

# iconCFD®

## MESH & WRAP

### Performance & Ease-of-use

With kind permission of:  
Koenigsegg Automotive AB



Prepared by:  
Mr. David Martineau  
[d.martineau@iconCFD.com](mailto:d.martineau@iconCFD.com)  
November 2016



# AGENDA

## iconCFD® MESH & WRAP

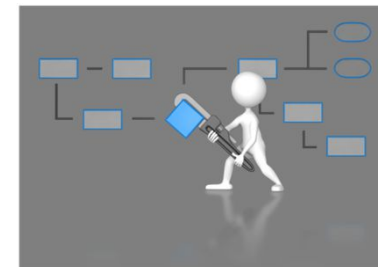
[www.iconCFD.com](http://www.iconCFD.com)

Introduction

Performance

Ease-of-use

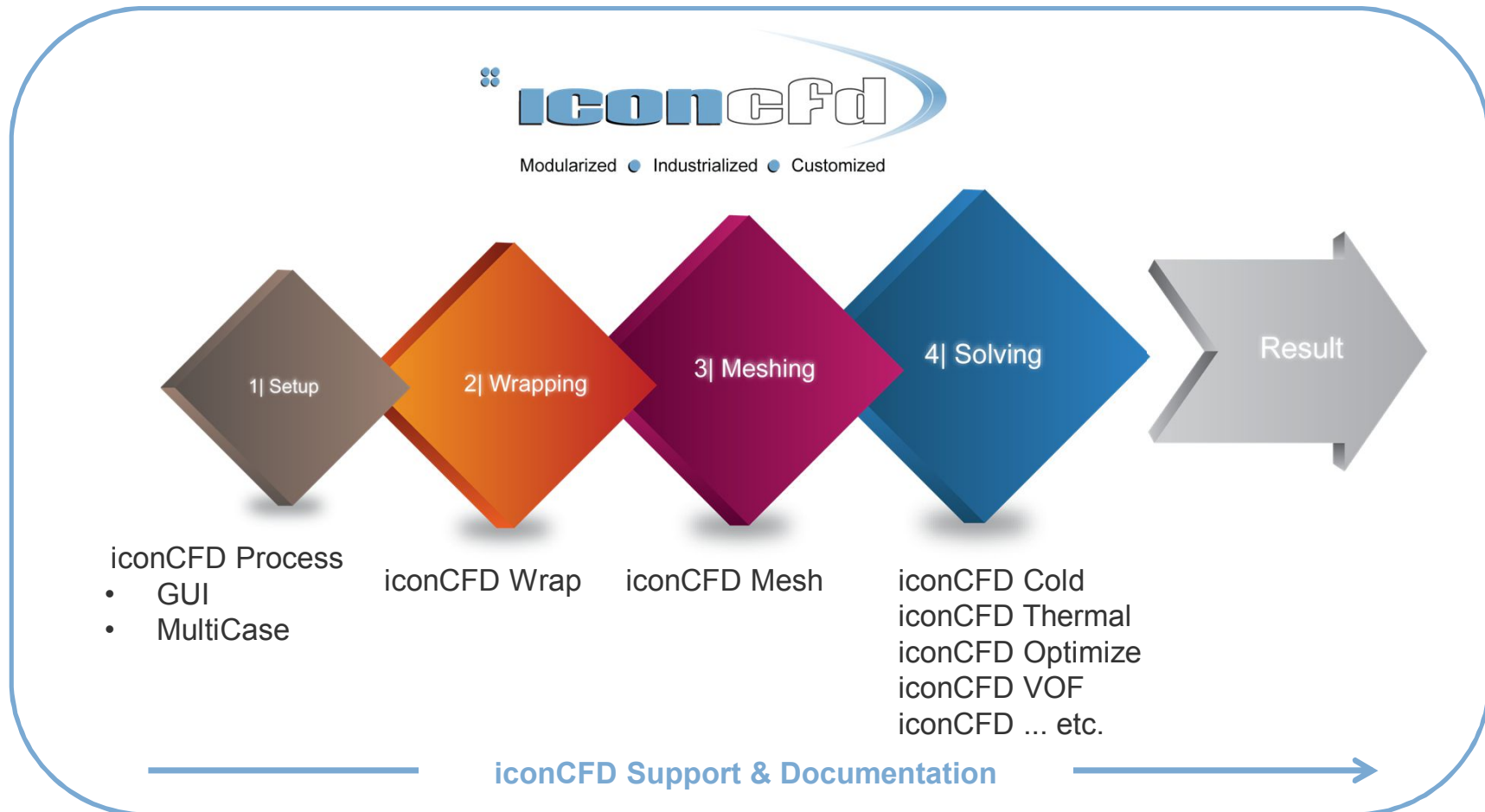
Conclusions



# INTRODUCTION

## iconCFD® WORKFLOW

[www.iconCFD.com](http://www.iconCFD.com)



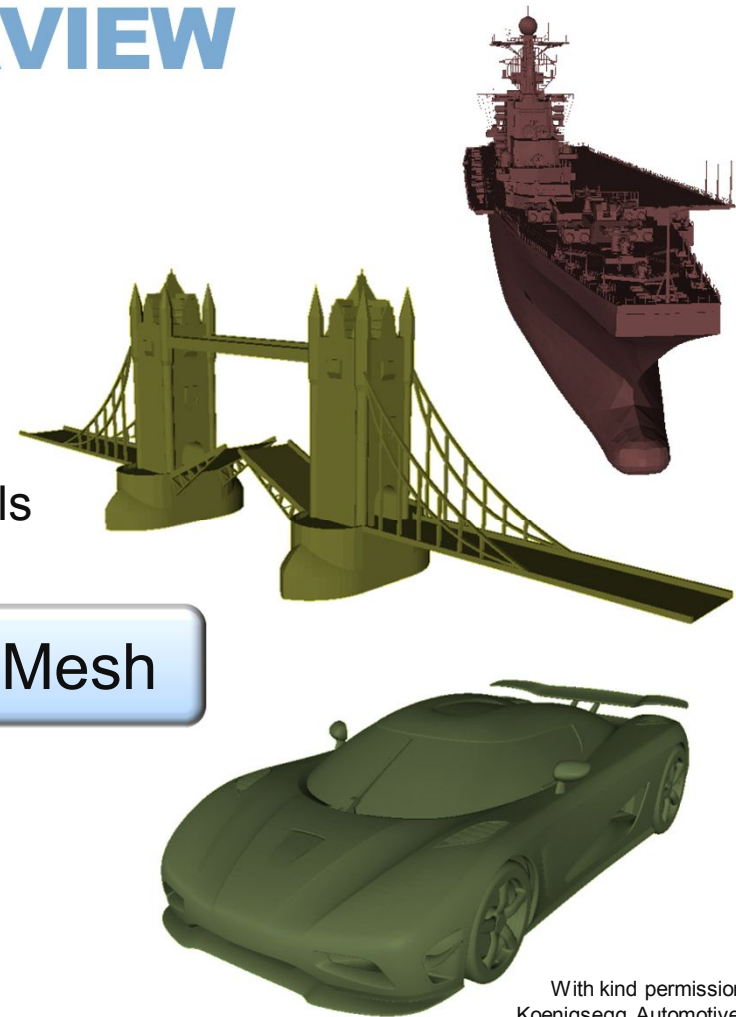
# INTRODUCTION

## iconCFD® MESH OVERVIEW

[www.iconCFD.com](http://www.iconCFD.com)

- Automatic hexahedral-dominant mesh generation
- Creation of meshes with guaranteed quality on highly complex industrial models
- Fully parallel meshing with dynamic load balancing
- Support for multiple volume regions with conformal or arbitrary grid interfaces

iconCFD® Mesh



With kind permission of:  
Koenigsegg Automotive AB

# PERFORMANCE

## HYBRID PARALLELISATION

[www.iconCFD.com](http://www.iconCFD.com)

### Aims:

- Reduce memory requirements
- Exploit many-core cluster hardware
- Future-proof the mesh generator for next generation HPC architecture

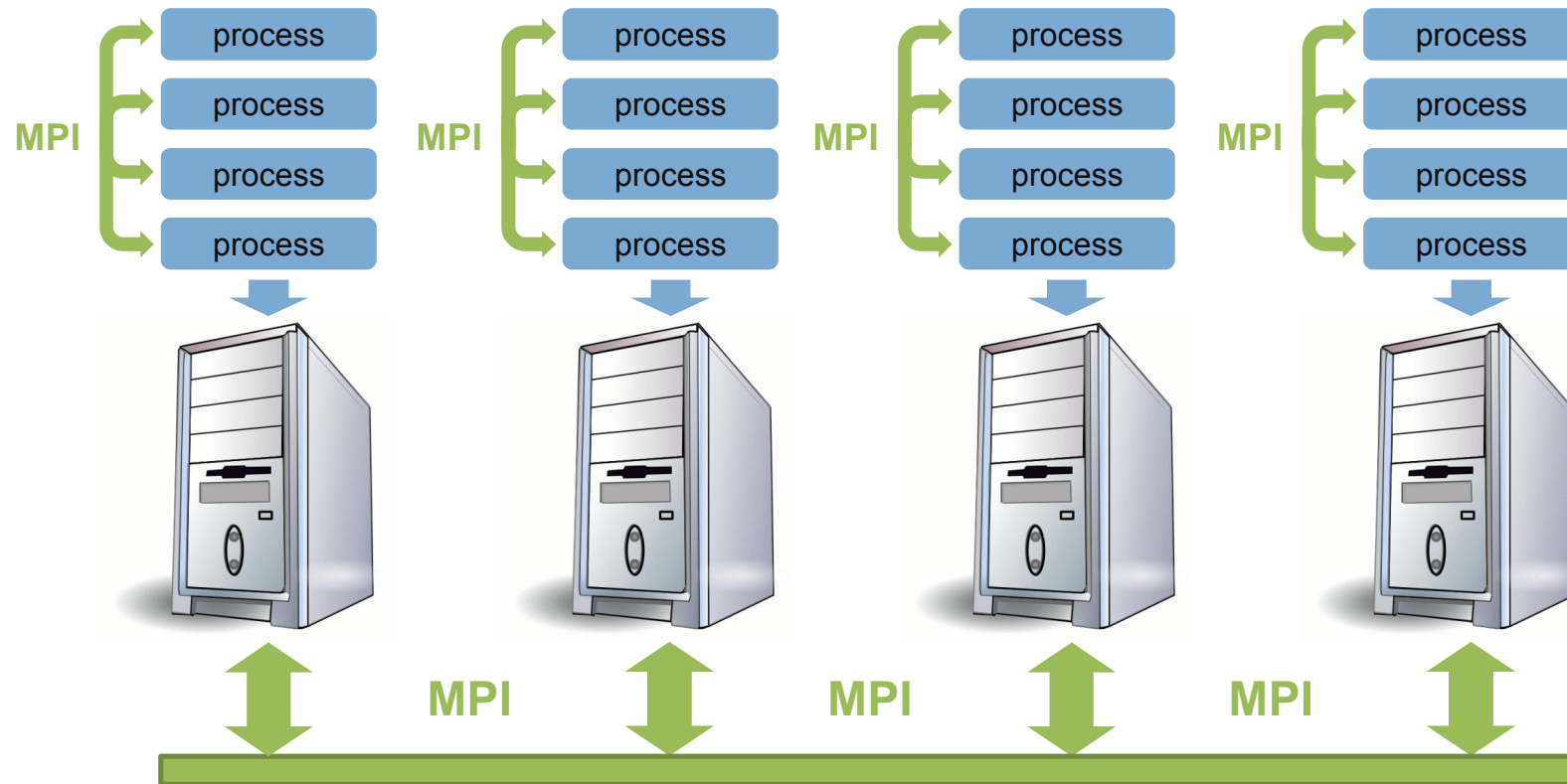
### Objective:

- Enable meshing using a combination of domain decomposition (inter-node) and multi-threading (intra-node)

# PERFORMANCE

## HYBRID PARALLELISATION

[www.iconCFD.com](http://www.iconCFD.com)

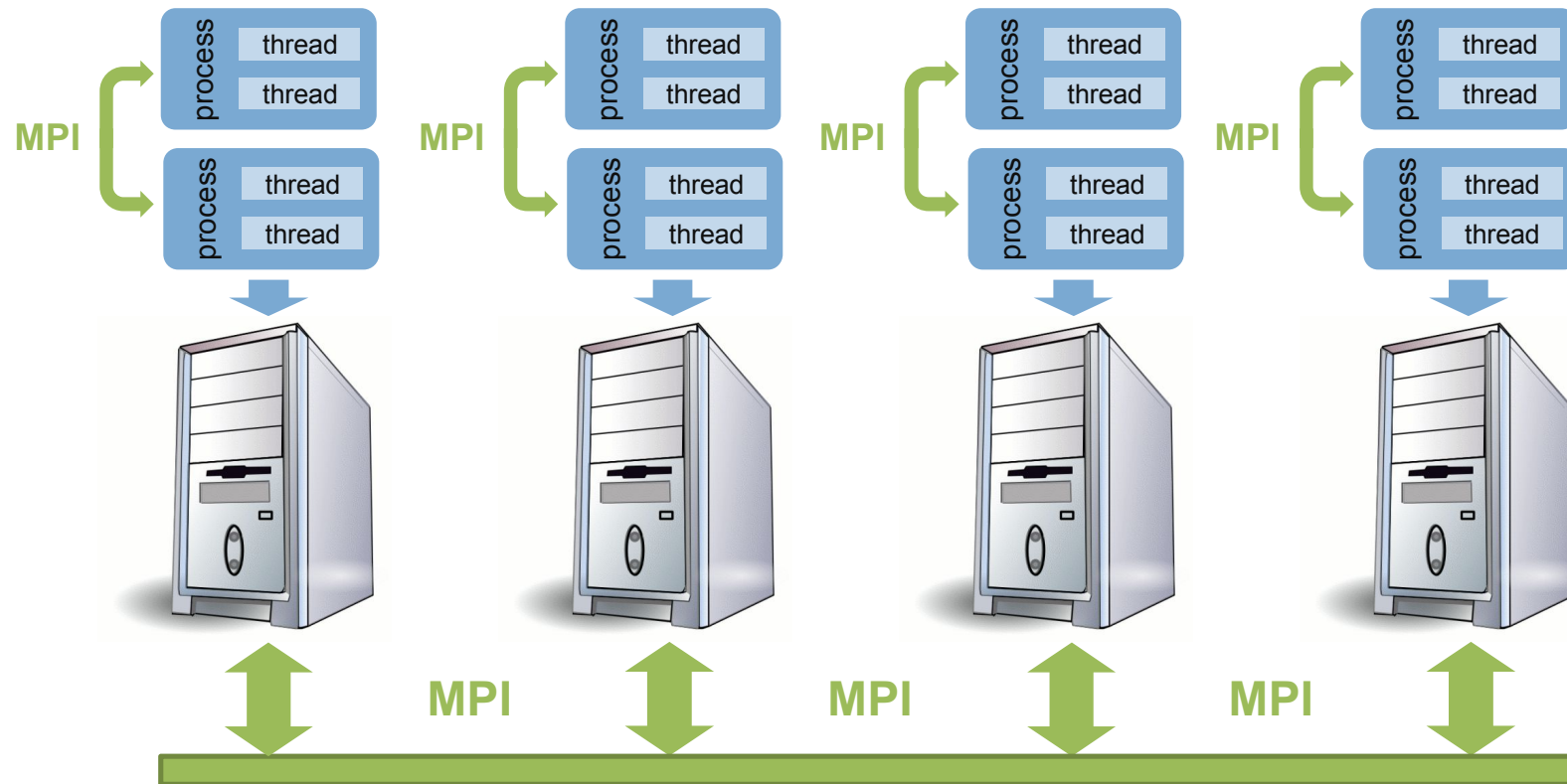


Standard domain decomposition (no multi-threading)

# PERFORMANCE

## HYBRID PARALLELISATION

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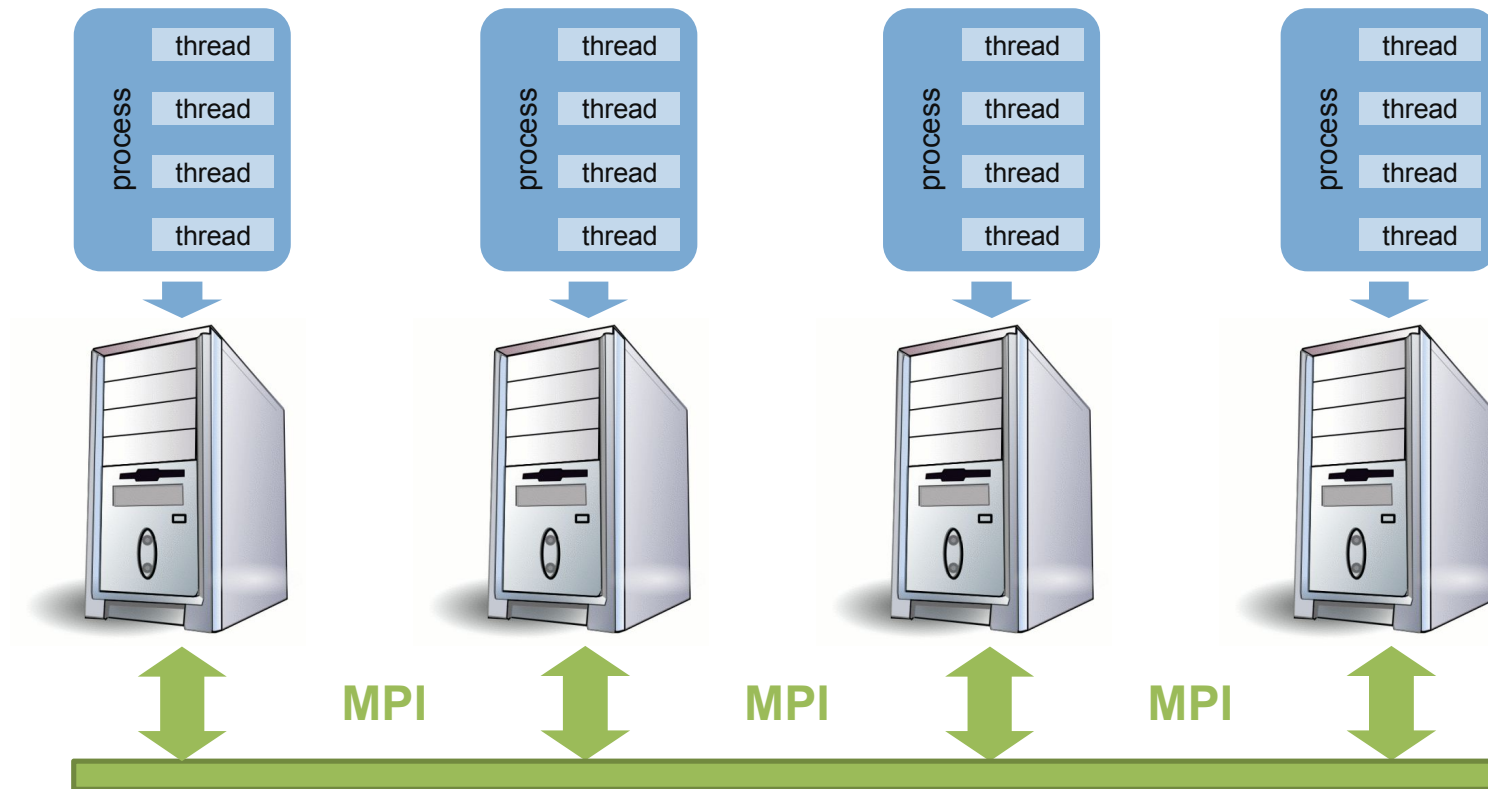


Combined domain decomposition & multi-threading

# PERFORMANCE

## HYBRID PARALLELISATION

[www.iconCFD.com](http://www.iconCFD.com)



Domain decomposition per node & multi-threading within node



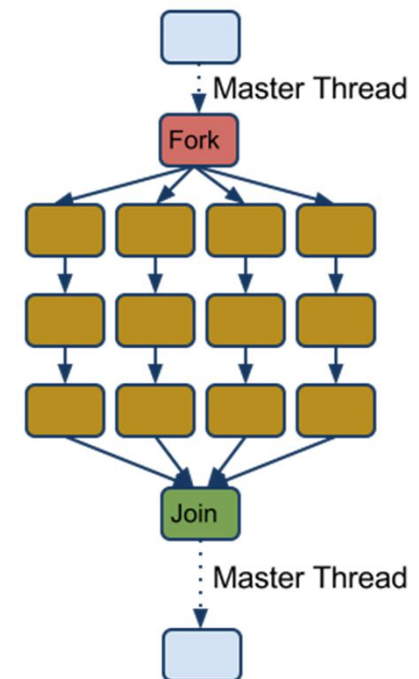
# PERFORMANCE

## HYBRID PARALLELISATION

[www.iconCFD.com](http://www.iconCFD.com)

### Implementation:

- Using “fork-join” multi-threading model
  - Multi-threading can be added progressively
- Added OpenMP directives to:
  - All mesh quality checks
  - Mesh topology relations
  - Cell and face quantities (e.g. cell centre & cell volume calculations)



# PERFORMANCE

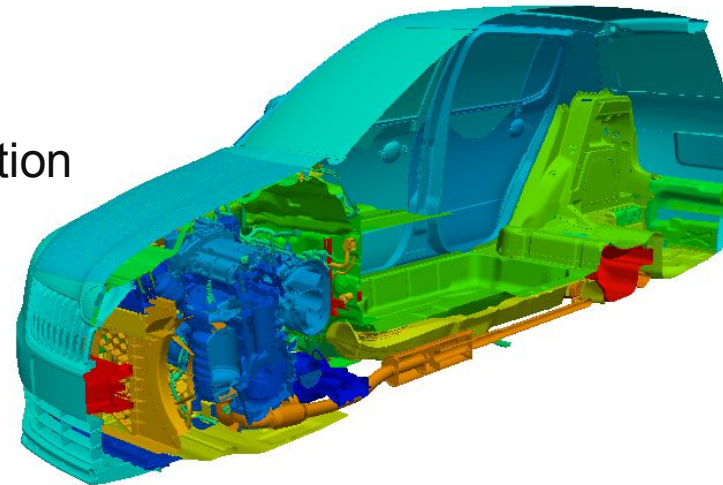
## HYBRID PARALLELISATION

[www.iconCFD.com](http://www.iconCFD.com)

### Testing:

- Mesh generated for industrial automotive case (Skoda Fabia II):
  - 30 million cells
- Combination of domain decomposition & multi-threading on cluster:
  - 64 processes x 1 thread
  - 32 processes x 2 threads
  - 16 processes x 4 threads
  - 8 processes x 8 threads

Geometry  
courtesy of  
Škoda Auto

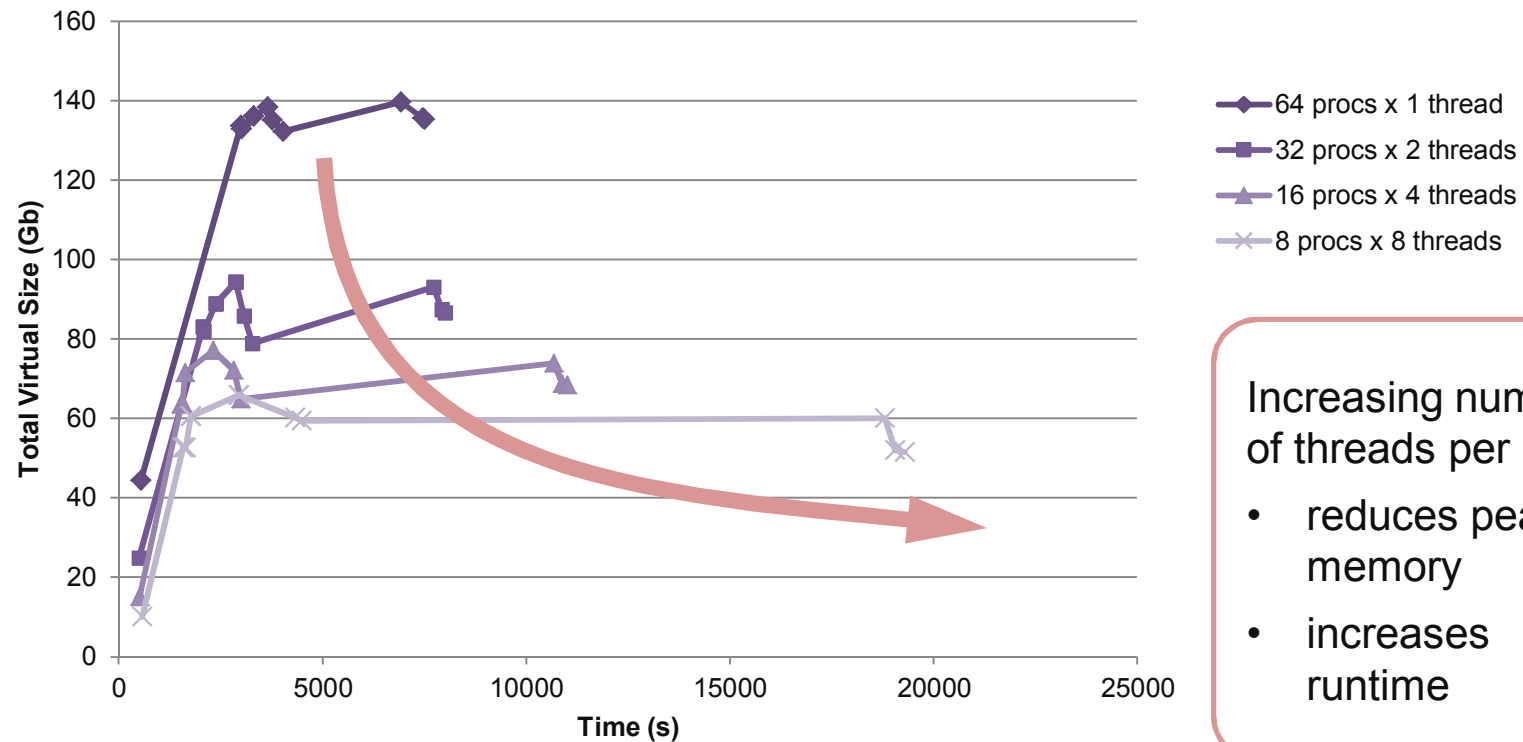


# PERFORMANCE

## HYBRID PARALLELISATION

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### Hybrid Parallelisation Performance



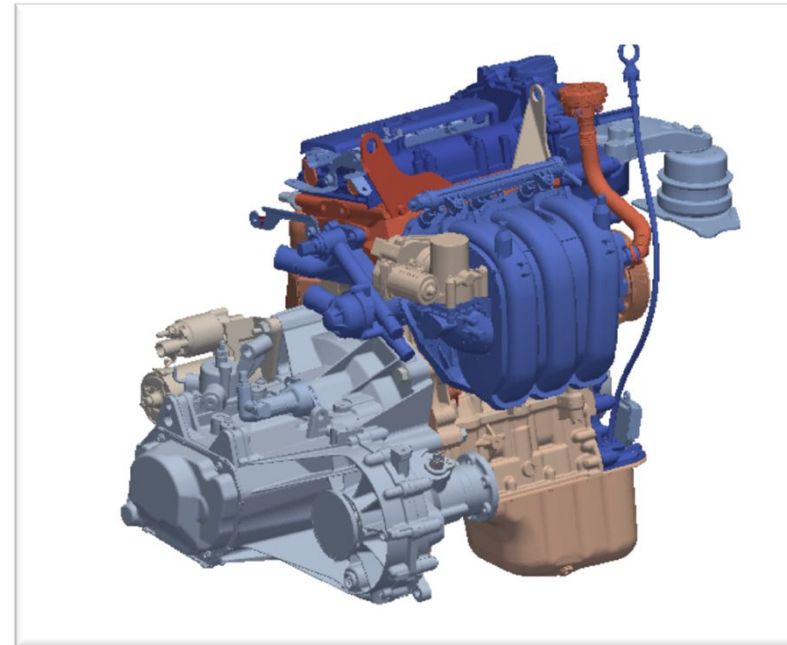
# EASE-OF-USE

## MOTIVATION

[www.iconCFD.com](http://www.iconCFD.com)

- Major bottleneck in mesh generation:
  - original CAD → watertight geometry representation
- Translation of geometry from native CAD results in:
  - Missing or duplicate parts
  - Small gaps or overlaps
- Resolving geometry issues
  - Labour-intensive
  - Time-consuming

Geometry  
courtesy of  
Škoda Auto

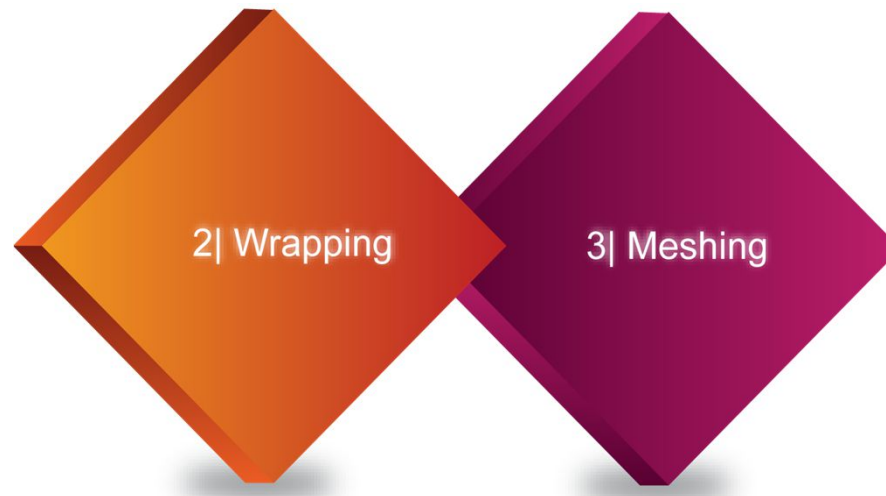


# EASE-OF-USE

## AIM

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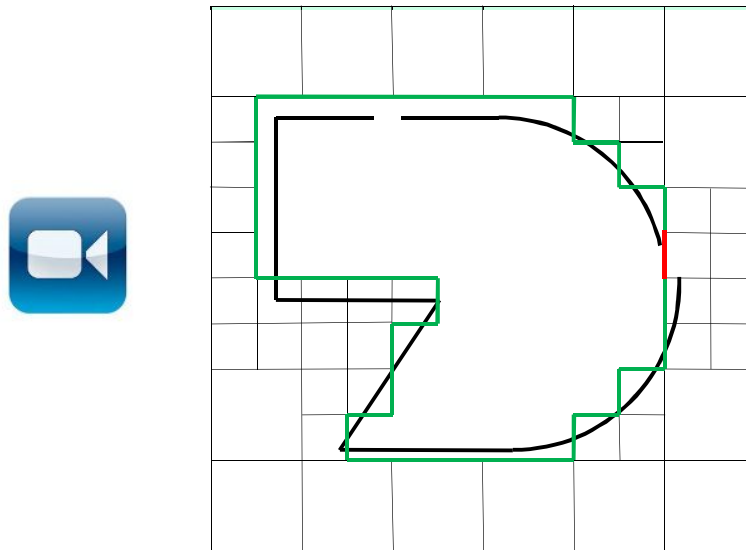
- Integrated approach to wrapping and mesh generation
  - Exploit existing adaptively-refined Cartesian grid generator
  - Simultaneously perform wrapping and meshing
  - Handle large gaps in model assemblies
  - Avoid re-sampling geometry



# EASE-OF-USE BACKGROUND

[www.iconCFD.com](http://www.iconCFD.com)

- Process of identifying fluid region:



- a) Geometry with gaps and refined mesh
- b) Boundary faces (green)
- c) Intersecting cells (red)
- d) Cells connected to keep point (green)
- e) Re-assignment of intersecting cells to keep region
- f) Mesh corresponding to fluid domain

# EASE-OF-USE

## COMBINED WRAPPING & MESHING

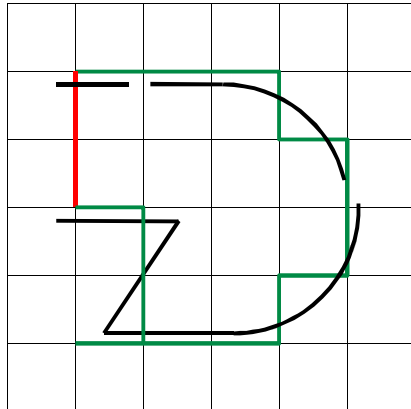
[www.iconCFD.com](http://www.iconCFD.com)

- **Current meshing process**

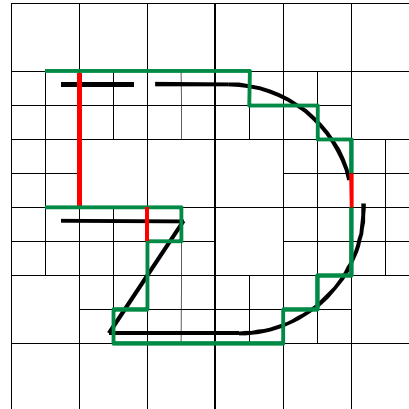
- ✓ Tolerant of small gaps (geometry is wrapped at finest mesh level)
- ✗ Doesn't handle large (fully-resolved) gaps

- **Solution:**

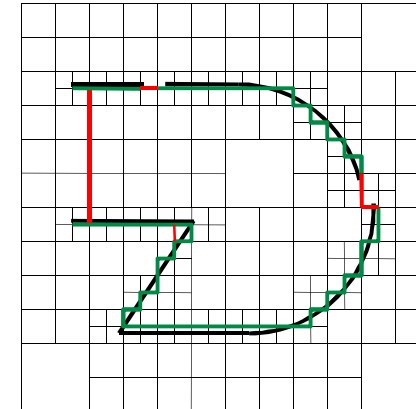
- Perform wrapping at coarser refinement levels:



Refinement level 1



Refinement level 2

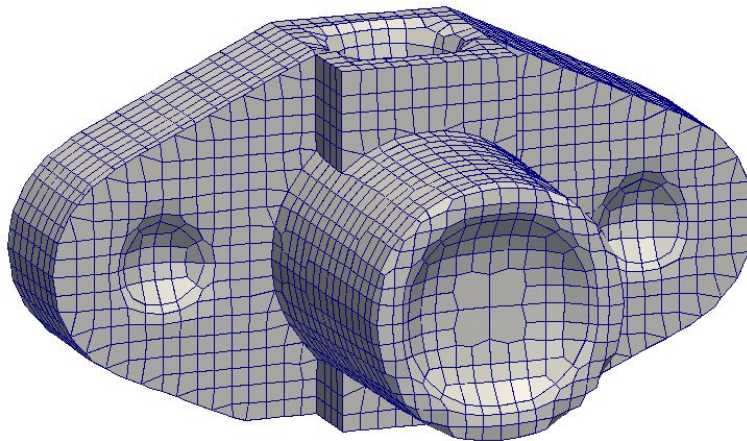
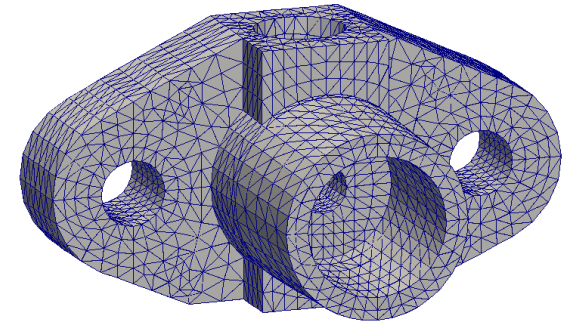


Refinement level 3

# RESULTS

## FLANGE

- Flange geometry from OpenFOAM® tutorial
- Initial uniform Cartesian mesh created enclosing the geometry
- The iconHexMesh mesh generator is then used to apply 4 levels of surface refinement



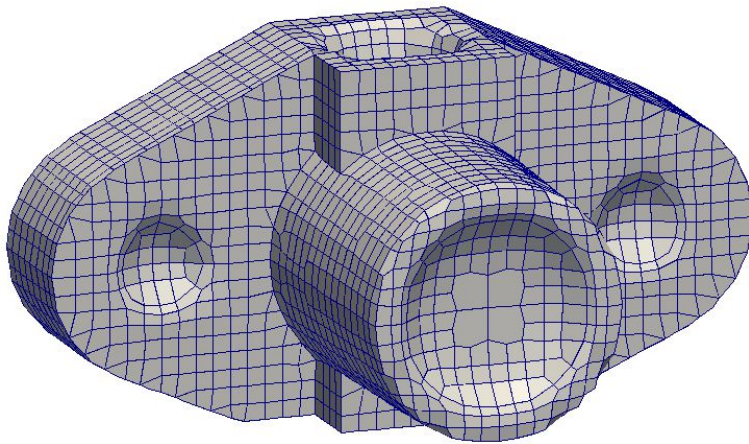
Result at wrap level = 2



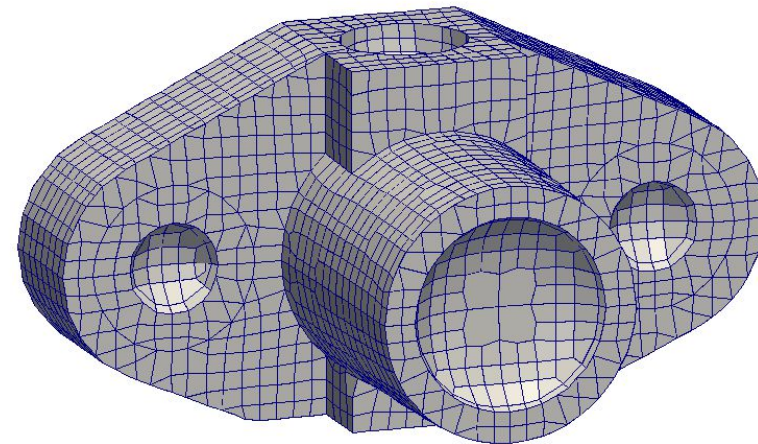
# RESULTS

## FLANGE

- Existing meshing functionality can be exploited to improve the capture of geometry features



Wrapped surface with basic  
surface snapping

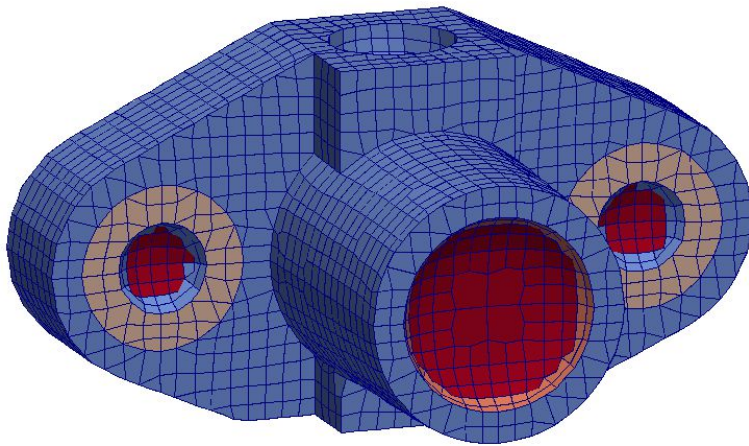


Wrapped surface with feature  
line snapping

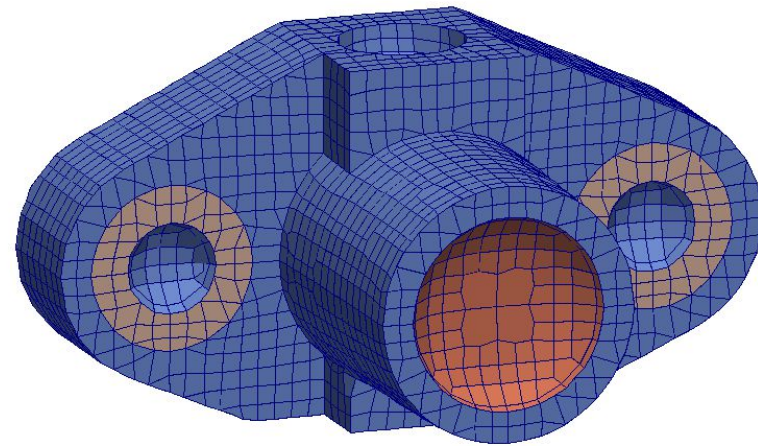
# RESULTS

## FLANGE

- Faces which close off holes in the geometry (gap faces) can be assigned to a separate patch or to neighbouring patches:



Gap faces (red) assigned to separate patch



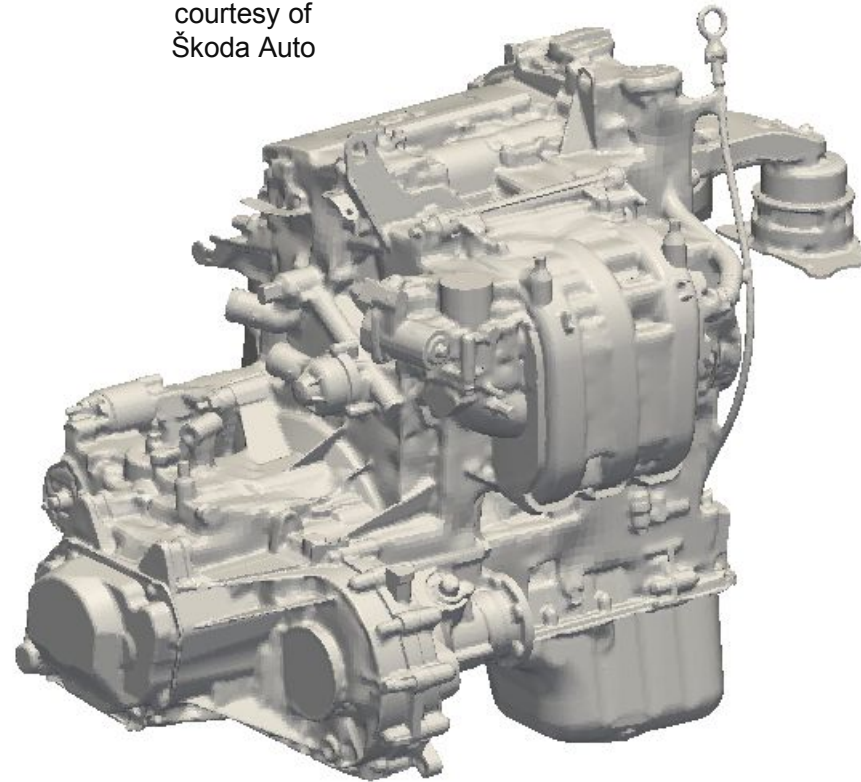
Gap faces assigned to neighbouring patches

# RESULTS

## ENGINE BLOCK

[www.iconCFD.com](http://www.iconCFD.com)

Geometry  
courtesy of  
Škoda Auto



- Highly detailed engine block
- Initial Cartesian mesh created with element size of 1.25m
- Uniform surface refinement of level 9 applied to engine
  - Small element size of 2.4mm
- Wrap level of 5 applied
  - Close holes < 40mm Ø
- Wrapping process took 278s
  - 2 Intel Xeon X5650 (2.67GHz) processors

Wrapped surface:  
Single closed manifold surface  
762,028 triangles



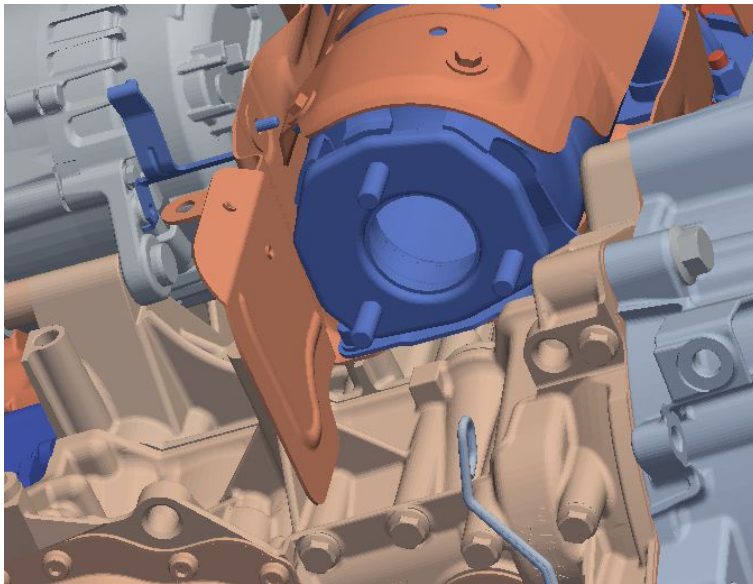


# RESULTS

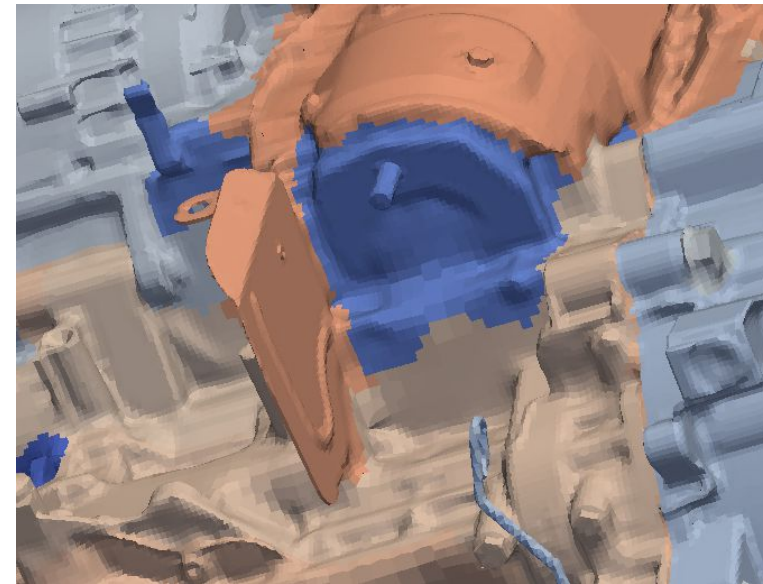
## ENGINE BLOCK

[www.iconCFD.com](http://www.iconCFD.com)

- Wrapping is able to close large holes in geometry, whilst still capturing fine details:



Engine geometry



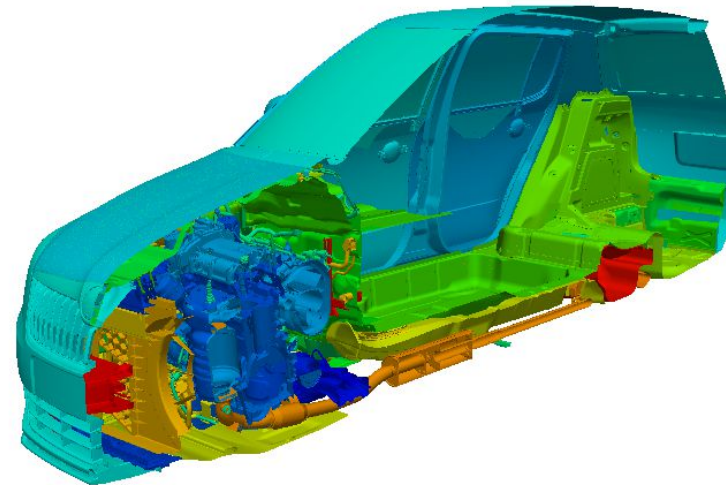
Wrapped surface

# RESULTS

## UHTM CASE

[www.iconCFD.com](http://www.iconCFD.com)

- Detailed model of Skoda Fabia II including:
  - electrical components
  - exhaust system
  - cooling
  - power-train
  - suspension
- 14 STL files:
  - 382 solids
  - 36 million triangles



Geometry  
courtesy of  
Škoda Auto

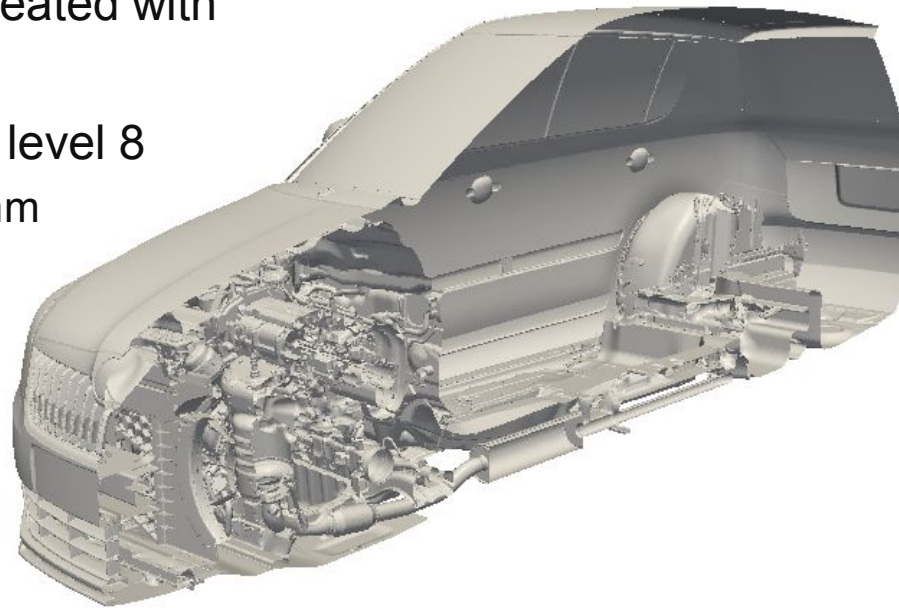
# RESULTS

## UHTM CASE

[www.iconCFD.com](http://www.iconCFD.com)

Geometry  
courtesy of  
Škoda Auto

- Initial Cartesian mesh created with element size of 0.625m
- Surface mesh refined to level 8
  - Element size of 2.44mm
- 2 levels of curvature refinement applied
- Wrap level of 4
  - 40mm hole size
- Complete process:
  - Completed in 2h 42m
  - 32 cores with Intel Xeon E5-2670 (2.60GHz) processors



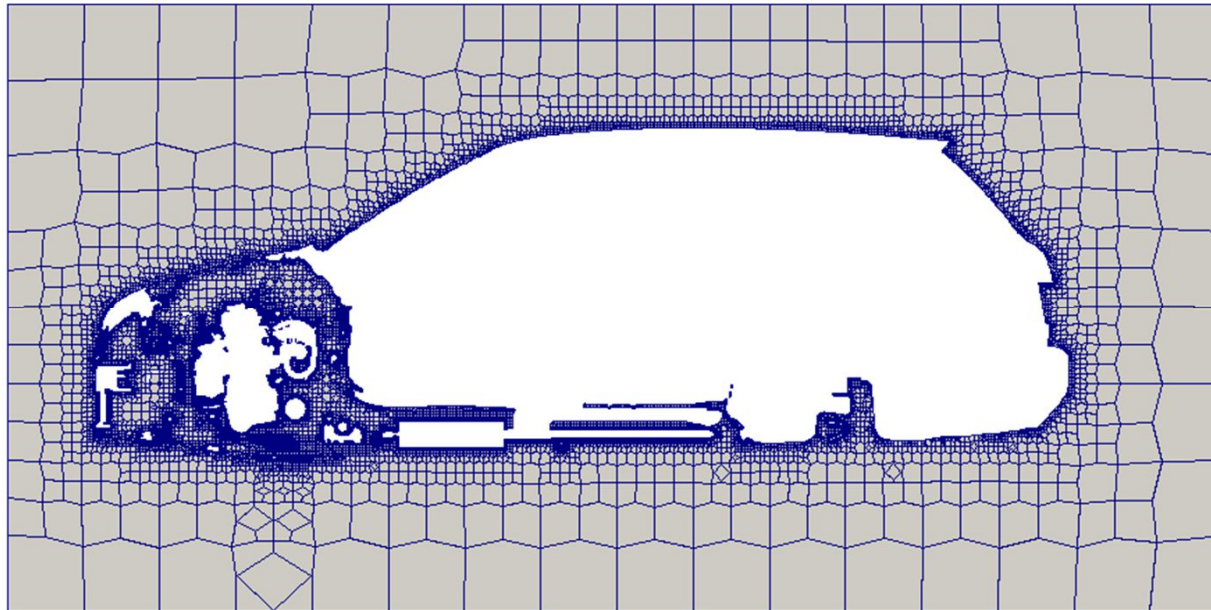
Wrapped surface:  
12.5M triangles

# RESULTS

## UHTM CASE

[www.iconCFD.com](http://www.iconCFD.com)

Background mesh with wrapping  
activated



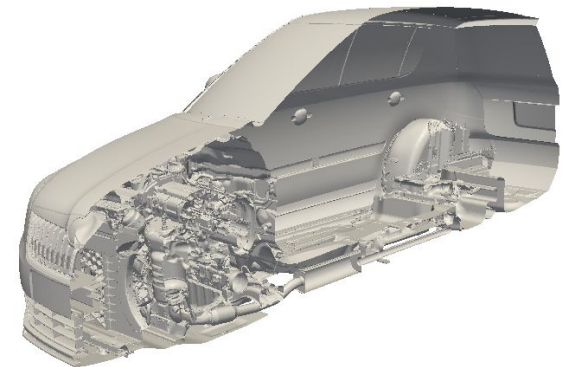
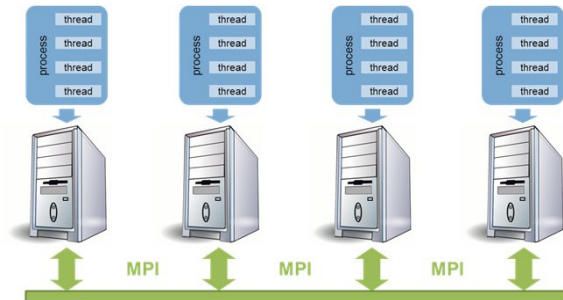
Geometry  
courtesy of  
Škoda Auto



# iconCFD® Mesh & Wrap CONCLUSIONS

[www.iconCFD.com](http://www.iconCFD.com)

- Domain decomposition and multi-threading can be effectively combined when meshing with iconCFD Mesh to fully exploit multi-core hardware architectures.
- Wrapping functionality can be employed directly within the iconCFD mesh generation utility to handle poor quality input geometry without labour-intensive CAD repair, and without sacrificing geometry fidelity.





# ACKNOWLEDGEMENTS

[www.iconCFD.com](http://www.iconCFD.com)

The authors would like to thank Skoda for their kind permission to use the Fabia II vehicle geometry.

**ŠKODA**



# QUESTIONS? MORE INFORMATION?

[www.iconCFD.com](http://www.iconCFD.com)



[www.iconCFD.com](http://www.iconCFD.com)  
[d.martineau@iconCFD.com](mailto:d.martineau@iconCFD.com)

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America :: Europe :: Asia  
E. [contact@iconCFD.com](mailto:contact@iconCFD.com)  
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