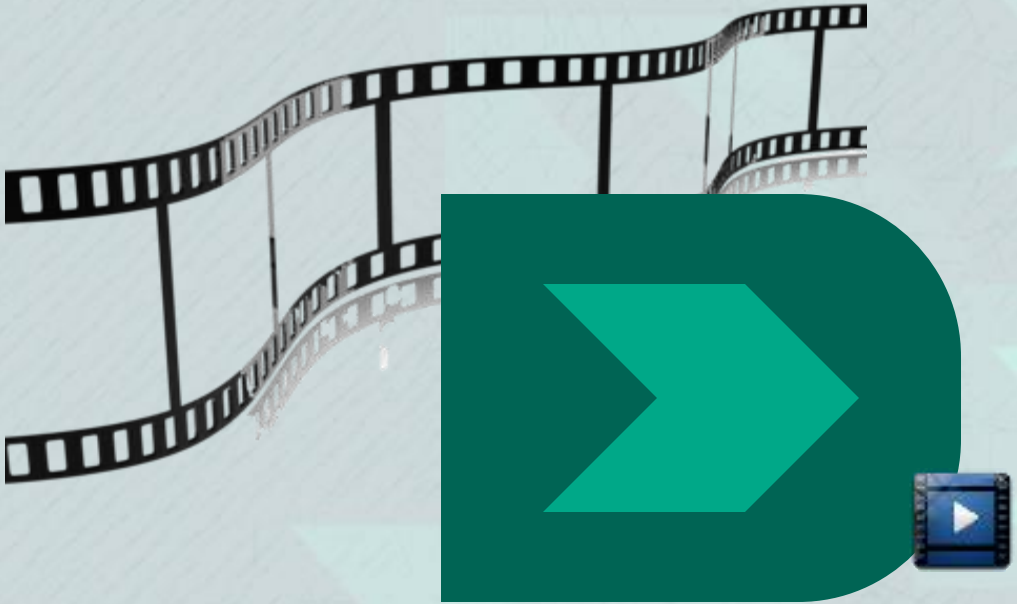
Unlocking Innovation: a Journey through Dumarey Virtual Engineering

GT European Roadshow

June 18th 2024

Giovanni Rovatti - Head of Virtual Engineering and NVH



The DUMAREY Group

Driving towards a SUSTAINABLE MOBILITY for ALL

SECTORS

Automotive
Industrial
Marine
Power Gen

CUSTOMERS WORLDWIDE

> 30

ANNUAL REVENUES

CLOSE to 1 BILLION €

INVESTMENTS over the last 10 years

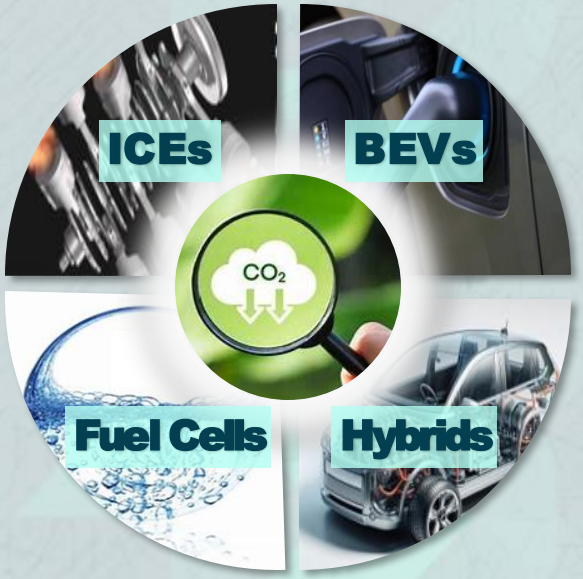
> 350 M€ CAPEX

DUMAREY ENGINEERING
DUMAREY ENGINES
DUMAREY HYDROCELLS
DUMAREY SOFTRONIX
DUMAREY POWERGLIDE
DUMAREY FLYBRID
DUMAREY FLOWMOTION

Dumarey BUSINESS UNITS

The road to DECARBONIZATION

technology diversity



DIVERSE PORTFOLIO of SOLUTIONS for a sustainable future

DIVERSE SET of PROPULSION TECHNOLOGIES to help meet all transportation needs

DUMAREY ENGINEERING

DUMAREY ENGINES

DUMAREY HYDROCELLS

DUMAREY SOFTRONIX

DUMAREY POWERGLIDE

DUMAREY FLYBRID

DUMAREY FLOWMOTION

Dumarey BUSINESS UNITS

product

PRODUCTS and SERVICES
of the Dumarey Group

ICEs
with conventional and low carbon fuels

Light-Mid-Heavy Duty, Large Bore, Marine; PFI-DI; dual fuel

DUMAREY ENGINEERING

DUMAREY ENGINES

Hydrogen Solutions
ICEs and FCs

H2 ICE: Light-Mid-Heavy Duty, Genset, Marine; PFI-DI; dual fuel

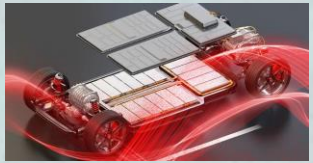
DUMAREY HYDROCELLS

Injection Systems
fuel injection and after-treatment

Gasoline, DEF, H2 ICE PFI-DI

DUMAREY FLOWMOTION

BEV
Thermal Management



DUMAREY ENGINEERING

product

PRODUCTS and SERVICES
of the Dumarey Group

Transmissions, Reducers & e-Drive Components

DUMAREY POWERGLIDE
JV with MARELLI

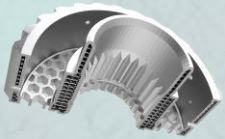
Kinetic Energy Recovery Systems

DUMAREY FLYBRID

Electronics, Software and Controls

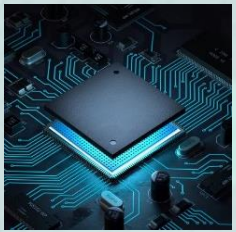
DUMAREY SOFTRONIX

Additive Manufacturing



MadeInAdd
(JV with CDP Venture Capital and MIMETE)

Artificial Intelligence

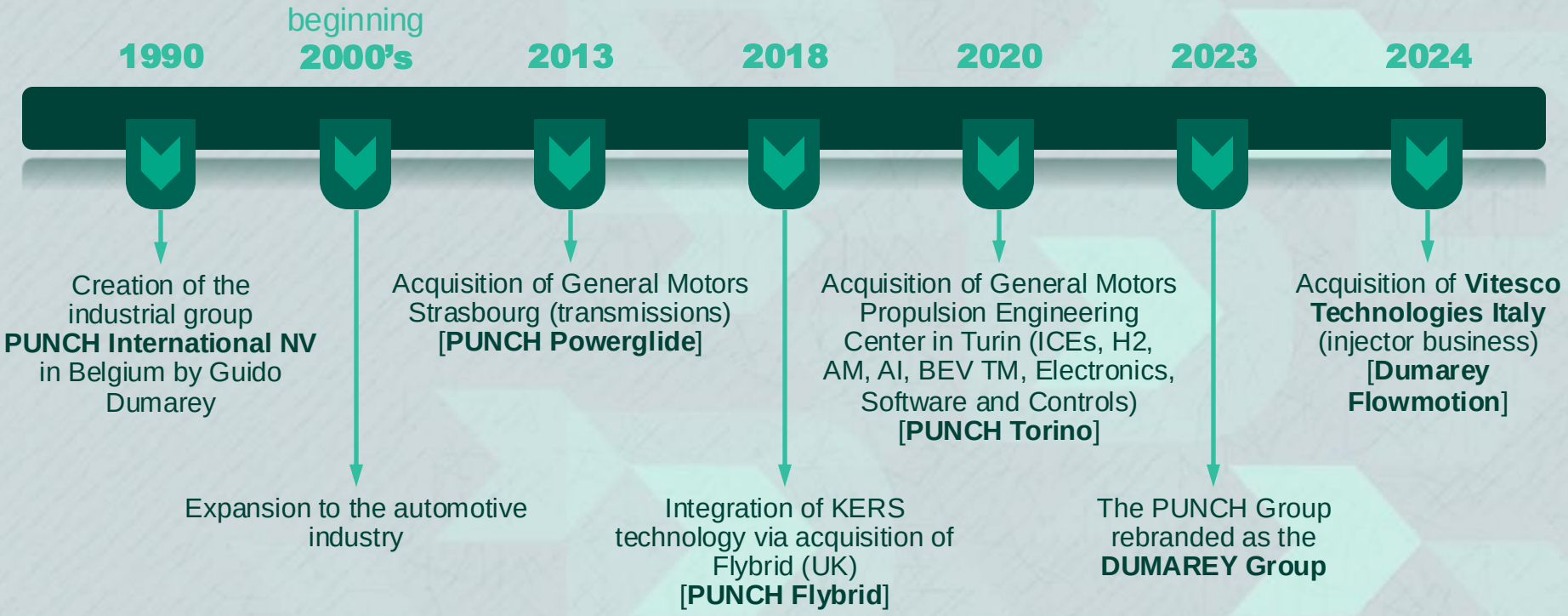


AITEM
(start-up)

Dumarey BUSINESS UNITS

- DUMAREY ENGINEERING
- DUMAREY ENGINES
- DUMAREY HYDROCELLS
- DUMAREY SOFTRONIX
- DUMAREY POWERGLIDE
- DUMAREY FLYBRID
- DUMAREY FLOWMOTION

Main milestones in the history of the Dumarey Group



The Network of the Dumarey Group

FERTILE and YOUNG ENVIRONMENT

CUSTOMERS and PARTNERS
all over the world

network with
UNIVERSITIES, START-UPs and TECH COMPANIES

RESEARCH PROJECTS
funding researches and PhD fellowships

TALENTS
world class HW and SW Engineers

LOCATIONS in 5 COUNTRIES
7

GRANTED PATENTS
> 450

CUSTOMERS WORLDWIDE
> 30

HIGHLY SKILLED PEOPLE
3,000

OWN PROJECTS and ENGINEERING SERVICES
1/3 of staff in R&D

From Concept to Start of Production… and beyond

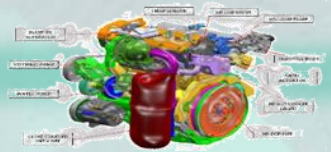
CAPABILITIES

HARDWARE ENGINEERING

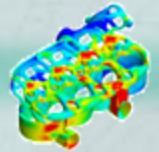
- ADVANCED ENGINEERING
- DESIGN & RELEASE
- VIRTUAL ENGINEERING
- DEVELOPMENT, NVH & VALIDATION
- CALIBRATION
- PRODUCT QUALITY

CONCEPT

DIGITAL MOCK-UP



VIRTUALIZATION



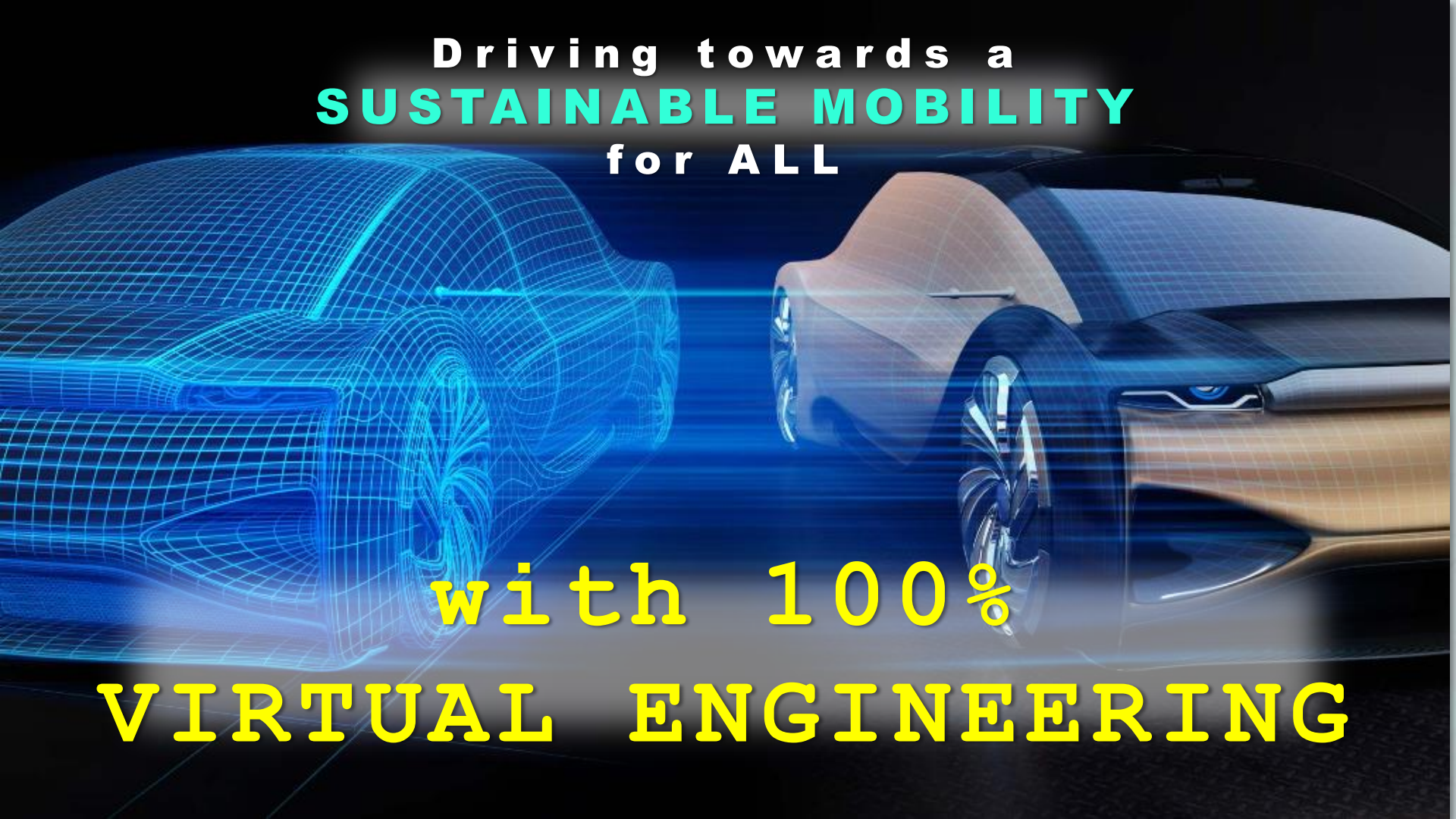
PRODUCT

ENGINEERING FIRMS SPACE

DUMAREY

ADV ENG / Pre-DEV | DEVELOPMENT | PROD and Post-PROD

SORP


Driving towards a
SUSTAINABLE MOBILITY
for ALL
with 100%
VIRTUAL ENGINEERING

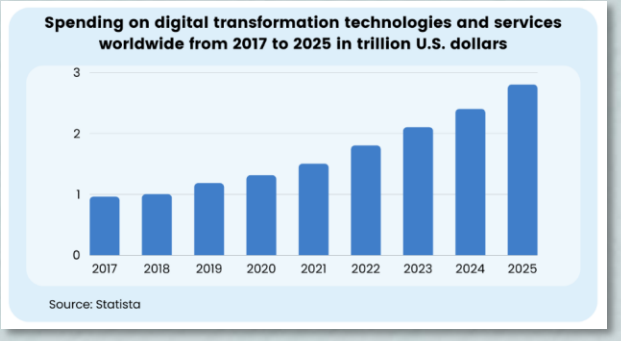
From CAE to Virtual Engineering

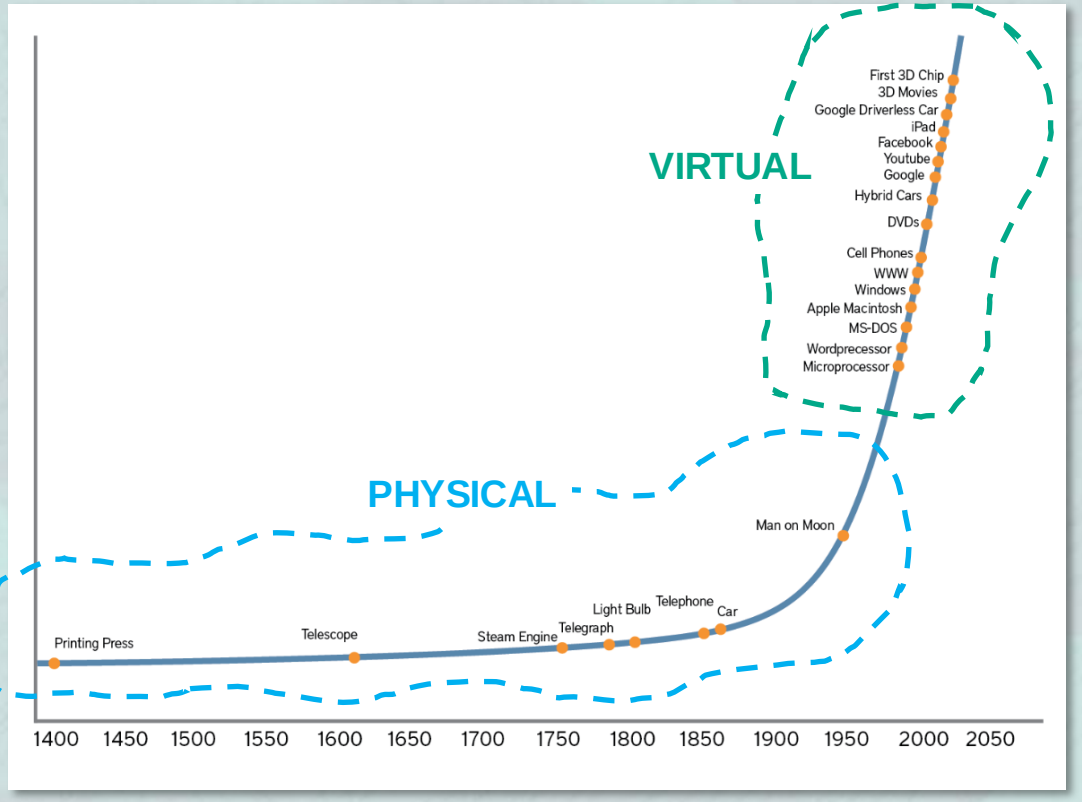
Virtual engineering offers a **COMPREHENSIVE APPROACH to PRODUCT DEVELOPMENT**, enabling companies to **streamline processes**, **reduce costs** and **deliver high-quality products more efficiently**

what we get

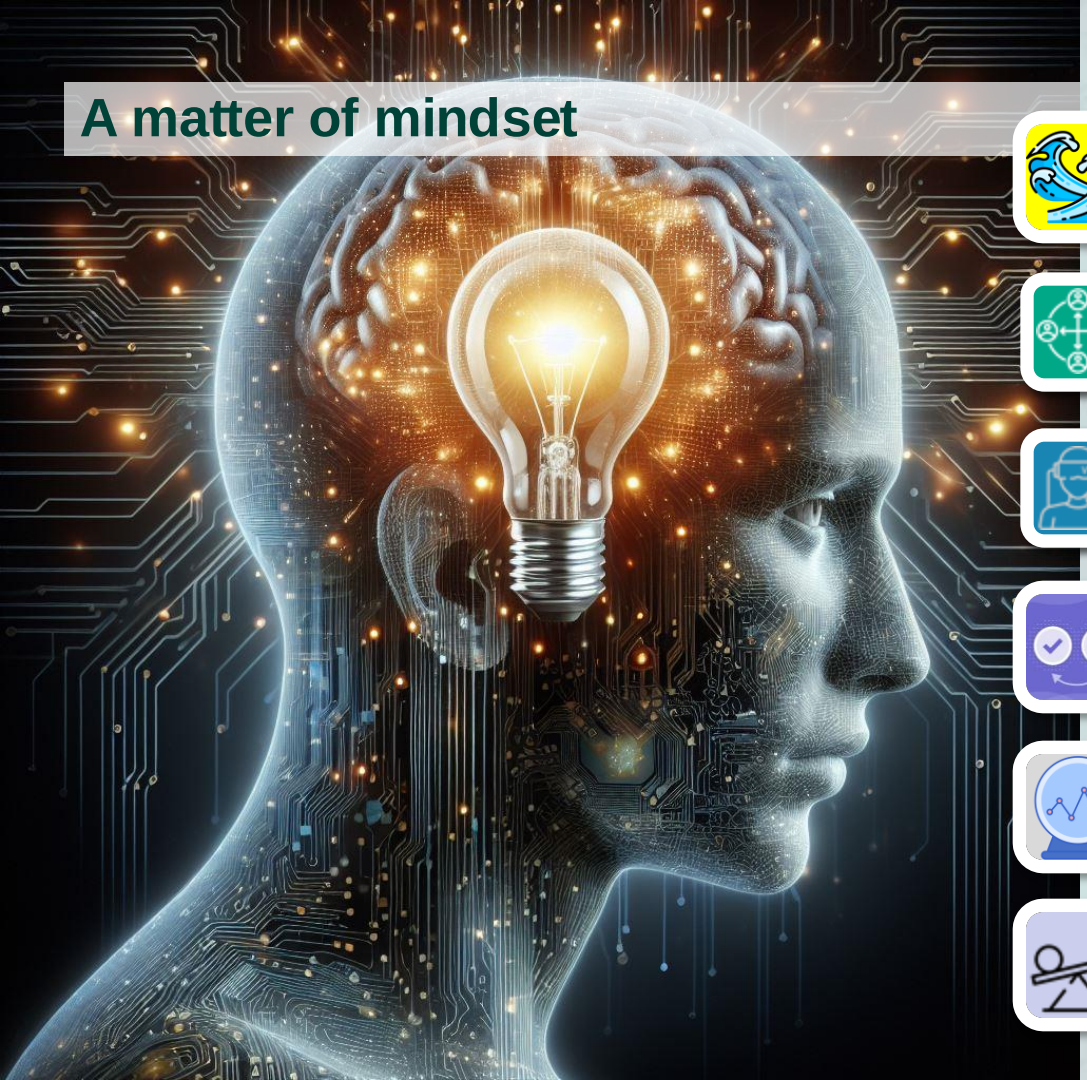
- ENHANCED COLLABORATION
- FLEXIBILITY and INNOVATION
- COST REDUCTION
- TIME SAVING
- HIGHER THROUGHPUT
- RISK MITIGATION and IMPROVED QUALITY
- SUSTAINABILITY

Digital Transformation and Accelerating Growth in Technology





A matter of mindset

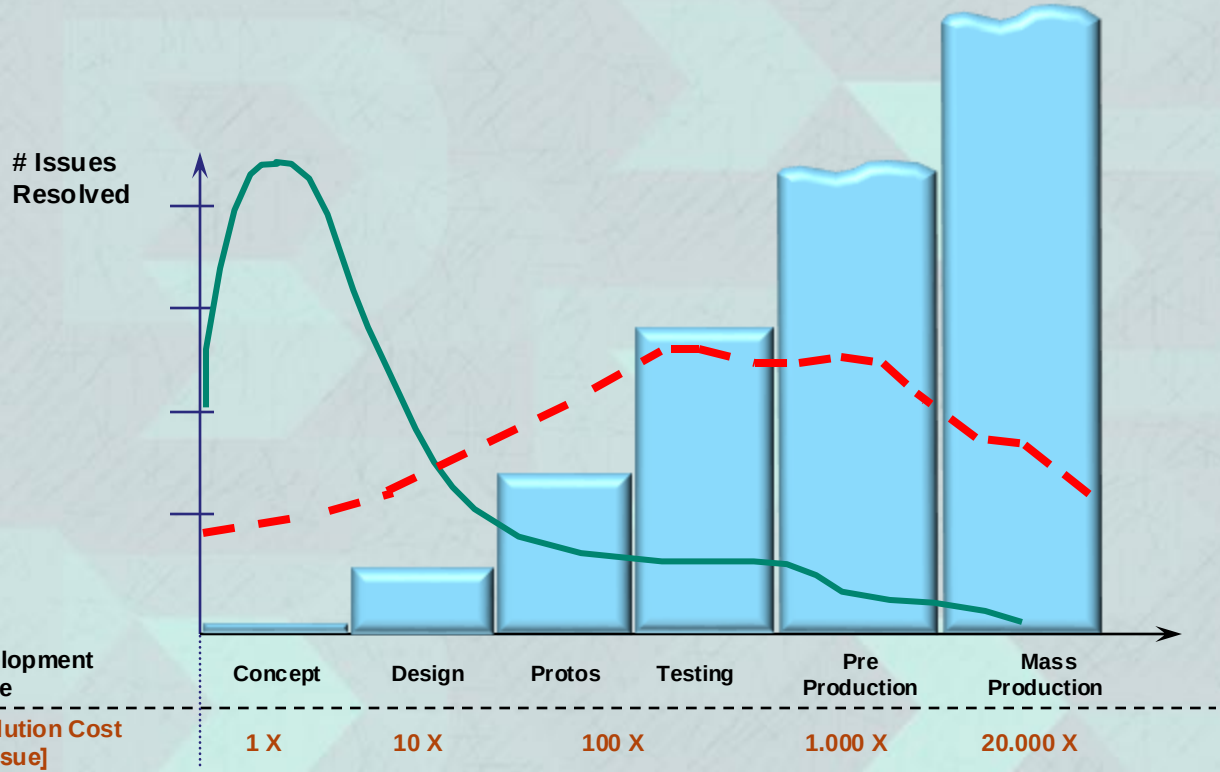


- **DOUBLE WAVE**, top-down and bottom-up
- **CROSS-FUNCTIONAL ALIGNMENT** is key for the success
- Virtual has to be **“GOOD ENOUGH”** to drive the decisions and meet customer’s needs
- **MOVE LEFT - LEARN EARLIER** and **FASTER**
- Provide **PREDICTIONS**, not reactive diagnosis
- Leverage on **AUTOMATION**, **OPTIMIZATION** and **VARIATION ANALYSIS**

Move Left: cost benefits

OLD WAY
Design, Build, Test

NEW WAY
Virtual leads the Design

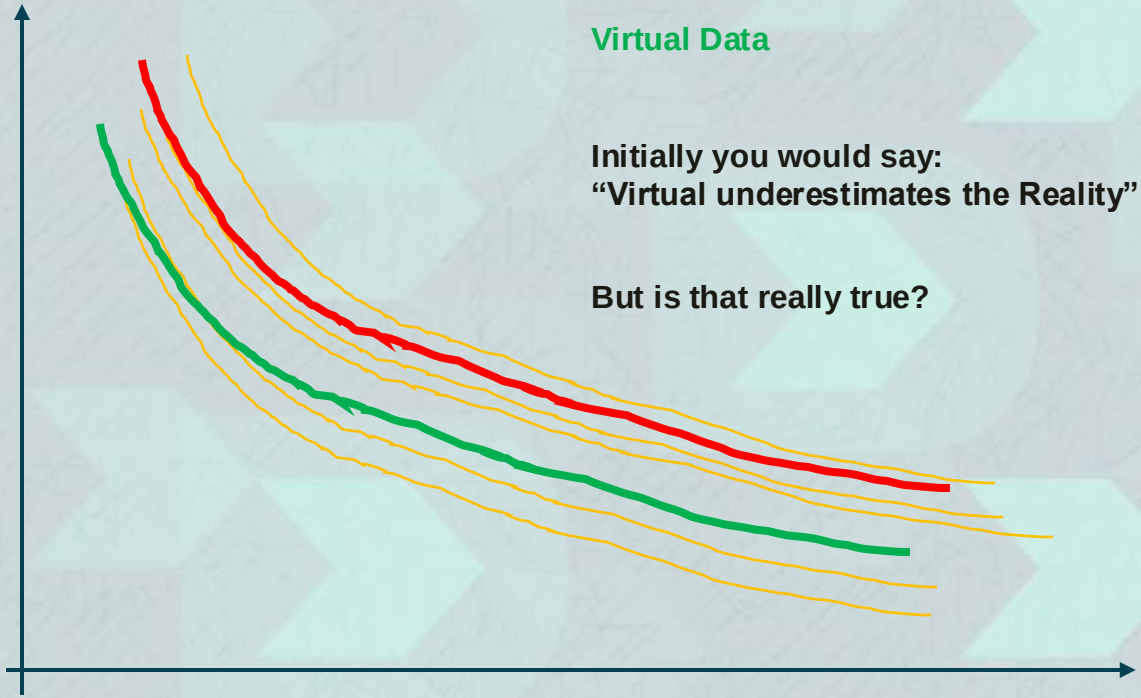


included safety issues, recall campaigns, reputation deterioration…

Virtual vs. Physical

Physical tests:

- **DO NOT EQUATE to physical phenomenon**
- **are themselves a "MODEL" of the REALITY of interest**



Physical Data: Experimental Test

Physical Data: Additional Experimental Tests

Virtual Data

Initially you would say:
"Virtual underestimates the Reality"

But is that really true?

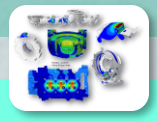
Virtual Engineering in the Dumarey Group

CAPABILITIES

~60 Engineering Experts - Leading Edge Virtual Solutions

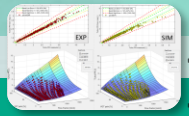
- STRUCTURAL INTEGRITY & SEALING
- DYNAMICS & ACOUSTICS
- 3D COMPUTATIONAL FLUID DYNAMICS
- 1D SYSTEM PERFORMANCE
- XiL & VIRTUAL CALIBRATION

ARCHITECTURE DEFINITION



System, Sub-system and component **VIRTUALIZATION**

PLANT MODELING for SW Development



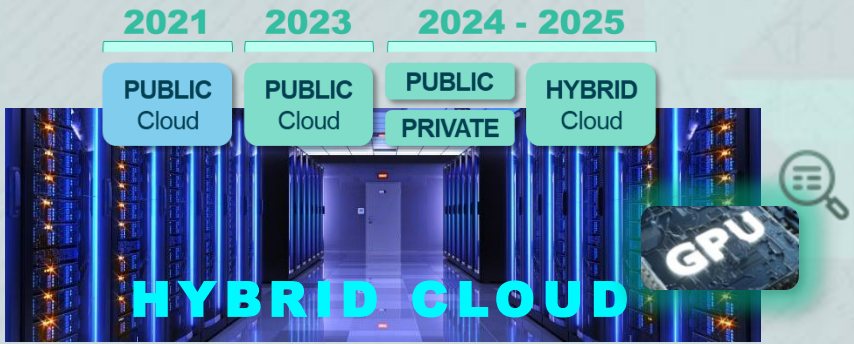
VIRTUAL CALIBRATION

HPC AND SW TOOLS ENVIRONMENT

- AUTOMATION and OPTIMIZATION
- DIGITAL TWIN
- ARTIFICIAL INTELLIGENCE
- MACHINE LEARNING

HPC and SW Tools Environment

HPC



as the ***best compromise*** in terms of

- scalability
- performance variability and latency
- control and customization
- security and compliance
- cost

MULTI provider
SINGLE provider

SW Tools

GAMMA TECHNOLOGIES
Altair
ENGINSOFT
DASSAULT SYSTEMES
CONVERGE CFD SOFTWARE
MathWorks
Romax TECHNOLOGY
STAR-CCM+
BETA
OpenFOAM®
TAITherm™
CF-MESH+
ParaView
PreonLab

Automation and Optimization

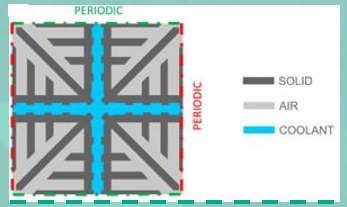
- **Single Domain Optimization (SDO)**
- **Multi-Disciplinary Optimization (MDO)**

AUTOMATION:

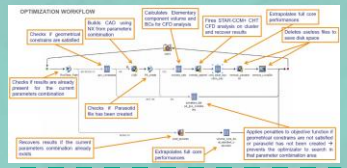
- streamlines **ITERATIVE** optimization
- swiftly refines design **VARIATIONS**
- enables efficient and effective design space **EXPLORATION**

MULTISCALE Modelling and Optimization of ADVANCED HEAT EXCHANGERS

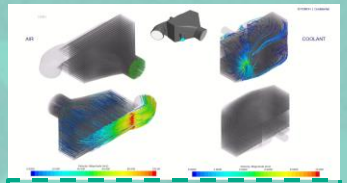
- Complete **automated** workflow
- Implementation of **Design for Additive Manufacturing (DfAM)** technology capabilities and requirements



From microscale…



…through core optimization…

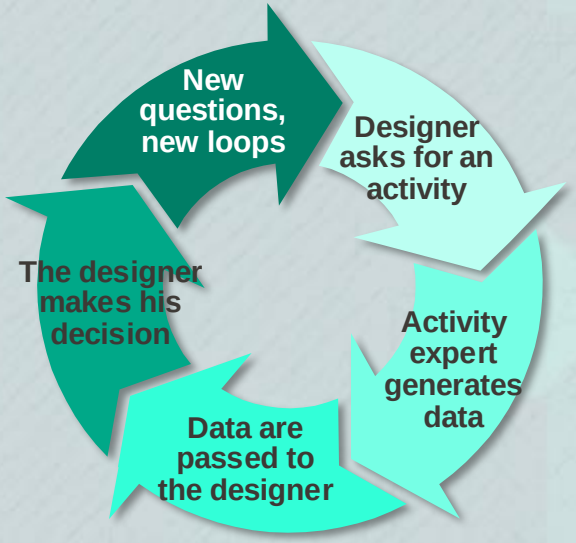


…to full scale CFD analysis for validation

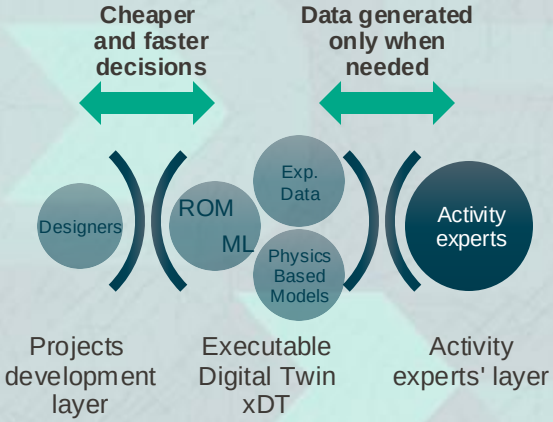
Digital Twin, Artificial Intelligence and Machine Learning
Data Flow in Virtual Engineering

DATA are the crude oil of 4th industrial revolution

CONVENTIONAL decision making process



EXECUTABLE DIGITAL TWIN decision making process

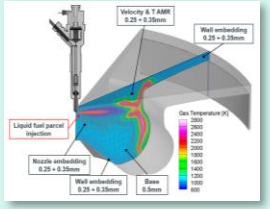


AI to combine physics and data into a comprehensive virtualization framework

Digital Twin, Artificial Intelligence and Machine Learning
Combustion xDT

GAMMA TECHNOLOGIES

Virtual Space Physics Based Model



DATA

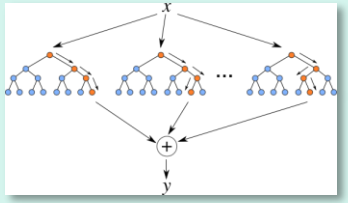
UNIFIED DATABASE

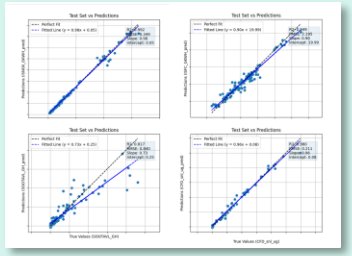
DATA

Physical Space Engine Test Bench

DATA

Virtual Space Reduced Order Model

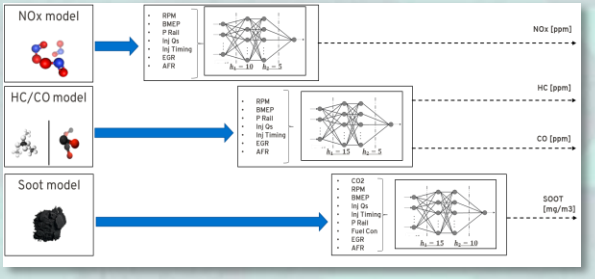


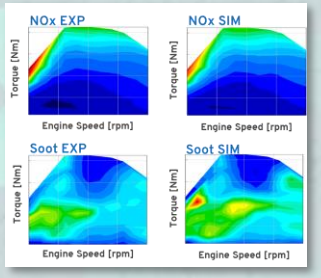


ML applications on engine-out and aftertreatment in GT-SUITE

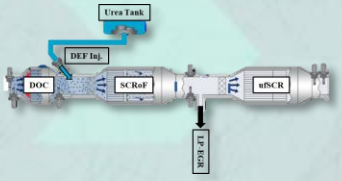
GAMMA TECHNOLOGIES

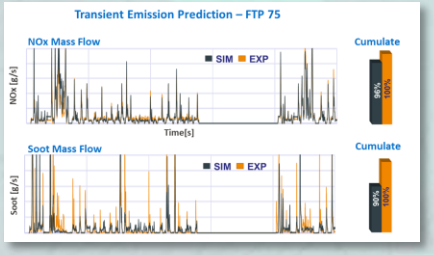
- **Modeling Unknown Physics with ML models**
  - feed-forward neural networks to estimate engine-out emissions utilizing an experimental DOE dataset

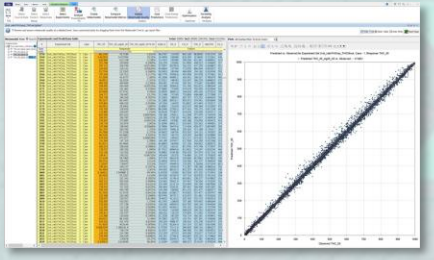


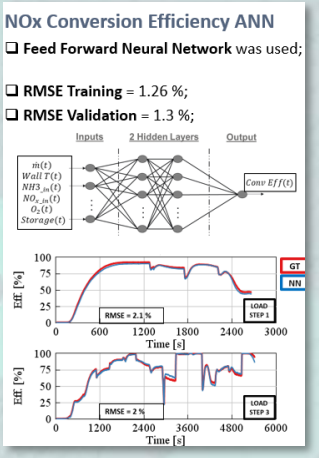


- **Reduced-Order ML models**
  - ML methodologies to reproduce aftertreatment high-fidelity models (HFM) at a lower computational cost
  - the data used for ML model training can be either virtual (i.e. generated by the HFM) or virtual and experimental, to increase accuracy





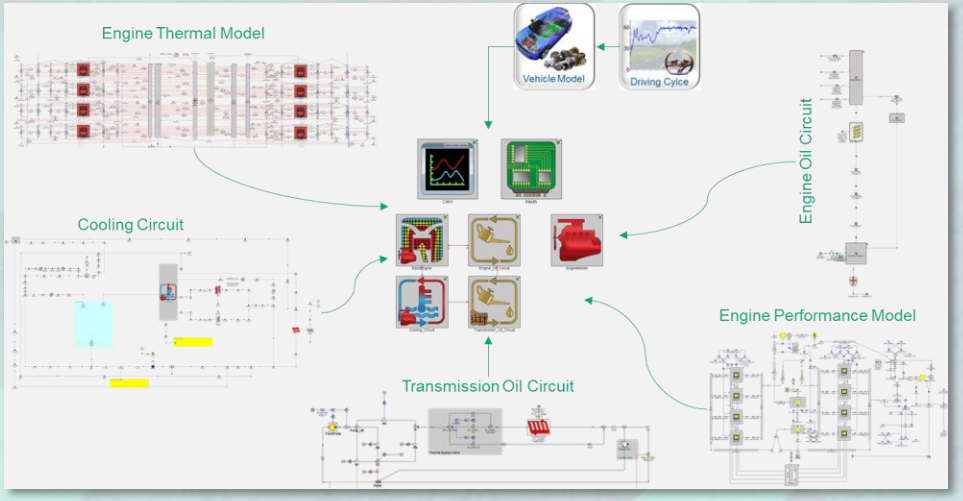




ICE Thermal Management

main features

- **Subsystems integration:**
  - Cooling and Lubricant
  - Thermal Mass
  - Gas Exchange
  - Vehicle
- **Integration of simplified control architecture**
- **Co-simulation with control software**



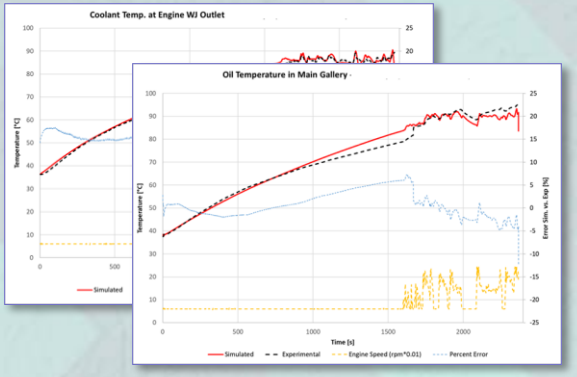
outcomes

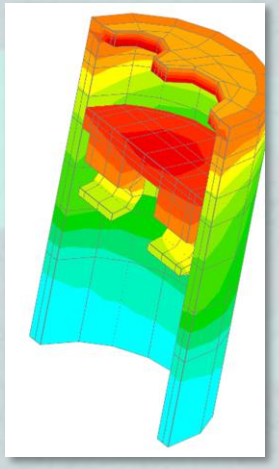
- **Definition and validation** of different components and architectures
- **Definition of calibration and control strategies** minimizing experimental activities

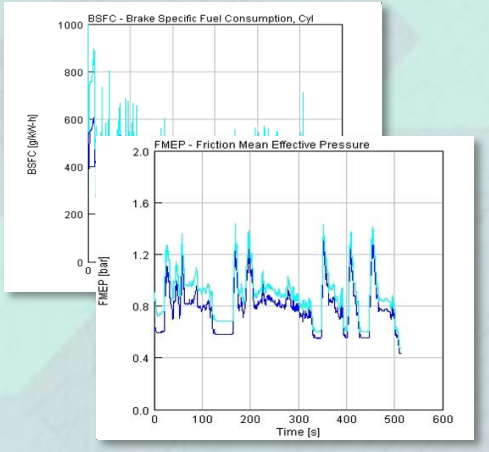
ICE Thermal Management

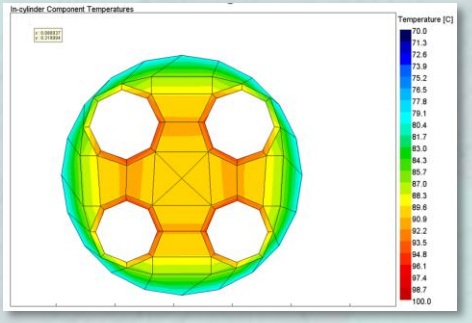
- **TEMPERATURE, PRESSURE and FLOW DISTRIBUTION PREDICTION for lubricant and coolant** over driving cycles and test cases
- **METAL TEMPERATURE PREDICTION** over test cases for hardware protection
- **THERMAL CALIBRATION STRATEGIES** impact on fuel economy

typical outputs







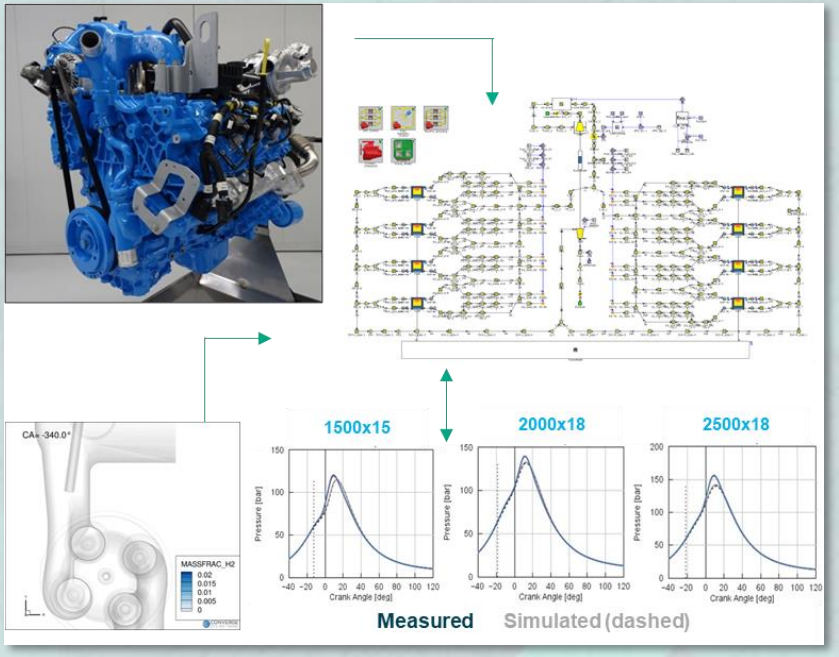


ICE Combustion: H2 PFI in GT-SUITE

GAMMA TECHNOLOGIES

- SITurb combustion, NOx and knock model
- Gas exchange / fuel injection: for in-cylinder trapped air-fuel ratio (lambda) and backfire combustion anomalies (due to the high H2 reactivity)
- The SITurb model is calibrated in steady state conditions, using dyno data and/or CFD-3D data, to best match the basic combustion properties

key features

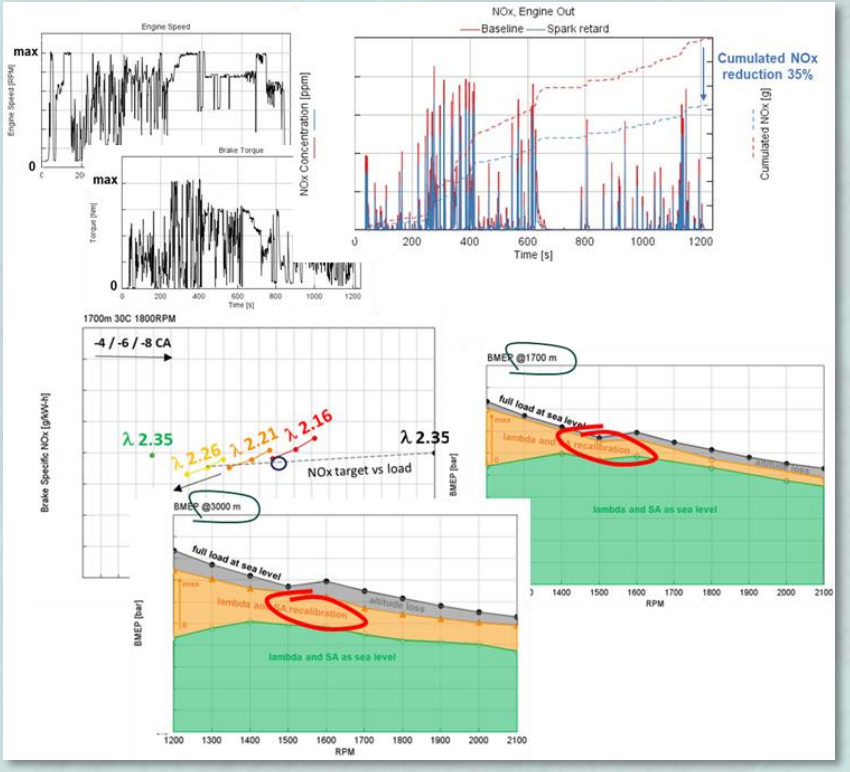


ICE Combustion: H2 PFI in GT-SUITE

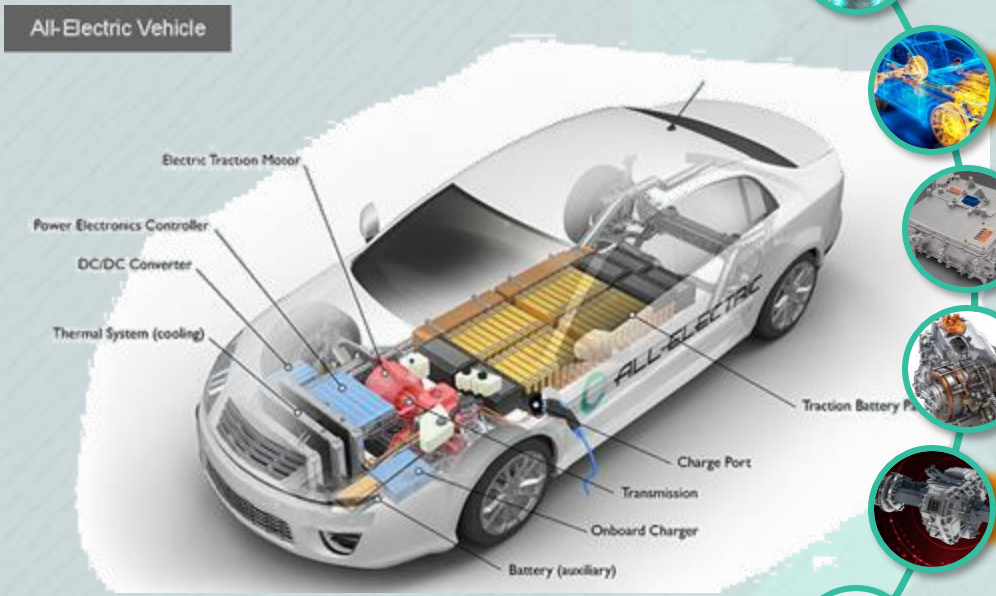
A comprehensive GT-SUITE model is heavily used:

- for **hardware development and optimization**:
  - Turbocharger
  - Intake manifold and injection straws
- **as plant model in MiL** for control development
- **to reduce dyno usage** when defining calibration boundaries and strategies
- **to generate combustion calibration compensation** for extreme ambient (temperature, pressure) conditions

outcomes



Holistic approach to BEVs



Vehicle Performance Modeling

Thermal Management Modeling and Optimization

Power Electronics Modeling

E-motor Modeling

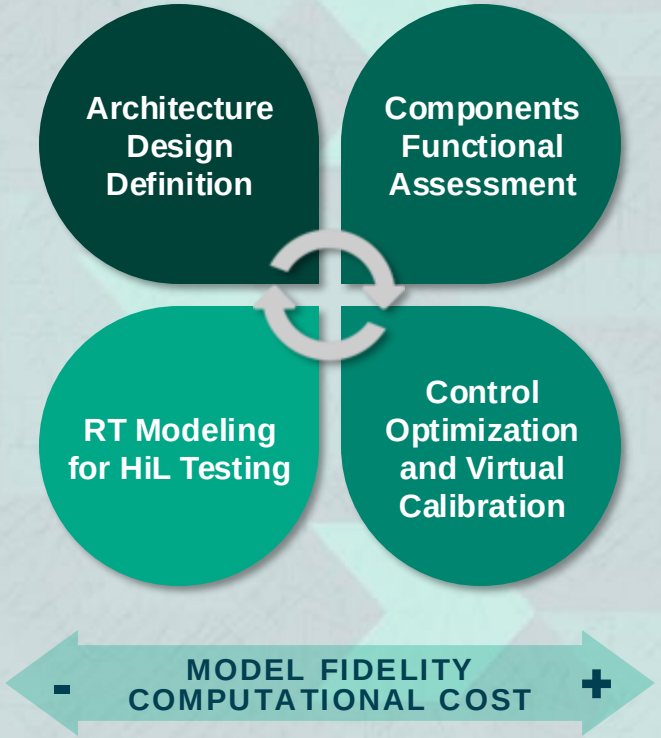
Full E-axle Modeling and Integration

Powertrain Integration in Platform

BEV: Thermal Management Modeling and Optimization

- **Subsystems integration**
  - Battery cooling loop
  - Power Electronics cooling loop
  - HVAC
  - Thermal Mass
  - Propulsion models (e-motor, battery)
  - Vehicle
- **Interaction between the different cooling loops**
  - all subsystems and components to work in the ideal thermal conditions
  - not overcoming critical temperatures
  - while minimizing energy consumption

main features

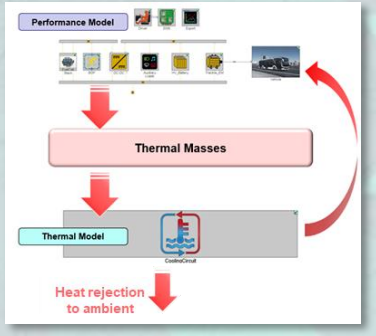


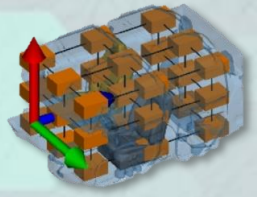
BEV: Thermal Management Modeling and Optimization

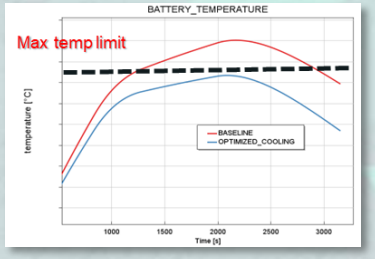
GAMMA TECHNOLOGIES

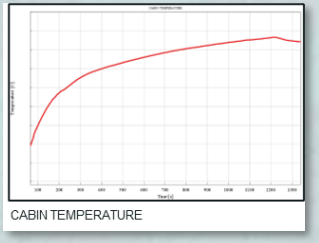
- **Coolant temperature, pressure and flow distribution** prediction over driving cycles and test cases
- **Cabin comfort prediction**
  - transient simulations for cabin temperature warm-up and cool-down
  - HVAC efficiency simulations in different ambient conditions
- **Battery safety and performance**
  - average battery temperature prediction in warm-up cycles, fast charging etc.
  - energy consumption, battery efficiency at different ambient temperature

outcomes

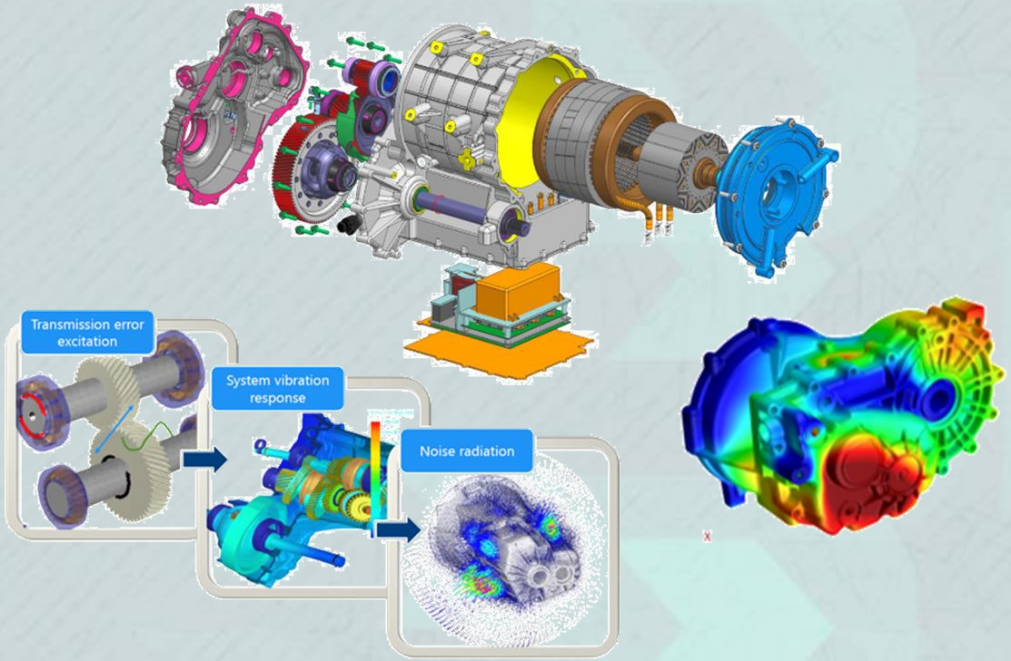







CABIN TEMPERATURE

BEV: E-axle simulation approach



CAPABILITIES

MECHANICAL DYNAMIC PARTS
GEARS, SHAFTS, BEARINGS, DIFFERENTIAL

STRUCTURES
HOUSING & COVERS

LUBE & THERMAL MGMT DEVICES
OIL PUMP, FILTER, COOLER, BAFFLES

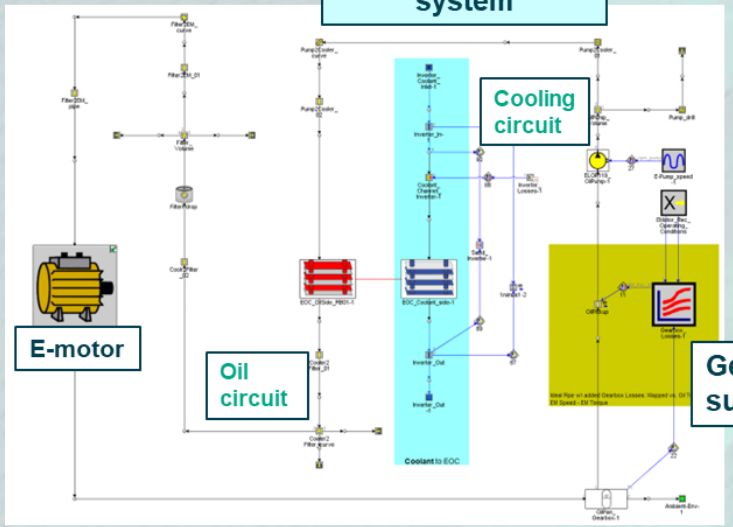
E-MOTOR & INVERTER
SYSTEM LEVEL INTEGRATION

MOUNTING SYSTEM & VEHICLE
TRANSFER PATH

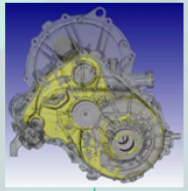
BEV: E-axle system simulation

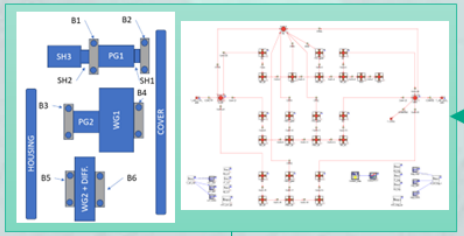
- Complete workflow for e-axle systems study and optimization
- Validated approach thanks to several correlation activities with customers

GAMMA TECHNOLOGIES



3D studies for gearbox lubrication assessment





HTC/wetting input

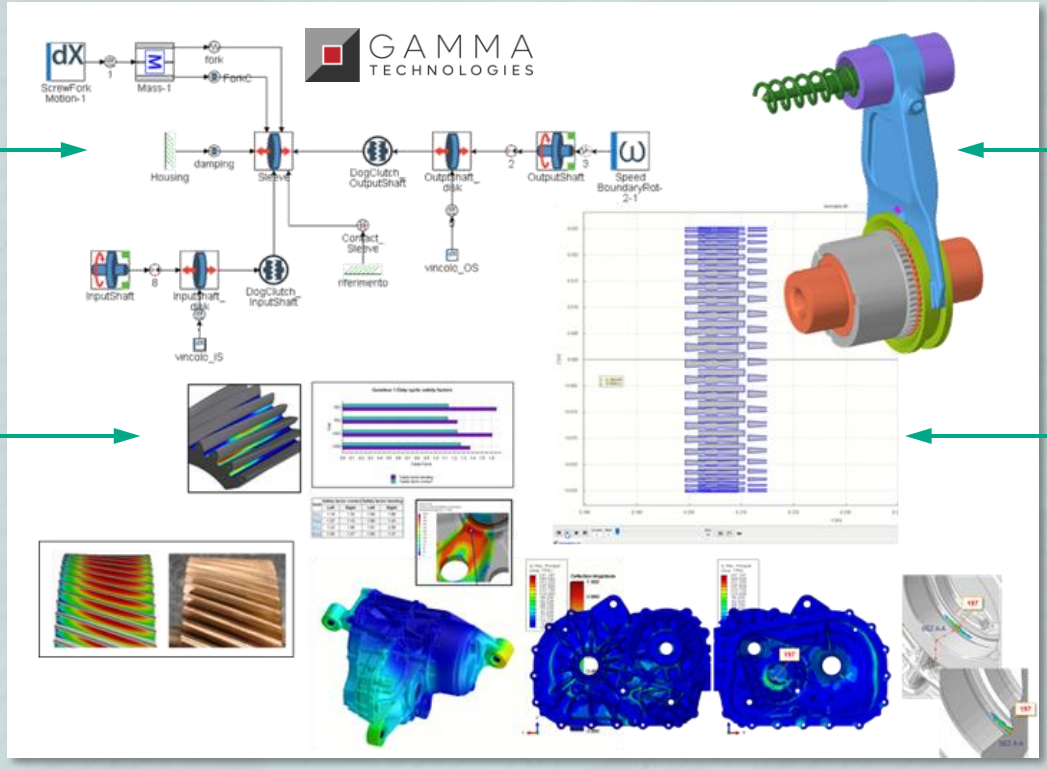
Typical analysis outcome:

- ✓ Oil and coolant temperatures along the circuits
- ✓ Flow distribution data
- ✓ Pumps performance
- ✓ Critical components temperature

BEV: E-axle mechanical and structural simulation

1D MECHANICAL SYSTEM SIMULATION

MULTIBODY SIMULATION



LINEAR and NON-LINEAR STATIC SIMULATION

DYNAMIC and NVH SIMULATION

Final Remarks

- Companies must **QUICKLY ADAPT** to uphold their competitiveness in R&D across dimensions such as time to market, cost, quality and new features roll-out

- Increasing technical challenges and complexity require **ROBUST INNOVATION**, entailing a transition in product development capabilities, processes and operational frameworks **from TRADITIONAL PHYSICAL ENGINEERING to VIRTUAL ENGINEERING**

- **DATA** will assume a crucial role in this context

- Advanced simulation techniques will increasingly leverage **AI-ML METHODOLOGIES**

- Implementing **DATA INFRASTRUCTURE and ARCHITECTURE** emerges as a fundamental necessity for propelling data-enabled engineering and virtualization forward

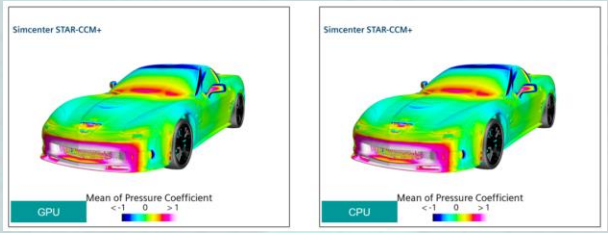
Change is inevitable, but Transformation is by conscious choice

DUMAREY VIRTUAL ENGINEERING stands at the forefront of this transformative journey

Attachments

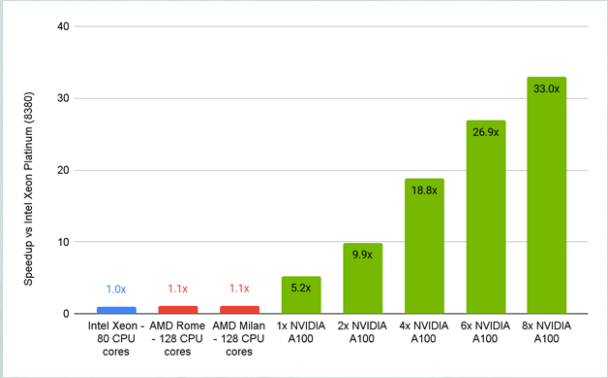
GPU vs. CPU

- Consistent results
- Faster simulations thanks to parallel processing



The **adoption** of GPU computing in Virtual Engineering applications is growing (SPH, AI-ML)

The **roadmap** for future years of GPU computing is promising, with **continued innovation** and **improvements in performance and efficiency**



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