SAVE
SHOCK & VIBRATION EXCHANGE

# Tutorials & Trainings

September 18 - 22, 2022
Denver, Colorado
WWW.SAVECENTER.ORG

# TRAINING TYPES & COSTS

## TUTORIALS

*DESCRIPTION:*
*THREE HOUR COLLEGE LEVEL COURSES (UNLESS OTHERWISE DESIGNATED) ON A SPECIFIC TOPIC. AVAILABLE TUTORIALS ARE LISTED HEREIN WITH A BRIEF DESCRIPTION OF THE MATERIAL TO BE COVERED.*

*WHAT'S INCLUDED?*
*REGISTERED ATTENDEES WILL RECEIVE A SET OF NOTES AND A CERTIFICATE OF COMPLETION. SOME STATES MAY AWARD CEUs/PDHs BASED ON THIS CERTIFICATE OF COMPLETION. ALL NOTES PROVIDED ARE PROPRIETARY TO THE PRESENTER. PERMISSION FOR DUPLICATION OR DISPERSION MUST BE ACQUIRED BY THE PRESENTER.*

*COST:*
*EACH THREE HOUR COURSE COSTS $225 OR ONE COURSE PER AVAILABLE TIME SLOT IS INCLUDED IN THE TRAINING PACKAGE. ATTENDEE MUST PRE-REGISTER TO ENSURE AVAILABILITY OF SPACE AND NOTES.*

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## TRAININGS

*DESCRIPTION:*
*COURSES RANGE IN DURATION FROM 45 MINUTES TO 120 MINUTES. ENTRY LEVEL PROFESSIONAL COURSES ON A SPECIFIC TOPIC. AVAILABLE TRAININGS ARE LISTED HEREIN WITH A BRIEF DESCRIPTION OF THE MATERIAL TO BE COVERED.*

*WHAT'S INCLUDED?*
*NO CERTIFICATE OF COMPLETION IS AWARDED FOR THESE COURSES. AVAILABILITY OF NOTES FOR EACH TOPIC DEPENDS ON INSTRUCTOR AVAILABILITY. ALL NOTES PROVIDED ARE PROPRIETARY TO THE PRESENTER. PERMISSION FOR DUPLICATION OR DISPERSION MUST BE ACQUIRED BY THE PRESENTER.*

*COST:*
*TRAININGS ARE PROVIDED TO PAID SYMPOSIUM ATTENDEES AT NO ADDITIONAL FEE. FOR ATTENDEES NOT ATTENDING THE TECHNICAL PROGRAM FOR THE 92ND SHOCK AND VIBRATION SYMPOSIUM, THE TRAINING PACKAGE MUST BE SELECTED AND PAID IN ADVANCE OF TRAINING ATTENDANCE. THERE IS, HOWEVER, NO NEED TO REGISTER IN ADVANCE FOR EACH SELECTED TRAINING TOPIC.*

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## HOW TO REGISTER

TO REGISTER IN CONJUNCTION WITH THE 92ND SHOCK AND VIBRATION SYMPOSIUM, PLEASE VISIT WWW.SAVECENTER.ORG/SYMPOSIUM AND FOLLOW THE LINKS FOR REGISTRATION.

TO REGISTER FOR THE TRAINING PACKAGE WITHOUT ATTENDANCE TO THE SHOCK AND VIBRATION SYMPOSIUM, PLEASE REGISTER USING THE LINK ON OUR HOMEPAGE.

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

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

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

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.

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

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

The Naval Surface Warfare Center Carderock Division Philadelphia (NSWCCD-SSES) Code 333 is NAVSEA 05P1's Delegated Approval Authority (DAA) for MIL-DTL-901E Surface Ship Shock. As the DAA, Code 333 engineers are responsible for review and approval of all Government Furnished Equipment (GFE) and heavyweight shock tested equipment. NSWCCD 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.

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**DDAM 101**
Mr. George D. (Jerry) Hill (SERCO)

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

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

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

***[SEE ADDITIONAL TOPICS FOR THIS SESSION ON PAGE 6]***

# TUTORIAL SESSION 1
# 8:00 - 11:00AM
# (CONTINUED)

**INTRODUCTION TO PYROSHOCK TESTING**
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.

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

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

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

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

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

*[SEE ADDITIONAL TOPICS FOR THIS SESSION ON PAGE 8]*

# TUTORIAL SESSION 2
# NOON - 3:00PM
# (CONTINUED)

**EFFECTIVE SOLUTIONS FOR SHOCK AND VIBRATION CONTROL**
Mr. Alan Klembczyk (Taylor Devices)
Dr. J. Edward Alexander (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. Examples of the vibration environment are discussed in terms of a power spectral density (PSD) and correlation of a PSD input and the maximum equipment RMS acceleration response, based on Miles equation. Matlab functions for SDOF equipment response based on characteristics of various shock isolators are described where example results are correlated to test data.

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**OVERVIEW OF UNDERWATER EXPLOSION PHENOMENOLOGY AND BULK CHARGE WEAPON EFFECTS**
**NOTE: LIMITED DISTRIBUTION D (SECURITY PAPERWORK REQUIRED)**
Mr. Greg Harris (Consultant)

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

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

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

**MIL-DTL-901E SUBSIDIARY COMPONENT SHOCK TESTING & ALTERNATIVE TEST VEHICLES**
Mr. Kurt Hartsough (NSWC Philadelphia)
Mr. Domenic Urzillo (NSWC Carderock)

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

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**ANALYSIS FOR A MEDIUM WEIGHT SHOCK TEST**
Mr. Josh Gorfain (Applied Physical Sciences)

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

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**REMOVING THE BOUNDARY CONDITION HOBGOBLINS IN VIBRATION QUALIFICATION TESTING WITH MODAL TECHNIQUES**
Mr. Troy Skousen (Sandia National Laboratories)
Mr. Randy Mayes (Consultant)

*Mitigating the field-to-laboratory boundary condition impedance mismatch for base excitation testing by controlling the test article fixed base elastic modes through appropriate base inputs*

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

*[CONTINUED ON PAGE 10]*

# TUTORIAL SESSION 3
# 4:00 - 7:00PM
# (CONTINUED)

The same approach can be applied to achieve much higher fidelity 3 DOF translation base input tests. The model can also be used to address unit-to-unit variability simply based on a laboratory random survey before the component qualification test is executed.

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

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**CAN METHODS FOR NUMERICAL TIME INTEGRATION IN COMMON USE BE REPLACED BY EQUIVALENT DIGITAL FILTERS?**

Prof. Kjell Ahlin (Xielalin Consulting)

Equivalent digital filters have been derived for conventional explicit methods used in numerical time integration of forced responses in mechanical systems. The methods are Runge-Kutta, Newmark beta, HHT-alpha and matrix exponential. To simulate forced response, modal superposition is used. For each mode there is a corresponding second order digital filter. The filter coefficients are calculated from the used sampling frequency (or time step), the residues and poles for the Frequency Response Function in question, and the actual original model parameters, such as alpha, beta and gamma for HHT-alpha method.

As modal superposition is used, there is a natural way to limit the calculation to a certain frequency range by using a limited number of modes. In that way the problem with high frequency modes is eliminated. If only a limited number of inputs and responses are of interest, the filter method is much faster, giving the same result.

As the filter method is equivalent with the conventional method, the filter properties can easily be used to map the properties for the original method. In that way properties like stability range and accuracy, both in time and frequency domain, are easily calculated. This means that the accuracy for a certain simulation may be exactly calculated in beforehand without doing any simulation. In that way a needed fixed time step for a defined accuracy can be calculated, avoiding the need for methods with changing time steps, like ODE45.

Comparison is made with a class of filters based on the convolution integral. It is shown that those filters may have better accuracy, putting the whole use of the conventional methods under question

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

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

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.

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

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.

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**APPLICATION OF ENGINEERING FUNDAMENTALS IN SOLVING SHOCK AND VIBRATION PROBLEMS**
Mr. Fred Costanzo (Consultant)

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

***[SEE ADDITIONAL TOPICS FOR THIS SESSION ON PAGE 12]***

# TUTORIAL SESSION 4
# 8:00 - 11:00AM
# (CONTINUED)

**COMMON ROADBLOCKS/MISTAKES FROM SHOCK QUAL.; PRACTICAL GUIDANCE & CASE STUDIES**
Mr. Patrick Minter (HII - Newport News Shipbuilding)

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

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

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

**SHOCK TEST FAILURE MODES**
Mr. Kurt Hartsough (NSWC Philadelphia)
Mr. Domenic Urzillo (NSWC Carderock)

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

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

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

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**QUANTITATVE METHODS FOR HIGH-G ELECTRONICS SURVIVABILITY**
**NOTE: LIMITED DISTRIBUTION D (SECURITY PAPERWORK REQUIRED)**
Mr. Curtis Mckinion (Air Force Research Laboratory)
Dr. Matthew Neidigk (Air Force Research Laboratory)

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

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

*[SEE ADDITIONAL TOPICS FOR THIS SESSION ON PAGE 14]*

# TUTORIAL SESSION 5
# 3:30 - 6:30PM
# (CONTINUED)

**SOME METHODS FOR ANALYZING NONLINEAR RANDOM VIBRATION**
Dr. Tom Paez (Thomas Paez Consulting)

All physical systems reflect nonlinear behavior, and most of those systems experience random vibration environments during their lives. Under some commonly observed circumstances, the level of nonlinearity in structural response is small, and a physical system can be modeled and analyzed as though it were linear. But there are also times when nonlinear behaviors must be understood and modeled. This tutorial starts with a brief review of linear random vibration. The idea of spectral density is developed on an intuitive level. Input-output relations for random vibration of linear structures are developed, culminating in the Fundamental Relation of Random Vibration. Next, some general ideas of nonlinear random vibration are presented. The reason why nonlinear random vibration yields non-Gaussian responses to Gaussian excitations is explained. Means for determining whether, and to some extent how much, nonlinearity is reflected in structural response are considered. The information obtained here can serve to determine whether or not nonlinearity must be modeled. Finally, a few methods for modeling nonlinear random vibration are developed. These include at least one “local linear” method where random vibration responses at various levels and with various distributions of frequency content serve to model and predict structural responses to arbitrary excitations. In addition, a fully nonlinear approach to modeling nonlinear random vibration behavior of a system is presented. An electronic copy of the presentation slides will be available to all tutorial participants, as well as MATLAB code to reproduce the examples in the presentation.

## SAMPLE TRAINING TOPICS (CONFIRMED TOPICS TO BE LISTED IN SUMMER 2022)

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|---|---|
| **INTRODUCTION TO MEDIUM WEIGHT SHOCK TESTING** | **120 MINUTES** |
| **SHOCK RESPONSE SPECTRUM PRIMER** | 90 MINUTES |
| **USING SUPERVISED LEARNING (PYTHON) TO QUANTIFY UNCERTAINTIES ABOUT A SHOCK EVENT** | **45 MINUTES** |
| **INTRODUCTION TO HEAVYWEIGHT SHOCK TESTING** | **120 MINUTES** |
| **INTRODUCTION TO UNDERWATER EXPLOSION PHENOMENA WITH BASIC APPLICATIONS TO STRUCTURES** | **90 MINUTES** |
| **CAN METHODS FOR NUMERICAL TIME INTEGRATION IN COMMON USE BE REPLACED BY EQUIVALENT DIGITAL FILTERS?** | **120 MINUTES** |
| **DSSM SHOCK TESTING (MIL-DTL-901E TOPIC)** | **60 MINUTES** |

# QUESTIONS?

## CONTACT OUR OFFICE

BY PHONE: 434.581.3041

ASHLEY.SHUMAKER@SAVECENTERORG