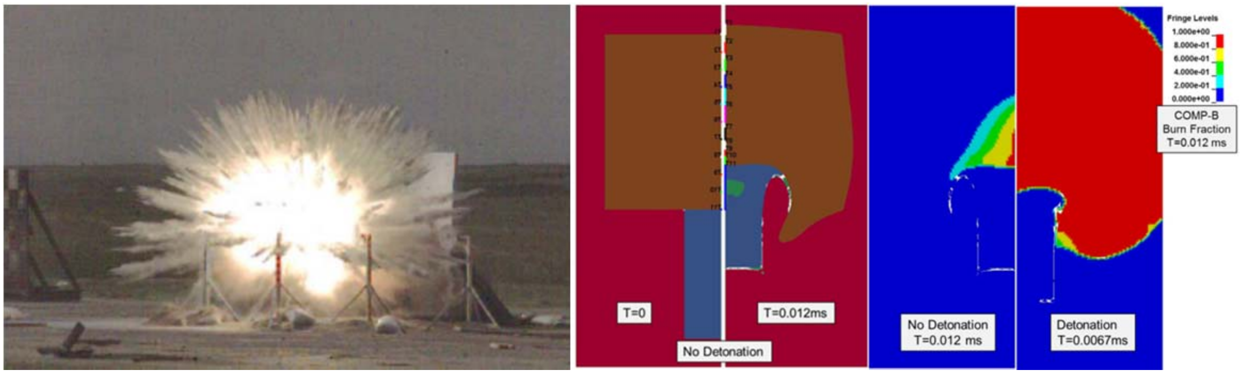
Revised April 2016

EXPLOSIVES MODELING FOR ENGINEERS

An LS-DYNA Training Class
Presented by

Paul Du Bois
Consultant
and
Len Schwer, Ph.D.
Schwer Engineering & Consulting Services



Abstract

LS-DYNA simulations involving explosives can be modeled on several engineering levels from simple application of equivalent pressure histories via *LOAD_BLAST_ENHANCED, explicit inclusion of explosive charges using an Equations-of-State and detonation via *INITIAL_DETONATION, and detonation of explosive due to impact using *EOS_IGNITION_AND_GROWTH_OF_REACTION_IN_HE. The analyst selects the appropriate degree of model sophistication to satisfy the intended use of the model results.

Modeling explosives is analogous to material modeling: LS-DYNA offers several models and the user needs to select an appropriate model based on both applicability and the availability of appropriate input parameter data. While the selection of an appropriate material model is often driven by the availability of the input parameter data, analysts over time develop a more in depth theoretical knowledge of some material models, a personal library of material parameters and thus a preference for certain material models. However, when it comes to explosive modeling, most engineers rely solely on literature references for equations-of-state with provided data. Typically, little effort is spent on acquiring any theoretical knowledge of the equations-of-state being used, nor how the input parameters were determined.

Photo credit: “Instability of Combustion Products Interface from Detonation of Heterogeneous Explosives” David L. Frost, Zouya Zarei, and Fan Zhang

Such cursory knowledge of explosives is often deemed acceptable, and may likely be acceptable in simulations involving fairly large standoff distances between explosive and target. However, for simulations where the explosive charge and target are not distant, or for sympathetic detonation of explosives, a more thorough knowledge of explosive modeling is required.

This class focuses on the application of LS-DYNA to modeling explosives. The modeling methods are illustrated through case studies with sufficient mathematical theory to provide the user with adequate knowledge to confidently apply the appropriate modeling method.

Intended Audience

This training class is intended for the LS-DYNA analyst possessing a comfortable command of the LS-DYNA keywords and options associated with typical Lagrange and Multi-Material Arbitrary Lagrange Eulerian (MM-ALE) analyses. The training class will attempt to provide the analyst with the additional tools and knowledge required to model explosives for a range of applications. The typical attendee is likely to have a background in defense applications, to include protective structures and vehicle vulnerability, Homeland Defense topics, and terrorist threat mitigation techniques. The theory and illustration portions of the class will benefit LS-DYNA users and non-LS-DYNA users alike.

Instructors

This LS-DYNA training class was introduced in 2013 to augment the instructors' existing popular Blast & Penetration modeling with LS-DYNA classes. Over the years of presenting the *Blast Modeling with LS-DYNA* class, starting in 2006, a significant amount of material was added to the Blast class. Topics related to explosive modeling were not extensive and were too often not presented due to the time limitations. To accommodate explosive modeling topics, and complement the existing Blast Modeling class, this new class was developed. Offering a separate one-day Explosives Modeling class before the Blast and Penetration Modeling classes, allows the attendee to select the appropriate combination of training and allocation of training resources.

Over 60 years of LS-DYNA experience in a wide range of commercial and defense applications allows the instructors to provide insights into many aspects of modeling and simulation. In addition, their presentation style has often been complemented for being clear, concise, useful, interesting, and at times hopefully also entertaining.

Paul Du Bois has worked as an independent consultant in the field of industrial application of large scale numerical simulations since September 1987. He has specialized in the application of explicit integration techniques for crashworthiness and impact problems. Amongst Paul's customers are most of the world's automotive assemblers such as Daimler, GM, Ford, Opel, Fiat, Porsche, Volvo, PSA, Renault, Toyota, Nissan, Honda, Hyundai and many others including automotive suppliers and design and engineering companies. Paul's more recent projects include a Daimler sponsored development of a generalized plasticity law for the simulation of plastics and the formulation of a tabulated hyper-elastic material law with damage for the simulation of rubber and foam. He was involved with the joint research organization of the German automotive industry, FAT, in the working groups: 'side impact dummies' from 1992 through 1997 and 'Foam materials' from 1996 until 2009. In 2003 Paul was asked by LSTC to perform a training mission at the Russian national laboratory in Snezinskh. Since 2004 he has also been a consultant to NASA and has worked on the space shuttle's 'return-to-flight' program. In the field of defense applications, he is a consultant to Rafael in Haifa, Israel where he was involved with the simulation of mine blast problems and helicopter crash landings.

Paul Du Bois also teaches the LS-DYNA training classes *Advanced Impact Analysis, User Material Implementation in LS-DYNA*, and *Polymeric Material Modeling with LS-DYNA*. He co-teaches, with Len Schwer, the LS-DYNA *Blast, Penetration, and Modeling & Simulation* classes.

Len Schwer has worked in the area of defense applications where failure prediction is of primary interest, for the past 40 years; he had been a DYNA3D user since 1983 and an LS-DYNA user since 1998. His early work at SRI International included modeling the collapse of deeply buried tunnels under very high pressure loadings. While at Lockheed Missile and Space Company he worked on high speed earth penetrators designed to penetrate reinforced concrete structures buried in soil. He has worked with the US Navy to develop an analysis capability for predicting the penetration & perforation of metallic, concrete, and soil targets associated with improvised explosive devices (IED's). He has a strong interest in verification and validation in computational solid mechanics, and is the past Chair of the ASME Standards Committee on Verification and Validation in Computational Solid Mechanics. Dr. Schwer is a Fellow of the American Society of Mechanical; Engineers (ASME) and the United States Association of Computational Mechanics (USACM).

Len Schwer also teaches the LS-DYNA training class *Concrete and Geomaterial Modeling with LS-DYNA*, and co-teaches, with Paul Du Bois, the LS-DYNA *Blast, Penetration, and Modeling & Simulation* classes.

Proposed Class Topics

Opening Remarks ***(Len)***

Detonation Waves and Explosives (***Paul***)

Flyer Plate Calibration of Detasheet EOS (***Len)***

Impact Detonation via Ignition and Growth of Reaction in High Explosives **(*Len*)**

*Driven Shocks (**Paul**)*

*Equivalency of TNT (**Len**)*

Simulation of Propellants with Application to Interior Ballistics (***Paul***)

Introduction to Non-Ideal and After Burning of Explosives (***Len**)*