Improving Aircraft Maintenance Performance through Prescriptive Maintenance Strategies

Beyond failure prediction for a post-prognostics decision-making

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Motivation

Cost savings potential in aviation MRO industry estimated to be about 3 bn. Euro annually – through implementation of digitalization technologies [1]

Mainly associated with development and utilization of Prognostics and Health Management (PHM) systems

Technical Implementation

PHM systems often in an early state of their development with low technological maturity [2]

Only a minor percentage of companies are capable of a continuous real-time monitoring of their assets [2, 3]

Definition of minimum performance criteria for the PHM systems needed for an efficient further development

Maintenance Execution

Hesitation to invest in the development of prognostics-based maintenance strategies due to absence of viable business case scenarios [2]

New PHM systems require new approaches for maintenance execution (MSG3+) [4]

Consideration of adjacent processes for holistic decision making and exploitation of full potential

Current Challenges in Industry and Research

Strong focus on monetary values

Past research has predominantly focused on the evaluation of monetary aspects of PHM technologies, neglecting other effects (such as asset availability, environmental impact, …).

Asset centricity

A major focus of existing work has been put on the asset (e.g. aircraft) itself and, therefore, only insufficiently addressed an airlines ecosystem.

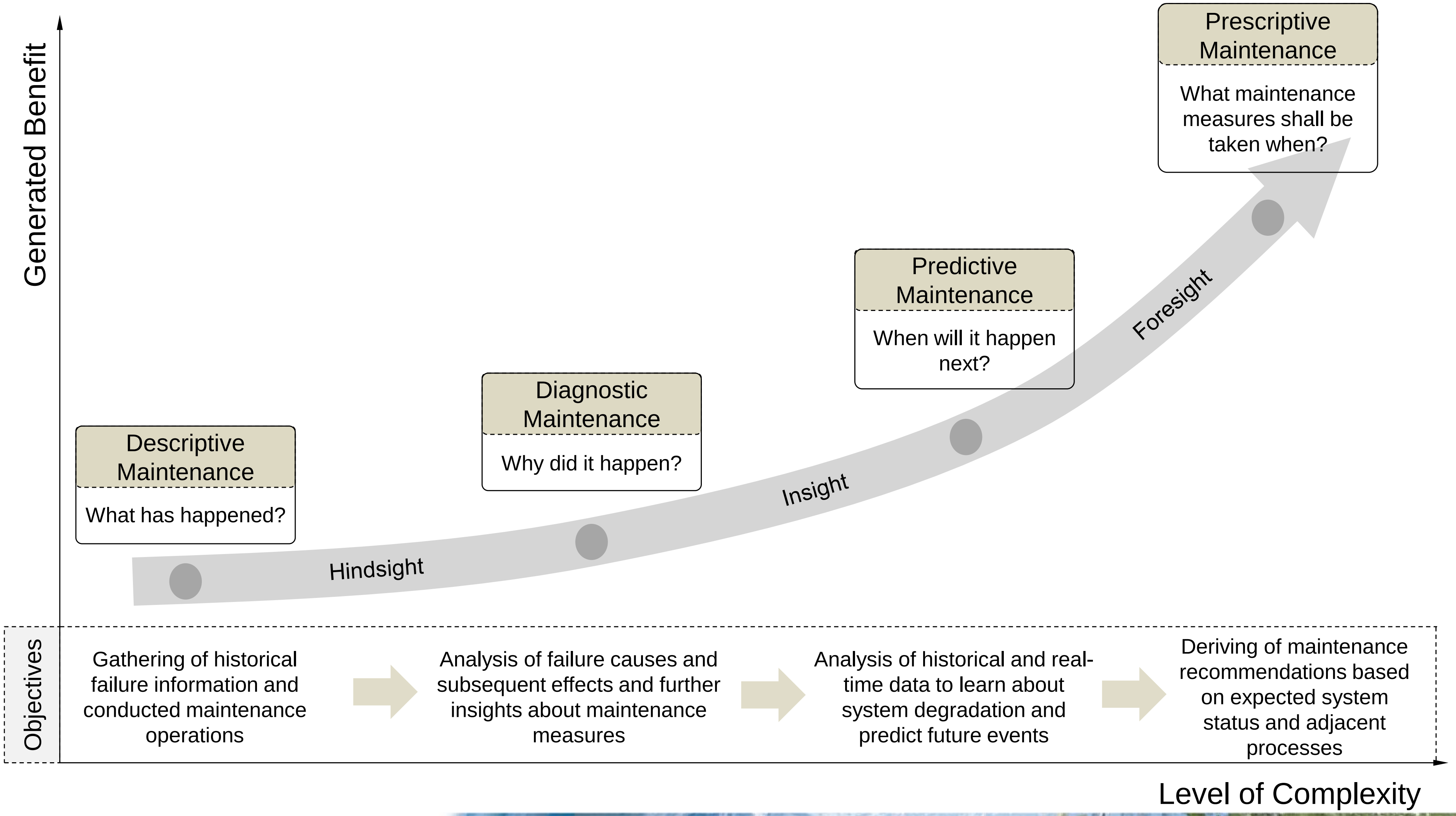
No difference in stakeholder objectives

All involved stakeholders posses different optimization objectives that need to be addressed individually. However, existing simulation tools often fail to account for these differences.

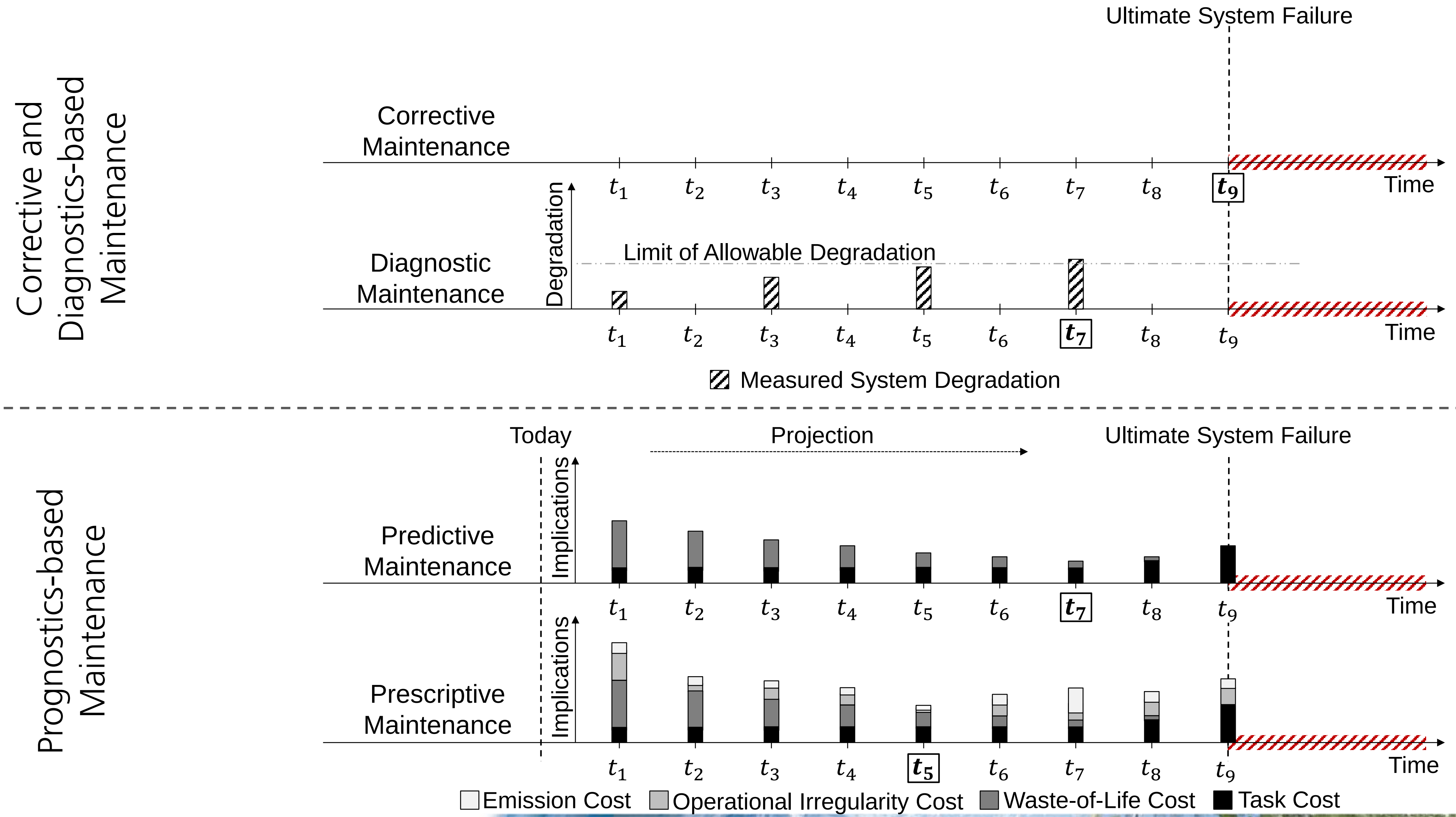
Ambient conditions neglected for degradation projection

A simple extrapolation of past (observed) degradation into the future incorporates inaccuracies due to changing operating conditions.

History of Condition-Based Maintenance Strategies

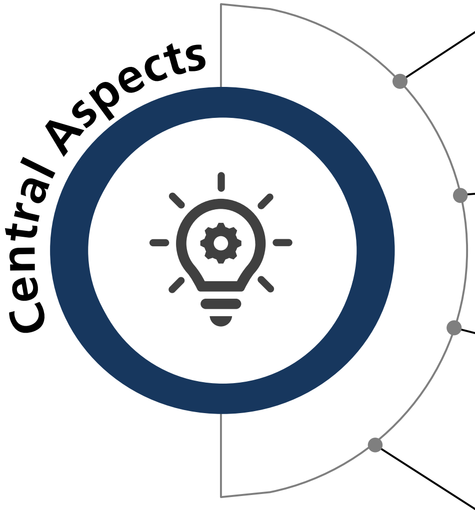


Different Outputs of Condition-Based Maintenance Strategies



Prescriptive Maintenance in the Aviation Industry

Prescriptive maintenance utilizes a system's failure projection to minimize the adversarial implications for the involved stakeholders by an optimized, proactive scheduling of necessary maintenance restoration tasks. Therefore, it is an evolution of a predictive maintenance approach, which solely forecasts upcoming system failures without providing recommendations of beneficial restoration downtimes.



Stakeholder Modeling

A key requirement for a holistic maintenance planning is the modelling of relevant stakeholders and their functional relationships.

Flexibility for Optimization Target

The scheduling targets can vary among the involved stakeholders and need to allow to be adapted accordingly.

Degradation Projection

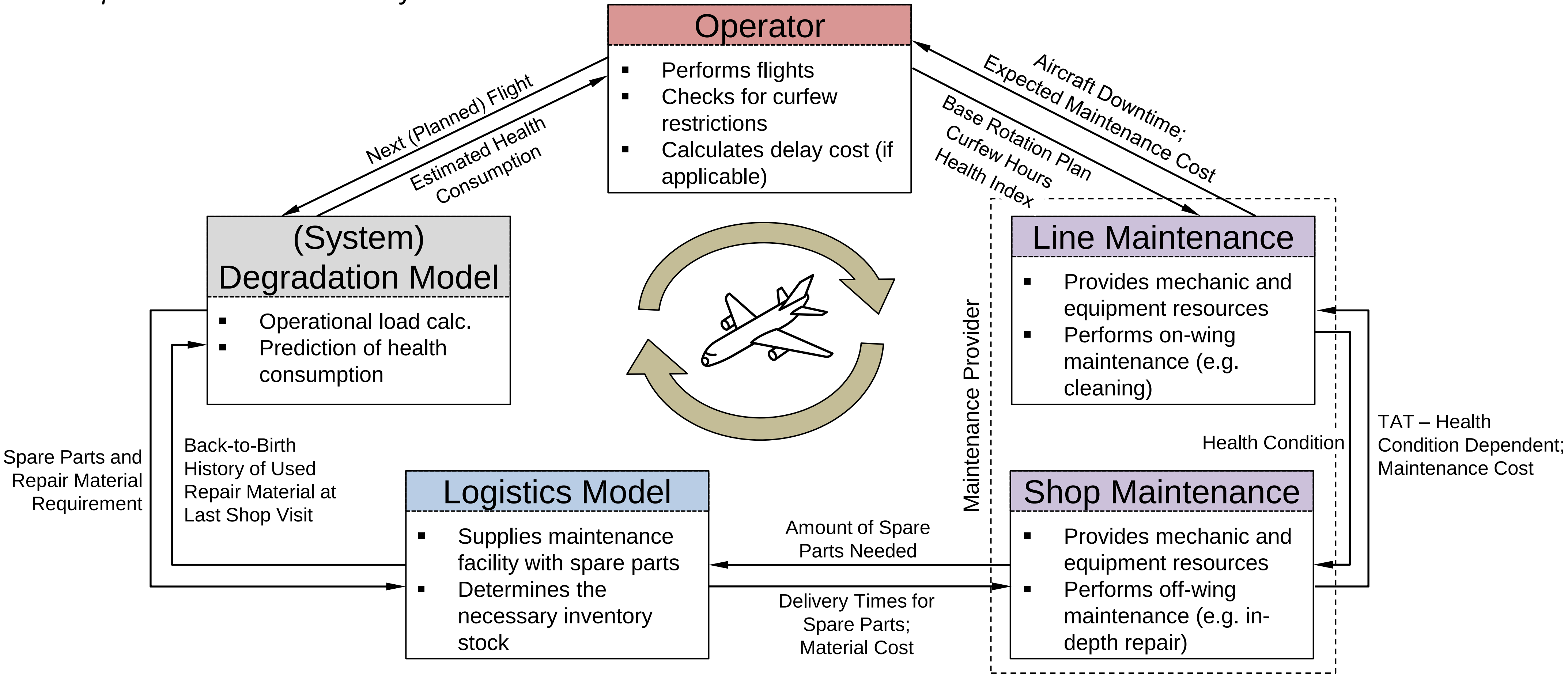
Maintenance restoration tasks are based on failure projections based on anticipated future utilizations and ambient conditions.

PHM Maturity Levels

As PHM technologies are often at early stages of their development, their prediction performance can vary significantly.

PreMaDe – Prescriptive Maintenance Developer

PreMaDe is intended to develop and evaluate prescriptive maintenance strategies for post-prognostics decision making in the aviation industry. Thus, it requires the modeling of all relevant stakeholders with their functional relationships and individual objectives.



PreMaDe – Prescriptive Maintenance Developer

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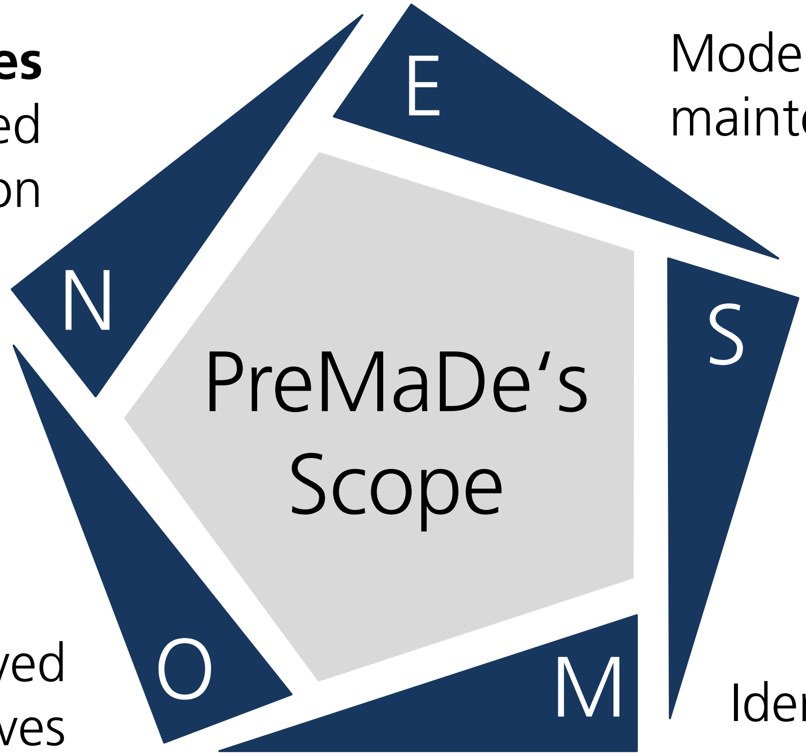
Inclusion of **non-monetary values** for the evaluation of the identified solution

Modeling of the essential aircraft maintenance **ecosystem**



Determination of the developed prescriptive maintenance strategy **system’s resilience**

Optimization towards the involved stakeholders’ individual objectives

Identification of **minimum performance criteria** for PHM technologies

Exemplary Use Cases and Findings

Research Question	How does the cost savings potential of a prognostics-based maintenance strategy change for different Prognostic Horizons (as expressions of technological maturity)?

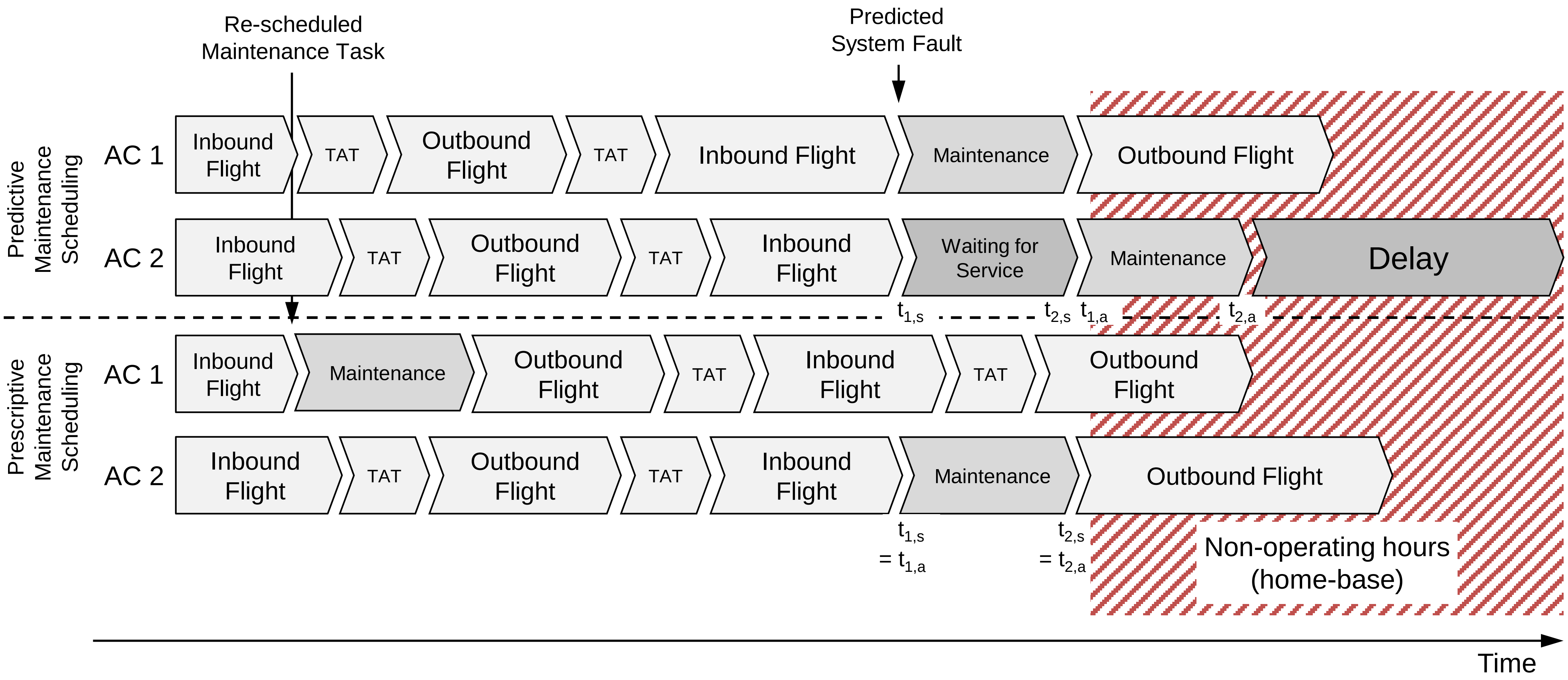
Method / Research Setting

- Discrete Event Simulation with focus on interaction between operations and line maintenance
- Aircraft fleet of 5 short-/medium-haul aircraft
- Modeling of ground resource limitations, i.e. available, qualified mechanics, and available maintenance hubs
- Variation of prognostic horizon of the underlying PHM technology and available maintenance staff
- Analysis of avoidable operational delays due to waiting times for service

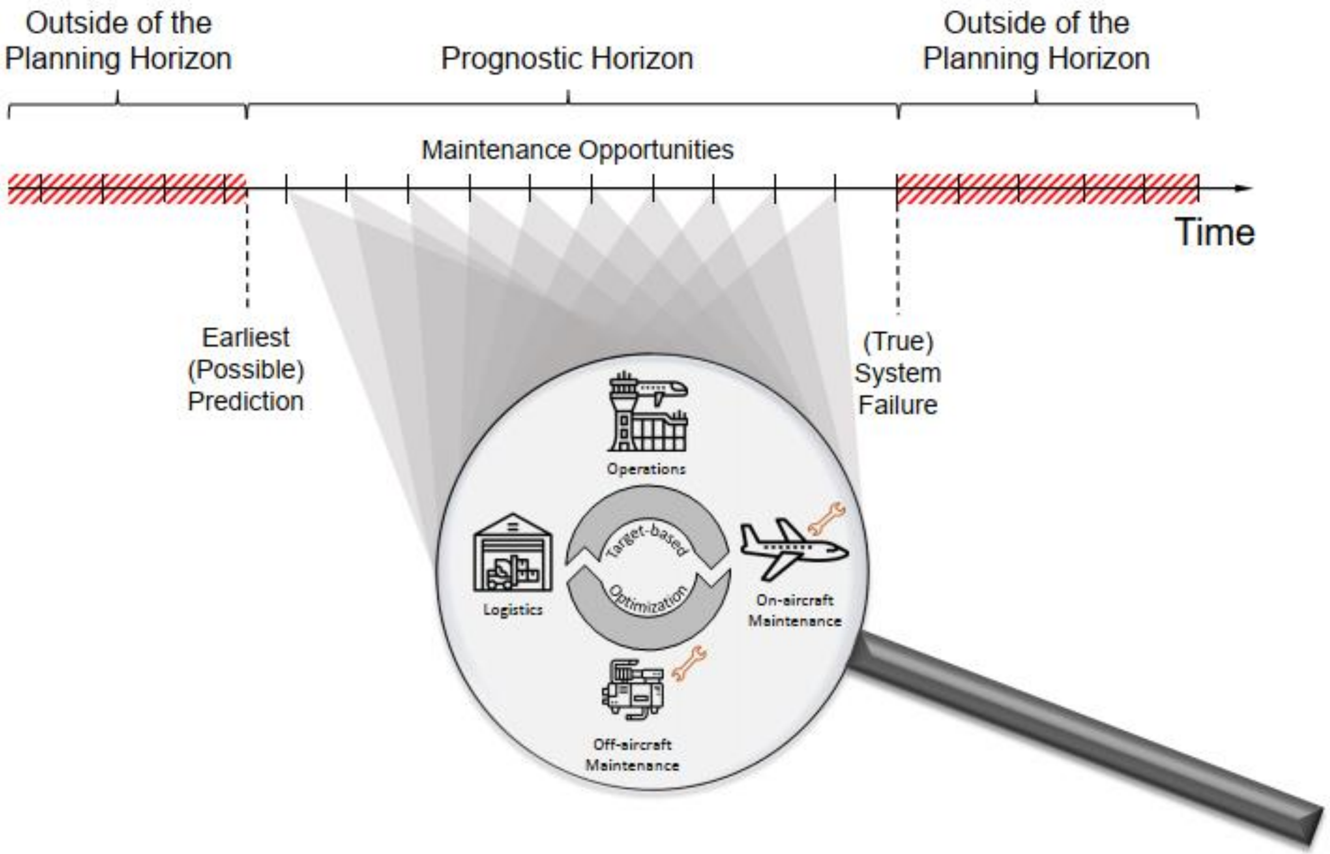
Key Findings

- Dependency of cost savings potential from technical maturity
- High improvements for additional developments with low level of technical maturity until saturation point
- Changes in the maintenance procedure necessary to fully exploit the PHM technology’s potential

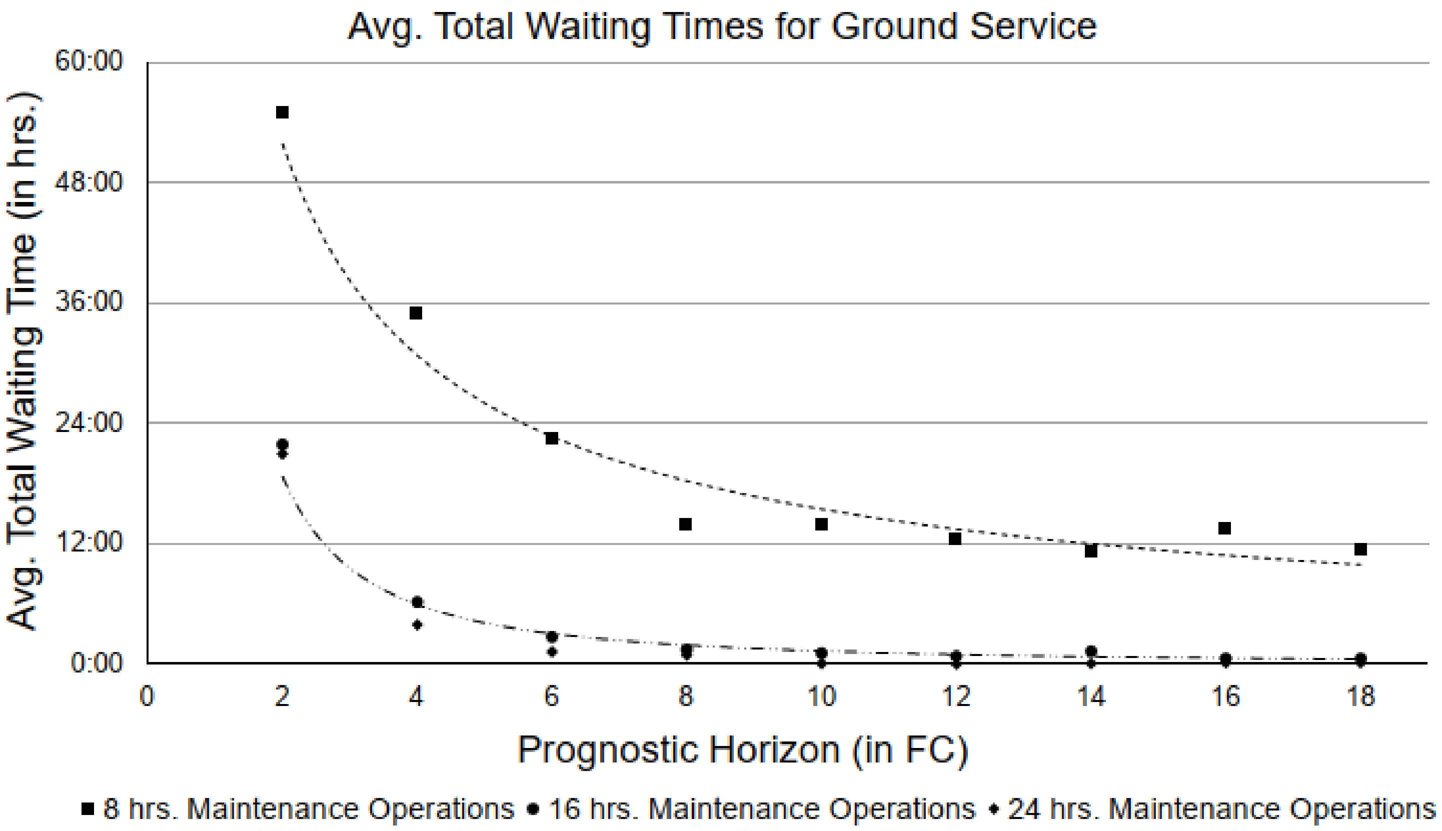
Exemplary Use Cases and Findings

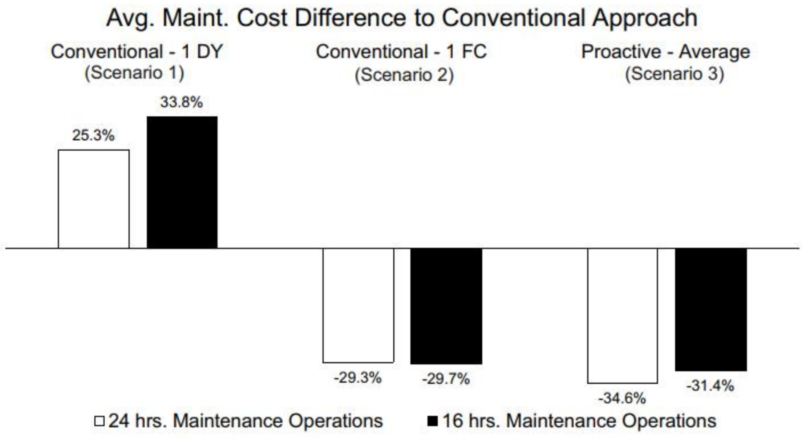


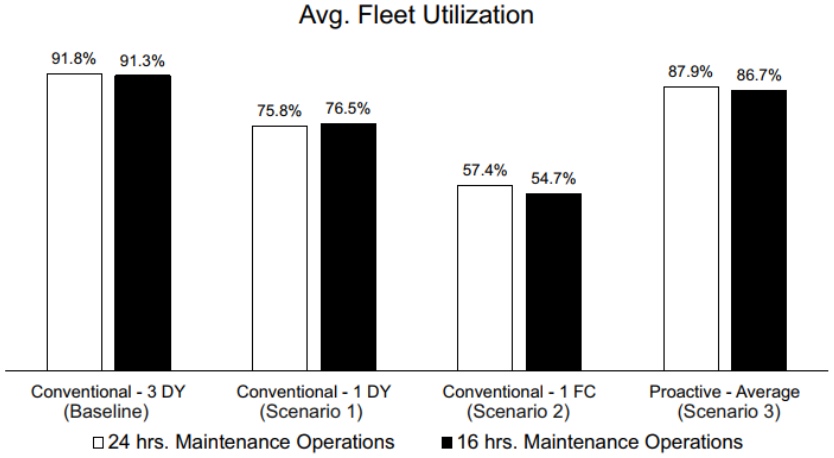
Exemplary Use Cases and Findings – Maintenance Opportunities



Exemplary Use Cases and Findings







Meissner, R., Meyer, H. and Wicke, K. (2021) *Concept and Economic Evaluation of Prescriptive Maintenance Strategies for an Automated Condition Monitoring System.* International Journal of Prognostics and Health Management, 12 (3). doi: [10.36001/ijphm.2021.v12i3.2911](https://doi.org/10.36001/ijphm.2021.v12i3.2911)

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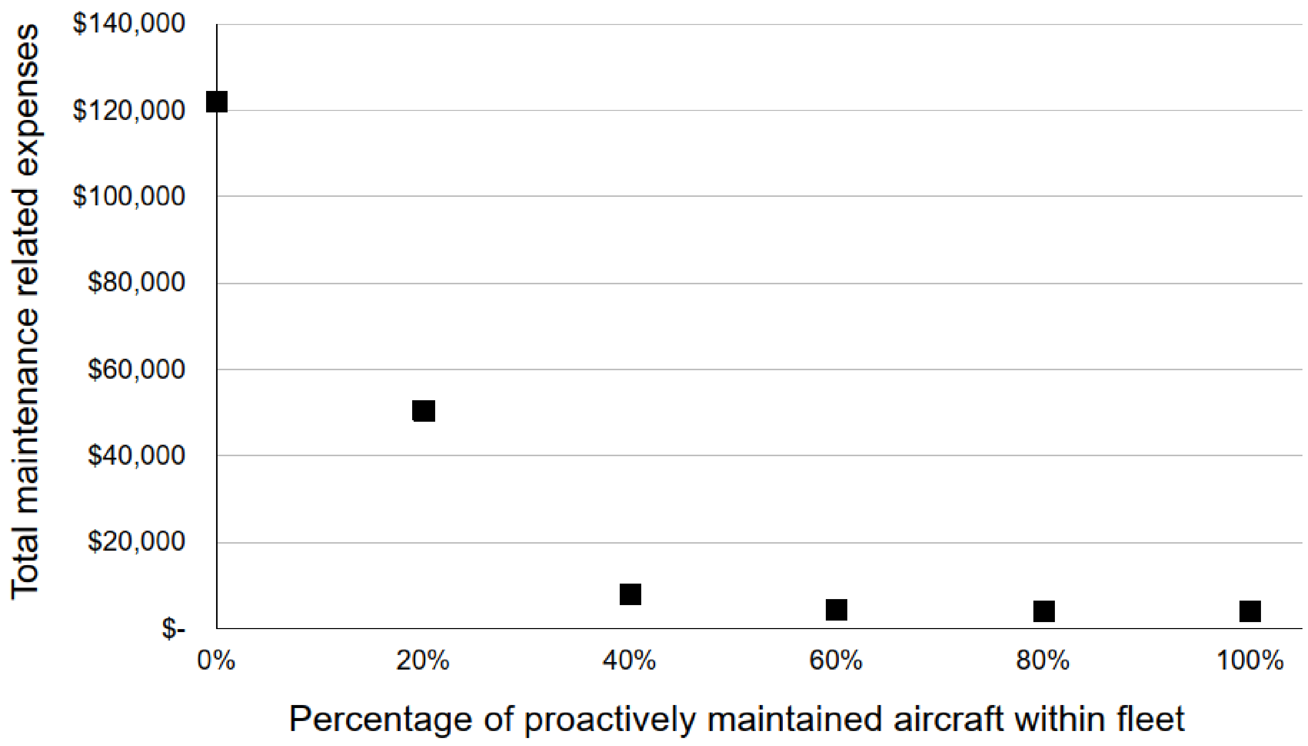
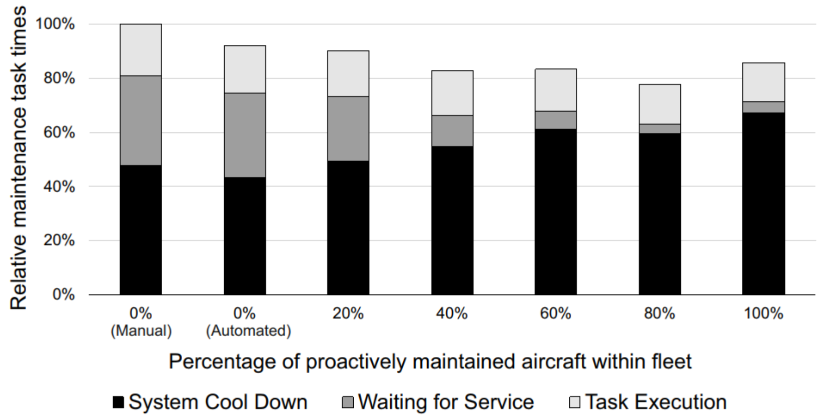
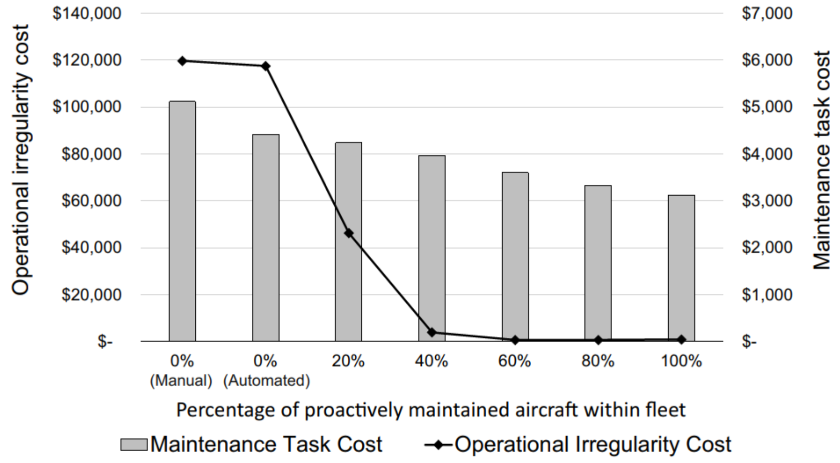
Exemplary Use Cases and Findings

Research Question	How does the cost savings potential of a prognostics-based maintenance strategy change for different utilization degrees within the aircraft fleet?
Method / Research Setting	▪ Discrete Event Simulation with focus on interaction between operations and line maintenance ▪ Aircraft fleet of 5 short-/medium-haul aircraft ▪ Modeling of ground resource limitations, i.e. available, qualified mechanics, and available maintenance hubs ▪ Variation of the utilization degree of PHM technologies within the fleet ▪ Analysis of avoidable operational delays due to waiting times for service, associated maintenance task cost, and environmental impact, i.e. CO_2 emission
Key Findings	▪ Dependency of cost savings potential from fleet utilization degree ▪ High improvements for additional PHM-equipped aircraft for low levels of fleet utilization until saturation point ▪ Excessive maintenance cost mainly caused by operational irregularity cost, i.e. flight delays or cancellations

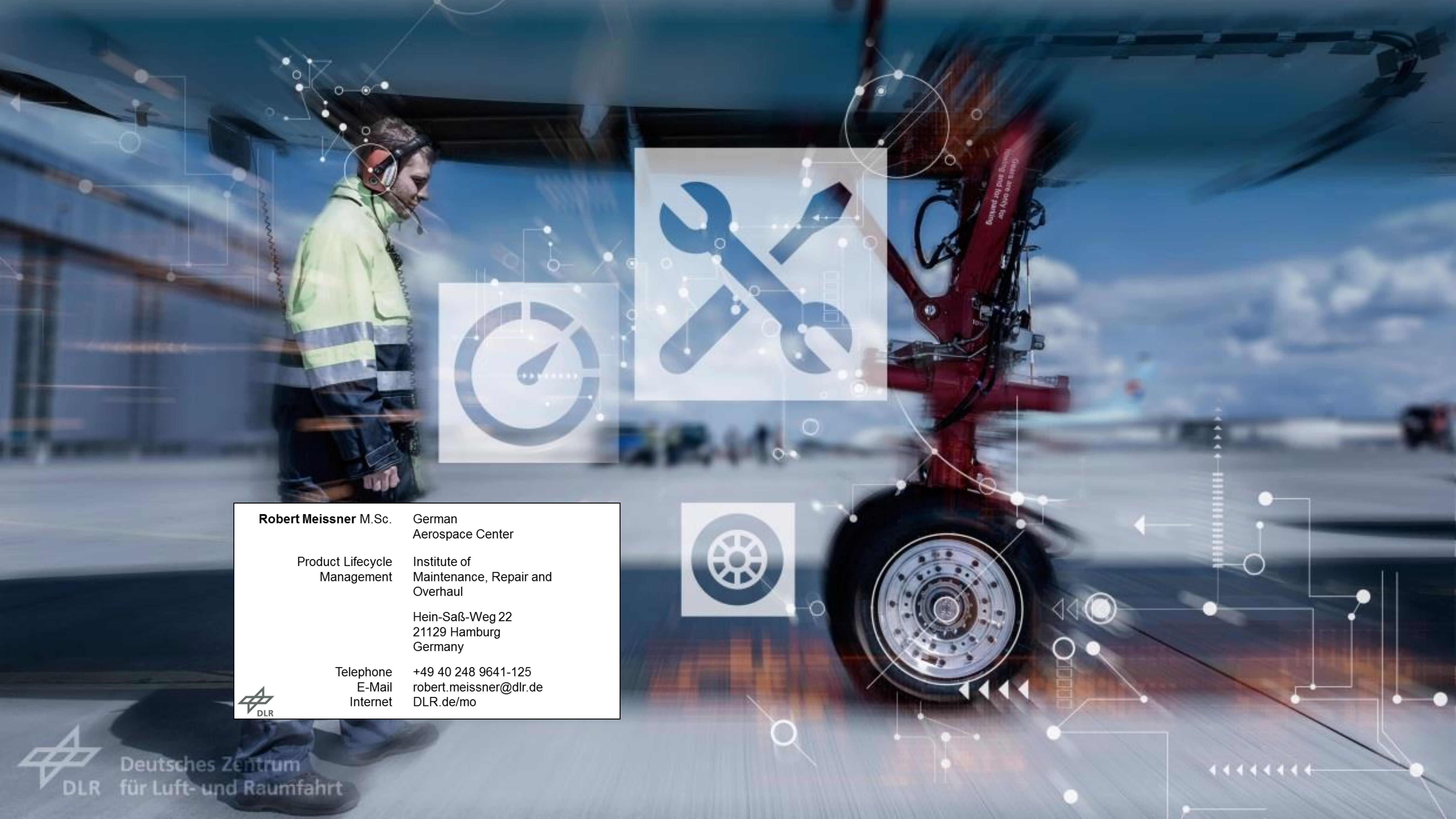
Exemplary Use Cases and Findings







Meissner, R., Rahn, A. and Wicke, K. (2021) Developing prescriptive maintenance strategies in the aviation industry based on a discrete-event simulation framework for post-prognostics decision making. Reliability Engineering & System Safety, 214. Elsevier. doi: 10.1016/j.ress.2021.107812



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References

[1] Groenenboom (2019), “The changing MRO landscape,” Athens, Greece, Sep. 18 2019. Accessed: Apr. 3rd 2020. [Online]. Available: https://www.iata.org/contentassets/81005748740046de878439e6c54f2355/d1-1100-1130-the-changing-mro-landscape_icf.pdf

[2] M. Haarman et al., “Predictive Maintenance 4.0: Beyond the Hype,” 2018. Accessed: Sep. 19th 2021. [Online]. Available: https://www.pwc.nl/nl/assets/documents/pwc-predictive-maintenance-beyond-the-hype-40.pdf

[3] A. Hess, G. Calvello, and P. Frith, “Challenges, Issues, and Lessons Learned Chasing the "Big P". Real Predictive Prognostics. Part 1,” in 2005 IEEE Aerospace Conference proceedings: March 5-12, 2005, [Big Sky, Montana], Big Sky, MT, USA, 2005, pp. 3610–3619.

[4] International Maintenance Review Board Policy Board, “Issue Paper 180: Aircraft Health Monitoring (AHM) Integration in MSG-3” Apr. 27th 2018. European Union Aviation Safety Agency Accessed. Accessed: Main, 6th 2022. [Online] Available: https://www.easa.europa.eu/download/imrbpb/IP%20180%20-%20AHM%20integration%20in%20MSG-3.pdf