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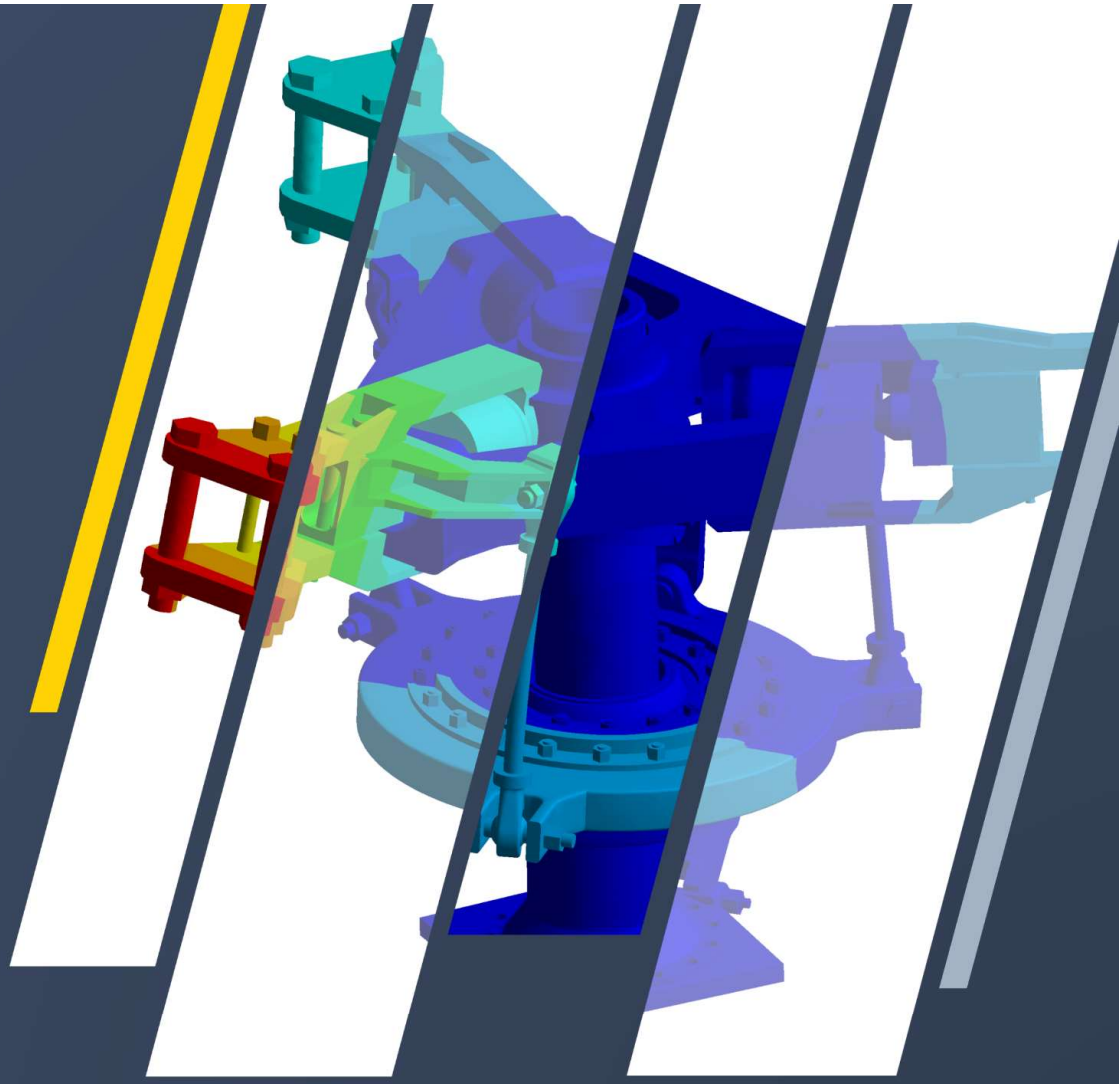
Introduction to LST and its products



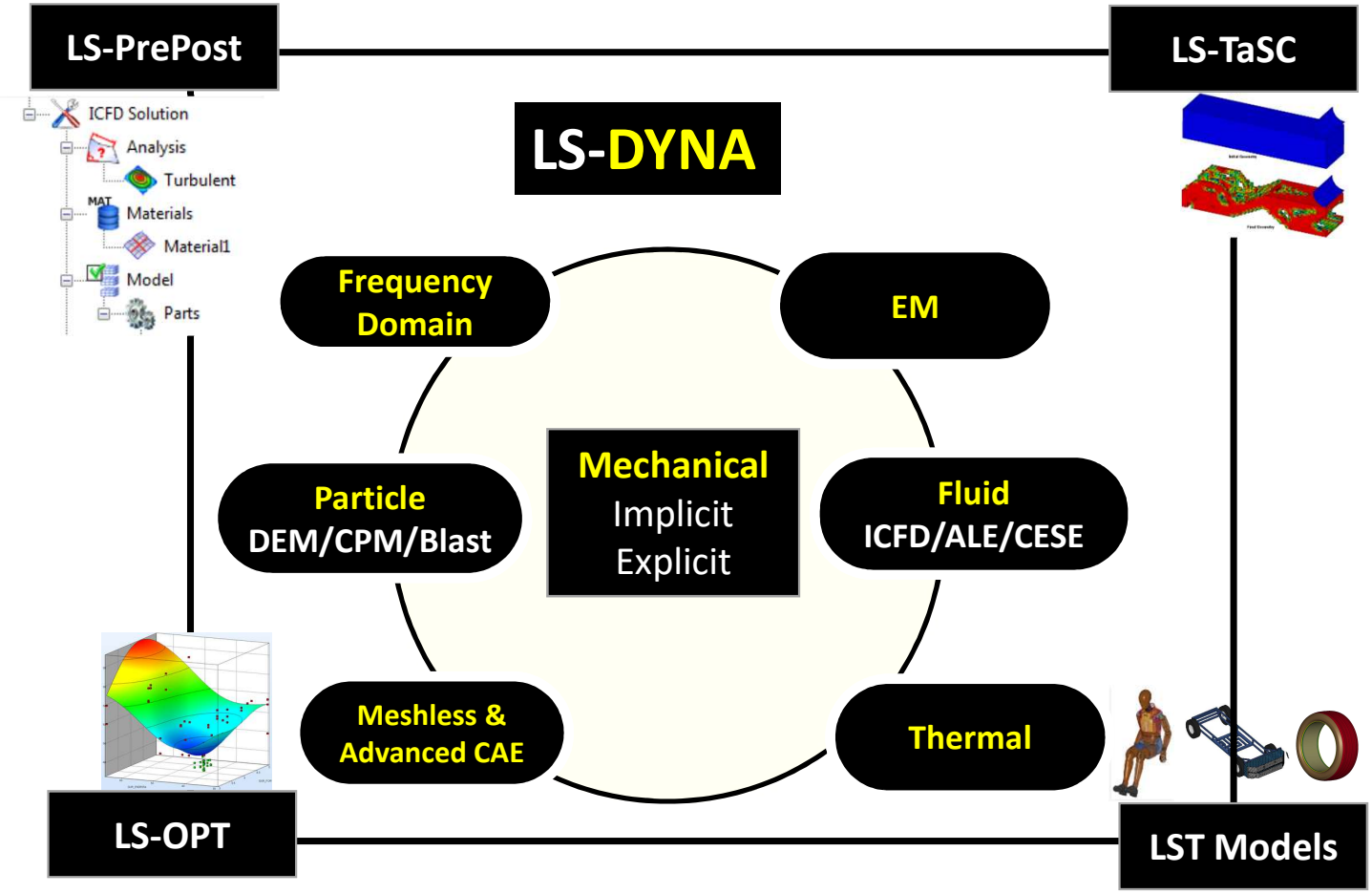
Isheng Yeh
ANSYS LST

2020 ACE Mechanical Summit

Agenda

- LS-DYNA
- Support tools
  - Optimization
  - FEA Models
- Industrial applications
- Summary

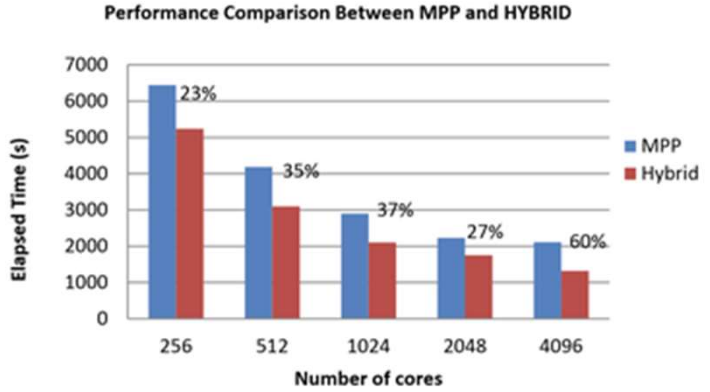
LS-DYNA | One-code for multi-physics simulation



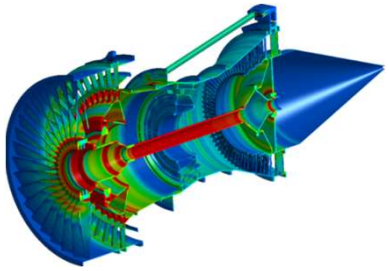
Strength of LS-DYNA

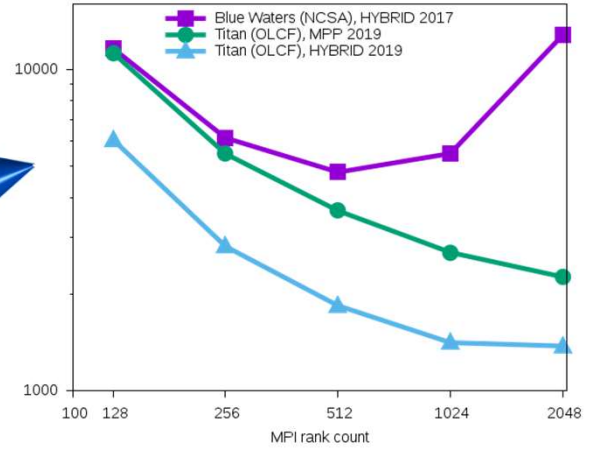
- Automatic contact

- High MPP scalability



Explicit: car-to-car





Implicit: Engine model of 35 million solid elements

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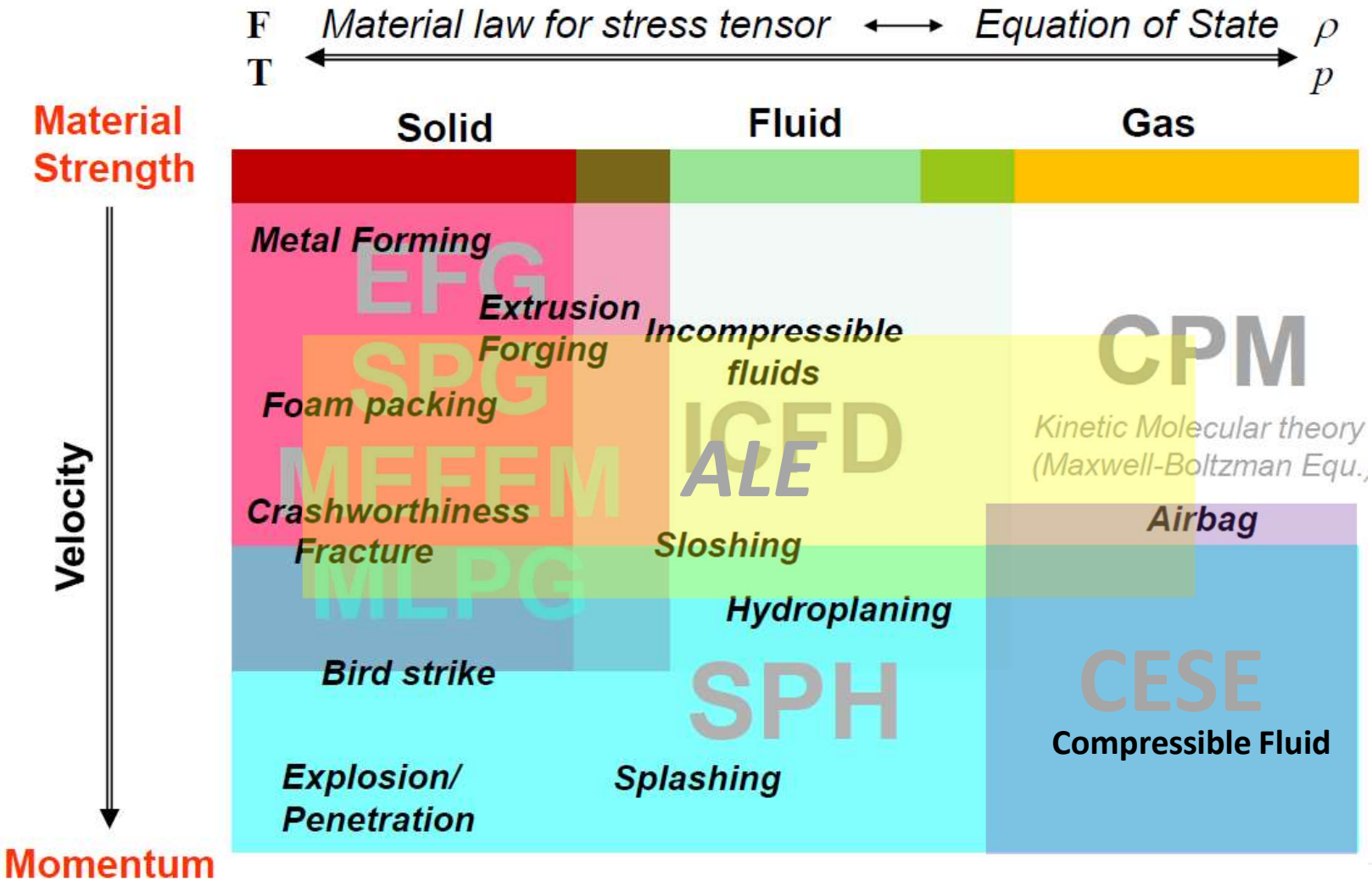
LS-DYNA | Application Map

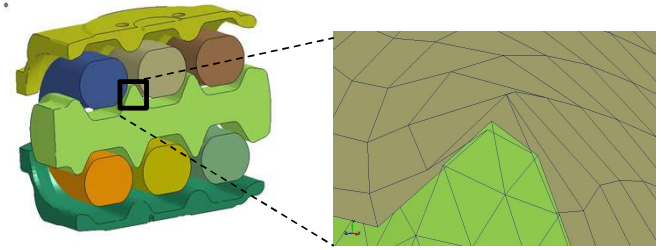


LS-DYNA | Implicit

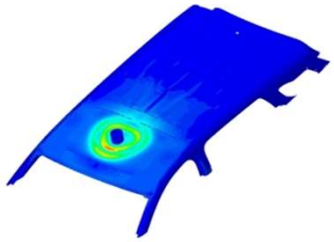
- most element formulations and materials
- most constraints, loadings and contacts
- multi-physics analysis
  - Structure, thermal, fluid, electromagnetism and their couplings
- Various analysis types
  - Linear analysis
    - Statics and dynamic analysis
  - Mode extraction
    - Frequency and mode shapes
    - Modal dynamics, Steady State Dynamics, Buckling,
  - Nonlinear analysis
    - Newton, quasi Newton, Arc length sol.,…
    - Static or dynamic
  - Combined explicit – implicit analysis
    - Manual or automatic

- Typical applications:
  - characterized by contacts, high order ele., rubbers and prestress,..

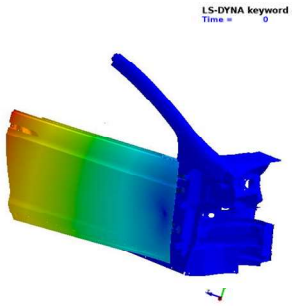
Dummy & HPM Positioning



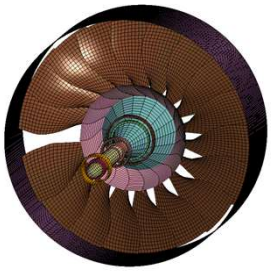
Rubber bushing



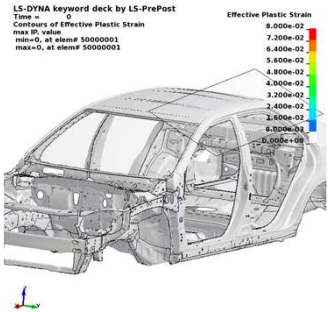
Oil canning



door sag



rotordynamics

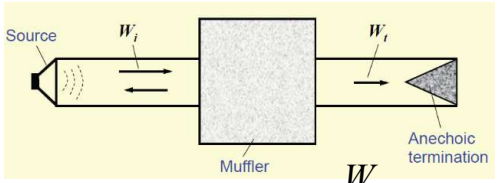


Roof crash

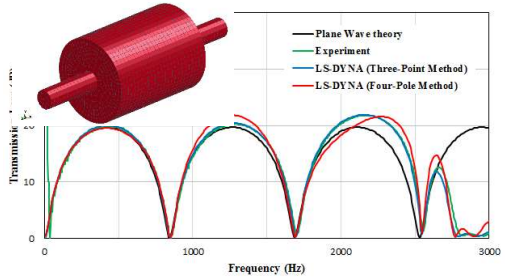
LS-DYNA | Frequency Domain Analysis

2020 ACE Mechanical Summit

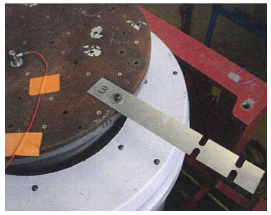
- Capabilities
  - Frequency response function
  - Steady state dynamics
  - Random Vibration
  - Response Spectrum Analysis
  - Acoustics: BEM and FEM
  - Fatigue: SSD and Random vibration
- Applications
  - NVH
  - Acoustic analysis
  - Defense industry
  - Fatigue analysis
  - Earthquake engineering

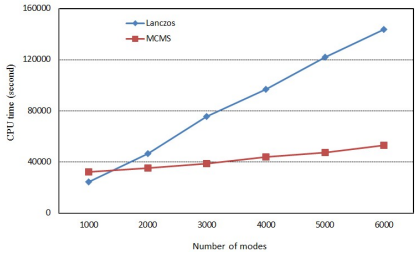


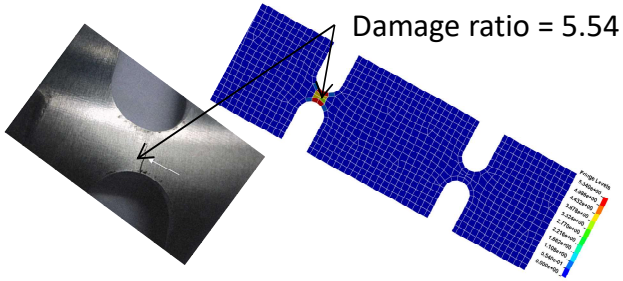
$$TL = 10\log_{10}\frac{W_i}{W_t}$$



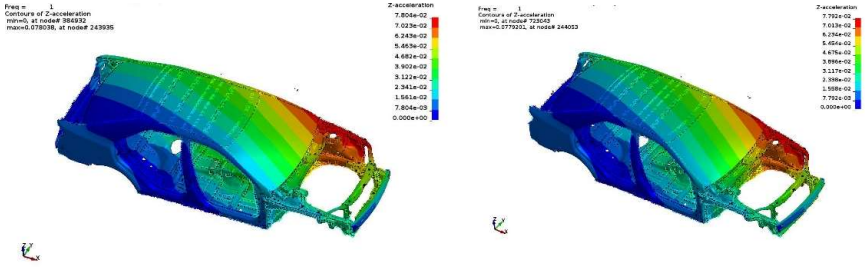
Muffler Transmission Loss, TL







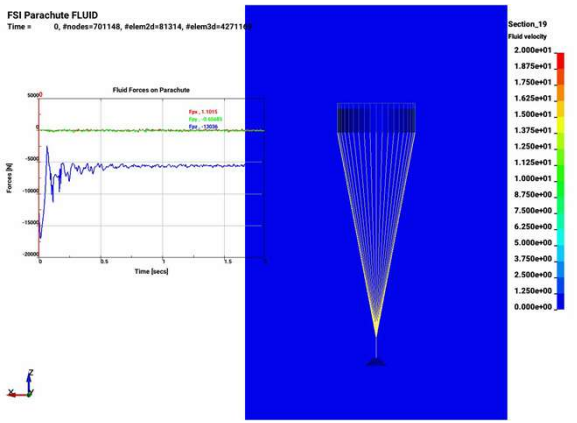
Fatigue of a beam on shaker table



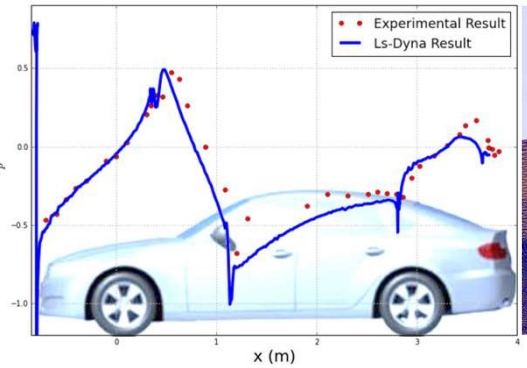
SSD by Multi-level Component Mode Synthesis

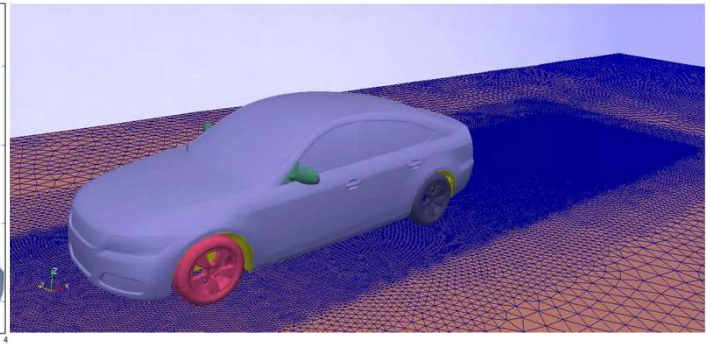
Multi-Physics Solver | ICFD for Incompressible Fluid

- An implicit CFD solver for incompressible flows.
- Automatic volume mesh generation including boundary layer mesh.
- Turbulence models for RANS/LES.
- Free surface flows
- Porous media flow
- Coupled to structural, EM & thermal solver
- Currently used by Toyota & Honda

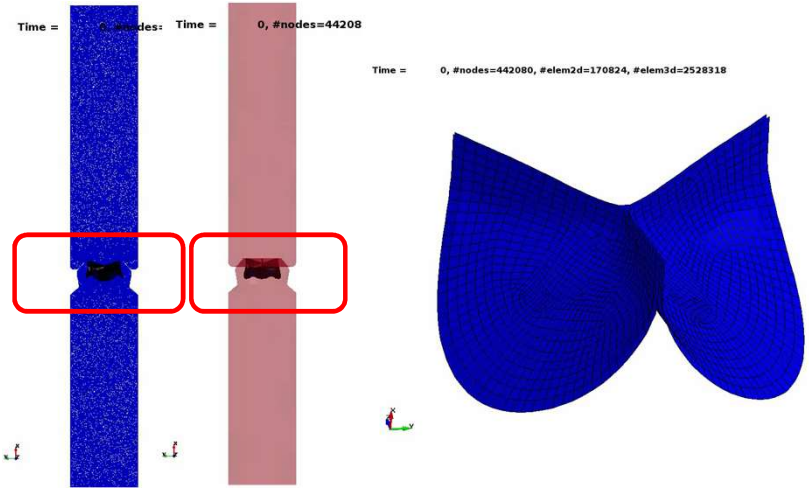


Porous Parachute Deployment



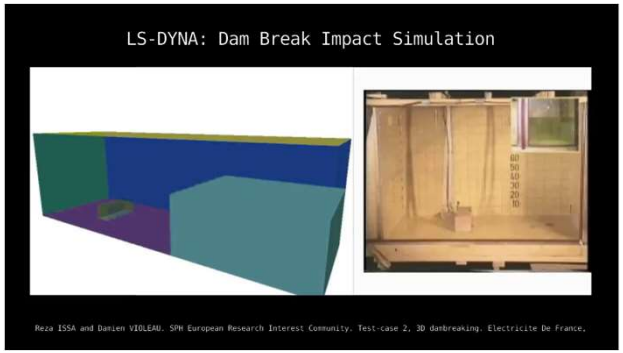


drag analysis

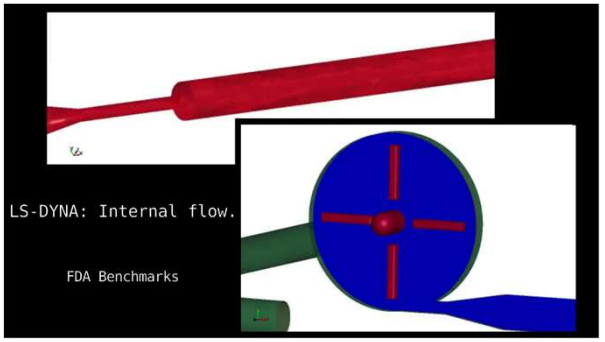


Prosthetic heart valve simulation

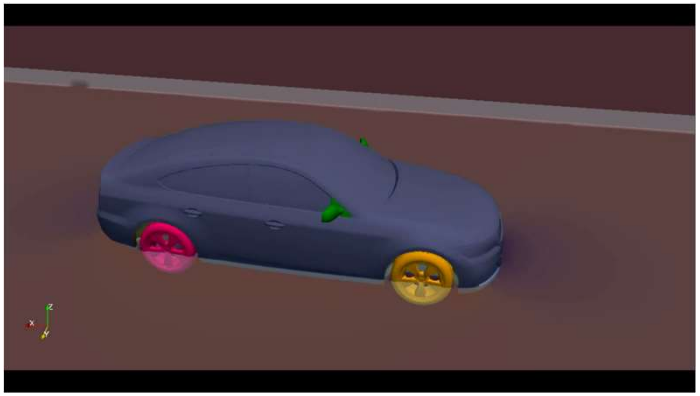
Multi-Physics Solver | ICFD Applications



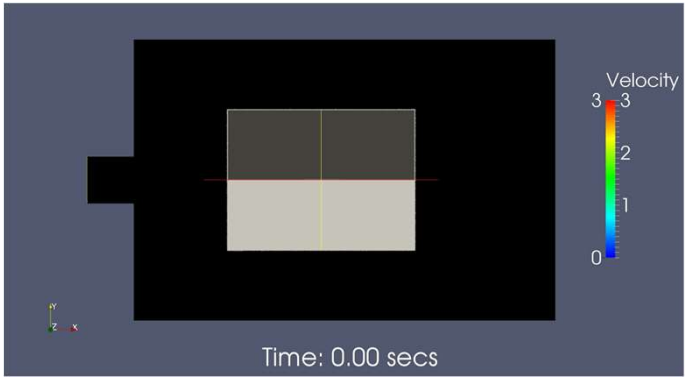
Free surface flow: Tank sloshing



Internal flow for medical devices



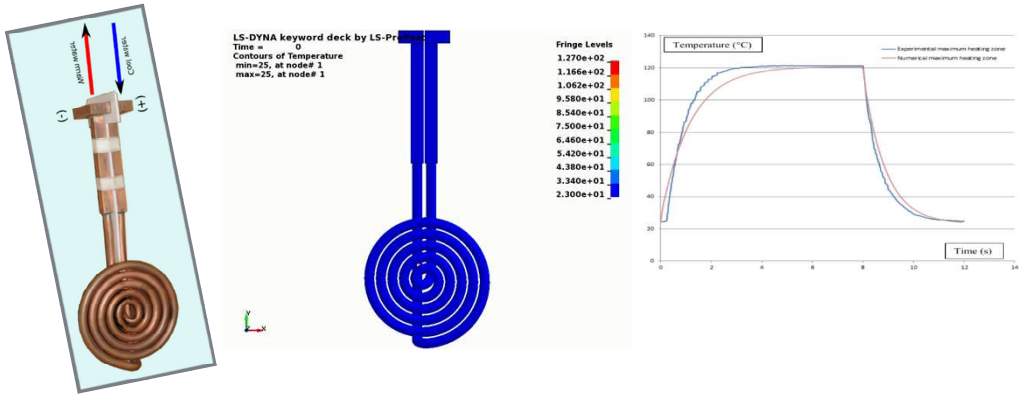
Coupling w. DEM to simulate mud or snow deposition



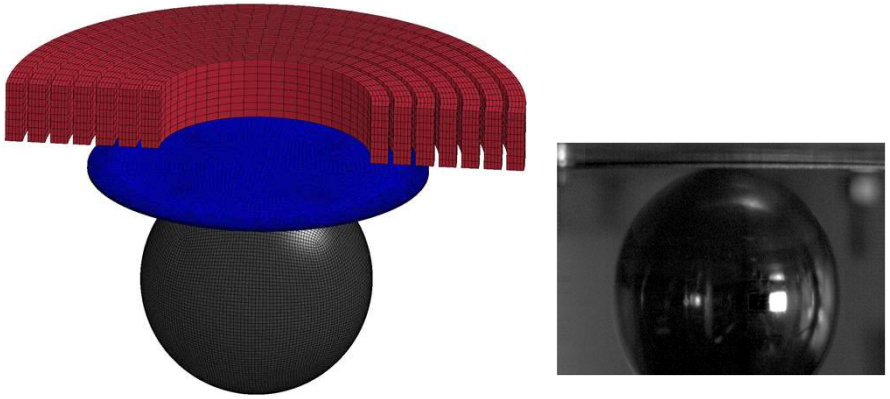
Porous media flow for RTM

Multi-Physics Solvers | Electromagnetics Solver

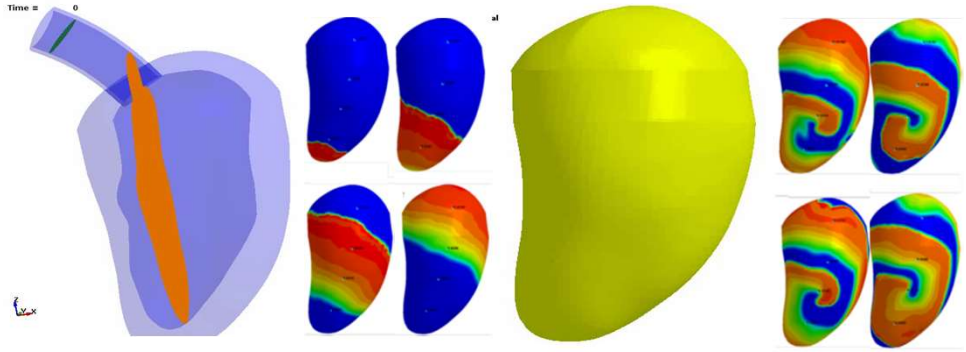
- EM solves the Maxwell equations using FEM & BEM in the Eddy current approximation.
- This is suitable for cases where the propagation of electromagnetic waves in air (or vacuum) can be considered as instantaneous.
- The main applications are magnetic metal forming or welding, induced heating, and battery abuse simulation.



ICFD + thermal + EM



EM pulse forming



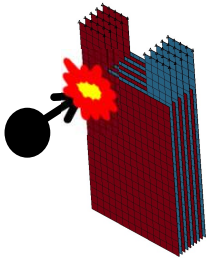
healthy arrhythmias

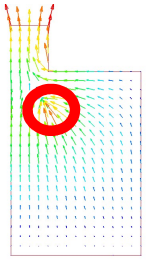
Ventricle simulation w. EP+Mechanical+ICFD

Multi-Physics Solvers | EM for battery abuse

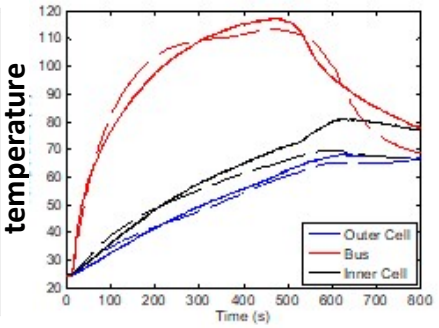
ONE FORD
ONE TEAM • ONE PLAN • ONE GOAL

- Predicts the combined structural, electrical, electrochemical, and thermal responses of automotive batteries to crush and short circuit.

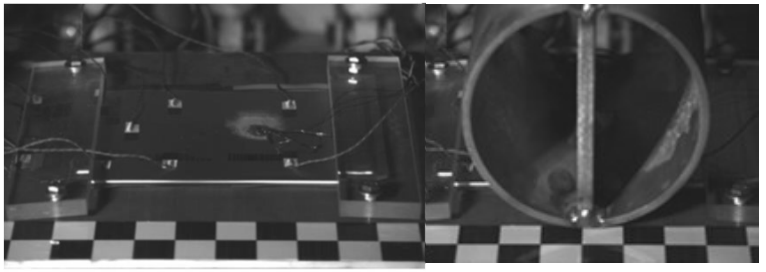


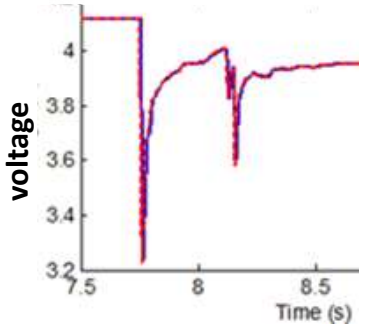


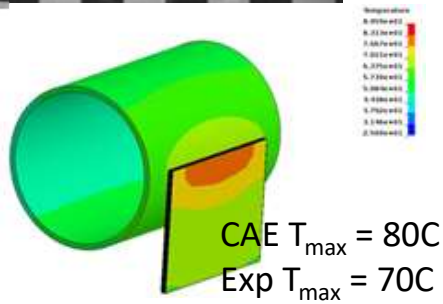
- Users: Ford, Land Rover & Jaguar
- Can be used for cylindrical, pouch & prismatic cell



External short of 4 cells connected in parallel





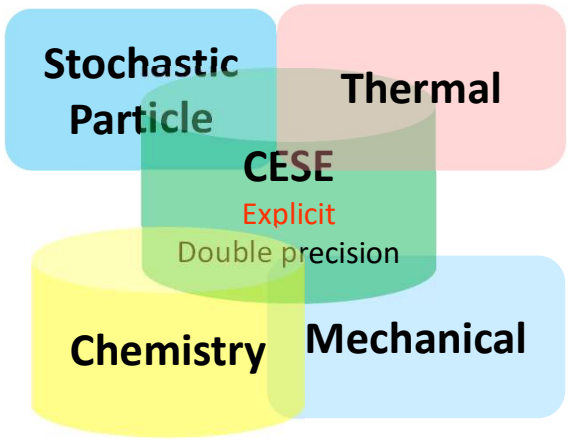


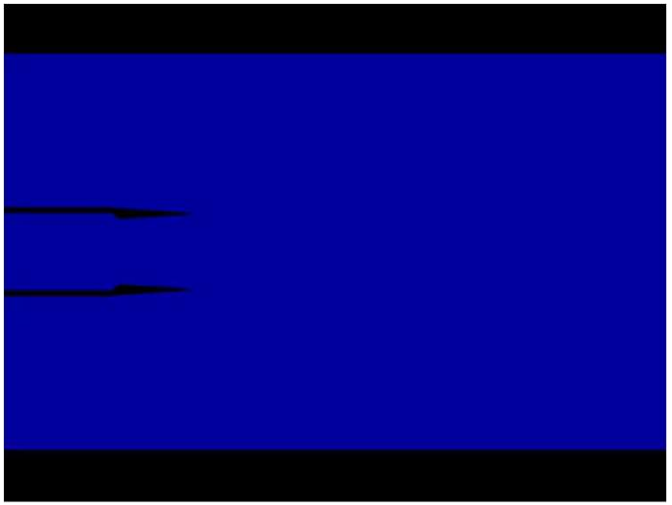
CAE T_{max} = 80C
Exp T_{max} = 70C

Internal short of a cell

Multi-Physics Solver | CESE for Compressible Fluid

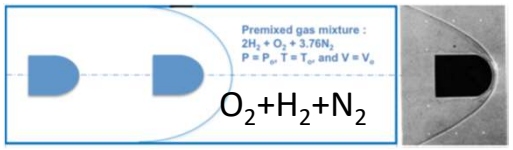
- A compressible CFD solver from NASA which performs high-accuracy explicit space-time solutions to the Euler and Navier-Stokes equations

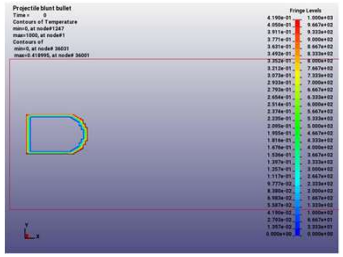




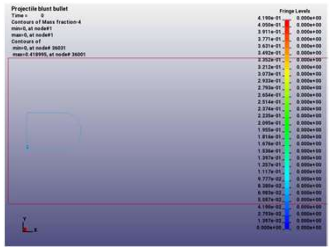
Flow structure of supersonic jets from conical C-D nozzles

- Stochastic Particle specifies spray particle or TBX explosive modeling using stochastic PDEs.
- Chemistry specifies chemistry databases and solution methods.
- Applications include detonation waves, shock/-acoustic wave interaction, cavitating flows, and chemical reaction flows.





Temperature

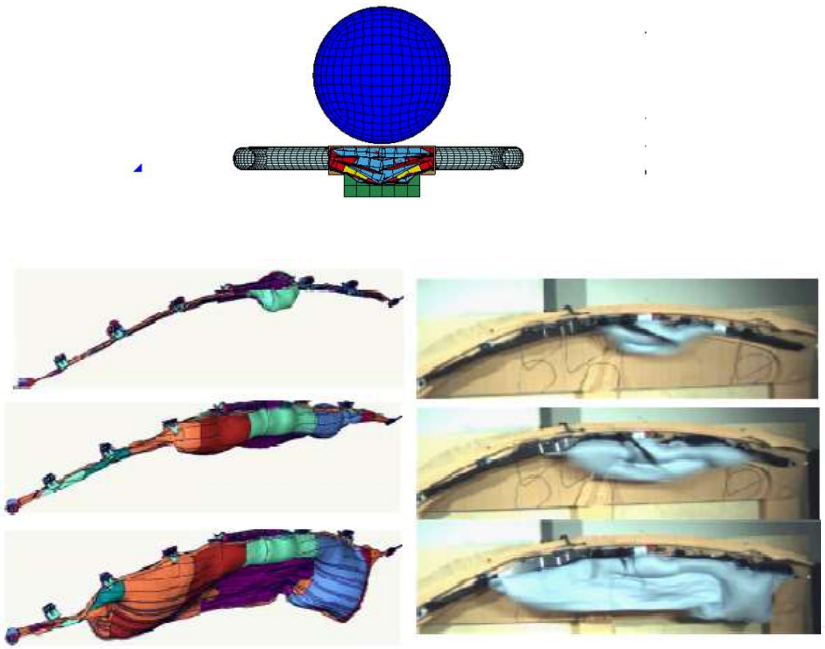


OH fraction

Shock-induced combustion

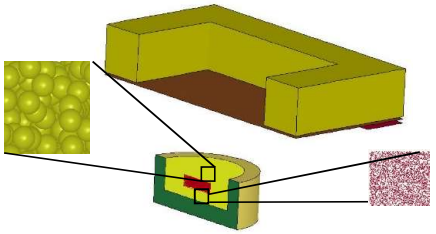
Particles | AIRBAG_PARTICLE and PARTICLE_BLAST

- AIRBAG_PARTICLE for airbag gas particles
  - Models the gas as a set of rigid particles in random motion

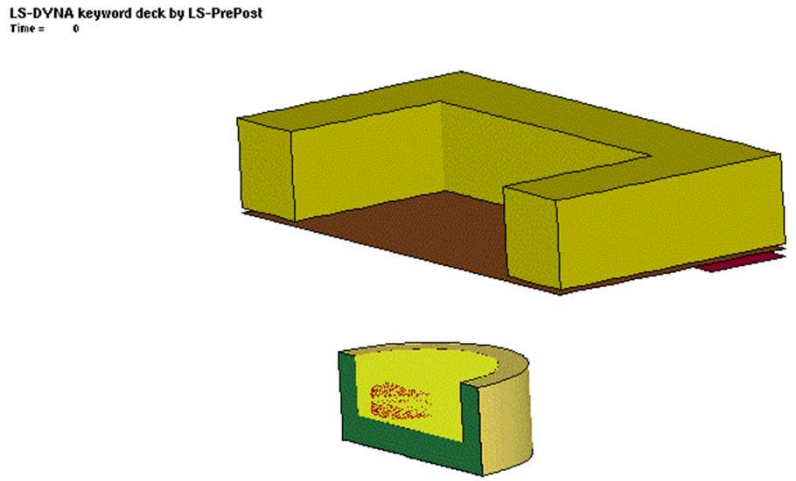


- PARTICLE_BLAST for high explosive particles

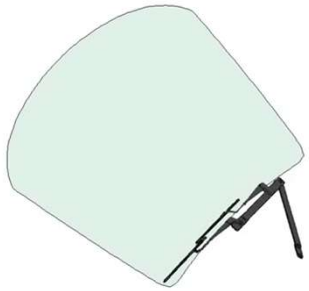
Sand modeled with DEM

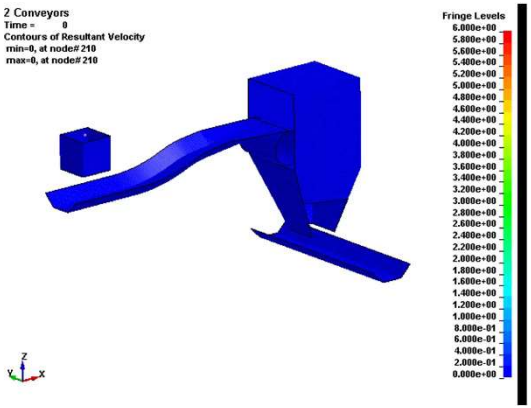


High explosive gas and air modeled Particle Gas



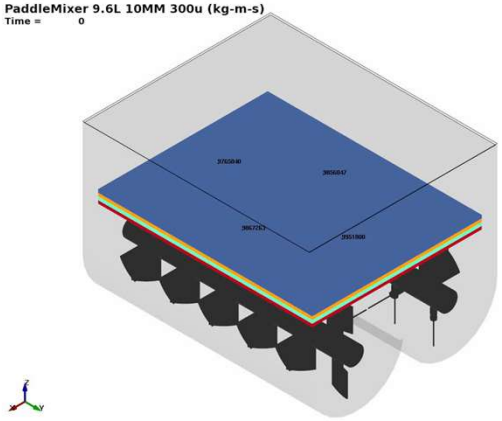
Particles | DEM



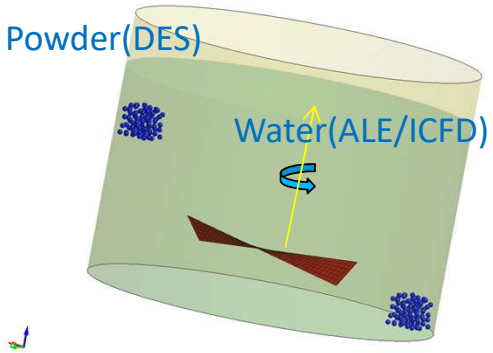


- Application includes agriculture and food handling, chemical and civil Engineering, mining, mineral processing

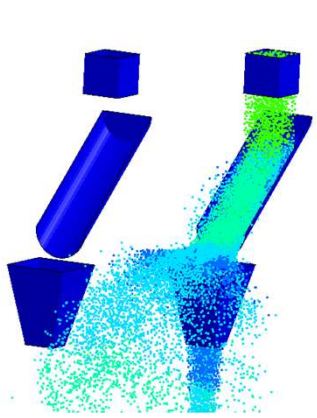
Silo discharging



Path tracing for paddle mixer



Coupling with ALE/ICFD



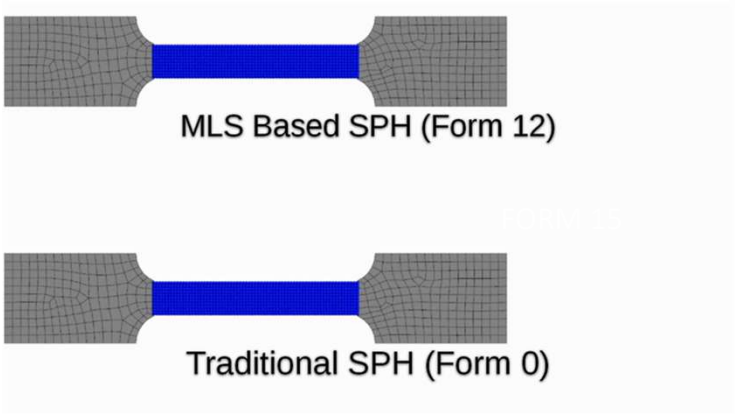
Wear prediction

Meshless | SPH

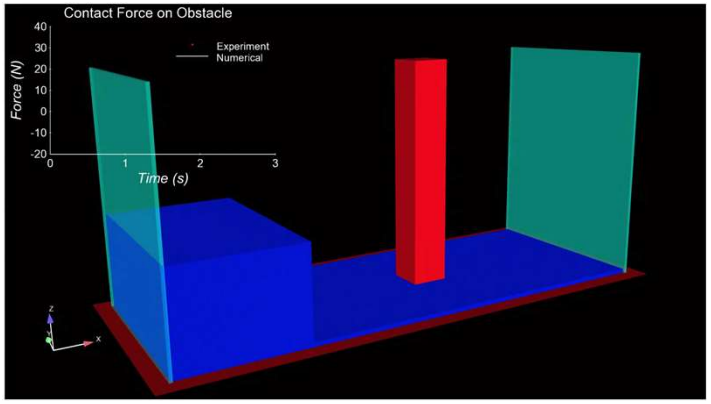
- SPH is the oldest meshless, in which the material decomposes into small fragments or droplets

Friction Stir Welding

Implicit SPH for wading type problems



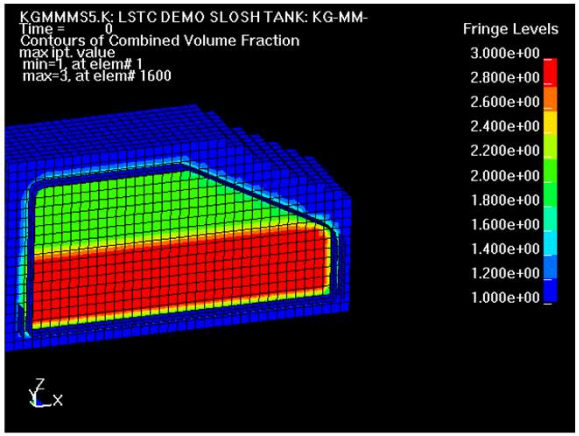
FORM 12 for tensile instability



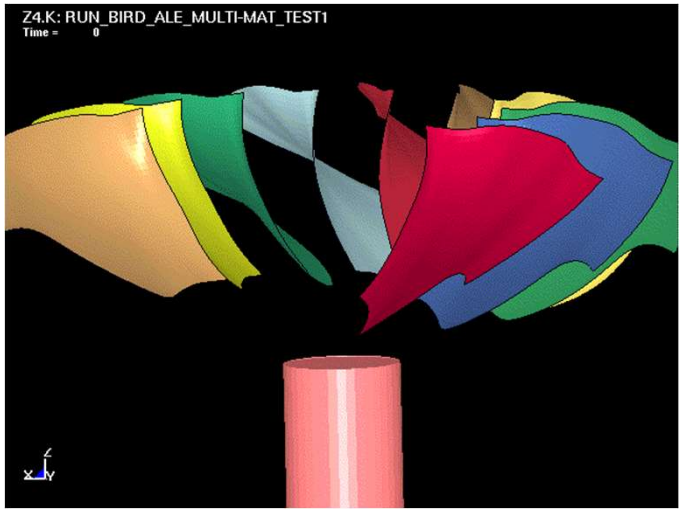
FORM 15 & 16 for better fluid simulation

Meshless | ALE

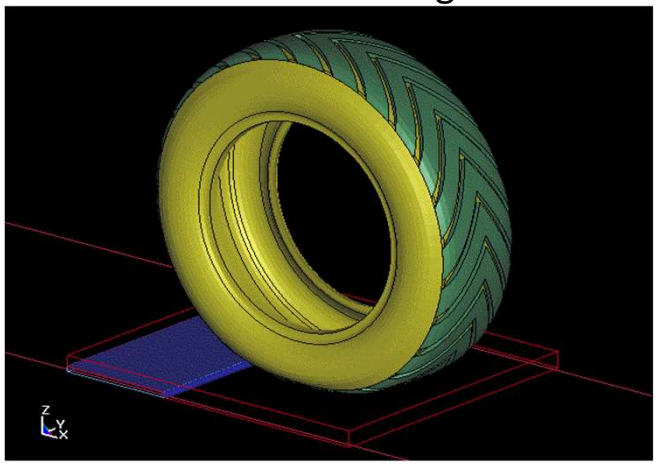
- MMALE translates, rotates and deforms the multi-material Eulerian mesh in a controlled way.
- Turbulence models for RANS/LES.
- Was the LS-DYNA's most popular FSI tool, applied to airbag deployment, tank sloshing, material cutting, RTM, deep water explosion and debris flow.
- Still popular among ls-dyna users



Tank Sloshing



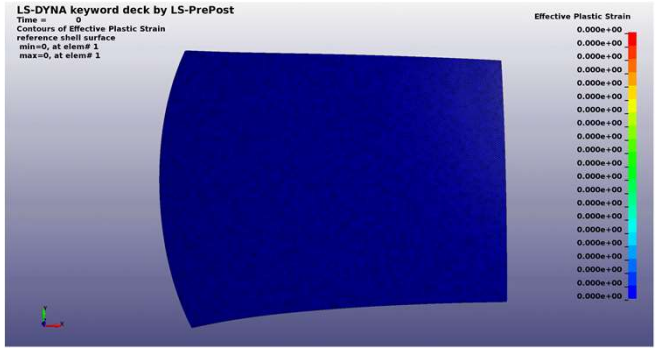
Material Cutting



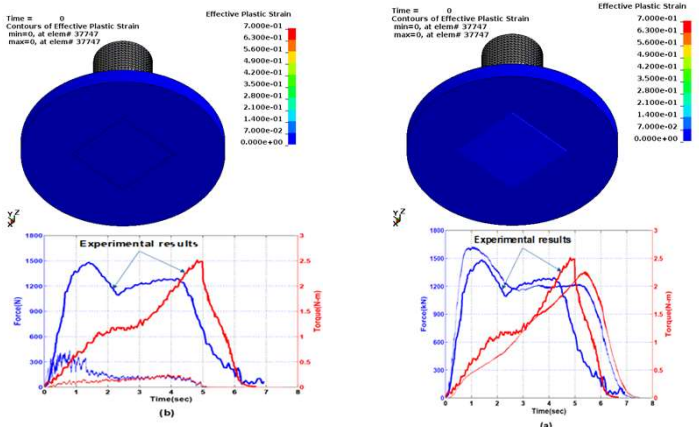
Hydroplaning

Advanced CAE | Peridynamics & SPG

- Peridynamics: for brittle mat. in 3D formulation



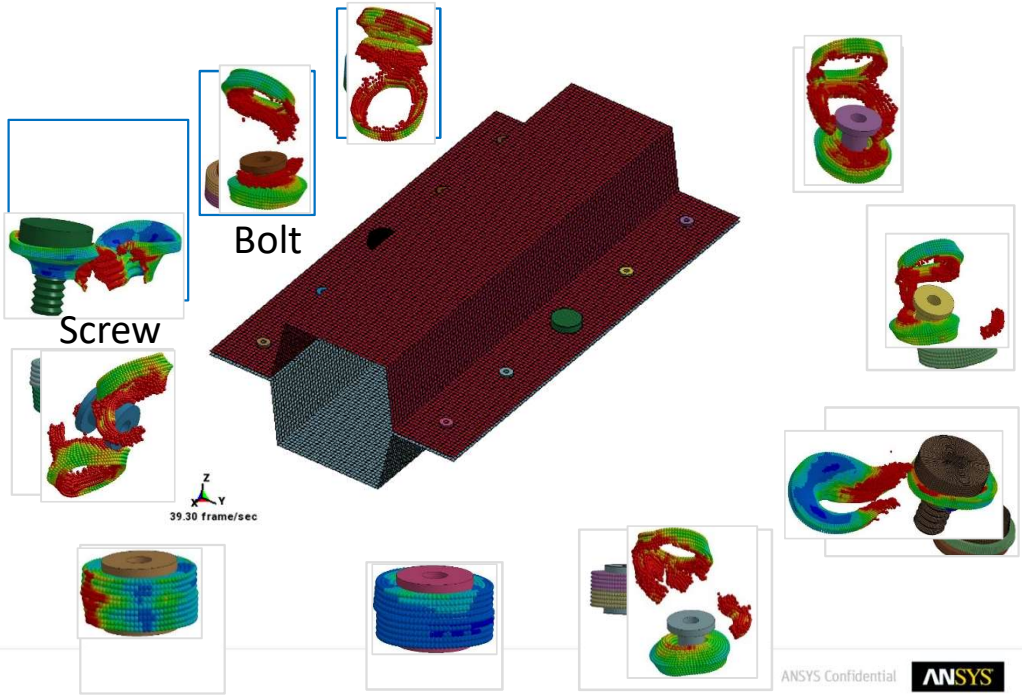
- SPG: for ductile materials in 3D formulation



FEA SPG

Courtesy of Ford

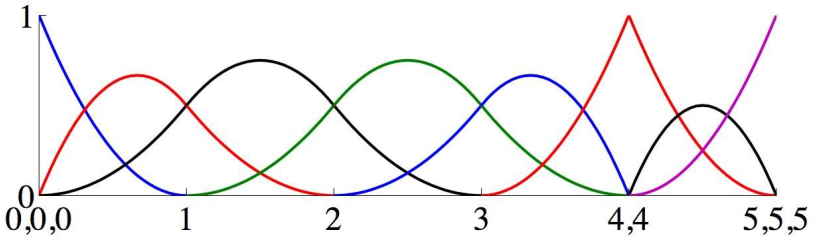
- Two-scale simulation
  - Joints are modeled by SPG method, structure is modeled by FEM shell elements.
  - No need for conforming mesh
  - Is able to model rupture failure in base material.
  - Currently is CPU (Macro)-CPU (Meso).

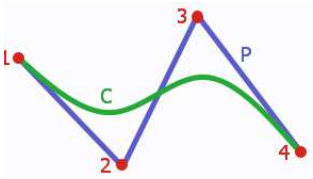


Advanced CAE |Isogeometric Analysis (IGA)

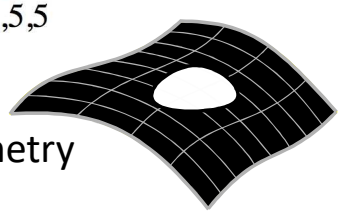
- Basis functions of NURBS (Non-Uniform Rational B-Spline) is used to replace the shape function of FEM, i.e., $x(\xi) = N_i x_i \Longrightarrow x(\xi) = N_{i,p}(\xi) B_i$

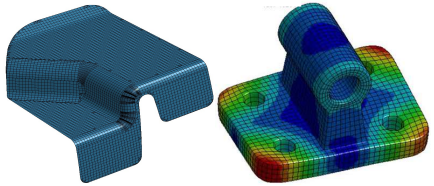
  where B_i is the control point, $N_{i,p}$ is the basis function



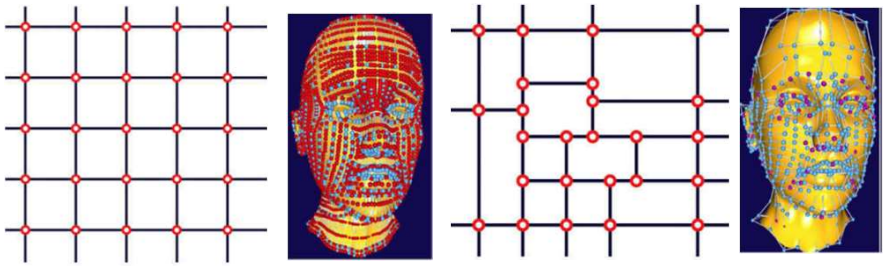


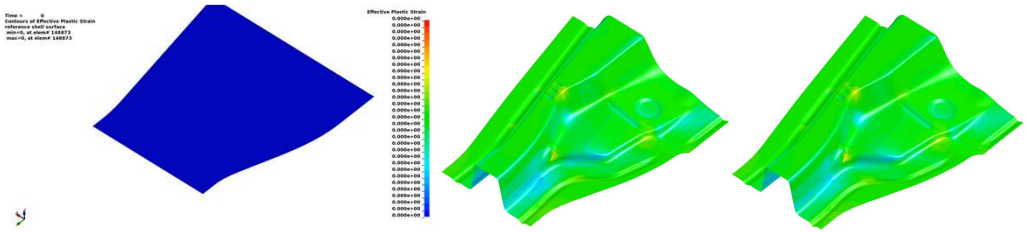
- Advantages of IGA
  - Easier and Better description of geometry
  - Better communication with CAD
- Current status of IGA in LS-DYNA
  - Support shell and solid
  - Explicit & implicit
  - Coupled with wulti-physics solver





- Supports T-spline,
  - a generalization of NURBS enabling local refinement
  - Allows more efficient modeling





$t_{min} = 1.35\text{mm}$ $t_{min} = 1.37\text{mm}$

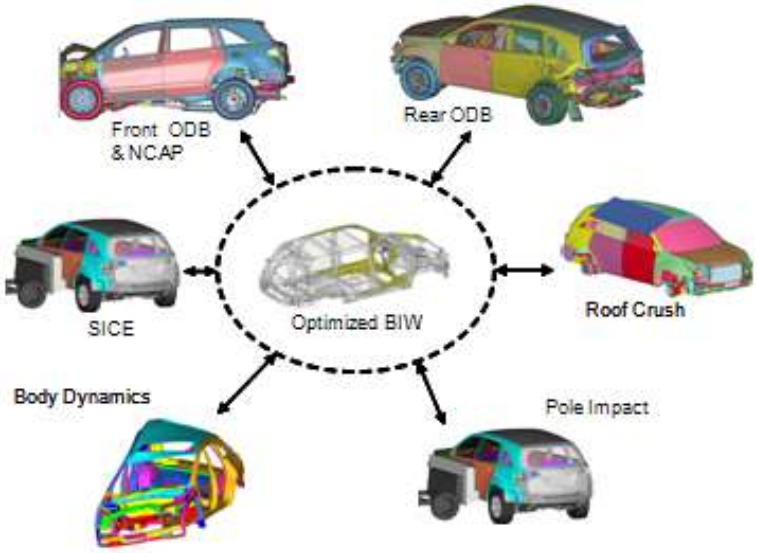
$t_{max} = 1.85\text{mm}$ $t_{max} = 1.82\text{mm}$

IGA 4mm, 3.6 hrs FEA 2mm, 2.2 hrs

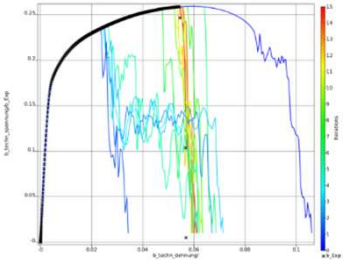
Stamping simulation w. IGA

Supporting tools | LS-OPT

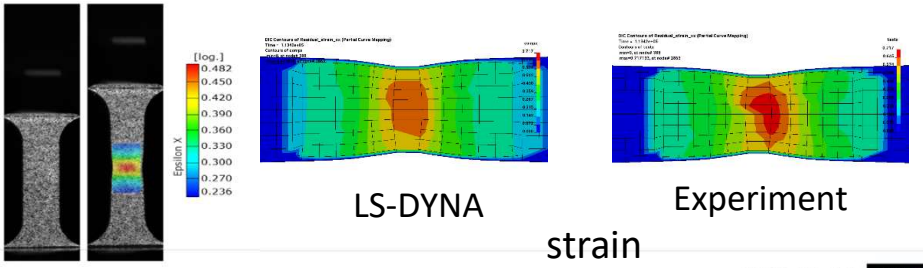
- A standalone optimization software
  - Existing interface to LS-DYNA, MSC-Nastran, Excel, Matlab
  - can be linked to any simulation code
- MDO, MOO & Multi-level optimization



- Statistics & Uncertainty
  - Reliability analysis
  - Robust Design
  - Sensitivity Analysis
  - Outlier Analysis
  - Classification
- Material Calibration
  - Hysteresis: Loading-Unloading
  - *Noise handling e.g. GISSMO*

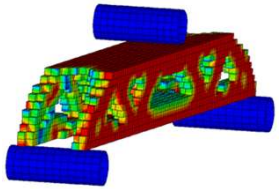


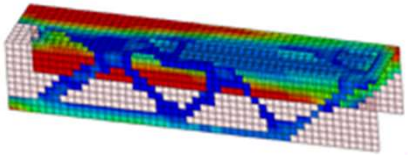
  - *Full-field Calibration w. Digital Image Correlation*

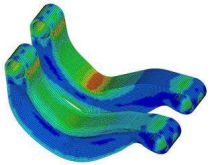


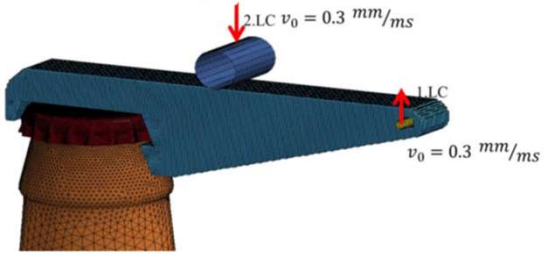
Supporting tools | LS-TaSC

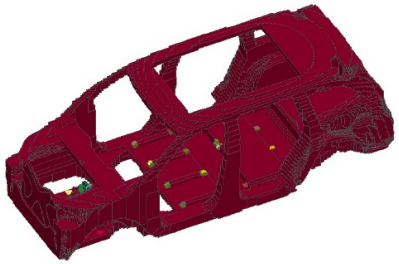
- for the topology and shape design of **nonlinear dynamic problems**. General capabilities include
  - Solid design using hexahedrons and tetrahedral elements
  - Shell design using quadrilateral and triangular elements
  - Free Surface Design
  - Global constraints
  - Multiple load cases

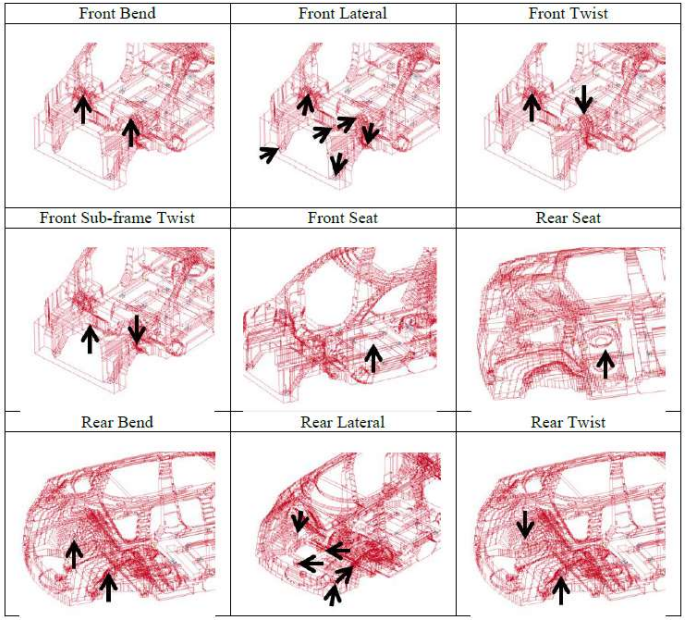












Two dynamic loads

Nine static loads

Supporting Tools | LST Models | dummies

- Frontal impact
  - Hybrid III, 5th, 50th and 95th

  - Hybrid 3-year-old and 6-year-old

- Free motion headform

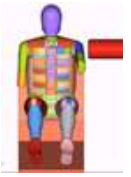
- Pedestrian leg form

- Side impact
  - Euro SID 2/2re

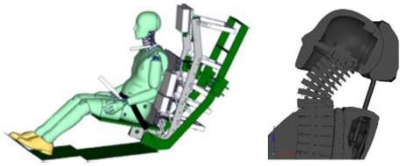
  - USSID

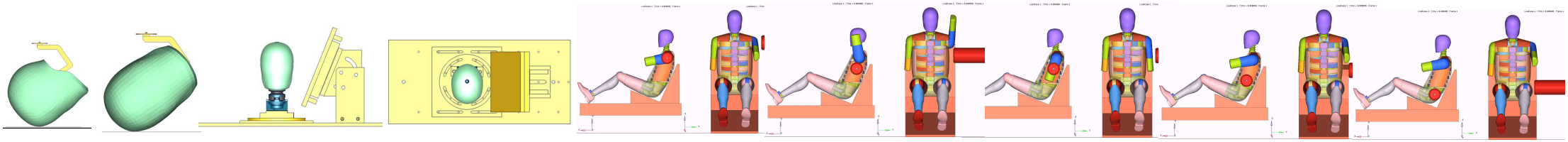
  - SID-IIs Rev D

  - World SID 50th



- Rear impact
  - Bio RID-II





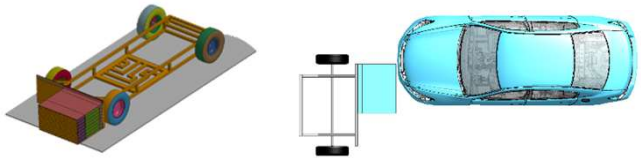
Validation matrix of world SID 50th, about 430k elements

Supporting Tools| LST Models | barriers

- Frontal impact
  - ODB: Euro NCAP

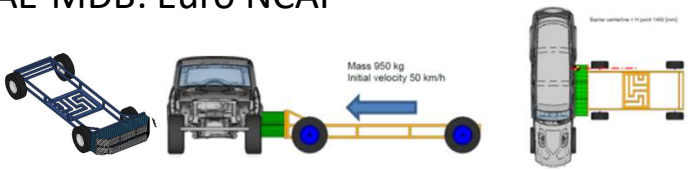
  - OMDB: IIHS small overlap & NHTSA oblique overlap

  - MPDB: NCAP



  - RCAR for low speed impact

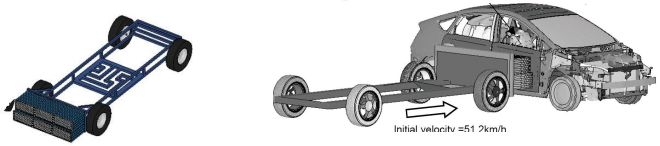
- Side impact
  - AE-MDB: Euro NCAP



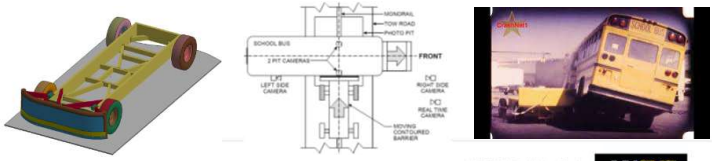
  - 214/301: FMVSS214,301

  - IIHS: IIHS

  - ECER95: ECE

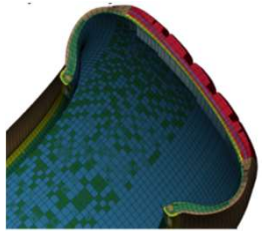


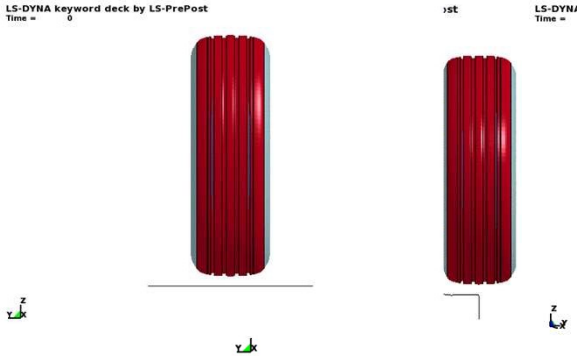
  - MCB: FMVSS301

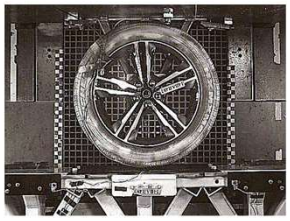


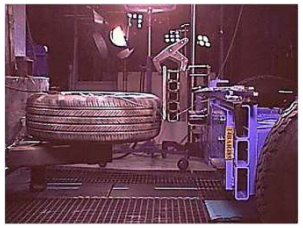
Supporting Tools| LST Models | tires

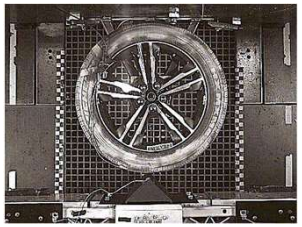
- Validation matrix of a tire model, about 250k elements



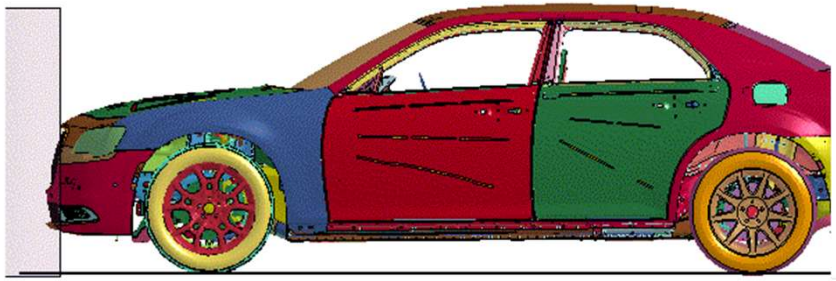








- System validation

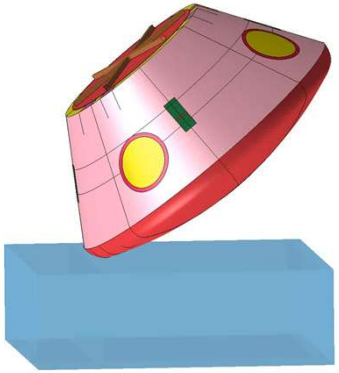


Applications | Automotive & Aerospace

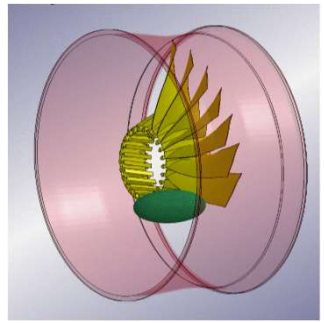
- Users include
  - OEMs: GM, Ford, FCA, Toyota, Honda, Mazda, Subaru, Mitsubishi, Daimler, BMW, VW & Audi, Volvo, Porsch, Jaguar & Land Rover, Hyundai, Kia, Tata, 90% of China OEMs, …
  - Suppliers: Autoliv, TRW, Joyson, Lear, Visteon, Delphi, Dow, Johnson Control, …
- Applications
  - Crash & safety, manufacturing & forming (cold, hot & EM), NVH & durability, battery abuse simulation, optimization, CFD (drag analysis, splashing & sloshing) etc.

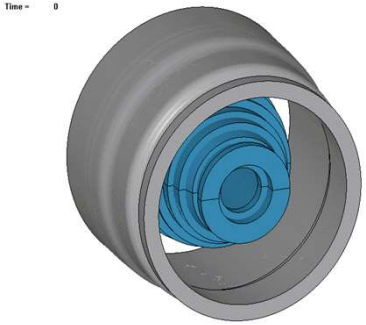
- Aerospace users include NASA, Airbus, Boeing, Rolls Royce, GE aerospace, Zodiac, Aerodyne,…
- Applications include survivability analysis, bird strike, engine blade-out dynamics. NVH & fatigue,…

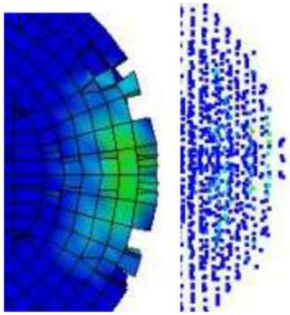
Orion lander



Bird Strike





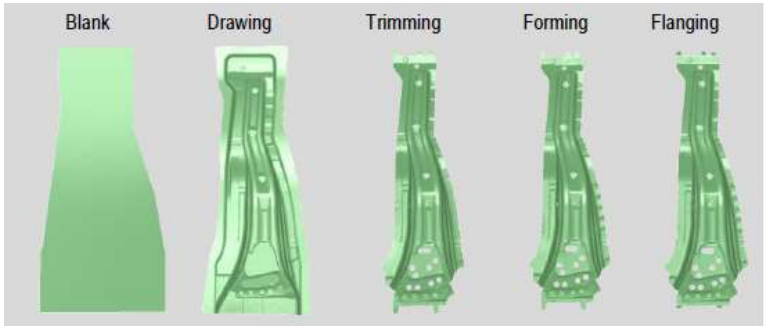


Compartment integrity

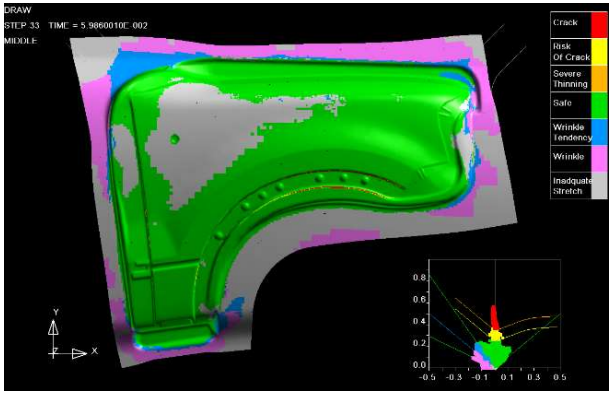
Hale Impact

Applications | Manufacturing & forming

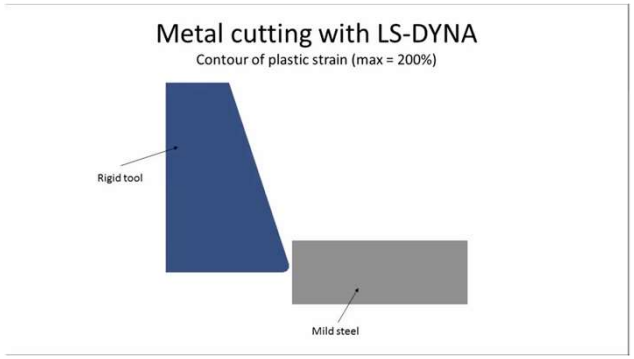
- Getting popular for forming simulation thanks to high accuracy. Users include Daimler, BMW, GM, VW & Audi, Ford, Toyota, Honda, ….



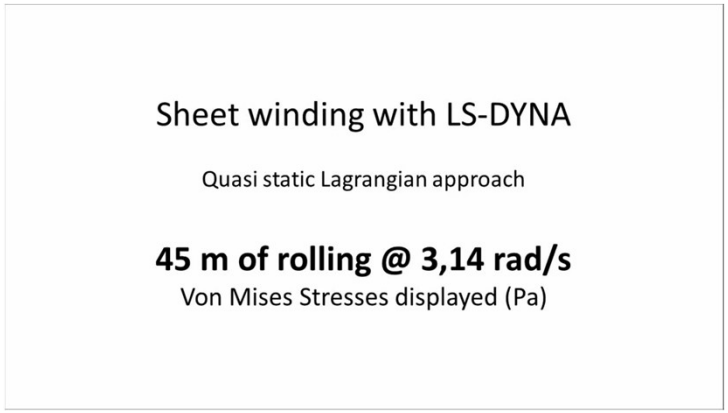
LS-DYNA forming application in BMW



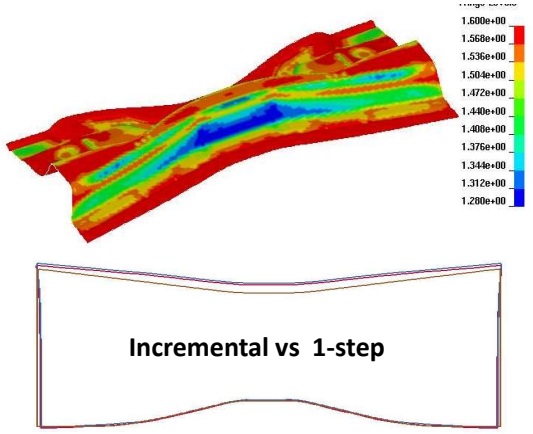
formability



Material cutting

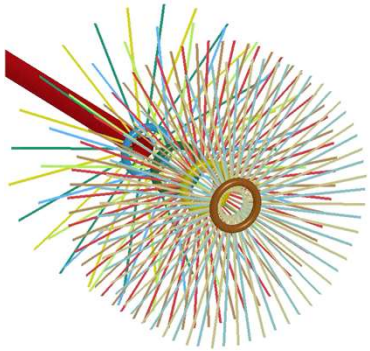


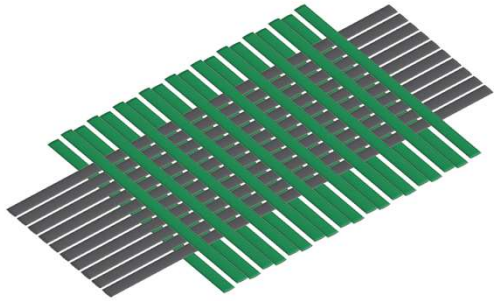
Sheet winding



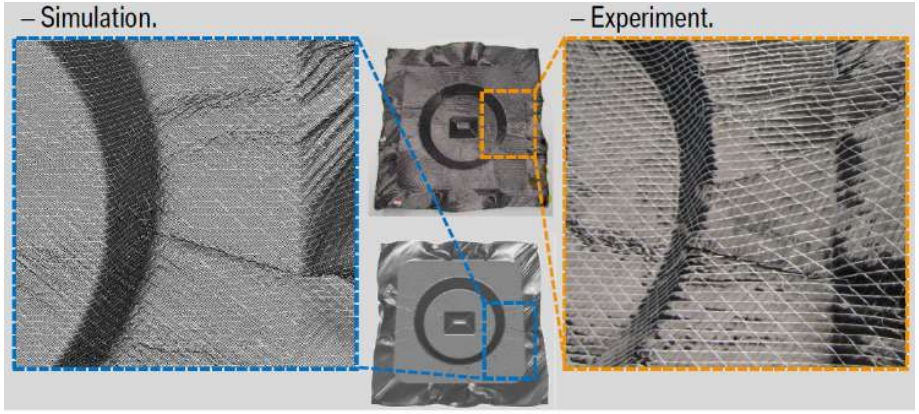
One-step method for Initial guess of blank size

Applications | Manufacturing & forming

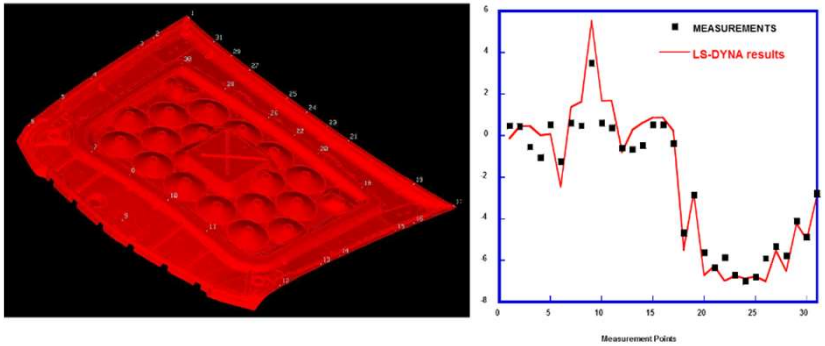




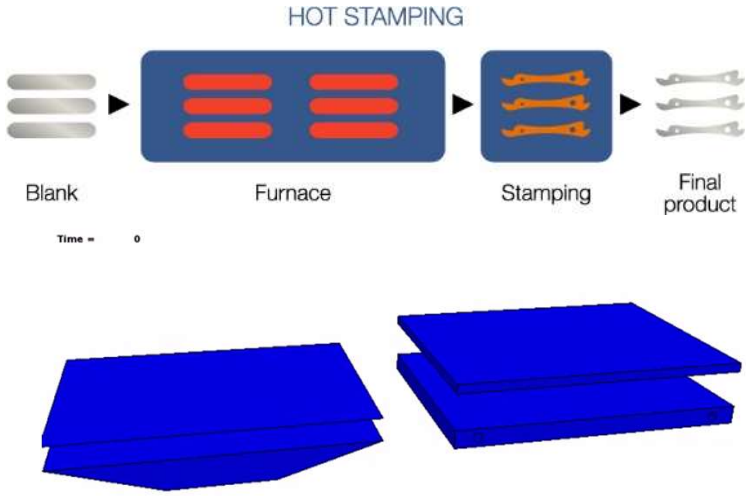
CFRP braiding/weaving



CFRP draping by BMW



Springback prediction

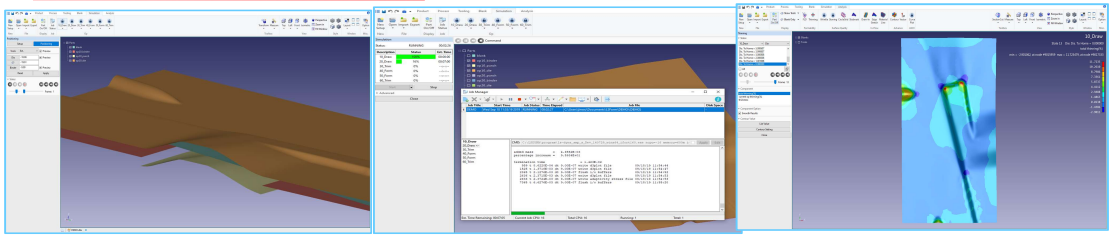


Hot forming by BMW, Audi, Volvo,..

Applications | LSFORM, a pre-post for forming

- The usage of LS-DYNA stamping simulation has been steadily increasing thanks to its accuracy.
- Forming users desire a lower technical threshold to use LS-DYNA.
- LSFORM, together LS-DYNA, provides a complete forming solution.

Pre-Processing | **Job-Submission** | **Post-Processing**

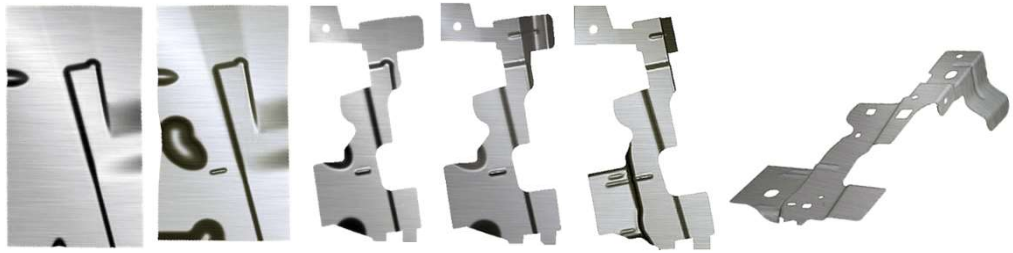


- Easy to define tool motion
- Easy to manage the tools
- No limitation of total tool number

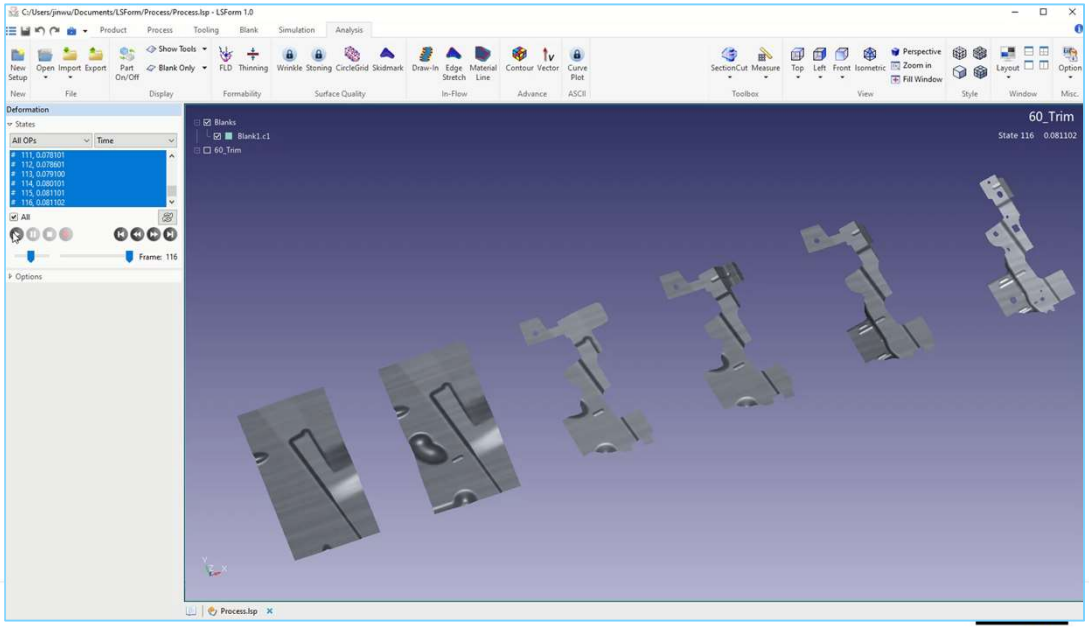
- Auto start sequential jobs stage by stage
- monitor job status
- Easy to stop/restart/queue

- New user-friendly GUI design
- Processing multi-stage jobs
- Multiple jobs in multiple window
- Up-to-date graphics rendering

- Multi-stage simulation



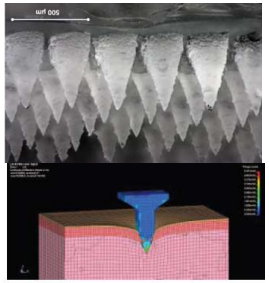
Toggle Draw | Air Draw | 1st Trimming and Piercing | Cam Flanging | Direct Flanging | 2nd Trimming and Piercing



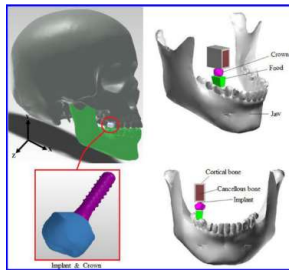
Applications | Bioscience & Consumer Products

2020 ACE Mechanical Summit

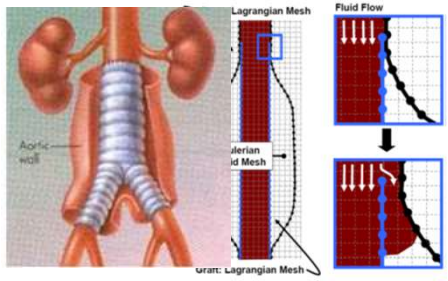
- Users:
  - Harvard U., U. Oxford, MIT, Duke U., UC Berkeley, U. Michigan, Gorman Cardiovascular Research Group, Henry Ford Health System, lMG Bennett & Associates Ltd UK, Sorin Biomedica Cardio Italy, Montreal Heart Institute, Pacific NW Nat. Lab., ..
- Application:
  - Design of protection devices, Injury mechanism investigation, Design and manufacturing of medical devices, Design of prosthesis, Choice of repair, Surgery simulator,….



Microneedle patch

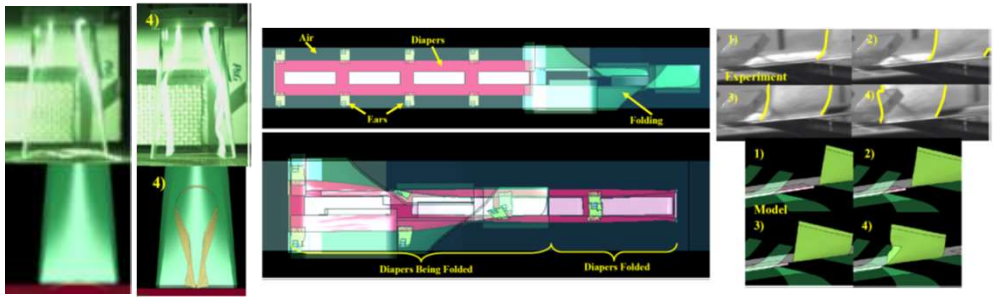


Dental implant

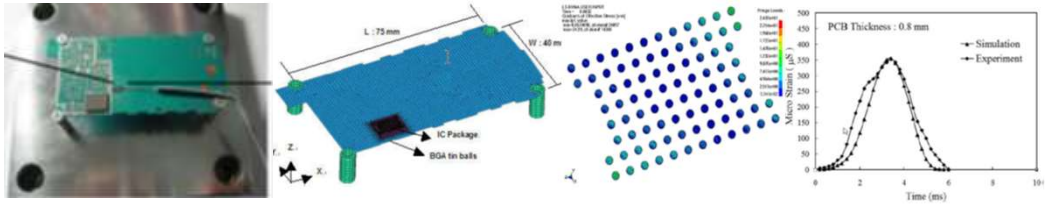


Stent Design

- Consumer products users: P&G, Black & Decker, Bosch, Whirpool, Pepsico, Hitachi, Sony, Nikkon, Cannon, Samsung, LG, SK Hynix, Levono, Motorola, Nokia, Micron Technology, Foxconn, TSM, Quanta, SPIL, Corning, …
- Applications: Toys, sport goods, drop analysis, package design, thermal analysis, manufacturing simulation, assembly simulation,…..



Diaper folding & trim removal (J. Seguro, P&G)



Drop test of PCB with BGA

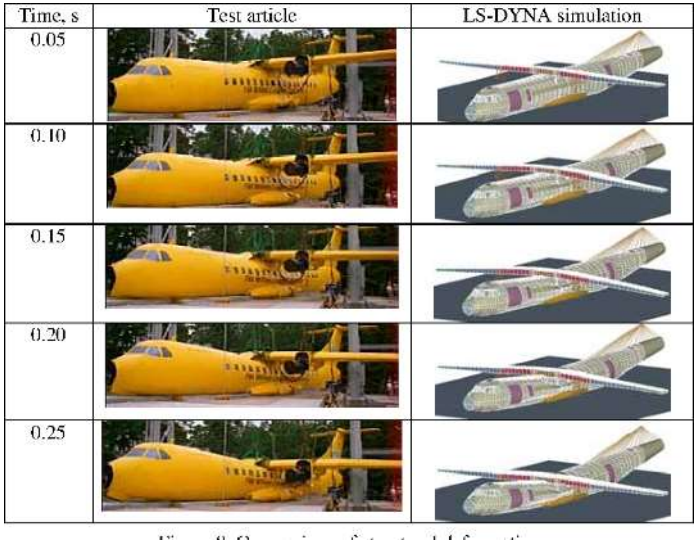
Strain correlation

 ANSYS

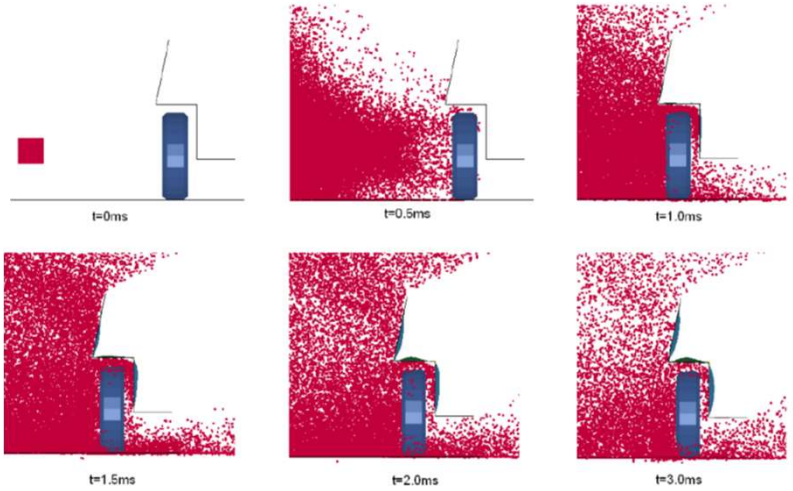
Applications | Defense

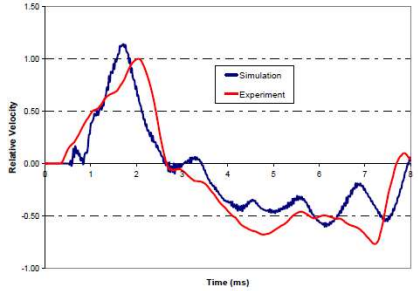
- Defense users: Lockheed Martin(1), Raytheon(2), BAE(3), Northrop Grumman (4), Boeing(5), General Dynamics(6), Airbus(7), Thales(9), Leonardo Finmeccanica(10), United Technologies(11),….
- Applications: homeland security, weapon design, penetration mechanics, insensitive munitions analysis,…..

MANPADS penetrations



Helicopter crash landing

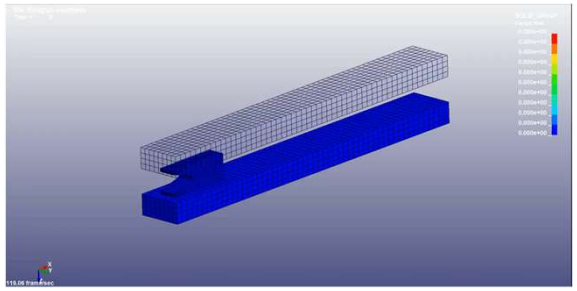


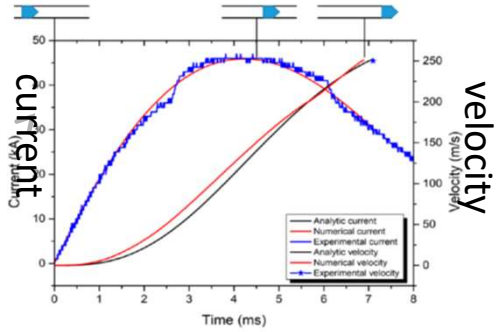


Vy of the side wall

Roadside blast on armored vehicle w. SPH

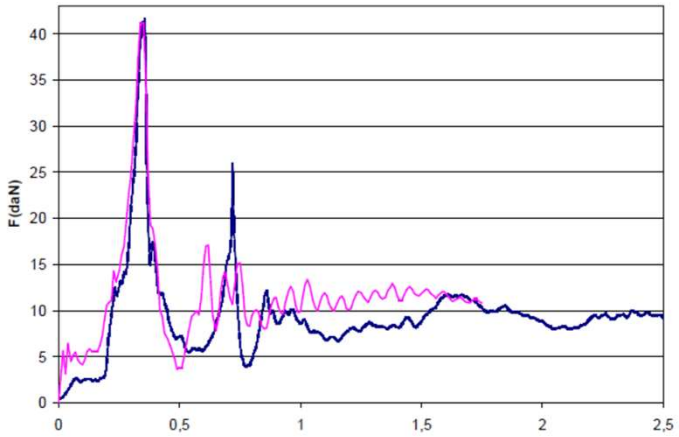
Applications | Defense





Electromagnetic launching system

LS-DYNA TEST LS-DYNA TEST



Air drop

Summary

- LST and its products were introduced.
- Typical applications were discussed.
- LS-DYNA has been the leader of explicit FEA. The closest competitor of explicit FEA is PAM-CRASH. COMSOL is the major competitor in multi-physics simulation. Continuous effort will be needed to keep, or even further, the dominance.
- For automotive industry, active safety and autonomous driving are currently in the center of attention.
- LSFORM is expected to bring in more forming users.
- In addition to forming, crash & safety, LS-DYNA has a lot of potential in other applications like 3C products, bio-science, defense, FDA analysis,….

