Recent Developments and Roadmap

12th International LS-DYNA User's Conference
June 5, 2012

LSTC
Livermore Software Technology Corp.

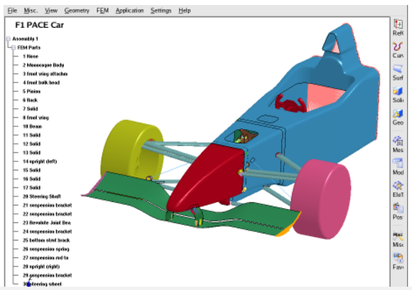
Outline

- Introduction
- Recent developments

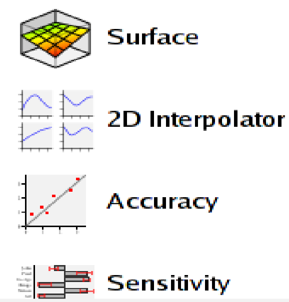
LS-PrePost	Mr. Philip Ho
Dummies	Dr. Christoph Maurath
Incompressible CFD	Dr. Facundo Del Pin
Electromagnetics	Dr. Pierre L'Eplattenier
ALE, DEM, SPH, Particle	Dr. Jason Wang

- Conclusions

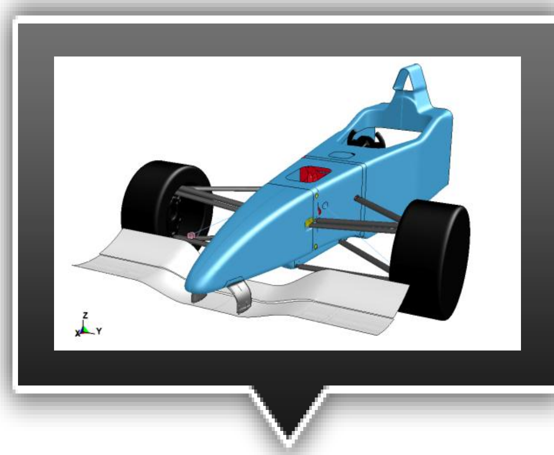
LSTC Products



LS-PrePost

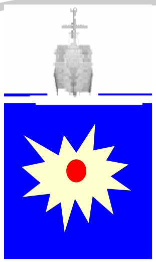


LS-OPT/LS-TaSC



LS-DYNA

Dummies & Barriers



USA

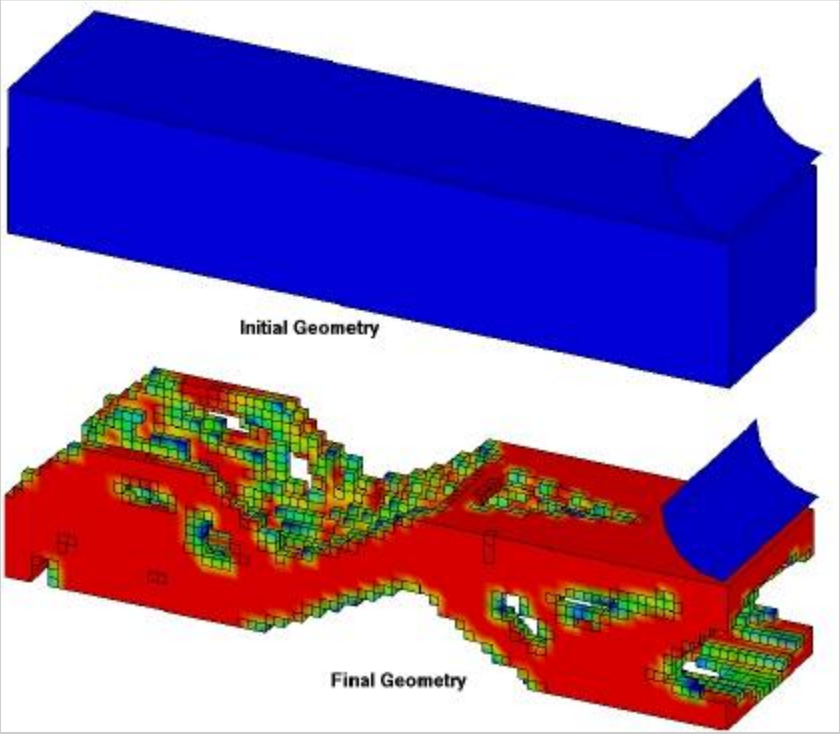
No additional license cost

LS-TaSC v2

Was LS-OPT/Topology for V1; renamed as LS-TaSC, Topology and Shape Computation, since V2.

For the topology optimization of non-linear problems involving dynamic loads and contact conditions.

Can be used to find a concept design for most structures analyzed using LS-DYNA.



LS-DYNA Application Areas

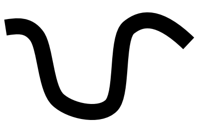
Development costs are spread across many industries

Automotive

- Crash and safety
- NVH
- Durability

Aerospace

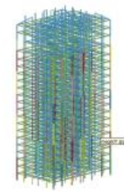
- Bird strike
- Containment
- Crash



Manufacturing

- Stamping
- Forging

Consumer Products

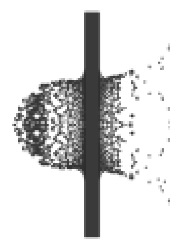


Structural

- Earthquake safety
- Concrete structures
- Homeland security

Electronics

- Drop analysis
- Package analysis
- Thermal



Defense

- Weapons design
- Blast response
- Penetration
- Underwater Shock Analysis

LS-DYNA One Code Strategy

"Combine the multi-physics capabilities into one scalable code for solving highly nonlinear transient problems to enable the solution of coupled multi-physics and multi-stage problems"

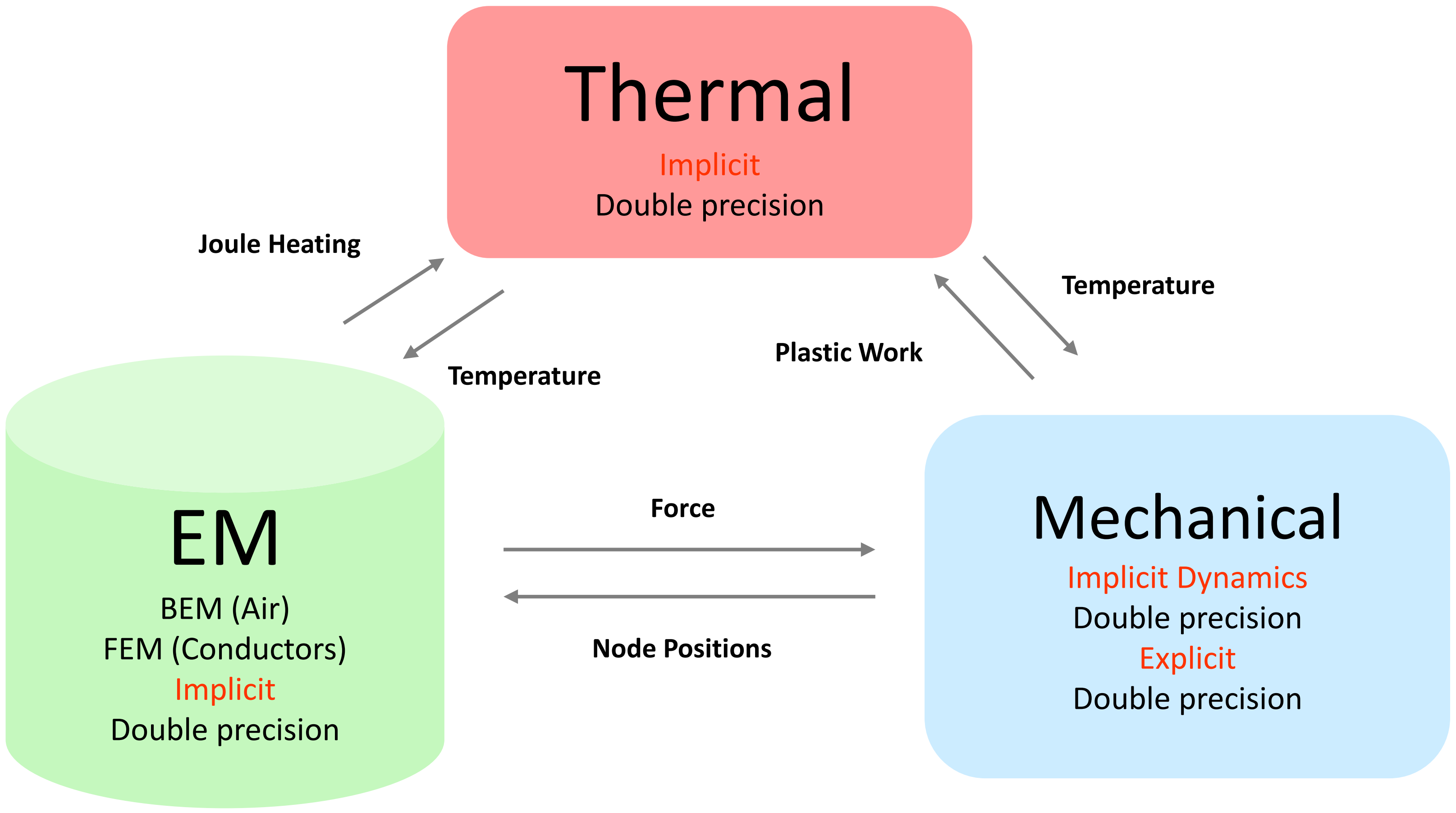
- Explicit/Implicit ✓
- Heat Transfer ✓
- ALE & Mesh Free ✓
  i.e., EFG, SPH, Airbag Particle
- User Interface ✓
  Elements, Materials, Loads
- Acoustics, Frequency Response, Modal Methods ✓
- Discrete Element Method ✓

After more than a decade the next major release includes:

- Incompressible Fluids
- CESE Compressible Fluid Solver
- Electromagnetics

Accommodates Coupled Simulations

Multiple field equations are strongly coupled

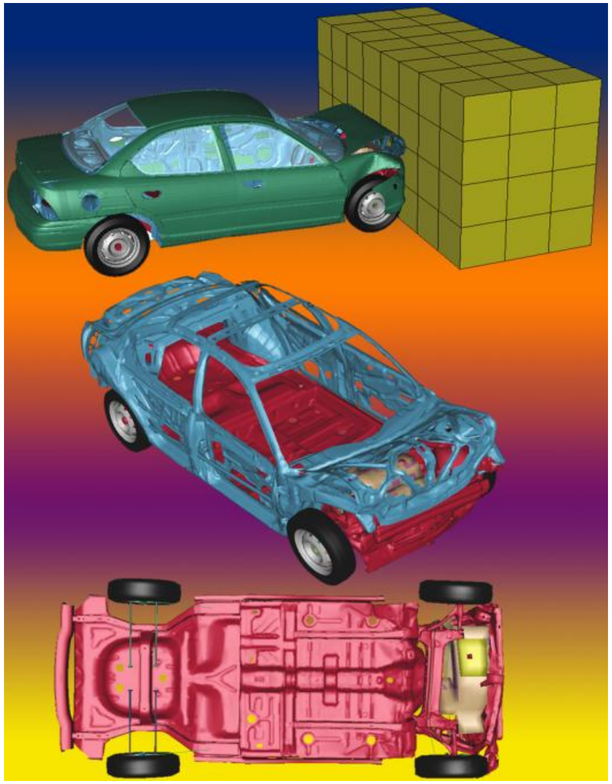


One Code Strategy

One Model

LS-DYNA

Multi-physics
Multi-stage
Multi-formulations
Massively parallel
Adaptive



Many Results

Manufacturing, Durability, NVH, Crash

One Code Strategy

Specialized codes for each problem

Multi-physics problems are difficult to solve.

Analysts must be trained in each specialized code

Limits career paths to specific applications.

Licensing costs are too high.

With one code.

Multi-physics problems are easily solved

Analysts can work on many types of related problems that are currently solved on multiple codes.

Flexibility in assignments

Flexibility in career paths

One Model for All Applications

Analysts work in parallel to reduce the time to produce the initial model. In crash, one model for frontal, side, offset, and rear impacts. Durability, NVH, and crash models are identical with possible adjustments related to mesh density

Only one model to revise for design changes.

Only one model to check for errors.

All models use the same connectors in assembly

Multi-physics problems can be addressed as needed

Easier database management

Initial stress, strain, and thickness distributions from manufacturing simulations are available in all performance simulations

Multi-Physics

- Multi-physics problems require solution methods from more than one discipline.
- Examples

Fluid-Structure Interaction
Tire Hydroplaning, Airbags

Bird Strike on Engine
Initial stresses, Impact + linear Response

Design Optimization
Optimization + Mechanics

Thermo-Mechanical
Hot Forging and stamping

Multi-Stage

- Multi-stage problems require sequential simulations
- Examples

Stamping

Binderwrap *Implicit Dynamics*
Stamping *Explicit*
Springback *Implicit Static*

Static Initialization Dynamic Simulations

Gravity loading prior to crash, durability and NVH
Spinning jet engine fan blades prior to impact or blade-off

Manufacturing Results into Performance Simulation

Stamping introduces texturing and thinning
Crash simulation accounts the effects of manufacturing

Crash simulation followed by Implicit Springback

- Requires one code with Implicit and Explicit solution

One Code Strategy: multi-formulations

- No single solution method is suitable for all applications.

- Solid mechanics

Non-linear Formulations	Linear Elements for Eigenvalues, Superelements, and Linear Analysis
Reduced and fully integrated SPH, DEM Element Free Galerkin Isogeometric	Higher Order Elements including Isogeometric
Large Deformation	Small Deformation

Degree of Deformation

One Code Strategy: multi-formulations

- Solid mechanics

  Dynamics

  Explicit methods for short duration transient problems.

  Implicit methods for static and long duration problems.

  Instantaneously switch between methods implicit to explicit and vice versa.

  Fluid mechanics formulations

  Incompressible flow.

  Compressible flow.

  Acoustics

  Airbag particle methods for bag deployment

One Code Strategy: multi-processing

- Massively Parallel Processing (MPP) is here to stay.
  - MPP is moving downscale: Desktop MPP under Windows or Linux environments
  - Heterogeneous processing.
    - Processing across high speed networks.
  - Large MPP machines have many parallel jobs running simultaneously on subsets of processors.
    - 32-256 are preferred for LS-DYNA
  - Stamping analysis with adaptivity is ideally suited to MPP machines due to the simplicity of contact.
- Hybrid LS-DYNA combines SMP and MPI to improve scalability to more than 10K cores

Adaptive

- To handle manufacturing simulations adaptive remeshing is necessary
  - Used in sheet metal stamping and forging today
- Advantages:
  - Reduces run time
  - While increasing accuracy
  - Initial meshing is simplified
- Types of adaptivity:
  - r-method, relocate nodes
    - Number of nodes are not constant , EFG forging
  - h-method, adapt element size h
    - LS-DYNA shell and solids in future releases

New single user license

- Node locked SMP Window license for single user O/S to allow usage of **16 processor cores from AMD and INTEL**
- **40% price reduction** compared to 16 cores with network license
  - 16 one core simultaneous jobs,
  - 8 two core simultaneous jobs,
  - 4 four core simultaneous jobs,
  - etc.
- Extension of security software to single user Window's O/S to license **MPP version is underway** to take advantage of better scaling
  - The SMP version does not scale well after 6 to 8 cores.
- For additional information contact sales@lstc.com

Development Speakers

LS-PrePost	Mr. Philip Ho
Dummies	Dr. Christoph Maurath
Incompressible CFD	Dr. Facundo Del Pin
Electromagnetics	Dr. Pierre L'Eplattenier
ALE, DEM, SPH, Particle	Dr. Jason Wang

LS-PrePost

Philip Ho

Outline of Talk

- Current status of LS-PrePost and the different releases
- New GUI of LS-Prepost 3.x/4.0
- New graphics rendering in 4.0
- Other New Features in LS-PrePost 3.2/4.0
- Current and future developments
- Summary and Conclusion

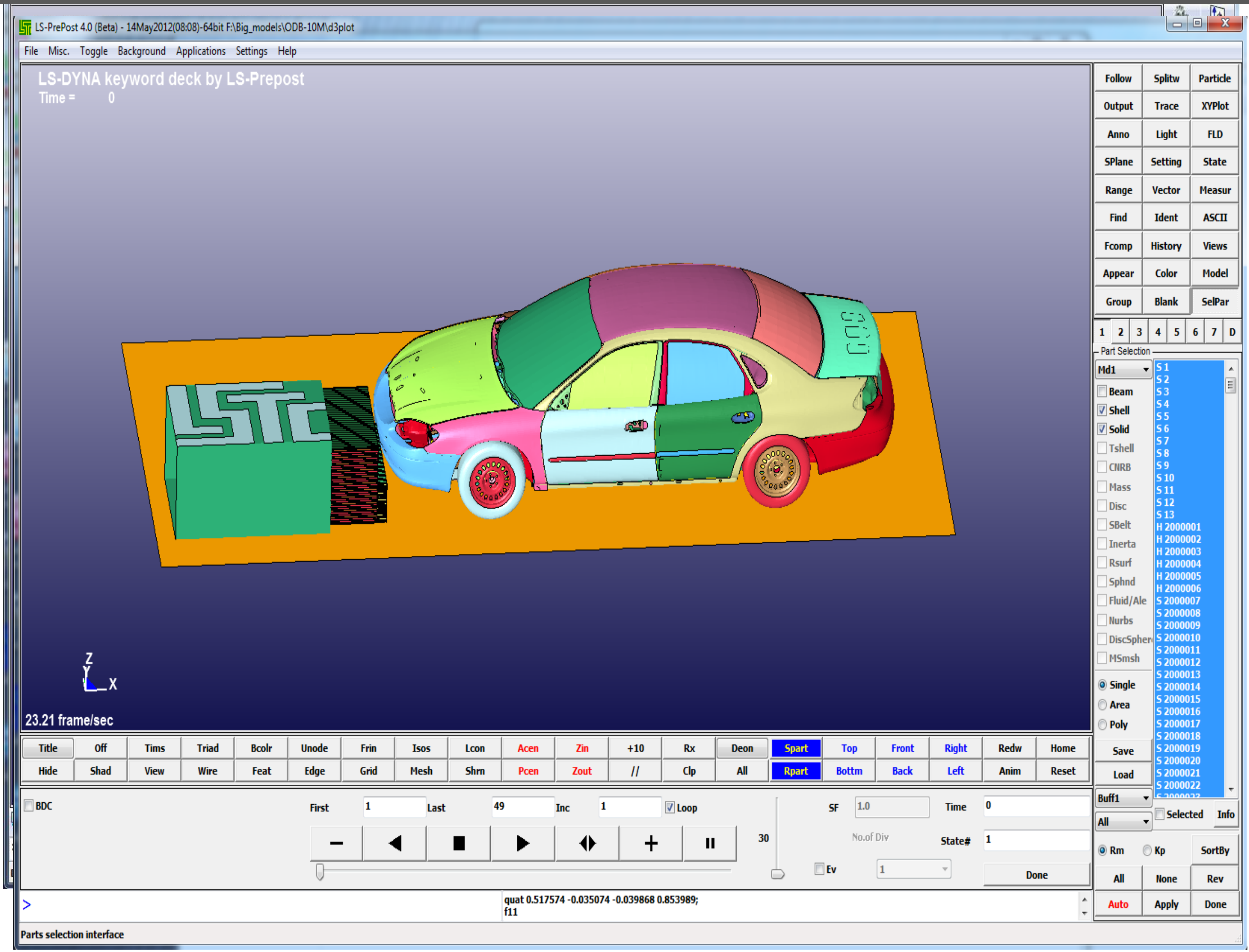
Current Status

- 3.2 is the current release of LS-PrePost
- Still support the old interface (version 2.4) users can toggle between old interface and new interface by F11 function key
- Tools to help users to transition from old to new interface
- Support Linux 64-bit systems, Windows 32bit and 64bits, Apple Mac OSX
- Continue to improve in stability, robustness and features
- Download: http://ftp.lstc.com/anonymous/outgoing/lsprepost/3.2

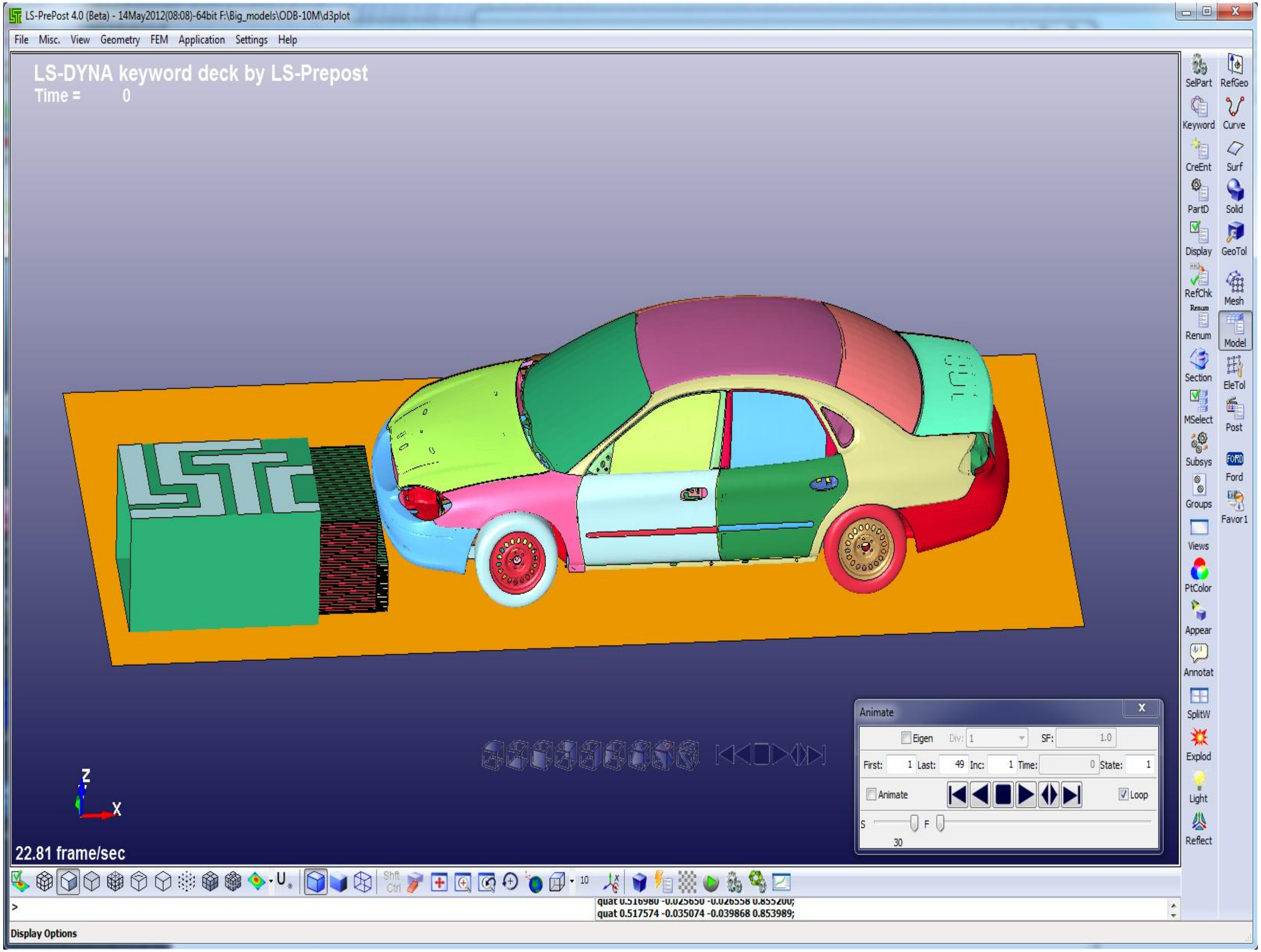
Development Version 4.0 beta

- New rendering technique to render the finite element model results many times faster than the older versions of LS-PrePost
- Latest features and updates will be implemented in this version
- Requires graphics cards that support openGL version 3.3 and higher
- Enter CNTL-L twice before loading data to disable new fast rendering
- Download: http://ftp.lstc.com/anonymous/outgoing/lsprepost/4.0

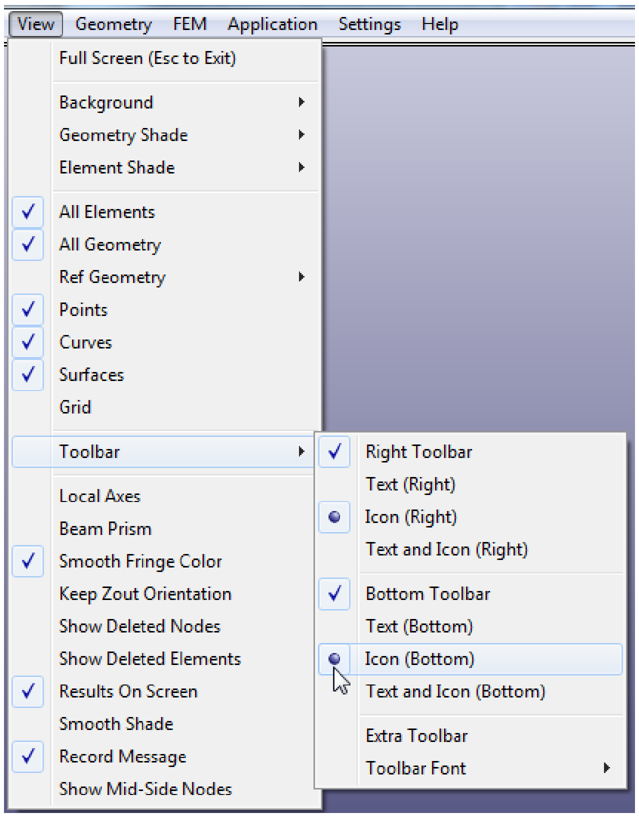
Old Interface

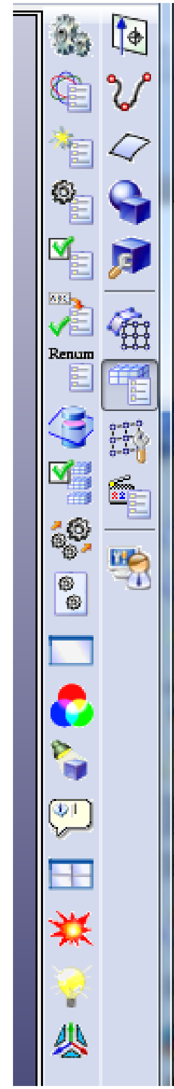


New Interface

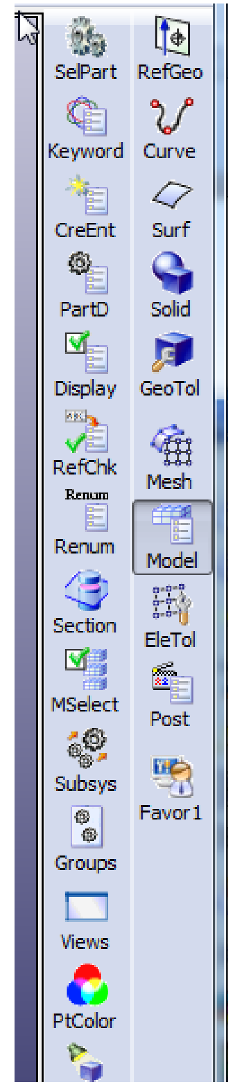


LS-PrePost 3.2/4.0 GUI





Icons



WithText

New Graphics Rendering in version 4.0

- Taken from a visualization research project at UCSD that was funded by Honda R&D North America (Mr. Ed Helwig)
- Part based data structure – more efficient data organization
- VBO – Vertex Buffer Objects reduce data communication between CPU and GPU
- GLSL – OpenGL Shading Language to compute polygon normal on GPU, no need to compute normal in CPU and to store it in main memory
- Viewport Culling – any part not within the viewport will not be rendered
- Sub-Part – divide a very large part into sub-parts to utilize viewport culling

New Rendering Performance

- 5.65million elements (4.29m Shells, 1.36m solids, some beams, 1680 parts), 59 states
- On HP Z800 8-core, with Nvidia Quadro 6000, timing in frames/sec

	Old	New
Static Rendering	2.1	30.4
Animation 1st loop	1.3	14.2
Avg. Animation	2.1	16.5

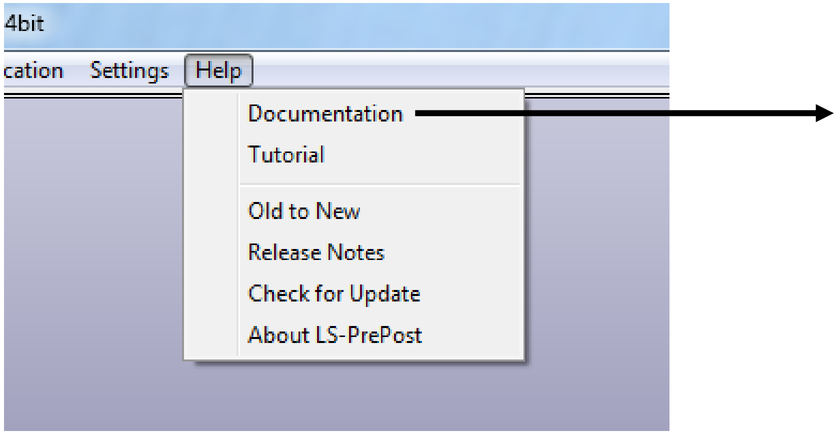
New Rendering Performance

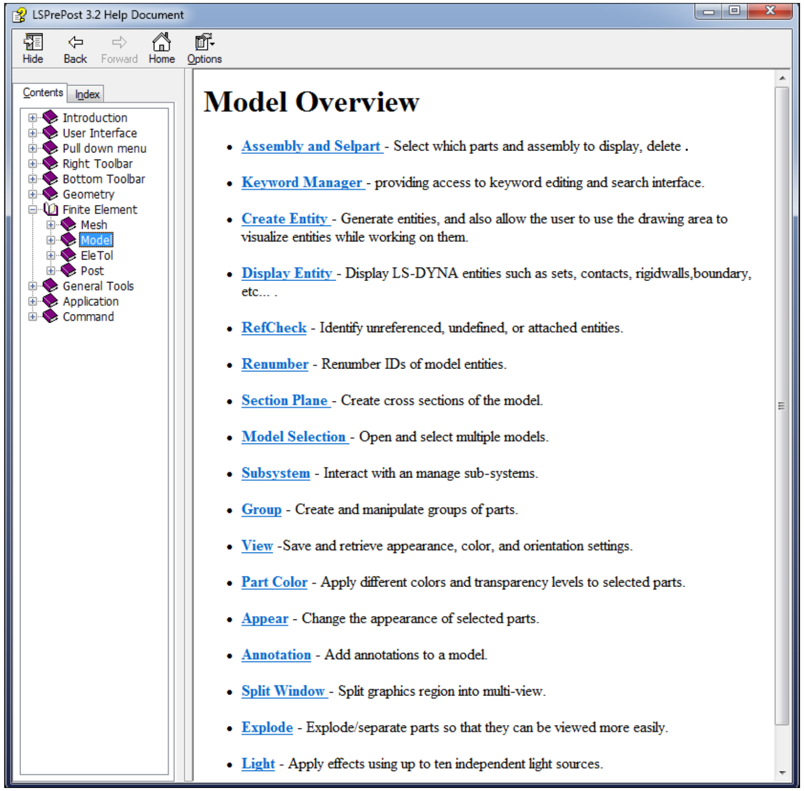
- 10.65million elements (8.44m Shells, 2.21m solids, 5223 beams, 816 parts), 49 states
- Spot weld beam was drawn as circle
- On HP Z800 8-core, with Nvidia Quadro 6000, timing in frames/sec

	Old	New	Speed up
Static Rendering	1.2	22.1	18
Animation 1st loop	0.4	10.2	--
Avg Animation loop	1.25	10.5	8.4

User group and Online Documentation

- User Group – more than 2200 members as of May, 2012
  - http://groups.google.com/group/ls-prepost
- Documentation and tutorials can be accessed from the pull down HELP menu





Other new features and improvements in LS-PrePost3.2/4.0

Batch mode Operation – (-nographics)

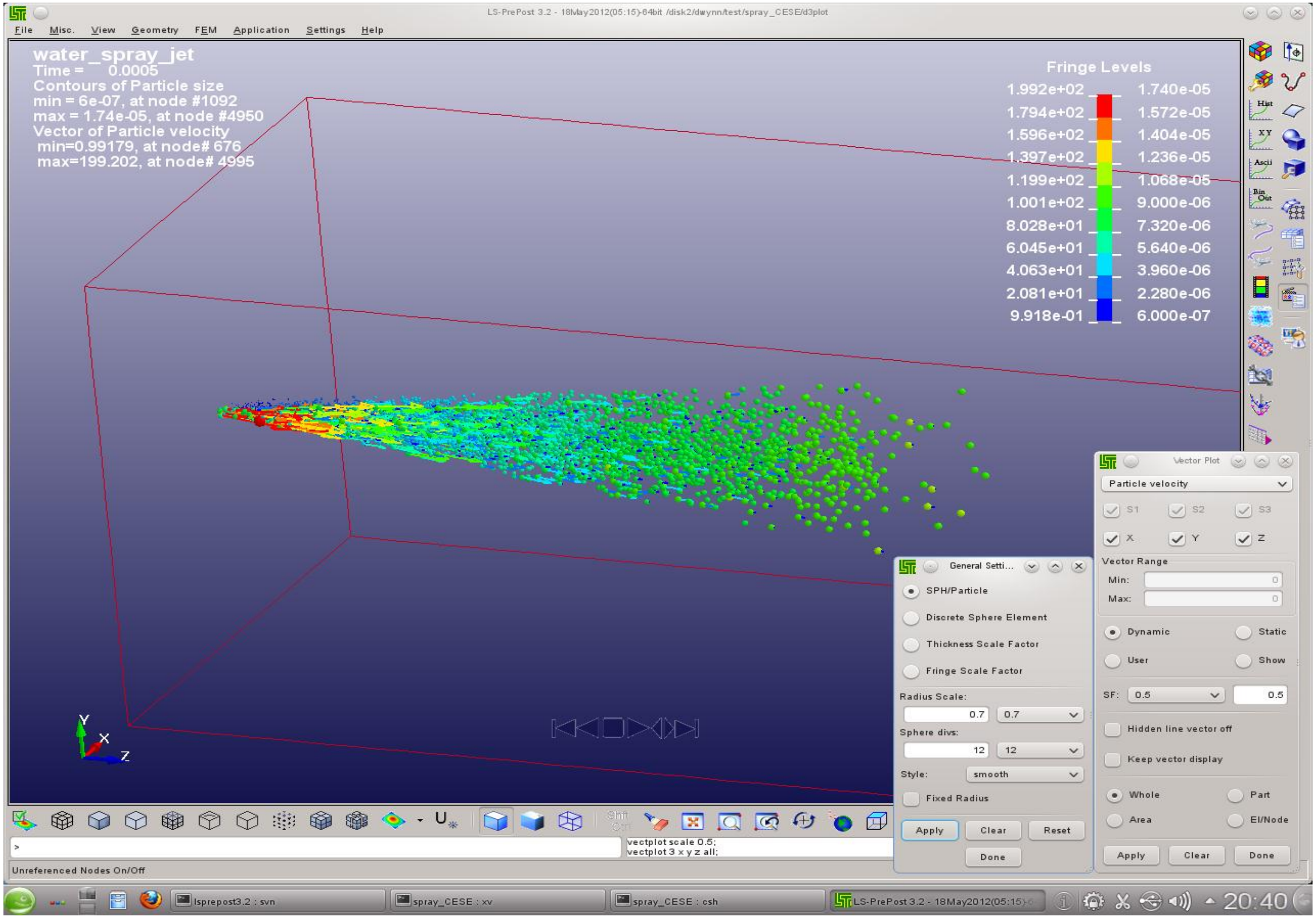
- Batch mode operation with full graphics capability using LS-Prepost
- Run lsprepost 3.2 with command file and use -nographics
- Works very well on PC/Windows platforms
- Has limitations on Linux platforms:
  - Machine to run lsprepost with –nographics must have OpenGL and X capability
  - Local machine that logs into the remote machine must also have OpenGL and X capability
  - If the above conditions not met, use the Linux virtual frame buffer (Xvfb) for batch mode:
    - Xvfb :2 -screen 0 1074x800x24

LS-PREPOST Features for LS-980

- Support for Multi-Physics keywords: *CESE, *ICFD and *EM
- Multi-Solver keyword files can be displayed and edited
- Models can be a mixture of Multi-Solver and Mechanical meshes
- ICFD modeling can be 2D or 3D with mesh adaption (re-meshing)
- Support for ICFD LevelSet functions

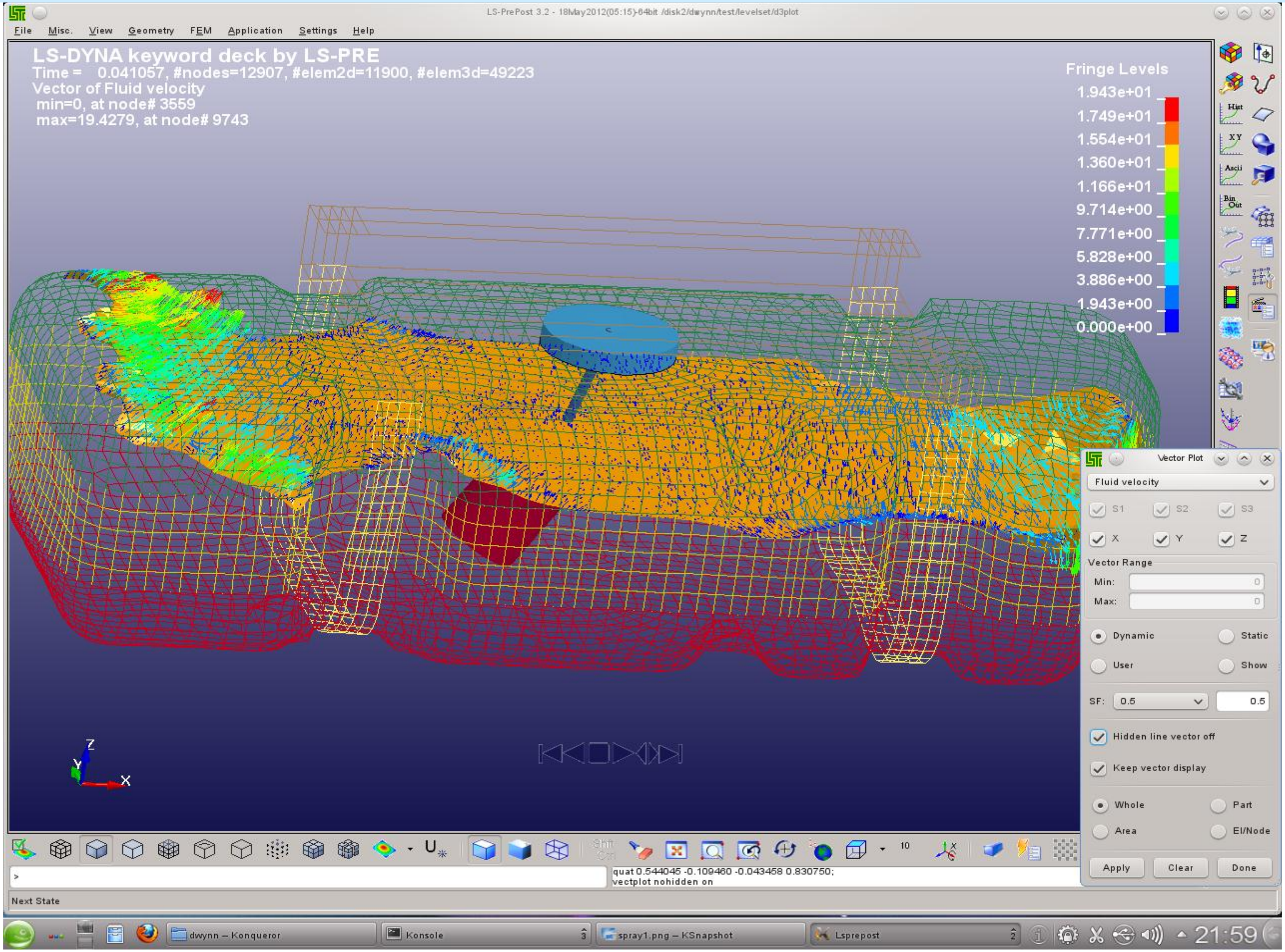
CESE with stochastic particles

Fringe by size with velocity vectors



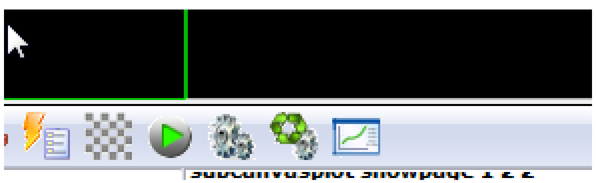
Fuel Tank Fluid Surface shown by Levelset part.

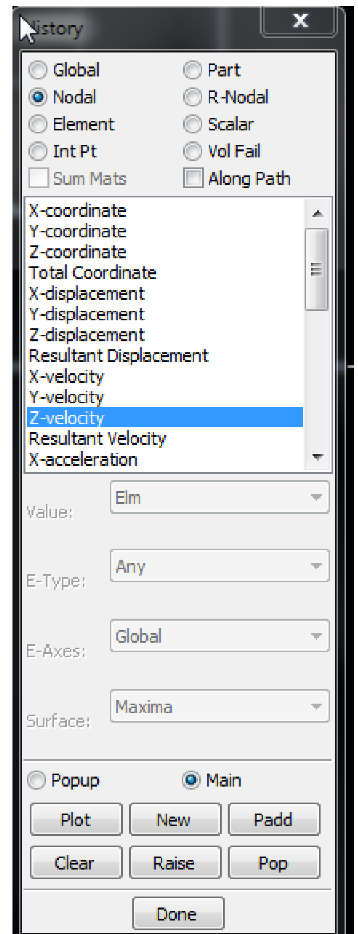
Levelset can be fringed with CFD variables, and with velocity vectors on the surface

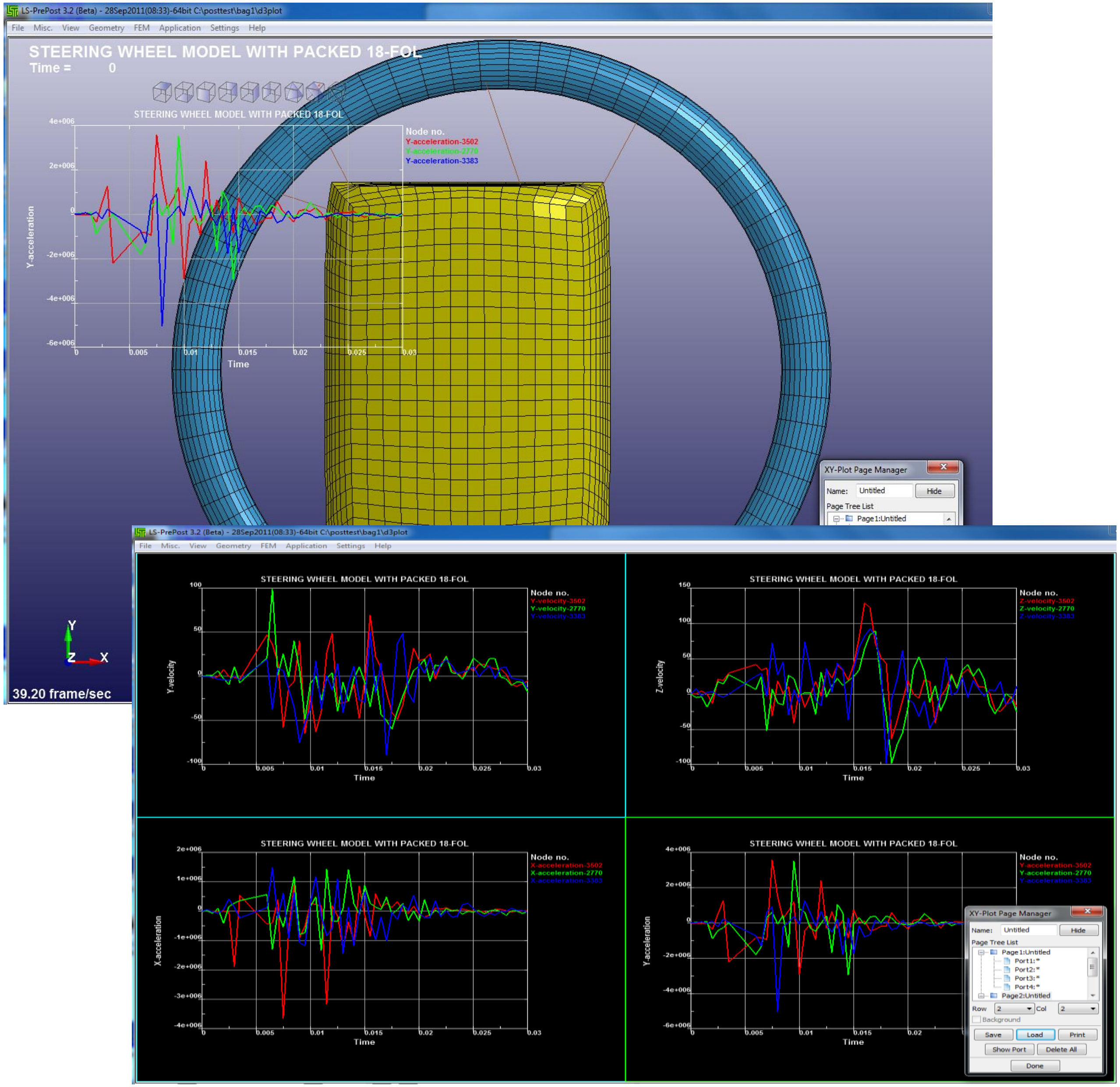


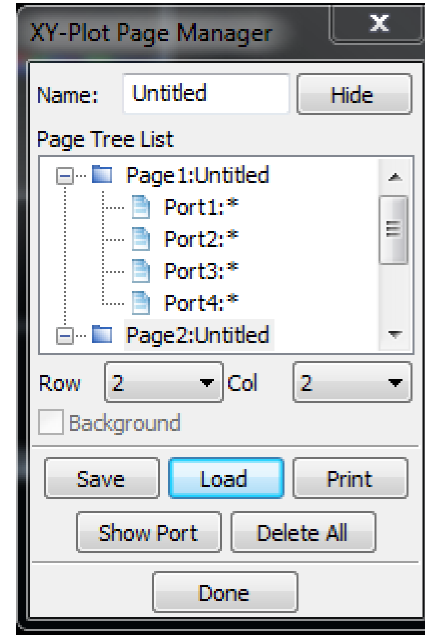
New XYPLOT layout

- New XY plot interface allows xy plots to be drawn to main graphics windows, or to a separate page with multiple plots per page

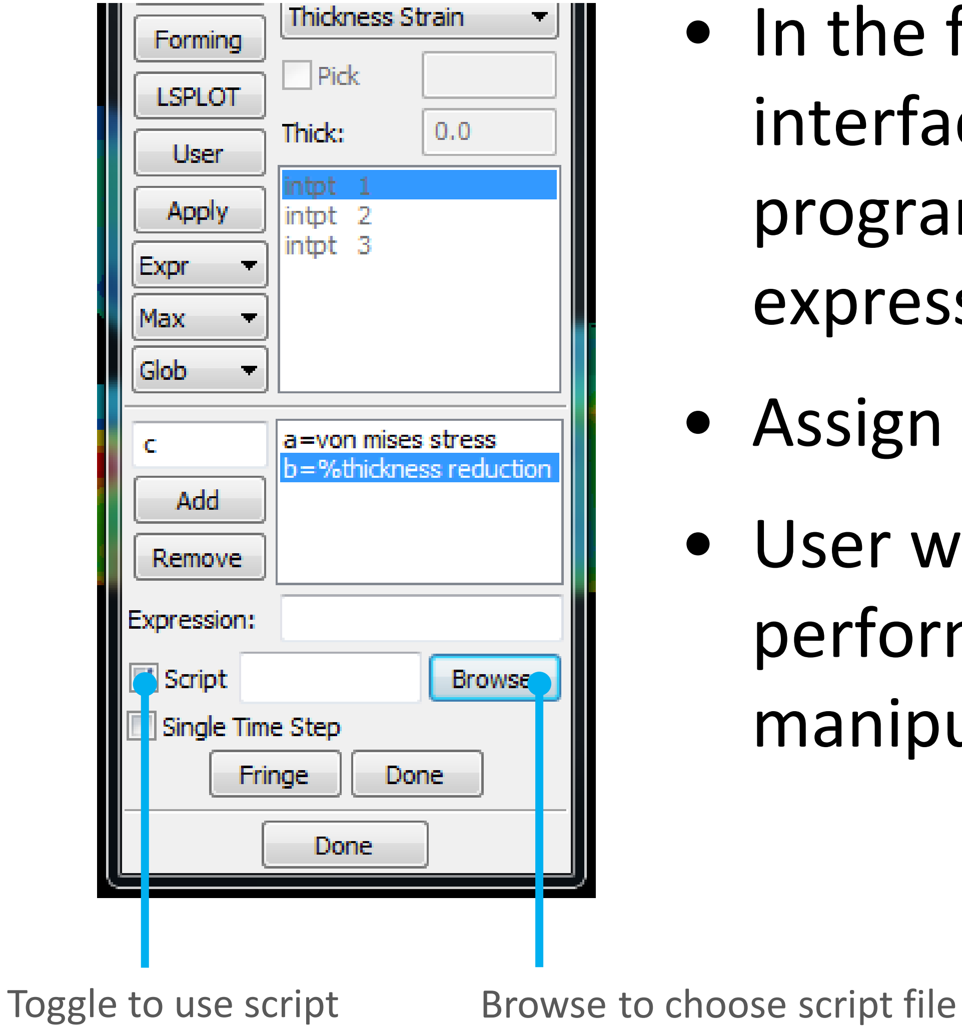





LS-PrePost 3.2 (Beta) - 28Sep2011(08:33)-64bit C:\posttest\bag1\d3plot
File Misc. View Geometry FEM Application Settings Help
STEERING WHEEL MODEL WITH PACKED 18-FOL
Time = 0
Y-acceleration
Time
Node no.
Y-acceleration-3502
Y-acceleration-2770
Y-acceleration-3383
39.20 frame/sec
XY-Plot Page Manager
STEERING WHEEL MODEL WITH PACKED 18-FOL
Y-velocity
Z-velocity
X-acceleration
Y-acceleration

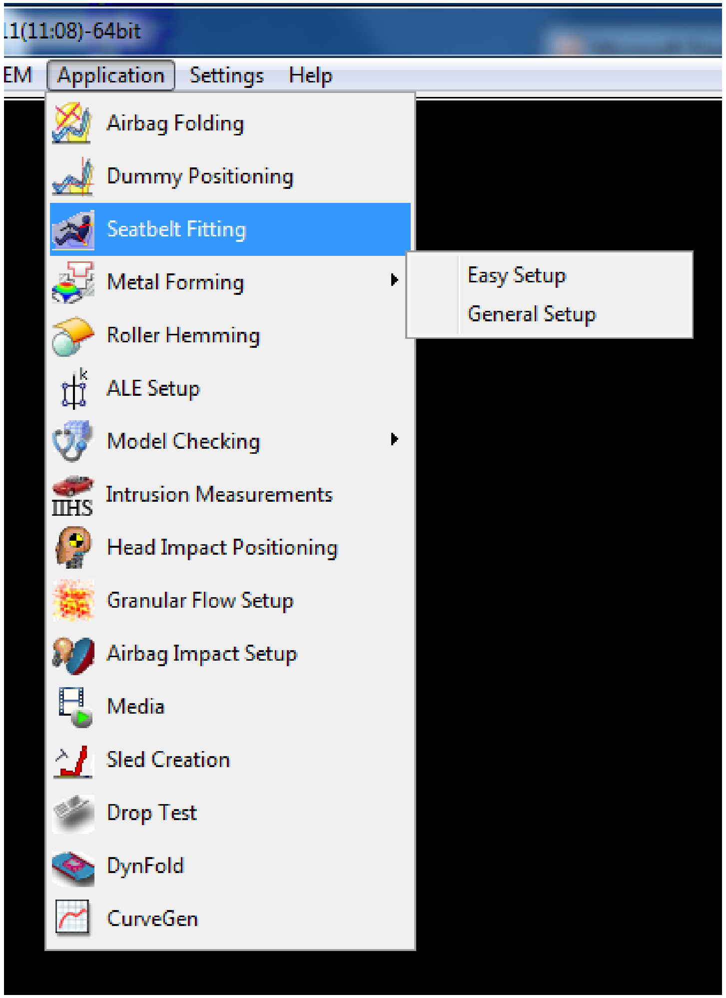

XY-Plot Page Manager
Name:
Untitled
Hide
Page Tree List
Page1:Untitled
Port1:*
Port2:*
Port3:*
Port4:*
Page2:Untitled
Row
2
Col
2
Background
Save
Load
Print
Show Port
Delete All
Done

Fringing by Script



- In the fringe expression interface, use script (a programming code) instead of expression
- Assign components to variables
- User writes the script (code) to perform whatever data manipulation to get final result

Metal Forming Application



Metal Forming Graphics User Interface (GUI) is designed to ease the setup of a stamping simulation input data using LS-DYNA.

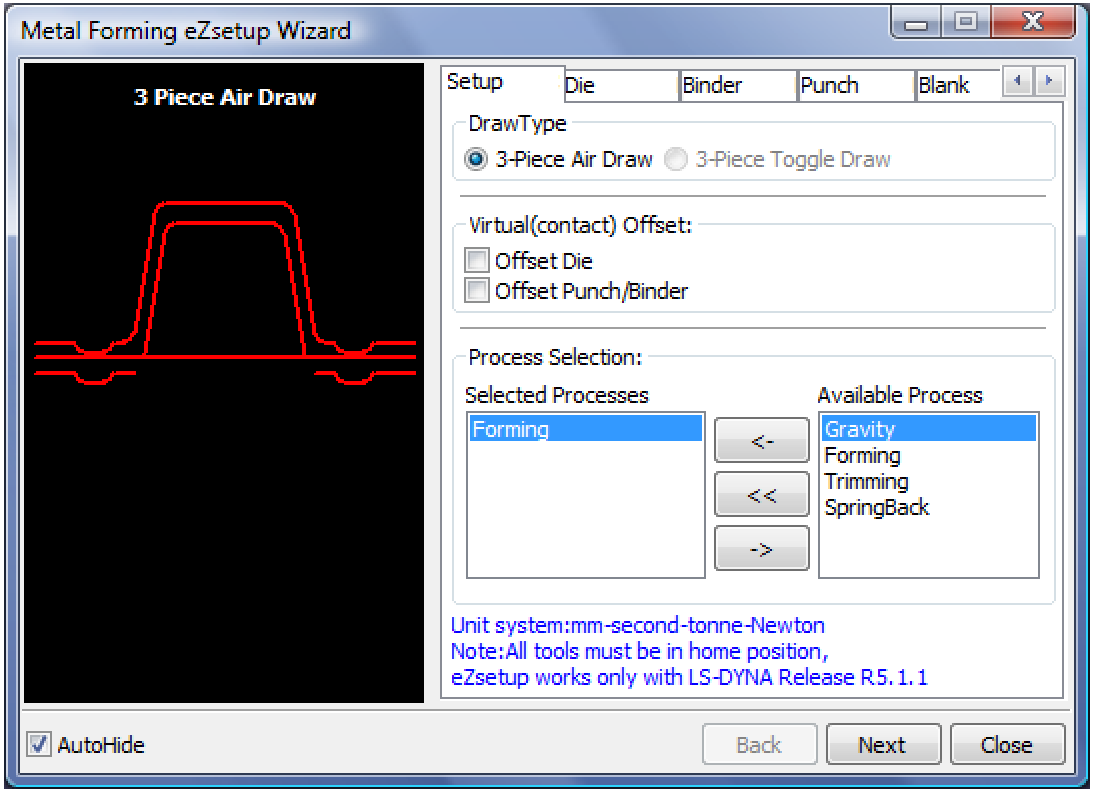
- **Easy Setup**
- **General Setup**

Metal Forming → Toolbar

Metal Forming Post-Processing

Metal Forming Pre-Processing

Metal Forming → eZsetup



- Standard draw type
- Step-by-step tool definition
- Easy draw bead modeling
- Automatic tooling position
- Multiple processes
- User control options

DynFold Application

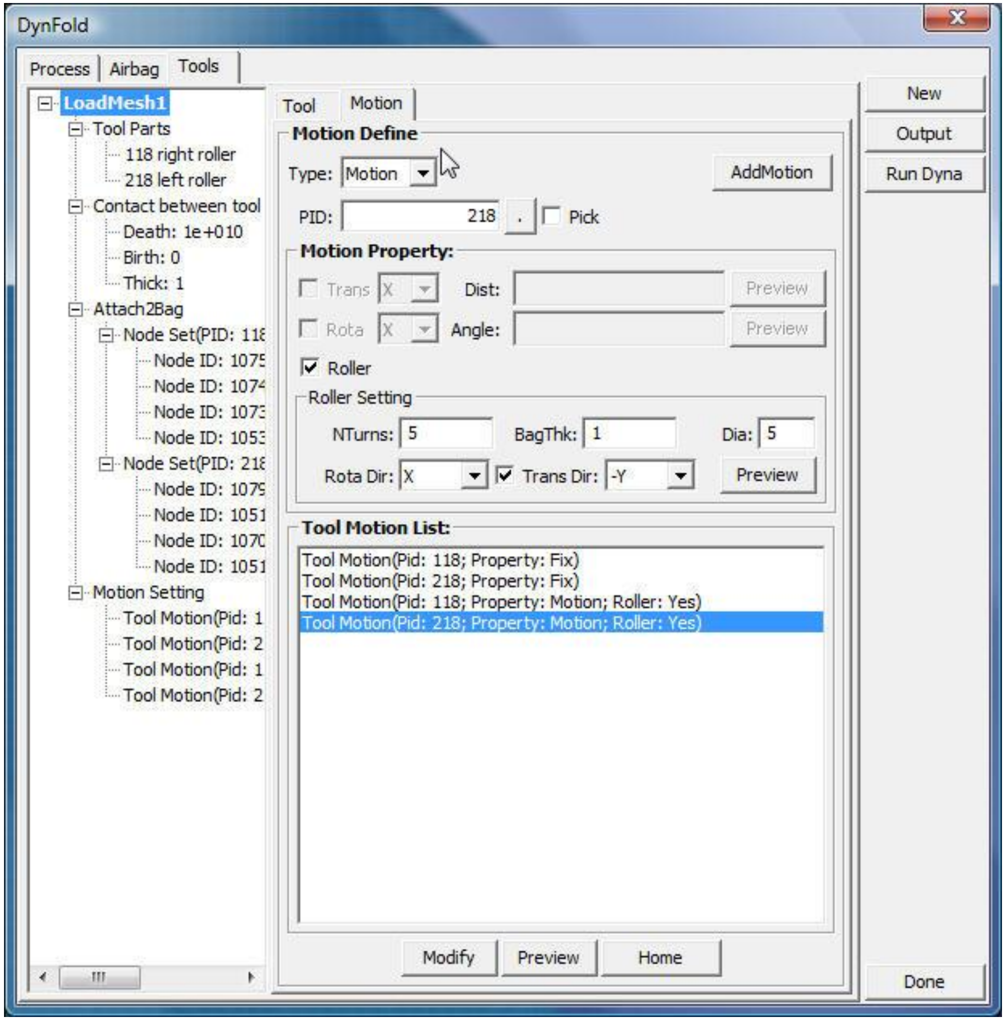
- Dynfold is designed to prepare input files for simulation based airbag folding process. Typical physical airbag folding process is done in 4 to 5 steps (runs of LS-DYNA).
- Dynfold user interface is designed to setup one step at a time. Often the deformed shape at the end of one folding step is used as a starting mesh for the next step.
- The airbag model is expected to have nodes, elements, part, section and material defined before using this interface.
- The physical folding process is generally of the following form:
  a. hold the bag in position while being folded
  b. clamp a portion of the bag to a folding tool
  c. Apply motion to the tool in translational direction or rotational direction or combination of both.
- At present 4 folding tools are supported: Loadmesh, SPC, BPMF(BOX), Stitching and Tuck

DynFold Setup Process

- Define Parameters: Define Project Step Name, Termination time, airbag tool Material Parameters.
- Load Airbag: Load finite element mesh, Position airbag by translate, rotation, etc.; show airbag, or turn off show.
- Define Airbag Folding Tools, currently there are four kinds of tools
  - Load meshing:
    - Load tool meshing file; Define tool attaching to bag.
    - Define Load Meshing Tools Motion.
    - Preview tool motion (Home position and Final position)
  - Spc_Birth_Death, BPMF(Box), Stitch

- Spc_Birth_Death, BPMF(Box), Stitch
    - Define boundary spc node set.
    - Define Constrained
    - Define Birth and Death time.
- BPMF(Box)
    - Define Original and Final position of the Box.
    - Define contact between box and airbag parameters .
    - preview of Original/Target position of the box in graphics view .
- Stitch
    - Define Stitch parts and parameters.
    - Define Get stitch start position and direction.
    - Define stitch Birth and Death time

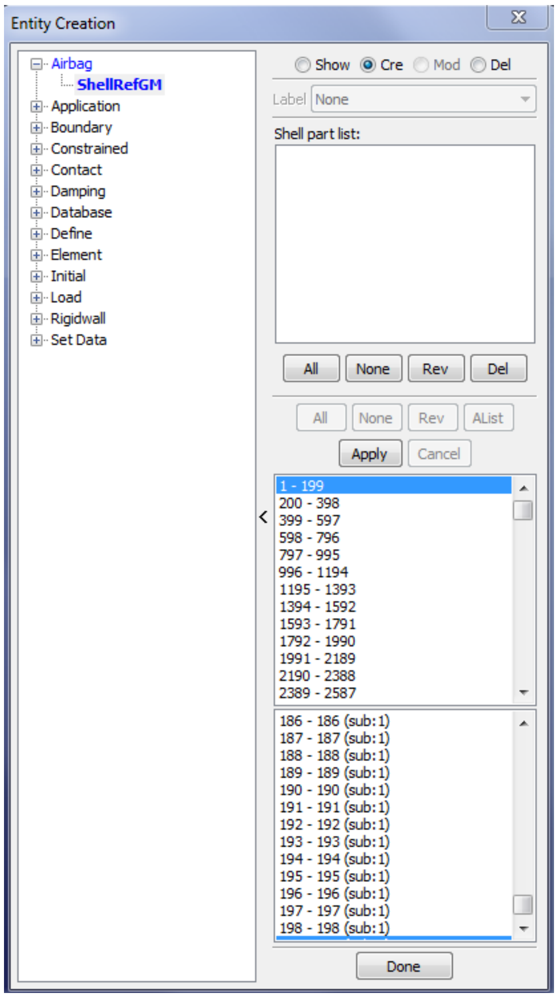
Define Part Motion with motion properties

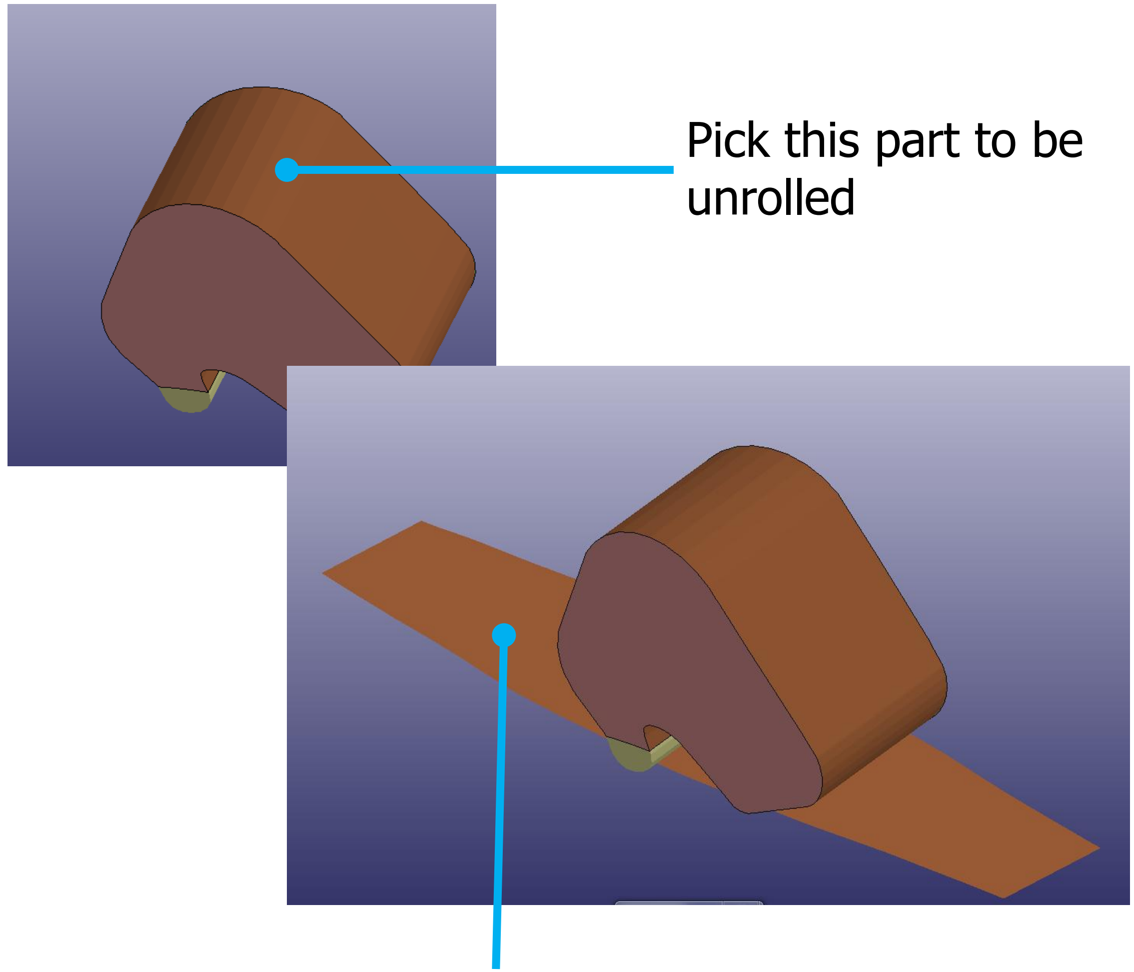


*Airbag_shell_reference_geometry

- *Airbag_shell_reference_geometry is the required data for airbag deployment in LS-DYNA
- LS-Prepost creates this data by asking user to pick the parts that make up the airbag in 3D final configuration and unrolls them into 2D flat panels.
- Element IDs are preserved with new nodal coordinates

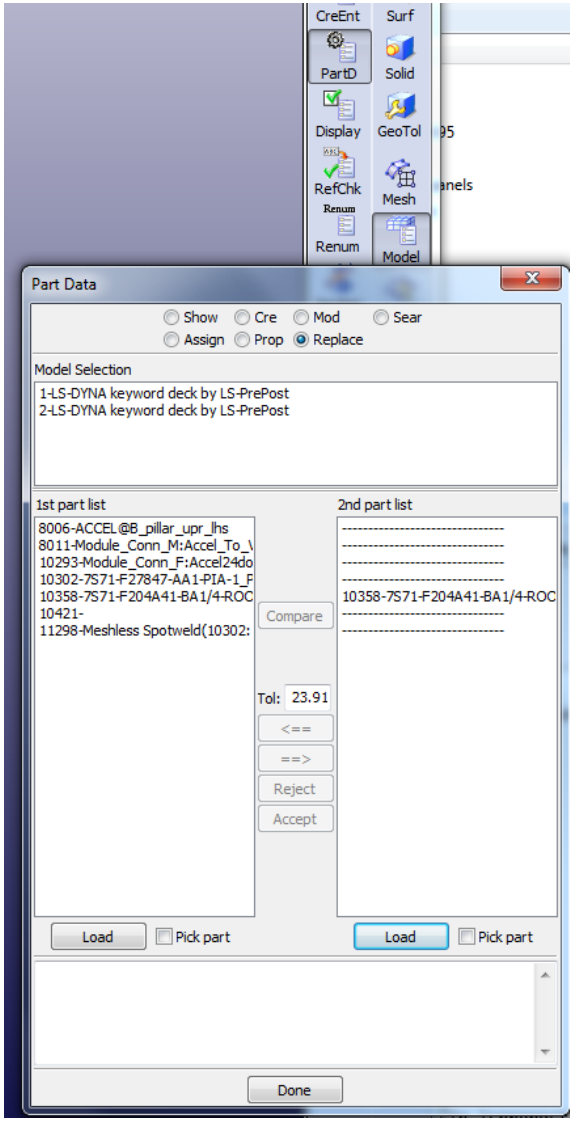
*Airbag_shell_reference_geometry



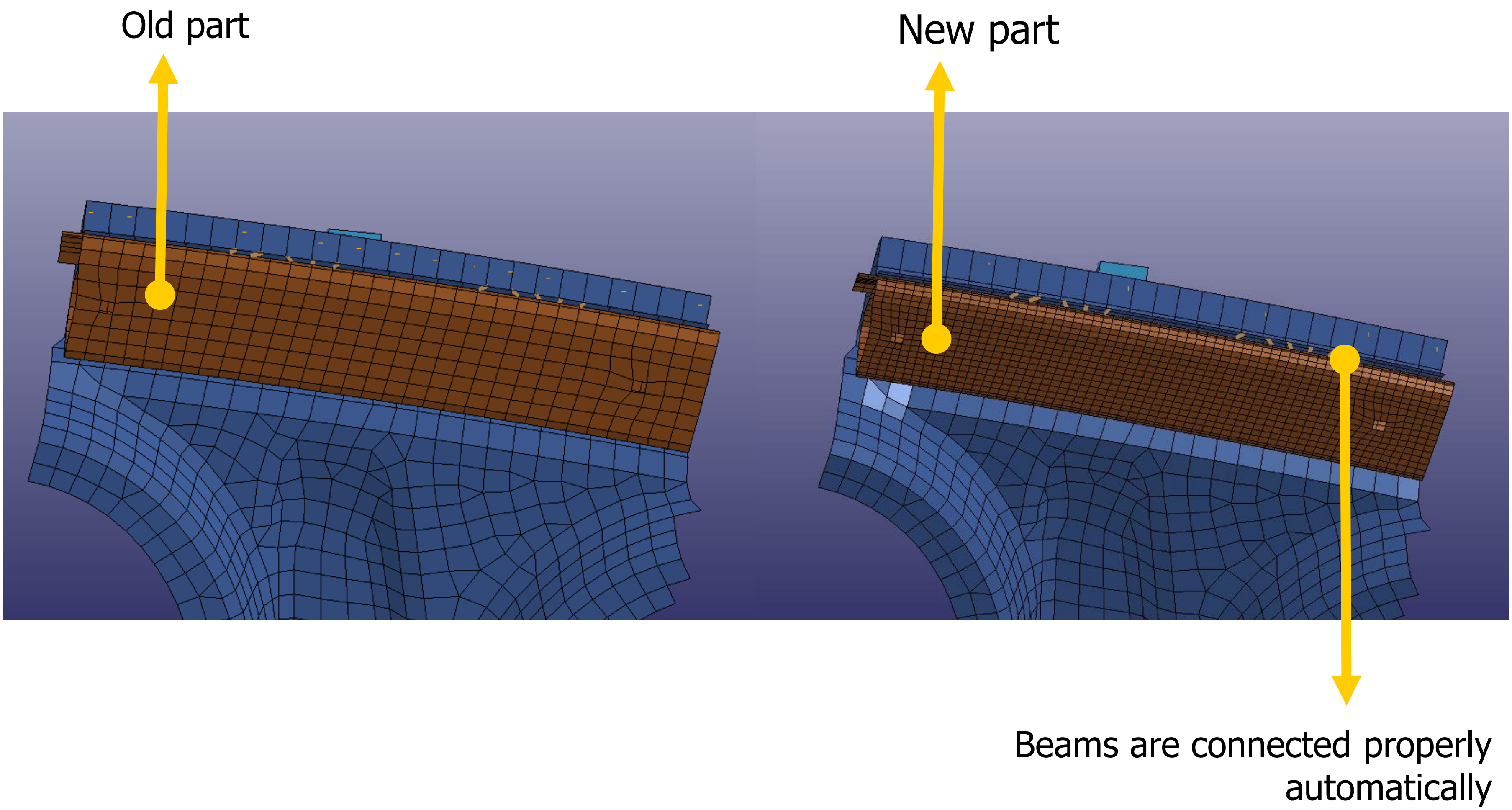


Part Replace

- Model->PartD->Replace
- To replace a part with another part
- The 2 parts do not need to be the same in no. of elements/nodes.
- Connection between others part will be done automatically when it is possible



Part Replacement



Other Miscellaneous Improvements

- Many bugs have been fixed in geometry engine
- Improved mid-surface generation from solid model
- More robust trimming and solid cutting
- Improved automatic solid meshing
- More robust LS-DYNA model checking with auto fixing
- Particle, temperature post-processing data support in FEMZIP format
- Solid element and seatbelt element splitting
- Element edit with check, locate and repair

User written script

- C-like programming scripting language to execute LS-PrePost commands
- Allows “if then else”, for, and while loop operations
- Uses LS-PrePost DataCenter to extract model data: like no. of parts, part ID, no. of elements, no. of nodes, etc.
- Extracted data can be used as variables to perform operations
- Most suitable to perform the same operations over different part of the model

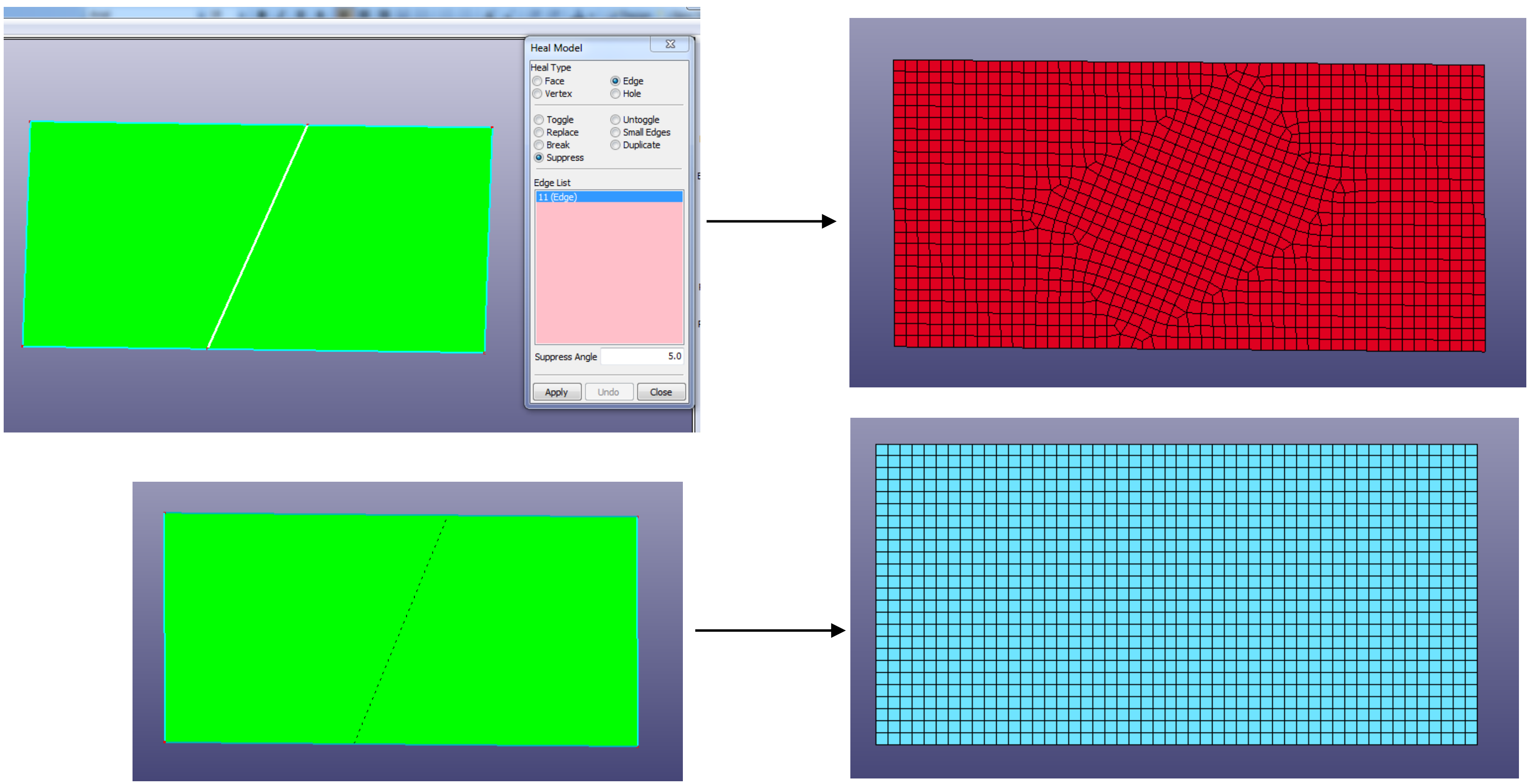
User written script

Sample script to extract no. of parts and all part IDs, then draw each individual part and print it to a file with the part id as file name

```
/*LS-SCRIPT:PartId repeat cmd*/
DataCenter dc;
Int partnum, *ids;
define:
void main(void)
{
Int i = 0;
char buf[256];
Int modelId;
modelId = GetCurrentModelID();
DataImportFrom(&dc,modelId);
partnum = DataGetValidPartIdList(&dc,&ids);
for(i = 0; i < partnum ; i = i+1)
{
sprintf(buf,"m %d",ids[i]);
ExecuteCommand(buf);
ExecuteCommand("ac");
sprintf(buf,"print png part_%d.png LANDSCAPE nocompress gamma 1.000 opaque enlisted
        \"OGL1x1\"", ids[i]);
ExecuteCommand(buf);
}
free(ids);
} main();
```

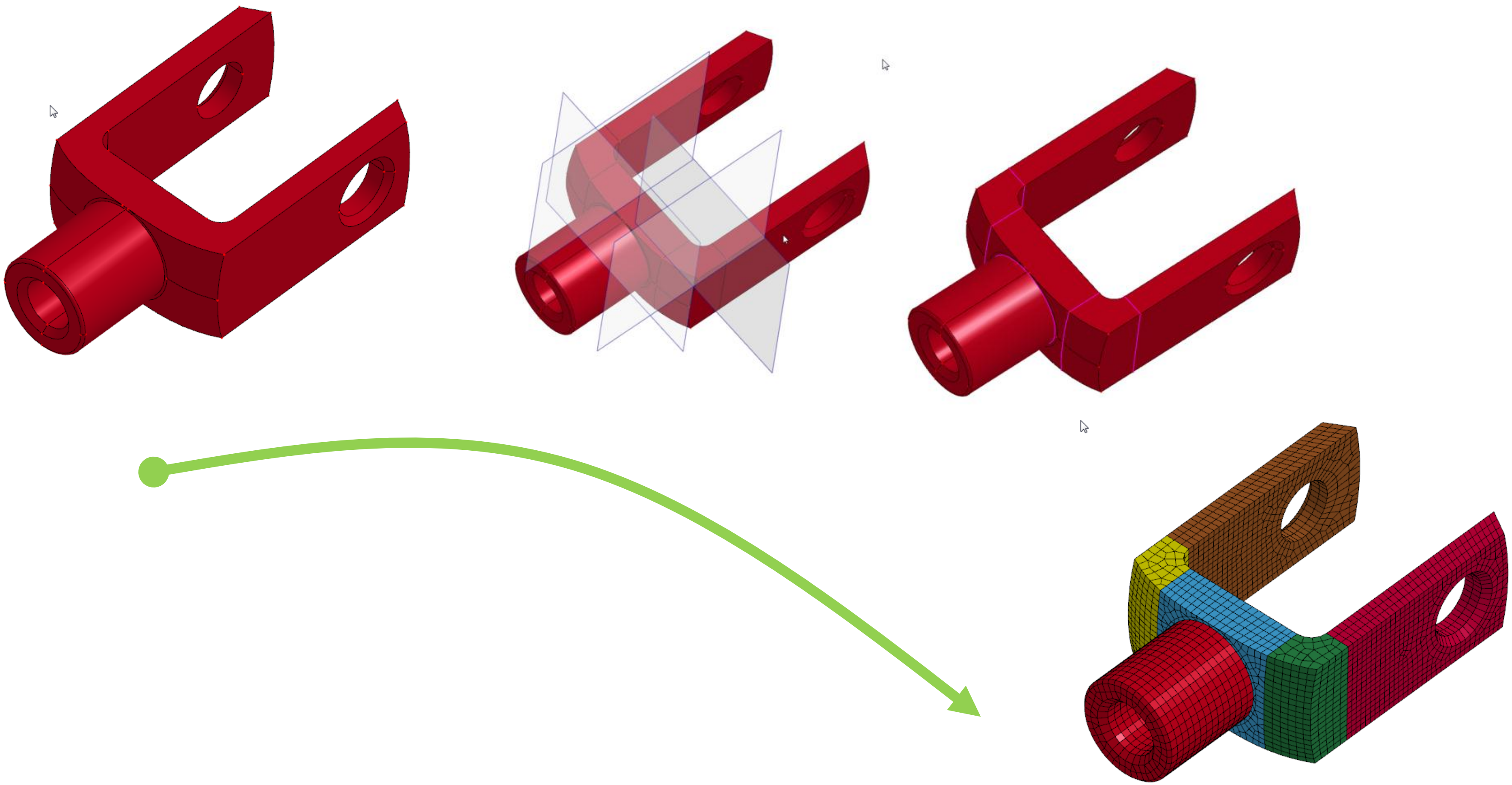
Suppress Boundary line for surface meshing

Common boundary lines between two surfaces can be suppressed to form a joint surface, this will allow the mesh to cross boundary lines to give better mesh



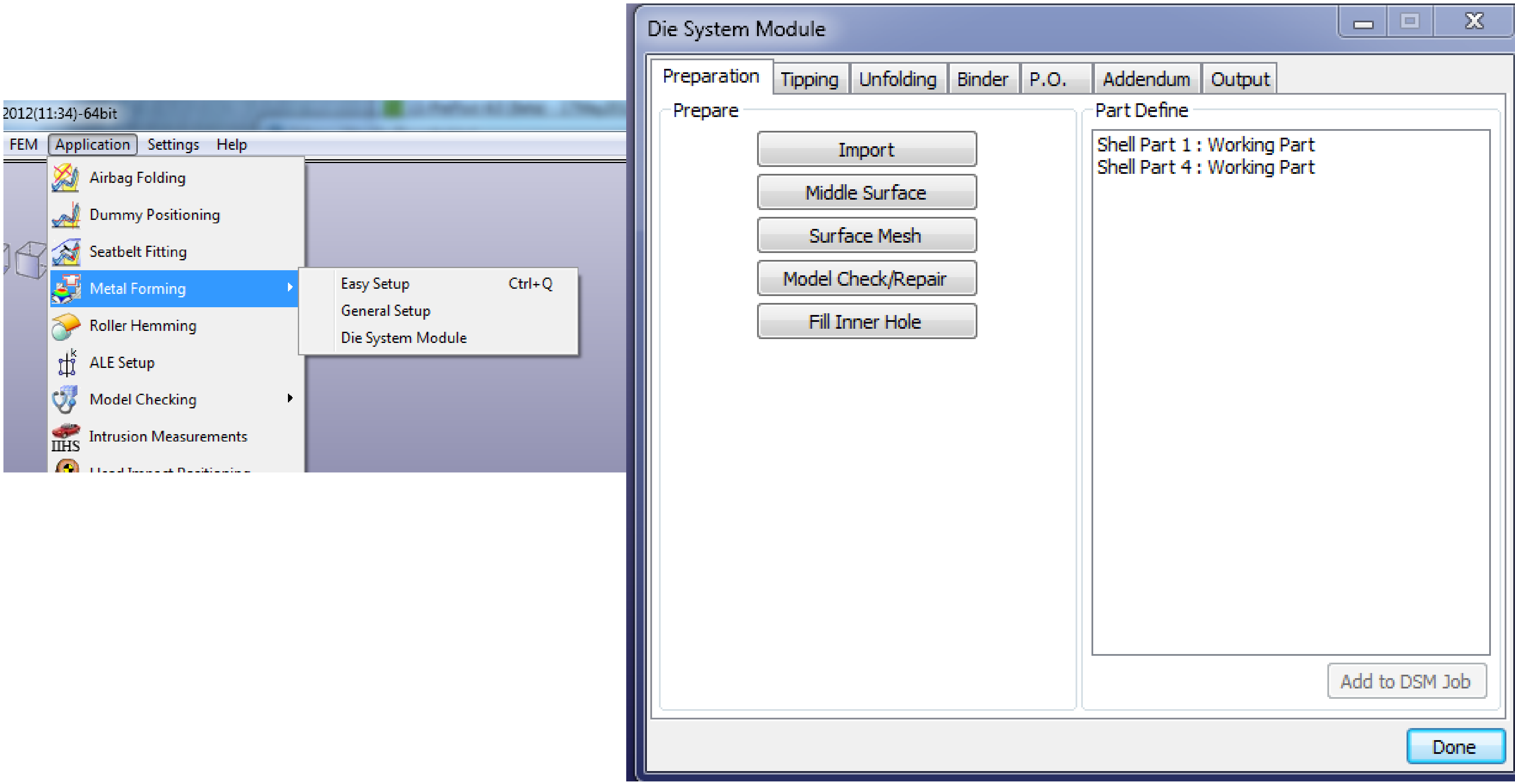
Solid Meshing with Hex Element

- Solid meshing by blocks - using cut and dice method and then sweeping



Metal Forming - Die System Module

Complete metal forming Die design system

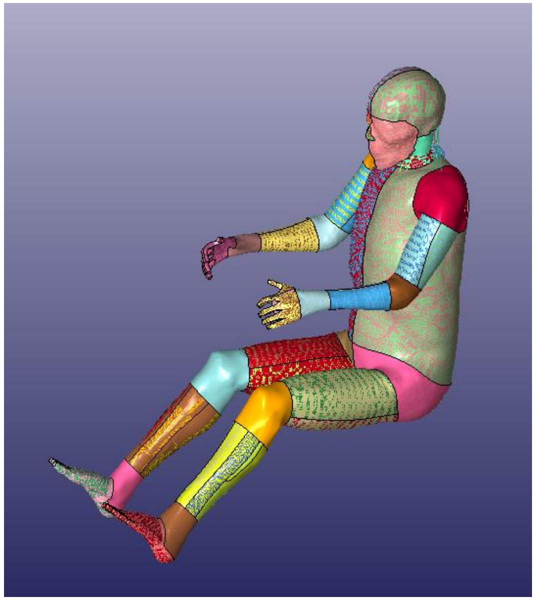


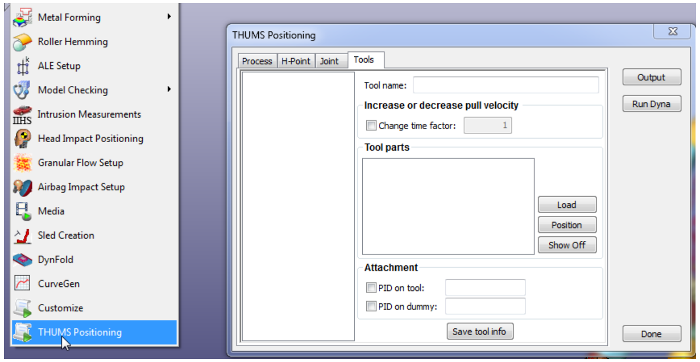
Metal Forming - Die System Module

- Provides a user friendly interface to design the complete tooling system
  - Starting from CAD geometry
  - Tipping: make sure that the part can be made without undercut
    - Many options are available to allow user to check and position the part with a desired orientation
  - Binder design is fully parametric
    - User can easily manipulate the binder surface
  - Addendum design – obtain a smooth surface that is tangent to both the tool part and the binder
    - To make sure that the part can be deformed correctly
    - Parametric patch method will be employed
  - Initial blank size estimation – one step solver

THUMS Positioning Setup

- THUMS – Total Human Model for Safety
- THUMS positioning Setup – Setup LS-DYNA keyword data to position the dummy by simulation
  - H-point and Joint method – define amount and direction of rotation at joint
  - Tools method – introduce tools to pull or move the limbs to a desired location





Summary

- New GUI provides better look and feel, also yields maximum windows space for graphics, at the same time old interface is still available to user
- Capabilities in the geometry engine allows CAD data to be modified and repaired before meshing and therefore eliminate tedious mesh modification
- New rendering in Version 4.0 employs the latest rendering techniques in OpenGL, speeds up the rendering by many times, viewing and animation of a very large model now is possible
- LS-DYNA model data check is a very important tool to ensure the validity of the data before running LS-DYNA
- Scripting language will be further developed to provide much more powerful capability

LS-PrePost Recap

LSTC is committed to continue to develop and enhance LS-Prepost by improving its stability, robustness and user friendliness

New features have been added continuously to keep up with the development of LS-DYNA both in the post-processing and pre-processing

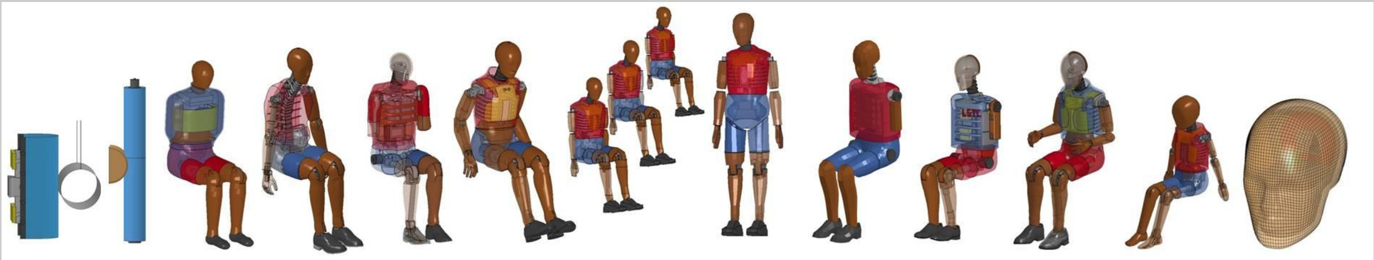
New Applications have been implemented to let user do special LSDYNA job setup easily and quickly

Users' feedback and suggestions are always welcome

Thank You !

Dummies & Barrier

Dr. Christoph Maurath



Released LSTC Dummy Models

Detailed Models
HYBRID III 5th
HYBRID III 50th
HYBRID III 95th (scaled)
SID IIs D
EuroSID 2
EuroSID 2re
USSID
HYBRID III 6-year-old
Free Motion Headform
Pedestrian Legforms
BioRID II (ALPHA)

FAST Models
HYBRID III 5th
HYBRID III 50th
HYBRID III 95th
SID IIs D
HYBRID III 5th Lower Body
HYBRID III 50th Lower Body
HYBRID III 50th standing

LSTC Dummy Models in Development

Model	Status
HYBRID III 3-year-old	Material Optimization
HYBRID III 95^{th}	Model Improvements and Material Optimization
HYBRID III 95^{th} FAST	Model Calibration and Sled Verification
BioRID II	Model Improvements and Material Optimization
WorldSID 50^{th}	Model Build-up
THOR NT	Meshing
Ejection Mitigation Headform	Material Optimization
HYBRID II	Meshing

Planned LSTC Dummy Models

- Pedestrian Headforms
- FAST versions of EuroSID 2 and EuroSID 2re
- Q-series child dummies
- Flex PLI
- WorldSID 5th percentile female

LSTC Dummy Models Recap

We committed to the continued development and support of our released and future dummy models

Dummy models are available at no additional cost to current LS-DYNA customers

All models are unencrypted and may be changed by customers

Feedback is greatly appreciated but not required

atds@lstc.com

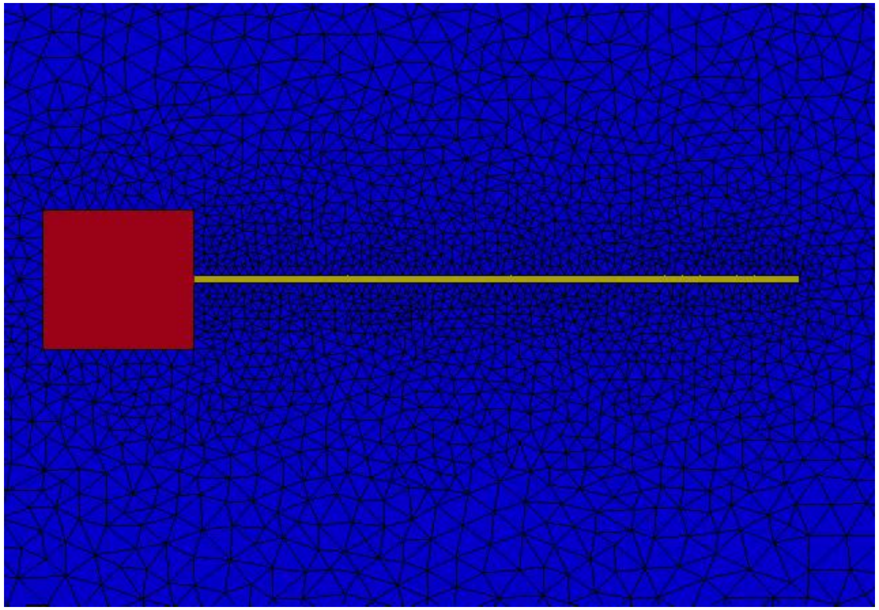
Thank You !

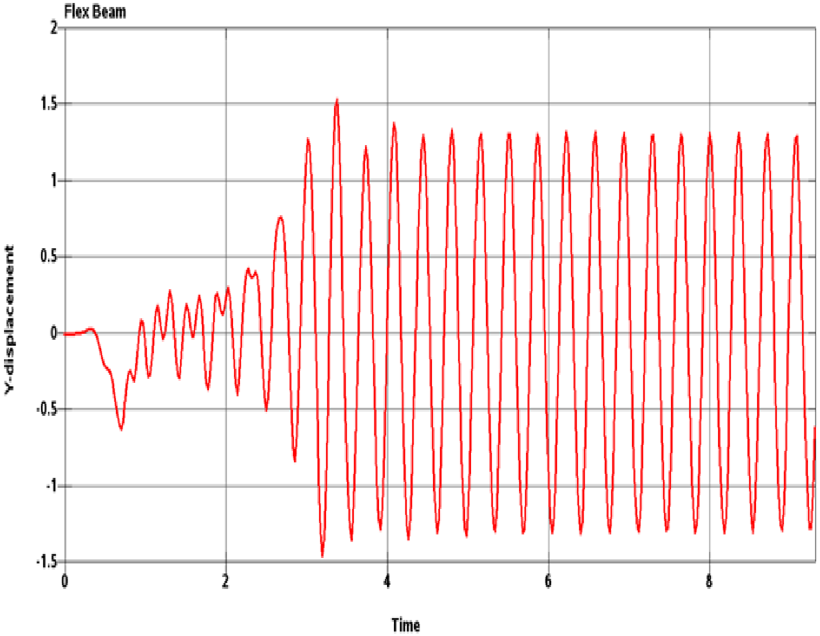
Incompressible CFD

Dr. Facundo Del Pin

Introduction to the Incompressible CFD solver

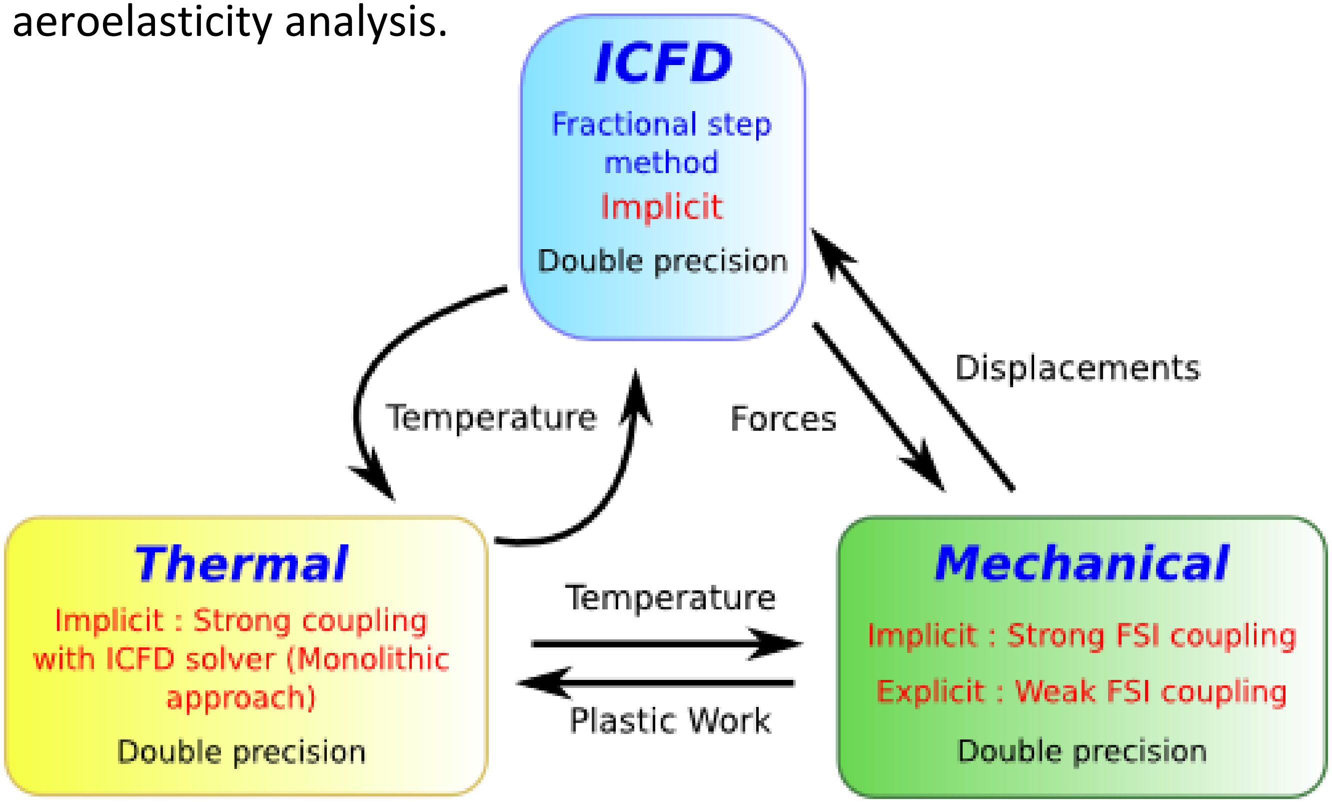
- Stabilized **Finite Element formulation** for the **Fluid Mechanics Navier-Stokes** equations
- **Free surface** capabilities and multi-phase approximations,
- Can run as a **stand alone implicit CFD** solver or be coupled with the structural (**FSI problems**) and thermal solvers of LS-DYNA,
- **ALE approach for mesh movement**, all **FSI boundaries are Lagrangian** and deform with the structure.





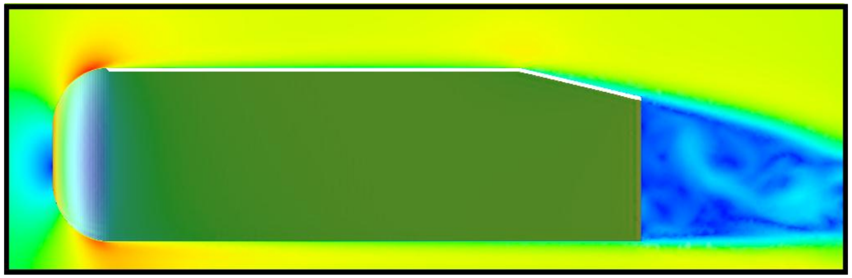
Coupling with other LS-DYNA solvers

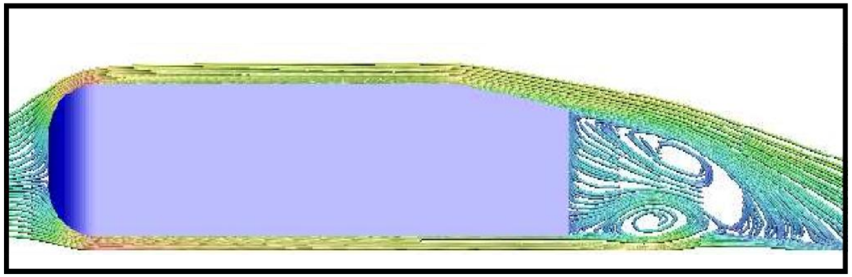
- Scope of the new 980 solvers to be coupled with LS-DYNA solvers in order to solve complex **fluid-structure** or **thermal** problems,
- **Strong coupling** is available for implicit mechanics. More robust but more costly,
- **Loose coupling** for explicit mechanics. Less robust and less costly. Suitable for simpler couplings.
  - E.g. aeroelasticity analysis.



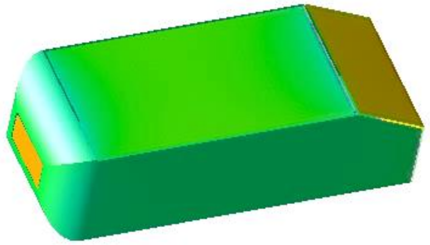
Applications : Aerodynamics

Ahmed bluff body example
Benchmark problem

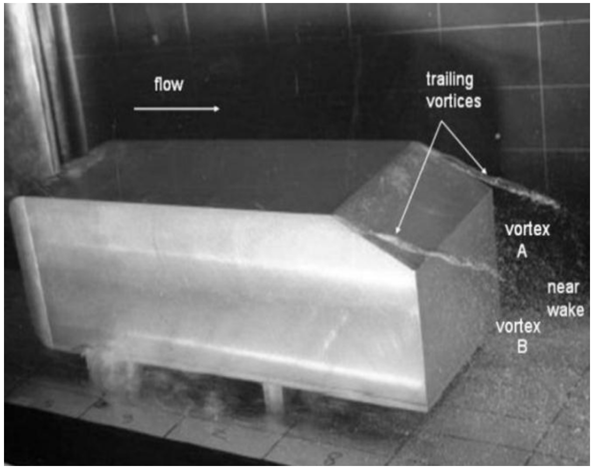




Drag calculation and Study of vortex structure,
Turbulence models available for solving
Can run as a CFD problem with static body or be transformed in a FSI problem with moving body (Eg : pitch or yaw movement).

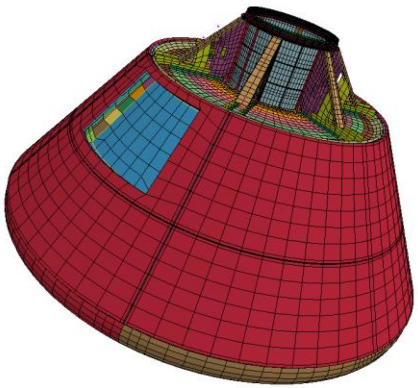


time[sec]: 0.000000

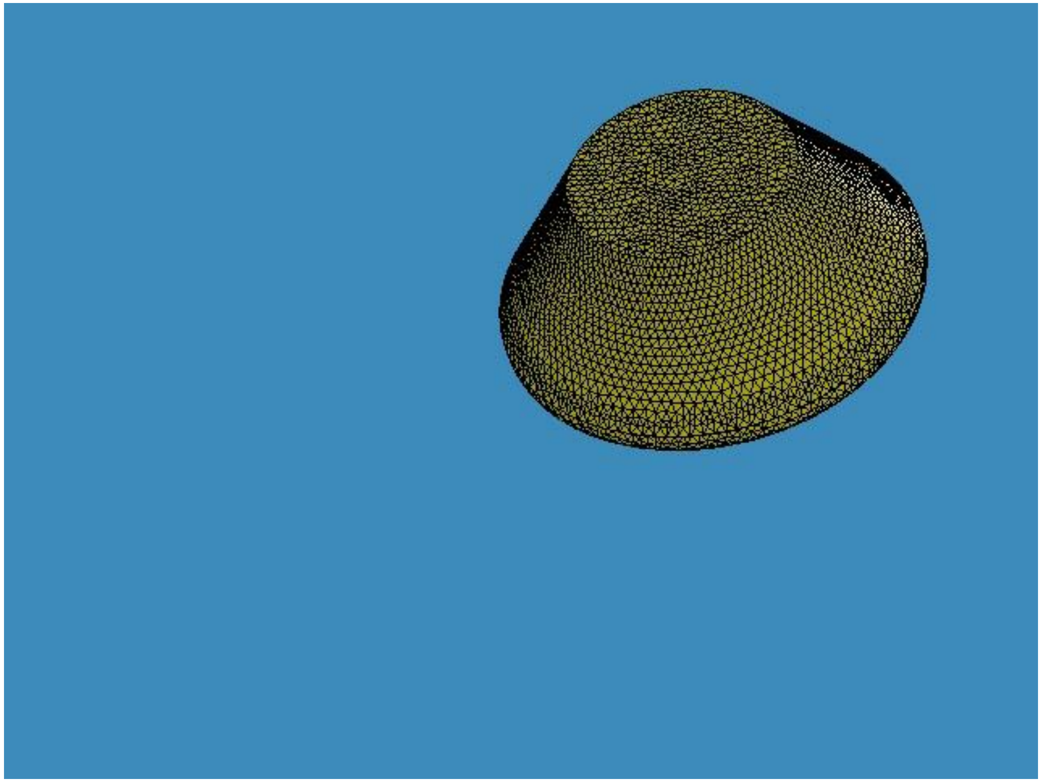


Applications : Slamming

Space Capsule impact on water (Slamming problem) :



Derived from Orion water landing module
/awg.lstc.com LS-DYNA Aerospace Working Group,
NASA NESC/GRC



Free fall impact / Strong FSI coupling

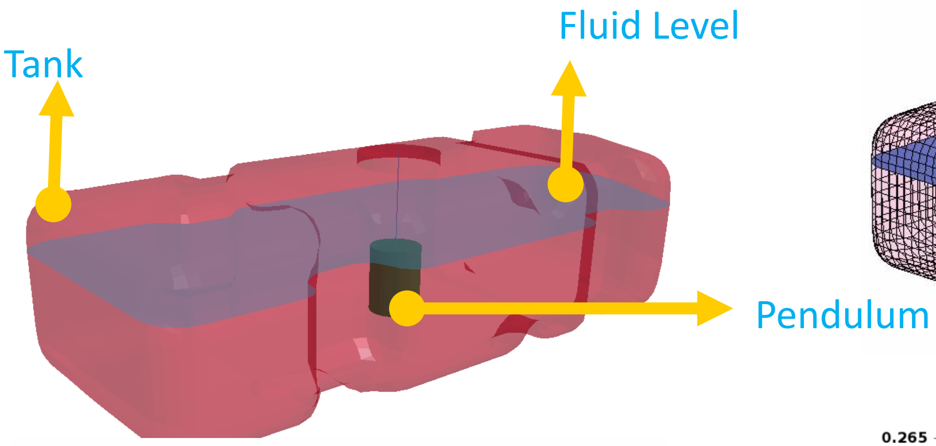
Proof of feasibility using ICFD solver

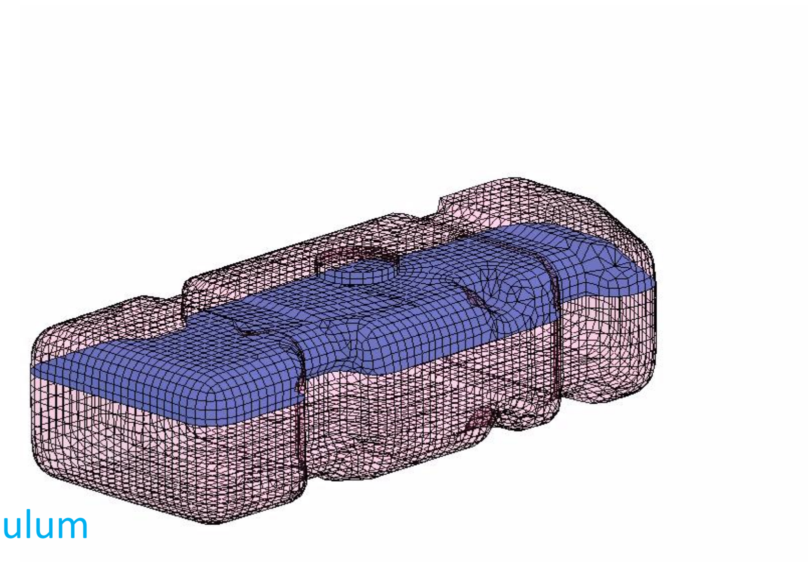
May be applied to similar Slamming problems

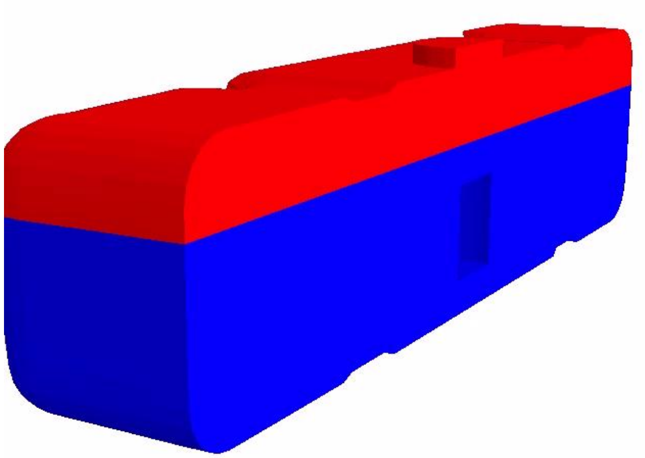
Sloshing

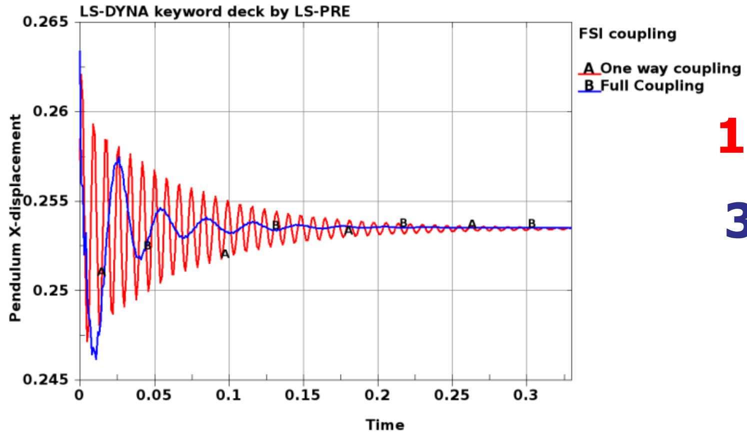
Water Tank example :

Moving Water Tank coming to a brutal halt,
Sloshing occurring,
Study of pendulum oscillations.





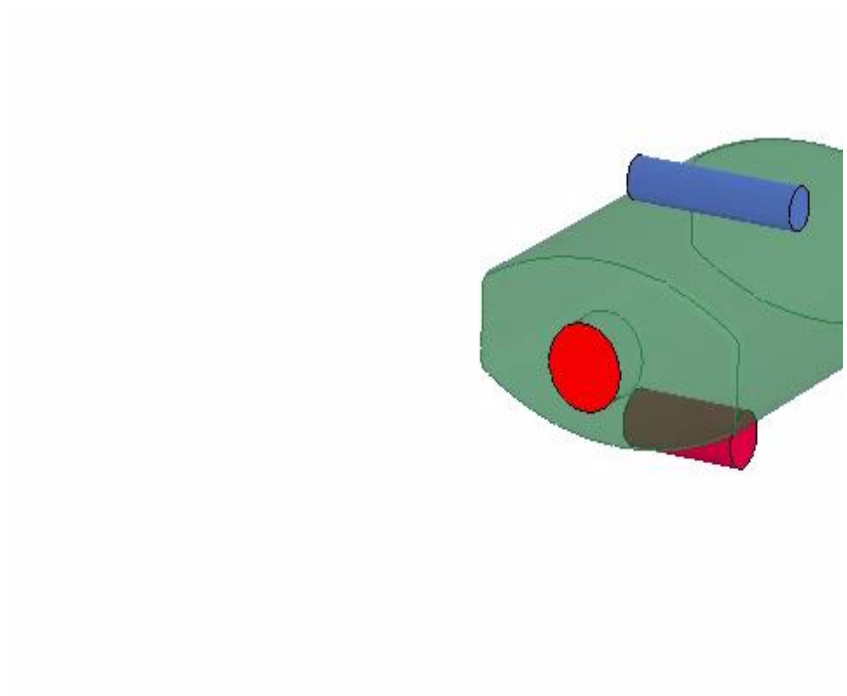




125 Hz

35 Hz

Strong FSI Coupling



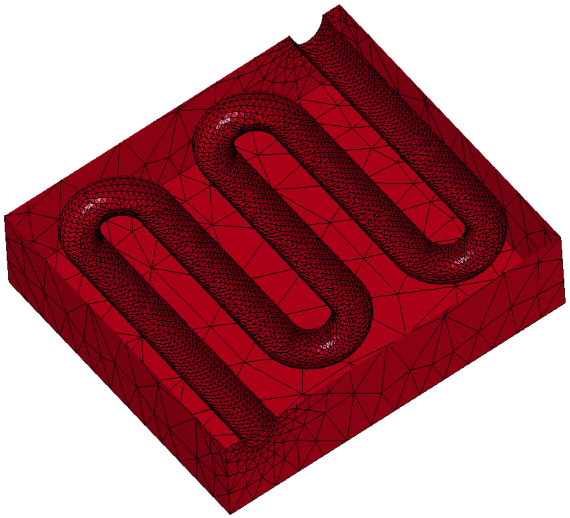
High viscosity Liquid coming out of bottle due to finger pressure

Simulation of synthetic heart valve. Density of Solid and Fluid (blood) very close: complex FSI strong coupling case.

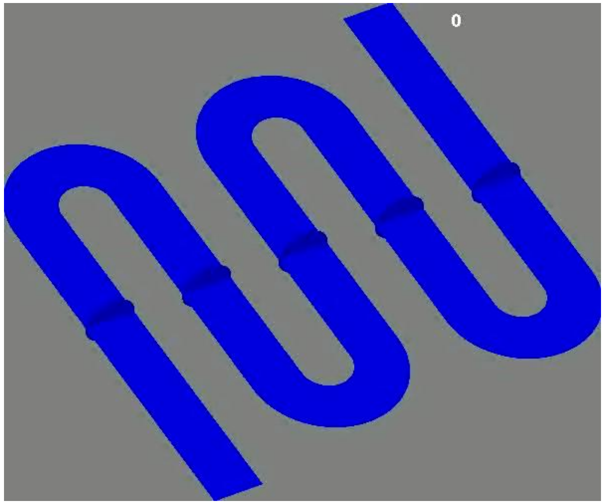
Conjugate Heat Transfer

Monolithic strong coupling between the solid and fluid thermal solvers providing good stability

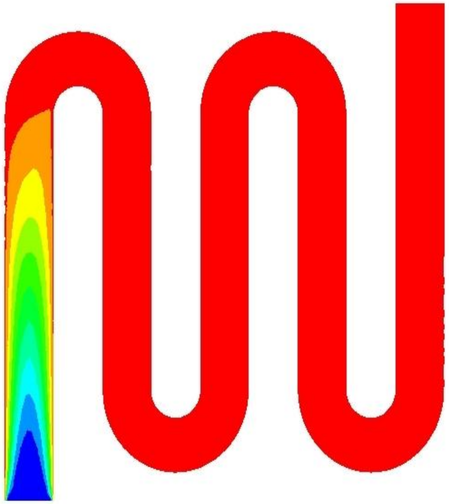
Thermal pipe flow example



Solid Mesh



Fluid velocities and Conjugate heat analysis (cut plane of fluid vel.)



Steady state fluid temperature (cut plane through the section)

Range of Applications

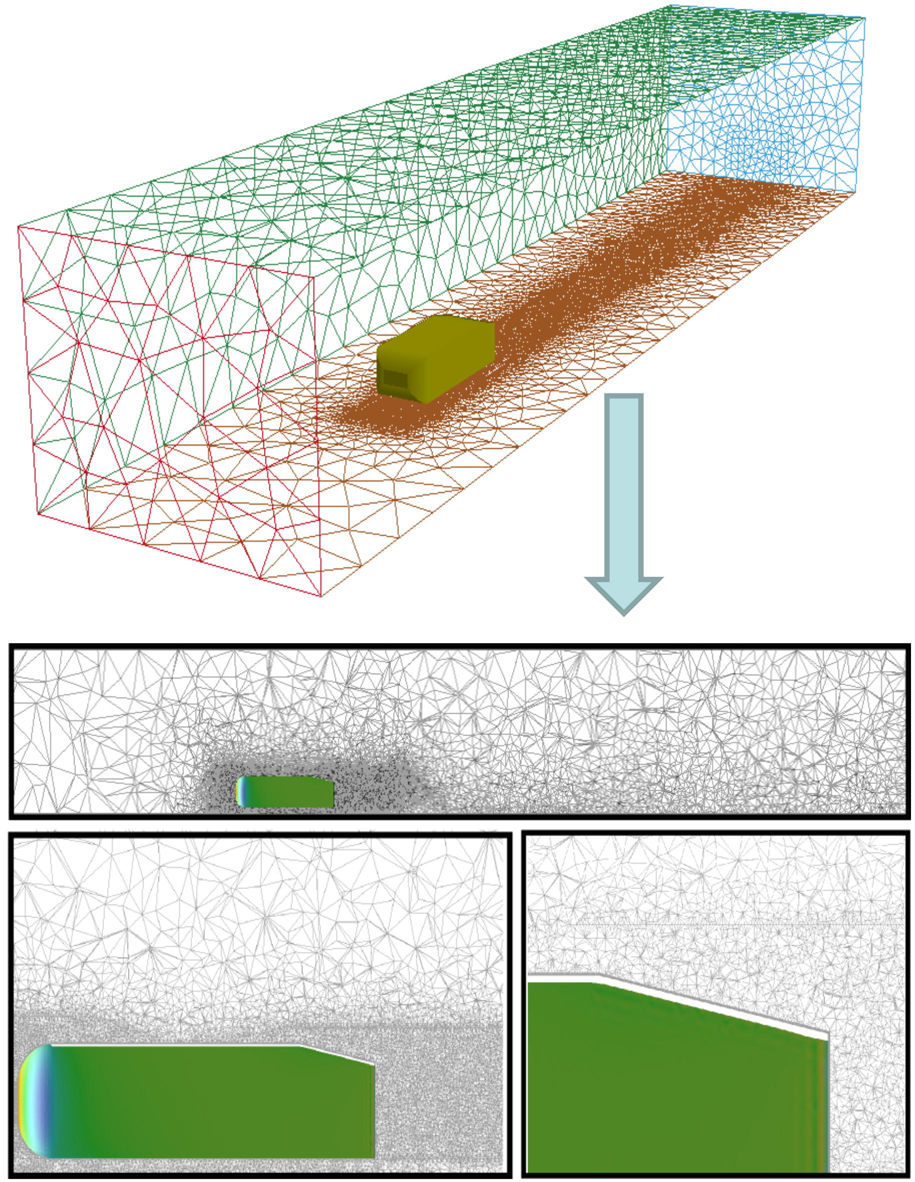
- **Most flows that we encounter in our daily activities are incompressible,**
- **Low Mach number (*Ma* < *0.3*).**
  In Air : *Vel* < *230 MPH* , *370 KPH*.

Examples:

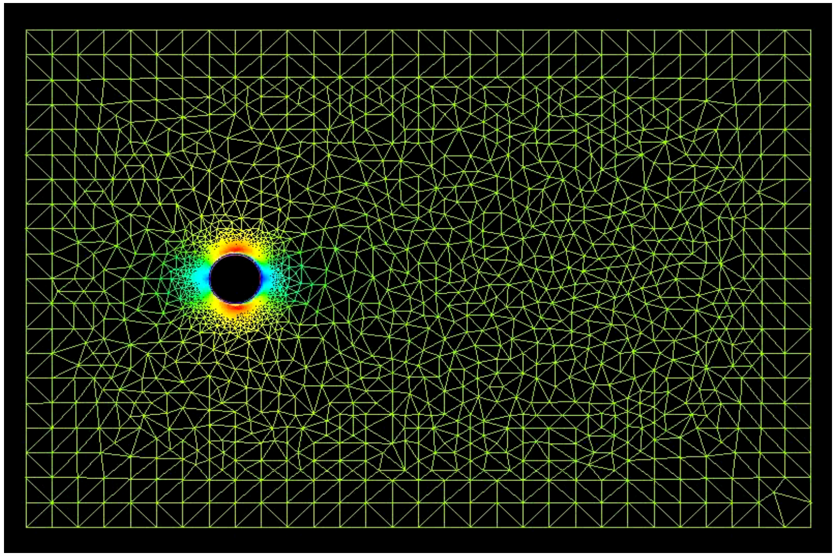
Ground vehicle aerodynamics, Free surface and Multi phase flows, Wind turbines, Human body, Ship hydrodynamics, etc.

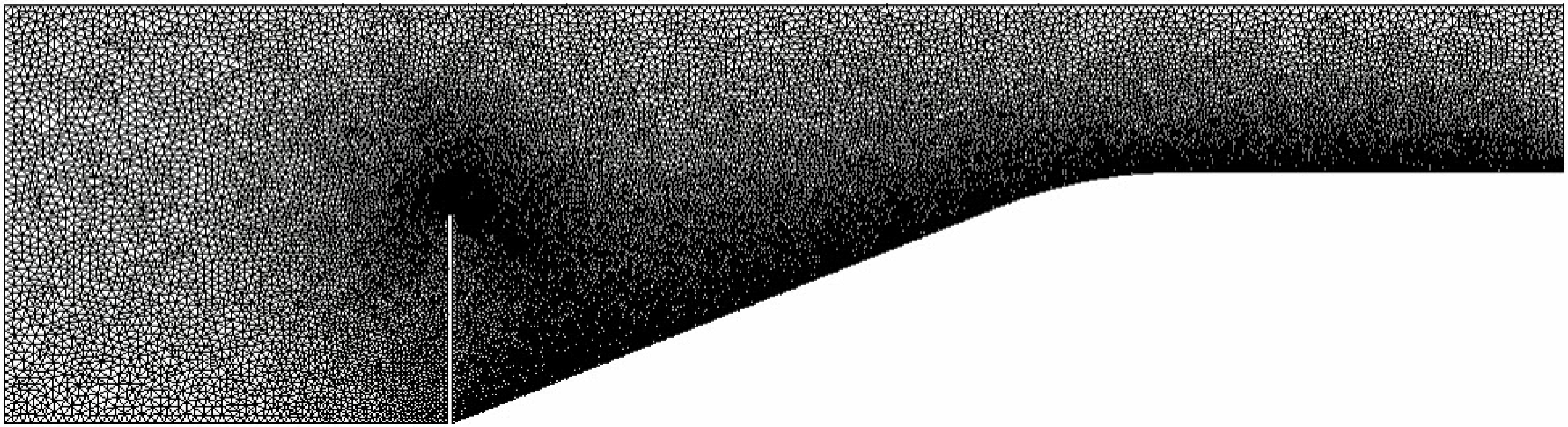
Automatic Fluid Volume Mesher

- In complicated geometries meshing for CFD problems could be a time consuming process for any commercial software
- **Simplification of the pre-processing stage**,
- Possibility to **specify local mesh size** for better resolution,
- Possibility to add **Boundary layer mesh**.
- Error estimators may be used to **automatically adapt the mesh**.



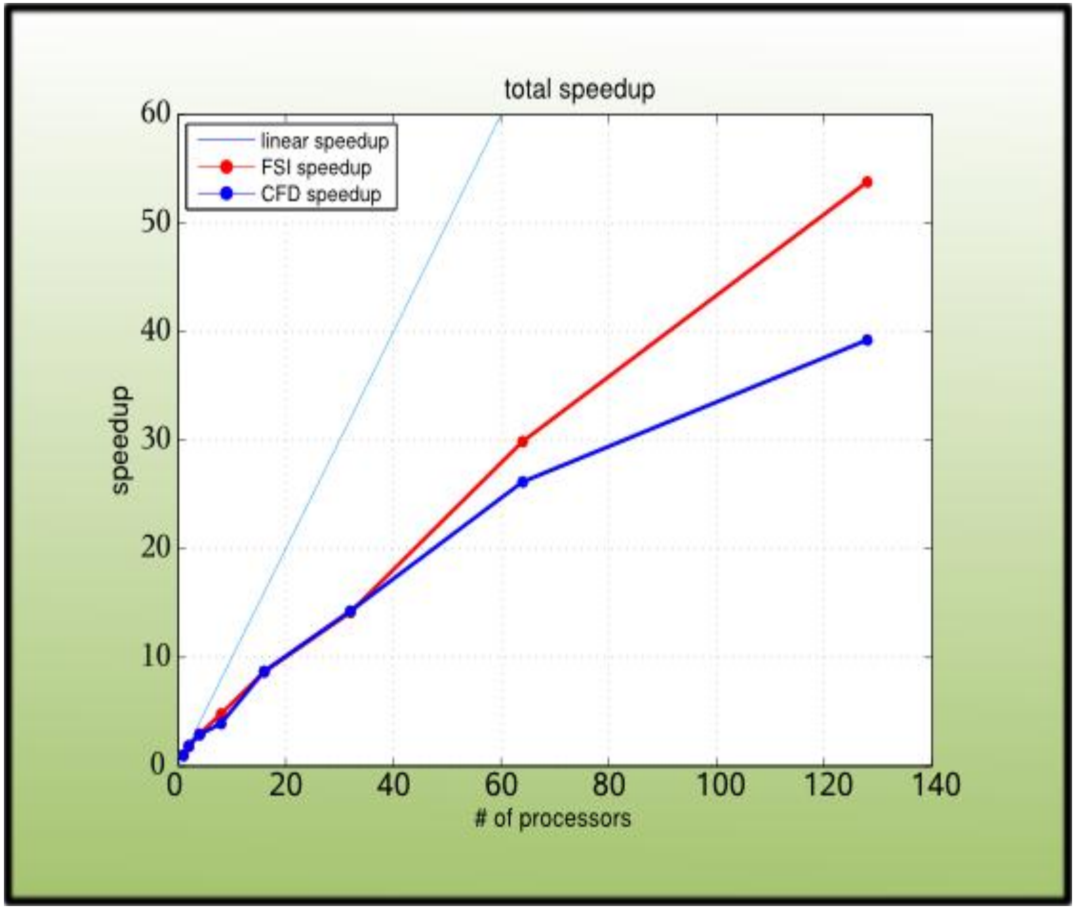
Error Control and Adaptive Re-Meshing





MPP Scalability: Real Car Model

The results show a **speedup of 40 for 128 cpus in the CFD** only case (2.1 M elements) and a **speedup of 55 for 128 cpus in the case of FSI** (3.6 M elements).



For the next development cycle further improvements will be implemented

Incompressible CFD Roadmap

Validation/Benchmarking process under way (problems will include FSI, Conjugate Heat transfer cases as well as more Aerodynamics and Free surface analyzes).

Additional post treatments and Tools with LSPP 3.2.

See Website for additional documentation

http://www.lstc.com/applications/icfd

Thank You !

Electromagnetism

Dr. Pierre L’Eplattenier

Presentation of the Physics

Source Electromagnetic Fields
(Source currents in Conductors,
External fields, …)

Magnetic and Electric fields as well as Induced Currents in conducting parts

Lorentz Forces

Possible Motion, and deformation of the Conductors which in turn changes EM related properties (fields, and currents).

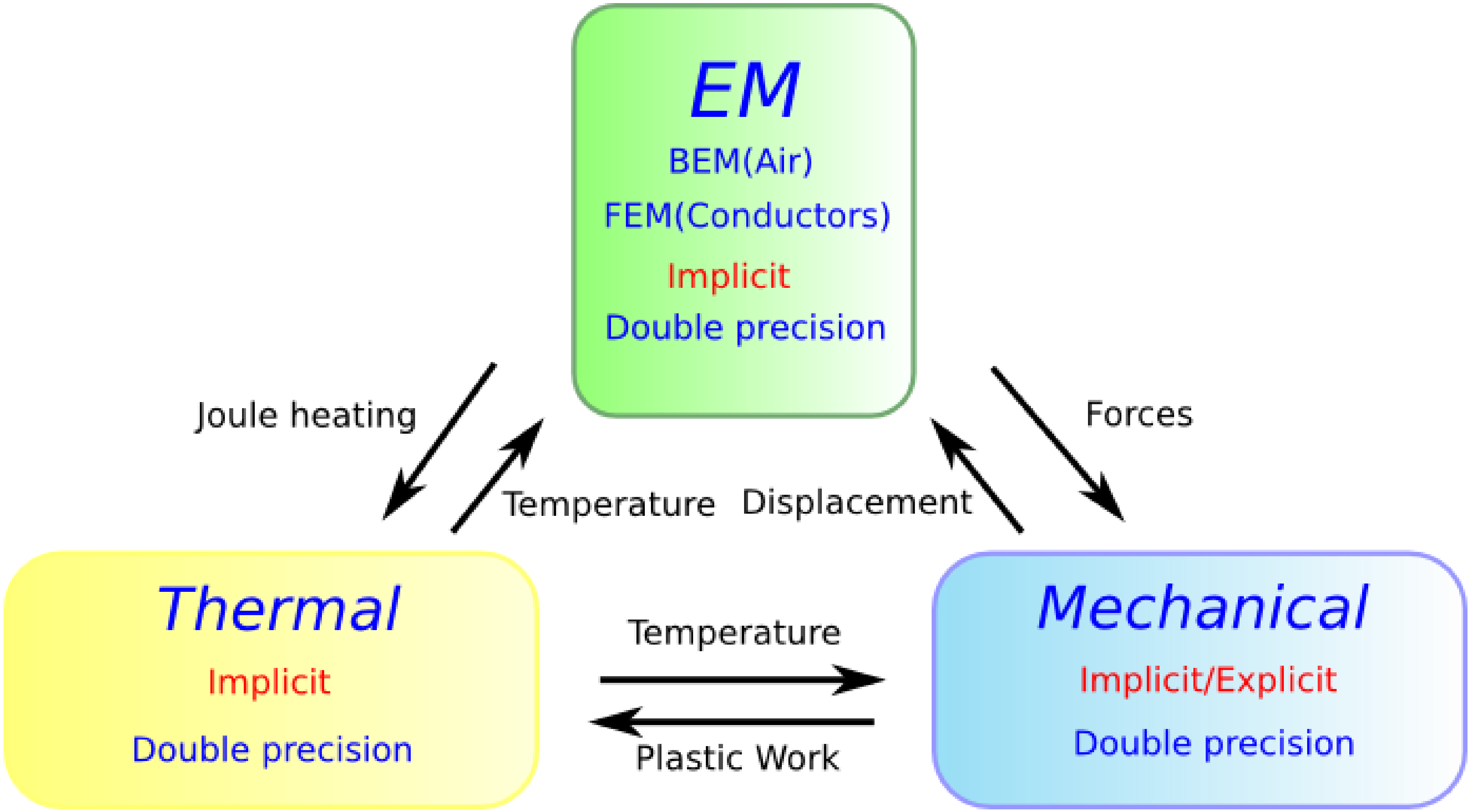
Joule heating

Possible heating which in turn changes EM related material properties (electrical conductivity, …).

Solver Coupling Needed

Coupling with other LS-DYNA Solvers

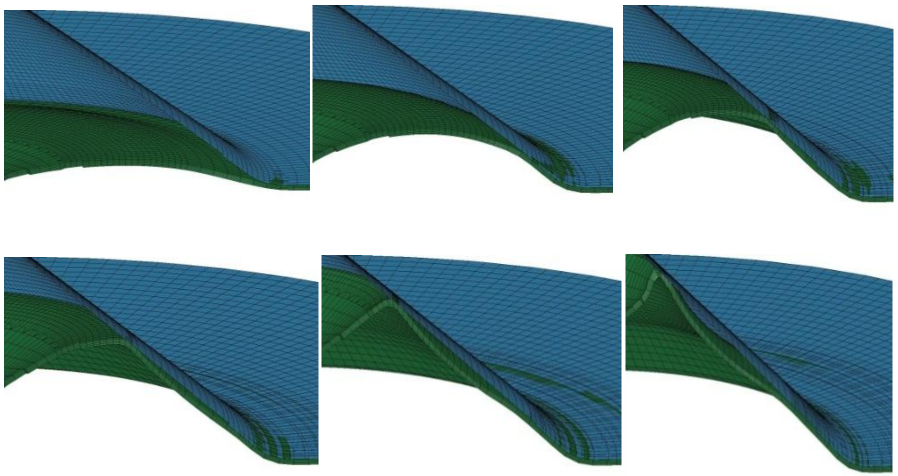
Scope of the new 980 solvers : to be coupled with LS-DYNA solvers in order to solve complex multi-physics problems

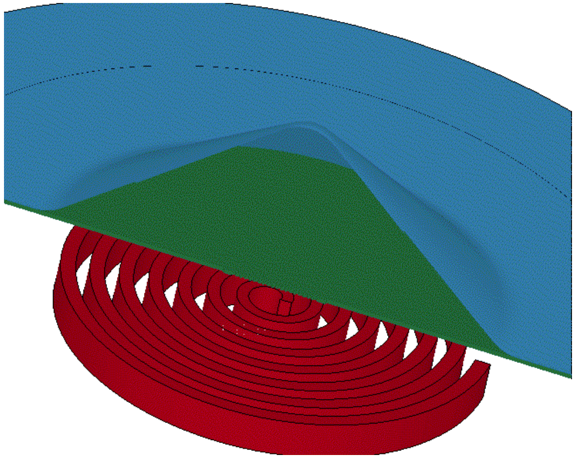


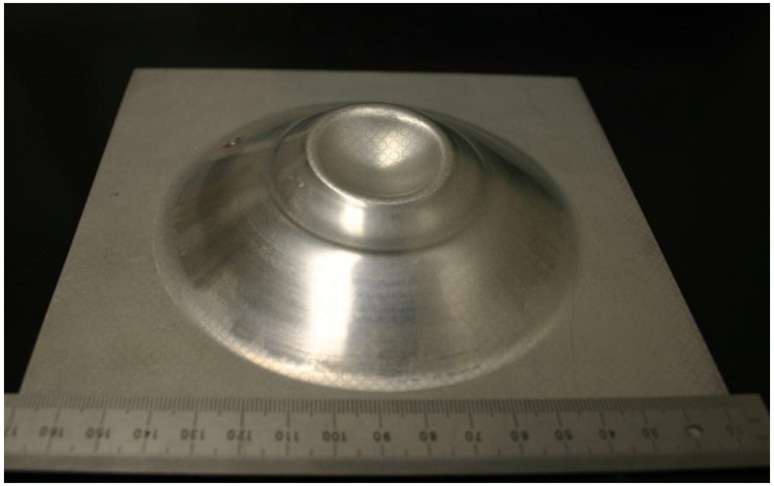
Electromagnetics for Magnetic Metal Forming

Al sheet forming on conical die :
In collaboration with:
M. Worswick and J. Imbert
University of Waterloo, Ontario, Canada

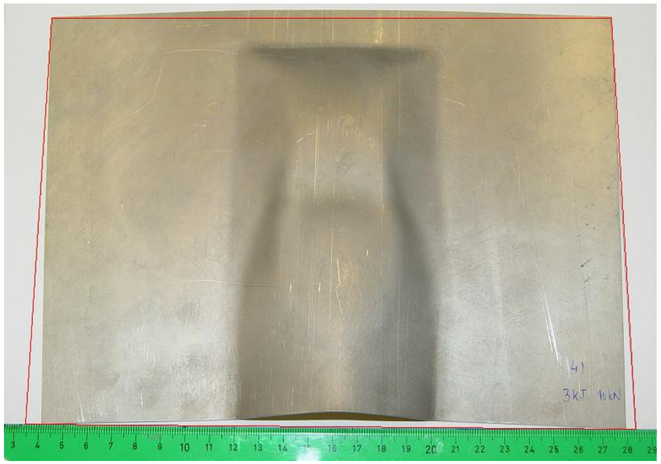
UNIVERSITY OF
WATERLOO

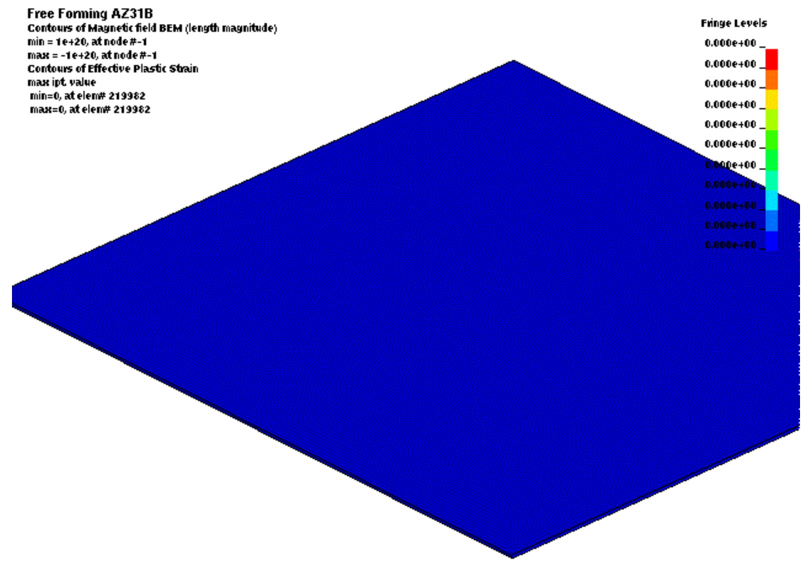




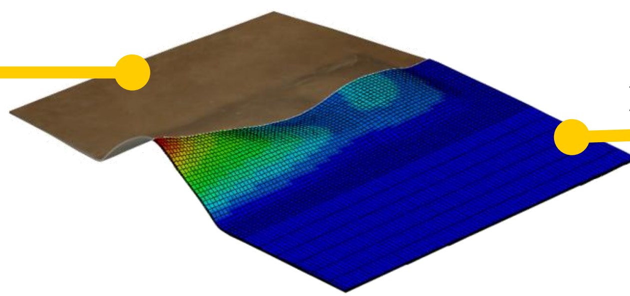


Electromagnetics for Magnetic Metal Forming

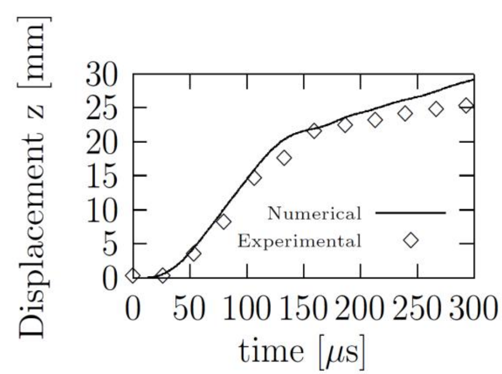




Experimental result



Numerical result

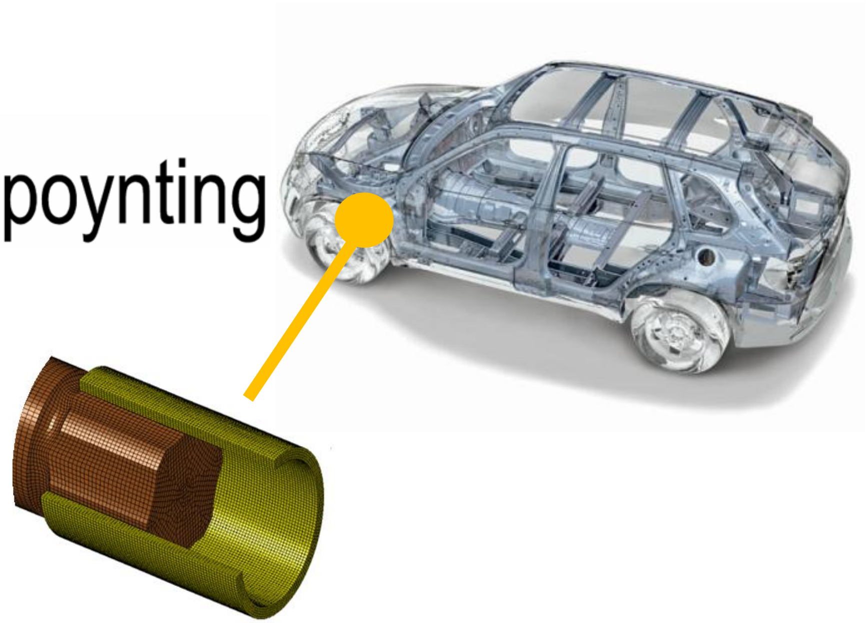


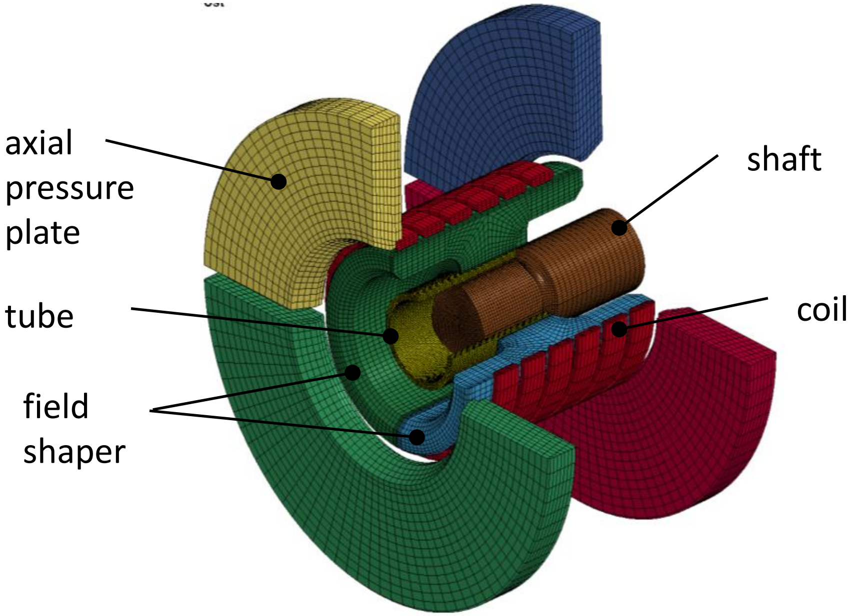
MONDRAGON UNIBERTSITATEA

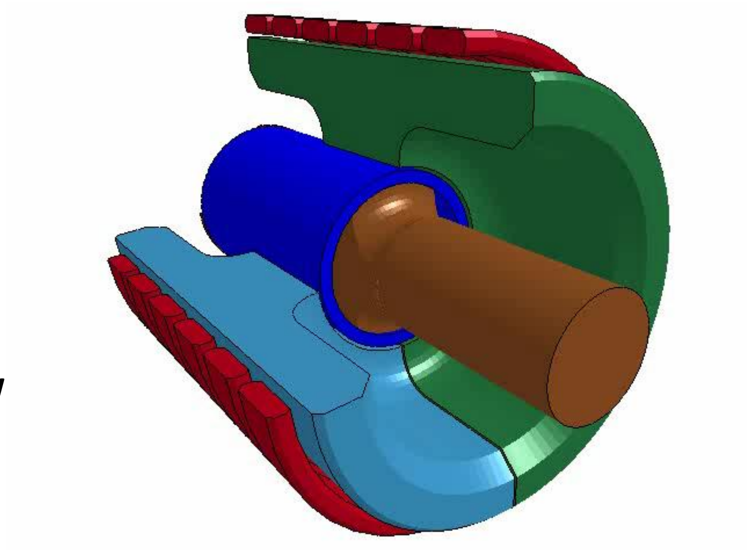
In collaboration with:

Ibai Ulacia , University of Mondragon, Gipuzkoa, Basque country

Electromagnetics for Magnetic Metal Forming







IWU

Simulation of a steel tube-shaft joint for Automotive power train component

In collaboration with:

Fraunhofer Institute for Machine Tools and Forming Technology IW Chemnitz, Dipl.-Ing. Christian Scheffler

Poynting GmbH, Dortmund, Dr.-Ing. Charlotte Beerwald

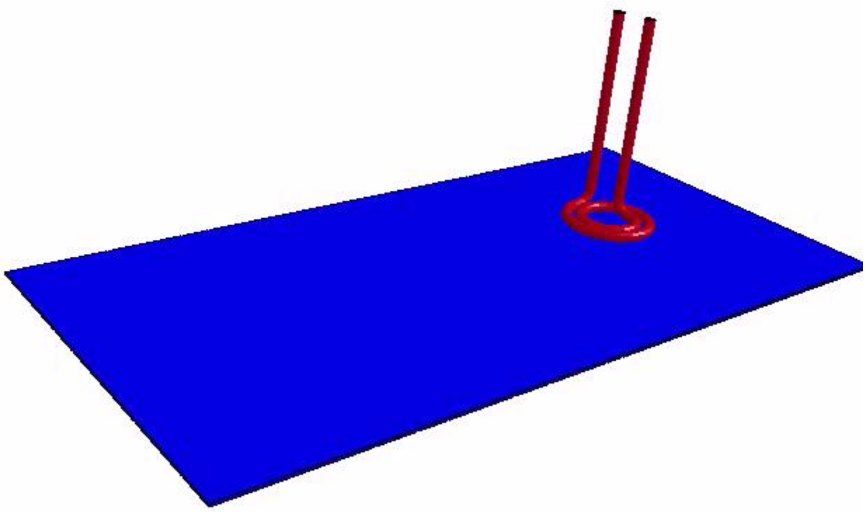
Electromagnetics for Inductive Heating

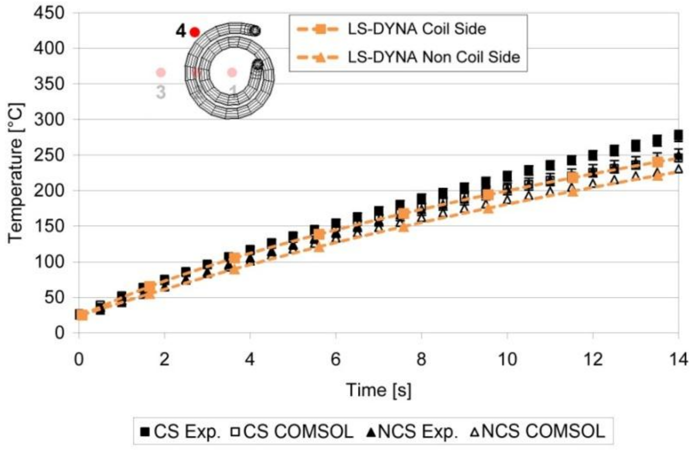
Institut für Verbundwerkstoffe

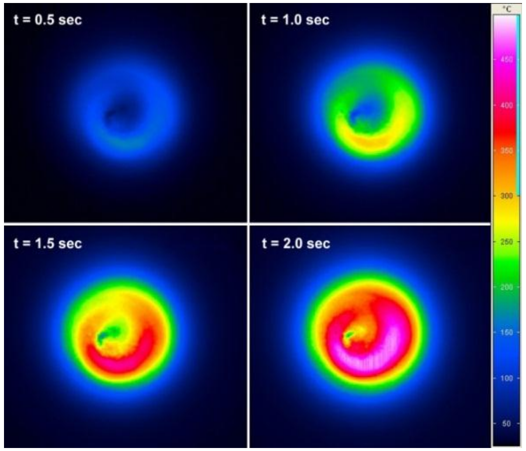
Heating of a steel plate by induction

In collaboration with:

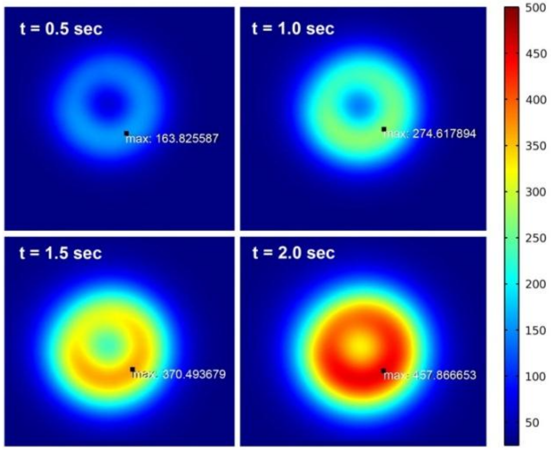
M. Duhovic, Institut für Verbundwerkstoffe, Kaiserslautern, Germany







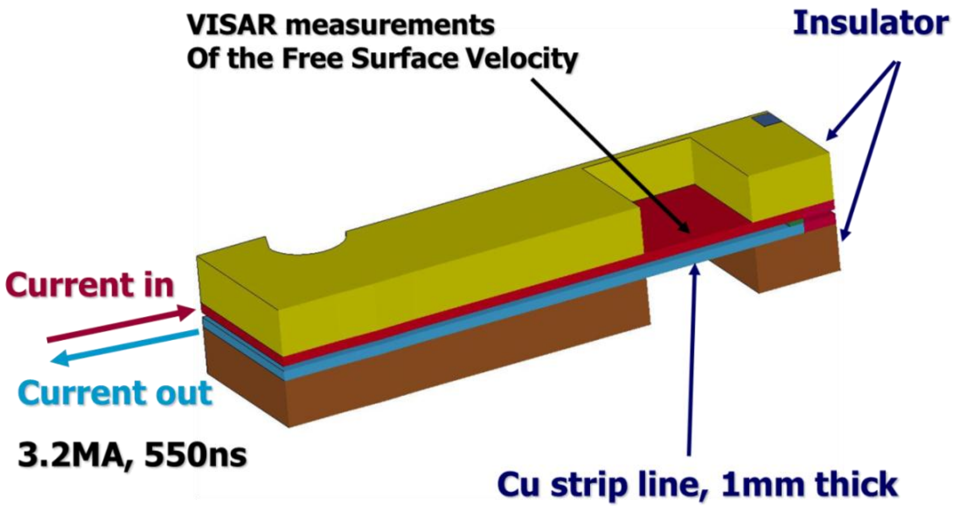
Thermal images from experiment



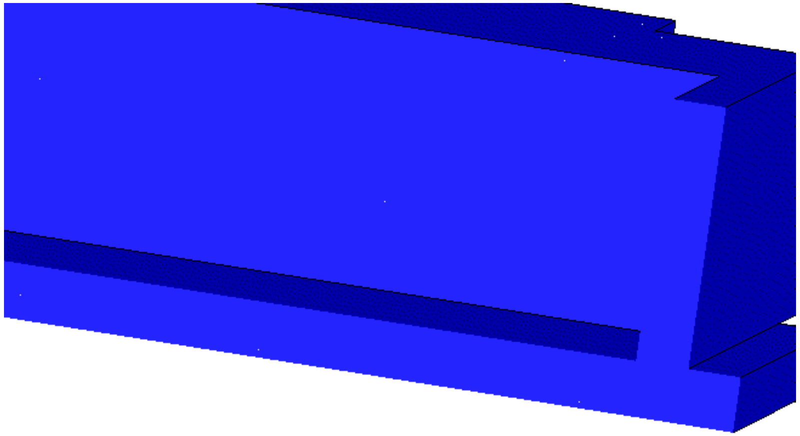
LS-DYNA temperature fringes

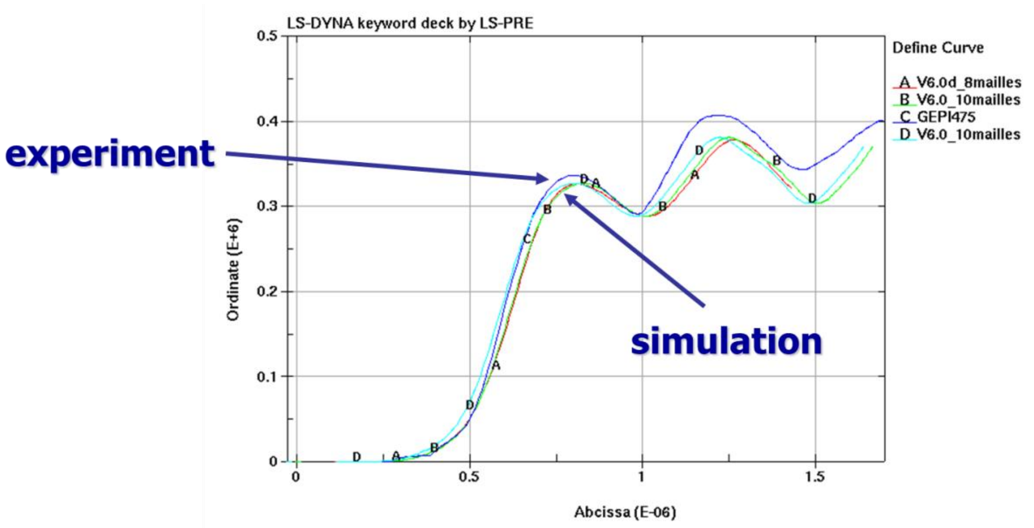
Electromagnetics for High Pressure Generation

G. Le Blanc, **G. Avrillaud**, **P.L.Hereil, P.Y. Chanal**,
Centre D'Etudes de Gramat (CEA), Gramat, France



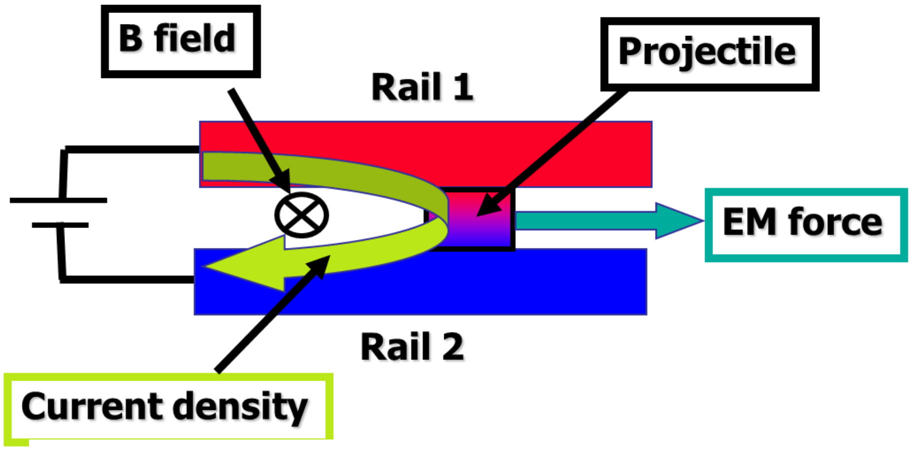
111,000 elements, 10 elements through line thickness

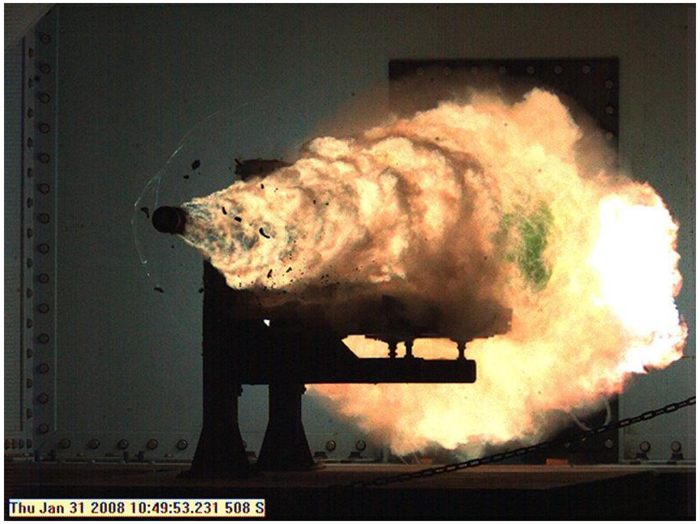


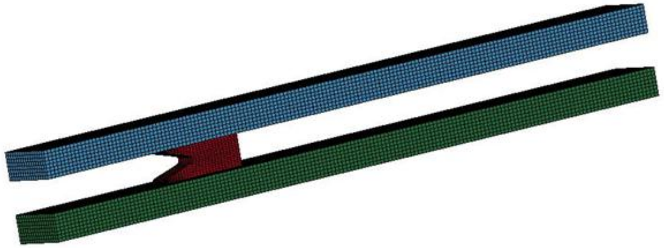


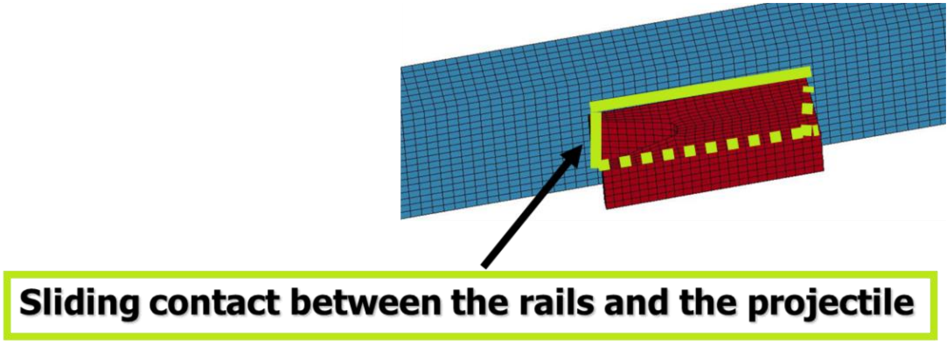
Free surface velocity vs time

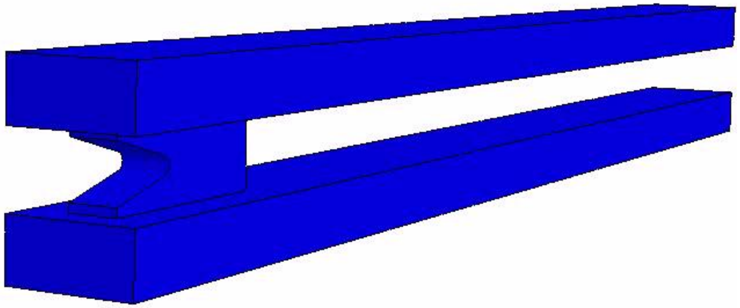
Electromagnetics for Railgun Simulations





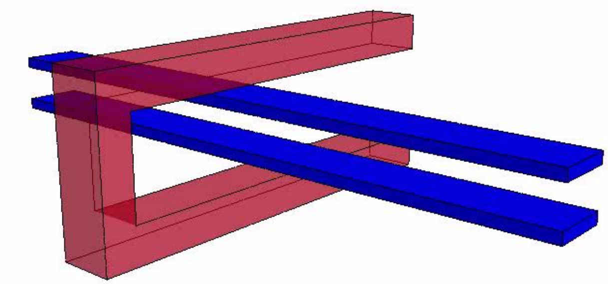




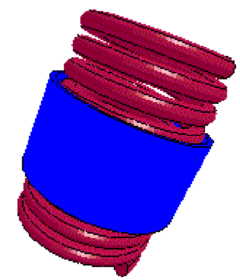


Other Possible Applications

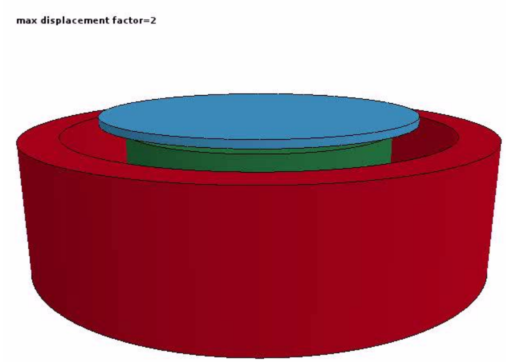
Magnetic Metal Welding in collaboration with
M. Worswick and J. Imbert,
University of Waterloo, Canada



Ring expansions experiments. Various Collaborations
- G. Daehn, Ohio State University.
- H. Kim, Edison Welding Institute, USA.
- D. Chernikov, Samara State Aerospace University, Russia.



And even
Levitating objects
!



Advancement Status

- All EM solvers work on solid elements (hexahedral, tetrahedral, wedges) for conductors.
- Shells can be used for insulator materials.
- Serial and MPP versions available.
- 2D axi-symmetric available.
- The EM fields as well as EM force and Joule heating can be visualized in LS-PREPOST :
    - Fringe components
    - Vector fields
    - Element histories

Plan for Future

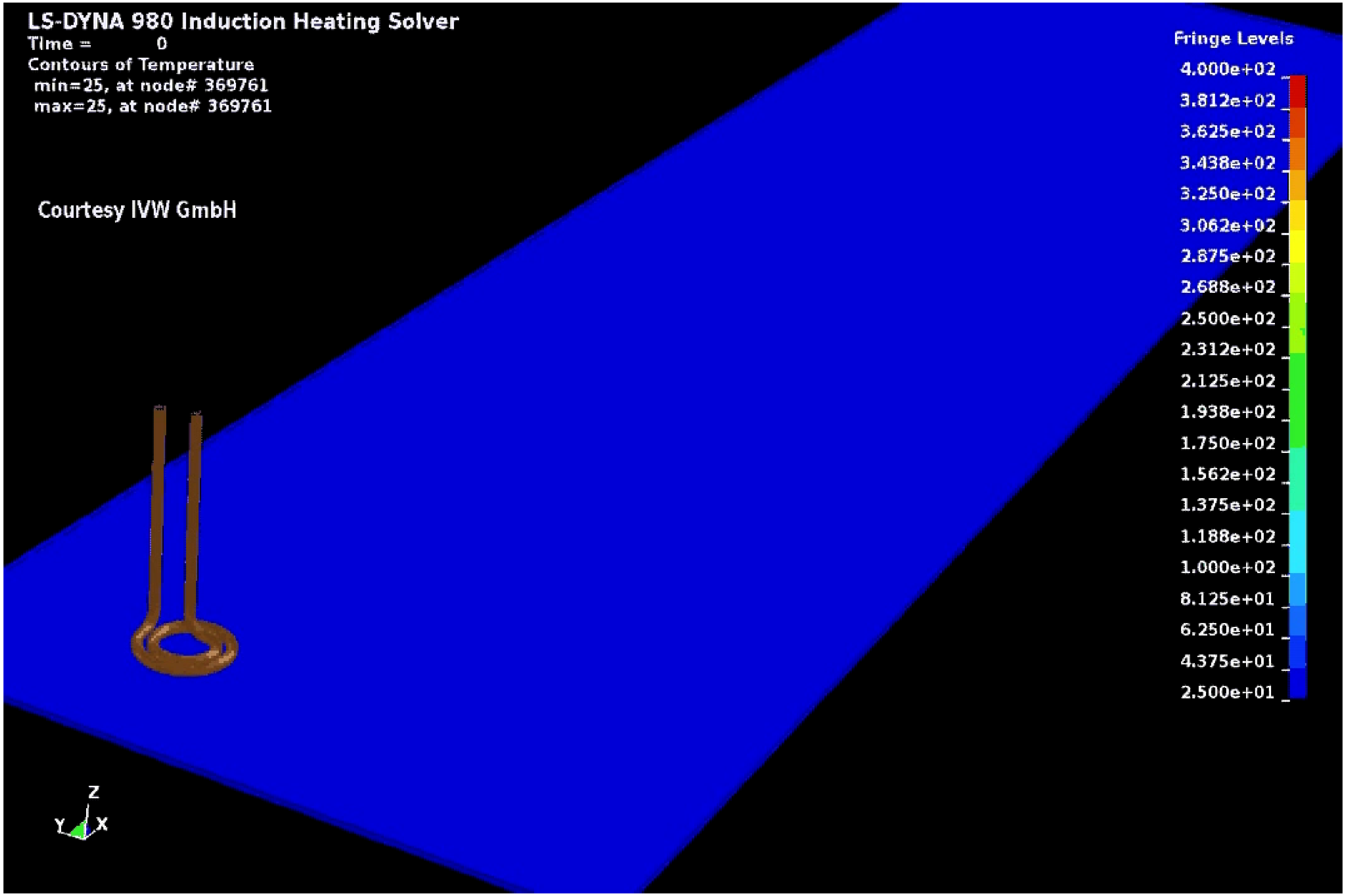
Introduction of Magnetic materials.

Further optimization of the FEM / BEM calculations.

Continue the validation process (T.E.A.M. problems).

Wishes from users. Please let us know !

Thank you for your Attention



Video: courtesy of M. Duhovic, Institut für Verbundwerkstoffe, Kaiserslautern, Germany

SPH, ALE, DEM, Airbag Particle
Dr. Jason Wang

SPH Thermal Solver

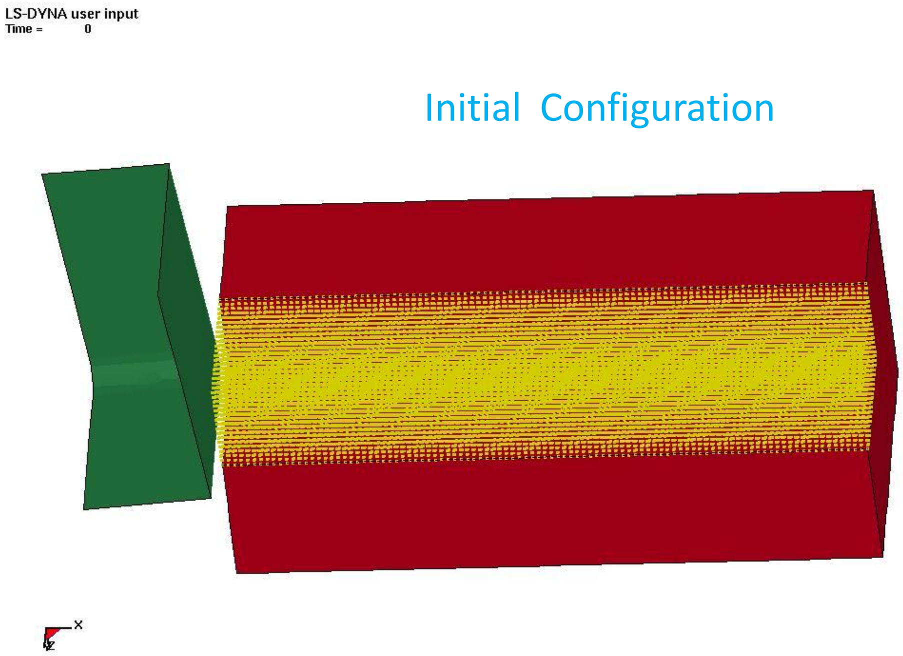
- An explicit thermal conduction solver is implemented for SPH analysis
- Following keywords and materials are supported

*INITIAL_TEMPERATURE_OPTION
*BOUNDARY_TEMPERATURE_OPTION
*BOUNDARY_FLUX_OPTION

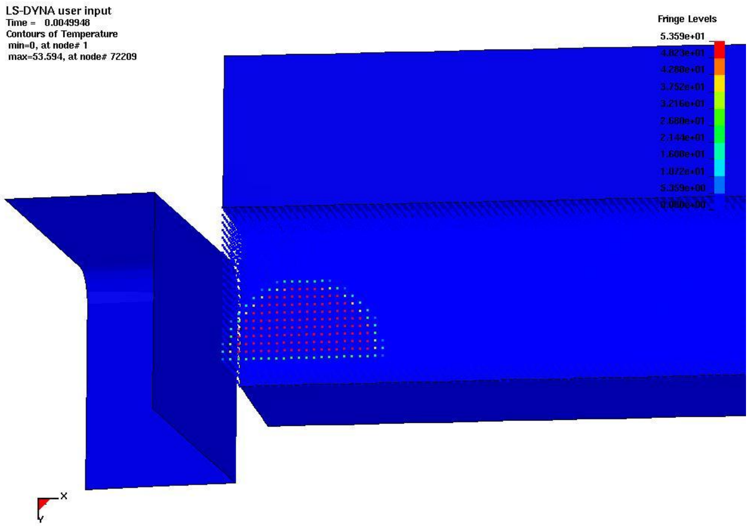
*MAT_THERMAL_ISOTROPIC
*MAT_ADD_THERMAL_EXPANSION
*MAT_VISCOELASTIC_THERMAL
*MAT_ELASTIC_VISCOPLASTIC_THERMAL
*MAT_ELASTIC_PLASTIC_THERMAL

- Thermal coupling with SPH is implemented

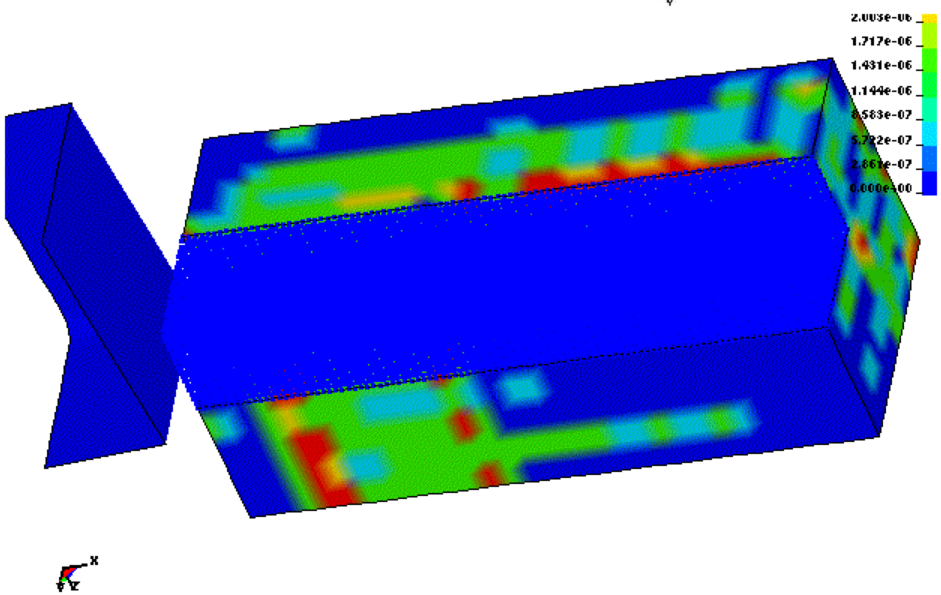
Metal Cutting with Heat



Initial Configuration



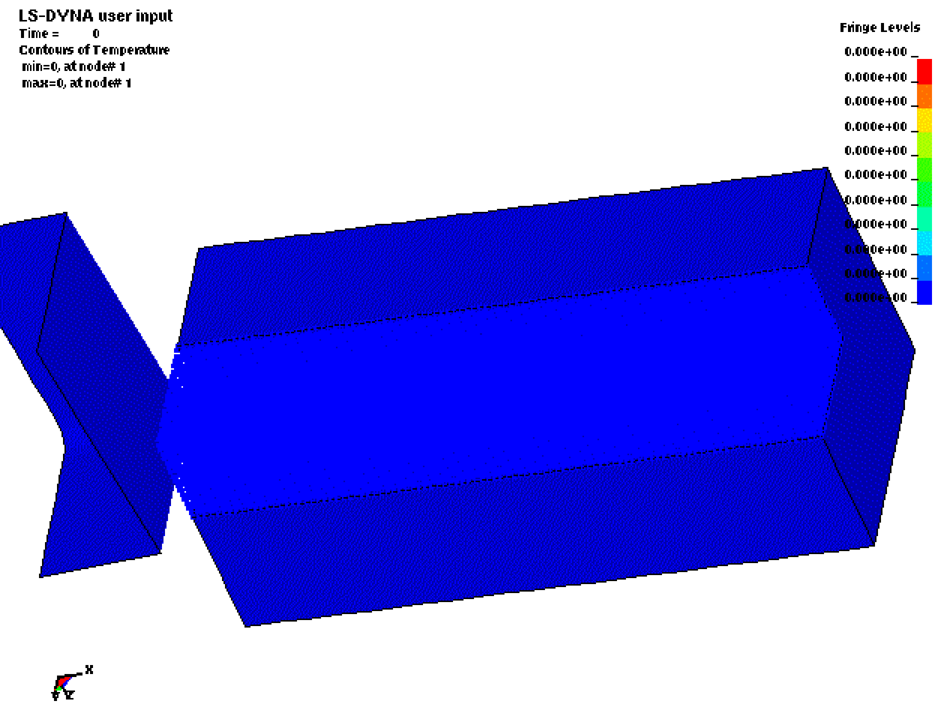
Initial Temperature



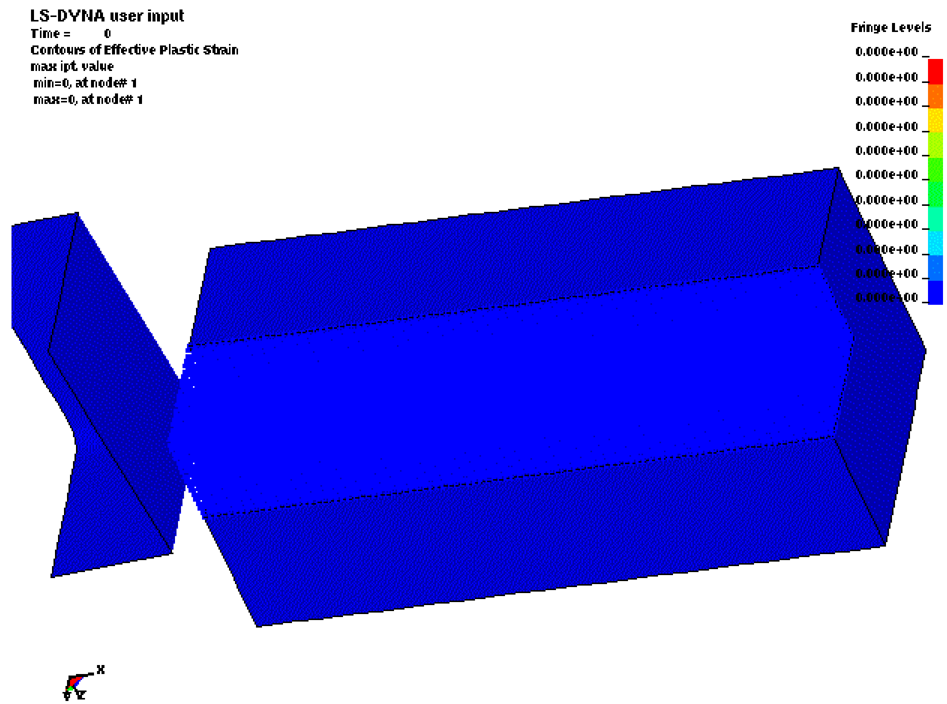
Von-Mises Stress

Metal Cutting with Heat

Heat source: *BOUNDARY_FLUX
*MAT_JOHNSON_COOK (stress flow depends on the temperature)



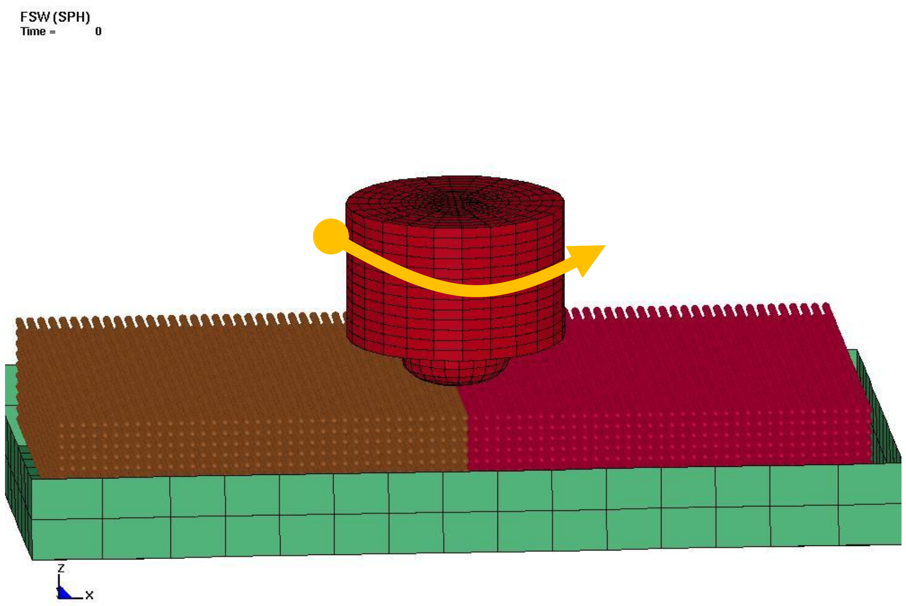
Temperature



Plastic Strain

Friction Stir Welding with SPH

Courtesy of Kirk A Frazer at ROCHE



Rigid body tools

Johnson cook Material with Viscoplasticity

Heat Capacity = 875, Thermal Conductivity = 175

EQHEAT = 1.0, FWORK=1.0 for heat source

ADD_THERMAL_EXPANSION for work-pieces

Friction Stir Welding with SPH

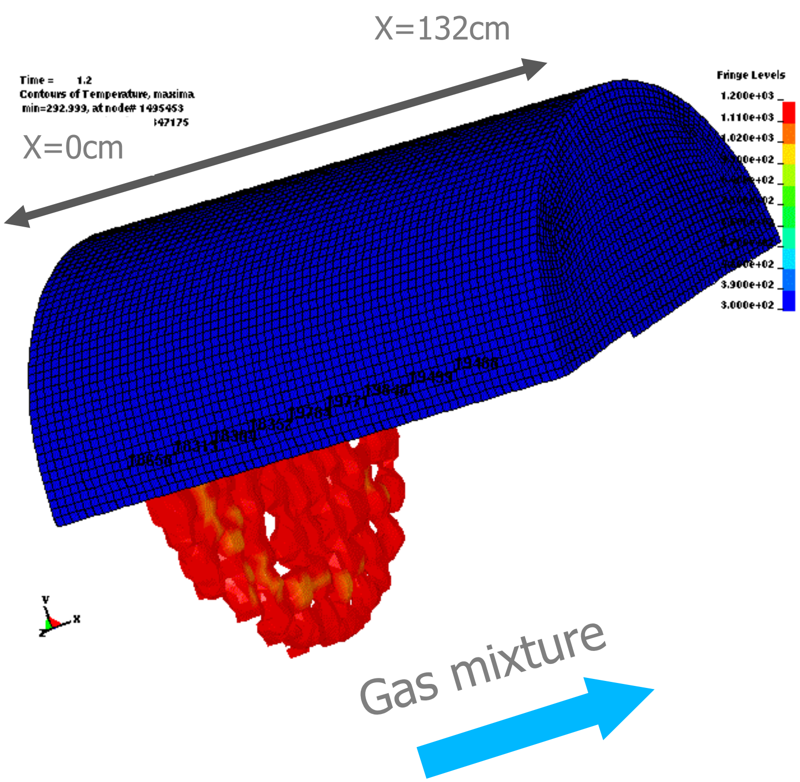
Courtesy of Kirk A. Fraser at ROCHE

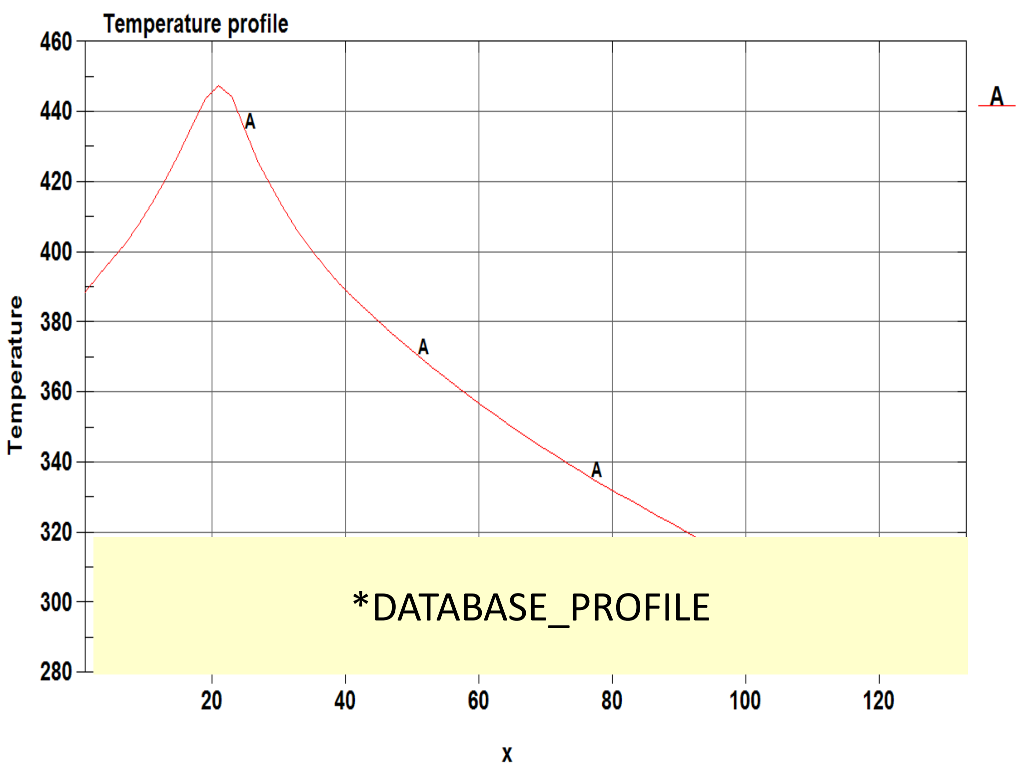
Deformation

Temperature

ALE and Thermal Coupling

ALE *MAT_GAS_MIXTURE coupled with shell structure using
*CONSTRAINED_LAGRANGE_IN_SOLID



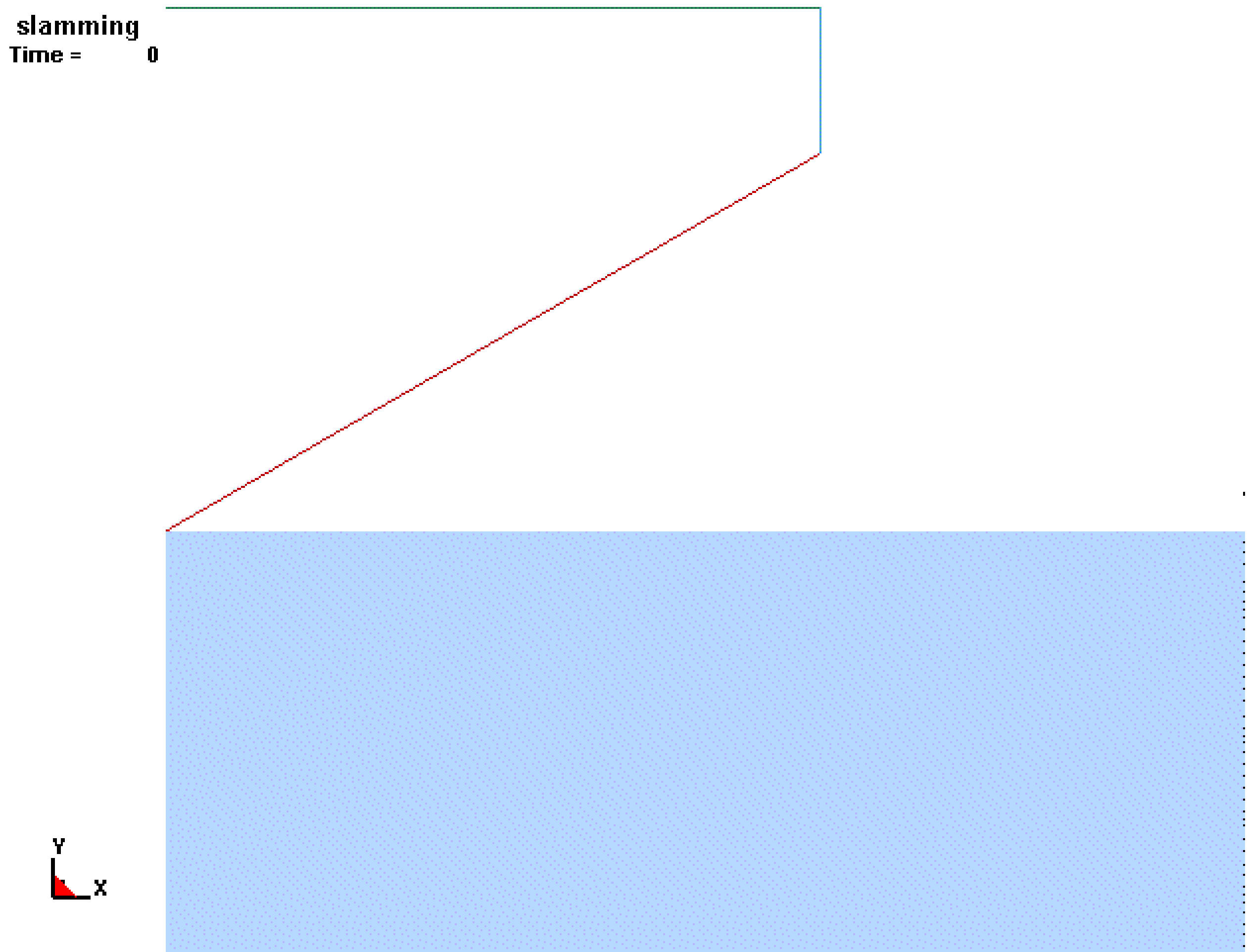


Energy is removed from gas and deposited to shell via heat convection
The energy is used as source term for thermal analysis

ALE Dynamic Adaptive

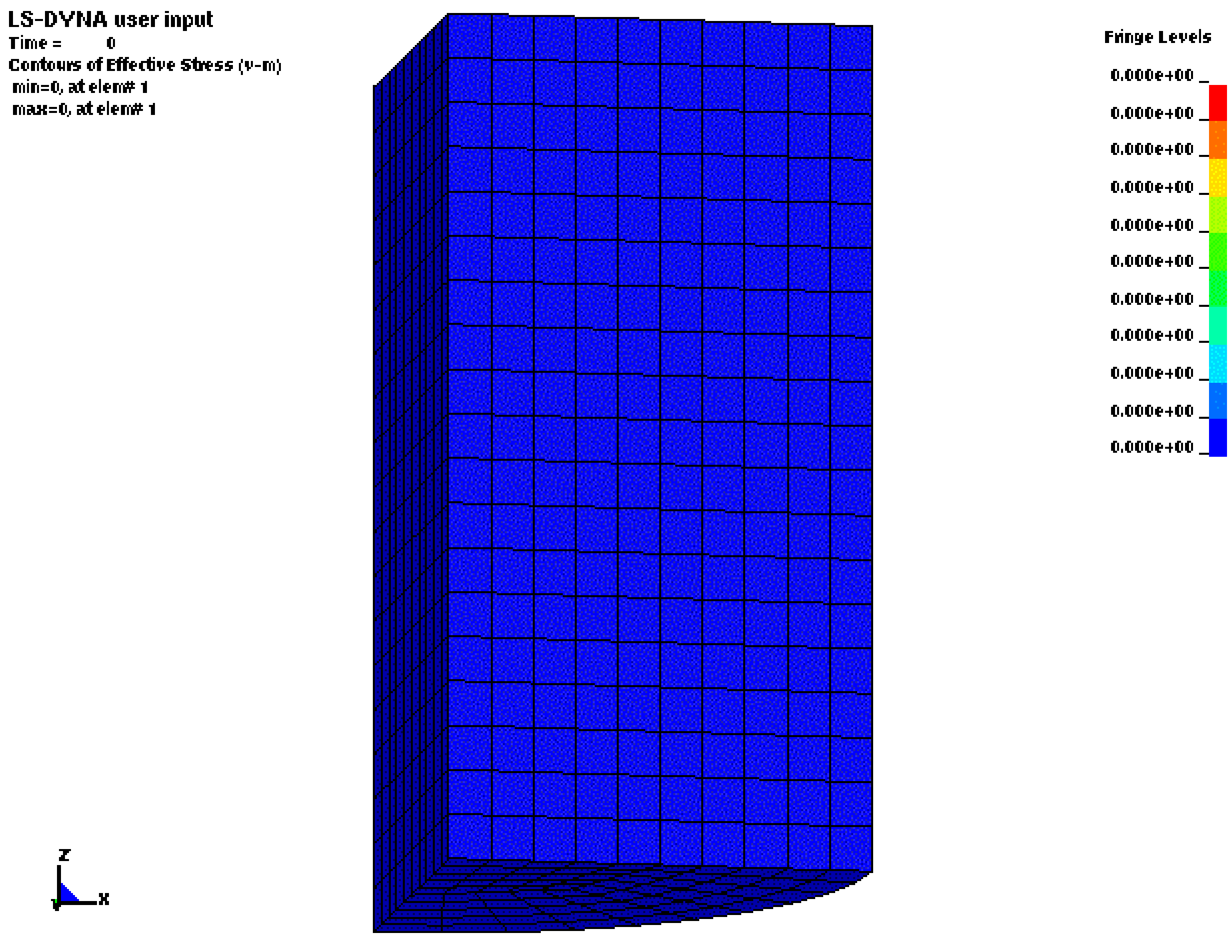
*REFINE_ALE

slamrfn.layrf3.avi



Dynamic Adaptive FEM Solid Mesh

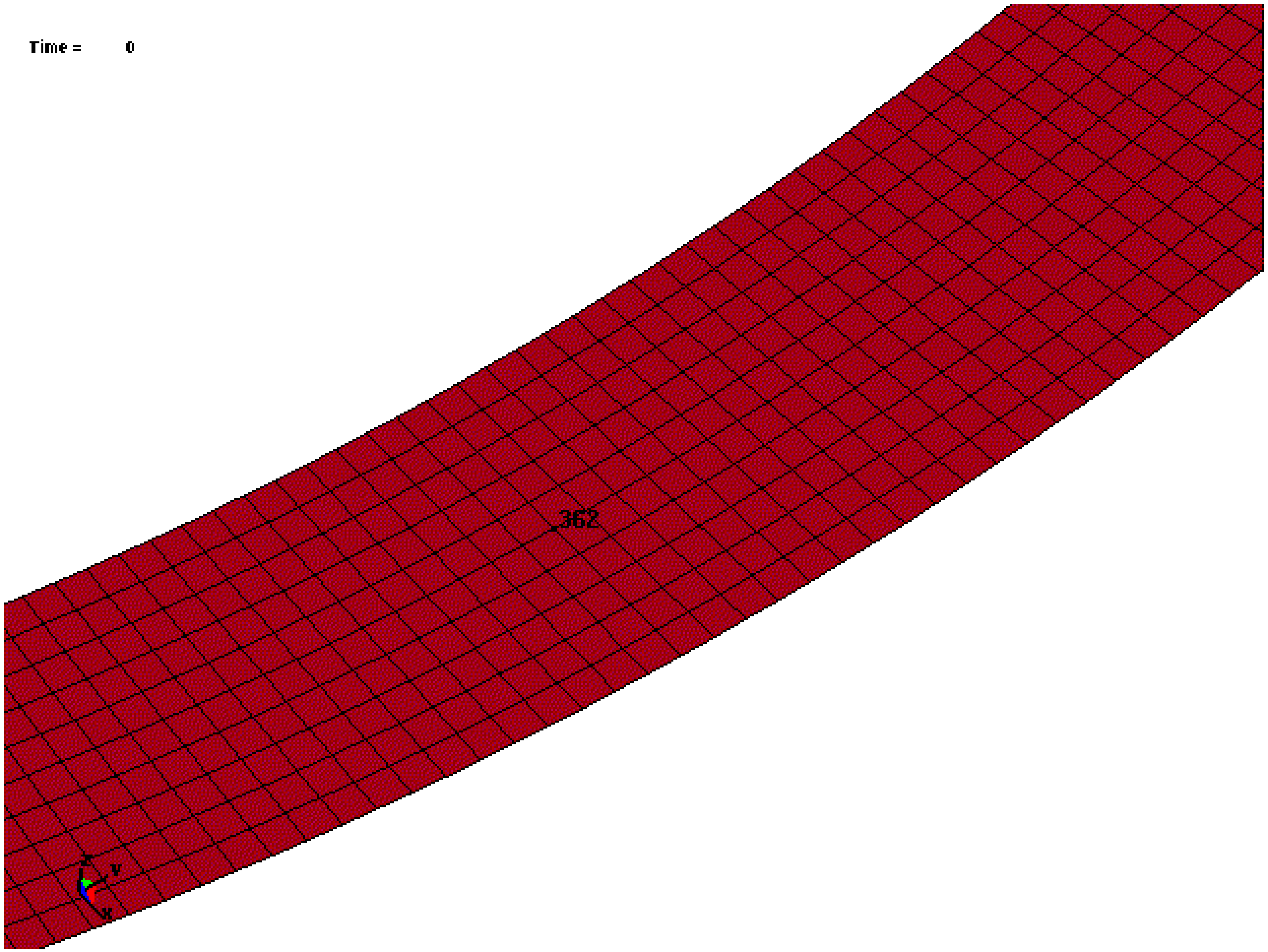
*REFINE_SOLID



sldrfn.taylor.avi

Dynamic Adaptive FEM Shell Mesh

*REFINE_SHELL



Particle based Blast Loading

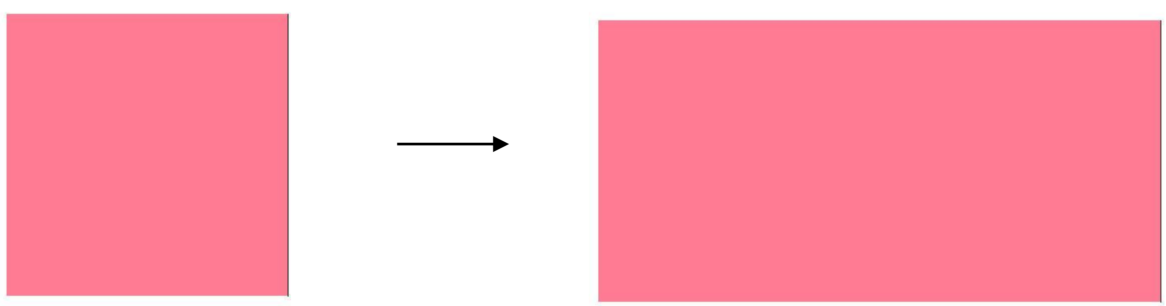
Real Gas Model of High Explosive Particle

- Air Particle
  - Modeled by ideal gas law: $pV=nRT$
  - The volume of molecules is neglected
  - Works for low pressure and moderate temperature
- High Explosive Particles
  - Modeled by real gases: $p(V-b)=nRT$
  - The co-volume effect is included
  - Works for high pressure and high temperature
  - Pressure drops sharply during adiabatic expansion

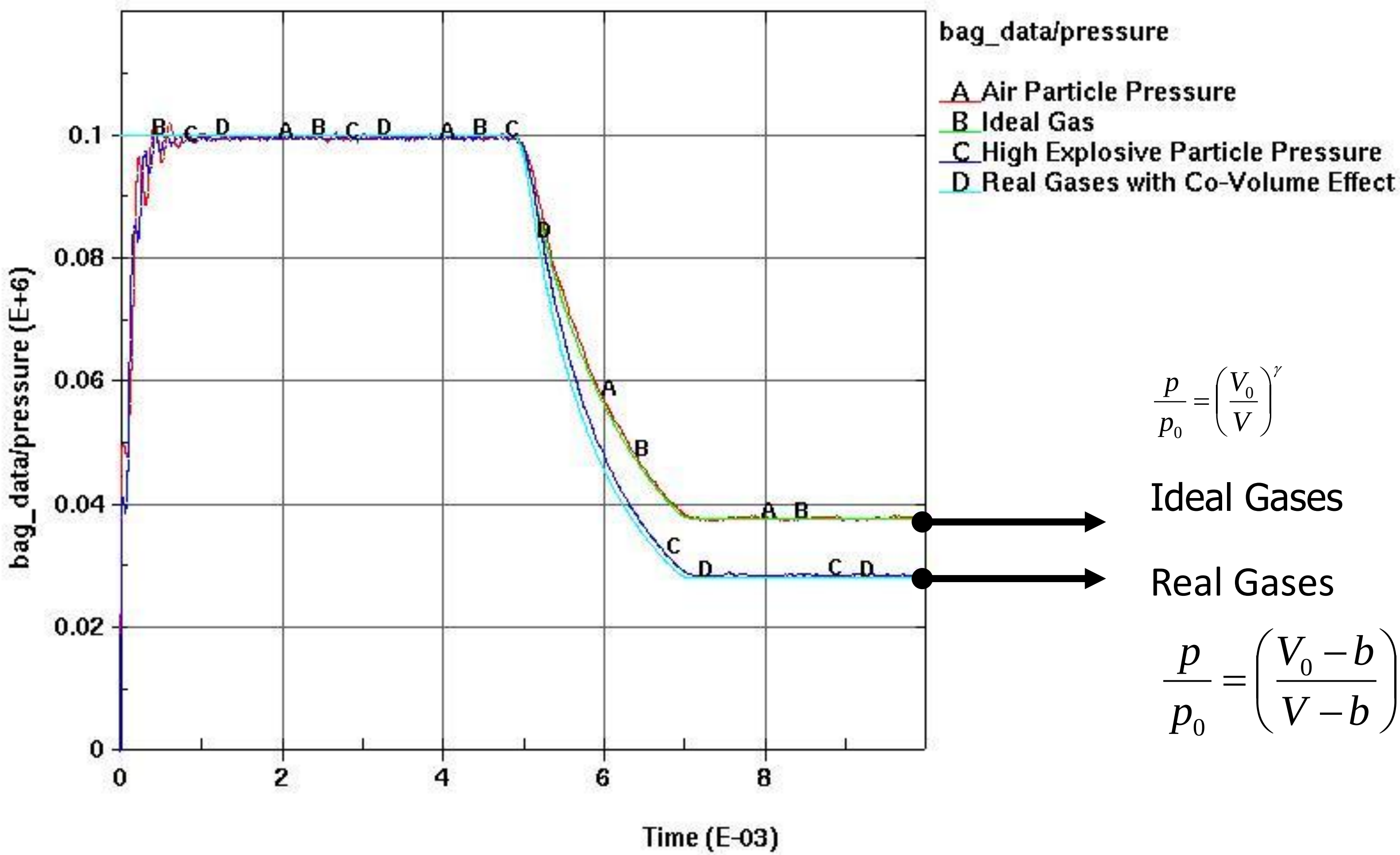
Adiabatic Expansion

- An 8 liter box filled up with air particles, the box is expanded to 16 liter
- Ratio of heat capacities $\gamma = 1.4$
- The same procedure is repeated with high explosive particles with

$$b = 0.32V_0$$



Adiabatic Expansion



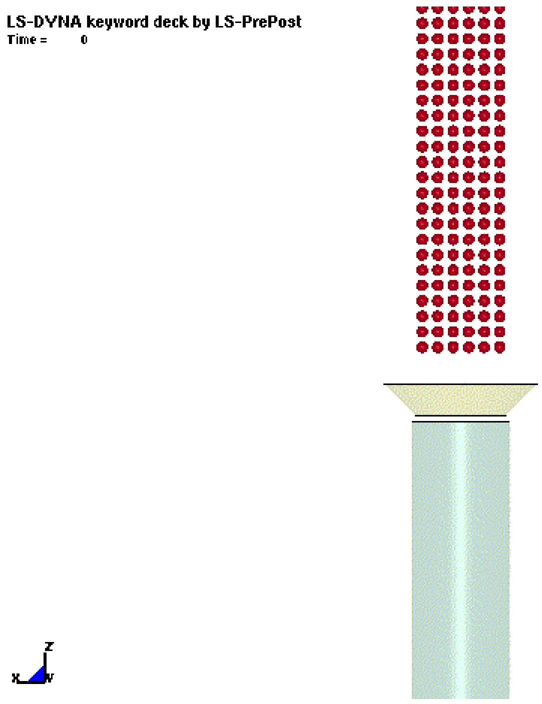
$$\frac{p}{p_0} = \left(\frac{V_0}{V}\right)^{\gamma}$$

Ideal Gases

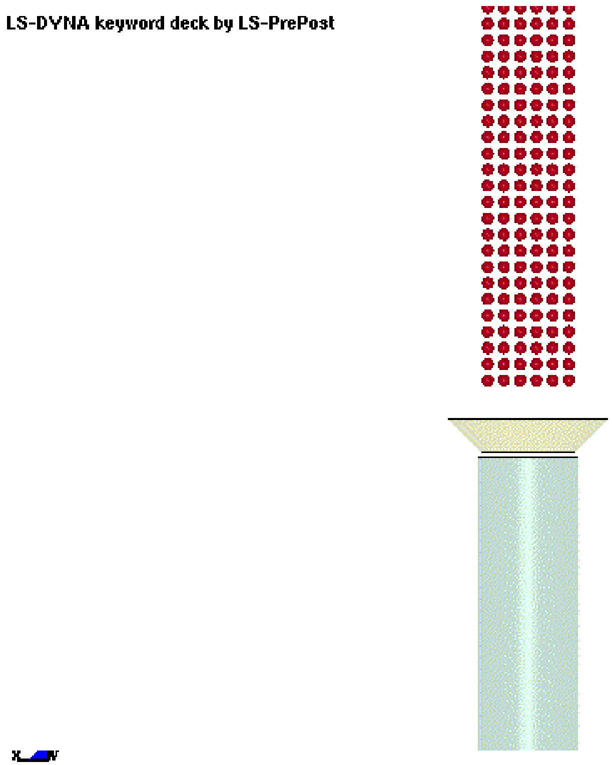
Real Gases

$$\frac{p}{p_0} = \left(\frac{V_0 - b}{V - b}\right)^{\gamma}$$

Discrete Element Sphere (DES)



Dry

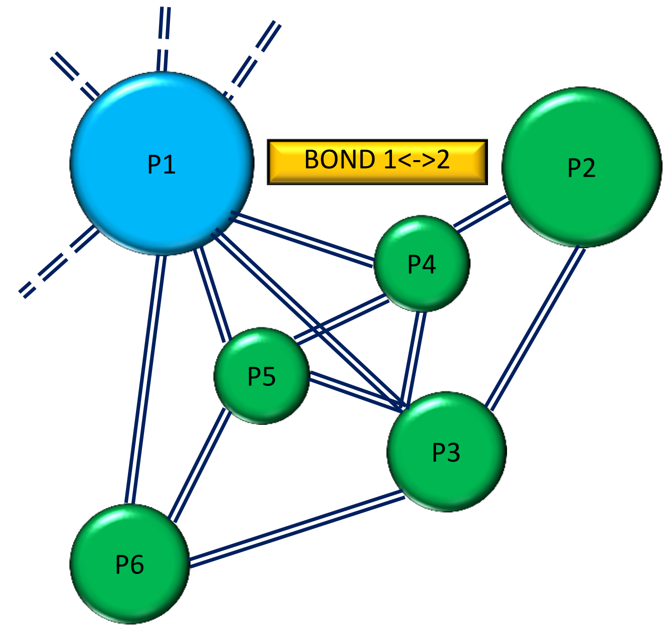


Wet

LSTC DES Bond Model

Emerge into Continuum Mechanics

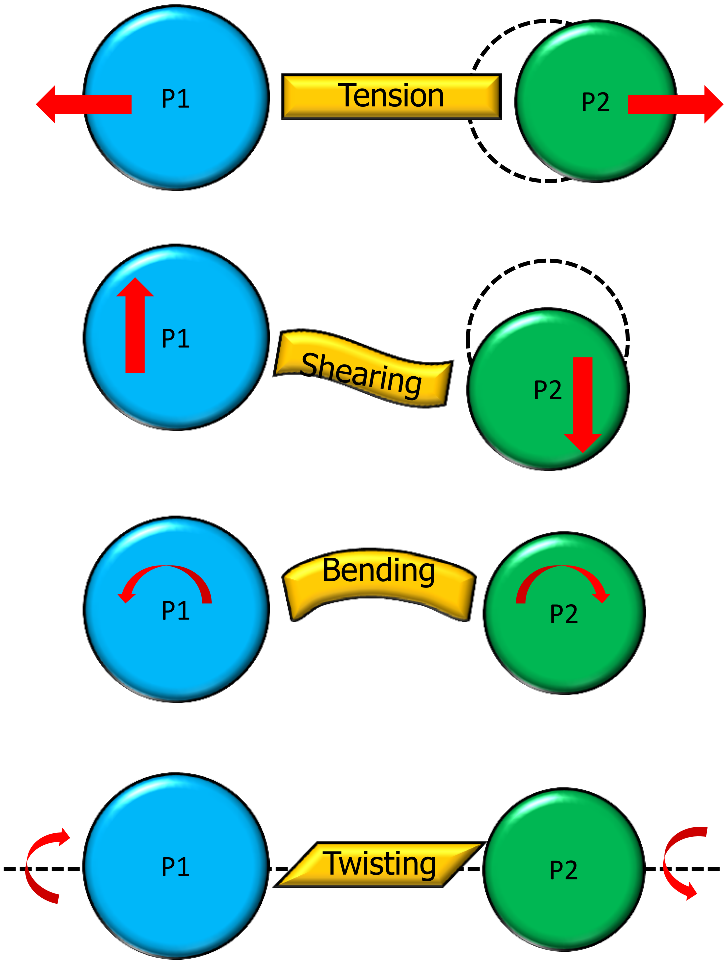
- All particles are linked to their neighboring particles through Bonds.
- The properties of the bonds represent the complete mechanical behavior of Solid Mechanics.
- The bonds are independent from the DES model.
- They are calculated from Bulk Modulus and Shear Modulus of materials.



Mechanical Behaviors

LSTC Bond Model

- Every bond is subjected to:
  - *Stretching*
  - *Shearing*
  - *Bending*
  - *Twisting*
- The breakage of a bond results in Micro-Damage which is controlled by the critical fracture energy value J_{IC}.

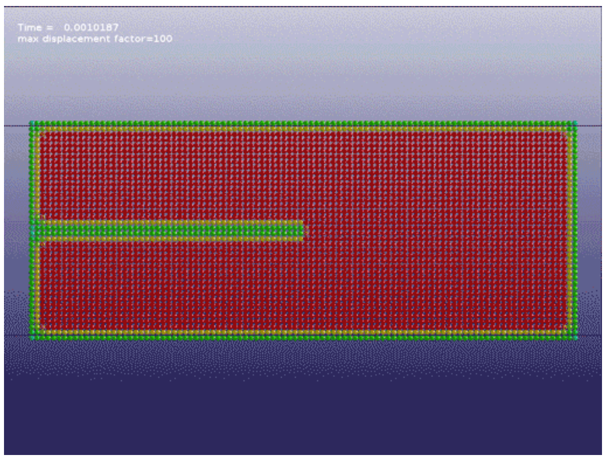


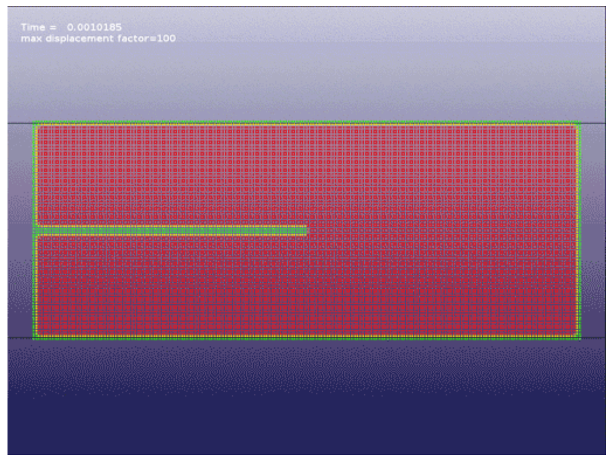
Fracture Analysis

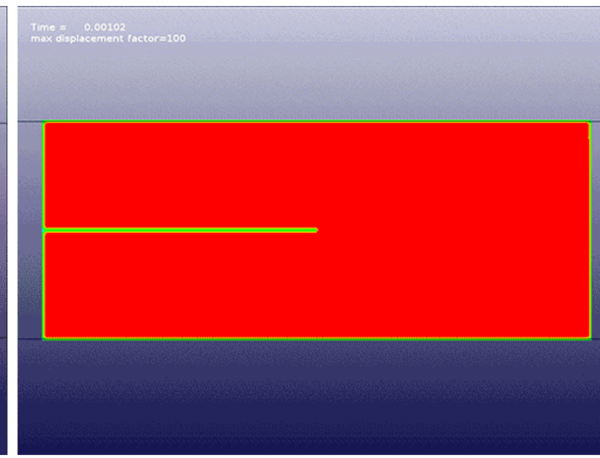
Pre-notched plate under tension

Quasi-static Loading | Material: Duran 50 Glass | Density: 2235kg/m^3

Young's Modulus: 65GPa | Poisson Ratio: 0.2 | Fracture Energy Release Rate: 204 J/m^2



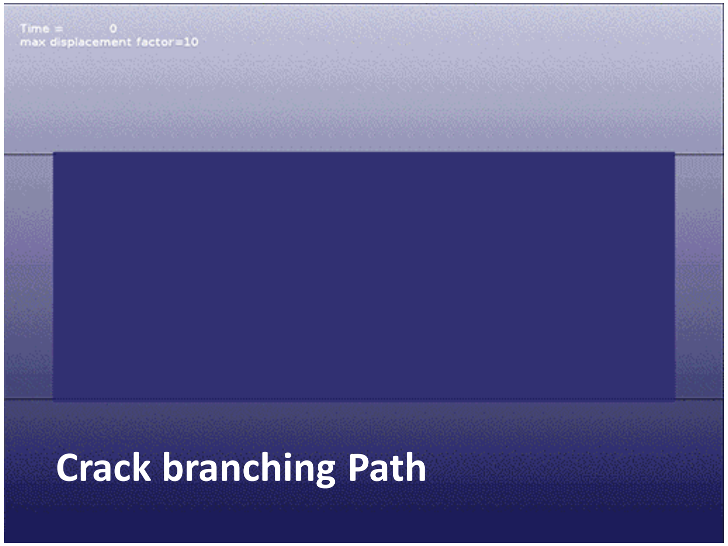


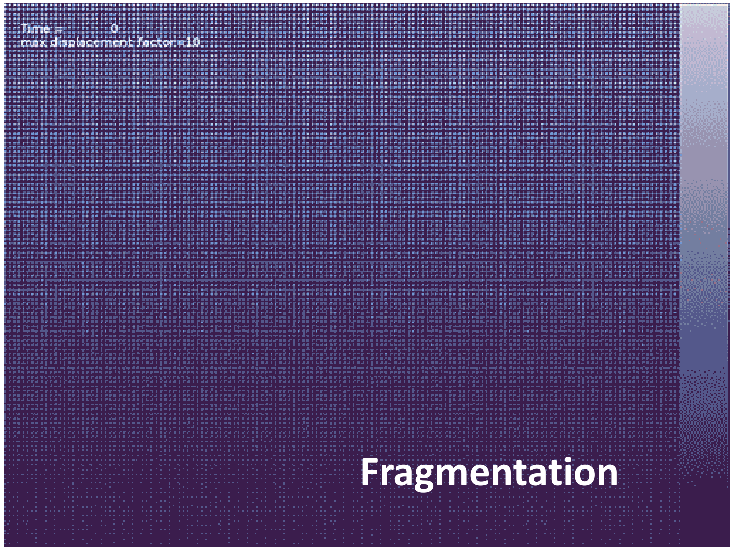


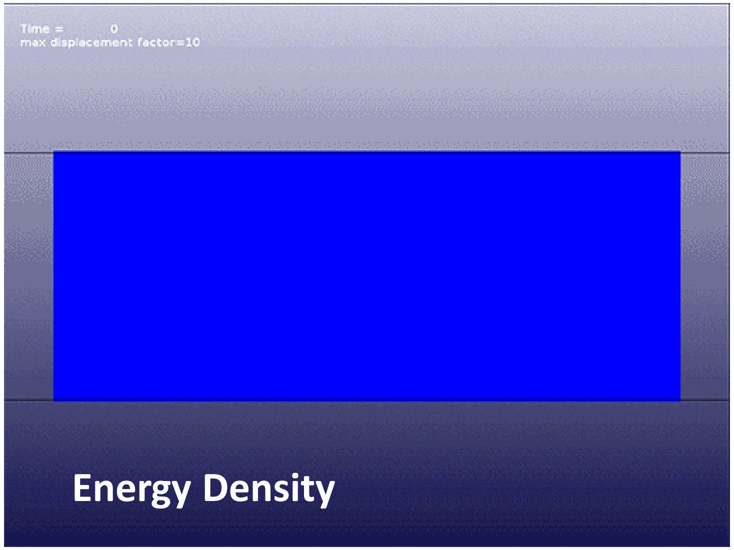
	Case 1:	Case 2:	Case 3:
Sphere Radius:	0.5 mm	0.25 mm	0.125 mm
N. of spheres:	4000	16000	64000
Crk Growth Spd:	2012 m/s	2058 m/s	2028 m/s
Fracture Energy:	10.2 mJ	10.7 mJ	11.1 mJ

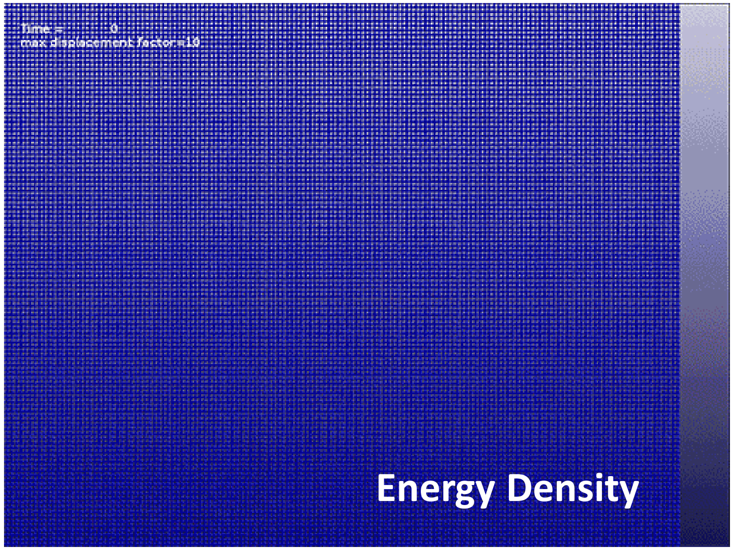
Fragmentation Analysis

Dynamic Loading









LS-DYNA Multi-Physics Solvers

	ALE	SPH	DES	PGas
ALE		▲	▲	
SPH			■	
DES				●
Pgas				

△ *ALE_COUPLING_NODAL

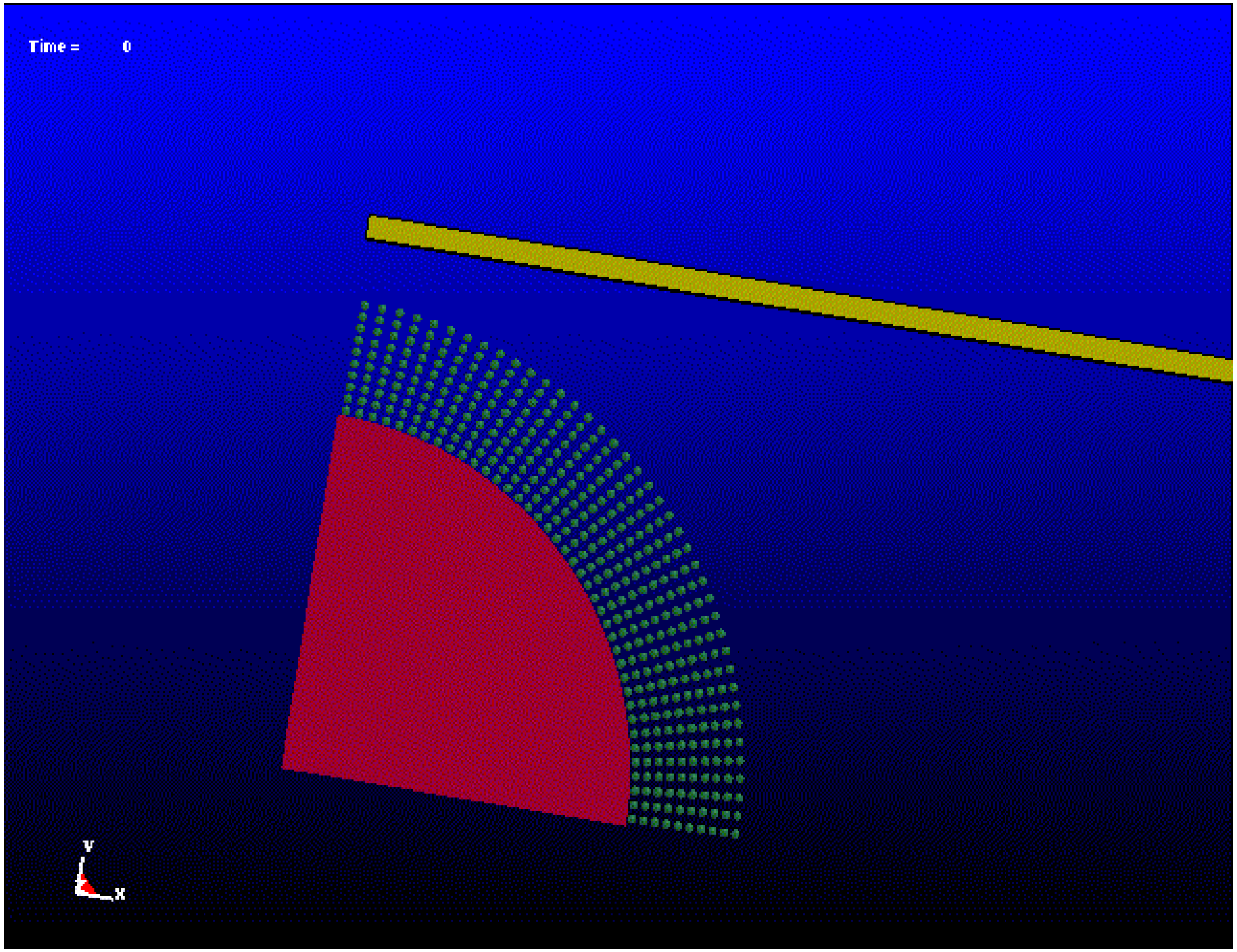
□ *DEFINE_SPH_TO_SPH_COUPLING

○ *PARTICLE_BLAST

● testing ● developing

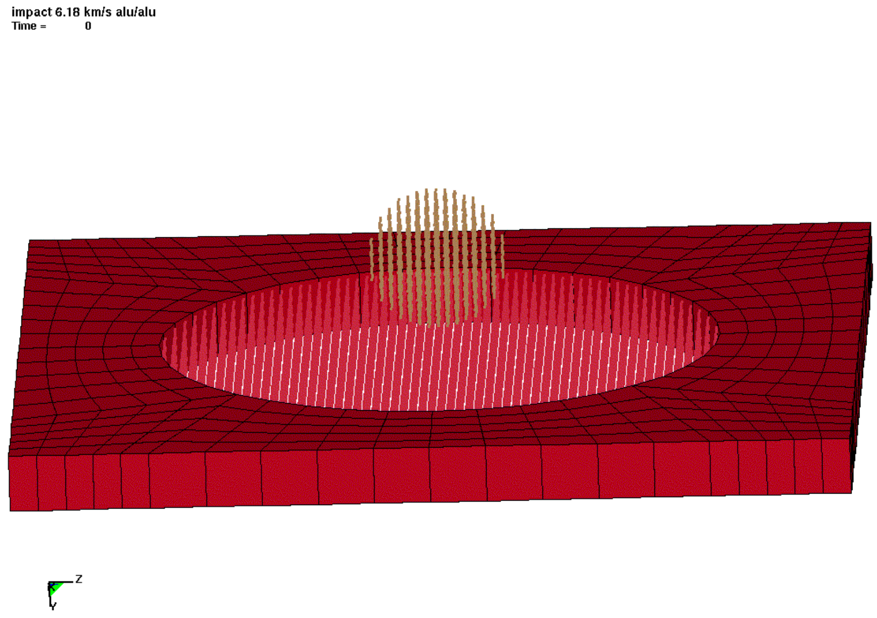
*ALE_COUPLING_NODAL

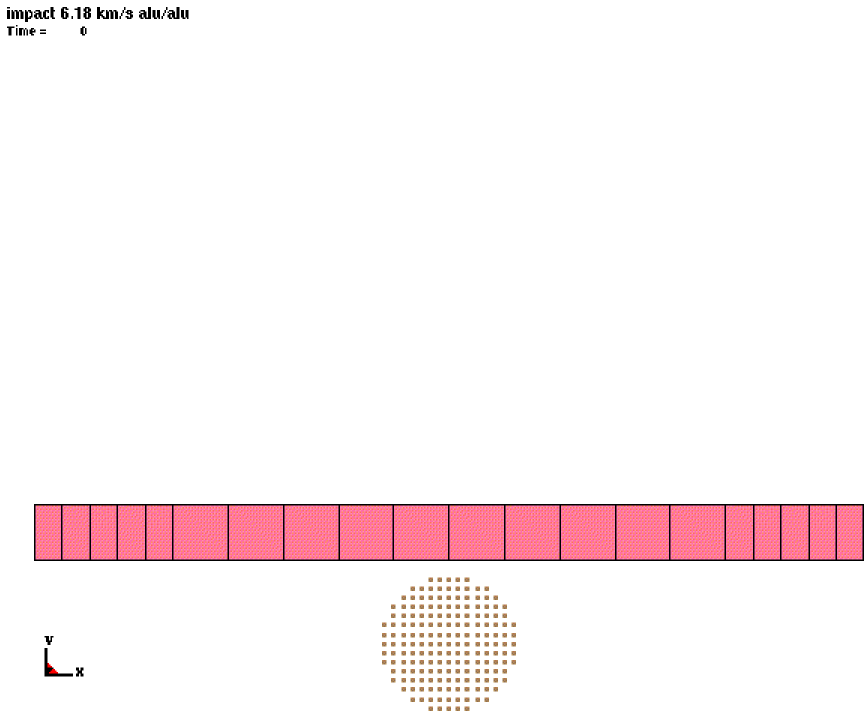
A simple test case modeling explosion driven sand grains hitting on a plate



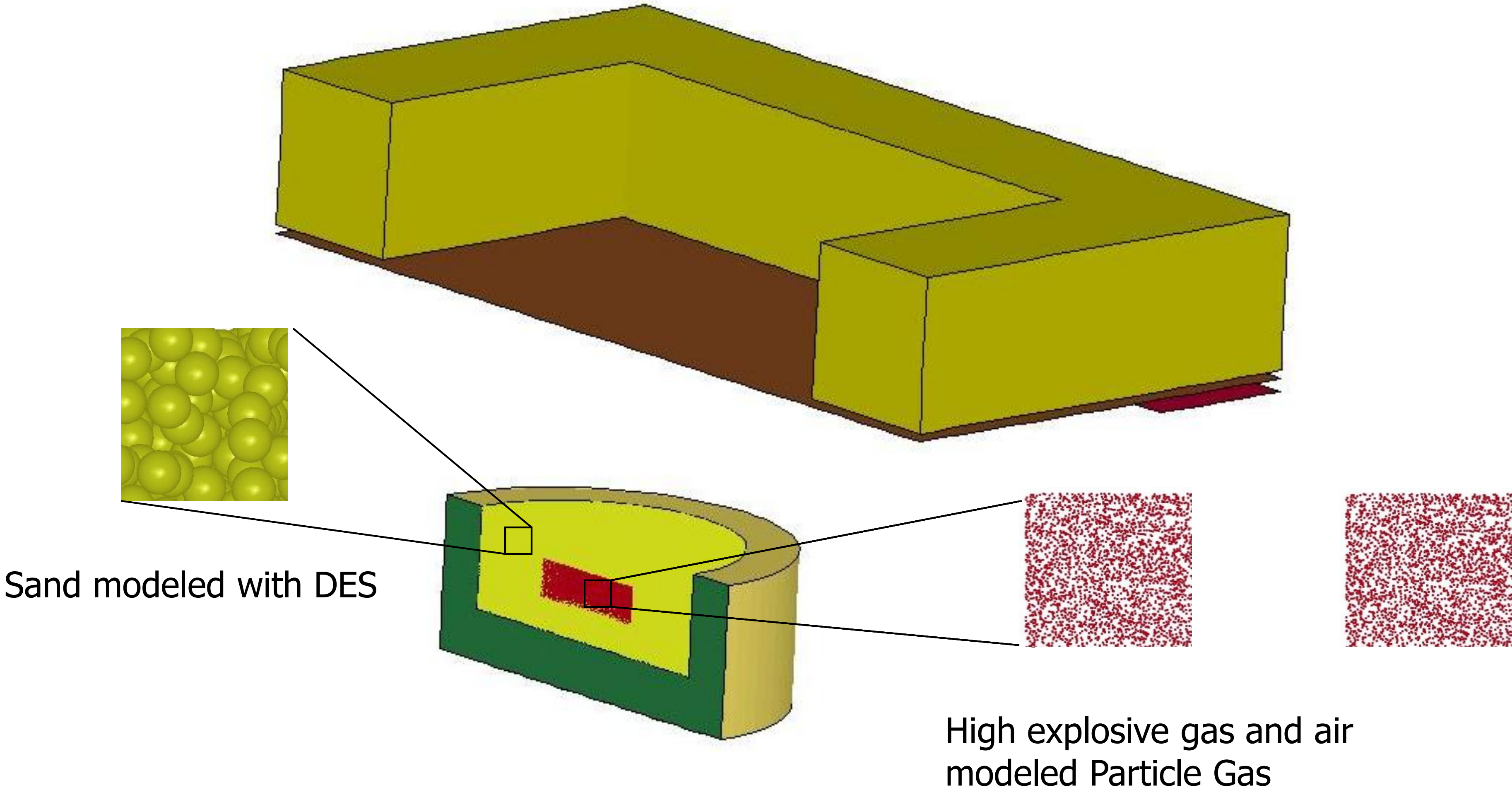
*DEFINE_SPH_TO_SPH_COUPLING

- Penalty based SPH to SPH particle contact
- Will be extended to SPH and DES coupling





*PARTICLE_BLAST



*PARTICLE_BLAST

Blast simulation with sand

Blast simulation without sand

Thank You !

Summary

- LSTC is working to be the leader in scalable, low cost, large scale, multi-physics simulations, leading to solutions to a variety of problems with a single universal numerical model. To make this possible:
  - LS-PrePost, LS-Opt, and LS-TaSC are continuously improving and gaining more usage within the LS-DYNA user community
  - LSTC is providing dummy, barrier, and head form models to reduce customer costs.
  - The incompressible flow solver is fully coupled to heat transfer and structures for FSI simulations
  - Also, the electromagnetics solver is coupled to heat transfer and structural elements for fully coupled simulations
  - Coupling between ALE methodology, SPH, discrete elements, and the airbag particle method will lead to new application areas in the future and improve current methodologies

Future

- LSTC is not content with what has been achieved
- New features and algorithms will be continuously implemented to handle new challenges and applications
  - Electromagnetics,
  - Acoustics,
  - Compressible and incompressible fluids
  - Isogeometric elements, contact, and related developments
  - Discrete element methodology for modeling granular materials
  - Simulation based airbag folding and THUMS dummy positioning underway
- Multi-scale capabilities are under development
  - Implementation underway (New approach which is more user friendly)
- Hybrid MPI/OPENMP developments are showing significant advantages at high number of processors for both explicit and implicit solutions

Thank You !