

# Use of GT-SUITE at Safran Tech for the study of **zero emissions** Aircrafts and propulsion systems

Alain LEFEBVRE  
Multiphysics systems expert  
GT-SUITE user conference  
Saclay - France  
June, 13 2024



# Agenda

---

**01**

Safran group

**02**

Safran Tech

**03**

Aeronautics CO<sub>2</sub> objectives

**04**

POC GT-SUITE

**05**

Multiphysic system approach

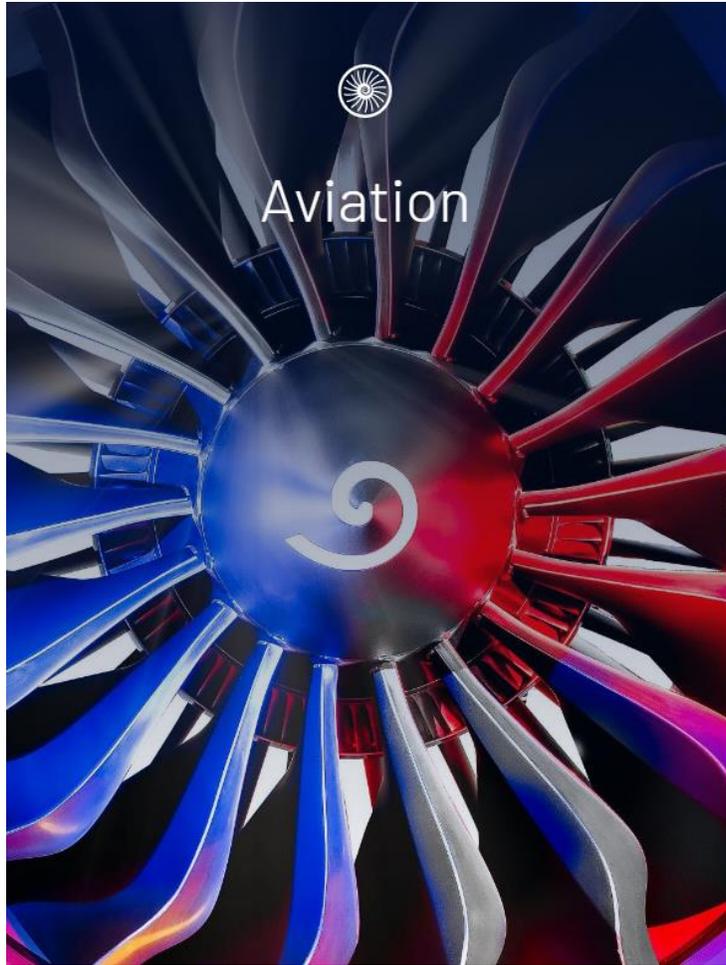
**06**

Use cases

**07**

Conclusions and perspectives

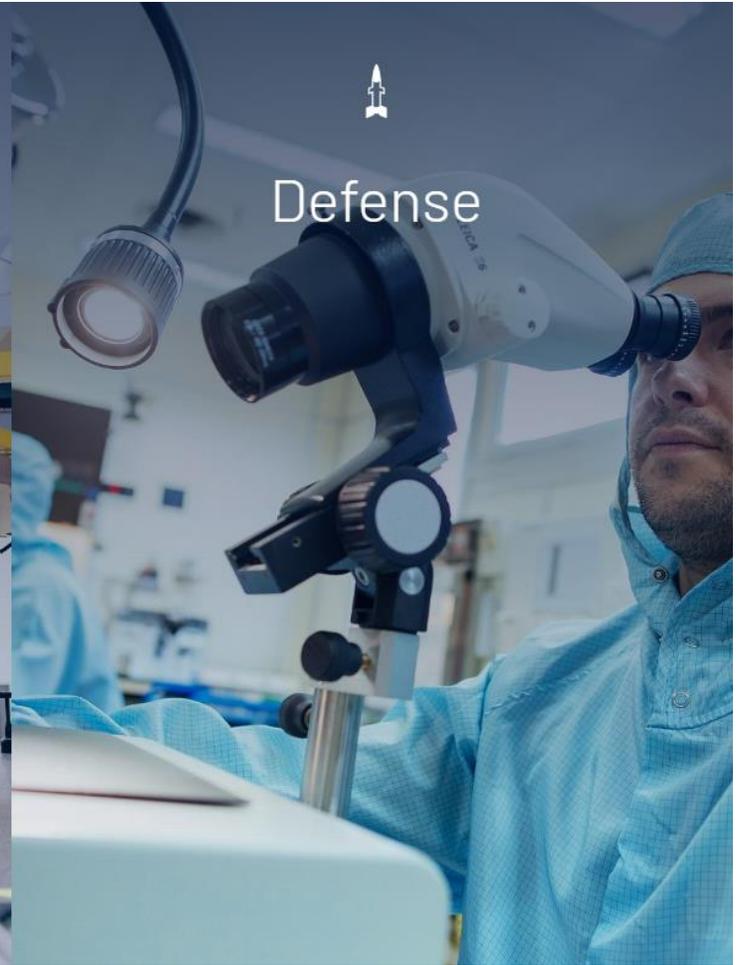
# Aviation ... but also space and defense



Aviation



Space



Defense



Activités de services  
et maintenance



Activités commerciales  
et administratives



Activités de R&D  
et de production

# Safran in France

More than  
**41 000**  
employees

More than  
**120**  
Years of presence in  
France

**75** sites



Safran Data Systems  
Safran Aircraft Engines  
Safran Engineering Services  
Safran Nacelles  
Safran Aerosystems  
Normandie



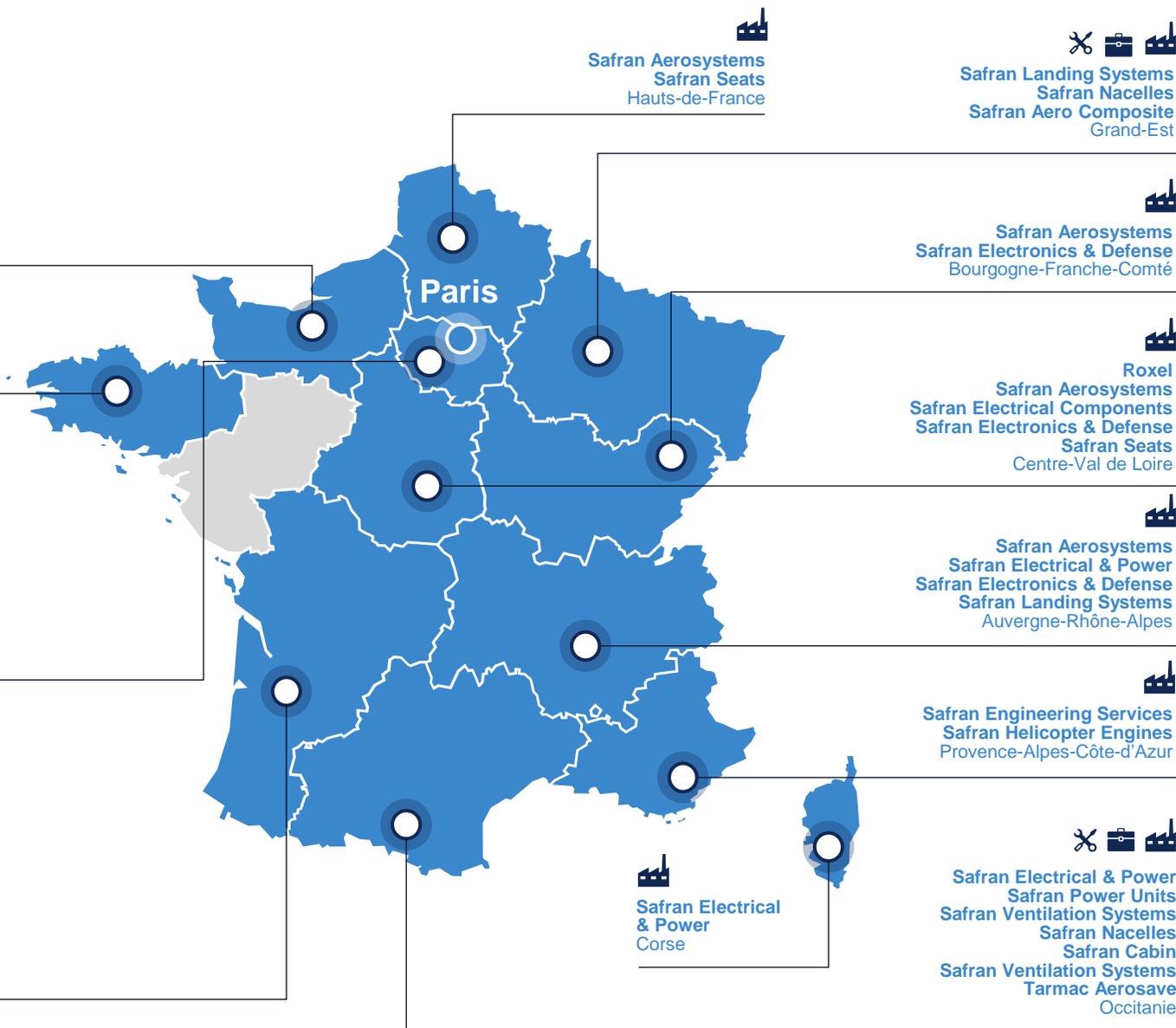
Safran Landing Systems  
Safran Electronics & Defense  
Bretagne



Safran Composites  
Safran Nacelles  
Safran  
Roxel  
Safran Electronics & Defense  
Safran Reosc  
Safran Seats  
Safran Transmission Systems  
**Safran Tech**  
Safran Landing Systems  
Safran Aircraft Engines  
Ile-de-France



Safran Aircraft Engines  
Famat  
Roxel  
Safran Aerosystems  
Safran Ceramics  
Safran Data Systems  
Safran Electrical & Power  
Safran Electronics & Defense  
Safran Filtration Systems  
Safran Helicopter Engines  
Safran Landing Systems  
Safran Engineering Services  
Nouvelle-Aquitaine



Activités de services  
et maintenance



Activités commerciales  
et administratives



Activités de R&D  
et de production

# Safran in the world



 Activités de services et maintenance

 Activités commerciales et administratives

 Activités de R&D et de production

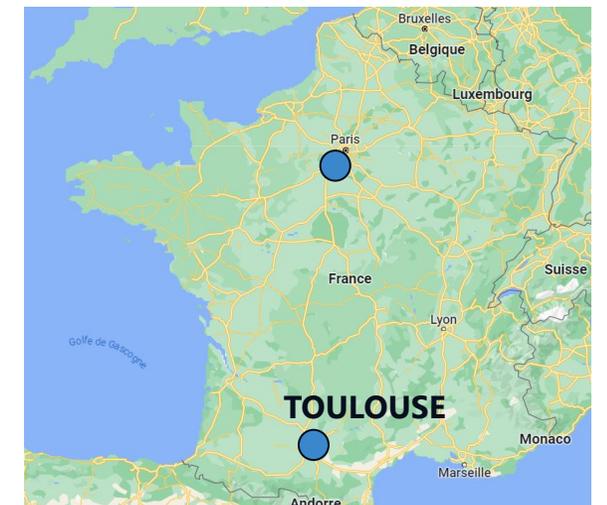
# Safran Tech

# Safran Tech : Research and Technology



Launched in January 2015, **the Group's Research & Technology Center Safran Tech** has been pooling expertise and fostering the development of new technology. This research center, dedicated exclusively to Safran, ensures the future competitiveness of the Group, which operates in a number of high-tech fields.

**CARBON NEUTRALITY  
FOR 2050**



Safran Tech

# Safran Tech

## SAFRAN TECH IN FIGURES

**1/4**

OF THE GROUP'S R&T ACTIVITIES

**20**

NATIONALITIES REPRESENTED AT SAFRAN TECH

**500**

EMPLOYEES

**100**

EXPERTS

**300**

INVENTION DECLARATIONS / YEAR

**Welcome to Safran Tech**

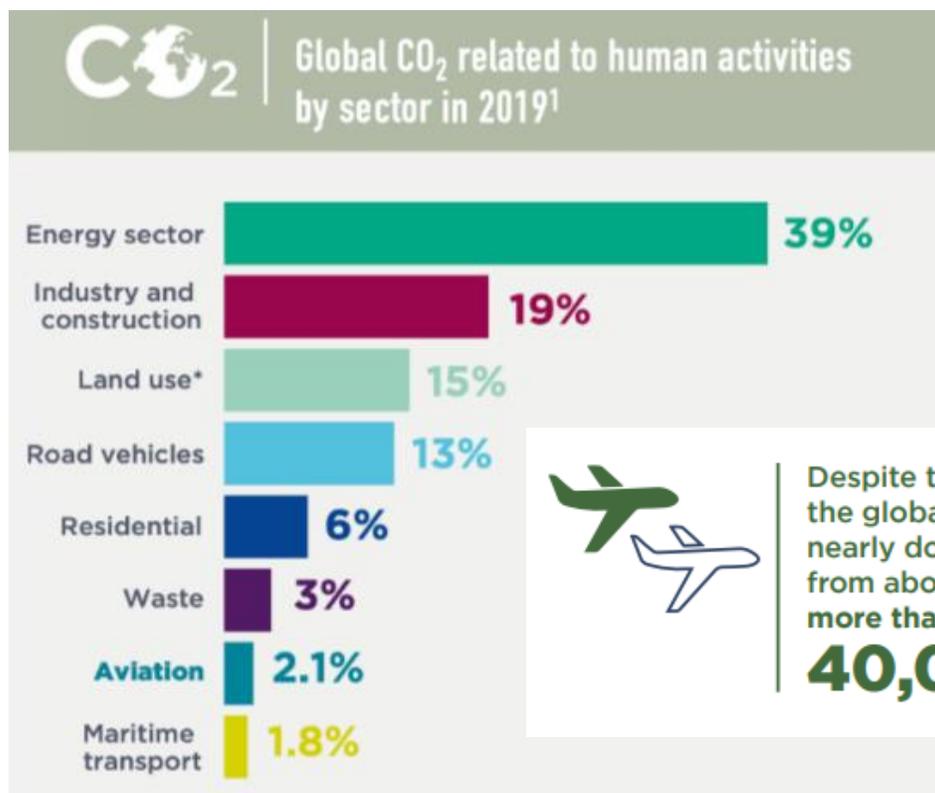
Safran Tech



# Objectives for aeronautics

# Aeronautics and CO<sub>2</sub>

## Decarbonizing aeronautics



Despite the impact of Covid-19, the global civil aircraft fleet should nearly double by 2040, growing from about 23,000 today to more than **40,000** in 2040.

# -30%

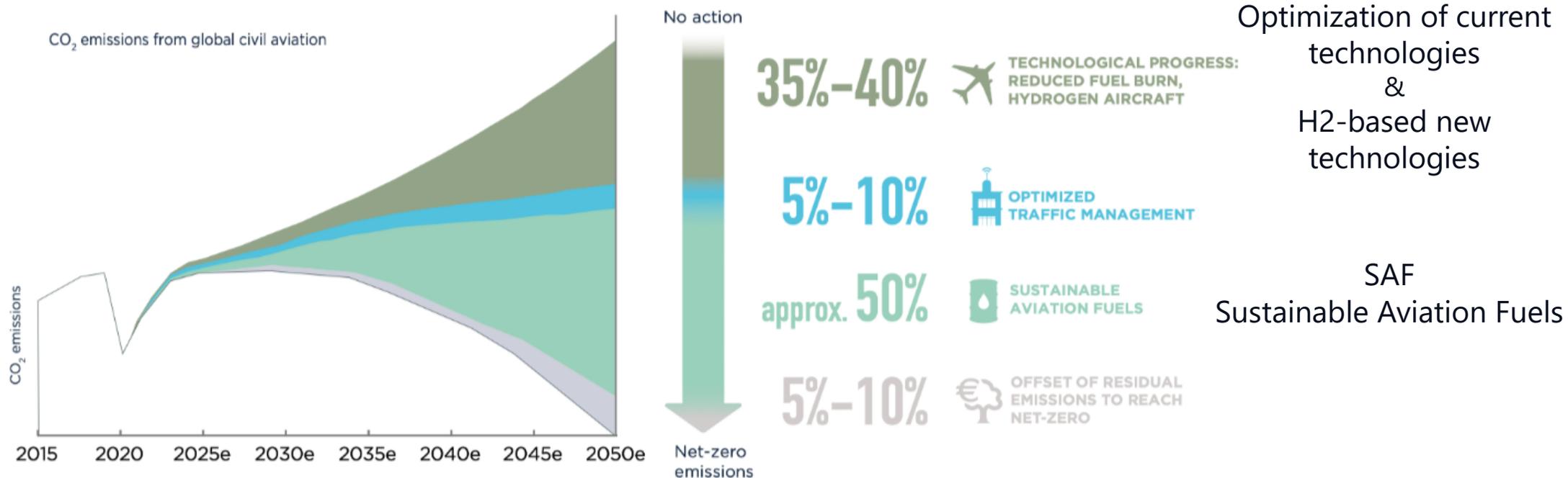
IN GREENHOUSE GAS EMISSIONS BY 2025, -50% BY 2030 vs 2018

2050 : aircraft's decarbonization reduce by **50 %** the carbon emissions in air transportation in 2050 vs 2005

## Aeronautics and CO<sub>2</sub>

# Aeronautics and CO<sub>2</sub>

## AN AMBITIOUS COMMITMENT TO REACH NET-ZERO CARBON EMISSIONS BY 2050



## Aeronautics and CO<sub>2</sub>

# Aeronautics and CO<sub>2</sub>



Towards "low-carbon" aircraft



Supporting the introduction of sustainable fuels



Developing electric propulsion and hybrid aircraft



Safran is strongly involved in decarbonization

# POC GT-SUITE at Safran Tech

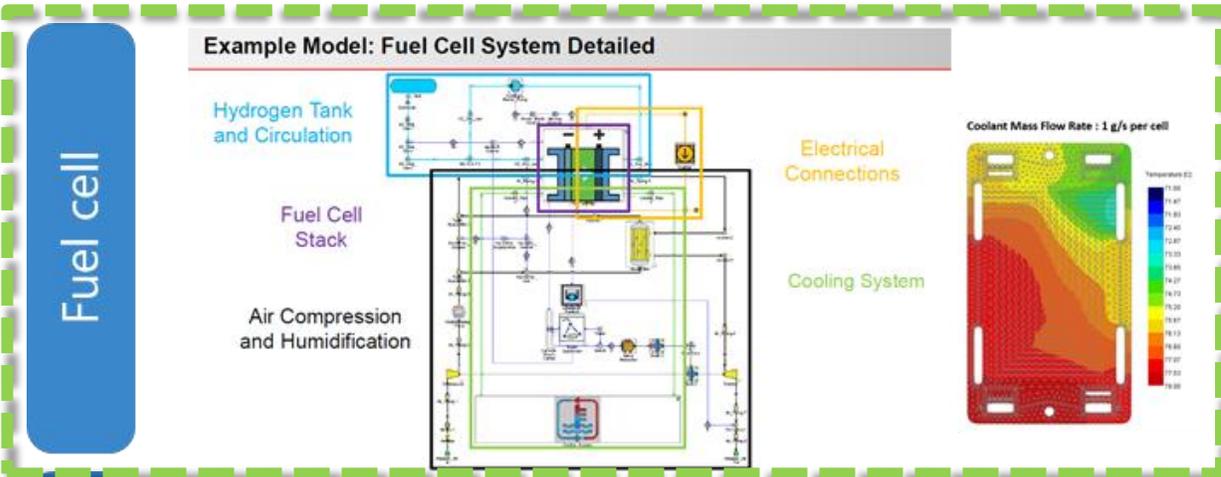
# Hydrogen modelling

- In June 2023, Safran Tech started a Proof of Concept to test GT-SUITE
- **Hydrogen mobility** chosen for the study
  - Hydrogen as a combustion fuel
  - Hydrogen as a fuel for **fuel cell**

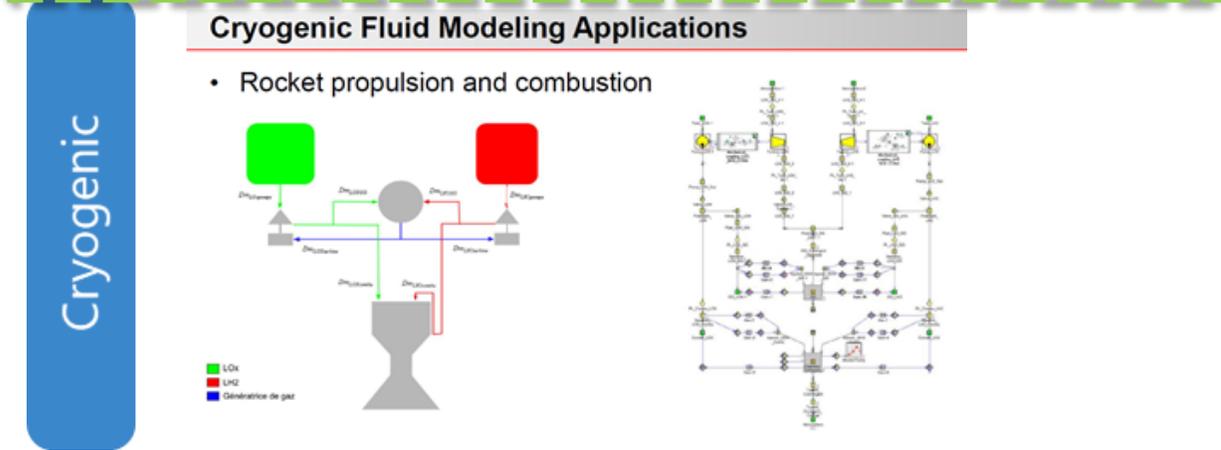


## Hydrogen modelling

# POC GT-SUITE



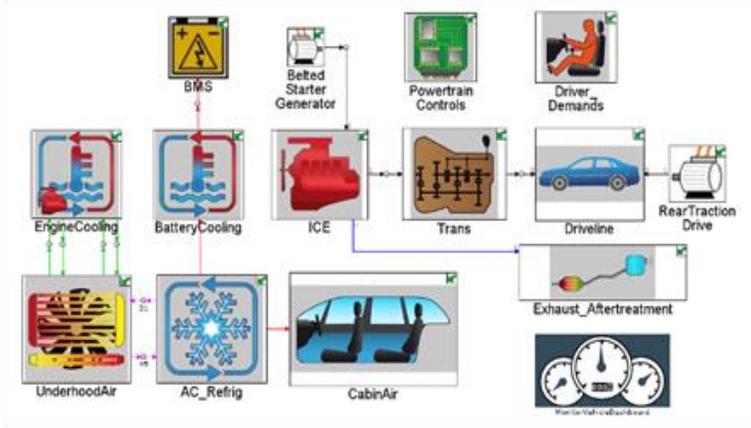
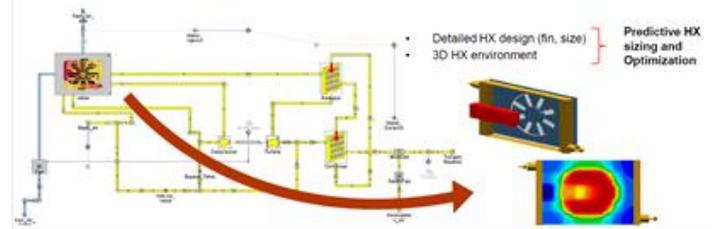
Heat exchangers



Advanced cooling

**Solutions for ECS – Heat Exchangers Requirements**

- Size Heat Exchangers
  - Different Levels of fidelity for Heat Exchanger modeling

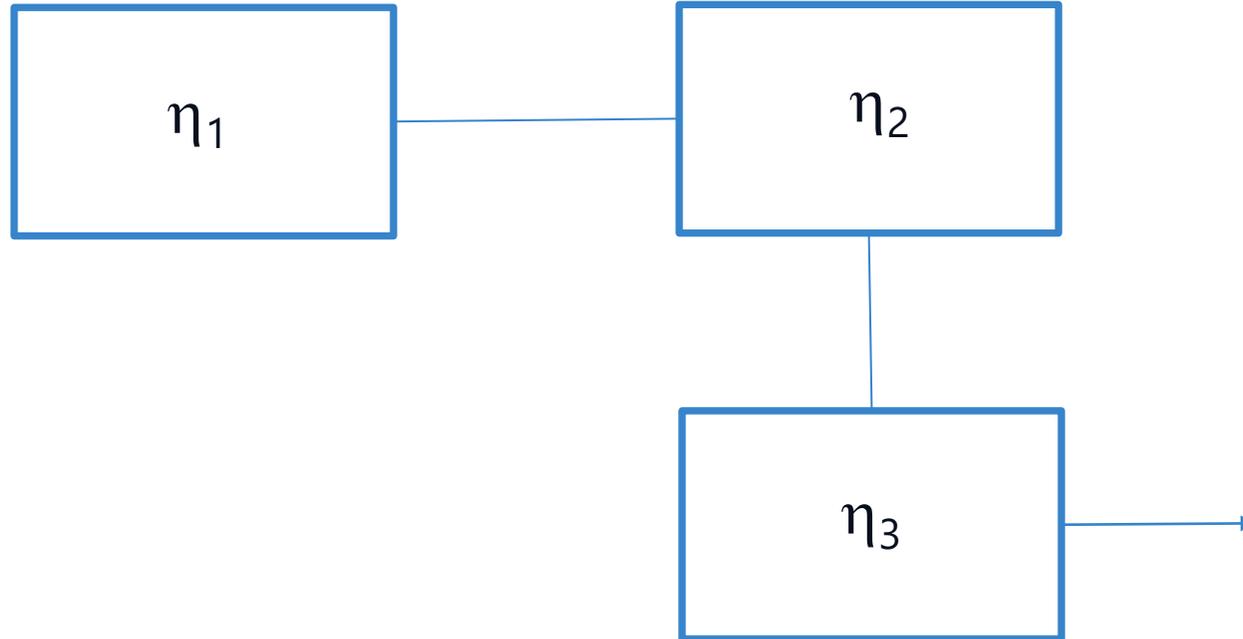


# POC GT-SUITE



# A multiphysic system approach

# System modeling

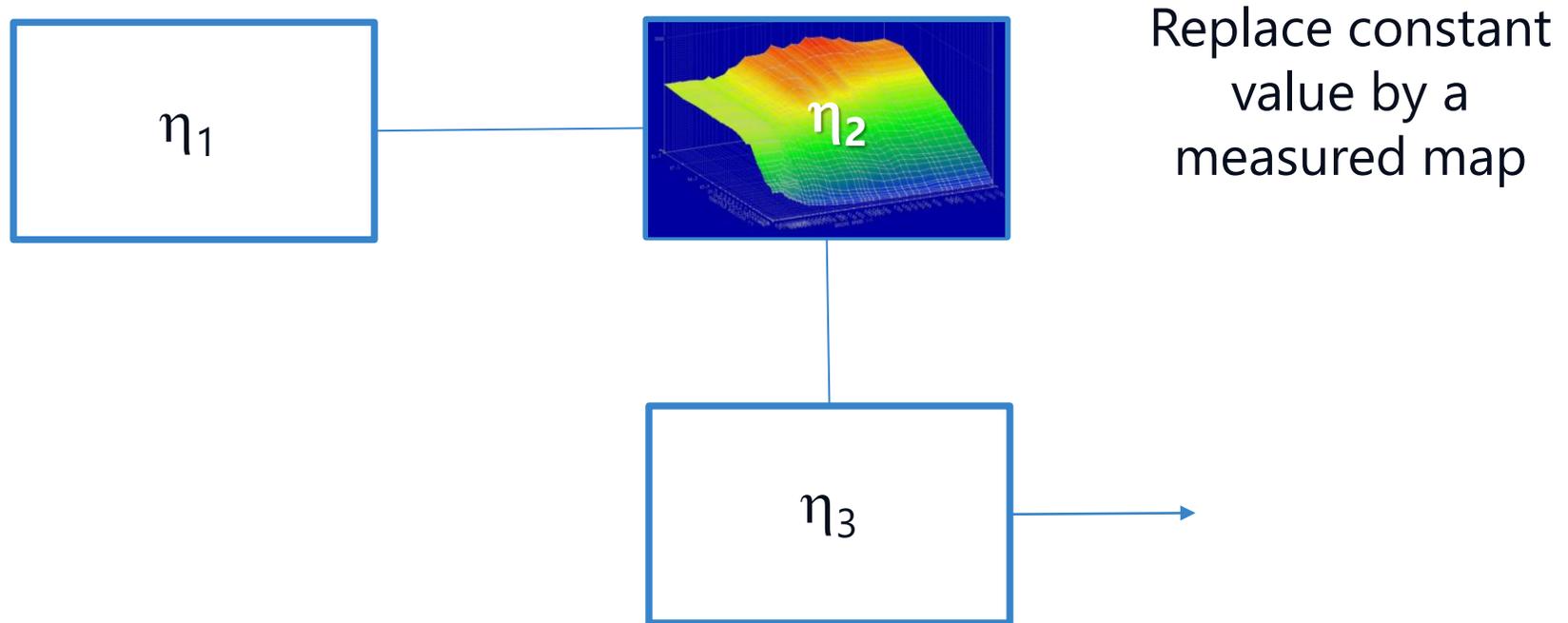


Values  
=  
constants

Example :  
efficiencies

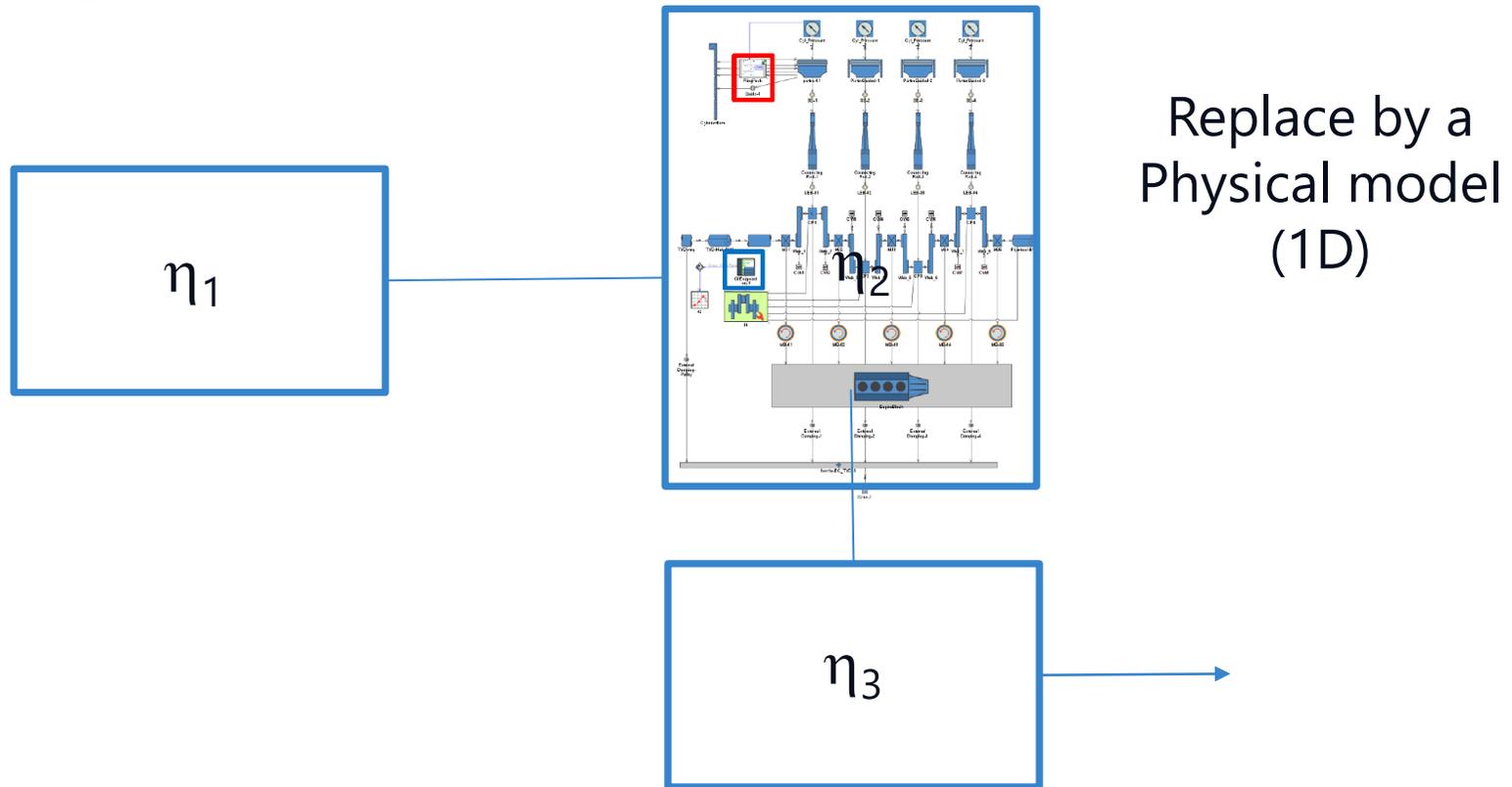
Start of an innovation project – architecture studies : 0D, Python

# System simulation



**Start of an innovation project – previous studies, supplier data, tests**

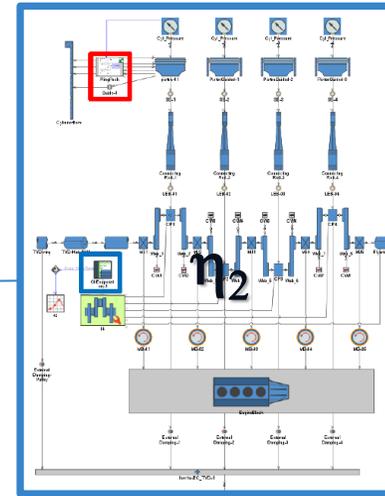
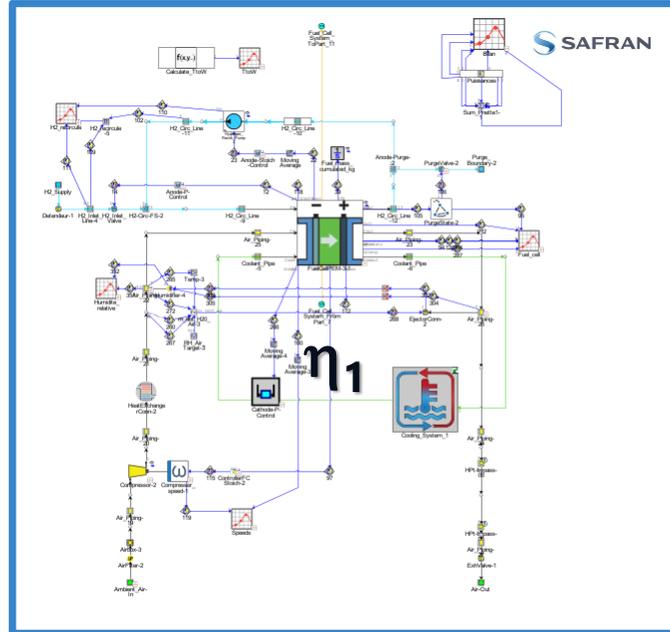
# Use of detailed physical models



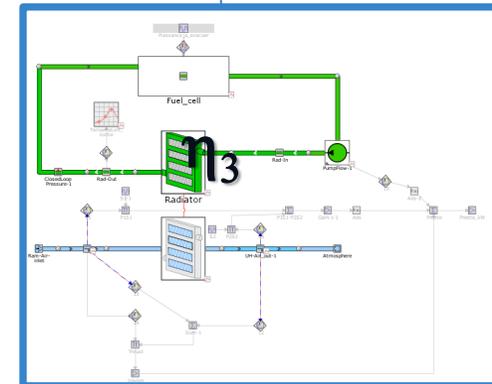
Issue : increased in the CPU time

Use of detailed physical models

# Use of detailed physical models



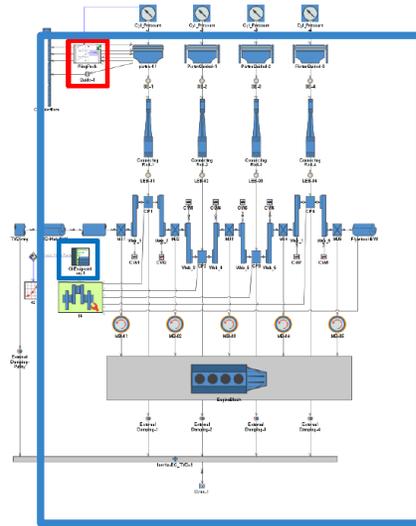
« Full Model »  
physique



Problème : augmentation des temps calcul

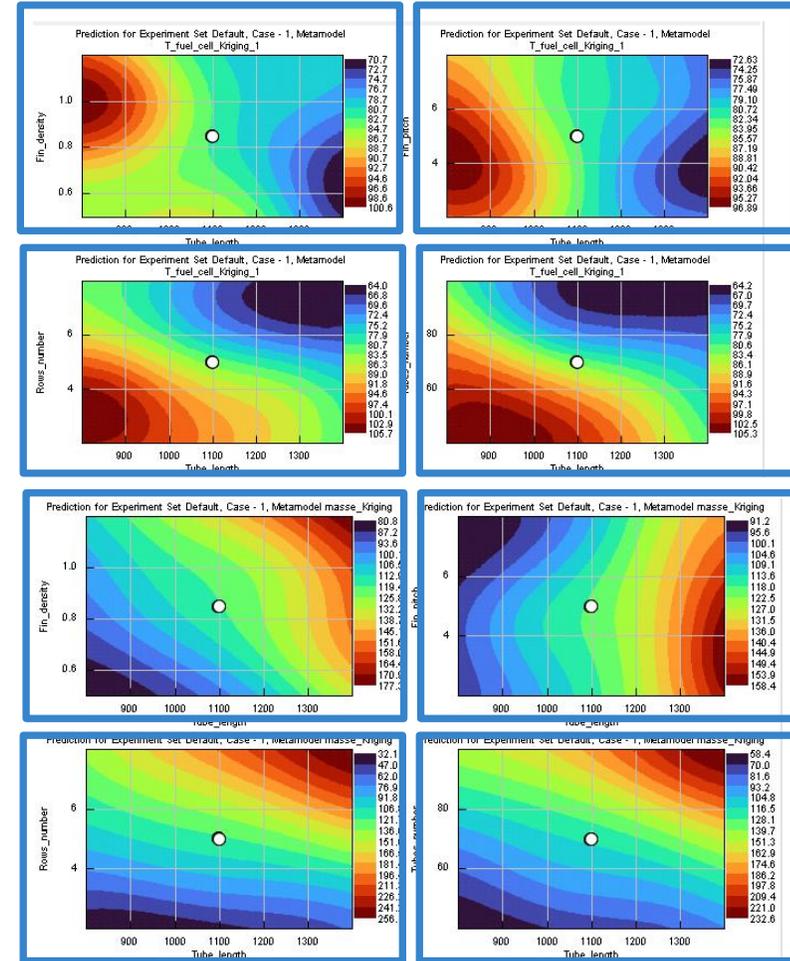
Use of detailed physical models

# Use of detailed physical models



DOE

Variables  
(input)

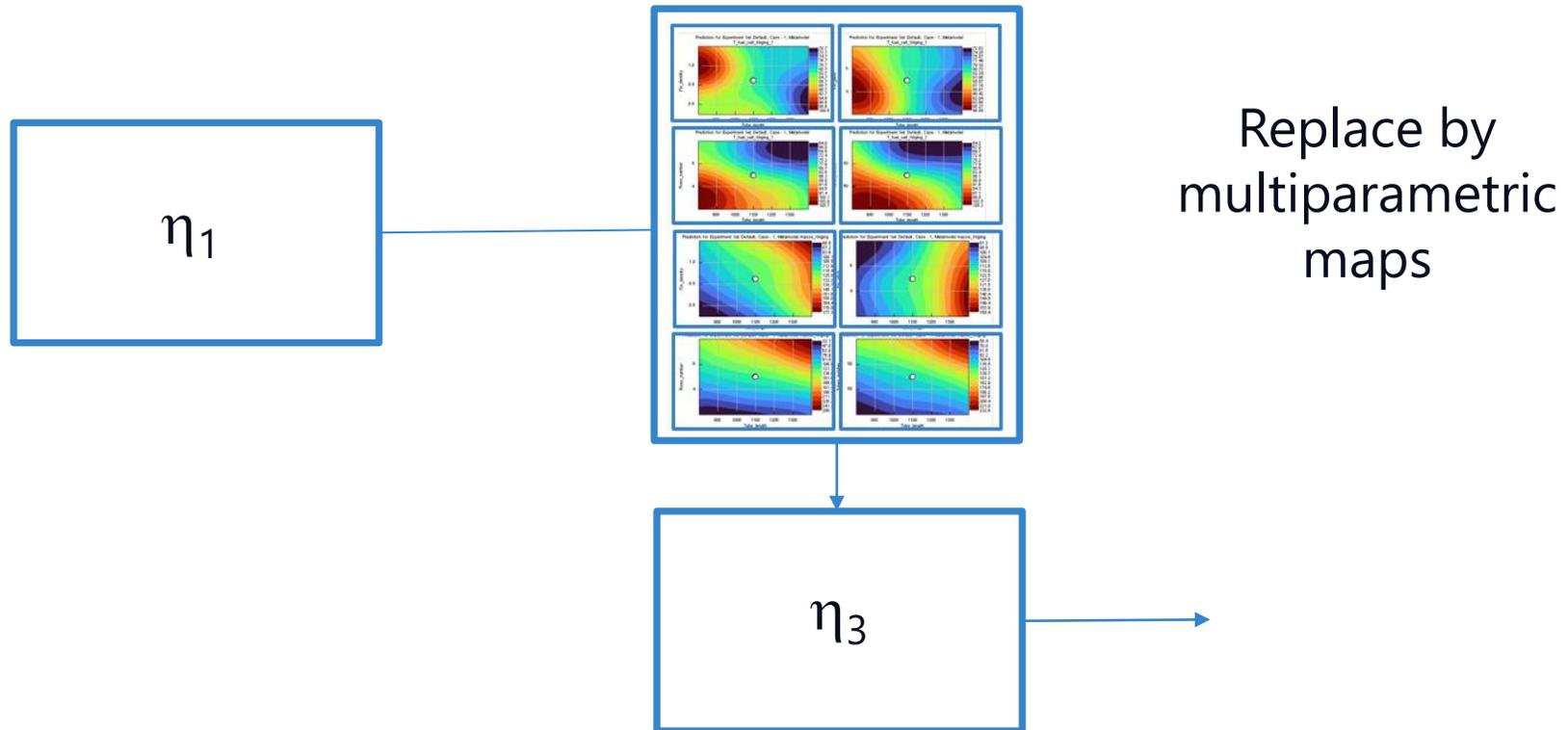


Responses  
(output)

Solution : use of a reduced model : multi-parameters maps

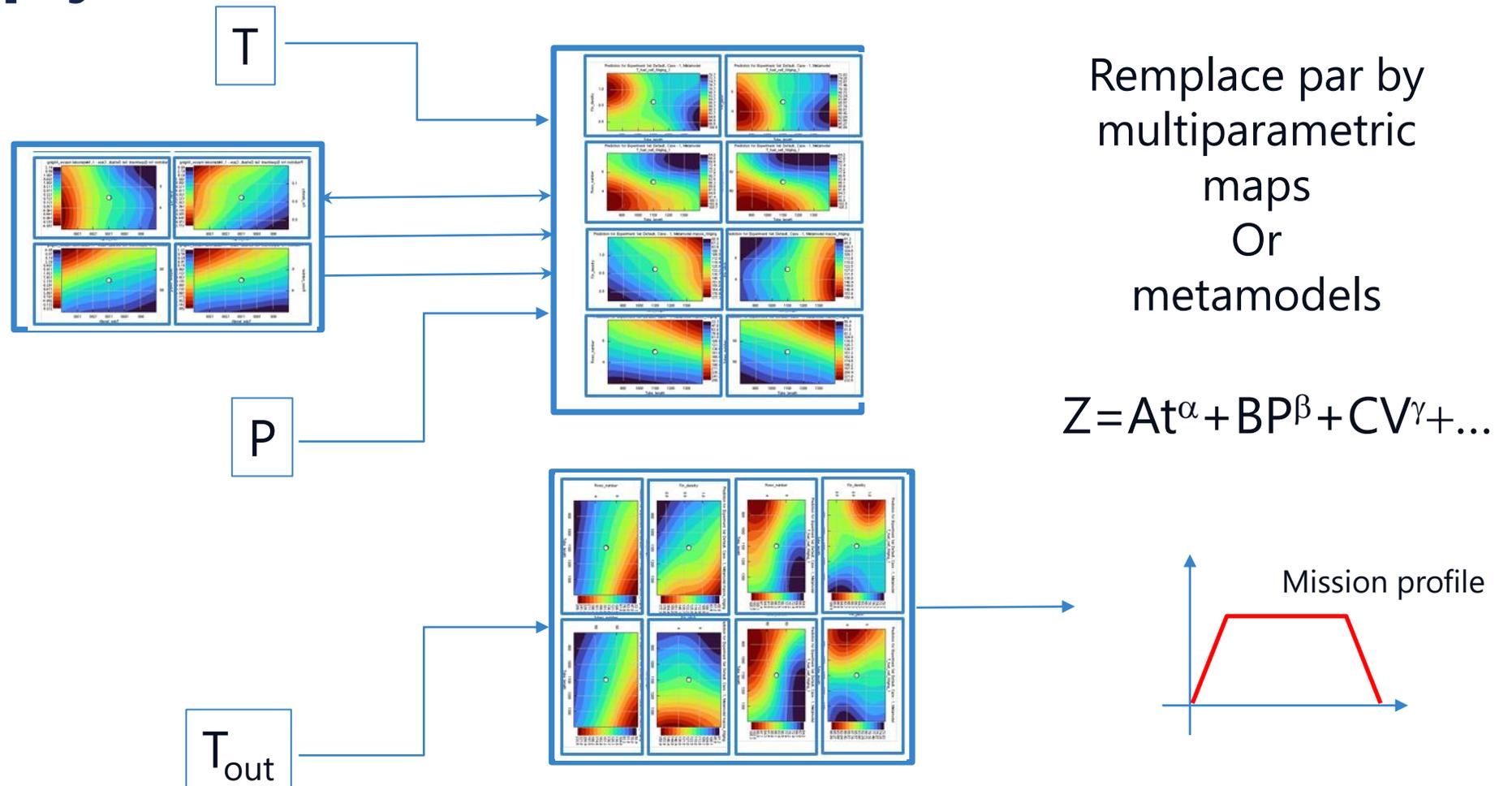
Use of detailed physical models → reduced models

# Use of detailed physical models



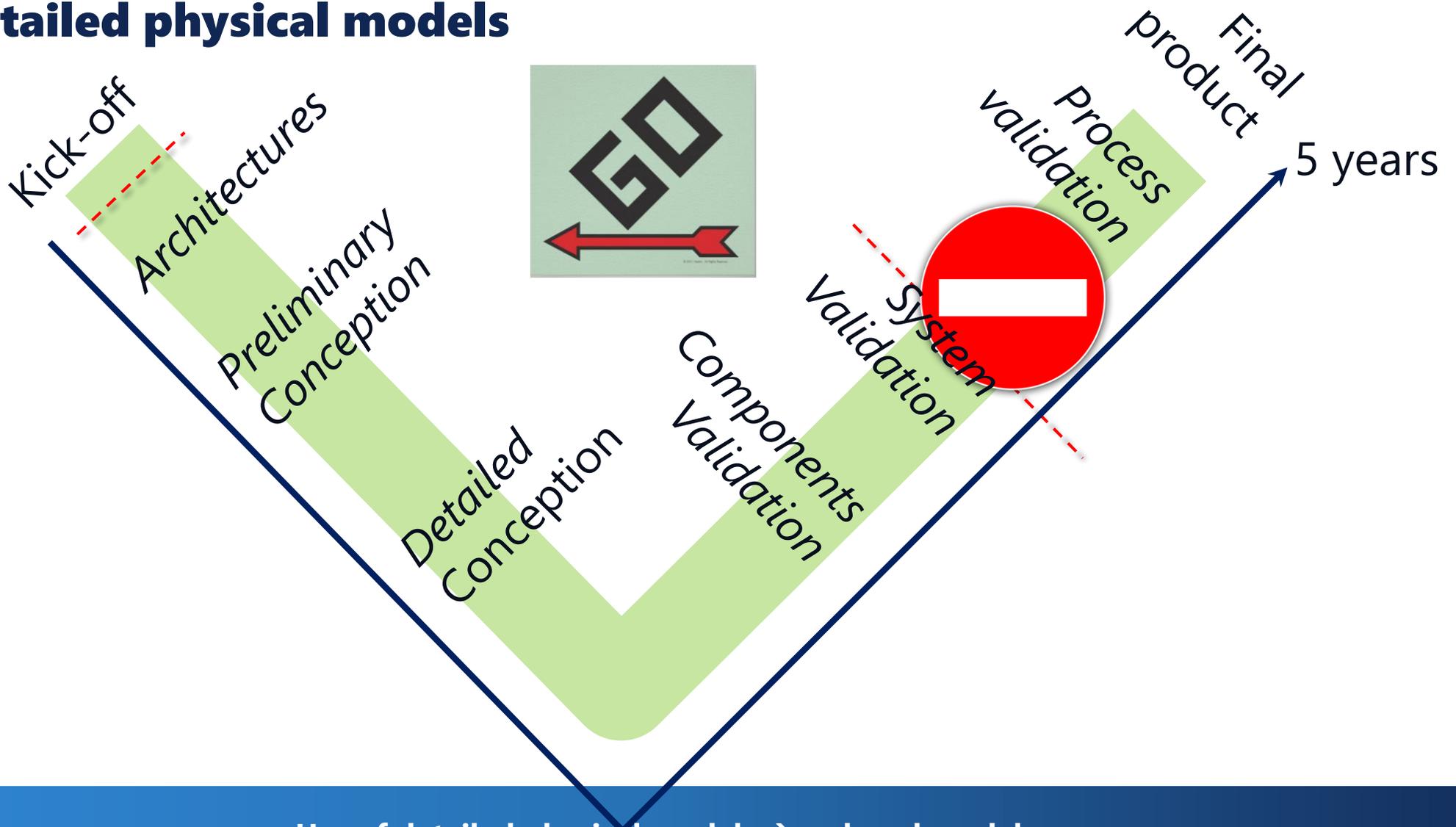
Use of detailed physical models → reduced models

# Use of detailed physical models



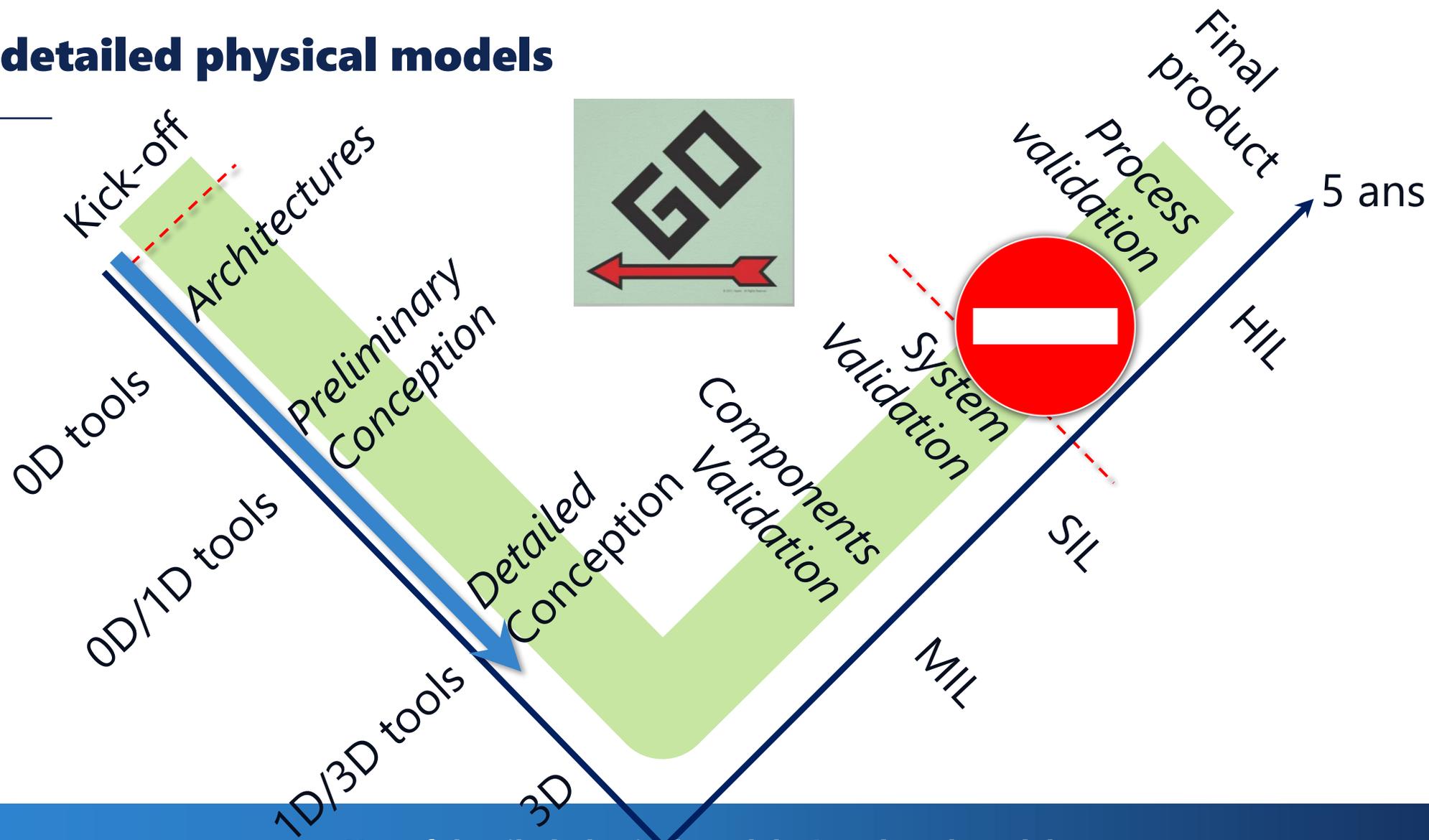
Use of detailed physical models → reduced models

# Use of detailed physical models



Use of detailed physical models → reduced models

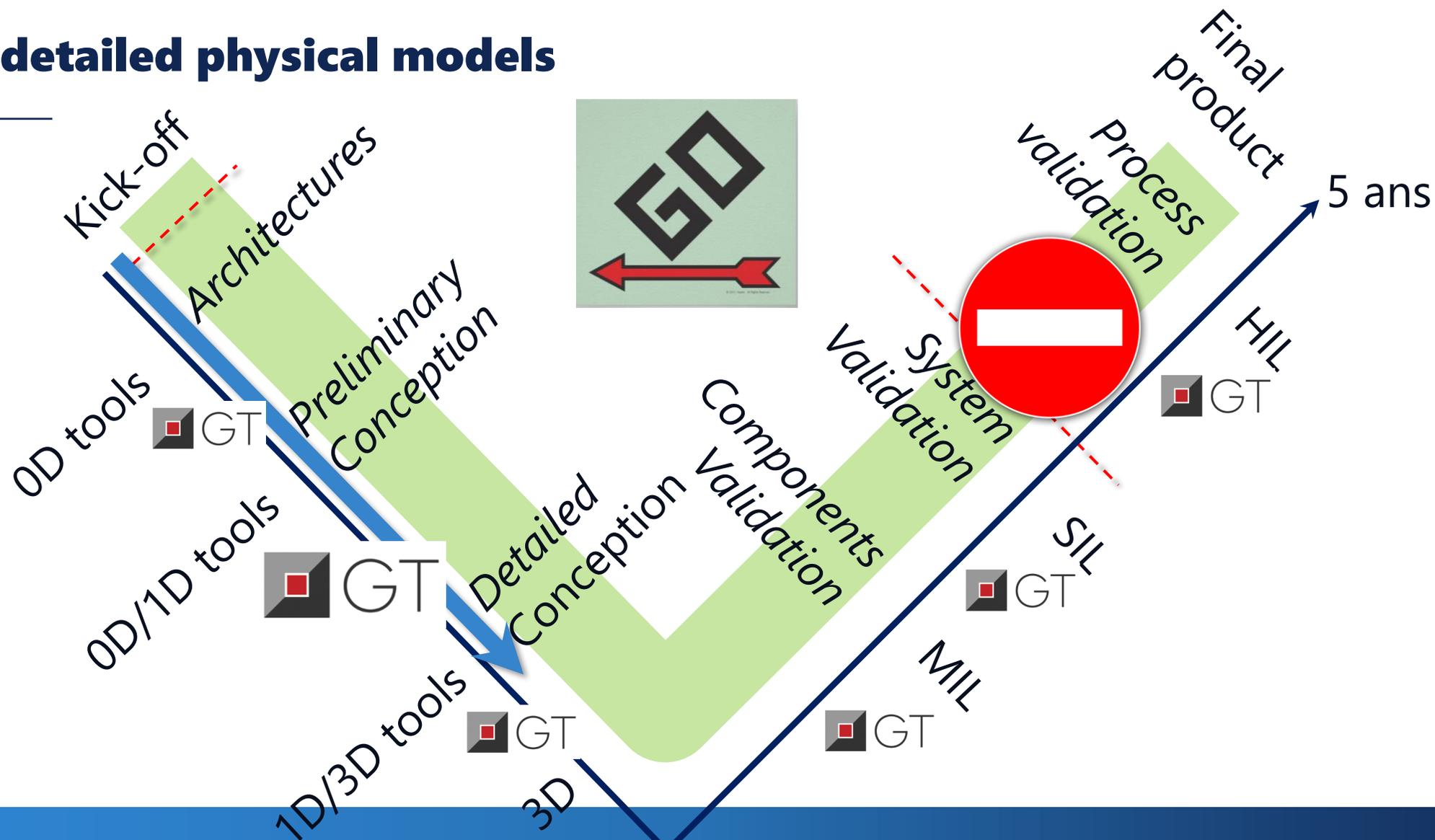
# Use of detailed physical models



**Use of detailed physical models → reduced models**

Department / Company / Date (menu "Insert / Header and footer" – "Insertion / En-tête et pied de page")

# Use of detailed physical models



Use of detailed physical models → reduced models

Department / Company / Date (menu "Insert / Header and footer" – "Insertion / En-tête et pied de page")

# Use case example

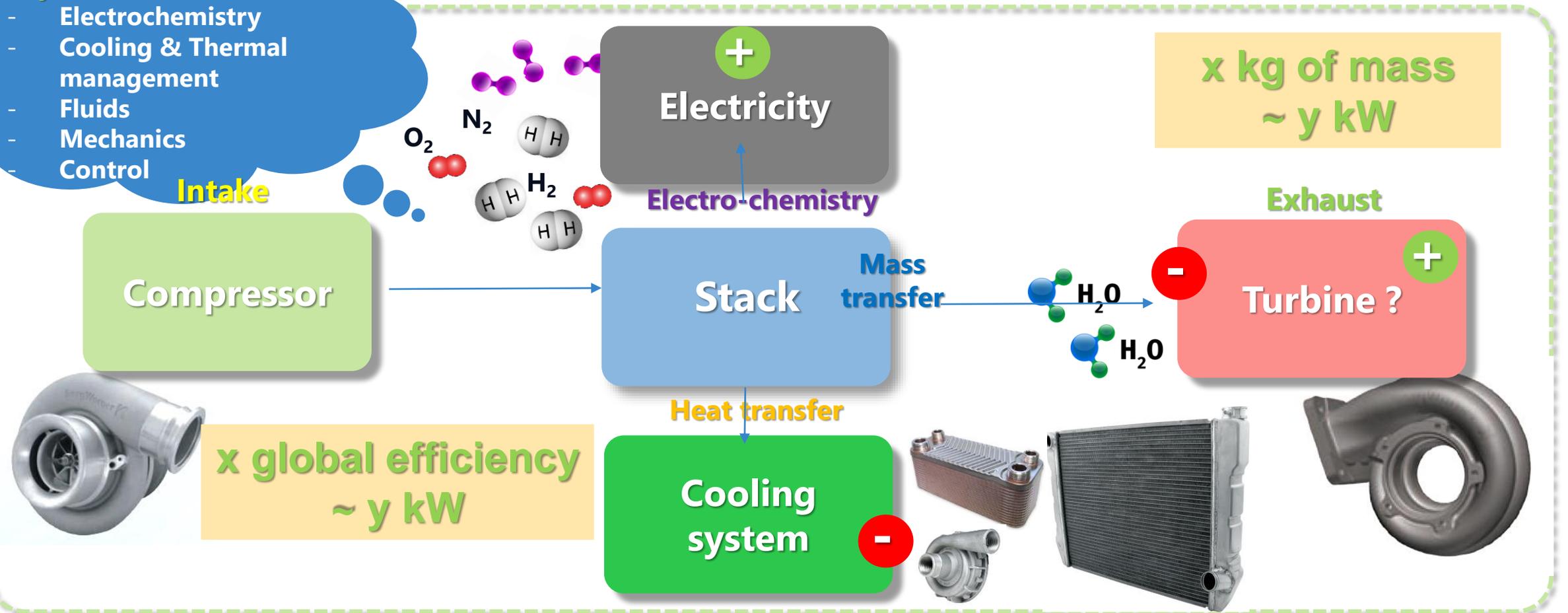
# Fuel cell modeling

# Detailed physical models – fuel cell

## Physics involved :

- Electrochemistry
- Cooling & Thermal management
- Fluids
- Mechanics
- Control

Intake



Use example : fuel cell

# Detailed physical models using

The more a large number of use cases have been simulated upstream (simulation in the top-down phase of the "V") the lower the risk of **non-functioning** later (validation phase)

The more physical the models, the more problems can be analysed

The earlier predictive models are used, the **better the architecture choices**

The earlier the physical models are used, the better the **control quality** will be



↓ Tests

↓ Risks

↓ Risks



↑ System performances

↓ Tests

↓ Risks



**Use of detailed physical models → less time and cost**

## Detailed physical models – objectives



Too large error → bad choice

Objective : < 10% max (and if possible 5%)

- Predict efficiencies +/ -2 points
- Predict masses +/ - 1 kg
- Predict global energy balance of the systeme by +/ -5%
- Check functioning
  - Steady conditions
  - Transient conditions



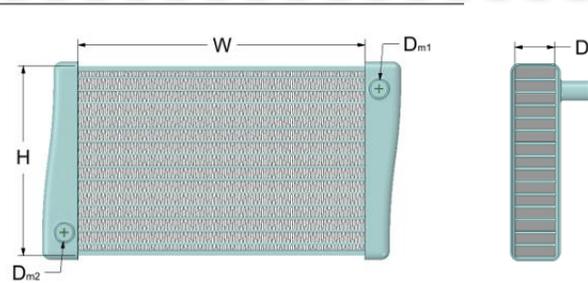
**Interest of a 1D/3D GT-SUITE approach**

# Components modelling

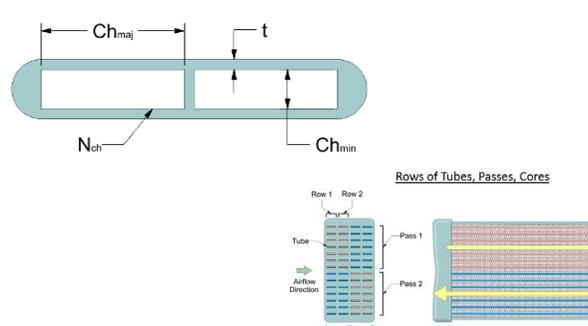
# Heat exchangers

## Tube-fin type

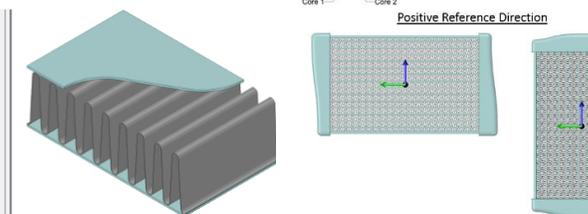
Attribute	Unit	Object Value
Tube Flow Orientation		Horizontal
Heat Exchanger Height (H)	mm	...
Heat Exchanger Width (W)	mm	...
Total Heat Exchanger Depth (D)	mm	...
Inlet Connection Diameter (Dm1)	mm	...
Outlet Connection Diameter (Dm2)	mm	...
Dry Mass of Tube and Fin Material	kg	...
Tube and Fin Material Properties Object		...
<input type="checkbox"/> Model Conduction Through Wall		



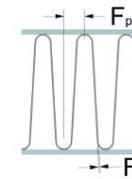
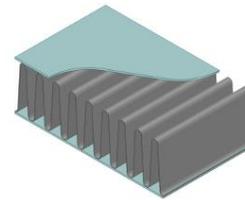
Attribute	Unit	Object Value
<b>Tube Shape</b>		
<input checked="" type="radio"/> Flat Tube		
<input type="radio"/> Circular Tube		
<b>Geometry of Single Channel</b>		
<input checked="" type="radio"/> Flat Channel Major Dimension (Chmaj)	mm	...
<input checked="" type="radio"/> Flat Channel Minor Dimension (Chmin)	mm	...
<input type="radio"/> Circular Channel Diameter (Chdia)	mm	...
<input type="radio"/> Custom Channel Cross-Sectional Flow Area	mm <sup>2</sup>	...
<input type="radio"/> Custom Channel Wetted Perimeter	mm	...
Tube Wall Thickness (t)	mm	...
Number of Channels in One Tube (Nch)		1
Reference Length for Reynolds Number	mm	def (=Automatic)
<b>Fin Geometry</b>		
Fin Shape		None



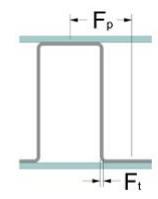
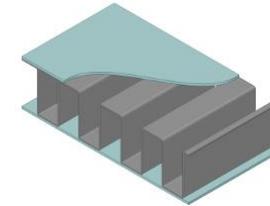
Attribute	Unit	Object Value
<b>Fin Geometry</b>		
Fin Shape		Triangular
<input type="checkbox"/> Louver Geometry		
Reference Length for Reynolds Number	mm	def (=Automatic)
<input checked="" type="radio"/> Fin Pitch (Fp)	mm	...
<input type="radio"/> Fin Density (1/Fp)	1/mm	...
Fin Thickness (Ft)	mm	...



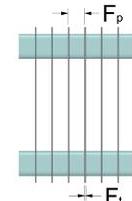
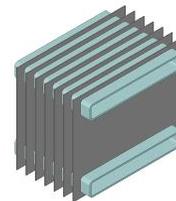
## External fins



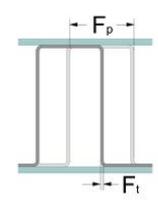
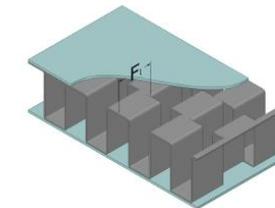
Triangular



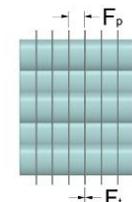
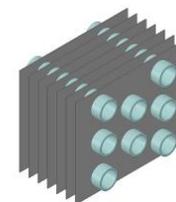
Rectangular/plain



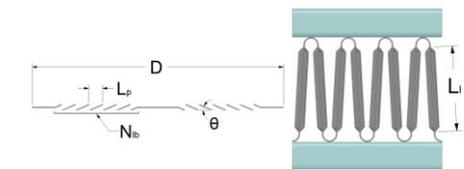
Plaques minces



Offset strip



Continuous with tubes



Louvers

## GT-SUITE heat exchangers templates

# Parametric study DOE (Design Of Experiment)

- ❑ Use a latin-cubic DOE to reduce the number of cases cas (350 cases) – tube/fins

## Take-Off

### Ram air velocity imposée

Altitude ~0 m

Patm = 1.013 bar

Tatm = 25°C

Glycol 40-60 water

Wall thickness = 0.6 mm

Fin thickness = 0.1 mm

Channels number = 2

Louver pitch = 1.5 mm

Louver length = 2 mm

Louver angle = 35°

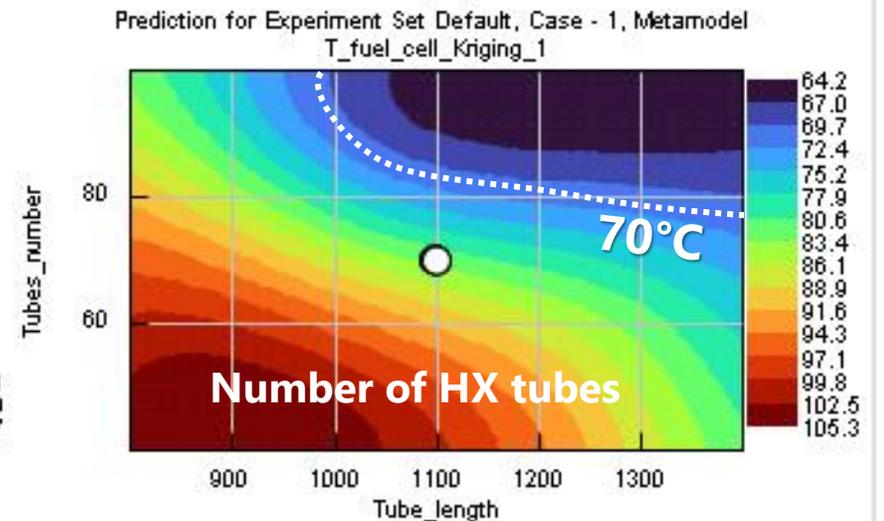
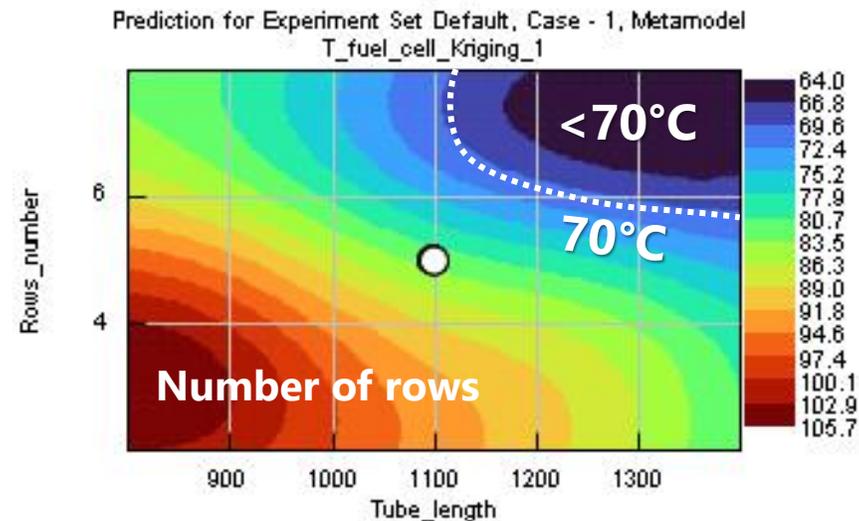
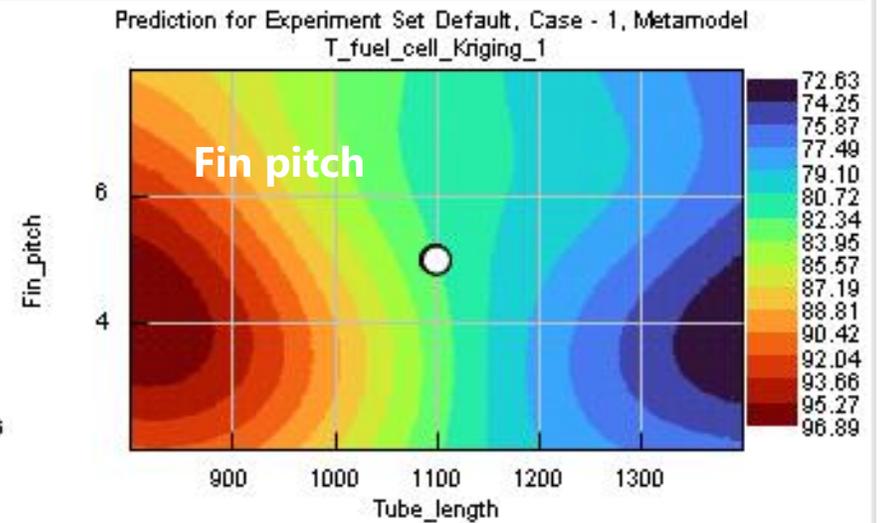
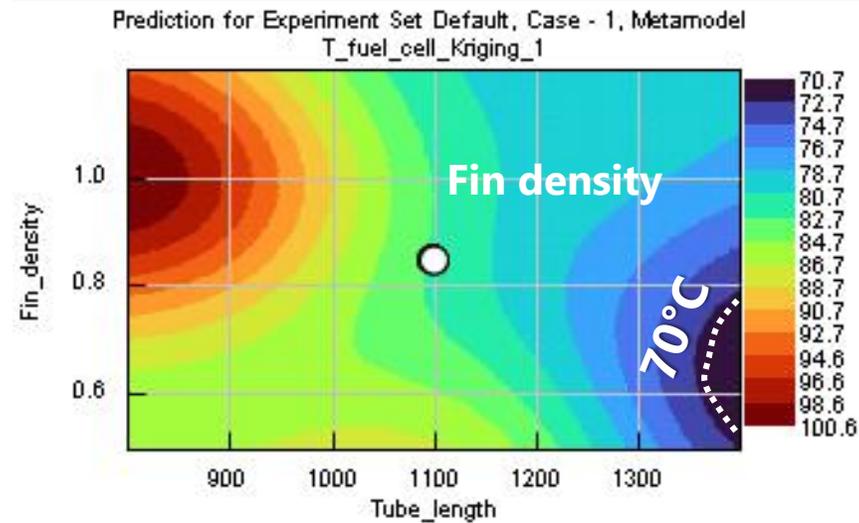
DOE parameters	Range [min ; max]
Tube length (mm)	[800 – 1400]
Stack height (mm)	[518 – 1540]
Heat exchanger depth (mm)	[53 – 830]
Tubes number [-]	[40 – 80]
Rows number	[2 – 8]
Channel width (mm)	[10 – 50]
Channel height (mm)	[4 – 7]
Fin density (1/mm)	[0.5 – 1.2]
Fin pitch (mm)	[2 – 8]

DOE

# Results

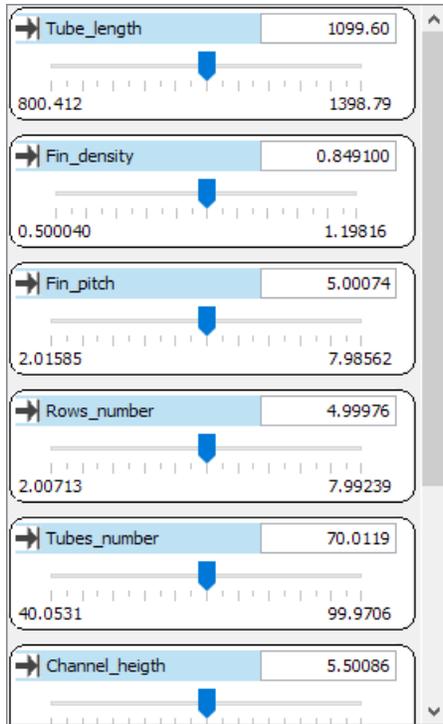
Response  
Surfaces

$T_{out}$  fuel cell



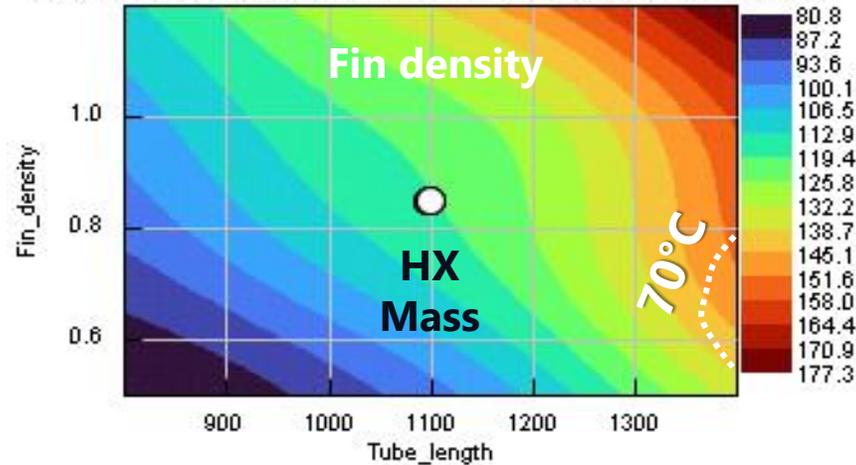
## DOE Results

# Results

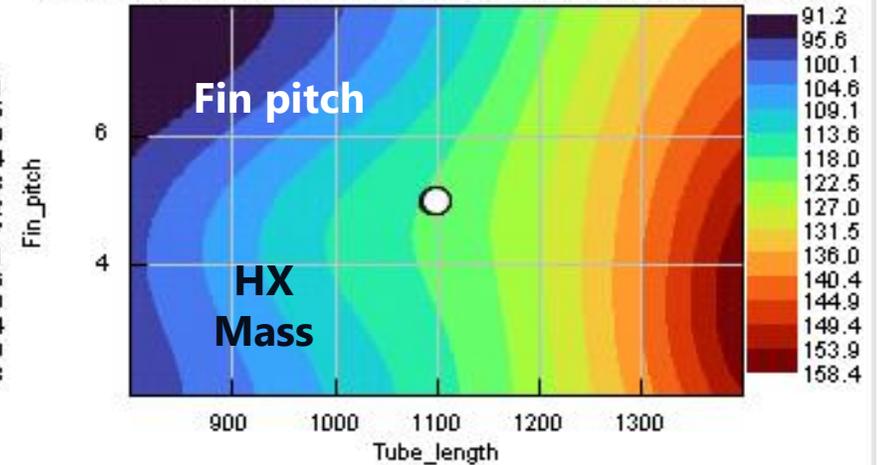


Results based on the response surfaces

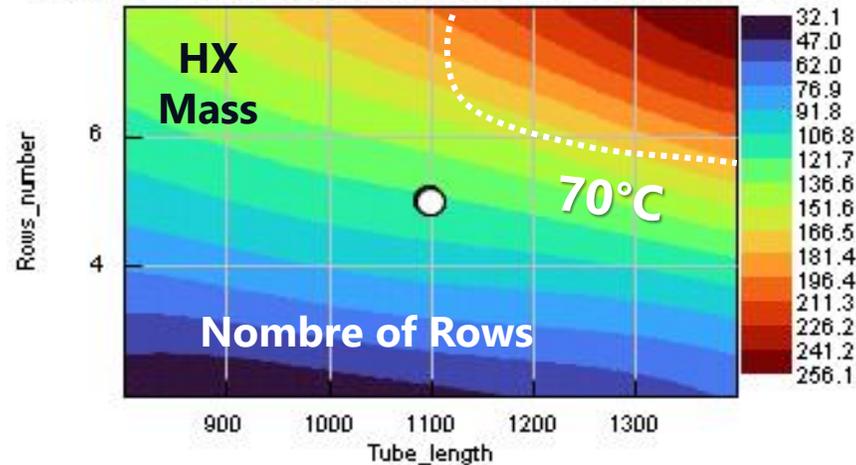
Prediction for Experiment Set Default, Case - 1, Metamodel masse\_Kriging



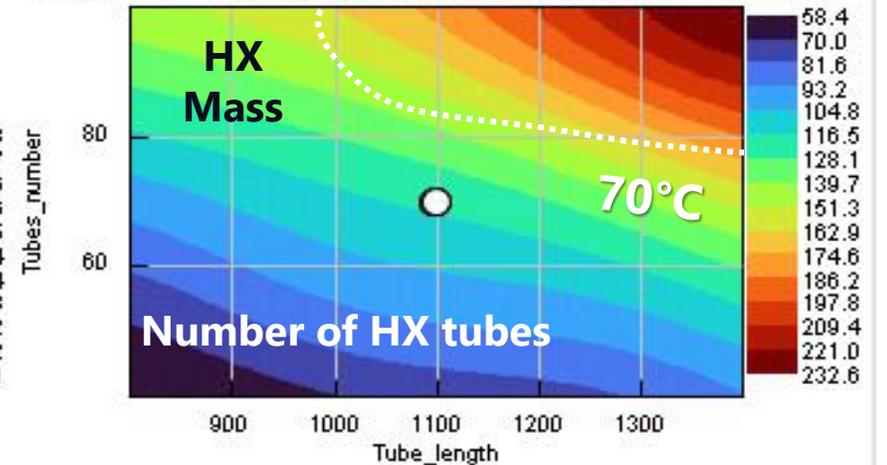
Prediction for Experiment Set Default, Case - 1, Metamodel masse\_Kriging



Prediction for Experiment Set Default, Case - 1, Metamodel masse\_Kriging



Prediction for Experiment Set Default, Case - 1, Metamodel masse\_Kriging



**HX mass directly calculated by GT-SUITE (based on material density (alu) and tube and fin dimensions)**



# Results

- Results on the response surfaces
- Building meta-models (*kriging*)
- Optimization with constraints (Target  $T_{out\ fuel\ cell}$ , minimizing the masse and the drag...)

The screenshot shows the 'Optimization Setup' window. On the left, there is a tree view under 'Optimization Runs' with 'Default' and 'Optimization\_1' (selected) and 'Arrays' below it. The main area is divided into several sections:

- Case Handling:**
  - Optimize Each Case Independently
  - Case-Sweep and Cross-Case Studies
- Multi-Objective Method (For Two or More Objectives):**
  - Pareto
  - Weighted-Sum
- Genetic Algorithm Settings:**
  - Population Size: def (=calculated) ...
  - Number of Generations: def (=20) ...
  - Show Advanced Settings:
- Factors:**

Attribute	1	2	3	4
Factor	Tube_length	Fin_density	Fin_pitch	Rows_number
Case Handling, or Fixed	Independent	Independent	Independent	Independent
Initial Value	def (=middle...)	def...	def...	def...
Integer Only	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Discrete Values Only	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
- Objectives:**

Attribute	1	2
Metamodel	T_fuel_cell_Kriging_1 ...	masse_Kriging ...
Objective	Target	Minimize
Target Value	70 ...	ign ...

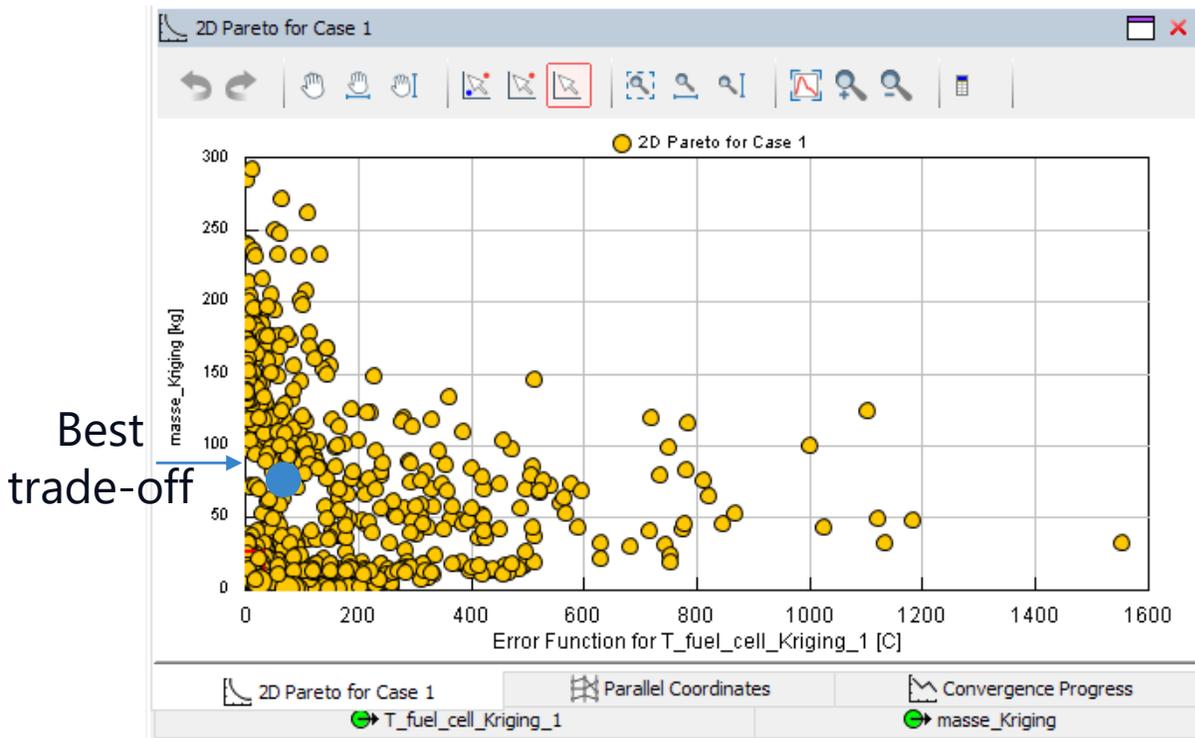
Below the objectives table, the text  $T_{out\ fuel\ cell} : 70^{\circ}C$  is displayed. At the bottom of the window, there is a 'Save and Start Optimization' button.

Mass : minimize

## Optimization

# Optimization

## Optimization with constraints



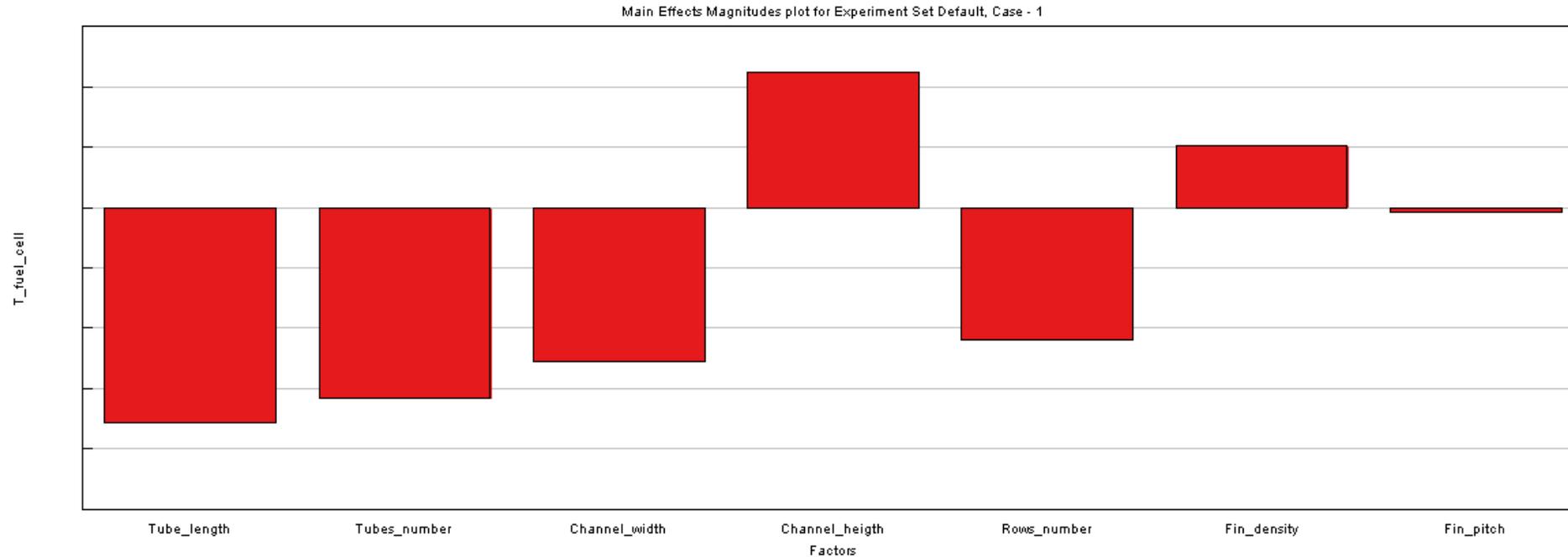
Status	Design ID	Case	T_fuel_cell_...	masse_Kriging	Tube_length...	Fin_density [...]	Fin_pitch [mm]	Rows_number	Tubes_number	Cha
●	1484	Case 1	78.558846	1.1148713	920.2058	0.6937859	3.4224465	3.0	57.0	5.62
●	1485	Case 1	76.61095	4.2751284	917.4862	0.69113946	3.125976	3.0	52.0	5.63
●	1486	Case 1	74.14216	7.387916	917.38934	0.67192054	3.4016666	3.0	50.0	6.07
●	1487	Case 1	78.993355	0.81647235	917.57825	0.69193333	3.762029	3.0	52.0	5.46
●	1488	Case 1	73.02745	13.141642	917.51324	0.69164187	2.3003159	3.0	58.0	6.21
●	1489	Case 1	70.44358	13.921483	1323.8967	0.6914917	5.7054214	3.0	44.0	5.55
●	1490	Case 1	72.733795	11.698468	918.7546	0.68933	2.5267353	3.0	52.0	6.04
●	1491	Case 1	73.90052	7.825141	900.35486	0.6746952	3.0881228	3.0	51.0	6.06

## Optimization - results

# résultats : analysis of the most influents parameters

Tout fuel cell

$[T_{\min} ; T_{\max}] = [57.8 - 119^{\circ}\text{C}]$

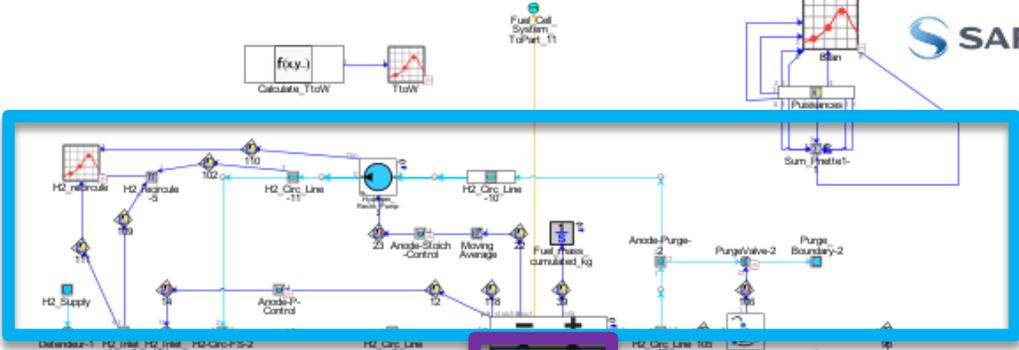


## Effect of the most influents parameters

**Responses = f(factors)**

# Sub-system modelling

# Fuel cell system

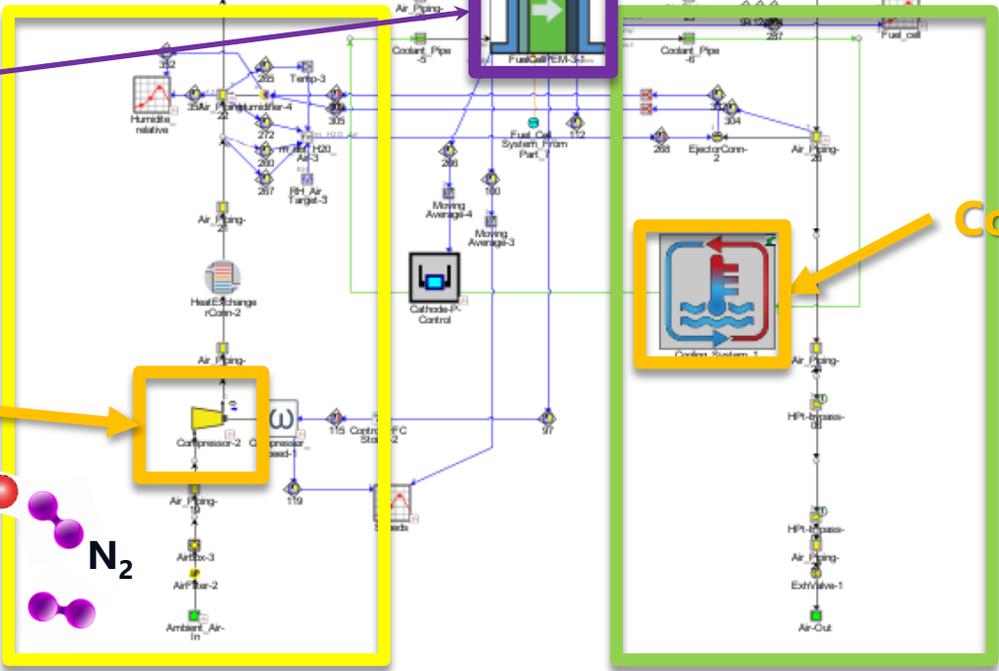
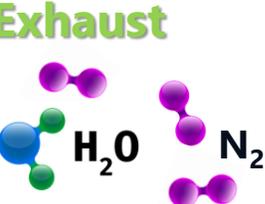
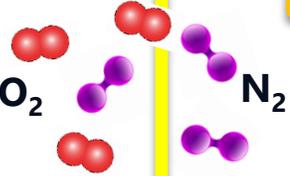


Advanced physical model of the stack

Intake

Cooling system

Compressor

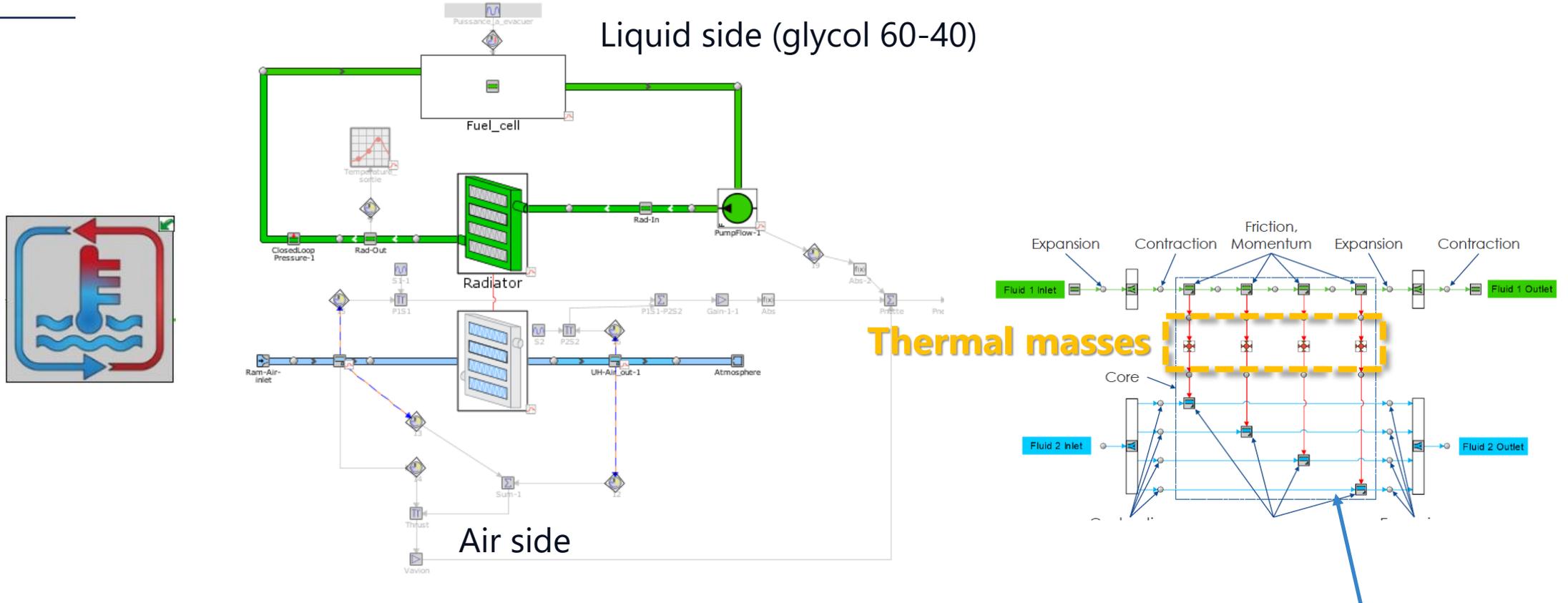


Fuel cell system is fully modelled, with the different components

## Fuel cell system



# Transient simulations

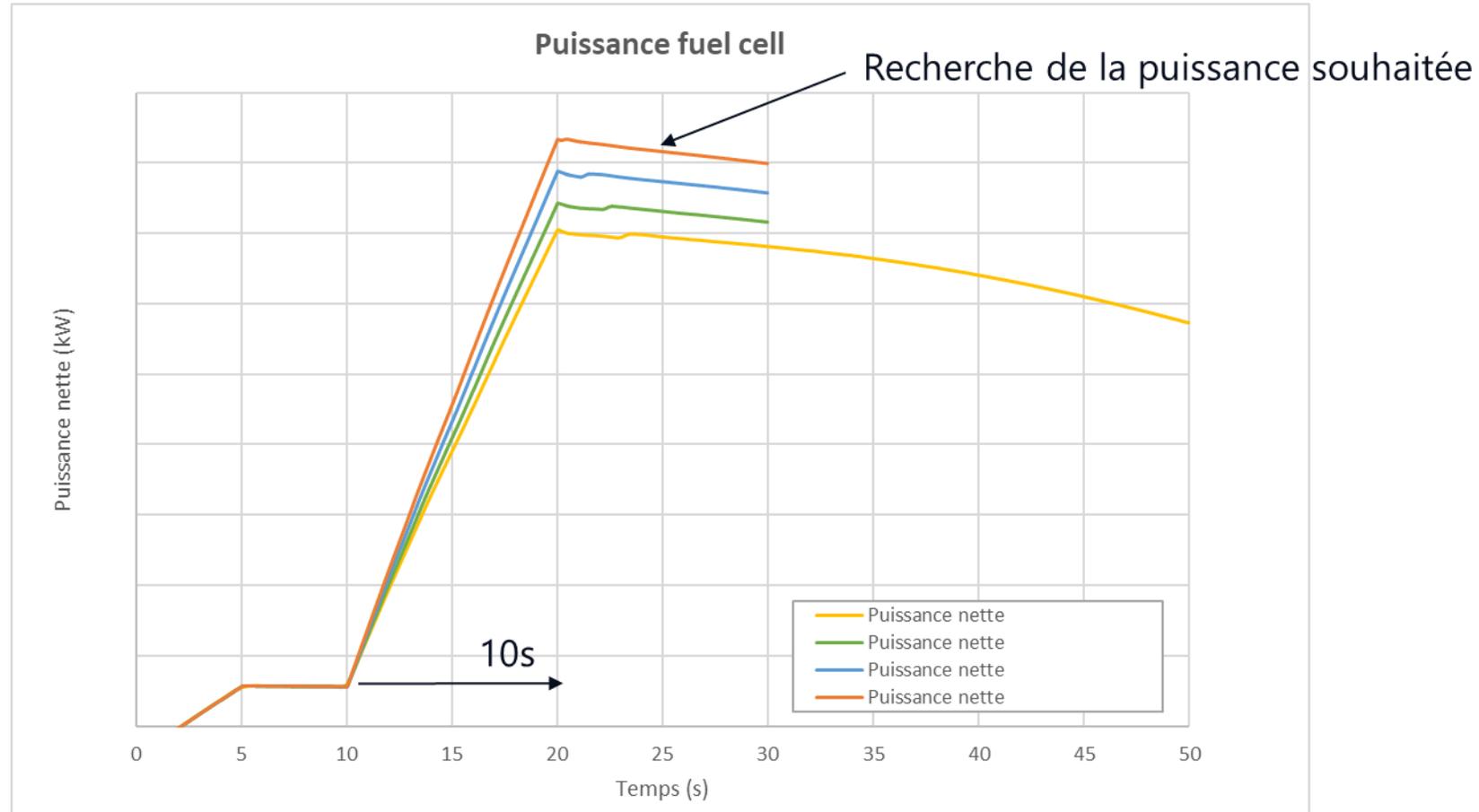


Cooling system transient behaviour is already modelled with mass/ thermal inertia

## Transient simulations – cooling system

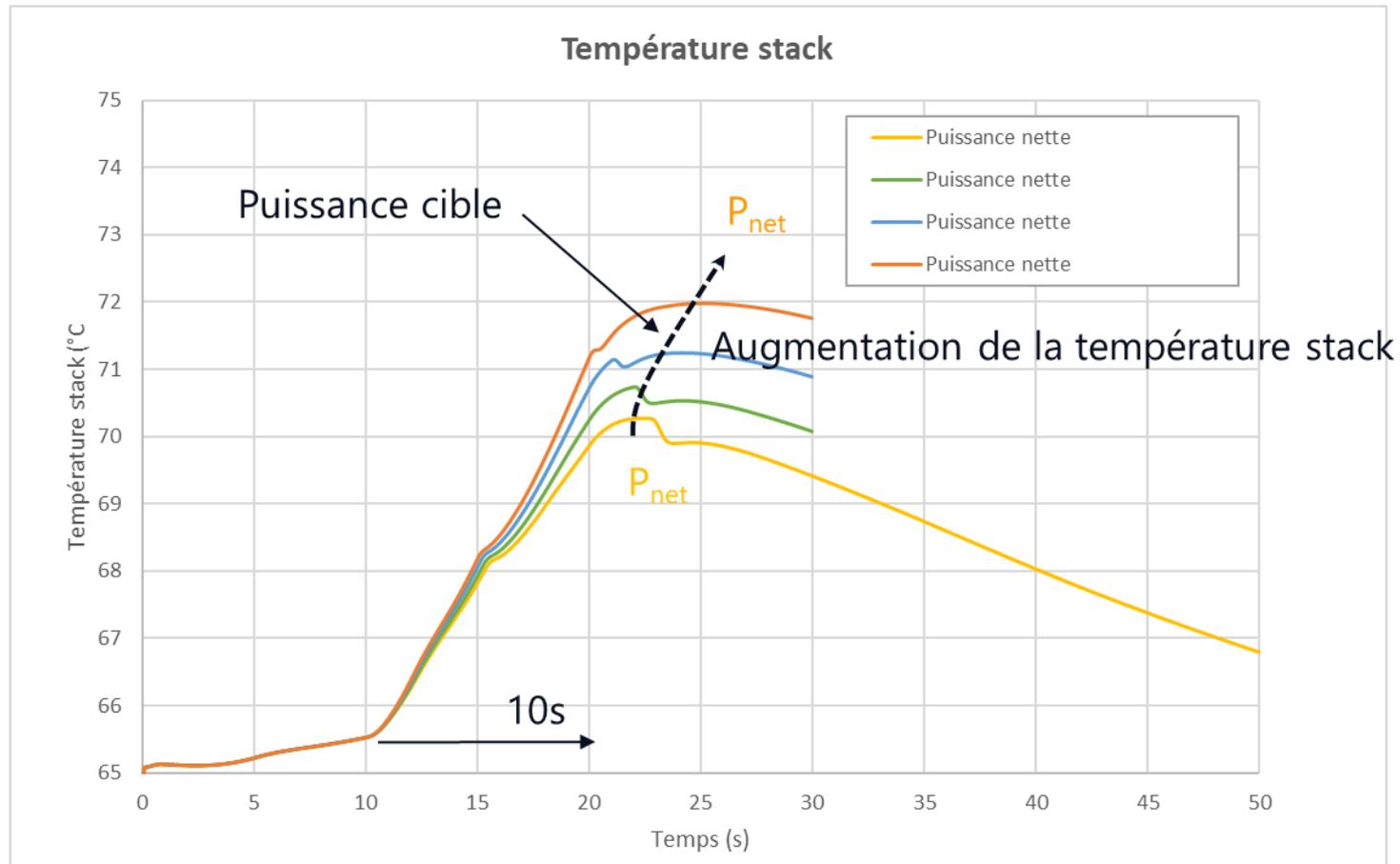
# Simulation "worst case" – $T_{\text{stack init}} = 65^{\circ}\text{C}$ – $T_{\text{amb}} = 45^{\circ}\text{C}$

$T_{\text{ambient}} : 45^{\circ}\text{C}$



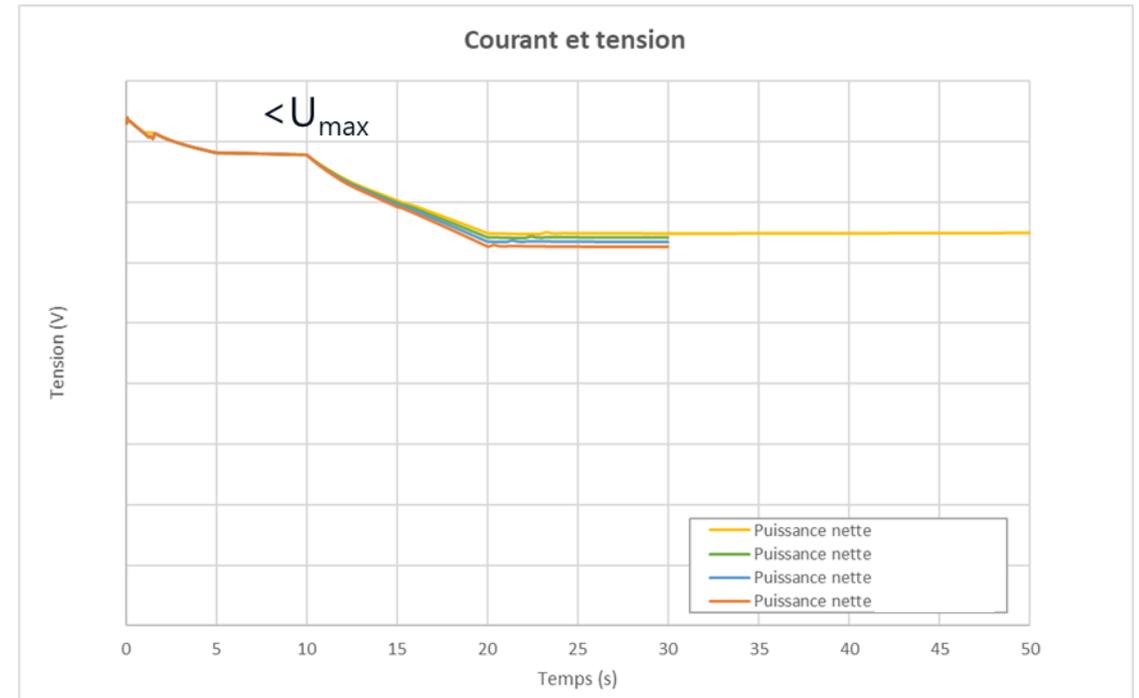
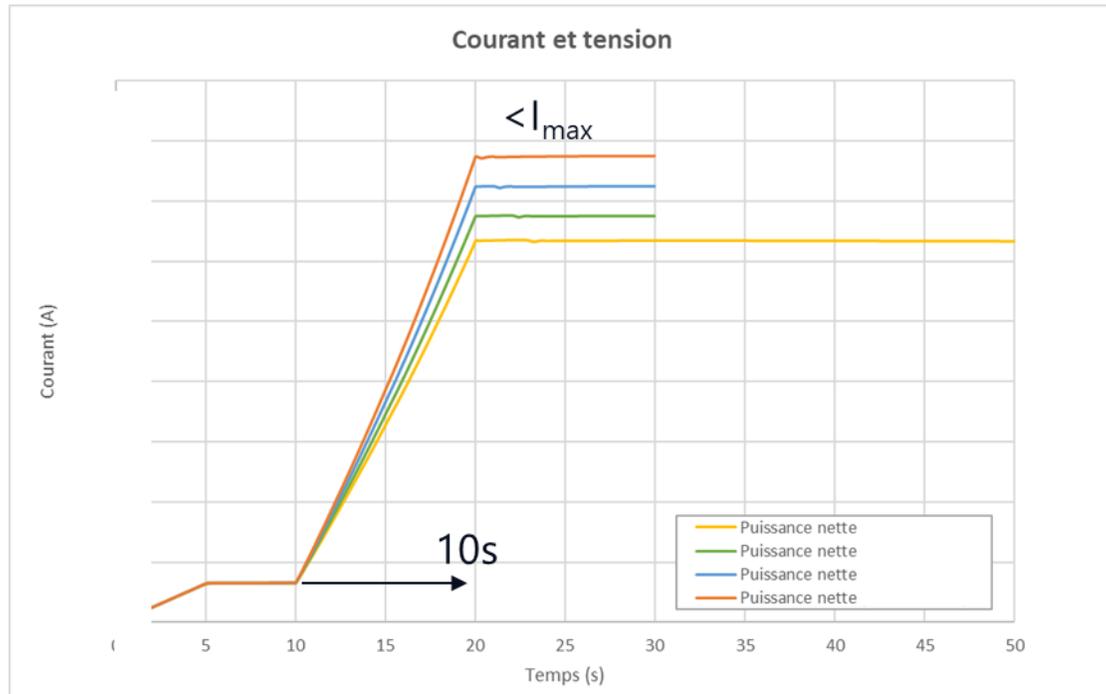
GT-SUITE as a **virtual test bench**

# Simulation "worst case" – $T_{\text{stack init}} = 65^{\circ}\text{C}$ – $T_{\text{amb}} = 45^{\circ}\text{C}$



GT-SUITE as a **virtual test bench**

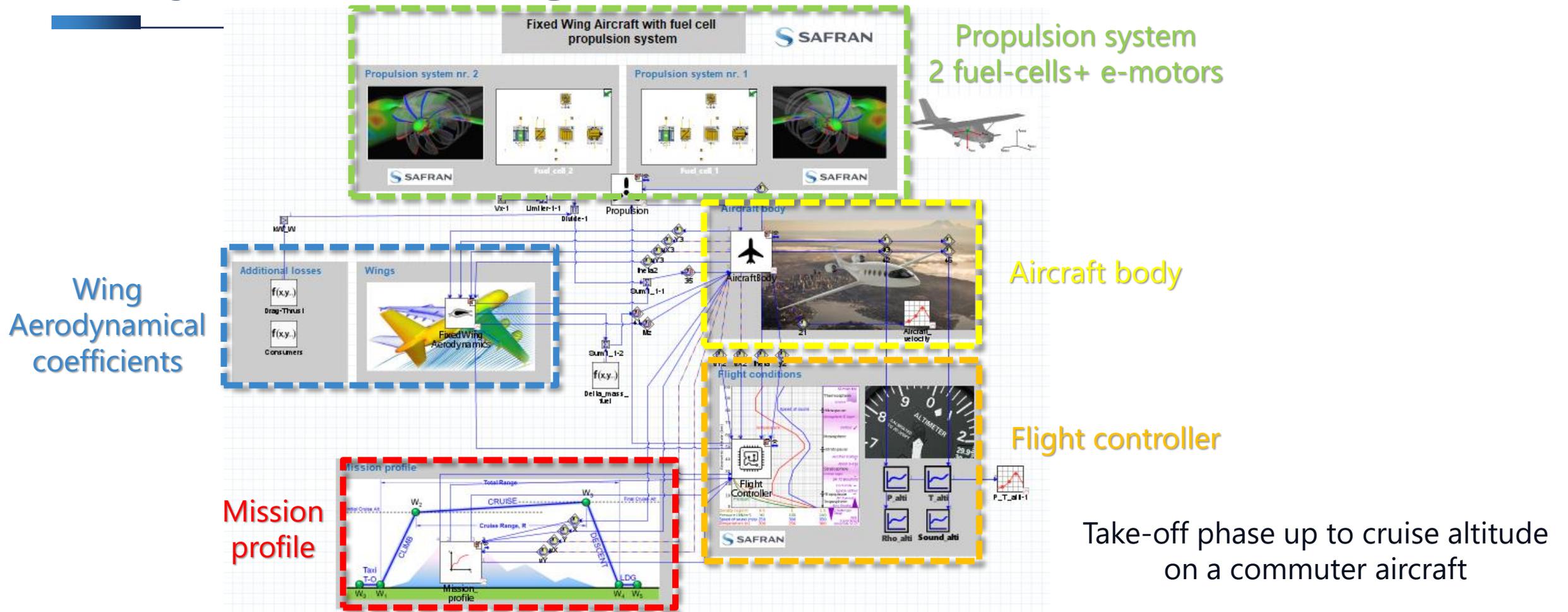
# Simulation "worst case" – $T_{\text{stack init}} = 65^{\circ}\text{C}$ – $T_{\text{amb}} = 45^{\circ}\text{C}$



GT-SUITE as a **virtual test bench**

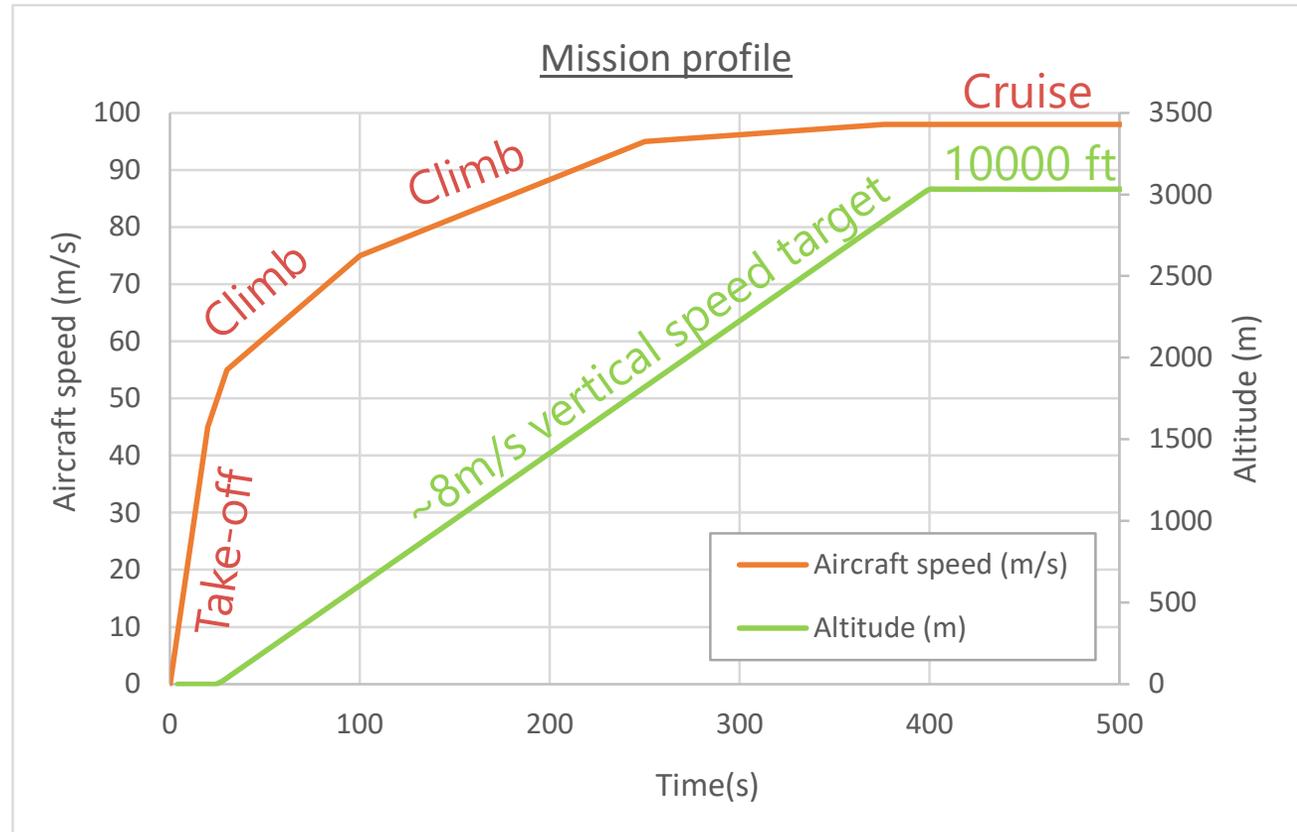
# « Full system » modelling

# Full system modelling



## Transient simulations – Full system modelling

# Transient simulations



Aircraft speed controlled by electrical motor torque

Vertical speed controlled thanks to AOA (Angle of Attack of the elevator)

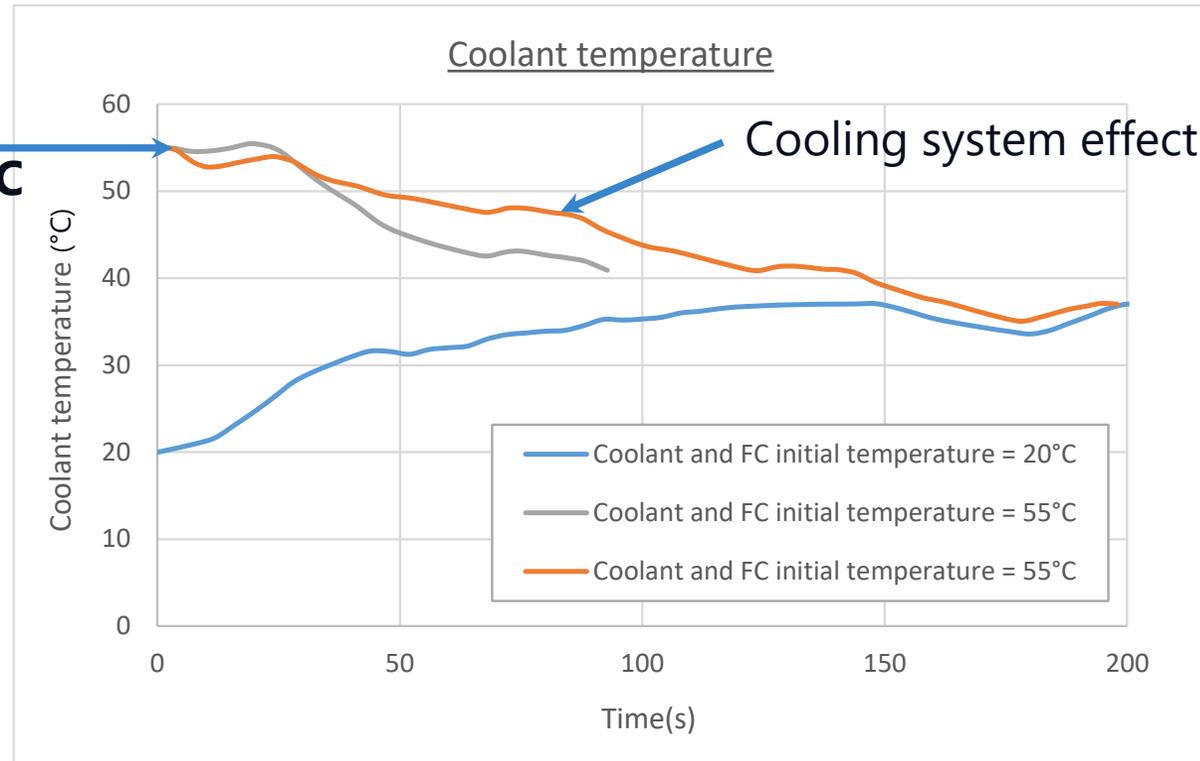
Pressure and temperature vary with altitude (ISA)

## Mission profile

# Transient simulations

Simulations with more severe conditions :  $T_{\text{init stack and cooling system}} = 55^{\circ}\text{C} + T_{\text{ext ground}} = 45^{\circ}\text{C}$  (Dubai conditions)

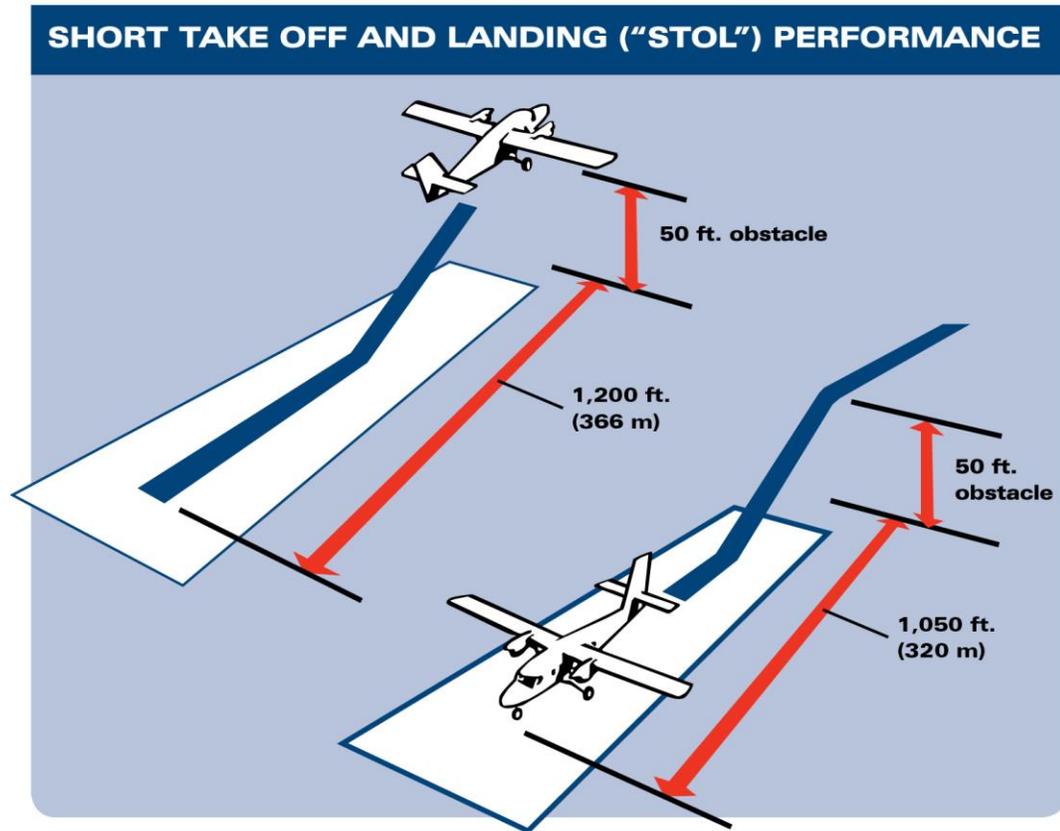
Initial temperature =  $55^{\circ}\text{C}$   
Ambient conditions =  $45^{\circ}\text{C}$



$T_{\text{max stack}} = 65^{\circ}\text{C}$  is respected even with these hot conditions

## Transient simulations – stack temperature

# Transient simulations



STOL : « Short Take Off and Landing »  
related to the stall velocity at 50 ft (15.2 m)

~410 m 😞

Above the 366 m target

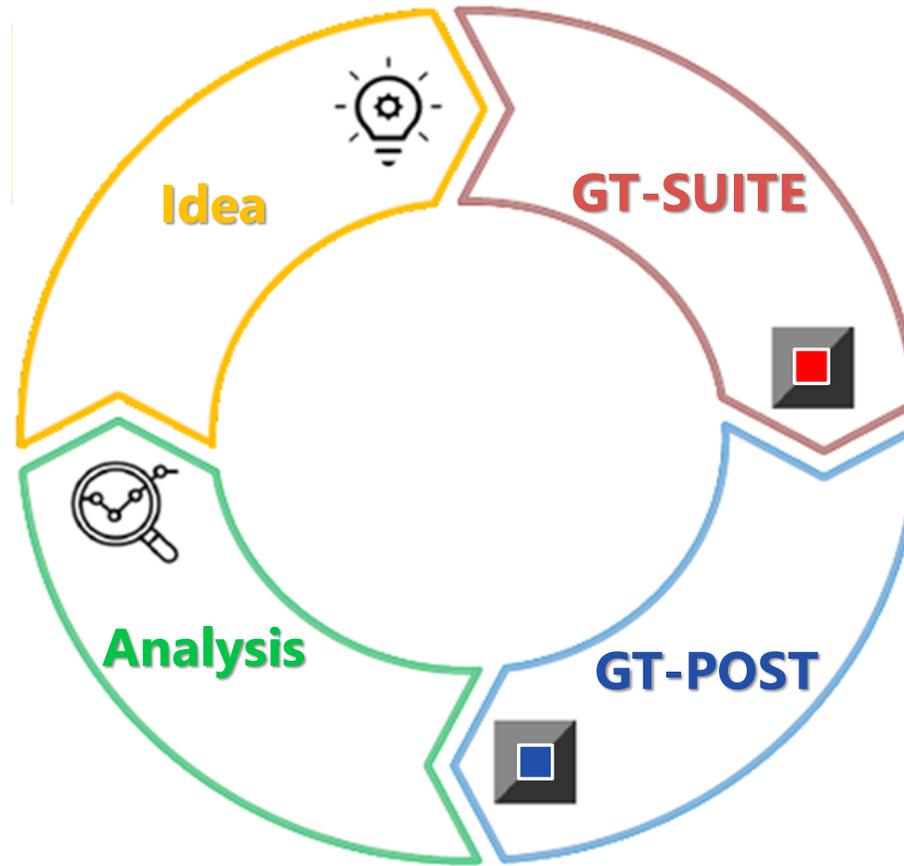
Can be achieved (~370m) by using more aggressive  
PID coefficients, but giving instabilities later



**Check of flight performances at take-off**

# Conclusions

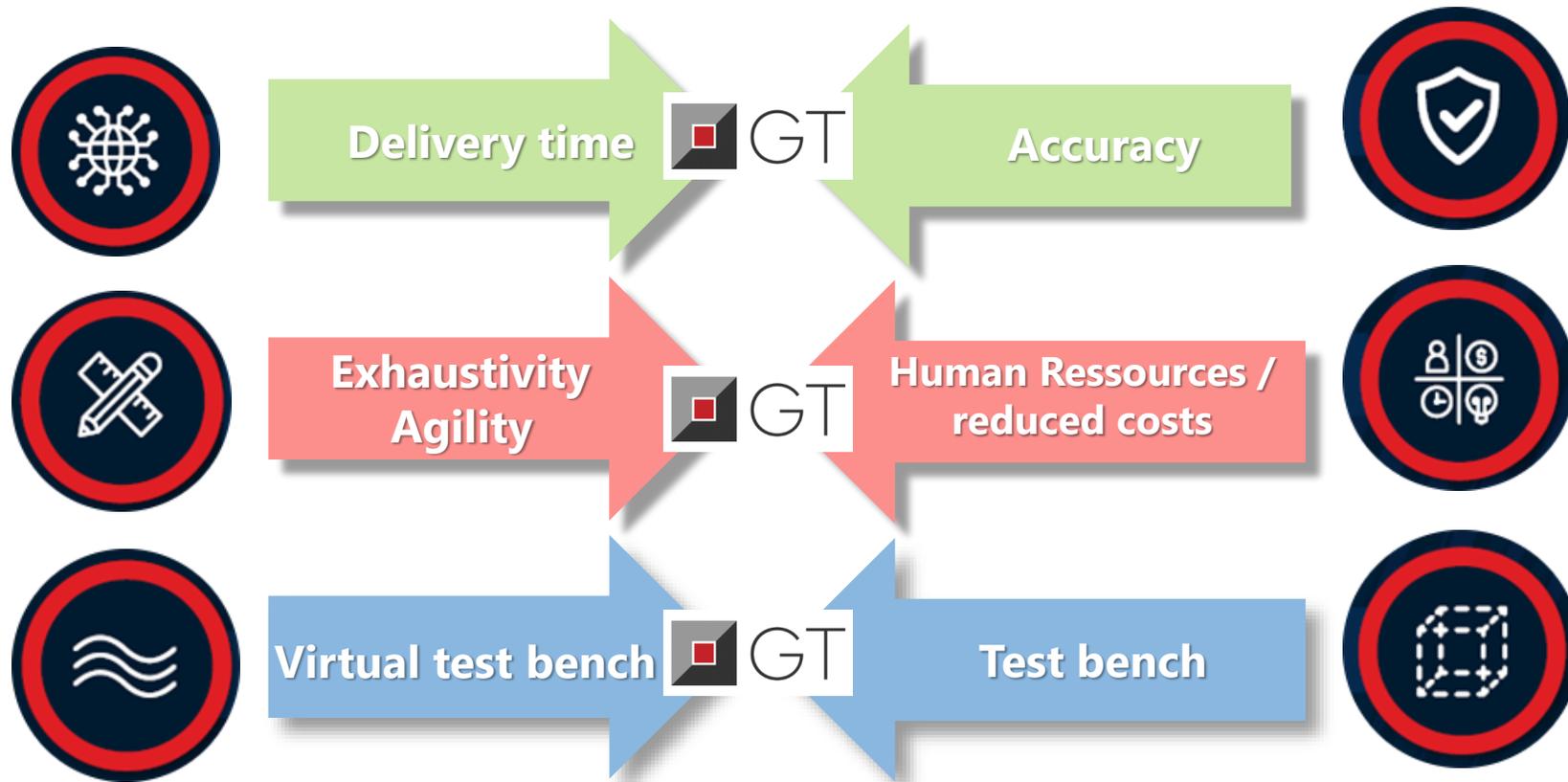
# Use of detailed physical models



Every tools necessary  
for the study of a  
new concept  
included in GT-SUITE

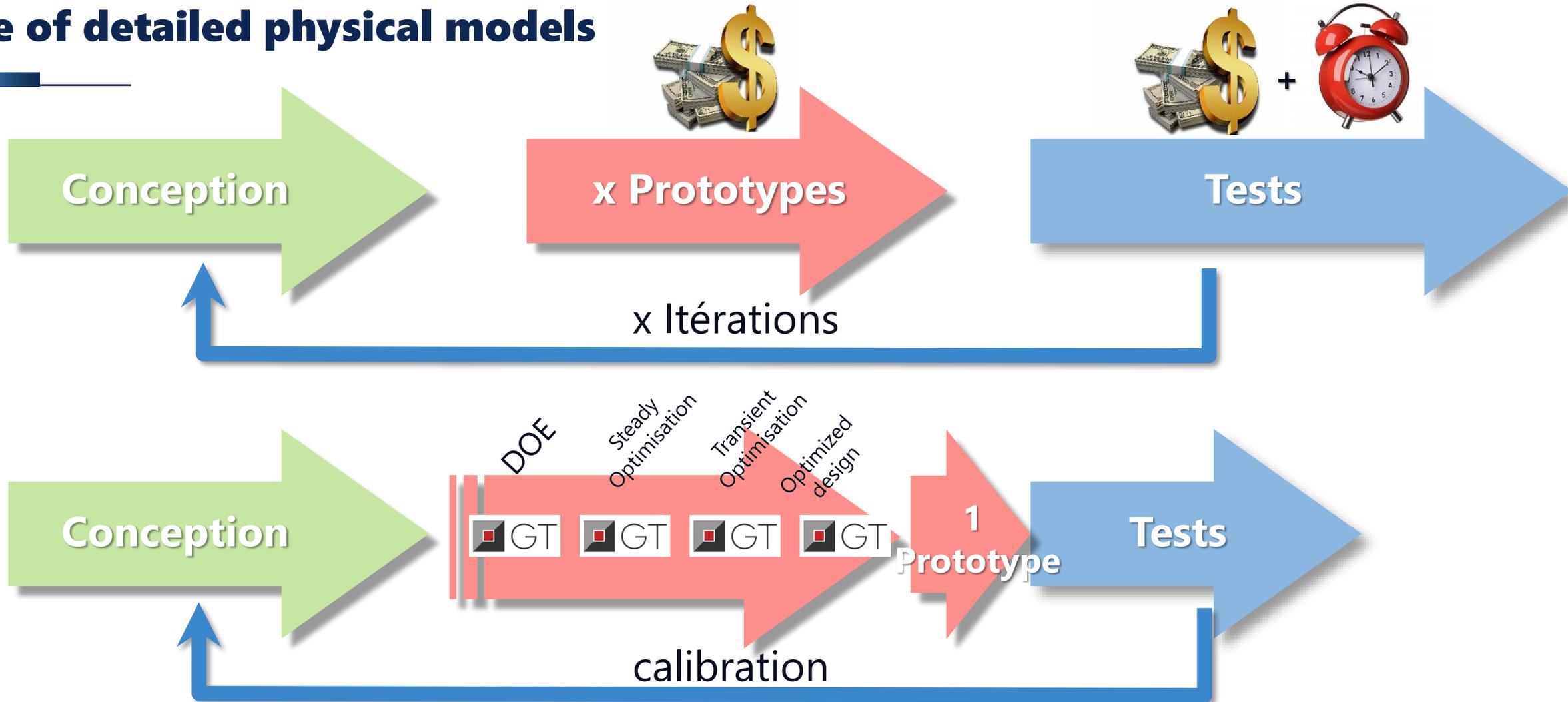
Interest of a 1D/3D GT-SUITE approach

# Use of detailed physical models



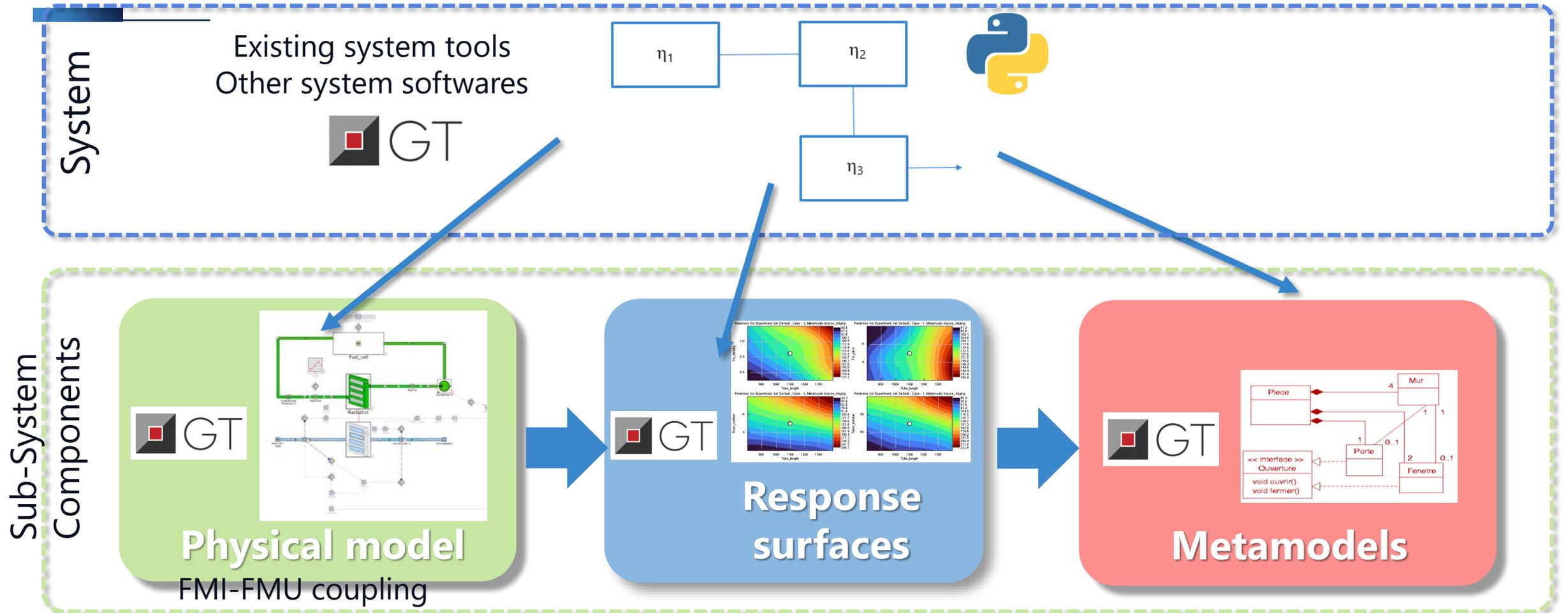
## Interest of a 1D/3D GT-SUITE approach

# Use of detailed physical models



**Interest of a 1D/3D GT-SUITE approach – reduced delivery time and costs**

# Use of detailed physical models



Interest of a 1D/3D GT-SUITE approach – reduced delivery time and costs

# Use of GT-SUITE

- Using GT-SUITE allows **multiphysics** advanced modellings already included pour la to take into account issues linked to hydrogen for **steady** and **transients** :
  - Fluids – 1D Navier Stokes
  - Cooling/thermal management
  - Two-phase flows
  - Mechanics
  - Advanced models of the fuel cell
- Coupling capabilities GT-SUITE (FMI-FMU, GT-automation) make easy to insert in the existing system workflows
- 1D-3D simulations allow **productivity** and **predictivity gains** for the innovative programs

## Conclusion & perspectives

# Perspectives

---



Thank you for your attention !

Safran is hiring advanced system simulation engineers !

[alain.lefebvre@safrangroup.com](mailto:alain.lefebvre@safrangroup.com)

**Job opportunities**