HEXAGON

Accelerating your simulations with HPC

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Agenda

- Context
- HPC Strategies with Actran
- Testing Cradle on HPC clusters
- Summary

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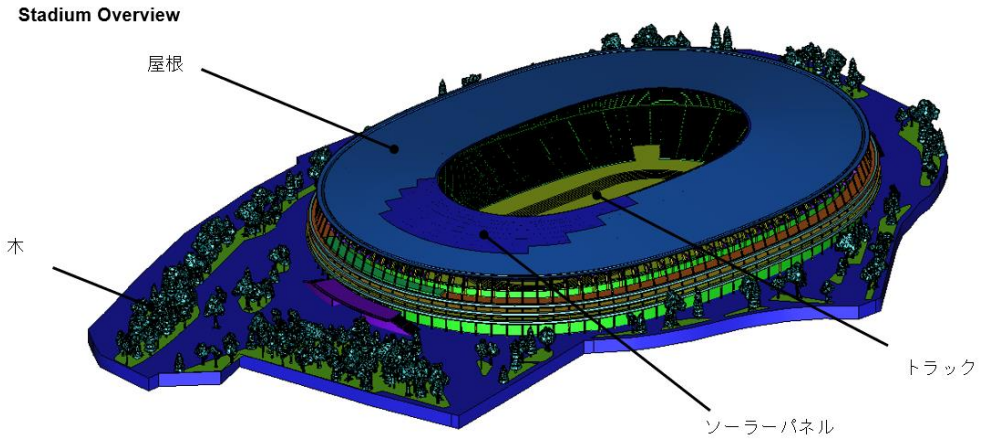
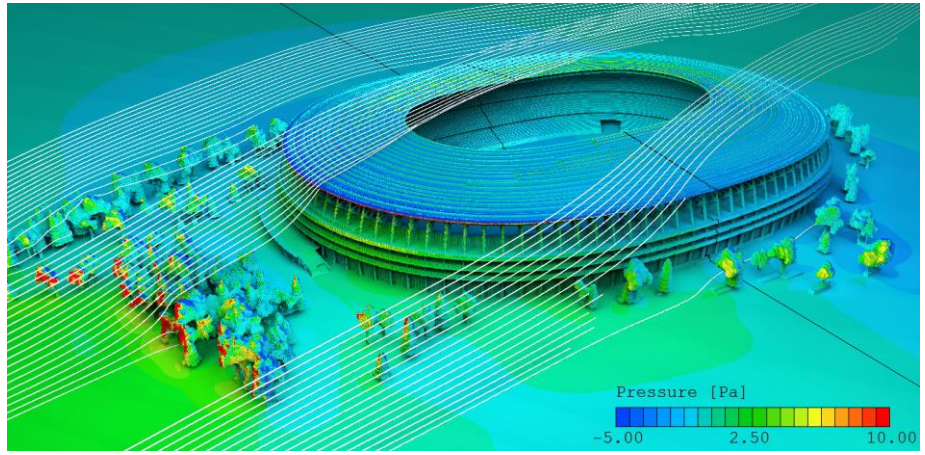
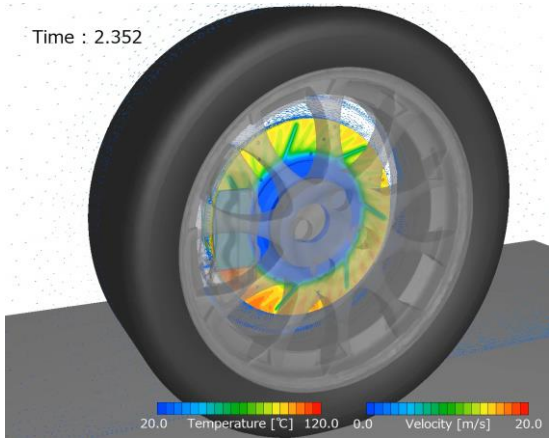
Model size is increasing

Due to higher fidelity and more complex modeling

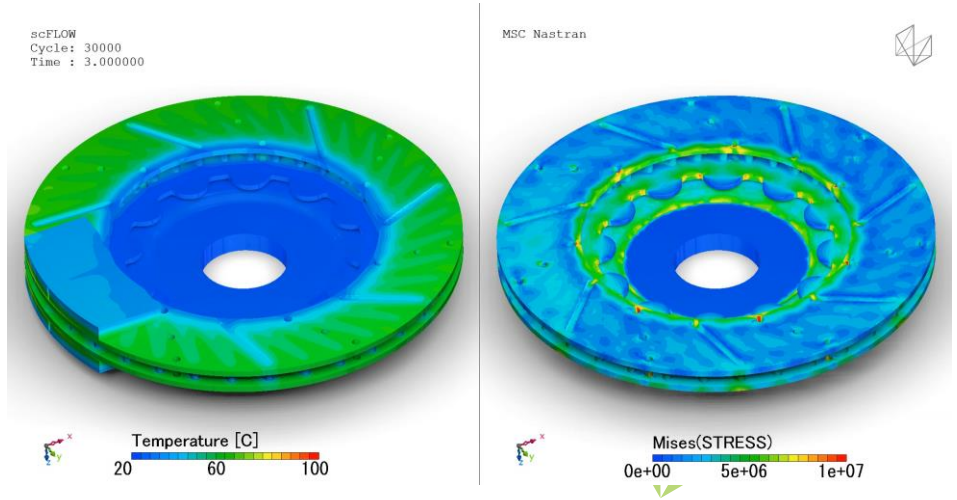


2 B elements

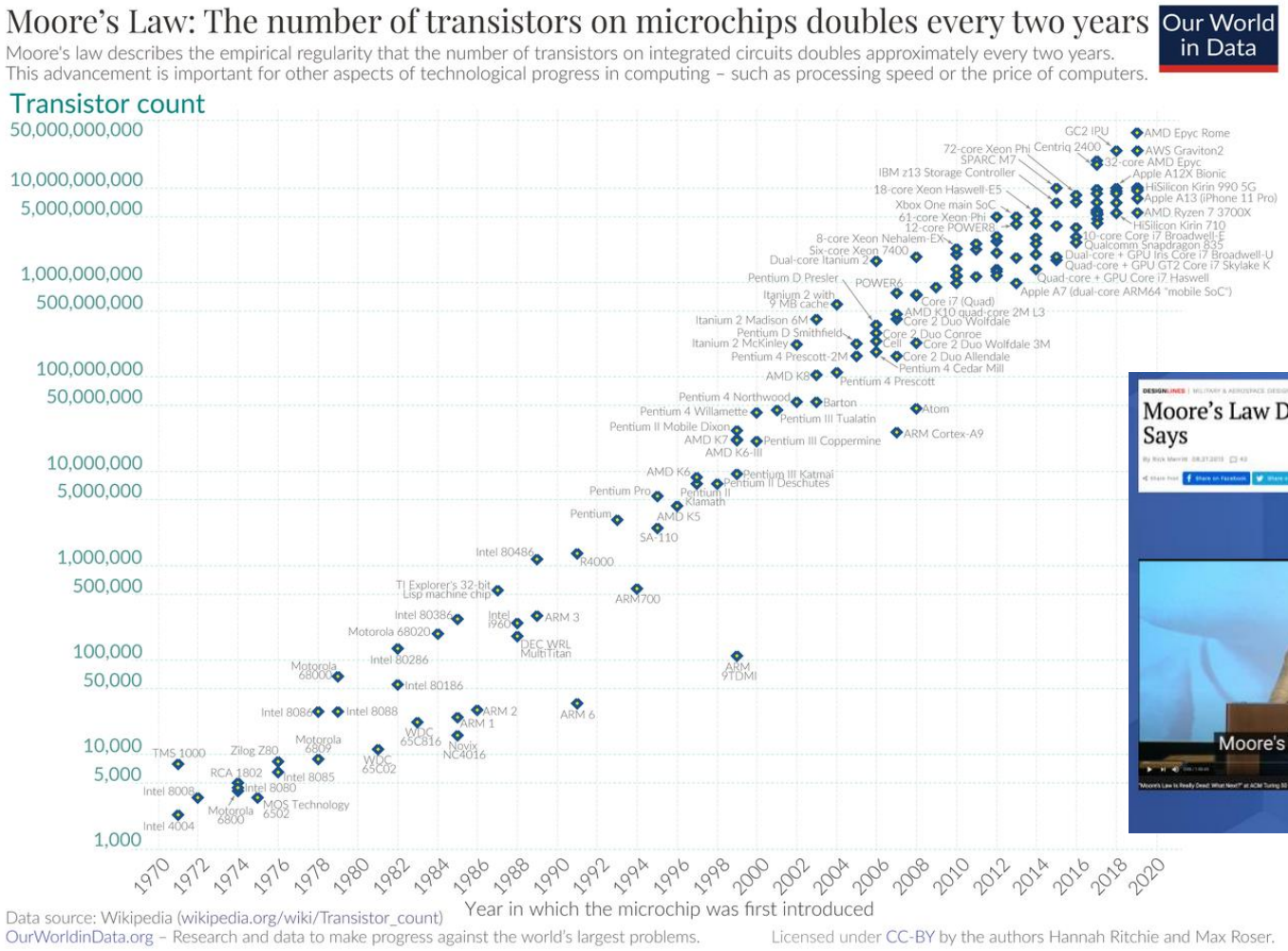


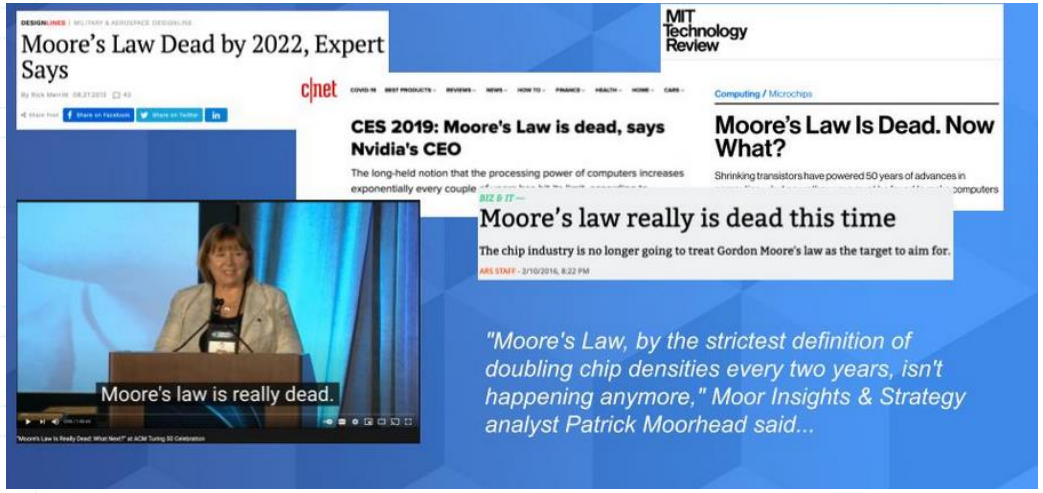


Multiphysics Coupling



Advances in computing





https://en.wikipedia.org/wiki/Moore%27s_law#/media/File:Moore's_Law_Transistor_Count_1970-2020.png

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HPC, why?

To tackle large problems

To run computations faster

To use a very large cluster efficiently

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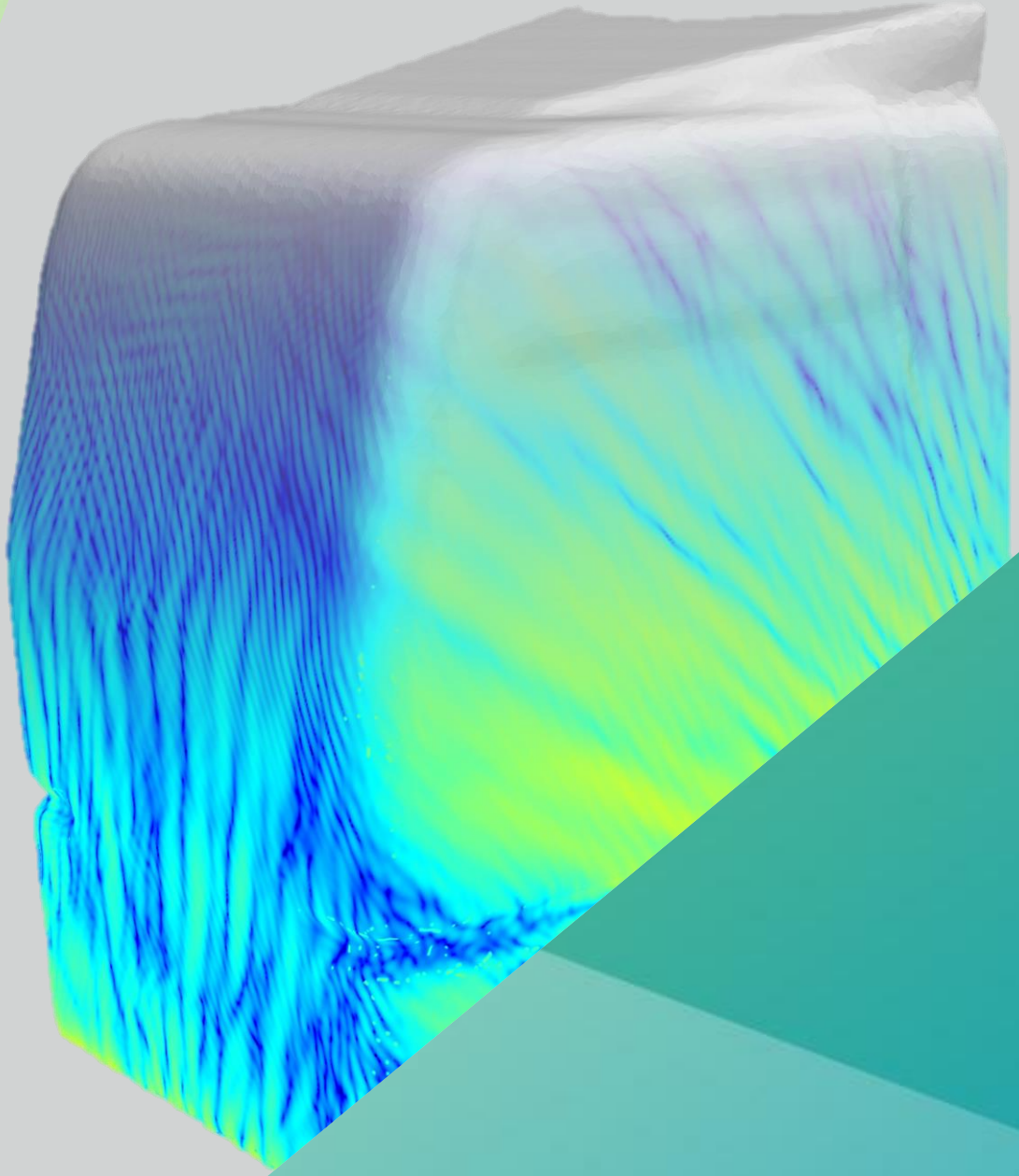

HPC Strategies with ACTRAN

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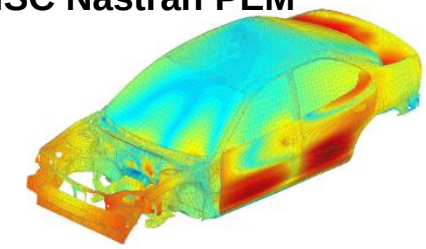
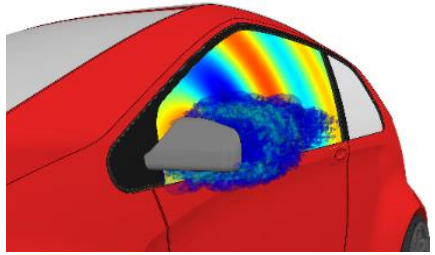
The Actran Software Suite

Actran for Trimmed Body

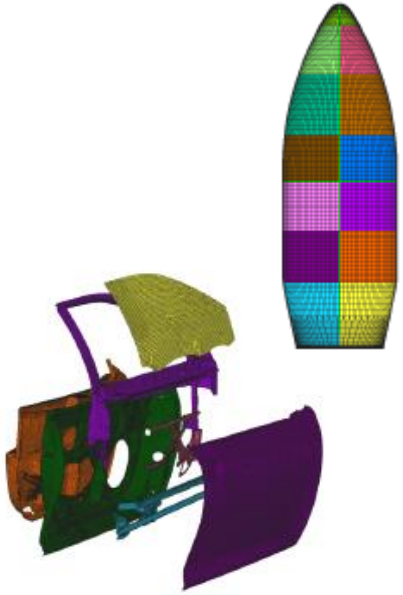
MSC Nastran PEM



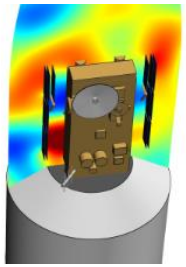
Actran SNGR



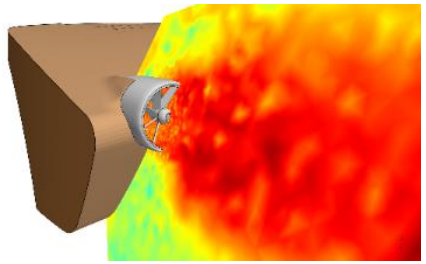
Actran SEA



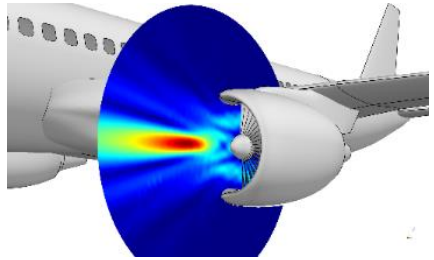
Actran Vibro-Acoustics



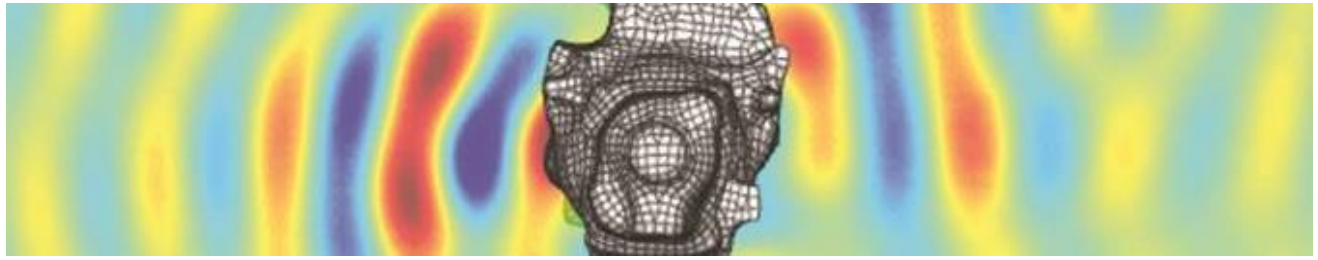
Actran Aero-Acoustics



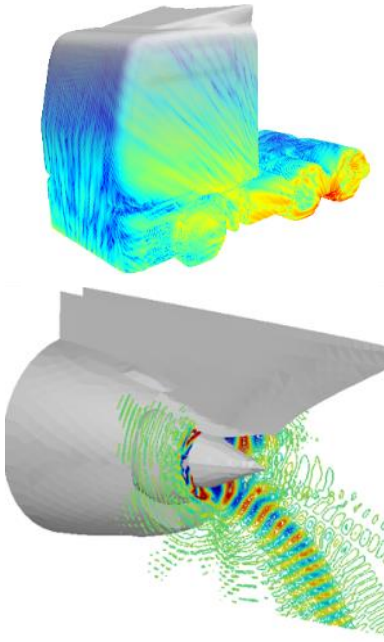
Actran TM



Actran Acoustics

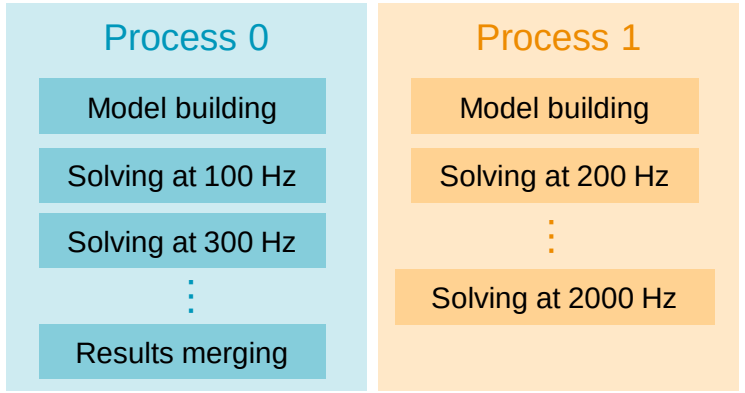


Actran DGM



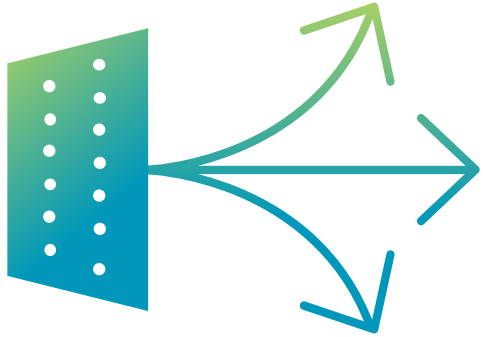
Definitions

Process parallelism



- Computation tasks are distributed to several processes
- Process memory is not shared between the different processes

Multithreading



- Distribute the work of a given process on multiple cores
- Process memory is shared among the different threads

GPU Acceleration

- Use of GPU-specific libraries to accelerate the matrix-matrix multiplications.
- The memory access efficiency is improved by new data structure management.

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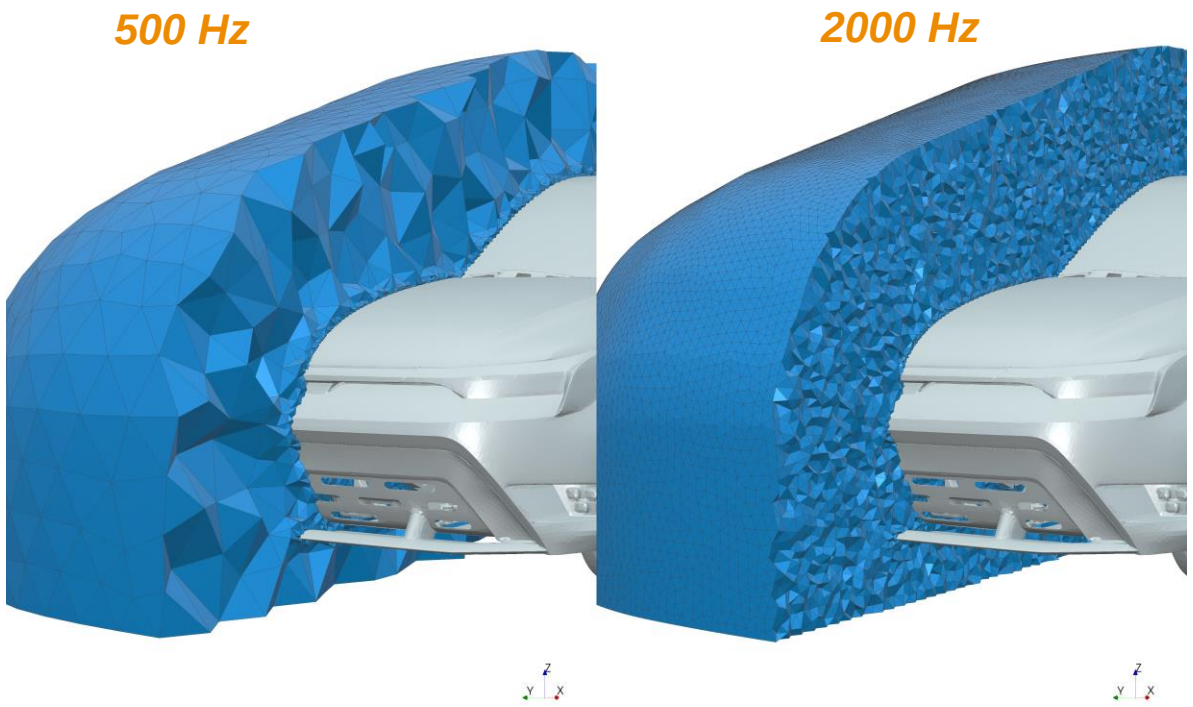
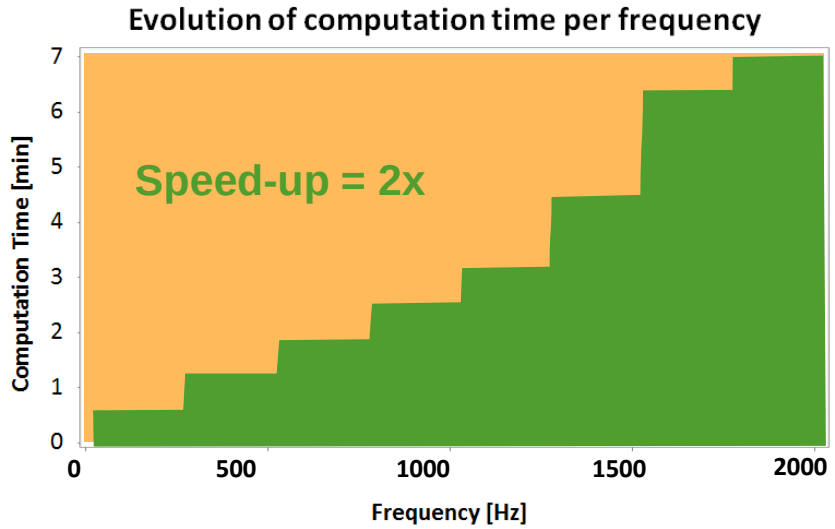
Adaptive mesh generation

The solver generates coarser meshes to solve lower frequencies for which mesh requirements are lower (because of the larger wavelength)



With mesh adaptivity

Without mesh adaptivity



The mesh is **adapted** to specific **frequency bands** to **optimize** the calculation

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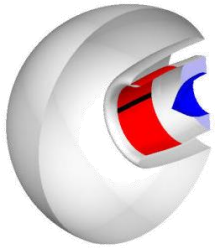
Direct Solver parameters

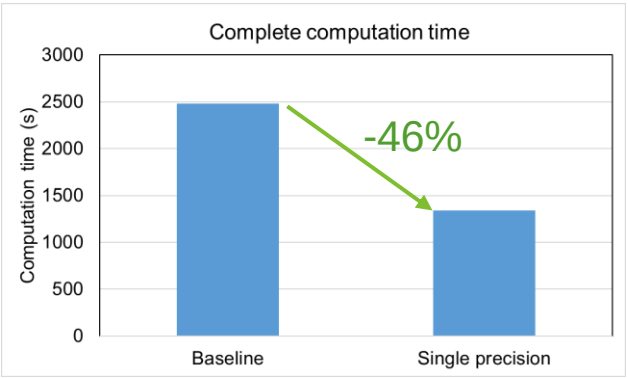
There are a number of direct solver parameters that can help accelerate simulations

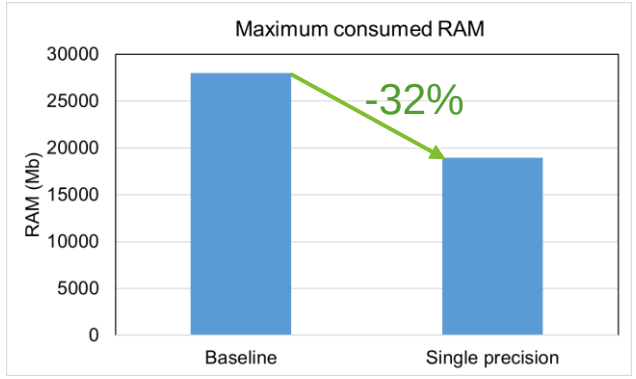
Single precision solver

- Using **Single Precision (SP)** instead of double precision → potential reduction of the computation resources with a limited impact on the solution accuracy



Single precision: high decrease of computation time and RAM consumption

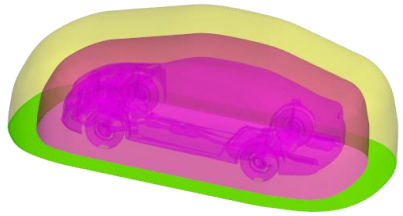


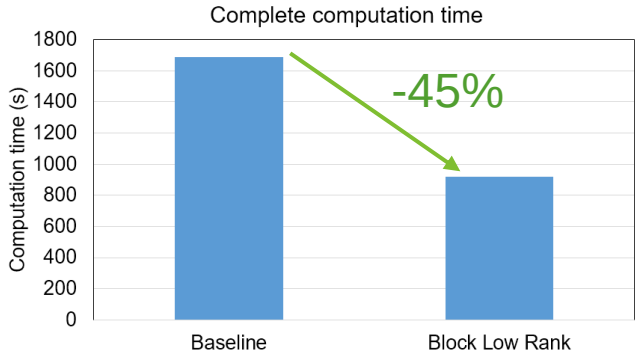


Block Low-Rank (BLR) approximation (MUMPS)

- **Block Low-Rank (BLR)** is an approximation for the factorization phase that provides performance gains with limited impact on the results

Block Low Rank: high decrease of computation time





Performance improvements and new solution strategies of Actran TM for nacelle simulations, Bernard Van Antwerpen et al, 20th AIAA/CEAS Aeroacoustics Conference)

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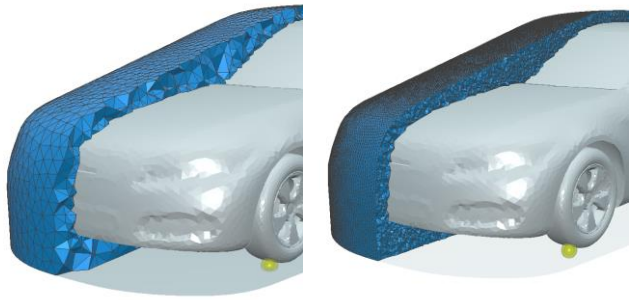
Strategies for accelerating Computing Time

Provide results fast and early in the development process

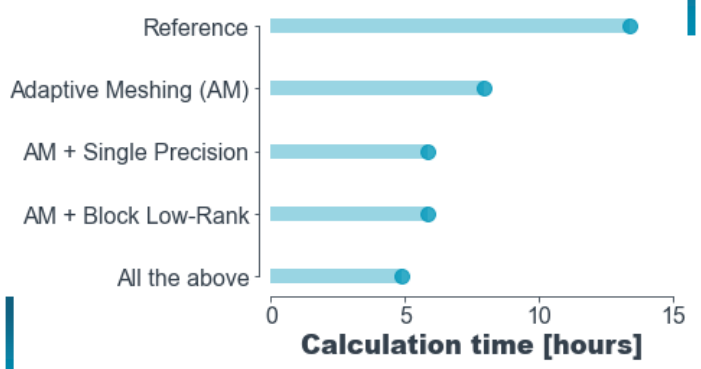
Adaptive mesh generation



500 Hz *2000 Hz*

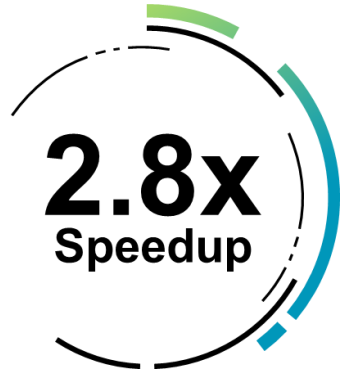
The computational mesh is adapted to the frequency, making the computation faster and more efficient

Solver optimization



Various solver settings can be used to reduce calculation time up to **3x**

Efficient parallelization



With 4 parallel processes

Try more solutions with efficient **parallelization** options

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Benchmark cases with ACTRAN

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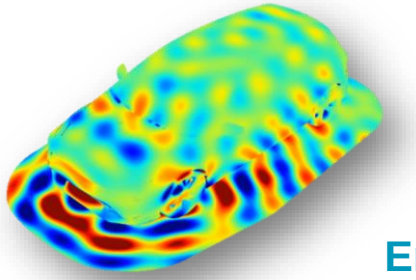
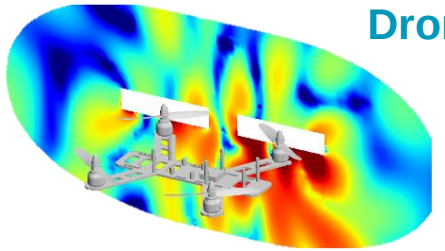
Collection of benchmark cases

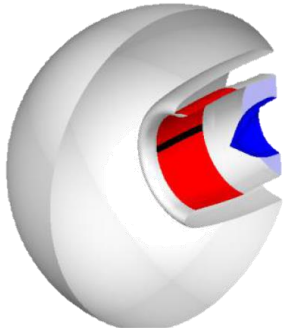
Electric vehicle



Drone



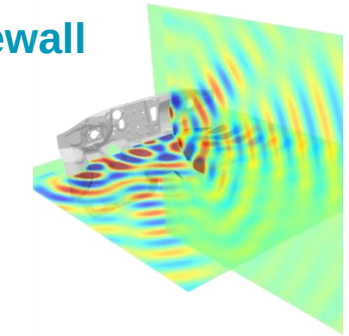
Engine inlet



Satellite

Loudspeaker in cavity

Firewall



A set of benchmark cases has been created that will allow users to test their HPC capabilities for their appropriate application

Applications

- Electric vehicle exterior radiation
- Drone noise
- Satellite vibration under diffuse sound field
- Engine inlet noise
- Loudspeaker integration up to 20,000 Hz in Actran DGM
- Firewall transmission loss

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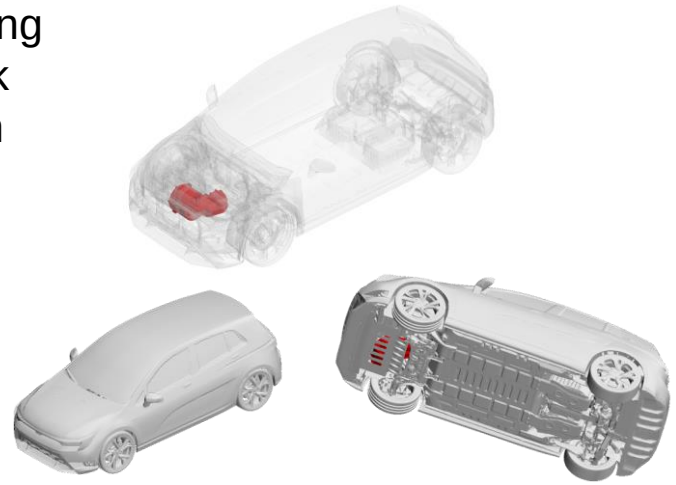
Exterior radiation of electric vehicle

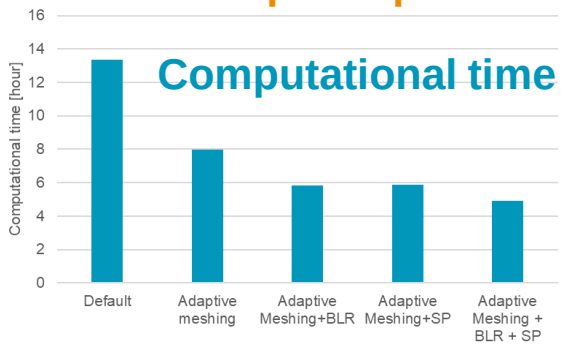
Exterior Radiation of EV	
Sequence	Direct Frequency Response
Solver	MUMPS
Number of DOF	4.4 million
Number of elements	19 million
Loadcases	12
Frequency range	50 to 2000 Hz, 50 Hz step

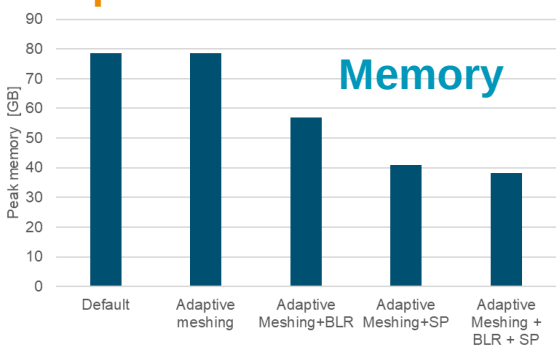
Methods:

- Multiprocessing with frequency (up to 8 processes)
- Multithreading (up to 32 threads)
- Solver parameters:
  - Adaptive meshing
  - Block Low-Rank
  - Single precision

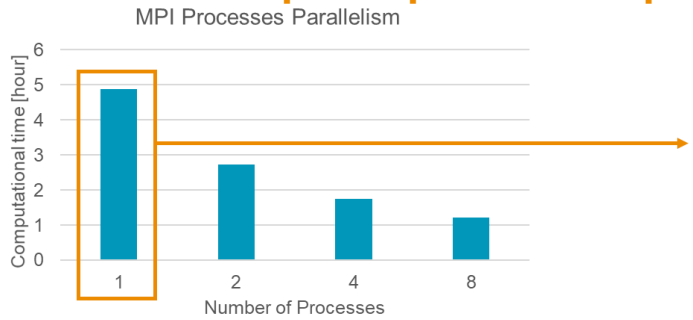


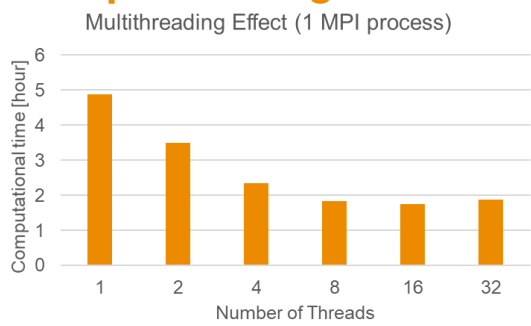
Speedup based on solver parameters

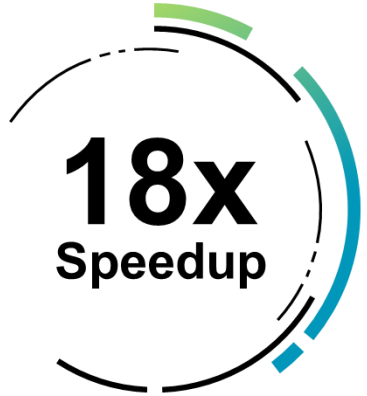




Speedup based on parallel processing

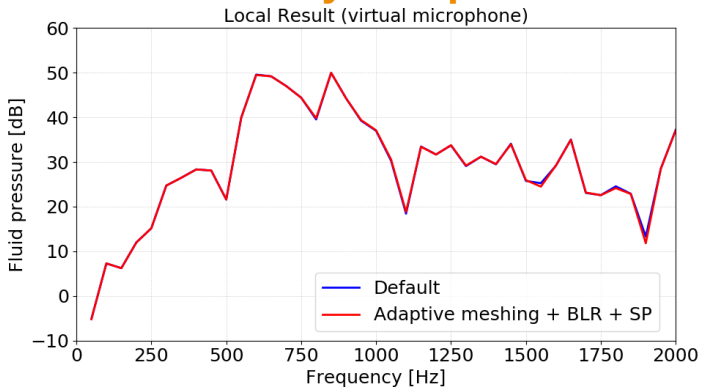






With 8 parallel processes and 6 threads

Accuracy comparison



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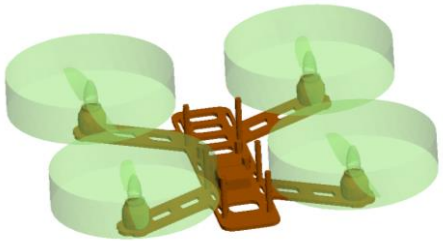
Drone noise

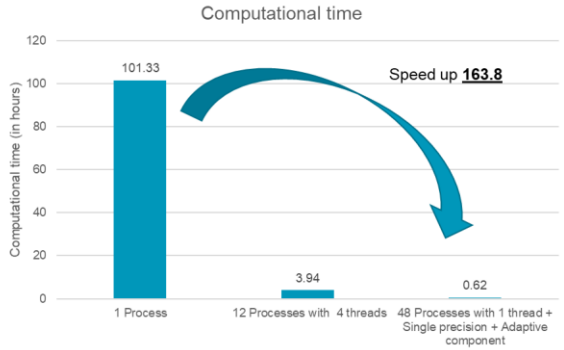
Drone noise (Aeroacoustics)	
Sequence	Direct Frequency Response
Solver	MUMPS
Source generation	ICFD
Number of DOF	617,260
Maximum frequency	5000 Hz
Number of frequencies	491
Number of loadcases	24

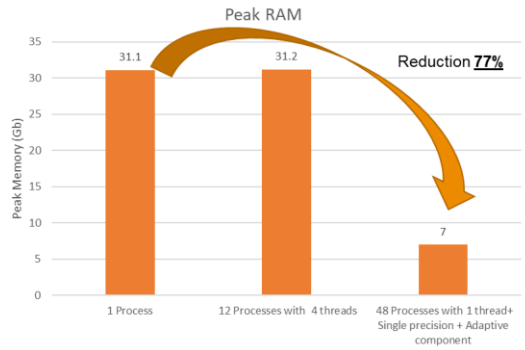
Methods:

- Multiprocessing with frequency (up to 48 processes)
- Multithreading (up to 4 threads)
- Solver parameters:
  - Adaptive meshing
  - Single precision

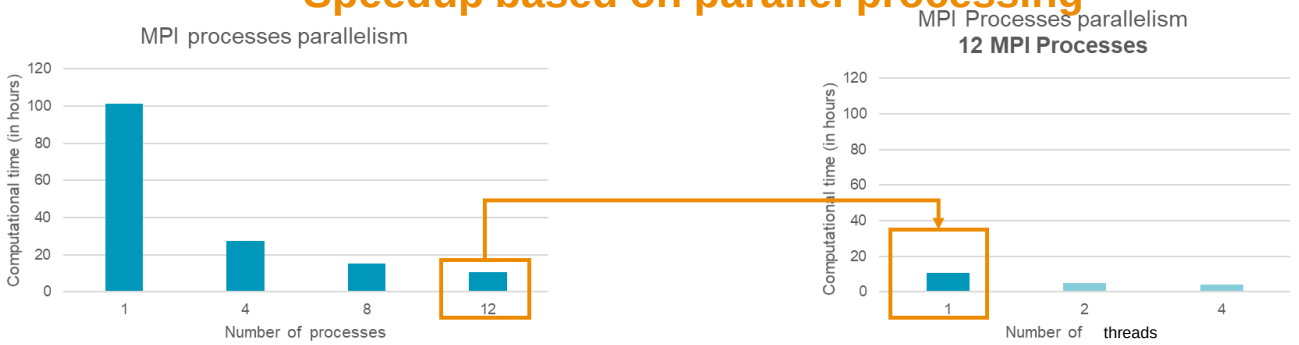


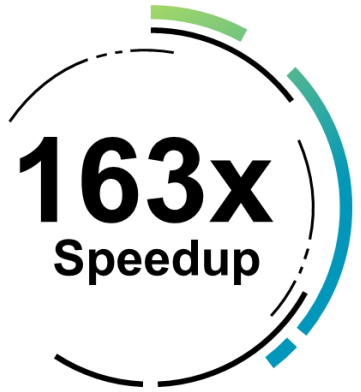
Speedup based on solver parameters





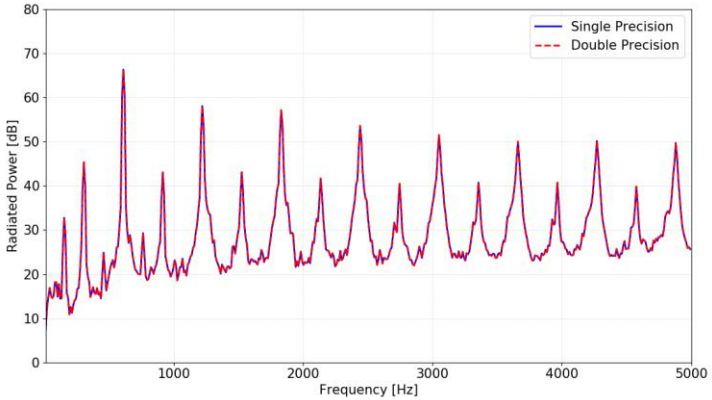
Speedup based on parallel processing





With 48 parallel processes and 1 thread

Accuracy comparison



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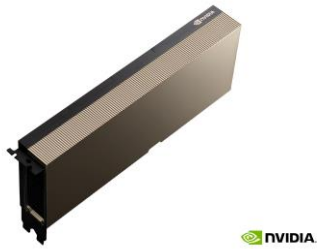
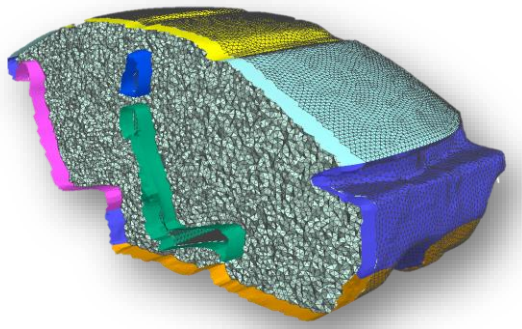
Loudspeaker in cavity with Actran DGM

Loudspeaker in cavity	
Sequence	Actran DGM
Cavity volume	2.84 m³
Number of DOF	540,694,708
Number of elements	1,493,037
Average element order	6.1
Maximum frequency	20,000 Hz

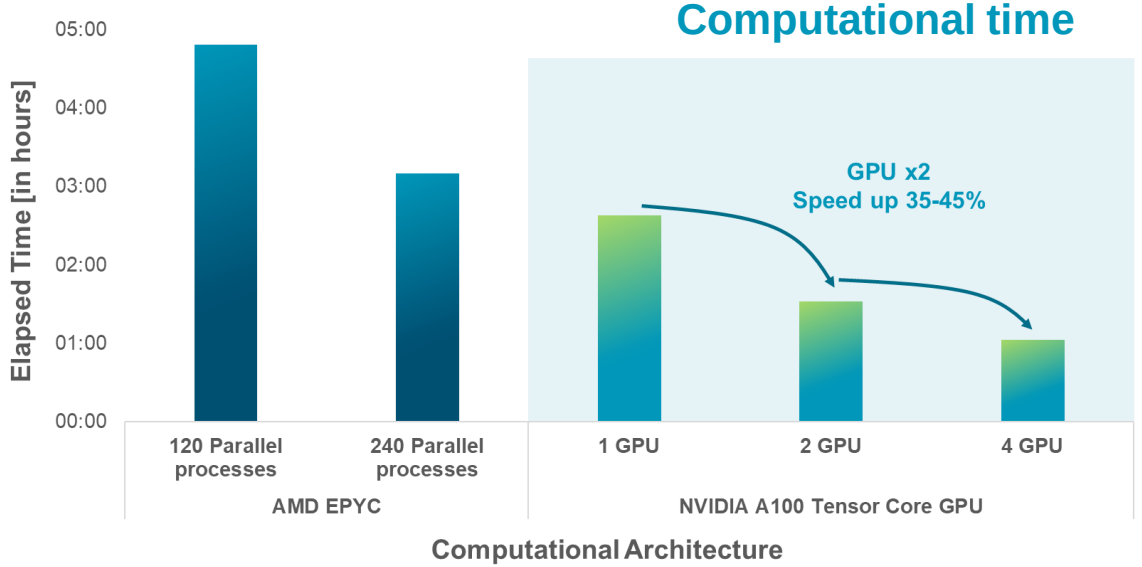
Methods:

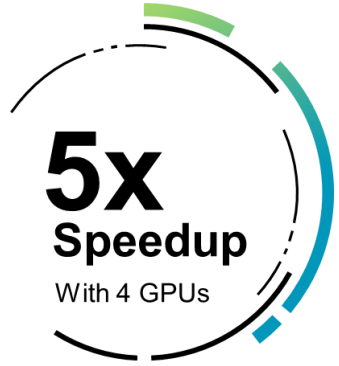
- Multiprocessing (up to 240 processes)
- GPU Acceleration (up to 4 GPUs)
- Domain parallelism in Actran DGM



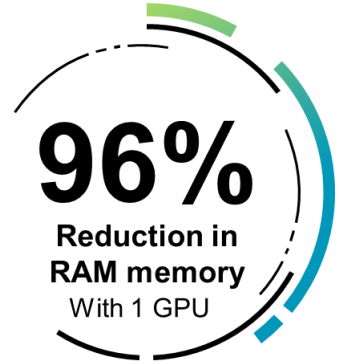


Speedup based on parallel processing and GPU acceleration



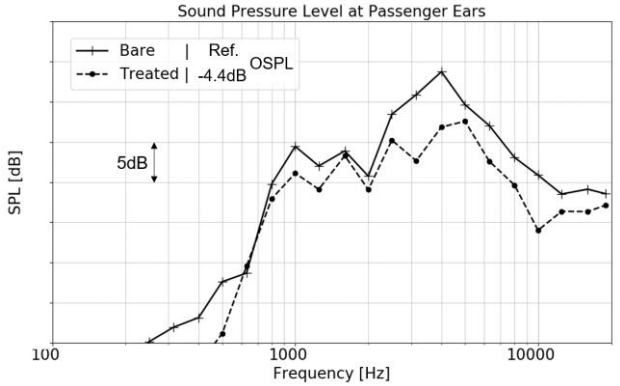


In comparison with 240 CPU processes



In comparison with 240 CPU processes

Acoustic results



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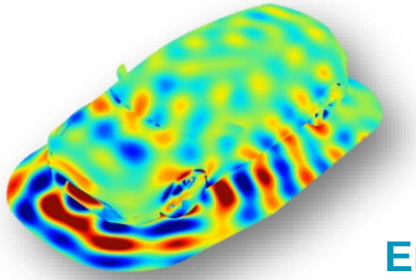
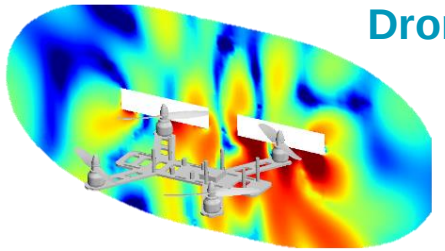
Actran HPC benchmark summary

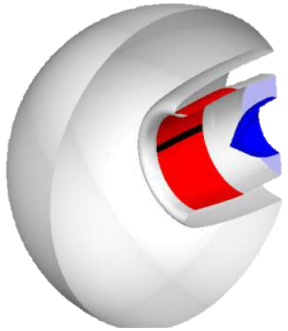
Electric vehicle

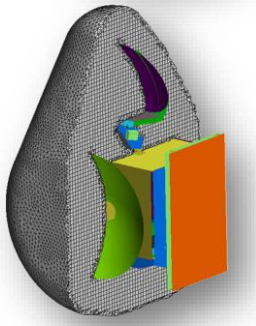


Drone



Engine inlet

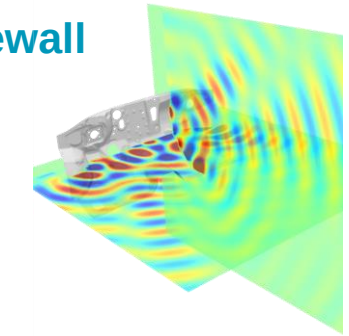




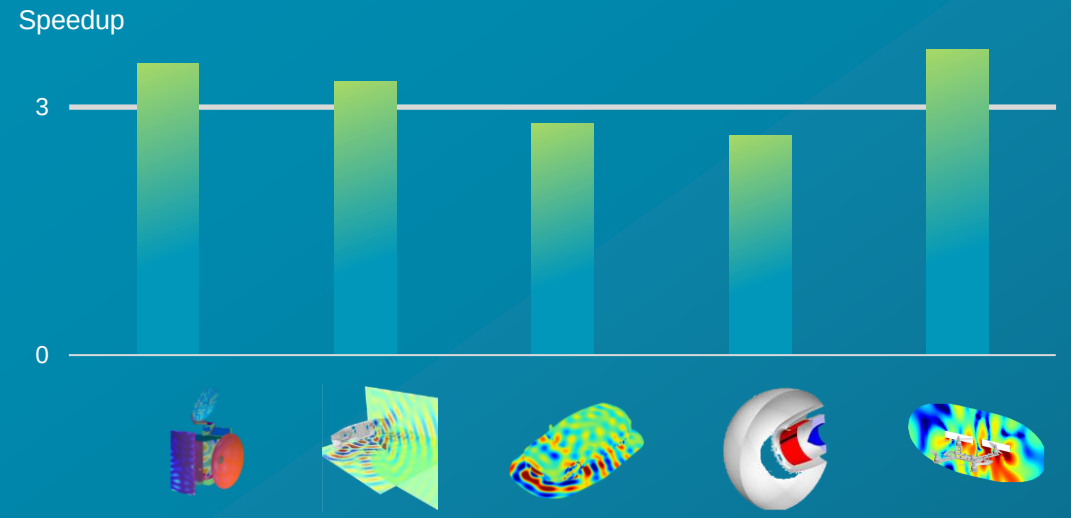
Satellite

Loudspeaker in cavity

Firewall



Speedup using 4 parallel processes



3.2x
Speedup

With 4 parallel processes

21x
Speedup

With more than 32 processes and threads

5x
Speedup

With 4 GPUs

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Testing HPC Clusters with CRADLE CFD

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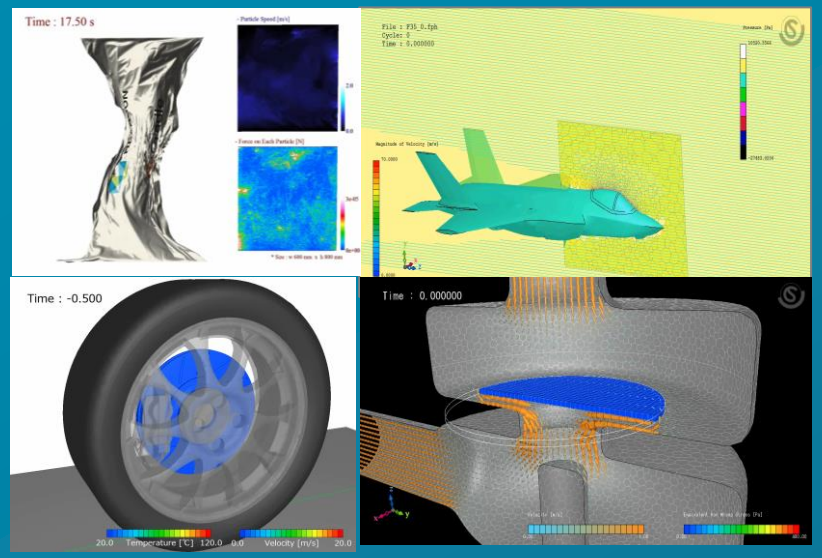
Hexagon's D&E Computational Fluid Dynamics Solutions

日本製
MADE IN JAPAN

Cradle CFD delivering the best multiphysics-focused CFD in the world with great user experiences

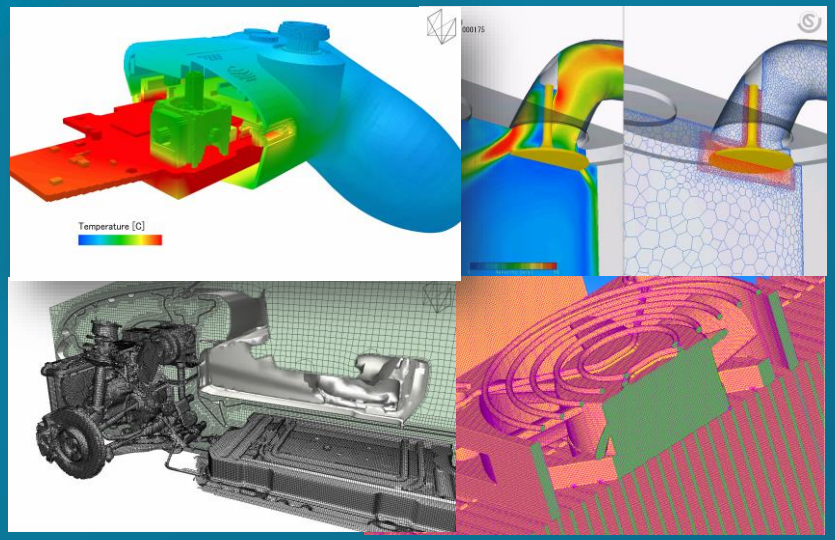
Multi Physics

Co-simulation via MSC**One**



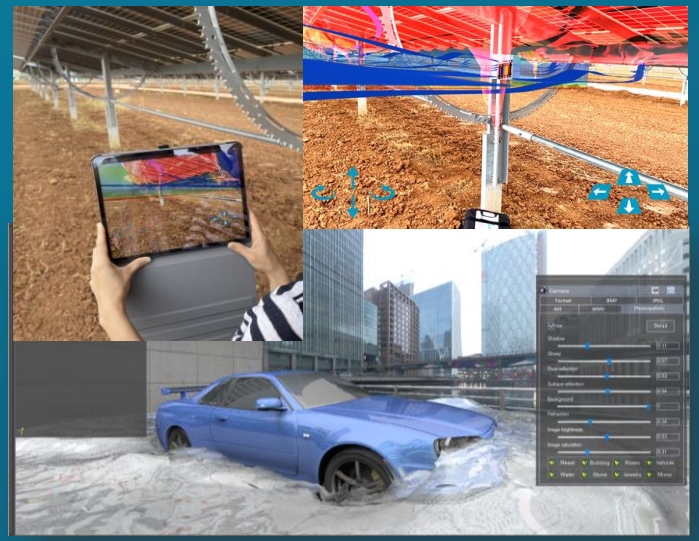
Productivity

Stability & speed of mesher / solver



Visualization

Photorealistic & Immersed (AR/VR)



- Robust, fast & accurate general purpose computational fluid dynamics software
- Unique solutions for electronic cooling and the construction industry
- Strong capabilities for multi-physics focused CFD co-simulation

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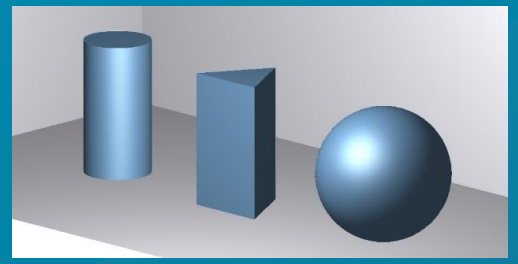
Cradle CFD

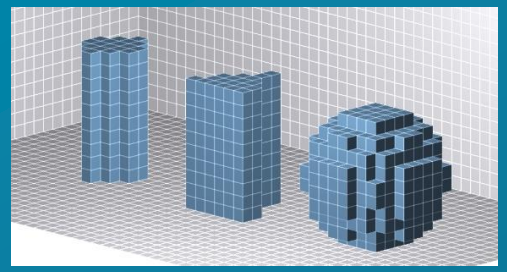
3D CAD model



Your tool of choice

Cradle | scSTREAM

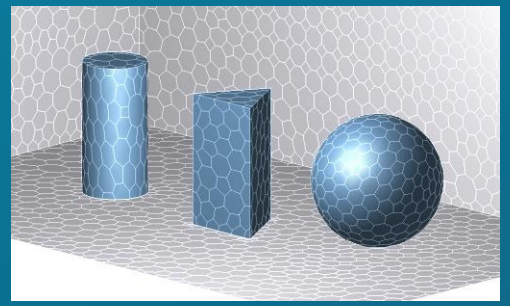
Structured mesh



Commonly used in:
- Electronics
- Architecture & Civil Engineering
- Application demanding huge models
- etc.

Cradle | scFLOW (*supersedes SC/Tetra*)

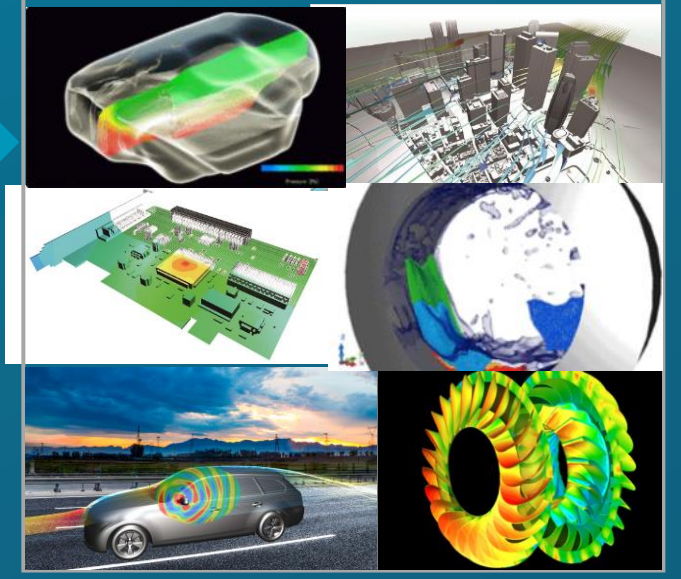
Un-structured mesh



Commonly used in:
- Automotive
- Aerospace
- Machinery
- Application demanding high-accuracy
- etc.

Cradle | scPOST

Powerful visualization



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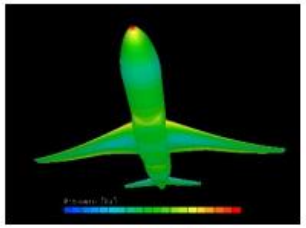
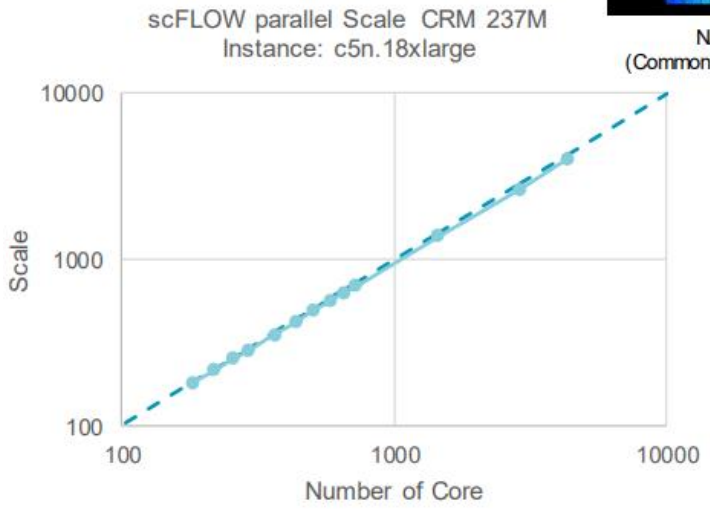
Testing CRADLE on INTEL XEON Platinum Architecture based

	Name	Specification
Instance	Amazon EC2 c5n.18xlarge	36 physical cores 192GiB
OS	CentOS 7.9	
CPU	INTEL XEON Platinum 8000 series	3.5 GHz
Interconnect	EFA	100 Gbps



NASA-CRM
(Common Research Model)



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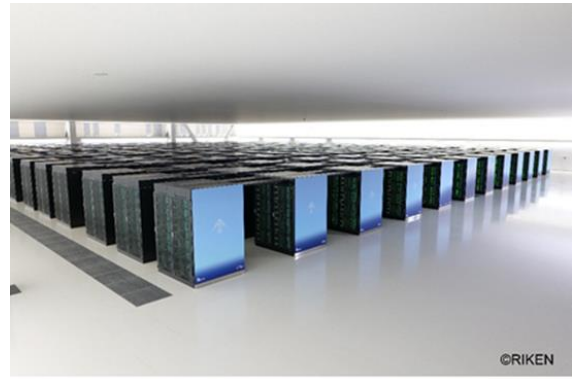
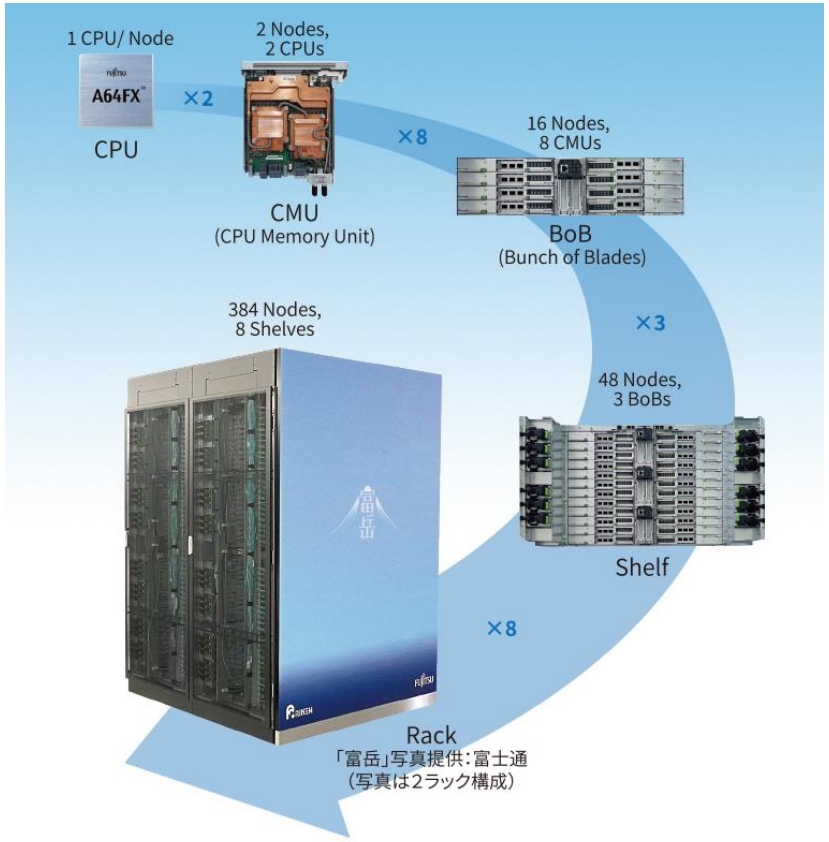
Testing CRADLE CFD on Fugaku, ARM-based architecture



- Fukaku is a Petascale supercomputer jointly developed by RIKEN and Fujitsu
- Speed reaching 442 PFLOPS, achieving 1,42 exaFLOPS with mixed Precision HPL-AI
- Ranked 2nd supercomputer in the world according to TOP500, 1st according HPCG (High Performance Conjugate Gradient), and 2nd on HPL-AI Benchmarks

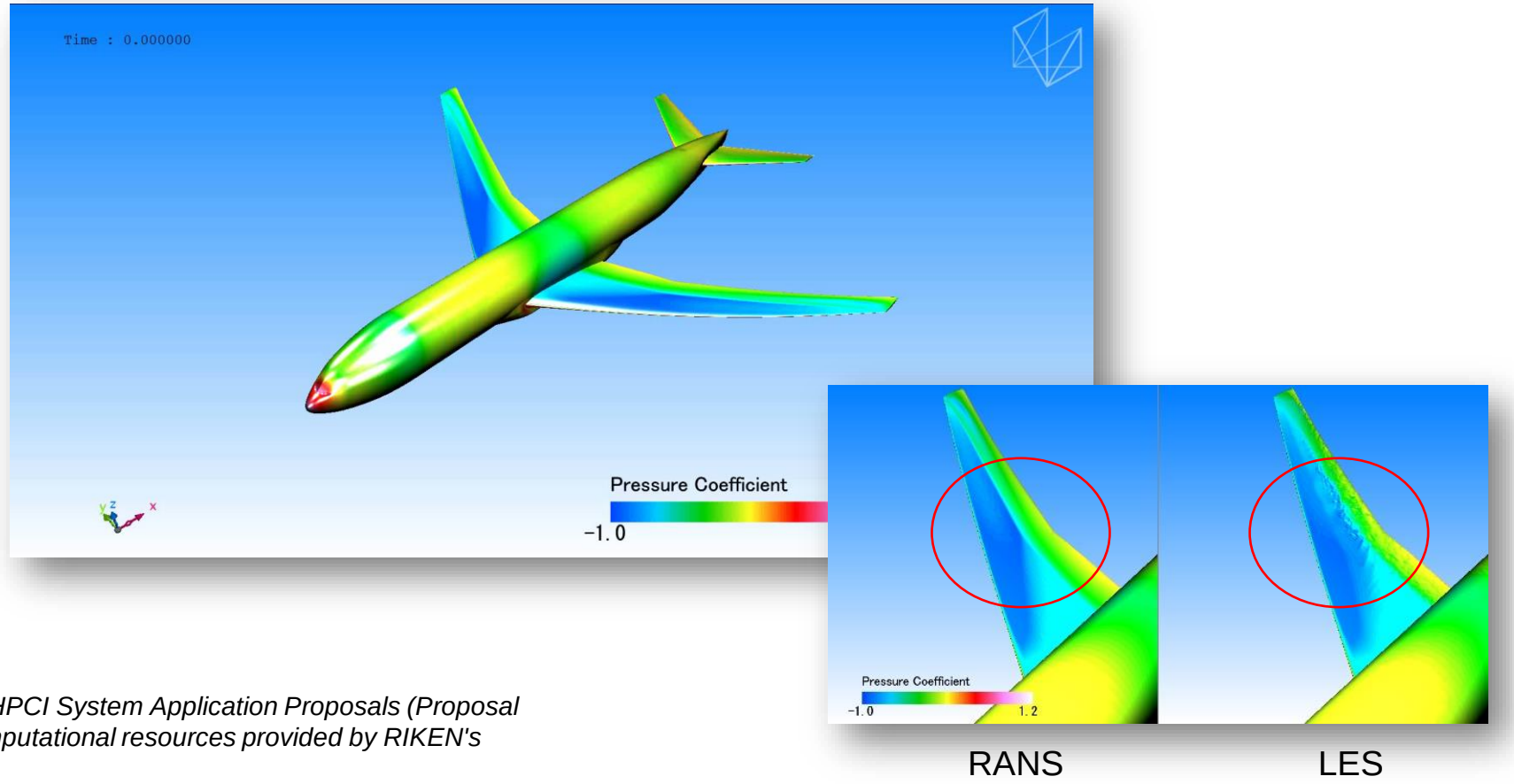
CPU	**Fujitsu A64FX**
Instruction set architecture	**Arm v8.2-A SVE 512 bit**
# of computational cores	**48 + 2 assistant cores**
Memory	**HBM2, 32 GiB, 1024 GB/s**
Interconnect	**Tofu Interconnect D (28 Gbps x 2 lane x 10 port)**
# of total nodes	**158,976**



Fugaku challenge

Large-Scale Analysis

- NASA-CRM
  - Mach number of uniform flow : 0.847
  - Angle of attack: 2.94 degrees
- Number of elements : 237,412,720
- Number of parallels : **192,000**
  - **4,000 nodes**
  - 48,000MPI process
  - 4 threads
- Compressible flow
- Density based solver
  - Multicolor Gauss Seidel
- LES transient analysis
  - SGS model: WALE model
- Initial field
  - Steady field by SST k-ω



This research was conducted through the HPCI System Application Proposals (Proposal No. hp200209 and hp200302) with the computational resources provided by RIKEN's supercomputer "Fugaku".

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Summary

Cradle CFD supports a wide range of computing environments.

- Test on Intel Xeon Based Architecture shows very good scalability

- Test on AWS AMD EPYC based architecture
  - Performance evaluation up to 384 nodes with 24,576 Parallels with very good scalability
  - High speed interconnect EFA is essential for Large scale parallel computations in CFD

- Test on Supercomputer Fugaku, ARM-Based architecture
  - 4,000 nodes and 192,000 MPI Processes were achieved, confirming that Cradle CFD can be operated in a very large scale and highly parallel HPC environment.

Summary

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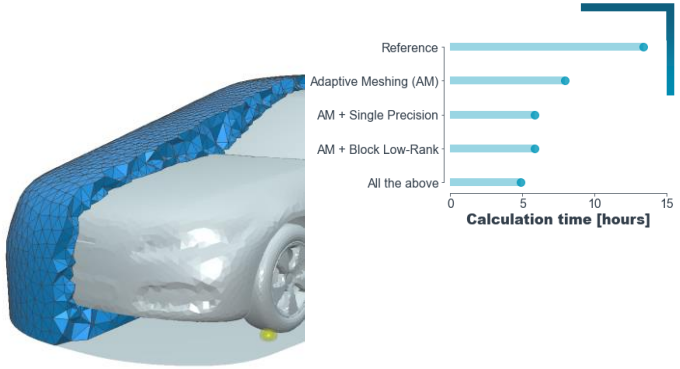
Summary

To provide results fast and early in the development process

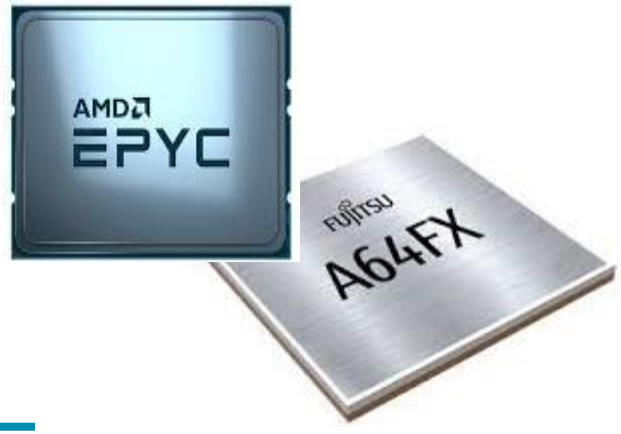
Intrinsic Software Strategies



500 Hz

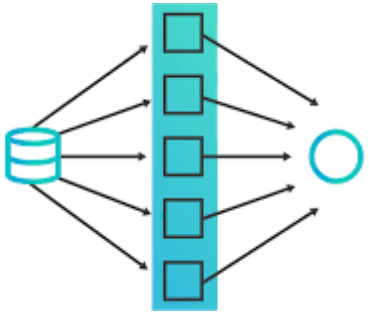
Using adequate parameters related to Software architecture (solver parameters or Mesh technics)

Jiggling with Architecture



Our softwares are tested on latest processors technologies to be able to tune correctly setting for achieving best performance and scalability

Efficient parallelization



Smart strategies for parallelization are necessary

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Thank you

Learn more

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Questions?

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