HYDROGEN SYSTEMS IN AVIATION: ADDRESSING KEY CHALLENGES FROM A MAINTENANCE PERSPECTIVE

Jennifer Ramm, Tim Hoff, Patrick Sieb, Geo Jacob, Simon Beckmann, Kai Wicke, Gerko Wende
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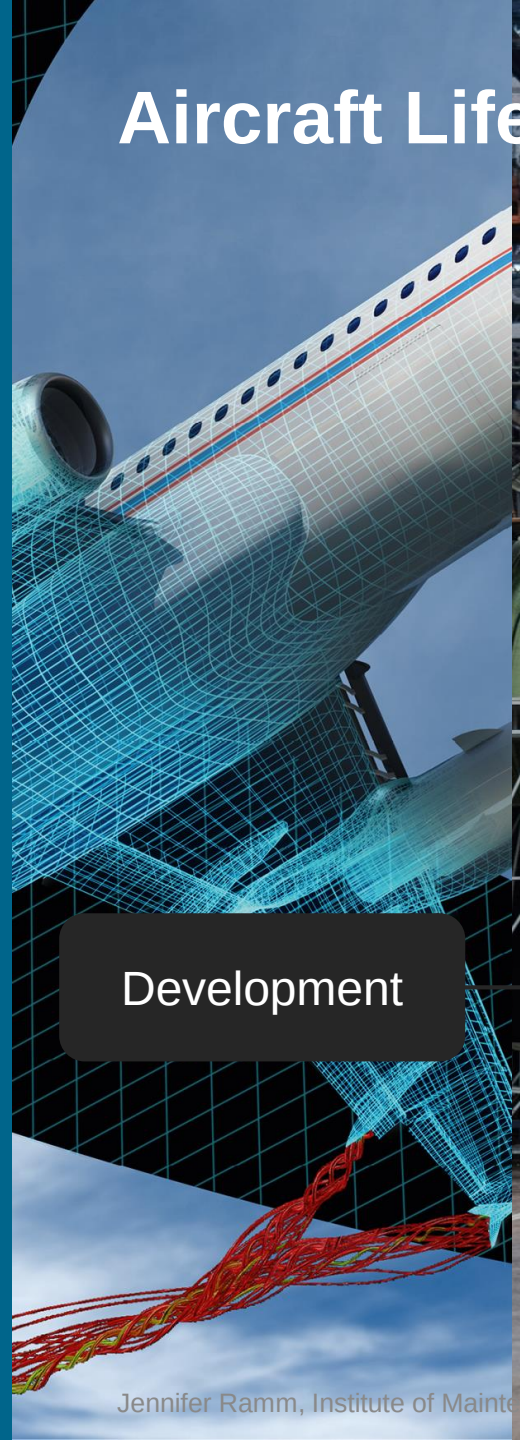
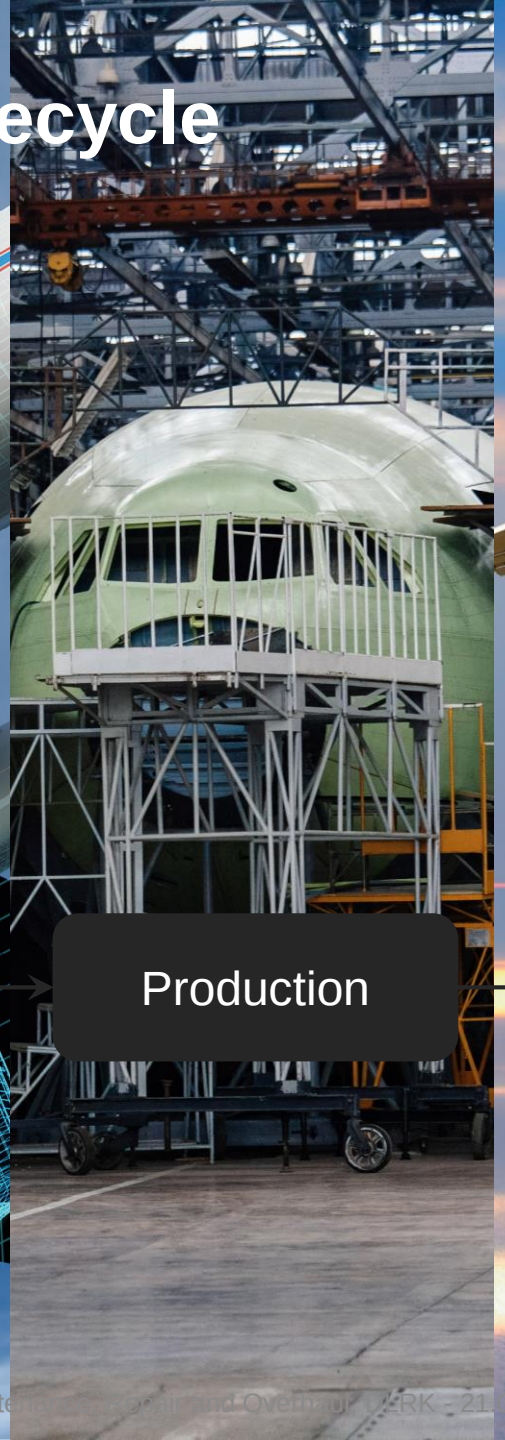
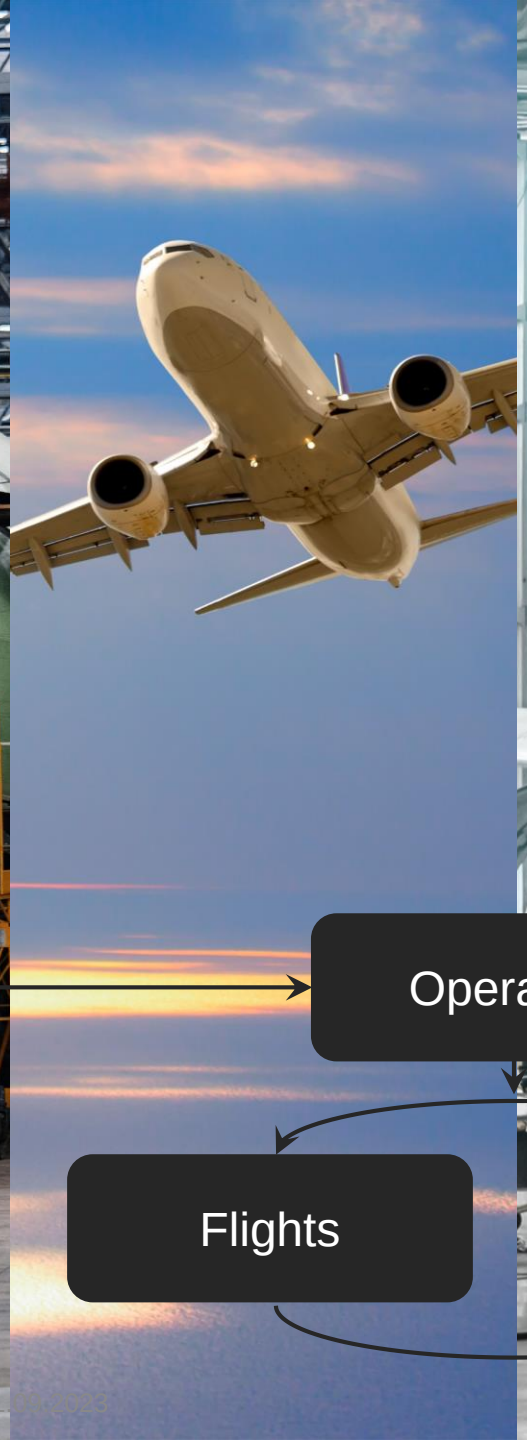
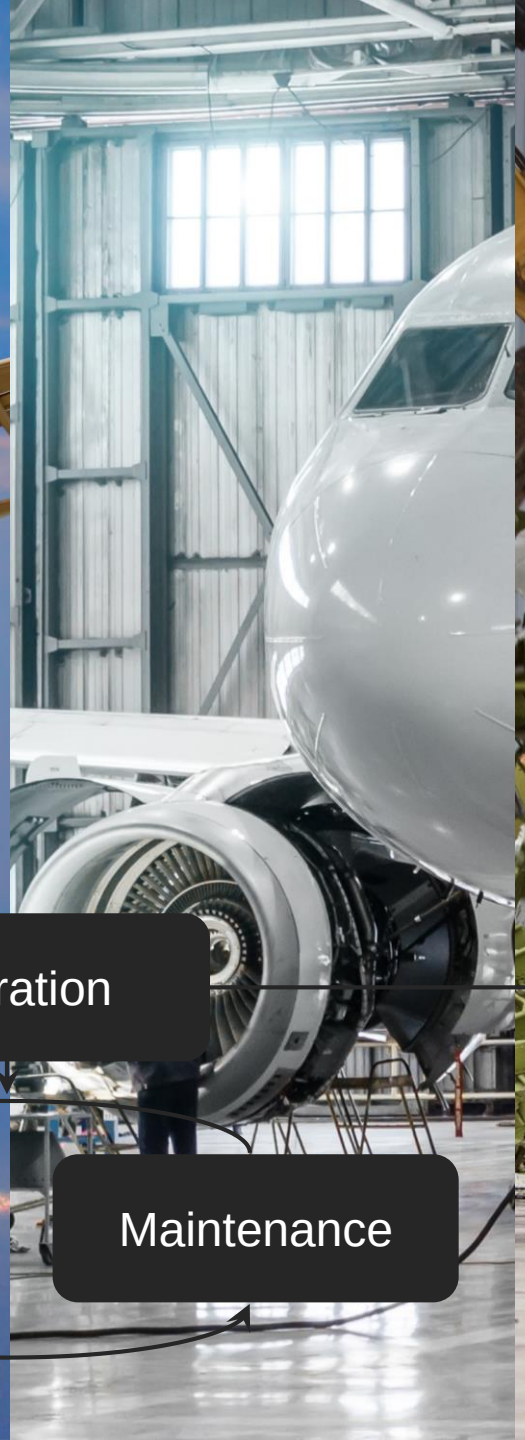
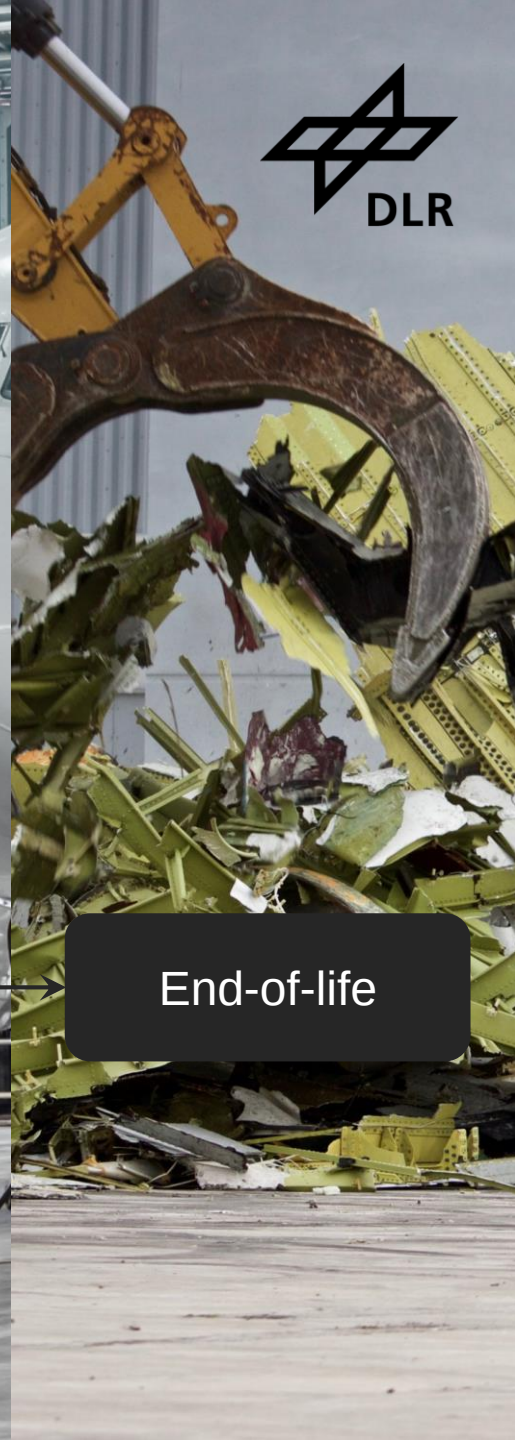
Aircraft Lifecycle









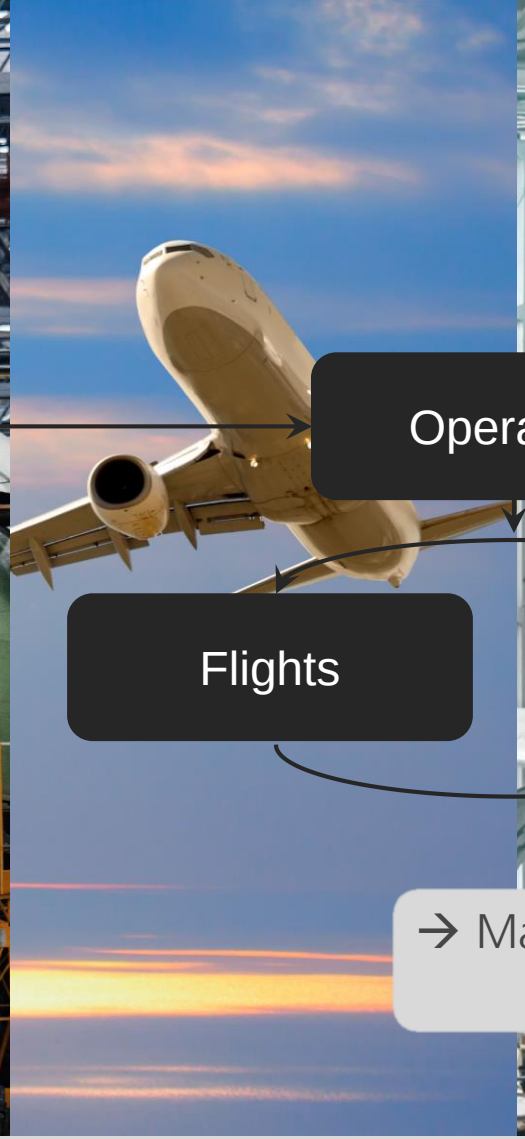


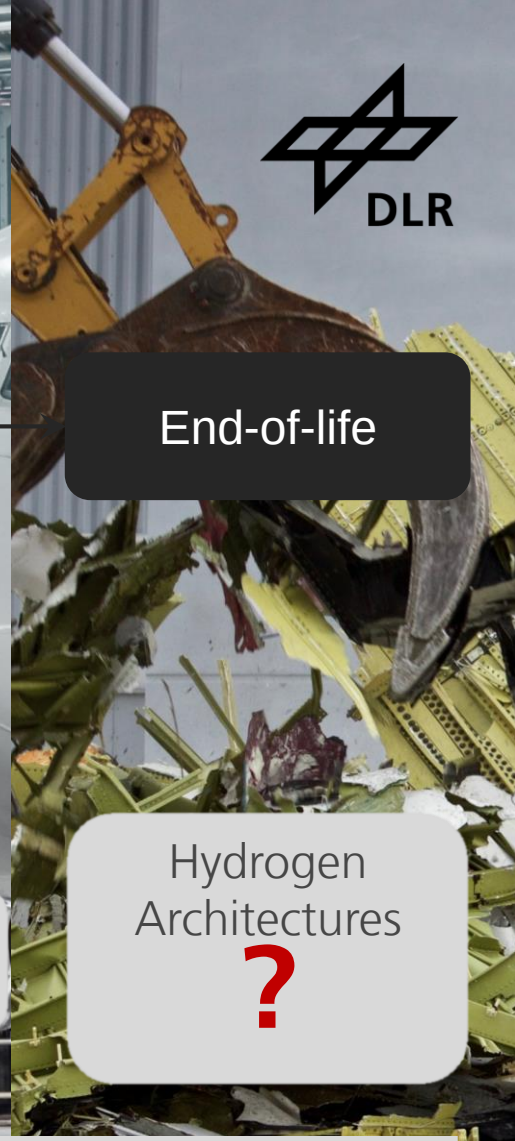
Development → Production → Operation → End-of-life

Operation ⇄ Flights

Operation ⇄ Maintenance

Aircraft Lifecycle





Development → Production → Operation → End-of-life

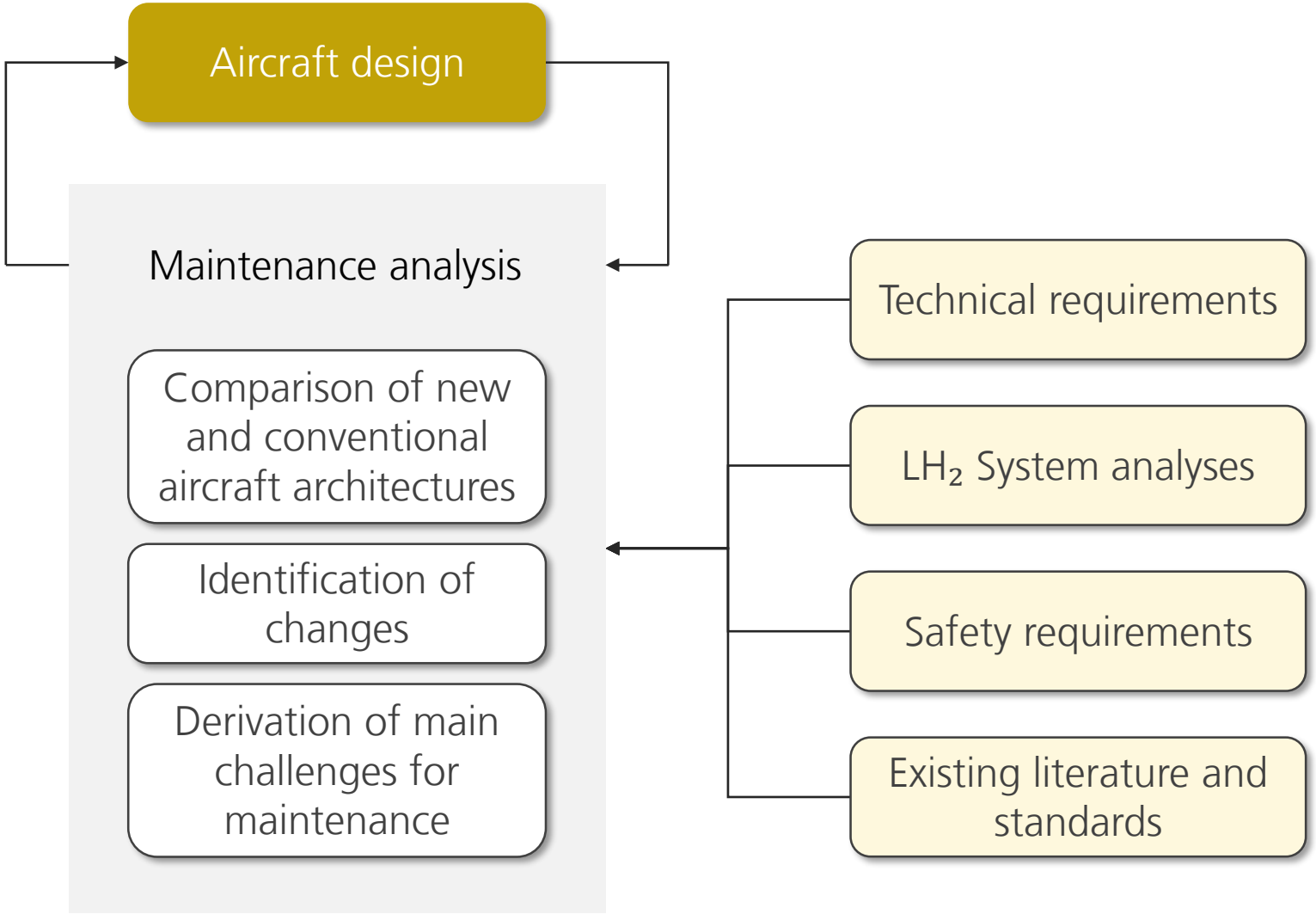
Flights ↔ Maintenance

→ Maintenance high impact on operation

Hydrogen Architectures ?

Extensive research and testing is needed to evaluate the **safety and reliability** of hydrogen systems in aviation and to determine the **technical requirements** for their integration into new aircraft designs

Method


Aircraft design
Maintenance analysis
Comparison of new and conventional aircraft architectures
Identification of changes
Derivation of main challenges for maintenance
Technical requirements
LH_2 System analyses
Safety requirements
Existing literature and standards

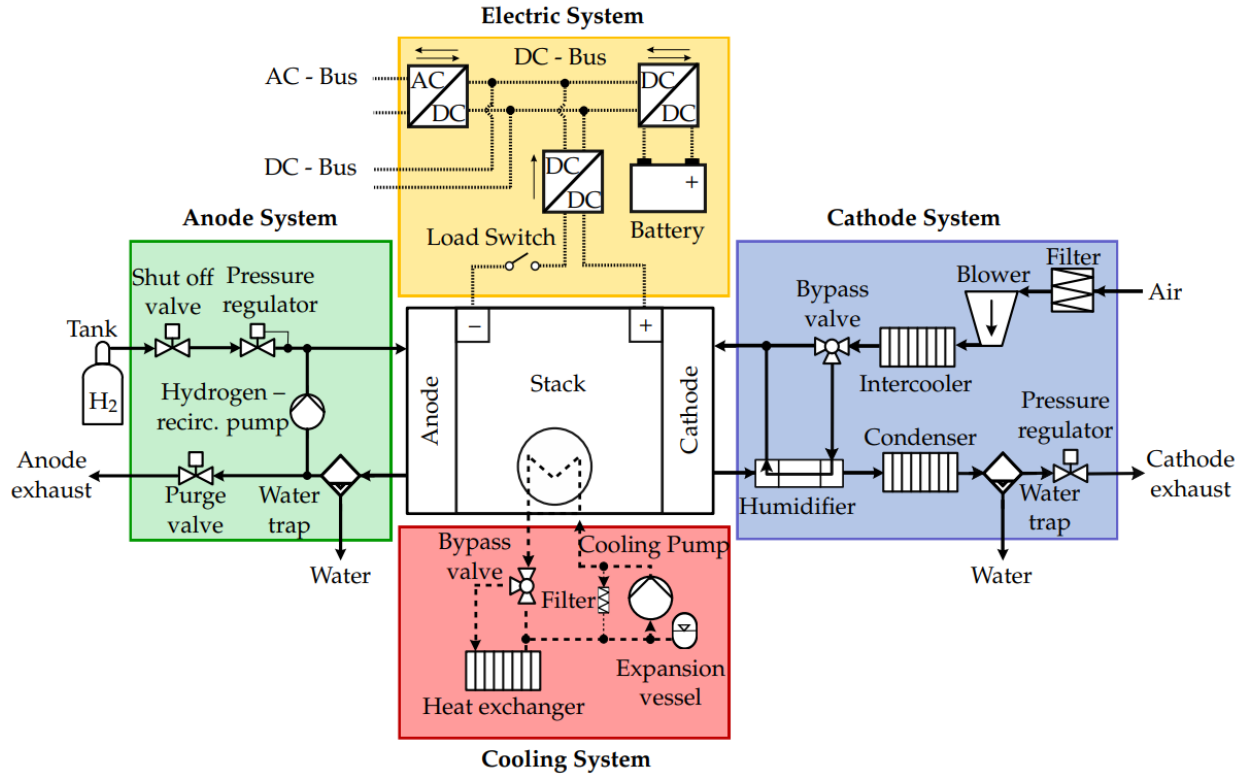
Use of hydrogen in aircraft

Possible consumer

Fuel Cell System

Hydrogen Combustion System

Exemplary rendering



Hoff, Tim, et al. "Implementation of Fuel Cells in Aviation from a Maintenance, Repair and Overhaul Perspective" Aerospace (2023) 10, no. 1: 23. doi: 10.3390/aerospace10010023

Use of hydrogen in aircraft

Possible consumer

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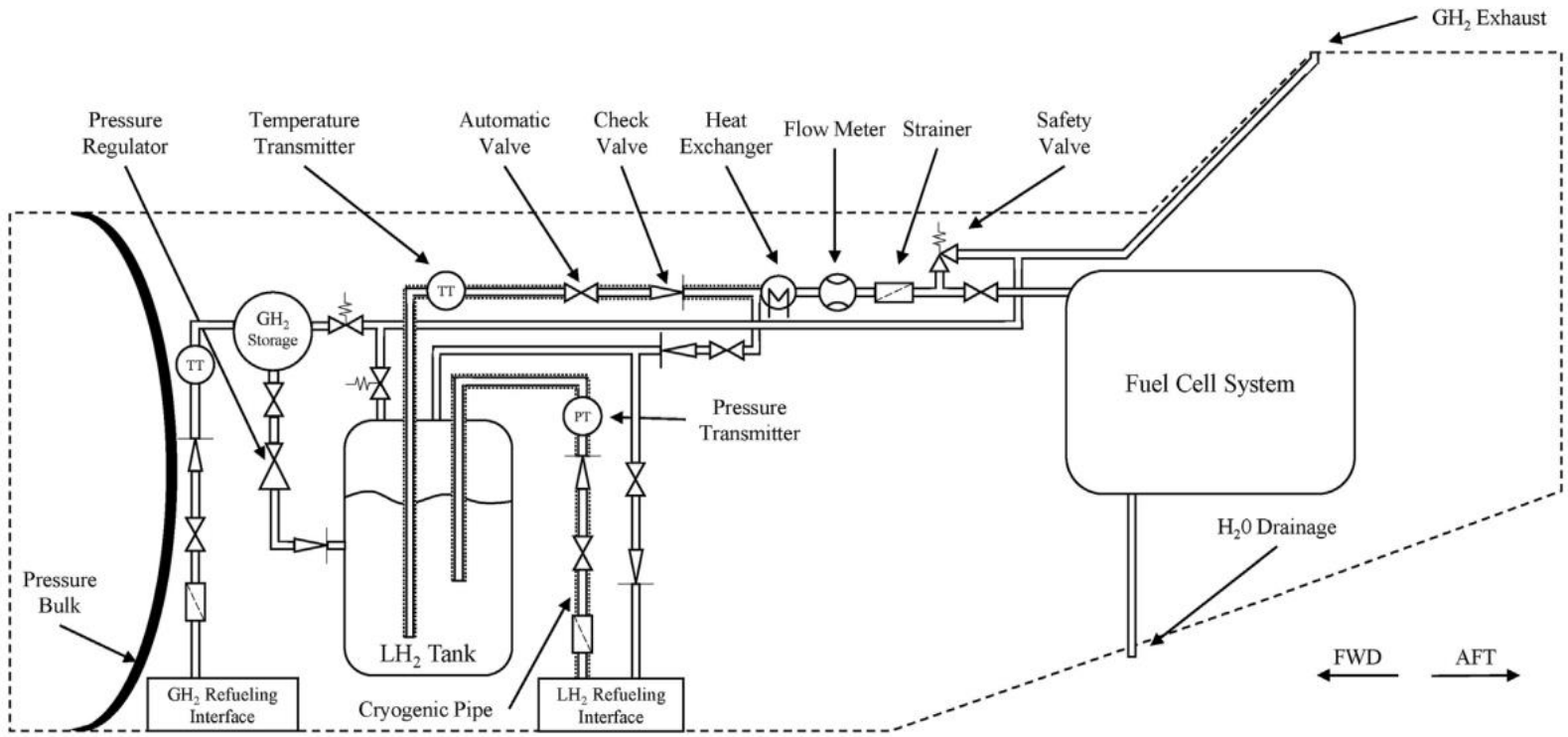
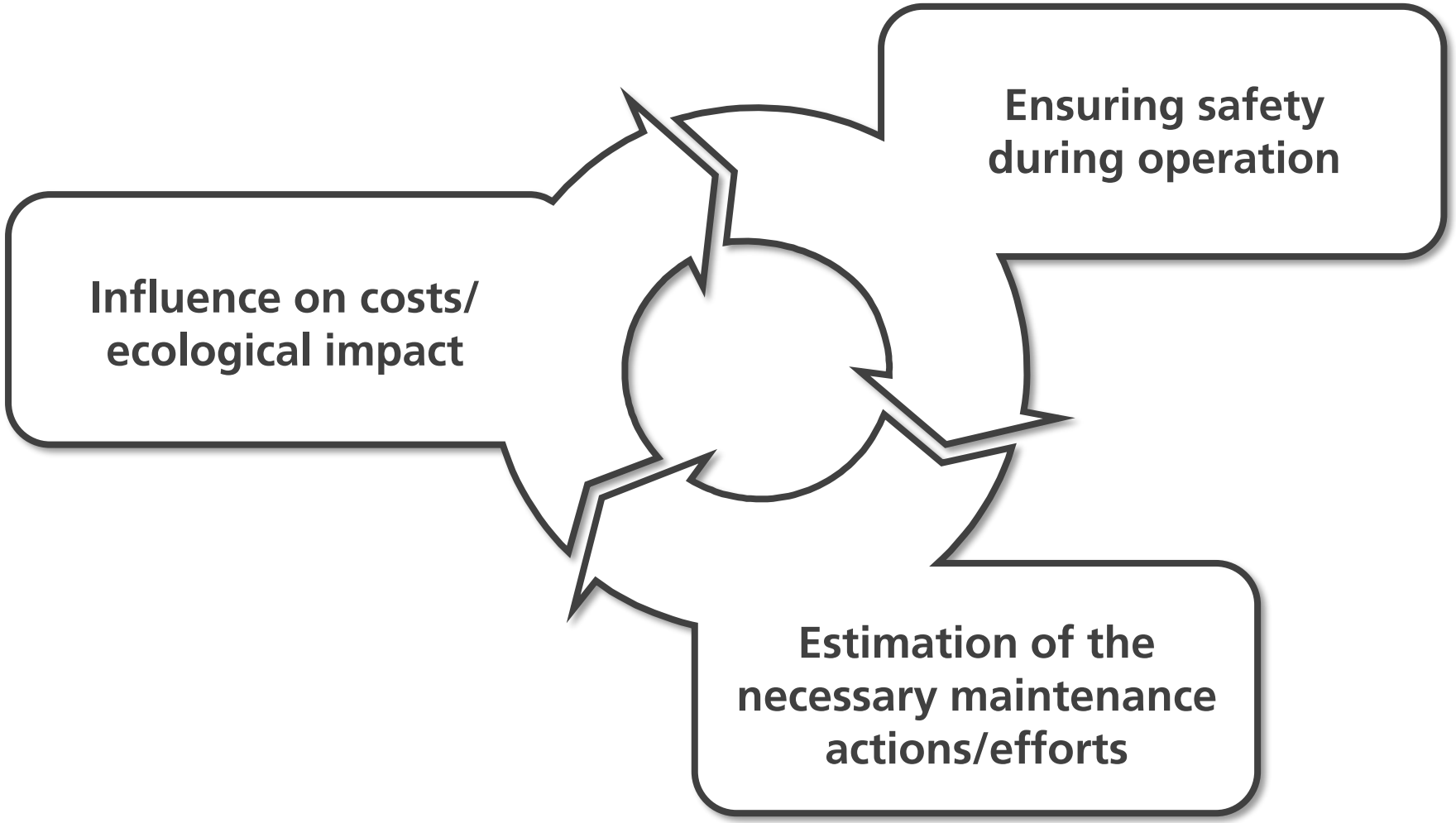
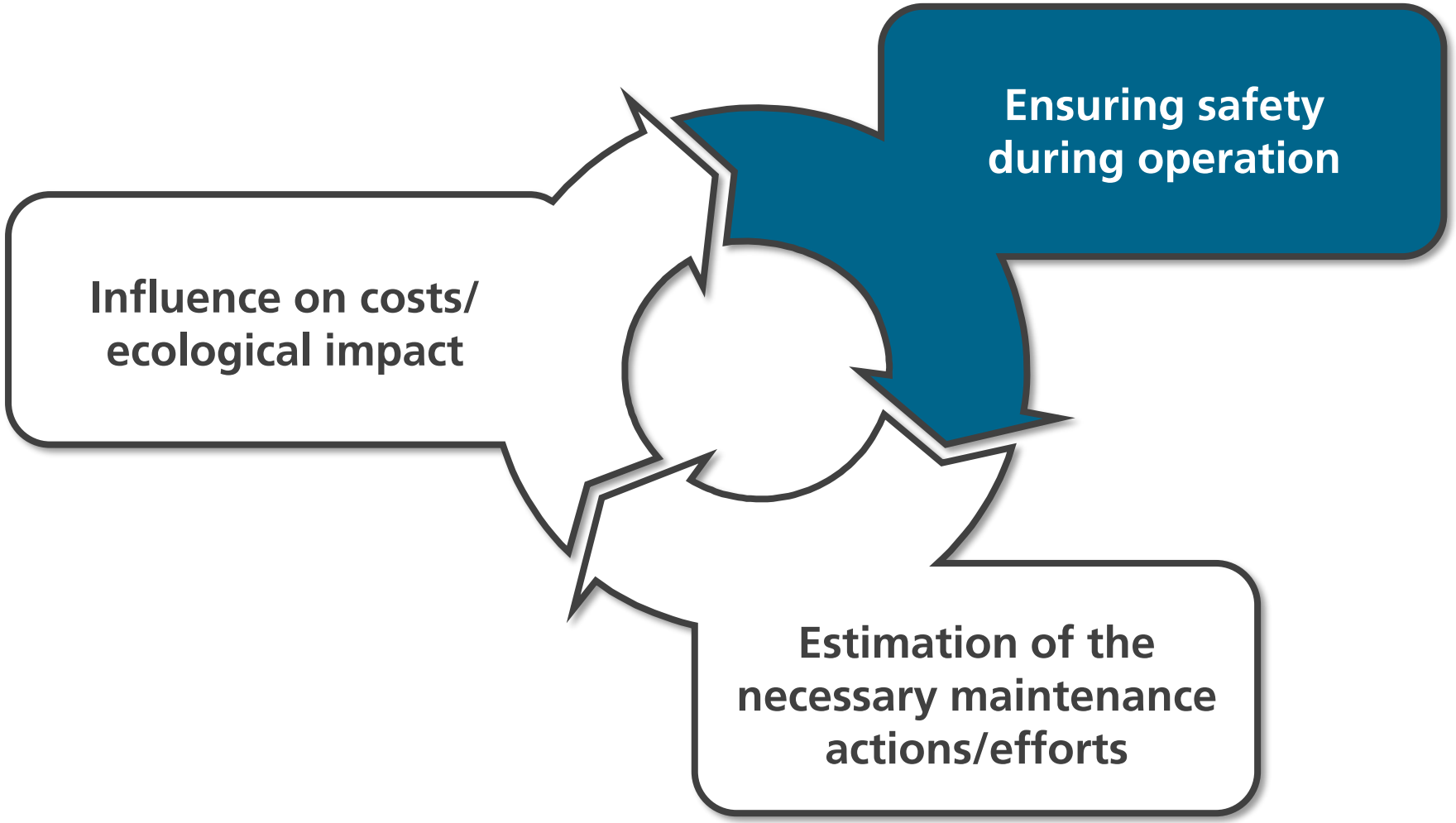


Meissner, Robert, et al. "Towards climate-neutral aviation: Assessment of maintenance requirements for airborne hydrogen storage and distribution systems." International Journal of Hydrogen Energy (2023). doi: 10.1016/j.ijhydene.2023.04.058

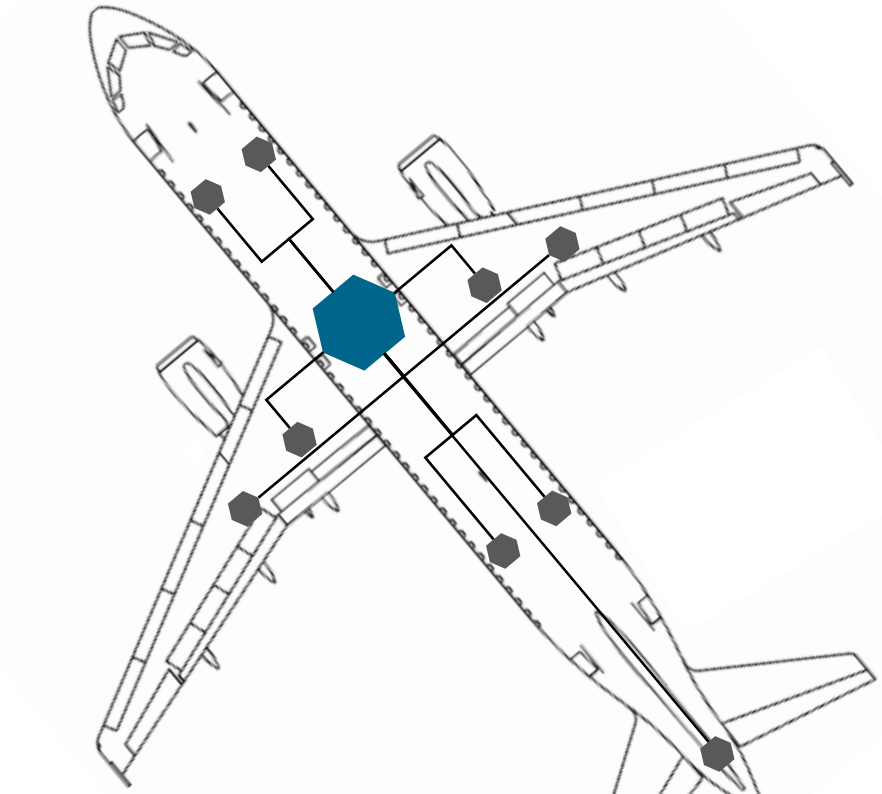
Key Challenges from a Maintenance Perspective



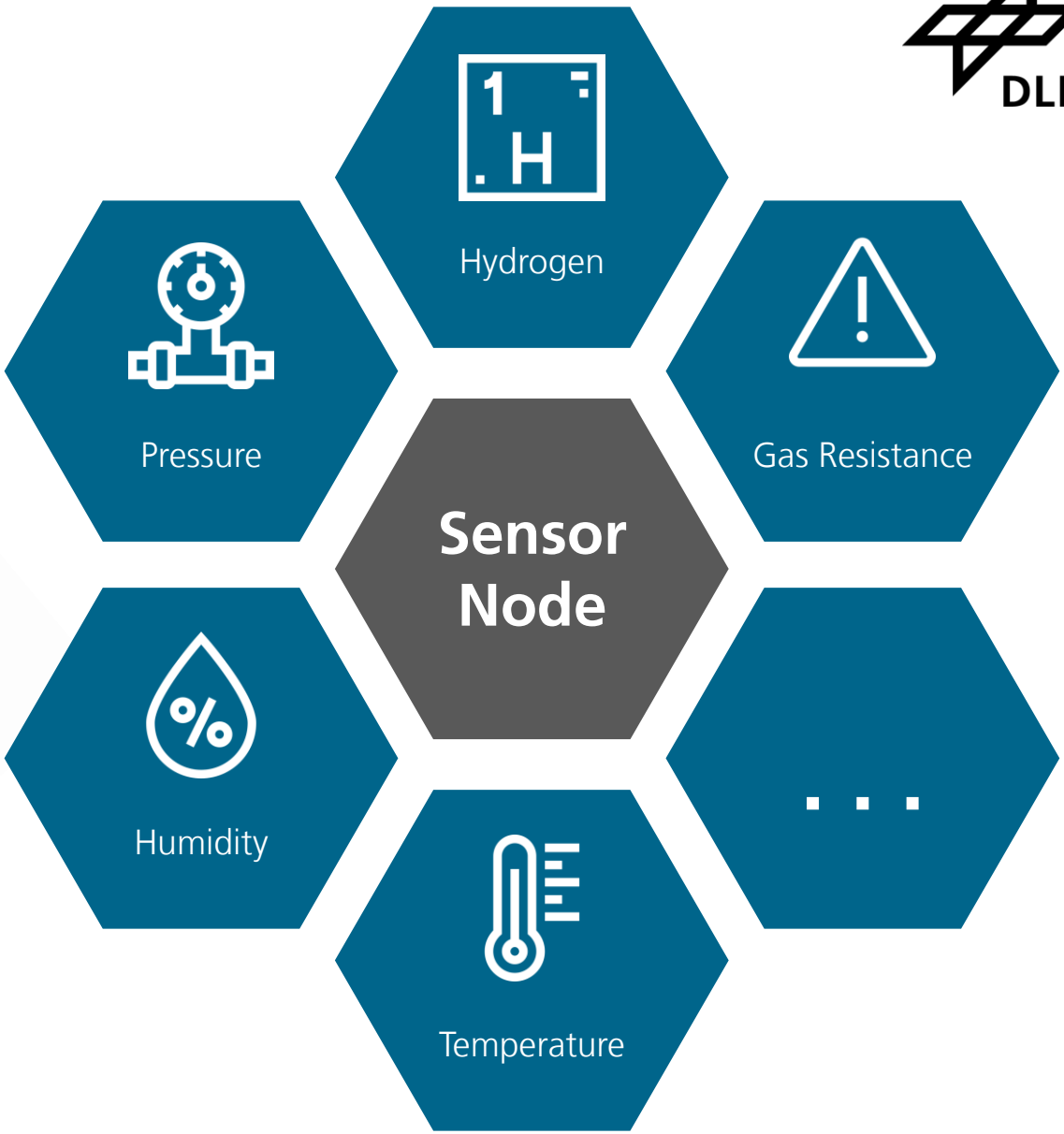
Addressing Key Challenges from a Maintenance Perspective



Distributed Sensor Network

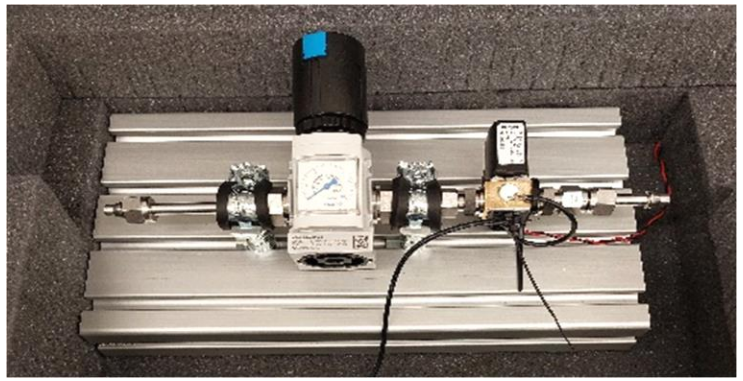


Master Command Control Unit Sensor Node

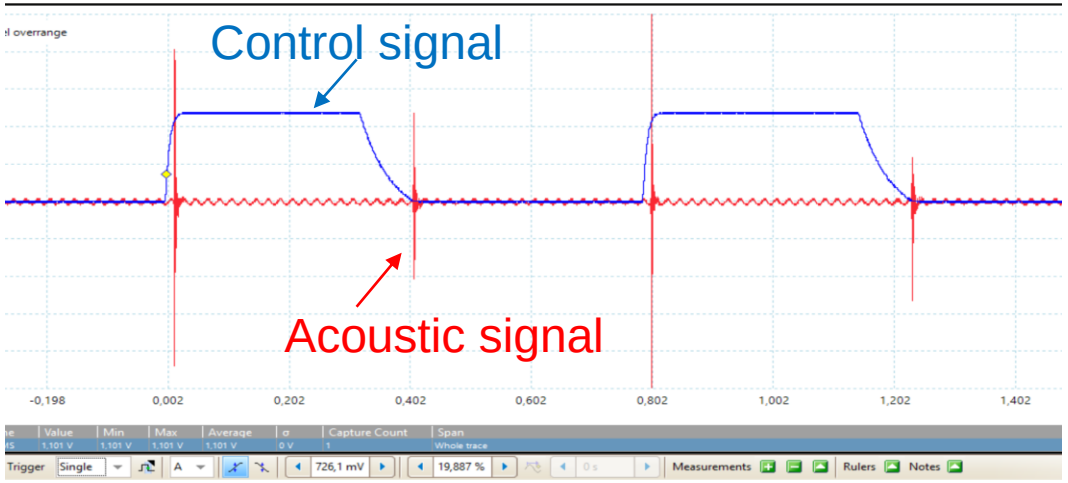


Key Results
Acoustic monitoring

- Components and subcomponents monitoring
- Passive monitoring to detect changes in
  - Operational parameters
  - Damage event detection and localization
- Development of data acquisition and data analysis techniques for monitoring tanks

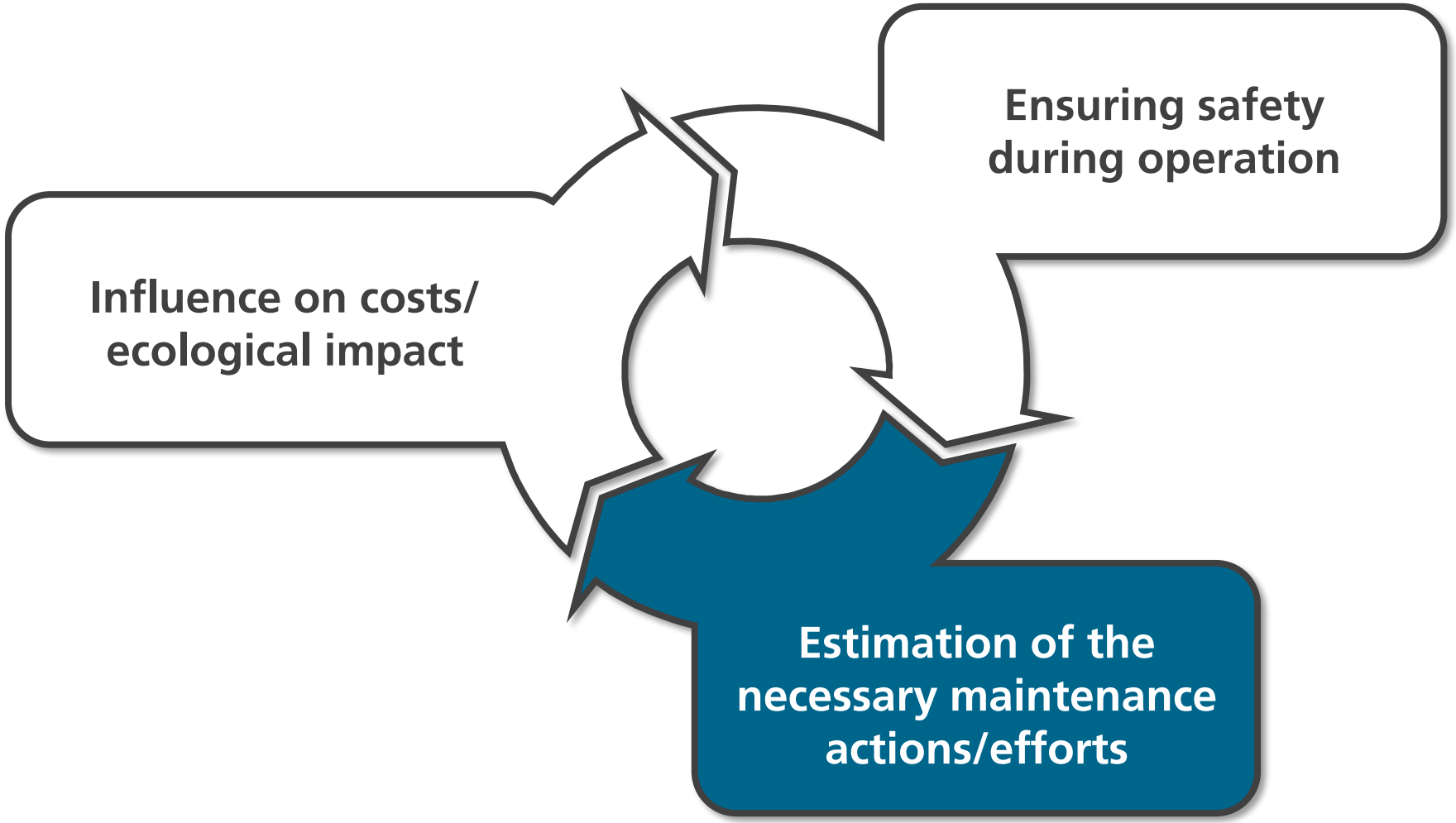


Simplified valve test setup with bonded piezo transducer



Continous monitoring of valve openings and closings

Addressing Key Challenges from a Maintenance Perspective



Maintenance Analysis According to MSG-3 Approach Goals & Method

A320hydro	MSG-3 Analysis – Fuel Tank Systems	Level 1 Analysis

Function	1	Functional Failure	1A	Failure Effect	1A1
To transport Hydrogen from the tank to the fuel cell		Fails to transport any H2 from the tank to the fuel cell		Fuel cell does not generate any power. Aircraft components can not be operated.	

1 Is the occurrence of a functional failure evident to the operating crew during the

A320hydro	MSG-3 Analysis – Fuel Tank Systems	Level 2 Analysis

Function Failure	1A	Failure Cause
Fails to transport any H2 from the tank to the fuel cell		**1A11:** Vaporizer defect **1A12:** Valve or check valve suffer a fault close failure **1A13:** Filter (entirely) clogged

2 Does th damag failure safety?

5 6 7 8 9 / A A A A A	Is a lubrication or servicing task applicable and effective?	Y / N ■	Lubrication / Servicing	**6A) NO:** There is no lubrication or servicing task available that would reduce the risk of a defect vaporizer as it is a electric component without any moving parts.
8 9 / B B	Is a check to verify operation applicable and effective?	Y / N	Operational Check / Visual Check	
5 6 7 8 9 / B B B C C	Is an inspection or functional check to detect degradation applicable and effective?	Y ■ / N	Inspection / Functional Check	**6B) YES:** Wear of the vaporizer can be detected with a functional check. Wear and functionality of (check) valves can be detected with a functional check.
5 6 7 8 9 / C C C D D	Is a restoration task to reduce the failure rate applicable and effective?	Y ■ / N	Restoration	**6C) YES:** In addition to regular functional checks, the vaporizer group shall be subject to regular restauration tasks for in-shop overhauls. → **Task No. 01** Similarly, the (check) valves shall also be replaced in regular intervals for an extensive in-shop overhaul. → **Task No. 02**
5 6 7 8 9 / D D D E E	Is a discard task to avoid failures or to reduce the failure rate applicable and effective?	Y ■ / N	Discard	**6D) YES:** Regular Replacement of the filters minimizes the risk of clogging → **Task No. 03**
5 8 / E F	Is a combination of any of the tasks above applicable and effective?	Y / N	Task combination	

4 Dc ad

Safety 5

No Task for Cat. 5,8 : Redesign is mandatory
No Task for Cat. 9 : Redesign is desirable
No Task for Cat. 6,7 : Redesign may be desirable

Task No.	Task Description	Interval Justification	Threshold	Interval	Applicability
01	REMOVAL VAPORIZER GROUP FOR IN-SHOP OVERHAUL		N/A		ALL
02	FUNCTIONAL CHECK OF (CHECK) VALVES		N/A		ALL
03	DISCARD OF FILTERS		N/A		ALL

Goals:

- Understanding the implications of flying with H2 for operation & maintenance
- Derivation of implications for on-aircraft maintenance

Procedure for maintenance analysis according to MSG-3 approach:

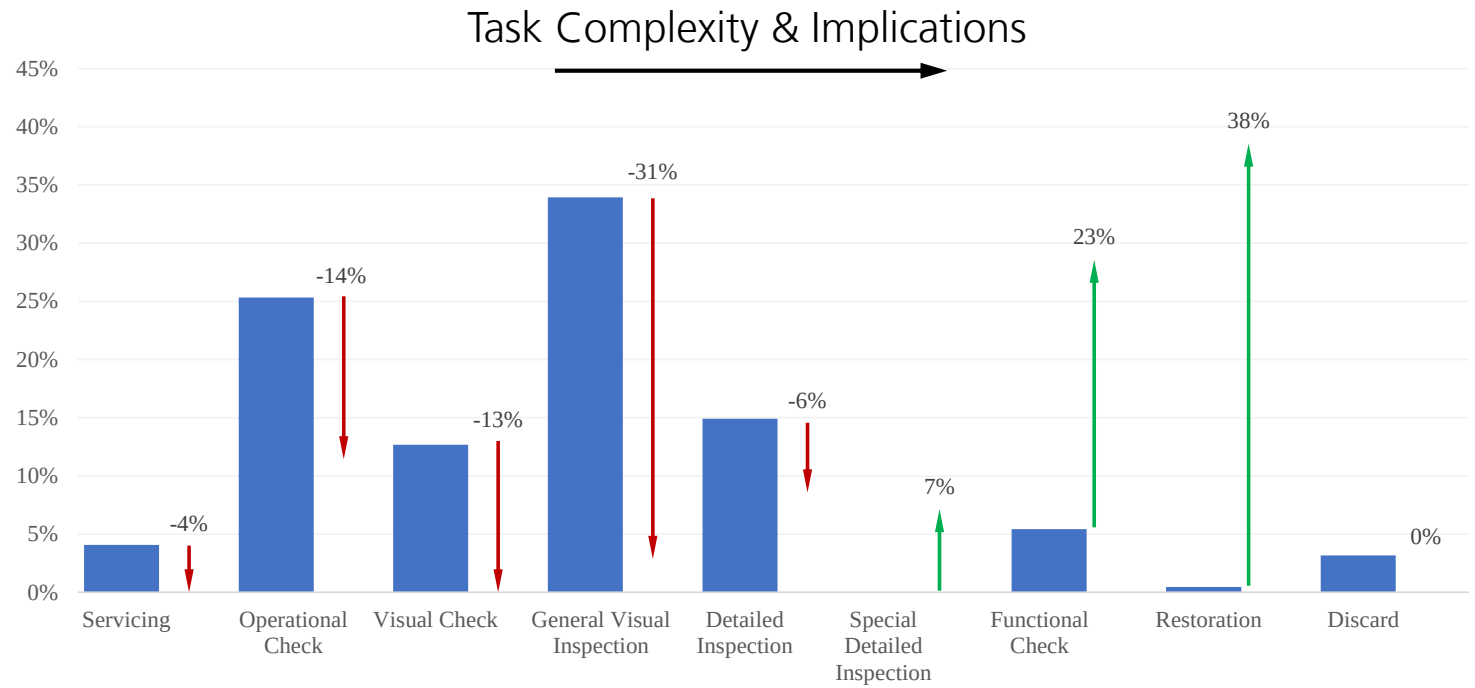
- Determine system functions, determine errors and consequences and identify effects
- Derive task to avoid the errors
- Determine intervals and estimate MMH

Maintenance Analysis According to MSG-3 Approach Results

Scheduled Maintenance Effort

Task Distribution

In-shop maintenance



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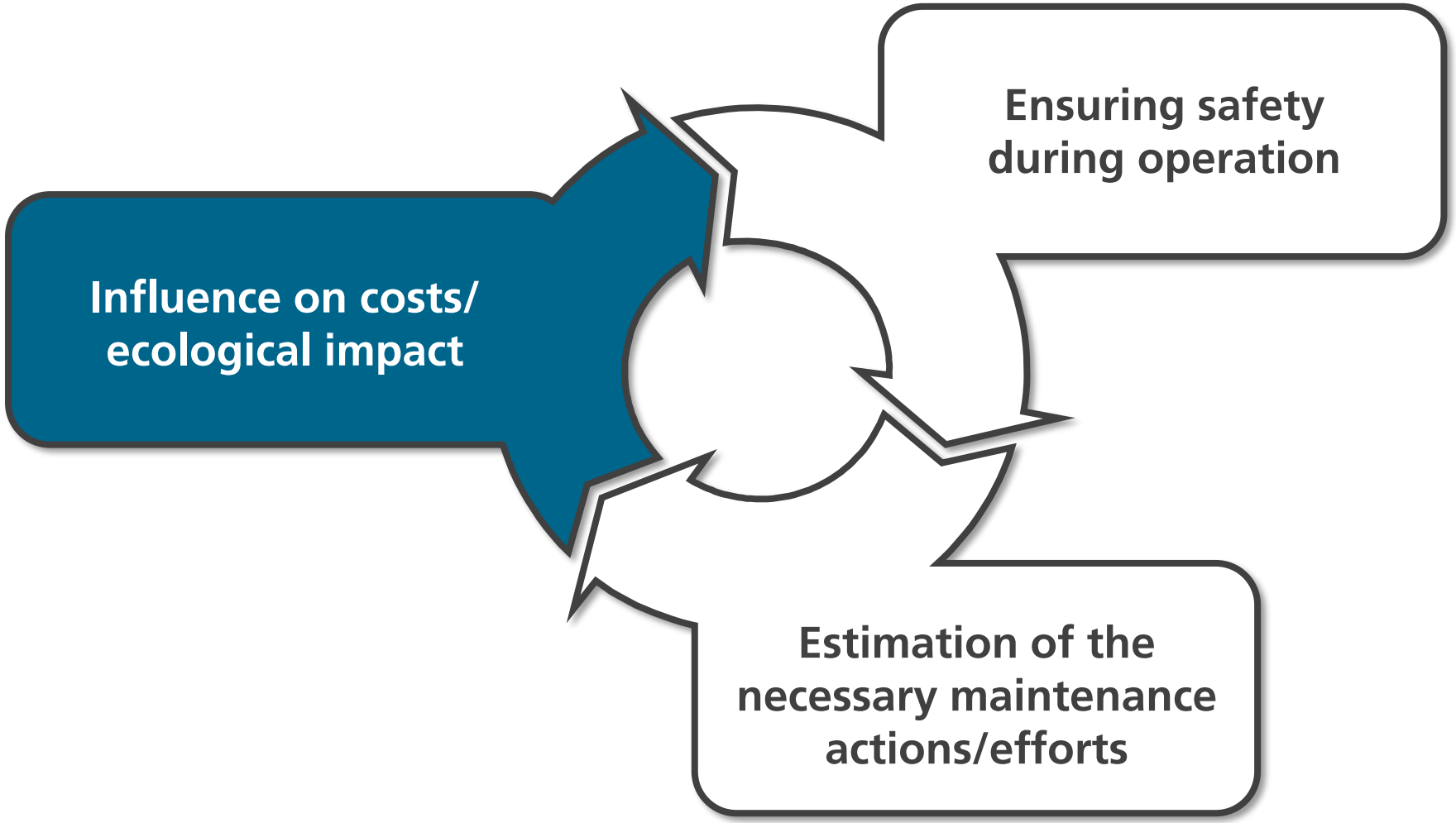
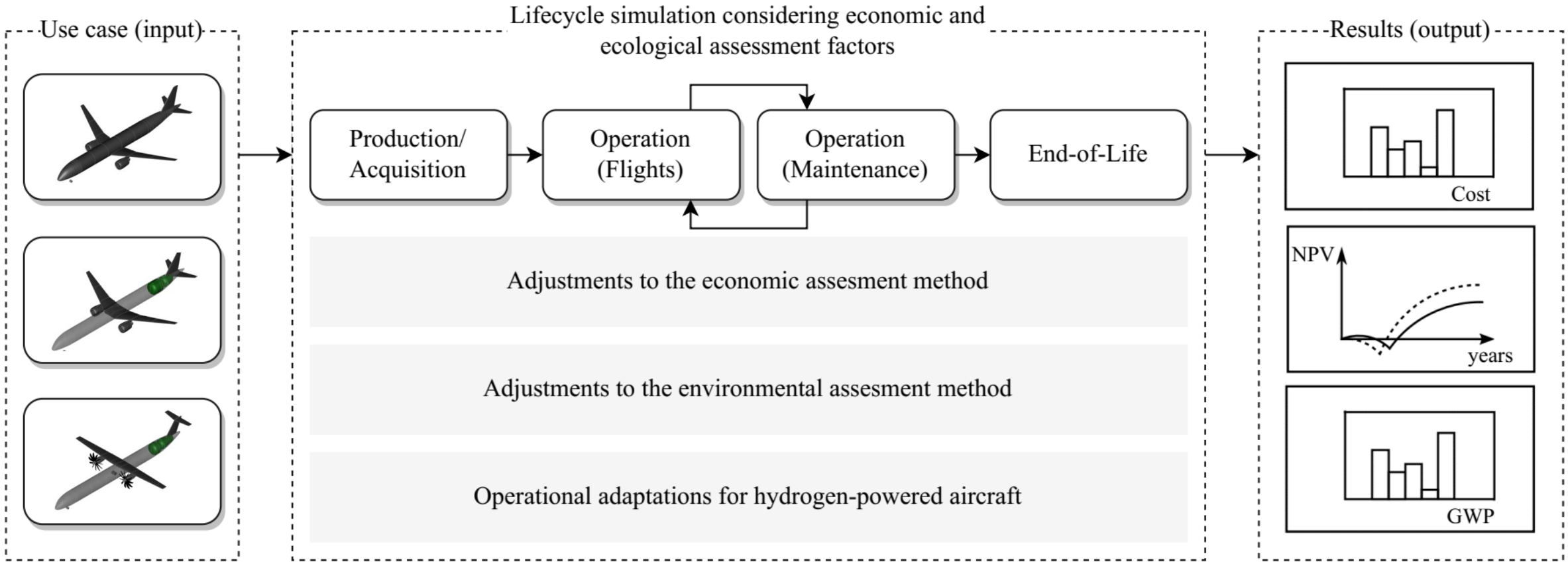
Addressing Key Challenges from a Maintenance Perspective



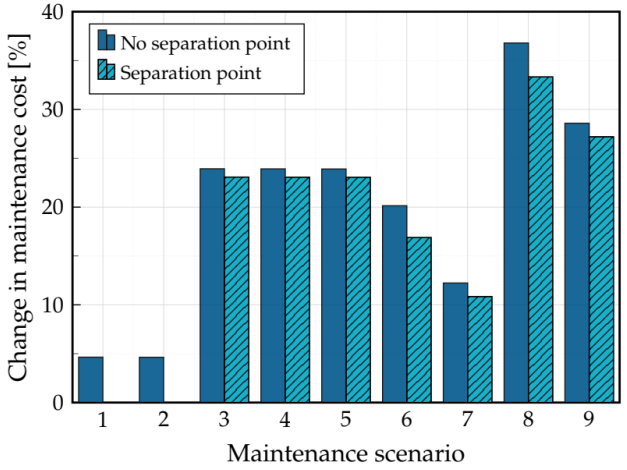
Economic and environmental assessment method - LYFE

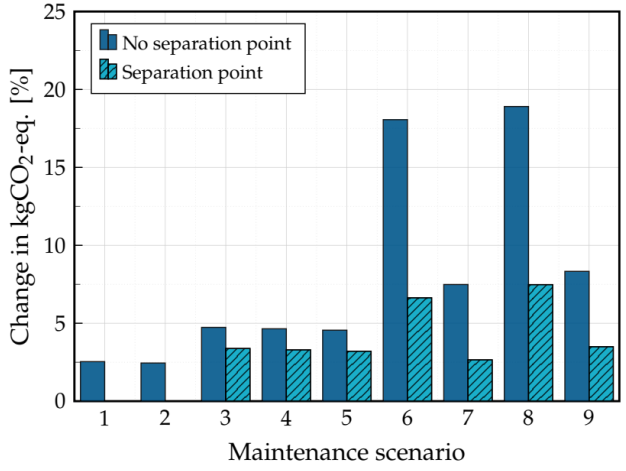


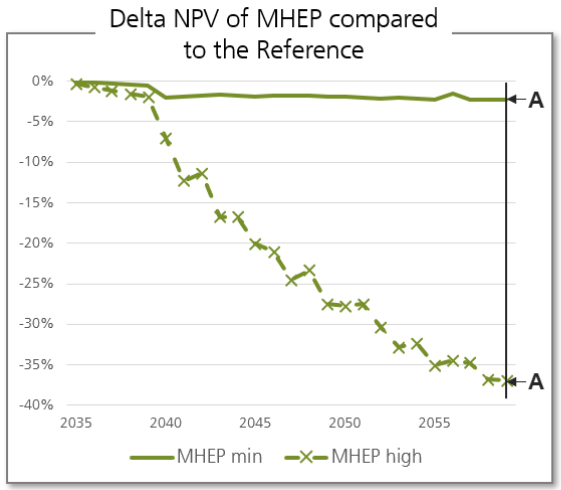
Wehrspohn, Jennifer, et al. "A detailed and comparative economic analysis of hybrid-electric aircraft concepts considering environmental assessment factors." AIAA Aviation 2022 Forum. 2022. doi: 10.2514/6.2022-3882

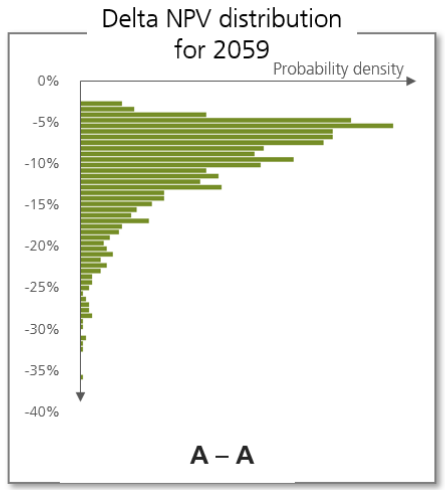
Economic and environmental assessment method

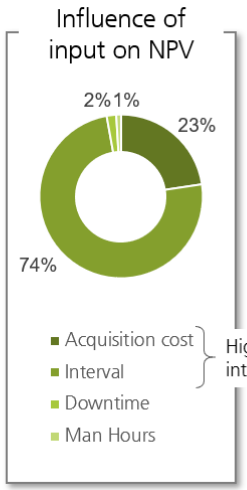
- Comparison of different aircraft concepts
- Comparison of different operational procedures (e.g. different maintenance actions)
- Analysis of uncertainty-impact in input variables on output











Challenges need to be considered for development of H_2 aircraft

→ Maintenance support for operation in the long term!

Thanks For Your Attention!

In case of any further questions:

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