90th Shock and Vibration Symposium

Atlanta | November 3-7, 2019

SAVE
SHOCK & VIBRATION EXCHANGE

HI-TEST
Laboratories, Inc.

Introduction

Welcome to Atlanta and the 90th 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. The following section features our corporate supporters:

EVENT HOST

SILVER LEVEL CORPORATE SUPPORTERS

BRONZE LEVEL CORPORATE SUPPORTERS

90th Shock and Vibration Symposium Committee*

Dr. Jeff Averett (USACE ERDC)
Mr. James Breault (Lansmont)
Mr. Sloan Burns (NSWC Dahlgren)
Mr. Justin Caruana (Cardinal Engineering)
Dr. Jeffrey Cipolla (Thornton Tomasetti)
Mr. Matthew Davis (HII—NNS)
Dr. Jacob Dodson (Air Force Research Laboratory)
Mr. Adam Goldberg (NSWC Indian Head)
Ms. Becky Grisso (NSWC Carderock)**
Mr. Alan Klembczyk (Taylor Devices)
Mr. Russ Kupferer (OSD/DOT&E)
Mr. Brian Lang (NSWC Carderock)**
Mr. Ken Lussky (BAE Systems)
Dr. Luke Martin (NSWC Dahlgren)
Dr. Ken Nahshon (NSWC Carderock)**
Mr. Drew Perkins (SAVE/HI-TEST)
Mr. John Pott (Sandia National Labs)
Mr. John Pryzbsyz (IDA)
Mr. Jeff Rybak (PCB Piezotronics)
Ms. Ashley Shumaker (SAVE/HI-TEST)
Mr. Ernie Staubs (Air Force Research Laboratory)
Mr. Jon Stergiou (NSWC Carderock)**

**TAG members in attendance at summer meeting for 90th S&V program review (held at NSWC Carderock)*

***NSWC Carderock hosts*

Table of Contents / Daily Outline / Hours for Exhibit Hall, Registration, & Internet Cafe

INTERNET CAFÉ	
Meeting Room: #217	
Sunday, Nov 3	9AM—8PM
Monday, Nov 4	9AM—8PM
Tuesday, Nov 5	7AM—8PM
Wednesday, Nov 6	7AM—8PM
Thursday, Nov 7	7AM—Noon

EXHIBIT HALL (Salon Ballroom) (Exhibitors Listed on Pages (32-40))		
Monday, Nov 4	*Setup*	*Noon—6:00PM*
	Reception	6:30PM—8:30PM
Tuesday, Nov 5	Exhibit Hall Open	7:00AM—5:00PM
	Exhibitors' Luncheon & Speaker	11:00AM—1:00PM
	Session Break—PM	3:00PM—3:40PM
Wednesday, Nov 6	Exhibit Hall Open	9:00AM—4:00PM
	Session Break—AM	10:00AM—10:25AM
	Awards Luncheon	Noon—1:30PM
	Raffle / Break	3:30PM—4:15PM
	Dismantle	*4:15PM—6:00PM*

REGISTRATION	
Meeting Room: #218	
Sunday, Nov 3	8AM—5PM
Monday, Nov 4	7AM—6PM
Tuesday, Nov 5	7AM—6PM
Wednesday, Nov 6	7AM—6PM
Thursday, Nov 7	7AM—NOON

Glossary of Terms & Abbreviations

Distribution Statements (all technical sessions have a distribution statement designation):

* Unlimited Distribution A - Approved for public release: distribution unlimited.
* Limited Distribution C - Distribution authorized to U.S. Government Agencies and their contractors ONLY—U.S. Citizens Only.
* Limited Distribution D - Distribution authorized to Department of Defense and U.S. DoD contractors ONLY—U.S. Citizens Only.
* NATO Citizens Only - Audience Limited to Citizens of: ALBANIA, BELGIUM, BULGARIA, CANADA, CROATIA, CZECH REPUBLIC, DENMARK, ESTONIA, FRANCE, GERMANY, GREECE, HUNGARY, ICELAND, ITALY, LATVIA, LITHUANIA, LUXEMBOURG, MONTENEGRO, NETHERLANDS, NORWAY, POLAND, PORTUGAL, ROMANIA, SLOVAKIA, SLOVENIA, SPAIN, TURKEY, THE UNITED KINGDOM, & THE UNITED STATES.

(p. #)	Corresponding page number for abstract (located in abstract book at back of program).
SH:	Short presentation (10 minutes total).
Training:	45-minute to 2-hour training and/or educational session on a specific subject. No additional fee to attend.

All Symposium Attendees Welcome at All F&B Events Listed Here
Guests Welcome at Monday Welcome Reception & Wednesday Evening Social

**Please note that all meals are paid for using revenue from Exhibitor & Corporate Supporter fees. No cost for meals are included in individual attendance fees.*

Monday, November 4

• Reception (w/ Beverages & Heavy Hors d'oeuvres)	6:30pm—8:30pm	Salon Ballroom (Exhibit Hall)

Tuesday, November 5

• Continental Breakfast	7:00am—8:30am	Salon Ballroom (Exhibit Hall)
• Exhibitors' Luncheon	11:00am—1:00pm	Salon Ballroom (Exhibit Hall)
• Ice Cream Social	3:00pm—3:40pm	Salon Ballroom (Exhibit Hall)

Wednesday, November 6

• Continental Breakfast	7:00am—8:30am	Salon Ballroom (Exhibit Hall)
• Awards Luncheon	Noon—1:30pm	Salon Ballroom (Exhibit Hall)
• Symposium Social/Dinner	7:00pm—10:00pm	Hard Rock Café

Thursday, November 7

• Continental Breakfast	7:00am—8:30am	Salon Ballroom (Exhibit Hall)

Welcome Reception

Monday, Nov. 4 • 6:30pm—8:30pm • Salon Ballroom (Exhibit Hall)

Beverages and Heavy Hors d'oeuvres

General Session 1: Elias Klein Keynote Lecture & Exhibitors' Luncheon

Tuesday, Nov. 5 • 11:00am—1:00pm • Salon Ballroom (Exhibit Hall)

Sponsored by: 90th Shock & Vibration Symposium Exhibitors

General Session 2: Awards Presentations & Awards Luncheon

Wednesday, Nov. 6 • Noon—1:30pm • Salon Ballroom (Exhibit Hall)

Symposium Social/Dinner at Hard Rock Café

Wednesday, Nov. 6 • 7:00pm—10:00pm

Hosted by: National Technical Systems, PCB Piezotronics, & HI-TEST Laboratories

SPECIAL TUTORIAL OFFERING / 10:00am-4:00pm

~ Optional 5-hour course w/ 1-hour lunch break. Attendees receive certificate and may receive CEUs/PDHs (varies by state). Additional fees apply to attend.~

MIL-DTL-901E Shock Qualification Testing **Meeting Room: #221**
Mr. Jeff Morris, Mr. Travis Kerr, & Mr. Braden O'Meara (HI-TEST Laboratories)

This training will cover the necessary background information and definitions relative to shock qualification per MIL-DTL-901E and is intended for engineers and product developers who are unfamiliar with the U.S. Navy's shock qualification process by test. Shock test requirements for all four test categories (lightweight, medium weight, heavyweight, and medium weight deck simulating) will be discussed to include the limitations of each method. Subjects covered include pre-test planning, procedure preparation, fixture selection and design, test set-up, test operations, instrumentation interpretation, and reporting. Some aspects of shock machine (LWSM, MWSM, and DSSM) and floating shock platform (FSP, IFSP, and LFSP) construction and operation will be covered so that the end user is familiar with how the machine or platform is utilized to meet the shock test requirements. Although specific guidelines are not included in MIL-DTL-901E, a brief summary of alternate test vehicles/machines will be introduced since the phrase appears more than 20 times in the detailed specification and may be approved as an appropriate qualification method when the limitations of the primary test methods are exhausted. In addition to this tutorial, separate training sessions for each test method will be held at various time during the conference for those that are interested in just a specific area.

Please note that current U.S. Navy shock policy will not be discussed in this session. The appropriate technical authority should be contacted with respect to questions concerning the interpretation of U.S. Navy shock policy.

NO ADDITIONAL SUNDAY TUTORIALS

TUTORIAL SESSION 1 / 8:00am-11:00am

~ Optional 3-hour courses. Attendees receive certificate and may receive CEUs/PDHs (varies by state). Additional fees apply to attend. ~

Introduction to Pyroshock Testing **Meeting Room: #222**

Dr. Vesta Bateman (Mechanical Shock Consulting)

This course discusses the concepts of Near Field, Mid Field Pyroshock and Far Field Pyroshock and their criteria. Instrumentation used for measurement of pyroshock and structural response to pyroshock is described. The development of pyroshock specifications using primarily the Shock Response Spectra is discussed in detail, and various other analysis techniques are presented as well. Simulation techniques for near field, mid field and far field pyroshock are presented and include both pyrotechnic simulations and mechanical simulations. Examples of actual test specifications and the resulting laboratory test configuration and measured results are discussed. In addition, recent problems and issues in the pyroshock community are described and analyzed.

The Measurement and Utilization of Valid Shock and Vibration Data **Meeting Room: #216**

Dr. Patrick Walter (PCB Piezotronics / TCU)

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 pro-vide 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.

A Toolbox in Octave for the Designer of Vibration Testing Programs **Meeting Room: #221**

Mr. Zeev Sherf (Consultant)

The principles and a set of programs to implement them, in the process of computerized vibration time series generation, simulated or measured vibration analysis and vibration testing programs generation based on damage or on energy accumulation will be presented. Modules that enable the simulation of time series for the different categories of Method 514 are described (random, narrow band on wide band, sweeping narrow band on wide band, sine on random, common carrier transportation etc.)

Common Roadblocks/Mistakes from Shock Qual.; Practical Guidance & Case Studies **Meeting Room: #309/#310**

Mr. Patrick Minter (HII-NNS)

This course will focus on errors and missteps common to the shock qualification process and how they can be avoided by walking attendees through qualification efforts for several real-life examples. The instructor will provide details on the issues that were faced, the utilized testing/analysis methodologies, related 901 requirements and lessons learned. The end-goal of the training is to provide attendees with a better practical understanding of shock qualification by test and extension. This course is aimed at those who are or will be responsible for shock qualifying naval equipment per 901 requirements. This course assumes the attendees have at least a base understanding that attendees have participated in the NSWC (Hartsough and Urzillo) 901 trainings or at least have a basic understanding of 901 requirements. There will also be a portion of the tutorial set aside for specific attendee questions and hypothetical scenarios.

TUTORIAL SESSION 2 / 12:00pm—3:00pm

~ Optional 3-hour courses. Attendees receive certificate and may receive CEUs/PDHs (varies by state). Additional fees apply to attend. ~

MIMO Control for Acoustics and Vibration Environmental Testing: Theory & Practice **Meeting Room: #216**

Mr. Umberto Musella & Mr. Mariano Blanco (Siemens Industry Software)

Environmental tests are performed to prove that a system and all the sub-components will withstand the harshness of a predicted environment during the operational life. These tests aim to replicate with a high degree of fidelity the structural responses of a Unit Under Test (UUT) in the in-service conditions. As far as dynamic tests are concerned, the replication of the environmental conditions is only effective if the UUT's dynamics is also faithfully represented in the lab. The common practice of Single-Input-Single-Output (SISO) control tests has known limitations and drawbacks. The most critical aspect is that SISO tests may lead to unacceptable UUT time to failure overestimation and different failure modes. On top of more practical aspects that make difficult (or even impossible) to perform SISO tests (e.g. testing large items), this is the main reason why Multi-Input-Multi-Output (MIMO) tests are nowadays the "go for" in the environmental testing community for both vibration and acoustics testing. Even though the benefits of MIMO testing are clear and widely accepted by the environmental engineering community ever since 1958, this practice experienced a very slow growth. Initially this was due to the available technology in terms of excitation mechanisms and computational power for the data acquisition hardware and vibration controllers. Just recently, the increased complexity, size and cost of the article to be tested increased the concern about replicating as close as possible the environments to be tested. The high degree of expertise needed to perform these tests and decades of SISO controlled excitation built meanwhile a legacy of standards that currently represents the main reference for the environmental test engineers. For this reasons nowadays MIMO tests are still considered a pioneering testing methodology. The objective of this course is to give a detailed insight on MIMO control for reproducing a more realistic vibration and acoustic environments. An introduction to the topic will provide the theoretical background needed to understand MIMO control tests. Two parts (acoustics and vibrations) will follow, that focus, at the light of the acquired background, on industrial application cases and research topics in the field.

Intro. to Aliasing, FFT, Filtering, SRS & More for FEA Users and Test Engineers **Meeting Room: #309/#310**

Dr. Ted Diehl (Bodie Technology)

User's of Explicit Dynamics codes (LS-Dyna, Abaqus/Explicit, Radioss, …) compute transient solutions that typically contain "solution noise" in addition to the expected "frequency-rich" content created by severe impacts, shocks, failure, etc. The overall characteristics of the frequency content vary within result quantities of acceleration, velocity, displacement, strain, stress, and reaction forces. Evaluating these simulation results with time-history plots and deformation and stress contour plots/videos can easily become highly inaccurate and misleading due to "noise" and distortions caused by aliasing. Test engineers face similar, but different, issues with noise in their physical measurements. This course provides guidance to both simulation analysts and test engineers on how to properly collect and process such data. Topics covered range from how to collect data correctly to avoid aliasing, how to use Fourier Spectrum methods to understand frequency content, and how to apply various filtering tools to remove noise - ultimately, uncovering significantly improved results. In addition, the course will explain how to use Shock Response Spectra methods to compare typical component shock specs (ie. 1,000*G, 1.0*msec) with transient acceleration data derived from simulations or tests to assess shock survivability, including a quick SRS calculation method to evaluate the influence of shock isolation when such isolation was not originally in the system. The 3-hour seminar covers highlights of DSP theory in the language of Mechanical Engineering pertinent to simulation analysts and test engineers along with numerous practical applications presented. This seminar introduces key aspects of working with transient data – specifically, clearly explaining time-domain and frequency domain analysis (DFS, FFT, PSD, SRS, PVSS); data collection (sampling, up-sampling, decimation, & aliasing); filtering (lowpass, highpass, IIR, & FIR), calculating Shock Response Spectrum 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, …). Simplified interactive demonstrations are presented to solidify key DSP aspects, along with many relevant real-world examples - including a penetration analysis that includes SRS estimates of benefits of adding a shock isolator, severe impact analysis of an electronic device, dynamic analysis of a snap-fit, and failure simulation of a metal component modeled with cohesive elements. Both FEA users and experimentalists will benefit from this training.

Effective Solutions for Shock and Vibration Control **Meeting Room: #223**

Mr. Alan Klembczyk (Taylor Devices) & Dr. Ed Alexander (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. Absolute and relative equipment transmissibility to a vibration environment are presented. 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.

COMMITTEE MEETING **1:30pm-3:30pm**	**DTE 022 Meeting: MIMO Recommended Practice Committee** **Meeting Room: #220** Chair: Dr. Marcos Underwood (Tu'tuli Enterprises) Using more than one shaker to test large or unusually shaped objects is becoming an accepted part of the vibration testing industry. As interest in simultaneously testing articles in multiple axis increases, the need for guidelines to understand MIMO (multiple input multiple output) testing grows more important. Come get up to speed and contribute to our growing database on multi shaker concepts, fixturing, control, and reporting.

TUTORIAL SESSION 3 / 4:00pm—7:00pm

~ Optional 3-hour courses. Attendees receive certificate and may receive CEUs/PDHs (varies by state). Additional fees apply to attend. ~

Introduction to Weapons Effects and Ship Survivability Analysis **Meeting Room: #223**

Mr. Jan Czaban (Zenginworks Limited)

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

DDAM 101 **Meeting Room: #222**

Mr. George D. Hill (Alion Science & Technology)

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

How Modal Analysis Can Bring Insight to Vibration Testing **Meeting Room: #216**

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

In this tutorial, a base mounted payload within a system undergoes a vibration environment. The apparently complex motion is "dissected" into a relatively small number of fixed base modes as well as its six rigid body modes. These modes give significant insight into the dynamic strain experienced by the payload. The complex field motion can be represented with a linear combination of these modes. Next, the motion is considered when the payload is mounted to a shaker table. The capability to reproduce the system response on a six degree-of-freedom shaker is demonstrated. Also, the response as typically controlled on a single degree-of-freedom shaker is demonstrated. Using an understanding of the fixed based modal response, and improved control can be demonstrated. The approach is first demonstrated with simple finite element beam models. A final example is demonstrated using real hardware in a system environment, and then mounted on a six degree-of-freedom shaker controlling to the system environment.

Application of Engineering Fundamentals in Solving Shock and Vibration Problems **Meeting Room: #221**

Mr. Fred Costanzo (Consultant)

This tutorial first presents 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. Next, simple tools are introduced to assist engineers in benchmarking solutions obtained for more complex UNDEX problems. Presented will be the generation of "bounding" estimates for the global dynamic response of surface ship and submarine structures subjected to underwater shock. Three well documented methodologies are presented, including the Taylor flat plate analogy for both air - and water-backed plates, the peak translational velocity (PTV) method, and the application of the conservation of momentum principle to estimating the vertical kickoff velocity of floating structures (spar buoy approach). Derivations of the governing equations associated with each of these solution strategies are presented, along with a description of the appropriate ranges of applicability. Finally, special case studies involving numerical methods applications in shock and vibration problems will be presented. Specific areas that are discussed include finite difference approximations, root finding techniques and other numerical solution strategies. For each area covered, the basic theory is briefly described, a shock and vibration application is set up and a solution algorithm is developed and implemented in the form of a Python script. Next, a solution is generated and the results are illustrated and discussed.

ALL 90TH S&V SYMPOSIUM ATTENDEES, AND THEIR GUESTS, ARE INVITED TO:

90th Shock & Vibration Symposium

Welcome Reception

Monday, November 4th

6:30pm—8:30pm

Exhibit Hall

Food & Drinks

TUTORIAL SESSION 4 / 8:00am—11:00am

~ Optional 3-hour courses. Attendees receive certificate and may receive CEUs/PDHs (varies by state). Additional fees apply to attend. ~

A Primer on Vibration Testing and Data Analysis **Meeting Room: #309/#310**

Dr. Luke Martin (NSWC Dahlgren)

This tutorial will give an introduction to vibration testing and will be concept focused. The tutorial will begin with an understanding of a typical laboratory vibration test setup, followed by a deeper dive of the fundamental components. Specifically, a typical single degree of freedom vibration test will be decomposed into its pieces: amplifier, shaker, slip table, test item, vibration controller, and reference profiles. Once the components of the control loop are understood, the tutorial will focus on data analysis required by both the vibration controller to conduct a test and by a user who wishes to use measured field data to develop a tailored vibration test profile. Along the way concepts that will be covered are: electrodynamic shakers, servo-hydraulic shakers, single degree of freedom testing, multiple degree of freedom testing, control vs measurement transducers, Miner's Rule, sinusoidal testing, random testing, mixed mode testing, MIL-STD-167, MIL-STD- 810, need for tailored vibration data, and digital signal processing used for data analysis.

Introduction to Designing Shock Mounted Systems using Shock Isolation Mount Prediction & Loading Estimates (SIMPLE) Software **Meeting Room: #223**

Mr. Dave Callahan (HII-NNS)

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 classis 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.

COMMITTEE MEETING

9:00am-11:00am

DTE 044 Meeting: Transient Waveform Replication **Meeting Room: #220**

Chair: Mr. Russ Ayres

The DTE-044 Working Group (WG) committee is tasked with creating a "Recommended Practices" (RP) document which will describe best practices for running Transient Waveform Replication (TWR) vibration tests on you lab. How well has your TWR test run?? What error criteria are used to measure the acceptability of your test?? What plots and data should be reported?? These and other questions will be discussed in the DTE-044 WG committee. Please join to the DTE-044 Committee meeting and help build guidelines and recommendations that will contribute to successful performance of your TWR vibration test.

General Session 1 incl. Elias Klein Keynote Lecture & Exhibitors' Luncheon

11:00am—1:00pm / Salon Ballroom (Exhibit Hall)

11:00am—11:05am	Call to Order by: Mr. Drew Perkins (SAVE / HI-TEST Laboratories)
11:05am—11:15am	Keynote Lecturer Introduction presented by: Mr. Alan Klembczyk (Taylor Devices)
11:15am—12:10pm	***Elias Klein Keynote Lecture - Dr. Harrison Schmitt***
12:10pm—1:00pm	Lunch

The Shock and Vibration Exchange recognizes ***Mr. Alan Klembczyk (Taylor Devices)*** *for his outstanding commitment to this year's Elias Klein Keynote Lecture*

The Shock and Vibration Exchange recognizes the following organizations for sponsoring this year's lecture:

★★★★

Sandia National Laboratories
Taylor Devices
HI-TEST Laboratories

★★★

BAE Systems
PCB Piezotronics
Shock Tech

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Gibbs & Cox
Hutchinson USA
National Technical Systems
Spectral Dynamics
Thornton Tomasetti

Elias Klein Keynote Lecturer

Dr. Harrison Hagan Schmitt

Harrison Schmitt walked on the Moon in December 1972 as the Lunar Module Pilot of Apollo 17. One of the twelve moonwalkers, he is the last person to step on the Moon and, as a geologist, he is the only scientist-astronaut to do so. He received his Bachelors degree in Science from Caltech and a PhD in geology from Harvard and became a qualified jet pilot with the United States Air Force and helicopter pilot with the United States Navy.

Dr. Schmitt spent two weeks in space, collecting 240 pounds of Moon rocks during 22 hours of lunar exploration. The extensive field context he provided for those lunar samples is unique among the Apollo missions. He continues to integrate the results of 50 years of ongoing lunar research by his colleagues with his field observations. Along with the United States, the world, and his fellow Apollo astronauts, this year he celebrated the 50th Anniversary of the first human landing on the Moon accomplished in 1969 by Neil Armstrong, Buzz Aldrin, and Mike Collins.

Bio:

Harrison Hagan Schmitt was born in New Mexico and grew up in the American West. He earned a Bachelors of Science from Caltech and a PhD in geology from Harvard, based on work in Norway as a Fulbright Scholar and a National Science Foundation Post-Doctorate Fellow. Schmitt is privileged to have received numerous honorary degrees from United States and Canadian universities.

Schmitt joined the United States Geological Survey's Astrogeology Branch in Flagstaff, Arizona, in 1964, leading the development of early lunar field geological methods under contract to NASA. Selected by NASA as a Scientist-Astronaut in 1965, he earned Air Force T-38 jet pilot wings in 1966 and Navy H-13 helicopter wings in 1967.

After supporting the operational preparations and geological training for Apollo missions to the Moon, including being the Backup Lunar Module Pilot for Apollo 15, Schmitt flew in space as Apollo 17's Lunar Module Pilot. He landed in the Moon's Valley of Taurus-Littrow on December 11, 1972. He is the only scientist and last of 12 men to step on the Moon, Schmitt collected, documented and returned 240 pounds of lunar samples. The extensive field context he provided for those lunar samples is unique among the Apollo missions. He continues to integrate the results of 50 years of ongoing lunar research by his colleagues with his field observations.

Elected to the United States Senate from New Mexico in 1976, Schmitt worked on a wide variety of national legislation and New Mexico constituent services. He served on the Commerce, Appropriations, Banking, Small Business, and Intelligence Committees and chaired the Commerce Subcommittee on Space and Technology and the Appropriations Subcommittee on Health and Human Services.

Senator Schmitt later served on President Reagan's Foreign Intelligence Advisory Board, the Army Science Board, and President H. W. Bush's Ethics Commission. From 2005 to 2008, he chaired the NASA Advisory Council. Schmitt was a Director of Orbital Sciences Corporation and Orbital ATK for 35 years, serving until 2018 when Northrop Grumman acquired the company. He also has been a director of several corporations in the banking, technology, mining, and medical fields.

As an Adjunct Professor at the University of Wisconsin-Madison, Dr. Schmitt taught "Resources from Space" and remains an Associate Fellow in the university's Department of Engineering, working with faculty members on the commercialization of fusion power. Schmitt is currently a member of the User Advisory Group of the National Space Council and of the Science Advisory Board to the Blue Moon project of Blue Origin. He has authored "Return to the Moon; Exploration, Enterprise and Energy in the Human Exploration of Space" and has published numerous scientific and public policy papers. Most recently, Schmitt and his co-authors published "Revisiting the field geology of Taurus-Littrow" in Icarus (2017). Schmitt's account of the Apollo 17 Mission to the Moon is currently being published online as "Apollo 17: Diary of the 12th Man."

	SESSION 1 **Multiple-Input-Multiple-Output Vibration** 1:00pm-2:35pm / Unlimited Dist. A Chair(s): Dr. Luke Martin (NSWC Dahlgren) Mr. William Barber (Redstone Test Center)	SESSION 2 **Blast I** 1:00pm-2:35pm / Unlimited Dist. A Chair(s): Dr. Peter Vo (Raytheon)	SESSION 3 **Testing & Analysis of Fuze Technology for Extreme Environments I** 1:00pm-2:35pm / Limited Dist. D 2:40pm-3:00pm / Unlimited Dist. A Chair(s): Dr. Alain Beliveau (Applied Research Associates) Mr. Curtis McKinion (Air Force Research Laboratory)
	THERE WILL NOT BE A CHAIR/PRESENTER MEETING. ALL PRESENTATIONS MUST BE PRELOADED IN ADVANCE OF THE SESSION (VIA SUBMITTAL TO SAVE BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).		
	Meeting Room: Galleria 1	***Meeting Room: Galleria 4***	***Meeting Room: #313-#314***
1:00	**Data Driven Approach for Estimating Environmental Testing Conditions and Parameters (1)** Mr. Kevin Moreno, Dr. Sriram Malladi, & Dr. Pablo Tarazaga (Virginia Tech)	**Enhancements in Version 2 of the Scenario and Target-Relevant Explosive Equivalence Tool: STREET (3)** Ms. Michelle Yokota & Mr. David Bogosian (BakerRisk), Mr. Arturo Montalva (Stone Security Engineering)	**Characterizing the Mechanical Properties and Dynamic Response of G-switches (5)** Mr. Curtis McKinion, Mr. Mark Todisco, Dr. Jacob Dodson, Mr. Shane Curtis, & Mr. Joshua Dye (Air Force Research Laboratory)
1:25	**Explorations in Multiple-Input Shaker Shock Testing (1)** Mr. Ryan Schultz (Sandia National Laboratories)	**Residual Capacity of RC Beams Subjected to Impact Loading (3)** Dr. Joosef Leppanen (Chalmers University of Technology), Dr. Morgan Johansson (Norconsult AB and Chalmers University of Technology), Dr. Mathias Flansbjer (RISE Research Institutes of Sweden and Chalmers University of Technology), Mr. Fabio J. Lozano (Norconsult), Mr. Josef A. Makdesi (Sweco)	**Evaluation of the Dynamic Tensile Failure in Pressed Energetic Simulants (6)** Dr. Alain Beliveau & Mr. Jonathan Hong (Applied Research Associates), Dr. Jacob Dodson & Mr. Eric Welle (Air Force Research Laboratory)
1:50	**New Method to Determine Optimized Reference SDM for MIMO Random or Acoustic Testing (2)** Dr. Marcos Underwood (Tu'tuli Enterprises)	**Drop Testing of the Expedient Retrofit for Existing Buildings (EREB) System on a Smooth System (4)** Dr. Genevieve Pezzola & Mr. Thomas Carriveau (US Army ERDC), Ms. Mya Chappell (Brigham Young University)	**Experimental Method for Extension of Pulse Duration using Hydraulic Driving Force (6)** Dr. Lauren Stewart, Dr. Nan Gao, & Ms. Rebecca Nylen (Georgia Institute of Technology)
2:15	**Combined Shaker-Acoustic Vibration Test Techniques (2)** Mr. Ryan Schultz (Sandia National Laboratories), Dr. Peter Avitabile (University of Massachusetts Lowell)	**The Effect of Charge Diameter to Ratio on Transferred Shallow Buried Blast Impulse (4)** Dr. John Reinecke, Mr. Mzwandile Mokalane, & Ms. Rayeesa Ahmed (CSIR), Prof. Ian Horsfall (Canfield University, Defence)	**Small-Scale Testing of Electronic Components in Shock Loading (6)** Dr. Salil Mohan (NSWC Indian Head), Dr. Vasant Joshi, Mr. Raafat Guirguis, Mr. Reid McKeown, Mr. John O'Conner, & Ms. Marie-Urlima Okeke (NSWC Indian Head Explosive Ordnance Disposal Tech. Div.)
2:40			**Utilizing Hopkinson Bar for High-G, High-Frequency Mechanical Shock Tests (7)** Mr. Bo Song (Sandia National Laboratories)

ICE CREAM SOCIAL

3:00PM - 3:40PM

REUNION BALLROOM (EXHIBIT HALL)

	SESSION 4 **Mechanical Shock I** 1:00pm-3:00pm / Limited Dist. C Chair(s): Mr. Matt Davis (HII Newport News Shipbuilding) Mr. Chris Wong (NSWC Carderock)	*VENDOR SESSION A* **Exhibitor Presentations including: Case Studies, New Developments/Technologies, Testing, Product Info, & Service Practices** 1:00pm-3:00pm / Unlimited Dist. A Chair(s): Mr. Bob Metz (PCB Piezotronics) Mr. Andy Hohla (Endevco)	*TRAINING I* **Manufacturing Process & Performance of Fasteners** 1:15pm-2:45pm / 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 BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).		
	Meeting Room: #311-#312	***Meeting Room: Galleria 3***	***Meeting Room: Galleria 2***
1:00	**Factors Influencing the Design of a Shock Isolated False Deck (SIFD) Principal Unit (7)** Dr. Michael Talley, Mr. Chris Campbell, & Mr. Michael Parnin (HII Newport News Shipbuilding)	**Protective Monitoring for Vibration Applications (9)** Mr. Chris Wilcox (m+p International)	**Manufacturing Process Effects on the Performance of Fasteners in Service (10)** Mr. George Avery (NSWC Philadelphia) 1:15pm-2:45pm
1:25	**Supporting Transient Analysis to Converge on a Shock Isolated False Deck (SIFD) Principal Unit Design for Environmental Qualification Testing (8)** Mr. Chris Campbell, Mr. Michael Parnin, & Dr. Michael Talley (HII Newport News Shipbuilding)	**Simple Synchronizing and Playback of High-Speed Video and Sensor Data (9)** Mr. Shane Kirksey (Photron)	
1:50	**Alternative Test Methods: Overview of Ballasted Spring Deck Fixture Research (8)** Mr. Matt Davis (HII Newport News Shipbuilding), Mr. Rick Griffen (Consultant)	**Multi-Resolution Spectrum Analysis (9)** Mr. Matt Millard (Crystal Instruments)	
2:15	**Alternative Test Methods: Class I and II Performance Testing on the Ballasted Spring Deck Fixture (8)** Mr. Matt Davis (HII Newport News Shipbuilding), Mr. Rick Griffen (Consultant)	**A High Resolution Broadband Accelerometer (9)** Mr. Andy Hohla (Endevco)	
2:40	**Alternative Test Methods: Class I and II Achieved Performance Capabilities of the Ballasted Spring Deck Fixture (8)** Mr. Matt Davis (HII Newport News Shipbuilding), Mr. Rick Griffen (Consultant)	**Performance Characteristics of Piezoelectric & Piezoresistive Pressure for Blast Applications (10)** Mr. Bob Metz (PCB Piezotronics)	

ICE CREAM SOCIAL
3:00PM - 3:40PM
REUNION BALLROOM (EXHIBIT HALL)

Tuesday PM (November 5)

	SESSION 5 **Shock & Vibration Modeling & Analysis I** 3:45pm-5:45pm / Unlimited Dist. A Chair(s): Mr. Sloan Burns (NSWC Dahlgren)	SESSION 6 **Instrumentation I** 3:45pm-4:30pm / Limited Dist. C 4:35pm-4:55pm / Unlimited Dist. A **Blast II** 5:00pm-6:10pm / Unlimited Dist. A Chair(s): Mr. Robert Sharp (Hutchinson)	SESSION 7 **Testing & Analysis of Fuze Technology for Extreme Environments II** 3:45pm-5:45pm / Limited Dist. D Chair(s): Dr. Vasant Joshi (NSWC Indian Head EODTD) Dr. Jacob Dodson (Air Force Research Laboratory)
	THERE WILL NOT BE A CHAIR/PRESENTER MEETING. ALL PRESENTATIONS MUST BE PRELOADED IN ADVANCE OF THE SESSION (VIA SUBMITTAL TO SAVE BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).		
	Meeting Room: Galleria 1	***Meeting Room: Galleria 4***	***Meeting Room: #313-#314***
3:45	**A Novel Distributed Force Vibration Test System Configurations - A Program (10)** Mr. Eliahu Elmalah (Consultant)	**Characterization and Compensation for Transverse Sensitivity in Shock Accelerometers (12)** Dr. Bryan Joyce, Mr. Garrett S. Wiles, Mr. Sloan C. Burns, Dr. Jon J. Yagla (NSWC Dahlgren)	**Testing and Evaluation of Fuze Systems at the Edge of Envelope (15)** Mr. Justin Welling (AFLCMC/EBD), Mr. Zachary Hamrick (Odyssey / AFLCMC/EBD)
4:10	**Assessment of Flight Vibration versus Reynold's Number for Black Brant IX Sounding Rockets (11)** Dr. Ricky Stanfield (Northrop Grumman)	**Comparison of Piezoelectric and Foil Strain Gauges for Applications in Shock and Vibration Strain Detection (12)** Mr. Robert Ponder & Mr. Sloan Burns (NSWC Dahlgren)	**Embedded Environment Measurement in Explosive Simulant during Sub-Scale Penetration tests at Cold and Ambient Temperature (16)** Dr. Alain Beliveau, Mr. James Scheppegrell, & Mr. Dustin Landers (Applied Research Associates), Mr. Curtis McKinion (Air Force Research Laboratory), Mr. Shane Curtis (Sandia National Lab)
4:35	**Development of Weapon Abnormal Environment High-G Shock Testing Bridging the Gap Between Actuator Testing and Rocket Sled Track or Flight Testing (11)** Mr. Patrick Barnes (Sandia National Laboratories)	**Implementing In-House Piggy-Back Shock Accelerometer Calibration (13)** Dr. Ted Diehl (Bodie Technology) & Mr. Mark Remelman (Spectral Dynamics)	**Testing Tactical Embedded Forward Assemblies for Functional Validation (16)** Mr. Dustin Landers, Mr. James Scheppegrell, & Dr. Alain Beliveau (Applied Research Associates)
5:00	**Exploring Margins of Safety for Bolted Joints Undergoing Random Vibration Environments (11)** Dr. Justin Wilbanks & Dr. Brian Owens (Sandia National Laboratories)	**Aggressor Vehicle Entry Readiness Technology (AVERT) Vehicle Barrier System (14)** Mr. Justin Roberts (US Army ERDC)	**Time Varying Temporal Moments for Penetration Data Analysis (16)** Mr. Craig Doolittle & Mr. Alma H. Oliphant (Applied Research Associates)
5:25	**Implementation of Peak Counting Methods and Fatigue Damage Evaluation in Random Loads Regime with OCTAVE (12)** Mr. Zeev Sherf (Consultant)	**Numerical Simulations of Large High Explosive Charge Detonating Near Ground Surface with Shallow Layer of Soil on Ground Rock (14)** Dr. Leo Laine (LL Engineering AB), Dr. Morgan Johansson (Norconsult AB), Mr. Ola Pramm Larsen (CAEwiz Consulting AS), Dr. Joosef Leppanen (Chalmers University of Technology)	**Modeling of the MEMS Fuze using DYSMAS (17)** Mr. Chris Cao, Mr. Sean Tidwell, Mr. Antonio Borckardt, & Dr. Vasant Joshi (NSWC Indian Head), Dr. Daniel Jean (NSWC Indian Head Explosive Ordnance Disposal Tech. Div.)
5:50		**Simulation Driven Design and Optimization of Hull for Blast Resistant Vehicles (15)** Mr. Ravi Kodwani & Mr. Ed Wettlaufer (Altair Engineering)	

	SESSION 8 **Close-In UNDEX & Whipping** 3:45pm-4:55pm / Limited Dist. D **Validation of UNDEX Simulations** 5:00pm-5:45pm / Limited Dist. D Chair(s): Dr. Ken Nahshon (NSWC Carderock)	*VENDOR SESSION B* **Exhibitor Presentations including: Case Studies, New Developments/Technologies, Testing, Product Info, & Service Practices** 3:45pm-6:10pm / Unlimited Dist. A Chair(s): Mr. Gary Marraccini (Spectral Dynamics) Dr. Ted Diehl (Bodie Technology)	*TRAINING II* **Type I Vibration Qualification** 3:45pm-4:30pm / Unlimited Dist. A *SESSION 9* **M&S of Munition Effects** 5:00pm-5:45pm / Limited Dist. D Chair(s): Mr. Ernie Staubs (Air Force Research Laboratory)
	THERE WILL NOT BE A CHAIR/PRESENTER MEETING. ALL PRESENTATIONS MUST BE PRELOADED IN ADVANCE OF THE SESSION (VIA SUBMITTAL TO SAVE BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).		
	Meeting Room: #311-#312	***Meeting Room: Galleria 3***	***Meeting Room: Galleria 2***
3:45	**Structural Response Evaluation of an Aluminum Hull Ship Using Navy Enhanced Sierra Mechanics: Close-In UNDEX With Bubble Jetting (17)** Mr. Raymond DeFrese (NSWC Carderock)	**Vibration Specifications and How to Plan and Conduct the Vibration Test (18)** Mr. Gary Marraccini (Spectral Dynamics)	**Type I Vibration Qualification in Accordance with MIL-STD-167-1, Common Misconceptions & Best Practices (20)** Mr. Thomas Borawski (NSWC Philadelphia) 3:45pm-4:30pm
4:10	**UNDEX Whipping Response of Surface Ships – A New Multi-Fidelity Approach (17)** Dr. Ken Nahshon & Mr. Kervin Michaud (NSWC Carderock), Dr. Jeffrey Cipolla & Mr. Corbin Robeck (Thornton Tomasetti)	**High Speed Digital Imaging Correlation in Ballistics Applications (18)** Dr. Kyle D. Gilroy (Vision Research)	
4:35	**Whipping Response of Surface Ships in Response to Underwater Explosions Using Hull-whip and NESM (17)** Dr. Jeffrey Cipolla & Mr. Corbin Robeck (Thornton Tomasetti), Dr. Ken Nahshon & Mr. Kervin Michaud (NSWC Carderock)	**Inductive Centering in Electrodynamic Shaker Systems (18)** Mr. Dominic Acquarulo (Bruel & Kjaer)	
5:00	**A General Framework for Assessing the Validation of Modeling and Simulation for a Specific Intended Use (18)** Mr. Christopher Abate (Electric Boat Corporation)	**Case Study for a 6 DOF Isolation with Precise Re-Positioning for UNDEX Applications (19)** Mr. Mike Mosher & Mr. John Metzger (Taylor Devices)	**A Framework for Automating Fast-Running Surface Response Models (20)** Dr. George M. Lloyd (ACTA SH), Dr. Li Cao (ACTA LLC), Mr. Fabien Tieuleres & Mr. Joe Magallanes (Karagozian & Case Inc.)
5:25	**A Probabilistic Approach for Assessing the Stability of Cylinders Subjected to Combined Hydrostatic and Shock Loading (18)** Mr. Dashiell Parsons & Mr. Christopher Abate (Electric Boat Corporation)	**Efficiently Processing Noisy Data with Kornucopia ML (19)** Dr. Ted Diehl (Bodie Technology)	**A Fast-Running Model for Multi-Strike Munitions Effects on RC Columns (21)** Dr. George M. Lloyd (ACTA SH), Mr. Ryan Schnalzer (ACTA), Mr. Dan Coleman & Mr. Joe Magallanes (Karagozian & Case Inc.)
5:50			

	SESSION 10	SESSION 11	SESSION 12
	SESSION 10 **Shock & Vibration Modeling & Analysis II** 8:00am-8:20am / Limited Distribution D 8:25am-10:00am / Unlimited Dist. A Chair(s): Mr. David Soine (Sandia National Laboratories)	*SESSION 11* **Experimental Techniques for Pyroshock Testing I** 8:25am-10:00am / Unlimited Dist. A Chair(s): Dr. Patrick Walter (PCB/TCU)	*SESSION 12* **Blast: Experimental & Numerical Methods** 8:00am-9:35am / Limited Dist. D Chair(s): Dr. Gregory Bessette (USACE ERDC) Mr. Roosevelt Davis (AFRL)
	THERE WILL NOT BE A CHAIR/PRESENTER MEETING. ALL PRESENTATIONS MUST BE PRELOADED IN ADVANCE OF THE SESSION (VIA SUBMITTAL TO SAVE BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).		
	Meeting Room: Galleria 1	***Meeting Room: Galleria 4***	***Meeting Room: #313-#314***
8:00	**Shock Test Specification via an Optimally Decomposed Time History (21)** Mr. Sloan Burns (NSWC Dahlgren)		**BlastX Integration with Navy Ship Vulnerability Tools (25)** Dr. Gregory Bessette (USACE ERDC), Mr. Keith G. Webster, Dr. Ken Nahshon, Mr. Kevin P. Rankin, & Mr. William A. Hoffman (NSWC Carderock)
8:25	**Estimation of Fundamental Natural Period for Shock Fixtures (21)** Mr. David Soine & Mr. Jonathan Hower (Honeywell)	**Pyroshock Replicate (23)** Mr. Matan Mendelovich (Rafael)	**Numerical Investigation of a New Muzzle Brake for Blast Overpressure Attenuation at Crew Positions on the 155 mm M777 Extended Range Cannon (26)** Dr. Robert Carson & Mr. David Marshall (U.S. Army CCDC Armaments Center)
8:50	**Computing the Maximum Expected Environment of a Small Data Set (22)** Mr. Chad Heitman (Sandia National Laboratories)	**Techniques for Repeatable Pyroshock Testing on an Air Gun Shock Machine for Lean Satellites (24)** Mr. Ibukun Oluwatobi Adebolu, Dr. Hirokazu, & Prof. Mengu Cho (Kyushu Institute of Technology), Mr. Isamu Inoue (iQPS)	**Measuring the Mechanical Response of a Steel Surrogate Door Resulting from Multiple Charges (26)** Mr. Roosevelt Davis & Ms. Sarah Folse-Vorgert (AFRL)
9:15	**Python & Qt, Powerful tools for Technical Computing (22)** Mr. Vincent Grillo (A.I. Solutions)	**Development of Non-Destructive "Alternative Pyroshock" Simulation for Extremely Large Systems (24)** Mr. Patrick Barnes (Sandia National Laboratories)	**Predictive Metrics for Response of a Hardened Steel Door to Multiple Charges (27)** Mr. David Bogosian & Dr. David Powell (BakerRisk), Mr. Roosevelt Davis (AFRL/RWML)
9:40	**A Random Field Model for Clustering Dynamics (22)** Dr. George Lloyd (ACTA), Dr. Tom Paez (Paez Consulting)	**MIL STD 810 Instrumentation Guidance Vs. Shock Measurement Systems Individuality (25)** Dr. Patrick L. Walter (PCB Piezotronics & TCU Engineering)	

Coffee Break in the Exhibit Hall

10:00am—10:25am (Salon Ballroom / Exhibit Hall)

	SESSION 13 **DYSMAS I: AIREX Development & Applications** 8:00am-9:10am / Limited Dist. D Chair(s): Dr. Cameron Stewart (NSWC Indian Head)	*VENDOR SESSION C* **Exhibitor Presentations including: Case Studies, New Developments/Technologies, Testing, Product Info, & Service Practices** 8:25am-10:00am / Unlimited Dist. A Chair(s): Mr. Chris Sensor (NVT Group/Data Physics) Mr. Kevin Westhora (Dytran Instruments)	*TRAINING III* **Intro to Heavyweight Shock Testing** 8:00am-10:00am / 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 BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).		
	Meeting Room: #309-#310	***Meeting Room: Galleria 3***	***Meeting Room: Galleria 2***
8:00	**Use of DYSMAS to Model Blast Propagation in a Simulated Urban Environment (27)** Dr. Marie Okeke, Mr. Roger Ilamni, & Dr. Thomas McGrath (NSWC Indian Head)		**Introduction to Heavyweight Shock Testing (30)** Mr. Travis Kerr (HI-TEST Laboratories) 8:00am-10:00am
8:25	**Multi-phase Discrete Element Method (27)** Dr. Cameron Stewart & Dr. Thomas McGrath (NSWC Indian Head)	**Advancements in Combined Controller/ Analyzer Design (28)** Mr. Chris Sensor (NVT Group/Data Physics) dp Data Physics	
8:50	**Mine Vulnerability M&S using DYSMAS (27)** Dr. Soonyoung Hong (NSWC Indian Head)	**Extremely Large Telescope Transport Using 2" Wire Rope Isolators (28)** Mr. Joshua Partyka & Mr. Ozzie Irowa (Vibro Dynamics) VIBRO DYNAMICS a Socitec company	
9:15		**Elasta Mega Isolation Mounts (EMIM) for Heavy Payloads (28)** Dr. Daryoush Allaei (Shock Tech) Shock Tech	
9:40		**Mechanically & Electrically Filtered High Shock Accelerometer (29)** Mr. Kevin Westhora (Dytran Instruments) DYTRAN INSTRUMENTS, INC.	

Coffee Break in the Exhibit Hall

10:00am—10:25am (Salon Ballroom / Exhibit Hall)

	SESSION 14 **Shock & Vibration Isolation** 10:25am-Noon / Unlimited Dist. A Chair(s): Mr. Alan Klembczyk (Taylor Devices)	SESSION 15 **Instrumentation II** 10:25am-Noon / Unlimited Dist. A Chair(s): Mr. Matt Strawbridge (NSWC Carderock)	SESSION 16 **Penetration Mechanics** 10:25am-10:45am / Limited Dist. D **Infrastructure Damage Mitigation** 10:50am-11:35am / Limited Dist. D 11:40am-Noon / Limited Dist. C Chair(s): Mr. Stephen Turner (USACE ERDC)
	THERE WILL NOT BE A CHAIR/PRESENTER MEETING. ALL PRESENTATIONS MUST BE PRELOADED IN ADVANCE OF THE SESSION (VIA SUBMITTAL TO SAVE BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).		
	Meeting Room: Galleria 1	***Meeting Room: Galleria 4***	***Meeting Room: #311-#312***
	Mid-Morning Break Continues in Exhibit Hall (10:00am-10:25am)		
10:25	**Materials Advancements Enabling a New Navy Mount for High Temperature and Extended Service Life (30)** Mr. Shawn Czerniak, Mr. Neil Donovam, & Mr. John Sailhamer (Hutchinson)	**Minimizing Noise Pick-up in Real World Sensor Measurements (33)** Mr. Alan Szary & Mr. Douglas Firth (Precision Filters)	**Constitutive Modeling of Jointed Rock (34)** Dr. John Furlow & Mr. Michael Thomas (Applied Research Associates)
10:50	**Isolation of Ultralight-Weight Electronics Enclosures (31)** Mr. Darko Gjoreski, Mr. Kevork Kayayan, & Dr. Daryoush Allaei (ShockTech)	**Push-Push Balanced Constant Current for Static and Dynamic Strain Measurements (33)** Mr. Douglas Firth & Mr. Alan Szary (Precision Filters)	**Evaluation of Systems for Defeat of High-Velocity Projectiles for Protection Against Infrastructure Threats (34)** Mr. Ernesto G. Cruz-Gutierrez, Ms. Amie Burroughs, & Mr. Brandon Everett (USACE—ERDC)
11:15	**Performance of Cup Isolation Mounts Subjected to Cold-Hot Temperatures (31)** Mr. Richard Rakowski, Mr. Kevork Kayayan, & Dr. Daryoush Allaei (ShockTech)	**Robust Triaxial High-G Accelerometers with Low-Noise Cable (33)** Mr. James Nelson (Endevco)	**Rapid Runway Repair by Removal of Concrete Using Explosive Methods (35)** Mr. Stephen Turner, Dr. J. Q. Ehrgott, Jr., & Mr. Denis Rickman (USACE—ERDC)
11:40	**Moving Delicate Air and Space Equipment (32)** Mr. Claude Prost & Mr. Joshua Partyka (Vibro Dynamics/Socitec)	**Characterizing Motion in 6 Degrees of Freedom (34)** Mr. Andy Hohla (Endevco)	**Area Damage Estimation Method based on High-Resolution Geospatial Data (35)** Mr. Jasiel Y. Ramos-Delgado, Mr. Joshua E. Payne, Mr. José A. Rullán, Dr. J. Q. Ehrgott, Jr., & Mr. Sean Griffin (USACE—ERDC)

	SESSION 17 **DYSMAS II: UNDEX Development & Applications** 10:25am-11:35am / Limited Dist. D 11:40am-Noon / Unlimited Dist. A Chair(s): Mr. Adam Goldberg (NSWC Indian Head)	SESSION 18 **Shock Qualification of Stowage Systems and Battery-Powered Systems** 10:25am-11:35am / Limited Dist. D Chair(s): Ms. Monica Black (NUWC Newport)	
	THERE WILL NOT BE A CHAIR/PRESENTER MEETING. ALL PRESENTATIONS MUST BE PRELOADED IN ADVANCE OF THE SESSION (VIA SUBMITTAL TO SAVE BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).		
	Meeting Room: #313-#314	***Meeting Room: #309-#310***	
	Mid-Morning Break Continues in Exhibit Hall (10:00am-10:25am)		
10:25	**Modeling Fluid-Filled Tanks using DYSMAS (36)** Dr. Alan Luton, Mr. Roger Ilamni, & Dr. Jeff St. Clair (NSWC IHDEODTD), Dr. Bradley Klenow (NSWC CD), Mr. Ralf Tewes, Ms. Alina Leppmeier, & Mr. Manfred Krueger (iABG)	**Weapon Stowage Cradle Validation and Optimization for Shock Survivability (37)** Mr. Maruti Kolluru, Mr. Kevin Behan, & Mr. Michael Lapera (NUWC Newport)	***<u>SAVE the Date</u>*** *91st Shock & Vibration Symposium* Oct 25-29, 2020 *Rosen Centre Hotel* Orlando
10:50	**Reverse Engineering the German UTA Test Pond Bottom Properties (36)** Mr. Martin Marcus (NSWC Indian Head)	**Shock Qualified Stowage Solutions for Submarine Applications (37)** Ms. Teresa Gangi & Mr. Kevin Behan (NUWC Newport)	
11:15	**Modeling Torpedo Impact Using DYSMAS (36)** Mr. Otto Quinones (NSWC Indian Head)	**Battery Shock Qualification, Challenges, and Goals (38)** Ms. Monica Black & Mr. Kevin Behan (NUWC Newport)	
11:40	**Investigating UNDEX Threats to the Marine Mammal Melon (36)** *Dr. Joe Ambrico (NUWC Newport) presenting* Dr. Emily Guzas, Ms. Monica DeAngelis, Mr. Thomas N. Fetherston, Ms. Rachel Hesse, Mr. Daniel Perez, Dr. Erin Gauch, & Ms. Lauren Marshall (NUWC Newport)		

General Session 2 incl. Awards Presentations & Awards Luncheon

Noon—1:30pm / Salon Ballroom (Exhibit Hall)

Noon—12:05pm	Call to Order by: Mr. Drew Perkins (SAVE / HI-TEST Laboratories)	
12:05pm—12:15pm	Henry Pusey Best Paper Award presented to:	 Dr. Michael T. Hale (Trideum Corp.)
12:15pm—12:25pm	Distinguished Service Award presented to:	 Mr. Alan Klembczyk (Taylor Devices)
12:25pm—12:40pm	Lifetime Achievement Award presented to: presented by:	 Mr. Greg Harris (NSWC Indian Head, ret.) Mr. Adam Goldberg (NSWC Indian Head)
12:40pm—1:30pm	Lunch	

Henry Pusey Best Paper Award Winner—Dr. Michael T. Hale (Trideum Corp.)

"Technique to Develop a Spectral Density Matrix with Synthesized Rotational Degrees-of-Freedom"

Technical Paper Abstract: Reference criteria for a multiple degree-of-freedom (MDOF) random vibration test is generally provided in terms of an acceleration based spectral density matrix (SDM). It is common practice that a SDM is developed in terms of the auto-spectral densities (ASD's) and cross-spectral densities (CSD's) computed from the time histories acquired from an appropriately placed and oriented set of linear accelerometers. A reference SDM in terms of the accelerations associated with the six classical motion degrees-of-freedom as defined at an arbitrary point of origin will be denoted as motion SDM . In a situation in which it is desired to expose a test article to 6-DOF excitation and there is a lack of appropriately placed transducers, one must exercise caution in the synthesis of a reference SDM to ensure the reference criteria remains physically realizable. The objective at hand is to demonstrate a technique to synthesize a physically realizable reference motion SDM given only predefined translational spectral shapes.

Distinguished Service Award Winner—Mr. Alan Klembczyk (Taylor Devices)

Since 2006, Mr. Alan Klembczyk has served on the Technical Advisory Group (TAG) for the Shock & Vibration Symposium. During his tenure with the TAG, he has been responsible for:

- Securing three Elias Klein Lecturers including Mr. William Shepherd (first U.S. astronaut to man International Space Station), Dr. Kit Miyamoto (global leader in earthquake engineering and earthquake disaster mitigation), & Dr. Harrison Schmitt (*this year's lecturer—see page 13*).
- Chairing eighteen technical sessions, from 2006-2019, at twelve different S&V Symposia.
- Teaching a 3-hour tutorial at ten of the past eleven S&V Symposia.
- Serving as the Featured Speaker for the New Engineers Forum of the 78th S&V Symposium in 2007.
- Teaching a 1-hour tutorial at six different S&V one-day seminars from 2007-2011.
- Attending over twenty TAG meetings in which he served as a primary driver and advisor for the general operation of SAVIAC/SAVE and the annual Shock & Vibration Symposium.

Lifetime Achievement Award Winner—Mr. Greg Harris (NSWC Indian Head, ret.)

Inscription on Lifetime Achievement Award - Mr. Gregory Harris is being recognized for his exemplary technical contributions to, and execution of, the DYSMAS US-German collaborative program. Mr. Harris has led the technical execution of the collaborative program to develop and deploy simulation software that accurately predicts the complex interaction of underwater weapons with naval structures over the course of four joint project agreements with the Federal Republic of Germany, spanning 20 years and $80M of joint investment.

Exhibitor Passport Program

- Each symposium attendee is given a "passport" with a listing of participating companies (exhibitors).
- Participating exhibitors are provided a customized stamp or sticker.
- As the attendees visit the participating exhibitors in the Passport Program, exhibitors "stamp" the passport of the attendee.
- Attendees who collected the stamp of all participating vendors are entered into the drawing* of multiple prizes.

  **Drawing will be held between 3:30pm-4:15pm on Wednesday , November 6th*

Thank You to the Organizations Participating in the Passport Program:

Spectral Dynamics · Hi-Test Laboratories, Inc. · Hi-Tech Techniques · E-Labs Fredericksburg, Virginia - USA

Meggitt · m+p International · NTS

Taylor Devices Inc. · iX Cameras · Vibration Research · Dytran Instruments, Inc.

Crystal Instruments · Shock Tech · ITT Enidine

Xcitex · Vision Research · ETS Solutions Advancing Technology in Dynamic Testing · Bodie Technology

DEWESoft™ measurement innovation · Data Physics · Lansmont · Team · Members of the NVT Group · IST instrumented sensor technology

Program Continues with More Technical Sessions, Tutorials, and Events →

	SESSION 19 **UNDEX: New Shock Testing Technology** 1:30pm-3:30pm / NATO Citizens Only Chair(s): Mr. James Breault (Lansmont) Dr. Jeffrey Cipolla (Thornton Tomasetti Appl. Sci.)	SESSION 20 **Structural Response & Analysis** 1:30pm-3:30pm / Unlimited Dist. A Chair(s): Mr. Jacob Mason (PMS 397)	SESSION 21 **Secondary Debris Prediction** 1:30pm-2:40pm / Limited Dist. D **Mechanical Shock II (Alternative/Custom Machines & Materials)** 2:45pm-3:30pm / Limited Dist. C Chair(s): Dr. Wije Wathugala (ACTA)
	THERE WILL NOT BE A CHAIR/PRESENTER MEETING. ALL PRESENTATIONS MUST BE PRELOADED IN ADVANCE OF THE SESSION (VIA SUBMITTAL TO SAVE BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).		
	Meeting Room: Galleria 1	***Meeting Room: Galleria 4***	***Meeting Room: #311-#312***
1:30	**Evolution in Shock Machine Design (38)** Mr. Kevin Gilman (Lansmont Corporation)	**Parametric Modelling to Obtain Full Field Structural Dynamics of an Unknown System from Limited Spatial Measurements (40)** Mr. Ellis Kessler, Dr. Pablo Tarazaga, Dr. Serkan Gugercin, & Dr. Sriram Malladi (Virginia Tech)	**Predict Secondary Debris Due to Buried Explosives: Part 1: Experiments (42)** Dr. Wije Wathugala (ACTA), Dr. George Lloyd (ACTA-SH), Mr. Tony Zimmerly (EMRTC, New Mexico Tech), Mr. Steven Mullins (SECOTEC)
1:55	**New Double Pulse Shock Testing System for WTD 71 (38)** Mr. Alexander von Bluecher (Bundeswehr Technical Center for Ships and Naval Weapons)	**Full-field Flight Environments via a Hybrid Experimental-analytical Method (40)** Dr. Brian Owens, Mr. Brandon Zwink, Mr. Moheimin Khan, Dr. Gregory Tipton, & Mr. Randy Mayes (Sandia National Laboratories)	**Predict Secondary Debris Due to Buried Explosives: Part 2: Numerical Simulations (43)** Dr. Wije Wathugala & Dr. Wenshui Gan (ACTA)
2:20	**Shock Qualification Testing using Seismic Airguns (38)** Mr. Callum Norris & Mr. Gavin Colliar (Thornton Tomasetti Defence Ltd.)	**Meshless Simulation Driven Design applied to Shipbuilding Industry (41)** Mr. Carlos de Lima, Mr. Rajesh Bishnoi, & Mr. Dakota Young-Grieco (Altair Engineering)	**Predict Secondary Debris Due to Buried Explosives: Part 3: Fast Running Models (43)** Dr. Wije Wathugala & Dr. Wenshui Gan (ACTA), Dr. George Lloyd (ACTA-SH)
2:45	**JASSO: A New Shock Testing Technology for Naval Equipment (39)** Mr. Gavin Colliar, Mr. Phillip Thompson, & Mr. Nick Misselbrook (Thornton Tomasetti Defence Ltd.)	**Fillet Weld Sizing Using Finite Element Methods (41)** Mr. Nicholas Pinco & Mr. Chris Campbell (HII Newport News Shipbuilding)	**Design of a High-Energy Shock Machine for Use Inside a Reactor Cavity (44)** Ms. Stephanie Booth, Mr. Ken Morris, & Dr. Carl Sisemore (Sandia National Laboratories)
3:10	**Analysis of the Shock Response Spectra Produced by the JASSO Shock Machine (39)** Mr. Gavin Colliar (Thornton Tomasetti Defence Ltd.), Mr. Alex McVey & Dr. Jeffrey Cipolla (Thornton Tomasetti Applied Science)	**A Mass Normalized Projection Approach to Component Testing (41)** Mr. Nick Corbin, Mr. Kameron Mize, & Dr. Pablo Tarazaga (Virginia Tech)	**Simulated Proof Testing of a Composite Mortar Baseplate (44)** Dr. Andrew Littlefield & Mr. David Alfano (US Army CCDC AC Benet Labs)

SESSION BREAK & PASSPORT PRIZE ANNOUNCEMENT
3:30PM - 4:15PM

Wednesday PM (November 6)

	SESSION 22	*SESSION 23*	*TRAINING IV / USERS GROUP*
	Subsidiary & Subassembly Component Test Design 1:30pm-3:05pm / Limited Dist. D **MIL-DTL-901E Shock** 3:10pm-3:30pm / Unlimited Dist. A Chair(s): Mr. Patrick Minter (HII NNS)	**eShock Web Database** 1:30pm-2:15pm / Limited Dist. D Chair(s): Ms. Kelli Gasswint (US Navy/NSLC) *DISC. GROUP* **High Speed Digital Imaging Correlation for Ballistics Applications** 2:25pm-3:25pm / Unlimited Dist. A	**Introduction to UERDTools** 1:30pm-3:30pm / Limited Dist. C
	THERE WILL NOT BE A CHAIR/PRESENTER MEETING. ALL PRESENTATIONS MUST BE PRELOADED IN ADVANCE OF THE SESSION (VIA SUBMITTAL TO SAVE BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).		
	Meeting Room: #309-#310	***Meeting Room: #313-#314***	***Meeting Room: Galleria 2***
1:30	**Subsidiary & Subassembly Component Test Design Overview (45)** Ms. Lisa McGrath (HII Newport News Shipbuilding)	**eShock Part 1 (46)** Ms. Kelli Gasswint, Ms. Nadeen Bogonis, & Mr. Benjamin Tiedgen (US Navy/NSLC)	**Introduction to UERDTools (47)** Mr. Brian Lang (NSWC Carderock / UERD) 1:30pm—3:30pm
1:55	**Subsidiary & Subassembly Component Test Design: Lightweight Subassembly Testing Case Study (45)** Mr. Bradley Harris (HII Newport News Shipbuilding)	**eShock Part 2 (47)** Ms. Kelli Gasswint, Ms. Nadeen Bogonis, & Mr. Benjamin Tiedgen (US Navy/NSLC)	
2:20	**Subsidiary & Subassembly Component Test Design: Medium Weight Subsidiary Testing Case Study (45)** Mr. Patrick Minter (HII Newport News Shipbuilding)	**High Speed Digital Imaging Correlation for Ballistics Applications** Mr. Kyle Gilroy (Vision Research) 2:25pm-3:25pm There has been a steadily growing interest in materials-testing protocols that demand both high spatial and temporal resolution. In this talk, we discuss how ultra-high-speed cameras can be combined with advanced software to characterize spatial and temporal strain, displacement, and vibration on the micro-scale, respectively. As will be demonstrated, this is ideal for weapons testing and analyzing projectile/materials interactions during high-velocity impacts. We talk about the overall workflow, results, and analysis from weapons and impact testing.	
2:45	**Subsidiary & Subassembly Component Test Design: Heavyweight Subsidiary Testing Case Study (46)** Ms. Lisa McGrath, Mr. Chris Campbell, & Mr. Steve Arturo (HII Newport News Shipbuilding)		
3:10	**NSRP Projects:: MIL-DTL-901E Cost Avoidance in Shock Applications and N30 Fireproof / Watertight Doors (46)** Mr. Michael Poslusny & Ms. Kristi Carroll (HII—Ingalls)		

SESSION BREAK & PASSPORT PRIZE ANNOUNCEMENT

3:30PM - 4:15PM

TUTORIAL SESSION 5 / 3:30pm—6:30pm

~ Optional 3-hour courses. Attendees receive certificate and may receive CEUs/PDHs (varies by state). Additional fees apply to attend. ~

Comparison of Two Spectral Estimators **Meeting Room: #223**

Dr. Thomas Paez (Thomas Paez Consulting)

The standard method for obtaining estimates of the spectral functions of random processes, including autospectral densities, cross-spectral densities, and frequency response functions, is Welch's Method. It has proven more than satisfactory in terms of speed and accuracy. Welch's Method is used in stand-alone applications where estimates of the spectral functions of random sources are required and recorded data from the sources are available, and it is used in real-time applications where running estimates of spectral functions are required. The forms of Welch estimators can be obtained using the Method of Maximum Likelihood; therefore, the estimators are asymptotically unbiased and consistent, and have many more favorable characteristics. These things make their use desirable. Yet, there are many other methods for obtaining spectral function estimates, including (1) simple mean square-based estimates, (2) Karhunen-Loeve expansion-based estimates, (3) autoregressive-moving average model-based estimates, and (4) Parzen-type estimates. It is often speculated that the latter estimate, the Parzen estimate, merits consideration for use in practical situations as an alternative to Welch's Method. This tutorial reviews the estimation of spectral functions using Welch's Method and it describes how error estimation is performed. The number of operations required to perform Welch's estimates is obtained. Then the estimation of spectral functions using Parzen's Method is developed. Error estimation for Parzen's Method is performed and the number of operations required to obtain spectral functions with Parzen's approach is specified. Comparisons between Welch's estimators and Parzen's estimators are performed via multiple examples. Particular attention is paid to estimator bias and estimation error.

Preparing Specifications for Multi Axes Multi Shaker Vibration testing-Stationary and Non Stationary Conditions **Meeting Room: #221**

Mr. Zeev Sherf (Consultant)

Part 1 - Several Aspects in the Preparation of Multi Axes Vibration Testing Specifications for Airborne Systems under Nonstationary Conditions: The application of the Multi Axes Multi Shaker Vibration testing technology, the use of which is expanding in the last years, requires the establishment of a methodology for the generation of testing specifications. It is the goal of this presentation to elucidate the elements of such a technology. The presentation will use simulated data. At the beginning, the generation methods of the data will be presented. Following, analysis methods of the non stationary data both in the frequency and in the time domain will be demonstrated. Next the definition of testing conditions to simulate the non stationary field regime are discussed and applied on the simulated data. Both methods in the time and in the frequency domain are presented. Use of energy considerents in the definition of testing conditions that simulate repetitive non stationary regimes times are presented. The software used in the work, based on the OCTAVE package is also described. Several summarizing remarks conclude the presentation.

Part 2 - Several Aspects in the Preparation of Multi Axes Vibration Testing Specifications for airborne systems –Stationary Flight Conditions: The Use and Application of the Multi Axes Vibration Technology that was also included in MIL STD 810G (Method 527) is expanding slowly but constantly. Its implementation requires the handling of several tasks. The assembling of the Vibration System from a set of shakers that simultaneously excite in several directions, the attachment of the tested item to the shakers using an appropriate set of hydro spherical bearings, the operation of an appropriate vibration control system (hardware and software) that will control the simultaneous excitation work of the shakers and last but not least a methodology for the preparation of appropriate multi axes vibration testing specifications. These specifications must enable the generation of a laboratory dynamic regime equivalent to the field regime. Equivalence meaning the same regime or the same effects (fatigue damage, energy content). While the preparation of vibration testing specification for single or dual shaker single axis tests is clear, the generation of multi shaker, multi axes vibration testing specification requires the clarification of several aspects. The goal of this paper is to do this. For its achievement the vibration regime at three location on an airborne store was simulated for different flight conditions (dynamic pressures).

Air Blast and Cratering: An Introduction to the ABC's of Explosion Effects in Air and on Land **Meeting Room: #222**

Mr. Denis Rickman (USACE ERDC)

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.

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ALL 90TH S&V SYMPOSIUM ATTENDEES, AND THEIR GUESTS, ARE INVITED TO:

Hard Rock CAFE

Wednesday, November 6th

7:00pm—10:00pm

Food, Drinks, & Entertainment

	SESSION 24	SESSION 25	SESSION 26
	UNDEX Testing & Analysis 8:00am-8:45am / Unlimited Dist. A **Vibration: Failure Analysis** 8:50am-9:35am / Unlimited Dist. A Chair(s): Ms. Rebecca Grisso (NSWC Carderock) Dr. Luke Martin (NSWC Dahlgren)	**Shock Damage Assessment** 8:00am-9:10am / Unlimited Dist. A **Ballistics** 9:15am-10:00am / Unlimited Dist. A Chair(s): Mr. Brian Lang (NSWC Carderock)	**Electronics Packaging for Extreme Environments - Methods, Materials, & Analysis** 8:00am-10:00am / Limited Dist. D Chair(s): Dr. Aisha Haynes (USACE ERDC)
	THERE WILL NOT BE A CHAIR/PRESENTER MEETING. ALL PRESENTATIONS MUST BE PRELOADED IN ADVANCE OF THE SESSION (VIA SUBMITTAL TO SAVE BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).		
	Meeting Room: #213-#214	***Meeting Room: #212***	***Meeting Room: #311-#312***
8:00	**Measurement of Underwater Explosion Bubble Jetting (47)** Dr. Julian Lee & Mr. S. Halaska (Defence R&D Canada Suffield), Dr. M.J. Smith, Dr. L. Gannon, & Dr. C. Marshall (Defence R&D Canada Atlantic)	**Boundary Condition Influence on Shock Test Damage Potential (49)** Dr. Vit Babuska, Dr. Carl Sisemore, & Mr. Robert Flores (Sandia National Laboratories)	**Electronics Packaging for Extreme Environments – Methods, Materials, and Analysis (51)** Mr. James Scheppegrell, Dr. Alain Beliveau, & Mr. Dustin Landers (ARA/AFRL)
8:25	**Effect of AI/O Ratio on Underwater Explosion Load and Energy Output Configuration of Aluminized Explosive (48)** Prof. Yuanxiang Sun & Prof. Cheng Wang (Beijing Institute of Technology)	**A Method for the Damage Assessment of a Component under Crash Shock Loading (49)** Prof. Qingming Li (The University of Manchester)	**Experimental Methods for Evaluating Electronics Survivability (51)** Mr. Curtis McKinion, Dr. Matthew Neidigk, & Mr. Mark Todisco (AFRL), Dr. Ryan Lowe (ARA)
8:50	**Analyzing Field Environments to Understand Product Failure Causes (48)** Mr. Casey DuBois (Vibration Research Corporation)	**Variations in Damage from Same Shock Response Spectra (50)** Dr. Arup Maji (Sandia National Laboratories)	**Designing for High G Survivability with Potting: A New Paradigm for Choosing the Right Potting (51)** Dr. Aisha Haynes, Dr. Catherine Florio, & Ms. Melissa Jablonski (U.S. Army CCDC Armaments Center), Dr. Jacob Dodson (AFRL), Dr. Alain Beliveau (ARA)
9:15	**Examples of using the Extremes' Counting and Fatigue Damage Accumulation Methods (48)** Mr. Zeev Sherf (Consultant)	**Explosively Driven Flyer Plate Velocity Time Profiles Transformed to Internal Explosive Pressure (50)** Mr. Marcus Chavez (Sandia National Laboratories)	**Characterization of Potting Materials for Electronics Assemblies Subjected to Dynamic Loads (52)** Dr. Vasant Joshi, Mr. Colin Qualters, Mr. Ezra Chen, Mr. Reid McKeown (NSWC Indian Head Explosive Ordnance Disposal Technology Division), Mr. Jaime Santiage (NSWC IHD)
9:40		**Gurney Analysis for High Shear Mixed Silver Acetylide-Silver Nitrate Explosive on Kapton Substrates (50)** Mr. Marcus Chavez (Sandia National Laboratories)	**Dynamic Confinement Characterization of Potting Materials Under Extreme Environments (52)** Mr. Brett Sanborn (Sandia National Laboratories), Dr. Aisha Haynes & Mr. Christopher Macrae (U.S. Army Combat Capabilities Development Command - Armaments Center)

Thursday AM (November 7)

	SESSION 27 **UNDEX Numerical Methods** 8:25am-9:35am / Limited Dist. D **Rotor Dynamics** 9:40am-10:00am / Limited Dist. C Chair(s): Mr. Jacob Mason (NSWC Carderock) Mr. Tim McGee (NSWC Carderock)	*TRAINING V / USERS GROUP* **UNDEX Modeling** 8:00am-9:30am / Unlimited Dist. A	*TRAINING V I / USERS GROUP* **Simulation Driven Design and Optimization of Hull for Blast Resistant Vehicles** 8:00am-9:00am / Unlimited Dist. A *TRAINING VII / USERS GROUP* **Meshless Simulation Driven Design applied to Shipbuilding Industry** 9:15am-10:00am / 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 BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).		
	Meeting Room: #309-#310	***Meeting Room: #216***	***Meeting Room: #222***
8:00		**Training / Users Group** **UNDEX Modeling by Coupling Abaqus/ Explicit and XFlow using the Abaqus Co-simulation Engine (54)** Mr. Ozgur Yapar (Dassault Systemes Simulia Corp.) 8:00am-9:30am	**Training / Users Group** **Simulation Driven Design and Optimization of Hull for Blast Resistant Vehicles (54)** Mr. Ravi Kodwani (Altair Engineering) 8:00am-9:00am
8:25	**The Model Convergence vs. Engineering Sufficiency Tradeoff (53)** Mr. Michael Miraglia, Dr. Nicholas Reynolds, Mr. Alan Hesu, & Mr. Jonathan Stergiou (NSWC Carderock Division)		
8:50	**DDAMX Base Excitation Validation (53)** Dr. Jeffrey Cipolla & Mr. Corbin Robeck (Thornton Tomasetti)		
9:15	**DDAMX Direct Pressure Fluid Loading V&V (53)** Mr. Corbin Robeck & Dr. Jeffrey Cipolla (Thornton Tomasetti)		**Training / Users Group** **Meshless Simulation Driven Design applied to Shipbuilding Industry (55)** Mr. Carlos de Lima (Altair Engineering) 9:15am-10:00am
9:40	**Static and Dynamic Load Equalization in Self-Equalizing Thrust Bearing Linkages (54)** Dr. Richard Armentrout (Curtiss-Wright EMD)		

	SESSION 28 **Shock & Vibration Modeling & Analysis III** 10:05am-10:50am / Unlimited Dist. A **Vibration** 10:55am-12:05pm / Unlimited Dist. A Chair(s): Mr. Ernie Staubs (Air Force Research Laboratory)	SESSION 29 **Experimental Techniques for Pyroshock Testing II** 10:05am-11:40am / Unlimited Dist. A Chair(s): Mr. David S. Soine (Sandia National Laboratories)	SESSION 30 **Submarine UNDEX** 10:05am-11:15am / Limited Dist. D **Vibration: Surveys & Boundary Conditions** 11:20am-12:05pm / Limited Dist. D Chair(s): Dr. Joseph Ambrico (NUWC Newport)
	THERE WILL NOT BE A CHAIR/PRESENTER MEETING. ALL PRESENTATIONS MUST BE PRELOADED IN ADVANCE OF THE SESSION (VIA SUBMITTAL TO SAVE BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).		
	***Meeting Room:* #213-#214**	***Meeting Room:* #212**	***Meeting Room:* #311-#312**
10:05	**Rapid Estimation of a Design Change's Effect on the Root Mean Square Stress and High-Cycle Fatigue Damage Response at a Location in a Structure Under Random Vibration Loading (55)** Mr. Sean Kelly (Cummins Inc.)	**Frequency Based Substructuring on Resonant Plate (58)** Ms. Erica Jacobson, Dr. Jason R. Blough, Dr. James P. DeClerck, & Prof. Charles D. VanKarsen (Michigan Technological University), Mr. David S. Soine (Honeywell)	**Simplified ONR Cylinder Analysis Using Navy Enhanced Sierra Mechanics (59)** Mr. Jeff Roper & Mr. Matt Davis (HII Newport News Shipbuilding)
10:30	**High-Fidelity Modeling and Structural Analysis of an Additively Manufactured Component with Defects (56)** Mr. Moheimin Khan, Dr. James Justin Wilbanks, & Dr. Brian Owens (Sandia National Laboratories)	**DAQ Evaluation and Specifications for Pyroshock Testing (58)** Ms. Erica Jacobson, Dr. Jason R. Blough, Dr. James P. DeClerck, & Prof. Charles D. VanKarsen {Michigan Technological University}, Mr. David S. Soine {Honeywell}	**In-Tube Implosion Experiments (59)** Dr. Joseph Ambrico, Mr. Ryan Chamberlin, & Mr. Craig Tilton (NUWC Newport)
10:55	**SMACSONIC - An Effective Layered Damping Material (56)** Dr. James Rall (ShockTech), Mr. Laurent Mallet & Mr. Pierre Lamy (Engineering, SMAC, Toulon, France), Dr. Daryoush Allaei (CTO AE-R&D Department, ShockTech, Inc.)	**Circuit Board Shock Damage Comparison by Test Method (59)** Mr. Alexander Hardt (Northrop Grumman Innovation Systems)	**UNDEX Initiated Implosion in Shallow Water of Confined Cylinders – Experiment and Model Comparisons (60)** Dr. Joseph Ambrico & Mr. Ryan Chamberlin (NUWC Newport)
11:20	**Who Represents the Naval Vibration Regime, Mil Std 167 B or Method 514 Ctg 21 of MIL STD 810 G? Pt1 Load Cycle Counts Considerations (57)** Mr. Zeev Sherf (Consultant)	**Defining Resonant Plate Shock Test Specifications in the Time Domain (59)** Dr. Carl Sisemore (Sandia National Laboratories)	**Spectrogram Analysis of Swept Sine Survey Data Both Pre-and Post-Vibration Testing (60)** Dr. Ricky Stanfield (Northrop Grumman)
11:45	**Who Represents the Naval Vibration Regime, Mil Std 167 B or Method 514 Ctg 21 of MIL STD 810 G? Pt2 Accumulated Damage and Energy Considerations (58)** Mr. Zeev Sherf (Consultant)		**A More Realistic Approach for Boundary Conditions during Combined Random Vibration and Inertial Loading to Better Approximate Flight Environments (60)** Mr. Matthew McDowell , Dr. Richard Jepsen, Dr. Garett Nelson, Dr. Garret Lopp, & Mr. James Milam (Sandia National Laboratories)

Thursday AM (November 7)

	SESSION 31 **DYSMAS III: UNDEX Developments & Applications** 10:05am-11:15am / Limited Dist. D Chair(s): Dr. Bradley Klenow (NSWC IHD / NSWC CD)	*TRAINING VIII* **Introduction to Medium Weight Shock Testing** 10:05am-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 BEFORE THE SYMPOSIUM OR AT ON-SITE SYMPOSIUM REGISTRATION).		
	Meeting Room: #309-#310	***Meeting Room: #216***	
10:05	**Development of an Enhanced Equation of State for Tillotson Water (61)** Dr. Francis Vangessel (NSWC Indian Head)	**Introduction to Medium Weight Shock Testing (61)** Mr. Jeff Morris (HI-TEST Laboratories) 10:05am-Noon	
10:30	**Podded Propulsor Modeling & Analysis (61)** Dr. Bradley Klenow (NSWC Indian Head / NSWC Carderock)		***SAVE the Date*** *91st Shock & Vibration Symposium* *Oct 25-29, 2020* *Rosen Centre Hotel* *Orlando*
10:55	**Simulating Incompressible Materials (61)** Ms. Rebecca Grisso (NSWC Carderock)		
11:20			
11:45			

1:00-2:30	**S&V Technical Advisory Group Meeting** — **Meeting Room: #213-#214** The annual meeting of the members of the SAVE Technical Advisory Group (TAG) will convene to review the 90th S&V Symposium and discuss plans for 2020.

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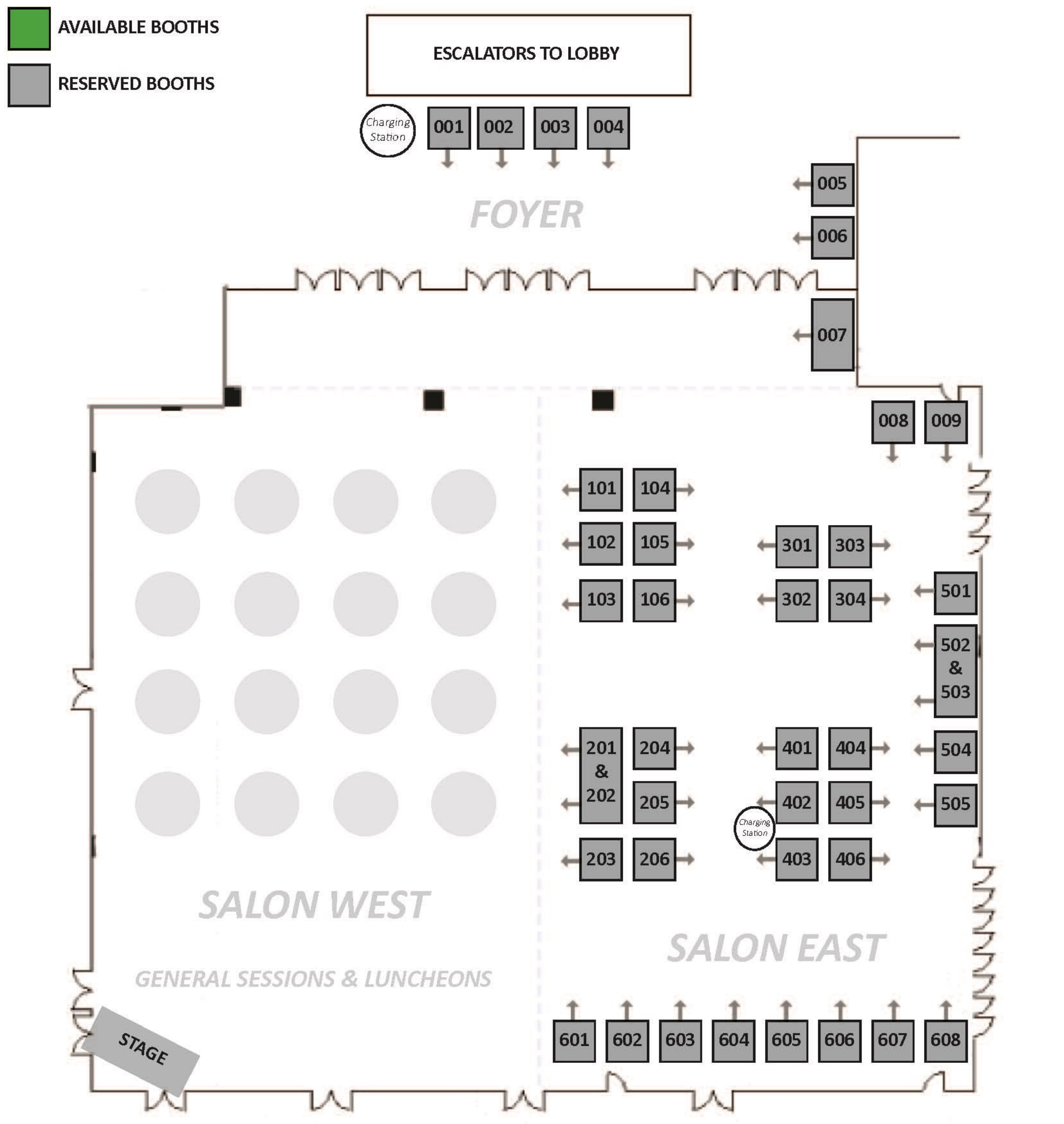
[1] *Hosting the Dinner Social (100% commercially hosted) on Wednesday Evening*
[2] *Sponsoring the Ice Cream Social in Exhibit Hall*
[3] *Sponsoring the Badge Lanyards*
[4] *Sponsoring the WiFi in Exhibit Hall*
[5] *Sponsoring the Notepads & Pens*
[6] *Sponsoring the Charging Stations*

Symposium Exhibitors (Exhibit Hill Layout)

Salon Ballroom



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.

Allied Defense Industries, Inc. (ADI) is an ISO 9001:2015 registered small business military distributor specializing in supply chain management and the provision and logistics of aftermarket spare parts to the U.S. Department of Defense, major prime contract holders/OEM's, and foreign military agencies. ADI has offered logistics support to military buying activities and their prime contractors for over 34 years.

Altair's corporate culture thrives on seeking out business and technology firsts to radically change the way organizations design products and make decisions. We are focused on the development and broad application of simulation technology to synthesize and optimize design, processes and decisions for our clients' improved business performance.

Applied Physical Sciences is a Research, Development and Engineering consulting firm specializing in Underwater Explosion (UNDEX) and In-Air Shock Analysis and Design, Ballistics, Platform Survivability, Composite Materials, Acoustics, Vibration and Marine Hydrodynamics. APS provides support, services and innovative products to the National Defense R&D community and the commercial market. APS consists of over 100 engineers (28% PhD and 44% M.S.) and technicians whose capabilities range from core mathematics and physics, theory application, design and analysis evaluation, optimization and testing.

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.

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.

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.

Founded in 1980, **Dytran Instruments, Inc.** is a leading manufacturer and designer of piezoelectric and DC MEMS sensors. Dytran offers a complete range of impulse hammers, piezoelectric force and pressure sensors, electronics, cables, and accessories for dynamic measurements, with full in-house customization capabilities.

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

Meggitt Sensing Systems is a leading supplier of high-performance sensing and monitoring systems for physical parameter measurements in extreme environments. Meggitt's **The Endevco**® range of piezoelectric, piezoresistive, Isotron® and variable capacitance accelerometers, piezoresistive pressure transducers and acoustic sensors ensures critical accuracy and reliability for shock, pressure and vibration measurements.

ETS Solutions offers affordable, high quality vibration test equipment. Utilizing extensive and innovative technical expertise ETS delivers a reliable long term solution to meet your test requirements. All systems comply with the European CE standards with full testing and certification from TUV-SUD Product Service GmbH.

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.

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. HII is also the creator of the patented Deck Simulating Shock Machine (DSSM), the newest Navy approved test method in MIL-DTL-901E.

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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!

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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.

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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.

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.

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

SINUS Messtechnik GmbH was founded 1990 and stands for robust, portable and flexible multi-channel measurement systems for the sound and vibration analysis. Our corporate philosophy of modular concepts and open systems enables us to offer an impressive product portfolio on a high technical level at fair prices, even as a small company. The Soundbook_MK2 family, in particular, combines our new 24-bit Apollo technology and the virtually indestructible Panasonic CF-19 Toughbook combined in a unique solution which allows extremely advanced real-time field analyses.

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

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.

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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.

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.

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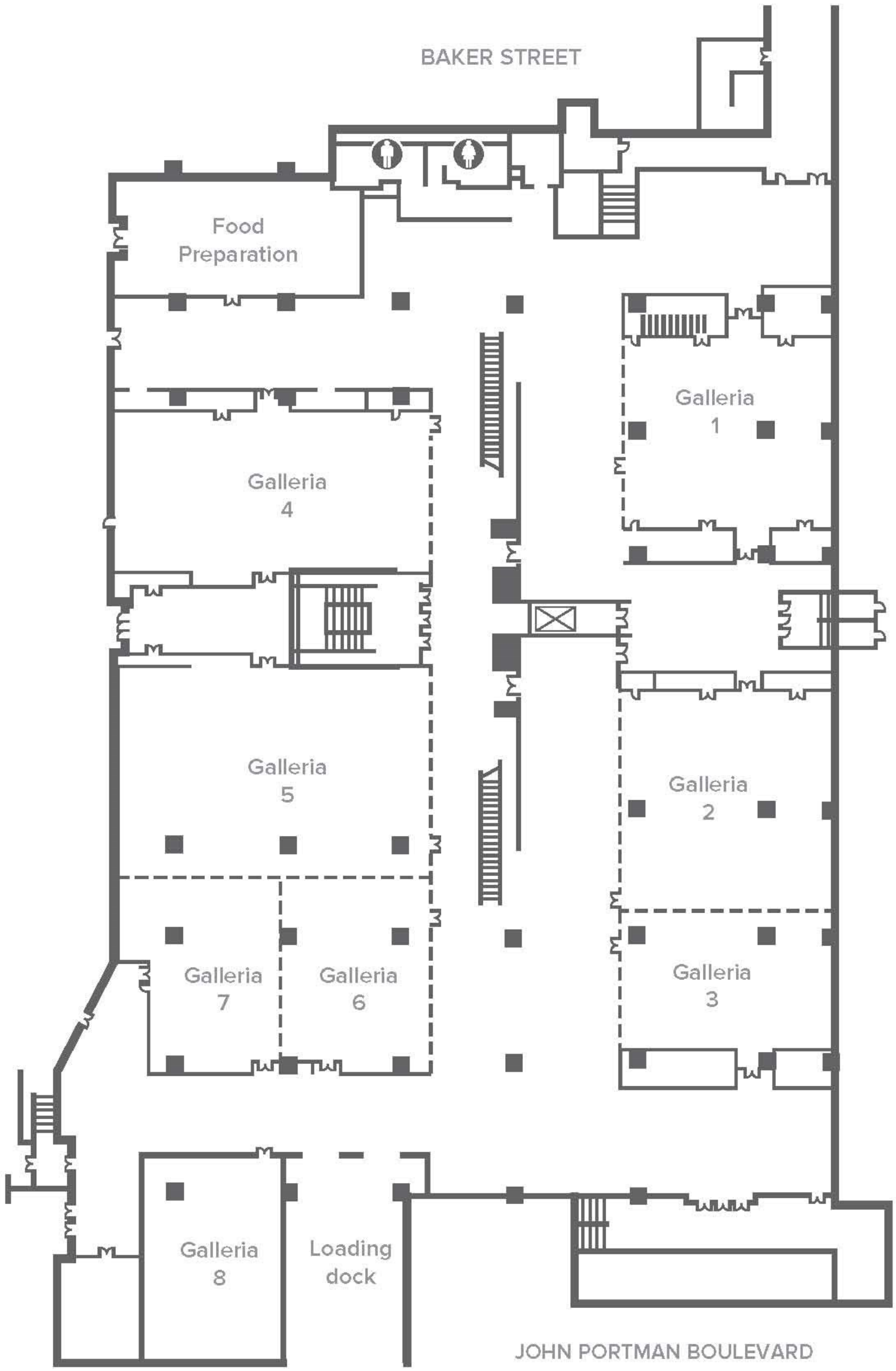
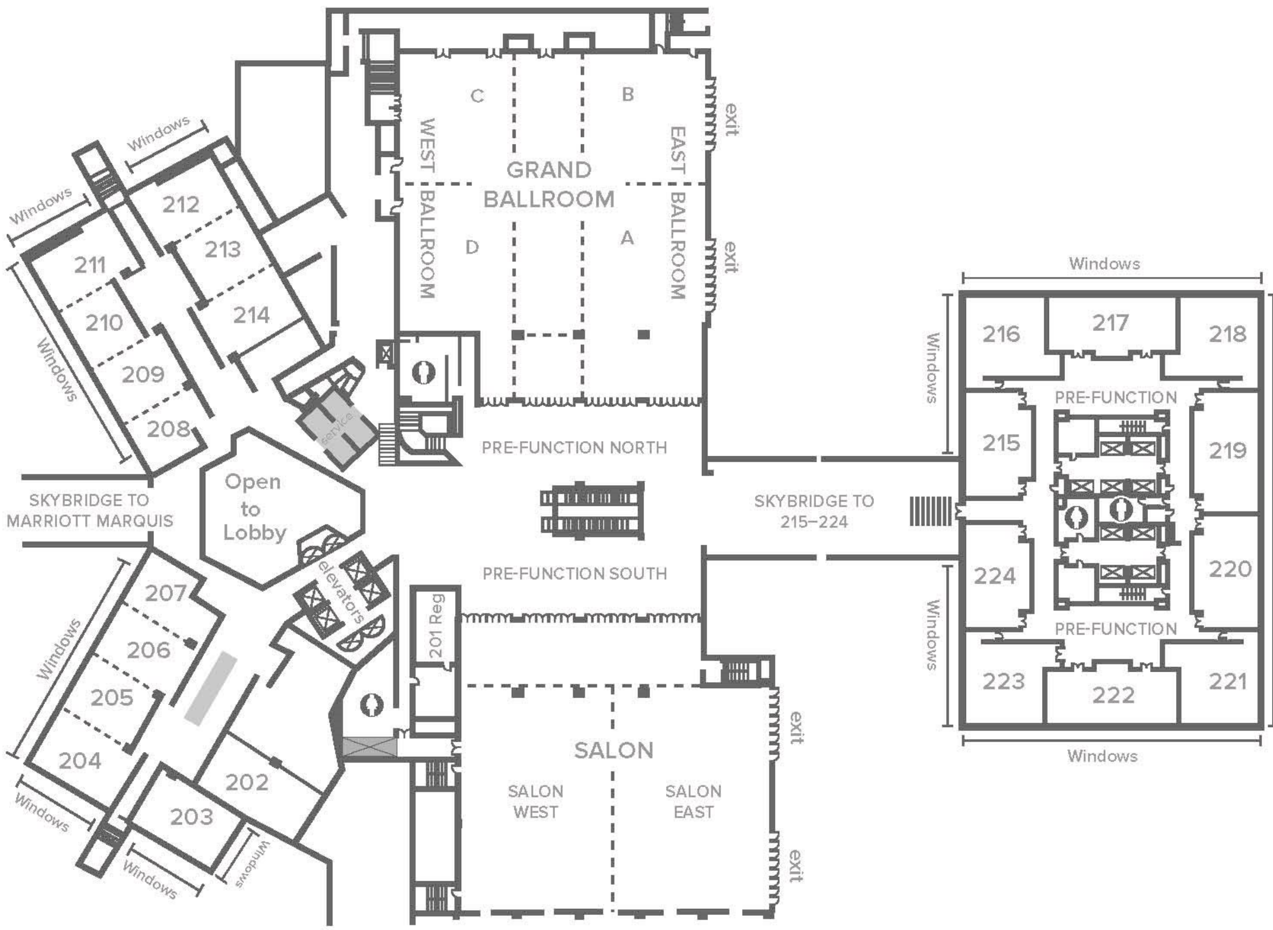
Galleria (Lower Floor)

meeting facilities

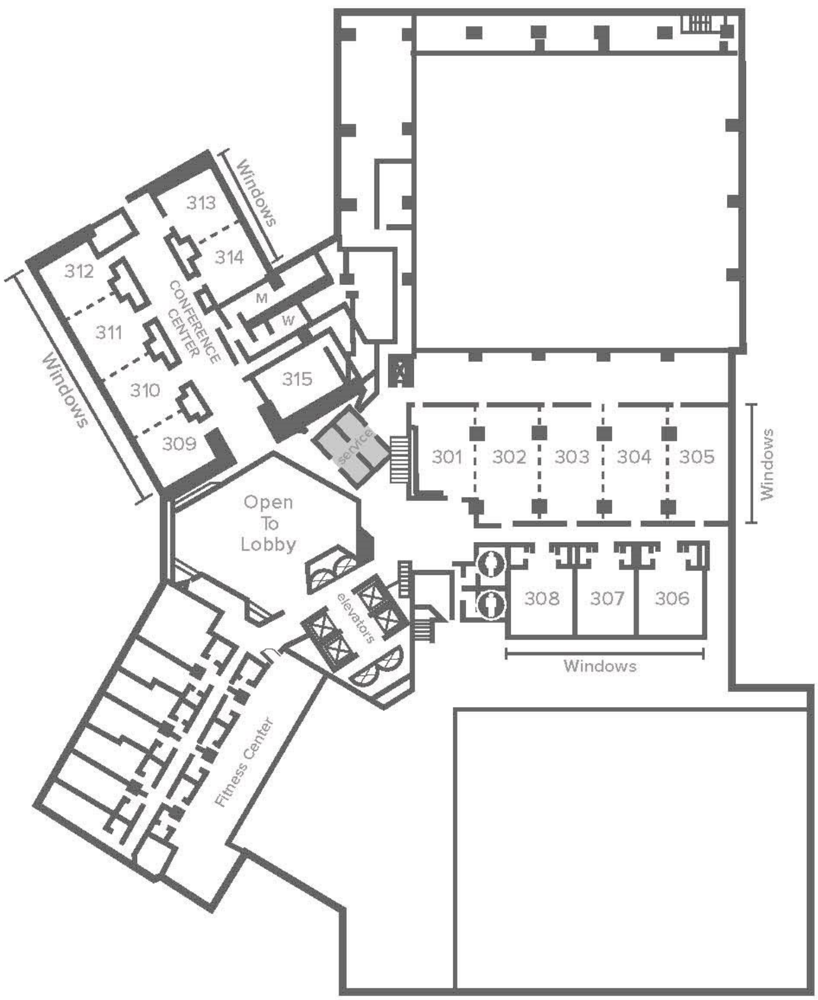


Second Floor
meeting facilities



Third Floor

meeting facilities



SAVE
SHOCK & VIBRATION EXCHANGE

ABSTRACTS

FROM THE

90TH SHOCK AND VIBRATION SYMPOSIUM
NOVEMBER 3 – 7, 2019
ATLANTA, GEORGIA

ABSTRACT BOOK
TABLE OF CONTENTS

SESSION 1: MULTIPLE-INPUT MULTIPLE-OUTPUT VIBRATION

DATA DRIVEN APPROACH FOR ESTIMATING ENVIRONMENTAL TESTING CONDITIONS AND PARAMETERS

Mr. Kevin Moreno, Virginia Polytechnic Institute and State University
Dr. Sriram Malladi, Virginia Polytechnic Institute and State University
Dr. Pablo Tarazaga, Virginia Polytechnic Institute and State University

Traditionally, environmental testing is used to certify structures or systems under harsh operational environments. Ballistic missiles, for example, need to be certified through testing for surviving high-g flight conditions without unexpected firing or detonation. However, thorough testing in a laboratory setting requires precise knowledge of the environmental parameters interacting with the structure, which is not always available. In recent literature, the Impedance Matched Multi-Axis Test (IMMAT) approach has been proposed to mitigate some of the current limitations of environmental testing. In this approach, the laboratory test parameters are determined based on modal testing and finite element models (FEM). As an extension of this, the present work investigates the use a data-driven approach to address the limitations of environmental testing. One of the advantages of this method comes from the nonrequirement of a FEM of the structure being tested. Also, the data-driven models capture more realistic test conditions (boundary conditions) of the test structure than FEMs. An experimental setup is designed to test the feasibility of the proposed approach.

The current experimental set up involves using a test structure with free-free boundary conditions and a FEM of the structure to find theoretical natural frequencies and mode shapes. Modal decomposition of the FEM was then performed to find "unique" points on the structure that could be optimal in driving the system with an exciter. A macro-fiber composite (MFC) actuator was placed where there are most "unique" points on the structure. Modal analysis was performed on the structure using the MFC and a laser vibrometer system. If the data-driven approach proves to be effective in addressing the limitations of environmental testing, then future work will include performing IMMAT on the same structure to compare the two methodologies. Experimental results from the modal analysis are presented.

EXPLORATIONS IN MULTIPLE-INPUT SHAKER SHOCK TESTING

Mr. Ryan Schultz, Sandia National Laboratories

Multiple shaker random vibration testing has gained favor in recent years due to the improved controllability and response accuracy allowed by utilizing multiple inputs at various locations and multiple-input/multiple-output control. As a typical vibration test workflow includes a range of inputs such as random vibration, sine sweeps, and shocks, it is important to extend multi-shaker test capabilities to include more than just random vibration. Several commercial control systems allow for multiple-input shock control, however this test technique is still niche. In this work, test design factors for multi-shaker shock tests are examined using simulations of an example test article. The effects of the number of shakers, their locations, and convolution errors are demonstrated and compared to a target shock response. Results of this study will provide useful guidance into how multi-shaker tests can be designed to improve accuracy of multi-input shocks.

NEW METHOD TO DETERMINE OPTIMIZED REFERENCE SDM FOR MIMO RANDOM OR ACOUSTIC TESTING
Dr. Marcos Underwood, Tu'tuli Enterprises

The new method applies generally to the field of vibration testing of test articles such as satellites, aerospace subsystems, transportation subsystems, civil structures, or any other test article whose reliability in operation may be evaluated using either mechanical or acoustic vibration testing. Specifically, the new method relates to the use of either: direct field or reverberant chamber acoustic testing systems (acoustic); or multiple-exciter (mechanical) testing systems to perform vibration testing. The new method improves the ability of MIMO acoustic testing systems to produce an acoustic field conforming to a predetermined initial reference specification and MIMO mechanical testing systems to produce vibration responses conforming to a predetermined initial reference SDM specification in the least mean-square error (LMSE) sense, with the minimum drive energy, by modifying the coherence and phase off-diagonal terms of the initially defined reference SDM to approximate its initially defined off-diagonal terms in the LMSE sense, yet maintaining its initially defined diagonal terms exactly, while better accounting for physical limitations that may exist in the MIMO testing system and/or facility, or in the MIMO control system. The method enables the ability of the overall testing system, for either the acoustic or mechanical MIMO vibration test, to thus to better match the initially defined diagonal PSD terms of the initially defined reference SDM, while approximating the initially defined off-diagonal terms in the LMSE sense, than previous methods that don't account for the coherence and phase of the initially defined reference SDM.

COMBINED SHAKER-ACOUSTIC VIBRATION TEST TECHNIQUES
Mr. Ryan Schultz, Sandia National Laboratories
Dr. Peter Avitabile, University of Massachusetts Lowell

Ground-based vibration testing is critical to the assessment of aerospace components and systems subjected to field acoustic or aero-acoustic environments. Traditionally, ground-based testing of these environments accomplished either with single-axis shaker testing or reverberant chamber acoustic testing. However, neither test method is perfect, with each having limitations due to mismatches in boundary conditions and load paths or the inability to achieve very high sound pressure levels. Here, a combined multi-shaker and acoustic vibration test technique is presented. This test technique utilizes the benefits of mechanical and acoustic inputs to achieve a desired response. While this combined-inputs test is similar to other multiple-input tests, the combination of shaker and acoustic inputs presents unique problems, for example in the distribution of input energy between the different types of inputs. To remedy this issue, an adaptive gain algorithm is presented which allows for automatic biasing of input energy to shaker or acoustic inputs. These techniques are demonstrated using simulations and also with experiments. Results indicate that combining shaker and acoustic inputs can provide a high accuracy vibration test with reduced input requirements over shaker-only and acoustic-only tests.

SESSION 2: BLAST I

ENHANCEMENTS IN VERSION 2 OF THE SCENARIO AND TARGET-RELEVANT EXPLOSIVE EQUIVALENCE TOOL: STREET

Ms. Michelle Yokota, BakerRisk
Mr. David Bogosian, BakerRisk
Mr. Arturo Montalva, Stone Security Engineering

Explosive equivalence is an expedient method for estimating blast loads from explosive charges composed of something other than a standard reference material. The weight of the given material is converted to an equivalent weight of a standard reference material which has been extensively characterized in terms of blast pressure and impulse as a function of scaled standoff. While approximate, this approach is straightforward and has been implemented in numerous government manuals, including UFC 3-340-01 and 3-340-02.

In recent years, the STREET tool has been developed as a means of collecting explosive equivalence data from numerous individual sources into a single easily-accessible software package. The tool was initially released in 2016, but has now been released as version 2.0 with additional functionality and enhanced features. The primary enhancement allows the user to calculate equivalent weight not only with regard to TNT (the typical standard reference explosive) but also Composition C-4. A number of new materials have also been added to the database, which now covers 148 different explosive compositions. The majority of these are improvised or home-made explosives (HMEs), but some are munitions grade explosives. The tool captures the sensitivity of equivalence to scaled standoff, a feature most strongly evident for HMEs, and it also provides estimates of uncertainty based on the scatter in the test data. It now provides reference data in tabular form from a dozen published references (government manuals and textbooks), which can be compared to the test data at the heart of the database.

The presentation will explain the principles underlying the code, particularly the methodology used to calculate C-4 equivalence; give an overview of the data contained; and illustrate the code's functionality. By using STREET, analysts, scientists, and engineers will have ready access to a comprehensive collection of equivalence data for a wide range of explosive materials.

RESIDUAL CAPACITY OF RC BEAMS SUBJECTED TO IMPACT LOADING

Dr. Joosef Leppanen, Chalmers University of Technology
Dr. Morgan Johansson, Norconsult AB and Chalmers University of Technology
Dr. Mathias Flansbjer, RISE Research Institutes of Sweden and Chalmers University of Technology
Mr. Fabio J. Lozano, Norconsult
Mr. Josef A. Makdesi, Sweco

Reinforced concrete is commonly used for protectives structures and how impact loading affects the structural response is an important issue. Knowledge gained from static loading is often also used in the design of impulse loaded structures. However, the response of an impact loaded structural member may be very different compared to a statically loaded one. Consequently, the plastic deformation capacity and failure modes of concrete structures can be different when subjected to impact loads; and hence it is not sure that the observations obtained from static loading are also valid for impact loading.

The aim of this paper is to study the residual capacity in reinforced concrete beams after they were first subjected to impact loading. Drop weight impact tests of 12 beams were carried out and the residual capacity were tested in three-point bending after the impact; six beams were statically tested as references. The beams were simply supported with a span length of 1.0 m and dimensions 0.1 x 0.1 x 1.18 m. The drop weight had a mass of 10.1 kg and was dropped from heights 2.5 m or 5.0 m. A high-speed camera, with 5 000 fps, was used during the impact tests. From the images obtained, digital image correlation (DIC) analyses were conducted, and deformations and crack propagation of the beams were measured.

The results showed, that the crack formation depended on the type of loading. For the statically loaded reference beams, mainly bending cracks occurred, while for impact loaded beams, distinctive diagonal shear cracks also formed below the impact zone and approximately midway to the support. In addition, initial bending cracks developed in the upper part of the beam during impact; which later closed.

The total plastic deformation capacity increased for beams first subjected to drop weight impact tests from a drop height of 5.0 m. For the lower drop height, the plastic deformation capacity was in the same order of magnitude as for the statically loaded reference beams. Bending failure were expected in all beams. However, one of the impact tested beams exhibited a shear failure at a significantly reduced load level when it was afterwards subjected to static loading; indicating that there might be a risk of reduced residual load capacity for impact loaded structures.

DROP TESTING OF THE EXPEDIENT RETROFIT FOR EXISTING BUILDINGS (EREB) SYSTEM ON A SMOOTH SYSTEM

Dr. Genevieve Pezzola, US Army ERDC
Ms. Mya Chappell, Brigham Young University
Mr. Thomas Carriveau, US Army ERDC

Current state-of-the-art practices for blast retrofits include a variety of techniques that require either saturants or epoxies that are temperature dependent and take days to cure, pre-measuring of the building to be retrofitted, or power tools for anchoring the system into the building. These requirements are not only cumbersome but impractical for use by Soldiers in a contested environment. The Expedient Retrofit for Existing Buildings (EREB) system was developed by the U.S. Army Engineer Research and Development Center to provide soldiers with a ballistic and blast retrofit that eliminates these requirements. EREB is modular in both height and width and can be installed within hours without any special tools or pre-measuring. Multiple series of drop tests were conducted to determine EREB's ability to stop secondary debris from a blast. EREB's effectiveness when installed on a smooth surface is presented. Secondary debris velocities ranging from 40 to 60 feet per second for hollow CMU blocks as well as dense stones were simulated. The results from the drop tests are presented, including the displacements and damage inhibited by the simulated secondary debris.

THE EFFECT OF CHARGE DIAMETER TO RATIO ON TRANSFERRED SHALLOW BURIED BLAST IMPULSE

Dr. John Reinecke, CSIR
Mr. Mzwandile Mokalane, CSIR
Ms. Rayeesa Ahmed, CSIR
Prof. Ian Horsfall, Canfield University, Defence

This paper presents the use of target force-time impulse response to determine the effect of the change of diameter-to-height ratio (D:H) of shallow buried flat cylindrical blast charges.

Most published work regarding the blast loading effects of charge geometry on a target are based on warheads which have relatively small diameter to length ratios (Baker ; Swisdak ; Cooper). Landmines differ markedly by having large diameters and small lengths. This diameter-to-height ratio (D:H) varies and is reflected in differing surrogate charge threat specifications for protection assessment standards. The standard assessment threats are generally based on the primary perceived threat of the particular nation.

The NATO landmine protection assessment standard, Allied Engineering Publication 55 (AEP-55) Volume 2, specifies three levels of blast threats all with a D:H of three-to-one (3:1) while the South African protection standard, RSA-MIL-STD-37, specifies a single level blast threat with a D:H of five-to-one (5:1). As live-fire protection assessments are extremely expensive, equivalence between different threats is required when evaluating competing bidders for protection technology procurement from nations who have different threat standards.

A Geometrically Similar Scaled blast rig (Reinecke, Horsfall, and Snyman) was used to quantify and evaluate the effect of charge D:H ratio on the impulse transferred to an intermediate-field target when subjected to a shallow buried blast-load. The scaled test rig measures the force-time response of a rigid target which is integrated to give the impulse response of the target from the blast load. A range of three D:H ratios were tested (Reinecke). The scaled impulse results were compared to similar, but not geometrically scaled, full sized shallow buried force-time impulse data (Snyman and Reinecke ; Turner).
The results clearly indicate an increasing target response impulse with increasing charge D:H ratio for a given Depth-of-Burial (DOB). Expanding this research to include damage effects as well as a range of DOBs enables equivalence to be drawn between differing landmine protection assessment standards.

SESSION 3: TESTING & ANALYSIS OF FUZE TECHNOLOGY FOR EXTREME ENVIRONMENTS I

CHARACTERIZING THE MECHANICAL PROPERTIES AND DYNAMIC RESPONSE OF G-SWITCHES

Mr. Curtis McKinion, AFRL
Mr. Mark Todisco, AFRL
Dr. Jacob Dodson, AFRL
Mr. Shane Curtis, AFRL
Mr. Joshua Dye, AFRL

The Air Force Research Laboratory in collaboration with Sandia National Laboratories are advancing smart embedded fuze technologies. One enabling technology is the mechanical g-switch used as an inertial sensor. Many parameters of the g-switch are estimated or unknown, such as: spring stiffness, preload, internal mass, distance to close the g-switch, and damping. A series of experiments are performed to characterize these parameters to enable accurate models for design of smart algorithms. Shock experiments are also performed on g-switches to evaluate the dynamic response. Understanding these properties of the g-switch will allow for improvements in embedded fuzing systems.

EVALUATION OF THE DYNAMIC TENSILE FAILURE IN PRESSED ENERGETIC SIMULANTS

Dr. Alain Beliveau, Applied Research Associates
Mr. Jonathan Hong, Applied Research Associates
Dr. Jacob Dodson, AFRL
Mr. Eric Welle, AFRL

The response of pressed energetic material to high-amplitude loading can lead to dynamic tensile failure, or spalling. Techniques used in determining the dynamic tensile behavior of geomaterials are used to assess the spall strength of various pressed explosive simulant and identify parameters of interest in improving pressed explosive material approaches for high-g applications. This work uses the spall tension approach based a Hopkinson bar technique and presents the experimental setup along with preliminary results.

EXPERIMENTAL METHOD FOR EXTENSION OF PULSE DURATION USING HYDRAULIC DRIVING FORCE

Dr. Lauren Stewart, Georgia Institute of Technology
Dr. Nan Gao, Georgia Institute of Technology
Ms. Rebecca Nylen, Georgia Institute of Technology

Weapons undergo long duration, high amplitude, multiaxial decelerations during the penetration of targets. This imparts momentum on the entire weapon system, which is correspondingly reduced due to the penetration resistance of the target. Even for the rigid body, the inertial deceleration forces can exceed 10,000 g and remain above that threshold over a long duration, often well in excess of 5 ms. The corresponding change in velocity typically requires ballistic or operational testing. Both testing methods are extremely costly, personnel intensive, and introduce both technical and safety risks. A new experimental technique was developed to extend pulse durations over those typically achieved by current laboratory methodologies that involve solely a transfer of momentum and energy via collision. This technique, which uses hydraulics as a driving force drives the specimen through a buffer material to increase the duration. In a relatively low velocity, prototype study (10 m/s), the technique was shown to increase the duration by 35% over the traditional impact method. Most importantly, these collective prototype experiments demonstrated the ability to control the waveform and demonstrated the unique capability of the system to actively drive the specimen into the buffer material, thus extending pulse durations that are not achievable with other testing techniques that involve solely a transfer of momentum and energy. This was accomplished without considering different buffer materials or adjusting the existing driving force, which could provide additional flexibility in generating the desired acceleration wave form.

SMALL-SCALE TESTING OF ELECTRONIC COMPONENTS IN SHOCK LOADING

Dr. Salil Mohan, NSWC Indian Head
Dr. Vasant Joshi, NSWC Indian Head
Mr. Raafat Guirguis, NSWC Indian Head
Mr. Reid McKeown, NSWC Indian Head
Mr. John O'Conner, NSWC Indian Head
Ms. Marie-Urlima Okeke, NSWC Indian Head

Survivability evaluation of electronic assemblies in fuze environment subjected to high impact requires dynamic characterization techniques, which can adequately impose required loading conditions to the printed circuit board assemblies. Different test setups may be required to evaluate response of fuze under various high G levels. While conventional mechanical test system may provide some level of loading, efforts are underway to have single shot high G loading as well as multi shot lower G loading for better understanding of printed circuit board failure. With advent of new non-conventional ways of impact mitigation materials, and higher velocities of munitions, requirement of higher levels of survivability of fuze assemblies have generated need of new test setups, which are capable of imparting even higher levels of acceleration. The test setup must also be capable of providing oscillatory as well as non-oscillatory acceleration, since higher frequency oscillations can cause most damage to the fuze circuit. We have developed a Hydro bulge test for imparting very high levels of acceleration in the shock regime, which is a relatively simple, single-shot test, based on a calibrated metal tube, expanding rapidly due to hydraulic pressure from inside. The test is modeled and calibrated with high-speed streak imaging in experimental setup. Details of this new experimental technique along with the modeled simulations will be presented.

UTILIZING HOPKINSON BAR FOR HIGH-G, HIGH-FREQUENCY MECHANICAL SHOCK TESTS

Mr. Bo Song, Sandia National Laboratories

Since it was invented a century ago, Hopkinson bar has been extensively utilized in shock or impact tests of materials, components, and small-scale structures. Currently, the primary application of a modified Hopkinson bar technique – split Hopkinson bar (or Kolsky bar) – is to determine dynamic stress-strain response of materials at strain rates on the orders of 102 to 104 s-1, under different loading modes, i.e., compression, tension, or shear. In the past decades, efforts have been put to the Hopkinson bar technique for extended applications, such as high-g, high-frequency mechanical shock tests. Complementary to the traditional drop table or resonant beam/plate tests, the Hopkinson bar is capable of actuating the test articles to higher g-level (up to ~100,000 g) and/or higher frequency (up to ~100,000 Hz) for simulating more severe mechanical environments for components. However, the Hopkinson bar tests need to be carefully and appropriately configured and designed to meet the test requirements. In this presentation, an overview of the Hopkinson bar technique will be given and followed with a focus of variable designs and configurations for high-g, high-frequency mechanical shock tests.

SESSION 4: MECHANICAL SHOCK I

FACTORS INFLUENCING THE DESIGN OF A SHOCK ISOLATED FALSE DECK (SIFD) PRINCIPAL UNIT

Dr. Michael Talley, HII Newport News Shipbuilding
Mr. Chris Campbell, HII Newport News Shipbuilding
Mr. Michael Parnin, HII Newport News Shipbuilding

This paper describes the factors that influence the design of a shock-isolated false deck (SIFD) principal unit (PU). The basic SIFD PU design couples distributed shock and vibration isolation with flexible infrastructure (FI). Factors, such as the SIFD design variables and their constraints, including test facility capabilities, are identified and evaluated for significance. Factors considered significant were included in the SIFD PU design objective statement. Alternative designs were then identified and a matrix of simulation runs was developed to support sensitivity analyses and converge on a PU design.

SUPPORTING TRANSIENT ANALYSIS TO CONVERGE ON A SHOCK ISOLATED FALSE DECK (SIFD) PRINCIPAL UNIT DESIGN FOR ENVIRONMENTAL QUALIFICATION TESTING

Mr. Chris Campbell, HII Newport News Shipbuilding
Mr. Michael Parnin, HII Newport News Shipbuilding
Dr. Michael Talley, HII Newport News Shipbuilding

This paper describes the supporting transient analysis to converge on a shock-isolated false deck (SIFD) principal unit (PU). The analysis performed included the following: 1) execution of a simulation run matrix that included variations of the design variables to converge on a PU design; 2) identification of SIFD PU design assemblies that need to be demonstrated by test to support model validation; 3) and development and simulation of virtual test scenarios using a higher fidelity FE plate model to verify SIFD PU design assemblies. Examples of analyses of SIFD PU test assemblies are also presented and discussed.

ALTERNATIVE TEST METHODS: OVERVIEW OF BALLASTED SPRING DECK FIXTURE RESEARCH

Mr. Matt Davis, HII Newport News Shipbuilding
Mr. Rick Griffen, Consultant

The Ballasted Spring Deck Fixture (BSDF) is a cost-saving test alternative to the floating shock platform that utilizes the medium weight shock machine. Over the last decade, significant research and development has been conducted with this fixture to provide an alternative test method that demonstrates an excellent alternative to the deck-simulating fixture for a wide range of candidate test items. This paper provides a review of the research surrounding this capability presented at the SAVE symposium to date and explores the key takeaways in the supporting research to inform follow-on presentations.

ALTERNATIVE TEST METHODS: CLASS I AND II PERFORMANCE TESTING ON THE BALLASTED SPRING DECK FIXTURE

Mr. Matt Davis, HII Newport News Shipbuilding
Mr. Rick Griffen, Consultant

The Ballasted Spring Deck Fixture (BSDF) is a cost-saving test alternative to the floating shock platform that utilizes the medium weight shock machine. Over the last decade, significant research and development has been conducted with this fixture to provide an alternative test method that demonstrates an excellent alternative to the deck simulating fixture for a wide range of candidate test items. This paper provides an overview of the representative Class I and Class II performance testing conducted on the BSDF. The test overview, execution and a high-level evaluation of the performance data are discussed.

ALTERNATIVE TEST METHODS: CLASS I AND II ACHIEVED PERFORMANCE CAPABILITIES OF THE BALLASTED SPRING DECK FIXTURE

Mr. Matt Davis, HII Newport News Shipbuilding
Mr. Rick Griffen, Consultant

The Ballasted Spring Deck Fixture (BSDF) is a cost-saving test alternative to the floating shock platform that utilizes the medium weight shock machine. Over the last decade, significant research and development has been conducted with this fixture to provide an alternative test method that demonstrates an excellent alternative to the deck simulating fixture for a wide range of candidate test items. This paper provides a deep dive into the performance capabilities of the BSDF to sufficiently test Class I and Class II equipment. The research to date provides objective quality evidence for testing Class I, II, I/II, and III equipment can be sufficiently challenged on the BSDF for a large range of test masses and frequencies as low as 4 Hz. This test method provides a cost-efficient alternative to testing equipment where other machines may be limited in applicability due to equipment frequency restrictions or simply cost restrictions. This paper provides test performance comparisons to the deck-simulating fixture objectives as well as recommended equipment size and frequency restrictions for successful use.

VENDOR SESSION A: CASE STUDIES, NEW DEVELOPMENTS/TECHNOLOGIES, TESTING, PRODUCT INFO, AND SERVICE PRACTICES

PROTECTIVE MONITORING FOR VIBRATION APPLICATIONS

Mr. Chris Wilcox, m+p International

A summary examination of the advantages and risks associated with using protective monitoring schemes for system-wide vibration testing. Over-protection, shaker interlock, and circular buffer recording systems are examined as well as real examples of failed tests and how they may be prevented in the future.

SIMPLE SYNCHRONIZING AND PLAYBACK OF HIGH-SPEED VIDEO AND SENSOR DATA

Mr. Shane Kirksey, Photron

Easily synchronize, record, and playback analog sensor and video data with Photron's intuitive software. This helpful software add-in is compatible with several National Instruments data acquisition devices and aids the end user in combining quantitative and qualitative data in one, easy-to-view format. Once the event is over, one can analyze data within seconds; customizing the views to fit application specific needs. Importing and exporting .csv files is straightforward allowing quick dissemination of information to determine if additional testing or adjusting of an experiment is required.

MULTI-RESOLUTION SPECTRUM ANALYSIS

Mr. Matt Millard, Crystal Instruments

Narrow band Fast Fourier Transform (FFT) spectrum analysis is widely used to analyze time domain data. Narrow band spectrum analysis by default produces a spectral resolution that is evenly spaced across the bandwidth measured. This type of evenly spaced resolution is not ideal in all cases. In many applications it is desirable to have increased resolution at lower frequencies. Crystal Instruments will introduce the concept of multi-resolution spectrum analysis, a software analysis tool that provides improved resolution at lower frequencies and illustrate use case examples.

A HIGH RESOLUTION BROADBAND ACCELEROMETER

Mr. Andy Hohla, Endevco

Piezoelectric accelerometers have long been used in applications that require high frequency measurements. Over the years, as test requirements have grown increasingly demanding and new applications have arisen, the need for higher and higher frequency response limits has increased. This year Endevco has added the model 7250B to its line of high frequency accelerometers, with capabilities up to 40KHz. Measurement principles and test results for the 7250B will be presented.

PERFORMANCE CHARACTERISTICS OF PIEZOELECTRIC & PIEZORESISTIVE PRESSURE FOR BLAST APPLICATIONS
Mr. Bob Metz, PCB Piezotronics

Quartz piezoelectric and silicon MEMS piezoresistive transducers are used for air-blast pressure measurements. This presentation will objectively compare strengths and weaknesses of MEMS and ICP pressure transducers focused only on their applicability to the air-blast environment. The analysis considers measurement errors found in air blast, which include thermal transients and acceleration/strain. Transducer performance parameters of dynamic range, ruggedness/survivability, frequency response, and self-check will also be reviewed.

TRAINING I

MANUFACTURING PROCESS EFFECTS ON THE PERFORMANCE OF FASTENERS IN SERVICE
Mr. George Avery, NSWC Philadelphia

Mechanical joints are an integral part of industry. They can be found in almost every engineering application from deep sea to deep space. Initially, the performance of fasteners in mechanical joints was assessed empirically through experimentation and the core data of those experiments has been relied upon by industry for over 70 years. Current advances in computer modeling allow for finite element modeling of mechanical joints to determine in service stresses for almost unlimited applications. This new capability greatly reduces the time needed for both design and testing which reduces costs and increases the efficiency of structural assemblies. One blind spot of this new approach is that computer models assume ideal material conditions unless other- wise specified in the model. Fasteners can be prone to a wide range of material defects due to design and manufacturing processes. Some of these defects are not easily detected and make themselves known only when the mechanical joint is in service and presents a risk to the individuals around it. The following presentation will describe fastener limitations created from design, manufacturing processes, and corrosion that reduce the capability of the fastener from starting from procurement to in service operation and safety factors associated with those limitations.

SESSION 5: SHOCK & VIBRATION MODELING & ANALYSIS I

A NOVEL DISTRIBUTED FORCE VIBRATION TEST SYSTEM CONFIGURATIONS - A PROGRAM
Mr. Eliahu Elmalah, Consultant

A novel technique is developed for vibration testing of flown captive or free flight of stores. The stores may be deployed on aircrafts or free flown as missiles or rockets or other flying stores, such as space crafts with fairings. It is the purpose of this article to set a program and relevant parameters for the development of this novel vibration system. The approach is directly dealing with the basics of flight aerodynamics.

At the present vibration simulation uses high rated big shaker/s (1to10 shakers, given the new multi shaker procedure of MIL 810 and others), or uses from time to time very expensive and low unavailability acoustic reverberant chambers. In this investigation we chose to simulates the forces involved during the flight. The simulation system comprises many very small shakers (8 to 100N) or comparable small pneumatic hammers tailored according to the real (or approximately real force distribution, depending on the envelope area discretization of the specific store. The proposed system is very flexible, allowing different configurations. Using small forces prevents totally the over test inherent when using big shakers as well as changing totally the store configuration by the attachment of big and heavy fixtures. In the proposed system, the store is suspended or free simulating the boundary conditions as in the real application. Almost no extra mass or rigidity is added to the tested store, resulting very similar dynamic response of the store. Since there are many inputs the system has the potential to present a better simulation of the whole store.

Assessment of Flight Vibration versus Reynold's Number for Black Brant IX Sounding Rockets
Dr. Ricky Stanfield, Northrop Grumman

The flight vibration environment for sounding rocket class vehicles has been characterized using several approaches through the years. From the mid 1970's to 2000, the environments were based on NASA hand-calculated power spectral density data of flight vibration measurements. From 2002 to 2017, work was started to trend flight vibration environments against common flight analysis parameters, such as flight dynamic pressure. This has been done within individual classes of sounding rocket vehicles and across the set of several sounding rockets classes. Trends have been good and have allowed the estimation of fight vibration environments for new sounding rocket configurations based on their predicted dynamic pressure profiles. To resolve small trend inconsistencies, the investigation sought other expressions for dynamic pressure which ultimately pointed back to Reynold's Number as a better reference for comparison. In this paper, we discuss the correlation between flight vibration magnitude and Reynold's Number and Dynamic Pressure for the Black Brant IX class of sounding rockets. We compare these same parameters other classes of sounding rocket vehicles.

Development of Weapon Abnormal Environment High-G Shock Testing Bridging the Gap Beween Actuator Testing and Rocklet Sled Track or Flight Testing
Mr. Patrick Barnes, Sandia National Laboratories

Test Engineers at the Mechanical Shock Facility have recently noted an interest in increasing the amplitude for abnormal environment specifications for mechanical shock, particularly in weapon safety components and flight test hardware; as such, a new capability has been developed to bridge the gap between relatively inexpensive and straightforward 20-inch Actuator shock tests and more complex and expensive rocket sled track or flight tests. Namely, the Mechanical Shock Facility at Sandia National Laboratories in Albuquerque, NM has developed a shock testing capability with its 6-inch Gas Gun to conduct high-g shock testing partnering with the Photometrics department to provide qualitative and quantitative high-speed video of the event. The high-speed video can measure acceleration, which is used as an independent measurement source to validate accelerometer data; additionally, the capability can compare the responses captured on high-speed video to model predictions, a diagnostic that is difficult to implement in a system-level test. Predictive tools have also been developed that assist engineers in designing fixtures, predicting pulse-programming material values, and predicting the amplitude, duration, and required impact velocity from test to test.

Exploring Margins of Safety for Bolted Joints Undergoing Random Vibration Environments
Dr. Justin Wilbanks, Sandia National Laboratories
Dr. Brian Owens, Sandia National Laboratories

Bolted joints are ubiquitous features of complex dynamic systems. In many applications, these bolts are subject to random vibration due to the environments in which the host system operates. Often these bolts are a critical point of failure for the host systems. Therefore, in the design of these dynamic systems it is beneficial to determine a conservative, yet meaningful, measure of the margin of safety of the bolts undergoing excitation from a random vibration environment. Acceleration spectral densities (ASDs) of random vibration environments are applied to an asymmetric geometry with a bolted joint to explore different measures of the margins of safety of the bolts. A method is obtained to provide a conservative estimate for the margins of safety of the bolts of the system to provide a reasonable conclusion on whether the bolts will yield or fail during the system's operational life. Forces and moments acting at the bolt when undergoing the random vibration environment are extracted from a modal-based structural dynamic analysis with simplified bolted connections. The resulting bolt loadings are used to determine representative margins of safety for each bolt of the assembly, which can be used to provide a reasonable conclusion on bolt yielding and failing during system operation in the environment.

IMPLEMENTATION OF PEAK COUNTING METHODS AND FATIGUE DAMAGE EVALUATION IN RANDOM LOADS REGIME WITH OCTAVE

Mr. Zeev Sherf, Consultant

The planning of equivalent damage laboratory vibration testing conditions requires the control of the load cycles counting methods , of appropriate fatigue models and their combination .The peak counting in regimes of random loads based on the PSD of the load is performed by implementing a mathematical apparatus developed by Rice [1], that was also summarized by Bendat in [2]. This apparatus enables the evaluation of the peaks' probability density pdpk(xp) , the cumulative probability density and the probability ppk(xp) of the load's peak xp to appear in the interval x , x+Δx. Also the total number of peaks per time unit Np can be evaluated. Given ppk(xp) , Np and T the number of peaks at level xp, np can be evaluated . This together with a appropriate fatigue law enables the evaluation of the accumulated damage. The loads counting can be implemented based on an existing mathematical apparatus. The paper will describe the methodology and the modules written in OCTAVE for its implementation.

SESSION 6: INSTRUMENTATION I

CHARACTERIZATION AND COMPENSATION FOR TRANSVERSE SENSITIVITY IN SHOCK ACCELEROMETERS

Dr. Bryan Joyce, NSWC Dahlgren
Mr. Garrett Wiles, NSWC Dahlgren
Mr. Sloan Burns, NSWC Dahlgren
Mr. Jon Yagla, NSWC Dahlgren

This paper summarizes techniques in the literature for characterizing in-axis and cross-axis responses of shock accelerometers. The authors examine methods to use accelerometer data from Hopkinson bar tests to digitally reduce the contribution from the sensor's transverse sensitivity on its measured response. This paper also compares the traditional in-axis and cross-axis calibration methods using only the peak output voltages and accelerations to methods using time-domain and frequency response function curve-fitting which use the full voltage and acceleration time histories.

COMPARISON OF PIEZOELECTRIC AND FOIL STRAIN GAUGES FOR APPLICATIONS IN SHOCK AND VIBRATION STRAIN DETECTION

Mr. Robert Ponder, NSWC Dahlgren
Mr. Sloan Burns, NSWC Dahlgren

Strain measurements provide critical information on the stresses experienced by a test article during shock and vibration. Historically strain has been recorded using foil strain gauges. These sensors are restricted by a complex and time consuming application process, a lack of reusability, and a poor signal-to-noise ratio. It is desirable to find an alternate strain sensor that is simpler and faster to apply, provides an adequate signal-to-noise ratio, and is reusable. Piezoelectric strain gauges provide a suitable substitute for foil strain gauges as they are easily adhered to a structure and produce measurements with high signal-to-noise ratios, especially in high frequency, low strain environments.

This work presents an experimental comparison between a commercial piezoelectric strain gauge and a foil strain gauge. The author intends to show that the piezoelectric strain gauge is an effective substitute to the foil strain gauge. Experimental results will be used to support the argument that measurements from the piezoelectric strain gauge are at least comparable to the foil strain gauge, and maybe better suited for certain applications. In this study, Laboratory analysis was performed on a cantilever beam instrumented with both sensor types in vibration and shock environments. An application case study of a gunfire event was also used to compare the two sensor types. The projected impact of this study is to improve effectiveness of data collection for strain sensing in a range testing environment by evaluating the performance of multiple sensor types.

IMPLEMENTING IN-HOUSE PIGGY-BACK SHOCK ACCELEROMETER CALIBRATION

Dr. Ted Diehl, Bodie Technology
Mr. Mark Remelman, Spectral Dynamics

Along with the recommended yearly calibration period for shock accelerometers, it is recommended best practice to perform a calibration (post-test sanity check) on shock accelerometers after a test that has produced unexpected results or after minor accelerometer cabling damage and repair has occurred. For testing facilities that have a shock table, we propose a cost-efficient and fast way to perform piggy-back calibration in-house that avoids the external spend and multi-day delay of sending accelerometers out to an external organization for calibration. The piggy-back technique, discussed in this paper, utilizes one of two types of mounting blocks that enable you to mount the unit under test (UUT) on the top side of the block and a lab reference accelerometer on the bottom of the block. The block is then secured to a shock table and impacted, causing both accelerometers to experience nearly identical shocks. This method is found to be more robust and less sensitive to test mounting variations than other existing methods which rely on a disc that is screwed into a reference shock accelerometer, upon which the UUT is then mounted. Our proposed test method uses multiple shock impacts at multiple acceleration levels to perform the calibration. In our studies, all data was captured with a Spectral Dynamics 5MSa/s high-speed broadband DAS and was processed and plotted into a single multi-tab MATLAB® figure via Kornucopia® ML™. The figure includes raw and filtered versions of the measured signals, FFT analysis of the signals, automated shock pulse duration calculation, and two methods of calibration (peak acceleration or error minimization over the entire pulse duration). The later method is less sensitive to the potential of calibration distortion due to high-frequency localized discrepancy at the signal value of peak acceleration location. The Kornucopia-generated figure is then saved for a complete record of the calibration and a single-page summary is also created for print-out to be placed in the accelerometer's box or other documentation storage. To address traceability, our approach uses a single selected accelerometer as the in-house reference. This reference accelerometer is used solely for in-house calibration and is itself calibrated once a year through an outside organization or OEM to establish NIST traceability.

SESSION 6: BLAST II

AGGRESSOR VEHICLE ENTRY READINESS TECHNOLOGY (AVERT) VEHICLE BARRIER SYSTEM

Mr. Justin Roberts, US Army ERDC

Urban events are attractive targets for perpetrators of hostile vehicle attacks because of their impact and increased vulnerabilities existent due to the lack of permanent security infrastructure. In recent years, the increasing number of vehicle ramming attacks on large crowds in urban environments worldwide has given merit to the hostile vehicle threat (HVT). These threats also extend to critical infrastructure assets that host large open areas accessible by the public. With approximately 1.3 million visitors a year at over 400 lakes and recreational project sites, the U.S. Army Corps of Engineers faces the unique security challenge of developing innovative hostile vehicle mitigation (HVM) solutions to protect the dam projects in its Civil Works portfolio against HVTs. Originally designed for military applications, the U.S. Army Engineer Research and Development Center (ERDC) has devoted efforts for the development of a patented Aggressor Vehicle Entry Readiness Technology (AVERT) rapidly-deployable barrier system that has been recognized as a viable HVM option. To tailor its functionality and performance to the unique requirements urban environments, advanced research on the AVERT system is currently underway. Operational and environmental concerns are being addressed and implemented at the design level. Computational modeling validated by full-scale vehicle ramming experiments will be conducted to improve our understanding of the upper and lower performance limits of the system. With a baseline operational and performance spectrum defined, component level design changes can be made to maximize the overall system performance and increase its capability to mitigate heavier vehicles impacting at higher rates of speed.

NUMERICAL SIMULATIONS OF LARGE HIGH EXPLOSIVE CHARGE DETONATING NEAR GROUND SURFACE WITH SHALLOW LAYER OF SOIL ON GROUND ROCK

Dr. Leo Laine, LL Engineering AB
Dr. Morgan Johansson, Norconsult AB
Mr. Ola Pramm Larsen, CAEwiz Consulting AS
Dr. Joosef Leppanen, Chalmers University of Technology

The numerical simulations were conducted in Autodyn 2D and 3D to study how a large HE explosive detonation near ground generates airblast, ground shock, and far field ground vibrations. The airblast and ground shock effects were systematically studied by comparing results with assumption of rigid ground, or with influence of different type of soils and their depths to rigid rock. Further, the influence of various ground slopes were studied to better understand their effects on airblast propagation along ground surface. The aim is to investigate, using numerical simulation in Autodyn, how accurately the shock wave in air, ground, and vibration propagation can be predicted. These simulations were conducted prior to the experimental test of a large HE detonation near ground surface within the SHIELD program.

The main simulation techniques to handle both nearfield and farfield accuracy is to use re-mapping techniques. Initially, multi-material Euler was used during detonation until shock wave propagation was properly initiated; after this remapping into Euler Flux Corrected Transport (FCT) elements were used to accurately simulate the airblast. To achieve good accuracy, both in nearfield ground shock propagation, cratering, and ground vibrations, an Arbritrary Eulerian Lagrangian (ALE) formulation was used for the soil and ground rock with Fluid Structure Interaction (FSI).

SIMULATION DRIVEN DESIGN AND OPTIMIZATION OF HULL FOR BLAST RESISTANT VEHICLES

Mr. Ravi Kodwani, Altair Engineering
Mr. Ed Wettlaufer, Altair Engineering

Hull of blast resistant vehicles has typical V shape design to deflect the pressure waves, in-order to safeguard the occupants, by maintaining the structural integrity. Based on the vehicle configurations like weight, CG, suspension, power-train, drive-train etc. the hull design would need to optimize for blast loading configurations. This paper describes the simulation driven work-flow for hull of a typical blast resistant vehicle using Altair HyperWork tools for explicit simulation with RADIOSS and optimization wih HyperStudy and OptiStruct.

Concept design study is performed with Arbitrary Lagrangian Eulerian (ALE) simulation using Radioss. Study of pressure impulse propagation and dynamic study of the structure response gives insight in earlier design phases. More detailed modeling of structure with vertical G values as response at occupant locations are typical indicators of the occupant injury probability. Concept hull is further optimized using simpler approach using linearization of loads and by non-linear optimization.

In training session demo of model set-up, details about the explosive and wave-structure interaction modeling for current simulation as well underwater explosion are reviewed. Design of Experimental (DoE) and Optimization set-up is also reviewed with details about design variables, responses, DoE and Optimization methods.

SESSION 7: TESTING & ANALYSIS OF FUZE TECHNOLOGY FOR EXTREME ENVIRONMENTS II

TESTING AND EVALUATION OF FUZE SYSTEMS AT THE EDGE OF ENVELOPE

Mr. Justin Welling, AFLCMC/EBD
Mr. Zachary Hamrick, Odyssey / AFLCMC/EBDT

With the development and expansion of penetrator weapons, a need arose to accurately define and predict a level at which the weapon was capable. Historically, just the fact that the weapon detonated was sufficient, but with the advanced materials, case design capability, explosive fills, and increasingly complex fuze components, a new requirement emerged. From this need an approach of defining the Edge of Envelope of the system and its components became necessary.

After investigating the various different types of impacts, a five sided approach was created to define the Edge of Envelope for the weapon system. These five impact conditions provide a specific condition to test the limits of the components of a penetrator weapon thus limiting the entire system based on the lowest common denominator. The five conditions are; Pure Axial, Axial Perforation, Ricochet, Aggressive Angle, and LP-STAB. Each of these conditions prove to limit the weapon and stress the system to very specific conditions, thus limiting the survivability of the weapon.

EMBEDDED ENVIRONMENT MEASUREMENT IN EXPLOSIVE SIMULANT DURING SUB-SCALE PENETRATION TESTS AT COLD AND AMBIENT TEMPERATURE

Dr. Alain Beliveau, Applied Research Associates
Mr. James Scheppegrell, Applied Research Associates
Mr. Dustin Landers, Applied Research Associates
Mr. Curtis McKinion, Air Force Research Laboratory
Mr. Shane Curtis, Sandia National Laboratories

Research activities on firesets embedded in fill material have led to the measurement of the embedded environment at ambient temperature (mainly acceleration and pressure) during hard target attack. The change in the environment with temperature and the ability of computer models to predict/reproduce the temperature effect has not been evaluated until recently. Sub-scale penetration tests were conducted at ambient and at -50C to measure the pressure and the acceleration changes in the environment caused by temperature. This presentation will discuss the technique used to conduct the tests, the test conditions and the experimental results observed in a single and multi-layer subscale concrete perforation tests at each temperature.

TESTING TACTICAL EMBEDDED FORWARD ASSEMBLIES FOR FUNCTIONAL VALIDATION

Mr. Dustin Landers, Applied Research Associates
Mr. James Scheppegrell, Applied Research Associates
Dr. Alain Beliveau, Applied Research Associates

The Air Force Research Lab is conducting testing to evaluate the performance and functionality of embedded fuzing systems. After initial testing to prove the survivability and functionality of inert embedded firesets (also known as forward assemblies or FA's), researchers at the Fuzes Branch of AFRL have moved to testing "tactical" firesets, or FA's that have a live LEEFI (Low Energy Exploding Foil Initiator). This evaluation includes a series of subscale cannon test against thin concrete target to verify that the forward assemblies performs correctly and meets the design requirements. Results of subscale cannon testing for two tactical embedded firesets are presented as well as the current status of testing.

TIME VARYING TEMPORAL MOMENTS FOR PENETRATION DATA ANALYSIS

Mr. Craig Doolittle, Applied Research Associates
Mr. Alma H. Oliphant, Applied Research Associates

Creative and rigorous analysis of on-board recorded penetration test data for multiple programs has provided program engineers and managers with valuable diagnostic methods and an actionable path forward to meet program objectives. One of these analysis methods is the use of time-variable temporal moments. This analysis technique has been used to identify the structure of a penetration signal, and tie the test observed behavior to known mechanical responses of the penetration system. This analysis can help diagnose a challenging environment, and how this environment may affect the fuzing system. This paper briefly explains the analysis technique, the mathematics behind the method, and possible applications of the approach. We also discuss a few examples, using recent penetration test data. Of particular interest to the fuzing community may be a comparison of the fuzewell and embedded environments.

Modeling of the MEMS fuze using DYSMAS

Mr. Chris Cao, NSWC Indian Head
Dr. Daniel Jean, NSWC Indian Head
Dr. Vasant Joshi, NSWC Indian Head
Mr. Sean Tidwell, NSWC Indian Head
Mr. Antonio Borckardt, NSWC Indian Head

The Micro-Electromechanical Systems (MEMS) based fuze is under development by NSWC IHEODTD for use in high-G applications. To better understand this high shock environment and its effect on the MEMS safe/arm chip, it will be modeled using DYSMAS Lagrangian solver (ParaDyn). The model will be verified using data gathered from the Very High G-machine (VHG), located at NSWC IHEODTD. This talk will discuss the modeling approach used to inform packaging for high shock survivability, particularly at the micro scale level, including empirical discussion on high-shock packaging and approaches.

SESSION 8: CLOSE-IN UNDEX & WHIPPING

Structural Response Evaluation of an Aluminum Hull Ship Using Navy Enhanced Sierra Mechanics: Close-In UNDEX With Bubble Jetting

Mr. Raymond DeFrese, NSWC Carderock

Abstract not available.

UNDEX Whipping Response of Surface Ships – A New Multi-Fidelity Approach

Dr. Ken Nahshon, NSWC Carderock
Mr. Kervin Michaud, NSWC Carderock
Dr. Jeffrey Cipolla, Thornton Tomasetti
Mr. Corbin Robeck, Thornton Tomasetti

A new multi-fidelity surface ship UNDEX whipping analysis approach is being developed using both a fast-running beam-whipping code, Hullwhip and high-fidelity coupled acoustic-FEA and Eulerian-FEA capabilities in NESM. The goals of this effort are to reduce the number of fully coupled Eulerian-FEA calculations and in parallel reduce modeling uncertainties through the automatic development and transfer of relevant inputs across model fidelity levels. This is being accomplished through a re-writing of Hullwhip and development of new supporting software tools to integrate Hullwhip and NESM analysis workflows.

Whipping Response of Surface Ships in Response to Underwater Explosions Using Hullwhip and NESM

Dr. Jeffrey Cipolla, Thornton Tomasetti
Mr. Corbin Robeck, Thornton Tomasetti
Mr. Kervin Michaud, NSWC Carderock
Dr. Ken Nahshon, NSWC Carderock

Hullwhip is a modal superposition beam code used to calculate whipping of surface ships in response to an UNDEX event. Hullwhip relies on superposition of modal shape functions and incorporates added mass and loading effects using the strip method. In this study we discuss introducing an FEM-derived structural representation computed through NESM into the Hullwhip solution procedure. The NESM

procedure uses first principles physics to compute the mode shapes and added mass terms to gain a more accurate representation of the whipping event.

SESSION 8: VALIDATION OF UNDEX SIMULATIONS

A General Framework for Assessing the Validation of Modeling and Simulation for a Specific Intended Use

Mr. Chris Abate, Electric Boat Corporation

Abstract not available.

A Probabilistic Approach for Assessing the Stability of Cylinders Subjected to Combined Hydrostatic and Shock Loading

Mr. Chris Abate, Electric Boat Corporation
Mr. Dashiell Parsons, Electric Boat corporation

Abstract not available.

VENDOR SESSION B: CASE STUDIES, NEW DEVELOPMENTS/TECHNOLOGIES, TESTING, PRODUCT INFO, AND SERVICE PRACTICES

Vibration Specifications and How to Plan and Conduct the Vibration Test

Mr. Gary Marraccini, Spectral Dynamics

Abstract not available.

High Speed Digital Imaging Correlation in Ballistics Applications

Dr. Kyle Gilroy, Vision Research

There has been a steadily growing interest in materials-testing protocols that demand both high spatial and temporal resolution. In this talk, we discuss how ultra-high speed cameras can be combined with advanced software to characterize spatial and temporal strain, displacement, and vibration on the micro-scale, respectively. As will be demonstrated, this is ideal for weapons testing and analyzing projectile/materials interactions during high-velocity impacts. We talk about the overall workflow, results, and analysis from weapons and impact testing.

Inductive Centering in Electrodynamic Shaker Systems

Mr. Dominic Acquarulo, Bruel & Kjaer

Armature positional data is imperative to accurate and reliable tests when using electrodynamic shaker systems. With market trends pushing test environments, products and simulated vibrations ever further, it’s important to ensure sensing the position of a moving mass at varying frequencies and displacements is accurate and unaffected by any environmental condition the product under test is being subjected to; these being fluctuating temperature, moisture and particle contaminant rich.

Moving sensor arrays away from the traditional vison-based systems, which can be affected by these environments, to an inductive system, removes the need for scheduled maintenance and calibration. The inductive sensor, through the application of fixed position sense coils, “coarse” and “fine” mounted on vibrator top plate, allowing precise measurements to be made at any length of displacement, converting induced analogue signals to a digital position output by reading the constant and absolute position of the ~4MHz resonant circuit target sensor mounted to armature. This technology is unaffected by the magnetic fields inherent in electrodynamic shaker systems delivering accuracy to ~0.1mm incremental definition.

The implementation has demonstrated that it is possible to use this technology in a standard and controlled assembly model and retrofitted into older systems through a conversion of signal and interfacing with existing vision-based control boards, opening opportunities to apply this to future products and in field systems.

CASE STUDY FOR A 6 DOF ISOLATION WITH PRECISE RE-POSITIONING FOR UNDEX APPLICATIONS

Mr. Mike Mosher, Taylor Devices
Mr. John Metzer, Taylor Devices

This presentation will outline the beginning of the life cycle process of providing a shock isolation system for a payload needing to meet a specified attenuation level when subjected to an UNDEX simulated shock application (i.e. MIL-S901). It will provide insight as to how the customer requirements effect possible isolator designs. A recent case study will be presented in which analytical methods (i.e. computer modeling) were utilized to develop the isolator parameters needed of the isolator design to be successful. Alternate isolator design solutions will be discussed as well.

EFFICIENTLY PROCESSING NOISY DATA WITH KORNUCOPIA® ML™

Dr. Ted Diehl, Bodie Technology

Working with noisy data, regardless of the source (physical testing or numerical simulation), can be very challenging. Several key steps in the analysis work-flow should be followed to ensure your data is properly captured (sampled), accurately processed, and appropriately interpreted. On top of that, working with a large number of signals containing highly noisy content from accelerometers, strain gages, lasers, and other sensors can quick become a daunting task without the right type of software to efficiently organize and analyze the data (typically using different calculations for different sensor types) , and to smarty create a large number of plots (10’s or 100’s) in an organize “workbook” (NOT MS Excel). This presentation utilizes examples from both physical testing and Explicit Dynamics FEA simulations to demonstrate important concepts such as: 1) proper data capture to avoid aliasing, 2) regularization of non-constant sampling from FEA and other sources, 3) Computing DFS spectra, 4) For shock cases, integrating acceleration to assess velocity change and then performing SRS analysis, including the advantages of PVSS over acceleration SRS, 5) For high-speed transient strain gage measurements in electrically-induced noisy environments, how to properly identify and remove high-frequency noise to significantly improve data interpretation, 6) How to correlate results between transient FEA and physical testing, especially in cases with vastly different raw bandwidths, and 7) How to manage a large number of noisy signals for fast data comparison, create reusable work-flows that are traceable, and how to save your results so they are easily shared or retrieved from an archive. All the items described will be demonstrated via Kornucopia® ML™, for use with MATLAB®.

TRAINING II

TYPE I VIBRATION QUALIFICATION IN ACCORDANCE WITH MIL-STD-167-1, COMMON MISCONCEPTIONS & BEST PRACTICES

Mr. Thomas Borawski, NSWC Philadelphia

As the DAA of Hull, Mechanical, and Electrical (HM&E) equipment for surface and subsurface ship classes, it is my responsibility to guide In-Service Engineering Agents, Life Cycle Managers, and other equipment owners through the process of gaining Type I vibration qualification in accordance with MIL-STD-167-1. Unfortunately, many individuals are unfamiliar with the vibration qualification process resulting in incorrect tests, over testing, wasted time, wasted money, short lead times, and missed deadlines. The accumulation of misconceptions and errors ultimately trickle down to negatively impact the fleet. By giving this training session, it is my goal to educate equipment owners and manufacturers to make them aware of their responsibility to gain qualification, what is involved in a successful test, what pitfalls to avoid, and the appropriate channels to obtain qualification.

SESSION 9: M&S OF MUNITION EFFECTS

A FRAMEWORK FOR AUTOMATING FAST-RUNNING SURFACE RESPONSE MODELS

Dr. George Lloyd, ACTA
Dr. Li Cao, ACTA
Mr. Fabien Tieuleres, Karagozian & Case
Mr. Joe Magallanes, Karagozian & Case

The application of high-fidelity physics-based (HFPB) codes to solving complex weapon/target interaction (WTI) problems has become an essential aspect of lethality and survivability planning. Such codes are able to predict in great detail and with high accuracy the elastic and inelastic response modes of targets subjected to highly dynamic munitions effects. Despite their inherent capabilities, there are many situations where HFPB codes cannot be used by weaponeers. For example, the time to configure and compute a solution for a particular scenario is often lengthy, oftentimes days or weeks. Moreover, it is typically the case that many of the parameters of a scenario are unknown, requiring numerous computations to bracket the solution and quantify the uncertainty. Because of these issues, various types of reduced-order fast-running surface response modeling techniques (generically referred to as FRMs) have been co-developed alongside HFPB codes. They are an increasingly important component in the modeling and simulation (M&S) tools used by weaponeers.

Despite the practical importance FRM's have assumed for many end-users, a lingering problem is that the design, training, and validation of FRMs developed with HFPB data can be an expensive and time-consuming problem in and of itself. Although the overall FRM development process is fairly well understood, many of its steps and the overall training and validation processes require extensive "human in the loop" effort. Further, many classical techniques for model selection, training, optimization and validation often need special enhancements which are unique to WTI problems. The result is that upfront FRM development costs are frequently very high in terms of time, money, and often reduced capability.

In this paper the authors will review the process of developing FRMs with HFPB data, as gleaned from a broad range of previous studies performed in the structural response domain. The application of this expertise to the design and implementation of a suitable software architecture for automating the individual steps as well as the overall FRM development process itself will be discussed.

A Fast-Running Model for Multi-Strike Munitions Effects on RC Columns

Dr. George Lloyd, ACTA
Mr. Ryan Schnalzer, ACTA
Mr. Dan Coleman, Karagozian & Case
Mr. Joe Magallanes, Karagozian & Case

Reinforced concrete columns are critical load-bearing structural components in many buildings. The direct effects of cased munitions on them are complex, particularly in scenarios where more than one weapon is used, and azimuthal variations can occur in addition to standoff and orientation variations. Since RC columns are load-bearing, estimates of reduced load-bearing capacity are necessary to evaluate lethality consequences such as progressive damage and progressive collapse. The coupling of biaxial material damage to concrete and reinforcement caused by multiple weapons to cumulative response measures of interest, such as residual capacity and failure mode, has been difficult to evaluate. Moreover, the number of experimental tests which have examined multiple strike effects is very small.

In this paper the authors will present the development of a fast-running model for predicting the residual capacity of RC columns to multiple strikes of conventional cased weapons. The model has been trained on a suite of high-fidelity physics-based calculations which have been extensively validated against the many tests which have been conducted for single weapons. The methodology for capturing multiple strike effects in a general way will be discussed.

SESSION 10: SHOCK & VIBRATION MODELING & ANALYSIS II

Shock Test Specification via an Optimally Decomposed Time History

Mr. Sloan Burns, NSWC Dahlgren

Shock test specifications are commonly defined by a table of Shock Response Spectrum (SRS) break-points. Using this method, an environment's acceleration time-history is measured, the SRS is calculated, and the SRS is manually simplified to produce a table of break-points which approximate it. This form of test specification provides a compact format but lacks the temporal information necessary to reproduce the environment's acceleration time-history and simplifies the shape of the SRS.

This presentation will show an alternate method for specifying a shock test by decomposing an acceleration time history into a table of damped sinusoids, which better approximates the environment's SRS. A novel method of optimally selecting the damped sinusoids in order to create a compact format will be shown. Using this method, a compact shock test specification can be created which provides the test lab a time-history that closely matches the SRS and the general characteristics of the field environment.

Estimation of fundamental natural period for shock fixtures

Mr. David Soine, Honeywell
Mr. Jonathan Hower, Honeywell

Simple models for estimating the fundamental natural period of a test article and adapter hardware when attached to a mechanical shock machine can be found in the literature for pulse shock testing. Today, there is an expectation that a finite element or other model will be used to inform the design and anticipate the dynamic performance of a test article in a shock environment. Unfortunately the cost and additional time required for modeling is not always allocated for the adapter hardware. This work reviews and evaluates the validity of estimation methods for the fundamental natural period of adapter hardware for laboratory shock environments, and explores the limitations of various approaches.

COMPUTING THE MAXIMUM EXPECTED ENVIRONMENT OF A SMALL DATA SET
Mr. Chad Heitman, Sandia National Laboratories

There is often very little data available from which to compute the maximum predicted environment (MPE) of a vibration or shock event. With very little data, the true distribution of the data is unknown and there is no data at the tails of the distribution where we wish to make statistical inferences. The MPE estimate depends on assumptions that are made about the true distribution. This paper describes a statistical simulation that computes MPE estimates using a simple envelope, normal tolerance limit, bootstrapping, and SMC Standard created with a small data set drawn from a truth distribution. The MPE estimates are compared with the true MPE and findings are discussed given the number of data points used and the MPE computation method.

PYTHON & QT, POWERFUL TOOLS FOR TECHNICAL COMPUTING
Mr. Vincent Grillo, A.I Solutions

The objective of this presentation is to give a brief overview of Python computer language and Qt for Python which provides an interface to Python for building graphical applications. The Qt language provides a method for rapid programming of Graphical User Interfaces (GUIs) that are highly scalable, robust and platform independent. Both Python and Qt provide a powerful set of tools for Dynamic Analysis which are based on Open-Source software. Many problems and calculations in Structural Dynamics such as Power Spectral Density, Shock Response Spectrum and Vibration Response Spectrum can be easily calculated using these tools. The advantage of using Open-Source software is the ability to create custom graphical user interfaces similar to Matlab without the expense of software licensing and the ability to customize the software to an organization's specific needs. Also, another advantage is the ability to know which algorithms are being used by the GUI, know the numerical limitations and scale to large size data sets. I will end the presentation by demonstrating a Structural Dynamics GUI I created that was designed primarily to interactively analyze Post Flight high speed data provided by the ground station telemetry networks.

A RANDOM FIELD MODEL FOR CLUSTERING DYNAMICS
Dr. George Lloyd, ACTA
Dr. Tom Paez, Paez Consulting

The need to simulate systems where random fields represent intrinsic sources of aleatoric and epistemic uncertainty arises in many disparate areas. Typical application areas include modeling of mesoscale features and flaws associated with heterogeneous continua composed of interspersed phases; another example is accounting for the spatial distribution of risk receptors. Without a flexible method for modeling the dynamics of the fields, particularly with respect to the two problems of calibrating from limited source data and being able to efficiently solve for equilibrium states, comparisons of simulations with validation data is difficult. For example, in a structural component where in-situ defects can be expected with some likelihood, the problems of design and accreditation are difficult to fully quantify without an understanding of the sensitivities of critical response variables to the properties of the class of random fields that could have generated the responses.

The Ising model is a classical random field lattice model in which the Hamiltonian for a system is available from first principles and techniques such as Markov Chain Monte Carlo are used to reach and sample from the equilibrium state of the model after commencing from an arbitrary naive state. In the sense of this paper the Hamiltonian is not a derivable quantity since the energy densities associated with local and non-local features are difficult to describe comprehensively from an analytical point of view. Rather, laboratory characterizations are the basis for defining and ranking states according to their significance for consequences and their likelihood.

In this paper we examine how Ising-type models can be applied to model arbitrary random fields in any dimension in the absence of a Hamiltonian when only "laboratory" data is available. For purposes of demonstration examples are limited to two dimensions. After addressing the concerns of calibrating a model, finding and sampling the equilibrium state of the model remains the final objective. Problems and approaches for doing this in the MCMC framework are discussed.

SESSION 11: EXPERIMENTAL TECHNIQUES FOR PYROSHOCK TESTING I

PYROSHOCK REPLICATE

Mr. Matan Mendelovich, Rafael

Pyrotechnic bolts and squibs are used for many applications in missiles and rockets including engine separation, wing deployment etc. The pyrotechnic shock caused by small pyrotechnic bolts or squibs may lead to significant faults during missile's free-flight phase in electronic components as well as in small and sensitive mechanisms. This causes a fast mechanic load that transfers to pressure waves.

The motivation to develop lab-test methodology is to replace expensive field operation and resources consuming field test. The presentation describes the methodology for pyrotechnic shock testing – from field measurements to laboratory testing. At first, filed measurement was taken using a mockup equipped with pyrotechnic bolts. The pyroshock acceleration was measured using high sampling rate data acquisition system.

The shock was measured on different locations along the mockup during the explosion. After data-processing, based on SRS calculation, numerical simulations were conducted in order to design adequate fixture for the laboratory test on shock testing machine. In addition, preliminary test parameters such as hammer height, mass and anvil types were decided according to the simulation and calibrated during the test procedure. During the test fine tuning were made for the test parameters in order to replicate the field test measurements. In the presentation I will present the shock testing machine and the influence of each parameters on the ability to get satisfying results for pyroshock replication in laboratory.

TECHNIQUES FOR REPEATABLE PYROSHOCK TESTING ON AN AIR GUN SHOCK MACHINE FOR LEAN SATELLITES

Mr. Ibukun Oluwatobi Adebolu, Kyushu Institute of Technology
Dr. Hirokazu, KIT'
Mr. Isamu Inoue, iQPS
Prof. Mengu Cho, KIT

An increase in the number of small satellites (especially CubeSats) launched on dedicated launch vehicles implies that small satellites must now be designed to withstand very high frequencies and accelerations generated during satellite separation. These pyrotechnic events are difficult to replicate during the verification phase in the laboratory. At least 6 shocks, 2 shocks per axis along each of the three mutually perpendicular axes (XYZ), are required during qualification testing; and 3 shocks (1 shock per axis) are required in the acceptance testing of the flight components as per NASA-STD-7003A. Generating such precise shocks on a representative test article has proven difficult in practice, requiring up to 25 trial-and-error tuning tests to determine the appropriate experimental setup parameters that can produce the required SRS. Performing these tuning tests repetitively subjects the test item to fatigue loads, which may lead to failure of components and jeopardize the mission. It is important to achieve the desired test levels in as few shocks as possible since many Commercial-Off-The-Shelf (COTS) components used in lean satellites are not usually designed to withstand severe environments. The air gun shock machine generates shock by propelling a projectile onto a shock table using compressed air. The generated shock is measured in terms of a shock response spectrum (SRS). The shape of the SRS generated is adjusted by changing the pressure, or projectile material or the absorber between the projectile and the shock table. The air gun shock machine can generate a shock on three axes simultaneously, reducing the number of shocks required to achieve the test requirements. In this study, the initial tuning conditions for a pyro shock test (6 dB/Oct for 100 – 2000 Hz, 1000 G at 2000 Hz) were derived from a database of previous shock tests using a weighted root mean square deviation algorithm. Using the derived conditions, shock tests were conducted with a representative test article and the results investigated for repeatability. At an appropriate pressure, a specified SRS may be generated on a test article if the strain history and loading sequence of the absorbers used in the test is known. The SRS generated using prestrained absorbers were in general more repeatable than SRS generated with virgin absorbers. A new tuning method, that takes account of absorber preconditioning, reduces number of tuning shocks to about 4 to 5 shocks, and minimizes over-testing in the high frequency region of the spectrum is proposed.

DEVELOPMENT OF NON-DESTRUCTIVE "ALTERNATIVE PYROSHOCK" SIMULATION FOR EXTREMELY LARGE SYSTEMS

Mr. Patrick Barnes, Sandia National Laboratories

Traditionally, pyroshock associated with flight stage-separation has been simulated using explosives similar to those used in a rocket's flight. In order to replace this explosive-based approach, a new capability was developed at Sandia National Laboratories to simulate the pyroshock environment using a modified Hopkinson Bar arrangement. This new capability allows tuning of the response for the bar to meet the specification as closely as practical during calibration test shots. Once the flight hardware is substituted to replace the similar mass mock test unit, low-level pyroshocks can be imparted into the test article to evaluate any concerning deviations from expected system response prior to building up to the full test-level shock. This new method eliminates the need for explosives (along with health and safety byproducts), allows for evaluation and tuning of the shock event prior to full-level shots, is non-destructive, and allows functional testing of all other system components immediately before, during, and after the event of interest.

MIL-STD-810 INSTRUMENTATION GUIDANCE VS. SHOCK MEASUREMENT SYSTEMS INDIVIDUALITY

Dr. Patrick L. Walter, PCB Piezotronics, Inc./TCU

Three basic sensor technologies are currently effectively being employed for severe shock measurement including pyroshock. These technologies can be described as (1) mechanically isolated and electrically filtered piezoelectric, (2) lightly damped silicon-based MEMS, and (3) essentially undamped silicon-based MEMS. Each of these technologies are differentiated by unique performance and signal conditioning requirements. This work first describes the reasoning behind the successive evolution of each technology. Once the uniqueness between each technology and its signal conditioning requirements is understood, requisite guidance is provided to augment the requirements of the military standard.

SESSION 12: BLAST: EXPERIMENTAL & NUMERICAL METHODS

BLASTX INTEGRATION WITH NAVY SHIP VULNERABILITY TOOLS

Dr. Gregory Bessette, USACE ERDC
Mr. Keith G. Webster, NSWC Carderock Division
Dr. Ken Nahshon, NSWC Carderock Division
Mr. Kevin P. Rankin, NSWC Carderock Division
Mr. William A. Hoffman, NSWC Carderock Division

The Navy's Advanced Survivability Assessment Program (ASAP) is a fast-running vulnerability assessment tool that can evaluate damage to a ship's structure and its critical components resulting from weapon effects. There is an ongoing effort to improve the blast modeling within ASAP to better capture the time-varying loading on compartment walls and propagation of the gas front between compartments. To this end, the BlastX fast-running airblast code is being integrated with ASAP. BlastX can predict the airblast environment associated with open-air and internal detonations. For the latter, the code can model the shock transmission through complex, multi-room structures. Further, it can track the later time gas flow throughout the structure. Traditionally, BlastX has been limited to nonresponding structures. For this integration effort, updates were made to expand the code's capability to handle responding structures. This was accomplished by incorporating components of the Navy's Blast Damage Assessment Model (BDAM) into BlastX. In particular, the algorithms evaluating structural response and plate rupture were implemented into BlastX. These updates allow for an evaluation of the structural response at each time step. This initially involves predicting the motion of individual plates within a compartment based on the current load state. The change in compartment volume over the time step is computed based on the plate motion. In turn, BlastX updates the quasi-static gas pressure to account for the change in volume with the process repeated over each time step in the calculation. The implementation also allows for plate rupture and the creation of new vents for blast propagation. The area of the newly formed vents is allowed to grow over time. This paper outlines the integration approach and details the implementation of BDAM with BlastX. At present, the integration with ASAP is conducted in a coarse manner by the creation of separate input and output files. Future work will focus on improving the efficiency of the data passing.
Permission to publish was granted by the Director, Geotechnical and Structures Laboratory.

NUMERICAL INVESTIGATION OF A NEW MUZZLE BRAKE FOR BLAST OVERPRESSURE ATTENUATION AT CREW POSITIONS ON THE 155 MM M777 EXTENDED RANGE CANNON

Dr. Robert Carson, U.S. Army CCDC Armaments Center
Mr. David Marshall, US Army - CCDC AC

This paper explores the numerical evaluation of a distinctive new muzzle brake to attenuate blast overpressure at multiple propellant charges for the crew of the 155 mm M777 Extended Range Cannon, armament for the M777 Towed Howitzer platform. Blast overpressure can cause significant harm to personnel operating a cannon system, especially systems where the crew is unprotected from the blast, as in this case with a towed howitzer system. Muzzle brakes are affixed to cannon systems in order to reduce the recoil of the cannon. The adverse impact of a muzzle brake is the increased blast overpressure on the crew. The difficulty in designing new muzzle brakes is to maintain system acceptable blast levels while obtaining the recoil reduction required. This study examined the blast overpressure of a baseline configuration muzzle brake in the numerical finite element code ALE3D and compared the results to experimental data obtained at Yuma Proving Ground (YPG). Once the simulation was validated, a new muzzle brake design was simulated in ALE3D and the results compared to the baseline. While the baseline muzzle brake exceeded the system recoil requirements, its blast overpressure was deemed excessive at both the highest and second highest propelling charges (Zone 6 and Zone 9S). The new muzzle brake met the recoil requirements of the system at both zones. At the second highest configuration propellant charge (Zone 6), the new muzzle brake lowered the peak overpressure compared to the baseline by 18% at multiple elevations of the gun. At the highest configuration propellant charge (Zone 9S), the new muzzle brake lowered the peak overpressure compared to the baseline by an average of 12% at multiple elevations of the gun. This new muzzle brake is being fabricated and will be experimentally verified at YPG. It will be part of the new 155 mm XM351 Cannon on the Towed M777 Extended Range Howitzer system.

MEASURING THE MECHANICAL RESPONSE OF A STEEL SURROGATE DOOR RESULTING FROM MULTIPLE CHARGES

Mr. Roosevelt Davis, AFRL
Ms. Sarah Folse-Vorgert, AFRL

Steel surrogate doors meant to structurally represent hermetic type door designs that would be found in some facilities were tested in a one room structure. These doors could pose as obstacles when gaining entry to or throughout a structure is an objective. It also may not be prudent to use typical munitions designed to engage multiple rooms within a structure. Some tactical desire may warrant caution due to collateral damage concerns, preservation of other sections of the structure, materials, or inability to reach certain areas within a structure with large munitions. Therefore the proposed experiments consider much smaller charges working in tandem attempting to defeat the presented surrogate steel doors.

This paper will present additional data from experiments previously presented. The experiments center on deploying single or multiple small charge configurations in close proximity to a steel surrogate door. The configurations vary spatial separation between the charges as well as charge configuration standoff from the surrogate door. Single small charges are also used by themselves either in very close proximity or in sequence where the sequenced experiments intent is to generate cumulative damage.

A brief explanation of experiments will be presented. Measurements of pressure were obtained representing the applied loads. Accelerometers were placed at different locations on the door to measure the doors response to the loads from the different charge configurations. The accelerometer measurements will provide velocities of the surrogate door’s surface as it is deformed from detonations.

Digital Imaging Correlation or DIC was also employed to acquire displacement and velocity data via high-speed camera images. The data will be presented in comparison to one another as well as individually. Some difficulties in making these measurements will also be presented.

PREDICTIVE METRICS FOR RESPONSE OF A HARDENED STEEL DOOR TO MULTIPLE CHARGES

Mr. David Bogosian, BakerRisk
Dr. David Powell, BakerRisk
Mr. Roosevelt Davis, AFRL/RWML

When evaluating blast-induced damage on a component, the challenge is to select an appropriate single metric that allows all such methods to be arrayed against one another in a truly comparative fashion, as well as one that adequately correlates to the damage achieved. This was certainly the case in a recent series of tests, in which AFRL sought to produce blowout of a hardened steel door by using a variety of charges, whether singly, in pairs, or in sets of three. The door was generic and intended to be representative of a variety of moderately hardened steel doors. The charges were arranged in various ways opposite the door and detonated simultaneously.

Given the door's response time relative to the duration of loading, use of impulse as a predictive metric was reasonably obvious. However, the gradient of impulse over the door's surface is pronounced and complex, particularly when multiple charges are involved. For maximum applicability, use of a single scalar to predict blowout would be far more effective than a complex two-dimensional array. In the test series under consideration, the blast distribution on the door was very well characterized using an array of ten pressure gauges. A method was devised which combines key metrics from these ten gauges into a single scalar which, when correlated to the damage observed in the tests, could be used to identify the threshold for failure.

SESSION 13: DYSMAS I: AIREX DEVELOPMENT & APPLICATIONS

USE OF DYSMAS TO MODEL BLAST PROPAGATION IN A SIMULATED URBAN ENVIRONMENT

Dr. Marie Okeke, NSWC Indian Head
Mr. Roger Ilamni, NSWC Indian Head
Dr. Thomas McGrath, NSWC Indian Head

The ability to accurately model air-blast phenomena (reflection, diffusion and diffraction) in a complicated environment is a growing interest to the DYSMAS user community. Assessment of the DYSMAS/FD Gemini code was performed using over-pressure data from two large-scale experiments (EMRTC's Straight Street and Open Square Test). These tests consist of high explosive charges detonated near a non-responding structure as well as a large number of over-pressure gages located on side walls. This talk will present correlations of simulation output with measured data resulting in respectable agreement.

MULTI-PHASE DISCRETE ELEMENT METHOD

Dr. Cameron Stewart, NSWC Indian Head
Dr. Thomas McGrath, NSWC Indian Head

This work presents a Discrete Element Method (DEM) modeling framework as an enhancement to the Navy's premier hydrocode DYSMAS. The DEM framework adds Lagrangian particles coupled to both the hydrodynamic solver Gemini, as well as the structure code Paradyn. Multiple particle-particle force models are presented, including a soft-sphere Hertzian model which explicitly models collisions, as well as a volume fraction gradient force for problems where high speed collisions lead to an overly restrictive timestep. The DEM framework development has been motivated by a fragmenting reactive material application. This reactive material application is discussed, and preliminary results are shown for a set of simulations utilizing the DYSMAS DEM framework.

MINE VULNERABILITY M&S USING DYSMAS
Dr. Soonyoung Hong, NSWC Indian Head

A prediction of a bomb output (pressure, impulse, and fluid velocity) was made to assess its effectiveness against mines using DYSMAS/FD Gemini code. The prediction was performed based on a single weapon test against a given laydown of mine targets. The bomb output varied by the specific bomb conditions, such as HE types, bomb delay time, tail or nose initiation, soil type, and AIREX and UNDEX. This talk will present the prediction and test output comparison.

VENDOR SESSION C: CASE STUDIES, NEW DEVELOPMENTS/TECHNOLOGIES, TESTING, PRODUCT INFO, AND SERVICE PRACTICES

ADVANCEMENTS IN COMBINED CONTROLLER/ANALYZER DESIGN
Mr. Chris Sensor, NVT Group/Data Physics

The addition of high speed processors to DAQ hardware has led to the ability to perform precise shaker control and/or multiple signal analyzer computations in parallel, regardless of channel count. Out-of-band vibration measurements, zoomed monitoring of product resonances, filtering and manipulation of time data, and kinematic transformations are just a few examples of this advanced real-time capability. Post processing is no longer required to analyze data from a vibration test, or to analyze data with different sets of test parameters.

EXTREMELY LARGE TELESCOPE TRANSPORT USING 2" WIRE ROPE ISOLATORS
Mr. Joshua Partyka, Vibro Dynamics
Mr. Ozzie Irowa, Vibro Dynamics

A full article presentation about transportation of space components in general is scheduled in this year's Symposium, but another exciting recent development has been the study by Socitec in Europe of the transport container (UTC) of the extremely large telescope (ELT) to Chile.

The ELT will be used to gather 13 times more light than the largest optical telescopes currently existing, and be able to correct for atmospheric distortion. It has around 256 times the light gathering area of the Hubble Space Telescope, and according to the ELT's specifications would provide images 16 times sharper than those from Hubble.

Such an extraordinary unit is very expensive, and therefore it is of paramount importance to ship its extremely fragile components, such as its mirrors and electronics, safely to the observatory.

The project is due in 2025 and construction is under way on site as well as in the various contributing European countries. The engineering problem of safely transporting the ELT to its final destination, and its solution of the use of extremely large wire rope isolators, will be reviewed in this vendor presentation.

ELASTA MEGA ISOLATION MOUNTS (EMIM) FOR HEAVY PAYLOADS

Dr. Daryoush Allaei, Shock Tech

The vibration and shock isolation of heavy payloads is essential in protecting both large infrastructures and massive subsystems. The application of such mounts provides increased stealth for submarines by reducing the detectable noise transmitted to the hull from the engines while protecting the engines from near miss underwater explosions.

Elasta Mega Isolation Mounts (EMIM) is a newly developed product suitable for heavy loads. EMIM is based on customized geometry, number of elastomeric elements, and elastomer durometer. Each individual mount is composed of a top and bottom metal plate and several spring elastomeric elements. The independent end plates allow for easy installation, repair, and replacement of each of the elastomers. Flexibilities in these elements allow for rapid insertion into projects with varying payload and size requirements. In other words, they are designed to have high maintainability.

Extensive tests have been performed on EMIM with six elastomer elements loaded with about 4,500 lbs. EMIM product line has been qualified for deployment aboard naval vessels. The suite of tests performed on the isolators included shock and vibration along with tests related to seaworthiness qualification. The isolator performance was characterized prior to and after each test. The initial load tests show a support of 34,500 pound at a deflection of 3 in. Shock tests were performed on the isolator per MIL-DTL-901E in accordance with MIL-PRF-32407A. Nine medium weight hammer drops were conducted on the isolator to fully characterize the shock attenuation of EMIM with varying orientation and drop heights. The acceleration of the payload on the isolator did not go above 8.8 Gs with the highest drop acceleration of 282.8 Gs. All posttest results were within 6% of the pre-shock test values. Vibration endurance tests were performed on the isolation mounts per MIL-STD-167 in accordance with MIL-PRF-32407A. Resonant frequencies were determined to be 7, 8 and 6 Hz in the vertical, shear and roll direction, respectively. The isolation mounts were vibrated along each direction dwelling at the respective resonant frequency for 2 hours. All posttests results were within 6% of the previbration endurance test values.

In general, traditional mounts fail during their lifetime due to the elastomer metal debonding issues. In the case of EMIM, failure tests were performed to evaluate metal-elastomer bonding for each elastomer. No sign of debonding were detected during our qualification tests. The latter is one of the key features of EMIM.

The elastomer-based heavy payload mount has been successfully tested for qualification of seaworthiness including subsequent successful barge testing by the customer and has been deployed aboard naval vessels. The isolator mounts provide a flexible design to fit a variety of payload and size requirements with high maintainability.

MECHANICALLY & ELECTRICALLY FILTERED HIGH SHOCK ACCELEROMETER

Mr. Kevin Westhora, Dytran Instruments

The new Dytran 3099AX Series is a mechanically and two-pole electrically filtered IEPE accelerometer that measures severe shocks and other high amplitude, short duration events.

Unlike many shock sensors on the market, the Dytran 3099AX has no issues with zero-shift phenomenon. This is because Dytran utilizes a quartz sensing element instead of the commonly used ceramic. Quartz ensures better stability and sensitivity value over time, ensuring that zero-shift does not corrupt typical

SRS plots. Model 3099AX is perfect for engineers that engage in high shock testing and use a Shock Response Spectrum (SRS).

Specific applications include explosive bolt testing used on rockets for fuel tank separation, shock testing of consumer electronics, high shock metal to metal impact, shaker shock, protective body gear testing as well as far-field blast, pyrotechnic, drop, vibration, shock and stage separation testing.

3099AX Series is case isolated to avoid ground loop interference and hermetically sealed for use in dirty environments. The electrical filter reduces signal ringing. Available in up to 60,000g range and 10kHz shock. Offered in three sensitivities: 0.05mV/g, 0.1mV/g, and 0.2mV/g.

TRAINING III

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 14: SHOCK & VIBRATION ISOLATION

MATERIALS ADVANCEMENTS ENABLING A NEW NAVY MOUNT FOR HIGH TEMPERATURE AND EXTENDED SERVICE LIFE

Mr. Shawn Czerniak, Hutchinson
Mr. Neil Donovan, Hutchinson
Mr. John Sailhamer, Hutchinson

Navy ships utilize a wide variety of equipment that are sources of structure born noise. Other equipment is sensitive to the shipboard shock and vibration environment. To protect this equipment and isolate the ship from structure born noise, the Navy employs resilient mounts.

Standard Navy resilient mounts, such as those meeting the requirements of specifications like MIL-DTL-17508, are not intended for use in high temperature environments. In the case where mounts are installed in locations of elevated temperatures, the mounts may not perform as intended. These higher temperatures can lead to inconsistent performance and reduced service life.

To remediate these challenges, one has generally two options. The first is to provide the mount with some level of protection from the environment. This is sometimes achieved through heat shielding, ventilation or changes in where the mounts are installed. The other option is to redesign the mount/material to meet the conditions of the environment in which the mount is installed. This method would not require any changes to the installation.

Since the design of these standard Navy mounts, there have been many advancements in elastomeric materials. By taking advantage of these material advancements, the resilient mount can be designed to withstand higher temperatures, reduce drift and increase the service life of the system. This paper presents a solution approach for Navy mounts in high temperature environments resulting in increased service life and improved performance.

ISOLATION OF ULTRALIGHT-WEIGHT ELECTRONICS ENCLOSURES

Mr. Darko Gjoreski, Shock Tech
Mr. Kevork Kayayan, Shock Tech
Dr. Daryoush Allaei, ShockTech

Shipboard components, such as mission critical electronic enclosures, must be protected against high shock loads due to near miss underwater explosions. Such components must meet MIL-DTL-901D/E requirements. Shock mitigation mounts are designed and evaluated for an unusually light-weight (17-pound) electronic enclosure which must qualify for heavyweight barge test (i.e. MIL-DTL-901D/E). Such barge tests represent near miss explosions that provide a harsh dynamics environment for mission critical electronic enclosures. The shock mitigation units must perform when mounted on 8, 14, or 25 Hz decks. In the case of 8, 14, and 25 Hz decks, the maximum shock inputs are 40 and 10 Gs, 60 and 10 Gs, 80 and 30 Gs in vertical and side-to-side directions, respectively. As for the output, accelerations are expected to stay below 20G for all conditions and total combined displacement (in all directions) must be limited to 5 inches for all three deck conditions.

In this work, each of the light-weight electronic racks is modeled as a rigid body with 6 degrees of freedom, three rotation and three translational motions. Each mount is modeled as a 6-degree of freedom subsystem with its own weight, and spring and damping rates. Non-linear spring rates and damping rates are experimentally measured and used as input data. The ultralight-weight electronic enclosure (17 lbs) was mounted on four isolators, each carrying 4.25 lbs. The shock mitigation is evaluated, and the results showed a huge success. In the case of 8 Hz deck, the maximum shock output is 14 Gs (65% reduction when compared with the input) and 12 Gs in vertical and side-to-side directions, respectively. In the case of 14 Hz deck, the maximum shock output is 19 Gs (68% reduction) and 10 Gs in vertical and side-to-side directions, respectively. In the case of 25 Hz deck, the maximum shock out-put is 14 Gs (83% reduction) and 18 Gs (40% reduction) in vertical and side-to-side directions, respectively. The displacement output is limited to a combined 3 inches in the positive and negative vertical direction.

PERFORMANCE OF CUP ISOLATION MOUNTS SUBJECTED TO COLD-HOT TEMPERATURES

Mr. Richard Rakowski, ShockTech
Mr. Kevork Kayayan, Shock Tech
Dr. Daryoush Allaei, ShockTech

In addition to motions or forces applied to a system in a short time interval (shock) and over a long period of time (vibration), isolated systems and subsystems are often subjected to wide range of temperature variations. These temperature extremes can range between -40°F to 200 °F in many aerospace applications. Shock loads can cause an instant failure while vibration loads can reduce system performance or causes fatigue failure. When combined with notable temperature variations, the isolator performance may degrade resulting in potential damage and failure. The latter is critically important in the elastomer-based isolators. Isolator performance is dependent not only on the stiffness of an elastomer mix, but the geometry of the rubber as designed between structural components. Much of this design is conducted based on spatial and installation requirements, fail-safe features, and environmental concerns including temperature, humidity, and fluid exposure. Change in stiffness of rubber with temperature is a basic material property, rubber stiffness decreases with higher temperature and increases with lower temperature. The goal of the systems designer is to provide an isolation system for attenuating excessive shock and vibration loads to acceptable levels that could result in maintenance-free life and system performance while the isolator maintains its performances when subjected to temperature changes.

In this work, a series of static and dynamic vibration tests are performed on a customized cup mount subjected to a wide temperature range. The main purpose is to determine the influence of temperature on the effective stiffness of elastomer-based cup mount designs. Typical effects of temperature on silicone rubber are not obvious for these isolators due to the hybrid design of the mount with significant pre-load. Static and dynamic tests at hot temperature shows that the cup mount has higher effective stiffness in all three directions (compression, tension, shear) than room temperature. The same tests at cold temperature showed much stiffer results in static testing but softer results in dynamic testing. Part of the experiment focused on measuring components at hot and cold temperatures to determine how their dimensions changed when subjected to temperature variations. At hot temperature, rubber expansion was greater than the stainless outer cup expansion, resulting in a higher pre-load. The observed 10-15% increase in effective stiffness is due to the extra pre-load outweighing the softening of the elastomer due to increased temperature.

MOVING DELICATE AIR AND SPACE EQUIPMENT

Mr. Claude Prost, Vibro Dynamics/Socitec
Mr. Joshua Partyka, Vibro Dynamics/Socitec

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

Surprisingly, even rugged components and assemblies used in air and space that are designed to withstand high g forces can be damaged during ground transport prior to flying. Static and dynamic inputs such as quasi-static forces, vibration and shock, as well as handling hazards are far from being negligible. While flying objects are usually designed to resist 10 g, at least in the launching axis, even a minor 10” drop may induce a short duration shock of few tens if not hundreds of g’s, therefore damaging the equipment. Another important factor is that flying vessels are extremely robust, much more than the transporting vehicle, which will deform and follow the road profile during transport, whereas the object being transported will not. Therefore, in order to avoid excessive stresses, providing compliance between the object and transport vehicle is of extreme importance. Further, the time scale of the projects and the size of the equipment make it virtually impossible to experiment until the final phase, making reliable simulation of the response critical.

Two real transportation cases studies experienced in Europe up to the final launching site in French Guyana will be discussed. The first is the transportation of the Soyouz launcher without isolators, while the second is the transportation of the Ariane 5 launcher cryogenic stage with wire rope isolators. In both cases, a full 250 degree-of-freedom Symos numerical analysis model will be introduced, and predictions will be compared with actual results. In addition, other similar cases will be mentioned in brief, including a telescope transportation protection and monitoring case, transportation of an aircraft wing, and mirror transportation.

SESSION 15: INSTRUMENTATION II

MINIMIZING NOISE PICK-UP IN REAL WORLD SENSOR MEASUREMENTS

Mr. Alan Szary, Precision Filters
Mr. Douglas Firth, Precision Filters

Acquiring high fidelity wide-band sensor data is a difficult task. Selecting the right sensor and assuring adequate bandwidth of the measurement system is only part of the solution. Electrostatic and electromagnetic noise are always trying to corrupt our hard earned data, and ground loops cause their own special problems. This discussion will explore best practices for minimizing noise pick-up in critical wide-band measurements. Topics covered will be understanding electrostatic vs. electromagnetic coupling mechanisms, filtering strategies, comparing noise immunity of different sensor instrumentation topologies, and understanding ground loop noise and how to minimize it.

PUSH-PUSH BALANCED CONSTANT CURRENT FOR STATIC AND DYNAMIC STRAIN MEASUREMENTS

Mr. Douglas Firth, Precision Filters, Inc.
Mr. Alan Szary, Precision Filters

Many factors must be considered when making static and dynamic strain measurements. The often used Wheatstone quarter and half bridge circuits are susceptible to noise pick-up and loss of gage sensitivity particularly for long cable runs with bridge completion residing in the signal conditioner. A five-wire half bridge configuration can be used to compensate for the loss of sensitivity due to long cable runs, but since heavy filtering is needed to eliminate the noise pick-up, it is very difficult to obtain high-fidelity dynamic data using this circuit.

In this presentation, we introduce the Push-PushTM BCCTM topology to address the problems that plague the Wheatstone bridge. For typical environments with moderate to long cable runs and potentially high ambient noise, we will show that the Push-Push BCC is superior to the Wheatstone bridge measurement in its ability to measure simultaneous static and dynamic strain with as few at 2-wires. For strain measurement applications at extreme temperatures, we will show that the fully balanced Push-Push BCC topology can achieve excellent thermal (apparent) strain compensation.

ROBUST TRIAXIAL HIGH-G ACCELEROMETERS WITH LOW-NOISE CABLE

Mr. James Nelson, Endevco

One poorly-understood parameter of high-shock accelerometer measurements is the contribution of the cable to the data. Endevco has developed a controlled test to quantify the output associated with a shock to the cable, which has led to understanding around which cable parameters are important to minimize shock induced output. This paper will share how the addition of a low-noise treatment on the new Model 7284A and 7274A accelerometers can decrease the error during high-shock events when the cable experiences significant motion. This paper will present data on the effectiveness of the low-noise treatment under a variety of tests on the completed sensor assemblies. Test methodologies and results will be shown for shock tests such as amplitude linearity and over-range survival, as well as frequency response and other tests. Additionally, the 7284A and 7274A will be checked for conformance to the MIL-STD-810G guidelines for shock accelerometers.

CHARACTERIZING MOTION IN 6 DEGREES OF FREEDOM

Mr. Andy Hohla, Endevco

To fully characterize the movement of an object, one needs to measure more than just linear motion, but to include the rate of rotation. One common practice of measuring angular motion utilizes a spaced array of linear accelerometers placed on the object. A six degrees of freedom (6DoF) sensor provides advantages over this method and provides the opportunity to the end user to make measurements that were previously impractical. This year, Endevco has enhanced its product portfolio by adding the model 7360A, a 6DoF sensor that provides analog output for three axes of linear acceleration and three axes of angular rate in a compact package. This presentation describes the advantages of an analog output 6Dof sensor and presents evidence to support.

SESSION 16: PENETRATION MECHANICS

CONSTITUTIVE MODELING OF JOINTED ROCK

Dr. John Furlow, Applied Research Associates
Mr. Michael Thomas, Applied Research Associates

Numerical modeling of jointed rock mechanics is often difficult due to the discontinuities of the wave propagation medium. These discontinuities manifest themselves as fractures distributed within in-situ rock mass. There are several methods to model this jointing, one method is to explicitly model each piece of continuous rock in contact with other pieces. Alternatively, one could account for the effects of jointing in the yield surface and hydrostatic response across the continuous media. The method presented here details numerical modeling via finite elements of jointed rock that accounts for jointing based on rock quality for a given intact rock type and porosity.

SESSION 16: INFRASTRUCTURE DAMAGE MITIGATION

EVALUATION OF SYSTEMS FOR DEFEAT OF HIGH-VELOCITY PROJECTILES FOR PROTECTION AGAINST INFRASTRUCTURE THREATS

Mr. Ernesto G. Cruz-Gutierrez, ERDC
Ms. Amie Burroughs, ERDC
Mr. Brandon Everett, ERDC

High-velocity projectiles have always been a significant threat in areas of conflict worldwide. Because of the explosive component that most projectiles contain, these devices have the potential to cause significant casualties as well as severe damage to structures and support facilities. The U.S. Army Engineer Research and Development Center (ERDC) conducted a series of laboratory and field penetration tests to address airfield infrastructure threats. The program utilized a combined modeling and simulation and experimental research approach to achieve field-ready, transitioned hardening and resiliency capabilities to mitigate specific munition threats. This paper will present an overview of several configurations with different dimensions and structural components tested to determine viable systems for defeating high-velocity projectiles.

Rapid Runway Repair by Removal of Concrete Using Explosive Methods

Mr. Stephen Turner, ERDC
Dr. Jay Ehrgott, ERDC
Mr. Denis Rickman, ERDC

Researchers at the U.S. Army Engineer Research and Development Center (ERDC) have conducted research under the Airfield Damage Repair (ADR) Modernization Program to develop new, expedient concrete pavement repair techniques for bomb-damaged airfields and to update repair guidance. In the event that runway craters occur due to detonations from enemy ordinance, the time that a damaged runway is removed from service must be reduced using fast methods and durable materials to reduce lost operational time and subsequent maintenance. One of the most time-consuming steps in the runway repair methodology is cutting out the damaged concrete pavement area using mechanical methods such as concrete saws. The Air Force Civil Engineer Center tasked ERDC to investigate if these mechanical methods could be replaced with explosive means. A literature review was conducted to determine typical runway design and crater dimensions. After bulk explosive options were conducted with inadequate results, arrays of commercially-available, miniature shaped charges were tested and proved more promising. Results showed that these shaped charges will fully penetrate through any typical runway, and, when placed at proper spacing, interconnecting cracking of the concrete will occur to yield a “cut” through the pavement. Since the initial phases of this work was presented at the 2017 Shock and Vibration Exchange Symposium, the ERDC has optimized the shaped charge cutting arrays to enhance pavement cutting performance, allow rapid deployment, and minimize hazardous debris.

Area Damage Estimation Method based on High-Resolution Geospatial Data

Mr. Jasiel Ramos-Delgado, ERDC
Mr. Joshua E. Payne, ERDC
Mr. José A. Rullán, ERDC
Dr. Jay Ehrgott, Jr., ERDC
Mr. Sean Griffin, ERDC

Damage assessment to structures and infrastructure during and after combat operations is a critical component in the evaluation of weapon effectiveness, tactical maneuverability, as well as a data source for determining potential humanitarian operations. Identifying building footprints and structural components along with relative levels of damage to those structures effected by combat operations with the use of imagery presents certain challenges and uncertainties. Building structures made up of a combination of varying shapes and elevations make it difficult to define building footprints and require the use of high-resolution geospatial data. The Engineer Research and Development Center (ERDC) in support of the National Geospatial-Intelligence Agency (NGA) was tasked to develop an area damage estimation (ADE) method by exploiting high-resolution geospatial products captured from stand-off systems currently available to US and allied forces. This effort utilized pre- and post-damage imagery and spatial resolution data to determine a relative level of damage to structures and building in a pre-selected area effected by recent combat operations. In order to conduct this effort the ERDC had to develop a systematic approach to define the structural footprints, the existing conditions of those structures prior to the operations, and the relative level of damage to those structures defined by the post-damage temporal data. The relative level of damage was determined by estimating the usability and serviceability of the building and/or structures using predetermined damage criteria. This paper will present the approach taken to develop this ADE methodology including the development of the different damage categories utilized in this effort.

SESSION 17: DYSMAS II: UNDEX DEVELOPMENT & APPLICATIONS

DYSMAS ENHANCEMENTS FOR FILLING TANKS IN NAVAL VESSELS

Dr. Alan Luton, NSWC Indian Head
Mr. Roger Ilamni, NSWC Indian Head
Dr. Jeff St. Clair, NSWC Indian Head
Dr. Bradley Klenow, NSWC Carderock
Mr. Ralf Tewes, iABG
Ms. Alina Leppmeier, iABG
Mr. Manfred Krueger iABG

When modeling the response of naval vessels to underwater explosion (UNDEX) phenomena, it is often important to account for the liquids in the major tanks to obtain an accurate trim and pre-stressed condition of the structure. Although a ship can have thousands of tanks, typically less than 100 need to have their fluids modeled. While the legacy DYSMAS process satisfies the basic required capability, it was designed with only a handful of tanks in mind. When dozens of tanks need to be filled the process is cumbersome, tedious, and prone to user errors.

The goal of the current effort is to build a streamlined workflow that will permit the user to uniquely define all information for tanks one time, while building the structural model. DYSMAS/P is being updated for this new capability, and will provide tank information to other DYSMAS pre-processing codes (Float, PreStress, and PreGemini) via include files. This arrangement allows alternatives to DYSMAS/P to be used as well. In addition, the amount of information that must be specified for each tank is reduced, thus lessening the burden on the user. New algorithms have also been implemented to provide better accuracy for trim conditions and coupled pressure in general.

REVERSE ENGINEERING THE GERMAN UTA TEST POND BOTTOM PROPERTIES

Mr. Martin Marcus, NSWC Indian Head

Abstract not available.

MODELING TORPEDO IMPACT USING DYSMAS

Mr. Otto Quinones, NSWC Indian Head

Abstract not available.

INVESTIGATING UNDEX THREATS TO THE MARINE MAMMAL MELON

Dr. Emily Guzas, NUWC Newport
Ms. Monica DeAngelis, NUWC Newport
Mr. Thomas N. Fetherston, NUWC Newport
Ms. Rachel Hesse, NUWC Newport
Mr. Daniel Perez, NUWC Newport
Dr. Erin Gauch, NUWC Newport
Ms. Lauren Marshall, NUWC Newport

Current U.S. Navy criteria to assess non-auditory physiological impacts of explosives on marine mammals relies on limited datasets derived from past experiments using small submerged terrestrial animals

subjected to UNDEX loading. Unfortunately, these 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) that is present in a subset of marine mammals (Odontoceti, or toothed whales). There is no terrestrial mammalian analogue to the marine mammal melon, which is used for beam-forming of various echolocating acoustic pulses. Since the 1970s and for obvious ethical reasons, no intentional UNDEX testing has been carried out on live animals. Some UNDEX testing has been carried out on marine mammal cadavers by D.R. Ketten et al., authorized through the required permitting process. Although the focus for these efforts was primarily on damage related to the marine mammal ear, hemorrhages were found in the acoustic jaw fats and melons of some test subjects. This presentation will cover simulation of a subset of these experiments producing a range-to-effect result on the melon. Simulations are carried out using the U.S. Navy fluid-structure interaction (FSI) code DYSMAS to simulate the UNDEX initiation and propagation through the fluid medium for a subset of these cadaver experiments. UNDEX pressure histories extracted at cadaver locations are used as inputs to a finite element model of a simplified melon structure, where the material and geometry are based on published information. For these preliminary simulations of the range-to-effect test series, shock spectrum results are examined to start investigating potential damage mechanisms and thresholds.

SESSION 18: SHOCK QUALIFICATION OF STOWAGE SYSTEMS AND BATTERY-POWERED SYSTEMS

WEAPON STOWAGE CRADLE VALIDATION AND OPTIMIZATION FOR SHOCK SURVIVABILITY

Mr. Maruti Kolluru, NUWC Newport
Mr. Kevin Behan, NUWC Newport
Mr. Michael Lapera, NUWC Newport

Weapon stowage cradles aboard VIRGINIA Class submarines provide several functions. They are integral to weapon shipping, weapon handling within the torpedo room and torpedo tube loading/unloading. The weapon stowage cradle, with stowed weapons, must also meet shipboard shock requirements. From 2015 through 2018, the Naval Undersea Warfare Center, Division Newport (NUWCDIVNPT) performed verification and validation (V&V) of a weapon stowage cradle and torpedo MK 48 transient shock analysis model. Once validated, the model was then exercised to evaluate cradle modifications with the intention to identify an optimized weapon stowage cradle and stowed torpedo configuration. The V&V and parametric studies will be discussed.

SHOCK QUALIFIED STOWAGE SOLUTIONS FOR SUBMARINE APPLICATIONS

Mr. Kevin Behan, NUWC Newport
Ms. Teresa Gangi, NUWC Newport

Naval Undersea Warfare Center Division, Newport (NUWCDIVNPT) developed shock qualified stowage solutions are used on various classes of United States submarines to safely store electronics, spare parts, and Temporary Alteration (TEMPALT) equipment in the torpedo room. Flat stowage solutions exist for SSN 688 and 21 CLASS submarines. Additionally, electronics enclosure racks were developed for stowage of electronics on SSN 688 and VIRGINIA Class submarines. TEMPALT hardware developers leverage these existing solutions to integrate new capabilities onto submarines while maintaining shock qualification. NUWCDIVNPT is currently developing a flat stowage solution for the VA CLASS torpedo room, which entails unique shock qualification challenges. This paper describes available and forthcoming stowage solutions and their shock qualification approaches.

Battery Shock Qualification, Challenges, and Goals

Ms. Monica Black, NUWC Newport
Mr. Kevin Behan, NUWC Newport

Battery-powered payloads and systems are being developed for use and stowage aboard US Navy vessels. Due to the non-structural hazards associated with modern battery systems, such as harmful gases, fire, and electrical hazards, shock testing is required to qualify these systems. These battery systems present a unique set of challenges associated with safety, environmental, and representative shock loading. This paper describes recent battery shock qualification efforts completed by the Naval Undersea Warfare Center Division, Newport (NUWCDIVNPT) on a Medium Weight Shock Machine (MWSM). Details include development of test plans, safety procedures, and considerations for fixture design.

SESSION 19: UNDEX: NEW SHOCK TESTING TECHNOLOGY

Evolution in Shock Machine Design

Mr. Kevin Gilman, Lansmont Corporation

Shock machines have traditionally used gravity, sometimes with "bungee" acceleration assistance, or pneumatics to produce the impact velocity necessary to achieve a desired shock test pulse. This method causes the shock machine's table to have an initial velocity (Vi) prior to the occurrence of the actual shock test pulse. This initial velocity is sometimes not representative nor desired for the intended simulation, and resulting modeling, where the specimen needs to be at rest (V_i=0) prior to shock event and/or where the effect of gravity needs to also considered. This challenge, along with the addition of more localized and global sequentially controlled pulses, has led to the evolution of shock machine design specific to defense applications for both ground and underwater blast simulation.

New Double Pulse Shock Testing System for WTD 71

Mr. Alexander von Bluecher, Bundeswehr Technical Center for Ships and Naval Weapons

Since 1985, German Naval ship building rules for shock resistance have required evaluation of laboratory shock testing by SRS's. Latest changes of these rules were applied with the 2017 edition of the BV 0230. This edition requires shock test machines with more demanding performance than the existing capabilities. New systems had to demonstrate higher performance in terms of displacement, velocity, and acceleration in the SRS. This led to the development of WTD-71's DP-VITS (Double Pulse Vertical Impact Test System) derived from ARL's IED simulation efforts. DP-VITS demonstrated full capability in July 2019 during FAT and will be operational in 2020.

Shock Qualification Testing using Seismic Airguns

Mr. Callum Norris, Thornton Tomasetti
Mr. Gavin Colliar, Thornton Tomasetti

Equipment destined for use in warships has a requirement to be robust against underwater explosions. Shock qualification is routinely carried out with equipment fitted within barges / FSP's. Traditionally, loading is applied using a non-contact underwater explosive. In 2012 the UK MoD approved the use of seismic air guns as a means of barge excitation. This method has proved particularly useful in generating upper deck level loadings when combined with deck shock fixtures. A summary of shock qualifications carried out to-date is presented.

JASSO: A NEW SHOCK TESTING TECHNOLOGY FOR NAVAL EQUIPMENT

Mr. Gavin Colliar, Thornton Tomasetti
Mr. Phillip Thompson, Thornton Tomasetti
Mr. Nick Misselbrook, Thornton Tomasetti

Warships are designed to be robust against underwater explosions, and in order to demonstrate that a warship has met the required standard of shock capability, a number of shock qualifications on equipment and systems are normally undertaken. The shock qualification tests undertaken cover range from individual equipment's and systems to tests covering the entire vessel. Shock machines are used to carry out some of these tests where the equipment size and desired levels are suitable or if it is not cost effective to carry out explosive or airgun shock barge testing.

In addition, all naval ordnance is required to withstand levels of shock to ensure safety and safety and serviceability when embarked on ships. This may also be extended to other weapons as there is a strong possibility that they may be sea transported at some point during their life where there may be a risk from UNDEX shock.

The JASSO machine was developed by Thornton Tomasetti Defence to address some of these limitations with the aim of developing a machine that could serve as general UNDEX shock machine but which also could be deployed to test ordnance of a variety of sizes and weights with a meaningful shock pulse.
This paper and presents recent work associate with the commissioning and capabilities of the JASSO Shock test machine particularly covering the following:

- That it is designed in a portable format which can be shipped to point of a test where live ordnance and or test equipment can be tested;
- That it is designed as a lean design that, in the event of an ordnance detonation the value of the machine is such that it can be written off; and
- The machine has a large degree of variability to match specific pulse shapes and extremes of acceleration and displacement while also applying the pulse as true time varying pulse to maintain the correct phase, something that is neglected in ordnance and general shaker shock tests.

ANALYSIS OF THE SHOCK RESPONSE SPECTRA PRODUCED BY THE JASSO SHOCK MACHINE

Mr. Gavin Colliar, Thornton Tomasetti
Mr. Alex McVey, Thornton Tomasetti
Dr. Jeff Cipolla, Thornton Tomasetti

The Air Gun-driven JASSO shock machine represents new technology for UNDEX qualification of equipment and ordnance. Its scalability, portability, and low cost offer significant advantages for testing in its weight class. Broad acceptance of the technology depends critically on demonstration that the base excitation shock spectra produced by JASSO are comparable to the spectra of familiar legacy machines, such as the LWSM and MWSM prescribed by MIL-S-901E. Here, we will show preliminary results comparing the experimentally measured JASSO spectra to those of standard 901E machines.

SESSION 20: STRUCTURAL RESPONSE & ANALYSIS

PARAMETRIC MODELLING TO OBTAIN FULL FIELD STRUCTURAL DYNAMICS OF AN UNKNOWN SYSTEM FROM LIMITED SPATIAL MEASUREMENTS

Mr. Ellis Kessler, Virginia Polytechnic Institute and State University
Dr. Pablo Tarazaga, Virginia Polytechnic Institute and State University
Dr. Serkan Gugercin, Virginia Polytechnic Institute and State University
Dr. Sriram Malladi, Virginia Polytechnic Institute and State University

Parametric data-driven modelling provides an opportunity to derive deeper knowledge of the structural dynamics of complex, unknown systems than other techniques. Traditional techniques often used in vibration testing require full finite element models, which may not always be possible to obtain or may be too difficult to model. When full system models are unavailable or inaccurate, data-driven modelling allows an avenue to obtain usable models from measurements alone; not requiring previous knowledge of the system itself. Adding some system knowledge such as boundary stiffnesses, or measurement locations, parametric methods allows data-driven modelling to create even more useful models which could then be used in place of a full finite element or analytical model. Previous work has shown that parametric data-driven modelling can be used to interpolate between different boundary stiffnesses at the clamped end of a beam, and accurately predict FRFs corresponding to a beam with a boundary stiffness within the range of tested stiffnesses. This work will explore the feasibility of using data-driven modelling to use a discrete number of spatially distributed measurements to create a parametric model capable of describing the full field structural dynamics of a previously unknown systems.

FULL-FIELD FLIGHT ENVIRONMENTS VIA A HYBRID EXPERIMENTAL-ANALYTICAL METHOD

Dr. Brian Owens, Sandia National Laboratories
Mr. Brandon Zwink, Sandia National Laboratories
Mr. Moheimin Khan, Sandia National Laboratories
Dr. Gregory Tipton, Sandia National Laboratories
Mr. Randy Mayes, Sandia National Laboratories

Flight testing provides an opportunity to characterize a system under realistic, combined environments. Unfortunately, the prospect of obtaining flight environments is often accompanied by restrictive instrumentation budgets, thereby limiting the information collected during flight testing. Instrumentation selection is often a result of bargaining to characterize environments at key locations/sub-systems, but may be inadequate to characterize the overall environments or performance of a system. This work seeks to provide an improved method for flight environment characterization through a hybrid experimental-analytical method, modal extraction, and model expansion.

This work will discuss the design of a flight experiment including hardware design, instrumentation, and data acquisition. The role of ground testing for model validation will be discussed as well as ground trials of the hybrid method. Finally, the results of fielding the experiment on a flight test will be presented. The work demonstrates a significant leap in our understanding of flight environments. Specifically, the ability to obtain full-field flight response predictions from limited measurements including non-measured quantities such as stress and strain.

MESHLESS SIMULATION DRIVEN DESIGN APPLIED TO SHIPBUILDING INDUSTRY
Mr. Carlos de Lima, Altair Engineering
Mr. Rajesh Bishnoi, Altair Engineering
Mr. Dakota Young-Grieco, Altair Engineering

The use of Finite Element Analysis (FEA) has grown significantly in past few years across multiple industries, but more importantly, it has expanded across the whole design cycle of products. For some industries, FEA has become crucial for modern engineering. It is also widely accepted to introduce FEA in the early stages of the design cycle in order to speed up the time to market of products. The biggest challenge for some industries is to build a full model with accuracy for FEA and perform all the necessary design changes to evaluate multiple scenarios under real-life conditions.

As a breakthrough alternative, Altair SimSolid does not use traditional Fine Element Model to simulate complex assemblies. It takes advantage of fully featured CAD and within minutes performs structural analysis by using an extension of the Theory of External Approximations.

This study demonstrates the use of this meshless analysis method applied to a full assembly of a tugboat ship model with thousands of parts. By eliminating geometry preparation and meshing, the design engineer has more time to understand the performance of the assembly, analyze multiple scenarios and make design changes to improve the performance even before sending the assembly to the analysts.

FILLET WELD SIZING USING FINITE ELEMENT METHODS
Mr. Nicholas Pinco, HII Newport News Shipbuilding
Mr. Chris Campbell, HII Newport News Shipbuilding

This paper discusses several methods for sizing fillet welds for any structural design or weld configuration. This paper will summarize several methods for weld sizing: 1) classic rigid body approach (weld by lines); 2) A newer approach that utilizes finite element analysis results (plate element forces and/or stresses). Goals for this paper are to: 1) go over the classic method, its assumptions, uses and limitations; 2) present a newer approach that uses shell element stress results from a finite element analysis to determine sufficient fillet weld leg size; 3) present a newer approach that uses shell element force results from a finite element analysis to determine sufficient fillet weld leg size. Both of the finite element analysis methods utilize shear flow along the weld to calculate the necessary weld size. Benefits of the new method include the ability to more accurately represent weld stresses by taking into account the structural stiffness, the ability to analyze curved welds, and the ability to analyze 3-dimensional weld patterns, which cannot be analyzed via the weld by lines method. Examples using all methods will be presented and discussed, and comparisons between them will be performed to determine the applicability and limitations of each method.

A MASS NORMALIZED PROJECTION APPROACH TO COMPONENT TESTING
Mr. Kameron Mize, Virginia Tech
Mr. Nick Corbin, Virginia Tech
Dr. Pablo A. Tarazaga, Virginia Tech

Fusion of test and analysis is a field that has garnered renewed interest due to its potential to reduce testing time, increase reliability, leverage modeling capabilities and ensure better and more efficient environmental certifications. With this in mind, the work herein will look at a modified projection method used to inform component testing and boundary condition selection. Proper component testing needs to address how assembled structures can be certified and tested as individual components with relevance to their assembled structure behavior and environment. This is of great interest as these techniques have the ability to validate components as they come out of production lines and experience down time before full assembly.

The method developed in this work looks at the mathematical vector projection of individual component modes to the corresponding degrees of freedom of the modes of interest of the assembled structure, which are considered to be the critical flexibilities. High correlations determine which modes should be tested in the individual component. Furthermore, by changing the boundary conditions of the individual component, the projection can be analyzed again and the optimal testing condition determined. Contrary to traditional methods, the method herein adds a mass normalization step which is able to provide the user with the same information for testing (i.e., high correlated modes) without the need to compute a pseudo inverse. Additionally, for cases of very large degrees of freedom, the new mass normalized formulation is expected to exhibit a reduction in computational time.

SESSION 21: SECONDARY DEBRIS PREDICTION

PREDICT SECONDARY DEBRIS DUE TO BURIED EXPLOSIVES: PART 1: EXPERIMENTS

Dr. Wije Wathugala, ACTA
Dr. George Lloyd, ACTA-SH
Mr. Tony Zimmerly, EMRTC, New Mexico TEch
Mr. Steven Mullins, SECOTEC

Estimating collateral damage due to accidental or intentional burial in soil and detonation of munitions is required for many militaries in the world. A multi-year effort to develop Fast Running Models (FRMs) predicting secondary debris generated when cased explosives explode under brick/paver/concrete pads were conducted by the ACTA team under the Air Force SBIR program. The results are presented here in three companion papers: (1) Experiments, (2) Numerical Simulations, and (3) Fast Running Models.

Secondary debris generated from buried explosives/munitions/IEDs can travel far increasing hazard radii (region) over primary fragments generated from cased explosives. Most experiments related to buried explosions found in literature are geared toward better understanding the effect of IED explosions on vehicle underbellies. Experiments designed to study trajectories of secondary debris generated from buried explosions were non-existent at the beginning of this project. However, there is a need for predicting secondary debris pertaining to collateral damage concerns from munitions that miss their intended target becoming buried instead. This paper presents details of five experiments, with charge mass ranging from 20 to 200 pounds, designed and performed to study all the phenomena associated with this application. These experiments were designed with replicate measurements for many important response quantities. In these experiments, cased explosive were buried at the center of a pad made with regular clay bricks, regular cement pavers and reinforced or unreinforced concrete. A large majority of the resulting debris was weighed, and their final locations were identified. Multiple synchronized high-speed cameras were used to record the debris cloud in-order to extract their 3D trajectories. The analyses of the results show replicate measurement agreeing with each other attesting to the good quality of the test data. The results of these tests provided the basis for creating and validating more quantitative collateral damage assessment tools.

PREDICT SECONDARY DEBRIS DUE TO BURIED EXPLOSIVES: PART 2: NUMERICAL SIMULATIONS

Dr. Wije Wathugala, ACTA
Dr. Wenshui Gan, ACTA

Estimating collateral damage due to accidental or intentional burial in soil and detonation of munitions is required for many militaries in the world. A multi-year effort to develop Fast Running Models (FRMs) to predict secondary debris generated when cased explosives explode under brick/paver/concrete pads were conducted by the ACTA team under the Air Force SBIR program. The results are presented here in three companion papers: (1) Experiments, (2) Numerical Simulations, and (3) Fast Running Models.

Understanding how to model explosions in soil is important in many military and civilian applications such as predicting consequences of buried mines/IEDs/munitions in soil and excavation operations involving explosives. In general, rapidly expanding detonation products (gases) push surrounding medium away from the explosion, causing the breakup of the medium and creating cracks through which gases can escape. Explosions in soil involve additional complexities due to the porous nature of soil. The amount of porosity and the size of pores through which gas can escape affect the rate of dissipation of high pressures generated in the explosion. Fast moving gases through soil pores can cause breakup of the medium. There is additional complexity in modeling the secondary debris generated from whole or broken up bricks, covering the soil, propelled into the air due to an underground explosion.

Efforts have consisted of improving numerical methods for this application and performing full scale experiments to validate them for several years. The companion paper provides results of the experimental program. In this paper numerical simulation details of buried munitions in soil using CartaBlanca are presented. Those results are then compared with experimental results. CartaBlanca is a multi-phase coupled code developed by the Los Alamos National Laboratory using the Material Point Method (MPM) for solid phase and the Arbitrary Lagrangian Eulerian (ALE) method for the fluid phase.

PREDICT SECONDARY DEBRIS DUE TO BURIED EXPLOSIVES: PART 3: FAST RUNNING MODELS

Dr. Wije Wathugala, ACTA
Dr. Wenshui Gan, ACTA
Dr. George Lloyd, ACTA-SH

Estimating collateral damage due to accidental or intentional burial in soil and detonation of munitions is required for many militaries in the world. A multi-year effort to develop Fast Running Models (FRMs) to predict secondary debris generated when cased explosives explode under brick/paver/concrete pads were conducted by the ACTA team under the Air Force SBIR program. The results are presented here in three companion papers: (1) Experiments, (2) Numerical Simulations, and (3) Fast Running Models.

A newly developed Fast Running Model (FRM) predicting secondary debris intended for assessing collateral damage effects (CDE) will be the subject of this paper. Five full scale experiments with explosive charges ranging from 20lb to 200lbs were designed and executed. Experiments were performed to study the phenomena and to validate numerical models. First principle High Fidelity Physics Based (HFPB) numerical methods were developed and validated by comparing predictions to experiments. Consequently, a suite of HFPB simulations in the parameter space of interest were implemented on DoD High Performance Computers (HPCs) and response data trends were studied. The FRM was fitted based on these simulation results together with data from experimental observations.

Based on user input of bomb dimensions, depth of burial, explosive fill, soil type, pavement material (brick, concrete paver, or concrete) that contributes to the secondary debris, the FRM generates a stochastic debris source model. The debris source model can then be used in Monte Carlo debris dispersion simulations allowing the risk of debris impact on nearby people and material to be evaluated. Comparison of FRM predictions with available experimental data and data trends of FRM predictions due to varying key input parameters such as charge mass, depth of burial will be presented.

SESSION 21: MECHANICAL SHOCK II (ALTERNATIVE/CUSTOM MACHINES & MATERIALS

DESIGN OF A HIGH-ENERGY SHOCK MACHINE FOR USE INSIDE A REACTOR CAVITY

Ms. Stephanie Booth, Sandia National Laboratories
Mr. Ken Morris, Sandia National Laboratories
Dr. Carl Sisemore, Sandia National Laboratories

A high-energy mechanical shock machine was needed to conduct experiments within the dry cavity of a research reactor at Sandia National Laboratories. Due to severe size limitations, the machine is vertically oriented, making use of a gravity-drop dead-blow projectile to deliver the shock impulse and a small, spring-mounted resonant plate. This paper documents the unique design challenges of this specialized shock machine. An overview of the machine's operation and sample test data from the first calibration and check-out tests are also presented. Preliminary tests have demonstrated the machine's ease of use and repeatability for research studies.

SIMULATED PROOF TESTING OF A COMPOSITE MORTAR BASEPLATE

Dr. Andrew Littlefield, US Army CCDC AC Benet Labs
Mr. David Alfano, US Army CCDC AC Benet Labs

Mortar baseplates made from composites offer weight savings over incumbent, metal baseplates, reducing burden on the soldier. 3D woven composites are well suited to handle the severe impact loads imparted during repeated firing of mortars, there-by overcoming delamination and other failures that have been observed in previous composite mortar baseplates fabricated via traditional 2D lay-up. Additionally, 3D weaving enables fabrication of the near net shape geometry of a mortar baseplate in a single, integrally woven part (in this case a bowl shaped baseplate with quantity 5 integrally woven legs extending normal from the surface). Currently field mortar baseplates are subjected to simulated proof testing in the lab as part of the production process. This simulated proof testing duplicates the traditional live fire proof testing but is done in a lab environment. To ensure that the composite mortar baseplates can survive firing loads it will be subjected to the exact same proof test as a standard metallic mortar baseplate. This presentation will review the design and manufacture process of the composite baseplate. It will then go over the standard baseplate simulated proofing process and how the test was adjusted for a composite baseplate. Finally the results of the proof test on the composite mortar baseplate will be presented.

SESSION 22: SUBSIDIARY & SUBASSEMBLY COMPONENT TEST DESIGN

SUBSIDIARY & SUBASSEMBLY COMPONENT TEST DESIGN OVERVIEW
Ms. Lisa McGrath, HII Newport News Shipbuilding

Subsidiary and subassembly component obsolescence is a primary driver for the need to requalify principal units. Subsidiary and subassembly component testing can be an economical means of providing a basis for requalification of a modified principal unit. Subsidiary or subassembly test designs range from simple to complex, depending on the extent of the change to the principal unit. This paper discusses when it is appropriate to perform subsidiary or subassembly testing and the methods used to design a subsidiary or subassembly test. Details discussed include; 1) defining the shock environment required to support extension to the principal unit; 2) determining which type of testing (lightweight, medium weight, heavyweight, non-standard) is appropriate; 3) determining subsidiary/subassembly test acceptance criteria; and 4) designing representative test fixtures. Three case studies are provided in subsequent papers for lightweight, medium weight, and heavyweight subsidiary or subassembly test designs.

SUBSIDIARY & SUBASSEMBLY COMPONENT TEST DESIGN: LIGHTWEIGHT SUBASSEMBLY TESTING CASE STUDY
Mr. Bradley Harris, HII Newport News Shipbuilding

Subassembly (Type C) shock testing involves accurately representing the subassembly's local environment when the principal unit undergoes naval shock loading. However, representing a subassembly's potential for failure extends beyond only testing its responses to local shock loading. The case study presented here summarizes the process for evaluating the shock environment of a motor encoder where the potential for failure additionally includes damage associated with motor impact by near components. The study details 1) the modeling used to predict component impact and 2) the analysis of a test fixture that attempts to replicate the impact potential. The goal of the study is to provide an example of the technical rigor required to evaluate a subassembly's potential for failure during a Type C shock test.

SUBSIDIARY & SUBASSEMBLY COMPONENT TEST DESIGN: MEDIUM WEIGHT SUBSIDIARY TESTING CASE STUDY
Mr. Patrick Minter, HII Newport News Shipbuilding

Several valve/motor actuator combinations were shock tested separately as subsidiary items using the Medium Weight Shock Machine. Dummy masses were designed to represent the respective actuators and valve reactions during these tests. However, later testing, which included combined valve/actuator setups, indicated some potential for vulnerability in the actuator electronics when mounted to corresponding valves. Since these failure modes were not present in the stand-alone actuator tests, it was concluded that the valve structural environment was more severe with regards to the actuator than the previously conducted tests. In order to mitigate risks, a series of simple analyses were conducted to characterize the valve bonnets and risers in order to determine combined valve/actuator tests that would encompass high and low frequency domains. These analyses were conducted using finite element methods. Medium weight tests were then planned on a subset of the total valve/actuator combinations.

SUBSIDIARY & SUBASSEMBLY COMPONENT TEST DESIGN: HEAVYWEIGHT SUBSIDIARY TESTING CASE STUDY

Ms. Lisa McGrath, HII Newport News Shipbuilding
Mr. Chris Campbell, HII Newport News Shipbuilding
Mr. Steve Arturo, HII Newport News Shipbuilding

Obsolescence of subsidiary components requires requalification of the principal unit, which is a primary driver of subsidiary component shock testing. This paper provides a case study of a heavyweight subsidiary component shock test performed on a replacement monitor that is used in several different principal units and shock environments. The new monitor replaced an obsolete monitor that was installed in workstations and bulkhead mounted enclosures, in both deck and hull environments. The shock environments (deck and hull) of the monitor installations were defined based on previous shock test results of the principal units, and a test fixture was designed that dynamically enveloped the intended installation environment. The test fixture response was evaluated using representative DSF transient inputs with FEA models developed in FEMAP and executed in NASTRAN.

SESSION 22: MIL-DTL-901E SHOCK

NSRP PROJECTS: MIL-DTL-901E COST AVOIDANCE IN SHOCK APPLICATIONS AND N30 FIREPROOF / WATERTIGHT DOORS

Mr. Michael Poslusny, HII Ingalls

The National Shipbuilding Research Program (NSRP) provides funding for technologies and processes that will reduce the total ownership cost of ships for the U.S. Navy and develop naval practices to improve the efficiency of the U.S. shipbuilding and ship repair Industry. NSRP members include U.S. shipyards and Navy sponsors. The bulk of NSRP funding goes to soliciting, selecting and executing R&D projects. The types of R&D project solicitations NSRP employs are Research Announcement Solicitations and Panel Project Solicitations. Ingalls Shipbuilding was recently awarded two RA projects: Cost Reduction of MIL-DTL-901E Shock Applications and Fire Resistant Watertight Structural Doors. This presentation will cover the status of the two projects and discuss the NSRP selection process.

SESSION 23: eSHOCK WEB DATABASE

ESHOCK PART 1

Ms. Nadeen Bogonis, US Navy
Ms. Kelli Gasswint, US Navy/NSLC
Mr. Benjamin Tiedgen, US Navy/NSLC

Electronic Shock is a web based tool built to assist various government entities and contracting activities in managing submission, tracking, approval, and records documentation required to ensure the execution to shock hardening requirements for Navy ships.

eShock Part 2

Ms. Nadeen Bogonis, US Navy
Ms. Kelli Gasswint, US Navy/NSLC
Mr. Benjamin Tiedgen, US Navy/NSLC

Electronic Shock is a web based tool built to assist various government entities and contracting activities in managing submission, tracking, approval, and records documentation required to ensure the execution to shock hardening requirements for Navy ships.

TRAINING IV

Introduction to UERDTools

Mr. Brian Lang, NSWC Carderock

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

SESSION 24 : UNDEX TESTING & ANALYSIS

Measurement of underwater explosion bubble jetting

Dr. Julian Lee, Defence R&D Canada Suffield
Dr. MJ Smith, Defence R&D Canada Atlantic
Dr. L. Gannon, Defence R&D Canada Atlantic
Dr. C. Marshall, Defence R&D Canada Atlantic
Mr. S. Halaska, Defence R&D Canada Suffield

The collapse of an underwater explosion bubble against a rigid surface has been studied extensively through theoretical analysis, numerical simulations, and experiments, however in situ measurements of the collapse process is difficult due to the extreme conditions of high flow speeds and pressures. The present work describes the development a method to perform direct measurements of the flow speed using a special gauge arrangement to detect the motion of the bubble interface during the collapse process. The gauge arrangement is designed to minimally disturb the flow, while providing time-of-arrival information of the gas-water interface at specific location along the axis of symmetry of the collapsing bubble. This method is used to specifically measure the speed of a water jet formed as an underwater explosion bubble collapses against a rigid wall. Through these direct measurements and comparisons with CFD simulations, insight is gained on the details of the jet formation process. This methodology can potentially be applied to scenarios of Naval platforms subjected to close-proximity UNDEX.

EFFECT OF Al/O RATIO ON UNDERWATER EXPLOSION LOAD AND ENERGY OUTPUT CONFIGURATION OF ALUMINIZED EXPLOSIVE
Prof. Yuanxiang Sun, Beijing Institute of Technology
Prof. Cheng Wang, Beijing Institute of Technology

In order to study the effect of Al/O ratio on underwater explosion load and energy output configuration of aluminized explosives systematically, four kinds of aluminized explosives are taken into account, and their Al/O ratio are 0, 0.16, 0.36 and 0.63, respectively. Coupled Eulerian Lagrangian method was used to simulate the whole process of underwater explosion of four kinds of aluminized explosives on the basis of verifying the effectiveness of numerical method. The coupling effect between shock wave and bubble was considered in the numerical simulation. The impact effect is explained from three aspects: shock wave, bubble and energy output configuration. Simulation results show that with the increase of Al/O ratio, shock wave attenuation constant, shock wave impulse, bubble period, bubble maximum radius and specific bubble energy of underwater explosion of aluminized explosives all increase. Shock wave peak pressure, energy flow density and specific shock wave energy reach the maximum when Al/O ratio is 0.36. The addition of aluminum increases bubble energy more significantly than shock wave energy.

SESSION 24: VIBRATION: FAILURE ANALYSIS

ANALYZING FIELD ENVIRONMENTS TO UNDERSTAND PRODUCT FAILURE CAUSES
Mr. Casey DuBois, Vibration Research Corporation

Product failures often require expensive repairs or replacements. Over-engineering adds to recurring costs and its success is uncertain if the failure's cause is not understood. Engineers need in-depth knowledge before attempting a re-design.

This case study focuses on bus seat failures not predicted by industry standard tests. The goal was to collect comprehensive field vibration data and analyze that data to understand the failure's cause. The study used accelerometers placed at various points in multiple seating configurations and across multiple field environments. Analysis identified transmissibility issues between axes of motion, as well as higher reliability seat configurations.

EXAMPLES OF USING THE EXTREMES' COUNTING AND FATIGUE DAMAGE ACCUMULATION METHODS
Mr. Zeev Sherf, Consultant

The paper exemplifies the application of peaks' counting methods and fatigue damage accumulation evaluation, to several practical problems. In the first the fatigue damage accumulation under an acoustic load is presented. In the second the probability of failure of an electronic board exposed to a random vibration excitation is described. The mechanical apparatus implemented in the work herein, is presented in [1] and in the references cited there. First the problem of acoustic noise induced fatigue is handled. Next the probability of an electronic board's failure under a random vibration load is discussed.

SESSION 25: SHOCK DAMAGE ASSESSMENT

BOUNDARY CONDITION INFLUENCE ON SHOCK TEST DAMAGE POTENTIAL

Dr. Vit Babuska, Sandia National Laboratories
Dr. Carl Sisemore, Sandia National Laboratories
Mr. Robert Flores, Sandia National Laboratories

Component testing is always performed independently of the actual system in which it is intended to be employed. As a result, the boundary interface stiffness and impedance in a component level test frequently differ from the system level conditions. Modal analysis can be used to identify differences between the test condition and the as-installed system level conditions. However, shifts in resonant modes do not always correlate with damage potential or component survivability under shock excitation. The Box Assembly with Removable Component (BARC) structure was developed as a challenge problem for investigating boundary condition effects on tests. A modified version of the basic BARC structure with external components was used to evaluate system damage due to shock excitation under different boundary conditions. Assessing damage is the most reliable method for determining the effects of boundary condition differences on a test. This paper presents the results of finite element modeling and experimental shock testing using two different boundary conditions comparing component damage. The results show that, for shock excitation, the resulting component damage is largely derived from the shock's peak acceleration rather than changes in the modal content as a result of variations in the boundary conditions.

A METHOD FOR THE DAMAGE ASSESSMENT OF A COMPONENT UNDER CRASH SHOCK LOADING

Prof. Qingming Li, The University of Manchester

Over the past decades, passive safety has become an important subject for the development of vehicle industry. Numerous studies have been performed on impact energy absorbers (IEA) made from various materials and structures, e.g., thin-walled tubes, advanced materials, and composite structures. To evaluate the crushing performance of an IEA, several crashworthiness indices have been proposed, e.g. energy absorption (EA), specific energy absorption (SEA), peak crushing force (PCF) and mean crushing force (MCF). These indices focus mainly on the overall performance of an IEA, but cannot describe their shock effects. Consequently, device damage and human injury criteria in a crash incident are usually described based on the overall response of the concerned object.

This study proposes a method to apply dual damage criteria for the assessment of structural damage (including device damage and human injury) based on the crushing signal in a crash incident. To assess the crashing effects, the original crush signal was decomposed into an equivalent crush signal and a residual shock signal. The characteristics of crush signal and the necessity of considering both Amax-ΔV diagram and shock damage are discussed. The empirical head injury criterion (HIC) is linked to Amax-ΔV diagram. The proposed damage criteria can be incorporated into the design of impact energy absorbers and applied to the damage and injury assessments in vehicle crashworthiness and other crashing incidents.

VARIATIONS IN DAMAGE FROM SAME SHOCK RESPONSE SPECTRA
Dr. Arup Maji, Sandia National Laboratories

Shock specifications and consequent testing is based on the Shock Response Spectra (SRS). The SRS captures the response of Single Degree of Freedom (SDOF) structures of differing frequency to the shock; the SRS therefore no longer contains the duration or other temporal parameters pertaining to the shock. A duration can often be specified in the recreation of an acceleration vs. time history from the specified SRS, however there is little basis for that beyond technical judgment. The loss of information at various stages makes it difficult to recreate the original shock waveform. Different waveforms can result in the same SRS while their effect on a system or component can be different.

In particular, this study focuses on the decay rate associated with various frequencies that comprise the overall shock. The decay rate can vary among the constituent frequencies leading to a variation in the cycles in the acceleration vs. time history. The cycles of acceleration can be correlated to a 'damage index' which captures fatigue damage imparted to the object under shock. This study investigates several waveforms that have the same SRS but varying rates of decay for either high or low frequency component of the shock. The resulting variation in stress cycles and damage index is discussed.

SESSION 25: BALLISTICS

EXPLOSIVELY DRIVEN FLYER PLATE VELOCITY TIME PROFILES TRANSFORMED TO INTERNAL EXPLOSIVE PRESSURE
Mr. Marcus Chavez, Sandia National Laboratories

Measurement of velocity is common in the shock physics world where Velocity Interferometry System for Any Reflector (VISAR) and Photonic Doppler Velocimetry (PDV) are the work-horses. In shock environments, the velocity of an interface, typically composed of a reflective material such as aluminum in intimate contact with an optical medium such as air or PMMA, can be captured and studied. Study of the imparted interface velocity allows for understanding of the development of the pressure wave within an energetic material as the reactive wave propagates from the ignition point. Alternatively, flyer plates can be accelerated by explosives with a flyer plate areal mass that is sufficiently low to allow the acceleration to be indicative of the explosive pressure development. The method described within captures flyer plate velocity time histories using a laser interferometer and transforms the velocity into the explosive's internal pressure output just before interaction with the flyer plate. This method is compared to experiments with explosive in contact with optical windows and numerical simulations to ascertain whether the technique is a valid approach.

GURNEY ANALYSIS FOR HIGH SHEAR MIXED SILVER ACETYLIDE-SILVER NITRATE EXPLOSIVE ON KAPTON SUBSTRATES
Mr. Marcus Chavez, Sandia National Laboratories

The explosive, silver acetylide-silver nitrate (SASN), has been used in flyer plate studies for many years at Sandia National Laboratories. Gurney analysis has been applied in order to reliably predict the terminal velocity for a given explosive mass loading of SASN. However, SASN is spray deposited without further processing, which produces a high amount of porosity leading to a large amount of variability in output. In addition, SASN was found to react with aluminum and stainless steel substrates, further adding to the variability issue. This variability was studied, and a solution was devised; high shear mix SASN to decrease porosity and spray deposit onto Kapton substrates. The solution has been used and the variability of terminal flyer plate velocity decreased from ±35% (2-σ) to ±12% (2-σ) and thus allowing for more accurate

Gurney analysis. The open-face Gurney equation was found appropriate for composite Kapton/aluminum (47µm/151µm thick) flyer plates, but not for 508µm thick Kapton flyer plates. In the latter case, the asymmetrical Gurney equation was better suited for the terminal flyer plate velocity data.

SESSION 26: ELECTRONICS PACKAGING FOR EXTREME ENVIRONMENTS – METHODS, MATERIALS, & ANALYSIS

ELECTRONICS PACKAGING FOR EXTREME ENVIRONMENTS – METHODS, MATERIALS, AND ANALYSIS

Mr. James Scheppegrell, Applied Research Associates/AFRL
Dr. Alain Beliveau, Applied Research Associates/AFRL
Mr. Dustin Landers, Applied Research Associates/AFRL

In order to better comprehend the full range of environments potentially experienced by an embedded Fuze, the need has arisen to operate a recorder in an extremely cold (~-50c) condition. One anticipated effect was that an increase in internal resistance would occur in any electrochemical energy storage devices used to power the device; this paper presents the results of load testing at various temperatures on a sample of devices, techniques attempted in order to mitigate the cold, and explores the results of the solution selected for use in a series of subscale tests.

EXPERIMENTAL METHODS FOR EVALUATING ELECTRONICS SURVIVABILITY

Mr. Curtis McKinion, AFRL
Dr. Matthew Neidigk, AFRL
Mr. Mark Todisco, AFRL
Dr. Ryan Lowe, AFRL

Printed circuit assemblies consisting of commercially available electronics are packed to improve survivability for hard target fuzing applications. Packaging strategies commonly include encapsulating with foam or epoxy, underfilling electronic parts, and adding elastomer coating over electronics. Effectiveness of electronic packaging strategies are predicted with modeling and simulation (M&S). Experimental test suites are conducted to improve and validate M&S, flag poorly packaged electronics, and identify successful packaging strategies. Both thermal and dynamic experiments are conducted to evaluate electronics survivability.

DESIGNING FOR HIGH G SURVIVABILITY WITH POTTING: A NEW PARADIGM FOR CHOOSING THE RIGHT POTTING

Dr. Aisha Haynes, U.S. Army CCDC Armaments Center
Dr. Catherine Florio, U.S. Army CCDC Armaments Center
Ms. Melissa Jablonski, U.S. Army CCDC Armaments Center
Dr. Jacob Dodson, AFRL
Dr. Alain Beliveau, AFRL/Applied Research Associates

The Combat Capability Development Command at Armaments Center has developed a framework coupling uncertainty quantification (UQ) methods with finite element (FE) tools to assist in selecting potting solutions for electronics packages subjected to high G environments (>3kG). The framework developed is a multi-step process that defines system performance sensitivities to potting behavior and identifies the optimal properties to meet performance specifications. The process has been applied to identify a potential potting solution for a Fuze package under development. The potting solution selected using this method was then evaluated experimentally to assess its ability to protect electronic

components from failure in High-G applications. This paper outlines the method developed, reports on the output of coupled UQ/FE framework and discusses the validity of the approach against high G testing of the Fuze package. A discussion of the development of experimental methods that can be used to correlate output of the UQ/FE framework with physical indicators of electronic component failure will also be provided.

CHARACTERIZATION OF POTTING MATERIALS FOR ELECTRONICS ASSEMBLIES SUBJECTED TO DYNAMIC LOADS

Dr. Vasant Joshi, NSWC Indian Head
Mr. Colin Qualters, NSWC Indian Head
Mr. Ezra Chen, NSWC Indian Head
Mr. Reid McKeown, NSWC Indian Head
Mr. Jaime Santiage, NSWC Indian Head

Failure of electronic components subject to impact and vibration was traditionally predicted based on handbook rules, test data on prototype boards, and physics of failure methods, where a derived loading spectrum was used to predict failure based on certain analytical failure criteria. These methods are not suitable for predicting component failure in very high impact situations. Providing improved material models for potting materials used in the design process for increase survivability of electronic component, based on material pedigree characterization using combination of different methods, is augmented by modeling and simulations. Obtaining reliable material models for appropriate strain and strain rate regime requires specific test data for the potting compounds used for obtaining damping analysis, and appropriate failure due to accumulated damage at high frequencies. The experiments conducted for characterization of materials provide stress vs. strain at different (high) strain rate for strain rate sensitivity, using conventional tensile and compression tests, Hopkinson bar, dynamic material analyzer (DMA) and a non-conventional accelerometer based resonance test with spectrum analysis method of obtaining high frequency data to obtain modulus vs. frequency at different temperature beyond the conventional DMA frequency range. It is important to verify if the material actually behaves ideally, in order to appropriately apply a given model. The model may work in a limited range, and drastic deviation at the extremities of the regime may occur in some of the materials. In this presentation, experimental results for different materials used for mitigating impact, and ways to combine data from resonance, DMA and high-strain rates will be presented.

DYNAMIC CONFINEMENT CHARACTERIZATION OF POTTING MATERIALS UNDER EXTREME ENVIRONMENTS

Mr. Brett Sanborn, Sandia National Laboratories
Dr. Aisha Haynes, U.S. Army CCDC
Mr. Christoper Macrae, U.S. Army CCDC

Electronics packaging in the form of potting or encapsulation is critical for component protection against shock and vibration loads. Encapsulation is usually achieved by filling the space inside an electronic component with resins or rubbery materials (called “potting materials”) to mitigate high-g and/or high-frequency mechanical shock. The encapsulation may also be subjected to various environmental temperatures from cold to hot during application. Though modeling and simulation are routinely used for component design and survivability assessments, little work has been done to experimentally evaluate the performance of potting materials under triaxial confinement over a wide range of temperature conditions and strain rates which would mimic application use. This gap exists due to the challenges associated with measuring the specimen confining pressure during the experiment. In this study, a method is presented that provides a calibrated measurement of the radial confining pressure generated by a sample subjected to an axial stress pulse using a Kolsky bar. An analysis of the multiaxial stress-strain response of a few potting materials at different temperatures and strain rates is presented.

SESSION 27: UNDEX NUMERICAL METHODS

THE MODEL CONVERGENCE VS. ENGINEERING SUFFICIENCY TRADEOFF

Mr. Michael Miraglia, NSWC Carderock
Dr. Nicholas Reynolds, NSWC Carderock
Mr. Alan Hesu, NSWC Carderock
Mr. Jonathan Stergiou, NSWC Carderock Division

In resource constrained environments, analysts have traditionally refined the mesh in their models to the maximum extent based on the available computing resources in order to achieve the greatest fidelity. As computing power increases, maximizing mesh refinement may have marginal improvements, compared to the underlying aleatoric uncertainty of the problems being modeled. Maximizing mesh refinement also comes at the expense of few analyses being performed and longer turn-around times. This dilemma is discussed in the context of a coupled shock UNDEX simulation, using previously established fluid convergence criteria.

DDAMX BASE EXCITATION VALIDATION

Dr. Jeffrey Cipolla, Thornton Tomasetti
Mr. Corbin Robeck, Thornton Tomasetti

The dynamic design analysis method (DDAM) is a Navy method of analyzing shock loading on ship components. However, no guidance is provided for usage of DDAM when the component is in a wetted environment and not driven by the boat's mechanical inputs (i.e. direct pressure fluid loading is relevant). A formulation for a finite element based external DDAM(X) procedure has been developed, that accounts for added fluid mass effects, and validated in two parts: base excitation and Direct Pressure Fluid Loading (DPFL). A recap is presented of the relevant DDAMX theory, previous verification work, and Validation against the RESCUE test series data.

DDAMX DIRECT PRESSURE FLUID LOADING V&V

Mr. Corbin Robeck, Thornton Tomasetti
Dr. Jeffrey Cipolla, Thornton Tomasetti

DDAM eXternal (DDAMX) is a formulation for a finite element based external DDAM procedure that accounts for added fluid mass effects through usage of a wetted modal analysis and to evaluate the effects of direct pressure fluid loading (DPFL). The formulation is split into two methods that can be used separately or combined: base excitation and direct pressure fluid loading. While both are novel the direct pressure fluid loading (DPFL) is an entirely new approach and therefore requires more rigorous V&V. A recap of the relevant DDAMX DPFL theory and a Verification & Validation study is presented using the RESCUE test series data as well as high fidelity Transient Shock Analysis (TSA) simulation data.

SESSION 27: ROTOR DYNAMICS

STATIC AND DYNAMIC LOAD EQUALIZATION IN SELF-EQUALIZING THRUST BEARING LINKAGES
Dr. Richard Armentrout, Curtiss-Wright EMD

Self-equalizing thrust bearings commonly consist of a circumferential array of thrust shoes supported on a mechanical linkage made up of interconnected leveling links. The leveling links, collectively referred to as the "linkage", are designed to provide uniform shoe loading in the presence of thrust runner static and dynamic misalignment. Because of the many interconnected components having varying kinematic constraints, the equalizing linkage is a complex mechanism that presents a number of design challenges. Among these is the need to maximize equalization to limit the pad-to-pad load variations, while also maintaining safe stress levels under worst-case operational loading. Contrary to the common notion that the "see-saw" nature of the leveling links assures equal loading among the pads, the effects of internal geometry changes can yield pad load variations reaching as high as ten-to-one, depending on the linkage design and runner misalignment. A case study is given in which a thermal runaway failure was partially attributed to load maldistribution among the pads of an 8-pad thrust bearing. The subsequent failure investigation led to the development of a computer model to help quantify the various design parameters affecting linkage performance. The model solves the linkage equations of motion in the time domain, capturing the effects of large-displacement geometry changes, leveling link mass-inertia, nonlinear (Hertz) pivot contact stiffness, and internal friction. The program is exercised through a set of examples that reveal the key design features affecting linkage static and dynamic load equalization.

TRAINING V/USERS GROUP

UNDEX MODELING BY COUPLING ABAQUS/EXPLICIT AND XFLOW USING THE ABAQUS CO-SIMULATION ENGINE
Mr. Ozgur Yapar, Dassault Systemes Simulia Corp

Predicting the response of externally loaded submerged structures by an UNDEX pressure shock wave can be accomplished by performing a coupled fluid-structure interaction (FSI) analysis. Abaqus Co-simulation Engine (CSE) is used for this coupling by simultaneously running the explicit finite element solver Abaqus/Explicit with the high-fidelity Lattice-Boltzmann CFD solver XFlow as a single, efficient and a sequentially run-time coupled analysis. The process and steps required to perform such a coupled FSI analysis will be outlined. The modeling procedures and guidelines will be demonstrated by using the Kwon & Fox UNDEX benchmark of a submerged test cylinder that was exposed to a 60-pound HBX-1 explosive charge (Kwon & Fox, 1993).

TRAINING VI

SIMULATION DRIVEN DESIGN AND OPTIMIZATION OF HULL FOR BLAST RESISTANT VEHICLES
Mr. Ravi Kodwani, Altair Engineering

Hull of blast resistant vehicles has typical V shape design to deflect the pressure waves, in-order to safeguard the occupants, by maintaining the structural integrity. Based on the vehicle configurations like weight, CG, suspension, power-train, drive-train etc. the hull design would need to optimize for blast loading configurations. This paper describes the simulation driven work-flow for hull of a typical blast resistant vehicle using Altair HyperWork tools for explicit simulation with RADIOSS and optimization wih HyperStudy and OptiStruct.

Concept design study is performed with Arbitrary Lagrangian Eulerian (ALE) simulation using Radioss. Study of pressure impulse propagation and dynamic study of the structure response gives insight in earlier design phases. More detailed modeling of structure with vertical G values as response at occupant locations are typical indicators of the occupant injury probability. Concept hull is further optimized using simpler approach using linearization of loads and by non-linear optimization.

In training session demo of model set-up, details about the explosive and wave-structure interaction modeling for current simulation as well underwater explosion are reviewed. Design of Experimental (DoE) and Optimization set-up is also reviewed with details about design variables, responses, DoE and Optimization methods.

TRAINING VII

MESHLESS SIMULATION DRIVEN DESIGN APPLIED TO SHIPBUILDING INDUSTRY
Mr. Carlos de Lima, Altair Engineering

The use of Finite Element Analysis (FEA) has grown significantly in past few years across multiple industries, but more importantly, it has expanded across the whole design cycle of products. For some industries, FEA has become crucial for modern engineering. It is also widely accepted to introduce FEA in the early stages of the design cycle in order to speed up the time to market of products. The biggest challenge for some industries is to build a full model with accuracy for FEA and perform all the necessary design changes to evaluate multiple scenarios under real-life conditions.

As a breakthrough alternative, Altair SimSolid does not use traditional Fine Element Model to simulate complex assemblies. It takes advantage of fully featured CAD and within minutes performs structural analysis by using an extension of the Theory of External Approximations.

This study demonstrates the use of this meshless analysis method applied to a full assembly of a tugboat ship model with thousands of parts. By eliminating geometry preparation and meshing, the design engineer has more time to understand the performance of the assembly, analyze multiple scenarios and make design changes to improve the performance even before sending the assembly to the analysts. In this training session, participants would be able to follow a demonstration of SimSolid and the various analysis types performed by this disruptive technology.

SESSION 28: SHOCK & VIBRATION MODELING & ANALYSIS III

RAPID ESTIMATION OF A DESIGN CHANGE'S EFFECT ON THE ROOT MEAN SQUARE STRESS AND HIGH-CYCLE FATIGUE DAMAGE RESPONSE AT A LOCATION IN A STRUCTURE UNDER RANDOM VIBRATION LOADING
Mr. Sean Kelley, Cummins Inc.

Many types of systems are subjected to oscillating loads which are random in nature. In the design phase, random vibration analysis is often carried out using Finite Element Analysis (FEA) to predict stress and fatigue damage. Generally, designs must go through many iterations before the structure is predicted to survive the desired service life.

Although FEA is a relatively fast method to validate products when compared to physical testing, evaluating design iterations can still take days to weeks. Therefore, it can be useful to use simpler analytical methods to screen design changes before proceeding to finite element modeling. This presentation will demonstrate how to rapidly estimate a design change's effect on the root mean square stress and high-cycle fatigue damage response at a location in a structure under random vibration loading. Alternatively, this method could be used to instantly update analytical predictions using experimental data rather than performing finite element model updating.

The method is based on several assumptions and requires an initial set of stress and damage results. Then, Miles' Equation and a Rayleigh stress distribution are used to estimate the effect of design changes or experimental data on stress and damage. The two most critical assumptions are that the stress response is dominated by a single mode resulting in a narrow-banded stress response PSD, and the damaging mode maintains its shape. The situations in which these assumptions are true are examined to provide guidance for when it is appropriate to use this method.

High-Fidelity Modeling and Structural Analysis of an Additively Manufactured Component with Defects
Mr. Moheimin Khan, Sandia National Laboratories
Dr. James Justin Wilbanks, Sandia National Laboratories
Dr. Brian Owens, Sandia National Laboratories

Additive manufacturing (AM) offers several advantages over traditional methods but resulting parts can contain defects such as porosity and geometric irregularity. X-ray computed tomography (XCT) scans are used to identify these defects and validate against an ideal geometry. However, it is often difficult to determine the influence of defects on quality or performance. For structural components, print defects can act as stress concentrations or reduce stiffness and mass. In this work, the presence of these defects is considered and the resulting effects on dynamic characteristics are quantified. A high-fidelity finite element (FE) model of the as-printed AM part is generated using an overlay-grid hexahedral meshing scheme. In addition, a simplified defect modeling approach is considered, and results are compared to the nominal case. Structural analysis is performed to determine the impact on dynamic response, stress response, and other quantities of interest. By utilizing the XCT scan data to generate an FE model, the effect of defects on structural response can be determined, which allows for more accurate failure assessment of the component.

SMACSONIC - An Effective Layered Damping Material
Dr. James Rall, ShockTech
Mr. Laurent Mallet, SMAC
Mr. Pierre Lamy, SMAC
Dr. Daryoush Allaei, ShockTech

The concept of layered damping has been theoretically and experimentally studied since 1930s. The use of layered highly damped deformable materials have shown to be effective for reducing vibrations and noise in the vicinity of resonances of surface structures. An improved method of layered damping is constrained-layer damping (CLD) used in applications where large surfaces or skins are subjected to excessive vibration and thereby radiated noise near one or more resonant frequencies. Such surfaces may be found in space, aerospace and military systems. Energy dissipation mechanism offered by CLD is based on shear-related motion between the constrained layer, damping layer, and surface of structures. In CLD, damping is in the form of thin viscoelastic layer. The performance of CLD is measured by its loss factor (η);

the higher loss factor, the better performance. Loss factor (η) is a dimensionless quantity that can be measured or predicted from the modal damping of a dynamic system. Several factors influence performance of CLD. Some of the key factors are properties of base surface structure, materials (modulus, damping and density) properties, thicknesses, coverage (location and coverage on base structure), and temperature.

In this paper, SMACSONIC is introduced and its performance evaluated. SMACSONIC is a high performance CLD bonded onto a skin structure to provide acoustic damping at or near resonate frequencies. SMACSONIC has the following distinct performance factors: lightweight solution, very high energy dissipation, applicable to wide frequency and temperature range, great adhesive performance, long term ageing, fire resistant and applicable to flow noise & fuselage flexural modes.

The performance of SMACSONIC is measured and reported under a wide frequency and temperature ranges. SMACSONIC is applied to a thin beam structure simulating an airplane fuselage. For Acoustic evaluation, sound fields transmitted through 2 mm thick aluminum panels with and without SMACSONIC are evaluated. The acoustic lab is composed of the big anechoic chamber connected to a semi-anechoic chamber by a rigid wall including an opening (window) where the test sample can be installed. The focus of the measurement was in the frequency band from 50 Hz to 8 kHz, broken into three sub-bands in order to improve signal to noise ratio. The improvement in loss factors were between 2 to 12 dB depending on the frequency. As for vibration, the damping characteristics were measured as an indication of vibration mitigation. The SMACSONIC is applied to two different size aluminum base beams. The shaker is placed into the climatic chamber with temperature range from -35°C to typically 35°C with increments of 5°C. It is shown that damping loss factor ranged from 18% to 42% for damping thicknesses from 1.3 to 2.4 mm, respectively, at cold temperature of -30C. It is shown that damping loss factor ranged from 28% to 48% at 0o C.

WHO REPRESENTS THE NAVAL VIBRATION REGIME, MIL STD 167 B OR METHOD 514 CTG 21 OF MIL STD 810 G? PT1 LOAD CYCLE COUNTS CONSIDERATIONS

Mr. Zeev Sherf, Consultant

The fact, that the naval vibration simulation regime presented in Mil Std 167 B [1] and reiterated in Method 528 of MIL STD 810 G[2], is totally unrepresentative of the real life's vibration conditions, was emphasized in several works published in the past [3],[4]. In MIL STDs 810 D,E,F it was mentioned that the real life vibration regime is described in Method 514. Category 21, and the testing guided by MIL STD 167 is for structural integrity evaluation. At the first glance it appears that the testing regime imposed by [1] is the severe one as compared to [2]. It is clear that the 2 hours sine sweep imposed by [1] are the opposite of a realistic description of the naval vibration regime, as learned through measurements in the field, but the question if is it really more severe, has still to be answered. The aim of this paper is to try to do this. In order to achieve the goal, load cycles counting methods were applied. The methods developed by J. Rice, described in [5] for the random loads [2] and conventional methods of harmonics counting for the loads described in [1]. Following this introduction the preparation of the data is described both the random and the harmonic. Next the counting methods are discussed followed by the presentation of the results and their comparison. Several summarizing remarks will conclude the presentation.

WHO REPRESENTS THE NAVAL VIBRATION REGIME MIL STD 167 B OR METHOD 514 CTG 21 OF MIL STD 810 G? PT2 ACCUMULATED DAMAGE AND ENERGY CONSIDERATIONS
Mr. Zeev Sherf, Consultant

In the first part of the paper the differences in terms of load cycle numbers between the two testing regimes have been presented. These differences, project on by the system accumulated damage and on the system, applied energy. The aim of the paper's second part is to elucidate the differences in terms of these two parameters: accumulated damage and applied energy. The methodologies of accumulated damage and applied energy evaluation are discussed first. The results of their application to the two loading regimes are presented in the following. Several summarizing remarks conclude the paper.

SESSION 29: EXPERIMENTAL TECHNIQUES FOR PYROSHOCK TESTING II

FREQUENCY BASED SUBSTRUCTURING ON RESONANT PLATE
Ms. Erica Jacobson, Michigan Technological University
Dr. Jason R. Blough, Michigan Technological University
Dr. James P. DeClerck, Michigan Technological University
Prof. Charles D. VanKarsen, Michigan Technological University
Mr. David S. Soine, Honeywell

Resonant plate pyroshock tests were originally designed to test one component axis at a time, while the qualification pyroshock tests often have multi-axis specifications to meet. Traditionally, one Shock Response Spectrum (SRS) is created for each single axis test. There is interest in creating a multi-axis shock test environment using traditional resonant plate test components to save time and create a more realistic test environment. LaGrange-Multiplier Frequency Based Substructuring (LM-FBS) is used to arrange single-axis resonant plate subsystems in different assembly configurations. The resonant plate component dynamics are mathematically assembled to create the substructured assembly dynamics. The multi-axis SRSs are computed from the inverse Fourier transform of the substructured assembly FRFs. Preliminary assembly iterations are performed on a finite element model, and the final multi-axis configuration is verified with testing.

DAQ EVALUATION AND SPECIFICATIONS FOR PYROSHOCK TESTING
Ms. Erica Jacobson, Michigan Technological University
Dr. Jason R. Blough, Michigan Technological University
Dr. James P. DeClerck, Michigan Technological University
Prof. Charles D. VanKarsen, Michigan Technological University
Mr. David S. Soine, Honeywell

Pyroshock events contain high-amplitude, extreme rise-time accelerations. Due to their extreme nature, these events can be difficult to capture, exceeding the performance limits of transducers, signal conditioning, and data acquisition (DAQ) equipment. This study assessed the ability of different data acquisition systems to record quality pyroshock data. Different tests characterized the data acquisition systems' anti-alias filter, out-of-band energy attenuation, number of effective bits, in-band gain, and slew rate. These tests include a sine sweep test and a high-amplitude low-frequency square wave test.

CIRCUIT BOARD SHOCK DAMAGE COMPARISON BY TEST METHOD
Mr. Alexander Hardt, Northrop Grumman Innovation Systems

A simple circuit board design utilizing a crystal oscillator was tested on multiple shock test platforms to determine if unit failures or shock damage varied by test methodology (beam, shaker and pyroshock) for the same SRS levels.

DEFINING RESONANT PLATE SHOCK TEST SPECIFICATIONS IN THE TIME DOMAIN
Dr. Carl Sisemore, Sandia National Laboratories

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. Examples are presented comparing peak acceleration and rainflow analysis, showing that the non-uniqueness of the shock response spectra can lead to substantially different strain results in the unit under test.

SESSION 30: SUBMARINE UNDEX

SIMPLIFIED ONR CYLINDER ANALYSIS USING NAVY ENHANCED SIERRA MECHANICS
Mr. Jeff Roper, HII Newport News Shipbuilding
Mr. Matt Davis, HII Newport News Shipbuilding

The ONR Cylinder model and associated shock test has been used to validate model approaches for many years. In this brief study, the ONR cylinder was modeled using a typical simplified beam model combined with a detail section model and evaluated using Navy Enhanced Sierra Mechanics (NESM). This simplified modeling approach is common to represent the low-frequency shock response of large platforms and this validation study serves to provide a point of reference for NESM users on the capability and workflow of SIERRA/SD for this type of problem. Recommended workflow improvements and validation comparisons are presented.

IN-TUBE IMPLOSION EXPERIMENTS
Dr. Joseph Ambrico, NUWC Newport
Mr. Ryan Chamberlin, NUWC Newport
Mr. Craig Tilton, NUWC Newport

A significant pressure wave can be created when a structure containing low-pressure compressible material (typically air) implodes from depth pressure. This pressure wave propagates outward and has the potential to cause damage to nearby objects. When the same structure implodes within confining, flooded structure (such as a tube), the implosion pressure wave is significantly altered. Small-scale experiments are conducted to characterize implosion occurring within a specific tube. Various configurations of implodable volumes are tested within the confining tube. Among the scenarios investigate are the implodable volume size, the water flow into the confining tube, and multiple implodable structures. For each test, the pressure waves inside and outside the tube are measured, as well as the response of the tube itself. Comparisons of the implosion among the different scenarios are made.

UNDEX Initiated Implosion in Shallow Water of Confined Cylinders – Experiment and Model Comparisons

Dr. Joseph Ambrico, NUWC Newport
Mr. Ryan Chamberlin, NUWC Newport

Typically, underwater implosion is a concern only at deep depths where there is significant hydrostatic pressure. At shallow depths, there is much less potential energy in an implodable volume since there is little pressure to drive the implosion. However, a shallow implosion can be amplified if it is initiated by a nearby underwater explosion (UNDEX). The overpressure from the UNDEX shock wave can accelerate the collapse and produce a significant implosion pressure pulse, even at shallow depth. An additional factor controlling the resulting implosion pressure pulse is whether the implodable volume is in a free-field or confined by surrounding structure. Confining structure affects water flow around the collapsing volume, and can significantly alter the implosion pressure pulse. The presentation will cover a specific case of shallow, UNDEX initiated, confined implosion. Detailed simulations of the case will be presented and compared to the experiments. Differences between the two will be discussed.

SESSION 30: VIBRATION: SURVEYS & BOUNDARY CONDITIONS

Spectrogram Analysis of Swept Sine Survey Data Both Pre-and Post-Vibration Testing

Dr. Ricky Stanfield, Northrop Grumman

The U.S. Navy Research Rockets Office in conjunction with their contractor team subjected a set of three identical Thrust Vector Control (TVC) assemblies to ground vibration testing. Prior to and after this battery of tests, a 1/2-G swept sine vibration measurement was made and three-axis vibration data was collected at many locations on the assembly. In this paper we show the process for down sampling the high rate data to more suitable data rates, the pre-processing of the data to remove DC biases and offsets, a time domain assessment of the data sets, and a spectrogram analysis of key sensor locations. We discuss the interactions of structural natural frequencies and the swept frequencies with its overtones, and interpret the spectrogram features.

A more realistic approach for boundary conditions during combined random vibration and inertial loading to better approximate flight environments

Mr. Matthew McDowell, Sandia National Laboratories
Dr. Richard Jepsen, Sandia National Laboratories
Mr. James Milam, Sandia National Laboratories
Dr. Garret Lopp, Sandia National Laboratories
Dr. Garrett Nelson, Sandia National Laboratories

During combined inertial testing with random vibration (Vibrafuge), the traditional methods for exciting the test article rely almost solely through base excitation in a single axis. Vibration through base excitation in one axis only can lead to both over and under testing of sensitive components. While this approach has still been shown to be beneficial in combining the environments in a more realistic test, it does not accurately approximate the realistic boundary conditions of flight whereby the vibration is generated through atmospheric interactions at the system's surface or aeroshell. We have developed and implemented a method to more realistically excite a system through the outer surface during testing that better represents the realistic boundary conditions experienced during flight. In addition, the method can excite the test article in multiple axes simultaneously while exposed to the inertial loads from the centrifuge. The design of the new approach along with some recent test data on a full flight system will demonstrate the feasibility and usefulness of this new technique with the Vibrafuge.

SESSION 31: DYSMAS III: UNDEX DEVELOPMENTS & APPLICATIONS

DEVELOPMENT OF AN ENHANCED EQUATION OF STATE FOR TILLOTSON WATER

Dr. Francis Vangessel, NSWC Indian Head

Abstract not available.

PODDED PROPULSOR MODELING AND ANALYSIS

Dr. Bradley Klenow, NSWC Carderock

Abstract not available.

SIMULATING INCOMPRESSIBLE MATERIALS

Ms. Rebecca Grisso, NSWC Carderock

This talk presents a summary of lessons learned in the simulation of nearly incompressible materials with DYSMAS. First, an overview of mesh considerations, locking potential, and integration schemes is presented. A description of a generic example model used to vary significant parameters and develop trends follows. Finally, results of the generic model trend study are summarized and offered to serve as shared knowledge for others solving similar problems.

TRAINING VIII

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.