AI in Engineering
to bring back statistics

16/11/2023 – Phimeca Day

François Deheeger – Senior Fellow AI & Data

Michelin ? A mobility company that also builds tires !

TIRES WHICH ARE TAILORED
TO OUR CUSTOMERS' NEEDS

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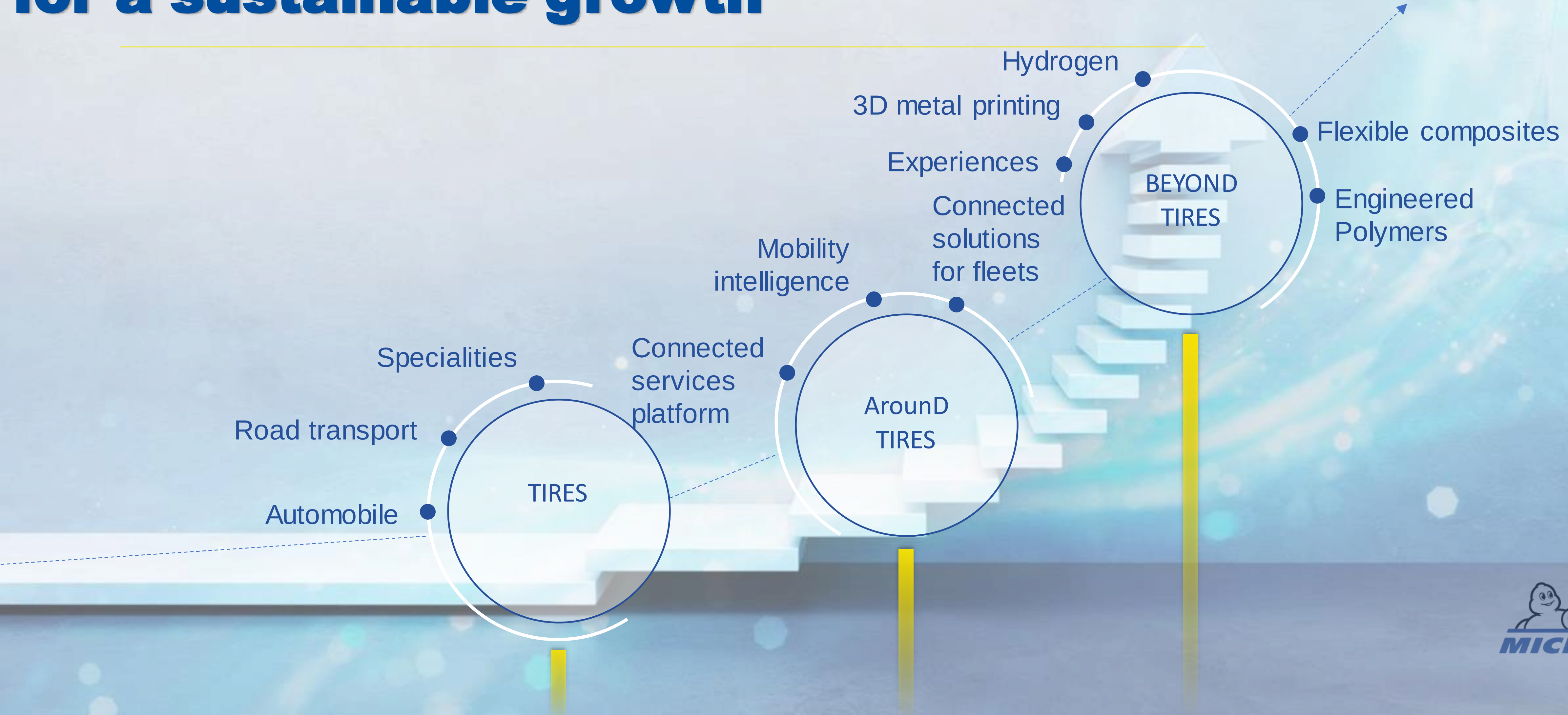
Three domains, for a sustainable growth



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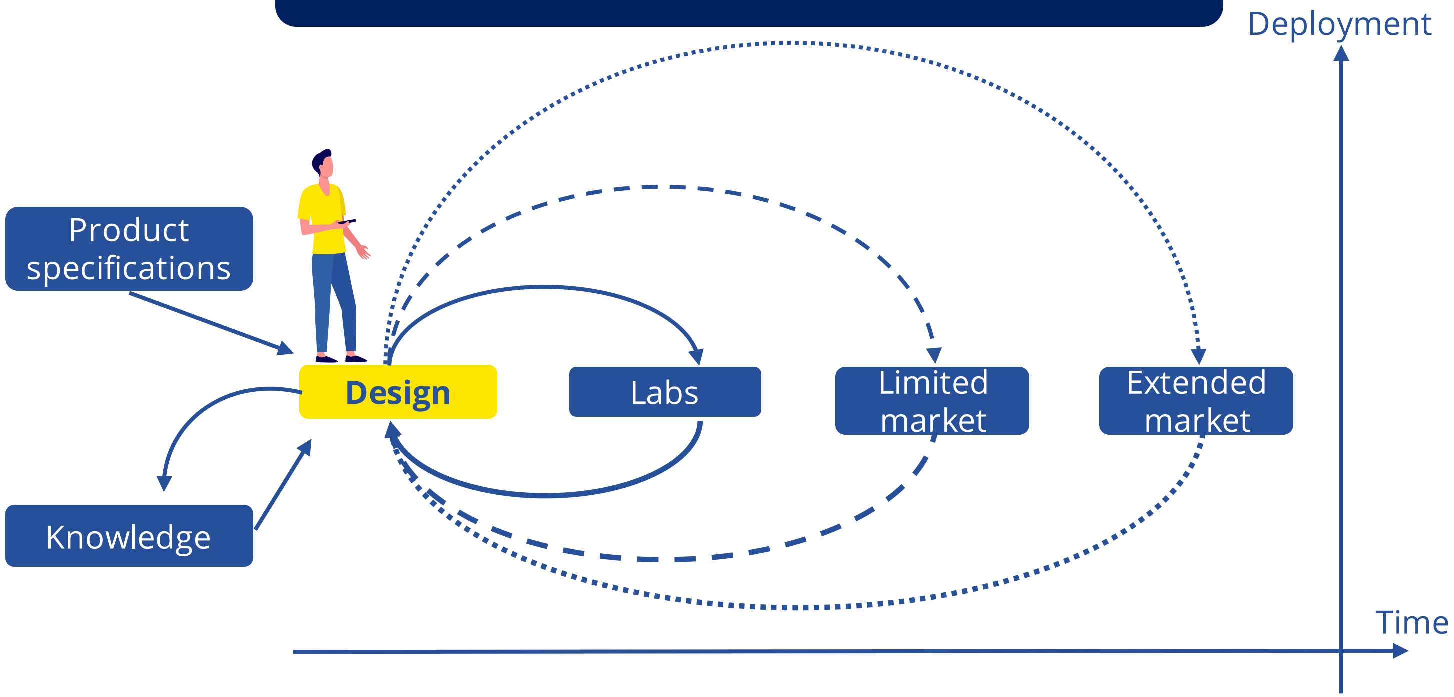
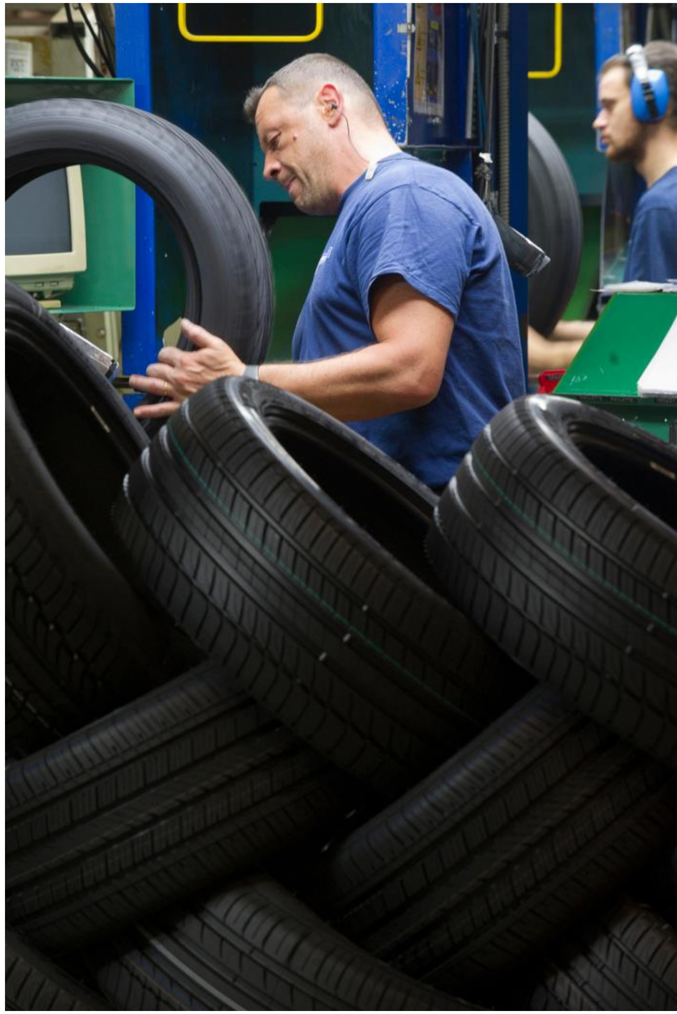
Our usual approach to ensure quality products

Fact Centric

Physical proofs

Higher maturity level → longer loops





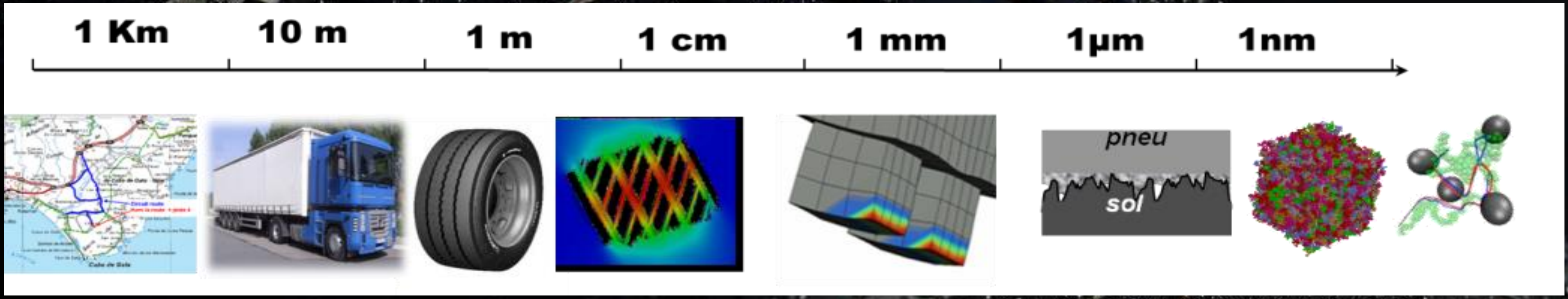
We are doing simulations from molecule to vehicle

Product performance

- virtual tire as a product
- virtual vehicle & tire co-design

Material conception levers

- optimize material recipe
- virtual material for simulation



Services & usage

- predictive maintenance
- real time condition assessment

Tire conception levers

- real-time performance prediction
- early integration of industry contraints

AI models: a key factor to accelerate … and more

Fact Centric

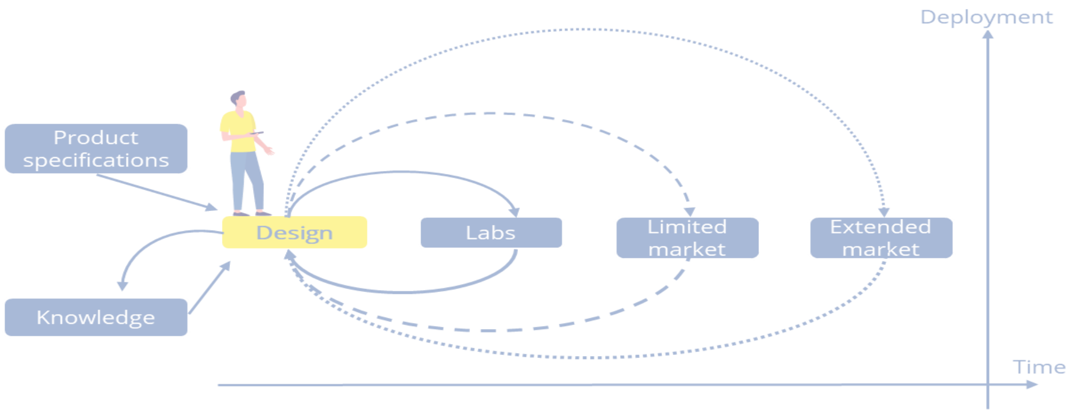
Physical proofs

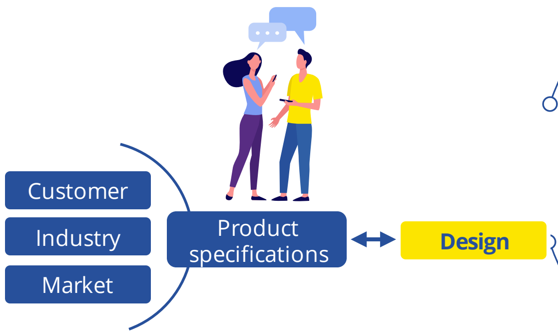
Higher maturity level → longer loops

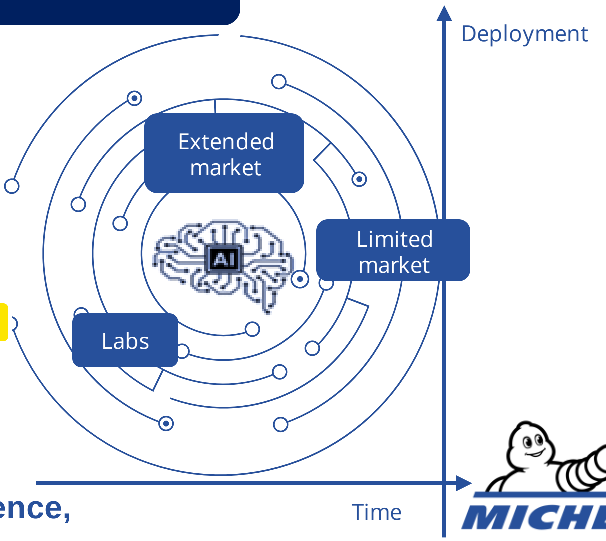
Multi factorial

Data Insights

Real Time







A designer connected to customer, usage diversity, manufacturing excellence, end-to-end

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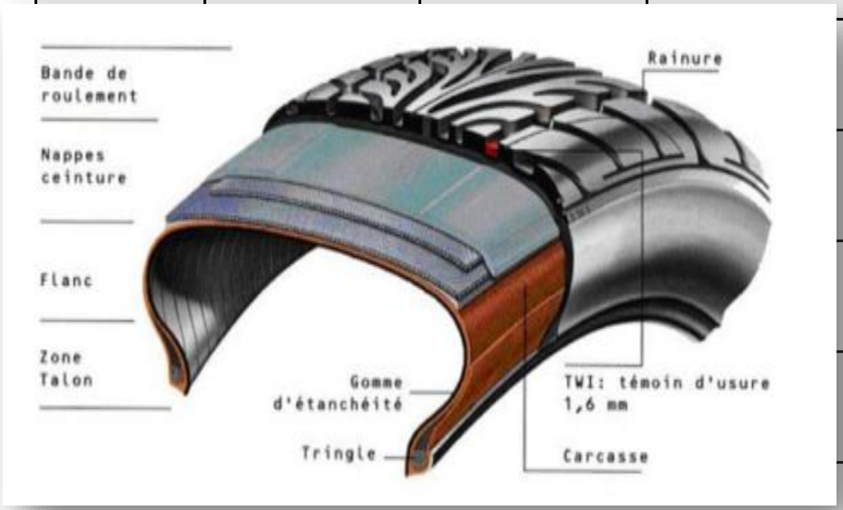
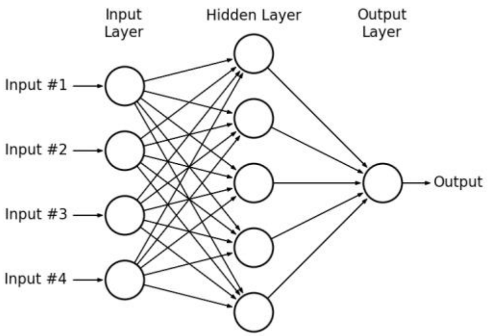
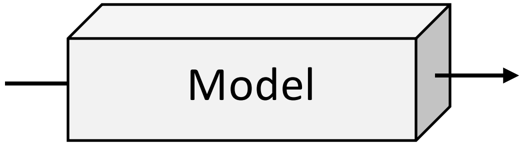
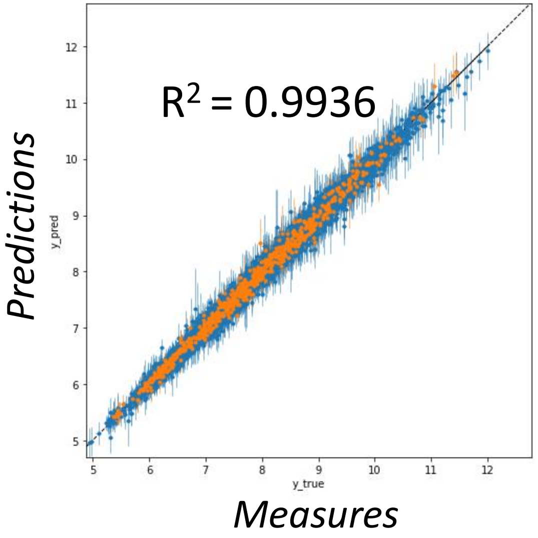
Machine learning applied to product data

ID	Material Id	Geometry	Tread Depth	Sre
1	KM1	0.87	2.7	Sre1
2	KM3	1.4	3.4	Sre3
3	KM1	5.2	5.1	Sre1
				Sre2
				Sre6
				Sre3
				Sre1









ID	RR
1	6.87
2	8.4
3	5.2
4	9.1
5	7.2
6	6.0
7	5.2

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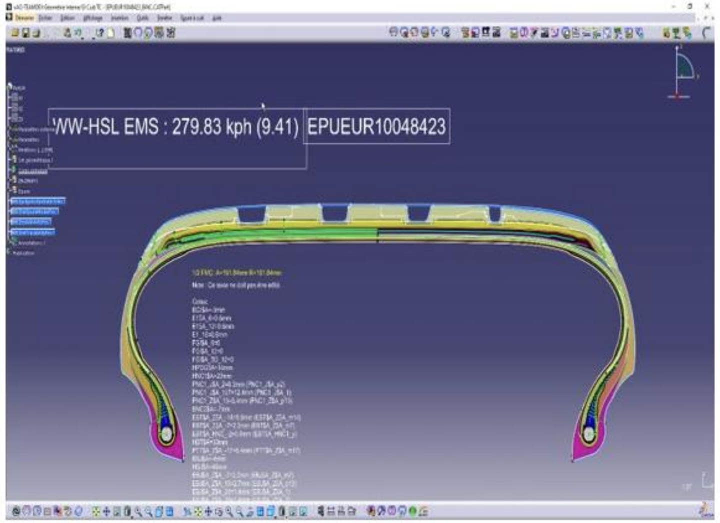
5 AI Models delivered to 250+ B2C Tyre Designers (Dz, RR, HSL, SW/OD, Mass)

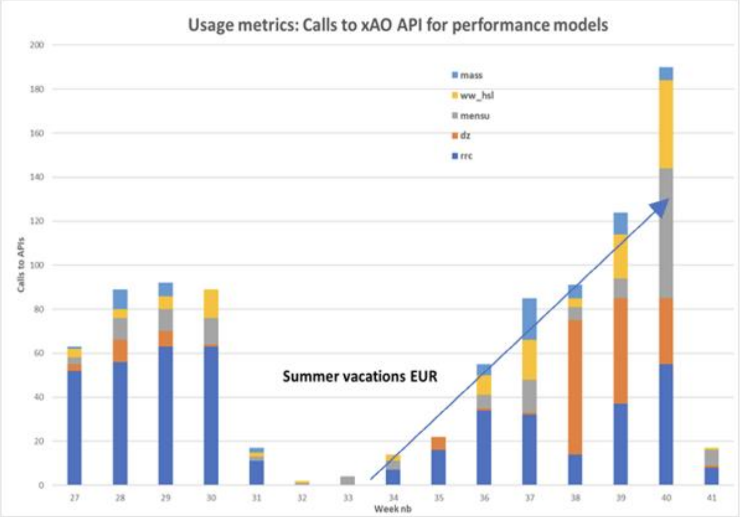
2021

Use-caseS consolidation

Models delivered to CATIA



Weekly Usage growing!



LOUIS CAPON : "The AI told me that the margin was sufficient in RR and VLI. Without these models, I would have asked for more letters in the factory."

PATRICK PALLOT : "The AI model is the most accurate model I've had to use

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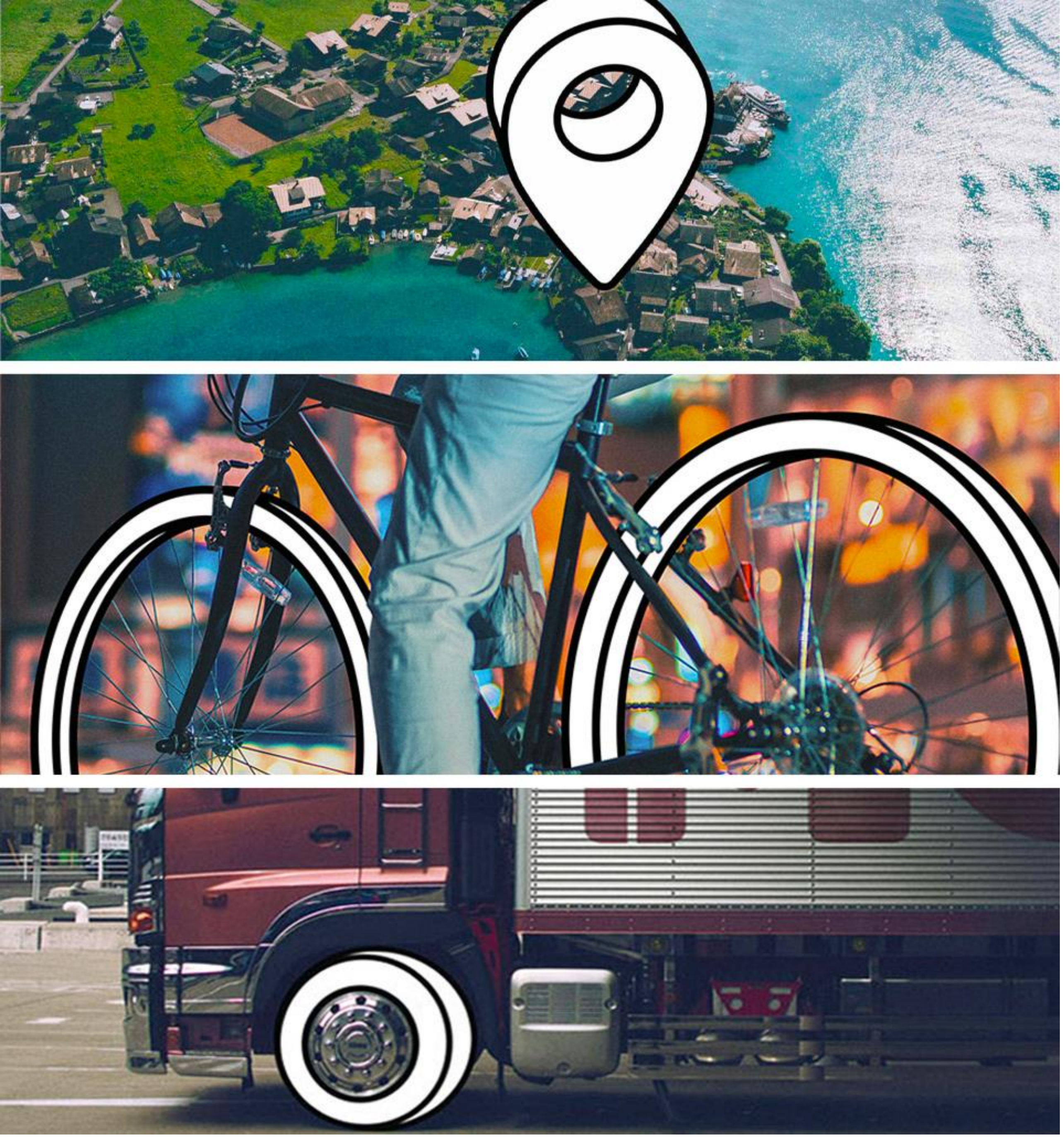

Great !

Is that the end of the story ?

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A systemic technology development

WE NEED to make sure they are good

2

Enable trust-worthy AI solutions for engineers
Through prediction uncertainty and
Exploitation domain assessment

Quantmetry
école normale supérieure paris–saclay

Well, give me a solution

3

A need to quickly assess the best trade-off
inside a defined perimeter *exploitation*
or beyond *exploration*

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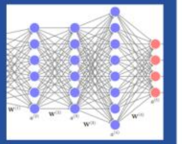


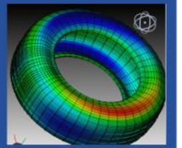
CERTIFICATION
EXPLAINABILITY

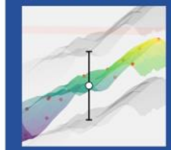
OPTIMIZATION
GENERATIVE

AI for engineering

PRIOR &PHYSICS
KNOWLEDGE

UNCERTAINTY
QUANTIFICATION





SystemX
INSTITUT DE RECHERCHE TECHNOLOGIQUE
école normale supérieure paris–saclay

Use physics knowledge in AI
Toward hybrid simulation for
accuracy and acceleration

1

WE NEED BETTER MODELS

sigma CLERMONT

Assess solutions robustness with respect
to real use uncertainty: manufacturing, usage,
to predict real life performance. Toward digital twin.

4

Is-this True ?

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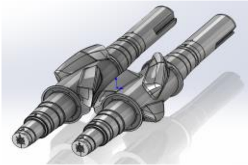
Let's have a look at two examples

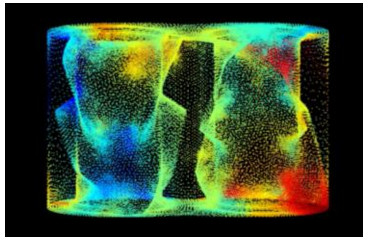
MIMO: a simulation-based **decision making assistant** for **mixing line process**

***Choose** a factory ; **Define** process parameters ; **Analyse** mix. properties*

≈ 100 **mix designers** & **industrializers** users WW



Modelling of rubber internal mixer is inaccurate but fast (minutes)

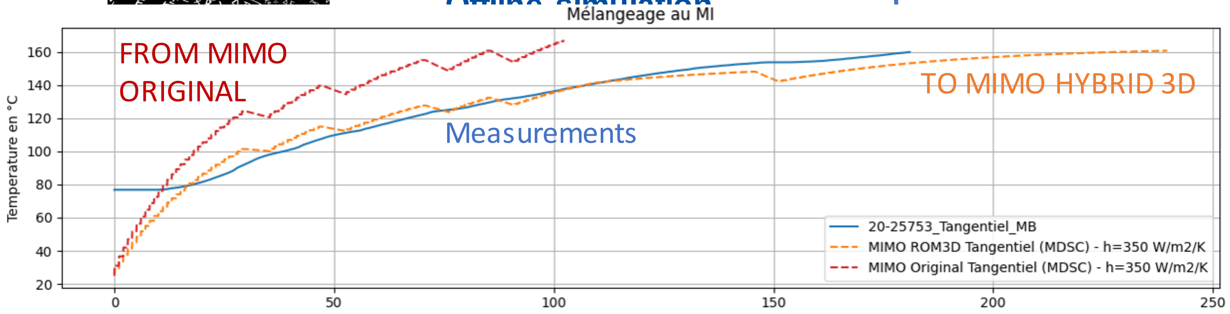


3D physics-based simulations are accurate but slow (days)

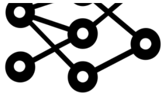
*Lead by **P. Tremblay***

Modelling trade-off: use **3D simulation** as a **data generator** for **machine learning**

New parameter set



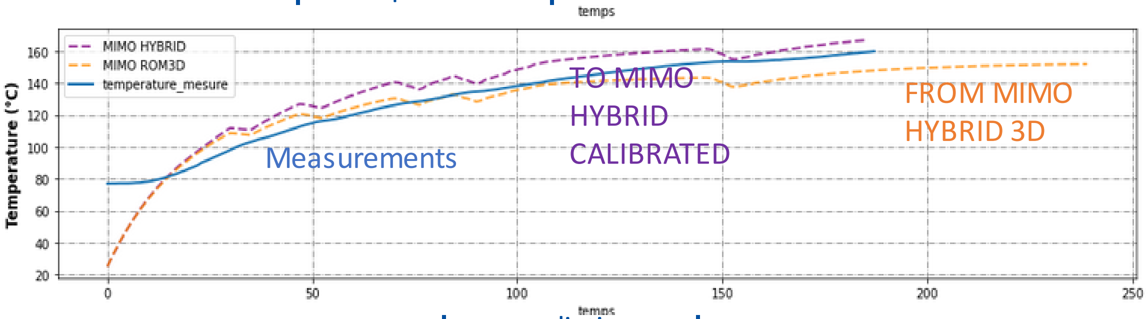
Parameter set n



Reduce cost and industrialization delays with augmented simulation

Still possible to improve modelling using **process measurements**

New parameter



prediction

Advanced research (3 last years) opens the way to **MIMOV2**

- K. Hayes (DORD/MAT) & P. Tremblay (PM/MAT): *"3D hybrid models will allow us to assess the **impact of rotor geometry** and define accurate **mixing criteria**"*
- **Prediction time compatible** with the needs of MIMO's user community

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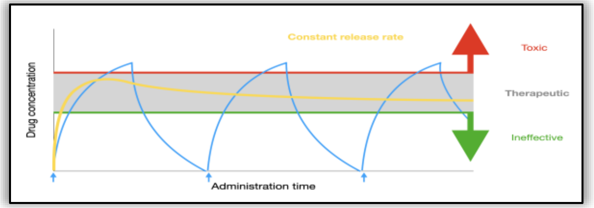
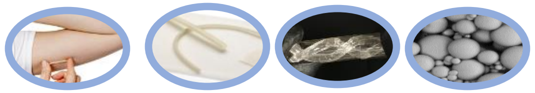
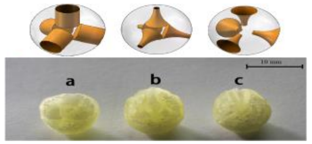
Controlled Release of Active Pharmaceutical Ingredients

SOLESIS

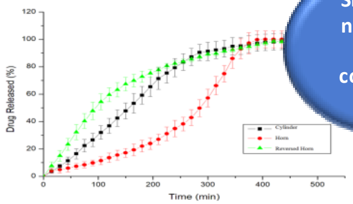




Poly-(Glycerol Sebacate) based implant



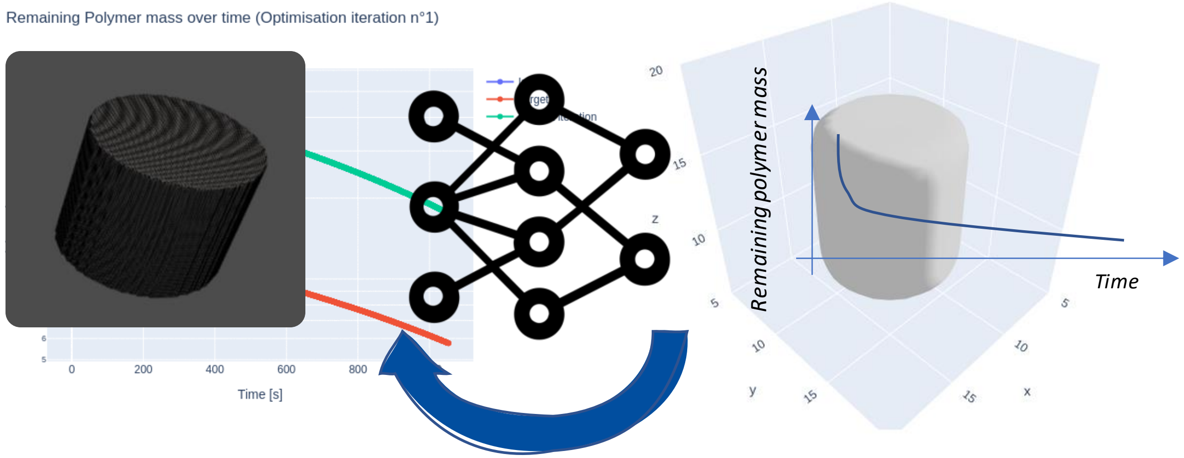
implant shape drive the release kinetics



Shape as a new lever for controlled release

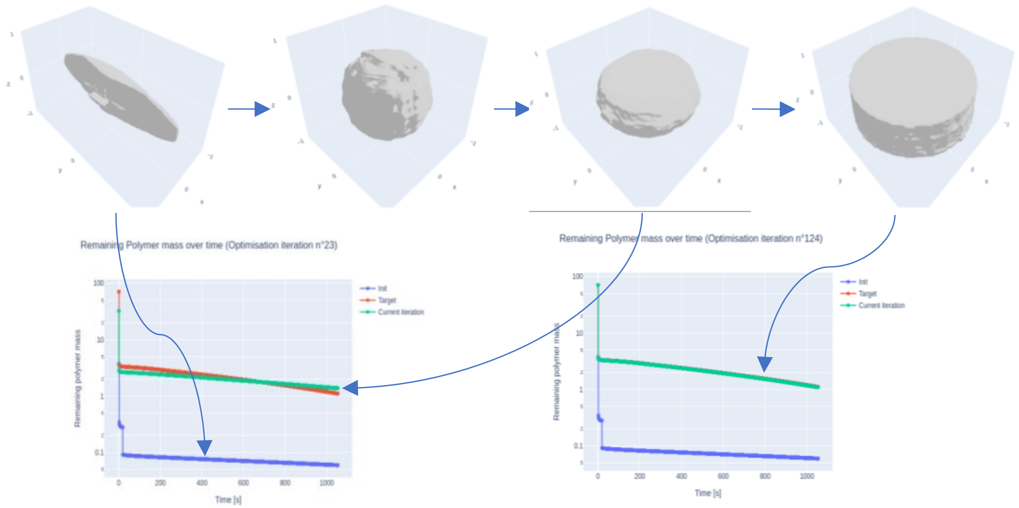
Xu, X., Zhao, J., Wang, M., Wang, L., & Yang, J. (2019). 3D printed polyvinyl alcohol tablets with multiple release profiles. Scientific reports, 9(1), 1-8.

Generative design, an example



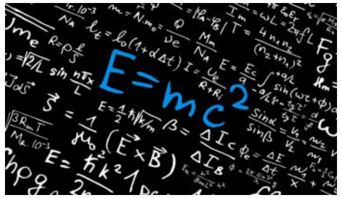
SOLESIS: discovering medical implants optimal shape

Navigate through different shapes



What's next ?

- ***Fast shape optimization** is one keyboard away*
- *Can be **used by anyone** (especially non numerical experts)*
- *Pluggable in **physics-based solvers***



- Generative design to **target other applications**:
  - Tire design
  - Belts
  - Materials

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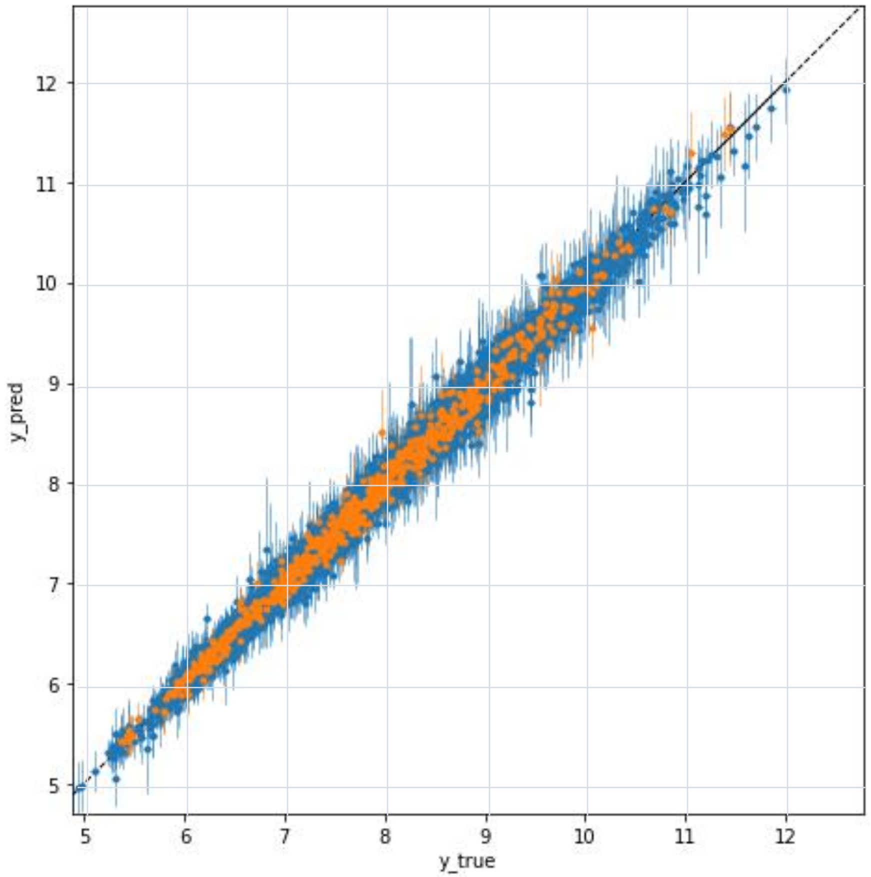
«All models are wrong, but some are useful »



- We all have ideas on how to compute the score of a model…

- But for homologation of the model, what is the right population to estimate error ?
  - the historical data ?
  - balanced by market coverage ?
  - balanced by future sales ?

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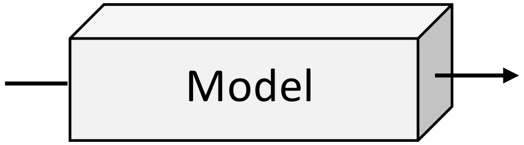
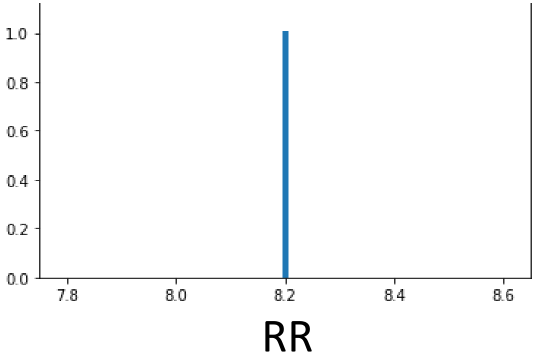
Quality with AI models requires to go beyond R^2

And... usually we build N AI models

ID	KM	Xao …	Hsre	sre
1	KM1	0.87	2.7	Sre1

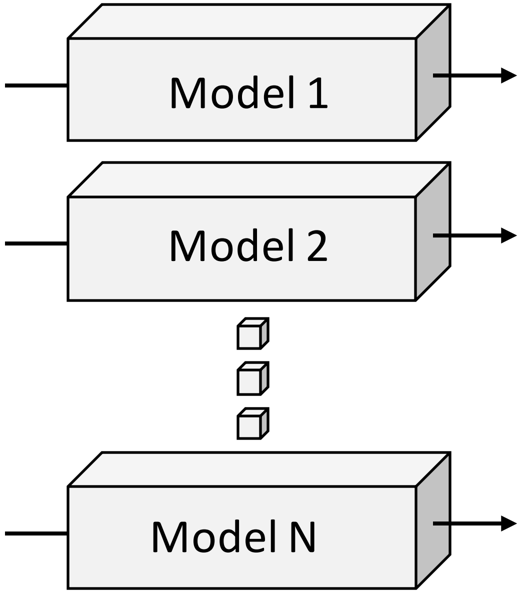
From Single point of view

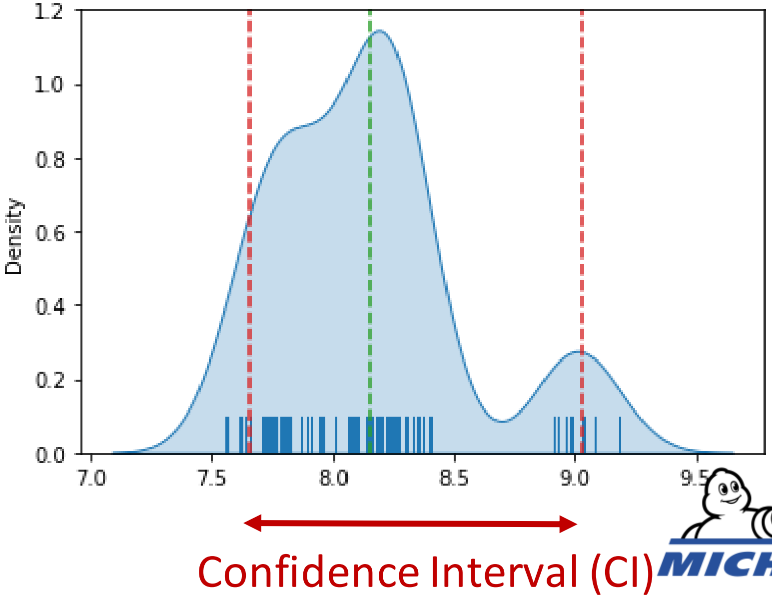




To an ensemble point of view

ID	KM	Xao …	Hsre	sre
1	KM1	0.87	2.7	Sre1





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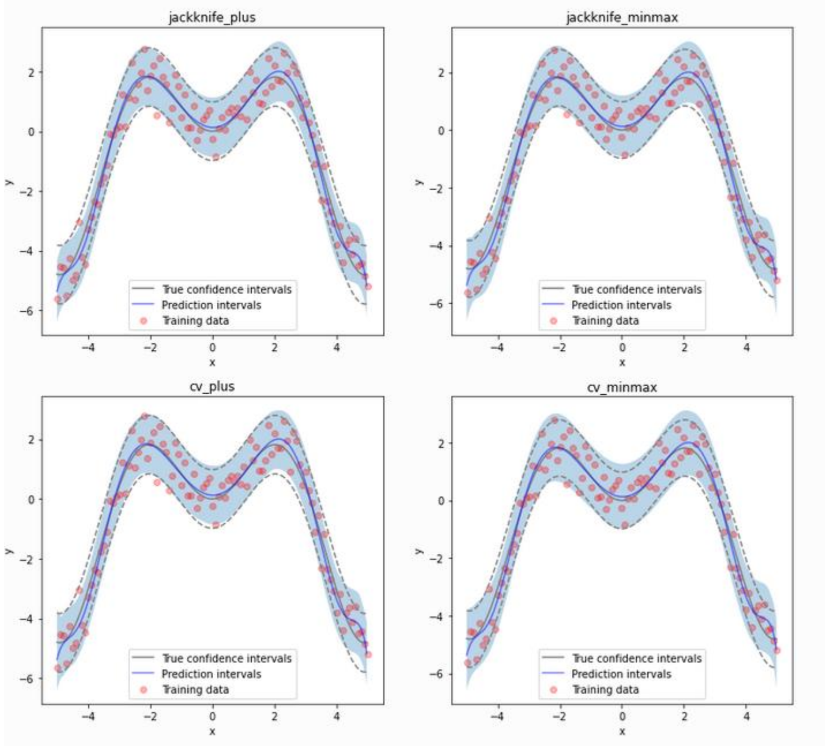
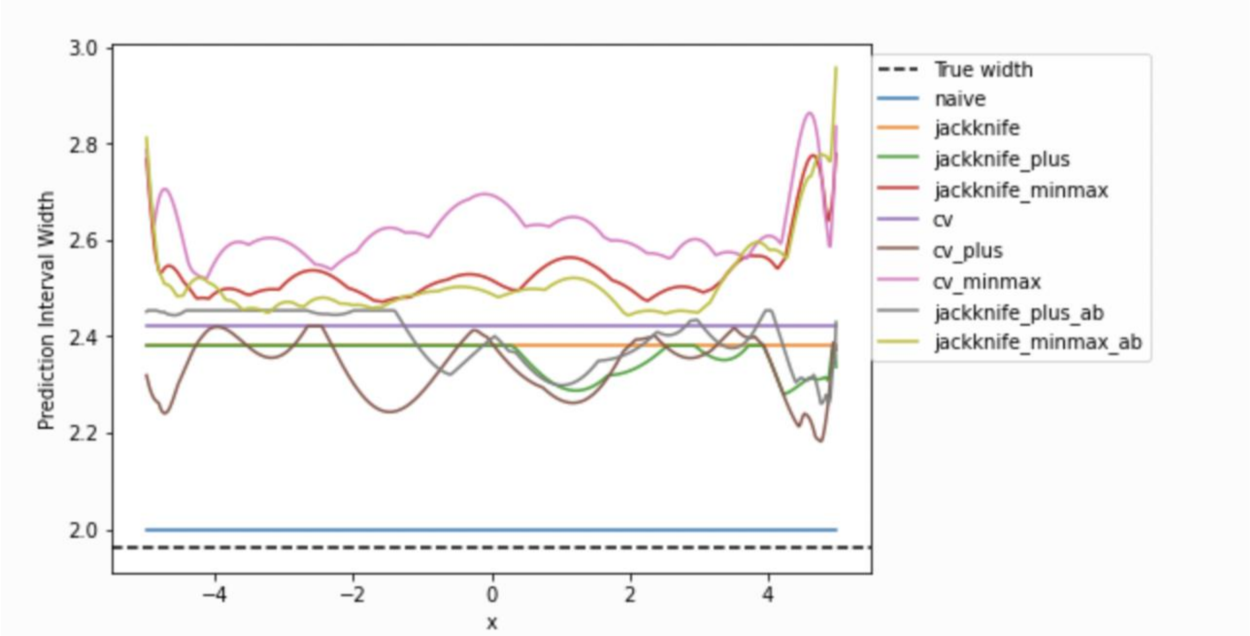
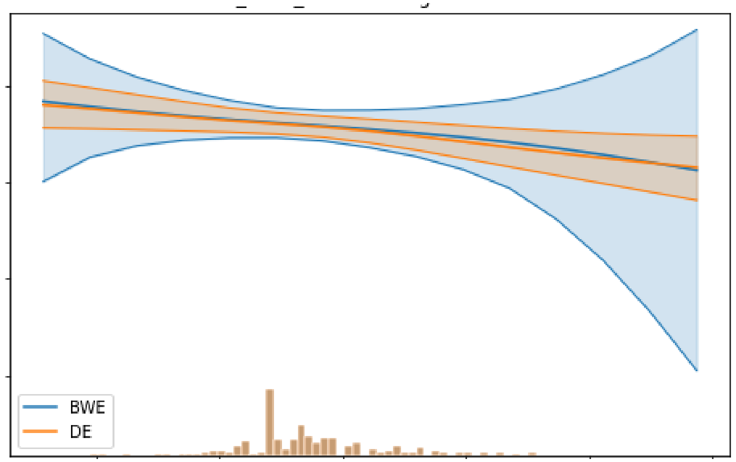
Assess quality from uncertainty approaches

Can we use local uncertainty ?



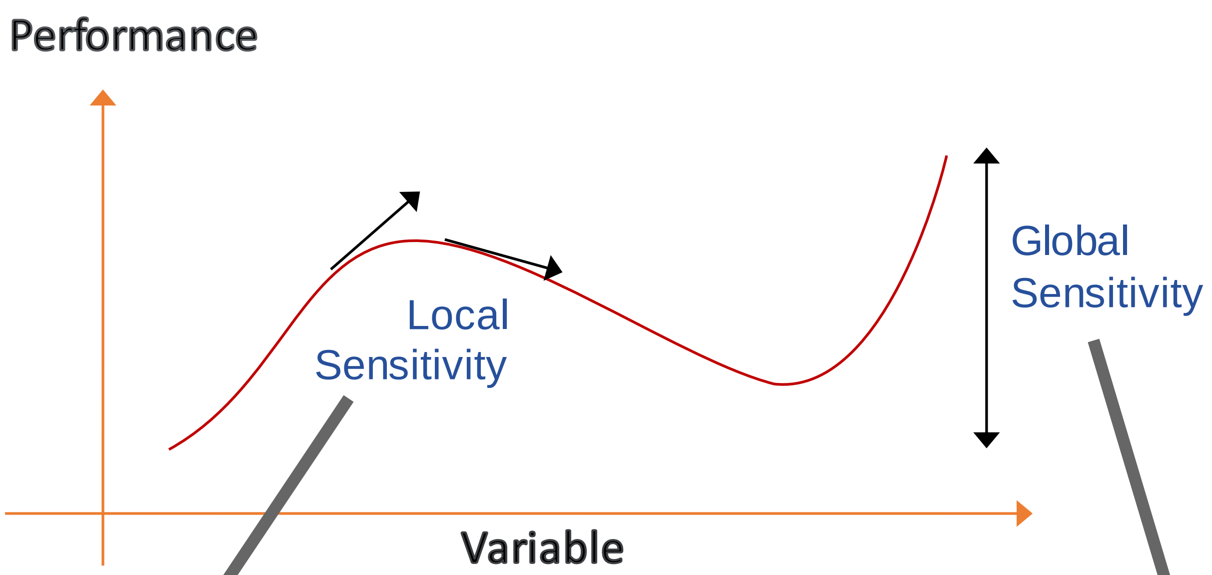
https://github.com/simai-ml/MAPIE

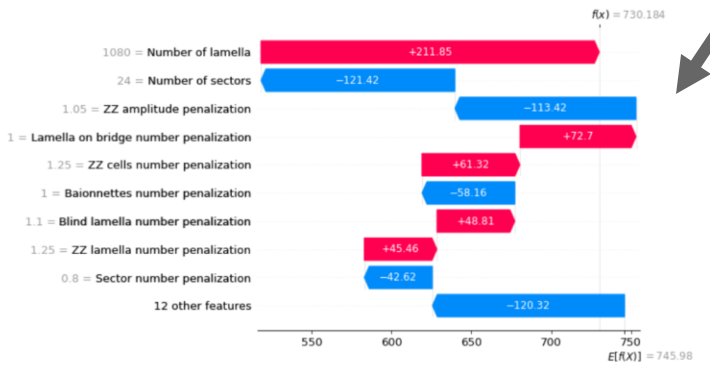




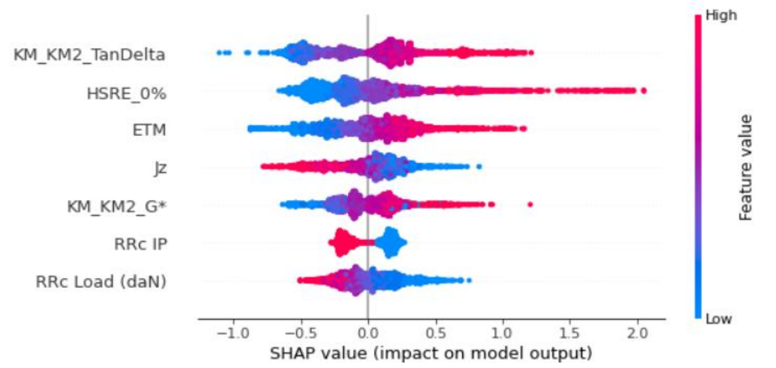
Physical validity – *to be assessed with Subject Matter Expert*

Intuition on
“eXplainable AI”





Sensitivities between 2 designs



Importance value over the domain

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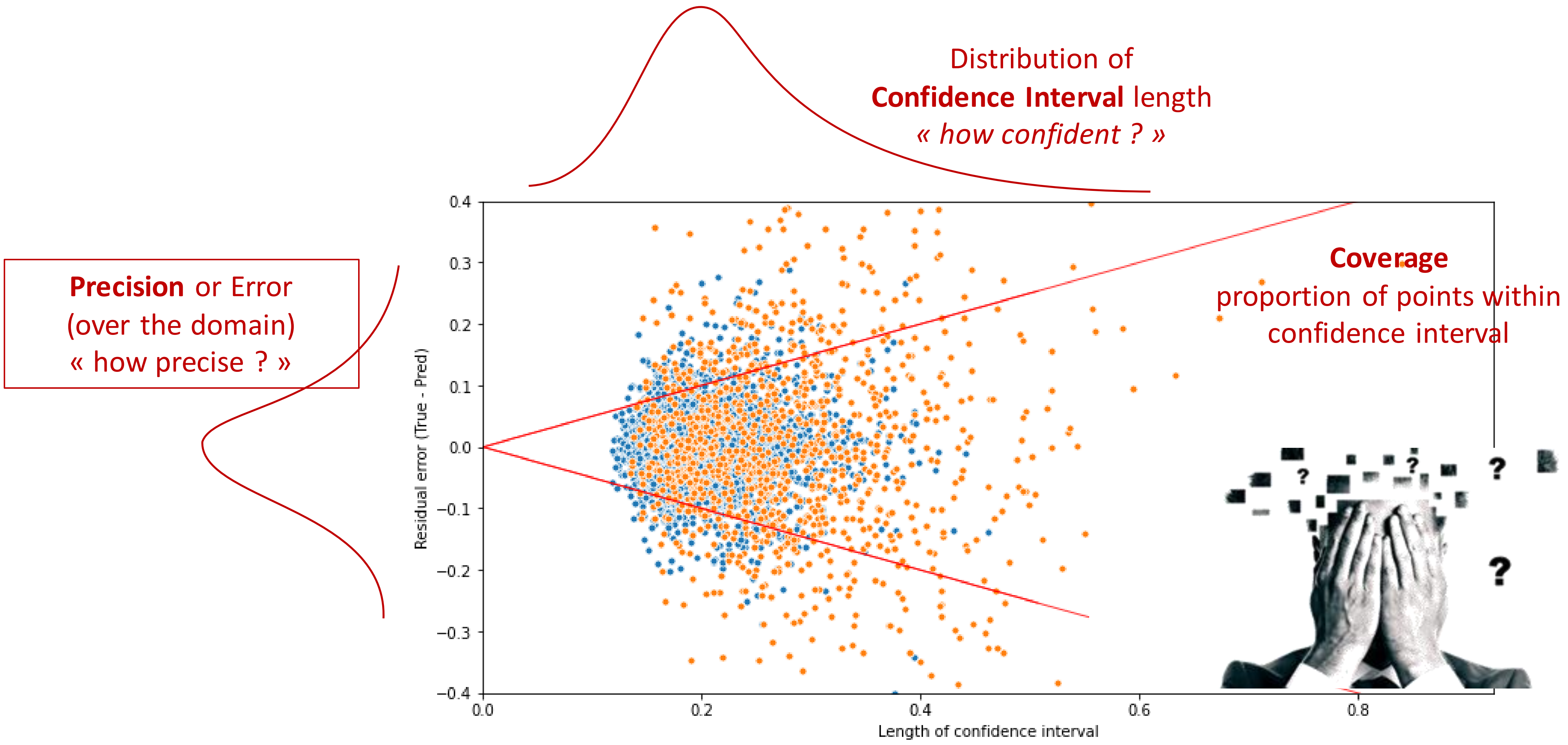
AI Model validation – beyond R^2

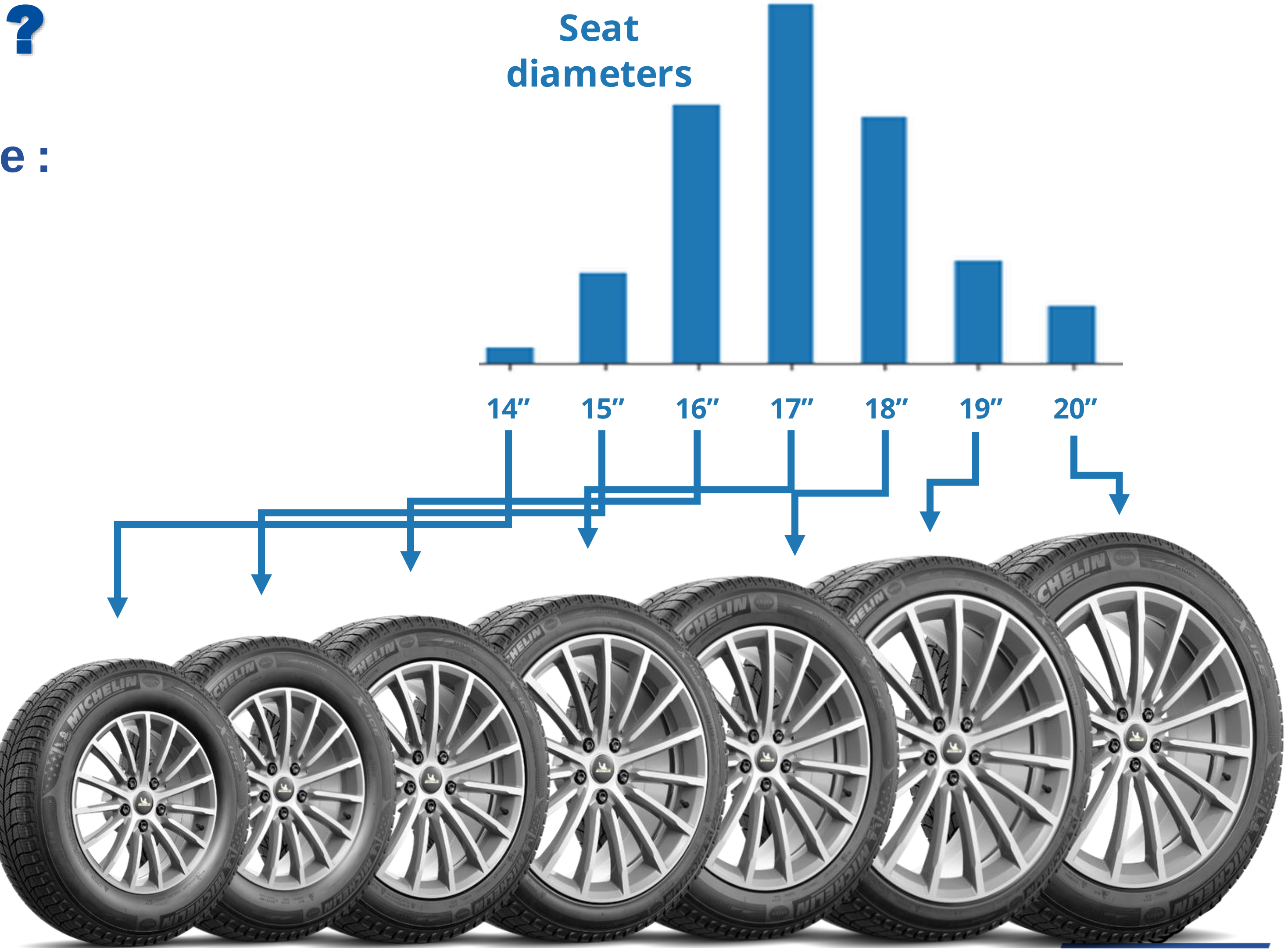


Which perimeters are ok ?

1) To identify the perimeters to analyse :

- Summer / Winter / Sporty tires

- Tire dimensions / Seat diameters
- Manufacturing process / Plants
- Etc…



2) For each perimeter, captation of possible biases and their impacts

Coverage and Precision :
key performance indicators to manage biaises

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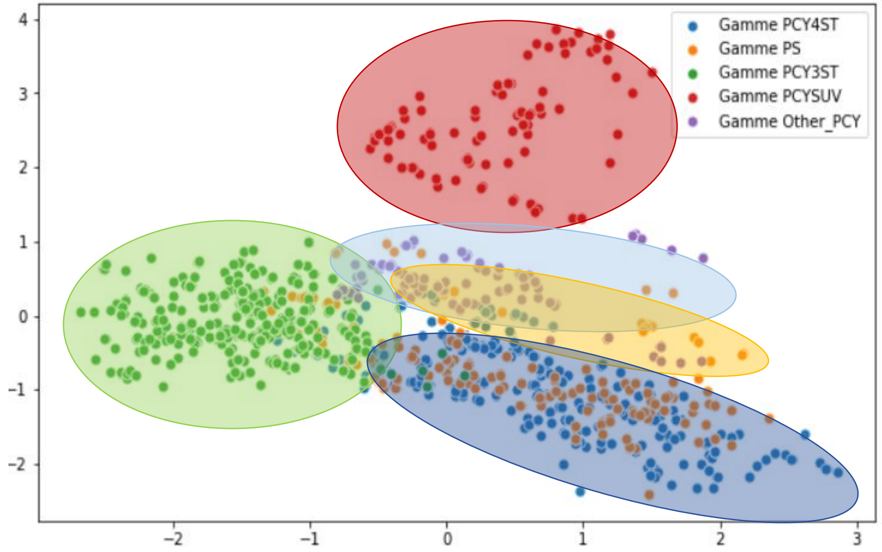
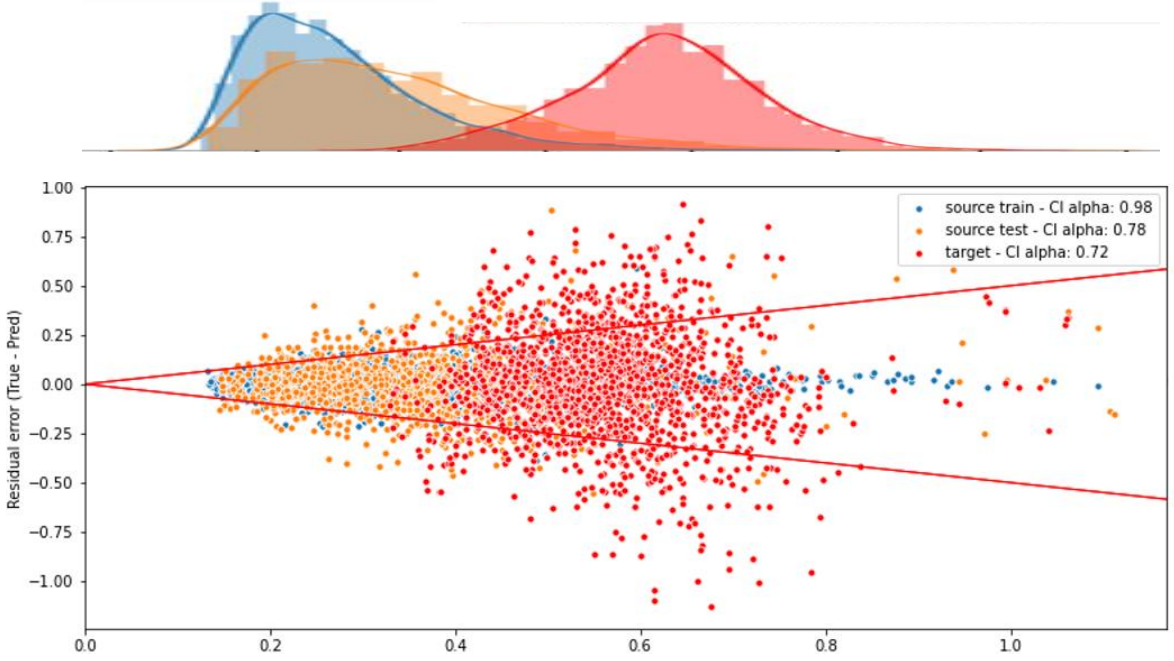
How to maintain AI performance over time ?

We played a game…

What if I remove one tireline, am I able to « detect » uncertainty zone ?

Tire design space projection





Length of confidence interval

Such indicator enables

- the maintenance of our model in operations – continuous learning – frugal
- the risk management on local decision

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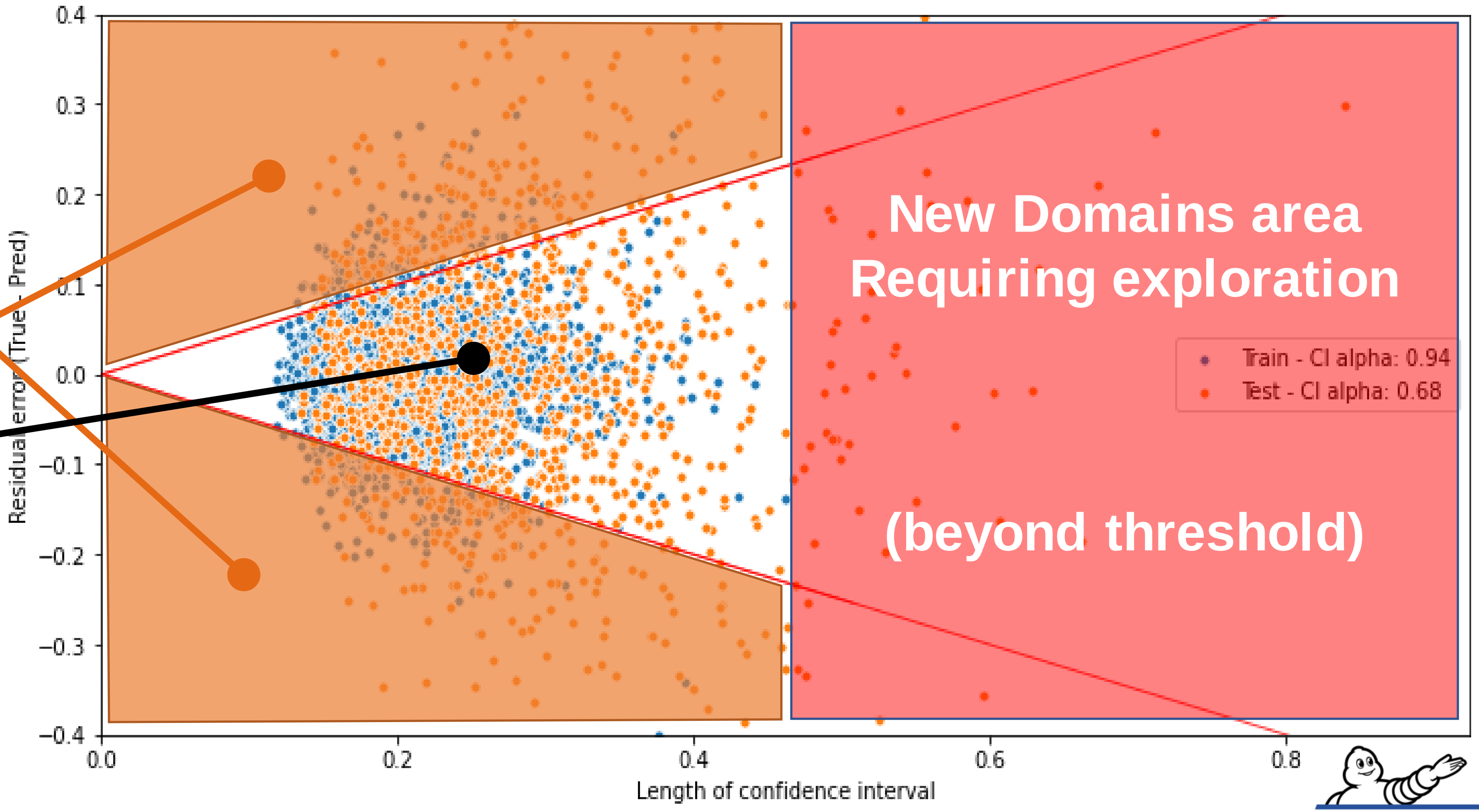
Uncertainty prediction to manage error risks ?

Global Risk = #pts in orange areas / #pts in blank area



Global risk estimation must be evaluated with respect to business stakes

Toward a model Audit framework
Different metrics for different actors

Expertise	Actors	Questions & Interactions with AI
High AI expertise Low *Metier* expertise	AI designer data scientist	- what is the performance of my model ? Its uncertainty ? - what are the key drivers of the model ? - Is there any biais in my dataset ?
Medium AI expertise High *Metier* expertise	Performance engineer AI co-designer	- Is the model aligned with its usage chain ? - Can I learn new rules from that model ? *sensitivity* - What is the validity domain ot the model ? *Stress test*
Low AI expertise High Metier expertise	AI consumer Mat/Tire designer	- What is the confidence in the prediction ? - What are levers around that conception point ? - How can we explain evolution between those 2 designs ?
Medium AI expertise High Metier expertise	AI Audit Fellow metier	- do we have an identity card of the model ? Validation, explicability, validation domain, risk assessment

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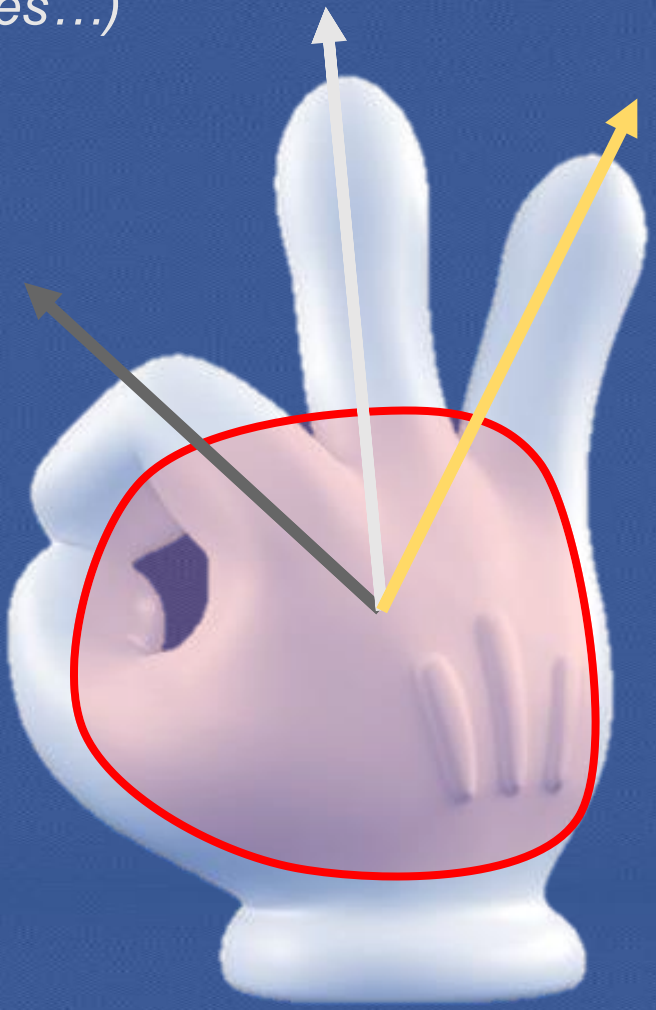
Validating models fits on Mickey's hand

Which domains are ok ?
(tirelines, process, zones…)

How long model stays valid ? (new tireline ?)

Physical validity ?
(ok with knowledge ?)



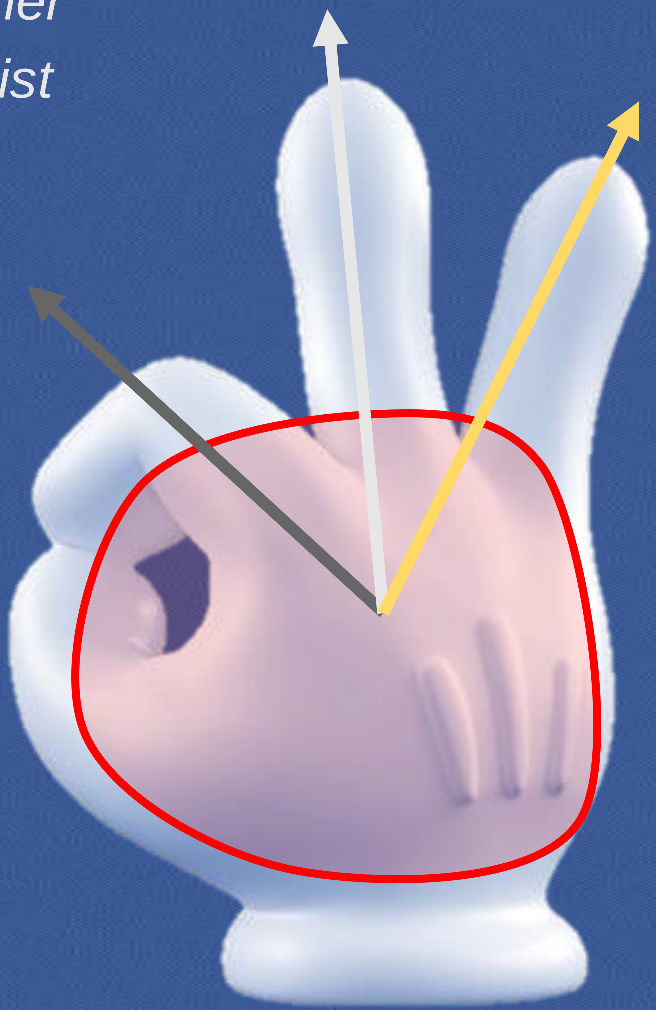
What are the usage limitations to manage error risks ?

To validate, a multidisciplinary team is key

Domains and bias

➔ *Product owner*

➔ *Data Scientist*



Validity with time

➔ *Data Scientist*

Physical validity

➔ *Performance analysts*
➔ *Experts*

Risk management

➔ *Quality partners*
➔ *Decision making process management*

It looks like … Uncertainty Quantification

What seems new on AI has been around in engineering

Simulation / Physical models	Data models (Statistics inc.)
Code quality, CI/CD	MLOps
Computation verifications	Error metrics
Uncertainty quantification	Prediction uncertainty
Sensitivity analysis	Explainability
Reproductibility	Model monitoring
Validation perimeter	Drift monitoring
H&Q with business	Human in the loop
Non-regression test basis	Data gouvernance & quality
Reception test-cases	Model score-card

Thus, a revival of interest for UQ (by true interest or fear …)

- UQ is getting a **new dynamic** from the data transformation with a better share of responsibilities
- Levers of models are more **business centric** in a way ?
- Business is asking to **homologate** product through models (even more since AI) – expecting more maybe ?
- **Not only** a Michelin challenge !

The way AI models are validated need to be certified ?

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Thanks for your attention !