Andrew Curtis Senior Simulation Engineer
Victoria Rothwell Group Leader Energy Attributes

Introduction to Polestar

Polestar CAE Development

Pandora Vehicle Simulation

Polestar – the guiding star.

We are an **electric performance brand**, determined to improve the society we live in.

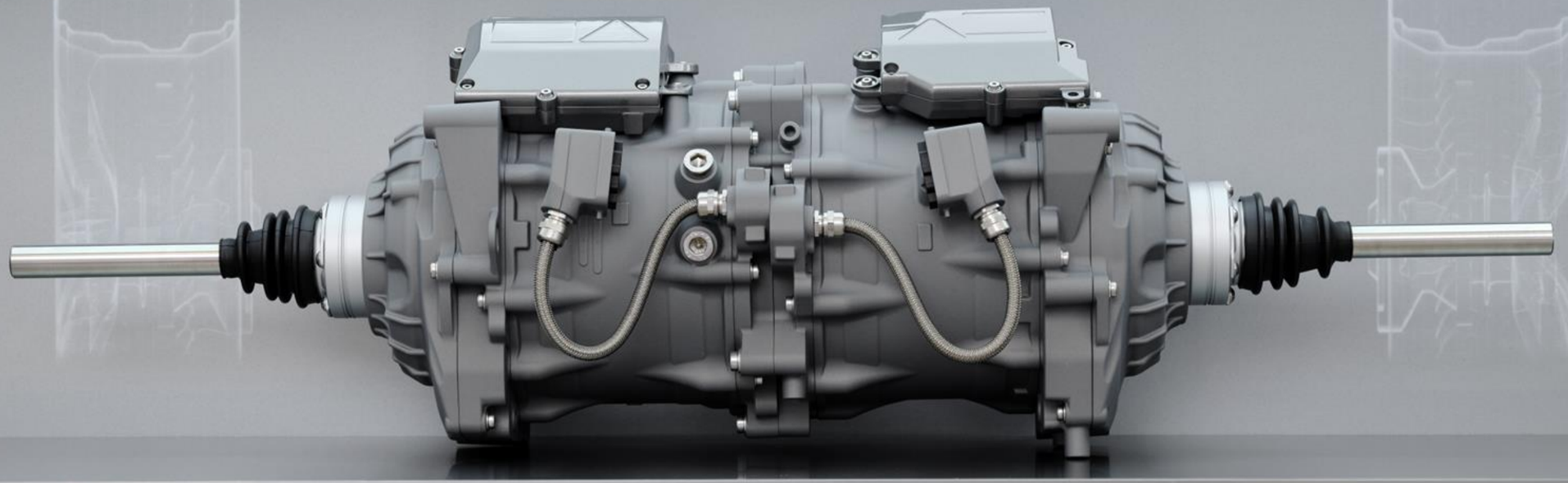
Our focus is on **uncompromised design and technology**. Passion and emotion drive us, electricity and innovation drive our cars. Our products are **excellent, efficient and entertaining**. In Polestar’s future, there is no room for shortcuts, excuses or compromises.

We are all in, dedicated to our ambition. Guiding our industry forward through **pure, progressive, performance**.

At Polestar, the sky is the limit.

Design great products with innovative technology that enables sustainable mobility

Powerful electric technology




Polestar 0 Project
0 tCO2e

Pandora Development

Summary

- Polestar has developed the Pandora simulation platform in 9 months to revolutionise its vehicle simulation capability

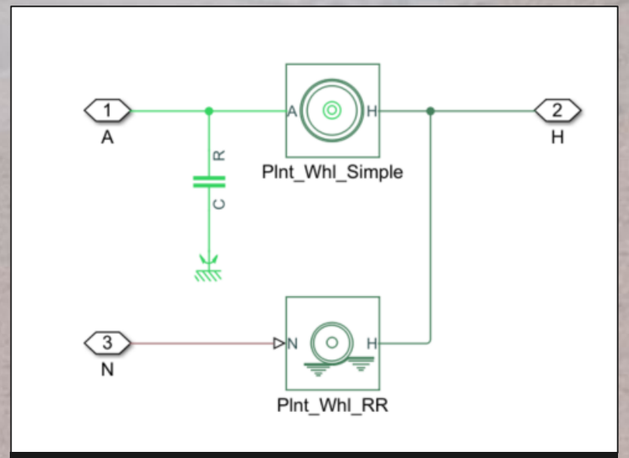
- Pandora vehicle simulations are being used for:
  - Vehicle range studies
  - System design studies
  - Software testing and development
  - Research and development projects

- Polestar will keep pushing the boundaries of CAE, adding more functionality and correlation to the Pandora system

Polestar CAE Development:
Pandora Platform Requirements and Goals

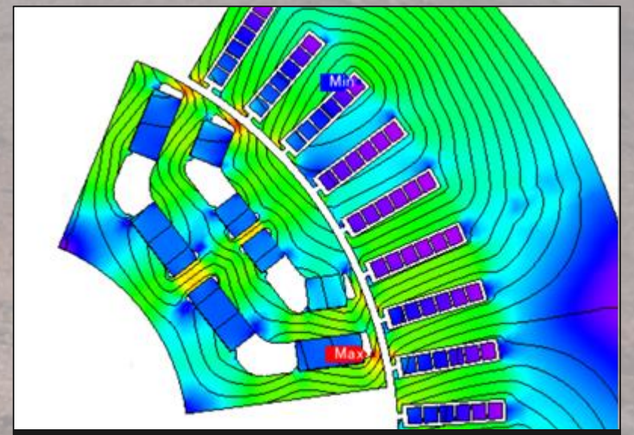
Polestar CAE Development

Polestar CAE Processes



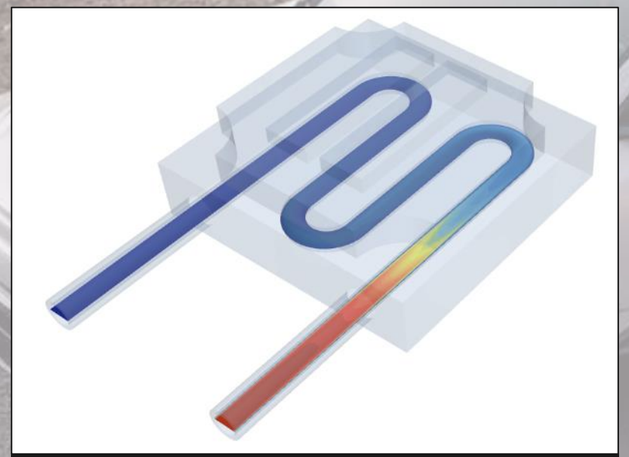
System Modelling

Data Driven Design



Multiphysics Motor Design

Computational Fluid Dynamics



Multiphase Flow

Finite Element Analysis

Polestar CAE Development

The Role of 1D Simulation in Vehicle Design & Development

1-Dimensional (1D) Simulation

System Performance

Control Systems

Design Optimisation

Goal

Develop a simulation platform to model electric vehicle performance

Polestar CAE Development

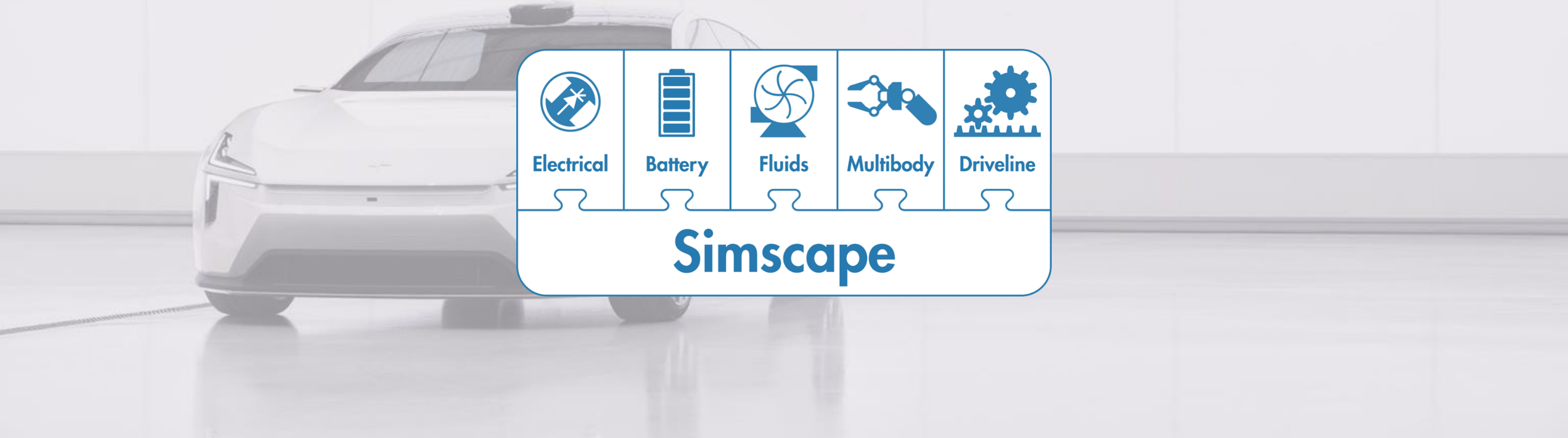
Pandora Platform Requirements

Modelling Requirements	Vehicle energy consumption
	Performance tests
	Thermal systems
	Powertrain behaviour
	Control systems
Functional Requirements	Single repository accessed by multiple users
	Model traceability
	Version control

Polestar CAE Development

Why Simulink?

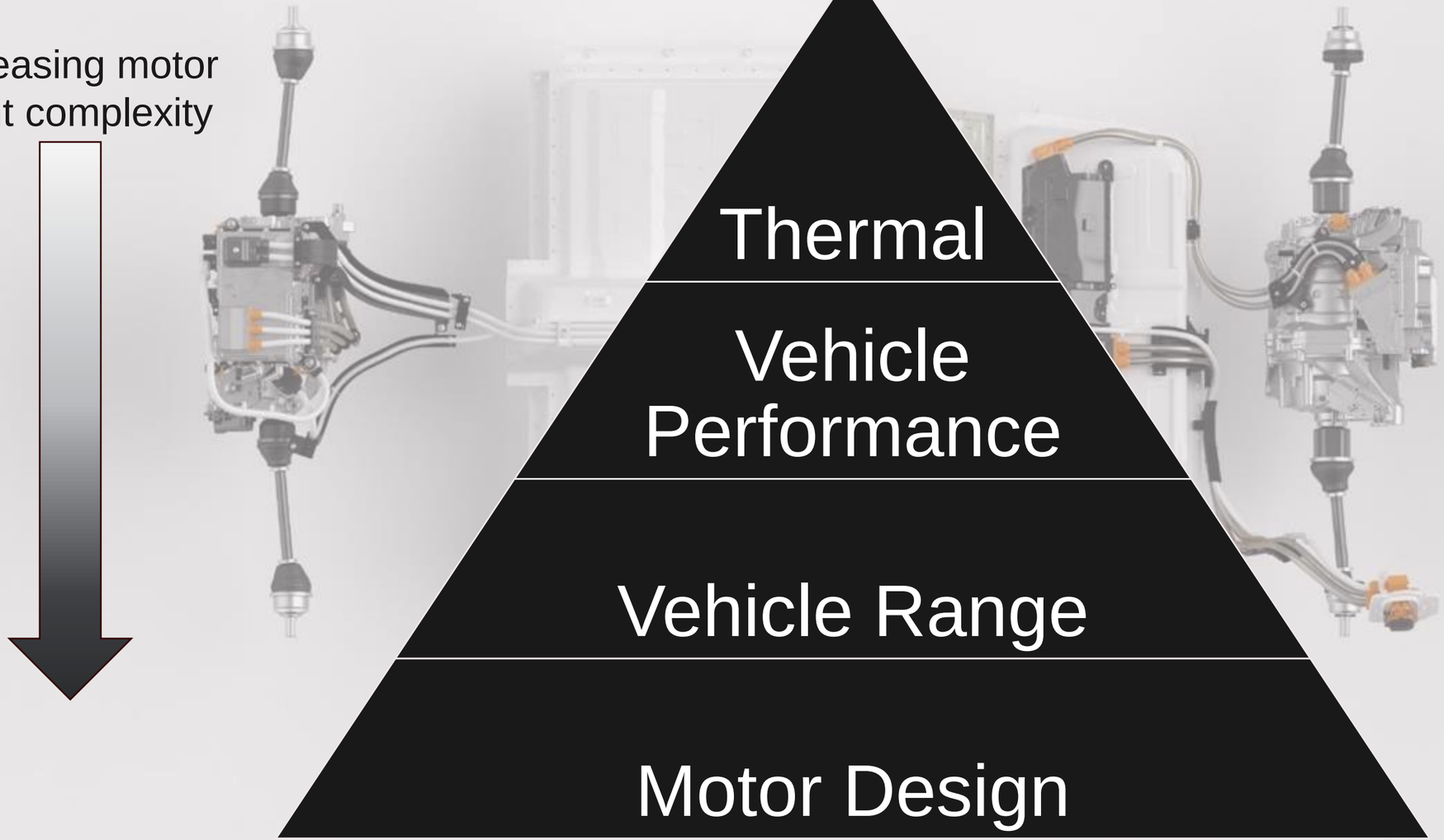
Simscape	Simulink
Physical Modelling Domain	Data Analysis Tools
Vehicle Component Library	Source Control Integration
	Control Systems



Polestar CAE Development

Electric Motor Plant Model Requirements

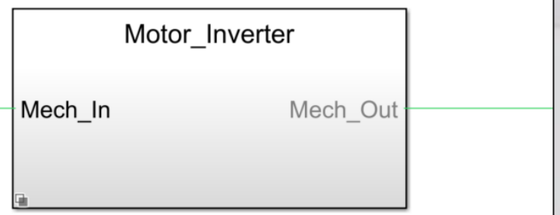
Increasing motor plant complexity



Polestar CAE Development

Plant Model Variants

Motor Plant

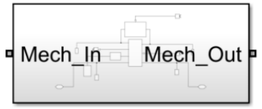


Motor_Variant

Motor Plant Variants

Motor

1
Mech_In

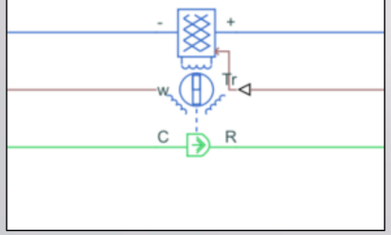


Motor_Inverter

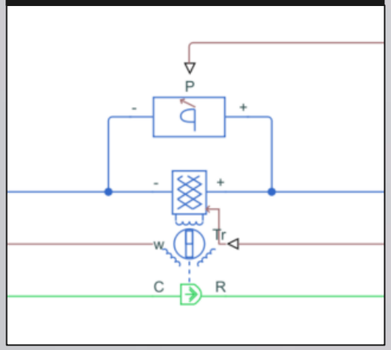
2
Mech_Out

Motor_Inverter_Thermal

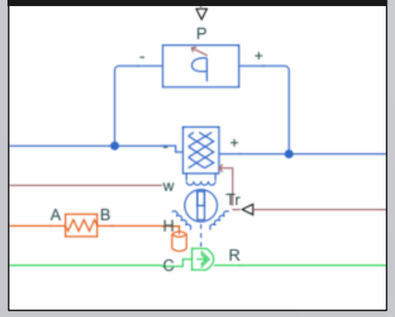
Simple Motor



Motor & Inverter



Motor & Inverter with Thermal



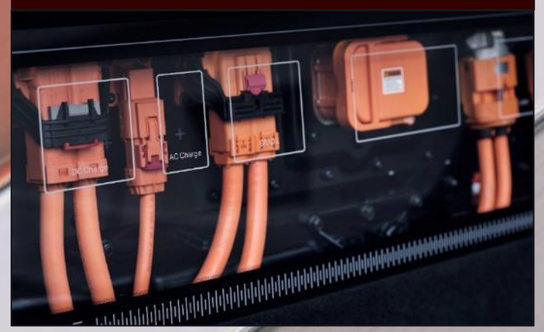
Polestar CAE Development

Simulation Inputs

Vehicle Dynamics

Aerodynamics

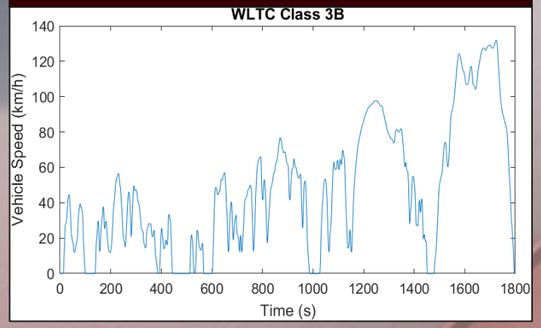
Electrical



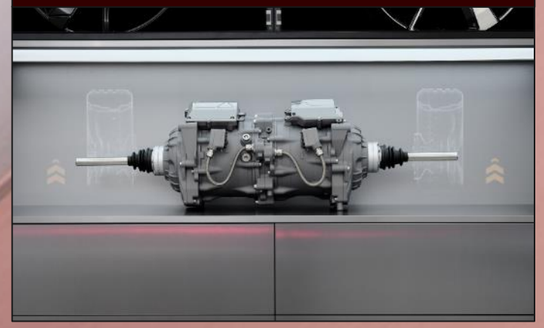
Climate

Battery

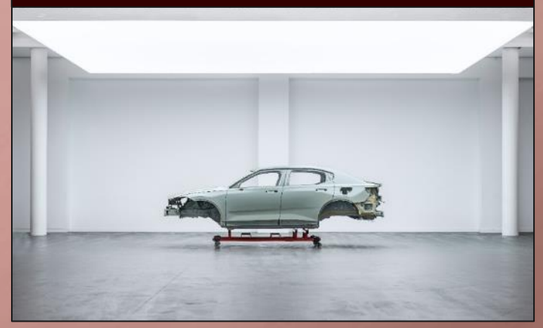
Homologation



Electric Drive

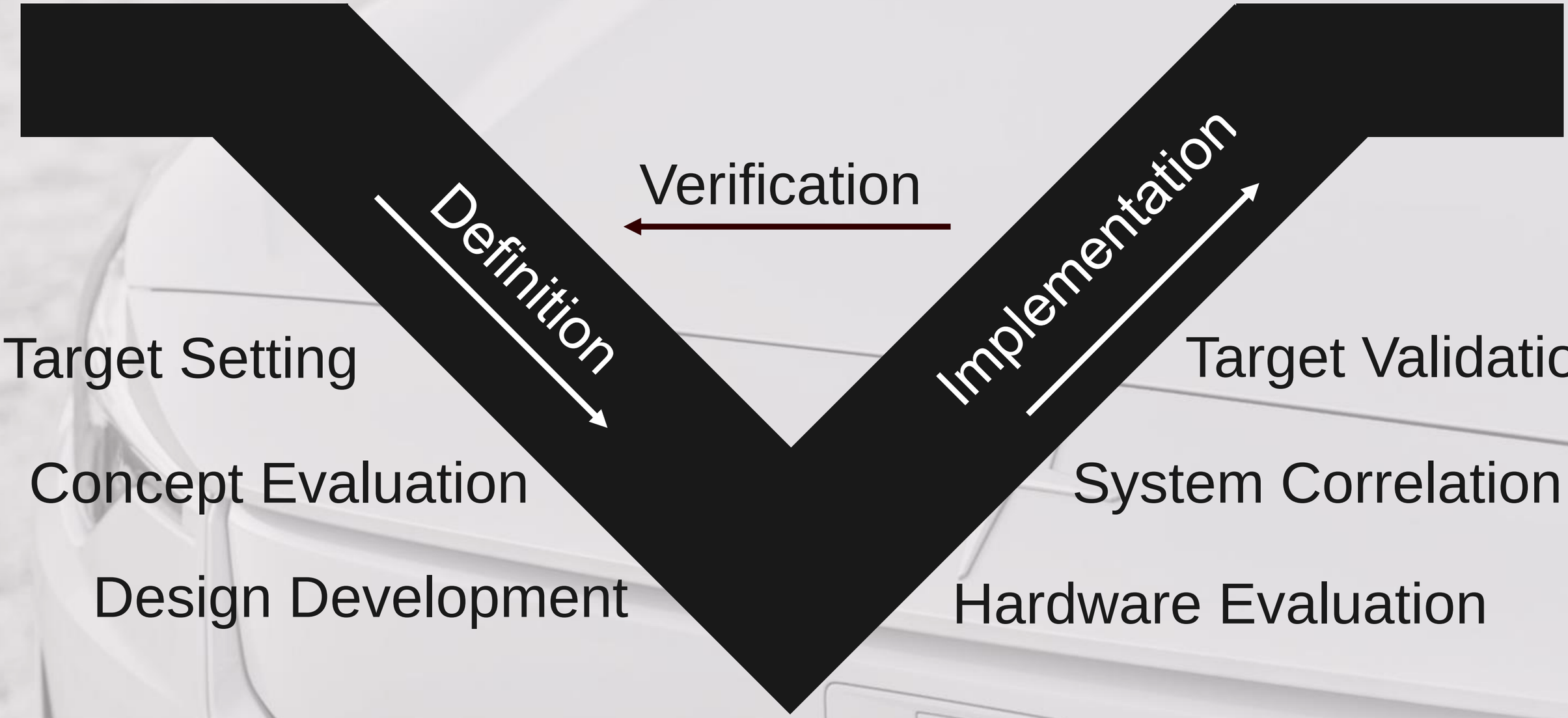


Chassis



Polestar CAE Development

Pandora Use Cases



Vehicle Simulation Results:

Pandora Vehicle Simulation Test Case

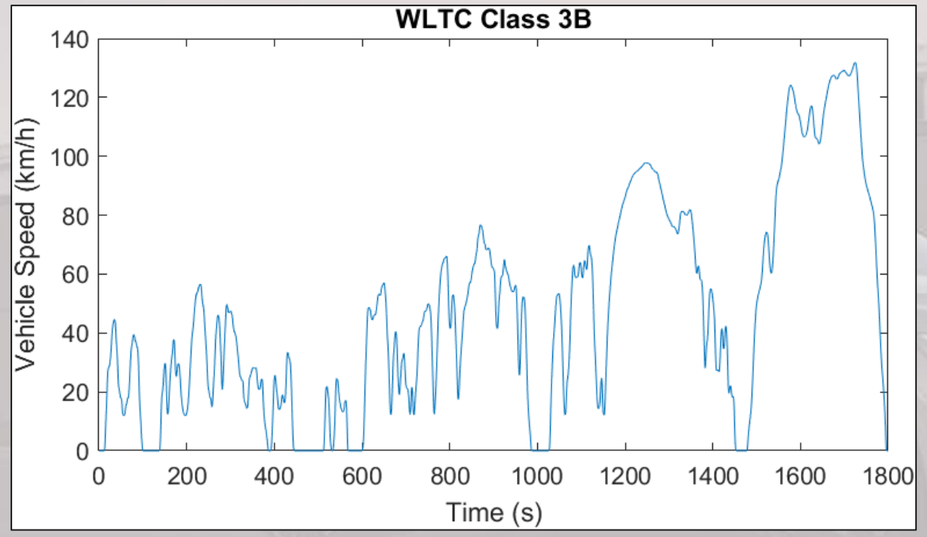
Vehicle Simulation Results

Tyre Rolling Resistance

- Pandora is used for vehicle range simulations to maximise the energy efficiency of all vehicle systems
- Tyres account for a significant portion of a vehicle’s energy consumption
- Friction between the tyre compound and the road results in a load on the vehicle’s motors

Vehicle Simulation Results

Simulation Test Case



Energy Efficiency Class	Rolling Resistance Coefficient
1	5.9
2	7.1
3	8.4
4	9.8
5	11.3
6	12.9

UN Regulation No. 154 - Worldwide harmonized Light vehicles Test Procedure (WLTP)

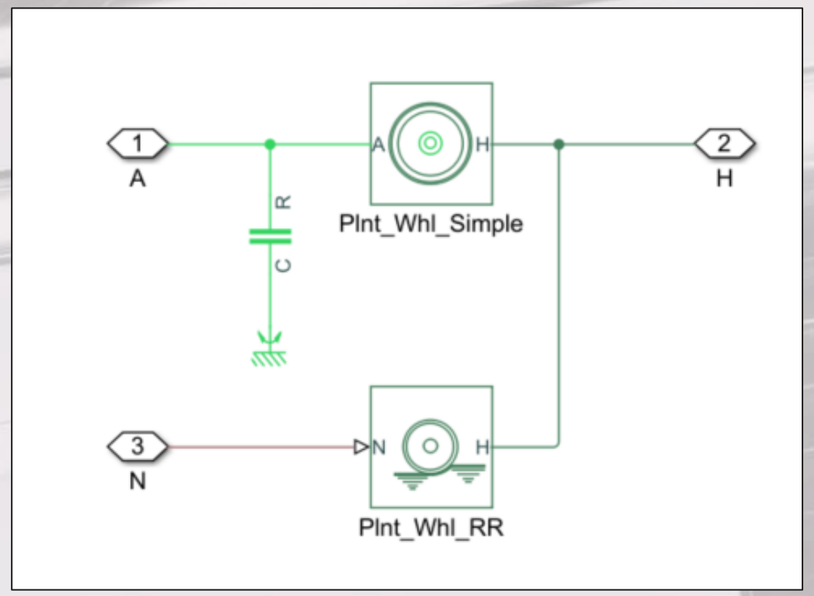
- A Pandora vehicle simulation investigates the energy benefit of reducing the tyre rolling resistance
- A Battery electric vehicle is simulated over a Worldwide harmonized Light vehicle Test Cycle (WLTC)
- Tyre rolling resistance for the WLTC cycle is divided into classes
  - Class 3 – 8.4 kg/tonne
  - Class 2 – 7.1 kg/tonne

Vehicle Simulation Results

Tyre Plant Model

Simscape Rotational Friction

- Parametrised wheel bearing loss
- Vehicle platform dependent



Simscape Wheel Model

- Parameterised with tyre geometry
- Ideal, friction, & Magic Formula slip

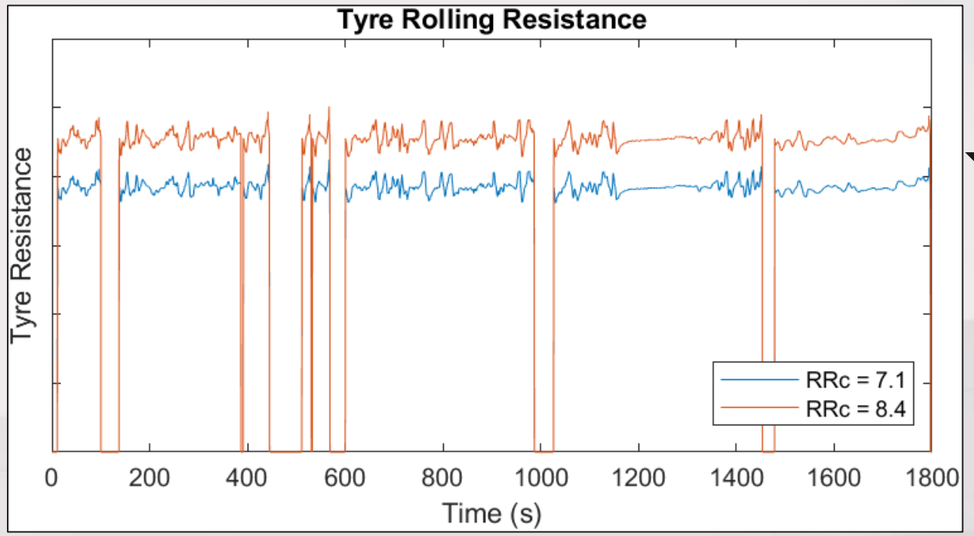
Simscape Rolling Resistance

- Modelling with constant rolling resistance
- Parabolic rolling resistance to simulate specific tyres

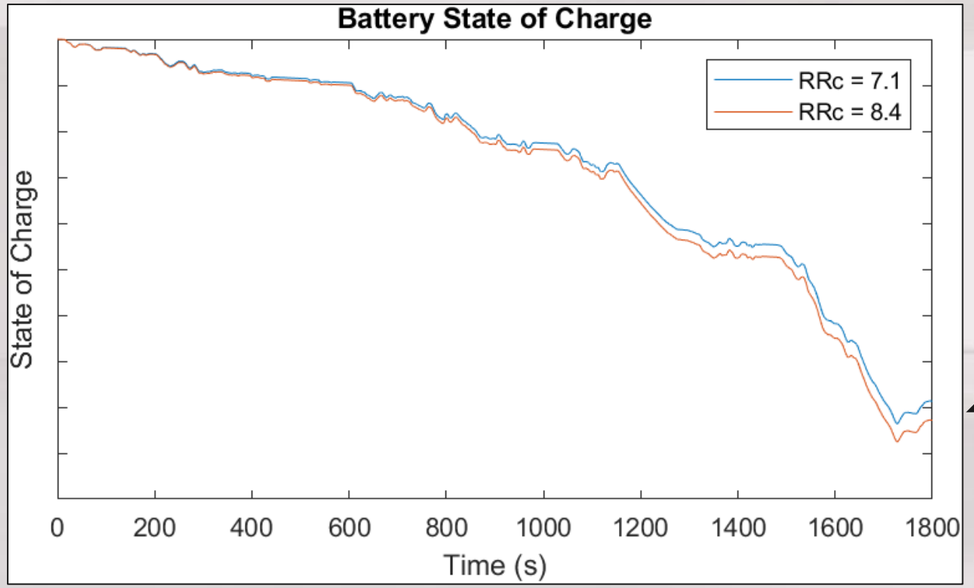
Vehicle Simulation Results

Vehicle Energy Reduction

- Changing from a Class 3 to a Class 2 tyre reduces the rolling resistance force by 15%
- 0.2% energy reduction over the WLTC cycle by reducing the motor power demand
- If this design change was applied to a Polestar 2, it would increase the range by over 13km
- The reduction in motor demand also benefits the thermal system by reducing power loss
- Simulations must be balanced with attribute performance
  - Vehicle Dynamics
  - NVH performance



15% Reduction in rolling resistance



0.2% Energy Improvement

Pandora Development:
Summary

Pandora Development

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References

- *Uniform provisions concerning the approval of light duty passenger and commercial vehicles with regards to criteria emissions, emissions of carbon dioxide and fuel consumption and/or the measurement of electric energy consumption and electric range (WLTP)*, Addendum 153 – UN Regulation No. 154, E/ECE/TRANS/505/Rev.3/Add.153 (22 January 2021)
- Polestar Automotive 2023, *Polestar 2 gets increased range, efficiency and performance alongside a lower carbon footprint,* Polestar Automotive, viewed 20 September 2023 (https://media.polestar.com/global/en/media/pressreleases/668835/polestar-2-gets-increased-range-efficiency-and-performance-alongside-a-lower-carbon-footprint)