Smart Maintenance in Cyber-Physical Systems

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Aim and outline

Aim of this presentation:

To present concepts that enable Smart Maintenance in Cyber-physical systems

Outline:

1. Cyber-physical systems
2. Smart Maintenance
3. Application of Smart maintenance in cyber-physical systems
4. Summary & Conclusion

1.Cyber-physical systems

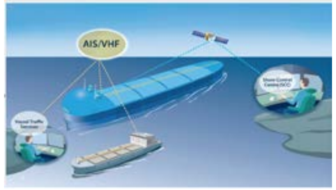
Age of sail

Steam engine

Diesel engine

Instrumentation &
automation of Engines

MUNIN project



1838: SS Great western

1911: Selandia

1937: 167 men for
operating an engine room!

1966: DNV E0

1961: M/S Kinkasan Maru

1969: M/S Taimyr

2012: Concept project
for deep sea vessel

1.Cyber-physical systems

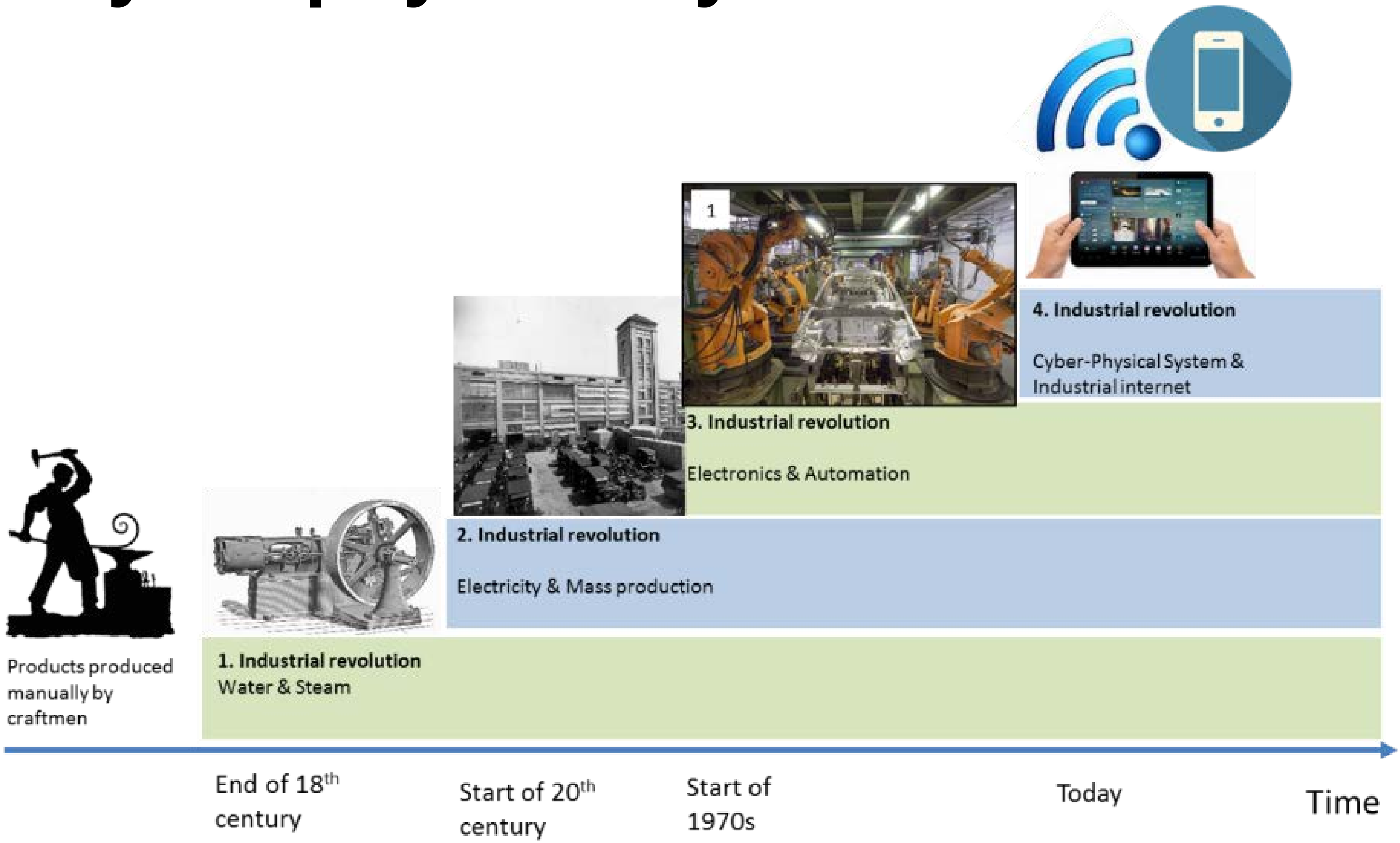


Figure 1: Four stages of industrial revolutions
Picture 1 collected from “1983 Industrial Robots KUKA IR160/60, 601/60”

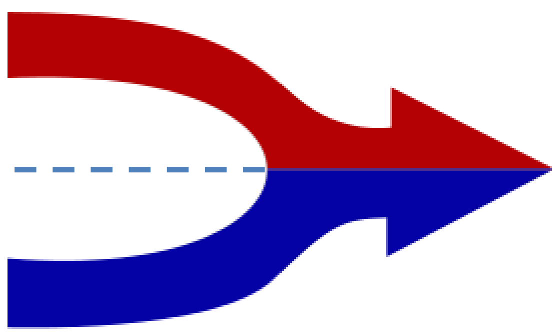
1.Cyber-physical systems

- Definition of Cyber-Physical systems (CPS) (Lee, Bagheri, & Kao, 2015): "***Transformative technologies** for managing **interconnected systems** between its **physical assets** and **computational capabilities**.*"

ICT systems:
Maintenance scheduled on time intervals

Virtual world

Physical world



CPS:
Convergence of the physical and virtual world

Equipment:
Visual inspections, manually registered before sent to the virtual world.

1.Cyber-physical systems

Example of an architecture for CPS:

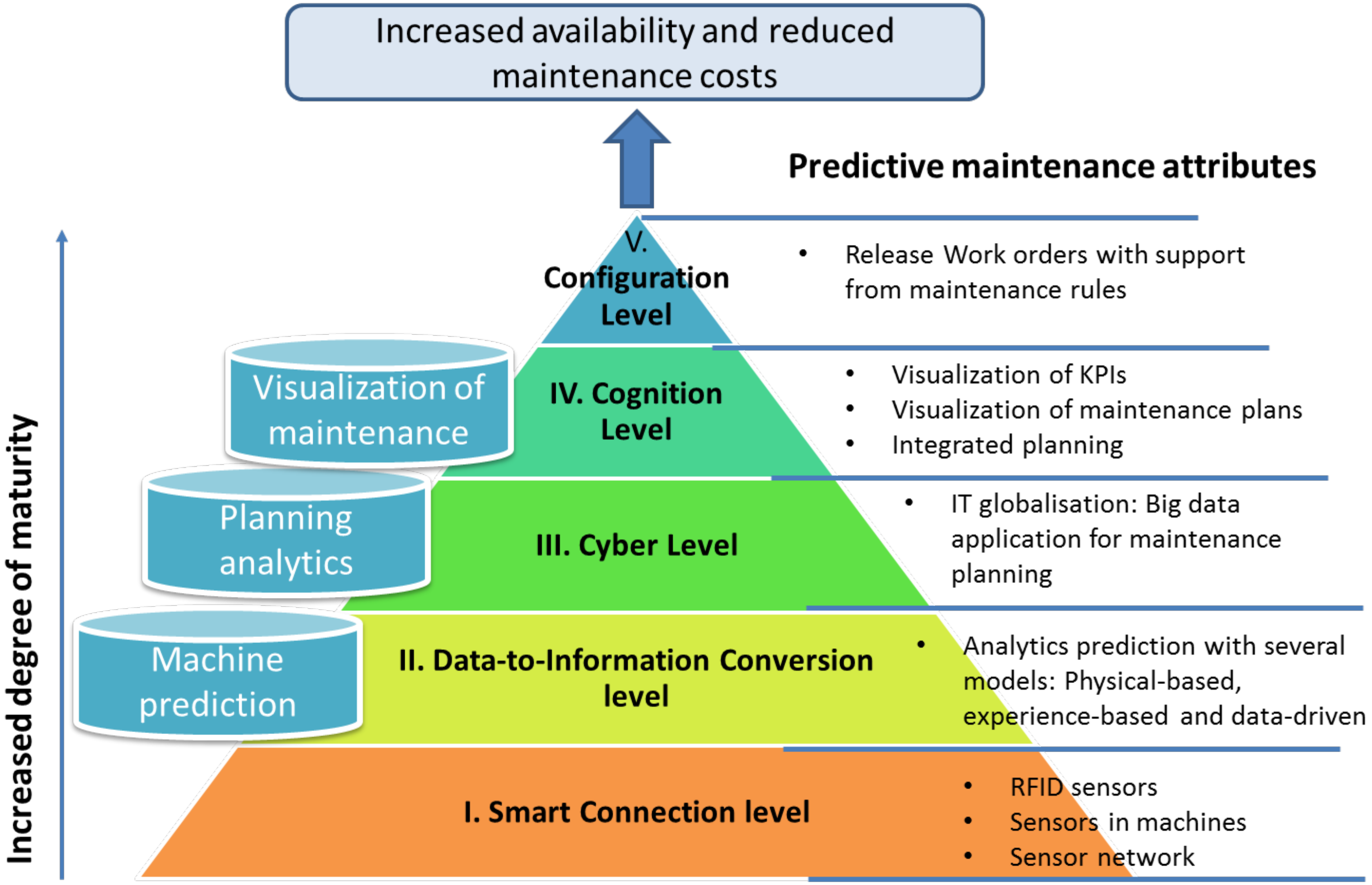


Figure 2: Architecture model for predictive maintenance (**Source:** Rødseth et. al., Euromaintenance 2016)

2. Smart Maintenance

- German Standardization Report for Industry 4.0 (DIN, 2016):

*“In Industry 4.0 in general, and specifically in the factory of the future – the smart factory – **maintenance will play a central role** as the guarantor of the availability and reliability of machines and systems... Without systematic development of maintenance into smart maintenance, the successful implementation of Industry 4.0 will be put at risk.”*

- Research priorities from the EU project Focus (www.focusonfof.eu): Optimized & Predictive Maintenance.

- Maintenance in digitalized manufacturing (Bokrantz et. al., 2017): Fact based maintenance planning.

2. Smart Maintenance

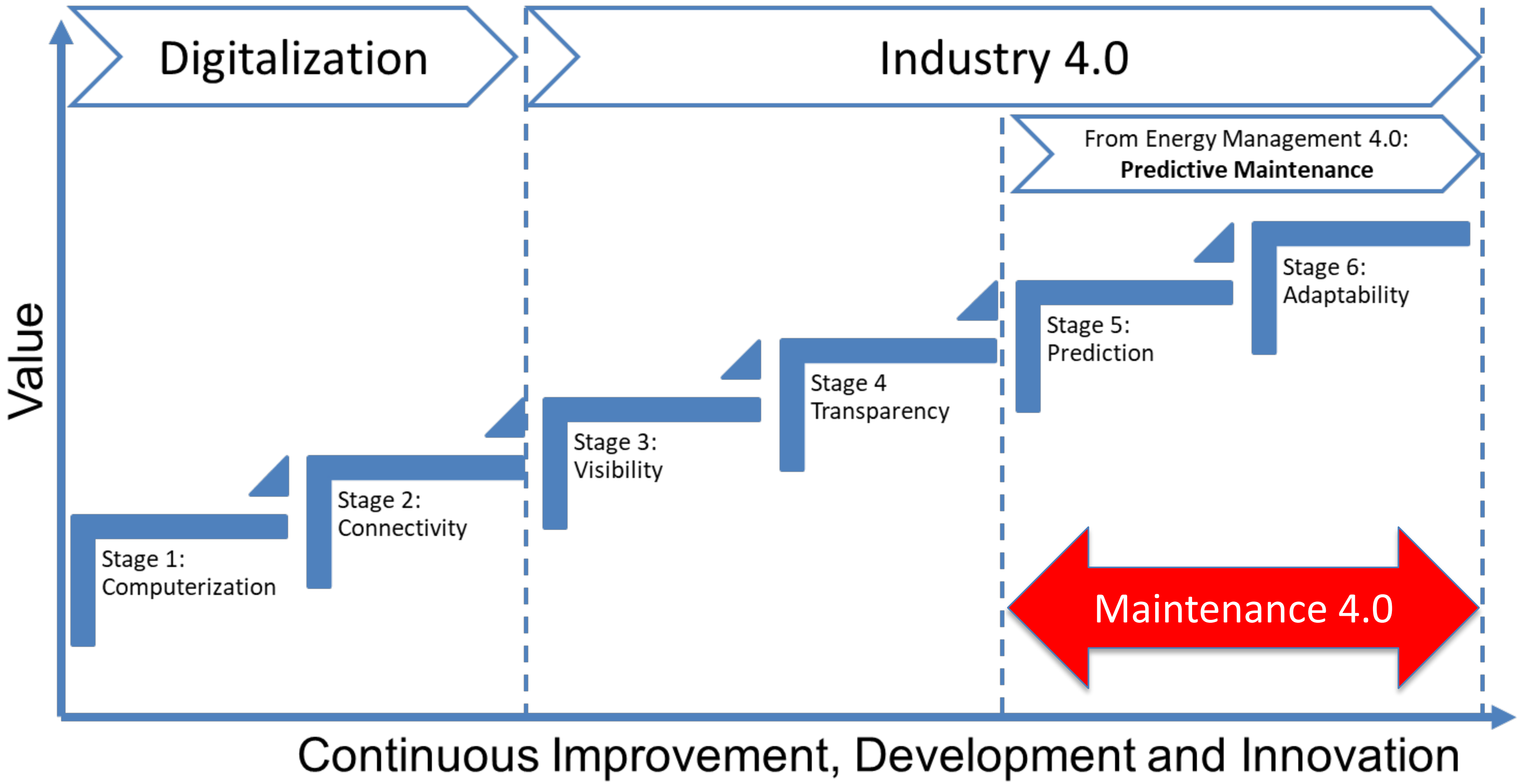


Figure 3: Industry 4.0 maturity model, adapted from (Nienke et.al., 2017) and (Schuh et. al., 2017)

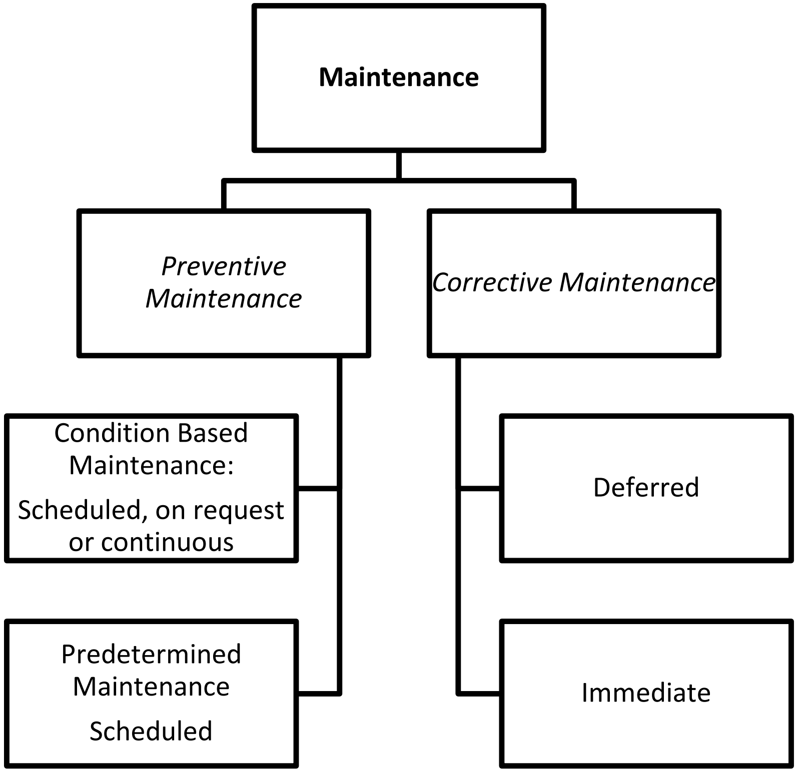
2. Smart Maintenance

Table 1: The main value drivers for Industrie 4.0 adapted from (McKinsey&Company, 2015).

	Value drivers	
	Service/aftersales	*Asset utilization*
Activities and technology	- Remote maintenance - Predictive maintenance	- Remote monitoring and control - Predictive maintenance - Augmented reality for MRO
Indicative impact	10-40 % reduction of maintenance costs	30-50% reduction of total machine downtime

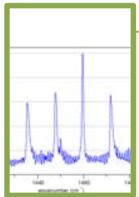
2. Smart Maintenance

- **Predictive maintenance** (En 13306, 2010): ***“****Condition based maintenance carried out following a forecast derived from repeated analysis or known characteristics and evaluation of the significant parameters of the degradation of the item”*



2. Smart Maintenance

- Condition-based maintenance
  - Diagnosis
  - Prognosis (Predictive maintenance)
    - Physical-based
    - Experience-based
    - Data-driven



Physical-based:

- Vibration analysis
- Magnetism monitoring
- Diesel Engine modelling
- Tribology analysis
- Process parameters analysis

Experience-based:

- Performance monitoring of engine
- Visual inspection

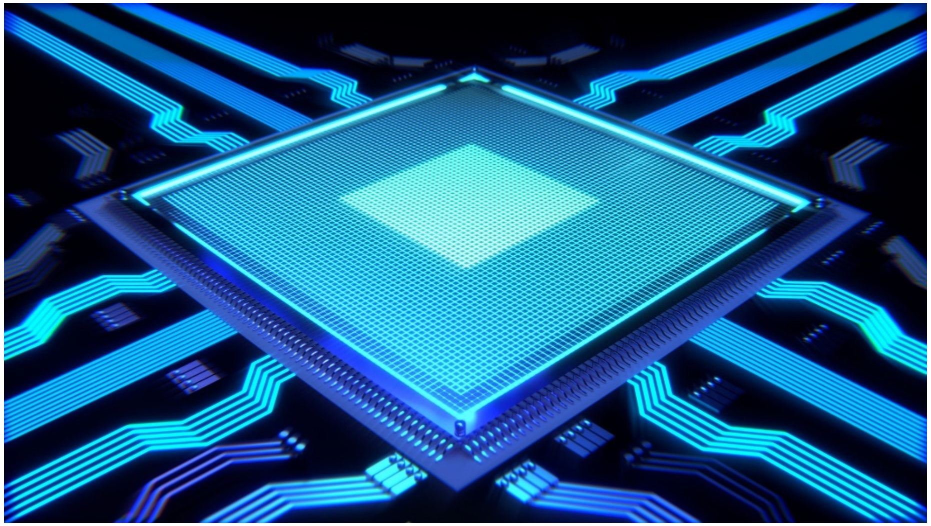
Data-driven:

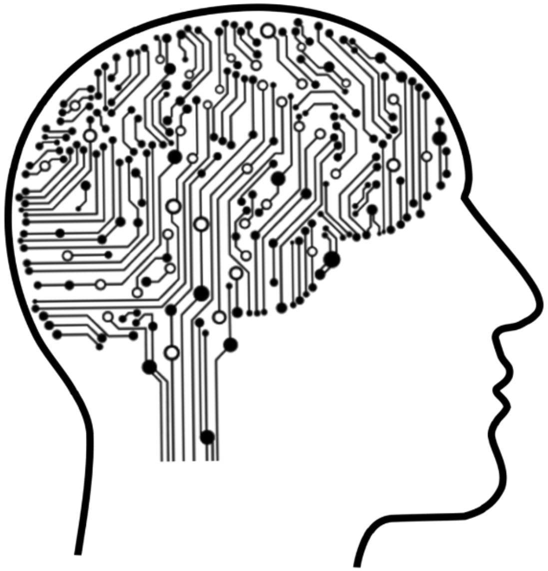
- Artificial Neural Networks (ANN)
- Statistical models, e.g. Statistical Process Control

Source: Asmai, S.A. et. al (2010) 2nd International Conference on Computer Research and Development

2. Smart Maintenance

- Machine learning teaches computers where several algorithms “learn” directly from data.
- Evolvement from Artificial Intelligence.
- Data is king with Moores Law.





2. Smart Maintenance

In *computerized maintenance management system* (CMMS):

Planned repair process, e.g. in SAP:

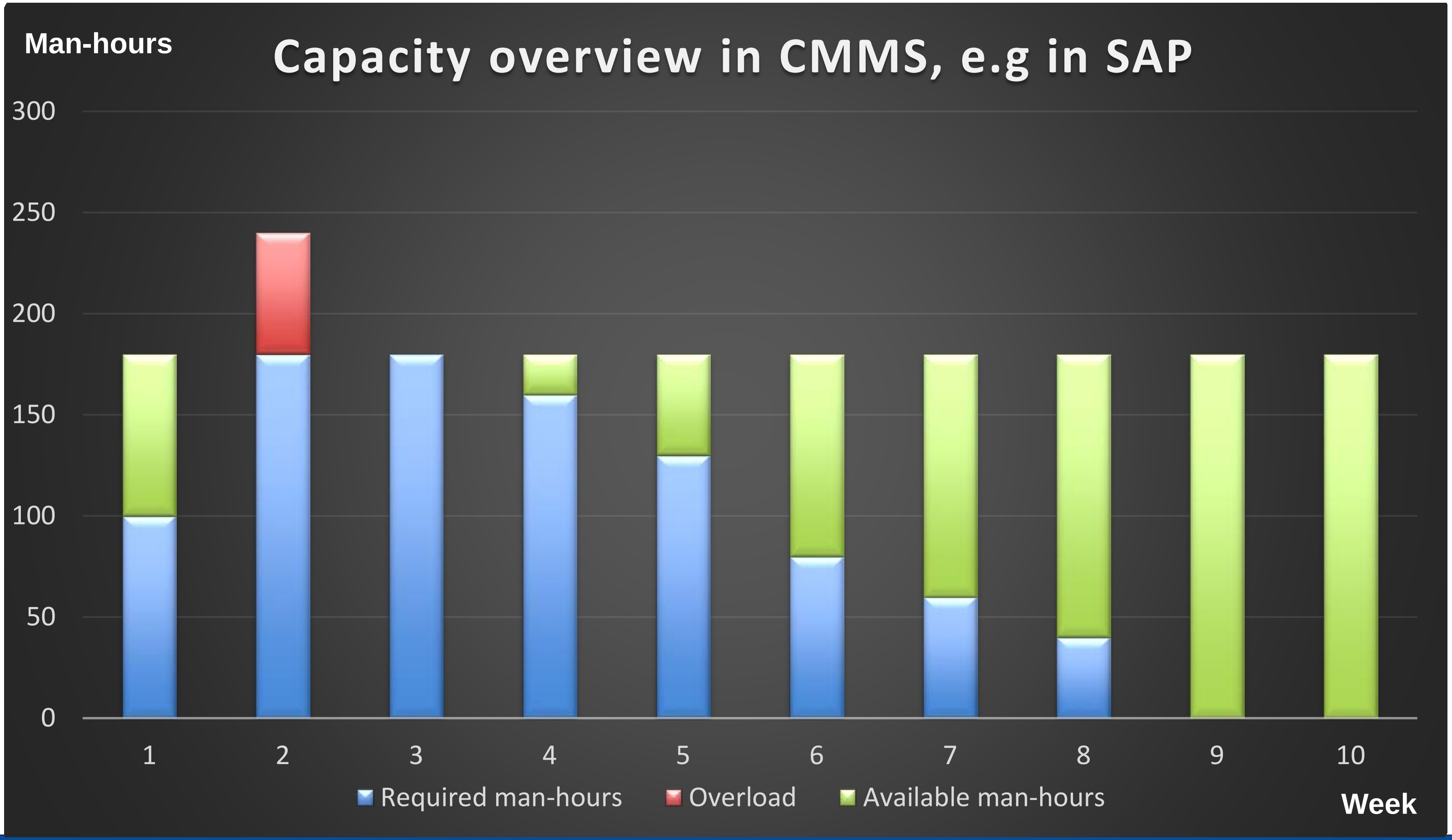
1. Notification: Technical object, date, description, priority
2. Planning: Work to be performed, material, tools, resource internal/external
3. Controlling: Order release, capacity leveling, paper printout, availability check
4. Implementation: Material withdrawal, external procurement
5. Completion: Time confirmation, technical completion & confirmation

Record of history:

Material usage, orders, notifications, information system, usage list

2. Smart Maintenance

What time window is needed in the maintenance system?



3. Application of Smart maintenance in cyber-physical systems

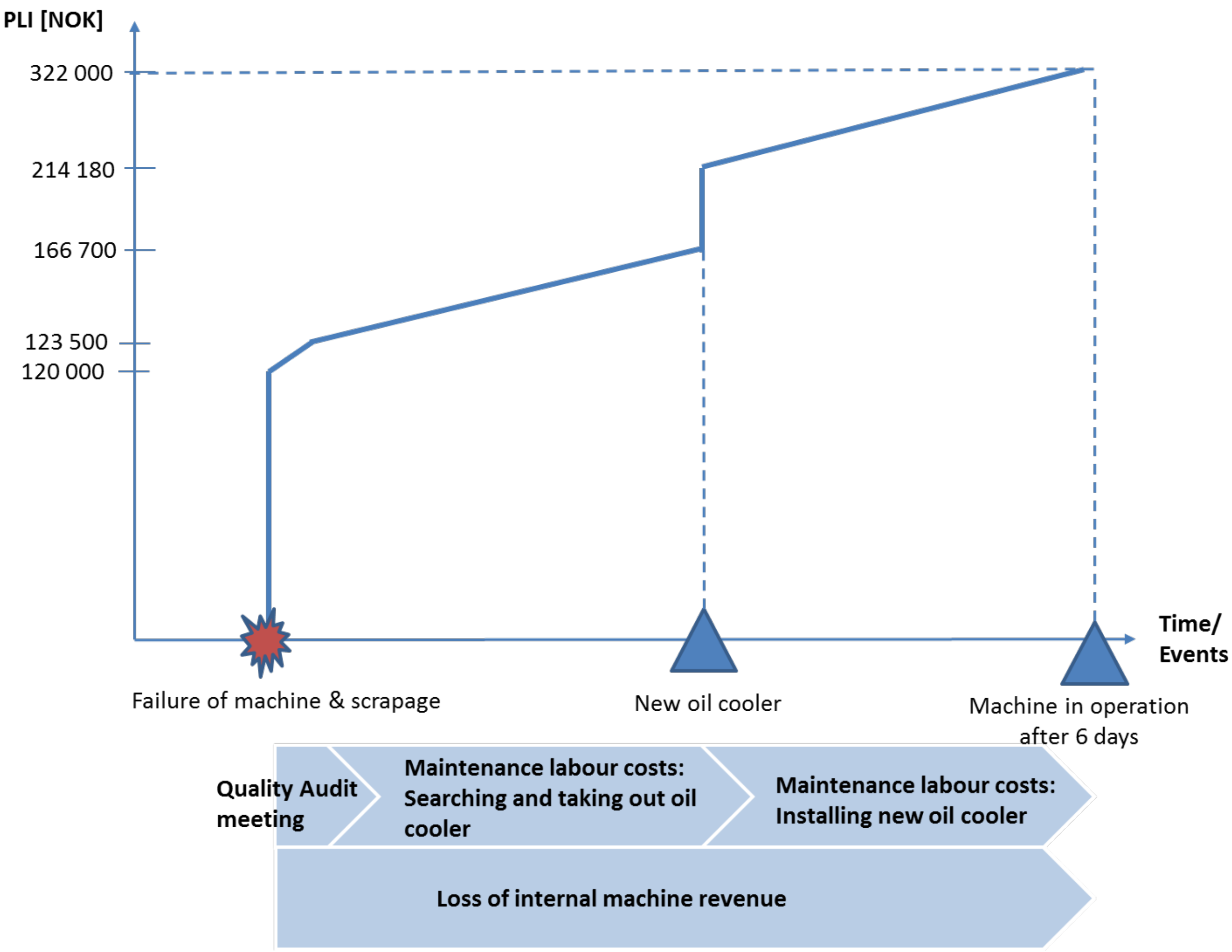


Figure 4: PLI calculations

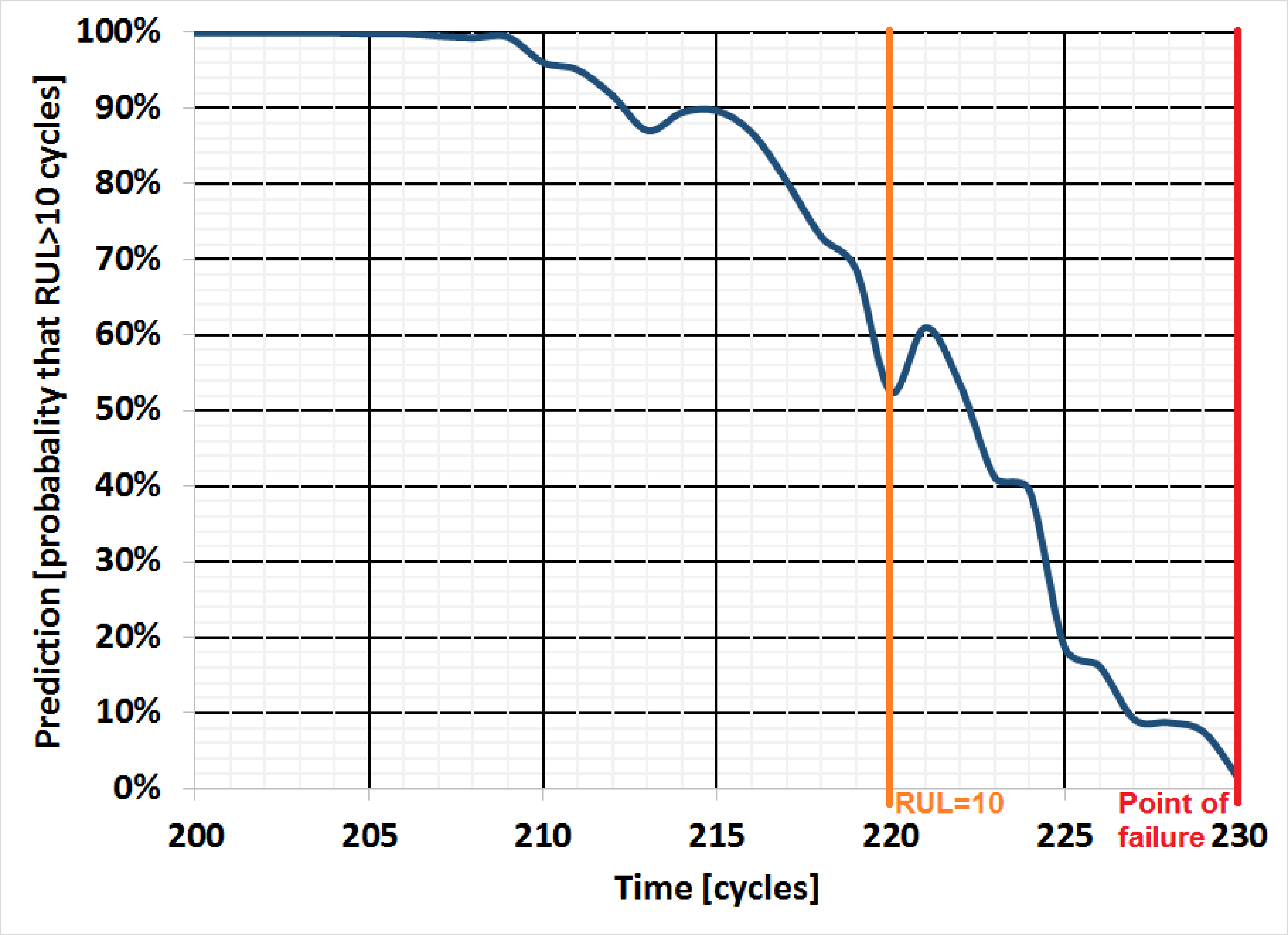
Source: Rødseth, H. and P. Schjølberg (2016). "Data-driven Predictive Maintenance for Green Manufacturing." Advanced Manufacturing and Automation VI, Atlantis Press. **24:** 36-41.

3. Application of Smart maintenance in cyber-physical systems

cycle	setting 1	setting 2	setting 3	sensor 1	sensor 2	......	sensor 20	sensor 21
1	-0.0007	-0.0004	100	518.67	641.82	......	39.06	23.419
2	0.0019	-0.0003	100	518.67	642.15	......	39	23.4236
3	-0.0043	0.0003	100	518.67	642.35	......	38.95	23.3442
4	0.0007	0	100	518.67	642.35	......	38.88	23.3739
5	-0.0019	-0.0002	100	518.67	642.37	......	38.9	23.4044
6	-0.0043	-0.0001	100	518.67	642.1	......	38.98	23.3669
7	0.001	0.0001	100	518.67	642.48	......	39.1	23.3774
8	-0.0034	0.0003	100	518.67	642.56	......	38.97	23.3106
9	0.0008	0.0001	100	518.67	642.12	......	39.05	23.4066
10	-0.0033	0.0001	100	518.67	641.71	......	38.95	23.4694

Source:
Rødseth, H., P. Schjølberg and A. Marhaug (2017). "Deep digital maintenance."
Advances in Manufacturing **5**(4): 299-310.

3. Application of Smart maintenance in cyber-physical systems



Source:
Rødseth, H., P. Schjølberg and A. Marhaug (2017). "Deep digital maintenance."
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4. Summary & conclusion

- Smart Maintenance applied in land based industry has been presented with a case of predictive maintenance.
- The benefit is to perform maintenance when actually needed.
- A challenge is to have sufficient relevant data for machine learning.
- To Transfer this Smart Maintenance into the maritime sector several issues must be reviewed:
  - The cost of 128 kbs bandwidth as satellite service (MUNIN vessel) for notifying a future maintenance action at deep sea. This service is a shared cost. Should this bandwidth be increased? How much data is actually necessary to transfer from vessel to shore?
  - Is the machinery equipped with sensors measuring sufficient data quality?
  - Big data analytics on device (at the vessel) or in cloud (at shore)?
  - To what extent has the maritime industry willing to share anonymous fleet data?
  - If Shipping 4.0 permits manning of vessel, which maintenance tasks can be performed during voyage?

The End

“Coming together is a beginning, staying together is progress, and working together is success.”

-Henry Ford-

Thank you for your attention!

Reference of open access publication
Rødseth, H., P. Schjølberg and A. Marhaug (2017). "Deep digital maintenance.“ Advances in Manufacturing **5**(4): 299-310.

Available at: https://doi.org/10.1007/s40436-017-0202-9