

PENETRATION MODELING WITH LS-DYNA®: APPLICATIONS TO PROTECTIVE STRUCTURES, VEHICLES AND HOMELAND SECURITY THREATS

*An LS-DYNA Training Class
Presented by*

Paul Du Bois

Consultant
and

Len Schwer, Ph.D.

Schwer Engineering & Consulting Services



Abstract

Penetration events form a class of simulation environments well suited to the solution capabilities of LS-DYNA. LS-DYNA is unique in offering the analyst the choice of Lagrange, Eulerian (ALE) and Meshfree Methods, and combinations of these methods, for simulating high energy events such as penetration and perforation. In addition to high energy, these events are typically associated with large deformations, damage, and failure both on the material and structural level. During the past decade successful modeling of such damage and failure has moved steadily from a 'Black Art' to a widely accepted engineering practice.

This class focuses on the application of LS-DYNA for the simulation of high energy events. The analysis methods, and modeling, are illustrated through case studies. An emphasis is placed on modeling techniques: guidelines for which technique(s) to select, insights into which techniques work well and when, and possible pitfalls in modeling choice selections. Sufficient mathematical theory is presented for each technique, especially Eulerian and Meshfree Methods, to provide the

typical user with adequate knowledge to confidently apply the appropriate analysis technique. However, this training class is not a substitute for the in-depth treatments presented in the associated LS-DYNA training classes, i.e. “ALE/Eulerian & Fluid Structure Interaction” and “Mesh-Free Methods (SPH-EFG),” respectively.

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 Lagrangian analyses. The training class will attempt to provide the analyst with the additional tools and knowledge required to model the above described class of high energy events. 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. Because the class uses example problems to illustrate concepts and techniques, numerous modeling ‘tricks’ and options are discussed, and this knowledge would benefit any LS-DYNA user.

Instructors



In 2010 the instructors decided to split the previously combined Blast & Penetration class into two separate classes. In the four years the combined class had been presented, a significant amount of material was added, mostly in the area of Blast. To accommodate this additional blast related material, the penetration portion of the class was diminished. Separating the two topics allows LS-DYNA users to select the most appropriate class, and provides for more in depth coverage of both important topics.

Over 50 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, and 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 Snezhinsk. 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 & Polymeric Material Modeling*, and co-teaches, with Len Schwer, the *LS-DYNA Blast* class and *LS-DYNA Modeling & Simulation* class. The Advanced Impact course notes were first edited as a book by LSTC in 2004 and the first revised edition will appear in 2009.

Len Schwer has worked in the area of defense applications where failure prediction is of primary interest, for the past 30 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 is currently working 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 is currently consulting with NASA LARC on crew vehicle recover simulations. 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 *Geomaterial Modeling with LS-DYNA* and co-teaches, with Paul Du Bois, the *LS-DYNA Blast* class and *LS-DYNA Modeling & Simulation* class. He is the Director of Geomaterial Modeling for FEA Information (www.feainformation.com) and contributes to the associated web site: www.geomaterialmodeling.com

Daily Class Schedule

Day 1

Opening Remarks (Len)

Introduction to Penetration Mechanics – Erosion Techniques (Len)

Constitutive Modeling:

Metals – Johnson-Cook Model –

Parameter Identification (Len)

Damage & Failure Modeling (Paul)

*OPTIONAL - Regularization - *MAT_NONLOCAL (Len)*

Concrete & Geomaterials – Simplified Input Concrete Models (Len)

OPTIONAL - Introduction to Arbitrary Eulerian Lagrangian - Techniques (Paul)

Day 2

Introduction to Meshfree Methods (Len)

Element Free Galerkin - EFG

Smooth Particle Hydrodynamics - SPH

SPH Application to Concrete Wall Perforation

Introduction 2D and Axisymmetric MM-ALE and Mapping to 3D (Paul)

Explosively Formed Projectiles and Shaped Charges (Paul)

Penetration & Perforation Primer (Len)

Penetration of Metal Targets by Deformable Projectiles (SPH & MM-ALE)

OPTIONAL - Penetration of Concrete Targets (Erosion-SPH & MM-ALE)