CAD2CRASH24: Driving Full-Vehicle Crash Analysis Down to a Day

Altair Engineering, together with Ford Motor Company, demonstrates that the **full-vehicle crash analysis** process can be compressed from weeks to **24 hours.**

By **Pradeep Srinivasan**

Since automobiles were first introduced, manufacturers have focused on making them safe. Over time, their efforts have involved developing active safety features, such as anti-lock braking systems, and passive safety features, such as deformation zones, seat belts and air bags.

In their safety development efforts, automotive manufacturers have also concentrated on crash-worthiness, testing their vehicles to ensure occupant safety in accidents. Because physical crash-vehicle testing is highly expensive, automotive manufacturers increasingly employ computer simulation as they strive to meet guidelines set by government agencies.

When car makers first began to use commercial simulation techniques for crash testing in the 1990s, analysts created simple, coarse models – fewer than 1,000 elements – of simple components, such as bumpers. They ran the models on mainframes or super-mini computers, and it took days to get the results for a single component. Full-vehicle analyses were not even practical because of the time, compute resources and cost required to perform them.

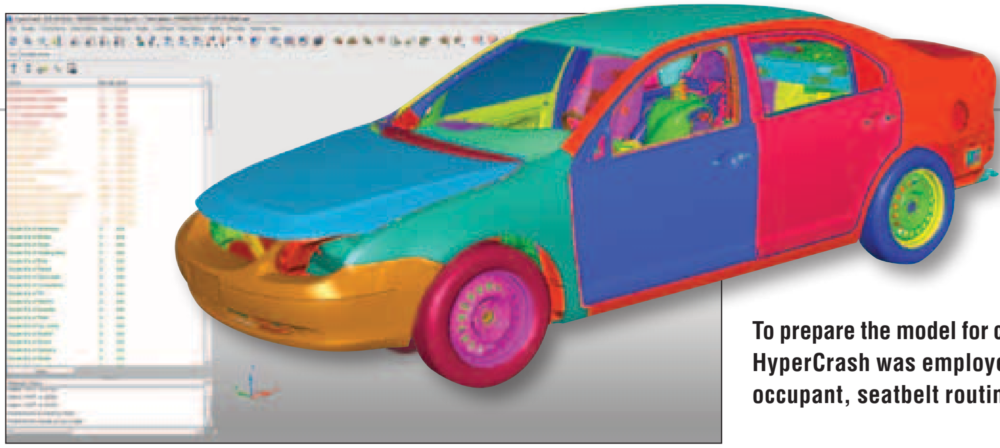
Today, analysts create complex, full-vehicle models – of millions of elements – in a process that typically takes four to six weeks. In April 2010, however, the CAD2CRASH24 Challenge rocked the status quo for full-vehicle crash analysis. This initiative compressed the time required to mesh, assemble and simulate a full-vehicle crash finite-element model – directly from OEM-native CAD data – to just 24 hours.

In this article, we examine the relevance of this milestone to the industry, explain the technological breakthroughs that made it possible and summarize the tools and steps.

Simulation Makes Sense

It makes sense to employ simulation for crash-worthiness testing. Manufacturers are under constant pressure to reduce costs even while product design increases in complexity. Simulation enables companies to explore more design alternatives and conduct studies to resolve design challenges and improve passenger safety performance.

In addition, simulation reduces the need for developing physical prototypes. Each physical test can run anywhere from $250,000 to $1 million. Performing virtual crashworthiness tests can reduce costs by



To prepare the model for crash simulation, Altair HyperCrash was employed to incorporate the occupant, seatbelt routing and airbag.

approximately 75%, according to some estimates. It also cuts time to compliance as manufacturers contend with meeting an ever-increasing number of safety regulations. What's more, simulation reduces overall time to market.

Technology has paved the way for greater acceptance of simulation tools. For example, the high-performance computing (HPC) platforms on which simulation tools typically run are faster, more powerful and less expensive than ever before.

In addition, simulation software has evolved to solve larger, more complex problems while fully leveraging hardware advancements to minimize turn-around time. Take, for example, RADIOSS, the Altair Engineering finite-element solver for linear and non-linear analysis. Part of the Altair HyperWorks suite, it features highly efficient solution algorithms and intelligent memory management that enable automotive, aerospace and other manufacturers to simulate structures with millions of degrees of freedom. The latest version of the software has been optimized to take advantage of multiple compute "cores" to speed processing.

RADIOSS, with its new hybrid solver approach, was used to simulate a frontal crash of a vehicle model with more than one million elements in November 2009 in less than five minutes. The virtual test was performed on a cluster based on the Intel Xeon processor 5560 series. In fact, the solver breakthrough provided the catalyst for the CAD2CRASH24 proof of concept.

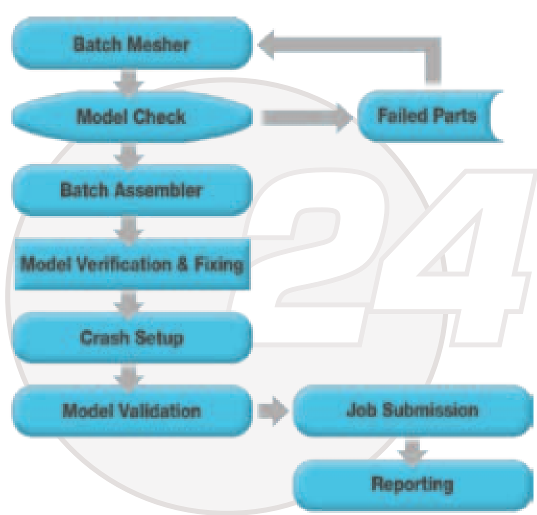
The Countdown Begins

Based on the November 2009 computational breakthrough in solver speed, Altair Engineering collaborated with Ford Motor Company to complete the full-vehicle crash analysis process in 24 hours. The process involved multiple steps including body-in-white (BIW) and sub-assembly meshing, assembly, load case setup, dummy management, trimming, model checking, analysis and post-processing.

Our team consisted of five members who worked separately in relay fashion on various parts of the project during the 24-hour time period. We wanted to demonstrate a "follow-the-sun" strategy, in which team members – theoretically around the world – would complete their portion of the project and then hand it off to other colleagues.

The first step in the process involved importing native CAD data for the full vehicle into Altair HyperMesh. The CAD model, a 2010 midsize Ford vehicle, consisted of more than 1,000 assemblies and 2,000 parts representing the BIW and sub-systems, instrument panel, powertrain, front bumper, seat assemblies, tires and suspension components, among others. Ford supplied the BIW CAD model. The sub-systems were morphed to fit the BIW model from the National Highway Traffic Safety Administration models.

As these parts were imported into HyperMesh, they were automatically added to the CAD2CRASH24 project



The Altair team completed a full frontal vehicle crash analysis – which typically takes weeks – in just 24 hours using only commerically released software in Altair HyperWorks.

and managed with Altair's embedded simulation data management solution.

HyperMesh includes CAD geometry healing tools, which helped to clean up the imported CAD data for batch meshing. This is a critical step to ensure high-quality finite-element mesh generation.

Batch meshing was performed in parallel for all the BIW and sub-systems. This effort, new to the industry, involved firing off groups of parts across multiple cloud compute nodes. As individual meshes were completed, another part would automatically be sent for meshing.

According to their specific connection schema – weldments, bolts, glues, etc. – we then assembled the BIW and sub-systems into a single model. Next, all the components were mass-trimmed to compensate for the mass differential between the CAE model and the bill-of-materials.

To complete the model for crash simulation, we incorporated the occupant, seatbelt routing and airbag into the model using Altair HyperCrash. The software includes user utilities for crash and safety modeling tasks such as part replacement and positioning, dummy positioning, seat deformation and seatbelt routing.

We also employed HyperCrash to handle mass balancing and to validate the model. Its crash model validation capabilities range from simple element checks to part connectivity to modeling errors in the input deck. Users visually review the state of each check represented by status color (red, orange and green).

Ready to Run

To simplify job submission and management, we used PBS Catalyst, an application-aware job management portal technology in PBS Works, Altair's on-demand software suite for advanced computing resource management. PBS Catalyst provides drag-and-drop job submission and management functionality directly from the desktop. It automatically understands the solver needed to run the submitted input file – in this case, RADIOSS – as well as the associated memory requirements.

Upon job submission, PBS Professional, the workload management solution in the PBS Works suite, distributed and managed the RADIOSS workload across 64 CPUs on Altair's Compute Cloud. PBS Professional makes it possible to create intelligent policies to manage distributed, mixed-vendor computing assets, including applications, as a single,

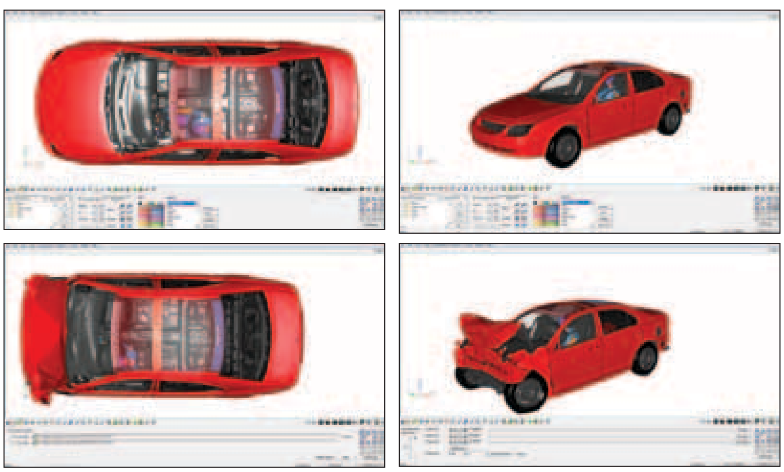
The Cloud Connection

The CAD2CRASH24 initiative leveraged Altair Engineering's "Compute Cloud" consisting of super-speed processors, high-speed networking and dedicated nodes for high security. Cloud computing models, such as this one, enable computing resources to be accessed and shared virtually in a scalable manner.

Specifically, the hardware configuration for the project included:

- 64 CPUs
- 32 GB of RAM
- Linux 64-bit operating system
- 64-bit Windows XP laptop
- Microsoft Windows operating system

Meshing, assembly and computation were performed on the Linux hardware. Crash setup was carried out on the 64-bit Windows XP laptop.



For the CAD2CRASH24 proof-of-concept, Ford supplied the BIW CAD model while the subsystem models from the National Highway Traffic Safety Administration were morphed to fit the BIW model. The top images (from left to right), show the top and iso views of the vehicle prior to the crash while the bottom images (left to right) show the crash results using Altair HyperView.

Inside the Technology Toolbox

For the CAD2CRASH24 proof of concept – in which Altair Engineering Inc. in collaboration with Ford Motor Company took only 24 hours to mesh, assemble and simulate a full-vehicle crash model – the team relied on commerically available software in the HyperWorks CAE simulation platform.

HyperMesh: This high-performance finite-element pre-processor provides a visual environment to analyze product design performance. Capabilities include surface and solid geometry modeling, shell meshing, solid mesh generation and batch meshing, among others.

HyperCrash: Specifically designed to automate the creation of high-fidelity models for crash analysis and safety evaluation, the software includes modules for quality checks; mesh editing; safety tools to set up, edit and define safety-related characteristics for crash simulation; and mass balancing, to manage the mass and inertia properties of each part and the entire crash model.

RADIOSS: This linear and non-linear solver can be used to simulate structures, fluids, fluid-structure interaction, sheet metal stamping and mechanical systems. Its features include a comprehensive material library; easy-to-read output file; NASTRAN environment compatibility; and access to finite-element dummy, barrier and impactor models.

HyperView: The software is a complete post-processing and visualization environment for finite-element analysis, multi-body system simulation, digital video and engineering data.

Other software tools that played a role in the successful proof of concept included:

HyperWorks Data Manager: With this software, users can capture, organize and manage data throughout the product development process. It can integrate with any existing PDM system, database and other enterprise system.

PBS Professional: Part of the Altair PBS Works suite, the software manages complex high-performance computing workloads to ensure the highest levels of resource utilization.

PBS Catalyst: This web portal enables users to easily submit and manage jobs for processing by dragging input files onto the PBS Catalyst icon on their desktop systems. Input data sets are automatically staged and output files returned when the job is completed.

unified system. Based on a policy-driven architecture, PBS Professional continually optimizes how technical HPC resources are used.

RADIOSS solved for a 65 ms New Car Assessment Program frontal crash test using a 50th percentile Hybrid III dummy from First Technology Safety Systems and a Reference Metric (IMM) airbag. PBS Catalyst was aware of when the job finished and automatically returned the results to the analyst's desktop.

The results were directly imported into HyperView, the HyperWorks results visualization and post-processing solution. Interactive standard reports, such as deformation animations, accelerations, energy plots and occupant injury criteria, were created.

Hitting the Mark

Before we started the proof of concept, we identified the time frame for the various tasks. We estimated it would take two hours each to complete the BIW and sub-assembly batch meshes; two hours for the BIW assembly (welding); and four hours for the sub-assembly assembly (bolts, welds, glues). We also allotted two hours each for mass trimming, crash setup and model validation. Running the crash simulation on 64 CPUs was estimated to take six hours and running the reports two hours.

When all was said and done, the majority of the tasks took less time than we anticipated. Some took longer than expected. In the mass trimming task, for example, some of the sub-assemblies were missing. We had to search for the correct models online and update them manually. We also had to make manual adjustments in the crash setup phase. Doing so mirrored what analysts typically encounter in their jobs on a daily basis. After having gone through the proof of concept, we gained a deeper understanding of the challenges involved in order to continue to refine the process.

In summary, the Altair CAD2CRASH24 process can be customized and implemented for manufacturers globally, offering weeks of additional simulation time annually to meet program objectives and product safety requirements. The process extends to any industry that must ensure the impact and safety performance of its products, including the execution of drop tests of cell phones, bird strikes on airplanes or fatigue analysis of implantable medical devices.

Pradeep Srinivasan is Senior Technical Specialist, Altair Engineering Inc., Troy, MI. Acknowledgements to Darius Fadanelli, Chirdeep Nithin, Bijoy Paul and Amar Marpu for their valuable contributions to CAD2CRASH24.

For more information about CAD2CRASH24, visit *www.altair.com/c2r* or check 01 on the reply card.