2006
KULI User Meeting

Methodology for Direct Coupling of KULI with PowerFLOW: Complete Integration of Air-Side Data from CFD

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April 7, 2006

Outline

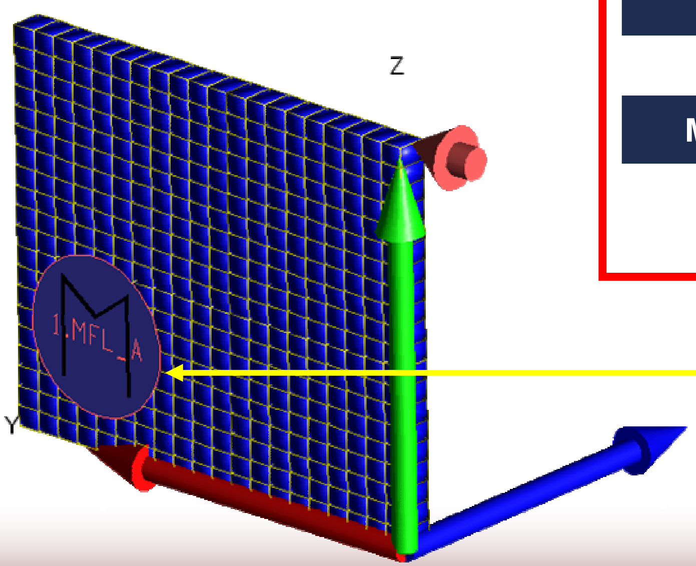
- Strategy for 1-way coupling
  - *Simple Method: Isothermal (cold) PowerFLOW simulation*
  - *Advanced Method: Thermal (hot) PowerFLOW simulation*
- Coupling PowerFLOW with KULI
  - *Process of data exchange*
  - *Example: Land Rover – Vmax (operating condition)*
- Proposed strategy for 2-way coupling
  - *Output coolant circuit data from KULI*
  - *Read data into PowerFLOW*
  - *Issues regarding 2-way coupling*
- Summary

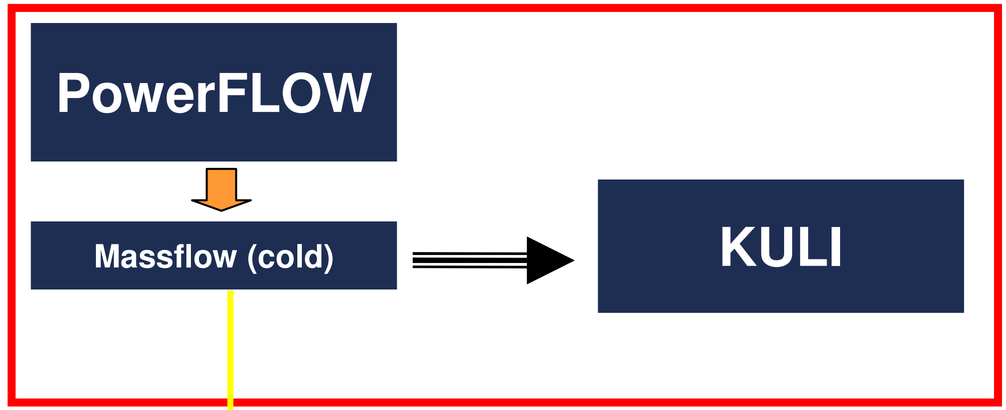
Coupling with KULI

- **Inputs to KULI**
  - *Heat exchanger (HX) data from Supplier*
    - HX Geometric details
      - Height, Width and Depth
      - Numer of tubes
      - Tube crosssection
    - Pressure drop characteristics (test data)
      - Pressure drop vs. massflow
    - Thermal characteristics (test data)
      - Net heat rejection
      - Air entry temperature (ambient)
      - Coolant entry and exit temperatures
  - *Operating conditions from OEM for each HX*
    - Net heat rejections
    - Coolant properties and flow rates

Simple 1-way Coupling with KULI

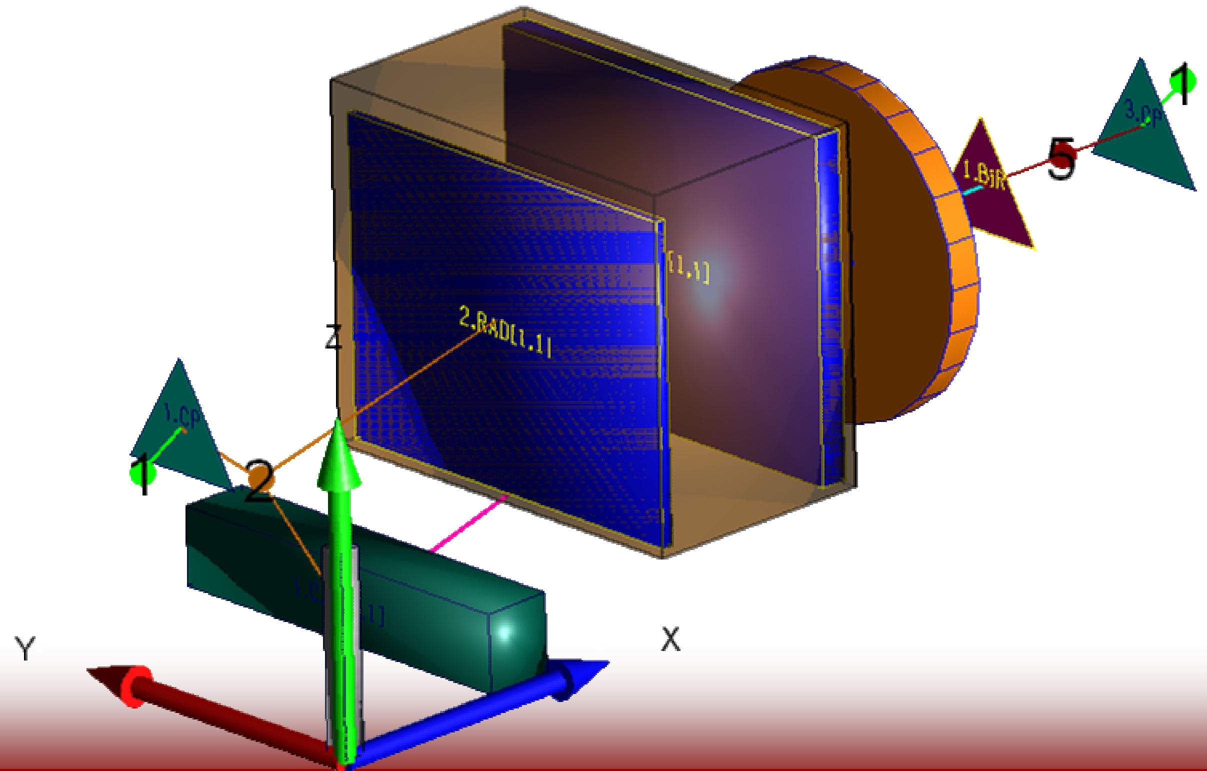
- Perform cold flow simulation with PowerFLOW
- Obtain massflow into the cooling package
  - *Massflow through grille*
- Provide this as "Massflow Target" to KULI





Simple 1-way Coupling with KULI

- **KULI calculates air-side properties**
  - *Simple 1D calculation for air-circuit*
  - *Can NOT handle recirculation*
  - *Ad hoc (manual) splitting of airflow through components*
    - User defined “air-paths”
    - Not sophisticated enough to handle most practical underhood flows

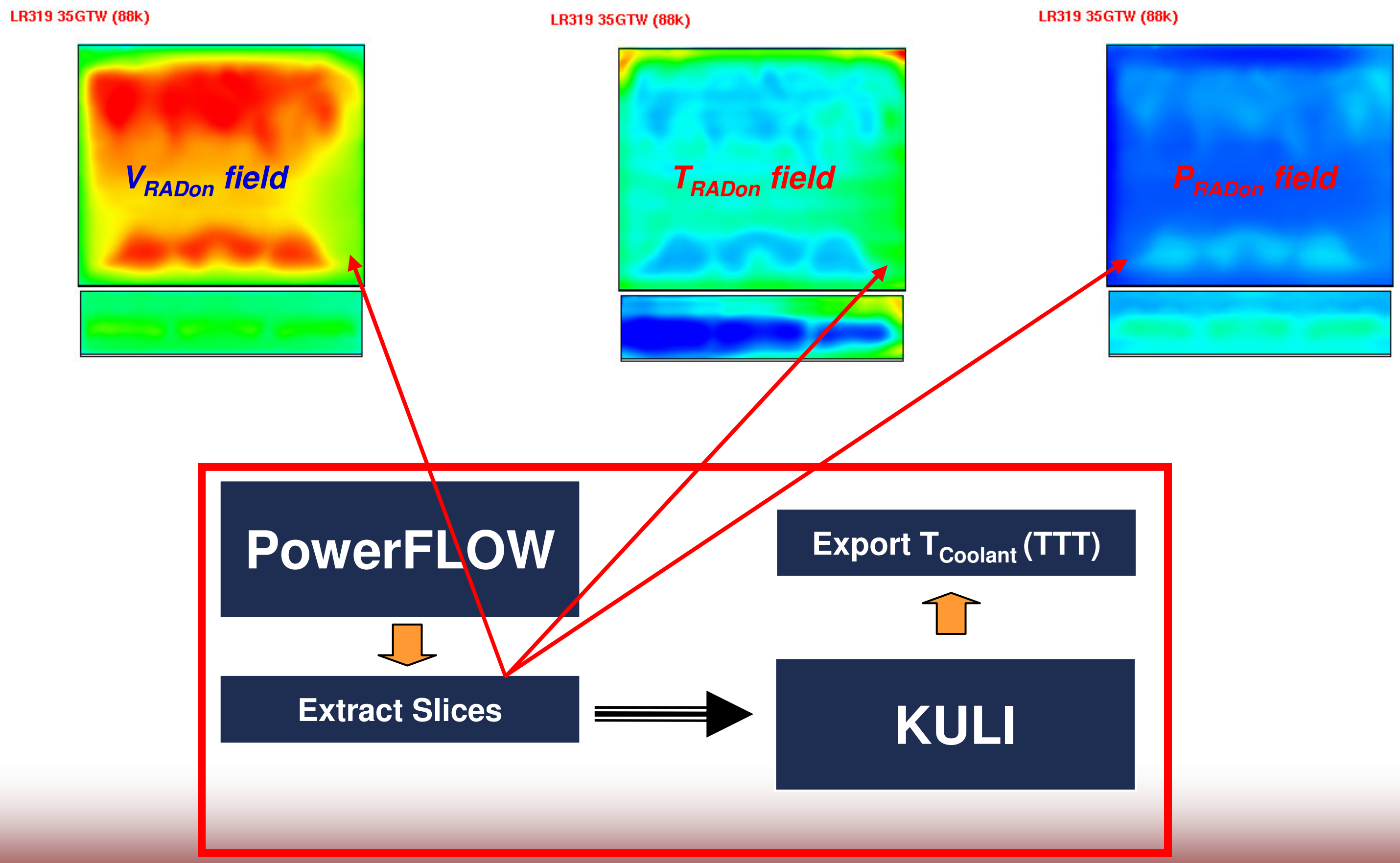


Need for Complete Integration of CFD data

- **Simple 1-way coupling**
  - *Pressure data from CFD is ignored*
  - *KULI recalculates air-side pressure field*
  - *Air density is calculated based on this*
  - *Creates discrepancies in massflows*
- **Advanced 1-way coupling**
  - *Disengage air-side calculation in KULI*
    - Pressure, Temperature & Velocity fields from PowerFLOW
  - *KULI solves the coolant circuit only*
    - Provides Top Tank Temperature
  - *Leverage strengths of both KULI & PowerFLOW*
    - Utilize thermal calculation in PowerFLOW

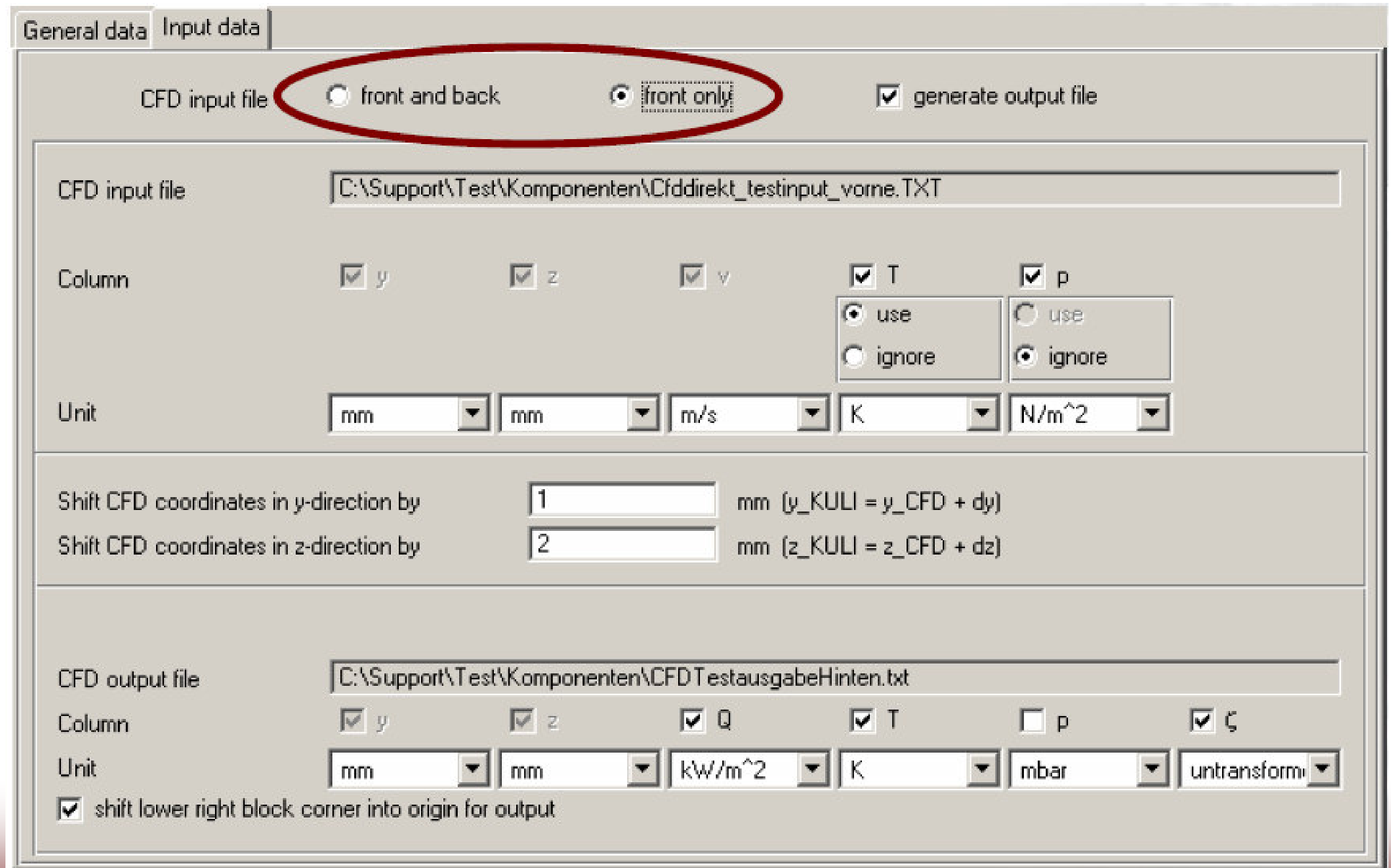
Advanced 1-way Coupling with KULI

- Perform Thermal simulation with PowerFLOW
- Provide V, T and P fields at front (and back) faces of each HX
- KULI 7.0 can NOW use Pressure data from CFD



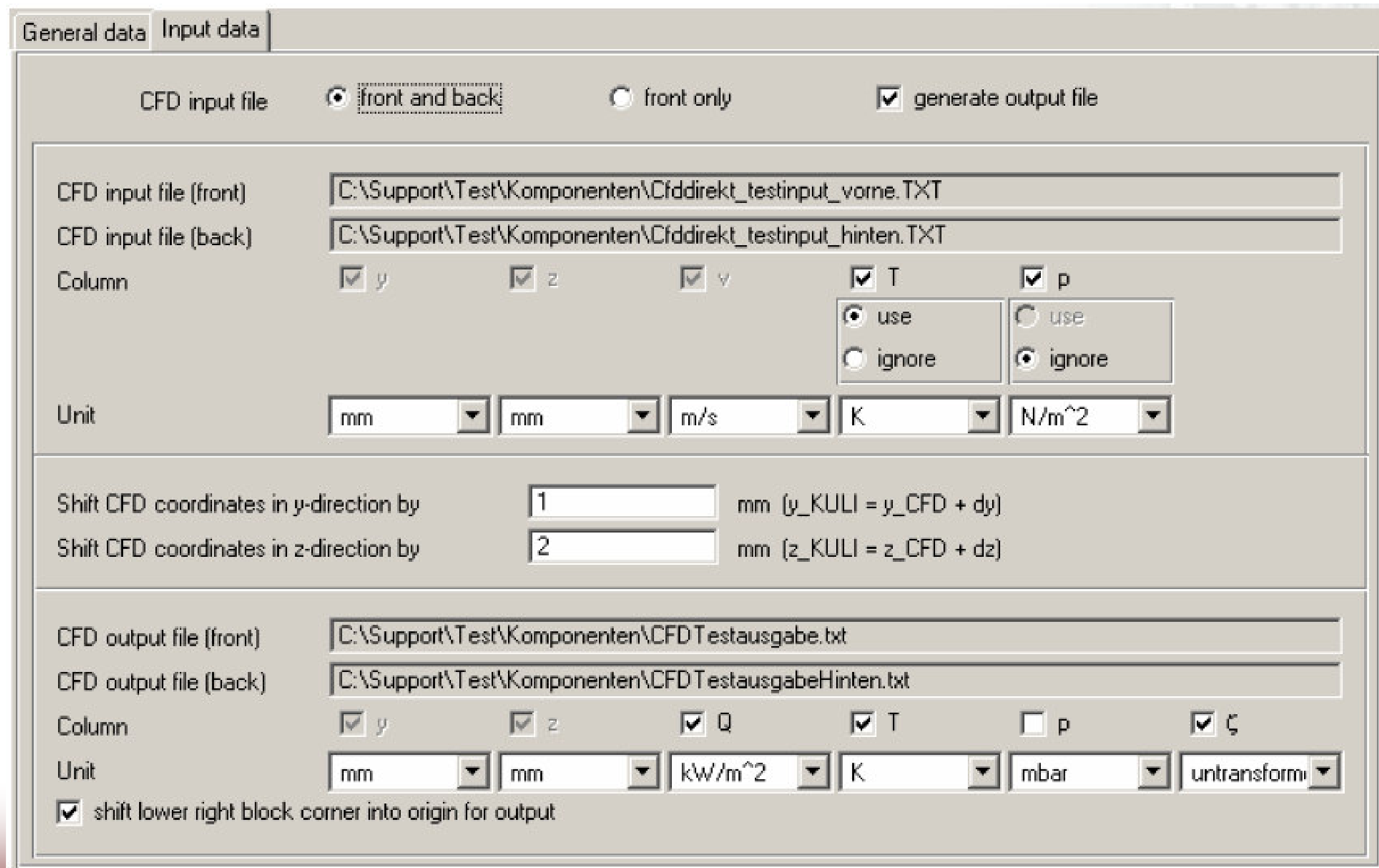
Data exchange with KULI

- **Without reverse flow, only front face data is needed**
  - *Output data is provided at the back face of HX*
- **KULI can NOW use Pressure data from CFD**
  - *Previous option was to read it in but "ignore" the data*



Data exchange with KULI

- **When input data for both front and back face of HX is provided:**
  - *If velocity is positive, entry values are taken from front side*
  - *If velocity is negative, entry values are taken from back side*



Exa CORPORATION

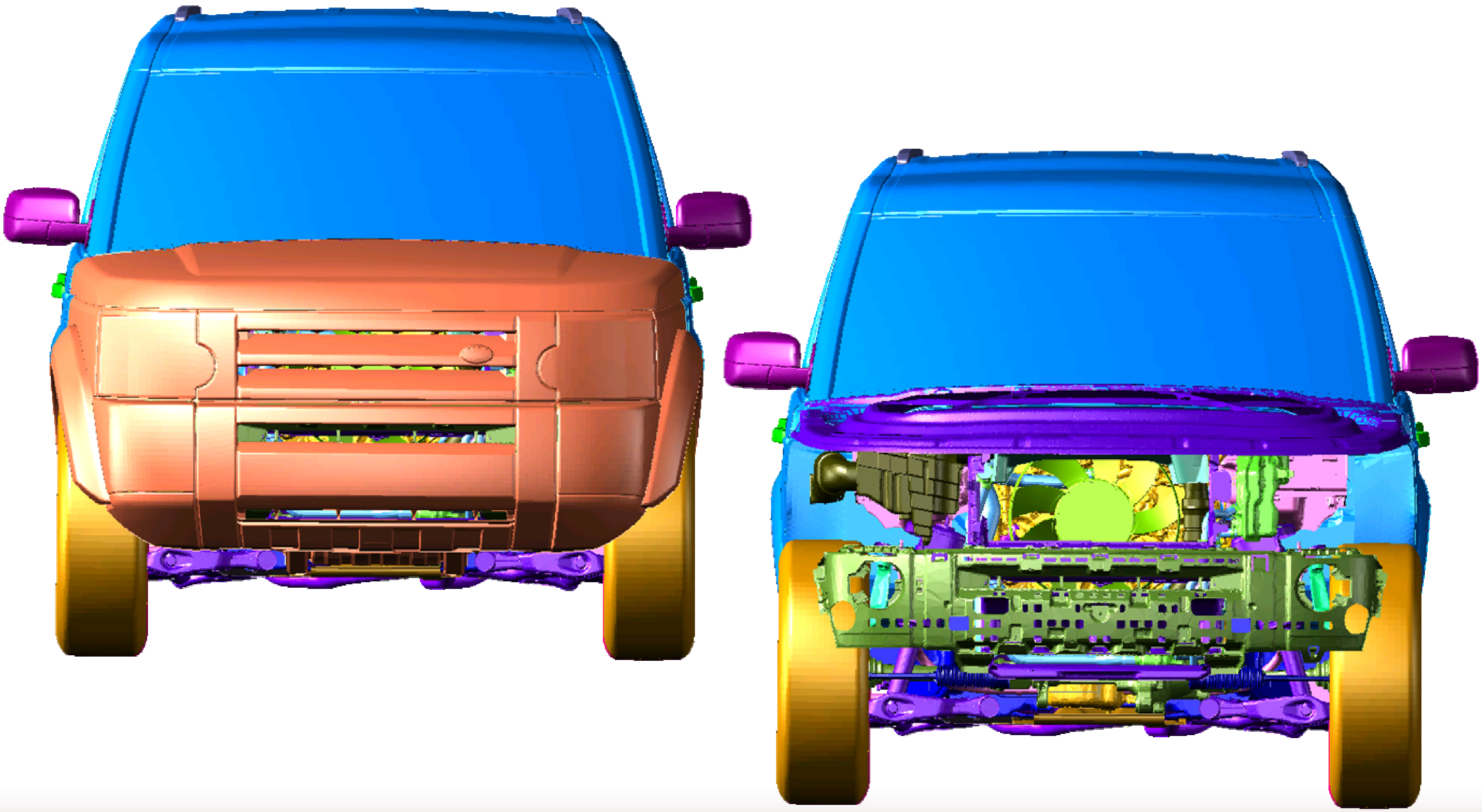
Format for CFD data to be imported

> **PowerFLOW distribution now contains a new script *gen_pm_plane_kuli* (based on exaritool), which**
  - *Reads in a specification file (pmspec.in)*
  - *Reads in a fluid file (*.mmh.nc)*
  - *Generates an ascii output with extension .txt*

> **Format of the output file to be imported into KULI:**

Y(m)	Z(m)	V(m/s)	T(K)	P(Pa)
0.620000E-02	0.400000E-02	0.607950E+01	0.296850E+03	0.1013237578E+06
0.620000E-02	0.120000E-01	0.608019E+01	0.296850E+03	0.1013238125E+06
0.620000E-02	0.200000E-01	0.607898E+01	0.296850E+03	0.1013238516E+06
0.620000E-02	0.280000E-01	0.607932E+01	0.296850E+03	0.1013238281E+06
0.620000E-02	0.360000E-01	0.608012E+01	0.296850E+03	0.1013239531E+06
0.620000E-02	0.440000E-01	0.608037E+01	0.296850E+03	0.1013238516E+06
0.620000E-02	0.520000E-01	0.608071E+01	0.296850E+03	0.1013239375E+06
0.620000E-02	0.600000E-01	0.608025E+01	0.296850E+03	0.1013239297E+06
0.620000E-02	0.680000E-01	0.607944E+01	0.296850E+03	0.1013238594E+06
0.620000E-02	0.760000E-01	0.607941E+01	0.296850E+03	0.1013238203E+06

Example: Land Rover – Geometry Details



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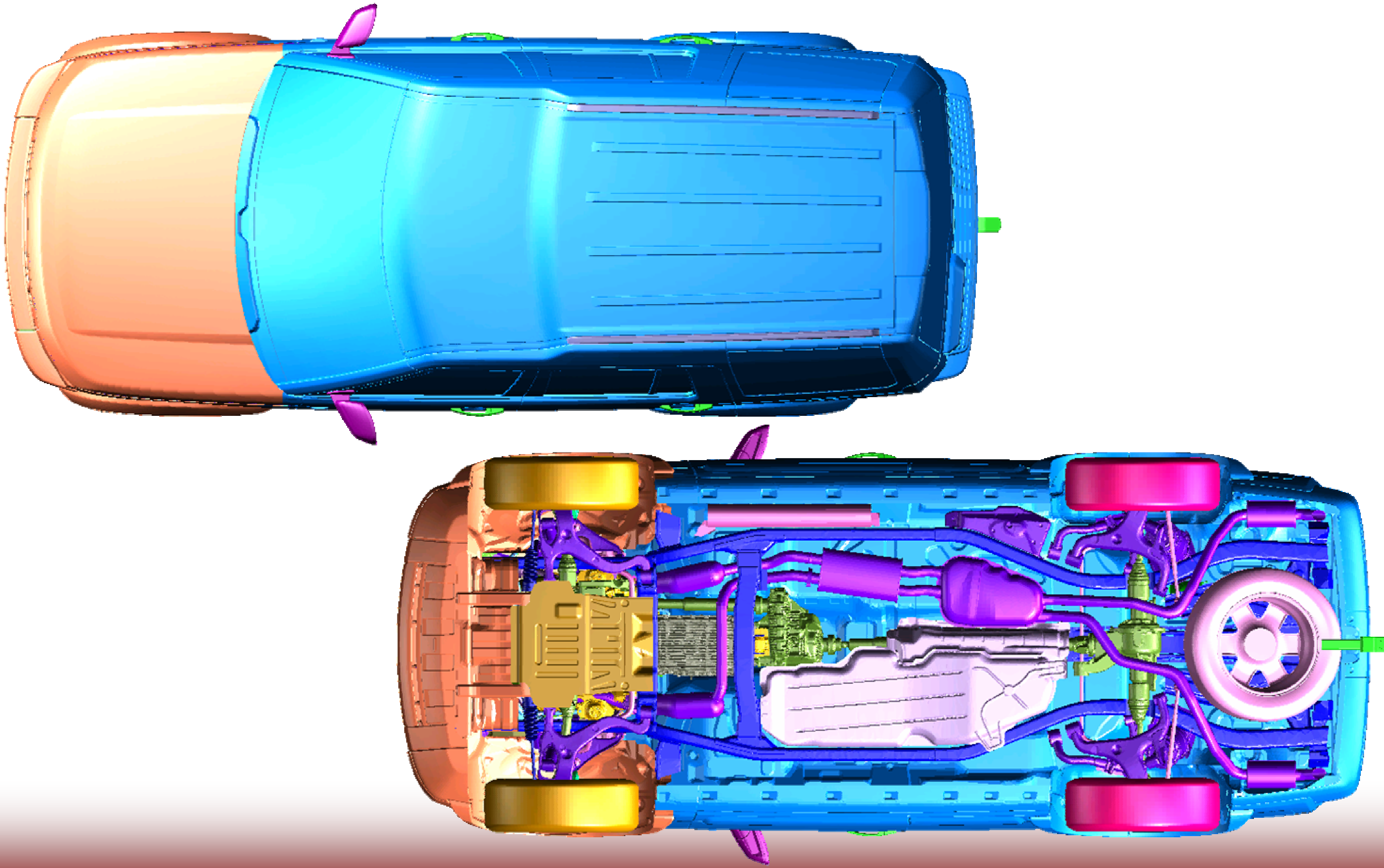

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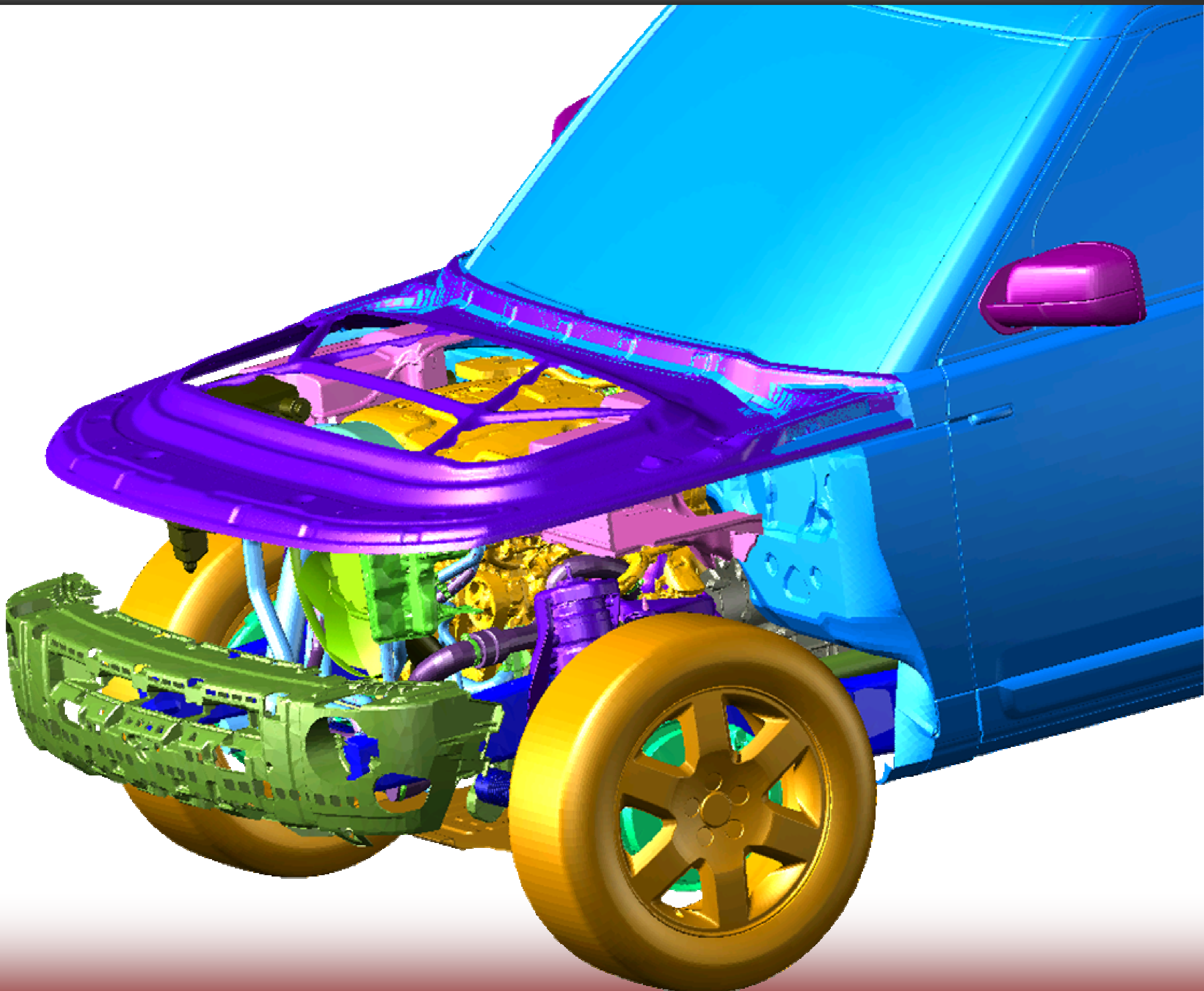

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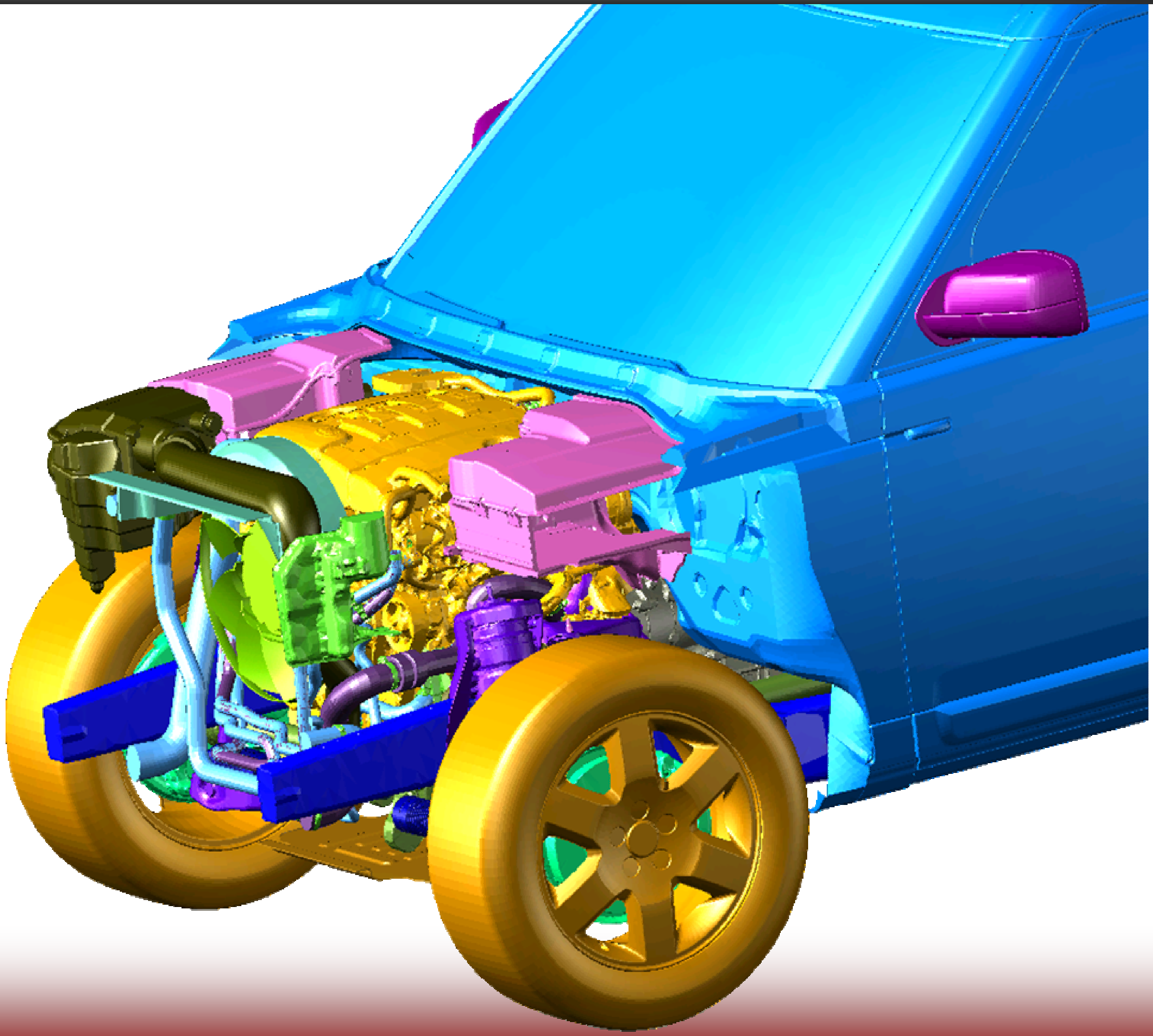

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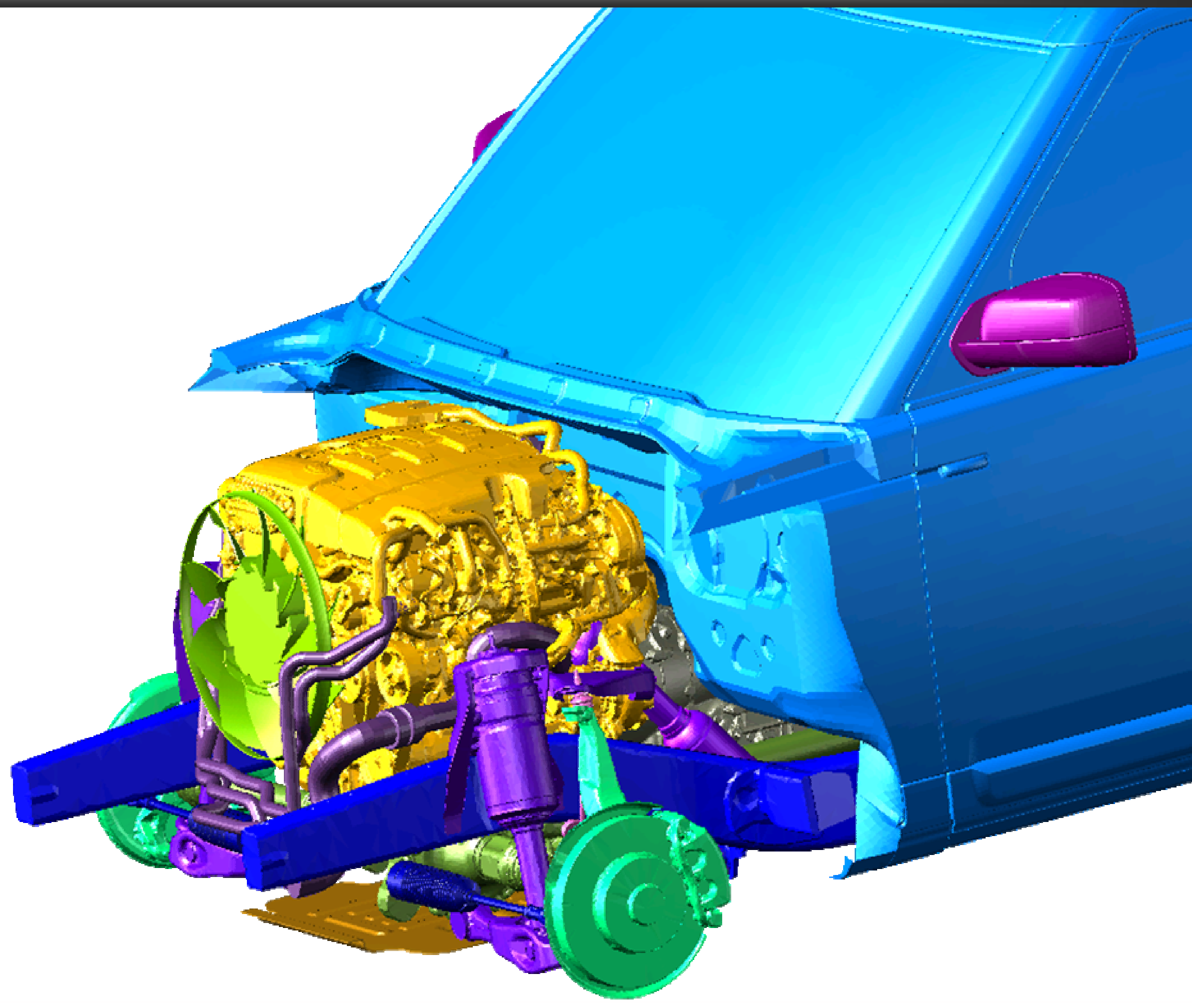
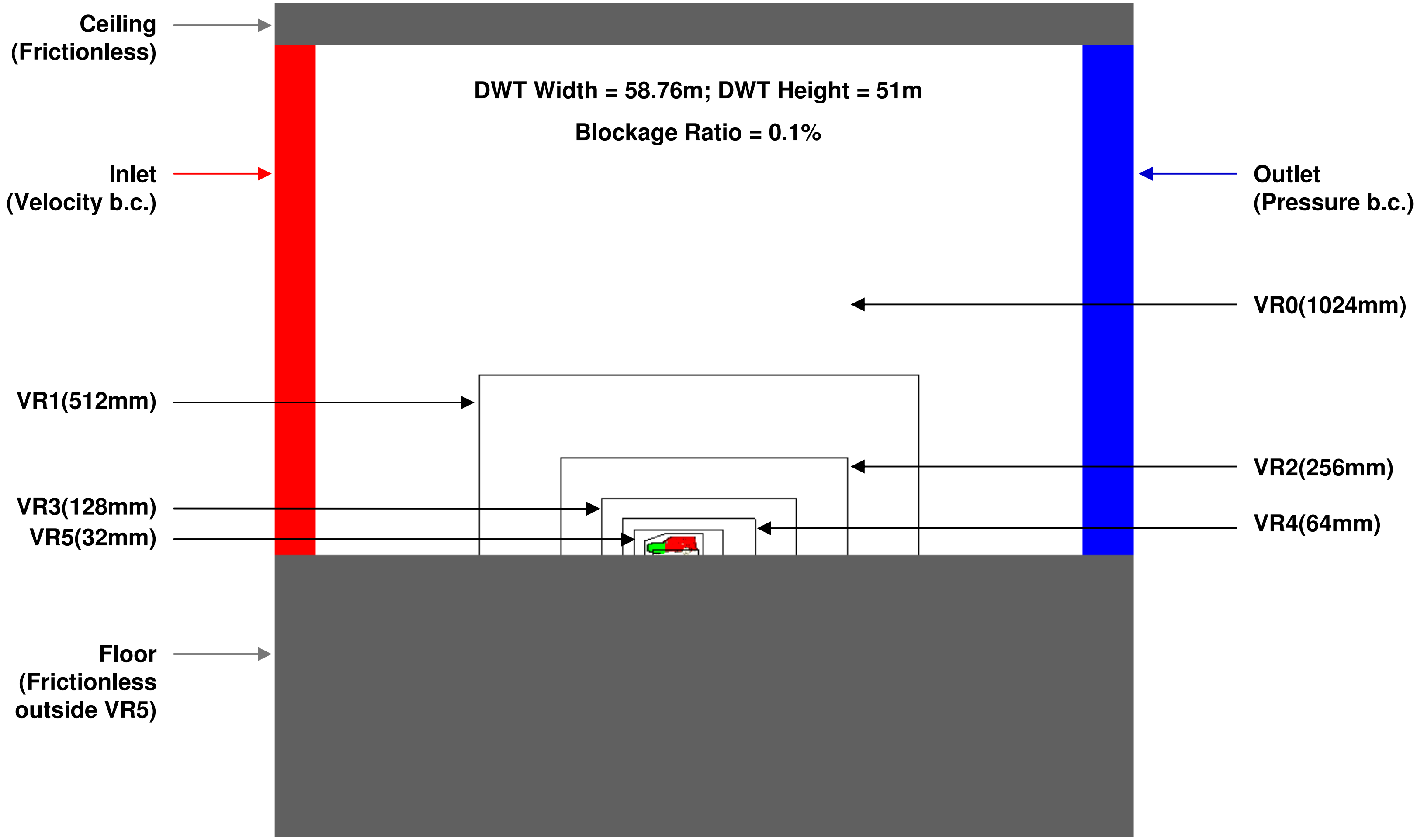


Example: Land Rover – PowerFLOW Setup



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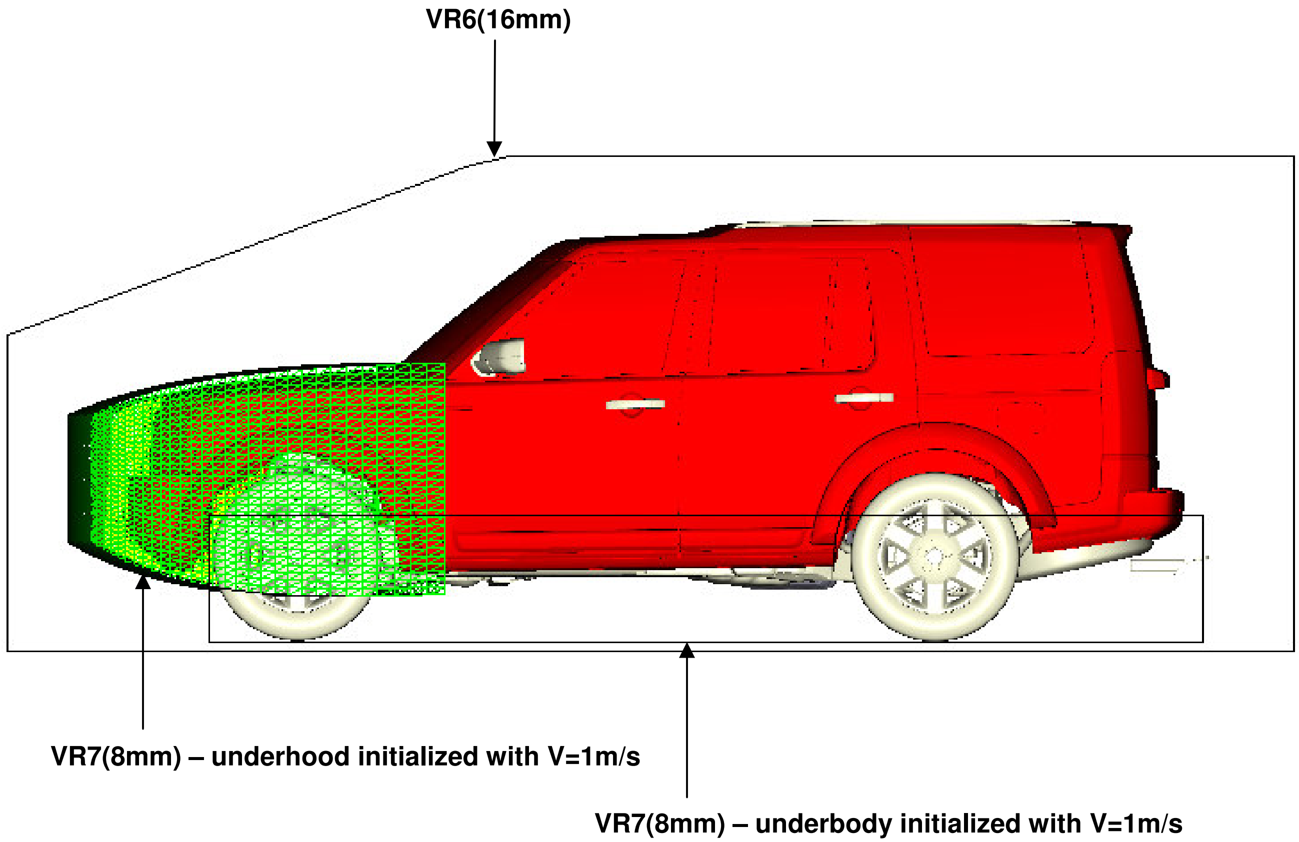

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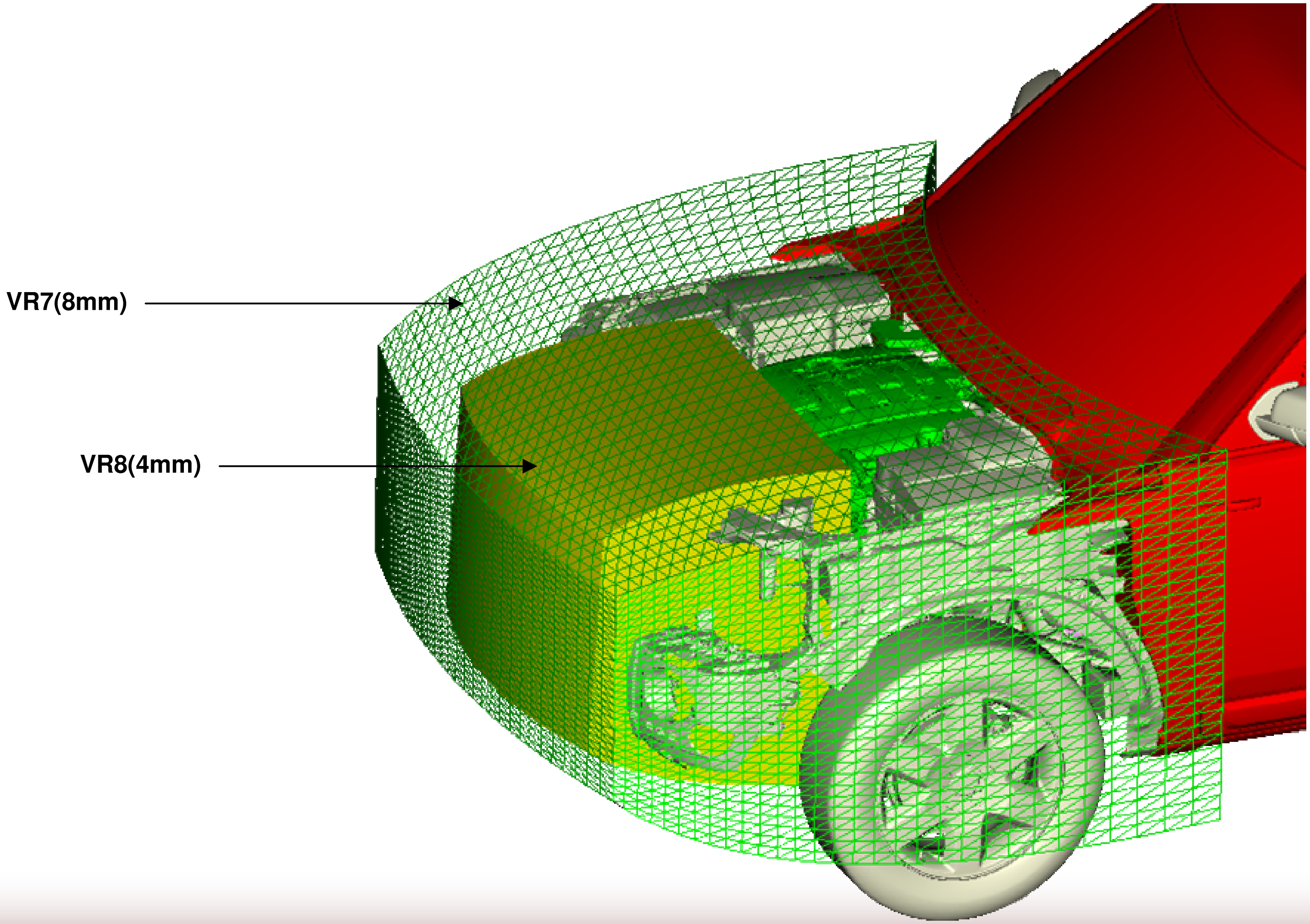
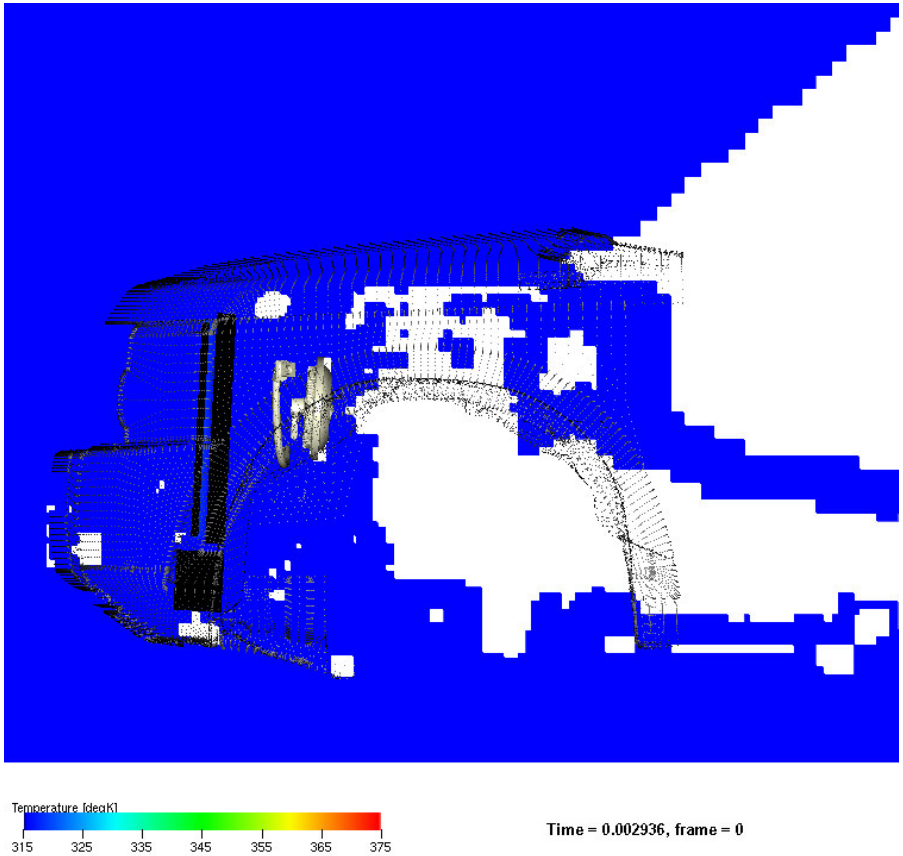
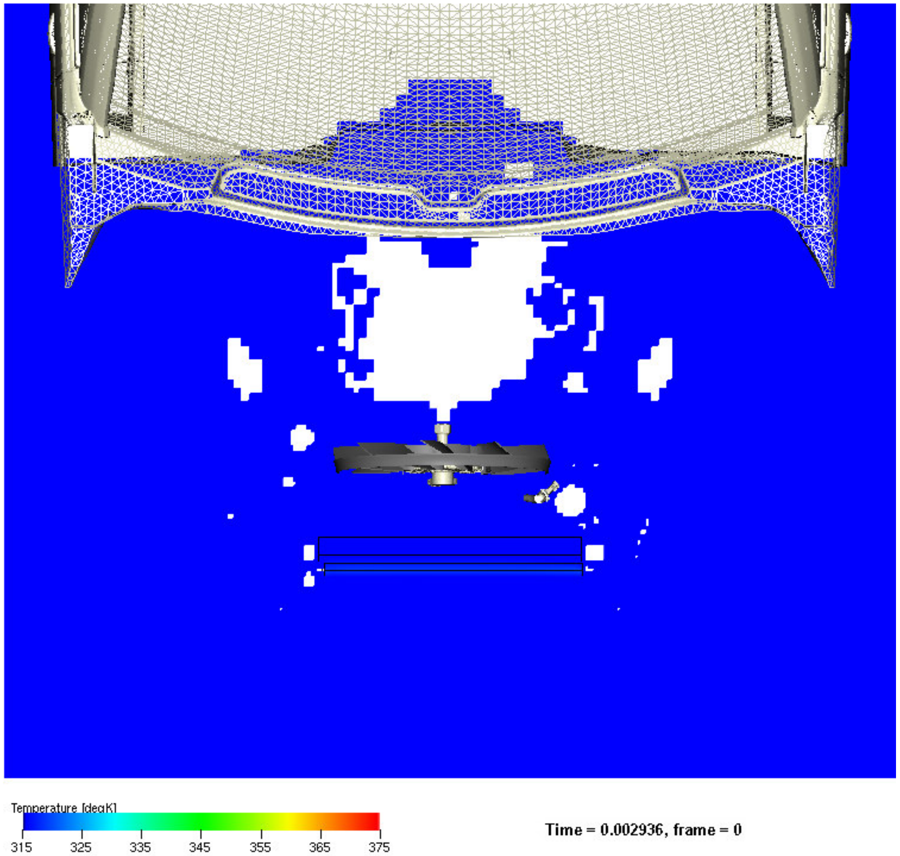


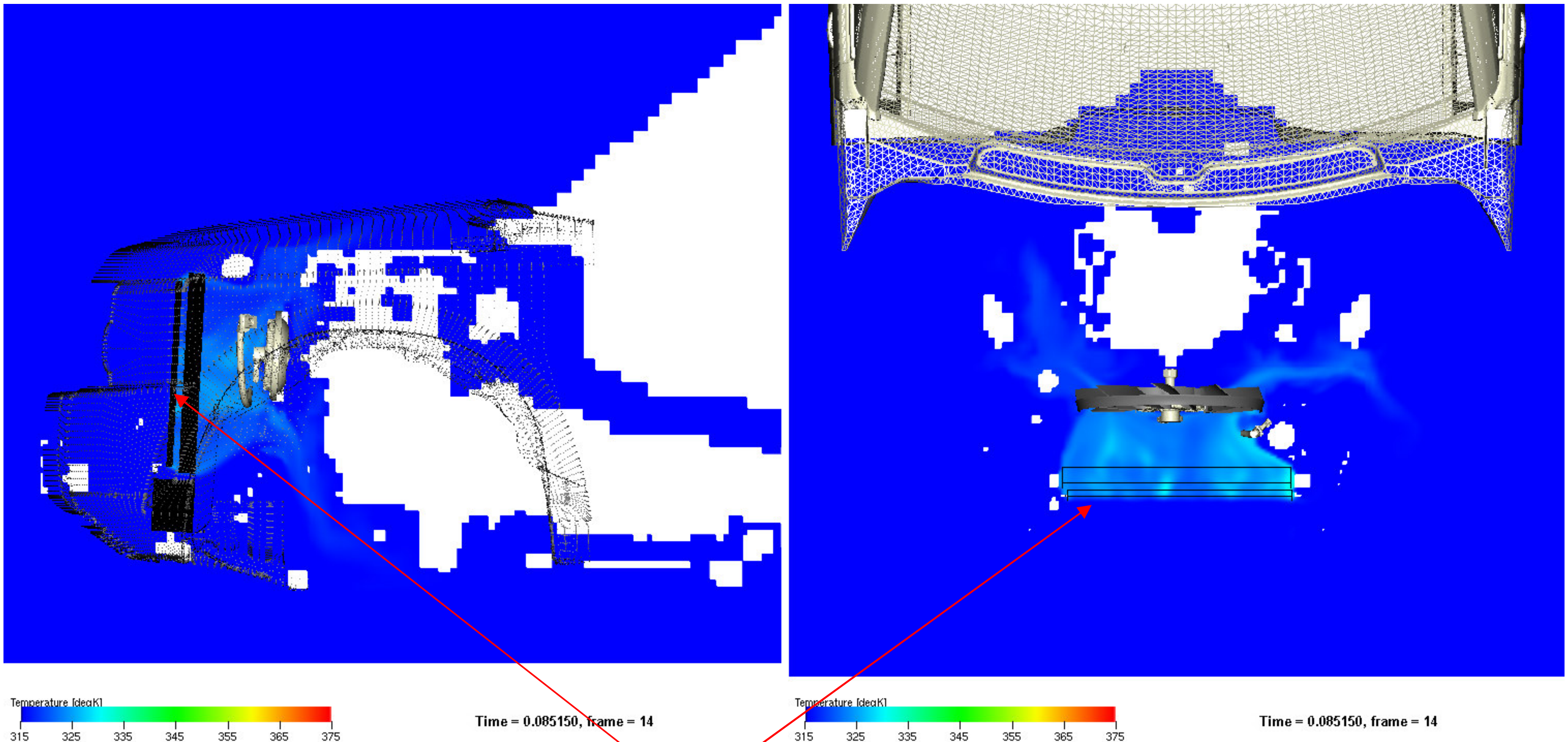
Example: Land Rover – Flow Results





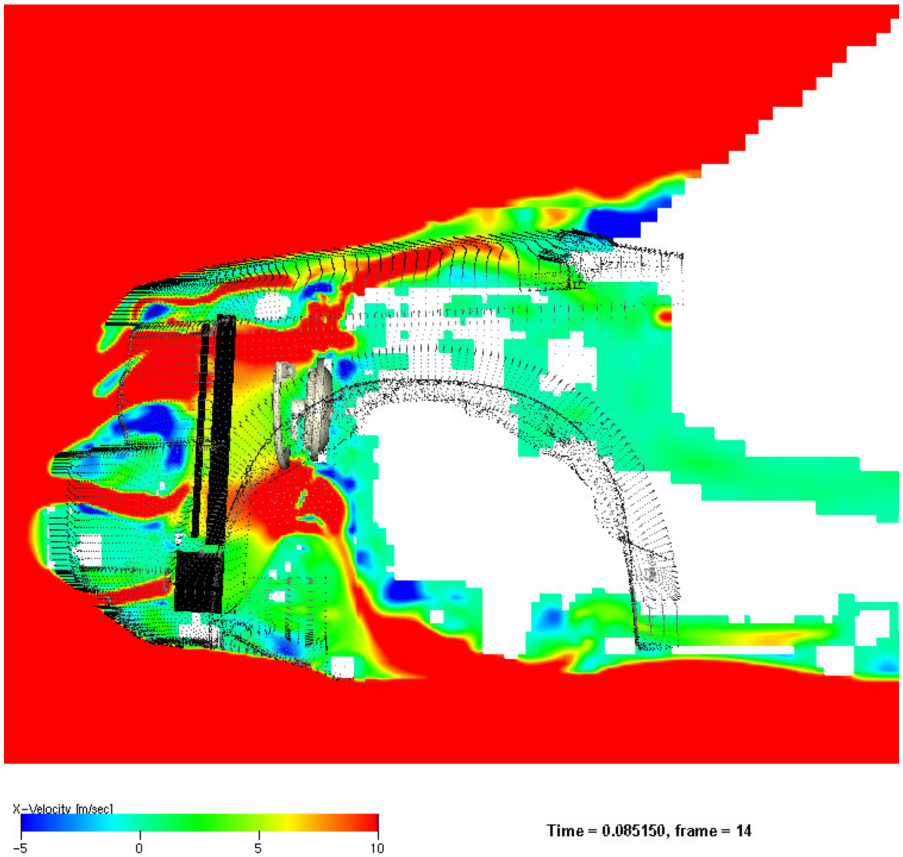
Flow was initialized with uniform temperature field (42.3C = 315.5K)

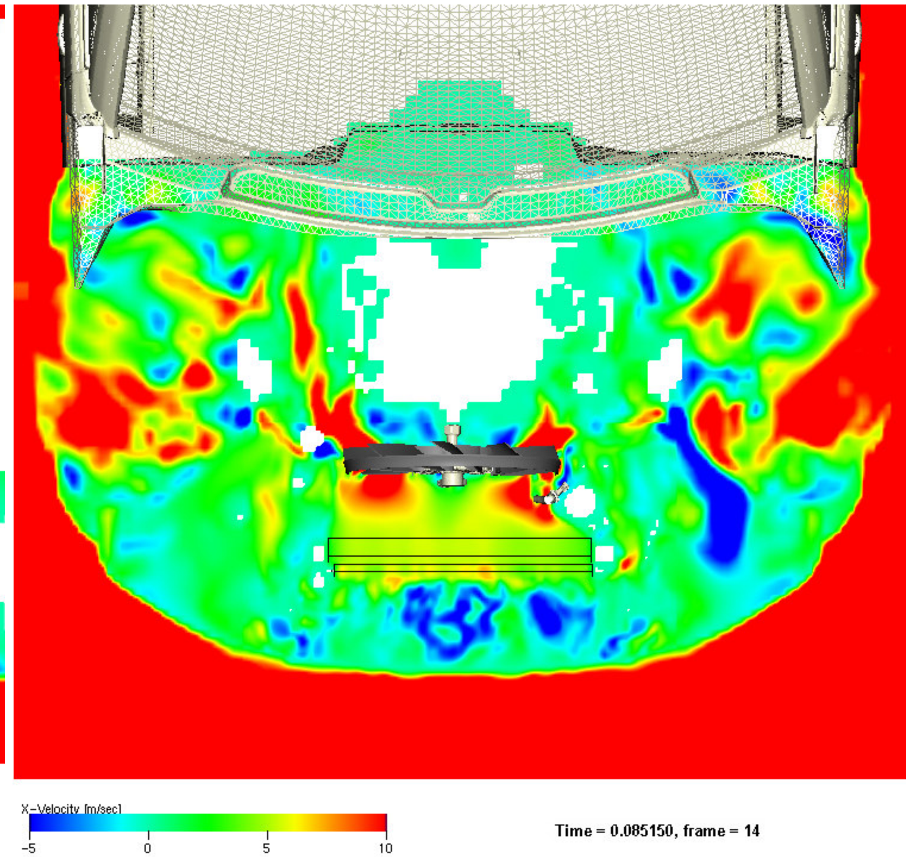
Example: Land Rover – Flow Results



Condenser produces uniform heating – heating up air entering the Radiator

Example: Land Rover – Flow Results

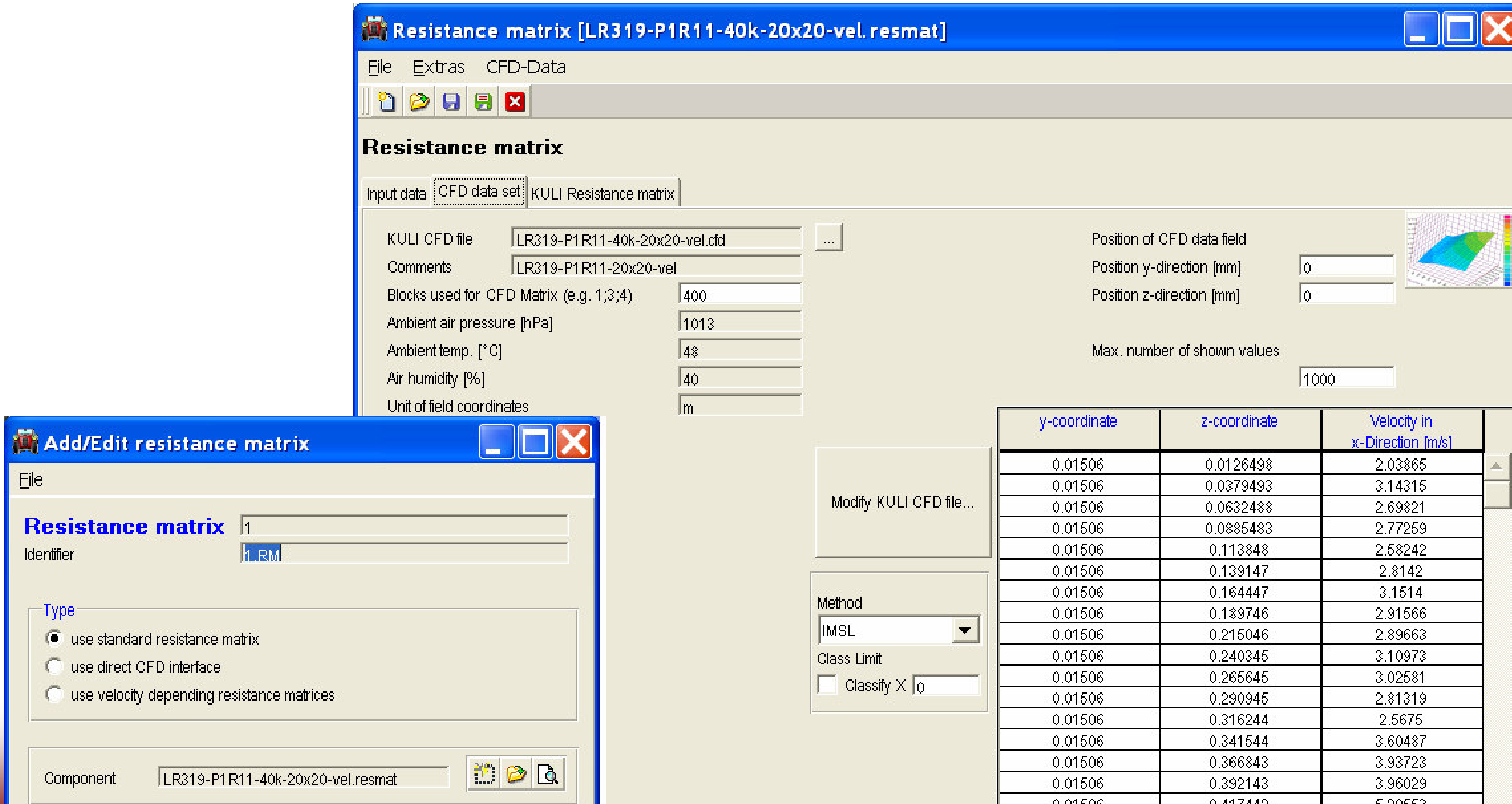




Velocity field on the Radiator face is fully established by 40,000 timesteps

Example: Land Rover – KULI Simulation

- **Simple 1-way coupling**
  - *Provided 20x20 Velocity field on Radiator face*
  - *Used Standard Resistance Matrix within KULI*



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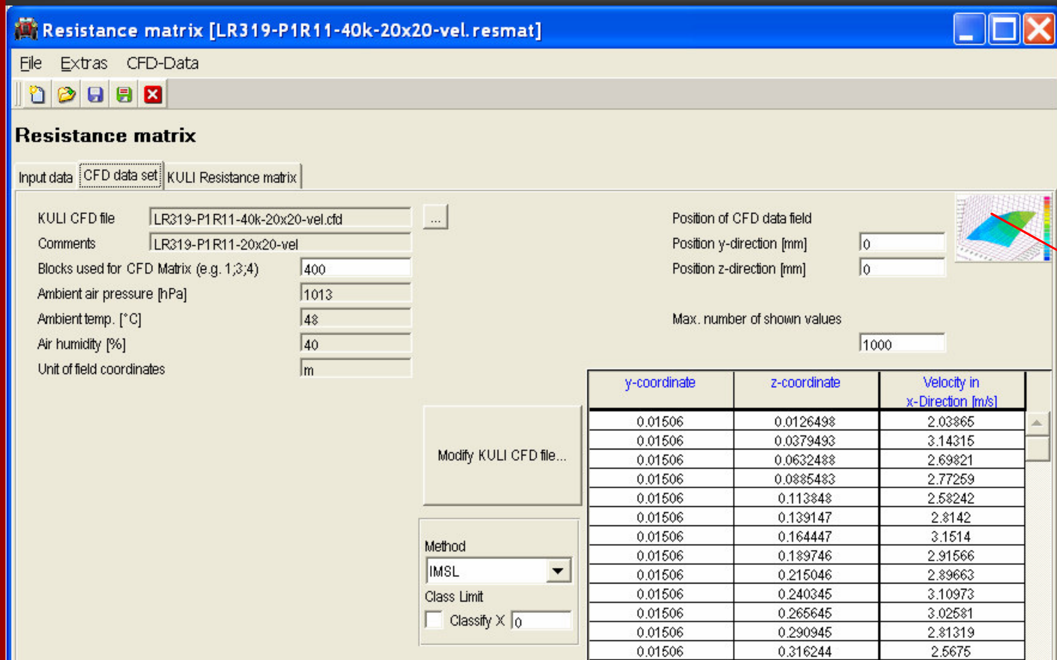
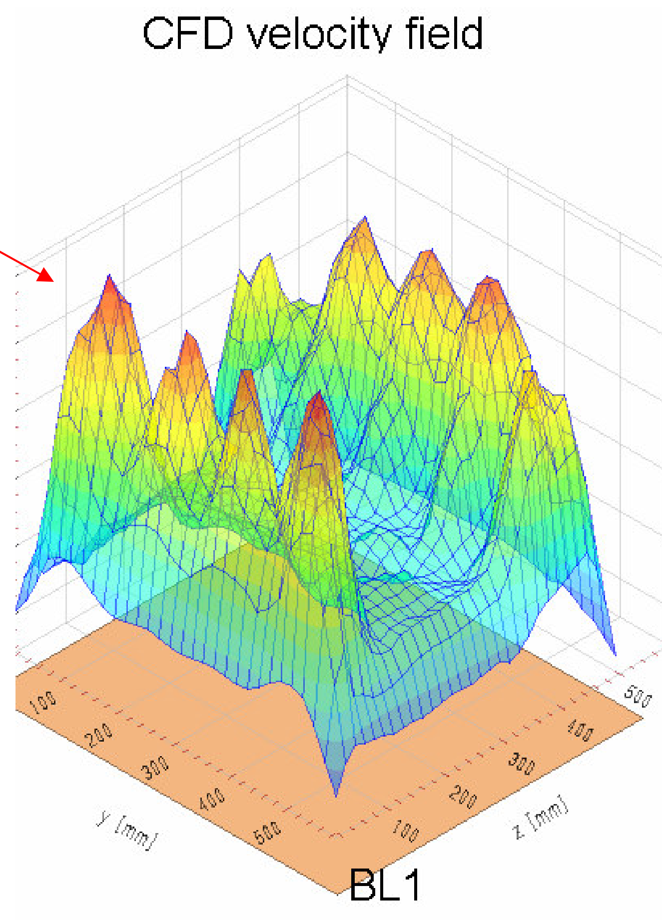
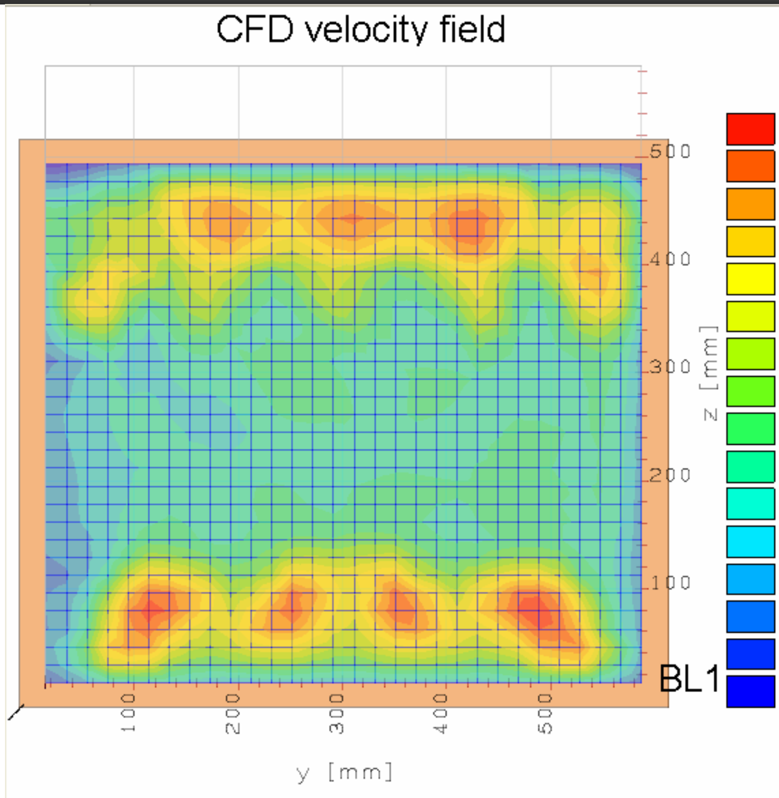
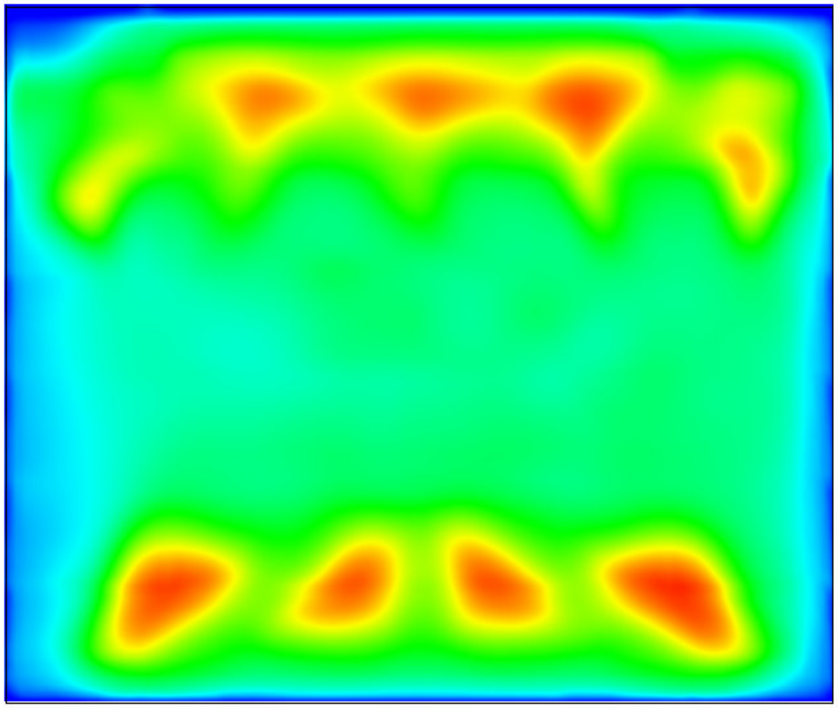




Example: Land Rover – KULI Simulation





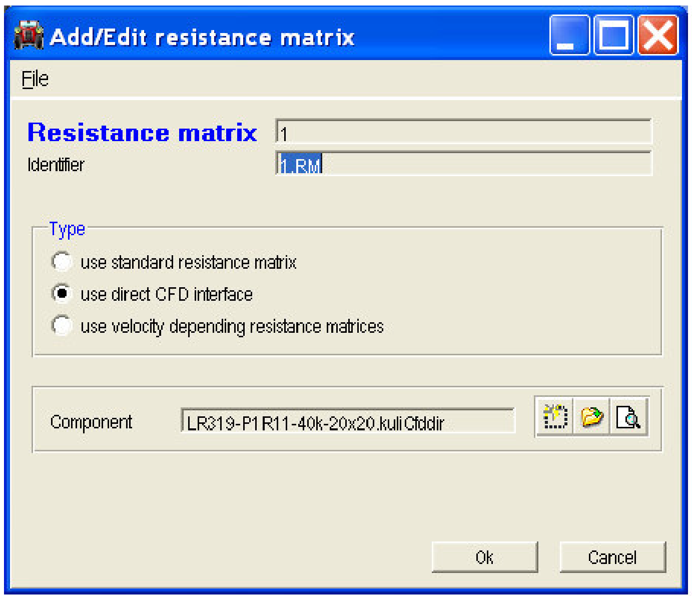
KULI – Velocity Map **(Driver's Point of View)** **PowerFLOW – Velocity Field**

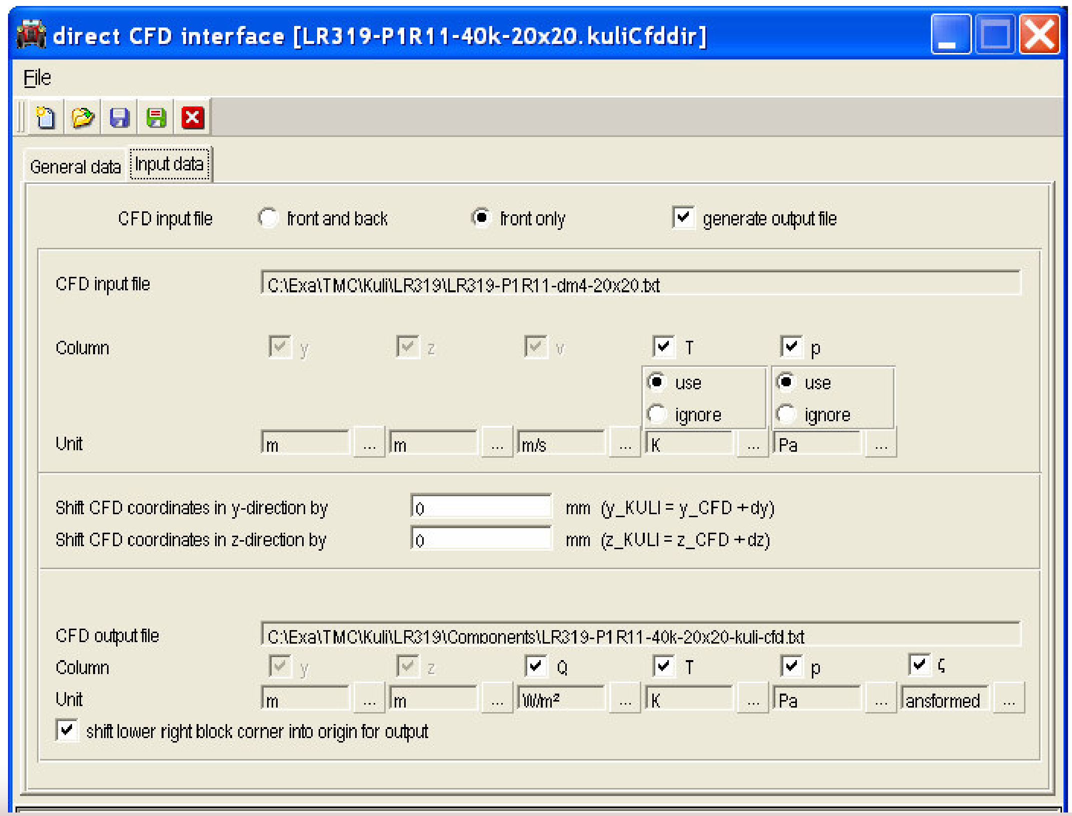
Mapping of Velocity field from PowerFLOW to KULI

Example: Land Rover – KULI Simulation

Advanced 1-way coupling

- *Provided 20x20 V,P,T fields on Radiator face*
- *Used Direct CFD interface*





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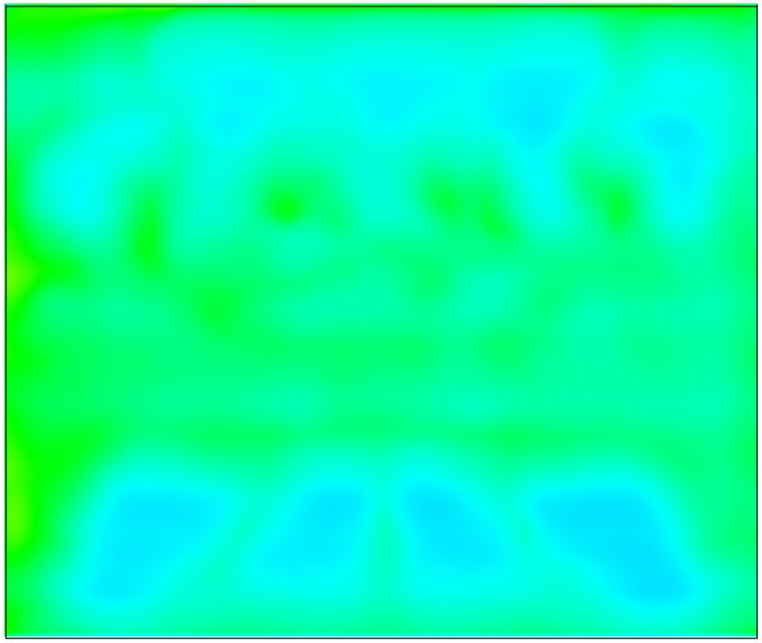
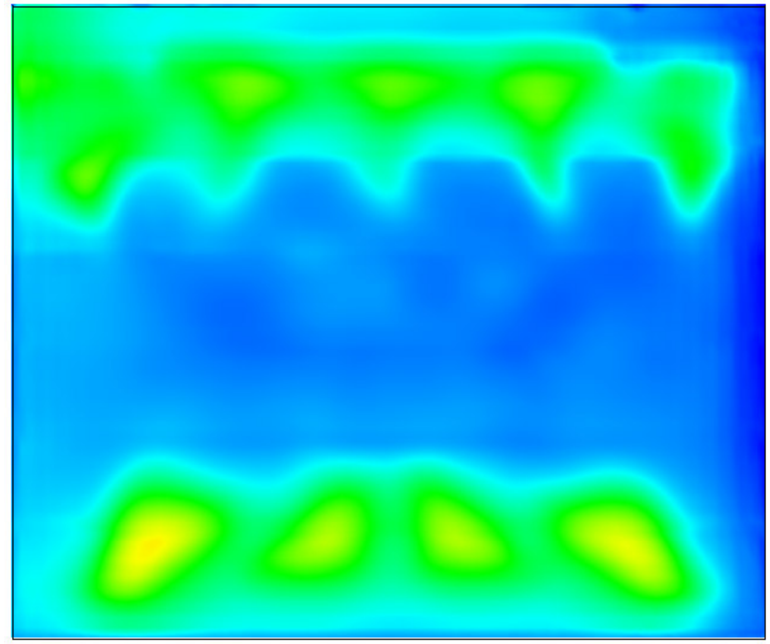
Example: Land Rover – KULI Simulation



PowerFLOW – Temperature Field



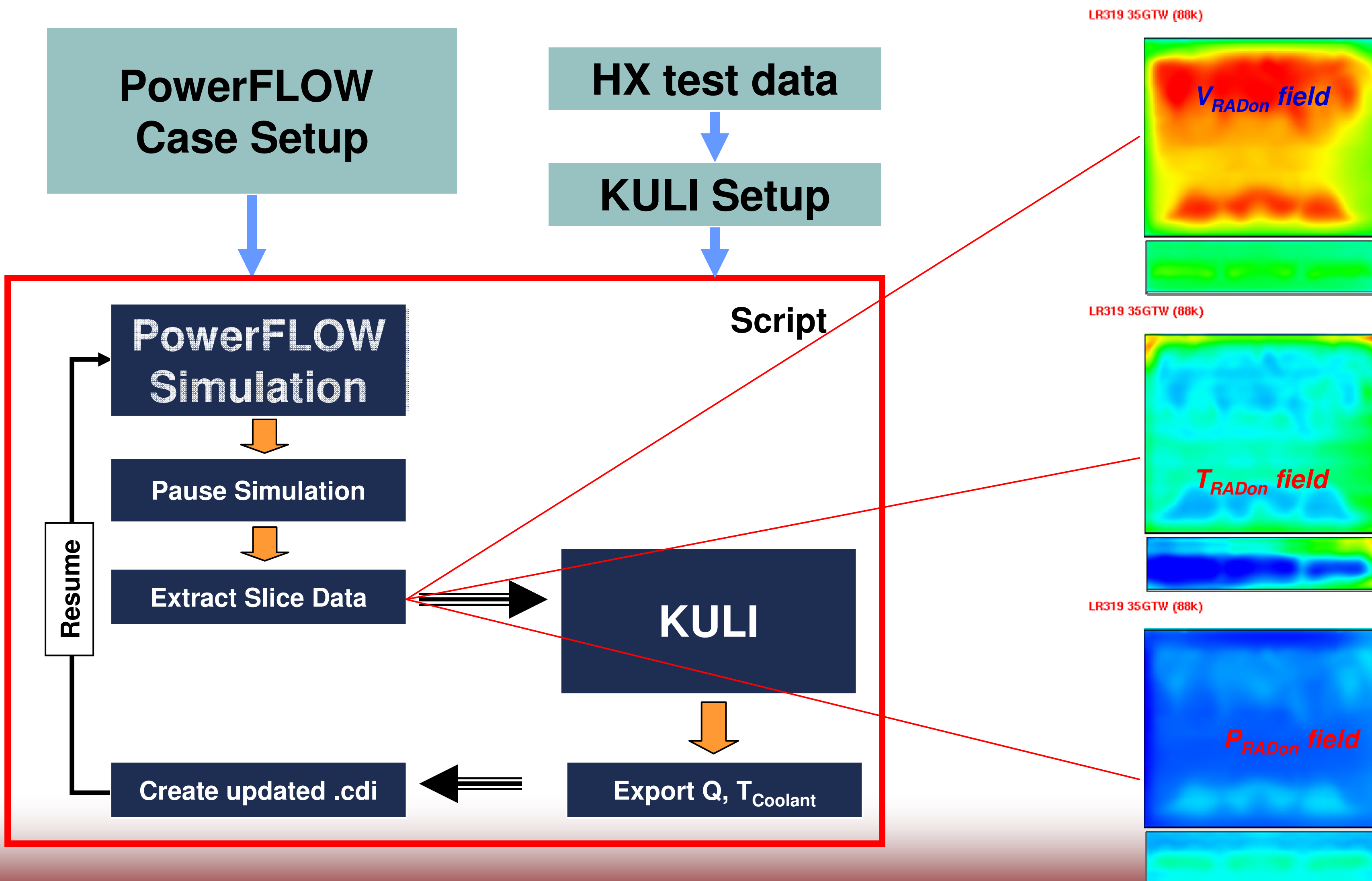
PowerFLOW – Static Pressure Field

Additional fields mapped from PowerFLOW to KULI

Example: Land Rover – KULI Results

KULI Output	Simple 1-way coupling (Standard Resistance Matrix)	Advanced 1-way coupling (Direct CFD interface)	Delta
Coolant Entry Temperature (TTT)			0.059 °C
Coolant Exit Temperature			0.059 °C
Air Massflow			0.049 kg/s
Cooling Air Massflux			0.16 kg/m^2/s
Air Entry Temperature			0.59 °C
Air Exit Temperature			-0.15 °C
Mean Volumetric Flow			-0.17 m^3/s
Mean Exit Speed			-0.55 m/s

Proposed 2-Way Coupling with KULI



Issues with 2-way coupling

- **Heat (Q) distribution can be output from KULI**
  - *Read into PowerFLOW*
  - *Prescribe local heat addition within HX*
  - *Need to develop the interface and methodology*
- **Platform dependence**
  - *KULI only runs under Windows*
  - *PowerFLOW (SIM) runs under UNIX/Linux*
- **Data exchange process**
  - *Requires sharing filesystem across mixed OS*
  - *Current process: manual sharing of data*
- **Coupling process control**
  - *Allow job control commands to work across OS*
    - UNIX/Linux to Windows
      - PowerFLOW sends signal to KULI
    - Windows to UNIX/Linux
      - KULI sends signal to PowerFLOW

Summary

- **Simple 1-way coupling**
  - *Already in use by PowerFLOW client(s)*
- **Advanced 1-way coupling now available**
  - *Script distributed with PowerFLOW*
  - *KULI now uses Pressure data from PowerFLOW*
  - *Complete integration of CFD data (P,V,T)*
- **2-way coupling with KULI**
  - *Poses some technical challenges*
  - *Need to provide heat (Q) from KULI to PowerFLOW*