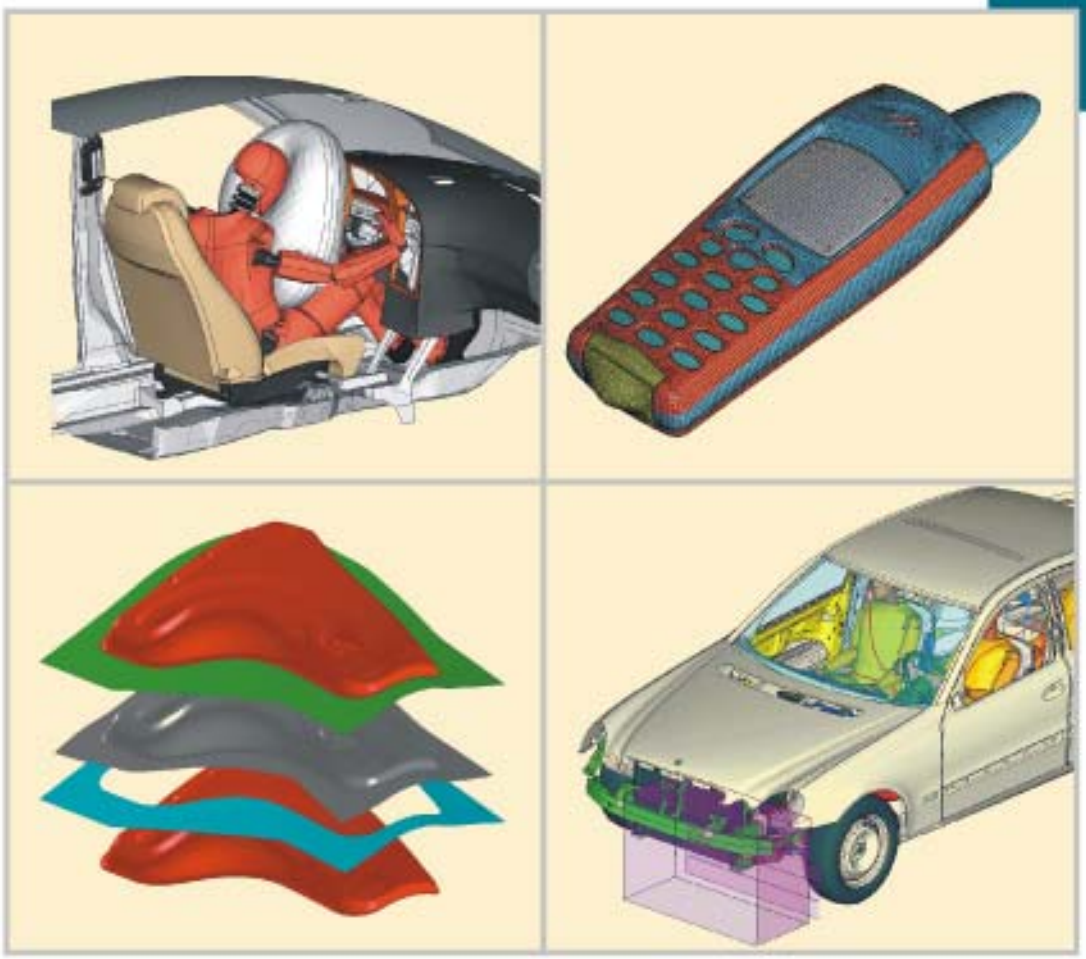
LS-DYNA

LS-PREPOST **LS-OPT**

One of the most advanced simulation tools for nonlinear structural analysis.



Nonlinear Dynamics
Large Deformation Dynamics
Crashworthiness
Occupant Safety
Impact

Metal Forming
Glass, and Plastics Forming
Multi-physics Coupling
Failure Analysis
Fluid-Structure Interaction

INTRODUCTION

LS-DYNA is a highly advanced general-purpose nonlinear finite element program that is capable of simulating complex real world problems. The distributed memory solver provides very short turnaround times on Unix, Linux, and Windows clusters. The major development goal of Livermore Software Technology Corporation (LSTC) is to provide within LS-DYNA capabilities to seamlessly solve problems that require

- ”MULTI-PHYSICS”,
- ”MULTIPLE STAGES”,
- ”MULTI-PROCESSING”.

LS-DYNA is suitable to investigate phenomena that involve large deformations, sophisticated material models and complex contact conditions. LS-DYNA allows running an analysis explicitly or implicitly and combining different disciplines such as coupled thermal analyses, fluid dynamics, fluid-structure interaction, SPH (Smooth Particle Hydrodynamics), EFG (Element Free Galerkin). For many products LS-DYNA is a key to reduce the time to market. Investigations with LS-DYNA help to design robust products. With the option of multidisciplinary simulations LS-DYNA increases the potential for developing innovative products significantly. All these advantages will help to reduce your development cost.

T. Frank, DaimlerChrysler AG

”With LS-DYNA we have excellent access to the vast developments in finite element technology for crash analysis.”

T. Zeguer, Jaguar Cars

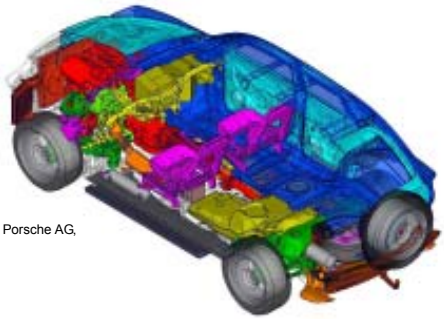
”LS-DYNA was effectively used for the new XJ car from concept to production.”

T. Belytschko, Northwestern University

”Hallquist’s development of effective contact impact algorithms, the use of one-point-quadrature elements and the high degree of vectorization made possible striking breakthroughs in engineering simulation.”

LS-DYNA TO DESIGN VEHICLES

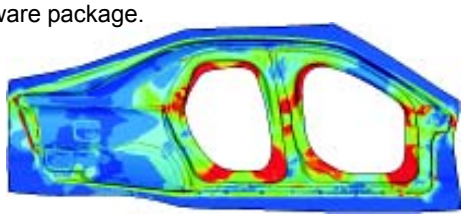
For many automotive companies LS-DYNA is indispensable to understand the mechanisms during the deformation of such complex systems as a vehicle structure. LS-DYNA is used to determine the behavior of a vehicle even before the first prototype is built. In general, far more crash scenarios can be investigated numerically than physical tests can be performed. LS-DYNA is a key product to enhance vehicle behavior regarding regulations and consumer tests. LS-DYNA is equipped with many specific features for automotive applications e.g. spot welds, airbag models, seat belt models, and retractors. Models of dummies are available as well as barrier models to speed up the development process. Specific evaluation features used in the automotive industry in the post-processing phase are provided by the LS-DYNA software package, e.g. filters. Besides crash applications, LS-DYNA is very well prepared to handle dynamic and static load cases typically considered in the vehicle development process. Examples are roof crush, door sag, abusive loading, and determination of load distributions for fatigue analysis.



Vehicle Model
By Courtesy of Dr. Ing. h.c. F. Porsche AG, Germany

LS-DYNA IN METAL FORMING

LS-DYNA allows simulating multi-stage sheet metal stamping processes with high accuracy. Subsequent to the simulation of the forming process you may simulate the trimming and the springback of the part. The simulation will allow you to perform a feasibility study of the part as well as its final shape after the manufacturing process. In addition, the design of the tools can be optimized with respect to the number of forming operations. Using the knowledge obtained with LS-DYNA the simulation can be crucial to help reduce manufacturing costs. The solver provides specific functionality like drawbead models and metal forming contact definitions to assist in the simulations. The solution offered by LS-DYNA is an incremental one that aims to obtain an accurate solution rather than having a very fast solution as provided by typical one step solvers. Specific sheet metal stamping features are provided by the pre- and post-processing tool LS-PREPOST that is included in the software package.



Stamping Simulation
By Courtesy of Volvo Car Corporation AB, Sweden

LS-DYNA – A MULTI-PURPOSE PROGRAM FOR AUTOMOTIVE SUPPLIERS

LS-DYNA allows the virtual testing of many components used in vehicles. The explicit and implicit time stepping schemes are capable of simulating static and dynamic tests using the same model. The manufacturing of a part can be investigated by LS-DYNA using the metal forming and thermal capabilities. Hence, only one model is required to address different problems. Ultimately, this results in lower cost for training and model creation as compared to other solutions. As an example of the beneficial usage of LS-DYNA, applications in seat design are outlined below. Seat manufacturers can consider the static and dynamic load cases for the seat frame; they can analyze the stability of the belt anchorage points and are able to determine maximal loads of locking mechanisms or failure loads of seat tracks. The influence of the seat for the occupant in a crash can be investigated as well as the stamping process of a gear wheel. This user group often uses LS-OPT, a state of the art optimization tool to enhance the design and to find a robust solution. Other examples for similar beneficial applications of LS-DYNA are in the design and manufacturing of crash boxes, bumpers, front ends, dashboards, trimmings, and tires.

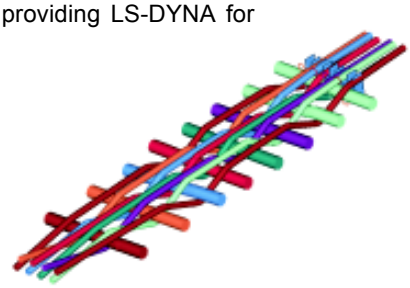
Tire Simulation
By Courtesy of Dunlop, Japan

LS-DYNA FOR CONTAINMENT AND DROP TEST ANALYSIS

LS-DYNA can be used to investigate the behavior of many different products under impact loading conditions. Consider the optimization of the durability of a toy or the analysis of the impact of a turbine blade on its housing. In the nuclear industry LS-DYNA assists in the design of containers that sustain possible dynamic loading during transportation or storage. Besides the wide range of material models equipped with complex failure mechanisms the flexible coupling and switching capabilities of LS-DYNA are essential for the following applications. For instance a liquid in a container can be modeled with the ALE or SPH Method coupled with the structure. This allows proper modeling of the liquid behavior during impact. For investigating the crack itself the Element Free Galerkin (EFG) Method can be used to eliminate the mesh influence during crack propagation. To determine the steady state deformation effectively LS-DYNA provides the flexibility to switch the time stepping scheme arbitrarily between explicit and implicit. Furthermore LS-DYNA allows for switching parts from rigid to deformable and vice versa. Often this feature is used to determine the position of one part against another during a falling phase before main impact.

LS-DYNA FOR RESEARCH APPLICATIONS

New technology is continuously being incorporated into LS-DYNA. For instance new methods like Element Free Galerkin (EFG), and Smooth Particle Hydrodynamics (SPH) are available in LS-DYNA. Important for many research applications is the possibility of investigating multi-physics problems by coupling the different methods. For instance, Eulerian and Lagrangian formulations can interact in one simulation. Solutions for thermal analysis and computational fluid dynamics (CFD) or the boundary element method are provided in LS-DYNA. The development of new constitutive equations is facilitated by providing an interface that allows incorporating new material routines. Detailed investigations of real world problems often require a huge amount of computational power. The excellent parallelization on MPP machines allows researchers to work with very detailed models with low hardware costs. LS-DYNA is extensively used in various research applications. One example is in the biomedical field where questions related to whiplash, bone fractures, and operating modes of heart valves or ankles are addressed. LSTC is very dedicated to providing LS-DYNA for educational purposes.

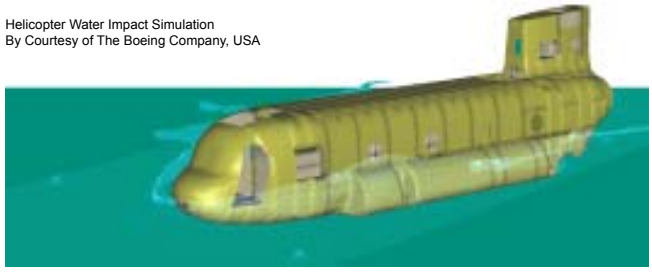


Textile Simulation
By Courtesy of University of Stuttgart,
ITV Denkendorf, Herman Finckh, Germany

LS-DYNA IN AEROSPACE AND DEFENSE INDUSTRY

LS-DYNA is a state of the art program to simulate high speed impacts, blasts, and explosions. ALE and SPH Methods are well suited for investigating high speed impact on textiles, metal sheets, and composites. The large library of constitutive equations with multiple options on material failure and non-localization complete the required features for many defense applications. Additionally, the 2D-capabilities and the automatic re-meshing and rezoning are used to investigate axi-symmetric problems. The multi-physics capabilities of LS-DYNA in conjunction with features developed for the automotive industry permit investigation of splashdown loads on tanks, rockets and emergency landing of airplanes. These features are also used to optimize the design of airplanes and turbine blades against collision with birds.

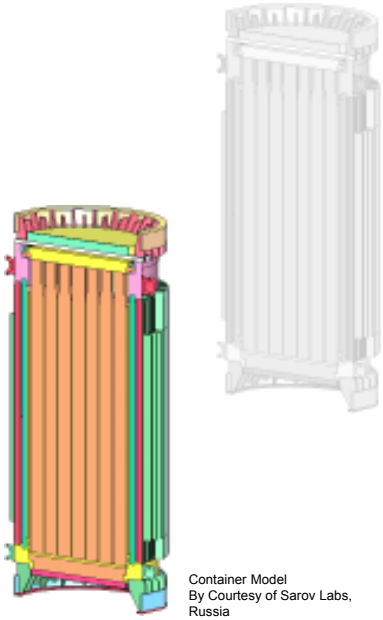
Helicopter Water Impact Simulation
By Courtesy of The Boeing Company, USA



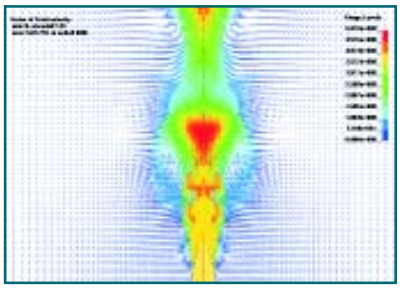
LS-DYNA´S MAIN APPLICATION AREAS

The wide range of features of LS-DYNA are used in many different fields. A list of common applications is given below.

- Crashworthiness simulations for automobiles, trains, ships
- Emergency landings of airplanes
- Occupant safety analysis
- Pedestrian safety analysis
- Automotive part manufacturing
  - Car body
  - Seats
  - Roofs
  - Doors
  - Hoods
  - Bumpers
  - Crash boxes
  - Girders
  - Steering wheels
  - Steering columns
  - Dash boards
  - Paddings
- Metal forming
  - Rolling
  - Extrusion
  - Forging
  - Casting
  - Spinning
  - Ironing
  - Superplastic forming
  - Sheet metal stamping
  - Profile rolling
  - Deep drawing
  - Hydroforming
  - Multi-stage processes
  - Springback
  - Hemming
- Metal cutting
- Glass forming
- Biomedical applications
- Stability/failure investigations
  - Cranes
  - Seat tracks
- Drop tests
  - Consumer products
  - Tools
  - Nuclear vessels
- Earthquake engineering
- Bird strike
- Jet engine blade containment
- Penetration
- Plastics, mold and blow forming
- Blast loading
- Spot-welded, riveted and bolted structures
- Fluid-structure interaction
- Shipping containers
- Can and container design
- Eigenvalue analysis



Container Model
By Courtesy of Sarov Labs, Russia



Fluid Simulation

LS-DYNA´S ANALYSIS CAPABILITIES

Different applications utilize one or a combination of the features listed below.

- Nonlinear dynamics
- Rigid body dynamics
- Quasi-static simulations
- Normal modes
- Linear static
- Nonlinear static
- Thermal analysis
- Fluid analysis
- Eulerian capabilities
- ALE (Arbitrary Lagrangian Eulerian)
- Fluid-structure interactions
- FEM-rigid multi-body dynamics coupling (MADYMO, ATB)
- Underwater shock coupling (USA)
- Failure analysis
- Crack propagation
- Real-time acoustics
- Design optimization
- Implicit springback
- Multi-physics coupling
- Structural-thermal coupling
- Adaptive re-meshing
- Rezoning
- Smooth particle hydrodynamics
- Element free methods
- 2D and 3D formulations
- Nastran reader
- Dynamic storage allocation
- Rigid to deformable switching
- Deformable to rigid switching
- Implicit to explicit switching
- Explicit to implicit switching
- Dynamic relaxation

Impact on Ski Safety Net
By Courtesy of DJC DALLOZ, France

LS-DYNA´S LIBRARY OF MATERIAL MODELS

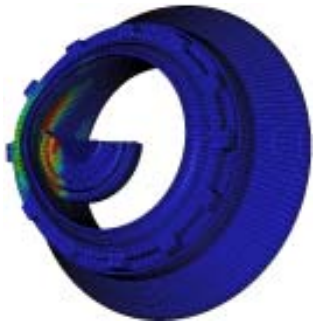
LS-DYNA provides more than 130 metallic and non-metallic material models, many of them equipped with failure criteria. Below are the most frequently modeled materials.

- Metals
- Plastics
- Visco-elastic
- Elasto-viscoplastic
- Glass
- Foams
- Fabrics
- Elastomers and rubbers
- Honeycombs
- Composites
- Concrete & soils
- High explosives
- Propellants
- Viscous fluids
- Biomedical models
- User-defined materials

LS-DYNA´S RIGID BODY DYNAMIC FEATURES

Many features used in multi-body applications are also provided in LS-DYNA. A selected set of features is listed below.

- Rigid Bodies
- Rigid to deformable switching
- Deformable to rigid switching
- Joints
  - Spherical joint
  - Revolute joint
  - Cylindrical joint
  - Translational joint
  - Locking joint
  - Motor joint
  - Pulley and screw joints
  - Cardan joint
  - Flexion/torsion joint
- Contact
  - Rigid body to deformable body contact
  - Rigid body to rigid body contact



Disc Impacting Inner Wall of Turbine
By Courtesy of Turbomeca, France

LS-DYNA´S LARGE ELEMENT LIBRARY

LS-DYNA has an extensive element library with both under-integrated and fully-integrated element formulations. The lower-order finite elements in LS-DYNA are accurate, efficient, and robust. For the under-integrated shell and solid elements, zero-energy modes are controlled by either viscosity or stiffness hourglass control formulations.

- Different solid elements
- 8-node thick shells
- Different 3- and 4-node shells
- Beams
- Welds
- Discrete zero length beams
- Trusses and cables
- Nodal masses
- Lumped inertias
- Arbitrary Lagrangian/Eulerian elements
- Eulerian elements
- Element Free Galerkin formulations
- SPH elements
- Elements for 2D-analysis

Vehicle Model
By Courtesy of Ford Motor Company of Australia Ltd., Australia

LS-DYNA´S CONTACT ALGORITHMS

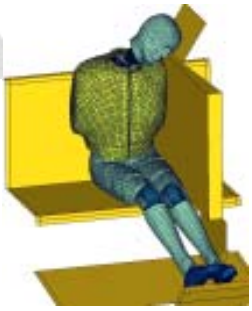
Constraint and penalty techniques have worked extremely well over the past 20 years in numerous applications. Coupled thermo-mechanical contact can also be handled. Over 25 different contact options are available. These options primarily treat contact of deformable to deformable bodies, single surface contact in deformable bodies and deformable or rigid to rigid body contact. Multiple definitions of contact surfaces are possible as outlined below.

- Single surface contact
- Contact with rigid walls
- Edge-edge contact
- Beam-beam contact
- Eroding contact
- Contact with CAD surfaces
- Tied surfaces
- 2D-contact
- Shell edges tied to shell surfaces
- Resultant force contact
- Fluid-structure interfaces
- Pinball contact
- Friction models:
  - Static and dynamic coulomb
  - Viscous friction
  - Pressure dependent friction
  - User-defined friction models

LS-DYNA´S SPECIALIZED AUTOMOTIVE FEATURES

LS-DYNA provides many well prepared features related to specific needs in automotive applications. A selection of features is listed below.

- Seatbelt
- Slip ring
- Pretensioner
- Retractor
- Sensor
- Accelerometer
- Airbag reference geometry
- Inflator models
- Hybrid III dummy model
- MADYMO-coupling
- ALE for out-of-position simulations

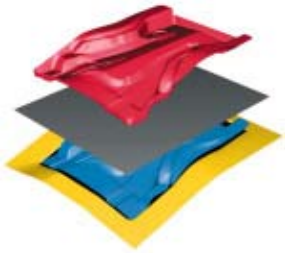


FAT USSID Dummy Model

LS-DYNA´S SPECIALIZED METAL FORMING FEATURES

Handling simulations in metal forming benefit from specific features implemented in LS-DYNA. With the prepared features LS-DYNA is tailored to achieve accurate results efficiently.

- IGES/VDA contact
- Rigid tooling
- Thermal contact
- 2D re-meshing and remapping
- Implicit springback
- Trimming
- Adaptive mesh refinement
- Mesh coarsening
- Look ahead adaptivity
- Analytic drawbeads
- Complex sliding algorithms
- Anisotropic plasticity (Hill, Barlat)

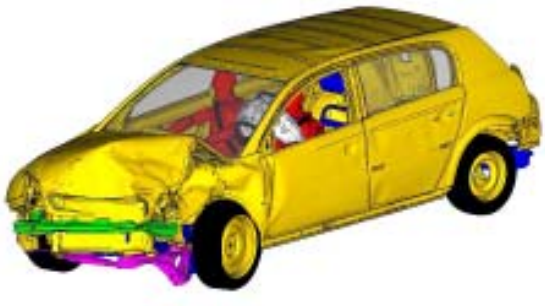


Stamping Simulation
By Courtesy of Arup, United Kingdom

MODELS FOR AUTOMOTIVE APPLICATIONS

Finite element models for almost all standard parts in automotive testing are available as already prepared input files. Depending on the requirements different levels of details and different degrees of validation are available. The highly validated parts are often third party products and come usually with full support from your local distributor. Available models are listed below.

- NHTSA barriers
- NCAP barriers
- IIHS barrier
- ECE barriers
- Euro-NCAP barrier
- Hybrid III dummies
- SID-IIs dummy
- Child dummies
- USSID dummy
- Eurosid dummy
- ES-2 dummy
- Free motion head form
- Pedestrian impactors
- Human models
- Moose model



Vehicle Model
By Courtesy of Adam Opel AG, Germany

PLATFORMS

LS-DYNA is ported to all common platforms. Massive Parallel Versions (MPP – Message Passing Programming) and Shared Memory Version (SMP – Symmetric Memory Processing) are available as well as single and double precision versions. For detailed information on the availability for the required operation system contact your local distributor. The most frequently used computers/OS are given below in alphabetical order.

- Fujitsu VPP5000
- Fujitsu Prime Power
- Hitachi SR8000 HI-UX/MPP 03-01
- HP Alpha OSF1 4.0f
- HP PA8000 HPUX 11.22 / 11.23
- IBM AIX 5.1 Power3
- IBM AIX 4.3 Power3
- Itanium 2 HPUX 11.22
- Itanium 2 Linux
- NEC SX5 Super-UX 11.1
- Opteron Linux
- PC/Linux
- PC/Windows
- SGI R10000 IRIX64 6.5
- SUN Ultra SUNOS 5.6~5.8

LSTC provides additional software packages for pre- and post-processing as well as for optimization.
They work seamlessly with LS-DYNA and are included free of charge with an LS-DYNA license.

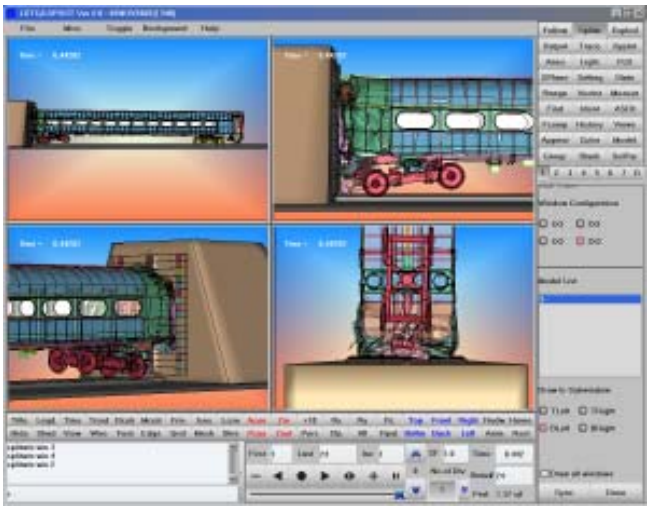
LS-PREPOST

LSTC's post-processor and model editor for LS-DYNA

LS-PREPOST is a full featured post-processor for all types of LS-DYNA simulations. The graphic user interface was carefully crafted to create a user friendly environment. It supports the latest Open-GL standards to provide fast rendering for fringe plots and animation results. It also handles the ASCII output data and links it to the input files and animations. Recent developments allow reading, visualizing, and modifying LS-DYNA input files. Many features for model editing are already included and meshing capabilities are currently being added.

A selection of LS-PREPOST features:

- Contour plots
- X-Y graphs
- Overlay plots
- Vector plots
- Animations
- Multiple view ports
- ASCII plotting
- Printing formats: PS, TIFF, PNG, JPG, VRML, GIF
- Movie formats: MPEG, AVI
- Full keyword reader for LS-DYNA 970
- Accessible via scripts
- Input deck manipulation
- Mesh manipulation
- Occupant positioning
- FMVSS 201 head positioning
- Metal forming related features
- SPH element generation

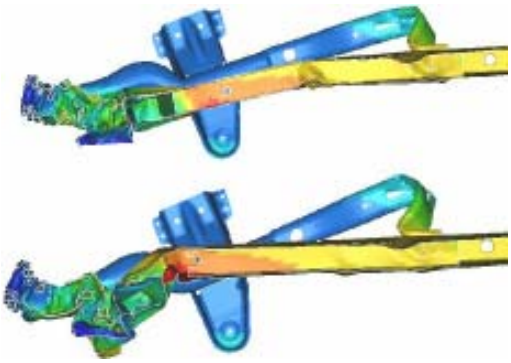


LS-PREPOST User Interface
Train Model is Courtesy of Applied Research Associates and the Federal Railroad Administration, USA

LS-OPT

LSTC's optimization tool for LS-DYNA

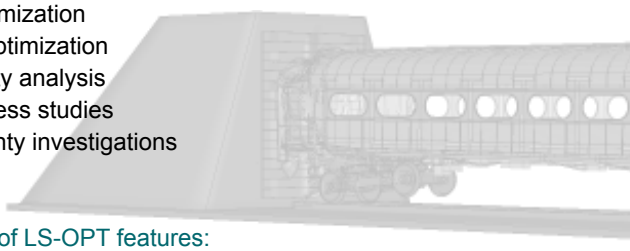
LS-OPT provides an environment to explore easily the design space and to find an optimum design. LS-OPT also provides a solution for system identification problems. LS-OPT is based on the Successive Response Surface Method (SRSM) and on statistical approaches (robustness analysis). Genetic algorithms (discrete methods) will be available soon. The graphical tool LS-OPT interfaces with LS-DYNA and provides an environment to specify optimization input, monitor and control parallel simulations and post-process optimization data as well as view multiple designs using LS-PREPOST.



Robustness Prediction of a Mechanism Design
By Courtesy of DaimlerChrysler AG, Germany

A selection of LS-OPT applications:

- Optimization for highly non-linear problems
- Multidisciplinary optimization (MDO)
- MDO with fully and partially shared variables
- Trade off studies
- Parameter identification
- Size optimization
- Shape optimization
- Sensitivity analysis
- Robustness studies
- Uncertainty investigations



A selection of LS-OPT features:

- Successive response surface method
- Stochastic and probabilistic analysis
- Graphical user interface (GUI)
- Identification of significant and insignificant variables
- Comprehensive LS-DYNA interface
- Mathematical expressions for objectives or constraints to combine several responses
- Capable of running simulations on an arbitrary network
- Interface to LSF, PBS and Loadleveler
- Graphical viewing of optimization results

Developer

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Pictures on front page

Upper left: Occupant simulation - Courtesy of Saab Automobile AB, Sweden

Upper right: Model of cellular phone - Courtesy of Ericsson Mobile Communications AB, Sweden

Lower left: Stamping simulation - Courtesy of Engineering Technology Associates Inc. (ETA), USA

Lower right: Vehicle model - Courtesy of DaimlerChrysler AG, Germany