



Innovation Through Simulation

Arwel Davies
Application Engineer



MISSION

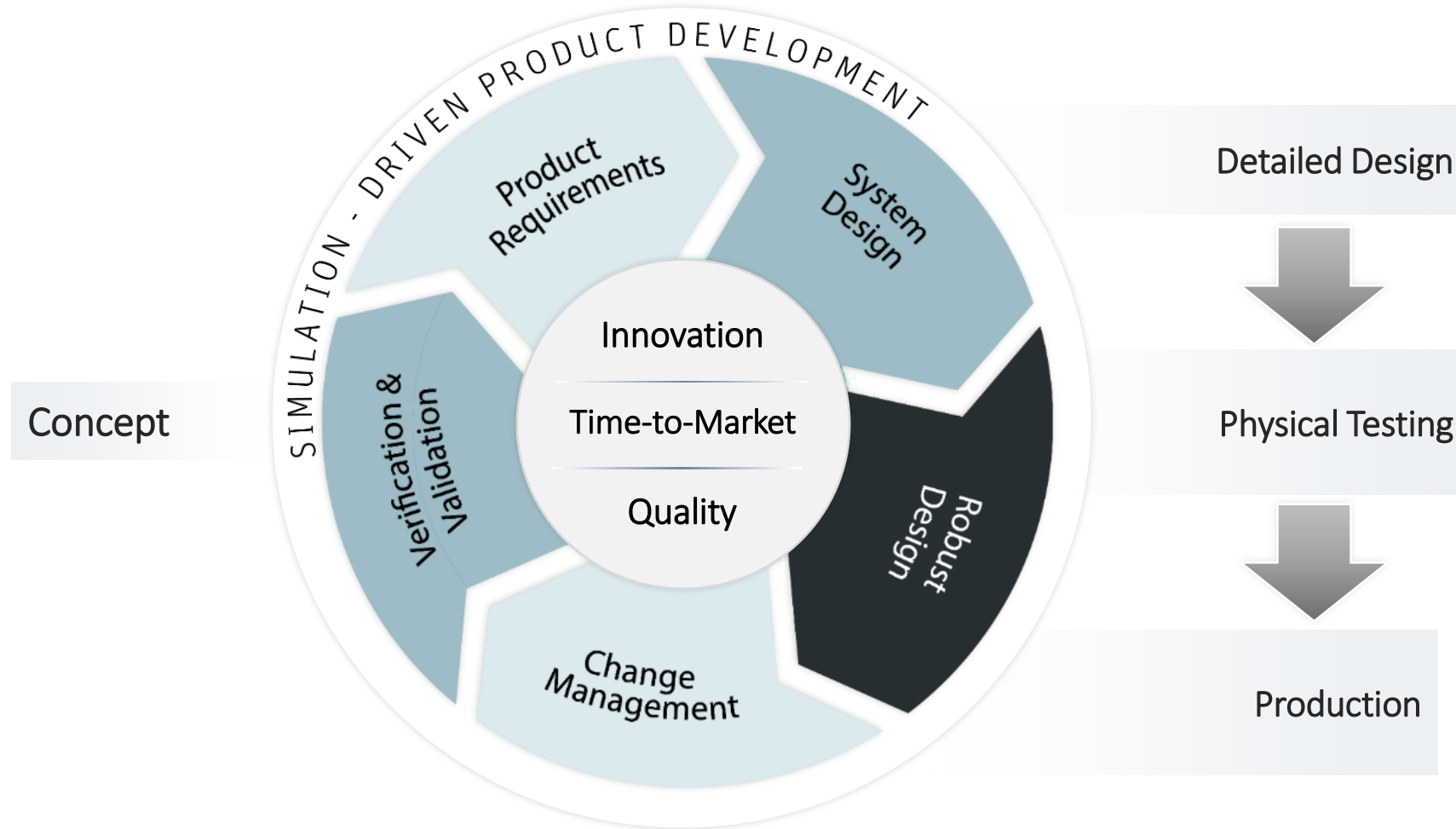
**EMPOWER OUR CUSTOMERS
TO DESIGN AND DELIVER
TRANSFORMATIONAL
PRODUCTS**



Traditional Product Development Process



Simulation-Driven Product Development Process



Pervasive simulation is continuous simulation with all physics across the entire lifecycle for all products

IDEATION

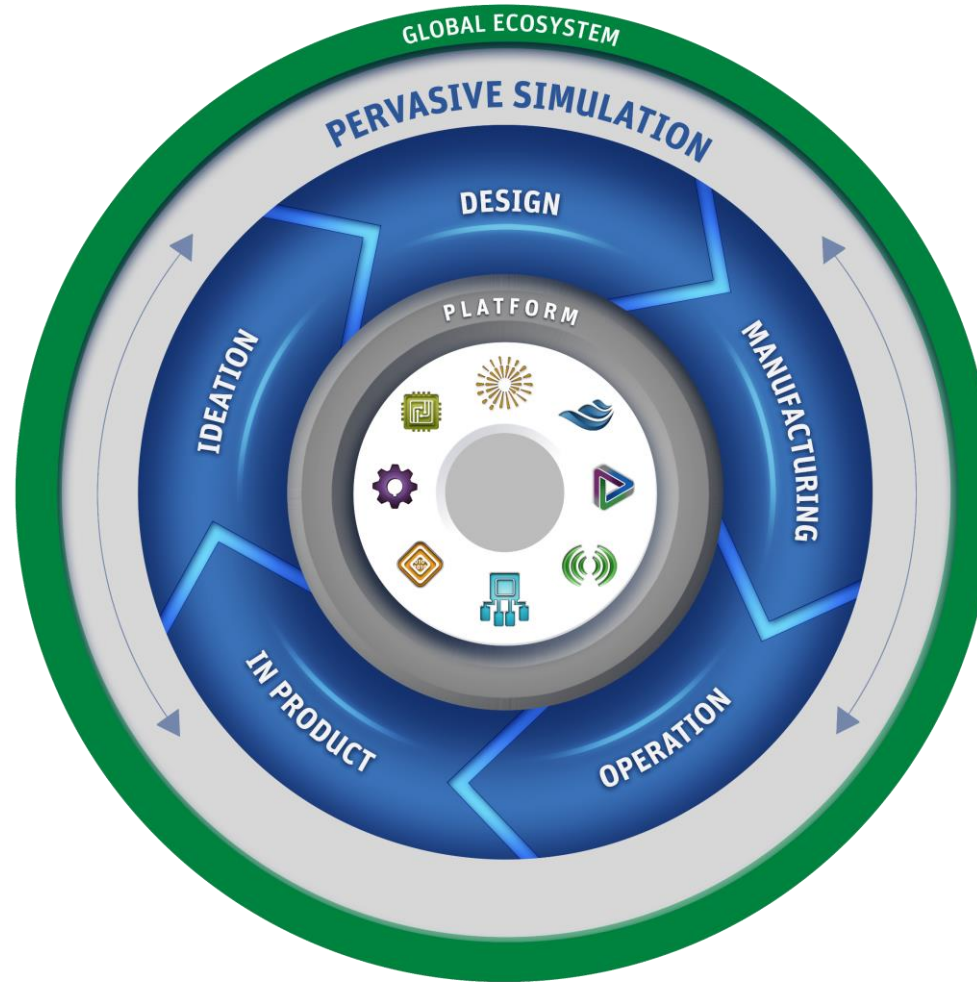


80% of costs locked in early in the design phase

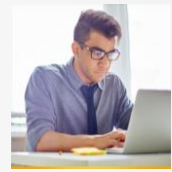
IN PRODUCT



Reduce time needed to validate autonomous vehicles from 10,000 years to 2-3 years



DESIGN



Reduce development time 9X while warranty costs 89% more likely to decrease

MANUFACTURING



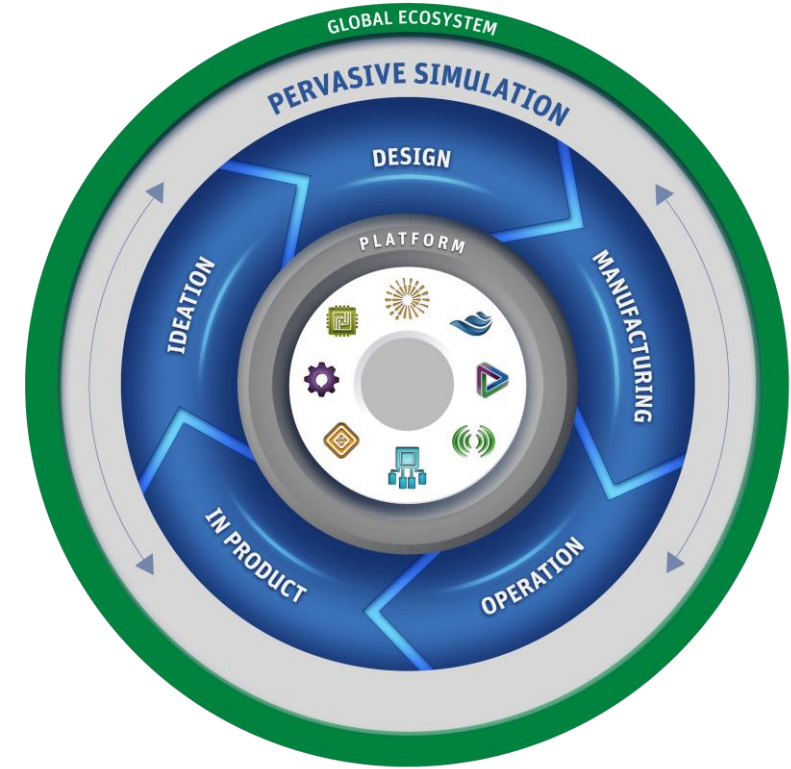
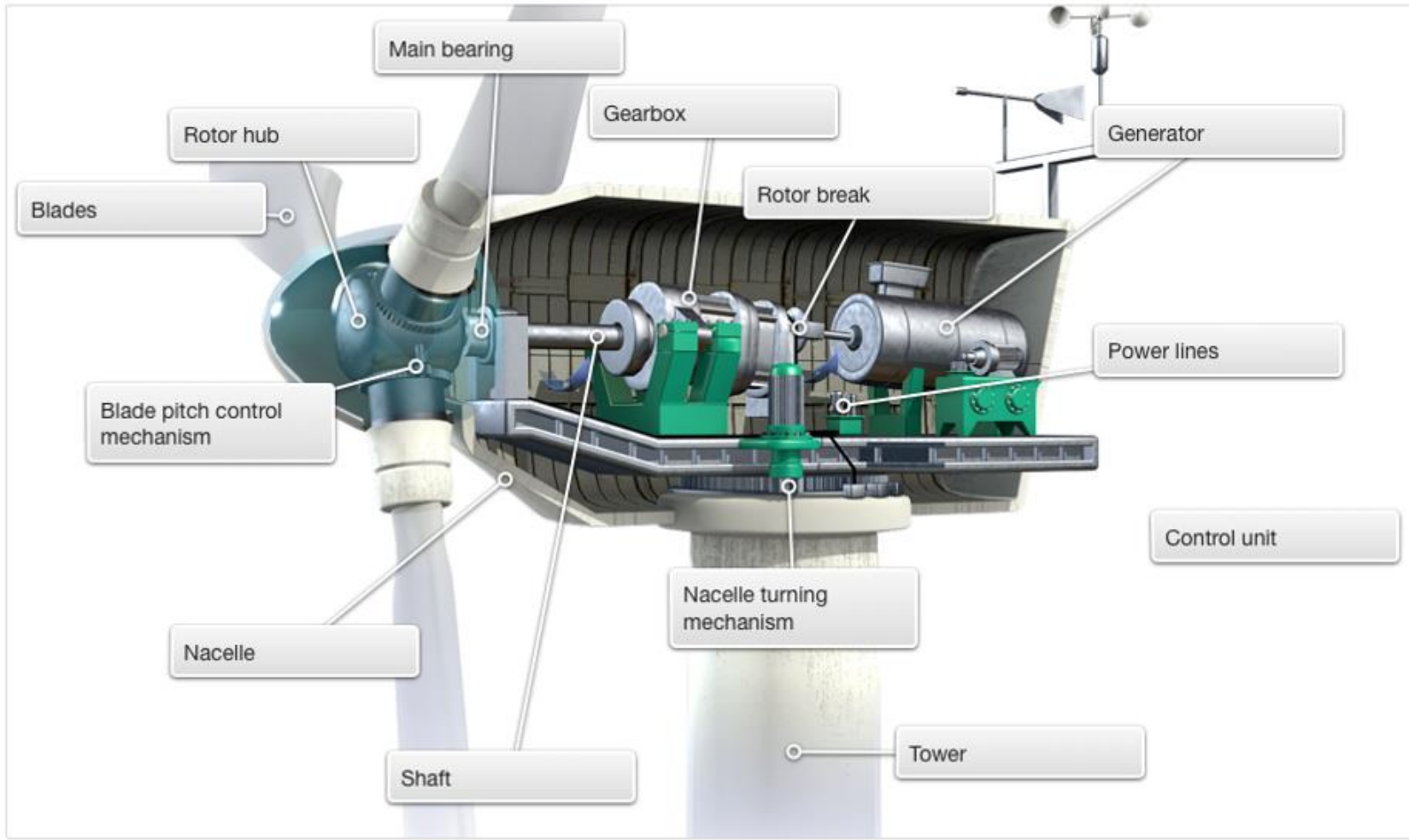
Reduce weight of part by 25% through topology optimization and additive manufacturing

OPERATIONS

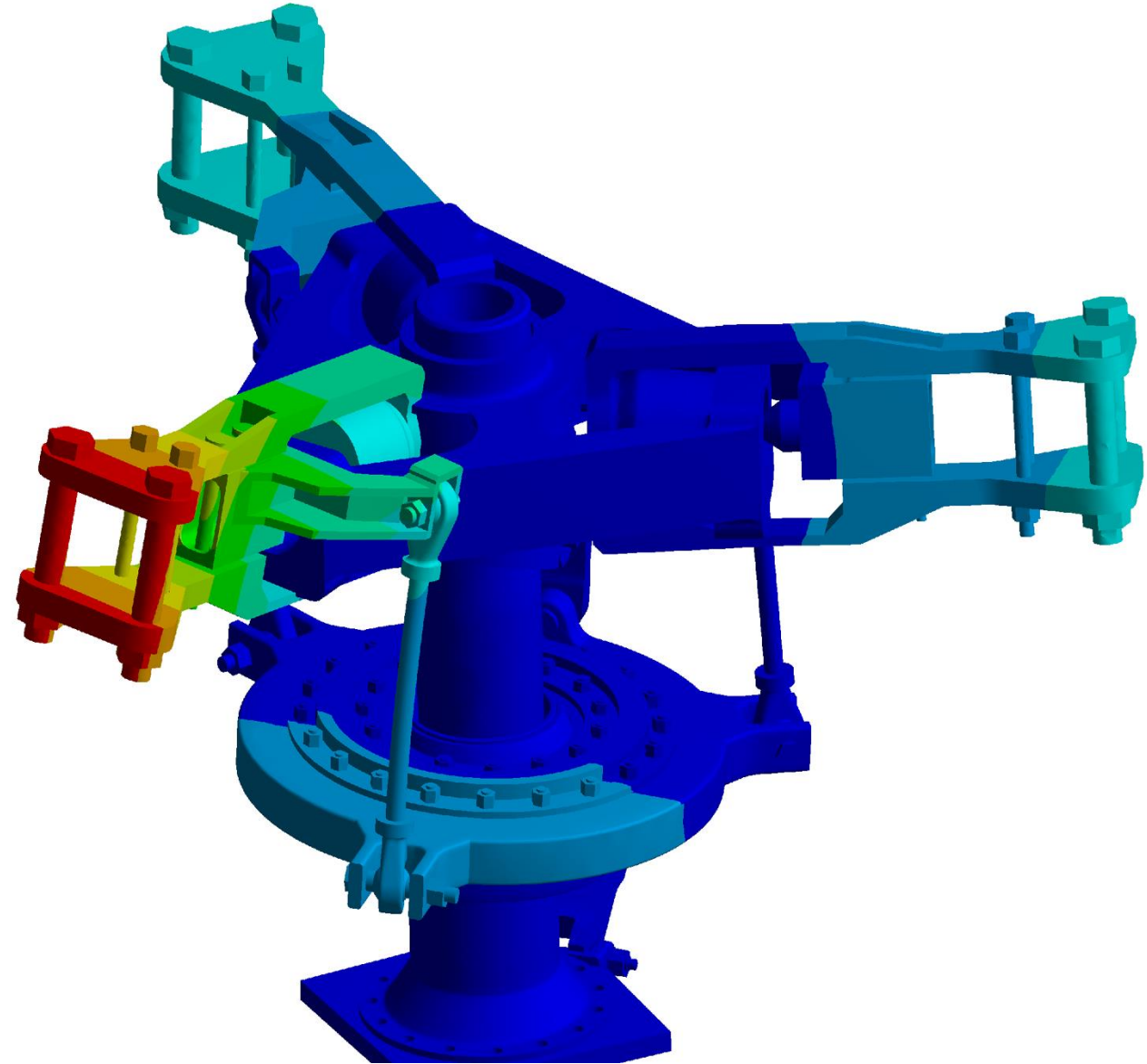


Increased performance with 10-20% reduction in maintenance costs

Detailed Product Design

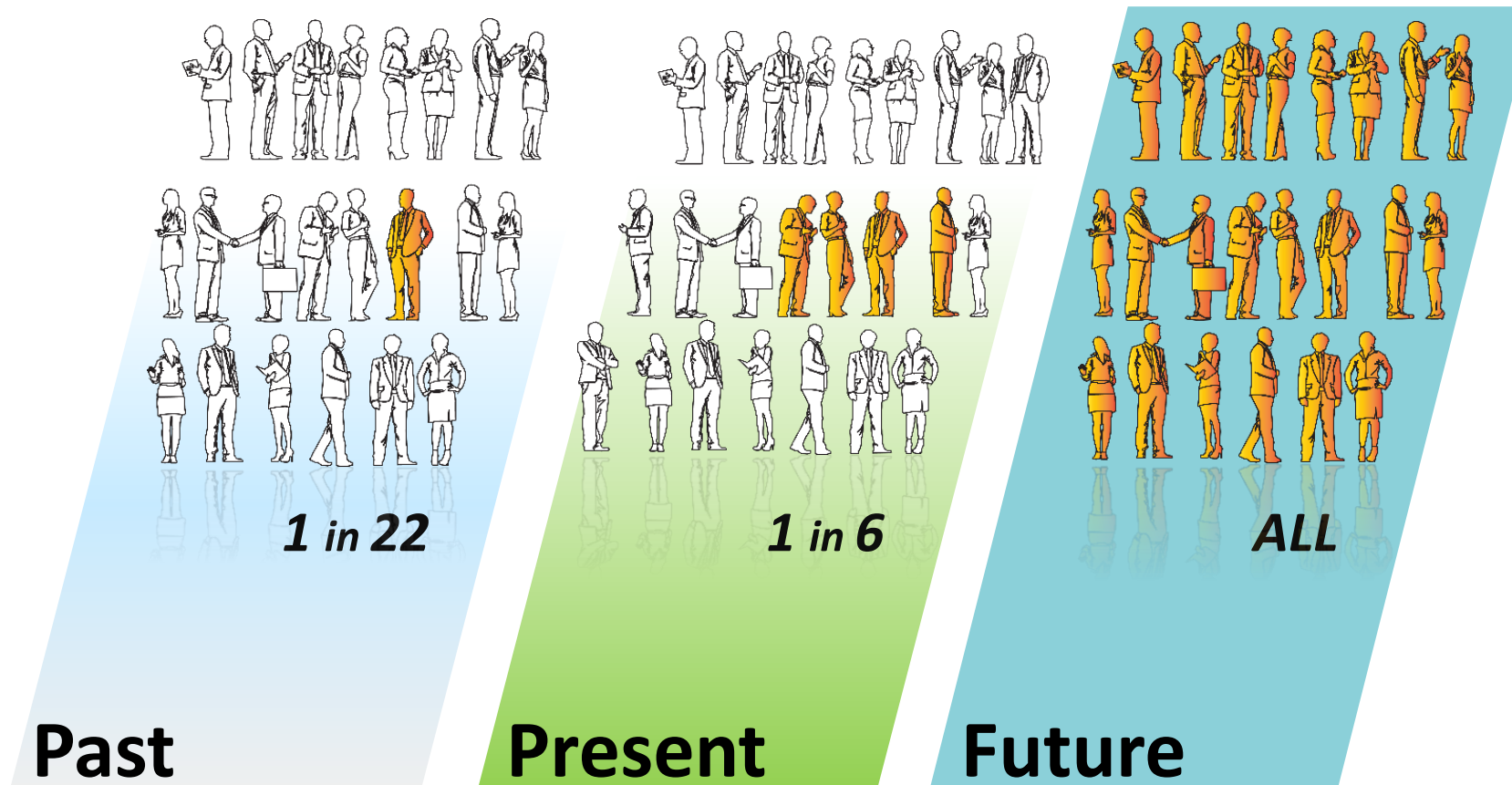


SIMULATION IS THE ANSWER



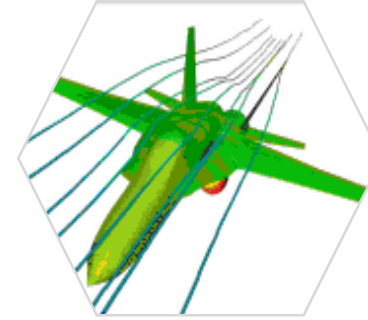
Every Engineer Will Use Simulation

Our Most Innovative Customers Are Rapidly Deploying Simulation



Why do I need simulation?

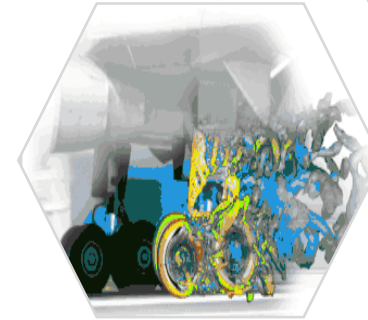
- Virtual experiments (Simulation-Driven Product Development)
- Troubleshooting
- Optimisation (Make it better)
- Digital twin



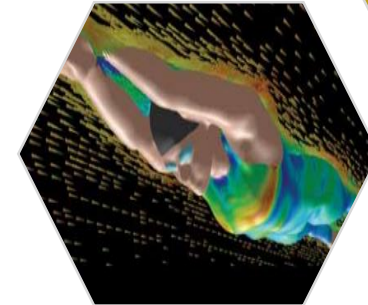
Courtesy of Astrobotic Technology Inc.



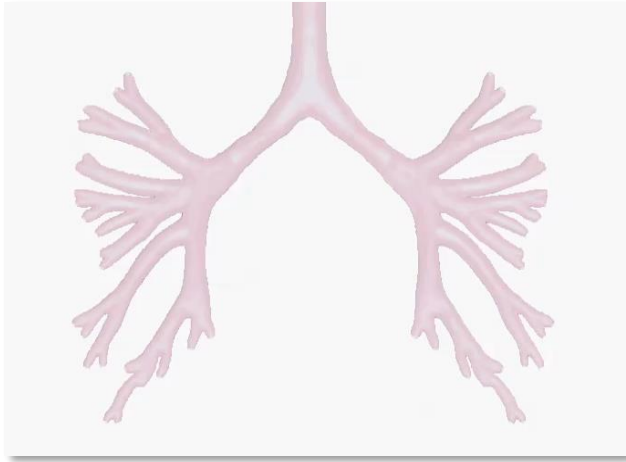
Courtesy of Red Bull Racing



Courtesy of Speedo

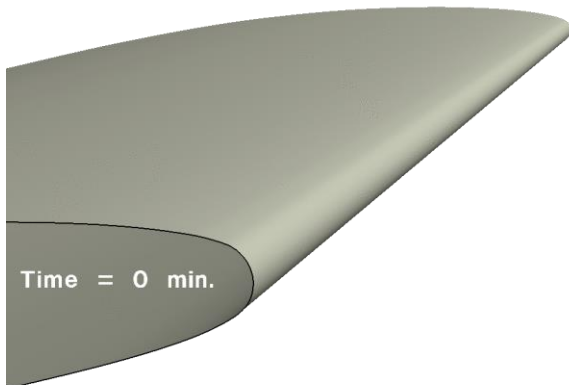


Virtual Experiments



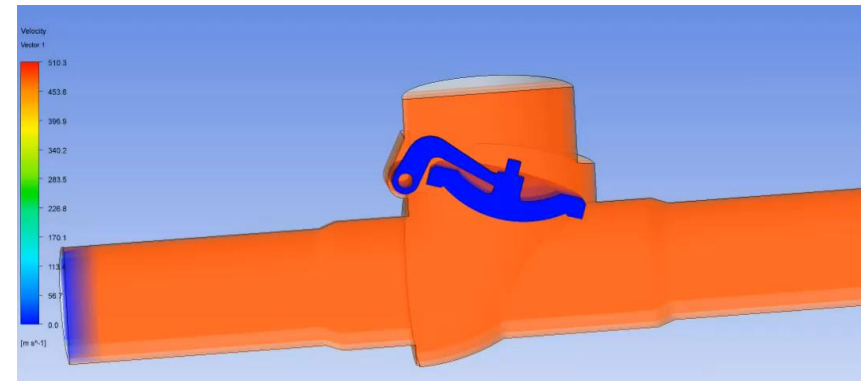
Drug particle distribution while inhaling
and exhaling

Wing ice build-up



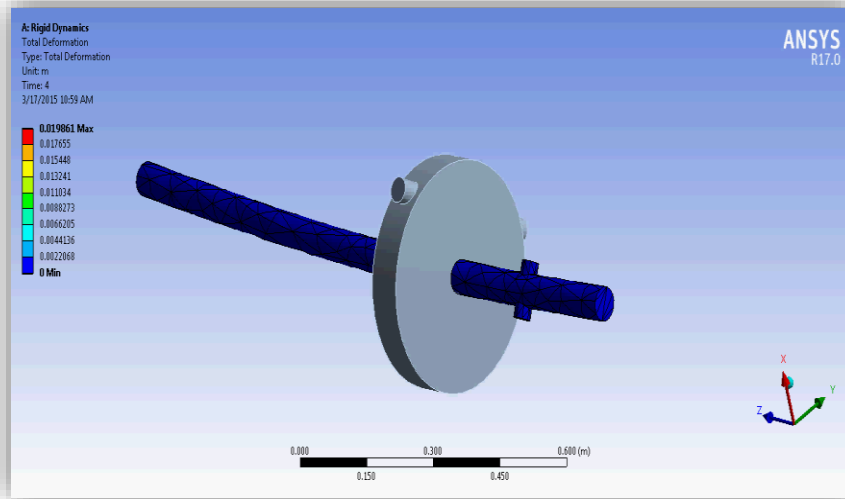
Water hammer test at 60 bar

Valve closing simulation

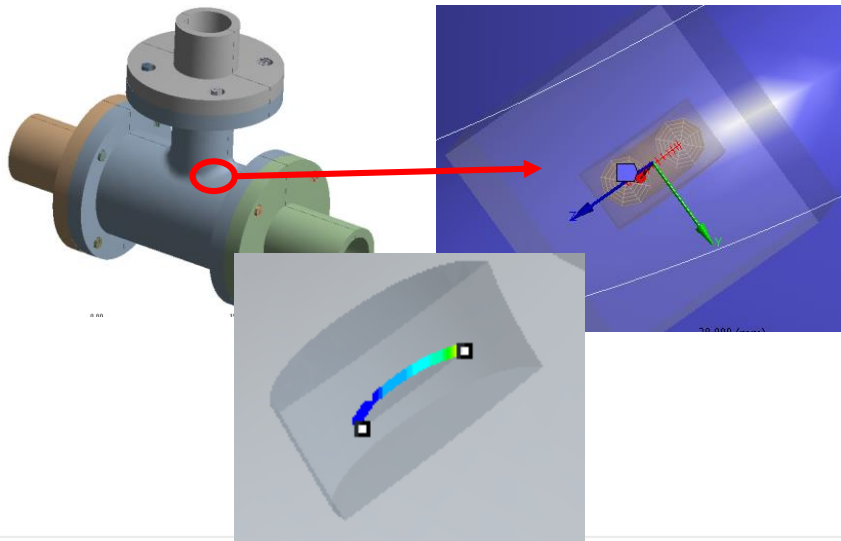


Videos courtesy of CAMERON - Tom
Wheatley

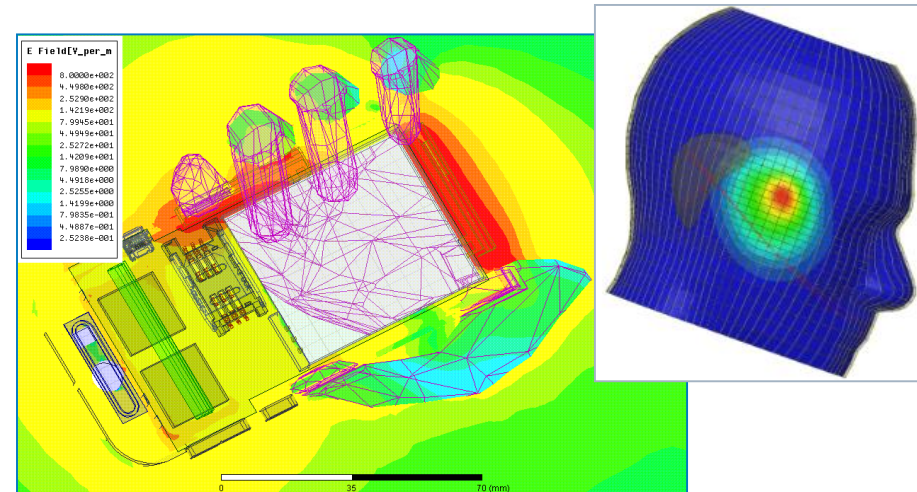
Troubleshooting



Determine and correct causes of failure

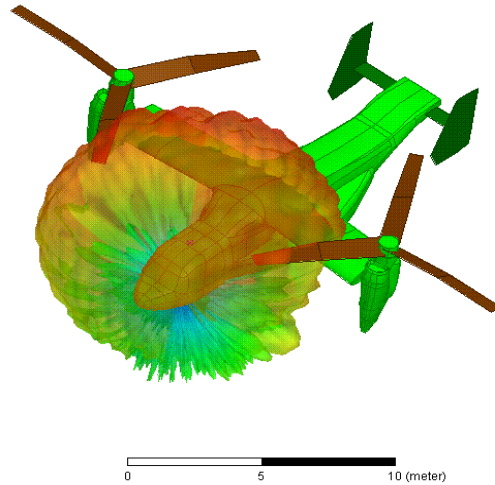


Troubleshoot poor performance

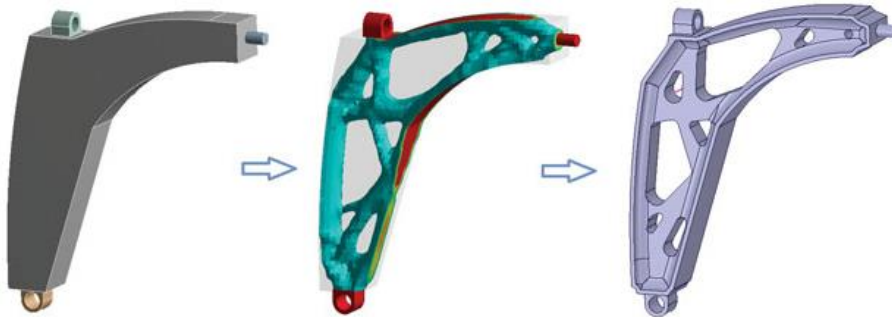


Assess severity of damage

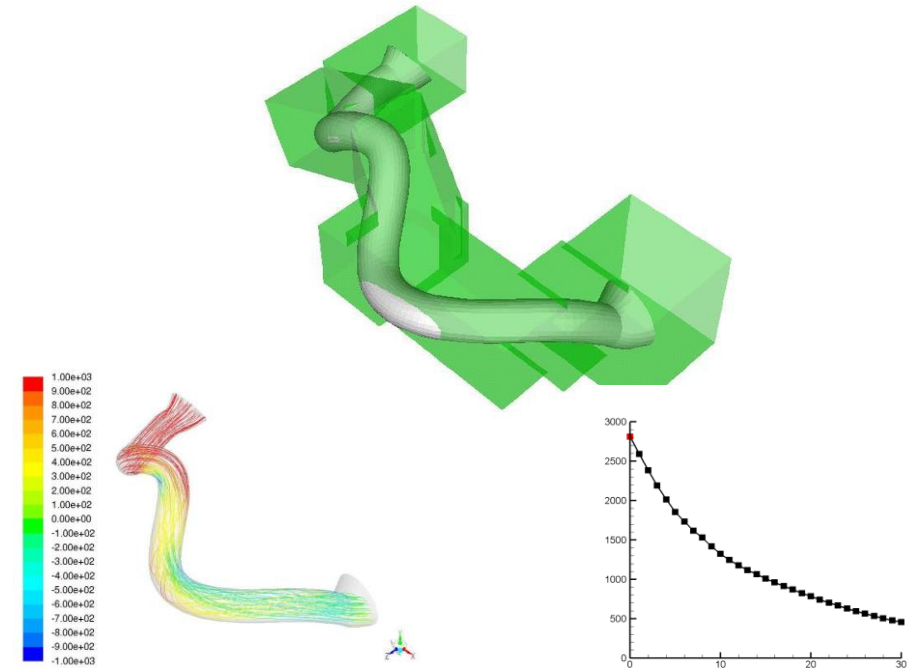
Optimisation



Optimise antenna placement for best transmission



Shape optimisation to reduce pressure drop



Topology optimization and reverse engineering

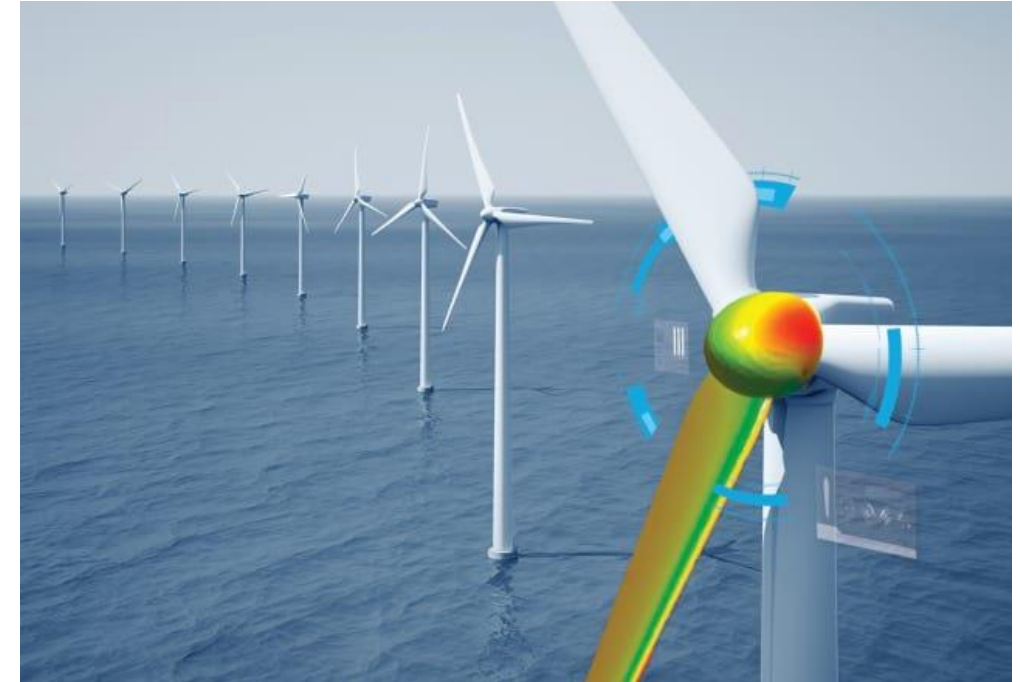
What is a Simulation Based Digital Twin?

**A Multi-Physics, Multi-Scale
(0D/1D/3D/Embedded software),
Simulator of an Industrial System in
service**

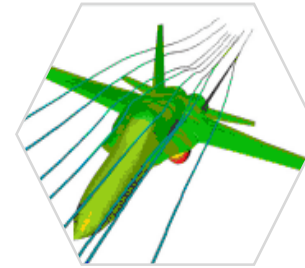
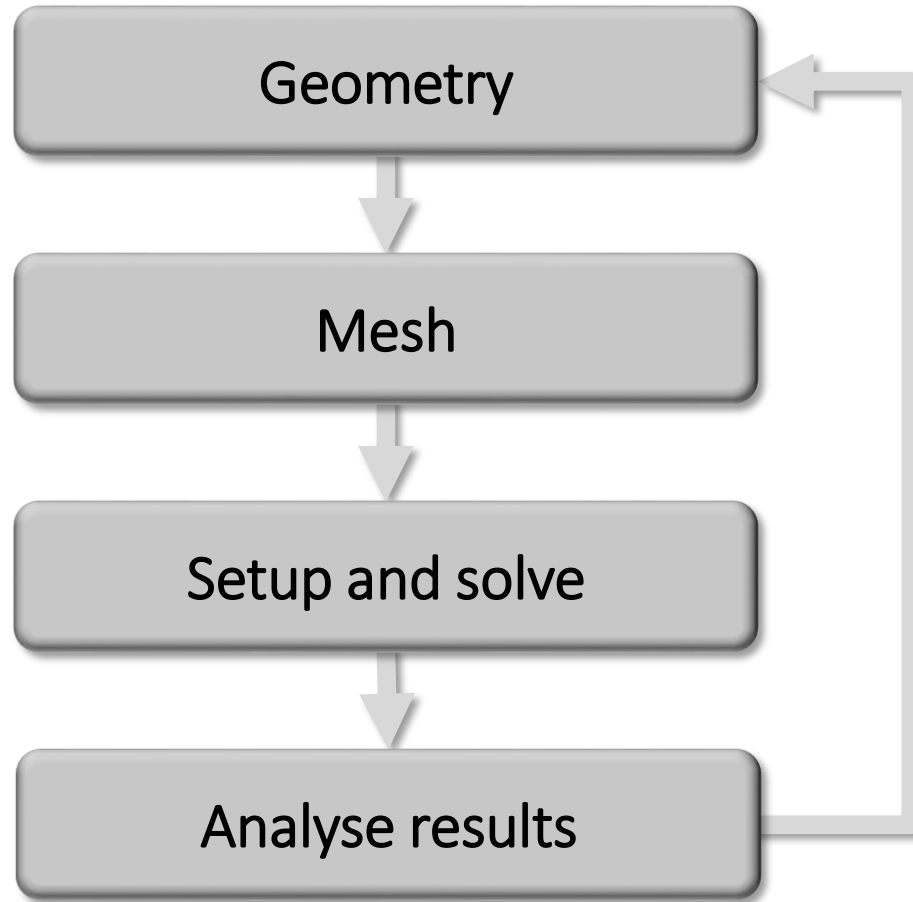
**That mirrors and reproduces its behavior
accurately**

To propose:

- **System validation and virtual integration**
- **System optimization**
- **Predictive maintenance and optimized asset management**



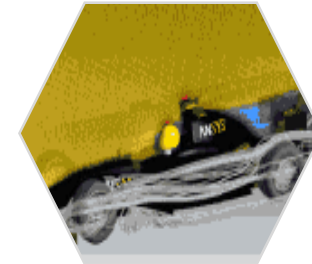
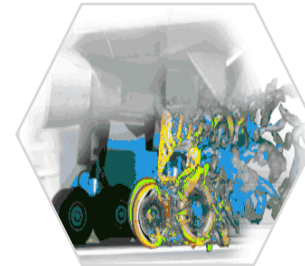
How do I simulate?



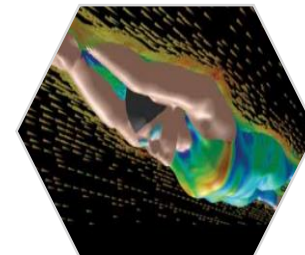
Courtesy of Astrobotic Technology Inc.



Courtesy of Red Bull Racing

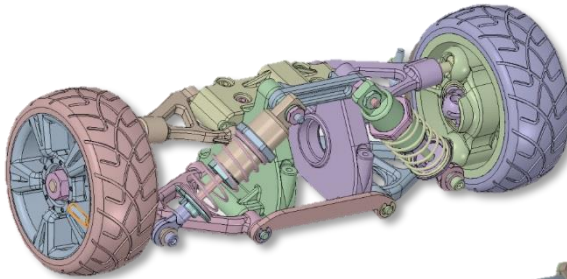


Courtesy of Speedo



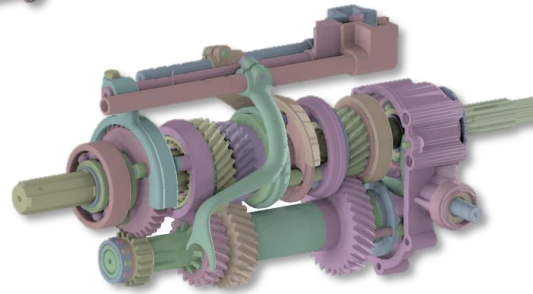
Geometry Creation/Preparation

Geometry import from both **CAD** and **neutral sources**

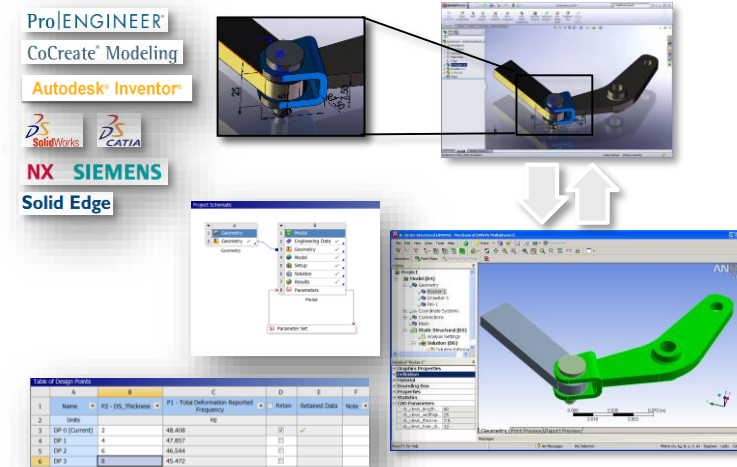


Suspension model imported from .SAT file

Gear box with advanced lighting and shading

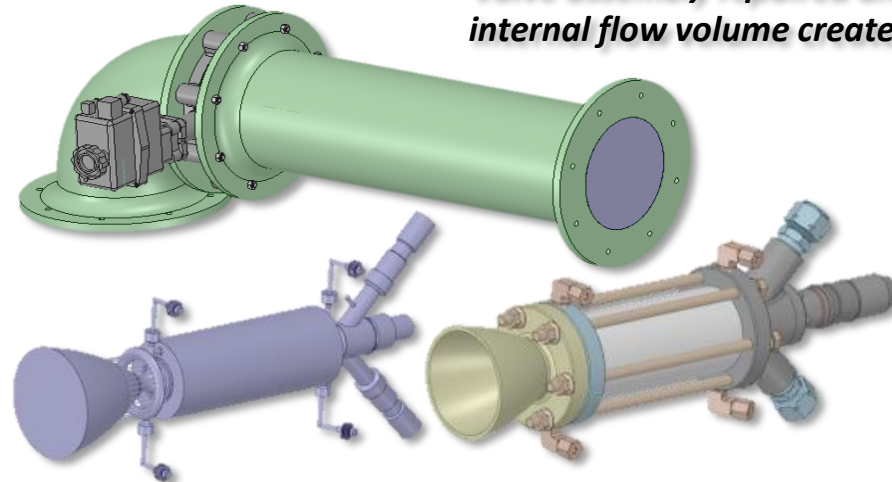


Quickly **clean-up, repair and simplify** geometry for simulation



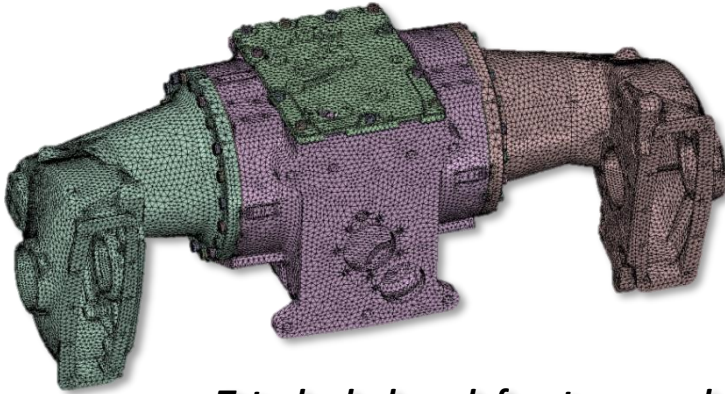
Native, **bi-directional integration** with all major CAD systems

Valve assembly repaired and internal flow volume created



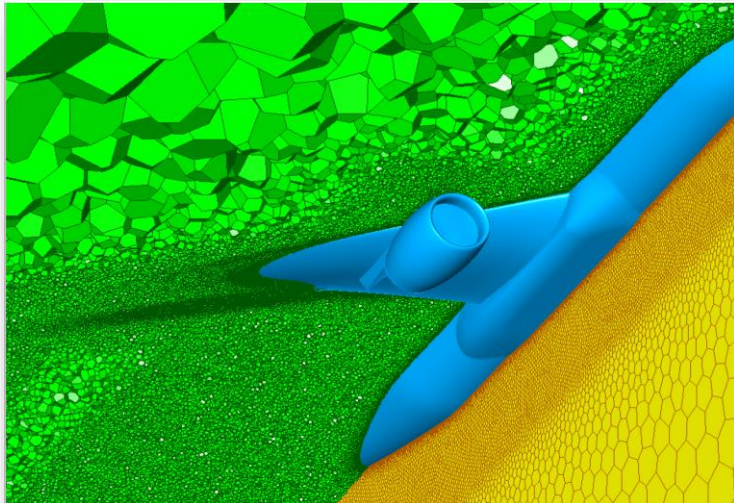
Extracted fluid volumes for flow simulation

Meshing



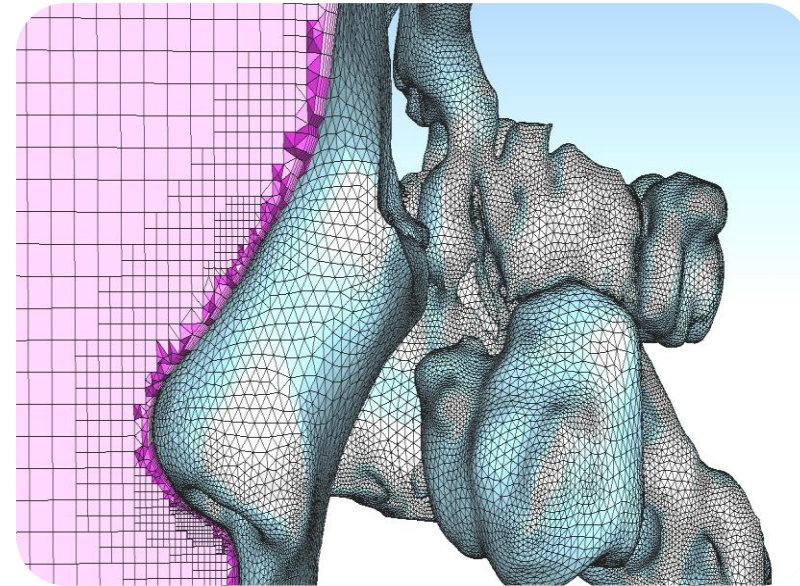
Tetrahedral mesh for stress analysis

Parallel mesh generation for tetrahedral and hexahedral meshing with inflation



Automated and **user defined** mesh resolution based on **engineering intent**

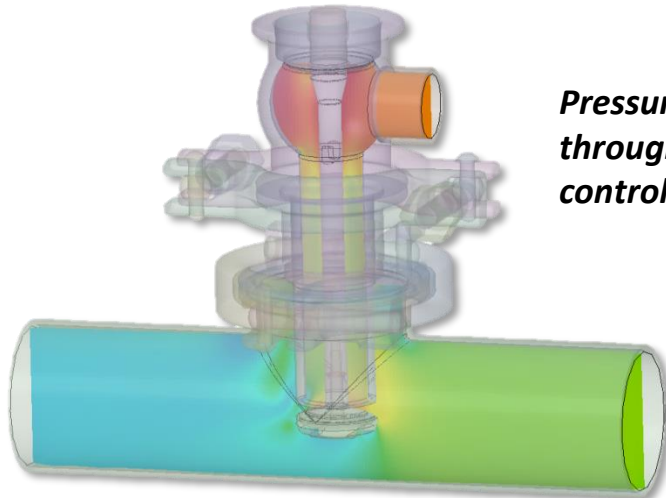
Courtesy of Materialise



Rapidly generate **high quality** meshes for **complex geometry**

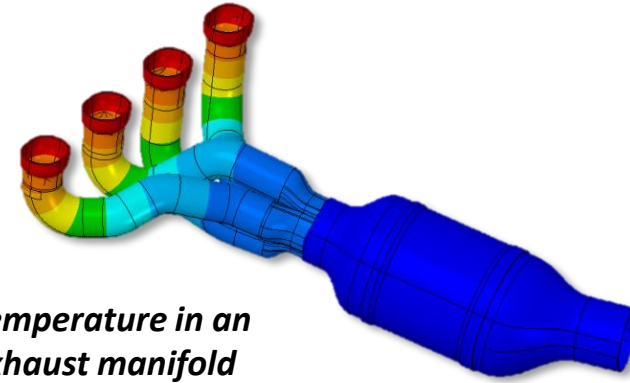
Setup and solve

Apply boundary conditions to represent interactions with external environment



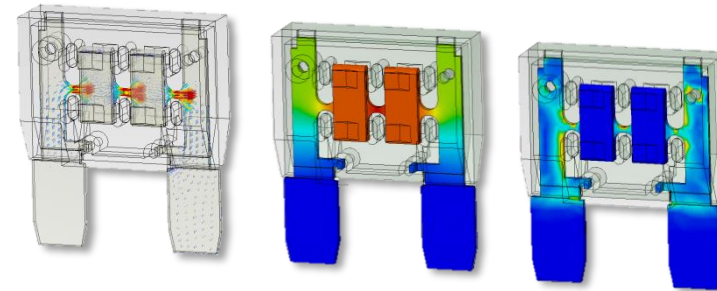
*Pressure drop
through flow
control valve*

Set material properties and physical models to describe internal behavior



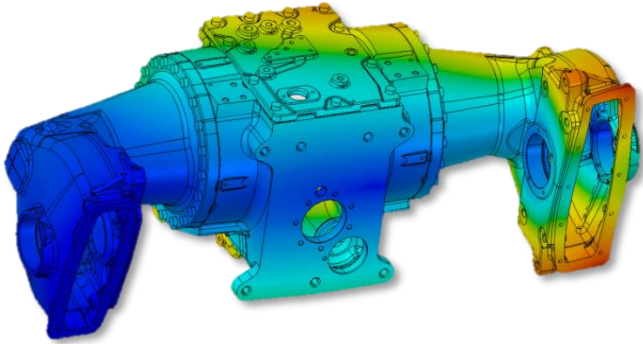
*Temperature in an
exhaust manifold*

Solve, taking advantage of parallel computing and robust solvers.



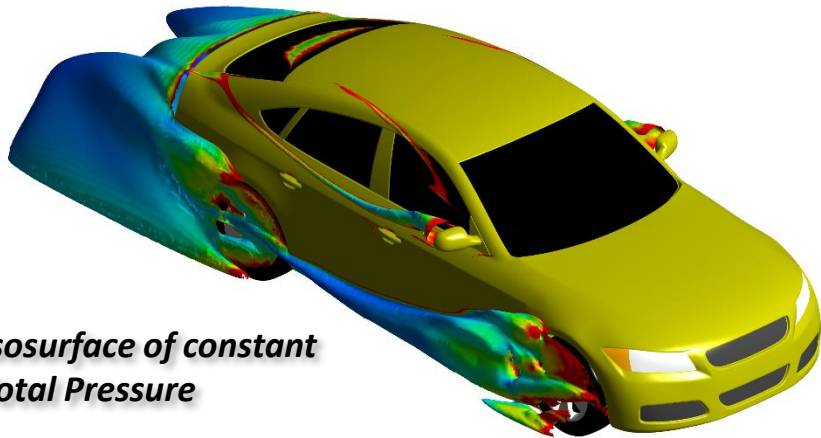
*Current density, temperature and equivalent
stress in fuse element*

Analyse Results



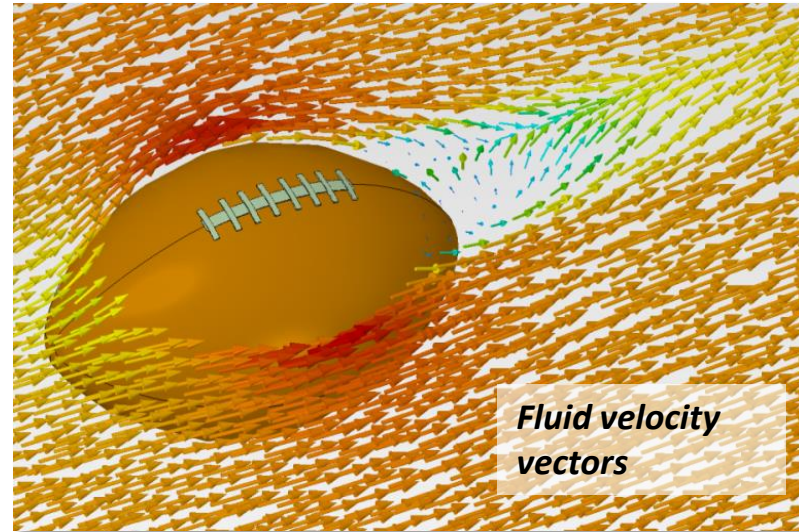
Contour plot of displacement magnitude

GPU and parallel CPU post-processing for both **qualitative** and **quantitative** output



*Isosurface of constant
Total Pressure*

Integrated **post-processing** and **results visualization** for all physics



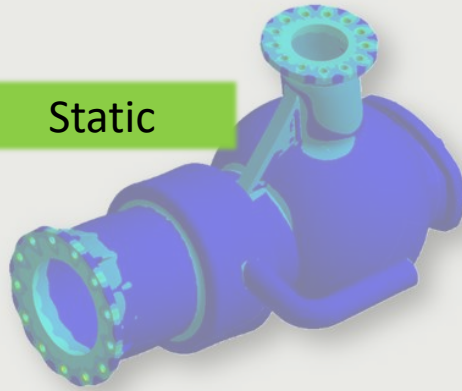
*Fluid velocity
vectors*

Create **meaningful graphics** to **effectively communicate** simulation results

LINEAR

STATIC

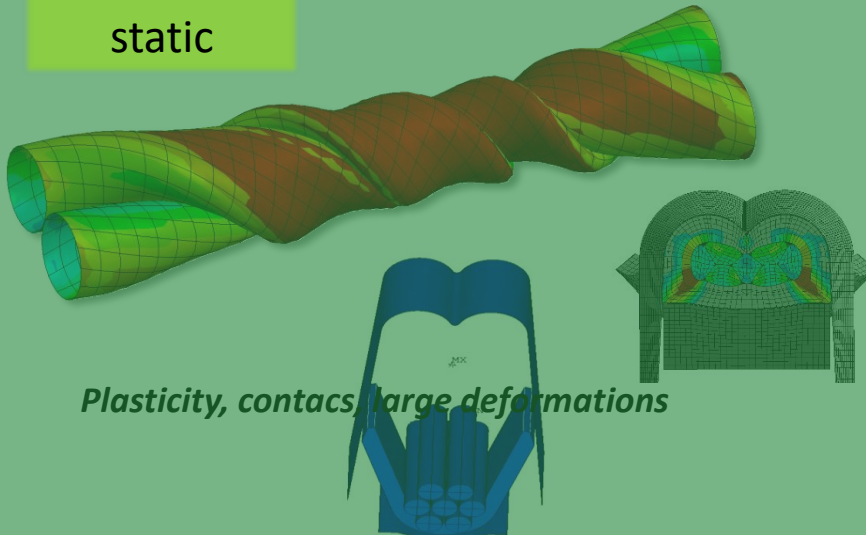
Static



Stresses & deformations

NONLINEAR

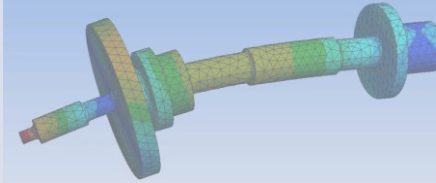
Non-linear static



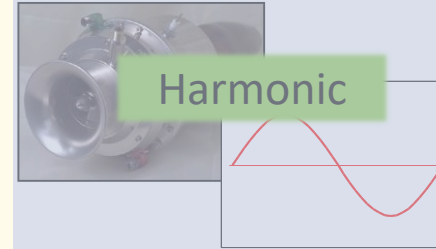
Plasticity, contacts, large deformations

DYNAMIC

Modal



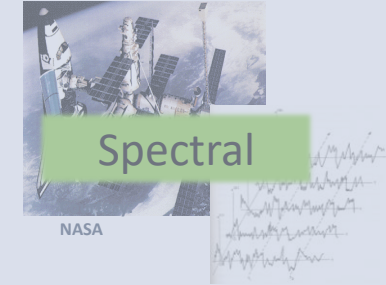
Vibrations - eigenmodes



Harmonic

Vibrations - Harmonic

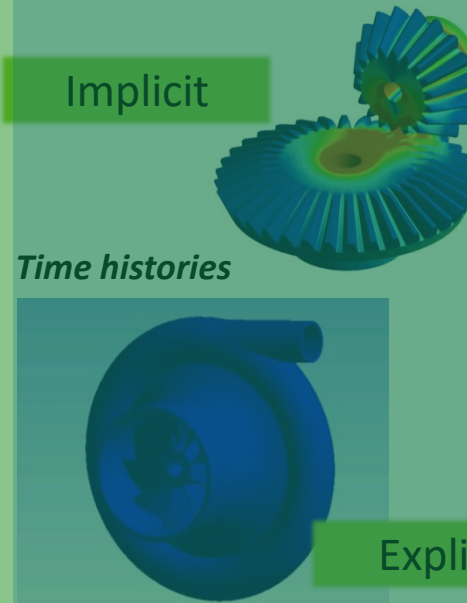
Spectral



Vibrations - Probabilistic

Implicit

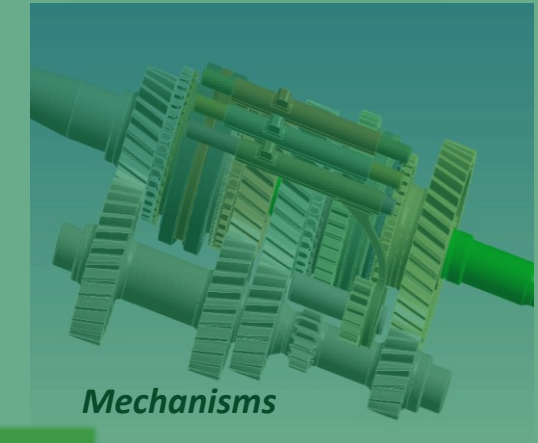
Time histories



Rigid Dynamics & Rigid/Flexible

Mechanisms

Explicit



The Tools

Strength Analysis

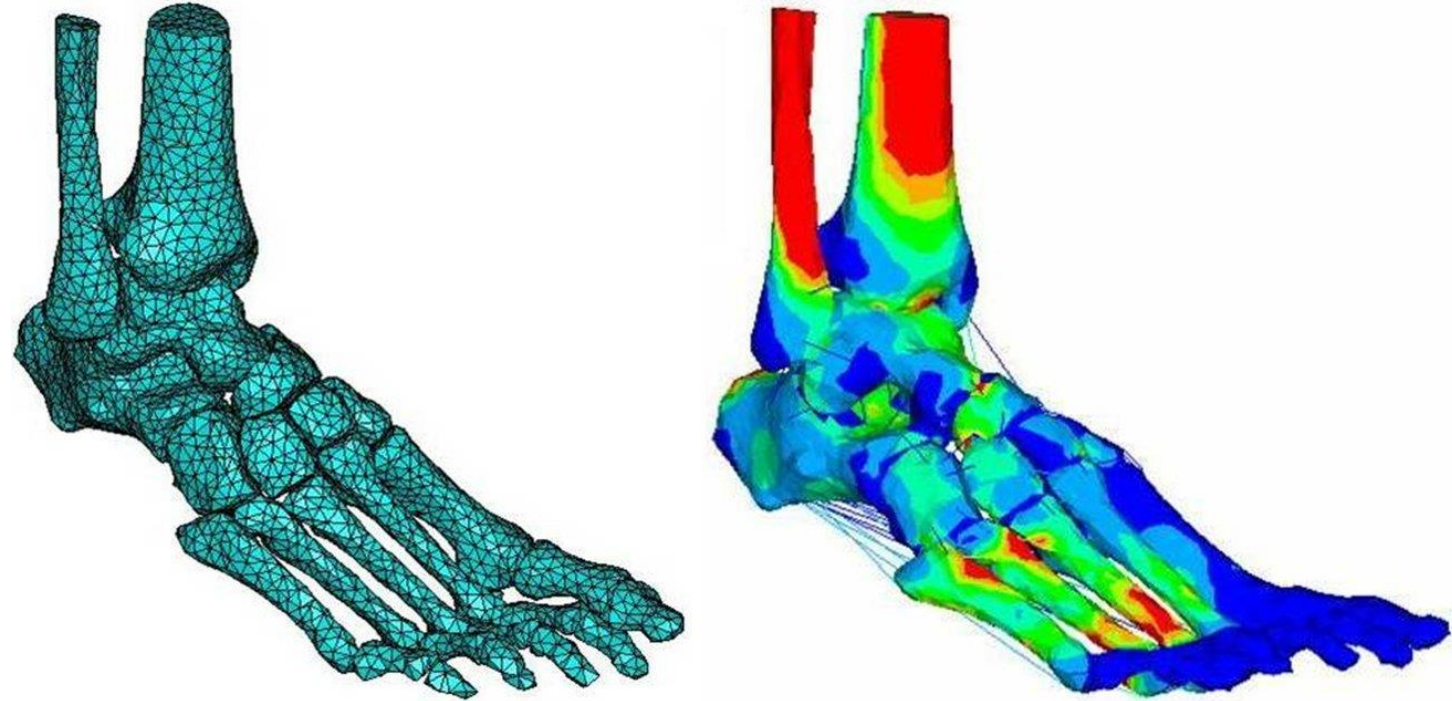
Static Structural

How will the product perform?

Will it meet design guidelines?

What was the cause of failure?

Can the product performance be improved?



Commonly sought Information

Deformed
shape

Stresses/Strains

Factor of safety

Meet design
code
requirements

The Tools

Vibration

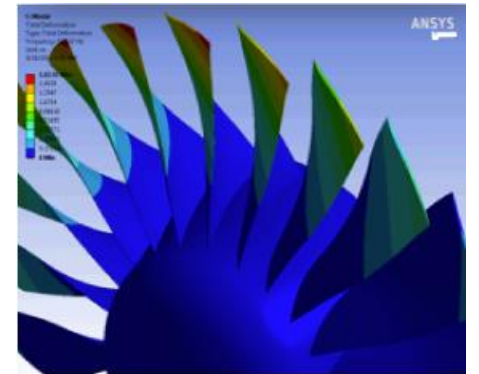
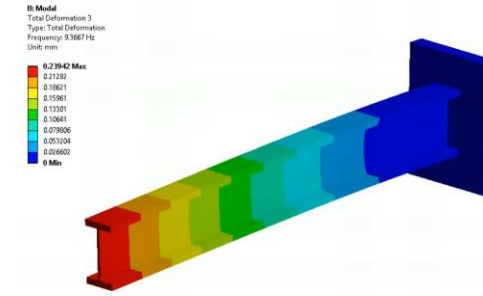
Modal Analysis, Harmonic Response,
Response Spectrum, Random Vibration

What is the natural frequency?

Safe speed to operate at?

Behavior under oscillatory/random
loads?

Will it survive transportation loads or an
earthquake?



Commonly sought Information

Vibration modes
and frequencies

Stresses/Strains

Statistical
information,
probability of
failure

The Tools

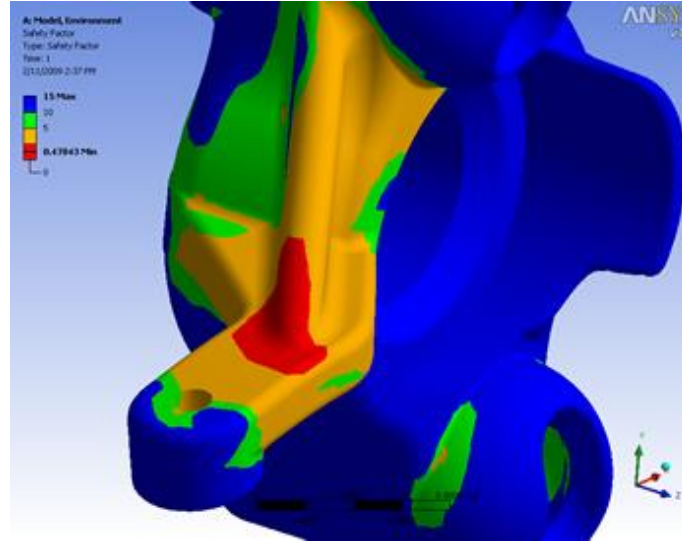
Durability Fatigue tool

What is the life of the product?

What is the remaining useful life?

Warranty issues: Why did the product fail?

When to offer Fatigue tool vs nCode?



Commonly sought Information

Cycles to
failure

Factor of
safety

Remaining
life

The Tools

Multibody Dynamics

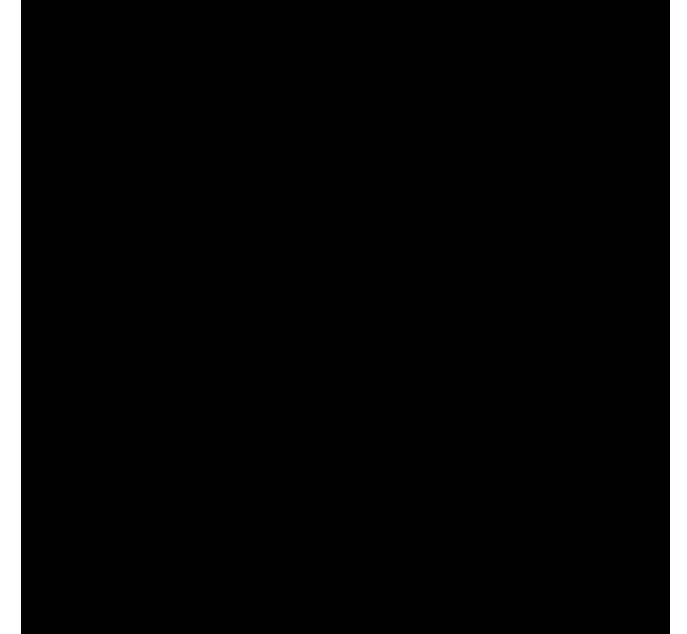
Transient Structural, RBD

Kinematic behavior (motion) of assembly of components?

Sizing and alignment of joints, bearings, gears etc.?

Gearbox noise?

Stresses in select individual components in an assembly?



Commonly sought Information

Stresses/loads in joints

Consequence of misalignment of parts

Noise, Vibration and Harshness (NVH)

The Tools

Rapid Events like Impact, Explosion, etc. Explicit Dynamics

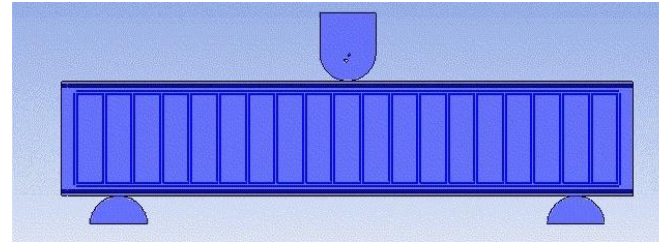
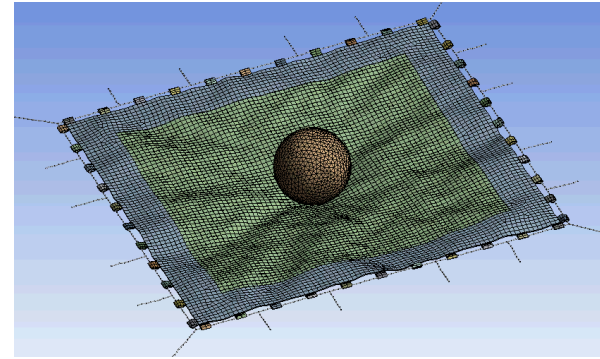
What if the device is dropped?

What will be the consequence of impact between bodies?

Consequence of catastrophic failure of parts?

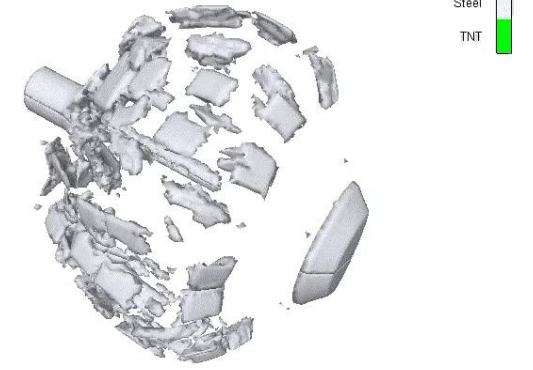
Bodies subjected to explosive loads?

Predict behavior during metal forming?



AUTODYN-3D v6.0 from Century Dynamics

Material Location



grenade
Cycle 9500
Time 9.979E-002 ms
Units mm, mg, ms

grenade fragmentation

Commonly sought Information

Stresses,
loads and
accelerations

Failure modes

Safe
operating
conditions

What we do?

ANSYS designs, develops, markets and globally supports the worlds leading CAE simulation software

A suite of multi-purpose software technologies for:

- ✓ Fluid Dynamics
- ✓ Structural Mechanics
 - Implicit
 - Explicit
- ✓ Electromagnetics
 - High Frequency
 - Low Frequency
- ✓ Semiconductors
- ✓ Systems
 - Autonomous Driving Simulator
- ✓ Optical Simulation
- ✓ Material Intelligence





The Record-Breaking Journey of Volkswagen Motorsport's Use of ANSYS Simulation Technology in the Pikes Peak International Hill Climb

Arwel Davies
Application Engineer



Why Pikes Peak?

- FIA Formula E – Strict regulations
- FIA eWRX – 2021
- PPIHC – Almost no regulations



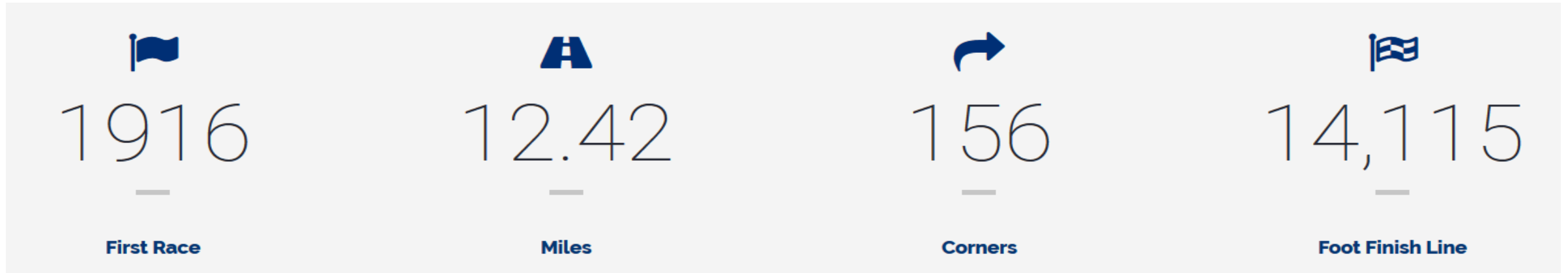
Pike's Peak International Hill Climb is a tough motorsports challenge for proving new technologies

“The Pikes Peak hill climb is one of the world’s most renowned car races. It poses an enormous challenge and is therefore perfectly suited to proving the capabilities of upcoming technologies.

“Our electric racecar will be equipped with innovative battery and drive technology. The extreme stress test posed by Pikes Peak will give us important feedback that will benefit future development, and it will showcase our products and their technologies.”



New Record



- Two electric motors, front and rear.
- Pure electric vehicle.
- **Results: Won the race and beat the record by full 15 seconds on June 24, with help from ANSYS technology.**

FAST, BUT BEAUTIFUL TOO —

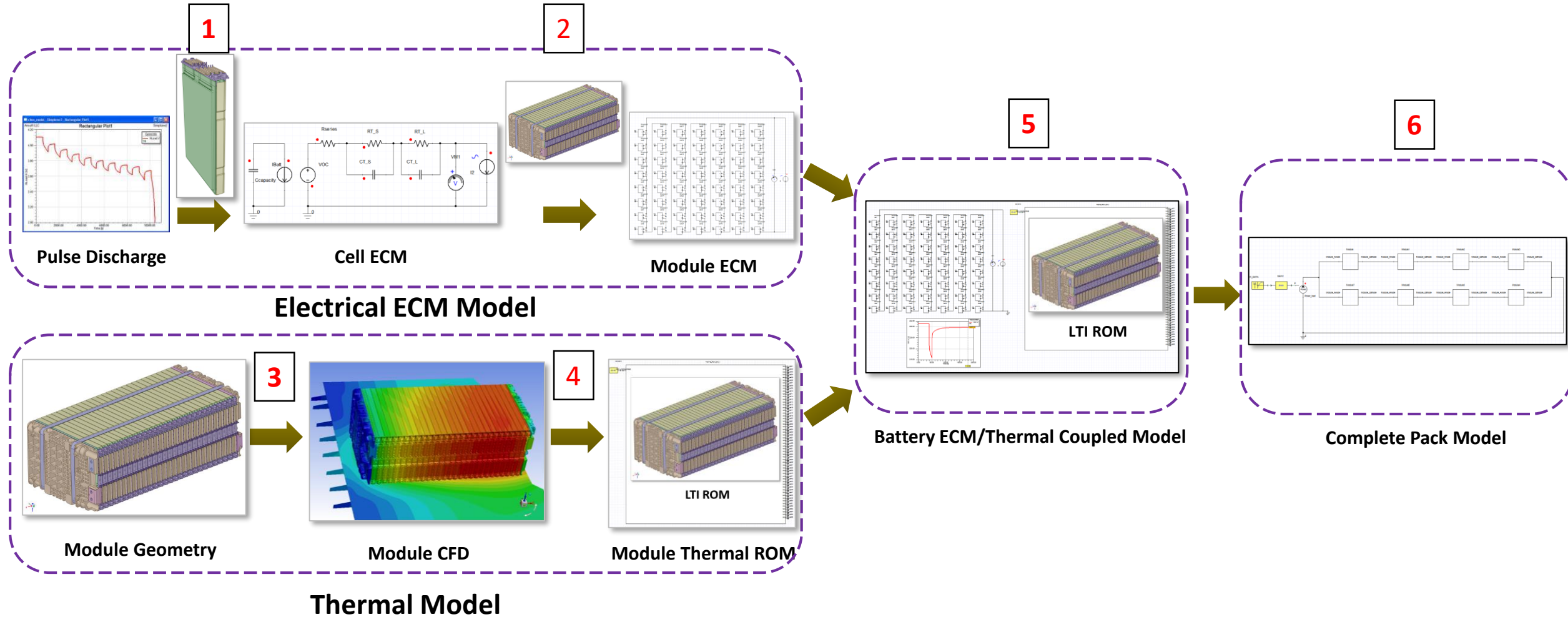
7:57:148—Volkswagen makes racing history with record-breaking electric race car

Electric power beats the internal combustion engine fair and square in major motorsport.

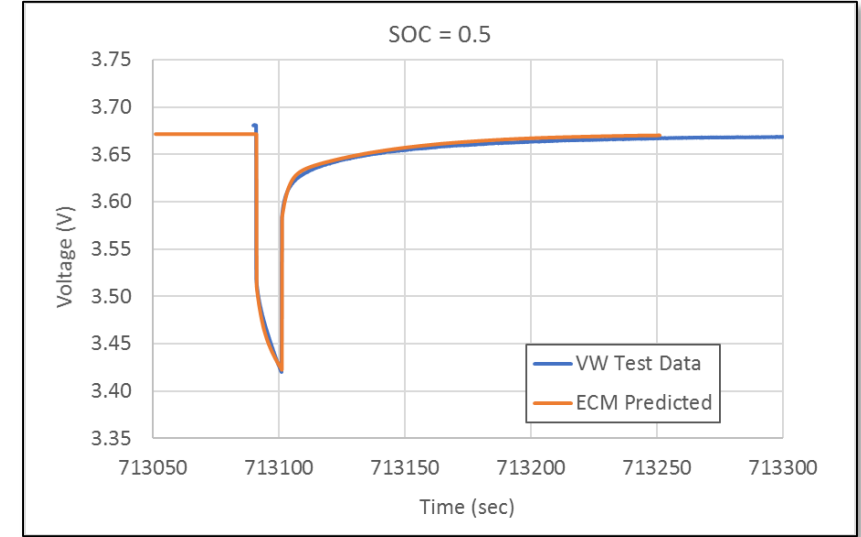
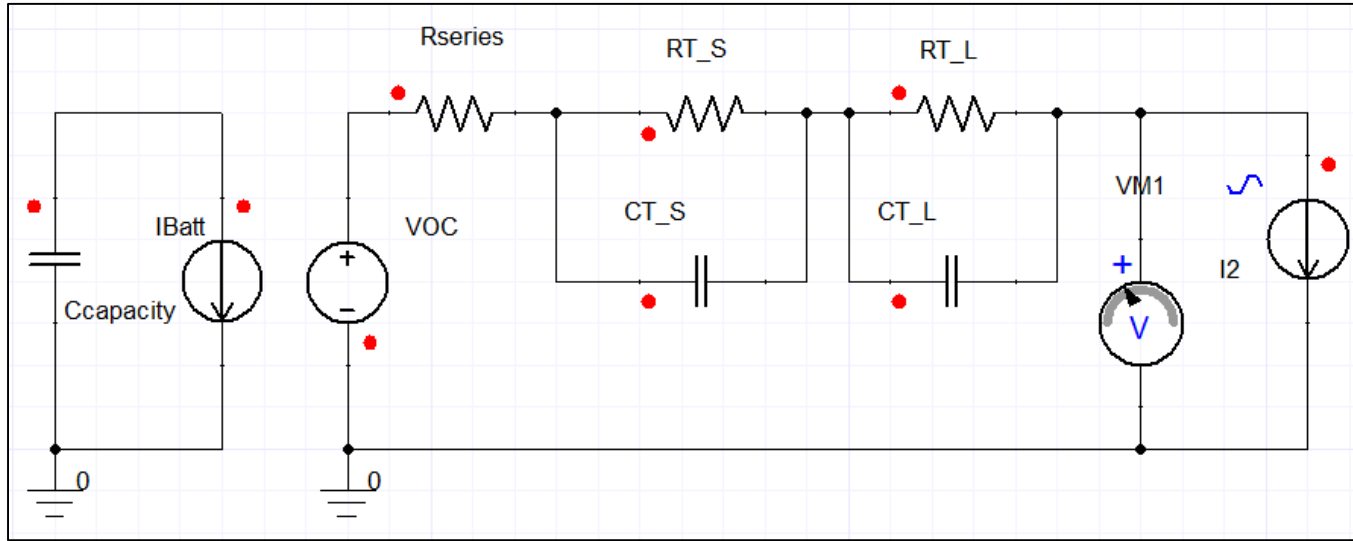
JONATHAN M. GITLIN - 6/29/2018, 7:30 AM



Approach Taken – ANSYS Battery Solution



Step 1: Battery Cell ECM Identification



- The 6P cell level ECM is identified from HPPC data.
- The ECM is a function of both SOC and temperature.
 - 11 SOC values.
 - 6 temperature values.
 - 2d lookup table is created for the 6 parameters.
 - 4P ECM (1RC pair) is also supported.

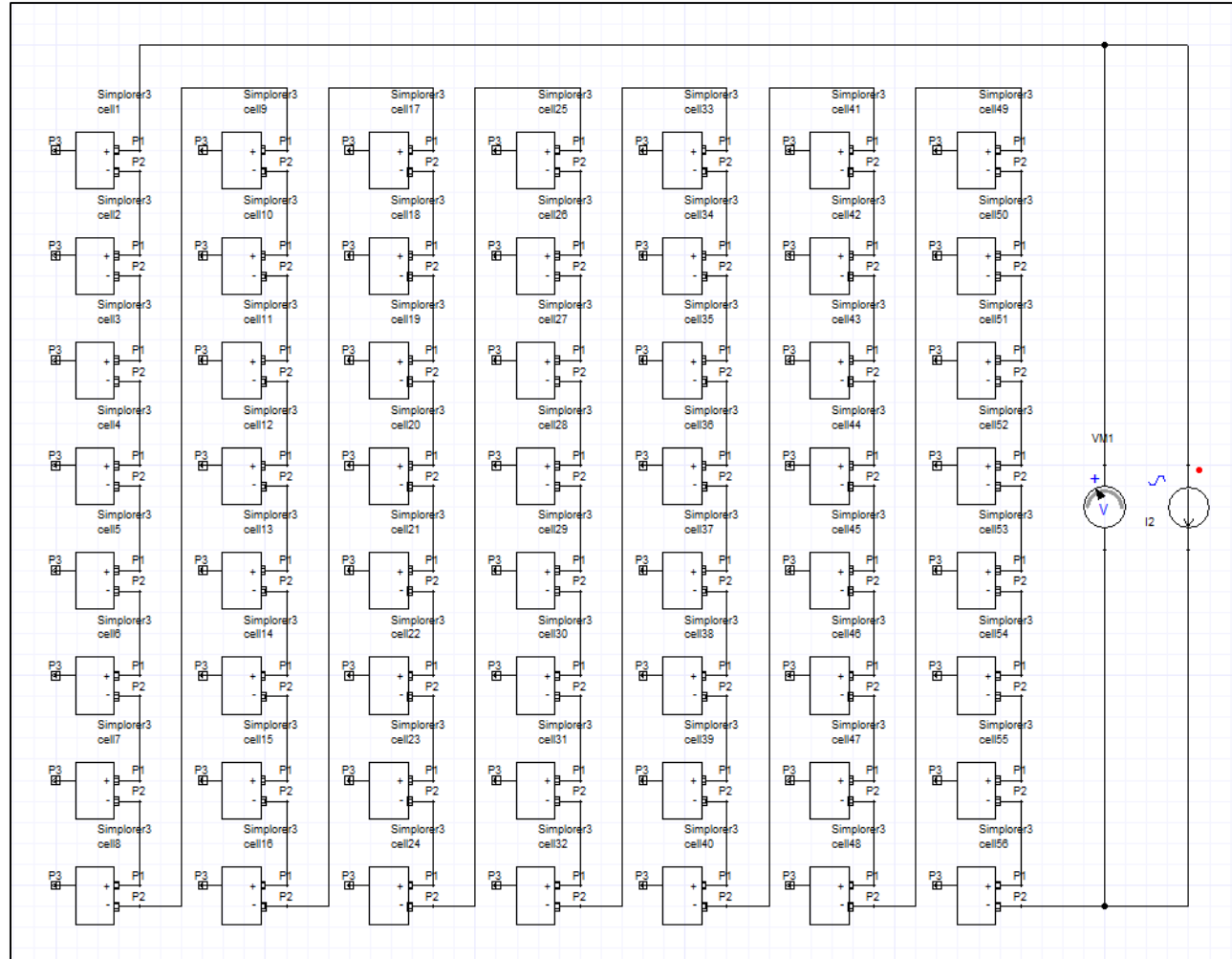
ECM Rs-parameter Data Table

6 Number of Temperature Levels
11 Number of SOC levels

	283.15	293.15	303.15	313.15	323.15	333.15
SOC						
0.05	0.0029111	0.00202965	0.0013733	0.00115555	0.00098665	0.0008415
0.145	0.0026266	0.00187087	0.00135748	0.00103519	0.00087727	0.00077979
0.24	0.00247438	0.00177512	0.00128562	0.0009979	0.00084237	0.00074075
0.335	0.00244905	0.00169528	0.00122835	0.00098923	0.00080749	0.00073051
0.43	0.00238904	0.00162386	0.00121198	0.00095926	0.00081125	0.00072964
0.525	0.0023611	0.00162854	0.00119555	0.00092965	0.00081224	0.00071373
0.62	0.00232357	0.0015855	0.00118284	0.00094931	0.00080772	0.00071231
0.715	0.00227823	0.00157045	0.00116318	0.00094571	0.00079944	0.0007127
0.81	0.00224739	0.00157999	0.00113688	0.00093052	0.00077881	0.00071883
0.905	0.00228518	0.00158663	0.00111703	0.00091739	0.00077547	0.00069606
1	0.00224295	0.0015852	0.0011452	0.0008963	0.00078815	0.00072

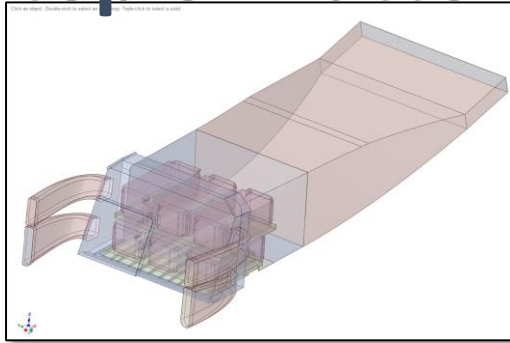
2d lookup table for R_s

Step 2: Battery Module ECM

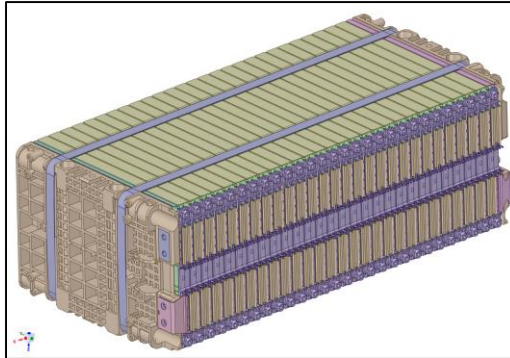


- Cells are connected in serial for the module ECM.
- A sub-circuit is created for each cell ECM for easier connection.

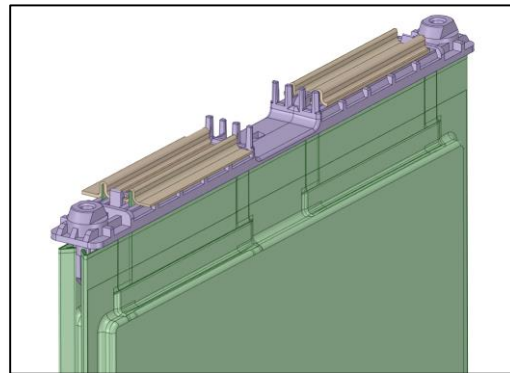
Step 3: Battery Module CFD Analysis



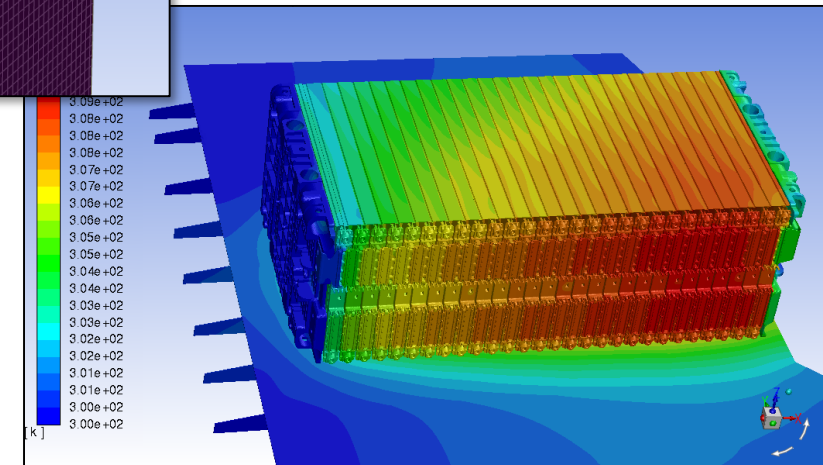
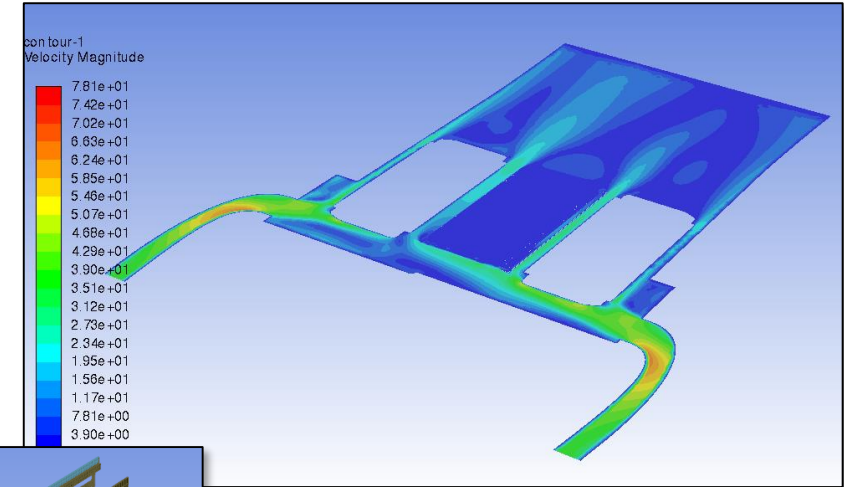
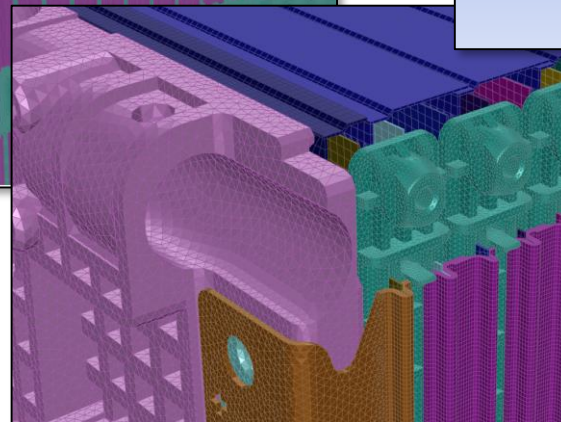
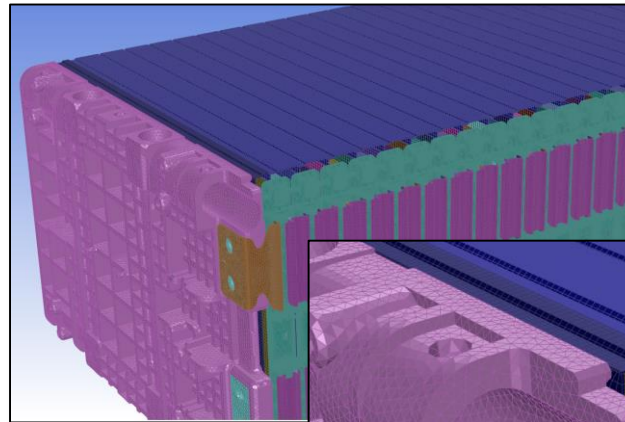
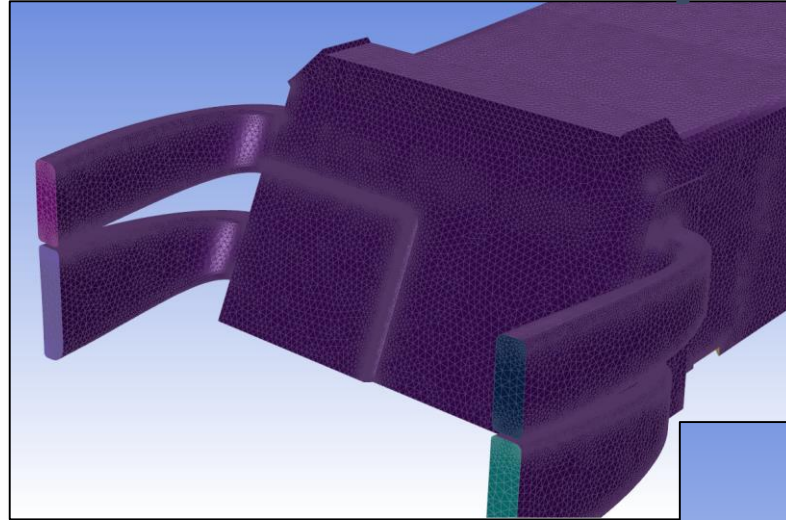
Housing



Module

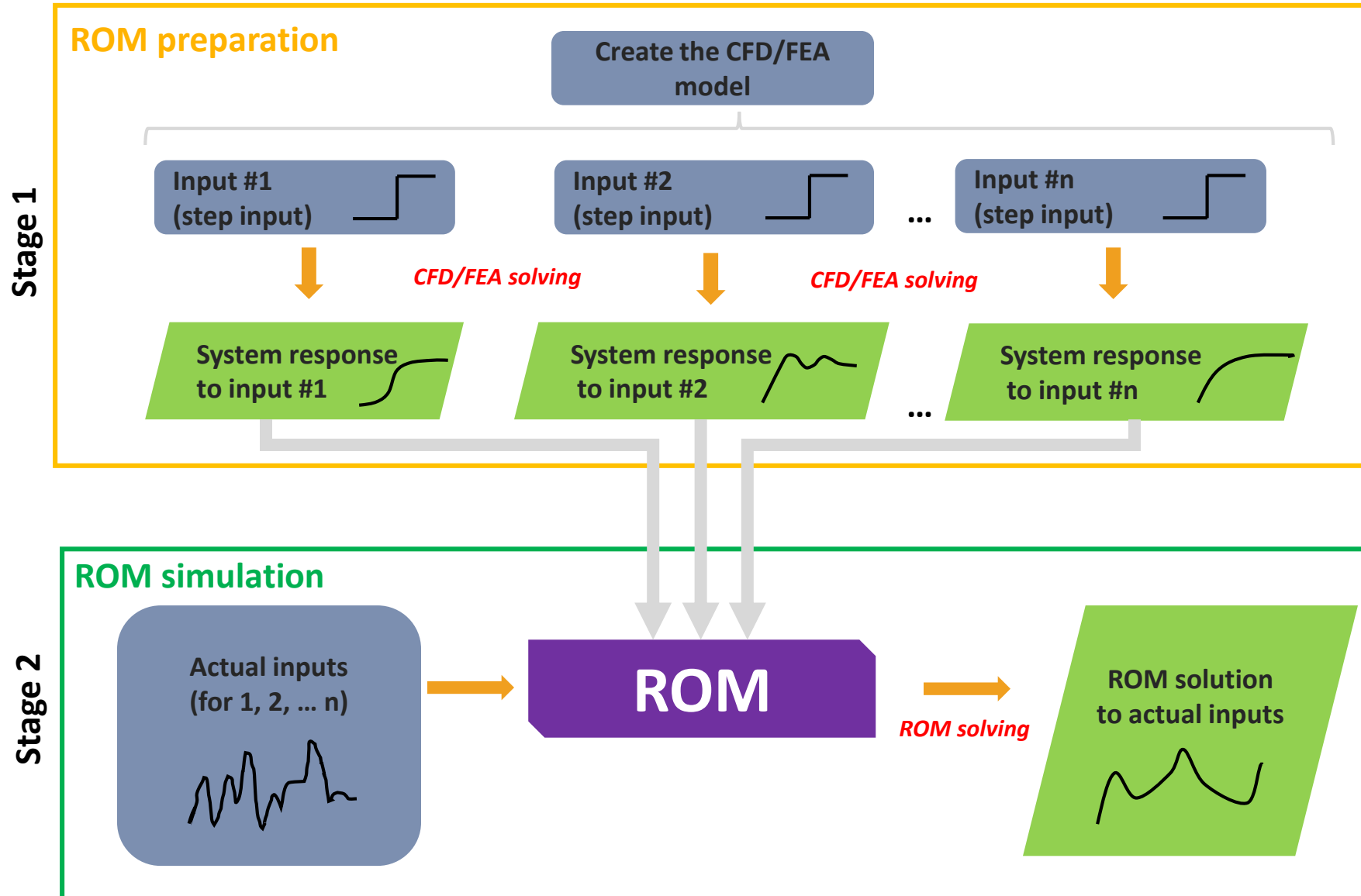


Cell

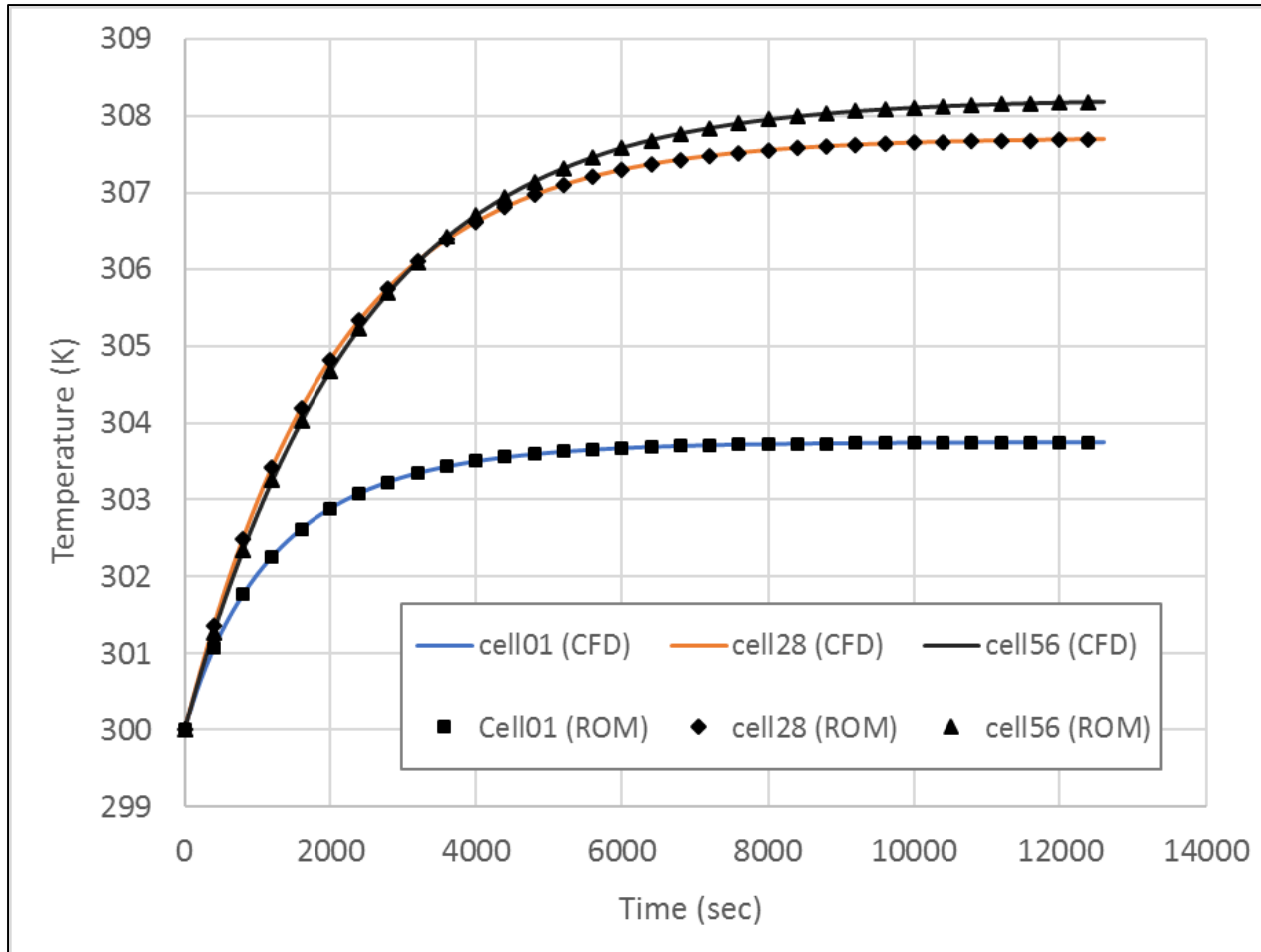


Step 4: Battery Thermal LTI ROM Extraction

ROM Generation Process

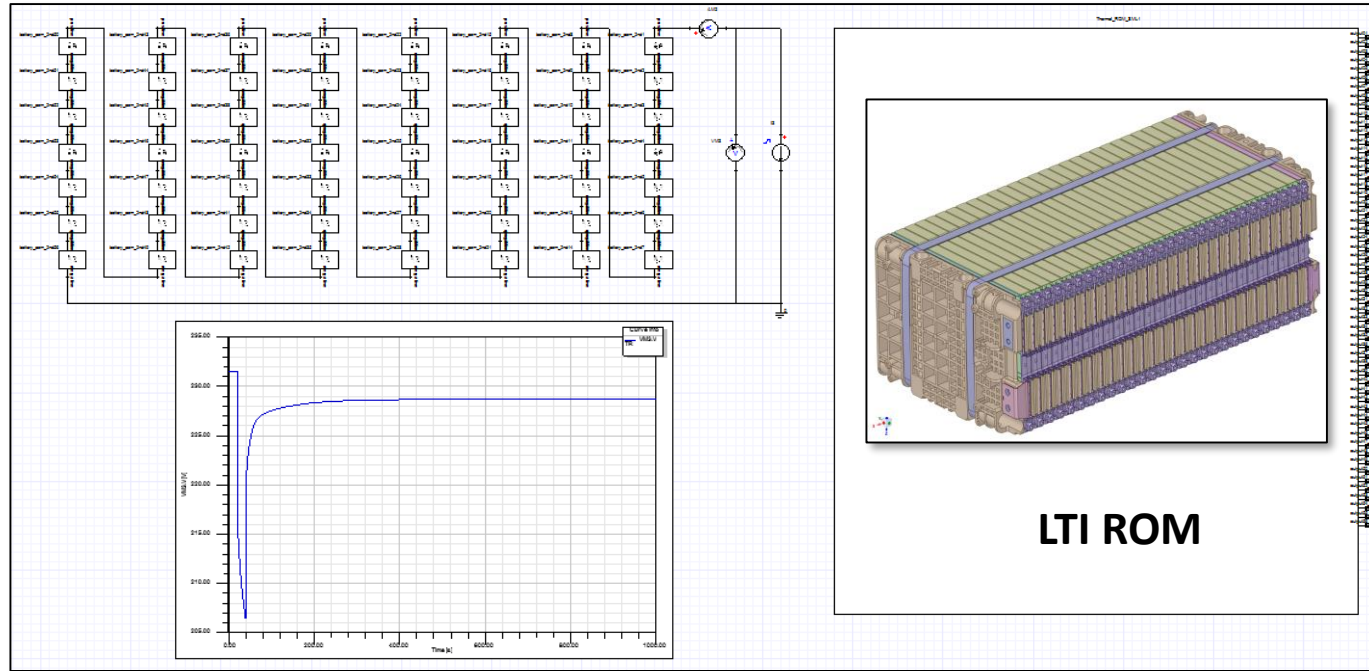


ROM Results Validation

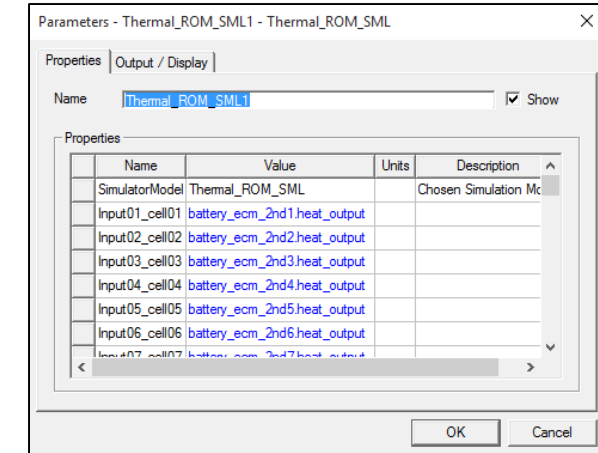


- While the ROM gives similar results as CFD, it runs orders of magnitude faster.

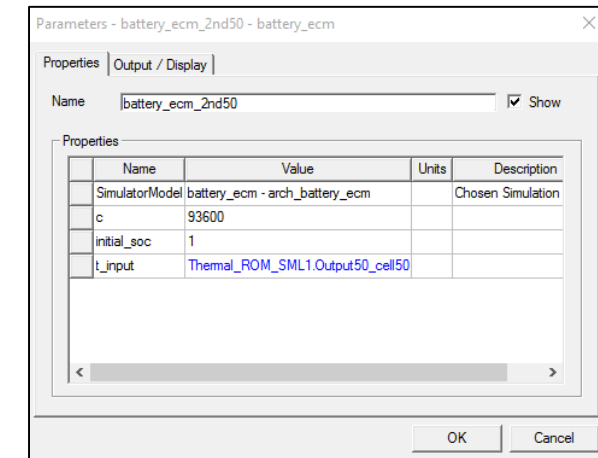
Step 5: Battery ECM Coupled with Thermal LTI ROM for Module



- The ECM is **two-way** coupled with the thermal LTI ROM.

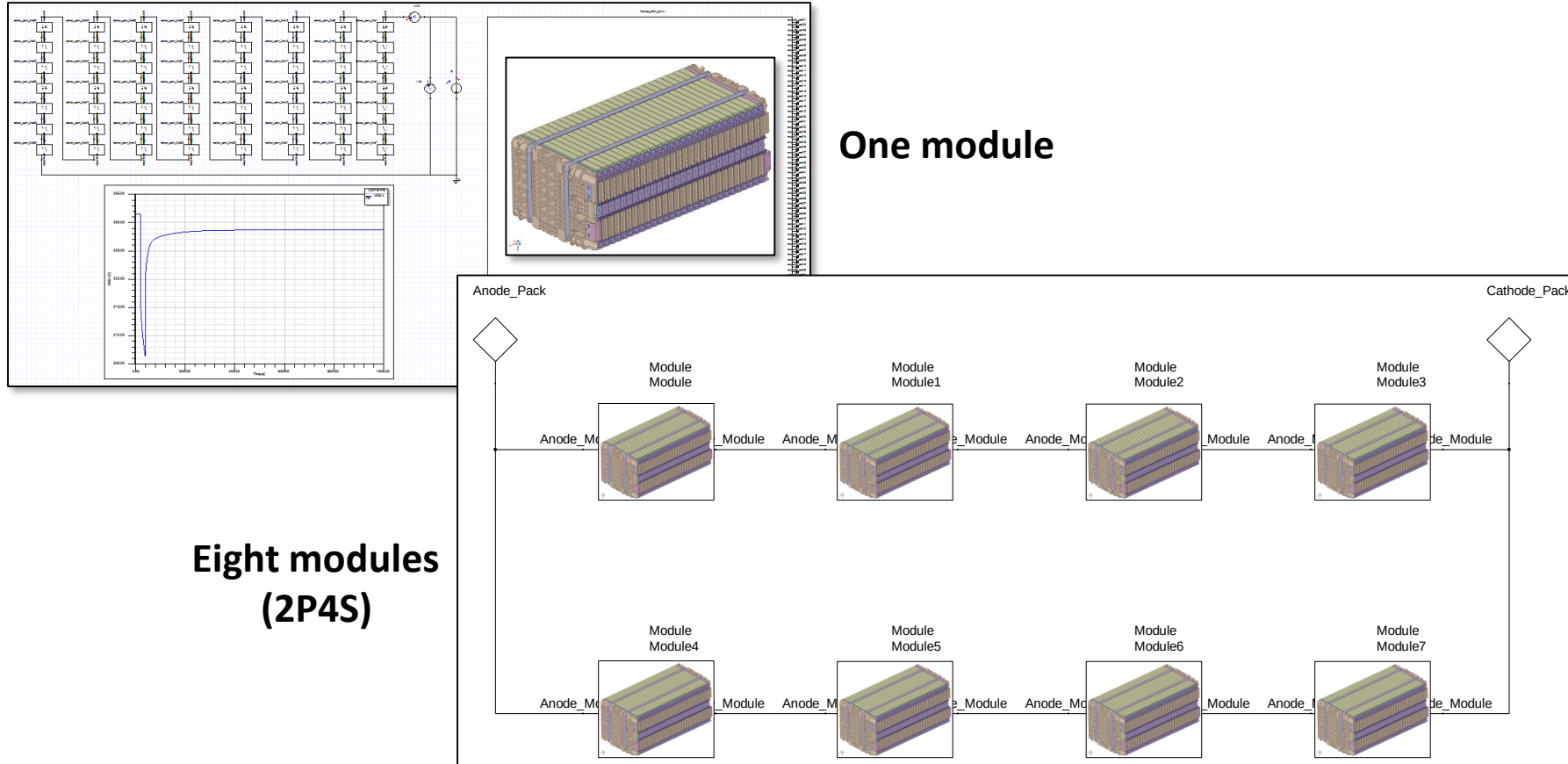


ROM heat source is from ECM



ECM temp. is from the ROM

Step 6: Full Battery Pack Model

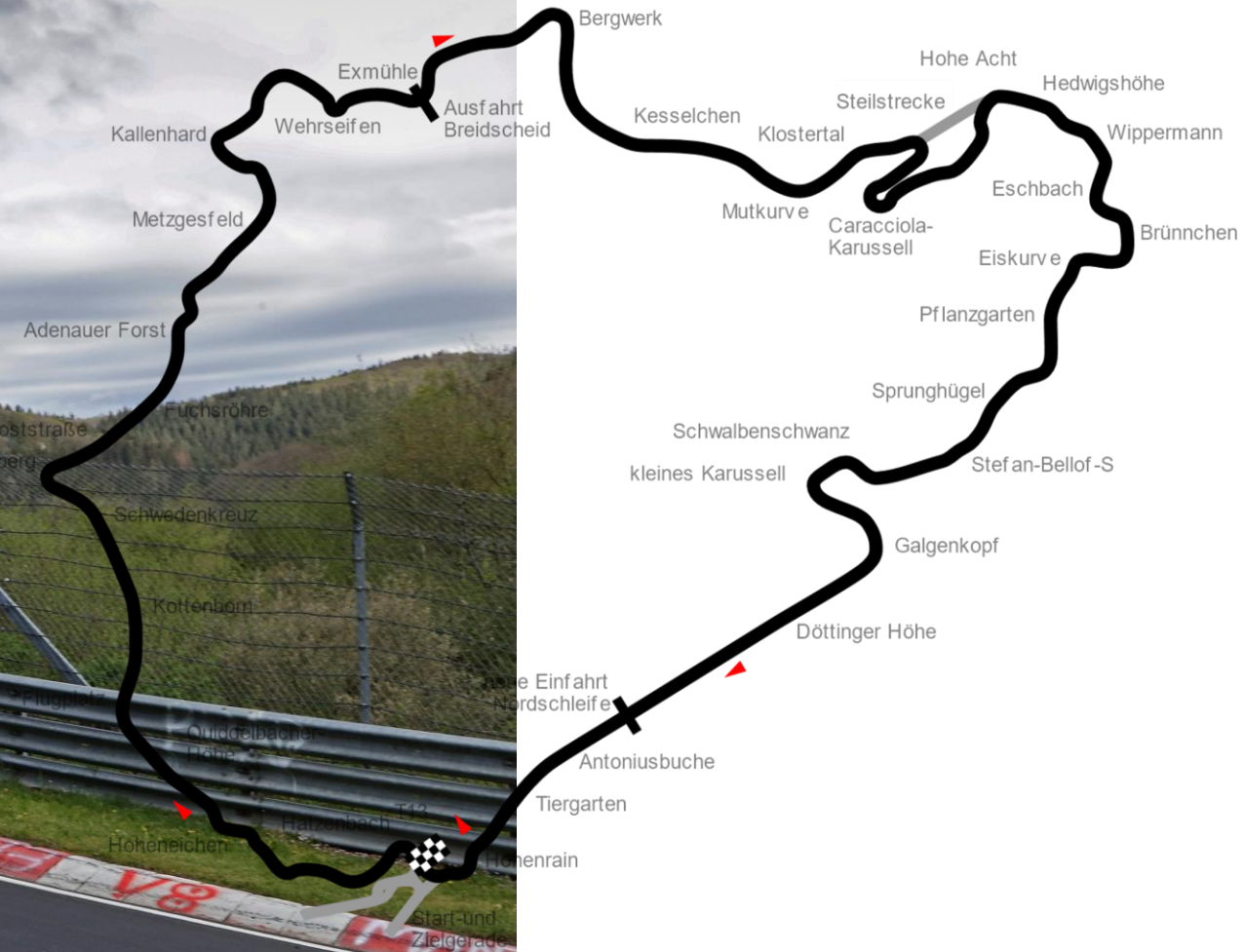


- From the module we can create a battery pack of 8 modules connected in 2P4S.
- This allows to quickly find the best pack arrangement and perform simulation such as power balance between module and cell and complete Battery Thermal Management simulation

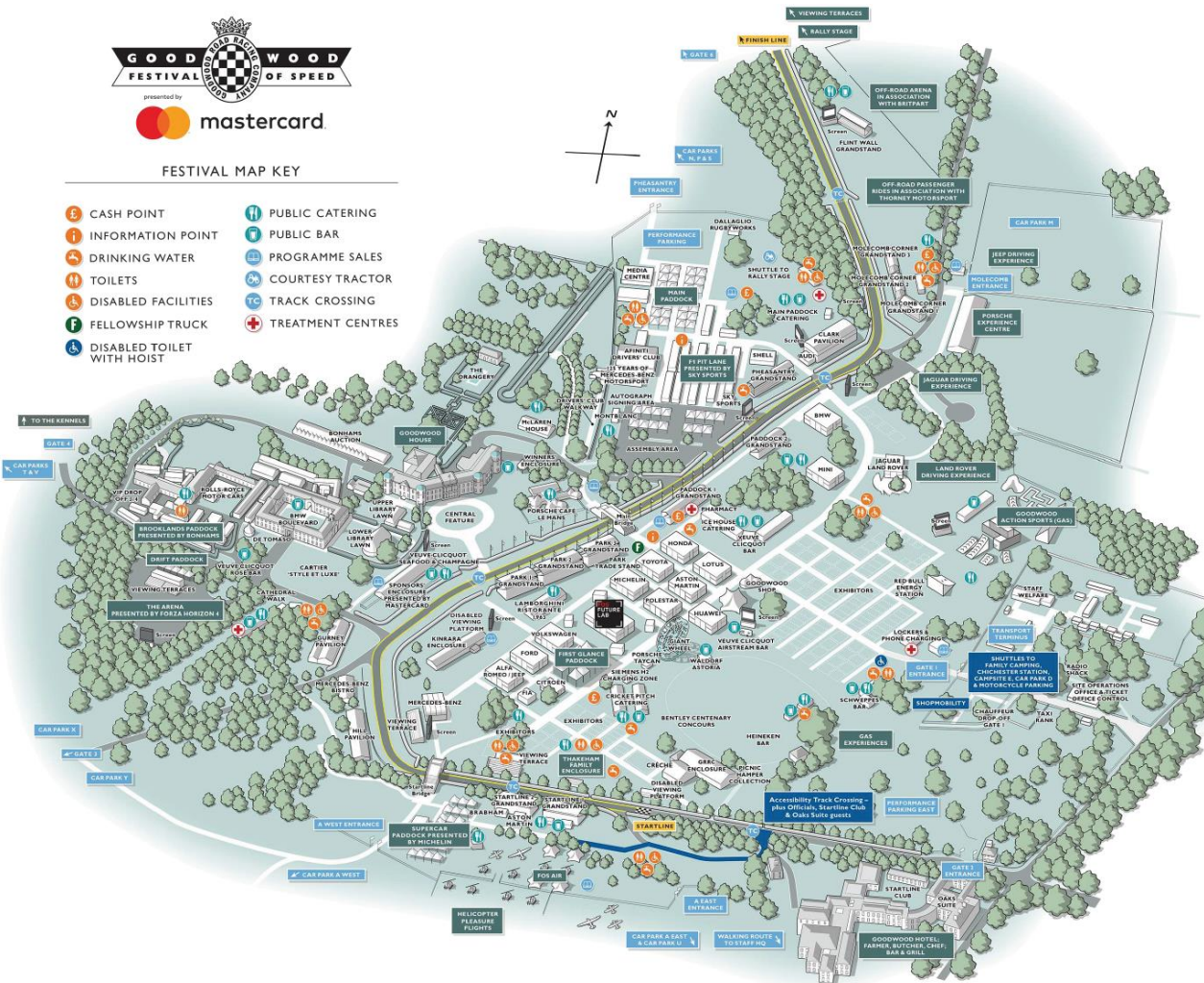
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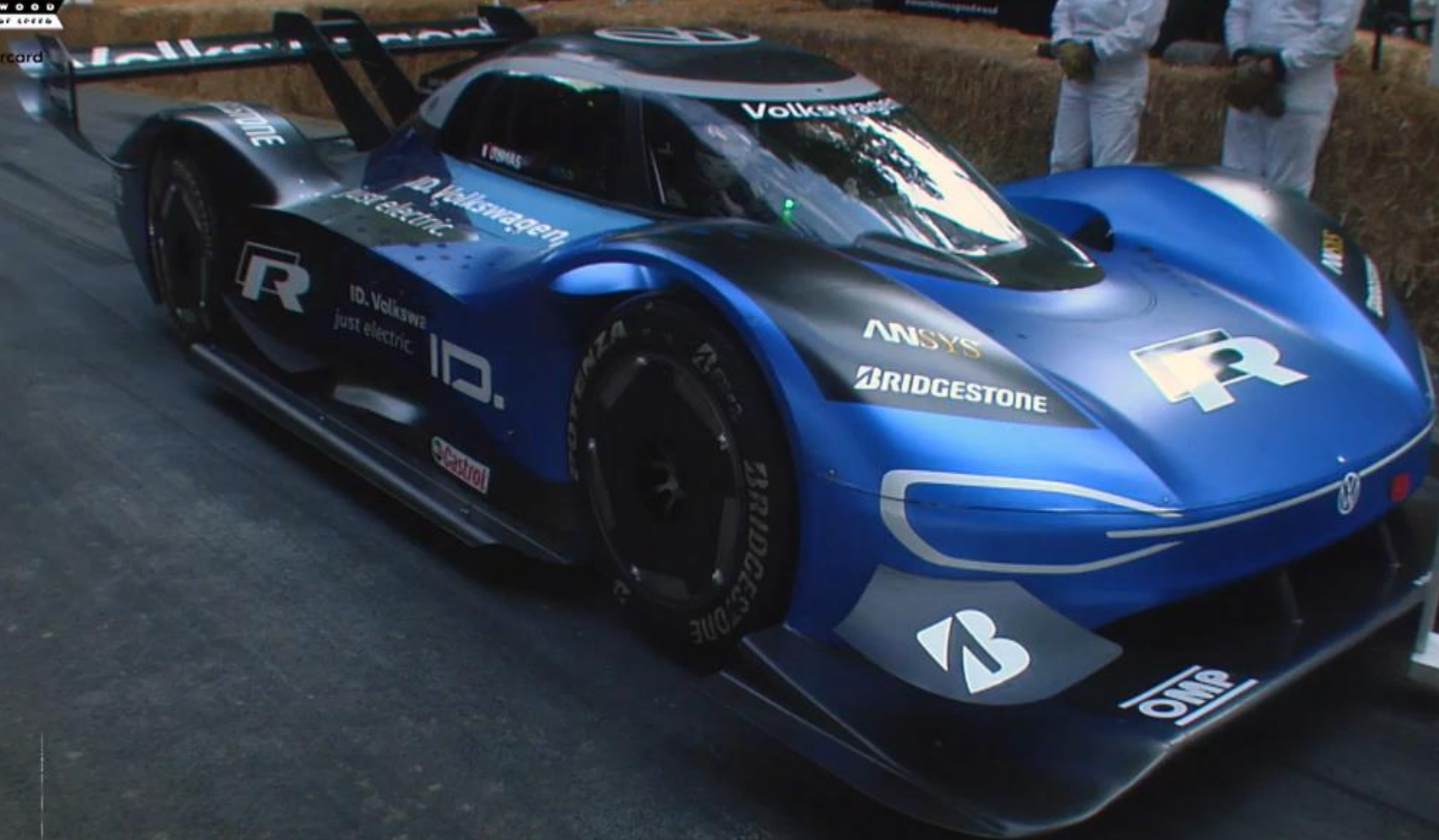
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