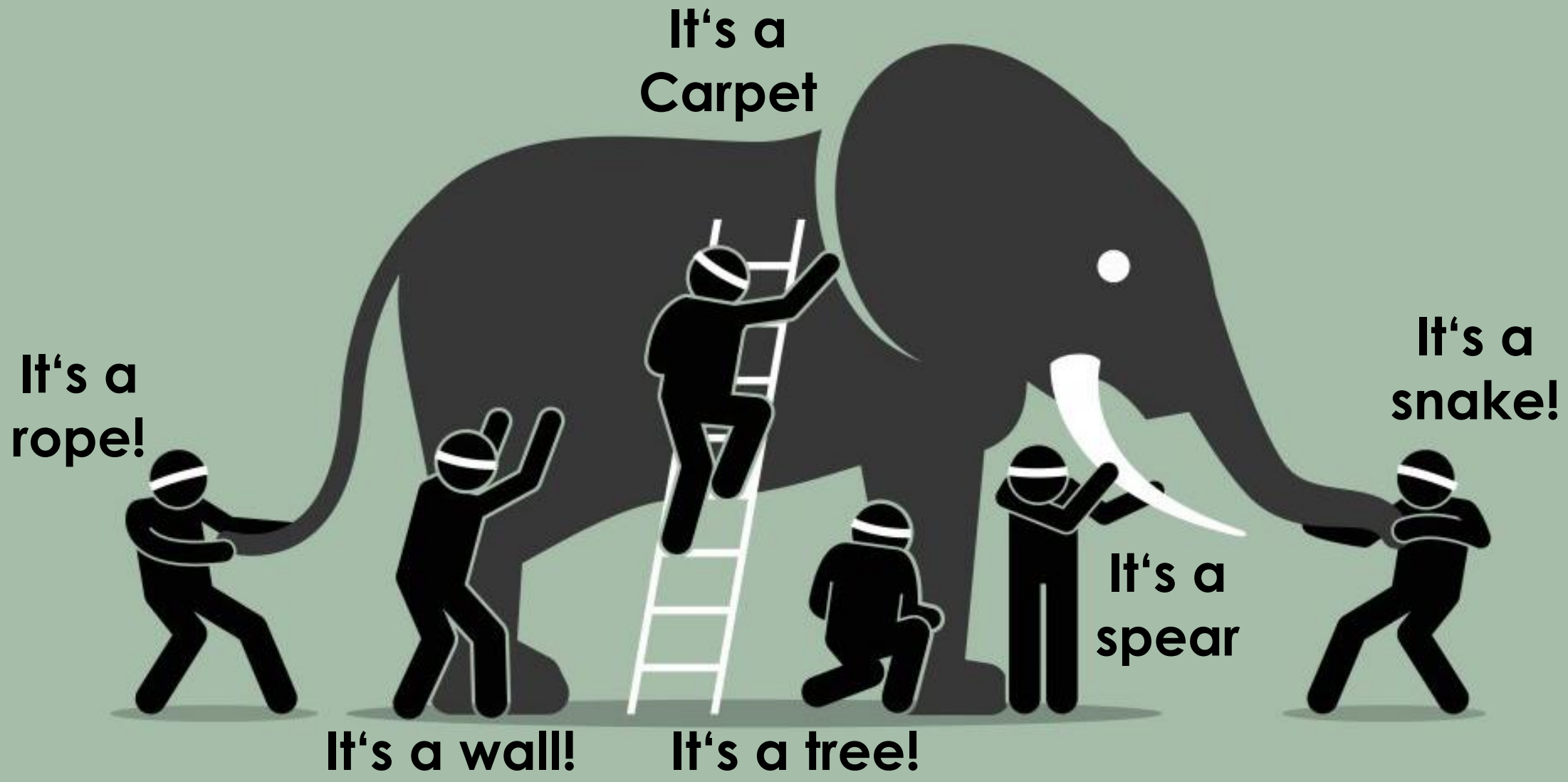
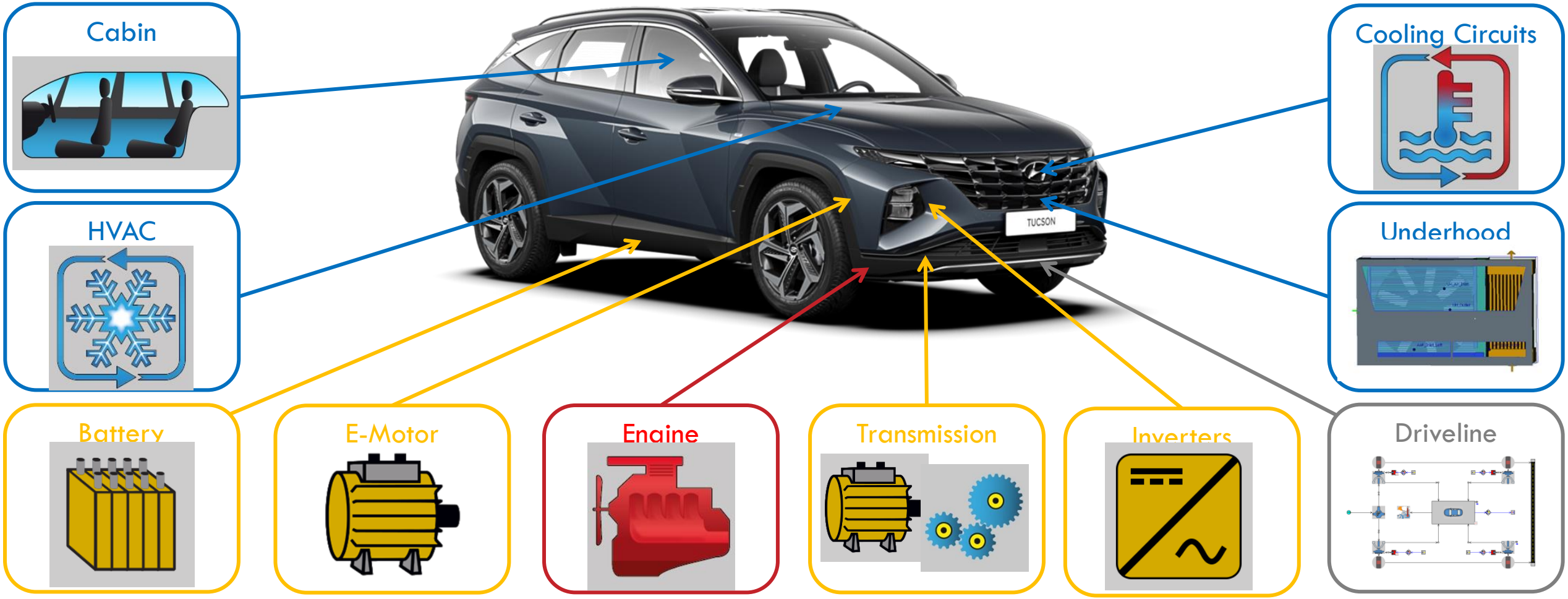
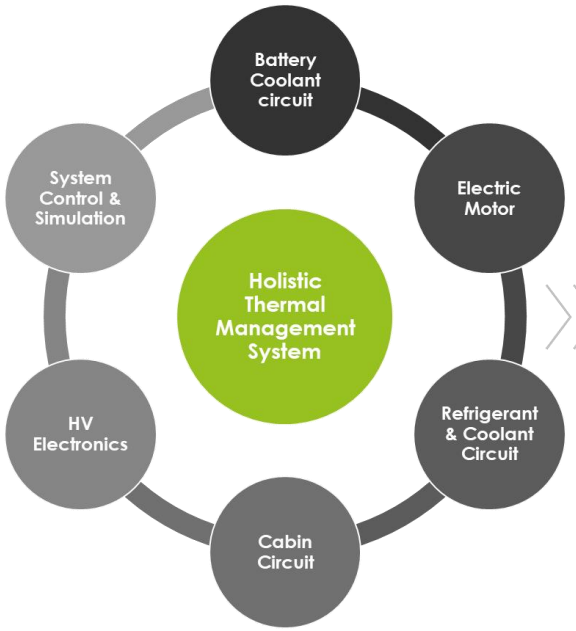

It‘s a Carpet
It‘s a rope!
It‘s a snake!
It‘s a spear
It‘s a wall!
It‘s a tree!

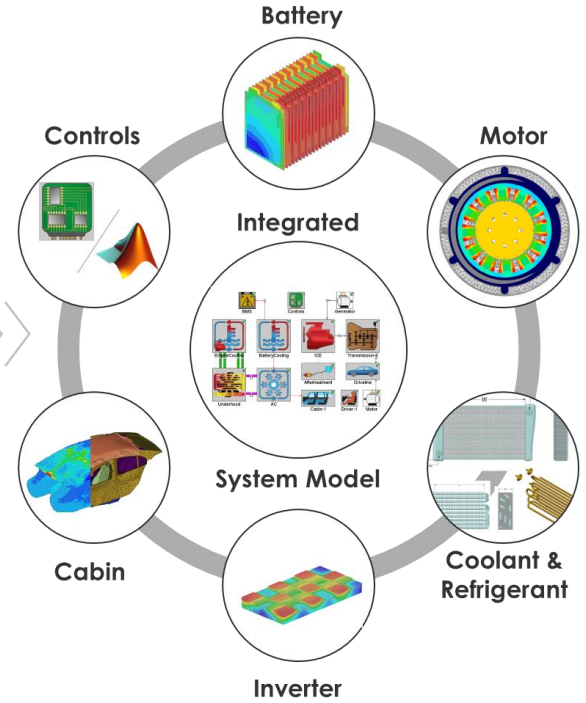


HYUNDAI

Movement that inspires

POWERTECH ENGINEERING

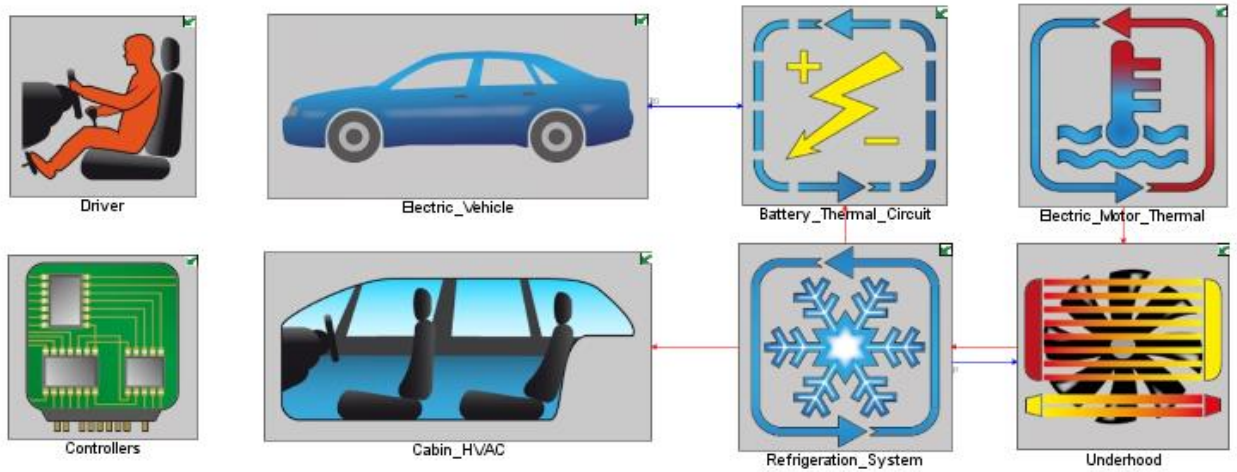




- Range
- Safety
- Performance
- Comfort
- Efficiency
- Charging
- Cost

Maximizing the power of system simulation in product development

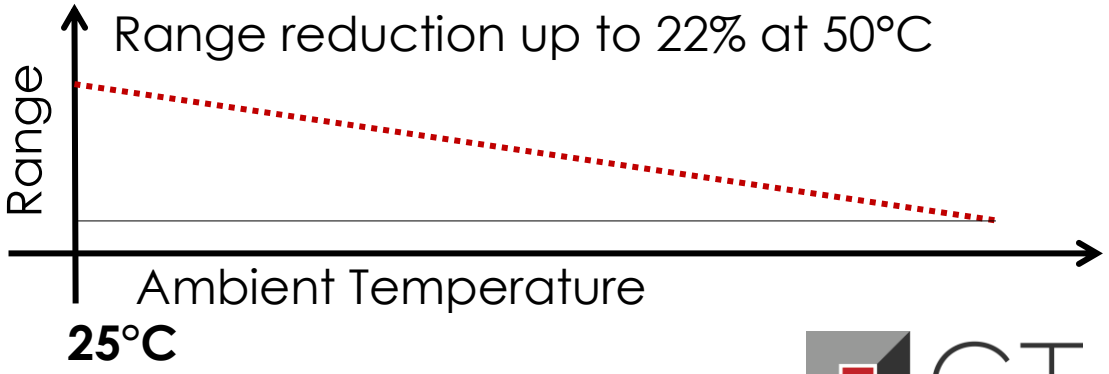
Holistic Vehicle Analysis @ Mahindra



Integrated Electric Vehicle Model

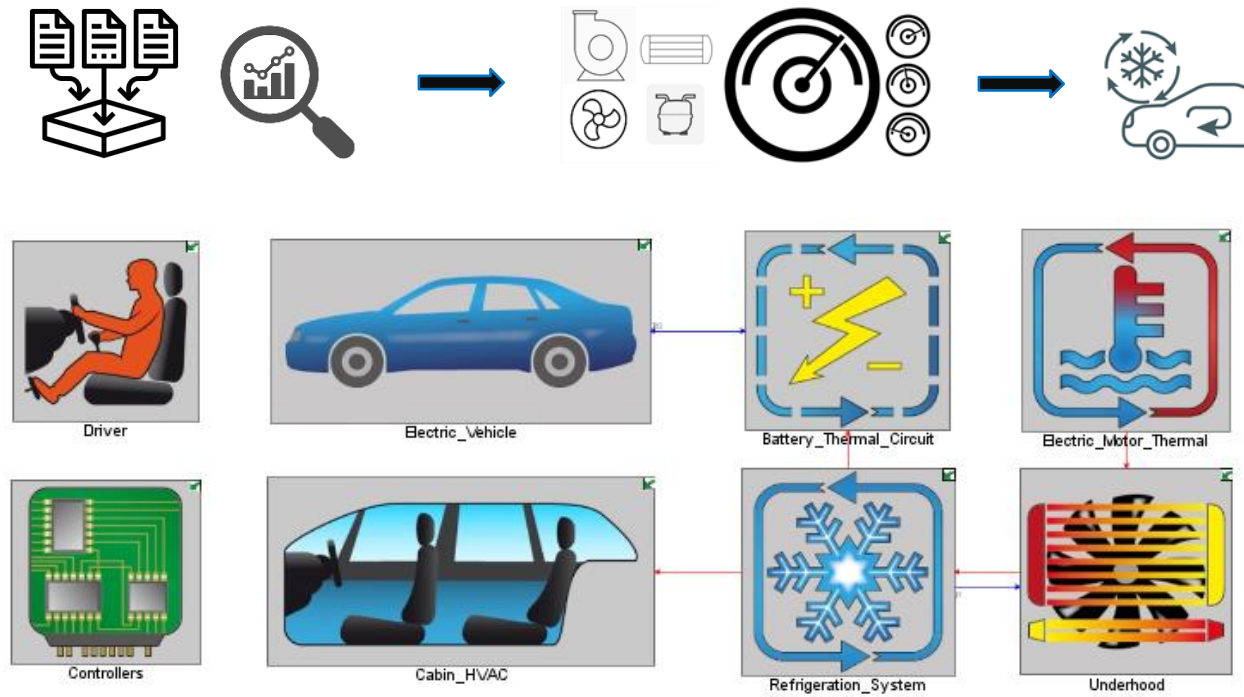
Ms. Padmavathi R.
Principal Engineer, Mahindra

Fast and accurate performance **prediction in extreme conditions** exclusively through virtual simulation



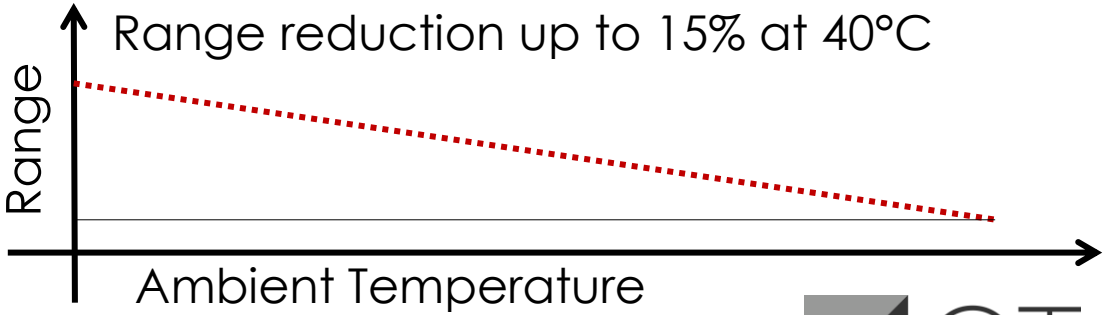
Holistic Vehicle Analysis @ Mahindra

Input Data Collection & Data Quality Check → **Component and System Level Model Building & Calibration** → **Integrated Thermal & Powertrain Model** → **Integrated Vehicle Model Validation** → **Range & Performance Prediction**

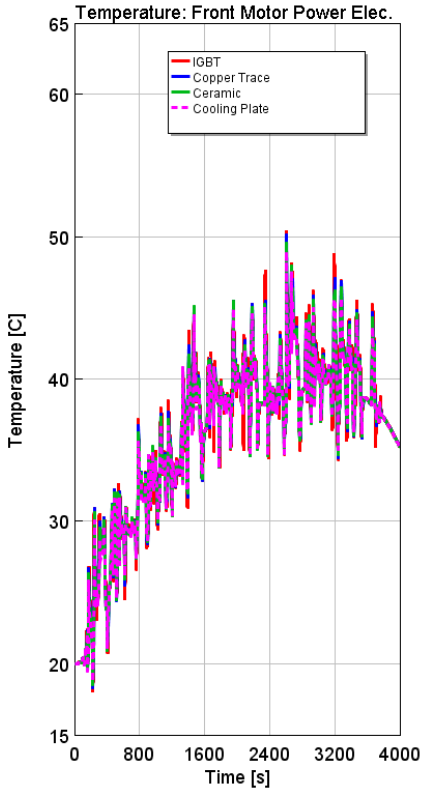


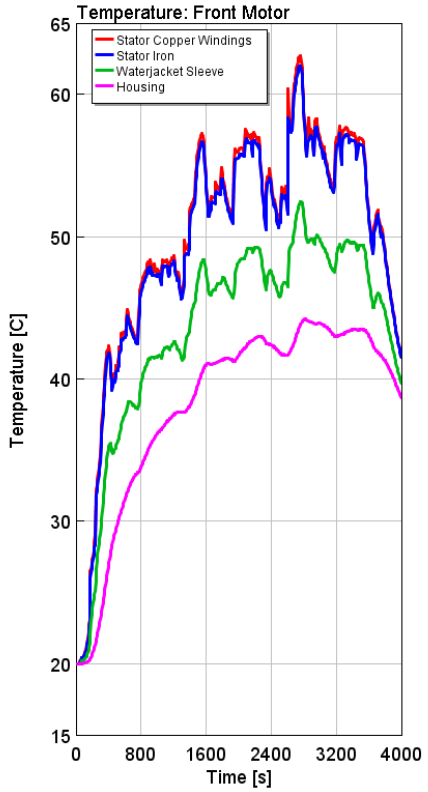
Integrated Electric Vehicle Model

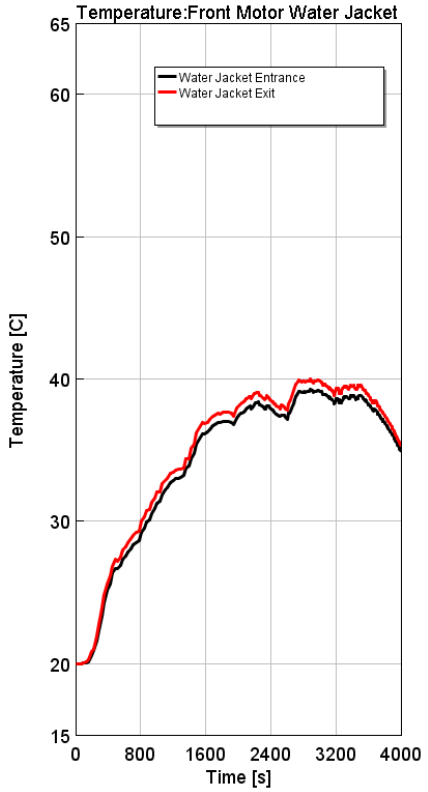
Fast and accurate performance **prediction in extreme conditions** exclusively through virtual simulation



Holistic E-Powertrain Design @ BorgWarner





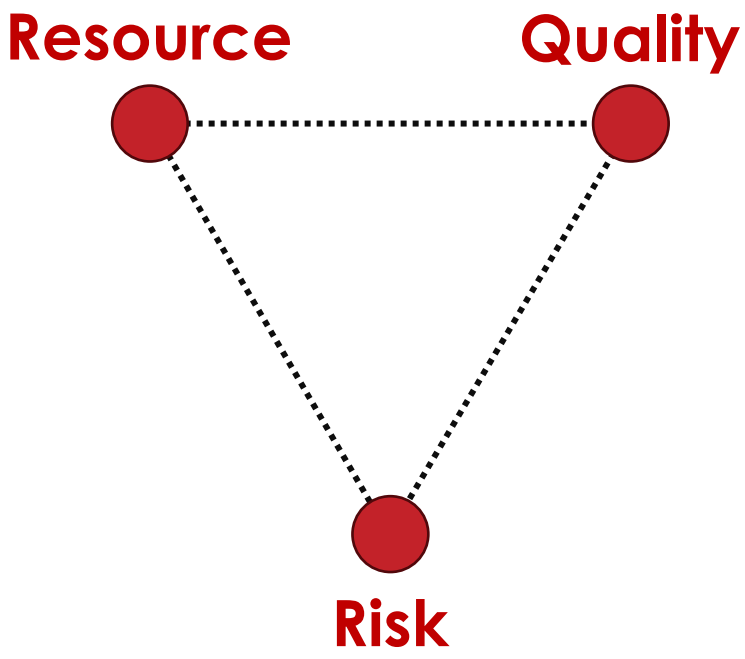


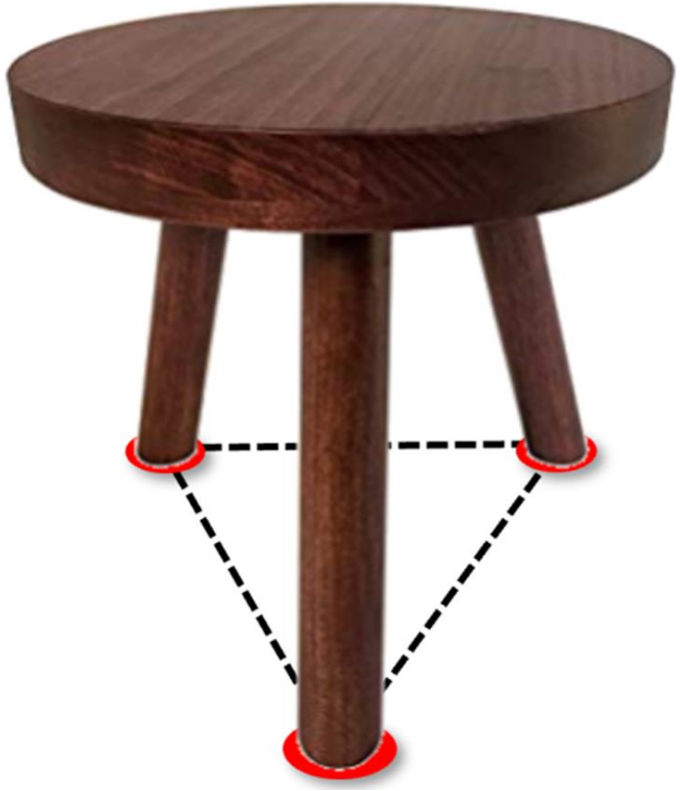
Dr. Philip Keller

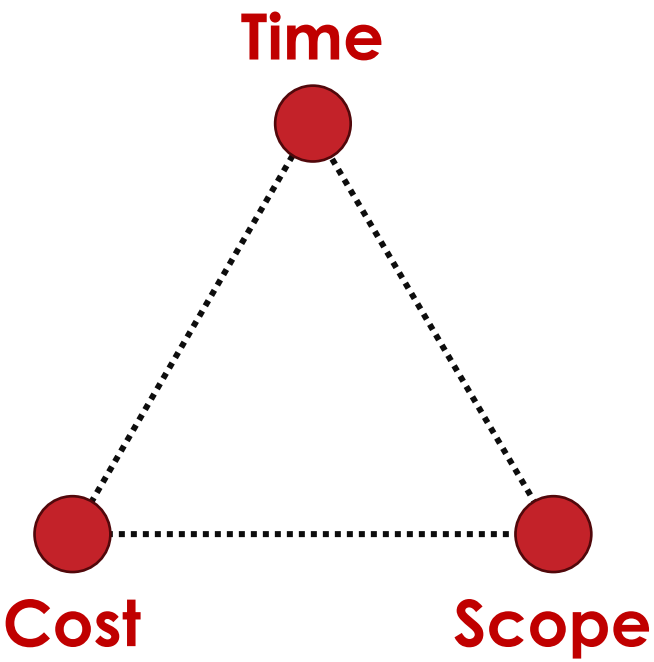
Simulation Specialist at BorgWarner Inc.

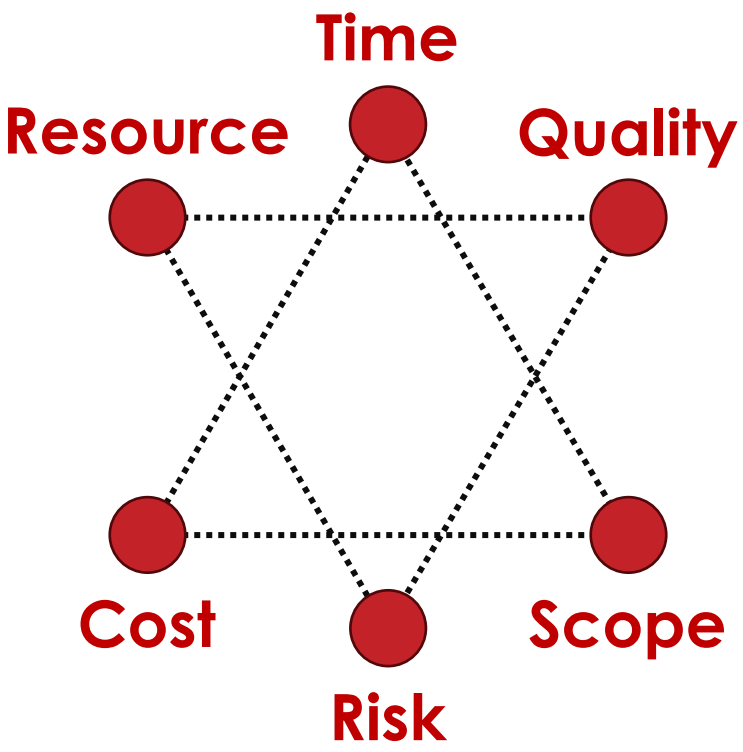
"Electric vehicle components needed to be developed in a system environment to help enable **downsizing of systems to achieve future targets and reduce Cost**"

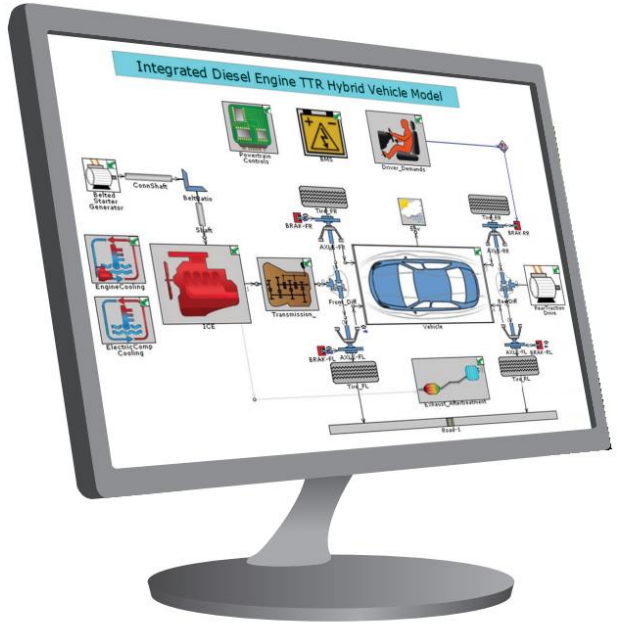
What are the challenges of a development cycle?











Virtualization of Complete Vehicle Design and Validation

The role of virtualization in achieving your project targets

Modular Model Management

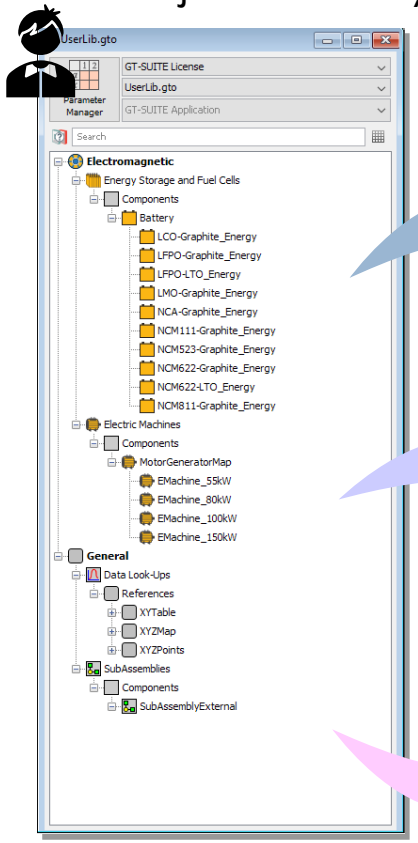
git Network or local model repository

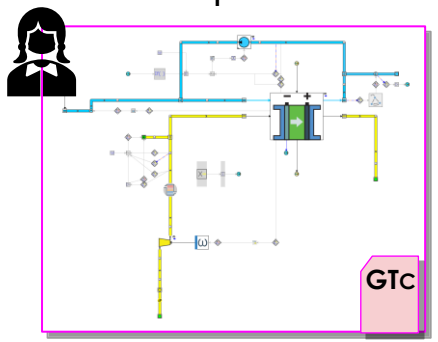
GT Object Library

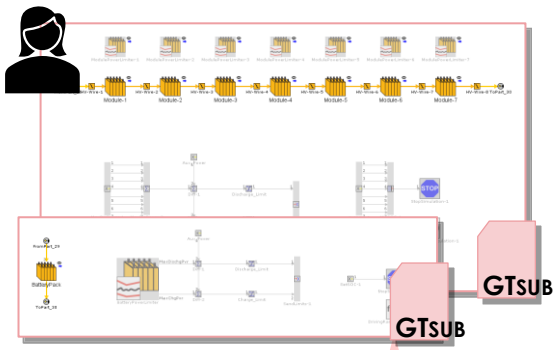
Compound

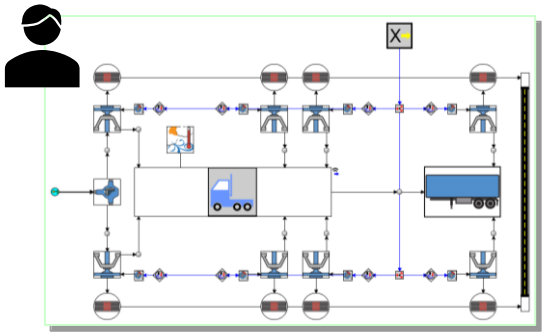
External Subassemblies

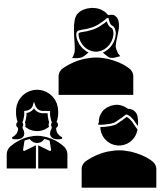
Internal Subassemblies

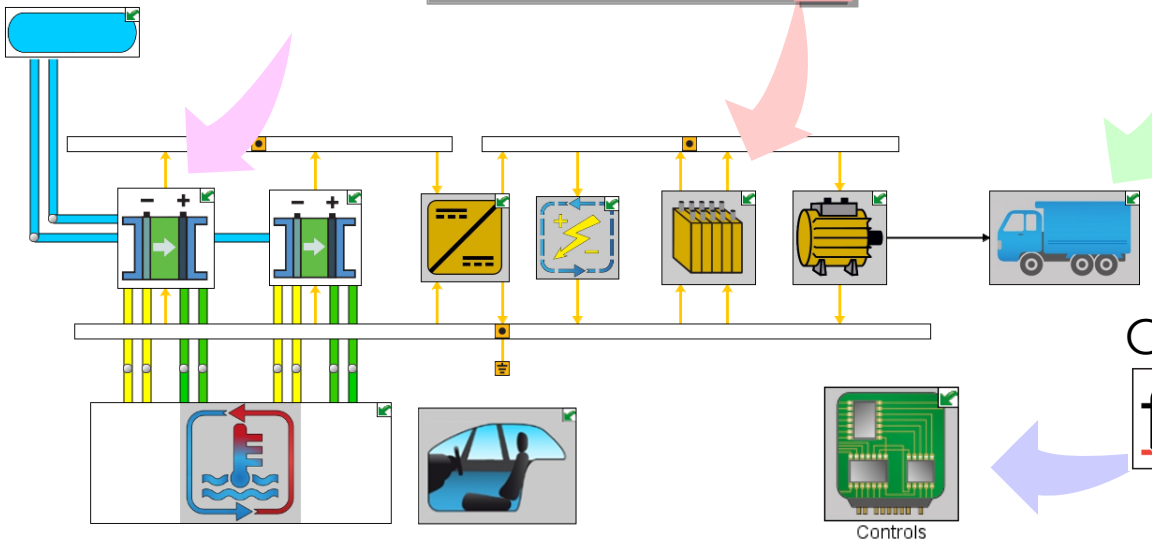






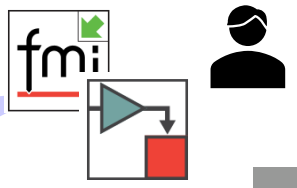






Automation

Co-Simulation

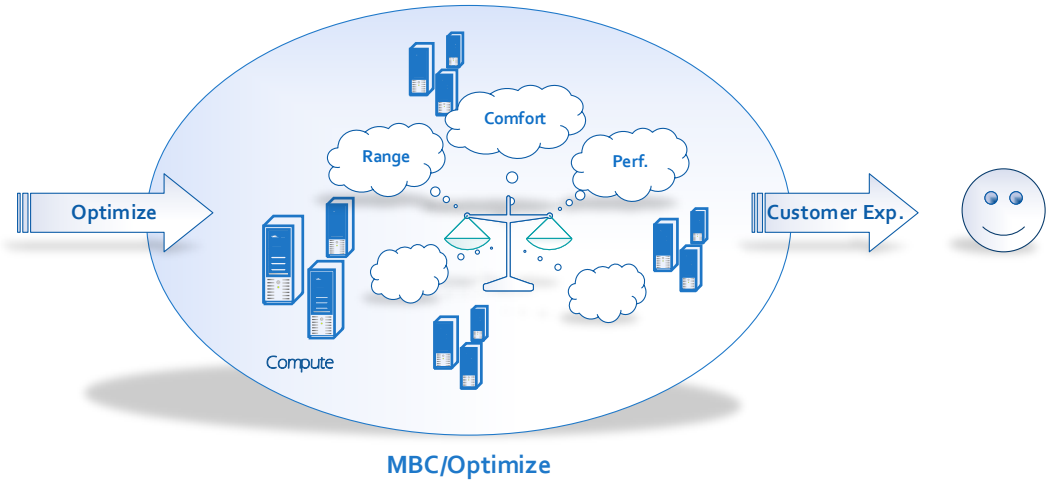


Vehicle Systems Analysis for Attribute Optimization

Vehicle design to meet customer requirements

Virtual Vehicle

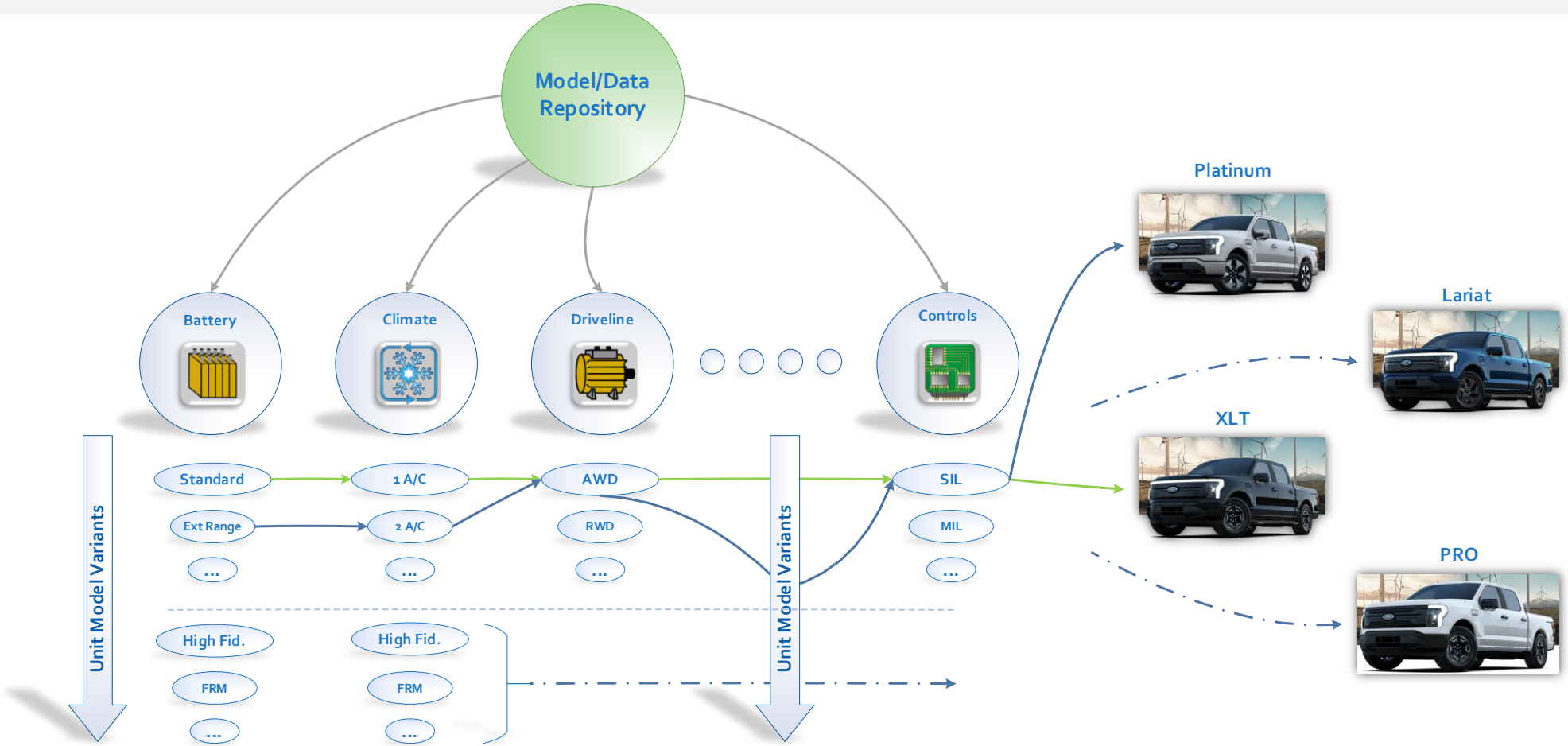
Virtual vehicles to reproduce vehicle behaviors



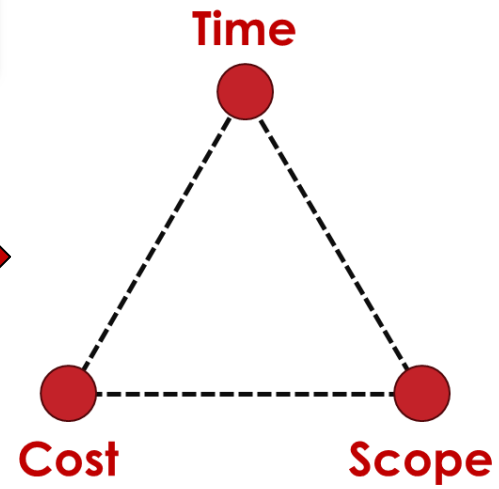
MBC/Optimize

Virtual vehicles to deliver customer satisfaction through **optimal designs during early stages** of development and **through optimal calibration during later stages** of development

Modular Plant Modeling

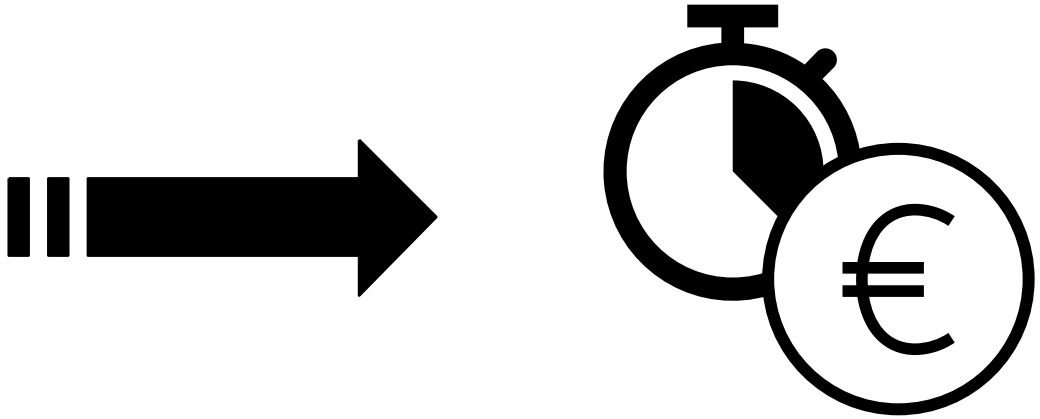


Modular plant modeling in GT-SUITE ensures that **any specific variant** of a vehicle family **can be auto built** in a virtual environment without manual intervention



Role of Automation

- Processes
- Modifications
- Human Errors
- Iterative actions
- …



Role of Automation

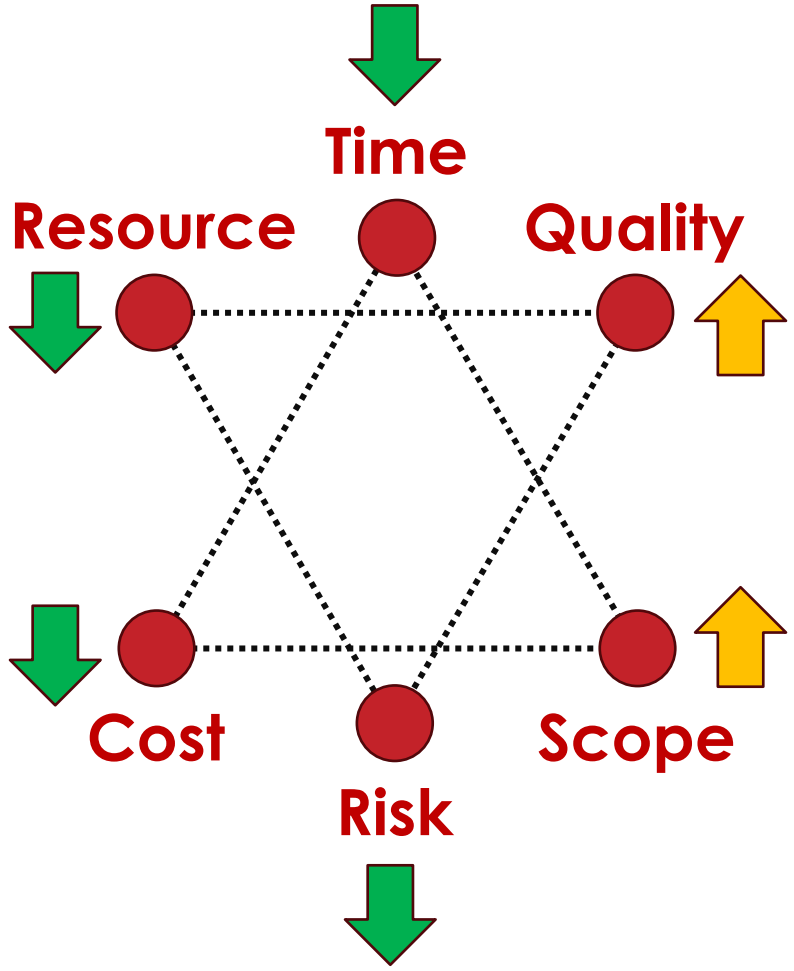
- Processes
- Modifications
- Human Errors
- Iterative actions
- …

GT-Automation

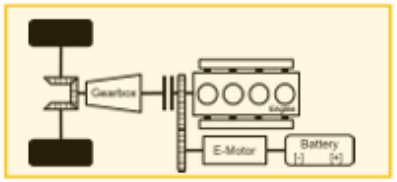
- Automated Process
- Mass modifications
- Reduce Errors
- Establish Workflows
- …

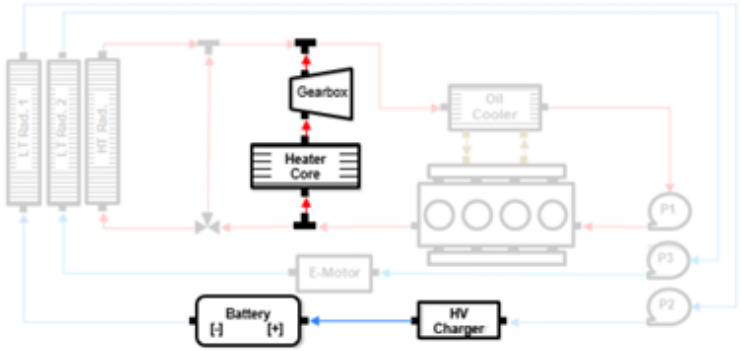
Role of Automation

- Automated Process
- Mass modifications
- Reduce Errors
- Establish Workflows
- …

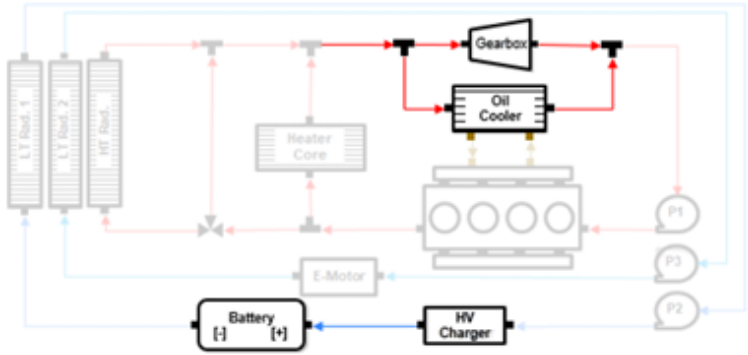


COOLING SYSTEM ARCHITECTURES

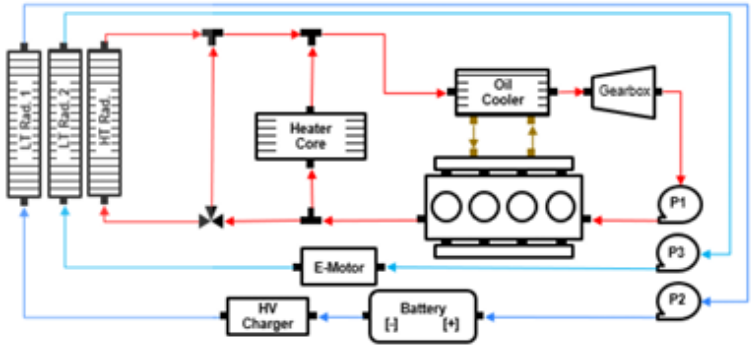




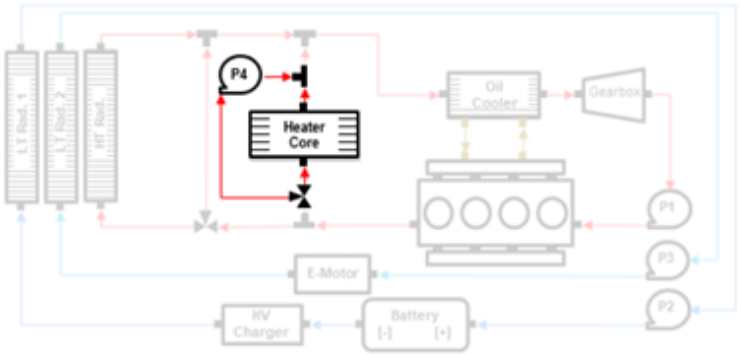
Alternative 2



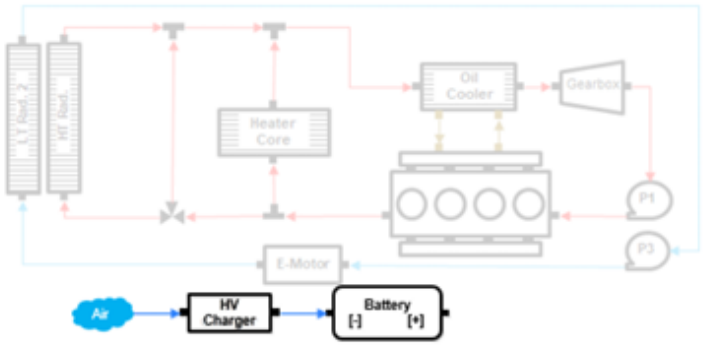
Alternative 1



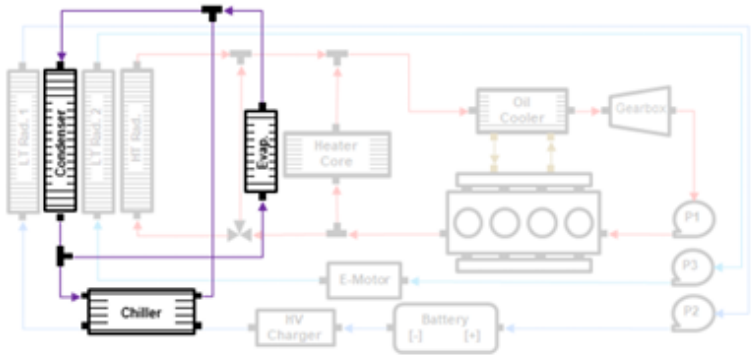
Reference



Alternative 3



Alternative 4

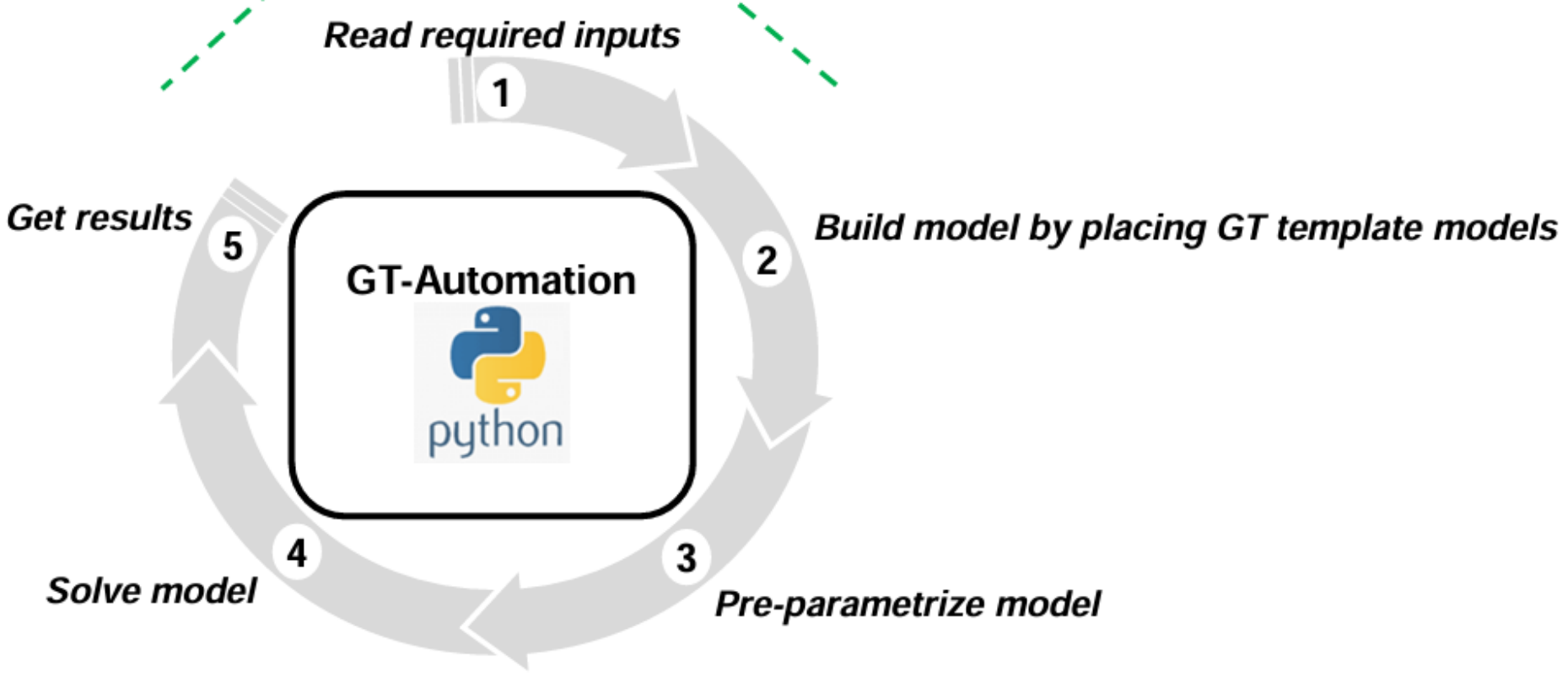


Alternative 5

Automated workflows to investigating different cooling system architects

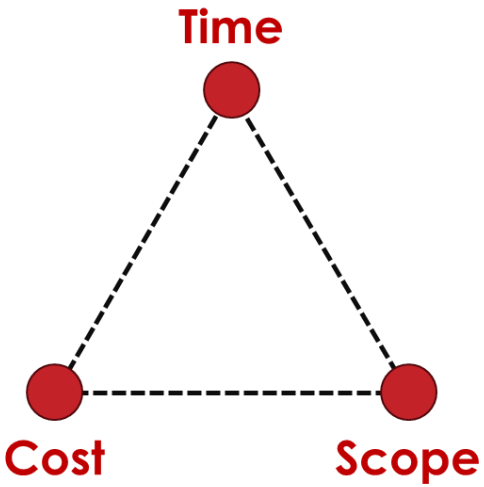
GT-AUTOMATION : OVERVIEW

Functional architectures generation → 3D optimization → **Energetical optimization** → Multicriteria Optimization

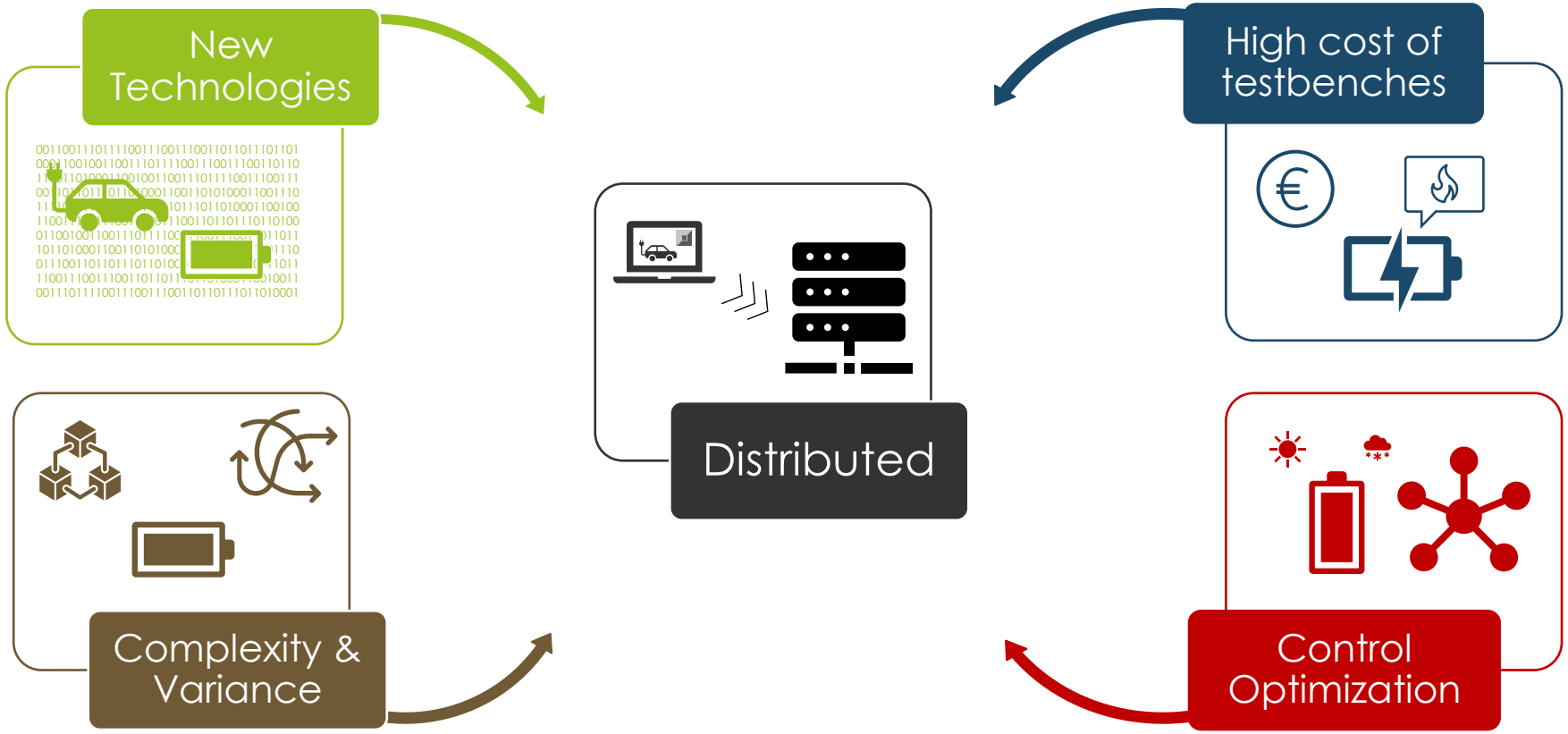


CONCLUSIONS

- A **framework** of **generation**, **optimization** and **evaluation** of cooling system architecture has been **introduced**
- The **framework** has been built **from the definition of the cooling system requirements**
- **GT-Automation & GT-SUITE** are used in **the evaluation step**. It allows us to :
  - automatically build physical models
  - automatically simulate and evaluate models
  - potential development time savings

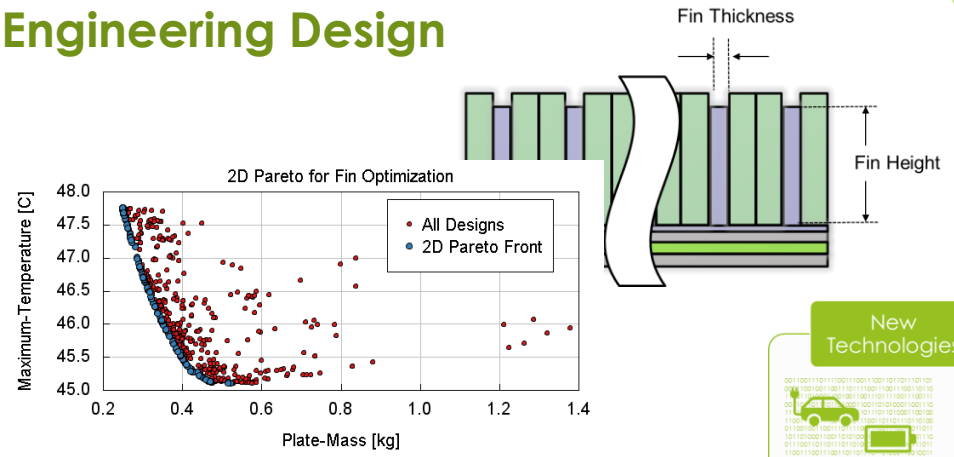


Aspects of Modern Development Cycle



Aspects of Modern Development Cycle

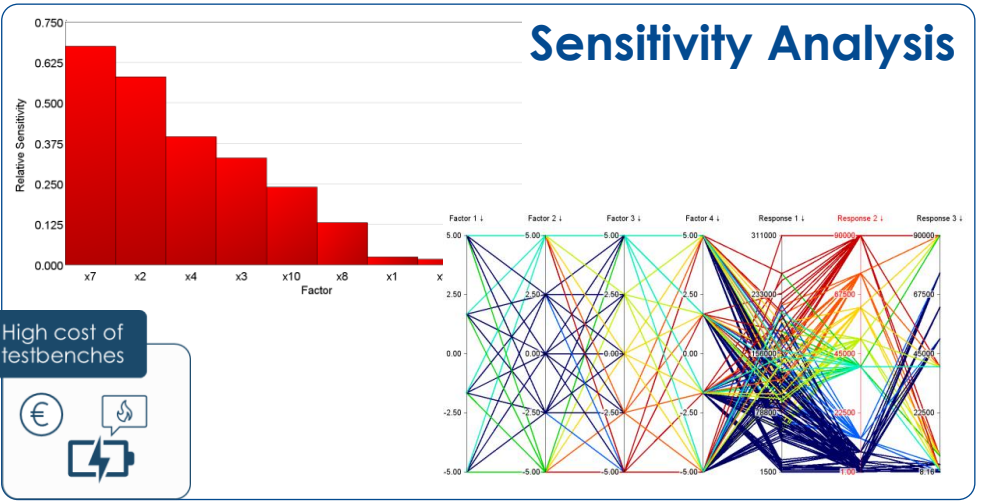
Engineering Design



New Technologies

High cost of testbenches

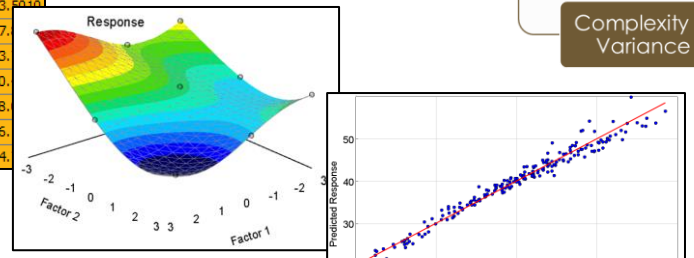
Sensitivity Analysis



Distributed

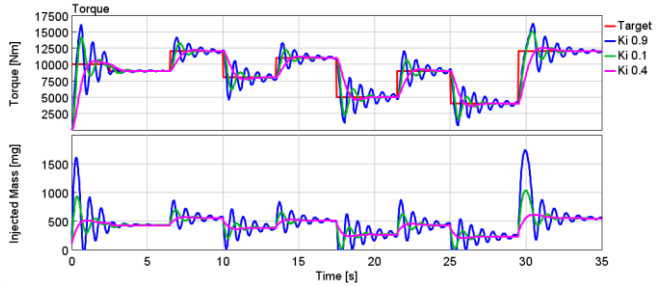
Machine Learning

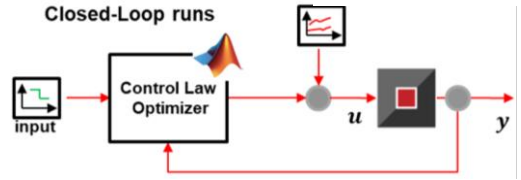
F1	F2	F3	Response
Factors			Responses
180.000	60.0000	40.0000	43.5010
180.000	60.0000	42.0000	37.
180.000	60.0000	44.0000	33.
180.000	60.0000	46.0000	30.
180.000	60.0000	48.0000	28.
180.000	60.0000	50.0000	26.
180.000	60.0000	52.0000	24.



Complexity & Variance

Control Optimization





Virtual Calibration

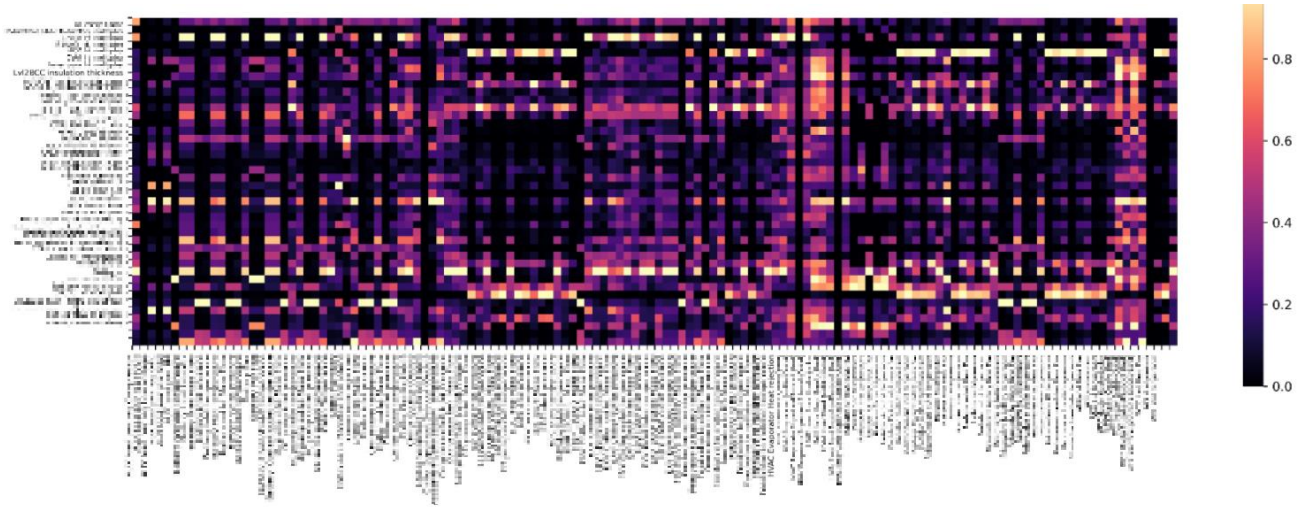
Holistic Vehicle Design Optimization @ CEVT

Y-axis Variables:

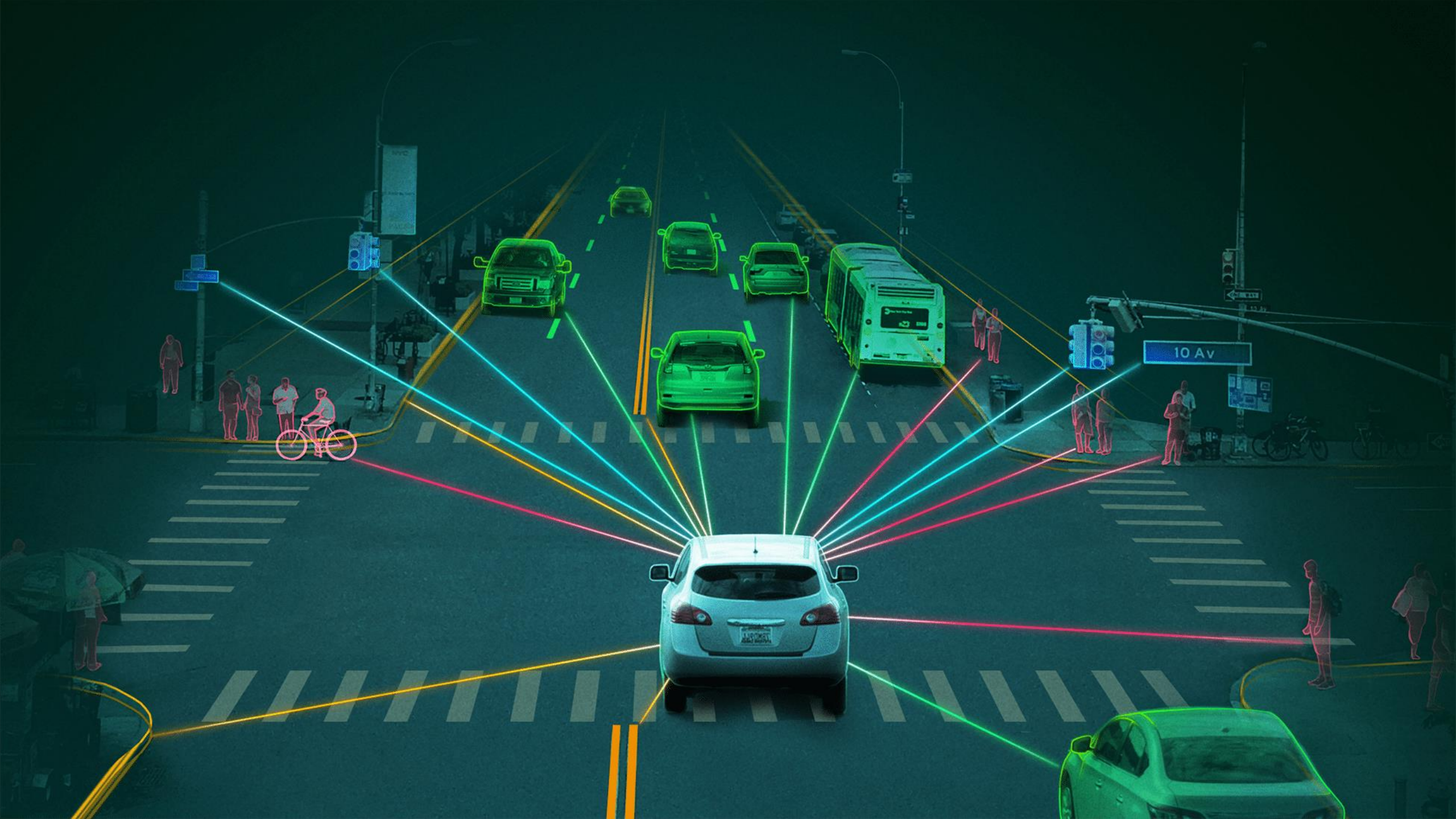
- Pump, Blower, compressor
- Cooling properties and Conditions
- Insulation properties
- Heat exchanger dimensions
- Windshield properties etc.

X-axis Targets:

- Cabin conditions, such as temperatures, humidity etc.
- Battery conditions, such as SOC profile, cell temperatures, cooling performance
- Auxiliary loads, energy usage for pumps, fans, compressor etc.

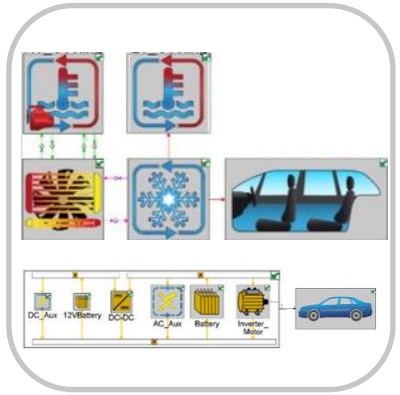


"Utilizing the full potential of a Holistic System Simulation to **answer the questions better, faster and with higher quality** - Not only the impact of a **system, subsystem, component** etc., but the **synergies within and between them**"


10 Av

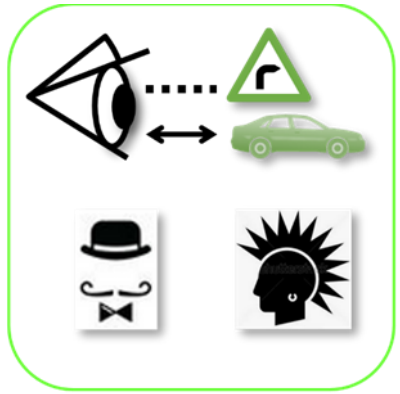
System engineering to make the future manageable

Vehicle Simulation in GT-SUITE



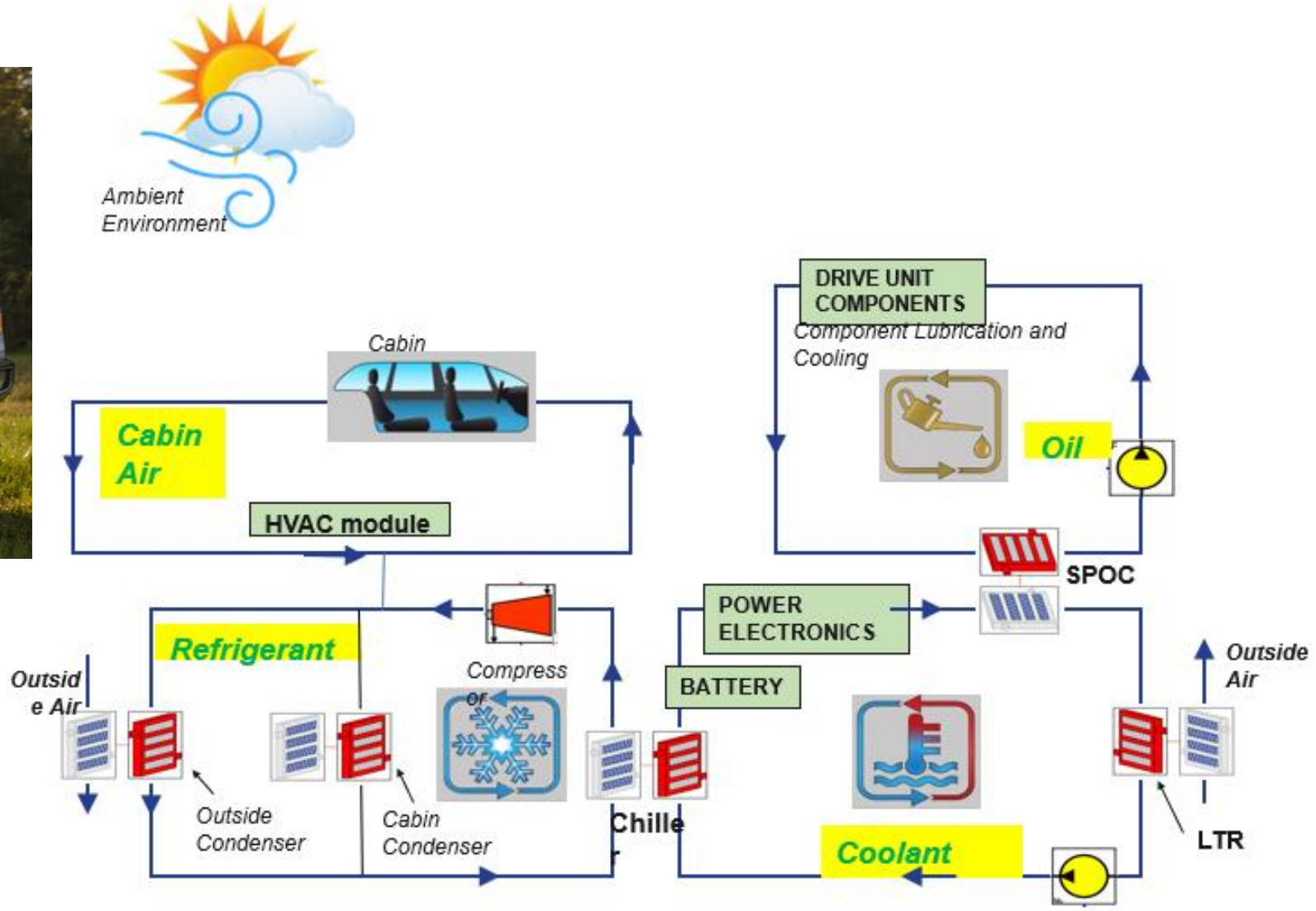
Fast Integrated Vehicle System Model

Environment & Route Generation

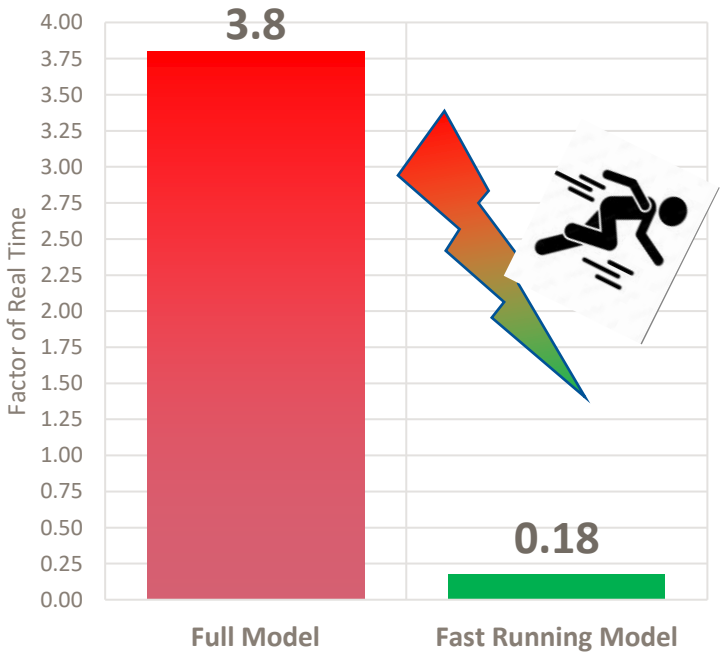


Deployment & Democratization

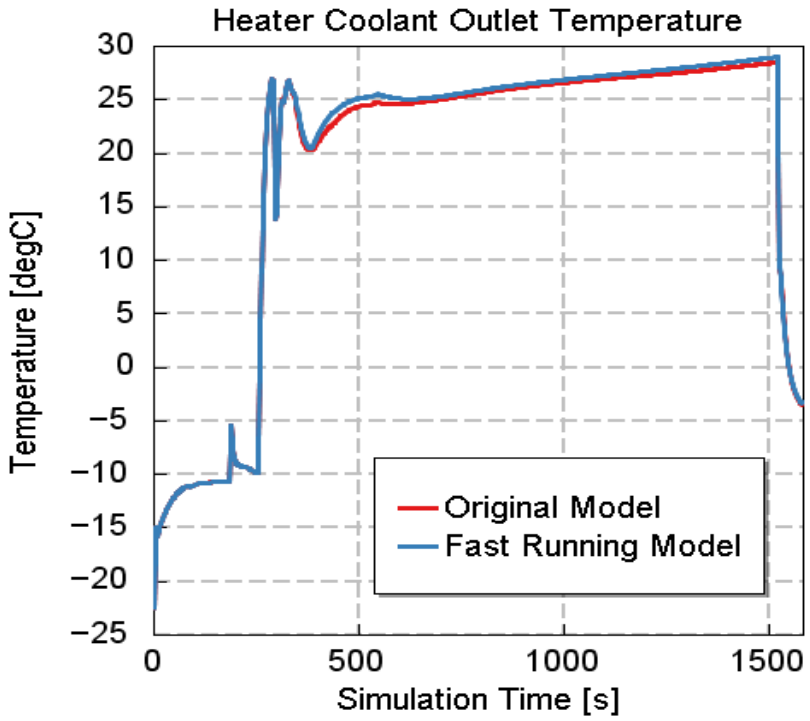
Electric Vehicle Integrated Thermal Model @ GM



Reduced Order Modeling in GT-SUITE for fast running XiL Simulations



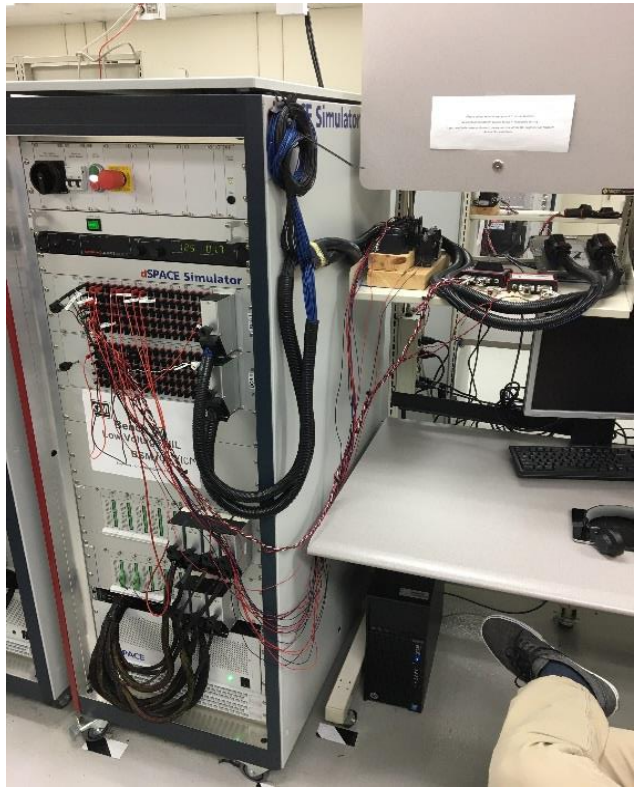
Physics-based fast running Reduced Order Model

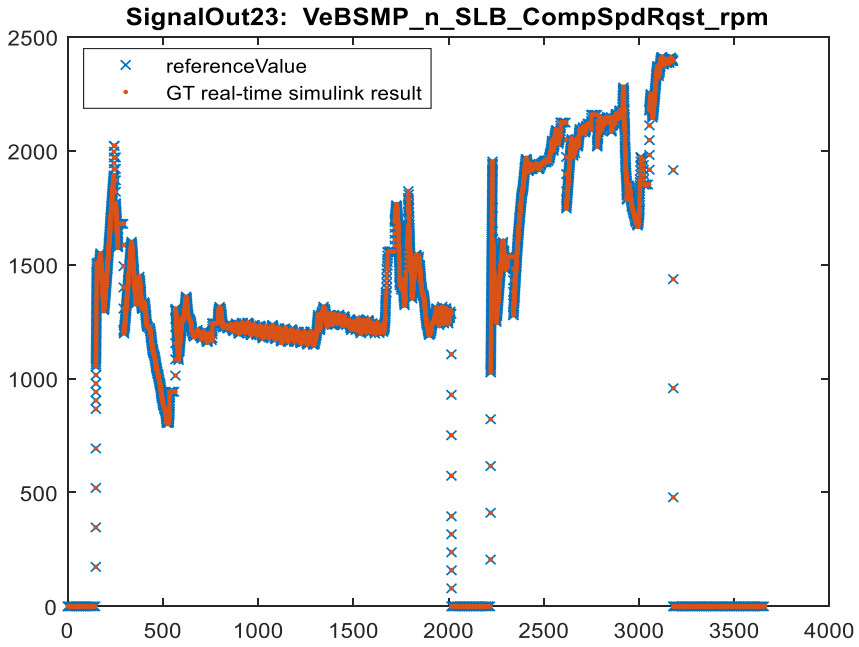


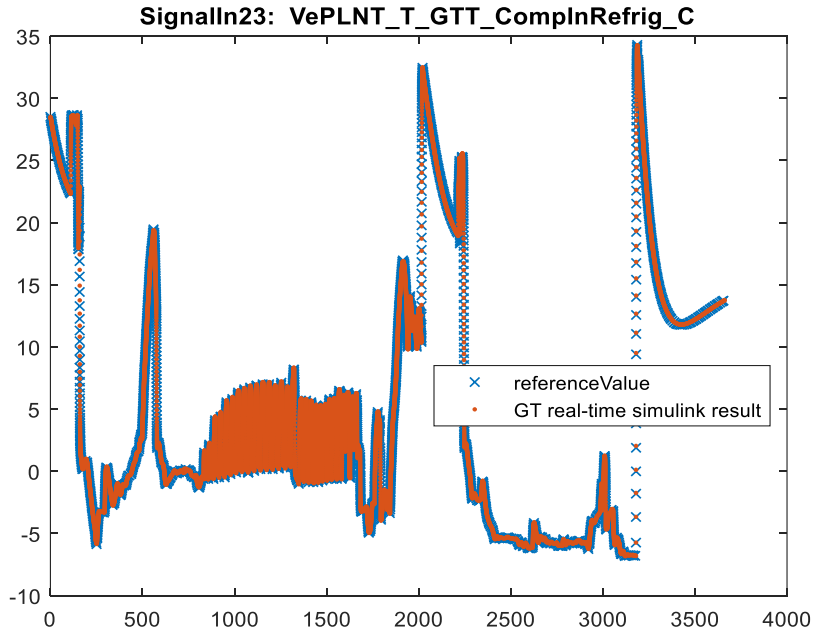
Accuracy is preserved in Reduced Order Model

HiL Deployment

- GT-Plant model integrated with **Battery Systems Electronic Control Module -** Example below is from ‘Hot Idle’ scenario.
  - ◄ **Left:** Compressor speed request
    Right ►: Compressor inlet Refrigerant temperature





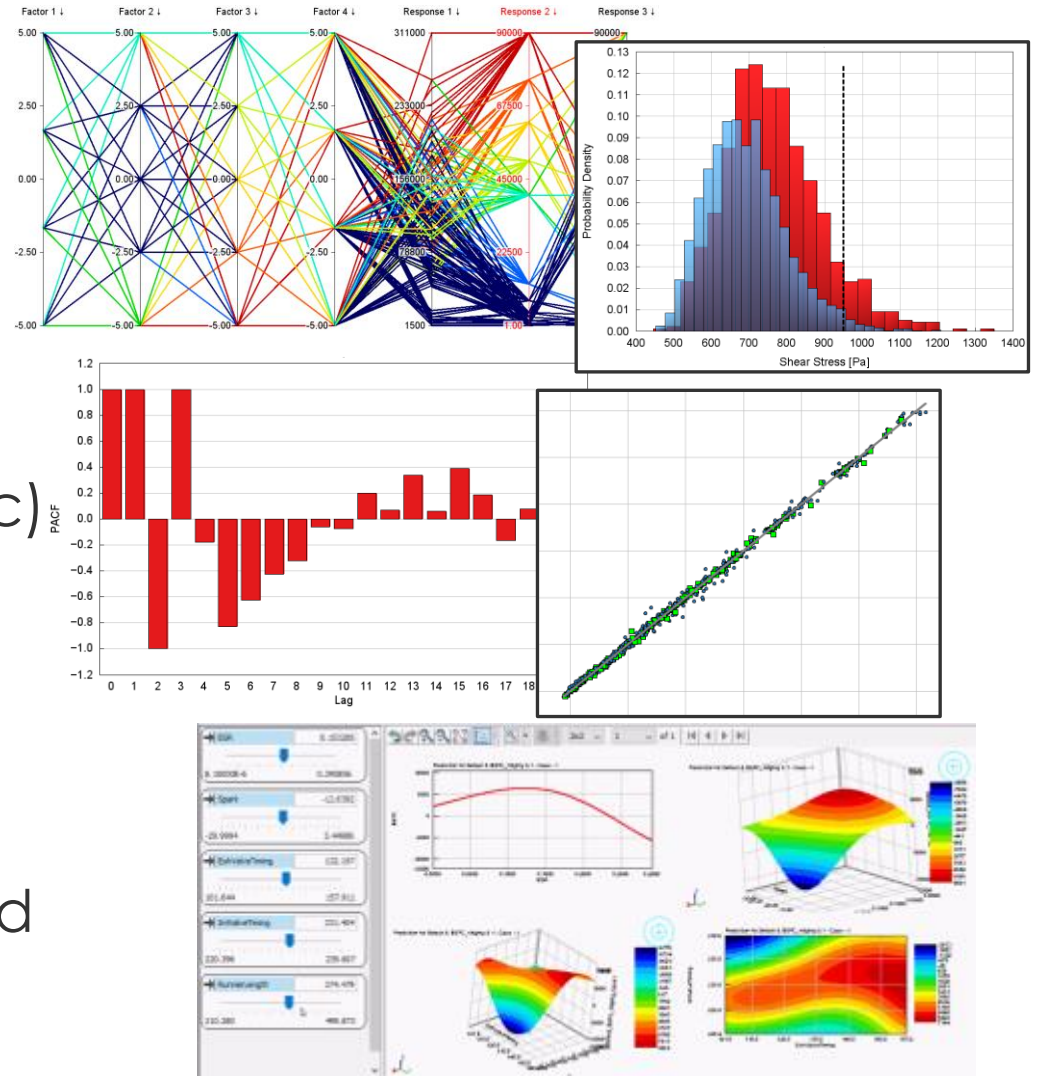


Conclusions and Future Work

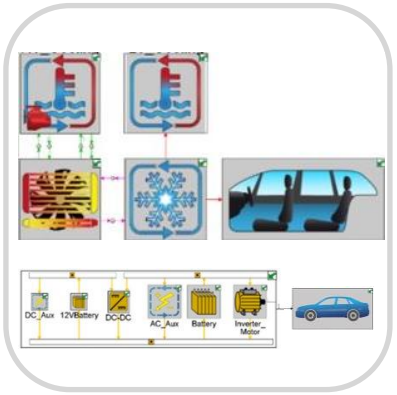
- GT-SUITE RT enables running **physics-based EV thermal** management models on a **HIL bench**
- The process of deriving such models from a detailed model is demonstrated
- Key **run-time optimization** techniques are provided
- The same approach is valid for **MiL** and **SiL**
- A **complex model** containing refrigerant, coolant, cabin, drive units and lubrication systems ran **on the HiL with good accuracy** and **no overruns**
- The new version of **GT-SUITE (v2024)** has additional **improvements**:
  - Faster refrigerant solution
  - Reduced # of volumes needed in heat exchangers for faster run time
  - Enhancements to the combine volumes wizard making it easier to generate fast running models

GT's Machine Learning Assistant

- Import GT simulation data, or measurement data from text/Excel files
- Train and assess how well metamodels generalize to unseen data (static & dynamic)
- Visualize and explore response surface
- Export metamodel to C-code for embedded systems (virtual sensors, controls)

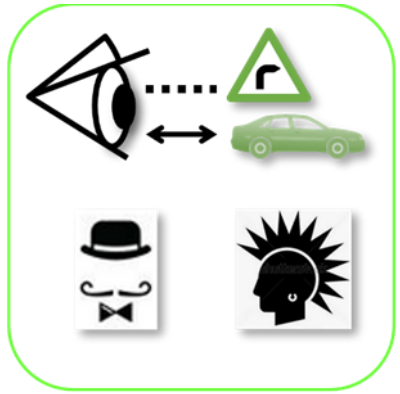


Vehicle Simulation in GT-SUITE



Fast Integrated
Vehicle System Model

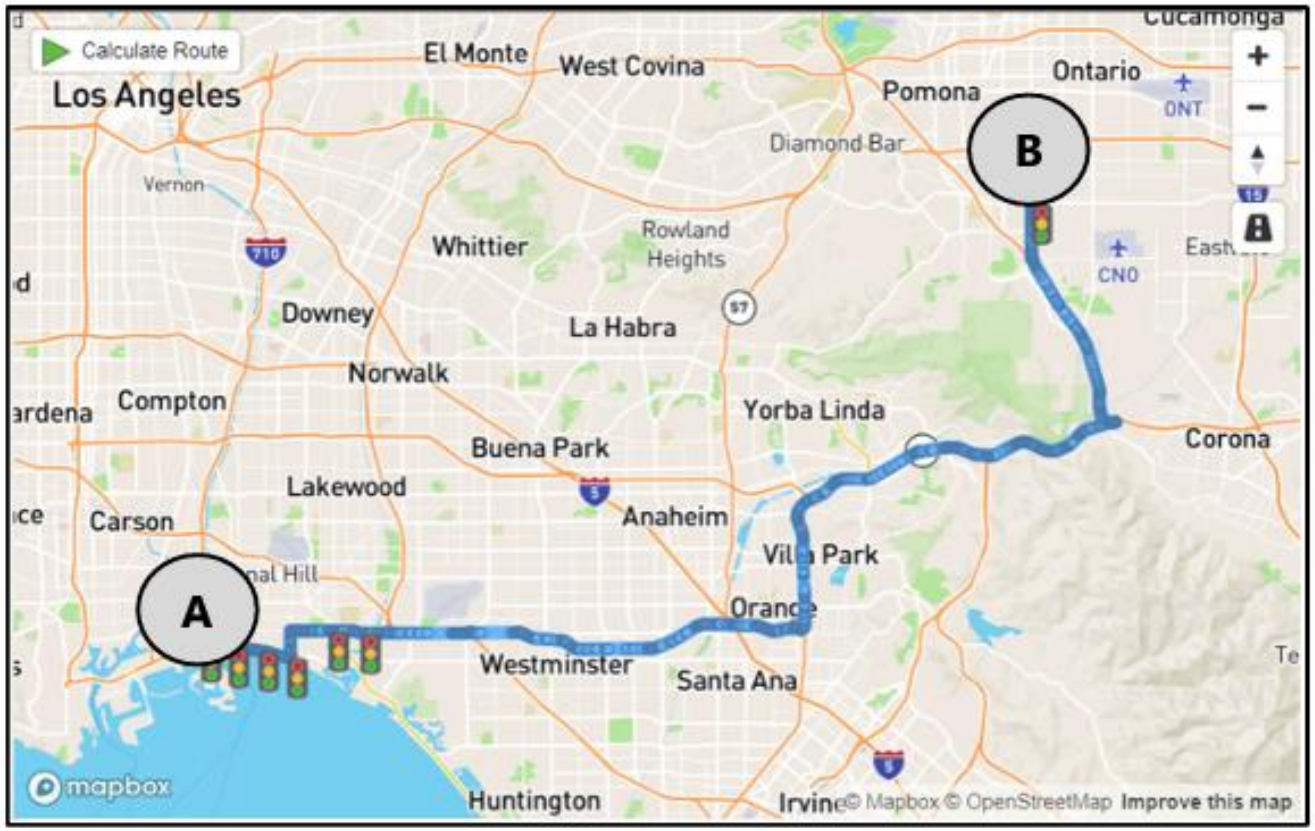
Environment &
Route Generation

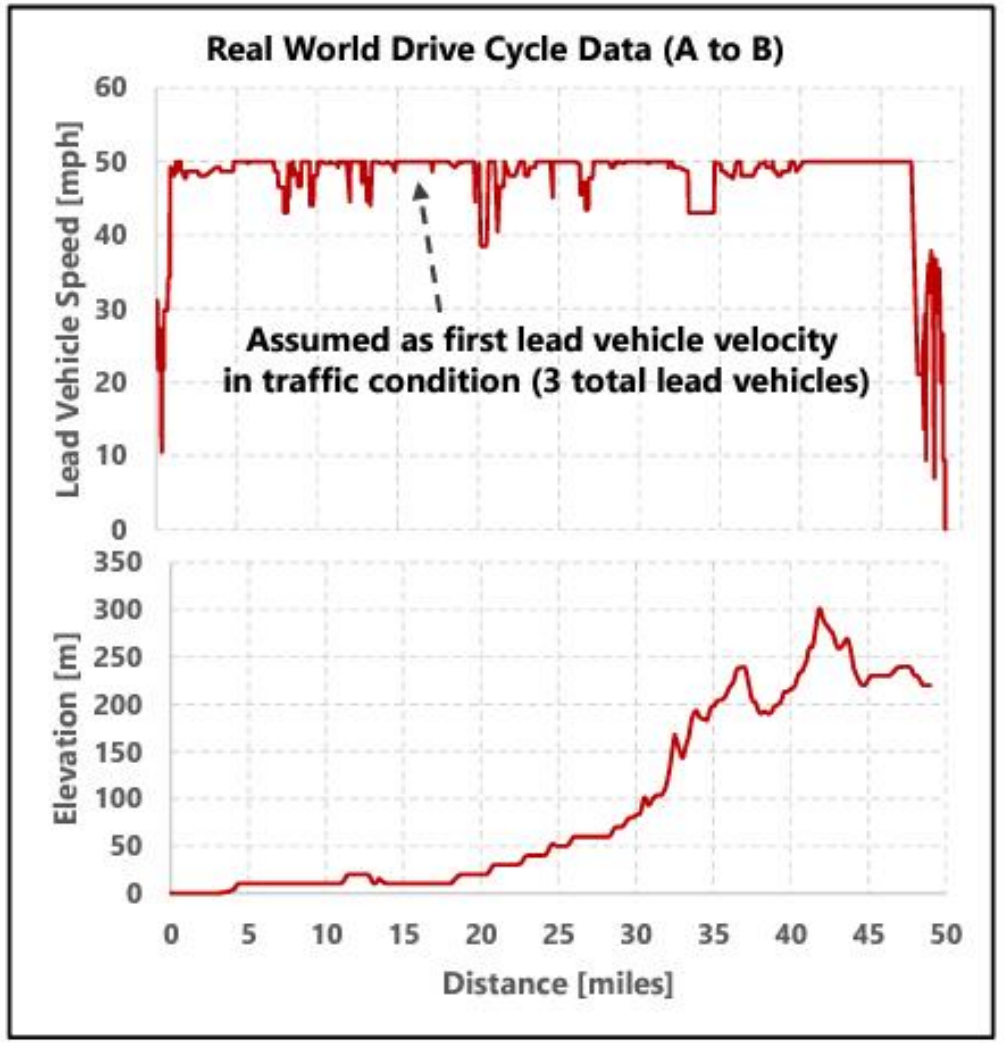


Deployment &
Democratization

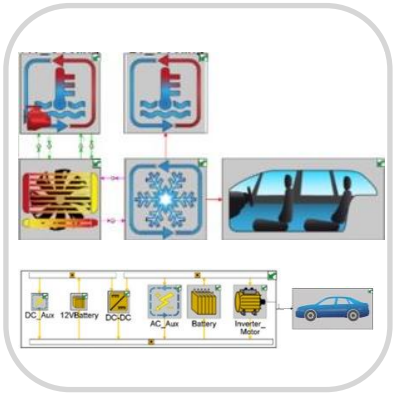
Understanding & Optimizing Real World Scenarios with **GT-RealDrive**

Route generated (A to B) using GT-RealDrive





Vehicle Simulation in GT-SUITE



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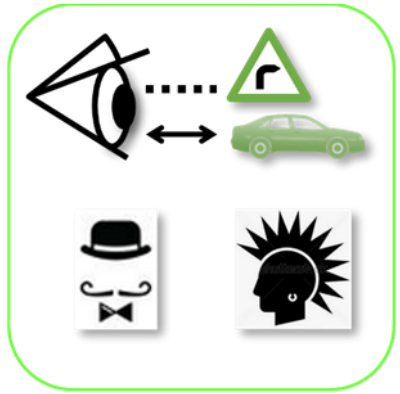
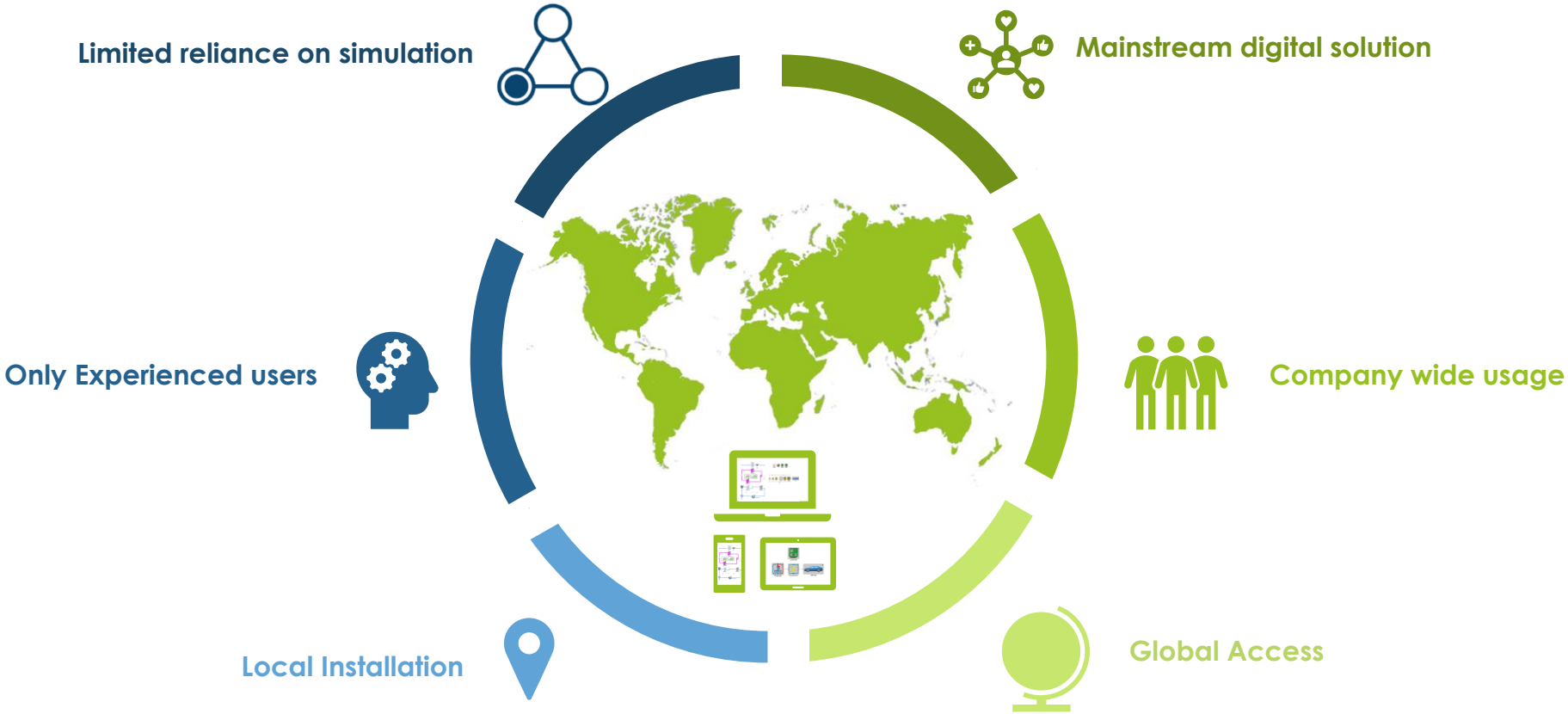


**Deployment &
Democratization**

Deploy models with **GT-Play**

Yesterday vs Today



Various usages in product performance evaluation

Examples of typical needs + results for each context and role :

Example 1 :
Project engineer

Value of GT-play for this end-user :
- ✓ Check perfo v sizing x refrigerant
- ✓ Quick pre-evaluation @customer's
- ✓ Test diagnostics

Expectations of this end-user :
1. Speed
2. Refrigerant change
3. Accuracy of the evaluation

Example 2 :
Test technician

Value of GT-play for this end-user :
- ✓ Test bench preparation
- ✓ Test results diagnostics
- ✓ New Test bench component sizing

Expectations of this end-user :
1. Reliability/Close link to experimental results
2. Accuracy of the evaluation
3. Diversity of the product library

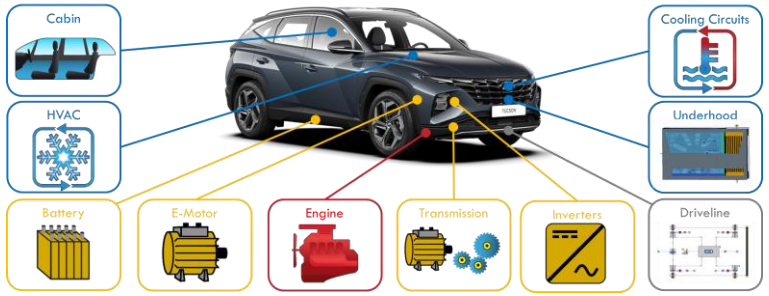
Example 3 :
Product engineer

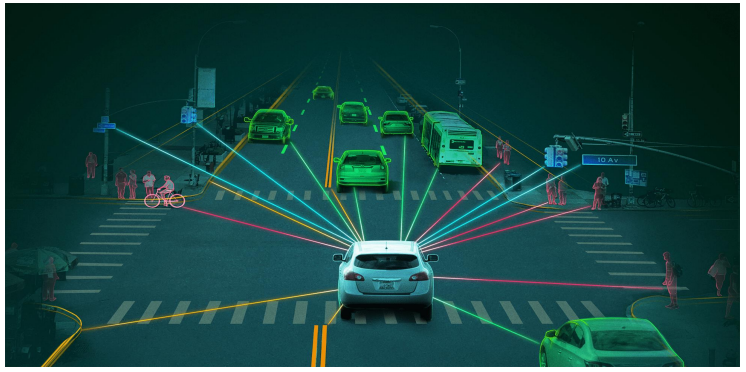
Value of GT-play for this end-user :
- ✓ Thorough selection of components
- ✓ Multi-response analysis
- ✓ Parametric optimization
- ✓ Tech.data sharing

Expectations of this end-user :
1. Design features accessibility
2. Accuracy of the evaluation
3. Adaptability of the models to specific needs
4. Ease-of-use in sharing models

Hisense Stronger Together SANDEN

In Summary …





- **Power of system focused design & development**
- **Virtualization to achieve development targets**
- **System engineering to make the future manageable**