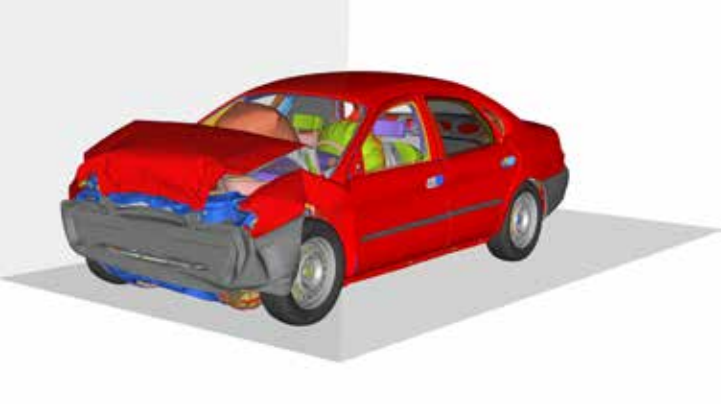
Optimizing High Fidelity Crash & Safety Simulation Performance

A Cray-Altair Solution for Manufacturing



While impact and crash simulation software are mature technologies addressing well-understood challenges, factors like increasingly complex load cases and higher fidelity simulations means companies need to continue pushing the envelope for efficient and powerful crash/safety simulation. This paper describes a high-performance computing (HPC) solution with Cray XC40 systems and Altair RADIOSS software, tested to over 16,000 cores, that gives engineers the power they need to improve speed and accuracy of their design analysis.

Solution Highlights

- Performance tested at over 16,000 cores
- Integrated software available for pre-processing, analysis setup, crash simulation with mass scaling, design exploration and HPC workload management
- Hardware recommendations for both larger and smaller systems

In this document:

Challenge: Massive-Scale Crash Testing for Design Innovation

Crashworthiness testing and other structural design simulations have become a core technology for manufacturers. However, the problem of creating a product that meets real-world safety requirements in an ideal fashion is far from solved – as the scale and variety of data continues to grow, and as high-core systems become more readily available, end users need well-engineered solutions for fast processing and efficient data management.

On the software side, applications must be ready to handle highly non-linear problems under transient dynamic loadings. In addition, in order to achieve greater innovation and better-performing designs, manufacturers are extensively utilizing new composite and high strength materials as well as simulating multiphysics phenomena, which applications must take into account. Applications must be engineered to perform well at very high core counts, as a requirement for getting products designed, built and delivered faster. Users also need powerful and reliable software tools for managing workload efficiently to maximize uptime and gain the highest possible system performance.

To support these applications, the hardware architecture must not only provide the **capability** for a single high-fidelity job to be completed in time to support the design schedule, but also the **capacity** to handle an enterprise-wide design process. This requires the scaling of individual jobs to thousands of compute cores and overall system capacity of tens of thousands of cores. With the trend toward design exploration and ensemble analysis techniques (e.g. stochastic methods), these compute requirement will likely increase by 10x or more.

Altair and Cray Solutions for Crash/Safety Testing

Altair's market-leading crashworthiness simulation solution consists of a suite of integrated software tools engineered to optimize design performance, throughput and usability:

- **HyperWorks** modeling, analysis and optimization software suite integrates the following components into a full solution:
  - **HyperMesh:** High-performance finite element pre-processing product to prepare even the largest models, starting from import of CAD geometry to exporting an analysis run for various disciplines.
  - **HyperCrash:** Analysis setup, including model checking, dummy positioning, airbag folding using Altair.
  - **RADIOSS:** Highly nonlinear structural analysis solver, which has been established for over 25 years as an industry standard for automotive crash and impact, with the highest levels of quality, robustness and scalability. With cutting-edge options like RADIOSS' Advanced Mass Scaling (AMS) technology, RADIOSS users can benefit from even better performance.
  - **HyperStudy:** State-of-the-art design exploration, approximation and optimization embedded software including shape optimization, direct parameterization, data mining, and direct RADIOSS results readers
- **PBS Works** award-winning* workload management software for high-performance computing (HPC) job scheduling, with high scalability and usability, proven for over 20 years at thousands of customer sites.

Cray offers a range of compute and storage solutions but all of them are designed specifically for production HPC environments. With the Cray XC40, which is based on Cray proprietary technology focused on maximum scalability, and the Cray CS400, which leverages industry standards for a broad range configuration options, Cray has delivered HPC solution for the largest simulation environment in the world. The Cray applications team works closely with the Altair development team to deliver a robust and high performance HPC solution.

Key Features & Benefits:

- Market-leading structural design and optimization solver for rapidly developing more lightweight and structurally efficient designs
- Interconnect architecture designed for maximum scalability and performance
- Market-leading HPC workload management software
- Consolidated HPC platform for comprehensive CAE design, simulation and analysis
- Unparalleled global expertise and support from the leaders in HPC and CAE
- An HPC production system which can efficiently and reliably scale to over 100,000 cores

RADIOSS' advanced multi-processor and multi-domain solutions enable optimal scalability for very large simulation models.

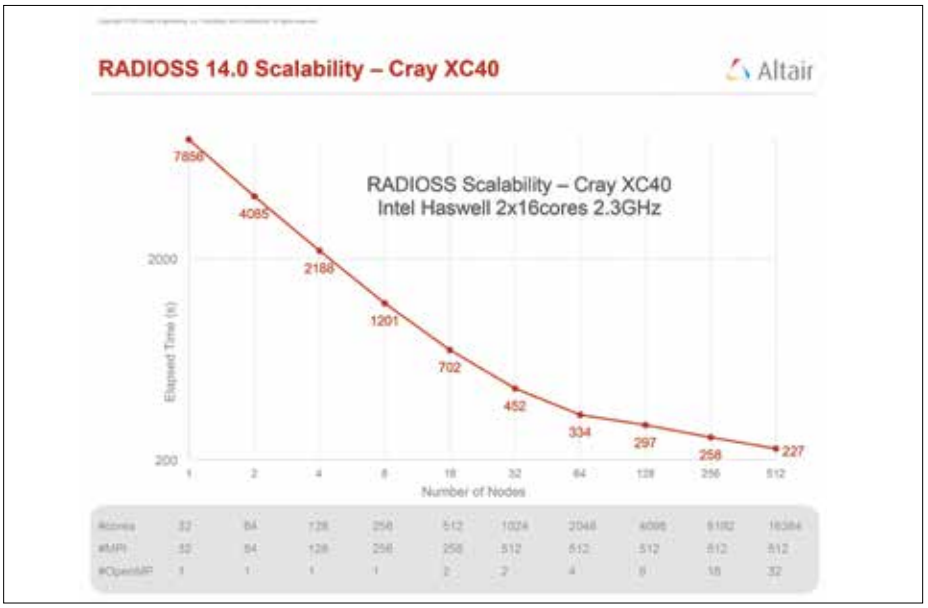
*Voted **"Best HPC Software Product or Technology"** in the 2014 Readers' Choice Awards.

Proof Points and Benchmark Results

To study the performance of RADIOSS crash simulation software at high core counts, Cray and Altair utilized a real-world model with the following characteristics:

- The input deck is derived from the public domain NCAC FORD Taurus model, adapted to RADIOSS with a refined mesh of nearly 10 million elements, including 330 K solids, 9 540 K shells and 4 K 1D elements, and safety airbags (without dummies here).
- The simulation time is restricted to the first 2 milliseconds, for benchmarking purposes, which is about 1 percent of a full crash simulation.
- The RADIOSS 14.0 beta version was used for this benchmark.

The Cray system used for testing was a Cray XC40 with the Intel® Xeon Processor E5-2698 V3 (16 core, 2.3 GHz). Up to 512 nodes were used for these simulations.



Benchmark testing results for RADIOSS on Cray XC40 system

As seen in the figure above, test results revealed:

- RADIOSS is a highly optimized hybrid MPI/OpenMP code. In addition to showing the excellent scaling of RADIOSS, the results also show how hybrid MPI/OpenMP scaling works in RADIOSS: For lower node counts, it is preferable to use pure MPI settings (i.e., no OpenMP threading). As the number of nodes increases, it is advised to mix the MPI ranks with the OpenMP threading on each node (up to 32 OpenMP threads and one MPI rank when using 512 nodes).
- For such a model size, the scaling remains very efficient up to approximately 64 to 128 nodes (i.e., less than ~4000 cores). In other words, although adding more nodes beyond 64 nodes improves performance, the gain in performance is relatively smaller compared to the performance gain when using lower node counts. This is principally due to the size of the model, with general recommendation to keep a ratio of ~4000 elements computed per core for optimum scaling. We expect that for very large models (say, one hundred million elements), the scaling would remain very efficient well beyond 512 nodes (i.e., using more than 16,386 cores).
- The standard Linux version of RADIOSS 14.0 based on Intel MPI 5.0 now runs natively under Cray MPT 7.0. This is achieved thanks to the MPICH Application Binary Interface (ABI) compatibility. This new feature simplifies maintenance and reduces deployment costs by allowing the same executable to run on Cray XC40 or CS400 as on any other Linux cluster, without wrappers or other modifications.
- In situations when scalability may be decreased (e.g. due to smaller per-processor domain size), hybridization helps -- as illustrated in the result that 16 threads was optimal at 8192 cores, but 32 threads was optimal at 16382 cores.

Key Benchmark Results:

- Performance speedup proven at 16,382 cores
- Quasi linear speedup at up to 1000 cores
- Hybrid parallelization of RADIOSS enables efficiency at both smaller and larger core counts

Configuration Recommendations

Cray and Altair recommend the following configurations for running RADIOSS for crash in both liquid cooled and air cooled environments.

"According to IDC, less than 1% of all codes scale above 10000 cores. RADIOSS is one of these few codes, and thanks to this collaboration with Cray, we were able to verify scalability of RADIOSS using massive parallelism. Being able to demonstrate such performance level is crucial to promote HPC adoption in the industry and I am confident that our customers will rapidly start running RADIOSS using 1000 cores and beyond for their industrial crash & safety simulations."

--Eric Lequiniou, HPC Director, Altair

Cray XC40 system configuration	**Large system where liquid cooling is available** (capability computing: many jobs at 1000 cores)
Compute	17,664 cores, 2.6GHz, 12C processors, 128GB memory per node
Interconnect	Cray Aries
Performance	734 TF peak
Footprint	4 Cabinets, 736 compute nodes
Storage	120TB Lustre file system
Power	480V input power
Cooling	Transverse liquid cooling

Cray CS400 system configuration	**Production CAE system for an air cooled data center environment** (capacity computing: many jobs at a few hundred cores)
Compute	5,760 cores, 2.6GHz, 12C processors, 128GB memory per node
Interconnect	FDR InfiniBand
Performance	240 TF peak
Footprint	4 racks, 240 compute nodes
Storage	60TB Lustre file system
Power	208V input power

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