Recent Developments in LS-DYNA – I

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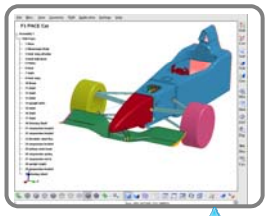
LS-DYNA®-Development

J.O. Hallquist

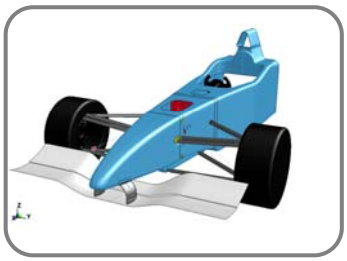
Outline of talk

- Introduction
- Current Developments
  - USA
  - LS-PrePost
  - LS-980
  - LSTC dummy developments
  - LSTC barrier developments
  - Hybrid LS-DYNA
  - Implicit update
- LS-DYNA 971 r4 and r5
- Conclusions

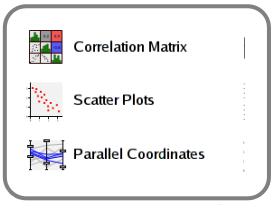
LSTC Products



LS-PrePost



LS-DYNA



LS-OPT
LS-OPT/Topology

DUMMIES

BARRIERS

USA

No license cost

Applications of LS-DYNA

Automotive
- Crash and safety
- Durability
- NVH

Aerospace
- Bird strike
- Containment
- Crash

Manufacturing
- Stamping
- Forging

Consumer products

Structural
- Earthquake safety
- Concrete structures
- Homeland security

Electronics
- Drop analysis
- Package design
- Thermal

Defense
- Weapon design
- Blast response
- Penetration
- Underwater shock analysis

LS-DYNA

One code strategy

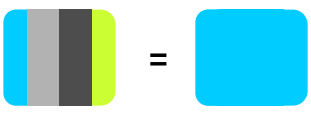
Combine the multi-physics capabilities into one scalable code for solving highly nonlinear transient problems to enable the solution of coupled multi-physics and multi-stage problems.

Explicit/Implicit Solver	✓
Heat Transfer	✓
EFG, SPH, Airbag particle method	✓
Incompressible fluids	980
CESE compressible fluid solver	980
Electromagnetism	980
Interfaces for users, i.e., elements, materials, loads	✓
Acoustics	✓

LSTC

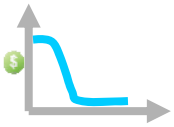
Development goals

- Reduce customer costs to encourage and enable massively parallel processing for large scale numerical simulations
- Multicore processors have resulted in a drastic reduction is computer hardware costs and a huge increase in LS-DYNA licenses worldwide
- Approaches used by LSTC to help reduce costs



1 core/job 4 core/job

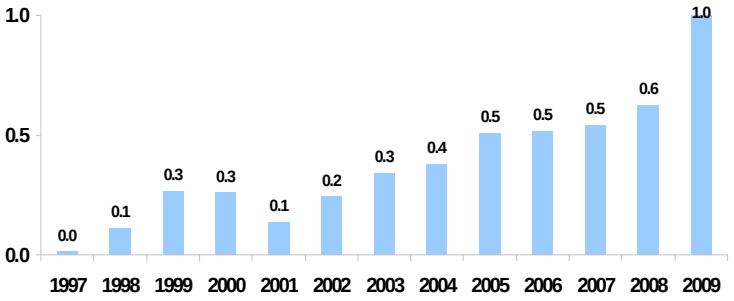
Unlimited Sitewide license



Steeply reducing license costs

LSTC

Number of cores evolution



two orders of magnitude growth every decade

Development goals

- Quickly update code to accommodate new features needed by users
- Reduce customer costs

LS-DYNA	No-cost LSTC Value Added Tools
•Increasing Computation Speed •Improving Scalability •Continuously recoding existing algorithms •Ensuring that LS-DYNA is fast, accurate, robust, and the most scalable software available	•LS-DYNA dummy, head and leg form, and barrier models •LS-DYNA dedicated pre and post processing software •LS-DYNA specific optimization software

Development goals

- Backwards compatibility without translation
- Open databases for third party applications
- Improved error checking of input data
  - In Version 5.0 all messages have unique IDs to enable us to trace the source of the error or warning to the line of code that generated it.
    - ensure that these messages are meaningful to both users and developers

Improved Error Checking

- Every message has a number and label

  ####

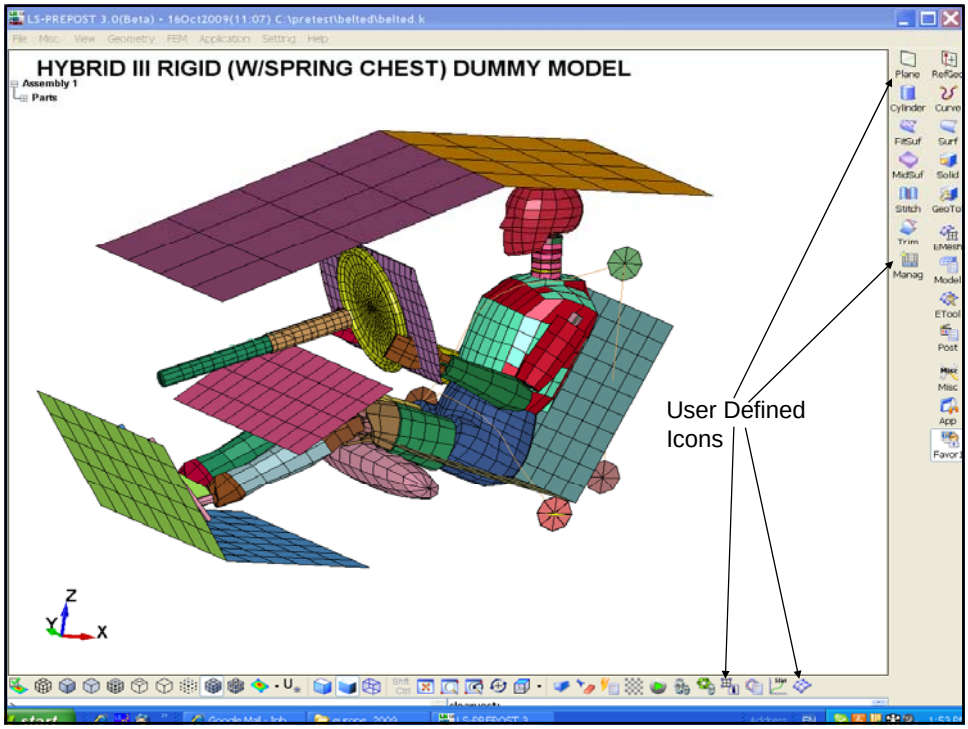
  KEY+###, STR+###, INI+###, SOL+###, MPP+###, IMP+###

```
Error message
*** Error 40752 (SOL+752)
        Specified maximum force level in curve ID : 1
      exceeds the elastic limit in beam element ID: 2
        yield stress: 1.0000E+00
        imposed stress max : 2.0000E+00
```

```
Warning message
*** Warning 20339 (STR+339)
     nodal contact forces are available only
     for the master side with node to surface
     contact types of interface #
```

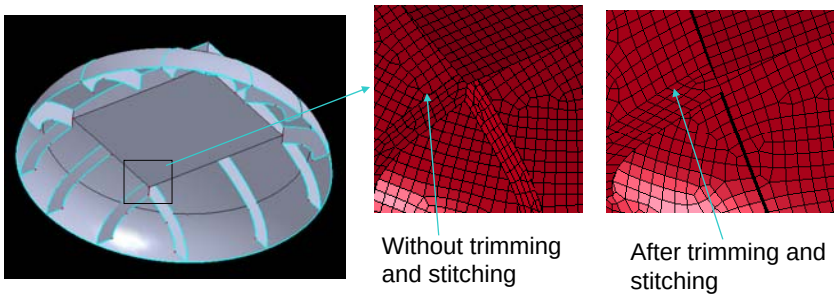
LS-PrePost 3.0

- LS-PrePost 3.0 is formally released May 2010
- Download: http://ftp.lstc.com/anonymous/outgoing/lsprepost/3.0
- New GUI in LS-PrePost 3.0 uses toolbar with icons and gives maximum graphics rendering space.
- New Geometry engine provides the capability to create, modify, and clean geometry data before meshing
- New Tool mesher for metal stamping applications is superior and much faster than the previous one
- Help menu now provides online documentation for all functionalities



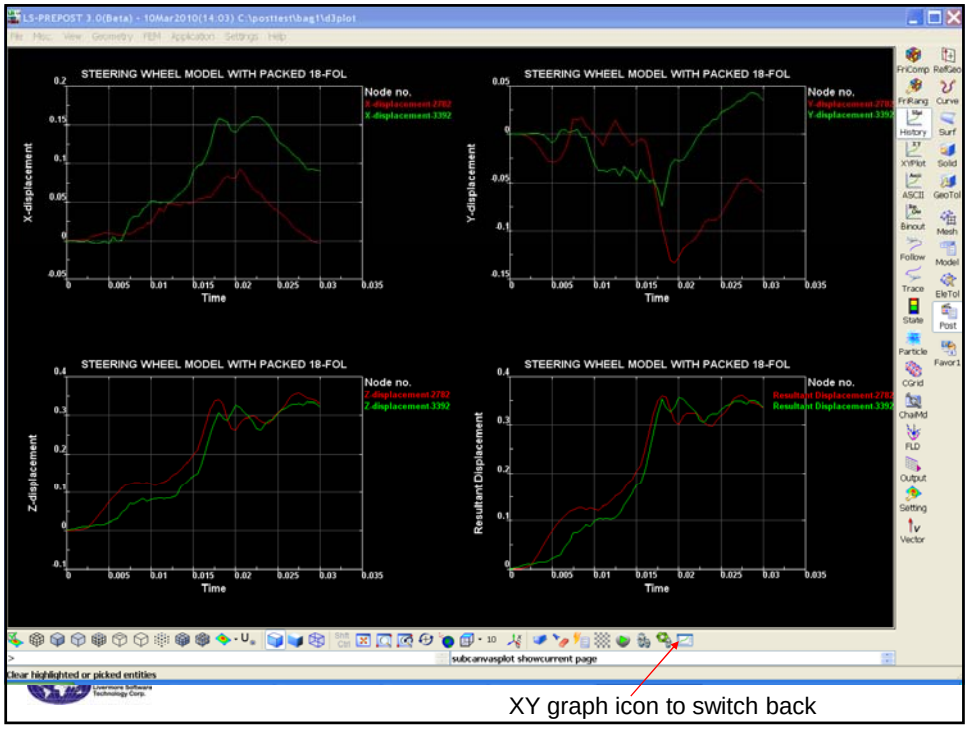
LS-PrePost 3.0

- Newly developed geometry processing engine allows bad geometry to be cleaned and modified. No need to later modify subsequent finite element mesh



LS-PrePost 3.0

- All LS971 Keyword data are supported
- Built in applications simplify:
  - Roller Hemming
  - ALE job setup
  - Granular flow
  - Airbag impact analysis
- Extended XY plot interface allows multiple plots per page (2x2, 3x3, etc.), multiple pages of XY plots are kept until deleted



LS980 solver summary

- New solvers in LS980 include:
  - An Eulerian compressible fluid solver
  - An electromagnetism solver
  - Lagrangian and ALE incompressible fluid solver
- All solvers feature 3D interaction with the structural solver.
- All are MPP enabled.
- The compressible flow and electromagnetism solvers are available for beta testing.
- The incompressible flow solver will be available for beta testing in late July, 2010.

CESE compressible fluid solver

- Conservation Element/Solution Element (CESE) Eulerian compressible fluid solver
  - 2D & 3D
  - Serial & MPP modes
  - Inviscid & viscous flows
- 3D Fluid / structure Interaction (FSI)
- Features
  - 2D axi-symmetric solver
  - Cavitating flow models
  - Stochastic particle modeling
  - Chemical reacting flows
  - Near-field Acoustics

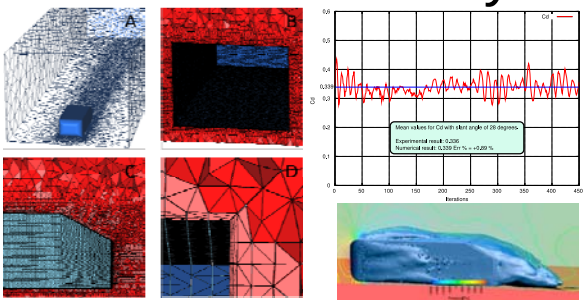
PFEM incompressible flow solver

- Based upon the Particle Finite Element Method (PFEM)
- Uses an ALE method with adaptive meshing
- Variable density flow
- Conjugate heat transfer
- Built-in LES turbulence modeling
- Implicit CFD and FSI analysis strongly coupled to implicit and explicit solid mechanics.
- High level mesh manipulation. Automatic volume meshing and run time re-meshing. Boundary Layer mesh.
- Free surface and multi-phase approximations.

Aerodynamics of a Bluff Body

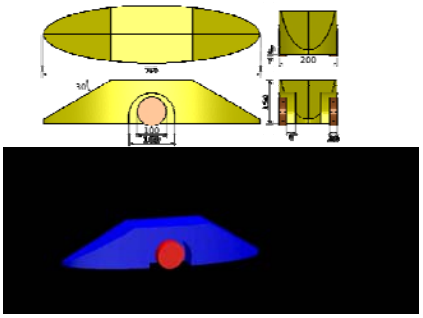
Ahmed Body Benchmark

* Incompressible Implicit CFD
* Reynolds Number 4.25e6
* Body-fitted mesh
* Boundary Layer mesh around vehicle body
* 1.7M Tet elements with 200K in the Boundary Layer
*Drag prediction within 1% of experimental data



Flow Around Wheel House and Rotating Tyre

* Study of the detached flow behind the wheelhouse
* Incompressible Implicit CFD
* Reynolds Number 9e5
* Boundary Layer mesh around vehicle and tyre
* 1.2M Tet elements with 250K in the Boundary Layer



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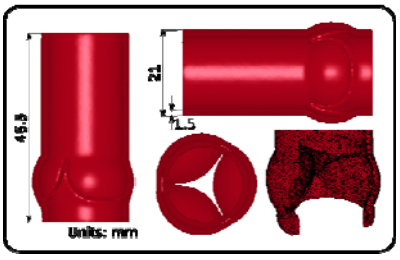
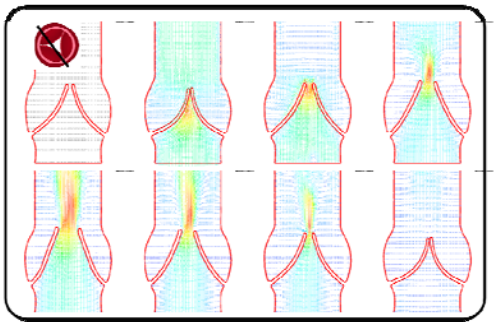
Heart Valve Simulation

* Strong Fluid-Structure interaction coupling is mandatory for bio-medical applications
* Miss-match fluid and structural mesh allows proper resolution for each domain
* Implicit CFD can couple with implicit or explicit solid mechanics





Electromagnetics Solver

- Electromagnetism module for 3D eddy-current problems which couples with the LS-DYNA structural and thermal solvers using a combined Lagrangian and boundary element method (BEM) approach
  - Boundary element method in the air coupled to finite elements in the conductor is used to avoid meshing the air.
- The EM fields, as well as EM force and Joule heating can be visualized with LS-PrePost.
- Example applications:
  - Electromagnetic free forming.
  - Electromagnetic flanging.
  - Electromagnetic forming with driver plate.
  - Strain rate parameter identification.
  - Electromagnetic tube welding.

LS980 electromagnetism

- MPP version available.
- Induction heating and resistive heating capabilities.
- Electromagnetism contact capability (rail gun, ...).
- Tetrahedral and wedge elements
- Small deck restart capability.

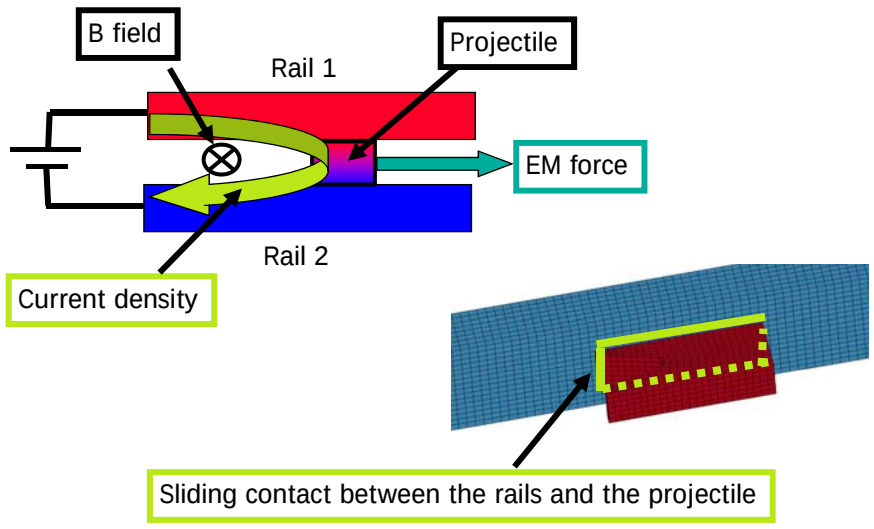
MPP run times

case	mesh1	mesh8	mesh16	mesh32	mesh64
#nodes	39,504	63,759	86,537	131,747	420,478
#elem	28,595	43,568	62,600	98,744	343,224
#BEM P	19,851	36,971	44,279	62,363	147,843
#BEM Q	39,688	73,920	88,532	124,688	295,648

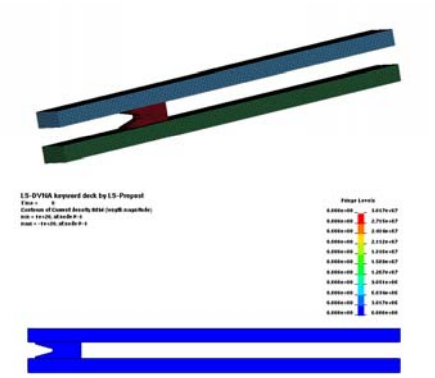
# cores	*Mesh1*	*Mesh8*	*Mesh16*	*Mesh32*	*Mesh64*
1	*24:16*	*55:41*			
2	*12:16*	*27:42*			
4	*6:28*	*14:13*			
8	*3:56*	*8:49*	*12:14*		
16	*2:29*	*5:15*	*7:34*	*15:53*	
32	*1:36*	*3:07*	*4:22*	*8:57*	*42:16*
64	*1:09*	*2:01*	*2:46*	*5:32*	*26:31*

Run time (hours:minutes)

Rail gun



Rail gun simulation (3D)



52,000 nodes
43,000 solid elements

Current density

B field

Dummies and barriers

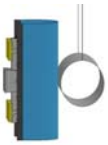
Dummy/barrier distribution

- For licensed LS-DYNA users
  - No separate licensing from LS-DYNA.
- Continuous updates and support from LSTC and LS-DYNA distributors
- The models generated by LSTC use TrueGrid® parametric meshing

Dummy/barrier distribution

- Feedback to LSTC on model performance is encouraged
- Companies may improve models and keep the improvements proprietary
- Companies may redistribute their improved models to their suppliers and subsidiaries for LS-DYNA simulations

Dummy model update



Available LSTC Dummy Models

- EuroSID 2re (Dynamore)
- EuroSID 2 (Dynamore)
- SID-IIs D
- Hybrid III 50th percentile (NCAC)
- Hybrid III Rigid-FE Adults
- Hybrid III 50th standing Rigid-FE
- USSID
- Free Motion Headform
- Pedestrian Legforms

All available models can be downloaded from LSTC's ftp site: http://ftp.lstc.com/user/

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Dummy model update

Model	Parts	Nodes	Number of Elements					
			Shell	Beam	Solid	Rigid	Deformable	Total
USSID	69	43868	12803	2712	41517	9914	47120	57034
Rigid-FE	96	4013	2054	1195	322	768	2810	3578
SID-IIs D	308	420816	7444	3823	307598	103050	215822	318872
ES-2	309	424433	20111	79	313363	121918	211647	333565
ES-2re	315	426201	20651	79	314138	122616	212264	334880
FMH	8	22467	2650	0	14462	8262	8850	17112
Legform	29	47402	2960	2	33664	21184	15445	36629
Upper Legform	22	50151	4902	0	29136	17488	16550	34038
Hybrid III 50th	363	228643	210439	242	186808	2338	395152	397490
Hybird III 95th Rigid-FE	116	7444	1636	3	2648	2453	1842	4295
Hybird III 50th Rigid-FE	116	7444	1636	3	2648	2453	1842	4295
Hybird III 5th Rigid-FE	116	7444	1636	3	2648	2453	1842	4295

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Dummy model update

LSTC Dummy Models in Development

- Hybrid III 3-year old
- Hybrid III 6-year old
- SID-IIs D Rigid-FE
- Hybrid III 5th percentile female
- Hybrid III 95th percentile
- BioRID II

LSTC

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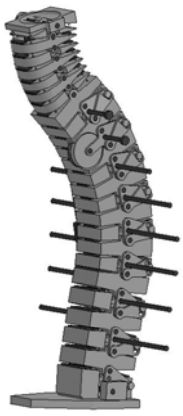
Dummy model update



BioRID II Update:

- Spine mesh complete
- Thorax flesh mesh complete

From LSTC's Hybrid III 50th percentile dummy model:

- Modified Hybrid III 50th head
- Modified Hybrid III 50th pelvis mesh
- Hybrid III 50th arms
- Hybrid III 50th legs

Certification test data received

Collaboration partners for development found

LSTC

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Dummy model update

Estimated Release Dates*

Hybrid III 3-year old	Summer 2010
Hybrid III 6-year old	Fall 2010
SID-IIs D Rigid-FE	Summer 2010
Hybrid III 5th percentile female (NCAC)	Summer 2010
Hybrid III 95th percentile (NCAC)	Winter 2010
BioRID II (Dynamore)	Fall/Winter 2010

*Estimated release dates cannot be guaranteed and may be delayed due to various circumstances.

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Dummy model update

Planned Dummy Models

- RigidFE versions of EuroSID 2 and EuroSID 2re
- Q-series child dummies
- Future Pedestrian Legform Impactors
- WorldSID

For questions, suggestions, or if you want to support our dummy model development, please contact us at atds@lstc.com .

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LSTC Barrier Models Update

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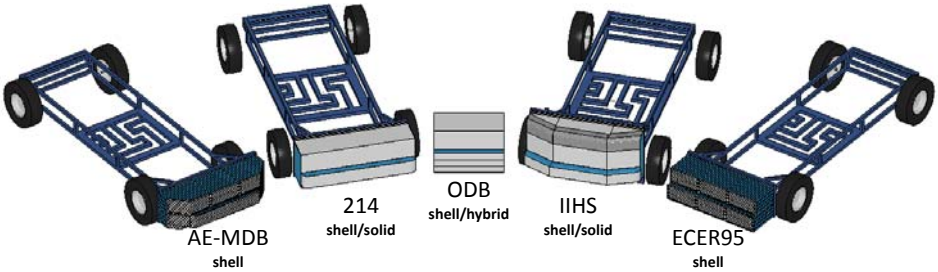
LSTC barrier models

- LSTC.ODB.100224_V2.0
- LSTC_214_SOLID_BARRIER.102408_V3.0
- LSTC_IIHS_SOLID_BARRIER.102408_V3.0
  - Honeycomb material coordinate system defined using –AOPT for easy positioning.
- LSTC_ECER95_SHELL_BARRIER.090625_V2.0
  - Addition of airbags and venting of trapped air
- LSTC_214_SHELL_BARRIER version 2 is released
  - 7 additional tests cases are added for barrier validation
- LSTC_AEMDB_V3.10_SHELL_BARRIER is released

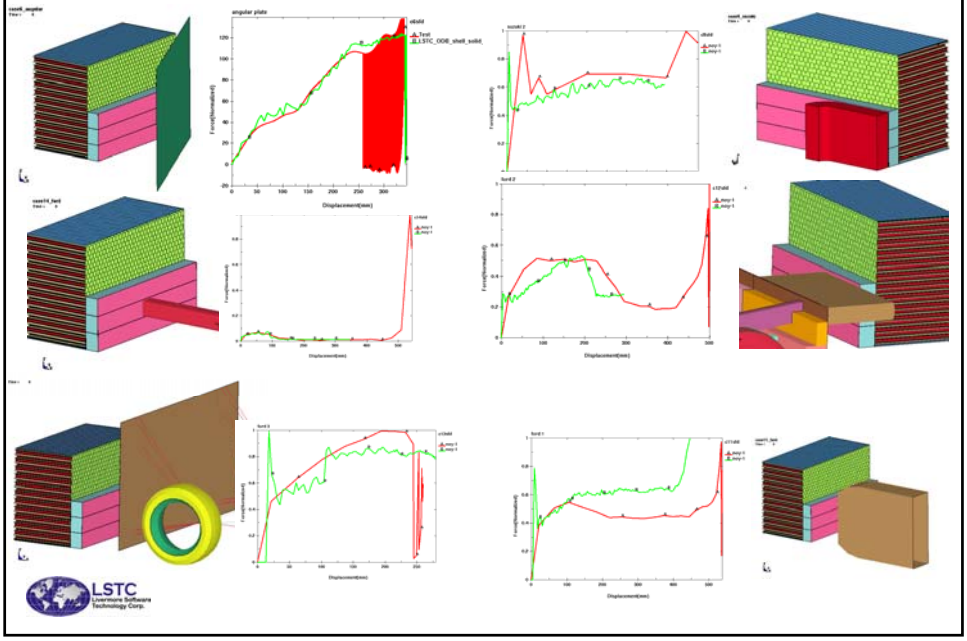
- UNITS
  - All LSTC barriers use the *mm-ms-kg-kN* unit system. Unit system conversion can be done by the *INCLUDE_TRANSFORM keyword.

- Contact Dilip at dilip@lstc.com for more information

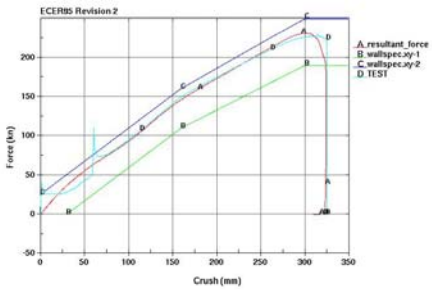
LSTC family of barriers

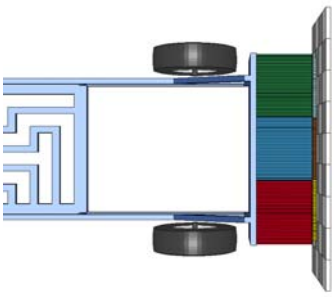


LSTC ODB shell results



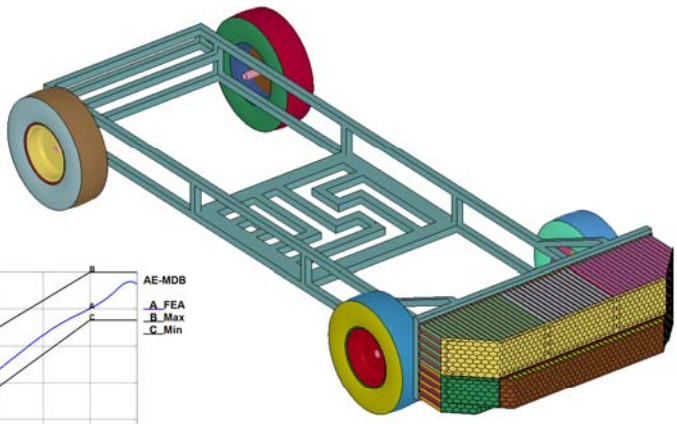
ECE rev 95

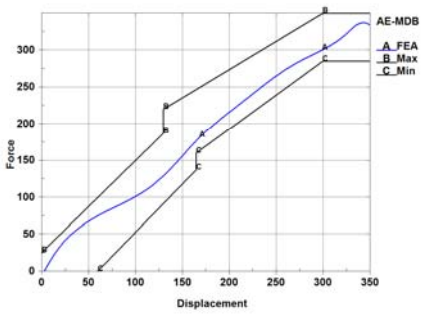




Flat wall Impact Setup

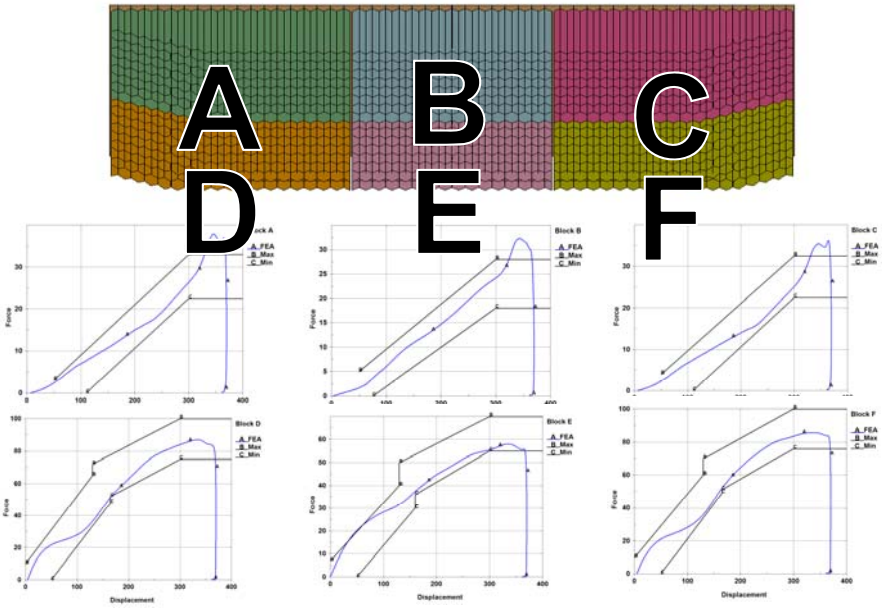
LSTC AE-MDB v3.10





Shell element version was developed at the request of an OEM
Validated according to Version 3.10

Block results

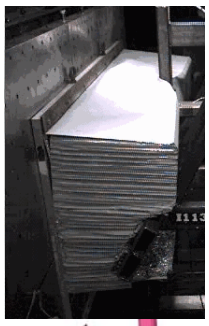


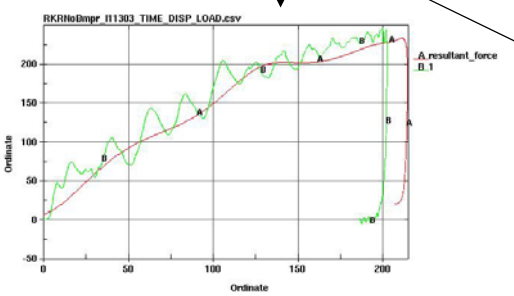
214 side impact barrier

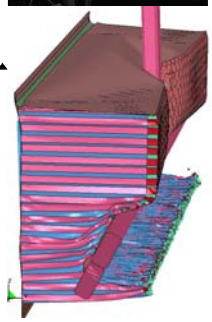
Shell version has been validated with 7 additional test cases

- Case2 - 0 degree Flat wall
- Case3 - Pole impact
- Case4 - 15 degree angle
- Case5 - 30 degree angle
- Case6 - 100 % rocker
- Case7 - 50 % rocker
- Case8 - 100 % no bumper

Version2 is now released







Hybrid LS-DYNA

Scalability

For multi-core/multi-socket clusters

- Scaling for a large number of processors, typically larger than 128, is not always good.
- An approach is available in the recent R5 which runs SMP within each processor and MPP between the processors.
- It is named **Hybrid LS-DYNA**.
- If the number of SMP threads per processor is increased, the results remain identical.
- To run the Hybrid option both SMP and MPP variables are set.

Scalability

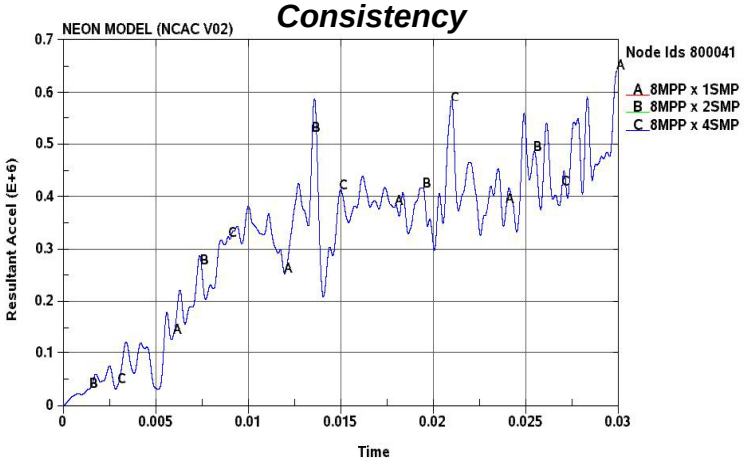
For multi-core/multi-socket clusters

- Setting variables
  - Consider a 16 node, dual socket, quad-core system:
    - A total of 128 processor
    - Set OMP_NUM_THREAD=4 (max four cores in each SMP)
  - mpirun –np 32 mpp971_hybrid i=input *ncpu=-1*
    - 32 Processors and 1 core in each = 32 cores
  - mpirun –np 32 mpp971_hybrid i=input *ncpu=-2*
    - 32 Processors and 2 cores in each = 64 cores
  - mpirun –np 32 mpp971_hybrid i=input *ncpu=-4*
    - 32 Processors and 4 cores in each =128 cores

Scalability

For multi-core/multi-socket clusters

Consistency

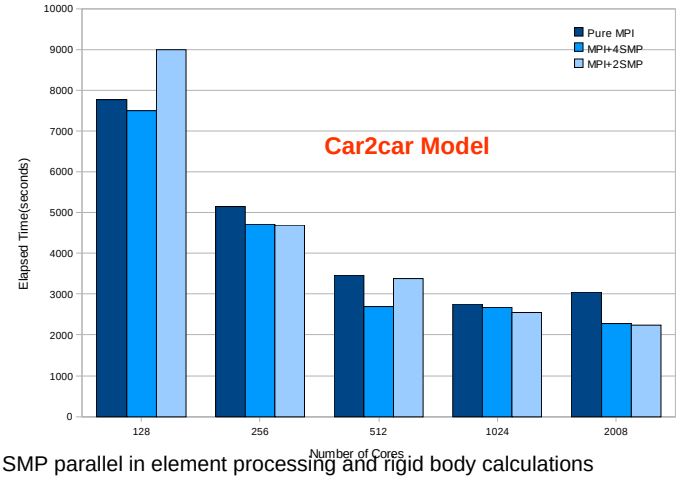


- Consistent results are obtained with fix decomposition and changing number of SMP threads

Scalability

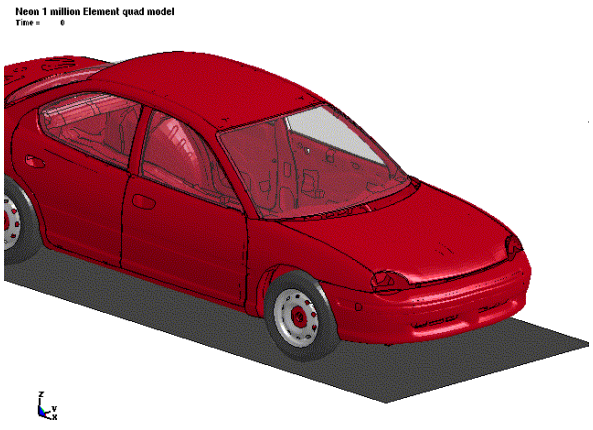
Multi-core/Multi-socket clusters

Performance Comparison on Windows Server 2008



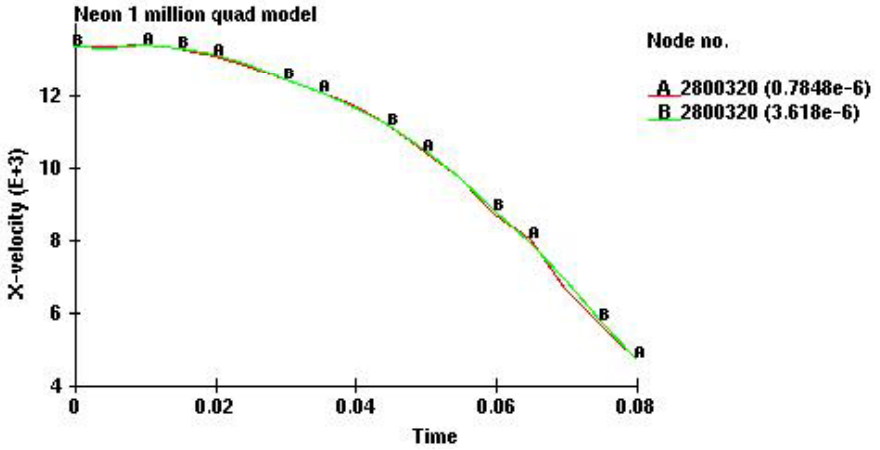
- SMP parallel in element processing and rigid body calculations
- SMP directives are now added to the MPP Contact---not reflected above

NCAC Neon 1 million elements



1056383 quad shells
130 beams
2852 solids
1 contact for the entire model
Termination time 0.080 secs
Timestep 3.618e-6 secs
Ascii and binary outputs disabled.
Pre-decomposed with 1cpu

NCAC Neon 1 million elements



NCAC Neon 1 million elements

128x2x4 Dt=7.85e-7 8% mass increase Conventional mass scaling	6 minutes 18 secs
128x2x4 Dt=3.618e-6 Selective mass scaling Ongoing development to support more features for selective mass scaling	5 minutes