New Developments in LS-DYNA®

Part I

LS-DYNA Users Conference

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Outline of talk

- Part I
  - Introduction
  - Version 980
  - New features in version 971 release 3
- Part II
  - New features in version 971 release 4
  - Conclusions

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LSTC products

- Our developments are concentrated on five products:
  - LS-Dyna
  - LS-Opt
  - LS-PrePost
  - FE Models: Dummies, barriers, head forms
  - USA (Underwater Shock Analysis)
- LS-PrePost, LS-Opt, the FE models and are part of the LS-Dyna distribution and do not require license keys.

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USA Developments

- LSTC completed purchased of USA with all intellectual rights in 2007.
- USA Version 6.51 is released with LS971 R2
- Versions beginning with 6.29, offer “non-conformal” Doubly Asymptotic Approximation (DAA) elements
  - Comparable results between nonconformal overlays, conformal overlays and 1-to-1 DAA meshes
- Cavitating Acoustic Spectral Element (CASE), a spectral volume element solver in version 6.51
  - Also released with LS971_R2 as executable separate from DAA solver (i.e., lsdyna.case vs.lsdyna.usa)

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Applications of LS-Dyna

- Automotive
  - Crash and safety
  - Durability
  - NVH
- Aerospace
  - Bird strike
  - Containment
  - Crash
- Manufacturing
  - Stamping
  - Forging
- Structural
  - Earthquake safety
  - Concrete structures
- Electronics
  - Drop analysis
  - Package design
  - Thermal
- Defense
  - Weapon design
  - Blast response
  - Penetration
  - Underwater shock analysis
- Also, applications in biomedical, sports, consumer products, etc.

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One code strategy

Combine the multi-physics capabilities

- Explicit/Implicit solver
- Heat Transfer
- ALE
- EFG, SPH, Airbag particle method
- Incompressible fluids (version 980)
- CESE compressible fluid solver (version 980)
- Electromagnetics (version 980)
- Acoustics
- Interfaces for users, i.e., elements, materials, loads

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

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Development goals

- Reduce customer costs to encourage and enable massively parallel processing
  - Multicore processors have resulted in a drastic reduction is computer hardware costs and a huge increase in LS-DYNA licenses worldwide
  - Two approaches used by LSTC to help reduce costs:
    - Unlimited site licenses
    - Steeply decreasing licensing fees per processor as the number of processors increase

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Development goals

- Further reduce customer costs by increasing computational speed and improving scalability
  - By continuously recoding existing algorithms and developing new more efficient methodologies
  - Ensuring that LS-DYNA is the fastest and most scalable software available
- And reduce costs by providing FEA models and peripheral software
  - LS-Dyna dummy and barrier models
  - LS-Dyna dedicated pre and post processing software
  - LS-Dyna specific optimization software

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Ultimate development goal

- Simulation results accepted in place of prototype testing
  - What is required?
    - Continued software improvements in LS-DYNA
      - Implicit-explicit compatibility and robustness
      - Constitutive models
      - Contact
      - FSI with SPH, ALE, Particle methods, etc.
      - Sensors and control systems
      - Improved element technology
    - Manufacturing simulations providing the initial geometry, with stress and strain distributions
    - Massively Parallel Computing

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LS-PrePost

- LS-PrePost 2.3 and 2.4 can be freely download from ftp://ftp.lstc.com/outgoing/lsprepost/2.3 or ftp://ftp.lstc.com/outgoing/lsprepost/2.4
- License key is not required for LS-PrePost
- LS-PrePost 2.3 is the current release, will be updated with bug fixes
- LS-PrePost 2.4 is beta version, new features will only be added to version 2.4
- 64bit version is available for both Unix, Linux, Win64 and Vista
- Online resources:
  - Documentation: http://www.lstc.com/lspp
  - Tutorials: http://www.lstc.com/lspp/content/tutorials.shtml
  - What's new: http://www.lstc.com/lspp/content/news.shtml
  - Frequently Ask Questions: http://www.lstc.com/lspp/content/faq.shtml
  - Users group: http://groups.google.com/ group/ls-prepost

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New features

- Added support for additional new keywords: (not a complete list)

  *BOUNDARY_PRESCRIBED_ORIENTATION_RIGID_VECTOR, *CONTACT_TIEBREAK_SURFACE_TO_SURFACE_ONLY, *DATABASE_DCFAIL, *DATABASE_ELOUTDET, *DATABASE_BINARY_BINOUT, *DATABASE_BINARY_BLSTFOR, *DATABASE_ATDOUT, *DEFINE_CONNECTION_PROPERTIES, *DEFINE_CONNECTION_PROPERTIES_ADD, *DEFINE_HEX_SPOTWELD_ASSEMBLY, *ELMENT_BEAM_SECTION_ORIENTATION, *ELMENT_MASS_MATRIX, *ELMENT_MASS_MATRIX_NODE_SET, *INITIAL_AXIAL_FORCE_BEAM, *INITIAL_CESE_CONSTANT, *LOAD_SEGMENT_SET_ANGLE, and *MAT_SPOTWELD_DAIMLERCHRYSLER
- Added 2D ALE post-processing capabilities: display ISO surface, fringe fluid material groups, and plot group histories
- Added thermal analysis post-processing capabilities: plot histories and fringe rate of change of temperature per node
- Added support for reading *DCFAIL* in the ASCII Interface
- Added support for reading and displaying Altair binary format (ABF) files
- Added ability to display any combination of principal stress and strain vectors (X, Y, and/or Z)
- Added ability to read PamCrash input data file (limited conversion)

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New features

- A more robust Metal forming Application setup
  - Metal forming application setup GUI
  - User's keyword templates
  - Automatic tooling positioning
  - Draw bead modeling
  - Material Library
  - Stamping operations
  - Single and multistage process
  - Rigid body motion preview
  - Full run LS-DYNA input deck generator
- Roller Hemming Processes
  - Flange bending use robotic hemming rollers
  - Support multi-roller definitions
  - Roller motion curves automatically generated
  - Easy simulation job setup
  - Use LS-DYNA explicit solver

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Version 980

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Version 980

- Version 980 has been under development for 5 years
- Adds to the multi-physics capabilities
  - Electromagnetics
  - Incompressible fluid solver
  - Compressible fluid solver based on CESE
- Full structural and thermal coupling between solvers

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Incompressible flow solver

- Incompressible fluid solver.
- Error Control and adaptive re-meshing MPP implementation.
- Separate meshes for fluid and structure.
- Allows weak and strong FSI coupling depending upon the problem.
- Coupling to explicit and implicit structural solvers
- Multifluid and Free-Surface flows.
- LES and RANS turbulent models

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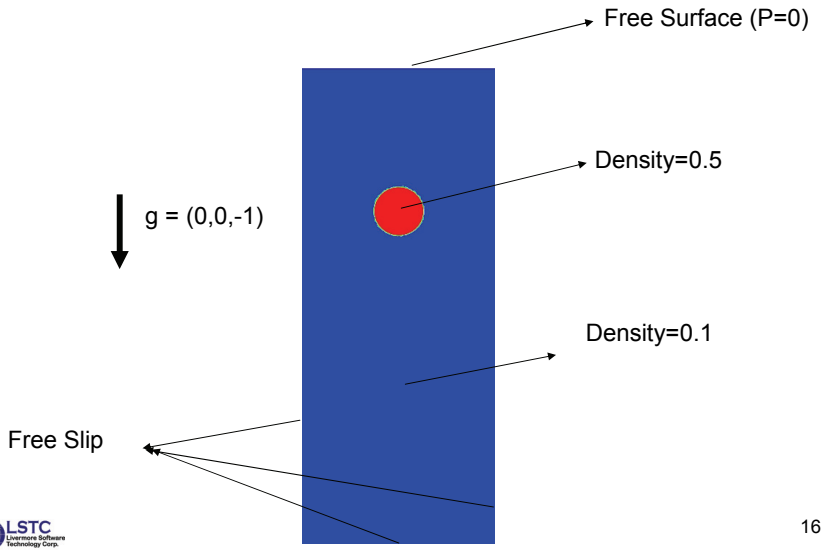
Bubble Drop: High Resolution Interface Capturing and Adaptive Re-Meshing



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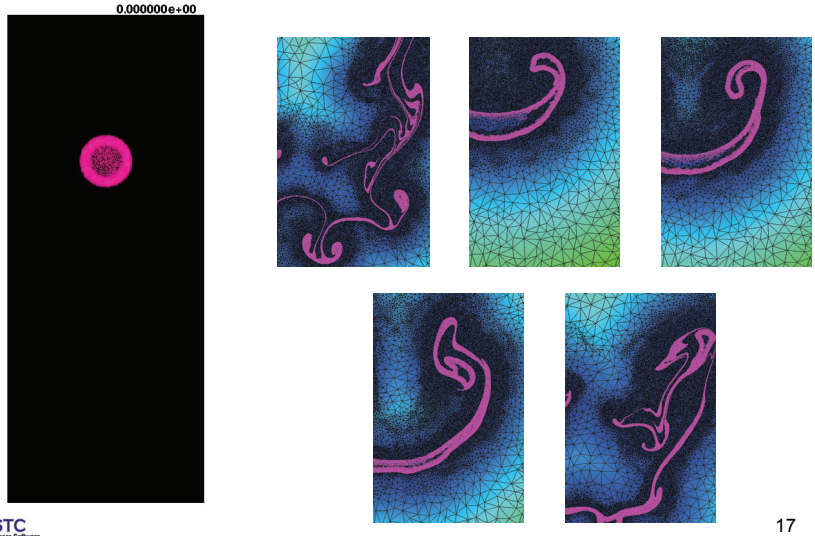
Bubble Drop: High Resolution Interface Capturing and Adaptive Re-Meshing



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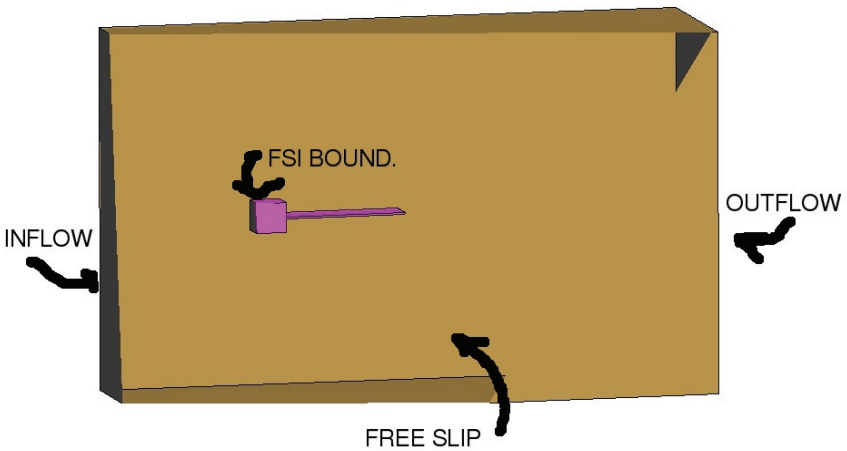
Flexible Beam With Error Control



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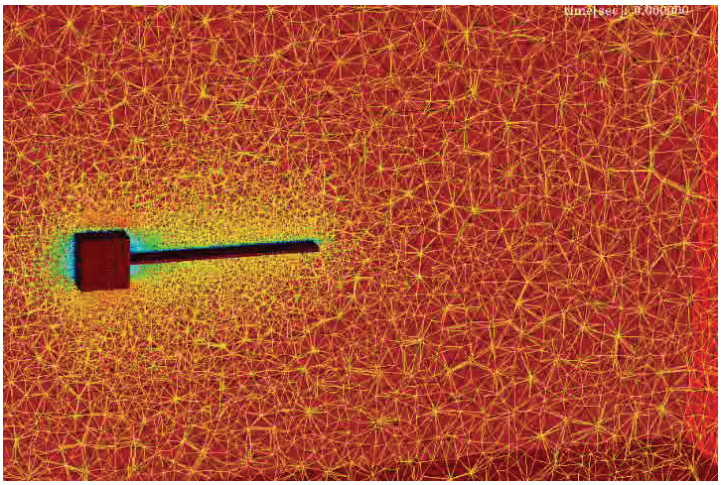
Velocity Field and Mesh



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CESE Method

- Advantage of CESE method for compressible flow:
  - Compressible inviscid & viscous flows
  - Hexahedra, wedges, tetrahedra
  - *Flux* conservations in *space and time* 2nd order accurate
  - Novel & simple shock-capturing strategy
  - Both strong shocks and small disturbances can be handled very well simultaneously
  - Boundary conditions can be implemented easily & accurately
  - MPP is fully implemented with excellent scalability

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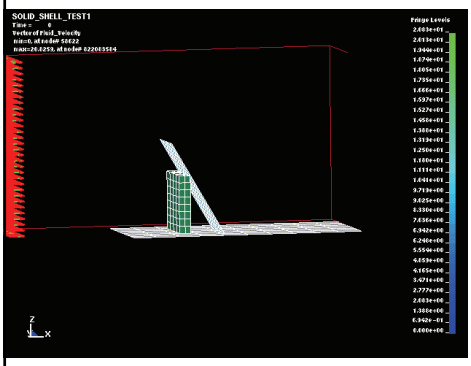
FSI with CESE



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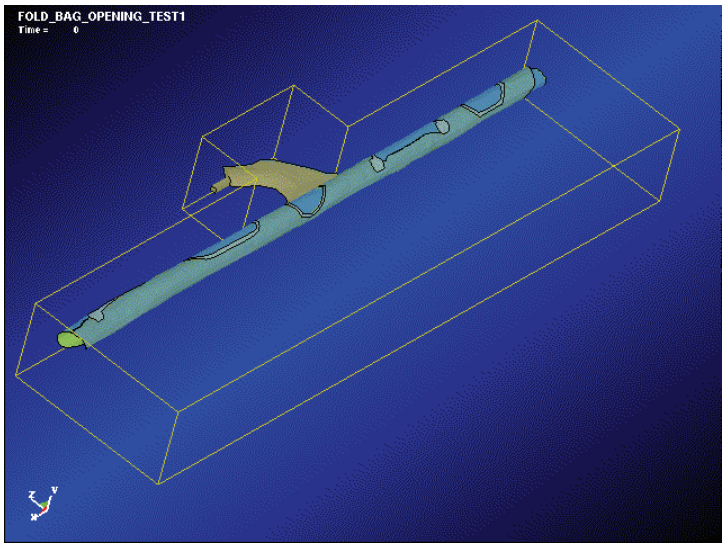
FSI with CESE



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Version 971_R3 developments

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Release of version 971_R3

- Version 971_R3 is compatible with the new LS-Dyna manual. Printed copies of the manual are now available.
- Froze new developments on September 1, 2007
  - Adding minor changes and updates as requested by beta users
  - First release is now available
- Major new developments are now added to version R4 and later releases.

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*Contact_force_transducer

- Scalability of LS-DYNA to hundred's of processors is limited by contact
  - Scalability for 1-2 contact definitions covering the entire vehicle is excellent
  - Scalability for 100's of contact definitions diminishes significantly as the number of processors increase
- Starting in version 971_R2 an optional master surface can be defined such that the reaction force is accumulated by the interactions of the slave and master surface

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Groupable contact option

- Users often prefer multiple contact definitions and resist changing to a single surface definitions with force transducers
- For these customers the *groupable* contact option is available. The contact definitions are internally combined in LS-Dyna to allow all contacts to be treated simultaneously across all processors

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Contact Comparison Example

- Test case
  - 75 SURFACE_TO_SURFACE contacts
  - 1151856 nodes
  - 1116160 shell elements
- Runs were completed using all cores on each node
  - 4 cores per socket, 2 sockets per node

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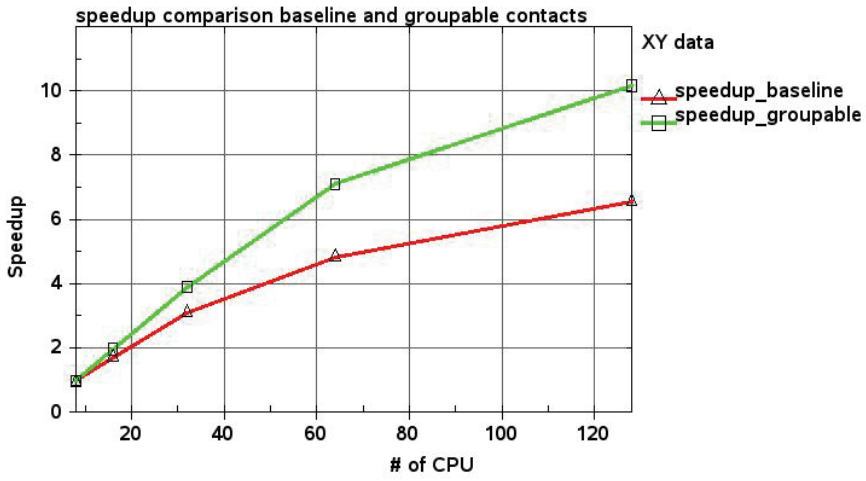
Baseline vs groupable



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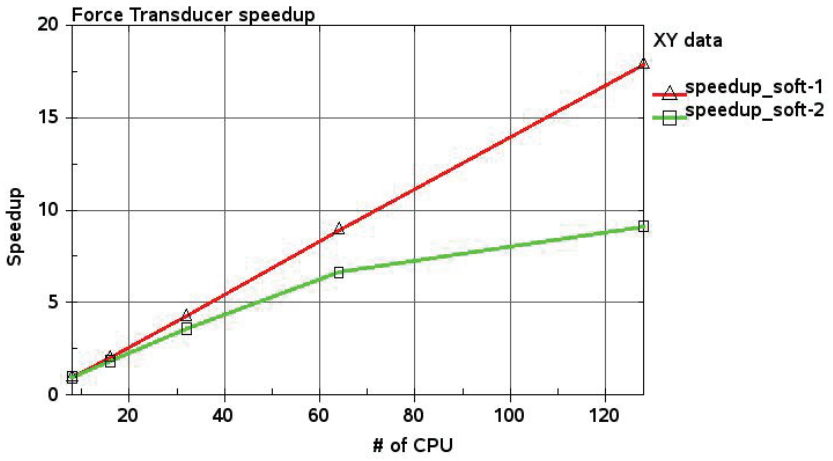
Force Transducers : soft=1 vs.2



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MPP Implicit Performance

- AWE Benchmark Problem – CYL1E6
  - 6 nested cylinders with contact between them
  - 921,600 Solid Elements
  - 1,014,751 Nodes
  - 3,034,944 Order of Linear Algebra Problem
  - 1 Nonlinear Implicit Time Step, 2 Factors, 2 Solves, 4 Force Computations
- SGI XE 16 node cluster with 2 quad core processors per node on May 2, '08

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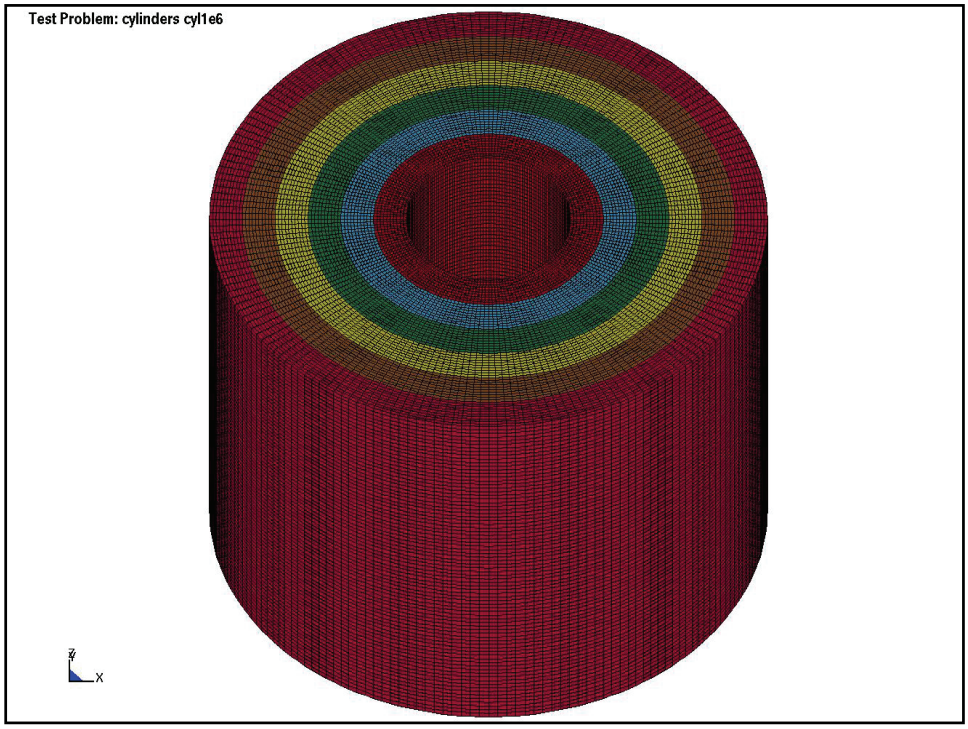

MPP Implicit Performance

No. of Processors	Elapsed Time	Speed Up	Single Factor	Single Solve
4	36911		16198	365
8	18443	2.0	8511	207
16	9012	2.0	4243	15
32	5263	1.7	2413	15
64	3073	1.7	1341	11
128	2313	1.3	916	34

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Wall Clock Time in Seconds

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MPP Implicit Performance

- Elapsed Time and Factor Time scales well.
- Solve time does not.
- Out-of-memory storage for factorization (used for large problems) really slows down parallel solves.
- It is okay to use all of the cores on each node of a cluster but using half of them may be better for overall performance.
- For eigenvalue problems use only 1 or 2 cores per node due to I/O considerations.

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Future? MPP hybrid (R4)

- LSTC is currently working with Intel and Fujitsu to improve scaling at large number of processors
- On 4 core processors, a hybrid implementation is possible where SMP is used on the processor/socket, and MPI between processor/sockets.
  - No problem for LS-DYNA since SMP directives coexists with MPI directives in source.
    - No significant software modifications of LS-DYNA, mainly MPI related.
- The hybrid implementation begins to show speed advantages for large number of processors. (3 car crash)

	Pure MPI	Hybrid base	Hybrid tuned
64c(16x4)	2802s	4567s	
128c(32x4)	1786s	2348s	
256c(64x4)	1425s	1455s	1292s

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Encrypted input

- Encryption is now available to protect proprietary material input data
  - Uses openPGP standard format, so data can be encrypted with widely available tools such as pgp
  - Public key encryption with 1024 bit DSA key and 128 bit AES
  - Any subset of input lines may be encrypted except *INCLUDE statements, and initial *KEYWORD
  - Multiple encrypted sections allowed, without limitation
  - Material properties defined in encrypted blocks will not be echoed to d3hsp or other output files.

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New network license server

- Until now, LS-DYNA used a single server to handle network licensing. When the server dies, initiating new runs is prohibited.
- We have now extended our license server into a Redundant Network License Server
  - License servers work in tandem. No problem if one dies.
  - Full recovery after restart even if all servers fail
  - Enhanced logging and diagnostics + remote diagnostics
  - Uninterrupted by changes in redundant servers
  - License file format adds new keys for servers & ports
  - Preferred license server order can be changed by customer
  - Port numbers can be changed by customer
- Testing at several large-customer sites is underway

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Particle method

- A particle method is now available for airbag deployment in the R3 release
  - Compared to ALE
    - Simpler input
    - Order of magnitude faster
    - More reliable results with tightly packed side curtain airbags

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Particle method

- Gas mixtures
- Moving point sources and multiple inflators
- Airbag deployment in moving vehicle
- Robust contact algorithms for tightly folded bags
- Fabric porosity
- Treat external and internal vents
- Blockage considered for porosity and venting
- Switch from particle method to control volume to save CPU time
- Serial, SMP, and MPP support

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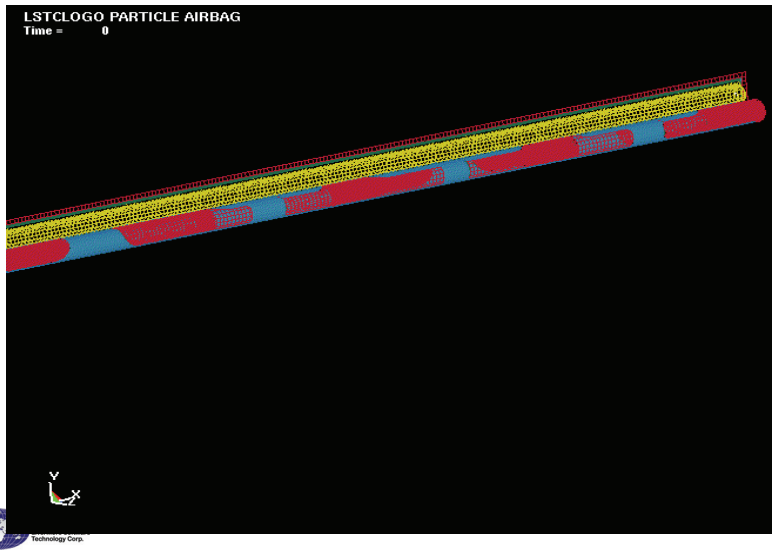
Particle method curtain bag



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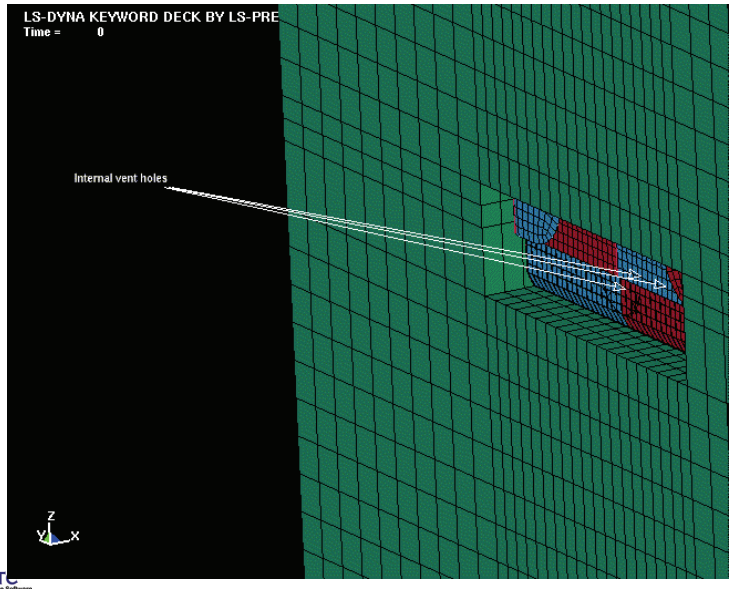
AIRBAG _PARTICLE Internal vents



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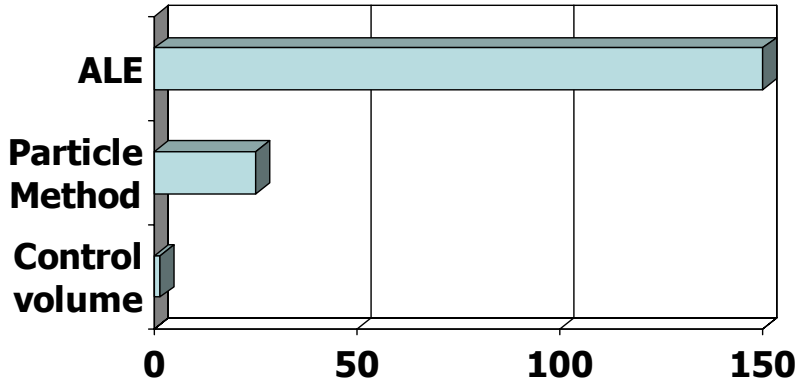
CPU minutes for the 3 methods



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Conclusions

- Dummy models
  - Rigid/FE H3 dummies are now available
  - SID IIs alpha version is released
  - H3 NCAC 50% dummy will be available by years end
  - H3 NCAC 5% and ES-2RE dummy development are underway
  - Child dummy development will start next year
- New CFD options and Electromagnetics are available in version 980
  - MPP implementation
- Version R3.2
  - Many new features including Airbag Particle Method

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