SAVE
SHOCK & VIBRATION EXCHANGE

96TH SHOCK AND VIBRATION SYMPOSIUM

TUTORIAL GUIDE

SEPTEMBER 20 - 24, 2026 | ORLANDO

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SUNDAY, SEPTEMBER 20
TUTORIAL SESSION I (8AM - 11AM)

MIL-DTL-901E SHOCK QUALIFICATION TESTING
Kurt Hartsough (901 E&T)

Instructor 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.

SUNDAY, SEPTEMBER 20
TUTORIAL SESSION II (1PM - 4PM)

MIL-DTL-901E SHOCK QUALIFICATION TESTING EXTENSIONS
Kurt Hartsough (901 E&T)

Instructor 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.

MONDAY, SEPTEMBER 21
TUTORIAL SESSION III (8AM - 11AM)

MIL-DTL-901E SUBSIDIARY COMPONENT SHOCK TESTING & ALTERNATIVE TEST VEHICLES
Kurt Hartsough (901 E&T)

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 instructor (Hartsough).

PLANNING LIFE CYCLE DESIGN, ANALYSIS, AND SHOCK AND VIBE QUALIFICATION OF NAVY EQUIPMENT
Dr. Christopher Merrill (CM&A Engineering)

This tutorial provides general simple techniques for use in parallel with long term Classical and Numerical Dynamic Analysis of Systems subjected to US Navy shock and vibration requirements over Navy equipment life cycles to maximize accuracy and minimize errors in Dynamic Analysis and Qualification of electronic and mechanical systems. The interaction of the US Navy shock and vibration requirements is a major driver of the efficacy of long-term Dynamic Analysis from the start.Apart from major issues that occur on any major long-term developmental programs, simple, seemingly minor, errors present in the analysis from the beginning can lead to huge cost and schedule impacts generally at the worst time for the program (FAT). Fortunately, there are procedural long-term Dynamic Analysis Quality Control techniques that can be used from the beginning and in parallel during the long-term dynamic analysis to mitigate the risk of such errors.This tutorial will provide examples of types and genesis of such errors, as well as, a process to perform at the beginning and in parallel with the long-term dynamic analysis in order to perform quality control comparisons to mitigate these errors. Finally, the importance of comparison of FAT dynamic test results to dynamic analysis including failure and use of prototyping will be included. The tutorial will end with an exercise where the trainer will attempt to stump the trainee with balky computer model results. The trainee will leave the tutorial with a list of types and genesis of discrete and basic errors, a process chart and algorithm for applying these Quality Control Techniques at the start and in parallel with the long-term dynamic analysis, and insight on improving techniques for planning Life Cycle Design, Analysis, and Shock and Vibe Qualification of Navy Equipment.

FUNDAMENTALS OF SINE AND RANDOM SHAKER TESTING
Chris Sensor (Siemens)

This tutorial will cover the fundamental concepts of shaker Sine and Random vibration testing. Swept Sine, Sine Dwell, Random, Sine-on-Random, Random-on-Random and Time Waveform Replication test modes will be covered. Additional topics such as response limiting, control channel averaging, kurtosis, and practical shaker considerations will also be discussed. Subjects will be accompanied by live demos of shaker tests, with opportunities for hands on participation by attendees.

ANALYSIS FOR A MEDIUM WEIGHT SHOCK TEST

Josh Gorfain (Quartus Engineering)

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.

MONDAY, SEPTEMBER 21
TUTORIAL SESSION IV (11:30AM - 2:30PM)

DATA INTEGRITY
John Hiatt (DEWESoft)

The data integrity training is designed as an overview of the data acquisition process and how each step in the measurement chain can affect your measured data. Primary focus of this session is on the data acquisition system (DAS). We will learn what happens in each step of the process and how to mitigate common measurement errors. The idea is to get the best possible data first time. Its hard to make good decisions with bad data. We also cover DAS specifications so users can be better prepared to compare system specifications.

FUNDAMENTALS OF CLASSIC SHOCK AND SRS SHAKER TESTING
Chris Sensor (Siemens)
Melissa Maze (PCB Piezotronics)

This tutorial will cover the fundamental concepts of shaker shock testing, from field data acquisition to Classic Shock and Shock Response Spectrum (SRS) wavelet synthesis in a vibration controller. The tutorial will cover shock data acquisition and analysis, classic shock pulses, SRS concepts, SRS and Pseudo Velocity Shock Spectrum (PVSS) data analysis, a review of Classic Shock and SRS test methods in MIL-STD-810H (including the "new" method of Te and TE), shock test tailoring and SRS wavelet synthesis for shaker SRS testing. A segment covering specialty shock sensors and instrumentation will also be presented. Subjects will be accompanied by live demos of data acquisition and shaker tests, with opportunities for hands on participation by attendees.

THE HISTORY OF RANDOM VIBRATION
Dr. Tom Paez (Consultant)

Random vibration is the study of the responses excited in structures by stationary (steady-state) and nonstationary stochastic inputs. A necessity for the implementation of random vibration analyses is random signal analysis; it is used to specify the functions that underly random input and response models. Random vibrations are ubiquitous in practice; hence, the theories of random vibration and random signal analysis are used frequently. This presentation defines the terminology and quantities used in random processes and random vibration, and it describes the fundamental operations that can be performed. It also shows how random signal analyses are used in connection with random vibration. The development of the theory of random vibration from the foundational paper written by Einstein (1905) to the present era are described. Course participants are provided with a link to a site with a color copy of the presentation slides as well as MATLAB functions that reproduce many of the examples in the presentation.

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MONDAY, SEPTEMBER 21
TUTORIAL SESSION IV (CONTINUED)

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 challenging. Some of the biggest challenges in this type of work are 1) properly collecting the initial raw data while avoiding aliasing, 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 tutorial provides guidance to 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 tutorial introduces key aspects of working with transient data – specifically, 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 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.

NUMERICAL METHODS USING MODERN FORTRAN

Dr. Robert Browning (Battelle)

Abstract Pending

MONDAY, SEPTEMBER 21
TUTORIAL SESSION V (3:00PM - 6:00PM)

DDAM 101
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.

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

This three-hour 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.

SOLVING SHOCK AND VIBRATION PROBLEMS: ISOLATION SYSTEMS
Shawn Czerniak (Hutchinson)

This tutorial will be structured in three parts to provide the attendee with: 1) Shock and Vibration fundamentals (Spring-Mass-Damper system, Linear vs Non-Linear, Material selection & Material influence) 2) Various examples of commercially available isolation solutions (Elastomeric, Metallic, Friction Damped, Air Damped, Application examples) , and 3) Real world examples of isolation systems at work (System parameters, Isolation system requirements, Analytical predictions & Shock test videos). The attendee will leave the tutorial with an enhanced understanding of how an isolator designer uses their expertise and available tools to craft a compliant isolation system that meets the needs of their customer.

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DIGITAL SIGNAL PROCESSING - FILTERING AND THE FOURIER TRANSFORM (GOING FROM TIME TO FREQUENCY DOMAIN)

John Hiatt (DEWESoft)

Two of the most common Digital Signal Processing (DSP) techniques are filtering and transforming data from the time domain to the frequency domain with the Fourier transform (FFT). Both mathematical processes can create unwanted effects on the data. This session will examine these effects on your data and how they can be mitigated. For the Fourier transform, we will also discuss the assumptions, inputs to the FFT and possible reasons FFT's calculated with two different software packages do not match. This training is designed to help new users understand how these processes and how they work to help prevent data processing mistakes.

TUESDAY, SEPTEMBER 22
TUTORIAL SESSION VI (8:00AM - 11:00AM)

OVERVIEW OF UNDERWATER EXPLOSION PHENOMENOLOGY AND BULK CHARGE WEAPON EFFECTS

NOTE: LIMITED DISTRIBUTION D (SECURITY PAPERWORK REQUIRED)

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.

FUNDAMENTALS OF MODAL ANALYSIS

Steff Nelson (Siemens)

The class will focus on hands-on demos related to tap testing modal analysis. It will begin with simple concepts such as what is a mode, what is damping, what is a natural frequency. It will build to more advanced concepts like modal curve fitting and best practices for taking data and setting up a test. Participants will be encouraged to bring a laptop to follow along, with some others being encouraged to participate in the modal hits. Also covered will be frequency response functions and coherence.

REMOVING THE BOUNDARY CONDITION HOBGOBLINS IN VIBRATION QUALIFICATION TESTING WITH MODAL TECHNIQUES

Troy Skousen (Sandia National Laboratories)
Randy Mayes (Consultant)

How a modal technique provides a simple modification to the base input mitigating the field-to-laboratory impedance mismatch for high confidence component qualification

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 degree of freedom (SDOF) shaker test specifications guarantees large response uncertainties when compared with the field environment responses due to the difference in laboratory boundary conditions. A brief review is provided showing how fixed-base 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 intuitive responses. This model demonstrates why 6DOF laboratory control can eliminate large uncertainties in traditional SDOF testing with a corresponding boost in qualification confidence. In fact, the model leads to modified base inputs for a greatly improved SDOF or 3DOF test.

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INTRODUCTION TO MIL-STD-461 ELECTROMAGNETIC INTERFERENCE QUALIFICATION REQUIREMENTS FOR SHIPBOARD & SUBMARINE ELECTRONICS EQUIPMENT

Jeffrey Viel (Element US Space & Defense)

This 3 hour tutorial provides a comprehensive overview of the Electromagnetic Interference (EMI) requirements and verification criteria for airborne, sea, space, and ground systems and platforms as defined in the most current version of MIL-STD-461G, the Electromagnetic Interference and Control Requirements for electrical and electronic subsystems. This course explains the basic cause and effects of EMI/E^3 within platform installations as well as their operating environments and how equipment and subsystems and platform systems are evaluated against these threats.

This course covers many common issues encountered during MIL-STD-461G/H compliance testing, including lessons learned and comparisons to previous versions of the standard to highlight important changes to these requirements overtime. Essential guidance on test/evaluation planning and formal test procedure development will be provided along with a detailed technical overview of the test & assessment methods defined in the standard.

RESONANT PLATE SHOCK TESTING FOR PYROSHOCK SIMULATION

Dr. Carl Sisemore (ShockMec Consulting)

Pyroshock is traditionally defined as a decaying, oscillatory structural response to a high-amplitude, high-frequency mechanical excitation. The other distinctive characteristic is the near zero momentum transfer from the shock event. The aerospace industry has long recognized the potentially destructive effect of pyroshock on sensitive electronics and electro-mechanical devices. The aerospace industry frequently utilizes the firing of explosive bolts, nuts, pins, cutters, and other similar pyrotechnic devices to perform operations in their systems due to the simplicity of operation and the high reliability of those mechanisms. Additionally, other non-explosive environments such as the sudden release of strain energy or metal-to-metal impacts can produce effects similar to pyroshock. Resonant plate shock testing is a common technique for simulating pyroshock events in the laboratory. Resonant plate testing can produce a very similar, high-amplitude, high-frequency oscillatory shock response in a test article. The concept is relatively simple, but the application of the test method is an art. There are many variables to consider when designing a resonant plate test: plate size and materials, boundary conditions and damping configuration, impacting mass, impact velocity and interface stiffness. All these variables interplay to create a pyroshock simulation in the test laboratory. This tutorial will provide an overview of resonant plate theory and the practical implementation of resonant plate shock testing. How should resonant plate shock environments and test specifications be defined. How to design resonant plates for frequency and performance. How to select impact hammers and test configurations for successful shock testing. Examples from actual resonant plate shock tests will also be used to demonstrate the theoretical results seen in practice.

WEDNESDAY, SEPTEMBER 23
TUTORIAL SESSION VII (3:30PM - 6:30PM)

SHOCK TEST FAILURE MODES
Kurt Hartsough (901 E&T)

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.

QUANTITATIVE METHODS FOR SURVIVABLE ELECTRONICS PACKAGING FOR COMBINED LOADING OF THERMAL AND HIGH AMPLITUDE MECHANICAL SHOCK
NOTE: LIMITED DISTRIBUTION D (SECURITY PAPERWORK REQUIRED)
Dr. Matthew Neidigk (AFRL)
Zachary Jowers (Applied Research Associates)

Fuze electronics intended for hard target defeat must survive both MIL-STD thermal cycle environments and extreme mechanical shock. Fuzes are often potted to prevent printed circuit board (PCB) flexure associated with component failure during impact. Potting techniques, or packaging strategies, may vary significantly by vendor and are often developed through trial and error. In many cases they are proprietary. Some packaging strategies include the application of elastomeric coatings to PCBs and components, or the use of epoxy underfills beneath components. Because most packaging materials are polymers, the disparity in thermal expansion between them and other fuze materials leads to a whole new series of problems during thermal cycling. As such, the DoD and the DOE have devoted considerable effort in the areas of material characterization, model development, and experimental validation, all with the goal of identifying survivable packaging strategies for use in both conventional and nuclear weapon stockpiles. Upon completion of this course, the user should have a basic understanding of the properties of common packaging materials, modeling and simulation tips and tricks, and latest developments in the design and evaluation of survivable packaging strategies for high-g electronics.

INTRODUCTION TO WEAPONS EFFECTS AND SHIP COMBAT SURVIVABILITY ANALYSIS
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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REVIEW OF PRACTICAL VIBRATION/SHOCK MITIGATION METHODOLOGIES

Dr. Daryoush Allaei (QRDC Inc)
Prof. Arezoo Emdadi (Missouri Univ. of Science & Technology)

Real-world vibration and shock mitigation strategies fall into three main categories: Source control - reduce vibration or shock load where it originates, Path control - interrupt or attenuate transmission, and Receiver protection - isolate or harden the sensitive system.

Source Mitigation Techniques (Eliminate or Reduce Excitation) is the most effective when feasible. Common Methods include balancing rotating components (reduces centrifugal forces), precision alignment of shafts and couplings, reducing excitation forces (lower speeds, smoother profiles), soft start / ramp control (limits transient shock), process redesign (e.g., replacing impact processes (inducing shock waves) with continuous ones), and eliminating resonance at the source avoids amplification downstream. Even small improvements here often yield large system-wide benefits.

Path Mitigation Techniques (Interrupt Transmission) address or modify how vibration or shock load travels through structures. Some of the well know methods are isolation using elastomer mounts (rubber, neoprene), spring isolators, and air mounts. The main idea is to reduce transmissibility when operating frequency > √2 × natural frequency. Damping treatments is another approach that is most effective near or at resonance frequency. Some of the damping treatments include viscoelastic damping layers, constrained layer damping (CLD), and tuned mass dampers (TMDs). One may modify structure by increasing stiffness (shift natural frequency), adding mass (lower response amplitude at high frequency), and introduce discontinuities (break transmission paths). It is noted that isolation works best for steady-state vibration while damping is critical for transient and resonant conditions.

Receiver Mitigation Techniques (Protect the Payload) is applied when source/path control is limited or impractical. Some of these methods are isolating systems, such as equipment mounts, floating platforms, and shock-mounted enclosures. Shock protection methods include foam packaging (energy absorption), wire rope isolators (high durability), and hydraulic dampers (high-energy shock). Structural hardening includes reinforced components, ruggedized electronics, and potting or encapsulation. It is noted that receiver isolation should consider payload fragility curves (G-level vs duration) while over-isolation can introduce instability or excessive motion.

Practical application of these methodologies will be discussed.

MIL-DTL-901E ENGINEERING TOPICS

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.