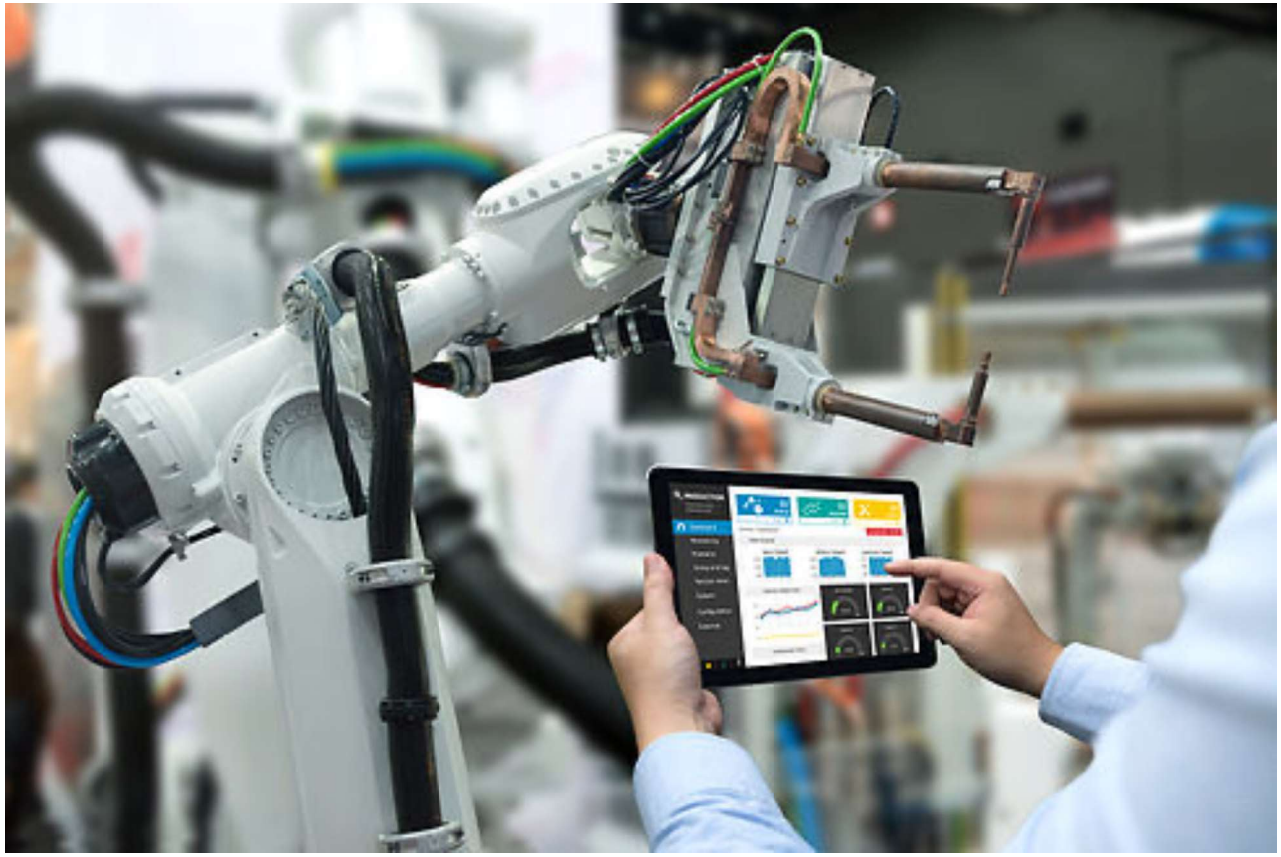
Predictive maintenance, heilige graal in zicht?

PrimaVera

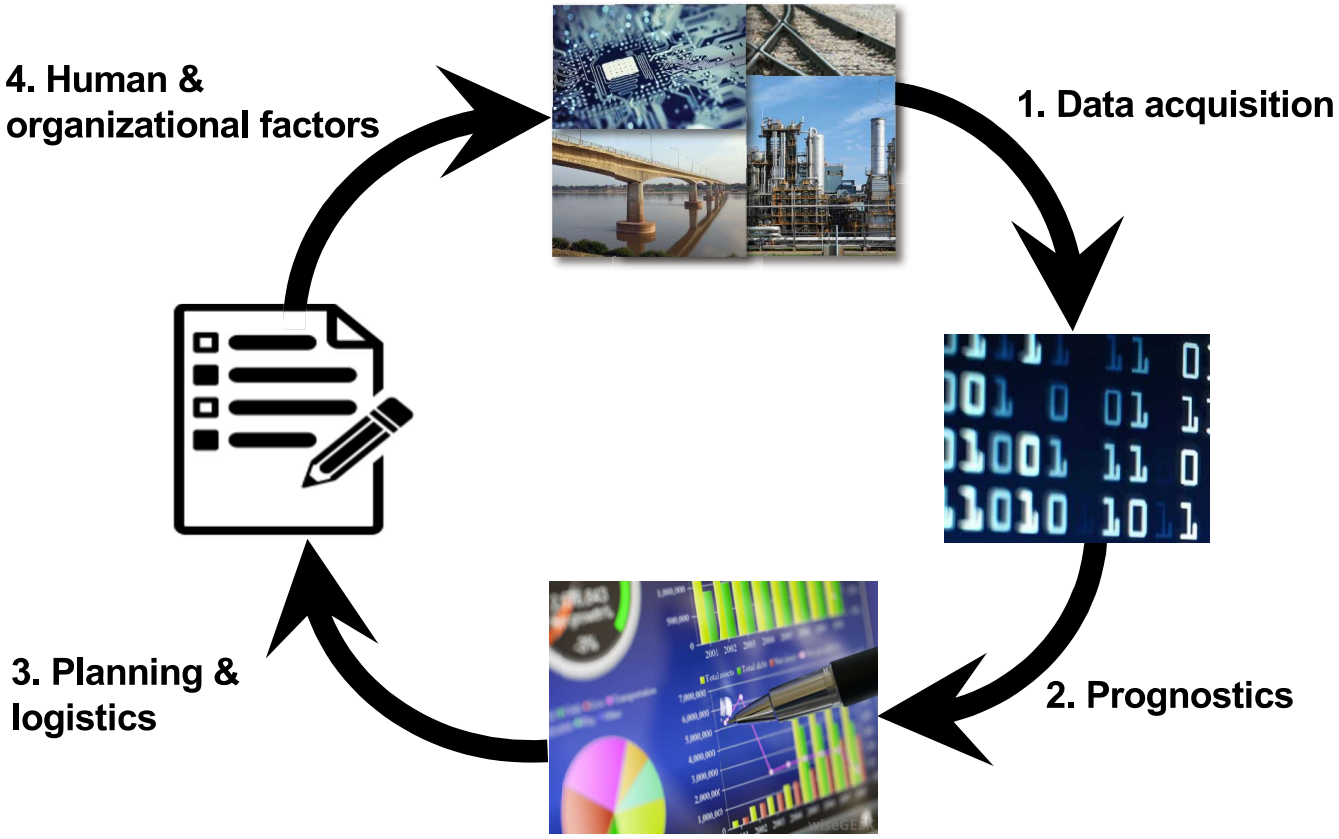
Predictive maintenance for Very effective asset management

Marielle Stoelinga

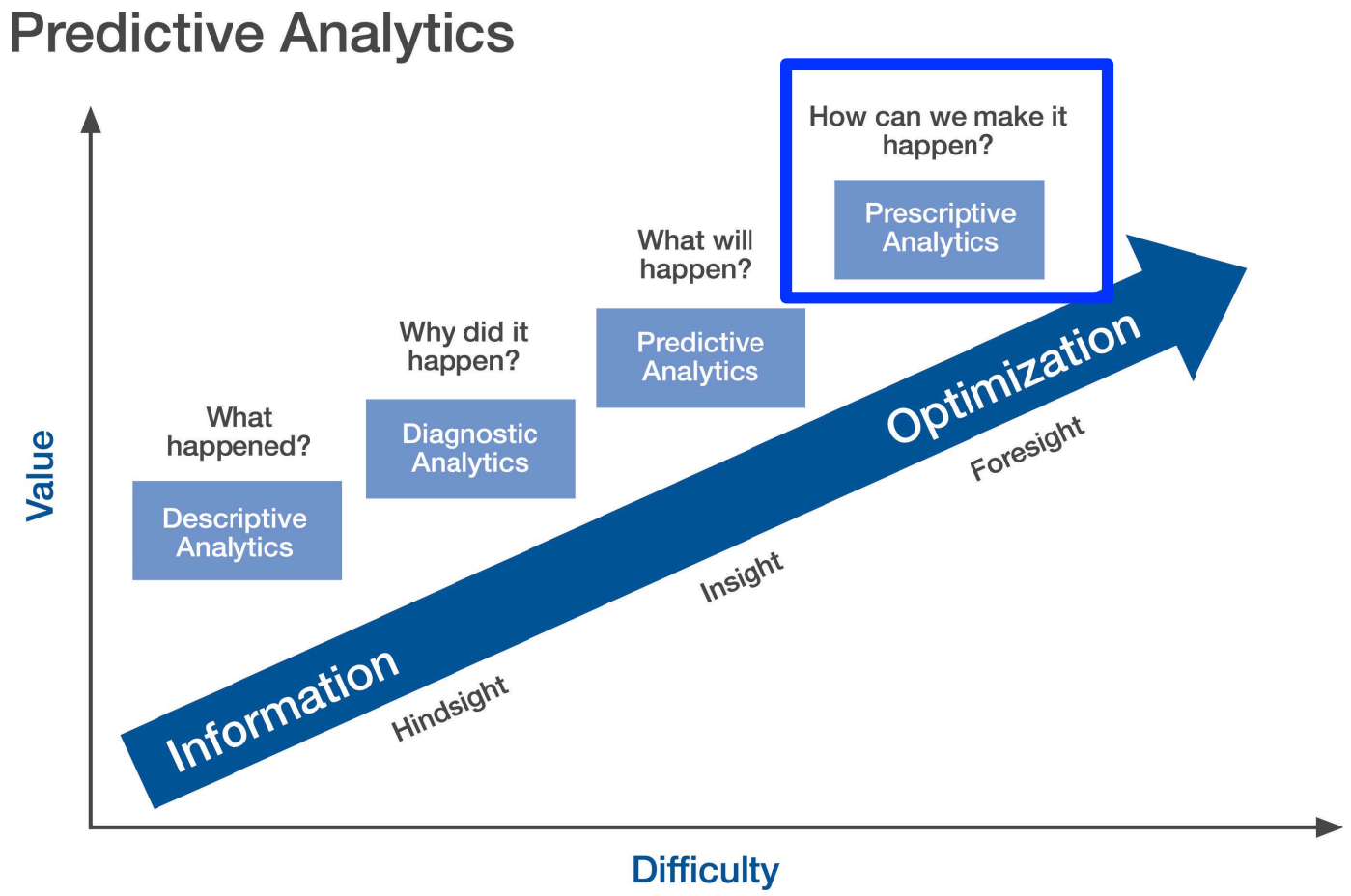
Predictive / data driven maintenance



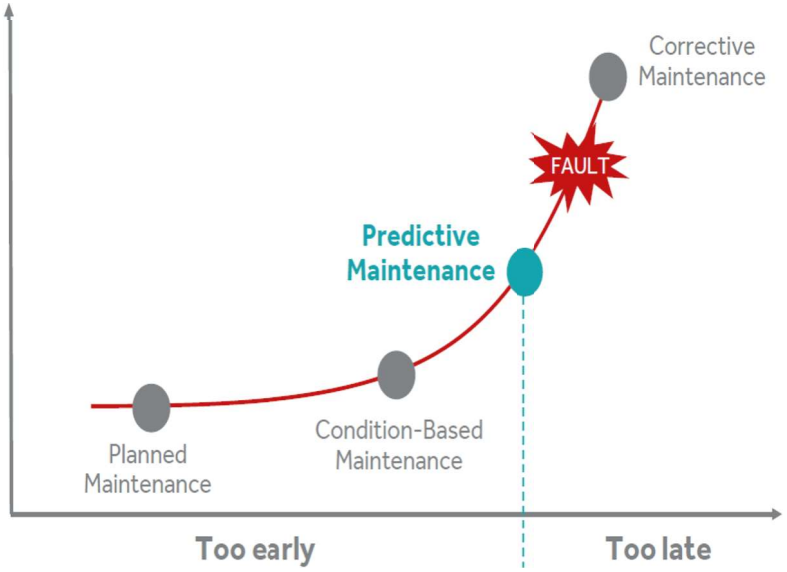
Predictive maintenance workflow



Predictive maintenance vs predictive analytics



Predictive maintenance

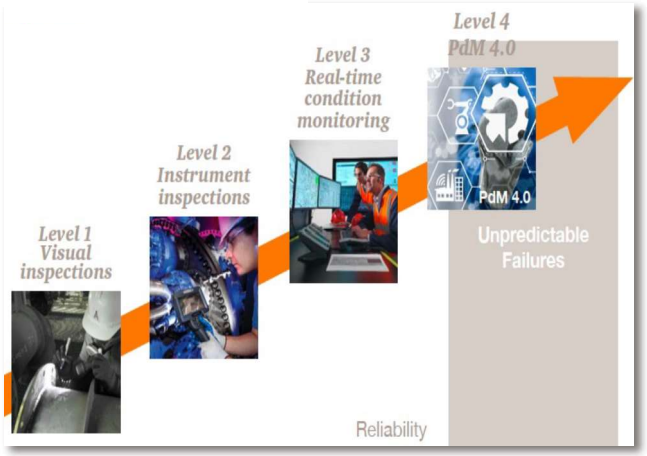


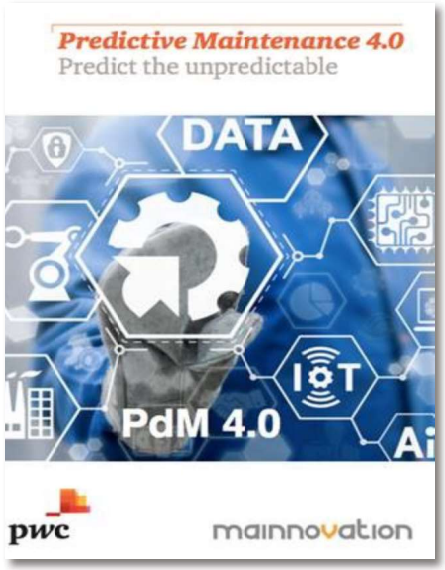
McKenzie

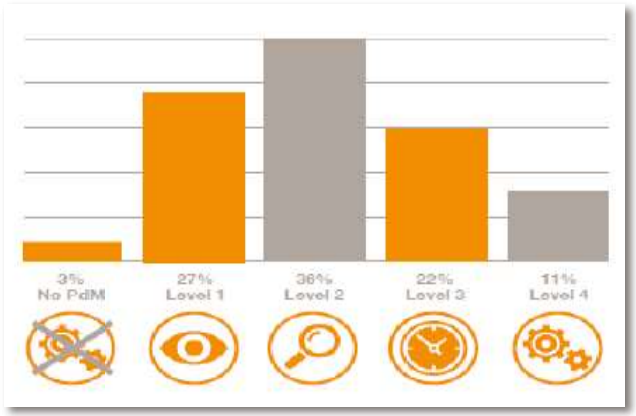
- PdM is most promising IoT application
- 63 billion / year cost savings
- 50% downtime reductions

https://www.mckinsey.com/~/media/mckinsey/industries/technology media and telecommunications/high tech/our insights/the internet of things the value of digitizing the physical world/the-internet-of-things-mapping-the-value-beyond-the-hype.ashx

Predictive maintenance: not easy







Realizing benefits not easy

- PdM technology not leveraged
- Small scale solutions, no holistic approach

https://www.pwc.nl/en/publicaties/predictive-maintenance-40-predict-the-unpredictable.html

Predictive maintenance: what is the problem?

Bottlenecks

- Solutions not leveraged
  - Integral approach to PM workflow needed
- Availability of data
  - Data lakes
  - Not right types
- Business case is complex
- Moving to data-driven culture
  - Lack of trust in solutions

Predictive Maintenance for Very Effective asset management

Goals

- Make predictive maintenance **easier** and **more effective**
- Realize the potential of PM:
  better performance, higher availability at lower cost

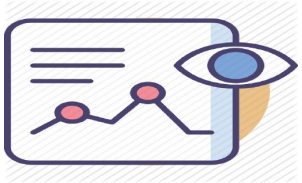
Koninklijke Marine

Rijkswaterstaat
Ministerie van Verkeer en Waterstaat

UNIVERSITY
OF TWENTE.

PrimaVera objectives

Measure better
- Intelligent data acquisition
- Data fusion
- Decision support: what, where, how to measure

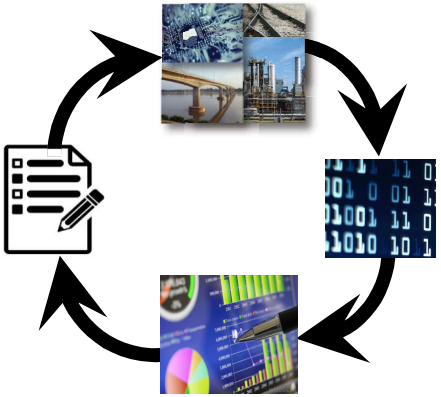


Predict better
- More scalable, robust and accurate algorithms
- automated root cause analysis

Plan better
- Maintenance strategy at asset and fleet level
- Cluster maintenance action

Organize better
- Organizational and human factors
- Solutions that work for people and organizations
- Help companies with **digital transition**

Above all:
Integral approach



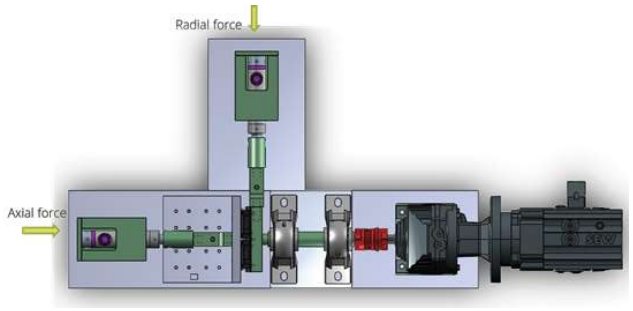
Scientific methodology

Action research

- **Not:** theory first, practical evaluation second.
- Rather: work with stakeholders on challenging problems
- **Scientific gain:** generalize specific solutions to general principles
- Fundamental: why do (or don't) solutions work?

See next talk

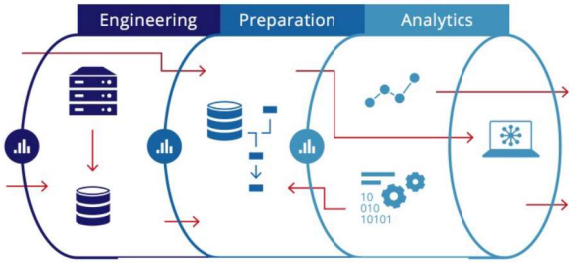
Results



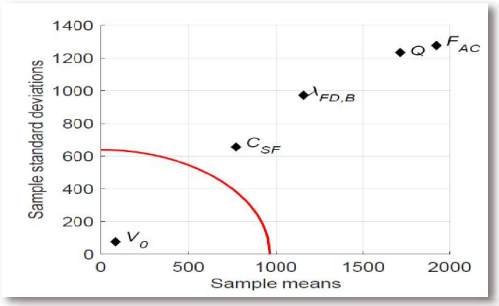
Test bench

Data challenge

Scrubber model (MDP)



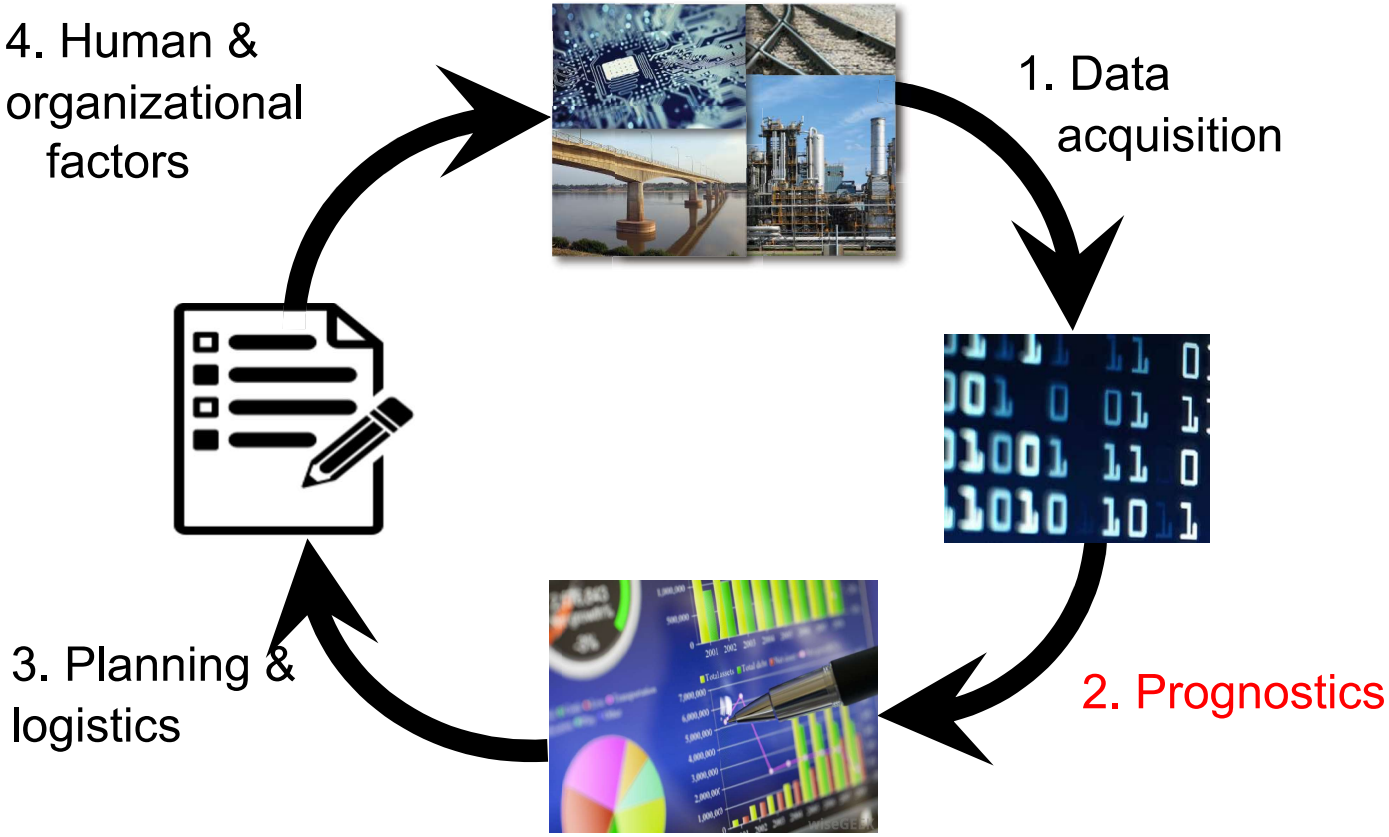
Data pipeline (Python)



Data selection pumts

- Crack propagation
- Optimization under partial observability
- Fault trees vs decision trees
- …

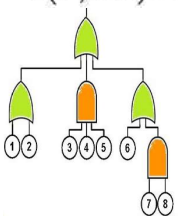
Predictive maintenance workflow

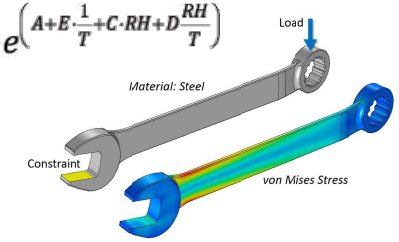


Prognostics: Model driven vs data driven

Model driven

$$L(T,RH) = \frac{1}{T} e^{\left(A+E\cdot\frac{1}{T}+C\cdot RH+D\frac{RH}{T}\right)}$$



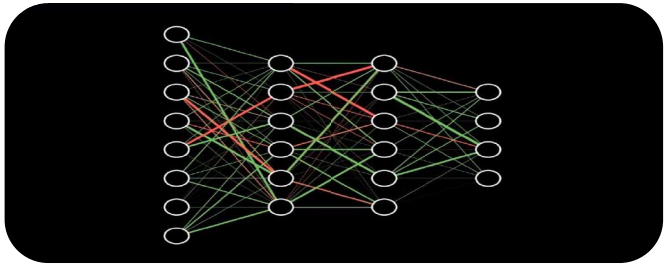


Several models

- Physical (TT, component level)
- Finite element models, differential equations
- Fault trees (MS, system level)

From the 50s

Data driven



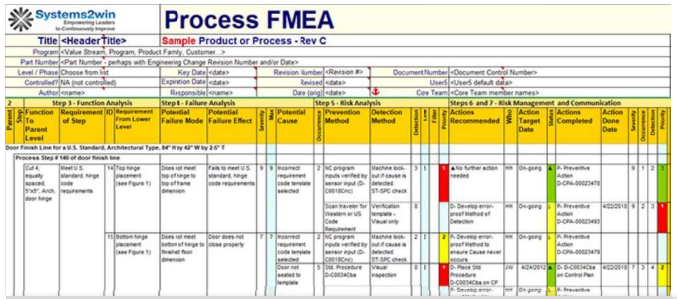
Several models

- Neural networks, Bayesian Networks, state vector machines, decision trees, genetic algorithms

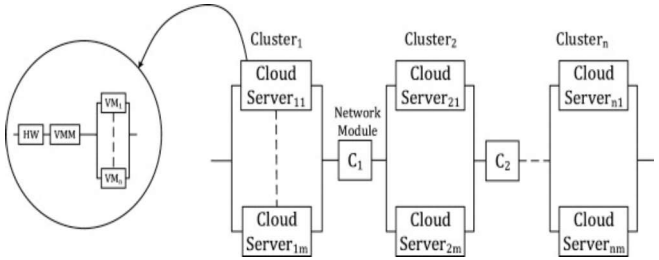
From the 50s!

SI roadmap: The challenge is to **reconcile** the perspective of the domain experts with their failure mode analyses with the perspective of the data analysts with their correlations between environmental and internal factors and degradation behavior.

System level models

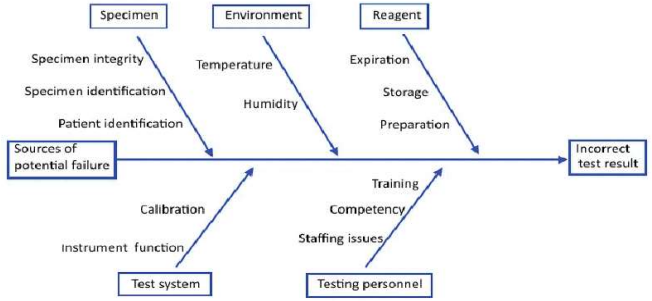


FMEA



Reliable block diagrams

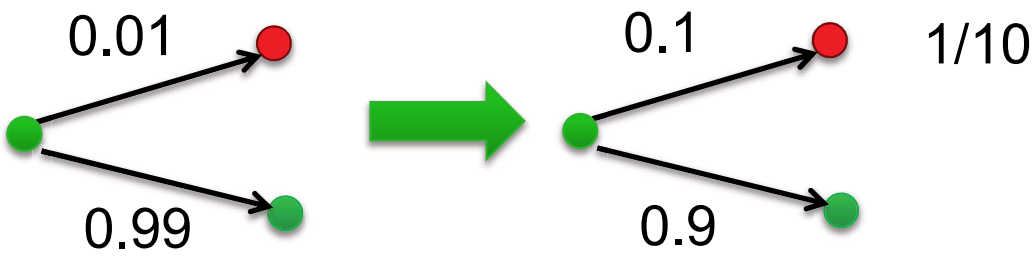
Bow ties: FTs + barrier + consequences



Fish diagrams

Rare event simulation

- Failures are rare
  - ... this makes Monte Carlo simulation hard
  - ... very many samples needed
- Solution: rare event simulation
  - ... increase the probability of a rare event
  - ... and compensate for it later
- Results
  - ... faster + more accurate FT simulation



Rare event simulation

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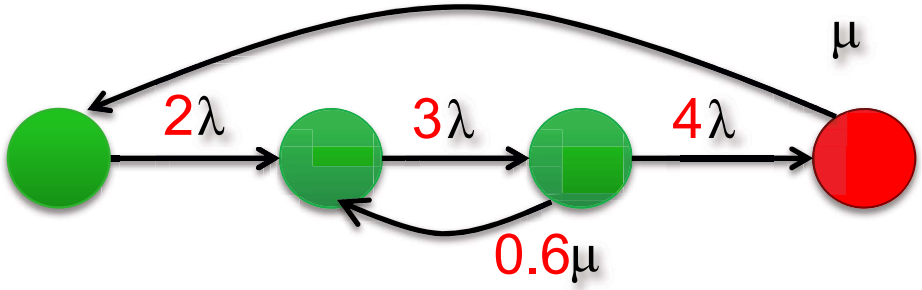
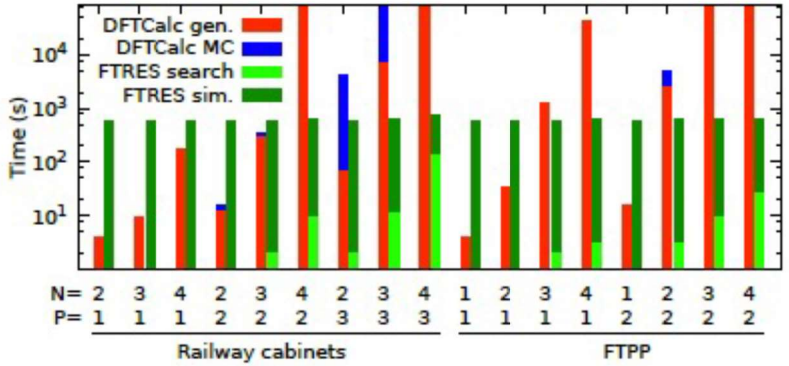
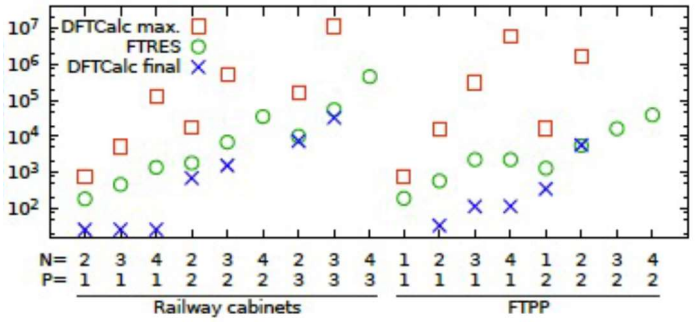


Results: faster analysis, more accurate results (CIs)



	N	P	Unavailability DFTCalc	FTRES	MC
Railway cabinets	2	1	$4.25685 \cdot 10^{-4}$	$[4.256; 4.258] \cdot 10^{-4}$	$[4.239; 4.280] \cdot 10^{-4}$
	3	1	$7.71576 \cdot 10^{-4}$	$[7.713; 7.716] \cdot 10^{-4}$	$[7.694; 7.751] \cdot 10^{-4}$
	4	1	$1.99929 \cdot 10^{-3}$	$[1.998; 2.000] \cdot 10^{-3}$	$[1.999; 2.004] \cdot 10^{-4}$
	2	2	$4.55131 \cdot 10^{-8}$	$[4.548; 4.555] \cdot 10^{-8}$	$[1.632; 4.387] \cdot 10^{-8}$
	3	2	$6.86125 \cdot 10^{-8}$	$[6.846; 6.873] \cdot 10^{-8}$	$[0.673; 1.304] \cdot 10^{-7}$
	4	2	—	$[2.358; 2.394] \cdot 10^{-7}$	$[2.282; 3.484] \cdot 10^{-7}$
	2	3	$5.97575 \cdot 10^{-12}$	$[5.714; 6.252] \cdot 10^{-12}$	—
	3	3	—	$[5.724; 7.914] \cdot 10^{-12}$	—
	4	3	—	$[0.337; 1.871] \cdot 10^{-11}$	—
FTPP	1	1	$2.18303 \cdot 10^{-10}$	$[2.182; 2.184] \cdot 10^{-10}$	—
	2	1	$2.19861 \cdot 10^{-10}$	$[2.198; 2.199] \cdot 10^{-10}$	—
	3	1	$2.21420 \cdot 10^{-10}$	$[2.213; 2.215] \cdot 10^{-10}$	—
	4	1	$2.22979 \cdot 10^{-10}$	$[2.229; 2.230] \cdot 10^{-10}$	$[0; 2.140] \cdot 10^{-8}$
	1	2	$1.76174 \cdot 10^{-20}$	$[1.761; 1.763] \cdot 10^{-20}$	—
	2	2	$1.76178 \cdot 10^{-20}$	$[1.756; 1.770] \cdot 10^{-20}$	—
	3	2	—	$[1.673; 1.856] \cdot 10^{-20}$	—
	4	2	—	$[1.257; 2.553] \cdot 10^{-20}$	—



Lessons learnt

1. **Start with a business objective**

2. **Align all stakeholders**

3. **Then: what do you need to measure?**

   Not other way around: we have data, let's see what we can do

4. **Treat data a the new gold**

5. **Just do it!**

Online biweekly webinar series

- Industry & academic speakers
- https://primavera-project.com/colloquium/
- m.i.a.stoelinga@utwente.nl

Discussion

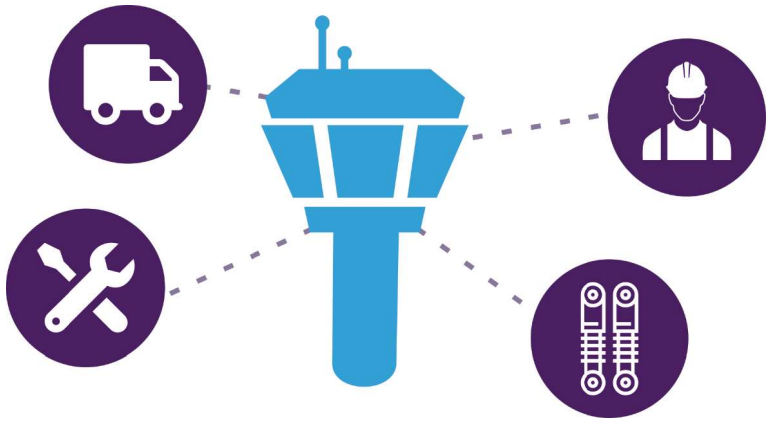
I am curious to hear

- What kind of predictive maintenance techniques to you use?
- Data push or data pull?
- … any other questions or issues …

Control tower: the connecting hub

Centralized system

- Manage & control service logistics of physical assets
- Real-time information
  - Monitoring health
  - Anticipating problems
  - Support workflow



Damage detection: 4 levels

1. Damage detection
    1. is damage present in the structure?
2. Damage localization,
3. where is damage present?
4. Damage quantification,
5. how severe is the damage
6. Damage prognosis,
7. what is the remaining service life of the structure?

Brief CV

Maths & Computer Science
Radboud University Nijmegen

PhD Computer Science
Radboud University

Postdoc
University of California

2004 – now

- Risk Management for High Tech
- Visiting Scholar:
  Trento, Oxford, SU New York
- Coordinator PrimaVera
- ERC consolidator

Outline

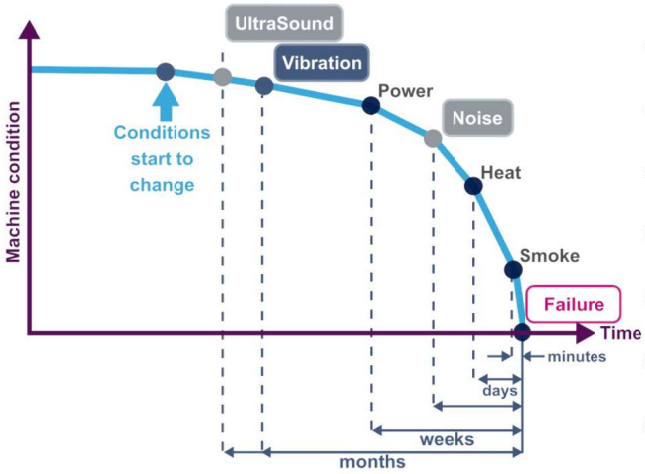
1. **Data driven and model driven prognostics**

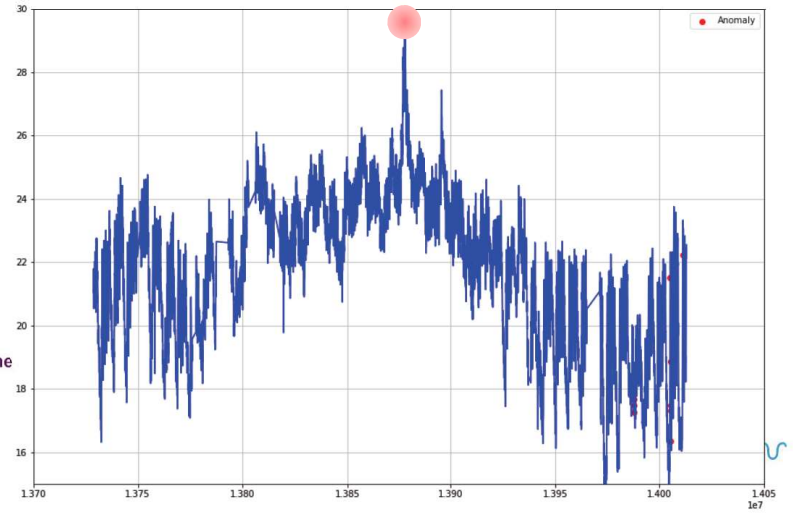
2. **Fault tree analysis**
   - What are fault trees
   - Qualitative and quantitive analysis

3. **Fault trees, data, and maintenance**
   - Analysis
   - Learning

4. **Conclusions**

Example





Condition monitoring

- Appropriate sensors
- Challenges: which sensors? how many? where?
- Variations in operational conditions