Understand the Power of CoTherm: How to Solve Complex Transients by Coupling Thermal & CFD Codes

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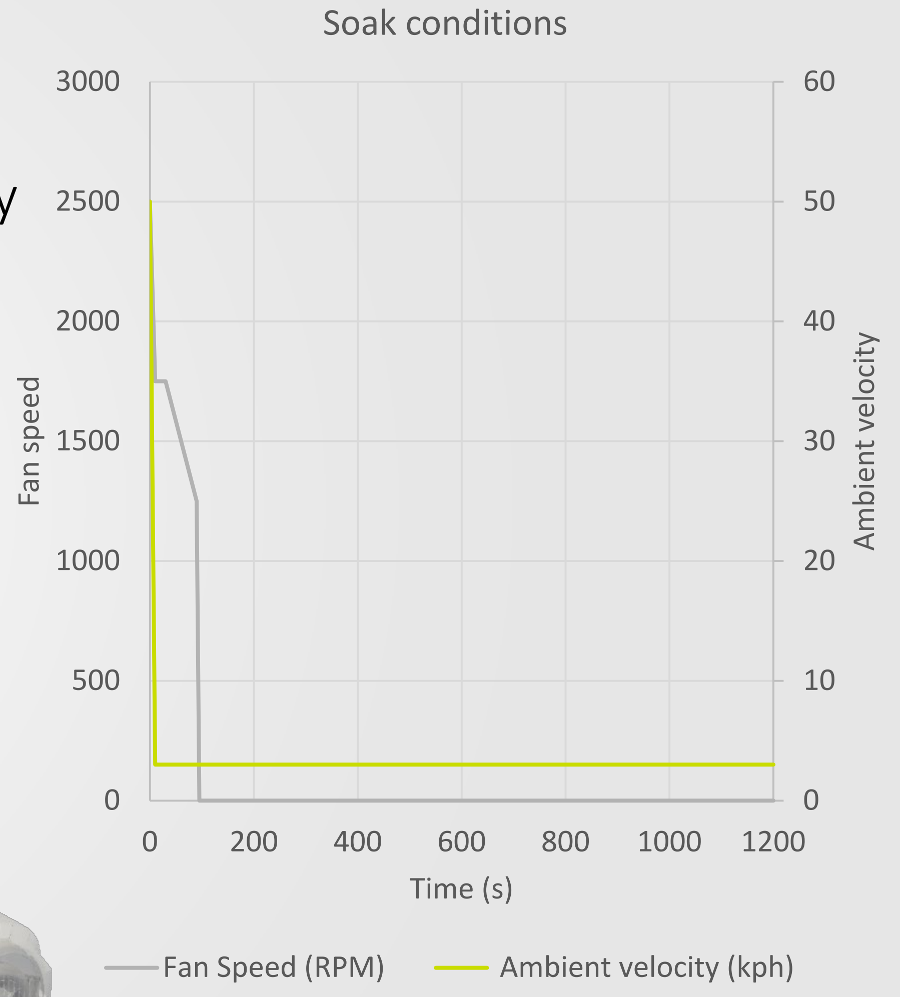
Background

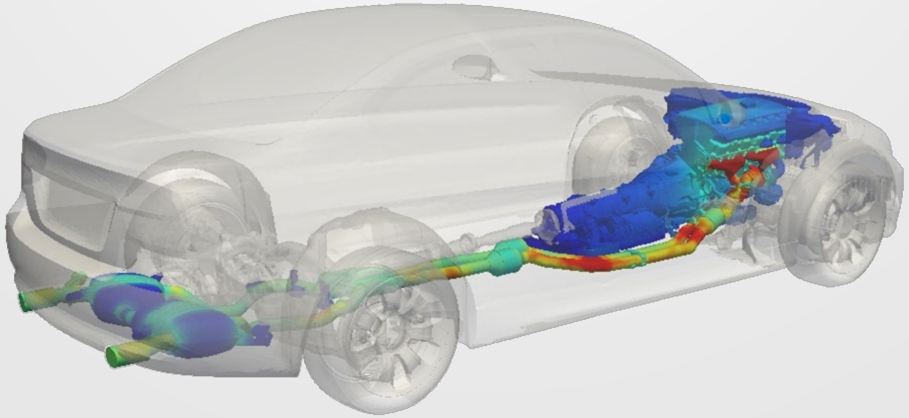
- Last month's webinar introduced the benefits of using TAITherm and CFD and demonstrated steady-state coupling
  - https://support.thermoanalytics.com
    - Webinars > "Shorter Run Times, Better Simulations: Leveraging the Strengths of TAITherm and CFD"

- These tools can also be leveraged to simulate complex transient scenarios
  - CoTherm automation software will be the basis for coupled simulation
  - Automotive underhood hot shutdown scenario will be demonstrated

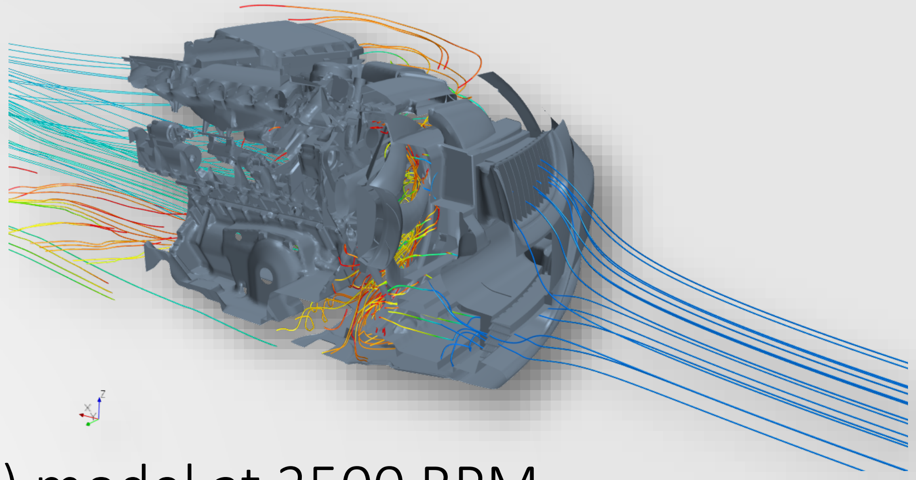
Problem Statement

- Hot shutdowns / key-offs are a challenging condition for underhood/underbody thermal management
  - Typical scenario: high engine load driving phase followed by a brief idle and vehicle shut-down
  - Less air movement available to dissipate thermal mass and internal residual heat
  - Can result in temperatures higher than steady-state
- Example hot-shutdown (high-performance sedan):
  - Initial condition: Steady-state uphill driving at 50 kph
  - Idle phase: 90s with vehicle stopped and cooling fan active
  - Soak phase: 18.5 minutes with engine and cooling fan off

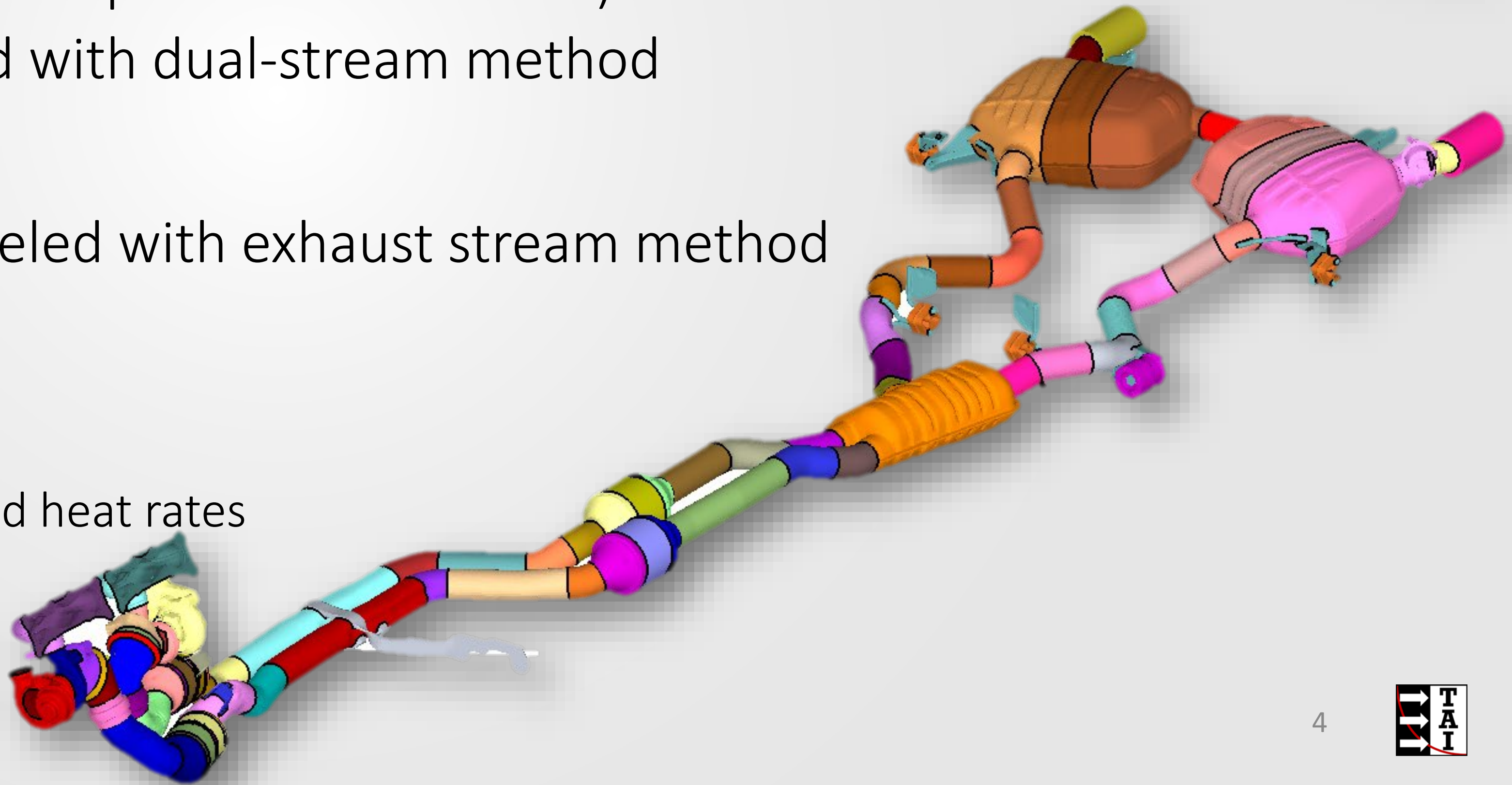




Model Setup: Driving Phase

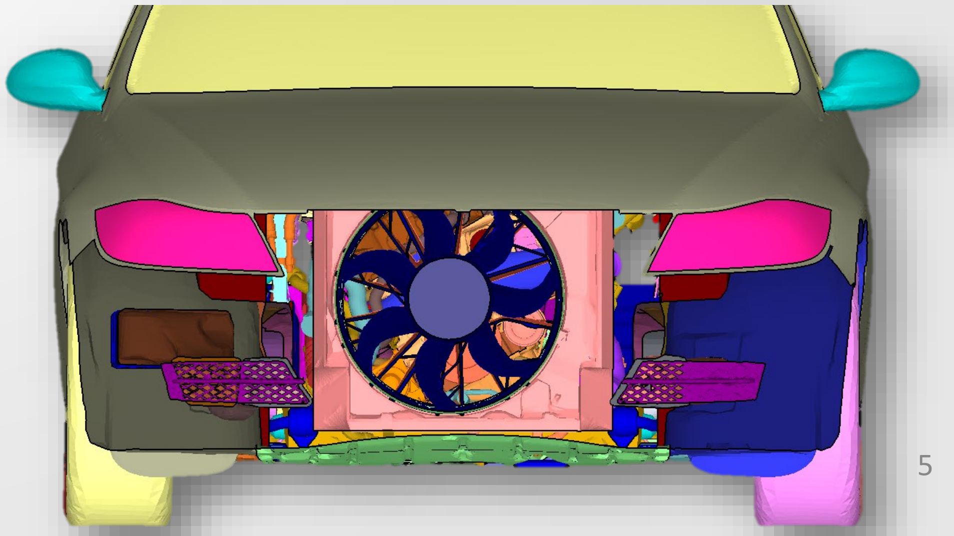


- CFD Model Setup
  - Ambient velocity 50 kph
  - Fan modeled with MRF (multiple reference frame) model at 2500 RPM
  - Heat exchangers modeled with dual-stream method
- Thermal Model Setup
  - Exhaust heat source modeled with exhaust stream method
    - Mass flow 0.18 kg/s
    - Inlet temp 750^{o} C
    - 2 turbo and 2 catalyst components with calculated heat rates



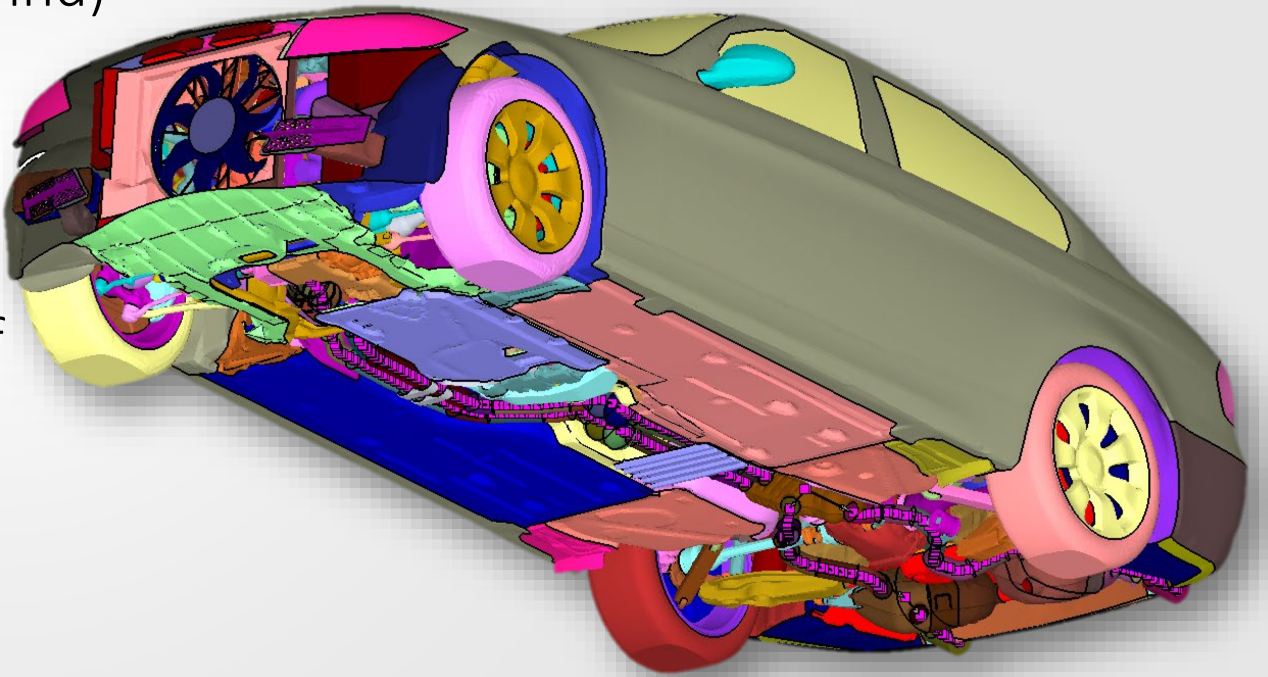
Model Setup: Idle Phase

- CFD Model Setup
  - Ambient velocity 3 kph (low-speed wind)
  - Fan modeled with MRF (multiple reference frame) model at 1000 RPM
  - Heat exchangers modeled with dual-stream method
- Thermal Model Setup
  - Exhaust heat source modeled with exhaust stream method
    - Mass flow 0.06 kg/s
    - Inlet temp 600° C @ 10s / 350° C @ 90s
    - 2 turbo and 2 catalyst components with calculated heat rates

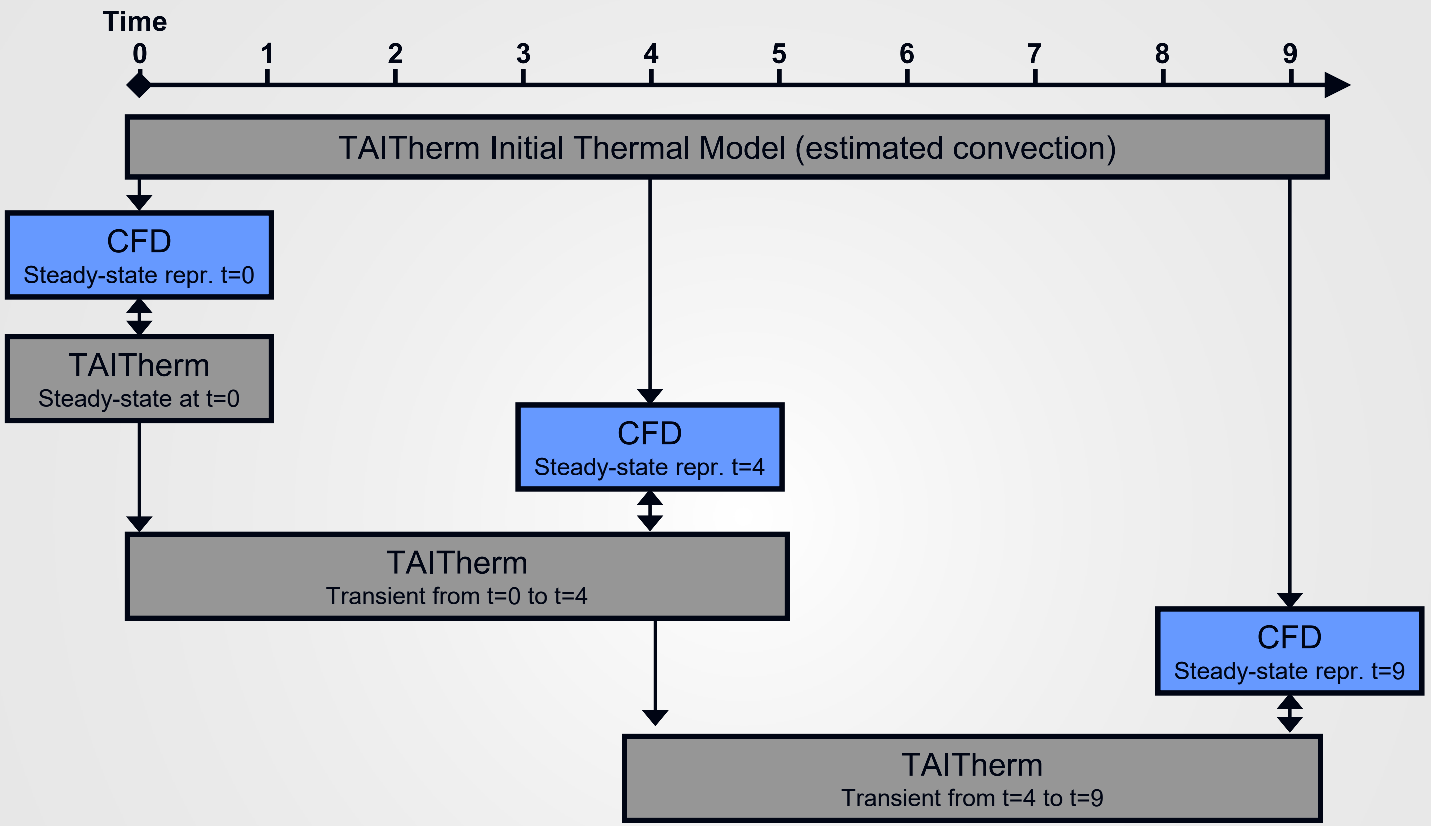


Model Setup: Soak Phase

- CFD Model Setup
  - Ambient velocity 3 kph (low-speed wind)
  - Fan turned off
  - Heat exchangers turned off
- Thermal Model Setup
  - Exhaust stream effectively turned off



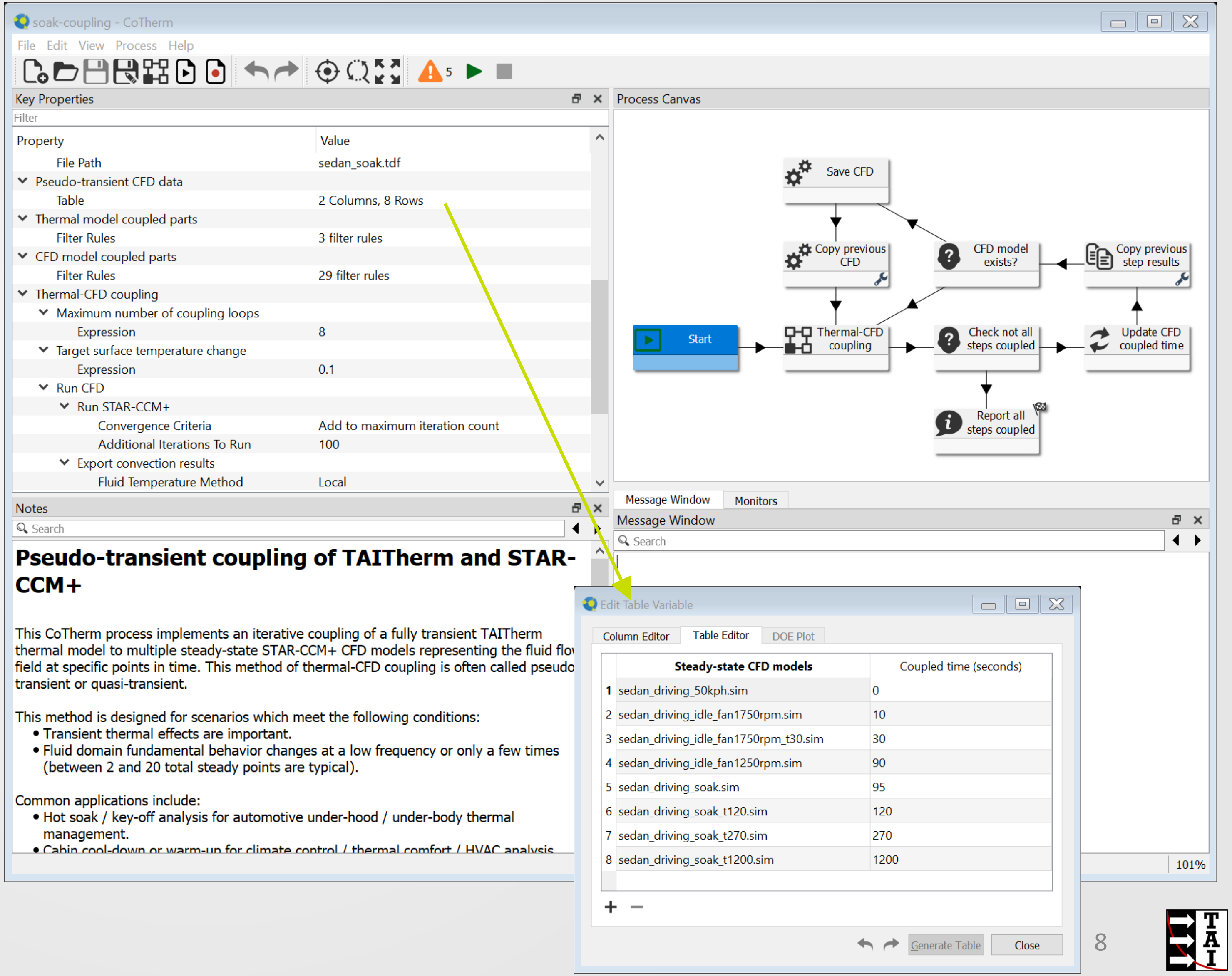
Pseudo-transient coupling method



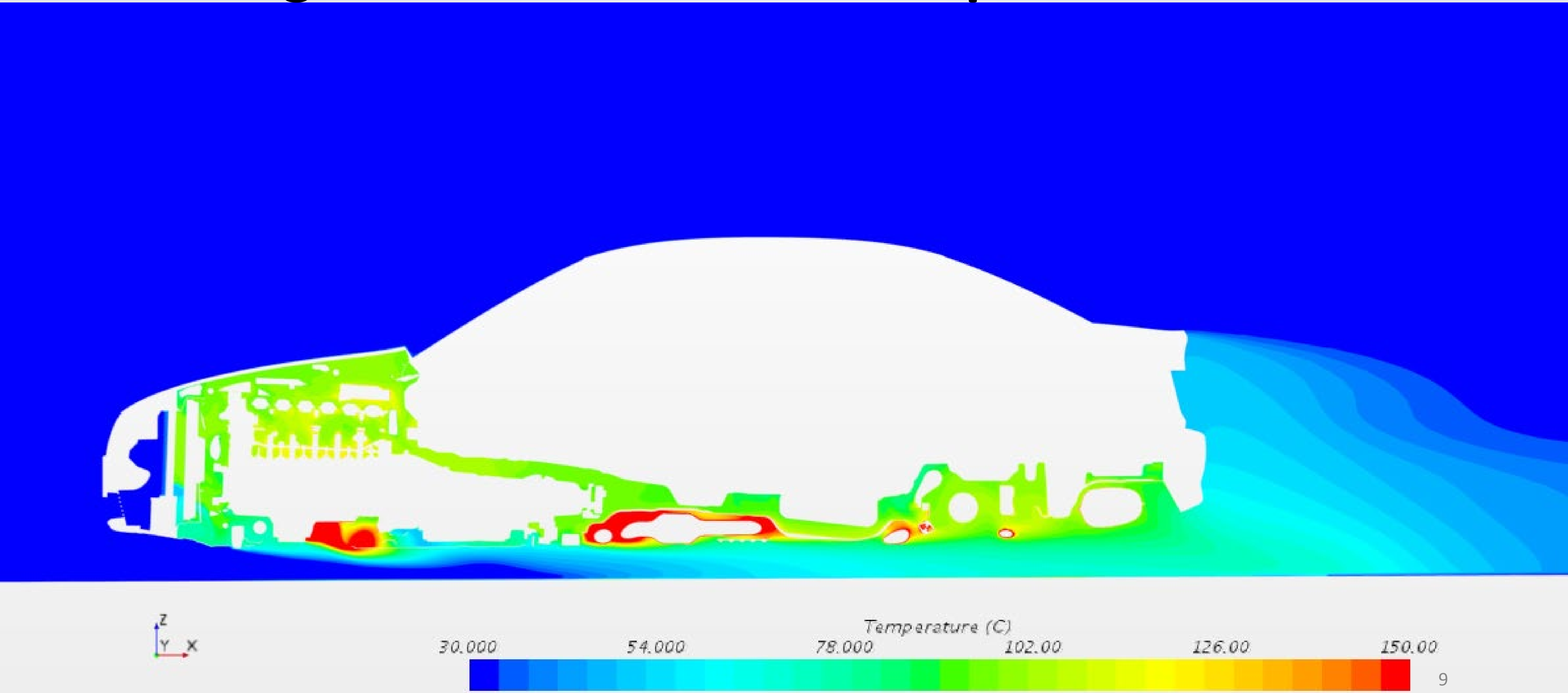
- Pseudo-transient coupling is a method for coupling between:
  - Fully transient TAITherm model
  - Multiple steady-state CFD models (“Snapshots” at different points in time)
- Number of CFD points coupled is arbitrary
- Fully supported in CoTherm

CoTherm Process Setup

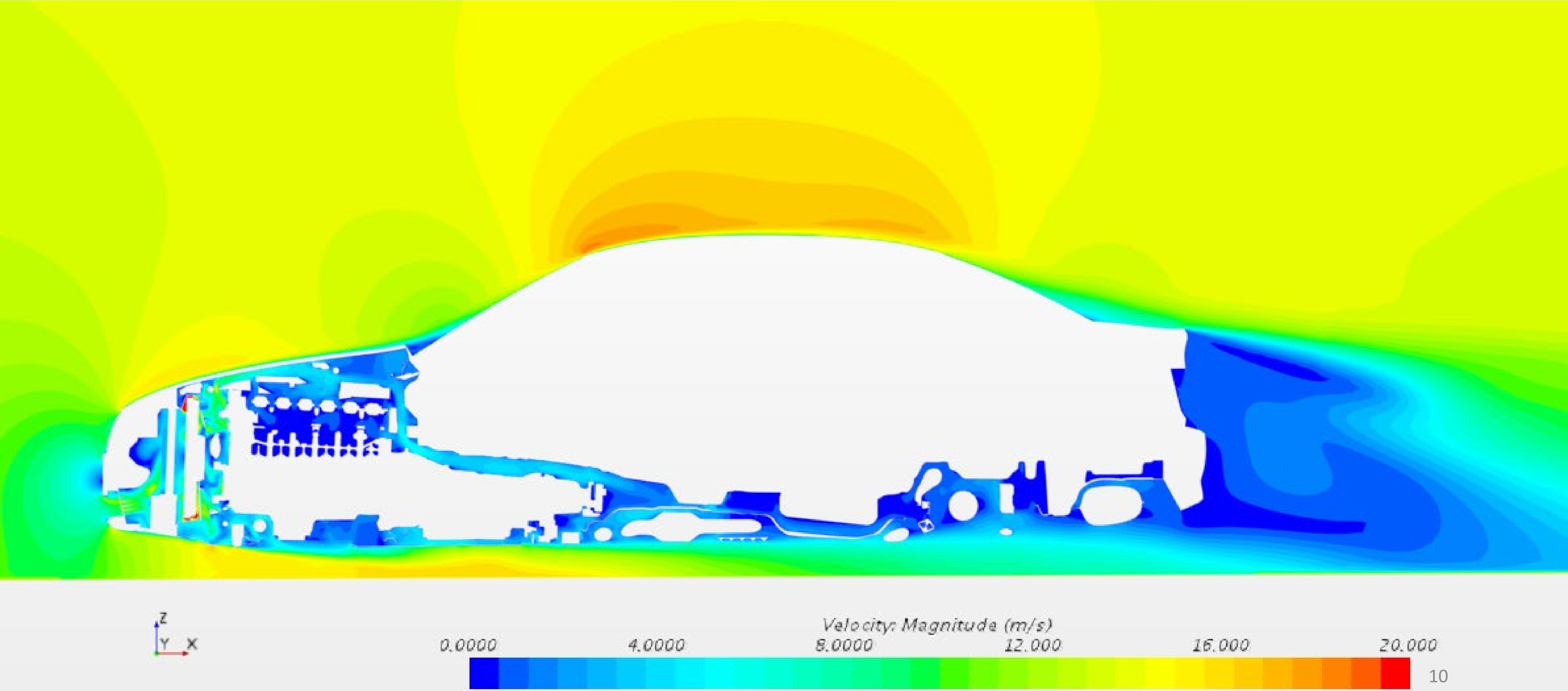
- Pseudo-transient thermal-CFD coupling document
  - Supported with standard examples for Fluent and STAR-CCM+ CFD models
- Process iterates over standard thermal-CFD coupling sub-process
- Key input is table of steady CFD models and corresponding times during transient scenario



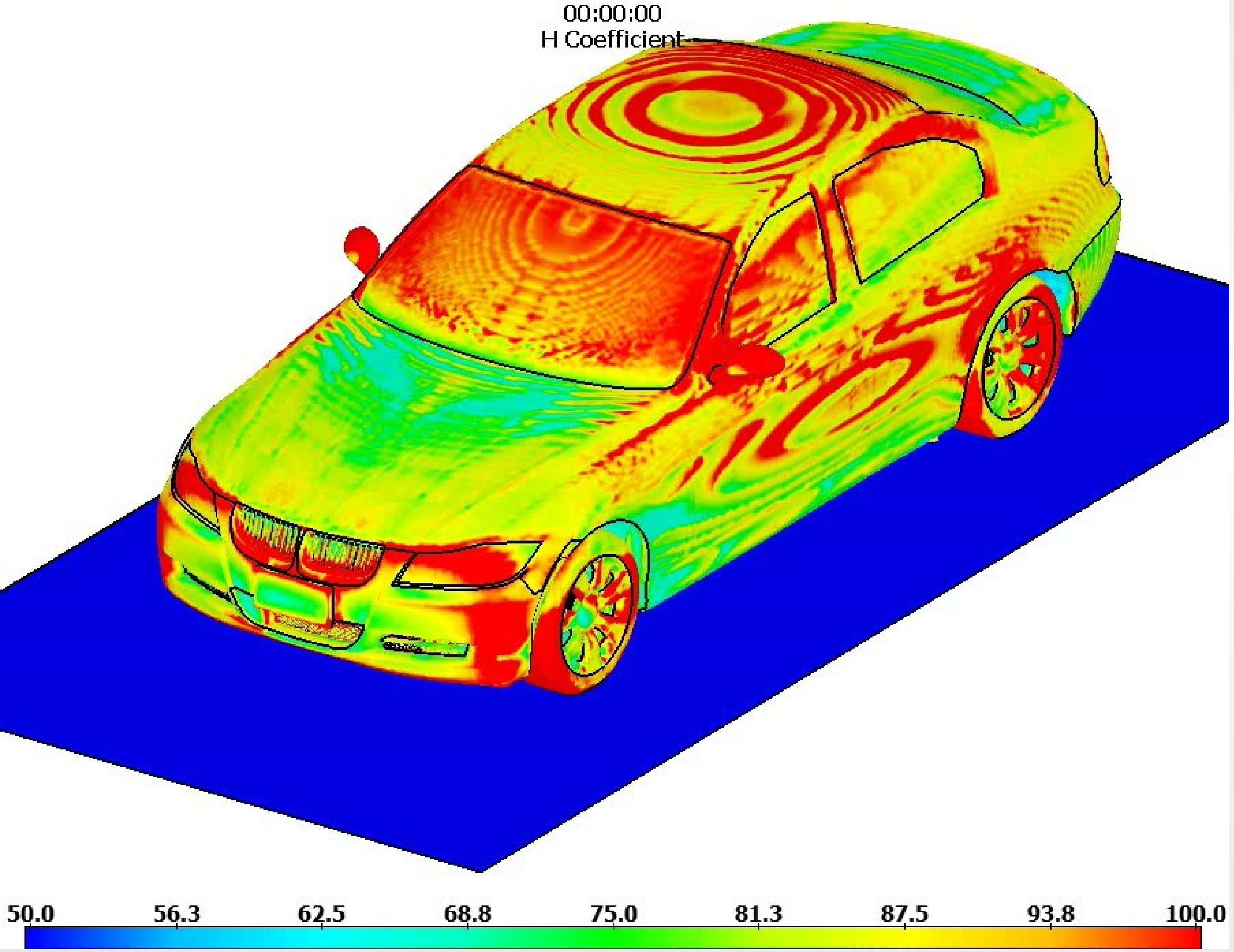
Driving Phase Results: CFD Temperatures



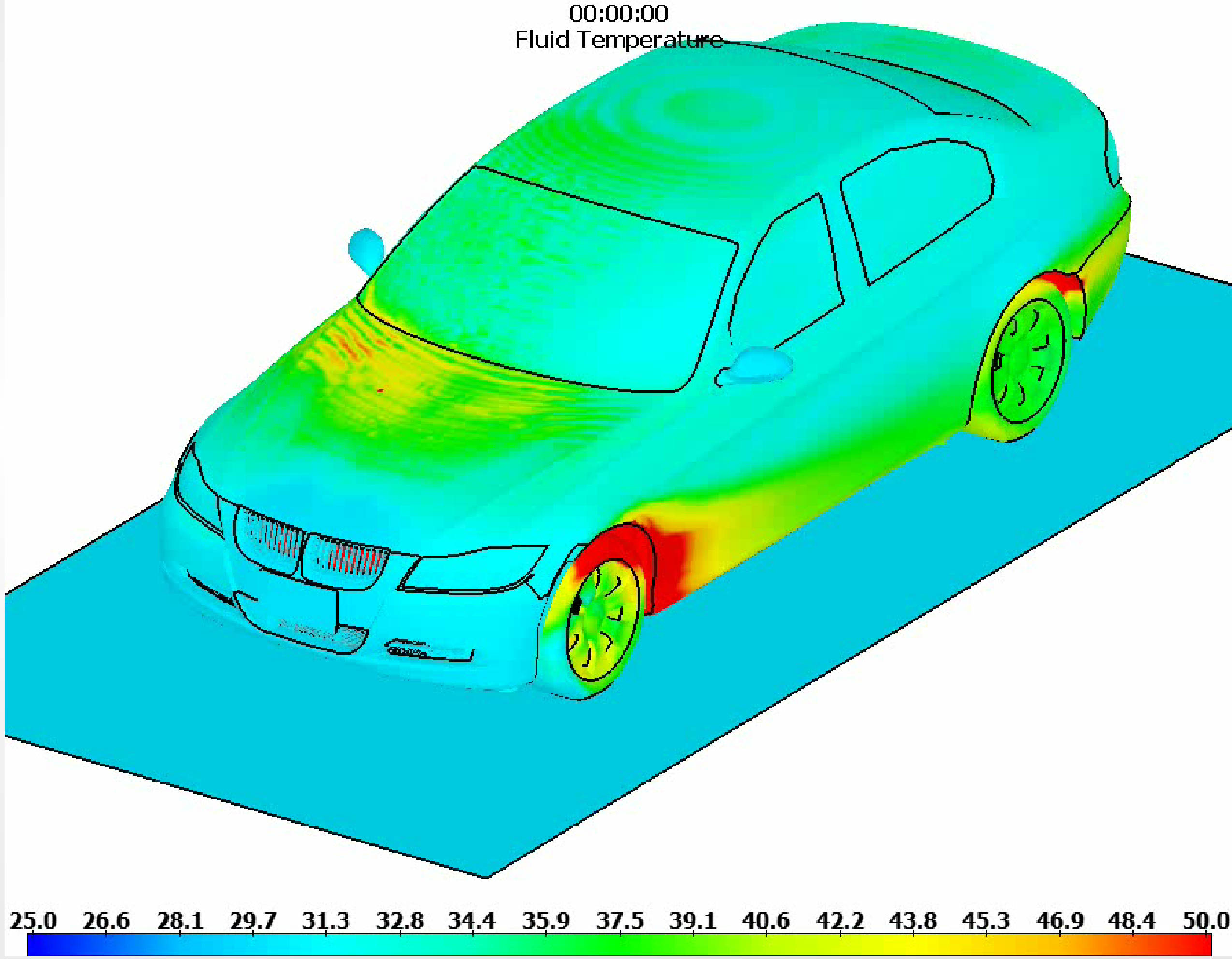
Driving Phase Results: CFD Velocities



Soak Results: Exterior Boundary Conditions

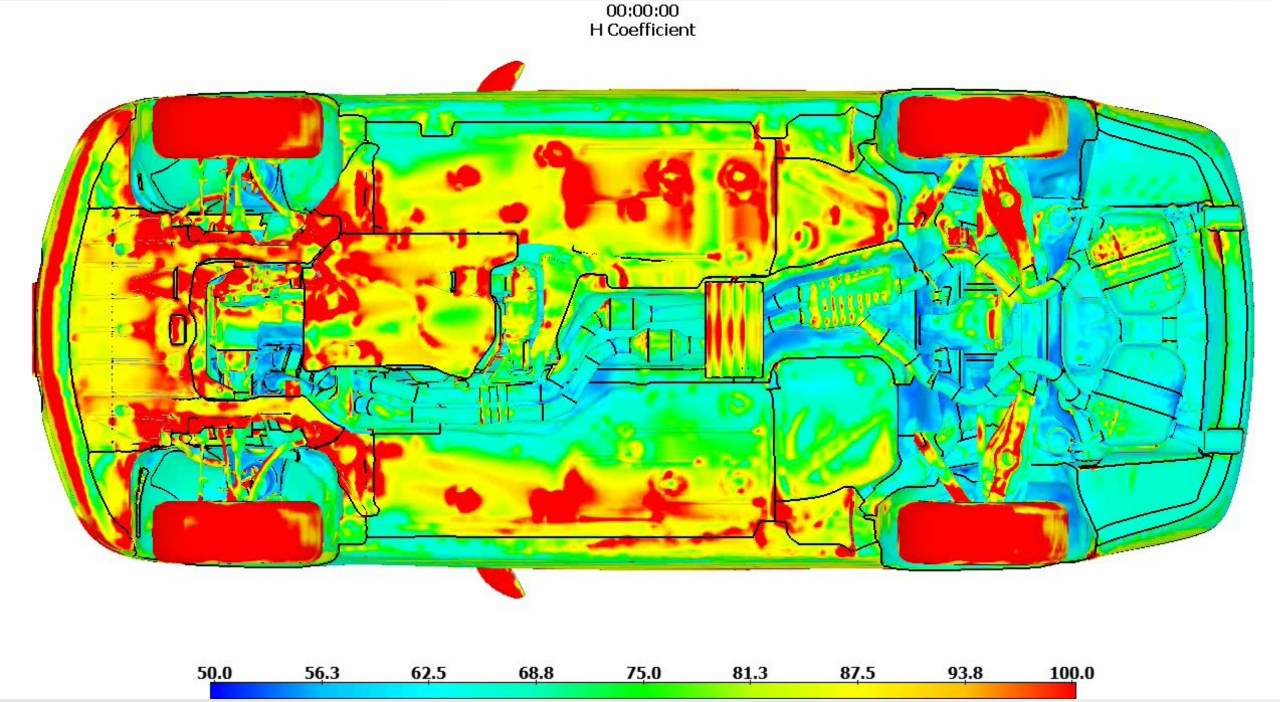


Heat Transfer Coefficients (W/m^2-K)

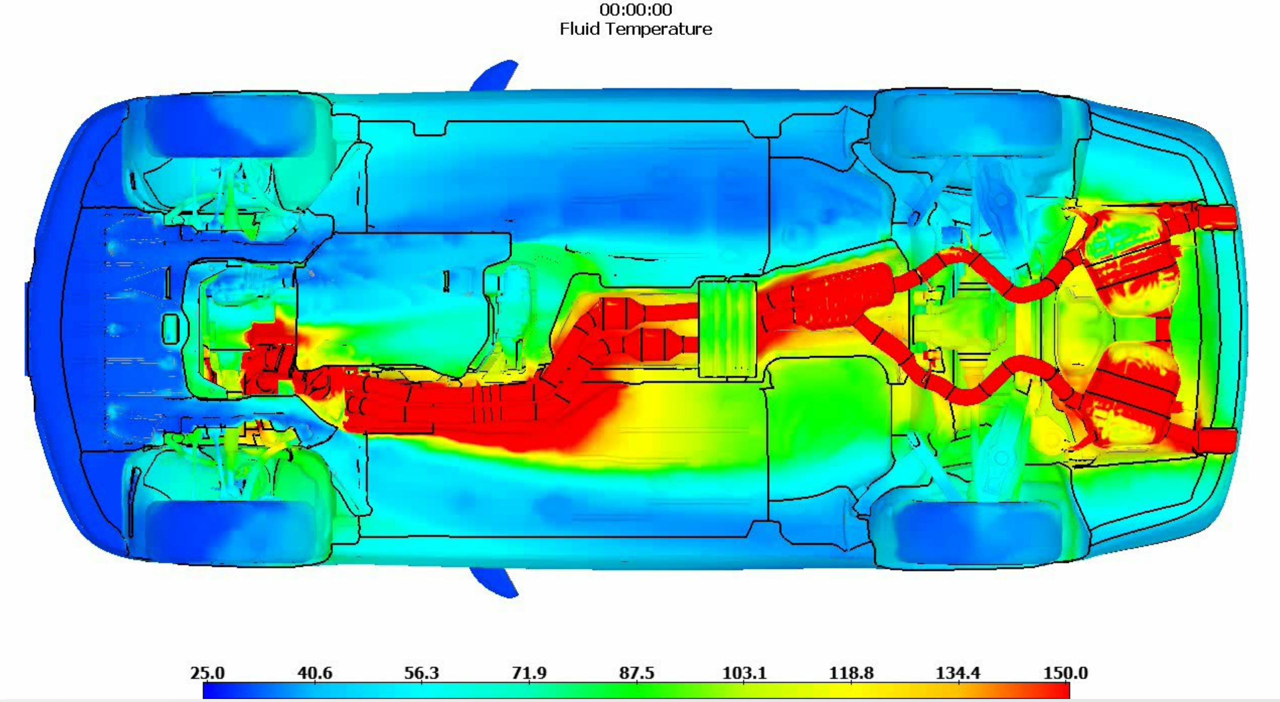


Fluid Temperatures (°C)

Soak Results: Underbody Boundary Conditions

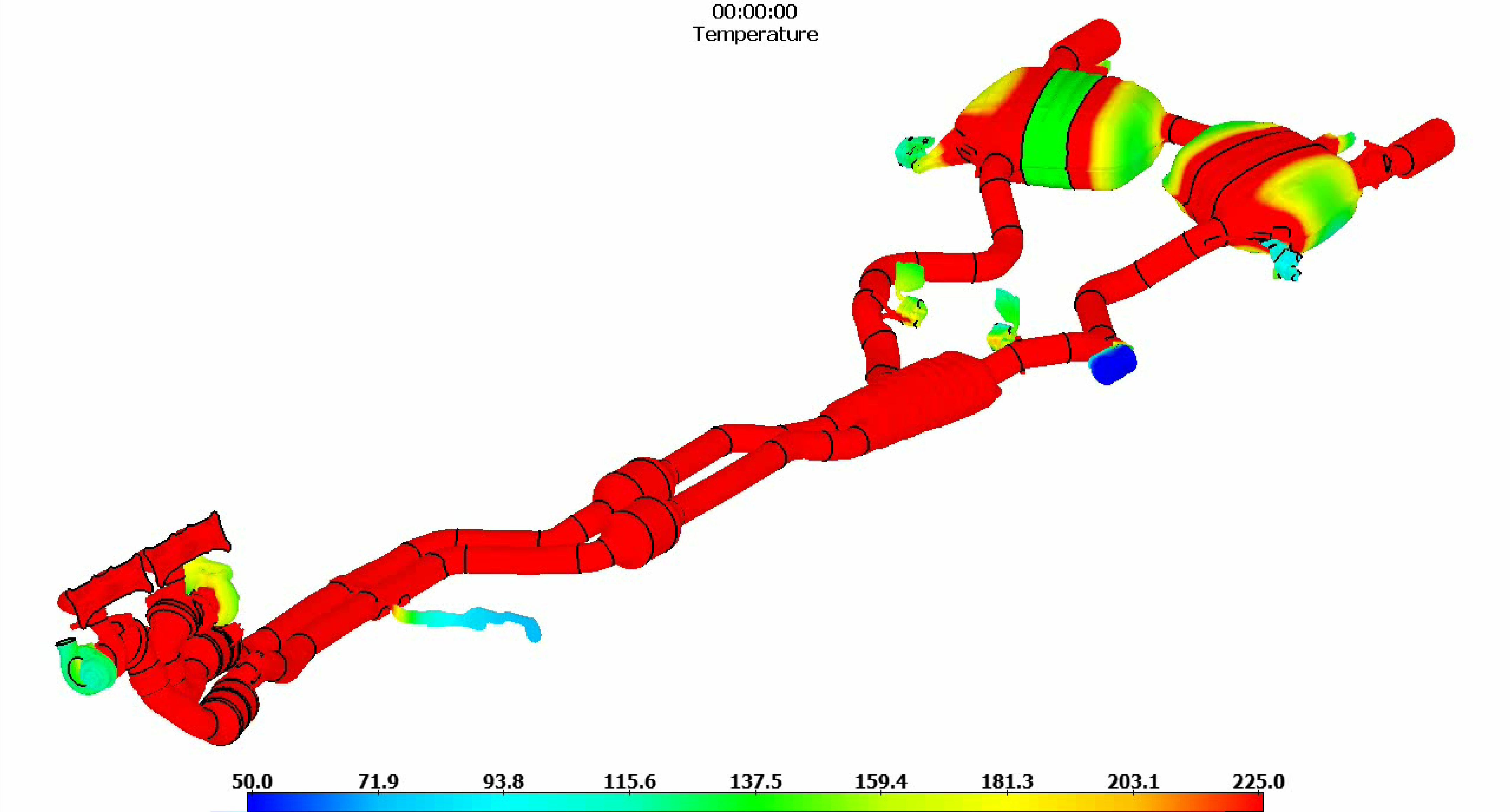


Heat Transfer Coefficients (W/m^2-K)

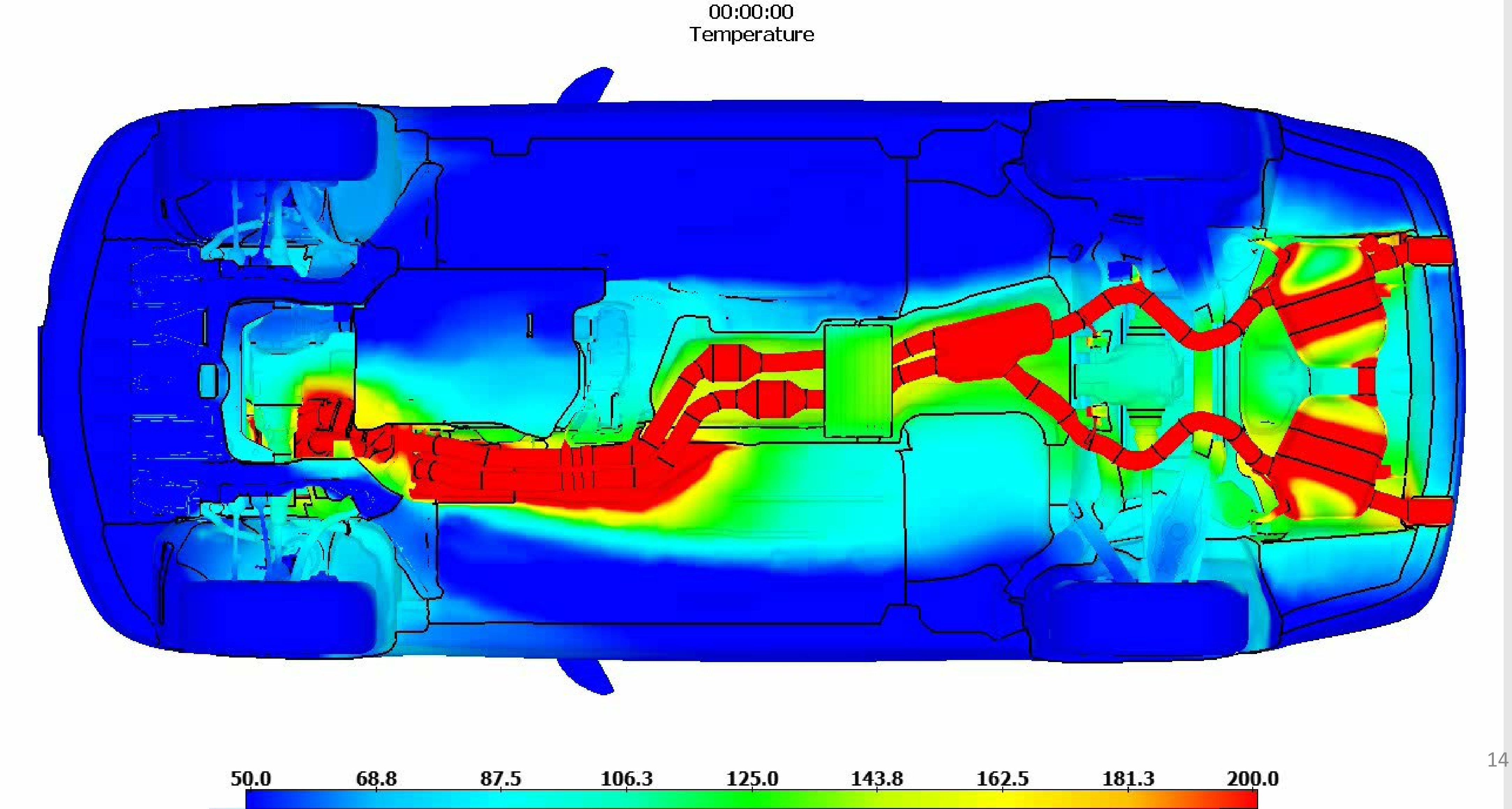


Fluid Temperatures (°C)

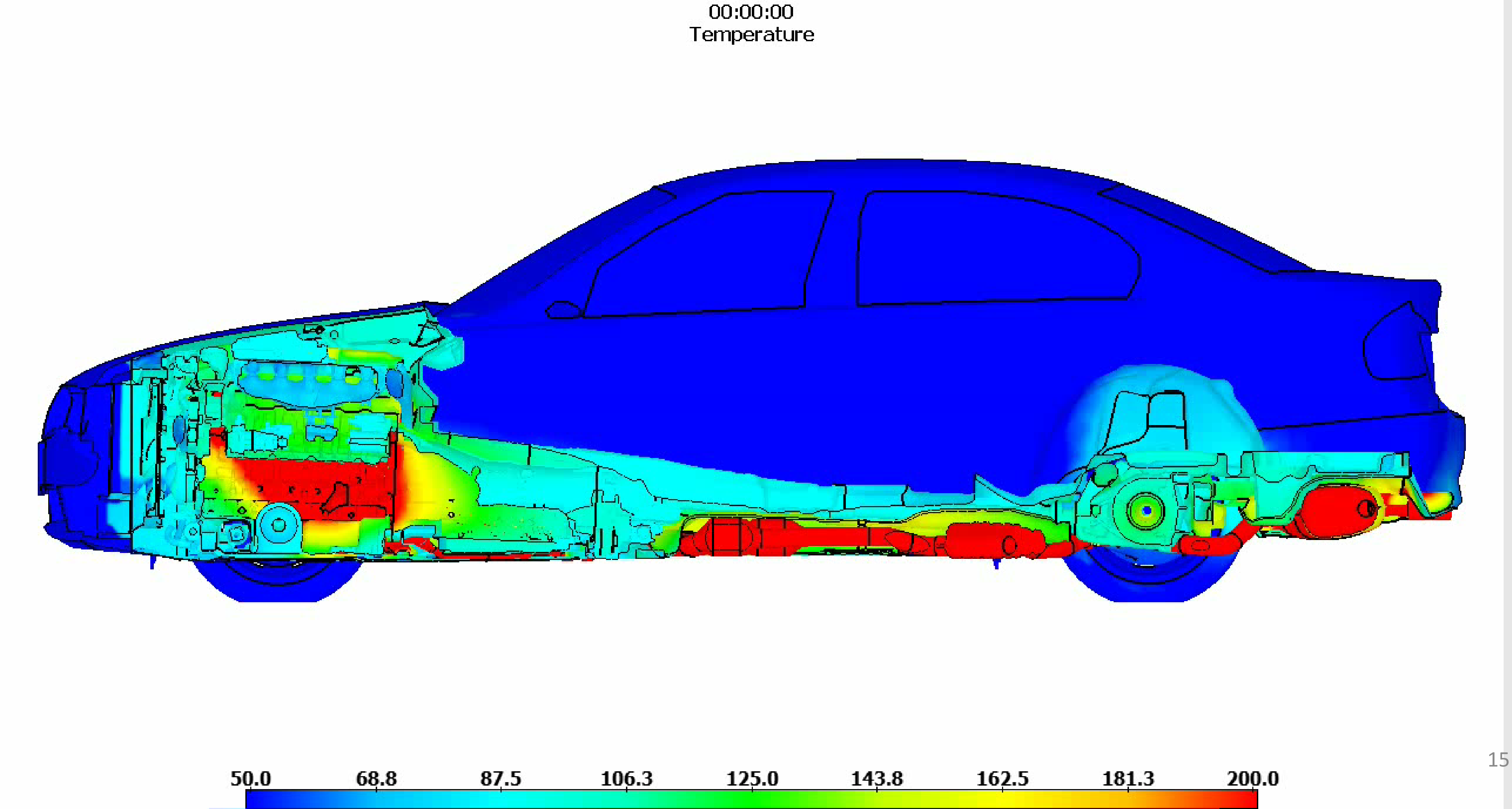
Soak Results: Surface Temperatures



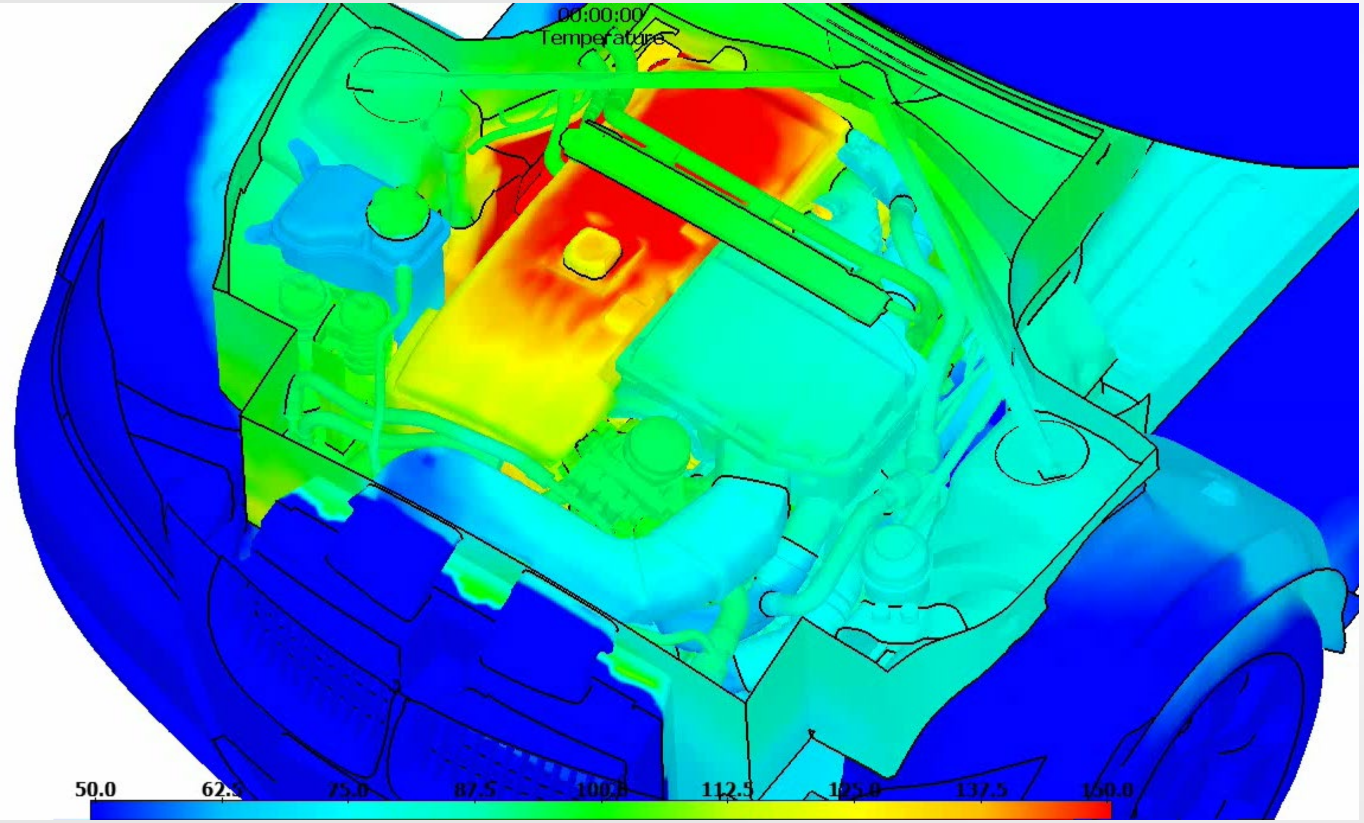
Soak Results: Surface Temperatures

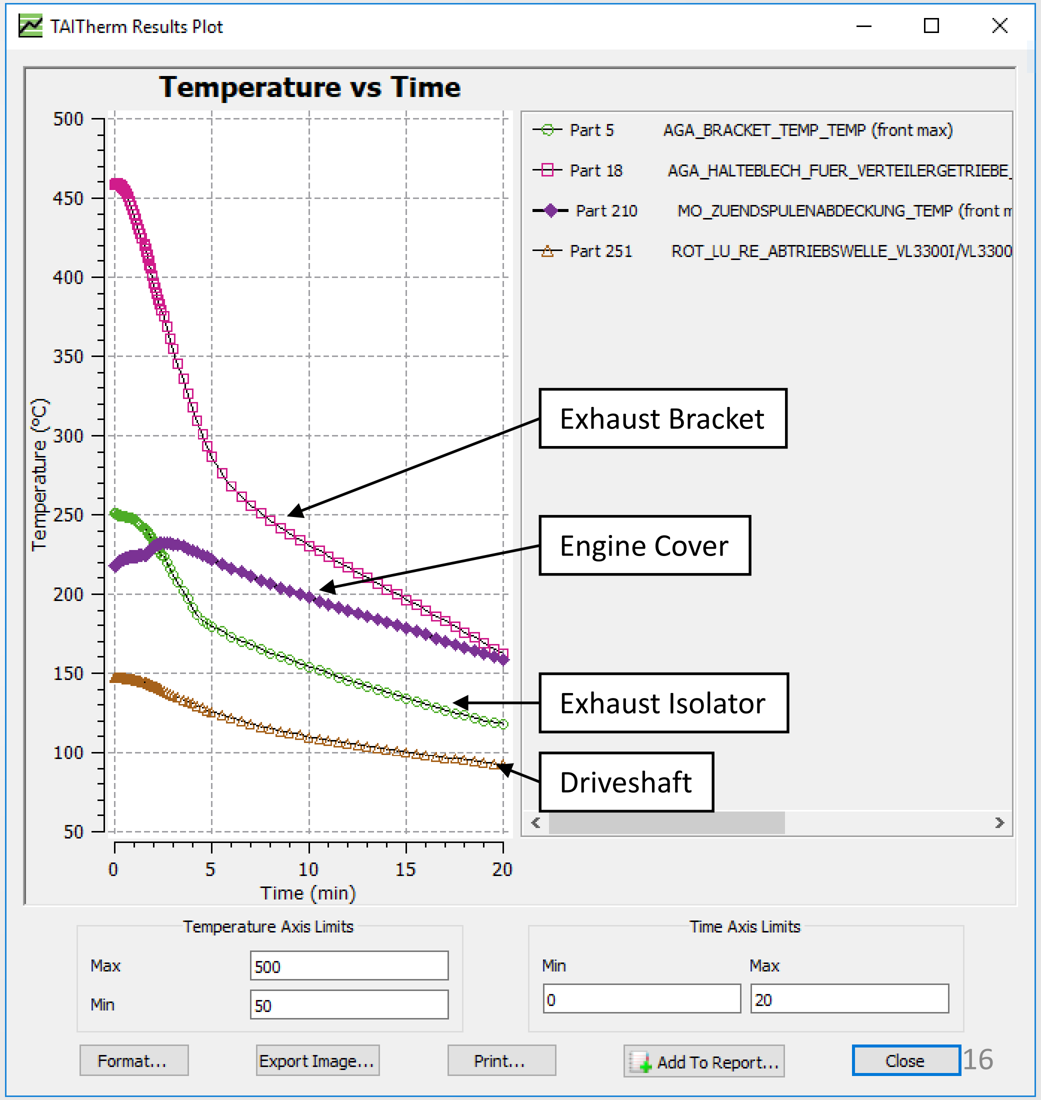


Soak Results: Surface Temperatures

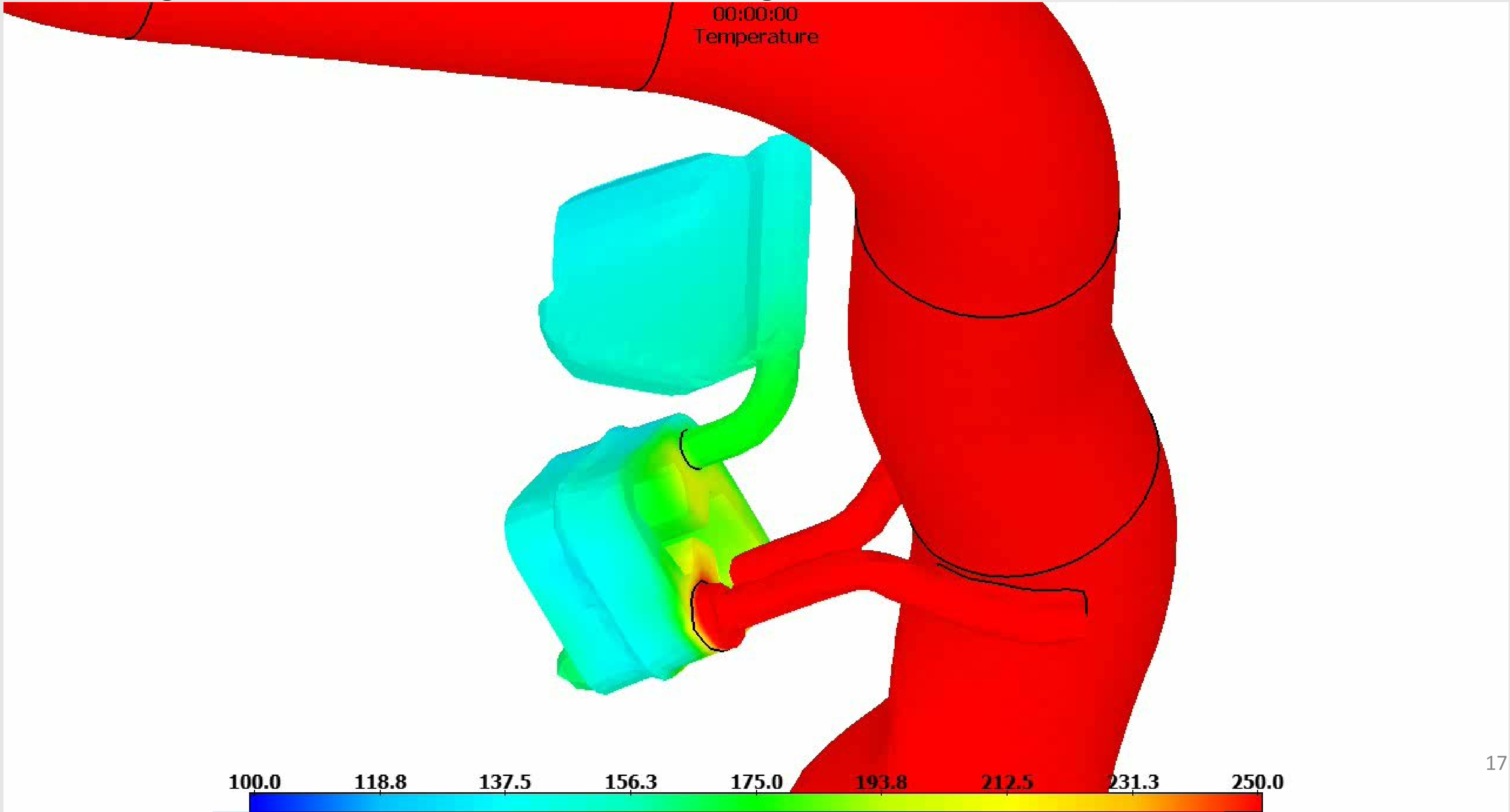


Soak Results: Surface Temperatures





Component-Level Temperature Predictions



Additional Post Processing Possibilities

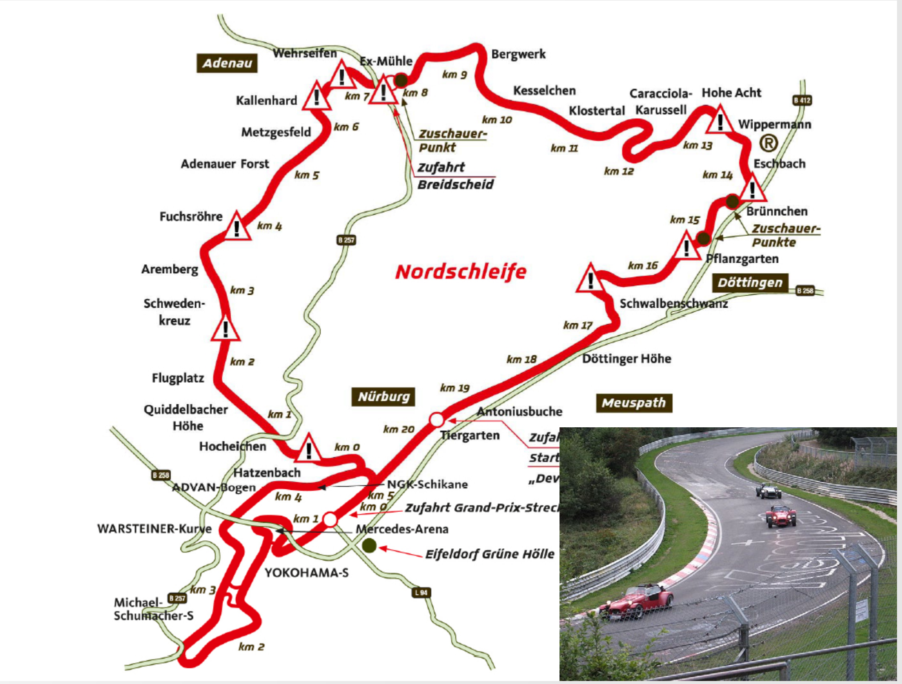
- Design temperatures
  - Part status: exceeding, near limit, or within limit
- Relations mode
  - Determine contributing heat sources
- Results export

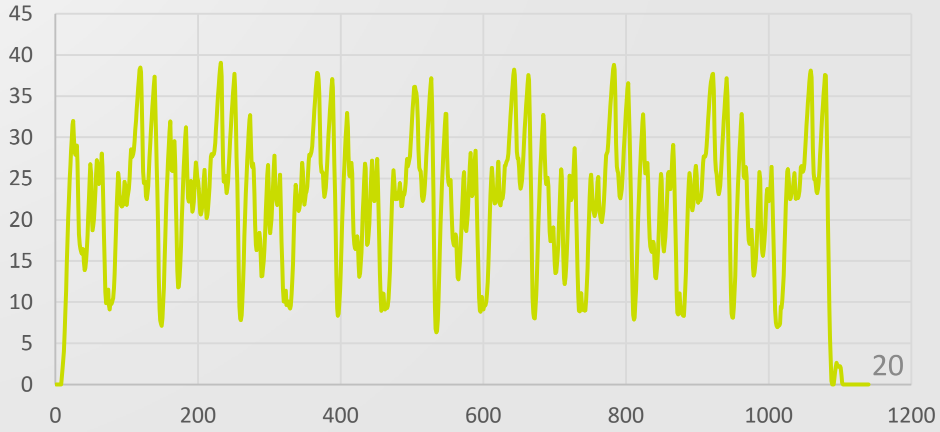
Conclusions

- CoTherm can be used to help simulate complex transient scenarios
- Peak component temperatures can be predicted under soak conditions
- The pseudo-transient coupling method is a good tradeoff between accuracy and run time for many automotive scenarios, such as idles and soaks

Where do we go from here?

- More complex transient scenarios may require more advanced methods
- Complex scenarios may be too computationally expensive to run with a standard pseudo-transient coupling process
- Join us next time for our webinar on modeling **Drive Cycles**





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Questions?

Thanks for your attention!

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