89^{th} Shock and Vibration Symposium

Dallas | November 4-8, 2018

SAVE
SHOCK & VIBRATION EXCHANGE

HI-TEST Laboratories, Inc.

Introduction

Welcome to Dallas and the 89th 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

HI-TEST Laboratories, Inc.

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89th Shock and Vibration Symposium Committee*

Dr. Jeff Averett (USACE—ERDC)
Mr. Sloan Burns (NSWC Dahlgren)
Mr. Matthew Davis (HII—NNS)
Mr. Adam Goldberg (NSEC Indian Head)
Mr. Bill Gregory (Applied Physical Sciences)
Mrs. Becky Grisso (NSWC Carderock)**
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Dr. Luke Martin (NSWC Dahlgren)
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Mr. Ernie Staubs (Air Force Research Laboratory)
Mr. Jon Stergiou (NSWC Carderock)**
Ms. Allison Vella (Gibbs & Cox)
Ms. Lauren Yancey (HI-TEST Laboratories)

**TAG members in attendance at summer meeting for 89th S&V program review (held at NSWC Carderock)*

***NSWC Carderock hosts*

DAILY OUTLINE & TABLE OF CONTENTS

SUNDAY, NOVEMBER 4	TUTORIAL (SPECIAL EDITION)	9:00AM—5:00PM	P. 5
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TUESDAY, NOVEMBER 6	TUTORIALS	8:00AM—11:00AM	P. 9
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ABSTRACT BOOK	ABSTRACTS FOR ALL PAPER/PRESENTATION SESSIONS	(IN BACK OF BOOKLET)

INTERNET CAFÉ	
HI-TEST Laboratories, Inc.	
Meeting Room: Reunion Ballroom	
Sunday, Nov 4	9AM—8PM
Monday, Nov 5	9AM—8PM
Tuesday, Nov 6	7AM—8PM
Wednesday, Nov 7	7AM—8PM
Thursday, Nov 8	7AM—Noon

EXHIBIT HALL (Reunion Ballroom E-H) (Exhibitors Listed on Pages 30-37)		
Monday, Nov 5	*Setup*	*Noon—6:00PM*
	Reception	6:30PM—8:30PM
Tuesday, Nov 6	Exhibit Hall Open	7:00AM—5:00PM
	Awards Luncheon & Speaker	11:00AM—1:00PM
	Session Break—PM	3:00PM—3:40PM
Wednesday, Nov 7	Exhibit Hall Open	9:00AM—4:00PM
	Session Break—AM	10:00AM—10:30AM
	Exhibitors' Luncheon & Speaker	12:05PM—1:15PM
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	Dismantle	*4:00PM—6:00PM*

REGISTRATION	
Meeting Room: Bogle's Billiards	
Sunday, Nov 4	8AM—5PM
Monday, Nov 5	7AM—6PM
Tuesday, Nov 6	7AM—6PM
Wednesday, Nov 7	7AM—6PM
Thursday, Nov 8	7AM—NOON

DISTRIBUTION STATEMENTS & SYMBOL KEY

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.
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(AB #) Corresponding page number in Abstract Book (located at back of program).

SH Short presentation (10 minutes total).

Food and Beverage Events

FOOD & BEVERAGE EVENTS

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

Monday, November 5

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

Tuesday, November 6

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

Wednesday, November 7

• Continental Breakfast	7:00am—8:30am	Reunion Ballroom (Exhibit Hall)
• Exhibitors' Luncheon	12:05pm—1:15pm	Reunion Ballroom (Exhibit Hall)
• Symposium Social/Dinner	7:00pm—10:00pm	Dallas World Aquarium

Thursday, November 8

• Continental Breakfast	7:00am—8:30am	Reunion Foyer

Welcome Reception

Monday, Nov. 5 • 6:30pm—8:30pm • Reunion Ballroom (Exhibit Hall)

Beverages and Heavy Hors d'oeuvres

General Session 1: Symposium Awards Luncheon w/ Keynote Speaker

Tuesday, Nov. 6 • 11:00am—1:00pm • Reunion Ballroom (Exhibit Hall)

General Session 2: Exhibitors' Luncheon w/ Elias Klein Speaker

Wednesday, Nov. 7 • 12:05pm—1:15pm • Reunion Ballroom (Exhibit Hall)

Sponsored by: 89th Shock & Vibration Symposium Exhibitors

Symposium Social/Dinner at Dallas World Aquarium

Wednesday, Nov. 7 • 7:00pm—10:00pm

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

SUNDAY (NOVEMBER 4)

SPECIAL TUTORIAL OFFERING / 9:00am-5:00pm

~ Additional fees apply to attend ~

MIL-DTL-901E Shock Training **Meeting Room: Pegasus B**

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

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

MONDAY AM (NOVEMBER 5)

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

~ CHOOSE ONE / ADDITIONAL FEES APPLY TO ATTEND ~

MIL-DTL-901E Shock Qualification Testing **Meeting Room: Reunion A**

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

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

Introduction to Pyroshock Testing **Meeting Room: Reunion B**

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.

Testing Program Generation for Multi-Axis Shaker Vibration Simulation **Meeting Room: Reunion C**

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). Normalized PSDs (rms=1) of the vibrations at each one of the locations were the data known at the start of the simulation. Also regression models of the rms vs dynamic pressure at each one of the location were defined. A set of six dynamic pressures was defined. The corresponding PSDs for each dynamic pressure were evaluated and from these PSDs time histories were generated. For each location six time histories. From these time histories SDM (Spectral Density Matrices) were evaluated. These matrices serve as the basis of the vibration testing specification's definition. For the testing duration definition energy considerations were used, this meaning that the testing has to be applied till the energy accumulated in field is duplicated in the laboratory. Following this introduction, the process of the time histories generation from the given PSDs and grms vs dynamic pressure model is described. Next the generation of SDMs for each dynamic pressure is presented. The use of energy considerations in the definition of the testing duration is described in the following. Several summarizing remarks conclude the work. The numerical simulation was performed using the OCTAVE software.

MONDAY PM (NOVEMBER 5)

TUTORIAL SESSION 2 / 12:00pm—3:00pm

~ CHOOSE ONE / ADDITIONAL FEES APPLY TO ATTEND ~

MIL-DTL-901E Shock Qualification Testing Extensions **Meeting Room: Reunion A**
Mr. Kurt Hartsough & Mr. Domenic Urzillo (NSWC Philadelphia)

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

A Primer on Vibration Testing and Data Analysis **Meeting Room: Reunion B**
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.

Effective Solutions for Shock and Vibration Control **Meeting Room: Reunion C**
Mr. Alan Klembczyk (Taylor Devices) & Dr. Ed Alexander (HI-TEST Laboratories Consultant)

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 is correlated to test data.

DDAM 101 **Meeting Room: Pegasus A**
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 linear-elastic 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.

COMMITTEE MEETING

1:30pm-3:30pm

DTE 022 Meeting: MIMO Recommended Practice Committee **Meeting Room: Pegasus B**
Chair: Dr. Marcos Underwood (Tutuli 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.

MONDAY PM (NOVEMBER 5)

TUTORIAL SESSION 3 / 4:00pm—7:00pm

~ CHOOSE ONE / ADDITIONAL FEES APPLY TO ATTEND ~

MIL-DTL-901E Subsidiary Component Shock Testing & Alternate Test Vehicles **Meeting Room: Reunion A**

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

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

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

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.

UNDEX Phenomena and Underwater Bulk Charge Weapon Effects (DISTRO D) **Meeting Room: Reunion C**

Mr. Greg Harris (NSWC Indian Head)

This training will provide an overview of underwater explosion (UNDEX) shock wave and bubble phenomena, including the effects of nearby boundaries such as the water surface and solid surfaces. This talk provides special emphasis on UNDEX bubble dynamics, bubble pulse loading, and bubble jetting phenomena. The procedures used to characterize the UNDEX shock and bubble output of explosives will be discussed. An overview of UNDEX effects on naval structures and submerged infrastructure will be given.

The Measurement & Utilization of Valid Shock and Vibration Data **Meeting Room: Pegasus A**

Dr. Patrick Walter (TCU / PCB Piezotronics)

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.

Welcome Reception

Monday, Nov. 5 • 6:30pm—8:30pm

Reunion Ballroom (Exhibit Hall)

TUESDAY AM (NOVEMBER 6)

TUTORIAL SESSION 4 / 8:00am—11:00am

~ CHOOSE ONE / ADDITIONAL FEES APPLY TO ATTEND ~

Changes from MIL-S-901D to MIL-DTL-901E Explained **Meeting Room: Reunion A**

Mr. Kurt Hartsough & Mr. Domenic Urzillo (NSWC Philadelphia) ~ Mr. Hartsough Presenting

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

MIL-DTL-901E Engineering Topics **Meeting Room: Reunion B**

Mr. Domenic Urzillo (NSWC Philadelphia)

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

Application of Engineering Fundamentals in Solving Shock and Vibration Problems **Meeting Room: Reunion C**

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.

Quantitative Methods for High-G Electronics Design **Meeting Room: Pegasus B**

Dr. Jacob Dodson & Mr. Matthew Neidigk (AFRL), Dr. Ryan Lowe (Applied Research Associates)

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

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

COMMITTEE MEETING

9:00am-11:00am

DTE 044 Meeting: Transient Waveform Replication **Meeting Room: Shawnee Trail A/B**

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. Keynote Lecture & Awards Luncheon

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

11:00am—11:05am	Call to Order by: Mr. Drew Perkins (SAVE / HI-TEST Laboratories)
11:05am—11:10am	Keynote Lecturer Introduction presented by: Mr. Fred Costanzo (Consultant)
11:10am—11:50am	**Keynote Lecture - Mr. Michael Riley (The Columbia Group)**
11:50am—12:20pm	Buffet Lunch
12:20pm—12:40pm	**Lifetime Achievement Award Presentation** *presented to Mr. Dave Ingler by Mr. Laurence O'Neill (Brach Head, Code 663, NSWC Carderock)*
12:40pm—12:50pm	**Henry Pusey Best Paper Award Presentation** "Using Temporal Moments to Detect Interactions during Simultaneous Shock Testing of Multiple Components" *presented to: Dr. Carl Sisemore, Dr. Vit Babuška, & Mr. Jason Booher*

Keynote Lecturer Bio (Mr. Michael Riley)

Mr. Riley has served the U.S. Navy for 50 years as a research engineer, naval officer, supervisor, senior executive, and RDT&E consultant on shock effects and marine structural dynamics. He attended 14 S&V Symposia from 1984 to 2004 and served on the S&V TAG from 1991 to 2003. He has authored or co-authored 95 government reports and professional society papers on the subject, and he has participated with shock working groups in Canada, Germany, the Netherlands, the United Kingdom, and Australia. He also achieved the rank of Captain as an Engineering Duty Officer with 30 years of service in the U.S. Naval Reserves. His educational background includes an Executive Leadership Certificate from the John F. Kennedy School of Government at Harvard University (2003); M.S. degree in Systems Engineering and Engineering Management, George Washington University (2004); M.S. degree in Engineering Mechanics, Old Dominion University (1978); Ensign, Naval Officer Candidate School (1972); B.S. degree in Engineering Mechanics, Virginia Polytechnic Institute and State University (1971).

Mr. Riley began his career with the Underwater Explosions Research Division (UERD) of the David Taylor Research and Development Center (now Naval Surface Warfare Center Carderock Division) as a cooperative education student in 1967. After graduation in 1971, he completed 5-years active duty, including teaching classical physics and reactor principles at the Naval Nuclear Power School, Bainbridge, MD. He then returned to UERD in 1976 and over the next 24 years served as a junior engineer, project leader, Applied Mechanics Branch Head, and in 1997 UERD Division Head. UERD's three technical branches were focused on improving the ability of surface ships and submarines to resist the damaging shock effects of underwater explosions. Mr. Riley participated in and analyzed data from numerous UNDEX tests, including scale-model and full-scale sections of cylindrical structures, full-scale ship sections, and numerous at-sea ship shock trails. He was Deputy Trials Director for the USS THEODORE ROOSEVELT CVN-71 Shock Trials in 1989.

In 2000 Mr. Riley was selected to be the Department Head of the Survivability and Weapons Effects Department at NSWC Carderock. He led the Department's six engineering branches in RDT&E initiatives to improve the survivability of U.S. Navy ships and submarines across a broad range of weapons effects and structural integrity disciplines, including air blast, underwater explosions, fragmentation effects, and shaped charges

In 2003 Mr. Riley was promoted to the Senior Executive Service as the Executive Director for Ship Survivability and Structural Integrity, SEA 05P, at Naval Sea Systems Command in Washington, D.C. The Directorate's responsibilities included the full spectrum of research, development, test, engineering, and naval architecture responsibilities for all in-service fleet ships and submarines, new acquisition designs, and future capabilities. He led five divisions: Surface Ship Structural Integrity, Submarine Structural Integrity, Ship Survivability, Damage Control and Firefighting, and Chemical and Biological Defense.

(continued next page)

General Session 1 incl. Keynote Lecture & Awards Luncheon (cont.)

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

(continued from Riley bio)

After his retirement from federal service in 2006, Mr. Riley joined The Columbia Group (TCG) in 2007 as a research consultant supporting the Naval Surface Warfare Center Carderock Division Detachment Norfolk, Combatant Craft Division (CCD). He led the development and execution of three rapid technology transition projects supporting high-speed craft operations, and he is the co-founder and currently the research lead for the Craft Motion Mechanics and Wave Slam Phenomenology Program. The research focuses on the cause-and-effect physical relationships between individual wave impact loads and subsequent shock effects on craft structure, equipment, and human comfort and performance.

Lifetime Achievement Award Winner

Mr. David Ingler

Mr. David (Dave) Ingler spent a career developing new and improved data acquisition and processing procedures that have greatly improved the quality of test data and the types of measurements available to the survivability community. These improved procedures and developments include a methodology for providing stable integration of long duration velocity and acceleration time histories, a state-of-the art and NIST traceable calibration system for sensors and data recorders, new transducers and data acquisition software that have enhanced the capabilities of shock and survivability analysts, and a sensor installation technique that allows for accurate measurements of glass/epoxy composite structures during and UNDEX event. Dave's persistence and commitment to quality was instrumental in the advancement of data recorder technology that utilizes advanced digital technology which greatly improved underwater explosion test data quality. All of these contributions have greatly improved the quality of the test data the types of measurements and the types of measurements available to the survivability community. His work will continue enabling analysts and Navy programs to have greater insight when evaluating the damaging effects of UNDEX across the breadth of Navy platforms.

Plaque Inscription: "Mr. David Ingler devoted a career to developing and improving dynamic measurement techniques, leading vital testing and instrumentation projects, and fostering a high standard of excellence in those he mentored. Dave's devotion to his field directly resulted in advances in the Navy's understanding of ship and equipment responses to weapons effects that will facilitate improvements in survivability for years to come."

Henry Pusey Best Paper Award Winner (*presented for best paper at previous symposium*)

"Using Temporal Moments to Detect Interactions during Simultaneous Shock Testing of Multiple Components"
by Dr. Carl Sisemore, Dr. Vit Babuška, & Mr. Jason Booher (Sandia National Laboratories)

Abstract: Small components are often tested in groups with several components mounted to a common test fixture and tested simultaneously. This test method is frequently used to reduce the time spent in the test laboratory. There is an inherent problem testing multiple identical components simultaneously since the overall fixture-component system will possess a number of closely spaced vibration modes. This is a direct result of the components all having nearly identical mass and stiffness. The ramifications of this is that the shock applied to the fixture may not be evenly distributed to all components, resulting in some being tested more severely than others. This is possible even with a well-designed fixture. This paper presents a novel application of temporal moments for detecting and quantifying the interaction between multiple components from a single shock test. The paper also presents a series of experimental results showing how the temporal moments shift as damage progresses through the multi-component system.

TUESDAY PM (NOVEMBER 6)

	SESSION 1 **Shock, Vibration, & Acoustic Testing** 1:00pm-3:00pm / Unlimited Dist. A Chair(s): Mr. Justin Caruana (Cardinal Engineering) Mr. Russ Ayres (Spectral Dynamics)	SESSION 2 **UNDEX Test Applications** 1:00pm-3:00pm / Limited Dist. D Chair(s): Mr. Adam Goldberg (NSWC Indian Head) Mr. Bradley Klenow (NSWC Carderock)	SESSION 3 **Packaging of High G Electronics: Perspective on Potting and Its Alternatives** 1:00pm-2:35pm / Limited Dist. D Chair(s): Dr. Aisha Haynes (US Army ARDEC)
	All Presenters and Chairs (for Nov. 6) are Required to Meet at 7:00AM in Pegasus A for Presentation Loading		
	Meeting Room: Reunion B	*Meeting Room: Pegasus B*	*Meeting Room: Pegasus A*
1:00	**Design of a Resonant Plate Shock Test for Simultaneous Multi-Axis Excitation (AB 1)** Mr. Ron Hopkins & Dr. Carl Sisemore (Sandia National Laboratories)	**Multi-Cycle UNDEX Bubble Dynamics and Loading: Overview of Test Program (AB 3)** Mr. Gregory Harris (NSWC Indian Head)	**The Prediction of the Impact Behavior of 3-D Printed Supports as an Alternative Electronics Packaging Method (AB 5)** Dr. Catherine Florio, Mr. Lyonel Reinhardt, & Dr. Jennifer Cordes (US Army ARDEC)
1:25	**Shock and Vibration Qualification of a Transparent Armor Window based on MIL-S-901D and MIL-STD-167-1A Test Methods (AB 1)** Mr. Leonardo Torres, Mr. Daniel Coleman, & Mr. Joseph Abraham (Karagozian & Case)	**Multi-Cycle UNDEX Bubble Dynamics and Loading: DYSMAS Enhancements (AB 4)** Dr. Georges Chahine (Dynaflow, Inc.), Dr. Tom McGrath (NSWC Indian Head)	**Experimental Techniques to Characterize Potting Materials Under Confinement at High Strain Rate (AB 5)** Mr. Brett Sanborn & Mr. Bo Song (Sandia National Laboratories), Dr. Aisha Haynes & Mr. Christopher Macrae (US Army ARDEC)
1:50	**A Better Approach to Deriving Shock Environments and Testing (AB 2)** Dr. Pat Grosserode (Northrop Grumman Innovation Systems)	**Multi-Cycle UNDEX Bubble Dynamics and Loading: DYSMAS Validation Examples (AB 4)** Mr. Chao-Tsung Hsiao (Dynaflow, Inc.)	**Dynamic Confinement Response of Unfilled and GMB-Filled Epon 828 and Temperature Effect (AB 6)** Mr. Bo Song & Mr. Brett Sanborn (Sandia National Laboratories), Dr. Aisha Haynes & Mr. Christopher Macrae (US Army ARDEC)
2:15	**Shock Strains Induced by Flight and Test (AB 2)** Mr. Scott Rowland (Northrop Grumman Innovation Systems)	**Overview of Hydrobulge Test Programs for Hydrocode Verification and Validation (AB 4)** Mr. Gregory Harris (NSWC Indian Head)	**Optimized Potting Solutions for High G Electronics: A Case Study (AB 6)** Dr. Aisha Haynes, Dr. Catherine Florio, Dr. Jennifer Cordes, & Ms. Melissa Jablonski (US Army ARDEC)
2:40	**Applications of Digital Adaptive Control to High Level Acoustic Testing (AB 2)** Dr. Marcos A. Underwood (Tu'tuli Enterprises)	**Characterization of Bulk Charge Underwater Explosion (AB 4)** Mr. Kent Rye (NSWC Carderock), Mr. Gregory Harris (NSWC Indian Head)	

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

TUESDAY PM (NOVEMBER 6)

	SESSION 4 **Air & Buried Blast** 1:00pm-2:35pm / Limited Dist. D 2:40pm-3:00pm / Unlimited Dist. A Chair(s): Mr. Roosevelt Davis (Air Force Research Laboratory) Mr. Ernie Staubs (Air Force Research Laboratory)	VENDOR SESSION A **Product and/or Service Overviews, Product Demos, & New Developments & Technologies** 1:00pm-3:00pm / Unlimited Dist. A Chair(s): Mr. Michael Quzor (iX Cameras)	TRAINING I **Introduction to UERDTools** 1:00pm-3:00pm / Limited Dist. C
	All Presenters and Chairs (for Nov. 6) are Required to Meet at 7:00AM in Pegasus A for Presentation Loading		
	Meeting Room: Moreno A/B	***Meeting Room: Reunion A***	***Meeting Room: Reunion C***
1:00	**Cumulative Damage Assessment Model for RC Bunkers in Multi-strike Scenarios (AB 7)** Dr. George M. Lloyd, Mr. Ryan Schnalzer, & Dr. Wije Wathugala (ACTA Inc.), Mr. Joe Magallanes & Mr. Shengrui Lan (Karagozian & Case Inc.)	**Dynamic Data Acquisition and Vibration Control with Crystal Instruments (AB 9)** Mr. Darren Fraser, Mr. Ali Farrokhian, & Mr. Trevor Ergas (Crystal Instruments)	**Introduction to UERDTools** 1:00pm—3:00pm Mr. Brian Lang (NSWC Carderock / UERD) 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 paper 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.
1:25	**Modeling of Secondary Debris Phenomenology with a Radiation Heat Transfer Analogy (AB 7)** Dr. George M. Lloyd, Dr. Wije Wathugala, & Dr. Li Cao (ACTA Inc.), Mr. Joe Magallanes & Mr. Joseph Abraham (Karagozian & Case Inc.), Mr. Randy Anderson (Cobia Research)	**Measurement Innovations (AB 9)** Mr. Dave Carter & Mr. Steve Ross (DEWESOFT)	
1:50	**Predicting Secondary Debris and Blast from Buried Explosions using Numerical Simulations (AB 8)** Dr. Wije Wathugala, Dr. Wenshui Gan, and Mr. Hugh Morgan (ACTA Inc.)	**Mechanically & Electrically Filtered Triaxial Accelerometer (AB 10)** Mr. Kevin Westhora (Dytran)	
2:15	**Research into Secondary Debris and its Potentially Damaging Effects on Personnel, Infrastructure, and Equipment (AB 8)** Mr. Ernie Staubs (Air Force Research Laboratory)	**Key Things to Consider when Evaluating a High-Speed Camera (AB 10)** Mr. Michael Quzor (iX Cameras)	
2:40	**The Effect of Charge Diameter to Ratio on Transferred Shallow Buried Blast Impulse (AB 9)** Dr. John Reinecke, Mr. Mzwandile Mokalane, & Ms. Rayeesa Ahmed (Council for Scientific and Industrial Research), Dr. Ian Horsfall (Cranfield Defence, Cranfield University)	**IMV's Smart ECO-Amplifiers Provide an Automatic Energy-saving Function for Reduced Operational Costs across All Force Ranges (AB 10)** Mr. Andy Cogbill (IMV America, Inc.)	

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

TUESDAY PM (NOVEMBER 6)

	SESSION 5 **Shock & Vibration Isolation I** 3:45pm-5:45pm / Unlimited Dist. A SESSION 6 **Shock Modeling** 5:50pm-6:10pm / Unlimited Dist. A Chair(s): Mr. Alan Klembczyk (Taylor Devices) Mr. Robert Sharp (Hutchinson)	SESSION 7 **Material Behavior I** 3:45pm-6:10pm / Unlimited Dist. A Chair(s): Dr. Peter Vo (Raytheon)	SESSION 8 **Blast to Structures & Vehicles from IEDs & Other Explosives** 3:45pm-4:30pm / Limited Dist. D 4:35pm-6:10pm / Limited Dist. C Chair(s): Mr. Garrett Doles (USACE—ERDC) Dr. Gregory Bessette (USACE—ERDC)
	All Presenters and Chairs (for Nov. 6) are Required to Meet at 7:00AM in Pegasus A for Presentation Loading		
	Meeting Room: Reunion B	***Meeting Room: Reunion C***	***Meeting Room: Pegasus B***
3:45	**Vision for an Adjustable Shock Mount (AB 10)** Mr. John Stenard (STEN-TEK)	**Non-Destructive Imaging and Residual Strength of Composite Materials after Exposure to Blast Loading (AB 13)** Ms. Monica Black, Dr. James LeBlanc, & Dr. Patric Lockhart (NUWC Newport), Dr. Shyamal Kishore & Dr. Arun Shukla (URI)	**Air Blast Experiments to Quantify Blast Wave and Structure Interaction for Ideal and Homemade Explosives (AB 17)** Mr. Garrett Doles, Ms. Alyson Doles, & Dr. T. Neil Williams (USACE—ERDC)
4:10	**Quest for an Adjustable Shock Mount (AB 11)** Mr. John Stenard (STEN-TEK)	**Hybrid Characterization and Design of Elastomeric Materials (AB 14)** Mr. Mehmet Emre Demir & Mr. Akin Dalkilic (ASELSAN)	**Solid Surface Debris from Buried Detonation (AB 17)** Mr. William Myers, Dr. John Ehrgott, Mr. Ernesto G. Cruz-Gutierrez, & Mr. Jasiel Y. Ramos-Delgado (USACE—ERDC)
4:35	**Considerations for Optimizing Structure Borne Noise Reduction in the Design of an Elastomeric Shock Mount (AB 11)** Mr. Shawn Czerniak, Mr. Neil Donovan, & Mr. John Sailhamer (Hutchinson)	**Determination of Johnson-Cook Material Properties from Taylor Impact Testing (AB 14)** Mr. Mehmet Emre Demir (ASELSAN)	**Experimental Techniques to Capture Near-Field Airblast Characterization of Unconfined Homemade Explosives (AB 18)** Mr. Stephen Turner, Dr. Andreas Frank, Dr. Jay Ehrgott, Mr. Donny Guynes, Mr. Sonny Johnson, Mr. Neill Stephens, Mr. Jim Hall III, Mr. Billy Bullock, & Mr. Tom Carriveau (USACE—ERDC)
5:00	**The Use of Shock Isolation Systems in Small High-Speed Planing Craft for Wave Slam Protection (AB 12)** Mr. Michael Riley (The Columbia Group), Mr. Brock Aron & Dr. Timothy Coats (NSWCCD, Combatant Craft Division)	**The use of Tensile Force in the Solder-Electronic Component Interface as a Means to Predict Survivability Against Inertial Loads (AB 15)** Dr. Catherine Florio, Dr. Jennifer Cordes, Mr. Lyonel Reinhardt, & Dr. Aisha Haynes (US Army ARDEC)	**Experimental Testing of Small Charges in Vehicle-Borne Improvised Explosive Devices (AB 18)** Mr. Daniel Vaughan, Mr. Joshua E. Payne, Mr. Jasiel Y. Ramos-Delgado, Mr. Ernesto G. Cruz-Gutierrez, Dr. John Q. Ehrgott, Jr., & Mr. Denis D. Rickman (USACE—ERDC)
5:25	**Usage of Larger Wire Rope Isolators (AB 12)** Mr. Claude Prost & Mr. Joshua Partyka (Vibro/Dynamics)	**Modeling Dynamic Behavior of Expanded Polypropylene (EPP) Polymeric Foam Utilizing Rate and Temperature Dependent Compression Test Results (AB 15)** Mr. Eren Koçak, Mr. Kenan Gürses, & Mr. Bülent Acar (Roketsan Inc.)	**A Fast-Running Tool for Mapping Loads from Wrap-Around Airblast (AB 19)** Dr. Gregory Bessette & Mr. Micael Edwards (USACE—ERDC)
5:50	**Shock Modeling and Shock Generation (AB 13)** Mr. Zeev Sherf (Consultant)	**Effects of Masonry-Mortar Bond Strength on the Blast Load Response of Masonry Walls (AB 16)** Ms. Kelsey Doan, Mr. John Hoemann, Dr. Catherine Stephens, & Mr. Don Nelson (USACE—ERDC), Dr. James Davidson (Auburn University)	**Analysis of Host Vehicle Fragments from Vehicle Borne IED Detonations (AB 19)** Mr. Jasiel Y. Ramos-Delgado, Mr. Joshua E. Payne, Dr. Z. Kyle Crosby, Mr. Ernesto G. Cruz-Gutierrez, Dr. John Q. Ehrgott, Jr., & Mr. Denis D. Rickman (USACE—ERDC)

TUESDAY PM (NOVEMBER 6)

	SESSION 9 **Navy Enhanced Sierra Mechanics (NESM) I** 3:45pm-6:10pm / Limited Dist. D Chair(s): Mr. Jon Stergiou (NSWC Carderock) Mr. Corbin Robeck (Thornton Tomasetti)	VENDOR SESSION B **Exhibitor Presentations including: Product and/or Service Overviews, Product Demos, & New Developments & Technologies** 3:45pm-5:15pm / Unlimited Dist. A Chair(s): Mr. Bill Gregory (Applied Physical Sciences) Ms. Leah Holber (Xcitex)	TRAINING II **Structural Dynamics with Octave** 3:45pm-5:15pm / Unlimited Dist. A SESSION 10 **National Shipbuilding Research Program (NSRP)** 5:25pm-6:10pm / Limited Dist. D Chair(s): Mr. Michael Poslusny (Ingalls Shipbuilding)
	All Presenters and Chairs (for Nov. 6) are Required to Meet at 7:00AM in Pegasus A for Presentation Loading		
	Meeting Room: Pegasus A	***Meeting Room: Reunion A***	***Meeting Room: Moreno A/B***
3:45	**Navy Enhanced Sierra Mechanics Updates (AB 20)** Mr. Jonathan Stergiou, Mr. Raymond DeFrese, Dr. John Gilbert, & Mr. Michael Miraglia (NSWC Carderock), Mr. Corbin Robeck & Dr. Badri Hiriyur (Thornton Tomasetti), Dr. Lynn Munday & Dr. Jesse Thomas (Sandia National Laboratories)	**Simulating Barge Shock Event Using Non-linear, 6 DOF (AB 22)** Mr. Eric Peiffer & Mr. Mark Downing (ITT Enidine)	**Structural Dynamics with Octave (an Open-Source Alternative to MatLab)** 3:45pm—5:15pm Mr. Robert Browning & Mr. Gustavo Emmanuelli (USACE—ERDC) Octave provides a graphical user interface that is similar to MatLab and uses a high-level programming language that is mostly compatible with MatLab, thus enabling many MatLab scripts to be run with minimal to no editing. All of this makes the program and the language very user-friendly. In addition, Octave is freely redistributable under the terms of the GNU General Public License (GPL) as published by the Free Software Foundation, so there is no cost to use it. This session is intended to introduce engineers and scientists to Octave with the aim of establishing a strong user-group in the field of structural dynamics. To that end, examples will be provided that cover typical problems encountered in structural dynamics. These will be used to introduce the basics of the language and demonstrate various techniques for visualizing data. Time will be allowed for questions and based on the interests of the audience more examples may be shown or more time given to discussion.
4:10	**Doan-Nickel Equation of State Implementation (AB 20)** Dr. John Gilbert & Mr. Raymond DeFrese (NSWC Carderock), Mr. Corbin Robeck (Thornton Tomasetti)	**Protecting Unit Under Test (UUT) During Vibration Testing (AB 22)** Mr. Chris Wilcox (m+p International)	
4:35	**Air Blast Verification and Validation in NESM (AB 20)** Mr. Raymond DeFrese, Dr. John Gilbert, & Mr. Michael Miraglia (NSWC Carderock), Mr. Corbin Robeck (Thornton Tomasetti)	**Seeing Vibration with VIBVUE™ - A Motion Amplification System (AB 22)** Mr. Andy Lerche (Mechanical Solutions, Inc.)	
5:00	**NEMO Load Balancer (AB 21)** Dr. Badri Hiriyur (Thornton Tomasetti), Mr. Michael Miraglia (NSWC Carderock)	**New Angular Rate Sensor Test Results (AB 22)** Mr. Ronald Poff—author & Ms. Jennifer MacDonell—presenter (Meggitt)	
5:25	**User-Defined Material Models in NESM ~Usage of VUMAT Capability in NESM~ (AB 21)** Mr. Michael Miraglia, Mr. Raymond DeFrese, & Mr. Jonathan Stergiou (NSWC Carderock)	**Numerical Simulation and Testing of Composite Materials under UNDEX Loading (AB 22)** Mr. Bill Gregory (Applied Physical Sciences)	**NSRP Standardization of Watertight Closures (AB 23)** Mr. Michael Poslusny & Mr. Kyle East (Ingalls Shipbuilding)
5:50	**NESM Implementation of DDAM for Submerged Items (DDAMX): A Formulation for Base Excitation and Direct-Pressure Fluid Loading (AB 21)** Mr. Corbin Robeck, Mr. Alex Kelly, & Dr. Jeff Cipolla (Thornton Tomasetti), Mr. Jacob Mason (NSWC Carderock)	**Video Capture and Motion Analysis Solutions (AB 22)** Ms. Leah Holber (Xcitex)	**NSRP ASTMF1387 Shock Testing of Mechanically Attached Fittings (AB 23)** Mr. Michael Poslusny (Ingalls Shipbuilding)

WEDNESDAY AM (NOVEMBER 7)

	SESSION 11 **Vibration I (w/ MIMO)** 8:00am-10:00am / Unlimited Dist. A Chair(s): Dr. Luke Martin (NSWC Dahlgren)	SESSION 12 **SVS18 - Computational Modeling of Airblast on Generic Structures and Vehicles** 8:00am-10:00am / Limited Dist. C Chair(s): Mr. Micael Edwards (USACE—ERDC) Dr. Ken Nahshon (NSWC Carderock)	SESSION 13 **Navy Enhanced Sierra Mechanics (NESM) II** 8:00am-10:00am/ Limited Dist. D Chair(s): Mr. Raymond DeFrese (NSWC Carderock) Mr. Brian Lang (NSWC Carderock)
	All Presenters and Chairs (for Nov. 7) are Required to Meet at 7:00AM in Pegasus A for Presentation Loading		
	Meeting Room: Reunion B	***Meeting Room: Pegasus A***	***Meeting Room: Pegasus B***
8:00	**Insights into Multiaxial Nonlinear Vibration Response of Electronic Assemblies via Study of Mechanical Proxy Structures (AB 23)** Prof. Abhijit Dasgupta, Prof. Samuel Massa, Prof. Xiao Lin, & Prof. R. Sridharan (University of Maryland), Mr. Washington DeLima (Kansas City National Security Campus)	**Experiments and Simulations to Quantify Blast Wave Interaction with Generic Vehicles for Ideal and Homemade Explosive Detonations (AB 25)** Ms. Alyson Doles, Mr. Garrett K. Doles, Dr. Neil T. Williams, & Dr. Jay Q. Ehrgott, Jr. (USACE—ERDC)	**Large Modal Analysis of a Full Ship Model (AB 28)** Mr. Brian Lang & Mr. Timothy McGee (NSWC Carderock)
8:25	**A Technique to Develop a Spectral Density Matrix with Synthesized Rotational Degrees-of-Freedom (AB 23)** Dr. Michael Hale (Trideum Corporation)	**Evaluation of MineX3D Generated Airblast Loadings Using LS-DYNA and ParaDyn (AB 26)** Mr. Micael Edwards, Dr. Greg Bessette, & Mr. David Roman-Castro (USACE—ERDC)	**A Comparative Assessment of Wetted Modal Analysis Techniques: Navy Enhanced Sierra Mechanics (NESM) Finite Element Analysis (FEA), Abaqus FEA, and Blevins' Analytic Techniques (AB 28)** Mr. Jacob Mason, Ms. Anna Bethel, Mr. David Shields, & Mr. Joshua Yates (NSWC Carderock)
8:50	**Preparation of Multi-Axis, Multi-Shaker Vibration Testing Programs for Stationary and Non-stationary Flight Conditions Simulation, Part I (AB 24)** Mr. Zeev Sherf (Consultant)	**A Comparison of Various Blast Loading Methods on Vehicle Structures (AB 26)** Mr. Sanjay Kankanalapalli & Mr. Kumar B Kulkarni (US Army Tank Automotive Research Development and Engineering Center), Dr. Neil Williams, Mr. Micael C. Edwards, & Dr. Gregory C. Bessette (USACE—ERDC)	**Acoustic Cavitation in Navy Enhanced Sierra Mechanics (AB 28)** Dr. Lynn Munday (Sandia National Laboratories), Dr. Murthy Guddati (North Carolina State University)
9:15	**Preparation of Multi-Axis, Multi-Shaker Vibration Testing Programs for Stationary and Non-stationary Flight Conditions Simulation, Part II (AB 24)** Mr. Zeev Sherf (Consultant)	**Simulations of the Generic Hull Vehicle with DYSMAS (AB 27)** Mr. Chris Cao, Mr. Roger Ilamni, & Dr. Tom McGrath (NSWC Indian Head), Dr. Neil Williams (USACE—ERDC)	**Application of the NESM Acoustic Fluid Model to Submarine Shock Problems (AB 28)** Mr. Bradley Klenow, Ms. Anna Bethel, & Mr. Timothy McGee (NSWC Carderock)
9:40	**Infrastructure and Methodology for Multi-Axis Vibration[SH] (AB 25)** Dr. Arie Elka (RAFAEL)	**Simulations of the Generic Hull Vehicle with DYSMAS-MineX3D (AB 27)** Mr. Alan Luton, Dr. Tom McGrath, Mr. Roger Ilamni, & Mr. Chris Cao (NSWC Indian Head), Dr. Greg Bessette & Mr. Micael Edwards (US Army—ERDC)	**Using Navy Enhanced Sierra Mechanics (NESM) for Simulating Implosion[SH] (AB 28)** Dr. Joseph Ambrico & Dr. Emily L. Guzas (NUWC Newport)

Coffee Break in the Exhibit Hall

10:00am—10:30am (Reunion Ballroom)

WEDNESDAY AM (NOVEMBER 7)

	SESSION 14 **Implosion** 8:00am-9:10am / Limited Dist. D SESSION 15 **Structural Response** 9:15am-10:00am / Unlimited Dist. A Chair(s): Dr. Joseph Ambrico (NUWC Newport)	VENDOR SESSION C **Exhibitor Presentations including: Product and/or Service Overviews, Product Demos, & New Developments & Technologies** 8:00am-10:00am / Unlimited Dist. A Chair(s): Mr. Steven Wood (Spectral Dynamics) Mr. Bryan Williams (Data Physics)	TRAINING III **Introduction to Heavyweight Shock Testing** 8:00am-10:00am / Unlimited Dist. A
	All Presenters and Chairs (for Nov. 7) are Required to Meet at 7:00AM in Pegasus A for Presentation Loading		
	Meeting Room: Cotton Bowl	*Meeting Room: Reunion A*	*Meeting Room: Reunion C*
8:00	**A Method and Automated Software to Determine if Implodable Items are Safely Arrange (AB 29)** Mr. Christopher Abate & Mr. Michael Valentine (Electric Boat Corporation)	**Things to Consider When Choosing a High Speed Camera (AB 31)** Mr. Tim Callenbach (Photron)	**Introduction to Heavyweight Shock Testing** 8:00am—10:00am 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.
8:25	**UNDEX Initiated Implosion in Shallow Water of Cylinders in a Confined Environment (AB 29)** Dr. Ryan Chamberlin (NUWC Newport)	**Multi Shaker Vibration Testing (AB 31)** Mr. Bryan Williams & Mr. Thomas Reilly (Data Physics)	
8:50	**A Basic Study of UNDEX Initiated Implosion in a Confined Environment[SH] (AB 29)** Dr. Joseph Ambrico, Dr. Ryan E. Chamberlin, & Dr. Emily L. Guzas (NUWC Newport)	**A Novel Mechanically Isolated, Electrically Filtered Triaxial Shock Accelerometer (AB 31)** Ms. Melissa Maze (PCB Piezotronics)	
9:15	**Using Bispectral Analysis to Detect the Onset of Fatigue Damage in Randomly Excited Structures (AB 30)** Dr. Carl Sisemore & Dr. Vit Babuška (Sandia National Laboratories)	**Introduction to Laser Doppler Vibrometry – A Non-contact Vibration Measurement Technique (AB 31)** Mr. Vikrant Palan (Polytec, Inc.)	
9:40	**2D-FE and 2DOF Simulations of Ground Shock Experiments – Total Structure's Spring Deflection Energy Dependency to the Charge´s and Structure´s Properties (AB 30)** Dr. Leo Laine (LL Engineering AB), Dr. Morgan Johansson (Norconsult AB), Mr. Ola Pramm Larsen (CAEwiz Consulting AS)	**Understanding the Components of a Vibration Control System - the Exciter, Cooling Blower, Amplifier, Fixture, Sensor and Controller and how they Interact to Complete a Vibration Test (AB 32)** Mr. Steven Wood (Spectral Dynamics)	

Coffee Break in the Exhibit Hall
10:00am—10:30am (Reunion Ballroom)

WEDNESDAY AM (NOVEMBER 7)

	SESSION 16 **Instrumentation** 10:30am-12:05pm / Unlimited Dist. A Chair(s): Mr. Laurence O'Neill (NSWC Carderock)	SESSION 17 **Projectile Modeling, Simulation, & Testing** 10:30am-12:05pm / Limited Dist. D Chair(s): Dr. Michael Oesterle (NAVFAC EXWC)	SESSION 18 **Material Behavior II** 10:30am-12:05pm / Limited Dist. D Chair(s): Mrs. Rebecca Grisso (NSWC Carderock)
	All Presenters and Chairs (for Nov. 7) are Required to Meet at 7:00AM in Pegasus A for Presentation Loading		
	Meeting Room: Reunion B	***Meeting Room: Pegasus B***	***Meeting Room: Pegasus A***
	Mid-Morning Break Continues in Exhibit Hall (10:00am-10:30am)		
10:30	**Dynamic Calibration of Pressure Transducers with Sinusoidal Excitation (AB 32)** Mr. Thomas Platte, Mr. Martin Iwanczik, & Mr. Michael Mende (SPEKTRA)	**Novel Light-weight System to Resist High Velocity Penetrators (AB 34)** Dr. David Stevens, Mr. Eddie O'Hare, & Mr. Matt Barsotti (Protection Engineering Consultants), Dr. Michael Oesterle & Mr. Brad Durant (NAVFAC EXWC), Mr. Mike Newberry (Syscom), Mr. Preston Reed & Mr. Casey O'Laughlin (Jacobs Technology)	**Establishing Crack Initiation Off Plunge EDM Flaws in Support of Hydraulic Fatigue Testing (AB 36)** Mr. Lucas Smith (US Army ARDEC)
10:55	**Shock Accelerometer Calibration and Performance Surety at the Manufacturer's Facility (AB 33)** Mr. David Ort (PCB Piezotronics)	**Development of Protective System for Defeat of High-Velocity Projectiles (AB 35)** Dr. Michael Oesterle & Mr. Brad Durant (NAVFAC EXWC), Mr. Joseph Magallanes & Mr. Brian Dunn (Karagozian and Case)	**Intermediate Strain Rate Tensile Testing and Analysis of Elastomeric Material Coupons (AB 36)** Mrs. Rebecca Grisso (NSWC Carderock)
11:20	**Zero Shift and Low Frequency Offset: Sensor or System Problem? (AB 33)** Mr. Anthony Agnello (PCB Piezotronics), Dr. Patrick L. Walter (Professor Emeritus, Texas Christian University / PCB Piezotronics)	**Evaluation of Systems for Defeat of High-Velocity Projectiles for Facility Protection (AB 35)** Mr. Ernesto G. Cruz-Gutierrez, Ms. Amie Burroughs, Mr. Brandon Everett, & Mr. Ray Moxley (USACE—ERDC)	**Shell Model of Dynamically Crushed Bisected Honeycomb Structure (AB 36)** Mr. Morris Berman (US Army Research Laboratory)
11:45	**Ruggedized High-Shock, Undamped Accelerometer with Strengthened, Low-Noise Cable (AB 33)** Mr. James Nelson (Meggitt Sensing Systems)	**Dynamic Strain Effects in Composite Overwrapped Gun Tubes (AB 35)** Dr. Andrew Littlefield & Dr. Michael Macri (US Army ARDEC)	**Testing of Metals at High Strain Rates with Pulsed Lasers (AB 37)** Dr. David Stevens, Mr. Matt Barsotti, & Dr. Eddie O'Hare (Protection Engineering Consultants), Dr. Sidney Chocron & Mr. Thomas Moore (Southwest Research Institute)

PANEL DISCUSSION **10:30am-Noon** **Limited Dist. / Statement D**	**Discussion Panel On the Topic Shock Isolation Mount Selection and Shock Testing** — **Meeting Room: Shawnee Trail A/B** Chair: Ms. Janet Bivens (NUWC Newport) Panelists: Mr. Kurt Hartsough (NSWC Philadelphia), Mr. Michael Talley (HII-NNS), Mr. Jeff Morris (HI-TEST Labs) Shock isolation mounts are used throughout Navy platforms as a means to mitigate shock and vibration effects to sensitive equipment. In order to effectively select, qualify for shock and utilize isolation mounts, engineers and vendors/contractors should have an understanding of the Naval Sea Systems Command (NAVSEA) expectations for mount selection in order to meet MIL-S-901 / MIL-DTL-901 requirements and subsequent high impact shock testing of isolated systems. This panel will discuss and address engineer and vendor assumptions and methods of verification.

WEDNESDAY AM (NOVEMBER 7)

	SESSION 19 **Computational Modeling for Design and Optimization of Structures to Resist Advanced Threats** 10:30am-11:15am / Limited Dist. D 11:20am-12:05pm / Limited Dist. C Chair(s): Mr. Robert Browning (USACE—ERDC) Mr. Andrew Barnes (USACE—ERDC)	VENDOR SESSION D **Exhibitor Presentations including: Product and/or Service Overviews, Product Demos, & New Developments & Technologies** 10:30am-11:35am / Unlimited Dist. A Chair(s): Mr. Alan Klembczyk (Taylor Devices) Mr. Claude Prost (Vibro/Dynamics)	TRAINING IV **Coupling Abaqus/Explicit with XFlow using the Abaqus Co-Simulation Engine** 10:30am-12:00pm / Unlimited Dist. A
	All Presenters and Chairs (for Nov. 7) are Required to Meet at 7:00AM in Pegasus A for Presentation Loading		
	Meeting Room: Cotton Bowl	***Meeting Room: Reunion A***	***Meeting Room: Reunion C***
10:00	***Mid-Morning Break Continues in Exhibit Hall (10:00am-10:30am)***		
10:30	**Modeling Combined Blast and Fragment Loading from Detonation though Structure Interaction (AB 37)** Mr. Andrew Barnes & Dr. James O'Daniel (USACE—ERDC)	**Dynamic Measurement Calibration Equipment (AB 39)** Mr. Michael Mende & Mr. Bruce Swanson (SPEKTRA)	**Coupling Abaqus/Explicit with XFlow using the Abaqus Co-Simulation Engine** 10:30am-12:00pm Mr. Ozgur Yapar & Mr. Jon Arata (Dassault Systemes / SIMULIA) In this training session we will outline the process and the steps required to perform a coupled fluid-structure interaction (FSI) analysis using the explicit finite element solver Abaqus/Explicit coupled through the Abaqus CSE with the high-fidelity Lattice-Boltzmann CFD solver Xflow. The Abaqus CSE is a set of built-in procedures used to solve multiphysics simulations in a single, efficient, sequentially run-time coupled analysis using the Abaqus structural solvers (/Standard and /Explicit). The particular problem we will use for this tutorial is of the launching of a mortar round through a deformable tube and the subsequent travel of that round through the air. However, we will approach the problem in this 3-hour session in a general manner so as to be broadly applicable to analysts looking to perform transient FSI analyses with potentially unsteady, multiphase flows with moving, deformable solid bodies.
10:55	**Computational Modeling of Impact and Depth of Penetration Experiments on PAM-35 Concrete Specimen (AB 38)** Dr. William Lawrimore, Mr. Robert S. Browning, Mr. Andrew T. Barnes, Mr. Jared L. Brown, & Dr. Jim L. O'Daniel (USACE—ERDC)	**Case Study of a 6 Degree-of-Freedom Isolation System in a Shock and Vibration Environment Including Analysis, Design & Field Measurements of System Performance (AB 39)** Mr. John Metzger & Mr. Alan Klembczyk (Taylor Devices)	
11:20	**Predicting Post-Blast Residual Capacity of Reinforced Concrete Structures Using the Advanced Fundamental Concrete (AFC) Model in Abaqus and Sierra (AB 38)** Mr. Andrew Groeneveld, Mr. Robert Browning, & Dr. Wes Trim (USACE—ERDC)	**Using the Same Wire Rope Isolators for the 8 Hz and 14 Hz Shock Testing Platform (AB 40)** Mr. Claude Prost & Mr. Josh Partyka (Vibro/Dynamics)	
11:45	**Parametric Analysis and Design Optimization of Reinforced Concrete Slabs under Advanced Threats (AB 39)** Mr. Jose Rullan-Rodriguez, Dr. William Lawrimore, Mr. Robert S. Browning, & Mr. Andrew T. Barnes (USACE—ERDC)	**enDAQ Platform Evolves to Meet Consumer Trends in Test & Measurement (AB 40)** Mr. Steve Hanly (Mide Technologies)	

General Session 2 incl. Elias Klein Lecture & Exhibitors' Luncheon

12:05pm—1:15pm / Reunion Ballroom (Exhibit Hall)

12:10pm—12:30pm	Buffet Lunch
12:30pm—12:35pm	Elias Klein Lecturer Introduction by: Dr. Patrick Walter (TCU Emeritus Professor / PCB Piezotronics)
12:35pm—1:05pm	***Elias Klein Lecture*** by: Mr. Tony "Brick" Wilson

Elias Klein Lecture Bio (Mr. Tony "Brick" Wilson)

Tony "Brick" Wilson was born in Fort Lauderdale, Florida and raised in New Port Richey, Florida. He enlisted in the United States Navy in 1991 as a nuclear power technician and served aboard the fast attack submarine USS Boise (SSN 764). Later, Tony was selected for the Enlisted Commissioning Program where he graduated from Old Dominion University with a B.S. in Mechanical Engineering and earned his commission as an Ensign. Brick's operational military experience includes a combat tour in F/A-18Cs with VFA-87 where he deployed to the Mediterranean Sea and the Middle East in support of Operation Iraqi Freedom (OIF) and a department head tour flying F/A-18F with VFA-102 in the Far East.

A graduate of the Air Force Institute of Technology with a M.S. in Aeronautical Engineering and the United States Naval Test Pilot School as a member of class 132; Tony started his test career as the F-35 ship suitability project officer at VX-23's Integrated Test Force. During his first tour, "Brick" worked many diverse projects including L-Class ship suitability, F-18E/F engine stall investigation, chemical/biological pilot flight equipment evaluation and Shipboard Rolling Vertical Landing (SRVL) evaluations in the Vectored-thrust Aircraft Advanced Control (VAAC) Harrier test aircraft. After his operational department head tour in Japan, Brick returned to VX-23 to serve as the lead F-35 carrier suitability officer and the officer-in-charge of initial ship trials. During his tenure, he oversaw the implementation of the F-35C's redesigned arresting hook system, developed new and innovative techniques for structural survey testing, and lead a diverse team of multi-national military, civil service and contractors during initial ship trials. In addition to carrier suitability testing, Brick has participated in high alpha, loads, buffet, flying qualities, aerial refueling and operational assessment testing of both the F-35 and F-18. In June, 2016, having completed 25 years in the Navy, Tony transitioned to civilian life and joined Lockheed Martin as a test pilot where he supports both the F-16 and F-35 programs. He has flown over 20 different types of aircraft including an experimental British Sea Harrier, the U-2 and the MiG-15. Brick has the distinction of being the first aviator to execute a shipboard arrestment when he successfully landing the F-35C aboard the USS Nimitz (CVN 68).

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 3:15pm-4:00pm on Wednesday , November 7th*

Thank You to the Organizations Participating in the Passport Program:

Spectral Dynamics
Hi-Test Laboratories, Inc.
General Dynamics Applied Physical Sciences
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Vibration Research
Dytran Instruments, Inc.
Crystal instruments
Shock Tech
ITT Enidine
Xcitex
Altair
IMV Secure the Future
Polytec
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 →

WEDNESDAY PM (NOVEMBER 7)

	SESSION 20 **Shock Testing** 1:15pm-2:25pm / Limited Dist. D 2:30pm-3:15pm / Limited Dist. C Chair(s): Ms. Anna Bethel (NSWC Carderock) Ms. Allison Vella (Gibbs & Cox)	SESSION 21 **Vibration II** 1:15pm-2:00pm / Limited Dist. C 2:05pm-3:15pm / Unlimited Dist. A Chair(s): Dr. Bryan Joyce (NSWC Dahlgren)	SESSION 22 **Shock Prediction & Shock Response Spectrum (SRS)** 1:15pm-2:50pm / Unlimited Dist. A Chair(s): Mr. Andrew Barnes (USACE—ERDC)
	All Presenters and Chairs (for Nov. 7) are Required to Meet at 7:00AM in Pegasus A for Presentation Loading		
	Meeting Room: Pegasus B	***Meeting Room: Pegasus A***	***Meeting Room: Reunion A***
1:15	**Application of Shock Evaluation Parameters To Encanistered Missile Shock Applications (AB 40)** Mr. Kenneth Lussky (BAE Systems)	**Static and Dynamic Load Equalization in Self-Equalizing Thrust Bearing Linkages (AB 42)** Dr. Richard Armentrout (Curtiss-Wright EMD)	**Using Recorded Data to Improve SRS Test Development (AB 45)** Mr. Joel Minderhoud (Vibration Research) *presented by:* Mr. Caleb Chamberlain (Vibration Research)
1:40	**Data Analytics and Potential Future UNDEX Qualification Processes (AB 40)** Dr. Jeffrey Cipolla & Mr. Fred Costanzo (Weidlinger Technology Ventures LLC), Dr. Juan Londono & Mr. Addison Martin (Thornton Tomasetti, Inc.)	**Combined Electromagnetic-Mechanical Environments: Testing and Analysis (AB 43)** Dr. Brian Owens, Dr. Richard A. Jepsen, Mr. Jonel Ortiz, Dr. Jeffery T. Williams, Dr. Isak C. Reines, Dr. Rebecca S. Coats, Dr. Larry K. Warne, & Mr. Roy K. Gutierrez (Sandia National Laboratories)	**Derivation of Shaker Shock Input of an Oscillatory Decaying Shock to Optimize High Frequency SRS "Flatline" (AB 45)** Mr. Chad Heitman & Mr. Jerome S. Cap (Sandia National Laboratories)
2:05	**Calibration of Paddlewheel Test Vehicle (PWTV) for Shock Testing Medium Size Penetrations[SH] (AB 41)** Mr. Timothy McGee, Mr. Jacob Mason, & Ms. Anna Bethel (NSWC Carderock)	**A Data-Driven Approach to Environmental Testing (AB 43)** Mr. Timothy Devine, Dr. Sriram Malladi, & Dr. Pablo Tarazaga (Virginia Tech)	**Several Remarks on the Shock Spectrum's Limitations as a Descriptor of a Shock (AB 46)** Mr. Zeev Sherf (Consultant)
2:30	**Using the DSSM in Accordance with MIL-DTL-901E (AB 41)** Dr. Michael Talley (HII - Newport News Shipbuilding)	**Video Motion Amplification vs. Operating Deflection Shapes for Vibration-based Diagnosis of Machinery (AB 44)** Mr. Andrew Lerche, Mr. William Marscher, Mr. Maki Onari, & Mr. Eric Olson (Mechanical Solutions, Inc.)	**Understanding Multi-Axis SRS Testing Results (AB 46)** Mr. Jonathan Markl, Ms. Erica Jacobson, Mr. William Larsen, Dr. Jason R Blough, Dr. James DeClerck, & Mr. Charles VanKarsen (Michigan Technological University), Mr. David Soine & Mr. Richard Jones (Honeywell)
2:55	**Test and Extension Methods for Subsidiary Components Installed in Navy-Approved Physical Open Architecture Enclosures (AB 41)** Ms. Lisa McGrath (HII - Newport News Shipbuilding)	**Improved Vibration Control Strategy Allowing the Replication of Operational Dynamic Environments at Component Level Testing (AB 44)** Mr. Umberto Musella, Mr. Mariano Alvarez Blanco, & Dr. Bart Peeters (Siemens Industry Software)	

SESSION BREAK & PASSPORT PRIZE WINNER ANNOUNCEMENT

3:15PM - 4:00PM

WEDNESDAY PM (NOVEMBER 7)

<table>
<tr>
<td></td>
<td>SESSION 23
Testing & Analysis of Fuze Technology for Harsh Mechanical Environments
1:15pm-3:15pm / Limited Dist. D

Chair(s):
Dr. Jacob Dodson (Air Force Research Laboratory)
Dr. Alain Beliveau (Applied Research Associates)</td>
<td>DISCUSSION GROUP I
Boundary Conditions Discussion Group (Round Robin) w/ Paper Presentation
1:15pm-2:40pm / Unlimited Dist. A</td>
<td>TRAINING V
DDAM-coupled Optimization Methods
1:30pm-3:00pm / Unlimited Dist. A</td>
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<tr>
<td></td>
<td colspan="3">***All Presenters and Chairs (for Nov. 7) are Required to Meet at 7:00AM in Pegasus A for Presentation Loading***</td>
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<td></td>
<td>*Meeting Room: Cotton Bowl*</td>
<td>*Meeting Room: Reunion C*</td>
<td>*Meeting Room: Reunion B*</td>
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<tr>
<td>1:15</td>
<td>**Test Observed Considerations for Embedded Smart Fuzing of Penetrating Munitions (AB 47)**
Mr. Alma Oliphant, Mr. Justin Bruno, Mr. Craig Doolittle, & Mr. Nick Jarrett (Applied Research Associates)</td>
<td>**Modal Approach to Matching Component Response Under Different Boundary Conditions (AB 48)**
Mr. Brandon Zwink & Mr. Troy Skousen (Sandia National Laboratories)</td>
<td rowspan="5">**DDAM-coupled Optimization Methods**

1:30pm-3:00pm
Mr. Leo Jeng (Altair, Inc.)

In this workshop, the focus will be on optimizing components for DDAM simulations for structural performance and cost. This workshop will demonstrate setting up the model in a FEA pre-processor, performing a DOE study to screen out variables, then running an analysis and optimization to generate a design that exceeds structural requirements while minimizing costs. Optimization techniques covered in this workshop include parametric and shape optimization to improve the performance of the model under DDAM shock simulation conditions. Additional post-processing of the analysis will be done to evaluate and compare the optimized and baseline designs.</td>
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<tr>
<td>1:40</td>
<td>**Subscale Test Designs for Edge of the Envelope Legacy Penetrating Munition Environments (AB 47)**
Mr. Alma Oliphant, Mr. Drew Malechuck, Mr. Phil Marquardt, Mr. Craig Doolittle, & Mr. Bryan Norris (Applied Research Associates)</td>
<td rowspan="4">**Boundary Conditions in Environmental Testing Round Robin**

1:40pm-2:40pm
Mr. Troy Skousen & Mr. David Soine (Sandia National Laboratories)

The current practices for component-level shock & vibration testing may result in over- or under-stressing the component as compared to the stress experienced in the next level assembly. While the success of the component test is dependent on several factors, a significant contributor is the boundary condition in the component test. Common test practices cause the component to have notably different dynamic boundary conditions between the component test and system configuration. This may be causing false failures in the component tests that are not indicative of the true system environments and/or leading us to miss failures in the component tests that would have occurred in the system.

A test bed, the Box Assembly with Removable Component (BARC), has been designed for interested parties to study this problem in a common framework. This round robin will include an overview of the hardware and problem statement followed by a discussion among current and prospective participants regarding approaches for improving the issues associated with differing boundary conditions. Current efforts are primarily focused on improved test specifications and fixture design optimization. Please join us!</td>
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<tr>
<td>2:05</td>
<td>**Experimental Evaluations of Fuze Components in Ultra High-G regimes (>100kG's) (AB 47)**
Mr. Shane Curtis, Mr. Josh Dye, Mr. Chad Hettler, & Mr. Caleb White (Sandia National Laboratories)</td>
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<tr>
<td>2:30</td>
<td>**Embedded Fireset Testing in Extreme Environment (AB 48)**
Dr. Alain Beliveau & Mr. James Scheppegrell (Applied Research Associates), 2d Lt Tiffany Hatcher & Dr. Jacob Dodson (AFRL/RWMF)</td>
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<tr>
<td>2:55</td>
<td>**Characterizing the Mechanical Properties and Dynamic Response of G-Switches (AB 48)**
Mr. Matt Croether, Mr. Curtis McKinion, & Dr. Jacob Dodson (Air Force Research Laboratory), Dr. Jeffrey Hill, Mr. Shane Curtis, & Mr. Joshua Dye (Sandia National Laboratories)</td>
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</table>

SESSION BREAK & PASSPORT PRIZE WINNER ANNOUNCEMENT

3:15PM - 4:00PM

TUTORIAL SESSION 5 / 3:30pm—6:30pm

~ CHOOSE ONE / ADDITIONAL FEES APPLY TO ATTEND ~

Shock Test Failure Modes **Meeting Room: Reunion C**

Mr. Kurt Hartsough, Mr. Domenic Urzillo, & Mr. Dan Moran (NSWC Philadelphia)

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

Analysis for Medium Weight Shock **Meeting Room: Pegasus B**

Mr. Josh Gorfain (Applied Physical Sciences) & Mr. Jeff Morris (HI-TEST Laboratories)

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

Analysis and Synthesis of Realistic Random Environments **Meeting Room: Reunion A**

Dr. Thomas Paez (Thomas Paez Consulting)

Students of random vibration often ask: "Do mechanical shocks ever occur during stationary random vibration environments?" Students of mechanical shock often ask: "Does stationary random vibration ever occur in the background when mechanical shocks are measured?" In fact, in the field, one environment seldom occurs without the other. For example, during launch, transportation, aircraft flight, and many other environments, stationary random vibration, nonstationary random vibration, and classical shocks occur together. This tutorial presents methods for the analysis of realistic environments and then the synthesis of realistic environments using models obtained during analysis. During analysis it is required to (1) use the methods of statistics to establish when a mechanical shock occurs during stationary random vibration. Once occurrence is established, the duration and shape of any classical pulse component must be estimated. The classical pulse is removed from the background signal. (2) The incidence or non-incidence of a realization from an oscillatory, nonstationary random process must identified, next. If such a realization is present, then the source must be identified, and the component must be removed from the background signal. (3) Finally, the characteristics of the sources of the remaining segments of stationary random process realizations must be identified. During synthesis, the classical pulse characteristics identified in (1), the nonstationary random process characteristics identified in (2), and the stationary random process characteristics identified in (3) must be used to generate random signals from the same source as the analyzed signal. The generated signals can be used as analytical excitations or test excitations to be realized on a shaker. The presentation follows analysis and synthesis of a measured, physical signal, provided by Jerry Cap of Sandia National Laboratories. Basic MATLAB software that executes the operations developed during the tutorial will be distributed to the attendees.

Comparison of Field-laboratory Equivalence Evaluation Methods: Accumulated Damage versus Energy Based Methods **Meeting Room: Reunion B**

Mr. Zeev Sherf (Consultant)

This tutorial will present a comparative description of methods aimed to evaluate the equivalence between in a laboratory simulated vibration regime to a field regime. Two groups of methods are handled. Those based on accumulated damage on one hand and those based on accumulated energy on the other one. For the first group it will be shown how measured vibrations in the field, accumulated as time histories are transformed in PSDs (Power Spectral Densities) one for each mission stage, by applying parametric modeling. Following it will be shown how the PSDs are used in the load cycle counting for each mission stage and for the entire mission respectively. The counting is performed by deriving from the PSD data the load cycles' probability of occurring in a certain level interval and the number of loads of different levels per time unit. With this data and the duration of each stage the number of cycles of different levels for each mission step is evaluated. The counted loads are combined with a fatigue model in order to evaluate the accumulated damage over the entire mission. For the field data PSDs an envelope PSD is evaluated. Based on it a laboratory vibration regime is determined. It is described by a PSD with the shape of the envelope PSD, with the level and the duration of application fitted to generate in the system exposed to the simulation regime, the same damage as that accumulated under the field conditions. One of the main shortcomings of this methodology is the lack of the fatigue model of the tested system. Under these circumstances usually some universal models are used that quite often are not relevant, and appropriate to the specific system. The way to overcome this shortcoming is to evaluate the equivalence between the field and the laboratory regime in terms of accumulated energy. Under this method no knowledge about the tested system is required. The knowledge of the in field measured vibration regime in terms of acceleration time histories is enough. From the acceleration time history the velocity time history is calculated. Based on the acceleration and velocity the power per mass unit and following the energy per mass unit are evaluated for each mission stage and following for the entire mission. Using the envelope PSD mentioned above, a simulation regime that generates an energy per mass unit equal to that of the field is derived. The testing duration derived based on energy considerations as compared to that derived based on damage accumulation is significantly longer, both according to the in the literature published data and to the author experience.

NTS

PCB PIEZOTRONICS INC.
MTS SYSTEMS CORPORATION

HI-TEST Laboratories, Inc.

ALL 89TH S&V SYMPOSIUM ATTENDEES, AND THEIR GUESTS,

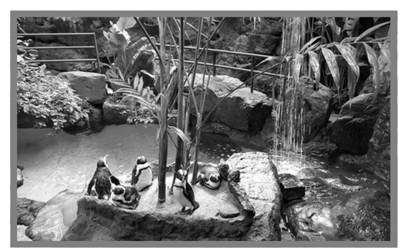
ARE INVITED TO:





THE DALLAS WORLD AQUARIUM





Wednesday, November 7th

7:00pm—10:00pm

Food, Drinks, & Entertainment

THURSDAY AM (NOVEMBER 8)

	SESSION 24 **Vibration III** 8:00am-9:10am / Unlimited Dist. A SESSION 25 **Mechanical Shock Response Analysis** 9:15am-10:00am / Unlimited Dist. A Chair(s): Mr. Corbin Robeck (Thornton Tomasetti)	SESSION 26 **Underbody Blast** 8:00am-10:00am / Limited Dist. D Chair(s): Dr. Ken Nahson (NSWC Carderock)	SESSION 27 **Shock Isolation & Analysis** 8:00am-9:35am / Limited Dist. D Chair(s): Mr. Matt Davis (HII—Newport News Shipbuilding)
	All Presenters and Chairs (for Nov. 8) are Required to Meet at 7:00AM in Pegasus A for Presentation Loading		
	Meeting Room: Reunion A	*Meeting Room: Pegasus B*	*Meeting Room: Pegasus A*
8:00	**Combined Environments Testing (AB 49)** Mr. Gabe Rizk (NSWC Dahlgren)	**Underbody Blast Testing of Aluminum Plates (AB 51)** Dr. Ken Nahshon, Ms. Jessica Dibelka, & Mr. Daniel Hart (NSWC Carderock), Mr. Denis Rickman & Mr. Garrett Doles (USACE—ERDC)	**Concepts for Designing Shock Isolated False Deck (SIFD) Systems for Shipboard Equipment (AB 53)** Dr. Michael Talley (HII - Newport News Shipbuilding)
8:25	**Propeller Aircraft Vibration Definition (AB 49)** Mr. Shawn Schneider & Dr. Luke Martin (NSWC Dahlgren)	**Modeling Underbody Blast Tests of Aluminum Plates using EPIC (AB 51)** Dr. Neil Williams, Mr. Garrett K. Doles, & Mr. Denis Rickman (USACE—ERDC), Dr. Ken Nahshon (NSWC Carderock)	**Modification of Shock Isolation Mount Predictions & Loading Estimates (SIMPLE) Program to Simulate with Nonlinear Mount Geometry Changes (AB 54)** Mr. David Callahan & Dr. Michael Talley (HII - Newport News Shipbuilding)
8:50	**Defining Shipboard Motion Environments for Design and Testing (AB 50)** Mr. Matt Forman & Mr. Prenn Tran (NSWC Dahlgren)	**Using Remotely Determined Soil Properties to Determine Relative Severity of Vehicle Underbody Blast Loading (AB 52)** Dr. Kyle Crosby, Mr. Ryan E. North, Dr. Stephen A. Akers, & Dr. John Q. Ehrgott, Jr, (USACE—ERDC)	**The Development and Use of a Mount Configurator Design Tool Supporting Shock Isolated False (SIFD) Systems (AB 54)** Mr. Chris Campbell & Dr. Michael Talley (HII - Newport News Shipbuilding)
9:15	**Scaling Shock Response Spectra – Contributing Factors (AB 50)** Dr. Arup Maji (Sandia National Laboratories)	**Testing Methodology/Operations for Underbody Blast Testing of Aluminum Plates (AB 52)** Mr. Garrett Doles, Mr. Denis Rickman, & Mr. Stephen Turner (USACE—ERDC), Dr. Ken Nahshon (NSWC Carderock)	**Shock Extension Analysis using SIMPLE and Nonlinear FEA to Capture Unexpected Ballistic Equipment Response (AB 54)** Mr. Matt Davis & Dr. Michael Talley (HII - Newport News Shipbuilding)
9:40	**Random Processes on Manifolds (AB 50)** Dr. George Lloyd (ACTA, Inc.), Dr. Tom Paez (Paez Consulting)	**Soil Model and Computational Strategy for Landmine Modeling (AB 53)** Dr. David Stevens, Mr. Matt Barsotti, & Mr. Eddie O'Hare (Protection Engineering Consultants), Mr. James Rasico, Mr. Craig Newman, & Mr. David Gerst (Navistar Defense)	

THURSDAY AM (NOVEMBER 8)

	SESSION 28 **Weapons Effects R&D** 8:00am-8:20am / Limited Dist. D 8:25am-10:00am / Unlimited Dist. A Chair(s): Mr. Vince Chiarito (Federal Highway Administration) Dr. David Stevens (Protection Engineering Cons.)	SESSION 29 **Alternative/New Shock Test & Analysis Methods** 8:00am-8:20am / Limited Dist. D+ 8:25am-10:00am / Unlimited Dist. A Chair(s): Mr. Tom Brodrick (NSWC Carderock)	TRAINING VI **Shock Response Spectrum Primer** 8:30am-10:00am / Unlimited Dist. A
	All Presenters and Chairs (for Nov. 8) are Required to Meet at 7:00AM in Pegasus A for Presentation Loading		
	Meeting Room: Reunion B	***Meeting Room: Cotton Bowl***	***Meeting Room: Reunion C***
8:00	**Conceptual Model of Transonic Weapon Penetration Process (AB 55)** Mr. Robert Couch, Mr. Jeff Duray, & Mr. Rob Cilke (Applied Research Associates), Mr. Craig Schwandt (McCrone Associates)	**Validation of New Test System for Simulating Firing Shock on Mortar Baseplates (AB 58)** Mr. David Alfano & Dr. Andrew Littlefield (US Army ARDEC)	**Shock Response Spectrum Primer** 8:30am—10:00am Dr. Carl Sisemore (Sandia National Labs) The shock response spectrum (SRS) is the most common way of characterizing transient excitation. The SRS is advantageous due to its ubiquity and ability to substantially reduce the shock data complexity to a manageable level. An overview of the origins and methods for calculating the SRS will be provided. The various types of shock spectra will be discussed in detail along with their applications. A comparison of SRS results from both classical and oscillatory shocks will be presented along with a discussion of the important characteristics of each type of shock when transformed to the SRS.
8:25	**An Open-Source CFD Software for Modeling Blast Propagation (AB 55)** Dr. David Stevens, Mr. Tim Brewer, & Mr. Eddie O'Hare (Protection Engineering Consultants), Mr. Peter Vonk (Synthetik Applied Technologies)	**Shock Transmission in Structures (AB 58)** Mr. Y.Z. Yan & Professor Q.M. Li (The University of Manchester)	
8:50	**New Paradigm for Creating Fast Running Models for Weapons Effects (AB 56)** Mr. Matt Barsotti & Dr. Eric Sammarco (Protection Engineering Consultants), Ms. Sherri Hodgson, Ms. Kellina Jeung, & Mr. Robert Kelleher (Applied Research Associates)	**Development of the Multiaxis Air Gun - Resonant Fixture Shock Test (AB 59)** Mr. Mikhail Mesh, Mr. Ronald N. Hopkins, Dr. Matthew A. Spletzer, Dr. Carl L. Sisemore, & Mr. William K. Bonahoom (Sandia National Laboratories)	
9:15	**Visualization, Measurement and Prediction of Building Debris for Large Magnitude, Long Duration Shock Loads (AB 57)** Dr. David Stevens, Mr. Kirk Marchand, & Mr. Matt Barsotti (Protection Engineering Consultants), Mr. Mohsen Sanai (SRI International)	**Characterization and Endurance Simulation of Gunfire Shocks for Developing a Naval System (AB 59)** Mr. Ron Moshe (RAFAEL)	
9:40	**An Overview of Force Protection in the Urban Environment (AB 57)** Dr. Catherine Stephens (USACE—ERDC)	**Classification of Transient Behavior in Time History Data (AB 60)** Ms. Angela Montoya (Sandia National Laboratories), Dr. Fernando Moreu (University of New Mexico), Dr. Thomas L. Paez (Thomas Paez Consulting)	

THURSDAY AM (NOVEMBER 8)

	SESSION 30 **Mechanical Shock Testing & Subsidiary Components** 10:05am-11:40am / Limited Dist. C 11:45am-12:05pm / Unlimited Dist. A Chair(s): Mr. Sloan Burns (NSWC Dahlgren) Dr. Luke Martin (NSWC Dahlgren)	SESSION 31 **Structural Response to UNDEX** 10:05am-10:50am / Unlimited Dist. A Chair(s): Mr. Leo Jung (Altair, Inc.)	SESSION 32 **Shock, Vibration, & Blast in Transportation** 10:05am-10:25am / Limited Dist. C 10:30am-11:15am / Unlimited Dist. A SESSION 33 **Soil & Rock Studies** 11:20am-12:05pm / Unlimited Dist. A Chair(s): Dr. Kyle Crosby (USACE—ERDC)
	All Presenters and Chairs (for Nov. 8) are Required to Meet at 7:00AM in Pegasus A for Presentation Loading		
	Meeting Room: Pegasus B	***Meeting Room: Reunion A***	***Meeting Room: Pegasus A***
10:05	**Aligned Axis 40' Drop Guidance System (AB 61)** Mr. Sloan Burns (NSWC Dahlgren)	**DDAM-coupled Optimization Methods for Ship Structures (AB 63)** Mr. Leo Jeng (Altair, Inc.)	**Finite Element Analysis of an ISO Container Subjected to Impulsive Loadings (AB 64)** Mr. David G. Román-Castro, Mr. Donald H. Nelson, Dr. Catherine S. Stephens, Dr. Paul A. Sparks, & Mr. Omar G. Flores (USACE—ERDC), Dr. Luis E. Suárez (University of Puerto Rico Mayagüez)
10:30	**Heavyweight Alternative Test for Vertical Launch Systems (AB 62)** Mr. Sloan Burns (NSWC Dahlgren)	**Digital Image Correlation Measurements on a 2-m Ship-like Panel Subjected to Underwater Explosions (AB 63)** Dr. Julian Lee & Mr. Shane Halaska (Defence R&D Canada - Suffield Research Centre), Dr. Malcolm Smith (DRDC - Atlantic Research Centre)	**Protocol Development for Multi-Axis Transportation Vibration (AB 64)** Dr. Jon Yagla (Bowhead Technical Services), Mr. Shawn Schneider & Dr. Luke Martin (NSWC Dahlgren)
10:55	**Subsidiary Component Testing Guidance Criteria: Data Analysis (AB 61)** Mr. Sloan Burns (NSWC Dahlgren)		**Simulating the Dynamic Behavior of a Shipping Container (AB 65)** Mr. Claude Prost & Mr. Joshua Partyka (Vibro/Dynamics)
11:20	**Time Waveform Replication of the Barge Environment (AB 61)** Mr. Mike Morrison (NSWC Dahlgren)		**Materials OnLine Encyclopedia (MOLE) Overview (AB 66)** Dr. Kyle Crosby, Dr. Stephen A. Akers, & Dr. John Q. Ehrgott, Jr. (USACE—ERDC)
11:45	**Literature Summary of Resonant Fixture Shock Testing (AB 62)** Mr. Jonathan Markl, Ms. Erica Jacobson, Dr. Jason R Blough, Mr. James DeClerck, & Mr. Charles VanKarsen (Michigan Technological University), Mr. David Soine & Mr. Richard Jones (Honeywell—KCNSC)		**Research Plan for ECM Required Earth Cover (AB 66)** Mr. Joshua Payne, Dr. John Q. Ehrgott, Jr., Mr. Denis D. Rickman, & Dr. T. Neil Williams (USACE—ERDC), Dr. Michelle M. Crull (U.S. Army Engineering and Support Center), Mr. Daniel L. Linehan (U.S. Army Technical Center for Explosives Safety)

THURSDAY AM/PM (NOVEMBER 8)

<table>
<tr><td></td><td>SESSION 34
Equipment Shock Design/Qualification
10:05am-11:40am / Unlimited Dist. A

Chair(s):
Mr. Justin Caruana (Cardinal Engineering)</td><td>TRAINING VII
Manufacturing Process Effects on the Performance of Fasteners in Service
10:30am-11:15 / Unlimited Dist. A</td><td>TRAINING VIII
Introduction to Medium Weight & Lightweight Shock Testing
10:00am-Noon / Unlimited Dist. A</td></tr>
<tr><td></td><td colspan="3">***All Presenters and Chairs (for Nov. 8) are Required to Meet at 7:00AM in Pegasus A for Presentation Loading***</td></tr>
<tr><td></td><td>*Meeting Room: Reunion B*</td><td>*Meeting Room: Cotton Bowl*</td><td>*Meeting Room: Reunion C*</td></tr>
<tr><td>10:05</td><td>**Submarine Component Design Tool to Assess Relative Resistance to Shock Loading Part 1 (AB 67)**
Mr. Justin Caruana, Mr. Connor Way, & Mr. Patrick Walker (Cardinal Engineering), Dr. Jeffrey Cipolla, Dr. Abilash Nair, Mr. Daniel Kadyrov, Dr. Juan Londono, & Mr. Addison Martin (Thornton Tomasetti)</td><td></td><td rowspan="5">**Introduction to Medium Weight & Lightweight Shock Testing**

10:05am—Noon
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</td></tr>
<tr><td>10:30</td><td>**Submarine Component Design Tool to Assess Relative Resistance to Shock Loading Part 2 (AB 67)**
Mr. Justin Caruana, Mr. Connor Way, & Mr. Patrick Walker (Cardinal Engineering), Dr. Jeffrey Cipolla, Dr. Abilash Nair, Mr. Daniel Kadyrov, Dr. Juan Londono, & Mr. Addison Martin (Thornton Tomasetti)</td><td rowspan="4">**Manufacturing Process Effects on the Performance of Fasteners in Service**

10:30am—11:15am
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 otherwise 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.</td></tr>
<tr><td>10:55</td><td>**Gaussian Process Regression Model as an Estimator of Shock Qualification Risk in Shipboard Systems and Components (AB 67)**
Mr. Maxwell Jenquin & Dr. Christopher Earls (Cornell University), Dr. Jeffrey Cipolla (Weidlinger Technology Ventures LLC)</td></tr>
<tr><td>11:20</td><td>**Trending of Sounding Rocket Flight Vibration with Reynold's Number (AB 68)**
Dr. Ricky Wayne Stanfield (Northrop Grumman Technology Services, Inc.)</td></tr>
<tr><td>11:45</td><td></td></tr>
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1:00-2:30	**S&V Technical Advisory Group Meeting** — **Meeting Room: Pegasus A/B** The annual meeting of the members of the SAVE Technical Advisory Group (TAG) will convene to review the 89th S&V Symposium and discuss plans for 2019.

SYMPOSIUM EXHIBITORS

Event Sponsor

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Applied Physical Sciences

ITT Enidine

National Technical Systems[1]

Northrop Grumman

NVT Group (Lansmont, TEAM, Data Physics)

PCB Piezotronics[1,2]

Spectral Dynamics[2,3]

Additional Exhibiting Organizations

Advanced Test Equipment Rentals
Altair Engineering
Boeing
Brüel & Kjaer
Crystal Instruments
Dayton T. Brown
DEWESOFT
Dytran Instruments
E-Labs[2]
Hi-Techniques
IMV Corporation
Instrumented Sensor Technology
iX Cameras
Kistler Instruments
m+p international
Mechanical Solutions
Meggitt
Photron
Polytec
Precision Filters
Shock Tech
Siemens
SPEKTRA
Taylor Devices
Thermotron
Unholtz-Dickie Corp.
Vibration Research Corporation
Vibrodynamics, SOCITEC Group
Vision Research
Xcitex

[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*

SYMPOSIUM EXHIBITORS

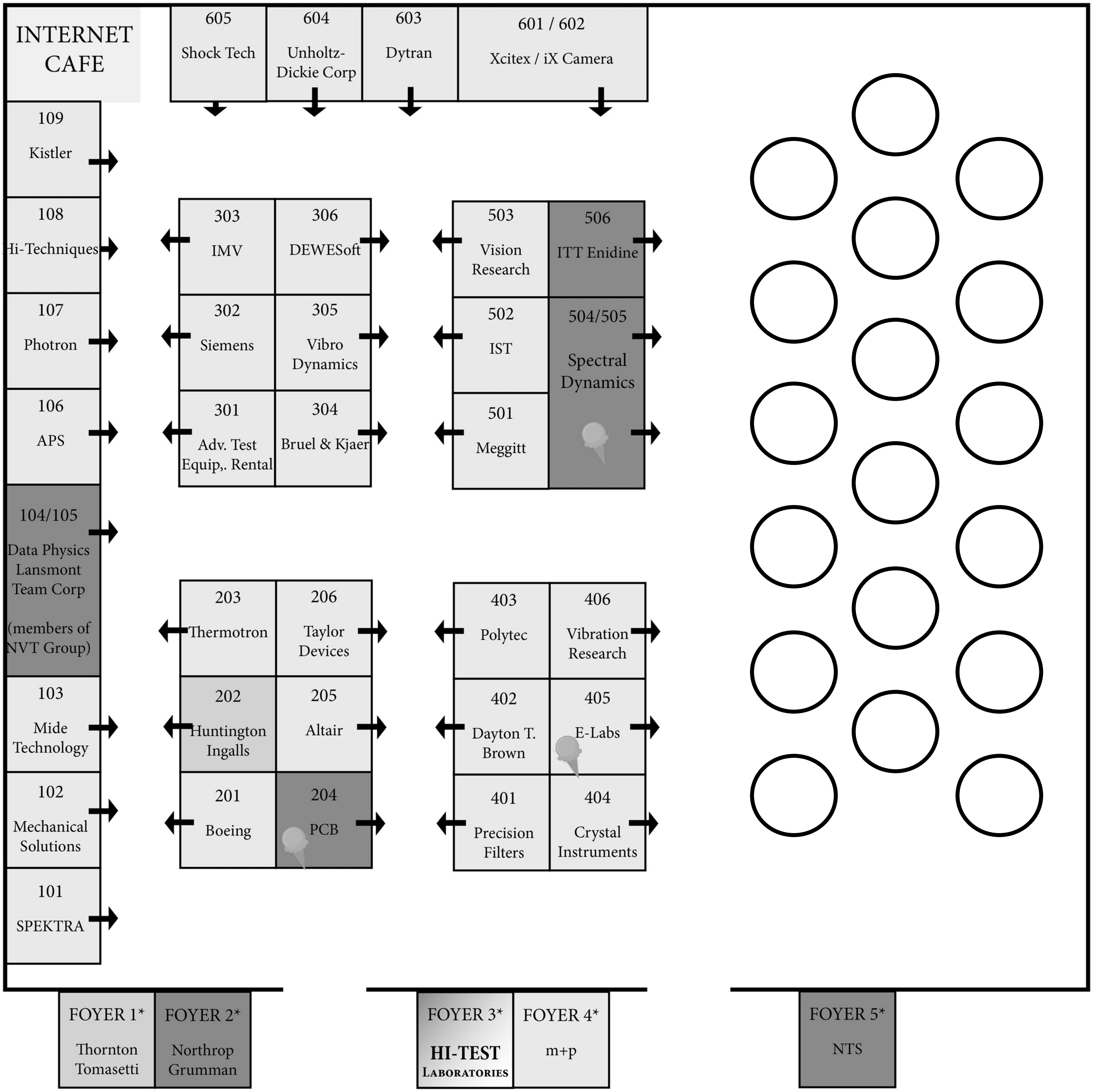


EXHIBIT HALL SCHEDULE

Monday, November 5, 2018

Exhibit Setup	12:00pm - 6:00pm
Reception (in Exhibit Hall)	6:30pm - 8:30pm

Tuesday, November 6, 2018

Exhibit Area Open	7:00am - 5:00pm
Breakfast (in/near Exhibit Hall)	7:00am - 8:30am
Luncheon (in Exhibit Hall)	11:00am - 1:00pm
Ice Cream Social	3:00pm - 3:40pm

Wednesday, November 7, 2018

Exhibit Area Open	9:00am - 4:00pm
Morning Break (in Exh. Hall)	10:00am - 10:30am
Exhibitors' Luncheon	12:00am - 1:30pm
Break w/ Passport Program Raffle	3:15pm - 4:00pm
Exhibitor Dismantle*	4:00pm - 6:00pm

**Exhibitors can also dismantle on Thursday (11/8/18) until noon, if desired, or if additional time is needed.*

EXHIBITOR INFORMATION

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.

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.

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.

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

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

EXHIBITOR INFORMATION

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.

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.

Since it was founded in 1957, **IMV Corporation** is a world's leading supplier of high reliability vibration test systems in Japan offering single-axis, sequential and simultaneous (up to 6 degree of freedom) multi-axis vibration test systems, vibration diagnostic instruments and engineering consultancy services with physical location in Anaheim, CA, USA.

EXHIBITOR INFORMATION

IST offers a full line of 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.

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

iX Cameras designs and manufactures a wide range of high-end, high-speed digital cameras. The revolutionary i-SPEED 726 features a 3 megapixel sensor capable of recording 8,500 full frames/second, 1080p HD images at 12,500 frames/second, 720p HD images at 23,000 frames/second, and top speeds in excess of one million frames/second.

The Kistler Group is the global market leader in dynamic measurement technology. Our technology measures pressure, force, acceleration and torque. Our instruments are used to measure and analyze physical processes, control industrial processes and optimize products. Our product offering is used in engine development and monitoring, vehicle technology, plastics processing and metal machining, as well as assembly and testing technology. We develop and supply sensors, electronics, and software, backed up by a full range of services. In short: everything from one single source.

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

MSI offers a range of engineering services in support of various industries and equipment for organizations throughout the United States and around the world. We specialize in field vibration testing and troubleshooting of critical service rotating and reciprocating machinery; turnkey machinery design and development; computer simulation and analysis including computational fluid dynamics (CFD) and finite element analysis (FEA); high-speed video and 3D spatial tracking; and much more. MSI is known for its outstanding track record in solving some of the world's most difficult technical problems.

Meggitt Sensing Systems is a leading supplier of high-performance sensing and monitoring systems for physical parameter measurements in extreme environments. Meggitt's 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.

EXHIBITOR INFORMATION

Midé Technology Corporation is a leading provider of advanced engineering products and services. Midé is committed to providing customers with high-quality deliverables that are on-time, on budget, and meet their expectations through the use of a quality management system focused on continual improvement. Midé uses industry best practices in both execution and cost effectiveness. Portable, powerful, & easy-to-use, Mide's range of compact stand-alone shock and vibration accelerometer data loggers enable quick, easy, accurate, and cost-effective shock and vibration measurement in almost any environment.

Northrop Grumman Innovation Systems designs, builds and delivers space, defense and aviation-related systems to customers around the world. Our main products include launch vehicles and related propulsion systems; missile products, subsystems and defense electronics; precision weapons, armament systems and ammunition; satellites and associated space components and services; and advanced aerospace structures

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

NVT Group (Data Physics, Lansmont, and Team) have proven expertise in measuring, simulating, and analyzing the effects of vibration, noise, shock, and other environmental variables for our industry customers. Our combined capabilities make us a leading global provider of test and measurement solutions.

PCB® manufactures precision sensors and sensor accessory products. Our product lines include sensors for the measurement of acceleration, acoustics, force, load, pressure, shock, strain, torque, and vibration. Our products are the first choice of engineers and scientists at leading businesses, research institutions, and independent laboratories around the world. We offer unmatched customer service, a global distribution network, 24-hour SensorlineSM, and a Lifetime Warranty to deliver Total Customer Satisfaction.

Photron was founded in 1974 to provide manufacturing, sales, and service for state-of-the-art professional film and video equipment used to capture thousands of high resolution images for playback and analysis. Photron has continually expanded their product line to aid in the advancement of photo optics and electronic technologies furthering research and development in the areas of digital imaging and slow motion analysis. Markets include microfluidics, military testing, aerospace engineering, automotive, broadcast, particle image velocimetry (PIV), digital image correlation (DIC), ballistics testing, and more.

Polytec is the market leader for non-contact, laser based vibration and velocity measurement instrumentation. Our innovative solutions allow customers to maintain their own technical leadership across many fields. Polytec has recently celebrated its 50th anniversary, earning an unrivalled reputation for technical support and offering an unmatched range of laser vibrometer solutions.

EXHIBITOR INFORMATION

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 LMS – 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 specializes in testing for Acoustics, Structural Dynamics, Rotating Machinery, Durability/Fatigue and Vibration Control and are the market leader for high-end data acquisition and test results visualization and post processing.

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.

SPEKTRA is the leading provider of Calibration and Test systems for the measurement of Shock, Vibration and Acoustics. The company develops, manufactures, sells and supports a broad range of test and calibration systems, from very low frequency to very high frequency systems, low g to high g shock, and both Primary (i.e. laser vibrometer) and Secondary measurement systems. These are fully automated systems for the test and recalibration of shock, vibration and motion transducers used in aerospace applications, in automotive crash testing, for seismic measurements, etc. SPEKTRA also offers calibration and test services as well as engineering services for the development of customized test solutions.

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

For more than 55 years, **Thermotron** has provided quality environmental test equipment. We've worked to establish a trusted reputation among our peers, and when people hear the name Thermotron, they have confidence in the testing of their own product. We've been building our name since 1962; now it's your turn. Quality. Trust. Confidence. Build yours with a Thermotron.

EXHIBITOR INFORMATION

Thornton Tomasetti provides engineering design, investigation and analysis services to clients worldwide on projects of every size and complexity. We have more than 60 years of experience in research, testing and software development for the U.S. Navy and Department of Defense in the fields of blast, underwater shock, impact and vibration effects.

Over the past 55+ years, **Unholtz-Dickie** has engineered vibration test solutions for thousands of customers in hundreds of industries in 45 countries. We are a unique source for vibration test systems because of our complete product offering and understanding of the total test system. Products include advanced high-efficiency air-cooled power amplifiers, high-performance electrodynamic shakers, long-stroke thrusters, integrated slip table assemblies for 3-axis testing, support instrumentation for measuring vibration environments, and Windows-based digital vibration control and analysis workstations. Together, these products, well regarded for high performance and reliability, provide complete and reliable test solutions for the vibration test industry.

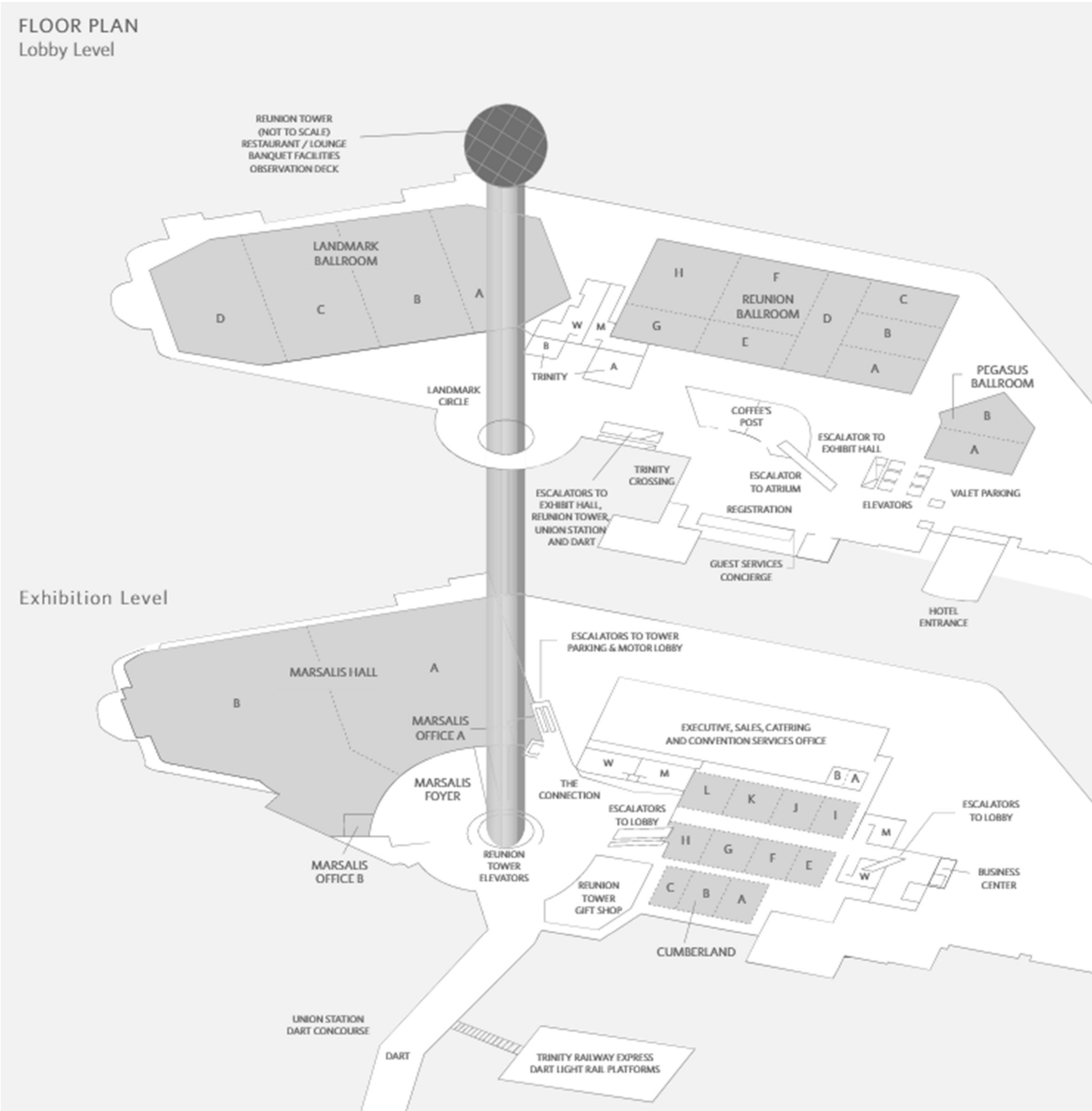
Vibration Research offers testing products, software and support with unrivaled value. Our VR9500 Controller and ObserVR1000 DAQ/Analyzer, along with VibrationVIEW and ObserVIEW software, include patented innovations used by world-wide testing labs and engineers. iDOF™, FDS, FDR, and Kurtosion® are some of VR's applications that ensure accurate, fast vibration testing.

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

Vision Research designs and manufactures high-speed digital imaging systems that are used in all military, industry, academic and entertainment sectors. Marketed under the Phantom® brand, our cameras allow you to analyze physical phenomena when it's too fast to see, and too important not to™. Please visit www.phantomhighspeed.com for additional information.

Xcitex is an innovator in the industries of motion analysis and video-based motion capture. ProAnalyst® is the world's leading software for extracting ("tracking"), analyzing, and presenting motion from pre-recorded video. MiDAS DA software combines and synchronizes data from a variety of sensors with your high-speed video.

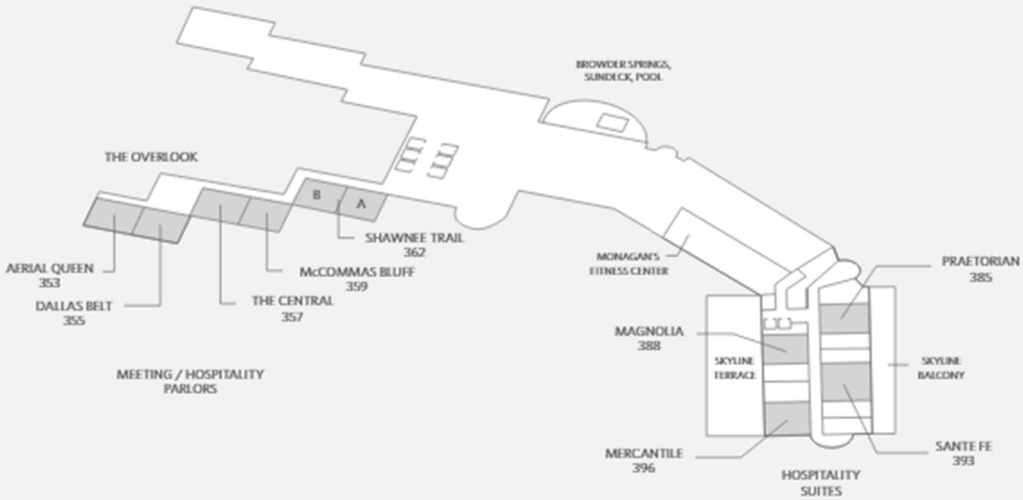
HYATT REGENCY DALLAS MEETING SPACE



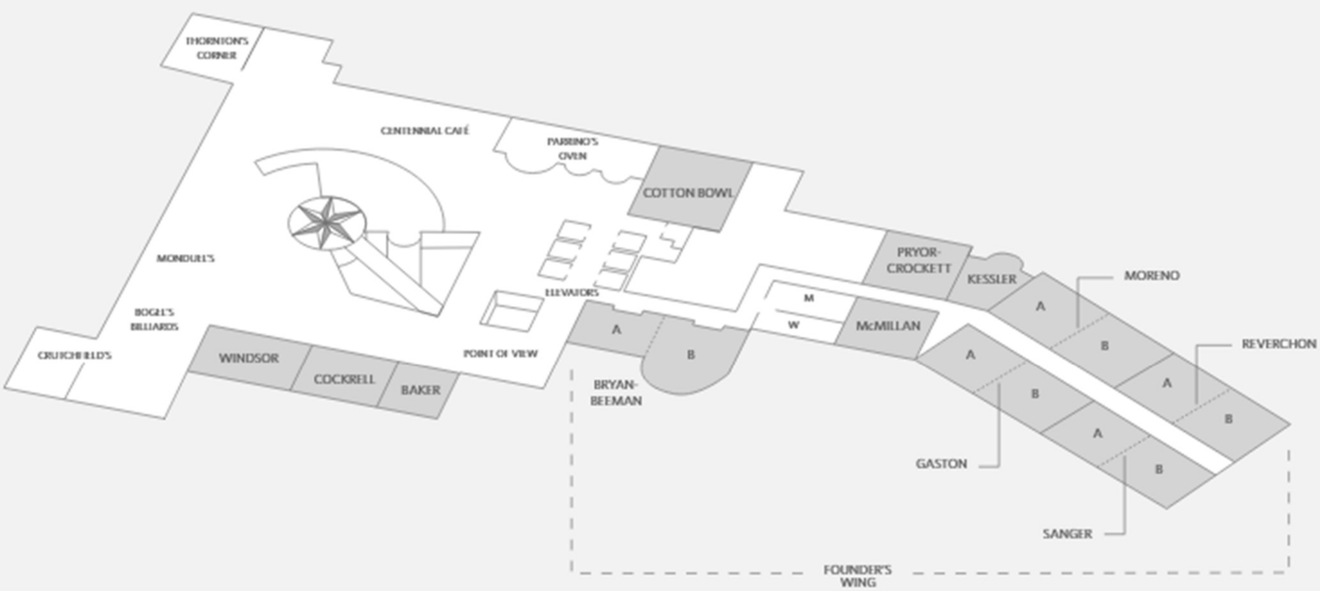
HYATT REGENCY DALLAS MEETING SPACE (cont.)

FLOOR PLAN

Third Level



Atrium Level (Second Floor)



SAVE
SHOCK & VIBRATION EXCHANGE

ABSTRACTS

FROM THE

89TH SHOCK & VIBRATION SYMPOSIUM
NOVEMBER 4 – 8, 2018
DALLAS, TEXAS

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SESSION 1: SHOCK, VIBRATION, & ACOUSTIC TESTING

DESIGN OF A RESONANT PLATE SHOCK TEST FOR SIMULTANEOUS MULTI-AXIS EXCITATION
Mr. Ron Hopkins, Sandia National Laboratories
Dr. Carl Sisemore, Sandia National Laboratories

Resonant plate testing is an accepted method for simulating high-frequency pyroshock type environments at the component and subassembly level. The typical test approach is to excite the unit under test three times, once in each of three mutually orthogonal axes. Exciting the same unit three time, albeit in orthogonal axes, risks over-exposing the unit to shock energy. This is particularly apparent at the higher frequency regimes due to the presence of cross-axis coupling. A concept was proposed to intentionally amplify this cross-axis coupling to develop a multi-axis component shock test. This paper presents the results of finite element modeling used to develop a multi-axis resonant plate configuration as well as experimental results demonstrating multi-axis shock excitation. The paper will discuss the advantages and drawbacks of this novel testing approach.

SHOCK AND VIBRATION QUALIFICATION OF A TRANSPARENT ARMOR WINDOW BASED ON MIL-S-901D AND MIL-STD-167-1A TEST METHODS
Mr. Leonardo Torres, Karagozian & Case
Mr. Daniel Coleman, Karagozian & Case
Mr. Joseph Abraham, Karagozian & Case

Combat critical systems to be installed on U.S. Navy ships must be designed to withstand shock pulses induced by underwater explosions as well as vibration environments excited by surrounding machinery. Current Navy specifications stipulate that system performance during shock and environmental vibration be qualified by means of MIL-S-901D and MIL-STD-167-1A, respectively. Literature documentation for carrying out these test methods on components such as electronics systems or doors is available; however, examples of applying these methods towards windows is less prevalent. Window systems are of particular interest in a shock problem as they support a brittle piece of transparency that's highly susceptible to impact fractures. This paper presents how shock and vibration qualification was accomplished for a window system. Additionally, it provides an example of how a medium-weight shock test article which extends beyond width of the standard Figure 15 fixture, as defined in MIL-S-901D, may be installed without the use of finite-element analysis to verify that adequate frequencies will be achieved.

The study also documents the specific acceleration histories seen during the various shock test blows. Instrumentation was provided at three locations on the test article to observe the differences in acceleration at the center of Figure 15 test fixture, the center of the interface plate designed to simulate the ship hull, and at the center of the window's transparency. Analysis has been provided to show the variations in power spectral density of the signals collected at each location as well as the response spectra computed for each signal.

A Better Approach to Deriving Shock Environments and Testing

Dr. Pat Grosserode, Northrop Grumman Innovation Systems

Deriving shock test levels for aerospace components is challenging. Flight and ground test data is limited. The correct location and effects of component mounting are usually not accounted for in the test levels. Shock test levels, in most cases, are defined the same in the component three orthogonal axes. This makes shock testing difficult, without a significant over-test in one or more axes. There is no standard test method for shock that addresses these issues.

The purpose of this paper is to present an alternative approach to deriving shock test levels and testing. The approach uses finite element analysis (FEA) of the flight structure to assess the component response to shock. A test fixture is designed and analyzed using FEA to subject the component to a flight like shock level with margin. The test is straight forward using a small amount of ordnance. The test fixture is light weight similar to the flight structure. Measuring the shock is not necessary, but recording the accelerometer data is desirable. The data can be used to assess the accuracy of the FEA.

It is hoped this approach is adopted by the aerospace community and eliminates unnecessary failures during shock testing.

Shock Strains Induced by Flight and Test

Mr. Scott Rowland, Northrop Grumman Innovation Systems

A component failing in flight is rare, but failing during a qualification test is common. Although failure of a component during qualification testing can be tied to a number of things, including conservatism in the derived level and over-test, how much of this is a result of the difference between the test method and actual flight configuration of the component?

An investigation was performed to understand the stresses/strains, in a component with three printed wiring boards (PWB). PWB acceleration and strains were measure during five common shock tests including shaker shock, beam shock, and several pyro-shock test methods. The measured strains, from these tests, were compared to the strains produced during a flight-like separation ground test.

The purpose of this paper is to present a description of the testing and summary of results. Test results will also be compared to finite element analysis (FEA). The paper presents justification, using measured data, for an alternate test approach. One of the goals is to assess how effective the use of the shock response spectrum (SRS) is predicting damage of flight components to shock.

Applications of Digital Adaptive Control to High Level Acoustic Testing

Dr. Marcos Underwood, Tu'tuli Enterprises

Recent developments in high-level acoustics testing have included Direct Field Acoustic Testing, DFAT, and improvements to traditional Reverberant Chamber High Intensity Acoustic Testing. Both of these approaches have greatly benefited from the introduction of narrowband as well as Multiple Input/ Multiple Output, MIMO, control techniques. This paper will discuss some of the advantages of using modern MIMO digital adaptive control technology in DFAT and reverberant testing and offer some approaches to these testing techniques.

MIMO DFAT control uses multiple independent drive signals, which are respectively sent to multiple acoustic exciters or loudspeaker stack subsystems via their amplifiers and associated signal conditioning, to control the acoustic field's response nth fractional octave spectra, as well as its relative phase and coherence, that's obtained from multiple control microphones placed at points within the acoustic field created by the acoustic excitation system resulting from the vector of multiple drive signals. Control is performed in the frequency domain by determining the control-response Spectral Density Matrix (SDM) from the vector of microphone responses using FFT processing, so that the respective microphone's PSD and sound pressure level (SPL) spectra match the corresponding diagonal elements of the test specified control-reference SDM, which represents the desired acoustic field with their specified PSD magnitudes for each microphone location as well as the relative phase and coherence between each pair of control microphone responses.

To use MIMO DFAT control, the user can input SPLs for each nth octave frequency band, where 1/3 octave is typical, and phase and coherence specifications with tolerance bands for each such narrow-band spectrum frequency, within the control frequency range. The control system will use the specified SDM spectra to generate independent drives, which are obtained using optimal adaptive control methods, to produce a complying acoustic environment at each control microphone, within the least mean-square error sense, using minimum drive energy, that's consistent with the physical limitations that may be associated with the measurement and excitation system; and the overall test facility.

In effect, this adaptive method controls the acoustic response levels of each control microphone, as well as their relative coherence and phase with respect to each other, to meet its individual requirement based on the inputs it receives from all of the independent drive signals, accounting for unavoidable nonlinearities, as a result of the modern adaptive optimal control approach it uses. The result can be a nearly incoherent acoustic field at the higher frequencies, with minimum variation (in the least mean-square error sense) between control microphones, except as may be limited by available power, speaker and microphone placements, and other such physical factors, for which the control methodology also accounts.

SESSION 2: UNDEX TEST APPLICATIONS

MULTI-CYCLE UNDEX BUBBLE DYNAMICS AND LOADING: OVERVIEW OF TEST PROGRAM

Mr. Gregory Harris, NSWC Indian Head

A series of underwater explosion (UNDEX) tests was conducted to gather data on bubble dynamics and loading from multiple bubble pulsations. The test parameters covered ranges of scaled depths representative of shallow and deep UNDEX events. Of particular interest were quantifying losses in bubble energy with each pulsation cycle, and the loading from each successive bubble pulse. This data will be used to support the implementation of numerical energy loss procedures in the DYSMAS code to accurately model multiple bubble pulsations. This talk will present representative data from the test program.

Multi-Cycle UNDEX Bubble Dynamics and Loading: DYSMAS Enhancements

Dr. Georges Chahine, Dynaflow, Inc.
Dr. Tom McGrath, NSWC Indian Head

It is well known that hydrocodes and most other UNDEX modeling tools do not accurately capture the energy losses for multiple bubble pulsations. This limitation has implications for analyses that require accurate loading simulations for later bubble pulsations. A generalized numerical procedure has been developed to remove energy during the simulation that matches the empirical data for the later pulsations. This talk will describe the approach taken, and its implementation into DYSMAS.

Multi-Cycle UNDEX Bubble Dynamics and Loading: DYSMAS Validation Examples

Mr. Chao-Tsung Hsiao, Dynaflow, Inc.

The new DYSMAS capability for modeling multi-cycle bubble dynamics and loading was used to simulate the results from the recent UNDEX bubble test series. This talk will show representative results using the new DYSMAS capability.

Overview of Hydrobulge Test Programs for Hydrocode Verification and Validation

Mr. Gregory Harris, NSWC Indian Head

There has been renewed recent interest in using precision experiments for verifying and validating modeling and simulation tools used for underwater explosion (UNDEX) phenomena. Beginning in the late 1990's, the DYSMAS program conducted a variety of precision experiments using aluminum tubes. These experiments were known as hydrobulge tests. A brief overview of the five different hydrobulge configurations will be presented.

Characterization of Bulk Charge Underwater Explosion Performance

Mr. Kent Rye, NSWC Carderock Divison
Mr. Gregory Harris, NSWC Indian Head

This talk provides an overview of the process used to characterize the output of bulk charge explosives fired under water. The compositions of explosives used for naval weapon applications will be summarized, and are grouped by application. The underwater explosion (UNDEX) testing procedures will be described to illustrate how the data are collected. The data analysis procedures are briefly detailed, which lead to the empirical similitude coefficients that characterize the underwater explosion performance for both UNDEX shock wave and bubble effects. The results are a reflection of 60+ years of consistent, precision measurements using specialized pressure gages, data acquisition hardware, and data analysis software developed by the testing group that now resides at the Naval Surface Warfare Center, Carderock Division.

SESSION 3: PACKAGING OF HIGH G ELECTRONICS: PERSPECTIVE OF POTTING AND ITS ALTERNATIVES

THE PREDICTION OF THE IMPACT BEHAVIOR OF 3-D PRINTED SUPPORTS AS AN ALTERNATIVE ELECTRONICS PACKAGING METHOD

Dr. Catherine Florio, US Army ARDEC
Mr. Lyonel Reinhardt, US Army ARDEC
Dr. Jennifer Cordes, US Army ARDEC

While the use of polymer epoxies is the most common means for protecting sensitive electronics against damage under the extreme dynamic loads experienced by armament systems, these epoxies are often associated with reduced reliability resulting from undesirable responses to thermal fluctuations and difficulty in establishing consist fabrication methods. Additive manufacturing has made the creation of many complex structures more feasible and can promote the creation of support structures that surround the electronic components of a printed circuit board. Therefore, in seeking more reliable methods of protecting the electronics against highly dynamic mechanical environments, additive manufactured structural supports may provide a feasible alternative to epoxy-based potting materials. The use of additive manufactured structural supports as part of an electronics packaging method that does not involve potting is explored in this work through computational modeling. The effects of the material properties of the support on the behavior of the enclosed circuit board is investigated along with the sensitivity of the results to the material models that are used to predict the behavior of the circuit board and the attached components. Design features of these structural supports that can enhance the protection of the circuit board will be identified. Comparisons are made to experimental results, and the range of mechanical loading environments where this alterative packaging method may be beneficial is estimated.

EXPERIMENTAL TECHNIQUES TO CHARACTERIZE POTTING MATERIALS UNDER CONFINEMENT AT HIGH STRAIN RATE

Mr. Brett Sanborn, Sandia National Laboratories
Mr. Bo Song, Sandia National Laboratories
Dr. Aisha Haynes, US Army ARDEC
Mr. Christopher Macrae, US Army ARDEC

Potting or encapsulation of electronics is a process in which an assembly is filled with an insulating material to protect against shock and vibration loads. Modeling and simulation are routinely used to improve design and assess survivability of encapsulated systems subjected to impact events. Since potting materials are typically subjected to triaxial confinement under impact, obtaining confined dynamic material properties is critical for accurate simulation. Although the well-established Kolsky compression bar technique can be used to obtain high strain rate material properties, no studies have been done exploring the confined high rate behavior of potting materials, likely due to the significant challenges of pulse shaping and quantitatively obtaining the confining pressure to the specimen. In this study, novel pulse shaping methods were used to generate constant strain rate deformation of passively-confined Epon 828. A new instrumented confining sleeve was used to obtain force generated by the potting material under dynamic compression, which can give new insight in computational simulations.

Dynamic Confinement Response of Unfilled and GMB-Filled Epon 828 and Temperature Effect

Dr. Aisha Haynes, US Army ARDEC
Mr. Christopher Macrae, US Army ARDEC
Mr. Bo Song, Sandia National Laboratories
Mr. Brett Sanborn, Sandia National Laboratories

Sensitive electronics need to be carefully designed and packaged to survive and operate under normal and abnormal thermomechanical environments. As a common practice, such electronic components are usually potted in resins to prevent failure under high-g impact loading in industrial and defense applications. This necessitates appropriate selection and/or optimization of potting material and process followed with thorough evaluation/assessment through numerical simulation. High-fidelity material property data are thus crucial for constitutive model development and calibration of the potting materials in the process of numerical simulation. In this study, dynamic compressive stress-strain response of two passively confined potting materials – unfilled Epon 828 and glass-micro-balloon (GMB) filled Epon 828 – were experimentally characterized with Kolsky compression bar technique at different strain rates and temperatures. The history of confining pressure to the specimens during dynamic compression was directly measured and synchronized with the compressive stress-strain curve, providing a better understanding of dynamic confinement response of the unfilled and GMB-filled Epon 828 under impact loading. Strain rate and temperature effects on the dynamic confinement response of the two materials were also determined.

Optimized Potting Solutions for High G Electronics: A Case Study

Dr. Aisha Haynes, US Army ARDEC
Dr. Catherine Florio, US Army ARDEC
Dr. Jennifer Cordes, US Army ARDEC
Ms. Melissa Jablonski, US Army ARDEC

The DoD requires electronics packages maintain reliability in high G shock and dynamic environments. The current state of the art in packaging electronics for shock, vibration, and dynamic loads involves encapsulation of the electronics components using a polymer or polymer composite potting compound. The structural reliability of these potted electronics is impacted by the mechanical response of the potting material under varying thermomechanical loading conditions. Changes in potting behavior with temperature, strain rate, and pressure may induce undesirable stresses on sensitive components. A statistical approach to identifying key performance parameters for potting that influence survivability has been employed to aid in deriving an optimal potting solution for a simple electronics package subjected to gun launch. The framework developed in this study couples Uncertainty Quantification with Finite Element Methods to identify the relationship between potting behavior and structural survivability of several electronics components and the optimal potting properties which minimize risks of structural failure during gun launch.

SESSION 4: AIR & BURIED BLAST

CUMULATIVE DAMAGE ASSESSMENT MODEL FOR RC BUNKERS IN MULTI-STRIKE SCENARIOS

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

Lethality assessment and vulnerability analysis of above ground and buried reinforced concrete hard targets is a standard weaponeering problem. The problem is complex since damage can occur from close-in coupled shock effects, large gas pressures from confinement, and from primary fragment impacts. Important damage consequence metrics include localized spall (tensile failure induced by reflected stress waves), and the development of local or disseminated venting and breaching. Additional metrics which are often important in targeting analyses are secondary debris characteristics and venting times. Capturing this large range of damage phenomenology in a reduced parameter space is difficult, but existing correlations based upon a large number of tests over the years adequately address the single-strike problem.

The need for models which can predict the onset of spall, breach, and other response measures in the case of multiple strikes is becoming acute for scenarios that include hardened targets and the use of smaller weapons. We describe the results of an effort to develop an analyst modeling framework for this class of problems based upon the results of a large number of carefully validated high-fidelity physics-based multi-strike calculations. This work builds on previous efforts in which material damage is used as the natural quantity for capturing the phenomenology of damage accumulation from one strike to the next, and a Markov Chain formalism is used as the natural approach for modeling the accumulation of this damage in a general way. Generalized correlations between material damage and structural displacement result from this approach and provide a means for validation.

MODELING OF SECONDARY DEBRIS PHENOMENOLOGY WITH A RADIATION HEAT TRANSFER ANALOGY

Dr. George Lloyd, ACTA Inc.
Dr. Wije Wathugala, ACTA, Inc.
Dr. Li Cao, ACTA, Inc.
Mr. Joe Magallanes, Karagozian & Case
Mr. Joseph Abraham, Karagozian & Case
Mr. Randy Anderson, Cobia Research

The cascading process of airblast through failing surfaces and more generally the progressive breakup of a multi-room structure due to internal or external blast creates vast amounts of secondary debris of a heterogeneous nature. The effects of this debris can be significant. The phenomenology of the overall process is well-understood; it may be described through the three sequential steps of secondary debris generation, secondary debris propagation, and secondary debris effects that lead to damage and additional loading on downstream building components and infrastructure. Nonetheless, developing a unified approach for modeling these three steps has been stymied by a number of fundamental issues.

We describe a new approach to the problem which is based on the observation that conceptually similar processes pertain to those which occur in radiation heat transfer. Namely, the radiosity flux or total

energy emitted from a surface is propagated into solid angles and arrives at receptors—surfaces which can further absorb, transmit, or reflect the transported energy. It is useful that a well-established methodology exists for performing engineering calculations for radiation heat transfer problems in arbitrarily complex enclosures. Although many complications ensue when photons are replaced by non-zero rest mass carriers, elements of the classical engineering approach for treating radiation heat transfer can be usefully extended to unify modeling of secondary debris phenomenology. Such an approach has been developed, implemented, and demonstrated for a number of different types of single and multi-story urban buildings.

PREDICTING SECONDARY DEBRIS AND BLAST FROM BURIED EXPLOSIONS USING NUMERICAL SIMULATIONS

Dr. Wije Wathugala, ACTA, Inc
Dr. Wenshui Gan, ACTA, Inc
Mr. Hugh Morgan, ACTA, Inc

Understanding how to model explosions in soil is important in many military and civilian applications such as in predicting the consequences of mines/IEDs/munitions buried in soil and excavations using explosives in the mining industry. In general, rapidly expanding explosion 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 thrown up in the air due to a shallow underground explosion. We have been improving numerical methods for this application and performing full scale experiments to validate them for several years. We had presented early results in previous SAVE conferences. Here, we will update latest developments from this project. In this paper we present details of numerical simulation of buried munitions in soil using CartaBlanca. Those results are then compared to 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.

RESEARCH INTO SECONDARY DEBRIS AND ITS POTENTIALLY DAMAGING EFFECTS ON PERSONNEL, INFRASTRUCTURE, AND EQUIPMENT

Mr. Ernie Staubs, AFRL

The harsh environments resulting from a detonation can injure inhabitants, infrastructure, and disrupt the operation of critical equipment in a target. Tools currently used to predict functional degradation and component damage often under predict the results. This can result in unnecessary sorties being conducted to insure a desired level of damage in a target, placing aircrews and the local population at additional risk. The Department of Defense conducts weapon effects experiments attempting to duplicate those harsh environments. The effect of these environments on personnel, infrastructure, and critical electronic equipment is not fully understood, so it isn't well modeled. Experiments were conducted investigating the response of urban structures to weapon detonations. In addition to the primary structural response objectives, the test team conducted research on the secondary debris generated by the detonation. The study is two-fold. The goal is to provide verification and validation data for fast running models that predict the generation of secondary debris and to determine the ability of this debris to cause additional damage or casualties.

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

Dr. John Reinecke, Council for Scientific and Industrial Research
Mr. Mzwandile Mokalane, Council for Scientific and Industrial Research
Ms. Rayeesa Ahmed, Council for Scientific and Industrial Research
Dr. Ian Horsfall, Cranfield Defence, Cranfield University

This paper presents the application of target force-time impulse 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 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) and 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, equivalence can be drawn between differing landmine protection threat assessments.

VENDOR SESSION A:

COMPANY OVERVIEW – CRYSTAL INSTRUMENTS

Mr. Ali Farrokhian, Crystal Instruments

No abstract available.

MEASUREMENT INNOVATIONS

Mr. Dave Carter, DEWESOFT
Mr. Steve Ross, DEWESOFT

From chart recorders to PC based data Acquisition Progression of sample speeds and types of measurements.

MECHANICALLY & ELECTRICALLY FILTERED TRIAXIAL ACCELEROMETER

Mr. Kevin Westora, Dytran

The Dytran series 3603AXT is a miniature, mechanically and electrically filtered triaxial accelerometer that uses the latest in planar shear technology coupled with 2-wire internal IEPE electronics. The mechanically & electrically filtered design allows the sensors to operate in environments with high frequency excitation without causing amplifier saturation and signal over-range. The sense elements are internally isolated from the outer case and are enclosed by a Faraday shield for good noise immunity. The accelerometers contains 3 sensing elements suspended inside the housing with a set of supports designed to stop high frequency propagation into the element structure to prevent “Zero-Shift” phenomenon. The 3603AXT series can be used in applications when high “out of band” energy exists causing saturation of the sensor’s internal IEPE amplifier or when measuring after a high g event. These applications include cylinder head vibration testing in automotive NVH testing, metal to metal impact high frequency testing applications, simulated far field pyrotechnic shock, and package drop testing among others.

KEY THINGS TO CONSIDER WHEN EVALUATING A HIGH-SPEED CAMERA

Mr. Michael Quzor (iX Cameras)

No abstract available.

IMV’S SMART ECO-AMPLIFIERS PROVIDE AN AUTOMATIC ENERGY-SAVING FUNCTION FOR REDUCED OPERATIONAL COSTS ACROSS ALL FORCE RANGES

Mr. Andy Cogbill, IMV America

No abstract available.

SESSION 5: SHOCK & VIBRATION ISOLATION I

VISION FOR AN ADJUSTABLE SHOCK MOUNT

Mr. John Stenard, STEN-TEK

An Adjustable Shock Mounting (ASM) is conceived to help reduce Total Ownership Cost (TOC) of Naval ships by up to $25M per ship, by making electronics upgrades on warships as straightforward and rapid as in the commercial sector. Commercial-sector IT upgrades are typically made over a weekend, with virtually no disruption, albeit often due to significant pre-planning by the IT team. For IT upgrades on warships, the hardware work scope is up to twenty times greater than in the commercial sector, as it requires engineering to integrate the COTS electronics into shock cabinets, testing of the integrated cabinets, the cost of the shock-qualified cabinets themselves, and the shipboard work of replacing the shock cabinets full of electronics, hotwork for access cuts and foundation replacements, and modifications to supporting ships systems, in addition to replacing the electronics. This requires scores of shipyard engineers and technicians and disrupts the ship’s schedule for several months. Navies world-wide have been designing their ships modularly to facilitate swapping large blocks of critical equipment, yet modularity alone will not eliminate the need for an industrial availability to replace the numerous cabinets, nor eliminate the cost of the cabinets themselves, nor the cost to integrate the payload equipment into each cabinet, nor the need for shock testing per MIL-DTL-901E.

With ASM the shock cabinet could be adjusted to new payloads (i.e. - mass and mass distribution of the new payload), such that only the electronics units themselves would need to be replaced, as in the commercial sector. The approach hinges on developing a high-performance adjustable shock mount that reliably attenuates MIL-DTL-901E to only 5g's, a level corresponding to ANSI/ASA S2.62-2009 "Shock Test Requirements for Equipment in a Rugged Shock Environment", which is an industry-standard baseline for virtually all COTS electronics manufacturers.

ASM is envisioned to enable savings of up to $25M TOC per surface warship, due to reduced work scope for life cycle electronics upgrades. ASM will facilitate Rapid Capability Insertion (RCI), as new equipment can be installed pier-side rather than at an industrial facility. Another benefit is the potential to shorten each ship's industrial down-time, so that more of the ship's service life is available for conducting missions. The vision for ASM includes a scalability feature to enable implementation of ASM technology to protect single components the size of a toaster over, through single and multiple 19" cabinets, to entire shipboard platforms and compartments.

QUEST FOR AN ADJUSTABLE SHOCK MOUNT

Mr. John Stenard, STEN-TEK

This paper examines the challenges of and insights gained from the endeavor to develop an adjustable shock mounting technology, in order to save Total Ownership Cost (TOC), facilitate Rapid Capavbility Insertion (RCI), and reduce warship industrial down-time. The key technical challenge is to develop a robust shock and vibration attenuation method that will reliably attenuate the MIL-DTL-901E shock disturbance to 5g's for a range of payload masses and mass distributions. The technical challenge is to simultaneously handle both shock and resonance in a single mounting schema.

Promising, preliminary results of testing on a six degree-of-freedom (6DOF) Technology Demonstrator (TD) prototype on the Deck Simulating Shock Machine (DSSM) are presented in which attenuation to 5g's was attained for a single payload mass. The paper outlines planned refinements to the Adjustable Non-Resonant Interface (ANRI) technology in the continuing quest to demonstrate 5g attenuation on the Floating Shock Platform (FSP).

CONSIDERATIONS FOR OPTIMIZING STRUCTURE BORNE NOISE REDUCTION IN THE DESIGN OF AN ELASTOMERIC SHOCK MOUNT

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

Navy ships have a significant amount of equipment that is sensitive to various high impact shock events and vibration environments. To ensure all systems perform in day to day service and in battle, each piece of equipment must be qualified to relevant military specifications. Through the years, significant work has been performed to design shock and vibration isolation systems to ensure equipment performance is not compromised. As the next generation of naval vessels are designed, increased significance is given to acoustic performance of the shock and vibration mounts. Mounts originally designed to protect equipment from shock and vibration are now being tasked with efficiently reducing structure borne noise in an effort to improve the ship's underwater radiated noise signature and improve working conditions for naval warfighters. The challenge is that the design considerations for the protection of equipment from shock events do not always align with those for the reduction of structure borne noise. This paper will discuss the design and materials parameters that affect both shock attenuation and structure borne noise reduction. A general solution will be discussed, along with guidelines for selecting isolators for an optimal compromise between the reduction of structure borne noise and the attenuation of high impact shocks.

THE USE OF SHOCK ISOLATION SYSTEMS IN SMALL HIGH-SPEED PLANING CRAFT FOR WAVE SLAM PROTECTION

Mr. Michael Riley, The Columbia Group
Mr. Brock Aron, NSWC Carderock
Dr. Timothy Coats, NSWC Carderock

There are many references that span multiple communities of interest related to the response of shock isolation systems to wave impact loads. The communities include military operations, government applied research and acquisition, academic studies, civilian seat designers, manufactures, and high-speed boating enthusiasts. Their common goals for dealing with a harsh and demanding environment are to improve comfort, avoid pain or injury, and sustain mission performance in marine craft.

The observation that deck peak accelerations caused by wave impacts can be amplified by passive shock isolation systems is not new. Theoretical assessments and experimental observations in numerous references have identified the phenomenon, but no systematic approach existed for avoiding this troubling outcome. Until recently there has been no engineering methodology or physics-based rationale for quantifying wave impact load or for quantifying the mitigation characteristics of a specific shock isolation system design prior to installation in a craft. As a result craft have been designed and isolation systems installed only to find out during subsequent seakeeping trials that the isolation systems provide little to no mitigation or that they actually amplify the wave impact load.

This paper presents a new and unique deterministic approach to quantifying wave impact load. Acceleration response mode decomposition and elements of classical structural dynamics are summarized, and the engineering rationale is presented for defining a shock input and response ratio that characterizes marine isolation systems. Acceleration data recorded during craft seakeeping trials and mitigation ratio calculations are presented that illustrate examples of dynamic amplification and successful shock mitigation. The paper shows how a shock response spectra ratio methodology can be used to evaluate passive isolation system characteristics using acceleration data recorded during laboratory testing before installation in a craft.

USAGE OF LARGER WIRE ROPE ISOLATORS (WRI)

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

The Socitec Group has been known for more than 40 years as the worldwide leader in wire rope isolators (WRI). 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.

WRIs are used in many different fields of activity, such as Navy, Army, oil research, seismic, and transportation. Until recently, the product range included isolators produced with cable spanning 1/32” to 1 ½” diameter. A number of new projects in the seismic and transportation segments have led the Socitec Group to develop a WRI series produced from 2” diameter cable.

There are several advantages in using larger isolators, such as a reduction in number of required isolators for larger loads, a large deflection capability, and simplified assembly of WRIs into equipment. For example, an equipment package that would have required 24 isolators potentially could be mounted on only 8 of the new, larger isolators.

Beyond the manufacturing challenge of being able to produce WRIs with 2” cable, it was critical to be able to reliably predict the properties of such a series of isolators in order to ensure that the time and tooling investment would be worthwhile. Over the years, Socitec has developed and verified an analytical model for WRIs. For a given cable construction, only the cable diameter, height, width, and number of loops need to be known in order to produce the static and dynamic characteristics of that WRI.

Once the WRI characteristics have been calculated using this analytical model, they are used in conjunction with the Socitec Group’s proprietary numerical solution program, Symos. Combining the analytical model with the capabilities of Symos means that a new WRI meeting a specific requirement for an application can be designed and reliably used in simulation analyses, saving time and costs related to the design of a new product.

The article will present detail on the extension of the current line of wire rope isolators, plus the general use of numerically simulating applications using data curves developed with the aforementioned analytical model. A number of real case studies are to be shown.

SESSION 6: SHOCK MODELING

SHOCK MODELING AND SHOCK GENERATION

Mr. Zeev Sherf, Consultant

A methodology of modeling a shock as a combination of a deterministic and a random time history is discussed. The determination of the deterministic model is presented and the identification of the AR parametric model of the random part is detailed. A good comparison of the modelled shock to the measured one is identified

SESSION 7: MATERIAL BEHAVIOR I

NON-DESTRUCTIVE IMAGING AND RESIDUAL STRENGTH OF COMPOSITE MATERIALS AFTER EXPOSURE TO BLAST LOADING

Ms. Monica Black, NUWC Newport
Dr. James LeBlanc, NUWC Newport
Dr. Patric Lockhart, NUWC Newport
Dr. Arun Shukla, University of Rhode Island
Dr. Shyamal Kishore, Univerisity of Rhode Island

An experimental study has been conducted to evaluate the compressive residual strength of glass fiber/epoxy laminates after exposure to air blast loading. Controlled blast loading experiments were conducted using a shock tube facility which induced damage on the panels. The resulting damage in the material was quantified using non-destructive imaging technologies, specifically Terahertz (THz) and Flash Infrared Thermography (FIRT). Residual compressive strength was subsequently measured using subpanels cut from the main panel, per ASTM D7137. Furthermore, an empirical relationship has been

developed to predict the residual compressive strength of the composite laminates as a function of a combined damage parameter based on individual damage mechanisms. The results show that THz and FIRT imaging can be used to quantify internal damage in a composite laminate after shock loading. Additionally, residual strength experiments show that increased shock damage causes a corresponding reduction in remaining compressive strength. The residual strength of the composite panel follows a linear trend as a function of a combined damage parameter.

HYBRID CHARACTERIZATION AND DESIGN OF ELASTOMERIC MAGNETODIELECTRIC MATERIALS FOR SURFACE DAMPING TREATMENT AND RADAR ABSORBER STRUCTURES

Mr. Mehmet Emre Demir, ASELSAN
Mr. Akin Dalkilic, ASELSAN

Elastomeric base material is a good candidate for absorption of both radar signals and vibrations. Radar absorbing materials (RAMs) are widely used in numerous military systems, like planes, ships and submarines in order to decrease the radar cross-section (RCS) of these structures. In this work, a nitrile based elastomeric dielectric material is utilized as the carrier matrix and filled with a highly electromagnetic powder. The material with magnetic filler is characterized in terms of permittivity (ε) and permeability (μ) parameters and a RAM design procedure is applied in order to acquire the aimed electromagnetic wave absorbing performance. In the proposed passive vibration control technique based on the use of RAM materials, viscoelastic components participate the significantly in the energy of vibration. The free and constrained damping treatment components are designed and added to the system for both high electromagnetic performance and dissipating maximum energy possible in order to reduce vibration amplitudes at desired frequency region. Thus, in this study, at the operational frequency of interest, desired electromagnetic performance elements to decrease RCS with adverse resonant vibration amplitude reduction is achieved.

DETERMINATION OF JOHNSON-COOK MATERIAL PROPERTIES FROM TAYLOR IMPACT TESTING

Mr. Mehmet Emre Demir, Aselsan

In this paper, identification of Johnson-Cook parameters from Taylor Impact Test simulations is presented. Taylor Impact Test phenomena is aimed to be performed by finite element analysis tool and the corresponding results are presented and discussed. In order to check the reliability of the results of analysis, these results are validated by using experimental results. Having validated the finite element analysis results, the identification of material properties of unknown material and optimization of the final material properties are presented.

This study introduced and briefly described the basic elements of Taylor Impact Test with experimental and numerical analysis point of view. For high strain rate applications it is one of the problems encountered that the correct modelling of the material. Making use of Taylor Impact Testing one can both verify own numerical model along with the material characteristics (Johnson-Cook parameters) from the presented details and examples that are very easy and clear to apply. The main advantage of this method that it needs only Taylor impact test for the whole identification procedure. The objective was to provide a detailed enough introduction of Taylor Impact Testing and numerical simulations which are compatible with the experimental results. Furthermore, making use of these results unknown material characterization becomes possible.

The Use of Tensile Force in the Solder-Electronic Component Interface as a Means to Predict Survivability Against Inertial Loads

Dr. Catherine Florio, US Army ARDEC
Dr. Jennifer Cordes, US Army ARDEC
Mr. Lyonel Reinhardt, US Army ARDEC
Dr. Aisha Haynes, US Army ARDEC

While there has been much work done to develop methods that can experimentally measure and numerically predict the behavior of packaged electronic systems under extreme dynamic environments, utilization of the simulation results to find a correlation between the preservation of the electronic function of the components during and after the dynamic event and mechanical measures that can be extracted from these numerical studies has not been well established. The lack of such a capability has limited the ability to predict the functional survivability of these systems, especially as they are being designed and developed. Under these extreme mechanical loading conditions, electronic components can fail due to a range of mechanical modes from excessive vibration, to flexural cracking, to detachment from the circuit board. Disassembly of an electronic component from the circuit board is a common means of failure in these systems, particularly for larger components which experience a more significant momentum changes as the dynamic environment becomes more extreme. Since the solder is used to secure the electronics to the board, conditions in the solder-component interface are critical to the maintenance of the function of the electronics and their connection to the board. The relationship between the magnitude of the tensile force that develops at this interface, the magnitude of the acceleration load to which the overall system is subjected under impact loading are explored in this work and comparisons are made to the experimentally observed behavior of component under such loads. The effects of the material model used to predict the behavior of the solder material and alternative means for modeling the solder pad itself are presented. In addition, methods to develop a single value to quantify the oscillatory force at the component-solder interface over the transient impact event are investigated with the aim of developing performance comparisons for evaluating different designs, loads, or materials in parametric studies.

Modeling Dynamic Behavior of Expanded Polypropylene (EPP) Polymeric Foam Utilizing Rate and Temperature Dependent Compression Test Results

Mr. Eren Koçak, Roketsan Inc.
Mr. Kenan Gürses, Roketsan Inc.
Mr. Bülent Acar, Roketsan Inc

EPP polymeric foam materials are widely used at home appliance, automotive and various fields of defense industry because of their important characteristics such as resilience, lightness, high porosity, high crushability, good energy absorption capacity and shock reduction. In most applications, they are mainly subjected to compressive loading and undergone large recoverable elastic deformations. Compressive stress-strain curves of typical EPP polymeric foams consist of three regions: elastic region, plateau region and densification region. Major parameters affecting the dynamic behavior of polymeric foams are foam cell structure, material density, temperature, and strain rate which directly influences shape of the compressive stress-strain curves.

EPP polymeric foam materials exhibit highly strain rate dependent behavior. In order to investigate this behavior, compressive stress-strain data of EPP polymeric foam specimens are measured at various constant strain rates by performing quasi-static (1.E-4, 1.E-3, 1.E-2, 0.16 [1/s]) and drop tower (20, 50, 100 [1/s]) uniaxial compression tests at room temperature. EPP polymeric foams exhibit not only strain

rate but also considerable temperature dependent behavior. Especially, in defense industry applications, these foams are obliged to operate at extreme temperature conditions. However, this extreme temperature behavior about EPP polymeric foams is rarely investigated in the previous literature. Therefore, it is aimed to perform quasi-static uniaxial compression tests both at various (1.E-4, 1.E-3, 1.E-2, 1.E-1 and 1.0 [1/s]) strain rates and temperatures (-40/+50 ['C]).

Afterwards, an existing seven parameters Phenomenological Constitutive Model (PCM), – representing the strain rate dependent macroscopic behavior of polymeric foam – is adapted to mimic compression test results by minimizing the error function. First of all, in order to identify seven parameters in the PCM, stress-strain data of the EPP foam material must be measured at least two different strain rates. Then, by means of processing these two sets of stress-strain data within a two-step optimization procedure PCM parameters are identified. After the identification of parameters in PCM, compressive stress-strain curves of foam material are established at both a wide range of strain rates and different temperatures. Furthermore, identified PCM is also verified by using FE analysis approach. To this end, stress-strain curves corresponding to various strain rates and temperatures generated by PCM are supplied into a commercial FE package (ABAQUS/Explicit) in order to simulate original compression test results.

It is shown that results of FE package and compression tests are fairly identical. Consequently, with the use of the PCM, the number of total test measurements that are needed to capture the dynamic behavior of Expanded Polypropylene (EPP) polymeric foam material is significantly reduced. Therefore, both cost and time reduction, which is also our motivation in this study, is achieved in the dynamic characterization of EPP foam material.

EFFECTS OF MASONRY-MORTAR BOND STRENGTH ON THE BLAST LOAD RESPONSE OF MASONRY WALLS

Ms. Kelsey Doan, US Army Engineer Research and Development Center
Mr. John Hoemann, US Army Engineer Research and Development Center
Dr. Catherine Stephens, US Army Engineer Research and Development Center
Mr. Don Nelson, US Army Engineer Research and Development Center
Dr. James Davidson, Auburn University

Due to its relative low cost, availability, versatility, and construction simplicity, masonry is commonly used throughout the world in building construction. From a blast protection perspective, masonry presents an enormous challenge: when subjected to blast loading, unreinforced masonry walls tend to break up into fragments that are propelled into the building interior at hazardous velocities. For this reason, the response of unreinforced masonry walls subjected to impulse loads has been extensively studied through testing and computational analyses, as well through case studies of accidental and intentional explosions. Concrete, masonry, and mortar constitutive models have also been studied extensively, but the weakest part of an unreinforced masonry wall system is the interface between the masonry unit and mortar as demonstrated by numerous experiments and post-event investigations. As determined from an extensive review of relevant research, there is still an enormous variation in approaches used to model the masonry-mortar bond. The objective of this work is to define the influence of masonry-mortar bond strength on the response of unreinforced masonry walls to far-field blast loads and provide guidance on an experimental methodology to determine strain rate effects on the masonry-mortar bond. This presentation will include a summary of relevant static and dynamic literature relating to masonry-mortar bond strength and static and dynamic loading and then uses high-fidelity finite element models to define the implications of the interface strength parameters. Results from parametric studies define the predominant factors and mechanisms. Subsequent phases of the

research will involve defining an experimental methodology intended to define the strain rate effects on the interface so that parameters for modeling the masonry-mortar interface in masonry walls subjected to blast load can be determined.

SESSION 8: BLAST TO STRUCTURES & VEHICLES FROM IEDS & OTHER EXPLOSIVES

AIR BLAST EXPERIMENTS TO QUANTIFY BLAST WAVE AND STRUCTURE INTERACTION FOR IDEAL AND HOMEMADE EXPLOSIVES

Mr. Garrett Doles, US Army Engineer Research and Development Center
Ms. Alyson Doles, US Army Engineer Research and Development Center,
Dr. T. Neil Williams, US Army Engineer Research and Development Center

Detonation of an explosive charge placed above the ground surface can produce high airblast pressure loads on a surrounding structure, such as a vehicle passing near the explosive at the time of detonation. The blast loading environment is a function of many factors including the explosive type, dimensions, mass, height of burst, and distance between the explosive charge position and the target structure. Due to the complex responses and interactions produced by such detonations, there is a need to better understand this environment in order to adequately design protective measures for aboveground structures. The development of the required prediction tools, however, is hampered by the lack of well-documented experimental results for these complex loads. The U.S. Army Engineer Research and Development Center (ERDC) has undertaken this research, providing both well-defined field experiments to capture these loads and supporting numerical simulations. The experimental results from this research provide much needed validation data for the blast wave interactions with a generic structure. The goal of this research was to quantify the influence of explosive size and type on the blast environment. This presentation discusses the experimental layout, execution, and test results.

SOLID SURFACE DEBRIS FROM BURIED DETONATIONS

Mr. William Myers, US Army Engineer Research and Development Center
Dr. John Ehrgott, US Army Engineer Research and Development Center
Mr. Ernesto Cruz-Gutierrez, US Army Engineer Research and Development Center
Mr. Jasiel Ramos-Delgado, US Army Engineer Research and Development Center

The Engineer Research and Development Center conducted tests in conjunction with the Naval Surface Warfare Center, Dahlgren Division to characterize the effects of buried detonations under solid surface roadways. Debris from buried detonations under solid surface roads is not well quantified but is of great interest because it can cause unintended collateral damage. The results of the testing will be used to improve collateral damage estimates and improve modeling capabilities. This paper will present an overview and comparison of the results of experiments conducted with simulated asphalt and concrete roads.

Experimental Techniques to Capture Near-Field Airblast Characterization of Unconfined Homemade Explosives

Mr. Stephen Turner, US Army Engineer Research and Development Center
Dr. Andreas Frank, US Army Engineer Research and Development Center
Dr. Jay Ehrgott, US Army Engineer Research and Development Center
Mr. Donny Guynes, US Army Engineer Research and Development Center
Mr. Sonny Johnson, US Army Engineer Research and Development Center
Mr. Neill Stephens, US Army Engineer Research and Development Center
Mr. Jim Hall III, US Army Engineer Research and Development Center
Mr. Billy Bullock, US Army Engineer Research and Development Center
Mr. Tom Carriveau, US Army Engineer Research and Development Center

The threat of Improvised Explosive Devices (IEDs) continues to evolve and grow around the world. These threats range from shallow-buried IEDs to personnel and large vehicle-borne IEDs. In order to evaluate and address these threats, there is a significant need to expand our current capability to characterize the loads and loading distributions from the detonation of homemade explosive (HME) formulations and non-ideal explosives used in these IEDs. Under the Adaptive Simulation to Characterize Emerging Non-Ideal Threats Program, the U. S. Army Engineer Research and Development Center has been conducting field research on various non-ideal explosives in order to better understand the physics, scalability, and spatial loading distributions of various non-ideal explosives. These results are then used to improve constitutive models in shock-physics codes. The overall goal is to improve the accuracy and flexibility of explosive models to better account for the differences in the burn rate, shock front, and confinement effects when compared to current ideal explosive models. Well characterized and highly instrumented experiments were conducted using several highly proliferated HME mixtures including Anfo, AN/Al, and KCL. This paper will present an overview of the test program, the design of a new test apparatus used for close-in airblast data collection, and some of the experimental data collected under this research effort.

Experimental Testing of Small Charges in Vehicle-Borne Improvised Explosive Devices

Mr. Daniel Vaughan, US Army Engineer Research and Development Center
Mr. Joshua E. Payne, US Army Engineer Research and Development Center
Mr. Jasiel Y. Ramos-Delgado, US Army Engineer Research and Development Center
Mr. Ernesto G. Cruz-Gutierrez, US Army Engineer Research and Development Center
Dr. John Q. Ehrgott, Jr., US Army Engineer Research and Development Center
Mr. Denis D. Rickman, US Army Engineer Research and Development Center

Vehicle-borne improvised explosive devices (VBIEDs) continue to pose a worldwide threat to U.S. forces, our Allies, and civilians. These weapons have the potential to cause significant human casualties and infrastructure damage. Post-blast analyses of VBIED attacks can provide valuable information for both characterizing the events and understanding future threats. The National Ground Intelligence Center (NGIC) and the U.S. Army Engineer Research and Development Center (ERDC) have conducted numerous VBIED experiments under the Forensic Encyclopedia Program (FEP) to better understand their forensic signatures, which will improve our ability to characterize future attacks. Prior to this year, ERDC's testing has been focused on VBIEDs with charge weights over 200 pounds, but VBIEDs employing smaller charge weights have been identified as an area of concern and there is little test data representing these threats. To address this need, the ERDC has performed a series of controlled VBIED experiments with Ammonium Nitrate-Fuel Oil (ANFO) charges ranging from 50 to 150-lbs. Information such as the ground

crater dimensions and host vehicle breakup was collected during these tests for use in VBIED forensic analysis tools. This paper presents an overview of those experiments.

A Fast-Running Tool for Mapping Loads from Wrap-Around Airblast

Dr. Gregory Bessette, US Army Engineer Research and Development Center
Mr. Micael Edwards, US Army Engineer Research and Development Center

The fast-running, engineering level model MineX3D was developed to predict the loading on a vehicle from either underbody blast or aboveground threats. The code predicts the temporal and spatially varying load on the vehicle. The load data can be mapped onto a finite element (FE) model for a follow-on structural analysis, a process referred to as a one-way coupling. The original model development focused on underbody blast. Recent development has focused on handling pure airblast phenomena associated with aboveground threats. The BlastX fast-running model has been linked with MineX3D to provide the load prediction from pure airblast, with MineX3D serving as a manager for FE model import and data export. The code can automatically map the load data onto either LS-DYNA- or ParaDyn-formatted models. A new capability has been implemented into the data manager which supports wrap-around airblast. Thus, the model can now predict loading on both the windward and leeward sides of a vehicle. The windward case refers to element faces in the line-of-sight to the charge subjected to either oblique shock or Mach region effects. The leeward case refers to non-exposed elements subjected to a diffracted shock environment that arises when the blast wraps around the edges of the vehicle. The magnitude and duration of the loading differs markedly between these regions, making it important to accurately capture the wrap-around airblast phenomena. This paper outlines the blast methodology, the implementation of the new wrap-around airblast capability, and recent model validation.

Analysis of Host Vehicle Fragments from Vehicle Borne IED Detonations

Mr. Jasiel Ramos-Delgado, US Army Engineer Research and Development Center
Mr. Joshua E. Payne, US Army Engineer Research and Development Center
Dr. Zachary K. Crosby, US Army Engineer Research and Development Center
Mr. Ernesto G. Cruz-Gutierrez, US Army Engineer Research and Development Center
Dr. John Q. Ehrgott, Jr., US Army Engineer Research and Development Center
Mr. Denis D. Rickman, US Army Engineer Research and Development Center

Among the many types of improvised explosive devices (IEDs), Vehicle-Borne IEDs (better known as VBIEDs) are among the most pervasive and potentially damaging. Thanks to their potential for impacting a wide variety of targets, assessing VBIED threats to determine the effective explosive mass employed based on their post-attack signatures is of critical importance to military and force protection planners. In order to improve assessments of VBIED threats, the National Ground Intelligence Center (NGIC) and the U.S. Army Corps of Engineers, Engineer Research and Development Center (ERDC) have conducted a series of carefully-controlled VBIED experiments. In these experiments, the location of host vehicle fragments, including distance and angles from ground zero (GZ), are obtained using RTK observations. Based upon these data, fragment "zones" can be developed and used to predict the regions of hazardous or fatal fragmentation produced by a VBIED attack of a given size class. Development of these expected fragment zones potentially allow for a better assessment of the amount of Net Explosive Weight used in a VBIED attack and the regions of greatest personnel hazard relative to the orientation of the VBIED vehicle.

SESSION 9: NAVY ENHANCED SIERRA MECHANICS (NESM) I

NAVY ENHANCED SIERRA MECHANICS (NESM) VERSION 6.1

Mr. Jon Stergiou, NSWC Carderock Divison
Mr. Raymond DeFrese, NSWC Carderock Divison
Dr. John Gilbert, NSWC Carderock Divison
Mr. Michael Miraglia, NSWC Carderock Divison
Mr. Corbin Robeck, Thorton Tomasetti Weidlinger Associates
Dr. Badri Hiriyur, Thorton Tomasetti Weidlinger Associates
Dr. Jesse Thomas, Sandia National Laboratories
Dr. Lynn Munday, Sandia National Laboratories

Navy Enhanced Sierra Mechanics (NESM) is the DoD HPCMP CREATE Ships Shock/Damage software product providing massively parallel computational tools for ship shock and structural vulnerability predictions due to threat weapon engagements. NESM is designed to take full advantage of High Performance Computing (HPC) systems allowing for solution of models needed for high physical fidelity. Some newer capabilities in NESM v6.1 include cavitating acoustic capabilities, additional fluid equations of state, coupled load balancing, DDAM for submerged items, and additional validation efforts. Upcoming capabilities are also highlighted, and the program's roadmap is discussed.

DOAN-NICKEL EQUATION OF STATE IMPLEMENTATION IN NEMO

Mr. Michael Miraglia, NSWC Carderock Divison
Mr. Ray DeFrese, NSWC Carderock Divison
Mr. Corbin Robeck, Thorton Tomasetti Weidlinger Associates

For many applications, the assumption that air is a perfect gas with a constant ratio of specific heats, γ, is a good approximation. However, for certain airblast applications in which the incident blast pressure exceeds about 250 psi, the assumption of a constant γ begins to break down and the perfect gas assumption ceases to be valid. The Doan-Nickel equation of state, developed by Larry Doan and George Nickel (1963), allows for a variable γ and has been widely used in airblast applications to model "real air" in the near-field (Needham, 2010). In this work, details on the implementation and verification of the Doan-Nickel equation of state into the Navy Energetic Modeling Oracle (NEMO) are presented.

AIR BLAST VERIFICATION AND VALIDATION IN NESM

Mr. Ray DeFrese, NSWC Carderock Divison
Dr. John Gilbert, NSWC Carderock Divison
Mr. Michael Miraglia, NSWC Carderock Division
Mr. Corbin Robeck, Thorton Tomasetti Weidlinger Associates

Recent equation of state (EOS) additions to the Navy Energetic Modeling Oracle (NEMO) hydrocode have enabled users to more accurately solve external air blast (AIREX) problems using the NESM toolkit. In particular, the Doan-Nickel equation of state (EOS) has been incorporated into NEMO for use in high blast pressure AIREX simulations. Following robust software engineering practices, the additional AIREX technologies have undergone thorough verification and validation (V&V) efforts to ensure a robust and reliable capability for the user community. These efforts include both extensive software verification via unit and regression tests, as well as comprehensive validation efforts via both uncoupled and coupled analyses of live fire tests. The status of V&V as well as plans for future AIREX efforts will be discussed.

Navy Energetic Modeling Oracle (NEMO) Load Balancer

Dr. Badri Hiriyur, Thorton Tomasetti Weidlinger Associates
Mr. Michael Miraglia, NSWC Carderock Divison

A typical coupled simulation using NEMO would involve modeling of various localized phenomenon such as fluid-structure interaction, mixing of multi-phase fluids, shock discontinuities, cavitation and explosive burn - each of which involves a variable computational cost per cell. This leads to load imbalance across multiple NEMO processes, if the fluid domain is partitioned naively such that each fluid process owns approximately the same number of fluid cells. In this talk, we present the NEMO Load Balancer (NLB) - a stand-alone tool that extracts timing information from each NEMO process, computes the load distribution across different processes and finally repartitions the fluid grid using the NEMO Partitioning Tool (NPT) to provide a more optimal load distribution. Preliminary results have shown time savings in the order of 25-30% with the use of the repartitioned grid generated from NLB.

Usage of VUMAT Capability in Navy Enhanced Sierra Mechanics

Mr. Michael Miraglia, NSWC Carderock Divison
Mr. Raymond DeFrese NSWC Carderock Divison
Mr. Jonathan Stergiou, NSWC Carderock Divison

Navy Enhanced Sierra Mechanics (NESM) incorporates Sandia National Labs (SNL) Sierra/SM Finite Element Code. Sierra/SM has an interface that allows for the use of ABAQUS-style VUMATs (user material models) with minimal modification. This capability exists for both solid and shell elements and provides access to a large library of material models developed by industry and academia. Furthermore these material models can be exercised for large scale simulations in Sierra/SM which has demonstrated excellent scalability (massively parallel). A capability overview, usage and novel applications will be presented.

NESM Implementation of DDAM for Submerged Items (DDAMX): A Formulation for Base Excitation and Direct-Pressure Fluid Loading

Mr. Corbin Robeck, Thorton Tomasetti Weidlinger Associates
Mr. Alex Kelly, Thorton Tomasetti Weidlinger Associates
Dr. Jeff Cipolla, Thorton Tomasetti Weidlinger Associates
Mr. Jacob Mason, NSWC Carderock Divison

Appendix A of the External Components PPD currently provides guidance for use of external DDAM. The guidance requires significant user input and judgement in order to generate a means of accounting for added fluid mass effects. No guidance is provided for usage of DDAM when the component is not driven exclusively by the boat's mechanical inputs (i.e. when direct pressure fluid loading is relevant). A formulation for a finite element based external DDAM procedure is presented that accounts for added fluid mass effects through usage of a wetted modal analysis and includes a new, innovative functionality to evaluate the effects of direct pressure fluid loading (DPFL). The DDAMX formulation is shown to be less computationally expensive and requires less engineering judgment than TSA and is designed to conform to standard NAVSEA DDAM practice to the greatest degree possible. The implementation of this new DDAMX formulation in the Navy Enhanced Sierra Mechanics framework is discussed as well. Finally a verification study is presentation outlining the methods comparison to traditional DDAM and analytical submerged item solution methods.

VENDOR SESSION B

SIMULATING BARGE SHOCK EVENT USING NONLINEAR 6 DOF
Mr. Eric Peiffer, ITT Enidine
Mr. Mark Downing, ITT Enidine

Simulating barge shock isolation using linear, single degree of freedom analysis may under predict system shock response. Due to asymmetry of system payload and non-linearity of shock isolators, a 6 DOF analysis is more appropriate when simulating a barge shock event for MIL-S-901. This paper addresses many of the factors involved when sizing a system for barge shock and shows the importance of fully analyzing a system.

PROTECTING UNIT UNDER TEST (UUT) DURING VIBRATION TESTING
Mr. Chris Wilcox, m+p International

No abstract available.

SEEING VIBRATION WITH VIBVUETM – A MOTION AMPLIFICATION SYSTEM
Mr. Andy Lerche, Mechanical Solutions, Inc.

No abstract available.

NEW ANGULAR RATE SENSOR TEST RESULTS
Mr. Ronald Poff, Meggitt (author)
Ms. Jennifer MacDonell, Meggitt (presenter)

The introduction of affordable angular rate sensors is making many measurements more straightforward and accurate. Angular motion can be measured directly rather than through complicated calculations from multiple accelerometers. Measurement principles and test results for the new Endevco® Model 7310 will be presented. Ranges from 100°/s to 18000°/s are available. A preview of a 6DOF, triaxial rate and acceleration sensor will also be included.

NUMERICAL SIMULATION AND TESTING OF COMPOSITE MATERIALS UNDER UNDEX LOADING
Mr. Bill Gregory, Applied Physical Sciences

Modeling and Simulation (M&S) was coupled with experimental testing to identify the response of composite materials in an UNDEX environment. The monitored response included accelerations, deflections and the associated panel failure and damage types and extent. The outcome of the experimental portion of this work was a shock test fixture platform that allowed for controlled and predictable UNDEX environments.

VIDEO CAPTURE AND MOTION ANALYSIS SOLUTIONS
Ms. Leah Holber, Xcitex

Abstract no available.

SESSION 10: NATIONAL SHIPBUILDING RESEARCH PROGRAM (NSRP)

NSRP STANDARDIZATION OF WATERTIGHT CLOSURES

Mr. Mike Poslusny, Ingalls Shipbuilding
Mr. Kyle East, Ingalls Shipbuilding

Abstract not available.

NSRP ASTMF1387 SHOCK TESTING OF MECHANICALLY ATTACHED FITTINGS

Mr. Mike Poslusny, Ingalls Shipbuilding

Abstract not available.

SESSION 11: VIBRATION I (WITH MIMO)

INSIGHTS INTO MULTIAXIAL NONLINEAR VIBRATION RESPONSE OF ELECTRONIC ASSEMBLIES VIA STUDY OF MECHANICAL PROXY STRUCTURES

Prof. Abhijit Dasgupta, University of Maryland
Prof. Samuel Massa, University of Maryland
Prof. Xiao Lin, University of Maryland
Prof. R. Sridharan, University of Maryland
Mr. Washington de Lima, Honeywell National Security Campus

Electronic packages are exposed to complex life-cycle environments, and in many cases that environment involves exposure to multiaxial vibration which can dangerously affect the integrity of the electronic package's functionality due to nonlinear amplification of the multiaxial response, in comparison to the corresponding uniaxial responses. This has particular implications in vibration durability testing of electronic assemblies, since conventional tests in industry are often run sequentially as a set of uniaxial tests along orthogonal axes. This is in part because multiaxial vibration tests can be expensive and complex when the response becomes significantly nonlinear. The severity of the nonlinear response is known to depend both on the multiaxial excitation parameters and on the component architecture. This paper will summarize recent work on this topic, using a combination of novel multiaxial vibration tests and nonlinear dynamic finite element modeling, to conduct systematic parametric studies. The parameters being varied include: (i) loading parameters along orthogonal axes such as frequency ration and relative phase; and (ii) component parameters such as mass and radius of gyration. The test specimens used in this study are mechanical proxy structures that mimic the dynamic characteristics of certain classes of electronic assemblies. The findings of this study will provide important guidance when developing guidelines about when multiaxial testing is important, instead of sequential uniaxial testing along orthogonal axes.

A TECHNIQUE TO DEVELOP A SPECTRAL DENSITY MATRIX WITH SYNTHESIZED ROTATIONAL DEGREES-OF-FREEDOM

Dr. Michael Hale, Trideum Corporation

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 SDMmotion. 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 SDMmotion given only predefined translational spectral shapes.

Preparation of multi axis, multi shaker vibration testing programs for stationary and non-stationary flight conditions simulation, Part I

Mr. Zeev Sherf, Consultant

The Use and Application of the Multi Axes Vibration Technology that was also included in MIL STD 810G (Method 527)[1] 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). Normalized PSDs (rms=1) of the vibrations at each one of the locations were the data known at the start of the simulation. Also regression models of the rms vs dynamic pressure at each one of the location were defined. A set of six dynamic pressures was defined. The corresponding PSDs for each dynamic pressure were evaluated and from these PSDs time histories were generated. For each location six time histories. From these time histories SDM (Spectral Density Matrices) were evaluated. These matrices serve as the basis of the vibration testing specification's definition. For the testing duration definition energy considerations were used, this meaning that the testing has to be applied till the energy accumulated in field is duplicated in the laboratory. Following this introduction, the process of the time histories generation from the given PSDs and grms vs dynamic pressure model is described. Next the generation of SDMs for each dynamic pressure is presented. The use of energy considerations in the definition of the testing duration is described in the following. Several summarizing remarks conclude the work. The numerical simulation was performed using the OCTAVE software[2].

Preparation of multi axis, multi shaker vibration testing programs for stationary and non-stationary flight conditions simulation, Part II

Mr. Zeev Sherf, Consultant

The definition of testing specifications for the performance of multi axis- multi shaker vibration testing for non stationary conditions is discussed. Non stationary conditions only in level and non stationary conditions both in level and frequency content. Analysis methods for the identification of the spectral content of the non stationary time series are presented and compared. The FFT method, the parametric modeling based spectral analysis and the direct filtering method. The advantages of the second and third method as related to the FFT method are elucidated. Definition of a testing CSP matrix based on the envelope CSP for the case of non stationarity in level and of time histories based testing regime for the case of non stationarity both in level and frequency is presented. The application of energy equivalence for the definition of accelerated testing conditions is demonstrated. Several summarizing remarks conclude the presentation.

Infrastructure and Methodology for Multi-Axis Vibration

Dr. Arie Elka, RAFAEL

Airborne structure is subjected to vibro-acoustic vibrations during flight, due to pressure fluctuations on the boundary layer surface. The induced vibrations act as acoustic-mechanical loads that can cause a mechanical or an electrical failure. The qualification of a system to environmental flight conditions in the laboratory is the ability to withstand the vibro-acoustic loads. Testing airborne systems with an electro-dynamic shaker is done from 1950. In this method, only a single axis vibration is controlled and all other axis are parasitic responses.

In the recent years, the technology of Multiple inputs Multiple outputs - MIMO control, enabled setup of multi-axis shakers, that can control at least three degree of freedom. The laboratory test is more realistic and can simulate the field loads measured in flight directly in several axis and locations. The benefit of shortening the time schedule with multi-axis vibration is also very important. We developed a methodology for qualification of an airborne store with a multi-axis shaker vibration infrastructure. The method comprise: A novel test facility with new methodology for defining the specification profile tests based on Auto-PSD and Cross-PSD or Coherence and Phase. Some examples will be demonstrated during the lecture.

SESSION 12: SVS18 – COMPUTATIONAL MODELING OF AIRBLAST ON GENERIC STRUCTURES AND VEHICLES

Experiments and Simulations to Quantify Blast Wave Interaction with Generic Vehicles for Ideal and Homemade Explosive Detonations

Ms. Alyson Doles, US Army Engineer Research and Development Center
Mr. Garrett K. Doles, US Army Engineer Research and Development Center
Dr. Neil T. Williams, US Army Engineer Research and Development Center
Dr. Jay Q. Ehrgott, Jr., US Army Engineer Research and Development Center

Detonation of an explosive charge placed above the ground surface can produce high airblast pressure loads on a surrounding structure, such as a vehicle passing near the explosive at the time of detonation. The blast loading environment is a function of many factors including the explosive type, dimensions, mass, height of burst, and distance between the explosive charge position and the target structure. Due to the complex responses and interactions produced by such detonations, there is a need to better understand this environment in order to adequately design protective measures for aboveground structures. The development of the required prediction tools, however, is hampered by the lack of well-documented experimental results for these complex loads. The U.S. Army Engineer Research and Development Center (ERDC) has undertaken this research, providing both numerical simulations and field experiments of these loads. The experimental results from this research provide much needed validation data for the blast wave interactions with a generic structure. The goal of this research was to quantify the influence of explosive size and type on the blast environment. This presentation discusses the experimental layout, test results, and comparison of CTH simulations with experimental data.

EVALUATION OF MINEX3D GENERATED AIRBLAST LOADINGS USING LS-DYNA AND PARADYN
Mr. Micael Edwards, US Army Engineer Research and Development Center
Dr. Greg Bessette, US Army Engineer Research and Development Center
Mr. David Roman-Castro, US Army Engineer Research and Development Center

MineX3D was used to generated airblast loads for LS-DYNA and ParaDyn models to evaluate the code's ability to accurately predict and map blast loadings on structures. The MineX3D code was originally developed to quickly and efficiently generate distributed loads from a buried charge onto the underbody of a vehicle. A recent development allows MinexX3D to link with BLASTX and thereby map airblast loads from aboveground charges. The code predicts loading on both the windward and leeward sides of a structure. The windward side refers to element faces in the line-of-sight to the charge subjected to either oblique shock or Mach region effects. The leeward side refers to non-exposed elements subjected to a diffracted shock environment that arises when the blast wraps around the edges of the structure. The magnitude and duration of the loading differ markedly between these regions, making it important to accurately capture the wraparound airblast phenomena. This work compares the results of both LS-DYNA and ParaDyn models using MineX3D generated airblast loads to physical experiment data. Additionally, the MineX3D loads are compared to loads generated by the Load Blast Enhanced card within LS-DYNA.

A COMPARISON OF VARIOUS BLAST LOADING METHODS ON VEHICLE STRUCTURES
Mr. Sanjay Kankanalapalli, US Army Tank Automotive Research, Development and Engineering Center
Mr. Kumar B Kulkarni, US Army Tank Automotive Research, Development and Engineering Center
Dr. Neil Williams, US Army Engineer Research and Development Center
Mr. Micael C. Edwards, US Army Engineer Research and Development Center
Dr. Gregory C. Bessette, US Army Engineer Research and Development Center

There is a continuous demand for a quicker turnaround time for modeling and simulating the effects of blast loading on vehicle structures and their occupants. One of the most widely used modeling and simulation (M&S) methods used is performing a finite element (FE) analysis using software such as ParaDyn, as well as, many commercially available software tools such as LSDYNA. Software tools offer many convenient ways of applying the blast loading on vehicle structures with or without explicitly modeling the blast event. In its simplest form, an implementation of an empirical blast model (CONWEP) exists such that engineers can conveniently identify the exposed surfaces on the vehicle structure model, the location and size of a blast source. Incident pressures on identified element segments are then calculated based on distance from the source and angle of incidence and applied directly. Although reflected pressure can be taken into account, tunneling and shadowing effects cannot be modeled. The most common method to include such effects especially while modeling buried blast problems, is simplified Arbitrary Lagrangian Eulerian (ALE) method. Here, the blast problem is modeled explicitly, including soil, charge and surrounding air with a background Eulerian mesh (fluids), while the vehicle structure model is modeled as foreground Lagrangian mesh (structure). Blast effects are determined through fluid structure interactions (FSI) at the interface. As the run time for these simulations are the most expensive, engineers are often focused on finding alternative methods of characterizing the blast loading on structures.

A fast-running, engineering level model, termed MineX3D, has been developed to characterize the loading environment on a vehicle when subjected to under-body blast. The code predicts the temporal and spatially varying load on the exposed portion of the vehicle. The load data can be mapped onto a finite element model for a follow-on structural analysis, a process commonly referred to as a one-way

coupling. MineX3D has an embedded capability to automatically map the loads onto either LSDYNA or ParaDyn models. Further, the mapping algorithm allows for the automatic generation of pressure patches/segments without the need to modify the original FE mesh. There has been recent development to extend the blast modeling capability to include loading from above-ground detonations. This has been accomplished by integrating the BlastX engineering level model with MineX3D. BlastX is designed to predict the air-blast environment associated with open-air and internal detonations. It has the capability to predict enhanced blast from neighboring reflecting surfaces, as well as the modified blast field in the Mach-stem region. It is important to capture these effects in any analysis of a vehicle's response to a close-in above-ground explosion. The approach taken in the integration allows for load prediction from blast originating either from buried or above-ground charges.

The scope of this paper is to compare the US Army TARDEC Generic Hull Vehicle Structure responses to blast loading using CONWEP, ALE-FSI & MineX3D/BlastX using LSDYNA software and compare the responses against physical test data.

Simulations of the Generic Hull Vehicle with DYSMAS

Mr. Chris Cao, NSWC Indian Head
Mr. Roger Ilamni, NSWC Indian Head
Dr. Tom McGrath, NSWC Indian Head
Dr. Neil Williams, US Army Engineer Research and Development Center

Side-on air blast scenarios of the Generic Hull Vehicle were simulated with the DYSMAS coupled (Gemini-ParaDyn) code. Three different charge configurations were explored corresponding to tests performed by ERDC. This talk will illustrate the explosive-air-structure interaction effects as well as shock wave pressure propagation effects. Additionally, comparisons of DYSMAS simulation results to measured data for pressure gages on the vehicle as well as free field gages will be presented.

Simulations of the Generic Hull Vehicle with DYSMAS-MineX3D

Mr. Alan Luton, NSWC Indian Head
Dr. Tom McGrath, NSWC Indian Head
Mr. Roger Ilamni, NSWC Indian Head
Mr. Chris Cao, NSWC Indian Head
Dr. Greg Bessette, US Army Engineer Research and Development Center
Mr. Micael Edwards, US Army Engineer Research and Development Center

XLoad (eXternal Load) is a new program in the DYSMAS hydrocode software suite. XLoad provides the capability for programs external to the DYSMAS framework to provide loading data to DYSMAS structural solvers such as ParaDyn. In cooperation with ERDC, XLoad has been enabled to operate with MineX3D. MineX3D, developed by ERDC, is a fast-running engineering-level code used primarily for predicting the loads on a vehicle. An overview of XLoad will be presented as well as ParaDyn-XLoad-MineX3D Generic Hull simulations with comparisons to test data from ERDC.

SESSION 13: NAVY ENHANCED SIERRA MECHANICS (NESM) II

LARGE MODAL ANALYSIS OF A FULL SHIP MODEL

Mr. Brian Lang, NSWC Carderock Divison
Mr. Tim McGee, NSWC Carderock Divison

Abstract not available.

A COMPARATIVE ASSESSMENT OF WETTED MODAL ANALYSIS TECHNIQUES: NAVY ENHANCED SIERRA MECHANICS (NESM) FINITE ELEMENT ANALYSIS (FEA), ABAQUS FEA, AND BLEVINS' ANALYTIC TECHNIQUES

Mr. Jacob Mason, NSWC Carderock Divison
Ms. Anna Bethel, NSWC Carderock Divison
Mr. David Shields, NSWC Carderock Divison
Mr. Joshua Yates, NSWC Carderock Divison

The purpose of this document is to describe work performed by Naval Surface Warfare Center Carderock Division (NSWCCD) Underwater Explosion Research and Development (UERD) Branch to assess the effectiveness of various techniques for determination of the wetted modal characteristics of several different structural models. The Sierra/SD GDSW Eigensolver, the Abaqus Lanczos Eigensolver, and Blevins' analytic techniques were compared to assess their relative capabilities. This assessment will serve as Objective Quality Evidence (OQE) to aid in determination of which wetted modal solution techniques are acceptable for use within the Dynamic Design Analysis Method – External (DDAM-X).

ACOUSTIC CAVITATION IN NAVY ENHANCED SIERRA MECHANICS

Dr. Lynn Munday, Sandia National Laboratories
Dr. Murthy Guddati, NC State

Abstract not available.

APPLICATION OF THE NESM ACOUSTIC FLUID MODEL TO SUBMARINE SHOCK PROBLEMS

Mr. Bradley Klenow, NSWC Carderock Divison
Ms. Anna Bethel, NSWC Carderock Division
Mr. Timothy McGee NAVSEA

Abstract not available.

USING NAVY ENHANCED SIERRA MECHANICS (NESM) FOR SIMULATING IMPLOSION

Dr. Joseph Ambrico, NUWC Newport
Dr. Emily L. Guzas, NUWC Newport

The Navy Enhanced Sierra Mechanics (NESM) suite of software tools includes several codes. For complex fluid-structure interaction modeling such as implosion simulations, NESM harnesses the Sierra/Structural Mechanics (SM) code for performing structural calculations, the Navy Energetic Modeling Oracle (NEMO) to handle fluid calculations, and the Navy Standard Coupler (NSC) to interface between the fluid and structural calculations. Notably, various algorithms developed under the ONR Implosion Future Naval Capability program have been rolled into the NESM suite. The current work involves modeling several implosion test cases using NESM and comparing simulation results to

experimental test data. The cases include: (1) unstiffened aluminum cylinder in the free-field, hydrostatic implosion; (2) stiffened aluminum cylinder in the free-field, hydrostatic implosion; (3) unstiffened aluminum cylinder in a confined environment, hydrostatic implosion; (4) unstiffened aluminum cylinder in the free-field, UNDEX-initiated implosion. Simulation results are compared to near-field pressure measurements from the experiments, with the simulation results looking promising. Additionally, feedback on code usability and performance has been provided to code developers.

SESSION 14: IMPLOSION

A METHOD AND AUTOMATED SOFTWARE TO DETERMINE IF IMPLODABLE ITEMS ARE SAFELY ARRANGED

Mr. Christopher Abate, Electric Boat Corporation
Mr. Michael Valentine, Electric Boat Corporation

Abstract not available.

UNDEX INITIATED IMPLOSION IN SHALLOW WATER OF CYLINDERS IN A CONFINED ENVIRONMENT

Dr. 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. Additionally, at shallow depth adjacent structures are at a smaller fraction of their collapse strength, so they have greater reserve strength and can withstand greater loading without damage. However, a shallow implosion initiated by a nearby underwater explosion (UNDEX) has the potential to be amplified by the UNDEX pressure. 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. A specific case of shallow, UNDEX initiated, confined implosion will be presented. The level of confinement and the material ductility of the implodable cylinder are investigated.

A BASIC STUDY OF UNDEX INITIATED IMPLOSION IN A CONFINED ENVIRONMENT

Dr. Joseph Ambrico, NUWC Newport
Dr. Ryan E. Chamberlin, NUWC Newport
Dr. Emily L. Guzas, NUWC Newport

A basic study is conducted to examine the differences between free-field and confined implosion when initiated by a nearby underwater explosion (UNDEX). A simple test case is developed, derived from an actual implosion experiment. Simulations of the test case are created by modifying the validated simulation of the experiment. Multiple simulation cases are created with the same implodable volume within different sized confining structures. Simple metrics are used to describe the level of confinement, which is then related to the resulting implosion. Results of the study show that the confining structure exhibits two effects that mitigate the UNDEX initiated implosion. First, the confining tube tends to shield the implodable volume from the UNDEX shock wave by reducing the pressure transmitted through the structure wall (even though it is water-backed). Second, the confining structure tends to starve the implosion, since there is limited water volume within the structure to drive the collapse.

SESSION 15: STRUCTURAL RESPONSE

USING BISPECTRAL ANALYSIS TO DETECT THE ONSET OF FATIGUE DAMAGE IN RANDOMLY EXCITED STRUCTURES

Dr. Carl Sisemore, Sandia National Laboratories
Dr. Vit Babuška, Sandia National Laboratories

When structures are excited using random vibration, the input excitation is traditionally Gaussian. If the structure is reasonably linear, the output will also be Gaussian or nearly Gaussian. In contrast, the introduction of damage into the structure, such as fatigue cracks, will result in a shift away from a linear response to a more non-linear, and hence non-Gaussian response. The bispectrum is a third-order spectrum that has unique properties that lend itself to the detection of non-Gaussian signals buried within Gaussian random excitation. This paper will present the results of experimental fatigue testing using random excitation along with the bispectral analysis of the response data. The results show the onset and progression of fatigue damage in simple structures.

2D-FE AND 2DOF SIMULATIONS OF GROUND SHOCK EXPERIMENTS – TOTAL STRUCTURE'S SPRING DEFLECTION ENERGY DEPENDENCY TO THE CHARGE´S AND STRUCTURE´S PROPERTIES

Dr. Leo Laine, LL Engineering AB
Dr. Morgan Johansson, Norconsult AB
Mr. Ola Pramm Larsen, CAEwiz Consulting AS

The aim for these studies is to find a methodology that can use simplified relationships for ground shock prediction, from e.g. ConWep, in combination with simplified models such as two-degree-of-freedom model (2DOF), to predict the structural response of e.g. a buried concrete wall.

This paper analyses, by using 2D axial symmetry Finite Element (FE) with Autodyn, the structural response of a well-defined structure; a suspended piston-spring system buried in sand subjected to ground shock from an explosive charge. The parameters varied in the simulations were charge size, charge distance, reflection area of the piston, piston mass, and spring stiffness. Earlier experiments from the 1980s, conducted by S. Hultgren, Swedish Fortifications, showed that the reflection pressure over time was dependent on the mass and stiffness of the structure. Here, more parameters were varied in simulations to see how well a 2DOF can capture the main behaviour of the structural response. The reflected pressure time history dependency on piston mass and spring stiffness has be confirmed by using 2DOF in earlier studies presented at SAVIAC 86, 87, and 88.

In this paper the focus is on what main parameters influence the total spring deflection energy. If the results are visualised in a 3D plot with coefficient of variation, the ratio of standard deviation and mean value, of the maximum spring energy in z-direction and the scaled charge distance and variation of piston area in x-, and y-directions, then the coefficient of variation maximum is 0.8, i.e. 80%, if one studies all results of the spring stiffness and piston mass variations. However, if the 3D plot was made for each spring stiffness 0.1 MN/m, 0.5 MN/m, and 1.2 MN/m, only study variation in mass results. This leads to that the coefficient of variation maximum drops down to 0.08, i.e. 8%, 0.025, i.e. 2.5%, and 0.03, i.e. 3.0%, respectively. This indicates that the influence of piston mass on the maximum spring energy is marginal, but the spring stiffness is important for the total spring energy during ground shock. This is also confirmed in 2D-FE simulation results where the particle velocity plots of the soil indicate that the flow of soil intensifies towards piston direction when spring stiffness value is decreased and that the moving ground shock finds the least resistant path from the detonation centre. The aim is to derive a simplified model for calculating maximum spring energy and spring deflection.

VENDOR SESSION C

THINGS TO CONSIDER WHEN CHOOSING A HIGH SPEED CAMERA
Mr. Tim Callenbach, Photron

High-speed imaging provides engineers with the video data necessary to perform detailed analysis of shock and vibration. There are a number of companies that manufacture high-speed cameras, so how do you know which model of camera to purchase? As Photron will discuss, there are many different factors to consider when procuring a high-speed camera, including necessary frame rate, resolutions, light sensitivity and a more.

MULTI SHAKER VIBRATION TESTING
Mr. Kevin McIntosh, Data Physics
Mr. Thomas Reilly, Data Physics

Data Physics and Team Corporation will make a presentation of recent advances in hardware and software technology for multi-shaker vibration testing. This will include multi-shaker single axis testing and multi-shaker multi-axis testing. Several examples of implementation of these technologies will be presented.

A NOVEL MECHANICALL ISOLATED, ELECTRICALLY FILTERED TRIAXIAL SHOCK ACCELEROMETER
Ms. Melissa Maze, PCB Piezotronics

A new series of piezoelectric, case isolated ICP® triaxial shock accelerometers are being introduced that are mechanically isolated, electrically filtered and hermetically sealed for harsh environments such as pyroshock. Compared to three independent shock accelerometers mounted on a tiaxial block, the new accelerometers bring the coordinate system closer to the mounting location, making for a better data quality and survivability for out-of-plane measurements.

Piezoelectric ICP® accelerometers afford a very high signal output (+/- 5 volts full scale) and the ease of two-wire electrical connectivity. Their inherent ruggedness enables them to be severely over ranged without damage. The addition of internal mechanical isolation minimizes the high frequency stress that would otherwise be encountered by their ceramic sensing elements. This mechanical isolation, coupled with an internal 2-pole electrical filter, built into the ICP® circuitry, tailors the overall accelerometer response to assure data quality to frequencies as high as 10 kHz. Depending on the specific model, accelerations up to 100 kg can be successfully measured. These modern designs, with their internal elastomeric isolation materials are verified through calibration to remain dynamically linear and are enabling piezoelectric accelerometers to operate in increasingly severe acceleration environments.

INTRODUCTION TO LASER DOPPLER VIBROMETRY – A NON-CONTACT VIBRATION MEASUREMENT TECHNIQUE
Mr. Vikrant Palan

Laser Doppler vibrometry has come a long way since its conception in the early 1970s. It is now widely used for non-evasive vibration characterization of micro, macro and meso scale structures. A laser

Doppler vibrometer (LDV) is a non-contact, laser-based vibration sensor. The non-contact nature, sub-picometer resolution and GHz frequency band-width lends itself well to applications in broad range of frequency and amplitude ranges. Stand-off distances of few mm to several meters is also an attractive feature, especially for shock and vibration community. The presentation will begin with the principle of laser Doppler vibrometry and explain the different types of vibrometers currently being used in the industry. The presentation will also include application based case studies.

UNDERSTANDING THE COMPONENTS OF A VIBRATION CONTROL SYSTEM – THE EXCITER, COOLING BLOWER, APLIFIER, FIXTURE, SENSOR, AND CONTROLLER AND HOW THEY INTERACT TO COMPLETE A VIBRATION TEST

Mr. Steven Wood, Spectral Dynamics

Often the vibration test is defined without an understanding of how the components of a vibration test system work together to properly deliver a vibration test that meets a customer's test specification. This presentation will discuss each part of the vibration test system and how it works with the other components to accomplish a good vibration test; and also point out issues that can arise with the components that could compromise a test.

SESSION 16: INSTRUMENTATION

DYNAMIC CALIBRATION OF PRESSURE TRANSDUCERS WITH SINUSOIDAL EXCITATION

Mr. Michael Mende, SPEKTRA
Mr. Thomas Platte, SPEKTRA
Mr. Martin Iwanczik, SPEKTRA

Pressure transducers are frequently used in dynamic environments such as combustion engines or aerospace applications. Like for every measurement task it is essential to know the uncertainty of the obtained measurement result, even in a dynamic environment. But most pressure sensors are only calibrated by static calibration methods. So the frequency response of the transducer and the uncertainty for the dynamic measurement result cannot be quantified.

This problem arises, because no national standard or traceability for the physical quantity “dynamic pressure” exists. Due to this lack of investigation methods the author has made an effort to develop a primary method to calibrate pressure transducers dynamically by means of sine excitation.

The exciter is a new developed pistonphone like apparatus with a piezo electrical drive. This exciter allows to measure the frequency response of a pressure transducer with sufficient dynamic pressure amplitudes up to 1.2 MPa. Due to the construction of the pressure generator frequencies up to 10 kHz can be reached.

Compared to the paper that was presented last year regarding this topic, the latest design of the developed apparatus will be shown and the new technical data will be explained. Further a new developed calibration technic will be presented. This pressure calibration method is based on laser interferometer measurements, which measure the movement of the piston. The working principle and the traceability of this calibration approach will be discussed. Additionally the first investigated measurement uncertainties will be outlined. This includes thermodynamically effects and oscillation modes of the exciter.

Shock Accelerometer Calibration and Performance Surety at the Manufacturer's Facility

Mr. David Ort, PCB Piezotronics

When an accelerometer is designed and manufactured there are three categories of testing that are performed. The first category is model qualification. When a sensor is initially designed, a statistically relevant number of sensors are tested to validate all quantifiable specifications. To ensure ongoing process control, additional sensors of this same model may have their specifications periodically recertified. The second category is sensor calibration. Calibration involves re-testing key specifications and supplying the results that match that specific sensor to the customer. Examples of key specifications included in the calibration process are acceleration sensitivity and frequency response. The last category is acceptance tests that are specifically designed to ensure shock measurement quality in the field. These tests extend beyond the sensor specifications and can include things such as examination of signal integrity and stability through complex shock application. This paper encompasses the preceding testing categories, which are all required to ensure quality sensor performance.

Zero Shift and Low Frequency Offset: Sensor or System Problem?

Mr. Anthony Agnello, PCB Piezotronics
Dr. Patrick L. Walter, Professor Emeritus Texas Christian University / PCB Piezotronics

After an important pyroshock test where offset in the low frequency Shock Response Spectra (SRS) has occurred, it is not unusual that the computed SRS's are sent to an accelerometer manufacturer with a comment such as: "I expected better performance than this?" This judgement is typically based on low frequency disagreement between the computed positive and negative SRS, along with an associated slope that doesn't fall within the expected 6 to 12 dB/octave attenuation rate. The faulty SRS data is typically accompanied by integrals of the associated acceleration-time records that do not terminate at or near zero. This inability to integrate to zero is an indication of offset in the data, and the accelerometer's performance is typically indicted as the culprit. Mathematics show that offsets in the acceleration-time records disproportionately impact the low frequency portion of the SRS, but to what extent?

This paper takes several data sets that were returned to the accelerometer manufacturer due to suspected performance "flaws". In each instance an overly simplified series of straight-line corrections were applied to the velocity slope of the data set enabling an approximation of the magnitude of the offset issues. The offsets are shown to be very small enabling one to query where, aside from the accelerometer, these offsets can originate?

Ruggedized High-Shock, Undamped Accelerometer with Strengthened, Low-Noise Cable

Mr. James Nelson, Meggitt Sensing Systems

The Endevco Model 7270A undamped accelerometer is an industry standard for high-shock measurements. The new 7270AM7, released in 2018, includes several features to improve reliability. The new, larger 34AWG cable has a low-noise treatment, demonstrating significant improvement in noise performance over the base 7270A cable. This model also includes shrink tubing on the cable at the housing interface for added protection against cable shear. A detailed overview of the new 7270AM7 will be presented, as well as shock, vibration, and temperature test results for both the new 7270AM7 and the base model 7270A.

SESSION 17: PROJECTILE MODELING, SIMULATION, & TESTING

NOVEL LIGHTWEIGHT SYSTEM TO RESIST HIGH-VELOCITY PENETRATORS

Dr. David Stevens, Protection Engineering Consultants
Mr. Eddie O'Hare, Protection Engineering Consultants
Mr. Matt Barsotti, Protection Engineering Consultants
Dr. Michael Oesterle, NAVFAC EXWC
Mr. Brad Durant, NAVFAC EXWC
Mr. Mike Newberry, Syscom
Mr. Preston Reed, Jacobs Technology
Mr. Casey O'Laughlin, Jacobs Technology

Military facilities and structures are often hardened against vertically oriented, high velocity penetrators. There are tradeoffs in the hardening requirements where cost and level of protection are balanced. Structures that house high value assets have the most stringent hardening requirements and larger costs are justified. General civil structures also require hardening and the cost/benefit ratio must be carefully considered.

Structures designed to resist penetrator threats are often placed underground with layers of boulder, concrete slabs, and sand but this is not feasible for general civil structures. Instead, mitigation methods are placed on top of the structures and employ different techniques to induce yaw and/or pitch in the penetrator. These systems typically employ both mitigation panels and catcher slabs, which deflect, stop, and contain detonation of incoming penetrators. Numerous research efforts have been performed to determine the most efficient type of mitigation panel strategies; these include precast concrete sections to create a slanted roof, barrel vaults, inverted barrel vaults, combo barrel vaults, precast pipes, piles, pelican stools, hollow tetrahedrons, tribars, dolos, hollow core precast panels, anisotropic concrete panels (slanted embedded steel plates) and slanted mitigation panels made out of concrete and steel sections. However, there is a continued need to develop cost-effective layered solutions that are suitable for general civil structures.

The Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC) and Protection Engineering Consultants (PEC) have developed and demonstrated a new overhead protection scheme that employs pressurized pipes to induce yaw and pitch in the penetrator. Numerical simulations of the concept were performed and showed significant ability to re-direct the penetrator. Jacobs Technology then led an effort to verify the overhead protection scheme through a series of fourteen small-scale tests performed at the Air Force Civil Engineering Center (AFCEC) Sky X Test Range at Tyndall AFB, FL. Numerical simulations were performed using the measured small-scale penetrator position, velocity and orientation right before impact as the initial conditions and the numerical results showed excellent agreement with the test data and videos.

DEVELOPMENT OF PROTECTIVE SYSTEM FOR DEFEAT OF HIGH-VELOCITY PROJECTILES

Dr. Michael Oesterle, NAVFAC EXWC
Mr. Brad Durant, NAVFAC EXWC
Mr. Joseph Magallanes, Karagozian and Case
Mr. Brian Dunn, Karagozian and Case

The defeat of high-velocity projectiles poses a significant challenge to engineers due to the considerable levels of kinetic energy involved and ability of advanced weapons to tunnel effectively through hardened construction materials. Protection of personnel and critical infrastructure from such threats has historically been achieved through the use of massive layers of concrete and soil. However, the ability to accurately simulate projectile impact event s using high-fidelity physics-based models provides the opportunity to design thinner and lighter solutions through optimization of various hardened construction layers. Naval Facilities Command (NAVFAC) Engineering and Expeditionary Warfare Center (EXWC) developed multi-layered hardening concepts for projectile defeat through the use of computational models which are capable of capturing the complex material responses associated with high-velocity impact. To validate the concept, EXWC collaborated with U.S. Army Engineer Research and Development Center (ERDC) to conduct an experimental test program involving several different configurations of layered hardening systems at a laboratory scale. The test series was supported by pre-test predictive simulations performed by EXWC, and the experimental results were utilized to improve the computational models. The combined effort of experimental research and modeling was successful in producing high-velocity projectile defeat solutions which are lighter and less costly than previously used systems.

EVALUATION OF SYSTEMS FOR DEFEAT OF HIGH-VELOCITY PROJECTILES FOR FACILITY PROTECTION

Mr. Ernesto Cruz-Gutierrez, US Army Engineer Research and Development Center
Ms. Amie Burroughs, US Army Engineer Research and Development Center
Mr. Brandon Everett, US Army Engineer Research and Development Center
Mr. Ray Moxley, US Army Engineer Research and Development Center

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 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.

DYNAMIC STRAIN EFFECTS IN COMPOSITE OVERWRAPPED GUN TUBES

Dr. Andrew Littlefield, US Army ARDEC
Dr. Michael Macri, US Army ARDEC

When a projectile moves down a gun bore it sends a strain wave ahead of it through the wall of the gun tube. As projectile speed increases the speed of this wave increases and can increase greatly over static predictions because the wall material cannot deform fast enough. In thin wall tubes this can lead to the failure of the gun tube. This phenomena is called dynamic strain and the speed at which the strain increases asymptotically is called the critical velocity. For steel gun tubes this phenomena is well

understood and analytical solutions were developed in the 1980's. It has been observed that an orthotropic jacket on the tube can greatly reduce this effect. Work was done in the 1990's and early 2000's to find analytical solution but resulted in two different solutions. Both of these solutions looked at the aggregate orthotropic properties but not any lower scales. It is theorized that some of the reduction in strains is due to the wave needing to pass through multiple interfaces. This work harmonizes the previous analytical solutions and develops a numerical one utilizing multi-scale modeling. By using multiscale modeling the effect of individual ply boundaries will be investigated and then extended down to fiber boundaries. The effect of adding nano-materials to the composite will then be investigated. The final goal is to present a method for designing a composite overwrap that is both structural and dampens the dynamic strains.

SESSION 18: MATERIAL BEHAVIOR II

ESTABLISHING CRACK INITIATION OFF PLUNGE EDM FLAWS IN SUPPORT OF HYDRAULIC FATIGUE TESTING

Mr. Lucas Smith, US ARMY ARDEC

Benét Laboratories regularly conducts hydraulic fatigue testing in order to establish a safe fatigue life on Cannons and Artillery as described in International Test Operations Procedure (ITOP) 3-2-829. One of the prerequisites for hydraulic testing is the presence of heat-check checking, before the test specimen can be evaluated in the laboratory.

For the case of thin walled pressure vessels, there is not sufficient firing data available to support the necessary heat-check cracking evaluation that is required before a hydraulic fatigue test is performed. A specific Testing and Operations Procedure (TOP) does not exist for the thin walled weapon systems. In support of establishing a method for evaluating initial bore damage, plunge EDM flaws were machined into thin walled pressure vessels to a known size to simulate heat-check cracking. The plunge EDM flaws were machined to sizes that could be identified with Non Destructive Testing (NDT). Crack propagation gages were utilized adjacent to the plunge EDM flaws and monitored during testing to isolate the point at which cracks initiated from the EDM flaw.

INTERMEDIATE STRAIN RATE TENSILE TESTING AND ANALYSIS OF ELASTOMERIC MATERIAL COUPONS

Mrs. Rebecca Grisso, NSWC Carderock Divison

Presentation of the work performed to capture and utilize shock-like strain rate tensile data for elastomeric materials relevant to the Navy. Lessons learned in finding an appropriate test apparatus, development of a test procedure, and adaptation to accommodate various materials are presented. Next, a discussion on data processing and comparison to equivalent static test data is presented. Finally, efforts to develop and exercise hyperplastic material models based on recorded test data are summarized.

SHELL MODEL OF DYNAMICALLY CRUSHED BISECTED HONEYCOMB STRUCTURE

Mr. Morris Berman, US Army ARDEC

A bisected aluminum honeycomb structure was modeled using an explicit formulation finite element code. The honeycomb material was Alcore Higrid with a density of 55 lb/ft^3. A fully integrated shell element formulation was utilized to model the dynamic crushing behavior of the structure. A submodel with symmetry boundary conditions was crushed axially. The crush behavior was compared to experiments to validate the modeling results.

TESTING OF METALS AT STRAIN RATES TO 10^7 S^{-1} USING HIGH ENERGY, PULSED LASERS

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

Explosions and high-velocity impacts can create strain rates on the order of 107-s-1 or higher in metallic materials. To simulate these events, first-principles codes require material models that are valid at these loading rates, for predictions of fracture and fragmentation. The amount of test data, material models and material constants for strain rates larger than 105-s−1 is extremely limited, and very expensive to obtain so an innovative and cost-effective laboratory test procedure is needed.

Protection Engineering Consultants (PEC) and Southwest Research Institute® (SwRI®) are addressing this need through development and testing of a novel high-rate and cost-effective laboratory test procedure that utilizes high-energy nanosecond pulsed lasers to generate strong and short duration shock waves within solid materials. The target set of material properties includes equation of state, spall-failure stress, and flow stress as a function of strain rate.

The experimental technique utilizes a laser to generate shock waves by superheating the surface of thin foil materials. This heating ablates the material and turns it into a high-pressure plasma. This plasma either directly generates a shock wave on a target or accelerates a flyer that impacts a target and generates shock waves in flyer and target.

High rate loading experiments have been conducted on aluminum materials using three different test configurations. The experiments successfully produced high strain rates in excess of 107-s-1. Multiple material properties were measured during the experiments, including the strain rate, maximum particle velocity, penetration velocity, shock velocity, and the Hugoniot Elastic Limit (HEL). The testing provided an excellent proof-of-concept demonstration for this platform, which is simpler, less-expensive, and faster to execute than alternative high rate testing methods, such as two stage light gas guns. The laser-based testing approach is being extended in an ongoing effort, to provide a complete suite of properties across a wide range of test velocities.

SESSION 19: COMPUTATIONAL MODELING FOR DESIGN AND OPTIMIZATION OF STRUCTURES TO RESIST ADVANCED THREATS

MODELING COMBINED BLAST AND FRAGMENT LOADING FROM DETONATION THOUGH STRUCTURE INTERACTION

Mr. Andrew Barnes, U.S. Army Engineer Research and Development Center
Dr. James O'Daniel, U.S. Army Engineer Research and Development Center

Accurate predictions of the threat environment and associated response of structures to that environment are critical to the design of protective structures. Recent work performed by the U.S. Army Engineer Research and Development Center (ERDC) has focused on modeling threat scenarios from initiation of fragmenting munitions through the response of structural elements subjected to the combined blast and fragment loadings produced by the detonation event. A threat scenario can be broadly divided into three major components based on differing length scales of the events: detonation of the threat, propagation and subsequent impingement of the generated blast and fragments onto a structure, and structural response of the target. Due to the distinct length and time scales of interest for each of those components, a single end-to-end simulation of the entire process would be computationally prohibitive for scenarios with large standoffs. Instead, each component requires its own computational approach and development of external algorithms to gather the requisite information from the outputs of one component to be used as inputs to the following component.

This presentation will discuss how combinations of the computational codes ALE3D, Zapotec, and CTH were used to adequately capture the relevant phenomena of a threat scenario. In order to validate the approach used, each component was benchmarked against experimental data. The fragment environment was benchmarked against the spatial and velocity distributions measured in a munition characterization arena experiment. The blast environment was benchmarked against pressure-time histories measured after detonation of subscale cased and uncased munitions on a blast pad. Finally, the subsequent structural response to the generated fragments and blast was benchmarked against a full-scale arena test which included representative structural elements.

COMPUTATIONAL MODELING OF IMPACT AND DEPTH OF PENETRATION EXPERIMENTS ON PAM-35 CONCRETE SPECIMEN

Dr. William Lawrimore, US Army Engineer Research and Development Center
Mr. Robert S. Browning, US Army Engineer Research and Development Center
Mr. Andrew T. Barnes, US Army Engineer Research and Development Center
Mr. Jared L. Brown, US Army Engineer Research and Development Center
Dr. Jim L. O'Daniel, US Army Engineer Research and Development Center

Even though research has been ongoing into high strength concretes for many years, most installations are still being built with conventional concrete. In order to push the use of high strength concrete, current standards need to be extended to include performance metrics for high strength concrete. Toward that goal, impact and Depth of Penetration (DOP) experiments have been conducted on PAM-35 cylindrical targets. A variety of target diameters and thicknesses were struck by 0.5 in. diameter ball bearings at a variety of impact velocities. Meshes for the targets and the projectiles were built using TrueGrid and imported into ParaDyn for finite element analysis. Results from the simulations were compared to those from the experiments to determine the predictive capacity of the simulation methodology.

PREDICTING POST-BLAST RESIDUAL CAPACITY OF REINFORCED CONCRETE STRUCTURES USING THE ADVANCED FUNDAMENTAL CONCRETE (AFC) MODEL IN ABAQUS AND SIERRA

Mr. Andrew Groeneveld, US Army Engineer Research and Development Center
Mr. Robert Browning, US Army Engineer Research and Development Center
Dr. Wes Trim, US Army Engineer Research and Development Center

Abstract not available.

Parametric Analysis and Design Optimization of Reinforced Concrete Slabs under Advanced Threats

Mr. Jose Rullan-Rodriguez, US Army Engineer Research and Development Center
Dr. William B. Lawrimore US Army Engineer Research and Development Center
Mr. Robert S. Browning, US Army Engineer Research and Development Center
Mr. Andrew T. Barnes, US Army Engineer Research and Development Center

The U.S. Army relies heavily on reinforced concrete structures to protect personnel and equipment from advanced threats. Ensuring that the design of a concrete structure is optimal for an application and threat can be very challenging due to the wide range of variability of the respective parameters. Because of this, the U.S. Army Engineer Research and Development Center (ERDC) is developing a methodology for parametric analysis and optimization of reinforced concrete slabs subjected to advanced threats, such as blast loads and combined blast and fragment loads. Historically, a design would be constructed via hand calculations and then checked using a small number of finite element (FE) analyses. However, the FE modeling did not provide any insight as to whether the design was optimal. To answer this question, many FE models must be run where parameters in the model can be varied intelligently to study the resulting effects on the structural response. This necessitated the use of a workflow manager and optimization software. A relatively new product offered on the Department of Defense supercomputers is a software developed by Stellar Science called Galaxy. It is a workflow manager and contains Dakota, an optimization software from Sandia National Laboratory (SNL). A custom program was developed at ERDC using the open source programming language Julia to construct the mesh of a reinforced concrete slab. This enabled the entire model (material properties, reinforcement size and spacing, slab thickness, etc.) to be optimized inside of a Galaxy/Dakota routine. The finite element code Sierra (also from SNL) was used to perform the simulations. While this process is still being refined, it is expected that this approach will be very applicable to a wide range of problems and will enable analysts to move away from single deterministic solutions and begin to provide more optimal designs and sophisticated answers for complex problems.

VENDOR SESSION D

Dynamic Measurement Calibration Equipment

Mr. Michael Mende, SPEKTRA
Mr. Bruce Swanson, SPEKTRA

Abstract not available.

Case Study of a 6 Degree-of-Freedom Isolation System in a Shock and Vibration Environment Including Analysis, Design & Field Measurement of System Performance

Mr. John Metzer, Taylor Devices
Mr. Alan Klembczyk, Taylor Devices

Abstract not available.

USING THE SAME WIRE ROPE ISOLATORS FOR THE 8HZ AND 14HZ SHOCK TESTING PLATFORM
Mr. Claude Prost, Vibro/Dynamics
Mr. Josh Partyka, Vibro/Dynamics

The Socitec Group is continuously looking to better serve the market. This can be in the form of new products, such as the recently introduced WRI made from 2” diameter cable, whose development was detailed in a separate technical article for this year’s symposium. This can also be done through the review of application practices in order to ensure the customer is provided the best possible solution.

Using SYMOS, the Socitec Group’s proprietary shock and vibration simulation software suite, the selection process for the DSSM and FSP can be streamlined, allowing for efficient consideration of different application techniques to fit each customer’s requirements. In this case, the possibility of using the same wire rope isolator solution for both the 8 Hz and 14 Hz testing platforms is reviewed, including discussion of the effects of taking such an application approach.

ENDAQ PLATFORM EVOLVES TO MEET CONSUMER TRENDS IN TEST & MEASUREMENT
Mr. Steve Hanly (Mide Technologies)

Abstract not available.

SESSION 20: SHOCK TESTING

APPLICATION OF SHOCK EVALUATION PARAMETERS TO ENCANISTERED MISSILE SHOCK APPLICATIONS
Mr. Kenneth Lussky, BAE Systems

This paper addresses how shock evaluation parameters are used in real world applications for missiles and canisters. Shock evaluation parameters of peak velocity, peak acceleration, average acceleration, acceleration Shock Response Spectra (SRS), pseudo velocity shock spectra (PVSS), and peak displacement are defined. Examples are given for how these shock evaluation parameters are applied to encanistered missile shock evaluation applications of shock input for a tailored qualification test, shock extension of components, shock qualification of components, and comparison of diverse shock environments. This paper is a discussion of the application of these shock evaluation parameters; it is not a theoretical discussion of the merits of the individual parameters. The use of these parameters in the missile and canister applications discussed has been accepted by SEA 05P, though SEA 05P has not reviewed or approved this paper.

DATA ANALYTICS AND POTENTIAL FUTURE UNDEX QUALIFICATION PROCESSES
Dr. Jeff Cipolla, Weidlinger Technology Ventures
Mr. Fred Costanzo, Weidlinger Technology Ventures
Dr. Juan Londono, Thornton Tomasetti
Mr. Addison Martin, Thornton Tomasetti

The Navy experiences considerable cost and schedule pressures in all of its shipbuilding programs. The necessity to qualify shipboard items for UNDEX, while essential to the warfighter mission, add to these costs and delays. Consequently, the Navy would like to ‘qualify by extension’ (QBE), i.e. without testing or extensive simulations, as many shipboard items as possible, without compromising the quality of

outcome. In this talk, we will discuss application of data analytic methods to modernize this process, improving fidelity and robustness while minimizing risk of QBE.

Currently, per NAVSEA MIL-S-901D and related specifications, QBE reviews entail the evaluation of similarities and differences between a candidate item and a single item of previously tested and shock-qualified equipment. This process is highly labor intensive. The 901D-type processes currently are also 'manual', in that both the 'user' (vendor/shipyard proposing a qualification) and the reviewer must apply rules by following various written guidelines.

Automation of the 901D-type processes – from simple queries through review and qualification – remains impossible because of the lack of a suitable data structure for UNDEX qualification information. More to the point of this work, the 901D-type processes themselves are constrained to remain within the strictures implicit in a paper-based, manual process, because of the lack of suitable data backbone and associated data analytic framework.

CALIBRATION OF PADDLEWHEEL TEST VEHICLE (PWTV) FOR SHOCK TESTING MEDIUM SIZE PENETRATIONS

Mr. Timothy McGee, NAVSEA
Mr. Jacob Mason, NSWC Carderock
Ms. Anna Bethel, NSWC Carderock

A calibration test series on the Paddlewheel Test Vehicle (PWTV) was conducted in November and December 2017 to investigate expansion of PWTV test specimen weight and size limits. This presentation provides details for the set-up, execution, and results of this calibration test series. This test review will include an overview of the specimen weight configurations, test setup, results of the test series and path forward.

USING THE DSSM IN ACCORDANCE WITH MIL-DTL-901E

Dr. Michael Talley, HII - Newport News Shipbuilding

This brief describes: 1) the DSSM referenced in MIL-DTL-901E; 2) how the DSSM works; 3) what class of deck mounted equipment can be tested in the DSSM; 4) mount system and deck frequency requirements; 5) how to specify the equipment mounting plane and orientation in Ship; 6) how to specify the equipment "shipboard" test orientation in DSSM; 7) how DSSM spring trays are configured; 8) what spring trays and drop heights are required; 9) how to get shock qualification approval of DSSM Tests; and 10) Type B and C tests in the DSSM.

TEST AND EXTENSION METHODS FOR SUBSIDIARY COMPONENTS INSTALLED IN NAVY-APPROVED PHYSICAL OPEN ARCHITECTURE ENCLOSURES

Ms. Lisa McGrath, HII - Newport News Shipbuilding

Physical Open Architecture (POA) utilizes standardized designs and architectures for hosting COTS equipment, developmental electronics, and electrical items in common equipment enclosures that successfully meet U.S. Navy environmental qualification requirements for Shock, Vibration, and Electromagnetic Interference (EMI). The POA program at Newport News Shipbuilding (NNS) has developed and received Navy approval for a 73" x 32" x 24" standardized shock isolated enclosure that can be installed as a single, standalone enclosure, or can be ganged together with other enclosures to create a multi-pack. Per MIL-DTL-901E definitions, the equipment hosted in these enclosures are defined as subsidiary components. NNS developed a standardized fixture for subsidiary component testing of equipment hosted in the standardized enclosures called the Shock Mounted Standardized Enclosure (SMSE). The SMSE is used on the vibration shaker table as a test fixture for subsidiary component vibration testing, and on the Deck Simulating Shock Machine (DSSM) as a test fixture for subsidiary component shock testing.

This paper describes the methods for testing subsidiary components that will be installed in Navy-approved, shock isolated, POA enclosures. A brief background of the POA design and qualification process is provided, along with descriptions of current Navy-approved enclosures. The Navy-approved standardized subsidiary component test fixture, the SMSE, is described in detail. Test methods for using the SMSE fixture for vibration and shock testing are provided. Subsidiary test criteria for SMSE vibration and shock testing is discussed in detail, and step-by-step instructions are given for executing the tests, including details on how to evaluate test data during the test. Additionally, details on how to document testing and process extensions for POA principal units are provided.

SESSION 21: VIBRATION II

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 consisting of interlinked 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.

COMBINED ELECTROMAGNETIC-MECHANICAL ENVIRONMENTS: TESTING AND ANALYSIS

Dr. Brian Owens, Sandia National Laboratories
Dr. Richard A. Jepsen, Sandia National Laboratories
Dr. Isak C. Reines, Sandia National Laboratories
Dr. Rebecca S. Coats, Sandia National Laboratories
Dr. Larry K. Warne, Sandia National Laboratories
Dr. Jeffery T. Williams, Sandia National Laboratories
Mr. Roy K. Gutierrez, Sandia National Laboratories
Mr. Jonel Ortiz, Sandia National Laboratories

Aerospace systems and components are designed and qualified against several operational environments. Some of these environments are climatic, mechanical, and electrical in nature. Traditionally, experimental and analytical capabilities are derived with the goal of qualifying a system or component to a suite of independent environments in series. True operational environments, however, are composed of complex, combined events and this should be considered in the development of design and qualification capabilities.

Vibration and electromagnetic radiation are both continuous environments and for many aerospace systems, a combined electromagnetic-vibration environment is a credible scenario. It is well known that electromagnetic shielding effectiveness is sensitive to gaps at joints/material interfaces and assembly tolerances are often considered in the design and qualification of systems under electromagnetic environments. Mechanical vibration, however, excites structural modes and can result in deformation at interfaces which can dynamically alter the shielding effectiveness of a system. Furthermore, structural deformation alters the geometry of internal cavities, thereby altering the internal electromagnetic modes of a system.

This work examines the development of new test and analysis capabilities to consider combined electromagnetic-mechanical environments. Electromagnetic-mechanical coupling is demonstrated using a custom experimental capability for considering stimulus under combined electromagnetic and vibration environments. Analytical methods for considering coupled electromagnetic-mechanical response have been developed and will also be discussed. These analytical and experimental methods are demonstrated on a research test article, and lessons learned will be presented.

A DATA-DRIVEN APPROACH TO ENVIRONMENTAL TESTING

Mr. Timothy Devine, Virginia Tech
Dr. Sriram Malladi, Virginia Tech
Dr. Pablo Tarazaga, Virginia Tech

Environmental testing aims to replicate, as closely as possible, field test conditions in a laboratory environment. Appropriately simulating testing conditions of sensitive equipment is crucial for the certification of equipment for field deployment. Recreating the operation environment in a lab can be difficult due to complex boundary conditions and unknown force inputs to the device under test. Presently, vibration controllers exist that are capable of using feedback techniques to recreate environmental conditions or prescribed certification requirements for single-input single-output systems, however such systems can be expensive. Furthermore, developing these controllers to be capable of optimizing multi-axial vibration testing is an active research effort.

The present work utilizes a data-driven modeling approach to reconstruct inputs to a dynamic system given a desired output response. Data-driven models have the potential to accurately represent the dynamic response of a system in complex and unknown boundary conditions. In contrast, an analytical or finite-element models have difficulties in the absence of accurate knowledge of the boundary and excitation conditions that determine the dynamics of the structure under test. The data-driven model is based on a vector fitting algorithm that obtains a state-space representation of the dynamic system with measured responses. The resulting multi-input multi-output (MIMO) dynamic model can be used to determine the optimal excitation locations based on simulations using such model.

Video Motion Amplification Vs. Operating Deflection Shapes for Vibration-Based Diagonsis of Machinery

Mr. Andrew Lerche, Mechanical Solutions, Inc.
Mr. William Marscher, Mechanical Solutions, Inc.
Mr. Maki Onari, Mechanical Solutions, Inc.
Mr. Eric Olson, Mechanical Solutions, Inc.

Operating Deflection Shapes (ODS) has been an important tool in visualizing the vibration of the machine and its system, including piping networks. The input for ODS is the phase-linked signal set from a group of accelerometers, often moved over hundreds of test points. The data is superimposed onto a CAD model, and then scaled-up vibrations are animated at frequencies of interest. This process is time-consuming and therefore expensive each time it is applied by experts, and is error-prone. An alternative method has been developed that is based on the evaluation and processing of high resolution/ high speed videos. The method provides information equivalent to a high-sensor-count ODS, by treating each pixel as an accelerometer, using the pixel's light intensity modulation to translate information embedded in the video into vibration motion able to be observed and interpreted by human investigators.

Improved Vibration Control Strategy Allowing the Replication of Operational Dynamic Environments at Component Level Testing

Mr. Umberto Musella, Siemens Industry Software
Mr. Mariano Alvarez Blanco, Siemens Industry Software
Dr. Bart Peeters, Siemens Industry Software

Recent research stressed out the limitations of current practices on component level environmental vibration testing. These limitations are typically associated with impedance mismatch due to differences between the operational and the test boundary conditions. General concern is that the real failure modes of the component are not correctly replicated, and more information might be needed to define a representative test practice. Does the current testing practice provide sufficient information? Is there a way to overcome the impedance mismatch between operational conditions and the test configuration by mean of simulations and adequate control strategy for environmental tests? This work presents recent results of an intensive test campaign performed on the Box Assembly with Removable Component (BARC). Multiple-Input Multiple-Output Random control and Time Waveform Replication results reveal to be promising technologies to pursue an advanced testing practice with the objective of accurately replicating operational dynamic environments for failure modes identification.

SESSION 22: SHOCK PREDICTION & SHOCK RESPONSE SPECTRUM (SRS)

USING RECORDED DATA TO IMPROVE SRS TEST DEVELOPMENT

Mr. Joel Minderhoud, Vibration Research
Mr. Caleb Chamberlain, Vibration Research

Shock Response Spectra (SRS) testing uses a synthesized pulse to drive a shaker, simulating a transient event. Originally developed to replicate Seismic shocks, the SRS approach is also widely used for defense and aerospace applications.

Engineers can implement a variety of synthetic waveform methods to create an SRS pulse, with the best choice depending on the application. For example, the Burst Random and Enveloped Burst Random methods produce long duration stationary random waveforms that work well in earthquake simulation tests. However, often there is no synthetic waveform that perfectly matches a real world transient event; engineers need a better, more realistic way to create an SRS test.

This presentation focuses on a unique approach, where the actual recorded field environment can be modified to meet or exceed a specified SRS. This provides a time waveform similar to the original field environment and, more importantly, it has the same frequency response function as the original field environment.

The session will first introduce the basic concepts of SRS, then step thru the details involved in using this new method with currently available software tools. Attendees will learn how to create analyze recordings and then generate an SRS test based on the compilation of field environments.

The final section of the presentation will compare an Enveloped Environment SRS waveform with various standard synthetic waveforms. The visual evidence makes a compelling case for the new approach.

DERIVATION OF SHAKER SHOCK INPUT OF AN OSCILLATORY DECAYING SHOCK TO OPTIMIZE HIGH FREQUENCY SRS "FLATLINE"

Mr. Chad Heitman, Sandia National Laboratories
Mr. Jerome Cap, Sandia National Laboratories

The goal of shaker shock testing is usually to match a Shock Response Spectra (SRS) derived from field data over the frequency range of interest. The field SRS often "flatlines" at high frequency when the response of the high frequency SRS oscillators to the low frequency content is greater than the contribution of the actual high frequency content. However, when synthesizing laboratory shaker shocks comprised of decayed sinusoids, it is often necessary to either 1) introduce high frequency tones to match the flat line thereby resulting in unnecessary high frequency content or 2) the high frequency response from the low frequency tones is actually higher than the desired SRS thereby resulting in an apparent over test. The derivation algorithm discussed in this paper investigated an approach for optimizing the broadband SRS using only low frequency sine tones. The algorithm builds on Single Input Multiple Output Monte Carlo shaker shock optimization techniques developed at Sandia.

SEVERAL REMARKS ON THE SHOCK SPECTRUM'S LIMITATIONS AS A DESCRIPTOR OF A SHOCK

Mr. Zeev Sherf, Consultant

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

UNDERSTANDING MULTI-AXIS SRS TESTING RESULTS

Dr. Jason R Blough, Michigan Technological University
Dr. James DeClerck, Michigan Technological University
Mr. Jonathon Markl, Michigan Technological University
Ms. Erica Jacobson, Michigan Technological University
Mr. William Larsen, Michigan Technological University
Mr. Charles VanKarsen, Michigan Technological University
Mr. David Soine, Honeywell
Mr. Richard Jones, Honeywell

This paper presents a study done on a round resonant plate fixture used for Shock Response Spectrum(SRS) testing. The goal of this study was to understand the magnitude and character of both on axis and off-axis, with respect to shock input, response of the plate at various locations. The resonant plate was both modeled using linear FEA as well as tested experimentally. Tools and approaches based on modal decomposition were developed to understand how the natural frequencies and mode shapes of the structure contribute to the SRS response at a given point and direction on the fixture and/or plate. It is seen that in some instances, the off-axis SRS response can have both a higher amplitude response as well as a different “knee” frequency which can make meeting a designated SRS target very difficult. It is shown that by understanding the modal properties of the plate/fixture assembly, the SRS results can be understood. These results will lead to the capability to predict both the on axis and off-axis SRS response for a given input/output set of locations and eventually the ability to choose the ideal locations to achieve a set of on and off-axis SRS responses to meet a given criteria.

SESSION 23: TESTING & ANALYSIS OF FUZE TECHNOLOGY FOR HARSH MECHANICAL ENVIRONMENTS

TEST OBSERVED CONSIDERATIONS FOR EMBEDDED SMART FUZING OF PENETRATING MUNITIONS

Mr. Alma Oliphant, Applied Research Associates
Mr. Justin Bruno, Applied Research Associates
Mr. Craig Doolittle, Applied Research Associates
Mr. Nick Jarrett, Applied Research Associates

The penetration community is pursuing embedded smart fuzing solutions for ground penetrating munitions systems. As part of ongoing legacy programs and emerging new programs, Applied Research Associates (ARA) has instrumented full-scale penetration sled tests, and sub-scale penetration gun tests, with measurement devices embedded within the inert simulant explosive fill. ARA has also conducted pre-test and post-test modeling and simulation (M&S) of these events, to increase the fidelity of these simulations in exploring these embedded environments. This paper will provide a brief snapshot of the current test data observations, and M&S results that highlight physical behaviors present during these events that could affect embedded smart fuzing solutions.

SUBSCALE TEST DESIGNS FOR EDGE OF THE ENVELOPE LEGACY PENETRATING MUNITION ENVIRONMENTS

Mr. Alma Oliphant, Applied Research Associates
Mr. Drew Malechuck, Applied Research Associates
Mr. Phil Marquardt, Applied Research Associates
Mr. Craig Doolittle, Applied Research Associates
Mr. Bryan Norris, Applied Research Associates

In 2014, the Legacy Weapon Improvement Program (LWIP) started an effort to map the survivability limits for legacy ground penetrating weapons. A product of this program is test and modeling and simulation derived structural dynamic shock environments for fuzing systems, at the edge of envelope for legacy penetrating munitions. In 2017, these shock environments were reported at the SAVE conference. Today's paper will highlight the simulation-based design methods, and results of these simulations, that were used to design prototype testing solutions for testing fuzes at these shock environment levels. The primary goal of this test design is to provide a ground testing method to reduce cost, schedule, and technical risk for penetrating fuzing systems.

EXPERIMENTAL EVALUATIONS OF FUZE COMPONENTS IN ULTRA HIGH-G REGIMES (>100KG'S)

Mr. Shane Curtis, Sandia National Laboratories
Mr. Josh Dye, Sandia National Laboratories
Mr. Chad Hettler, Sandia National Laboratories
Mr. Caleb White, Sandia National Laboratories

In packaging electronics to survive traditional high-g environments (>10kG's), two mechanisms are generally believed to be responsible for component failures: Printed Circuit Board (PCB) flexure and inertial forces. Packaging methods in this regime most often include encapsulating the assembly in a thermoset epoxy to both dampen high frequency shock and support the electronics. However, in ultra high-g environments (>100kG's), other failure methods and packaging schemes must be considered due to the intensity of the shock load. For example, failures in the components themselves due to spalling, material phase changes, piezoelectric effects, or other mechanisms could be present in addition to

yielding and fracture of support materials due to high inertia loads. In this study, we look at the survivability of multiple electronics components that are common to conventional fuzing applications (e.g., high voltage capacitors and switches, boost converters, etc.) in a series of powder gun tests performed at the Energetic Materials Research and Testing Center (EMRTC) at New Mexico Tech. In the test series, the electrical components are packaged using both a "traditional" encapsulation scheme and a hard mounted approach designed to prevent PCB deflection. The test articles are shot into a water catch at several elevated impact velocities and high speed camera footage is used to determine the deceleration profile of each projectile. Results from Finite Element Analysis (FEA) and experimentation are presented.

EMBEDDED FIRESET TESTING IN EXTREME ENVIRONMENTS

Dr. Alain Beliveau, Applied Research Associates
Mr. James Scheppegrell, Applied Research Associates
Dr. Jacob Dodson, AFRL/RWMF
2nd Lt. Tiffany Hatcher, AFRL

Abstract not available.

CHARACTERIZING THE MECHANICAL PROPERTIES AND DYNAMIC RESPONSE OF G-SWITCHES

Mr. Matt Croether, AFRL
Mr. Curtis McKinion, AFRL
Dr. Jacob Dodson, AFRL
Dr. Jeffrey Hill, Sandia National Laboratories
Mr. Shane Curtis, Sandia National Laboratories
Mr. Joshua Dye, Sandia National Laboratories

The Air Force Research Laboratory in collaboration with Sandia National Laboratories are advancing technologies within embedded fuzes. One advance is to use a g-switch to detect layers. 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. The testing I will do this summer will provide insight on these unknowns and allow a greater understanding of the g-switch. The proposed testing will be executed on a drop tower. We plan to collect data from the g-switches and accelerometers to see at what speed the g-switches open and close and how sensitive the thresholds are for the g-switch. A test matrix is developed to characterize the g-switches under various loading conditions. Processing this data will help draw conclusions on the unknown characteristics such as spring stiffness, preload, internal mass, and distance to close the g-switch. Understanding these properties of the g-switch will allow for improvements in the embedded fuzing systems.

DISCUSSION GROUP: BOUNDARY CONDITIONS

MODAL APPROACH TO MATCHING COMPONENT RESPONSE UNDER DIFFERENT BOUNDARY CONDITIONS

Mr. Brandon Zwink, Sandia National Laboratories
Mr. Troy Skousen, Sandia National Laboratories

The Box Assembly with Removable Component (BARC) developed for the Boundary Condition Challenge Problem presents a case in which the dynamic response of the removable component to a specific environment in the assembly needs to be re-created using a component test configuration. A review of

the modal response of the component in the BARC assembly subjected to its prescribed impulse excitation was investigated. Then an investigation was made to determine what modal inputs would be required to replicate the component responses in a traditional rigid test fixture, showing that it is very difficult to perfectly match the response of the removable component. For this study, an approach was developed, using a mode shape transformation, to replicate the dynamics of the removable component as well as possible using rigid fixture.

SESSION 24: VIBRATION III

COMBINED ENVIRONMENTS TESTING

Mr. Gabe Rizk, NSWC Dahlgren

Prior to being fielded, it is expected that all DoD materiel will be qualified through environmental testing to ensure the systems are both functional and safe after exposure to the expected environments of their lifecycle. Because the expected lifecycles of differing materiel are often unique, guidance is given for tailoring environmental testing strategies based on the anticipated life of a given materiel. One option for tailoring is the consideration of combining different environments and the impact it might have on a given materiel. One of the most common combinations is temperature and vibration because the dynamic and fatigue properties of most materials change with extreme temperature changes.

This brief will discuss the methodology by which combined environment testing is conducted at NSWCDD. Recent test events raised concerns about the legacy approach taken to provide temperature conditioning to vibration test items. Laboratory experiments were conducted at the Explosive Experimental Area Building 9465 studying various fixture designs and nozzle geometries to improve the temperature conditioning process. The results from these studies were utilized to tune Computational Fluid Dynamics models, which ultimately provided the insight necessary to improve the testing methodology. The brief will conclude with results from recent tests and resulting improvements.

PROPELLER AIRCRAFT VIBRATION DEFINITION

Mr. Shawn Schneider, NSWC Dahlgren
Dr. Luke Martin, NSWC Dahlgren

Propeller aircraft are a common means of transportation of DoD materiel and, as such, they are also a common test environment for the qualification of DoD materiel. There are numerous reports, both modern and legacy, that define the vibration environments of various propeller aircraft. These reports all agree that the vibration environment has two primary components; 1. the random background influenced by air buffeting, engine noise, and local and global dynamics of the aircraft and 2. the effects of pressure waves coming from the propeller blades impacting the fuselage and the associated harmonic effects. The major point of disparity in these reports is whether the blade pass component should be defined as narrow band random or as sinusoidal tones.

This brief will make a subjective review of various datasets collected on C130 aircraft. Various data analysis techniques will be discussed as well as data trends discovered. A recommendation will be made for all future propeller aircraft vibration profile definitions.

DEFINING SHIPBOARD MOTION ENVIRONMENTS FOR DESIGN AND TESTING

Mr. Matt Forman, NSWC Dahlgren
Mr. Prenn Tran, NSWC Dahlgren

For equipment and systems that are sensitive to the large translational and angular displacements associated with ship motion, testing is an important verification method to assess system performance and survivability. DOD-STD-1399 provides general guidelines for ship motion and attitude by which ship systems can be designed. However, DOD-STD-1399 does not provide ship motion parameters useful to recreate a multi-axis test definition for the assessment of weapon system performance. Defining these parameters for multi-axis motion test require a tailored profile to be developed.

This presentation will review a data collection effort that was used to create a multi-axis, low frequency ship motion test specification for use on a 6-Degree of Freedom(DOF) motion table. The authors will detail the instrumentation setup utilized for data collection, data post-processing techniques, evaluation criteria, and finally the derived test specification.

SESSION 25: MECHANICAL SHOCK RESPONSE ANALYSIS

SCALING SHOCK RESPONSE SPECTRA – CONTRIBUTING FACTORS

Dr. Arup Maji, Sandia National Laboratories

Shock Response Spectra (SRS) are a succinct and convenient means of characterizing a shock event. The SRS converts the shock event in terms of how a SDOF (Single Degree of Freedom) system would respond to the shock. Unfortunately, much of the original information content of the original shock event is no longer available in the SRS and the relationship between the SRS and the shock acceleration-time history is non-unique. An issue of interest to designers therefore is how the component SRS level changes when the Input shock the system (System SRS) changes. Design of components and systems are often done in parallel. Representative systems and components are not available to test or to otherwise determine system to component transfer functions. Examination of scaling is therefore useful.

This paper examines some typical variations in system (input) SRS and the resulting component response. Results are captured in terms of deviation from linear scaling (extent to which component SRS does not scale in the same proportion as the system SRS). Extent of deviation from linear scaling was captured using Monte-Carlo simulations of the Transfer Function with varying damping parameters. Critical examination of the results made it possible to further understand the influencing factors (such as that of higher frequencies to lower frequencies, nature of the decay of a SDOF system response to the overall SRS, etc.)

RANDOM PROCESSES ON MANIFOLDS

Dr. George Lloyd, ACTA, Inc.
Dr. Tom Paez, Thomas Paez Consulting

A manifold is a point set with additional attributes upon which a function can be defined. For our purposes it can be thought of as providing the intrinsic geometrical framework for the function. Frequently it is the case that a manifold is embedded in a higher-dimensional space; the case of the 2-sphere in three-dimensional Euclidean space is an archetypical example. Random processes may be defined upon a manifold. It is also the case that in many situations estimation of a model for random process is based on data in which the observation space greatly exceeds the dimensionality of the underlying manifold on which it is defined. In such situations, including those involving shock and vibration, modeling often begins with some form of linear dimensionality reduction, and without explicit consideration of the supporting manifold. Many difficulties in estimation and modeling can arise in these situations.

The Karhunen–Loève expansion (KLE) is well-known and general framework for the non-local characterization of multi-dimensional discrete or continuous random processes. The KLE is a useful point of departure because it provides a useful (albeit non-local) way of creating a preliminary, possibly reduced-order, stochastic model. The non-locality of the KLE does not preclude its use when the data lie on a non-Euclidean manifold. In conjunction with, for example, Markov Chain Monte Carlo algorithms, it can be demonstrated to perform well—provided truncation is minimal. However, when the observation space is very large truncation is imperative, and seeking a means for constructing non-linear parameterizations of the data is desirable.

In this paper we introduce a number of recent developments in the field of random processes on manifolds which can accomplish non-linear dimensionality reduction in order to estimate the low-dimensional "coordinates" of the manifold. Once the manifold is characterized in this fashion, the steps of estimation and modeling of the random process defined thereon are more readily performed. Applications to problems involving shock and vibration are discussed to illustrate these new techniques.

SESSION 26: UNDERBODY BLAST

UNDERBODY BLAST TESTING OF ALUMINUM PLATES

Dr. Ken Nahshon, NSWC Carderock Divison
Ms. Jessica Dibelka, NSWC Carderock Divison
Mr. Daniel Hart, NSWC Carderock Division
Mr. Denis Rickman, US Army Engineer Research and Development Center
Mr. Garrett Doles, US Army Engineer Research and Development Center

Recently, a test series examining the response of 5083-H116 aluminum plates to underbody blast was conducted with the motivation of generating control data for a newly designed underbody armor concept. A newly designed test fixture was utilized and was moved along a single controlled soil bed to maintain consistency from one test event to the next. The test data, which includes dynamic displacement measurements, fixture jump height, and post-test laser scans, demonstrates that the test to test variation in loading and plate response is significantly lower than is generally understood. It is anticipated that the data will be of utility in validating numerical codes used to predict underbody blast response of vehicles.

MODELING UNDERBODY BLAST TESTS OF ALUMINUM PLATES USING EPIC

Dr. T. Neil Williams, US Army Engineer Research and Development Center
Mr. Garrett K. Doles, US Army Engineer Research and Development Center
Mr. Denis Rickman, US Army Engineer Research and Development Center
Dr. Ken Nahshon, NSWC Carderock

A test series examining the response of 5083-H116 aluminum plates subjected to underbody blast was conducted to serve as a control for future armor concepts. The tests were conducted in a single, well-

controlled test bed. The U.S. Army Engineer Research and Development Center (ERDC) has investigated the relationship between buried charges and soil materials, and their effect on fixture jump height and final deformation based on laser scans in previous test series. The new data provided in this test series (dynamic displacement) will allow further verification of current modeling capabilities. The soil used in these tests was previously characterized at the ERDC Geodynamic Research Facility (GRF) for similar field conditions. A Hybrid-Elastic-Plastic (HEP) model fit was generated from the GRF lab data and used to model the soil in these test events. This presentation discusses ERDC's use of the Elastic-Plastic Impact Computations (EPIC) software to model these tests with the given data.

Using Remotely Determined Soil Properties to Determine Relative Severity of Vehicle Underbody Blast Loading

Dr. Kyle Crosby, US Army Engineer Research and Development Center
Dr. Steven A. Akers, US Army Engineer Research and Development Center
Dr. John Q. Ehrgott, Jr, US Army Engineer Research and Development Center
Mr. Ryan E. North, US Army Engineer Research and Development Center

Well defined soil properties are needed for a broad range of problems including, but not limited to, vehicle mobility, contaminant transport through groundwater, and vehicle underbody blast. The ability to remotely determine soil properties is of great interest because many areas where the soil properties are needed are not easily accessible. To help define the current state of remote sensing capabilities, the US Army Engineer Research and Development Center (ERDC) has conducted a demonstration of several of the most common remote sensing techniques that are currently available. For this demonstration, several locations were chosen and samples were taken to determine the actual soil type, moisture, and density. The actual soil properties were then compared with the results from those determined using remote sensing techniques. Differences in the remotely determined soil properties from actual soil properties could result in significant differences in the loading experienced during a vehicle underbody blast. In this work, the impulse loading from a buried charge is calculated using soil properties from the remote sensing efforts and compared with the impulse from the actual soil properties. This will offer insight on the viability of the current remote sensing techniques for determining underbody blast loading and provide a target for future capabilities.

Testing Methodology/Operations for Underbody Blast Testing of Aluminum Plates

Mr. Garrett Doles, US Army Engineer Research and Development Center
Mr. Denis Rickman, US Army Engineer Research and Development Center
Mr. Stephen Turner, US Army Engineer Research and Development Center
Dr. Ken Nahshon, NSWC Carderock

Detonation of an explosive charge placed below the ground surface can produce extremely damaging blast loads on an overhead structure, such as a vehicle passing over the explosive at the time of detonation. Many underbody armor concepts have been designed to protect vehicles from this blast loading environment. One of the major limiting restrictions for vehicle designers is the added weight of such armor packages and the resulting mobility reduction. A newly designed underbody armor concept utilizes 5083-H116 aluminum plates that are light weight but would still meet blast protection criterion. Due to the complex responses and interactions produced by underbody blast detonations, there is a need to better understand this environment in order to adequately predict this material's protective capabilities against such threats. The Naval Surface Warfare Center (NSWC) Carderock Division, partnering with the U.S. Army Engineer Research and Development Center (ERDC), has undertaken this research, providing both well-defined field experiments to capture these loads and the resulting

material responses. The experimental results from this research provide much-needed control data for the material's response when subjected to representative explosive threats. The goal of this research was to quantify the plate response for a range of material thicknesses when subjected to underbody blast event in a consistent, well-controlled soil testbed. This presentation discusses the experimental layout, execution, and test results.

Soil Model and Computational Strategy for Landmine Modeling

Dr. David Stevens, Protection Engineering Consultants
Mr. Matt Barsotti, Protection Engineering Consultants
Mr. Eddie O'Hare, Protection Engineering Consultants
Mr. James Rasico, Navistar Defense
Mr. Craig Newman, Navistar Defense
Mr. David Gerst, Navistar Defense

Successful landmine modeling requires constitutive models that represent the nonlinear and rate-dependent behavior of soil and a computational strategy that accommodates the range of soil deformation, from large compressive strains to dissociation and fly out of the soil mass. Given the importance of vehicle protection to the warfighter, substantial research and development into these topics have occurred over the past 15 years. The authors have developed a sandy soil model specifically for landmine simulations, using the Pseudo Tensor material model and the Tabulated Compaction equation of state within LS-DYNA; only two inputs are required: dry sand density and moisture content. A number of computational strategies have been proposed and investigated by the authors using LS-DYNA, due to its ability to also model armored vehicles. These strategies encompass numerical methods such as FEM, ALE, SPH, and DEM. In this paper, a hybrid FEM-SPH landmine modeling approach is demonstrated to provide high accuracy at reasonable computational expense, through appropriate sizing of the smoothing length value and determination of the coefficient of restitution. This approach also allows for visualization of each soil particle's path throughout the event, enabling the analyst to quantify the benefit of shielding provided by non-armor components. The final landmine modeling strategy provides an accurate all-Lagrangian approach for application to full-scale vehicle models in LS-DYNA. The soil model and FEM-SPH conversion are demonstrated through full-scale vehicle modeling and an assessment of the effects of field testing procedures on landmine performance.

SESSION 27: SHOCK ISOLATION & ANALYSIS

Concepts for Designing Shock Isolated False Deck (SIFD) Systems for Shipboard Equipment

Dr. Michael Talley, HII - Newport News Shipbuilding

This paper describes concepts for designing shock isolated false deck (SIFD) systems for shipboard equipment. The basic SIFD design concept is to couple distributed shock and vibration isolation with flexible infrastructure. Concept design goals include: 1) elimination of 'HOT' work, sway mounts & foundations, backing structure, and supplier costs to develop equipment shock isolated systems; 2) lower dynamic force levels on equipment; 3) interface features to achieve equipment upgrades in fewer hours during scheduled ship availabilities; 4) flexibility to relocate shock qualified equipment from one compartment to another and across platforms; and 5) ability to host equipment without adversely affecting other neighboring equipment. Examples of SIFD layouts are presented and discussed.

Modification of Shock Isolation Mount Predictions & Loading Estimates (SIMPLE) Program to Simulate With Nonlinear Mount Geometry Changes

Mr. David Callahan, HII - Newport News Shipbuilding
Dr. Michael Talley, HII - Newport News Shipbuilding

This paper describes the implementation and validation of nonlinear mount geometry changes to the program Shock Isolation Mount Predictions & Loading Estimates (SIMPLE). The dynamic mount geometry changes resulting from multi-axis deformations that occur during shock testing are modeled and simulated. The implementation involves: 1) transforming the relative displacements and velocities from the reference frame of a mounted item into the mount's local coordinate system, which is undergoing mount geometry changes at each time step; 2) using the displacements and velocities in the mount's local coordinate system to calculate forces; and 3) transforming the forces back into the mounted item reference frame where they are applied. The modifications to SIMPLE improves the accuracy of shock isolation predictions leading to validation and assurance of shock mount selection and configuration for equipment racks, consoles, cabinets, and other structures. This paper also provides a practical application of the program.

The Development and Use of a Mount Configurator Design Tool Supporting Shock Isolated False Deck (SIFD) Systems

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

This paper describes the development and use of a mount configurator design tool supporting shock isolated false deck (SIFD) system designs for shipboard equipment. To aid in specifying the distributed shock mount part numbers under the SIFD, a mount configurator tool was developed. The mount configurator tool is an excel spread sheet that integrates loadouts for equipment, wire ways, etc. on SIFD structural members and identifies the distribution of shock mounts under the structure to achieve optimum shock mitigation performance. The tool will incorporate the use of flexible infrastructure fittings (e.g., light and medium fittings, bridges, etc.) and their allowable loads in SIFD configurations. It will also include rules needed for handling non-standard SIFD layouts. Examples of mount configurator tool use are presented and discussed.

Shock Extension Analysis Using SIMPLE and Nonlinear FEA to Capture Unexpected Ballistic Equipment Response

Mr. Matt Davis, HII - Newport News Shipbuilding
Dr. Michael Talley, HII - Newport News Shipbuilding

This paper describes the effort conducted to establish a validated model of an item tested on the MIL-S-901 Floating Shock Platform (FSP) for use in shock qualification by extension analysis. A representative FSP input and nonlinear mount models were determined using the fast running Shock Isolation Mount Predictions & Loading Estimates (SIMPLE) program. Nonlinear transient finite element analysis was used to determine equipment response and compare to test data. Initial comparisons showed shortfalls in the high-frequency regime. Further study posited a significant impact event may have attributed to the poor comparison. The finite element model was updated to allow part of the equipment representation to respond with ballistic motion and contact nearby structure, bringing predictions and test into good correlation. After shortfalls in equipment representation were adjudicated, the finite element analysis model was validated to assess post-test design changes in support of a shock qualification by extension.

SESSION 28: WEAPONS EFFECTS R&D

CONCEPTUAL MODEL OF TRANSONIC WEAPON PENETRATION PROCESS

Mr. Robert Couch, Applied Research Associates
Mr. Jeff Duray, Applied Research Associates
Mr. Rob Cilke, Applied Research Associates
Mr. Craig Schwandt, McCrone Associates

This summary paper presents a conceptual model of the weapon penetration process. The model focuses on the target response and the observed, recorded, and inferred processes that develop during the advance of a penetrator into granitic rock and concrete semi-infinite targets. The Defense Threat Reduction Agency has conducted numerous penetration tests over the last ten years. This model was developed using detailed posttest field observations and microstructure study from 20 gun delivered penetrators, and over 60, transonic, air-delivered and inert, inventory bombs into granite and concrete. Much of the penetrator/target phenomena in this paper was observed in past testing by Sandia National Laboratories (SNL), but was not well understood. The primary focus of past tests was on penetrator performance and development of predictive analytic methods, but not the response of the target. Wayne Young's unpublished typical penetration event was developed at SNL and is the basis for our expanded model.

After excavation and removal of the penetrator weapon case from the rock or concrete target, the penetration pathway was studied in detail, with the recognition that important forensic evidence was preserved in the target materials. Selected target material samples from the penetration hole were studied, utilizing various analytical tools, such as petrographic optical and scanning electron microscopy. These tools revealed the preserved deformation fabrics, textural trends, compositional, and phase changes of the target matrix components. Samples taken from the surface of the penetrator case were also studied. The field and microscopy forensic observations reflected the end state of the damaged target material. Importantly, the test results were well documented with active instrumentation, including as high speed photography (impact parameters and initial projectile penetration), onboard accelerometers, and other various sensors. Additionally, the conceptual model development also benefited from predictive and postdictive analytical modeling.

The working model presented here primarily illustrates (and helps to understand) the penetration process. It captures newly observed processes revealed by detailed study of target damage. The penetration process is a continuum unfolding within 40 ms after impact, depicted in the conceptual model by six convenient identifiable stages: Impact, Cratering, Penetration Initiation, Tunneling, Lock-in and Rebound.

AN OPEN-SOURCE CFD SOFTWARE FOR MODELING BLAST PROPAGATION

Dr. David Stevens, Protection Engineering Consultants
Mr. Tim Brewer, Protection Engineering Consultants
Mr. Eddie O'Hare, Protection Engineering Consultants
Mr. Peter Vonk, Synthetik Applied Technologies

blastFOAM is a new software tool for modeling the physics of compressible multi-fluid flow in explosive detonations. blastFOAM was developed from OpenFOAM, an unrestricted, parallel, open-source solver that provides a readily extensible and widely used library, is supported by a large and active community, and provides mesh generation and pre/post-processing utilities.

blastFOAM has been validated through comparisons with experimental data from laboratory tests of enclosed detonations and simple field tests with a reflective surface. Recent work has focused on validation for urban settings.

A series of large-scale explosive tests were performed in a simulated urban environment at the Energetic Materials Research and Testing Center in Socorro, New Mexico, US. A large number of blast gages were employed and repeated tests with the same scenario were performed to quantify the variability in the data.

As discussed in this paper, a blastFOAM model was developed and executed to simulate the urban canyon tests. The synthetic and experimental pressure-impulse data were compared, and the quality of the agreement was found to be very high, particularly given that book values for the equations of state were used, with a mesh that was developed in less than an hour. The man-hours required to develop the model and the CPU-hours required to execute the model are reported as are the comparisons between the predicted and measured data.

NEW PARADIGM FOR CREATING FAST RUNNING MODELS FOR WEAPONS EFFECTS USING MACHINE LEARNING

Mr. Matt Barsotti, Protection Engineering Consultants
Dr. Eric Sammarco, Protection Engineering Consultants
Ms. Sherri Hodgson, Applied Research Associates
Ms. Kellina Jeung, Applied Research Associates
Mr. Robert Kelleher, Applied Research Associates

Fast running models (FRMs) are often employed for rapid calculation of physical system behavior. Modern vulnerability and weaponeering codes widely employ FRMs for background calculations. Broader use of such methods may be found in many branches of science and engineering, where they may be denoted as “empirical” or “engineering” models.

In response to growing complexity of physical problems, FRM developers have increasingly turned to a range of machine learning and big-data type solutions (neural networks, etc.). These “black box” tools can perform regression fits of highly-complex, multi-variable data, and they do not require deep phenomenological insight on the part of the user. However, the underlying mathematics are generic, tend to require the tuning of many constants, and usually bear no resemblance to the physics equations that actually govern the dynamic system behavior. For these reasons, large data sets are required to create smooth fits. Because FRM developers often do not enjoy a surplus of source data, problems can result with overfitting, asymmetric predictions, boundary discrepancies, and non-monotonic models. Even where successful, such models are typically not extensible to similar problems that fall outside the original domain, and they are difficult to examine and interpret. Significant expertise of machine learning methods is often required to produce stable and robust models.

The Air Force Research Laboratory (AFRL) sponsored a Small Business Innovative Research (SBIR) effort to create a new software toolset for generating fast-running models (FRMs), which was undertaken by Protection Engineering Consultants and Applied Research Associates. The technical approach followed a deliberate “physics-first” strategy that avoids black-box fitting methods. It can be used to rapidly generate FRMs that make physical sense and can be extended beyond their basis datasets.

VISUALIZATION, MEASUREMENT AND PREDICTION OF BUILDING DEBRIS FOR LARGE MAGNITUDE, LONG DURATION SHOCK LOADS

Dr. David Stevens, Protection Engineering Consultants
Mr. Kirk Marchand, Protection Engineering Consultants
Mr. Matt Barsotti, Protection Engineering Consultants,
Mr. Mohsen Sanai, SRI International

Airblast loads from nuclear weapon detonation in an urban environment can create fragments in several size regimes. Immediate loading of structural components at very high overpressures will result in fragmentation at the small scale. In contrast, at lower overpressures sustained over longer durations, larger scale debris on the size of structural elements are created by flexure and shear failures. To evaluate the threat posed by facade fragments, Protection Engineering Consultants (PEC), the Defense Threat Reduction Agency (DTRA) and SRI International undertook a combined experimental and analytical effort.

For small-scale fragmentation, 16 small shock tube tests were conducted with square specimens that were simply supported by a plate with a circular opening. For large-scale fragmentation, 5 tests were conducted in a large diameter shock tube with square structural panels. For both test series, concrete masonry, and glass specimens were evaluated. Fragments were soft-captured and measured; videographic analysis was used for in-flight velocity and mass measurement. This data was used to generate cumulative distributions of fragment mass and velocity, normalized by average values. Following this, probability density functions (PDFs) and cumulative distribution functions (CDFs) were fit to the normalized data. Overall, Weibull and power law distributions produced the best fits.

This paper presents an overview of the experimental techniques, a summary of results, and successes and failures in the testing, data collection and data analysis techniques.

AN OVERVIEW OF FORCE PROTECTION IN THE URBAN ENVIRONMENT

Dr. Catherine Stephens, US Army Engineer Research and Development Center

The urbanization that is occurring across the globe will require the U.S. Army to operate in the urban environment, and it does not currently have the force protection technologies for these operations. Force Protection in the Urban Environment is a five year, Deputy Assistant Secretary of the Army for Research and Technology funded, science and technology program that aims to develop and demonstrate an integrated suite of force protection solutions to enable the Soldier in the urban environment. The program focuses on efficient selection, rapid assessment, and survivability enhancement of existing structures; rapidly deployable protection systems; and decision support tools and tactics, techniques, and procedures (TTPs) all with consideration for a complex three-dimensional threat. This presentation will give an overview of the projects included in Force Protection in the Urban Environment including an expedient vehicle barrier and applications for ballistic and fragmentation resistance of common urban materials, wall failure and secondary debris from blast, and design of overhead protection for existing buildings.

SESSION 29: ALTERNATIVE/NEW SHOCK TEST & ANALYSIS METHODS

VALIDATION OF NEW TEST SYSTEM FOR SIMULATING FIRING SHOCK ON MORTAR BASEPLATES

Mr. David Alfano, US Army ARDEC
Dr Andrew Littlefield, US Army ARDEC

The increased use of mortars in current conflicts has placed a high priority in getting mortar baseplates to the field. To ensure that the baseplate is safe for use in the field it must undergo acceptance testing. The purpose of the acceptance testing, as defined by Test Operations Procedure (TOP) 3-2-050 Testing of Mortar Systems, is "to disclose any deficiency or malfunction that would preclude its further use." For a baseplate these deficiencies could arise from either material or manufacturing methods.

Traditionally acceptance testing has been carried out on all baseplates via live fire testing as defined in the TOP. There are a number of reasons why this is not desirable. First is that the test site is not collocated with the production site, so large numbers of plates must be boxed, shipped to the test site and then returned to the production site for final inspection prior to shipment for field use. Second is availability and response time for the proof site. Higher priority workload, such as ammunition lot acceptance testing, could cause baseplate testing to be delayed. Additionally weather conditions can often cause delays. Third is that every round that is used for testing is a round that is no longer available for use in the field. Finally, and most importantly, is the cost. The test site's costs can vary greatly due to quantity and workload but have historically been over $2000 per baseplate, not including transportation or ammunition.

Previously, Benét had validated a system for simulating the shock load from a proof firing for the various types of baseplates. This approach used a pile driver to apply the load through a hydraulic medium and a solid link with the baseplate supported in a rubber mold. This works for single hit proof load testing, but the rebound caused by the rubber mold made it ill-suited for fatigue tests. Additionally being able to accommodate the entire load range (approximately 15 kips to 300+ kips) meant using different impact systems and hard stops to limit the applied force.

To address these shortcomings, a new system has been designed that still uses a smaller weight drop but can arrest any rebound motion, avoid double hits, and is easily variable for the different load cases through greater impact velocities. This paper will cover the method developed and validate it against firing data for multiple baseplate types.

SHOCK TRANSMISSION IN STRUCTURES

Mr. Y.Z. Yan, The University of Manchester
Professor Q.M.Li, The University of Manchester

Pyroshock/ballistic shock is the dynamic response of a main structure to an explosion or impact loading. For aerospace structures, shock environment can be further divided into three categories, i.e. near-field, mid-field and far-field, respectively, according to the distance of the sensitive component location from the pyroshock source. In the far-field range especially, there are many electric and optic components (e.g. relay and quartz), which are sensitive to shock vibration. In an overall shock damage risk analysis process, the main difficulties are to describe the shock environment, e.g. using shock response spectrum, at sensitive component interface. It relies mainly by analysis and numerical modelling because precise shock measurement is almost unavailable inside equipment. Therefore, it is important to understand the shock transmissibility from equipment interface to component interface. The shock transmissibility of a printed circuit board is studied, based on the shock response spectrum analysis and structural dynamics. The most important shock information at equipment interface is recognized, and the new concept of shock response spectrum is proposed. An algorithm with graphical user interfaces, which is implemented in Matlab, is developed base on the finite impulse response filter and shock response spectrum. The explicit numerical simulation of a printed circuit board under shock induced by metal-to-metal impact is carried out using Abaqus. The outcome of this study can help structural engineers to design and test equipment and component under pyroshock/ballistic shock environment.

DEVELOPMENT OF THE MULTIAXIS AIR GUN- RESONANT FIXTURE SHOCK TEST

Mr. Mikhail Mesh, Sandia National Laboratories
Mr. Ron Hopkins, Sandia National Laboratories
Dr. Matthew Spletzer, Sandia National Laboratories
Dr. Carl Sisemore, Sandia National Laboratories
Mr. William Bonahoom, Sandia National Laboratories

Many systems are subjected to shock environments during operation. Most often these are multi axis environments. To qualify components, such environments must be reproduced in the laboratory setup. To achieve that goal, a Light Initiated High Explosive (LIHE) test has been employed at Sandia National Laboratories. The test is performed by spraying explosive on a specially designed fixture. The test article is attached to the fixture and explosive is initiated simultaneously on multiple sides of the fixture. While being effective in achieving desirable conditions, the LIHE test has its shortcomings. It is a very expensive and potentially hazardous test with limited opportunity to perform fine tuning of the test parameters.
An alternative to the LIHE test is air gun impact or resonant plate test. The test article is attached to the resonant plate and a projectile is shot at the center of the plate. Traditionally this test is used to produce a uniaxial shock environment. We propose a modification of the resonant plate test by introducing both off-center impact and, if necessary, offset position of the test article on the plate. Parametrized finite element models of the plate and the test article are developed and analyzed using Sandia's Sierra/SD massive parallel structural dynamics analysis software. To find the optimal impact location and plate geometry, design of experiments or optimization is performed using geometric parameters as variables. Results are postprocessed and compared to test specifications.

This approach was successfully implemented for several different components and subsystems. It was demonstrated that it is achievable to design a resonant plate test to produce the desired 3 axis environment in a single test. Further, this test methodology allows for finetuning to achieve desired pulse shaping, damping and allows for electrical testing of components during the test. All that was achieved at significant cost and time reduction compared to traditional LIHE tests.

CHARACTERIZATION AND ENDURANCE SIMULATION OF GUNFIRE SHOCKS FOR DEVELOPING A NAVAL SYSTEM

Mr. Ron Moshe, RAFAEL

The developing of a naval system needs to withstand a gunfire shocks during its life cycle, according to a defined profile mission.

In the past the system was qualified to a ground environmental condition. According to a new customer requirement, the system shall be determine naval environmental conditions. One of the significant inequalities between the ground and naval environmental condition is the endurance of the system to a gunfire shocks. The ground system qualification test contained a road transportation shocks, whereas the naval system need to withstand severe gunfire shocks from a 76mm gun(Mk-75- "OTO-MELARA"), which is located on the vessel platform. The system criteria for a success test is without a functional and mechanical failures.

To answer this dilemma, a new novel methodology was developed.
The main steps of the methodology:
A) Performing measurement test of gunfire shocks at the input of the system
B) Calculating SRS (Shock response Spectrum)curves from the time history records of the firing events
C) Describing the gunfire shocks intensity versus the azimuth direction of the barrel gun

For gunfire shocks characterization, a dedicated measurement test was performed and included accelerometers that were located at several system locations close to the gunfire source. The field test plan that was performed required several firing events at the maximum gun firing rate, including the closest distance between the barrel gun and the system.

The laboratory gunfire shock simulation was performed by acceleration time history replication on a shaker. In order to define the severe accelerometer time history, calculation of the SRS shocks were estimated for each firing event. The goal is to find a maximum SRS bound for all the firing events. Using both the SRS analysis and the Gpeak results from the gunfire shock time history, revel the physical phenomena that can describe the gunfire shock intensity versus the azimuth direction of the barrel gun.
This paper will describe in detail all the steps conducted for qualifying the system to a naval environmental conditions.

CLASSIFICATION OF TRANSIENT BEHAVIOR IN TIME HISTORY DATA

Ms. Angela Montoya, Sandia National Laboratories
Dr. Fernando Moreu, University of New Mexico
Dr. Thomas L. Paez, Thomas Paez Consulting

Acceleration time history data is collected to specify shock and vibration environmental tests. Typically, these data exhibit multiple characteristics. Portions of a measurement may be described as stationary random vibration, while the remainder displays varying degrees of transient behavior. Standard analysis methods are not equipped to describe variety in transient response, instead focusing on peak values. This approach may lead to over-conservative descriptions of the environment in various ways. For instance, categorizing shock events with different probability distributions together may skew upper tolerance limit calculations.

This paper introduces a technique to examine transient events in acceleration time history data for use in data analysis. The intent is to develop a tool for future research in environmental specification development and testing. Rather than focusing solely on the severity of an event, features selected for analysis are intended to capture general geometric and temporal characteristics. Similarity between features is then expressed as a distance metric that may be used to cluster shock events by temporal behavior. Future research includes using this method to create a statistical model of a shock environment. A numerical example is presented to demonstrate the procedure.

SESSION 30: MECHANICAL SHOCK TESTING & SUBSIDIARY COMPONENTS

ALIGNED AXIS 40' DROP GUIDANCE SYSTEM

Mr. Sloan Burns, NSWC Dahlgren

Forty-Foot Drop testing is a required assessment to ensure munitions are safe for disposal after an unintentional drop during pier-side loading/unloading operations. Testing requirements are defined in MIL-STD-331, MIL-STD-2105, and STANAG 4375 where tight tolerances on drop height, impact velocity, release angle, and impact angle are defined. Adhering to these tolerances, specifically those of impact angles, can prove difficult for certain items. Various factors such as release timing, wave propagation, and aerodynamic drag can significantly complicate the ability to predict how an item will respond while in free-fall. This led to the development of a guidance system that significantly reduces the risk of out-of-tolerance drops, with the overall goal of avoiding costly "no-test" results.

This presentation will review 40-foot drop test requirements and depict the complexities presented when attempting to predict impact angles. A drop guidance system will then be presented as an alternate method of drop testing which ensures test requirements are upheld and impact dynamics are not significantly impacted. Multiple test cases with and without the carriage drop system will then be reviewed and compared. Results from these cases will be discussed.

HEAVYWEIGHT ALTERNATIVE TEST FOR VERTICAL LAUNCH SYSTEMS

Mr. Sloan Burns, NSWC Dahlgren

The WOX-7B, a MIL-S-901 Alternative Vehicle shock machine, was developed for testing weapons such as torpedoes or missiles. The addition of the Dahlgren Shipboard Shock Simulator (DS3) fixture to the WOX-7B allows the shock testing of Vertical Launch Systems (VLS) while utilizing only one blow to excite all axes, in the portions similar to those observed shipboard during an Under Water Explosive (UNDEX) event.

This presentation will provide an overview of the operation of the WOX-7B with the DS3 fixture. The calibration theory will be discussed using data from four recent tests which show the linearity of the machine. The machine's linear response supports calculation of a desired peak velocity after three lower energy blows are imparted into the system. Previous WOX-7B with DS3 testing required a mass simulant calibration series prior to the live event, to determine the potential energy required to meet qualification levels. Results from a 2018 test series will show the machine may be used to qualification levels without a pre-test calibration, reducing the test magnitude by half.

APPLICATION OF SUBSIDIARY COMPONENT TEST GUIDANCE CRITERIA

Mr. Sloan Burns, NSWC Dahlgren

SEA O5P has generated guidance criteria for the qualification of subsidiary components from MIL-DTL-901 principal unit test data. These criteria are provided on a case-by-case basis and require O5P concurrence. The criteria detail quantitative and qualitatively means of comparing the subsidiary component shock test data to principal unit test data to determine acceptance. The fundamental principal is that the subsidiary shock test should meet or exceed the principal unit shock test in shock severity. The guidance criteria provide tolerances and methods of quantifying shock severity to support this data analysis.

This presentation will show excerpts of the O5P subsidiary component testing guidance criteria and will apply the guidance criteria to a data set. Methods of conducting the data analysis will be shown in detail. As the data analysis is presented, NSWCDD lessons learned for developing an acceptable subsidiary shock test pulse and the effects of the required post-test low pass filtering on acceptance will be highlighted.

TIME WAVEFORM REPLICATION OF THE BARGE ENVIRONMENT

Mr. Mike Morrison, NSWC Dahlgren

MIL-DTL-901E allows for shock qualification by extension in cases where new subsidiary components are substituted for those represented during the original principal unit shock test. Evidence is required to prove that the new subsidiary components are in compliance with the requirements for high-impact shipboard shock. Time waveform replication of the barge environment on a shaker table is a viable test approach to provide such evidence under the appropriate conditions. The process to determine the feasibility, development, and acceptance for qualification of a time waveform replication shock test will be presented.

The specific example to be discussed includes subsidiary components from a Class I/II, deck mounted electronics cabinet that are being substituted as part of a tech refresh. This cabinet was previously qualified as a principal unit via heavyweight shock testing for 14 Hz and 25 Hz decks. Acceleration data was captured at multiple cabinet locations during this testing. The tech refresh involves replacement of several circuit cards in the isolated portion of the cabinet. Modal testing of the circuit cards has been completed to establish the dynamic characteristics of each card.

A shock response spectrum based qualification requirement is derived from the heavyweight shock test accelerometer data. Utilizing knowledge gained from the modal testing, an applicable frequency range can be determined for this requirement. The modal testing also provides the data necessary to determine the allowable high pass filtering cutoff frequency for development of a time waveform from the accelerometer data. An effort is made to preserve as much of the frequency content as possible within the capabilities of the shaker table being employed. All frequency content that might excite the dynamics of the subsidiary component must be retained for the test to be considered qualification level. Upon completion of the time waveform replication testing, shock response spectra are computed from the accelerometer data and compared to the qualification requirement and applicable deviation criteria.

LITERATURE SUMMARY OF RESONANT FIXTURE SHOCK TESTING

Mr. Jonathan Markl, Michigan Technological University
Ms. Erica Jacobson, Michigan Technological University
Dr. Jason Blough, Michigan Technological University
Dr. James DeClerck, Michigan Technological University
Mr. Charles VanKarsen, Michigan Technological University
Mr. David Soine, Honeywell
Mr. Richard Jones, Honeywell

This paper will summarize literature which describes Resonant Fixture Shock Testing. The paper will start with a brief discussion of the origin of the Shock Response Spectrum (SRS) and move through resonant fixture shock excitation techniques, testing machines, and end with multi-axis resonant fixture shock testing. The structural dynamics aspects of resonant fixture shock will be emphasized. The main goal of this paper is to summarize the published background information necessary for engineers and technicians to understand the physics and limitations of resonant fixture test techniques, as shock testing methodology moves toward multi-axis shock specification, generation, and measurement.

SESSION 31: STRUCTURAL RESPONSE TO UNDEX

DDAM-coupled Optimization Methods for Ship Structures

Mr. Leo Jeng, Altair

The traditional design process for structural components often involves many iterations between the designer and the analyst. If the structure is being designed to withstand specific shock conditions, the iterative process can be much more involved. Historically, design validation for structural integrity occurs near the end of the design life cycle. By incorporating structural design that has been optimized for DDAM shock analysis, the iterative design cycle can be dramatically reduced. Optimization driven design brings validation and performance optimization as well as cost considerations early into the design phase.

This paper presents a case study using DDAM-coupled optimization methods to improve the structural performance of a ship component. DDAM-coupled optimization methods allow engineers to account for shock loading early in the design phase to generate structural designs that can improve the performance of the structure and/or installed equipment. The case study used in this paper will demonstrate a complete optimization process beginning with a design of experiments exploration to observe the effects each input has on the performance of the structure and screen out variables that are not important to the structural characteristics of the model. Next, design fine tuning optimization tools help to adjust the inputs to optimize the output characteristics needed for the structural objective. Finally, a cost optimization study will be shown to find the minimum cost structure while meeting the structural requirements. Design variable screening and cost optimization will be performed using HyperStudy, a solver-neutral design exploration tool for multi-disciplinary simulations. The structural optimization and validation is performed using OptiStruct, a commercially available simulation software that not only validates structures using DDAM, but has unique built-in optimization capabilities for maximizing performance while reducing weight and design cycle times. Optimized results show an improvement in both the structural performance and cost of the part and will be compared to the baseline model.

Digital Image Correlation Measurements on a 2-m Ship-like Panel Subjected to Underwater Explosions

Dr. Julian Lee, Defence R&D Canada - Suffield Research Centre
Mr. Shane Halaska, DRDC - Suffield Research Centre
Dr. Malcolm Smith, DRDC - Atlantic Research Centre

This paper presents the results of underwater explosion (UNDEX) testing of a 2-m floating square panel. This experimental study is part of an effort to understand the detailed mechanisms of close-proximity UNDEX on ships, and highlights the use of Digital Image Correlation (DIC) techniques in a scenario where the dynamic deformation must be captured for an unusually large DIC test specimen subjected to a complex shock and bubble collapse loads. The measured response of the panel shows localized deformation, vibrational response, and global rigid-body motion. In addition to the response to UNDEX loading, these series of experiments also present the challenges of performing DIC in field environments, as well as the value of measuring the motion and strain of the entire target specimen as opposed to only gauge measurements at specific locations.

SESSION 32: SHOCK, VIBRATION, & BLAST IN TRANSPORTATION

FINITE ELEMENT ANALYSIS OF AN ISO CONTAINER SUBJECTED TO IMPULSIVE LOADINGS

Mr. David Roman-Castro, US Army Engineer Research and Development Center
Mr. Donald Nelson, US Army Engineer Research and Development Center
Dr. Catherine Stephens, US Army Engineer Research and Development Center
Dr. Paul Sparks, US Army Engineer Research and Development Center
Mr. Omar G. Flores, US Army Engineer Research and Development Center
Dr. Luis Suárez, University of Puerto Rico

Intermodal freight shipping containers can be converted into Life Support Areas and Tactical Operations Centers in contingency operations where ease of relocation or modularity for reconfiguration is important. During contingency operations, the containers can be subjected to blast loading. Consequently, it is important to understand the effects of blast loads on the containers in order to improve the protection of the assets. The primary focus of this research was to develop and validate a finite element model (FEM) of an ISO container with internal finishings subjected to blast loads. A detailed model of the 20-ft ISO, Type 1A container was developed with an internal finish consisting of wood studs and plywood walls. The computational model was validated based on full-scale experimental field tests. The computational results showed that the maximum deformation of the container's reflective wall agrees reasonably well with the full-scale experimental data. Furthermore, the computational results showed that the structural integrity of the internal finish was intact.

PROTOCOL DEVELOPMENT FOR MULTI-AXIS TRANSPORTATION VIBRATION

Dr. Jon Yagla, Bowhead Technical Services
Mr. Shawn Schneider, NSWC Dahlgren
Dr. Luke Martin, NSWC Dahlgren

All recent versions of MIL-STD-810 for transportation vibration testing have encouraged users to develop their own test protocols based on the life cycles of their equipment. However, this had never been done to support multi-axis testing of a US Navy System. We did a rigorous build-up of transportation vibration data for encanistered missiles being transported on various trailers being towed by road tractors on interstate highways, US highways, state highways and rural roads. The effort required testing with several trailers and driving thousands of miles. A road tractor with a sleeper compartment was modified to create a laboratory for recording 50 channels of acceleration, temperature, and navigation data. The data was then used to develop test protocols that replicate the environment for multi-axis testing in our laboratory. The multi-axis test protocols were reviewed and approved by authorities and the tests were carried out. The tests were successful and missiles are now being transported. Meanwhile, we developed a second set of profiles for air transportation, using data from flight tests in C-130 aircraft. The tests were also with complete success.

Recently we were asked to do transportation vibration testing for another customer with a second type of missile and another type of canister. This involved one to four missiles loaded into a canister with four cells, and other types of trailers than were used for the previous missiles. Again, with no precedent, we carried out an analysis that led to a way to test the four missiles by adapting the previous protocols to the four-missile canisters with full and partial load-outs.

The key to our being able to modify and adapt the experimentally developed profiles for the first system to the second system, with no available profiles, was to slightly reword, without changing the intent, rules for dynamic similarity in MIL-STD-810. Calculations to establish the limits of dynamic similarity between the two systems were then carried out. It became apparent how to adjust the profiles for testing the first system with one missile to test the second system with up to four missiles. The tests for highway and air transportation of the four-missile system have since been carried out at huge saving in cost, by not having to do any highway or aircraft testing to develop protocols.

SIMULATING THE DYNAMIC BEHAVIOR OF A SHIPPING CONTAINER

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

Shipping containers are widely used in the military for the storage and transport of a large variety of fragile equipment, such as missiles, bombs, warheads, jet engines, radar components, and electronics in general. The life profile of such containers is well defined in some MIL and packaging standards, including MIL-STD-810, AECP, and ATA. The use of measured data, when available, is preferred over these standards.

Dynamic inputs are expressed in terms of sinusoidal or random vibration, while shock impulses or drops represent the container's hazards during transport. Military containers typically are approved through a lengthy and expensive series of environment tests, which ideally should be carried out only one time. These containers usually incorporate various types of elastic mountings reducing the response to the load to acceptable levels, such as foam, rubber isolators and wire rope isolators. As far as mechanical tests are concerned, it is extremely important to be able to anticipate the potential difficulties at as early a stage as possible. Amongst others, the response in terms of acceleration shock response spectrum on the unit, the size of the isolators, and the sway space defining the container size must be evaluated.

The Socitec Group and its US branch, Vibro Dynamics, have been pioneering a high level of refinement to the numerical simulation of such systems through the use of its proprietary software package Symos. Models usually possess 12 degrees of freedom, but can reach 500 when the transported item eigenmodes interfere with the eigenmodes of the isolators, which typically occurs when the cradles are not stiff enough, there is a missile canister with inner isolator pads, or even when it is desired to model the whole vehicle.

Symos has been discussed in previous symposia mostly for the modeling of the shock testing machines of MIL-S-901D and seismic events. It is the purpose of this article to present how shipping containers can also be reliably simulated, demonstrating the advantages of sizing the isolators and detecting potential problems at an early stage. A few typical cases with various degrees of complexity will be presented and models will be compared with actual test results.

SESSION 33: SOIL & ROCK STUDIES

MATERIALS ONLINE ENCYCLOPEDIA (MOLE) OVERVIEW

Dr. Kyle Crosby, US Engineer Research and Development Center
Dr. Steven A. Akers, US Engineer Research and Development Center
Dr. John Q. Ehrgott, Jr, US Engineer Research and Development Center

Extensive testing has been performed at the US Army Engineer Research and Development Center on a large number of soil, rock, and cementitious materials over the past few decades. That test data is useful for a broad range of relevant problems including vehicle mobility, vehicle underbody blast, projectile penetration, force protection, etc. However, some data is often difficult to find and is in danger of being lost as paper reports and files disappear over time. To increase the accessibility and prevent the loss of this valuable data, the Materials OnLine Encyclopedia (MOLE) is being developed to provide a web-accessible collection of material properties, corresponding model fits, and other relevant information. MOLE will not only preserve multiple generations of material test data but will provide a portal to access all of the useful information and resources associated with a particular soil, rock, or cementitious material.

RESEARCH PLAN FOR ECM REQUIRED EARTH COVER

Mr. Joshua Payne, US Engineer Research and Development Center
Dr. John Q. Ehrgott, Jr., US Engineer Research and Development Center
Mr. Denis D. Rickman, US Engineer Research and Development Center
Dr. T. Neil Williams, US Engineer Research and Development Center
Dr. Michelle M. Crull, U.S. Army Engineering and Support Center
Mr. Daniel L. Linehan, U.S. Army Technical Center for Explosives Safety

The U.S. Army has a very large number of earth-covered magazines (ECMs) for storing ammunition and explosives. The majority of these earth-covered magazines are arch type structures with widths of 26.5 ft and lengths varying from 40 ft to 80 ft. These magazines are generally sited for a maximum of 250,000 or 500,000 lbs net explosive weight (NEW). These magazines are designed to have a minimum of 2 ft of earth cover as specified in DoD 6055.09-M, DoD Ammunition and Explosives Safety Standards. Over time, the earth cover may erode resulting in an earth cover that is somewhat less than 2-ft thick. In accordance with DoD 6055.09-M paragraph V2.E5.5.3.2, the earth-covered magazine must then be sited as an above-ground magazine (AGM). This potentially impacts quantity-distance requirements, usually resulting in the need to lower the quantity stored in the magazine. However, the origin of the 2 ft of earth cover requirement is not documented, and it is not clear that the requirement is realistic. In order to address this issue, the U.S. Army Technical Center for Explosives Safety (USATCES) requested support from the U.S. Army Engineering & Support Center, Huntsville (CEHNC) and the U.S. Army Engineer Research and Development Center (ERDC), Vicksburg to address the general issue of the effect of varying earth covers for ECMs. Of particular interest is the point at which an ECM behaves as an AGM, both from the perspective of a donor of and an acceptor for explosive loading. This paper will present the initial series of planned experiments that will be conducted at ¼ scale to begin understanding the reduction in ECM loading due to varying earth cover thickness.

SESSION 34: EQUIPMENT SHOCK DESIGN/QUALIFICATION

SUBMARINE COMPONENT DESIGN TOOL TO ASSESS RELATIVE RESISTANCE TO SHOCK LOADING PART 1

Mr. Justin Caruana, Cardinal Engineering
Mr. Connor Way, Cardinal Engineering
Mr. Patrick Walker, Cardinal Engineering
Dr. Jeff Cipolla, Thorton Tomasetti
Dr. Abilash Nair, Thorton Tomasetti
Dr. Juan Londono, Thorton Tomasetti
Mr. Daniel Kadyrov, Thorton Tomasetti
Mr. Addison Martin, Thorton Tomasetti

In this presentation, Cardinal Engineering, with team member Thornton Thomasetti - Weidlinger Associates Inc, provides an overview of their solution to a Navy SBIR topic which sought an innovative, cost and time efficient design tool that can evaluate new Navy Submarine equipment designs for shock survivability to mitigate non-recurring engineering (NRE) hours. This new software design tool termed Comparative Design Assessment Tool (CDAT) allows users to determine if a newly designed and non-tested component required to satisfy MIL-S-901D IC#2 is as resistant to high intensity shock loadings as a previously designed and MIL-S-901 qualified component with the goal of eliminating high cost testing. When used, CDAT provides assurance to the component designer that the low-cost shock qualification by extension process has a high likelihood of success. Perhaps even more powerful, when the results of CDAT indicate that a component is not as resistant or is high risk relative to previously designed and qualified units, the designer can focus on a low risk, iterative redesign process leveraging CDAT.

SUBMARINE COMPONENT DESIGN TOOL TO ASSESS RELATIVE RESISTANCE TO SHOCK LOADING PART 2

Mr. Justin Caruana, Cardinal Engineering
Mr. Connor Way, Cardinal Engineering
Mr. Patrick Walker, Cardinal Engineering
Dr. Jeff Cipolla, Thorton Tomasetti
Dr. Abilash Nair, Thorton Tomasetti
Dr. Juan Londono, Thorton Tomasetti
Mr. Daniel Kadyrov, Thorton Tomasetti
Mr. Addison Martin, Thorton Tomasetti

In this presentation, Cardinal Engineering, with team member Thornton Thomasetti - Weidlinger Associates Inc, provides a demonstration of CDAT.

GAUSSIAN PROCESS REGRESSION MODEL AS AN ESTIMATOR OF SHOCK QUALIFICATION RISK IN SHIPBOARD SYSTEMS AND COMPONENTS

Mr. Maxwell Jenquin, Cornell University
Dr. Christopher Earls, Cornell University
Dr. Jeff Cipolla, Weidlinger Technology Ventures

The cost of rigorous shock qualification, be it computational effort or in experimental expense, motivates the development of a predictive system to aid in component and system design, and as a decision aid for NAVSEA authorities. By leveraging prior shock qualification experience and test

performance outcomes, a forecasting system can yield not only the predicted outcome of whether or not a new article will pass a shock test, but also predict levels of certainty surrounding this prediction.
This talk will detail the development of such a predictive system based on Gaussian Process (GP) regression, a powerful type of nonparametric data model which is still somewhat underutilized in the engineering disciplines. The proposed system admits physics-based insight, test data, physical simulation data, and expert opinion in a natural way. The result is a predictive model capable of providing high-certainty estimates on shock test outcomes in between known data points (i.e. those with previously quantified performance outcomes) within a given design space. Several techniques for data regularization in high-dimensional parameter spaces will be discussed, as will broader ideas about utilizing GP regression in wider testing contexts.

TRENDING OF SOUNDING ROCKET FLIGHT VIBRATION WITH REYNOLD'S NUMBER

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The flight vibration environment for sounding rocket class vehicles has been characterized using several techniques 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. These vibration levels have proven very effective, through may be more conservative than necessary. NASA and Navy sounding rocket projects have continued to use these same environments even to this day. 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 all 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. Post flight comparisons have validated these predictions. However, some subtle mismatches exist in the patterns between dynamic pressure and vibration magnitudes during these flights. This drove an investigation into other expressions for dynamic pressure which ultimately pointed 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 how that differs from the correlation between flight vibration magnitude and dynamic pressure. We also explain the statistical roll-up of slope coefficients for the ratio of vibration magnitude to Reynold's Number and how these coefficients can be used to estimate the vibration history of an entirely new sounding rocket.