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VEHICLE COMFORT MODELLING & TESTING

Dr D R Bridge

MIRA Ltd.

Coventry University
Cranfield University
Jaguar
Land Rover
MIRA
Ricardo
Tata
WMG Innovative Solutions
Zytek Automotive

AIM

To evaluate Radtherm Comfort Module under highly transient conditions:-

- Typical AC pull-down scenario
- Typical heater warm-up scenario
- Both unrealistic of driver behaviour (no comfort regulation)

OVERVIEW

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- Context
- Model set-up
- Model verification against test
- Comfort measurements
- AC pull-down results
- Heater warm-up results
- Conclusions

CONTEXT

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- Work conducted as part of a larger project looking at all aspects Low Carbon Vehicle Technology
- Project partners shown below
- Comfort assessment as part of a sub-project involving:-
  - MIRA
  - Coventry University
  - Jaguar Land Rover

Coventry University · Cranfield University · Jaguar · Land Rover · MIRA · Ricardo · Tata · WMG Innovative Solutions · Zytek Automotive

Model Set-Up

- Vehicle based on JLR LW XJ
- Construction based on known material parameters and estimations based on expected part weights
- Final model had 278 parts and 158k elements resulting in 665K thermal nodes
- Model run on 4 processors & took overnight to complete

Model Set-Up – Parts

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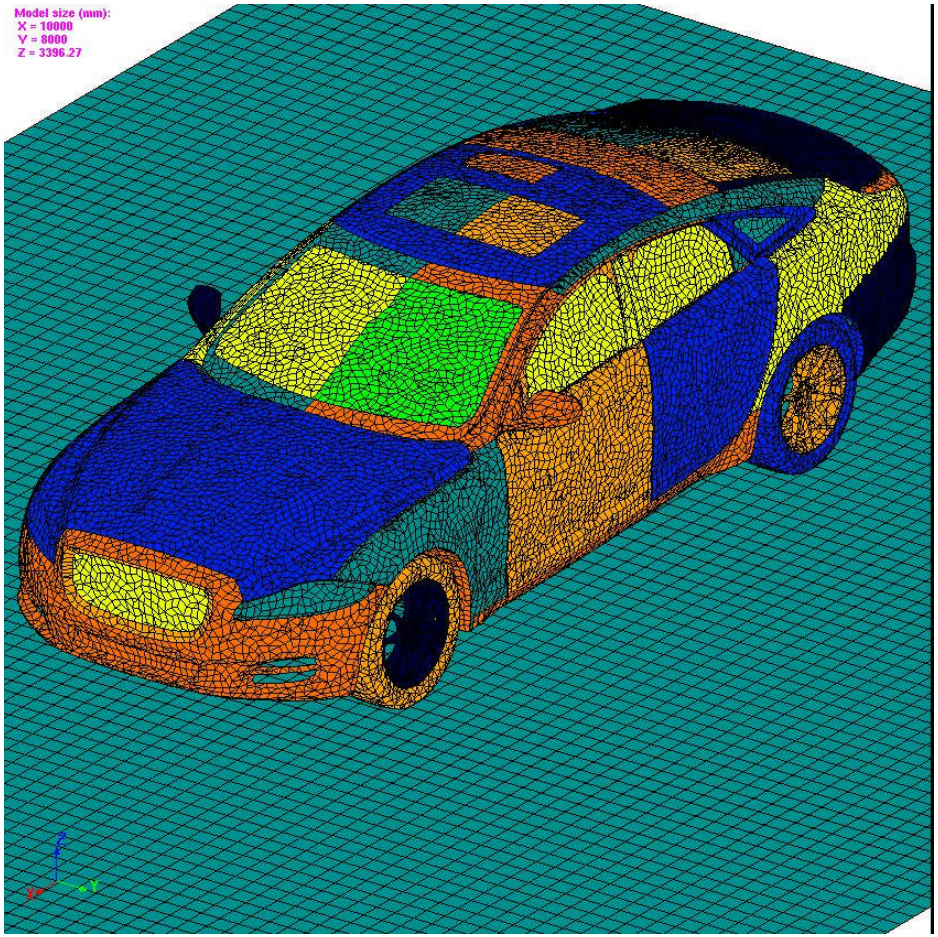
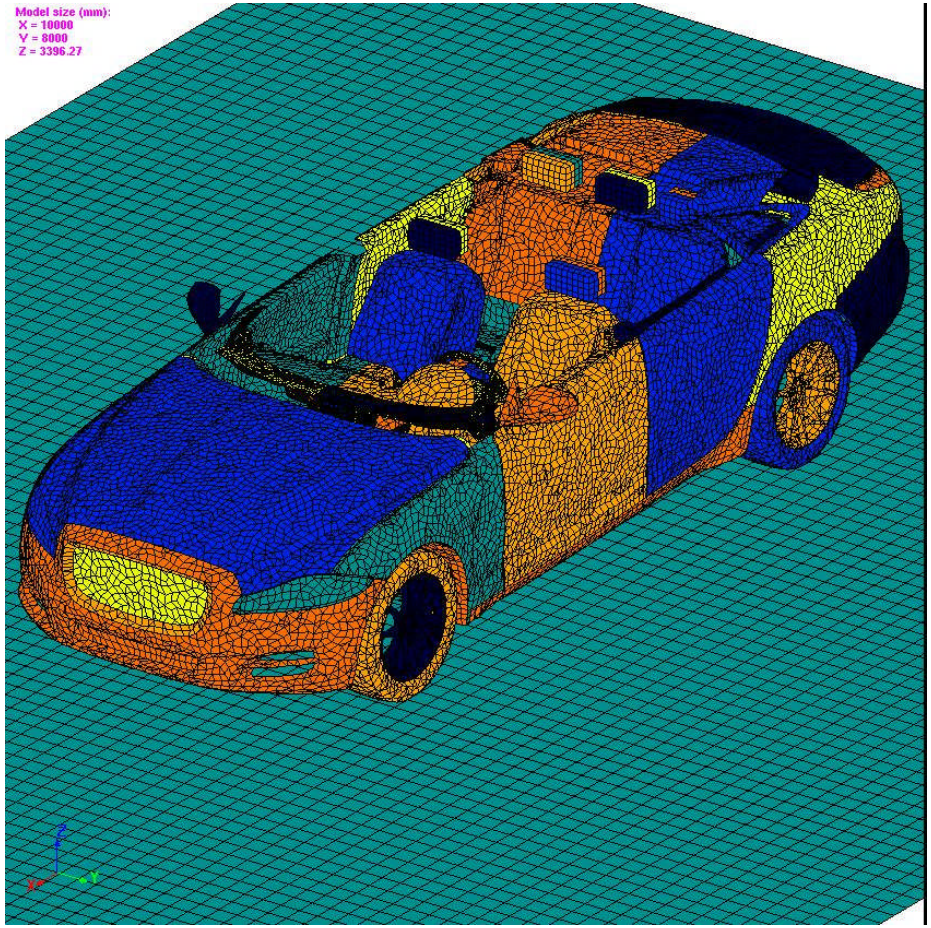
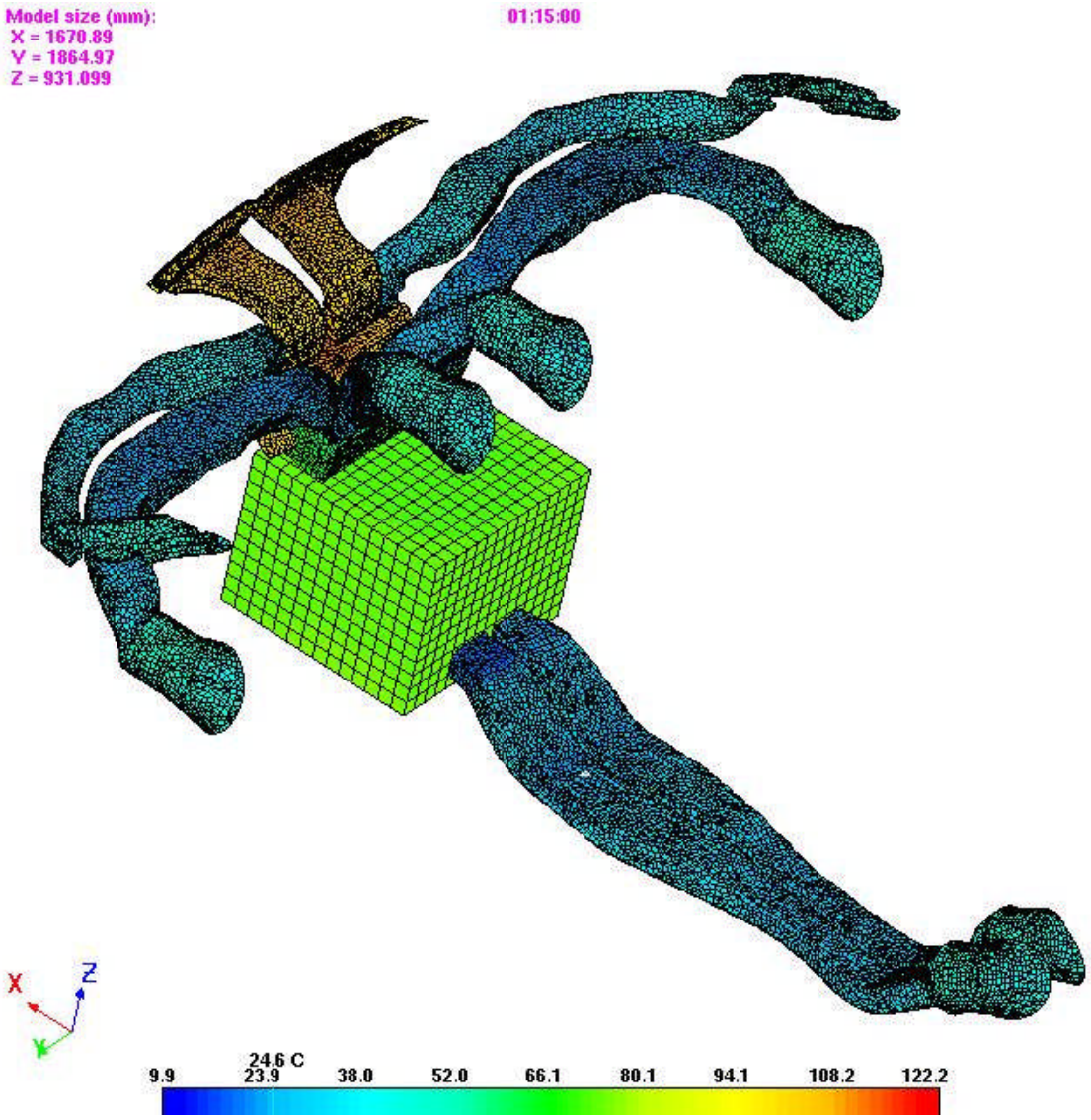
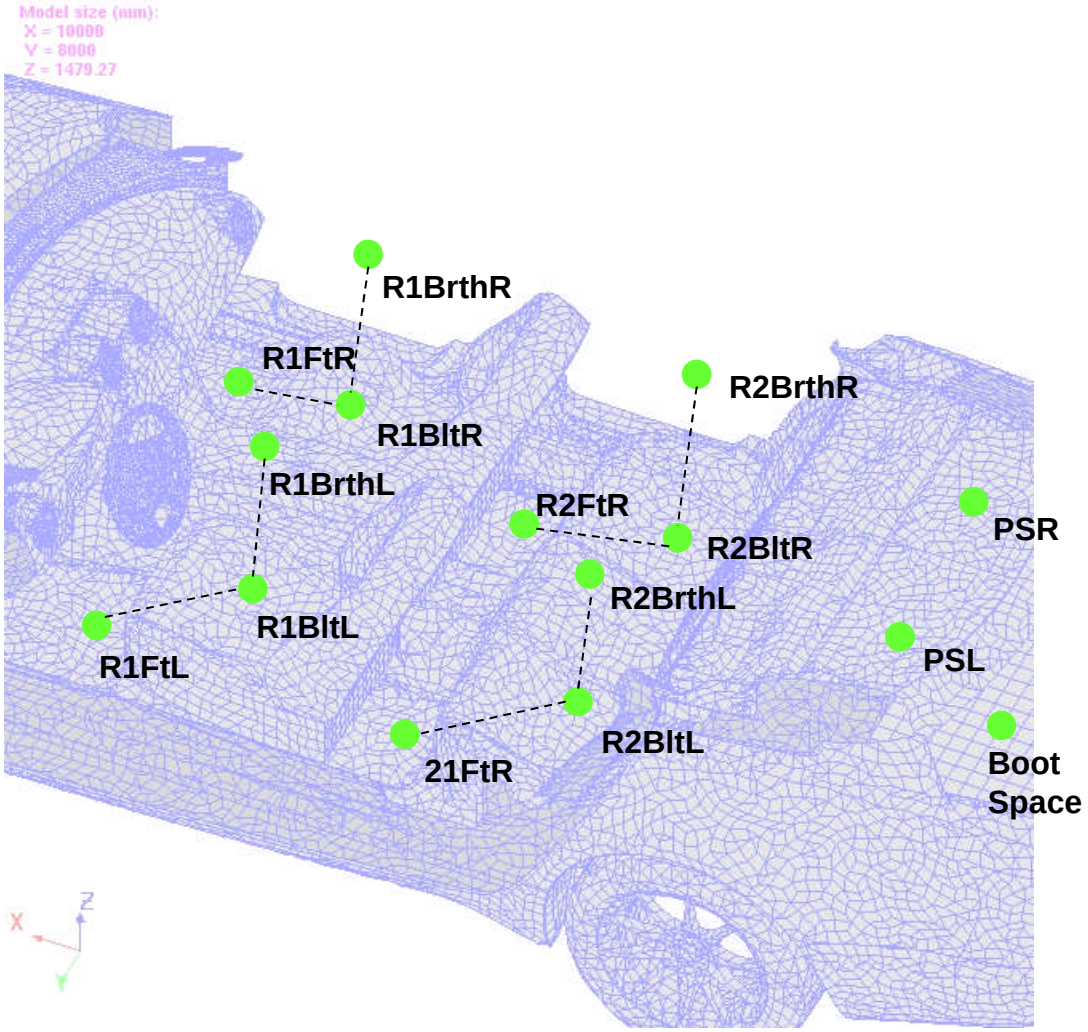




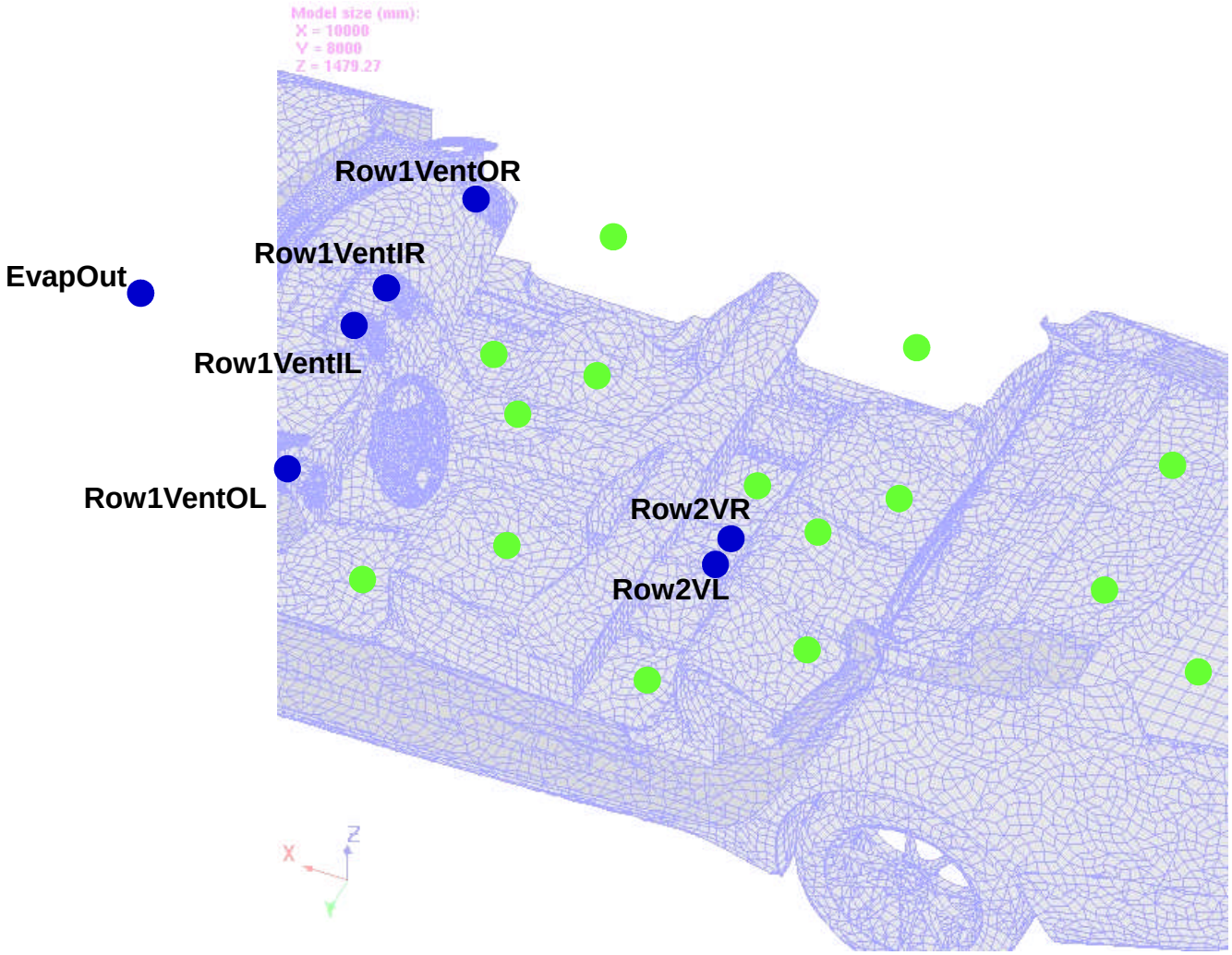
Ducting



Interior Cabin Nodes



Inlet Nodes (AC)



Inlet Nodes (AC)

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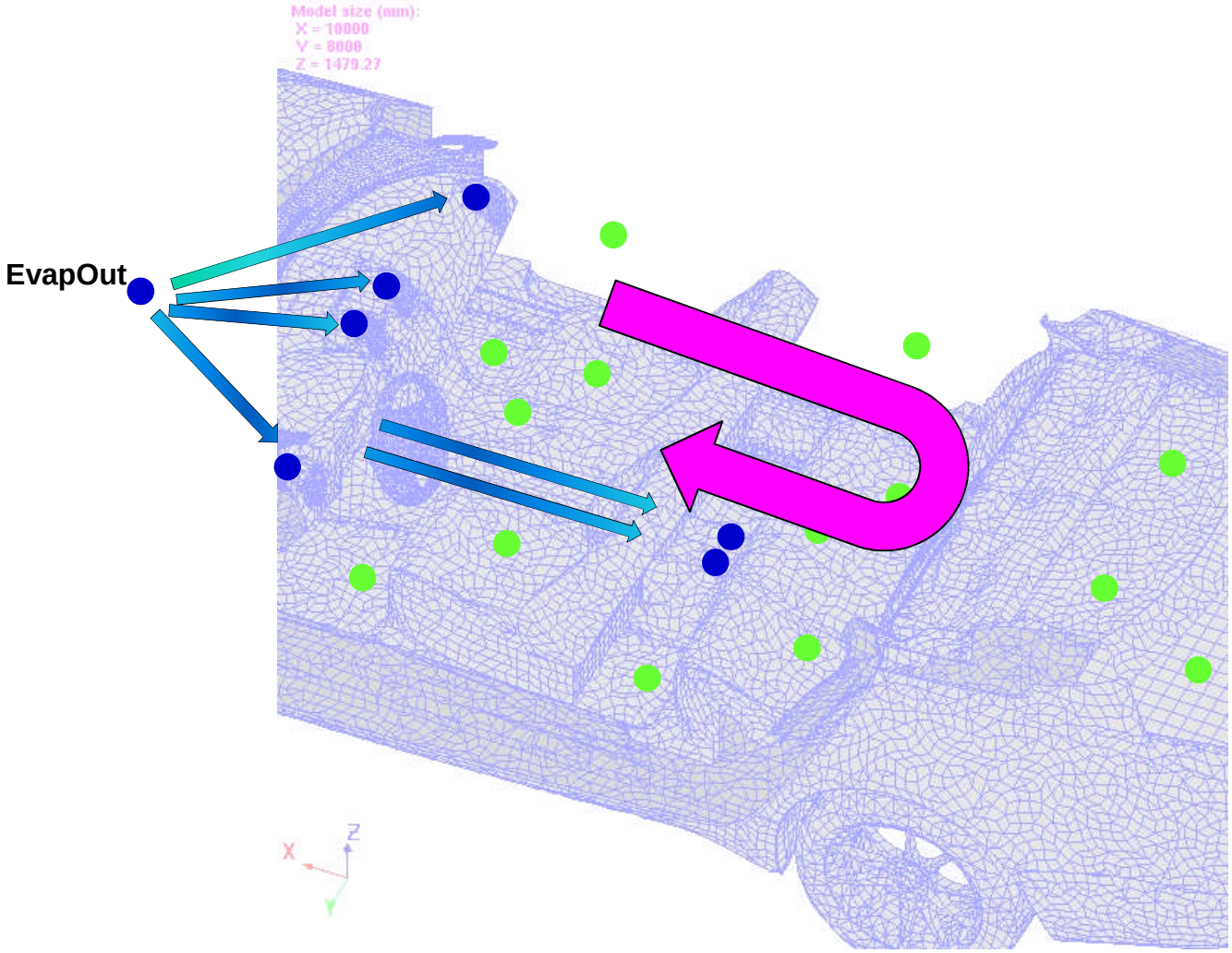
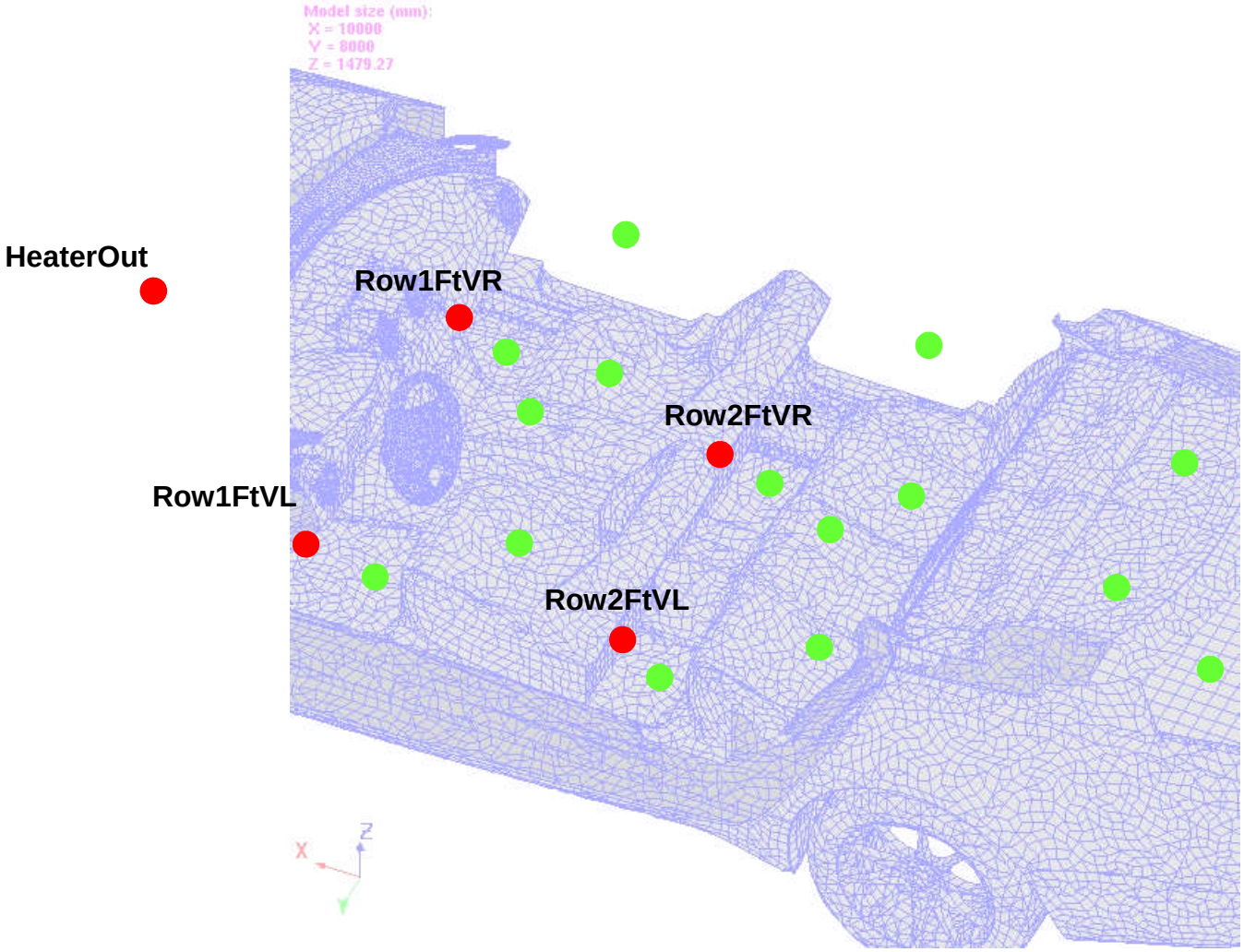


Inlet Nodes (Heater)



Inlet Nodes (Heater)

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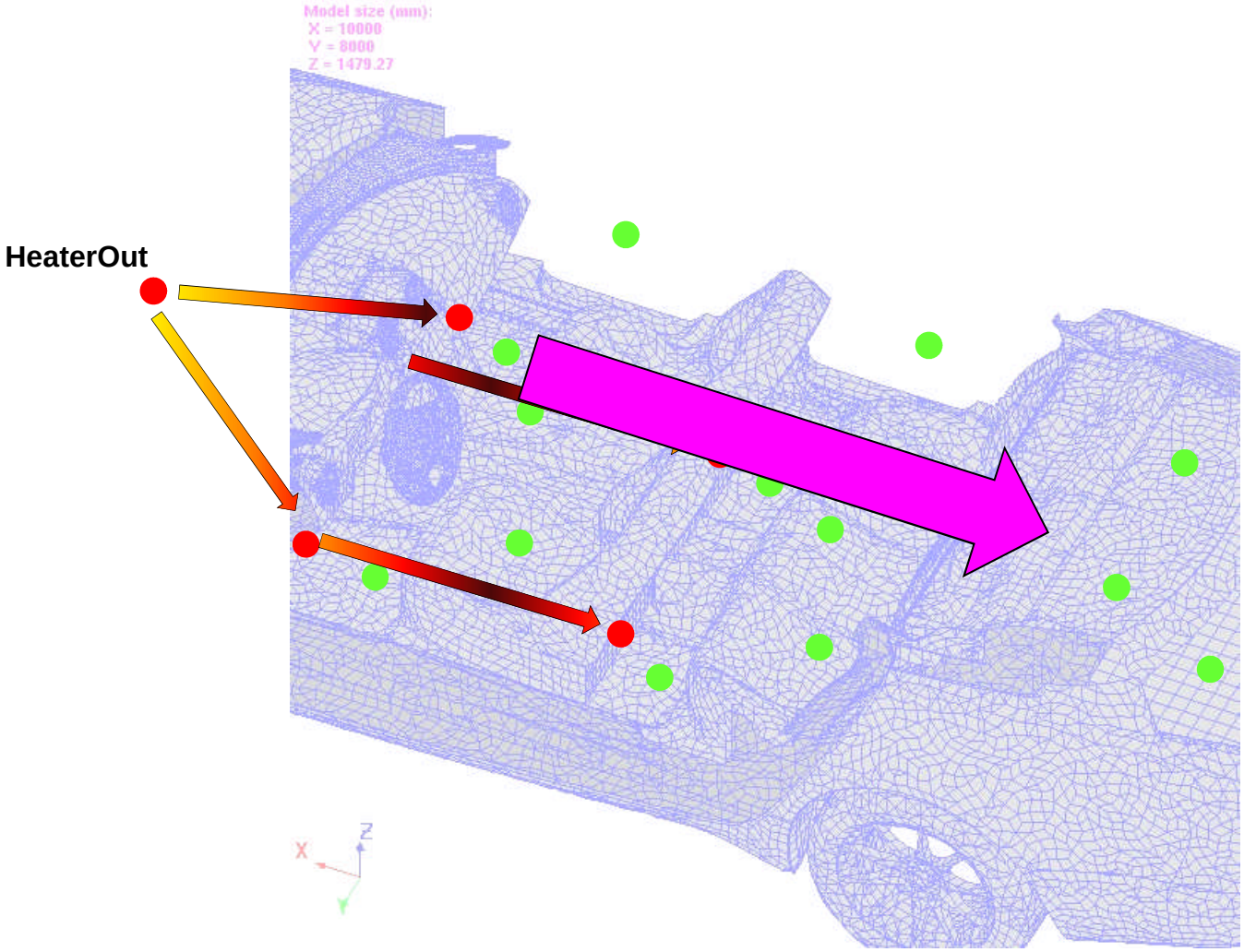
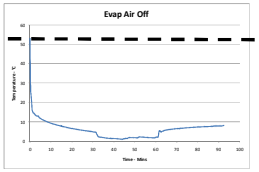


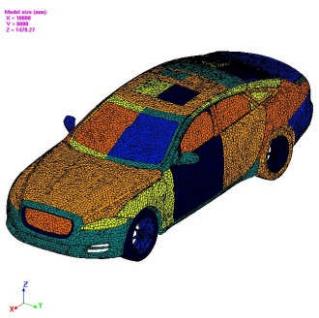
Model Process - AC

Boundary condition I/P

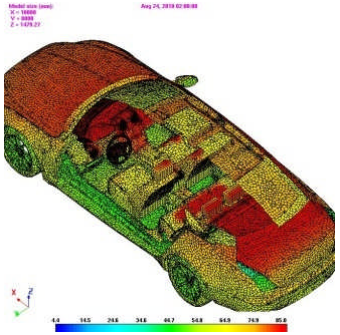
New boundary condition I/P



- Evap curve
- Face 2 face paths
- Manikin airflows

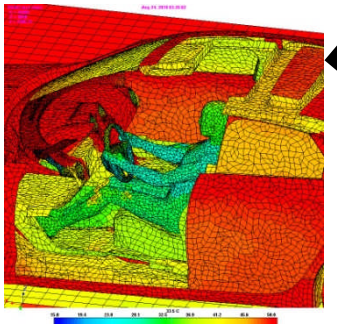


2 hour soak



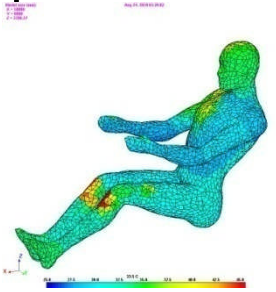
Initialise Transient Soln

90 min run

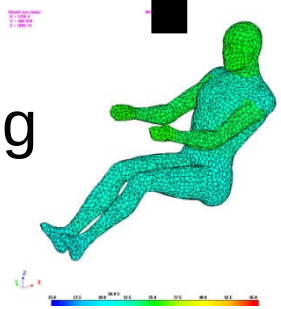


Vehicle parameters

Comfort parameters



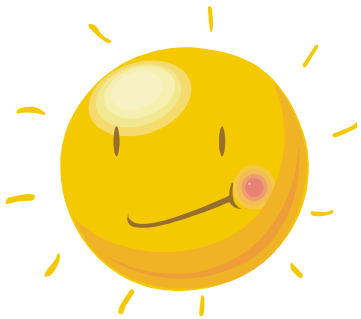
Pre-Conditioning



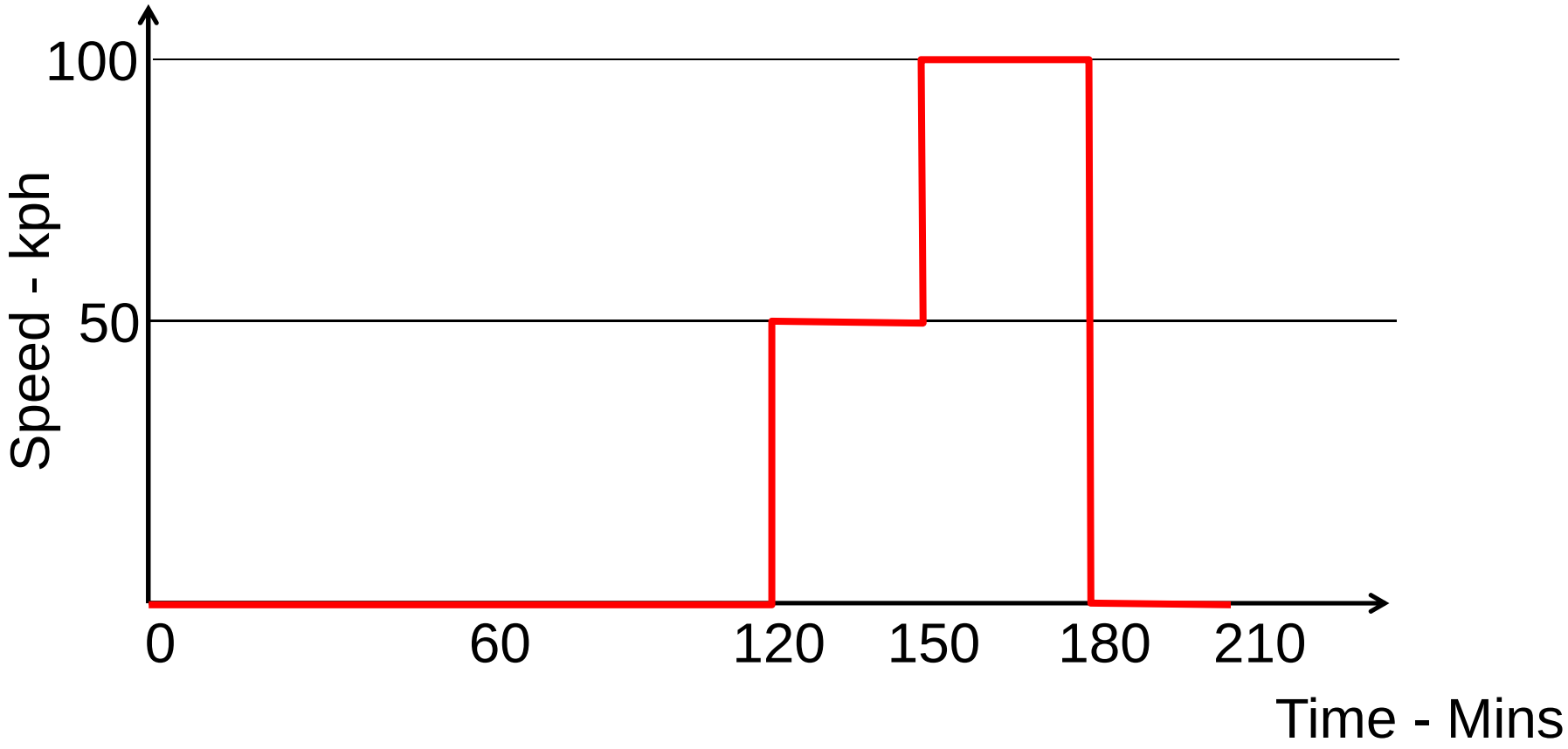
Step Rate

- On restart, model diverges if step rate is too fast:-
  - Every 1 seconds for 10 seconds
  - Every 2 seconds for 10-30 seconds
  - Every 5s for 30 to 60 seconds
  - Every 10s for 1 – 2 mins
  - Every 0.5 mins for 2 – 5 mins
  - Every 1 min thereafter

AC Test



+ 43°C



Human Environment

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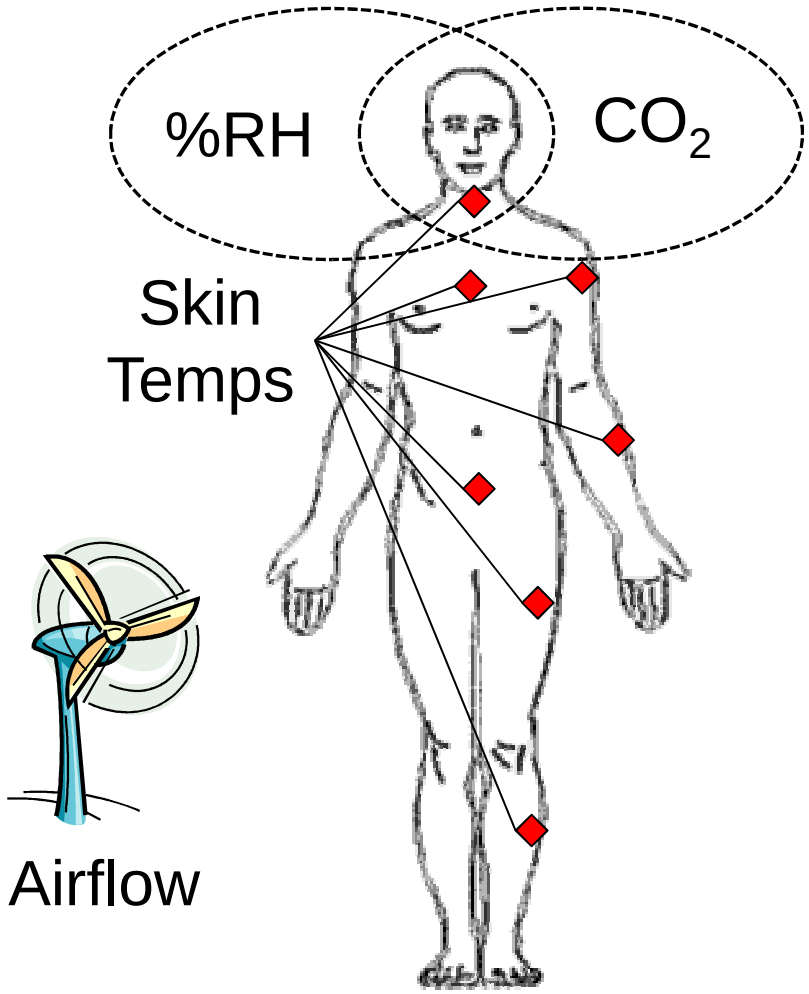
Air Temperature Stratification

Dew Point Stratification



Cabin Surfaces & Solar Loads

Vehicle Test

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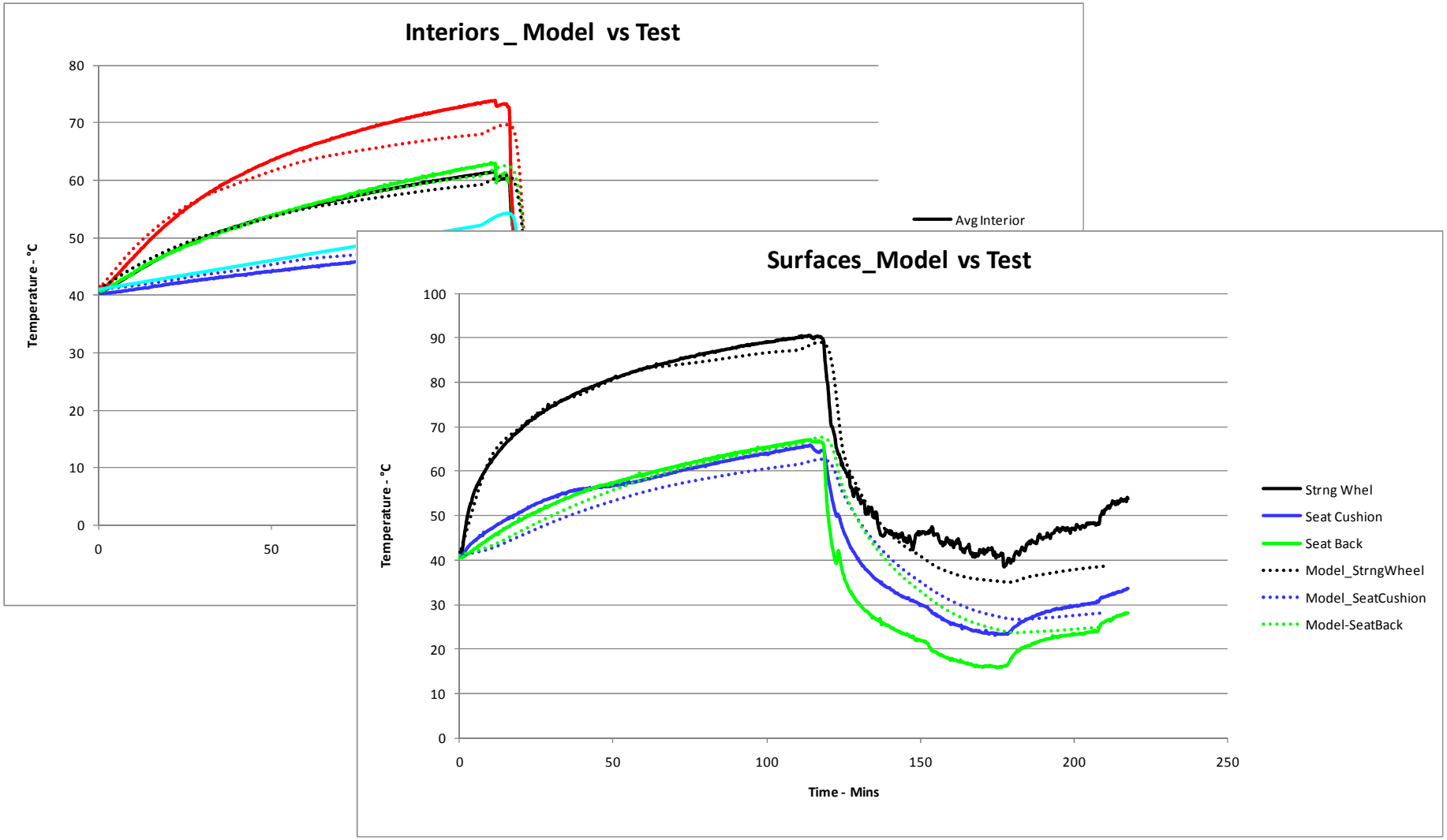
Vehicle Model vs Vehicle Test



Subjective Model Results

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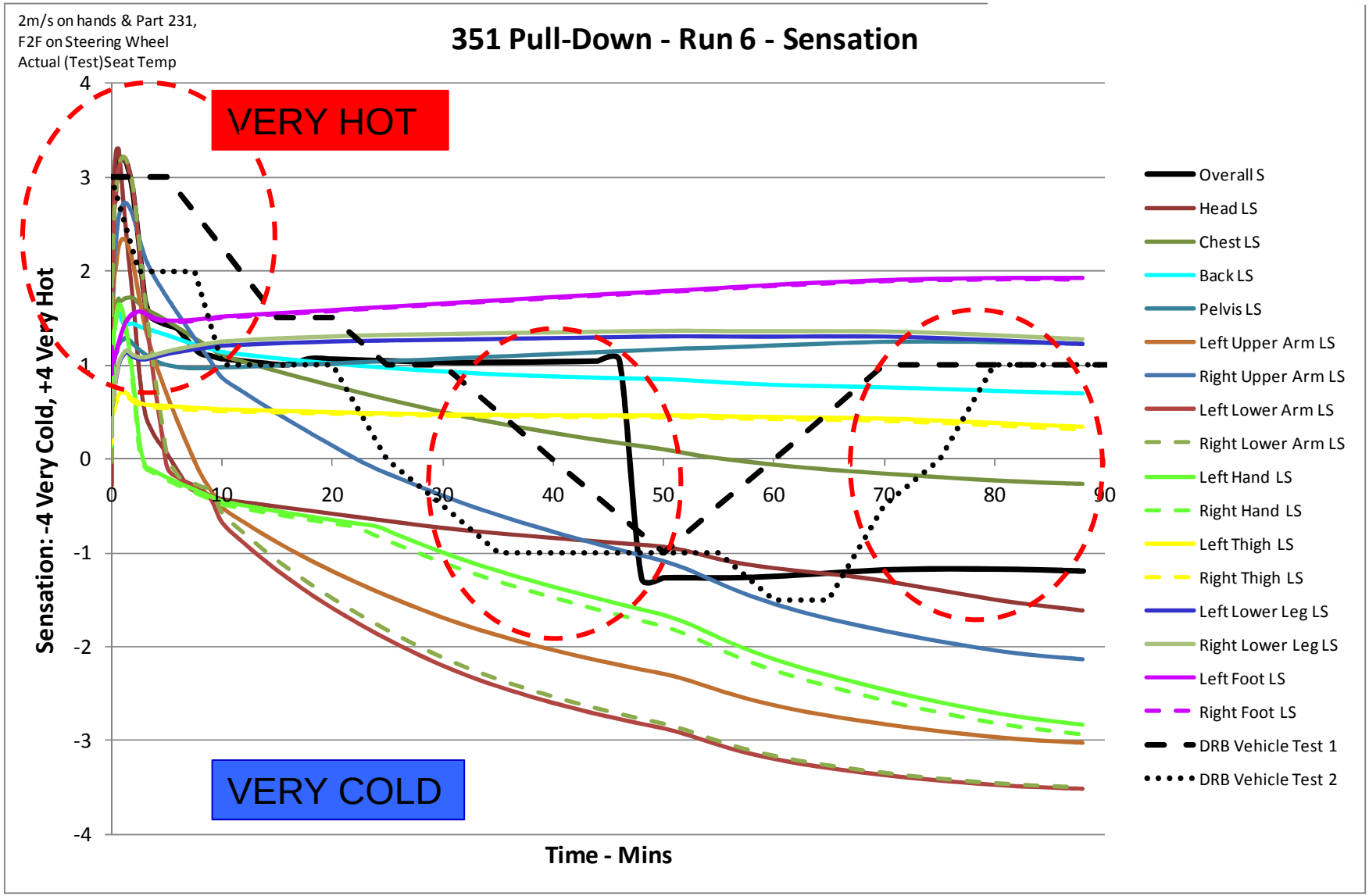
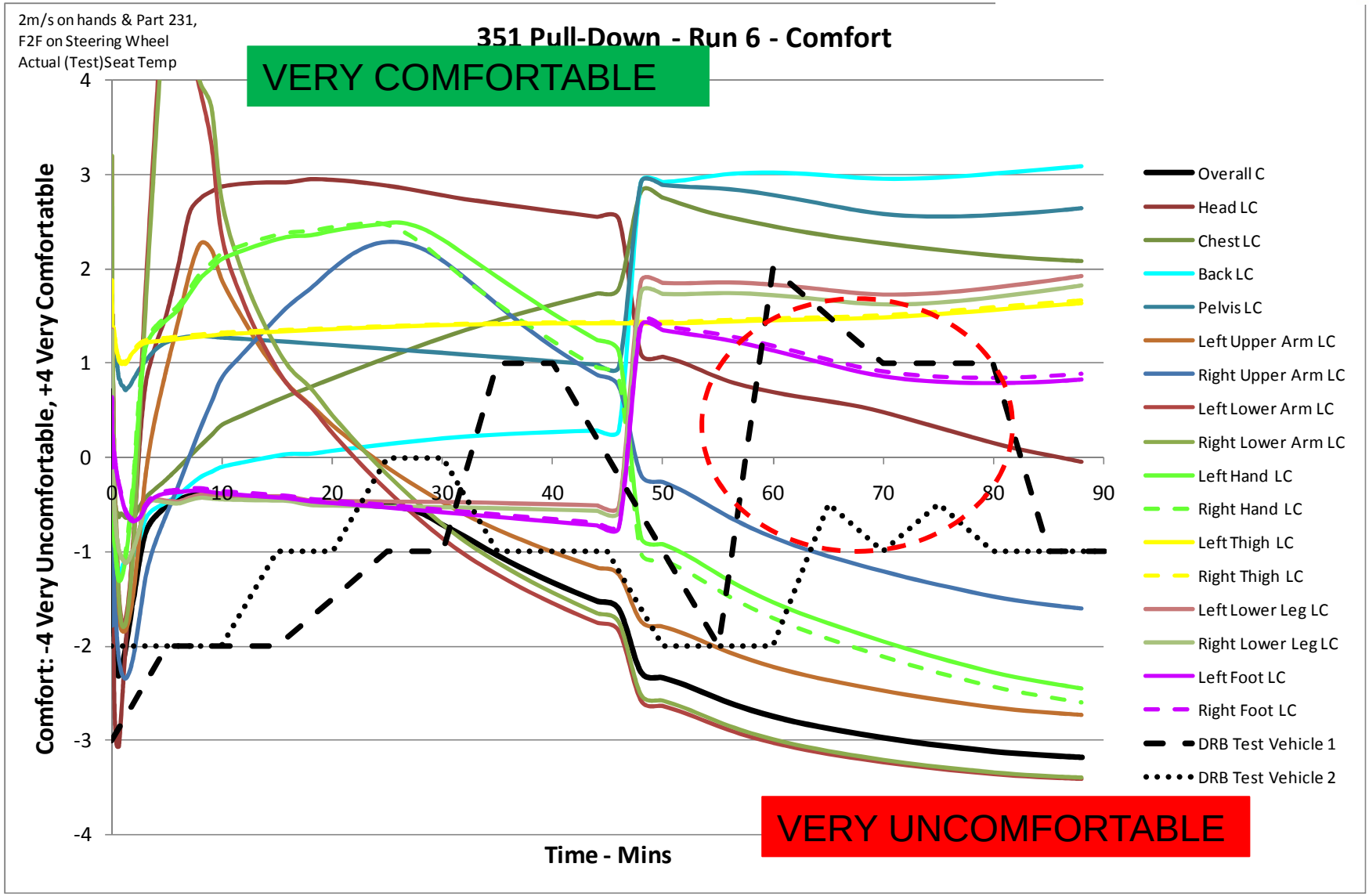


Subjective Model Results



Subjective Model Results

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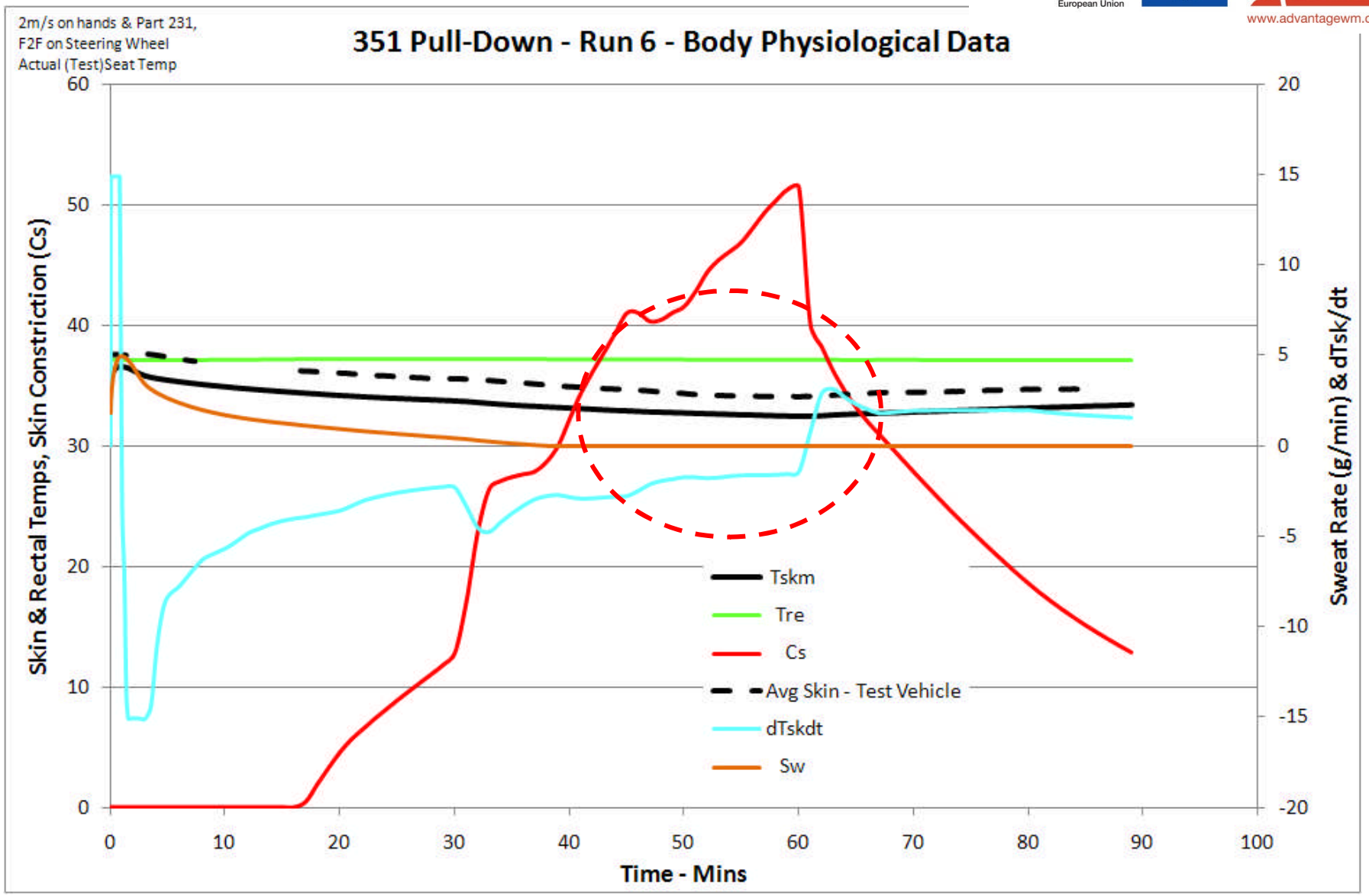

Vehicle Environment - AC

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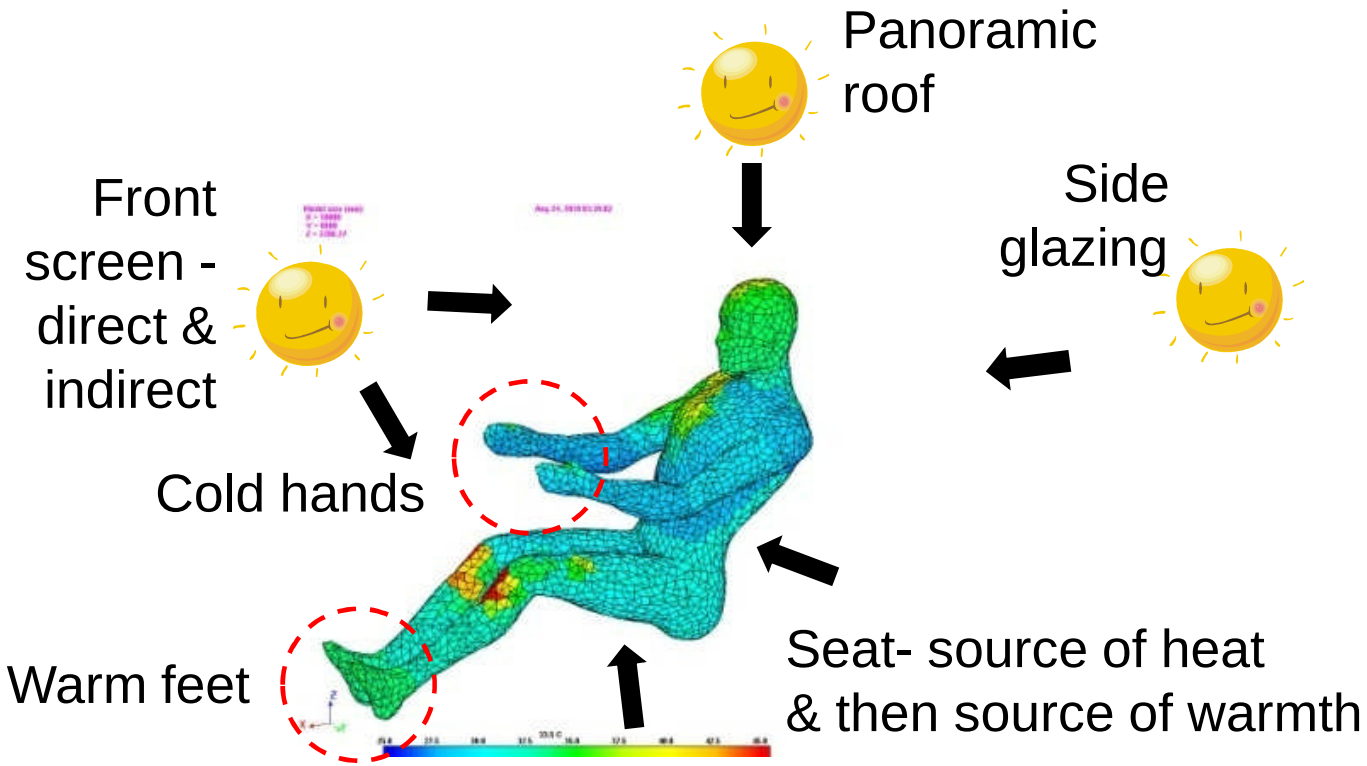
- Pull-down is highly transient
- Significant asymmetries



Model Process–Heater Warm-Up

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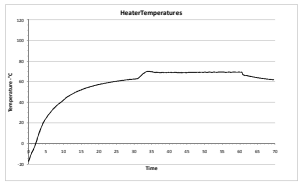
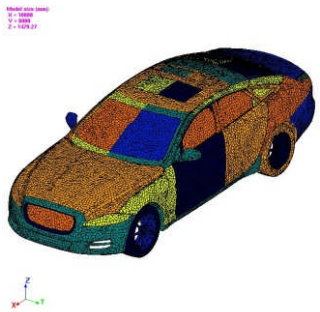
Boundary condition I/P

- Heater curve
- Face 2 face paths
- Manikin airflows

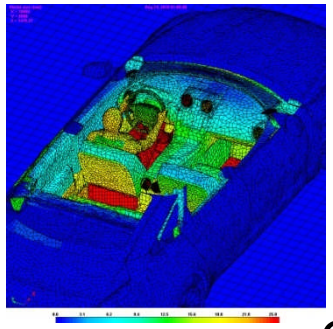


Vehicle parameters



Transient Soln

70 min run



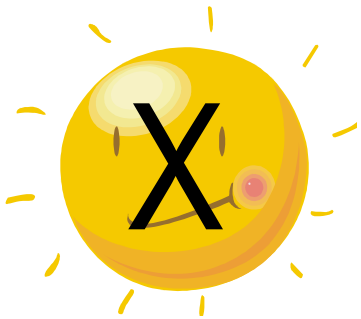
Comfort parameters

Pre-Conditioning

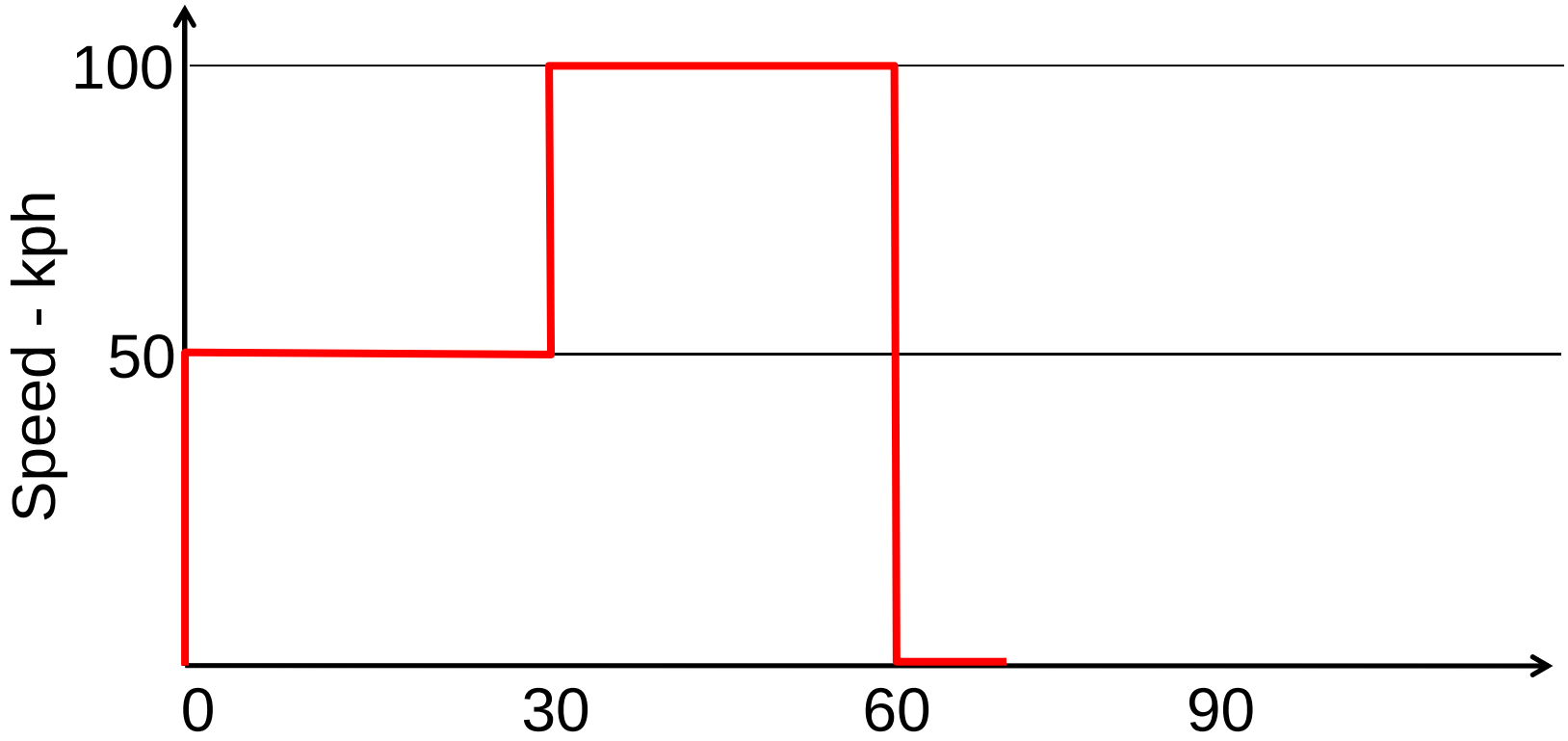
Step Rate

- Warm-up could tolerate a coarser step rate
  - Every 0.2 mins for 0 – 1 minutes
  - Every 0.8 mins for 1 – 5 minutes
  - Every 1 min for 5 - 10 minutes
  - Every 2 mins for 10 – 60 minutes
  - Every 1 min for 60 – 70 mins

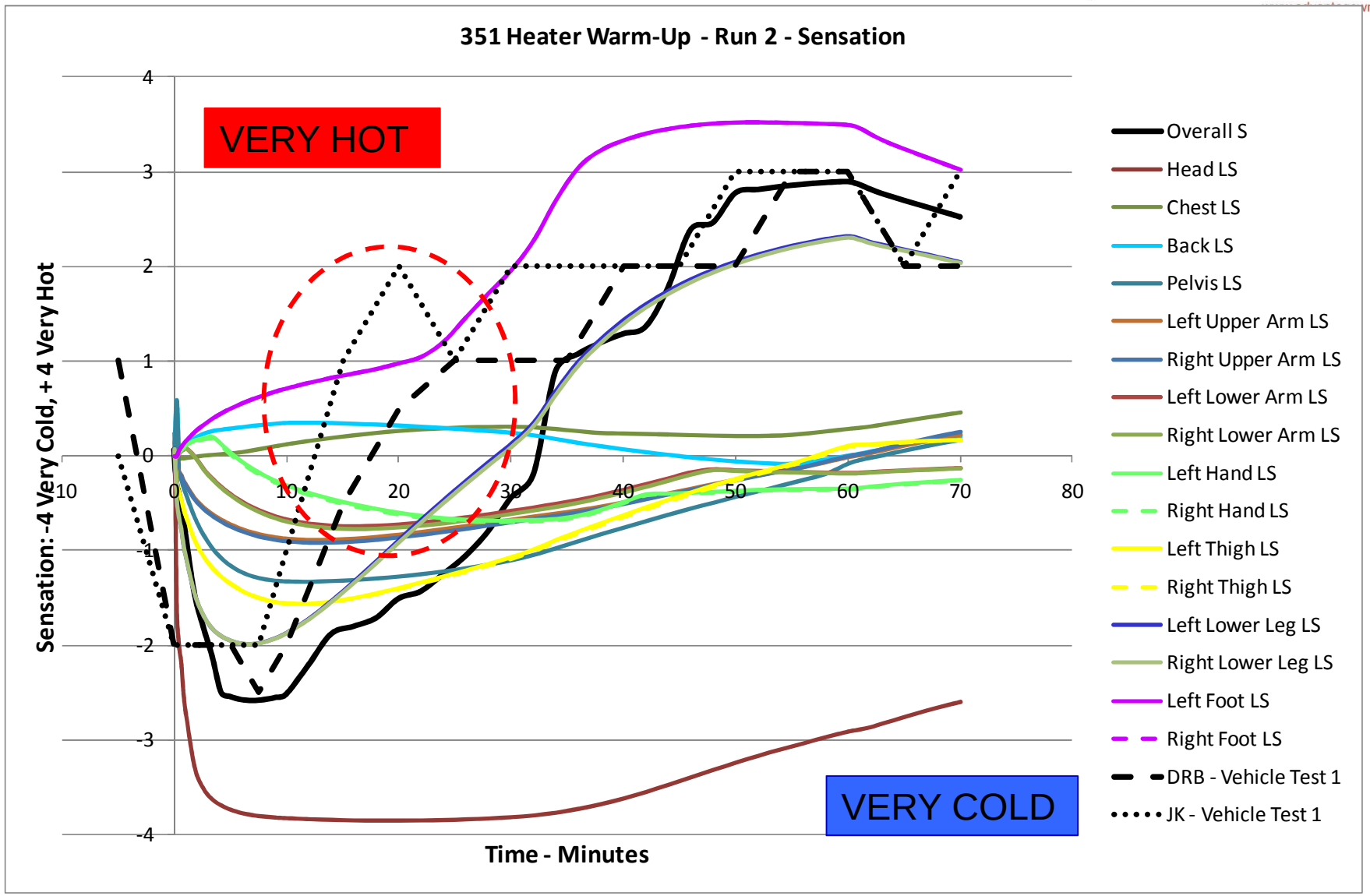
Heater Test



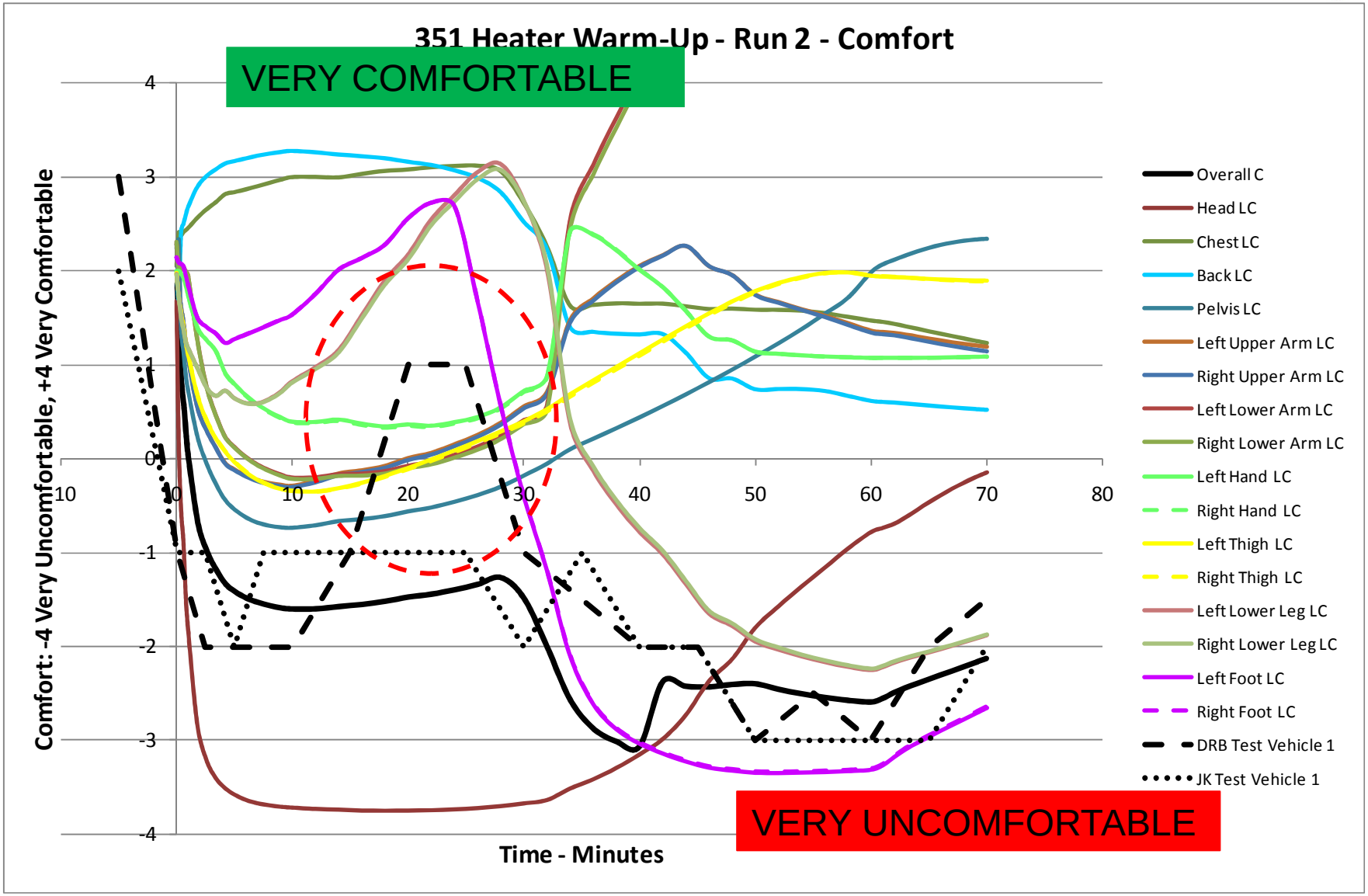
- 18°C



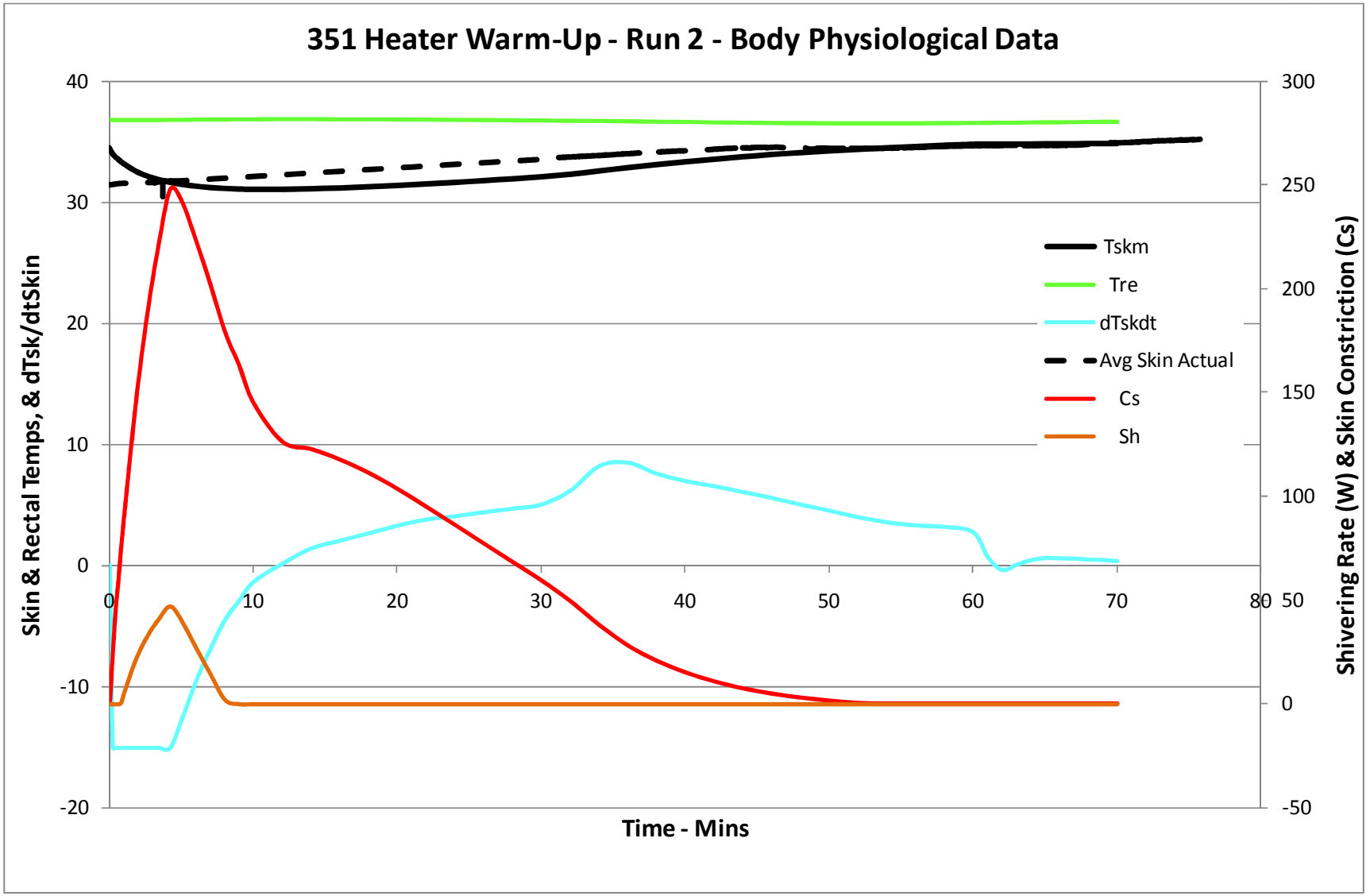
Subjective Model Results



Subjective Model Results



Subjective Model Results



Vehicle Environment - Heater

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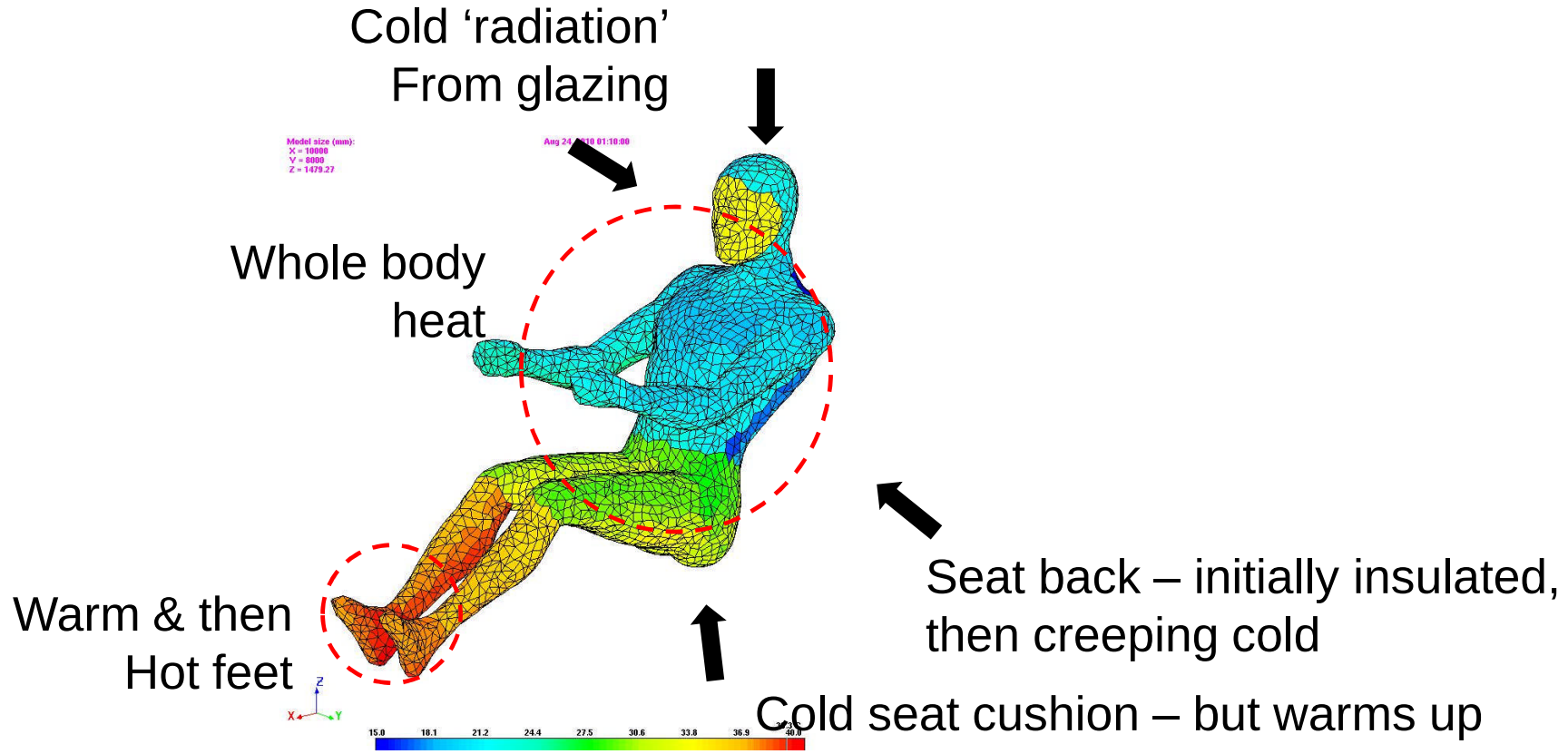
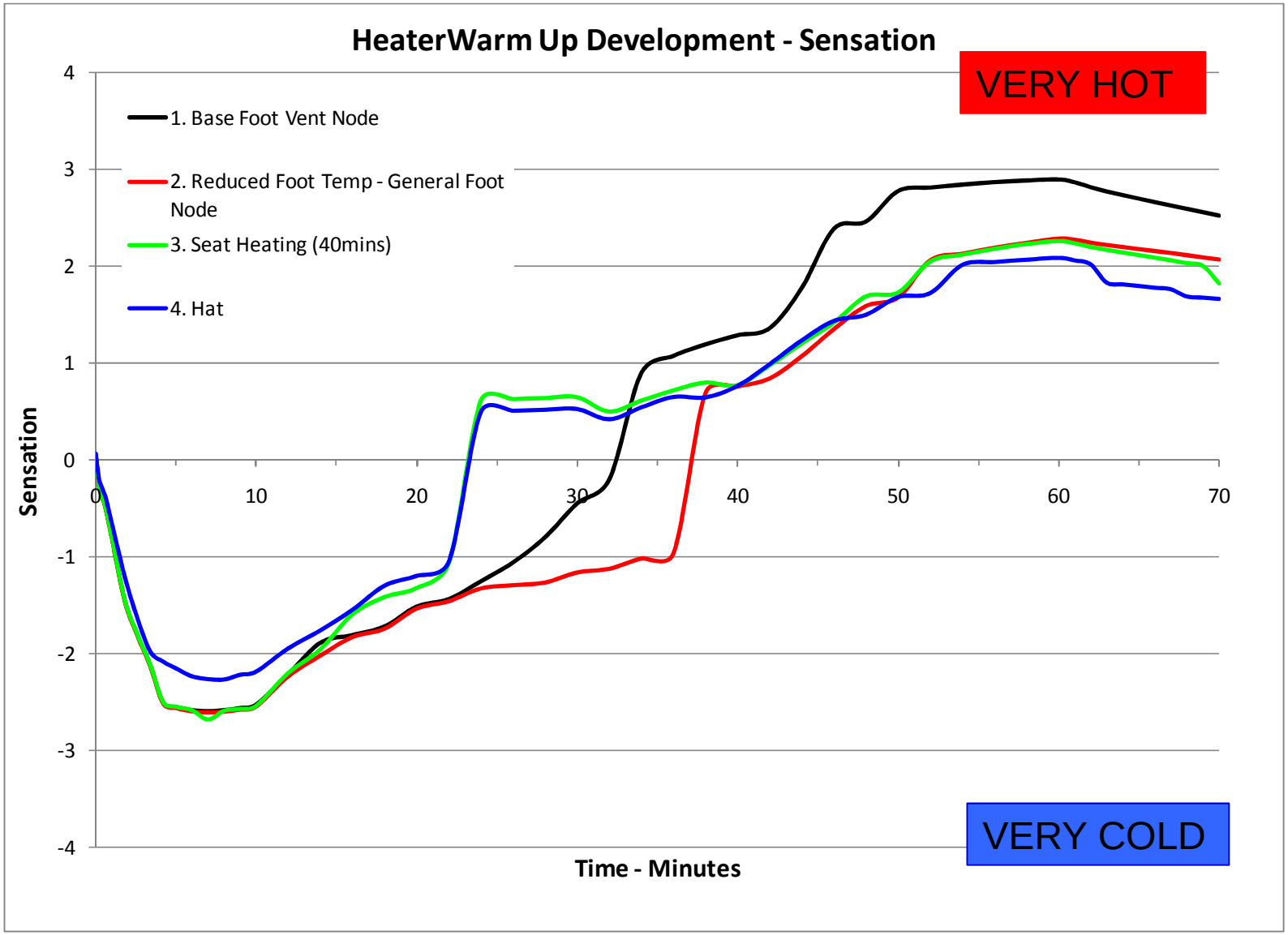
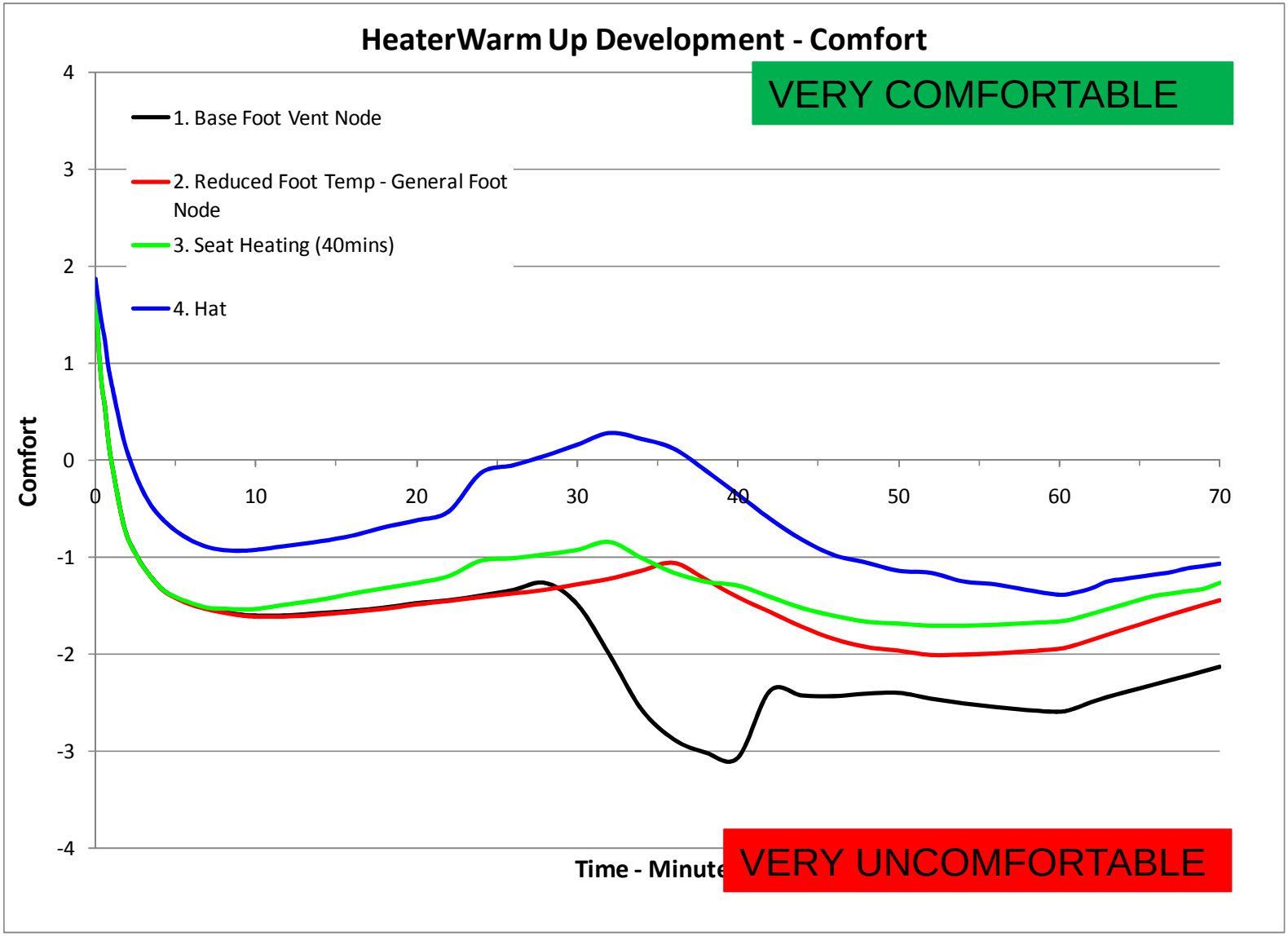
- Warm-up is highly transient
- Significant asymmetries



Model Development



Model Development



Summary - General

- Pull-Down and Warm-Up are extremely challenging scenarios to model
  - Highly transient
  - High levels of asymmetrical thermal loads
  - Unrealistic of actual driver practise
- How does the Berkley Model cope?
  - PMV
- Accuracy of (Radtherm) model set-up
  - Model vs actual

Summary - AC

- Model appears to accurately replicate cabin environment
  - > Cabin air temperatures
  - > ~Surface temperatures

- Sensation trends same at start but not at end of pull-down
- Comfort trends same at start but not at end
- Model suggests more sudden swings in perception than seen in (limited) study
- Actual air flow on hands and lower arms may have an effect not seen in model (constant flow)

Summary – Heater Test

- This scenario is less complicated (no solar)
- Sensation trends show a much better fit compared with (limited) test
- Comfort trends show much better fit

- Model is very useful in examining impact of cabin environment or occupant clothing on comfort and sensation
  - > eg hat/no hat
  - > Impact of seat heating (level, time etc)

Future Work

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- Better understanding of variances between model and test
- Focus on smaller perturbations around steady state conditions
  - Jury results
- Better understanding of occupant environment
  - Subjective assessments
  - Instrumentation development
  - Thermal manikin measurements
- Better understanding of model, PMV and the applicability to vehicles

Acknowledgements

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Thermal Comfort Evaluation Team

- Coventry University – Cogent Computing Applied Research Centre
  - Prof E Gaura
  - Dr J Brusey
  - Dr J Kemp
  - R Wilkins
  - D Hintea
- JLR Research
  - Eur Ing Neil Beloe

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