2015 Automotive Simulation World Congress

Total Vehicle Simulation of the Volvo S80 with a New Common Model Approach

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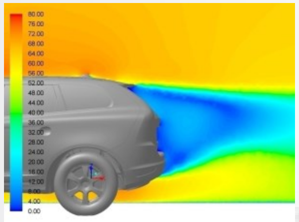
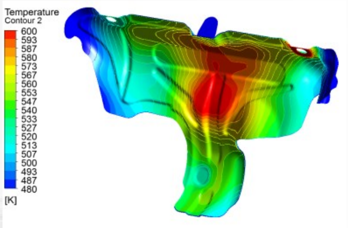
Agenda

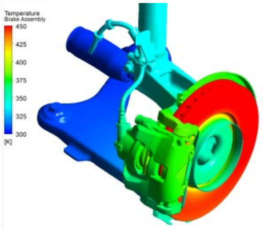
- Motivation
- Workflow
- Current Study
- Results
- Potential Future Work

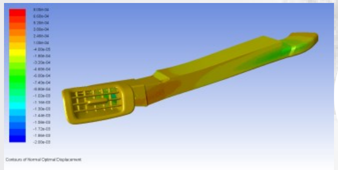
Motivation

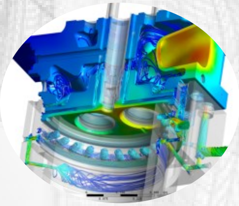
- Within the automotive OEMs, it is common to have separate teams for different areas of simulation focus
  - Aerodynamics
  - Underhood Thermal Management
  - Aero Acoustics
  - Engine CHT
  - Brakes
  - Exhaust After-treatment
  - Climate Comfort
  - Contamination (Snow, Dust, Rain)
  - ...

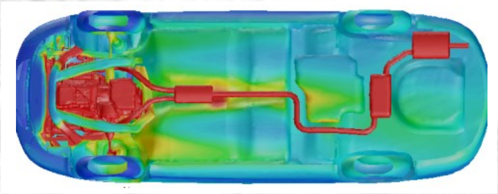












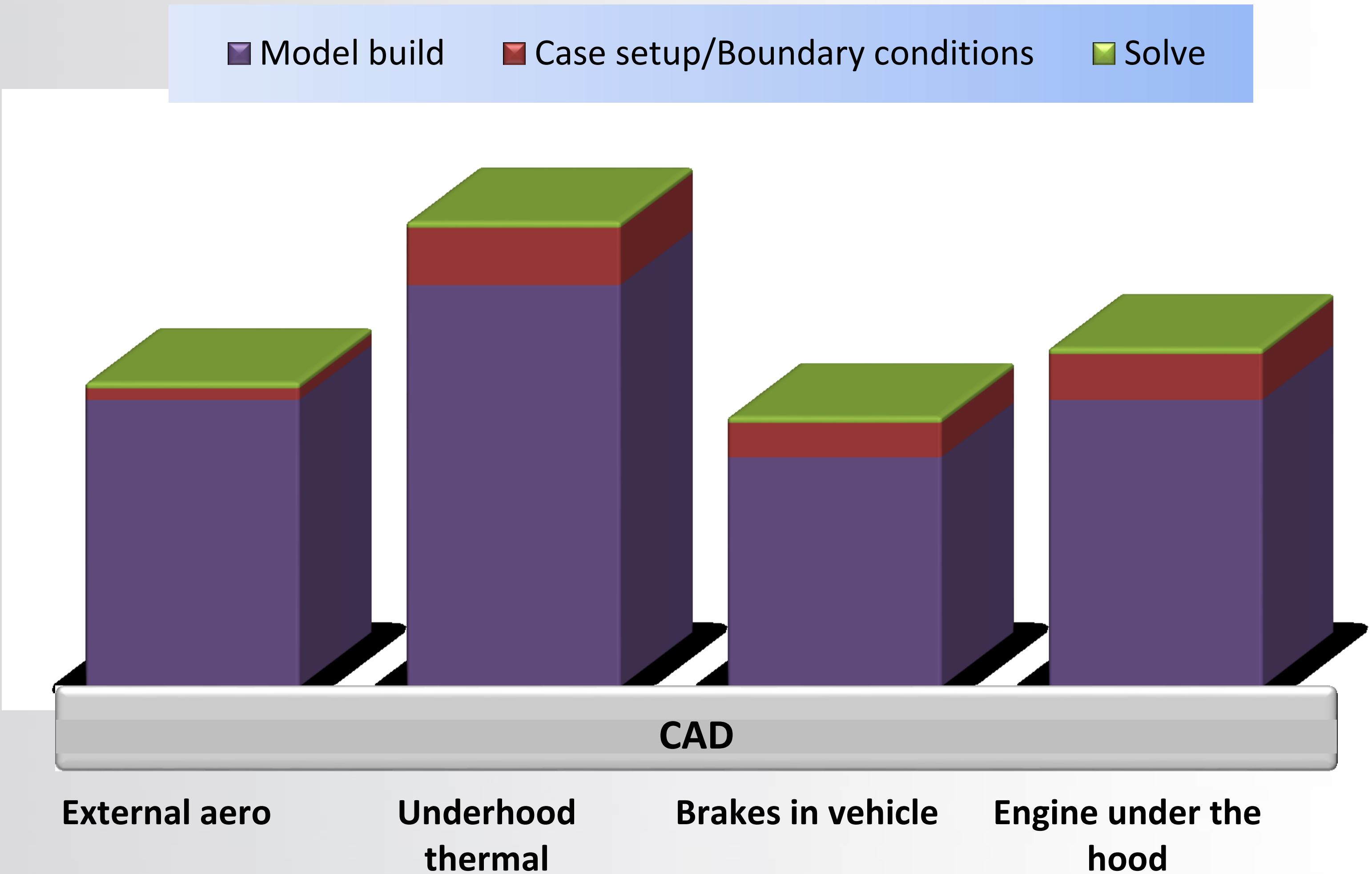
- This allows each team to focus on individual areas.
- However, potential inefficiencies with this setup are
  - Duplication of CAD work (Cleanup/assembly)
  - Duplication of Meshing
  - Inconsistency and excessive need of boundary conditions and material data
  - Potential compromise on accuracy due to interdependencies
  - Non-optimal simulation times

Motivation

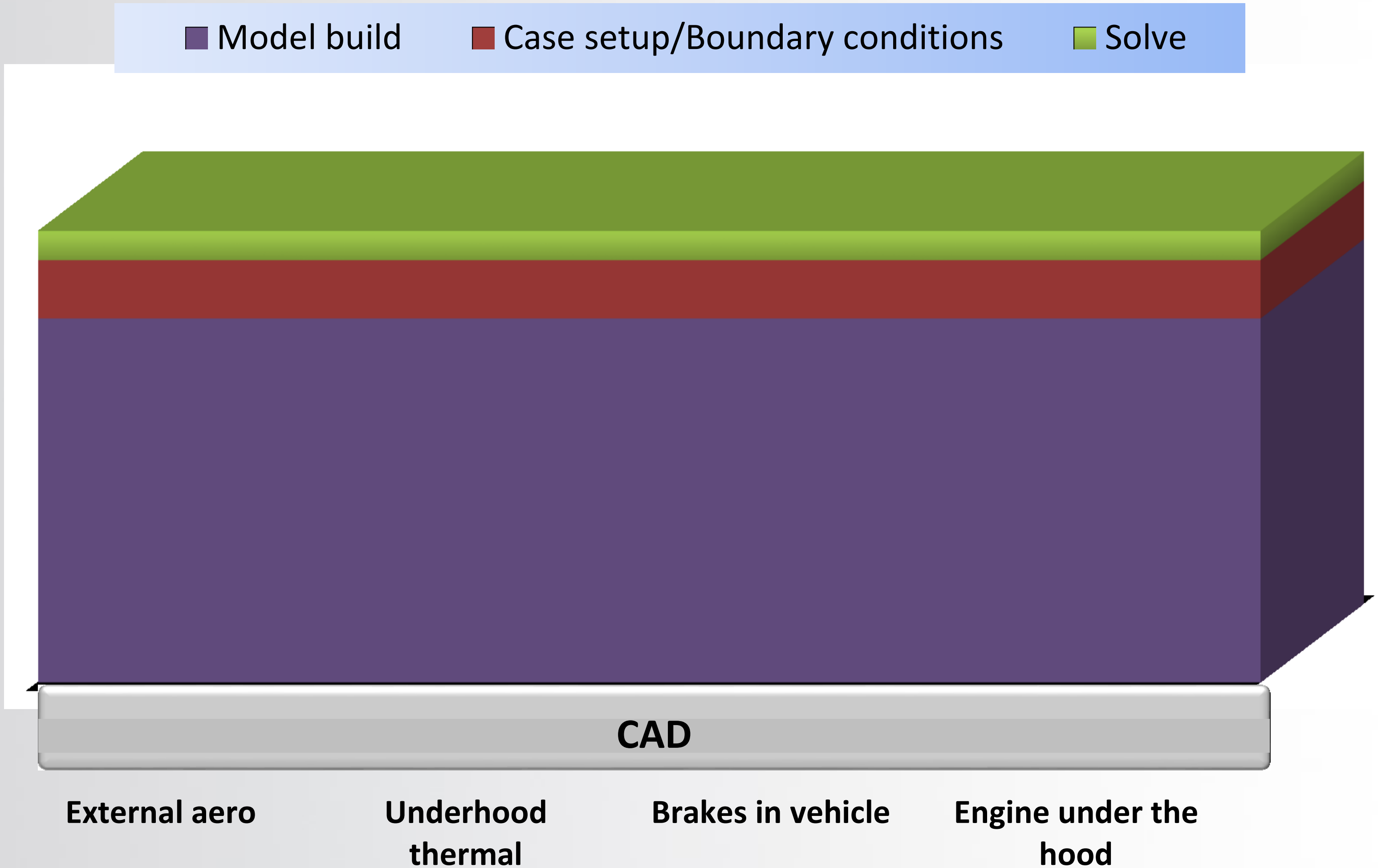
- Using a common multi-objective model allows for
  - Minimizing time spent on CAD assembly and CAD cleanup within the company
  - Including all relevant physics within one simulation
  - Minimizing the need for gathering boundary conditions and material data
    - E.g. for the engine CHT, only one or two boundary conditions are needed
  - Using a common material database for all simulations
  - Consistent meshing strategy
  - No compromise/assumptions on boundary conditions at the interface of differenet attributes
  - Respecting the coupled nature of the various subsystems as in the real world
  - Separate mesh strategies
  - Common model MDO

- Specific simulations, where only selected physics or attributes are to be included, can be performed by using the common CAD model with
  - Seperate surface meshing strategies, e.g. refining/coarseing the mesh
  - Separate volume meshing strategies, e.g. redistributing volume mesh refinement and/or excluding prism layers on exterior if Aerodynamics is excluded

Model per Attribute



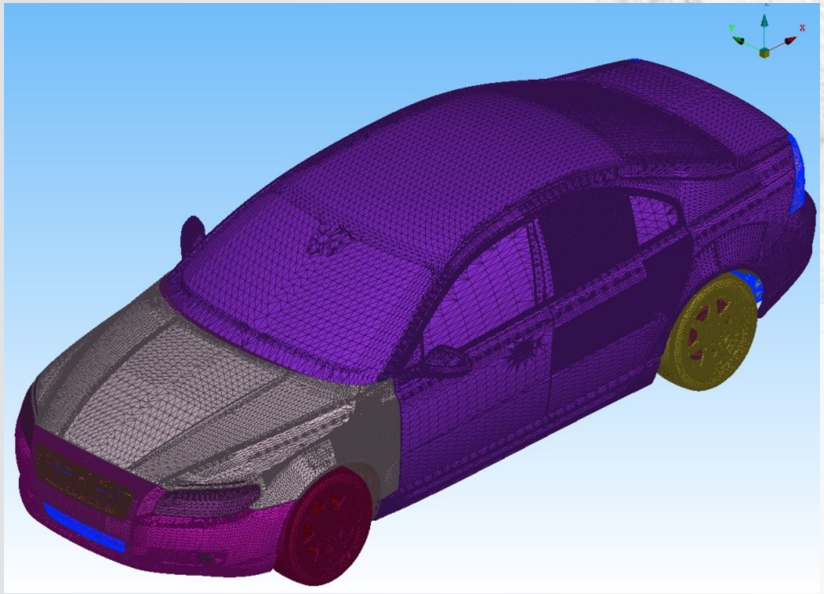
Common Multi-Objective Model



Ideal Workflow (Current Study)

CAD

- CAD/Tesselated representation of the complete vehicle



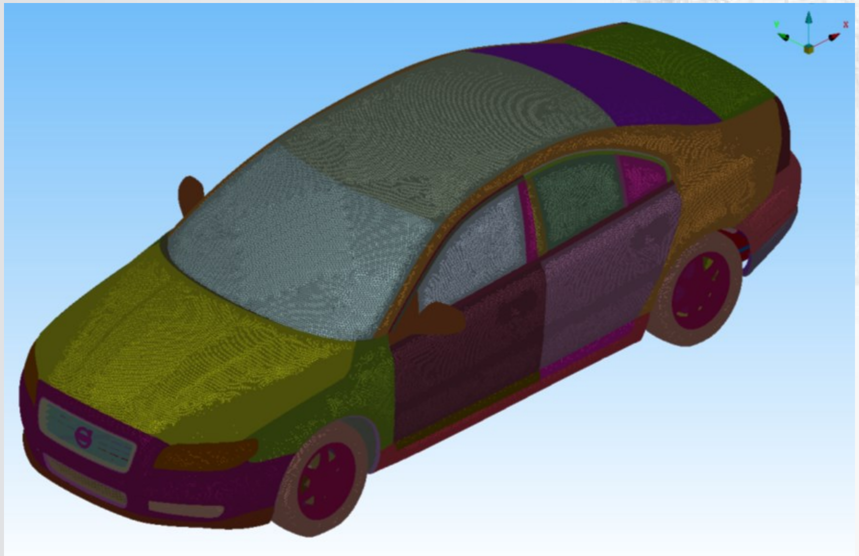
Ideal Workflow (Current Study)

CAD
- CAD/Tesselated representation of the complete vehicle

→

Conformal HQ surface mesh
- Surface mesh suitable for all attributes

→

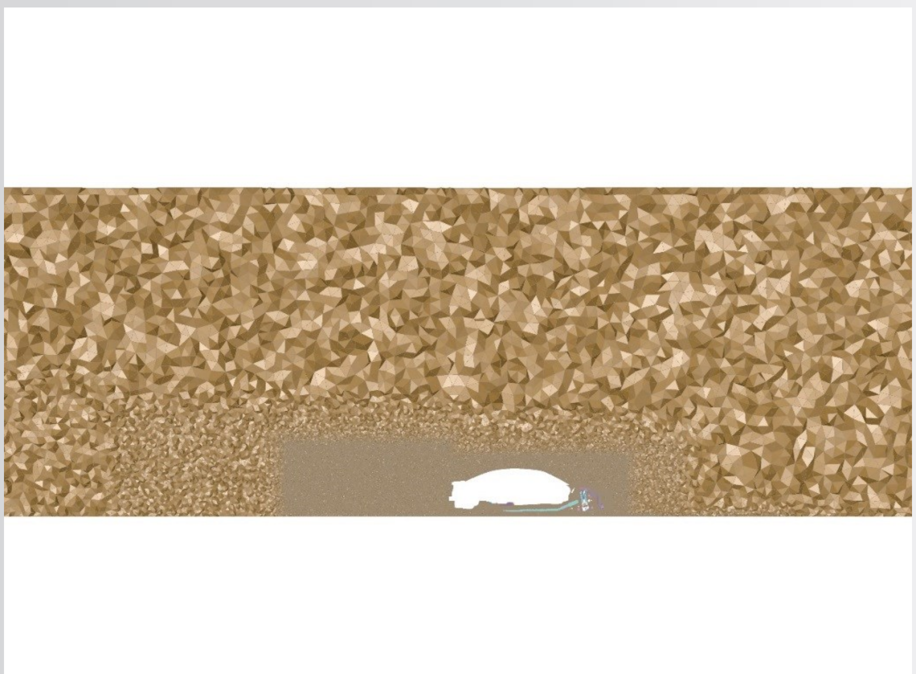


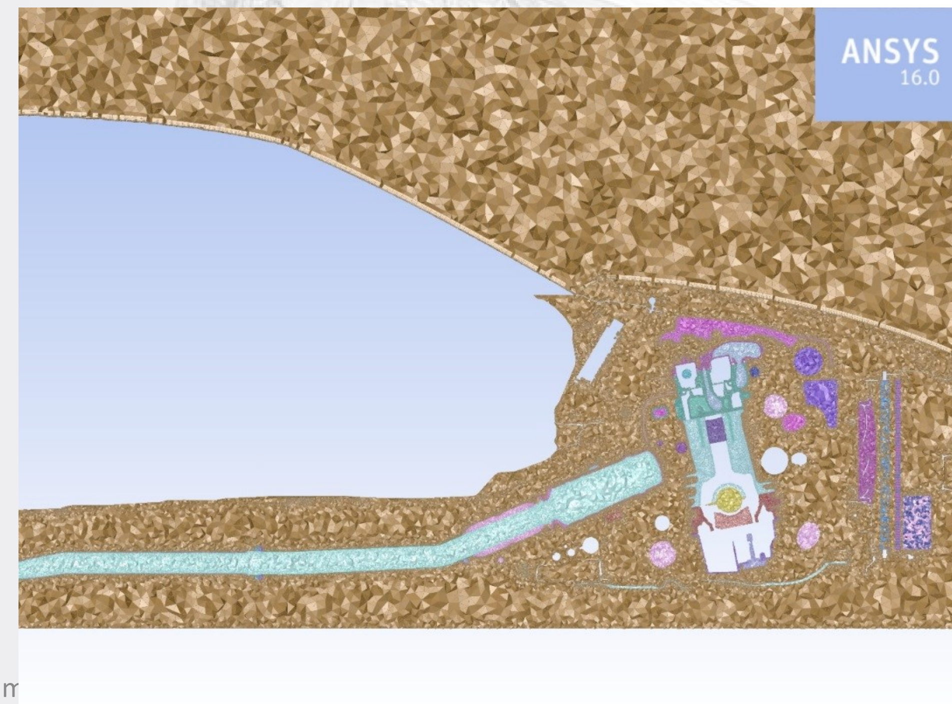
Ideal Workflow (Current Study)

CAD
- CAD/Tesselated representation of the complete vehicle

Conformal HQ surface mesh
- Surface mesh suitable for all attributes

Volume Mesh
- Volume mesh suitable for all attributes





Ideal Workflow (Current Study)

CAD
- CAD/Tesselated representation of the complete vehicle

Conformal HQ surface mesh
- Surface mesh suitable for all attributes

Volume Mesh
- Volume mesh suitable for all attributes

Case Setup
- Automated set up for all attributes

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Zone ID	Wall Zone	Adj Cell Zo	Shadow Zc	Material	Wall BC Ty	Temperatu	HeatFlux	Convectio	HTC Ref	Ext Emiss	Ext Temp	Int Emiss	Wall Thick	Diff Fractic	FPSC	Shell Cond	Critical Zoi	VF?	CAF
2	22	bbox	fluid-main	xxxxxx	aluminum	heatflux	300	0	0	300	1	300	1	0	1	1	no	no	yes	1
3	1897	fan-hub	solid-hub	fan-hub-sl	aluminum	coupled	300	0	0	300	1	300	1	0	1	1	no	no	yes	1
4	23	fan-hub-sh	solid-fan-4	fan-hub	aluminum	coupled	300	0	0	300	1	300	1	0	1	1	no	no	yes	1
5	2	fan-hub:0(	solid-hub	fan-hub:0	aluminum	coupled	300	0	0	300	1	300	1	0	1	1	no	no	yes	1
6	17	fan-hub:0(	solid-fan-2	fan-hub:0	aluminum	coupled	300	0	0	300	1	300	1	0	1	1	no	no	yes	1
7	3	fan-hub:0(	solid-hub	fan-hub:0	aluminum	coupled	300	0	0	300	1	300	1	0	1	1	no	no	yes	1
8	16	fan-hub:0(	solid-fan-3	fan-hub:0	aluminum	coupled	300	0	0	300	1	300	1	0	1	1	no	no	yes	1
9	4	fan-hub:0(	solid-hub	fan-hub:0	aluminum	coupled	300	0	0	300	1	300	1	0	1	1	no	no	yes	1
10	15	fan-hub:0(	solid-fan-1	fan-hub:0	aluminum	coupled	300	0	0	300	1	300	1	0	1	1	no	no	yes	1
11	5	fan-hub:0(	solid-hub	fan-hub:0	aluminum	coupled	300	0	0	300	1	300	1	0	1	1	no	no	yes	1
12	14	fan-hub:0(	fluid-mrf	fan-hub:0	aluminum	coupled	300	0	0	300	1	300	1	0	1	1	no	no	yes	1
13	1898	fan-tip	solid-fan-3	fan-tip-sh	aluminum	coupled	300	0	0	300	1	300	1	0	1	1	no	no	yes	1

Workflow Alternatives

CAD
- CAD/Tesselated representation of the complete vehicle

Conformal surface mesh
- Surface mesh suitable for all attributes

Volume Mesh
- Volume mesh suitable for all attributes

Case Setup
- Automated set up for all attributes

- Fine-tuned surface mesh for selected attributes
- Allows for centralized CAD assembly and clean-up (LCC, Junior Engineers)

- Fine-tuned volume mesh per attribute
- Prism layers
- Refinement zones
- Solids
- Part Swapping

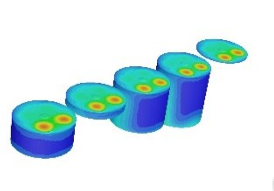
- Modified volume mesh per attribute
- Solids

- Modifications per load case
- Morphing
- MDO
- 0D/1D couplings
- Multiphysics

Common Model

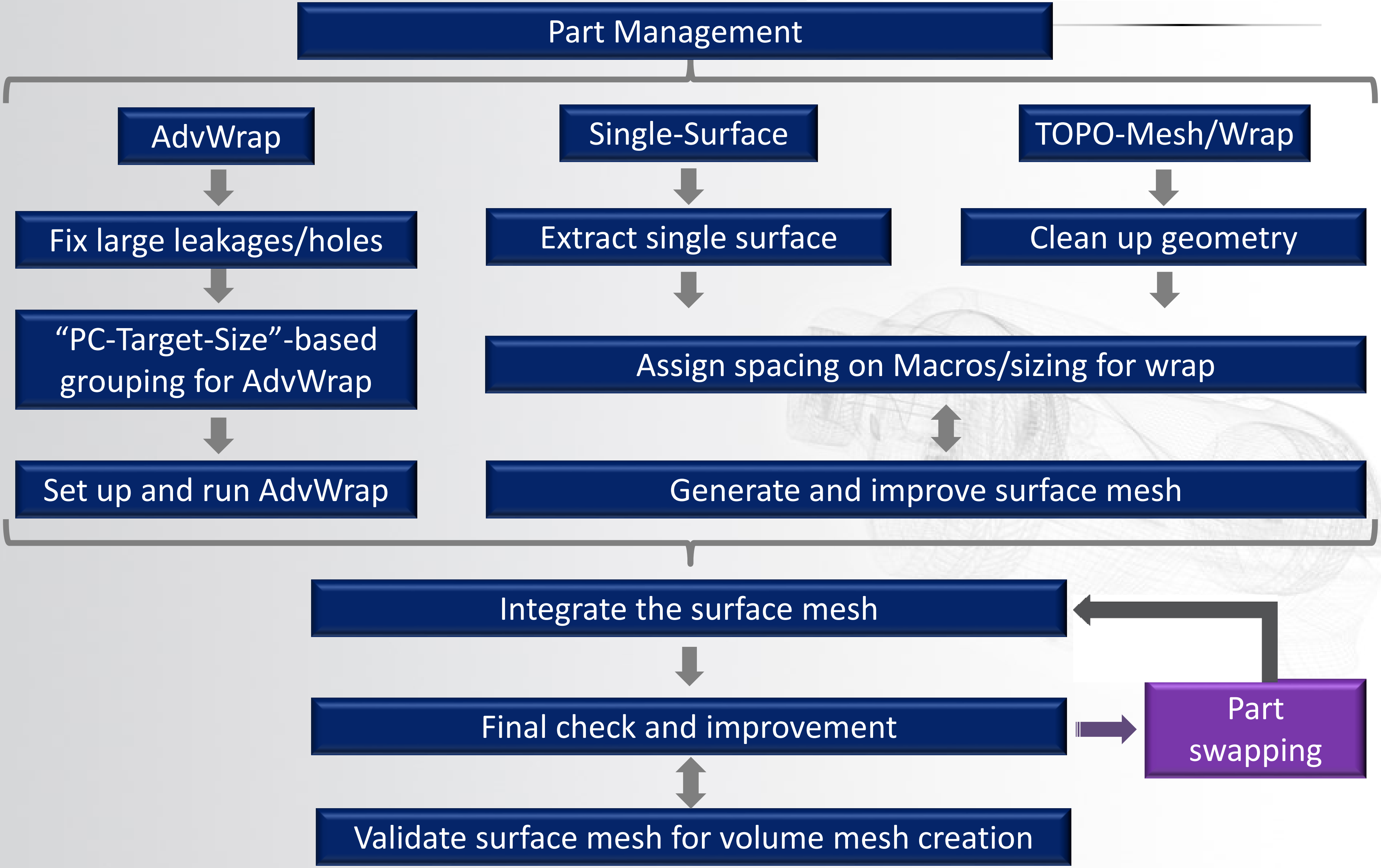
- Volvo S80 D5 MY2012
- 2.4-litre, 5-cylinder Twin-turbo Diesel Engine, 215 hp and 440 Nm
- Attributes included
  - Aerodynamics
  - Underhood Thermal Management
  - Engine CHT/Under the hood
  - Cooling system
  - Brake system
  - Air intake system
  - Exhaust system
- ~400 Solids
- ~50 Shells (readily extensible to 1000's)

- Use case
  - Vehicle moving at 110 kph; Engine rpm: 2050

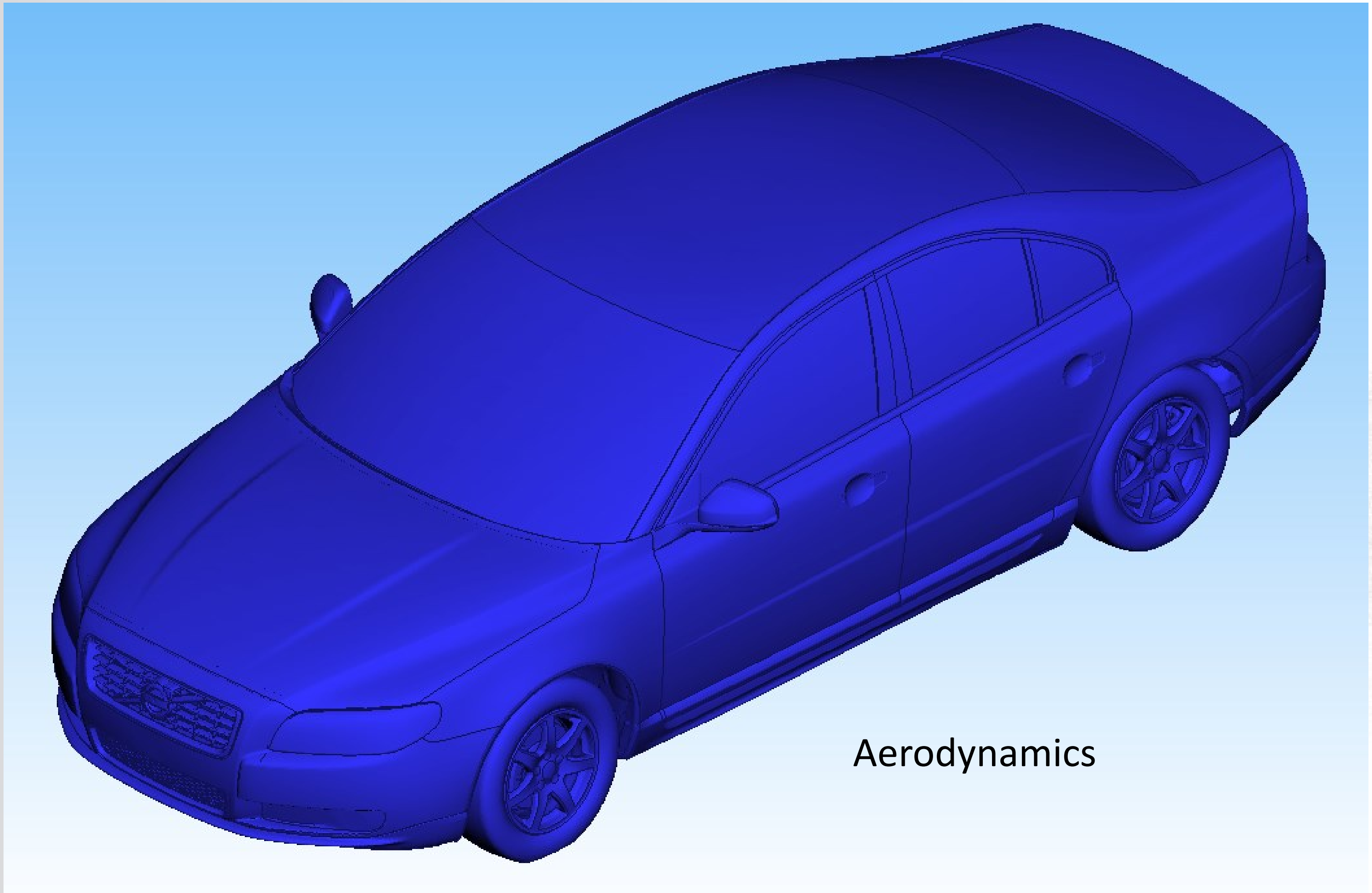


  - Thermal sources:
    - Combustion heat in cylinders
    - Hot exhaust gas into exhaust system and environment
    - Frictional heat in brake rotor
  - Brakes engaged
  - Turbo and pump
  - CRFM
    - Fans and HXs

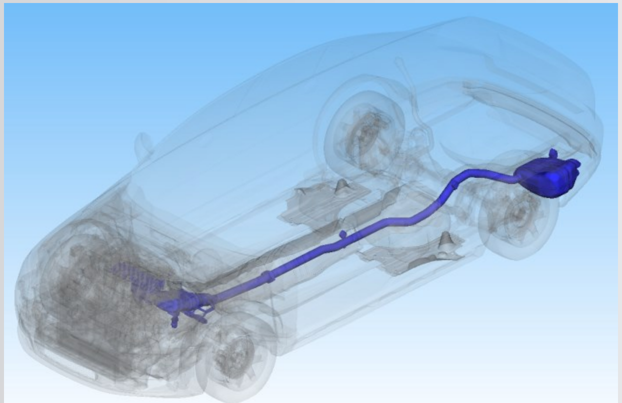
Model Build Process



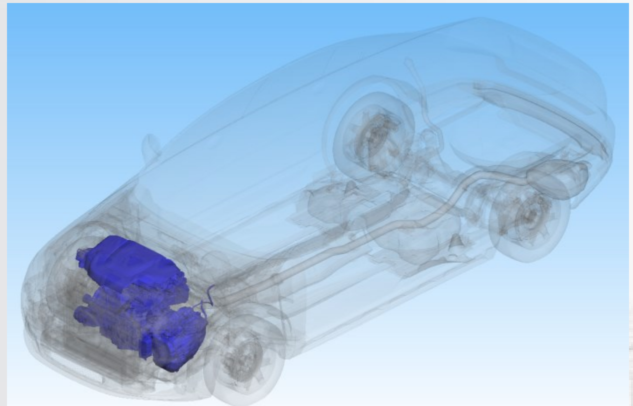
Sub Systems



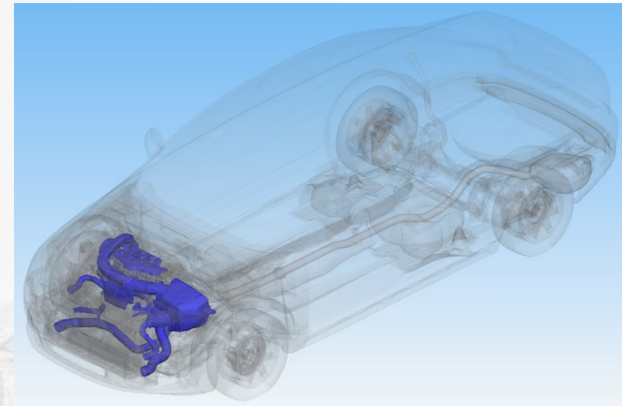
Sub Systems



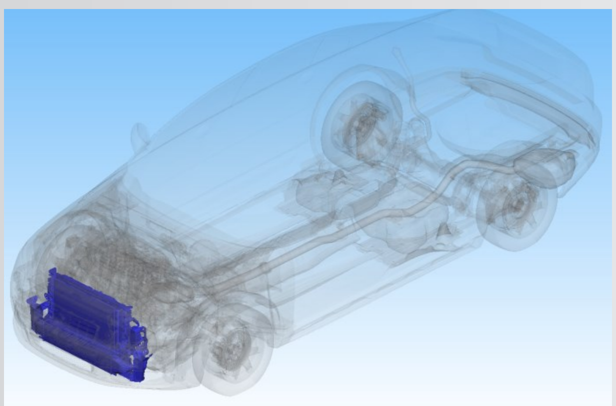
Exhaust System



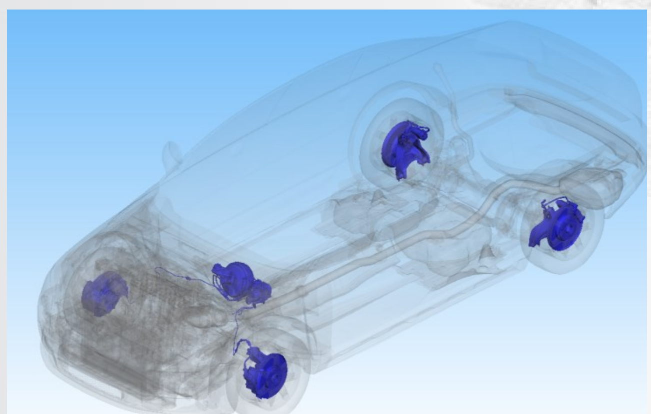
Engine



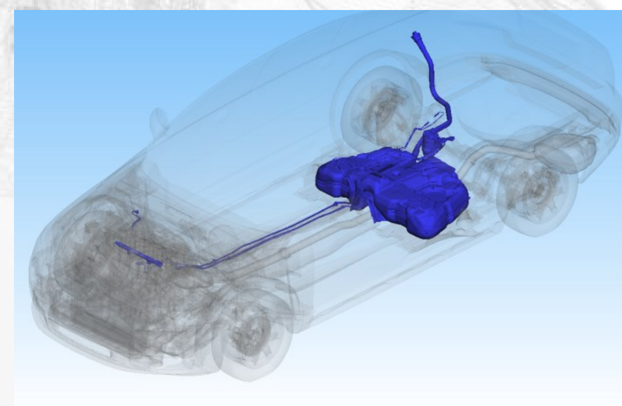
Air Intake System



Cooling System



Brake System

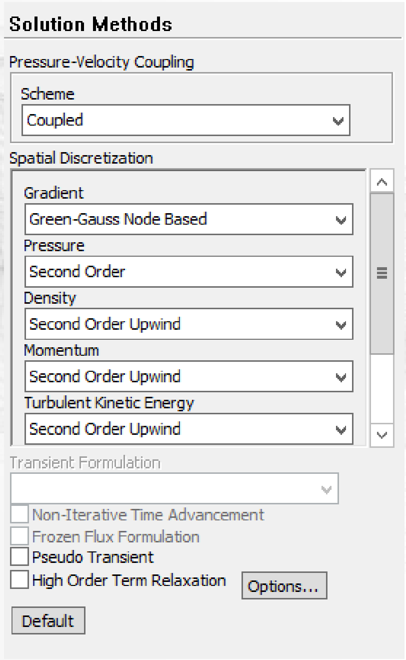


Fuel System

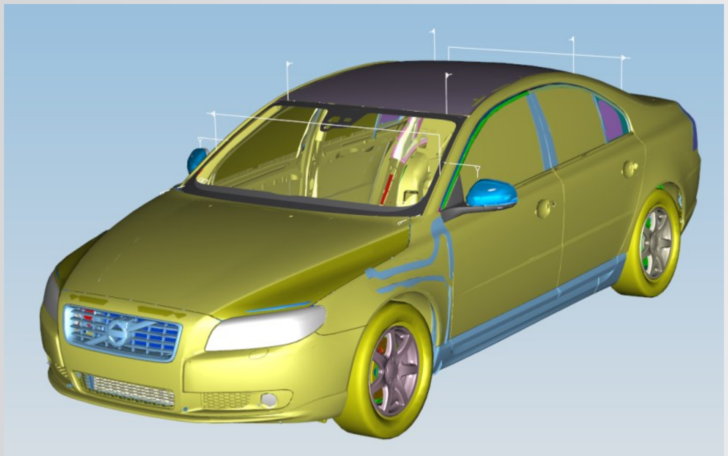
Simulation Details

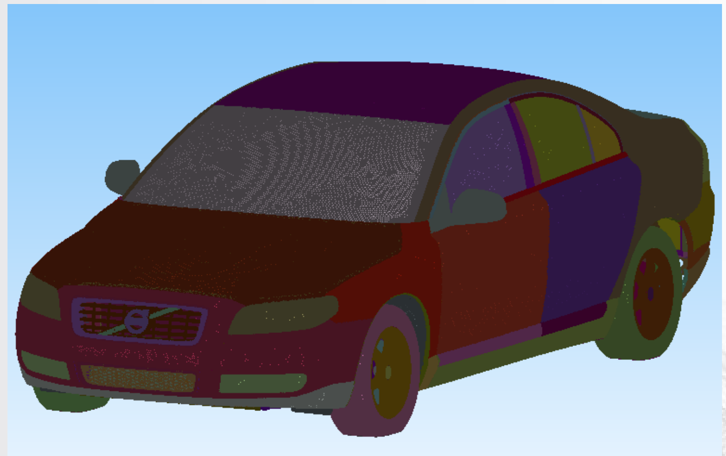
- One single simulation
- Realizable k-ε Turbulence Model with Enhanced Wall Function
- Second Order Upwind discretization, Coupled Solver, GGNB
- Surface to Surface (S2S) Radiadion Model
- Secondary streams
  - Exhaust
  - Air intake system
  - Cooling

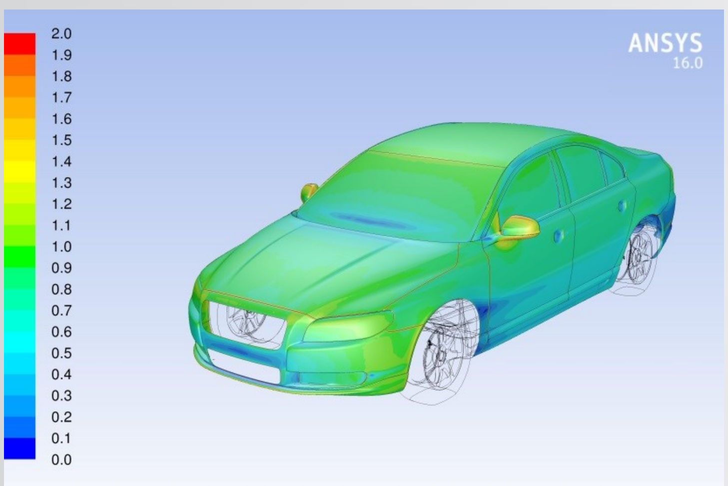
  (Exhaust and Air intake system: Mix at EGR)
- Ideal gas
- Turbocharger modeled using MRF, 140k rpm
- 110 kph, 35°C inlet
- Fans, RPM from supplied data
- Water pump modeled with MRF, 2050 rpm
- 3000 iterations



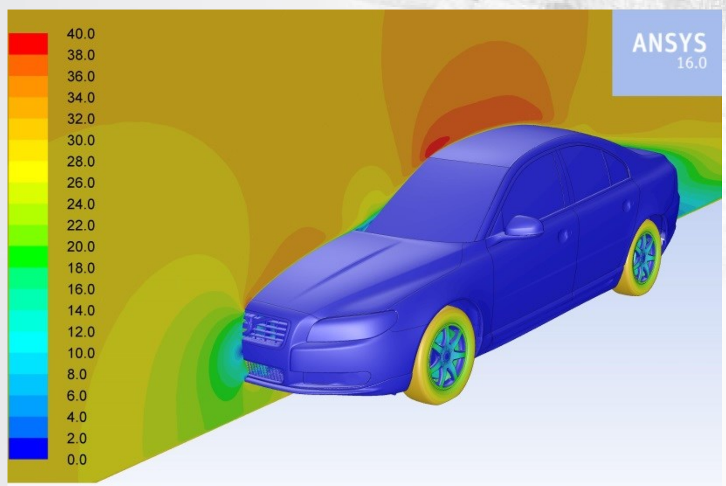
CAD, Mesh, Results – Aerodynamics







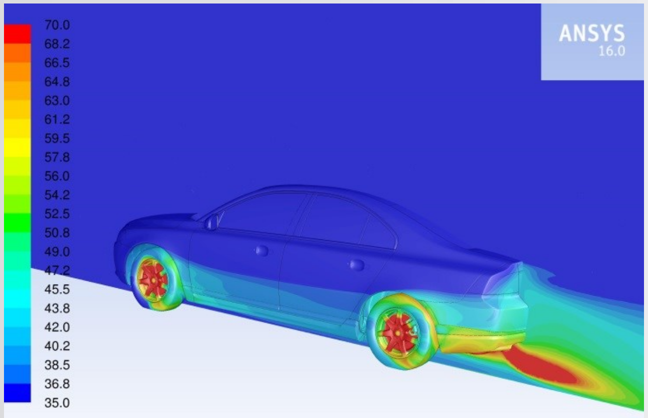
Contours of Wall Yplus



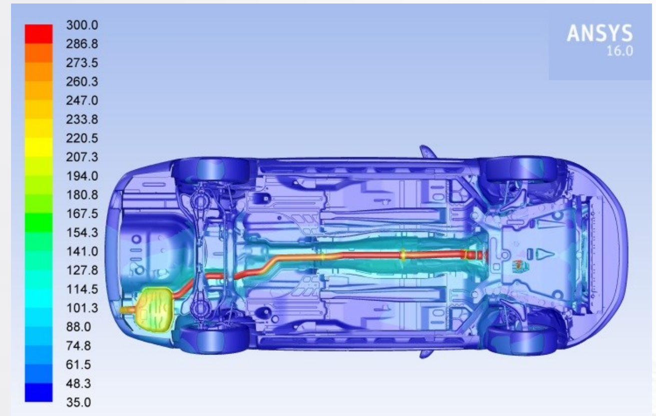
Contours of Velocity Magnitude (m/s)

- Detailed capture of all styled surfaces with no deviation from the exterior geometry
- 12 prism layers on styling surfaces with first height 0.02mm
- Rotating rims (MRF)
- Moving ground
- Refinement regions at wake and flow separation regions

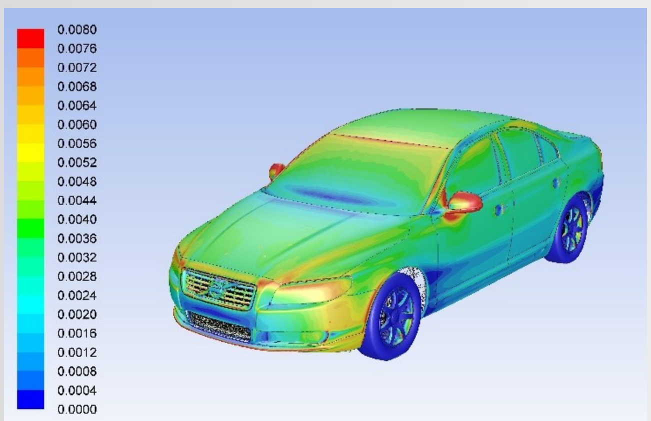
CAD, Mesh, Results – Exterior



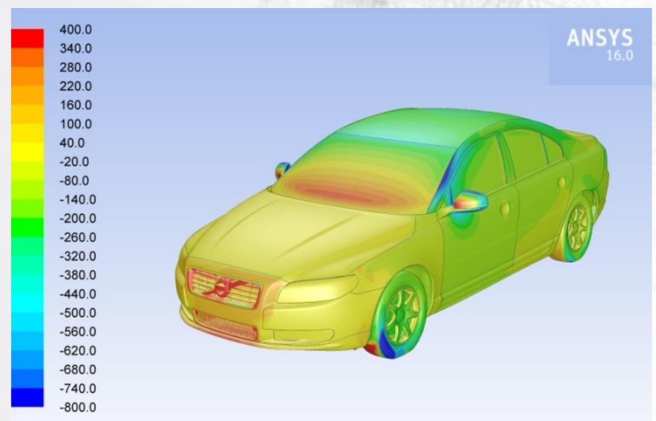
Contours of Static Temperature (c)



Contours of Static Temperature (c)

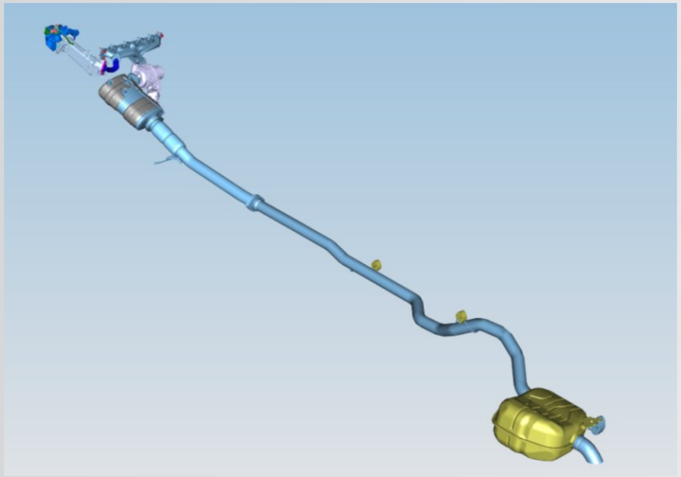


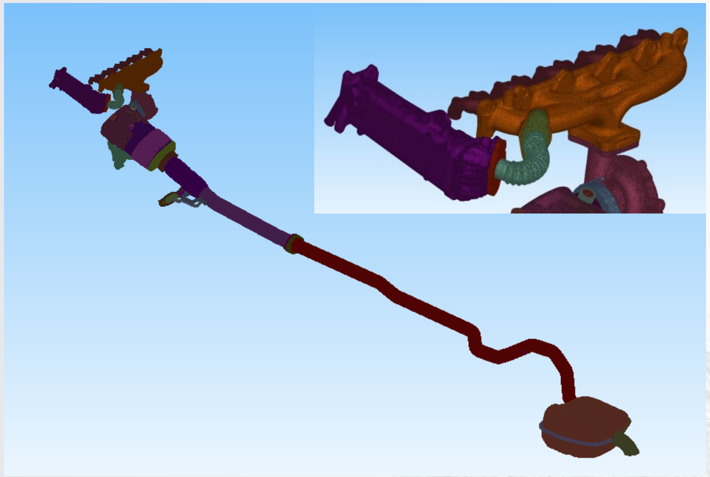
Contours of Skin Friction Coefficient

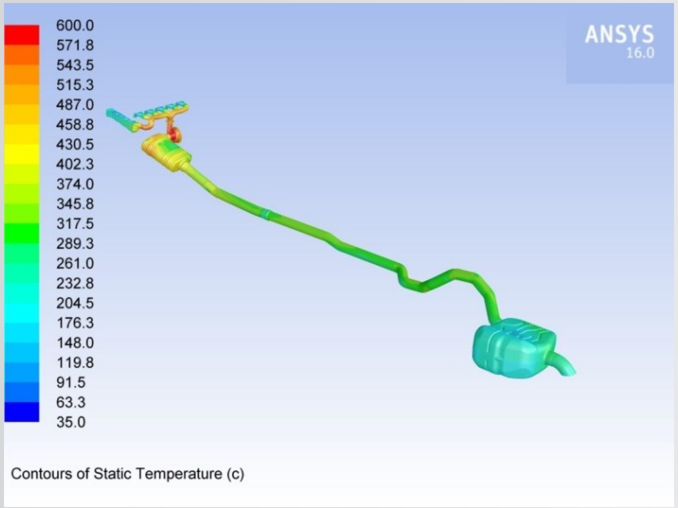


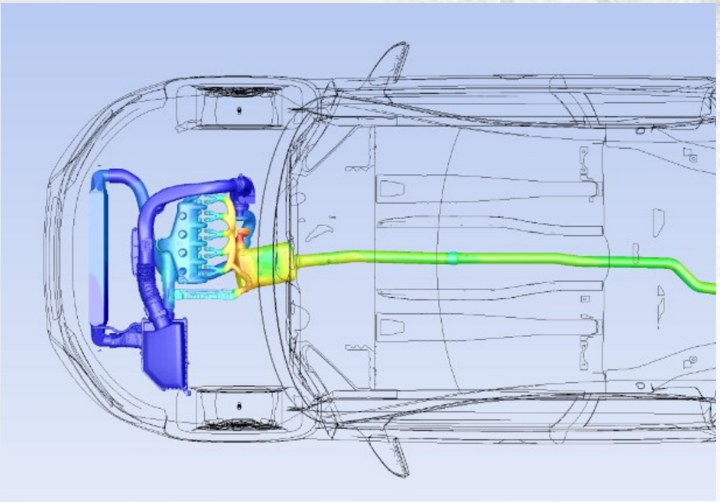
Contours of Static Pressure (pascal)

CAD, Mesh, Results – Exhaust



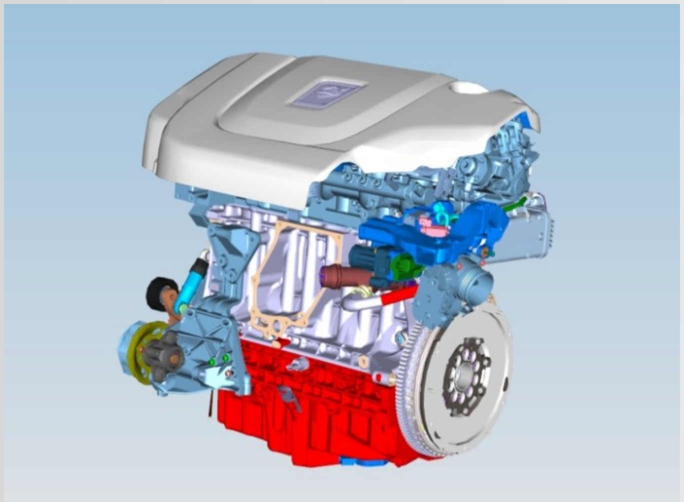


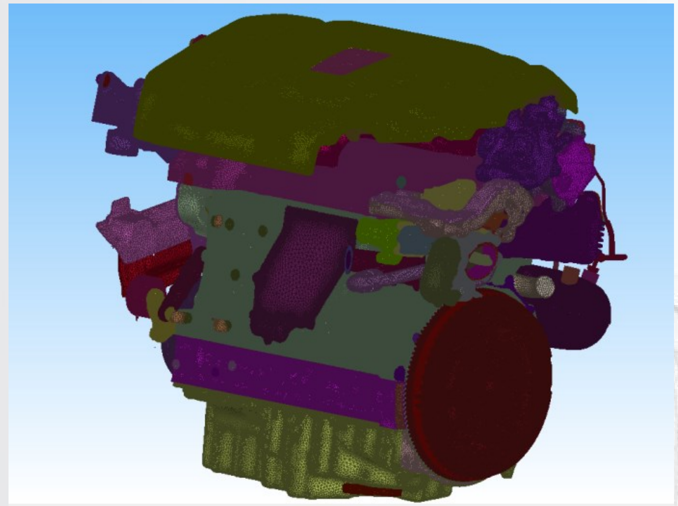


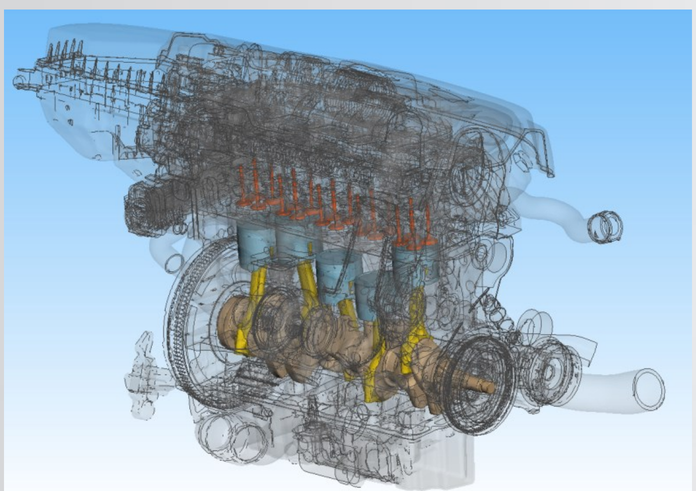


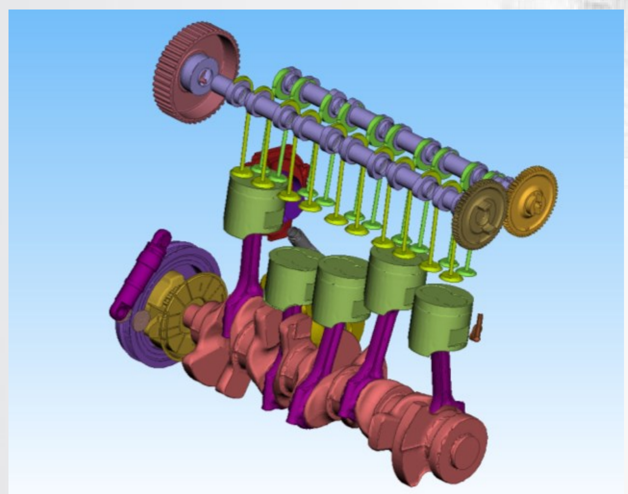
- Complete exhaust system from ports through tailpipe including manifold, turbo and EGR
- Gas flow mixes with AIS stream at EGR
- Includes hangers, brackets, bars as solids

CAD, Mesh, Results – Engine









- Internal components included: head, block, crank and case, camshaft, valves, pistons, pins, rods, pulleys, gear sets, oil sump, fuel pump, oil separator, mounts
- Manifold heat shield is laminated steel/ceramic

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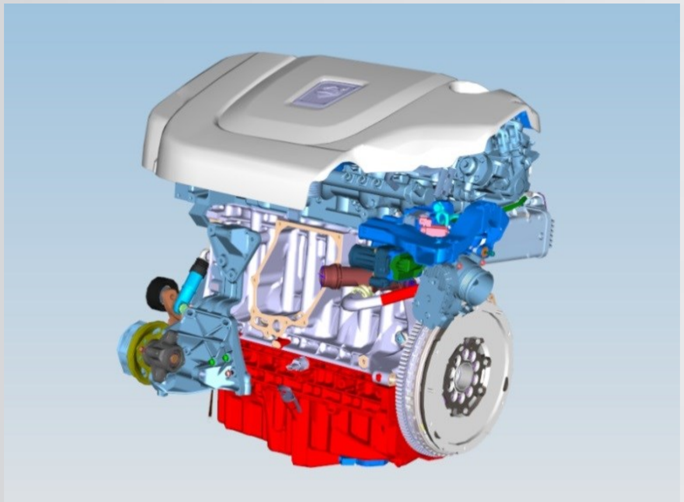
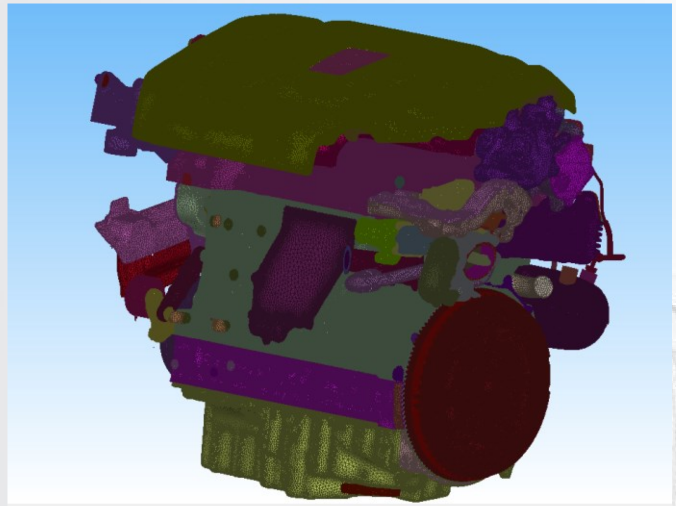
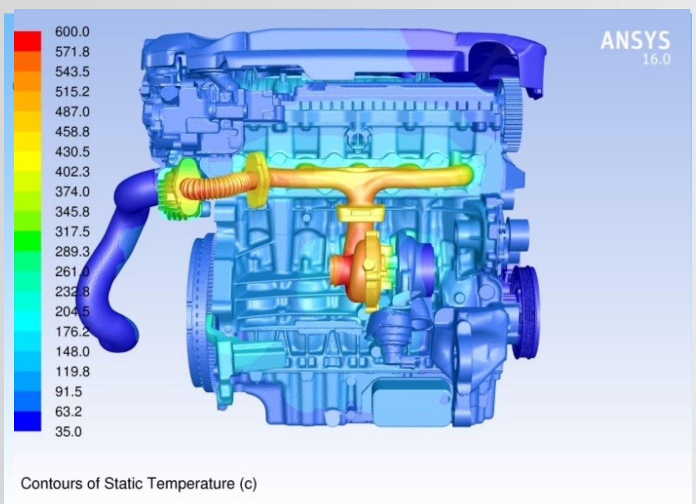
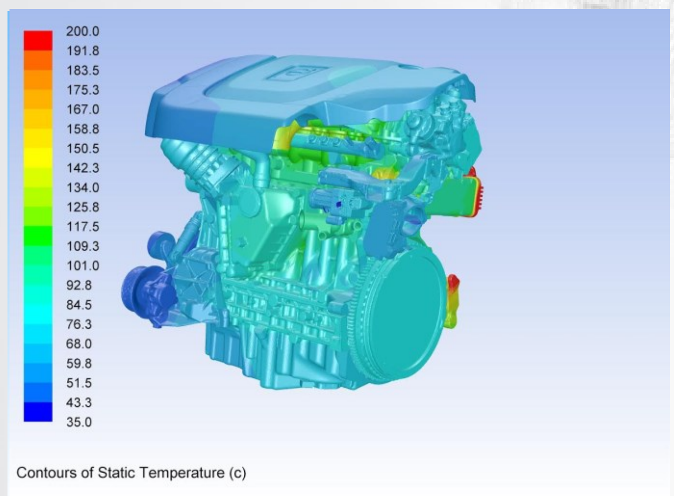
CAD, Mesh, Results – Engine



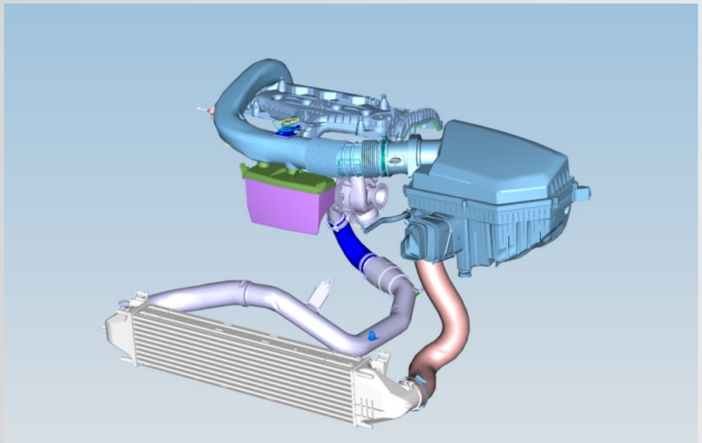


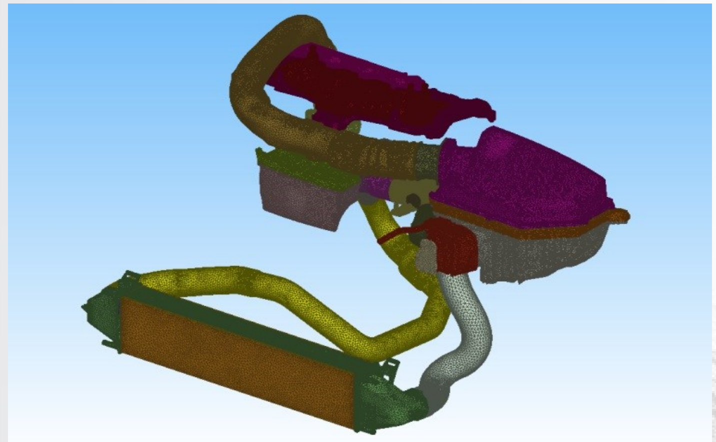


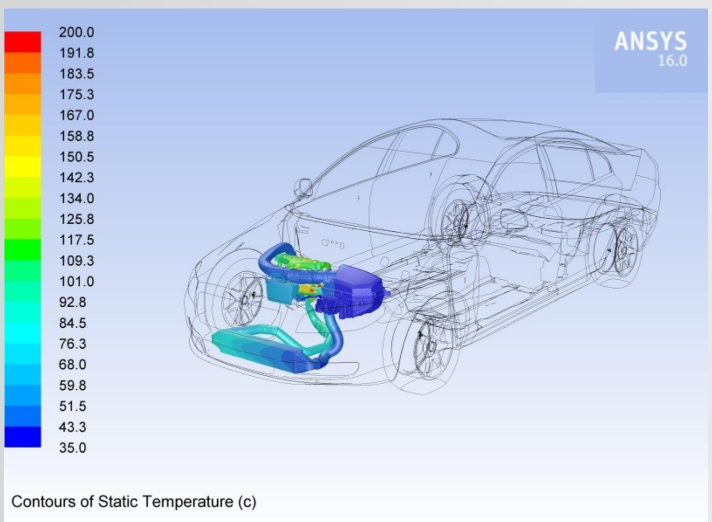


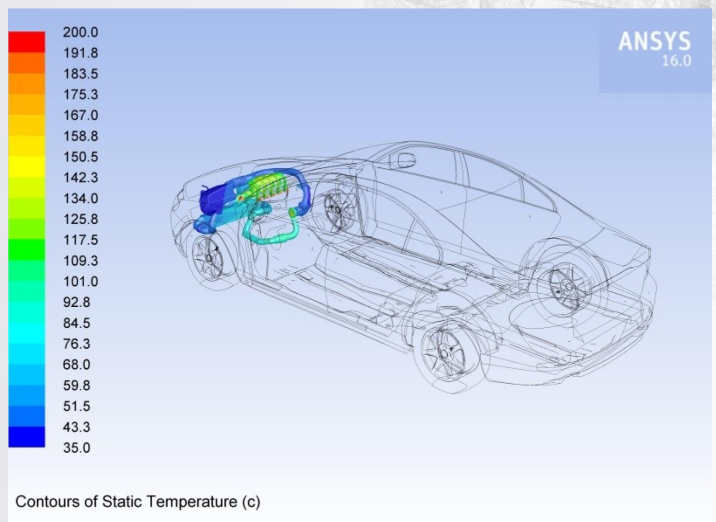
- Internal components included: head, block, crank and case, camshaft, valves, pistons, pins, rods, pulleys, gear sets, oil sump, fuel pump, oil separator, mounts
- Manifold heat shield is laminated steel/ceramic

CAD, Mesh, Results – Air Intake System



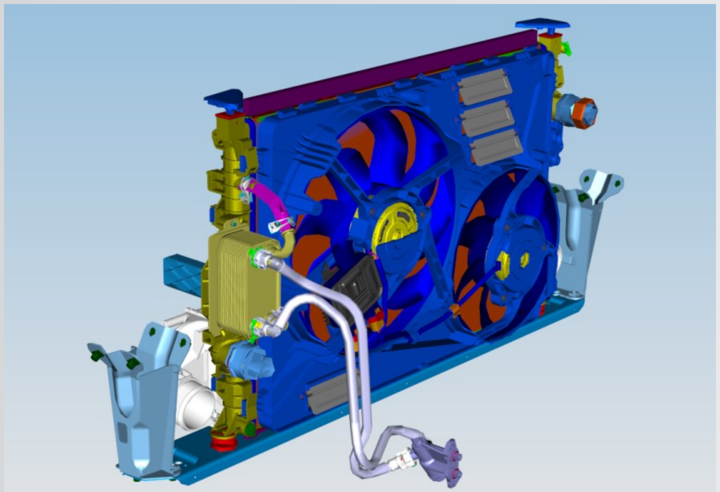


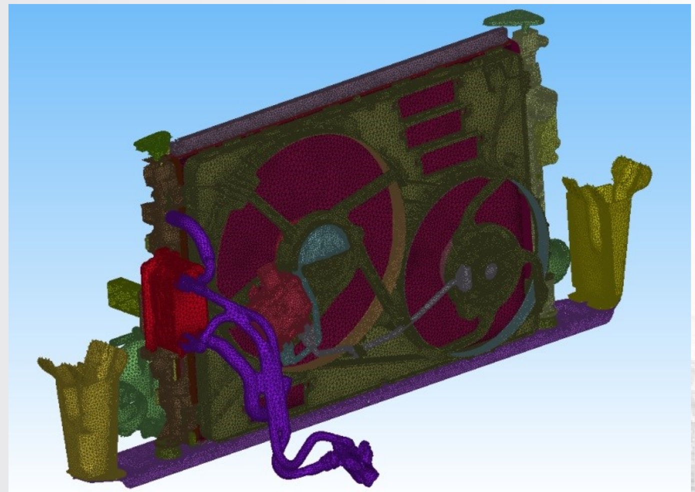


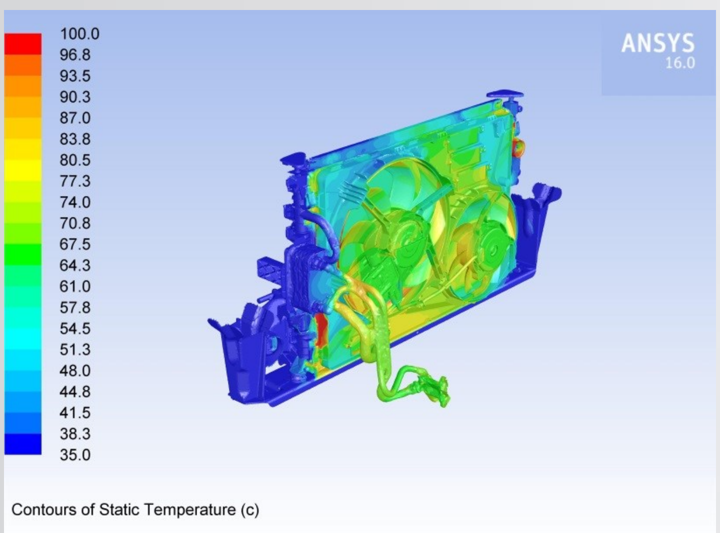


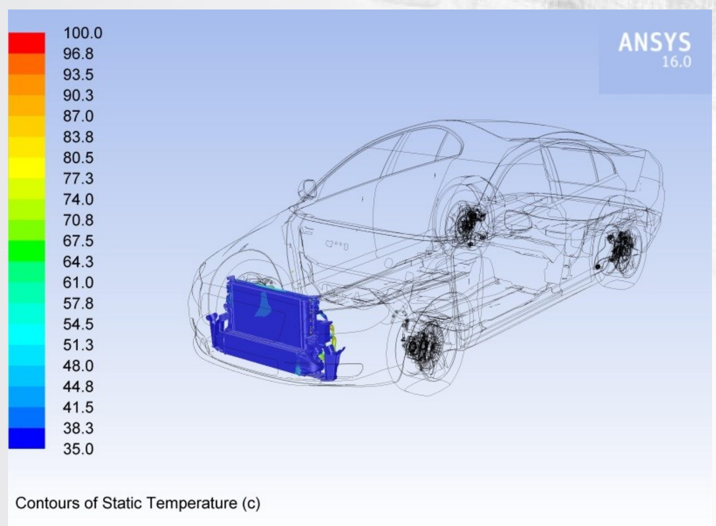
- From ambient to ports including turbo, CAC, EGR manifold
- Mix with Exhaust stream at EGR

CAD, Mesh, Results – CRFM



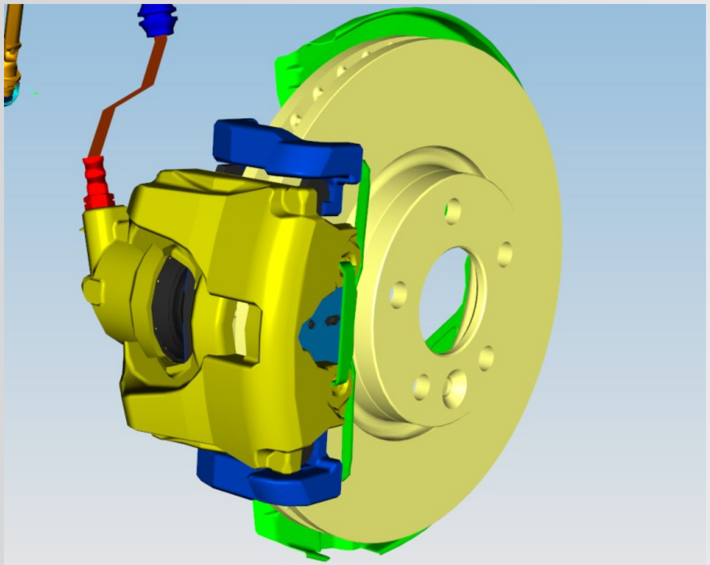


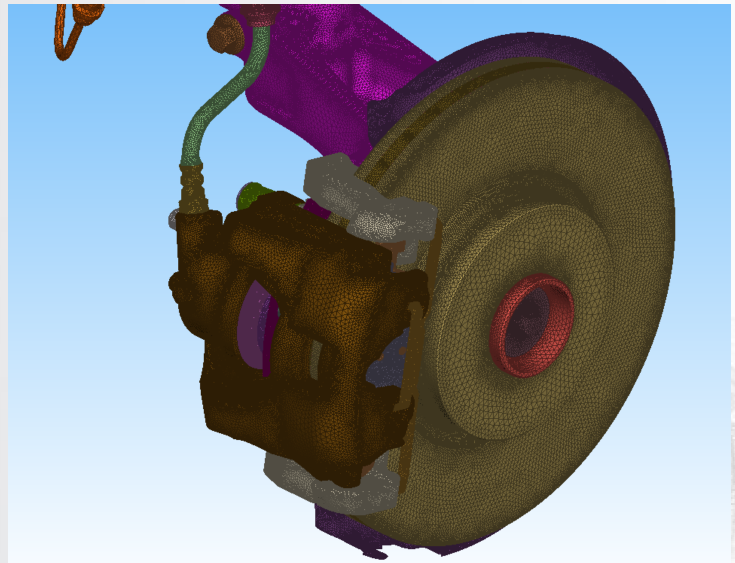




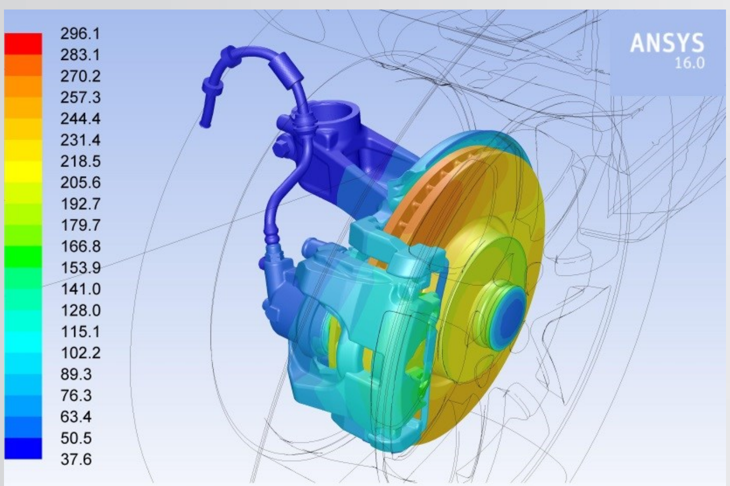
- Dual-Fan setup
- Fans modeled with MRF

CAD, Mesh, Results – Brakes

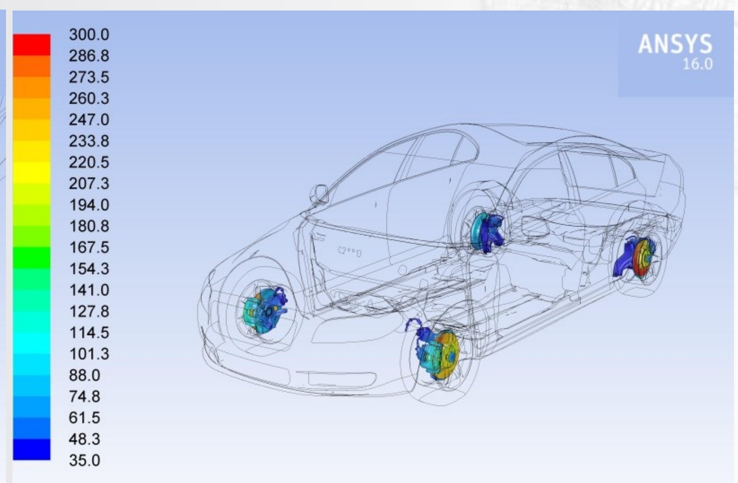




- ~200 solid zones
- All components accounted for
- MRF zones for the cooling slots (2x40)
- Frictional heat applied in the brake rotor

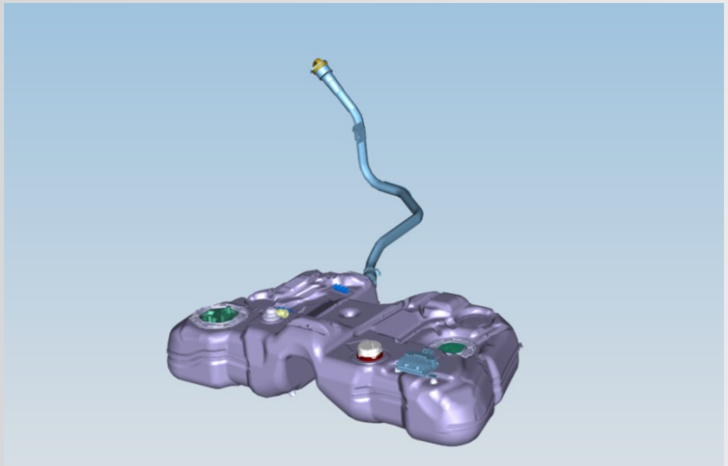


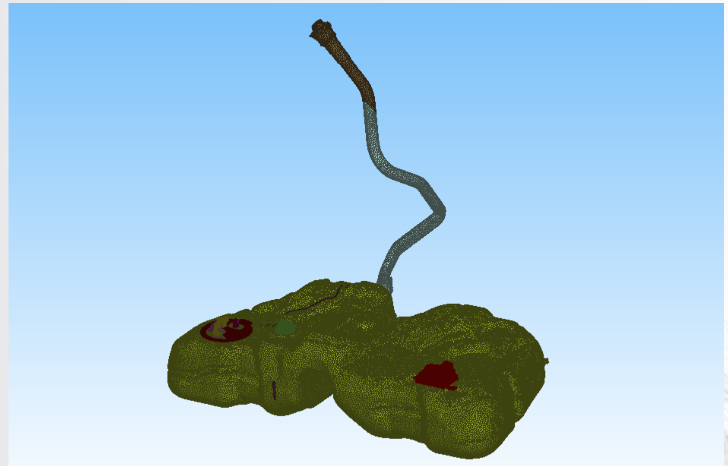
Contours of Static Temperature (c)

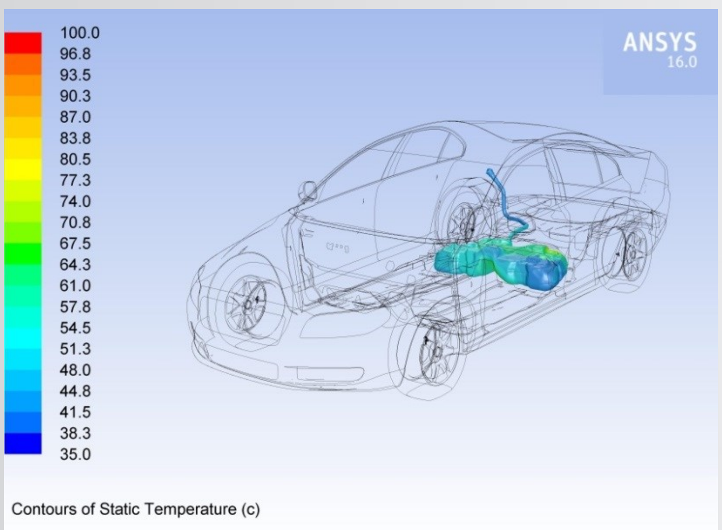


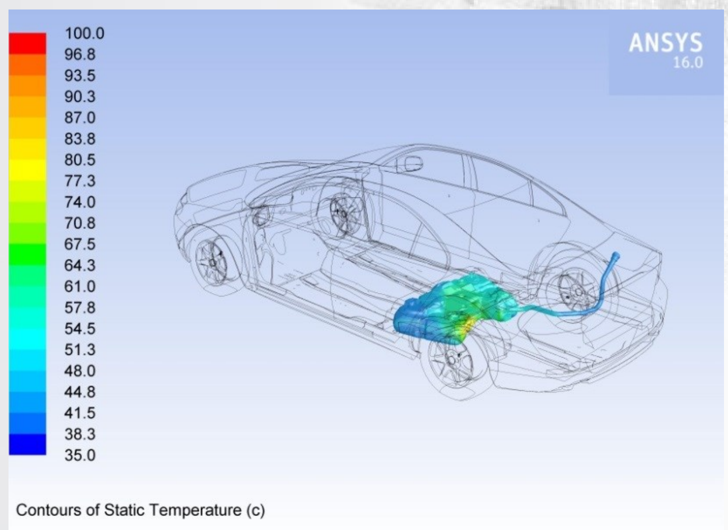
Contours of Static Temperature (c)

CAD, Mesh, Results – Fuel Tank



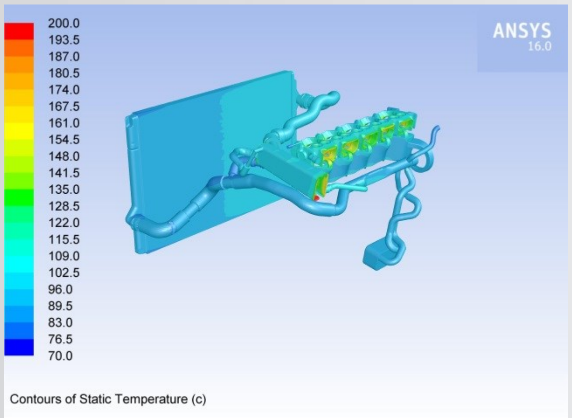




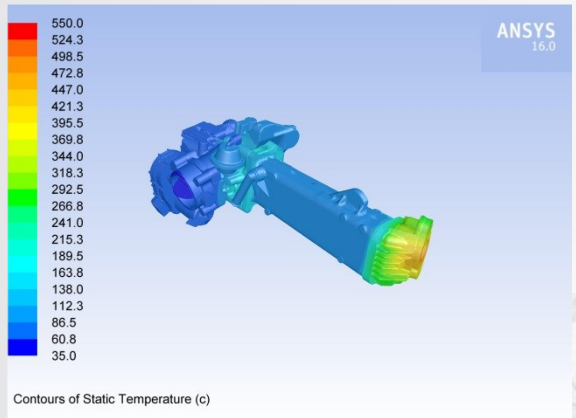


- Fluid-like material in the fuel tank
- Simplified internal components
- Accounts for accumulation of heat within the fuel tank

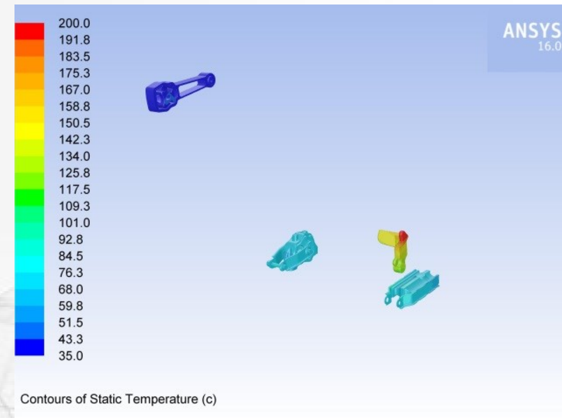
Results – Misc



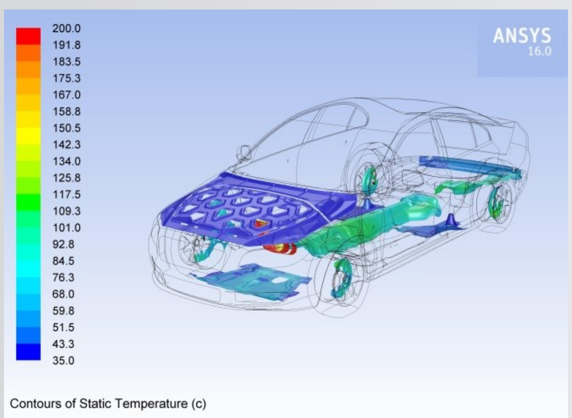
Coolant Stream



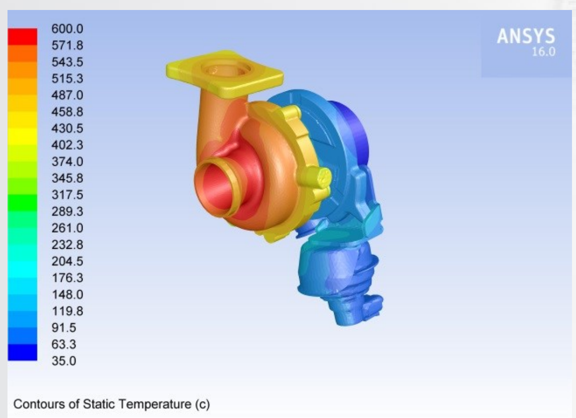
EGR



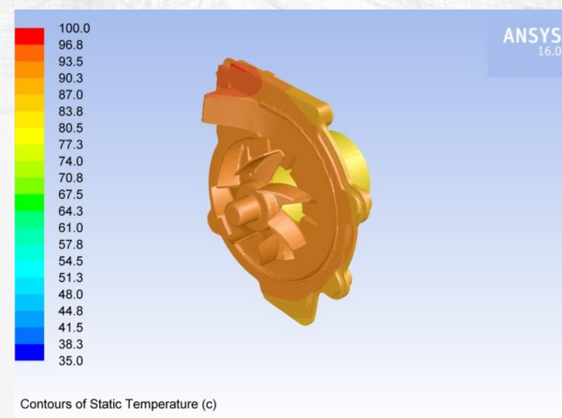
Mounts



Shields



Turbo



Water Pump

Potential Future Work

- Integrated, common model MDOs
- Approach is natively compatible with full FSI
  - Aeroelasticity
  - Thermo-mechanical+life simulations of components and subassemblies under realistic loads from the above 3d system level simulations
- In-cylinder combustion integration
- Transient studies
  - Aero Acoustics
  - Thermal Soak
  - Driving Cycles
  - Lubrication
  - Splashing/Wading with thermal effects
- Exhaust gas entrainment into the cabin