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## **Detonation & DDT: Theory, Modeling and Experiments**

**3 days 3 instructors**

### OVERALL OBJECTIVES:

The objectives of this class are to make class members familiar with:

1. The main points concerning Chapman-Jouguet, Zel'dovich-von Neumann-Doering and Detonation Shock Dynamics models of detonation, and how observed behaviors of conventional and insensitive high explosives are described by those models (or not!),
2. Experiments and modeling approaches to calibrate reaction-rate laws and detonation-product Isentropes that describe sensitivity, output and behaviors such as detonation corner-turning,
3. Principal processes that occur in deflagration-to-detonation transition (DDT) in solid explosives, in which a rapid combustion process is converted into a wave-mechanics-controlled process, and
4. A multi-phase flow model of DDT

This class will be conducted at a graduate level. Class members will learn the capabilities and limitations of each of these models, and how to apply them where they are useful. In addition, ways to design experiments to investigate behaviors for both fundamental and applied design or analysis purposes will be discussed with the class.

### LEARNING OBJECTIVES:

It is intended that students learn what behaviors are described by processes included in each of the energetic material reaction modes, and be able to figure out ways to make pertinent experimental measurements that can be used in analysis based on each model. The principal processes of concern in the understanding of explosive material reactions driving detonation and/or DDT are detonation waves, detonation output, initiation of detonation, ignition of combustion and transition from rapid combustion (deflagration) to detonation. Students will learn how to recognize evidence of all these behaviors, design experiments to study them scientifically or characterize them in munition applications, and identify steps that can be taken in an experiment or a device to promote attainment of the desired reaction mode.

Specific topics with which students are expected to become conversant include:

- characteristic waves, which describe the C-J model and reaction-zone coupling in ZND model
- coupling of effects of energy release and gas production from the reaction zone to the detonation front,
- steady and unsteady detonation flows,
- calculation of effects of energy release and compaction processes in the P-v plane,
- structure of the self-similar Taylor wave that controls isentropic expansion of detonation product gases,
- measurements of detonation wave propagation and DDT processes in experiments with rate sticks, cylinder tests, microwave interferometry and photon-Doppler interferometry.
- use of Cheetah thermochemical-equilibrium code to estimate detonation and combustion states, and wave-propagation codes to solve multi-dimensional full-flow-field problems involving output from detonating explosives,
- appreciation of role of damage in promoting DDT in accident situations, and
- approaches toward solution of experiment and device design problems in this class of issues

In-class exercises or short quizzes will be carried out to check student progress and proficiency.

#### IMMEDIATE BENEFITS:

Students are expected to develop confidence about how to approach and assess problems involving detonation and DDT in design, threat and post-event investigation circumstances. Students will understand analytic, computational and experimental tools available to help them analyze or solve problems. They will be in a position to devise and design experiments to investigate behaviors of interest, even in cases of unusual behaviors. Staff members who are involved in experimental work or weapon design work will appreciate what can be accomplished by analytical and computer modeling of behaviors such as output and initiation of explosives. Conversely, those involved in analysis will come to understand what types of experimental data may be gathered to confirm an idea or validate a model.

#### INSTRUCTORS:

Instructors for this course will be Dr. Blaine Asay of Los Alamos National Laboratory; Dr. James Kennedy of HERE, LLC; and Prof. D. Scott Stewart of the U of Illinois Dept. of Mechanical and Industrial Engineering. Dr. Asay has responsibility for a LANL group that investigates special-purpose detonation applications, and he was involved in expository experiments at LANL to establish the mechanism of DDT in porous beds of explosives. Dr. Kennedy has over 40 years experience mostly at Sandia and Los Alamos in explosives work and now teaches a graduate class on detonation at NM Tech. His main research experience related to these topics has been gas-gun impact experiments on shock initiation of explosives and small-scale experiments on detonation spreading in insensitive high explosives. Prof. Stewart consulted for LANL and Eglin AFB for many years, and developed the Detonation Shock Dynamics model with Dr. J. Bdzil during that time. This model is especially suited for analysis

of behaviors that are exaggerated in insensitive high explosives, such as difficulty in detonation corner-turning and detonation transients.