

# 2006 KULI User Meeting

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

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# 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**

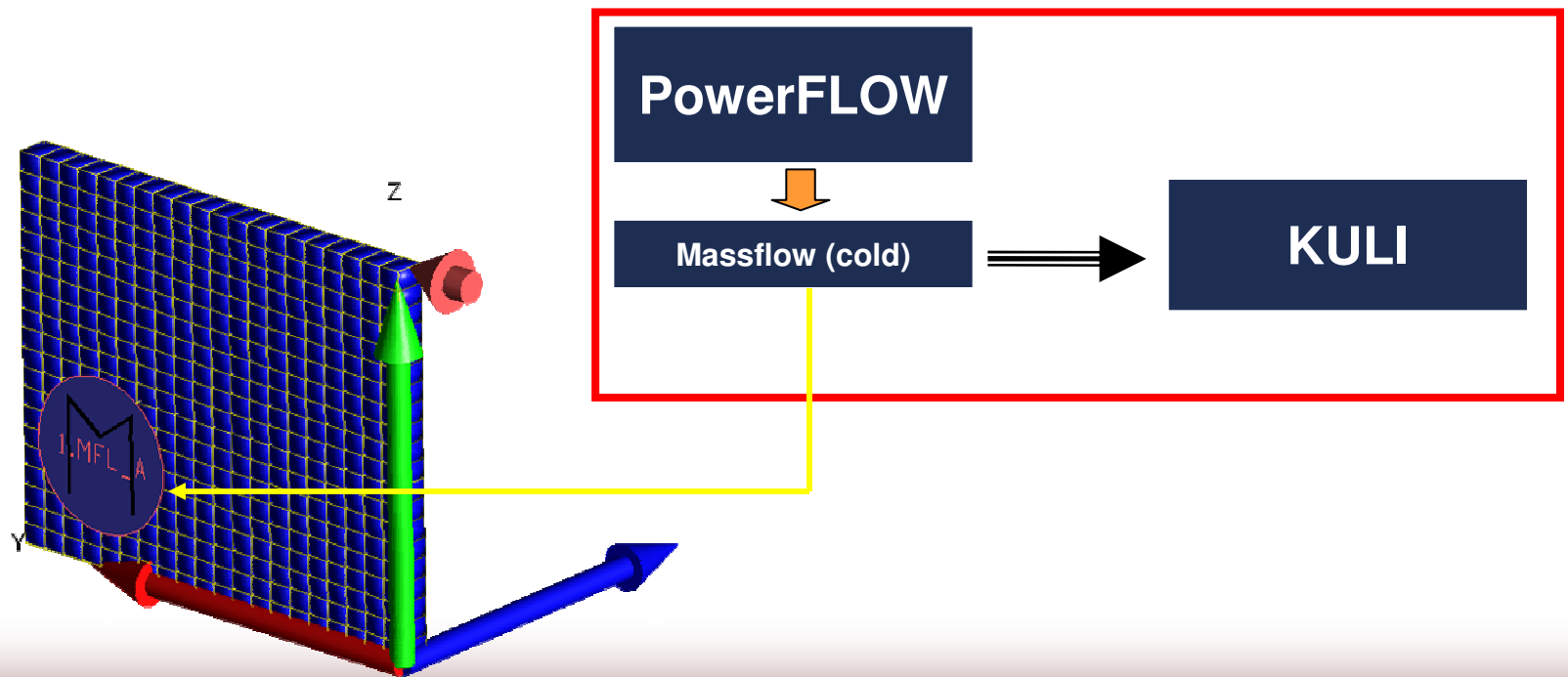
# Coupling with KULI

## > 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

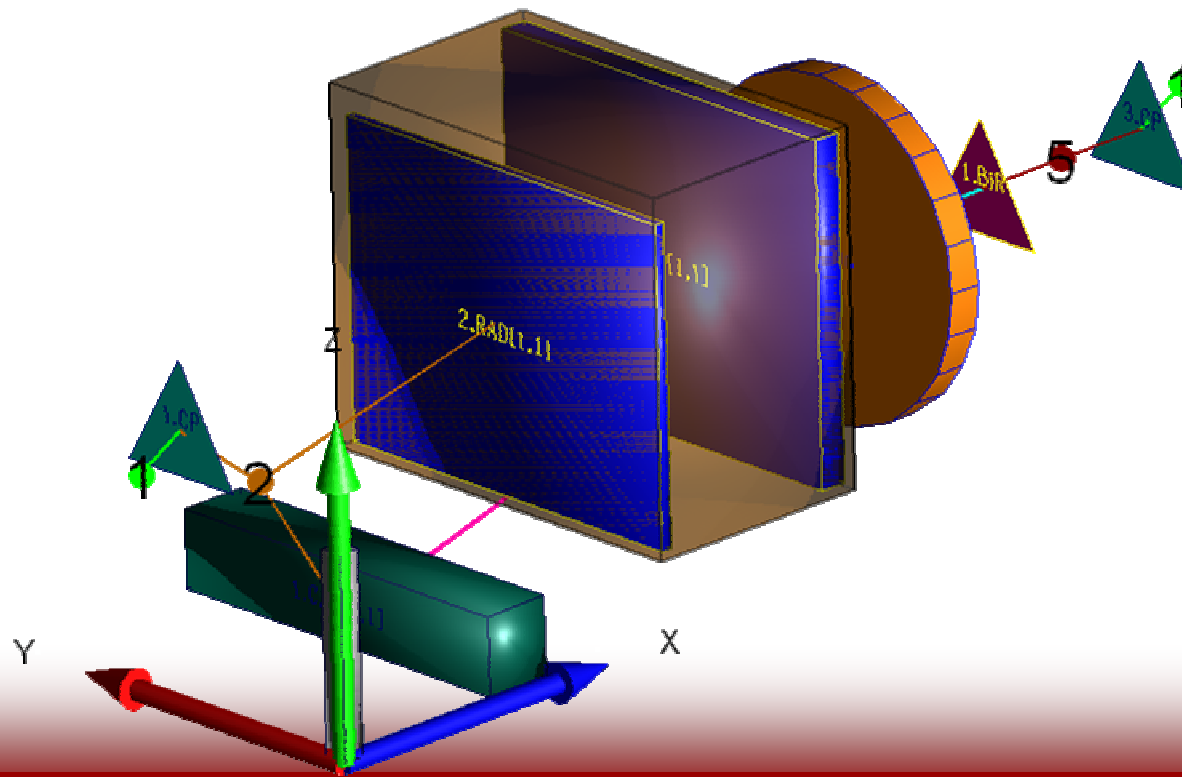
# Simple 1-way Coupling with KULI

- > 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*

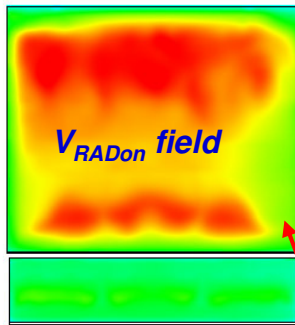
## > Advanced 1-way coupling

- *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*

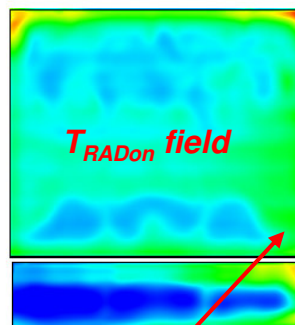
# Advanced 1-way Coupling with KULI

- > 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

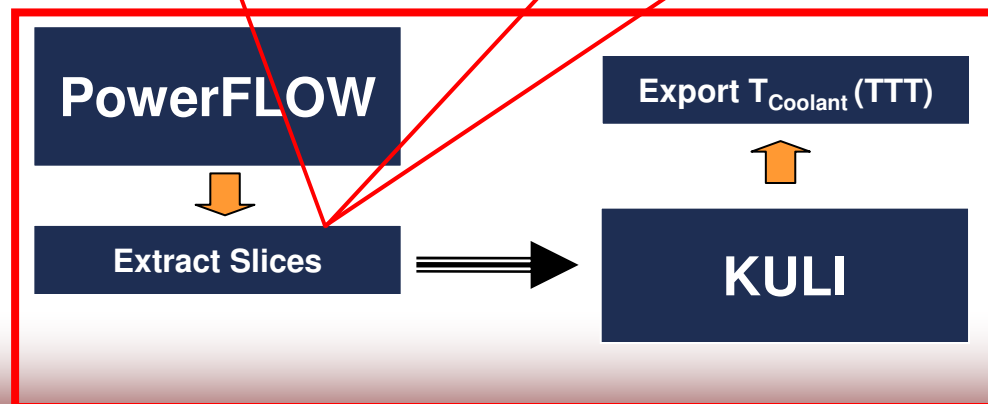
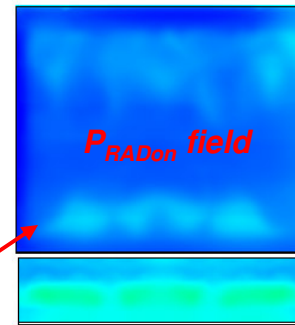
LR319 35GTW (88k)



LR319 35GTW (88k)



LR319 35GTW (88k)



# 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

General data Input data

CFD input file ☐ front and back ☒ front only ☒ generate output file

CFD input file C:\Support\Test\Komponenten\Cfddirekt\_testinput\_vorne.TXT

Column ☒ y ☒ z ☒ v ☒ T ☒ p  
☒ use ☐ ignore ☐ use ☒ ignore

Unit mm mm m/s K N/m^2

Shift CFD coordinates in y-direction by 1 mm ( $y_{KULI} = y_{CFD} + dy$ )  
Shift CFD coordinates in z-direction by 2 mm ( $z_{KULI} = z_{CFD} + dz$ )

CFD output file C:\Support\Test\Komponenten\CFDTestausgabeHinter.txt

Column ☒ y ☒ z ☒ Q ☒ T ☐ p ☒ ζ  
☒ use ☐ ignore ☐ use ☒ ignore

Unit mm mm kW/m^2 K mbar untransform

☒ shift lower right block corner into origin for output



# 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

General data | Input data

CFD input file ☒ front and back ☐ front only ☒ generate output file

CFD input file (front) C:\Support\Test\Komponenten\Cfddirekt\_testinput\_vorne.TXT

CFD input file (back) C:\Support\Test\Komponenten\Cfddirekt\_testinput\_hinten.TXT

Column ☒ y ☒ z ☒ v ☒ T ☒ p

☒ use ☐ ignore ☐ use ☒ ignore

Unit mm mm m/s K N/m<sup>2</sup>

Shift CFD coordinates in y-direction by 1 mm ( $y_{KULI} = y_{CFD} + dy$ )

Shift CFD coordinates in z-direction by 2 mm ( $z_{KULI} = z_{CFD} + dz$ )

CFD output file (front) C:\Support\Test\Komponenten\CFDTestausgabe.txt

CFD output file (back) C:\Support\Test\Komponenten\CFDTestausgabeHinten.txt

Column ☒ y ☒ z ☒ Q ☒ T ☐ p ☒  $\zeta$

Unit mm mm kW/m<sup>2</sup> K mbar untransform

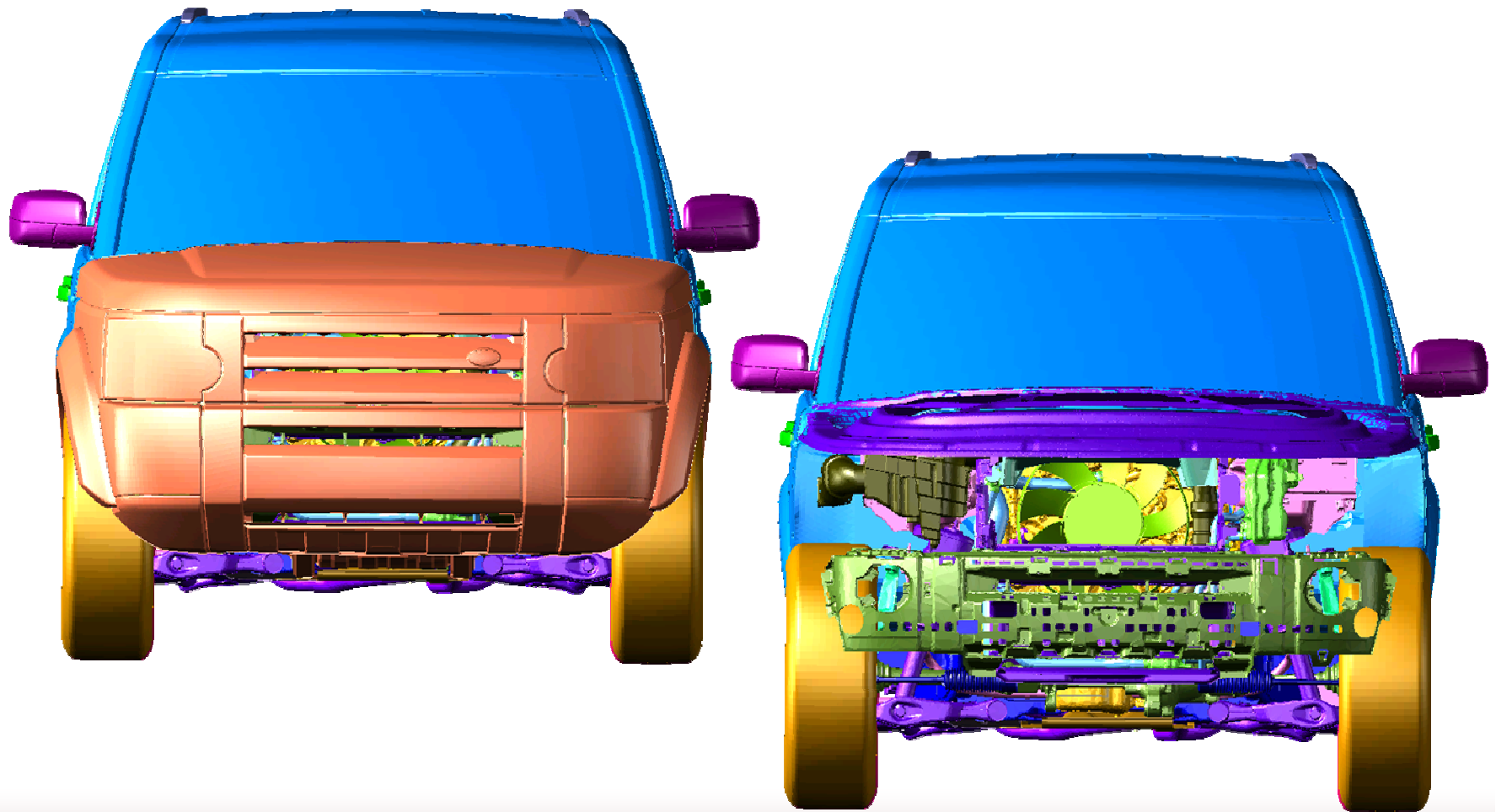
☒ shift lower right block corner into origin for output

# Format for CFD data to be imported

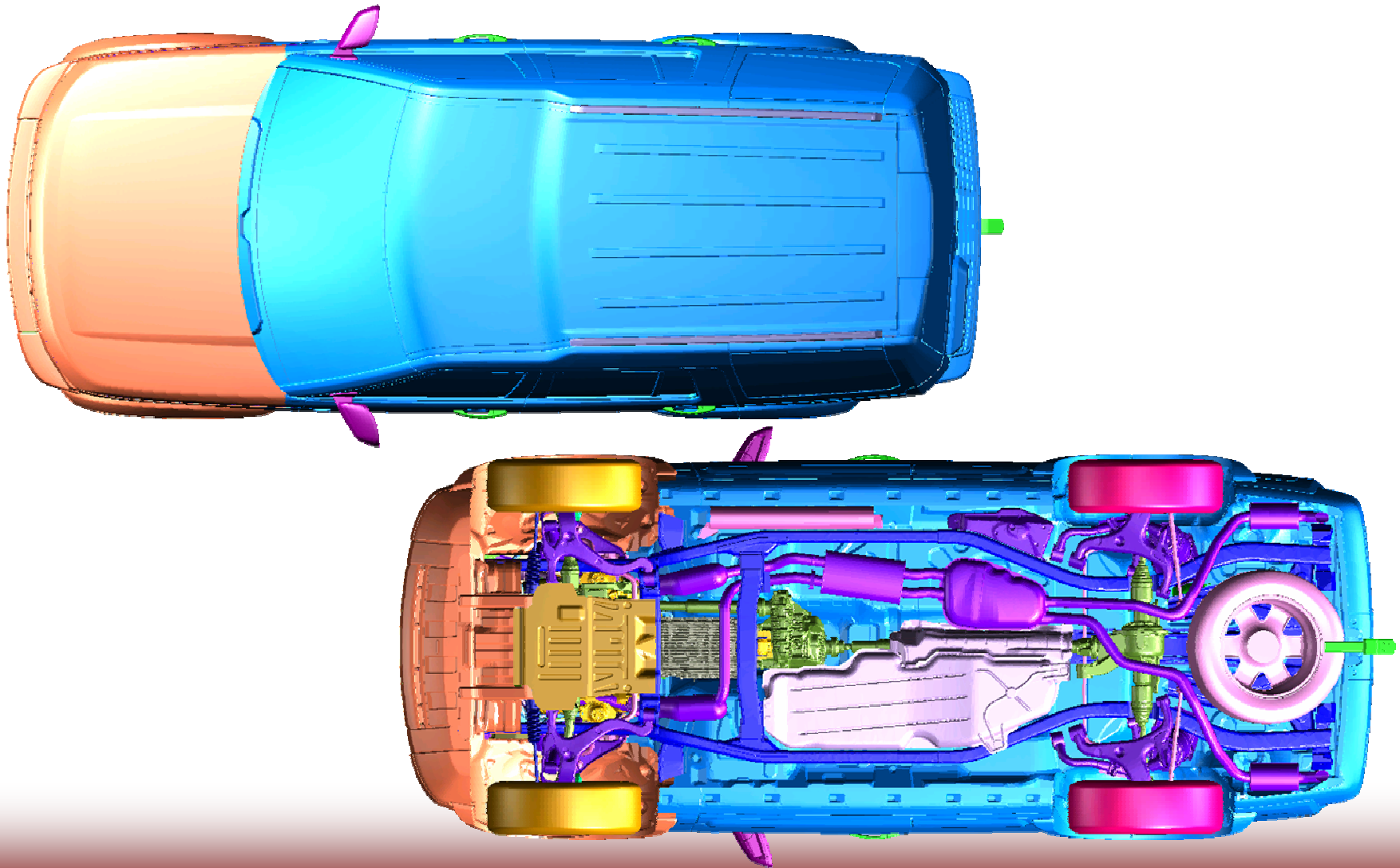
- > PowerFLOW distribution now contains a new script ***gen\_pm\_plane\_kuli*** (based on exaritool), which
  - Reads in a specification file (*pmspec.in*)
  - Reads in a fluid file (*\*.mmh.nc*)
  - Generates an ascii output with extension *.txt*
- > Format of the output file to be imported into KULI:

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

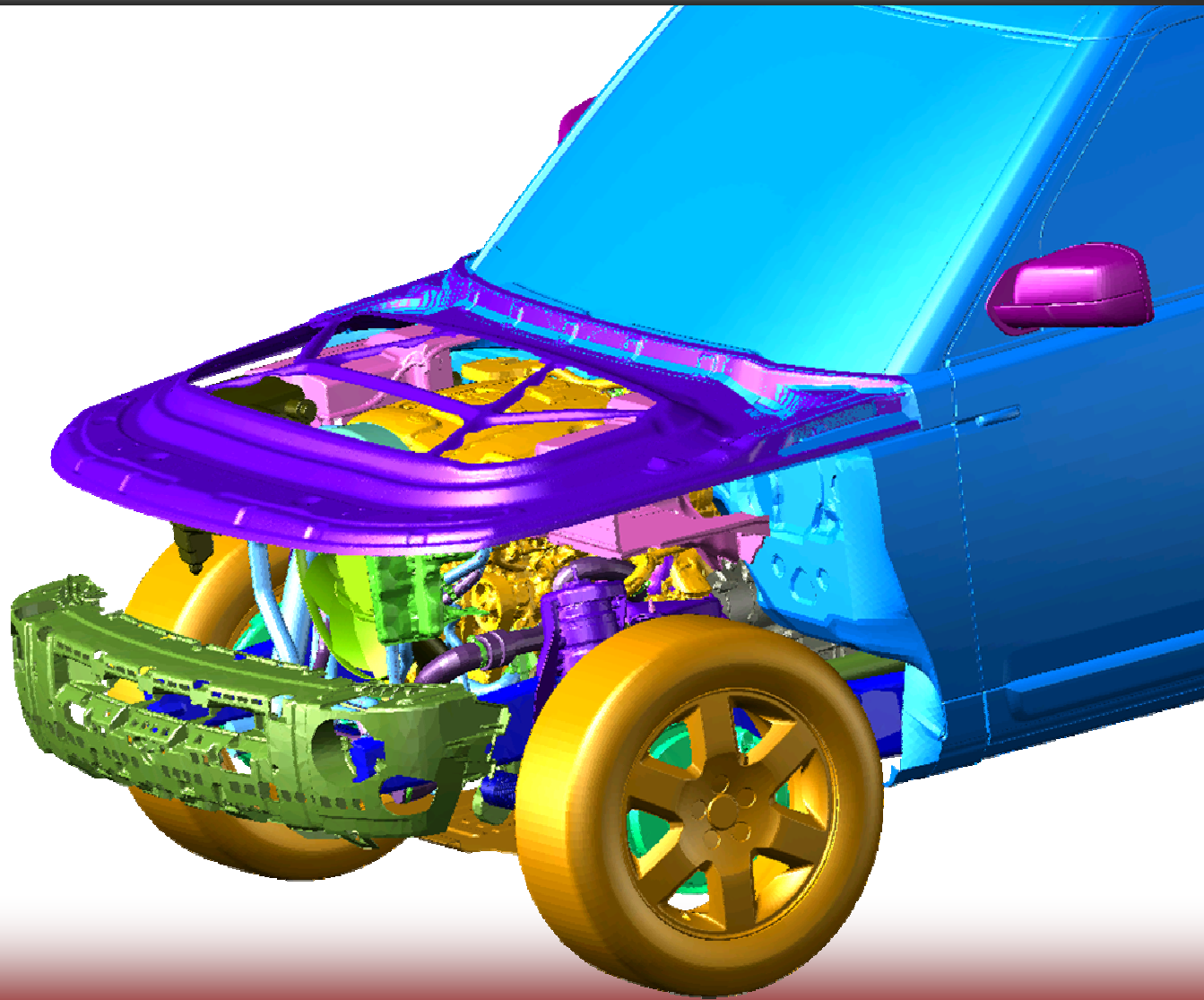
# Example: Land Rover – Geometry Details



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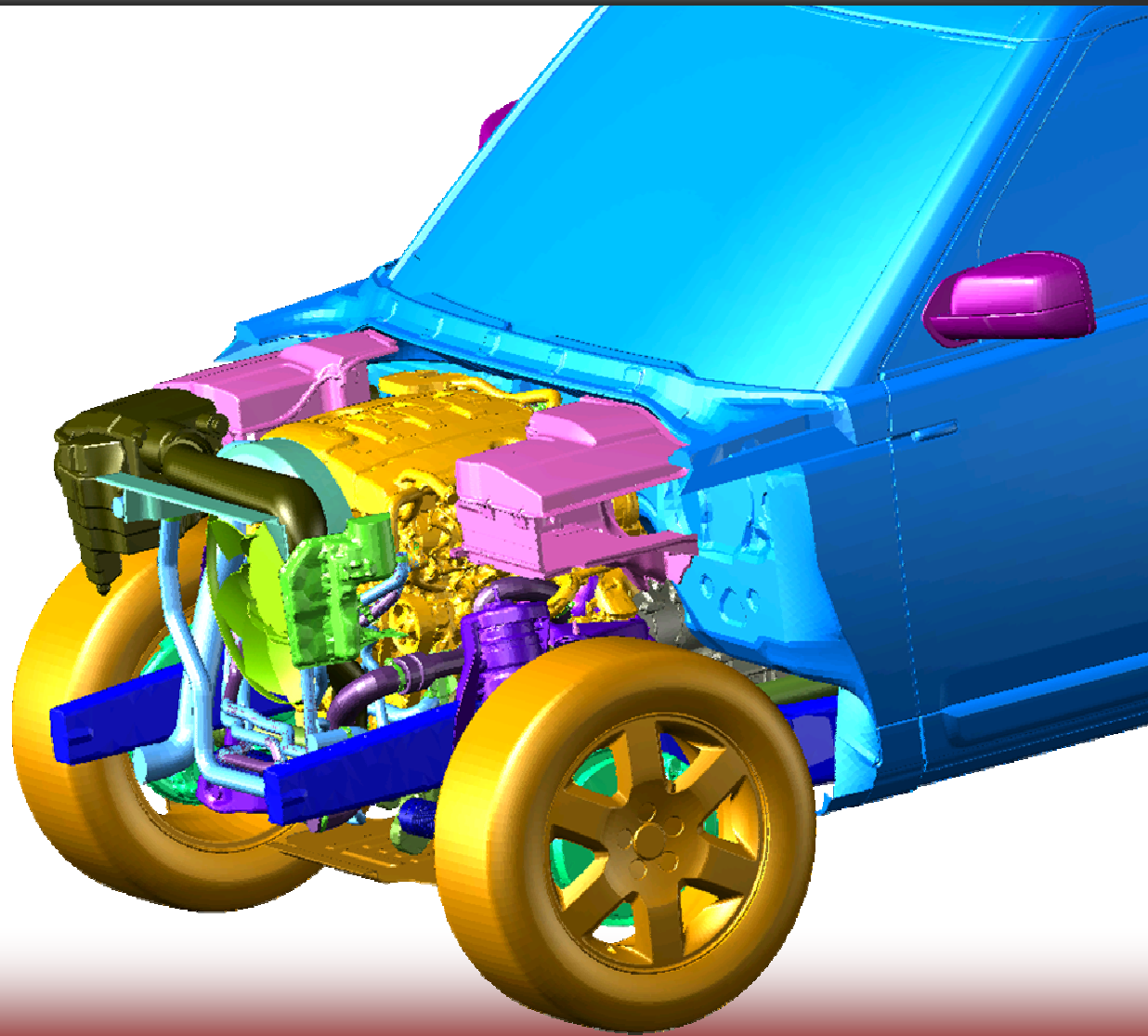


# Example: Land Rover – Geometry Details

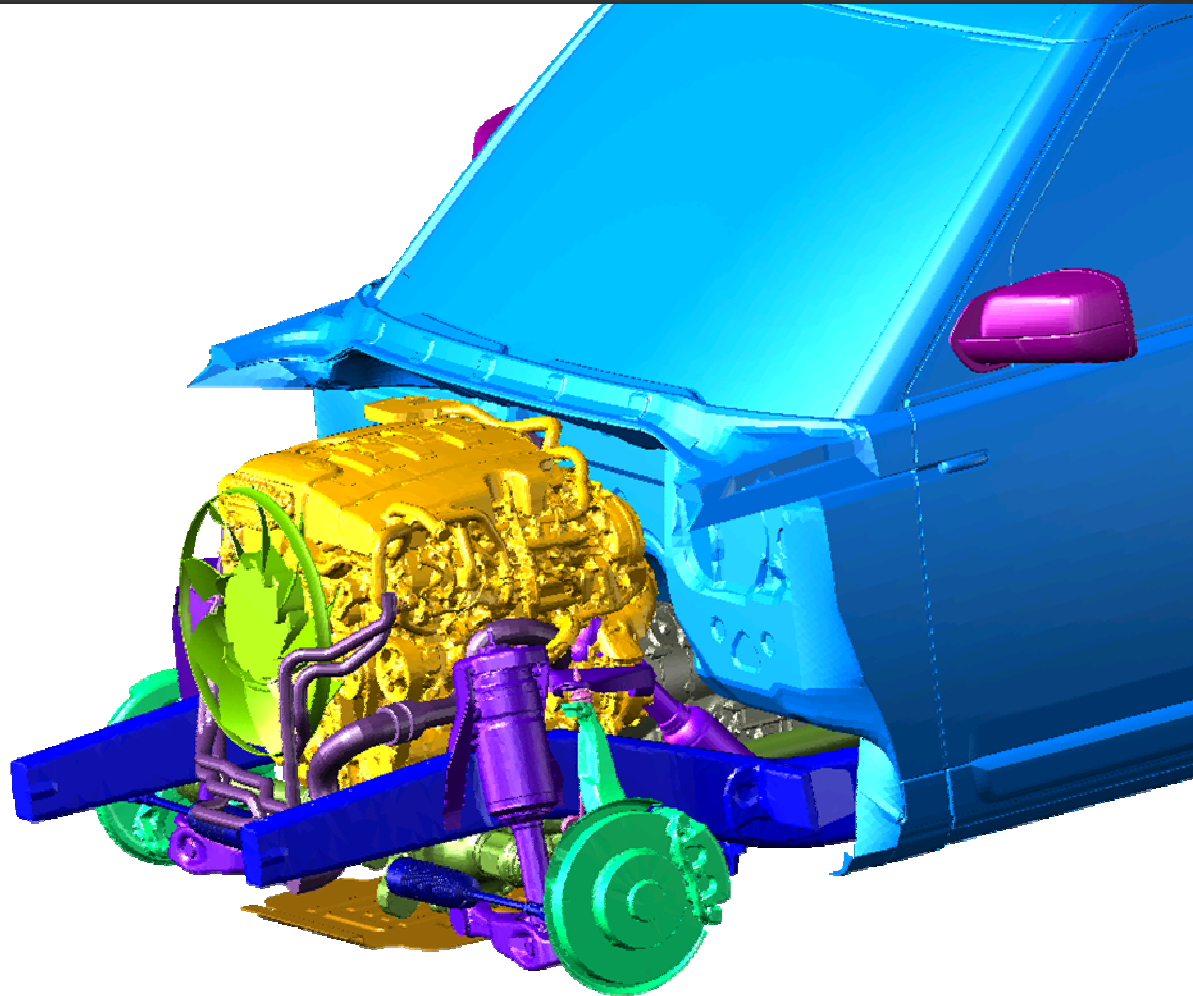




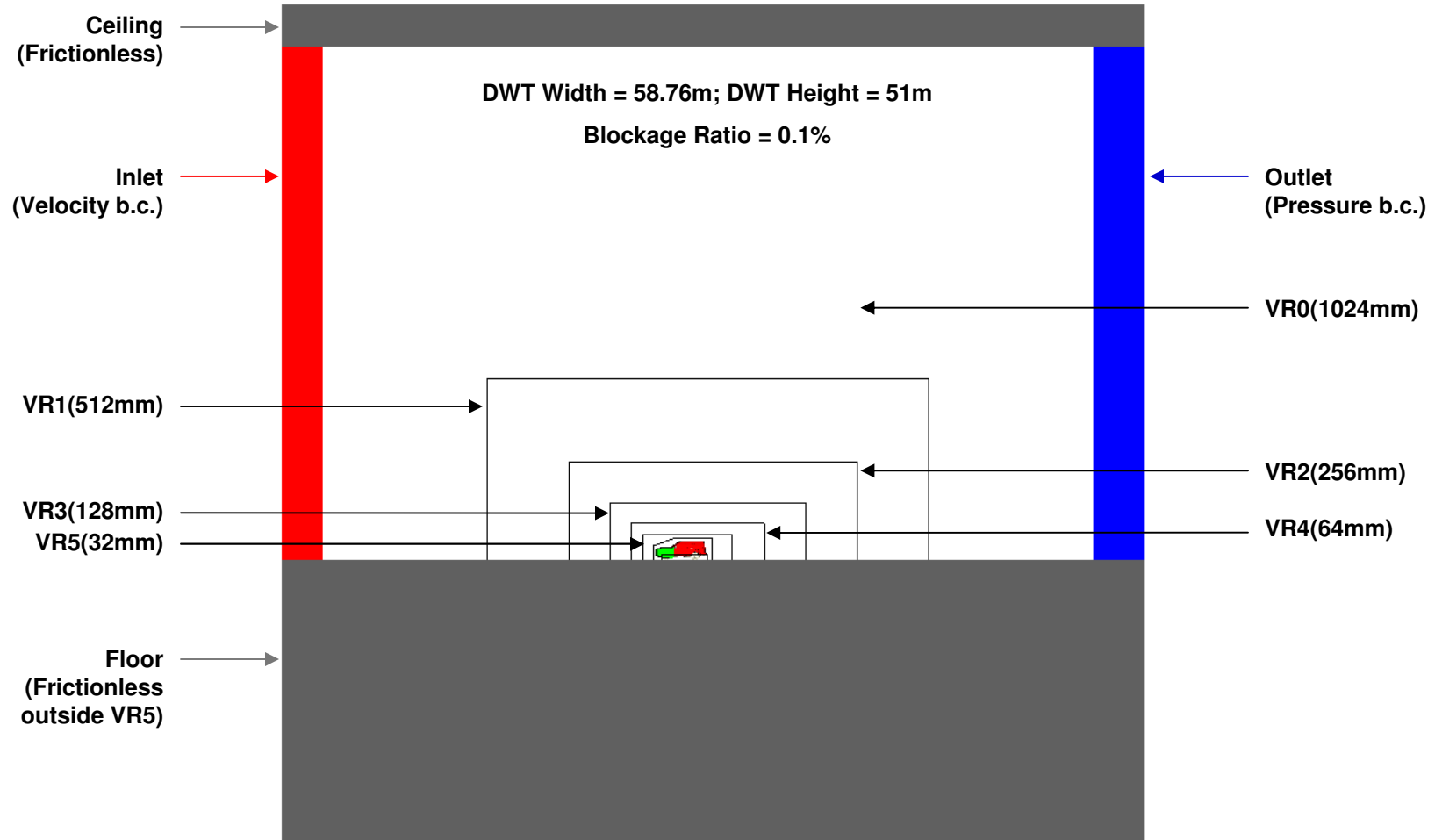
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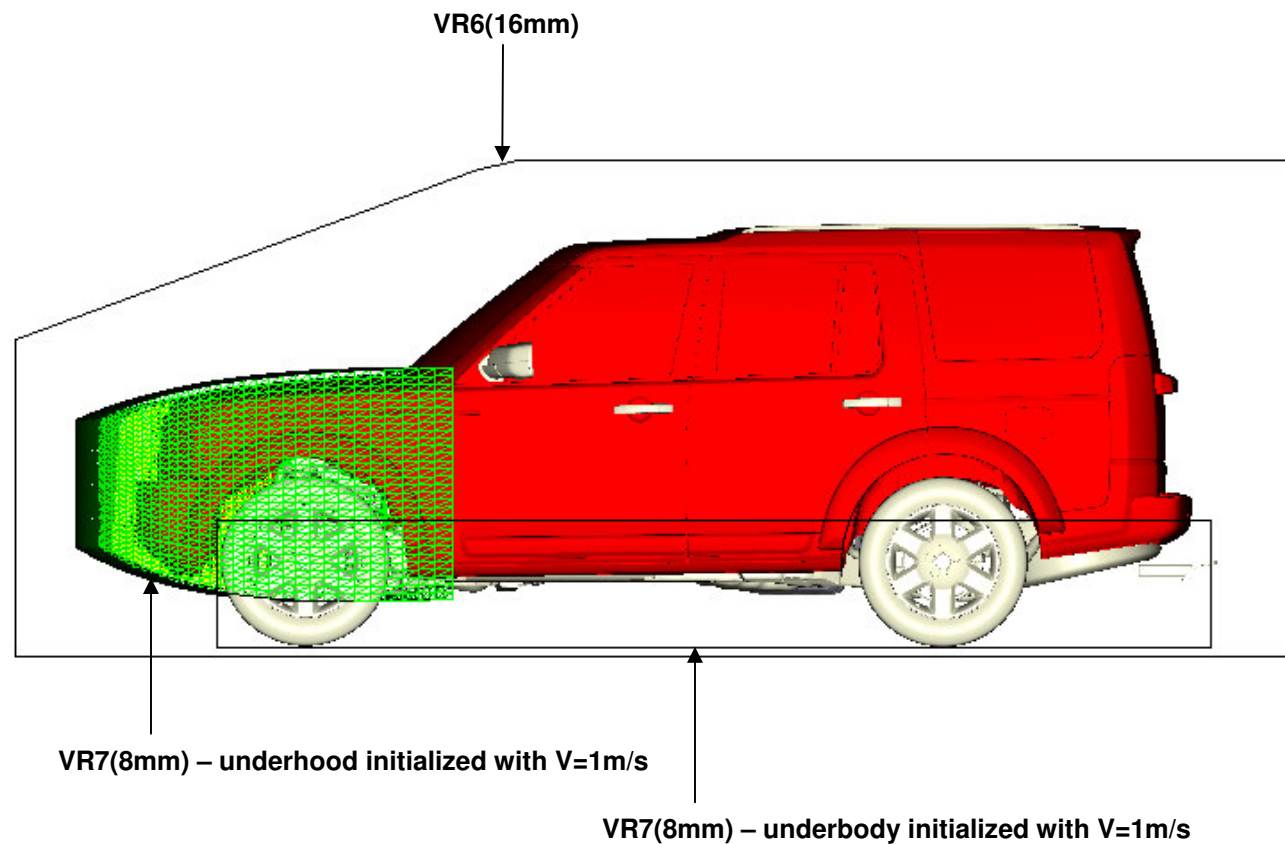


# Example: Land Rover – PowerFLOW Setup

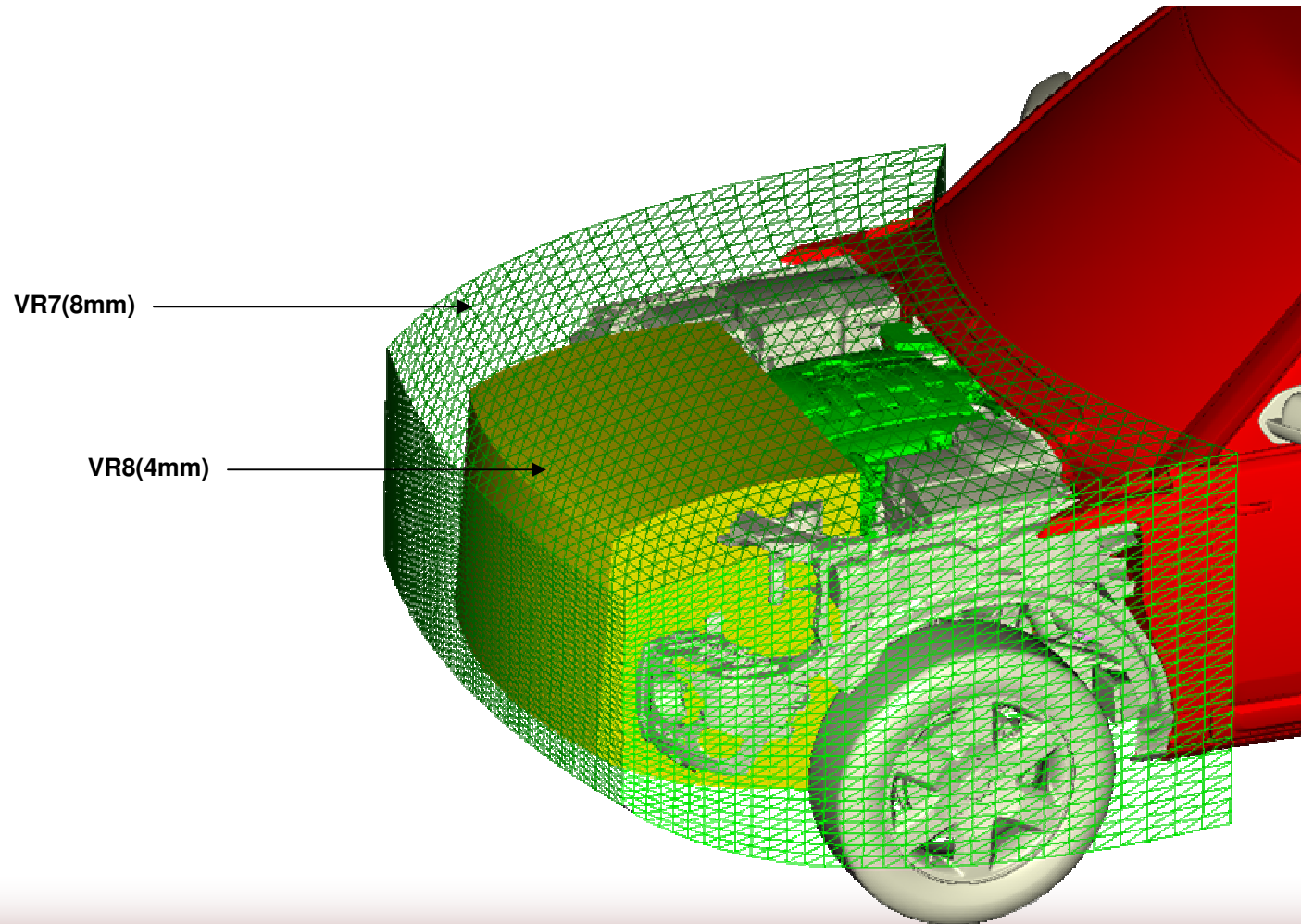




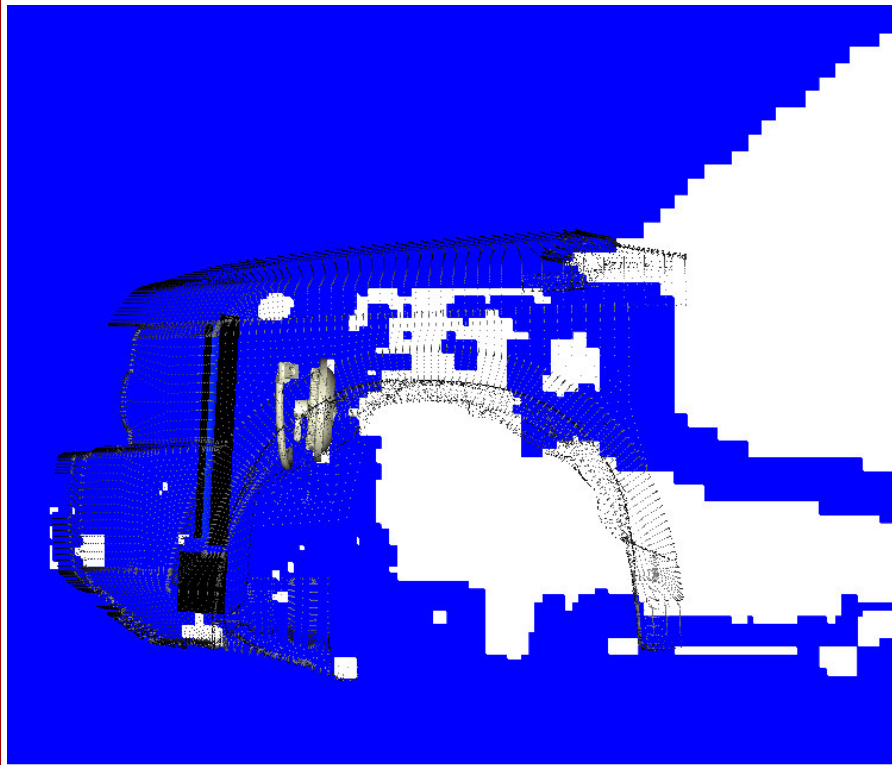
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# Example: Land Rover – PowerFLOW setup

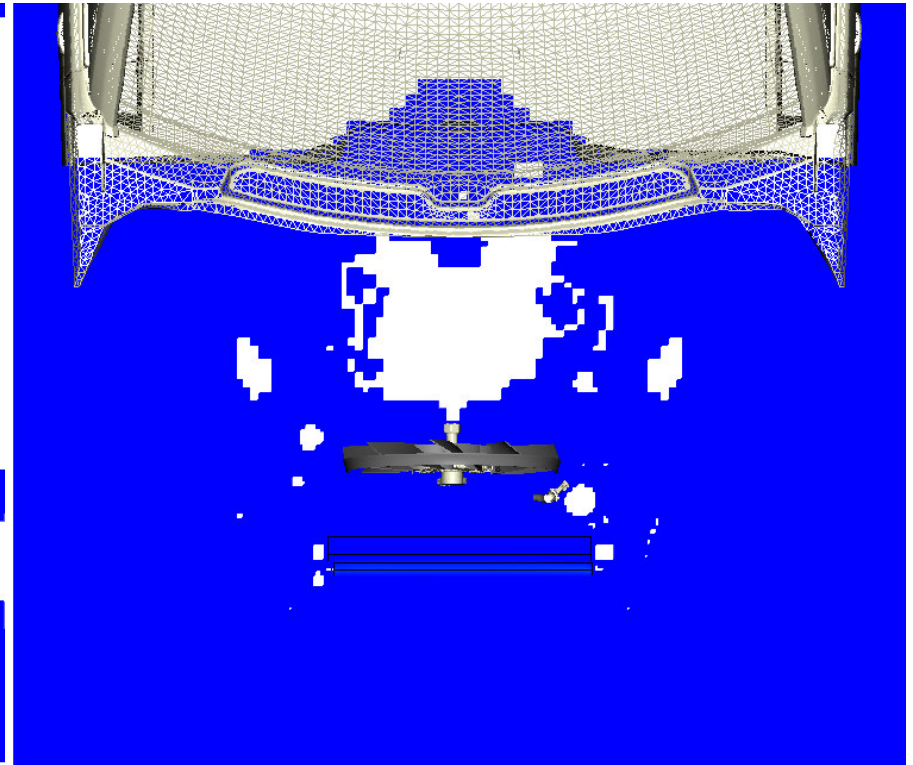


# Example: Land Rover – Flow Results



Temperature [degK]  
315 325 335 345 355 365 375

Time = 0.002936, frame = 0

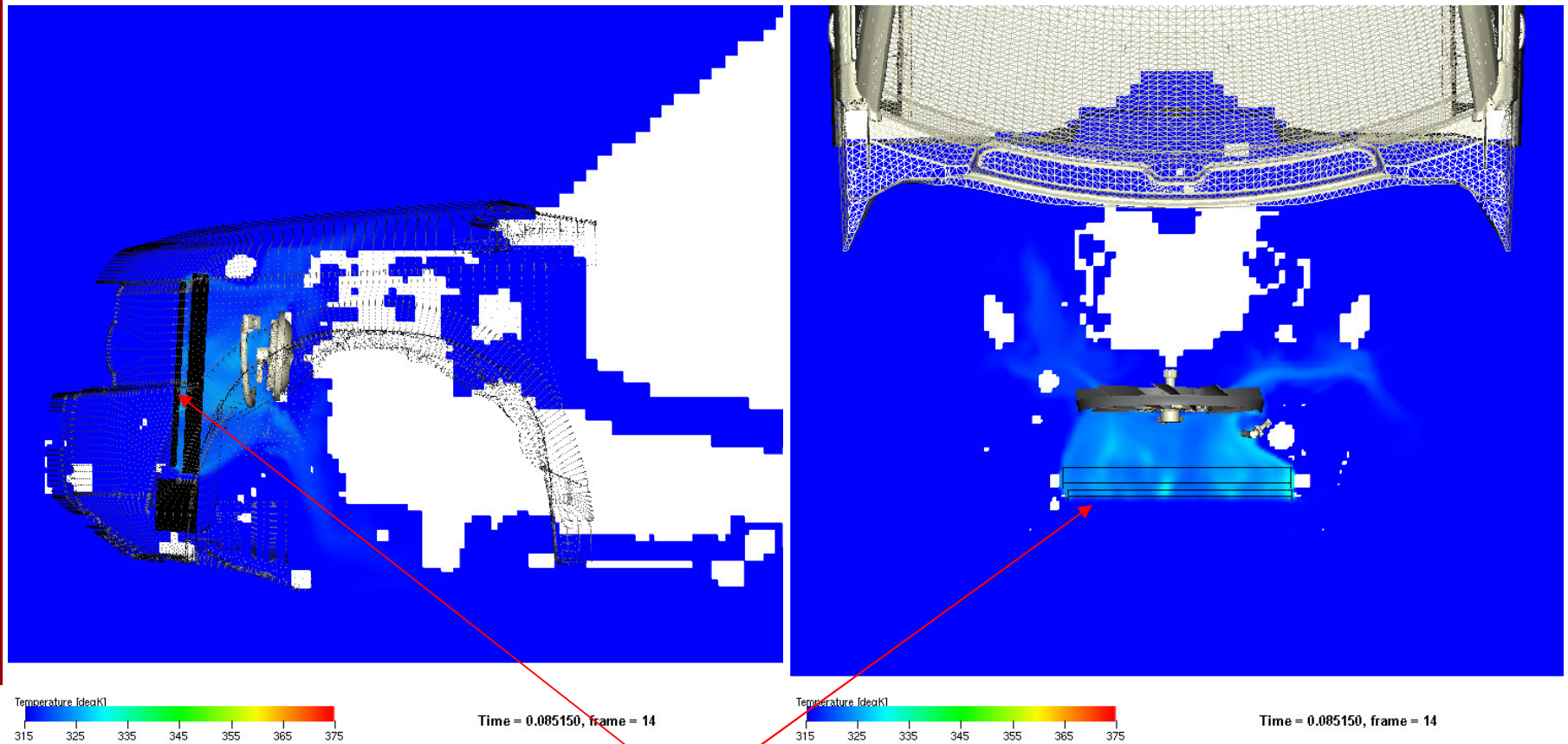


Temperature [degK]  
315 325 335 345 355 365 375

Time = 0.002936, frame = 0

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

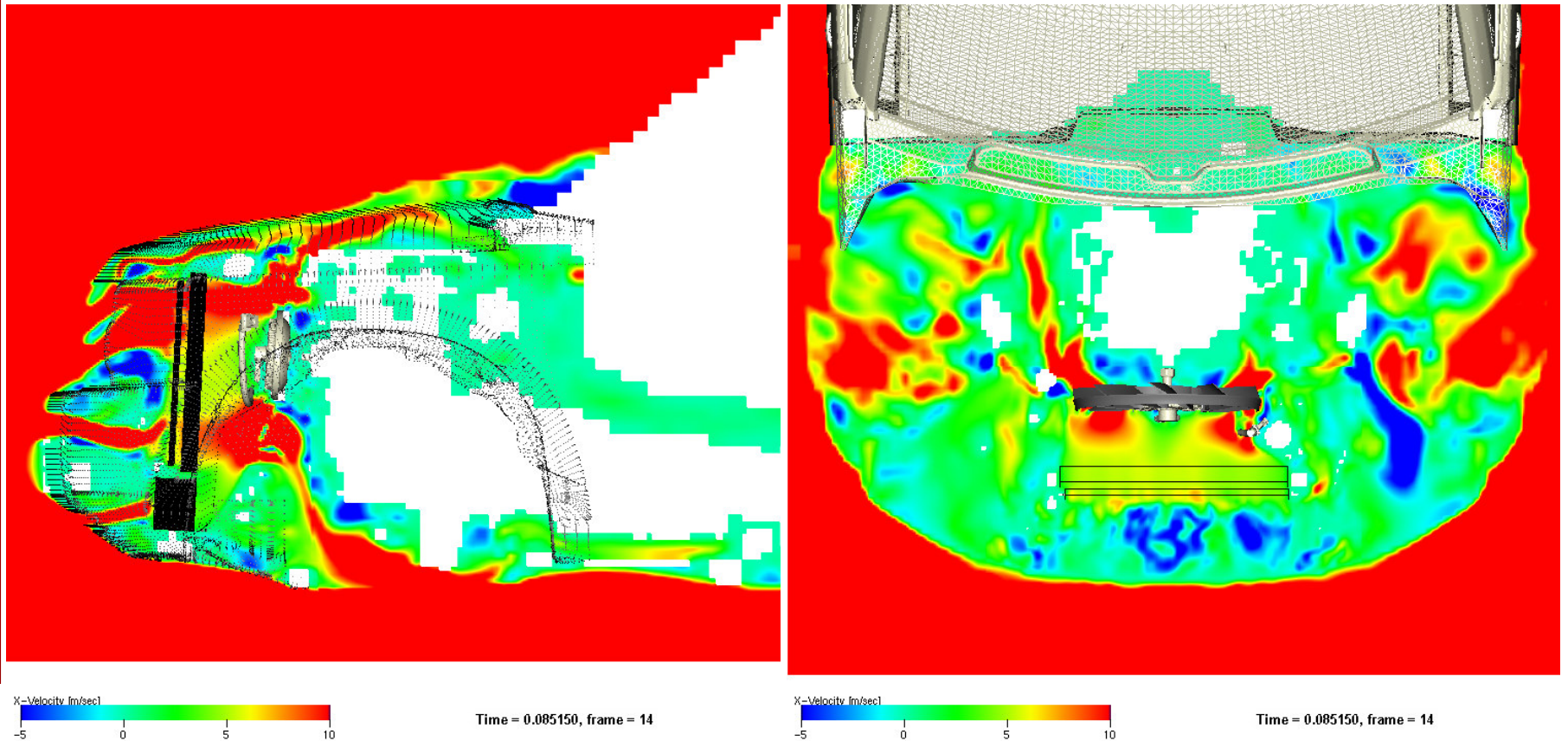
# Example: Land Rover – Flow Results



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*

The screenshot displays the KULI software interface. The main window is titled "Resistance matrix [LR319-P1R11-40k-20x20-vel.resmat]". It features a menu bar with "File", "Extras", and "CFD-Data". Below the menu bar is a toolbar with icons for file operations. The main area is divided into sections for input data, comments, and various parameters.

**Resistance matrix dialog:**

- Input data:** "CFD data set" (selected), "KULI Resistance matrix"
- KULI CFD file:** "LR319-P1R11-40k-20x20-vel.cfd"
- Comments:** "LR319-P1R11-20x20-vel"
- Blocks used for CFD Matrix (e.g. 1,3,4):** "400"
- Ambient air pressure [hPa]:** "1013"
- Ambient temp. [°C]:** "48"
- Air humidity [%]:** "40"
- Unit of field coordinates:** "m"
- Position of CFD data field:** "Position y-direction [mm]: 0", "Position z-direction [mm]: 0"
- Max. number of shown values:** "1000"

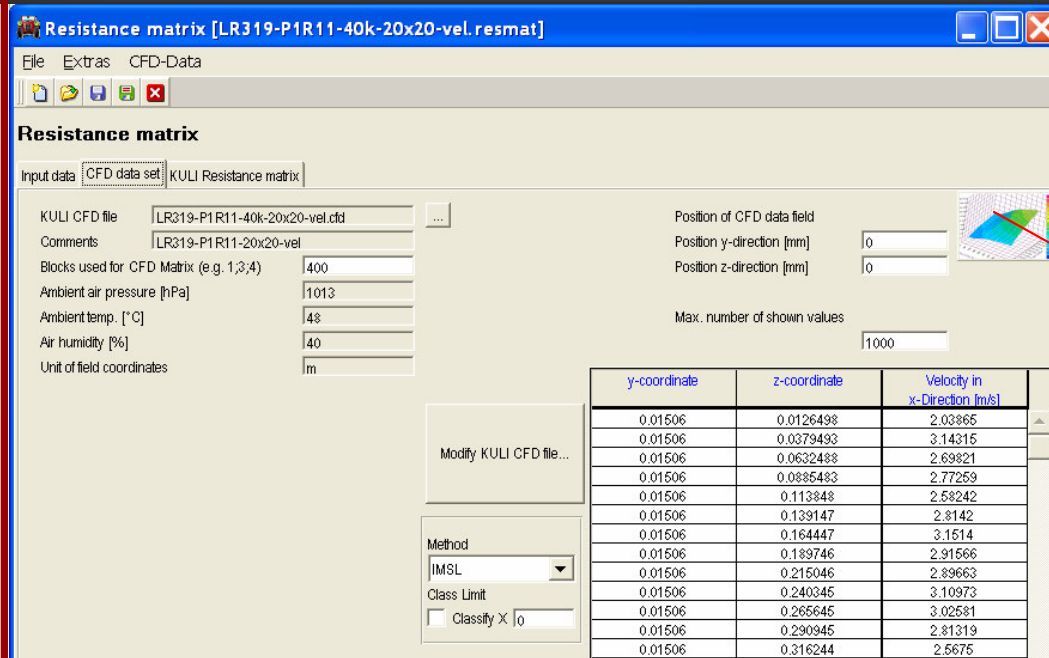
**Add/Edit resistance matrix dialog:**

- File:** "Resistance matrix" (selected), "1"
- Identifier:** "LRM"
- Type:** "use standard resistance matrix" (selected), "use direct CFD interface", "use velocity depending resistance matrices"
- Component:** "LR319-P1R11-40k-20x20-vel.resmat"
- Method:** "IMSL" (selected), "Classify X: 0"

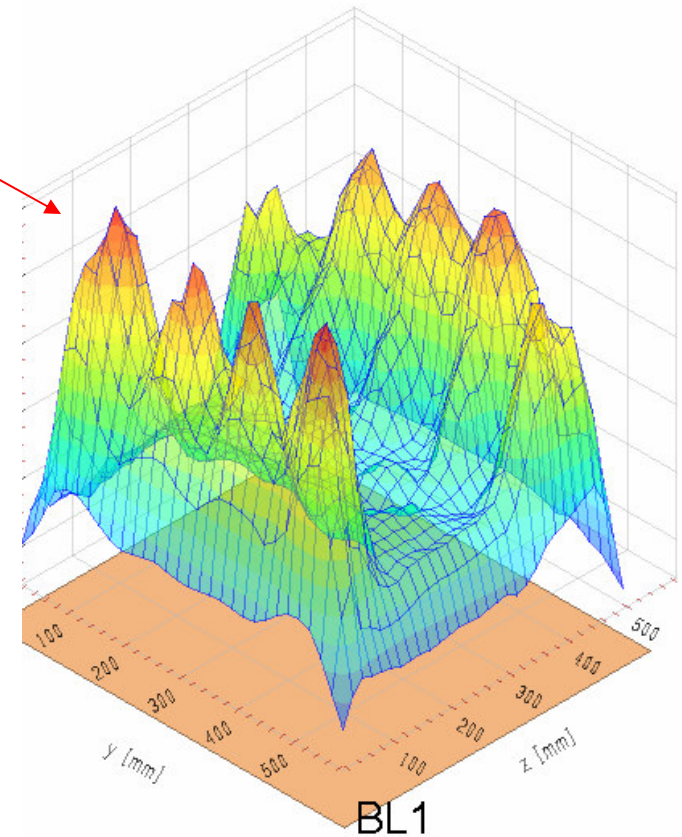
**Table of data:**

y-coordinate	z-coordinate	Velocity in x-Direction [m/s]
0.01506	0.0126498	2.03865
0.01506	0.0379493	3.14315
0.01506	0.0632488	2.69821
0.01506	0.0885483	2.77259
0.01506	0.113848	2.58242
0.01506	0.139147	2.8142
0.01506	0.164447	3.1514
0.01506	0.189746	2.91566
0.01506	0.215046	2.89663
0.01506	0.240345	3.10973
0.01506	0.265645	3.02581
0.01506	0.290945	2.81319
0.01506	0.316244	2.5675
0.01506	0.341544	3.60487
0.01506	0.366843	3.93723
0.01506	0.392143	3.96029
0.01506	0.417442	5.20553

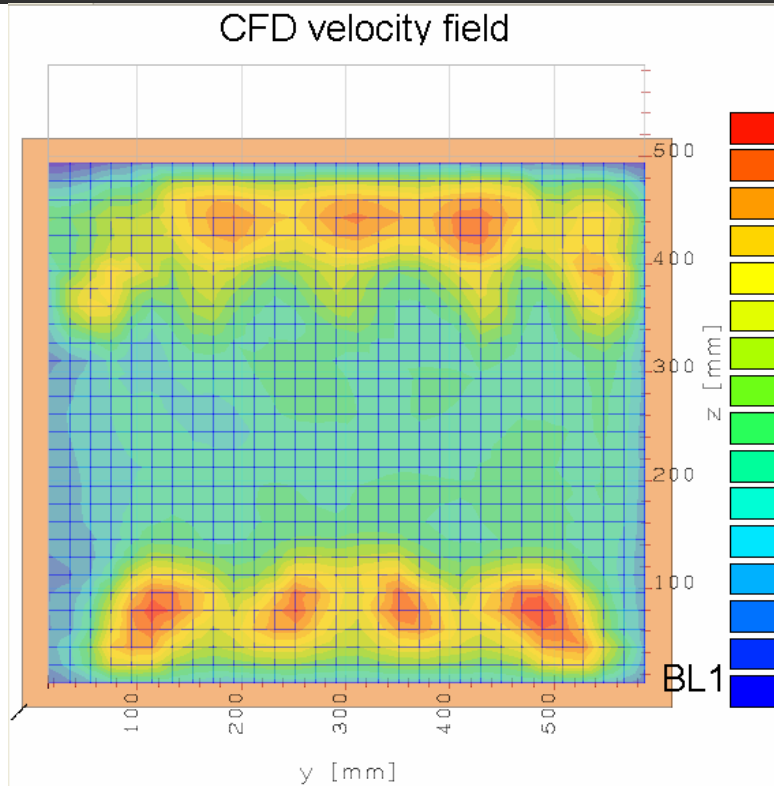
# Example: Land Rover – KULI Simulation



CFD velocity field

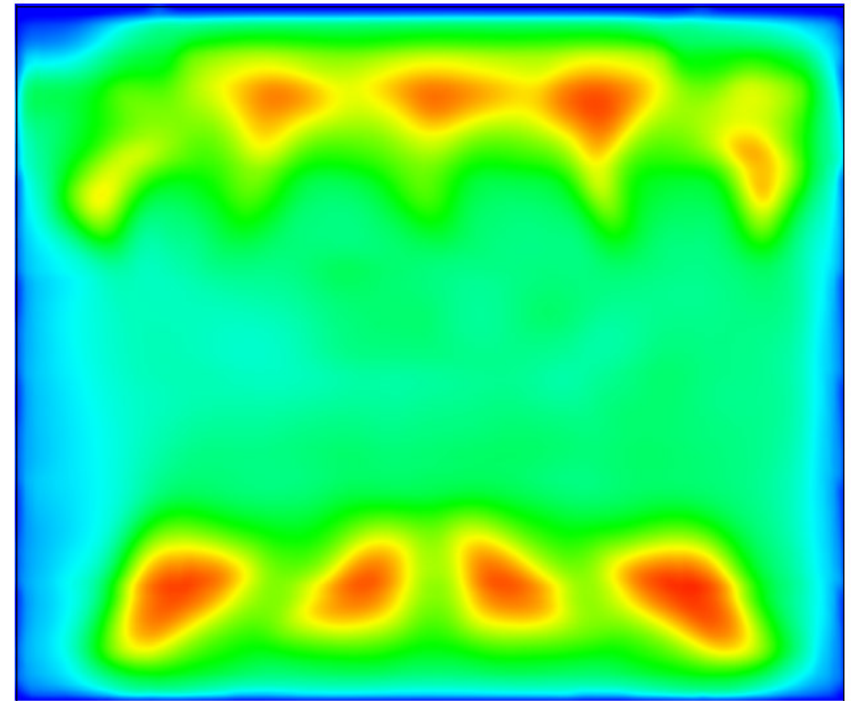


# Example: Land Rover – KULI Simulation



KULI – Velocity Map

(Driver's Point of View)



PowerFLOW – Velocity Field

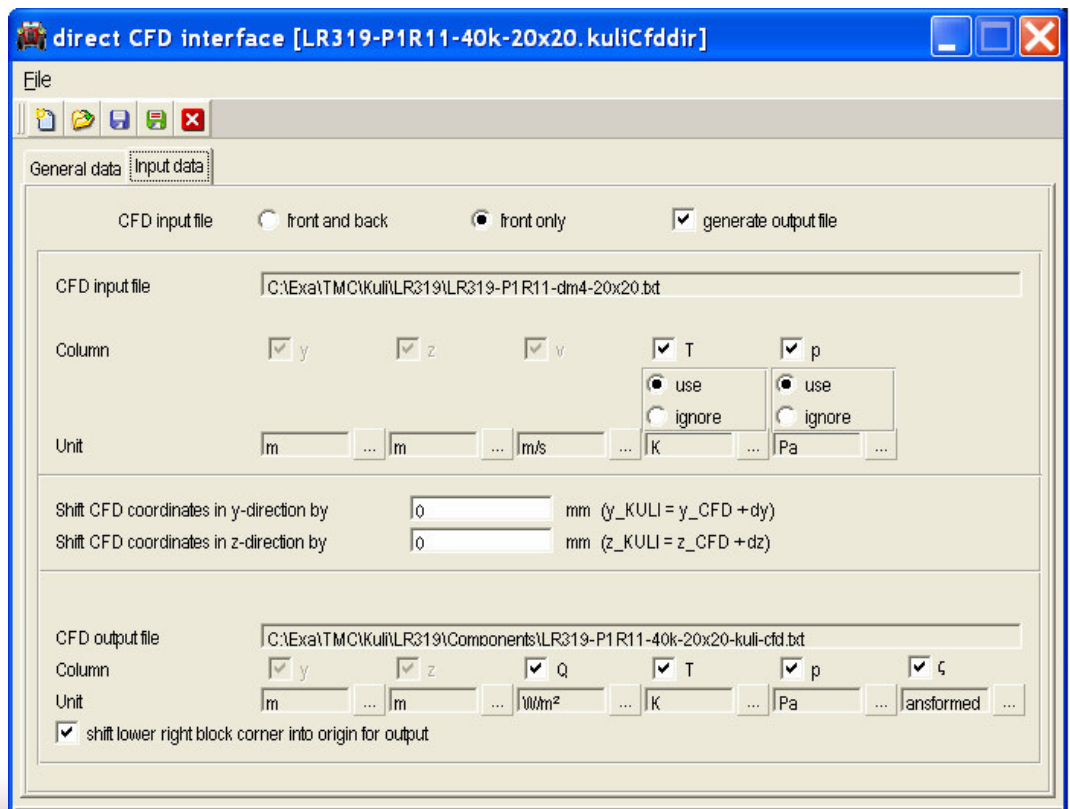
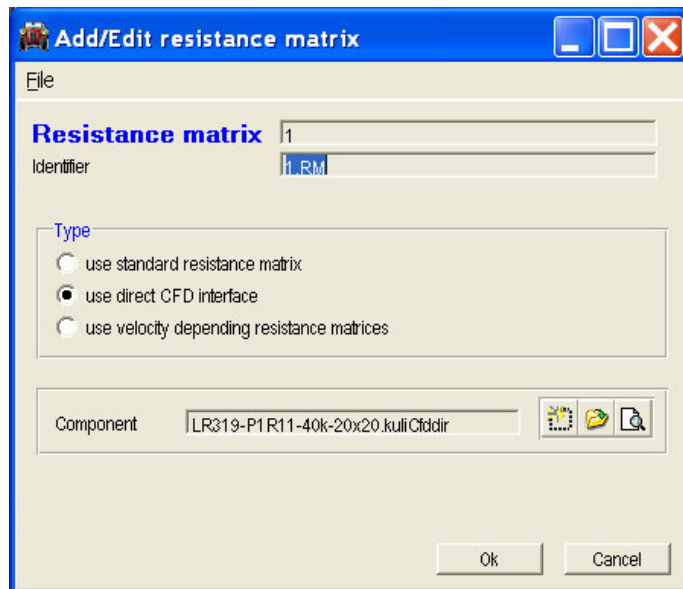
## Mapping of Velocity field from PowerFLOW to KULI



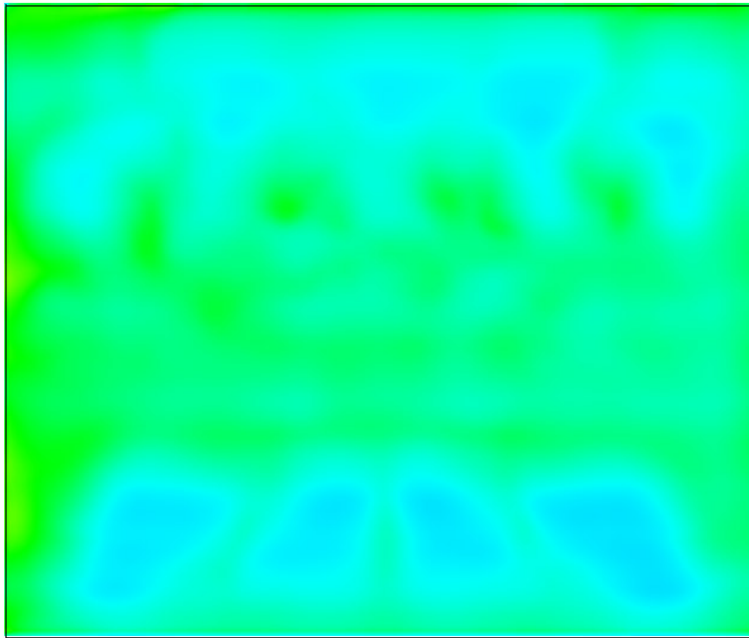
# Example: Land Rover – KULI Simulation

## Advanced 1-way coupling

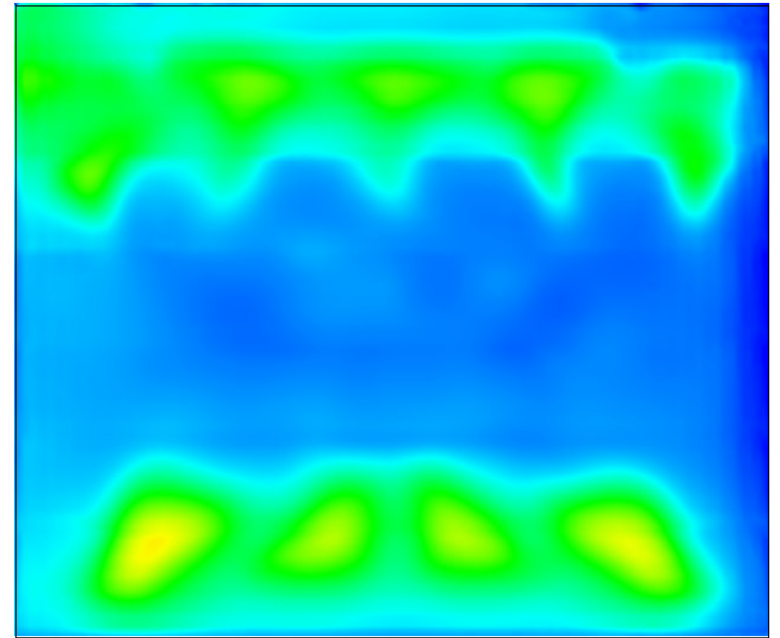
- *Provided 20x20 V,P,T fields on Radiator face*
- *Used Direct CFD interface*



# Example: Land Rover – KULI Simulation



PowerFLOW – Temperature Field



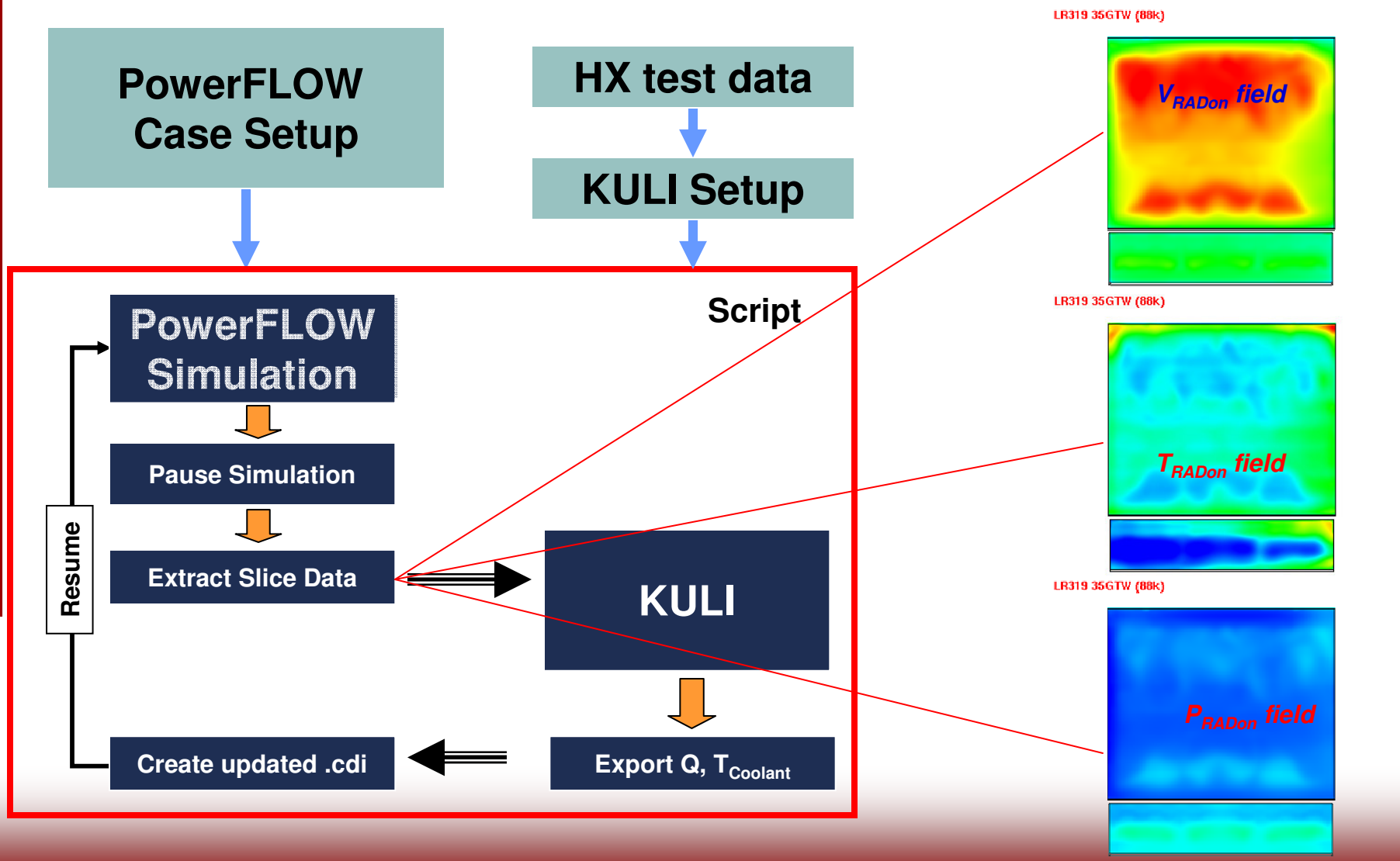
PowerFLOW – Static Pressure Field

**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 <sup>2</sup> /s
Air Entry Temperature			0.59 °C
Air Exit Temperature			-0.15 °C
Mean Volumetric Flow			-0.17 m <sup>3</sup> /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

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- > **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*