SUNDAY
9:00AM – 5:00PM

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.

MONDAY
8 – 11AM

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.

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.

The Measurement & Utilization of Valid Shock and Vibration Data
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.

A Toolbox in Octave for the Designer of Vibration Testing Programs
Mr. Zeev Sherf (Consultant)

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

Common Roadblocks and Mistakes from Shock Qualification; Practical Guidance and Case Studies
Mr. Patrick Minter (Huntington Ingalls, 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 that were faced, the utilized testing/analysis methodologies, related 901 requirements and lessons learned. The end-goal of the training is to provide attendees with a better practical understanding of shock qualification by test and extension. This course is aimed at those who are or will be responsible for shock qualifying naval equipment per 901 requirements. This course assumes the attendees have at least a base understanding that attendees have participated in the NSWC (Hartsough and Urzillo) 901 trainings or at least have a basic understanding of 901 requirements. There will also be a portion of the tutorial set aside for specific attendee questions and hypothetical scenarios.

MONDAY
NOON – 3PM

MIL-DTL-901E Shock Qualification Testing Extensions
Mr. Kurt Hartsough (NSWC Philadelphia)
Mr. Domenic Urzillo (NSWC Carderock)

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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.

Multiple-Input Multiple-Output Control for Acoustics and Vibration Environmental Testing: Theory and Practice
Mr. Umberto Musella (Siemens Industry Software)
Mr. Mariano Blanco (Siemens Industry Software)

Environmental tests are performed to prove that a system and all the sub-components will withstand the harshness of a predicted environment during the operational life. These tests aim to replicate with a high degree of fidelity the structural responses of a Unit Under Test (UUT) in the in-service conditions. As far as dynamic tests are concerned, the replication of the environmental conditions is only effective if the UUT's dynamics is also faithfully represented in the lab. The common practice of Single-Input Single-Output (SISO) control tests has known limitations and drawbacks. The most critical aspect is that SISO tests may lead to unacceptable UUT time to failure overestimation and different failure modes. On top of more practical aspects that make difficult (or even impossible) to perform SISO tests (e.g. testing large items), this is the main reason why Multi-Input-Multi-Output (MIMO) tests are nowadays the "go for" in the environmental testing community for both vibration and acoustics testing.

Even though the benefits of MIMO testing are clear and widely accepted by the environmental engineering community ever since 1958, this practice experienced a very slow growth. Initially this was due to the available technology in terms of excitation mechanisms and computational power for the data acquisition hardware and vibration controllers. Just recently, the increased complexity, size and cost of the article to be tested increased the concern about replicating as close as possible the environments to be tested. The high degree of expertise needed to perform these tests and decades of SISO controlled excitation built meanwhile a legacy of standards that currently represents the main reference for the environmental test engineers. For this reasons nowadays MIMO tests are still considered a pioneering testing methodology.

The objective of this course is to give a detailed insight on MIMO control for reproducing a more realistic vibration and acoustic environments. An introduction to the topic will provide the theoretical background needed to understand MIMO control tests. Two parts (acoustics and vibrations) will follow, that focus, at the light of the acquired background, on industrial application cases and research topics in the field.

An Introduction to Aliasing, FFT, Filtering, SRS & More for FEA Users and Test Engineers
Dr. Ted Diehl (Bodie Technology)

User's of Explicit Dynamics codes (LS-Dyna, Abaqus/Explicit, Radioss …) compute transient solutions that typically contain "solution noise" in addition to the expected "frequency-rich" content created by severe impacts, shocks, failure, etc. The overall characteristics of the frequency content vary within result quantities of acceleration, velocity, displacement, strain, stress, and reaction forces. Evaluating these simulation results with time-history plots and deformation and stress contour plots/videos can easily become highly inaccurate and misleading due to "noise" and distortions caused by aliasing. Test engineers face similar, but different, issues with noise in their physical measurements.

This course provides guidance to both simulation analysts and test engineers on how to properly collect and process such data. Topics covered range from how to collect data correctly to avoid aliasing, how to use Fourier Spectrum methods to understand frequency content, and how to apply various filtering tools to remove noise - ultimately, uncovering significantly improved results. In addition, the course will explain how to use Shock Response Spectra methods to compare typical component shock specs (ie. 1,000*G, 1.0*msec) with transient acceleration data derived from simulations or tests to assess shock survivability, including a quick SRS calculation method to evaluate the influence of shock isolation when such isolation was not originally in the system.

The 3-hour seminar covers highlights of DSP theory in the language of Mechanical Engineering pertinent to simulation analysts and test engineers along with numerous practical applications presented. This seminar introduces key aspects of working with transient data – specifically, clearly explaining time-domain and frequency domain analysis (DFS, FFT, PSD, SRS, PVSS); data collection (sampling, up-sampling, decimation, and aliasing); filtering (lowpass, highpass, IIR, and FIR), calculating Shock Response Spectrum from transient data, and numerous unique aspects related to explicit dynamics FEA data (non-constant time increments, massively over-sampled data, short transient signals with non-zero end conditions, …).

Simplified interactive demonstrations are presented to solidify key DSP aspects, along with many relevant real-world examples - including a penetration analysis that includes SRS estimates of benefits of adding a shock isolator, severe impact analysis of an electronic device, dynamic analysis of a snap-fit, and failure simulation of a metal component modeled with cohesive elements. Both FEA users and experimentalists will benefit from this training.

Effective Solutions for Shock and Vibration Control

Mr. Alan Klembczyk (Taylor Devices)
Dr. Ed 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. 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.

MONDAY
4 – 7PM

MIL-DTL-901E Subsidiary Component Shock Testing & Alternate 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).

Introduction to Weapons Effects and Ship 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.

DDAM 101
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 nequipment and outfitting on naval combatants using normal mode theory, originally extended from earthquake analysis methods. The DDAM requires linearelastic model behavior and employs a statistical method of modal superposition yet has persisted to today as the U.S. Navy required method for shock qualification by analysis. This, in spite of the rapid advancement of dynamic transient simulation technology and techniques for representing nonlinearities including material plasticity and contact behavior. The tutorial will address: how the method works, how the shock spectral input values are presented in DDS-072-1, what is the role of modal weights and participation factors, why has the method persisted including what are its strengths and also what are its weaknesses. The tutorial will provide a basic understanding of the method, requirements, and procedures to those who expect to be involved in shock analysis and will demystify the procedure for many who are current users.

How Modal Analysis Can Bring Insight to Vibration Testing
Mr. Troy Skousen (Sandia National Laboratories)
Mr. Randy Mayes (Sandia National Laboratories)

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

Sandia National Laboratories is a multi-mission 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.

Application of Engineering Fundamentals in Solving Shock and Vibration Problems
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.

TUESDAY
8 – 11AM

Changes from MIL-S-901D to MIL-DTL-901E Explained
Mr. Kurt Hartsough (NSWC Philadelphia)
Mr. Domenic Urzillo (NSWC Carderock)

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

MIL-DTL-901E Engineering Topics
Mr. Domenic Urzillo (NSWC Carderock)

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.

A Primer on Vibration Testing and Data Analysis
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.

Quantitative Methods for High-G Electronics Design
Dr. Jacob Dodson & Dr. 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.

Introduction to Design Shock-Mounted Systems Using Shock Isolation Mount Prediction & Loading Estimates (SIMPLE) Software

Mr. Dave Callahan (Huntington Ingalls, 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 and vibration analysts, mount vendors and shock qualification reviewers/approvers.

WEDNESDAY
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.

Comparison of Two Spectral Estimators
Dr. Thomas Paez (Thomas Paez Consulting)

The standard method for obtaining estimates of the spectral functions of random processes, including autospectral densities, cross-spectral densities, and frequency response functions, is Welch's Method. It has proven more than satisfactory in terms of speed and accuracy. Welch's Method is used in stand-alone applications where estimates of the spectral functions of random sources are required and recorded data from the sources are available, and it is used in real-time applications where running estimates of spectral functions are required. The forms of Welch estimators can be obtained using the Method of Maximum Likelihood; therefore, the estimators are asymptotically unbiased and consistent, and have many more favorable characteristics. These things make their use desirable.

Yet, there are many other methods for obtaining spectral function estimates, including (1) simple mean square-based estimates, (2) Karhunen-Loeve expansion-based estimates, (3) autoregressive-moving average model-based estimates, and (4) Parzen-type estimates. It is often speculated that the latter estimate, the Parzen estimate, merits consideration for use in practical situations as an alternative to Welch's Method.

This tutorial reviews the estimation of spectral functions using Welch's Method and it describes how error estimation is performed. The number of operations required to perform Welch's estimates is obtained. Then the estimation of spectral functions using Parzen's Method is developed. Error estimation for Parzen's Method is performed and the number of operations required to obtain spectral functions with Parzen's approach is specified. Comparisons between Welch's estimators and Parzen's estimators are performed via multiple examples. Particular attention is paid to estimator bias and estimation error.

Finally, an electronic copy of the course slides, and the numerical examples are provided to each course participant. The numerical examples include MATLAB/OCTAVE software for computing sample autospectral densities, cross-spectral densities, and frequency response functions following Welch's Method and Parzen's Method. Data from a physical source are included. Software to generate random data is included. And the software used to compare the estimates obtained using Welch's and Parzen's Methods are included.

Applying Method 525 of MIL STD 810 G -Calculation of Parameters for the Evaluation of the Field to the Laboratory Equivalence

Mr. Zeev Sherf (Consultant)

The evaluation of the field to laboratory vibration simulation equivalence under Method 525 (Time Wave Replication-TWR), requires the calculation of a wide range of characteristic parameters in singles or in pairs. When analyzing in detail the requirements, it will be found that the method's application requires a good control of time series analysis methods and tools for their implementation. As a matter of fact, when the Method is applied in parallel to the vibration control system, a good time series analysis package must be operated. On simulated time histories from the "field" and from the "laboratory" the use of Method 525 will be exemplified.