Fred Folch-Pi, Raytheon - RTX
Wen-Te Wu, Raytheon - RTX

Phalanx Grade B Shock Qualification for five major items was conducted by Raytheon with the NAVSEA in 2024. These five items are: Media Converter Assembly, Master Control Module, Radar Sensor Assembly, PAO Heat Exchanger, and Local Control Display Panel. Each item is analyzed and qualified for MIL-DTL-901E Grade B Shocks on surface ships with 8 Hz and 14 Hz frequency decks. DDAM and dynamic transient shock analysis are performed for hard mounted or wire rope isolated equipment. Some items are qualified by extension based on previous shock tests and additional analysis.

INFLUENCE OF BOUNDARY CONDITIONS ON UNDERWATER EXPLOSIONS - EXAMPLES TYING THEORY TO TEST DATA

Brian Lang, NSWC Carderock

The presence of nearby boundaries can have significant influence on underwater explosion test results. Several examples are given that demonstrate the effect of boundary conditions on underwater explosion test results, sometimes expected and at other times not.

SESSION 16: STRUCTURAL RESPONSE: WEAPONS EFFECTS

EVALUATION OF ANALYTICAL EQUATIONS FOR FRAGMENT EFFECTS TO TARGETS

David Lichlyter, US Army ERDC
Dr. T. Neil Williams, US Army ERDC
Christopher M. Shackelford, US Army ERDC

The U.S. Army Corps of Engineers Engineer Research and Development Center (ERDC) under its Terminal Weapons Effects (TWE) program is determining the best ways to predict how a fragmenting munition affects a structural target. Analyses at different levels of fidelity work together to provide a timely and complete impact to a structure. This effort focuses on evaluating existing equations as well as modified equations developed under the ERDC TWE program against experimental data and accepted methods for predicting fragment penetration and perforation of targets.

FRAGMENTATION OF A FACADE STRUCTURE AT FULL-SCALE USING THE LARGE BLAST/THERMAL SIMULATOR

Sheera Lum, Applied Research Associates
Joe Crepeau, Applied Research Associates
Jakob D. Brisby, Applied Research Associates
Mohsen Sanai, SRI International
Damian L. Cano, Applied Research Associates
Waylon M. Weber, Applied Research Associates
Sean P. Cooper, Applied Research Associates

The work described herein was performed as part of the effort to strengthen predictions of air blast effects on fragmentation and breakup of full-scale structures. A test was performed for this pursuit at the Large Blast/Thermal Simulator (LBTS) at White Sands Missile Range (WSMR), New Mexico. Spanning a length and diameter of 560 ft and 65 ft, respectively, the LBTS can generate static overpressures ranging from 2-35 psi. For this test, a facade wall was subjected to air blast loading representative of a nuclear blast. The wall was constructed to imitate that of a store front and consisted of glass doors and windows framed by concrete masonry unit (CMU) blocks reinforced by concrete and rebar. Placed in the center of the driven section of the LBTS shock tube and supported by a steel frame, the wall was subjected to the desired blast wave during the test, shattering it into large and small fragments. Both direct and indirect measurement techniques were used to assess the test environment. Pressure gauges installed upstream and downstream of the wall provided direct measurements of the pressure environment and indicated that the dynamic pressure impulse was significantly reduced due to the presence of the wall. Synchronized high-speed cameras allowed for wall motion and fragment velocities and masses to be assessed in two- and three-dimensional (3D) space using the ProAnalyst® software package. Wall movement downstream after shock impact was analyzed by plotting its position over time. The trajectories and weights of fragments were quantified by implementing stereographic techniques in ProAnalyst® that allowed these characteristics to be approximated in 3D. For test data comparison, the facade shot test was modeled and simulated in Tether, a numerical simulation code developed to capture the interdependency of applied load and structural response over similar time scales. Tether tightly couples the high-fidelity, computational fluid dynamics (CFD) code, SHAMRC, with the ANSYS computational structural dynamics (CSD) code, LS-DYNA. The Tether calculation was the first large-scale application of the code in this blast-loading regime. The initial response of the CMU block wall from the calculation agrees well with video data from the test. This study chronicles the LBTS facade wall test and juxtaposes the test data and Tether calculations completed thus far.

INVESTIGATING THE EFFECTS OF BREACH AREA REPRESENTATION ON INTERNAL BLAST PRESSURE PREDICTIONS

Christopher Shackelford, US Army ERDC
T. Neil Williams, US Army ERDC
John Q. Ehrgott, Jr., US Army 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 investigation into, and enhancement of current assumptions used in these codes when predicting internal blast pressure of a breached room subjected to external detonations. Currently, standard tools represent the breach area of this room as a singular hole on a wall equivalent to the total breached area of the wall. While this assumption has led to internal blast pressure predictions, we need to understand how multiple holes affect these results. To investigate this correlation, multiple CTH calculations have been conducted investigating the internal blast overpressure of a room with various explosive standoff ranges and breach hole representations. The work presented here provides an overview of these calculations, initial breach hole quantity and size correlations to internal blast pressure, and how this methodology can be applied to fragmenting munition terminal performance against structural targets calculations in the future.

ANALYSIS OF PENETRATOR FAILURE MODES WITH HYBRID FINITE ELEMENT MODEL

Logan Rice, US Army ERDC
Dr. Mark Adley, US Army ERDC
David Lichlyter, US Army ERDC
Ernesto G. Cruz, US Army ERDC

Projectile penetration research is an area of extreme importance in the areas of military defense and offense. This area allows for effective design and analysis of defensive infrastructure. However, finite element simulations of penetration scenarios can have significant runtimes, resulting in inefficiency in mission planning. In order to ensure access to faster predictions for these scenarios, a hybridized finite element model method was developed that involved higher mesh density in areas of interest and lower mesh density in less important areas to reduce runtime. The hybrid models constitute case and fill models that provide access to fast results for case damage to the projectiles, with the areas of interest determined by running more detailed models and analyzing the results from those runs. These hybrid models use surrogates of projectile components to give other damage results such as explosive fill deflagration by capturing the movement of the explosive fill inside the weapon as well as thread failure for fuzes. This case and fill damage can be given through algorithms added to PENCURV+ v2.9, removing the need for a finite element expert to interpret results.

ADVANCED CONCRETE REINFORCEMENT MODELING WITH SECOND-ORDER FINITE ELEMENTS USING EXPLICIT METHODS

Dr. Kent Danielson, US Army ERDC
William M. Furr, US Army ERDC

Over the last decade, higher-order lumped-mass finite elements have greatly matured, with viable ones becoming available in popular nonlinear explicit codes. The lumped-mass explicit approach is well-suited for large response/short duration modeling, like impact/penetration or explosive blast applications, but can produce distinct nuances that severely affect element performance differently from static, implicit, or modal transient methods. A C0 basis is also attractive for modeling common discontinuities, like those from contact/impact, inelasticity, tearing, or fragmentation. In addition, the very small time increments inherent to explicit methods can improve accuracy for highly nonlinear applications, where large changes can occur over even only a single very small increment. This paper focuses on transient analysis of reinforced concrete subjected to impact and explosively driven loads using nodal lumped-mass second-order C0 isoparametric Lagrange type finite elements with an explicit central difference scheme. A particular emphasis is on different rebar meshing/modeling schemes exploiting recent developments in element and meshing technologies. Higher-order bar, beam, and solid formulations can improve accuracy over using first-order ones in modeling flexure without hourglass control, assumed strains, incompatible modes, or shear locking. Furthermore, they can greatly ease reliable mesh generation for analyses with material near-incompressibilities by permitting unstructured automatic tetrahedral or hexahedral-dominant meshing without concern for volumetric locking. While performing well as flexural elements, higher-order solid elements also maintain their versatility to represent curved shapes more precisely as well as the ability to model contact innately on multiple surfaces of the same element. A single layer of second-order solid elements, for example, can naturally model a circular cross-section and large flexural responses of individual rebar accurately while also inherently providing inelastic shear deformation mechanisms. Although higher-order elements are more expensive individually, they can also drastically reduce model sizes over using first-order ones and the diagonal lumped-mass matrix significantly changes solution costs.

VENDOR SESSION D: EXHIBITOR PRESENTATIONS

STAINLESS STEEL HIGH DAMPING WIRE ROPE ISOLATORS

Tyler Feingold, VMC Group
Alex Jason, VMC Group

Stainless Steel High Damping Wire Rope Isolators (HDRIs) are advanced vibration isolation devices widely used in aerospace, defense, industrial, and transportation applications. These isolators consist of helical stainless steel wire ropes clamped between mounting bars, providing resilience and energy dissipation under dynamic loads. Their key advantage lies in their high damping capacity, which effectively reduces the transmission of vibrations and shocks, enhancing equipment longevity and performance.

The unique structure of HDRIs allows them to perform well under multi-directional loads, offering flexibility and stability across a wide frequency range. Unlike conventional rubber or polymer-based isolators, stainless steel wire rope isolators are highly durable, corrosion-resistant, and function effectively in extreme temperatures and harsh environments. Their nonlinear stiffness and damping properties enable efficient energy absorption, making them suitable for sensitive equipment such as electronic enclosures, optical instruments, and vehicle-mounted systems.

This paper explores the mechanical properties, design considerations, and performance characteristics of stainless steel HDRIs. It also discusses their applications in mitigating vibrations in critical infrastructure and machinery. The study highlights recent advancements in optimizing HDRI configurations for improved damping efficiency and load-bearing capacity. As industries seek more resilient and maintenance-free vibration isolation solutions, stainless steel HDRIs emerge as a reliable and cost-effective choice for ensuring operational stability in demanding conditions.

INTEGRATING PHYSICS-BASED MODELING AND AI FOR SCALABLE, REAL-TIME DIGITAL TWIN SOLUTIONS

Ray Deldin, Altair Engineering

As the maritime & defense industries increasingly shift toward model-based systems engineering and data-driven decision-making, the Digital Twin has emerged as a cornerstone of digital transformation strategies. This presentation explores Altair Engineering's multidisciplinary approach to developing scalable Digital Twin frameworks that integrate physics-based simulation with artificial intelligence and machine learning (AI/ML).

Through real-world case studies in aerospace, automotive, and heavy machinery, we demonstrate how Altair's ecosystem enables continuous system monitoring, predictive maintenance, and operational optimization by fusing high-fidelity simulation models with live sensor data and AI algorithms.

In addition to technical methods, this session will present measurable outcomes from selected deployments, including reduced downtime, improved product lifecycle efficiency, and enhanced situational awareness. The goal is to provide both a research foundation and practical roadmap for organizations seeking to accelerate their Digital Twin maturity using integrated AI and multiphysics simulation.

MIL-DTL-901E DISCUSSION

Kurt Hartsough, 901E&T

No abstract available.

SESSION 17: SHOCK & VIBRATION MOUNT DESIGN & ANALYSIS

ANALYSIS OF SNUBBED MOUNT DYNAMICS

Jordan Poehler, NSWC Carderock
Matt Stevens, NSWC Carderock

No abstract available.

Highly Damped Shipboard Shock Mounts: A Review of Design Parameters & Analytical Predictions (Part 1)

Shawn Czerniak, Hutchinson Aerospace & Industry
Grete Bressner, Hutchinson Aerospace & Industry

As advancements are made within Naval shipboard applications, the need for improvements to on-board isolators increases. High deflection capacity arched mounts are a proven solution for protecting on-board equipment from high-impact shock events, such as those outlined in MIL-DTL-901E. In recent years, Hutchinson has worked to improve the shock attenuation of these mounts, and this paper will present a case study, in two parts, on those improvements to performance.

Part one of this case study will review the design and analysis of elastomer geometry and explain how that evaluation is used to set targets for performance and material requirements. System analyses will be performed to estimate the shock attenuation of the improved design. These results will then be compared to the current design.

Part two of this study will then outline both material and part test results. The results will then be compared to the requirements defined in part one. Both material and part testing will be focused on damping level evaluation, with the intent being to improve the correlation between system shock analysis and testing.

Highly Damped Shipboard Shock Mounts: A Review of Test Validation on Elastomer Samples & Full-Scale Mounts (Part 2)

Grete Bressner, Hutchinson Aerospace & Industry
Shawn Czerniak, Hutchinson Aerospace & Industry

As advancements are made within Naval shipboard applications, the need for improvements to on-board isolators increases. High deflection capacity arched mounts are a proven solution for protecting on-board equipment from high-impact shock events, such as those outlined in MIL-DTL-901E. In recent years, Hutchinson has worked to improve the shock attenuation of these mounts, and this paper will present a case study, in two parts, on those improvements to performance.

Part one of this case study will review the design and analysis of elastomer geometry and explain how that evaluation is used to set targets for performance and material requirements. System analyses will be performed to estimate the shock attenuation of the improved design. These results will then be compared to the current design.

Part two of this study will then outline both material and part test results. The results will then be compared to the requirements defined in part one. Both material and part testing will be focused on damping level evaluation, with the intent being to improve the correlation between system shock analysis and testing.

Comparison of Experimental Characterization of Nonlinear Stiffness and Damping between Wire Rope Isolators and Taylor Devices' Pumpkin Isolators in Shear, Roll, and Angled Installations

Gordon Fox, Taylor Devices, Inc

A detailed comparison of experimental characterization of wire rope isolators and Taylor Devices' Pumpkin isolators is described in this paper. Both were tested in shear, roll, and 22.5°, 30°, and 45°

shear/roll angled installations. Nonlinear stiffness and hysteretic damping results are shown, including effects of input frequency and amplitude. The nonlinear damping behavior is linearized at different operating points to show how the equivalent linear damping coefficient varies with the stroke amplitude. Coupling between axes is investigated, such as how the compression or tension at a point in time affects the shear stiffness. Applications that each type of isolator are particularly suited for are briefly discussed in conclusion.

SESSION 18: INSTRUMENTATION DATA ANALYSIS

A New Perspective on Structural Response in Shaker Testing

Sean Hollands, RDI Technologies

In classical vibration shaker testing, the response of a device under test (DUT) is typically measured with accelerometers or strain gauges. These tools, while widely used, introduce mass loading and provide only limited spatial resolution. Despite decades of advancement in control systems and shaker hardware, the fundamental challenge remains: engineers are making critical design and qualification decisions based on a handful of single-point measurements that may not capture the full structural behavior.

This work explores a shift in how dynamic response is characterized, focusing on comprehensive, spatially resolved motion across the entire DUT. By analyzing full-field displacement and visualizing deflection shapes, engineers can observe the structural behavior of a system in context. This includes how different regions move relative to one another, where resonant modes manifest, and how those modes interact with geometry, fixtures, or boundary conditions. Temporal and spatial dynamics can be directly compared to simulation results, allowing for more effective validation of finite element models and improved correlation to real-world performance.

This full field measurement approach brings to light subtle phenomena such as out-of-phase behavior, localized responses and fixture-induced motion. These insights are often masked or missed entirely with traditional techniques. The result is not simply an increase in data volume, but a qualitative improvement in the type of information available. It offers a more complete picture of structural response and supports confident decision-making in design validation, qualification testing, and system optimization.

Understanding and Preventing Shock Waveform Distortion Caused by Measurement System Limitations

Dr. Thomas Gerber, Precision Filters
Alan Szary, Precision Filters, Inc.
Douglas Firth, Precision Filters, Inc.

Obtaining valid test measurements of shock is critical to ensure damage potential and severity can be accurately quantified. Despite numerous advances in accelerometer design over the last few decades, the very nature of shock waveforms will challenge the circuitry required to properly amplify and condition the sensor signal for digital conversion. A harsh, spectrally-rich transient shock pulse can be significantly distorted by an improperly designed measurement system, distortion that, insidiously, may not be readily apparent in sampled data. This distortion can be especially difficult to mitigate when the target shock signal is contaminated by out-of-band energy due to high-frequency accelerometer ringing or noise from the test environment. In this presentation, we demonstrate how clipping distortion and slew rate distortion – both of which arise due to fundamental limitations in amplifier circuitry – modify shock pulses prior to sampling. Using a novel technique for synthesizing realistic shock waveforms as input, we model the distortion to quantify the error between the true signal and the low-pass filtered and sampled output for varying levels of clipping and slew rate truncation. We then discuss the key signal conditioning components that must be in place to minimize the risk of such errors, including distributed gain, real-time overload detection, and judicious analog filtering.

IMPROVING FFT-BASED FILTERING OF TRANSIENT SHOCK DATA BY PLAUSIBLY HONORING THE PERIODICITY REQUIREMENT
Dr. Ted Diehl, Bodie Technology

Transient acceleration and strain records from impact or shock events almost always demand filtering before meaningful analysis can be performed. Two filtering approaches dominate practice: (1) time domain convolution, widely implemented for lowpass, highpass, bandpass, and bandstop filters, and (2) FFT domain filtering, where a one shot spectrum of the entire record (without windowing or block averaging) is multiplied by a user defined transfer function (TF) and then inverse transformed back to the time domain. The FFT route is particularly attractive when a TF such as an anti resonance, or compensation/mapping function is desired to be applied.

The classic FFT-based filtering technique typically involves the following steps:
A) Compute a one-shot FFT of the transient signal (without windowing or block averaging).
B) Define the desired TF behavior in the frequency domain, computing its real and imaginary coefficients.
C) Multiply the TF with the FFT spectrum of the signal in a point-by-point fashion.
D) Perform the inverse FFT to obtain the filtered signal back in the time domain.

However, a significant problem arises when the signal does not meet the periodicity requirement of the Fourier Transform. This can result in severe data distortions, especially at the start and end of the processed signal. While time-domain data windowing, such as using a Hann window, is common in forward-only FFT analysis to enforce periodicity, this technique is impractical when the goal is to return to the time domain, as the zero-amplitude tails of the Hann window create numerical singularities during inversion.

We present a novel method that resolves this issue by plausibly extending the time-domain signal (at the end, and sometimes also at the beginning) with tailored extensions and applying a Hann-like taper to these extensions. This approach ensures periodicity without altering the original duration portion of the signal. After performing the inverse FFT, the artificially extended portions are removed, resulting in a clean, accurately filtered signal.

To demonstrate this technique, we applied it to a transient shock signal synthetically distorted by an accelerometer sensor’s resonance, employing an anti-resonance FFT-based filtering method to eliminate the distortion. Without utilizing the periodicity-inducing extensions, the filtered signal displayed significant end-effect distortions. In contrast, using the proposed extension method yielded a result nearly identical to the solution with no resonance distortion. These techniques are demonstrated using Bodie Technology’s Kornucopia® ML™ software.

IMPROVING HIGH-G SHOCK MEASUREMENTS: A PRACTICAL CASE STUDY FOR PHYSICAL TESTING AND/OR NUMERICAL SIMULATION
Dr. Ted Diehl, Bodie Technology, Inc.

Accurately measuring severe mechanical shock is notoriously difficult due to sensor limitations, data acquisition challenges, and physical test variability. This presentation describes a simple, repeatable shock test setup that organizations can use to assess and improve the accuracy of their shock measurements and the credibility of their simulation-to-test correlations. The test configuration — a steel ball impacting a clamped aluminum cantilever beam — is easy to replicate in most shock-capable labs and severe enough to expose common pitfalls in high-G shock measurement.

Two different accelerometers (a piezoresistive and an IEPE) and a pair of high-speed laser displacement sensors were used in a piggyback configuration to measure the response of the beam. By integrating acceleration to velocity and displacement, and comparing them to independent displacement measurements from the lasers, the study reveals multiple real-world issues including DC bias errors, resonance-related distortion, signal drift, and base-strain-induced artifacts. The role of high sampling rates and proper filtering is also emphasized.

A key improvement demonstrated when using adhesively mounted accelerometers on thin structures involved the use of simple aluminum mounting blocks to isolate the sensors from base strain, which significantly improved acceleration, velocity, and displacement results — especially when evaluated using time-domain trends and PVSS (Pseudo-Velocity Shock Spectrum) analysis. The presentation also explores the limits of post-processing salvage techniques like high-pass filtering, showing that these methods are effective only when base-strain effects have first been mitigated mechanically.

This talk distills a longer hands-on workshop into a concise overview highlighting actionable insights for engineering teams aiming to improve the reliability of their shock measurements and validate simulation models. Attendees will leave with practical guidance on how to replicate the test, interpret results, and spot signs of distortion that might otherwise go unnoticed in typical high-G environments.

SESSION 19: MECHANICAL SHOCK & VIBRATION TEST METHODS AND EVALUATION

ADVANCING SYSTEM AND SUBSYSTEM SHOCK EXPERIMENTAL CAPABILITIES WITH REBOUNDING SLED FOR VELOCITY SHOCKS

Joshua Nowlin, Sandia National Laboratories
Dr. Nancy Winfree, Sandia National Laboratories
Adam Slavin, Sandia National Laboratories

As current and future flight systems demand harsher, more efficient shock tests, Sandia National Laboratories has implemented new shock testing machines such as the 6-inch gas gun and modern drop tables. While effective at the component scale, high acceleration and long duration velocity shock environments cannot currently be achieved at the subsystem/system level due to change-in-velocity (ΔV) limits. The 20-inch actuator at Sandia's Mechanical Shock Complex (MSC) has the potential to solve this problem at an indoor facility without explosives. A novel approach is presented to use a rebounding sled, rather than the conventional two-sled impact, to increase ΔV, thereby enabling the actuator to be a more efficient and tunable system to meet the demands of harsher shock environments at the subsystem and system level.

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.

FIVE METHODS TO CREATE A SINGLE-AXIS SHOCK ENVIRONMENT FROM A MULTI-AXIS SHOCK RESPONSE

Dr. Vit Babuska, Sandia National Laboratories
Dr. Brian Evan Saunders, Sandia National Laboratories
Douglas Coombs, Sandia National Laboratories

Often one must generate single-axis shock environments from a multi-axis shock response. This need arises for various reasons. For example a component needs a specified transverse shock environment. The transverse environment is needed not for convenience but because the specific orientation is not unique. In many situations, the orientation and location of the forces that produce a shock on a structure can vary in the field environment, and we only have a limited amount of data available to define a bounding shock envelope. Ideally there would be data from a series of tests where the force is applied at different orientations, but often we only have one data set because we cannot test the same unit multiple times in different orientations, we do not have multiple units to test, or simulations at multiple orientations are not computationally tractable. Nevertheless, we need to create the transverse shock environment from the single orientation test.

Consider the drop shock of a system idealized as the "chicken nugget" body. The chicken nugget body experiences a single axis shock – a force is generated in the impact axis at the point of impact – but any point in the blob can have a multi-axial response because of the way that the impact force propagates through the structure, and the structure's dynamic characteristics (modal frequencies and mode shapes). The specific example is a cylindrical body that impacts with a specific pitch angle and roll angle, but while the pitch angle is deterministic, the roll angle is arbitrary in the field environment. The question is: How do we define a shock environment at a component in the body, shown as the green square in Figure 2, so it is conservative and can serve as a transverse shock environment specification?

The presentation and paper will cover five methods to generate a single transverse shock environment from a multi-axis response:

a)the maxi-max SRS of the X and Y-axis responses;
b)the SRS of the magnitude of the X and Y-axis responses;
c)an SRS of the X and Y-axis response magnitude at each SRS frequency;
d)a circle envelope SRS inspired by Ref. [1];
e)a hypercricle SRS, based on Ref. [1].

The maxi-max SRS is simple and often used. The SRS of the magnitude of the X-axis and Y-axis accelerations is not a good choice. Computing the SRS from the magnitudes of SDOF accelerations in the SRS calculation (b) is slightly more conservative than the maxi-max SRS. It accounts for the differences in the X-axis and Y-axis responses and perhaps envelopes the roll angle uncertainty. The circle envelope SRS (d) is the most conservative and also accounts for the uncertainty in the roll angle. The time domain hypercircle SRS (e) is less conservative than the SRS domain circle envelope SRS (d) but more conservative than the maxi-max SRS (a). The hypercircle SRS also appears to be identical to the SDOF acceleration magnitude SRS method (c).

References

[1]Irvine, Tom, "Hypersphere Shock Response Spectrum,"
https://vibrationdata.wordpress.com/2016/07/16/hypersphere-srs/, July 19, 2016.

ENERGY BASED SEVERITY COMPARISON OF MULTI-DOF TRANSIENT ENVIRONMENTS

Dr. Mattia Dal Borgo, Siemens Digital Industries Software
Dr. Alberto Garcia de Miguel, Siemens Digital Industries Software
Roberto Fagioli, Politecnico di Milano
Umberto Musella, Siemens Digital Industries Software
Dr. Emilio di Lorenzo, Siemens Digital Industries Software

Structural vibration qualification of a spacecraft is usually carried out by performing single-axis shaker tests along each of the three orthogonal directions. In contrast, the spacecraft's response to transient launch loads is determined via a coupled load analysis (CLA) that simulates the integrated spacecraft-launcher system. In this process, different forces representing distinct flight events are applied to a coupled numerical model of both spacecraft and launcher. The CLA then produces a set of interface forces and accelerations. The accelerations are used to generate an equivalent sine spectrum at the interface, which – together with the spectrum defined by the launch authority – forms the basis for the sine-sweep qualification profiles.

Although single-axis sine control tests are effective for qualification, they can lead to either overtesting or undertesting when compared to the CLA results. Undertesting happens because a single-axis test excites only one resonance at a time (under linearity assumption), whereas a transient launch event would excite multiple resonances simultaneously. Overtesting, instead, originates from the difference in boundary conditions: during shaker tests, the spacecraft is driven along one axis and is nearly fully constrained in the other five degrees of freedom (DOFs). To protect sensitive components and avoid overtesting, the sine spectrum is commonly "notched" to limit interface forces, moments, and accelerations at specific locations.

Undertesting can be solved by replicating the acceleration time traces at the interface, instead of using the sine-sweep on the envelope of the environments. However, while doing so, overtesting may occur as it is not always possible to guarantee the same boundary conditions even in multi-axis shaker setups. In this scenario, it is desirable to have a metric that captures how much severe an environment (test) is with respect to another.

In single-axis tests, the severity is captured by the shock response spectrum (SRS), and – in a similar manner – the severity of multi-axis environments is commonly represented by the interface forces along each axis.

In this paper we present an approach that encapsulates the multi-DOF environment in a single metric, the relative input energy, which allows to compare the severity of different transient environments with respect to each other. The paper also shows the results of this method applied to representative data and use cases.

INTEGRATING DYNAMIC DESIGN ANALYSIS METHODS (DDAM) WITH OPERATIONAL SIMULATIONS FOR SHIPBOARD PERFORMANCE OPTIMIZATION

Kory Soukup, Altair Engineering

This presentation introduces a simulation-driven workflow based on a standardized Dynamic Design Analysis Method (DDAM) template developed to accelerate shock qualification and structural optimization in naval vessel design. The template enables efficient evaluation of shipboard components and assemblies subjected to shock loading, in accordance with military standards, by automating key steps in the DDAM process. Integrated with optimization techniques, the workflow supports weight reduction and structural refinement while ensuring compliance with shock performance criteria. By embedding this process within a broader digital framework, it enables rapid iteration, consistent validation, and data-driven design decisions, ultimately improving survivability and supporting lightweighting strategies.

SESSION 20: NAVY ENHANCED SIERRA MECHANICS (NESM)

PERKS AND PITFALLS OF BAND DAMPING

Dr. Nicholas Reynolds, NSWC Carderock

No abstract available.

EFFECT OF SHELL T/L RATIOS ON STRUCTURAL RESPONSE IN SIERRA/SM.

Keenan Powers, NSWC Carderock
Ari Bard, NSWC Carderock
Rohan Bardhan, NSWC Carderock
Michael Miraglia, NSWC Carderock
Dr. Nicholas Reynolds, NSWC Carderock

No abstract available.

GPU ENABLED SPEEDUPS FOR MODAL ANALYSES IN SIERRA/SD

Mr. Rohan Bardhan, NSWC Carderock
Ari Bard, NSWC Carderock
Michael Miraglia, NSWC Carderock
Keenan Powers, NSWC Carderock
Dr. Nicholas Reynolds, NSWC Carderock

No abstract available.

NAVY ENHANCED SIERRA MECHANICS (NESM) DYNAMIC DESIGN ANALYSIS METHOD (DDAM) STUDY

Ian Larson, NSWC Carderock

No abstract available.

TRAINING V: PHANTOM CINE ANALYZER

PHANTOM CINE ANALYZER – A PYTHON BASED OPEN-SOURCE PLATFORM FOR ADVANCED IMAGE-BASED MOTION ANALYSIS

Dr. Kyle Gilroy, Vision Research

The Phantom Cine Analyzer is a novel, free, and open-source software platform developed in Python, designed for comprehensive image analysis across diverse applications. Leveraging Python's robust ecosystem, including libraries such as OpenCV, NumPy, and SciPy, Cine Analyzer enables precise measurements, object tracking, and rotational and vibrational analysis from video data. The platform supports high-resolution video analysis, sub-pixel tracking routines, and customizable workflows, making it accessible to users with varying levels of technical expertise. Its modular architecture facilitates simple

tasks, such as distance and angle measurements, as well as complex analyses, including multi-object tracking, frequency-based vibrational studies, and particle tracking velocimetry (PTV). This abstract outlines the software's technical capabilities and its applications, followed with practical examples spanning academia, industry, and government.

TRAINING VI: INTRODUCTION TO HEAVYWEIGHT SHOCK TESTING

INTRODUCTION TO HEAVYWEIGHT SHOCK TESTING

Travis Kerr, HI-TEST Laboratories, Inc.

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: SHOCK AND VIBRATION ISOLATION

SHOCK PERFORMANCE COMPARISON OF ARCH MOUNTS™ AND INDUSTRY STANDARD WIRE ROPE MOUNTS

Andrew Liberatore, Shock Tech, Inc.
Darko Gjoreski, Shock Tech, Inc.
Richard Rakowski, Shock Tech, Inc.

Wire rope mounts have been used for shock and vibration mitigation since the early 1980s, with minimal changes in design or improvements in performance. In the early 2000s, Shock Tech Inc. introduced the original Arch Mount™—a high-displacement elastomeric solution designed to better mitigate shock, vibration, and noise. The Arch Mounts™ have since been widely adopted across the U.S. Navy's surface and submersible fleets. In this paper, Shock Tech's six-degree-of-freedom (6DOF) discrete dynamic analysis software is used to compare the shock performance, as defined by MIL-DTL-901E, of standard industry wire rope mounts and similarly sized Arch Mounts™.

IMPROVING MODELING OF HEIGHT-DEPENDENT LATERAL PERFORMANCE OF WIRE ROPE ISOLATORS FOR ENHANCED SIMULATION OF SHOCK AND VIBRATION SYSTEMS

Joshua Partyka, Isolation Dynamics Corporation

This presentation explores the variation in lateral performance curves of wire rope isolators positioned at different heights within a structural system, with the goal of enhancing simulation fidelity for complex shock and vibration isolation scenarios. A series of controlled tests and numerical simulations were conducted to evaluate how isolator height influences lateral stiffness, damping characteristics, and system-level dynamic response. The research presented is intended to better characterize nonlinearities and height-dependent behavior that are not captured in traditional models. The goal is to improve predictive accuracy in transient shock conditions by integrating height-position effects into the simulation framework, underscoring the need to account for geometric configuration and boundary interactions when modeling isolator behavior in real-world applications. Ultimately, this work supports the development of more reliable, high-fidelity analytical tools for engineers working on critical isolation systems in aerospace, defense, and industrial applications.

Design and Qualification of a Passive Dynamic Vibration Absorber for Ariane 6 Using Wire Rope Isolators

Jean-Pierre Tartary, Socitec US
Osadolo Irowa, Socitec US

To mitigate a critical transient vibration identified during the development of the Ariane 6 launcher, SOCITEC has designed and qualified a passive Dynamic Vibration Absorber (DVA) using metallic wire rope isolators. The targeted vibration occurs at around 19 Hz and originates from overpressure waves produced during the ignition of the solid rocket boosters, which locally amplify acceleration levels in the lower Vulcain engine bay. In response to Ariane Group's request, SOCITEC proposed a robust, simple, and industrially viable solution.

The developed DVA follows the tuned mass damper (TMD) principle—combining mass, stiffness, and damping to absorb energy at a critical frequency and thus significantly reduce structural vibrations. It was designed under strict requirements, including thermal resistance from –50 °C to +20 °C, no use of lubrication or organic materials, high mechanical load capacities (up to 15 g input and ±50 mm displacement), and a total weight under 20 kg.

The choice of metallic wire rope dampers was key, offering high damping, excellent reliability, and thermal stability. The DVA consists of a vertically moving mass guided by a mechanical frame and flanked by two shear-mounted wire rope dampers. Fine tuning of stiffness is achieved via loop diameter adjustment, and optional removable masses allow further tuning.

The mechanical performance of the DVA was validated through finite element simulations to ensure structural integrity under launch loads. A nonlinear dynamic model, incorporating SOCITEC's existing hysteresis-based formulations (including a Dahl-type damping law), was developed to predict in-situ behavior and integrate into the global launcher model. Simulation results demonstrated excellent correlation with expected damping performance and vibratory reduction.

A full dynamic qualification campaign was carried out at 6NAPSE laboratories, including sine sweep tests from 13 to 2000 Hz and shock simulations representing booster separations, all at various operational temperatures. Experimental results confirmed the model predictions, showing resonance frequencies within specified limits and low unit-to-unit variability.

Now flight-ready, the DVA has been adopted for serial integration into Ariane 6, proving the reliability and industrial scalability of the design. This successful development exemplifies SOCITEC's capacity for innovation in extreme environments and paves the way for broader application of this technology in space and high-vibration industrial systems.

SESSION 22: BLAST DAMAGE

DAMAGE EFFECTS OF SURFACE CHARGES ON MASSIVE CONCRETE MIXTURE SPECIMENS

Gabriel Riveros, USACE ERDC

The U.S. Army Corps of Engineers (USACE) seeks to better understand threats posed by vehicle-borne improvised explosive devices (VBIEDs) and waterborne improvised explosive devices (WBIEDs). Therefore, the Engineer Research and Development Center (ERDC) has conducted extensive research to analyze the structural response of concrete gravity dams subjected to surface charges using scaled models with small-aggregate concrete at compressive strengths of 5,000–7,000 psi or greater.

This presentation reveals the results of an experimental study on the damage impact of surface charges on large-scale concrete specimens with a maximum aggregate size of 3-1/2 inches and a 28-day compressive strength of 2,800 psi. The primary objectives were to improve understanding of the material properties of typical cast-in-place massive concrete mixtures (CIPR-MCM) used in large structures, assess joint displacement interactions under surface charges, and validate a mesoscale numerical modeling approach to predict damage in MCM concrete.

The results of these experiments, along with the development and validation of a mesoscale MCM model for damage prediction, will be presented. Additionally, this work contributes to a multiscale modeling methodology for damage assessment. The presentation will highlight key damage parameters, experimental observations, and the computational model used for high-fidelity material simulations.

USE OF LIDAR POINT CLOUDS AND FINITE ELEMENT MODELING TO ASSESS RESIDUAL CAPACITY OF BLAST-DAMAGED INFRASTRUCTURE

Cadet Samuel Benson, U.S. Military Academy
Samuel Keys, United States Military Academy
Eric Williamson, United States Military Academy

While finite element (FE) modeling can be used to evaluate the residual capacity of damaged structural systems, the integration of realistic, post-damage geometries remains technically complex. Standard modeling techniques often depend on idealized assumptions or manually adjusted geometry, which may not reflect localized damage features seen in real-world scenarios. Advances in LiDAR-based remote sensing offer an efficient means of capturing fine-scale surface deformations with high spatial resolution, enabling point cloud source geometry updates to structural models. This research explores a remote assessment workflow in which LiDAR point clouds are processed and converted into simulation-ready finite element models for small-scale reinforced concrete bridge piers subjected to blast and ballistic effects. Bridge pier specimens were damaged using both M855A1 ballistic rounds and C4 contact charges. LiDAR scans were taken before and after damage, producing dense point clouds that were processed using open-source software, then reconstructed as solid objects in a commercially available 3D modeling software widely used by architects. Subsequently, the geometric models were meshed and then analyzed using the finite element (FE) software ABAQUS. The resulting FE models used simplified material models to evaluate deflection changes under compressive loading to determine the suitability of the developed workflow. Although these models excluded reinforcement and nonlinear concrete behavior, they were effective in identifying changes in structural performance correlated to damage mode and severity.

This work demonstrates a proof-of-concept for remote, geometry-driven capacity assessment that reduces dependency on direct human inspection. The approach highlights challenges in mesh preparation and geometric fidelity but also further demonstrates potential for integrating sensor data into structural diagnostics. Future efforts will aim to expand this method toward automated model generation and more advanced simulation techniques.

HIGHER-ORDER BEAM ELEMENTS FOR EXPLICIT METHODS IN NONLINEAR DYNAMICS

William Furr, US Army ERDC
Atharva Kulkarni, US Army ERDC
Dr. J.N. Reddy, US Army ERDC
Dr. Arun Srinivasa, US Army ERDC
Dr. Kent T. Danielson, US Army ERDC

This work details the development and benchmarking of a shear deformable beam element using C0 continuous higher-order Lagrange interpolation functions that is suitable for finite deformation explicit dynamic simulations. Higher order elements perform better in bending while naturally avoiding various forms of locking (e.g. shear and membrane locking) and zero-energy modes (hourglassing) without special ad hoc treatments. Structural elements like beams, plates, and shells are specifically formulated for these applications where bending is a primary loading scenario. However, higher-order shape functions and rotational degrees of freedom complicate calculating an all-positive lumped mass matrix – a requirement for an explicit simulation. C0 continuity allows for significant smoothness where needed while allowing discontinuities for problems with significant plasticity, damage, and contact. Using row-summation mass lumping and well-known beam element formulations for static and implicit dynamic problems, a robust C0 modestly higher-order shear deformable beam element is developed. This element is then benchmarked against a class of problems spanning thin (length: height > 25) and thick (length: height < 10) beams with elastic and finite plastic deformation. Comparisons are made against proven beam element and continuum element formulations. Further discussions are presented on extending this work to shell element formulations.

SESSION 22: BALLISTICS

GUN BARREL BEAM VIBRATIONS AND ACCURACY

Dr. Jon Yagla, Dynamics, Thermodynamics, and Ballistics LLC

High speed, maneuvering targets, sometimes in swarms, demand extremely accurate weapons to defend against them. Targets must be engaged quickly with a minimum expenditure of ammunition and barrel heating.

When a projectile arrives at the exit plane of the muzzle, its trajectory has already been adversely by effected by barrel vibrations. Barrel vibrations are induced by asymmetries in recoil forces, barrel curvature, unbalance in the projectile, and balloting motions allowed by rattle space between the barrel and projectile. Vibrations of the gun supporting structure often affect firings. The shot is already on an unintended trajectory before it leaves the gun. Figure 1.

Fire control systems calculate gun train and elevation orders to point the gun. Accurate models of trajectories are required. To calculate the trajectories, precise values for the initial conditions at the muzzle are required. Barrel vibrations are plainly seen in videos. The most apparent vibrations are like the

bending vibrations of a clamped bar. The fundamental mode is a whipping motion. The barrel bends, usually up and down, and is pointing in a direction inclined to trajectory when the projectile reaches the end of the barrel. For tracked vehicles the vibrations are at the rate the track pads slap the ground. For gun barrels protruding from an airplane, vortex shedding excites bending vibrations.

Figure 3. shows a cross wind causing barrel vibrations in a barrel protruding from an AC-130J airplane. Barrel vibrations cause pointing and throw off shooting errors. Beam vibrations are calculated using separation of variables. The “pointing error” is caused by the barrel not being pointed at the target. It is proportional to the slope at the end of the barrel. This angle in milliradians is the miss distance at the target in “mils.” The transverse velocity component causes “lateral throw off.” These motions are 90 degrees out of phase.with each other. There is no obviously good time to fire.

Figure 4 shows calculations of beam vibration of a cylindrical barrel. Yy = aoymax + ∑▒(a_n cos wt⁡〖(kn X〗)+b_n (sin⁡〖knX 〗) + c_n 〖cosh(〗⁡〖knX 〗)+d_n (sinh⁡〖knX)〗 (I'm sorry!)
A real beam would have dimensional length, say in meters. The value at the end of the beam is L meters. The deflection formula is valid for interior points at x<L, and can be found on the dimensionless beam at x/L.

Our vision is to embed fiber optic strands with Bragg gratings into the barrel. The barrel shape, as a continuous function of time, as determined at the Bragg gratings, will be input to a PINN (physics informed neural network) trained to calculate the a, b, c, d, and ω coefficients. We measured temperature as a continuous function along a fiber on a firing 30mm gun barrel April 2025. We previously trained a PINN to determine the range, bearing, and explosive yield of an underwater explosion using data from two accelerometers on the keel of a ship. The PINN will prepare the gun to eject a projectile at the time the error function is zero.

GUN BARREL DYNAMICS VIA HIGH SPEED MOTION AMPLIFICATION

Sean Hollands, RDI Technologies

Understanding the dynamic response of a rifle barrel during live firing is critical for optimizing performance, improving accuracy, and validating structural models. We will present a novel application of high-speed video analysis combined with RDI Technologies’ Motion Amplification® to visualize and quantify the deflection shapes of a gun barrel in response to a live munition event.

By treating every pixel in the video as a non-contact sensor, this approach reveals the transient flexural and vibratory modes excited during and immediately after firing. Unlike traditional instrumentation, this method captures full-field displacement data with high spatial resolution, enabling a deeper understanding of how the barrel reacts under live-load conditions without altering its dynamics or requiring surface preparation.

The results provide actionable insight into how different ammunition loads affect barrel behavior, offering a pathway to optimize firearm configurations for improved consistency and accuracy. In addition, the technique supports model validation workflows by allowing users to directly correlate Finite Element Analysis (FEA) predictions with actual motion profiles observed during firing. This represents a significant advance for those designing or analyzing weapons systems and related shock-dynamic structures.

During the presentation we will share example visualizations, early test results, and discuss the broader implications for design optimization, load selection, and correlation to predictive modeling.

SESSION 23: MECHANICAL SHOCK AND VIBRATION TEST APPLICATIONS

SHIPBOARD EQUIPMENT VIBRATION MITIGATION WITH SEMI-ACTIVE CONTROL OF SMART DAMPERS

Maxim Veilleux, University of Connecticut
Dr. Richard Christenson, University of Connecticut
Dr. Jiong Tang, University of Connecticut

This research seeks to characterize the system dynamics of notional shipboard equipment traditionally mounted on wire rope isolators and develop semi-active control to improve structural response when subject to excessive vibration. The use of smart dampers is proposed to supplement the isolation of the structure from unwanted vibration. Smart dampers, a type of semi-active device, are controllable in nature with the ability to change their damping characteristics in real time based on measured responses of the structural system and a command signal sent to the damping device. The use of smart dampers has the potential to provide a low-power, high-performance solution to mitigate vibration of shipboard equipment while maintaining the ability to provide passive damping in the event of failure. Proper control strategies must be employed to supply the required command signal to the smart damper to achieve the desired damping capacity. The implementation of such control strategies must address computational costs, system and modeling complexities and uncertainties, effects of hysteresis, and instrumentation noise and sensitivities for various excitations. The effectiveness of smart dampers for use with notional shipboard equipment is evaluated and validated through analytical, numerical, and experimental methods.

SHOCK AND VIBRATION PROPERTIES OF ADDITIVELY MANUFACTURED STAINLESS STEEL

Troy Pacheco, Los Alamos National Laboratory
Dr. Sandra Zimmerman, Los Alamos National Laboratory
Ryan Hemphill, Los Alamos National Laboratory

Additively Manufactured (AM) materials present a new horizon for capabilities of aerospace projects. It is well known that the AM process introduces anisotropies within the microstructure of a metal that can impact its mechanical properties. These tests, however, are performed under quasi-static conditions with large displacements and high stress. This contrasts with typical environments experienced during the launch of a payload. These environments are random vibration during ascent and pyroshock during separation. The research team performed one-to-one comparisons of an additively manufactured stainless steel (SS) cantilever beam and a conventionally manufactured SS beam in a vibrational environment similar to a standard launch using an electromechanical shaker measuring responses from 20-2000Hz. The research team also tested the cantilever beams on a mechanically excited resonant beam to test shock responses up to 10,000Hz. Unlike quasi-static tension tests, the AM SS beam and conventionally manufactured SS beam had identical responses in the vibrational environment. In the shock environment, the AM SS beam had a consistently higher Shock Response Spectra (SRS) above 2000Hz. Possible root causes for the discrepancies between quasi-static tests and behavior in the vibrational environment as well as causes for the divergence of the AM and conventionally manufactured beams above 2000Hz in the shock environment are discussed.

SHOCK INDUCED CAVITATION IN A HYDRAULIC CYLINDER

Dr. Jon Yagla, Dynamics, Thermodynamics, and Ballistics LLC

Visualize a hydraulic cylinder with the flat base pointing up on a table. The cylinder rod is fully extended (all the way up), say h= 4 feet, and the space between the face of the rod piston and the bottom of the cylinder is filled to capacity with hydraulic fluid. The pressure of the fluid at the base is rho x g x h. Rho is the density, g is the gravitational constant, and h is the length the fluid column. The table is impulsively accelerated upward to 400g. The lamina of fluid on the inner surface of the base must accelerate all the fluid above it to 400g. This requires a pressure, P, of rho x 400g x h. The fluid is not totally incompressible. It has a bulk modulus, B. The fluid column is slightly compressible and responds according to delta V = -V x delta P / B. The fluid pulls away from the piston creating a free volume delta V.

We put an open sample of hydraulic fluid under a bell jar, evacuated the jar with a vacuum pump, and saw the hydraulic fluid boil (cavitate) at room temperature when the pressure got very low.

In the hydraulic cylinder at 400g, the fluid column shortens. A free surface is formed. The free surface cavitates forming a bubble of volume delta V. When acceleration abruptly ceases, the bubble is very slow to absorb back into the remaining liquid. The forward inertia of the column of liquid below the bubble compresses the bubble into a very small volume. The pressure in the bubble becomes extremely high. The liquid is driven rearward by a compression wave moving at the speed of sound in the liquid. The compression reflects off the base and returns to the free surface where it is reflected rearward as an expansion wave.

The Raleigh-Plesset differential equation was modified to determine the volume of the bubble as a function of time. It is a second order nonlinear ordinary differential equation. We used MatLab ODE15 to solve the "very stiff" differential equation for the volume versus time. Then we calculated the pressure by assuming adiabatic compression of the vapor.

We found very high cyclical pressures. The pressures were much higher than the operating pressure of the cylinder. The pressure pulses would have caused early failure due to fatigue in other parts of the system under study.

An experiment was carried out with accelerometers , strain gauges to track stress waves, and pressure transducers at the base and head of the cylinder. An impulsive input of 400 g was applied at the base. Wave diagrams were constructed using the data and clearly showed up and down wave motion. Validity of the Rayleigh-Plesett cavitation model was confirmed.

SESSION 23: ELECTRONICS SURVIVABILITY

THERMAL VULNERABILITY FO POTTED SURFACE MOUNT RESISTORS AND WHAT TO DO ABOUT IT

Dr. Joel Limmer, Sandia National Laboratories

High-voltage circuits may need to both survive high shock and fit into small spaces. Epoxy potting can protect high voltage circuits from shock, and surface mount components can reduce circuit volume, but surface mount components may also be more vulnerable than leaded components to the thermal stress caused by the epoxy potting process and by temperature cycling. This study uses finite element modeling to compare thermal stress in epoxy-potted leaded and surface mount resistors. The effects of geometric factors such as size, lead forming, and epoxy depth are compared. Stresses and strains in leaded and surface mount components of equivalent resistance and power rating are compared, confirming the vulnerability of surface mount components. Further modeling suggests that an alternate high voltage standoff strategy—coating with a vapor-deposited polymer such as parylene—can drastically reduce stress in surface mount components. Smaller, surface-mount-based circuits could then be used in environments that, with epoxy encapsulation, only leaded-component circuits could reliably survive.

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.

Electronics Fixturing for Microbead Potting as Shock Mitigation

Natasha Wilson, Sandia National Laboratories
Cayden Boll, Sandia National Laboratories

Electronics that must survive through mechanical shock environments traditionally use thermoset polymer potting. Such potting supports the electronic components but leaves residual stresses on the electronics from the thermal cure. Thermal excursions post-cure increases the stresses in electronics due to the mismatches in coefficients of thermal expansion (CTE) of the potting and the electrical components (circuit board, capacitors, etc.). Thermoset polymers also cause great difficulty in, or prohibit, accessing electronics for recovery or rework.

The induced thermal stresses and the recovery and rework issues can be solved by replacing thermoset potting with unbonded yittria stabilized zirconia granular beads to support the electronics. Such 0.3-0.4 mm microbeads potted electronics and have been shown to reduce thermal strains, support electronics through mechanical shock, and decrease high frequency shock content. Recovery of electronics for inspection or rework is as simple as opening the housing and pouring the microbeads out.

This presentation will focus on the results of repeated shock tower drops on microbead potted electronics either floating or mounted on standoffs in the microbeads. Component survivability, circuit board strain, and input vs board acceleration will be presented.

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.

SESSION 24: MECHANICAL SHOCK TESTING AND DATA ANALYSIS

APPLICATIONS FOR PRINTED HYBRID ELECTRONIC (PHE) ASSEMBLIES SUBJECT TO EXTREME MECHANICAL SHOCK AT MULTIPLE TEMPERATURES

Maj. Hayden Richards, University of Maryland
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 DEVCOM Army Research Laboratory, employed an accelerated-fall drop tower for 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 and temperatures from 25 °C to 125+ °C. Research efforts were focused on characterizing the behavior of electronic assemblies fabricated by the 'mill-and-fill' method, where multiple components, printed silver traces, and printed solder interconnects were recessed into milled cavities and trenches on the surface of injection-molded polysulfone thermoplastic substrates. Planar substrates were supported for testing in clamped-clamped beam geometries with no secondary impact.

Various metrics were used to measure circuit performance over the course of a multi-drop test cycle at a range of acceleration levels (up to 100,000 g) and temperatures (up to 125 °C), with eventual circuit failure occurring upon component separation from the substrate. Peak substrate strain magnitude was ~50,000 µm/m at rates up to 1,000 /s. Number of drops to failure was recorded for four different component locations at each test point. Component separation occurred due to cracking within the sintered silver trace adjacent to the component induced by extremely high plastic strain magnitudes within the silver. These strain levels were determined by experimentally-matched finite element modeling and used, together with number of drops to failure, to generate an application-agnostic low-cycle fatigue curve for sintered silver for mechanical shock / elevated-temperature applications.

These results facilitated the design of more complex circuits on a variety of different substrate materials and geometries, and enabled the prediction of cycles to failure through modeling. Ultimately these PHE assemblies have the compelling opportunity to replace conventional electronic packages for operationally-relevant integrated circuits in extreme environments.

ATTENUATION IN RESONANT FIXTURE SHOCK TESTS WITH A TRANSMISSIBILITY-INFORMED CASE STUDY

Brian Saunders, Sandia National Laboratories
Dr. Vit Babuska, Sandia National Laboratories
Gabrielle Graves, Sandia National Laboratories

When qualifying mechanical structures, there are several important aspects that contribute to a good shock test: test fixture design, input pulse shape, laboratory boundary conditions, etc. Equally important in the design of a structure is the ability to protect sensitive components or regions by promoting the attenuation of the shock across distance or across structural members such as bulkheads or joints. There are a number of NASA and MIL documents that provide generalized recommendations of shock attenuation over distance or across joints, developed from studies done in the 1980s or earlier. More recent works have pointed out areas of improvement that ought to be examined to account for newer materials used in structural design and different operating environments. The goal of this work is to examine the shock attenuation across structural members from a resonant-fixture shock testing data set. Various metrics, such as peak acceleration, frequency spectrum, MMAA SRS, and energy will be presented with a focus on the attenuation/amplification characteristics. A case study will also be presented on how the attenuation metrics can be treated like transmissibility functions to tailor a resonant fixture shock test.

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and 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-NA-0003525. SAND2025-06544A.

COMPARATIVE ANALYSIS OF CONVENTIONAL AND HEAD-WEAK FASTENERS: SHOCK SURVIVABILITY
LeeYung Chang, NSWC Carderock

No abstract available.

COMPARATIVE SHOCK TESTING OF CONVENTIONAL AND HEAD-WEAK FASTENERS
LeeYung Chang, NSWC Carderock

No abstract available.

SHOCK QUALIFICATION OF ADDITIVELY MANUFACTURED METAL PARTS FOR US NAVY APPLICATIONS
Jacob Mason, NSWC Carderock

No abstract available.

TRAINING VII: INTRODUCTION TO LIGHTWEIGHT SHOCK TESTING

INTRODUCTION TO LIGHTWEIGHT SHOCK TESTING
Jeff Morris, HI-TEST Laboratories

This training will cover the necessary background information relative to lightweight shock testing. This session is intended for engineers and product developers who are unfamiliar with the lightweight shock testing process. Subjects covered include pre-test planning, fixture selection, test set-up, test operations, and reporting. Some aspects of lightweight shock machine operation will be covered. Shock test requirements applicable to lightweight shock testing will be discussed.

TRAINING VII: INTRODUCTION TO MEDIUM WEIGHT SHOCK TESTING

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.

SESSION 26: SHOCK & VIBRATION MODELING & SIMULATION

DESIGN EXPLORATION FOR SHOCK-RESISTANT SHIPBUILDING

Kory Soukup, Altair Engineering

Type your abstract here (500 words or less). Hint: type your abstract into Microsoft Word or other software first for spellchecking, then copy and paste into this field.This presentation outlines a simulation-driven design exploration approach for enhancing shock resistance in shipbuilding and offshore platform structures. Emphasis is placed on capturing the complex dynamic response of large-scale structures subjected to extreme loading events such as underwater explosions and accidental impacts. Design space exploration techniques are applied to investigate the influence of geometry, materials, and structural configurations on shock absorption and energy dissipation. The approach enables rapid assessment of design alternatives, supports optimization against multiple performance criteria, and aids in meeting stringent regulatory and safety requirements.

ACCELERATING SHOCK-QUALIFIED CASTING DESIGN IN SHIPBUILDING WITH AI-BASED REDUCED-ORDER MODELS

Giri Prasanna, Altair Engineering

This presentation highlights the application of AI-driven reduced-order modeling (ROM) to accelerate casting prediction in support of shock-qualified shipboard structures. High-fidelity casting simulations are essential for identifying defects that can compromise structural integrity under dynamic loading, yet their computational expense often limits iteration during early design phases. By applying machine learning to simulation data, reduced-order models are created to rapidly predict thermal behavior, flow characteristics, and potential defect formation with high accuracy and minimal computational cost. This enables rapid assessment of casting quality across design variants, supporting lightweighting and manufacturability without sacrificing shock performance. The approach enhances upstream material fidelity, ultimately contributing to more robust and survivable components in vibration- and shock-sensitive naval applications.

MODERNIZING THE EXODUS PROFILE FOR STREAMLINED SHIPBOARD SHOCK ANALYSIS

Jason Krist, Altair Engineering

This presentation details the latest enhancements to a simulation template built around the Exodus file format to support advanced shock and vibration analyses for shipboard systems. Designed to seamlessly interface with Sierra solvers, the template automates model setup, load case generation, and boundary condition application within an Exodus-centric workflow. This approach ensures efficient data exchange, consistent mesh metadata management, and streamlined results extraction, reducing manual effort and minimizing errors. The template’s deep integration with Exodus enables scalability, traceability, and reuse across complex naval qualification programs, accelerating design iterations and improving confidence in survivability assessments.

Evaluation of Transportation Shock and Testing for Failure and Damage

Dr. Arup Maji, Sandia National Laboratories

Quantification of the consequence of shock specifications is important to determine if testing replicates worst-case field environments. One approach is to evaluate how the response of the test article can be related to imparted damage or potential for firs

t-passage (brittle) failure. While damage is related to stress cycles, first-passage failure can be related to the energy imparted or absorbed in the test article. 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. Absorbed energy can likewise be computed for various shock inputs based on known or assumed structural response. The relative significance of 'damage' and/or 'absorbed energy' 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 shock events is complicated since the content in the field events are typically captured and replicated during tests by the Shock Response Spectra (SRS) which can be higher or lower at different frequencies. The number of hits in the tests is also small compared to numerous shocks encountered in real life. It then becomes important to quantify the consequences of various test specifications, or to ensure tests done to specifications can be used to ascertain safety when requirements and usage has changed later in the product development phase.

The presentation will provide the technical basis for evaluating fatigue damage and peak absorbed energy (related to brittle failure) from field and laboratory shock events. Codes developed with greater computational efficiency and associated theoretical approximations will be discussed, along with results comparing rigorous and approximate methods.

SESSION 27: INSTRUMENTATION APPLICATION

Cryogenic Performance of High-G Damped Accelerometers: Further Testing

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 is an extension of last year's paper, Cryogenic Performance of High-G Damped Accelerometers, U-029. The new data includes test results on 20,000g and 60,000g range sensors, with repeated full-scale Hopkinson bar tests at -300°F, and extended temperature cycles between -300°F and room temperature. These latest results are summarized with previous testing on amplitude linearity and long-term exposure. The results demonstrate the performance at cryogenic temperatures for an Endevco high-G piezoresistive accelerometer. The shock accelerometer was not originally rated for cryogenic temperature applications, but the results show that it performs competently in this environment.

Securing Accelerometers Under Extreme Conditions: A Review of Adhesives and Installation Practices

Samuel Stone, Lawrence Livermore National Laboratory

While mechanical fastening is typically preferred for securing instrumentation, adhesive mounting is often necessary in situations where mechanical solutions are impractical, resulting in varying degrees of success. This study investigates the performance of different adhesives and installation methods for mounting accelerometers subjected to high-G shock and thermal cycling. A gunpowder driven nail gun serves as the testbed, delivering high-frequency, high-amplitude mechanical shocks to devices under test. The effects of adhesive type, surface preparation, bond thickness, and thermal preconditioning on shock adhesion are systematically evaluated. Shock accelerometers, complemented by high-speed video analysis, are used to quantify shock magnitudes and provide detailed insights into adhesive failure mechanisms. The results offer practical guidance for selecting and applying adhesives to ensure reliable accelerometer mounting in extreme environments.

Data Recorder Survivability in High Shock Environments

Victor Nevarez, Sandia National Laboratories

Shock testing limitations arise from the challenges of accurately characterizing the shock regime and conducting tests in such environments. Various methods have been employed to achieve different shock profiles, including drop towers for longer shock events. However, one of the significant limitations in testing under harsher shock conditions is the need for onboard data recorders that can withstand these extreme events.The Anomalous Environment Data Recorder is specifically designed for such environments. Over the past decade, these recorders have been tested in multiple settings, including sled tracks, drop towers, and rocket-assisted pull-down tests. Each of these environments presents unique challenges, with some pushing the boundaries of existing shock testing capabilities.We have observed failures in recorders due to crushing and anomalies in the data along with many instances where they survived conditions beyond current standards. Every test and dataset captured provides crucial information regarding the survivability of data recorders. We hope that sharing this knowledge will aid in testing even more intense shock environments.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.SAND2025-07816A

Optical Measurement Techniques for Dynamic Characterization of a DUT During Vibration and Acoustic Testing

Kory Soukup, Altair Engineering

No abstract available.

SESSION 28: NOVEL UNDEX & MECHANICAL SHOCK INVESTIGATIONS

MODELING AND SIMULATION OF BURSTING PRESSURE VESSELS DUE TO THERMAL RUNAWAY EVENTS OF INTERNAL LITHIUM-ION BATTERIES

Ben Medina, NSWC Carderock

Underwater vehicles, electric ground vehicles, and aircraft are all utilizing lithium-ion batteries (LIBs) to a greater extent to boost capability over legacy alkaline, lead acid, or nickel cadmium batteries. While LIBs have excellent energy density advantages, they can also pose a significant hazard during a thermal runaway (TR) event. When LIBs experience TR in confined pressure vessels (PVs) they react rapidly leading to heat and gas generation that can burst PVs and pose a risk to adjacent structure/personnel. Currently, no widely accepted analysis methodology to assess the impact of LIB TR within a confining structure, i.e. battery canister, exists. The research presented aims to develop that method. Instrumented physical model testing utilizing high speed video and digital image correlation (DIC) was conducted to obtain validation data for the numerical methods. Analysis methods were developed to model the heat and gas buildup during thermal runaway, and the resultant burst of the enclosing PV.

ENHANCED TESTING GUIDED BY MODELING AND SIMULATION OVERVIEW

Timothy McGee, NSWC Carderock
Jake Mason, NSWC Carderock
Matthew Stevens, NSWC Carderock
Rachel McIntyre, NSWC Carderock

No abstract available.

UNDERWATER EXPLOSION PERFORMANCE CHARACTERIZATION

Noah Moffeit, AFRL
Dr. Brian Taylor, AFRL
Daniel Vu, AFRL
Samuel Schemmer, AFRL
Kent Rye, NSWC Carderock
Brian Mills, NSWC Carderock
Dominic Farole, US Army

No abstract available.

SESSION 28: VULNERABILITY ASSESSMENTS

REDUCED ORDER MODELLING FOR DAMAGE ASSESSMENT

Dr. Juan Londono, Thornton Tomasetti
Caleb Penner, Thornton Tomasetti
Andrew Shakalis, Thornton Tomasetti
Samantha Wu, Thornton Tomasetti
Trevor Conklin, NSWC Carderock
Sadie Johnson, NSWC Carderock
Greta Ouimette, NSWC Carderock
Benjamin Adam, NSWC Carderock

No abstract available.

AN IMPROVED ASSESSMENT FRAMEWORK FOR SUBMARINE ENVIRONMENTS

Greg Gorman, Thornton Tomasetti
Chris Craig, Thornton Tomasetti
Rebecca Dickey, NSWC Carderock
James Mills, NSWC Carderock
Jonathan Lee, NSWC Carderock
Christopher Bradel, NSWC Carderock

No abstract available.

SESSION 29: GROUND SHOCK, BLAST EFFECTS, & PENETRATION

APPLICATIONS OF SECOND-ORDER FINITE ELEMENT ANALYSIS FOR GROUNDSHOCK

Ivan Arnold, US Army ERDC
Dr. Kent Danielson, US Army ERDC
Photios Papados, US Army ERDC

The modeling and simulation of explosive groundshock and subsequent dynamic structural response is often complicated by multiple mechanisms, including 1) accuracy of available constitutive models for the geologic medium through which the shock propagates, 2) presence of joints/fractures, 3) specific construction and layout of the structures subjected to shock, etc. This work addresses the accuracy in modeling these situations through a series of well documented tests using known materials and configurations, allowing for a rigorous examination of the methodology used to simulate the propagation of shock and structural response.

The Lagrangian finite-element codes EPIC and ParaAble were used to investigate the usage and benefits of hex-dominant meshing techniques with higher-order finite elements in the simulation of extreme loading and shock propagation in well-characterized concrete structural test specimens. Hex-dominant meshing provides the computational efficiency of hexahedral elements wherever possible, while allowing for tetrahedral solutions in areas where hexahedral meshes are difficult or impossible to construct. Higher-order finite elements provide accurate representations of flexure and curved surfaces with coarse meshes. Higher-order elements have also been shown to address element locking easily, and provide reduced wave propagation dispersion error [1].

This work presents a comparison of results for both first- and second-order finite element methods, with applications to groundshock. A discussion of the benefits and usage of higher-order, hex-dominant meshes is presented, including a review of the suite of compatible elements required to successfully construct such meshes. Results from the simulations in this work are being used in conjunction with the ERDC Virtual Material Laboratory to construct a constitutive model fit for the specific concrete used in the tests.

ENHANCED STANDOFF OBSTACLE BREACHING USING SLURRY LINE CHARGE EXPLOSIVE

Stephen Turner, US Army ERDC
George Vankirk, US Army ERDC
John Q. Ehrgott, Jr., US Army ERDC
Denis D. Rickman, US Army ERDC
Dr. Darren L. Rice, US Army ERDC
Ernest F. Moore, DEVCOM AC
Cole T. Becker, DEVCOM AC
Amy Wilson, DEVCOM AC

The Enhanced Standoff Obstacle Breaching Research and Development Program is a cooperative effort between the DEVCOM Armaments Center, 20th Engineer Brigade, and the US Army Engineer Research and Development Center, Geotechnical and Structures Laboratory. It was started in FY 2024 to develop new delivery methods and technologies to use linear explosive charges in the standoff breaching of various obstacles such as minefields, concertina wire and concrete barriers, and improvised rubble barriers in urban warfare. This document will provide an overview of the development and testing results from preliminary concept testing. Results will be compared with current explosive obstacle breaching technologies.

CHARACTERIZATION OF SIMPLIFIED SURROGATE MUNITION

Marcus Barksdale, US Army ERDC
Austin Hopkins, US Army ERDC
Bowen Woodson, US Army ERDC

The ability to rapidly evaluate the impact of innovative munitions on targets is essential for advancing munition designs in modern warfare. Continued development of advanced weapon systems and high-preformance target materials creates capability gaps in the current weapons effects analysis tools. This gap necessitates the evolutionary development of enhanced modeling and simulation capabilities and fast running weaponeering tools.. However, these advanced tools cannot be fully developed without validation from physical experiments. Thus, the U.S. Army Engineer Research and Development Center (ERDC) previously conducted multiple series of 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, code named SCS107. The ERDC subsequently conducted a series of arena experiments to examine the cumulative damage effects of surrogate munitions against steel and concrete targets. In recent months, the ERDC conducted seven additional target arena experiments utilizing the surrogate munition. The purpose of these recent experiments was to gain additional insight into the combined blast and fragmenting effects of the cased weapons against concrete and steel targets. These experimental efforts provide the ERDC's numerical modeling team and tool developers with additional data to fill gaps from the previous experimental series. Data collected captured peak midspan deflection, maximum residual midspan deflection, target perforation areas, fragment velocities, and blast side-on pressure. This presentation provides an overview of the latest experimental series, compares results to the previous series, and highlights the importance of conducting physical experiments for the improvement of existing tools critical to the U.S. Army's mission.

HOLMQUIST JOHNSON COOK CONSTITUTIVE MODEL MATERIAL CONSTANTS FITTING TO DECELERATION AND VELOCITY TEST DATA

Miroslav Tesla, US Army DEVCOM Armaments Center
Donald Carlucci, US Army DEVCOM Armaments Center
Eric Marshall, US Army DEVCOM Armaments Center

A Finite Element Analysis (FEA) model was developed in Abaqus to calibrate material constants in the Holmquist Johnson Cook (HJC) constitutive material model. The HJC model is intended for the simulation of the mechanical response and failure behavior subjected to large strains, high strain rates and high pressures. The predicted deceleration and the predicted exit ve-locity were compared with the test values as output variables. Modeling and simulation was used to predict decelerations and velocities during projectile penetration through concrete block. The test article was placed in a 155 mm projectile and instrumented with a uniaxial accelerometer as shown in fig.1. The instrumented projectile was fired from a cannon into a 4 feet thick concrete block from 15 feet away. The concrete block was modeled using the HJC material model and pre-dicted decelerations and exit velocity were compared with experimental results. HJC material constants were modified to achieve the best fit of predicted deceleration and velocity to experi-mental data. The effects of different HJC material constants were investigated through parametric modeling. Fig.2, right, shows reasonably good match between projectile predicted and tested de-celerations and velocities during penetration through the concrete wall. This method demon-strated significantly improved prediction compared with the baseline;

TRAINING VIII: SHOCK RESPONSE SPECTRUM PRIMER

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.