Altair

Innovation Intelligence®

Staying Out of the Wind Tunnel with Virtual Aerodynamics

Greg Clifford, Stephen Behling, Farzin Shakib, Marc Ratzel, Yaser Khalighi,

Scott J. Suchyta (Just the presenter ☺)

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Special Thanks

- Greg Clifford, Manufacturing Segment Manager
- Stephen Behling, Benchmarking Engineer

- Farzin Shakib, VP, CFD Technology
- Marc Ratzel, Director, CFD Solutions
- Yaser Khalighi, Development Manager

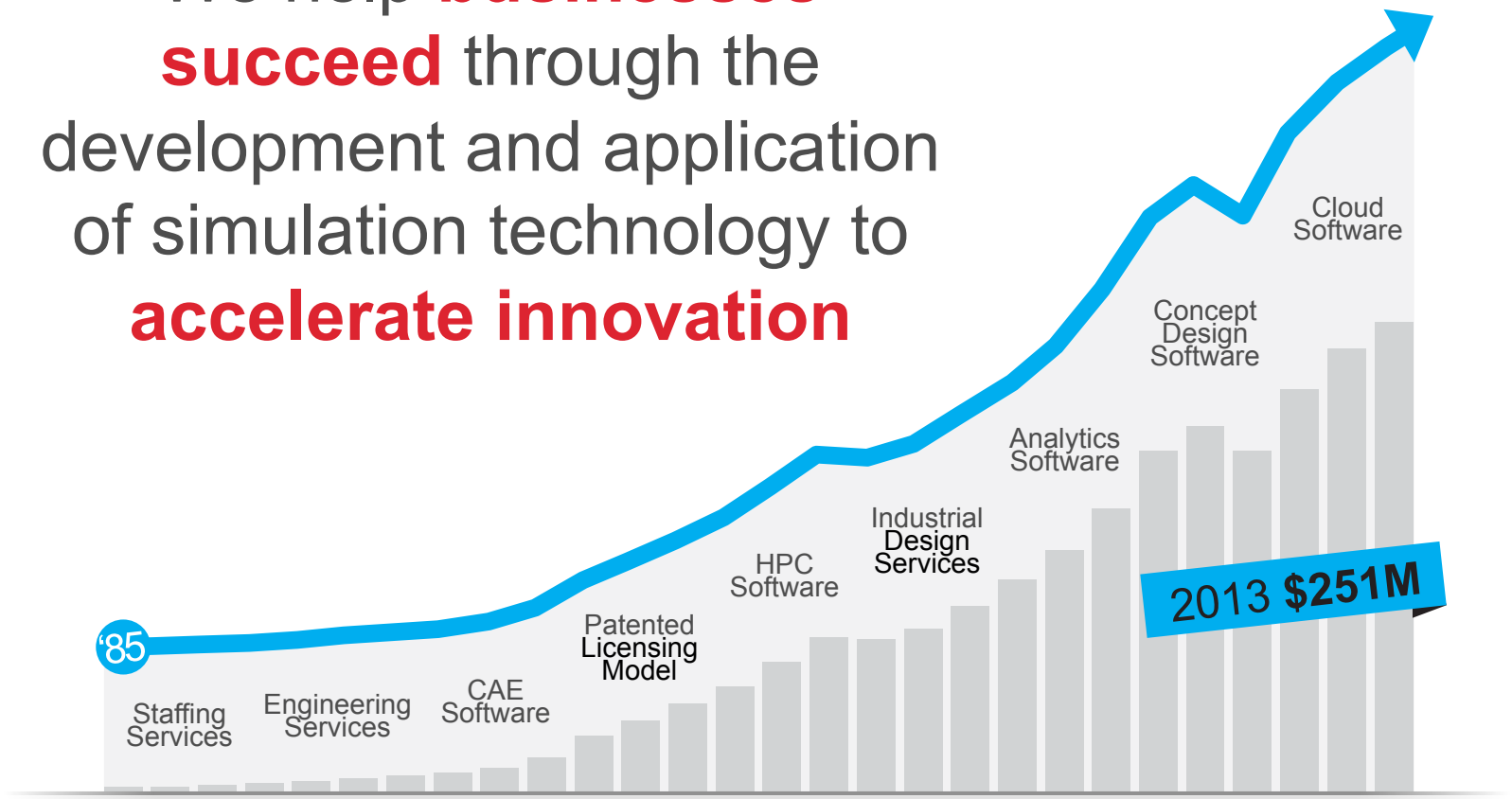
Quick Overview:

What We Do

About Us

Altair

We help **businesses succeed** through the development and application of simulation technology to **accelerate innovation**



Altair Knows HPC

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Altair is the only company that

***makes* HPC tools…**

Altair | PBS Works™

***AND develops* HPC applications..**

Altair | HyperWorks®

***AND uses* these to solve real problems**

Altair | ProductDesign

700+ Altair engineers worldwide
use HPC every day
to design, simulate, and optimize
highly-engineered products

Virtual Wind Tunnel

What is it?

Altair's Virtual Wind Tunnel

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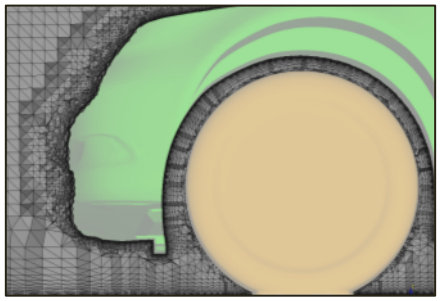
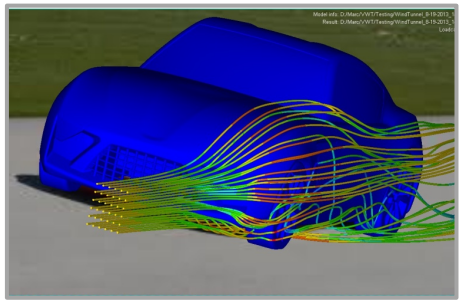
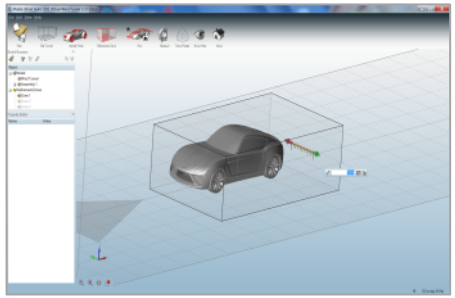
Vertical solution for **external-aerodynamics** analyses, **efficient** in process and **accurate & robust** in solution.



Advanced meshing



Accurate, robust & scalable CFD solver



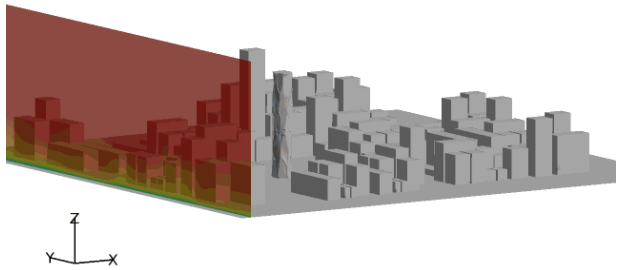
Automated & streamlined workflow

Execution on HPC

Non automotive applications:

Bicycles

Architecture



Challenges of external aerodynamic simulations *(CFD)*

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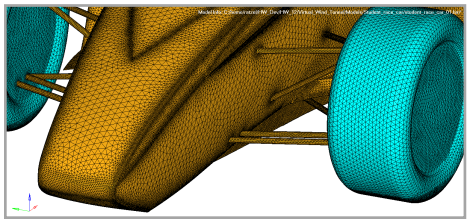
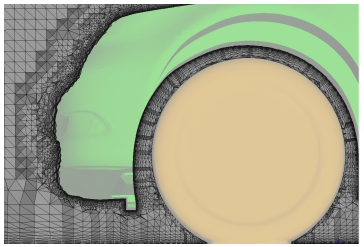
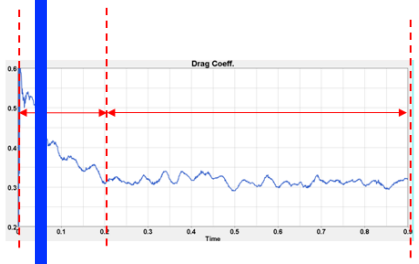


- **Preparation**
  - up to 4 weeks *(clean-up / surface meshing)*
  - Shell mesh ~ 4-7Mio triangular shell elements



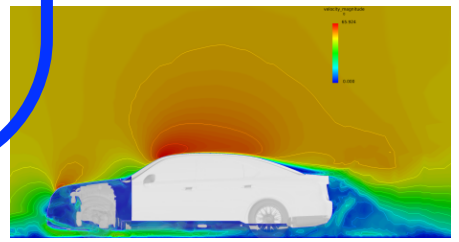
- **Model**
  - Volume mesh ~ 70-150Mio *(mixed elems, 1-6h meshing time)*
  - 1st layer height ~ 1e-4m *(y+ ~ 10)*
  - 10-15 boundary layers



- **CFD run**
  - 100-400 cores *(formula 1 teams use up to 3000 cores)*
  - Transient: 48h or more *(physical time 1-6 sec)*
  - Steady: over night ~ 10h

- **Post-processing**
  - Data size up 100GB
  - Batch process

Virtual Wind Tunnel



Altair's Virtual Wind Tunnel

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External automotive CFD analysis

File Edit View

Files Views Measure Move Edit Tunnel Identify Parts Refinement Zone Section Cuts Probe Points Material Run

Run Virtual Wind Tunnel

Name of run: Variant_DX128
Number of cores: 256
Analysis setup
Inflow speed: 38.8
Analysis type: Transient
Run time: 3 s
Time step: 0.0001 s
Number of steps: 30000
Fluid Material: Air
Moving ground
Rotating wheels
Meshing
Results
Restore Export Run Close

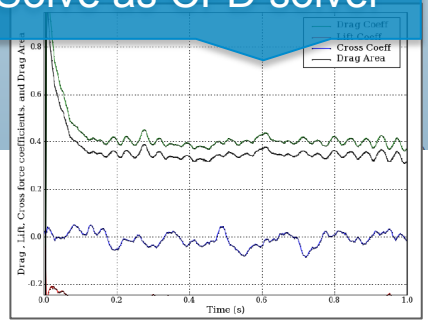
Advanced physics (rot. wheels, radiator, FSI)

Efficient case setup

velocity_magnitude
0.626205
80.520
0.000

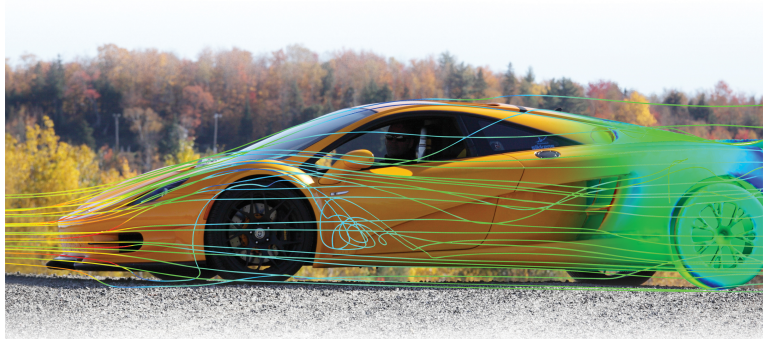
Automatic post-processing

AcuSolve as CFD solver



Why VWT ?

- **Speed**
  - Fast transient AND steady simulations



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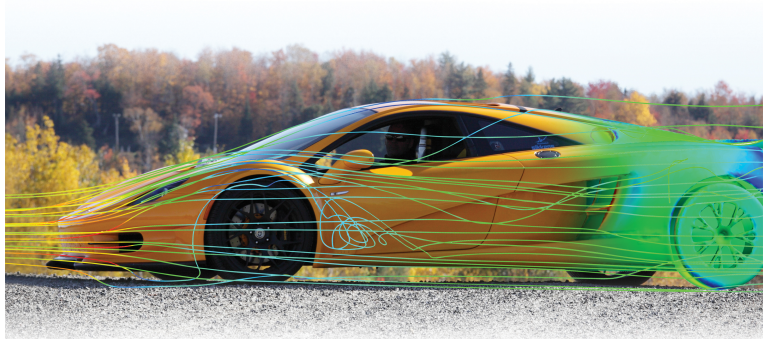
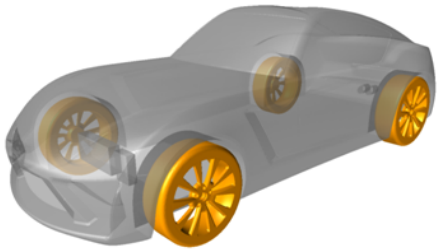
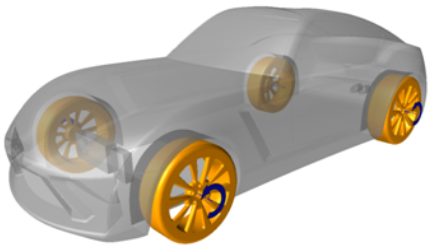


- **Efficient case setup**
  - For example smart logic for wheel definition



Identify parts as wheel

via mouse click



Wheel Rpm	
Rpm	1473
Wheel Center	
Wheel Center X	1.6669
Wheel Center Y	-0.76955
Wheel Center Z	0.3269
Wheel Axis	
Wheel Axis X	1.44E-005
Wheel Axis Y	-1
Wheel Axis Z	-5E-006

Automatic computation of wheel setup parameters

Why VWT ?

Altair

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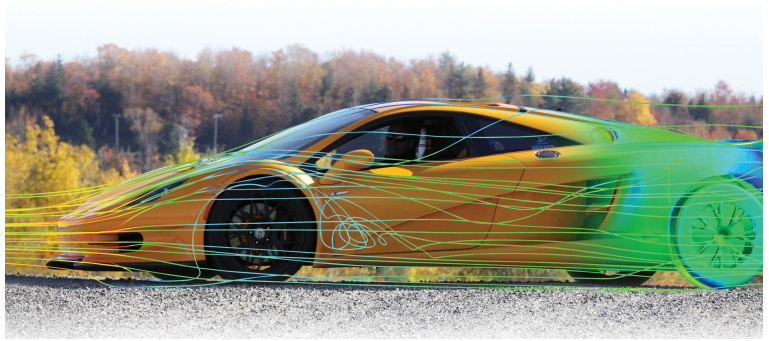
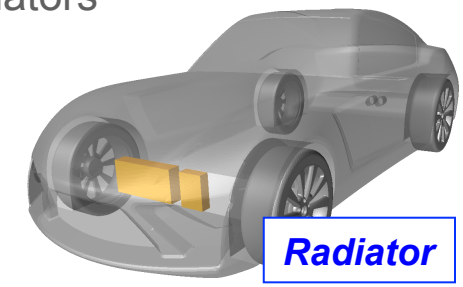
  - Fast transient AND steady simulations

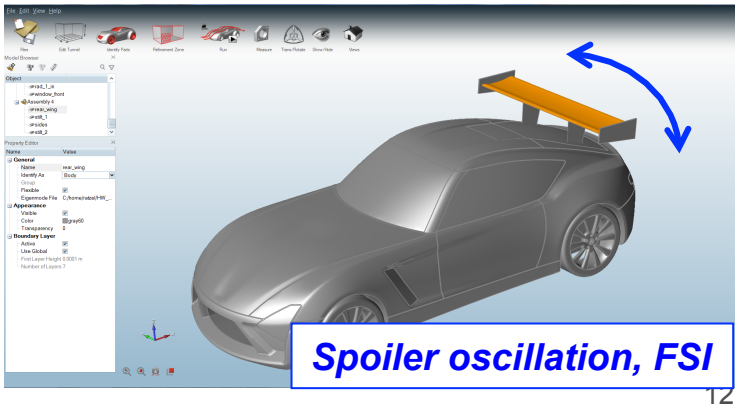


- **Efficient case setup**
  - For example smart logic for wheel definition

- **Advanced physics**
  - Fluid-Structure interaction
  - Radiators



Radiator



Spoiler oscillation, FSI

Aerodynamic Optimization

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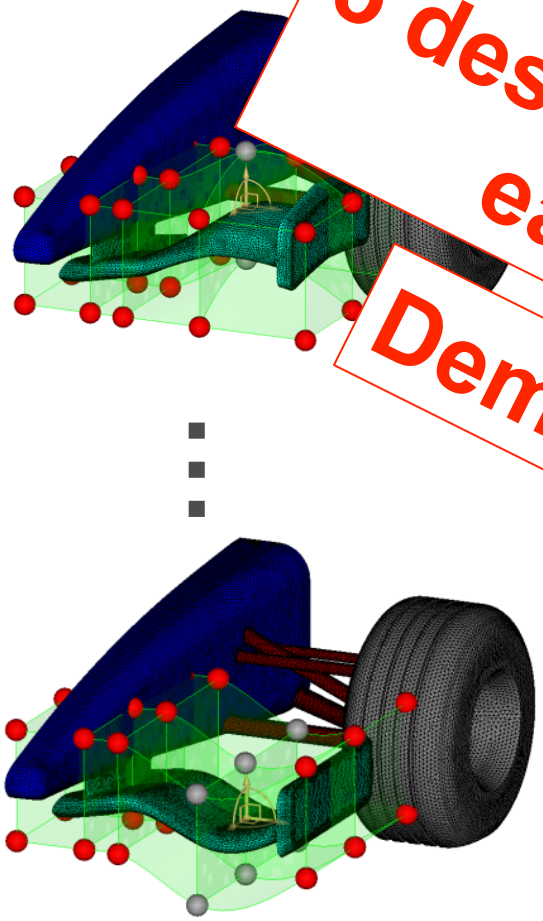
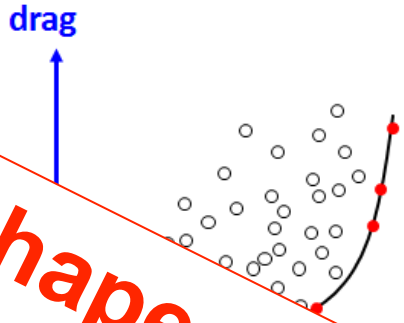
5 design variables (shape changes) each w/ 3 levels = 75 runs

Demand for fast hardware!!



Design space
(Shape variations)



Optimization
(Multi-objective optimization)

Pareto front
(trade off between downforce and drag)

VWT Requires HPC Hardware…

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- Jobs run in parallel on multiple processors
- Need fast connections on high-performing systems
- **Altair and Cray** have collaborated to test Virtual Wind Tunnel on Cray XC systems
- Cray will now present their external aerodynamics solutions AND recommended configurations for Virtual Wind Tunnel…

CRAY

Supercomputing Benefits Application Users

Cray Inc. provides scalable, high performance computer systems designed to solve the most challenging computational problems.

Hardware

- **Cray XC40**
  - Cray designed Aries™ dragonfly network with Intel processors
  - Available with NVIDIA GPUs or Intel Phi co-processors
- **Cray CS400**
  - Flexible, scalable InfiniBand based clusters with Intel processors
  - Available with NVIDIA GPUs or Intel Phi co-processors
  - Cray's Advanced Cluster Engine™ management software
- Cray Sonexion™
  - Scalable, dense external Lustre parallel file system; demonstrated > 1 TB/s.
- Cray Urika-XA and Urika-GD specializing in data analytics

Software

- Linux based OS; optimized communication and scientific libraries; compilers, debuggers, performance analyzers

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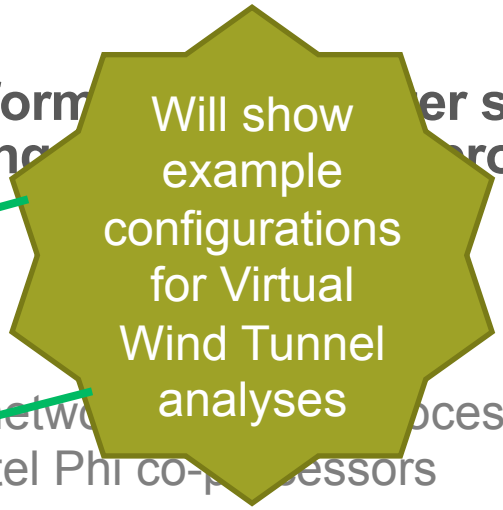

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HPC Centers running CAE applications

- CAE codes scaling to over 10,000 cores
- Both In-house and ISV applications
- Key to introducing leading edge HPC to commercial companies

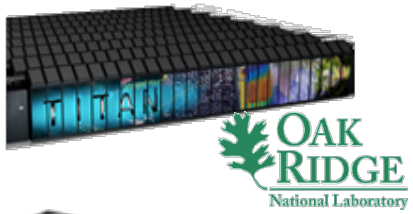
EPSRC
Engineering and Physical Sciences Research Council

Los Alamos NATIONAL LABORATORY EST. 1943
Sandia National Laboratories

KTH PDC

H L R S

AFRL DSRC SUPERCOMPUTING RESOURCE CENTER



OAK RIDGE National Laboratory

NERSC

ERDC DSRC DoD Supercomputing Resource Center

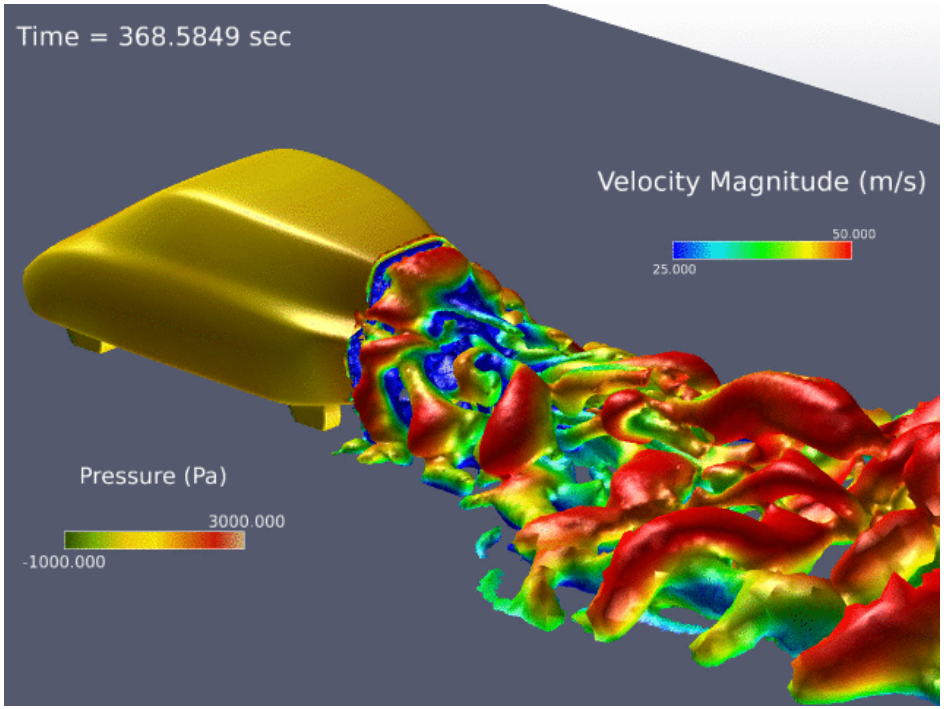
Case Studies

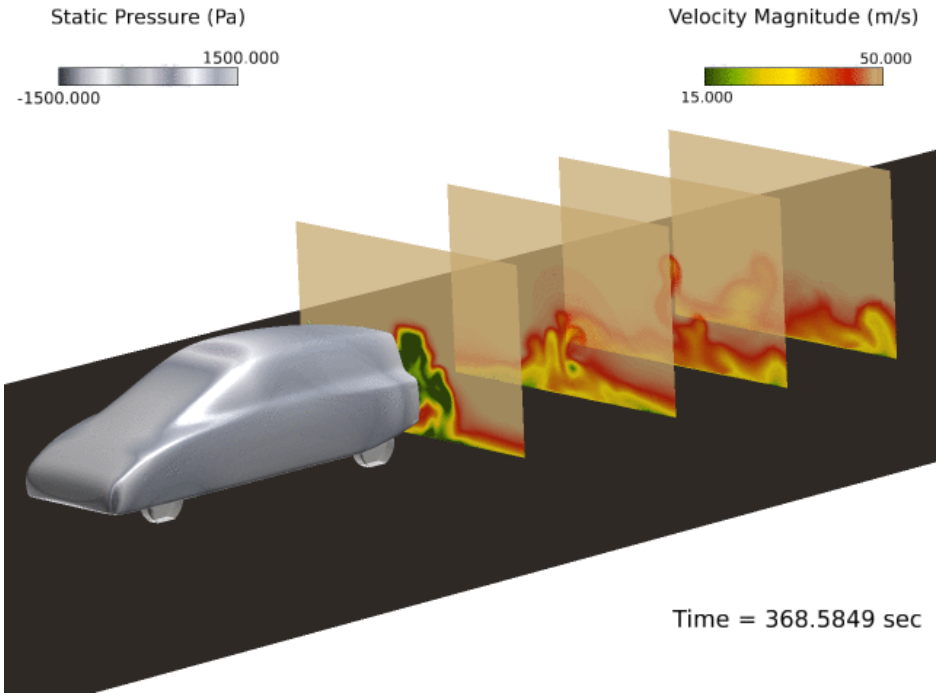
Case Studies

Case studies are real-life engineering problems
All tests are performed in-house by Cray

- **Case Study #1: Aerodynamics of a car model (ASMO)**
  - 22 million elements (small test case)

Cray test system:
- XC30
- 2.7 GHz
- 12-core (2 sockets per node) Intel® Xeon® E5-2600 v2

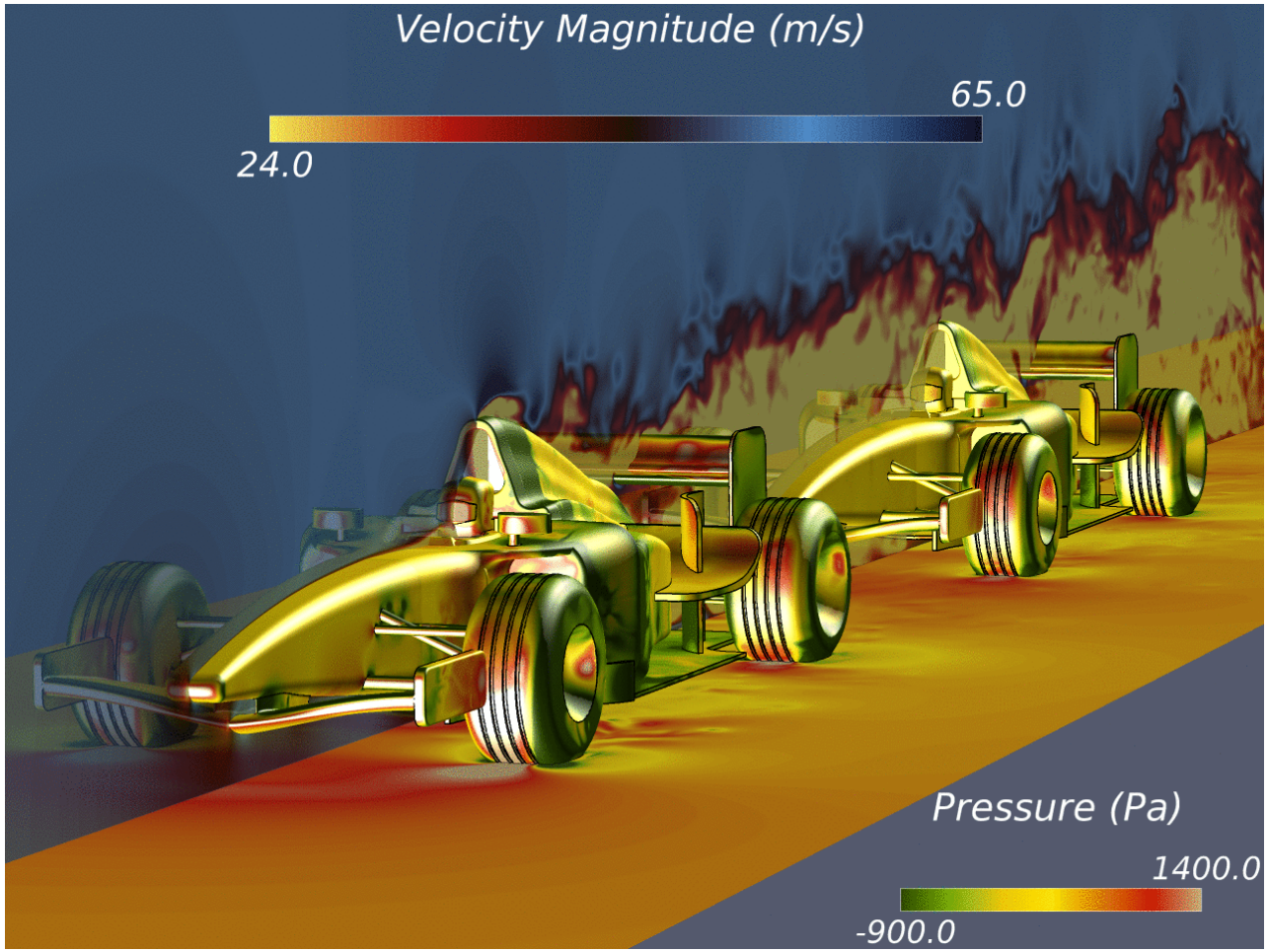




Results post-processed by AcuFieldView, an OEM version of Intelligent Light's leading CFD post-processor FieldView

Case Studies

- **Case Study #2: Formula 1 drafting**
  - 1 billion elements (large test case)



Cray test system:
- XC30
- 2.7 GHz
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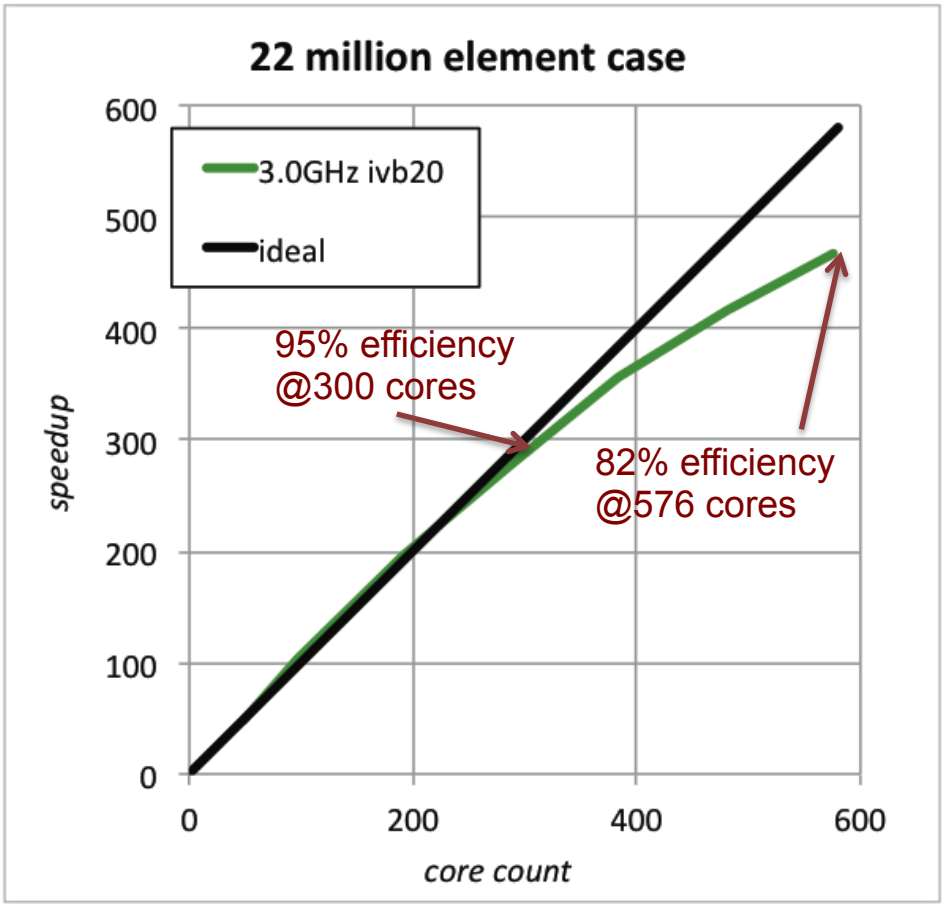
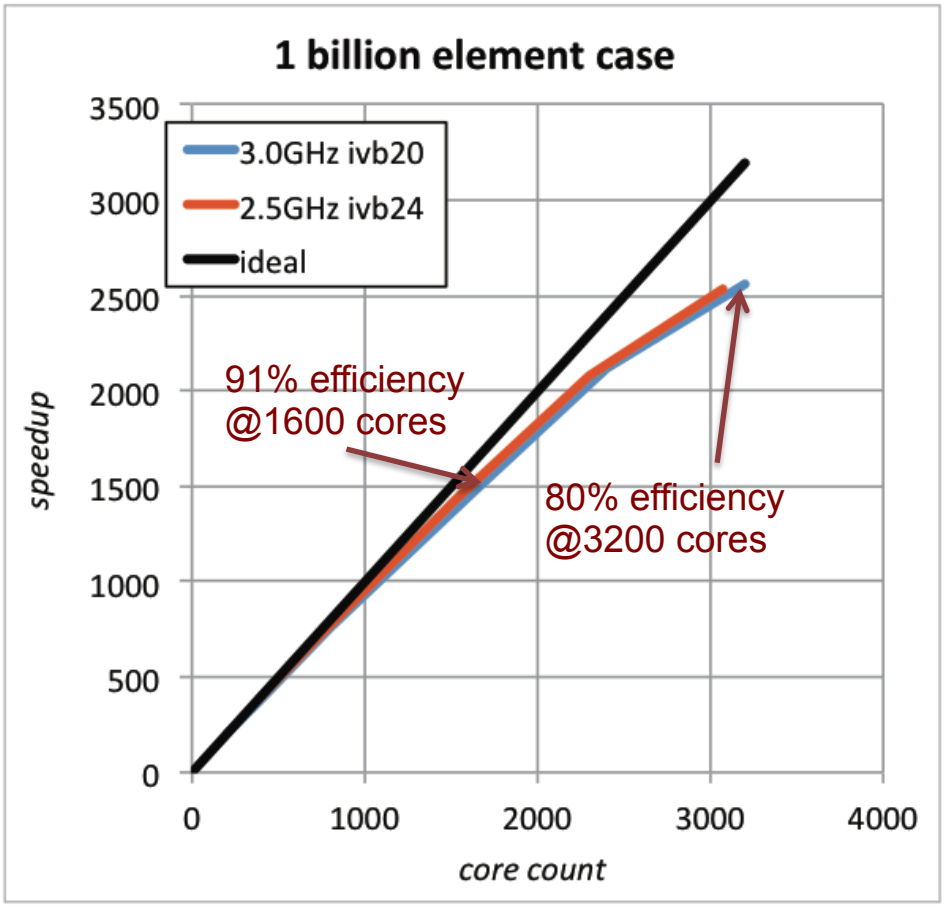
Results post-processed by AcuFieldView, an OEM version of Intelligent Light's leading CFD post-processor FieldView

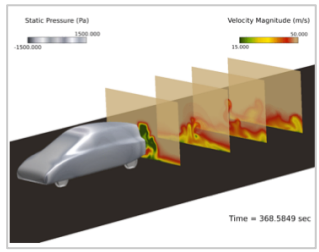
Scalability results



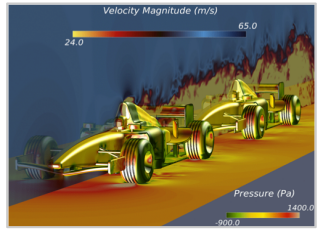


Conclusions

- **Results for 22 million element model:**
  - Nearly ideal efficiency (over 95%) up to 300 cores
  - Very good efficiency (over 80%) at 576 cores



- **Results for 1 billion element model:**
  - Excellent efficiency (over 90%) up to 1600 cores
  - Very good efficiency (80%) at 3200 cores



- **Key takeaways:**
  - For even modest-sized models, Altair + Cray can significantly scale up performance to meet tight turnaround requirements
  - Virtually ideal performance scaling to 300 cores
  - Very good to excellent performance for larger problems at 576--3000+ cores
  - Note: Virtual Wind Tunnel allows significantly larger simulation time increments compared to explicit solvers, which leads to very fast overall turnaround

Tips for Optimizing Your VWT Solution

- **Enable Cray-specific AcuSolve executables**
  - Fine-tuned for Cray architecture, in particular the inter-connect
- **Steady or unsteady?**
  - External aero problems are unsteady in nature
  - Depending on the geometry and the problem of interest, the steady approximation can provide much faster solution with adequate accuracy
- **Automatic convergence detection within VWT**
  - Determine when the transient solution is stationary and simulation can be stopped

Closing

Choosing the Right VWT Environment

- **Large VWT simulations require a scalable solution (potentially scaling to 1000s of compute cores). This requires a high speed interconnect and overall compute environment that is designed for high performance.**
  - The system should be tightly integrated and designed for HPC simulations. This includes the system hardware, software, storage, and applications that are well integrated and balanced for an HPC workload.
- **A Cray XC40 system is the best choice if…**
  - Need to scale individual simulations to over 1000 cores
  - The priority is a tightly integrated system which can scale to >>10,000 cores.
- **A Cray CS400 system is the best choice if…**
  - You require more flexibility in the system configuration or the data center environment (e.g. the power requirement/rack)
  - Modest scaling requirements (e.g. 200 to 400 cores per simulation)

A Cray XC40 example for a virtual wind tunnel

The XC40 is designed for production environments where scalability is the priority. The Cray interconnect enables applications to scale across the whole system.

Cray XC40 Configuration	For simulations scaling to **3200 cores** (i.e. emphasis on capability computing)
Hardware	**XC-40AC**, two chassis configuration, Cray "Aries" interconnect)
Compute nodes	**120 dual socket nodes**, 2.3 GHz "Haswell" (16 cores/processor, 3712 total compute cores)
Memory	**64 GB** per node (assumes several nodes used for large simulation, hence less memory required per node)
Storage	**120 TB** of storage, Lustre file system

A Cray CS400 example for a virtual wind tunnel

The CS400 cluster architecture is designed for HPC environments requiring moderate scaling and where configuration flexibility is the priority. The InfiniBand interconnect enables application scaling to hundreds of cores.

Cray CS400 Configuration	For simulations scaling to **320 cores** (i.e. emphasis on capacity computing)
Hardware	**CS400**, 1/2 rack configuration, FDR InfiniBand interconnect)
Compute nodes	**30 dual socket nodes**, 2.3 GHz “Haswell” (16 cores/processor, 960 total compute cores)
Memory	**128 GB** per node (fewer nodes per simulation requires larger memory/node)
Storage	**40 TB** of storage, NFS file system

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***makes* HPC tools…**

Altair | PBS Works™

***AND develops* HPC applications..**

Altair | HyperWorks®

***AND uses* these to solve real problems**

Altair | ProductDesign

700+ Altair engineers worldwide
use HPC every day
to design, simulate, and optimize
highly-engineered products

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