The Living Digital Twin: 3 factors to get beyond the hype

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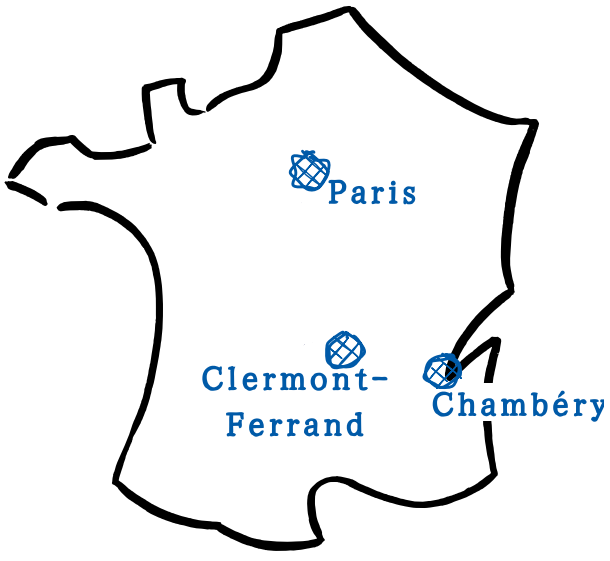
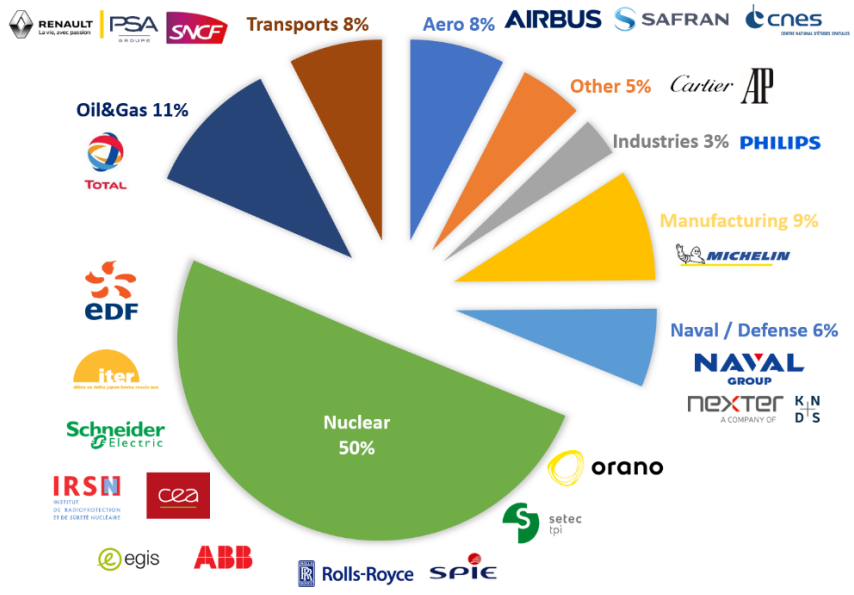
Phimeca: the responsible engineering

Build together, through innovative engineering, an industry caring for human and its environment.





- Since 2001
- 30 engineers and PhDs
- Tech. studies, software development, R&D, consulting, training

“Digital twin”: a buzzword?

Quite like “artificial intelligence” digital twin is

- a catch-all term with fascinating connotation,
- an old concept revived during the last decade with lots (overly?) alluring promises,
- achieving impressive results, *in some particular settings*.

We ear that (some flavour of) digital twin are on the verge of industrialisation. . .

. . . but to many of us it mostly brings frustration or disillusion.

Disclaimer: our definition

Let call *digital twin*

\+ a physical model capable of simulation
\+ and a procedure for regular confrontation with observations
→ to produce a service.

NOT a digital copy of something "real".

↑ The differences are subtle... can you see it?

« No word ever has exactly the same meaning twice. » – Simon I. Hayakawa, *Language in Thought and Action* (1949).

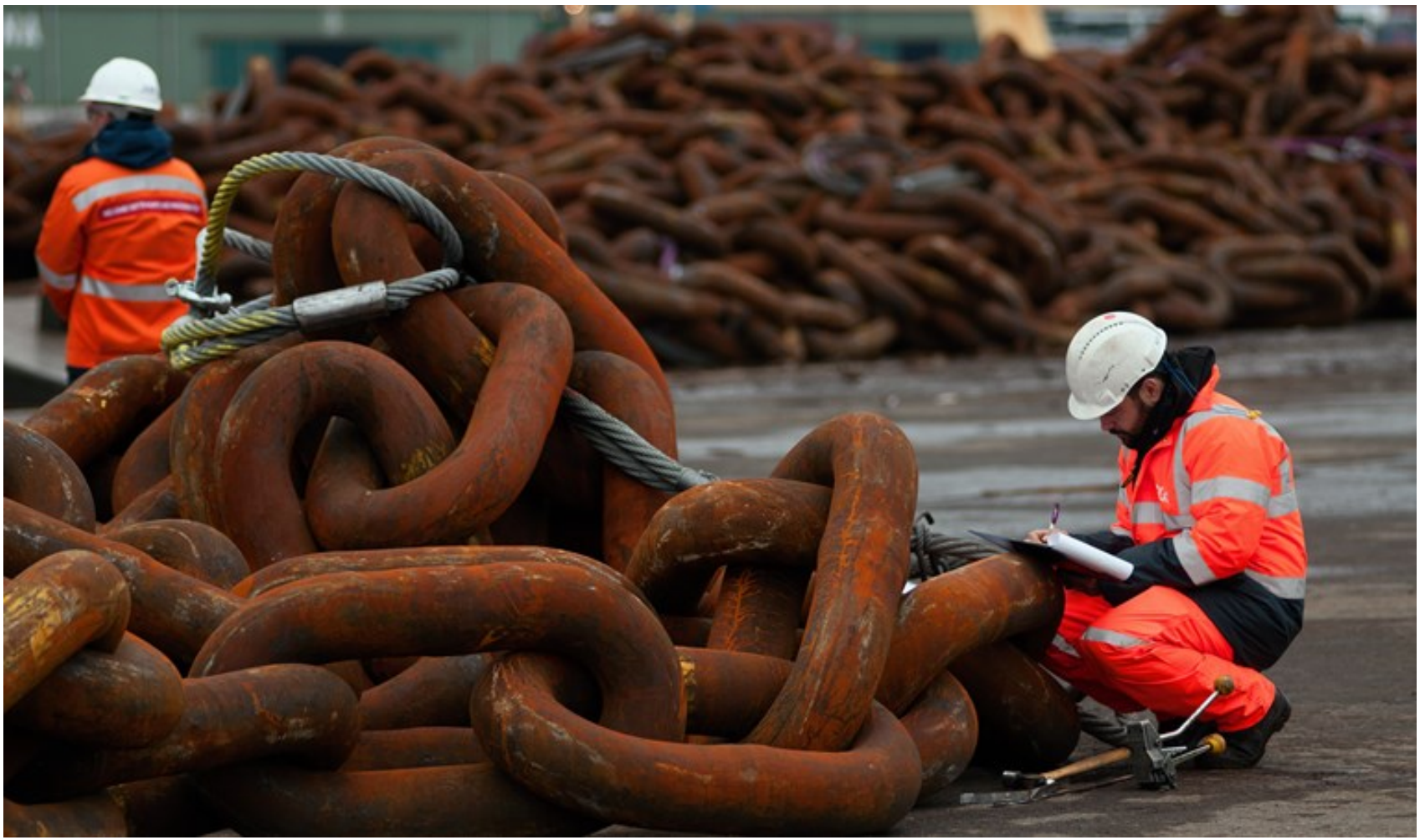
Keeping it alive: 3 levers

1. **Robust and interpretable machine learning**

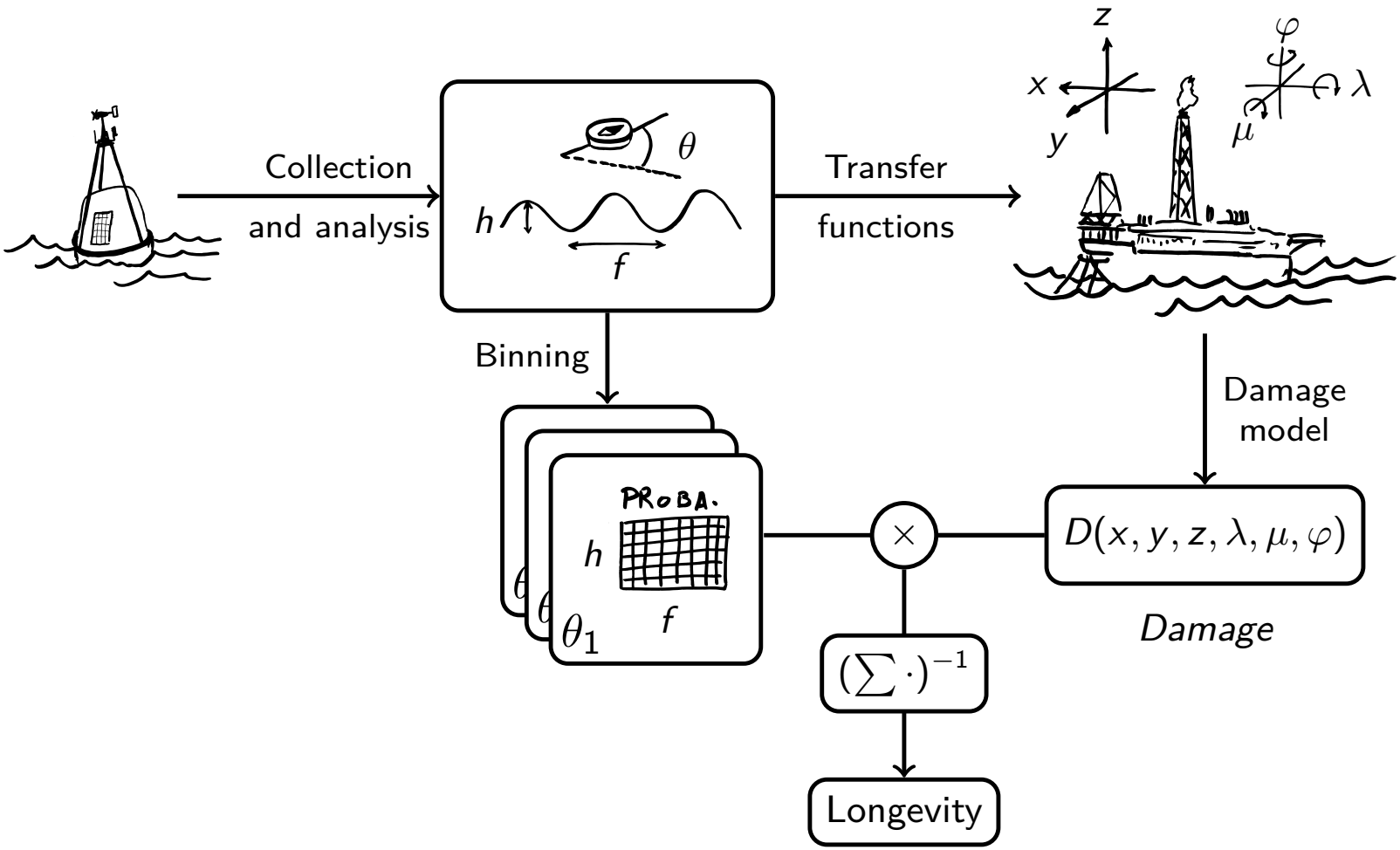
Example: monitoring offshore mooring lines

Bend a paper clip over and over again. . .

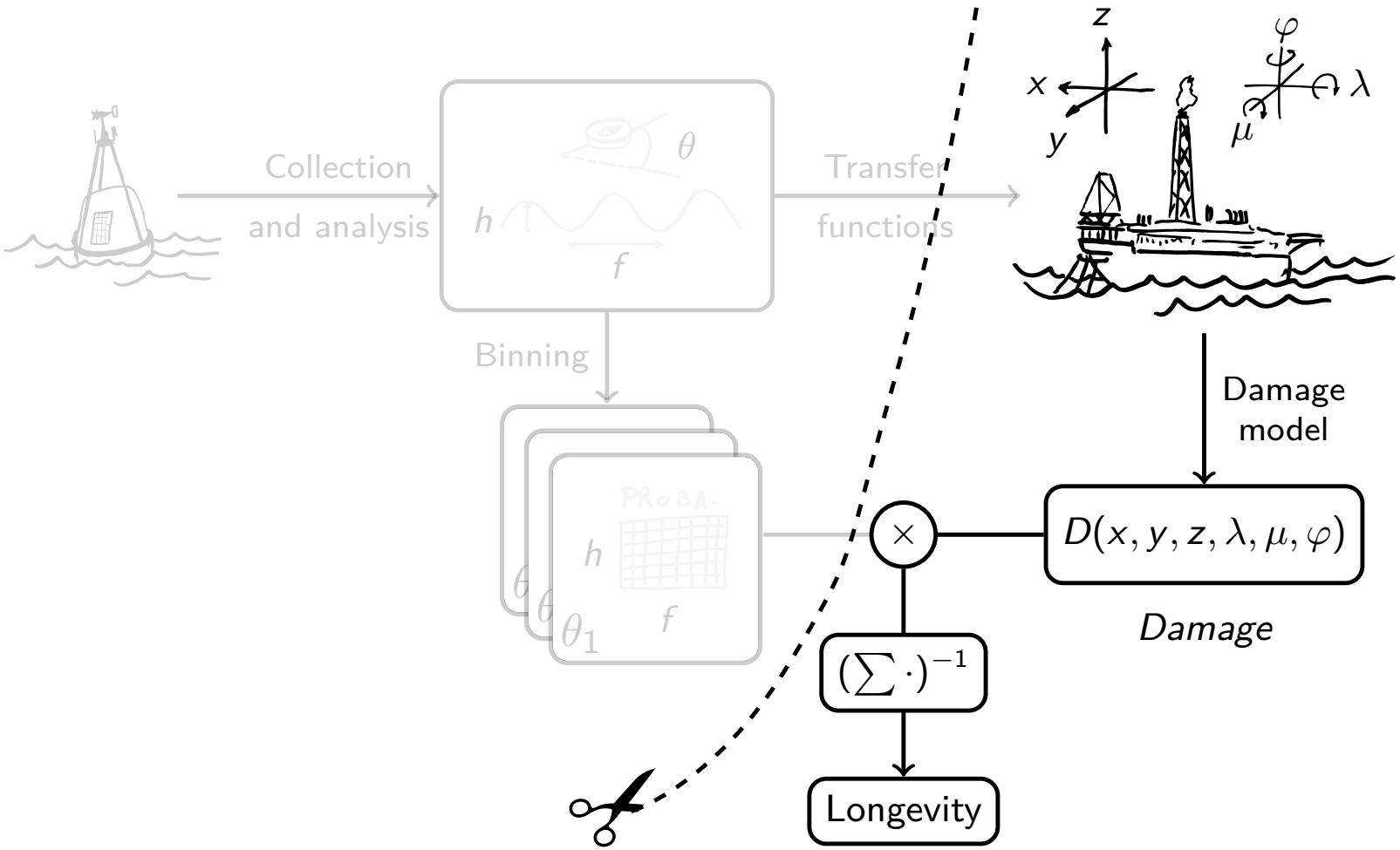
. . . it suddenly breaks by mechanical fatigue.



Traditional longevity prognosis

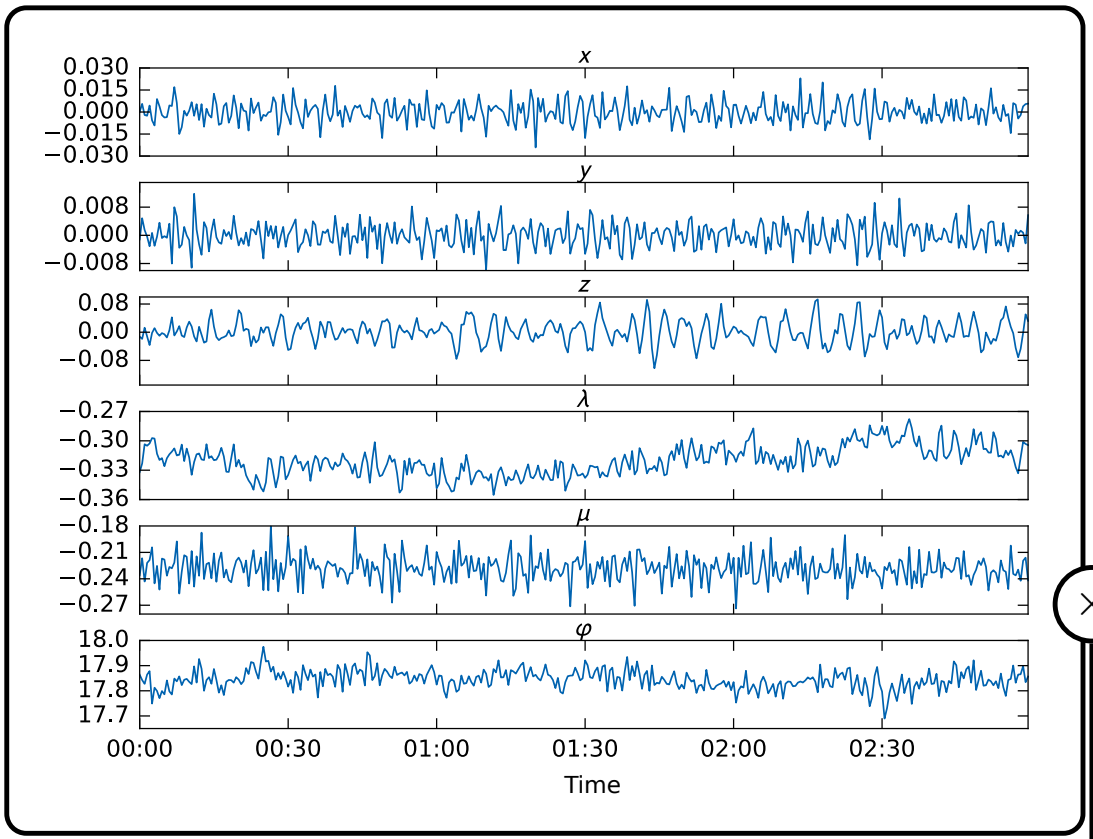


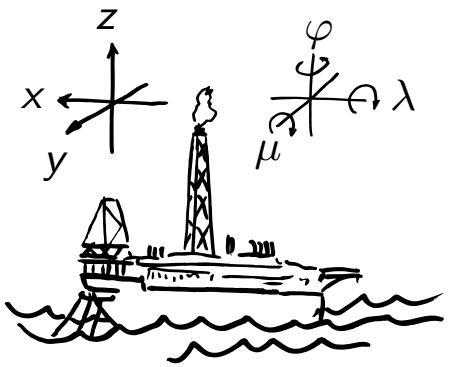
Let use onboard motion recording



We care about motion not waves!

High regression problem → neural net ?





Damage model

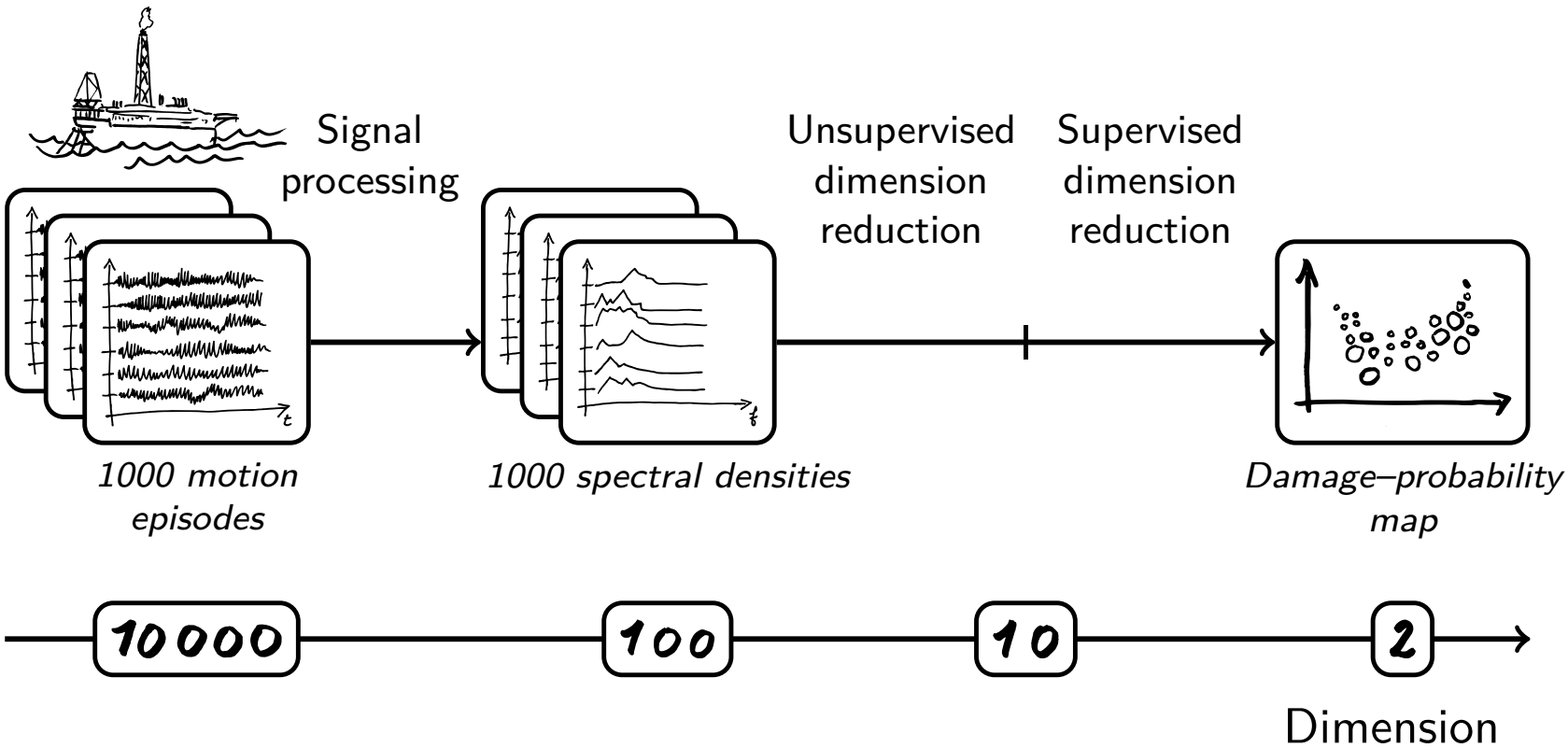
$D(x, y, z, \lambda, \mu, \varphi)$

Damage

×

Longevity

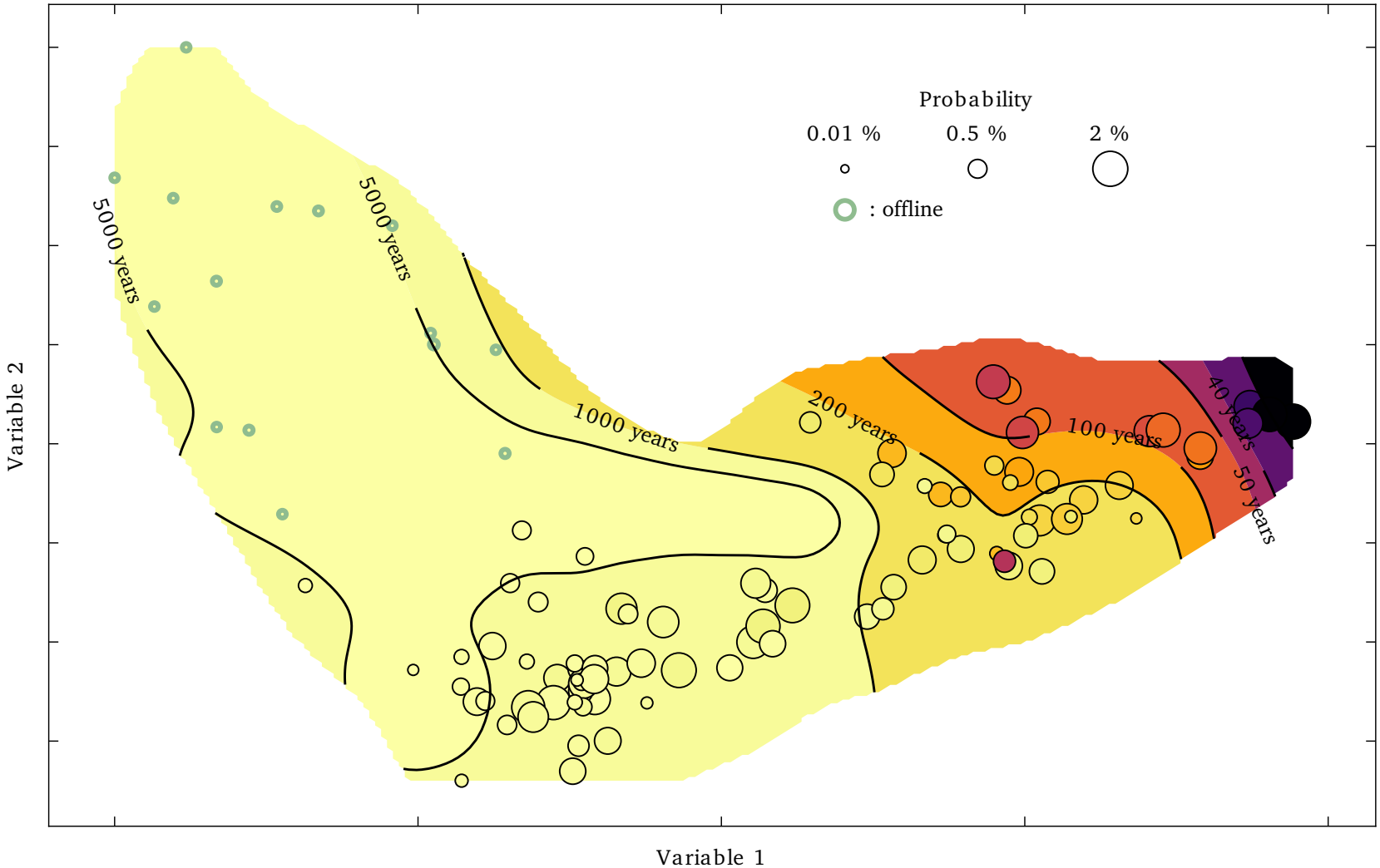
Supervised dimension reduction



We find a topology invariant projection with a few hundred simulations only.

$\rightarrow$ PCA-like methods e.g. Sliced Inverse Regression (supervised) or Auto-associative Model (non-linear).

Continuously updated damage map



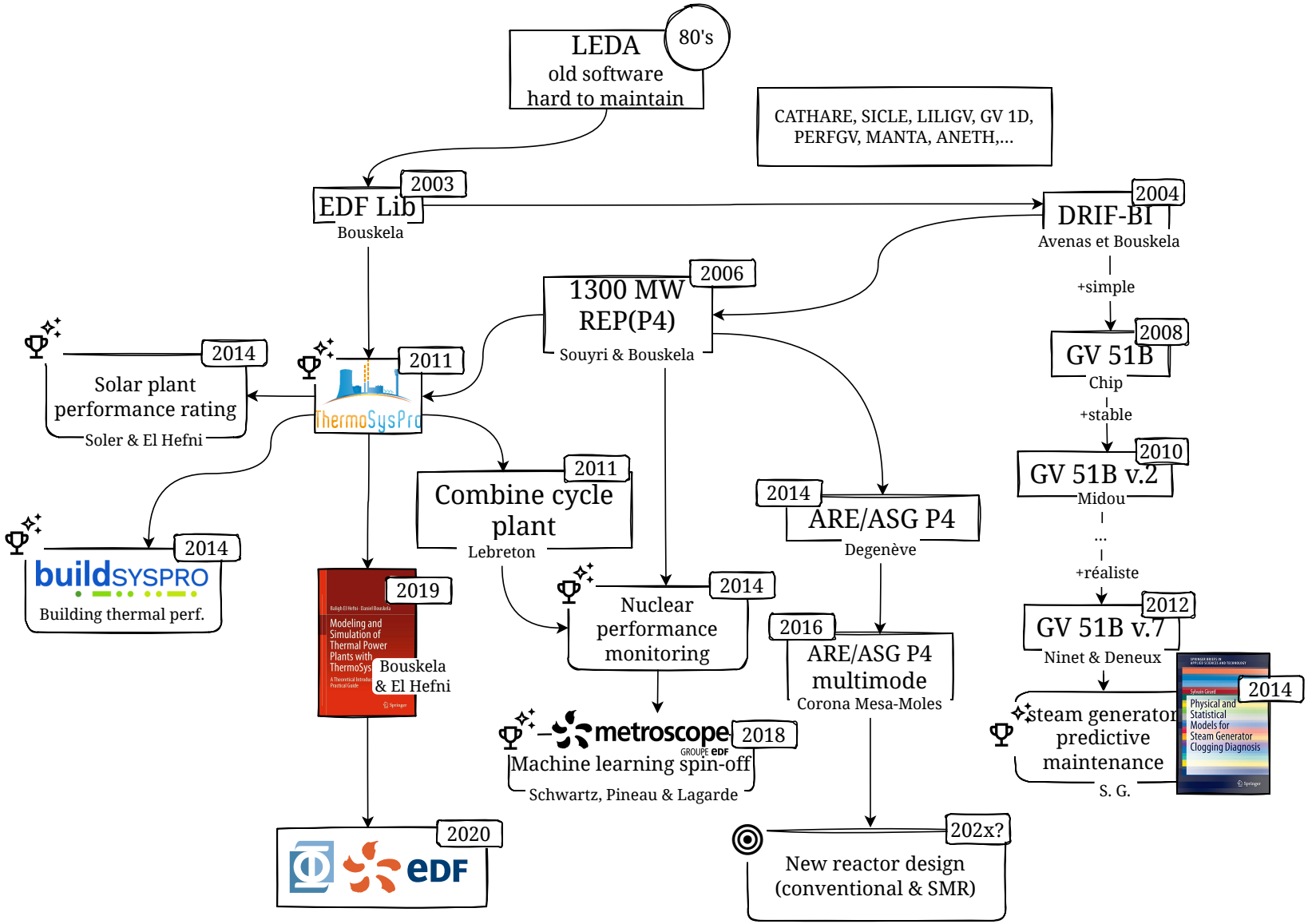
- Motion is encoded in 2D.

Keeping it alive: 3 levers

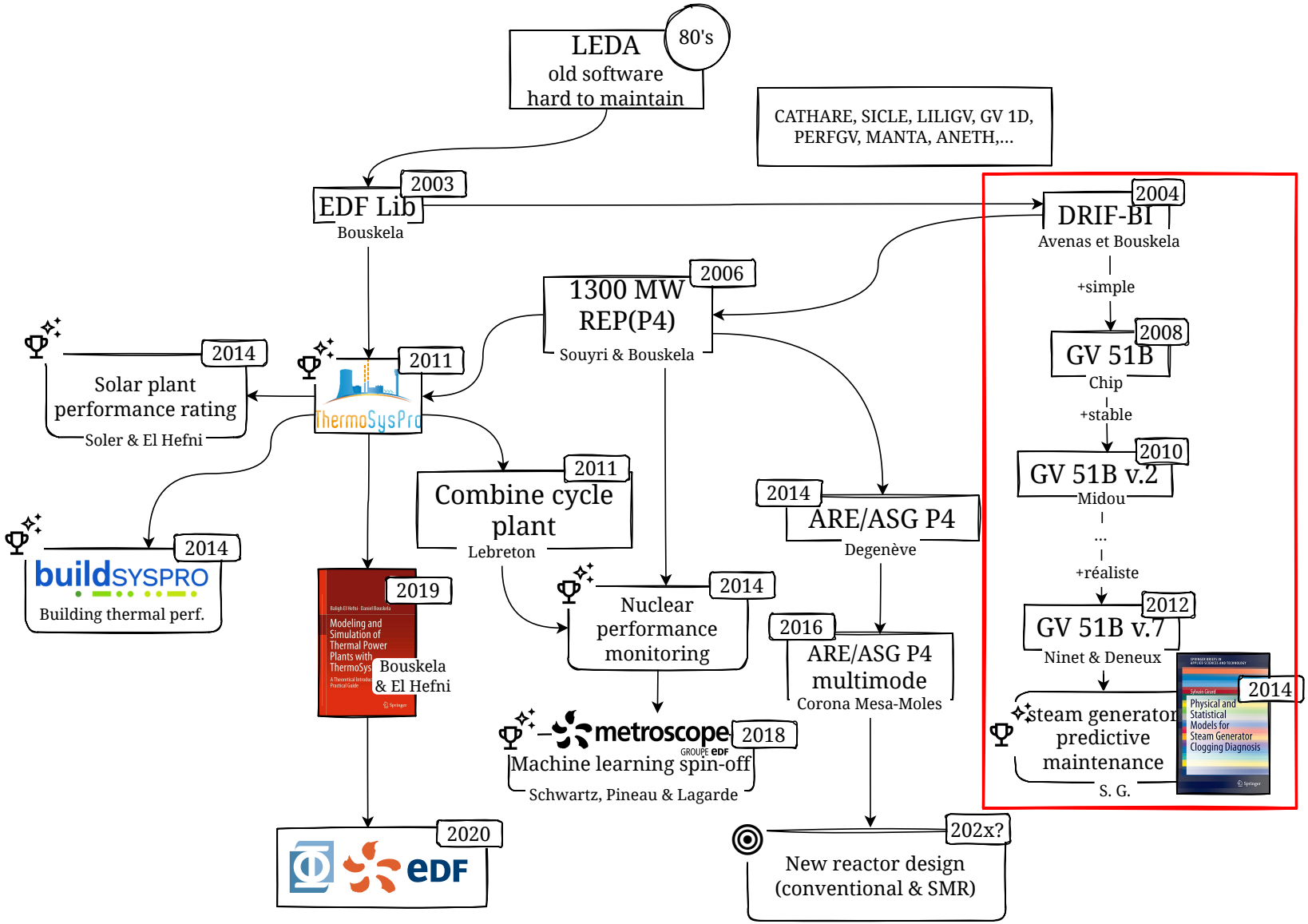
1. **Robust and interpretable machine learning**

2. **Physical modelling as a knowledge creation process**

20 years of model driven innovation at EDF



Starting from scratch every 2 years. . . seriouly?



All knowledge is tacitly rooted

Explicit

- Text,
- Equations,
- software,
- mock-up,
- specifications,
- drawing,
- procedure. . .

Can be transcribed in a formal language

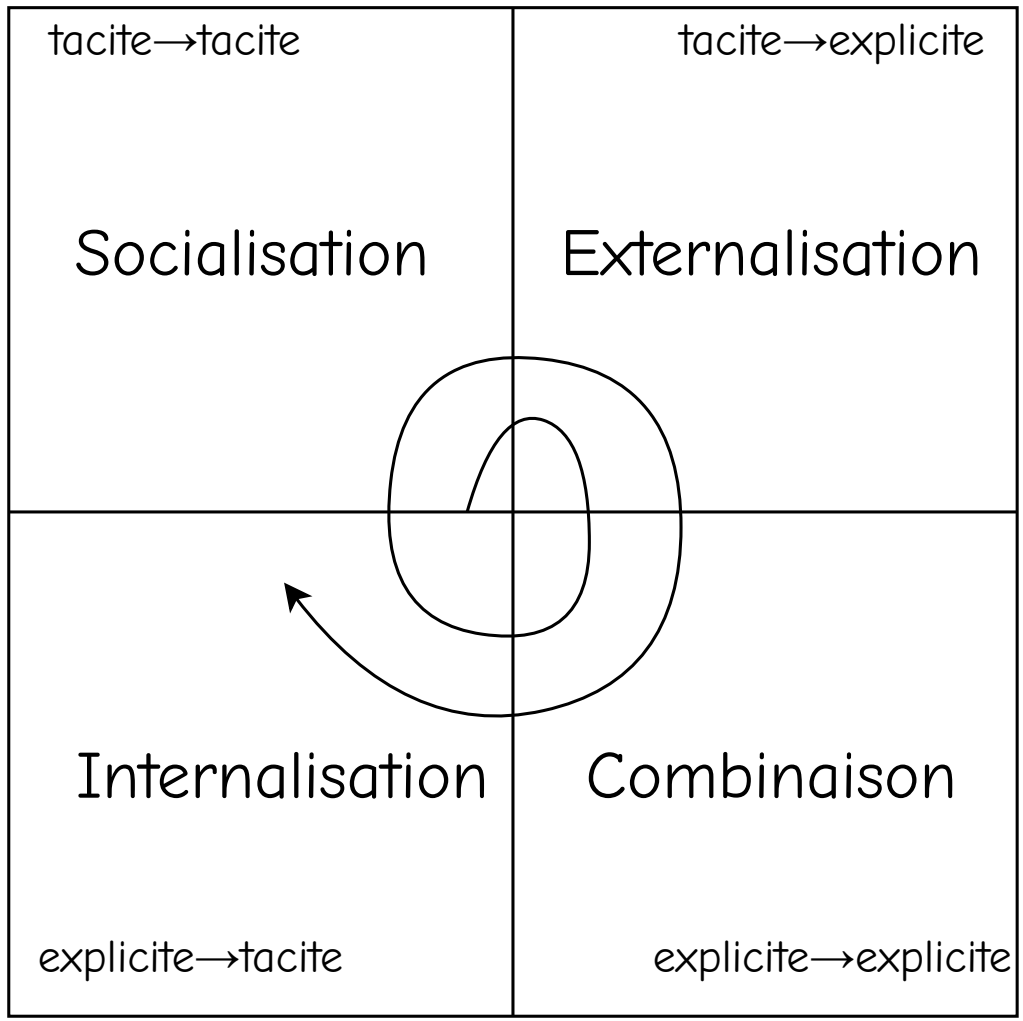
Tacit

- Beliefs
- view point,
- value systems,
- intuition,
- know-how. . .

Personnal et context depedent

Michael Polanyi, *« The tacit dimension »*, 1966.

The « SECI » knowledge creation model is highly relevant to physical modelling



Nonaka, Ikujiro & Takeuchi, Hirotaka « *The knowledge-creating company* », 1995.

4 dimensions to physical modelling

 **Individual** : Understand $\rightarrow$ build knowledge

 **Group** : knowledge amplification $\rightarrow$ the organisation innovates

 **Simulation** : quantify physical constraints

$\rightarrow$ *Sizing, margin allocation, optimisation...*

 **Digital twin** : models produce services

$\rightarrow$ *Monitoring, predictive maintenance, decision making...*

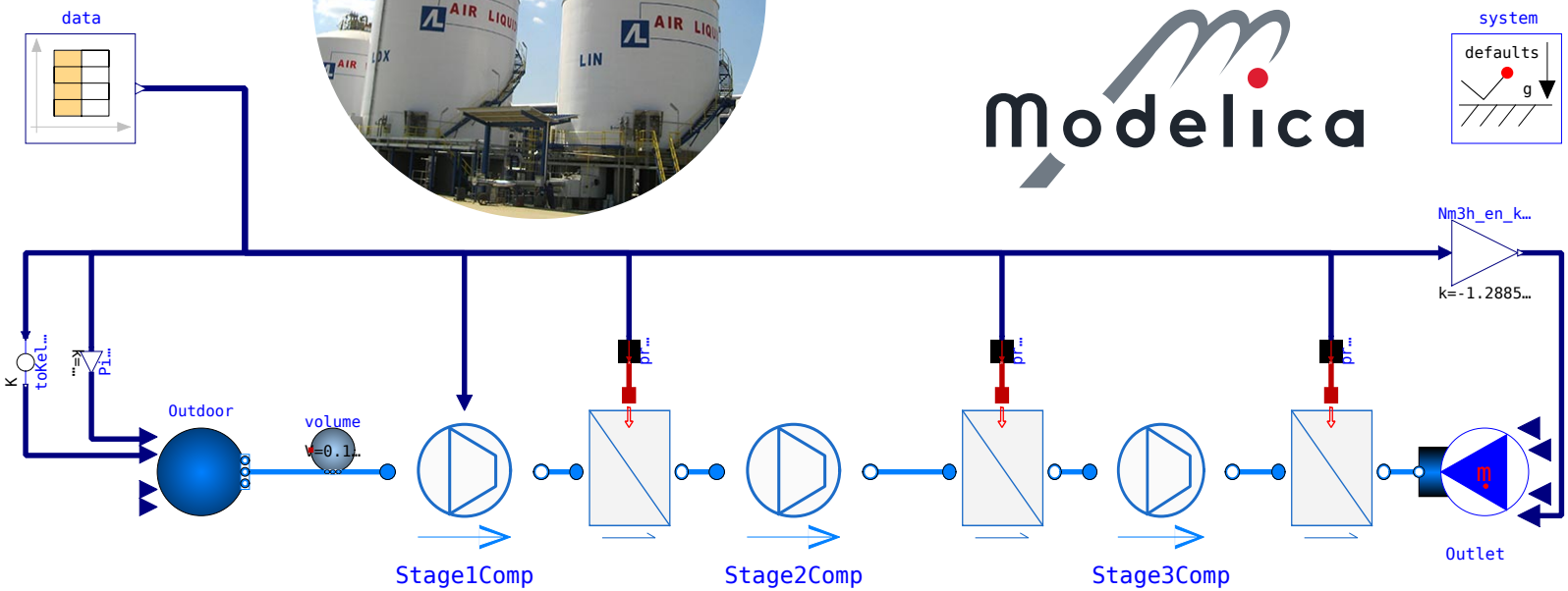
Keeping it alive: 3 levers

1. **Robust and interpretable machine learning**

2. **Physical modelling as a knowledge creation process**

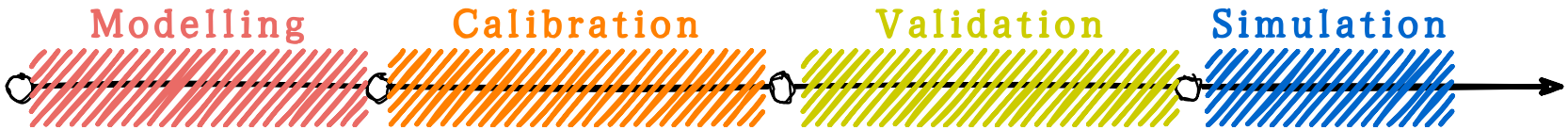
3. **Continuous reassessment of models**

Example: an air compressor model

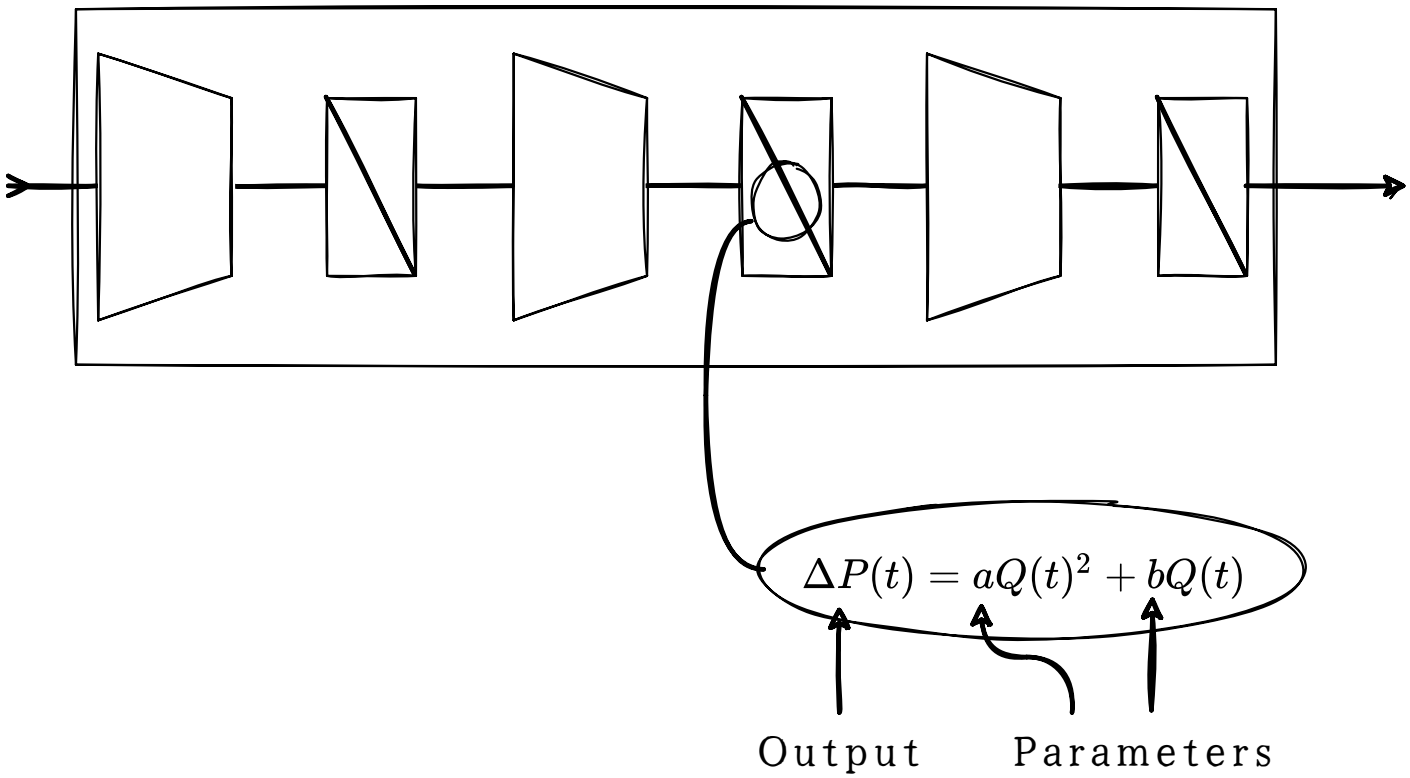


Traditional model development

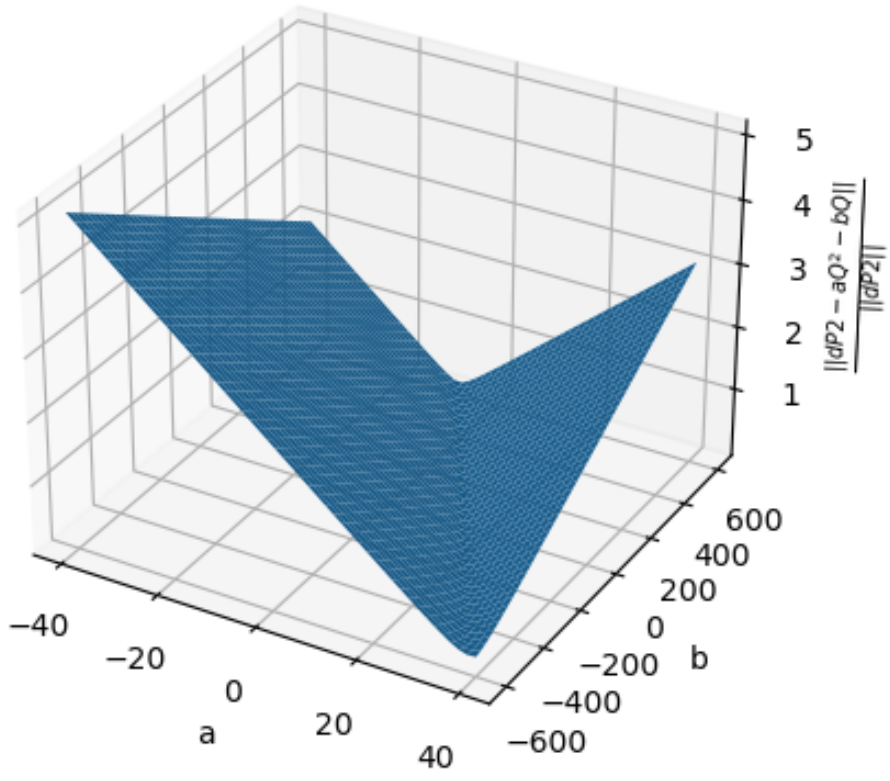
- **Once and for all**: fit *then* use



- **Local** calibration: component by component

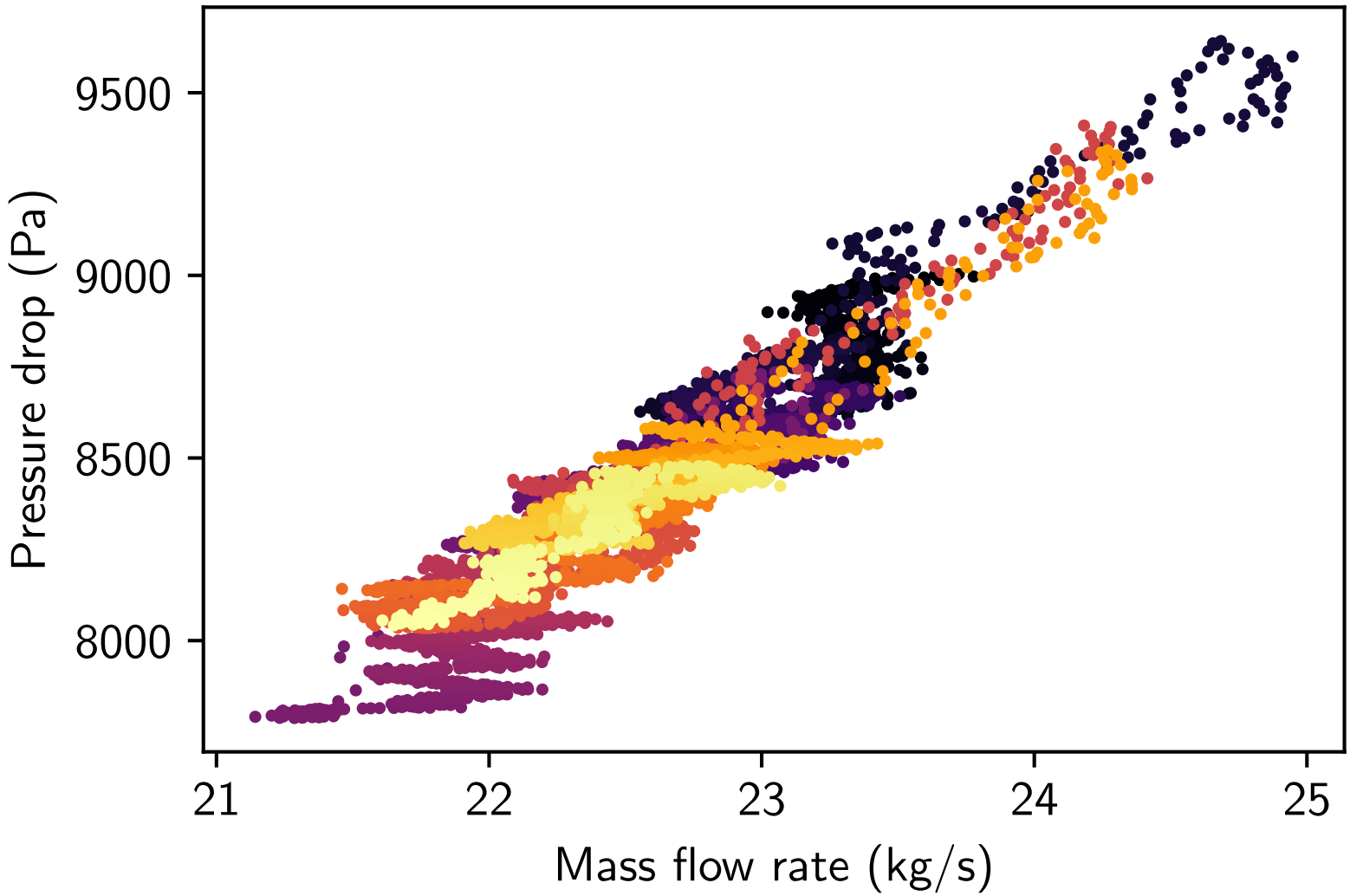


Parameter fitting is often ambiguous



At the bottom of the "pit", any $(\hat{a}, \hat{b})$ pair is (almost) as good as any other

“Best” parameters may fluctuate in time



Colour indicates date of measurement.

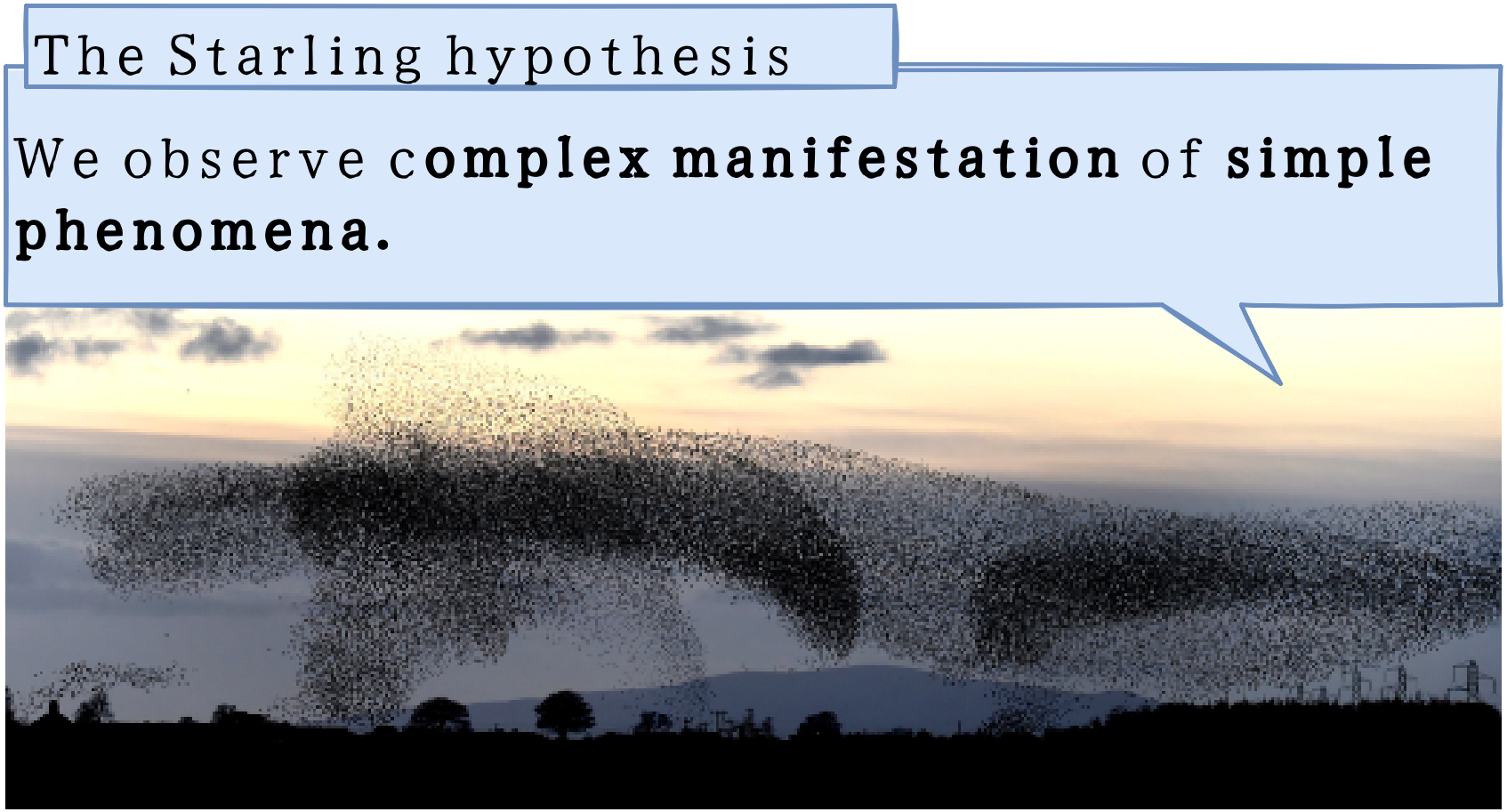
Towards more dynamic and holistic model development

1. Conjunction of local optima $\neq$ global optimum

2. Represented objects, context, and available knowledge continuously evolve $\rightarrow$ so should the model :

3. The whole distribution of simulation–observation difference carry a lot more information than a single simulation

Robust and interpretable machine learning



- (Supervised) dimension reduction is an example of robust, interpretable, frugal and theoretically founded machine learning.

Physical modelling as a knowledge creation process

Models are mostly **reasonings**, thus **intangible** and partially **tacit.**

- Emphasis the first two dimensions of physical modelling:
  1. **Individual**
  2. **Group**
  3. Simulation
  4. Digital twin

Continuous reassessment of models

How can you tell whether discrepancies stem from the **model**, **observer**, or "**reality**"?

- Use a Bayesian framework to track evolution of posterior distribution of parameters.

Thank you for your attention.

Let keep in touch

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