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## **Design & Development of Explosive Components & Explosive Trains 2 days, 3 instructors**

### OVERALL OBJECTIVES:

This course will consist of three days of lectures punctuated by group problem-solving sessions, and inert demonstrations of explosive component test and evaluation techniques. This course is intended to familiarize each student with energetic materials and design configurations that can potentially be employed to produce adequately safe and reliable explosive components, which will serve critical roles in the explosive train of a fuze for a weapon system. The fuze is designed to result in the reliable function of the warhead, or serve an ancillary function to perform mechanical work, ignite a rocket motor, sever an escape canopy, initiate a gas generator, or perform a destruct function on a critical asset when the proper stimuli are applied. The course will discuss components fired with low and with high energy, loaded with primary and/or secondary high explosives, propellants, or pyrotechnic materials, and the safe handling, manufacturing and testing processes used to characterize their sensitivity and output. Students will be shown means through which an explosive component configuration is designed, based upon system-level requirements, how appropriate energetic materials, materials of construction, and mechanism of initiation are chosen, and how a suitable and efficient development and test plan should be planned and executed to characterize the component for its critical attributes.

### LEARNING OBJECTIVES:

At course completion, each student should be able to understand:

Why particular types of explosive components or trains are chosen for a given application

- strengths & weaknesses of primary & secondary explosives and pyrotechnic materials
- families of explosive component types, e.g., detonators, actuators, squibs, igniters
- functionality and range of sensitivity for various component types
- cost and complexity required to design, develop, and produce various types of components & trains
- history and evolutionary basis that has led us to use the explosives and configurations currently employed in explosive components
- critical data that you must gather about the energetic material, component configuration and interactions between components to assure a safe and reliable explosive train
- basic manufacturing techniques, along with pitfalls that a process engineer may encounter.
- interaction of an explosive's physical properties and overall performance

Safe handling techniques for processing, storing, and transferring primary explosives

- proper anti-static precautions (grounding, bonding, maintenance of proper humidity)
- use of static-dissipative tools & containers
- avoidance of grit sensitizers
- minimization of working quantities
- prudent use of shields & PPE
- regular inspection of materials for anomalous morphologies
- proper phlegmatization in storage

Design of components for reliable actuation by a firing source

- power as a fundamental criterion for initiation
- ignition/initiation criteria and design analysis

Standard low-cost test techniques for component characterization

- steel dent plate, consistency of function time, all-fire and no-fire levels
- statistical test techniques for go/no-go testing
- stray-voltage testing
- non-destructive test methods for EED characterization (such as electrothermal response)
- discrete and serial application of adverse environmental exposures
- Mil-DTL-23659 pin-pin, pin-case ESD testing & 1W/1A no-fire tests
- time-of-arrival/breakout probes (TOADS, ionization probes, SIP gages)

Component interface analysis methods

- statistical models & methods (Bruceton, Probit, Logit, D-Optimal)
- VARICOMP and VARIDRIVE
- progressive arming
- margin for reliability
- excess transit time and timing consistency

Component failure analysis techniques

- point-source radiography
- live component disassembly
- detection of chemical incompatibilities (DSC, TGA)

Suitability of a given energetic material or mixture for use in an explosive component

- *Performance*: initiability, critical diameter/thickness, growth-to-detonation distance, detonation pressure, priming ability
- *Manufacturability*: pressing characteristics, dead-press susceptibility
- *Safety and Stability*: dielectric strength, chemical compatibility, long-term thermal stability, potential for recrystallization
- *Cost & Availability*

Development & implementation of a component qualification plan

- environmental test plan with proper controls, derived from the stockpile-to-target characteristics of the end item
- long-term chemical compatibility and aging
- HERO, EMI, and ESD robustness

Proficiency of each student will be evaluated in part through a series of group problem-solving sessions, in which each small group will be given an assignment similar to one of the following:

- (1) Data from a hypothetical in-service failure of a component or explosive train will be provided. The group will be tasked to formulate a written test plan in order to

- determine the most probable cause of the failure in a safe and cost-effective manner, and provide expedient short- and long-term solutions to the problem.
- (2) End-item requirements for an explosive train for a fuze will be specified, as well as a set of operational environments. The group will be tasked to choose a configuration of explosive components that will best meet the sensitivity, output, reliability, and safety requirements for the end-item application, as well as a risk-mitigation strategy. In addition, they will define an appropriate development, test, and evaluation plan for the components and component interfaces.

#### IMMEDIATE BENEFITS:

Class notes will provide students with awareness of appropriate applications for low-energy and high-power explosive components, and guidance for approaches to their design, evaluation of the performance and reliability, and safety tips for handling of primary explosives and pyrotechnics. Class exercises will acquaint students with the types of decisions a component designer, systems engineer or analyst may be called upon to perform, and feedback from instructors on the exercises will provide useful experience concerning component design, testing and selection issues. Students will be familiarized with methodologies available for testing and statistical evaluation of the interfaces between components of an explosive train so that they may do so independently in the future. Such familiarity will also enable them to objectively evaluate the attributes of explosive components & trains designed by others, to judge the suitability of the energetic materials chosen, and to properly interpret data concerning the robustness of a component or train design produced within the laboratory, or from elsewhere.

#### INSTRUCTORS:

Instructors for this course will be Mr. Gerald Laib of NSWCIH DIV, Mr. Al Munger of Los Alamos National Laboratory (LANL), and Dr. Jim Kennedy, of HERE, LLC. Mr. Laib has over 34 years experience in explosives work including the development & qualification of new primary explosive materials & explosive components, formulation of primer, igniter, and other energetic mixtures, and performance of VARICOMP, VARIDRIVE, SSGT and LSGT tests on many new experimental explosive configurations. He has conducted many explosive post-accident investigations and failure analyses on weapon systems and sub-systems. For 15 years, Mr. Laib served as the Manager of the Explosive Components Branch at NSWC, White Oak, MD during which he oversaw the development and fleet introduction of many new explosive components and devices that are still in service. Mr. Munger worked as a product engineer at the Mound Research Laboratory for thirty years supporting the National Laboratories that designed and maintained the national nuclear stockpile for the Department Of Energy. He then started and managed for seven years a small ordnance company, PerkinElmer Miamisburg in Ohio. He now works for Los Alamos National Laboratory supporting design and development of ordnance devices that enhance the surety of our nuclear stockpile. Much of his 44 years in the ordnance field has been spent designing and manufacturing pyrotechnic devices. Dr. Kennedy worked for 32 years at Sandia National Labs and LANL during his 50-year career in explosives. He specialized in development, miniaturization and characterization of high-power detonators, with special emphasis on slapper detonators and detonator arrays.