VOLVO

# Digital Twins and Optimization of Cabin Thermal Management


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Sumit Kumbhar

Sanket Shah

**Volvo Trucks**

THERMAL MANAGEMENT SUB STREAM - TMSS



01-02-2023

# Agenda

- Volvo Thermal Management Sub Stream by Bhargav Varanasi
  - Role of Simulations and Digital Twins
  - Definition of Digital Twin
  - New Technology Challenges and Solution
- Cabin Thermal Management by Sumit Kumbhar
  - Overview
  - Modelling Approach
  - Validation @ 0 kmph and -$20^0$ C
  - Base Case @ 90 kmph and -$20^0$ C
  - Improvements (Insulation + Thermal Cocooning + Comfort Based Controls)
  - Results and Conclusions
- Digital Twins by Sanket Shah
  - Definition, Modeling Architecture, Collaboration and Sharing
  - Future Scope

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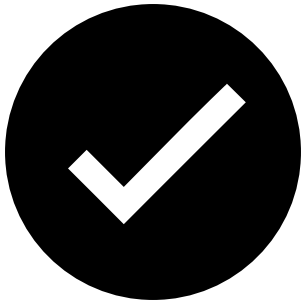
# Role of Simulations & Digital Twins

## Virtual Simulations in your Organisation?

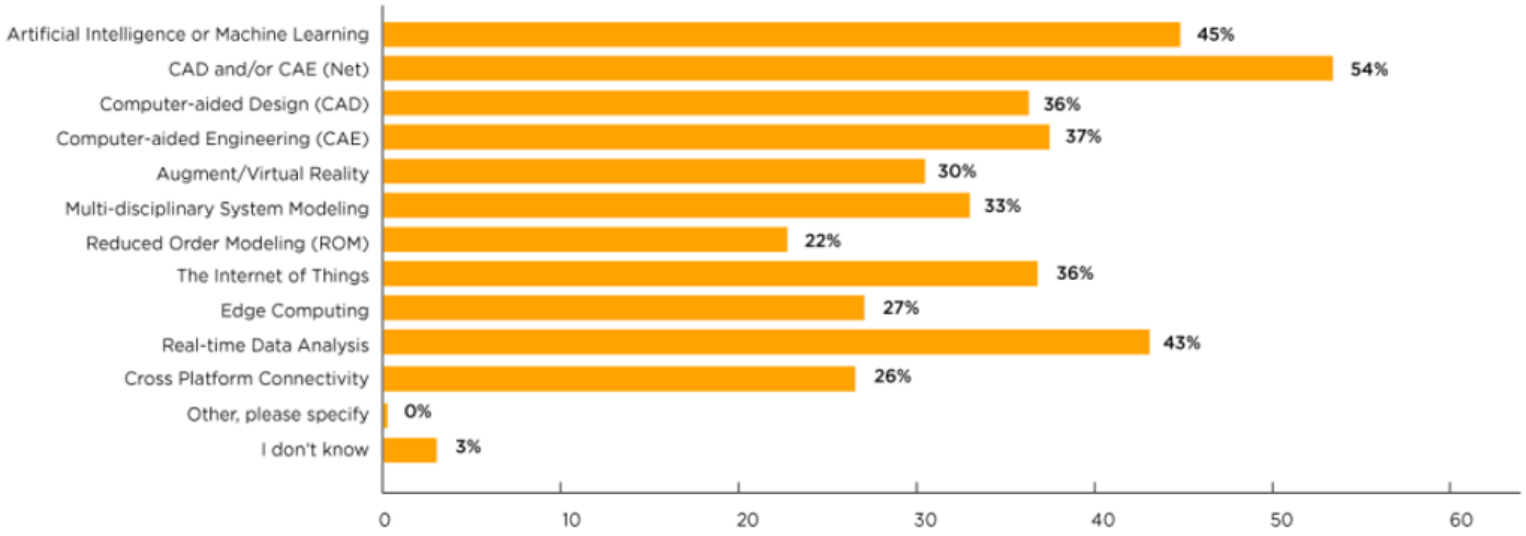


## Digital Twins in your Organisation?

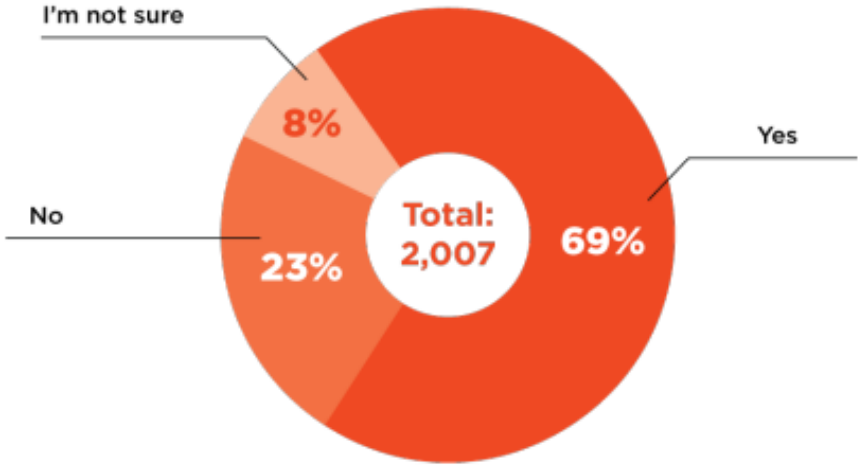
# Role of Simulations & Digital Twins

## Digital Twins in your Organisation?

**Which of the following technologies do you associate with digital twin capabilities?**




**Does your organization leverage digital twin technology (as defined previously)?**




Source: 2022 Digital Twin Global Survey Report by ALTAIR

# Digital Twins:

A LIVING LEARNING virtual representation of a truck


*

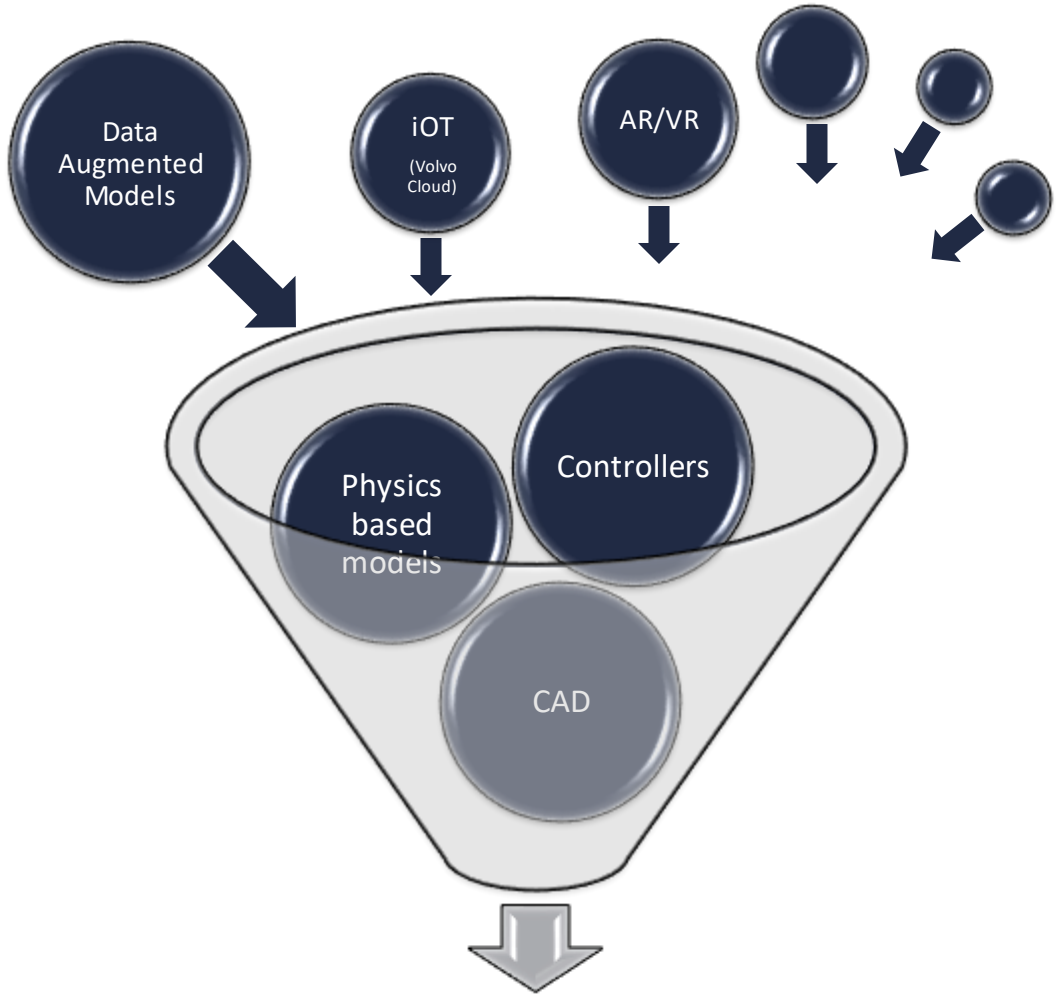





*Image used from DC Velocity Magazine

Presenters definition only, could vary from others

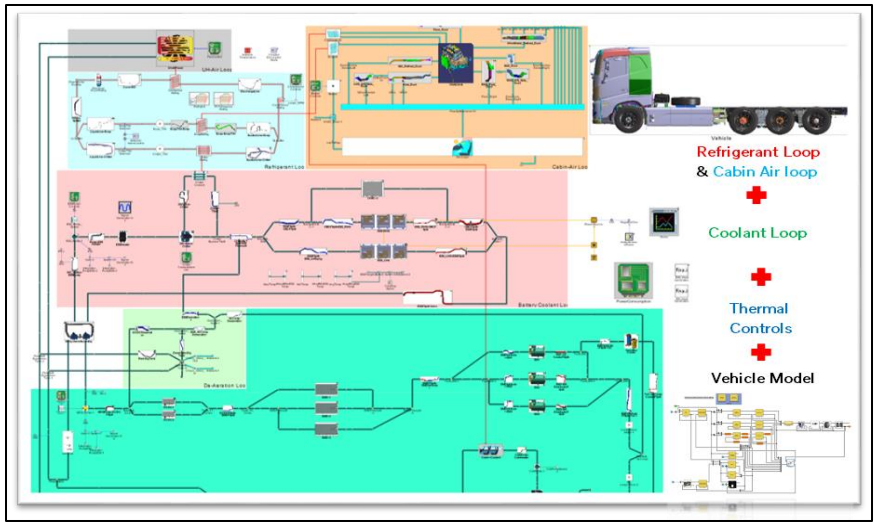
# Role of Simulations & Digital Twins

## Digital Twin*

Physical Truck

Data

Information




Virtual Truck

- Simulations, theoretically validate the product would meet it's requirements
- Digital Twins, calibrated simulation models with real time input data that could predict the future performance of physical product

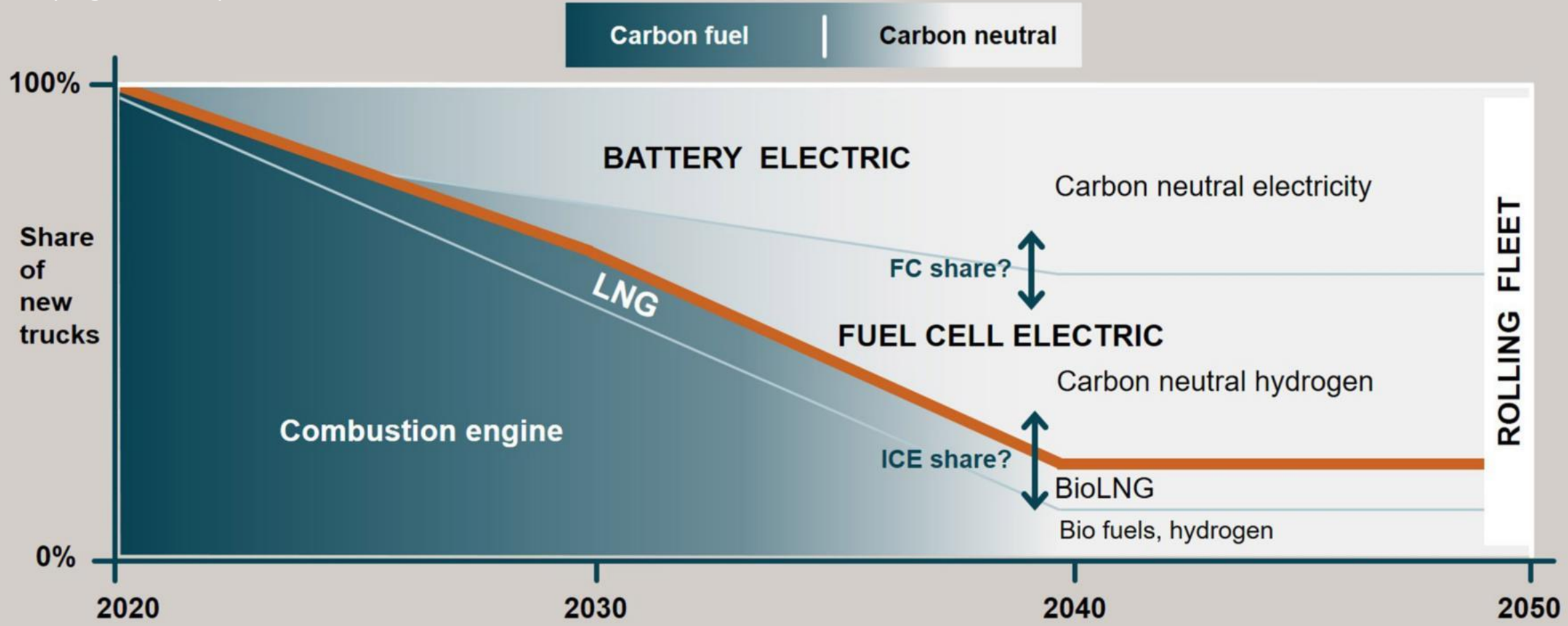


Presenters definition only, could vary from others

Twin*

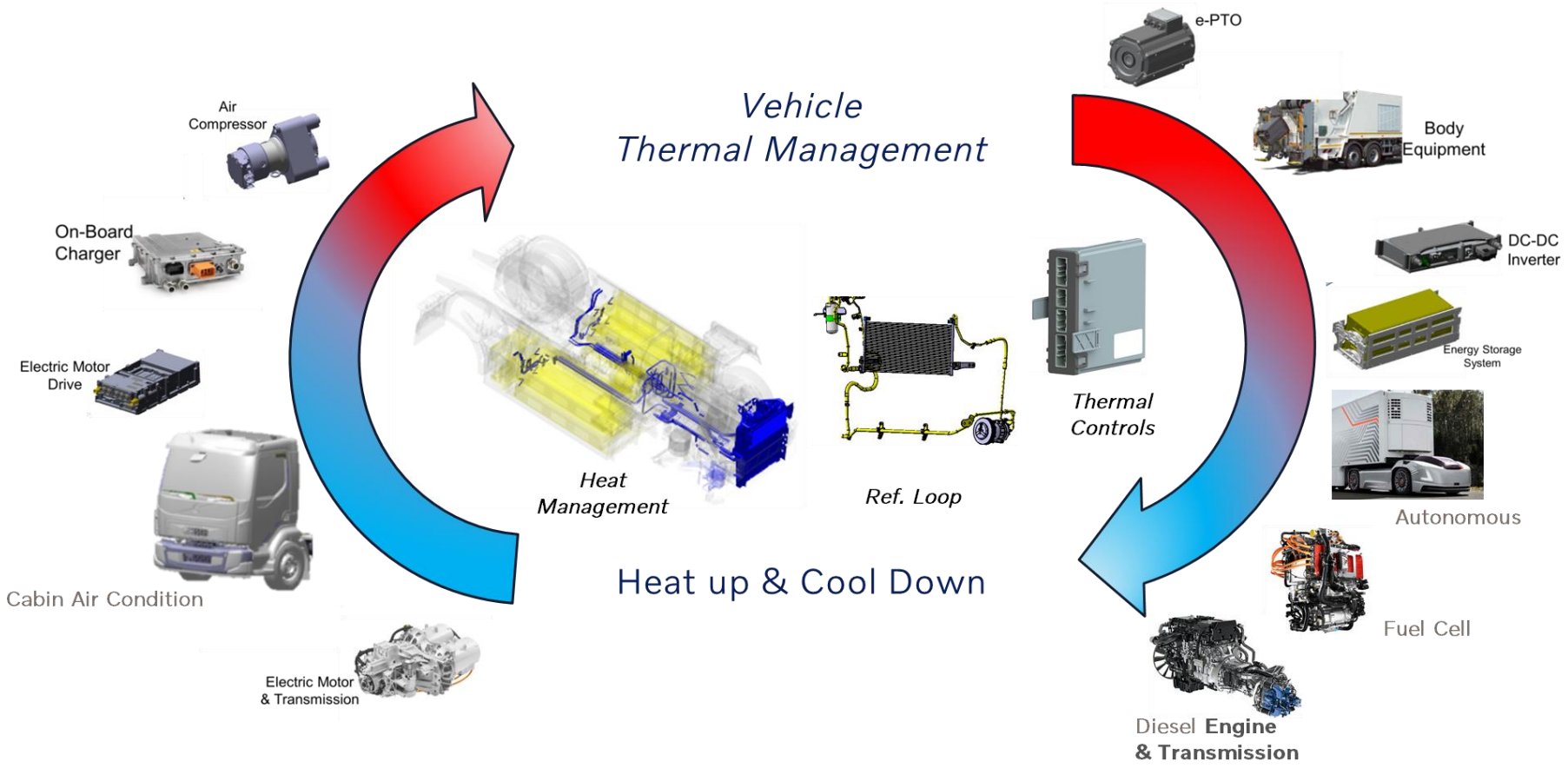
# Fossil free roadmap

Developing business portfolio

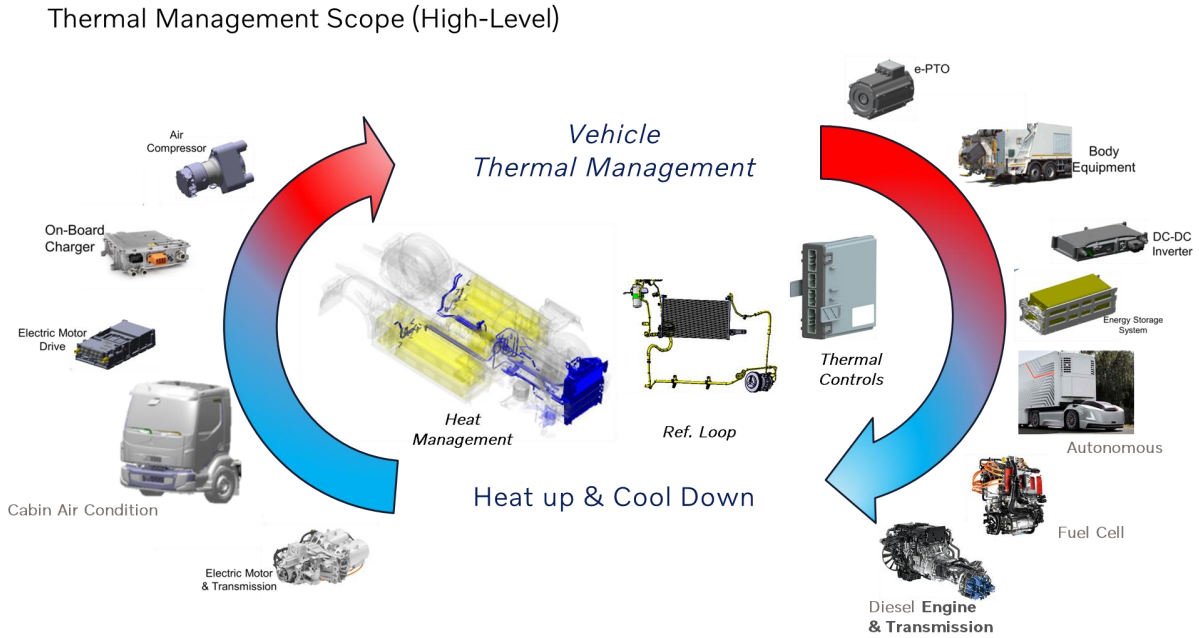


# Volvo Trucks, Thermal Management Sub-Stream

## Thermal Management Scope (High-Level)



# Volvo Thermal Management Sub-Stream




***New Tech: BEV, FCEV & Automation***

- Complex Thermal Systems
- Redundant Thermal Systems
- Energy Management / Range
- Data augmented model

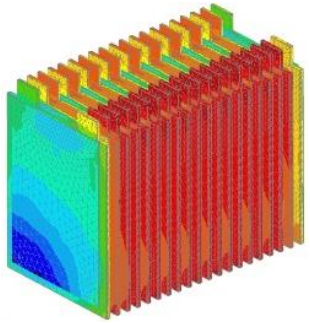
- New Methods Development
- Safe & efficient systems
- System & controls optimisation
- Digital Twins with AI/ML

# Challenges and Solution: Balance between Comfort and Performance

One example for discn.

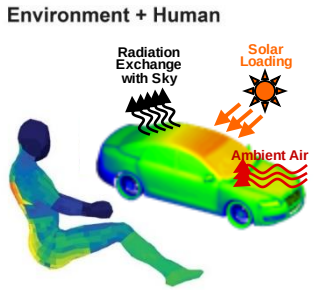
## Battery Thermal System

- Efficient Battery Pack Design
  - Battery Electrochemistry
  - Battery Cooling Method and Circuit Design



## Cabin Thermal System

- Optimum Cabin Comfort
  - Component Selection
  - Human Thermal Comfort



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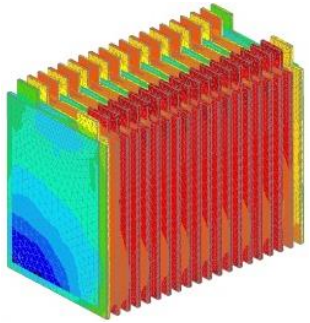

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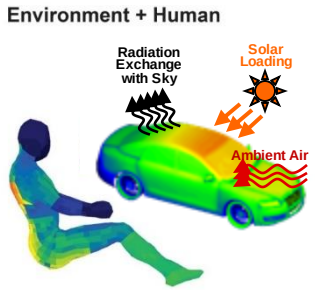


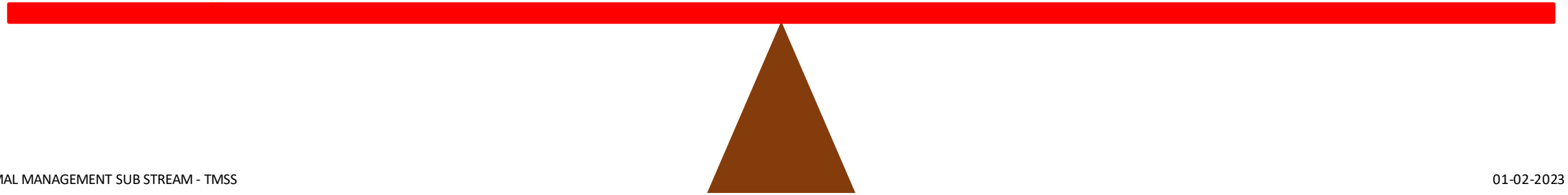

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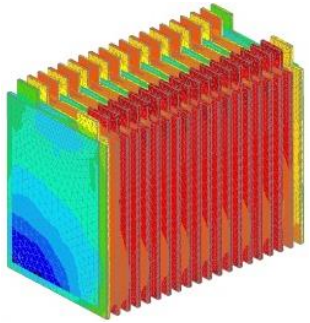

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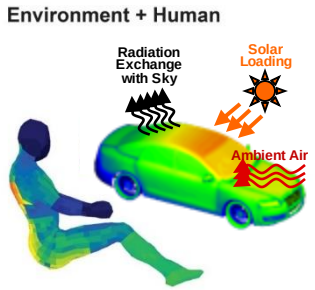

# Challenges and Solution: Energy Management and Controls

One example for discn.

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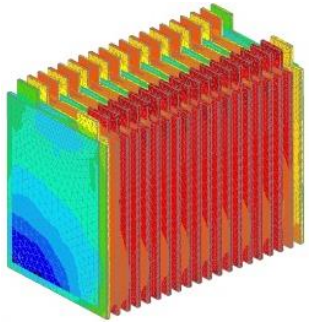

Balance using sophisticated control strategies and optimum Veh. thermal management

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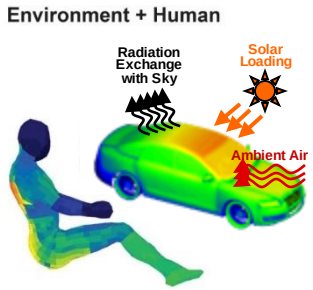

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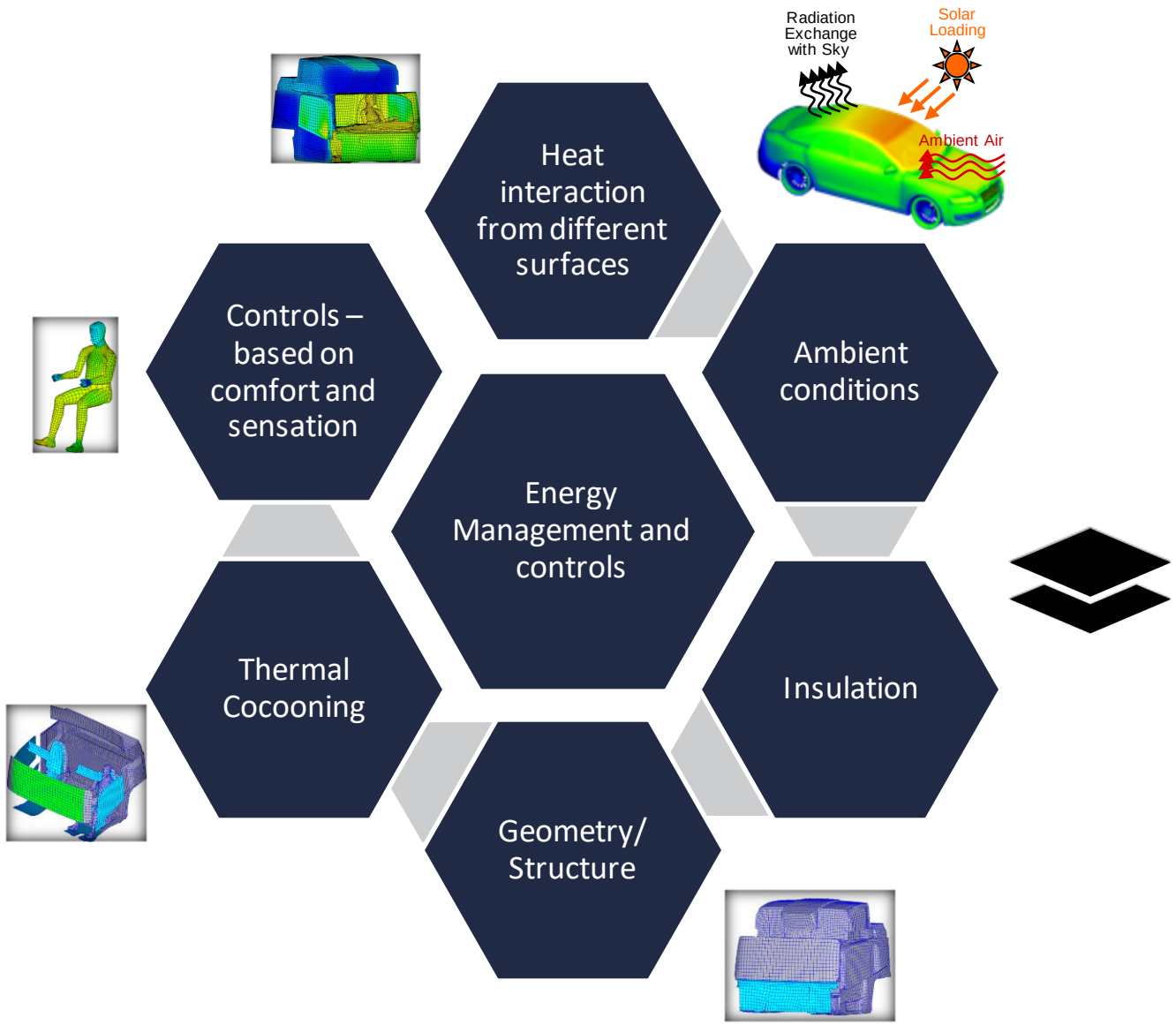
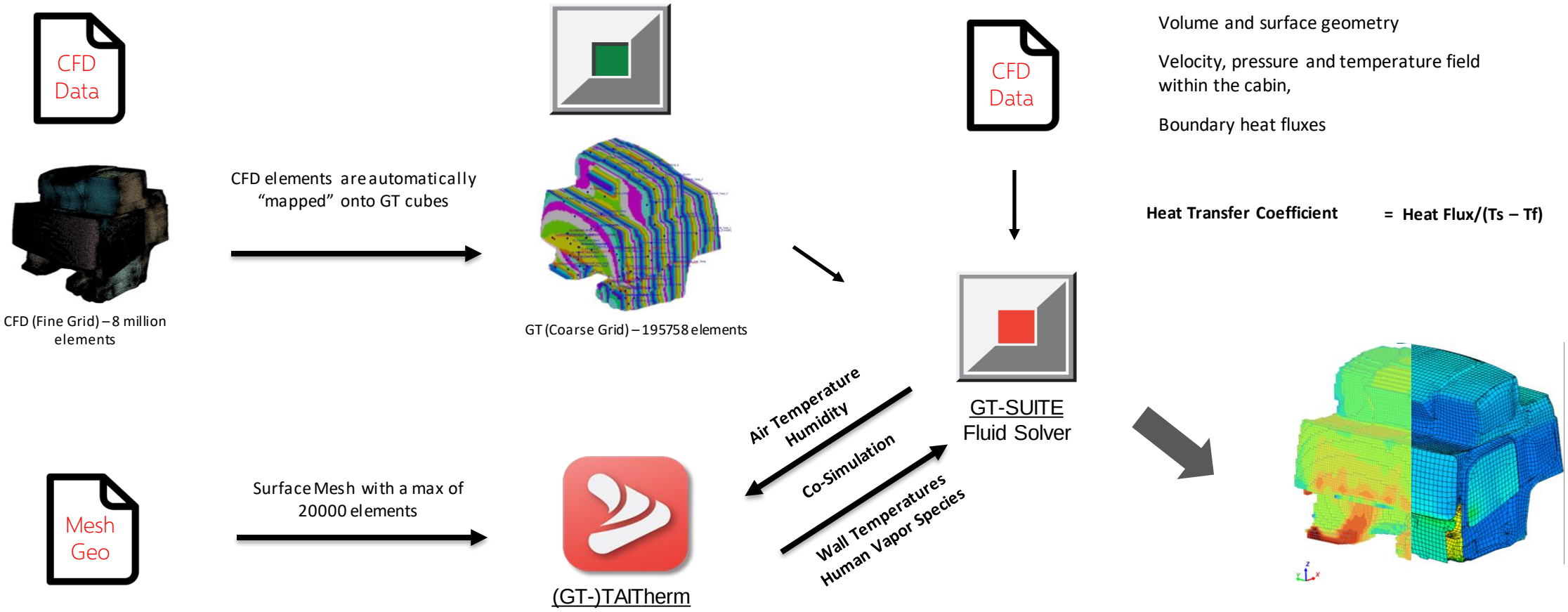
# Cabin Thermal Management: Overview

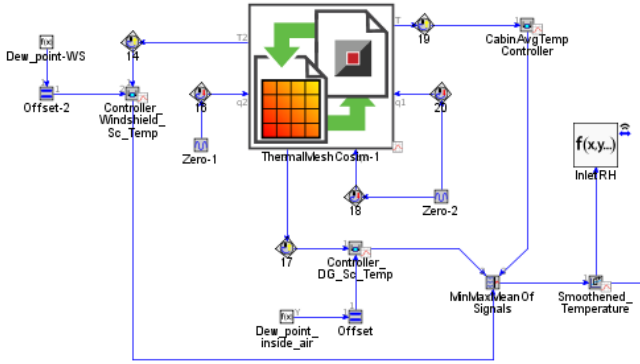


# Modelling Approach: GT-SUITE + GT-TAITherm + StarCCM+



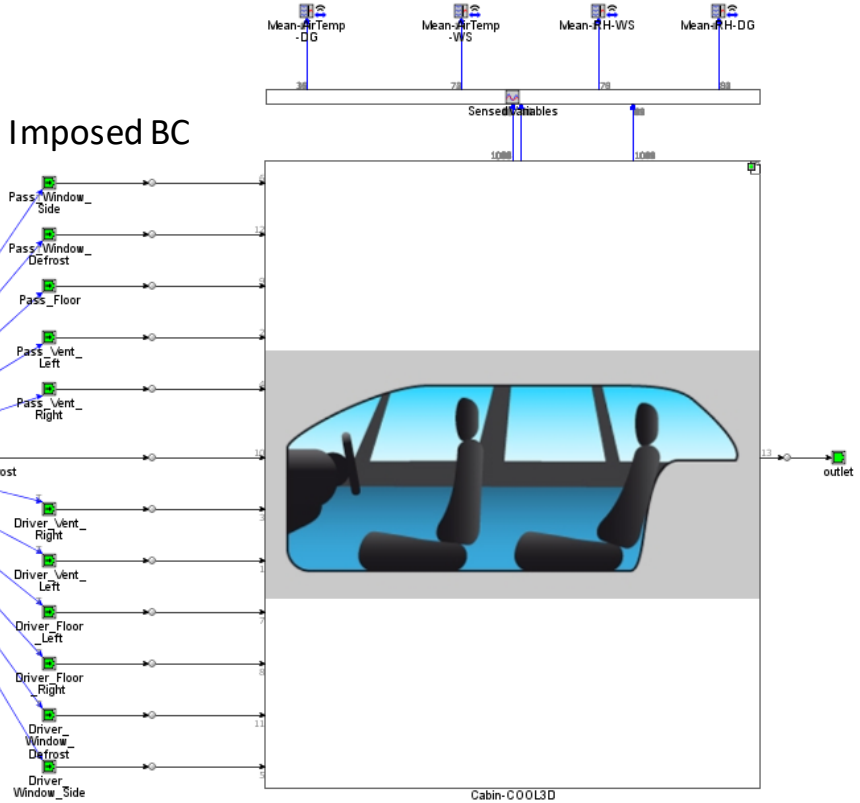
# Modelling Approach: Model

Co-Sim Template

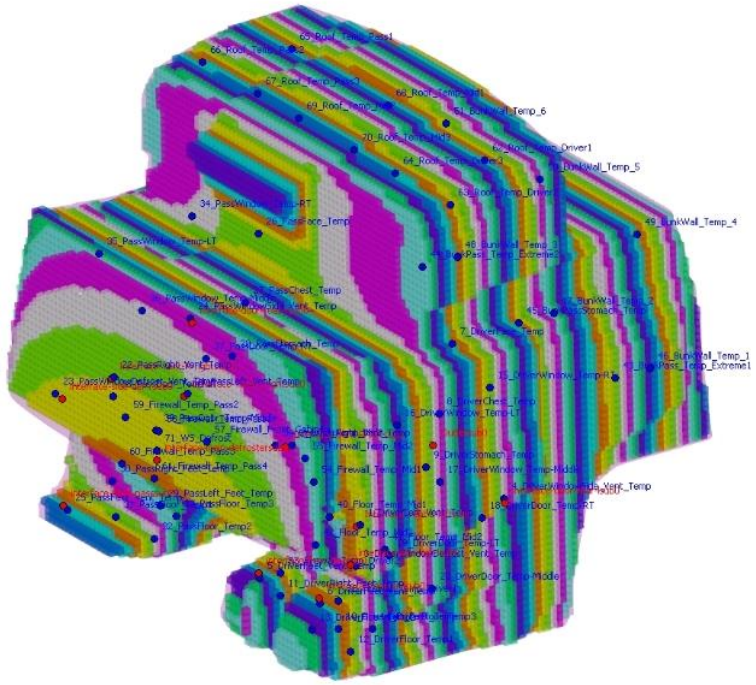



Fogging control logic

Imposed BC




Discretised cabin in COOL 3D



Cabin Discretized Flow Volume

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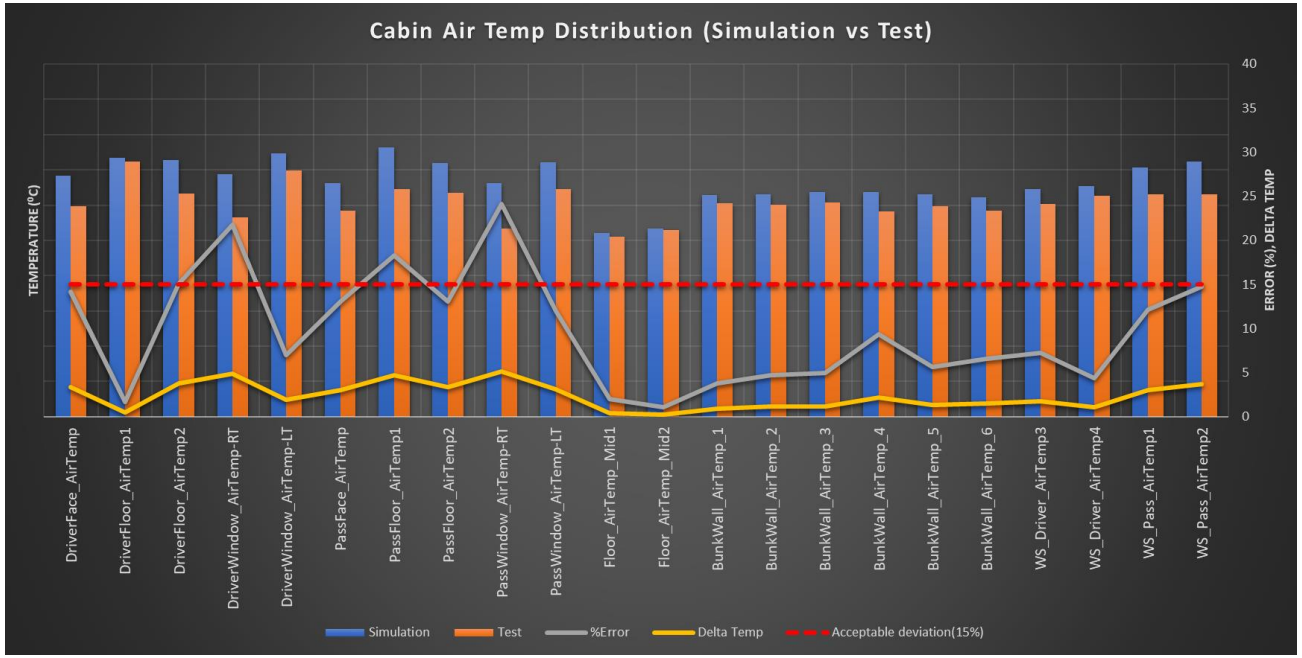
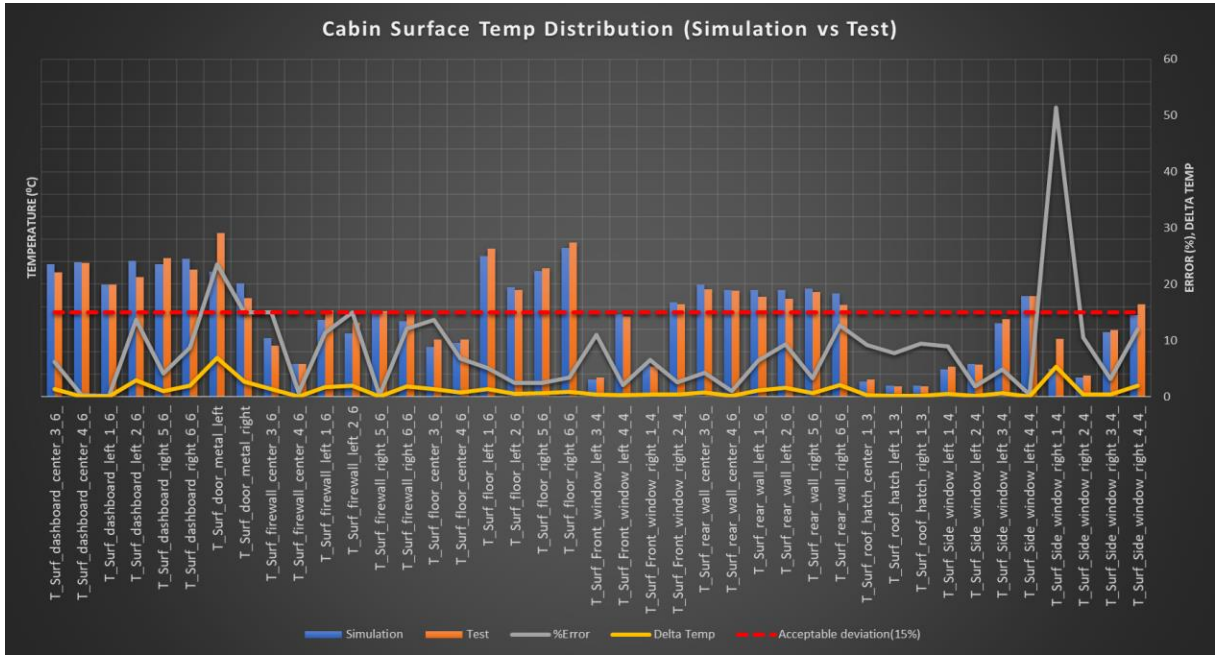
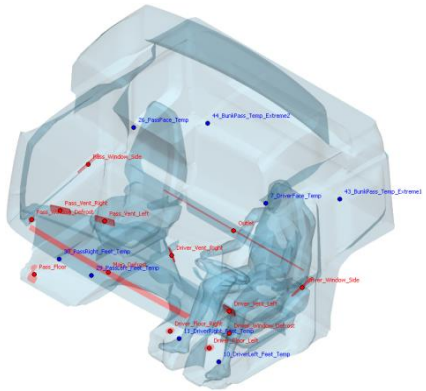
## Validation: Cabin Air Temperatures after 90 mins



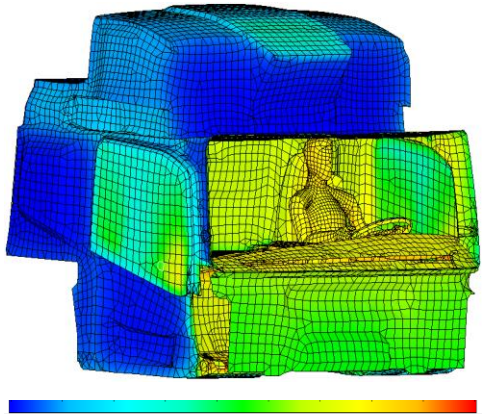

## Validation: Cabin Surface Temperatures after 90 mins



Window photos, driver side (left), driver front (center left), passenger front (center right), passenger side (right).

| left side window | front window | front window | right side window |
|---|---|---|---|
| 1 2 | left 3 | right 1 | 2 1 |
| 3 4 | left 4 | right 2 | 4 3 |



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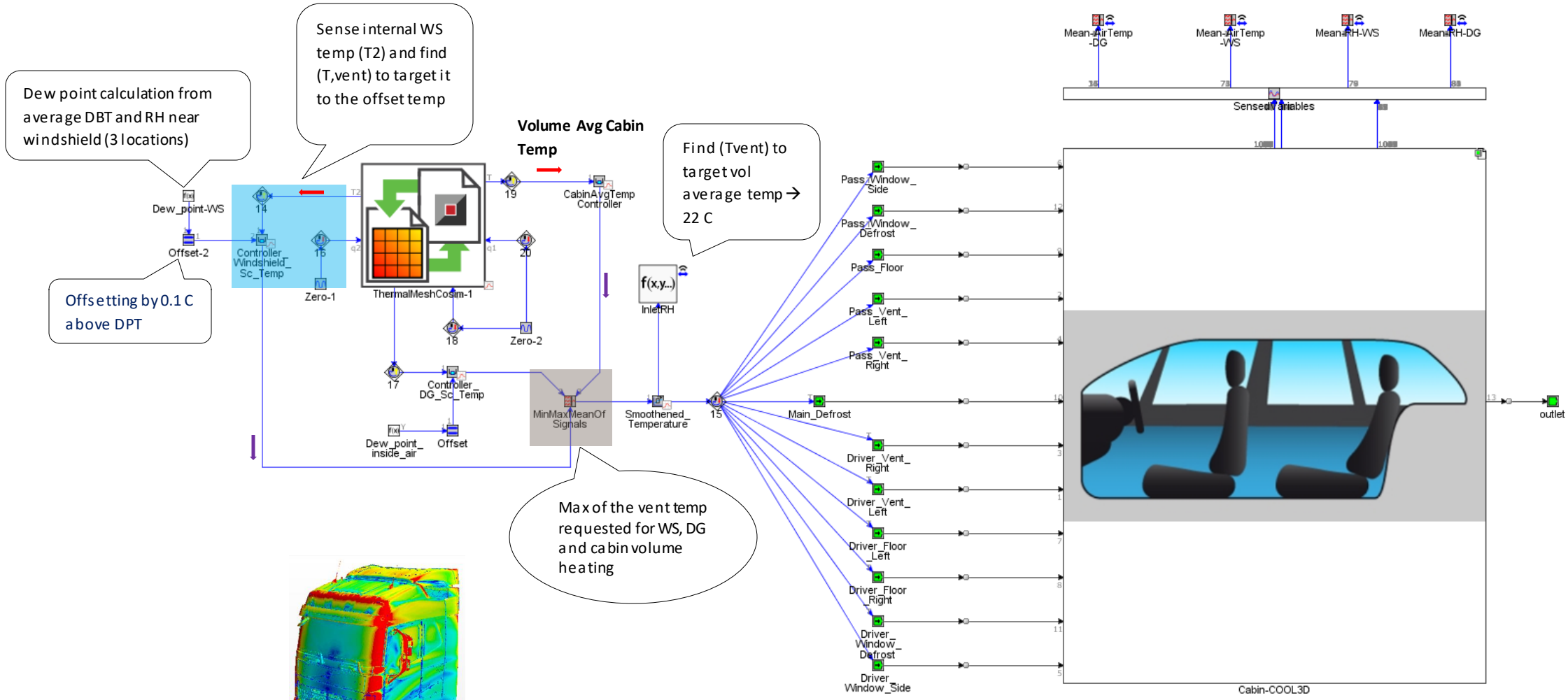
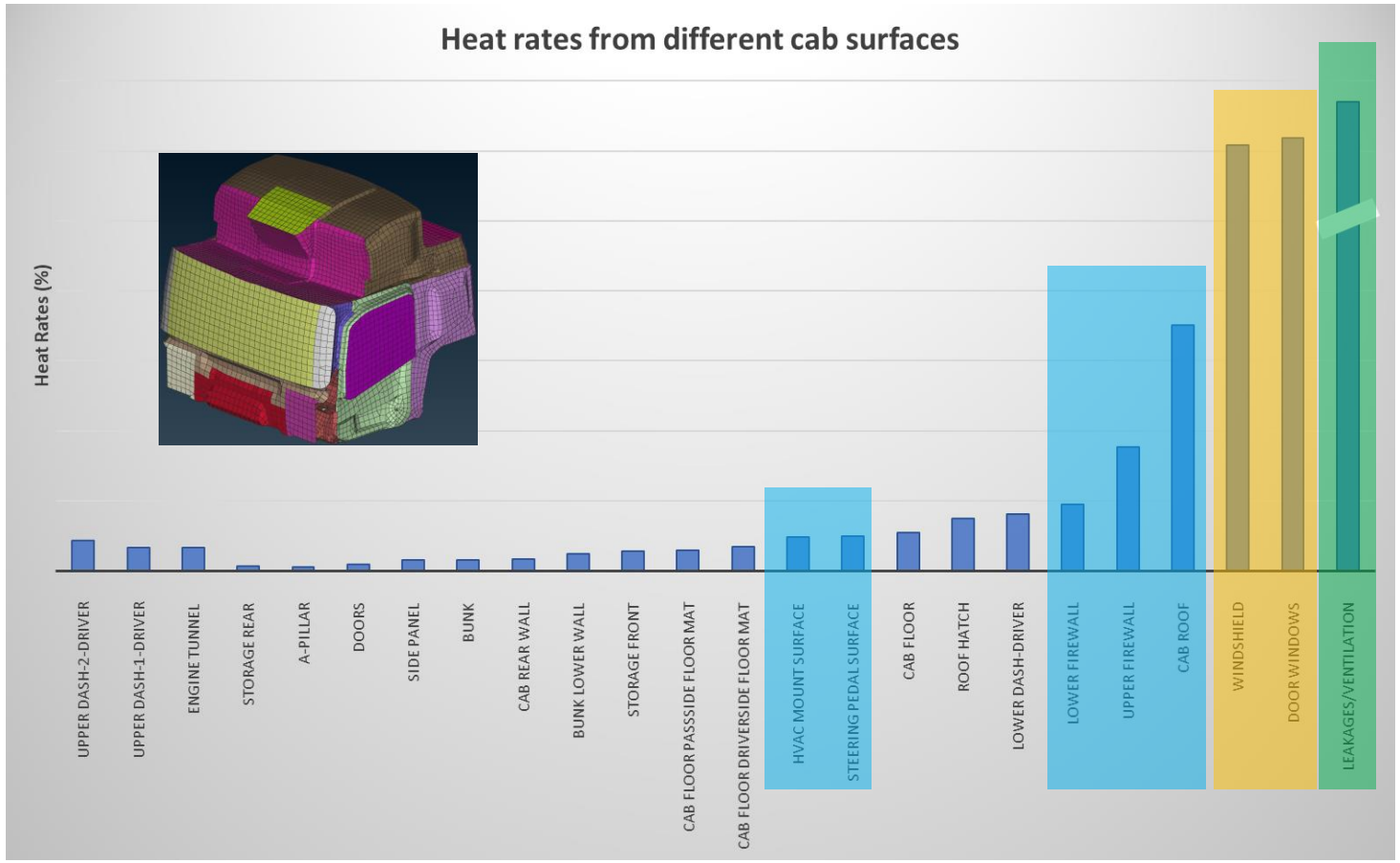
# Base Model – Vent Temperature Targeting






CFD external flowfield – Velocities imposed on the external surfaces in the GT-TAITherm model

# Base Model – Opportunities for Energy Savings




Opportunities for Energy Savings

Leakages/ventilation (+++) – Alleviate the need to heat the cabin air to very high temperatures

Glasses (++) – Changing glass properties

Surfaces (+) – Insulation

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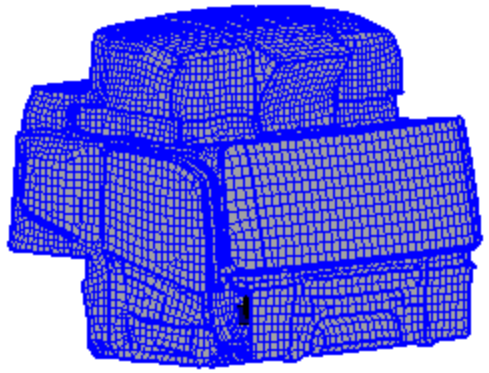
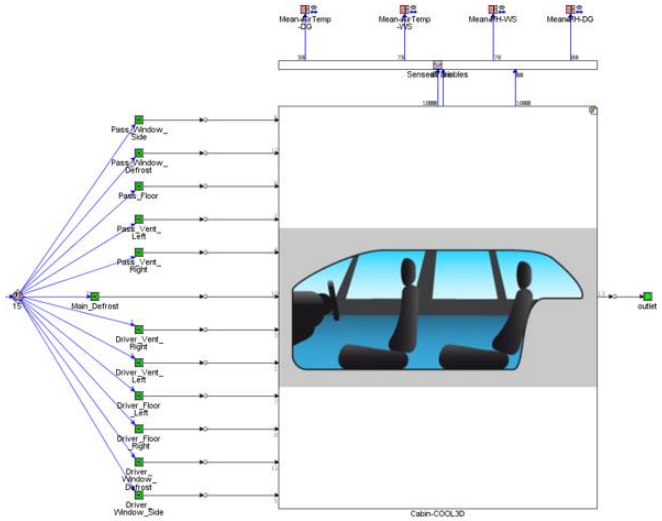
# Improvements



Approach 1

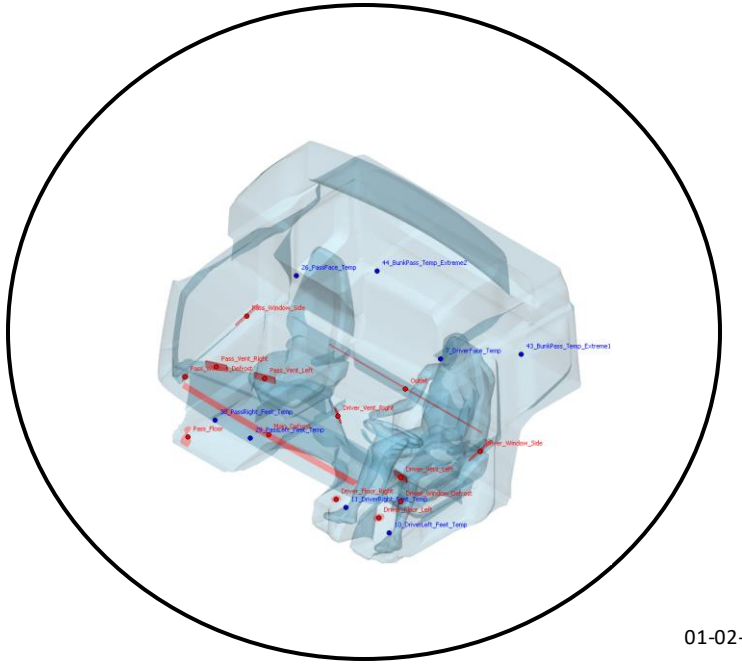
Targeting Average Cabin Temperature




Controller

Approach 2

Targeting local temperatures



- Thermal cocooning
- Insulation
- Comfort based controls (localized cooling/heating)

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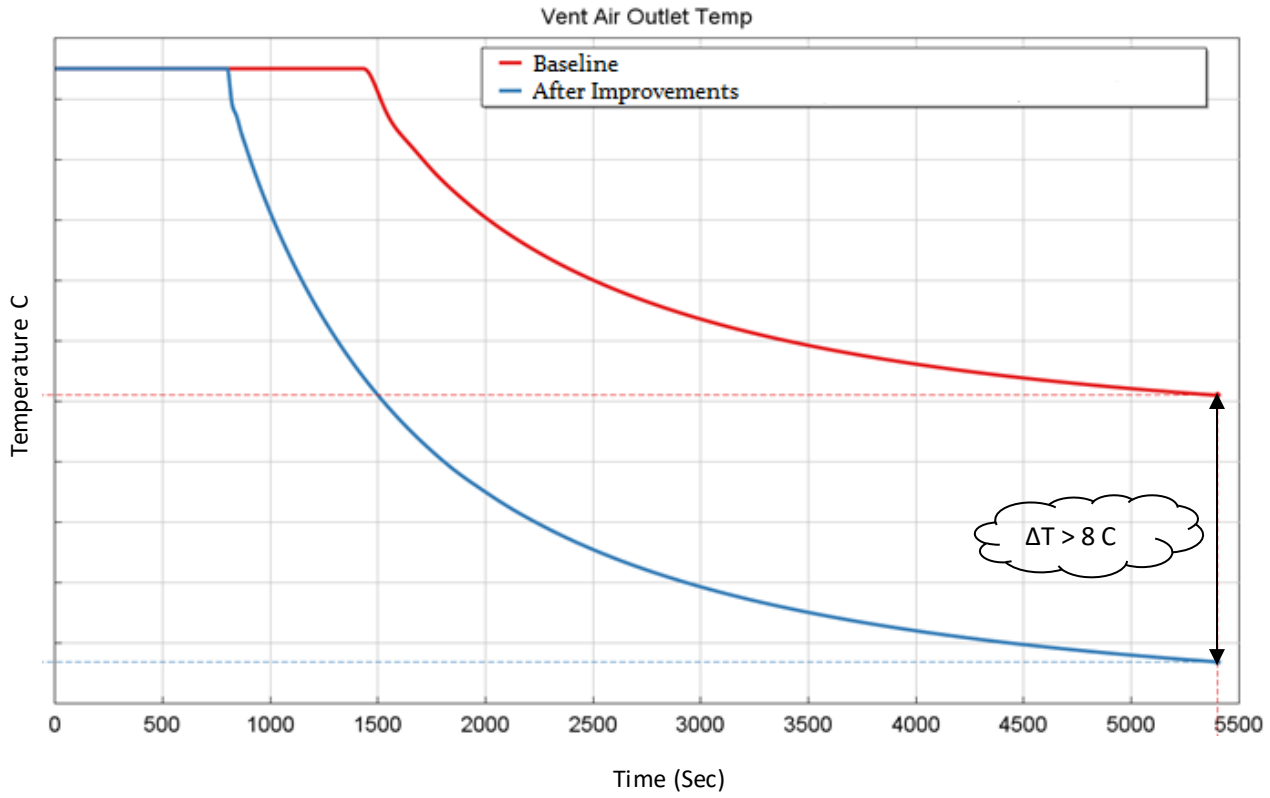
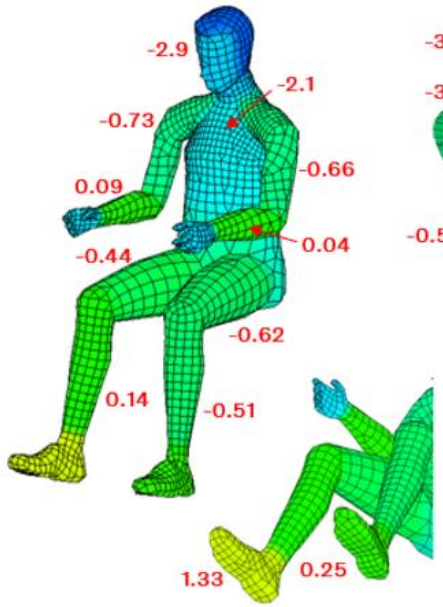
# Results: Vent Air Outlet Temperature Comparison

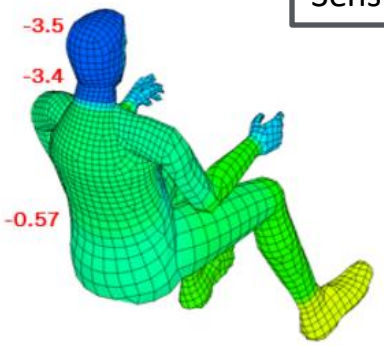



Vent air outlet temperature indicates:

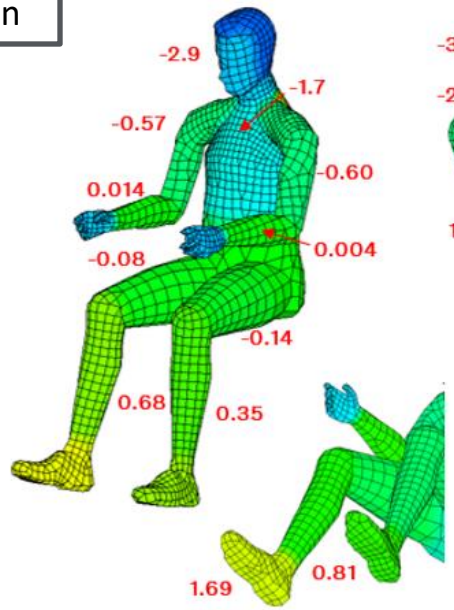
1. Air is heated to lower temperatures to meet the target temps
2. Resulting in reduction of heater heat rates → energy saving
3. Considering steady state – 10 to 15 % heater power saved.

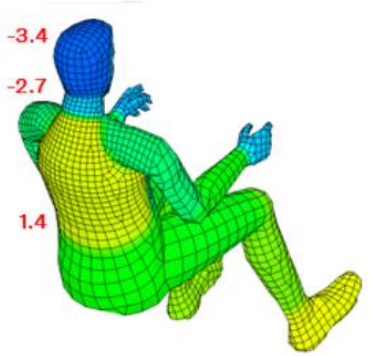
Sensation




Without Improvements

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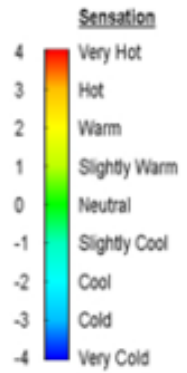
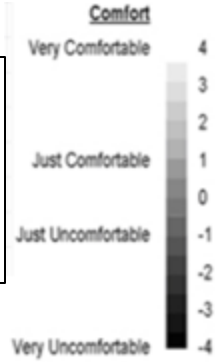
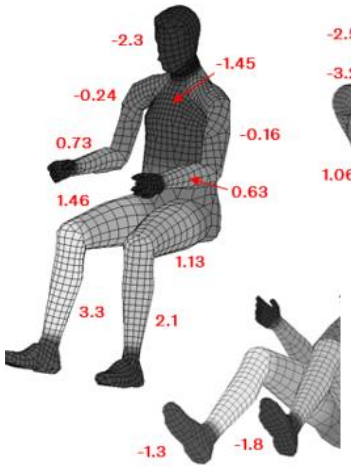


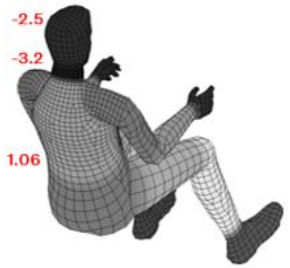

Comfort




Thermal comfort metrics :

1. Environmental - Predicted Mean Vote (PMV)
2. Physiological - Berkeley Comfort Model

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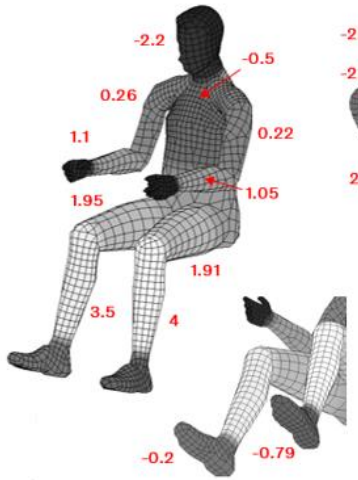
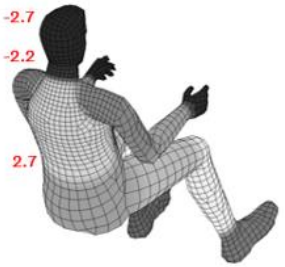
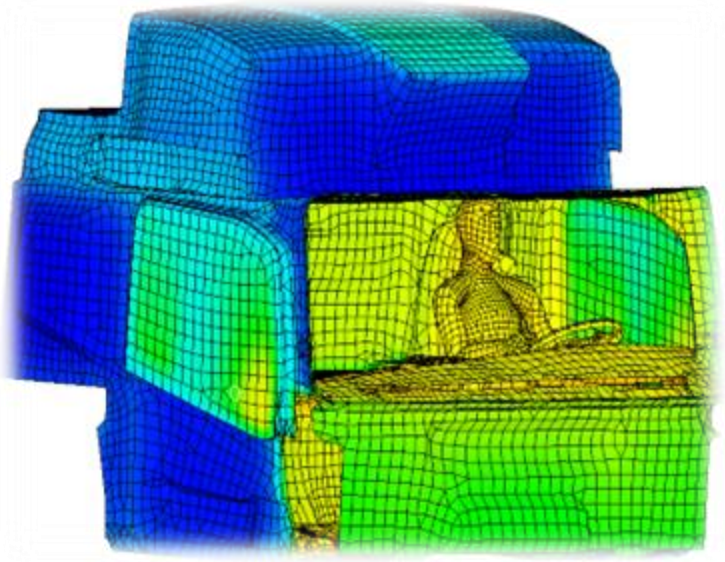



With Improvements

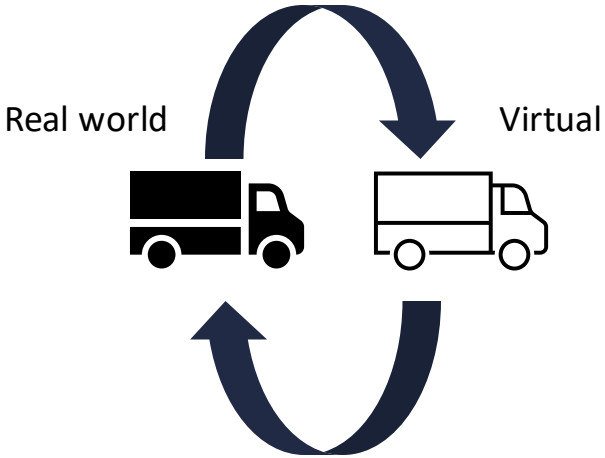
# Conclusions and Next Steps



**Conclusions:**

- GT-TAITherm - suitable for studying various energy saving techniques.
- Modelling Technique allows many iterations and DOEs
- Thermal cocooning, Insulations and comfort-based controls – Promising behavior

- **Future Work:**
- Investigate further model improvements e.g., partial recirculation, Effect of low E and IR reflective glasses.
- Integrating these models with the digital twin



# Agenda

- Volvo TMSS: Role of Simulations and Digital Twins
- Volvo TMSS: Simulation Roadmap and Targets
- New Technology Challenges and Solution
- Cabin Thermal Management
  - Overview
  - Modelling Approach
  - Validation @ 0 kmph and -$20^0$ C
  - Base Case @ 90 kmph and -$20^0$ C
  - Improvements (Insulation + Thermal Cocooning + Comfort Based Controls)
  - Results
  - Conclusions
- Digital Twins
  - Definition, Modeling Architecture, Collaboration and Sharing
  - Future Scope

# Digital Twins: Definition, Modelling Architecture, Collaboration and Sharing

A LIVING LEARNING virtual representation of a truck


*

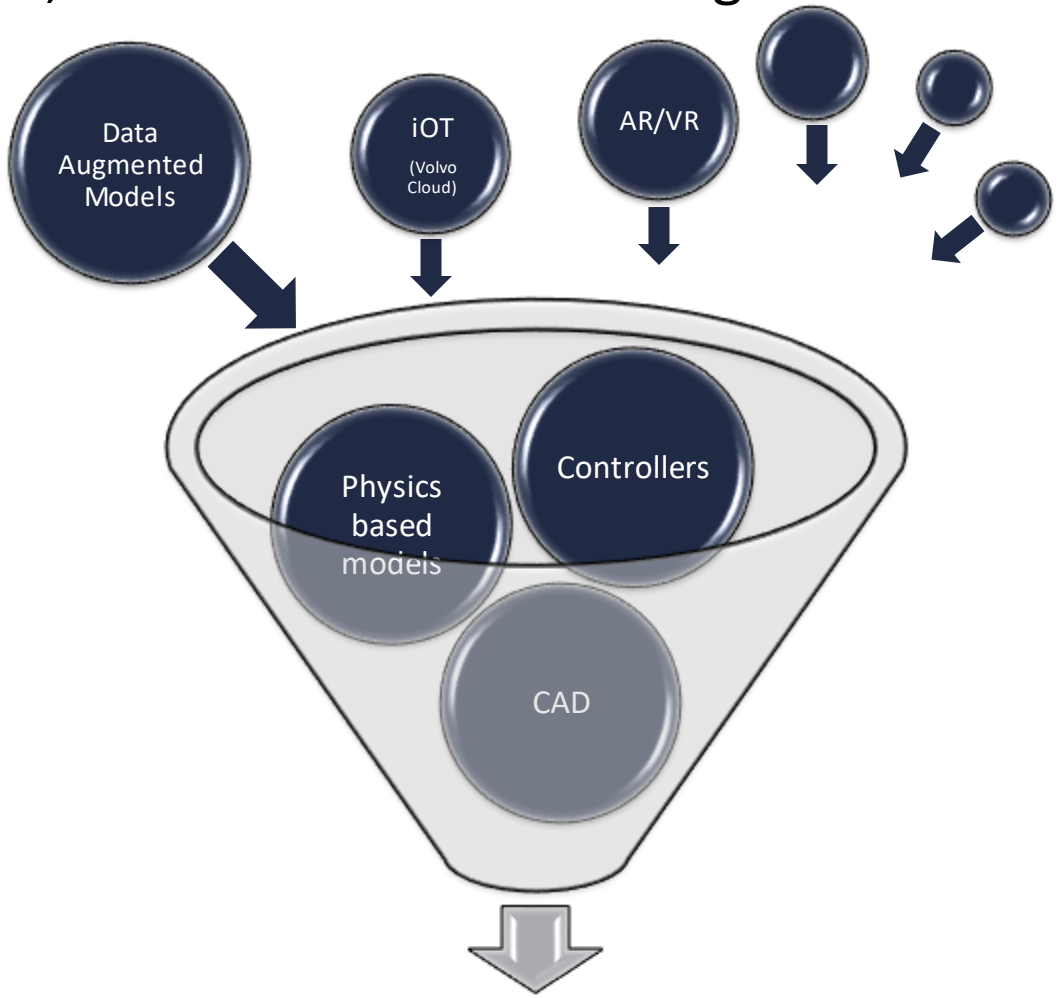
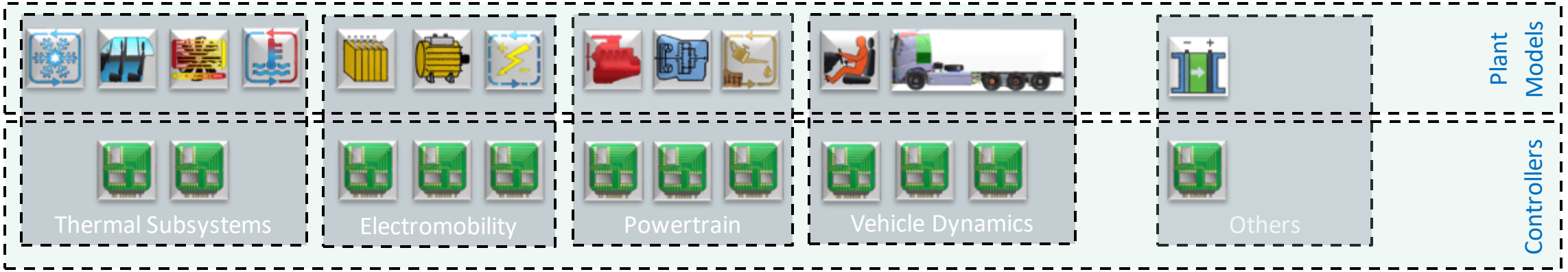





*Image used from DC Velocity Magazine

# Digital Twins: Definition, Modelling Architecture, Collaboration and Sharing

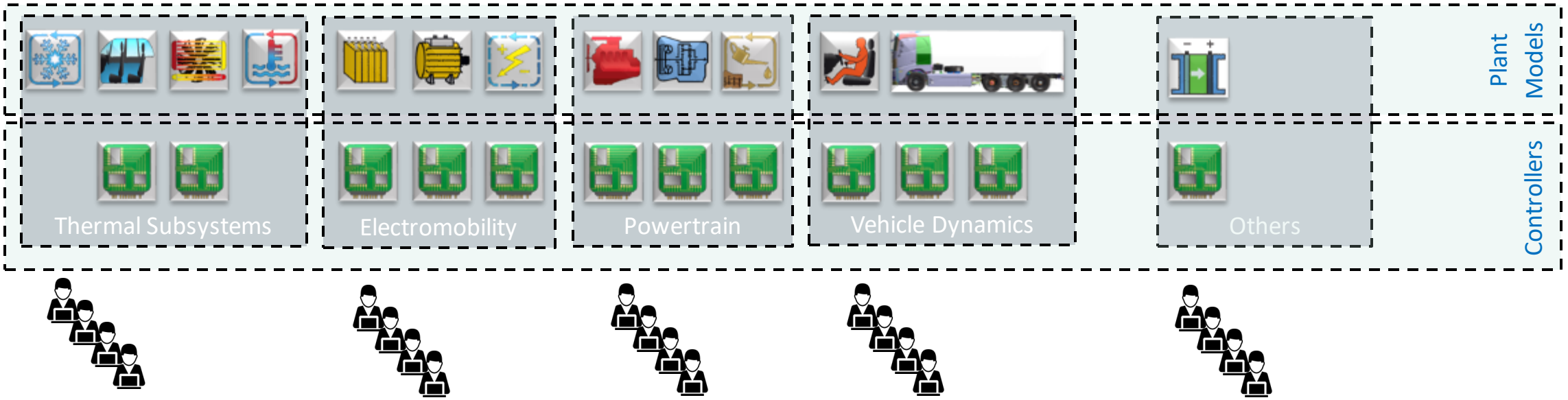



What?

A breakdown of a complete vehicle into subsystems models, further broken into super subsystems, created using:

- ✓ Predefined guidelines
- ✓ Structured naming conventions
- ✓ Sound test data sources
- ✓ Agreed methods of calibration and validation
- ✓ Layered Approaches

# Digital Twins: Definition, Modelling Architecture, Collaboration and Sharing

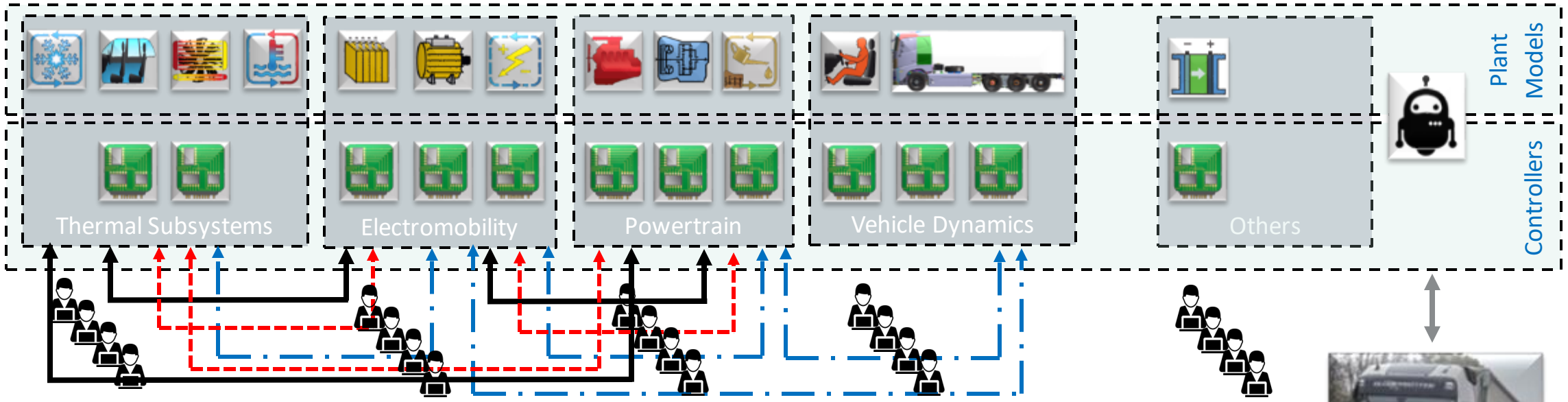



Why?

A well-defined modelling architecture creates/enables/fosters:

- ✓ Ownership & delegation

# Digital Twins: Definition, Modelling Architecture, Collaboration and Sharing



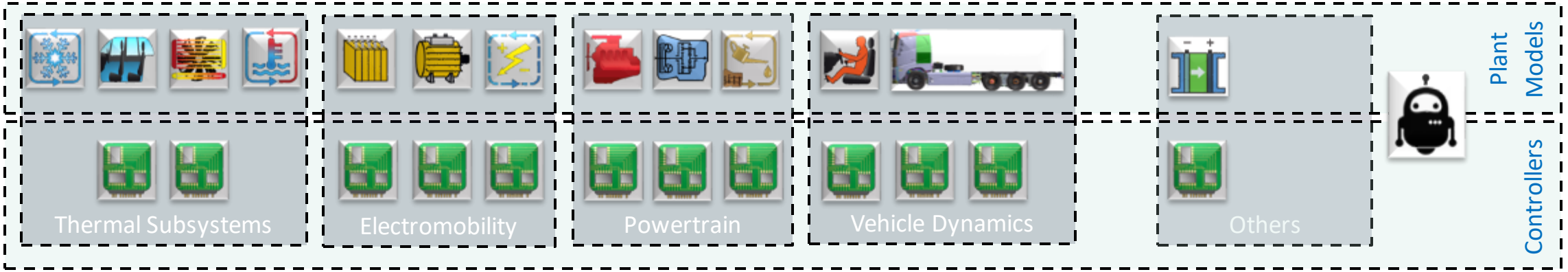

Why?

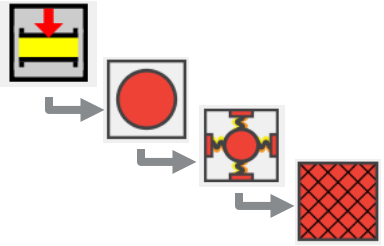
A well-defined modelling architecture creates/enables/fosters:

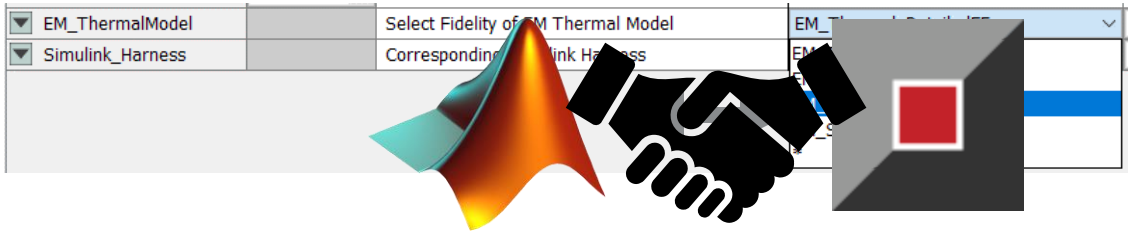
- ✓ Ownership & delegation
- ✓ Frozen interfaces

  (fluid, thermal, signals, IoT, etc.)

# Digital Twins: Definition, Modelling Architecture, Collaboration and Sharing





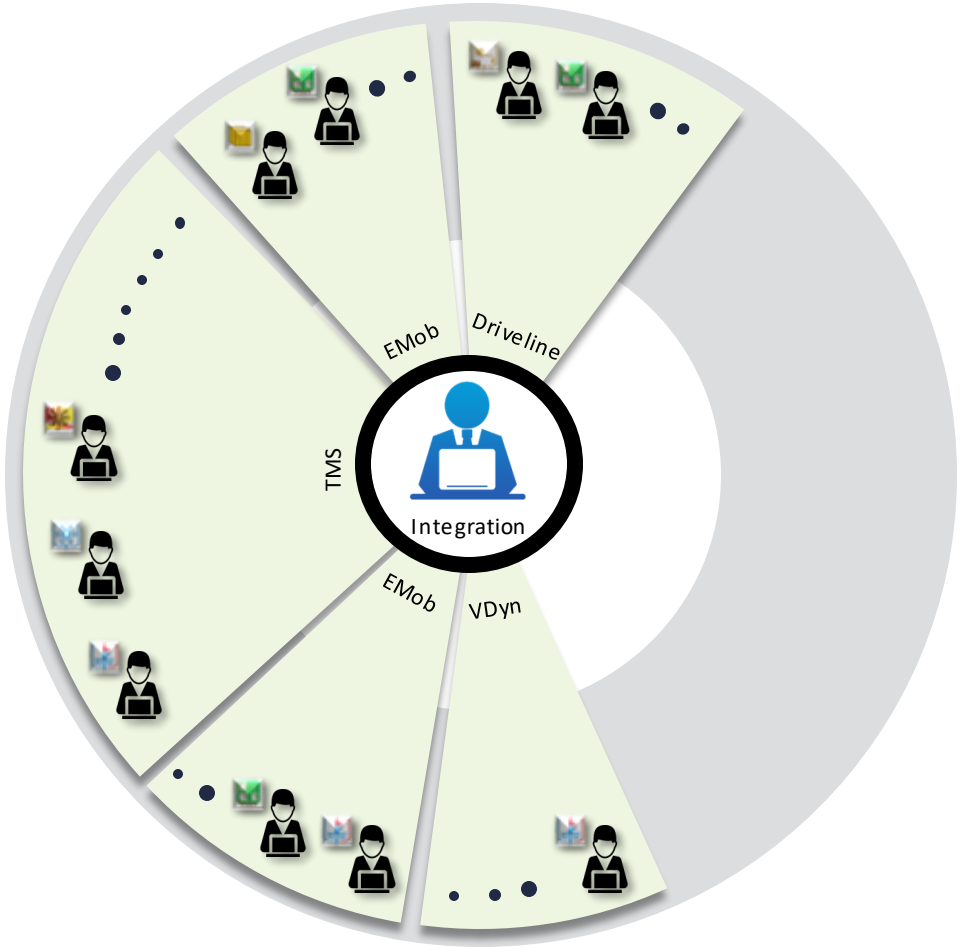

Why?

A well-defined modelling architecture creates/enables/fosters:

- ✓ Ownership & delegation
- ✓ Frozen interfaces

  (fluid, thermal, signals, IoT, etc.)
- ✓ Familiarity and consistency of variants
- ✓ Flexibility to use different fidelity models
- ✓ Error free co-simulation between tools
- ✓ New pathways for sharing and automation

# Digital Twins: Definition, Modelling Architecture, Collaboration and Sharing

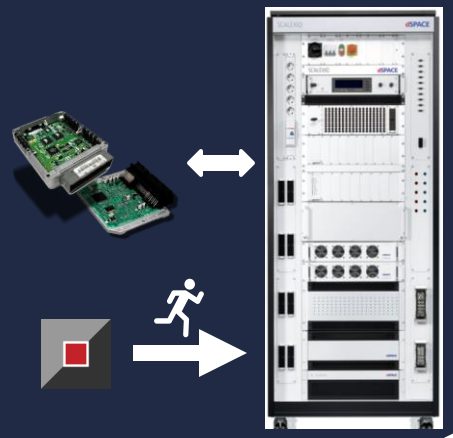



GT-SUITE user community, Controls Engineers, etc. across Volvo Group

# Digital Twins: Next Milestones

01

**Fast Running Models → SiL → HiL**



02

**Deployment to non-simulation engineers**

GT-PLAY

TKINTER

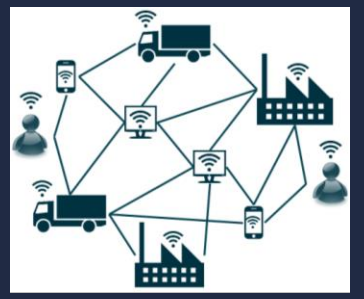
JS

03

**Adaptive systems & machine learning**

04

**Internet of Things**



05

**Automation and AR/VR**

VOLVO