SAVE
SHOCK & VIBRATION EXCHANGE

91st Shock & Vibration Symposium

September 19 - 23, 2021
Orlando, Florida

www.savecenter.org

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Welcome

WELCOME TO ORLANDO AND THE 91ST SHOCK AND VIBRATION SYMPOSIUM!

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

The symposium is presented by **HI-TEST Laboratories** and the **Shock and Vibration Exchange**.

Thank You

IN ADDITION TO OUR EVENT HOSTS, WE WOULD LIKE TO RECOGNIZE OUR CORPORATE SUPPORTERS:

Silver Sponsors

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Schedule at a Glance

(WITH DAILY OUTLINE AND HOURS)

DAY/DATE	PROGRAM FEATURE TYPE	TIME	PAGE
SUNDAY (09/19)	REGISTRATION (SALON 10)	8:00AM - 5:00PM	
	TUTORIALS (SPECIAL SESSION)	10:00AM - 4:00PM	PG. 6
MONDAY (09/20)	REGISTRATION (SALON 10)	7:00AM - 6:00PM	
	TUTORIALS	8:00AM - 7:00PM	PG. 7-10
	EXHIBIT HALL SETUP (EXECUTIVE BALLROOM)	NOON - 6:00PM	
	WELCOME RECEPTION (EXECUTIVE BALLROOM)	6:30PM - 8:30PM	PG. 11
TUESDAY (09/21)	REGISTRATION (SALON 10)	7:00AM - 6:00PM	
	EXHIBIT HALL OPEN (EXECUTIVE BALLROOM)	7:00AM - 5:00PM	
	TUTORIALS	8:00AM - 11:00AM	PG. 12
	GENERAL SESSION 1 & EXHIBITOR LUNCHEON	11:00AM - 1:00PM	PG. 13
	TECHNICAL PAPER SESSIONS & TRAINING	1:00PM - 5:45PM	PG. 14-17
WEDNESDAY (09/22)	REGISTRATION (SALON 10)	7:00AM - 6:00PM	
	TECHNICAL PAPER SESSIONS & TRAININGS	8:00AM - NOON	PG. 18-21
	GENERAL SESSION 2 & AWARDS LUNCHEON	NOON - 1:30PM	PG. 22
	TECHNICAL PAPER SESSIONS & TRAININGS	1:30PM - 3:30PM	PG. 24-25
	TUTORIALS	3:30PM - 6:30PM	PG. 26-27
	EXHIBIT HALL DISMANTLE	4:15PM - 6:00PM	
	COMMERCIALLY SPONSORED SOCIAL EVENT	7:00PM - 10:00PM	PG. 28-29
THURSDAY (09/23)	REGISTRATION (SALON 10)	7:00AM - NOON	
	TECHNICAL PAPER SESSIONS & TRAININGS	9:00AM - 11:00AM	PG. 30-31
	S&V TAG COMMITTEE MEETING (SALON 3)	1:00PM - 2:30PM	PG. 30-31
	EXHIBIT HALL LAYOUT & VENDOR DESCRIPTIONS		PG. 32-49
	HOTEL MEETING SPACE FLOOR PLANS		PG. 40-41
	ABSTRACTS FOR ALL PAPER/PRESENTATIONS		APPENDIX A

GLOSSARY OF TERMS & ABBREVIATIONS

DISTRIBUTION STATEMENTS (ALL TECHNICAL SESSIONS HAVE A DISTRIBUTION STATEMENT):

- UNLIMITED DISTRIBUTION A: APPROVED FOR PUBLIC RELEASE/DISTRIBUTION LIMITED
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TRAINING: 45-MINUTE TO 2-HOUR TRAINING AND/OR EDUCATIONAL SESSION ON A SPECIFIC SUBJECT; NO FEE
TUTORIAL: 3-HOUR FOCUSED COURSE. ADDITIONAL FEE TO ATTEND; CERTIFICATE OF COMPLETION PROVIDED

Food & Beverage Events

(All Symposium attendees are welcome to attend events listed below*)

MONDAY (09/20)	**WELCOME RECEPTION** (EXECUTIVE BALLROOM / EXHIBIT HALL) *BEVERAGES & HEAVY HORS D'OEUVRES* **GUESTS OF SYMPOSIUM ATTENDEES ARE WELCOME.*	6:30PM - 8:30PM
TUESDAY (09/21)	**BREAKFAST** (EXECUTIVE BALLROOM / EXHIBIT HALL)	7:00AM - 8:30AM
	GENERAL SESSION 1 AND EXHIBITORS LUNCHEON (EXECUTIVE BALLROOM / EXHIBIT HALL)	11:00AM - 1:00PM
	ICE CREAM SOCIAL (EXECUTIVE BALLROOM / EXHIBIT HALL)	3:00PM - 3:40PM
WEDNESDAY (09/22)	**BREAKFAST** (EXECUTIVE BALLROOM / EXHIBIT HALL)	7:00AM - 8:30AM
	GENERAL SESSION 2: AWARDS LUNCHEON AND GUEST SPEAKER (EXECUTIVE BALLROOM / EXHIBIT HALL)	NOON - 1:30PM
	SYMPOSIUM SOCIAL/DINNER **AT OFFSITE LOCATION (MAIN EVENT).** **COMMERCIALLY SPONSORED BY:** **PCB PIEZOTRONICS AND HI-TEST LABORATORIES** **GUESTS OF SYMPOSIUM ATTENDEES ARE WELCOME.*	7:00PM - 10:00PM
THURSDAY (09/23)	**BREAKFAST** (EXECUTIVE BALLROOM / EXHIBIT HALL)	8:00AM - 9:30AM

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

SPECIAL TUTORIAL SESSION
10:00AM - 4:00PM

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

MIL-DTL-901E SHOCK TRAINING
Mr. Kurt Hartsough (NSWC Philadelphia)
Mr. Domenic Urzillo (NSWC Carderock)

SALON 7/8

MIL-DTL-901E, signed out in June of 2017, replaces MIL-S-901D (1989). The MIL-DTL-901E is the integration of MIL-S-901D-IC2 and all of the MIL-S-901D clarifications letters (2001-2012) and standardization of the Deck Simulating Shock Machine (DSSM) as an approved test platform for shock isolated deck mounted equipment. The full day training will cover, in depth, the new MIL-DTL-901E test requirements, including all of the cost reduction areas critical to a cost effective shock hardening test program. In addition, the Navy's shock qualification policy, OPNAVINST 9072.2A (2013) and NAVSEA Tech Pub T9072-AF-PRO-010 (Shock Hardening of Surface Ships) will be covered. NAVSEA Tech Pub T9072-AF-PRO-010 (Shock Hardening of Surface Ships) replaces the canceled NAVSEAINST 9072.1A.

End Sunday Events

SAVE BUSINESS CENTER

DOCUMENTS TO PRINT, EMAILS TO ANSWER, OR PRESENTATIONS TO REVIEW?

WE HAVE COMPUTERS AND PRINTERS AVAILABLE IN REGISTRATION (SALON 10) FOR ADDED CONVENIENCE OF OUR ATTENDEES.

SPONSORED BY:

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TUTORIAL SESSION 1
8:00AM - 11:00AM

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

MIL-DTL-901E SHOCK QUALIFICATION TESTING
Mr. Kurt Hartsough (NSWC Philadelphia)
Mr. Domenic Urzillo (NSWC Carderock)

SALON 7/8

The Naval Surface Warfare Center Carderock Division Philadelphia (NSWCCD-SSES) Code 333 is NAVSEA 05P1's Delegated Approval Authority (DAA) for MIL-DTL-901E Surface Ship Shock. As the DAA, Code 333 engineers are responsible for review and approval of all Government Furnished Equipment (GFE) and heavyweight shock tested equipment. NSWCCD Code 333 will be presenting the requirements for shock qualification testing as detailed in MIL-DTL-901E and interpreted by NAVSEA 05P1. Shock testing theory, MIL-DTL-901E shock test devices and facilities, detailed specification requirements, cost avoidance and clarification and MIL-DTL-901E IC#2 will be covered. Attendees should include anyone involved in the acquisition, specification, review and approval of Navy shipboard equipment including PARMs and LCMs and contracting officers, contractors having to deal with the Navy and wishing to supply shock qualified equipment to the Navy, Ship Program Managers and Ship Logistic Managers responsible for the acquisition & maintenance of shock hardened Navy ships and shock qualification test facilities.

THE MEASUREMENT & UTILIZATION OF VALID SHOCK AND VIBRATION DATA
Dr. Patrick Walter (TCU / PCB Piezotronics)

SALON 5/6

Significant focus is often provided to applying sophisticated analysis techniques to data resulting from shock and vibration tests. However, inadequate focus is often provided to assuring that valid shock and vibration data are acquired in the first place. This tutorial attempts to correct this deficiency. For the instrumentation novice it will provide an introduction to shock and vibration measurements, the physics of piezoelectric and silicon based accelerometers, and motion characterization. For the experienced test technician or engineer it will provide additional insight into topics such as optimized measurement system design, accelerometer and measurement system calibration, accelerometer mounting effects, analog filtering, data validation, data utilization, and more. For the analyst or designer it will provide a series of simple observations and back of the envelope calculations that he/she can make on data to validate its credibility before using it in product design.

INTRODUCTION TO DESIGNING SHOCK MOUNTED SYSTEMS USING SIMPLE SOFTWARE
Mr. Dave Callahan (HII - Newport News Shipbuilding)

SALON 3

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

TUTORIAL SESSION 2
NOON - 3:00PM

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

MIL-DTL-901E SHOCK QUALIFICATION TESTING EXTENSIONS

SALON 7/8

Mr. Kurt Hartsough (NSWC Philadelphia)
Mr. Domenic Urzillo (NSWC Carderock)

The Naval Surface Warfare Center Carderock Division Philadelphia (NSWCCD SSES) Code 333 is NAVSEA 05P1's Delegated Approval Authority (DAA) for MIL-DTL-901E Surface Ship Shock. As the DAA, Code 333 engineers are responsible for review and approval of all Government Furnished Equipment (GFE) and heavyweight shock tested equipment. NSWCCD Codes 333 will be presenting the requirements for shock qualification extensions as detailed in MIL-DTL-901E and interpreted by NAVSEA 05P1. Shock extension specification requirements, MIL-DTL-901E design guidelines and shock design lessons learned will be covered. Attendees should include anyone involved in the acquisition, specification, review and approval of Navy shipboard equipment including PARMs and LCMs and contracting officers, contractors having to deal with the Navy and wishing to supply shock qualified equipment to the Navy, Ship Program Managers and Ship Logistic Managers responsible for the acquisition & maintenance of shock hardened Navy ships and shock qualification test facilities.

AN INTRODUCTION TO ALIASING, FFT, FILTERING, SRS & MORE FOR FEA USERS AND TEST ENGINEERS

SALON 5/6

Dr. Ted Diehl (Bodie Technology)

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

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

AN OVERVIEW OF THE MIL-STD-461G ELECTROMAGNETIC INTERFERENCE CONTROL REQUIREMENTS FOR SUBSYSTEMS AND EQUIPMENT DEPLOYED ON SURFACE SHIPS AND SUBMARINES

SALON 2

Mr. Jeff Viel (National Technical Systems - NTS)

This college level tutorial addresses the essentials of the MIL-STD-461G standard including a brief history of the standard, test applicability, hardware configuration setup requirements, test procedures development and Test methodologies including basic formulas and calculations. This tutorial discusses some of the most common product compliance issues encountered during EMI testing, and provides insight into practical mitigation and design techniques. It is suited for students, technicians, engineers, and project managers, and anyone seeking a thoughtful understanding of these requirements, and guidance on practical application of test limits levels and ranges.

[SEE ADDITIONAL TOPICS FOR THIS SESSION ON PAGE 9]

EFFECTIVE SOLUTIONS FOR SHOCK AND VIBRATION CONTROL

SALON 4

Mr. Alan Klembczyk (Taylor Devices)
Dr. J. Edward Alexander (Consultant)
Mr. Kenneth Lussky (BAE Systems)

This presentation provides an outline of various applications and methods for implementing isolation control of dynamic loads and damping within a wide array of dynamic systems and structures. Photos, videos, and graphical results are presented of solutions that have been proven effective and reliable in the past. Design examples are given and typical applications are reviewed Additionally, key definitions and useful formulae are presented that will provide the analyst or systems engineer with the methods for solving isolation problems within the commercial, military, and aerospace sectors. A wide range of isolation mounts and systems are covered including liquid dampers, elastomer and wire rope isolators, tuned mass dampers, and engineered enclosures. Engineering guidelines are presented for the selection and evaluation of isolation control products. Protection of COTS electronic equipment and probable damage levels are reviewed for the preparation of design and test specifications. Applications involve shipboard, off-road vehicles and airborne projects. Included also are industrial equipment and seismic control of structures and secondary equipment. Field and test data such as MIL-DTL-901E barge test measurements are presented. The use of Shock Response Spectra (SRS) for equipment assessment as well as isolator analysis is discussed. Details and examples of shock and vibration analyses are presented including case studies with step by step description of engineering calculations. The shock and vibration environment and corresponding equipment response is characterized primarily in terms of the peak response of a single degree of freedom (SDOF) system. This includes peak equipment acceleration response given by the SRS (shock response spectrum), the peak equipment velocity response given by the PVSS (pseudo-velocity shock spectrum) and the maximum total energy input to the equipment given by the energy input spectrum (EIS). An example is presented where the peak energy input to both linear and nonlinear base excited MDOF (multi-degree of freedom) systems is strongly correlated to the SDOF EIS. Examples of the vibration environment are discussed in terms of a power spectral density (PSD) and correlation of a PSD input and the maximum equipment RMS acceleration response, based on Miles equation. Matlab functions for SDOF equipment response based on characteristics of various shock isolators are described where example results are correlated to test data.

HOW MODAL INFORMATION CAN IMPROVE CONFIDENCE IN VIBRATION QUALIFICATION

SALON 3

Mr. Troy Skousen (Sandia National Laboratories)
Mr. Randy Mayes (Contractor)

Random vibration laboratory testing is used to qualify components to survive in-service responses to system environments. Using realistic research hardware and an analytical rocket system, we show that traditional single input (SDOF) base excitation laboratory test specifications generate large response uncertainties when compared with the field environment responses. A brief review is provided showing how mode shapes are derived from test data. A model utilizing fixed base and rigid body modes of the component on its vibration test fixture is used to decompose the component field motion into a few insightful modal responses. This model is used to develop a greatly improved SDOF base input test. It is used to develop 6DOF laboratory control that eliminates large uncertainties with a corresponding boost in qualification confidence. The same model can also be used to address unit-to-unit variability simply based on a laboratory random survey before the component qualification test is executed.

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.

TUTORIAL SESSION 3
4:00PM - 7:00PM

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

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

SALON 7/8

Mr. Kurt Hartsough (NSWC Philadelphia)
Mr. Domenic Urzillo (NSWC Carderock)

The MIL-DTL-901E Subsidiary Component Shock Testing and Alternate Test Vehicles course will cover the following areas: NAVSEA 05P1's current policy for testing subsidiary components, description of test environment requirements, examples of recent successful test programs, alternate test vehicle descriptions, alternate test vehicle limitations, discussions on shock spectra, Multi-Variable Data Reduction (MDR) and various shock isolation systems. This course is intended to give the necessary information to equipment designers and program managers who intend to shock qualify COTS equipment that will require frequent upgrades due to obsolescence, equipment upgrades, change in mission, etc.

INTRODUCTION TO WEAPONS EFFECTS AND SHIP COMBAT SURVIVABILITY ANALYSIS

SALON 3

Mr. Jan Czaban (Zenginworks Limited)

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

DDAM 101

SALON 5/6

Mr. George D. (Jerry) Hill (SERCO)

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

Welcome Reception

HI-TEST Laboratories, Inc.

ALL SYMPOSIUM & TRAINING ATTENDEES, AND THEIR GUESTS, ARE INVITED TO ATTEND.

6:30PM - 8:30PM
FOOD & DRINKS
EXHIBIT HALL/EXECUTIVE BALLROOM

End Monday Events

TUTORIAL SESSION 4
8:00AM - 11:00AM

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

CHANGES FROM MIL-S-901D TO MIL-DTL-901E EXPLAINED
Mr. Kurt Hartsough (NSWC Philadelphia)

SALON 7/8

The intent of this tutorial is to cover the changes between MIL-S-901D and MIL-DTL-901E. This tutorial will provide an opportunity to discuss specific situations related to shock qualification testing with NAVSEA 05P1's Delegated Approval Authorities for Surface Ships and Submarines. Areas covered include: updated and new definitions, reduce shock test schedules, shock isolation, use of standard and non-standard fixtures, reduced hammer blows, reduced multiple operating mode requirements, reduced retesting, Shock Response Frequency (SRF) and more.

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

SALON 2

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

SOME MODERN FRAMEWORKS FOR SHOCK MODELING
Dr. Tom Paez (Thomas Paez Consulting)

SALON 5/6

Accurate specification of mechanical shock tests has long been a fundamental goal of environment analysts. The de-facto standard for shock test specification, today, is the method of shock response spectra (SRS), first developed in 1932. The method has its shortcomings. Although it is possible to specify tests that somewhat accurately reflect field environments, practical implementations tend to yield over-tests that do not accurately resemble the field environments they are meant to represent. Yet many alternatives to the method of SRS are available. This presentation discusses four data-based alternatives for modeling oscillatory shocks, alternatives for which tolerance limit-based test time histories can be specified. These are: (1) The Karhunen-Loeve Expansion; (2) Continuous Wavelet Transform; (3) The Priestley Model for Nonstationary Random Processes; and (4) Least Favorable Response. The methods are all data-based; they permit the use of small or large ensembles for the specification of tolerance limit-based, test time histories. Some are more mathematically complex than the others, but software can be written that permits the simple specification of test time histories. This presentation develops the methods in as much detail as possible during a limited-duration exposition. Examples of the use of the four methods will be presented. MATLAB programs for the implementation of the four methods will be distributed to those who wish to have them.

AIR BLAST AND CRATERING:
AN INTRODUCTION TO THE ABC'S OF EXPLOSION EFFECTS IN AIR AND ON LAND
Mr. Denis Rickman (USACE ERDC)

SALON 3

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

EXHIBITORS' LUNCHEON (GENERAL SESSION I) 11:00AM - 1:00PM

EXECUTIVE BALLROOM

11:00AM —11:15AM	**CALL TO ORDER & OPENING REMARKS** Mr. Drew Perkins (SAVE / HI-TEST Laboratories)	
11:15AM—11:45PM	**EXHIBITOR MEET & GREET**	
11:45AM—1:00PM	**LUNCH**	

ENJOY TIME TO PERUSE THE EXHIBIT HALL DURING THE

Exhibitor Meet & Greet!

DON'T FORGET TO GET STARTED ON YOUR "PASSPORT"! PRIZES TO INCLUDE:

PROGRAM PRIZES

$250 AMAZON GIFT CARD
CHROMEBOOK
BOSE WIRELESS SPEAKER

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MINI MISSILE DESTROYER WARSHIP
$100 AMAZON GIFT CARD
FLAT SCREEN TV
S&V DATA RECORDER
SHOCK ACCELEROMETER
EXHIBITOR APPAREL & SWAG

DRAWING TO BE HELD DURING WEDNESDAY AFTERNOON BREAK IN THE EXHIBIT HALL!

	Session 1	Session 2	Session 3
	SESSION 1: **ISOLATION AND DAMPING I** 1:00-2:35PM / UNLIMITED DIST. A CHAIR(S): MR. ALAN KLEMBCZYK (TAYLOR DEVICES) MR. ROB SHARP (HUTCHINSON)	*SESSION 2:* **MATERIAL RESPONSE & EFFECTIVENESS** 1:00-1:45PM/ UNLIMITED DIST. A **BALLISTICS** 2:15-2:35PM / UNLIMITED DIST. A CHAIR(S): DR. ANDREW LITTLEFIELD (US ARMY BENET LABS) MR. DAVID ALFANO (US ARMY BENET LABS)	*SESSION 3:* **DYSMAS I** 1:00-3:00PM / LIMITED DIST. D CHAIR(S): DR. EMILY GUZAS (NUWC NEWPORT)
	THERE WILL NOT BE A CHAIR/PRESENTER MEETING. ALL PRESENTATIONS MUST BE PRELOADED IN ADVANCE OF THE SESSION (VIA SUBMITTAL TO SAVE STAFF BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).		
	SALON 3	SALON 4	SALON 7/8
1:00	**IMPROVEMENTS TO A LEGACY DESIGN FOR HIGHER LOAD CAPACITY & INCREASED DAMPING TO IMPROVE SHOCK ATTENUATION ON LARGE SHIPBOARD SYSTEMS (1)** *Mr. Shawn Czerniak, Mr. Adam Meyer, & Mr. Josh Jones (Hutchinson)*	**OVERVIEW OF PENCURV+ FOR ANALYSIS OF PROJECTILE PENETRATION EFFECTS (2)** *Mr. Reid Bond, Mr. Ernesto G. Cruz, Dr. Kyle Crosby, Mr. Mark Adley, Ms. Dorothy Boswell, & Dr. Jay Ehrgott (US Army ERDC)*	**TESTS AND SIMULATIONS OF SHOCK PROPAGATION IN A REPRESENTATIVE SHIPBOARD TANK (4)** *Mr. Bradley Klenow & Dr. Tom McGrath (NSWC Indian Head), Mr. Kent Rye, Mr. Bill Lewis, Ms. Machel McIntyre & Ms. Rebecca Grisso (NSWC Carderock), Mr. Greg Harris (ATR)*
1:25	**DESIGN, COMPONENT LEVEL TESTS, AND BARGE TEST RESULTS OF A NEW, RESILIENT SHOCK AND VIBRATION MOUNT WITH HIGH CAPACITY & PRECISE SPRING FUNCTION WITH HIGH DAMPING CHARACTERISTICS (1)** *Mr. Alan Klembczyk (Taylor Devices) & Mr. Phillip Thompson (Thornton Tomasetti)*	**CONSTITUTIVE MODELING OF A POLYURETHANE ELASTOMER SUBJECT TO LARGE DEFORMATIONS AT HIGH RATE (3)** *Mr. John Puryear (Applied Physical Sciences), Ms. Lynsey Reese (NAVFAC EXWC)*	**MODELING NUCLEAR EXPLOSION AIR BLAST IN THE DYSMAS HYDROCODE (4)** *Mr. Frank VanGessel & Dr. Tom McGrath (NSWC Indian Head)*
1:50	**SHOCK ANALYSIS COMPARISON - SIMPLE VS. HUTCHINSON'S PROPRIETARY BARRYSOFT (1)** *Mr. Josh Jones & Mr. John Sailhamer (Hutchinson)*		**PREDICTIVE MODELING OF WATER PLUME DAMAGE TO OVERHEAD TARGETS (5)** *Dr. Nicholas Nechitailo & Dr. Jason Hackl (NSWC Indian Head)*
2:15	**DEFINING A PROCESS TO DERIVE A LINEARIZED DAMPING APPROXIMATION FOR WIRE ROPE ISOLATORS (2)** *Mr. Luke Joy (Enidine)*	**CRITICAL VELOCITIES OF ANISOTROPIC TUBES UNDER A FAST MOVING PRESSURE (3)** *Dr. Andrew Littlefield (US Army DEVCOM AC Benet Labs), Prof. X.L. Gao (Southern Methodist University)*	**AN IMPROVED WATER EQUATION OF STATE AND WAVEBENDING MODELING CAPABILITY FOR UNDERWATER EXPLOSION SIMULATIONS IN DYSMAS (5)** *Mr. Frank VanGessel & Dr. Tom McGrath (NSWC Indian Head)*
2:40	KEEP A LOOK OUT FOR THIS QR CODE! SCAN TO NOMINATE ANY PRESENTATION YOU FEEL DESERVING OF OUR ANNUAL *HENRY C. PUSEY BEST PAPER AWARD*. FULL AWARD CRITERIA AND NOMINATION FORM AVAILABLE BY SCANNING THE QR CODE.		**USING DYSMAS TO SIMULATE HYPERSONIC PROJECTILES BREACHING A WATER SURFACE (6)** *Dr. Jeff St. Clair, Mr. Roger Ilamni, Mr. Jason Hackl, & Mr. Horacio Nochetto (NSWC Indian Head), Mr. Aiden Leavy (US Naval Academy)*

3:00 - 3:40

Ice Cream Social

EXECUTIVE BALLROOM (EXHIBIT HALL)

	SESSION 4: **BLAST STUDIES INCL. CRATERING** 1:00-3:00PM / LIMITED DIST. D CHAIR(S): MR. JEFF AVERETT (US ARMY ERDC) MR. JASIEL RAMOS-DELGADO (US ARMY ERDC)	*VENDOR SESSION A:* **EXHIBITOR PRESENTATIONS INCLUDING CASE STUDIES, NEW DEVELOPMENTS, TESTING & PRODUCTS** 1:00-2:35PM / UNLIMITED DIST. A CHAIR(S): MR. JIM BREAULT (LANSMONT/NVT) DR. TED DIEHL (BODIE TECHNOLOGY)	*TRAINING I:* **SHOCK RESPONSE SPECTRUM PRIMER** 1:00-2:30PM / UNLIMITED DIST. A
	THERE WILL NOT BE A CHAIR/PRESENTER MEETING. ALL PRESENTATIONS MUST BE PRELOADED IN ADVANCE OF THE SESSION (VIA SUBMITTAL TO SAVE STAFF BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).		
	SALON 5/6	SALON 2	SALON 9
1:00	**EXPERIMENTAL INVESTIGATIONS OF CRATERING EFFECTS FROM ABOVEGROUND DETONATIONS OF CASED WEAPON SURROGATE CHARGES (6)** *Mr. Daniel Vaughan, Mr. William Pratt, Mr. Joshua Payne, Mr. Denis Rickman, & Dr. Jay Ehrgott (US Army ERDC)*	**ADVANCEMENTS IN FIELD DATA RECORDER TECHNOLOGY (8)** *Mr. Jim Breault (Lansmont/NVT Group)*	**SHOCK RESPONSE SPECTRUM PRIMER (9)** *Dr. Carl Sisemore* *(Sandia National Laboratories)* 1:00 - 2:30pm
1:25	**OVERVIEW OF A FINITE ELEMENT/ EMPIRICAL MODEL FOR RUNWAY CRATER PREDICTIONS FROM BURIED HIGH-EXPLOSIVE DETONATIONS (6)** *Mr. Ernesto Cruz, Ms. Jessica Fulk, Mr. Connor Fulk, Dr. Mark Adley, Mr. Jason Roth & Dr. Jay Ehrgott (US Army ERDC), & Ms. Dorothy Boswell (ARA)*	**PROPERLY PROCESSING NOISY INVARIANT QUANTITIES SUCH AS PRINCIPAL STRAIN AND MISES STRESS – BOTH FOR FREQUENCY CONTENT AND FOR FILTERING (8)** *Dr. Ted Diehl (Bodie Technology, Inc.)*	
1:50	**CRATER ALGORITHM DESIGN FOR EXPLOSIVE CHARGE ANALYSIS (CALDERA) VALIDATION IN NON-ROADBED SCENARIOS (7)** *Mr. Jasiel Ramos-Delgado, Mr. William Myers, Dr. Jay Ehrgott (US Army ERDC)*	**INTRODUCTION TO NON-CONTACTING VIBRATION MEASUREMENTS USING DIGITAL IMAGE CORRELATION (9)** *Mr. Alistair Tofts (Correlated Solutions)*	
2:15	**FAST-RUNNING KINETIC ENERGY CRATER MODEL FOR CONCRETE TARGETS (7)** *Ms. Keri Bailey (AFRL), Mr. Mark Green (Geomechanics Research and Analysis (GmRA)*	**DEVELOPMENT OF HIGH DEFLECTION ELASTOMERIC ISOLATORS (9)** *Mr. Ali Shehadeh (VibroDynamics)*	
2:40	**ANALYSIS OF M107 BLAST PAD DATA FOR TNT AND COMPOSITION B FILLS (8)** *Ms. DeBorach Luckett & Dr. Gregory Bessette (US Army ERDC), Dr. Roosevelt Davis (AFRL/RWML)*	**KEEP A LOOK OUT FOR THIS QR CODE!** **SCAN TO NOMINATE ANY PRESENTATION YOU FEEL DESERVING OF OUR ANNUAL *HENRY C. PUSEY BEST PAPER AWARD*.** **FULL AWARD CRITERIA AND NOMINATION FORM AVAILABLE BY SCANNING THE QR CODE.**	

3:00 - 3:40

Ice Cream Social

EXECUTIVE BALLROOM (EXHIBIT HALL)

	SESSION 5: **SHOCK RESPONSE SPECTRUM I** 3:45-5:45PM / UNLIMITED DIST. A CHAIR(S): Mr. Rob Sharp (Hutchinson) Mr. Casey DuBois (Vibration Research)	SESSION 6: **BLAST I** 3:45-5:45PM / UNLIMITED DIST. A CHAIR(S): Mr. Bruce Patterson (AFRL)	SESSION 7: **DYSMAS II** 3:45-5:45PM / LIMITED DIST. D CHAIR(S): Mr. Roger Ilamni (NSWC Indian Head) Mr. Alan Luton (NSWC Indian Head)
	THERE WILL NOT BE A CHAIR/PRESENTER MEETING. ALL PRESENTATIONS MUST BE PRELOADED IN ADVANCE OF THE SESSION (VIA SUBMITTAL TO SAVE STAFF BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).		
	SALON 3	SALON 4	SALON 7/8
3:45	**Method for Computing Best fit Half-Sine Pulse from a Shock Response Spectrum (10)** *Mr. Becker Awqatty (Mide Technology)*	**Implementation of the Rickman-Murrell Clearing Model into BlastX (12)** *Ms. Krystal Rodriguez-Soto & Dr. Gregory Bessette (US Army ERDC)*	**Underwater Holing Fixture Testing & Analysis (14)** *Mr. Andrew Glass, Mr. Scott Natkow, Mr. TW Shaw, & Dr. Ken Nahshon (NSWC Carderock)*
4:10	**Defining a Better Shock Requirement (10)** *Mr. Scott Rowland & Mr. Alexander Hardt (Northrop Grumman Space Systems)*	**Full-Scale Blast Testing of Masonry Walls with Arching (13)** *Mr. Justin Gilliland, Dr. Genevieve Pezzola, Mr. Bob Walker, Mr. Donald Nelson, & Dr. Catherine Stephens (US Army ERDC)*	**Implementation of Boundary Element Code DFBEM into HULLWHIP (15)** *Mr. Georges Chahine & Mr. Chao-Tsung Hsiao (DynaFlow), Mr. Gregory Harris (ATR)*
4:35	**Shock Analysis and Testing for System Optimization and Qualification Risk Reduction Part 1: Tailoring of Shock Response Spectrums to Achieve Specific Time History Attributes (11)** *Mr. John Sailhamer (Hutchinson Aerospace & Industry)*	**Experimental Validation of the Blast Performance of Compression-Installed Blast/Ballistic Resistant Window and Door Systems (13)** *Mr. David Senior & Mr. John Judson (US Army ERDC), Mr. Craig Ackerman (US Department of State)*	**Implosion Testing of Cylinders in Confined Environments (15)** *Dr. Joe Ambrico, Mr. Craig Tilton, Mr. Ryan Chamberlin (NUWC Newport)*
5:00	**Shock Analysis and Testing for System Optimization and Qualification Risk Reduction Part 2: Validation and Optimization (11)** *Mr. John Sailhamer (Hutchinson Aerospace & Industry)*	**Performance of Adaptable Lightweight Impact Proof Plates (13)** *Dr. Jun Han, Dr. James Rall, Dr. Daryoush Allei, & Mr. Benjamin Reydel (Shock Tech)*	**Simulated Hydrostatic Implosions of a Cylinder within a Closed Box (15)** *Dr. Emily Guzas, Dr. Joe Ambrico, Mr. Craig Tilton, & Mr. Ryan Chamberlin (NUWC Newport)*
5:25	**Using Recorded Data to Improve SRS Test Development (11)** *Mr. Casey DuBois (Vibration Research)*	**Interpretation of Data from an Elevated Non-Hemispherical Charge Configuration Against a Wall Structure (14)** *Mr. Justin Roberts (US Army ERDC)*	**Using Air Bubbles in DYSMAS as Approximations of In-tube, Hydrostatic Implosion (16)** *Mr. Craig Tilton, Dr. Joe Ambrico, Dr. Emily Guzas, & Mr. Ryan Chamberlin (NUWC Newport)*

SESSION 8:	*VENDOR SESSION B:*	*TRAINING II:*
BLAST: BURIED MUNITIONS & MINES 3:45-4:55PM / LIMITED DIST. D **BLAST: WEAPONS EFFECTS & SIGNATURE STUDIES** 5:00-5:45PM / LIMITED DIST. D CHAIR(S): MR. ERNIE STAUBS (AFRL)	**EXHIBITOR PRESENTATIONS INCLUDING CASE STUDIES, NEW DEVELOPMENTS, TESTING & PRODUCTS** 3:45-5:45PM / UNLIMITED DIST. A CHAIR(S): MR. MIKE POSLUSNY (GIBBS & COX)	**CHECKING A FINITE ELEMENT MODEL** 3:45-4:45PM / UNLIMITED DIST. A

THERE WILL NOT BE A CHAIR/PRESENTER MEETING. ALL PRESENTATIONS MUST BE PRELOADED IN ADVANCE OF THE SESSION (VIA SUBMITTAL TO SAVE STAFF BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).

	SALON 5/6	SALON 2	SALON 9
3:45	**EFFICACY OF CALDERA FOR THE FORENSIC ASSESSMENT OF ANTI-TANK MINE BLASTS (16)** *Mr. William Myers, Dr. Jay Ehrgott, Mr. Jasiel Ramos-Delgado, & Mr. Carl Flowers (US Army ERDC), Mr. Daniel Danko & Mr. James Swain (TBD)*	**MARITIME CAPABILITIES (18)** *Mr. Michael Poslusny (Gibbs & Cox)*	**CHECKING A FINITE ELEMENT MODEL** (19) *Mr. Bart McPheeters (Gibbs & Cox)* 3:45 - 4:45pm
4:10	**LATE-TIME SIMULATIONS OF MK-82 BURIED TESTS FOR COLLATERAL DAMAGE ESTIMATION (16)** *Mr. William Furr, Dr. Neil Williams, Dr. Stephen Akers, & Dr. Jay Ehrgott (US Army ERDC), Mr. Marc Rivera & Mr. Michael Hopson (NSWC Dahlgren)*	**CONVENIENTLY MONITOR SHOCK AND VIBRATION WITH NEW ENDAQ CLOUD (18)** *Mr. Steve Hanly (Mide Technology)*	
4:35	**THE INFLUENCE OF SOIL TYPE ON GROUND SHOCK AND ABOVEGROUND BLAST WAVE PROPAGATION FOR SHALLOW BURIED HELLFIRE R9E DETONATIONS (17)** *Mr. Garrett Doles, Mr. William Myers, & Dr. John Q. Ehrgott, Jr. (US Army ERDC)*	**MONITORING SYSTEMS AND FACILITIES FOR ENTIRE ENVIRONMENTAL TEST LABORATORY (19)** *Mr. Chris Wilcox (m+p International)*	
5:00	**OVERVIEW OF AFRL JOINT WEAPON EFFECTS RESEARCH (17)** *Mr. Ernest Staubs (Air Force Research Laboratory)*	**MARINE MACHINERY ASSOCIATION - CAPABILITIES MATRIX (19)** *Mr. John Rhatigan (MMA)*	**SCAN TO NOMINATE A PRESENTATION FOR OUR ANNUAL *HENRY C. PUSEY BEST PAPER AWARD.***
5:25	**FORENSIC ENCYCLOPEDIA RESULTS RETRIEVAL AND EVALUATION TOOL FOR FORENSIC CHARACTERIZATION AND METHODOLOGY (18)** *Ms. Katelyn Polk & Mr. Cameron Thomas (US Army ERDC)*	**ADVANCEMENTS IN MULTI AXIS VIBRATION TECHNOLOGY (19)** *Mr. Kevin McIntosh (TEAM Corporation)*	

End Tuesday Events

	SALON 3	SALON 4	SALON 7/8
	SESSION 9: **PYROSHOCK** 8:25-9:10AM / UNLIMITED DIST. A CHAIR(S): Mr. Britton Kreitz (NTS)	*SESSION 10:* **VIBRATION TESTING APPLICATIONS** 8:25-9:35AM / UNLIMITED DIST. A CHAIR(S): Dr. Russ Ayres (Spectral Dynamics)	*SESSION 11:* **MECHANICAL SHOCK** 8:25-9:10AM / LIMITED DIST. C CHAIR(S): Mr. Calvin Milam (HI-TEST Laboratories)
	THERE WILL NOT BE A CHAIR/PRESENTER MEETING. ALL PRESENTATIONS MUST BE PRELOADED IN ADVANCE OF THE SESSION (VIA SUBMITTAL TO SAVE STAFF BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).		
8:00	**SCAN TO NOMINATE A PRESENTATION FOR OUR ANNUAL *HENRY C. PUSEY BEST PAPER AWARD*.**		
8:25	**Influence of Test Setup Parameters on the Time Domain Test Specification of Resonant Plate Shock Test (19)** *Dr. Washington DeLima & Mr. William Zenk (Kansas City National Security Campus)*	**Vibration Effects on Laser Optical Train (20)** *Dr. Jeremy Kolansky, Dr. Pablo Tarazaga, & Dr. Scott Huxtable (Virginia Tech), Dr. Luke Martin (NSWC Dahlgren)*	**Post-Yield Shock Energy Propagation: Testing and Numerical Simulation of a Simple Beam (21)** *Mr. Austin Hughes (United Launch Alliance), Mr. Joshua Gorfain (Applied Physical Sciences)*
8:50	**Finite Element Analysis of Mechanical Impulse Pyroshock Simulator (MIPS) Tests to Predict the Shock Response Spectrum Levels (20)** *Ms. Claudia Northrup, Dr. Logan McLeod, & Mr. Da Cheng (National Technical Systems)*	**Vibration Resiliency of Laser Optical Trains (21)** *Dr. Jeremy Kolansky, Dr. Pablo Tarazaga, & Dr. Scott Huxtable (Virginia Tech), Dr. Luke Martin (NSWC Dahlgren)*	**Drop Shock Fixture Analysis on a Short Duration Pulse Using SWAT Force Reconstruction (22)** *Mr. Ryan Jennings, Mr. Jonathan Hower, & Mr. Brad Wohletz (Kansas City National Security Campus)*
9:15		**Deriving Best SDOF Shaker Inputs from 6 DOF Base Input Payload Models (21)** *Mr. Randy Mayes (Consultant)*	

9:35 - 10:00

Coffee Break with the Exhibitors

EXECUTIVE BALLROOM (EXHIBIT HALL)

SESSION 12: **BLAST: STRUCTURE & MATERIAL RESPONSE I** 8:00-9:10AM / LIMITED DIST. D 9:15-9:35AM / LIMITED DIST. C CHAIR(S): Mr. Ernie Staubs (AFRL) Dr. Jay Ehrgott (US Army ERDC)	VENDOR SESSION C: **EXHIBITOR PRESENTATIONS INCLUDING CASE STUDIES, NEW DEVELOPMENTS, TESTING & PRODUCTS** 8:00-9:35AM / UNLIMITED DIST. A CHAIR(S): Mr. Alan Klembczyk (Taylor Devices) Mr. Bob Metz (PCB Piezotronics)	TRAINING III: **AN INTRODUCTION TO DYNAMIC ANALYSIS** 8:00-9:00AM / UNLIMITED DIST. A
THERE WILL NOT BE A CHAIR/PRESENTER MEETING. ALL PRESENTATIONS MUST BE PRELOADED IN ADVANCE OF THE SESSION (VIA SUBMITTAL TO SAVE STAFF BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).		

Time	SALON 5/6	SALON 2	SALON 9
8:00	**Measuring and Analyzing the Airblast Environment within a Multi-room Structure Consisting of Opened, Closed, and Sealed Doors (22)** *Mr. Roosevelt Davis & Mr. Ernest Staubs (Air Force Research Laboratory)*	**Temperature Limits for Shock Testing (24)** *Mr. Bob Metz (PCB Piezotronics)*	**An Introduction to Dynamic Analysis (24)** *Mr. Bart McPhetters (Gibbs & Cox)* 8:00 - 9:00am
8:25	**Evaluation of the Response of High-Performance Concrete Elements to Proliferated Weapons Systems (23)** *Mr. Cameron Thomas (US Army ERDC)*	**New High-Capacity 6 DOF Hybrid Isolator including Component-Level and Barge Test Results (24)** *Mr. Alan Klembczyl (Taylor Devices)*	
8:50	**Repair and Enhancement of Concrete Barriers Using High-Performance Concrete (23)** *Mr. Stephen Turner (US Army ERDC)*	**Helping Cut Cords in Data Acquisition (24)** *Mr. Jake Rosenthal (DEWESoft)*	
9:15	**Perforation Testing Into A36 Steel Targets Using Ogive, Hemispherical, and Conic-Nose Steel Projectiles (23)** *Dr. Kyle Crosby, Mr. Reid Bond, Mr. Ernesto Cruz, & Dr. Jay Ehrgott (US Army ERDC)*	**Introduction to High-Speed Imaging for Digital Image Correlation (24)** *Dr. Kyle Gilroy (Vision Research)*	

9:35 - 10:00

Coffee Break with the Exhibitors

EXECUTIVE BALLROOM (EXHIBIT HALL)

	SESSION 13: **DROP SHOCK MITIGATION** 10:00-10:45AM / UNLIMITED DIST. A **STRUCTURAL RESPONSE** 11:15-11:35AM / UNLIMITED DIST. A CHAIR(S): MR. JEFF MORRIS (HI-TEST LABORATORIES)	*SESSION 14:* **THE CABLE: IT IS THE RODNEY DANGERFIELD OF THE INSTRUMENTATION SYSTEM, PART I** 10:00AM-NOON / UNLIMITED DIST. A ***In appreciation for decades of service to dynamic measurements, this session is dedicated to Dr. Patrick Walter, who has helped numerous test facilities make better measurements.*** CHAIR(S): DR. PAT WALTER (PCB PIEZOTRONICS) MR. JAMES WOERNLEY (PRECISION FILTERS)	*SESSION 15:* **DEDICATED SESSION: MECHANICAL SHOCK: COMPUTATIONAL & EXPERIMENTAL METHODS FOR FUZE TECHNOLOGY I** 10:00-11:10AM / LIMITED DIST. D 11:15-11:35AM / UNLIMITED DIST. A CHAIR(S): MR. MICHAEL DAVIS (AFRL) DR. ALAIN BELIVEAU (ARA)
	THERE WILL NOT BE A CHAIR/PRESENTER MEETING. ALL PRESENTATIONS MUST BE PRELOADED IN ADVANCE OF THE SESSION (VIA SUBMITTAL TO SAVE STAFF BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).		
	SALON 3	SALON 9	SALON 7/8
10:00	**REUSABLE, HIGH PERFORMANCE HONEYCOMB FOR AIRDROP APPLICATIONS (25)** *Mr. Benjamin Reydel, Dr. Daryoush Allaei, Dr. James Rall, & Dr. Jun Han (Shock Tech)*	**THE CRITICAL ROLE OF FULL-SCALE SYSTEMS TESTING IN MODEL VALIDATION AND THE ESTABLISHMENT OF COMPONENT TEST REQUIREMENTS (27)** *Dr. Patrick Walter (Consultant/PCB Piezotronics)*	**THERMAL AND MECHANICAL ANALYSIS OF FUZE PACKAGING SCENARIOS AND RESULTING IMPLICATIONS (28)** *Dr. Matthew Neidigk & Mr. Curtis McKinion (AFRL), Dr. Alain Beliveau, Mr. Jared Hammerton, Dr. Adriane Moura, & Mr. James Scheppegrell (Applied Research Associates)*
10:25	**DYNAMIC SIMULATIONS FOR AIRDROP PLATFORM (25)** *Dr. Jun Han, Mr. Benjamin Reydel, Dr. Daryoush Allaei, & Dr. James Rall (Shock Tech)*	**THE BASICS (HIGH/LOW FREQUENCY TIME CONSTRAINTS, IMPEDANCE CONSIDERATIONS, LINEAR PHASE/FLAT AMPLITUDE RESPONSE) (27)** *Dr. Patrick Walter (Consultant/PCB Piezotronics)*	**THERMAL AND HIGH-G EXPERIMENTS FOR FUZE ELECTRONICS PACKAGING (28)** *Mr. Curtis McKinion & Dr. Matthew Neidigk (AFRL), Dr. Alain Beliveau, Mr. Jared Hammerton, Dr. Adriane Moura, & Mr. James Scheppegrell (Applied Research Associates)*
10:50		**WHAT MANUFACTURERS CAN AND CANNOT CERTIFY ABOUT SENSOR PERFORMANCE (27)** *Dr. Patrick Walter (Consultant/PCB Piezotronics)*	**EFFECTS OF PCB DESIGN PARAMETERS ON THE ENCAPSULATED ELECTRONICS STRESS-STATE IN HYPERSONIC ENVIRONMENTS (29)** *Mr. Caleb White & Mr. Shane Curtis (Sandia National Laboratories)*
11:15	**ANOMALOUS ZONES FOR IMPULSIVELY LOADED STRUCTURES (26)** *Dr. Nicholas Nechitailo (NSWC Indian Head)*	**CHALLENGES AND PITFALLS IN PLANNING FOR A SPECIFIC HIGH FREQUENCY SHOCK TEST TO SATISFY MIL-STD-810 INSTRUMENTATION REQUIREMENTS (28)** *Dr. Patrick Walter (Consultant/PCB Piezotronics) & Mr. James Woernley (Precision Filters)*	**EVALUATION OF VERSALINK 143 AS AN ISOLATION LAYER FOR HIGH-G SURVIVAL (29)** *Dr. Joel Limmer & Mr. Shane Curtis (Sandia National Laboratories)*
11:40	**SCAN TO NOMINATE A PRESENTATION FOR OUR ANNUAL *HENRY C. PUSEY BEST PAPER AWARD.***	**TEST DATA RESULTS & THE CRITICAL IMPORTANCE OF END-TO-END MEASUREMENT SYSTEM CHARACTERIZATION (28)** *Mr. James Woernley (Precision Filters)*	

Tip

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

SESSION 16: **BLAST: STRUCTURE & MATERIAL RESPONSE II** 10:00-11:35AM / LIMITED DIST. D CHAIR(S): DR. GREGORY BESSETTE (US ARMY ERDC) DR. JAY EHRGOTT (US ARMY ERDC)	SESSION 17: **STRUCTURAL RESPONSE: MODELING & SIMULATION** 10:00-10:20AM/ LIMITED DIST. D **UNDEX ANALYSIS I** 10:50-11:10AM / LIMITED DIST. D 11:15AM - NOON / LIMITED DIST. C CHAIR(S): MR. GREG HARRIS (ATR) MR. JOHN PRZYBYSZ (IDA)	TRAINING IV: **INTRODUCTION TO HEAVYWEIGHT SHOCK TESTING** 10:00AM-NOON / UNLIMITED DIST. A

THERE WILL NOT BE A CHAIR/PRESENTER MEETING. ALL PRESENTATIONS MUST BE PRELOADED IN ADVANCE OF THE SESSION (VIA SUBMITTAL TO SAVE STAFF BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).

	SALON 5/6	SALON 4	SALON 2
10:00		**MODELING OF LABORATORY SHOCK-BASED STRUCTURAL HEALTH MONITORING FOR NAVAL WEAPONS APPLICATIONS (32)** *Mr. Robert Ponder & Mr. Daniel Holder (NSWC Dahlgren)*	**INTRODUCTION TO HEAVYWEIGHT SHOCK TESTING (33)** *Mr. Travis Kerr (HI-TEST Laboratories)* 10:00AM - NOON
10:25	**MODELING GAS FLOW IN THE BLASTX FAST-RUNNING MODEL (30)** *Dr. Greg Bessette (US Army ERDC) & Dr. Alan Ohrt (AFRL)*		
10:50	**HOW WILL IT SURVIVE? INFORMING DESIGN DECISIONS FOR TUNNELS SUBJECT TO HIGH-YIELD WEAPONS USING FINITE-ELEMENT MODELING (30)** *2LT Johnathon Scheerer, 2LT Antonio Viera, CDT Mark Quesnel, MAJ Mike Meier and MAJ Jes Barron (US Military Academy)*	**HULLWHIP: RECENT DEVELOPMENTS FOR WHIPPING ANALYSIS (32)** *Dr. Ken Nahshon (NSWC Carderock); presented by Greg Harris (ATR)*	
11:15	**EVALUATION OF EFFECT OF EARTH-COVER THICKNESS ON ECM LOADING: 1/4 SCALE CORRUGATED ARCH DONOR RESULTS (31)** *Mr. Joshua Payne, Dr. T. Neil Williams, Dr. Jay Ehrgott, & Mr. Denis Rickman (US Army ERDC), Dr. Michelle Crull (US Army ESC), Mr. Paul Cummins & Ms. Andrea O'Brien (Defense Ammunition Center)*	**VALIDATION "GRADER" FOR TRANSIENT SHOCK MODELING AND SIMULATION (32)** *Dr. Russ Miller & Mr. John Przybysz (Institute for Defense Analyses)*	
11:40		**A PRIORI AND A POSTERIORI MODELING AND SIMULATION GUIDANCE FOR COMPLEX SUBMARINE HULL STRUCTURES (33)** *Mr. Fred Costanzo (M&J Engineering), Dr. Jeffrey Cipolla (Raytheon), Mr. Alex Kelly, Mr. Ostap Gladoun, & Mr. Ryan Anderson (Thornton Tomasetti)*	

SEE A PRESENTATION WORTHY OF OUR HENRY C. PUSEY AWARD? REMEMBER TO NOMINATE THAT PAPER WHEN WE PROVIDE THE LINK!

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

Noon—12:05pm	**CALL TO ORDER** Mr. Drew Perkins (SAVE / HI-TEST Laboratories)	
12:05pm—12:15pm	**HENRY PUSEY BEST PAPER AWARD** Presented to:	 Dr. Carl Sisemore, Sandia National Laboratories
12:15pm—12:25pm	**DEDICATED SERVICE AWARD** Presented to:	 Mr. Ernie Staubs, Air Force Research Laboratory
12:25pm—12:45pm	**REFLECTIONS FROM THE CAREER OF A LIFETIME ACHIEVEMENT AWARD WINNER** Introduction by: Reflections by:	 Mr. Bob Metz, PCB Piezotronics Dr. Pat Walter, TCU/PCB Piezotronics
12:45pm—1:30pm	**LUNCH**	

Henry Pusey Best Paper Award Winner

"Defining Resonant Plate Shock Test Specifications in the Time Domain"
Dr. Carl Sisemore, Sandia National Laboratories

Technical Paper Abstract - Resonant plate testing, commonly used for simulating high-energy pyroshock events in the laboratory, is traditionally defined by a shock response spectrum. This test definition methodology is uniquely different from almost all other shock test methodologies. Most shock test methods are defined in terms of physical properties such as drop height, velocity change, impact velocity, charge standoff, pulse duration, or similar. In contrast, the shock response spectrum definition for a resonant plate test allows for a wide range of test inputs due to the non-unique nature of the spectrum transformation. This paper investigates the feasibility of defining resonant plate test specifications in terms of temporal parameters rather than spectral parameters. The paper presents a comparison of two methods to evaluate potential test tolerance ranges. The paper also presents a case for the importance of controlling shock duration as a means of limiting fatigue damage in the unit under test. An example is presented comparing peak acceleration and rain-flow analysis, showing that the non-uniqueness of the shock response spectra can lead to substantially different exposure results in the unit under test.

Dedicated Service Award Winner

Mr. Ernest (Ernie) Staubs from the Air Force Research Laboratory's Munititions Directorate at Eglin AFB has been a regular attendee of the Shock and Vibration Symposium since 2003. He solidified his permanence to our forum in 2008 when he joined the SAVIAC Technical Advisory Group. Ernie has presented over a dozen technical papers at annual events and has volunteered to chair as many sessions during his tenure.

During the transition from SAVIAC to SAVE, Mr. Staubs was invaluable in our annual event's success by securing the Keynote Speaker for the first Shock and Vibration Symposium with a SAVE namesake in 2012. Since that time, Ernie has taken it upon himself to find an avenue for Limited Distribution papers from our annual Symposium to be published through DTIC. He coordinates this process annually as the liason between SAVE and DTIC.

Mr. Staubs has generously provided much of his time and input into our ongoing operations. He is truly a champion for our forum and a trusted source of guidance for our team.

Exhibitor Passport Program

PLAY PASSPORT CHALLENGE

HOW IT WORKS:

- Each Symposium attendee is given a "Passport" with a listing of participating exhibitors.
- Participating exhibitors are provided a custom stamp/sticker.
- As the attendees visit the participating exhibitors, exhibitors "stamp" the passport of the attendee.
- Attendees who collect the stamp of at least 15 participating vendors are entered into the drawing.
- Prizes range from gift cards to gadgets to new exhibitor products!
- *Drawing to be held during the Wednesday afternoon break (3:30pm - 3:45pm).*

Thank You to the exhibitors participating in the Passport Program:

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	SESSION 18: **SHOCK** 1:30-2:15PM / UNLIMITED DIST. A **SHOCK RESPONSE SPECTRUM II** 2:45-3:30PM / UNLIMITED DIST. A CHAIR(S): Dr. Jason Blough (Michigan Tech. Univ)	SESSION 19: **DEDICATED SESSION: THE CABLE: IT IS THE RODNEY DANGERFIELD OF THE INSTRUMENTATION SYSTEM (PART II)** 1:30-3:30PM / UNLIMITED DIST. A CHAIR(S): Mr. Alan Szary (Precision Filters) Dr. Patrick Walter (PCB Piezotronics)	SESSION 20: **DEDICATED SESSION: MECHANICAL SHOCK: COMPUTATIONAL & EXPERIMENTAL METHODS FOR FUZE TECHNOLOGY II** 1:30-3:30PM / LIMITED DIST. D CHAIR(S): Mr. Curtis McKinion (AFRL) Mr. Caleb White (Sandia National Labs)
	THERE WILL NOT BE A CHAIR/PRESENTER MEETING. ALL PRESENTATIONS MUST BE PRELOADED IN ADVANCE OF THE SESSION (VIA SUBMITTAL TO SAVE STAFF BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).		
	SALON 3	SALON 9	SALON 7/8
1:30	**Cost Reduction of Shock Application (33)** *Mr. Wesley Rogler & Mr. Michael Thompson (Ingalls Shipbuilding)*	**Characterizing the Sensor Cable Pair as a Simple RC Circuit (36)** *Mr. Alan Szary (Precision Filters)*	**Instrumentation Methods for Distributed Embedded Fuzes Environment in Hard Target Attack (37)** *Dr. Alain Beliveau & Mr. Alma Oliphant (Applied Research Associates), Dr. Jacob Dodson (AFRL)*
1:55	**Fire Resistant Watertight Structural Doors (34)** *Ms. Parisa Ghandehari, Mr. Michael Thompson, & Mr. John Walks (Ingalls Shipbuilding)*	**What is the R? (36)** *Mr. Alan Szary (Precision Filters)*	**On-board Recorder Testing for Embedded Fuzing (37)** *Mr. Dustin Landers & Dr. Alain Beliveau (Applied Research Associates), Mr. Michael Davies (AFRL)*
2:20		**What is the C? (36)** *Mr. Alan Szary (Precision Filters)*	**Test and Model Observed Target Media Mapping of Embedded Smart Fuzing (38)** *Mr. Alma Oliphant (Applied Research Associates)*
2:45	**Prescribed and Controlled Shock Transients Can Be Used To Better Match Operational Shock Transients and Reduce Artificial Shock Test Failures (35)** *Mr. Monty Kennedy, Dr. Jason Blough, Mr. Chuck Van Karsen & Mr. Jim DeClerk (Mich. State Univ), Mr. William Zenk (Honeywell)*	**Examples of Cable Roll-Off Calculations (37)** *Mr. Alan Szary (Precision Filters)*	**Evaluation of the Dynamic Tensile Failure in Pressed Energetic Simulants (38)** *Dr. Adriane Moura & Dr. Alain Beliveau (Applied Research Associates), Mr. Michael Davies & Dr. Jacob Dodson (AFRL)*
3:10	**A Model Created to Support Efforts to Characterize Shock Events in the Time Domain (36)** *Ms. Cora Taylor, Dr. Jason Blough, Mr. James DeClerk (Michigan Technological University), Mr. William Zenk (Honeywell)*	**Verifying Cable Roll-Off Predictions (37)** *Mr. Alan Szary (Precision Filters)*	**Delayed Comparison Error Minimization (39)** *Mr. James Scheppegrell, Dr. Adriane Moura, & Dr. Alain Beliveau (Applied Research Associates), Dr. Jacob Dodson (AFRL)*

3:30 - 4:15

Break & Passport Program Drawing

EXECUTIVE BALLROOM (EXHIBIT HALL)

SESSION 21: **UNDEX APPLICATIONS** 1:55-2:05PM / LIMITED DIST. D **MARINE MAMMAL STUDIES** 2:45-3:05PM / LIMITED DIST. D 3:10-3:30PM / UNLIMITED DIST. A CHAIR(S): DR. EMILY GUZAS (NUWC NEWPORT) DR. JOE AMBRICO (NUWC NEWPORT)	*VENDOR SESSION D:* **EXHIBITOR PRESENTATIONS INCLUDING CASE STUDIES, NEW DEVELOPMENTS, TESTING & PRODUCTS** 1:30-3:05PM / UNLIMITED DIST. A CHAIR(S): MR. GARY MARRACCINI (SPECTRAL DYNAMICS)	*TRAINING V:* **INTRODUCTION TO UNDERWATER EXPLOSION PHENOMENA WITH BASIC APPLICATIONS TO STRUCTURES** 1:30-3:00PM / UNLIMITED DIST. A

THERE WILL NOT BE A CHAIR/PRESENTER MEETING. ALL PRESENTATIONS MUST BE PRELOADED IN ADVANCE OF THE SESSION (VIA SUBMITTAL TO SAVE STAFF BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).

	SALON 5/6	SALON 2	SALON 4
1:30		**MECHANICALLY & ELECTRICALLY FILTERED TRIAXIAL SENSORS FOR SHOCK APPLICATIONS (41)** *Mr. Kevin Westhora (Dytran)*	**INTRODUCTION TO UNDERWATER EXPLOSION PHENOMENA WITH BASIC APPLICATIONS TO STRUCTURES (42)** *Mr. Frederick Costanzo* 1:30 - 3:00pm
1:55	**DEVELOPMENT OF A COMPREHENSIVE IMPLOSION KNOWLEDGEBASE (39)** *Dr. Abilash Nair, Mr. Alex McVey, & Mr. Adam Hapij (Thornton Tomasetti), Mr. Benjamin Medina (NSWC Carderock), Dr. Joe Ambrico & Dr. Emily Guzas (NUWC Newport)*	**HOW DOES MASS RATIO EFFECT HEAVYWEIGHT SHOCK TESTING? (41)** *Mr. Calvin Milam (HI-TEST Laboratories)*	
2:20		**INTEGRATED CONTROLLER AND ANALYZER ADVANCEMENTS FOR SHOCK TESTING (41)** *Mr. Chris Sensor, Data Physics*	
2:45	**INVESTIGATING IMPULSIVE DAMAGE TO THE MARINE MAMMAL MELON VIA DROP TESTS (40)** *Dr. Emily Guzas (NUWC Newport), Ms. Monica DeAngelis, Ms. Lauren Marshall, Mr. Thomas Fetherston*	**DIRECT FIELD TESTING THE ACCEPTED ALTERNATIVE ACOUSTIC TEST METHOD WITH MORE THAN 170 SUCCESSFUL SATELLITE TESTS TO DATE (42)** *Mr. Gary Marraccini (Spectral Dynamics)*	
3:10	**VALIDATION OF A SURROGATE MODEL FOR MARINE MAMMAL LUNG DYNAMICS UNDER UNDERWATER EXPLOSIVE IMPULSE (40)** *Dr. Emily L. Guzas, Dr. Stephen Turner, Mr. Thomas N. Fetherston, & Joseph Ambrico (NUWC Newport), Mr. Matthew Babina & Mr. Brandon Casper (NSMRL)*	***PLEASE USE THE NEXT BREAK AS THE LAST CHANCE TO VISIT WITH THE VENDORS IN THE EXHIBIT HALL!***	

3:30 - 4:15

Break & Passport Program Drawing

EXECUTIVE BALLROOM (EXHIBIT HALL)

TUTORIAL SESSION 5
3:30PM - 6:30PM

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

SHOCK TEST FAILURE MODES

SALON 4

Mr. Kurt Hartsough (NSWC Philadelphia)
Mr. Domenic Urzillo (NSWC Carderock)

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

OVERVIEW OF UNDERWATER EXPLOSION PHENOMENOLOGY AND BULK CHARGE WEAPON EFFECTS

SALON 5/6

NOTE: LIMITED DISTRIBUTION D (SECURITY PAPERWORK REQUIRED)
Mr. Greg Harris (Consultant)

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

This talk contains Controlled Unclassified Information (CUI) / Distribution Statement D: Distribution authorized to DOD agencies and US DOD contractors.

QUANTITATIVE METHODS FOR HIGH-G ELECTRONICS SURVIVABILITY

SALON 7/8

NOTE: LIMITED DISTRIBUTION D (SECURITY PAPERWORK REQUIRED)
Mr. Curtis McKinion (Air Force Research Laboratory)
Dr. Matthew Neidigk (Air Force Research Laboratory)

The design of high-g electronics remains more of an art than a science. Ensuring the correct operation of an electronics assembly undergoing dynamic loading can be challenging in practice. This tutorial will introduce quantitative methods useful for the design and evaluation of high-g electronics. This tutorial will focus on the design of electronics with loadings that result from a sudden change in velocity (velocity shock). In general the presented methods were developed for applications with accelerations greater than 10,000 g. Emphasis will be placed on the mechanical and thermal aspects of the design process.

The tutorial presentation will be Distribution D. Specifics about electrical components and their survivability in laboratory scale testing will be discussed. Weapon systems, their electrical components, and their high-g performance will not be discussed at the tutorial. A list of attendees will be collected during the presentation. Co-authors can choose to share none, some, or all of their presentation materials with attendees.

[SEE ADDITIONAL TOPICS FOR THIS SESSION ON PAGE 27]

ANALYSIS FOR A MEDIUM WEIGHT SHOCK TEST

SALON 3

Mr. Josh Gorfain (Applied Physical Sciences)

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

Join us at the

MAIN EVENT

A COMMERCIALLY SPONSORED SOCIAL EVENT

ALL 91ST SHOCK AND VIBRATION SYMPOSIUM ATTENDEES AND THEIR GUESTS ARE INVITED!

LOCATED AT POINTE ORLANDO (10-15 MINUTE WALK) OR A QUICK UBER RIDE.

Wednesday

7:00PM - 10:00PM

FOOD, DRINKS, & ENTERTAINMENT

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End Wednesday Events

	SESSION 22: **VIBRATION: SPECTRAL DENSITIES** 9:00-10:10AM / UNLIMITED DIST. A CHAIR(S): DR. CARL SISEMORE (SANDIA NATIONAL LABS)	*SESSION 23:* **ISOLATION AND DAMPING II** 9:00AM-11:00AM / UNLIMITED DIST. A CHAIR(S): MR. ROB SHARP (HUTCHINSON) MR. SHAWN CZERNIAK (HUTCHINSON)	*SESSION 24:* **TEST METHODS** 9:00-9:45AM / UNLIMITED DIST. A **INSTRUMENTATION** 10:15-11:00AM / UNLIMITED DIST. A CHAIR(S): DR. RUSS AYRES (SPECTRAL DYNAMICS)
	THERE WILL NOT BE A CHAIR/PRESENTER MEETING. ALL PRESENTATIONS MUST BE PRELOADED IN ADVANCE OF THE SESSION (VIA SUBMITTAL TO SAVE STAFF BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).		
	SALON 3	SALON 4	SALON 5/6
9:00	**QUANTIFICATION OF CONSERVATISM IN THE MAXI-MAX POWER SPECTRAL DENSITY FUNCTION (42)** *Dr. Carl Sisemore & Ms. Melissa C de Baca (Sandia National Laboratories)*	**DESIGN AND TESTING OF A CALIBRATION DEVICE FOR PRECISION STATIC AND DYNAMIC TESTING AT ELEVATED LOADS (44)** *Mr. Robert Sharp & Mr. Kieran Cochrane (Hutchinson Aerospace & Industry)*	**IMPROVEMENTS IN DIRECT FIELD ACOUSTIC NOISE TESTING (DFAN) (46)** *Mr. Chris Sensor (Data Physics)*
9:25	**SPECTRAL DENSITIES: STATISTICS AND PROBABILITY IN THE FREQUENCY DOMAIN, PART I (43)** *Mr. Neil Loychik (Los Alamos National Laboratory)*	**APPLYING WIRE ROPE ISOLATORS FOR PROTECTION OF 5G CELLULAR TOWERS AGAINST WIND INDUCED VIBRATION (44)** *Mr. Joshua Partyka (Vibro/Dynamics)*	**NONLINEAR ELASTIC METAMATERIALS AS PULSE SHAPING DEVICES FOR SHOCK TEST APPLICATIONS (46)** *Dr. Samuel Wallen & Prof. Michael Haberman (The University of Texas at Austin), Dr. Washington DeLima (Honeywell, Federal Systems)*
9:50	**SPECTRAL DENSITIES: STATISTICS AND PROBABILITY IN THE FREQUENCY DOMAIN, PART II (43)** *Mr. Neil Loychik (Los Alamos National Laboratory)*	**HIGH PERFORMANCE SILICONES FOR IMU ISOLATION - BACKGROUND, MATERIALS, AND LESSONS LEARNED (45)** *Mr. Robert Sharp & Mr. Kevin Underwood (Hutchinson Aerospace & Industry)*	
10:15	**SCAN TO NOMINATE A PRESENTATION FOR OUR ANNUAL *HENRY C. PUSEY BEST PAPER AWARD.***	**ADVANCES IN ELASTOMETRIC TECHNOLOGIES AND THEIR APPLICATION IN EXTREME ENVIRONMENTS (45)** *Mr. Shawn Czerniak, Mr. Kevin Underwood, & Mr. Adam Meyer (Hutchinson Aerospace & Industry)*	**MORE REPEATABLE TESTING OF HERMETICALLY SEALED ELECTRONIC COMPONENTS BY COMPUTERIZING THE PARTICLE IMPACT NOISE DETECTION (PIND) TEST (47)** *Mr. Stewart Slykhous (Spectral Dynamics)*
10:40		**SIMPLIFYING VEHICLE ROAD LOAD COLLECTION TO DRIVE FINITE ELEMENT STRUCTURAL MODELS (45)** *Mr. Edward Wettlaufer (Altair Engineering)*	**COMPARISONS OF THE STRUCTURAL RESPONSE OF A TEST ARTICLE EXCITED BY DFAT DIFFUSE AND NON-DIFFUSE ACOUSTIC FIELDS (47)** *Dr. Marcos Underwood (Tu'tuli Enterprises and MSI Chief Scientist)*

12 - 1PM

S&V TECHNICAL ADVISORY GROUP (TAG) MEETING — **SALON 3**

The annual meeting of the members of the SAVE Technical Advisory Group (TAG) will convene to review the 91st Shock and Vibration Symposium and discuss plans for 2021.

SESSION 25: **BALLISTICS: MODELING & SIMULATION** 9:00-10:10AM / LIMITED DIST. D **BALLISTICS: RAPID SYSTEM** 10:15-11:00AM / LIMITED DIST. D CHAIR(S): MR. BOB METZ (PCB PIEZOTRONICS) MR. OMAR ESQUILIN-MANGUAL (ERDC)	SESSION 26: **INSTRUMENTATION** 9:00-9:45AM / LIMITED DIST. D 9:50-10:10AM / LIMITED DIST. C **DEBRIS AND DAMAGE MODELING** 10:15-11:00AM / LIMITED DIST. D CHAIR(S): MR. CALVIN MILAM (HI-TEST LABORATORIES)	TRAINING VI: **INTRODUCTION TO MEDIUM WEIGHT SHOCK TESTING** 9:00-11:00AM / UNLIMITED DIST. A
THERE WILL NOT BE A CHAIR/PRESENTER MEETING. ALL PRESENTATIONS MUST BE PRELOADED IN ADVANCE OF THE SESSION (VIA SUBMITTAL TO SAVE STAFF BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).		

Time	SALON 7/8	SALON 9	SALON 2
9:00	**EVALUATION OF MODELING AND SIMULATION TO PREDICT IMPACT SIGNATURES IN SMALL ARMS BALLISTIC EVENTS (47)** *Mr. David Lichlyter, Dr. T. Neil Williams, Dr. Kyle Crosby, & Dr. Jay Ehrgott (US Army ERDC)*	**AUTOMATED VIDEO PROCESSING FOR FRAGMENTING WARHEAD ASSESSMENT: A FAST-FRAG FOCUS (49)** *Dr. Eddie O'Hare, Mr. Matt Barsotti, & Mr. David Stevens (Protection Engineering Consultants), Mr. Scott Mullin & Mr. James Mathis (Southwest Research Institute)*	**INTRODUCTION TO MEDIUM WEIGHT SHOCK TESTING (52)** *Mr. Jeff Morris* *HI-TEST Laboratories* 9:00 - 11:00AM
9:25	**TERMINAL BALLISTICS MODELS FOR A36 STEEL PLATES AGAINST SMALL ARMS AND FRAGMENTS (48)** *Mr. Daniel Rios-Estremera, Mr. David Roman-Castro, & Dr. Jesse Sherburn (US Army ERDC)*	**TESTING OF METALS AT HIGH STRAIN RATES WITH PULSED LASERS: A SIGNAL PROCESSING FOCUS (50)** *Dr. Eddie O'Hare, Mr. Matt Barsotti, & Mr. David Stevens (Protection Engineering Consultants), Mr. Thomas Moore & Dr. Sydney Chocron (Southwest Research Institute)*	
9:50	**VALIDATION OF HIGH-SPEED IMPACT MODELS FOR SMALL ARMS AGAINST ULTRA-HIGH PERFORMANCE CONCRETE USING EPIC (48)** *Mr. Jean Santiago Padilla, Dr. Jesse Sherburn, Mr. David Roman-Castro, & Mr. Daniel Rios-Estremera (US Army ERDC)*	**AN OVERVIEW OF PIEZORESISTIVE PRESSURE TRANSDUCER USE FOR AIRBLAST MEASUREMENT APPLICATIONS (51)** *Mr. Daniel Coats, Mr. Denis Rickman, Mr. Joshua Payne, & Mr. John Hoemman (US Army ERDC), Mr. Kyle Moss (SvEB)*	
10:15	**RAPID SYSTEM - A PASSIVE FORCE PROTECTION FOR THE URBAN ENVIRONMENT (48)** *Mr. Erik Chappell & Mr. Omar Esquilin-Mangual (US Army ERDC)*	**CUMULATIVE DAMAGE ASSESSMENT MODEL FOR CONCRETE WALLS IN MULTI-LOAD SCENARIOS (PART 2) (51)** *Dr. George Lloyd (ACTA), Mr. Ryan Schnalzer (ARCTOS), Mr. Joe Magallenes & Mr. Shengrui Lan (Karagozian & Case)*	
10:40	**DEMONSTRATION OF THE READY ARMOR PROTECTION FOR INSTANT DEPLOYMENT SYSTEM (49)** *Mr. Omar Esquilin-Mangual & Mr. Erik Chappell (US Army ERDC)*	**SECONDARY DEBRIS EFFECTS ON BUILDING INFRASTRUCTURE DERIVED FROM EXPERIMENTS (52)** *Dr. George Lloyd, Mr. Jake Allyn, & Dr. Tom Paez (ACTA)*	

12 - 1PM

S&V TECHNICAL ADVISORY GROUP (TAG) MEETING — SALON 3

The annual meeting of the members of the SAVE Technical Advisory Group (TAG) will convene to review the 91st Shock and Vibration Symposium and discuss plans for 2021.

Exhibitor list

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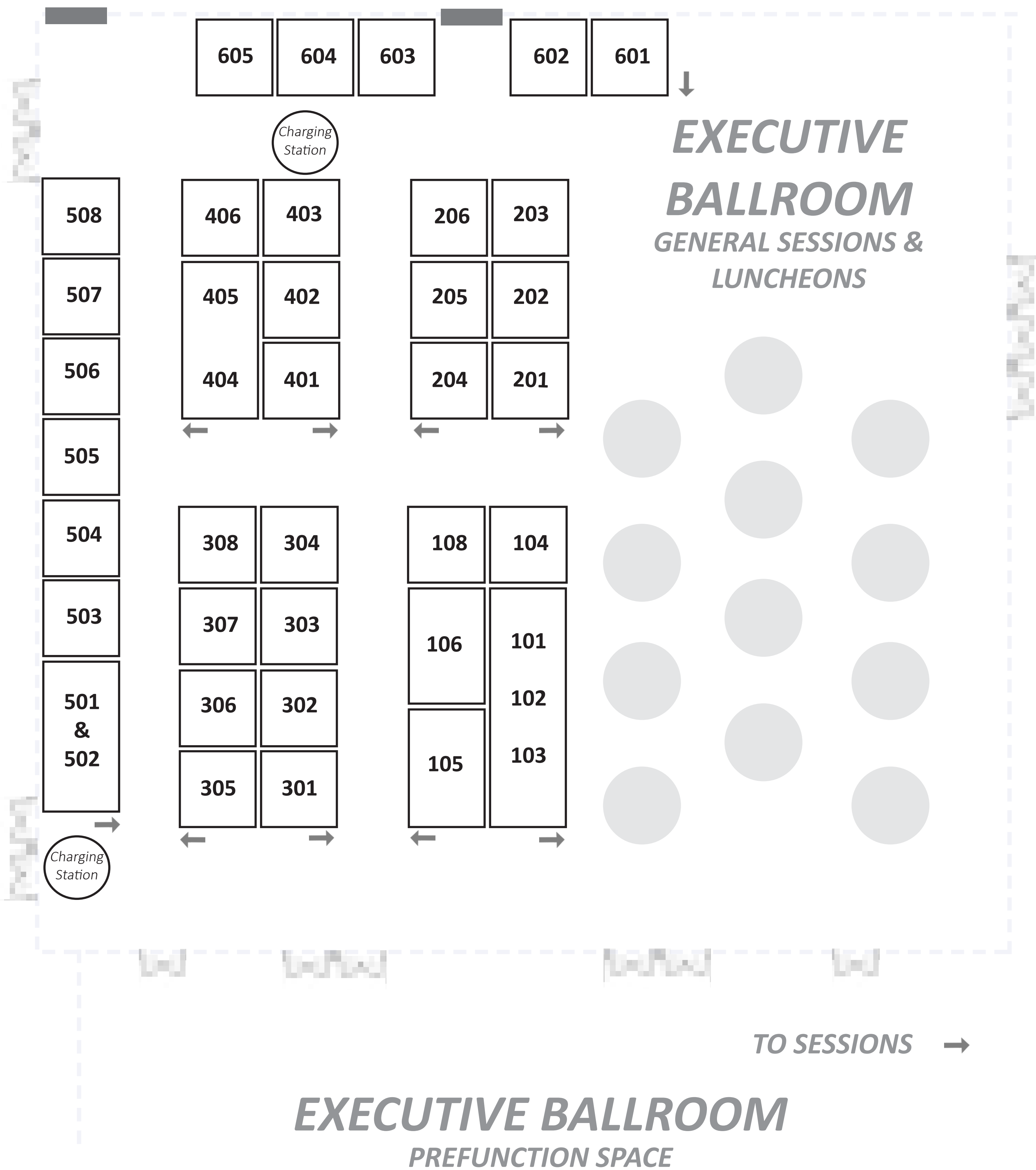
Exhibit Hall layout



Exhibitor Descriptions

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

AMS GROUP provides innovative technologies and equipment with a full range of integrated logistics support services to U.S. and international customers in the defense and security markets.Our mission is to provide qualified aerospace, defense and security equipment with integrated product support that meets or exceeds our customer's expectations. We seek to become an efficient and attractive trading partner dedicated to the highest standards of professional performance, ethics and integrity.

BodieTech.com

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

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

From high-force electrodynamic shakers to palm-sized modal and measurement exciters, **BRÜEL & KJÆR OFFERS** a range of vibration test solutions. With a large selection of power amplifiers and vibration controllers, as well as matching slip tables, head expanders and thermal barriers, we meet all your vibration testing needs.

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

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

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

Exhibitor Descriptions

DEWESOFT, a privately held company, is a World leading provider of data acquisition software and hardware serving all. The DEWESoft software and hardware synchronizes Analog, Digital, Video, GPS, CAN, ARINC 429/1553, PCM and Chapter 10 support. The instruments have wide temperate and shock ranges and are available in many configurations. We design and manufacture versatile and robust data acquisition systems that make test and measurement easier than riding a bike. Our instruments are designed to be easy and fun to use, modular and extendable, and can work with any signal and sensor. Dewesoft instruments are built to be robust and can be used in every environment.

Founded in 1980, **DYTRAN INSTRUMENTS, INC**. is a leading manufacturer and designer of piezoelectric and DC MEMS sensors. Dytran has expanded its product line beyond piezoelectric technology to include VC-MEMS based accelerometers, digital output, USB-powered triaxial accelerometers, and the highly innovative bus-based sensor communication and machinery diagnostic platform CAN-MD® (Controller Area Network - Machinery Diagnostic).

GIBBS & COX is the largest independent naval architecture and marine engineering firm in the United States. Our world class draftsmen, designers, naval architects, engineers and program managers solve challenges across the entire spectrum of today's marine industry, from concept development through production and in-service support. From icebreakers to sportfish yachts, naval combatants to deep ocean research vessels – and many in between – our breadth of clients and services enables us to tailor best practices for the specific needs of each customer, commercial and government alike. Our rigorous quality system undergoes annual third-party ISO 9001 audits in support of partnerships with Industry and Governments both domestically and internationally, reducing cost and risk to achieve their expectations.

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

HI-TEST LABORATORIES, INC. is an unparalleled testing, research and design facility that provides testing and evaluation services to government and industry since 1975. Today, HI-TEST continues to provide our customers with the very best in test program solutions. From pre-test analysis to post-test report generation, we offer our analytical engineering tools and expertise alongside our testing and design capabilities to make your test run as smoothly and efficiently as possible. HI-TEST is the only commercial facility in the country to offer all NAVSEA approved MIL-S 901 shock testing facilities. Our engineers, instrumentation technicians and craftsmen are here to serve as an extension of your own engineering team. Our customers receive complete test program support, including design, fabrication and installation of test fixtures, equipment repairs, maintenance and on-site modifications.

HUNTINGTON INGALLS INDUSTRIES (HII) is America's largest military shipbuilder. HII specializes in providing shock and vibration qualification and support through recognized expertise in testing and advanced shock analysis. For more than a century, HII's Newport News and Ingalls shipbuilding divisions in Virginia and Mississippi have built more ships in more ship classes than any other U.S. naval shipbuilder. HII's Technical Solutions division provides mission-critical national security solutions to government and commercial customers worldwide. HII is also the creator of the patented Deck Simulating Shock Machine (DSSM), the newest Navy approved test method in MIL-DTL-901E.

Exhibitor Descriptions

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

IST offers a full line of acceleration instruments from low cost shock detectors and shock & vibration loggers to full-featured shock & vibration waveform recorders and high speed/large memory units for demanding airborne measurements. We offer systems for applications ranging from low level seismic (milli-g range) to high g shock applications up to several thousand (2,000+ gs). We also offer specialized instruments for 6-axis measurement including roll, pitch and yaw as well as high speed atmospheric pressure recorders for specialized air drop & rate of descent testing. We even offer a miniaturized unit for in-situ helmet testing during sporting events or military or industrial training. Stop by and see our new EDR-5 recorder!

Headquartered in Long Island, NY, **ISOLATION DYNAMICS CORP (IDC)** is a leader in the design, engineering, and manufacture of Shock & Vibration Isolation systems for both military and commercial applications. Specializing in rugged, all-metallic, cable type isolators, IDC has amassed an impressive list of shock qualified systems for the US Navy and all branches of the military.

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

IX CAMERAS is a world-leading technology and product company specializing in the field of high-speed (slow motion) imaging. Based on proprietary innovative technologies, we design, build and sell cutting-edge ultra-fast cameras and software for a wide range of advanced scientific research applications. Our commitment to innovate and push the boundaries of high-speed video science is the reason we develop technically superior and easy-to-use products that our customers need to attain the highest scientific achievements and creativity. iX Cameras introduced the revolutionary i-SPEED 7 Series, the fastest high-speed, high-resolution camera in the market. We followed this up with the introduction of the new i-SPEED 5 Series -- three new mid-range cameras that strike the perfect balance between speed, size, and memory. All of our i-SPEED cameras are backed by our world-class service and support teams, ensuring our customers' success.

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

MECALC aims to be at the forefront of innovation while consistently delivering the highest quality at all levels, with unwavering dedication. We are committed to fighting for the best results while harmonizing as a team to keep our vision alive. Driven to position ourselves at the forefront of new development and thinking, we research, design, develop and manufacture advanced acquisition and control systems. Used to optimise noise, vibration and structural integrity in prototype or quality control testing, our PAK MKII and QuantusSeries hardware ranges are crucial to markets where exceptional development and production quality are essential.

Exhibitor Descriptions

For over a half-century, **NTS** has helped manage your toughest environmental test requirements. Leveraging our national network of laboratories, we are uniquely qualified to guide clients through the Navy shipboard MIL-Standard requirements. Our engineers are experts in shock and vibration, possessing extensive knowledge of ship design and dynamic structural analysis.

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

NVT GROUP (DATA PHYSICS, LANSMONT, AND TEAM) have proven expertise in measuring, simulating, and analyzing the effects of vibration, noise, shock, and other environmental variables for our industry customers. Our combined capabilities make us a leading global provider of test and measurement solutions.

- DATA PHYSICS designs, builds and supports high-performance test and measurement solutions for noise and vibration applications.
- LANSMONT designs, builds and supports test and measurement solutions for drop, shock, vibration and compression.
- TEAM CORPORATION designs, builds and supports high performance single and multi-axis vibration test systems.

PCB® Piezotronics, Inc. is a designer and manufacturer of microphones, vibration, pressure, force, torque, load, and strain sensors, as well as the pioneer of ICP technology used by design engineers and predictive maintenance professionals worldwide for test, measurement, monitoring, and control requirements in automotive, aerospace, industrial, R&D, military, educational, commercial, OEM applications, and more. Our products are the first choice of engineers and scientists at leading businesses, research institutions, and independent laboratories around the world. We offer unmatched customer service, a global distribution network, 24-hour SensorlineSM, and a Lifetime Warranty to deliver Total Customer Satisfaction.

Since 1975, **PRECISION FILTERS, INC. (PFI)** has been a global provider of instrumentation for test measurements. You can rely on a single source for signal conditioning and switching—a complete range of instrumentation—products optimized to work together to provide high performance at reasonable cost. PFI designs and manufactures precision product solutions that include a family of analog signal conditioning, filtering and switching systems. The 28000 Signal Conditioning System provides a complete range of transducer conditioning with up to 256 channels per chassis. Precision's solid-state switch provides up to 256x256 cross-point switching and replaces tedious manual patch panels. The PF-1U provides 8 or 16 channels of high performance filter/amplifiers in a compact package with Ethernet control.

SHOCK TECH designs, manufactures and tests shock attenuation and vibration isolation mounting systems for the most demanding environments. We provide solutions for your equipment's dynamic protection problems and are experts at quick-turn, affordable results.

Exhibitor Descriptions

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

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

THORNTON TOMASETTI provides engineering design, investigation and analysis services to clients worldwide on projects of every size and complexity. We have 70 years of experience in research, testing and software development for the U.S. Navy and Department of Defense in the fields of blast, underwater shock, impact and vibration effects. We are an independent organization of engineers, scientists, architects and other professionals who collaborate from offices worldwide to help you achieve your goals. We are committed to being a sustainable, diverse and enduring organization and the global driver of change and innovation in our industry.

VIBRATION RESEARCH (VR) is the innovator in vibration testing control, field data acquisition, and dynamic signal analysis. Our VR9500 Vibration Controller and tightly integrated VibrationVIEW software are used in testing labs around the world, working with electrodynamic, servo-hydraulic, and servo-electric shakers; control options include single-axis, dual axis, dual phase, three-axis, multi-loop, and seismic control. The new ObserVR1000 Dynamic Signal Analyzer captures, displays, and analyzes field data, controlled by the VR Mobile smartphone app or ObserVIEW software running on a tablet, laptop, or PC. Come by our booth to discuss your testing and analysis requirements with VR's industry experts.

Since 1964, **VIBRO/DYNAMICS** has been the leader and pioneer in the design and manufacture of vibration isolation and shock control systems. Our Products and Services are designed to effectively reduce transmitted shock and vibration and to provide an adjustment means to precisely level, align, and properly support industrial machinery. We also provide systems that protect machinery and building structures from incoming vibration caused by machinery, railroads, earthquakes, etc. In 2014, Vibro/Dynamics became a member of the Socitec Group, worldwide leader and specialist of wire rope isolators and elastomeric solutions.

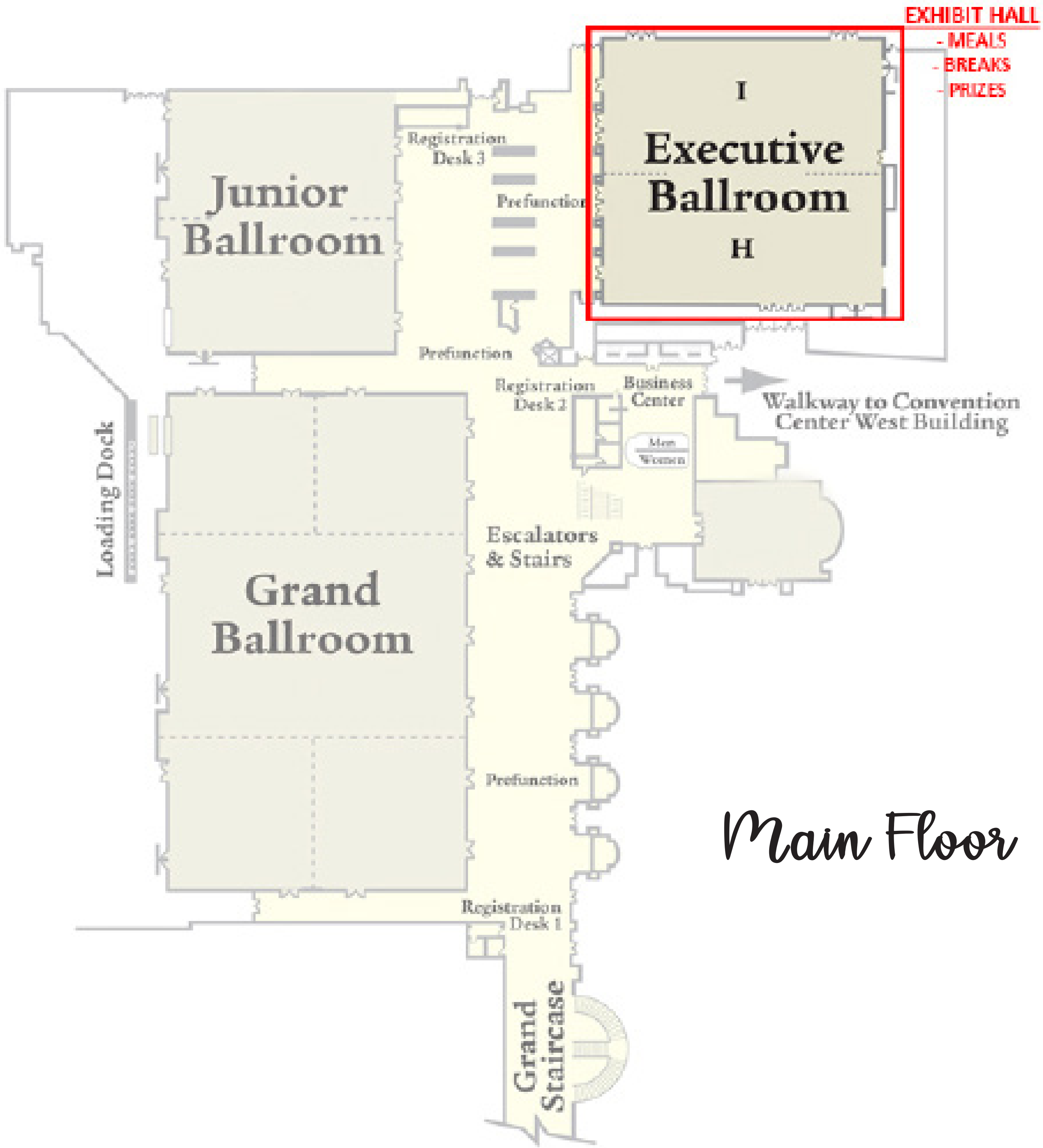
VISION RESEARCH designs and manufactures high-speed digital imaging systems that are used in military, industrial, academic, machine vision, and entertainment sectors. Phantom cameras allow you to analyze physical phenomena when it's too fast to see, and too important not toTM. Vision Research prides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

Exhibitor Descriptions

WEISS TECHNIK TESTING SERVICES (formerly CSZ Testing) is an A2LA Accredited test laboratory with extensive experience in a large array of testing applications. We provide a full range of environmental simulation testing services including temperature, humidity, and /or Vibration, HALT & HASS, shock, vibration, thermal shock, altitude, corrosion, salt spray and more. Serving you from two locations in Cincinnati, OH and Sterling Heights, MI. Visit www.wnatesting.com for more information.

XCITEX is an industry leader in video-based motion capture and motion analysis. Our engineers introduced the first synchronized high-speed video/data system -- MiDAS 1.0 -- in 1998 to take advantage of the first high-speed computer-based camera systems. We followed in 2005 with the introduction of ProAnalyst software that revolutionized the auto-tracking and motion analysis industry. The ProAnalyst line of software products has since expanded to include numerous innovative, award-winning editions for tracking various types of objects and for accurately tracking projectiles in flight.

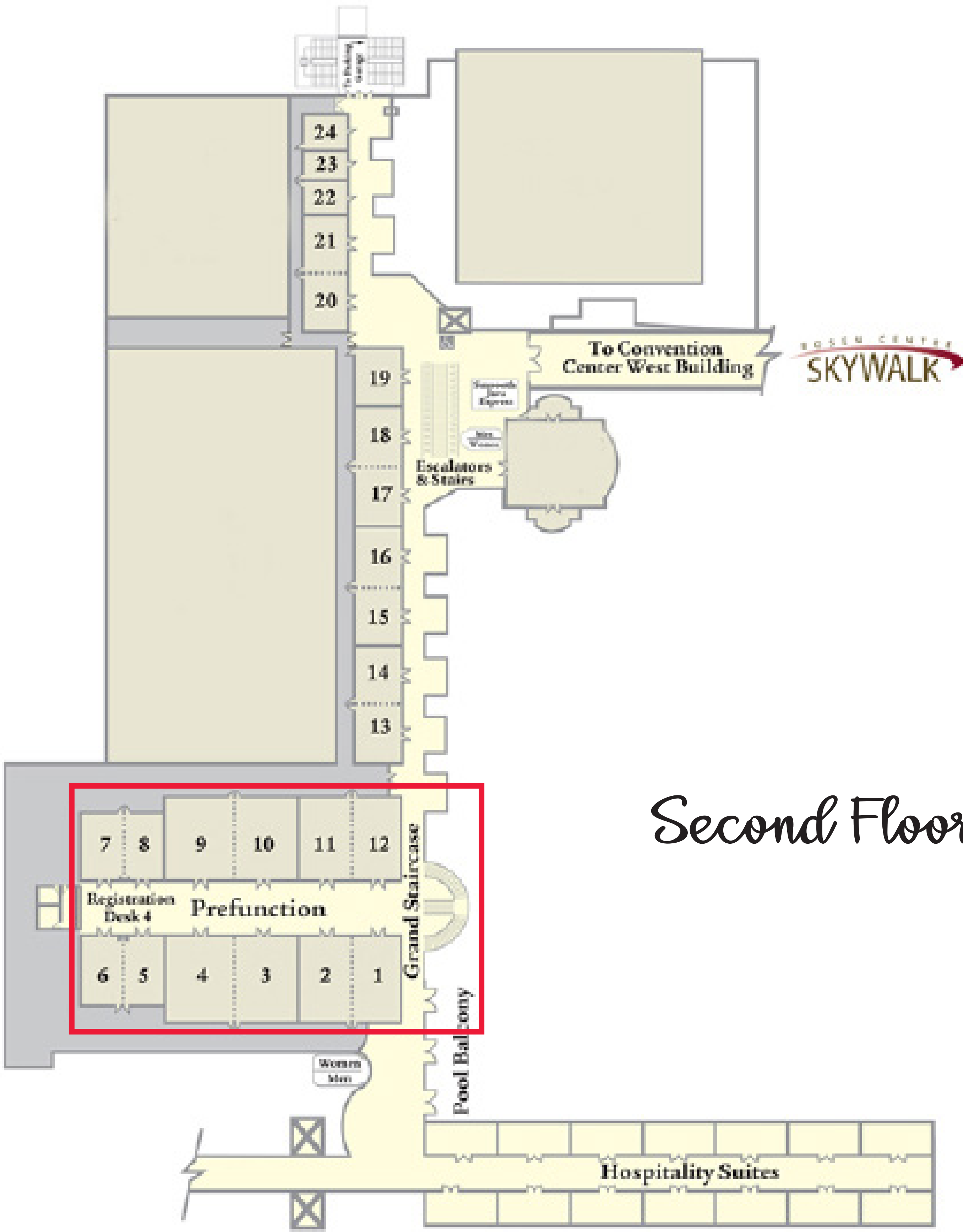
Rosen Centre Meeting Space layout



Main Floor

To LOBBY

Rosen Centre Meeting Space layout



Second Floor

91ST SHOCK & VIBRATION SYMPOSIUM

ABSTRACTS

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SESSION 1: ISOLATION AND DAMPING I

IMPROVEMENTS TO A LEGACY DESIGN FOR HIGHER LOAD CAPACITY & INCREASED DAMPING TO IMPROVE SHOCK ATTENUATION ON LARGE SHIPBOARD SYSTEMS

Mr. Shawn Czerniak, Hutchinson
Mr. Adam Meyer, Hutchinson
Mr. Josh Jones, Hutchinson

In today's Navy, defensive systems continue to grow larger forcing improvements to Legacy designed shock mounting systems. As equipment gets heavier, the need for shock mounts with higher load capacity increases. Additionally, as some systems become more sensitive to shock, the need to increase damping for improved shock attenuation is necessary. This paper will examine a Legacy design and review the geometric and material advancements made to the mount for improved load carrying capacity and increased shock attenuation.

DESIGN, COMPONENT LEVEL TESTS, AND BARGE TEST RESULTS OF A NEW, RESILIENT SHOCK AND VIBRATION MOUNT WITH HIGH CAPACITY & PRECISE SPRING FUNCTION WITH HIGH DAMPING CHARACTERISTICS

Mr. Alan Klembczyk, Taylor Devices, Inc.
Mr. Phillip R Thompson, Thornton Tomasetti

Shock and Vibration Isolators offer significant protection against the harmful effects of dynamic transient events. Many types of isolators are available, with various advantages and disadvantages. This paper presents the unique design, component level parametric test results and barge test results of a revolutionary new type of isolator that draws from the historic design of the "X" and "Y" Mounts. These historic mounts have been widely used for decades by allied navies. The new patent protected "PUMPKIN™ Mount" is presented here and is shown to offer improvements as compared to historic X and Y Mounts and provide protection in 6 degrees-of-freedom for a wide range of isolated masses. Quantified characteristics of PUMPKIN™ Mounts will be outlined and compared to other types of mounts including existing elastomer mounts, wire rope isolators, hybrid steel-elastomer mounts and some types of fluid-based isolators. Manufactured from a combination of stainless steel and a specialized high-damping compound, the PUMPKIN™ Mounts have been subjected to barge testing and have demonstrated excellent isolation capabilities within a relatively small height, while providing predictable and consistent isolation attributes (spring rate and damping). PUMPKIN™ Mounts range in nominal payload capacity from 44 lbs. to 2,000 lbs. each with a maximum supported mass for the largest in the range of 3,200 lbs. per mount. Previous and future research and development efforts will be described within the context of this paper.

SHOCK ANALYSIS COMPARISON – SIMPLE VS HUTCHINSON'S PROPRIETARY BARRYSOFT

Mr. Josh Jones, Hutchinson Aerospace and Industry
Mr. John Sailhamer, Hutchinson Aerospace and Industry

Almost anyone who works in the world of Navy Shock has had some degree of exposure to the SIMPLE (Shock Isolation Mount Prediction & Loading Estimates) Software. For quite some time, SIMPLE has been used very effectively to analyze systems that may be exposed to shock environments and allows the user to make an informed decision on the use of shock isolation mounts. Hutchinson, formerly Barry Controls, has an internally written software program called BarrySoft which it has been using for decades to analyze

systems that are exposed to shock and vibration. Each of these software tools allow the user to define the equipment (mass, size, CG, etc.), define the shock mounts (quantity, location, orientation, etc.), and define the shock input (14Hz deck, 8Hz deck, hull, etc.). This paper will provide a comparison of these two software programs – each of which has been validated with real world shock testing. Test validation will be demonstrated through the use of an EnDAQ data acquisition system.

DEFINING A PROCESS TO DERIVE A LINEARIZED DAMPING APPROXIMATION FOR WIRE ROPE ISOLATORS

Mr. Luke Joy, Enidine

The scope of this paper is to recount the challenges in defining a process to measure the linearized damping ratio for wire rope product applications. Wire ropes are highly nonlinear spring-dampers and damping has a notorious reputation for being wide-ranging based on application specifics. Linear models provide a computationally efficient means of estimating field performance within reasonable error margins on most product applications. The importance of defining a process for linearizing a situational damping rate is in 1.) establishing a standard practice within the company for current and future employees, and 2.) to enable the company to clearly communicate the origins of damping considerations with customers.

Through iterative experimental trials, the Enidine team established a process to analytically derive and experimentally support a reasonable linearized damping ratio for its product applications. The goal of the paper is to share the history of this process and discuss the benefits and drawbacks of the final method.
Experimental approaches included measuring quasi-static hysteresis, mean offset vibration, drop testing, and free response measurement to initial conditions. Each of these test methods are applied to a wire rope product, a wire rope encased in elastomer (Enidine's HERM product series), and on a new HERM variant currently in development.

SESSION 2: MATERIAL RESPONSE & EFFECTIVENESS

OVERVIEW OF PENCURV+ FOR ANALYSIS OF PROJECTILE PENETRATION EFFECTS

Mr. Reid Bond, US Army ERDC
Mr. Ernesto G. Cruz, US Army ERDC
Dr. Kyle Crosby, US Army ERDC
Mr. Mark Adley, US Army ERDC
Ms. Dorothy Boswell, US Army ERDC
Dr. Jay Ehrgott, US Army ERDC

Projectile penetration predictive capabilities are an area of critical importance in the development of force protection to mitigate specific munition threats. These capabilities enable the development of effective structural design and analysis of military and civilian installations to determine possible vulnerabilities. The U.S. Army Engineer Research and Development Center (ERDC) has conducted research in order to develop an advanced penetration analysis software called PENCURV+. PENCURV+ is a computational tool which utilizes a suite of penetration algorithms that quickly and accurately predict the terminal effects of a projectile against a variety of targets. The software allows the user to design a projectile impact scenario and quickly calculate depth of penetration, exit velocity, and a number of other results of interest. This paper will present how PENCURV+ can be utilized to quickly analyze a variety of impact problems as well as improvements that are being implemented such as the addition of wood and steel materials.

CONSTITUTIVE MODELING OF A POLYURETHANE ELASTOMER SUBJECT TO LARGE DEFORMATIONS AT HIGH RATE

Mr. John Puryear, ABS Consulting
Ms. Lynsey Reese, NAVFAC EXWC

Polyurethane elastomers have been observed to increase the blast and penetration resistance of hardened systems. Incorporation of elastomers into hardening design requires the material be characterized. In this paper, candidate constitutive models for the elastomer behavior are examined. The candidate models are implemented in LS-DYNA and include the following:

- *MAT_187: *MAT_SAMP-1
- *MAT_187L: *MAT_SAMP_LIGHT
- *MAT_181: *MAT_SIMPLIFIED_RUBBER/FOAM

Examination of the constitutive model includes discussion of the assumptions made in solid mechanics to develop them, their potential advantages for representing an elastomer of interest and observed limitations.

Laboratory tests to measure a particular elastomer's properties were performed: tensile and compressive at low and high rates, shear, biaxial, Poisson ratio, cyclic, dart impact, solid density and split Hopkinson. The results of these tests are summarized in the paper. In addition, the viability of the candidate constitutive models for representing the elastomer is discussed, based on comparison to the laboratory data.

Finally, because blast and penetration commonly involve material damage and failure, damage and failure models for the elastomer are also examined. These include models that are built into the constitutive models and models that are overlaid on them to represent the transition from plastic flow to strength degradation and ultimate failure. The performance of these damage and failure models is similarly compared to the laboratory data.

SESSION 2: BALLISTICS

CRITICAL VELOCITIES OF ANISOTROPIC TUBES UNDER A FAST MOVING PRESSURE

Dr. Andrew Littlefield, US Army DEVCOM AC Benet Labs
Prof. X.-L. Gao, Southern Methodist University

Conventional gun tubes made from metallic materials tend to be heavy and often need to be stiffened. To mitigate these challenges, lightweight gun tubes have been developed by using polymer, ceramic or metal matrix composites. Recently, a patented composite gun tube design was proposed at Benét Laboratories by employing a three-layer cylindrical structure [1]: a metallic liner (inner layer) to enable gas sealing and projectile sliding, a thermal barrier coating (middle layer) to mitigate heat conduction and an overwrapped composite jacket (outer layer) to withhold the moving pressure induced by a high-velocity projectile.

It has been experimentally observed that dynamic strains in a metallic gun tube caused by flexural waves resulting from a high-velocity moving pressure can exceed three times of those static values predicted by Lamé's formulas for pressurized thick-walled tubes. This happens when the projectile velocity approaches the lowest critical velocity of the gun tube. Hence, it is very important to determine critical velocities of such gun tubes.

For isotropic tubes subjected to a uniform pressure moving at a constant speed, a closed-form formula has been derived using the thin shell theories of Love and Flügge. For orthotropic tubes under a moving pressure, a critical velocity formula has also been reported (but without derivations) based on Love's thin cylindrical shell theory. However, these thin shell theories do not consider the effects of shear deformations and rotary inertia. As a result, more accurate formulas that account for these effects are still in need.

In this study, closed-form formulas for critical velocities of anisotropic tubes under a high-velocity moving pressure are derived using the Love-Kirchhoff thin shell theory incorporating the rotary inertia effect, which was recently extended in [2]. The formulation is based on the general 3-D constitutive relations and provides a unified treatment for orthotropic, transversely isotropic, cubic and isotropic tubes, which can represent various composite gun tubes. It is shown that when the rotary inertia effect is suppressed and the plane stress state is assumed, the newly derived formulas for the critical velocities of orthotropic and isotropic tubes recover the existing ones mentioned above as special cases.

References
[1] Mulligan, C. P., Littlefield, A. and Root, J., 2018, Multi-layered mortar tube, U.S. Patent 9,939,222.
[2] Zhang, G. Y., Gao, X.-L. and Littlefield, A. G., 2021, A non-classical model for circular cylindrical thin shells incorporating microstructure and surface energy effects, Acta Mechanica (published online on 03/03/2021).

SESSION 3: DYSMAS I

TESTS AND SIMULATIONS OF SHOCK PROPAGATION IN A REPRESENTATIVE SHIPBOARD TANK

Mr. Bradley Klenow, NSWC Indian Head
Dr. Tom McGrath, NSWC Indian Head
Mr. Greg Harris, ATR
Mr. Kent Rye, NSWC Carderock
Mr. Bill Lewis, NSWC Carderock
Ms. Rachel McIntyre, NSWC Carderock
Mrs. Rebecca Grisso, NSWC Carderock

Ship and submarine platforms commonly contain fluid-filled tanks for storage of fuel, water and other types of fluid. In the event of an underwater explosion (UNDEX) near a platform, shock loading propagates through such tanks and into internal components within the platform. Therefore, it is important to understand how shock waves propagate through these fluid-filled tanks. This presentation discusses the comparison of simulations of shock propagation through tanks conducted within the Dynamic System Mechanics Advanced Simulation (DYSMAS) suite of codes to data from an UNDEX test series conducted using a representative shipboard tank structure that was filled in various configurations with water and/or an aviation fuel substitute.

Modeling Nuclear Explosion Air Blast in the DYSMAS Hydrocode

Mr. Frank VanGessel, NSWC Indian Head
Dr. Tom McGrath, NSWC Indian Head

A systematic approach for modeling nuclear air blasts within the DYSMAS hydrocode is presented. The presented methodology utilizes a two-stage modeling procedure with an initial high energy density region that is evolved to obtain a representative solution field that can easily be employed in an array of weapons effect simulations. A simple analytical relation between weapon yield and energy density of the initial superheated region is developed. This relation is obtained by minimizing the error between calculated and standard values for the nuclear shockwave time of arrival across a range of standoffs and weapon yields. The modeling procedure, in conjunction with the analytical relationship, is shown to exhibit excellent agreement with standard nuclear weapon metrics such as time of arrival, maximum overpressure, and maximum dynamic pressure. A representative simulation of a nuclear blast over water further demonstrates the modeling capability, successfully reproducing characteristic profiles of the nuclear air shock. The approach detailed in this presentation enables DYSMAS-based nuclear weapon effect analyses for a wide array of threat scenarios.

Predictive Modeling of Water Plume Damage to Overhead Targets

Mr. Nicholas Nechitailo, NSWC Indian Head
Mr. Jason Hackl, NSWC Indian Head

This work is focused on the analysis of the dynamics of water plumes produced by shallow underwater explosions. The plumes can carry significant kinetic energy, damaging overhead targets such as tall bridges. Our approach included experimental data, simplified analytical solutions, and high-fidelity modeling and simulation. We analyzed experiment-based scaling laws for small and very large charges. Our DYSMAS models helped us better understand motion and deformation modes of the gas bubbles produced by submerged charges, as well as the formation of upward water jets. These studies revealed effective mechanisms of conversion of the charge energy into the directed water plume energy. The charge size and its depth are among the most important factors influencing the formation and subsequent motion of the water plume. Among the main challenges were the sensitivity of the water plume geometry to the initial conditions and the loss of the water plume symmetry, as well as predicted strength of the overhead targets under multiple impacts from cavitating water.

An Improved Water Equation of State and Wavebending Modeling Capability for Underwater Explosion Simulations in DYSMAS

Mr. Frank VanGessel, NSWC Indian Head
Dr. Tom McGrath, NSWC Indian Head

We present an improved equation of state (EOS) for modeling the underwater explosions occurring in the presence of a non-uniform sound velocity profile. The presented EOS improves upon the existing EOS by simultaneously reproducing both the sound velocity profile and the shock Hugoniot of water. The improved EOS is parameterized by matching to an accepted acoustics model while applying an optimization algorithm to minimize the calculation error of shock properties and obtain the remaining terms in the EOS. Accurate representation of the sound velocity profile allowed for the modeling of wave bending effects, which modulate the pressure pulse propagating away from an underwater explosion. Simulations performed in the U. S. Navy hydrocode, DYSMAS, validated this capability. Comparison of DYSMAS simulations to two sets of shot data show that wave bending influence on pressure time histories is accurately reproduced. The calculated shockwave impulse error is significantly reduced compared to

simulations performed with an existing water EOS, which produces a nearly-uniform sound velocity field. The presented EOS and corresponding wave bending modeling capability extend the U. S. Navy's ability to simulate weapons effects and target response to a wider range of underwater explosion scenarios.

USING DYSMAS TO SIMULATE HYPERSONIC PROJECTILES BREACHING A WATER SURFACE

Dr. Jeffrey St. Clair, NSWC Indian Head
Mr. Roger Ilamni, NSWC Indian Head
Mr. Jason Hackl, NSWC Indian Head
Mr. Horacio Nochetto, NSWC Indian Head
Mr. Aiden Leavy, U.S. Naval Academy

Projectiles and weapons that can travel at speeds that are considered super or hypersonic are gaining an increased interest within the Department of Defense; this interest includes the capability to use such weapons against maritime threats. The work presented showcases recent efforts in modeling and simulation of a simple tungsten projectile traveling at hypersonic speeds breaching a water surface from the air. The goal is to achieve an improved understanding of the projectile's range, capability, and survivability as it breaches and descends through the water column. Effect of flight parameters such as initial speed and angle of impact as well as modeling methodologies are studied and discussed. The results can then be used to gage the feasibility of more complex hypersonic weapons that are being considered by the defense community.

SESSION 4: BLAST STUDIES INCL. CRATERING

EXPERIMENTAL INVESTIGATIONS OF CRATERING EFFECTS FROM ABOVEGROUND DETONATIONS OF CASED WEAPON SURROGATE CHARGES

Mr. Daniel Vaughan, US Army ERDC
Mr. William Pratt, US Army ERDC
Mr. Joshua Payne, US Army ERDC
Dr. Jay Ehrgott, US Army ERDC
Mr. Denis Rickman, US Army ERDC

Conventional, indirectly fired munitions such as artillery rounds, rockets, and mortars have been identified as an emerging area of concern for U.S. forces, our Allies, and civilians. These weapons have been used across the globe for decades, with a long history of human casualties and infrastructure damage. By studying the clues left after such an attack, trained analysts can gain valuable information about the threat, but there is very little research available on the forensic signatures of these munitions. The National Ground Intelligence Center (NGIC) and the U.S. Army Engineer Research and Development Center (ERDC) have conducted numerous aboveground detonations using conventional munitions such as 152mm artillery rounds, 120mm mortars, and 240mm rockets experiments under the Forensic Encyclopedia Program (FEP) to better understand their forensic signatures, building upon previous research efforts studying improvised weapons. One of the key outcomes of this research is a fast-running engineering tool for analyzing and predicting the cratering behavior for indirect, aboveground detonations characteristic of these munitions. ERDC has performed several series of controlled detonations using a wide range of munitions, as well as cased and uncased surrogate charges, and the data collected during these experiments has led directly into development of the aboveground cratering tool. This paper is focused on presenting the results of the cased and uncased surrogate experiments, comparing that data against the results from tests using actual munitions, and some ideas for future studies.

OVERVIEW OF A FINITE ELEMENT/EMPIRICAL MODEL FOR RUNWAY CRATER PREDICTIONS FROM BURIED HIGH-EXPLOSIVE DETONATIONS

Mr. Ernesto Cruz, US Army ERDC
Ms. Jessica Fulk, US Army ERDC
Mr. Connor Fulk, US Army ERDC
Dr. Mark Adley, US Army ERDC
Ms. Dorothy Boswell, Applied Research Associates
Mr. Jason Roth, US Army ERDC
Dr. Jay Ehrgott, US Army ERDC

Military airfields serve a critical role in both aerial warfare and the deployment of troops and their supplies in combat regions. Because they are of strategic importance, airfield runways are often targeted by advisories utilizing a variety of ground and air delivered weapons systems. Some of the weapons systems are specifically designed with penetrating warheads to deliver embedded detonation to create maximum damage and disruption to the airfields. Depending on the amount of damage caused by the threat weapon, the runway can become un-usable until repairs are completed. To estimate the potential damage to runways from attack scenarios, the U.S. Army Engineer Research and Development Center (ERDC) developed a hybrid tool called the RW-CRATER code. This code combines finite element models to simulate the runway surface and empirically based models to calculate sub-grade behavior. Using this combination of both models, RW-CRATER allows for an accurate and relatively faster prediction of runway crater sizes and upheaval of the surface caused by the detonation of an embedded high-explosive warhead. This tool provides a valuable asset for evaluating potential damage from threat weapon systems to support mission planning and sustainment requirements at these critical military airfields. This work will present an overview of the current development of the RW-CRATER code, capabilities of the code, and future improvements planned for the code.

CRATER ALGORITHM DESIGN FOR EXPLOSIVE CHARGE ANALYSIS (CALDERA) VALIDATION IN NON-ROADBED SCENARIOSL

Mr. Jasiel Ramos-Delgado, US Army ERDC
Mr. William Myers, US Army ERDC
Dr. John Q. Ehrgott, US Army ERDC

Attacks against U.S. and Allied forces using improvised explosive devices (IEDs) and conventional munitions are an ongoing threat. An accurate assessment of these attacks is crucial in understanding these threats, how they are being utilized, or vulnerabilities to our protective systems. To assist analysts and Explosive Ordnance Disposal (EOD) personnel in making these assessments the National Ground Intelligence Center (NGIC) and the U.S. Army Engineer Research and Development Center (ERDC) developed the Crater ALgorithm Design for Explosive chaRge Analysis (CALDERA). CALDERA estimates the amount of explosive that formed the crater found at an attack site using dimensions of the crater and information about the soil and its characteristics. CALDERA was developed with data from well-controlled experiments on testbeds similar to secondary roadways. As tactics change and attacks occur off well-traveled roads, it is unknown how well CALDERA will estimate the charge size. This paper will present the results of field experiments conducted at several unprepared but trafficable locations to validate the performance of CALDERA in non-roadbed scenarios.

Fast-Running Kinetic Energy Crater Model for Concrete Targets

Ms. Keri Bailey, Air Force Research Laboratory
Mr. Mark Green, Geomechanics Research and Analysis (GmRA)

The Air Force Research Laboratory Munitions Directorate (AFRL/RW) has developed a new, fast-running model (FRM) capable of simulating the formation of craters caused by the kinetic energy of penetrating weapons impacting and perforating concrete targets. The model is capable of capturing the size/shape of both impact and exit craters for all relevant classes of concrete used to construct building and bunker targets. In addition, this model was developed for a wide-range of impact conditions and captures the time-evolution of the crater growth. AFRL utilized a large database of experimental data to formulate the FRM framework and to calibrate the model coefficients. This briefing will include an overview of the model development activities and comparisons with experimental data. This model will be made available to the broader DoD weaponeering community for inclusion in future AF mission planning toolsets.

Analysis of M107 Blast Pad Data for TNT and Composition B Fills

Ms. DeBorah Luckett, US Army ERDC
Dr. Gregory Bessette, US Army ERDC
Dr. Roosevelt Davis, AFRL/RWML

In 2008, the Air Force Research Laboratory (AFRL) conducted a series of tests involving the M107 155-mm artillery round at their blast pad facility. The goal was to characterize the blast field of the cased charge environment using range and azimuth calculations. The testing involved rounds filled with TNT and Composition B. Data captured during this testing included the time-of-arrival, incident peak pressure, and impulse at gages arrayed about the round. Revisiting these data helped gain insight into the influence of casing effects on the blast field, such as determining the bare charge weight that would produce the same incident peak pressure and impulse at each gage location. Comparisons are drawn against the bare charge equivalent weights computed using case-reduction formulas such as Fano and Modified Fano. These empirically based formulas do not account for the influence of range or orientation about the cased charge. The analysis discussed in this paper seeks to assess the strengths and weaknesses of these commonly used formulas, as well as outline a more robust approach for determining a bare-charge equivalent weight as a function of range and azimuth about a cylindrically shaped cased charge. The longer-term goal is to incorporate the improved methodology into fast-running blast models such as the BlastX code.

VENDOR SESSION A: EXHIBITOR PRESENTATIONS INCLUDING CASE STUDIES, NEW DEVELOPMENTS, TESTING & PRODUCTS

Advancements in Field Data Recorder Technology

Mr. Jim Breault (Lansmont/NVT Group)

Field Data Recorders continues to evolve, facilitating measurement research and characterization across a broader and more complex range of dynamic environments. Lansmont will review advancing techniques for MDOF dynamic measurements, data analysis, and seamless transition to laboratory simulation. This presentation will also highlight recent advancements in wireless communication and cloud-based data management.

PROPERLY PROCESSING NOISY INVARIANT QUANTITIES SUCH AS PRINCIPAL STRAIN AND MISES STRESS – BOTH FOR FREQUENCY CONTENT AND FOR FILTERING
Dr. Ted Diehl (Bodie Technologies)

Invariant quantities such as principal stress (or strain) and Mises stress are commonly used to assess damage potential and failure due to mechanical shock/impact events. Transient simulations or physical testing of such environments often requires the processing and interpretation of frequency-rich signals comprised of “real content” plus “noise”. The use of typical Fourier Spectrum techniques and digital filtering cannot be applied directly to the invariant quantities because they contain partially rectified quantities that severely distort the frequency content. Proper processing of such data requires doing DSP calculations on the underlying tensor components and then re-computing the invariants from filtered tensor components. This task requires the manipulation of a lot of channels of data, especially when 3-D tensors are involved. Moreover, re-computing 3-D principal values (stress or strain) from tensor components is typically quite cumbersome. This presentation demonstrates how the tools in Kornucopia® ML™ make this complex task easy to perform, enabling accurate DSP analysis of noisy transient invariant quantities. Along with showing the correct approach to process such data, we also demonstrate how highly distorted and incorrect results occur when DSP is improperly applied directly to the invariant quantities.

NEW APPLICATION EXAMPLES USING DIC TO FIND OD'S
Mr. Alistair Tofts (Correlated Solutions)

No abstract provided.

DEVELOPMENT OF HIGH DEFLECTION ELASTOMERIC ISOLATORS
Mr. Ali Shehadeh (Vibrodynamics)

The Socitec Group has been known for more than 40 years as the worldwide leader in wire rope isolators (WRI) as well as related services, including numerical simulations. The US branch, Vibro/Dynamics, based just outside of Chicago, provides the same engineering and production capabilities upon which the Socitec Group has built its reputation.

While known for WRI, Vibro/Dynamics and the Socitec Group also possess a line of elastomeric shock isolators for many of the same applications. Developments are in progress for an extension of this elastomeric shock isolator product line to provide larger displacement capabilities, which are critical for shock isolation. The design and performance of this new isolator will be presented.

An overview of activities and interesting applications within the Socitec Group in the last two years will also be presented.

TRAINING I: SHOCK RESPONSE SPECTRUM PRIMER

SHOCK RESPONSE SPECTRUM PRIMER

Dr. Carl Sisemore (Sandia National Laboratories)

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

SESSION 5: SHOCK RESPONSE SPECTRUM I

METHOD FOR COMPUTING BEST FIT HALF-SINE PULSE FROM A SHOCK RESPONSE SPECTRUM

Mr. Becker Awqatty, Mide Technology

To ensure that an object can withstand an environment defined by a given pseudo velocity shock spectrum (PVSS) or acceleration shock response spectrum (SRS), it is common practice to physically simulate the environment via a shaker table. One of the simpler methods for configuring a shaker table is to specify a half-sine pulse of acceleration, with a designated amplitude and duration. These two parameters should be chosen such that the PVSS/SRS of the half-sine pulse envelopes the PVSS/SRS of the environment to simulate, such that if the object can withstand the pulse, it can withstand the environment. However, if the pulse's spectrum is excessively more intense than that of the environment, the object may fail under the pulse when it would in fact properly withstand the environment, which renders test failures inconclusive. Thus, a pulse of optimal duration and amplitude is desirable.

To calculate such an optimal pair of duration and amplitude parameters, typical methods involve
- sweeping over a range of duration values,
- calculating for each duration the corresponding minimum amplitude s.t. the pulse's PVSS minimally envelopes the environment's PVSS, and
- choosing the "best" duration/amplitude pair to minimize some physical limit of the shaker table, like max velocity, max displacement, etc.

However, performing this calculation requires a sweep over all PVSS values for each pulse duration considered, which can be slow to perform.

We herein propose a simpler method for calculating a near-optimal duration/amplitude. This method approximates the PVSS of a half-sine pulse as a two-piece piecewise function, where both pieces are linear on its Bode plot. These "linear" pieces have fixed slopes, and their offsets, which together determine the duration/amplitude values to use, can each be readily calculated from a single sweep over the environment's PVSS values. This simplistic method requires significantly less computation time than the typical duration-sweep method, and produces a result that is sufficiently optimal for this form of testing.

Defining a Better Shock Requirement

Mr. Scott Rowland, Northrop Grumman Space Systems
Mr. Alexander Hardt, Northrop Grumman Space Systems

Recent efforts over the last couple years by Northrop Grumman have evaluated the Shock Response Spectrum (SRS) for the tools ability to estimate damage potential and piece part failure. The data has demonstrated that the SRS does not correlate with damage potential, is not a good predictor for failure, and results in strain differences for the same SRS of more than an order of magnitude.

With this objective evidence, Northrop Grumman is leveraging developed advanced analytical techniques, historical test database, and on-site test capabilities to determine a methodology that does correlate with damage potential, is a good predictor for failure, and narrows the strain differences between the application and test set-up. This paper seeks to document the issues with the Shock Response Spectrum (SRS) and present the efforts to provide a better solution.

Shock Analysis and Testing for System Optimization and Qualification Risk Reduction Part 1: Tailoring of Shock Response Spectrums to achieve Specific Time History Attributes

Mr. John Sailhamer, Hutchinson Aerospace and Industry

Numerous commercially available software packages allow the synthesis of shock time histories from Shock Response Spectrums (SRS's). As well, methods to evaluate temporal moments of a shock time history are quite simple to employ, allowing a user to ensure time histories are representative of actual events. During product development, it is often beneficial to have the ability to tailor a synthesized shock time history and effectively (if not completely) meet the requirements of a specific SRS and distinct temporal moments while staying inside the functional limitations of available shaker testing capabilities. This paper will discuss methodologies used to tailor Shock Response Spectrums to ensure a generated time history can run on a given piece of equipment and simple methodologies used to ensure a generated time history meets the temporal moment characteristics that define it.

Shock Analysis and Testing for System Optimization and Qualification Risk Reduction Part 2: Validation and Optimization

Mr. John Sailhamer, Hutchinson Aerospace and Industry

The high costs associated with shock isolation system design and qualification testing makes the quality of the analysis paramount in avoiding cost and schedule overruns. The non-linear nature of most elastomeric shock isolation systems greatly adds to the complexity of accurately predicting the performance of these systems. This paper offers a strategy for avoidance of cost overruns caused by failed shock qualification testing during development of shock isolation systems. It will demonstrate a method to develop relatively inexpensive pre-qualification tests designed to characterize key non-linear isolator components, tune mathematical models, and validate the use of relevant linear or non-linear characteristics in final system analysis. By utilizing this methodology, system designers can synthesize representative shock time histories which can be run on the relatively small shakers typically accessible to isolator suppliers. Iterative comparisons of test data to analytical models will validate the designer's linear and non-linear analytical parameter predictions, allowing rapid and inexpensive design optimization. This process can help manufacturers bring systems to full scale testing without costly iterations at the system level.

Using Recorded Data to Improve SRS Test Development

Mr. Casey DuBois, Vibration Research

The shock response spectrum (SRS) uses a synthesized pulse to drive a shaker and simulate a transient event. Although developed to replicate seismic events, the SRS is also widely used for defense and aerospace applications. It provides valuable information about the maximum dynamic load as a function of frequency.

Test engineers can select from industry-standard synthetic waveforms to create an SRS pulse; the best choice depends on the application. However, there are often situations where no synthetic waveform closely matches a real-world transient event. In such cases, engineers need a more realistic way to create an SRS test.

This presentation focuses on a unique approach where the recorded field environment is modified to meet or exceed a specified SRS. This method provides a time waveform like the original field environment and, most importantly, with the same frequency response function.

The process involves enveloping data from recordings and generating an SRS test from the enveloped data. A recorded data set only represents a single event and, as the basis for creating a synthesized SRS waveform, it gives an incomplete description of shock vibrations that may occur. A better approach uses multiple recorded data sets to generate one representative waveform.

For transient events, the proper way to combine multiple data sets is not to find their average accelerations but the maximum value at each frequency. This max enveloping technique produces an SRS curve with the maximum acceleration value from a group of real-world data sets for each frequency.
Following the max enveloping technique, the engineer can use SRS synthesis parameters to create a pulse matching a specified SRS curve. Running the test will generate a data file for the synthesized waveform they can compare to the real-world data.

The presentation will introduce the basic concepts of SRS and then discuss using this new method with available software tools. To conclude, we will evaluate an enveloped environment SRS waveform by comparing it with various standard synthetic waveforms. The visual evidence makes a compelling case for the new approach.

SESSION 6: BLAST I

Implementation of the Rickman-Murrell Clearing Model into BlastX

Ms. Krystal Rodriguez-Soto, US Army ERDC
Dr. Gregory Bessette, US Army ERDC

BlastX is a fast-running software designed to predict the airblast environment of explosive detonations relative to a fixed structure. A new clearing model, based on the work of Rickman and Murrell (2005), has been implemented into BlastX. The clearing phenomenon refers to the fact that a shock wave impinging on a structure of finite size may not sustain the reflected pressure for the full duration of the waveform. Relief waves emanating from the edge of a wall can significantly reduce the later time reflected pressure on the front face of the structure, thereby reducing the overall loading on the structure. From a protective design standpoint, properly accounting for this phenomenon can lead to a savings in construction costs or allow enhanced hardening in other elements of the structure. There were limitations on the range of applicability for the legacy clearing model in BlastX, making it necessary to implement a more robust model. This paper outlines the Rickman-Murrell clearing model, its implementation into BlastX, and comparisons against experimental data involving a range of standoffs from the structure.

FULL-SCALE BLAST TESTING OF MASONRY WALLS WITH ARCHING

Mr. Justin Gilliland, US Army ERDC
Ms. Genevieve L.F. Pezzola, US Army ERDC
Mr. Bob E. Walker, US Army ERDC
Mr. Donald H. Nelson, US Army ERDC
Dr. Catherine S. Stephens. US Army ERDC

The U.S. Army Engineer Research and Development Center (ERDC) has been conducting research to better understand the response of masonry walls to blast including secondary debris hazard. This research has shown that the boundary conditions during blast testing significantly influence the response of walls. The ERDC designed a reaction structure that allows for arching forces to fully develop during full-scale blast testing. This reaction structure and method of measuring arching forces are presented. The set up and results of three full-scale tests of hollow and fully grouted masonry walls with arching are shown. These results are then compared to previous full-scale tests without arching.

EXPERIMENTAL VALIDATION OF THE BLAST PERFORMANCE OF COMPRESSION-INSTALLED BLAST/BALLISTIC RESISTANT WINDOW AND DOOR SYSTEMS

Mr. David Senior, US Army ERDC
Mr. Craig Ackerman- US Department of State
Mr. John Judson, US Army ERDC

Windows and doors are common components of a building that are vulnerable in the event of an attack and can cause injury to occupants if they fail. With increased terrorist threats around the globe, there is a need for technologies that can be quickly installed to upgrade these components for enhanced protection. To address this need, the U.S. Department of State (DOS) tasked the U.S. Army Engineer Research and Development Center with the fabrication and experimental validation of multiple hardened window and door systems. The systems were designed by DOS to use compression-type frames for simplified installation into new or existing facilities and provide blast, ballistic, and forced entry resistant protection. The systems are collectively labeled BBROWS (Blast and Ballistic Resistant Operable Window System), BBERGS (Blast, Ballistic and Entry Resistant Glazing System), BBERGS-H (Blast, Ballistic, and Entry Resistant Glazing System – Heavy) and BBERDS (Blast, Ballistic and Entry Resistant Door System). A full-scale experimental blast test was conducted to validate the new prototype designs and ensure that they meet the DOS requirement for blast threats. This presentation will provide an overview of the fabrication, installation, and blast performance of the systems.

PERFORMANCE OF ADAPTABLE LIGHTWEIGHT IMPACT PROOF PLATES

Dr. Jun Han, Shock Tech
Dr. James Rall, Shock Tech
Mr. Benjamin Reydel, Shock Tech
Dr. Daryoush Allaei, Shock Tech

The prediction of non-linear dynamic response of a mortar weapon baseplate to impact loading is challenging due to the complexity of the baseplate structures and loading conditions. To simulate the

dynamic response of the baseplate, the authors developed a finite element modelling methodology based on ANSYS-FEA package. The FE model was used to evaluate a new design of a baseplate, Adaptable Lightweight Impact Proof Plate (ALIPP) developed at Shock Tech. ALIPP is optimized for handling high impact loading to improve impact resistance and reduce deformation while reducing weight and cost. The numerical FE modeling of the impact resistance baseplates was conducted using the transient analysis approach. Dynamic responses, including deformation and stress, with an impact load of 500 kips were simulated. The developed FE models are capable for simulating non-linear dynamic properties of mortar weapon baseplates. The conventional baseplate and ALIPP were compared. The maximum deformation of ALIPP was found to be 30% lower than the conventional baseplate, and the maximum stress of ALIPP was found to be 51% less than the conventional baseplate. The lighter weight (9%) of ALIPP together with the improved performance, provide significant advantages for this new impact resistance baseplate.

INTERPRETATION OF DATA FROM AN ELEVATED NON-HEMISPHERICAL CHARGE CONFIGURATION AGAINST A WALL STRUCTURE

Mr. Justin Roberts, US Army ERDC

A close-in airblast experiment was conducted subjecting a soil-filled concrete wall structure to the blast loading of a large vehicle-bourne explosive device (LVBIED). The experimental goals were to assess wall performance and collect pertinent data for comparison to a high-fidelity computational model. Various sensors were used to characterize the blast environment, dynamic behavior, and blast-induced stress wave propagation through the wall. Interpretation of data collected in the close-in airblast region using ideal charge geometries (hemisphere on the ground) presents a challenge; however, elevating a non-hemispherical charge creates a complex flow field resulting in data anomalies. Accurate interpretation of the data becomes ambiguous as changes from ideal charge configuration occur. A detailed evaluation of the data delves into this phenomenon, seeking distinction between the signal and noise and exploring plausible explanations of the anomalies observed.

SESSION 7: DYSMAS II

UNDERWATER HOLING FIXTURE TESTING & ANALYSIS

Mr. Andrew Glass, NSWC Carderock
Mr. Scott Natkow, NSWC Carderock
Mr. TW Shaw, NSWC Carderock
Dr. Ken Nahshon, NSWC Carderock

Near-contact underwater explosions resulting in plating rupture involve venting of explosive reaction products into the target along with eventual backflow during the bubble under-pressure phase. A combined testing and analysis effort using a newly designed test apparatus, the UNDEX Holing Fixture (UHF), is being undertaken to explore these phenomena. In this talk, the experimental setup, along with numerical predictions, will be presented.

Implementation of Boundary Element Code DFBEM into HULLWHIP

Mr. Georges Chahine, DynaFlow
Mr. Chao-Tsung Hsiao, DynaFlow
Mr. Gregory Harris, ATR

The DFBEM Boundary Element Code was developed by DYNAFLOW, INC. as part of the DYSMAS hydrocode suite to add an accurate and efficient capability for simulating underwater explosion bubble dynamics. This presentation discusses on-going DFBEM implementation into the HULLWHIP beam analysis software for simulating hull girder whipping. Recently completed work focused on UNDEX bubble loading of the ship hull for close-in geometries where the current 2D bubble-structure interaction approximation breaks down. Results using the DFBEM loading will be presented to illustrate highly 3D flow effects on the hull girder loading and response for close-in cases. In parallel, ongoing work at DYNAFLOW to include 3D bubble jet loading effects will be briefly described.

Implosion Testing of Cylinders in Confined Environments

Dr. Joe Ambrico, NUWC Newport
Mr. Craig Tilton, NUWC Newport
Mr. Ryan Chamberlin, NUWC Newport

Pressure vessels exposed to external depth pressure in water have the potential to collapse. The resulting implosion can create a high-pressure wave that radiates outward in the water. When a pressure vessel is located within some sort of confining structure, that structure can restrict or affect the water flow that drives the implosion. This effect can either mitigate or enhance the implosion magnitude, depending on several factors. A series of tests are designed and conducted to evaluate the parameters that affect confined implosion. A specific test fixture is designed and fabricated to roughly represent a scale version of real hardware that is of interest. A series of tests is conducted to evaluate the effect of implodable volume size, number of implodable volumes, implodable volume material and construction, and water flow path into the confining structure. The test results provide a significant data set describing confined implosion, and demonstrate several trends.

Simulated Hydrostatic Implosions of a Cylinder within a Closed Box

Dr. Emily Guzas, NUWC Newport
Dr. Joe Ambrico, NUWC Newport
Mr. Craig Tilton, NUWC Newport
Mr. Ryan Chamberlin, NUWC Newport

This paper covers a series of numerical experiments performed to investigate the effect of the presence of a closed water-backed confining structure (rectangular box) on the hydrostatic implosion dynamics of a cylindrical pressure vessel (implodable volume) located inside the box structure. We present DYSMAS simulation results for the hydrostatic implosion of a small cylinder for various combinations of box dimensions and plate thicknesses. As a reference point, we compare select time histories from confined implosion cases to simulated hydrostatic implosion results at the same sensor locations for the same cylinder at the same depth in an unconfined (free-field) environment. Additionally, we propose a method to characterize the confining box’s influence on the implosion. We describe a way to determine the characteristic static volumetric stiffness (measured deformed volume corresponding to applied pressure) for boxes of varied dimensions and plate thicknesses. We cross-reference key features of the hydrostatic implosion simulations against the simulated characteristic pressure-volume response behavior for each box.

Using Air Bubbles in DYSMAS as Approximations of In-tube, Hydrostatic Implosion

Mr. Craig Tilton, NUWC Newport
Dr. Joe Ambrico, NUWC Newport
Dr. Emily Guzas, NUWC Newport
Mr. Ryan Chamberlin, NUWC Newport

No abstract provided.

SESSION 8: BLAST: BURIED MUNITIONS & MINES

Efficacy of CALDERA for the Forensic Assessment of Anti-tank Mine Blasts

Mr. William Myers, US Army ERDC
Dr. Jay Ehrgott, US Army ERDC
Mr. Jasiel Ramos-Delgado, US Army ERDC
Mr. Carl Flowers, US Army ERDC
Mr. Daniel Danko, US Army ERDC
Mr. James Swain, US Army ERDC

Anti-tank mines are an ongoing threat to U.S. and Allied forces. These weapons have been used across the globe for decades and cause great damage to equipment and personnel. Forensic data recovered from the scene of an attack can be analyzed to gain valuable information about the threat, how it is being utilized and the response or vulnerabilities or our protective systems. The Crater ALgorithm Design for Explosive charge Analysis (CALDERA) was developed by the National Ground Intelligence Center (NGIC) and the U.S. Army Engineer Research and Development Center (ERDC) to estimate the Effective-Net Explosive Weight (E-NEW) of buried charges based on forensic data gathered at the scene. CALDERA has been used successfully by the intelligence community and Explosive Ordnance Disposal (EOD) personnel to estimate the E-NEW of shallow-buried improvised explosive devices or IEDs after an attack. To date, little research has been conducted relating the craters produced by buried anti-tank mines to those from bare explosive charges. Since CALDERA was developed and validated for improvised explosive devices and bulk explosives, it is unknown if CALDERA will accurately calculate the E-NEW of craters formed by anti-tank mines. This paper will present the results of field experiments and will provide an assessment of the efficacy of using CALDERA for calculating the E-NEW of craters formed by anti-tank mines.

Late-Time Simulations of Mk-82 Buried Blast Tests for Collateral Damage Estimation

Mr. William Furr, US Army ERDC
Dr. Neil Williams, US Army ERDC
Dr. Stephen A. Akers, US Army ERDC
Dr. John Q. Ehrgott, Jr. US Army ERDC
Mr. Marc Rivera, NSWC Dahlgren
Mr. Michael Hopson, NSWC Dahlgren

Over the past several years, the joint services have focused considerable attention to characterize the blast field and secondary debris that is generated when weapons are buried in structures or in the ground. One of the primary goals is to understand those secondary debris influences in order to refine our ability to estimate collateral damage in a strike situation. To support this effort the Enhanced Weaponeering and Collateral Damage Estimation Program, with funding from the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME), has been working on a shock physics modeling and simulation (M&S)

methodology to evaluate weapon burial scenarios. This methodology will be used in enhancing collateral damage predictions by augmenting the limited, costly field tests. The popular hydrocode CTH has a long history of predicting blast response from munitions in geomaterials. However, accurate collateral damage estimations require not only accurately predicting airblast and soil response, but also the final crater size and ejecta. These requirements result in both long simulation and execution times. The work presented here details the process and summary of achieving a consistently stable calculation in CTH, and compares calculation results with field test measurements for air and soil response and crater measurements of two Mk-82 tests at different burial depths.

The Influence of Soil Type on Ground Shock and Aboveground Blast Wave Propagation for Shallow Buried Hellfire R9E Detonations

Mr. Garrett K. Doles, US Army ERDC
Mr. William S. Myers, US Army ERDC
Dr. John Q. Ehrgott, Jr., US Army ERDC

Burial of warheads is a relatively new tactic being employed to reduce collateral damage from blast and fragment impact where high-value military targets are surrounded by protected civilian/ noncombatant objects. The U.S. Army Engineer Research and Development Center is participating in a multi-year effort to obtain experimental data to quantify the effects of burial on weapon performance. As part of this research effort, a series of well-defined field experiments were conducted to quantify the effects of soil type and warhead depth of burial on the ground shock and aboveground blast environments produced by the detonation of a Hellfire warhead. The experiments were conducted at two depths of burial in well characterized testbeds using multiple soil types ranging from a dry sand, moist clayey sand, and wet fat clay. The experiments utilized soil accelerometers and soil stress gauges to characterize the ground shock in the testbed and side-on overpressure and pencil probe gauges to characterize the above ground blast environment. This paper summarizes the results from the series of experiments and presents comparisons of the above ground blast and ground shock environments with soil type and depth of burial in an effort to better understand the effects of buried warheads.

SESSION 8: BLAST: WEAPONS EFFECTS & SIGNATURE STUDIES

Overview of AFRL Joint Weapon Effects Research

Mr. Ernest Staubs, Air Force Research Laboratory

With trends to smaller munitions, it becomes more important to accurately predict damage resulting from a strike with high confidence. The purpose of this joint testing program with the Army Research Lab is to collect empirical data needed to develop, improve, and validate predictive codes used for weapon design trades, strike planning, post-strike damage and collateral damage assessments with an emphasis on urban target construction. Ten joint live fire test campaigns have been conducted since 2012 to gather data critical to weapon effects model development. Test objectives are to obtain data for the purpose of developing predictive analytic tools to estimate target penetration, structural response, air blast propagation, secondary debris generation, and the resulting damage to critical equipment and infrastructure. This paper gives an overview of the testing conducted, describes the objectives and scope of the tests. Data from this testing is available to the broader DoD community.

FORENSIC ENCYCLOPEDIA RESULTS RETRIEVAL AND EVALUATION TOOL FOR FORENSIC CHARACTERIZATION AND METHODOLOGY

Ms. Katelyn Polk, US Army ERDC
Mr. Cameron Thomas, US Army ERDC

Weapons attacks have been an ongoing problem for U.S. and Allied forces. This has driven the National Ground Intelligence Center (NGIC) to partner with the U.S. Army Engineer Research and Development Center (ERDC) to perform a series of field experiments. In order to develop forensic analysis tools that could allow identifying weapon systems used in attacks based on post-attack forensic signatures, the NGIC and ERDC have performed analyses of the forensic signatures left behind by the firing of various weapons systems. This has helped to improve the understanding and characterization of these threats. These weapon firings are conducted in controlled environments to determine the weapon signatures through forensic investigation including the collection and analysis of weapon signatures against various armor targets including munition and target photos, residual munition fragments, and will be used to further develop the Forensic Encyclopedia Results Retrieval and Evaluation Tool (FERRET) database which allows the identification of threat weapon systems through a comparative analysis of post-strike signatures. This paper will provide an overview of the characterization of weapons based on the methodologies developed under FERRET which can be used to collect data conditions after an attack has occurred.

VENDOR SESSION B: EXHIBITOR PRESENTATIONS INCLUDING CASE STUDIES, NEW DEVELOPMENTS, TESTING & PRODUCTS

MARITIME CAPABILITIES

Mr. Michael Poslusny (Gibbs & Cox)

Design services provided by Gibbs & Cox, a wholly owned subsidiary of Leidos, rely on an experienced team of marine and engineering specialists. This work involves a wide range of activities, beginning with concept and feasibility design and continues through detailed design, construction support, life-cycle support and into ship-alt design for service-life extensions. This presentation will focus on G&C capabilities and our current projects; including the DARPA Sea Train Concept, T-AGOS(x), Large Unmanned Surface Vessel (LSUV) and DDG(x). G&C was recently purchased by Leidos, expanding our marine autonomy and cybersecurity expertise.

CONVENIENTLY MONITOR SHOCK AND VIBRATION WITH NEW ENDAQ CLOUD

Mr. Steve Hanly (Mide Technology)

enDAQ (formerly called Slam Stick) has long offered vibration and shock sensors unrivaled in both the quantity and quality of data it records. Now offering devices that include an embedded WiFi module, these can upload data directly to the cloud for processing so you no longer need to wait until the end of a test to analyze your data.

Once in the cloud, the fun begins! The enDAQ cloud is truly unique in its ability to allow the user to completely customize both the analysis algorithms and data visualization dashboards with user-generated Python code (services are also available for enDAQ to provide the customization for the user). So now a user can monitor the exact vibration or shock conditions that matter most for each unique application. A demonstration of the cloud capabilities will be provided along with a recap of both available and coming-soon products.

MONITORING SYSTEMS AND FACILITIES FOR ENTIRE ENVIRONMENTAL TEST LABORATORY
Mr. Chris Wilcox, m+p International

Avoiding damage to unit under test and facility hardware is of utmost importance for the responsible test engineer. By monitoring both the unit under test as well as various facility parameters, safety can be greatly increased as well as documented with a continuous online data monitoring system. While monitoring all measurements against preset alarms and abort conditions, with TTL outputs to initiate shutdowns, this can be achieved. With the advent of modern processing and hardware performance increases, all measurements can be stored in the time domain before, during, and after an anomaly is detected and responded to, allowing for analysis to determine fault conditions leading to the anomaly.

MMA - CAPABILITIES MATRIX
Mr. John Rhatigan, Marine Machinery Association

No abstract provided.

ADVANCEMENTS IN MULTI AXIS VIBRATION TECHNOLOGY
Mr. Kevin McIntosh, TEAM Corporation

Presentation of interesting topics concerning new developments in multi axis vibration testing capabilities

TRAINING II: CHECKING A FINITE ELEMENT MODEL

CHECKING A FINITE ELEMENT MODEL
Mr. Bart McPheeters, Gibbs & Cox

Instructor will go through a list of checks that anyone working with finite elements should run on their model. Instructor will cover things that a user should do as well as things a reviewer should check. These will basic common sense checks and things that FEA programs will help you with, as well as some basic sanity checks that can give you confidence in your model model. Again, this will be code neutral. Instructor will use Nastran and FEMAP examples, but the checks are universal and apply equally to all FEA programs.

SESSION 9: PYROSHOCK

INFLUENCE OF TEST SETUP PARAMETERS ON THE TIME DOMAIN TEST SPECIFICATION OF RESONANT PLATE SHOCK TEST
Dr. Washington DeLima, Kansas City National Security Campus
Mr. William Zenk, Kansas City National Security Campus

SRS (Shock Response Spectrum) is the current metric to evaluate the impact of mechanical shock events on components. This approach has limitations since more than one time domain event can have the same SRS. There is interest to implement a new method to evaluate mechanical shock events that uses the time domain event parameters (peak amplitude, duration and knee frequency) as metrics. This paper investigates the influence of test setup parameters (plate, projectile weight, firing pressure and velocity) on the test specification parameters (peak amplitude, duration and knee frequency). The results set up a baseline of understanding of how the time domain events can be used as test metric for shock events and their impact in the test producibility of mechanical shock.

Finite Element Analysis of Mechanical Impulse Pyroshock Simulator (MIPS) Tests to Predict the Shock Response Spectrum Levels

Ms. Claudia Northrup, National Technical Systems
Dr. Logan McLeod, National Technical Systems
Mr. Da Cheng, National Technical Systems

National Technical Systems (NTS) had previously developed an explicit finite element model for ordnance-induced pyrotechnic shock testing which was shown to successfully predict the acceleration time histories as well as the Shock Response Spectrum (SRS) levels for a specific test configuration. In this work a similar approach is implemented to explicitly model the Mechanical Impulse Pyroshock Simulator (MIPS) test. Traditionally, the MIPS test has been an empirical process, where the initial test configuration is largely based on the experience of the test engineer and then, through a trial-and-error process, the test parameters and configuration are modified until acceptable SRS levels have been achieved. The predictive modeling tool developed may be used to assist with test configuration design for particularly challenging test requirements or to streamline the process of arriving at acceptable test levels during the equalization phase of a test program.

The explicit finite element analysis will be developed with a focus on correctly modeling the metal to metal contacts and the damping materials within the test setup, as well as matching the knee in the SRS requirements. Other modeling parameters will be explored to assess the sensitivity of these modeling parameters on the analysis and results. Test data for these test configurations will be presented for comparison with model predictions. Post-processing of the model results in order to facilitate comparison with measured test data will also be discussed. The finite element analysis will be done in LS-DYNA.

SESSION 10: VIBRATION TESTING APPLICATIONS

Vibration Effects on Laser Optical Train

Dr. Jeremy Kolansky, Virginia Tech
Dr. Pablo Tarazaga, Virginia Tech
Dr. Scott Huxtable, Virginia Tech
Dr. Luke Martin, NSWC Dahlgren

Traditionally laser optical trains are tested and developed on optical benches that are isolated from vibration and base disturbance effects. However, with the modern progress in laser technology these systems are being transitioned to operational environments that are vibrationally harsh and isolation is no longer a reasonable assumption.

However, given this transition there is minimal research into the mechanical effects on the laser systems. Here we present some experimental research into the properties of laser systems when subject to vibration, and show that the effects, particularly for strong dominant vibration modes, nonlinearly weight the laser power away from the center of the beam.

VIBRATION RESILIENCY OF LASER OPTICAL TRAINS

Dr. Jeremy Kolansky, Virginia Tech
Dr. Pablo Tarazaga, Virginia Tech
Dr. Scott Huxtable, Virginia Tech
Dr. Luke Martin, NSWC Dahlgren

Laser optical trains are traditionally tested and deployed on vibration isolation tables to prevent unwanted dynamics and distortions. However, with recent advancements these systems are being field deployed into vibrationally harsh environments. We present vibration resilience analyses of optical train configurations.

Vibration disturbances cause significant distortions of laser beam patterns and characteristics, and the effects are not linearly dependent upon the disturbance. Vibration effects compound in a non-linear fashion: a disturbance in a lens's position will be amplified by downstream elements, as extrapolated from Snell's Law. Vibration resilient design recommendations are presented.

DERIVING BEST SDOF SHAKER INPUTS FROM 6 DOF BASE INPUT PAYLOAD MODELS

Mr. Randy Mayes, Consultant

We assume here that sufficient field vibration measurement data have been gathered on the base mounted payload. Given that, we show how a 6 DOF base input payload model can reproduce the field response on the payload. This is performed through a sum of the rigid body modes and a relatively small number of fixed base payload modes. Since most qualification testing is done on SDOF vibration machines, we utilize the payload model to determine the best input for the SDOF test as well as the associated uncertainty in matching the field data. The required portions of the 6 DOF payload model can be directly extracted from random surveys of the payload on either 6 DOF or SDOF machines. The structural strain damage potential can be quantified in the potential energy of each fixed base mode which provides significant mechanical insight.

SESSION 11: MECHANICAL SHOCK

POST-YIELD SHOCK ENERGY PROPAGATION: TESTING AND NUMERICAL SIMULATION OF A SIMPLE BEAM

Mr. Austin Hughes, United Launch Alliance
Mr. Joshua E. Gorfain, Applied Physical Sciences Corp.

Describing how shock energy propagates through a structure while that material is yielding is of interest for two main reasons. First, many shock sources such as frangible joints function by locally yielding a material to the point of failure and the propagation of that energy into the rest of the structure is critical. Second, while flight structures are unlikely to yield in a nominal operating environment, standard testing practices require adding sufficient uncertainty to the maximum predicted environments (MPE) such that structure occasionally yields and fails when exposed to qualification testing environments. This work seeks to understand the fundamentals of the propagation of shock energy through a material as it passes through different elastic and plastic regions of the stress strain curve by focusing on a simplified test setup of aluminum beams of various thicknesses and yield strengths. The test beam was heavily instrumented with accelerometers and digital image correlation (DIC), and a number of metrics including shock response spectra and post-mortem strain were compared to determine how yielding affects the energy

propagation. Explicit dynamic finite element analysis was also completed and correlated well with the test results.

DROP SHOCK FIXTURE ANALYSIS ON A SHORT DURATION PULSE USING SWAT FORCE RECONSTRUCTION

Mr. Ryan Jennings, Kansas City National Security Campus
Mr. Jonathan Hower, Kansas City National Security Campus
Mr. Brad Wohletz, Kansas City National Security Campus

Drop shock machines are commonly used to create a single sided shock pulse that is characterized by an amplitude and a pulse length. While the amplitude of the pulse input is critical in determining a majority of the stresses found in a test article, the pulse length determines the frequency content excited by the shock and can also have an effect on stress. Current simulation methods to model the drop shock machine environment typically use an experimentally measured acceleration on the surface of the drop tower carriage as the input. This measurement assumes that the surface of the drop table is rigid through the shock event, due to a lack of knowledge about the true input force on the drop table during the shock event. However, recent work has shown that the dynamics of the drop shock machine carriage can affect the measured response and impart base strain on the unit under test, particularly during a short (~3ms or less) duration pulse. Recent work has also shown that the SWAT technique is able to use the carriage measured response to create a validated force input and better characterize the shock event seen by a test article. This work aims to apply that method to a particular unit under test and perform analysis on the fixture design. Results from laboratory modal and drop tests, force reconstruction using SWAT, and FEM analysis are presented. The Department of Energy's Kansas City National Security Campus is operated and managed by Honeywell Federal Manufacturing & Technologies, LLC under contract number DE-NA0002839.

SESSION 12: BLAST: STRUCTURE & MATERIAL RESPONSE I

MEASURING AND ANALYZING THE AIRBLAST ENVIRONMENT WITHIN A MULTI-ROOM STRUCTURE CONSISTING OF OPENED, CLOSED, AND SEALED DOORS

Mr. Roosevelt Davis, Air Force Research Laboratory
Mr. Ernie Staubs, Air Force Research Laboratory

Several airblast experiments were performed within a multi-room structure containing a single bare charge and several doorways in different conditions during each of the experiments. The doorways are adjacent to the detonation or source room with conditions of the doorways being opened, closed, and sealed. Intentions are to measure the different airblast environments to determine how each door condition impacts airblast throughout the structure.

This paper will present data from the experiments collected from instrumentation. Instrumentation consisted of pressure transducers, optical switches, and high-speed cameras. The multi-room structure has pressure transducers mounted at various locations throughout the structure for determining pressure and impulse. Optical switches and high-speed cameras are used to determine timing for doors being dislodged or opened during experiments.

The experimental setup and door types will be presented. A brief comparison of the different airblast environments will be made also. Pressure and impulse calculations will be used to describe the different airblast environments.

Evaluation of the Response of High-Performance Concrete Elements to Proliferated Weapons Systems
Mr. Cameron Thomas, US Army ERDC

The need for improved methods for protecting our mounted and dismounted soldiers from munitions and weapons systems is an ongoing problem for deployed U.S. Forces. In an effort to address this problem, the U.S. Army Engineer Research and Development Center (ERDC) has been tasked with an effort to evaluate the effects of specific munition threats against a set of targets composed of High-Performance Concrete (HPC). The classes of munitions and weapon systems selected will be a subset of those regarded as "proliferated" or likely to encounter due to their widespread and common usage. As part of the evaluation, a set of controlled experiments were conducted by dynamically firing the selected weapons systems into the HPC targets at common ranges and impact conditions. The results of test firings on the HPC targets were compared to those of identical munitions against other target materials commonly used for force protection or found in combat environments. The comparable test articles used are composed of reinforced concrete and conventional military vehicle armors such as rolled homogeneous armor (RHA) and aluminum. Digital photography and measurement tools will document the effects of munition(s) and response of the target materials. This paper presents an overview of the experiment design and the results from this effort.

Repair and Enhancement of Concrete Barriers Using High-Performance Concrete
Mr. Stephen Turner, US Army ERDC

The US military uses a significant number of concrete barriers (such as Alaska barriers) to support expeditionary operations, including construction and maintenance of forward operating base defensive perimeters. Concrete barrier walls, for example, may be damaged or destroyed by various attack vectors, thereby impacting the defensive posture of deployed forces. Currently, there are no deployable methods for repairing walls of this type in the field to restore their useful function. ERDC has been tasked with evaluating a High-Performance Concrete (HPC) material to expediently repair damaged concrete barriers. The HPC was chosen to be evaluated due to its ability to easily be deployed in remote locations, quick setting time, high bond strength, and minimal surface preparation. This effort will determine if the HPC technology can provide an acceptable repair of concrete barriers under austere conditions. The HPC will also be evaluated to determine if it can be used to enhance the blast resistance of various structural elements.

Perforation Testing Into A36 Steel Targets Using Ogive, Hemispherical, and Conic-Nose Steel Projectiles
Dr. Kyle Crosby, US Army ERDC
Mr. Reid Bond, US Army ERDC
Mr. Ernesto Cruz, US Army ERDC
Dr. Jay Ehrgott, US Army ERDC

A series of perforation tests was conducted using 1.563" diameter, 8.761" long steel projectiles into A36 steel targets. Three projectile nose shapes were tested including a 3.0 CRH ogive, hemisphere, and truncated conic nose. The projectiles were fired at velocities from 750 ft/s to 1500 ft/s using an 83mm powder gun into target plates with thicknesses measuring 0.25, 0.50, and 1.0 inch. High-speed video was used to measure impact velocity, exit velocity, and projectile trajectory after target perforation. Photogrammetry was used to generate 3D crater geometry. On-board accelerometers were also tested to determine their suitability for metal target impact. The data generated from this series of tests will be used to calibrate and validate steel perforation predictive models.

VENDOR SESSION C: EXHIBITOR PRESENTATIONS INCLUDING CASE STUDIES, NEW DEVELPPMENTS. TESTING & PRODUCTS

TEMPERATURE LIMITS FOR SHOCK TESTING
Mr. Bob Metz (PCB Piezotronics)

Shock accelerometer temperature specifications are often overlooked as a limiting factor when setting up a test. This session will review four different commercially available shock measurement technologies and their associated operating capabilities with respect to cold and hot testing.

NEW HIGH-CAPACITY 6 DOF HYBRID ISOLATOR INCLUDING COMPONENT-LEVEL AND BARGE TEST RESULTS
Mr. Alan Klembczyk (Taylor Devices)

No abstract provided.

HELPING CUT CORDS IN DATA ACQUISITION
Mr. Jake Rosenthal (DEWESoft)

The long runs of cables for shock testing is a challenge for every test environment since the beginning. When your test article has safety restrictions or trying to do those unique camera angles create unique challenges. DEWESoft has come up with a Mesh WIFI system to help cut some of those cables. We will show how our Mesh WIFI along with the DEWESoft software has allowed for remote access to test environments and eliminated those long cable runs to the DAQ or Control Consoles.

INTRODUCTION TO HIGH-SPEED IMAGING FOR DIGITAL IMAGE CORRELATION
Dr. Kyle Gilroy, Vision Research

In this talk, we introduce the concept and theoretical basis of Digital Image Correlation (DIC) – a non-contact characterization technique that utilizes digital images of deforming targets to calculate full-field deformation, strain, and vibration profiles. Then, discussed is how high-speed cameras can be integrated with DIC code to handle experiments when material deformation occurs at high rates, such as during split-Hopkinson bar setups, device drop tests, impact tests, vehicle crashes, and more. We also summarize the key challenges involved in configuring high-speed cameras for performing high-speed DIC tests. We conclude with some key case studies and discussions regarding the future of DIC.

TRAINING III: AN INTRODUCTION TO DYNAMIC ANALYSIS

AN INTRODUCTION TO DYNAMIC ANALYSIS
Mr. Bart McPheeters, Gibbs & Cox

An introduction what constitutes an dynamic analysis and when it might be needed. I'll cover the different types of dynamic analyses that are used. A description of the basic equations of motion that describe each type and the inputs needed and outputs generated from each type. This will be code-neutral in that I may use Nastran examples, but the principals will be applicable to any finite element program.

SESSION 13: DROP SHOCK MITIGATION

REUSABLE, HIGH PERFORMANCE HONEYCOMB FOR AIRDROP APPLICATIONS

Mr. Benjamin Reydel, Shock Tech
Dr. Daryoush Allaei, Shock Tech
Dr. James Rall, Shock Tech
Dr. Jun Han, Shock Tech

The use of crushable materials to dissipate ground impact energy, or any large shock energy, is essential in protecting military gears, medical equipment, and other hardware when dropped from an aircraft. The application of such materials allows military entities to safely transport, evac and air-drop critical supplies, ammunition, and vehicle into previously hard to reach areas. Additionally, for civilian applications, such as air shipping, and ground transport, damage-free cargo relies heavily on these crushable materials, often in some sort of honeycomb structure.

This work is focused on the development of Shock-Honeycomb (SHoc), a reusable, high performance, elastomeric product suitable for replacing fielded disposable paper honeycomb. SHoc is based on a modular geometry, number of connectable elastomeric parts and elastomer durometer. Each part fits together into a larger pod of six and is designed to be assembled by packing crew without the use of cutters or glue. The geometry of SHoc allows for flexibility in isolation footprint. Pods can be assembled and grouped according to the shape of the cargo or payload to be isolated. Once assembled, the overall footprint of SHoc can be equivalent to that of paper honeycomb while offering far more flexibility for a variety of shapes without using cutters. Once disassembled, however, SHoc offers 97% space savings over paper honeycomb. Most importantly, due to its elastomeric properties Shock-Honeycomb is reusable. After every airdrop, or once an applied shock load is released, SHoc will rebound back to its original dimensions and geometry, ready to absorb more energy again. The biggest saving is when used in training exercises. The training payload or bundle will not need to be rebuilt after each training drop. SHoc can be dropped more than 25 times without showing any performance degradation; resulting in huge saving in labor hours.

Extensive tests have been performed on SHoc including static, dynamics, usability, size, reusability, and environmental. A single 12” x 12” x 3” pod of Shock-Honeycomb has to date experienced 25 direct impact tests and still shows no signs of dynamic performance degradation. As a reference, a paper honeycomb pod of equal dimensions can only last one impact. Additionally, marine testing of the two products shows SHoc’s significant advantage over traditional paper honeycomb. After being submerged for 1 minute in room temperature water, paper honeycomb catastrophically failed our high-energy impact testing whereas Shock-Honeycomb was held underwater for 10 minutes and showed no signs of performance degradation.

DYNAMIC SIMULATIONS FOR AIRDROP PLATFORM

Dr. Jun Han, Shock Tech
Dr. James Rall, Shock Tech
Mr. Benjamin Reydel, Shock Tech
Dr. Daryoush Allaei, Shock Tech

Airdrop platforms have been widely used in military for delivering rescue materials, medicines, food, and water etc. to specific areas. Although parachutes may largely reduce the dropping speed, landing of airdrop platforms may be subjected to failure due to dynamically complex impact to ground. Currently, the design for airdrop platforms is mainly evaluated through experiments at qualification test facilities and/or actual airdrop tests. The approach is time-consuming and costly. Computer simulation, as an effective numerical analysis method, may simulate airdrop environment and obtain dynamic information at any drop location, which is difficult to achieve though experiments. Simulation can reduce the testing cost and save time. To simulate the dynamic response of airdrop platforms, the authors developed a finite element model utilizing ANSYS-FEA package. The FE model was constructed using Explicit Dynamic solver to evaluate an airdrop platform design, Lightweight Adaptable Airdrop Platform (LAAP), developed at Shock Tech. LAAP was optimized for handling light weight airdrop platform to support G12 parachute employment in special operations and rescue vehicles. To achieve a set of optimized structural parameters, the modeling analysis and experimental investigations were carried out for evaluating the dynamic response of the platform, and its impact resistance performance. The developed FE models are capable of simulating non-linear dynamic properties of airdrop platforms and can aid in designing efficient airdrop platforms in timely manner and minimum cost.

SESSION 13: STRUCTURAL RESPONSE

ANOMALOUS ZONES FOR IMPULSIVELY LOADED STRUCTURES

Dr. Nicholas Nechitailo, NSWC Indian Head

This paper describes anomalous deformation and failure of impulsively loaded structures including ordinary plates, beams, and shells. Related structural behavior is called paradoxical, counterintuitive, anomalous, and unpredictable.

Typically, metal plates deflect in the direction of the applied pressure. The final shapes of plastically deformed circular plates are similar to hemispherical shells. It was discovered that under rather common loading conditions, such as underwater explosion and air blast, metal plates obtained final deflections towards the source of the explosion.

Aluminum and steel plates lost their axial symmetry and deformed into shells with periodic symmetry such as folded six-corner stars. These final shapes were similar to the known complex vibration and buckling modes of circular plates. Several plates developed localized high-temperature rings with very large plastic strains. Some plates produced unusual cracks.

Our additional experiments revealed anomalous behavior in steel rods. Under impulsive tension, these rods elongated plastically. Subsequently, they obtained final shapes similar to the classical shapes of slender rods buckled under static axial compression. In another set of our experiments, thin rods and wires were stretched statically, and then abruptly unloaded. They obtained final shapes similar to the known shapes of the rods buckled under impulsive axial compression, for example, as a result of an impact from one end.

Our finite-difference modeling of purely elastic domes under relatively small internal pulse loads revealed zones of instability, transient chaos, and collapse. Their buckling modes were similar to those observed in shallow domes under external static pressure. We discovered that small charges can be used for inducing anomalous deformation and resonant self-destruction of various structures.

Parametric analysis revealed anomalous zones where reputable finite-difference and finite-element codes were not able to reliably predict the motion of ordinary elastic-plastic beams and plates. Very small variations in the applied loads, material properties and computational parameters lead to considerably different results. These findings revealed major mathematical and computational challenges potentially for a wide range of mechanical and non-mechanical nonlinear systems modeled by similar equations and analyzed using similar numerical methods.

In the anomalous zones, various structures exhibited transient chaos and post-chaotic self-organization. We believe that there is some predictability for the final states of beams, plates, and shells, based on their geometric and material characteristics, such as eigenvalues. Observed results helped us formulate the following principle, "in the anomalous zones, very different loads can produce similar final states."

Engineering textbooks and design manuals contain little or no information about the anomalous zones. Structures can fail under much smaller than expected loads if they are designed using existing engineering manuals.

SESSION 14: THE CABLE: IT IS THE RODNEY DANGERFIELD OF THE INSTRUMENATION SYSEM, PART I

THE CRITICAL ROLE OF FULL-SCALE SYSTEMS TESTING IN MODEL VALIDATION AND THE ESTABLISHMENT OF COMPONENT TEST REQUIREMENTS

Dr. Patrick Walter, Consultant/PCB Piezotronics

The critical role of full-scale systems testing in model validation and the establishment of component test requirements is reviewed. Shock wave physics associated with initial structure material response, responsible for subsequent elastic-plastic and elastic structural response is described. A proposed and completed experiment is described to compare/illustrate limitations in frequency transmission via various cable types.

THE BASICS (HIGH/LOW FREQUENCY TIME CONSTRAINTS, IMPEDANCE CONSIDERATIONS, LINEAR PHASE/FLAT AMPLITUDE RESPONSE)

Dr. Patrick Walter (Consultant/PCB Piezotronics)

The history of shock accelerometer development from 1965 through today (PE, IEPE, mechanically isolated IEPE, and MEMS technology) is spanned with lessons learned along the way identified.

WHAT MANUFACTURERS CAN AND CANNOT CERTIFY ABOUT SENSOR PERFORMANCE

Dr. Patrick Walter (Consultant/PCB Piezotronics)

The history of shock accelerometer development from 1965 through today (PE, IEPE, mechanically isolated IEPE, and MEMS technology) is spanned with lessons learned along the way identified.

CHALLENGES AND PITFALLS IN PLANNING FOR A SPECIFIC HIGH FREQUENCY SHOCK TEST TO SATISFY MIL-STD-810 INSTRUMENTATION REQUIREMENTS

Dr. Patrick Walter, Consultant/PCB Piezotronics
Mr. James Woernley, Precision Filters

Mil-Std 810 is used as a basis for actual shock test validation of a predictive model for multi-conductor cables. The resultant measured mechanical shock data are shown to be compatible with this model.

TEST DATA RESULTS & THE CRITICAL IMPORTANCE OF END-TO-END MEASUREMENT SYSTEM CHARACTERIZATION

Mr. James Woernley, Precision Filters

Test data results are summarized and shown to be compatible with an overall model developed for multiconductor cables. The critical importance of end-to-end measurement system characterization is conclusively proven by test results.

SESSION 15: DEDICATED SESSION: MECHANICAL SHOCK: COPITATIONAL & EXPERIMENTAL METHODS FOR FUZE TECHNOLOGY I

THERMAL AND MECHANICAL ANALYSIS OF FUZE PACKAGING SCENARIOS AND RESULTING IMPLICATIONS

Dr. Matthew Neidigk, Air Force Research Laboratory
Mr. Curtis McKinion, Air Force Research Laboratory
Mr. Jared Hammerton, Applied Research Associates
Dr. Alain Beliveau, Applied Research Associates
Dr. Adriane Moura, Applied Research Associates
Mr. James Scheppegrell, Applied Research Associates

Various Fuze electronics packaging strategies were analyzed with respect to survivability in both thermal and mechanical shock environments. Coupled physics modeling was used to assess stress contributions from both thermal manufacturing and mechanical shock resulting in the "total" state of stress. Important considerations such as potting fillers, elastomer coatings, and adhesion were investigated and compared to experimental results. Survivable packaging strategies were identified.

THERMAL AND HIGH-G EXPERIMENTS FOR FUZE ELECTRONICS PACKAGING

Mr. Curtis McKinion, Air Force Research Laboratory
Dr. Matthew Neidigk, Air Force Research Laboratory
Mr. Jared Hammerton, Applied Research Associates
Dr. Alain Beliveau, Applied Research Associates
Dr. Adriane Moura, Applied Research Associates
Mr. James Scheppegrell, Applied Research Associates

Fuze electronics are packaged to survive high-g impact environments. Packaging designs are engineered primarily to reduce high-g dynamic stresses, while often overlooking manufacturing and thermal stresses. This paper discusses experiments to measure and evaluate the combined thermal and mechanical environments. Conformal coating, particle filler, and boundary conditions are some of the design features that are studied. This paper also discusses experimental methods to achieve accurate measurements and compare to simulation results.

Effects of PCB Design Parameters on the Encapsulated Electronics Stress-State in Hypersonic Environments

Mr. Caleb White, Sandia National Laboratories
Mr. Shane Curtis, Sandia National Laboratories

The transition into hypersonic environmental regimes introduces greater complexity in the design of component packaging and survivability. Embedded and/or encapsulated fuzes are subjected to extremely harsh environments with parameter spaces often being highly constrained. Care must be taken to mitigate stress inducers typically deemed unimportant or of little-to-no effect in traditional fuzing designs. The encapsulant serves to physically support the fuzing electronics while simultaneously attenuating high-frequency mechanical excitations. Various design parameters—such as loading direction, boundary condition, mounting orientation, etc.—can drastically affect the resultant electronic stress-state when combined in adverse configurations. To examine the singular and combined effects of these parameters on the resultant stress-state, a multi-dimensional, parametric, Finite Element Analysis (FEA) study is conducted by loading simplified, test-bed geometries with generic high-G shock inputs. Additionally, a small validation experiment is conducted by subjecting generic test articles to high-G mechanical excitations on a drop tower.

Evaluation of Versalink 143 as an Isolation Layer for High-G Survival

Dr. Joel Limmer, Sandia National Laboratories
Mr. Shane Curtis, Sandia National Laboratories

In the past, test-vehicle-mounted instrumentation modules that record sensor data during shock and vibration events have been coated with a polymer isolation layer to enhance survivability. This study uses finite element modeling to evaluate the effectiveness of the isolation material Versalink 143 on reducing stress in an instrumentation module. The modeling shows that while the isolation layer does attenuate stress due to high frequency shock and vibration, it also amplifies stress due to lower frequency shock and vibration. Thicker layers tend to attenuate high frequency stress more and amplify low frequency stress less. In addition, at higher test temperatures thermal expansion of the isolation layer can cause static stress in the module far greater than the stress due to shock, depending on how the module is constrained within the test vehicle. When designing and implementing vehicle-mounted instrumentation modules, the expected input shock spectrum, mounting constraints, and static effects of temperature must be carefully considered.

SESSION 16: BLAST: STRUCTURE & MATERIAL RESPONSE II

Performance of Modified ISO Containers Against Indirect Fire

Mr. David Roman-Castro, US Army ERDC
Mr. Daniel H. Ríos-Estremera, US Army ERDC
Mr. Donald H. Nelson, US Army ERDC
Dr. Paul A. Sparks, US Army ERDC

International Organization for Standardization (ISO) containers can be modified into Life Support Areas and Tactical Operation Centers. In contingency operations, these modified ISO containers' structural responses to extreme events such as indirect fire are of significant interest to the government, industry, and scientific communities. Modeling these events poses a challenge due to complex target and penetrator failure mechanisms during extreme high-rate, impulsive loadings [1]. LS-DYNA is a nonlinear

transient dynamic finite element analysis software that can capture large deformations caused by impulsive loadings [2]. LS-DYNA contains complex models that allow the numerical generation of explosive blast loads for different burst positions and threat types (i.e., hemispherical surface burst, spherical free-air, and non-spherical warheads) [3]. Furthermore, terminal ballistic effects of fragments can be modeled [4, 5]. Various indirect fire threats will be considered to characterize the survivability of a modified ISO container using LS-DYNA. Numerical simulations of the design fragment penetration and blast loadings are presented.

MODELING GAS FLOW IN THE BLASTX FAST-RUNNING MODEL

Dr. Greg Bessette, US Army ERDC
Dr. Alan Ohrt, Air Force Research Laboratory

BlastX is a fast-running engineering-level code designed to predict the airblast environment associated with explosive detonations in complex multi-room structures. These detonations can be either internal or external to the structure. As an engineering-level code, BlastX makes a number of simplifying assumptions in order to obtain a fast-running solution of the blast environment. Foremost of these is the assumption that the shock and gas phases can be modeled independently. A new gas phase model has been implemented into BlastX, specifically to improve the treatment of gas flow within multi-room structures subjected to an internal detonation. The new model supports a time-dependent fill for the rooms within a structure and incorporates both the quasi-static and dynamic gas pressure contributions in the blast assessment. The time-dependent fill model characterizes the leading edge of the gas front and its arrival at a gage point in the target model. Further, the model predicts the time-dependent decay of the gas pressure until the room reaches a fully filled, or quasi-steady, state. This paper outlines the new gas model and its submodels employed for problem-dependent model geometries. Submodels include determination of the gas expansion velocity in both the detonation and neighboring rooms, incorporating plume effects for gas traversing through an opening, and special handling for hallways. Comparisons are drawn against data from experiments conducted by the Air Force Research Laboratory. These experiments were designed to characterize the gas flow within multi-room structures and have proven useful for model calibration and validation.

HOW WILL IT SURVIVE? INFORMING DESIGN DECISIONS FOR TUNNELS SUBJECT TO HIGH-YIELD WEAPONS USING FINITE-ELEMENT MODELING

2LT Johnathon Scheerer, US Military Academy
2LT Antonio Viera, U.S. Military Academy
CDT Mark Quesnel, U.S. Military Academy
MAJ Jes Barron, PE, U.S. Military Academy
MAJ Mike Meier, U.S. Military Academy

Tunnels, bunkers, and underground facilities are used by many countries to hide and protect their most important strategic assets from targeting by their adversaries. Understanding the vulnerabilities of these underground structures to explosive loading is of strategic importance both offensively and defensively. To improve our understanding of this complex problem, a team of Cadets at the United States Military Academy examined high-yield blast effects on tunnels using U.S. Army Corps of Engineer field data and finite element modeling. The purpose of the project was to generate design recommendations to improve the survivability of underground structures exposed to surface blast loading. The objectives were to capture the current state of understanding in the literature, examine various finite element programs, create validated finite element models of surface blasts effects on tunnels, and to examine the impacts of survivability design features within the validated models to inform design recommendations. Real world

empirical data was obtained from the U.S. Army Corps of Engineers project 3.2 Operation Snowball (1967). This experiment detonated a 500-ton TNT surface burst at the Suffield Experimental Station in Canada to determine the blast effects on small reinforced concrete arch structures shallow-buried in sand. Two-dimensional modeling of Operation Snowball was performed in the RocScience program RS2 2019 using a variety of modeling techniques. Validated base models of Operation Snowball were then modified with various survivability design features. Model results were compared to inform design decisions and future research regarding methods to harden underground facilities. As of 16 December 2020, the team has generated four validated models using various modeling techniques in RS2 and is generating design ideas to examine. Initial concepts include low density backpacking, grout curtain shields, additional steel reinforcement, higher strength concrete, and changes to the buried structure's geometry.

Evaluation of Effect of Earth-Cover Thickness on ECM Loading: ¼ Scale Corrugated Arch Donor Results

Mr. Joshua Payne, US Army ERDC
Dr. T. Neil Williams, US Army ERDC
Dr. John Q. Ehrgott, US Army ERDC
Mr. Denis D. Rickman, US Army ERDC
Dr. Michelle M. Crull, U.S. Army Engineering and Support Center
Mr. Paul A. Cummins, Defense Ammunition Center
Ms. Andrea R. O'Brien, Defense Ammunition Center

The U.S. Army has a very large number of earth-covered magazines (ECMs) for storing ammunition and explosives. These magazines are designed to have a minimum of 2 ft of earth cover as specified in DoD 6055.09-M, DoD Ammunition and Explosives Safety Standards. Over time, the earth cover may erode resulting in an earth cover that is less than the required 2-ft thickness, thereby reclassifying the ECM as an aboveground magazine (AGM) and significantly reducing the allowable storage capacity. In order to address this issue, the U.S. Army Technical Center for Explosives Safety (USATCES) requested support from the U.S. Army Engineering and Support Center (CEHNC), Huntsville and the U.S. Army Engineer Research and Development Center (ERDC), Vicksburg to research and evaluate the effects of varying earth covers for ECMs. A series of experiments were developed, code-named Magazine EaRth Cover Update/Reassessment studY (MERCURY), to investigate the effects of varying earth-cover thicknesses for ECMs. The original goal of this experimental effort was to provide sufficient data to justify updates to the current requirements and allow an accurate and reasonable reduction based on actual soil cover depths below the current two-foot cutoff, thus eliminating the "sudden" transition from ECM to AGM requirements. However, these experiments provided benchmark data for comparison to and validation of results from companion numerical simulations that ERDC now proposes as a means of augmenting the evaluation of the effect of ECM earth cover in numerical simulations likely affecting future ECM design criteria. This paper will focus on the results of the second series of experiments, which utilized a corrugated arch magazine as the donor ECM and well-instrumented testbeds and berms to capture critical airblast and groundshock data transmitted to the near-field area.

SESSION 17: STRUCTURAL RESPONE: MODELING & SIMULATION

MODELING OF LABORATORY SHOCK-BASED STRUCTURAL HEALTH MONITORING FOR NAVAL WEAPONS APPLICATIONS

Mr. Robert Ponder, NSWC Dahlgren
Mr. Daniel Holder, NSWC Dahlgren

The mechanical integrity of many structures can have an impact on human safety and system operation. System stakeholders must evaluate the condition of a structure or sub-component. Condition-based structural evaluation of system components is often more efficient and effective at predicting damage than time or use-based evaluation. Condition-based structural evaluation ensures that maintenance or component replacements are implemented in a timely and safe manner. Naval gun weapon systems present an example in which failure to properly maintain or repair a structure can have catastrophic consequences. Structural health monitoring is a concept aimed at evaluating a system during regular operational use. Structural health monitoring comes in many forms; including vibration or shock-based structural health monitoring (SHM) with transducers such as accelerometers or strain gages. A shock-based SHM system has the potential to use the excitations produced by routine operation of a naval gun system, such as gunfire and autoloader shock, to characterize the health of the structure. A small-scale laboratory test setup provides early insight into the effectiveness of shock-based SHM using operational excitation.

The objective of this work is to use low-level shock inputs as a means for performing SHM on a weapon system. Three steps describe the work. The first step shows the development and characterization of a simplified gun system structure for use in laboratory experimentation. The second step displays the generation of accelerometer and strain data from a model of the laboratory test setup undergoing a low-level shock. The third step discusses using the previously generated accelerometer and strain data in conjunction with a simple structural health-monitoring algorithm to evaluate the ability for the laboratory test setup to simulate detectable structural damage. This work builds a platform for further laboratory development of an SHM system for naval weapon systems.

SESSION 17: UNDEX ANALYSIS I

HULLWHIP: RECENT DEVELOPMENTS FOR WHIPPING ANALYSIS

Dr. Ken Nahshon, NSWC Carderock

A review of recent progress in updating and modernizing the Hullwhip beam-whipping code will be presented. Major updates include the introduction of an inelastic beam capability, modernized output formats, and enhancements for reading external loads.

VALIDATION "GRADER" FOR TRANSIENT SHOCK MODELING AND SIMULATION

Dr. Russ Miller, Institute for Defense Analyses
Mr. John Przybysz, Institute for Defense Analyses

IDA is currently developing a validation grader that employs a multi-metric approach with regression coefficients to objectively grade the accuracy of transient shock simulation predictions using test data as a basis of comparison. The grades it generates for the individual predictions can be used in modeling and simulation (M&S) validation. To best assess the acceptability of M&S predictions of real-world shock events, it is important that the validation metrics included in the grader software tool accurately capture the subjective evaluation of the subject matter expert (SME). This is an active area of current research where many metrics have been proposed, some metrics have been combined, and all metrics have shortcomings when applied to transient shocks. Statistical methods are used to down-select the metrics most closely correlated with SME grades. To be judged as offering a good correlation, the M&S should replicate the test data in both the time and frequency domains. Shock analysts often assess correlation by comparing velocity time histories and the corresponding shock response spectra (SRS). Common error metrics include peak deflection, peak velocity, peak acceleration, impulse, and the energy input spectrum. Our approach introduces additional metrics based on SME observations. In addition to generation of grades, we present examples showing that the grader may also be used as a diagnostic tool for identifying model areas and gages of concern. The examples also show the importance of defining M&S-specific intended uses when applying the grader.

A PRIORI AND A POSTERIORI MODELING AND SIMULATION GUIDANCE FOR COMPLEX SUBMARINE HULL STRUCTURES

Mr. Fred Costanzo, M&J Engineering
Dr. Jeffrey Cipolla, Raytheon Missiles & Defense
Mr. Alex Kelly, Thornton Tomasetti
Mr. Ostap Gladoun, Thornton Tomasetti
Mr. Ryan Anderson, Thornton Tomasetti

No abstract provided.

TRAINING IV: INTRODUCTION TO HEAVYWEIGHT SHOCK TESTING

INTRODUCTION TO HEAVYWEIGHT SHOCK TESTING

Mr. Travis Kerr (HI-TEST Laboratories)

This training will cover the necessary background information relative to heavyweight shock testing. This session is intended for engineers and product developers who are unfamiliar with the heavyweight shock testing process. Subjects covered include pre-test planning, procedure preparation, fixture design, test setup, test operations, instrumentation interpretation, and reporting. Construction and use of the floating shock platforms (FSP, IFSP, and LFSP) will be covered. Shock test requirements applicable to heavyweight shock testing will be discussed.

SESSION 18: SHOCK

COST REDUCTION OF SHOCK APPLICATION

Mr. Wesley Rogler, HII Ingalls
Mr. Michael Thompson, HII Ingalls

Shock testing has been a significant cost driver and schedule concern for U. S. Navy acquisition programs for many years, particularly for the lead ship of a class or a major baseline upgrade of an existing ship class. For Navy ship contracts, shipyards are required to compile documentation to validate all vendor furnished equipment meets the applicable grade-of-shock qualifications for the location where it is installed. If the shipyard and/or vendor provides inadequate or deficient documentation, they will be required to shock test that component and submit a shock test report. For deck mounted equipment, the proof of meeting the standard has generally been accomplished with heavyweight barge testing, where the equipment under test is mounted on a specially-designed barge in a pond. The barge is then subjected

to a series of underwater explosions. This is an expensive, time-consuming, and hazardous test method. Some machine-based shock testing equipment exists, but there are significant limits on their applicability. The National Shipbuilding Research Program (NSRP) has sponsored a project to address ways to reduce the costs associated with shock qualification testing for U. S. Navy ship programs. The project team has investigated several aspects of shock testing that are potential cost saving initiatives with the cooperation of the Naval Sea Systems Command (NAVSEA) Technical Warrant Holder for Shock. Several opportunities are available to reduce the overall cost of shock qualification for the fleet.

The following subjects are being addressed in the project:

1. Create standard test fixture designs for the Light Weight, Medium Weight and Deck Simulating Shock Machine (DSSM) shock testing machines, build prototypes, and perform validation testing
2. Development of guidelines for proper selection and use of shock isolators
3. Proposed shock qualification process for low risk items
4. Draft language and drawing updates to the 901E Standard

The project team will discuss the results of the project, and will describe the accomplishments, and path to implementation of project results.

FIRE RESISTANT WATERTIGHT STRUCTURAL DOORS

Ms. Parisa Ghandehari, HII Ingalls
Mr. Michael S. Thompson, HII Ingalls
Mr. John P. Walks, HII Ingalls

Watertight closures have been a significant cost driver for acquisition programs, particularly for U.S. Navy ship programs that require shock qualification of watertight closures. The previous National Shipbuilding Research Program (NSRP) Research Announcement project, “Design for Maintenance and Repair,” identified watertight doors as a significant driver of life cycle support cost, based on multiple comments from repair yards.

Additionally, with the impact of increased fire resistance requirements invoked by NAVSEA on ship programs, and lack of structural doors (i.e., watertight) that are also fire resistant, the industry can benefit from having a compliant option for structural doors that maintains required internal shipboard fire zone boundaries, using only one structural door.

A fire resistant watertight door design will reduce area and volume penalty to ship designs compared to alternate methods and ship cost due to having fewer doors to purchase and install.

For ship programs that require shock qualification of watertight closures, unique door designs that somehow deviate from the Navy standard design are not considered to be shock qualified. In some cases, the design is similar to a previously-qualified design and may receive qualification by extension. Other door designs are mandated by the Navy to be tested to prove shock resistance of the door design. In either case, shipyards incur additional costs to achieve shock approvals for watertight doors.

Currently, to meet NAVSEA fire resistance requirements, using either legacy Navy standard watertight single doors or the new standardized family of watertight single doors (shock qualified during the NSRP project), installation of two doors in close proximity to one another at fire zone boundaries are required, one that serves as a fire barrier and the other serving to maintain watertight integrity.

As the Standardization of Watertight Closures project provided design documentation to support new Navy standard drawings for a family of approved and qualified door designs, the Fire Resistant Watertight Structural Doors project is evaluating various marine fire protection systems and design concepts to design, test, and develop revised drawings for a fire resistant variant of two sizes of new standardized family of watertight single doors for installation at fire zone bulkheads. This project will also seek shock approval by extension for these designs.

Upon incorporation in a revised Navy standard drawing, drawings are expected to be invoked on current and future shipbuilding contracts, which will provide a strong basis for widespread implementation after

SESSION 18: SHOCK RESPONSE SPECTRUM II

PRESCRIBED AND CONTROLLED SHOCK TRANSIENTS CAN BE USED TO BETTER MATCH OPERATIONAL SHOCK TRANSIENTS AND REDUCE ARTIFICIAL SHOCK TEST FAILURES

Dr. Jason Blough, Michigan Technological University
Mr. Monty Kennedy, Michigan Technological University
Mr. Chuck Van Karsen, Michigan Technological University
Mr. Jim DeClerk, Michigan Technological University
Mr. William Zenk, Honeywell

SRS analysis and testing to SRS is known to be conservative since SRS is generated from maxi-max shock transient data, maximum peaks are assumed to occur for each mode simultaneously, and the structural dynamics are not accounted for between the shock source and the test article.

Understanding the structural dynamics of a shock test setup it is possible to subscribe a force shock transient applied at a particular strike location and direction to achieve a reference shock transient at the test reference accelerometer. The SRS at this test accelerometer reference location can be used to compare to the reference SRS, but the key reference is the shock transient not the SRS, which should lead to more realistic shock testing that better matches operational shock transient data and reduces artificial test failures that don't occur in operational usage.

The desired test shock transient should match operational shock transients. As such, the test shock transient should look similar to the operational shock transient and have similar positive and negative peaks, the same shape, and the same duration. Many shock transients can be created that satisfy an SRS, but better control of these shock transient parameters is needed to better match operational shock transients so that more realistic and less conservative shock testing can be performed.

Three different shock transients are presented that satisfy a given SRS and the results are compared for an electronic board (test article) attached to a circular plate.

A MODEL CREATED TO SUPPORT EFFORTS TO CHARACTERIZE SHOCK EVENTS IN THE TIME DOMAIN

Dr. Jason Blough, Michigan Technological University
Ms. Cora Taylor, Michigan Technological University
Mr. James DeClerk, Michigan Technological University
Mr. William Zenk, Honeywell

Michigan Tech has worked for many years alongside others in the industry to improve shock testing and how it is characterized. It is understood that the shock response spectrum that is commonly used to characterize shock events is a non-unique transformation, meaning many different inputs can produce similar SRS. This work presents a MATLAB model of a MDOF system. This model can be employed to understand the characteristics of an induced shock and the system's response to that shock. The goal of this model is to understand the SRS from a given input and work towards defining temporal parameters for shock characterization that are unique to an individual shock event.

SESSION 19: DEDICATED SESSION: THE CABLE: IT IS THE RODNEY DANGERFIELD OF THE INSTRUMENTATION SYSTEM (PART II)

CHARACTERIZING THE SENSOR CABLE PAIR AS A SIMPLE RC CIRCUIT

Mr. Alan Szary, Precision Filters

Characterizing the sensor cable pair as a simple RC circuit. This session will introduce the fundamental concept of the singe real pole RC filter. Various examples will superimpose the RC filter with the well-known 2 pole sensor resonance transfer function to gain a basic understanding of the effects of cable roll-off. The session will end soliciting the proper questions “What is the R?” and “What is the C?”.

WHAT IS THE R?

Mr. Alan Szary, Precision Filters
Mr. Thomas Gerber, Precision Filters

This session explores the resistive elements of the Wheatstone bridge and MEMS sensors and defines the effective resistance useful in the determination of cable roll-off. Secondly, the effect of cable series resistance is discussed and it’s additive effect on effective resistance.

WHAT IS THE C?

Mr. Alan Szary, Precision Filters

What is the C? This session will introduce the component level model of a cable identifying the important constituent elements of capacitance useful in the determination of cable roll-off. Conductor to shield capacitance and conductor to conductor capacitance will be discussed as well as the differences between paired cable and non-paired cable. Secondly the cable model will be used to define the total effective capacitance used in determining cable roll-off in the full bridge sensor. Methods of determining cable capacitance will be discussed including bench-top measurement techniques as well as how to interpret manufacturer’s specifications for cable capacitance.

Examples of Cable Roll-Off Calculations
Mr. Thomas Gerber, Precision Filters

Examples of cable roll-off calculations. The methods described in sessions 1-3 will be used to calculate cable roll-off for several scenarios using popular MEMS sensors and various 4 conductor cables.

Verifying Cable Roll- Off Redictions
Mr. Alan Szary, Precision Filters

Verifying cable roll-off predictions. This session will propose methods of using common instrumentation (signal generator and DVM) to make bench top measurements verifying predictions of cable roll-off. Also, a novel technique will be described utilizing sinusoidal current injection to assess installed cable roll-off in-situ from the convenience of the instrumentation room.

SESSION 20: DEDICATED SESSION: MECHANICAL SHOCK: COMPUTATIONAL & EXPERIMENTAL METHODS FOR FUZE TECHNOLOGY II

Instrumentation Methods for Distributed Embedded Fuzes Environment in Hard Target Attack
Dr. Alain Beliveau, Applied Research Associates
Ms. Alma Oliphant, Applied Research Associates
Dr. Jacob C. Dodson, Air Force Research Laboratory

With the growing interest in replacing/augmenting aft and nose hard mounted fuzes with Distributed Embedded Fuze System (DEFS) for hard target attack weapons, comes a need to understand (thru measurements and simulations) the embedded environment experienced by any DEFS. Knowledge and predictions of the environment is important for the design of the embedded system as well as for the development of smart algorithm for increase weapon performance. In this presentation, we will review the factors influencing the environment, the parameters typically used to define the environment, and approaches that have been used to measure this environment. Experimental results for full and sub-scale tests, along with some comparisons with simulation predictions will be reviewed.

On-board Recorder Testing for Embedded Fuzing
Mr. Dustin Landers, Applied Research Associates
Dr. Alain Beliveau, Applied Research Associates
Michael Davies, Air Force Research Laboratory

The Air Force Research Lab is conducting testing to evaluate the performance and functionality of the High Speed On-board Recorder (HS-OBR) developed by Advanced Electronics Lab, Inc. (AEL). Under a JFTP research effort focusing on embedded fuzing, AFRL has worked with AEL to develop a recorder that can be packaged within the booster cup of an inert embedded fuze to monitor functionality/electrical performance and give insight to the environment experienced during hard target penetration. This paper presents an overview of the HS-OBR, and the results of both laboratory and subscale cannon testing.

Test and Model Observed Target Media Mapping of Embedded Smart Fuzing

Mr. Alma Oliphant, Applied Research Associates
Mr. Bruce Brown, Applied Research Associates
Mr. Craig Doolittle, Applied Research Associates

The purpose of this paper is to highlight the need for the ground penetration community to design and execute tests that will cover a wide range of target media strengths and the need to develop and refine predictive analysis methods to support embedded smart fuzing solutions.

As part of ongoing legacy programs and emerging new programs, Applied Research Associates (ARA) has fielded embedded instrumentation within the explosive fill, in full-scale sled and sub-scale penetration tests. ARA has also conducted Modeling and Simulation (M&S) of test events. The primary and most important of lesson we have learned over the last several years has been the need to generate test data for, and develop modeling methods to address, the embedded system physics during penetration of natural or geological target media. In summary, we are finding the primary hurdle in smart fuzing is how the strength of the target media interacts with the physics of the embedded environment. Ultimately, certain combinations of these factors can generate confusing structural dynamic responses that can be challenging for smart fuzing.

In order to meet customer needs in the future, we recommend the community generate test data and build modeling techniques to capture events that bound the inherent variability in the environment. This includes all ranges of target media strengths, from very hard concretes to weathered geology and soft soils. We recommend the community balance penetration testing objectives with embedded smart fuzing test objectives.

Evaluation of the Dynamic Tensile Failure in Pressed Energetic Simulants

Dr. Adriane Moura, Applied Research Associates
Mr. Michael Davies, Air Force Research Laboratory
Dr. Alain Beliveau, Applied Research Associates Inc
Dr. Jacob Dodson - Air Force Research Laboratory

The goal of this work is to measure the relative tensile strength of inert pressed pellets with various binders and particle sizes to provide a composition to minimize spalling in LEEFI (Low Energy Explosive Foil Initiator) pellets. Previously, we developed a technique to measure the tensile strength of pressed pellets by adapting techniques commonly used for geomaterials and evaluated several compositions. 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 location of the spall and the tensile strain in the sample. In this work, we extended the previous work by expanding the testing capabilities to generate larger strains and investigating additional compositions. Finally we summarize the results for all the compositions tested and draw conclusions for the strongest pellet composition.

DELAYED COMPARISON ERROR MINIMIZATION

Mr. James Scheppegrell, Applied Research Associates
Dr. Adriane Moura, Applied Research Associates
Dr. Alain Beliveau, Applied Research Associates
Dr. Jacob Dodson, Air Force Research Laboratory

Presented is work on using a novel technique, Delayed Comparison Error Minimization, hosted on a standalone system on chip (SOC) to process accelerometer output in real-time to estimate the state of a system. Delayed Comparison Error Minimization allows for frequency-based state-detection with reduced latency when compared to the standard FFT-based approach. The system being monitored is the Air Force Research Lab's Dynamic Reproduction of Projectiles in Ballistic Environments for Advanced Research test bed (DROPBEAR), a cantilevered beam with a fixed end and a roller support that can vary its position along the beam's length. As the location of the roller varies along the beam, the changing response is measured with an accelerometer. Delayed Comparison Error Minimization is used to determine the primary frequency of the cantilevered beam's vibration, allowing rapid estimation of the roller location. Location estimates will be analyzed for accuracy by comparing them with direct measurements of roller location. The latency of the system will be measured as well, with an examination of how responsibility for latency is divided between the measurement and processing stages.

SESSION 21: SHOCK QUALIFICATION & UNDEX APPLICATIONS

DEVELOPMENT OF A COMPREHENSIVE IMPLOSION KNOWLEDGEBASE

Mr. Adam Hapij, Thornton Tomasetti
Dr. Abilash Nair, Thornton Tomasetti
Mr. Alex McVey, Thornton Tomasetti
Mr. Ben Medina, NSWC Carderock
Dr. Joe Ambrico, NUWC Newport
Dr. Emily Guzas, NUWC Newport

The US Navy community has seen an extensive amount of physical and numerical research in the area of hydrostatic and UNDEX-induced implosion in the last two decades. Various organizations have championed the research of different implosion phenomena, identifying trends in the response data and developing predictive technology for the benefit of the US Navy. In 2021, PMS406 funded tasking resulting in the development of an implosion database utility (IDU). This framework facilitates the critical review of large data sets for both computed implosion assessment data and experimental implosion data. By cataloging and parameterizing implosion datasets, with the associated underlying physical parameters, into a consistent digital knowledgebase, the IDU serves as a critical step in the development of machine learning models for comprehensive fast-running implosion assessments in the 21st century.

SESSION 21: MARINE MAMMAL STUDIES

INVESTIGATING IMPULSIVE DAMAGE TO THE MARINE MAMMAL MELON VIA DROP TESTS

Dr. Emily Guzas, NUWC Newport
Ms. Monica DeAngelis, NUWC Newport
Ms. Lauren Marshall, NUWC Newport
Mr. Thomas Fetherston, NUWC Newport

Current criteria to assess non-auditory physiological impacts of explosives on marine mammals rely on limited datasets derived from past experiments using small submerged terrestrial animals subjected to underwater explosive (UNDEX) loading. Unfortunately, these past experiments do not provide any insight into the UNDEX vulnerability of the marine mammal melon, which is a large fatty body (sited on the skull) presumed to be essential for echolocation use in a subset of marine mammals (Odontoceti, or toothed whales). This paper covers the experimental design and results from a series of drop weight impact experiments performed to investigate the response of marine mammal melon tissue to impulsive loading. The intent of this test series was to capture data on the energy absorbed and deformation experienced by marine mammal melon samples during an impact event that imparts similar impulse levels to those from previous UNDEX tests on marine mammal cadavers in which observed post-test melon damage (or lack thereof) was recorded (Ketten 2004, Rye 2019). We discuss a novel nondestructive screening method for identifying potential damage in the melon samples and present cross-plots of measured quantities with data points delineated by presumed damage status. Finally, we include select digital image correlation (DIC) results for the drop-tested samples, to be used as validation data in the future for finite element models of marine mammal melons.

VALIDATION OF A SURROGATE MODEL FOR MARINE MAMMAL LUNG DYNAMICS UNDER UNDERWATER EXPLOSIVE IMPULSE

Dr. Emily Guzas, NUWC Newport
Dr. Joseph Ambrico, NUWC Newport
Dr. Stephen Turner, NUWC Newport
Mr. Thomas N. Fetherston, NUWC Newport
Mr. Matthew Babina, NSMRL
Mr. Brandon Casper, NSMRL

Very little is known about marine mammal susceptibility to primary blast injury (PBI) except in rare cases of opportunistic studies. As a result, traditional techniques rely on analyses using small-scale terrestrial mammals as surrogates for large-scale marine mammals. For an In-house Laboratory Independent Research (ILIR) project sponsored by the Office of Naval Research (ONR), researchers at the Naval Undersea Warfare Center, Division Newport (NUWCDIVNPT), have undertaken a broad 3-year effort to integrate computational fluid-structure interaction techniques with marine mammal anatomical structure to numerically simulate the dynamic response of a marine mammal thoracic cavity and air-filled lungs to shock loading.

In the absence of appropriate test data from live marine mammals, a crucial part of this work involves code validation to test data for a suitable surrogate test problem. This research employs a surrogate of an air-filled spherical membrane structure subjected to shock loading as a first order approximation to understanding marine mammal lung response to UNDEX. This approximation incrementally improves upon the currently used 1-dimensional spherical air bubble approximation to marine mammal lung

response in that it provides an encapsulating boundary for the air, but with minimal complication of marine mammal species-specific and individual animal differences in tissue composition, rib mechanics, and mechanical properties of interior lung tissue.

NUWCDIVNPT partnered with the Naval Submarine Medical Research Lab (NSMRL) to design and execute a set of experiments to investigate the shock response of an air-filled rubber dodgeball in a shallow underwater environment. These tests took place in the 2.13 m (7-ft) pressure tank at the University of Rhode Island, with test measurements including pressure data and digital image correlation data captured with high-speed cameras in a stereo setup. The authors developed 3-dimensional computational models of the dodgeball experimental setups using Dynamic System Mechanics Advanced Simulation (DYSMAS), a Navy code that has been validated against UNDEX, implosion, and structural response data for a variety of different problems involving submerged pressure vessel structures containing air.

Proper validation of fluid structure interaction simulations is quite challenging, requiring measurements in both the fluid and structure domains. This paper details the development of metrics for comparison between test measurements and simulation results, with a discussion of potential sources of uncertainty.

VENDOR SESSION D: EXHIBITOR PRESENTATIONS INCLUDING CASE STUDIES, NEW DEVELOPMENTS, TESTING & PRODUCTS

MECHANICALLY & ELECTRICALLY FILTERED TRIAXIAL SENSORS FOR SHOCK APPLICATIONS
Mr. Kevin Westhora, Dytran

No abstract provided.

HOW DOES MASS RATIO EFFECT HEAVYWEIGHT SHOCK TESTING?
Mr. Calvin Milam, HI-TEST Laboratories

The short answer is significantly, but first an understanding of both the history and physics of mass ratio are necessary. 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.

INTEGRATED CONTROLLER AND ANALYZER ADVANCEMENTS FOR SHOCK TESTING
Mr. Chris Sensor, Data Physics

Laboratory Shock simulation on ED or Hydraulic shakers often requires the use of both a controller and data recorder. Data Physics 900 Series Hardware and Software enables the user to create and execute both shock and data recording on the same integrated platform using multiple, different sample rates, block size, filtering, and channel math all off the same input channel.

DIRECT FIELD TESTING THE ACCEPTED ALTERNATIVE ACOUSTIC TEST METHOD WITH MORE THAN 170 SUCCESSFUL SATELLITE TESTS TO DATE

Mr. Gary Marraccini, Spectral Dynamics

No abstract provided.

TRAINING V: INTRODUCTION TO UNDERWATER EXPLOSION PHENOMENA WITH BASIC APPLICATIONS TO STRUCTURES

INTRODUCTION TO UNDERWATER EXPLOSION PHENOMENA WITH BASIC APPLICATIONS TO STRUCTURES

Mr. Frederick Costanzo

This training session is divided into two major parts. The first segment consists of a brief primer in underwater explosion (UNDEX) fundamentals and shock physics. Included in this discussion are the features of explosive charge detonation, the formation and characterization of the associated shock wave, bulk cavitation effects, gas bubble formation and dynamics, surface effects and shock wave refraction characteristics. In addition, analyses of associated measured loading and dynamic response data, as well as descriptions of supporting numerical simulations of these events, are presented. The second segment involves basic applications of UNDEX-induced dynamic shock wave loadings to the estimation of both local and global responses of simple floating and submerged structures. Three primary well-documented methodologies are presented, including the Taylor Flat Plate analogy for estimating the responses of both air-backed and water-backed plates, the Peak Translational Velocity method for estimating the response of submerged cylindrical bodies, and the application of the conservation of momentum principle for estimating the vertical kickoff velocity of floating structures (Spar Buoy approach). Derivations of the governing equations associated with each of these solution strategies are briefly presented, along with a description of the appropriate ranges of applicability. Applications of each of these methodologies will be illustrated using simple examples.

SESSION 22: VIBRATION: SPECTRAL DENSTITES

QUANTIFICATION OF CONSERVATISM IN THE MAXI-MAX POWER SPECTRAL DENSITY FUNCTION

Dr. Carl Sisemore, Sandia National Laboratories
Ms. Melissa C de Baca, Sandia National Laboratories

The maxi-max Power Spectral Density function is frequently used to evaluate non-stationary vibration environments. The resulting PSD are often subsequently used as test specifications, either separably or enveloped with other vibration PSD environments. It is also known that the maxi-max PSD is generally conservative and overpredicts the vibration environment. This paper investigates the range of conservatism inherent in the maxi-max PSD formulation for both stationary and non-stationary vibration environments and its subsequent impact on environmental testing. The paper also presents a recommendation for correcting maxi-max PSD estimates based on event duration and character to better represent the underlying environment.

SPECTRAL DENSITIES: STATISTICS AND PROBABILITY IN THE FREQUENCY DOMAIN

Mr. Neil Loychik, Los Alamos National Laboratory

Statistical behavior is often characterized by a probability density (e.g. a bell shaped curve). Simplified descriptors of the probability density are: variance being the relative width, skewness being the asymmetry of the distribution, and kurtosis being the extremes at the tails of the distribution. Of these, variance is the only statistical parameter to have a frequency-domain decomposition through the power spectral density (PSD). This presentation derives spectral densities of higher-order statistics (skewness, kurtosis, probability density), applies the transform to cases of interest, and investigates the uncertainty of estimate.

This presentation first discusses the proposed higher-order spectral densities in the context of existing tools like the PSD, response spectrum, and the wavelet in order to orient the audience. Next, we derive the analytical expressions for a spectral density that can compute variance in addition to higher-order statistics with emphasis on the skewness spectral density (SSD), kurtosis spectral density (KSD), and the probability density spectral density (PDSD). The new transform aims to behave similarly to the PSD by being 1) Physical and statistical, 2) Convergent, 3) Integrable and obey a Parseval-like relationship, and 4) be differentiable. By retaining these behaviors, it is expected that the transforms can support Newtonian mechanics problems for sound, vibration, turbulence, etc.

Second, this presentation demonstrates the capabilities of the higher-order spectral densities (SSD, KSD, and PDSD) through a series of case studies analyzing simulation and experimental data. The cases are examples of foundational problems in sound and vibration that can be enhanced through higher-order spectral densities: 1) mass-spring-damper transmissibility, 2) fluid turbulence energy cascade, 3) sound recognition (timbre), 4) machine health monitoring.

Last, this presentation derives a means to bound error to asses transform accuracy and repeatability. A functional form to error bounds is proposed that accommodates both the bias and random error inherent to the signal. The functional form is tested through a convergence study that estimates the dispersion of an estimate though repeated simulation spectral densities.

SPECTRAL DENSITIES: STATISTICS AND PROBABILITY IN THE FREQUENCY DOMAIN (PART 2)

Mr. Neil Loychik, Los Alamos National Laboratory

Statistical behavior is often characterized by a probability density (e.g. a bell shaped curve). Simplified descriptors of the probability density are: variance being the relative width, skewness being the asymmetry of the distribution, and kurtosis being the extremes at the tails of the distribution. Of these, variance is the only statistical parameter to have a frequency-domain decomposition through the power spectral density (PSD). This presentation derives spectral densities of higher-order statistics (skewness, kurtosis, probability density), applies the transform to cases of interest, and investigates the uncertainty of estimate.

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SESSION 23: ISOLATION AND DAMPING II

Design and Testing of a Calibration Device for Precision Static and Dynamic Testing at Elevated Loads

Mr. Robert Sharp, Hutchinson Aerospace and Industry
Mr. Kieran Cochrane, Hutchinson Aerospace and Industry

Reduced dynamic to static springrate ratio is critical in high load carrying isolators for consistent dynamic performance over multiple inputs and reduced static offset and drift. This requirement is common to shipboard, heavy equipment, and seismic structural applications. Increasing demands for tighter control of those dynamic and static springrates of larger mounts across various load states has revealed a need for more precise test calibration methods. An adjustable device of known static and dynamic springrates with minimal influence by hysteresis or other energy loss was needed. Hutchinson has developed a large array of precision springs with an associated support and restraint structure. A program of inspection, repeated testing at various loads, grading, and statistical analysis was implemented to fully document the calibration device, and a set of instructions was developed for applying the device to various load cases.

Applying Wire Rope Isolators for Protection of 5G Cellular Towers Against Wind Induced Vibration

Mr. Joshua Partyka, Vibro/Dynamics LLC

Tuned mass dampers (TMD), or dynamic absorbers, have been used in many types of applications, such as ships, bridges, and chimneys. As technology is an ever-growing component of our lives, communications companies are looking to implement efficiently designed towers that can last for decades, leading to the development of a new vibration isolation application: to protect 5G cellular against vibration due to vortex shedding.

Vortex shedding occurs when air flows around objects, most commonly circular in profile, which creates a periodic vibration transverse to the air flow due to alternating vortices that form just past the object. For any object, there is a wind velocity that can lead to very high vibration amplitudes and damage to the tower. In the case of the 5G towers, the damage would most likely occur at the point of highest stress due to this vibration: the anchorage of the tower to its concrete foundation.

An effectively designed and implemented TMD will significantly lower the magnitude of vibrations induced by vortex-shedding, increasing resistance to wind damage, allowing the designer more options in their tower design. A final TMD design involves a controlled iterative process that considers mass, stiffness, and damping of the TMD, which requires complete knowledge of all components of the TMD. With WRI, this necessitates full definition of stiffness and damping in all axes, as well as the means to incorporate this data into the analysis process.

This article will briefly summarize the basic theory of TMDs, discuss common approaches, and then go into detail to discuss the approach to designing a TMD solution for 5G cellular towers that utilizes wire rope isolators (WRI). At least one case model will be presented, showing the combination of multiple analysis tools in the analysis process, including the Socitec Group's numerical analysis software, SYMOS.

HIGH PERFORMANCE SILICONES FOR IMU ISOLATION - BACKGROUND, MATERIALS, AND LESSONS LEARNED
Mr. Robert Sharp, Hutchinson Aerospace and Industry
Mr. Kevin Underwood, Hutchinson Aerospace and Industry

Increasingly sophisticated Inertial Measurement Units (IMUs) require more robust, more precise isolation systems. Furthermore, changes in performance due to the environmental, vibration, or shock input are becoming increasingly undesirable. Traditionally the material for these isolation systems has been high performance silicone elastomer, but even this material has seen pressure for improvement as the IMU systems evolve and environments become more severe. Hutchinson has long been a leader in silicone compounding, molding and testing, and has several proprietary compound families targeted for specific applications or environments. Recently several new formulations have been explored for improved performance in specific applications. In this paper we present some fundamental elastomeric properties, and illustrate those properties through isolator testing. We then discuss historical compounding and recent experimental work as well as lessons learned during isolator development.

ADVANCES IN ELASTOMERIC TECHNOLOGIES AND THEIR APPLICATION IN EXTREME ENVIRONMENTS
Mr. Shawn Czerniak, Hutchinson
Mr. Kevin Underwood, Hutchinson
Mr. Adam Meyer, Hutchinson

Today, we continue to see Aerospace & Defense customers pushing the limits on operating environments for elastomeric isolators. Among these increasingly common environments is low temperature (high altitude, space & cold weather defense), high temperature (exhaust systems and propulsion systems), and caustic atmospheres (high performance jet fuel). Each of these scenarios requires a precision approach to ensure the product will perform as needed in the intended environment. A case study will be included to review how a traditional isolator has performed in a jet fuel atmosphere, and a comparison with the current solution Hutchinson is using to meet the application requirements.

SIMPLIFYING VEHICLE ROAD LOAD COLLECTION TO DRIVE FINITE ELEMENT STRUCTURAL MODELS
Mr. Edward Wettlaufer, Altair Engineering

One of the most challenging aspects of structural modeling ground vehicles is obtaining loads to drive the model. Historically, data would be measured with expensive, custom made force transducers or strain gauges, whose measurements would be used in a process to predict the forces required to generate the measured response. An analytical alternative is modeling with multi-body dynamics to generate forces on the structure, but the accuracy of the analysis is heavily dependent upon road profiles and tire models.

Additionally, applying lengthy time history excitation to dynamic models representing entire vehicles can lead to very long solution times. This paper is intended to quantify the accuracy of a proposed method to measure a specimen's dynamic response to forced displacements and directly apply them to a finite element model, using Modal Transient Response Analysis.

A simplified proof of concept was executed in a laboratory environment on an appropriate specimen. The method is intended to qualify the process of collecting accelerometer data from a vehicle as it is driven over road surfaces; apply the accelerations to a Finite Element model, using Transient Modal Analysis; and recover stress and strain from the solution.

The method intends to exploit the accuracy and ease of use of accelerometers; the reality of discreet and continuous events typical of a physical Proving Ground; the reduced CPU times of the Transient Modal Analysis solution.

SESSION 24: TEST METHODS

IMPROVEMENTS IN DIRECT FIELD ACOUSTIC NOISE TESTING (DFAN)

Mr. Chris Sensor, Data Physics

Chris Sensor received his BE in Mechanical Engineering from Stevens Institute of Technology located in Hoboken NJ. Chris has been working in vibration test, modal analysis, and data acquisition field since 2011. He joined Data Physics Corporation in 2017 as an account manager for eastern North America. In addition to his sales role, Chris provides training, application support, and practical testing advice to his customers.

NONLINEAR ELASTIC METAMATERIALS AS PULSE SHAPING DEVICES FOR SHOCK TEST APPLICATIONS

Dr. Samuel Wallen, The University of Texas at Austin
Prof. Michael Haberman, Applied Research Laboratories & The Univ. of Texas at Austin
Dr. Washington DeLima, Honeywell

Metamaterials (MM) have become a very active topic for research in numerous domains of engineering and science because of their promise to create materials, structures, and devices that can control wave propagation in ways that exceed the capabilities of conventional homogeneous and composite materials. Most research on acoustic and elastic MM has been focused on linear behavior. However, linear MM suffer from a few notable drawbacks, for example, i) the novel effective material properties for the application of interest are often limited to narrow frequency bands that cannot be changed by external stimuli, and ii) they have very limited usefulness in applications where nonlinearity is unavoidable or essential, e.g., shock testing or high-intensity focused ultrasound. Nonlinearity has therefore been explored as a means to expand the palette of accessible dynamic response of synthetic materials to external stimuli. Examples of desirable behavior include increased bandwidth of specific performance criteria by creating tunable band gaps via material configurability, enhanced harmonic generation, and improved control over the magnitude and shape of propagating elastic waves. In this work, we investigate applications for nonlinear elastic MM as pulse shaping materials for shock testing. By using high-resolution finite element methods in concert with direct numerical simulations of reduced-order dynamic models, we examine the propagation of elastic pulses under the influence of various types of nonlinear elastic response (e.g., strain-hardening, strain-softening, and buckling) and identify means to obtain them. These simulations demonstrate the potential for nonlinear elastic MM to significantly expand the space of accessible excitations for shock testing, using a relatively small number of design parameters.

SESSION 24: INSTRUMENTATION

MORE REPEATABLE TESTING OF HERMETICALLY SEALED ELECTRONIC COMPONENTS BY COMPUTERIZING THE PARTICLE IMPACT NOISE DETECTION (PIND) TEST

Mr. Stewart Slykhous, Spectral Dynamics

Particle Impact Noise Detection (P.I.N.D.) is a dynamic test method combining shock, vibration, and acoustics accepted world-wide to greatly increase the reliability of hermetically sealed electronic components by detecting dangerous contaminants within the cavity. Tens of millions of parts have been tested over the past fifty years by this test method specified in MIL-STDs 833, 750, 202, and 39016D. Recent advancements in computer technology have given the users much improved accuracy in the motion creation as well as the details of the acoustic detection. These advances also allow more advanced motion environments allowing tighter links between these three disparate technologies. This paper will describe results of actual testing from these advancements and their effects in helping the test systems to better be much more accurate and repeatable to handle the challenge presented by larger today's' larger hybrids circuits and the multiple sources of FOD.

COMPARISONS OF THE STRUCTURAL RESPONSE OF A TEST ARTICLE EXCITED BY DFAT DIFFUSE AND NON-DIFFUSE ACOUSTIC FIELDS

Dr. Marcos A. Underwood, Tu'tuli Enterprises & MSI Chief Scientist

This paper discusses the results from Direct Field Acoustic Tests (DFAT) performed at MSI to evaluate how effectively nearly diffuse (low coherence) and non-diffuse (high coherence) acoustic fields, using MIMO and MISO control, excite the structural resonances of a test article. The criteria used is to compare the frequency of the resonances excited by the resulting acoustic fields to what Modal Analysis predicts the modes of vibration, their natural frequencies, and damping to be. Test results from using the various DFAT produced acoustic fields to excite the test article, in the form of PSDs obtained from accelerometers mounted on it, will be presented that show the relative ability of various type of acoustic fields to properly excite test articles by seeing how well the resonances shown by the PSDs match those predicted by the damped resonant frequencies predicted by Modal Analysis.

SESSION 25: BALLISTICS: MODELING & SIMULATION

EVALUATION OF MODELING AND SIMULATION TO PREDICT IMPACT SIGNATURES IN SMALL ARMS BALLISTIC EVENTS

Mr. David Lichlyter, US Army ERDC
Dr. T. Neil Williams, US Army ERDC
Dr. Z. Kyle Crosby, US Army ERDC
Dr. John Q. Ehrgott Jr., US Army ERDC

The identification of small arms munitions based on their post-impact signatures is an important step in the application of effective protective measures and threat analysis. The Forensic Encyclopedia Program, funded by the National Ground Intelligence Center, was initiated to fulfill this need through well-characterized experimental testing and data analysis for a variety of munitions from different sources. The limitations of experiments, cost, test conditions, and munition availability creates a significant challenge for this program and can result in a reduced confidence level for intelligence analysis. The objective of this research effort was to investigate the capability to utilize validated modeling and simulations (M&S) tools and techniques to predict accurate post-impact signatures in order to supplement and expand current experimental data. This initial phase of research focused on small arms impacting common protective armor materials.. The experimental results required to validate this M&S, which covered light ball and armor piercing ammunitions and incendiary rounds, increased confidence in the simulations' application to various small arms. The post-signature review of the simulations mirrored that of the experiments with cross-comparisons conducted for each condition, standoff and impact angle, considered. The post-impact comparisons between M&S and experiments considered feature measurements and damage characteristic commonly collected and used for forensic analysis Overall, the M&S showed significant fidelity when compared to the experimental results.

TERMINAL BALLISTICS MODELS FOR A36 STEEL PLATES AGAINST SMALL ARMS AND FRAGMENTS

Mr. Daniel Rios-Estremera, US Army ERDC
Mr. David Roman-Castro, US Army ERDC
Dr. Jesse Sherburn, US Army ERDC

Structural steels, such as A36, are widely available and used in construction and can serve as a low-cost armor option in expeditionary passive protection applications. Understanding and modeling terminal ballistic effects in A36 provides the capability to determine protection levels against diverse small arms and fragmentation threats. For this research, ballistic limit and residual velocity data from the U.S. Army Engineer Research and Development Center (ERDC) Fragment Simulating Facility was used. The data includes small arms projectiles (5.56-mm to 14.5-mm) and fragment simulating projectiles (7.62-mm to 20-mm) impacting various thicknesses of A36 plates. Empirical models were developed using similitude methods. This study presents the resulting models and findings.

VALIDATION OF HIGH-SPEED IMPACT MODELS FOR SMALL ARMS AGAINST ULTRA-HIGH PERFORMANCE CONCRETE USING EPIC

Mr. Jean Santiago Padilla, US Army ERDC
Dr. Jesse Sherburn, US Army ERDC
Mr. David Roman Castro, US Army ERDC
Mr. Daniel Rios Estremera, US Army ERDC

Accurate penetration models provide a cost-effective approach to the design of protective structures against ballistic threats. The Lagrangian explicit dynamics code, Elastic-Plastic Impact Computation (EPIC), is used to simulate several armor-piercing rounds against both thin and semi-infinite ultra-high performance concrete (UHPC) targets. The model development is presented, and the Advanced Fundamental Concrete (AFC) material model is introduced to define the constitutive equations that govern the dynamic response of the UHPC targets. Models are compared against experimental results, which include residual velocity and depth of penetration data. The study also evaluates the modeling capabilities of the fast-running code, PENCURV, in an effort to validate its use for small caliber armor-piercing weapons.

SESSION 25: BALLISTICS: RAPID SYSTEM

RAPID SYSTEM - A PASSIVE FORCE PROTECTION FOR THE URBAN ENVIROMENT

Mr. Erik Chappell, US Army ERDC
Mr. Omar Esquilin-Mangual , US Army ERDC

No abstract provided.

DEMONSTRATION OF THE READY ARMOR PROTECTION FOR INSTANT DEPLOYMENT SYSTEM

Mr. Omar Esquilin-Mangual, US Army ERDC
Mr. Erik M. Chappell, US Army ERDC

The development of scalable and rapidly deployable expedient passive protective barriers to defeat various threats remains a challenge. Soil-filled or concrete barriers are commonly used, but they require coordination of large construction equipment, large volume of materials, and personnel. For example, 30 feet long by 48 inches tall soil-filled barrier could be placed in approximately one man-hour but only if a front end loader is available for construction. The soil-filled barriers also require fill materials that may not be available in every environment (such as an urban environment). Urban operations will require a rapidly deployable solution that can be tailored for different threats and can be moved and reconfigured quickly and easily. To address these constraints, the U.S. Army Engineer Research and Development Center (ERDC) developed the Ready Armor Protection for Instant Deployment (RAPID) system. RAPID can be deployed in approximately one man-hour and requires no heavy construction equipment for deployment. The system is easy to recover and reuse with minimal logistical burden since the container is hardened and integrated into the line of defense. The system provides line-of-sight denial, mitigates hostile vehicle ramming attacks, and protects against ballistic and fragmentation threats. A summary of RAPID demonstration events will be presented. These demonstration events highlight RAPID's ability to be easily deployed, recovered, and moved, as well as how the protection level of RAPID can be tailored for different threats.

SESSION 26: INSTRUMENTATION

AUTOMATED VIDEO PROCESSING FOR FRAGMENTING WARHEAD ASSESSMENT: A FAST-FRAG FOCUS

Dr. Eddie O'Hare, Protection Engineering Consultants
Mr. Matt Barsotti, Protection Engineering Consultants
Dr. David Stevens, Protection Engineering Consultants
Mr. Scott Mullin, Southwest Research Institute
Mr. James Mathis, Southwest Research Institute

A novel wedge witness panel device has been developed for assessment of fragmenting warheads. The wedge device is a low risk improvement to traditional arena test data collection that can be used as a replacement for flash panels and in conjunction with Celotex bundles. Two witness panels are oriented at an angle, similar to the covers of a partially opened book. Fragments perforate the entry panel, transit across the space between panels, and then exit by perforating the second panel before embedding into an optional soft catch bundle. A video camera points into the mouth of the wedge. The field of view is set such that both interior witness panel faces are in frame. The resulting video footage provides sufficient data to describe a complete trajectory for each fragment, including velocity, lateral flight angle in the plane of the video, and out-of-plane flight angle orthogonal to the image. Owing to the number of fragments involved in each test, manual processing of the video is time consuming and subjective. Therefore, an alternative approach was required.

Protection Engineering Consultants (PEC) has developed an automated computer-vision algorithm, PyTrack, to improve data analysis speed and efficiency and ensure objective repeatable measurements. PyTrack was developed in a Python environment because it is simple, intuitive, and contains extensive open-source libraries.

The approaches for fragment tracking, and witness panel measurements are described in this paper. The fragment tracking process uses detected observations of fragments in each frame to calculate trajectories, velocities, and fragment properties, such as area and aspect ratio. Extrapolated trajectories provide a method to estimate back-projection and identify the probable fragment source location and outlier trajectories. The witness panel measurement algorithms transform the observed fragment locations from the video space to a flattened panel space, allowing estimation of the entry and exit perforation locations on the panels.

Initial wedge device tests included rigid witness panels idealized for tracking fast moving fragments ahead of the shock wave. However, once the shock reaches the device, rigid panels dislodge from their supporting frame. Recovery and post-test photographs of the rigid witness panels are utilized in the automated process to detect fragment perforations and correlate them to the video observations, thereby increasing the solution accuracy.

Overall, PyTrack provides a method to calculate out-of-plane trajectory information for each fragment while using only one camera per wedge device. Methods are currently being extended to correlate multiple wedge devices within a single arena test and to calculate uncertainty of the PyTrack results.

TESTING OF METALS AT HIGH STRAIN RATES WITH PULSED LASERS: A SIGNAL PROCESSING FOCUS

Dr. Eddie O'Hare, Protection Engineering Consultants
Mr. Matt Barsotti, Protection Engineering Consultants
Dr. David Stevens, Protection Engineering Consultants;
Dr. Sydney Chocron, Southwest Research Institute
Mr. Thomas Moore, Southwest Research Institute

Explosions and high-velocity impacts can create strain rates on the order of 10^5 to 10^7 s^-1 or higher in metallic materials. To simulate these events, first-principles codes require material models that are valid at these loading rates to predict fracture and fragmentation. The amount of test data, material models and material constants for strain rates larger than 10^5 s^-1 are extremely limited and very expensive to obtain, so an innovative and cost-effective laboratory test procedure is needed.
Protection Engineering Consultants (PEC) and Southwest Research Institute® (SwRI) have teamed to address this need through development of a novel high-rate cost-effective laboratory test device. The new approach utilizes high-energy nanosecond pulsed lasers to launch miniature flyer foils to generate strong and short duration shock waves within solid target materials. Material properties are assessed utilizing a frequency-shifted photon Doppler velocimetry (PDV) system. The intended material properties to measure include the Hugoniot Elastic Limit (HEL), Equation of State (shock velocity vs. particle velocity curve), and spall-failure stress.

This paper will briefly discuss the experimental technique and test program, in which more than 500 flyer impact tests were conducted. Target materials included aluminum, stainless steel, and nickel-based alloys. The major focus of the paper, however, is a detailed discussion of the various signal processing techniques employed to extract the material properties. The small-scale nature of the testing presented several challenges in producing clear and consistent data. The large volume of test data required the development of an efficient semi-automated batch framework. Several signal processing techniques were developed within this framework utilizing a Python environment to convert oscilloscope measurements into velocity time histories: (1) Short-Time Fourier Transform (STFT), (2) Hilbert transform, and (3) Short-Time Auto Regression (STAR).

Development of these techniques resulted in a suite of tools for processing batches of test data. The STAR method was able to distinguish multiple signal features more clearly than STFT or Hilbert. Overall, the explored signal processing techniques provided an efficient and accurate solution for extracting desired material properties from pulsed laser test data.

AN OVERVIEW OF PIEZORESISTIVE PRESSURE TRANSDUCER USE FOR AIRBLAST MEASUREMENT APPLICATIONS

Mr. Daniel Coats, US Army ERDC
Mr. Denis Rickman, US Army ERDC
Mr. Joshua Payne, US Army ERDC
Mr. John Hoemann, US Army ERDC
Mr. Kyle Moss, SvEB

The US Army Engineer Research & Development Center (ERDC) typically employs piezoresistive pressure transducers to measure various airblast parameters. When properly fielded, these transducers provide excellent, repeatable airblast measurements over a wide range of pressures, including the negative pressure phase. Critical aspects of airblast pressure measurement include the selection of the proper transducer, use of the optimal mounting fixture, and proper location and orientation of the transducer. Pressure transducer calibration is also key to ensure that accurate data are measured. The purpose of this paper is to provide an overview of how piezoresistive pressure transducers are used for the measurement of airblast pressures at ERDC, and what improvements are underway regarding their application.

SESSION 26: DEBRIS AND DAMAGE MODELING

CUMULATIVE DAMAGE ASSESSMENT MODEL FOR CONCRETE WALLS IN MULTI-LOAD SCENARIOS

Dr. George Lloyd, ACTA
Mr. Ryan Schnalzer, ARCTOS
Mr. Joe Magallanes, Karagozian & Case
Mr. Shengrui Lan, Karagozian & Case

The cumulative damage assessment model has been developed to predict the onset of spall, breach, and other response measures in the case of multiple loading events. In previous work we described a generalized methodology for predicting spall and breach (so-called damage state outcomes) of reinforced concrete walls under such multiple loading event scenarios. The methodology is based on a number of carefully validated high-fidelity physics-based calculations for which material damage as well as damage state outcome become the basis for rationally generalizing existing single-loading surrogate models to the loading effects caused by an arbitrary set of loading events. In essence, material damage metrics are adopted as the natural quantity for capturing and quantifying the phenomenology of damage accumulation from one strike to the next, and a Markov Chain formalism is used as the natural approach for modeling the accumulation of this damage in a general way. Well-defined correlations between material damage and structural displacement are shown to result from this approach; they provide a means for validation.

The focus of the current work which is described herein has been to expand the training set sufficiently to cover the full range of loading scenarios, expand the calculation set for training to a greater variety of walls (scaled and unscaled), and importantly to quantify uncertainty. The cumulative damage methodology is also shown to extend to other response measures such as secondary debris velocity.

SECONDARY DEBRIS EFFECTS ON BUILDING INFRASTRUCTURE DERIVED FROM EXPERIMENTS

Dr. George Lloyd, ACTA
Mr. Jake Allyn, ACTA
Dr. Tom Paez, ACTA

Secondary debris (such as that propagated during progressive collapse) is often the dominant cause of functional impairment or more serious damage to building infrastructure outside the charge room. This phenomenon, demonstrated conclusively by recent experiments, results because in this weapon effects regime airblast effects attenuate rapidly as does the density of primary fragments, while the net impulse imparted by secondary debris can increase in conjunction with the concomitant increase in the density of secondary debris impacts which occurs.

In this paper we examine in detail the experimental data that has been captured during several blast experiments in which the failing surfaces were CMU and brick wall construction. These collected data include that from pressure gages in and outside the charge room to measure airblast loads, high-speed video that tracks the wall break up and debris cloud evolution, motion data obtained from equipment items instrumented with accelerometers, and post-test 3D surveys of terminal secondary debris location and overall equipment damage. The dynamic data are analyzed to decouple the secondary debris effects from airblast-induced effects so that innate fragility of equipment to debris can be deduced. The data are also analyzed to deduce realistic load models that can be applied to arbitrary debris receptors.

These load models are then applied to multi-degree of freedom equipment models such as panel boards, electrical transformers and HVAC systems. These equipment models are able to simulate the responses from multiple secondary debris impacts as well as airblast. The models have sufficient fidelity to provide multipoint estimates of the accelerations, velocities, and displacement from distributed discrete debris impacts. Post-test comparisons are made for equipment that was instrumented in the tests.

TRAINING VI: INTRODUCTION TO MEDIUM WEIGHT SHOCK TESTING

INTRODUCTION TO MEDIUM WEIGHT SHOCK TESTING

Mr. 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.