LEVERAGING MUMPS TO ENHANCE PERFORMANCE OF ALTAIR SOLVERS

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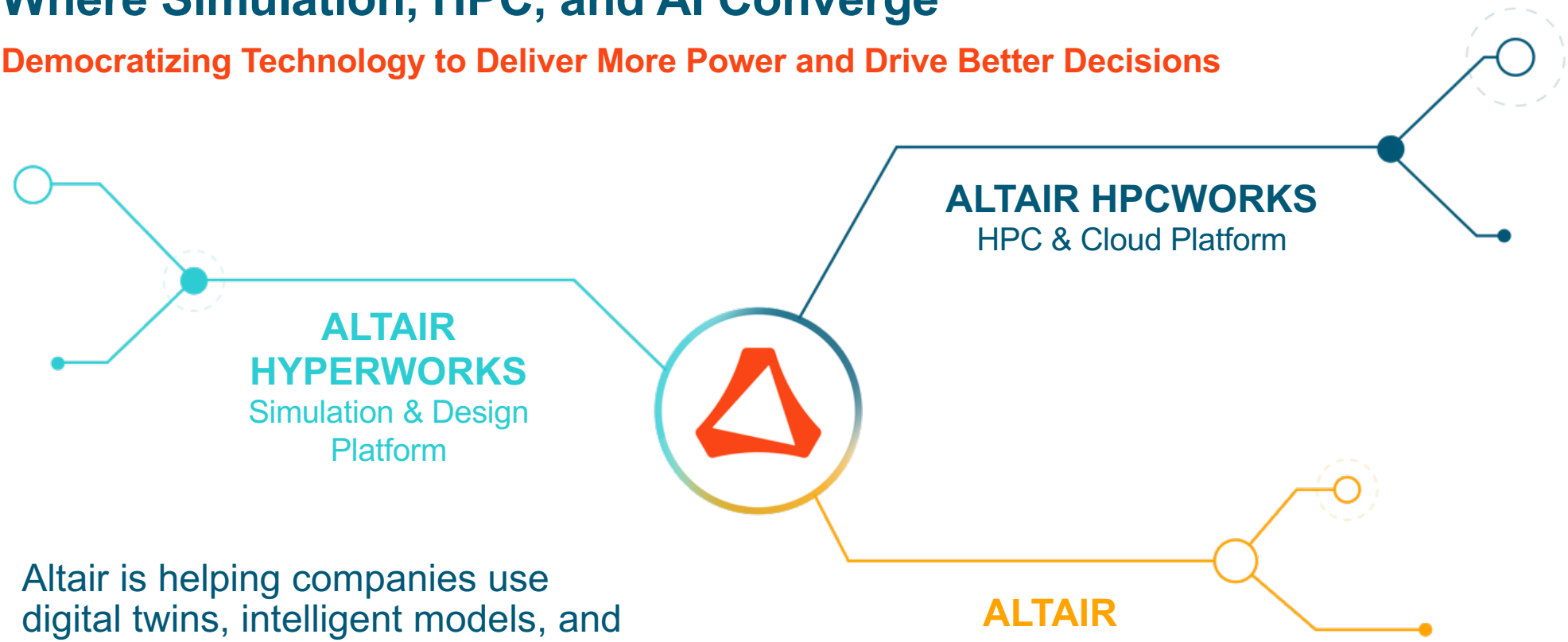
Where Simulation, HPC, and AI Converge

Democratizing Technology to Deliver More Power and Drive Better Decisions



Altair is helping companies use digital twins, intelligent models, and the convergence of simulation, HPC, and AI to predict and optimize system outcomes

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Altair-at-a-Glance

$572M
FY22 Revenue

74
Offices in 27 Countries

3,000+
Engineers, Scientists, and Creative Thinkers

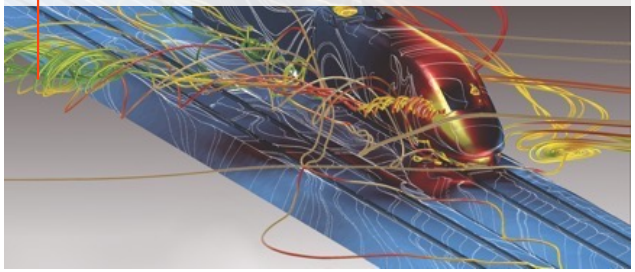
150+
Altair and Partner Software Products

13,000+
Customers Globally

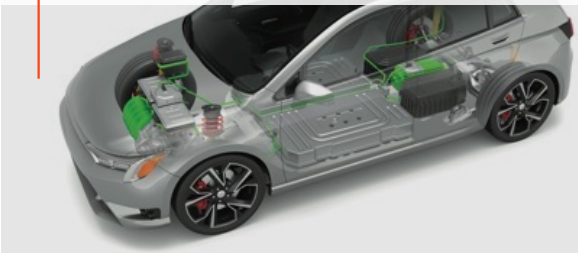
Broad Solutions Portfolio

Data Analytics / AI

Physics Simulation



Design, Modeling & Visualization



Internet of Things

High-Performance Cloud Computing

Altair Partner Alliance (APA)

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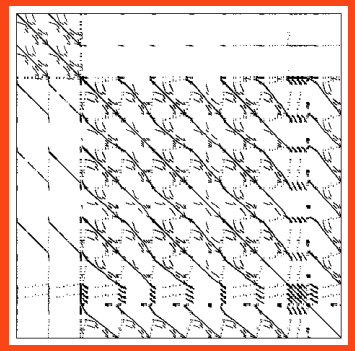
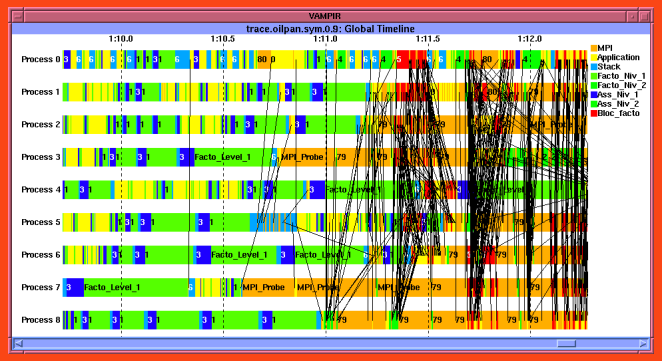
ALTAIR PARTNERSHIP WITH MUMPS





Courtesy of MUMPS Technologies

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A Fruitful Collaboration Story with MUMPS

Radioss® using MUMPS for implicit

2012: Integration of MUMPS in OptiStruct®

2013: Altair acquired Feko®

2014: Altair joined the consortium at its beginning

2016: Altair acquired Flux®

2019: Collaboration project MUMPS on GPUs

Altair's continuous support as a gold member since the start of MUMPS Technologies

P2P meeting in Grenoble in 2017

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ALTAIR OPTISTRUCT™

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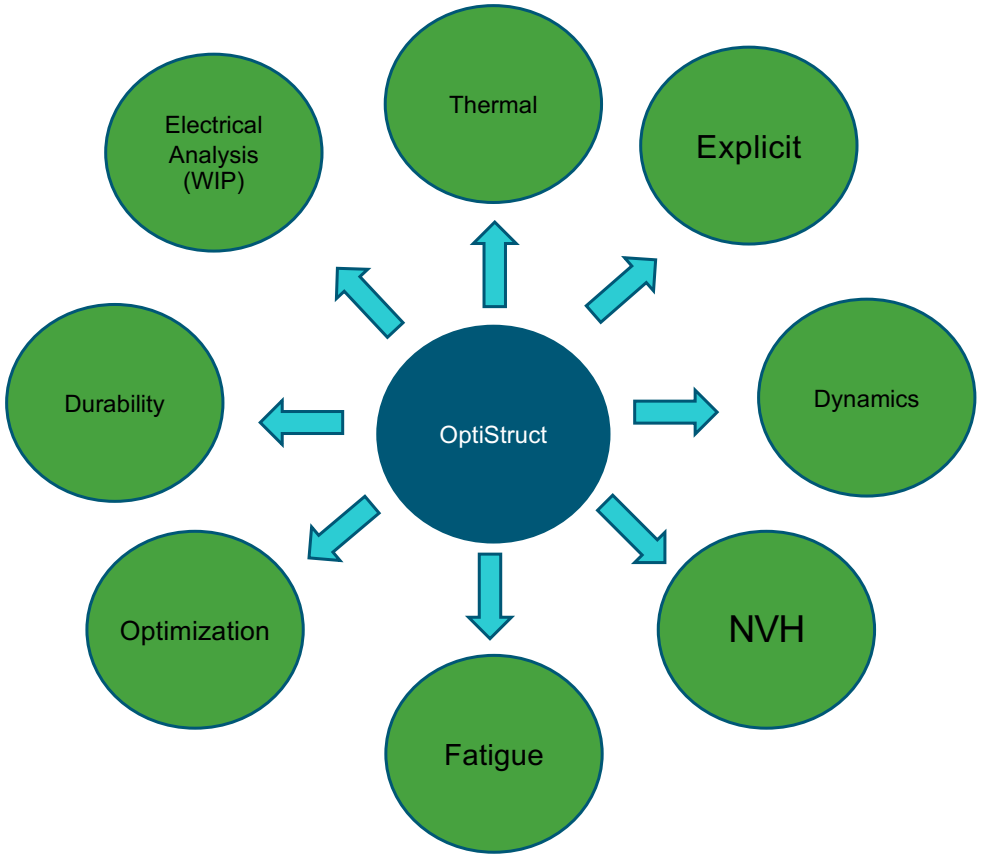
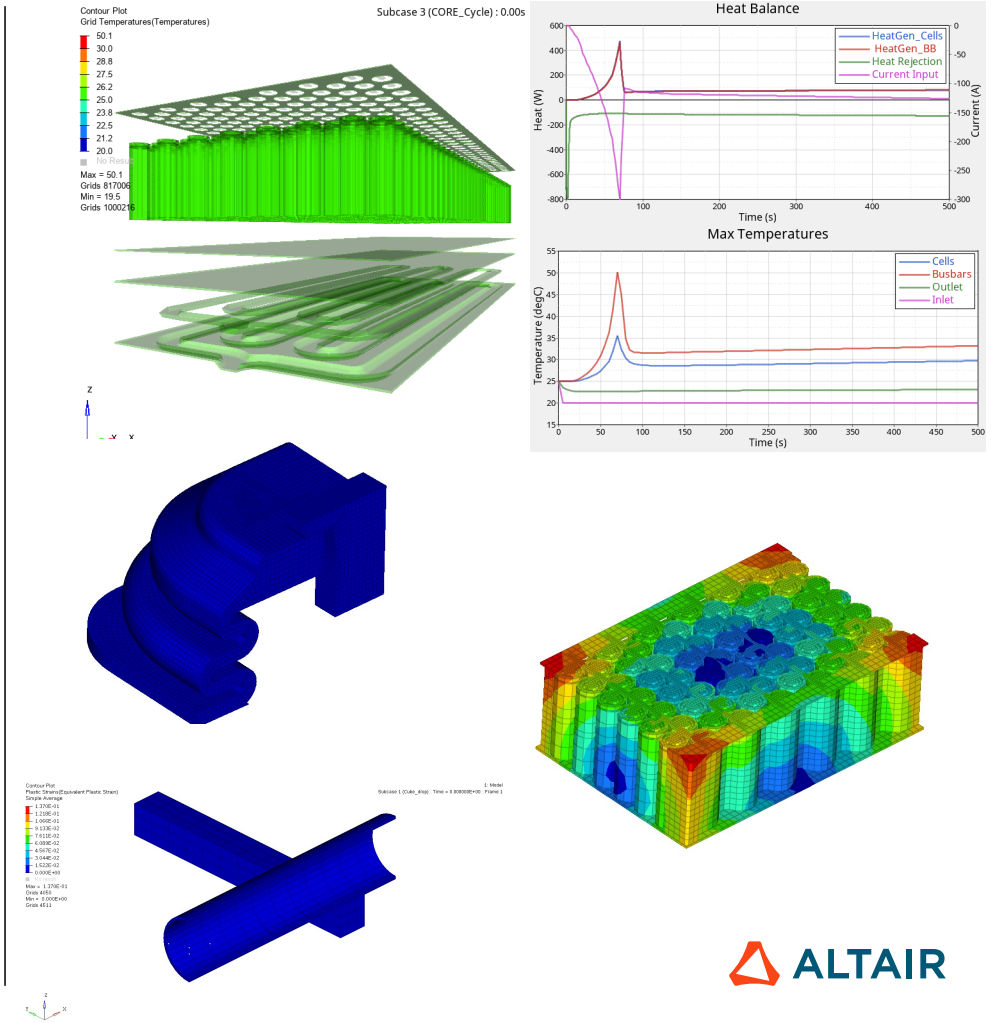
Altair OptiStruct™ - Complete and Competitive Solutions





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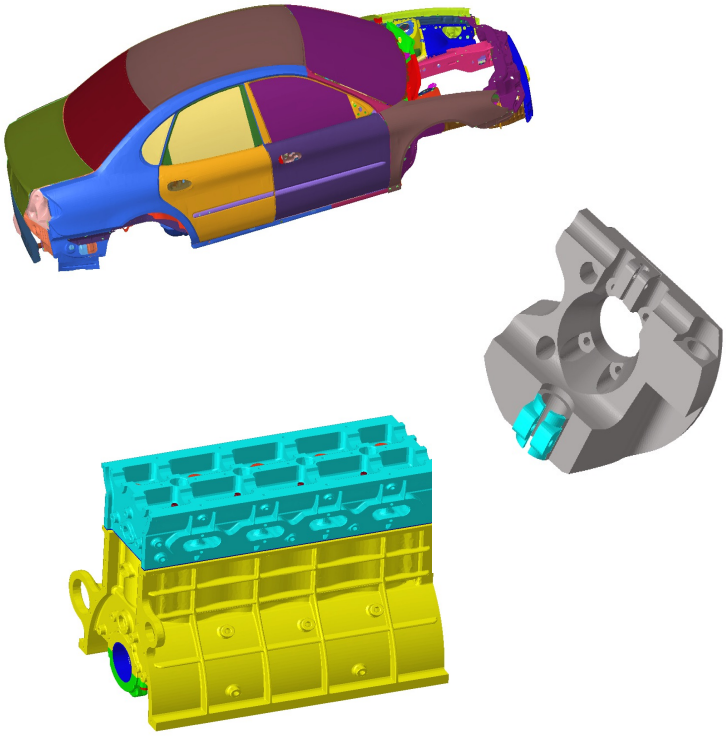
Benchmark MUMPS 5.6.0consortium

Standard Public Models:

- Carbody
  - High order shell, 18M DoF, Linear static
- Knuckle
  - Solid, 8.5M DoF, Linear static
- Engine
  - Solid, 4.6M DoF, Nonlinear static



Cluster test:
8 nodes with 512 GB RAM
Intel E5-2697A v4 32 cores @ 2.60GHz

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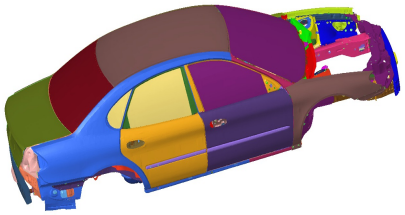
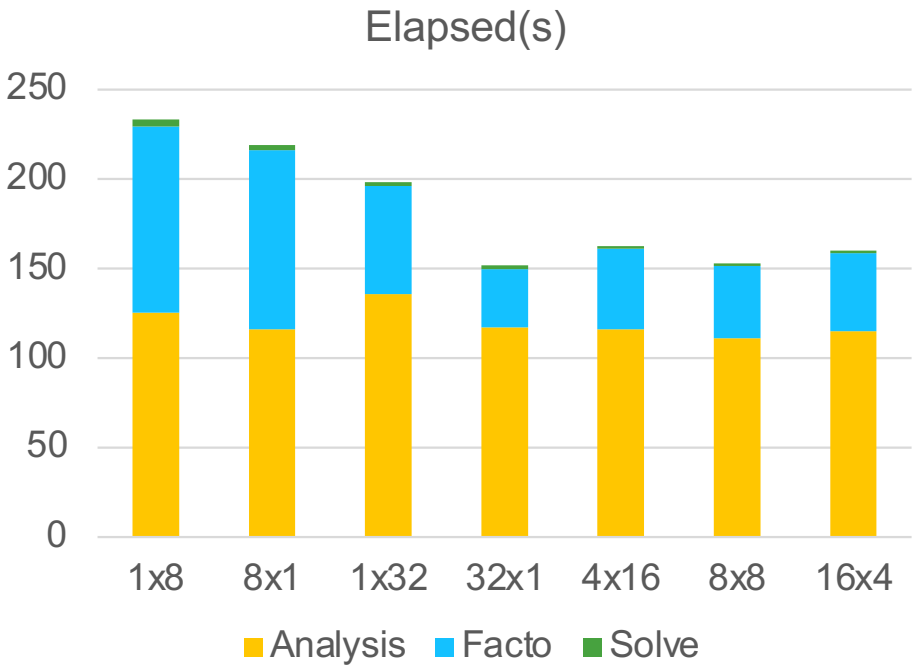
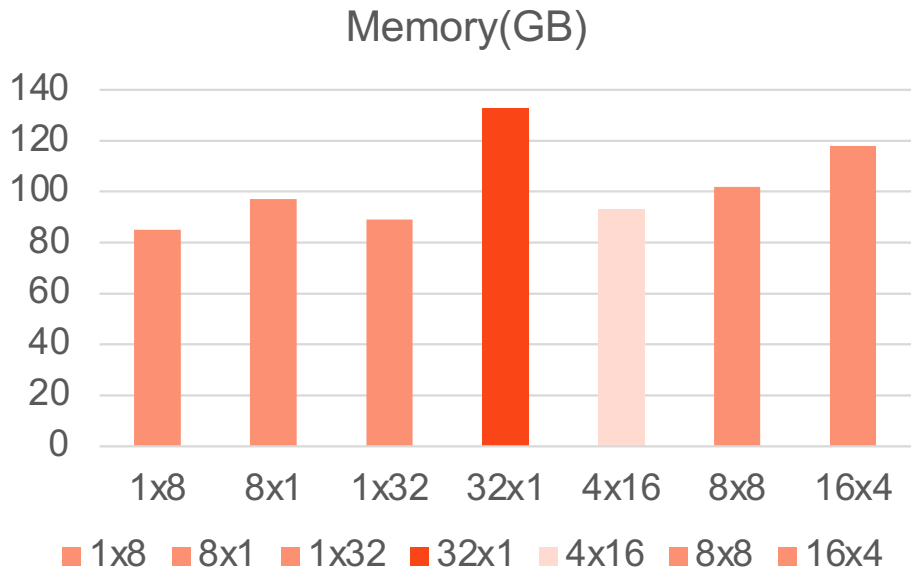
Benchmark – Carbody (2.5D)







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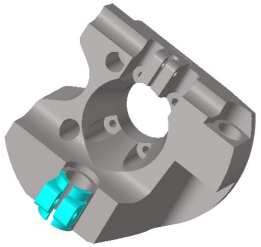
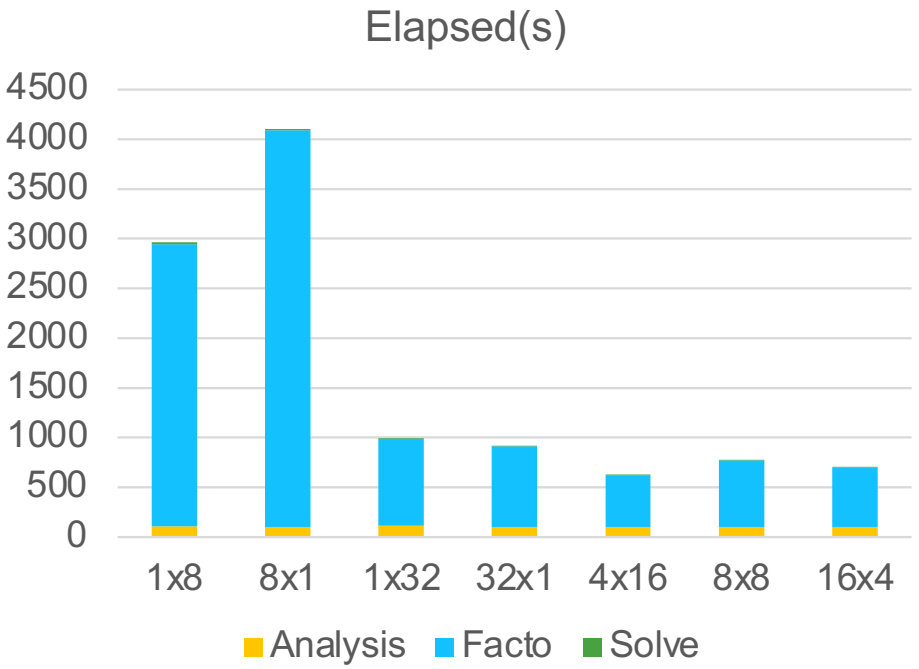
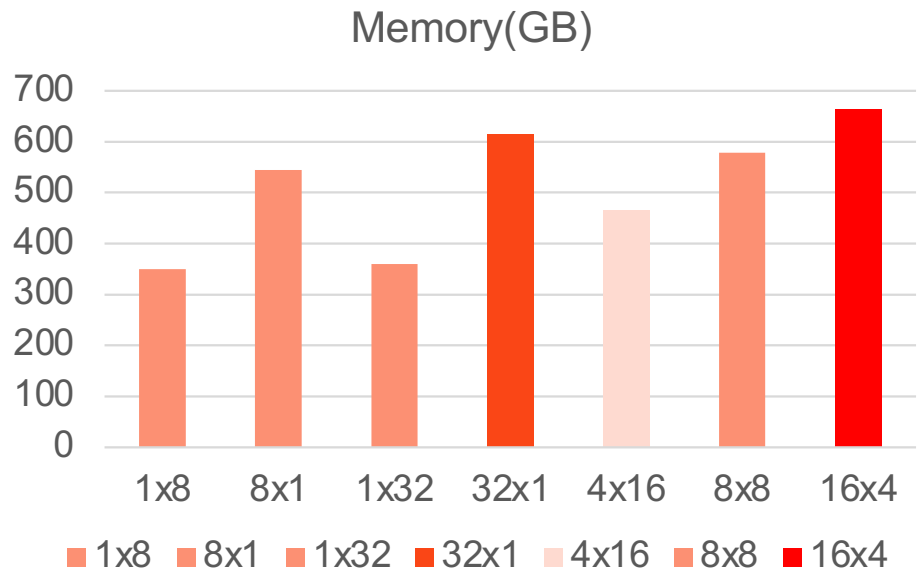
Benchmark – Knuckle (3D)







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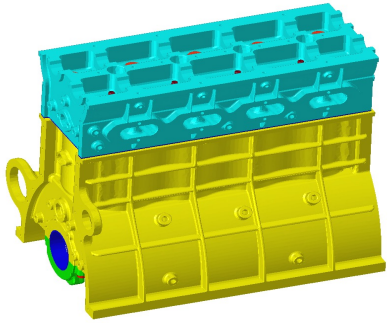
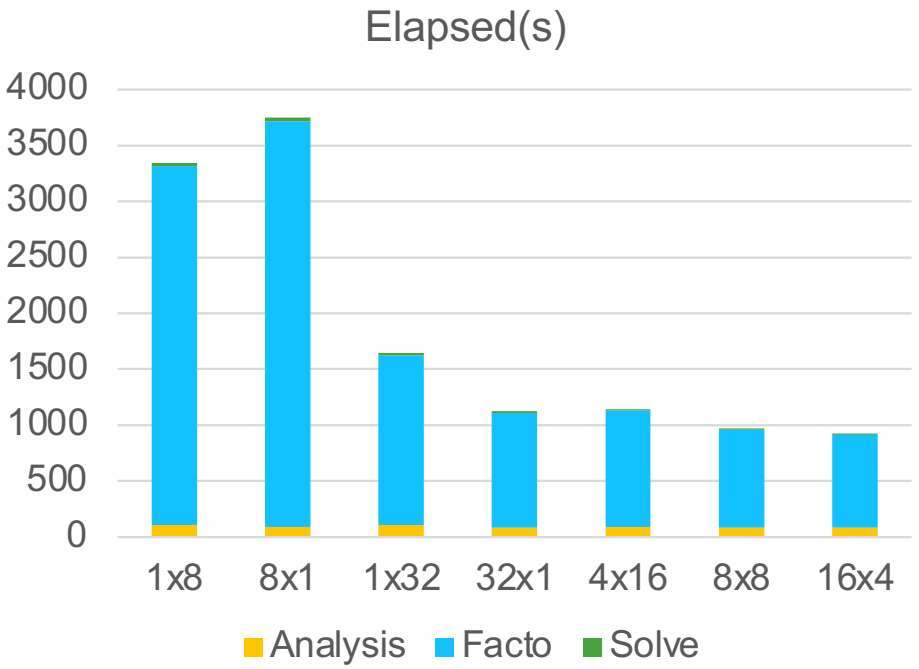
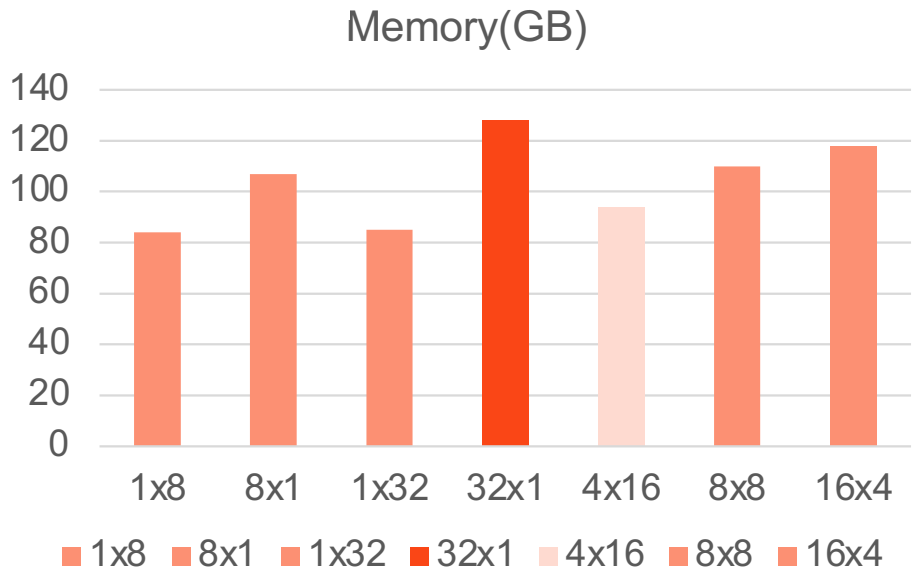
Benchmark – Engine (3D)



21 NL iterations





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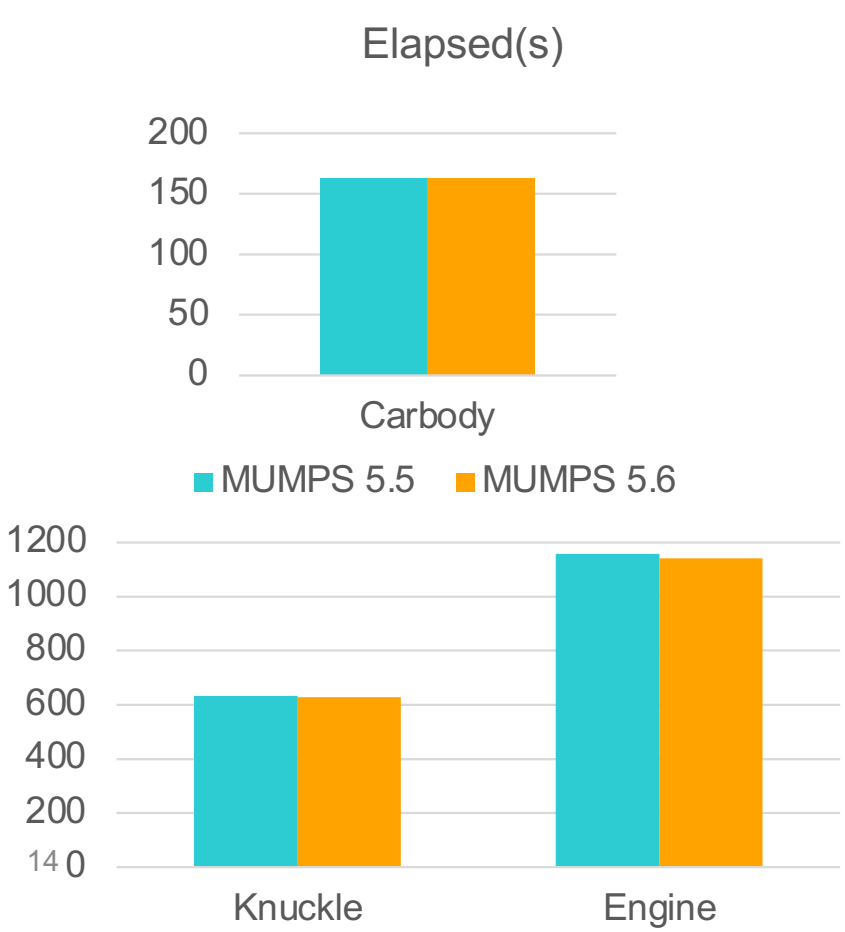
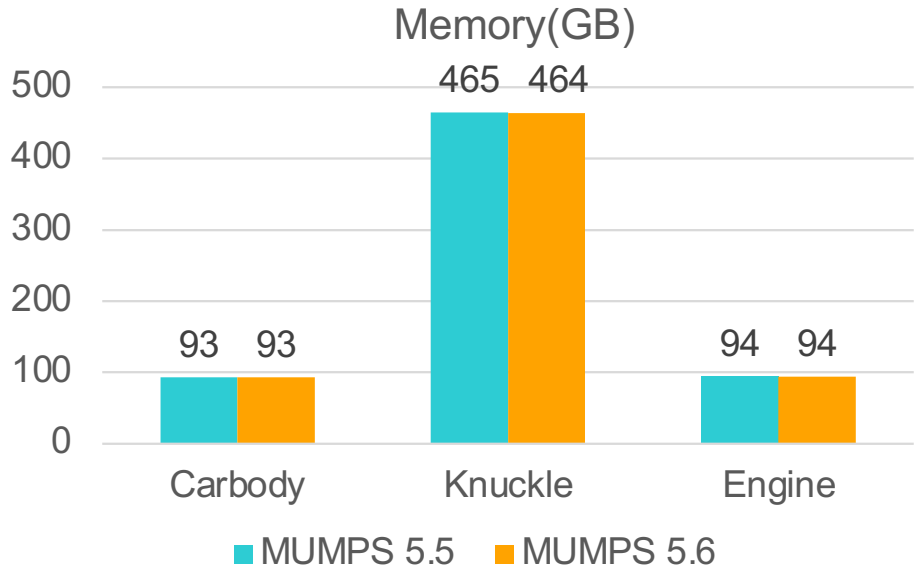
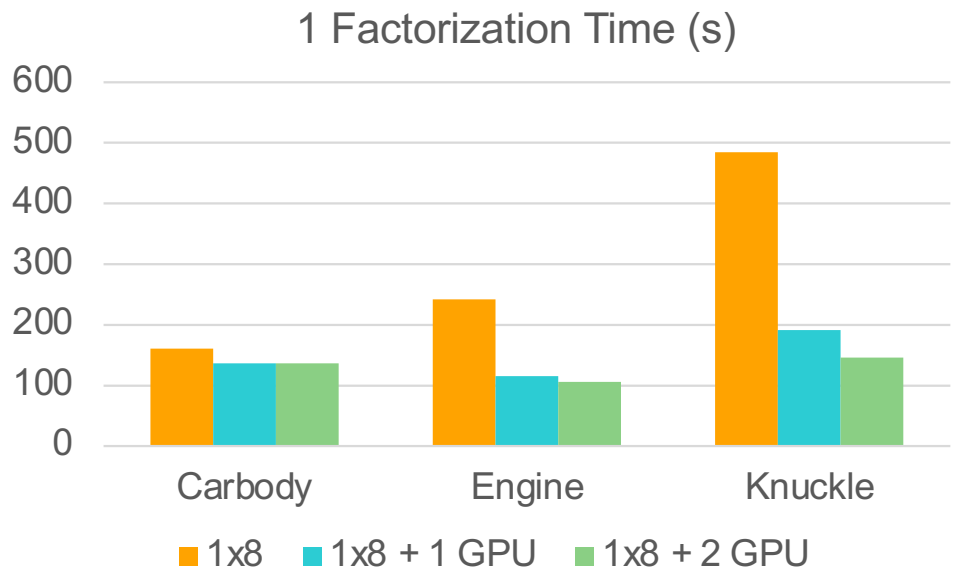
Benchmark – Versions Comparison (4 MPI x 16 OMP)





Consistent results and stable performance between MUMPS 5.5 and 5.6 version

Benchmark – GPU Acceleration (8 MPI x 1 OMP) MUMPS 5.6.0c



2x Quadro GV100 32GB RAM
Intel E5-2687W 16 cores @ 3.10GHz
256 GB memory

Good acceleration for 3D models
A coarser version of the Knuckle is used due to some memory limitation on the platform tested (2.8M DoF)
Larger compute intensive cases show scaling beyond 2 GPUs

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ALTAIR FEKO™

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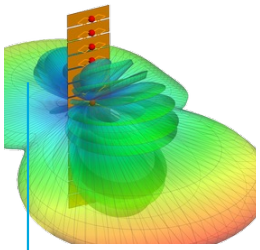
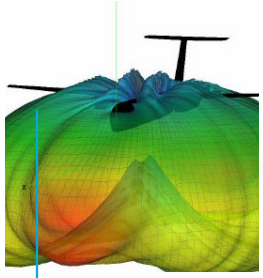
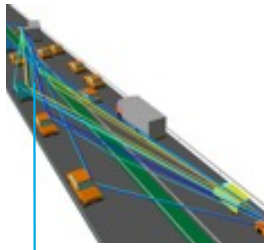
Altair Feko™ – A Comprehensive Electromagnetic Solver



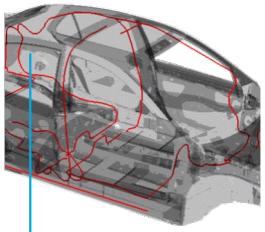
Antenna Design



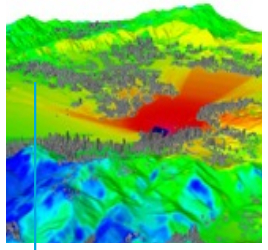
Antenna Placement & Coupling



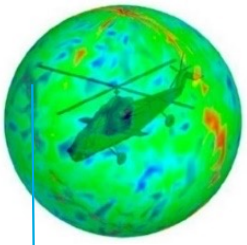
Virtual Drive & Flight Tests for Platform Connectivity & ADAS



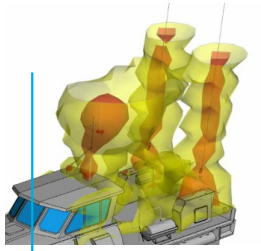
Electromagnetic Compatibility



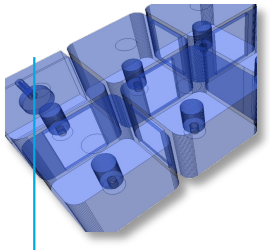
Radio & Radar Coverage & Planning



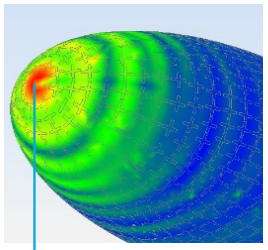
Scattering & RCS



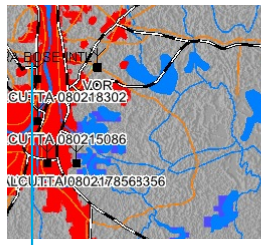
RADHAZ & Bio-Electromagnetics



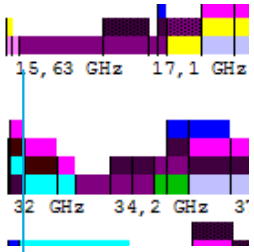
RF Device Design



Radomes including FSS



Radio Frequency Interference



Spectrum Management

Wave propagation modeling, radio network planning and spectrum management applications are done with WinProp and WRAP tools, which are part of Feko

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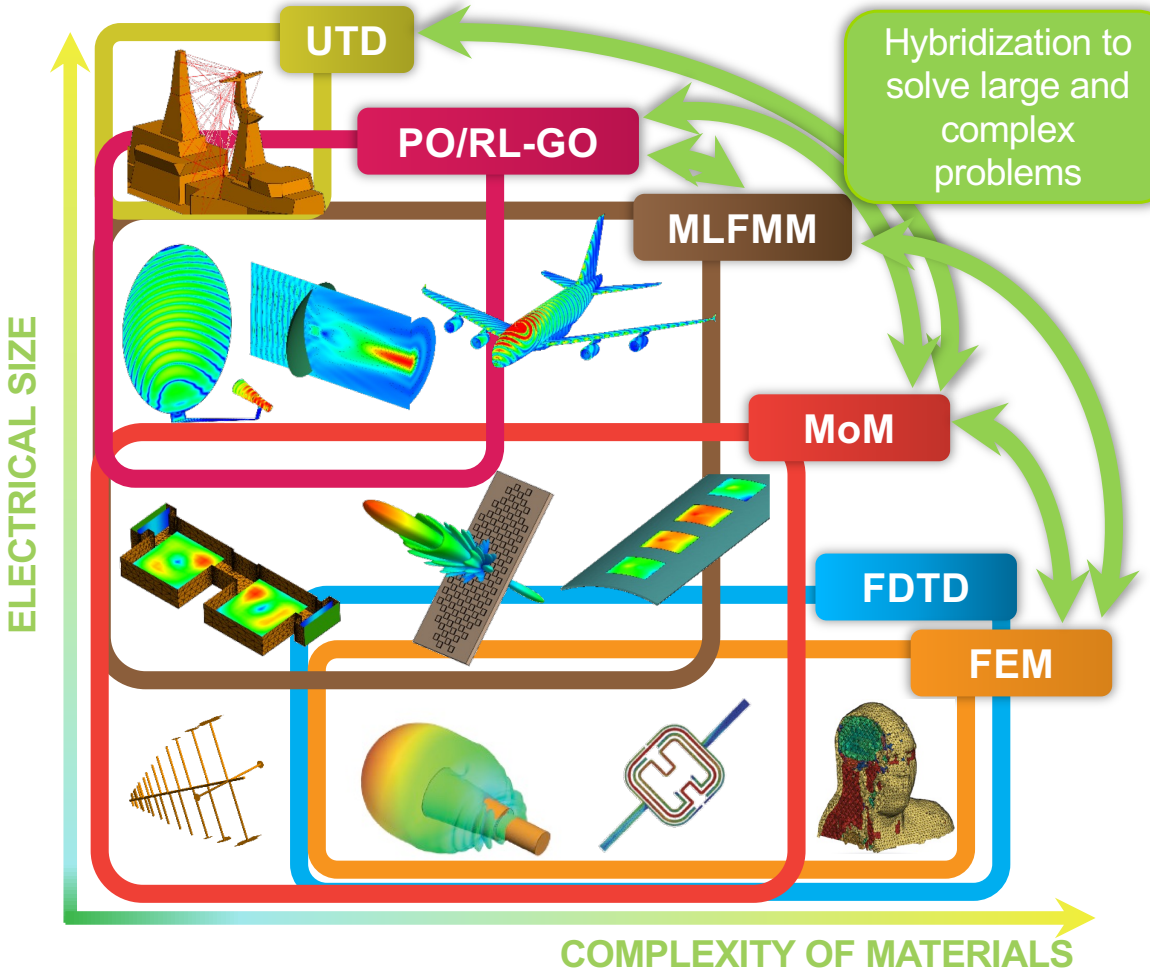
Solvers in Feko – Simulation Map



Asymptotic Methods
(high-frequency approximation)

Full-wave Methods
(physically rigorous solution)

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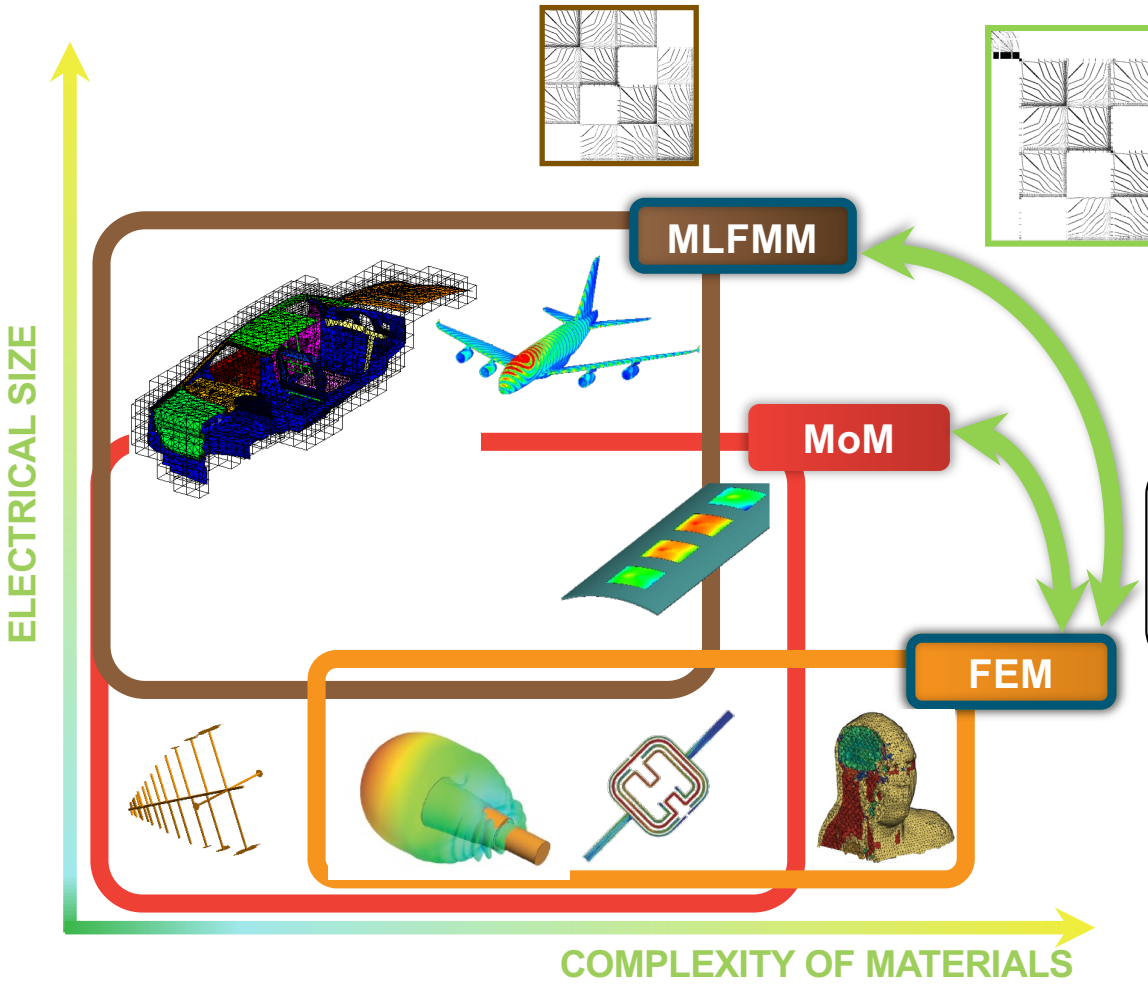
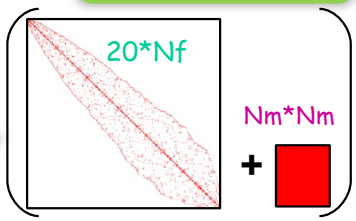
Solvers in Feko Using MUMPS



MLFMM/FEM

Hybridization to solve large and complex models

MoM/FEM



MUMPS used in the MPI version to compute preconditioners for the hybrid solvers that employ sparse algebraic methods: MLFMM, Hybrid MLFMM/FEM, Hybrid MoM/FEM, FEM

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Overview of MUMPS Usage in Feko

Features of MUMPS (5.6.0consortium) used in Feko

- The matrix is complex, unsymmetrical and in distributed assembled format in coordinate form
- Selective 64-bit integer support
- Working host (PAR=1)
- Ordering algorithm selection by MUMPS

  AMD, PORD, METIS (64-bit), SCOTCH (6.0.5r3), PT-SCOTCH (6.0.5r3)
- Advanced performance settings of consortium version

  ‘L0 thread’ ; ‘MPI to k OpenMP’ …
- Block Low Rank (BLR) is the default in Feko’s preconditioners:

  For select classes of models BLR brings a memory and performance benefit

  For others BLR is comparable in memory and performance to full-rank
- Analysis-by-blocks is used for the MLFMM

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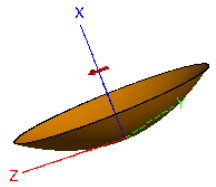
BLR in Preconditioning

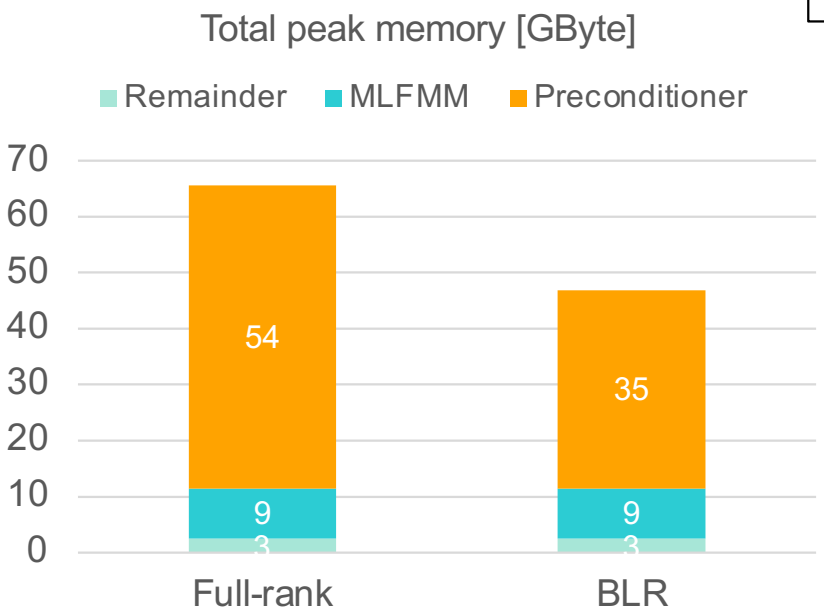
MUMPS 5.6consortium Block Low Rank (BLR) compared to full-rank single precision

BLR threshold: 1E-4

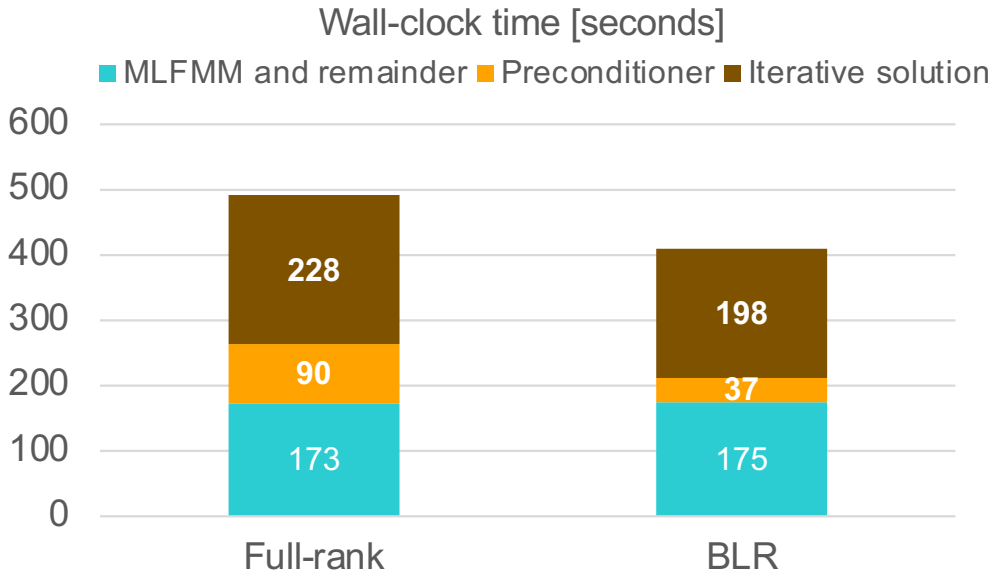
8 MPI processes



Parabolic dish at 30 GHz
- 2.6 M unknowns
- MLFMM: 408 M non-zero's (sparsity: 0.0061 %)
- Sparse matrix: 4.576 GByte
- Iterative solution convergence: 13 iterations



Preconditioner: MUMPS analysis and factorisation



Preconditioner: MUMPS analysis and factorisation
Iterative solution: includes MUMPS solves for preconditioning

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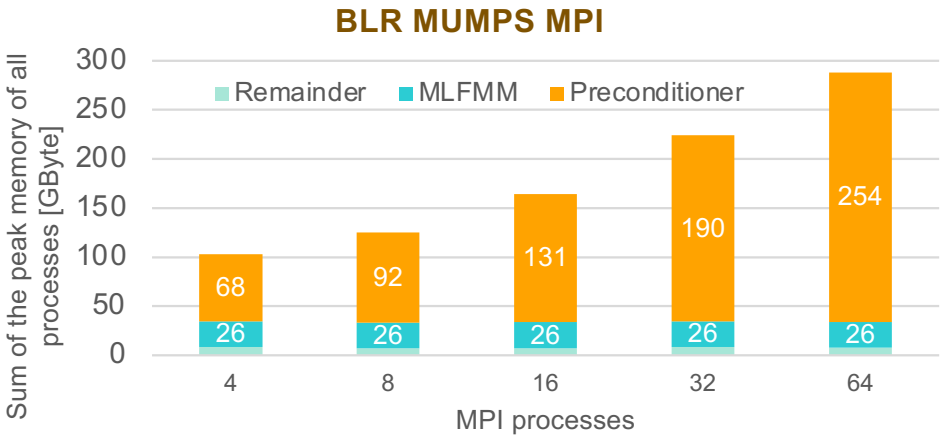
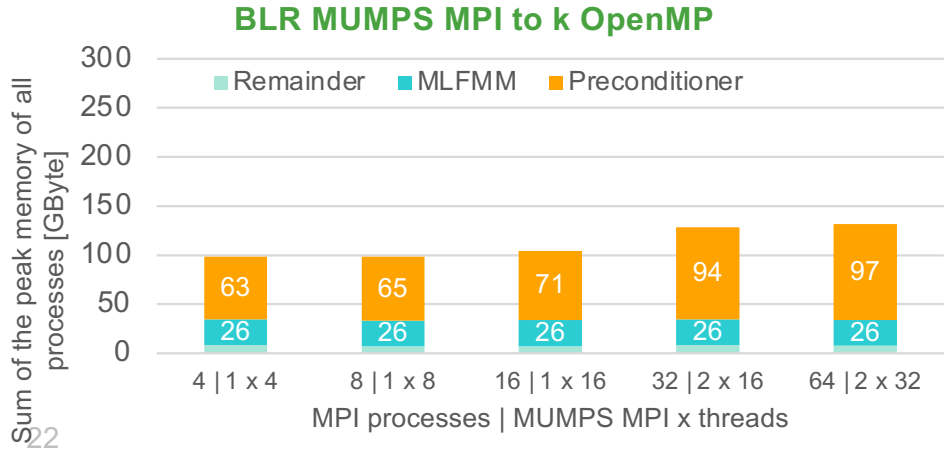
Experiment with MUMPS “MPI to k OpenMP”

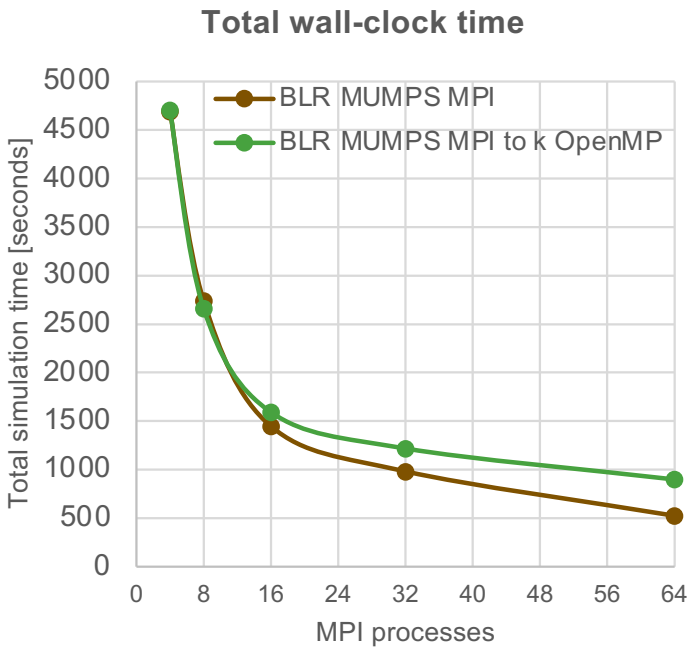




Preconditioner: MUMPS analysis and factorisation

Missile at 5.9 GHz

- 500 k unknowns
- MLFMM: 2200 M non-zero’s (sparsity: 0.7989 %)
- Sparse matrix: 24 GByte
- Number of boxes at the finest level: 20 k



Goal: Reduce preconditioner memory footprint (scalability) while maintaining performance in Feko’s traditionally distributed-memory, parallel MPI environment

ALTAIR FLUX™

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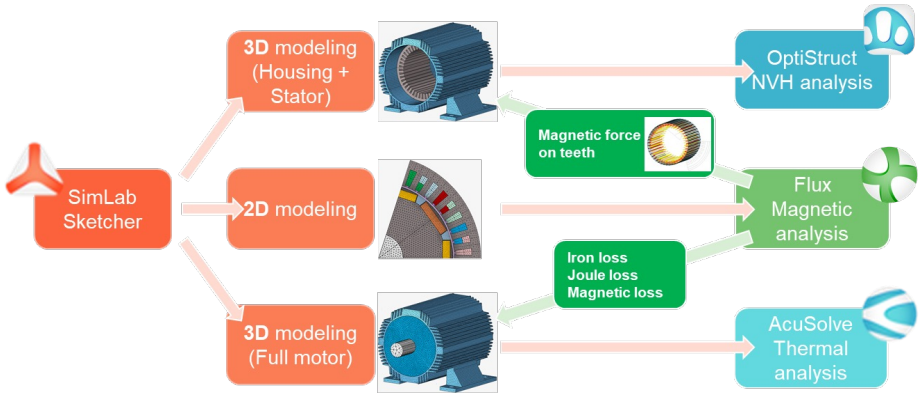
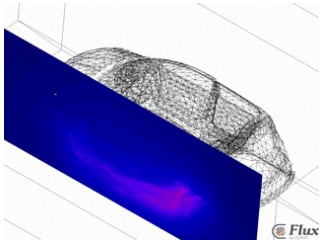
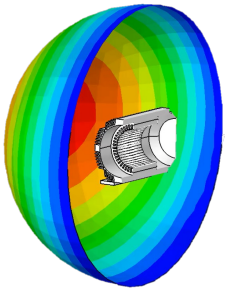
Altair Flux – Solution for Low Frequency Electromagnetics

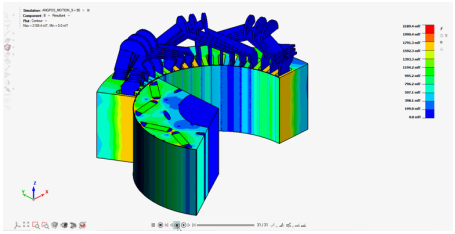
Flux addresses the broadest set of low frequency electromagnetic, electric, and thermal simulations, and is closely linked to Altair global solutions for multidisciplinary design exploration and optimization

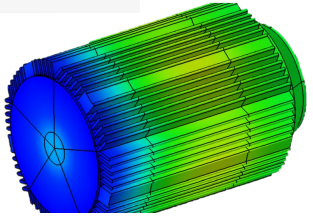


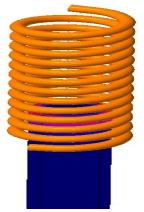
Multiphysics

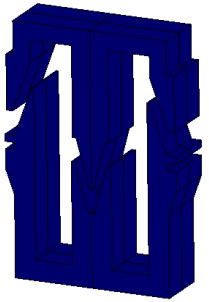


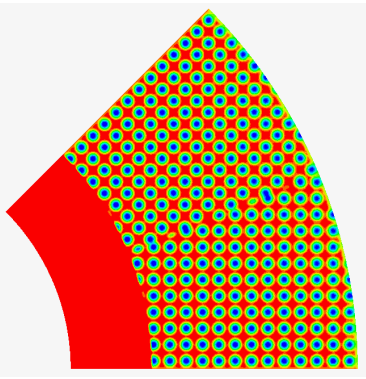












Topology Optimization

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Benchmark Examples & Recommendations

Characteristics	
Dimension	2D / Skew(=2.5D) / 3D
Application	Magnetostatic
Number of nodes	~1 000 to several millions
Cores	1 to 24
Solver	MUMPS 5.5.0consortium

Hardware Configuration
E5-2697A v4 2x16 cores @ 2,6 GHz
512 GB Memory

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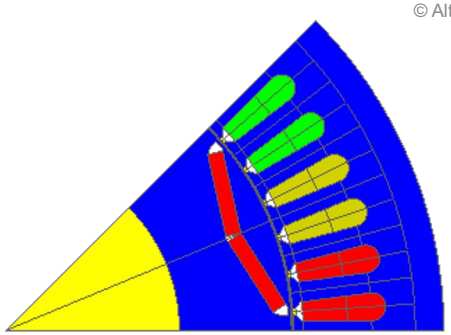
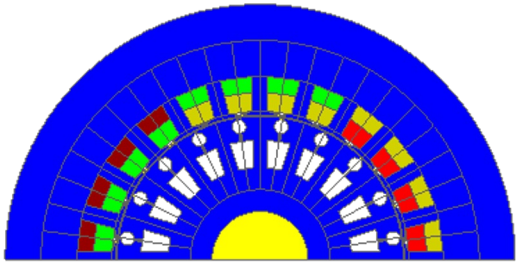
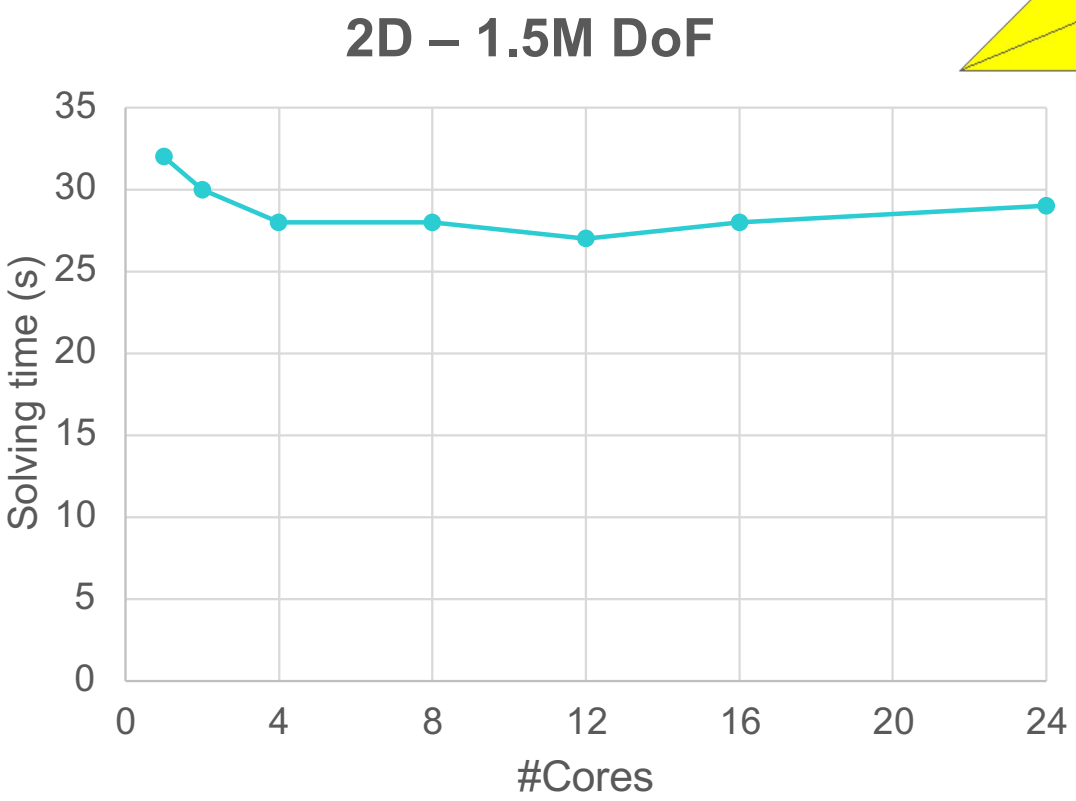
2D Scalability Test







- 1.5 GB
- No parallel speed-up
- A lot faster than iterative solver (~x2.8)

✓ MUMPS using 1 to 4 cores recommended on all 2D applications

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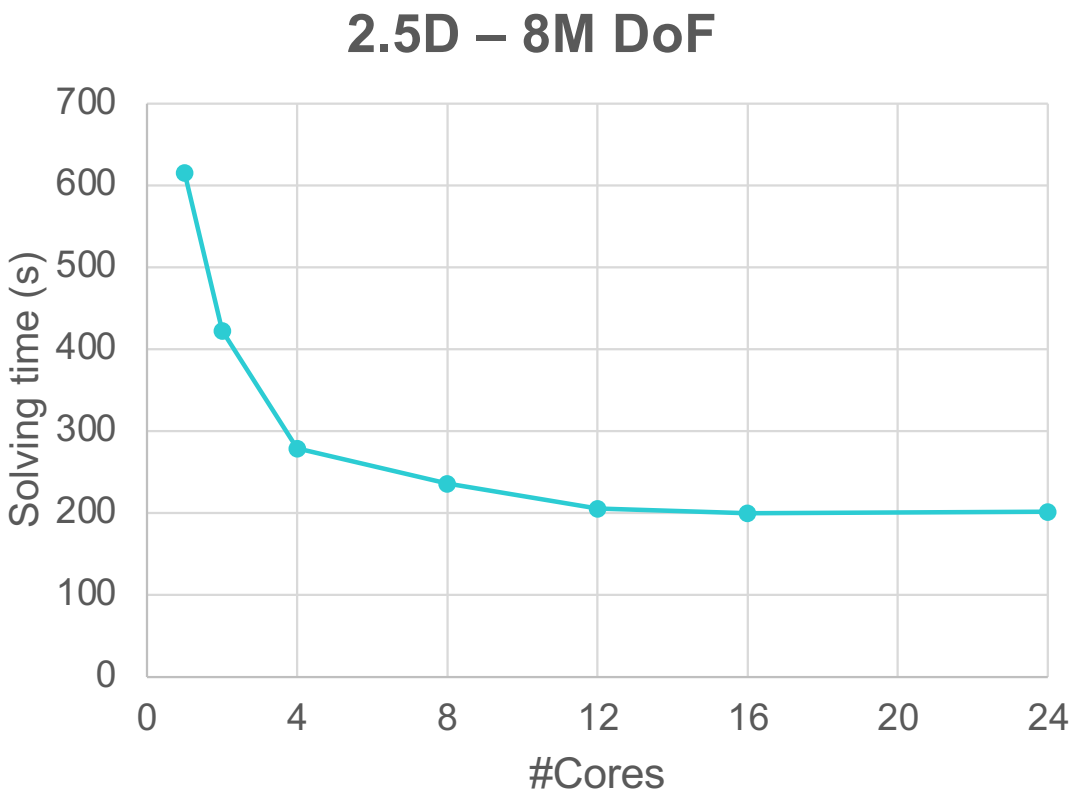
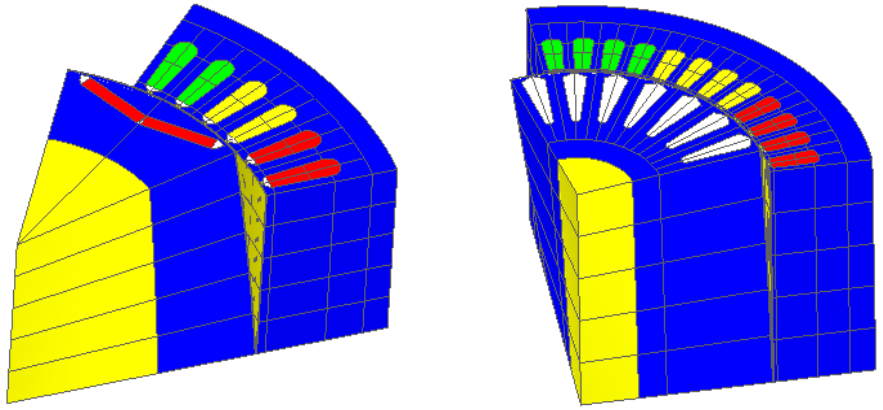
2.5D Scalability Test





- 21 GB
- Good parallel speed-up up to 8/12 cores
- A lot faster than iterative solver (~x1.7)

✓ MUMPS using 1 to 12 cores recommended on all 2.5D applications

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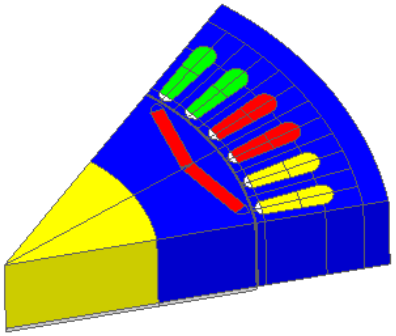
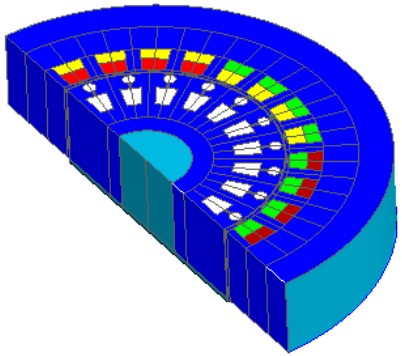
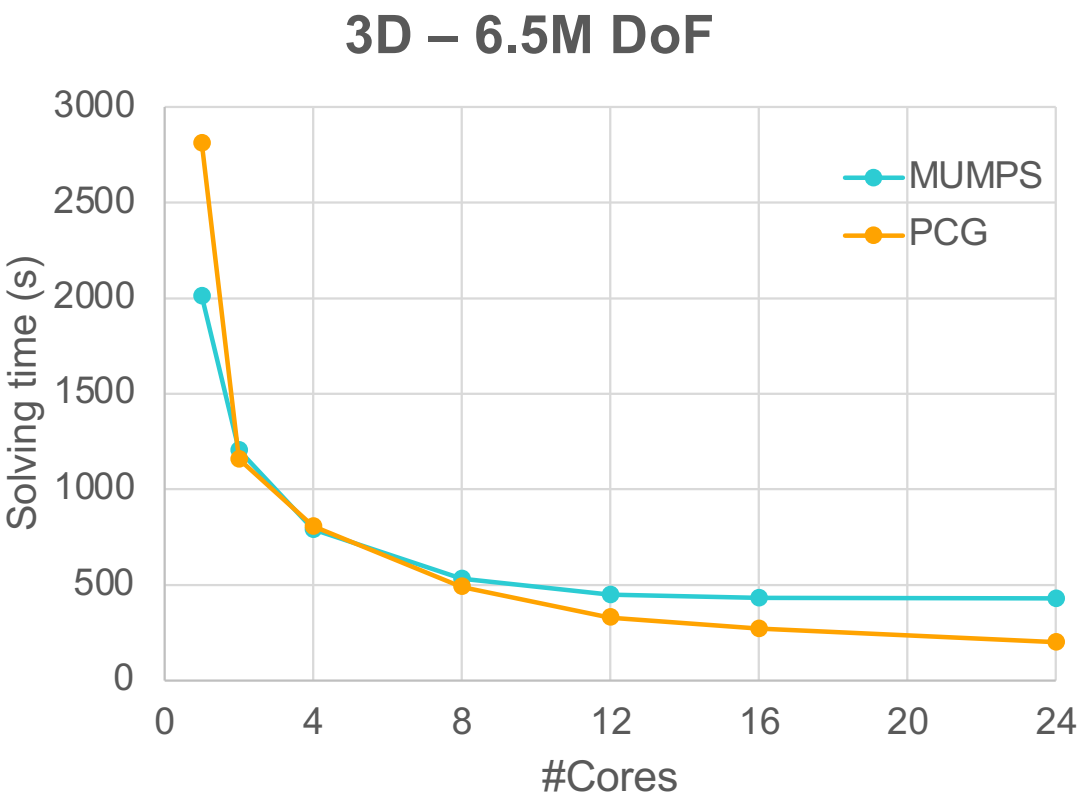
3D Scalability Test







- 80 GB
- Good parallel speed-up up to 8/12 cores

❖ Higher memory consumption (80GB vs 4GB with iterative solver)

❖ Iterative solver faster (~x1.8) thanks to higher scalability

✓ MUMPS recommended using 1 to 8 cores on 3D projects < 300k DoF, iterative solver otherwise

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ALTAIR RADIOSS™

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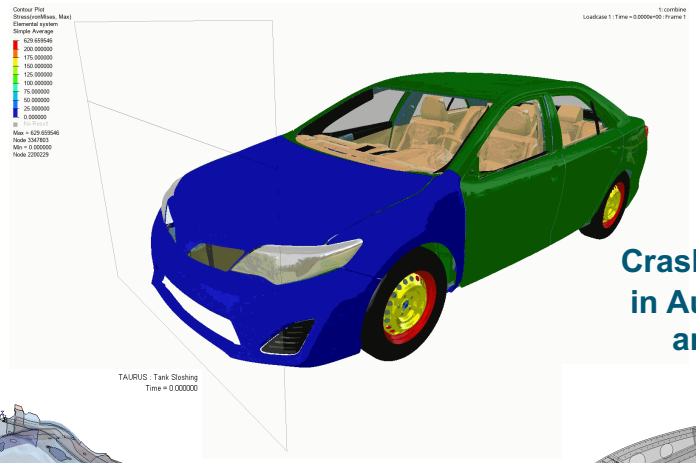
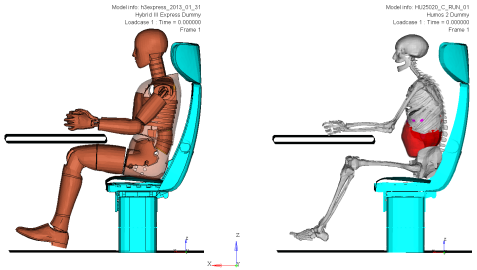
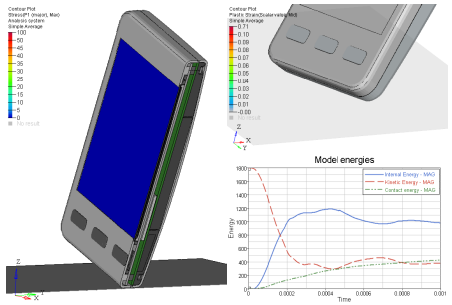
Altair Radioss – Proven Crash & Impact Simulation Software

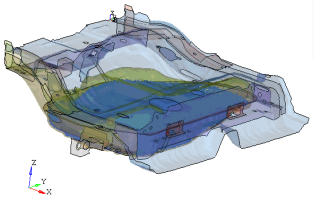


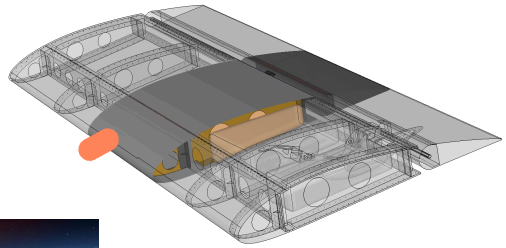
Crash & Safety in Auto, Aero and Rail

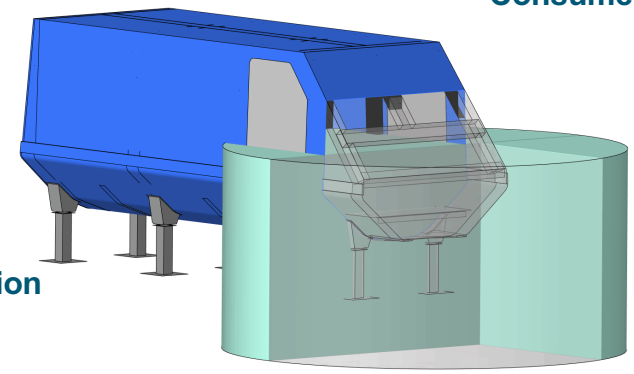


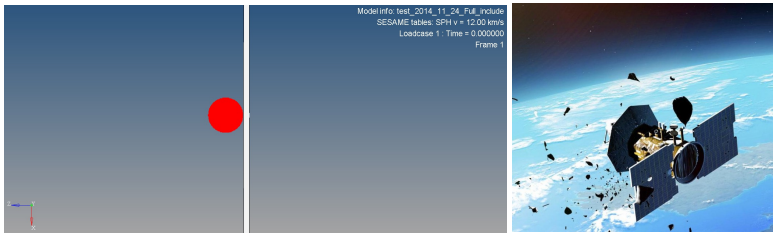


Drop & Impact in Electronics and Consumer Goods









Fluid Structure Interaction for Defense & Civil

Large Scale Computing and Parallelization

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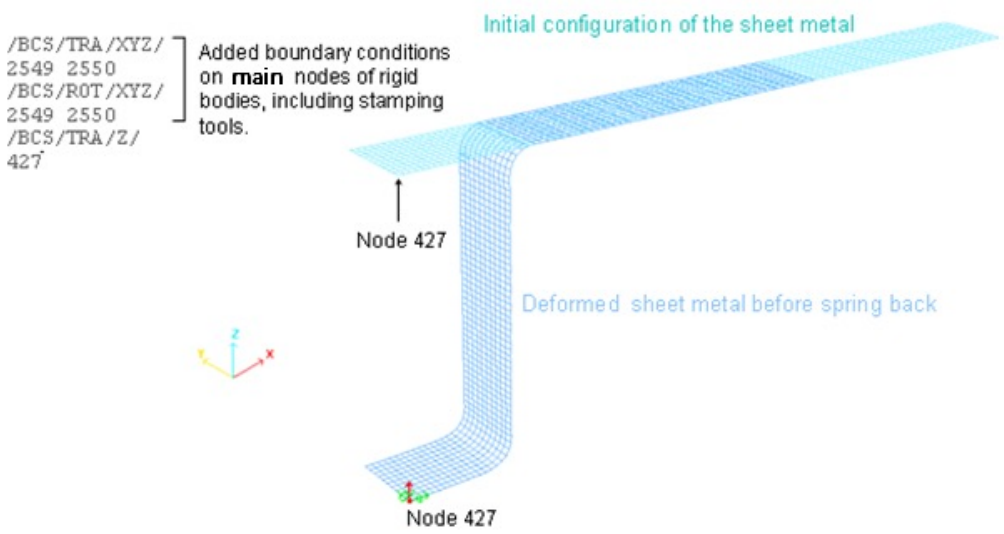
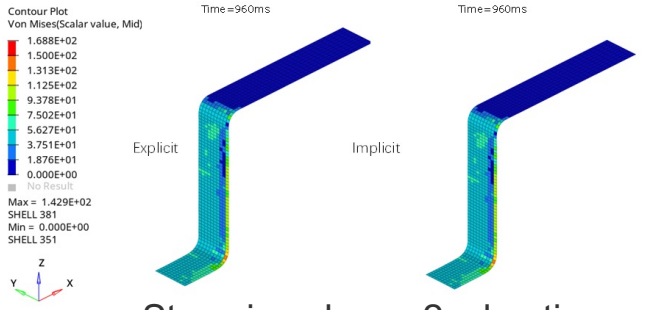
MUMPS Usage in Radioss

Use the public version MUMPS 5.5.1

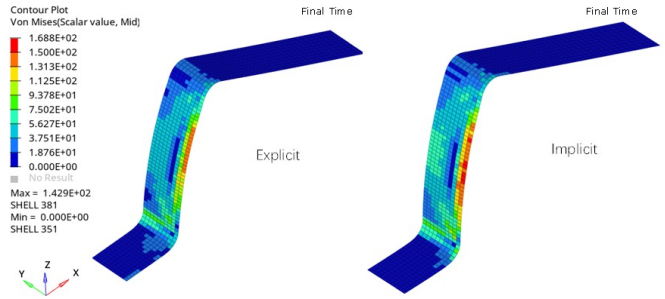
Main usage: Spring Back in manufacturing (+ Navier-Stoke solver in FSI)



Timing (s)	Stamping	Spring back	Total
Explicit	43	160	203
Implicit	68	92	160
Explicit-Implicit	43	92	**135**



Stamping phase: 2s duration



Spring back phase : 6s duration

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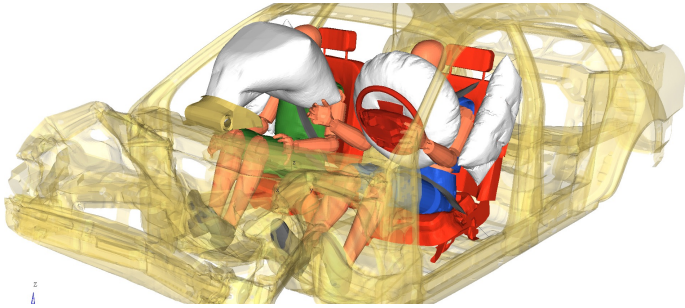
Altair Radioss & OpenRadioss™ – Commercial Open-Source Software Model

OpenRadioss open-source version

- Source code publicly accessible from: https://github.com/OpenRadioss
- Upstream version, contributions from a fast-growing community
- Precompiled Linux & Windows executables to run latest builds with no license check
- Support from the community, via forum



www.openradioss.org

Altair Radioss commercial version

- Commercial releases with extensive QA, professional support, documentation and maintenance priority
- Available under Altair Units license
- Encrypted models for dummies & barriers
- Channel valuable community contributions into industrial release

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THANK YOU

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elequiniou@altair.com

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