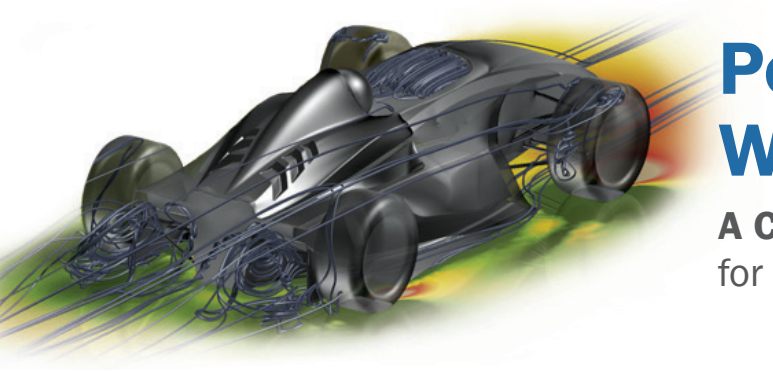


Powering Virtual Wind Tunnel Simulations

A Cray-Altair Solution
for Optimized External Aerodynamics

Cray and Altair are leaders in providing the powerful, usable technology engineers need to perform external aerodynamics analysis with greater speed and accuracy. With Altair's HyperWorks Virtual Wind Tunnel running on Cray XC30 or CS300 systems, manufacturers of all sizes can now predict a vehicle's external aerodynamic performance and improve the cooling, comfort, visibility and stability features in their designs -- without the need for numerous physical wind tunnel tests.

Why a virtual wind tunnel?

- Dramatically improve your designs – quickly and easily
- Save on the cost of repeated physical testing
- Reduce time to deliver models to physical testing and production

In this document:

- Solution features
- Benchmark results
- Configuration examples on Cray hardware

Challenge: Predicting Aerodynamic Performance To Improve Design Quality

External aerodynamic simulation plays an important role in modern automotive design. A vehicle's fuel consumption, stability, engine cooling, interior cabin noise, windshield-wiper performance, and more are all influenced by aerodynamic forces, so it's important to study the effects of these forces prior to production.

While performance can be tested in physical wind tunnels, doing so is extremely costly – and it can require numerous test runs to determine the changes needed to improve results. Virtual wind tunnel simulations provide an alternative by allowing design engineers to study aerodynamic loads prior to physical testing – reducing the need for physical wind tunnel experiments during a vehicle's development process.

About HyperWorks Virtual Wind Tunnel

Altair's HyperWorks Virtual Wind Tunnel (HyperWorks VWT) brings new levels of accuracy and speed to predicting a vehicle's external aerodynamic performance.

HyperWorks VWT is an all-in-one environment that integrates state-of-the-art meshing and simulation technologies with a highly automated workflow. Users can bring in the surface mesh, set up the problem, submit the simulation and obtain a final report – all from an intuitive, easy-to-use interface. Using HyperWorks VWT to simulate and analyze performance – including lift, drag, pressure distribution, flow field (flow separation), aero-acoustics and other factors – results in safer, better-performing, and more fuel-efficient vehicles.

Powering Virtual Wind Tunnel Simulations

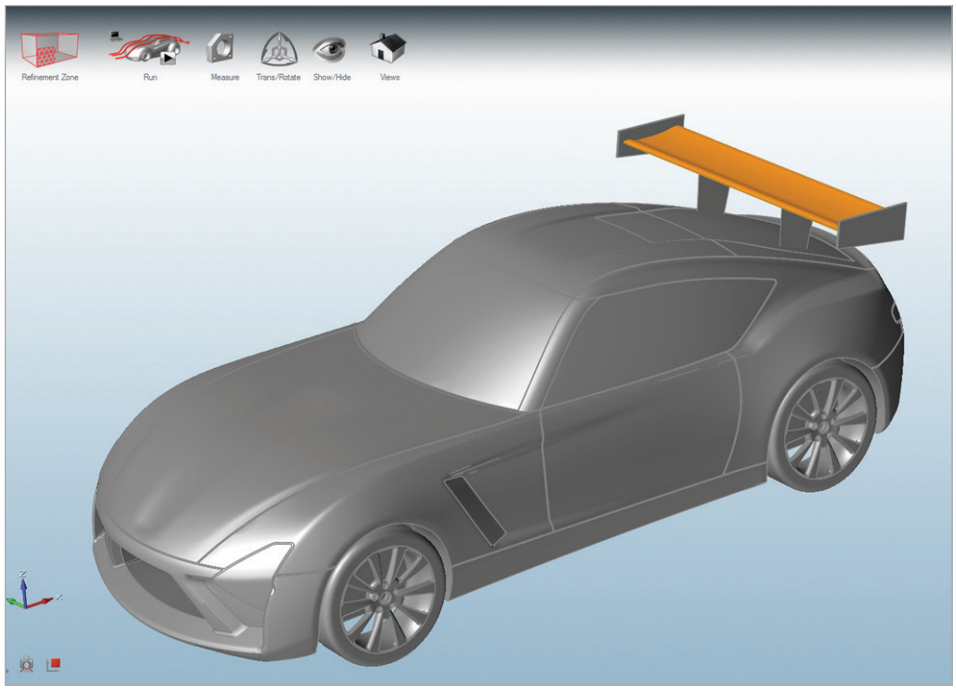
HyperWorks Virtual Wind Tunnel capabilities include:

- **Accurate, robust and scalable solver:** HyperWorks VWT is powered by AcuSolve®, a finite-element based computational fluid dynamics (CFD) flow solver capable of efficiently solving the most demanding, large-scale industrial problems. Accurate external aerodynamics results can be achieved for both steady-state and transient simulations.
- **Advanced meshing:** HyperWorks VWT's fast, fully-automated unstructured mesher supports advanced techniques such as boundary layer propagation, surface and volume extrusion, anisotropic and edge blend meshing, region of influence and user-defined functions.
- **Friendly, intuitive user environment:** HyperWorks VWT is an all-in-one environment with a highly automated setup and user-friendly workflow.
- **Advanced CFD post-processing:** Through AcuSolve, advanced post-processing can be performed for the largest, most complex CFD data visualization.
- **Optimized workload management:** HyperWorks VWT integrates with Altair's PBS Professional to optimize resource utilization on Cray hardware.

Cray for Aerodynamics

To capture the details of the flow field around a side view mirror or to perform a large eddy simulation for a complete vehicle requires a detailed mesh – and hence a scalable compute environment to deliver the required performance.

Cray, Inc is known for building powerful computer systems to solve the world's most challenging problems, and HyperWorks Virtual Wind Tunnel's solver is proven to scale well on Cray systems.



HyperWorks VWT: Realistic and complete modeling environment including FSI simulation

Cray offers two products for HPC:

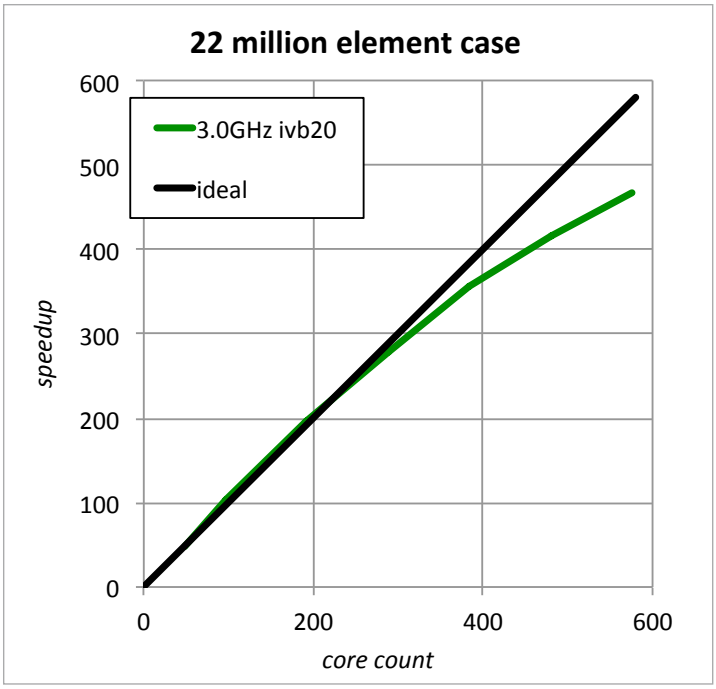
- Cray CS300 is a cluster architecture leveraging the latest x86 processors (e.g. Intel "Ivy Bridge") and several interconnect options (e.g. FDR InfiniBand). The compute blades are designed specifically for HPC with a focus on reliability and configuration flexibility.
- Cray XC30 is also a node interconnect architecture but is designed for maximum scalability and performance. It incorporates the latest Intel processors and is based on the Cray proprietary high speed "Aries" interconnect. The Aries interconnect and associated system software delivers industry leading scalability and performance. The Cray XC30 is able to scale simulations to over 5000 cores.

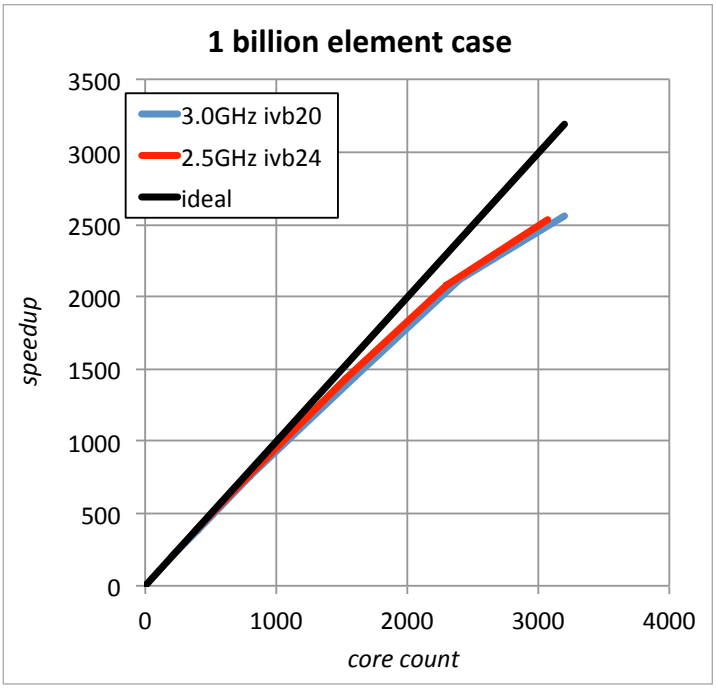
Proof Points: HyperWorks VWT on Cray Systems

Running HyperWorks VWT on a Cray XC30 system yields dramatic performance improvements, as shown in the charts on page 3.

Key Features & Benefits:

- **Speed and accuracy**: Perform fast and accurate transient and steady-state simulation
- **Robustness**: Handle elements with high aspect ratios and distortions
- **Scalability**: HyperWorks VWT solver scales to over 5000 cores
- **Advanced physics:** Perform Fluid-Structure Interaction (FSI), aero-elastics and aero-acoustics simulation and more
- **Streamlined workflow**: Operate in a simplified, automated and intuitive user environment
- **Customizable, auto-generated reports:** Get the data you need to make better decisions
- **Maximized hardware ROI:** Ensure your resources are fully utilized
- **Cost efficiency:** Reduce costly physical wind tunnel testing





HyperWorks VWT on Cray: Excellent scalability and parallel efficiency

To study the scalability of HyperWorks VWT at varying core counts, Cray and Altair focused on two problems of different sizes:

- Relatively small problem (22 million finite element cells): External aerodynamic analysis of a benchmark car model known as the ASMO model
- Large problem (1 billion finite element cells): Drafting simulation of two Formula-1 cars

The smaller (22 million element) problem demonstrates scalability on a Cray XC30 system with 2.7 GHz 12-core (2 sockets per node) processors from the Intel® Xeon® E5-2600 v2 family, familiarly known as "Ivy Bridge." The number of finite element cells in this model is rather small for a full-scale automotive case; however, it is useful in demonstrating the scaling performance for even a modest size model.

Results for 22 million element model:

- Excellent, nearly ideal scaling efficiency (over 95%) for up to 300 cores
- Very good scaling efficiency (over 80%) at 576 cores

Thus, for even a modest size model, HyperWorks VWT software combined with Cray hardware can significantly scale up performance to meet turnaround requirements.

The second problem involves the simulation of the drafting behavior of two Formula-1 cars. The number of finite element cells in this case is 1 billion – approximately 50 times larger than the smaller model – which represents a large-size external aerodynamic problem. The scalability, throughput, and I/O were tested on two Cray XC30 systems: one with 2.5 GHz 12-core Ivy Bridge processors and another with 3.0 GHz 10-core Ivy Bridge processors (2 sockets per node for both systems).

Results for 1 billion element model:

- Excellent parallel efficiency (over 90%) for up to 1600 cores
- Very good parallel efficiency (80%) at 3200 cores

Key Benchmark Results:

- Virtually ideal efficiency when scaling to 300 cores
- For smaller problems, strong performance up to 576 cores
- For large problems, excellent performance up to 1600 cores, with very good performance at 3000+ cores

As shown in these results, where supercomputing performance is a requirement, the HyperWorks VWT and Cray solution provides efficient scaling to meet increasingly tight product design schedules. Also note that HyperWorks VWT allows significantly larger simulation time increments compared to explicit solvers, which leads to very fast turnaround-time.

Configuration Examples

Cray and Altair suggest the following configurations examples for an efficient virtual wind tunnel compute solution. For these examples, the Cray CS300 is configured with an emphasis on capacity computing (i.e. moderate scaling for many simultaneous simulations); the Cray XC30 is configured for capability computing (i.e. scaling to 1000s of compute cores):

Cray CS300 Configuration	For simulations scaling to **240 cores** (i.e. emphasis on capacity computing)
Hardware	CS300, ½ rack configuration, QDR InfiniBand interconnect
Compute Nodes	30 dual socket nodes, 2.7 GHz “Ivy Bridge” (12 cores/processor, 720 total compute cores)
Memory	64 GB per node
Storage	20 TB of storage, NFS file system

Cray XC30 Configuration	For simulations scaling to **2400 cores** (i.e. emphasis on capability computing)
Hardware	XC30-AC, two chassis configuration, Cray “Aries” interconnect
Compute Nodes	120 dual socket nodes, 3.0 GHz “Ivy Bridge” (10 cores/processor, 2400 total compute cores)
Memory	64 GB per node
Storage	80 TB of storage, Lustre file system

“HyperWorks Virtual Wind Tunnel benchmarks correlate exceptionally well with actual wind tunnel results. The ease, flexibility, accuracy and speed of HyperWorks VWT will benefit not only the auto industry but also other fields where external aerodynamic simulation is crucial, such as wind-turbine development and architecture engineering and construction.”

Farzin Shakib,
VP of CFD Technology, Altair

“Simulation is no longer bound by the high-end data center, and Cray's new XC30-AC system continues the company's tradition of creating purpose-built systems that appeal to new customers in expanding segments of the supercomputing market.”

Earl Joseph,
HPC VP, IDC

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Getting Started

- Read about HyperWorks VWT at: www.altairhyperworks.com/vwt
- Request a demo: www.altairhyperworks.com/schedule-demo
- Learn more about Cray’s offerings for automotive design: www.cray.com/IndustrySolutions/Manufacturing.aspx
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Altair Engineering, Inc., World Headquarters: 1820 E. Big Beaver Rd., Troy, MI 48083-2031 USA
Phone: +1.248.614.2400 • Fax: +1.248.614.2411 • www.altair.com • info@altair.com